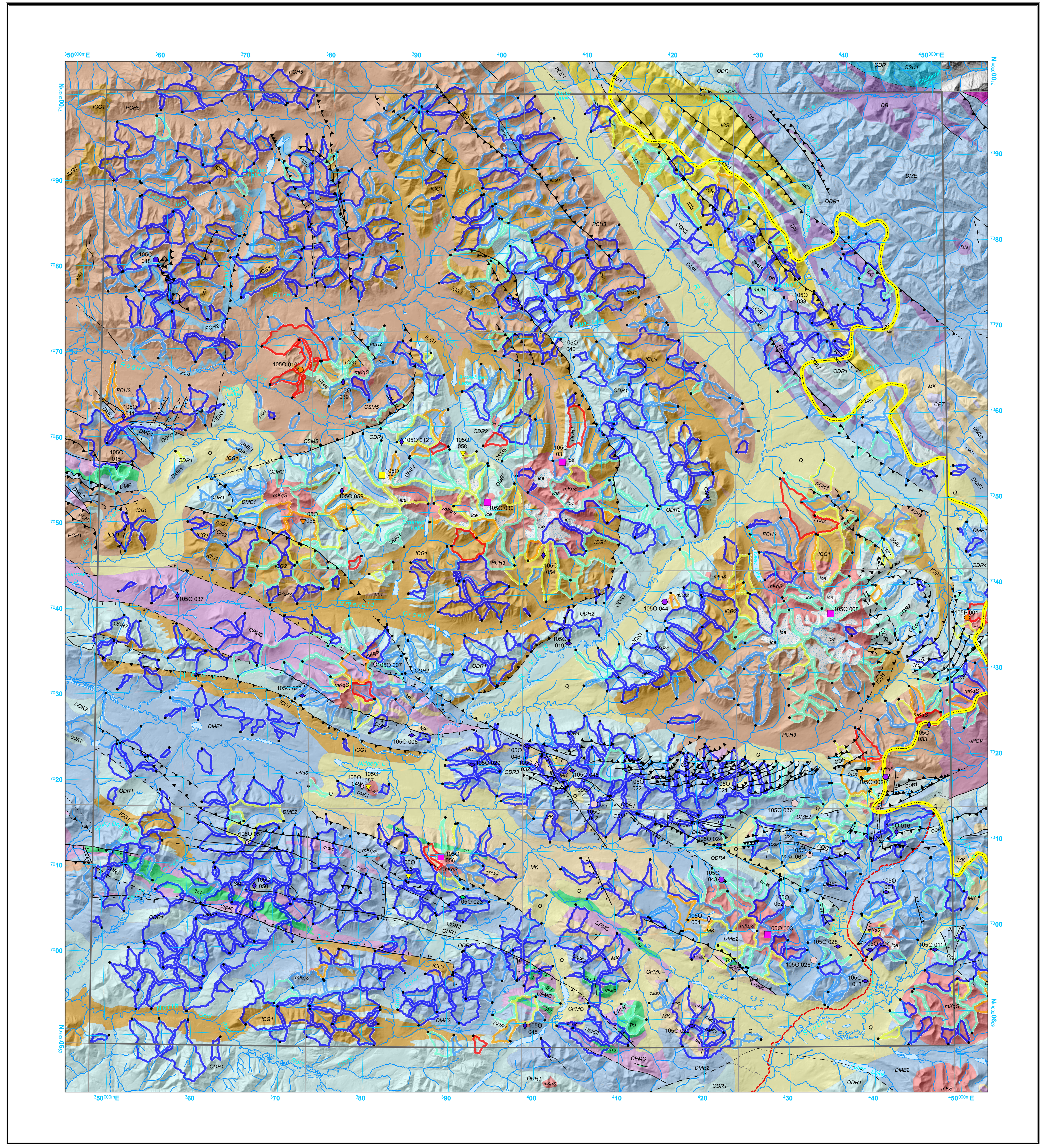
Yukon Geological Survey

Heberlein Geoconsulting
Extracting value from geochemistry

Yukon
Energy, Mines and Resources



Weighted Sums Modelling

The application of Weighted Sums Modelling (WSM) to exploration geochemistry was described by Garrett and Grunsky (2001) as a means to model multi-element data using a priori knowledge of the mineralogy and element composition of the sought after mineral deposit (Kane, 1977; Garrett et al., 1980). In this procedure weights or relative importances are assigned to each variable, or a subset of variables, according to some geochemical or mineralogical model of the target mineral deposit type or geological process. Weighted sums (WS) are new variables calculated from the multi-element geochemical results. Like Principal Components Analysis (PCA) or Factor Analysis scores, WS scores have the form of normal or standardized scores with a mean of zero and a standard deviation of one. The main difference between WSM and traditional multivariate statistical methods is that the user assigns the variable weightings rather than determining them with a covariance/correlation matrix for the dataset, as is done in PCA. Furthermore WSM is a robust statistical technique that is not influenced by the presence of outliers (Beckman & Cook, 1983).

The reader is referred to Garrett and Grunsky (2001) for a description of the WS calculation. In summary, relative importance is assigned for each variable. A weighting of 3, for example, means that that particular element is three times more important than an element with a weighting of one. Weighting can be positive or negative. Positive weightings mean that the target model is associated with elevated concentrations of an element. Negative weightings indicate that low concentrations or depletions of an element are important.

Individual relative importance is converted into weights that sum to one by dividing each importance by the sum of the absolute values of importance (i.e., ignoring the negative signs). A requirement of the method is that the sums of the squares of the final weights also equal one. This is achieved by dividing each weight by the square root of the sum of the squares of the weights.

The next step involves calculation of the normal scores for the variables included in the model for each individual sample. To do this, robust estimates of the mean and standard deviation are used. The median (or 50th percentile) is used as a robust estimate of the mean and the inter-quartile range (IQR) multiplied by 0.7413 is used as a robust estimate of the standard deviation. IQR is the difference between the 75th and 25th percentiles of the data distribution and therefore covers a band of data 25% wide (or 0.67449 standard deviation units) on either side of the mean. The constant 0.7413 is used to convert the IQR, which covers a range of 1.3490 standard deviation units to an equivalent standard deviation[1]. Weighted sums are then calculated by multiplying the normal scores for each element by the element's corresponding weight and summing for each sample. The high resistance of the median and IQR to outliers mean that it is not usually necessary to trim outlier and far outliers from the dataset before calculation.

[1] For a normal distribution the standard deviation is equal to 0.7413*IQR, where 0.7413 is the reciprocal of 1.349.

Models and Weightings

Six mineral deposit types (SEDEX, Porphyry Cu, W-Skarn, IRCG, Polymetallic veins and Carlin) that are either known or believed to occur in the map sheet areas and one geochemical process (hydromorphic dispersion) are modeled using the WS method. Included elements and their relative importance are presented in Table 1.

Data Presentation

Results of each WS model are attached to the corresponding catchment basin polygons using a spatial join in ArcGIS. This process allows for the entire polygon to be assigned a colour based on its WS score. Colours are assigned on the basis of the following percentile breaks:

0-50% Dark blue
50-75% Pale blue
75-90% Pale green
90-95% Yellow
95-98% Orange
98-100% Red

With this scheme, catchment basins with the hotter colours represent samples with geochemical characteristics consistent with the mineralization style being modelled.

Table 1: Table of Relative Importances used to calculate weighted sums models

Deposit Type	Ag	Au	As	Ba	Bi	Cd	Co	Cu	Cs	Fe	Hg	K	Mn	Mo	Ni	Pb	S	Sb	Tl	W	Zn
Polymetallic Veins	4	4	3			4	1	2		1	1		1	1	1	5		3			5
W-Skarn			3		3					1		3		3						5	1
Porphyry Cu	2	2			1			5	3					3			2				
Intrusive Related Cu-Au	1	2	5		5			2		1	5		1	2		1		1		2	
SEDEX				5		3									1	5		1	5		5
Carlin	2	1	5	2							4							5			
Hydromorphic Dispersion	2		1			4	5	2		5			5	2	4	2		1			3

LEGEND

Regional Geochemistry Sample (RGS) location

National Topographic System grid (1:250 000 scale)

National Topographic System grid (1:50 000 scale)

Yukon-Northwest Territories border

highway, paved

highway, unpaved

local road, unpaved

watercourse

waterbody

wetland

Bi (Levelled)

WSM Percentiles: WSM Score, Number of RGS Samples

0 - 50%: -2.160 - -0.215, 476 samples

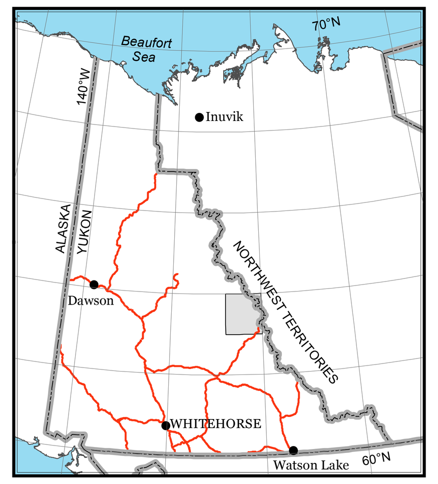
50 - 75%: -0.214 - 0.315, 235 samples

75 - 90%: 0.316 - 1.234, 138 samples

90 - 95%: 1.235 - 1.913, 46 samples

95 - 98%: 1.914 - 2.920, 26 samples

98 - 100%: 2.921 - 6.492, 17 samples



1:250 000-scale topographic base data produced by CENTRE FOR TOPOGRAPHIC INFORMATION, NATURAL RESOURCES CANADA

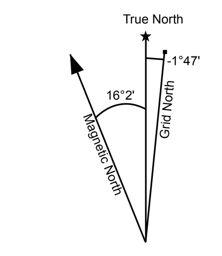
ONE THOUSAND METRE GRID
Universal Transverse Mercator Projection
North American Datum 1983
Zone 9

CONTOUR INTERVAL 100 METRES
Elevations in metres above Mean Sea Level

WEIGHTED SUMS MODEL AND GEOLOGY
Bi (LEVELLED)
YUKON

SCALE 1:250 000

0 1 2 3 4 5
kilometres



Use diagram only to obtain numerical values
APPROXIMATE MEAN DECLINATION 2013
FOR CENTRE OF MAP

106C NADALEEN RIVER	106B BONNET PLUME LAKE	106A MOUNT EDUNI
105N LANSING RANGE	105O THIS MAP	105P SEKWI MOUNTAIN
105K TAY RIVER	105J SHELDON LAKE	105I LITTLE NAHANNI RIVER

QUATERNARY

Q — QUATERNARY: unconsolidated glacial, glaciofluvial and glaciolacustrine deposits; fluviatile silt, sand, and gravel, and local volcanic ash, in part with cover of soil and organic deposits

MID-CRETACEOUS

mKS — SELWYN SUITE: plutonic suite of intermediate (g) to more felsic composition (q); equivalent felsic dikes

mKgS — SELWYN SUITE: resistant, blocky, fine to coarse grained equigranular to porphyritic (K-feldspasr) biotite quartz monzonite and granodiorite and minor quartz diorite; minor leuco-quartz monzonite and syenite

mKqS — SELWYN SUITE: equigranular to porphyritic (K-feldspar) biotite hornblende muscovite granite, quartz monzonite and granodiorite; porphyritic biotite hornblende granite with large smoky grey quartz phenocrysts and locally K-feldspar phenocrysts

MIDDLE TO UPPER TRIASSIC

TrJ — JONES LAKE: brown to buff weathering, calcareous fine-grained sandstone, argillite, and shale; extensive ripple cross-lamination and bioturbation; massive,light grey weathering, fine crystalline, dark grey limestone; minor orange weathering platy limestone

CARBONIFEROUS TO PERMIAN

CPMC — MOUNT CHRISTIE: burrowed, interbedded greenish grey cherty shale and green shale; thin to medium bedded, light grey-green to black chert; black siliceous slate and siltstone; minor quartzite, limestone and dolostone; locally abundant, large grey barite nodules

CPT — TSICHU: thin to medium-bedded siliceous calcarenite, dolostone, sandy dolostone and minor grey quartzite; buff and grey weathering, thick bedded, dark grey bioclastic limestone; black to silvery shale; minor chert, and chert pebble conglomerate

MISSISSIPPIAN

MK — KENO HILL: massive to thick-bedded quartz arenite; thin to medium-bedded quartz arenite interstratified with black shale or carbonaceous phyllite; local scour surfaces and shale intraclasts; locally foliated and lineated

DEVONIAN AND MISSISSIPPIAN

DME — EARN: complex assemblage of submarine fan and channel deposits (1) or within black siliceous shale and chert (2); barite common, and many occurrences of stratiform Pb-Zn

DME1 — EARN: thin bedded, laminated slate with thin to thickly interbedded fine to medium-grained chert-quartz arenite and wacke; thick members of chert pebble conglomerate; black siliceous siltstone; nodular and bedded barite; rare limestone

DME2 — EARN: silvery blue weathering black shale, argillite, cherty argillite and thin bedded chert; nodular and bedded barite; rare limestone

ORDOVICIAN TO LOWER DEVONIAN

ODR — ROAD RIVER - SELWYN: black shale and chert (1) overlain by orange siltstone (2) or buff platy limestone (3); locally contains beds as old as Middle Cambrian (4); correlations with basinal strata in Richardson Mountains include: ODR1 with CDR2 (upper part) and ODR2 with CDR4

ODR1 — ROAD RIVER - SELWYN: black, gun-blue, or silvery white weathering black graptolitic shale and black chert; resistant grey weathering, thin to medium bedded, light grey to black, greenish grey or turquoise chert; minor argillaceous limestone

ODR2 — ROAD RIVER - SELWYN: rusty dark green to orange buff weathering, pyritic, burrowed, thin to thick bedded, argillite and dolomitic siltstone with members or partings of black shale and chert; minor bright orange dolostone

ODR3 — ROAD RIVER - SELWYN: blue-grey weathering, black limestone; tan, buff, or dark grey weathering platy, silty limestone

ODR4 — ROAD RIVER - SELWYN: black shale; limestone, limestone conglomerate, and interstratified argillite and pale yellow limestone

CAMBRIAN TO SILURIAN

CSM — MARMOT: lower Paleozoic mostly mafic volcanics, in locally thick accumulations (1) - (6) but also of common occurrence as undifferentiated thin scattered members within other units

CSM1 — MARMOT: resistant, dark grey weathering, massive, locally pillowed, dark grey-green basalt, tuff and breccia

CSM5 — MARMOT: massive brown to green, basic lapilli tuff, breccias, flows, sills, and dikes; intraclast breccia and conglomerate; brown weathering, green to grey, medium to very thick-bedded volcaniclastic sandstone

UPPER CAMBRIAN AND ORDOVICIAN

COR1 — RABBITKETTLE: thin bedded, wavy banded, silty limestone and grey lustrous calcareous phyllite; limestone intraclast breccia and conglomerate; massive to laminated, grey quartzose siltstone and chert and rare black slate; local mafic flows, breccia, and tuff

COR2 — RABBITKETTLE: as in COR1, but may include Middle Cambrian and Middle Ordovician beds undivided

LOWER CAMBRIAN

ICG1 — GULL LAKE: shale, siltstone, and mudstone, locally bioturbated, with minor quartz sandstone; rare green-grey chert; local basal limestone and limestone conglomerate; phyllite to quartz-muscovite-biotite schist (garnet, sillimanite, staurolite, andalusite)

ICG2 — GULL LAKE: dark green massive to fragmental mafic metavolcanic and volcaniclastic rocks; siltstone and argillite

UPPER PROTEROZOIC TO LOWER CAMBRIAN

PCH — HYLAND: consists upwards of coarse turbiditic clastics (1), limestone (2), and fine clastics typified by maroon and green shale (3); includes scattered mafic volcanic rocks (5)

PCH1 — HYLAND: thin to thick-bedded, brown to pale green shale, fine to coarse-grained quartz-rich sandstone, grit, and quartz pebble conglomerate; minor argillaceous limestone; phyllite, quartzofeldspathic and micaceous psammite, gritty psammite, and minor marble

PCH2 — HYLAND: grey weathering, dark grey to grey white, thin to thick bedded, very fine crystalline limestone, locally sandy; calc-silicate and marble; may locally include carbonate members within (1) or (4)

PCH3 — HYLAND: distinctive, recessive, maroon weathering, interbedded maroon and apple-green slate; "Oldhamia" trace fossils; rare grey chert; locally basal member and interbeds of quartz siltstone, sandstone and quartz-pebble conglomerate

PCH5 — HYLAND: dark brown and green to light grey weathering, dark green volcanic rocks, commonly with calcite filled vesicles, breccia, tuff, and agglomerate; minor interbedded shale, chert, siltstone, and limestone

MIDDLE DEVONIAN

DH1 — HUME: buff-brown weathering argillaceous to silty, dark grey, fine-grained limestone, platy to thin bedded; minor intercalated irregularly banded orange weathering dolostone and thin beds of resistant; orange-brown weathering limestone; richly fossiliferous

DH2 — HUME: massive, thick-bedded, fine to medium-grained, light grey weathering limestone

DH4 — HUME: buff-orange weathering, thin to medium-bedded silty limestone

DL — LANDRY: thin to very thick bedded, resistant, light grey weathering, medium to light grey and brownish crypto-grained limestone; massive and thick-bedded bioclastic, locally reefoid limestone; black, platy limestone

DN — NATLA: dark grey weathering, platy, thin bedded, recessive sooty limestone, in part crinoidal; uncommon beds of massive crinoidal limestone

DA — ARNICA: thin and thick-bedded dark grey to black commonly laminated dolostone; minor light grey dolostone and light grey to medium grey weathering dark grey to black limestone; striped dolostone; local massive vuggy breccia

UPPER LOWER TO LOWER MIDDLE DEVONIAN

DB — GRIZZLY BEAR: limestone, white grey weathering, cliff forming, blocky partings, massive, fine to medium crystalline; scattered corals, brachiopods, bryozoans, and twin canal echinoderm ossicles

LOWER DEVONIAN

lDS — SOMBRE: light and medium grey, even bedded, fine-grained dolostone; silver-grey dolostone; locally three members of light grey dolostone (lower); dark grey dolostone, in part crinoidal (middle); alternating light and dark grey dolostone (upper)

UPPER SILURIAN TO LOWER DEVONIAN

SDD — DELORME: buff to orange weathering, well bedded, buff, light grey, brownish grey and dark grey, very fine grained dolostone; platy to flaggy, wavy banded blue-grey silty limestone with rare thin beds of buff weathering dolostone

UPPER CAMBRIAN TO SILURIAN

CSH — HAYWIRE: undivided medium to thick-bedded, white to dark-grey dolostone, locally cherty; rare amygdaloidal basalt and tuff; basal member of grey-white dolostone, quartz arenite, and maroon mudstone

UPPER ORDOVICIAN AND SILURIAN

OSK2 — KINDLE: thick-bedded, black, coarse-grained dolostone and interbedded grey weathering laminated dolostone with nodules and bands of black chert; medium grey weathering, platy, grey argillaceous limestone with minor chert shale; massive and reefoid dolostone

OSK4 — KINDLE: thick bedded to massive light grey dolostone and limestone; dark grey, fetid limestone; includes undifferentiated beds as young as Lower Devonian

MIDDLE ORDOVICIAN

OS — SUNBLOOD: mainly buff, rouge and light grey weathering platy dolostone and limestone; local interbedded light and dark grey fine crystalline and white coarse crystalline dolostone at base; rare thick beds of light blue-grey limestone

UPPER CAMBRIAN AND ORDOVICIAN

COF2 — FRANKLIN MOUNTAIN: well banded, rhythmically bedded, grey and buff-orange dolostone; includes grey to black dolostone and dark grey to black limestone; local basal member of maroon dolostone and sandstone, silver-grey sandstone, and sandy dolostone

MIDDLE CAMBRIAN

mCH — HESS RIVER: shale, black, pyritic, unfossiliferous; occurs as interstratified thick units of black calcareous shale and rusty black shale

mCR — ROCKSLIDE: recessive, dark grey weathering, laminated, platy calcareous shale, and silty, dark grey fine to crypto-grained limestone; minor thin beds of light brown to grey weathering platy dark crypto-grained limestone and rare bands of buff dolostone

LOWER CAMBRIAN

lCS — SEKWI: limestone, locally wavy bedded and nodular; limestone conglomerate slope breccia; massive grey dolostone; medium to thick-bedded quartz sandstone; purple siltstone; bright orange weathering, fine crystalline dolostone

UPPER PROTEROZOIC TO LOWER CAMBRIAN

uPCV — VAMPIRE: dark brown weathering. thin-bedded, argillaceous fine-grained sandstone and siltstone, minor interbedded medium to coarse-grained white to light grey orthoquartzite; phyllite, slate, and argillite

PCB1 — BACKBONE: light grey, red-brown, white, and pink, thick-bedded, medium to coarse-grained orthoquartzite; minor brown or maroon phyllite, platy siltstone, silty shale, thin-bedded fine-grained quartzite, grey limestone, and sandy to pebbly limestone

fault, defined, movement undefined
fault, defined, normal/reverse
fault, defined, thrust, upright
fault, approximate, movement undefined
fault, approximate, normal/reverse
fault, approximate, thrust, upright
fault, approximate, dextral
fault, assumed, movement undefined
fault, assumed, thrust, upright
fault, extrapolated, movement undefined
fault, extrapolated, normal/reverse
fault, extrapolated, thrust, upright
fault, extrapolated, dextral

Table 2: List of Mineral Occurrences for NTS map sheets 105O and part of 105P

OCCURRENCE #	OCCURRENCE NAME	ALIAS(ES)	DEPOSIT TYPE	STATUS	ECONOMIC COMMODITIES	OTHER COMMODITIES
105O 001	TOM		Sedimentary Exhalative Zn-Pb-Ag (Sedex)	Deposit	Pb, Ag, Zn, Ba	Sb, barite, Cu
105O 002	MACTUNG		W Skarn	Deposit	W	Cu
105O 003	JEFF		Porphyry Mo (Low F-Type)	Showing		Mo
105O 004	ALP		Au-Quartz Veins	Showing		Au, Ag
105O 005	NIDDERY		Plutonic Related Au	Prospect		barite, Cd, Cu, Au, Ni, Ag
105O 006	SCOT		Sedimentary Exhalative Zn-Pb-Ag (Sedex)	Drilled Prospect		Cu, Ni, Ag, Zn
105O 007	ART		Au-Quartz Veins	Prospect		Sb, As, Bi, Au, Pb, Ag
105O 008	KEELE		Porphyry Mo (Low F-Type)	Showing		Mo
105O 009	EMERALD		Porphyry-related Au	Showing		Bi, Cu, Au, Mo, Ag, W
105O 010	HORN		Cu Skarn	Prospect		Cu, Au
105O 011	BEN		Sedimentary Exhalative Zn-Pb-Ag (Sedex)	Showing		Pb, Zn
105O 012	ARROWHEAD		Polymetallic Veins Ag-Pb-Zn+/-Au	Showing		Cu, Pb, Zn
105O 013	RACICOT		Sediment-Hosted Barite	Deposit	barite	Zn
105O 015	INCA		Polymetallic Veins Ag-Pb-Zn+/-Au	Past Producer	Ag	Pb, Zn
105O 016	STANDARD		Polymetallic Veins Ag-Pb-Zn+/-Au	Showing		Pb, Ag, Zn
105O 018	ODD		Mississippi Valley-Type Pb-Zn (MVT)	Drilled Prospect		Pb, Ag, Zn
105O 019	JASON		Sedimentary Exhalative Zn-Pb-Ag (Sedex)	Deposit	Pb, Ag, Zn	barite
105O 020	SAMOVAR	TEA	Sediment-Hosted Barite	Deposit	barite	
105O 021	WALT	BAR	Sediment-Hosted Barite	Deposit		barite, Cu, Pb, Ag, Zn
105O 022	TRYALA		Sediment-Hosted Barite	Drilled Prospect		barite, Ba, Cu, Pb, Ag, Zn
105O 023	DRIZZLE	RAIN	Shale-Hosted Ni-Zn-Mo-PGE (Nick)	Showing		barite, Cu, Pb, Mo, Ni, V, Zn
105O 024	NIDD		Sedimentary Exhalative Zn-Pb-Ag (Sedex)	Drilled Prospect		barite, Ag, Zn
105O 025	BREMNER		Unknown	Drilled Prospect		Cu, Pb, Zn
105O 026	DICKIE		Sedimentary Exhalative Zn-Pb-Ag (Sedex)	Unknown		Cu, Pb, Mo, Zn
105O 027	GARY	GARGANTUA	Sediment-Hosted Barite	Deposit	barite	
105O 028	FETCH		Sediment-Hosted Barite	Drilled Prospect		barite, Zn
105O 029	GOW	TH	Sedimentary Exhalative Zn-Pb-Ag (Sedex)	Anomaly		barite
105O 030	GRIZZ		Porphyry Mo (Low F-Type)	Showing		Au, Mo, Ag, W
105O 031	VAN ANGEREN		Porphyry Mo (Low F-Type)	Showing		Mo
105O 032	NEVE	BRICK	Au-Quartz Veins	Drilled Prospect		Sb, Au, Ag, Zn
105O 033	KELVIN	BORD	Polymetallic Veins Ag-Pb-Zn+/-Au	Prospect		Sb, Au, Pb, Ag
105O 036	FAN		Unknown	Showing		barite
105O 037	LONER		Barite Veins	Showing		Ba
105O 038	DUET		Unknown	Anomaly		Zn
105O 039	OLD CABIN		Polymetallic Veins Ag-Pb-Zn+/-Au	Showing		Cu, Au, Pb, Mo, Ag
105O 040	URSA		Unknown	Anomaly		Cu
105O 041	FANGO		Polymetallic Veins Ag-Pb-Zn+/-Au	Prospect		Sb, Au, Pb, Ag, Zn
105O 042	FAL		Unknown	Unknown		
105O 043	SIM		W Skarn	Showing		Pb, W, Zn
105O 044	NUT		W Skarn	Showing		Cu, Pb, Ag, W, Zn
105O 045	STROSHEIN		Sediment-Hosted Barite	Showing		barite
105O 046	MINORCO		Sediment-Hosted Barite	Showing		barite
105O 048	NUKE		Polymetallic Veins Ag-Pb-Zn+/-Au	Showing		Sb, As, Bi, Cu, Au, Pb, Ag
105O 049	FAENZI		Au-Quartz Veins	Showing		As, Au
105O 050	NORTH MACMILLAN		Barite Veins	Showing		
105O 051	DALL	HARLAN	Au-Quartz Veins	Prospect		Cu, Au
105O 052	BAILES		Unknown	Unknown		Cu, Au, Pb, Ag, Zn
105O 054	ROGUE		Polymetallic Veins Ag-Pb-Zn+/-Au	Prospect		Au, Pb, Ag, Zn
105O 055	CHRISTINA		Subvolcanic Cu-Au-Ag (As-Sb)	Showing		Cu, Au, Ag
105O 056	GOLD		Porphyry Mo (Low F-Type)	Anomaly		
105O 057	STUMP	NID	Plutonic Related Au	Showing		As, Cu, Au, Pb, Ag
105O 058	LM		Plutonic Related Au	Drilled Prospect		Cu, Au, Ag
105O 059	SCRONK		Polymetallic Veins Ag-Pb-Zn+/-Au	Showing		Sb, Bi, Cu, Au, Ag, Zn
105O 060	HASTEN		Unknown	Drilled Prospect		Zn
105O 061	FUN		Unknown	Anomaly		Pb, Zn
105P 001	MEHITABEL		Cu Skarn	Drilled Prospect		Au

Mineral Occurrence Deposit Type (Total on map)

Au-Quartz Veins (5)
Barite Veins (2)
Cu Skarn (2)
Mississippi Valley-Type Pb-Zn (MVT) (1)
Plutonic Related Au (3)
Polymetallic Veins Ag-Pb-Zn+/-Au (9)
Porphyry Mo (Low F-Type) (5)
Porphyry-related Au (1)
Sediment-Hosted Barite (8)
Sedimentary Exhalative Zn-Pb-Ag (Sedex) (7)
Shale-Hosted Ni-Zn-Mo-PGE (Nick) (1)
Subvolcanic Cu-Au-Ag (As-Sb) (1)
Unknown (7)
W Skarn (3)

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RECOMMENDED CITATION

HEBERLEIN, D., 2013. Yukon Geochemistry Weighted Sums Model for NTS 105O and parts of 105P: Bi (Levelled). Yukon Geological Survey, Open File 2013-16, 116 sheets. Scale 1:250 000.

Digital cartography by J.O. Bruce, Yukon Geological Survey.

Any revisions or additional geological information known to the user would be welcomed by the Yukon Geological Survey.

Paper copies of this map and the accompanying report may be purchased from Yukon Geological Survey, Energy, Mines and Resources, Government of Yukon, Room 102 - 300 Main St., Whitehorse, Yukon, Y1A 2B5. Ph. 867-667-3201, Email geosales@gov.yk.ca.

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Funding for this project was provided by the Canadian Northern Economic Development Agency (CanNor) through their Strategic Investments in Northern Economic Development initiative.

Yukon Geological Survey
Energy, Mines and Resources
Government of Yukon

Open File 2013-16

Yukon Geochemistry Weighted Sums Model and Geology for NTS 105O and parts of 105P: Bi (Levelled) (1:250 000 scale)

by

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Agence canadienne de développement économique du Nord