# WERNECKE BRECCIA D07

(**Profile name changed from "iron oxide breccias and veins P-Cu-Au-Ag-U"; no longer includes magnetite-apatite deposits – see Hitzman, 2000**)

by David V. Lefebure[1]
**Modified for Yukon by A. Fonseca and then J. A. Hunt (in progress)**
**Refer to preface for general references and formatting significance.**
**May 30, 2005**

## *IDENTIFICATION*

SYNONYMS: Proterozoic iron oxide (Cu-U-Au-REE), Olympic Dam type, iron oxide-rich deposits.

COMMODITIES (*BYPRODUCTS*): Fe, Cu, Au, Ag, U (*potential for REE, Co, Ba, F*).

EXAMPLES: **(Yukon): Slab (106D 070)**;
(British Columbia - *Canada/International*): *Ernest Henry (Australia), Olympic Dam (Australia), Candelaria (Chile), Salobo (Brazil), Aitik (Sweden).*

## *GEOLOGICAL CHARACTERISTICS*

CAPSULE DESCRIPTION: Low $TiO_2$ magnetite- and/or hematite-rich mineralization ± Cu ± Co ± Au ± U ± REE occurs as veins and disseminations. **Wernecke Breccia vein and disseminated mineralization occurs within and peripheral to breccia bodies.**

TECTONIC SETTING: Intracratonic extensional tectonics. Upper crustal sedimentary rocks (presence of evaporites may be important) and/or igneous rocks.

DEPOSITIONAL ENVIRONMENT/ GEOLOGICAL SETTING: Found crosscutting a wide variety of sedimentary and igneous rocks; spatially associated with regional-scale faults. **Wernecke Breccias cut Lower Proterozoic sedimentary rocks ± igneous rocks and are spatially associated with regional- and local-scale faults.**

AGE OF MINERALIZATION: Proterozoic to Tertiary commonly roughly coeval with spatially associated igneous rocks. **Wernecke Breccia is *ca.* 1.6 Ga.**

HOST/ASSOCIATED ROCK TYPES: Veins and breccias crosscut, or are conformable with, a wide variety of continental sedimentary and volcanic rocks and intrusive stocks, including felsic volcanic breccia, tuff, clastic sedimentary rocks and granites. There may be a spatial association with a igneous rocks (check recent work by Pollard). Fe oxides have been reported as common accessories in the associated igneous rocks. In some deposits the Fe oxide forms the matrix to heterolithic breccias which are composed of lithic and oxide clasts (commonly hematite fragments), hematite-quartz microbreccia and fine-grained massive breccia. Some deposits have associated hematite-rich breccias. **Bodies of Wernecke Breccia were emplaced into Early Proterozoic Wernecke Supergroup marine sedimentary rocks that are crosscut by small mafic to intermediate dykes and sills of the Bonnet Plume River Intrusions suite; minor amounts of mafic to intermediate subaerial volcanic rocks (Slab volcanics) are also present locally in the host rock package.**

[1] British Columbia Geological Survey, Victoria, B.C., Canada

DEPOSIT FORM: Discordant pod-like zones, veins (dyke-like), tabular bodies and stockworks.

TEXTURE/STRUCTURE: Cu-U-Au mineralization is typically hosted in the Fe-oxide matrix as disseminations with associated microveinlets and sometimes rare mineralized clasts. Textures indicating replacement and microcavity filling are common. Intergrowths between minerals are common. Hematite and magnetite may display well developed crystal forms, such as interlocking mosaic, tabular or bladed textures. Some of the deposits (typically hematite-rich) are characterized by breccias at all scales with Fe oxide and host rock fragments which grade from weakly fractured host rock on the outside to matrix-supported breccia (sometimes heterolithic) with zones of 100% Fe oxide in the core. Breccias may be subtle in hand sample as the same Fe oxide phase may comprise both the fragments and matrix. Breccia fragments are generally angular and have been reported to range up to more than 10 m in size, although they are frequently measured in centimetres. Contacts with host rocks are frequently gradational over scale of centimetres to metres. **Wernecke Breccias vary from cm to km size; clasts vary from centimetres to several hundred metres; metallic minerals occur as veins, disseminations, breccia clasts, and/or form the breccia matrix. Copper-uranium-gold-cobalt minerals occurs within and/or spatially separate from iron-oxide minerals. Multiple phases of mineralization and brecciation are evident.**

ORE MINERALOGY (Principal and *subordinate*): Hematite-magnetite deposits with varying amounts of Cu sulphides, Au, Ag, uranium minerals and REE (Olympic Dam type). Hematite (variety of forms), specularite, magnetite, bornite, chalcopyrite, chalcocite, pyrite; *digenite, covellite, native copper, carrolite, cobaltite, Cu-Ni-Co arsenates, pitchblende, coffinite, brannerite, bastnaesite, monazite, xenotime, florencite, native silver and gold and silver tellurides.* At Olympic Dam, Cu is zoned from a predominantly hematite core (minor chalcocite-bornite) to chalcocite-bornite zone then bornite-chalcopyrite to chalcopyrite-pyrite in the outermost breccia. Uraninite and coffinite occur as fine-grained disseminations with sulphide minerals; native gold forms fine grains disseminated in matrix and inclusions in sulphide minerals. Bastnaesite and florencite are very fine grained and occur in matrix as grains, crystals and crystal aggregates. **Wernecke Breccia: chalcopyrite is the dominant copper mineral; uranium occurs mainly as pitchblende and brannerite; cobalt occurs as cobaltian pyrite; gold values are generally associated with copper mineralization.**

GANGUE MINERALOGY (Principal and *subordinate*): Gangue occurs intergrown with ore minerals, as veins or as clasts in breccias. Sericite, carbonate, chlorite, quartz, fluorite, barite, and sometimes minor *rutile and epidote*. Hematite breccias are frequently cut by 1 to 10 cm veins with fluorite, barite, siderite, hematite and sulphides.

ALTERATION MINERALOGY (Principal and *subordinate*): A variety of alteration assemblages with differing levels of intensity are associated with these deposits, commonly with broad lateral extent. Olympic Dam type: Intense sericite and hematite alteration with increasing hematite towards the centre of the breccia bodies at higher levels. Close to the deposit the sericitized feldspars are rimmed by hematite and cut by hematite veinlets. Adjacent to hematite breccias the feldspar, rock flour and sericite are totally replaced by hematite. Chlorite or K-feldspar alteration predominates at depth. **Wernecke Breccia: associated with extensive sodic and/or potassic alteration overprinted by carbonate alteration.**

WEATHERING: Supergene enrichment of Cu and U. **Wernecke Breccia: malacite ± azurite staining; cobalt bloom; pitchblende and minor uranium bloom.**

ORE CONTROLS : Strong structural control with emplacement along faults or contacts, particularly narrow grabens. Mid-Proterozoic rocks particularly favourable hosts. Hydrothermal activity on faults with extensive brecciation. May be associated with felsic volcanic and alkalic igneous rocks. In some deposits calderas and maars have been identified or postulated. Deposits may form linear arrays more than 100 km long and 40 km wide with known deposits spaced 10-30 km along trend. **Wernecke Breccia: formed in weak and/or permeable zones e.g., faults, shear zones, fold axes; strong spatial relationship to regional- and local-scale faults.**

ASSOCIATED DEPOSIT TYPES: Volcanic-hosted U (D06)?; alkaline porphyry Cu-Au deposits (L03); supergene uranium veins.

COMMENTS: Hitzman *et al.* (1992) emphasize that these are low-Ti iron deposits, generally less than 0.5% $TiO_2$ and rarely above 2% $TiO_2$ which allows distinction from Fe oxides associated with anorthosites, gabbros and layered mafic intrusions. Fe and Cu sulphide minerals may be more common with hematite Fe oxides.

## *EXPLORATION GUIDES*

GEOCHEMICAL SIGNATURE: Anomalously high values for Cu, U, Au, Ag, Ce, La, Co, ± P, ± F, and ± Ba in associated rocks and in stream sediments.

GEOPHYSICAL SIGNATURE: Large positive gravity anomalies because of Fe oxides. Regional aeromagnetic anomalies related to magnetite and/or coeval igneous rocks. Radiometric anomaly (such as airborne gamma-ray spectrometer survey) expected with polymetallic deposits containing uranium.

OTHER EXPLORATION GUIDES: Proterozoic faulting with associated Fe oxides (particularly breccias), possibly related to intracratonic rifting. Widespread hematite, sericite or chlorite alteration related to faults. Possibly form linear arrays 100 or more kilometres long and up to tens of kilometres wide. **In Yukon, many occurrences are proximal to ca. 1.71 Ga Bonnet Plume River Intrusions (e.g., Hunt et al., 2002).**

## *ECONOMIC FACTORS*

TYPICAL GRADE AND TONNAGE : Deposits may exceed 1000 Mt grading greater than 20 % Fe and frequently are in 100 to 500 Mt range. Olympic Dam deposit has estimated reserves of 2000 Mt grading 1.6% Cu, 0.06% $U_3O_8$, 3.5 g/t Ag and 0.6 g/t Au with a measured and indicated resource in a large number of different ore zones of 450 Mt grading 2.5% Cu, 0.08 % $U_3O_8$, 6 g/t Ag and 0.6 g/t Au with ~5000 g/t REE. The Ernest Henry deposit in Australia contains 100 Mt at 1.6% Cu and 0.8 g/t Au. Sue-Dianne deposit in the Northwest Territories contains 8 Mt averaging 0.8% Cu and 1000 g/t U and locally significant gold. The Kiruna district contains more than 3000 Mt of Fe oxide apatite ore grading 50-60% Fe and 0.5 -5 % P. The largest orebody at Bayan Obo deposit in Inner Mongolia, China contains 20 Mt of 35 % Fe and 6.19% REE. **The Pagisteel deposit in Yukon contains 0.9 Mt grading 29.2% Fe.**

ECONOMIC LIMITATIONS: Larger Fe oxide deposits may be mined for Fe only; however, polymetallic deposits are more attractive. **Exploration in the Wernecke Breccia district of northern Yukon is hindered by remoteness and poor infrastructure, as most occurrences are more than 100 km from the nearest major road.**

IMPORTANCE: These deposits continue to be significant producers of Fe and represent an important deposit type for producing Cu, U and possibly REE. **Mineralization in the Wernecke Breccia district in northern Yukon is believed to be temporally and spatially associated with the giant Olympic Dam deposit in Australia.**

ACKNOWLEDGEMENTS: This deposit profile represents the results of a literature review. The only "ground truthing" is thanks to instructive conversations with Sunil Gandhi of the Geological Survey of Canada and Tom Setterfield of Westminer Canada Ltd.

## *SELECTED BIBLIOGRAPHY*

**Archer, A.R. and Schmidt, U., 1978. Mineralized breccias of Early Proterozoic age, Bonnet Plume River District, Yukon Territory. CIM Bulletin, vol. 71, p. 53-58.**

**Brideau, M-A., Thorkelson, D.J., Godin, L. and Laughton, J.R., 2002. Paleoproterozoic deformation of the Racklan Orogeny, Slats Creek (106D/16) and Fairchild Lake (106C/13) map areas, Wernecke Mountains, Yukon. *In:* Yukon Exploration and Geology 2001, D.S. Emond, L.H. Weston and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p.65-72.**

Cox, D.P., 1986. Descriptive Model of Olympic Dam Cu-U-Au; *in* Mineral Deposit Models, Cox, D.P. and Singer, D.A., Editors, *U.S. Geological Survey*, Bulletin 1693, 379 pages.

Einaudi, M.T. and Oreskes, N., 1990. Progress Toward an Occurrence Model for Proterozoic Iron Oxide Deposits - A Comparison Between the Ore Provinces of South Australia and Southeast Missouri; *in* The Midcontinent of the United States - Permissive Terrane for an Olympic Dam Deposit?, Pratt, W.P. and Sims, P.K. Editors, *U. S. Geological Survey*, Bulletin 1392, pages 589-69.

Gandhi, S.S., 1994. Geological Setting and Genetic Aspects of Mineral Occurrences in the Southern Great Bear Magmatic Zone, Northwest Territories; *in* Studies of Rare-metal Deposits in the Northwest Territories, Sinclair, W.D. and Richardson, D.G, Editors, *Geological Survey of Canada*, Bulletin 475, pages 63-96.

Gandhi, S.S. and Bell, R.T., 1993. Metallogenetic Concepts to Aid in Exploration for the Giant Olympic Dam Type Deposits and their Derivatives; Proceedings of the Eighth Quadrennial IAGOD Symposium, in Ottawa, Ontario, August 12-18, 1990, International Asssociation on the Genesis of Ore Deposits, Maurice, Y.T., Editor, *Schweizerbar'sche Verlagsbuchhandlung*, Stutggart, pages 787-802.

Hauck, S.A., 1990. Petrogenesis and Tectonic Setting of Middle Proterozoic Iron Oxide-rich Ore Deposits; An Ore Deposit Model for Olympic Dam Type Mineralization; *in* The Midcontinent of the United States - Permissive Terrane for an Olympic Dam Deposit?, Pratt, W.P. and Sims, P.K. Editors, *U. S. Geological Survey*, Bulletin 1932, pages 4-39.

Hildebrand, R.S., 1986. Kiruna-type Deposits: Their Origin and Relationship to Intermediate Subvolcanic Plutons in the Great Bear Magmatic Zone, Northwest Canada; *Economic Geology*, Volume 81, pages 640-659.

Hitzman, M. W., Oreskes, N. and Einaudi, M. T., 1992. Geological Characteristics and Tectonic Setting of Proterozoic Iron Oxide (Cu-U-Au-REE) Deposits; *Precambrian Research*, Volume 58, pages 241-287.

**Hunt, J.A., Laughton, J.R., Brideau, M., Thorkelson, D.J., Brookes, M.L. and Baker, T., 2002. New mapping around the Slab iron oxide-copper-gold occurrence, Wernecke Mountains (parts of NTS 106C/13, 106D/16, 106E/1 and 106F/4), Yukon. *In:* Yukon Exploration and Geology 2001, D.S. Emond, L.H. Weston and L.L. Lewis (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 125-138**.

Laznicka, P. and Gaboury, D., 1988. Wernecke Breccias and Fe, Cu, U Mineralization: Quartet Mountain-Igor Area (NTS 106E); *in* Yukon Exploration and Geology, *Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada*, pages 42-50.

Oreskes, N. and Einaudi, M.T., 1990. Origin of Rare Earth-enriched Hematite Breccias at the Olympic Dam Deposit, Roxby Downs, South Australia; *Economic Geology*, Volume 85, pages 1-28.

Parak, T., 1975. Kiruna Iron Ores are not "Intrusive-magmatic Ores of the Kiruna Type"; *Economic Geology*, Volume 68, pages 210 -221.

Reeve, J.S., Cross, K.C., Smith, R.N. and Oreskes, N., 1990. Olympic Dam Copper-Uranium-Gold-Silver Deposit; *in* Geology of the Mineral Deposits of Australia and Papua New Guinea, Hughes, F.E., Editor, *The Australasian Institute of Mining and Metallurgy*, pages 1009-1035.

Research Group of Porphyrite Iron Ore of the Middle-Lower Yangtze Valley, 1977. Porphyrite Iron Ore - A Genetic Model of a Group of Iron Ore Deposits in Andesitic Volcanic Area; *Acta Geological Sinica*, Volume 51, No. 1, pages 1-18.

Roberts, D.E. and Hudson, G.R.T., 1983. The Olympic Dam Copper-Uranium-Gold Deposit, Roxby Downs, South Australia; *Economic Geology*, Volume 78, pages 799-822.

**Thorkelson, D.J., 2000. Geology and mineral occurrences of the Slats Creek, Fairchild Lake and "Dolores Creek" areas, Wernecke Mountains, Yukon Territory (106D/16, 106C/13, 106C/14). Exploration and Geological Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 10, 73 p.**

Thorkelson, D.J., Mortensen, J.K., Davidson, G.J., Creaser, R.A., Perez, W.A. and Abbott, J.G., 2001. Early Mesoproterozoic intrusive breccias in Yukon, Canada: The role of hydrothermal systems in reconstructions of North America and Australia. Precambrian Research, vol. III, p. 31-35.

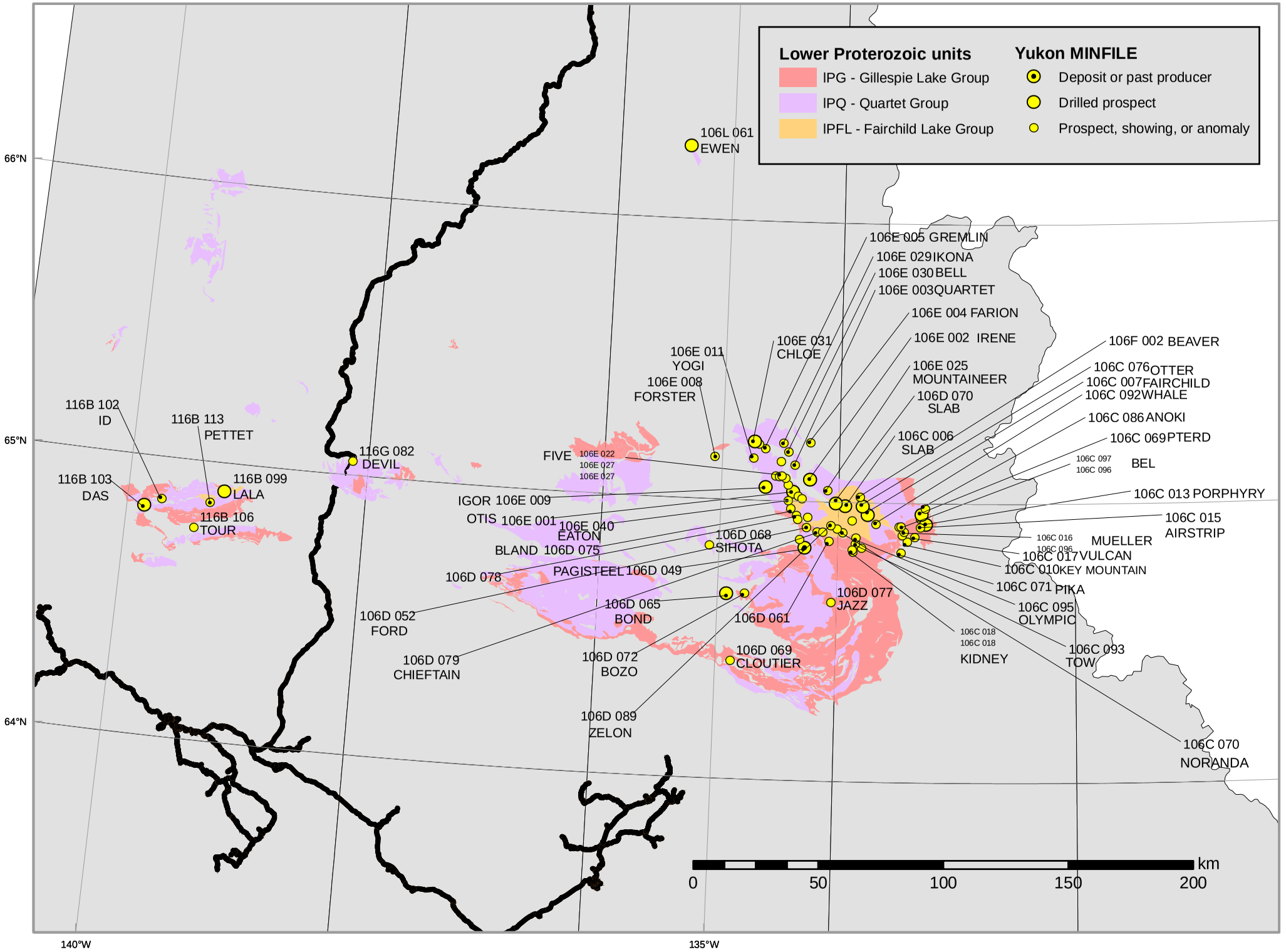
# D07 - Wernecke Breccias - World Deposits

| Deposit | country | tonnes | Cu% | $U_3O_8$ % | Au (g/t) | Ag (g/t) | Fe % | REE % |
|---|---|---|---|---|---|---|---|---|
| Olympic Dam | AUST | 2 000 000 000 | 1.6 | 0.06 | 0.6 | 3.5 | | |
| Pagisteel | CNYT | 910 000 | | | | | 29.2 | |
| Eastern Henry | AUST | 100 000 000 | 1.6 | | 0.8 | | | |
| Sue-Dianne | CNNT | 8 000 000 | 0.8 | 0.1 | | | | |
| Bayan Obo | CHIN | 20 000 000 | | | | | 35 | 6.19 |

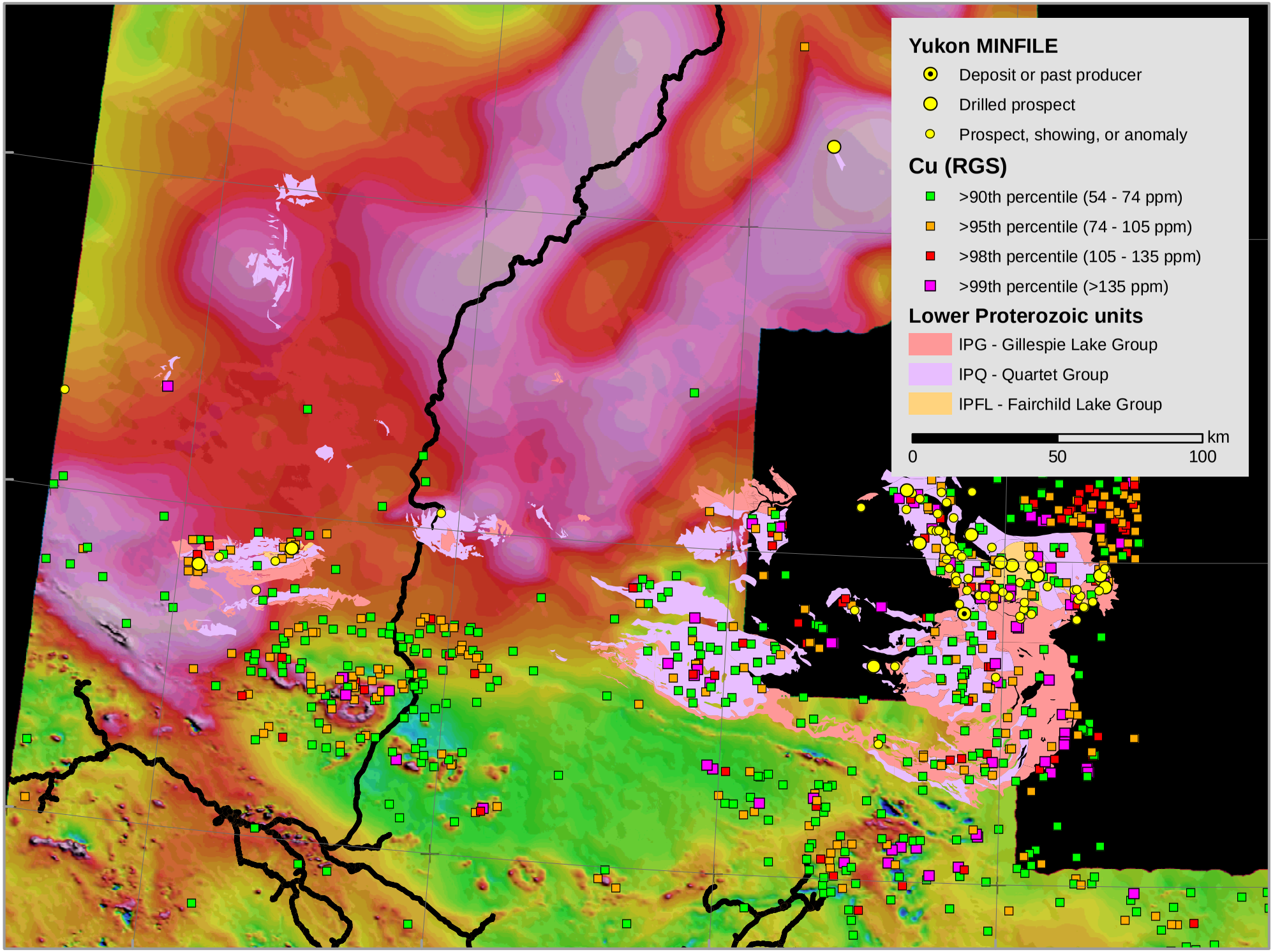
## Yukon MINFILE

| MINFILE | NAMES | STATUS |
|---|---|---|
| 106D 049 | PAGISTEEL | DEPOSIT |
| 106C 006 | PLUME, SLAB | DRILLED PROSPECT |
| 106C 007 | FAIRCHILD | DRILLED PROSPECT |
| 106C 013 | PORPHYRY | DRILLED PROSPECT |
| 106C 069 | PTERD | DRILLED PROSPECT |
| 106C 076 | OTTER | DRILLED PROSPECT |
| 106D 065 | BOND | DRILLED PROSPECT |
| 106D 070 | SLAB | DRILLED PROSPECT |
| 106D 077 | JAZZ | DRILLED PROSPECT |
| 106E 001 | OTIS | DRILLED PROSPECT |
| 106E 002 | IRENE | DRILLED PROSPECT |
| 106E 009 | IGOR | DRILLED PROSPECT |
| 106E 031 | DARNEY | DRILLED PROSPECT |
| 106L 061 | EWEN | DRILLED PROSPECT |
| 116B 099 | LALA | DRILLED PROSPECT |
| 116B 103 | DASH, DAS, LALA | DRILLED PROSPECT |
| 116G 082 | DEVIL, CANADIAN OLYMPIC | DRILLED PROSPECT |
| 106C 012 | CIRQUE | PROSPECT |
| 106C 086 | ANOKI | PROSPECT |
| 106D 052 | FORD | PROSPECT |
| 106D 078 | PITCH, ARCTOS | PROSPECT |
| 106E 005 | GREMLIN | PROSPECT |
| 106E 023 | RADIO | PROSPECT |
| 106E 024 | BREAK | PROSPECT |
| 106E 026 | HELIKIAN | PROSPECT |
| 106E 027 | FIVE | PROSPECT |
| 106C 010 | KEY MOUNTAIN | SHOWING |
| 106C 015 | AIRSTRIP | SHOWING |
| 106C 016 | MUELLER | SHOWING |
| 106C 017 | DOBBY, VULCAN | SHOWING |
| 106C 018 | KIDNEY | SHOWING |

| MINFILE | NAMES | STATUS |
|---|---|---|
| 106C 070 | NORANDA | SHOWING |
| 106C 071 | PIKA | SHOWING |
| 106C 090 | TOW | SHOWING |
| 106C 092 | WHALE | SHOWING |
| 106C 093 | ATHENS | SHOWING |
| 106C 095 | OLYMPIC | SHOWING |
| 106C 096 | JULIE | SHOWING |
| 106C 097 | BEL | SHOWING |
| 106D 061 | FOUND | SHOWING |
| 106D 062 | GNUCKLE | SHOWING |
| 106D 068 | SIHOTA | SHOWING |
| 106D 072 | BOZO | SHOWING |
| 106D 075 | BLAND | SHOWING |
| 106D 076 | FACE | SHOWING |
| 106D 079 | CHIEFTAIN | SHOWING |
| 106D 087 | SNOWSTAR | SHOWING |
| 106D 096 | REID | SHOWING |
| 106D 097 | BEAR RIVER | SHOWING |
| 106E 003 | QUARTET | SHOWING |
| 106E 004 | FARION | SHOWING |
| 106E 006 | CHLOE | SHOWING |
| 106E 011 | YOGI | SHOWING |
| 106E 022 | SPHINX | SHOWING |
| 106E 025 | MOUNTAINEER | SHOWING |
| 106E 028 | RAPITAN | SHOWING |
| 106E 029 | IKONA | SHOWING |
| 106E 030 | BELL | SHOWING |
| 106E 040 | EATON | SHOWING |
| 106F 002 | BEAVER | SHOWING |
| 116B 102 | WIZARD, ID | SHOWING |
| 116B 113 | PETTET, ROB | SHOWING |
| 116B 106 | TOUR | ANOMALY |
| 116F 068 | YINGEN | ANOMALY |
| 106C 068 | LAW | UNKNOWN |




Map of the Wernecke Mountains, northeast Yukon showing the distribution of Lower Proterozoic rocks and Wernecke Breccia occurrences




Map of the Wernecke Mountains showing Lower Proterozoic rocks, Wernecke Breccia occurrences, regional magnetics and copper geochemistry