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ABSTRACTS

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Windowglass Hill – a tension vein array gold prospect in southwest Newfoundland

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The Windowglass Gold prospect, located in southwestern Newfoundland, comprises one of a series of auriferous vein-type gold prospects along a 10 km segment of the Cape Ray Fault Zone, a major Late Silurian to Early Devonian reverse-oblique fault zone. The Cape Ray Fault extends for 100 km and is up to several hundreds of metres wide and represents a major terrane collision event in the Late Silurian of the Newfoundland Appalachians. Mineralization along the Cape Ray Fault Zone is interpreted to be the end-product of terrane collision and attendant metamorphism and magmatism. The mineralization is bracketed between 415 Ma, post-peak metamorphism, and 386 Ma, the age of the Isle Aux Mortes Granite which cuts mineralized structures.

Mineralization along the Cape Ray Fault Zone typically consists of steeply dipping, northeast trending fault-fill quartz breccia veins within meta-volcanics and sediments of the Windsor Point Group. Mineralization at the Windowglass Hill Gold prospect comprises several arrays of flat-lying to shallowly west-dipping, sulphide-rich extensional quartz veins within the Windowglass Hill Granite. Five individual vein arrays have now been outlined over a distance of 1.5 km within the Windowglass Hill Granite, including the previously documented Main Zone. The 2004 program comprised regional prospecting surveys, structural mapping, development of a 3D geological model and diamond drilling. Thirteen drillholes tested previously untested surface exposures of four of five vein arrays while three drillholes tested the Main Zone. All drillholes intersected mineralized veins, however, at the Main Zone, drill hole WGH-04-11 intersected 7.54 g/t Au and 49.1 g/t Ag over 5.15 m including 14.5 g/t Au and 60.8 g/t Ag over 2.2 m. The 2004 work indicates that these extensional west-dipping veins comprise a more-or-less coherent 200 m long southwest plunging tension vein array open down plunge to the southwest.

The Windowglass Hill vein systems interpreted to be en échelon tension vein arrays, are a vein configuration common in major fault zones but which are difficult to identify because of complex geometry. The tension vein arrays at the Windowglass Hill prospect have no obvious association with local faults or shear zones but must have a distinct relationship to the parent Cape Ray Fault Zone. The pre to syn-tectonic Windowglass Hill Granite (ca 424 Ma) probably acted as a competent island within the ductile Cape Ray Fault Zone and subsequent deformation events along the Cape Ray Fault Zone likely causing strain refraction and buffering against post-mineral strain events. The mineralization at Windowglass Hill is similar to that comprising many other Tension Vein Array gold deposits. The world-class Sunrise Dam deposit (6 million ozs), and the Cadia Deposit (2.5 million ozs) are considered tension vein array type gold deposits.

Natural disasters and geological hazards in the St. John's area

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St. John's has the dubious distinction of being one of the most dangerous of Canadian cities in terms of natural hazards. A combination of terrain, extreme weather events, and unfortunate location of buildings have proven to be a poor mix, and at least 8 people have been killed in 4 separate incidents in The Battery and along Southside Road over the last 80 years or so. Construction of the Harbour Arterial above Southside Road in the early 1970s, and installation of protective fences above The Battery in 1998, have significantly reduced the risk from hazard in these areas.

The Battery is located under the slopes of Signal Hill on the north side of The Narrows. Originally established as a fishing community, The Battery has suffered at least 3 major and several minor avalanches. These were the result of snow loading the overlying slopes and the development of a cornice that eventually fails, a rapid fall in temperature followed by a heavy snowfall, a period of freezing rain followed by snow or a combination. The earliest recorded avalanche was in 1921, which destroyed several houses and seriously damaged fishing stages and flakes, and although there were injuries there was no loss of life. In the same year however, Albert Delahunty was killed in an avalanche during a snow storm on his way to work. The most serious incident was during a severe winter storm in 1959 when 5 residents were killed in their homes by an avalanche. Further incidents in 1960 and 1987, coupled with a risk of rockfall, prompted the City of St. John's to erect protective fences above The Battery at a cost of about $300,000.

Southside Road runs along the base of the Southside Hills east of the Waterford River, extending from the east side of the harbour toward Bowring Park. This area has a history of flooding from the Waterford River, and landslides from the thin glacial sediments that overlie sandstone and conglomerate bedrock. Landslides in this area are triggered by heavy rainfall events, which saturate the overburden to the point of failure, following which debris flows or torrents occur. Landslides in 1912, 1934 and 1953 caused extensive property damage and evacuation of residences. However, fatalities occurred in 1936 when Theresa Bryne (aged 4) was smothered by debris from a landslide that entered her home at 207 Southside Road; and in 1948 when Maureen Windsor (aged 3) died from trauma during a landslide in her house at 387 Southside Road. The construction of the Harbour Arterial road above Southside Road has reduced the risk of subsequent landslides by directing water into culverts, although minor sediment movement has been reported as a result of construction of houses along Southside Road.

Although the risk has been reduced, the factors contributing to geological hazard remain. Public awareness and consideration of geological hazards in municipal planning decisions are important considerations in St. John's and other municipalities in Newfoundland and Labrador, and thus warrant inclusion of these issues in the Geoscape project.

Geochemical landscapes of St. John's – a contribution to Geoscape St. John's

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An objective of the *Geoscape* project is to provide Canadians with better access to important local geoscience information. In our presentation, we argue that mapping of the urban geochemical landscape provides information for health and environmental agencies to: (i) understand the geochemical conditions in which urban residents live, (ii) identify problem areas, and (iii) develop primary prevention strategies to reduce exposure risk. Such information delivered effectively to local residents empowers them to make personal decisions and to take appropriate actions.

St. John's is an old city, with a long history of domestic coal burning, vehicular traffic, and painted clapboard houses. The legacy of these activities appears to be levels of lead, arsenic, zinc, copper and other elements in urban soils that exceed national soil guidelines, and which may have implications for human health. These elements also naturally occur in the rocks and soils of the St. John's area, albeit at much lower levels. The potential anthropogenic sources of soil metals were not uniform across St. John's leading to distinct spatial patterns of soil geochemistry across the city and on residential properties. These urban geochemical maps are an important first step in the assessment of public health risk and the development of strategies for landscape remediation.

Significance of newly discovered Cambrian macrofossils from the Phillips Brook and North B Brook anticlines, Western Newfoundland

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Sixty-four macrofossil collections have been obtained from newly discovered fossiliferous areas/localities in shelf carbonates and lesser shales and siltstones of the Middle to Late Cambrian Port au Port Group in the Phillips Brook and North Brook Anticlines of western Newfoundland. The fauna is dominated by trilobites and inarticulate brachiopods, but also includes ostracodes and gastropods in some of the younger beds.

The March Point Formation, 50 m of limestone and minor shale and siltstone, has yielded a sparse late Middle Cambrian fauna of small trilobite fragments and inarticulate brachiopods. The conformably overlying Petit Jardin Formation comprises 340 m of limestone, dolostone and shale, divisible into several members. Much of the formation hosts a fairly rich early Late Cambrian (Dresbachian) fauna that is dominated successively by *Arapahoia raymondi* Lochman, 1938 and *Crepicephalus rivus* Kindle, 1948. The presence of *Irvingella major* Ulrich and Resser, 1924 in a mound bed just 90 m below the top of the formation indicates that the limestones of the formation range into uppermost part of the medial Late Cambrian (Franconian) *Elvinia* zone. Ostracodes also occur with the Franconian faunas.

The Berry Head Formation comprises a lower dolostone member and an upper member of peritidal limestone, dolostone and minor shale. The lower member is barren except for local inarticulate brachiopods. The basal part of the upper member contains the latest Cambrian (Trempealeauan) trilobites *Calvinella tenuisculpta* Walcott, 1914, *Plethopeltis armatus* (Billings, 1860) and *Stenopilus* sp. undet., plus inarticulate brachiopods, ostracodes and some gastropods (including *Sinuopea*).

Urban rivers and flooding in northeast Avalon

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Rivers in northeast Avalon occupy bedrock valleys connecting fens, former meadows, and ponds. All are 'cascade' streams, with straight short reaches and ponds and pools that act to store sand and gravel. Pools are flushed by spring flooding. Downstream movement of sediment provides suitable spawning sites for fish, but also leads to channel obstruction that can accentuate flooding.

River valleys have been partially infilled and used for construction of roads and buildings. Flooding results from late winter rain-on-snow storms, spring snowmelt, and hurricanes. O'Leary's Brook has overflowed during several storm events in the past 10 years, resulting in flooding of the Avalon Mall. The areas surrounding the Rennies River, Quidi Vidi Lake, and Virginia River, and short cascade streams in Torbay, Portugal Cove, and Conception Bay South also are subject to flooding. More than 60 floods have occurred along the Waterford Valley since 1934.Floods may occur at any time during the year following heavy rainfalls, notably the more than 120 mm of rain brought by Tropical Storm Gabrielle in September 2001. Rapid runoff into the Waterford River from steep slopes and paved surfaces results in flooding almost immediately after any storm with more than 40 mm of rainfall within 24 hours. Flooding in the northeast Avalon would be influenced by changes in the magnitude, number, and timing of hurricane events. Overall precipitation has increased in Atlantic Canada, in accordance with predictions from climate change models. An increase in precipitation, coupled with marginal decreases or no change in winter temperatures, would make rain-on-snow events more likely.

Flooding events are not statistically associated with overall wet years, and total annual precipitation increases do not directly imply increased flood risk. Anomalously dry years are not necessarily associated with reduced risk of flooding, and flood events are not directly associated with heavy precipitation following dry conditions. Precipitation records show annual variation in excess of 100% for Torbay. The available data does not indicate a definitive link between overall regional climate variation and flood frequency. Most flood events involve combinations of one (or more) natural causes coupled with anthropogenic factors. Drainage infrastructure that is unable to evacuate water rapidly, buildings erected in vulnerable locations, and diversions or modifications of natural drainage are common factors. Construction in upslope positions increases flood risk in lower areas. Municipal planning is critical to avoid, mitigate, or resolve anthropogenic factors contributing to flooding. Maintenance of infrastructure is a major factor in limiting damage from successive rainfall events.

Hurricanes, autumn and winter storms, spring rain-on-snow events, and ice jams are consequences of the natural environment. Even under the predicted climate change that will influence the northeast Avalon in coming decades, the styles of flooding due to natural causes will not differ in the future. Although some flooding is inevitable and unavoidable, human choices can be made that minimize community and individual vulnerability. Flood mapping, analysis, and socio-economic assessment provide information towards these goals.

The genesis of Carlin-type gold deposits – current models and future research

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Carlin-type gold deposits, first discovered in northern Nevada in the early 1960s, have enormous gold endowments and have made the Carlin trend one of three gold districts in the world to produce more than 50 million ounces of gold. Forty years of mining and numerous studies have provided a detailed geologic picture of deposits, yet a comprehensive and widely accepted genetic model remains elusive. Currently considered models relate deposits to 1) epizonal plutons that contributed heat and possibly fluids and metals, 2) meteoric fluid circulation resulting from crustal extension and/or widespread magmatism, and 3) metamorphic fluids, possibly with a magmatic contribution, from deep crustal levels. Difficulties in unravelling deposit genesis are directly related to complications in studying the deposits. Minerals that are part of the Carlin event are fine-grained, volumetrically minor, and common (pyrite, quartz, kaolinite, illite). The regions where the deposits are located have experienced several hydrothermal events, and these common minerals precipitated repeatedly in response to many different processes. As a result, bulk analyses of samples simply produce a signal that is a mixture of several events. Microanalyses can produce a signal from a single geologic event, but require careful petrography to distinguish "Carlin" crystals from pre- or post-Carlin crystals.

A number of geochronological studies during the past 5 to 10 years have led to a consensus that the deposits formed during the late Eocene, permitting us to confidently relate the deposits to their tectonic setting. We now recognize that continental rifting followed by compressional orogenies provided a pre-mineral architecture of steeply dipping faults that acted as fluid conduits, high-level shallowly dipping "traps" or aquitards that inhibited fluid ascent to the surface, and reactive calcareous host rocks. Miogeoclinal sequences that formed following active rifting of the continental margin contain reactive silty calcareous rocks, which are the primary host rocks in almost every Carlin-type deposit including all of the >5 million ounce deposits. The main host unit for Carlin-type deposits is the lower plate to the Roberts Mountain thrust. Most giant deposits lie within 100 meters of the thrust or its projection. The thrust is important as it formed a regional aquitard by placing non-reactive, fine-grained siliciclastic rocks with less inherent rock permeability above favorable carbonate stratigraphy and it forced fluids laterally away from conduits and into reactive rock types. NNW and WNW-striking basement and Paleozoic normal faults were inverted during post-rifting compressional events, resulting in structural culminations (anticlines and domes) that in the Eocene served as depositional sites for auriferous fluids. These culminations are now exposed as erosional windows through the siliciclastic rocks of the Antler allochthon.

Extension during the Eocene in the Great Basin was broadly oriented northwesterly to westerly (280° to 330°). The underlying rifted plate margin and northwesterly oriented Paleozoic faults were subparallel to the extension direction and were reactivated as strike-slip or oblique-slip faults. Northeasterly oriented pre-Jurassic fault fabrics were favourably oriented for extension. Mineralization is associated with the heterogeneous shear and tensional reactivation of these older, variably oriented, structures. Fluid flow and mineral deposition appear to have been fairly passive as there is little evidence for overpressured hydrothermal fluids, complicated multistage vein dilatancy, or significant syn-mineralization slip. Geologic reconstructions and fluid inclusions indicate that deposits formed within a few kilometers of the surface.

Ore fluids were moderate temperature (~180–240°C), low salinity (~ 2–3 wt % NaCl equivalent), CO_2-rich (< 4 mole %), and CH_4-poor (<0.4 mole %) with sufficient H_2S (10^{-1} to 10^{-2} m) to transport gold. The singular occurrence of "invisible" gold in pyrite in unoxidized ore indicates that ore fluids were undersaturated in gold until fluids reacted with wallrocks. Fluid-rock reaction liberated reactive Fe in the wallrock, which reacted with sulphur in the fluid to form pyrite. This reaction reduced the aH_2S in the fluid, destabilized the gold-bisulphide complex, and gold and other bisulphide complexed metals were captured as submicrometer structurally bound or native particles in the pyrite. Ore fluids additionally decarbonatized, argillized, and locally silicified wall rocks.

Isotopic studies constrain sources of ore fluid components, but do not provide unequivocal sources or clearly indicate a preferred genetic model. O and H isotopes of minerals and fluid inclusions at the Getchell deposit consistently indicate that ore fluids had a deep magmatic or metamorphic source. However, most similar studies of deposits in the northern Carlin trend and at Jerritt Canyon have identified a meteoric fluid. Sulphur isotopes in ore pyrite from all districts can be derived from a sedimentary sulphur source. However, sulphur in ore-stage pyrite at Getchell exhibit values near 0 per mil, consistent with a magmatic source. Two recent studies at the 30 million ounce Betze-Post deposit in the northern Carlin trend are also consistent with a magmatic sulphur source; however, other studies at this deposit identified higher sulphur isotopic ratios that are not consistent with a traditional magmatic sulphur source. He isotopic studies have been conducted only at the Getchell deposit where inclusion fluids in late-ore stage galkhaite, orpiment, and fluorite contain He with an unequivocal but highly diluted mantle signature.

A compilation of data from all trends and districts provides compelling similarities and requires that all Carlin-type deposits formed in response to similar geologic processes. We propose a deep fluid model in which primitive ore-related fluids were generated in response to removal of the Farallon slab, which promoted deep crustal melting, prograde metamorphism, and devolatilization. Primitive fluids travelled upward through the crust, scavenging ore fluid components along the fluid pathway, and were diluted by deeply circulating meteoric water in the upper crust prior to reacting with wallrocks and depositing gold.

Stratigraphic, structural setting and mineralization of the Jaclyn Zone, Golden Promise Property, Central Newfoundland

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The Golden Promise Property is centred approximately 30 km west of the Town of Grand Falls-Windsor and encompasses the Town of Badger and occurs entirely within NTS sheets 12A/16 and 02D/13. Access to the property is excellent along several logging and skidder roads and by the Trans-Canada and Buchans highways which transect the property.

High-grade gold-bearing quartz vein float was discovered during the spring of 2002 by local prospector Mr. William Mercer, leading to the discovery of the Jaclyn Zone. From August 2002 to December 2004, Rubicon along with its partner Placer Dome Inc., have completed 46 holes for a total of 5950 m of NQ and HQ core diamond drilling resulting in the discovery of the Jaclyn, Jaclyn North and Jaclyn South and Christopher zones. Highlights include intersections of up to 16.57 g/t Au over an estimated true thickness of 1.64 m; 25.74 g/t Au over an estimated true thickness of 0.63 m; and 68.95 g/t Au over an estimated true thickness of 0.21 m. Results from diamond drilling document the Jaclyn vein system as developed over a minimum 375 m strike length to a vertical depth of 192 m. Rubicon and Placer have also completed 8250 line km of high-resolution airborne geophysical surveys (magnetics, resistivity) over the Golden Promise Property, in additional to regional prospecting, soil sampling, and geological mapping. Drilling during the fall of 2004 was successful in intersecting the Christopher (3.4 g/t Au) and the Jaclyn North (3.8 g/t Au over 0.4 m) zones that represent possible extensions to the Jaclyn and Jaclyn North vein systems 600 and 400 m to the west of the previously drilled zones, respectively.

The property is located within the Exploits subzone near the western edge of the Dunnage Zone, just south of the Red Indian Line. It is underlain by Badger Group sedimentary rocks that conformably overlie Caradocian black shales, which in turn overlie Middle Ordovician epiclastic and sedimentary rocks of the Victoria Lake supergroup. The Victoria Lake, Caradoc, and Badger stratigraphy has been deformed about tight to isoclinal, upright, northeast-plunging folds. F_1 folds are cut by the 411±6 Ma Hodges Hill granite stock in the north. Quartz veins and major fault zones throughout the area trend northeast (070°), easterly (120°) and are related to deformation during formation of F_1 folds. Carbonatized, buff coloured mafic dykes are observed to intrude the local stratigraphy and occupy the same structure as gold-bearing quartz veins of the Jaclyn and Jaclyn North Zones.

A comparative analysis of gold occurrrences from the Sops Arm area – the first gold-only producers in Newfoundland

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Seven auriferous occurrences in the Sops Arm area were examined. Mineralization is hosted by two different units of the Silurian Sops Arm Group, i.e., the Lower Volcanic Formation composed dominantly of rhyolite with lapilli tuff and silicic ash, and the Simms Ridge Formation, a sedimentary unit comprised of numerous rock types including limestone, siltstone and shale. Sulphides present are mainly pyrite and galena, with lesser amounts of bornite, chalcopyrite, and/or pyrrhotite. Most sulphides occur in quartz and quartz-carbonate veins, alluding to a structural control on mineralization.

Hydrothermal alteration associated with the auriferous zones consists of varying degrees of potassic alteration and sericitization. Carbonates are also commonplace with minor chlorite and epidote. Sulphur isotope geothermometry calculations and fluid inclusion homogenization temperatures both indicate formation temperatures in the range of 200 – 350°C. Additionally, fluid inclusion data suggest a low salinity fluid (<6% NaCl). Pb isotope data from galena separates indicate that the Pb was derived from two sources, Grenville basement rocks and Silurian (?) supracrustal rocks, and that the Pb ratios are mixtures of the two sources with the ratios of individual occurrences distinguished by proximity to the either of the two sources. Visible gold was not observed at any location and gold was not detected in petrographic or SEM analysis. LAM-ICP-MS analyses, however, indicate that gold is present in pyrite (up to 4600 ppm) and galena (up to 4.9 ppm) as either: (1) a "refractory", or sulphide-bound, component, or, (2) as micro-inclusions. Electrum micro-inclusions may be present locally. Pyrite crystals have As-enriched rims (up to 75 ppm As) to cores with lower As contents (4 ppm); chalcopyrite has less As-enriched rims. The rims suggest late-stage As precipitation from ore fluids.

The apparent structural control on mineralization, fluid properties (temperature and salinity), and variation in host rock lithology strongly suggest an orogenic lode gold deposit model. As such, the Sops Arm veins are distinctly different from Carlin auriferous systems, but are similar to auriferous vein systems developed in Grenvillian basement rocks 15 km to the NE.

St. John's Geoscapes: the use of local stone in buildings and structures

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Many buildings in the City of St. John's have used local stone in their construction since the building of the 18th-century forts that used stone for battlements. Detailed mapping by Dr. Art King indicates that the geology of St. John's has three main components. In the western area of St. John's, the green-grey, siliceous, turbiditic siltstone and sandstone are part of the Conception Group. In the central part of St. John's, including the Downtown area, the dark grey, variably cleaved, sandstone, siltstone, and shale define the St. John's Group. To the east, the grey, green and red sandstone and conglomerate form the Signal Hill Group. The gradational but consistent changes in rock type and colour across St. John's permits the assignment of the local building stones to a particular stratigraphic unit.

The battlements of Fort William were made from grey sandstone of the St. John's Group. Many of the 19th-century buildings have foundations made from grey, flaggy sandstone and siltstone also from St. John's Group. The outside walls of the Basilica, St. Patrick's Church, and the Anglican Cathedral are known, from reports, to have been faced with grey sandstone from quarries in the Renews Head Formation of the St. John's Group in the Shea Heights area. Several buildings and retaining walls in the Downtown area have been constructed from the red and cream sandstone of the Gibbett Hill and Quidi Vidi Formations of the Signal Hill Group, e.g., the Temperance Street houses. The barracks and battlement at the Queen's Battery and the Powder Magazine near Cabot Tower are constructed from the grey-green and red sandstone of the Gibbett Hill and Quidi Vidi formations of the Signal Hill Group. Government House on Military Road was built in 1831 and is faced with the red sandstone of the Quidi Vidi Formation. On Signal Hill, the base of Cabot Tower is composed of red pebble conglomerate and sandstone from the adjacent Cabot Tower Member of the of the Cuckold Formation of the Signal Hill Group. There is currently little use of new local building stone but some of the old stones are recycled during restoration work and the construction of retaining walls.

Raising awareness of the materials used in prominent buildings in the city will promote a better understanding of local geology, geological history and the importance of resources in the historic development of St. John's.

Geology and U-Pb geochronology of high-grade gold mineralization: the example of the Goldcorp Red Lake mine, Canada

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The giant Campbell-Red Lake deposit, actively mined by Placer Dome Inc. (Campbell mine) and Goldcorp Inc. (Red Lake mine), represents one of the largest and richest Archean gold deposits. The total deposit size (past production + reserve) is approximately 840 t of gold and an average grade of 21 g/t Au. The Goldcorp High-grade Zone at the Red Lake mine has produced more than 2 M oz at an impressive average grade of 88 g/t Au since the beginning of its extraction in 2001. Reserves (proven and probable) are established at 1.775 million metric tonnes at an average grade of 80.6 g/t Au. Such high-grade mineralization provides an opportunity to define fundamental geological parameters controlling the formation of high-grade ore and to assist in developing exploration guidelines for similar prime targets.

The Campbell-Red Lake gold deposit is hosted mainly by tholeiitic basalt of the Mesoarchean Balmer assemblage. Peridotite komatiite, variolitic basalt, rhyolite and associated mafic intrusions of the ca. 2.99–2.96 Ga Balmer assemblage, and felsic pyroclastic rocks with clastic and chemical sedimentary rocks of the ca. 2.984 Ga Bruce Channel assemblage complete the sequence in the mine. The deposit is stratigraphically below a folded regional unconformity marking the contact between locally overturned Balmer assemblage volcanic rocks and overlying volcanics of the ca. 2.75–2.73 Ga Confederation assemblage. Gold mineralization in the Goldcorp High-grade Zone is related to silicification and brecciation of pre-existing cm- to m-wide foliation-parallel and oblique extensional, barren to low grade iron-carbonate±quartz colloform-crustiform veins and cockade breccias that are extensively developed in basalt. High-grade replacement mineralization is also present in the arsenopyrite-rich selvages hosting the silicified veins. Gold mineralization in the High-grade Zone is syn-D_2 deformation, a protracted event that resulted in NE-SW directed shortening in the vicinity of the Campbell-Red Lake deposit.

New U-Pb geochronological data combined with detailed mapping and cross-cutting relationships between high-grade ore and intrusive dykes provides timing constraints and new insights into the formation of the exceptionally-rich High-grade Zone in relation to the geological evolution of the Red Lake district and the Superior Province. The results show that the main stage of the high-grade mineralization is pre-2712 Ma, and that a second stage of gold mineralization, much smaller in terms of total gold content but extremely spectacular in terms of grade, is post-2702 Ma. It is proposed that the main stage of high-grade mineralization formed between ca. 2723–2712 Ma, possibly synchronous with emplacement of the Dome and McKenzie Island stocks, the Abino granodiorite and Hammell Lake batholith, as well as with penetrative D_2 tectono-metamorphism. The second stage is attributed to gold remobilization. Lamprophyre dykes spatially associated with the deposit postdate main-stage mineralization by at least 10 Ma. The presence of the lamprophyre dykes indicates that the structural corridor hosting the Campbell-Red Lake deposit has deep roots that facilitated the emplacement of lamprophyric magmas to higher crustal levels.

A folded and metamorphosed polymictic conglomerate located above the Campbell-Red Lake deposit, deposited after ca. 2747 Ma, is correlated with the Huston clastic assemblage. Cross-cutting relationships between the conglomerate and the alteration indicate protracted multistage aluminous and iron-carbonate ± quartz veining/alteration event(s) pre- and post-conglomerate deposition. The conglomerate confirms that the Campbell-Red Lake deposit is proximal to a folded regional unconformity supporting the empirical relationship between gold deposits and unconformities elsewhere in greenstone belts. Proximity to such paleosurface represents a key first order exploration target for world-class gold deposit.

Timing and global tectonic controls of gold deposits in metamorphosed terranes

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Epigenetic gold deposits in metamorphic terranes include those of the Precambrian shields (approx. 23,000–25,000 t Au), particularly the Late Archean greenstone belts and Paleoproterozoic fold belts, and of the late Neoproterozoic and younger Cordilleran-style orogens (approx. 22,000 t lode and 15,500 t placer Au), mainly along the margins of Gondwana, Laurentia, and the more recent circum-Pacific. Prior to the last 25 years, ores were defined by grades of 5–10 g/t Au; present-day economics and improved mineral processing procedures allow recovery of ores of ~1 g/t Au, which has commonly led to the recent reworking of lower grade zones in many historic orebodies. Most of these deposits formed synchronously with late stages of orogeny and are best classified as orogenic gold deposits, which may be subdivided into epizonal, mesozonal, and hypozonal subtypes based on pressure-temperature conditions of ore formation. Ore formation was concentrated during the time intervals of 2.8–2.55 Ga, 2.1–1.8 Ga, and 600–50 Ma. The temporal pattern, from episodic to more cyclic, broadly mirrors that of crustal growth. The older Precambrian deposits remained protected from uplift and erosion in the centers of buoyant cratons, but such deposits are rare between ca. 1.7 Ga and 600 Ma due to change to more modern-style plate-tectonic processes, with non-preservation of deposits of this age due to uplift and erosion of the ore-hosting and more-vulnerable younger orogenic belts. Giant orogenic gold deposits (>500 t Au) occur in all areas of the globe and formed during each of the time spans. A second type of deposit, termed intrusion-related gold deposits (IRGD), developed landward of Phanerozoic accreted terranes in the Paleozoic of eastern Australia and the Mesozoic of the northern North American Cordillera. These have an overall global distribution that is still equivocal, and are characterized by an intimate genetic association with relatively reduced granitoids.

The distribution of gold in sulphides from the Lodestar Prospect, Newfoundland, as determined by LAM-ICP-MS analyses

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At the Lodestar Prospect, eastern Newfoundland, sulphide-mineralized, polylithic, magmatic-hydrothermal breccias have significant gold contents including 58.5 g/t Au in a grab sample of massive arsenopyrite. Other sulphide phases do not contain such highly anomalous Au values. Based on this observation, it was concluded that Au at the Lodestar Prospect is directly related to the arsenopyrite. A variety of analytical techniques, including ore microscopy, INAA, SEM, and EMP, were utilized in an attempt to determine where the Au was located in the sulphides and all were unsuccessful. Consequently we decided to analyse sulphides in polished thin sections by in-situ Laser Ablation Microprobe Inductively-Coupled-Plasma

Mass Spectrometery (LAM ICP-MS). The LAM ICP-MS results demonstrate that the Lodestar arsenopyrite contains up to 201 g/t Au and that Au is homogeneously (i.e., no nugget effect) contained, chemically bound, within the structure of arsenopyrite. Such gold is typically termed "refractory" or "invisible". Pyrite and chalcopyrite contain very low levels of Au. Gold contents within individual arsenopyrite crystals vary, related to arsenic concentrations.

New perspectives on the origin and distribution of Cenozoic epithermal gold-silver deposits in the northwestern United States

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Epithermal Au and Ag deposits form at <1 km depth and <300° C, mostly within the central, up-flowing parts of high-temperature hydrothermal systems that develop mainly at convergent plate margins in association with arc magmatism, as well as in intra-arc, back-arc and post-collisional rift settings. Numerous schemes for classification of epithermal deposits have been proposed based on minerals and textures observable in hand specimen, and in a few cases, distinctive igneous rock affiliations. Several classification schemes that reflect acid-base and reduction-oxidation fluid-mineral equilibria distinguished acid-pH-type deposits (acid-sulphate or alunite-kaolinite) from near-neutral pH type deposits (adularia-sericite). Epithermal deposits also can be distinguished by their ore mineral assemblages in terms of their high (HS), intermediate (IS), or low (LS) sulphidation state with HS deposits corresponding to acid-sulphate deposits and IS and LS deposits corresponding to adularia-sericite deposits.

In the northwestern United States, Cenozoic epithermal Au-Ag deposits are widespread but unevenly distributed in time and space. They are most abundant in the northern Great Basin and sparse in the Western Cascades, northern Rocky Mountains, and Columbia Plateau. In the northern Great Basin, most deposits are Miocene and younger and are spatially related to two igneous suites: (1) bimodal basalt-rhyolite and (2) western andesite. In contrast, few epithermal deposits in this region are exposed in the more voluminous Eocene to early Miocene igneous rocks of the interior andesite-rhyolite assemblage; the largest deposit is the Round Mountain LS deposit. The bimodal suite is a reduced, high-K tholeiitic series, mostly of basalt, andesite, and rhyolite, formed during continental extension. In the bimodal suite, LS Au-Ag deposits formed in two distinct settings: (1) rhyolite flow domes and (2) mafic igneous rocks of the northern Nevada rift. The LS deposits include Midas, Sleeper, Mule Canyon, Buckskin-National, and Delamar; HS and IS deposits are absent. The western andesite suite is an oxidized, high-K calc-alkaline series of andesites and dacites formed in a subduction-related continental-margin arc along western North America. HS, IS, and sparse LS Au-Ag and porphyry Cu-Au deposits are present in the western andesite suite and include Comstock Lode, Tonopah, Goldfield, Bodie, Paradise Peak, and Rawhide.

Compared to epithermal deposits in the western andesite suite, LS Au-Ag deposits in the bimodal suite formed under low fO_2 and fS_2 and generally have low base-metal contents, low Ag:Au ratios, and common selenide minerals. Petrologic studies suggest that these differences reflect variations in the petrotectonic settings of the associated magmatic assemblages. The contrasting types of epithermal deposits and associated igneous rocks suggest that there is a strong genetic link between epithermal Au-Ag deposits and magmatism.

The dearth of epithermal deposits in the interior andesite-rhyolite assemblage, including in the northern Rocky Mountains (Challis Volcanics), and in the Eocene to Pliocene Western Cascades arc in Oregon and Washington may reflect (1) preservation, (2) eruptive style or rates, (3) basement rocks, (4) tectonic setting, (5) depth of magma generation, or (6) a combination of these or other factors. These topics are the subject of ongoing research.

Geology and geochemistry of the Rattling Brook gold deposit, western Newfoundland: An assessment in the context of new exploration models

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The Rattling Brook gold deposit is a large, dispersed, low-grade system in which auriferous sulphides are disseminated or present in myriad tiny veinlets. Larger and more continuous quartz vein systems typical of most gold deposits are conspicuously absent. The dominant host rocks are altered Precambrian granites, but some of the best mineralization occurs in altered Precambrian metadiabase dykes and in Cambrian quartzite, limestone and phyllite. The mineralization must be post-Cambrian, but its timing is otherwise unconstrained, although a Silurian or younger age is implied by its undeformed character. The commonality of textures in mineralized rocks, and broadly similar alteration sequences, suggest that a single process deposited gold in all of these host rocks. Petrological and metallurgical studies indicate that free gold is very rare and imply that much of the gold is refractory, likely held within sulphides. The most likely candidates are gold-rich arsenopyrite or gold-rich arsenian pyrite, but the latter has yet to be firmly identified. Geochemical data indicate that there is very little associated Ag, and essentially no enrichment in Cu, Zn, Pb, Co, or Ni. There are strong Au-As-S correlations, and a diffuse Au-Ag correlation, but essentially no correlation between gold and the base metals. Auriferous samples are also commonly enriched in Te and W, and there is more diffuse enrichment in Sb. A few auriferous samples display marginal enrichment in Tl, but no obvious enrichment in Hg or Se is present. The geochemical characteristics and associations resemble those described from sedimentary-rock-hosted micron ("Carlin-type") gold deposits or generally similar noncarbonate-hosted disseminated-stockwork gold deposits. These conclusions are encouraging in the context of new exploration models for western Newfoundland. However, there remains a pressing need for more extensive and precise trace element geochemistry, and for more information on sulphide mineral assemblages and the precise habitat of the gold.

Meguma gold deposits of Nova Scotia: complexities of mesothermal, sediment-hosted gold mineralization revealed

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Meguma gold deposits (MGD) have long been considered classic examples of lode-gold mineralization hosted by slate-rich sedimentary successions. The MGD occur in the Meguma Terrane (MT) of southern Nova Scotia, an area dominated by two lithotectonic units, the Cambro-Ordovician Meguma Group metasedimentary rocks and 380 Ma peraluminous South Mountain Batholith (SMB). The area was subjected to a protracted deformational history, commencing with the Acadian Orogeny at ca. 410 Ma, but continuing intermittently through the Carboniferous. Gold mineralization is dominantly of quartz (±carbonate±sulphide) - vein type with emplacement of veins controlled by strain associated with deformation of the Meguma Group. The development of chevron- and box-folds during deformation promoted flexural shear in the inter-bedded sandstone-siltstone sequence, thus vein types are dominated by bedding-concordant veins arrays (including massive and laminated bedding parallel, saddle-reef, and en echelon) and discordant types. Extensive studies of MGD over the years have documented the structural controls on vein emplacement, both relative and absolute (Re-Os, Rb-Sr, $^{40}Ar/^{39}Ar$) age(s) of vein formation, and the nature of vein-forming fluids (isotopes, fluid inclusions). Importantly, these data indicate that: (1) the vein-forming fluids are exotic to the Meguma Group, (2) multiple periods of vein emplacement occurred, (3) the fluid corresponds to the global aqueous-carbonic gold fluid, and (4) variable interaction with the host rocks occurred. A model for MGD formation, involving vein-fluid generation and vein emplacement, involves metamorphic devolitization of basement rocks and ascent of this fluid into the overlying Meguma Group with subsequent focussing of fluids into structurally favourable sites during periods of fold reactivation. Importantly, a flexural-fold mechanism of vein formation, as demonstrated here, provides a predictable framework for exploration and development of MGD. Robust age constraints indicate at least two periods of vein formation, one at ca. 408 Ma and the other at 380 Ma, but additional periods are possible (e.g., Alleghanian reactivation). More recent developments of MGD will also be discussed, including the ongoing exploration for disseminated gold mineralization of the Touquoy type at Moose River, where a current resource of ca. 571,000 oz (843 Mt @ 2.1 g/t) has been delineated, and the potential for intrusion-related gold mineralization associated with the voluminous 380 Ma intrusions such as the SMB.

Inverted geotherms within accretionary complexes: implications for the metamorphic orogenic gold deposit model

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There is considerable evidence for a metamorphic origin for lode gold deposits, although the fluid isotopic signature, episodic nature of fluid expulsion, and gold solubility considerations are problematic. The oxygen isotopic signature of quartz and carbonate within the vein systems are typically between 15‰ and 10‰, which between 350° and 250°C is associated with fluids between 10‰ and 1‰. This range of fluid compositions typically falls on the isotopically light end and even outside of the D-O metamorphic water box. However, high-T dehydration reactions of sedimentary and even low-T, seawater-altered mafic volcanic rocks at depth should typically yield fluids of heavier isotopic composition. Given a normal metamorphic gradients, these infiltrating fluids should subsequently deposit quartz and carbonates at lower T's within greenschist-grade shear zones; the oxygen isotopic composition of quartz and carbonate should then be higher than is typically observed. Magmatic and meteoric fluids have been used to explain the relatively light oxygen isotopic values inferred for the mineralizing fluid; these models invoke hydrothermal circulation systems with magmatic heat sources driving isotopically light fluid convection. This, however, is generally inconsistent with the permeability structure and syndeformational prograde metamorphic assemblages present.

An alternate model involves progressive dehydration reactions within a region of inverted geotherms to account for the light oxygen isotopic signatures of the infiltrating early metamorphic fluid. Within large (old) accretionary wedge complexes, internal radioactive heating, magmatic heating across the buttress, and mid-wedge level frictional heating occurs (Barrovian-like). The continuous subduction of hydrated ocean crust (old, cold) with fore-arc and trench sediments undergoing progressive dehydration during underplating provides a continual source of isotopically light, low salinity, low-T fluids that are heated during upward egression through the deforming wedge complex. Even with these high fluid/rock, heterogeneous isotopic re-equilibration is typical and chemical modifications are common as most of the fluid flux would be focused along fabrics and shear zones, possibly forming gold mineralization near the brittle-ductile transition (upper part of wedge), if the fluid fluxes were high. The lower T's involved in the lower wedge would enhance gold-bisulphide complexing and would be consistent with the low pH alteration and retrogression to greenschist-grades typically seen within shear zones. Lastly, the evolution of the accretionary complex to a terminal collisional orogen (possibly with slab rollback) would result in dehydration reactions related a normal thermal gradient being established. These later metamorphic fluids would also be focused along reactivated shear zones within the exhuming orogen.

Geoscape St. John's – a new initiative

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The Geoscape concept was created by John Clague and Bob Turner of the Geological Survey of Canada, and was launched in 1995 with Geoscape Vancouver. The Geoscape project aims to better inform Canadians about important geoscience issues in their communities and to improve "geoliteracy" through a series of products. Canadian communities can be more sustainable if they understand their local geological landscape – their water resources, natural hazards, earth resources, and environmental services. Benefits include: protection of groundwater and surface water supplies; mitigation of natural hazards such as floods, landslides, earthquakes, radon; development of earth resources such as aggregate and minerals; and protection of natural services provided by soils, streams, and wetlands.

The heart of the project has been a series of posters that are widely distributed within the communities that are supplemented by other material – web sites, transparencies, slide sets, thematic posters. They have been backed up by workshops and field trips for teachers. Eleven Geoscape posters have been completed (Vancouver, Victoria, Nanaimo, Fort Fraser, Whitehorse, Edmonton, Calgary, southern Saskatchewan, Toronto, Ottawa, Montreal, and Quebec City), and five more are in preparation (Halifax, Grand River, northern Saskatchewan, Northwest Territories and Nunavut). A Geoscape geological map of Canada has also been prepared.

Each poster is prepared based on contributions form the local geological community, but an examination of the posters prepared to date shows some common themes. The basic layout consists of an arresting central image, surrounded by 10 – 12 panels, each illustrating a single theme. The panels rely mainly on graphics to illustrate the theme, accompanied by 200–400 words of explanation. All posters to date cover themes encompassing bedrock geology, glaciation, groundwater, and mineral resources, and most cover hazards (earthquakes, landslides, volcanism, flooding). These common themes are supplemented by those of more local relevance – agriculture, radon, water resources, building stone.

St. John's is an ideal site for a Geoscape poster, with a city landscape much influenced by geology, a long history of geological hazards (flooding, avalanches, landslides), and a strong local geological community. Some themes have been tentatively identified (bedrock geology, plate tectonics, glaciation, urban rivers and flooding, geochemical landscape, St. John's harbour, landslides and avalanches, and building stone). It is anticipated that this meeting will provide a focus for discussion, consolidate possible themes, and lead to development of a draft poster in the course of 2005, with a projected production date in 2006.

Geoscience education in our community

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Our lives are inextricably linked to the Earth. Everyday conversations, the television, and the newspapers are full of references to earth science – volcanic events, earthquakes, tsunamis, mud slides, availability of underground water, and exploration of other planets. Geological processes have influenced the shape of the land upon which we live and provided resources to fulfill our basic needs. However, many people are not aware of the integral role earth science plays in our lives.

As citizens, we are required to make decisions about socio-scientific aspects of these problems, and frequently, uniformed or misinformed but concerned citizens make these decisions. To make knowledgeable decisions we must critically review all scientific information presented. This means that earth science concepts, and science as a whole, should be understood in a significant way by all citizens.

Nowhere is this more true than in Newfoundland and Labrador. For the last 7500 years, the people of this land have extracted its resources (fish and animals, minerals and rock, oil and gas) to survive. Very few of the residents of our province are aware of the significance that ancient geological processes have played in providing the valuable resources which brought them to this new land in the beginning and upon which they now depend. Nor are they aware of the magnitude of the importance of the rock on which they live.

We must strive for improvements in the earth science education of students, teachers and all residents of this province. Through partnerships within the geoscience community – government, industry, academia, and museums – we can fulfill an important role in promoting the understanding and awareness of earth science. The Geoscape St. John's partnership is an excellent initiative aimed at increasing the awareness of geoscience issues facing the citizens of this community. EdGEO is another such excellent initiative, bringing together partners from all walks of the geoscience community to better the earth science knowledge of teachers in our schools. GEO Classes, offered at the Johnson GEO CENTRE with the assistance of members of the local geoscience community, are engaging, interactive, hands-on classes aimed at motivating K–12 students in the province to take an interest and see the value in earth science.

There must be a move toward greater scientific literacy, so that earth science teaching becomes more closely focused on preparing all Newfoundlanders and Labradorians for life in the scientific and technological world. Together we can turn earth science apprehension into comprehension, and enable our people to adopt values and interests consistent with their being guardians of the present fragile environment of our province and our planet.

Neoproterozoic epithermal and intrusion-related gold systems in accreted terranes of the Newfoundland Appalachians

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The formation and preservation of precious-metal bearing epithermal and intrusion-related systems are integral aspects of the Late Neoproterozoic tectonic history of the volcano-plutonic arc complexes that characterize the peri-Gondwanan accreted terranes of the eastern Appalachian Orogen. Neoproterozoic high-sulphidation, low-sulphidation and intrusion-related gold systems in peri-Gondwanan terranes in the Newfoundland segment of the orogen were generated during several precisely dated, metallogenically significant, regional magmatic-hydrothermal pulses. These Avalonian gold systems formed in a once-contiguous, Pan-African-cycle orogenic belt, composed of complex assemblages of 760 to 540 Ma calc-alkaline to alkaline arcs and intervening marine and terrestrial siliciclastic sedimentary basins. Accretion of the mineralized arcs to the inboard Paleozoic elements of the Appalachians ocurred primarily in the Silurian and Devonian, during closure of the Cambro-Ordovician Iapetus Ocean.

Gold in the Neoproterozoic high-sulphidation systems occurs with copper in vuggy silica and in breccias and/or network fracture systems, within zones of polyphase silica alteration, enveloped by regionally developed zones of quartz–pyrophyllite–andalusite–alunite-bearing metamorphosed advanced argillic alteration. In other instances, regionally developed (and apparently barren) pyrophyllite–diaspore-bearing advanced argillic alteration zones, related to either weakly developed or deeply eroded high-sulphidation systems, are juxtaposed with younger Neoproterozoic low-sulphidation colloform-crustiform banded, silica–adularia vein and breccia systems that contain significant gold grades. Several of the epithermal belts are spatially associated with breccia-hosted Cu-Au and Au-Cu-Zn mineralization, however, most of this intrusion-related gold formed during demonstrably earlier magmatic events.

Large tracts of the mineralized Avalonian belt became submerged by the end of the Proterozoic and remained so, through the early Paleozoic, until Appalachian-cycle collision. Where the Avalonian rocks are far removed from the Appalachian hinterland, Neoproterozoic low-sulphidation mineralization is exceptionally well preserved. Deeper and more extensively tectonized high-sulphidation systems are preserved proximal to and within the Appalachian mobile belt on the Burin Peninsula and Hermitage Flexure regions of southern Newfoundland, respectively. Early tilting of the mineralized succesions and subsequent arc-rifting, collapse and marine incursions, during Late Neoproterozoic through Early Paleozoic break-up and dispersal of the Avalonian belt, helped significantly reduce the rate of erosion, allowing their preservation through time. The recognition of the geochemical, mineralogical and textural signatures of modern high- and low-sulphidation epithermal systems in these deformed rocks allows the distinction from mainly younger, shear-zone related (e.g. orogenic) gold systems formed at deeper crustal levels, within the Paleozoic orogenic hinterland.

Preliminary geochronological, geochemical, and isotopic studies of auriferous systems in the Botwood Basin and environs, central Newfoundland

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Gold exploration within the Botwood basin began in the late 1980s and subsequently several styles of mineralization were recognized in the region including low-sulphidation epithermal and orogenic (or mesothermal) lode types. More recently, the presence of possible Carlin and intrusion-related styles has been postulated. In fact, the suggestion of, and evidence for, sedimentary-hosted, Carlin-type gold occurrences in the basin created a staking rush in central Newfoundland during 2002. With the recognition of the basin as a possible host to a wide variety of gold occurrence types, it has become essential to fully understand the geological history of this area and the inter-relationships of the occurrence types. The purpose of this project is to study and compare 20 gold occurrences from within the basin and surrounding lithologies. A key question to be answered is whether regional intrusive suites (granitic to gabbroic) had anything to do with the ore-forming systems, acting as heat sources driving ore fluids, or just as rheologically contrasting host lithologies.

Preliminary conclusions from this study include the following: (1) Geochronological data indicate a common ca. 430 Ma age for granite and gabbro plutonism in the Botwood basin. Zircon inheritance in the granitoids suggests that they were generated through crustal anatexis of lower crustal material by mantle-derived gabbroic melts. Different gabbroic intrusive suites in the basin are defined by whole-rock geochemistry. (2) There are wide ranges in sulphur isotope ratios for sulphide mineral separates from different occurrences and the dominant control appears to be a lithological source of the sulphur, e.g. occurrences within deep marine sedimentary lithologies are negative in terms of $\delta^{34}S$(‰), occurrences in proximity to intrusive suites are around 0‰, and occurrences in which S was derived from igneous rocks have ratios that are slightly to moderately positive in terms of $\delta^{34}S$(‰). (3) Trace element compositions of pyrite suggest that different auriferous deposit types have recognizable signatures and that pyrite from the Mustang and Bowater prospects resembles Carlin-type pyrite, pyrite from the Bruce Pond Epithermal Prospect resembles that from low-sulphidation epithermal types of occurrences and pyrite from orogenic lode gold occurrences are not notably enriched in a trace metal contents.

Investigation of a late Proterozoic mafic sill and its environs – Cape St. Francis, Newfoundland

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The aim of this study is to characterize a mafic sill and its environs in the vicinity of Cape St. Francis, Newfoundland, and then investigate its implications for late Proterozoic bimodal magmatism in the Avalon Zone of the Appalachian orogenic belt. The sill defines a prominent ridge, approximately 600 m long and 87 m thick and is commonly bounded by northwesterly dipping arkosic sandstones and overlying sequences of pillow basalt and pillow breccia. Field observations, however, indicate that the sill locally cuts the pillow basalts near the westerly boundary of the ridge. To the north, cogenetic rhyolite domes puncture the sandstone. The sill itself has a bulk trachyandesite composition with a layered appearance, which is characterized by thin (1–2 mm) seams that are parallel to contacts and closest together near contacts. In some cases the sill has a banded appearance due to cm-scale leucocratic and melanocratic layers. An examination of the millimeter scaled variations of mineralogy within the layers using the Scanning Electron Microscope work indicated that there were two types of seams. One type has a highly silicic composition while the other has the same composition but is finer grained than the layers in which it occurs. Further examination of these layers will be completed using Microprobe analysis. Detailed ground-based magnetic and elevation surveys were carried out to build a three dimensional model of the sill morphology and extent below the surface. Regional geophysical surveys including vertical magnetic gradient, total magnetic field, and VLF-EM total field were analysed and compared with the ground magnetic survey. Geochemical analysis for major and trace elements has been completed on rock units that include basalt, rhyolite, arkosic sandstone, trachyandesite, and silicic seams.

Orogen-scale understacking and the preservation of old metamorphic rocks in the interior of a hot wide orogen: an example from the Grenville Province

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The Grenville Orogen is a crustal-scale thrust stack composed of longitudinal belts with distinctive *P-T* conditions and/or timing of metamorphism. Recent work has shown that adjacent belts with Ottawan metamorphism (ca. 1090–1020 Ma) exhibit metamorphic signatures implying development at very different levels in the orogen. The H*P* Belt, which is characterized by peak metamorphic conditions of ca. 1800 MPa/850 °C, is overlain by an M*P* Belt in which metamorphic conditions were ca. 800–1000 MPa/850 °C. Both belts are locally juxtaposed against the Non-Metamorphic Lid in which penetrative Grenvillian fabrics are absent and metamorphic temperatures were $500>T>350$ °C. Thus sections of the lower crust (60–70 km depth), mid crust (~ 30 km depth) and upper orogenic crust (depth undetermined) are preserved in close proximity to each other. The elevated temperature of regional metamorphism in the Ottawan H*P* and M*P* belts was associated with the emplacement of mantle-derived magmas locally, implying a mantle contribution to the thermal budget of the orogen. Mid- to late Ottawan juxtaposition of the lower-crustal H*P* Belt with the upper-crustal Non-Metamorphic Lid took place by the combined processes of tectonic extrusion and orogenic collapse, the latter probably facilitated by a ductile melt-weakened mid-crust. By the time of renewed convergence at ca. 1005 Ma during the Rigolet Orogeny, the H*P* and M*P* belts were in the upper crust and active ductile deformation in the orogen took place principally beneath them and nearer the foreland. Metamorphism during the Rigolet Orogeny was Barrovian in character and led to substantial crustal thickening in the vicinity of the Grenville Front and the parautochthonous northern margin of the orogen. The orogen thus grew by crustal-scale understacking resulting in preservation of the older metamorphic rocks in the orogenic superstructure. Post-Rigolet normal faulting affected the full thickness of the orogenic crust and displaced the Moho locally, implying orogen-scale orogenic collapse. The great width of the Grenville Orogen (> 600 km on the Laurentian side alone) and the prevailing high temperatures of Ottawan metamorphism reflect a Himalayan-scale orogen characterized by massive horizontal tectonic transport within a ductile lower and mid crust.

Tsunami – landslides, asteroids and quakes

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In the few short weeks since December 26th, 2004, the word *tsunami*, meaning “harbour wave” in Japanese, has gone from specialized scientific usage to global currency as a synonym for disaster. The catastrophe in southeast Asia is merely the most recent of many human disasters involving tsunami, which include the devastation of parts of southern Newfoundland in 1929 following an earthquake and submarine landslide on the Grand Banks. Newfoundland remains vulnerable to tsunami from such causes, and the island also lies in the path of tsunami that could result from potential lateral collapses of large shield volcanoes in the Canary Islands.

This presentation explains the physical nature of tsunami waves and how they differ from waves at the beach. It shows computer simulations of the many sources of tsunami, including earthquakes, submarine landslides, asteroid impacts and volcanic explosions. The cases examined span waves just a few inches high to “mega-tsunami” which involve entire ocean basins. It also presents new hot-off-the-press models of the 2004 Sumatra tsunami, and touches upon tsunami forecasting as highlighted in the recent push for expanded tsunami warning systems.

Gold mineralization in Newfoundland: an overview of established and potential environments

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Over the last century, gold production in Newfoundland amounts to some 64 tonnes, of which about half represents byproducts from polymetallic VMS deposits. Three gold-only deposits (Hope Brook, Nugget Pond and Hammerdown) have operated in the last 25 years. The Pine Cove deposit is anticipated to be the next such producer, and the Duck Pond Zn-Cu deposit will also yield significant gold. No world-class gold deposits are yet known in the province, but it is increasingly recognized as a favourable and underexplored environment, because it hosts several diverse environments of Precambrian and Paleozoic gold mineralization.

Auriferous VMS deposits are associated with Cambro-Ordovician arc volcanic sequences, and the most gold-rich are typically in calcalkaline sequences including felsic rocks, such as Rambler, Buchans and Duck Pond. Epithermal-type mineralization is dominantly of late Proterozoic age, within the Avalon Zone of eastern and southern Newfoundland, and includes both high- and low-sulphidation subtypes. The Hope Brook deposit of southern Newfoundland is considered to be a metamorphosed high-sulphidation epithermal deposit. Epithermal-type gold mineralization of Paleozoic age is now also recognized in central Newfoundland, notably within the “Botwood basin” area. Lode gold mineralization of mesothermal type dominates the Dunnage Zone of central Newfoundland, and displays the typical features of “orogenic” gold deposits, i.e., it is late-orogenic (Silurian ?) in timing, and associated with major faults and shear zones. Most of this mineralization is associated with discrete quartz and quartz-carbonate vein systems, although there are examples of manto-type replacements of iron-rich sedimentary rocks, such as the Nugget Pond deposit. This locality, as its name suggests, was renowned for many spectacular examples of native gold. The most significant new gold discoveries in central Newfoundland are Golden Promise, hosted by multiple quartz vein systems in deformed turbidites, and Valentine Lake, hosted by quartz-tourmaline veins in a Neoproterozoic granite. Both examples open up new areas for gold exploration. Possible intrusion-related gold mineralization occurs in southern Newfoundland, associated with Cu, Mo and W mineralization, but its characteristics are not well established. Unusual disseminated gold mineralization in the Humber Zone of western Newfoundland is hosted by Precambrian granitoid rocks, Precambrian dykes and Cambrian sedimentary rocks, including carbonates. Some geochemical features of this mineralization suggest possible affinities with Carlin-type systems, and current exploration activity is based on such models.

Although gold production in Newfoundland now dates back 100 years, systematic exploration for gold-only deposits has a much shorter history. In the last 25 years, a wide range of gold-bearing geological environments have been revealed, which augers well for exploration and production in years to come.