GEOLOGICAL SURVEY OF CANADA COMMISSION GÉOLOGIQUE DU CANADA

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CORDILLERAN GEOLOGY AND EXPLORATION ROUNDUP

FORUM SUR L'EXPLORATION ET LA GÉOLOGIE DE LA CORDILLÈRE

Program and Abstracts

Programme et résumés

Geological Survey of Canada

Commission géologique du Canada

Hotel Vancouver
Vancouver, B.C.
February 6-9, 1990

Hôtel Vancouver
Vancouver, C.-B.
Du 6 au 9 février 1990

Énergie, Mines et Ressources Canada

Energy, Mines and Resources Canada

Canada

CORDILLERAN GEOLOGY AND EXPLORATION ROUNDUP

HOTEL VANCOUVER

February 6-9, 1990

PROGRAM - FEBRUARY 6

9:00 am - 12:15 TECHNICAL PRESENTATIONS Geological Survey of Canada; and Geological and Exploration Services, Indian and Northern Affairs Canada, Yukon

GEOLOGICAL SURVEY OF CANADA

9:00 - 9:10 **H. Gabrielse** Celebration of a career - J.O. Wheeler

9:10 - 9:30 **D.J. Tempelman-Kluit** *(Director, Cordilleran Division)* Highlights of Cordilleran regional mapping

9:30 - 9:55 **W. Goodfellow** Recent advances in mineral deposits research in the Cordillera and Pacific margin

9:55 - 10:20 COFFEE

10:20 - 11:00 GEORGIA BASIN PROJECT

J.W.H. Monger Project scope and basin tectonic setting

T. Hamilton Submarine geology and geophysics

G. Lynch Gambier Group of the Fire Lake area: basement to the Georgia Basin?

GEOLOGICAL SURVEY OF CANADA AND INDIAN AND NORTHERN AFFAIRS CANADA

11:00 - 11:40 SELWYN-WERNECKE TRANSECT, YUKON: A JOINT INAC-GSC PROJECT

S.P. Gordey, J.G. Abbott, and **C. Roots** Off the edge of the continent in three 1:50 000 map areas

R. Turner and **J.G. Abbott** MARG volcanogenic massive sulphide deposit, Selwyn Basin

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INDIAN AND NORTHERN AFFAIRS CANADA

1:40 - 12:05 **T. Bremner** 1989 Yukon mining and exploration activity

12:05 - 12:15 **R. Hill** *(Manager, Mineral Resources Program, Yukon Territorial Government)* 1990 update of Government of Yukon mining and exploration program

12:30 - 2:00 LUNCHEON: B.C. and Yukon Chamber of Mines

2:00 - 5:00 pm POSTERS: Geological Survey of Canada; Indian and Northern Affairs Canada, and university students

FORUM SUR L'EXPLORATION ET LA GÉOLOGIE DE LA CORDILLÈRE
HÔTEL VANCOUVER

Du 6 au 9 février 1990
PROGRAMME DU 6 FÉVRIER

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9 h - 12 h 15	EXPOSÉS TECHNIQUES offerts par la Commission géologique du Canada et les Services de géologie et d'exploration, Affaires indiennes et du Nord Canada, Yukon

COMMISSION GÉOLOGIQUE DU CANADA

9 h - 9 h 10	**H. Gabrielse** Hommage rendu à un collègue - J.O. Wheeler
9 h 10 - 9 h 30	**D.J. Tempelman-Kluit** *(Directeur, Division de la Cordillère)* Travaux de cartographie dans la région de la Cordillère - Faits saillants
9 h 30 - 9 h 55	**W. Goodfellow** Progrès récents de la recherche sur les gisements dans la Cordillère et la marge du Pacifique
9 h 55 - 10 h 20	CAFÉ
10 h 20 - 11 h	PROJET RELATIF AU BASSIN GEORGIE
	J.W.H. Monger Envergure du projet et milieu tectonique du bassin
	T. Hamilton Géologie et géophsyique sous-marines
	G. Lynch Le groupe de Gambier dans la région de Fire Lake constitue-t-il le socle du bassin Géorgia ?

COMMISSION GÉOLOGIQUE DU CANADA ET
AFFAIRES INDIENNES ET DU NORD CANADA

11 h - 11 h 40	TRANSECT DE SELWYN-WERNECKE, AU YUKON : UN PROJET CONJOINT AINC/CGC
	S.P. Gordey, J.G. Abbott, et **C. Roots** Exploration au delà des limites continentales dans trois secteurs cartographiques (l'éschelle de 1/50 000)
	R. Turner et **J.G. Abbott** Dépots de sulphures massifs d'origine volcanique (gisement MARG), dans le bassin de Selwyn

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AFFAIRS INDIENNES ET DU NORD CANADA

11 h 40 - 12 h 5	**T. Bremner** Exploration et exploitation minière au Yukon : bilan des activités en 1989
12 h 5 - 12 h 15	**R. Hill** *(Gestionnaire du Programme des ressources minérales, gouvernement du Yukon)* Le point sur le programme territorial d'exploration et d'exploitation minière de 1990
12 h 30 - 14 h	DÉJEUNNER de la Chambre des mines de la C.-B. et du Yukon

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14 h - 17 h	EXPOSITION D'AFFICHES présentées par la Commission géologique du Canada, Affaires indiennes et du Nord Canada et des étudiants de niveau universitaire

ENERGY, MINES AND RESOURCES CANADA

GEOLOGICAL SURVEY OF CANADA

CORDILLERAN DIVISION

100 West Pender Street, Vancouver, B.C., V6B 1R8

DIRECTOR

Dr. Dirk Tempelman-Kluit	666-0529
FAX	666-1124

BEDROCK GEOLOGY AND MINERAL DEPOSITS

Including all kinds of rocks and their distribution, age, folds, faults, origin, history, related mineralization, mineral localities, geochemistry, aeromagnetics, geophysics.

St. Elias Mountains - Chris Dodds	666-3956
Spatsizi area - Carol Evenchick	666-7119
Brian Ricketts	666-6022
Queen Charlotte Islands - Jim Haggart	666-8460
Bob Thompson	666-0408
Northeastern B.C. - Hu Gabrielse	666-2958
Central Yukon - Steve Gordey	666-2116
Charlie Roots	666-1129
Lower Mainland of B.C. - Jim Monger	666-6743
Murray Journeay	666-1130
Coast Mountains - Glenn Woodsworth	666-6787
Bob Anderson	666-2693
Central B.C. - Bert Struik	666-6413
Cathie Hickson	666-3955
Howard Tipper	666-0844
Northern Yukon - Rocky Mountains - Bob Thompson	666-0408
Western and central Yukon - Dirk Tempelman-Kluit	666-0529
Southern B.C. - John Wheeler	666-6708
Dirk Tempelman-Kluit	666-0529
Murray Journeay	666-1130

HYDROCARBON GEOLOGY

Bob Thompson	666-0408

PLATE TECTONICS AND REGIONAL GEOLOGY

Jim Monger	666-6743
John Wheeler	666-6708
Hu Gabrielse	666-2958

GRANITES AND RELATED MINERAL DEPOSITS

Bob Anderson	666-2693
Jim Roddick	666-2378
Glenn Woodsworth	666-6787

VOLCANOES AND RECENT VOLCANISM

Jack Souther	666-0528
Cathie Hickson	666-3955

HOT SPRINGS, GEOTHERMAL ENERGY

Jack Souther	666-0528

MINERAL DEPOSITS - GENERAL

Ken Dawson	666-0260
Bob Turner	666-4852

FOSSILS

Macrofossils - Howard Tipper	666-0844
Jim Haggart	666-8460
Microfossils - Mike Orchard	666-0409

GRAVITY AND GEOPHYSICS

Jack Sweeney	666-1131

RECENT GEOLOGICAL HISTORY

Including surficial geology, glaciations, sea level fluctuations, land and rock slides, debris flows, placer deposits, earthquakes

for B.C. - John Clague	666-6565
for Yukon - Lionel Jackson	666-3409

FRASER DELTA AND STRAIT OF GEORGIA

John Luternauer	666-0788

CANADIAN JOURNAL OF EARTH SCIENCES

John Clague *(Editor)*	666-1123

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ÉNERGIE, MINES ET RESSOURCES CANADA
COMMISSION GÉOLOGIQUE DU CANADA
DIVISION GÉOSCIENTIFIQUE DE LA CORDILLÈRE

100, rue Pender Ouest, Vancouver, C.-B. V6B 1R8

DIRECTEUR

Dr. Dirk Tempelman-Kluit	666-0529
	FAX 666-1124

GÉOLOGIE DU SOUBASSEMENT ET DÉPOTS DE MINERAI

Incluants toutes sortes de roches et leurs distribution, âge, plissements, failles, origine, histoire, location et association minérales, géochimie, géophysique, et aéromagnetisme.

Montagnes St. Elias - Chris Dodds	666-3956
Région Spatsizi - Carol Evenchick	666-7119
Brian Ricketts	666-6022
Ilses de la Reine Charlotte - Jim Haggart	666-8460
Bob Thompson	666-0408
Nord-est de la Colombie Britanique - Hu Gabrielse	666-2958
Yukon centrale - Steve Gordey	666-2116
Charlie Roots	666-1129
Continent antérieure de la Colombie Britanique - Jim Monger	666-6743
Murray Journeay	666-1130
Côte Montagne - Glenn Woodsworth	666-6787
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Colombie Britanique centrale - Bert Struik	666-6413
Cathie Hickson	666-3955
Howard Tipper	666-0844
Yukon du Nord - Montagnes Rocheuses - Bob Thompson	666-0408
Yukon ouest et centrale - Dirk Tempelman-Kluit	666-0529
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VOLCAN ET VOLCANISME RÉCENT

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SOURCES THERMALES ET ÉNERGIE GÉOTHERMIQUE

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DÉPOTS DE MINERAI - GÉNÉRALE

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FOSSILES

Macrofossiles - Howard Tipper 666-0844
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GRAVITÉ ET GÉOPHYSIQUE

Jack Sweeney 666-1131

GÉOLOGIE HISTORIQUE RÉCENTE

Incluant geologie de la surface, glaciations, fluctuations dans le niveau des océans, glissement de terrain, chute de débris, gîte de placer, tremblements de terre

pour la Colombie Britanique - John Clague 666-6565
pour le Yukon - Lionel Jackson 666-3409

DELTA DU FLEUVE FRASER ET DU DÉTROIT DE GEORGIA

John Luternauer 666-0788

JOURNAL CANADIEN DES SCIENCES DE LA TERRE

John Clague *(Directeur scientifique)* 666-1123

BIBLIOTHEQUE

Mary Akehurst et Fontaine Hwang 666-3812

BUREAU DE VENTE DES CARTES ET DES PUBLICATIONS

Olga Langenhaun et Zdenka Svitek 666-0271

Abstracts of Talks

Highlights of Cordilleran Regional Mapping

D.J. Tempelman-Kluit
Geological Survey of Canada, 100 W. Pender Street, Vancouver, B.C. V6B 1R8

The Cordilleran Division, GSC's downtown Vancouver office, is responsible for providing and disseminating up-to-date geoscience data and ideas for much of British Columbia and Yukon. Effective assessment of, and exploration for, resources are the prime aim; the data are also intended for sound policy formulation and geohazard mitigation.

During the last several years GSC mapping has focused on the western Cordillera. The Coast Plutonic Belt and Intermontane Basins are frontiers where geoscience data collection has lagged and we have moved to correct this. In the Coast Belt we are concentrating on the stratified and metamorphosed rocks. New understanding of ductile deformation fabrics and improved radiometric dating will lead to ideas and data not possible when the focus in this region was on the granitic rocks alone. In the Intermontane Belt improved sedimentological understanding, better biostratigraphy through new fossil groups, better road access and new detailed mapping are bringing improved understanding.

GSC's mapping in the Coast Mountains includes the compilation of new 1:250 000 scale geological maps of the St. Elias and northern Coast Mountains by Chris Dodds. These fine maps, available soon on open file, provide a sound basis for resource assessments and resource exploration in the region; it will take major advances before they are outmoded.

Bob Anderson has been working in the Iskut "golden triangle" to compile and synthesize the diverse field work of many industry geologists and of B.C. Geological Survey scientists in the region. His 1:250 000 scale geological compilation of Iskut River map-area is a keenly awaited product which will see immediate and widespread use by many geologists currently interested in this region for its precious metals. A forerunner copy

Résumes des Presentations Orales

Travaux de cartographie dans la région de la Cordillère : faits saillants

D.J. Tempelman-Kluit
Division de la géologie de la Cordillère, Commission géologique du Canada, 100, rue Pender Ouest, Vancouver (C.-B.) V6B 1R8

L'objectif de la Division de la géologie de la Cordillère, l'un des bureaux de la CGC situé au coeur de la ville de Vancouver, est la production et la diffusion des données récentes et des idées nouvelles en sciences de la Terre, sur le territoire du Yukon et la presque totalité de la Colombie-Britannique. Quoi sont d'abord destinées ces données ? Une bonne évaluation des ressources et à des projets d'exploration, ainsi qu'à la formulation de politiques rationnelles et à la diminution des risques reliés aux phénomènes géologiques.

Au cours des dernières années, la CGC a surtout cartographié la partie ouest de la Cordillère. La ceinture plutonique Côtière et les bassins intermontagneux sont des régions frontières où un retard s'est fait sentir dans l'accumulation de données géoscientifiques; les derniers changements visent à combler cette lacune. Dans le Domaine Côtier, les recherches portent principalement sur les roches stratifiées et métamorphisées. Une nouvelle détermination des fabriques de la déformation ductile et l'amélioration de la datation radiométrique permettront d'élaborer de nouvelles théories et d'accumuler des données récentes qui ne pouvaient voir le jour à l'époque où dans cette région seules les roches granitiques étaient étudiées. Les connaissances sur le Domaine intermontagneux sont en progrès constant grâce à une meilleure compréhension de la sédimentologie, une biostratigraphie augmentée de nouveaux groupes de fossiles, un réseau plus étendu de routes d'accès et une cartographie détaillée plus récente.

Dans la chaîne Côtière, le travail de cartographie de la CGC comprend la compilation, par Chris Dodds, de nouvelles cartes géologiques à l'échelle de 1/250 000 couvrant les régions de la chaîne St. Elias et de la chaîne Côtière septentrionale. Ces cartes détaillées, qui seront disponsibles bientôt, constituent une bonne base of Anderson's map is on display at this meeting.

Tom Heah and Susie Gareau, two graduate students working with us, are producing detailed maps of the east and west margins of the Central Gneiss Complex, the metamorphic core of the Coast Mountains west of Terrace. Heah considers that on the east the complex is bounded by northeast dipping ductile extension faults similar to those surrounding metamorphic core complexes elsewhere.

Peter van der Heyden, a new Post Doctoral Fellow, has made profound changes to the geological map on the east margin of the Coast Mountains east of Bella Coola. He discovered a new metamorphic welt, the Atnarko Complex and speculates that the Paleogene dextral transtensional faults which bound it are part of a regional set of breaks along the east margin of the Coast Mountains. The Atnarko Complex may thus be the offset equivalent of the Gamsby Complex farther north and the through-going faults may be important zones of fluid flow and perhaps mineral concentration.

Murray Journeay, Greg Lynch and Jim Monger, working in the southern Coast Mountains, are bringing new ideas on mineral genesis and new tools for looking at deformed granitic rocks to the Coast Mountains. This is producing an exciting new picture of Coast Mountains history in which low angle reverse faults figure prominently.

Monger and others are studying Georgia Basin evolution. The main driving interest is the hydrocarbon potential of this region, but improved understanding of this area, where more than 10% of Canada's population lives, is a second important objective. Georgia Basin, resting depositionally on the Coast Mountains on the northeast, is apparently faulted against the Cascades on the southeast and is thrust southwestward over Wrangellian strata on Vancouver Island. The basin continues to fill to this day and its Cretaceous and Tertiary sedimentary fill is many kilometres thick. However the internal stratigraphy and geometry of the basin are essentially unknown. Georgia Basin study offers the opportunity to understand the general principle behind the formation of Intermontane basins on the North American continent edge.

In the Queen Charlotte Islands Bob Thompson and Jim Haggart, in collaboration with many other scientists, have been turning the geology of this region upside down. The geological map of the Charlottes is undergoing major revision as a result of painstaking and detailed 1:50 000 scale mapping over the last several years. The complex stratigraphy is becoming clearer; a model in which the stratigraphy is controlled or strongly influenced by block faults has replaced the crustal flexure model. The Rennell Sound strike slip fault system has been reinterpreted as a northeast striking compres-

tant pour l'évaluation des ressources que pour l'exploration dans ces régions; des progrès considérables devront être réalisés avant qu'elles soient désuètes.

Bob Anderson, quant à lui, a travaillé dans le "triangle aurifière" d'Iskut. Il a compilé et résumé les divers travaux de terrain menés dans cette région par de nombreux géologues de l'industrie et des scientifiques du bureau de la Commission géologique en C.-B. Sa compilation géologique de la région de la rivière Iskut (à l'échelle de 1/250 000) est grandement attendue; elle aura des applications immédiates et répandues pour de nombreux géologues qui travaillent actuellement sur les métaux précieux de cette région. Une copie préliminaire de cette carte sera exposer à la tenue du Forum.

Tom Heah et Susie Gareau, deux étudiants gradués de notre équipe, travaillent à la production de cartes détaillées des marges orientale et occidentale du Complexe du Gneiss Central, le coeur métamorphique de la chaîne Côtière, situé à l'ouest de Terrace. Heah pense qu'à l'est, le Complexe est délimité par des failles ductiles de distension à pendage nord-est, semblables à celles entourant les autres complexes de ce genre.

Peter van der Heyden, un nouveau confrère aux études post-doctorales, a apporté d'importants changements à la carte géologique de la marge orientale de la chaîne Côtière, à l'est de Bella Coola. Il a découvert un nouveau bombement métamorphique, en l'occurrence le Complexe d'Atnarko, et a posé l'hypothèse que les failles dextres de transtension du Paléogène qui le délimitent font partie d'un ensemble de cassures régionales, observées le long de la marge orientale de la chaîne Côtière. Ainsi, le Complexe d'Atnarko pourrait être l'équivalent décalé du Complexe de Gamsby plus au nord et les failles qui le traversent constitueraient d'importantes zones d'écoulement fluide et probablement de concentration minérale.

Dans la partie sud de la chaîne Côtière, Murray Journeay, Greg Lynch et Jim Monger élaborent de nouvelles théories sur la genèse minérale et conçoivent de nouveaux instruments pour étudier les roches granitiques déformées de la chaîne Côtière. Il en résulte une autre vision très intéressante de l'évolution de la chaîne Côtière, où les failles inverses à pendage faible prédominent.

Monger et d'autres collègues se penchent sur l'évolution du bassin Georgia. Ils visent d'abord la détermination du potentiel en hydrocarbures de ce bassin, mais comme 10 % de la population canadienne s'y trouve, l'amélioration des connaissances sur cette région constitue le deuxième objectif en importance. Au nord-est, le bassin Georgia repose en contact sédimentaire sur la chaîne Côtière; au sud-est, il est en contact de faille avec la chaîne des Cascades; sur l'île de Vancouver, il chevauche les strates de Wrangellia.

sional fold belt; it lacks demonstrable strike-slip. Similarly the Sandspit fault is now seen as a down-to-basin normal fault on which the Tertiary Queen Charlotte basin evolved. By showing that the basement under much of the Queen Charlotte basin has affinities with Wrangellia, Glenn Woodsworth has enlarged the region considered to be underlain by good hydrocarbon source rocks. Queen Charlotte Islands biostratigraphers, Mike Orchard, Howard Tipper, Tim Tozer, Beth Carter and Paul Smith and his students, are providing cutting edge data on the zoning of microfossils and macrofossils. Intercalibration of ammonites, conodonts and radiolarians in the Triassic-Jurassic section is providing a benchmark type section for rocks of this age world wide.

A comprehensive volume encompassing the results of all the first phase of Queen Charlotte activities is to be released this spring.

In the Intermontane Belt GSC is concentrating on three projects; from north to south these include the Bowser Basin, the McLeod Lake region and the Chilcotin-Nechako region. Carol Evenchick is mapping the northern Bowser Basin at reconnaissance scales and has detailed the regional stratigraphy where large coal resources are known. She has demonstrated that basin strata are imbricated on northeast directed thrust faults and folds, which have duplicated the stratigraphy and shortened the sequence by 30% or more. Bowser Basin should be thought of as a northwest trending fold and thrust belt rather than simply a sedimentary basin. The structural thickening implies that the maturation level of strata may locally be inverted. Thermally mature strata and therefore significant gas or oil resources may be present under thrust sheets of overmature beds.

An implication of the Bowser Basin structural story is that the northern Intermontane Belt northwest and southeast of Bowser Basin may be also foreshortened. The geology of the northern Intermontane Belt will have to be re-examined in this light.

Catherine Hickson is studying the geology of the Chilcotin-Nechako hydrocarbon province, a large region where much remains to be learned because the geology is obscured by Quaternary cover and by Tertiary volcanic rocks. The geological data base is obsolete and among other factors this hinders assessment of the resource base. The region holds promise for hydrocarbon exploration; source rocks with exciting organic contents are known, maturation levels are well within the oil window, and reservoir rocks are common. Beside 1300 km of industry seismic reflection data that have been shot in the region at least nine wells have been drilled. The cover hides three economically interesting stratigraphic units: the Jurassic Bowser Lake Group in the north, the Cretaceous Skeena Group farther south and an Eocene sequence which occurs lo-

Encore aujourd'hui, le bassin est en phase de remplissage et les sédiments crétacés et tertiaires que le tapissent atteignent plusieurs kilomètres d'épaisseur. Cependant, la stratigraphie et la configuration géométrique à l'intérieur du bassin demeurent fondamentalement inconnues. L'étude du bassin Georgia offre la possibilité d'élucider le principe général régissant la formation des bassins intermontagneux observés à la marge du continent nord-américain.

La géologie des Îles de la Reine-Charlotte a été complètement changée par Bob Thompson et Jim Haggart, avec l'aide de nombreux autres scientifiques. La carte géologique de ces îles est en cours de révision majeure, résultat d'une cartographie détaillée et soignée à 1/50 000, effectuée au cours des dernières années. La stratigraphie complexe de cette région se précise et le modèle de flexure de la croûte fait place à un nouveau concept où la stratigraphie découle ou a été grandement influencée par le morcellement par failles. Le système de failles à rejet directionnel de Rennell Sound est maintenant considéré comme une ceinture plissée de compression, d'orientation nord-est. La raison : le manque de preuve des mouvements de décrochement. De même, l'interprétation de la faille de Sandspit n'est plus la même; on parle maintenant d'une faille normale plongeant vers le bassin sur laquelle le bassin tertiaire de Queen Charlotte s'est formé. Quant à Glenn Woodsworth, ses arguments à l'appui de l'hypothèse que le socle sous-jacent à la presque totalité du bassin de Queen Charlotte a des affinités avec le terraine de Wrangellia ont permis de considérer qu'un plus grand territoire recouvrait des roches mères riches en hydrocarbures. Finalement, des biostratigraphes des Îles de la Reine-Charlotte, Mike Orchard, Howard Tipper, Tim Tozer, Beth Carter, Paul Smith et leurs étudiants, travaillent à l'élaboration de données précises sur la zonation des microfossiles et des macrofossiles. La calibration comparative des ammonites, des conodontes et des radiolaires du Trias au Jurassique a permis de décrire un stratotype repère pour les roches de cette époque, utilisable dans le monde entier.

Un volume complet donnant tous les résultats de la première phase des travaux menés dans les Îles de la Reine-Charlotte paraîtra au printemps.

Dans le Domaine intermontagneux, la CGC a entrepris trois projets. Du nord au sud, les zones étudiées sont le bassin de Bowser, la région de McLeod Lake et celle de Nechako-Chilcotin. Carol Evenchick travaille à la cartographie de reconnaissance de la partie nord du bassin de Bowser; aux endroits reconnus pour leurs importantes ressources en charbon, elle a établi une stratigraphie détaillée à l'échelle régionale. Ses travaux ont permis de démontrer que les strates du bassin sont imbriquées sur les failles de chevauchement et les plis cally. The region is not one basin with three blanket units. Instead each unit occupies one or more discrete small basins which may overlay each other. The tectonics and basin controls are unknown.

Bert Struik in the McLeod Lake region is producing a new map of McLeod Lake map area and documenting the idea that the Wolverine Mountains are a metamorphic complex bounded on two sides by dextral strike slip faults and on the two other sides by gently dipping extension faults. As in core complexes elsewhere Struik speculates that precious metals may be concentrated along the extension faults.

In the Yukon, GSC is conducting a cooperative one-year project with Indian and Northern Affairs Canada northeast of Mayo that includes 1:50 000 geological mapping and a study of the MARG volcanogenic massive sulphide occurrence. The project provides an exceptional opportunity to study the regional setting of an exciting new exploration target (the MARG), and to examine critical stratigraphic and structural relationships in the northern Cordilleran miogeocline where many significant components are exposed. New geologic maps of this area by Steve Gordey (GSC), Charlie Roots (GSC) and Grant Abbott (INAC) will be available at this meeting for the first time. The results of Bob Turner's (GSC) study of the MARG occurrence will be released by next fall.

This list details GSC's current Cordilleran field activities. Our expertise extends beyond the current project boundaries and provides Cordillera-wide data for the public and industry to draw on.

d'orientation nord-est, ce qui est à l'origine de la répétition de la stratigraphie et du raccourcissement de la séquence d'un facteur d'au moins 30 %. Le bassin doit donc être considéré comme une zone de plissement et de chevauchement d'orientation nord-ouest, et non comme un simple bassin sédimentaire. L'épaississement structural signifie que le degré de maturation des strates peut être inversé par endroits. Les strates matures du point de vue thermique et, par conséquent, considérées comme des ressources significatives en gaz et en pétrole peuvent s'observer sous les nappes de chevauchement des lits surmatures.

L'une des conséquences de ce nouveau contexte structural du bassin de Bowser réside dans le fait que le Domaine intermontagneux septentrional, situé au nord-ouest et au sud-est de ce bassin, pourrait également avoir subi une contraction. Il sera donc nécessaire de reconsidérer la géologie du Domaine intermontagneux septentrional en tenant compte de ce nouvel argument.

Catherine Hickson, elle, étudie la géologie de la province riche en hydrocarbures de Chilcotin-Nechako. Cette région couvre un vaste territoire où tout est à découvrir en raison de la couverture quaternaire et des roches volcaniques tertiaires qui masquent la géologie. La désuétude de la base de données géologiques, entre autres facteurs, retarde l'évaluation des ressources de cette région. L'exploration des hydrocarbures s'annonce bien; on a observé des roches mères contenant d'intéressants pourcentages en matière organique, les degrés de maturation de la fenêtre à huile sont suffisamment élevés et les roches-réservoirs sont abondantes. En plus des 1 300 kilomètres de données de sismique-réflexion relevées par l'industrie dans la région, au moins neuf puits ont été forés. Trois unités stratigraphiques intéressantes du point de vue économique ont été détectées sous la couverture; il s'agit du Groupe de Bowser Lake (Jurassique) dans le nord, du Groupe de Skeena (Crétacé) plus au sud et d'une séquence Éocène observée localement. La région ne se résume pas à un bassin comprenant trois unités minces de grande étendue. La réalité, c'est plutôt que chaque unité tapisse un ou plusieurs petits bassins bien distincts qui peuvent se superposer. Le cadre tectonique et le mécanisme de formation des bassins sont encore mal compris.

Dans la région de McLeod Lake, Bert Struik travaille à la production d'une nouvelle carte (région cartographique de McLeod Lake) et tente de documenter la théorie voulant que les monts Wolverine constituent un complexe métamorphique délimité sur deux côtés par des décrochements dextres et sur les deux autres par des failles de distension à pendage faible. Struik suppose que des concentrations en métaux précieux pourraient s'observer le long des failles de distension, comme c'est le cas des autres complexes à coeur métamorphique.

Au Yukon, la CGC participe à un projet d'un an en collaboration avec le ministère des Affaires indiennes et du Nord canadien, au nord-est de Mayo. Le but du projet est la cartographie de la géologie de cette région à l'échelle de 1/50 000 et l'étude d'une occurrence de gîtes Marg de sulfures massifs volcanogènes. Ce projet offre une chance exceptionnelle de mieux comprendre le contexte régional d'une nouvelle cible d'exploration des plus intéressantes (les gîtes Marg) et d'analyser les relations stratigraphiques et structurales majeures dans le miogéoclinal de la Cordillère du Nord, où sont réunis de nombreux éléments significatifs. Au Forum, il sera possible de se procurer pour la première fois de nouvelles cartes géologiques de cette région, compilées par Steve Gordey (CGC), Charlie Roots (CGC) et Grant Abbott (MAIN). Les résultats de l'étude de Bob Turner (CGC) sur l'occurrence de gîtes Marg seront publiés l'automne prochain.

C'est ainsi que se termine le résumé détaillé des travaux de terrain en cours dans la Cordillère. Nos connaissances ne se limitent pas aux frontières des projets décrits ci-haut et des données sur toute la Cordillère sont disponibles; le public et les industries sont invités à les utiliser.

Recent advances in mineral deposits research in the Cordillera and Pacific margin

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Introduction

The Mineral Resources Division of the Geological Survey of Canada (GSC) has a national mandate to i) develop new models for the formation and degradation of ore deposits so that criteria can be established for their exploration, and ii) to conduct resource evaluations, particularly in areas such as the offshore and national parks, not normally accessible to the minerals exploration industry.

To achieve these objectives, mineral deposits research is organized on the basis of deposit-class and controlling ore-forming processes. The metamorphic overprinting of the products of primary ore-forming processes at many ancient deposits has made it advantageous to work on modern offshore hydrothermal deposits and less deformed older deposits in Canada and, for deposit-types not well represented or preserved in Canada, elsewhere in the world. In all cases, new deposit models and exploration concepts are tested in the differ-

Progrès récents dans la recherche sur les gîtes minéraux de la cordillère et de la marge pacifique

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Introduction

La Division des ressources minérales de la Commission géologique du Canada (CGC) a un rôle d'envergure nationale. Elle se charge i) de la conception de nouveaux modèles de formation et de dégradation des gîtes minéralisés, afin d'établir des critères pour leur exploration, ainsi que ii) de l'évaluation des ressources dans les régions généralement non accessibles à l'industrie de l'exploration minérale, notamment les zones océaniques et les parcs nationaux.

La recherche sur les gîtes minéraux est organisée en fonction des types de gisements et des processus de minéralisation dans le but d'atteindre ces objectifs. La surimpression métamorphique des produits formés par les processus primaires de minéralisation de nombreux gîtes anciens justifie la décision, au Canada, d'étudier les gisements hydrothermaux modernes de milieu océanique et les vieux gisements les moins déformés. Pour ce qui est des types de gisements peu fréquents ou ent regions of Canada in an effort to develop new exploration targets and expand the potential of existing mineral districts through improved methods of detecting ore at depth.

The following is a summary of some of the highlights of mineral deposits research undertaken in the Cordillera and Pacific Margin over the past year.

Modern seafloor hydrothermal deposits (W.D. Goodfellow, J.M. Franklin, I.R. Jonasson, J.W. Lydon)

Modern seafloor hydrothermal deposits represent natural laboratories where deposits can be observed at various stages of formation and degradation in the ambient marine environment, and where both products and ore-forming fluids along an evolutionary pathway can be sampled and studied. Many of the insights gained from modern hydrothermal systems have revolutionized concepts of ore genesis and are now being used in exploration for ancient sulphide deposits. Highlights of this research include:

1) Sediments overlying spreading centres play an important role in thermally insulating the oceanic lithosphere thereby prolonging periods of geothermal activity and, because of their low permeability, in focusing fluids at a restricted number of vent sites thereby generating sulphide deposits that are on average an order of magnitude larger than deposits formed at sediment-bare ridges (e.g. Middle Valley, Escanaba Trough, Guaymas Basin). This may explain why ancient SEDEX deposits are on average less abundant but an order of magnitude larger than VMS deposits.

2) Because sulphide textures and the primary pyrrhotite-isocubanite-wurtzite assemblage are rapidly overprinted by pyrite, marcasite, sphalerite and covellite within a geologically short time-period of thousands of years, earlier assumptions about primary sulphide mineralogy in many ancient deposits are probably incorrect. This observation calls into question genetic models built on the assumption that the present form and distribution of sulphides in ancient deposits reflects primary conditions of sulphide formation.

3) Two types of alteration zones surround hydrothermal vents in Middle Valley. Type 1 consists of minerals of hydrothermal origin that have formed by the lateral migration of hot metalliferous fluids into permeable units during exit to the seafloor. Type 2 consists of authigenic Mg-smectites and carbonates formed locally by the conductive heating of pore waters by hydrothermal fluids. Because of their widespread distribution, thermal aureoles present a large target for mineral exploration assuming they can be seen through the overprinting effects of metamorphism.

4) Along the eastern Galapagos Rift, massive sulphide deposits are spatially and temporally associated

mal préservés sur le territoire canadien, ils ont été étudiés dans d'autres pays. Dans tous les cas, les modèles de gisement et concepts d'exploration établis sont mis à l'essai dans les différentes régions du Canada, pour en arriver à identifier de nouvelles cibles d'exploration et augmenter le potentiel des districts minéraux déjà connus, compte tenu de l'existence de méthodes améliorées pour la détection des gîtes profonds.

Ce qui suit est un résumé des recherches les plus importantes des dernières années sur les gîtes minéraux de la Cordillère et de la marge Pacifique.

Gisements hydrothermaux modernes du fond sous-marin (W.D. Goodfellow, J.M. Franklin, I.R. Jonasson et J.W. Lydon)

Les gisements hydrothermaux modernes du fond sous-marin sont des laboratoires naturels, en ce sens qu'il est possible d'y observer la formation et la dégradation des gisements à diverses étapes dans leur milieur marin ambiant, en plus d'échantillonner et d'étudier tant les produits que les fluides de formation du gisement, tout en suivant leur évolution. De nombreuses informations tirées des systèmes hydrothermaux modernes ont révolutionné les concepts de genèse des gîtes et sont maintenant considérées dans l'exploration d'anciens sulfures. Les apports de cette recherche sont les suivants :

1) Les sédiments déposés dans les zones d'accrétion créent un effet d'isolement thermique de la croûte océanique, prolongeant ainsi les périodes d'activité géothermique, mais aussi de concentration des fluides à l'emplacement d'un nombre restreint de cheminées, vue leur perméabilité réduite. Il en résulte des sulfures qui sont normalement d'une taille supérieure aux gisements formés sur les dorsales dénudées de sédiments, comme ceux de Middle Valley, de la fosse Escanaba et du bassin Guaymas. Ce fait explique pourquoi les anciens gisements de type SEDEX sont en général observés moins fréquemment mais sont de plus grande taille que les gisements VMS.

2) Les hypothèses énoncées auparavant sur la minéralogie primaire des sulfures de nombreux gisements anciens sont probablement erronées, puisqu'on a découvert que la texture des sulfures et l'assemblage primaire de pyrrhotite-isocubanite-wurtzite étaient rapidement remplacées, sous forme d'une surimpression, par de la pyrite, de la marcasite, de la sphalérite et de la covellite; ce processus s'est fait sur une période d'à peine quelques millions d'années, ce qui est considéré comme rapide à l'échelle des temps géologiques. Cette observation remet en question les modèles génétiques selon lesquels la forme actuelle des sulfures et leur répartition dans les anciens gisements témoignent des conditions

with highly fractionated volcanic rocks, and are underlain by feeder-pipes consisting of stockwork and vein sulphides, and hydrothermal altered lavas. A lack of replenishment of high-level magma bodies combined with an enhanced cooling rate due to efficient hydrothermal circulation in fractured oceanic crust has resulted in extensive fractional crystallization. The observation that exceptional fractionation of basalts has a spatial and genetic relationship to sulphide deposits is of great importance in determining the resource potential of older marine volcanic sequences preserved on land.

Ancient seafloor sulphide deposits (W.D. Goodfellow, R. Turner, J.W. Lydon)

SEDEX deposits represent an important mineral resource comprising 31% and 61% of the world's Pb and Zn mineral reserves, respectively. Most deposits occur in rift-controlled intracontinental Proterozoic and Paleozoic sedimentary basins. The Cordillera is endowed with some of the largest and best preserved SEDEX deposits in the world that formed during four major time-periods: Middle Proterozoic (e.g. Sullivan), Early-Middle Cambrian (e.g. Anvil District), Early Silurian (e.g. Howards Pass Camp) and Middle-Late Devonian (e.g. Macmillan Pass District, Gataga District). The principal characteristics of this deposit-class are:

i) All deposits form in rift controlled basins during the post-extensional reactivation stage; ii) All deposits formed from hydrothermal fluids discharged along extensional faults into an ambient anoxic water column; iii) Episodes of hydrothermal activity commonly overlap periods of mafic (alkalic) magmatism; iv) The TOM and JASON deposits near Macmillan Pass are underlain by a feeder zone that has invaded and partially replaced sedimentary barite with galena, sphalerite, pyrrhotite and ferroan carbonates. The increase in ore grades and grain size accompanying this process has important implications for deposit development and ore benefication, respectively. v) The JASON, BOUNDARY CREEK and TOM deposits occur within widespread alteration zones characterized by ferroan carbonate. These alteration zones probably formed by the lateral migration of hydrothermal fluids into permeable units from centres of hydrothermal discharge. The large extent of these alteration zones relative to the sulphide bodies make them an excellent exploration target for SEDEX deposits. vi) The TOM deposit is overlain by hundreds of metres of carbonaceous mudstone and chert that contains many intervals of finely laminated pyrite and barite. This pyrite and barite is of hydrothermal origin, is restricted to the area above the deposit and formed during the waning stages of the TOM hydrother-

primaires de formation des sulfures.

3) Dans la région de Middle Valley, il existe deux types de zones d'altération aux environs des cheminées hydrothermales. Le type 1 se compose de minéraux hydrothermaux qui dérivent de la migration latérale de fluides chauds métallifères vers des unités perméables, alors qu'ils étaient expulsés sur le fond sous-marin. Le type 2 présente des smectites authigènes à Mg et des carbonates, formés ça et là sous l'effet du réchauffement conductif de l'eau interstitielle par les hydrothermalytes. Les auréoles thermiques, parce qu'elles sont largement répandues, constituent une cible importante en exploration minérale, surtout qu'elles ne sont pas masquées par la surimpression métamorphique.

4) Les sulfures massifs observés le long de la dorsale Galapagos orientale sont en association spatio-temporelle avec des roches volcaniques fortement différenciées et sont sus-jacentes à des cheminées d'alimentation composées de stockwerk et de veines minéralisées en sulfures, ainsi que de laves hydrothermales altérées. L'importante cristallisation fractionnée a été causée par un manque de matériel pour alimenter les corps magmatiques de haut niveau, associé à un taux de refroidissement plus élevé en raison d'une circulation efficace des hydrothermalytes dans la croûte océanique fracturée. Le lien spatial et génétique établi entre la différenciation exceptionnelle des basaltes et les gisements de sulfures est primordial dans la détermination du potentiel en ressources des séquences volcaniques marines plus vieilles, aujourd'hui observables sur le continent.

Anciens sulfures du fond sous-marin (W.D. Goodfellow, R. Turner et J.W. Lydon)

Les gisements de type SEDEX constituent une importante ressource minérale puisqu'ils représentent respectivement 31 % et 61 % des réserves mondiales en Pb et en Zn. La plupart des gisements se trouvent dans des bassins sédimentaires intracontinentaux du Protérozoïque et du Paléozoïque formés par les rifts. Dans la Cordillère, on retrouve quelques uns des gisements SEDEX les plus importants et les mieux préservés au monde, dont la formation remonte à quatre période de temps majeures, soit le Protérozoïque moyen (Sullivan), le Cambrien précoce à moyen (district d'Anvil), le Silurien précoce (camp du col Howards) et le Dévonien moyen à tardif (district du col Macmillan, district de Gataga). Les principales caractéristiques de ce type de gisement sont les suivantes :

i) Tous les gisements se sont formés dans des bassins de rift, postérieurement à la période de réactivation des mouvements de distension; ii) Les gisements dérivent tous d'hydrothermalytes éjectées le long de failles de distension dans une colonne d'eau à milieu ambiant mal system. Because of the close spatial and genetic association with the TOM deposit, and the fact that hydrothermal sediments persist well into the overlying sedimentary sequence, they represent an ideal target for exploring for buried SEDEX deposits.

Mesozoic/Cenozoic lode gold deposits, Sulphurets area, B.C. (R.V. Kirkham, S.B. Ballantyne, D.C. Harris)

The Sulphurets area in the Coast Mountains of northwestern B.C. contains porphyry Cu and Mo, and a variety of precious metal occurrences associated with widespread pyritic alteration zones within Triassic-Jurassic sedimentary, volcanic and alkalic intrusive rocks. Extensive Cu- and Mo-bearing quartz vein stockworks have been flattened into ptygmatic folds and dismembered vein structures, and phyllic and argillic alteration zones now form large areas of quartz-sericite-pyrite schist. In addition to early synvolcanic and synintrusive deposits, some bonanza-grade Au (Ag)-bearing quartz (carbonate, K-feldspar and/or barite) veins are probably younger and formed by syntectonic processes.

Lithogeochemical studies indicate areas with Cu-Au, Mo-Au, Cu-Mo-Au, As-Au and Sb-Ag-Au associations and other areas with Cu and Mo but negligible Au. Most major Sb-Ag-Au quartz-carbonate veins contain argentian tetrahedrite, pyrargyrite, polybasite and electrum.

MOUNT SKUKUM, Yukon (D.A. Love, W.D. Goodfellow, J. Hodgson)

The hydrothermal system at MOUNT SKUKUM comprises two distinct facies: the mineralized Cirque, Brandy and Lake Zones, which occupy shear fractures and are associated with adularia-sericite alteration envelopes, and a barren acid-sulphate pipe, the Alunite Cap Zone. Whereas the advanced argillic alteration was controlled by synvolcanic faults, and has textural and mineralogical features strongly suggestive of formation from magmatic volatiles, the structures which host the mineralized veins display strike-slip movement and are interpreted as later Riedel shear fractures controlled by regional stresses. The mineralized veins therefore are not related either to acid-sulphate alteration, or to volcanic caldera structures but to an evolving stress regime established between the Tintina and Shakwak transform faults.

The ANTONIUK Au deposit, Mount Freegold, Yukon (B.I.A. McInnes, W.D. Goodfellow, J.H. Crocket)

The ANTONIUK deposit is a large (450 m x 300 m) sub-oval diatreme breccia complex intruded by rhyolite and subordinate andesite dykes. It is one of three large breccia bodies in the Freegold Mountain area which may be structurally controlled by small transcurrent faults parallel to and coeval with the Tintina fault. The rhyolite dykes, dated at 78 Ma, increase in grain size

anoxique; iii) Les périodes d'activité hydrothermale succèdent souvent à des épisodes de magmatisme mafique (alcalin); iv) Les gîtes Tom et Jason près du col Macmillan reposent sur une zone d'alimentation qui s'est infiltrée et a partiellement remplacé la barytine sédimentaire par de la galène, de la sphalérite, de la pyrrhotine et des carbonates ferreux. Ce processus est accompagné d'une augmentation de la teneur en minerai et de la granulométrie, ce qui a des conséquences importantes sur l'exploitation du gisement et la mise en valeur du minerai. v) Les gîtes Jason, Boundary Creek et Tom se trouvent dans de vastes zones d'altération dont la caractéristique est la présence de carbonates ferreux. Ces zones d'altération dérivent probablement de la migration latérale des hydrothermalytes, de leur lieu de décharge vers des unités perméables. Ces zones d'altération représentent une excellente cible d'exploration pour les gisements SEDEX, vue leur grande étendue par rapport aux corps minéralisés. vi) Le gîte Tom est sous-jacent à des centaines de mètres de mudstone carboné et de chert, comprenant de nombreux intervalles de pyrite et de barytine finement laminées, d'origine hydrothermale. Ces minéraux se trouvent uniquement dans la région recouvrant le gîte Tom et se sont formés pendant la période d'affaiblissement du système hydrothermal. La relation spatiale et génétique étroite qui les lie au gîte Tom et la présence persistante de sédiments hydrothermaux dans la séquence sédimentaire sus-jacente sont des facteurs qui justifie le fait qu'ils représentent une cible idéale dans l'exploration pour les gisements enfouis de type SEDEX.

Gisements d'or filonien du Mésozoïque et du Cénozoïque de la région de Sulphurets, en C.-B. (R.V. Kirkham, S.B. Ballantyne et D.C. Harris)

Dans la région de Sulphurets de la chaîne Côtière (partie nord-ouest de la C.-B.), on observe des porphyres de Cu et de Mo de même qu'une variété d'occurrences de métaux précieux, associés aux grandes zones d'altération pyriteuse des roches sédimentaires, volcaniques et intrusives (à composition alcaline), d'âge triasique à jurassique. Les vastes stockwerk de veines de quartz minéralisés en Cu et en Mo ont été aplatis, résultant en une série de plis ptygmatiques et de veines fragmentées; les zones d'altération en minéraux phylliteux et argileux font maintenant place à d'importantes régions où on observe des schistes à quartz, séricite et pyrite. En plus des gisements précoces, comtemporains du volcanisme et de la période d'intrusion, quelques veines de quartz (avec présence ou absence de carbonates, de feldspaths potassiques ou de barytine) enrichies en or (et parfois en argent) au stade bonanza sont probablement plus jeunes et découlent de processus syntectoniques.

and abundance at depth and appear to represent the uppermost portion of a medium-grained alaskitic intrusion. Gold occurs disseminated throughout the breccia and is associated with arsenopyrite, pyrite and quartz. The diatreme is interpreted to have formed by the explosive escape of volatiles evolved during retrograde boiling of alaskite at depths less than 1.5 km below the paleosurface.

Des études lithogéochimiques ont mis à jour des régions présentant les associations minérales suivantes : Cu-Au, Mo-Au, Cu-Mo-Au, As-Au et Sb-Ag-Au. D'autres régions minéralisées en Cu et Mo, mais dont la présence d'Au était négligeable ont été observées. La majorité des veines de quartz et de carbonates contiennent également de la tétrahédrite argentifère, de la pyrargyrite, de la polybasite et de l'électrum.

Le MONT SKUKUM au Yukon (D.A. Love, W.D. Goodfellow et J. Hodgson)

Le système hydrothermal du mont Skukum se compose de deux faciès distincts, soit les zones minéralisées de Cirque, Brandy et Lake, localisées dans les fractures de cisaillement et ayant un lien avec les roches environnantes altérées à adulaire et séricite ainsi qu'une cheminée non minéralisée de sulfates acides, appelée la zone du d'Alunite Cap. Bien que l'importante altération en minéraux argileux soit régie par des failles synvolcaniques et présente des caractéristiques textuelles et minéralogiques qui suggèrent fortement une formation dérivée d'éléments volatils magmatiques, les structures encaissantes des veines minéralisées sont marquées par des mouvements de décrochement. Elles sont appelées les fractures postérieures de cisaillement de Riedel et ont été produites par des contraintes régionales. Ainsi, les veines minéralisées ne sont pas plus associées à l'altération en sulfates acides qu'à des caldeiras volcaniques, mais plutôt à un régime de contraintes en évolution, délimité par les failles transformantes de Tintina et de Shakwak.

Le gîte aurifère d'ANTONIUK, mont Freegold au Yukon (B.I.A. McInnes, W.D. Goodfellow et J.H. Crocket)

Le gîte d'Antoniuk est un important complexe de forme quasi ovale (450 m par 300 m), composé de brèches de diatrème et recoupé par des dykes de rhyolite et d'andésite secondaire. Il constitue l'un des trois grands complexes de brèches à contrôle structural de la région du mont Freegold, qui dérivent de petites failles de coulissage parallèles à celle de Tintina et contemporaines de cette dernière. La granulométrie et l'abondance des dykes de rhyolite, dont l'âge se situe à 78 Ma, augmentent avec la profondeur et semblent occuper la zone supérieure d'une intrusion d'alaskite à grain moyen. L'or est disséminé dans toute la brèche et est associé à l'arsénopyrite, la pyrite et le quartz. La formation du diatrème s'explique par la libération, sous forme d'explosion, d'éléments volatils qui se sont accumulés au cours d'une période d'ébullition rétrograde de l'alaskite, à des profondeurs inférieures à 1,5 km de la paléosurface.

Georgia Basin project: scope and basin tectonic setting

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Scope of project

The purpose of Georgia Basin project is to investigate hydrocarbon potential of those Upper Cretaceous to Neogene sedimentary rocks distributed around Georgia Strait in southwestern British Columbia that collectively constitute Georgia Basin. The project, funded in 1989 under Frontier Geoscience Program (FGP), will provide new information within four general categories: (1) controls of basin formation/deep basin geometry; (2) internal geology/basin evolution; (3) processes governing hydrocarbon generation, accumulation and preservation; (4) hazards and constraints to development. Work wholly or partly funded under FGP (categories in brackets) includes: (1) mapping by the writer in central and western Coast Mountains to decipher the poorly known regional structure of that part of the basin basement; (2) palynological studies (G.E. Rouse, U.B.C.) to date and correlate basin strata; (3) maturation studies on basin strata (R.M. Bustin, U.B.C.); (4) Fraser Delta studies (J.L. Luternauer, GSC), neotectonics of southwestern B.C. (J.J. Clague, GSC), and landslide and debris flow investigations (S.G. Evans and L.E. Jackson, GSC). Regionally related GSC projects, not funded by FGP, include regional mapping and economic mineral studies within the southern Coast Mountains (M. Journeay and G. Lynch, both GSC) and marine gravity and shallow seismic reflection in Georgia Strait by T. Hamilton (GSC).

Basin rocks and structures

Georgia Basin includes up to 4 km of Upper Cretaceous marine and nonmarine Nanaimo Group strata and locally over 6 km of nonmarine lower Tertiary Chuckanut, Burrard and Kitsilano formations. Proposed depositional settings for these strata are forearc and strike-slip basins, although the original basin configuration is unknown. These rocks were folded and faulted and are overlain unconformably by the southwesterly tilted Oligocene to Miocene Huntingdon Formation.

Regional structural controls

Georgia Basin lies on three different basements: Wrangellian terrane on Vancouver Island to the west, Cascade Mountains to the southeast, and Coast Mountains to the northeast. Basin evolution is controlled by events more clearly recorded in the better exposed and more varied rocks of the basements than in the poorly exposed basin itself. Based partly on LITHOPROBE

Projet du bassin de Georgia : buts poursuivis et cadre tectonique

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Buts poursuivis

L'objectif du projet du bassin de Georgia est de déterminer le potentiel en hydrocarbures des roches sédimentaires du Crétacé supérieur au Néogène qui s'observent tout autour du détroit de Georgia (dans le sud-ouest de la Colombie-Britannique) et qui composent le bassin de Georgia. Le projet, lancé en 1989 et financé par le Programme géoscientifique des régions pionnières (P.G.R.P.), apportera de nouveaux renseignements dans quatre grands champs d'intérêt, en l'occurrence (1) les lois régissant la formation du bassin et la géométrie de sa partie profonde; (2) la géologie interne et l'évolution du bassin; (3) les processus de génération, d'accumulation et de préservation des hydrocarbures; (4) les imprévus et les contraintes à l'exploitation. Les travaux entièrement ou partiellement subventionnés par le P.G.R.P. et portant sur les quatre grandes catégories mentionnées ci-haut sont les suivants : (1) cartographie, par l'auteur, des parties centre et ouest de la chaîne Côtière, visant à décrire le cadre structural régional, encore peu connu, du socle de cette partie du bassin; (2) études palynologiques menées par G.E Rouse de la U.B.C., dans le but de dater et de corréler les strates du bassin; (3) études sur la maturation des strates du bassin (R.M. Bustin, U.B.C.); (4) études sur le delta du Fraser (J.L. Luternauer, CGC), la néotectonique de la partie sud-ouest de la C.-B. (J.J. Clague, CGC) ainsi que les glissements de terrain et les coulées de débris (S.G. Evans et L.E. Jackson, CGC). Les projets d'envergure régionale non financés par le P.G.R.P. comprennent la cartographie régionale et des études sur les minéraux économiques de la région de la chaîne Côtière méridionale (M. Journeay et G. Lynch, CGC), ainsi que des levés de gravimétrie marine et de sismique réflexion en milieu peu profond dans le détroit de Georgia (T. Hamilton, CGC).

Lithologies et structures du bassin

Dans le bassin de Georgia, on observe jusqu'à 4 km de strates marines et non marines du Groupe de Nanaimo (Crétacé supérieur) et, par endroits, plus de 6 km de lithologies non marines du Tertiaire inférieur des formations de Chuckanut, Burrard et Kitsilano. Sur une base hypothétique, on assume que ces strates aient été déposées dans deux types de bassin, soit d'avant-arc et de décrochement, bien que la structure initiale du bassin ne soit pas connue. Ces roches plissées et faillées sont en deep seismic reflection data on Vancouver Island, and partly on regional mapping, the crustal structure of the basin region is hypothesized to be a stack of crustal thickness of (mainly) west-vergent thrust fault slices that formed in Cretaceous to Recent time in response to underthrusting of Pacific Ocean crust beneath western North America. Within the thrust stack, Wrangellian and central and western Coast Mountains rocks appear to act in a relatively rigid manner (in comparison with flanking rocks) and to be internally imbricated along steeply northeast-dipping reverse and (thrust?) faults. Central and western Coast Mountains and Wrangellian rocks are flanked to northeast and southwest by more deformed and locally more metamorphosed rocks. Structurally overlying rocks in the eastern Coast Mountains (east of Harrison Lake) are correlative with rocks in the Cascade Metamorphic Core and Northwest Cascades System. Rocks lying structurally below Wrangellia on Vancouver Island, (Leech River schist; Pacific Rim Terrane) are probably correlative with melanges in the westernmost Cascade foothills. Georgia Basin strata probably were deposited in a transpressional tectonic setting mainly upon the relatively rigid Coast Mountains-Wrangellian block, when to the east at least, there was disruption of the thrust stack by (1) dextral strike-slip faults in Late Cretaceous-Eocene time (70?-40 Ma), and (2) by northeast-trending faults in Neogene time (25-18 Ma). Georgia Basin strata are preserved in a Neogene to Recent structural depression that extends from Alaska to Oregon, which lies approximately 150 km east of the present plate margin.

contact discordant sous la formation de Huntingdon, basculée vers le sud-ouest et d'âge oligocène à miocène.

Contrôle structural à l'échelle régionale

Le bassin de Georgia est sus-jacent à trois socles différents, soit le terrane de Wrangellia à l'ouest, sur l'île de Vancouver, le socle de la chaîne des Cascades au sud-est et celui de la chaîne Côtière au nord-est. L'évolution du bassin est régie par des événements plus facilement observables dans les roches des socles, plus variées et aux affleurements plus nombreux, que dans celles du bassin lui-même. Selon, d'une part les données de sismique réflexion profonde enregistrées sur l'île de Vancouver (programme LITHOPROBE), et d'autre part la cartographie régionale, l'interprétation de la structure de la croûte dans la région du bassin se résume à un empilement de lithologies crustales d'une certaine épaisseur, mises en place en tranches par les failles de chevauchement à vergence ouest (principalement), lesquelles remontent au Crétacé et à l'Holocène et découlent des contraintes dues au sous-charriage de la croûte de l'océan Pacifique sous l'Amérique du Nord occidentale. Dans l'empilement dû au chevauchement, les roches de la Wrangellia et des parties centre et ouest de la chaîne Côtière semblent se comporter comme des matériaux relativement rigides (en comparaison avec les roches adjacentes) et être très profondément imbriquées le long des failles inverses et de chevauchement ? à pendage fort d'orientation nord-est. Au nord-est et au sud-ouest des roches de la chaîne Côtière (parties centre et ouest) et de la Wrangellia, on observe des lithologies plus déformées et localement plus métamorphisées. Dans la chaîne Côtière orientale (à l'est du lac Harrison), les roches structuralement sus-jacentes sont équivalentes à celles du coeur métamorphique des Cascades et de la partie nord-ouest du système des Cascades. Quant aux roches en contact structural sous le socle de la Wrangellia (île de Vancouver), en l'occurrence les schistes de Leech River du terrane du Pacific Rim, elles peuvent être corrélées avec les mélanges des contreforts de la chaîne des Cascades (extrémité ouest). Les strates du bassin de Georgia ont probablement été déposées dans un cadre tectonique de transpression, en grande partie sur le bloc relativement rigide de la chaîne Côtière et du socle de la Wrangellia, alors qu'à l'est (et peut-être ailleurs), on assistait au démantelèment de l'empilement dû au chevauchement par (1) des décrochements dextres du Crétacé tardif à l'Éocène (de 70 ? à 40 Ma) et (2) des failles d'orientation nord-est d'âge néogène (25 à 18 Ma). Les strates du bassin de Georgia se sont conservées dans une dépression structurale du Néogène à l'Holocène qui s'étend de l'Alaska à l'Oregon et se trouve approximativement à 150 km à l'est de la marge actuelle de la plaque.

Georgia Basin: submarine geology and geophysics

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It is possible to use regional geology, seismicity, shallow reflection seismology and potential field data to show that the depression containing Georgia Strait is the product of the complex interaction of tectonic and glacial processes, despite the paucity of deep boreholes and modern multichannel seismic data. Within the depression are preserved Upper Cretaceous, Tertiary and Quaternary strata that collectively form the fill of Georgia Basin. Rationale for studying Georgia Basin includes hydrocarbon exploration, underground gas storage, and geotechnical and foundation studies in this region of potential earthquake hazards.

Tectonic controls

Georgia Basin is located approximately 300 km from the edge of the Cascadia subduction zone, over the downward bend in the subducting Juan de Fuca Plate. Seismicity occurs beneath the entire basin, throughout the thickness of the North America Plate and in the underlying Juan de Fuca Plate. The larger number of events occurring on the Pacific side of the basin axis suggests a concentration of deformation on that side. The deeper events confirm the underlying, ongoing cause for basin deformation. Shallow events suggest that some faults cutting basin fill may be seismically active.

The bedrock surface is a gentle dish in profile, with 3-5° sideslopes, inflecting sharply to 20° into the Coast Mountains. Bedrock surface beneath the Lower Mainland, Fraser Delta, and southern Georgia Strait is generally up to 600-750 m below sea-level, with the gentle relief of the surface outlining broad, shallow valleys 3-10 km across and < 200 m deep. This interpretation is that the unconformity represents prolonged, post-Oligocene erosion, and the erosional surface subsided at average rates of 0.04 mma^{-1} to the present configuration. Some buried valleys are probably fault controlled; this control may be reflected in the location of modern drainage systems such as the Main Arm of Fraser, Nicomekl, Serpentine, Sumas and Vedder rivers.

Glacial products and processes

Georgia Strait and environs constitute a "megafiord", located within and parallel to the continental margin. With water up to 400 m deep and an unconsolidated section up to 700 m thick, geophysical methods are required to investigate basin geology. Morphology of the bedrock surface beneath Georgia Strait, a series of northwest-trending troughs containing

Géologie et géophysique du bassin de Georgia

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Malgré le petit nombre de forages profonds effectués et le manque de données sismiques modernes obtenues par voies multiples, on peut utiliser les données sur la géologie régionale, la sismicité, la sismique réflexion de faible profondeur et le champ potentiel pour démontrer que la dépression où coule le détroit de Georgia résulte de l'interaction complexe entre des processus tectoniques et glaciaires. Dans cette dépression, appelée le bassin de Georgia, on observe des strates du Crétacé supérieur, du Tertiaire et du Quaternaire. L'étude de ce bassin se fait pour différentes raisons; elle vise notamment l'exploration des hydrocarbures, l'enfouissement souterrain de gaz et une meilleure compréhension de la géotechnique et des fondations dans cette région exposée aux risques de séismes.

Cadre tectonique

Le bassin de Georgia se trouve à une distance approximative de 300 km du bord de la zone de subduction de Cascadia, sur la flexure descendante de la plaque Juan de Fuca, en cours de subduction. Des séismes ont été rapportés sous le territoire entier couvert par le bassin, sur toute l'épaisseur de la plaque nord-américaine, ainsi que dans la plaque sous-jacente Juan de Fuca. Les événements plus fréquents sur le flanc de l'axe du bassin le plus proche du Pacifique suggèrent une concentration des déformations de ce côté. Les événements les plus profonds corroborent l'hypothèse d'une source de déformation sous-jacente au bassin et encore active. Quant aux événements peu profonds, ils permettent de supposer que quelques failles recoupant le matériel de remplissage du bassin puissent être actives du point de vue sismique.

Le profil de la surface du socle ressemble à une cuvette aux courbes peu accentuées dont les flancs ont un pendage de 3 à 5°, sauf dans la chaîne Côtière où ils passent rapidement à un pendage de 20°. La surface du socle sous le Lower Mainland, le fleuve Fraser et le détroit de Georgia méridional se situe généralement de 600 à 750 m sous le niveau de la mer, et possède le même relief faible que la surface dans les grandes vallées peu profondes, d'une largeur de 3 à 10 km et d'une profondeur inférieure à 200 m. D'après cette interprétation, on déduit que la discordance est le signe d'une longue période d'érosion postérieure à l'Oligocène et que la surface d'érosion s'est enfoncée à une vitesse moyenne de 0,04 mm/a pour en arriver à la configuration actuelle. Quelques vallées enfouies se sont pronon-interconnected elongate deeps, resembles that of high-gradient alpine valleys. This morphology probably formed at the onset of a glacial cycle, due to the combination of high gradient valley glaciers flowing into a pre-existing tectonic depression, deflected and channelled southeastwardly down the basin by the buttress of Vancouver Island mountains. Most deposition probably occurred during glacial advances, and is observed in seismic reflection profiles as a lower unit with strong horizontal reflectivity (from well-stratified glaciomarine turbidites), and an upper unit with discontinuous, inclined or absent reflectors (representing diamictites and coarse grained sands). In places, this couplet of acoustic facies is superimposed two or three times. Proglacial deposition ceased once the basin was infilled by grounded ice, and was bypassed and overridden by the regional ice wedge extending from the Coast Mountains.

Postglacial through modern sedimentation

Postglacial sedimentary deposits are thin and highly variable in character, ranging from the oldest late glacial facies of glaciomarine turbidites, to the youngest (post-6 Ka) silt detritus supplied by the Fraser River. To the north of Ballenas and Thormanby islands and to the south of Point Roberts the seafloor is mostly relic and there is no extensive reworking or postglacial sedimentation (this is significant for the age constraints on young faulting and substrate stability for geotechnical/-risk evaluation). In the vicinity of the Fraser River, the majority of postglacial sedimentation is in three bathyal foredeep silt lobes in front of the main, middle and north arms.

Bedrock geology and Tertiary structures

Different bedrock packages may be recognized in the seismic reflection record and correlated with nearby emergent outcrops. Tertiary strata beneath southern Georgia Strait have gentle dips and a distinctive sequence of reflectors with great lateral continuity. Cretaceous strata are more intensely folded, with less continuity than the Tertiary. South of the International Boundary, less deformed Tertiary rocks overlie more deformed Cretaceous rocks. Elsewhere either unit overlies the most deformed and least continuous reflectors that represent Jurassic and older igneous and metamorphic basement to the basin.

Reflection seismic and potential field data locate major crustal faults between different bedrock types and structural blocks. Those with largest offsets are subparallel to basin elongation. Offsets of deformed Cretaceous and Tertiary strata indicate that most displacement is probably post-Eocene. The major faults are: Texada Fault along the northeast boundary of the Comox Basin, from Quadra Island to the north end of

bablement formées sous l'action de failles, ce qui se reflète dans l'endroit où se trouvent les réseaux de drainage modernes comme le bras principal du Fraser, ainsi que les rivières Nicomekl, Serpentine, Sumas et Vedder.

Sédiments et processus glaciaires

Le détroit de Georgia et les environs forment un "méga-fjord", faisant partie de la marge continentale et parallèle à celle-ci. La hauteur de la colonne d'eau peut atteindre 400 m et l'épaisseur des sédiments non consolidés qui tapissent le fond, 700 m. Il est donc nécessaire de faire appel aux méthodes géophysiques pour étudier la géologie du bassin. La morphologie de la surface du socle sous le détroit de Georgia s'apparente à celle des vallées alpines à pente forte; elle se compose d'une série de cuvettes d'orientation nord-ouest qui contiennent des fosses sous-marines allongées non reliées entre elles. Cette morphologie s'est probablement mise en place à l'aube d'un cycle glaciaire engendré par la combinaison de glaciers de vallée à pente forte s'écoulant dans une dépression tectonique déjà en place, qui ont été déviés et canalisés vers le sud-est en aval du bassin par les contreforts des montagnes de l'île de Vancouver. On suppose que la sédimentation a principalement eu lieu lors des avancées glaciaires; à l'aide des profils de sismique-réflexion, on a identifié une unité inférieure à réflectivité horizontale élevée, caractéristique des turbidites glaciomarines bien stratifiées, et une unité supérieure à réflecteurs discontinus et inclinés ou sans réflecteurs, donc composée de diamictites et de sables à grain grossier. Par endroits, cet ensemble de faciès accoustiques se superpose deux ou trois fois. La sédimentation proglaciaire a cessé dès que le bassin a été rempli de glace échouée et couvert par le coin de glace d'envergure régionale, s'étendant de la chaîne Côtière jusqu'au bassin.

Sédimentation du postglaciaire à aujourd'hui

Les dépôts sédimentaires post-glaciaires sont minces et de nature très variable, allant des faciès glaciaires tardifs les plus vieux, composés de turbidites glaciomarines, à ceux les plus jeunes (postérieurs à 6 ka), formés par les détritus de silt du fleuve Fraser. Au nord des îles Ballenas et Thormanby et au sud de la pointe Roberts, le fond sous-marin est principalement relique, sans aucune trace de remaniement majeur ou de sédimentation postglaciaire. Ce fait est significatif dans la détermination des contraintes de temps qui ont agi sur les failles récentes et de la stabilité du substrat, en vue d'une étude géotechnique et de l'évaluation des risques. Aux environs du fleuve Fraser, la sédimentation postglaciaire se concentre dans trois lobes bathyaux d'avant-fosse composés de silt, se trouvant respectivement en avant des bras principal, moyen et septentrional.

Texada Island; Malaspina Fault(?) along Malaspina Strait; and Gulf Islands Fault along the southwestern margin of the Tertiary Whatcom Basin, parallel with the northeastern margins of Valdez, Galiano, Mayne, Saturna and Orcas islands.

Geodynamics

The Coast Mountains are currently being uplifted while Georgia Basin is subsiding. Evidence includes: geodetic surveying, heat flow, radiometric dates and tilted glaciomarine sediment. An estimate of the tilt rate for southern Howe Sound for the last 12 Ka (0.064 mma^{-1}) agrees with rates inferred from reset ages since 10 Ma. Shorter term geodynamic rates are even greater. The significance of this is that deformation is ongoing, as seismicity and structures would indicate.

Organic sources and thermogenic gas

Cretaceous and Tertiary sedimentary successions contain coals and abundant terrigenous kerogen that are sources for gaseous hydrocarbons. Gas is acoustically apparent in unconsolidated sediments, typically making absorbent screens that mask other features or brightening reflectors while limiting penetration. Concentrations of "acoustic" gas occur in both glacial and postglacial deposits over Cretaceous and Tertiary bedrock. It is associated with buried faults and up-dip pinchouts. The widespread occurrence of gas in unconsolidated sediments is not significant in terms of production, but is an indication of source rocks and hydrocarbon maturation.

Géologie du socle et structures du Tertiaire

Selon la sismique-réflexion, différents types de socles peuvent être identifiés et corrélés avec des affleurements des environs. Les strates tertiaires sous le détroit de Georgia méridional présentent des pendages faibles et une séquence distincte de réflecteurs à grande continuité latérale. Les strates du Crétacé ont subi un plissement plus intense et sont moins continues que celle du Tertiaire. Au sud de la frontière internationale, des roches tertiaires moins déformées reposent sur des lithologies crétacées qui le sont davantage. Partout ailleurs, les unités recouvrent les réflecteurs les plus déformés et les moins continus, à savoir le socle du bassin d'âge jurassique ou plus vieux, composé de roches ignées et métamorphiques.

Les données de sismique-réflexion et de champ potentiel ont permis d'identifier les principales failles de la croûte qui se logent entre les différents types de socles de même que les blocs structuraux. Les failles dont les décalages sont les plus importants sont subparallèles à l'axe du bassin. Les décalages observés dans les strates déformées du Crétacé et du Tertiaire suggèrent que la plupart des mouvements seraient probablement postérieurs à l'Éocène. Les principales failles sont les suivantes : la faille de Texada, suivant la limite nord-est du bassin Comox et allant de l'île Quadra jusqu'à l'extrémité nord de l'île Texada; la faille de Malaspina (?), longeant le détroit de Malaspina et la faille de Gulf Islands, observée le long de la marge sud-ouest du bassin tertiaire Whatcom, selon une direction parallèle aux marges nord-est des îles Valdez, Galiano, Mayne, Saturna et Orcas.

Géodynamique

Actuellement, la chaîne Côtière connaît un soulèvement alors que le bassin de Georgia s'enfonce. Cette affirmation se fonde sur des levés géodésiques, le flux thermique, des dates radiométriques, de même que sur la présence de sédiments glaciomarins basculés. Dans le détroit de Howe, on estime le taux de basculement des 12 derniers milliers d'années à 0,064 mm/a, ce qui correspond aux taux déduits pour les 10 derniers millions d'années. court terme, les taux estimés par la géodynamique sont encore plus élevés. Cela signifie que le processus de déformation est en cours, comme l'indiqueraient la sismicité et les données structurales.

Sources de matière organique et gaz thermogéniques

Les successions sédimentaires du Crétacé et du Tertiaire présentent des charbons et de grandes quantités de kérogène terrigène, deux sources d'hydrocarbures gazeux. Les gaz des sédiments non consolidés ont une réponse acoustique; ils forment des écrans absorbants qui masquent les autres données ou des réflecteurs brillants qui limitent la pénétration de l'appareil. Des concentrations de gaz acoustiques s'observent tant dans les dépôts glaciaires que postglaciaires sus-jacents au socle crétacé et tertiaire. Ce phénomène est relié aux failles enfouies et aux biseaux en amont pendage. Les nombreuses occurrences de gaz des sédiments non consolidés n'ont pas d'incidence significative en terme de production, mais témoignent de la présence de roches mères et de la maturation des hydrocarbures.

Gambier Group of the Fire Lake area: basement to the Georgia Basin?

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The Fire Lake Group occurs as one of a scattered series of Early Cretaceous pendants in the southern Coast Belt. These formed in an island arc setting. Rocks are correlated with the Gambier Group, which contains significant volcanogenic massive sulphide mineralization, including the BRITANNIA Cu-Zn orebody.

The Peninsula Formation occurs at the base of the group, and was deposited as a fining upwards sequence during volcanic quiescence. Facies progress upwards from fluvial, to beach, to marine shelf, and record a period of subsidence during normal faulting. The overlying Brokenback Hill Formation is a complex volcanic sequence dominated by subaqueous crystal tuff, autoclastic and epiclastic rocks of mostly intermediate composition, as well as welded pyroclastic rocks of likely subareal origin at the top of the formation. Thin to thick bedded gypsum occurs locally within the Brokenback Hill Formation. Such beds contain disseminated pyrite, display syn-depositional brecciation textures, and are interpreted to represent submarine exhalative activity.

Epigenetic hydrothermal veining and mineralization in the pendant is closely linked to deformation and faulting. Three phases of deformation are recorded. The earliest is characterized by southeast-directed shallow angle thrusting, emplacing the Peninsula Formation onto the Brokenback Hill Formation. The age of this event is bracketed by the Early Cretaceous age of the Fire Lake Group, and Late Cretaceous second phase deformation. The thrusting records a period of orogen-parallel shortening, likely in conjunction with strike-slip faulting along the continental margin in the manner of transpressional terrains. The second deformation is distinguished by large-amplitude non-cylindrical folds, in association with steep-angle southwest directed thrusting accommodating arc-normal shortening and up-

Le groupe de Gambier dans la région de Fire Lake constitue-t-il le socle du bassin de Géorgia ?

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Le Groupe de Fire Lake constitue l'un des lambeaux de toit épars du Crétacé précoce qui s'observent dans la chaîne Côtière méridionale. Ces structures se sont formées dans un environnement d'arc insulaire. Le Groupe de Fire Lake est un équivalent du Groupe de Gambier, minéralisé significativement en sulfures massifs volcanogéniques et comprenant entre autres le corps minéralisé en Cu-Zn de Britannia.

La Formation de Peninsula se trouve à la base du Groupe de Fire Lake et se compose d'une séquence granoclassée, déposée au cours d'une période de latence du volcanisme. Les faciès présentent une gradation du bas vers le haut, passant d'un environnement fluvial à un autre de plage et finalement à un milieu de plate-forme marine. La formation sus-jacente de Brokenback Hill est une séquence volcanique complexe composée principalement de tuf subaquatique à cristaux, de roches brèchiques et détritiques de composition majoritairement intermédiaire, de même que de roches pyroclastiques soudées d'origine vraisemblement subaérienne (au sommet de la séquence). Dans la Formation de Brokenback Hill, il y a, par endroits, du gypse en lits minces à épais. Ces lits possédant les caractéristiques suivantes : présence de pyrite disséminée et textures de brèchification synsédimentaire. On pense qu'ils sont le résultat d'une exhalaison sous-marine.

Dans le lambeau, les phénomènes reliés à l'épigenèse hydrothermale, soit la formation de veines et la minéralisation, sont en rapport étroit avec la déformation et les failles. Trois phases de déformation ont marqué ces roches. La plus jeune est un chevauchement à faible pendage d'orientation sud-est, à l'origine de l'emplacement de la Formation de Peninsula sur celle de Brokenback Hill. L'âge de cet événement se situe entre celui du Groupe de Fire Lake (Crétacé précoce) et celui lift. The Fire Creek thrust is an important structure within this group in localizing mesothermal Cu-Au deposits; mineralized veins occur along the fault, as well as in the footwall in association with bedding parallel shear related to folding. An extensive set of Tertiary dextral-normal dip-slip faults which strike northeast characterizes the latest deformation. In other areas, similar structures are known to localize high-level felsic plutons and epithermal mineralization.

de la deuxième phase de déformation (Crétacé tardif). Le chevauchement signifie qu'il y a eu une période de raccourcissement parallèle à l'orogène, vraisemblablement contemporaine d'une série de décrochements dont le déplacement s'est opéré le long de la marge continentale, comme on l'observe dans les terrains de transpression. La deuxième déformation est caractérisée par des plis non cylindriques à grande amplitude, accompagnés d'un chevauchement sud-ouest à fort pendage qui a engendré un raccourcissement arc normal et un soulèvement. Le chevauchement de Fire Creek est une structure majeure de ce groupe parce qu'elle permet de localiser les gisements mésothermaux, minéralisés en Cu-Au. Les veines minéralisées s'observent le long de la faille ainsi que dans le mur, en association avec le cisaillement parallèle au litage dû au plissement. La troisième déformation se différencie à ses failles dextres normales à rejet incliné, datant du Tertiaire et d'orientation nord-est. Des structures semblables observées dans d'autres régions sont reconnues pour leur utilité à localiser des plutons felsiques de haut niveau et la minéralisation épithermale.

Selwyn-Wernecke transect, Yukon—a joint INAC-GSC project

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The Department of Indian and Northern Affairs and the Geological Survey are conducting a cooperative one-year project northeast of Mayo, Yukon that includes 1:50 000 geologic mapping as well as a study of the MARG volcanogenic massive sulphide occurrence.

Mapping at 1:50 000 scale has been undertaken in NTS 106D/8 by C. Roots (GSC), in 106D/1 by J.G. Abbott (DIAND), and in 105M/16 by S.P. Gordey (GSC). C. Roots and J.G. Abbott jointly mapped 106D/7 east-half. R. Turner (GSC) examined the MARG deposit. In addition, P. Mustard and A. Donaldson (Carleton University) with Roots, examined general

Transect dans la région de Selwyn-Wernecke au Yukon : projet de coopération entre le M.A.I.N. et la CGC

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Le ministère des Affaires indiennes et du Nord Canadien et la Commission géologique se sont lancés conjointement dans un projet d'un an au nord-est de Mayo, au Yukon. Le projet vise à produire une carte géologique au 1/50 000 de cette région et à étudier les gîtes Marg de sulfures massifs volcanogéniques.

C. Roots (CGC) s'est chargé de la région couverte par la carte 106 D/8 du système national de référence cartographique à l'échelle de 1/50 000, J.G. Abbott (M.A.I.N.) de la carte 106 D/1 et S.P. Gordey (CGC) de la carte 105 M/16. C. Roots et J.G. Abbott ont joint leurs efforts pour la moitié orientale de la carte 106 D/7.

stratigraphic features in Proterozoic carbonate of the Gillespie Lake Group at scattered localities in Nash Creek map area (106D).

The project provides an exceptional opportunity to study the regional setting of an exciting new exploration target (i.e. the MARG), as well as to examine critical stratigraphic and structural relationships in the northern Cordilleran miogeocline where many significant components are exposed. It will provide detailed structural and stratigraphic data in a north-south transect that will assist in the exploration for, and assessment of, other deposits in the region, and act as a framework to guide geologic work in poorly understood areas adjacent to the transect. Interaction with industry regarding logistics, geological discussion and access to unpublished data were critical to the project

Quant à R. Turner (CGC), il a mené l'étude sur les gîtes Marg. Tous ces travaux ont été complétés par une analyse des grandes caractéristiques stratigraphiques propres aux roches carbonatées protérozoïques du Groupe de Gillespie Lake, observées à divers endroits dans la région cartographique du ruisseau Nash (106 D). Ce sont P. Mustard et A. Donaldson de la Carleton University et C. Roots qui étaient responsables de cette étape.

Le projet offre une chance exceptionnelle d'étudier le cadre régionale d'un nouvelle cible d'exploration des plus intéressantes, les gîtes Marg, mais aussi de faire une analyse des liens stratigraphiques et structuraux importants du miogéoclinal de la Cordillère septentrionale, où plusieurs éléments significatifs sont observables. Le projet fournira des données détaillées sur le cadre structural et la stratigraphie du corridor d'étude (orienté selon un axe nord-sud), lesquelles serviront tant à l'exploration qu'à l'évaluation des autres gisements de la région et feront office de guide aux travaux géologiques dans les régions adjacentes au corridor d'étude encore peu connues. Il est à noter que l'interaction avec l'industrie en ce qui a trait à la logistique, l'argumentation sur des phénomènes géologiques et l'accès à des données inédites a été essentielle à la bonne marche du projet.

Selwyn Mountains geology: NE Mayo map area (105M/16)

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The Tiny Island Lake map area (105M/16) is underlain by three main stratigraphic assemblages that form the hanging wall of the Robert Service thrust. The oldest, of late Proterozoic-Cambrian age, consists of slate, quartzite, and minor limestone of the Hyland Group. This is overlain unconformably by slate, chert, chert pebble conglomerate and felsic volcanics of probable Devono-Mississippian age. The youngest unit consists of Triassic-Jurassic slate, sandstone and carbonate.

These strata are complexly folded under conditions of low metamorphic grade, the complexity of deformation increasing with proximity to the Robert Service thrust.

The Devono-Mississippian strata are similar to and correlate with the Earn Group, an assemblage that elsewhere in the northern Cordillera is known for hosting stratiform barite-lead-zinc-silver mineralization. In this region the assemblage is underexplored relative to its

Géologie du chaînon Selwyn, dans le nord-est de la région de Mayo (carte 105 M/16), au Yukon

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La région cartographique du lac Tiny Island (105 M/16) comprend trois assemblages stratigraphiques majeurs qui constituent le toit du chevauchement de Robert Service. Le plus vieil assemblage, du Protérozoïque tardif au Cambrien, se compose de schiste ardoisier, de quartzite et de calcaire (secondaire) du Groupe de Hyland. Il est recouvert par des lithologies en contact discordant, en l'occurrence des schistes ardoisiers, des cherts, des conglomérats à cailloux de chert et des roches volcaniques felsiques datant probablement du Dévonien au Mississippien. L'unité la plus jeune est représentée par des schistes ardoisiers, des grès et des roches carbonatées du Trias au Jurassique.

Ces strates ont subi un plissement complexe sous l'influence d'un métamorphisme faible; la complexité de la déformation augmente à proximité du chevauchement de Robert Service.

Les strates du Dévonien au Mississippien sont sem-potential for these and volcanogenic massive sulphide deposits.

blables au Groupe d'Earn et en constituent un équivalent. Ce groupe est observé dans la Cordillère septentrionale où il est reconnu pour sa minéralisation stratiforme en barytine, plomb, zinc et argent. Cet assemblage n'a d'ailleurs pas été suffisamment exploré si on considère son potentiel pour les minéraux mentionnés ci-haut et la présence de sulfures massifs volcanogéniques.

Geology of the Patterson Range, SE Nash map area (106D/1)

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Deep water clastics of the Upper Proterozoic and Lower Cambrian Hyland Group are juxtaposed, across the Dawson Thrust, against mid-Proterozoic to Devonian shelf carbonate rocks. The shelf and offshelf sequences are overlapped by shale with lesser amounts of quartzite, sandstone, limestone, and volcanics that previously included the Cretaceous Keno Hill Quartzite, the Jurassic "Lower Schist", and an unnamed Triassic unit. The "Lower Schist" probably includes Devonian to Jurassic strata. The Keno Hill Quartzite is probably Mississippian and laterally equivalent to parts of the "Lower Schist". As originally mapped, the Keno Hill Quartzite includes black siliceous shale and felsic volcanic rocks (host to the MARG massive sulphide deposit) and quartz grit (possibly equivalent to the Hyland Group). Lack of correlation between two parts of the "shelf sequence" across the Kathleen Lakes Fault and between the "shelf" and "offshelf" sequences across the Dawson Thrust suggest that they represent reactivated Paleozoic faults.

Géologie du chaînon Patterson, dans le sud-est de la région de Nash (carte 106D/1), au Yukon

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Des roches clastiques d'eau profonde du Groupe de Hyland du Protérozoïque supérieur au Cambrien inférieur sont juxtaposées, à travers la zone chevauchante de Dawson, à des roches carbonatées de plate-forme du Protérozoïque moyen au Dévonien. Les séquences de plate-forme et d'extra plate-forme sont recouvertes de shale et d'une faible quantité de quartzite, de grès, de calcaire et de roches volcaniques qui comprenaient dans le passé le quartzite crétacé de Keno Hill, le "schiste inférieur" jurassique et une unité triasique non désignée. Le "schiste inférieur" comprend probablement des couches du Dévonien au Jurassique. Le quartzite de Keno Hill date probablement du Mississippien et est latéralement équivalent à des parties du "schiste inférieur". Le quartzite de Keno Hill, tel que cartographié à l'origine, contient du shale siliceux noir et des roches volcaniques felsiques (roches encaissantes du gisement de sulfures massifs Marg) et du grès grossier à quartz (probablement équivalent au Groupe de Hyland). L'absence de corrélation entre deux parties de la "séquence de plate-forme" à travers la faille des lacs Kathleen et entre les séquences de "plate-forme" et "d'extra plate-forme" à travers la zone chevauchante de Dawson indique que ces deux parties pourraient représenter des failles paléozoïques réactivées.

Wernecke Mountains geology—SE Nash Creek map area (106D/8)

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Géologie des monts Wernecke dans le sud-est du ruisseau Nash, au Yukon

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The INAC Open File map of bedrock geology for NTS 106D/7 (east half) and 106D/8 reveals at least four panels containing Middle Proterozoic Gillespie Lake dolostone (up to 1.2 km thick) sandwiched between less competent older Quartet and overlying shaly rocks. The surface geometry of these panels imply that the thrust faults bounding them flatten southwards within two km of surface. The overlapping early Paleozoic dolostone contains isoclinal keels that indicate regional detachment near the base of the Mackenzie Platform. Together these structures demonstrate the long-suspected thin-skinned nature of the Cordilleran fold-thrust belt across central Yukon.

Zinc-lead-silver veins at BLENDE property occupy the hanging-wall panel of Gillespie Lake dolostone; although mineralization predated deposition of the overlying shaly unit, it appears to be concentrated in the core of a gentle anticline resulting from late Mesozoic contraction. Other stratabount occurrences may occur in the upper Gillespie Lake Group, which is widely exposed in the Wernecke Mountains, and similar structures are common in the mapped area. Base metal mineralization is also present where Gillespie Lake dolostone is disconformably overlain by early Paleozoic limestone (KATHLEEN) and with barite along faulted sandstone and Paleozoic dolostone (ZAP). These showings form a broad southeast-trending belt extending beyond the mapped area and parallel to the edge of Proterozoic shelf strata.

The southern Ogilvie and Wernecke mountains comprise erosional inliers of thrust-thickened Middle and Late Proterozoic shelf strata, surrounded by early Paleozoic carbonate. The oldest rocks, the Quartet and Gillespie Lake groups, show remarkably consistent rock types over 350 km westward from the mapped area. In contrast, the overlying siliciclastic unit, informally called the Pinguicula group (northeast of the mapped area) and Fifteenmile group (in the Ogilvie Mountains) shows regional facies variations. Up to 4 km of shallow water dolostone are present farther north and west, while the mapped area is predominantly shale, and lacks the overlying conglomerate and volcanic unit (Windermere-equivalent rocks). The southern Wernecke Mountains were in deeper water and were possibly 'off-shelf' between 1300 and 600 Ma. The Pinguicula facies relations testify to the changeable nature of the platform margin of ancient North America.

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La carte de la géologie du substratum rocheux publiée dans les dossiers publics du MAINC pour les zones 106D/7 (moitié est) et 106D/8 de la SNRC révèle la présence d'au moins quatre panneaux contenant la dolomie du lac Gillepsie du Protérozoïque moyen (jusqu'à 1,2 km d'épaisseur) entre les roches du Groupe de Quartet, moins compétentes et plus anciennes, et des shales sus-jacents. La géométrie de surface de ces panneaux indiquent que les failles de chevauchement qui les limitent s'applatissent vers le sud à moins de 2 km de la surface. La dolomie du Paléozoïque inférieur qui les recouvre contient des quilles isoclinales reflétant un détachement régional près de la base de la plate-forme de Mackenzie. Considérées dans leur ensemble, ces structures confirment le décollement depuis longtemps présumé des couches superficielles de la zone de plissement-chevauchement traversant le centre du Yukon.

Les filons de zinc-plomb-argent, à la propriété BLENDE, occupent le panneau de toit de la dolomie du lac Gillepsie. Bien que la minéralisation ait précédé l'accumulation de l'unité de shale sus-jacente, elle semble se concentrer dans le coeur d'un faible anticlinal causé par une contraction pendant la fin du Mésozoïque supérieur. D'autres occurrences stratabound pourraient être contenues dans la partie supérieure du Groupe de Gillepsie Lake qui affleure sur une grande surface dans les monts Wernecke, et plusieurs structures semblables ont été observées dans la zone cartographiée. On trouve également une minéralisation en métaux de base là où la dolomie du lac Gillepsie est surmontée en discordance par une dolomie du Paléozoïque inférieur (KATHLEEN) et par de la barytine le long de grès faillé et de dolomie paléozoïque (ZAP). Ces indices forment une vaste zone à direction sud-est se prolongeant au-delà de la zone cartographiée et parallèle à l'extrémité des couches de plate-forme protérozoïques.

Dans le sud des monts Ogilvie et Wernecke, on trouve des fenêtres d'érosion de couches de plate-forme épaissies par chevauchement du Protérozoïque moyen et supérieur, entourées de roches carbonatées du Paléozoïque inférieur. Les roches les plus anciennes, les groupes de Quartet et de Gillepsie Lake, présentent une pétrologie remarquablement constante sur 350 km à l'ouest de la zone cartographiée. Au contraire, l'unité silico-clastique sus-jacente, appelée informellement groupe de Pinguicula (dans le nord-est de la zone cartographiée) et groupe de Fifteenmile (dans les monts Ogilvie), affiche des variations de faciès régionales. On trouve vers le nord et l'ouest de la zone cartographiée jusqu'à 4 km de dolomie d'eau peu profonde tandis que dans la zone elle-même le shale prédomine et l'unité de conglomérats et de roches volcaniques sus-jacentes est absente (roches équivalentes à celles de Windermere). Les roches dans le sud des monts Wernecke se trouvaient en eau plus profonde et probablement au large de la plate-forme, entre 1300 et 600 Ma. Les relations de faciès de Pinguicula confirment la nature variable de la marge de plate-forme du protocontinent nord-américain.

MARG volcanogenic massive sulphide deposit, Selwyn Basin

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The MARG deposit is 42 km northeast of Keno City, Yukon (64°01'N, 134°28'W; NTS 106D/1). Indicated and inferred reserves of 1 922 000 tonnes grading 1.96% Cu, 5.19% Zn, 2.72% Pb, 1.97 opt Ag, and 0.03 opt Au make the MARG the largest volcanogenic massive sulphide deposit discovered to date in the Yukon. Drilling in 1989 intersected extensions of the mineralized zones beyond the reserve blocks.

Regional setting

In the southern Patterson Range, south- to southeast-dipping strata, mapped by Green as Keno Hill Quartzite, are imbricated along northerly directed thrust faults. Three main thrust sheets, here referred to as the northern, central, and southern panels have been recognized between the Robert Service Thrust to the south and the Tombstone Thrust(?) to the north. Each thrust panel contains quartzite, black siliceous phyllite, quartz grit, and felsic volcanic rocks, with the MARG massive sulphide deposit in the central panel. The stratigraphic order in each panel is disrupted by internal deformation.

Regional stratigraphy

The Hyland Group (PCh) is composed of massive, grey weathering calcareous and noncalcareous, quartz (and minor feldspar) grit, phyllite, chloritic phyllite, and limestone. Similar buff weathering siliceous quartz grit 200-300 m thick form the lowest parts of the central and southern panels. The Hyland Group is overlain by recessive black siliceous phyllite interbedded with quartzite, quartz-muscovite and quartz-chlorite phyllite

Gîte MARG de sulfures massifs volcanogènes, bassin de Selwyn

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Le gisement MARG est situé à 42 km au nord-est de Keno City (Yukon) (64°01'N, 134°28'W; SNRC 106D/1). Des réserves indiquées et inférées de 1 922 000 tonnes à 1,96 % Cu, 5,19 % Zn, 2,72 % Pb, 1,97 oz/t Ag et 0,03 oz/t Au font du gisement MARG le plus important gisement de sulfures massifs d'origine volcanique découvert à ce jour au Yukon. Le forage effectué en 1989 a recoupé des prolongements des zones minéralisées au-delà des blocs de réserves.

Cadre régional

Dans le sud du chaînon Patterson, un arc convexe de couches plongeant vers le sud-sud-est d'environ 8 km de largeur, cartographié par Green sous la désignation de Quartzite de Keno Hill, est imbriqué le long de failles de chevauchement à direction nord. Trois nappes de charriage principales, a[illegible]s dans la présente panneaux septentrional, ce[illegible]dional, ont été identifiées entre la zone de charriage de Robert Service, au sud, et la zone de charriage de Tombstone (?), au nord. Chacun des panneaux de charriage contient du quartzite, de la phyllite siliceuse noire, du grès grossier quartzique et des roches volcaniques felsiques, et le gisement de sulfures massifs MARG se trouve dans le panneau central. L'ordre stratigraphique de chaque panneau est perturbé par une déformation interne.

Stratigraphie régionale

Le Groupe de Hyland (PCh) est composé de roches calcaires et non calcaires d'altération, massives et grises, ainsi que de grès grossier à quartz (et à feldspath

(DMvs). An infold or thrust repetition of these rocks within quartzite (Mq) of the central panel hosts the MARG deposit. These rocks are likely of volcanic origin, perhaps tuffs. Igneous zircons in quartz muscovite phyllite at the MARG deposit have yielded an Early Mississippian radiometric age (J. Mortensen, pers. comm.).

Massive, resistant, dark grey weathering vitreous quartzite (Mq) is the dominant rock type in the thrust belt and forms structural units up to 70 m thick. Dark grey phyllite and siliceous siltstone (DMps) forms a homogeneous sequence about 500 m thick at the top of the northern panel where it overlies a thick, massive quartzite. Hornblende diorite forms tectonically dismembered lenses up to 200 m thick and 3 km long.

Regional structure

Two phases of penetrative deformation are recognized. The first phase (D1) is characterized by rodding and an intense mineral lineation (L1), mesoscopic scale recumbent isoclinal folds (F1), and a strong axial planar foliation (S1). The pervasive, moderately south to southeast dipping foliation is the dominant fabric in phyllite and volcanic rocks. The Robert Service and other large thrusts roughly parallel S1 and the orientation of L1 mineral lineations is consistent with northwesterly movement on the thrusts. The second phase (D2) is a steeply dipping, spaced cleavage (S2) that strikes about 160° and dips steeply northeast, accompanied by upright, tight to isoclinal small scale folds (F2).

Lithotypes in the MARG sequence

The MARG deposit occurs in a 4 km long east-trending fault repetition or recumbent infold of Unit DMvs within the central thrust panel. This "MARG sequence" is overlain by massive quartzite and is in fault contact with similar underlying quartzite. The MARG deposit stratigraphically overlies a 30 m sequence of metavolcanic schists and is overlain by 200 m of carbonaceous siliceous rock. Metavolcanic schists all contain minor quartz phenocrysts and include quartz sericite, sericite-carbonate-quartz-pyrite-, and chlorite-bearing schists. Quartz-sericite schist is interbedded with carbonaceous metachert above the ore horizon. Sericite-carbonate-quartz-pyrite schist is the major lithology below the ore horizon, and carbonate-quartz bands that compose up to 70% of the schist are interpreted as syn-ore footwall veinlets. Chlorite-bearing schists occur below the sulphide horizon lateral to sericite-carbonate-quartz schist.

Black sooty siliceous pyritic metachert is interbedded with the sulphide horizon, and occurs as a thick sequence above the sulphide body. Black phyllite over 150 m thick occurs above the sulphide horizon and is overlain by quartzite.

en faible quantité), de phyllite, de phyllite chloritique et de calcaire. Du grès grossier à quartz siliceux d'altération chamois semblable mesurant de 200 à 300 m d'épaisseur forme la partie inférieure des panneaux du centre et du sud. Le Groupe de Hyland est recouvert de phyllite siliceuse noire de régression, interstratifiée à de la phyllite à quartzite, à quartz-muscovite et à quartz-chlorite (DMvs). Une enveloppe ou une répétition de chevauchement de ces roches au sein du quartzite (Mq) du panneau central renferme le gisement MARG. Ces roches sont vraisemblablement d'origine volcanique, peut-être des tufs. La datation radiométrique de zircons ignés dans de la phyllite à quartz-muscovite au gisement MARG indique un âge correspondant au début du Mississippien (J. Mortensen, comm. pers.).

Un quartzite vitreux d'altération, gris foncé, massif et résistant (Mq) est le type de roche qui prédomine dans la zone de chevauchement et où il forme des unités structurales mesurant jusqu'à 70 m d'épaisseur. Une phyllite gris foncé et un siltstone siliceux (DMps) forment une séquence homogène d'environ 500 m d'épaisseur au sommet du panneau septentrional où elle repose sur un quartzite massif épais. Une diorite à hornblende forme des lentilles tectoniquement démembrées mesurant jusqu'à 200 m d'épaisseur et 3 km de longueur.

Structure régionale

Deux phases de déformation pénétrante ont été déterminées. La première phase (D1) est caractérisée par un rouleau et une linéation minérale intense (L1), des plis isoclinaux couchés d'échelle mésoscopique (F1) et une forte schistosité de fracturation (S1). La schistosité pénétrante moyennement inclinée vers le sud-sud-est est la fabrique dominante de la phyllite et des roches volcaniques. De grandes zones de chevauchement, comme celle de Robert Service, sont relativement parallèles à S1 et l'orientation des linéations minérales L1 est conforme au déplacement nord-ouest sur les zones de chevauchement. La deuxième phase (D2) est un clivage espacé à pendage abrupt (S2) orienté vers 160° environ et plongeant fortement vers le nord-est, accompagné de plis à petite échelle verticaux, de serrés à isoclinaux (F2).

Lithotypes dans la séquence MARG

Le gisement MARG se trouve dans une répétition de failles à direction est de 4 m de longueur ou dans une enveloppe couchée de l'unité DMvs au sein du panneau de chevauchement central. Cette "séquence MARG" est recouverte de quartzite massif et est en contact de faille avec un quartzite sous-jacent semblable. Le gisement MARG repose stratigraphiquement sur une séquence de 30 m de schistes volcaniques métamorphisés et est recouvert de 200 m de roches siliceuses carbonées. Les

Massive sulphide deposit

The MARG deposit is a folded sheet-like body or series of bodies over a kilometre long. Most drilling has concentrated on the eastern portion where the sulphide body appears to be deformed into an overturned isoclinal fold that verges to the northeast and plunges moderately southeast. In Section 2510, the upper limb of the sulphide body is a single horizon 2-7 m thick, whereas on the lower limb, the sulphide body comprises up to seven sulphide layers 30 cm to 2 m thick interbedded with carbonaceous metachert and quartz-sericite schists. The sulphide body consists of fine-grained massive to semi-massive pyrite intergrown with quartz, ferroan carbonate, lesser sphalerite, chalcopyrite, and galena, and minor tetrahedrite and arsenopyrite. The sulphides are massive to banded with a granulated submylonitic texture in thin section. Augen (up to 3 cm) of ferroan carbonate, quartz and sulphides occur locally within banded sulphide rock.

In the eastern part of the MARG deposit, the sulphide body can be divided into three facies based on proportions of the dominant minerals pyrite, quartz and ferroan carbonate. A central core of carbonate-rich semi-massive pyrite (pyrite-carbonate facies) is surrounded by a transitional envelope of semi-massive quartz-rich pyrite (pyrite-quartz facies) and distal massive pyrite (pyrite facies). In addition, the sulphide body is zoned with respect to metal ratios. Elevated ratios of Cu/Pb, Zn/Pb, Ag/Pb and Cu/(Cu+ Zn+ Pb) coincide with the extent of the pyrite-carbonate and pyrite-quartz facies. This enrichment decreases outwards through pyrite-quartz and pyrite facies.

Sericite-carbonate-quartz-pyrite and carbonate-quartz-sericite-pyrite schists occur in an elongate zone underlying much of the pyrite-carbonate facies of the sulphide horizon. These carbonate-bearing schists are flanked by pyritic quartz-sericite schists that underlie the pyrite-quartz facies and proximal part of the pyrite facies. Chlorite-quartz schists occur down dip on the upper fold limb underlying pyrite facies.

Depositional setting of massive sulphide

A volcanic origin of the quartz-sericite-chlorite-rich schists in the MARG sequence is supported by (1) an early Mississippian U-Pb age for zircons, (2) the presence of quartz phenocrysts, and (3) the copper-rich nature of the sulphide body, a characteristic of volcanogenic but not sedimented-hosted sulphide deposits. The sulphide body overlies a sequence of schists, and is overlain by black phyllite and carbonaceous pyritic metachert suggesting that sulphide deposition coincided with waning of volcanic activity within an anoxic deep marine basin.

schistes volcaniques métamorphisés contiennent tous une faible quantité de phénocristaux de quartz et comportent des schistes à séricite quartzique, à séricite-carbonate-quartz-pyrite et à chlorite. Le schiste à quartz-séricite est interstratifié avec du chert métamorphisé carboné au-dessus de l'horizon minéralisé. Le schiste à séricite-carbonate-quartz-pyrite est la principale lithologie au-dessous de l'horizon minéralisé, et les bandes de carbonate-quartz qui composent jusqu'à 70 % du schiste sont interprétées comme des filonnets de mur synchrones à la minéralisation. Des schistes à chlorite se trouvent au-dessous de l'horizon sulfuré, latéralement au schiste à séricite-carbonate-quartz.

Du métachert pyritique siliceux fuligineux noir est interstratifié avec l'horizon sulfuré et forme une séquence épaisse au-dessus du massif sulfuré. De la phyllite noire mesurant plus de 150 m d'épaisseur se trouve au-dessus de l'horizon sulfuré et est recouvert de quartzite.

Gisement de sulfures massifs

Le gisement MARG est un massif plissé en forme de nappe ou une série de massifs s'étendant sur un kilomètre de longueur. La plupart des forages ont été réalisés dans la partie orientale là où le massif sulfuré semble être déformé en un pli isoclinal déversé à vergence vers le nord-est et à pendage moyen vers le sud-est. Dans la coupe 2510, le flanc supérieur du massif sulfuré est un horizon unique de 2 à 7 m d'épaisseur tandis que sur le flanc inférieur, le massif sulfuré comprend jusqu'à sept couches de sulfures de 30 cm à 2 m d'épaisseur interstratifiées avec du métachert carboné et des schistes à quartz-séricite. Le massif sulfuré est composé de pyrite de massive à semi-massive à grain fin enchevêtrée avec du quartz, du carbonate ferrugineux, une quantité moindre de sphalérite, de chalcopyrite et de galène et une faible quantité de tétrahédrite et d'arsénopyrite. Les sulfures varient de massifs à zonés et leur texture est sub-mylonitique grenue en lame mince. Des yeux (jusqu'à 3 cm) de carbonate ferrugineux, de quartz et de sulfures sont présents par endroits dans la roche sulfurée zonée.

Dans la partie orientale du gisement MARG, le massif sulfuré peut se diviser en trois faciès selon les proportions des minéraux dominants qui sont la pyrite, le quartz et le carbonate ferrugineux. Un noyau central de pyrite semi-massive riche en carbonates (faciès de pyrite-carbonates) est entouré d'une enveloppe de transition composée de pyrite semi-massive riche en quartz (faciès de pyrite-quartz) et de pyrite massive distale (faciès de pyrite). En outre, le massif sulfuré est zoné en fonction des rapports des métaux. Des rapports élevés de Cu/Pb, Zn/Pb, Ag/Pb et Cu/(Cu+ Zn+ Pb) coïncident avec l'étendue des faciès de pyrite-carbonate

Exploration significance

In eastern and central Yukon, Mississippian alkaline intermediate to felsic volcanic rocks with associated Cu-Zn-Pb sulphide deposits were only known in the Pelly Mountains west of the Tintina fault prior to the discovery of the MARG deposit. This quartzite, carbonaceous siliceous shale and felsic volcanic assemblage represents a new exploration target. Equivalent strata have been traced across central Yukon intermittently from Dawson to Nahanni map areas. Association of the sulphide-bearing schists with well exposed quartzite should serve as a useful exploration guide.

The MARG deposit is a member of a family of Devonian and Mississippian sediment-hosted and volcanic-hosted exhalative sulphide and barite deposits that occur within the Cordillera from Alaska to Mexico. Volcanogenic massive sulphide deposits include the AMBLER, ALASKA, CLEAR LAKE, and MM (Yukon), and SAMATOSUM, SILVER, and HOMESTAKE (B.C.). Studies of the ARCTIC, MM, and SAMATOSUM deposits all indicate association with alkaline volcanic rocks typical of rift environments; host stratigraphies suggest an outer continental margin setting.

Model for massive sulphide ores

A model for the formation of the MARG deposit is proposed. The core of the hydrothermal upflow zone is represented by carbonate-quartz stockwork in sericite-carbonate-quartz-pyrite altered volcanic rock and overlying carbonate-rich massive sulphide. Quartz-rich massive sulphide rock and quartz-sericite-pyrite altered volcanic rocks represent a more peripheral alteration associated with the upflow zone. Pyrite facies massive sulphide reflects less altered sedimentary sulphides, and chlorite-quartz schists reflect less altered volcanic rocks away from the centre of hydrothermal alteration. The presence of ferroan carbonate-enrichment in the vent zone has been described in only a small group of volcanogenic massive sulphide deposits such as MATTABI (Ontario) and MADENKOY (Turkey).

et de pyrite-quartz. Cet enrichissement diminue vers l'extérieur à travers les faciès de pyrite-quartz et de pyrite.

Les schistes à séricite-carbonate-quartz-pyrite et à carbonate-quartz-séricite-pyrite occupent une zone allongée sous-jacente à la grande partie du faciès de pyrite-carbonates de l'horizon sulfuré. Ces schistes contenant des carbonates sont flanqués de schistes à quartz pyritique-séricite qui sont sous-jacents au faciès de pyrite-quartz et à la partie proximale du faciès de pyrite. Des schistes de chlorite-quartz se trouvent en aval-pendage sur le flanc du pli supérieur, au-dessous du faciès de pyrite.

Cadre d'accumulation des sulfures massifs

L'hypothèse d'une origine volcanique pour les schistes à quartz-séricite-chlorite dans la séquence MARG est appuyée par 1) une datation au Mississippien inférieur par la méthode U-Pb sur zircons, 2) la présence de phénocristaux de quartz et 3) la haute teneur en cuivre du massif sulfuré, caractérisant les gisements d'origine volcanique mais pas les gisements de sulfures dans des roches sédimentaires. Le massif sulfuré repose sur une séquence de schistes et est surmonté par une phyllite noire et un métachert pyritique carboné indiquant que l'accumulation de sulfures a coïncidé avec la diminution de l'activité volcanique dans un bassin marin anoxique profond.

Importance en matière d'exploration

Dans l'est et le sud du Yukon, les roches volcaniques alcalines d'intermédiaires à felsiques du Mississippien, associées à des gisements de sulfures à Cu-Zn-Pb, n'ont été relevés dans les monts Pelly, à l'ouest de la faille de Tintina, qu'avant la découverte du gisement MARG. Cet assemblage de quartzite, de shale siliceux carboné et de roches volcaniques felsiques représente une nouvelle cible d'exploration. Des couches équivalentes ont été retracées de façon discontinue à travers le centre du Yukon, de la zone de Dawson à celle de Nahanni. L'association des schistes sulfurés avec le quartzite affleurant devrait constituer un guide d'exploration utile.

Le gisement MARG fait partie d'une famille de gisements de sulfures et de barytine exhalatifs du Mississippien formés dans des roches sédimentaires et volcaniques de la Cordillère, de l'Alaska au Mexique. Les gisements de sulfures massifs d'origine volcanique sont entre autres AMBLER, ALASKA, CLEAR LAKE et MM (Yukon) et SAMATOSUM, SILVER et HOMESTAKE (C.-B.). L'étude des gisements ARCTIC, MM et SAMATOSUM indique qu'ils sont associés à des roches volcaniques alcalines caractéristiques de milieux d'effondrement; la stratigraphie des roches encaissantes laisse supposer un cadre de marge continentale extérieure.

Modèle de formation des minerais de sulfures massifs

Un modèle de formation du gisement MARG est proposé. Le noyau de la zone d'écoulement hydrothermal ascendant est représenté par un stockwerk de carbonate-quartz dans une roche volcanique altérée à séririte-carbonate-quartz-pyrite et des sulfures massifs sus-jacents riches en carbonates. Les roches de sulfures massifs riches en quartz et les roches volcaniques altérées à quartz-séricite-pyrite correspondent à une altération plus périphérique associée à la zone d'écoulement ascendant. Les sulfures massifs à faciès de pyrite sont le reflet de sulfures sédimentaires moins altérés, et les schistes à chlorite-quartz sont le reflet de roches volcaniques moins altérées situées à l'extérieur du centre d'altération hydrothermale. La présence d'un enrichissement en carbonates ferrugineux dans la zone de cheminée n'a été mentionnée que pour un petit groupe de gisements de sulfures massifs d'origine volcanique comme MATTABI (Ontario) et MADENKOY (Turquie).

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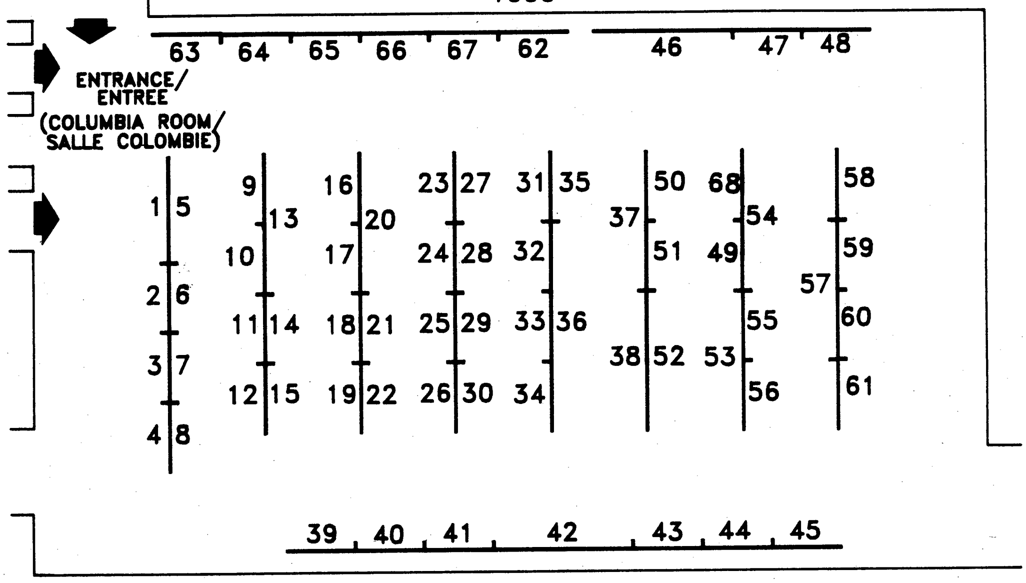

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<u>Georgia Basin, Lower Mainland, Southern Coast Mountains, Southern Vancouver Island</u>

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   Seismic risk in the Fraser delta
3. **R. Linden, J. Clague**
   Earthquake disturbance in Vancouver Island lakes
4. **P. Bobrovsky, J. Clague**
   Possible evidence for Holocene earthquakes in Saanich Inlet
5. **J.M. Journeay**
   Structural and tectonic framework of the southern Coast Belt
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   Georgia Basin project
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11. **T. Heah**
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12. **P. Van der heyden**
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14. **M. Bevier, R. Anderson**
    U-Pb and K-Ar geochronometry, Iskut River area, NW B.C.
15. **S. Ballantyne**
    Geochemistry of Sulphurets area, B.C.
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    Gold-rich skarns of the Canadian Cordillera
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    Metallogeny of the Canadian Cordillera
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27. **H. Gabrielse**
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Chilcotin/Nechako area, Central and S.E. B.C.

28. **C. Hickson**
The Chilcotin-Nechako hydrocarbon province

29. **J. Hunt, R. Bustin**
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30. **J. Souther**
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Golden trees map fault

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33. **D. Seemann, D. Holliday, J. Sweeney**
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34. **D. Murphy**
Canoe River: a new 1:250 000 geological compilation

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35. **A. Jones, R. Kurtz, D. Boerner, J. Craven, G. McNeice, J. Delaurier, I. Gough**
Electromagnetic studies, Lithoprobe Cordilleran transect

36. **H. Lyatsky, R. Currie, D. Seemann, D. Teskey, G. Woodsworth**
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37. **C. Spencer, A. Green, R. Clowes, F. Cook, P. Carroll**
Lithoprobe seismic reflection profiling, southern Cordillera

38. **J. Todd, M. Pilkington**
Regional aeromagnetic surveys in B.C.

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39. **J. Haggart**
Cretaceous stratigraphy and hydrocarbons, Q.C.I.

40. **J. Hesthammer, J. Indrelid**
Geology of central Graham Is., Q.C.I.

41. **S. Taite**
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42. **C. Hickson**
The Masset Formation, Q.C.I.

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L. Jurassic ammonite biostratigraphy, Q.C.I.

44. **H. Tipper, E. Carter, M. Orchard**
Triassic-Jurassic boundary at Kennecott Point

45. **B. Sawyer, D. Seemann**
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46. **C. Dodds, R. Campbell et al**
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47. **L. Jackson, R. Barendregt, E. Irving**
Magnetostratigraphy of the Selkirk Volcanics

48. **J. Mortensen**
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49. **D. Picklyck**
Office for technology transfer

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Yukon: Selwyn and Wernecke Mountains

50. **S. Gordey (GSC)**
Selwyn mountains geology: NE Mayo area (105M/16), Yukon

51. **J.G. Abbott (INAC)**
Geology of the Patterson Range, SE Nash area (106D1), Yukon

52. **C. Roots (GSC), J.G. Abbott (INAC)**
Wernecke Mountains geology: SE Nash Creek map area, Yukon

53. **R. Turner (GSC), J.G. Abbott (INAC)**
MARG volcanogenic massive sulphide deposit, Selwyn Basin

INDIAN AND NORTHERN AFFAIRS CANADA, EXPLORATION AND GEOLOGICAL SERVICES DIVISION, YUKON

54. **Indian and Northern Affairs Canada Staff**
1989 Yukon mining and exploration overview

55. **R.L. Hughes (deceased), F.J. Hein, S.R. Morison**
Sedimentologic evidence of glacial-age alluvial sedimentation: Sixtymile River area, Yukon

56. **K. Ridgeway**
Middle Cenozoic syn-tectonic sedimentation along the Denali Fault system, St. Elias Mountains, Yukon Territory

57. **C. Hart, J. Radlof**
Late Triassic sinistral displacements along the Tally Ho shear zone and associated mineral deposits

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58. **T. DeBoer**
Implications for regional mineralization from the Brownes Lake skarn deposit, Pioneer Mountains, Montana

59. **G. Hurban**
Potential economic significance of structural history, depth of emplacement, and age relationships of plutons in the Holden area, north Cascades, Washington

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60. **D. Peterson**
Structure and styles of mineralization on Tillicum Mountain, SE B.C.

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61. **R. Rushton**
Fluid inclusion and stable isotope study of mesothermal gold-quartz veins in the Klondike Schist, Yukon

62. **P. Erdmer**
A lithoprobe transect proposal across the northern Cordillera, Northwest Territories, Yukon, and British Columbia

UNIVERSITY OF BRITISH COLUMBIA

63. **C. Leitch, C. Chen, C. Hood**
Silver Queen Mine, a joint NSERC/Industry project at Owen Lake, B.C.

64. **H. Cookenboo, R.M. Bustin**
Stratigraphy of coal-bearing strata of the northern Bowser Basin

65. **M. Lamberson, R.M. Bustin**
Characteristics of lithotypes in selected coal seams of the Gates Formation, northeastern B.C.

66. **S. Cook and W.K. Fletcher**
Distribution and dispersion of platinum in soils of the Tulameen Ultramafic Complex, southern B.C.

67. **G.L. Dawson, C.I. Godwin**
Gold-skarn mineralization associated with a sediment-sill complex, south-central B.C.

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68. **G. Beaudoin, D. Sangster**
Ag-Pb-Zn vein deposits, northern Kokanee Range, B.C.

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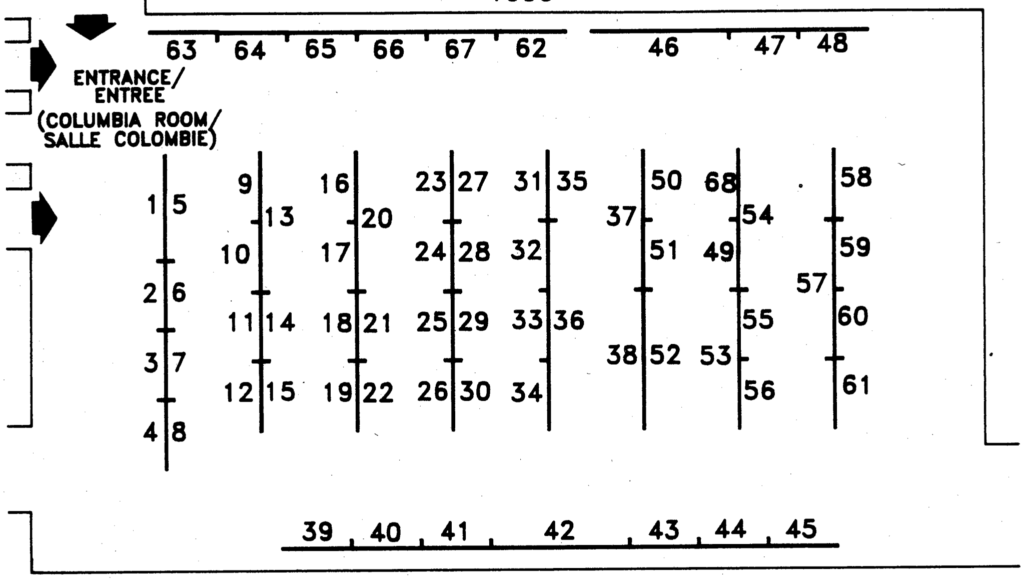

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1. **Projets: Division géoscientifique de la Cordillère**

<u>Basin Georgia, delta Fraser, chaîne côtière sud, Isle Vancouver sud</u>

2. **J. Luternauer**
Risques de séismes dans la région du delta du Fraser
3. **R. Linden, J. Clague**
Perturbations séismiques dans les lacs de l'Ile de Vancouver
4. **P. Bobrowsky, J. Clague**
Preuve possible de tremblements de terre holocènes dans la région de l'inlet Saanich
5. **J.M. Journeay**
Cadres structural et tectonique de la chaîne côtière méridional
6. **J. Monger**
Projet du bassin Georgia
7. **G. Lynch**
Géologie de la région du lac Fire, dans le sud-est de la chaîne côtière
8. **T. Hamilton, D. Seemann, I. Frydecky, G. Jewsbury, J. Halpenny, D. Flint, B. Posthumus, T. Missiaen, C. Finn, L. Rhoads**
Levée géophysique marin du bassin de Georgia-Puget
9. **C. Kilby**
Minéraux lourds du domaine littoral, partie nord du détroit de Juan de Fuca

<u>Chaîne côtière centrale</u>

10. **S. Gareau**
Géologie de la région de la rivière Ecstall, dans le centre de la chaîne côtière, en C.-B.
11. **T. Heah**
Marge du complexe du gneiss central, près de Terrace, en C.-B.
12. **P. Van der heyden**
Marge orientale de la chaîne côtière, dans le centre ouest de la C.-B.

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14. **M. Bevier, R. Anderson**
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15. **S.B. Ballantyne**
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17. **R. Kirkham**
Géologie de la région de Sulphurets, en C.-B.

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18. **S.B. Ballantyne**
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19. **S.B. Ballantyne, D. Harris**
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20. **R. Bell, S. Gandhi**
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21. **K. Dawson**
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24. **S. Irwin, M. Orchard**
Âges des conodontes de gîtes minéraux stratiformes

Bassin Bowser et nord C.-B.

25. **C. Evenchick**
Cadre structural et stratigraphie de la région cartographique de Spatsizi ouest

26. **B. Ricketts**
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27. **H. Gabrielse**
Ceinture de "jade" de la region Cry Lake, dans la nord de la C.-B.

Région Chilcotin/Nechako, C.-B. central et du s.e.

28. **C. Hickson**
Province d'hydrocarbures de Chilcotin-Nechako

29. **J. Hunt, R. Bustin**
Stratigraphie et roches de source petrolifières de la région de Chilcotin-Nechako

30. **J. Souther**
La chaîne Ilgachuz - un volcan-bouclier du néogène tardif

31. **L. Struik**
L'or dans les arbres delimite une faille

32. **J. Sweeney, D. Seemann, L. Struik**
Détection de failles à l'aide de la méthode gravimétrique, dans le centre de la C.-B.

33. **D. Seemann, D. Holliday, J. Sweeney**
Levée gravimétrique de la région du Lac Williston, dans le nord de la C.-B.

34. **D. Murphy**
Nouvelle compilation de la géologie de la région de Canoe River à l'échelle de 1/250 000

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36. **H. Lyatsky, R. Currie, D. Seemann, D. Teskey, G. Woodsworth**
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41. **S. Taite**
Géologie de la région de Sewell Inlet-détroit de Tasu, I.R.-C.

42. **C. Hickson**
Formation de Masset, I.R.-C.

43. **G. Jakobs, J. Palfy, P. Smith**
Biostratigraphie des ammonites du jurassique inférieur, I.R.-C.

44. **H. Tipper, E. Carter, M.J. Orchard**
Limites entre le triassique et le jurassique à la pointe Kennecott

45. **B. Sawyer, D. Seemann**
Série de cartes bathymétriques et gravimétriques du bassin de la Reine-Charlotte

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46. **C. Dodds, R. Campbell et al.**
Cartes géologiques des parties s.-o. du Yukon et n.-o. de la C.-B., dans le cadre de l'opération Saint Elias

47. **L. Jackson, R. Barendregt, E. Irving**
Magnétostratigraphie des roches volcaniques de Selkirk

48. **J. Mortensen**
Klondike géologie, géochronologie et sources de l'or alluvionnaire

Autres

49. **D. Picklyck**
Bureau de transfert de la technologie

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50. **S. Gordey (CGC)**
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51. **J.G. Abbott (AINC)**
Géologie du chaînon Patterson, dans le sud-est de la région de Nash (carte 106d/1), au Yukon

52. **C. Roots (CGC), J.G. Abbott (AINC)**
Géologie des Monts Wernecke, dans le sud-est du Ruisseau Nash, au Yukon

53. **R. Turner (CGC), J.G. Abbott (AINC)**
Gîtes Marg de sulfures massifs volcanogéniques dans le bassin de Selwyn

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54. **Staff**
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55. **R. Hughes (décédé), F. Hein, S. Morison**
Évidence sédimentologique de sédimentation alluvial d'âge glaciaire, région Sixtymile River, Yukon

56. **K. Ridgeway**
Sédimentation d'âge cénozoïque moyen duront l'activité tectonique au long du system de faille Denali, les montognes Saint Elias, territoire du Yukon

57. **C. Hart, J. Radloff**
Déplacements sénestres d'âge Triasique supérieur au long du zone de cisaillement Tally Ho et les dépots de minerais associés

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58. **T. DeBoer**
Implications pour la minéralization régionale du dépôt de skarn Brownes Lake, chaînon Pioneer, Montana

59. **G. Hurban**
Signification économique potentiel de l'histoire structurale, profondeur d'emplacement, et relations d'age des plutons dans la région Holden, Cascades du norel, Washington

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60. **D. Peterson**
Structure et styles de minéralization sur la montagne Tillicum, s.-e. C.-B.

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61. **R. Rushton**
Étude des inclusions de fluides et d'isotopes stables dans les veines de quartz aurifières mésothermiques du schiste Klondike, Yukon

62. **P. Erdmer**
Proposition pour une traverse de sondage lithoprobe à travers le nord de la cordillè, les Territoires du Nord Oust, Yukon, et la Colombie Britanique

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63. **C. Leitch, C. Chen, C. Hood**
La mine Silver Queen, projet joint CNRS/industrie au lac Owen, C.-B.

64. **H. Cookenboo, R.M. Bustin**
Stratigraphie du charbon dans le nord du basin Bowser

65. **M. Lamberson, R.M. Bustin**
Charactéristiques des types lithologiques dans les couches de charbon choisies de la formation Gates, n.-e. C.-B.

66. **S. Cook and W.K. Fletcher**
Distribution et dispersion de la platine dans le sol du complexe ultramafique Tulameen, C.-B. du sud

67. **G.L. Dawson, C.I. Godwin**
Minéralization de skarn aurifière associée à un complexe de sill-sédimentaire, C.-B. sud-central

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68. **G. Beaudoin, D. Sangster**
Dépots de veines Ag-Pb-Zn, nord du chaînon Kokanee, C.-B.

Abstracts of posters

(Columbia Room)

Geology of the Patterson Range, SE Nash map area (106D/1), Yukon

Géologie du Chaîne Patterson, dans le S.-E. de la région de Nash (carte 106D/1), au Yukon

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Deep water clastics of the Upper Proterozoic and Lower Cambrian Hyland Group are juxtaposed, across the Dawson Thrust, against mid-Proterozoic to Devonian shelf carbonate rocks. The shelf and offshelf sequences are overlapped by shale with lesser amounts of quartzite, sandstone, limestone, and volcanics that previously included the Cretaceous Keno Hill Quartzite, the Jurassic "Lower Schist", and an unnamed Triassic unit. The "Lower Schist" probably includes Devonian to Jurassic strata. The Keno Hill Quartzite is probably Mississippian and laterally equivalent to parts of the "Lower Schist". As originally mapped, the Keno Hill Quartzite includes black siliceous shale and felsic volcanic rocks (host to the MARG massive sulphide deposit) and quartz grit (possibly equivalent to the Hyland Group). Lack of correlation between two parts of the "shelf sequence" across the Kathleen Lakes Fault and between the "shelf" and "offshelf" sequences across the Dawson Thrust suggest that they represent reactivated Paleozoic faults.

Mesozoic and Cenozoic evolution of Iskut River area, NW B.C.

Evolution Mésozoique et Cénozoique de la région de la Rivière Iskut, dans le N.-O. de la C.-B.

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The poster summarizes contributions of 1989 summer field work in Iskut River map area (56-57°N, 130-132°W; NTS 104B) to Mesozoic stratigraphy, plutonic style, and structure *(Anderson and Thorkelson)*, biostratigraphy *(Smith)* and Quaternary volcanism *(Russell)*. Rocks as old as Early Devonian occur in the map area and Paleozoic rocks are common north of the Iskut River. However, Mesozoic and Cenozoic rocks are the most widespread, are most prospective for precious metal veins, and record the evolution of Stikinia with inception of the Middle and Upper Jurassic Bowser Basin to the northeast and Jurassic and Tertiary Coast Belt to the southwest. Pre- and post-glaciation Quaternary volcanism has helped shape the present landscape.

Stratigraphy, structure, plutonism and mineral deposits

The map area, located northwest of Hyder, Alaska and Stewart, B.C. and northeast of the international boundary, is a focus of federal and provincial government geological surveys and intense mineral exploration. Most precious and base metal deposits presently being developed in the area occur within Upper Triassic (e.g. KERR, DOC, INEL, SNIP, and STONEHOUSE deposits), Lower Jurassic (e.g. PREMIER–SILBAK and SULPHURETS deposits) and lower Middle Jurassic (e.g. ESKAY CREEK deposit) strata intruded by alkaline Early Jurassic plutons or dykes (Fig. 1).

Lower Devonian, Mississippian and Lower Permian coralline limestone reefs and mafic to felsic volcanic rocks of the Stikine assemblage form the basement for the Mesozoic rocks of principal exploration interest. The Paleozoic unit includes some of the most intensely deformed rocks in the region and may have undergone two periods of deformation (Devono–Mississippian and Permo–Triassic).

Bimodal or intermediate to mafic Upper Triassic Stuhini Group volcanic rocks change to basinal dun feldspathic greywacke and siltstone to the east and northeast. Upper Triassic Stuhini Group grades into Lower Jurassic Hazelton Group near Treaty Creek.

The Lower and Middle Jurassic Hazelton Group comprises three heterogeneous volcanogenic formations and one heterogeneous, mainly sedimentary formation. Unuk River Formation, composed of andesitic breccia, tuff and marine siliceous siltstone is the oldest. Heterogeneous maroon to green volcanic conglomerate, breccia and greywacke of the Betty Creek Formation overlie it. The youngest volcanic unit is Mount Dilworth formation felsic tuff and tuff breccia, an important regional marker representing a climactic volcanic event of Hazelton volcanism.

Lower Middle Jurassic Salmon River Formation (of Bajocian? age) consists of heterogeneous lower and upper members. A thin, belemnoid-rich, upper Lower Jurassic sandy limestone to calcareous sandstone occurs at the base. The overlying lower Middle Jurassic member has three facies that form north-trending belts. Eastern siliceous shale and tuff turbidite (Troy Ridge facies) changes to a medial felsic and mafic pillowed lava, shale and limestone unit that hosts the ESKAY CREEK deposit (Eskay Creek facies). To the west, a speculative western facies comprises andesitic, calc-alkaline volcaniclastic rocks (Snippaker Mountain facies).

Existing and new geochronometry, reported by Bevier and Anderson in the adjacent poster, define four intrusive episodes: Late Triassic (228–213 Ma, Stikine plutonic suite); Early Jurassic (196–189 Ma, Texas Creek plutonic suite), Middle Jurassic (about 177 Ma, Three Sisters plutonic suite), and Eocene (62–44 Ma, Hyder plutonic suite). The Mesozoic plutonic suites have coeval volcanic rock associations in the Upper Triassic Stuhini Group, Lower Jurassic Unuk Formation of the Lower and Middle Jurassic Hazelton Group, and the Middle Jurassic Salmon River Formation, Eskay Creek facies. Early Jurassic alkaline plutons or dykes of Texas Creek plutonic suite that intrude Upper Triassic and Lower Jurassic strata are spatially associated with many precious metal veins and one base metal deposit presently being developed in the area (e.g. INEL, PREMIER, SNIP, STONEHOUSE, SULPHURETS, and KERR deposits).

The Middle and Upper Jurassic Bowser Lake Group facies also change but less systematically than in the Salmon River Formation. Middle Jurassic pencil shale, greywacke, and rare chert-pebble conglomerate at the base grade to monotonous Middle and Upper Jurassic greywacke and shale.

Some structures that involve Lower Jurassic and older strata and members of the Early Jurassic Texas Creek plutonic suite are best preserved as discrete, scattered zones of high ductile strain within hydrothermally altered zones. Tectonism may have pre-dated the widespread, sub-Toarcian unconformity, the development of an extension-related(?) Middle Jurassic basin and the intrusion of coeval, extension-related Middle Jurassic (about 177 Ma) Three Sisters plutonic suite. Later, contraction-related, map-scale orthogonal folding of the Middle and Upper Jurassic Bowser Lake Group characterizes a different structural style congruent with the mid-Cretaceous and Tertiary Skeena Ranges fold and thrust belt to the northeast.

Jurassic biostratigraphy

A high resolution Jurassic biochronology using macro- and microfossils could have important applications in the tectonically complex Iskut map area where Jurassic sediments accumulated in a shallow marine, volcanically active area characterized by abrupt lateral facies changes. Reconnaissance work in the upper drainage of the Unuk River has produced Pliensbachian to possibly Oxfordian age ammonite and radiolarian faunas, some of which are anomalous with respect to currently available geological maps. The presence of Jurassic radiolarians in well-rounded clasts of Jurassic conglomerates may offer the opportunity of constraining periods of Jurassic tectonism.

Upper Pliensbachian ammonites were collected stratigraphically below the Eskay Creek deposit. A limestone clast from a conglomerate above the deposit has yielded radiolarians that indicate a Middle Toarcian to Early Bajocian age.

Quaternary volcanism

Along and south of the Iskut River, Quaternary volcanic rocks occur as scattered monogenetic cinder cones and lava flows. These volcanic centres comprise the Iskut River volcanic rocks and include localities at: Iskut Canyon, Cone Glacier, Cinder Mountain, King Creek, Second Canyon Creek, and Lava Fork Creek. All the Iskut River volcanic rocks are basaltic. Representative samples were collected from the six volcanic centres and will form the basis of future petrographic and chemical work. Preliminary petrography indicates each centre is characterized by phenocryst content of basalt flows; orthopyroxene is an unusual phenocryst phase which distinguishes some centres.

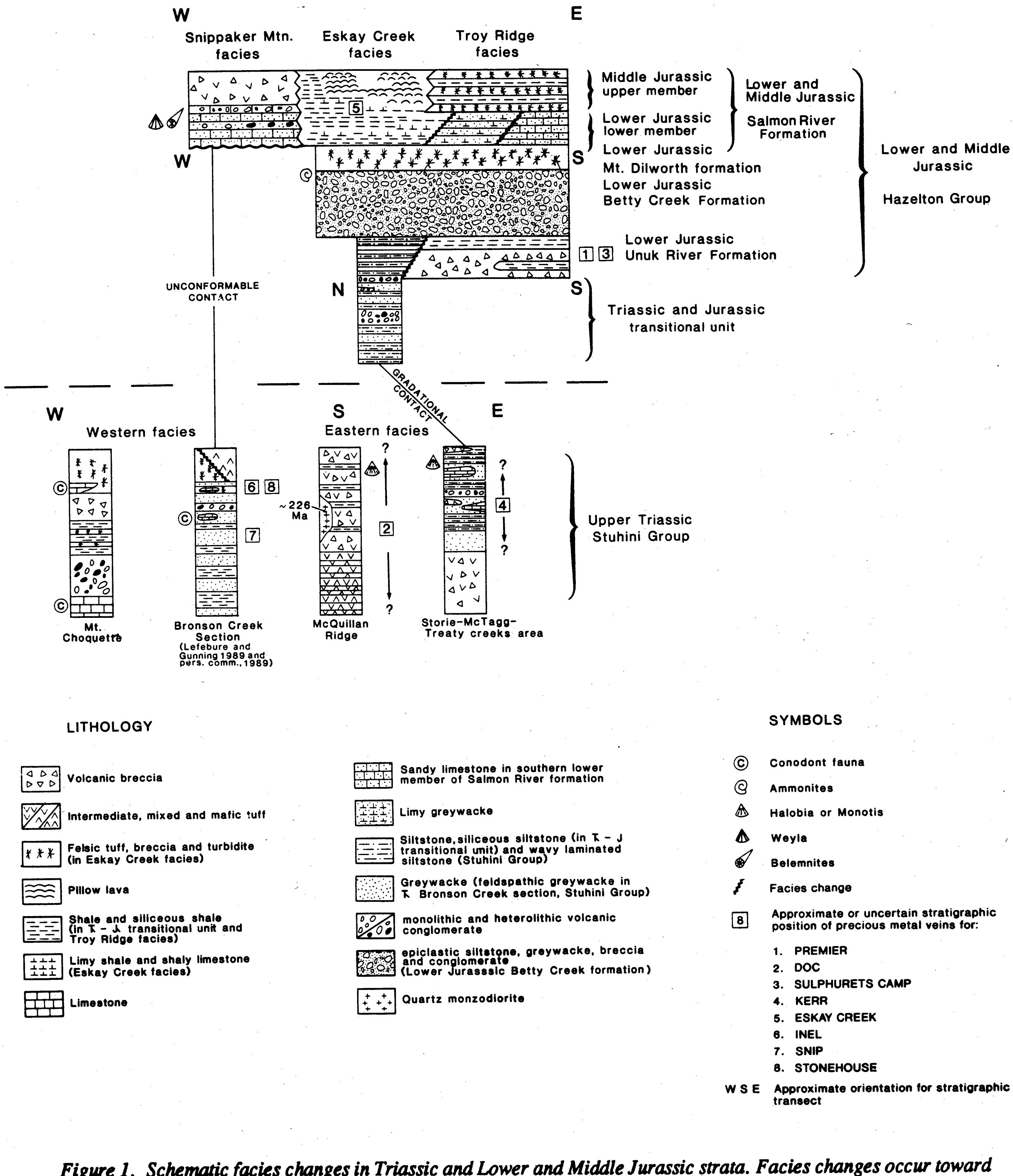

Figure 1. Schematic facies changes in Triassic and Lower and Middle Jurassic strata. Facies changes occur toward the east and northeast for Upper Triassic Stuhini Group and both south to north and east to west for Upper and Middle Jurassic Salmon River Formation in Iskut River map area.

Gold hydrogeochemistry: application in the Cordillera?

Possibilités d'utilisation de l'hydrogéochimie de l'or dans la Cordillère

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The application of gold hydrogeochemistry to exploration for precious metals is currently being tested in the Cordillera. One litre sample collection followed by bromine-hydrochloric acid desorption of Au lost to container walls, evaporation and measurement by graphite furnace atomic absorption spectrometry are proposed as cost effective field and laboratory procedures.

This investigation has tested spring, stream, pond, or lake and mine water (approximately 200 samples). Regional orientation stream water survey data (NTS 104M) shows that most water (pH 5.9–7.5) contains less than 0.2 ppm Au, yet, anomalous results of up to 3.9 ppt were obtained. Stream water monitoring of Graham Creek (NTS 104M/9) yielded anomalous Au contents ranging from 1.0–7.0 ppt at pH 7.57 from year to year.

The data suggest that enhanced hydromorphic dispersion of gold may be restricted to specific gold-ore deposit types.

Mount Mye, Yukon: Bolivian-type Ag-Sn breccias?

Brèches du type Bolivien, minéralisées en Ag et en Sn, région du Mont Mye, au Yukon

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The Mount Mye–Cody Ridge breccia zones or veins are located east of Faro, Yukon in the mid-Cretaceous Anvil Batholith (NTS 105K).

Microprobe and SEM studies have documented repeated brecciation of early quartz veins with later introduction and microbrecciation of quartz-chalcedony, rhodocrosite (banded-colloidal to crystalline) and the polymetallic mineral assemblage which includes pyrite, non-silver-bearing galena, Fe-rich sphalerite, arsenopyrite, stannite, needle cassiterite, canfieldite, silver-bearing tetrahedrite, diaphorite, semseyite, miargyrite, pyrargyrite, and acanthite.

Perhaps the first equivalents of southern Bolivian Ag-Sn deposits to be recognized in Canada, the fracture controlled mineralization may have formed as a consequence of caldera development of coeval South Fork Volcanics or repeated seismic movements related to regional extensional tectonism along the Tintina Trench fault system.

Anomalous Sn, Sb, Mn, Zn, Pb, As and Ag are distinctive features of National Geochemical Reconnaissance stream sediment data for the area.

Geochemistry of Sulphurets area, British Columbia

Géochimie de la région de Sulphurets, en C.-B.

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Results from whole rock and trace element lithogeochemical studies of drill core, underground and regional surface outcrop samples are presented. Extensive quartz-sericite-pyrite alteration zones hosting both porphyry Cu-Mo, Mo and precious metal mineralization are characterized by geochemical enrichment of K_2O (often 5 wt%) and S (about 4 wt%) and strong Na_2O depletion (consistently 1 wt%).

The distinctive Ag-Au-Sb enrichment anomaly describes the BRUCEJACK LAKE precious metal ores. At the KERR Cu porphyry elevated Se concentrations are present in drill core samples from important Cu-Au zones.

Some Mo enriched areas are associated with F and W anomalies both in drill core and outcrop samples.

Geochemical classification based on whole rock analysis of unaltered samples is in progress. The volcanic suite includes rhyolite, rhyodacite, lati-andesite, quartz-latite, dacite, latite, trachyte, lati-basalt and basalt while the granitoid suite includes monzodiorite, syenodiorite, monzonite, syenite-granite, quartz-syenite and diorite.

Olympic Dam-type deposits: potential in Canada

Potentiel des gisements du type Olympic Dam au Canada

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The giant Fe-Cu-U-Au-Ag-REE Olympic Dam deposit in South Australia shares many features with other monometallic and polymetallic deposits such as Kiruna in Sweden and Pea Ridge in Missouri. These deposits belong to a clan that includes magnetite-rich veins, breccia-fillings, dissemination and skarns, in and adjacent to porphyrites.

Most of the deposits are related to ensialic, post-tectonic, rhyolite-dominated sequences, different from subduction-related, andesite-dominated magmatic arcs. Their parent magmas were probably generated by crustal underplating. The most favourable conditions for the formation of these magmas developed with gradual decline in secular radiogenic heat which about 1.9 Ga ago led to major cratonization. Significant transfer of uranium to near-surface environments at this time marks an important episode in uranium metallogeny.

Discovery of the Olympic Dam deposit resulted from the search for a progenitor of Cu (+ U+ Fe) deposits in younger Adelaidian diapirs. As such, these younger deposits are termed "derivative". Some deposits in the African Copperbelt and Wernecke Mountains in Yukon are of this type. Wernecke megabreccia-hosted deposits show several episodes of mineralization, the oldest being 1280 Ma and the youngest being 400 Ma.

U-Pb and K-Ar geochronometry, Iskut River area, NW B.C.

Géochronométrie U-Pb et K-Ar dans la région de la Rivière Iskut (N.-O. de la C.-B.)

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New U-Pb (zircon, sphene), K-Ar (hornblende, biotite) ages and previous geochronometry for plutonic rocks from Iskut River map area help define four intrusive episodes: Late Triassic (228–213 Ma, Stikine plutonic suite); Early Jurassic (196–189 Ma, Texas Creek plutonic suite), Middle Jurassic (about 177 Ma, Three Sisters plutonic suite), and Eocene (62–44 Ma, Hyder plutonic suite). The Mesozoic plutonic suites have coeval volcanic rock associations in the Upper Triassic Stuhini Group, Lower Jurassic Unuk Formation of the Lower and Middle Jurassic Hazelton Group, and the Middle Jurassic Salmon River Formation, Eskay Creek facies (Fig. 1). Early Jurassic alkaline plutons or dykes of Texas Creek plutonic suite which intrude Upper Triassic and Lower Jurassic strata are spatially associated with many precious metal veins and one base metal deposit presently being developed in the area (e.g. INEL, PREMIER, SNIP, STONEHOUSE, SULPHURETS, and KERR deposits).

Triassic dates include those for McQuillan Ridge pluton hornblende monzodiorite (226 + 6/-2 Ma; U-Pb), Katete Mountain hornblendite (228± 5 Ma, K-Ar, hornblende) and Seraphim Mountain pluton quartz monzoranite (213± 4 Ma, K-Ar, biotite). The McQuillan Ridge pluton intrudes Upper Triassic Stuhini Group strata that include hornblende-phyric andesitic volcaniclastic rocks dated at 220± 5 Ma (K-Ar, hornblende).

The Early Jurassic Texas Creek plutonic suite includes megacrystic quartz monzonite of McLymont Creek pluton (192 + 9/-1 Ma, U-Pb; 189± 3 Ma, K-Ar, biotite), and Katete Mountain pluton quartz monzodiorite (192± 1 Ma; U-Pb)

Middle Jurassic plutons are common along the western margin of Stikinia in the map area and include Mount Choquette gabbro (152± 5 Ma, K-Ar, hornblende), Warm Springs Mountain pluton quartz monzodiorite (177± 2 Ma, U-Pb; 159± 2 Ma, K-Ar biotite), and Middle Mountain pluton monzodiorite (177± 1 Ma, U-Pb). The Late Jurassic reset K-Ar systematics of the Mount Choquette and Warm Springs Mountain samples are anomalous and difficult to explain but are characteristic of the Middle Jurassic Three Sisters plutonic suite.

K-Ar dates for different phases of the Zippa Mountain syenite pluton are not easily interpreted. The oldest phase, a biotite alkali-feldspar syenite, yielded a K-Ar biotite date of 78± 2 Ma. Hornblende from the next-intruded, hornblende-plagioclase porphyry was dated at 98± 2 Ma. The youngest, biotite-hornblende quartz monzonite phase of Zippa Mountain pluton yielded discordant dates of 167± 4 Ma (hornblende) and 77± 1 Ma (biotite). U-Pb analyses of zircon from the pluton are underway.

Tertiary plutons define the eastern, intrusive margin of the Coast Belt at this latitude. They include: Saddle

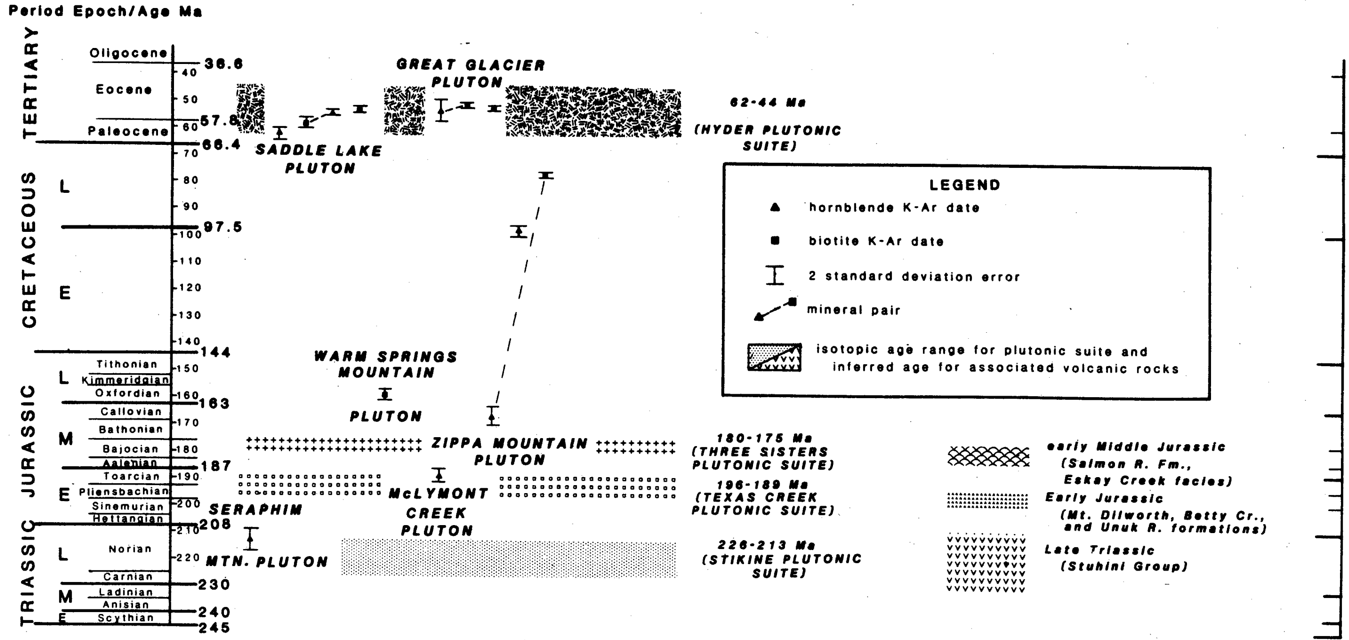

Figure 1. Some K-Ar and U-Pb geochronometry for Iskut River map area. Patterned intervals indicate plutonic episodes and equivalent volcanic strata with reference to DNAG time scale.

Lake pluton quartz monzodiorite (56± 6 Ma, U-Pb, and 62± 2 Ma, K-Ar hornblende for the same sample; also for other samples, mineral pair 53± 1 Ma, K-Ar, biotite and 47± 5, K-Ar, hornblende, and mineral pair 58± 2 Ma, K-Ar, biotite and 54± 1 Ma, K-Ar, hornblende); and Great Glacier pluton monzogranite (51± 1 Ma, U-Pb and 52± 1 Ma, K-Ar, biotite, for the same sample; also for other samples, mineral pair 53± 4 Ma, K-Ar, hornblende, and 51± 1 Ma, K-Ar, biotite).

Feldspar Pb data were used to correct the U-Pb analyses for common Pb. The data can be used to test proposed timing of metallogenic events based on common lead signatures for galena associated with precious metal veins.

Possible evidence for Holocene earthquakes in Saanich Inlet

Preuve possible de tremblements de terr Holocenes dans la région de l'Inlet Saanich

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Three piston cores collected from Saanich Inlet, British Columbia, in January 1989, contain a record of episodic, Holocene, sediment gravity flows which may have been triggered by large earthquakes. Saanich Inlet, near the southern end of Vancouver Island, is 26 km long, up to 8 km wide, and has average and maximum depths of 120 m and 236 m, respectively. A bedrock sill at the north end of the inlet rises to within 70 m of the sea surface and restricts normal water circulation. The lower part of the water column (150 m below sea level in December) is anoxic.

Much of the sediment in Saanich Inlet comprises alternating dark and light laminae (varves). The light laminae consist mainly of diatoms and are interpreted to be products of spring and summer blooms. Dark laminae are dominantly silt- and clay-size mineral detritus, derived in large part from Cowichan River and deposited from suspension during fall and winter. Sediment couplets produced by this seasonal cycle are preserved in the deeper parts of the inlet where there are no bottom-dwelling organisms that can disturb or destroy the stratification.

Varved sequences in the three cores are interbedded with massive mud beds ranging from a few centimetres to several tens of centimetres thick. These beds lack sedimentary structures such as cross-beds, laminae, and disrupted layers, although many are capped by a prominent, thick, light-coloured lamina. Upper contacts typically are sharp; some basal contacts are also sharp, whereas others are gradational. The massive beds are coarser than enclosing varved sediments, but show no vertical variations in particle size. Kuenen-type structures (e.g., low amplitude folds and load features), indicative of *in situ* liquefaction, were not observed. These observations indicate that the massive beds were emplaced by sediment gravity flows (grain flows or debris flows). Varve counts and radiocarbon ages suggest that these flows have occurred on average once every 100 years over the last 1500 years. Although sediment gravity flows can be caused by a variety of processes, those in Saanich Inlet most likely have been triggered by earthquakes. If so, it may be possible through this study to obtain a rather precise chronology of prehistoric Holocene earthquakes in coastal southwestern British Columbia.

Metallogeny of the Canadian Cordillera

Métallogénie de la Cordillère Canadienne

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The Canadian Cordillera is a region of great geologic and metallogenic diversity. Just as each Cordilleran terrane preserves a stratigraphic record different from neighbouring terranes, characteristic suites of mineral deposits as integral parts of their host terranes reflect fundamental differences in depositional environments.

Metallogenic analysis of craton, pericratonic and accreted terranes of the Canadian Cordillera demonstrates a consistent relationship between the lithotectonic character of host terranes and the type and composition of their typical suites of mineral deposits. The distinctive lithophile character of typical cratonic ore element assemblages probably reflects their origin in an upper crustal silicate protolith. In comparison, the mainly chalcophile ore element assemblages of typical Intermontane Belt deposits form sulphide ores genetically related to deep-seated igneous rocks of lower crustal or oceanic origin. Metallogeny, therefore, readily distinguishes Cordilleran cratonic terranes and their displaced equivalents from accreted arc and oceanic terranes.

Present knowledge of the time of tectonic, plutonic and metallogenic events, although imperfect, allows classification of mineral deposition according to the accretionary history of the host or immediately adjacent terrane. In terranes of cratonic affinity several periods of pre-accretionary mineralization may have been generated, in part, by rifting events recognized in Late Proterozoic and early Paleozoic time.

Pre-accretionary mineral deposits are predominantly stratiform types, hosted by sedimentary and volcanic strata. Not only are certain syngenetic pre-accretionary deposits uniquely associated with specific crustal types of terranes, e.g. manganiferous chert in oceanic terranes, and Kuroko-type volcanogenic massive sulphides in calc-alkaline island arcs, but also accretionary and post-accretionary deposits, regardless of age, correlate strongly with host and/or basement lithology.

Deposits of clearly accretionary timing are minor, partly because of the inherent rarity of metamorphogenic mineralization, but mainly due to the difficulty in unequivocally ascribing the generation of a plutonic suite and attendant mineralization to a specific accretionary event.

The majority of granitoid-related porphyry, skarn and vein deposits are post-accretionary. Post-orogenic magmatic events, widespread in Middle Jurassic, mid- and Late Cretaceous and early Tertiary times correspond to important post-accretionary metallogenic epochs that include, for example, W and Zn, Pb skarns of the Omineca Belt, most Cu, Mo porphyries of the Intermontane Belt and precious metal veins throughout the Canadian Cordillera.

Gold-rich skarns of the Canadian Cordillera

Skarns aurifière de la Cordillère Canadienne

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Five types of skarn gold deposits are recognized in the Canadian Cordillera: one contains sufficient gold to be mined for that commodity alone, others include skarns associated with porphyry Cu deposits, with Cu skarns associated with barren stocks, with calcic magnetite deposits and with Zn, Pb skarns and replacements.

1. Gold skarns in addition to having a relatively high

Au grade, are rich in As, Bi and Te, deficient in base metals, contain a higher clastic component in host rocks and are associated with intrusions of more mafic character relative to other skarn gold subtypes. Canadian Cordilleran examples including HEDLEY, TILLICUM MOUNTAIN, QUESNEL RIVER, and DIVIDEND–LAKEVIEW are hosted mainly by Upper Triassic volcanic arc rocks of the accreted Quesnellia in association with Early to Middle Jurassic dioritic intrusions.

2. Gold-bearing skarns associated with porphyry Cu, Au and Cu, Mo deposits are relatively large, low in Au grade, and rich in andraditic garnet, diopsidic pyroxene, disseminated Cu sulphides, magnetite and hematite. Au occurs with sulphides either in prograde skarns or in zones of intense retrograde alteration. Most Canadian Cordilleran examples are associated with alkaline porphyries: INGERBELL, GALORE CREEK, and CARIBOO BELL. CRAIGMONT is associated with the calc-alkaline Guichon Batholith.

3. Cu, Au skarns are distinguished from porphyry Cu, Au skarns mainly by lack of disseminated Cu and Mo sulphides in the generally more mafic-associated intrusions, and also by the smaller size, more massive nature and higher Au grade of the ore bodies. They are associated with, and may grade into Fe skarns. All examples in the northern North American Cordillera, including the world-class districts of Greenwood and Whitehorse Copper Belt and smaller deposits in the Insular Belt and Alaska, are hosted by Upper Triassic accreted oceanic-arc terranes.

4. Fe, Au skarns are associated with large calcic magnetite skarns in which Au, with Co and As, is concentrated with erratically distributed Fe and Cu sulphides rather than Fe oxide ore. Examples include COAST COPPER, MARBLE BAY, and TASU in the Insular Belt, the ORO DENORO and EMMA deposits of the Greenwood district, and the RAMBLER deposit, Alaska.

5. Zn, Pb skarns are more commonly enriched in Ag than in Au. Three replacement deposits in the northern Cordillera, i.e. MIDWAY, YP, and RAY, contain important minor values in Au, mainly in proximal skarn. TILLICUM MOUNTAIN and BANKS ISLAND Au skarns contain substantial amounts of Pb and Zn.

Geological maps, Operation Saint Elias, SW Yukon and NW B.C.

Cartes géologiques des parties S.-O. du Yukon et N.O. de la C.-B., dans le cadre de l'Opération Saint Elias

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And many others...

Operation Saint Elias was undertaken by the Geological Survey of Canada to determine the geology, to assess the mineral potential and to produce 1:250,000 scale geological maps of the Saint Elias Mountains of southwesternmost Yukon and northwesternmost British Columbia, Canada. The area includes SW Kluane Lake (part of 115G & F(E1/2)), Mount St. Elias (part of 115B & C(E1/2)), SW Dezadeash (part of 115A), NE Yakutat (part of 114O) and Tatshenshini River (part of 114P) map areas. The mountains, the highest and among the youngest in North America, are underlain by segments of major fault-bounded allochthonous terranes which have undergone a long and complex geological history. Most of Saint Elias Mountains in Yukon are included within Kluane National Park and Kluane Game Sanctuary, and the area as a whole affords spectacularly beautiful mountain scenery and a wide variety of fauna and flora. Among the more significant mineral occurrences in the region are WINDY CRAGGY (Cu,Au,Ag,Co massive sulphide) and WELLGREEN (Ni,Cu,PGE magmatic) deposits, which lie outside the park boundaries.

The intent is to publish coloured GSC A-Series 1:250,000-scale geological maps of the entire Saint Elias Mountains of Canada. These maps will show distribution and structure of the main rock units and mineral occurrence, fossil and age data locations, and will be accompanied by a single comprehensive legend common to all sheets. To allow earlier release of the maps and legend, uncoloured versions at 1:250,000-scale accompanied by the legend in booklet form will be issued first as open files. The new maps and legend extensively revise and update the previously published Operation Saint Elias 1:125,000-scale geological maps and legend (GSC Open Files 829, 830, 831, 926, 927) for the region.

Trees and seaweeds: use as metal indicators, southern B.C.

Utilisation des arbres et des algues comme indicateurs de concentrations métallifières dans le sud de la B.-C.

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Nickel Plate Mine, Hedley: Gold Skarn

A study conducted in the summer of 1988 revealed unusually high gold and arsenic concentrations in outer bark scales of Lodgepole Pine from the vicinity of the skarn-hosted gold mineralization currently being open-pit mined (Dunn, 1989). Preliminary evidence suggested that anomalous concentrations of these metals in the bark extend over an area of at least 20 km^2. Tests indicated that these high values were not the result of airborne contamination from the pit, but more conclusive evidence was needed.

In early June, 1989, the area was revisited and several trees were dissected that had yielded high metal values previously. Analysis of the trunk wood and inner bark (in which there can be no particulate contamination) proved to contain metal enrichments that substantiated the earlier assumption: metals within the trees are derived from the substrate, not from airborne dust.

The survey area was extended; new data indicate that there is above background enrichment of gold and arsenic in the vegetation over an area of about 100 km^2.

Over Lookout Mountain immediately north of the open pit, there are distinct and separate zones of lead, copper, antimony, cadmium, and bismuth enrichment. This suggests that there are haloes of trace metals associated with the mineralizing event.

Texada Island: Small-scale Au skarns

Samples of bark from Douglas fir and western hemlock were collected at 87 sites over the northern half of Texada Island. In addition, detailed sampling of many species was conducted near zones of known mineralization (e.g. Little Billy Mine [abandoned] near Vananda). Preliminary results indicate that the Douglas fir is of more value than the hemlock in outlining zones of mineralization. Local enrichments of As, Mo, W, Sb, and Se in the vegetation attest to the presence of mineralization. Close to the Little Billy mine alders contain up to 1000 ppm Mo in ash of twigs and bark, whereas in other species (e.g. willow twigs) Mo concentrations were below the detection limit of 2 ppm. However, gold concentrations at this site proved to be highest in willow twigs, suggesting that willow has a propensity to accumulate gold in carbonate-rich environments. Studies conducted elsewhere in Canada indicate that willow has poor sensitivity to gold in the more acidic milieu of the Canadian Shield.

Texada Island: Seaweed Chemistry

Samples representing the three main groups of seaweed — brown, green, and red — were collected from two shoreline sites. Near the Little Billy mine the brown seaweeds (especially Sargassum) were moderately enriched in As compared to those obtained from a 'background' site at Shelter Point, on the opposite side of the island. At both sites U levels were higher than usually found in terrestrial vegetation. Consideration of the availability and practicality of collection of several species, and the value of the chemical information derived from them (based on study of 43 elements), indicate that the brown seaweeds may be of use in identifying certain types of near shore mineralization, and in environmental monitoring (Dunn, 1990).

Grand Forks Area–Franklin Mining Camp

The complex of Mesozoic and Tertiary igneous rocks in the vicinity of Franklin Mountain, 60 km NNE of Grand Forks, has long been known to host Cu-Au-Ag-PGE mineralization. Six sites in the vicinity of the old Union mine and the Maple Leaf adit were visited in order to obtain a range of vegetation samples, and determine relative concentrations of trace metals in ashed tissues. This information would provide an indication of the sensitivity of various trees and shrubs to the type of mineralization present in this climatic regime. Data obtained could assist in the design of future biogeochemical exploration surveys.

A preliminary evaluation of the first set of multi-element instrumental neutron activation data shows great variation in the Au and Ag content of the various plants. According to the plant species and tissue type sampled from the same site, the Au concentrations range from 14 ppb in cottonwood leaves and bark, to 560 ppb in twigs of Engelmann spruce. Similarly, cottonwood tissues contain less than 2 ppm Ag, whereas twigs of the conifers contain up to 18 ppm. The vegetation analysis shows that W enrichment occurs in association with the mineralization, and that there is no appreciable enrichment of As. At this time data are not available on the distribution of the platinum-group metals and Cu.

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Stratigraphy and structural style of west Spatsizi map area

Stratigraphie et cadre structural de la région cartographique de Spatsizi ouest

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West Spatsizi map area is underlain by four regional stratigraphic units: 1) the Lower to Middle Jurassic Hazelton Group, 2) the Lower to Middle Jurassic Spatsizi Group, 3) the Middle Jurassic to Cretaceous(?) Bowser Lake Group, and 4) Pliocene basalt flows that overlie folded Bowser Lake Group. Cretaceous and older strata are part of a regional fold belt with shortening locally up to 50% (Evenchick, 1988, 1989).

Stratigraphy

Bowser Lake Group: Most of west Spatsizi map area is underlain by Bowser Lake Group, with the underlying Hazelton and Spatsizi groups exposed only in the north. The Bowser Lake Group is divided into five units, of which only one, the Ashman Formation, is a regionally mappable unit. The other four are not conventional rock-stratigraphic units. They are based on common lithologies, sequences, sedimentary structures, and fossils. These features reflect general environments of deposition, which probably overlap in time and repeat in a vertical section.

Ashman Formation: The Ashman Formation is at least 1400 m thick where it overlies the Spatsizi Group. It consists of black-weathering siltstone and very fine grained sandstone. Lenses and laterally continuous sheets of conglomerate are also present. It is similar to Ashman Formation mapped to the east (Gabrielse and Tipper, 1984) and south (Tipper and Richards, 1976).

Turbidites: The southwest corner of the map area is underlain by intervals of siltstone to very fine-grained sandstone, alternating with fine- to medium-grained sandstone. Sedimentary structures include parallel lamination, graded bedding, soft sediment folds, massive beds, tool marks and flute casts. The abundance of graded bedding, the common sole marks on the bottom of massive, medium-grained sandstone beds, and the monotonous, rhythmic repetition of siltstone and sandstone suggest that these are turbidites. More than 500 m of siltstone and conglomerate similar to the Ashman Formation overlies at least 1400 m of turbidites.

Shallow marine to nonmarine clastic rock (locally coal-bearing): A wide range in bed thickness and in the proportion of fine-grained to coarse-grained clastic sediment characterizes many areas. Typical sections include: 10–30 m thick coarsening-up cycles with coal and/or carbonaceous siltstone at the base and chert-pebble conglomerate at the top, similar sections with less conspicuous cycles, less conglomerate and no coal, and thick sections of fine and medium grained sandstone and rare coal. Two units are mapped based on the presence or absence of coal. Marine fossils in strata above and below coal-bearing strata indicate fluctuations between marine and nonmarine conditions.

Nonmarine clastic rock: Typical sequences fine upward from conglomerate, through massive sandstone, platy sandstone with interbeds of siltstone, thin bedded sandstone and siltstone, dark green sandstone and siltstone, into carbonaceous siltstone with abundant plants, and locally coal. Fining-up sequences with an abundance of delicate plant fossils and absence of marine fossils suggest a nonmarine environment of deposition.

Maitland Volcanics: The Maitland volcanics (Souther, in press) are Pliocene flat-lying basalt flows that occur as erosional remnants at high elevations. Fourteen basalt necks, rising much as 200 m above the surrounding topography, are assumed to be the feeders.

Structural style

The style, orientation, and scale of folds in west Spatsizi map area are diverse. Axial surfaces of folds range in trend from northeast, north-northeast, northwest, west-northwest, and west. The range in trend contrasts with the consistent northwest trend of folds in central and east Spatsizi map area (Evenchick, 1988, 1989). In some areas the different trends interfere or are noncylindrical, producing complicated fold patterns. Other areas are dominated by only one trend. Gentle large scale folds near contacts with the Hazelton Group contrast with the smaller scale, close or tight folds elsewhere. Thrust faults are also present.

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Cry Lake jade belt

Ceinture de jade de la région Cry Lake

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Since the mid-1960s the Cry Lake area in northern British Columbia has been one of the world's leading producers of nephrite jade. Production has come from boulders and talus blocks generally near their source areas or from *in situ* lenses enclosed in serpentinite of the Cache Creek Complex. The host rocks occur mainly in a belt of ultramafic, volcanic, sedimentary and mafic plutonic rocks more than 80 km long and ranging from 6 to 15 km wide, extending from southwest of Eagle River to east of Kutcho Creek. The belt is bounded to the north and east by the Thibert and Kutcho faults and to the south and west by the King Salmon Fault. The ultramafic rocks are readily recognized in the field by their dun brown to serpentine green weathering and general lack of vegetation. Jade lenses from 1 to 10 m wide and up to several tens of metres long are discontinuous and relatively rare. High quality material constitutes only a small part of a lens because of schistosity resulting from deformation postdating the formation of jade.

Several constraints on the environment of jade formation are provided by structural and petrological studies of the Cache Creek Complex. The distribution of the various lithologies suggests the style of a structural melange. Many of the contacts between rock units are faults and all units are discontinuous over a wide range of scales. Where faults bound ultramafic bodies they are marked by zones of listwanite or highly sheared, fish-scale serpentinite. Attitudes of slickensides, the lensoid form of jade bodies and pervasive foliation indicate the effects of rotation, boudinaging and shearing.

High pressure and possibly low temperature metamorphism within the Cache Creek Complex is shown by the local presence of riebeckite, crossite and jadeite. Stilpnomelane is widespread in mafic rocks and, in places, muscovite is conspicuous in metasedimentary rocks. Near jade occurrences serpentinite commonly consists of hornfelsic, feathery reticulated antigorite. This texture is identical to that of the fine grained jade, suggesting the possibility that the jade formed from antigorite simply by addition of calcium and perhaps silica in zones of metasomatism.

The integration of structural and petrological data noted above point to the deformation of accretionary and oceanic lithologies in a subduction zone resulting in a structural melange and relatively high pressures and low temperatures of metamorphism. In this environment nephrite jade lodes formed from antigoritic serpentinites along zones of metasomatism. In most, if not all cases, the metasomatism has taken place where the serpentinites were in contact with sedimentary or volcanic rocks.

Geology of the Ecstall River area, central Coast Belt, B.C.

Géologie de la région de la Rivière Ecstall, dans le centre de la chaine côtièree, en C.-B.

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Four new 1:50 000 scale maps show the structure and distribution of lithologies in the Ecstall River pendant, between the Skeena River and Douglas Channel.

The belt is located between Douglas Channel and the Skeena River and bounded on the west by the mid-Cretaceous Ecstall pluton and on the east by the Paleogene Quottoon pluton. The belt consists of metamorphosed sedimentary and volcanic rocks of Paleozoic age intruded by mid-Devonian Big Falls and Jurassic Foch Lake and Johnson Lake orthogneissic bodies. The pendant hosts several economically interesting sulphide occurrences, including the ECSTALL and SCOTIA massive sulphide properties.

Intense folding and paucity of kinematic indicators characterize the structural style of the area. Development of a strong planar fabric and three subsequent episodes of folding have affected the metamorphic belt between mid-Devonian emplacement of the Big Falls orthogneiss and Cretaceous emplacement of the Ecstall pluton. Early Jurassic regional deformation and metamorphism accompanied by intrusion of Johnson Lake and Foch Lake orthogneisses is inferred from the age of the Johnson Lake and Foch Lake bodies and Pb loss recorded in zircons of the Big Falls orthogneiss. At least two episodes of folding occurred subsequently to Early to Middle Jurassic plutonism. Paleogene deformation associated with Quottoon intrusion is restricted to the easternmost 2 km of the metamorphic belt.

4 to 5 kbars and 500 to 550C metamorphic conditions are recorded by rare and unevenly distributed pelitic rocks of the Ecstall area. The distribution of sillimanite and kyanite indicates an increase in metamorphic grade towards the east. In the Ecstall area, metabasic rocks have been metamorphosed between epidote-amphibolite

and upper amphibolite facies under medium pressure conditions. Variations in mineral compositions suggest subtle and gradual easterly increase in metamorphic grade across the Ecstall pendant. Garnet-hornblende geothermometry provides temperature estimates around 520C in the metavolcanic unit and reaching 580C in a mafic dyke located within 1 km of the eastern margin of the metamorphic belt. A south to north metamorphic gradient is suggested by increasing proportion of migmatites in all units as well as disappearance of chlorite, primary features and compositional variety from the metavolcanic rocks.

Selwyn Mountains geology: NE Mayo map area

Géologie des Monts Selwyn, dans le Nord-Est de la région de Mayo (105M/16), Y.T.

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The Tiny Island Lake map area (105M/16) is underlain by three main stratigraphic assemblages that form the hanging wall of the Robert Service thrust. The oldest, of late Proterozoic–Cambrian age, consists of slate, quartzite, and minor limestone of the Hyland Group. This is overlain unconformably by slate, chert, chert pebble conglomerate and felsic volcanics of probable Devono–Mississippian age. The youngest unit consists of Triassic–Jurassic slate, sandstone and carbonate.

These strata are complexly folded under low grade metamorphic conditions, the complexity of deformation increasing with proximity to the Robert Service thrust.

The Devono-Mississippian strata are similar to and correlate with the Earn Group, an assemblage that elsewhere in the northern Cordillera is known for hosting stratiform barite-lead-zinc-silver mineralization. In this region the assemblage is under-explored relative to its potential for these and volcanogenic massive sulphide deposits.

Cretaceous stratigraphy & hydrocarbons, Q.C.I.

Stratigraphie du Crétacé et hydrocarbures des Iles de la Reine-Charlotte

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Three stratigraphic packages have been recognized in the Cretaceous of the Queen Charlotte Islands. The oldest package is the Lower Cretaceous (Tithonian? to Aptian) Longarm Formation, consisting of basal conglomerate fining upward into sandstone, shale, and turbidite deposits. The Longarm Formation, a transgressive sequence, was deposited in a regime of rising sea level and represents deposition in a variety of shelf to upper slope environments.

The second stratigraphic package in the islands is represented by the middle Cretaceous (Albian to Turonian) Haida and Skidegate formations of the Queen Charlotte Group, also consisting of conglomerate, sandstone, shale, and turbidite deposits. The Haida and Skidegate formations also represent a transgressive sequence, deposited in shallow marine through outer shelf and deeper basin environments.

The uppermost Cretaceous stratigraphic package includes the Honna Formation, a locally thick unit of conglomerate and sandstone, and a conformably overlying sequence of unnamed shales. Local volcanics are associated with the Honna Formation. The Honna reflects progradation of fan-delta complexes into the basin during the Coniacian and Santonian, this event correlating closely with observed eustatic sea level drop. The fining upward trend displayed through the Honna Formation and the overlying unnamed shale succession is also a transgressive sequence, reflecting renewed sea level rise. The unnamed shale succession reflects a return to shelf depos ition in the Santonian and Campanian.

Previously suggested hiatuses between the stratigraphic packages are now represented by complete stratigraphic sections. Deposition thus occurred continuously in the islands through the Cretaceous. Most of the strata accumulated on the shelf but some deeper water environments are represented. The shelf appears to have been approximately 10–20 km in width. Deposition of the stratigraphic succession appears to have been controlled principally by sea level rise, probably eustatic trends, and local block faulting.

A series of migrating strandlines can be constructed for the Cretaceous of the islands, reflecting eastward-directed transgression. The distribution of Cretaceous facies belts essentially parallels the strandline trend. Potential hydrocarbon reservoir rocks occur in the basal transgressive facies of the Cretaceous succession and the distribution of these rocks offshore can be predicted.

Georgia–Puget basin marine geophysical survey

Levée geophysique marin du bassin de Georgia–Puget

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The Neogene depression extending from Georgia Strait to Puget Sound was the focus of a high resolution geophysical survey. With expanses of deep water and thick unconsolidated sediments, geophysics is the only way to efficiently assess underlying geology, regional structures and faulting. Between Oct. 23 and Nov. 03, 1989 the G.S.C. collected 4240 km of trackline geophysical information aboard the C.S.S. John P. Tully. The open waters of Georgia Strait between latitude 50°N (Campbell River, B.C.) and 48.75°N (Bellingham, WA), were covered by a dense grid of N-S and E-W lines at 3.5 km. spacing. Profiles were also collected in: Malaspina Strait, Jervis Inlet, Howe Sound, the Gulf Islands, Rosario Strait, Haro Strait, eastern Juan de Fuca Strait and Puget Sound. These marine data do not generally come closer than 750 m to shore or shallow subtidal platforms. Routinely recorded were: gravity, magnetics, high resolution bathymetry and 3.5 kHz shallow subbottom profiles. Included in the above total are 460 km of single channel seismic data. The gravity data were collected with a gyroscopically stabilized Lacoste & Romberg air/sea meter (SL1) using a 5 minute filter and digitally recorded at 1.0 second. Owing to the calm sea state and the ship's stability at the constant survey speed (7-10 knots), high quality gravity data were obtained. The magnetic data were collected with a Barringer proton precession magnetometer - model 123. Single channel seismic data were collected with a Bolt 600b airgun and a 15 m, 50 element array at 60 to 600 Hz. The unprecedented frequency at which the gravity data were recorded was made possible by the Starfix navigational system. Starfix provided 2-D coordinate information 24 hours per day with an update frequency of 0.5 seconds. A positioning accuracy of about 5 m was maintained throughout the cruise.

The purpose for these new data is to assess regional geological architecture and geohazards. Specifically, they can be used to address the subsurface extent of the various basement terranes and the nature of their boundaries. The data can also be used to delineate the constituent sedimentary basins of the region and to map and put constraints on young faulting. The survey was designed to have an accuracy of about 1 mGal. This can resolve faults which cut the glacial fill having bedrock offsets as small as 25 m. Off Vancouver and Victoria, several new faults were discovered which appear to cut glacial and younger sediments consequently offsetting the modern seafloor. These features are seen in both the seismic and potential field data. In addition to this recent faulting, seismic profiles in Howe Sound and adjacent to Campbell River also give evidence of ongoing crustal deformation in the form of geodynamic tilting.

Mineralogy of the Sulphurets–Brucejack Lake area, B.C.

Minéralogie de la région de Sulphurets–Lac Brucejack, en B.-C.

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The Sulphurets–Brucejack Lake area in northwestern British Columbia exhibits large pyrite-sericite alteration zones spatially related to copper and molybdenum porphyries and several precious metal styles of mineralization. The porphyry deposits contain molybdenite, chalcopyrite as the principal copper mineral and minor tennantite. Some of the Ag-Au zones are hosted in quartz vein-stockwork breccia systems that have Sb-enriched mineralization with electrum, native silver and silver sulphosalts (argentian tetrahedrite, pyrargyrite, polybasite). Associated ore minerals are sphalerite, galena and rare chalcopyrite. Other important Au zones are more As enriched and depleted in Ag and Sb. On a local scale, complex multiple episodes of mineralization are evident both in gangue and sulphide mineralogy.

Margin of the Central Gneiss Complex near Terrace, B.C.

Marge du Complexe du Gneiss Centrale, près de Terrace, en C.-B.

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The eastern margin of the Central Gneiss Complex (CGC) in the Shames River area west of Terrace has been interpreted as a high-angle fault, an east-vergent thrust, and a denudational fault. Along Shames River, deformed granitoid rocks of the CGC are in steep fault contact with volcanic and sedimentary strata of Stikinia. Extensional ductile movement in the CGC was directed northeast near Shames River, and northeast and southwest near Exstew River. East of Shames River, earlier northeast-vergent thrusting gave rise to an inverted metamorphic sequence of amphibolite over greenschist facies volcanic and plutonic rocks. This region thus records a change from compressional to extensional tectonics, and shows similarities to metamorphic core complexes elsewhere.

Geology of central Graham Island, Q.C.I.

Géologie du centre de l'Ile Graham, Iles de la Reine-Charlotte

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Jurassic rocks of central Graham Island comprise interbedded shales, silts and sandstones of Lower Jurassic age (Hettangian to Aalenian) and unconformably overlying Middle Jurassic (Bajocian) volcanic derived sedimentary rocks and volcanic rocks. Major folds in these strata trend northwest. A minor fold set trends northeast. Large scale thrust faults and normal faults are subparallel to the major folds, the normal faults being the youngest. A minor fault set trends northeast and is probably related to strike-slip faulting. Abundant strike-slip faults are observed in outcrops and may reflect the latest deformation phase. Several detachment surfaces occur throughout the Peril and Sandilands formation sof the Kunga Group providing decollements for the thrust faults.

Cretaceous rocks of central Graham Island are composed of Hauterivian to Coniacian mudstones, sandstones, and conglomerates of the Longarm, Haida, Skidegate, and Honna formations. Post-Late Cretaceous compression is recorded as gentle to close, northwest-trending folds, with locally overturned bedding. From regional distribution of Cretaceous strata large scale northwest-trending extensional faults are inferred. The predominant structures recorded in outcrop are small scale strike-slip faults of Tertiary age, which reflects the latest period of deformation in the area.

The Masset Formation, Graham Island, Q.C.I.

La Formation de Masset dans les Iles de la Reine-Charlotte

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The Masset Formation was the focus of a two year project under the Queen Charlotte Frontier Geoscience Program (FGP). Portions of Graham Island with exposure and dominantly underlain by rocks of the Masset Formation were mapped at 1:50,000 scale (103K/3E, 103F/14E, 103F/10W, 104F/10E and 103F/9). Other areas were studied at a reconnaissance level. The maps and report will be published as part of a combined FGP volume on the Queen Charlotte Islands.

The Masset Formation is a Late Oligocene to Early Pliocene (Fig. 1) suite of volcanic rocks. Chemically,

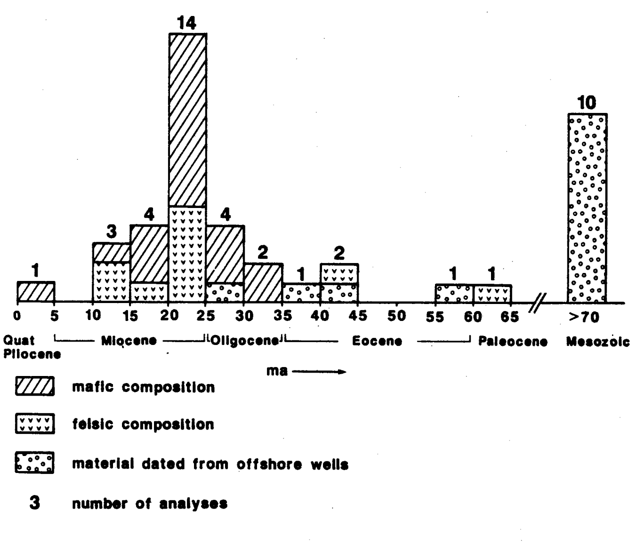
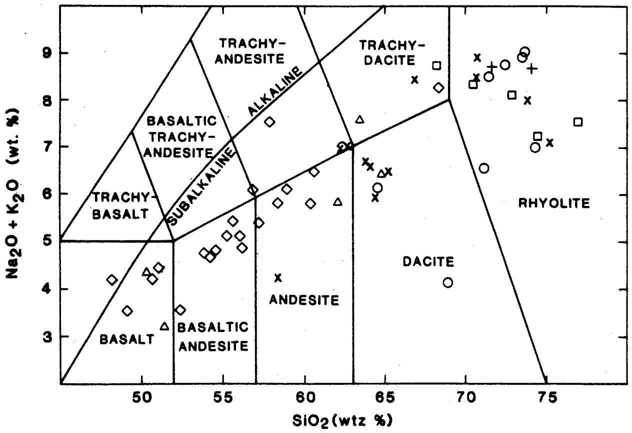


Figure 1: Histogram of K-Ar dates from rocks correlated with the Masset Formation.



FIELD CLASSIFICATION

Mafic to Intermediate	Map Unit	Felsic TMf	Map Unit
◇ Basalt	TMmb	○ Aphanitic	TMfa
△ Aphanitic; mafic	TMma	□ Feldsparphyric	TMfc
x Intermediate; pyroxenphyric	TMfg	+ Quartzphyric	TMfe

Figure 2: Total alkalis vs. SiO_2 for samples from the Masset Formation. Fields from LeBas et al. (1986).

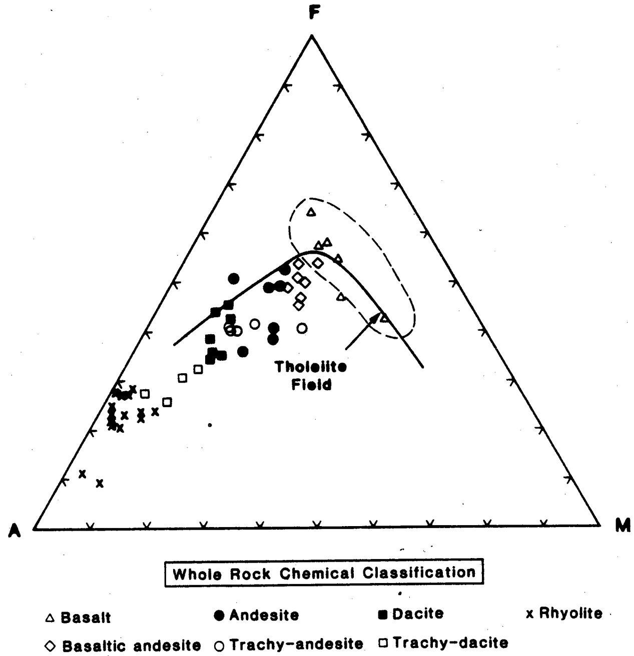
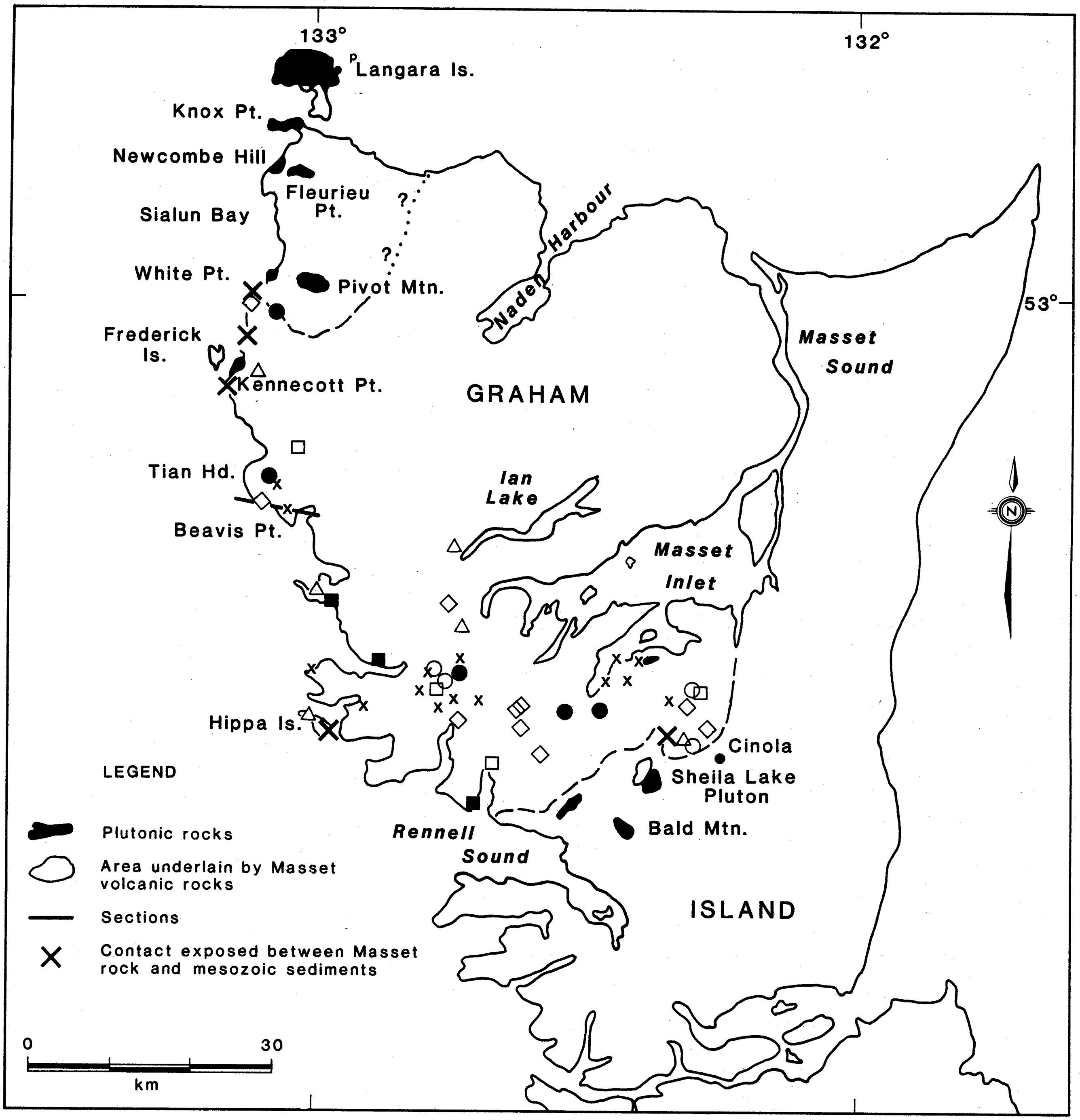


Figure 3: AFM diagram of whole-rock chemical analyses of samples from the Masset Formation.

they are subalkaline (Fig. 2) and tholeiitic to calc-alkaline (Fig. 3). They underlie much of Graham Island. These lavas, with minor intercalated felsic pyroclastic flows, underlie eastern Graham Island (Fig. 4) but probably do not extend any great distance beneath Hecate Strait. The Formation comprises intercalated, aphyric to feldspar phyric, mafic to felsic lava flows and pyroclastics. Thick rhyolite flows, core inland hills along the west coast and may represent vent areas from which volcanic products and sediments were shed east and west. Three possible vent areas are shown on Figure 4. K-Ar dates suggest eruptions climaxed from 20 to 25 Ma (Fig. 1); there was contemporaneous extrusion of felsic and mafic magmas; mafic magmas dominate volumetrically and travelled farthest from vent areas. The extrusion of these rocks was rapid, leaving little time for sedimentation or weathering between eruptions. Epiclastic sediments consist mostly of debris flow deposits.

The Masset Formation is undeformed except for steep north-trending faults. Bedding attitudes represent primary slopes of constructional volcanic landforms.

Basaltic lavas found in offshore drilling in Queen Charlotte Sound and Hecate Strait are older and lithologically distinct from the bulk of Masset rocks and it is proposed that they represent one or more volcanic episodes distinct from the Masset eruptions. Older volcanic rocks were also found intercalated within the Honna and Haida formations. These volcanic rocks are distinct in that they contain hornblende phenocrysts which were not found in the Masset Formation of Graham Island.



Whole Rock Chemical Classification

△ Basalt ● Andesite ■ Dacite x Rhyolite

◇ Basaltic Andesite ○ Trachy-Andesite □ Trachy-Dacite

***Figure 4:** Distribution of the Masset Formation, exposed plutons of the Kano plutonic suite and basement exposures. Also noted are the location and compositions of whole rock chemical samples.*

The Chilcotin–Nechako Hydrocarbon Province

La Province d'Hydrocarbures de Chilcotin–Nechako

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Hydrocarbon exploration in the Chilcotin–Nechako Hydrocarbon Province (formerly referred to as the Nechako Basin and the Tyaughton Trough or the Chilcotin–Nechako Basin) began in the 1930s and has continued intermittently since that time. Eight exploratory wells have been drilled and 1300 km of vibroseismic data recorded.

Due to uncertainty over what strata comprise the basin, the area is referred to as a 'hydrocarbon province'. This wording is meant to reflect the importance of both the Jurassic 'Nechako Basin' strata and that of the poorly studied, discontinuous outcroppings of Cretaceous strata referred to as the 'Nazko Basin' (Hunt and Bustin, 1990; Rouse and Mathews, 1990) as well as Tertiary basins (Rouse and Mathews, 1990) within the Chilcotin–Nechako geographic area (Fig. 1).

The eastern limit of the Chilcotin–Nechako Hydrocarbon Province is the Fraser Fault and the northern boundary coincides with the Skeena Arch (Fig. 1). The area covers all or parts of map areas 92O, 92N, 93B to 93G, and 93J to 93L. Because the region is large, emphasis will be on the southern half (Anahim Lake (93C), Quesnel (93B), Taseko Lakes (92O) and the northeast corner of Mt. Waddington (92N)).

The southwestern Chilcotin–Nechako region is underlain by Jurassic and Cretaceous supracrustal rocks of the Tyaughton–Methow Basin (Tyaughton Trough of Koch, 1973: Fig. 1; Jeletzky and Tipper, 1968; Tipper, 1969; Kleinspehn, 1985). These rocks are bounded to the west and south by the Coast Belt. The Taseko Lakes area (92O), where sediments of the Tyaughton Trough are well exposed, has been the focus of recent detailed mapping (Garver et al., 1989; Schiarizza et al., 1989; Glover and Schiarizza, 1987; Glover et al., 1987; McLaren, 1987) by the staff of B.C. Geological Survey. These and other works provides a basis for extending and integrating structure and stratigraphy northward into the poorly exposed areas in the heart of the region.

Most of the Chilcotin–Nechako area is viewed as part of Stikinia (Monger and Berg, 1984). Triassic and Jurassic supracrustal and plutonic rocks assigned to Stikinia are dominantly marine arc volcanic and sedimentary rocks belonging to the Triassic Stuhini Group and the Early to Middle Jurassic Hazelton Group (Fig. 2).

Within the region, the change from basin sedimentation (Bowser Lake Group) to emergent, dominantly volcanic conditions (Kasalka, Ootsa Lake and Endako groups), took place at the end of the Jurassic. This emergence was followed by an Early to mid-Cretaceous marine transgression (Skeena Group, Fig. 2).

Much of the west-central Chilcotin–Nechako region appears to have a crystalline basement underlying the Mesozoic strata. High grade metamorphic rocks in the Tatla Lake area (Fig. 1) belong to an Eocene extensional core complex that may extend beneath much of the region (Friedman and Armstrong, 1989). During the development of the complex, mid-crustal rocks were deformed ductily and then high-grade metamorphic rocks were denuded tectonically and exposed at the surface. Large grabens with thick accumulations of sedimentary rocks and organic matter were formed. Some of these basins yield coal; the Hat Creek Basin, southeast of the study area is an example.

Regional reconnaissance and related detailed studies were started during the summer of 1989. Preliminary findings can be found in papers in Current Research 1990 by J.A. Hunt and R.M. Bustin (1990) on the stratigraphy, organic maturation and source rock potential of Cretaceous strata; G.E. Rouse and W.H. Mathews (1990) on a palynological and geochronological investigation of Mesozoic and Cenozoic rocks in the region; and P. van der Heyden (1990) on structural evolution of the western margin of the region.

Outcrops of Cretaceous strata are sparse between the Tyaughton–Methow and Skeena basins. They have been reported in drill holes (Fig. 1; Canadian Hunter Exploration Ltd. unpub. report, 1983), and during this field season outcrops of black shale of Cretaceous Hauterivian(?) age (J. Haggart, pers. comm., 1989) were found southeast of Tatla Lake (Fig. 2). This area was previously thought to contain Jurassic Hazelton Group equivalents and unnamed Hauterivian and younger volcanics. Future work by Hunt and Bustin and others will help to correlate the isolated outcrops of Cretaceous strata. The question is whether they comprise one continuous, time-transgressive basin as suggested by H.W. Tipper (pers. comm., 1989) or whether they are a series of small disconnected basins.

In the Tyaughton–Methow basin outcrops of Cadwallader Group (Late Triassic Stuhini age-equivalents, Fig. 2) composed of limestone, greywacke, and pebble conglomerates are found. Previously similar limestones, near the Chilcotin River, were correlated with the Cache Creek Group (Monger and Berg, 1984). More recent findings suggest that these are Cadwallader Group equivalents (H.W. Tipper and G.J. Woodsworth, pers. comm., 1989; Wheeler and McFeely, 1987;

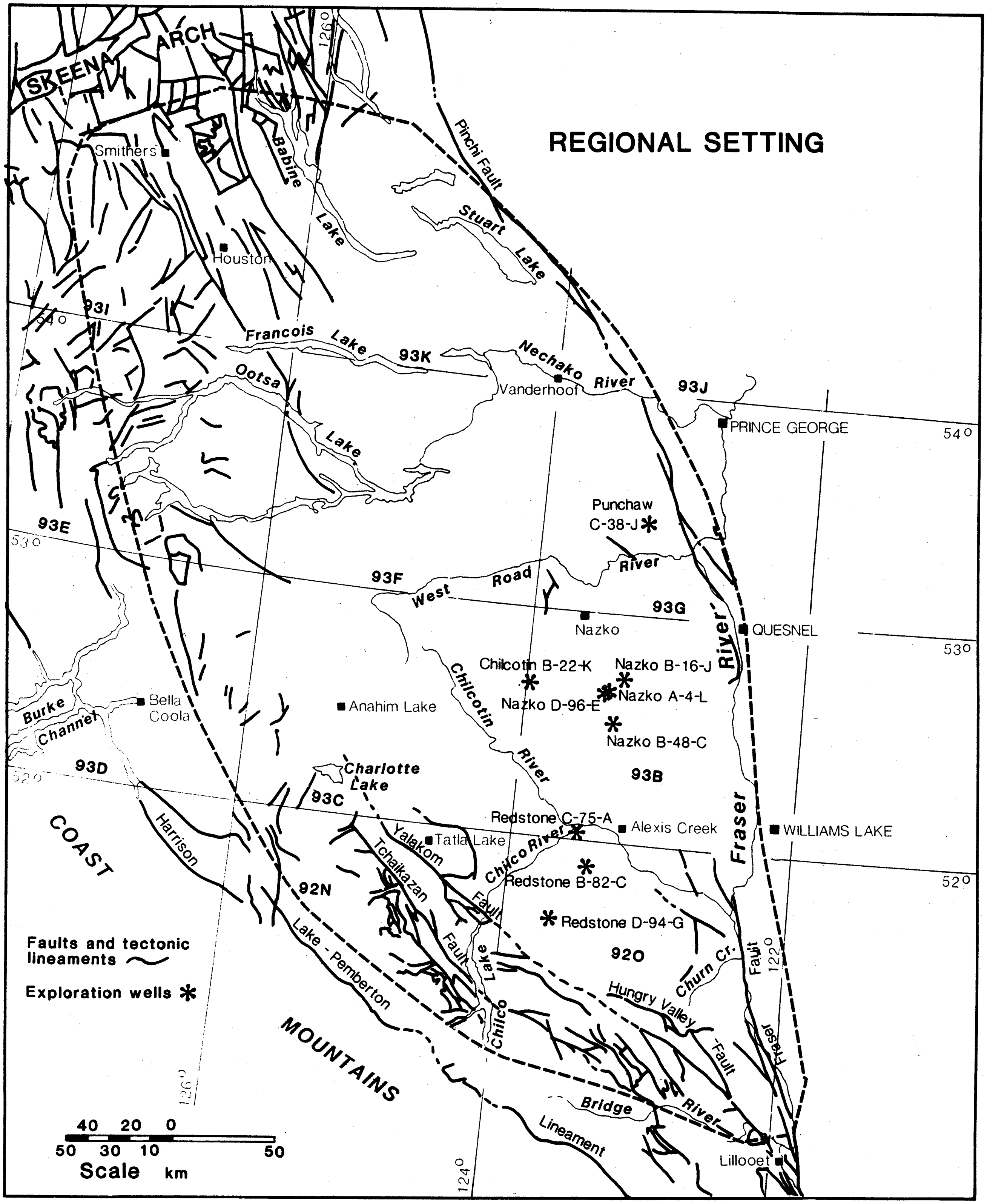

Figure 1: Area covered by the Chilcotin–Nechako Hydrocarbon Province showing the boundary as a dashed line, NTS grid, main faults (modified from Wheeler and McFeely, 1987), and hydrocarbon exploration wells.

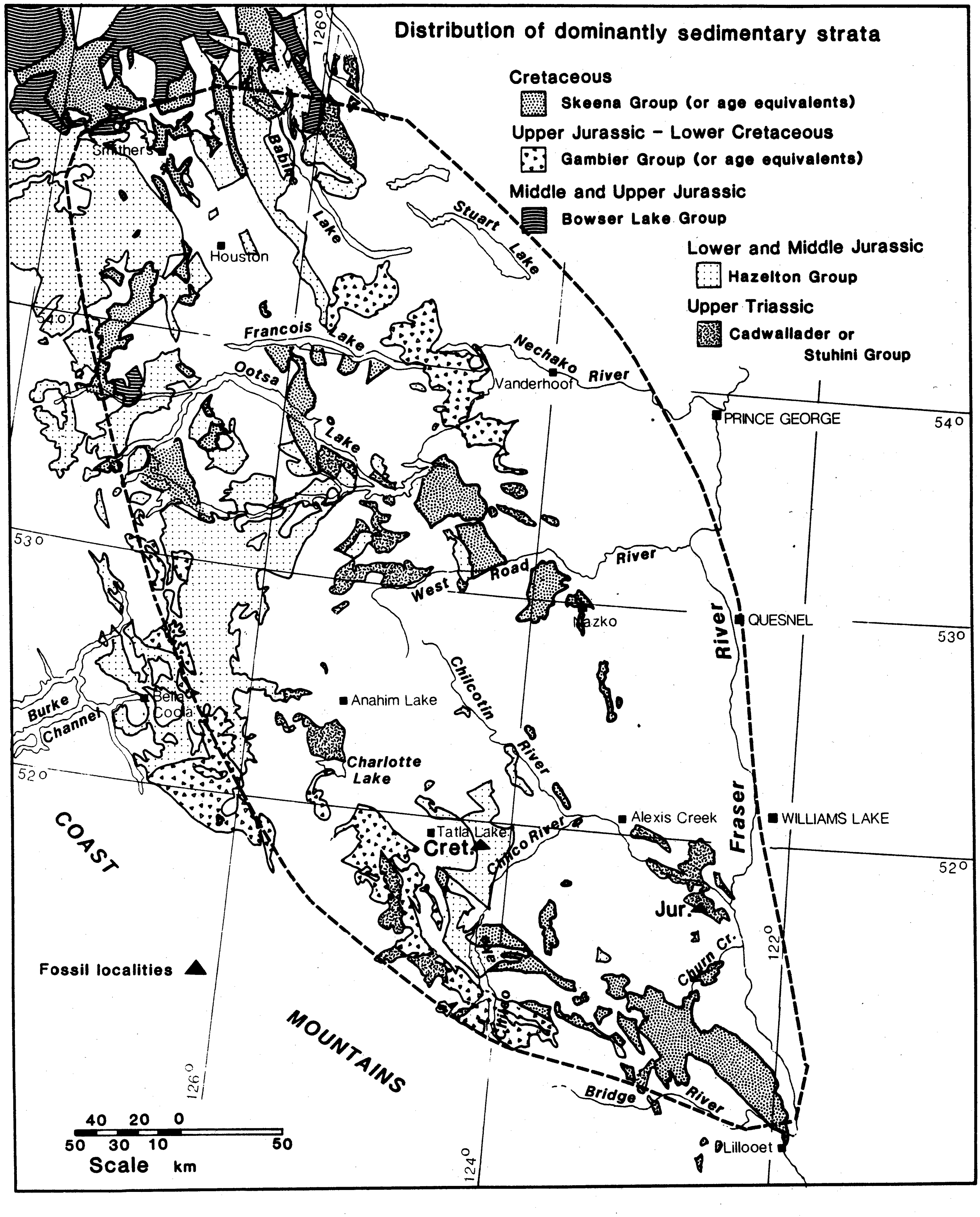

Figure 2: Distribution of dominantly sedimentary strata within the Chilcotin–Nechako region (modified from Wheeler and McFeely, 1987). Bowser Lake Group strata are part of the Nechako Basin and Skeena Group rocks part of the Nazko Basin.

Gabrielse and Yorath, 1989). This summer's discovery of Jurassic (Toarcian, H.W. Tipper, pers. comm., 1989) black shale along the south side of the Chilcotin River provides evidence Cadwallader Terrane strata extend northward from the Tyaughton–Methow area.

North of the Chilcotin River (near Bald Mountain) we discovered an outcrop of ultramafic rock. Several other outcrops of ultramafic rock have been found near this local by T.A. Richards (pers. comm., 1989). These may represent the remnants of oceanic crust, preserved when Cadwallader Terrane was sutured to ancestral North America.

Regional gravity data for the study area hints at large through-going structures subparallel to the northwesterly tectonic strike. Gravity data were obtained by Canadian Hunter Petroleum Co. and they interpret a major fault near Alexis Creek (Canadian Hunter Exploration Ltd. unpub. report, 1983). In their interpretation, the structure trends northwest and has a large graben on its downthrown, west side. It is estimated that the graben contains a 6000 m thick section of sediments and terminates north of Alexis Creek. This structure lies almost equidistant between the Fraser and Yalakom faults (Fig. 2).

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Stratigraphy and source rocks, Chilcotin–Nechako region

Stratigraphie et roches de source petrolifière de la région de Chilcotin–Nechako

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In the Chilcotin–Nechako region of central British Columbia a highly varied succession of marine, transitional marine and non marine, coarse to fine grained clastic rocks crop out. These strata define two basins: the Jurassic Nechako Basin and the Cretaceous Nazko Basin. The Nechako Basin is defined by rocks of the Ashman Formation of the Bowser Lake Group. The Nazko Basin includes rocks of the Skeena, Relay Mountain, Jackass Mountain, Taylor Creek and Kingsvale groups. Marine Cretaceous rocks occur throughout the Chilcotin–Nechako region, suggesting that the Cretaceous Nazko basin may have extended from Smithers to the Methow Basin. The lateral extent of the Nechako Basin was probably similar to that of the Nazko Basin extending from the Skeena Arch to the Tyaughton Trough. Preliminary studies indicate the level of organic maturation and petroleum source rock quality is highly variable. Moderate to good source rocks, within the oil window, occur at least locally in Upper Jurassic strata.

Conodont ages of stratiform mineral deposits

Ages des conodontes des gîtes minéraux stratiformes

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Conodonts are extremely useful in dating Paleozoic through Triassic strata due to their high temporal resolution, widespread geographic distribution, and resilience to diagenetic and metamorphic processes. They have been useful in dating rocks in many areas of economic importance, not least of which are the Devono–Carboniferous stratiform sulphide and barite deposits in the epicratonic Earn Group sediments of the Selwyn and Kechika Basins. Examples from Macmillan Pass, Gataga, and Midway, sites of barite and barite-lead-zinc within the marginal basin sediments of northern B.C. and southern Yukon, are used to show the application of conodont biostratigraphy.

On the basis of conodont ages, barite mineralization at Macmilland Pass apparently occurs as three different levels: 1) CATHY property—Eifelian to early Frasnian; 2) PETE, JEFF, GARY, and GHMS properties—middle to late Frasnian; 3) TEA property—Early Carboniferous. In addition, barite-lead-zinc mineralization at TOM and JASON properties likely occurs during the middle to late Frasnian. In the Gataga area barite and barite-lead-zinc mineralization have been recognized at several temporally distinct levels within the early and middle Famennian: 1) Lower rhomboidea Zone; 2) Lower marginifera Zone; 3) Upper marginifera Zone. Several other mineralized horizons are bracketed within marginifera Zone and Upper crepida through marginifera Zone. Within the Midway area, the stratiform barite mineralization at the EWEN and PERRY properties is of Early Carboniferous, Tournaisian age. The PERRY and EWEN barite mineralization correlates with the TEA barite property in the Macmillan Pass area.

Magnetostratigraphy of the Selkirk Volcanics

Magnétostratigraphie des roches volcaniques de Selkirk

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Paleomagnetic study has shown that the Selkirk Volcanics and interstratified glacial and nonglacial sediments are excellent recorders of the paleofield. Comparisons with the geopolarity time scale show that the Selkirk Volcanics were erupted during the Matuyama Chron. The oldest pre-Reid glaciation occurred prior to the start of the Olduvai Subchron (1.87 Ma). The younger pre-Reid glaciation occurred in the post-Olduvai part of the Matuyama (0.79–1.67 Ma). Placer deposits in glaciated areas of Yukon beyond the Reid limit are the culmination of at least 0.8 and as much as 1.5 Ma of weathering and alluviation.

L. Jurassic ammonite biostratigraphy, Q.C.I.

Biostratigraphie des ammonites du Jurassique inférieur, dans les Iles de la Reine-Charlotte

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The Queen Charlotte Islands have provided several stratotypes for a Lower Jurassic ammonite zonation being developed for North America. This zonation is providing time constraints for sedimentary modelling, mapping and regional tectonic analyses.

The Sinemurian of the Queen Charlotte Islands is represented by the upper Sandilands Formation. Successive ammonite faunas include *Badouxia–Metophioceras*, *Coroniceras?*, *Arnioceras*, *Asteroceras*, *Paltechioceras–Oxynoticeras* and *Paltechioceras* assemblages followed by a level of the abundant bivalve *Entolium balteatum* near the Sinemurian/Pliensbachian boundary. The Lower Sinemurian rocks exposed at Kennecott Point (NW Graham Island) yielded fossiliferous beds near the Hettangian/Sinemurian boundary, although the correlation with the European standard zones is still controversial. On the Yakoun River, a newly found section spans the upper Lower Sinemurian to Lower Pliensbachian interval. A second new section of the Sandilands Formation at Kunga Island includes the entire Sinemurian and part of the Pliensbachian.

The contact between the Sandilands and Ghost Creek formations is diachronous, younging from northwest to southeast, so that during the Early Pliensbachian these formations were partly laterally equivalent. This calls into question the present practice of including the Sandilands Formation within the Kunga rather than the Maude Group. The coarsening-upwards sequence from the Ghost Creek into the Fannin Formation was initiated in the Early Pliensbachian with up to 60 m of sandstones and some breccias accumulating during the Late Pliensbachian in the Skidegate–Cumshewa Inlet area.

The Toarcian is represented in the Queen Charlotte Islands by the uppermost Fannin, the entire Whiteaves and the lowermost Phantom Creek formations. The Lower Toarcian contains species of *Dactylioceras*, *Taffertia*, *Tiltoniceras*, *Harpoceras*, *Leukadiella* and *Hildaites*. The Middle Toarcian is represented almost exclusively by *Phymatoceras* with some species of *Peronoceras* and *Haugia*. The Upper Toarcian contains species of *Grammoceras*, *Phymatoceras*, *Hammatoceras*, *Sphaercoeloceras*, *Phlyseogrammoceras* and *Pleydellia*. An hiatus of variable duration is present between the lower coquinoid member and the upper belemnite sandstone member of the Phantom Creek Formation. Stratigraphic and faunal evidence suggest that the belemnite sandstone member is Aalenian in age. The hiatus appears to be at its maximum in the southern part of the Phantom Creek exposure in the Charlottes and at its minimum to the north along the Yakoun River. A regression at the time of deposition of the coquinoid member and a topographic high to the south may account for the difference.

Electromagnetic studies, Lithoprobe Cordilleran transect

Analysis électromagnétiques dans le cadre du programme LITHOPROBE de la Cordillère

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As part of the LITHOPROBE Southern Cordilleran Transect investigations, a novel combination of Transient ElectroMagnetic (TEM) sounding and natural source MagnetoTelluric Profiling (MT) surveys were performed successfully from June to October, 1989. The EM profiles extend from the Valhalla Gneiss complex to the Coast Plutonic Complex and were designed as reconnaissance tools for studying the crustal and upper mantle properties across southern British Columbia. Striking changes in the data were observed as the survey crossed tectonic boundaries suggesting structural control of conductivity anomalies. The reconnaissance surveys have been augmented by detailed profiling over the seismic "bright spot" observed at approximately 15 km depth on line 15. Interpreting the shallow TEM survey will permit more reliable information from greater depths to be extracted from the MT data. These surveys also offer the exciting opportunity to improve further the interpretation of the lower crust's composition and state by incorporating structural constraints from seismic refraction and reflection surveys. Preliminary results of both surveys will be presented.

Structural and tectonic framework of the southern Coast Belt

Cadre structural et tectonique de la chaine côtière méridional

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Assembly of crustal fragments within the Coast Belt (CB) of southern British Columbia is linked to progressive shortening and transcurrent displacements along the continental margin since E. Cretaceous time.

Shortening began along the eastern flank of the CB with thin-skinned imbrication and SW-directed thrust faulting of volcanic arc and flanking oceanic sequences, and culminated in the L. Cretaceous with thick-skinned imbrication and westward overthrusting of the Cascade Metamorphic Core (CMC). NW-striking transcurrent faults of the Harrison Lake Shear Zone (HLSZ) are partly coeval with this thrust system, and suggest that strain may have been partitioned into components of both orthogonal shortening and orogen-parallel displacement during early Late Cretaceous evolution of the Coast Belt.

Late Tertiary fault structures are represented by a system of NE-striking dextral transcurrent faults and associated NW-striking high-angle reverse faults, and may record crustal shortening associated with eastward subduction of oceanic lithosphere in the Late Tertiary.

Nearshore heavy minerals, northern Juan de Fuca Strait

Minéraux lourds du domaine littoral, partie nord du Détroit de Juan de Fuca

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High concentrations of heavy minerals in nearshore sediments may form economic placer deposits. In the present study we hope to identify such deposits in an area that extends along the northern Strait of Juan de Fuca (Sooke Bay to San Juan Point), from the shoreline to the 100 m isobath. The approach is twofold: (1) the distribution of surficial sediments within this area is being mapped, and (2) the mineralogy and concentration of heavy mineral fractions found within these sediments is being examined. Onshore, the Lower to Middle Eocene Metchosin volcanics, Tertiary Sooke Gabbro and Jurassic to Cretaceous Leech River metaclastic and metavolcanic rocks may act as sources for a variety of heavy minerals.

Placer gold occurs along the southwestern side of Vancouver Island. These fluvial placers are associated with the Leech River, Sooke River, Muir Creek, San Juan River, and other coastal streams. More significant, however, are the occurrences of placer beach sands which were mined during the early part of this century. Near Ucluelet, gold-platinum-bearing black sands of Florencia Bay (formerly known as Wreck Bay) were mined between 1900 and 1935, producing over 1500 oz. gold. Within the study area, Sombrio River Point was the site of an extensive hydraulic-placer-mining enterprise in 1910, with five hydraulic and four creek mining leases and a twenty-man camp. The amount of gold recovered from this site was not recorded. The site is being re-examined.

Following stream and glacial erosion heavy minerals may become concentrated in nearshore sediments as a result of marine winnowing processes. The identification, in 1984, of titaniferous placer deposits on the inner continental shelf (under 20 to 120 m of water) in Queen Charlotte Sound and Hecate Strait, has revealed the potential for heavy mineral concentration along the British Columbia coast, as a result of such factors as marine conditions, glacial processes, and sea-level fluctuations.

The present study is based on 194 offshore samples collected during two cruises in 1988 and 1989, as well as archive samples from cruises in 1979 and 1981. Of these samples, 22 were vibracores (up to 2.5 m long), and the others were grab or dredge samples. In 1988 and 1989 extensive geophysical surveys were conducted in the area providing side-scan sonar images of the seafloor as well as subbottom profiling to determine sediment depth and character and to identify bedrock outcrops. To complement the offshore work, and to provide material to assess provenance of any distinct heavy mineral assemblages offshore, grab samples were collected along the coastline. Four major streams which drain this coastline, Sombrio River, Loss Creek, Jordan River and Muir Creek, were bulk-sampled above the high-tide mark for examination of the heavy mineral assemblage entering at that point.

Analytical work is in progress, but some preliminary results are of particular interest. High percentages of heavy minerals in offshore and beach sediments occur regularly, with a mean of 21% (by weight), and a range of 0.18% to 53%, for the sand size fraction. The highest values have been encountered on the beach and shallow shelf at Sandcut Beach, east of Jordan River. On this beach, a maximum heavy mineral concentration of 51% was measured, with values decreasing eastward. Two hundred metres offshore, in 5 m of water, a grab sample yielded 53% heavy minerals. Magnetite appears to represent only a small part of these percentages, about 1% of the raw sample by weight. In general, it rarely exceeds 15% of the heavy mineral fraction and generally averages less than 10%.

Mineralogical work has so far been restricted to X-ray diffraction performed on the sand size heavy mineral fraction of six samples. In general, the results show a relatively wide variety of heavy minerals which, at this point, may differ with either depth or location within the study area. Amphibole, epidote and augite are the major minerals in all samples, whereas magnetite and almandine garnet are present in lower proportions. Other minerals found in the samples were ilmenite, rutile, chlorite, kyanite, staurolite and enstatite. Microscopic mineral counts are planned for the heavy mineral fine sand fractions, and geochemical analyses for the silt and mud fractions.

Ultimately, it is hoped that an overall picture will emerge of heavy mineral assemblages in the nearshore sediments with any anomalous zones identified along with their possible provenance.

Sulphurets area, British Columbia: geology

Géologie de la région de Sulphurets, en C.-B.

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The Sulphurets area in the Coast Mountains of northwestern British Columbia contains a succession of Triassic and Jurassic sedimentary, volcanic and alkalic intrusive rocks that host coeval large, siliceous and sericitic, pyritic alteration zones with porphyry copper and molybdenum and a variety of coeval and probably also younger precious metal occurrences. Since 1960, the area has been explored for copper, molybdenum and precious metals with major exploration programs in the area by several companies over the past few years.

The area has been subjected to low-grade regional metamorphism and heterogeneous penetrative deformation and a complex post- and syn-mineral fault history. Extensive original copper- and molybdenum-bearing quartz vein stockworks have been deformed into flattened ptygmatic and dismembered vein structures and phyllic and argillic(?) alteration zones form large, penetratively deformed areas of quartz, sericite, pyrite schist with scattered buckle-folded quartz veins. In addition to the early synvolcanic and synintrusive deposits, some bonanza-grade Au-(Ag) bearing quartz (carbonate, K-feldspar and/or barite) vein systems were probably syntectonic and formed during later deformational and metamorphic events.

Earthquake disturbance in Vancouver Island lakes

Perturbations séismiques dans les lacs de l'Ile de Vancouver

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EG&G boomer (300 joule) seismic lines have been collected in Comox, Horne, and Nitinat lakes to document disturbance caused by the 1946 Vancouver Island earthquake (M7.2) and prehistoric seismic events. These seismic lines provide a baseline data set for documenting the effects of future earthquakes on these lakes.

Large slump and flow features in Comox Lake mark failures of the slopes of the Cruickshank and Puntledge River deltas during the 1946 earthquake. Sediments mobilized during this earthquake can be found up to 1.5 km from their source. Features which may be related to loading and liquefaction also have been noted in the records. Quaternary (largely late-glacial and postglacial) sediments in the deepest part of Comox Lake exceed 75 m in thickness.

Landslide deposits in Horne Lake are similar to those in Comox Lake, although they are not as extensive. Some of the deposits perhaps were emplaced during the 1946 earthquake, but others are covered by thick undisturbed sediments and clearly are much older. Quaternary sediments in Horne Lake are up to 60 m thick.

In contrast, the sediment fill in Nitinat Lake appears to be largely undisturbed. Although the seismic records are poor, with little internal structure, the bottom topography is smooth and gives no indication that the sediments below the surface are deformed. There are, however, small slumps at the base of some steep bedrock slopes. Quaternary sediments in Nitinat Lake are locally thicker than 150 m.

Seismic risk in the Fraser Delta

Risques de séismes dans la région du delta du Fraser

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These investigations, jointly supported by the Geological Survey of Canada and the Municipality of Richmond, form part of our study of the geoarchitecture, evolution and seismic risk assessment of the Fraser River delta. The focus during the previous reporting period (Finn et al., 1989) and this past summer has been on understanding the character of the subsurface in the vicinity of the seaward dyke of the Municipality. During this past summer an additional 7 sites in the southern part of the dyke were probed with the electric and seismic cone penetrometer to depths as great as 50 m. The accumulated data suggest that the sediments below the dyke become progressively less dense and potentially more prone to liquefaction towards the south.

Magnetic and gravity studies in the Insular Belt, B.C.

Etudes magnétiques et gravimétriques dans la Ceinture Insulaire, en C.-B.

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This study aims to elucidate the large-scale structure of the Canadian part of the Insular Belt by correlating potential-field anomalies with geologic structure and physiographic lineament patterns. The purpose is to constrain crustal movements in the Mesozoic and Cenozoic, thus helping reconstruct the tectonic history of the area and the evolution of its sedimentary basins.

Airphotos and topographic and bathymetric maps were used to identify conspicuous linear features. Aeromagnetic anomalies, which are controlled largely by the distribution of magnetite in supracrustal rocks, were enhanced by side-lighting the data (inclination 30°, declination 45 and 90°) to facilitate correlation with surface geology and physiography. This work suggests that:

1. The trend of the magnetic anomaly associated with the Rennell Sound structural feature is not unique. Similarly oriented magnetic anomalies occur in northern Graham Island and eastern and southern Queen Charlotte (QC) Sound.
2. The magnetic lineament spatially associated with the Sandspit Fault is discontinuous in northern Graham Island but reappears in the Dixon Entrance.
3. Both the Kitkatla and Principe–Laredo fault systems continue to the northwest, past the point of their intersection. The northern segment of the Principe–Laredo Fault is actually a part of the Kitkatla system.

To investigate large-scale and deep-seated structure, the magnetic data were upward continued to 5 km and 20 km. This procedure involved filtering the data numerically on the basis of anomaly wavelength. The NNW ("Cordilleran") trends were largely rejected by the filter, except at the QC Fault. The most prominent trends are NS, EW and NE. Onshore, mappable geologic structures with these orientations commonly appear to predate the NNW-oriented structures, suggesting that ancient but repeatedly reactivated structural fabrics may be observable. The NE-trending magnetic-gradient zone in southern Hecate Strait may be a fault bounding a domain of magnetic highs (plutons?) to the south. Lineaments related to the Kitkatla, Principe–Laredo and Sandspit fault systems and to the Rennell Sound structural feature are not apparent in upward-continued data. Localized magnetic highs over QC Islands may be related to plutonism.

Anomaly orientations observed in gravity data are similar to those in the magnetic data. One of the largest highs, which trends NNW, coincides spatially with QC Islands and continues into Dixon Entrance. It is bounded on the east by a gravity-gradient zone associated with the Sandspit fault system. Another positive anomaly, having a WNW trend, is conspicuous on northern Vancouver Island and Scott Islands. These gravity anomalies, which persist when the data are upward continued to 5 km and 20 km, are related to uplifted crustal blocks, which may be the largest, but not necessarily the oldest, structures.

The geophysical and physiographic lineaments in the study area are distributed widely, and their domains overlap. Geologic mapping in the surrounding land areas has so far revealed no evidence for significant translational or rotational displacements of large crustal blocks east of the QC Fault. The known fault systems appear to accommodate motions which were largely vertical. If large-scale lateral tectonic displacements did occur in the study area, the accommodating fault zones must be located beneath Hecate Strait or QC Sound. However, the results of our study provide little evidence to suppose that the structural style in the offshore parts of the Insular Belt is significantly different from that seen onshore. The data are compatible with a fault-block structural pattern for the entire area.

None of the structural or geophysical-anomaly fabrics observed can be related unambiguously to a rifting episode in the Cenozoic. It appears that lateral crustal movements which accompanied the formation of the Tertiary QC Basin were relatively small. The interpretation of the QC Basin as a pull-apart system bounded by strike-slip faults is also complicated by the results of our study. However, the lack of considerable tectonic mobilization of rocks in the study area during the late Mesozoic and Cenozoic favours the preservation of early Mesozoic petroleum source (?) rocks in the southern QC Sound and QC Strait, suggesting a possible exploration target offshore. The relative tectonic stability of the Insular Belt in the Mesozoic and Cenozoic, in spite of several orogenic pulses nearby, suggests that the area may be underlain by a rigid block of pre-Mesozoic continental or transitional crust.

A decision between conflicting models of basin formation and structural evolution of the study area cannot, of course, be made solely on the basis of the data presented. With sufficient imagination, many models can be reconciled with the observed potential-field patterns. However, our hypothesis has the significant advantage of avoiding conflict with geologic data onshore while remaining consistent with geophysical constraints.

Geology of the Fire Lake area, SE Coast Belt

Géologie de la région du Lac Fire, dans le sud-est de la chaine côtière

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The Fire Lake Group occurs as one of a scattered series of Early Cretaceous pendants in the southern Coast Belt. These formed in an island arc setting. Rocks are correlated to the Gambier Group, which contains significant volcanogenic massive sulphide mineralization, including the Britannia Cu-Zn ore body.

The Peninsula Formation occurs at the base of the group, and was deposited as a fining upwards sequence during volcanic quiescence. Facies progress upwards from fluvial, to beach, to marine shelf, and record a period of subsidence during normal faulting. The overlying Brokenback Hill Formation is a complex volcanic sequence dominated by subaqueous crystal tuff, autoclastic and epiclastic rocks of mostly intermediate composition, as well as welded pyroclastic rocks of likely subareal origin at the top of the formation. Thin to thickly bedded gypsum occurs locally within the Brokenback Hill Formation. Such beds contain disseminated pyrite, display syn-depositional brecciation textures, and are interpreted to represent submarine exhalative activity.

Epigenetic hydrothermal veining and mineralization in the pendant is closely linked to deformation and faulting. Three phases of deformation are recorded. The earliest is characterized by southeast-directed shallow angle thrusting, emplacing the Peninsula Formation onto the Brokenback Hill Formation. The age of this event is bracketed by the Early Cretaceous age of the Fire Lake Group, and Late Cretaceous second phase deformation. The thrusting records a period of orogen-parallel shortening, likely in conjunction with strike-slip faulting along the continental margin in the manner of transpressional terrains. The second deformation is marked by large amplitude non-cylindrical folds, in association with steep-angle southwest directed thrusting accommodating arc-normal shortening and uplift. The

Fire Creek thrust is important structure in localizing mesothermal Cu-Au deposits; mineralized veins occur along the fault, as well as in the footwall in association with bedding parallel shear related to folding. An extensive set of Tertiary dextral-normal dip-slip faults which strike northeast characterizes the latest deformation. In other areas, similar structures are known to localize high-level felsic plutons and epithermal mineralization.

Georgia Basin project

Projet du Basin Georgia

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Scope of project

The purpose of Georgia Basin project is to investigate hydrocarbon potential of those Upper Cretaceous to Neogene sedimentary rocks distributed around Georgia Strait in southwestern British Columbia that collectively constitute Georgia Basin. The project, funded in 1989 under Frontier Geoscience Program (FGP), will provide new information within four general categories: (1) controls of basin formation/deep basin geometry; (2) internal geology/basin evolution; (3) processes governing hydrocarbon generation, accumulation and preservation; (4) hazards and constraints to development. Work wholly or partly funded under FGP (categories in brackets) includes: (1) mapping by the writer in central and western Coast Mountains to decipher the poorly known regional structure of that part of the basin basement; (2) palynological studies (G.E. Rouse, U.B.C.) to date and correlate basin strata; (3) maturation studies on basin strata (R.M. Bustin, U.B.C.); (4) Fraser Delta studies (J.L. Luternauer, G.S.C.), neotectonics of southwestern B.C. (J.J. Clague, G.S.C.), and landslide and debris flow investigations (S.G. Evans and L.E. Jackson, G.S.C.). Regionally related G.S.C. projects, not funded by FGP, include regional mapping and economic mineral studies within the southern Coast Mountains (M. Journeay and G. Lynch, both G.S.C.) and marine gravity and shallow seismic reflection in Georgia Strait by T. Hamilton (G.S.C.).

Basin rocks and structures

Georgia Basin includes up to 4 km of Upper Cretaceous marine and nonmarine Nanaimo Group strata and locally over 6 km of nonmarine lower Tertiary Chuckanut, Burrard and Kitsilano formations. Proposed depositional settings for these strata are forearc and strike-slip basins, although the original basin configuration is unknown. These rocks were folded and faulted and are overlain unconformably by the southwesterly tilted Oligocene through Miocene Huntingdon Formation.

Regional structural controls

Georgia Basin lies on three different basements: Wrangellian terrane on Vancouver Island to the west, Cascade Mountains to the southeast, and Coast Mountains to the northeast. Basin evolution is controlled by events more clearly recorded in the better exposed and more varied rocks of the basements than in the poorly exposed basin itself. Based partly on LITHOPROBE deep seismic reflection data on Vancouver Island, and partly on regional mapping, the crustal structure of the basin region is hypothesized to be a stack of crustal thickness of (mainly) west-vergent thrust fault slices that formed in Cretaceous to Recent time in response to underthrusting of Pacific Ocean crust beneath western North America. Within the thrust stack, Wrangellian and central and western Coast Mountains rocks appear to act in a relatively rigid manner (in comparison with flanking rocks) and to be internally imbricated along steeply northeast-dipping reverse and (thrust?) faults. Central and western Coast Mountains and Wrangellian rocks are flanked to northeast and southwest by more deformed and locally more metamorphosed rocks. Structurally overlying rocks in the eastern Coast Mountains (east of Harrison Lake) are correlative with rocks in the Cascade Metamorphic Core and Northwest Cascades System. Rocks lying structurally below Wrangellia on Vancouver Island, (Leech River schist; Pacific Rim Terrane) are probably correlative with melanges in the westernmost Cascade foothills. Georgia Basin strata probably were deposited in a transpressional tectonic setting mainly upon the relatively rigid Coast Mountains–Wrangellian block, when to the east at least, there was disruption of the thrust stack by (1) dextral strike-slip faults in Late Cretaceous–Eocene time (70?–40 Ma), and (2) by northeast-trending faults in Neogene time (25–18 Ma). Georgia Basin strata are preserved in a Neogene to Recent structural depression that extends from Alaska to Oregon, which lies approximately 150 km east of the present plate margin.

Geology, geochronology, and placer gold sources, Klondike

Klondike géologie, géochronologie, et sources des ors alluvionnaires

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Regional and detailed mapping and U-Pb geochronology of the Klondike District provide new information on the geology and mineral potential of the Klondike District. The area is underlain by a sequence of thrust panels of regional extent. A continuously mappable sequence of interlayered metasedimentary and metavolcanic rocks were intruded by a variety of deformed metaplutonic rocks within two of these thrust sheets. Layering in the metasediments and metavolcanics is considered to be at least in part transposed stratigraphy.

U-Pb age determinations indicate that the uppermost thrust panel (Assemblage I), which underlies most of the Klondike District, consists largely of metamorphosed felsic plutonic, subvolcanic, and tuffaceous rocks of mid-Permian age. Beneath Assemblage I is a second thrust panel (Assemblage II), also of large areal extent, consisting of metasedimentary and mafic and felsic metavolcanic rocks, intruded by a large body of latest Devonian–Early Mississippian granitic augen orthogneiss.

The earliest stage of deformation and metamorphism (F1) produced the pervasive recrystallization fabric characteristic of metamorphic bedrock in the terrane, and occurred between mid-Permian and Late Triassic time. Thrust faulting, presumed to be north- or northeast-directed, post-dates Late Triassic, but is pre-mid-Cretaceous in age. The second phase of deformation (F2) was either synchronous with or later than thrust faulting. Metamorphic cooling ages for hornblende and muscovite range from 156–143 Ma. Monazite ages in Devonian–Mississippian augen orthogneiss indicate that at least local metamorphism and/or deformation lasted until Early Cretaceous time.

At least four distinct styles of lode mineralization which may have contributed to placer gold deposits have been recognized in the Klondike District. The best studied and probably most important of these consists of discordant, low-sulphide, mesothermal quartz veins, which occur throughout the Klondike, and are known to be at least locally gold-bearing. Other possible sources include syngenetic pyrite (barite, base metals) deposits and related oxide-facies iron formation in mid-Permian felsic metatuffs (e.g. LONE STAR, BRONSON), epithermal mineralization in mid-Eocene felsic tuffs and subvolcanic intrusions (e.g. GERMAINE CREEK), and low-temperature epithermal alteration zones of Quaternary age which affect both bedrock and overlying White Channel Gravel deposits. The complex bedrock and placer geology of the Klondike, together with the clear evidence for a multiplicity of styles of lode mineralization, has been an inevitable source of controversy regarding the origin of the placer gold.

Canoe River (83D): a new 1:250 000 geological compilation

Nouvelle compilation de la géologie de la région de Canoe River (83D), l'echelle de 1:250 000

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Canoe River map area (83D) lies in eastern British Columbia and western Alberta between 52°N and 53°N. The map area straddles the southern Rocky Mountain Trench (SRMT) near the town of Valemount, B.C. and includes parts of the southern Cariboo Mountains, northern Monashee Mountains, and the Park and Selwyn Ranges of the western Rocky Mountains.

Canoe River map area comprises parts of the Rocky Mountain fold and thrust and Omineca belts of the Canadian Cordillera. In this area, the boundary between the two belts has traditionally been placed in the SRMT; however, the occurrence in the Bearfoot thrust sheet east of the SRMT of Early Proterozoic orthogneissic basement and para-autochthonous metasedimentary rocks with structural histories similar to Omineca Belt rocks warrants relocation of part of the boundary to the Bearfoot fault (McDonough and Simony, 1989). The SRMT at this latitude is occupied by faults with early dextral strike-slip (around 50 km displacement) and later down-to-the-west normal dip slip (Campbell, 1968, 1972; McDonough and Simony, 1988; Murphy, 1990a).

The Rocky Mountain fold and thrust belt in Canoe River map area is composed primarily of faulted, folded, and weakly metamorphosed strata ranging in age from Late Proterozoic to Triassic (Miette Group of the Windermere Supergroup; Gog Group; Snake Indian, Eldon, Pika, Arctomys, Lynx, Survey Peak formations; Fairholme Group; Sassenach, Palliser, and Banff formations; and Rundle and Spray River groups; Campbell, 1968, 1972; Craw, 1978; Mountjoy and Price, 1985, 1989). Originally deposited at or near the western margin of North America, these strata were shortened intermittently during the late Jurassic to Paleocene interval by displacement on an imbricate and interlocking array of mainly NE-vergent thrust faults (Price and Mountjoy, 1970). The structurally highest thrusts in the western Main Ranges are synmetamorphic and may correlate with Early Cretaceous synmetamorphic NE-vergent folds and thrust of the Omineca Belt (Leonard, 1985; Currie, 1988; McDonough and Simony, 1988; Mountjoy and Grasby, 1990; Dechesne, 1990; Murphy, 1990b).

The Omineca Belt at this latitude consists primarily of multiply deformed and variably metamorphosed rocks of the Late Proterozoic Windermere Supergroup (lower clastic and semipelite-amphibolite units of the Horsethief Creek Group and Kaza and Cariboo groups) and Proterozoic gneiss considered to be basement to the North American continental margin sequence (Malton, Yellowjacket, Bulldog, Hugh Allan, Mt. Blackman gneisses and unnamed gneiss in the Cariboo Mts.; Campbell, 1968; Simony *et al.*, 1980; Morrison, 1982; Pell, 1984; Currie, 1988; Walker and Simony, 1989; Murphy, 1990b; Sevigny and Simony, 1989). The basement/cover contact is conformable in the Cariboo Mountains, but is the locus of shear zones in the northern Monashee and Rocky mountains (Simony, *et al.*, 1980; Oke, 1982; Morrison, 1982; McDonough and Simony, 1988; Murphy, 1990b). Regardless of the nature of the basement/cover contact, the overlying stratigraphy can be correlated between ranges, suggesting that shearing is concentrated along a basal unconformity. Neither the age nor magnitude of displacement along the contact are known.

In addition to the Early Cretaceous NE-vergent synmetamorphic phase of deformation shared with rocks of the Rocky Mountain belt, rocks of the Omineca Belt also exhibit older polyphase deformation, metamorphism, and plutonism and younger extensional faulting. The early history includes Middle Jurassic SW-vergent folding, thrusting, regional metamorphism, and plutonism, early Late Triassic and Devono–Mississippian plutonism, and pre-Middle Jurassic NE-vergent deformation (Campbell, 1968, 1973; Pigage, 1977; Brown *et al.*, 1986; Gerasimoff, 1988; Murphy, 1987a, b, 1989, unpublished data; Leonard, 1985; Charland, 1989). Extension leading to unroofing and exposure of deep crustal levels occurred during the Eocene, accommodated by structures such as the North Thompson–Albreda fault, late normal faults in the SRMT, and an array of oblique dextral-normal faults in the western Cariboo Mountains and Quesnel Highlands (Sevigny *et al.*, 1989; Murphy, 1987a; Struik, 1985).

Juxtaposition of the rocks of Rocky Mountain and Omineca belts probably occurred during the Early Cretaceous by displacement on NE-vergent thrusts. The detailed geometry of that deformation at deep structural levels in both belts is controversial and the focus of current research.

An open file version of this map will be released in 1990.

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Office for Technology Transfer

Bureau de Transfert de la Technologie

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The Office for Technology Transfer was created in the GSC to be a unit responsible for the commercial exploitation of technologies developed in the Survey in the course of the research by its scientists. The office will assist in arranging licensing agreements with Canadian companies or participating in the patenting process performed by Canadian Patents and Development Limited. In addition to providing a service to the GSC scientists, the office also serves as a central point for industry to access various government assistance program in EMR and other government departments. Examples are the Industrial Assistance Program (IRAP) of NRC and the Technology Inflow Program of External Affairs Canada. The office also serves as the administrative unit for collaborative research agreements between industry, other levels of government or the universities.

Sedimentology of the lower Bowser Lake Group, B.C.

Sédimentologie de la partie inférieur du Group de Bowser Lake, en C.-B.

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Preliminary investigation of the lower part of the Bowser Lake Group in Spatsizi and eastern Telegraph map areas, indicates a continuum of lithofacies ranging from relatively deep water submarine fans, prodelta-slope with many incised submarine gullies and canyons, fan deltas and interfan shelves. Alluvial equivalents to this marine succession occur but have been examined only briefly. The succession, having a composite thickness of at least 2000 m, ranges in age from late Bathonian or Callovian to possible Oxfordian. The transition from the fan delta-shelf facies assemblages to the prodelta-slope assemblage appears to pass through a depositional hinge, which in some places appears conformable (but abrupt), and in other places discordant; the possibility of a regional lacuna cannot be dismissed. This transition may prove to be a useful stratigraphic marker.

The submarine gullies and canyons, some more than 200 metres thick and fed by a system of fan deltas and interfan shelves, permitted coarse sediment to bypass the slope region and feed coarse grained submarine fans. Candidates for proximal and middle fan facies have been identified. Preliminary paleocurrent analysis indicates turbidity current transport towards the southwest. Deposition in the submarine fans was dominated by a variety of sediment gravity flow mechanisms; such mechanisms were also active on the outer, seaward portions of fan deltas. Abrupt vertical and lateral facies changes indicate a dynamic depositional realm wherein sediment supply rates and transport routes changed frequently, probably in response to active tectonism in the sediment source terrain, and rapid basin subsidence.

Wernecke Mountains geology: SE Nash Creek map area, Yukon

Géologie des Monts Wernecke, dans le sud-est de la région de Nash Creek, au Yukon

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The DINA Open File map of bedrock geology for NTS 106D/7 (east half) and 106D/8 reveals at least four panels containing Middle Proterozoic Gillespie Lake dolostone (up to 1.2 km thick) sandwiched between less competent older Quartet and overlying shaly rocks. The surface geometry of these panels imply that the thrust faults bounding them flatten southwards within 2 km of surface. The overlapping early Paleozoic dolostone contains isoclinal keels that indicate regional detachment near the base of the Mackenzie Platform. Together these structures demonstrate the long-suspected thin-skinned nature of the Cordilleran fold-thrust belt across central Yukon.

Zinc-lead-silver veins at BLENDE property occupy the hanging-wall panel of Gillespie Lake dolostone; although mineralization predated deposition of the overlying shaly unit, it appears to be concentrated in the core of a gentle anticline resulting from late Mesozoic contraction. Other stratiform occurrences may occur in the upper Gillespie Lake Group, which is widely exposed in the Wernecke Mountains, and similar structures are common in the mapped area. Base metal mineralization is also present where Gillespie Lake dolostone is disconformably overlain by early Paleozoic limestone (KATHLEEN) and with barite along faulted sandstone and Paleozoic dolostone (ZAP). These showings form a broad southeast-trending belt extending beyond the mapped area, and parallel to the edge of Proterozoic shelf strata.

The southern Ogilvie and Wernecke mountains comprise erosional inliers of thrust-thickened Middle and Late Proterozoic shelf strata, surrounded by early Paleozoic carbonate. The oldest rocks, the Quartet and Gillespie Lake groups, show remarkably consistent rock types over 350 km westward from the mapped area. In contrast, the overlying siliciclastic unit, informally called the Pinguicula group (northeast of the mapped area) and Fifteenmile group (in the Ogilvie Mountains) shows regional facies variations. Up to 4 km of shallow water dolostone are present further north and west, while the mapped area is predominantly shale, and lacks the overlying conglomerate and volcanic unit (Windermere-equivalent rocks). The southern Wernecke Mountains were in deeper water and were possibly 'off-shelf' between 1300 and 600 Ma. The Pinguicula facies relations testify to the changeable nature of the platform margin of ancient North America.

Queen Charlotte Basin bathymetry/gravity map series

Série de cartes bathymétriques et gravimétriques du Bassin de la Reine-Charlotte

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A detailed bathymetric-topographic map of the Queen Charlotte Basin and adjacent deep seafloor has been compiled from data provided by the Canadian Hydrographic Service (D.F.O.), the Geological Survey of Canada and the Surveys and Mapping Branch (E.M.R.).

The shallower basin and continental shelf data are comprised of more than 70 original field sheets from surveys dating as far back as 1911. Survey grids ranged from a few hundred metres for the small field sheets to 1500 metres for the largest. Soundings were converted from fathoms to metres and recontoured at 5 metre intervals.

Continental slope and deep-ocean data (500 m depths) were compiled from recent Natural Resource Charting field sheets (7 km survey grid) and contoured at 50 m intervals. Data for nearshore and inland waters were recontoured from published C.H.S. charts. Land elevations were recontoured at 50 m intervals from 1:50,000 NTS maps.

Intermediate compilations were reduced to a scale of 1:150,000, then matched and redrawn on a common base. For clarity, the contours have been "illuminated" from a westerly direction.

Gravity anomaly overlay:

The gravity data shown on this map have been retrieved from the National Gravity Data Base, Ottawa. This publicly accessible data base consists of approximately 600,000 measurements throughout Canada and the adjacent offshore.

Regional mapping of the gravity field began in the late 1940s and is still ongoing with areas in northern B.C. and the Yukon Territory yet to be completed. West coast marine surveys commenced in 1972 and by 1985 had systematically mapped the offshore with bathymetry, gravity and magnetic coverage out to 200 nautical miles (Canadian Economic Zone). Station spacing on land has typically been between 6 to 13 km while offshore it is more or less continuous along ship tracklines (due to space requirements only 5 minute data have been plotted).

Gravity data on land is presented in the form of Bouguer anomalies, while offshore, Free Air anomalies are displayed. The data were gridded at 2 kilometres and contoured at 5 mGal intervals.

From east to west the gravity field generally rises from a -100 mGal low over the mainland coast mountains to a linear high of up to 80 mGal along the western edge of the Queen Charlotte archipelago. This high closely parallels a pronounced offshore gravity low, below -90 mGal in places. These paired anomalies produce an exceptionally steep gradient which overlies the Queen Charlotte Fault, the boundary between the Pacific and North America plates.

These maps, plus a proposed bathymetry-magnetic map will soon be available for distribution at selected GSC outlets.

Regional gravity survey, Williston Lake area, B.C.

Levée gravimétrique de la région du Lac Williston, dans le nord de la C.-B.

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About 840 new gravity measurements were made by the GSC in northern B.C. during the summer of 1989. The survey area lies between 55 and 58°N and 122 to 126°W. The area extends from the western approaches of the Alberta Basin across the Foreland and Omineca belts to the eastern side of the Bowser Basin. Gravity stations are spaced at about 10 km intervals and were positioned using a helicopter-mounted Litton inertial navigation system operated by the Geodetic Survey of Canada.

The gravity values are shown as Bouguer anomalies that have been terrain corrected with GSC software including a one kilometre digital terrain file of the Canadian Cordillera. The map scale is 1:1 000 000 with a 5 mGal contour interval.

The Bouguer anomaly field shows major northwesterly trends parallel to regional tectonic strike. Near-surface structural and lithological trends are also evident. For example, felsic bodies are clearly defined as discrete gravity lows.

The Ilgachuz Range—a Late Neogene shield volcano

Le chaîne Ilgachuz—un volcan-bouclier du Néogene Tardif

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The Ilgachuz Range is one of three large shield volcanoes in the Anahim Volcanic Belt of central British Columbia. It is nearly circular in plan and about 25 km in diameter. The gently sloping concave surface of the outer shield rises from the nearly flat Chilcotin Plateau to a cluster of central peaks where deeply dissected radial valleys expose remnants of a central dome and caldera complex.

Based on mapping at a scale of 1:25,000, the volcanic pile has been subdivided into 16 map units representing 6 major episodes of activity. Fifteen K-Ar dates range from 6.1 to 4.0 Ma and chemical analyses indicate a compositional range from oversaturated peralkaline rocks to basanite.

The initial activity produced a broad, low-profile shield of comenditic trachyte flows that formerly extended far beyond the present limits of the pile. This was followed by the eruption of multiple, steep-sided domes of alkali rhyolite from a central vent. This massive effusion of rhyolite was followed by the collapse and infilling of a central caldera and finally by two episodes of basaltic flank eruptions.

The Ilgachuz Range lies in the west-central part of the Nechako Basin where potential hydrocarbon-bearing strata are thought to underlie much of the extensive lava and glacial cover. The discovery of crystalline basement rocks beneath the Ilgachuz lavas suggests that the volcano may be underlain by a structurally high Tertiary gneiss dome rather than by Jurassic or younger sediments. Further work is planned to search for additional subvolcanic outcrops in canyons around the periphery of the range.

The geology and petrology of the rocks of the Ilgachuz Range are being compiled as part of a Geological Survey of Canada Bulletin dealing with the regional geology of two 1:50,000 map sheets (Christiansen Creek, 93C/14 and Carnlick Creek, 93C/11).

LITHOPROBE seismic reflection profiling, southern Cordillera

Profil de sismique réflexion dans le sud de la Cordillère, programme LITHOPROBE

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LITHOPROBE is a multidisciplinary project investigating the lithosphere beneath Canada. It has recently completed a major seismic reflection survey in southwestern British Columbia.

The survey involved the collection of 950 km of 18s Vibroseis data supplemented by two special projects. Near Powell River data were shot to allow imaging of structures as deep as 85 km, and on the west side of Arrow Lake, south of the Monashee Mountains, data were recorded using an areal configuration designed to image structures in three dimensions. Highlights of this survey include a spectacular series of reflections from the south end of the Monashees that penetrate almost the entire thickness of the crust, and dipping events seen at

15s two way travel time recorded near the coast, perhaps these are related to the top of the subducting Juan de Fuca plate. At one location in the Coast Plutonic Complex, a seismic "bright spot" is observed; this event may originate at the top of a magma chamber associated with the recent volcanism observed in the region. Preliminary results from a line crossing the Fraser River seem to indicate that reflectors are continuous beneath the Fraser River fault at depths as shallow as 12 km. Another notable result is the continuous, flat moho seen throughout the eastern part of the transect at a depth of approximately 11s.

We shall present seismic section showing the most important features of both these datasets.

Golden trees map fault

L'or dans les arbres delimite un faille

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Most of the western part of the McLeod Lake map area is covered in Quaternary glacial drift, till, lacustrine and fluvial deposits. Those deposits hide a Tertiary and older bedrock that is seen in surrounding areas to be broken by numerous Tertiary faults. In some places those Tertiary faults are the conduits for epithermal mineralization; for example the nearby Pinchi Fault and its associated mercury deposits. Near Weedon Lake, there should be a fault between the sillimanite-grade metasediments and granitoids of the Wolverine Metamorphic Complex and the chlorite-grade basalt and sedimentary rocks of the Takla Group. That fault may be a shallowly dipping extensional fault such as those described from the borders of metamorphic core complexes of the southern Cordillera—faults that are commonly associated with warm water hydrothermally deposited mineralization.

During late May of 1988 and 1989, 130 white and black spruce trees straddling the suspected location of the Weedon Lake Fault, between Weedon and Joanne lakes, were sampled and later analyzed for a range of metals and minor elements. Sample lines followed forestry roads that were approximately perpendicular to the fault zone, and parallel lines between the roads. Samples were taken at kilometre intervals away from the fault zone and at half kilometre intervals within 2 km either side of the zone. Samples consisted of 3 to 8 year-old live twig growth, both wood and needles, and weighed between 100 and 400 grams. They came from the base of trees of approximately the same size, although some variation was forced on the survey because of the sample spacing, the diversity in growth, and the logged areas. Samples were collected in cloth bags and shipped in cardboard boxes to Ottawa for sample preparation.

The analyses were done through a contract laboratory by neutron activation on .6 to 1.2 gr of the woody component. Elements analyzed included: Au, Ag, As, Ba, Br, Ca, Co, Cr, Cs, Fe, Hf, Hg, Ir, K, Mo, Na, Ni, Rb, Sb, Sc, Se, Sr, Ta, Th, U, W, Zn, La, Ce, Nd, Sm, Eu, Tb, Yb, and Lu. The Hg and Ir were undetectable with the procedure.

The fault zone may be located by the concentrations of Fe, Co, and Cr. These elements are more abundant in mafic rocks such as those of the Takla Group, and less abundant in felsic rocks such as those of the Wolverine Metamorphic Complex. The higher concentrations of the elements are found to the southeast in the area thought to be underlain by Takla Group basalt. The transition zone between higher and lower concentrations of Fe, Co, and Cr is along the anticipated fault between the Takla Group and Wolverine Metamorphic Complex. Concentrations of Au and Mo appear to be slightly higher than that anticipated for spruce trees (C. Dunn, pers. comm., 1989), although the highest concentrations are not localized.

Finding faults with gravity, central British Columbia

Détection de failles avec l'aide de la méthode gravimétrique, dans le centre de la C.-B.

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One to 4 km spaced gravity measurements were made across the Pinchi, McLeod Lake and Weedon faults in central British Columbia. Combined with the regional gravity field of the region determined last year, we have calculated the dip on these faults to depths of 5 km. The Pinchi and McLeod Lake faults have large density contrasts across them, and reasonable interpretations of their dips can be made. Across two traverses, one along the Yellowhead (16) highway and the other east of Fort St. James the Pinchi Fault dips moderately steeply to the east, placing Cache Creek Terrane under eastern Quesnel Terrane. At McLeod Lake, the McLeod Lake Fault dips steeply to the west, placing basalt of Slide Mountain Terrane over limestone and sandstone of the Rocky Mountain assemblage. The large density contrast between the basalt and the limestone make the dip relationship at this site unequivocal. A traverse across the McLeod Lake Fault to the south along the Fraser River showed much less of a density contrast. There the fault separates metasediments of the Wolverine Metamorphic Complex from limestone and sandstone of the Rocky Mountain assemblage. The gravity gradient may indicate that the fault dips steeply to the west. The Weedon Fault separates high-grade metasediment and granite of the Wolverine Complex from low-grade basalt of Quesnel Terrane. The regional and more detailed gravity surveys revealed weak density gradients across the fault, which could be due to a thin cover of Quesnel Terrane basalt on the lower density Wolverine Complex rocks. Such a configuration could be satisfied with either a southeast dipping shallow Weedon Fault or a thrust fault with Quesnel Terrane basalt over calcareous and clastic rocks. About 100 km to the south, the Quesnel Terrane is thrust over garnet-grade metasedimentary rocks.

Geology, Sewell Inlet–Tasu Sound area, Q.C.I.

Géologie de la région de Sewell Inlet–Détroit de Tasu, dans les Iles de la Reine-Charlotte

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A regional mapping project began in the Sewell Inlet-Tasu Sound region of the Queen Charlotte Islands in 1989. Most lithologic units mapped in the Queen Charlotte Islands have been recognized within the map area; notable exceptions are the Maude Group and the Longarm Formation. Dominant map scale features are north trending, steeply dipping faults, in contrast to the strongly developed northwest trending structural fabric found elsewhere. Multiple extensional and compressional phases of deformation are indicated. Areas of most intense deformation are restricted to discrete zones and are coincident with most abundant dyke intrusion. The pre-Yakoun Group unconformity is well exposed within the study area, and ranges from a disconformity to a pronounced angular unconformity. The Jurassic Yakoun lithologies are diverse, including matrix and clast supported conglomerates, tuffs, breccias, and occasionally fossiliferous sandstones and siltstones. Cretaceous Haida and Skidegate formations appear to be laterally equivalent; the transitional contact between them may reflect basin morphology during Cretaceous time. The Honna Formation is locally interbedded with Skidegate Formation turbidites and could represent channelized conglomerates and overbank levee deposits.

Both the Selwyn Inlet and Tasu Sounds dyke swarms are abundant within the area, and are likely related to both Jurassic igneous activity and Tertiary volcanism. Tertiary rocks within the study area include volcanic debris flows, banded rhyolites, and welded tuffs, and may have been proximal to an extrusive centre.

Triassic–Jurassic boundary at Kennecott Point

Limites entre le Triassique et le Jurassique à la Pointe Kennecott

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A minor discordance in beds of the Sandilands Formation at Kennecott Point, Queen Charlotte Islands, possibly indicates the Triassic–Jurassic boundary. Paleontological evidence based on ammonites, conodonts, and radiolarians support this possibility but does not prove it unequivocally. The "unconformity" has well-bedded siltstone above (Jurassic?) and coarsely bedded sandstone (Triassic?) with very gently undulating beds below. Exotic blocks of sandy limestone are embedded in the highest beds of the Triassic sands. Faunas from the beds above the unconformity are clearly Jurassic (Lower? Hettangian) or most probably so and the beds below are clearly Triassic; the ammonites, radiolarians and the conodonts indicate the age is Crickmayi zone, the highest ammonite zone of the Triassic. Although the boundary appears reasonably constrained, there is at least a 20 m zone below the unconformity from which no faunas were recovered. The exact position of the contact must therefore be determined by further work.

Regional aeromagnetic surveys in B.C.

Levées aéromagnétiques régionaux en C.-B.

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The GSC conducts regional aeromagnetic surveys throughout Canada. The parameters of these surveys are governed by three factors: target, logistics and cost. In British Columbia the topography and geology engender a particular set of constraints and these are examined with reference to recent surveys.

Surveys targeted at shallow source rocks differ significantly from those aimed at investigating greater depths. Typically, shallow source surveys are flown closer to the land surface and with a tighter line spacing. In all cases, the flight line direction is perpendicular to the predominant strike of the rock units.

Logistically, factors such as terrain and accessibility to the survey area are important. Mountainous terrain can necessitate the use of a helicopter if the survey is to be drape flown, i.e. flown at a mean terrain clearance (MTC). Safety factors preclude the use of fixed wing aircraft for such work. Aircraft, both fixed wing and helicopter, require extensive maintenance facilities within reasonable flying range of the survey area.

Economics often play the deciding role in determining which consideration is traded off against another. The closer the line spacing, the farther the study area from airport facilities, the more expensive is the survey. Cost also increases in the more mountainous terrain where either sophisticated navigational aids are required or even a helicopter. Both options involve supplementary data compilation work. As the role of the GSC is to provide regional data which will encourage further exploration by the private sector, a tradeoff must be made between detail and extent of coverage.

In British Columbia the rugged terrain is usually the determining factor in the layout of an aeromagnetic survey. Where the topographic gradients are too steep for MTC flying, areas are flown at a constant barometric elevation. Whether drape or barometrically flown, the results of a survey can be post-processed to reflect the other technique.

Sander Geophysics flew several areas in B.C. during 1987/88. These surveys combined both constant barometric and MTC flying to accommodate the variation in topography. Two of the 1:50 000 map sheets have been post-processed to transform the barometrically flown data to reflect MTC results. The computer process is called draping.

Draping involves the continuation of the field measured at constant barometric altitude onto a surface with a specified MTC. First, an equivalent source distribution is computed on the terrain surface using the radar altimeter data. The effect of this distribution of magnetic sources matches the observed aeromagnetic field to a few nanoTeslas. The total field due to the sources is then calculated on a surface with a specified MTC. This then constitutes the draped field.

Maps have been prepared to compare the barometric and MTC results and a correlation to the known geology has been done.

MARG volcanogenic massive sulphide deposit, Selwyn Basin

Gîtes MARG de sulfures massifs volcanogéniques dans le Bassin de Selwyn

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The MARG deposit is 42 km northeast of Keno City, Yukon (64°01'N, 134°28'W; NTS 106D/1). Indicated and inferred reserves of 1,922,000 tonnes grading 1.96% Cu, 5.19% Zn, 2.72% Pb, 1.97 opt Ag, and 0.03 opt Au make the MARG the largest volcanogenic massive sulphide deposit discovered to date in the Yukon. Drilling in 1989 intersected extensions of the mineralized zones beyond the reserve blocks.

Regional setting

In the southern Patterson Range, south- to southeast-dipping strata mapped by Green as the Keno Hill Quartzite are imbricated along northerly directed thrust faults. Three main thrust sheets, here referred to as the northern, central, and southern panels have been recognized between the Robert Service Thrust to the south and the Tombstone Thrust(?) to the north. Each thrust panel contains quartzite, black siliceous phyllite, quartz grit, and felsic volcanic rocks, with the MARG massive sulphide deposit in the central panel. The stratigraphic order in each panel is disrupted by internal deformation.

Regional stratigraphy

The Hyland Group (PCh) is composed of massive, grey weathering calcareous and noncalcareous quartz (and minor feldspar) grit, phyllite, chloritic phyllite, and limestone. Similar buff weathering siliceous quartz grit 200–300 m thick form the lowest parts of the central and southern panels. The Hyland Group is overlain by recessive black siliceous phyllite interbedded with quartzite, quartz-muscovite and quartz-chlorite phyllite (DMvs). An infold or thrust repetition of these rocks within quartzite (Mq) of the central panel hosts the MARG deposit. These rocks are likely of volcanic origin, perhaps tuffs. Igneous zircons in quartz muscovite phyllite at the MARG deposit have yielded an Early Mississippian radiometric age (J. Mortensen, pers. comm.).

Massive, resistant, dark grey, weathering vitreous quartzite (Mq) is the dominant rock type in the thrust belt and forms structural units up to 70 m thick. Dark grey phyllite and siliceous siltstone (DMps) forms a homogeneous sequence about 500 m thick at the top of the northern panel where it overlies a thick, massive quartzite. Hornblende diorite forms tectonically dismembered lenses up to 200 m thick and 3 km long.

Regional structure

Two phases of penetrative deformation are recognized. The first phase (D1) is characterized by rodding and an intense mineral lineation (L1), mesoscopic scale recumbent isoclinal folds (F1), and a strong axial planar foliation (S1). The pervasive, moderately south to southeast dipping foliation is the dominant fabric in phyllite and volcanic rocks. The Robert Service and other large thrusts roughly parallel S1 and the orientation of L1 mineral lineations is consistent with northwesterly movement on the thrusts. The second phase (D2) is a steeply dipping, spaced cleavage (S2) that strikes about 160 and dips steeply northeast, accompanied by upright, tight to isoclinal small scale folds (F2).

Lithotypes in the MARG sequence

The MARG deposit occurs in a 4 km long east-trending fault repetition or recumbent infold of Unit DMvs within the central thrust panel. This "MARG sequence" is overlain by massive quartzite and is in fault contact with similar underlying quartzite. The MARG deposit stratigraphically overlies a 30 m sequence of metavolcanic schists and is overlain by 200 m of carbonaceous siliceous rock. Metavolcanic schists all contain minor quartz phenocrysts and include quartz sericite, sericite-carbonate-quartz-pyrite-, and chlorite-bearing schists. Quartz-sericite schist is interbedded with carbonaceous metachert above the ore horizon. Sericite-carbonate-quartz-pyrite schist is the major lithology below the ore horizon, and carbonate-quartz bands that compose up to 70% of the schist are interpreted as syn-ore footwall veinlets. Chlorite-bearing schists occur below the sulphide horizon lateral to sericite-carbonate-quartz schist.

Black sooty siliceous pyritic metachert is interbedded with the sulphide horizon, and occurs as a thick sequence above the sulphide body. Black phyllite over 150 m thick occurs above the sulphide horizon and is overlain by quartzite.

Massive sulphide deposit

The MARG deposit is a folded sheet-like body or series of bodies over a kilometre long. Most drilling has concentrated on the eastern portion where the sulphide body appears to be deformed into an overturned isoclinal fold that verges to the northeast and plunges moderately southeast. In Section 2510, the upper limb of the sulphide body is a single horizon 2 to 7 m thick, while on the lower limb, the sulphide body comprises up to seven sulphide layers 30 cm to 2 m thick interbedded with carbonaceous metachert and quartz-sericite schists. The sulphide body consists of fine-grained massive to semi-massive pyrite intergrown with quartz, ferroan carbonate, lesser sphalerite, chalcopyrite, and galena, and minor tetrahedrite and arsenopyrite. The sulphides are massive to banded with a granulated submylonitic texture in thin section. Augen (to 3 cm) of ferroan carbonate, quartz and sulphides locally occur within banded sulphide rock.

In the eastern part of the MARG deposit, the sulphide body can be divided into three facies based on proportions of the dominant minerals pyrite, quartz and ferroan carbonate. A central core of carbonate-rich semi-massive pyrite (pyrite-carbonate facies) is surrounded by a transitional envelope of semi-massive quartz-rich pyrite (pyrite-quartz facies) and distal massive pyrite (pyrite facies). In addition, the sulphide body is zoned with respect to metal ratios. Elevated ratios of Cu/Pb, Zn/Pb, Ag/Pb and Cu/(Cu+ Zn+ Pb) coincide with the extent of the pyrite-carbonate and pyrite-quartz facies. This enrichment decreases outwards through pyrite-quartz and pyrite facies.

Sericite-carbonate-quartz-pyrite and carbonate-quartz-sericite-pyrite schists occur in an elongate zone underlying much of the pyrite-carbonate facies of the sulphide horizon. These carbonate-bearing schists are flanked by pyritic quartz-sericite schists that underlie the pyrite-quartz facies and proximal part of the pyrite facies. Chlorite-quartz schists occur downdip on the upper fold limb underlying pyrite facies.

Depositional setting of massive sulphide

A volcanic origin of the quartz-sericite-chlorite-rich schists in the MARG sequence is supported by (1) an early Mississippian U-Pb age for zircons, (2) the presence of quartz phenocrysts, and (3) the copper-rich nature of the sulphide body, a characteristic of volcanogenic but not sedimented-hosted sulphide deposits. The sulphide body overlies a sequence of schists, and is overlain by black phyllite and carbonaceous pyritic metachert suggesting that sulphide deposition coincided with waning of volcanic activity within an anoxic deep marine basin.

Exploration significance

In eastern and central Yukon, Mississippian alkaline intermediate to felsic volcanic rocks with associated Cu-Zn-Pb sulphide deposits were only known in the Pelly Mountains west of the Tintina fault prior to the discovery of the MARG deposit. This quartzite, carbonaceous siliceous shale and felsic volcanic assemblage represents a new exploration target. Equivalent strata have been traced across central Yukon intermittently from Dawson to Nahanni map areas. Association of the sulphide-bearing schists with well exposed quartzite should serve as a useful exploration guide.

The MARG deposit is a member of a family of Devonian and Mississippian sediment-hosted and volcanic-hosted exhalative sulphide and barite deposits that occur within the Cordillera from Alaska to Mexico. Volcanogenic massive sulphide deposits include the AMBLER, ALASKA, CLEAR LAKE, and MM (Yukon), and SAMATOSUM, SILVER, and HOMESTAKE (B.C.). Studies of the ARCTIC, MM, AND SAMATOSUM deposits all indicate association with alkaline volcanic rocks typical of rift environments; host stratigraphies suggest an outer continental margin setting.

Model for massive sulphide ores

A model for the formation of the MARG deposit is proposed. The core of the hydrothermal upflow zone is represented by carbonate-quartz stockwork in sericite-carbonate-quartz-pyrite altered volcanic rock and overlying carbonate-rich massive sulphide. Quartz-rich massive sulphide rock and quartz-sericite-pyrite altered volcanic rocks represent a more peripheral alteration associated with the upflow zone. Pyrite facies massive sulphide reflects less altered sedimentary sulphides, and chlorite-quartz schists reflect less altered volcanic rocks away from the centre of hydrothermal alteration. The presence of ferroan carbonate-enrichment in the vent zone has been described in only a small group of volcanogenic massive sulphide deposits such as MATTABI (Ontario) and MADENKOY (Turkey).

Eastern margin of the Coast Belt, west-central B.C.

Marge orientale de la chaîne côtière, dans le centre ouest de la C.-B.

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The eastern margin of the Coast Belt between 52 and 55°N is a complex, arc-related plutonic and metamorphic assemblage dominated by Middle Jurassic plutons, Late Jurassic metamorphic tectonite complexes, Cretaceous and Tertiary plutons, and Paleogene extensional metamorphic complexes. Recent advances in structural and geochronometric studies have enabled the development of preliminary tectonic models for the evolution of this complex region.

The eastern Coast Belt near 52°N is subdivided into three north-northwest trending zones. The Atnarko Complex, which occupies the central zone, is a Late Jurassic(?) metamorphic tectonite complex characterized by steep, mainly north-northwest trending dextral mylonites. The tectonites are exposed in a wedge-shaped structural culmination, surrounded by lower grade plutonic and volcanic rocks. This structural culmination grades into and appears to be an integral part of a Middle–Late Jurassic plutonic basement to unconformably overlying Early Cretaceous volcanics, exposed in the western zone. Late Jurassic(?) volcanics in the eastern zone may also lie unconformably on this basement.

The Atnarko Complex bears a remarkable resemblance to the Late Jurassic Gamsby Complex in the Whitesail Lake area, near 53°N. Both complexes are characterized by metamorphic tectonites that appear to reflect Late Jurassic, dextral transpression along the east margin of the ancestral Coast Belt. The tectonite zones were uplifted and exhumed in Late Jurassic–Early Cretaceous time, covered by Early Cretaceous volcanics, and intruded by Cretaceous and Tertiary plutons. Major fault zones disrupt and bound the Atnarko and Gamsby complexes on the west and belong to a regionally extensive set of Paleogene, en echelon, dextral transtensional faults along the east margin of the Coast Belt.