MISSISSIPPI VALLEY-TYPE (MVT) Pb-Zn E12

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Refer to preface for general references and formatting significance.
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IDENTIFICATION

SYNONYMS: Alpine-type Pb-Zn, Appalachian Zn, Low-temperature epigenetic Pb-Zn.

RELATED DEPOSIT TYPE: Irish-type Zn-Pb (E13) is classified with MVT deposits in some studies.

COMMODITIES (BY-PRODUCTS): Pb, Zn, ± Ag (Cd, Ge, barite, fluorite)

EXAMPLES: **(Yukon): Goz (106C 020), Blende (106D 064), Craig (106C 073);** (British Columbia - *Canada/ International*): Robb Lake (94B005), Monarch (82N020), Kicking Horse (82N282); *Nanisivik, Pine Point, Polaris (Northwest Territories), Gays River (Nova Scotia), Newfoundland Zinc (Newfoundland) / Mascot-Jefferson City, Copper Ridge district (Tennessee, United States), Old Lead Belt and Viburnum Trend (Missouri, United States), Tri-State (Oklahoma, Kansas and Missouri, United States), Harberton Bridge (Ireland), Upper Silesia (Poland), Raibl, Bleiberg (Austria)*

GEOLOGICAL CHARACTERISTICS

CAPSULE DESCRIPTION: Epigenetic, low-temperature, stratabound deposits of galena, sphalerite, pyrite and marcasite, with associated dolomite, calcite and quartz gangue in platformal carbonate sequences having primary and secondary porosity.

TECTONIC SETTINGS: Most commonly stable interior cratonic platform or continental shelf. Some deposits are incorporated in foreland thrust belts.

DEPOSITIONAL ENVIRONMENT / GEOLOGIC SETTING: Host rocks form in shallow water, particularly tidal and subtidal marine environments. Reef complexes may be developed on or near paleotopographic basement highs. The majority of deposits are found around the margins of deep-water shale basins; some are located within or near rifts (Nanisivik, Alpine district).

AGE OF MINERALIZATION: Proterozoic to Tertiary, with two peaks in Devonian to Permian and Cretaceous to Eocene time. Dating mineralization has confirmed the epigenetic character of these deposits; the difference between host rock age and mineralization age varies from district to district. **Known Yukon deposits are hosted in Proterozoic strata, but true mineralization ages of these epigenetic deposits are poorly constrained.**

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HOST / ASSOCIATED ROCK TYPES: Host rocks are most commonly dolostone, limestone, or dolomitized limestone. Locally hosted in sandstone, conglomerate or calcareous shale. **In Yukon, MVT deposits are hosted in Proterozoic to Paleozoic carbonate rocks of the North American margin: Goz is hosted by dolomite of the Proterozoic Backbone Ranges Formation; the Val and Blende deposits are hosted by Middle Proterozoic Gillespie Group dolomite; and Craig is hosted by dolomite within a late Proterozoic shale unit.**

DEPOSIT FORM: Highly irregular. May be peneconcordant as planar, braided or linear replacement bodies. May be discordant in roughly cylindrical collapse breccias. Individual ore bodies range from a few tens to a few hundreds of metres in the two dimensions parallel with bedding. Perpendicular to bedding, dimensions are usually a few tens of metres. Deposits tend to be interconnected thereby blurring deposit boundaries.

TEXTURE / STRUCTURE: Most commonly as sulphide cement to chaotic collapse breccia. Sulphide minerals may be disseminated between breccia fragments, deposited as layers atop fragments (“snow-on-roof”), or completely filling the intra-fragment space. Sphalerite commonly displays banding, either as colloform cement or as detrital layers (“internal sediments”) between host-rock fragments. Sulphide stalactites are abundant in some deposits. Both extremely fine-grained and extremely coarse-grained textured sulphides minerals may be found in the same deposit. Precipitation is usually in the order pyrite (marcasite) → sphalerite → galena.

ORE MINERALOGY (Principal and *subordinate*): Galena, sphalerite, *barite, fluorite*. Some ores contain up to 30ppm Ag. Although some MVT districts display metal zoning, this is not a common feature. The Southeast Missouri district and small portions of the Upper Mississippi Valley district are unusual in containing significant amounts of Ni-, Co-, and Cu-sulphides.

GANGUE MINERALOGY (Principal and *subordinate*): Dolomite (can be pinkish), pyrite, marcasite, *quartz, calcite, gypsum***.**

ALTERATION MINERALOGY: Extensive finely crystalline dolostone may occur regionally, whereas coarse crystalline dolomite is more common close to ore bodies. Extensive carbonate dissolution results in deposition of insoluble residual components as internal sediments. Silicification (jasperoid) is closely associated with ore bodies in the Tri-State and northern Arkansas districts. Authigenic clays composed of illite, chlorite, muscovite, dickite and/or kaolinite accumulate in vugs; minor authigenic feldspar (adularia).

WEATHERING: Extensive development of smithsonite, hydrozincite, willemite, and hemimorphite, especially in non-glaciated regions (including upstanding hills or monadnocks). Large accumulations of secondary zinc minerals can be mined. Galena is usually much more resistant to weathering than sphalerite. Iron-rich gossans are not normally well-developed, even over pyrite-rich deposits.

ORE CONTROLS: Any porous unit may host ore; porosity may be primary (rare) or secondary. Dissolution collapse breccias are the most common host although fault breccias, permeable reefs, and slump breccias may also be mineralized. Dissolution collapse breccias may form through action of meteoric waters or hydrothermal fluids. Underlying aquifers may be porous sandstone or limestone aquifers; the limestones may show thinning due to solution by ore-bearing fluids.

GENETIC MODELS: Deposits are obviously epigenetic, having been emplaced after host rock lithification. Ore-hosting breccias are considered to have resulted from dissolution of more soluble sedimentary units, followed by collapse of overlying beds. The major mineralizing processes appear to have been open-space filling between breccia fragments, and replacement of fragments or wall rock. The relative importance of these two processes varies widely among, and within, deposits. Fluid inclusion data show that these deposits formed from warm (75°- 200°C), saline, aqueous solutions similar in composition to oil-field brines. Brine movement out of sedimentary basins, through aquifers or faults, to the hosting structures is the most widely accepted mode of formation. Two main processes have been proposed to move ore solutions out of basin clastics and into carbonates:

A. Compaction-driven fluid flow is generated by over-pressuring of subsurface aquifers by rapid sedimentation, followed by rapid release of basinal fluids.
B. Gravity-driven fluid flow flushes subsurface brines by artesian groundwater flow from recharge areas in elevated regions of a foreland basin, to discharge areas in regions of lower elevation.

In addition to fluid transport, three geochemical mechanisms have been proposed to account for chemical transport and deposition of ore constituents:

1. Mixing - Base metals are transported by fluids of low sulphur content. Precipitation is effected by mixing with fluids containing hydrogen sulphide; replacement of diagenetic iron sulphides; and/or reaction with sulphur released by thermal degradation of organic compounds.
2. Sulphate reduction - Base metals are transported together with sulphate in the same solution. Precipitation is the result of reduction of sulphate by reaction with organic matter or methane.
3. Reduced sulphur - Base metals are transported together with reduced sulphur. Precipitation is brought about by change in pH, dilution, and/or cooling.

ASSOCIATED DEPOSIT TYPES: Fracture-controlled, fluorine-dominant deposits (with subordinate Ba, Pb, and Zn) such as those of Illinois-Kentucky, the English Pennines and the Tennessee Sweetwater F-Ba-Pb-Zn district (E10, E11). "Irish-type carbonate-hosted Zn-Pb" (E13) is described as a separate deposit type in the BC Mineral Deposit Profiles, others regard these deposits as a variant of MVT deposits. In the latter case, they are viewed as a sub-group of MVT deposits which are associated with tensional regimes and rifts. Oxide zinc deposits have evolved from weathering and alteration of MVT deposits (Skorpion, Berg Aukas, Namibia: B09).

COMMENTS: British Columbia has prospective strata for MVT deposits in the miogeoclinal carbonate platform rocks along its eastern border. MVT deposits are distinct from syngenetic carbonate-hosted Pb-Zn deposits (Mt. Isa, Australia; E14) and high-temperature epigenetic deposits or mantos (Midway, British Columbia; Santa Eulalia, Mexico; J01).

EXPLORATION GUIDES

GEOCHEMICAL SIGNATURE: Readily detectable positive anomalies of Zn in residual soils and stream sediments. Regionally anomalous amounts of Pb, Zn, Cu, Mo, Ag, Co, Ni, Cd, Mg, F in insoluble residues of carbonate rocks. Background lithogeochemical concentrations for unmineralized carbonates: Pb = 9 ppm; Zn = 20; Cu = 4; Ag = 0.01.

GEOPHYSICAL SIGNATURE: Deposits may be detected by IP, resistivity, gravity and EM (CS-AMT/AFMAG) systems. Test seismic lines have yielded ambiguous results. In southeast Missouri magnetic and gravimetric surveys have been used to outline basement topographic highs (knobs) which control the distribution of favourable sites of deposition.

OTHER EXPLORATION GUIDES: Reef complexes in platformal carbonate successions. Proximal to, or updip from, petroleum fields in large (continental-scale) sedimentary basins. Peripheral to basement highs. Aligned along basement lineaments.

ECONOMIC FACTORS

TYPICAL GRADE AND TONNAGE: Data for individual deposits are difficult to obtain because deposits tend to be interconnected. Most deposits are small and fall in the range 1 to 10 Mt. Grades generally range between 5% to 10% combined lead-zinc, with a majority being decidedly zinc rich (Zn/Zn+Pb = 0.8). Silver content is not commonly reported since it typically occurs only in solid solution in base metal sulphides. MVT deposits tend to occur in clusters, usually referred to as districts. The Pine Point district , for example, contains more than 80 deposits, the Upper Mississippi Valley district more than 400. Deposits in such districts, therefore, can collectively contain extremely large tonnages. Of more than 80 deposits in the Pine Point district, 40 were mined for a total production of 80 Mt grading 6.5% Zn and 3% Pb. The largest deposit (X15) was 17.4 Mt and the richest deposit (N81) produced 2.7 Mt of ore grading 12% Zn and 7% Pb. The Robb Lake deposit in British Columbia contains 5.3 Mt grading 5.0% Zn and 2.3% Pb. **The Craig deposit of Yukon has a geological resource of 964 500 tonnes averaging 13.5% Pb, 8.5% Zn and 123.4 g/t Ag. The Blende deposit contains a geological resource of 19.4 million tonnes grading 55.9 g/t Ag and 5.85% Pb-Zn.**

ECONOMIC LIMITATIONS: Mining districts may extend over many hundreds of square kilometres, increasing mining costs (stripping, haulage to mill, etc.). One of the more favourable attributes of MVT deposits is the normally large grain size, resulting in good mineral separation and high metal recoveries (typical zinc recovery exceeds 90%). Recovery is especially high in deposits with little or no pyrite (Newfoundland Zinc, Gays River and the east and central Tennessee districts).

IMPORTANCE: Metal production from MVT districts can be similar to production from giant stratiform, sediment-hosted (SEDEX) deposits. The Tri-State district was one of the world's major producers of lead during the 20th century, yielding 500 Mt of ore. The Viburnum Trend produced over 123 Mt grading 5.8% Pb,
0.8% Zn, 0.14% Cu and 17 g/t Ag between 1960 and 1984.

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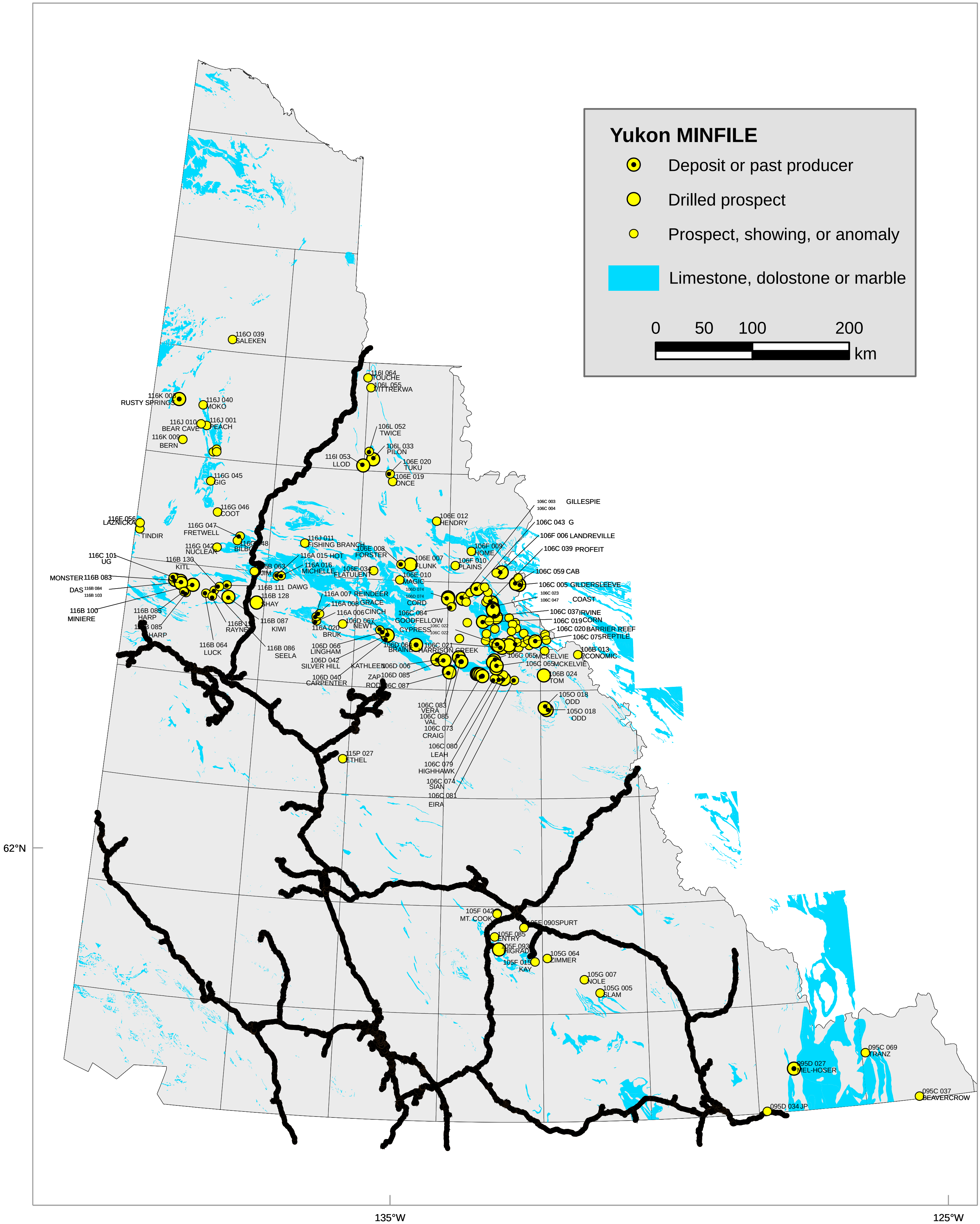
E12 - Mississippi Valley Type Zn-Pb-Ag - World Deposits

Deposit	Country	tonnes	Zn (%)	Pb (%)	Ag (g/t)
CENTRAL MISSOURI	USMO	1 000 000	0.60	2.00	0
N ARKANSAS-OZARK	USAR	1 090 000	2.00	0.12	0
MONARCH	CNBC	1 490 000	5.10	4.67	27.4
NEWFOUNDLAND ZINC	CNNF	4 900 000	7.70	0.00	0
ROBB LAKE	CNBC	5 500 000	5.00	2.30	0
NANISIVIK	CNNT	6 400 000	11.50	1.20	0
FRIEDENSVILLE	USPA	17 900 000	6.10	0.00	0
KENTUCKY-ILLINOIS	USKY	22 000 000	4.00	0.70	1
POLARIS-ECLIPSE	CNNT	23 600 000	14.00	4.30	34
METALLINE	USWA	36 000 000	2.50	1.10	1.4
AUSTINVILLE	USVA	36 400 000	3.90	0.80	0
GAYNA RIVERL	CNNT	58 200 000	4.79	0.60	2.25
ALPINE	AAIY	85 400 000	6.10	1.50	0
PINE POINT	CNNT	95 500 000	6.20	2.50	0

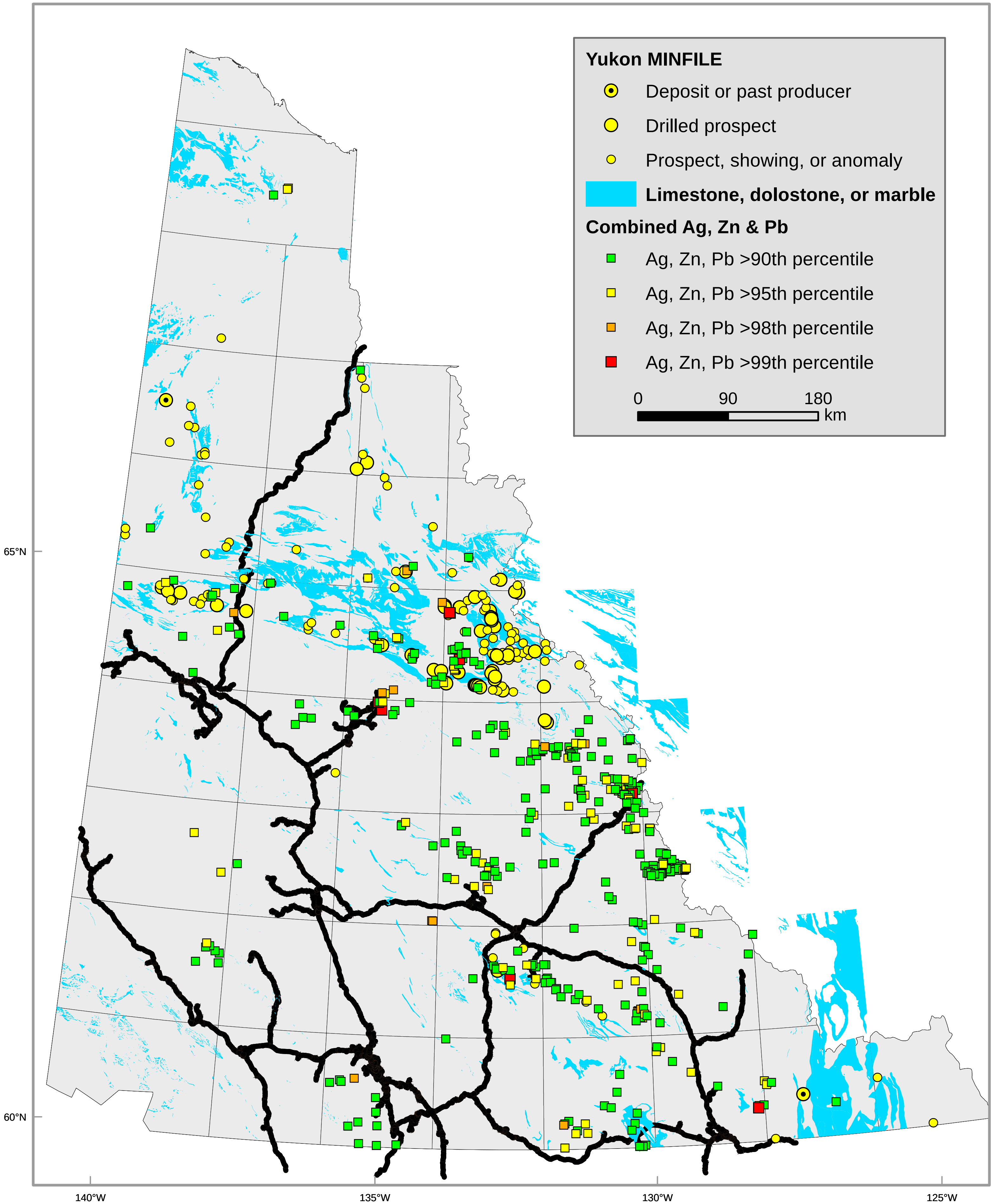
Yukon MINFILE

MINFILE	NAMES	STATUS
106C 020	GOZ, BARRIER REEF	DEPOSIT
106C 073	CRAIG	DEPOSIT
106C 085	VAL	DEPOSIT
106D 064	BLENDE, BRAINE	DEPOSIT
105O 018	ODD	DRILLED PROSPECT
106B 024	BIRKELAND, TOM, MOM	DRILLED PROSPECT
106C 005	GILDERSLEEVE	DRILLED PROSPECT
106C 019	CORN	DRILLED PROSPECT
106C 021	HARRISON, HARRISON CREEK	DRILLED PROSPECT
106C 022	CYPRESS	DRILLED PROSPECT
106C 023	COB, CORN CREEK PROPERTY	DRILLED PROSPECT
106C 037	FRIGSTAD, IRVINE	DRILLED PROSPECT
106C 038	SPECTROAIR	DRILLED PROSPECT
106C 039	PROFEIT	DRILLED PROSPECT
106C 043	DOWSER, G	DRILLED PROSPECT
106C 044	LEARY	DRILLED PROSPECT
106C 054	GAL	DRILLED PROSPECT
106C 059	CAB	DRILLED PROSPECT
106C 065	MCKELVIE	DRILLED PROSPECT
106C 074	SIAN	DRILLED PROSPECT
106C 075	REPTILE	DRILLED PROSPECT
106D 006	KATHLEEN	DRILLED PROSPECT
106D 042	SILVER HILL	DRILLED PROSPECT
106D 074	CORD	DRILLED PROSPECT
106D 085	ZAP	DRILLED PROSPECT
106E 007	FLUNK	DRILLED PROSPECT
106F 006	LANDREVILLE	DRILLED PROSPECT
106L 033	PILON	DRILLED PROSPECT
116B 083	MONSTER	DRILLED PROSPECT
116B 084	TART	DRILLED PROSPECT
116B 087	KIWI	DRILLED PROSPECT
116B 100	MINIERE	DRILLED PROSPECT
116B 128	REIN	DRILLED PROSPECT
116I 053	LLOD	DRILLED PROSPECT
116K 003	RUSTY SPRINGS, TERMUENDE	DRILLED PROSPECT
106C 026	NEST, BAR	PROSPECT
106C 027	TOPOROWSKI	PROSPECT
106C 031	GENTRY	PROSPECT
106C 046	CANWEX	PROSPECT
106C 050	BOB	PROSPECT
106D 040	CARPENTER	PROSPECT
106E 008	FORSTER	PROSPECT
106E 020	TUKU	PROSPECT
106E 034	FLATULENT	PROSPECT
106F 007	COLLEY	PROSPECT
106F 010	PLAINS	PROSPECT
116A 015	HOT	PROSPECT
116J 041	WART	PROSPECT
116O 039	SALEKEN	PROSPECT
095D 027	JONI, MEL EAST, MEL-HOSER	SHOWING
105F 015	KAY	SHOWING
105F 085	ENTRY	SHOWING
105G 007	PLUMB, NOLE	SHOWING
105G 064	ZIMMER, NEW	SHOWING
106B 014	ANDY	SHOWING
106B 015	NECO	SHOWING
106B 030	MARTHA	SHOWING
106C 003	GILLESPIE	SHOWING

MINFILE	NAMES	STATUS
106C 024	ZOG	SHOWING
106C 025	GOODMAN	SHOWING
106C 030	GUS	SHOWING
106C 032	CADET	SHOWING
106C 034	LOG	SHOWING
106C 036	MOUSE	SHOWING
106C 040	POO	SHOWING
106C 041	CARNE	SHOWING
106C 042	DAN	SHOWING
106C 047	COAST	SHOWING
106C 056	ENVOY	SHOWING
106C 062	DUNE	SHOWING
106C 063	SNAKE	SHOWING
106C 077	JAM	SHOWING
106C 078	BLUSSON	SHOWING
106C 079	HIGHHAWK	SHOWING
106C 080	LEAH	SHOWING
106C 088	SUPERDAVE	SHOWING
106D 066	LINGHAM	SHOWING
106D 067	NEWT	SHOWING
106E 010	MAGIC	SHOWING
106E 012	HENDRY	SHOWING
106E 019	ONCE	SHOWING
106F 003	VYE	SHOWING
106F 009	HOME	SHOWING
106L 052	TWICE	SHOWING
106L 055	VITTREKWA	SHOWING
115P 027	ETHEL	SHOWING
116A 016	MICHELLE	SHOWING
116A 020	BRUK	SHOWING
116B 085	OZ, HARP	SHOWING
116B 086	SEELA, KIM	SHOWING
116B 130	TOLBERT, KITL	SHOWING
116C 101	UGLY, UG	SHOWING
116F 015	TINDIR	SHOWING
116F 056	LAZNICKA	SHOWING
116G 042	NUCLEAR	SHOWING
116G 046	COOT	SHOWING
116G 047	FRETWELL	SHOWING
116G 048	BILBO	SHOWING
116J 001	PEACH	SHOWING
116J 011	FISHING BRANCH	SHOWING
116J 040	MOKO	SHOWING
116J 043	YUM	SHOWING
116J 044	BULLIS	SHOWING
116K 009	BERN	SHOWING
095C 069	TRANZ	ANOMALY
095D 034	JP	ANOMALY
106C 028	ANGLO	ANOMALY
106C 029	MONITOR, PLU	ANOMALY
106C 033	CARDIGAN	ANOMALY
106C 035	KENDAL	ANOMALY
106C 051	BRANDON	ANOMALY
106C 058	TAPIN	ANOMALY
106C 081	EIRA	ANOMALY
116B 110	RAYNER, BRX	ANOMALY
116B 111	DAWG	ANOMALY
116G 045	GIG	ANOMALY
116J 010	BEAR CAVE	ANOMALY



Map of Yukon illustrating the distribution of carbonate rocks and possible MVT type occurrences



Map of Yukon illustrating the distribution of carbonate rocks, possible MVT style occurrences and combined Ag, Zn and Pb regional geochemistry