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Geological Association of Canada
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1996 Annual Meeting

From Cape Chidley to Cape Race: Exciting New Developments in Mineral and Petroleum Exploration

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Organising Committee, Geological Association of Canada - Newfoundland Section

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Potential for Voiseys Bay style discoveries considered high in northernmost portions of the Nane Plutonic Suite, Labrador!!

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The Reid Brook Intrusion of the Nain Plutonic Suite contains enormous, high grade Ni-Cu-Co massive sulphide bodies that are considered the richest, low-cost deposits in the world. The Nain Plutonic Suite, a coalesced assemblage of composite intrusions which include anorthosite, troctolite, norite, gabbro and granite, covers an area of approximately 60 x 100 km.

Between July and December, 1995, a number of nickeliferous sulphide occurrences were discovered by several different mineral exploration groups north of the Voiseys Bay discovery, related to anorthositic to troctolitic rocks within a "structurally" prepared area of up to 35 km east of the contact between the Rae and the Nain Provinces. Although a detailed and consistent genetic model has yet to be developed, all of the new reports of nickeliferous sulphide appear to be proximal to the suture. Castle Rock Exploration Corporation, a Vancouver-based junior mining company with a strong presence in the Voiseys Bay area, succeeded in discovering three new nickeliferous sulphide occurrences, the NBK, the Krinor and the OKG, located between Webb Bay and Okak Bay within this "structurally" prepared area.

At the NBK property, a number of massive sulphide pods occur over an area of 60 x 400 m within anorthositic phases of the NPS. Assays of grab samples from the massive sulphides yielded values up to 1.71% Ni, 1.9% Cu and 0.23% Co. Subsequent airborne and ground geophysics revealed a northwest-trending EM anomaly associated with a distinct magnetic high, coincident with the sulphide mineralization.

At the Krinor property spectacular gossans are exposed along a 1.5 to 2.0 km long, fault-defined, northeast-trending cliff face. The gossans are developed on multiple zones of massive sulphide. Associated lithologies include norite and olivine-bearing gabbro. The sulphides contain immiscible silicate inclusions, indicating that a silicate magma was intimately associated with the parental sulphide liquid. Grab samples from the massive sulphides provided assays up to 1.31% Ni, 0.52% Cu and 0.16% Co.

At the OKG property, a joint venture with United Compass Resources Limited, a 500 m long intermittent exposure of massive sulphide mineralization is exposed along the south side of a 3 km wide valley a few kilometers east of the suture. The sulphide mineralization consisting of coarse grained pyrrhotite, pentlandite and chalcopyrite, is hosted by anorthosite with pyroxenite interlayers up to 30 m wide. Surface sample values ranging up to 1.78% Ni, 1.44% Cu and 0.21% Co were recorded. Last fall, three of five holes intersected multiple pyroxenite layers that contained massive to disseminated sulphides similar to the surface showing. The thickest layer intersected to date was 7.5 m thick grading 0.88% Ni, 0.56% Cu and 0.05% Co. Ore formation by the settling of immiscible sulphides from a mafic-ultramafic magma is suggested.

A discussion of the geology and geophysical responses over some of Cartaway Resources Okak Bay properties, northwest of Nain, Labrador

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Cartaway Resources has one of the largest land positions for Ni-Cu-Co exploration in Labrador, with in excess of 29,000 claims. At the present time, in the winter of 1996, Cartaway is conducting geophysical exploration and diamond drilling at Kyfanan Lake in the Port Hope Simpson area of southern Labrador, on the south side of the Harp Lake Intrusive Complex, at Cabot Lake southwest of Voiseys Bay, and in the Okak Bay area. This talk describes airborne and ground geophysical responses and the known geology on three Cartaway properties in the Okak Bay area, including the 'Cirque' prospect, 90 km northwest of Nain in the northern part of the Nain Plutonic Suite.

A survey of thermal maturation indicators for western Newfoundland strata: key tools in the search for hydrocarbons

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A number of thermal maturation indicators from various Paleozoic strata of western Newfoundland are examined as tools in the search for hydrocarbons. Among the indicators tested, acritarchs provide the most sensitive results for strata in and around the oil window. Graptolites, while abundantly recorded in rocks of western Newfoundland, are not particularly sensitive to shallow burial metamorphism. They are, however, significant indicators for more deeply buried rock. Distribution maps for the thermal alteration indicators clearly identify surface exposures of the most prospective rocks.

The Duder Lake Au Prospects - archetypes of mesothermal mineralization in the eastern Dunnage Zone

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The Duder Lake Prospects consist of the Flirt, Goldstash, Corvette and Stinger showings, all of which are epigenetic, arsenopyrite-rich, mesothermal gold occurrences; the Flirt and Stinger are vein-type whereas the Goldstash and Corvette represent altered host rock replacement-type mineralization. The showings occur within the eastern Dunnage Zone of the Appalachian Orogenic Belt of northeastern Newfoundland and are the most intensely studied gold prospects in this tectonic region. The Stinger prospect is hosted by graphitic siltstone of the Ordovician to Silurian Davidsville Group. The other three are hosted by Siluro-Devonian gabbroic rocks that cut the Davidsville Group. The mineralization at the Duder Lake showings is localized to secondary to tertiary structures related to the regionally significant, northeasterly-trending Dog Bay Line; best mineralization is hosted by Riedel shears. Gabbro hosts to mineralization have a well-developed alteration halo which reflects varying CO_2/H_2O ratios with distance from the veins. Fluid inclusion data indicate homogenization temperatures of ~320°C and salinities of 3 to 7 wt. % NaCl in the ore fluids. O, C, and S isotope data for the occurrences have typical mesothermal values. The ore fluids were probably derived through metamorphic devolatization of Gander Zone basement rocks and allochthonous cover rocks of the Dunnage Zone during a Silurian orogenic event, resulting in an overall heterogeneous geochemical signature.

The Goldstash showing has been traced for >600 m, is open along strike, and widens with depth. Geophysical data indicate that the host structure continues for at least 2000 m and includes the Corvette Showing.

A geochemical survey, using Fe-Mn oxide coatings on stream pebbles as a medium, indicated anomalous Au, Ag, Sb and As values downstream from the Stinger showing, and suggests that the region of auriferous mineralization may be larger.

Hype or Bonanza? An economic comparison of Voiseys Bay with other exceptional Canadian mineral discoveries

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The Voiseys Bay nickel copper deposit has been labelled the best discovery in Canada in the past several decades. This presentation examines this premise by presenting three possible development scenarios for the Voiseys Bay deposit. Economic criteria are used to assess both the size and profitability for each of the three development scenarios. These results are then compared with similar economic characteristics for other exceptional Canadian discoveries including Kidd Creek, Hemlo, Brunswick 12, and Sullivan.

The "Nugget Pond" type of gold mineralization

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The recently discovered Nugget Pond deposit is hosted by a sedimentary horizon (Nugget Pond Horizon) that extends for approximately 15 km between the massive sulphide deposits of Betts Cove and Tilt Cove. The deposit is associated with a strong gold anomaly in soils. Geophysical surveys indicate that the Nugget Pond Horizon is regionally characterized by a high magnetic susceptibility. The deposit seems to correspond to a "magnetic low" within this regional "magmatic high". The Nugget Pond Horizon is also associated with an I.P. anomaly. Within the Horizon, the known mineralization coincides with the center of the conductive zone, but does not represent the highest value of the survey. The VLF survey failed to locate the known mineralization.

On the Nugget Pond property, the sedimentary horizon consists from base to top of (1) red-green turbidites, (2) dark green sedimentary rocks, and (3) grey-green turbidites. In the vicinity of the deposit, an iron formation and a tuffaceous sandstone are present at the base of the horizon. A black shale or intense stilpnomelane alteration is observed in the dark green sedimentary rocks where it corresponds to Zone 1 of the deposit. It is also observed at the top of the tuffaceous sandstone and the iron formation. The strike, dip and thickness of the different units of the sedimentary horizon are quite constant on the Nugget Pond property and the rocks appear to be homogeneously deformed. At the southwest limit of the deposit, an offset of the lower contact of the Nugget Pond Horizon is marked by the thickening of the red-green turbidites. The iron formation is everywhere located on the southwest side of this offset, whereas the tuffaceous sandstone is observed on the northeast side.

The deposit contains 337 073 tonnes of ore grading 16.53 g/t Au (uncut) and consists of three stratabound zones rak-

ing to the south. The gold mineralization is associated with coarse pyrite. Generally, it is associated with a strong stilpnomelane alteration (black shale) usually extensively veined by quartz-albite-carbonate-pyrite (coarse). The dark green sedimentary rocks contain a halo of anomalous gold values around the deposit and are depleted in Na_2O for their entire strike on the Nugget Pond property. Gold values are reported from both the footwall and hangingwall lavas. They are mainly associated with veins similar in composition to those observed in the ore zones. Furthermore, altered volcanic rocks are present in the immediate footwall of the deposit.

New perspectives on the stratigraphy, structure and metallogeny of island-arc volcanic rocks in the Ordovician Roberts Arm Group, Notre Dame Bay

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A new interpretation of the Roberts Arm Group suggests that it comprises five basalt-dominated tectonic terrains (*s.l.*), which are separated by variably steepened, south to southeast-dipping, north-directed thrust faults. The structural base of the group is the Boot Harbour terrain, which contains well-preserved submarine felsic volcanic rocks, possibly erupted under deep marine conditions. The structurally overlying Pilleys Island terrane contains distinctly different fragmental felsic rocks representing more violent (shallow-water?) volcanism, associated with significant VMS mineralization and alteration. These are structurally overlain by basalts of the Mud Pond terrane, which have a regional hematite (± epidote) alteration signature. The structural top of the calc-alkaline sequence is the Triton terrane, containing fresh basalts and voluminous mafic intrusive rocks. These four terranes are probably in turn structurally overlain by tholeiitic basalts and associated sedimentary rocks of the Crescent terrane. The structural polarity in the area is directly opposite to previous proposals, and the four calc-alkaline terranes are logically viewed as the disrupted, lower limb of a northward-overturned anticlinal nappe structure. The Springdale Group rests unconformably upon different Robert's Arm Group terranes, suggesting some pre-Middle Silurian deformation and imbrication. Later deformation is largely brittle, and is related to dextral transcurrent and/or southeast-directed reverse motions along the Lobster Cove Fault and similar structures.

The most significant VMS mineralization is restricted to the Pilleys Island terrane, and is associated with structurally modified, sericitized dacitic pyroclastic rocks. Recent exploration activity has demonstrated the potential for "blind" ore bodies, and for structural repetition of ore horizon rocks. Elsewhere, VMS mineralization appears to be restricted to stockwork-style occurrences associated with chloritized tholeiitic basalts of the Crescent Lake terrane. Minor VMS mineralization is also associated with sericitized felsic rocks at the Handcamp prospect. Epigenetic mineralization within the Robert's Arm Group is extensive and consists of structurally-controlled quartz veins and disseminated mineralization, locally superimposed upon pre-existing VMS occurrences. This style is particularly well developed within the Mud Pond terrane. Examples include Cu (± Ag)-bearing quartz veins at the Crescent Lake mine, Au-bearing pyritic quartz veins at the Chignic showing, and disseminated auriferous pyrite at the Handcamp prospect.

A multidisciplinary approach to detect multiple source reservoirs and processes in the formation of turbidite-hosted gold mineralization: an example from the Meguma Terrane of Nova Scotia

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Meguma lode-gold deposits (historical production 1.2 million oz.) are vein-type mesothermal deposits hosted by metasedimentary rocks of the Lower Paleozoic Meguma Group (Nd model age 1.6 Ga) of southern Nova Scotia. High-grade ortho- and paragneisses, with model Nd ages of ca. 1 Ga, are restricted to the central Meguma Terrane (Liscomb area), record emplacement at ca. 380 Ma ($^{40}Ar/^{39}Ar$ ages) and contain xenoliths of deformed Meguma Group lithologies. The Meguma Group and overlying Silurian-Devonian volcanic sedimentary rocks were deformed during the Acadian Orogeny (ca. 400 Ma) which records the docking of the Meguma Terrane with Avalonia or ancestral North America. The Meguma Group and Liscomb gneisses were subsequently intruded at ca. 370 Ma by peraluminous granites and temporally related gabbros and mafic dykes (lamprophyres), the latter of which contain granulite-facies xenoliths (14 kbars, 1000°C) of Avalonian heritage with Nd model ages of 600 Ma. It is within this setting that the Meguma gold deposits formed.

The gold deposits occur throughout the basal, sandstone dominant part of the Meguma Group (Goldenville Formation) and are found in both greenschist and amphibolite facies rocks. Deposits generally occur in domal structures with veins favouring steep to overturned southern, limbs. Most deposits consist of numerous bedding concordant veins with lesser discordant type veins; saddle reefs (*sensu stricto*) and ac veins are rare (e.g., Dufferin and West Gore, respectively). Vein structures suggest emplacement into brittle/ductile shear environments of subvertical orientation (i.e., subvertical mineral lineations) within which the mean principal stress axes rotated (e.g., δ_1 flat to sub-vertical) and fluid over-pressuring

occurred. Wallrock alteration is cryptic to intensely developed, with silicification, sulphidization, carbonatization and sericitization the most common. Veins are dominated by quartz, carbonate and sulphides, but a wide variety of accessory minerals occur, locally forming pegmatoid veins (amphibole-plagioclase-biotite-tourmaline-apatite). The chemistry of vein minerals [e.g., Fe/(Fe+Mg) of mica] indicate fluids were wall rock-bufferred and indicate peak temperatures of ca. 350 to 500°C. Veining is constrained to ca. 370 ± 8 Ma based on $^{40}Ar/^{39}Ar$ dating of vein minerals which agrees with field relationships in deposits found within the contact aureoles of 370 Ma granites. Recently, vein-free types of gold mineralization have been found associated with zones of carbonate and sericite alteration.

Fluid inclusion studies indicate the vein fluids were low-salinity H_2O-CO_2-NaCl type, record a large range in P_{fluid} (≤1 to 6.5 kbars), suggest over-pressuring was common, and that fluid unmixing was rare (West Gore, Tangier). All vein types have similar inclusion types and chemistry (thermometric and gas chemistry). Isotopic data (C, S) record interaction of the vein fluids with Meguma Group lithologies and local derivation of reduced carbon and sulphur. Isotopes of O ($\delta^{18}O_{fluid}$ = 8-12‰) and D (-40 to -60‰) are most consistent with a metamorphic origin, with some overlap into the magmatic field. Strontium isotopes for vein carbonates and tourmaline indicate a mixed reservoir, one of which must be non-Meguma Group (i.e., Sr_I<0.712 at 370 Ma). However, when the Sr isotope data are combined with Pb isotope data for vein galena the Liscomb Gneisses can be finger printed as the sole reservoir. These data are consistent with REE data for vein carbonates that show a wide range in ΣREE and fractionation, again suggesting multiple reservoirs.

This multidisciplinary study indicates that the fluids which formed the Meguma gold deposits are generally not unique geochemically, but instead owe their origin to a variety of processes from the time they were generated deep within the crust until they precipitated as vein material within brittle/ductile shear zones. Interaction of the fluids with wall rocks during their passage through the crust has resulted in the inheritance of many geochemical signatures, all of which bear witness to this interaction. Recognition of such camouflaging is important when discussing sources of fluids or metals, and genetic models.

Vinland petroleum and the emerging west coast oil play

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Vinland Petroleum Incorporated, a Newfoundland company, has been involved since the beginning of the current round of exploration on the west coast of Newfoundland. The company has a considerable land position both onshore and offshore western Newfoundland. It is currently involved with Talisman Energy of Calgary in the drilling of the Long Range A-09 well, sited on the tip of the Port au Port Peninsula to test a structure on Vinland's offshore Bay St. George acreage.

Vinland Petroleum is also currently pursuing opportunities and strategies to explore its land holdings in the Deer Lake basin, Castor River and Main Brook areas.

Sea-level history, quaternary geology and implications for mineral exploration, northeastern Newfoundland

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Quaternary mapping over the Roberts Arm-Buchans group of northeast Newfoundland, Canada, has been undertaken as part of a multidisciplinary project in support of mineral exploration.

The ice-flow history is dominated by north to northeast ice flow, with some perturbation caused by topographic drawdown during deglaciation. Till cover is extensive inland, but the coastal areas are dominated by glaciomarine and marine reworking of sediment in falling sea levels following deglaciation. Radiocarbon dates, geomorphology and palaeontology are used to refine the sea-level history in this area.

Use of till as a sampling medium for geochemical exploration in the area is hampered to by a lack of till in coastal regions, and the probability of reworking by marine processes below 58 to 75 m asl. Most diamictons in low lying coastal areas appear to be glaciomarine rather than glacial, as shown by the common occurrence of fossils, and conventional drift prospecting methods cannot be applied. Farther inland, till sampling should be more successful due to the combination of good sampling media and a comparatively simple ice flow history. However, no dispersal train is apparent from some known mineral occurrences, despite reasonable sampling media and coverage. Thus the 1 to 2 km sample spacing used in this study may not be adequate to completely delineate mineralization in the area.

Virtually integrated: digital geoscience atlases of Newfoundland and Labrador

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Geologists like maps! Overlaying maps containing different types of information—geological, geophysical, geochemical, topographic, and so on—remains a very commonly used technique of data collation and interpretation in geoscience for many purposes, from mineral exploration to land-use planning.

Geographic Information Systems (GIS) are used to capture, organize and overlay geoscience (and other map-based) information, and GIS can also be used to perform sophisticated mathematical modelling and analyses of this information. Because of its versatility and complexity, a GIS requires a lengthy period of training for anyone to use it to full effect, creating the "GIS specialist". A GIS is of little direct use to most practicing geoscientists, who contribute the data, and who should be the ones to interpret it.

Desk-top mapping systems allow practicing geoscientists to use information organized in a GIS. Arcview 1.0, in particular, provides superb overlay capabilities as well many simple techniques for exploring complex, multi-layered data collections. A series of Digital Atlases are being assembled at the Geological Survey in Arcview format. These atlases can be linked and are accessible over an internal LAN. They are also being written to CD-ROM for external distribution. The recently completed Digital Geoscientific Atlas of the Buchans-Roberts Arm Belt will be demonstrated to illustrate the concept.

Gold metallogeny of the Betts Cove ophiolite

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The mineral occurrences and the main mineral potential of the Betts Cove ophiolite is represented by two broad classes of deposits: (1) volcanogenic Cu-Zn-Au deposits within the lower pillowed basalt and in the upper part of the underlying sheeted dyke unit, and (2) gold occurrences within sulphide and oxide facies iron formations overlying the lower pillowed basalt.

The Nudulama, Mount Misery and Betts Cove deposits occur in the uppermost parts of the sheeted dyke unit. They exhibit abundant shearing and brecciation. The Betts Cove "massive sulphide" contains the highest gold values (1 to 16 grams) with highest values in Zn-rich samples. Gold content of Nudulama is erratic with highest values of 26 grams associated with enrichments of As, Co, and Ni, resulting in the assemblage chalcopyrite-gold-gersdorfite-cobaltite in massive sulphide breccia matrix.

The Tilt Cove massive sulphide occurs within the lower basalt which at the site is entirely hyaloclastite. Sulphides occur principally as a subvolcanic replacement of hyaloclastite. Gold contents are lower than other deposits with higher values circa 1 gram associated with specular hematite-rich ores. The abundance of hyaloclastite and the association of gold with oxide minerals suggests that the deposit formed subvolcanically under fairly shallow water column with oxidizing water conditions.

Nugget Pond is the main pure Au occurrence containing about 400,000 tonnes grading about 14 gm/tonne. The deposit contains disseminated megacrystic pyrite replacing pre-existing pyrite and magnetite (sulphide/oxide iron formation in part) within red hematitic and green distal turbidites overlying the basal pillowed volcanic unit. The deposit is associated with a quartz-feldspar-carbonate stockwork of Devonian age (374 ± 8 Ma). Two other occurrences, Castle Rock and Long Pond East occur in isolated tectonic fragments of what is probably Nugget Pond Horizon rocks near Tilt Cove. Both occurrences contain hematite/magnetite iron formation and red and green pyritic and non pyritic argillite. However, at both locations, anomalous gold contents show a direct spatial association with talc-carbonate schist that is believed to be a product of Devonian alteration and tectonism of the lower ultramafic units of the ophiolite.

Geology of a new cluster of blind massive sulphide deposits discovered by Phelps Dodge Canada at Spencer's Dock on Pilleys Island, central Newfoundland

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An exploration program conducted by Phelps Dodge Corporation of Canada, Limited has resulted in the discovery of three new VMS deposits in central Newfoundland. The deposits occur in the Ordovician Robert's Arm Group, 2 to 3 km west of the old Pilleys Island Mine. The Spencer's Dock, Rowsell's Cove and Jane's Cove deposits are only partially delineated by wide-spaced drilling but are evidently members of a larger population within a partially explored volume of altered felsic volcanic rocks. Though larger than the Pilleys Island deposits and with massive sulphide intersections up to 35 m, base metal grades to date are subeconomic. Massive and resedimented breccia sulphide facies deposits

are present, similar to the Buchans deposits, 110 km along strike to the southwest. The deposits are accompanied by a very large alteration system dominated by sericite and pyrite but also includes chlorite, silica, epidote and K-feldspar alteration facies. The distribution of alteration and mineralization within the felsic intrusive-extrusive complex was controlled, in part, by the widespread development of perlitic cracks. It is evident that a significant portion of the massive sulphide facies was deposited by replacement of glassy felsic flow material. Lithogeochemical alteration scores are uniformly high throughout the felsic package.

The recognition and correlation of a number of important low-angle thrust faults has been a key element in the exploration program. The Spencer's Dock deposits occur within a south-plunging antiformal stack which occurs at the same structural horizon as a separate, but similar stack to the east which hosts the previously known Pilleys Island deposits. Within the Spencer's Dock antiformal stack, sulphide deposits occur within two of three shallowly dipping panels of felsic volcanic rocks.

The prognosis for exploration remains good with a large volume of favourable rock yet to be explored. The model employed puts the discoveries to date within the pyritic periphery of an ore-grade massive sulphide system.