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R.I. Thompson, J.L. Nelson, S. Paradis, C.F. Roots, D.C. Murphy,

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Ancient Pacific Margin NATMAP Project, year one[1]

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Abstract: The Ancient Pacific Margin NATMAP Project, developed in response to demand from the mineral industry, is a comprehensive analysis of the Cordillera-long belt of complexly deformed and metamorphosed rocks of pericratonic character known primarily as the Yukon-Tanana and Kootenay terranes.

During the project's first operational year, geological mapping began in the Wolf Lake–Jennings River area on the British Columbia–Yukon Territory border and continued in the Vernon area of southern British Columbia. Detailed metallogenic studies were undertaken in both the Kootenay and Yukon–Tanana terranes. Bedrock and surficial geology reconnaissance studies in the Stewart River area provide the basis for future work.

The various components of the project will address the following: correlation between terranes; paleogeographic settings with emphasis on mineral-deposit modelling; timing and nature of tectonic events; terrane mobility relative to the North American craton; the nature of tectonic boundaries.

Résumé : Le Projet de l'ancienne marge du Pacifique du CARTNAT, mis en oeuvre à la demande de l'industrie minérale, comporte l'analyse complète de la ceinture de roches péricratoniques métamorphisées et déformées de façon complexe qui longe la Cordillère et que l'on appelle principalement «terrane de Yukon–Tanana» et «terrane de Kootenay».

Au cours de cette première année de travaux, on a commencé la cartographie géologique dans la région du lac Wolf et de la rivière Jennings près de la limite de la Colombie-Britannique et du Territoire du Yukon et on a poursuivi les travaux déjà amorcés dans la région de Vernon, dans le sud de la Colombie-Britannique. Des études métallogéniques détaillées ont été entreprises dans les terranes de Kootenay et de Yukon–Tanana. Des études de reconnaissance de la géologie du substratum rocheux et des dépôts en surface menées dans la région de la rivière Stewart serviront de point de départ pour des travaux futurs.

Les diverses études menées dans le cadre du projet aborderont les sujets suivants : la corrélation entre les terranes; les contextes paléogéographiques, en particulier la modélisation des gisements minéraux; la chronologie et la nature des événements tectoniques; la mobilité des terranes par rapport au craton nord-américain; et la nature des limites tectoniques.

[1] Contribution to the Ancient Pacific Margin NATMAP Project

INTRODUCTION

The Ancient Pacific Margin NATMAP Project is a comprehensive analysis of the Cordillera-long belt of complexly deformed and metamorphosed rocks of pericratonic character known primarily as the Yukon-Tanana and Kootenay terranes, but including some elements of the Dorsey, Slide Mountain, and Quesnel terranes (Fig. 1). It was developed in response to mineral industry demand for new mapping, new geophysics, new metallogenic studies, and new syntheses of these poorly understood terranes. Attention is focused on the pericratonic terranes because of recent discoveries of volcanic-associated massive sulphide deposits in the Yukon-Tanana Terrane near Finlayson Lake, Yukon Territory.

During the project's first operational year, geological mapping began in the Wolf Lake–Jennings River area on the British Columbia–Yukon Territory border (Fig. 1) and continued in the Vernon area of southern British Columbia. Detailed metallogenic studies were undertaken in both the Kootenay and Yukon–Tanana terranes. Bedrock and surficial geology reconnaissance studies in the Stewart River area provide the basis for more intensive future work. In late August, a field trip in the Finlayson Lake area provided a common ground for participants from far-flung field locations.

The target rock assemblages make up one of three fundamental tectonostratigraphic subdivisions of the Cordillera (Fig. 1). For a strike length of over 2000 km from south-central British Columbia to east-central Alaska, pericratonic rocks lie between North American continental-margin strata and rocks to the west that evolved in and atop fragments of crust derived from elsewhere in the Pacific Ocean basin and were later attached to the ancestral North American plate margin during tectonic assembly of the Cordilleran mountain belt. The zone of pericratonic terranes is thought to represent the outer plate margin of the North American continent, from initial rifting and formation of the Pacific Ocean to arc collision in the Early Jurassic. Although commonly referred to as a 'passive margin', the outer plate margin was actually a dynamic interface between the continent and the shifting plates of the proto-Pacific. Within the pericratonic belt are stratigraphic assemblages marked by profound changes in thickness and facies and so rich in volcanic components that it is difficult to establish whether they correlate with strata of the continental margin or one of the terranes of proto-Pacific oceanic or arc affinity. Deformation and metamorphism have obscured stratigraphic relationships, thereby posing a significant challenge to deciphering paleogeography through time. Some assemblages are truly allochthonous and are now tectonically juxtaposed with distal North American rocks.

The various components of the NATMAP project will address the following questions: Are all the assemblages currently called pericratonic truly correlative (e.g. are Yukon-Tanana and Kootenay terranes the same)? If so, what paleogeographic settings are recorded by the pericratonic elements and how did they evolve through time? If not, what do they each represent? In what paleogeographic settings did the various types of mineral deposits form and how can these be linked into a metallogenic model? What were the timing and nature of tectonic events that affected the pericratonic elements and are these recorded in more proximal strata of the North American continental margin? If not, why not? Were pieces of the outer margin mobile with respect to the North American craton and, if so, how mobile? What is the nature of the tectonic boundaries that separate plate-margin rocks from exotic, proto-Pacific terranes farther outboard?

The newly discovered volcanogenic massive sulphide deposits in the Finlayson Lake belt, Kudz Ze Kayah, and Wolverine, are strikingly similar in age and character to long-known deposits in the Kootenay Terrane of southern British Columbia, making the pericratonic belt a metallotect of continental proportions. The stratigraphic assemblages in and around these deposits are remarkably similar to assemblages along strike in northern British Columbia and to the gross stratigraphic signature of rock assemblages in central and southern British Columbia. Identifying and mapping correlative rock associations are not only important to understanding how the continental margin evolved, but they also identify prospective 'ground' for future exploration and contribute raw material for the creation of new mineral exploration models.

The five-year project will bring to a modern standard all or part of several key, 1:250 000 scale maps along the pericratonic belt, including Stewart River (115 N, O), relevant parts of Wolf Lake (105 B) and Jennings River (104-O), Vernon (82 L), Bonaparte Lake (92 P), and Seymour Arm (82 M). It also will include 1:50 000 mapping in the Yukon-Tanana and affiliated terranes in the Finlayson Lake and Glenlyon map areas (Yukon Territory), metallogenic studies along the belt, and surficial studies geared to understanding the recent geological evolution of the Stewart River map area and to identifying favourable areas for placer exploration.

SOUTHERN COMPONENT: VERNON–SEYMOUR ARM–BONAPARTE RIVER MAPPING PROJECT

Participants: R.I. Thompson (GSC Pacific); K. Breitsprecher, J.M. Moore, D. Thorkelson (Simon Fraser University); K.L. Daughtry (Discovery Consultants); P. Erdmer, P. Glombick, L. Heaman, R. Creaser, J. Unterschutz (University of Alberta); R.M. Friedman (University of British Columbia)

Exciting new interpretations of south-central Cordilleran geology are emerging as mapping proceeds in the Vernon area (82 L). At this early stage, we speculate that the margin splayed north of the Vernon map area such that one or more elongate blocks of continental crust became physically separated from the continent proper; however, at southern latitudes, the splay apparently failed and is manifest instead as one or more zones of crustal thinning without discrete openings floored by oceanic crust.

Our evidence derives from new regional and detailed mapping designed to investigate the nature of geological linkages within North American plate-margin rocks, as well as linkages between these rocks and those considered to have

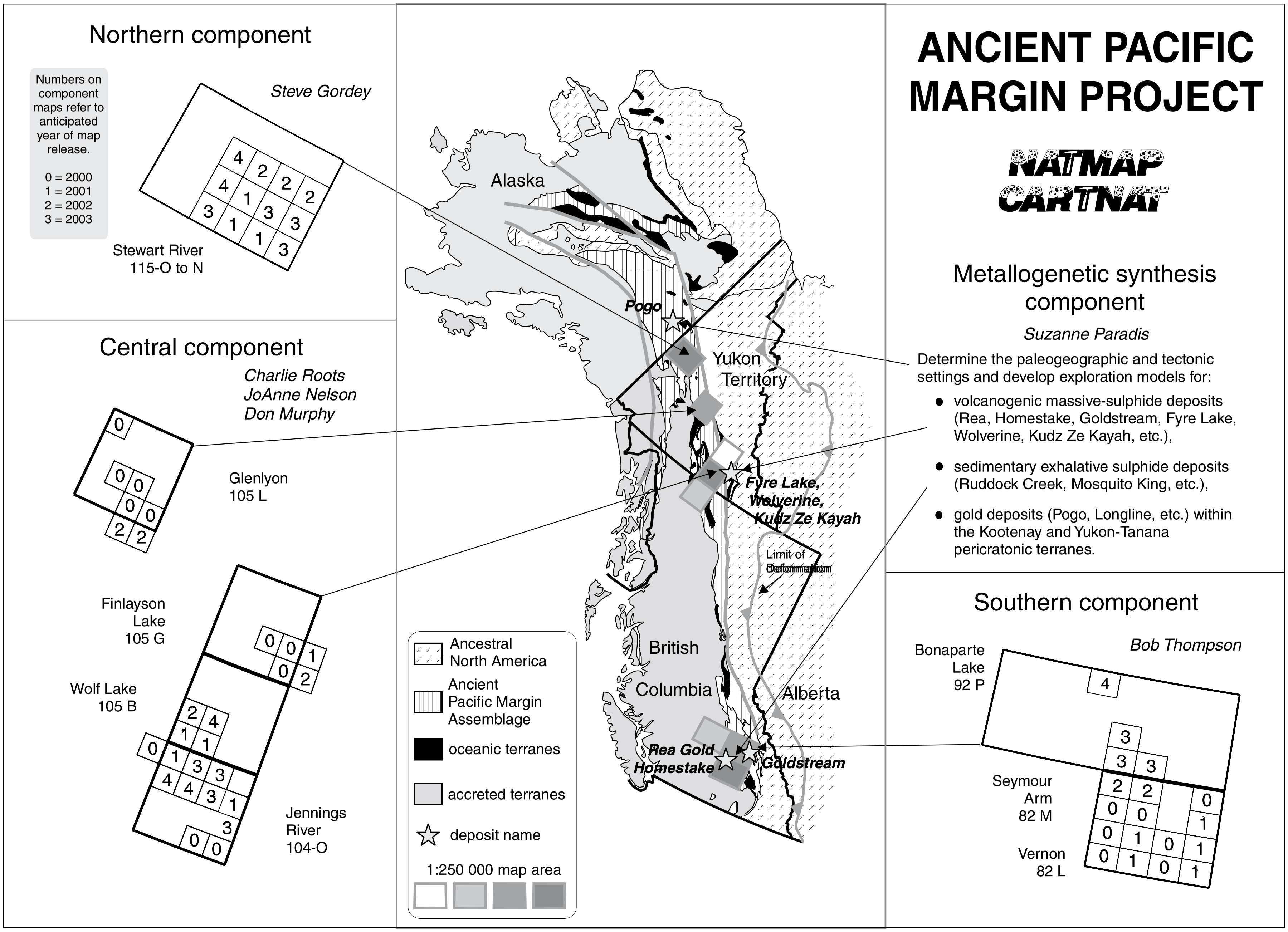

Figure 1. *Ancient Pacific Margin NATMAP Project study areas shown relative to the three major lithotectonic subdivisions of the Cordillera. The enlarged maps show specific, 1:50 000 map areas and anticipated year of map production.*

been accreted to the margin as a consequence of collision and obduction — defined as ‘Quesnel terrane’ in most contemporary models (e.g. Monger and Nokleberg, 1996). We are increasingly able to demonstrate that the Vernon map area (82 L) and much of the Ashcroft map area (92 H) to the west are underlain by a block of North American crust and that the Quesnel terrane and subjacent rocks with volcanic arc affinities such as the Harper Ranch Group evolved in a broad back-arc basin built on that crustal block (Thompson et al., 1999a, b; Glombick, 1999; Unterschutz et al., 1999; Erdmer et al., in press).

The Vernon map area (82 L) provides an opportunity to study the basement to the Quesnel terrane and use this information as an analogue for interpreting the basement to Quesnel terrane farther north where levels of exposure are not as deep. Detailed mapping by Unterschutz et al. (1999), Erdmer et al. (1998), and Moore (2000) and regional mapping by Thompson and Daughtry (1998, 2000) show the difficulty in distinguishing regional stratigraphic relationships within a rock package that is both highly strained and highly metamorphosed. However, the continuity of individual lithofacies, combined with distinctive geochemical and geochronological signatures, provide benchmarks for regional correlation. For example, a schist, marble, and conglomerate succession, the Spa Creek assemblage (new), contains two-mica-granite clasts dated at 555 Ma, demonstrating association with continental crust. This succession overlies pre-Devonian schist and gneiss typical of the continental margin regime and is overlain by Upper Triassic metasiltstone and metagreywacke that give sharply negative ε_{Nd} values. We think that the Spa Creek assemblage — at least its homotaxial equivalent — persists as far west as the Nicola Horst in the central Ashcroft map area.

Regional mapping is also addressing the hypothesis that zinc occurrences in the region are part of a single stratigraphic succession with significant regional distribution, thereby increasing the exploration potential for similar occurrences across the region. A physical linkage of Kingfisher (Colby) and Big Ledge zinc-lead occurrences has not yet been fully demonstrated, but all the right signs are there (Thompson and Daughtry, 2000).

The eastern half of the Vernon map area is interpreted to have undergone gravitational collapse during the Eocene when the crust, thickened during Jurassic and Cretaceous compression, became gravitationally unstable as compressive forces relaxed, allowing it to extended laterally both to the east across the Columbia River Fault and to the west across the Okanagan Valley Fault (Parrish et al., 1988). Problems with this interpretation are based on new geochronological results and regional map relations (Thompson and Daughtry, 1998). The Okanagan Valley Fault is apparently plugged by an undeformed Jurassic pluton (R.M. Friedman, pers. comm., 1998) at the latitude of Wood Lake and, farther north, map units carry across the North Okanagan valley with only minor disruption. Detailed mapping by Erdmer et al. (1998), Glombick (1999), and Glombick et al. (1999, 2000) is beginning to sort out the complex geometrical relationships in and adjacent to the northern Okanagan valley. Steep, west-dipping faults with minor displacement seem to be the dominant feature controlling the location and physiography of the valley north of Kelowna; this has yet to be reconciled with the interpretation farther south along the valley that large-scale displacement occurred across a crustal-scale detachment fault.

In the western Vernon map area, a volcano-sedimentary succession, the Chapperon Group, with unknown stratigraphic affinity was both deformed and metamorphosed prior to deposition of Upper Triassic clastic rocks of the Slocan Group. Detailed mapping of this succession was initiated by Daughtry et al. (2000) and geochemical and geochronological investigations are planned to put the Chapperon Group into proper stratigraphic and paleogeographic contexts.

Extensive mapping of Eocene volcanic strata was completed by Read (1996). Follow-up work on several outliers of Eocene volcanic rocks was initiated by Breitsprecher et al. (2000) to define their internal stratigraphy, petrology, and geochemistry as a means of interpreting tectonic and magmatic regimes coeval with volcanism.

A four-day field excursion to compare and contrast the geology of the Greenwood area with that of the Vernon and Ashcroft areas was led by J.T. Fyles.

Preliminary versions of several 1:50 000 scale maps are planned for open-file distribution, including 82 L/3, 82 L/6, 82 L/7 and portions of 82 L/5, 82 L/11, and 82 L/12. Output so far includes GSC publications, seminars, abstracts, and poster sessions, and one paper submitted for publication in a scientific journal.

The following work is planned for fiscal year 2000–2001: the field component of investigations by Glombick, Unterschutz, and Breitsprecher will be completed; regional mapping north from 82 L/7 into 82 L/10 and west into 82 L/8 to follow up on the hypothesis that zinc- and lead-bearing rocks are part of a single stratigraphic succession with regional extent; detailed mapping in 82 L/13 and 82 M/4 to investigate facies relations within the Eagle Bay assemblage; continued work on the characterization of North American rocks west of the Okanagan valley; including work in the Ashcroft map area where inliers of subQuesnel terrane rocks provide an opportunity to better characterize the stratigraphic, structural, and metamorphic history of these tantalizing exposures.

CENTRAL COMPONENT: WOLF LAKE–JENNINGS RIVER REGIONAL MAPPING PROJECT

Participants: C.F. Roots and S.P. Gordey (GSC Pacific); M.G. Mihalynuk, J.L. Nelson, S. Cook, and A. Dixon-Warren (British Columbia Geological Survey); M. de Keijzer (University of New Brunswick); T. Harms (Amherst College); R.M. Friedman and J. Mortensen (Uiversity of British Columbia); P. Erdmer (University of Alberta); S. Johnston (University of Victoria); M. Villeneuve (GSC Ottawa); S. Paradis (Mineral Resources Division)

Regional mapping commenced in the Wolf Lake/Jennings River (105 B/104-O) area on the British Columbia–Yukon Territory border. This major new mapping initiative is the core aim of the Ancient Pacific Margin NATMAP Project's central component (Fig. 1). In all, eleven 1:50 000 maps and one new 1:250 000 map are planned.

In this first summer of the project, a contract helicopter and fixed camp facilitated scientific collaboration between past and present workers in the area and exploration companies. The camp, at Morley Lake on the British Columbia–Yukon Territory border, hosted staff from the GSC, the British Columbia Geological Survey, and the Yukon Geology Program as well as university researchers. In addition to the detailed studies described by Roots et al. (2000), de Keijzer et al. (2000), Mihalynuk et al. (2000), and Nelson (2000), reconnaissance/correlation traverses over a large area enabled researchers to co-ordinate their stratigraphic and structural work.

The five-fold assemblage division of the Dorsey Terrane by Harms and Stevens (1996) is robust and extends into new areas. The Big Salmon complex (Gabrielse, 1969) in northwestern 104-O is subdividable into at least five continuous units (Mihalynuk et al., 1998), which Roots et al. (2000) extend to the north end of Hazel Ridge in 105 B (Hazel assemblage of Harms and Stevens, 1996). The Klinkit assemblage is subdividable into at least three consistent units (T. Harms, pers. comm., 1999).

Contacts between the various assemblages remain contentious, although new observations shed light on their character. The top of the Dorsey assemblage may in part be a series of detachment faults, as shown by shear bands and top-down, gentle to steep normal faults concentrated near it. The Mississippian–Pennsylvanian Screw Creek limestone, part of the Klinkit assemblage, depositionally overlies the Swift River assemblage.

Future field work will concentrate on subdividing assemblages and interpreting interassemblage contacts in order to elucidate the geological history of this complex pericratonic terrane.

CENTRAL COMPONENT: GEOLOGICAL MAPPING AND JOINT FIELD TRIP, YUKON TERRITORY

Principal investigators and field trip leaders: Don Murphy and Maurice Colpron (Canada–Yukon Geoscience Office)

Ongoing mapping of the Yukon–Tanana Terrane in the southern Yukon Territory, which is not physically contiguous to the Wolf–Jennings map area, is an important phase of the central component. In the Finlayson project, Murphy (Murphy and Piercey, 1999, 2000) of the Yukon Geoscience Program and collaborators have covered the area of the Kudz Ze Kayah and Wolverine volcanogenic massive sulphide properties, providing a preliminary stratigraphic template that is useful for workers in parts of the terrane where volcanogenic potential is less well known. Colpron (1999, 2000) has mapped two areas in the Teslin Zone, the continuation of Yukon–Tanana Terrane southwest of the Tintina Fault. In August, Murphy and Colpron hosted the inaugural Ancient Pacific Margin NATMAP field trip. The purpose of this and future trips is to give NATMAP and industry participants the opportunity to examine different sections of the pericratonic belt and through observation and discussion, to derive insight into the variety of geological and metallogenic environments in the belt and how they may (or may not) relate to one another in time and space. To that end, twenty-two participants from the GSC, the British Columbia Geological Survey, the Yukon Geology Program, universities, and industry were led through two different stratigraphic sections of the Yukon–Tanana Terrane, one southwest of the Tintina Fault and the other in the Finlayson Lake massive sulphide district northeast of the Tintina Fault.

Participants were shown a cross-strike section of the terrane exposed along the Campbell Highway section on the north shore of Little Salmon Lake. Colpron's mapping along and north of the road has defined a folded, weakly deformed, stratigraphically intact sequence of subgreenschist-grade, felsic and mafic, metavolcanic and metavolcaniclastic rocks, limestone/marble, and gritty, metaclastic rocks. Syngenetic mineralization was recently discovered in metarhyolite of this sequence (Colpron, 1999), affirming the significant mineral potential of this part of the Yukon–Tanana Terrane. Preliminary geochronological constraints indicate that the Little Salmon Lake section may be in part coeval with the Finlayson Lake massive sulphide belt, but is mostly younger with a somewhat different structural and stratigraphic evolution.

Field-trip participants went on a two-day tour of the Finlayson Lake massive sulphide district. They spent the first day at Kudz Ze Kayah, Cominco Ltd.'s 11.3 Mt, preciousmetal-rich, polymetallic, volganogenic massive sulphide deposit, examining the pre-ore, ore, and post-ore stratigraphy. On the second day, they examined evidence for an unconformable relationship between Kudz Ze Kayah rocks and those hosting the Wolverine deposit, the 6.2 Mt, precious-metal-rich, polymetallic, volcanogenic massive sulphide deposit of Expatriate Resources and Atna Resources. Participants walked a transect through the deposit, then examined the nature of the contact between the deposit and overlying rocks of the Campbell Range Belt. This contact was previously interpreted as the terrane boundary between the Yukon–Tanana and Slide Mountain terranes and has been re-interpreted as stratigraphic, extending the range of environments of what is considered the Yukon–Tanana Terrane.

METALLOGENY COMPONENT

Coordinator: Suzanne Paradis (Mineral Resources Division)

Participants: G. Abbott, D.C. Murphy (Yukon Geology Program); S. Bailey, S. Johnston, S. Song, D. Tutt (University of Victoria); E. Balon (Fairfield Minerals Ltd.); M. Cathro, T. Hoy, J. Logan, M.G. Mihalynuk, J.L. Nelson (British Columbia Geological Survey); K.L. Daughtry (Discovery Consultants); L. Doyle (Barker Minerals Ltd.); C. Dusel-Bacon

(United States Geological Survey); B. Friesen (Teck Exploration Ltd.); P. Holbec (Atna Resources Ltd.); I. Jonasson, J. Peter (GSC); J. Froese (INMET Mining Corp.); T. Liverton (Tarmachan Exploration Service); P. MacRobbie, W. Wolfe (Cominco Ltd.); J. Marr (Geodex Minerals Ltd.); J. Mortensen, S. Piercey (Mineral Deposit Research Unit, University of British Columbia); W. Roberts (Columbia Gold Mines); D. Wilder (Remedios and Co.)

This project addresses thematic research on one of Canada's most significant deposit types — an exciting and challenging new suite of volcanogenic masive-sulphide prospects hosted by the Kootenay and Yukon–Tanana Cordilleran terranes, British Columbia and Yukon Territory. The NATMAP vehicle facilitates close integration of GSC mineral deposit and regional metallogenic studies with thematic studies conducted within the GSC Bedrock Geoscience Program, and with provincial and territorial surveys, universities, and industry.

During June and July 1999, geological mapping and sampling was undertalen in the Eagle Bay Assemblage in the Johnson–Adams Lake area, southeastern British Columbia, which hosts the (?)volcanogenic massive sulphide Twin Mountain, Samatosum, and Rea deposits. The Twin Mountain deposit consists of sulphide-bearing, quartz-carbonate-barite lenses hosted by sericitized and silicified schists designated as map unit EBG by Schiarizza and Preto (1987). The Rea deposit consists of at least two massive sulphide lenses structurally overlain by cherty, tuffaceous exhalite and structurally underlain by barite-rich layers. Overall, the Samatosum deposit is a stratabound, sulphide-rich, quartz-vein system that could be interpreted as a stockwork zone associated with volcanogenic massive sulphide lenses.

Both deposits occur within an overturned, metasedimentary sequence of sericitized and silicified argillite that is structurally overlain by mafic, volcaniclastic rocks and flows. The stratigraphic sequences at the Rea and Samatosum deposits are very similar and we suggest that structural repetition by faulting occurred and that the sedimentary and volcanic succession is of Devonian and Mississippian age (Bailey et al., 2000a, b). However other scenarios are possible, such as repetition by folding or the presence of two similar sedimentary and volcanic sequences in stratigraphic contact. Dating, petrographic and geochemical studies, and more geological mapping are planned in the area to resolve the structural and genetic natures of these deposits and their host rocks.

Preliminary lithogeochemical results show that felsic metavolcanic rocks hosting volcanogenic massive sulphide deposits in the Finlayson Lake district have calc-alkaline arc-like affinities as well as within-plate characteristics. These characteristics are typical of extensional regimes in rifted arcs and ensialic back-arc basins. Furthermore, this style of magmatism is associated with felsic metavolcanic rocks with elevated emplacement temperatures and extensional tectonic activity that would provide the regionally developed, elevated heat flow and ground preparation required for the generation of hydrothermal systems (Piercey and Paradis, in press).

NORTHERN COMPONENT: SURFICIAL MAPPING, STEWART RIVER MAP AREA

Participants: Lionel Jackson and Kazuharu Shimamura (Terrain Sciences Division); Crystal Huscroft (Simon Fraser University); Duane Froese (University of Calgary); Edward Little (University of Alberta); Randy Enkin (GSC Pacific); Mike Villeneuve (GSC Ottawa); William LeBarge and Grant Lowey (Yukon Geology Program, Whitehorse)

Regional surficial geology mapping of the Stewart River map area (115-O, N) and immediately adjacent areas of the Stevenson Ridge map area (115 J, K) began in the 1999 field season. All or parts of 115 J/14, 15, and 16 and 115-O/1, 2, and 3 were covered using boat, all-terrain-vehicle, and foot traverses.

Placer gold has been mined from this area since the end of the nineteenth century. The bedrock source of the gold in this region has never been identified and bedrock exploration has been relatively limited. Little natural bedrock exposure exists in the area and artificial exposures are confined to placer mines and related roads and airstrips. Field work had the following six objectives: ground confirmation of airphoto interpretation as a part of surficial geological mapping of the area; extension of stratigraphy established for early Pleistocene sedimentary rocks and interstratified basalts (Jackson et al., 1996) in the Carmacks map area (115-I) down the Yukon River valley into the Stewart River map area; investigation of the stratigraphic setting of gold placers; testing of the area's previously mapped glacial limits; survey of rock types present within placer basins that host gold placers through sampling and identification of gravel-clast lithology; testing of dual-frequency GPS technology under field conditions that, if successful, would allow precise elevations to be determined for the many early Pleistocene to Pliocene or late Miocene terraces in the region, which, in turn, could allow determination of the degree of neotectonic warping or faulting in the area.

Two papers were prepared, one detailing the results of the investigation of glacial limits and basin lithology based on an examination of placer gravels (Jackson and Huscroft, 2000) and another detailing the results of the GPS trial along the Yukon River between the mouth of the White River and Dawson City (Shimamura et al., 2000).

NORTHERN COMPONENT: BEDROCK MAPPING, STEWART RIVER MAP AREA

Principal investigator: Steve Gordey (GSC Pacific)

In the Stewart River area, bedrock investigations were limited to an initial assessment of logistical and geological problems in preparation for a planned full field season of mapping in summer 2000. Work included a six-day boat reconnaissance of the Yukon River between Minto and Dawson and a two-day road excursion in the Dawson map area to the north. Representative samples for petrographic work and isotopic dating were collected.

ACKNOWLEDGMENTS

The Finlayson Lake part of the field trip, central component of the project, could not have been undertaken without the help of Cominco Ltd., who offered the use of their Kudz Ze Kayah camp and access to their properties; Expatriate Resources and Atna Resources, who permitted access to their Wolverine property; and Atna Resources who helped offset some of the cost of the trip. We thank them for both their generosity and their participation.

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