CONFERENCE REPORTS

Workshop on subaqueous hot-spring deposits of Eskay Creek-type

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INTRODUCTION

On 25 November 1999 about 110 people attended this event, convened by the Vancouver Mining Exploration Group (MEG), at the downtown Vancouver campus of Simon Fraser University. The workshop was sponsored by the Vancouver MEG, the British Columbia and Yukon Chamber of Mines (BCYCM), and the British Columbia Geological Survey (BCGS). This special event was organized by the MEG as part of its mandate to promote "the sociable exchange of exploration information and experience through a series of luncheon meetings featuring talks on new discoveries, breaking developments in technology and current geological knowledge of prospective belts or deposit types." Homestake Canada Inc. kindly provided coffee and refreshments.

The workshop included 10 talks, plus rock specimens and poster displays designed to follow up a new BCGS release *Potential for Subaqueous Hot-Spring (Eskay Creek-Type) Deposits in British Columbia* (Massey *et al.*, 1999) and a new Society of Economic Geologists Inc. (SEG) release *Volcanic-Associated Massive Sulfide Deposits: Processes and Examples in Modern and Ancient Settings* (Barrie and Hannington, 1999). The workshop drew people from the mining industry, the British Columbia Ministry of Energy and Mines, the Geological Survey of Canada, and the University of British Columbia.

The Eskay Creek deposit is one of the world's highest-grade gold and silver mines with reserves of 1.36 million tonnes grading 57.6 g/t Au and 2492.5 g/t Ag. Production began in January 1995 and to the end of 1999, the mine has produced in excess of 1.2 million ounces of gold and 59 million ounces of silver. Production for 1999 was an estimated 309,000 ounces of gold and 13.1 million ounces of silver; owing to successful exploration since start-up, the mine now has a higher reserve base than at mine opening in 1995 (British Columbia Mineral Exploration Review 1999, 2000). The bulk of the ore (62%) is shipped directly to smelters in Japan and eastern Canada; the remainder is processed on-site through a gravity and flotation circuit. Over the past decade, Homestake Canada Inc., the Mineral Deposits Research Unit (MDRU) at the University of British Columbia, and other researchers have studied this intriguing subaqueous hot-spring deposit and generously shared this knowledge with others in the geoscience community. The workshop provided updates on recent developments in the deposit geology and the deposit model, with regional and site-specific examples from the Eskay Creek area. The papers on "Subaqueous Hot-Spring Deposits: A Global Overview" and " Eskay Creek-Type Potential in British Columbia" provided a basis for both worldwide and provincial exploration for this remarkable deposit type.

GLOBAL OVERVIEW OF SUBAQUEOUS HOT-SPRING DEPOSITS

Keynote speaker Mark Hannington of the Geological Survey of Canada (GSC), Ottawa, led off with an excellent global review and perspective of subaqueous hot-spring deposits. Since 1991, Mark has combined the study of ancient volcanic massive sulphide deposits with exploration of active hydrothermal systems on the modern seafloor. He has participated in 15 research cruises to vent sites on the Juan de Fuca Ridge, Mid-Atlantic Ridge, and island areas of the western Pacific region. This work has focussed on the mineralogy, geochemistry, and genesis of massive sulphide deposits on the seafloor. More recently, he has begun investigating occurrences of shallow submarine hydrothermal systems with similarities to subaerial epithermal gold deposits. Mark's well-illustrated presentation, his enthusiasm, and his broad expertise on the topic set the stage for discussion throughout the day. The growing recognition that a number of world-class, precious metal-rich deposits may have formed in shallow submarine-to-subaerial environments, and the increasing number of gold-rich hot springs now being found in similar settings on the modern seafloor highlights their exploration potential. These deposits of the VMS-epithermal transition include a wide range of deposit types with geological characteristics that are in part typical of ordinary VMS deposits but also resemble subaerial epithermal deposits (*i.e.*, a continuum of deposit types that may include auriferous polymetallic sulphides, pyritic gold-rich stockworks, and stratiform Au-Ag barite deposits). A number of factors involved in precious metal enrichment of the VMS-epithermal transition were discussed, including boiling of the hydrothermal fluids and the presence of magmatic volatiles that may contribute gold directly to near-surface hydrothermal fluids. Precambrian examples discussed included Boliden, Bousquet and Selbaie; Phanerozoic examples included Eskay Creek and Pueblo Viejo, and deposits in Indonesia, the Philippines, Japan, Fiji, China and Eastern Australia. Mark's discussion of modern island arc settings, such as those of the western Pacific (e.g. White Island, New Zealand; Lihir, Papua, New Guinea) provided particularly compelling examples of submarine epithermal-style mineralization. It is noteworthy that precise analogs of the Eskay Creek Au-Ag deposit and the Boliden Cu-Au-Ag deposit have not yet been found outside their type localities. Atypical deposits of this kind should be important targets for exploration in other shallow marine volcanic arc environments.

ESKAY CREEK DEPOSIT

Regional Setting

Bob Anderson and Carol Evenchick, with the GSC in Vancouver, spoke on the "Early to Middle Jurassic Arc to Basin Transition West of Bowser Basin (Iskut to Anyox areas)," in northwestern British Columbia. Regional mapping and stratigraphic studies of volcanic, sedimentary and plutonic rocks combined with biochronology and U-Pb, Ar-Ar, and K-Ar geochronology by them and numerous other workers help define the character and nature of this Middle Jurassic transition in northwestern Stikinia, an interval proven prospective for Eskay Creek-type base and precious metal deposits. Their focus was the closely similar Jurassic tectonic histories in the Iskut River (which encompasses the Eskay Creek mine), Anyox pendant, and Georgie River areas. These talks provided an excellent regional framework for the rest of the day.

Local Geological Environment

Peter Lewis, Lewis Geoscience Services Inc., discussed the "Geological Setting of the Eskay Creek Area," with a passionate and important emphasis on structural controls. Between 1991 and 1994 Peter worked on the structural and stratigraphic setting of mineral deposits of the Iskut River area, as a Post-Doctoral Fellow with the MDRU at the University of British Columbia. Structural, stratigraphic, geochemical and geochronological studies conducted over the last decade have identified geological characteristics unique to the Eskay Creek deposit area, and help to constrain both deposit evolution and exploration models for similar deposits. Syn-volcanic faults mapped near the Eskay Creek deposit controlled volcanic facies distribution and thickness prior to and during mineralization. Cretaceous-Tertiary (post-Eskay Creek time) structural styles vary according to crustal level: within the well-stratified Bowser Lake Group, thin-skinned fold and thrust styles are dominant, while at deeper levels within the arc sequences, shortening is accommodated by reverse faulting and penetrative fabric development. The Eskay Creek deposit lies on the west limb of the Eskay Anticline.

Figure 1 The old and the new: Tom MacKay's original cabin, from his early, mid-1900s prospecting programs in the Eskay Creek area, is in stark contrast to the modern, helicopter-supported program that discovered and developed the rich Eskay Creek deposit into one of the world's highest-grade gold and silver mines. Note the helicopter tail boom behind the cabin to the right. Photograph by R.G. Anderson, August 1991.

Ore Mineralization: Style and Character

Tina Roth came to the University of British Columbia in 1991 to work with the MDRU Iskut River Project and completed an M.Sc. in 1993. Since then, she has been conducting Ph.D. research studies on the orebodies at Eskay Creek mine: completion is anticipated in mid-2000. Between December 1994 and September 1998 Tina worked on-site as mine geologist and exploration geologist for Homestake Canada Inc. She was part of a team that has identified significant new reserves at the mine. At the workshop, Tina discussed "The Eskay Creek Mine: Complex Mineralization in a Precious-Metal Rich VHMS Deposit." She briefly reviewed the exploration history of the area, which dates back to 1932 (Fig. 1), and culminates with the discovery of the Eskay Creek deposit in the fall of 1988. Tina also addressed the regional geological setting of the deposit and the mineralization styles of the various zones, and provided a clear and concise model for ore deposition (Fig. 2).

The 21 zone contains a number of subzones distinguished by varying mineralogy, textures, grades and metallurgical characteristics. Stratiform mineralization is hosted in marine mudstone at the contact between underlying rhyolite and overlying basalt packages. The 21A, 21B and NEX zones occur at this stratigraphic contact. The HW zone is located stratigraphically higher in the sequence, usually above the first basaltic sill. Stockwork vein and disseminated mineralization (including sphalerite ± galena ± pyrite ± tetrahedrite ± native gold) are present in the 109, 21C and Pumphouse zones. The 21 zone contains the bulk of the ore and consists of clastic sulphide-sulphosalt beds, including sphalerite, tetrahedrite-freibergite, boulangerite, jamesonite, stibnite, galena, pyrite, electrum and amalgam (Fig 2). Sedimentary facies variations are well preserved locally, although commonly overprinted by later sulphosalts and locally stibnite ± rare

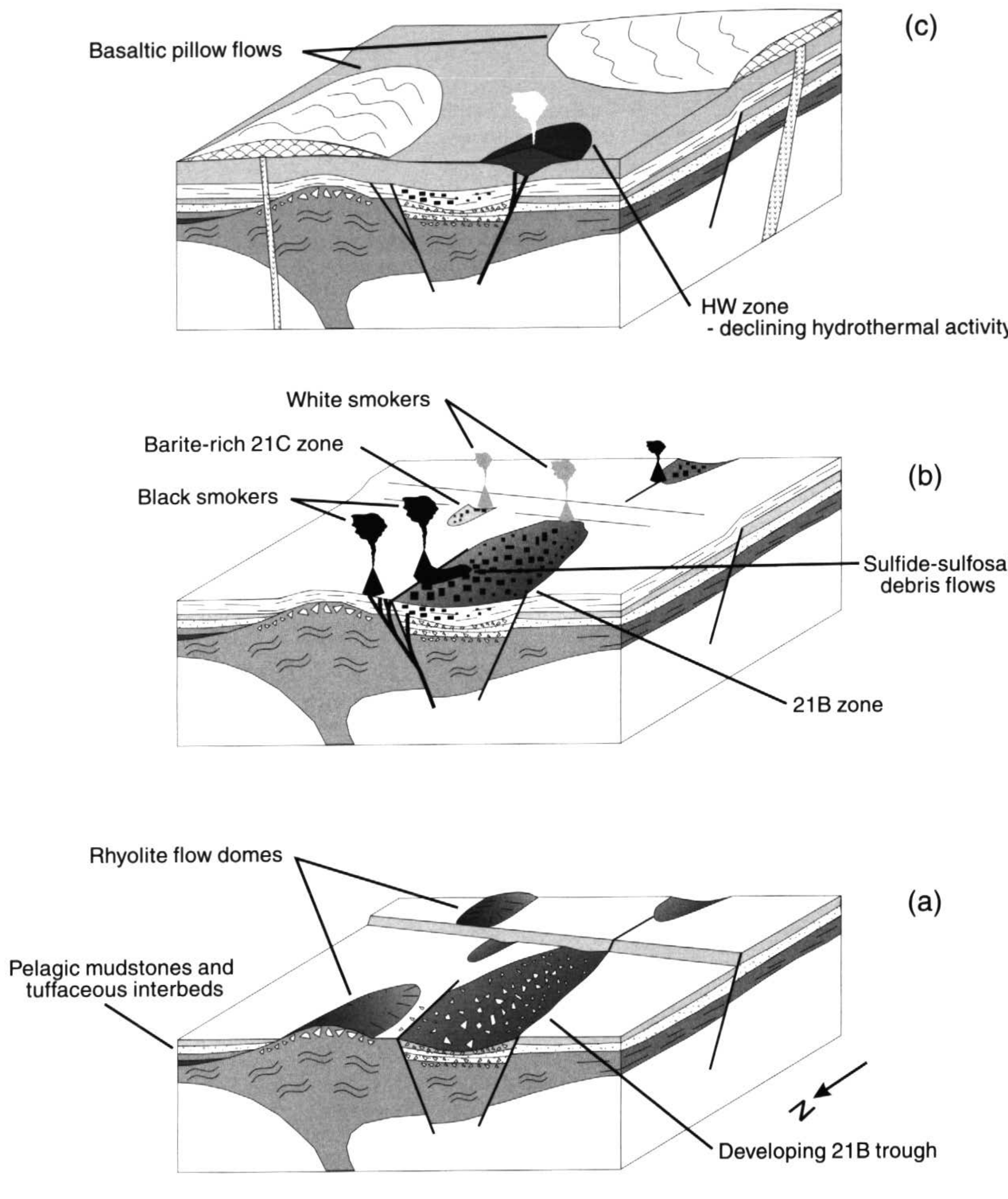

Figure 2 Block model in three stages for the development of the Eskay Creek 21 zone orebodies. (**a**) Rifting, basin development, and intrusion/extrusion of rhyolite flow domes. Coarse volcaniclastic debris from extrusive portions of flow domes is deposited along the developing 21B zone trough. (**b**) Hydrothermal activity is focussed through rift faults, forming chimneys and mounds on the seafloor. Collapse or disruption of these mounds forms clastic sulfide-sulphosalt debris which is redeposited in the 21B zone trough. Other small basins provide sites for similar mineralization and barite-rich zones related to white smokers. (**c**) The HW zone of massive sulfide forms higher in the mudstone stratigraphic pile and basaltic dikes and flows are emplaced/extruded during the waning stages of hydrothermal activity. (From Roth *et al.*, 1999)

cinnibar in the core of the deposit. The thickest beds and coarsest clasts occur in the core of the orebody. Clast size and bed thicknesses typically decrease stratigraphically upward and laterally outward, progressively thinning to fine laminations and disseminated sulphides and sulphosalts in mudstone.

Most of the significant mineralization at Eskay Creek formed on the seafloor in an active volcanic environment, during an interval of mainly pelagic sedimentation (Fig. 2). In Early Jurassic time, fragmental and tuffaceous calc-alkaline volcanic rocks were erupted into a shallow water environment, forming the lower footwall units at Eskay Creek. In Middle Jurassic time, bimodal volcanism, marked by the emplacement of rhyolite flow domes, the footwall rhyolite, and the subsequent intrusion and extrusion of basaltic magmas (the hangingwall basalts), is interpreted to reflect the extension and rifting of the Hazelton arc. The distinctive tholeiitic geochemistry of the rhyolites and basalts at Eskay Creek suggests the importance of significant local, deep rift structures that probably also focussed hydrothermal activity. The presence of peperitic breccias around both the rhyolites and basalts suggests that the time interval between rhyolitic and basaltic volcanism was relatively small.

The hydrothermal system at Eskay Creek was probably initiated soon after the emplacement of the rhyolite domes. Sulphides and sulphosalts formed initially in mounds or chimney structures similar to those in modern black smoker environments. The mineralization formed at low temperatures (120°C to 210° C) and a water depth of less than 1000 m, possibly as shallow as 160 m. The mound and chimney structures collapsed at recurring intervals, redistributing broken and fragmented clasts within the north-trending basin. Lateral facies changes reflect the geometry of the trough, whereas similar vertical facies changes suggest a gradual decline in hydrothermal activity during pelagic sedimentation.

During and following the deposition of sulphide-sulphosalt beds, and burial by pelagic mudstone, the hydrothermal system may have evolved, or became reactivated, resulting in local replacement in the 21B zone. The local importance of clastic barite beds in both the 21B and 21C zones suggests that white smokers were active in the area (Fig. 2). The fact that the HW zone occurs stratigraphically higher in the contact zone indicates that the hydrothermal system operated over a significant time period at Eskay Creek. The higher Cu content of the HW zone suggests that higher fluid temperatures prevailed during this stage of declining hydrothermal activity.

Ore Mineralization: Geochemical Evidence

Ross Sherlock, another member of the MDRU Iskut River project during the early 1990s, and currently with Steffen, Robertson and Kirsten Consulting Engineers and Geoscientists in Vancouver, provided a summary of the "Formation of the Eskay Creek Mineralization: Geochemical Evidence." He included abundant lithogeochemical, fluid inclusion and stable isotope evidence relating to the origin of the Eskay Creek deposit. The hydrothermal system that formed the deposit was low temperature (<200° C) with a relatively high gas content. Fluid inclusion petrography and measured gas ratios are consistent with liquid-vapour phase separation occuring in the hydrothermal system. Fluid inclusion leachates suggest mixing between a seawater-derived fluid and a lower-temperature (~100° C), more saline fluid which had high K/Na and Cl/Br ratios compared to normal seawater. The high-salinity fluid had halogen and cation ratios that are consistent with a magmatic-derived fluid. Sulphur isotape data suggest that the sulphide sulphur may have been derived from either an igneous source or by reduction of seawater sulphate. Ross identified the best modern-day analogue of Eskay Creek mineralization as the JADE hydrothermal field in the Okinawa trough.

FINDING MORE ESKAY CREEK-TYPE DEPOSITS

Nick Massey, BCGS, gave a talk entitled "Finding the Next Eskay! An Overview of Eskay Creek-type Potential in British Columbia." He highlighted the results of his recently completed compilation work (BCGS Open File 1999-14). The Open File is also available for download (in pdf format) from the Ministry website: http://www.em.gov.bc.ca/geology/Economic%20Geology/MetallicMinerals/eskay/esk_home.htm.

The study compiled and documented geological, mineral deposit, and geochemical data useful in identifying areas of potential for Eskay Creek-type deposits at the provincial scale on two coloured 1:2 000 000-scale maps with associated notes. Twenty-two prospective areas were delineated across the province. MINFILE (British Columbia's mineral data base system) descriptions are included for 10 definite and 20 possible Eskay Creek-type deposits in the province. Factors considered in the study include: 1) favourable geology; 2) selected MINFILE occurrences, including five sets of occurrence "types"; and 3) pathfinder regional geochemical survey anomalies. The majority of the prospective areas are underlain by Lower to Middle Jurassic volcanic sequences of the Hazelton Group, the host of the Eskay Creek deposit. This regionally extensive package of rocks in northern British Columbia still remains the most important target for exploration for subaqueous hot-spring deposits. Sequences of other ages were also examined but appear to have less potential.

PROSPECTIVE PROPERTIES

The latter part of the workshop was devoted to selected individual property descriptions in the Eskay Creek region, and in the Smithers region to the south-east.

Henry Awmack, Rimfire Minerals Corporation, presented an overview on the 21-km long RDN property, located 40 km north of the Eskay Creek mine. Property mapping, geochemical sampling, and a modest diamond drilling program in 1999 confirmed that it is largely underlain by an upright section of Jurassic Hazelton Group stratigraphy similar in age, lithology, alteration and mineralogy to that hosting the Eskay Creek mine. The Eskay Creek stratiform orebodies lie at a similar stratigraphic position within argillite along the contact between a felsic flow-dome and a pillow basalt. More than 10 km of this favourable contact have been identified on the southern half of the RDN property, but remain relatively unexplored, due to the recessive nature of this contact. Henry also described the presence of high-grade quartz-sulphide veins, with high gold, silver and base metal contents similar to the Snip mine, that form part of the same Early to Middle Jurassic hydrothermal system as the Eskay Creek-style stratiform targets.

Helgi Sigureison, a consultant to Kenrich Mining Corp., provided an overview entitled "Subaqueous Hot-spring Potential of the Corey Property." Approximately 15 km of the favourable upper Hazelton Group bimodal volcanic sequence cross the property in two north to south trending belts, approximately 10 km south of the Eskay Creek mine. A number of mineralized showings exist (*e.g.*, Cumberland, TV and HSOV zones). The company is currently looking for joint venture or option agreements on this property or parts of it.

On behalf of his co-authors, Richard Haslinger and James Oliver, and the current owners of the property, Heritage America Resources Corp., Mark Rebagliati gave a presentation on the "Sib Project - Lulu Zone Discovery." Between 1989 and 1991 Copeland Rebagliati and Associates conducted exploration on the SIB claims on behalf of American Fibre Corporation and Silver Butte Resources Ltd. The time-stratigraphic succession on the claims, approximately 5 km south of the Eskay Creek mine, is the southward strike extension of the Middle Jurassic, upper Hazelton Group strata hosting the Eskay Creek deposits. Highly deformed strata hosting stacked, stratiform sulphide-sulphosalt bodies occur within a portion of the Lulu zone on the SIB claims. These bodies carry strong gold-silver mineralization occurring in thinly laminated barite and/or in hairline fractures cutting the host mudstone unit. The integration of high-density multi-element soil geochemistry, detailed VLF and IP surveys, and small-scale geological mapping led to modest diamond drilling programs on the Lulu prospect during 1990 and 1991. No further work has been done since then; the potential for this property remains excellent.

Paul Wojdak, BC Ministry of Energy and Mines, Smithers, examined the "Eskay Creek-Type Potential in the Smithers Area." He briefly described the Hazelton Group strata in the Babine Range east of Smithers and discussed the Ascot, Del Santo and SU volcanogenic massive sulphide occurrences, with respect to their potential to host an Eskay Creek-type deposit. The Nilkitkwa Formation of the Hazelton Group in the Smithers area includes bimodal volcanism in a marine environment with VMS mineralization. However, the stratigraphic position and tectonic setting is somewhat different from Eskay Creek. Nonetheless, the area is under-explored and represents a good target for VMS deposits; discovery of a precious metal-enriched deposit may result.

KEY POINTS

Dani Alldrick, BCGS, wrapped up the workshop with a synthesis of some key points discussed during the day:

- Eskay Creek deposits are products of an ore-forming process that generates a spectrum of related deposit types, at global and minesite scales (Hannington, Roth);
- Subaqueous hot-spring deposits may form at depths ranging from shallow water to greater than 1.5 km (Sherlock, Hannington);
- Noteworthy observations by participants included the potential use of carbonate compensation depth to constrain seawater depth at sites of sulphide deposition (David Bridge), and the importance of Homestake Inc.'s innovative choice of direct-shipping ore that facilitated mine permitting (Peter Holbek);
- Eskay Creek-type hot-spring deposits characteristically have associated elevated mercury values. This highly mobile metal is particularly suitable for detection by reconnaissance scale geochemical programs. A consequence of this high mobility is that Hg geochemistry may not be a reliable tool for detailed follow-up surveys once a regional-scale target is outlined (Hannington, Massey, Roth);
- A powerful package of proven exploration strategies and tools is provided by combining Mark Rebagliati's detailed approach to property-scale exploration with Peter Lewis's inventory of key regional-scale exploration criteria;
- The hangingwall pillow lava succession is significant for mineralization at property and regional scales; similar age-equivalent volcanic packages throughout the region have not been extensively explored (Anderson, Evenchick, Awmack);
- Regional-scale GSC studies of depositional environments for VMS deposits in northwestern British Columbia by Evenchick and Anderson parallel USGS studies by Cliff Taylor in the nearby Alexander Terrane rocks of southeastern Alaska. The Greens Creek VMS mine of southern Alaska demonstrates that mafic volcanic-dominated successions are equally prospective for precious-metal enriched VMS deposits.

All speakers and registrants are congratulated for their participation in this informal "workshop" format, which fostered discussions throughout the program. The bottom line is clear: Eskay Creek deposits are very attractive targets!

Future one-day workshops are being contemplated by the Vancouver MEG. Comments or suggestions for future topics should be addressed to Tom Schroeter.

REFERENCES

Barrie, T.C. and Hannington, M.D., 1999, eds., Volcanic-Associated Massive Sulphide Deposits: Processes and Examples in Modern and Ancient Settings: Reviews in Economic Geology, v. 8, 408 p.

British Columbia Mineral Exploration Review 1999, 2000, Information Circular 2000-1: British Columbia Ministry of Energy and Mines, January 2000, 22 p.

Massey, N.W.D., Alldrick, D.J. and Lefebure, D.V., 1999, Potential for subaqueous hot-spring (Eskay Creek) deposits in British Columbia: British Columbia Ministry of Energy and Mines, Open File 1999-14, (2 maps & rpt).

Roth, T., Thompson, J.F.H. and Barrett, T.J., 1999, The Precious Metal-Rich Eskay Creek Deposits, Northwestern British Columbia, *in* Barrie, C.T. and Hannington, M.D., eds., Volcanic-Associated Massive Sulfide Deposits: Processes and Examples in Modern and Ancient Settings: Reviews in Economic Geology, v. 8, p. 357-373.