EPITHERMAL Au-Ag-Cu: HIGH SULPHIDATION H04

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Refer to preface for general references and formatting significance.
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IDENTIFICATION

SYNONYMS: (Epithermal) acid-sulphate, quartz-alunite Au, alunite-kaolinite ± pyrophyllite, advanced argillic, Nansatsu-type, enargite gold. The deposits are commonly referred to as *acid-sulphate* type after the chemistry of the hydrothermal fluids, *quartz-alunite* or *kaolinite-alunite* type after their alteration mineralogy, or *high-sulphidation* type in reference to the oxidation state of the acid fluids responsible for alteration and mineralization.

COMMODITIES (*BYPRODUCTS*): Au, Ag, Cu (*As, Sb*).

EXAMPLES: **(Yukon): Yukon Antimony (105D 027), Wheaton Mountain (105D 031), Brown-McDade (115I 064), Webber (115I 065), Tally-Ho (105D 030), Skukum (105D 158), Laforma (115I 054);** British Columbia - *International*): Mt. McIntosh/Hushamu (EXPO, 92L240), Taseko River deposits - Westpine (Empress) (92O033), Taylor-Windfall (92O028) and Battlement Creek (92O005); *Goldfield and Paradise Peak (Nevada, USA), Summitville (Colorado, USA); Nansatsu (Japan), El Indio (Chile); Temora (New South Wales, Australia), Pueblo Viejo (Dominica), Chinkuashih (Taiwan), Rodalquilar (Spain), Lepanto and Nalesbitan (Philippines).*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Veins, vuggy breccias and sulphide replacements ranging from pods to massive lenses occur in volcanic sequences associated with high level hydrothermal systems marked by acid-leached, advanced argillic, siliceous alteration.

TECTONIC SETTING: Extensional and transtensional settings, commonly in volcano-plutonic continent-margin and oceanic arcs and back-arcs. In zones with high-level magmatic emplacements, where stratovolcanoes and other volcanic edifices are constructed above plutons.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Subvolcanic to volcanic in calderas, flow-dome complexes, rarely maars and other volcanic structures; often associated with subvolcanic stocks and dikes, breccias. Postulated to overlie, and be genetically related to, porphyry copper systems in deeper mineralized intrusions that underlie the stratovolcanoes.

AGE OF MINERALIZATION: Tertiary to Quaternary; less commonly Mesozoic and rarely Paleozoic volcanic belts. The rare preservation of older deposits reflects rapid rates of erosion before burial of subaerial volcanoes in tectonically active arcs. **In Yukon, high sulphidation epithermal deposits and occurrences of the Wheaton District are associated with Eocene volcanic rocks. Deposits of the Mt. Nansen-Laforma area are associated with Cretaceous volcanic rocks.**

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HOST/ASSOCIATED ROCK TYPES: Volcanic pyroclastic and flow rocks, commonly subaerial andesite to dacite and rhyodacite, and their subvolcanic intrusive equivalents. Permeable sedimentary intervolcanic units can be sites of mineralization.

DEPOSIT FORM: Veins and massive sulphide replacement pods and lenses, stockworks and breccias. Commonly irregular deposit shapes are determined by host rock permeability and the geometry of ore-controlling structures. Multiple, crosscutting composite veins are common.

TEXTURE/STRUCTURE: Vuggy 'slaggy' silica derived as a residual product of acid leaching is characteristic. Drusy cavities, banded veins, hydrothermal breccias, massive wallrock replacements with fine-grained quartz.

ORE MINERALOGY (Principal and *subordinate*): pyrite, enargite/luzonite, chalcocite, covellite, bornite, gold, electrum; *chalcopyrite, sphalerite, tetrahedrite/tennantite, galena, marcasite, arsenopyrite, silver sulphosalts, tellurides including goldfieldite.* Two types of ore are commonly present: massive enargite-pyrite and/or quartz-alunite-gold.

GANGUE MINERALOGY (Principal and *subordinate*): Pyrite and quartz predominate. Barite may also occur; carbonate minerals are absent.

ALTERATION MINERALOGY (Principal and *subordinate)*: Quartz, kaolinite/dickite, alunite, barite, hematite; sericite/illite, amorphous clays and silica, pyrophyllite, andalusite, diaspore, corundum, tourmaline, *dumortierite, topaz, zunyite, jarosite, Al-P sulphates (hinsdalite, woodhouseite, crandalite, etc*.) and native sulphur. Advanced argillic alteration is characteristic and can be areally extensive and visually prominent. Quartz occurs as fine-grained replacements and, characteristically, as vuggy, residual silica in acid-leached rocks.

WEATHERING: Weathered rocks may contain abundant limonite (jarosite-goethite-hematite), generally in a groundmass of kaolinite and quartz. Fine-grained supergene alunite veins and nodules are common.

ORE CONTROLS: In volcanic edifices - caldera ring and radial fractures; fracture sets in resurgent domes and flow-dome complexes, hydrothermal breccia pipes and diatremes. Faults and breccias in and around intrusive centres. Permeable lithologies, in some cases with less permeable cappings of hydrothermally altered or other cap rocks. The deposits occur over considerable depths, ranging from high-temperature solfataras at paleosurface down into cupolas of intrusive bodies at depth.

GENETIC MODEL: Recent research, mainly in the southwest Pacific and Andes, has shown that these deposits form in subaerial volcanic complexes or composite island arc volcanoes above degassing magma chambers. The deposits can commonly be genetically related to high-level intrusions. Multiple stages of mineralization are common, presumably related to periodic tectonism with associated intrusive activity and magmatic hydrothermal fluid generation.

ASSOCIATED DEPOSIT TYPES: Porphyry Cu±Mo±Au deposits (L04), subvolcanic Cu-Ag-Au (As-Sb) (L01), epithermal Au-Ag deposits: low sulphidation type (H05), silica-clay-pyrophyllite deposits (Roseki deposits) (H09), hotspring Au-Ag (H03), placer Au deposits (C01,C02).

COMMENTS: High-sulphidation epithermal Au-Ag deposits are much less common in the Canadian Cordillera than low-sulphidation epithermal veins. However, they are the dominant type of epithermal deposit in the Andes. **In Yukon, high sulphidation epithermal deposits are more common than low-sulphidation.**

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Au, Cu, As dominate; also Ag, Zn, Pb, Sb, Mo, Bi, Sn, Te, W, B and Hg.

GEOPHYSICAL SIGNATURE: Magnetic lows in hydrothermally altered (acid-leached) rocks; gravity contrasts may mark boundaries of structural blocks.

OTHER EXPLORATION GUIDES: These deposits are found in second order structures adjacent to crustal-scale fault zones, both normal and strike-slip, as well as local structures associated with

subvolcanic intrusions. The deposits tend to overlie and flank porphyry copper-gold deposits and underlie acid-leached siliceous, clay and alunite-bearing 'lithocaps'.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: There is wide variation in deposit types ranging from bulk-mineable, low-grade to selectively mined, high-grade deposits. Underground mines range in size from 2 to 25 Mt with grades from 178 g/t Au, 109 g/t Ag and 3.87% Cu in direct smelting ores (El Indio) to 2.8 g/t Au and 11.3 g/t Ag and 1.8% Cu (Lepanto). Open pit mines with reserves of <100 Mt to >200 Mt range from Au-Ag mines with 3.8 g/t Au and 20 g/t Ag (Pueblo Viejo, Dominica) to ore bodies such as the Nansatsu deposits, Japan that contain a few million tonnes ore grading between 3 and 6 g/t Au. Porphyry Au (Cu) deposits can be overprinted with late-stage acid sulphate alteration zones which can contain in the order of ~1.5 g/t Au with 0.05 to 0.1% Cu in stockworks (Marte and Lobo) or high-grade Cu-Ag-Au veins (La Grande veins, Collahausi). More typically these late stage alteration zones carry <0.4 to 0.9 g/t Au and >0.4 to 2% Cu (Butte, Montana; Dizon, Philippines). **In Yukon, individual deposits are smaller than 1 Mt, but groups of deposits in epithermal camps such as in the Mt. Nansen and Wheaton River areas may be economically viable.**

ECONOMIC LIMITATIONS: Oxidation of primary ores is commonly necessary for desirable metallurgy; primary ores may be refractory and can render low-grade mineralization noneconomic.

IMPORTANCE: This class of deposits has recently become a focus for exploration throughout the circum-Pacific region because of the very attractive Au and Cu grades in some deposits. Silica-rich gold ores (3-4 g/t Au) from the Nansatsu deposits in Japan are used as flux in copper smelters.

SELECTED BIBLIOGRAPHY

Albino, G.V., 1994. Time-pH-fO_2 Paths of Hydrothermal Fluids and the Origin of Quartz-Alunite-Gold Deposits; *United States Geological Survey*, Bulletin 2081, pages 33-42.

Berger, B.R., 1986. Descriptive Model of Epithermal Quartz-Alunite Au; *in* Mineral Deposit Models, Cox, D.P. and Singer, D.A, Editors, U.S. *Geological Survey*, Bulletin 1693, page 158.

Hart, C., 1992. Skukum Creek property. *In:* Yukon Exploration 1991, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 27-34.

Henley, R.W., 1991. Epithermal Gold Deposits in Volcanic Terranes; *in* Gold Metallogeny and Exporation, R.P. Foster, Editor, *Blackie and Sons Ltd*, Glasgow, pages 133-164.

Lowe, D.A., 1989. Geology of the epithermal Mount Skukum gold deposit, Yukon Territory. GSC Open File 2123.

McDonald, B.W.R. , Godwin, C.I. and Stewart, E.B., 1986. Geology and genesis of the Mount Skukum epithermal gold-silver deposit, southwest Yukon Territory. *In:* Yukon Geology, Volume 1, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, , p. 11-18

McInnes, B., 1987. Geological and precious metal evolution at Freegold Mountain, Dawson Range, Yukon. Unpublished M.Sc. thesis, McMaster University, Hamilton, Ontario.

Mosier, D.L. and Menzie, W.D., 1986. Grade and Tonnage Model of Epithermal Quartz-Alunite Au, *in* Mineral Deposit Models, Cox, D.P. and Singer, D.A., Editors, U.S. *Geological Survey*, Bulletin 1693, page 158.

Panteleyev, A., 1991. Gold in the Canadian Cordillera - A Focus on Epithermal and Deeper Environments. *In:* Ore Deposits, Tectonics and Metallogeny in the Canadian Cordillera, *B. C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1991-4, pages 163-212.

Saager, R. and Bianconi, F., 1971. The Mount Nansen gold-silver deposits. Mineralium Deposita, Volume 6, p. 209-224.

Sillitoe, R.H., 1993. Epithermal Models: Genetic Types, Geometric Controls and Shallow Features; *Geological Association of Canada*, Special Volume 40, pages 403-417.

Stroshein, R. , 1999. A summary report on the geology of the Brown-McDade gold-silver deposit, Mount Nansen mine area, Yukon. ***In:*** **Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 231-236.**

White, N.C., 1991. High Sulfidation Epithermal Gold Deposits: Characteristics and a Model for their Origin; *in* High-temperature Acid Fluids and Associated Alteration and Mineralization, *Geological Survey of Japan*, Report No. 277, pages 9-20.

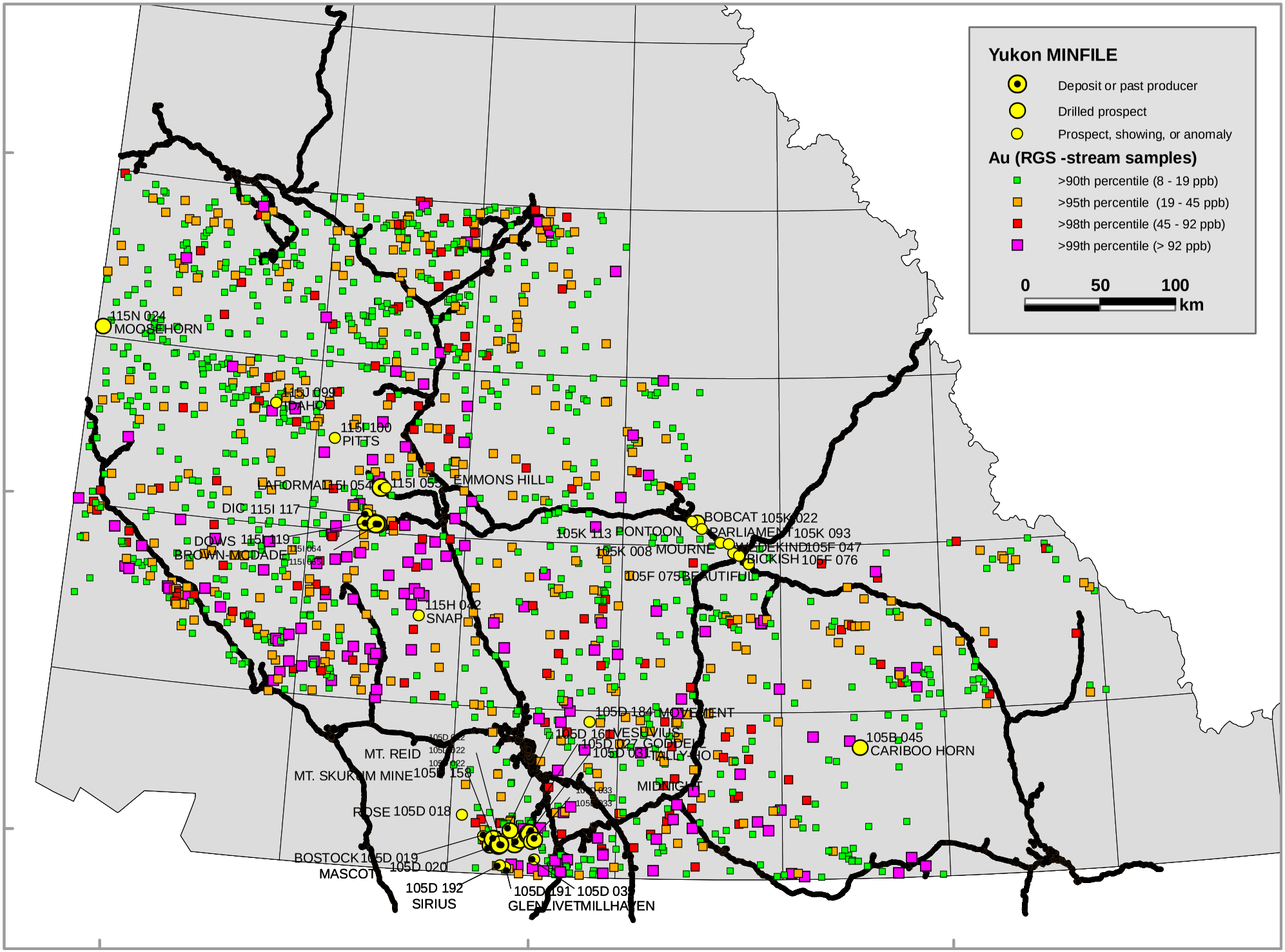
White, N.C. and Hedenquist, J.W., 1990. Epithermal Environments and Styles of Mineralization: Variations and their Causes, and Guidelines for Exploration. *In:* Epithermal Gold Mineralization of the Circum-Pacific: Geology, Geochemistry, Origin and Exploration, II, Hedenquist, J.W. , White, N.C. and Siddeley, G., Editors, *Journal of Exploration Geochemistry*, Volume 36, pages 445-474.

H04 - High sulphidation epithermal Au-Ag-Cu - BC and Yukon deposits

Deposit	Country	tonnes	Au (g/t)	Ag (g/t)	Cu %	Pb %	Zn %
WHEATON MOUNTAIN	CNYK	4 535	17.10	34.30	0.00	0.00	0.00
DUSTY	CNBC	93 392	6.49	112.99	0.00	0.00	0.00
MOUNT NANSEN	CNYK	109 000	5.90	268.00	0.00	0.00	0.00
BAKER	CNBC	120 449	17.87	269.67	0.00	0.00	0.00
METS	CNBC	144 000	11.30	0.00	0.00	0.00	0.00
MT. SKUKUM (CIRQUE)	CNYK	149 000	25.00	20.50	0.00	0.00	0.00
VAULT	CNBC	152 000	14.00	0.00	0.00	0.00	0.00
LAFORMA	CNYK	152 261	5.62	0.00	0.00	0.00	0.00
GOLD WED	CNBC	329 000	24.90	201.20	0.00	0.00	0.00
BLACKDOM	CNBC	368 343	21.48	78.86	0.00	0.00	0.00
GOLDEN	CNBC	500 000	2.70	0.00	0.00	0.00	0.00
LAWYERS	CNBC	528 337	8.42	168.29	0.00	0.00	0.00
NEW MOON	CNBC	609 900	0.99	15.43	0.00	0.00	0.00
BROWN MC-DADE	CNYK	617 000	6.02	53.40	0.00	0.00	0.00
MT SKUKUM (BRANDY & LAKE)	CNYK	915 100	16.50	0.00	0.00	0.00	0.00
SHASTA	CNBC	1 071 033	4.09	217.50	0.00	0.00	0.00
SULPHUR	CNBC	1 437 000	11.50	783.60	0.00	0.00	0.00
SILBAK	CNBC	7 065 528	9.03	188.92	0.03	0.40	0.14
CINOLA	CNBC	23 800 000	2.47	3.10	0.00	0.00	0.00

Yukon MINFILE

MINFILE	NAMES	STATUS
105D 030	TALLY-HO	UNDERGROUND PAST PRODUCER
115I 064	BROWN-MCDADE	OPEN PIT PAST PRODUCER
115N 024	LONGLINE, MOOSEHORN	OPEN PIT PAST PRODUCER
105D 022	MT. REID, SKUKUM CREEK, COMBINATION	DEPOSIT
105D 025	GODDELL	DEPOSIT
105D 031	WHEATON MOUNTAIN	DEPOSIT
105K 009	GREW CREEK, MAIN ZONE	DEPOSIT
115I 054	LAFORMA	DEPOSIT
115I 065	MOUNT NANSEN, WEBBER, HUESTIS	DEPOSIT
105B 045	SHOOTAMOOK	DRILLED PROSPECT
105D 168	DICKSON HILL, ODD	DRILLED PROSPECT
105F 075	BEAUTIFUL	DRILLED PROSPECT
105K 022	BOBCAT	DRILLED PROSPECT
105K 113	PONTOON	DRILLED PROSPECT
115I 055	EMMONS HILL	DRILLED PROSPECT
115I 119	DOWS	DRILLED PROSPECT
105D 192	SIRIUS	PROSPECT
105K 008	MOURNE	PROSPECT
105D 191	GLENLIVET	SHOWING
115H 042	SNAP	SHOWING
115I 100	PITTS	SHOWING
105K 093	PARLIAMENT, 400 ZONE	ANOMALY
105F 076	BICKISH	UNKNOWN
105K 015	EYE, CANYON, RAN	UNKNOWN
105K 107	WEDEKIND, ERN	UNKNOWN



Map of Yukon showing high sulphidation epithermal occurrences and Au regional geochemistry