United Nations ECE/ENERGY/GE.3/2024/12

Economic and Social Council

Distr.: General
16 April 2024

English only

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Management

Fifteenth session
Geneva, 22-26 April 2024
Item 7 (b) (i) of the provisional agenda
Decision support: Development and deployment of the United Nations Framework Classification for Resources: Applications: Minerals

Classifying the production of lithium, caesium and tantalum from the Tanco Mine, Manitoba, Canada, according to the United Nations Framework Classification for Resources – A Case Study

Prepared by members of the Minerals Working Group of the Expert Group on Resource Management*

* Members of the Minerals Working Group of the Expert Group on Resource Management; Tania Martins, Manitoba Geological Survey; Claude Deveau, Tantalum Mining Corporation of Canada Ltd., part of Sinomine Resource Group Co., Ltd; and, Hendrik Falck, Department of Industry, Tourism and Investment, Government of the Northwest Territories and Chair.

Contents

Tables

Summary

The United Nations Framework Classification for Resources (UNFC) has been developed to readily allow the comparison between projects producing minerals, oil and gas, renewable energy, groundwater, underground storage, and anthropogenic resources. The classification tool was developed for policy formulation, government resource management, industry business process management and capital allocation. The basis of UNFC comprises determinations of the environmental, social and economic viability (E axis), the technical (F axis) and the uncertainty (G axis) also referred to as the geological axis of a project. The clear distinctions make UNFC very useful as a communications tool while due to its flexibility and granularity UNFC allows rapid and clear comparisons even of complex resource projects. This is true not only as single snapshots but also allows their evaluation through time. Given the interest in critical mineral resources this examination of an active operation demonstrates the challenges of the classification of multiproduct mines.

This document presents a summary description and a classification of the Tanco pegmatite deposit in Manitoba, Canada. This study is not intended for use as a resource estimate and may not be to the standard required for disclosures to financial institutions or investors. The report has been conceived and written with publicly available information. While the most reliable information available has been emphasized for discussion, a variety of governance and corporate competitive advantage issues, prevent the full disclosure of the calculation methods and do not allow the full verification of the resources estimates.

Instead of a proper classification, this study is intended to emphasize the issues and problems practitioners may face with situations where a classification is required but information is either not available, its quality is suspect or current information is limited. Under these conditions, the results will not be to the standard required for disclosures to financial institutions or investors. This study presents a classification intended for a jurisdictional database that provides decision makers with the best information available to allow for informed decisions regarding land use planning, infrastructure planning and training programmes. The information presented highlights how since the discovery of the Tanco deposit, the main commodity has changed a number of times as have the secondary minerals of interest changed according to the demands and needs of society. The geological context of this deposit is important in terms of understanding the challenges for classification. It is an unusually large and highly fractionated pegmatite with complex zonation. The unique characteristics of this deposit also extend to the distribution of resources. The elements of interest are concentrated in minerals that are abundant in relatively discrete parts of the pegmatite. Consequently, selective mining can be applied to the deposit to extract only the truly economic minerals. Even with the use of selective mining, some commingling does occur and minerals are imperfectly recovered resulting in an additional resource that has been identified in the mine tailings. The purpose of the study is to demonstrate how to use UNFC and its application to a critical minerals resource that has an extended production history and multiple commodities.

I. Introduction

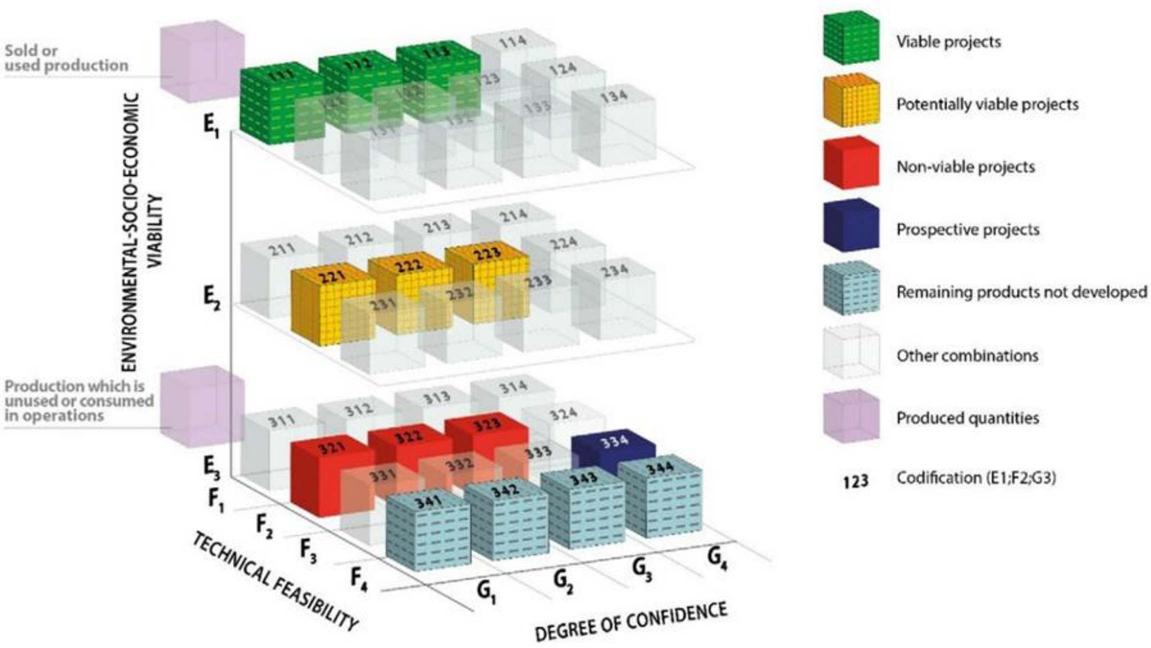
1. The Tanco pegmatite is a well-known deposit for its large size, unique and diverse mineralogy, high degree of fractionation, and productivity. This extensively studied pegmatite is part of a vast suite, the Cat Lake-Winnipeg River Pegmatite field as defined by Černý *et al.* (1981). Tanco belongs to the Bernic Lake pegmatite group, which represents a distinct collection of pegmatites in the region that exhibit a wide range of minerals and demonstrate quite distinct degrees of fractionation. The pegmatites belonging to the Bernic Lake pegmatite group, including the Tanco pegmatite, have been studied previously by several authors (*e.g.*, Černý *et al.*, 1996; Bannatyne, 1985; Lenton, 1979; Anderson *et al.*, 1998; Kremer, 2010; van Lichtervelde *et al.*, 2006).

2. This report aims to provide general geology and ore processing information on the Tanco pegmatite and demonstrate the application of the United Nations Framework Classification for Resources (UNFC) as a case study. UNFC comprises the technical (F axis), the environmental, social, and economic viability (E axis) as well as the degree of confidence (G axis) of a project. This report examines the historical production record of the Tanco mine and demonstrates how these principles can be applied to the different commodities that the mine has produced as well as its technical and socio-economic status. It should not be considered as an accurate reflection or a comprehensive estimate of the current reserves or resources.

II. UNFC Classification

3. UNFC aims to be a tool for management of all socio-economical, technological and uncertainty aspects of energy and mineral projects by providing clear and consistent specifications, guidelines and best practices for all energy and mineral sectors. The classification is based upon three criteria: Environmental-Socio-Economic Viability (E), Technical Feasibility (F) and Degree of Confidence (G). These three parameters are visualized in a diagram with three-axes (Figure I) using a numerical coding system (e.g., E1, F2, G3). These parameters are classified individually, and each parameter is divided into three to four subclasses based on the maturity of the project.

Figure I
The UNFC classification system*



* UNECE.

4. UNFC classifies resource quantities on the basis of three fundamental criteria that reflect technical, socio-economic and planning dimensions. To classify a mineral deposit properly using the UNFC classification system, the mineralization needs to be described in terms of the level of confidence in estimates of the future quantities to be produced. For the example of a producing mine the classification would ideally be E1F1G1. Several case studies are available using different deposit types demonstrating the applicability of the UNFC classification scheme (e.g., graphite in Northern Norway, ECE/ENERGY/GE.3/2022/15). More discussion is also presented in the Guidance for the Application of the United Nations Framework Classification for Resources for Mineral and Anthropogenic Resources in Europe (UNECE, 2022).

III. History of the mine

5. The rocks that are today known as the Tanco pegmatite were discovered during a drilling programme by Jack Nutt Mines, Limited in the late 1920’s exploring for tin. As a “blind discovery”, the pegmatite itself does not outcrop and the bulk of the pegmatite is under Bernic Lake. A mill was constructed to produce tin concentrates, but in the end the low quantities of tin ore extracted meant the operation was unfeasible. Diamond drilling of the pegmatite body revealed a section of spodumene but there was little interest in lithium at the time. By 1932, the renamed Consolidated Tin Corporation Limited abandoned the property with the claims reverting to the Crown. From 1934 to 1940 there was minor open pit production of lithium ore from other nearby pegmatites of the Bernic Lake pegmatite group (Buck, Pegli and Coe) and tin exploration continued in the area.

6. In 1955, Montgary Petroleum Corporation Ltd. acquired the claims at Bernic Lake and drilled about 26,000 feet (almost 8 km) of drill core to explore the lithium potential of the pegmatite. Meanwhile road access construction started as well as infrastructure to supply electricity to the mine site. By 1957, Montgary Petroleum, renamed Montgary Explorations Limited, sunk a shaft to 334 feet (about 100 m). The internal zonation of the pegmatite was defined by Hutchinson (1959) and pollucite (Cs ore) was identified. Operations were suspended for financial reasons and did not recommence until the spring of 1959.

7. In 1960, Chemalloy Minerals Limited (formerly Montgary Explorations Limited) carried out extensive drilling of the pegmatite to evaluate its lithium potential. Pollucite and amblygonite (Caesium and Lithium minerals) were mined with 2,500 tons[1] produced prior to the operation being placed on care and maintenance in 1961.

8. It was not until 1966 that the mine once again saw some signs of life when the pegmatite was evaluated for its tantalum potential. A concerted programme of metallurgical testing, drilling and mine development both at the surface and underground, resulted in the first tantalum concentrates being produced. The Tanco Grand Opening was held on 8 September 1969, and from that time to 1977, the mine was active extracting tantalum but also exporting pollucite to Russia. Tantalum Mining Corporation's ore reserves at the end of 1970 as reported by the Geological Survey of Canada were 1,643,742 tons (1,670,119 tonnes) grading 0.23 per cent Ta_2O_5, of which an estimated 467,839 tons (475,346 tonnes) would remain in pillars (Dawson, 1974).

9. In 1984, a summary of pegmatite resources in Manitoba was published by the Geological Services division of the Manitoba Department of Energy and Mines (Bannatyne, 1984). The summary of the Bernic Lake pegmatites and the mine included a compiled reserve estimate as of 31 December 1982.

[1] Calculations or estimates of weights have been converted to Metric Tonnes and are identified as tonnes, which are equal to 2004 lbs (1000kg). Where additional information is not available historical values are expected to be measured in Imperial Tons equivalent to 2240 lbs (1016 kg). However, some may represent Short tons equivalent to 2000 lbs (907 kg). Where sufficient clarification for the units was not available they are quoted in the units provided but not converted to metric tonnes.

Tantalum

(a)	Underground	1,047,000 tonnes	0.144% Ta_2O_5
(b)	Tailings	647,000 tonnes	0.065% Ta_2O_5
	Preproduction	1,879,136 tonnes	0.216% Ta_2O_5

Lithium

(a)	Spodumene zone	6,667,719 tonnes	2.75% Li_2O
(b)	Lepidolite	97,705 tonnes	2.24% Li_2O

Caesium

(a)	Main pollucite zone	317,520 tonnes	23.89% Cs_2O
(b)	Additional "drill-indicated"	54,430 tonnes	"Slightly lower grade"
(c)		145,150 tonnes	5% Cs_2O

10. It should be noted that although the estimation methods are not reported, there were also resources for other secondary commodities provided, including Beryllium, Gallium and Quartz.

11. In 1986, the commercial production of ceramic grade spodumene began and by 1988 Tanco was the major supplier for Corning Incorporated. The extremely pure spodumene was important to produce Visionware and later Corningware. In 1993, Cabot Corporation of Boston acquired 100% interest in Tantalum Mining Corporation of Canada Limited (Tanco) and by 1995, the construction of a plant to produce caesium formate brine had begun.

12. Market fluctuations driven by supply and demand for each of the commodities produced by the mine has continually affected the focus of the operation and the production levels.

13. By 1998, the mine had milled 1 million tonnes of spodumene ore and by 2004, the mine had milled 4 million tonnes of tantalum ore. In 1999, the caesium formate plant was expanded to 700 barrels per month and in 2001, the plant underwent a further expansion in enable the manufacturing of conventional caesium chemicals.

14. In June 2009, tantalum operations were suspended indefinitely due to low prices. And later the in same year, the same happened to the spodumene operations due to poor markets and low prices. In 2011, Tanco recommenced tantalum production and continued until March 15, 2013.

15. Between 2010 and 2013, the mine suffered two significant "Fall of Ground" incidents from Crown Pillars. The mining operations were temporarily suspended and remediation efforts were undertaken to increase the underground safety. A proposal for damming a portion of Bernic Lake was submitted to the Manitoba Government. Public comments were numerous and strident, that the lake was a significant part of many people's lives including Sagkeeng First Nation, Brokenhead Ojibway Nation, Roseau River First Nation, Hollow Water First Nation, Black River First Nation, and Manitoba Métis Federation, the local Indigenous people. Ultimately, the proposal was withdrawn and other less visible changes to the mine were made to ensure the ongoing safety of the mine.

16. In 2013, a project summary was submitted to the Manitoba Government with a consolidated mine operating summary for a notice of alteration permit approval process which has become part of the public record (Tetratech, 2013). In the project description, a mineral reserve and Mine life summary was included but no details regarding the estimation methods were included.

Tantalum

17. From 1969-2013, 4,595,675 tonnes of tantalum ore have been mined at an average feedgrade of 0.106%. Production of tantalum was suspended on 15 May 2009 and has not restarted since then.

18. As of 2010, the mine resources reported are (Tetratech, 2013):

- Proven – 414,521 tonnes at an average feedgrade of 0.073%.

- Indicated – 1,019,680 tonnes at an average feedgrade of 0.076%.
- Inferred – 519,848 tonnes at an average feedgrade of 0.080%.

Lithium

19. Spodumene has been mined since 1984 with 1,836,243 tonnes mined to date at an average feedgrade of 2.76%. Spodumene production was suspended on 3 September 2009 and resumed in 2021. Remaining reserves as of 2010 were:

- Proven – 427,674 tonnes at an average feedgrade of 2.4%.
- Indicated – 1,303,232 tonnes at an average feedgrade of 2.7%.
- Inferred – 657,694 tonnes at an average feedgrade of 2.6%.

Caesium

20. Pollucite has been mined since 1997 with 205,180 tonnes mined to date at an average feedgrade of 13.27%. Production was suspended temporarily from 13 May 2009 to 21 January 2010. As of 1 October 2010, the remaining pollucite reserves were 137,000 tonnes at an average feedgrade of 13.8%. Pollucite is currently being mined although reserves have not been publicly updated since 2013. Information on the companies' website disclosures that Tanco currently has 82% of the world's known reserves of pollucite (caesium ore).

21. The proven Category estimate has been assumed to represent reserves exclusive of resources. This is however not mentioned in the Tetratech report and should be acknowledged as an assumption. It should also be apparent that the grades are reported in feedgrade concentrations and not an in-situ basis. The degree to which dilution was incorporated into the indicated and inferred categories has not been stated.

22. In 2021, the mine was acquired by Sinomine Resource Group Co., Ltd. The wholly owned Tantalum Mining Corporation of Canada, Limited (Tanco) is a branch of the North American Business Division owned by Sinomine (Hong Kong) Rare Metals Resource Co., Ltd. (a subsidiary of publicly traded non-government owned entity – Sinomine Resources Group). The purchase of the mine was a response to the opportunities of a surging lithium market. Sinomine renovated and restored the spodumene processing system with spodumene ore production resuming in 2021. An expectation is to reach yearly production of 30,000 tons (27,215 tonnes) of 5.5% Li_2O (Sinomine, 2021). The news release for the revamped processing system also mentions an evaluation report that reported resources of 4.6028 million tons (4.1755 million tonnes) of proved spodumene resources ($Li_2O \geq 1\%$), average Li_2O@2.44%, or 112,200 tons (101,786 tonnes) of Li_2O as part of the incentive for the process plant improvements. No details on the nature of the resource estimate are available.

23. In 2023, Sinomine Resources Group released the 2022 Annual Report for the Shenzhen Stock Exchange in Hong Kong (Sinomine 2023). This report provided the resources of a new conceptual open pit mine model and an update of current underground resources. An additional interim report was also released providing more details regarding the remaining tantalum resources. The in-situ pegmatite deposit has a mineable resource (includes measured, indicated and inferred) in current underground operations of:

- 2,324,400 tonnes with a Li_2O grade of 1.859% containing a Li_2O metal quantity of 43,206.78 tonnes.
- 3,709,570 tonnes with a Ta_2O_5 grade of 0.109% containing a Ta_2O_5 metal quantity of 4,037.52 tonnes.
- 116,400 tonnes with a Cs_2O grade of 13.83% containing a Cs_2O metal quantity of 16,100 tonnes.

24. The results reported in these information releases will be discussed as part of the classification section of this case study.

IV. Geological setting

25. The Tanco pegmatite is part of the Winnipeg River-Cat Lake pegmatite field (Černý *et al.*, 1981). This vast pegmatite field has been subdivided into two pegmatite districts, and subsequently into several different pegmatite groups according to their mineralogy, geochemistry, and location (Černý *et al.*, 1981). Table 1 presents a summary of the main characteristics of the different groups of pegmatites within the Cat Lake-Maskwa Lake district, and the Winnipeg River district.

Table ***1***
Main pegmatite groups found in the Cat Lake-Winnipeg River pegmatite field*

Pegmatite district	*Pegmatite group*	*Host rock/contacts*	*Morphology and structure*	*Enrichment*	*Other characteristics/comments*
Winnipeg River	*Shatford Lake*	Sharp contacts with negligible biotization in metabasaltic rocks	Generally concordant with layering and foliation of the host rocks; exceptions dip at shallow angles or sub-horizontal	Be, Sn, Nb-Ta, Zr, REE, U, Th	Individual pegmatites are dyke-like or flat-lenticular; internal structural is highly variable; possibly NYF-type pegmatites
	Lac du Bonnet	Truncate layering and foliation of the host rocks	Dipping steeply or vertically	Li (P)	These pegmatites are not accessible at the present time
	Greer Lake	Pinching and swelling within the foliation	Concordant bodies	Be, Nb-Ta (Li)	Hydrothermal alteration or supergene weathering is virtually absent; largest dykes attain 400 m in length and 15 m in width
	Eaglenest Lake	Contacts with gneissic wall rocks are sharp	Fracture-filling bodies parallel-walled dykes without conspicuous pinch or swell undulations; locally offset by later transecting faults	Be	This group is poorly exposed. Internally, dykes are homogenous or slightly concentrically zoned; only one of the pegmatites carries beryl
	Axial Lake	Located in the body of subvolcanic Birse Lake granodiorite; sharp contacts	Concordant with the S_2 foliation; pinch and swell with attendant warping of the foliation	(Li?)	Individual bodies are flat-lenticular; internal structure is mostly irregular
	Birse Lake	Hosted by the Bernic Lake Formation; predominantly sharp contacts (only locally diffuse)	Essentially concordant to bedding, layering and foliation of host rocks; locally show offsets along joints (local *en echelon* patterns)	B (Be)	Shape of the pegmatites is irregular: contorted lenticular dykes predominate in the E; flat lenses and elongate dykes are typical in the W
	Rush Lake	Sharp contacts; minor biotization in metavolcanics; muscovite in metasedimentary wall rocks	Generally concordant to layering and foliation of country rocks; however, some examples	Li, Rb, Cs, Be, Sn, Ta-Nb, B, P, F	Two textural and paragenetic types: very simple and generally unzoned; complex type with zoning and replacement veining

Pegmatite district	*Pegmatite group*	*Host rock/contacts*	*Morphology and structure*	*Enrichment*	*Other characteristics/comments*
			crosscut the foliation dipping both northward or eastward at shallow angles		
	Bernic Lake	Intrude extrusive and intrusive mafic metavolcanic rocks; bulbous and sharp contacts are observed	Varied attitudes from striking east-west to northeast, and dipping sub horizontal to near-vertical	Li, Rb, Cs, Be, Sn, Ta-Nb, B, P, F	Tanco is part of this group, together with other pegmatites with very different dimensions and rare metal enrichment
Cat Lake-Maskwa Lake	*Eagle-Irgon*	Biotite flakes occur sporadically along the contacts	Flat-lenticular with common pinch and swell; essentially concordant, striking west-northwest to west and dipping nearly vertically	Li	Internal structure is homogeneous; variations in thickness are common; locally some pegmatites seem to be segmented along strike
	Beryl-Tourmaline	Intrudes the greenstone belt just north of Cat Lake	North striking and steeply dipping; crosscuts regional foliation at high angles	Be	Internal structure is heterogeneous and patchy; small bodies (< 15 m in length); maximum thickness ~20 cm; strong N-S lineament
	Cat Lake	Intrudes metabasaltic rocks; contacts are sharp, and locally sheared	Concordant to the foliation; dipping in near-vertical attitudes	Li, Be	Simple paragenesis; geochemically indicates moderate degree of fractionation
	Central Claim	Intrudes the Maskwa Lake quartz diorite	Sub-horizontal, tabular body ~4 m thick and extends ~850 m	Li, Be, Ta-Nb	Group represented by a single pegmatite; well zoned; primary zonation overprinted by metasomatism
	Maskwa Lake series	Contacts are generally sharp; holmquistite and biotite are found in the country rock	Pegmatites strike northeasterly, and dip subvertically; 3 different types: spodumene-bearing, petalite-bearing and pollucite-bearing	Li; Li, Rb; Cs, Ta-Nb (Be)	Closely-spaced swarm of pegmatites with geochemical similarities but paragenetically different.

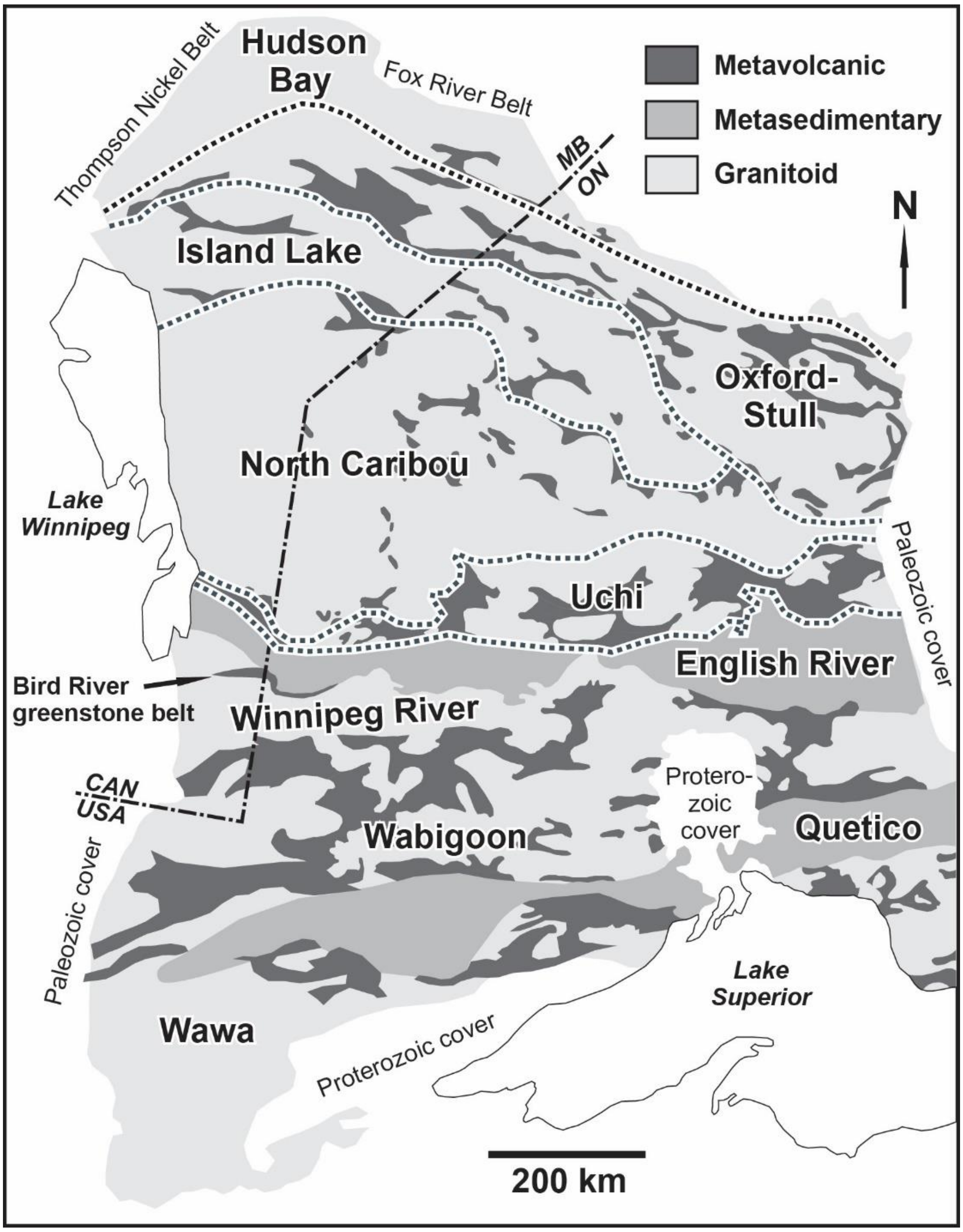
* Adapted and updated after Černý et al., 1981).

26. The Bernic Lake pegmatite group (which includes the Tanco pegmatite) is located in the Bird River greenstone belt, which is part of the Archean Superior Province (Figure II). The Bird River greenstone belt has been historically described as a large, synclinal keel (Trueman, 1980; Černý *et al.*, 1981); however, mapping by the Manitoba Geological Survey has led to a re-interpretation of the volcanostratigraphic framework of the belt (Gilbert, 2006; Gilbert, 2007; Gilbert *et al.*, 2008). Gilbert (2008) has subdivided the southern part of the Bird River greenstone belt into two distinct (northern and southern) panels, both of which are composed of ca. 2.75-2.72 Ga juvenile, arc-type metavolcanic and associated metasedimentary rocks. These two metavolcanics panels are separated by the fault bounded

enclave of the Booster Lake Formation (<2712 ± 17 Ma, Gilbert, 2006), a turbiditic sequence with classic Bouma-type features, penecontemporaneous with clastic sedimentary rocks of the Flanders Lake Formation (Gilbert, 2006).

Figure II

Simplified geology of the northwestern Superior Province showing the location of the Bird River greenstone belt*



* Based on Percival et al. (2006) and Stott et al. (2010).

Note: Abbreviations: MB- Manitoba, ON- Ontario, CAN- Canada.

27. Table 2 shows the sequence, age, and summarised description of the geological formations of the Bird River greenstone belt. A summary description of the rock units is presented below. The reader is referred to Gilbert (2006; 2007) and Gilbert *et al.* (2008) for detailed description of the geology of Bird River greenstone belt (Figure III).

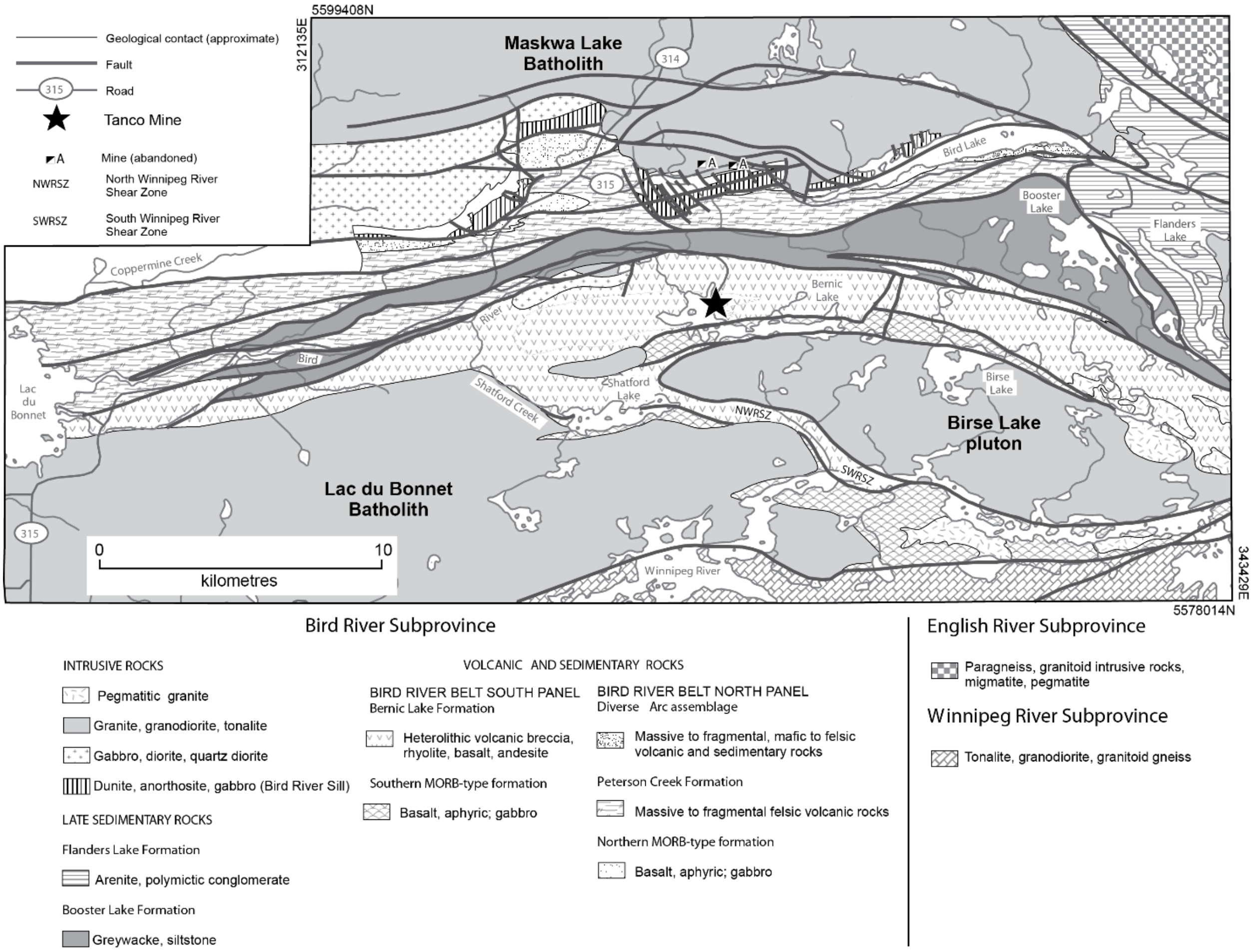
Table ***2***
Geological formations of the Bird River greenstone belt*

Late intrusive rocks
Granite, pegmatite, granodiorite, tonalite, quartz diorite
Tanco pegmatite, 2640 ±7 Ma[1]; Marijane Lake pluton, 2645.6 ±1.3 Ma[2]; Lac du Bonnet Batholith, 2660 ±3 Ma[3]
Sedimentary rocks
Flanders Lake Formation, 2697 ±18 Ma[4]
Lithic arenite, polymictic conglomerate
** ***Fault, inferred*** *******************
Booster Lake Formation, 2712 ±17 Ma[4]
Greywacke-siltstone turbidite, conglomerate
~~ ***Unconformity, inferred*** ~~~~~~~~~~~~~~~~~~~~~~~~~~
Intrusive rocks
MISCELLANEOUS INTRUSIONS
Gabbro, diorite, quartz-feldspar porphyry; granodiorite
Birse Lake pluton, 2723.2 ±0.7 Ma[2]; Maskwa Lake Batholith II, 2725 ±6 Ma[3]; Pointe du Bois Batholith, 2729 ±8.7 Ma[3]
Tanco gabbro, 2723.1 ±0.8 Ma[2]
Metavolcanic and metasedimentary rocks
Bernic Lake Formation 2724.6 ±1.1 Ma[2]
Basalt, andesite, dacite and rhyolite (massive to fragmental); related intrusive rocks and heterolithic volcanic fragmental rocks
Peterson Creek Formation, 2731.1 ±1 Ma[2]; 2734.6±3.1 Ma[6]
Dacite, rhyolite (massive to fragmental); felsic tuff and heterolithic felsic volcanic fragmental rocks
Diverse Arc Assemblage 2706 ±23 Ma[5]
Basalt, andesite, rhyolite, related fragmental and intrusive rocks; heterolithic volcanic fragmental rocks; greywacke-siltstone turbidite, chert, iron-formation; polymictic conglomerate (contains clasts derived from Bird River Sill)
~~ ***Unconformity, inferred*** ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Intrusive rocks
Bird River Sill, 2744.7 ±5.2 Ma[3]; 2743.0±0.5 Ma[7]
Dunite, peridotite, picrite, anorthosite and gabbro
** ***Fault, inferred*** ******************************
Metavolcanic and metasedimentary rocks
MORB-type Volcanic rocks
Basalt (aphyric to plagioclase-phyric; locally pillowed, amygdaloidal or megacrystic); related volcanic breccia; oxide-facies iron formation
** ***Fault, inferred*** *****************************
Eaglenest Lake Formation
Greywacke-siltstone turbidite
Older intrusive rocks
Granodiorite, diorite (Maskwa Lake Batholith I, 2782 ±11 Ma[3], 2832.3±0.9Ma[2], 2852.8 ±1.1 Ma[2], 2844 ±12 Ma[3])

* From (Gilbert et al., 2008).

Note: References for geochronological data: (1) Baadsgaard and Černý, 1993; (2) Gilbert et al., 2008; (3) Wang, 1993; (4) Gilbert, 2006; (5) Gilbert, 2008; (6) Gilbert, unpublished data, 2007; (7) Scoates and Scoates (2013).

Figure III
Simplified geology of the Bird River greenstone belt including the location of Bernic Lake and the Tanco mine*



* After Gilbert et al. (2008).

V. The Tanco pegmatite

28. The Tanco pegmatite is a sub horizontal, essentially undeformed, bilobate, saddle-shaped body. The pegmatite is about 1520 m long, 1060 m wide, and up to ~100 m thick, thinning toward the edges. The volume of the pegmatite has been estimated as ~21,850,000 m^3, the mass is ~57,430,000 tonnes, and its average density is 2.63 g/cm^3 (Stilling *et al.*, 2006). It occurs mostly under Bernic Lake in southeastern Manitoba and has only been examined by drill core and underground mining exposures.

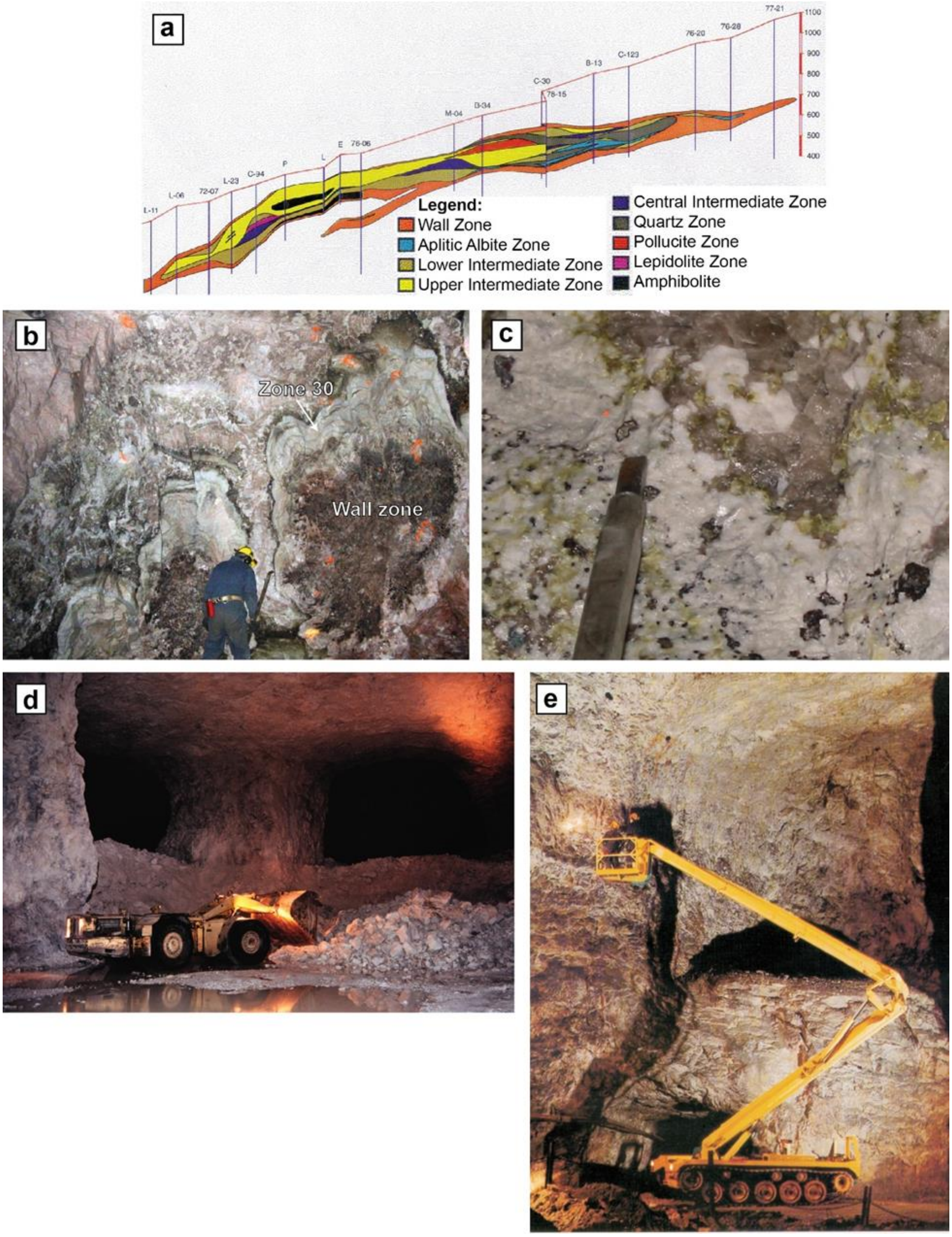
29. The Tanco pegmatite has fascinated geoscientists, the entire pegmatite community and mineral collectors around the world. It is a big, highly complex and fractionated body that has been the target of scientific research since the 1970's. The most recent general review on Tanco pegmatite was completed by Černý in 2005. Subsequently, new data has been published on bulk rock geochemistry (Stilling *et al.*, 2006), new mineral discoveries (Cooper *et al.*, 2009), mineral and mineralization studies (*e.g.* van Lichtervelde *et al.*, 2006; 2007; 2008; Brown et al. 2017), and structural studies (Kremer and Lin, 2006; Kremer 2010).

A. Zoning of the Tanco pegmatite

30. The Tanco pegmatite is a classic example of a complexly zoned pegmatite (Figure IV). In each of the different zones it is possible to find the different combinations of minerals in association including the ones containing the elements of economic interest: Ta, Li, and

Cs. The zonation consists of nine discrete zones. The zones are substantive enough and distinct enough to be mapped but also individually characterized for mining purposes. This allows for mine planning to target the zones that contain those elements that are in demand while allowing the less economic commodities to be bypassed until the commodity price increases or a suitable contract can be negotiated with a buyer. The outer zones are concentric, whereas the inner zones are layered segments that are locally complex in shape. The mineralogy and petrography of the different zones have been described in detail by several authors (*e.g.* Černý, 2005; Černý *et al.*, 1996; 1998; Stilling *et al.*, 2006). A description of the zonation of the Tanco pegmatite is given in Table ***1*** Table 3 which summarizes the mineralogy, texture and geochemistry that can be found for of each zone. Figure IVa and IVb illustrate the wall zone and its albite-quartz assemblage, and tantalum mineralization from the 511 zone, respectively.

Figure IV
Cross section of the pegmatite and underground photos at Tanco mine*



* With permission of Sinomine.

Note:
(a) East-West fence section 9700 N through the Tanco pegmatite (looking North) showing its complex internal zoning (modified from Černý, 2005). Scale bar is in metres; (b) Wall zone in contact with a saccharoidal albite-quartz assemblage (located in the Beryl Pit area near the base of Zone 30). The darker patches in the lower portion of the picture (in front of and behind the person) are Wall Zone (Zone 20). A layer of banded pale blue saccharoidal albite (Zone 30) is drapped over the Wall Zone. This albite is in contact with quartz (the smokey fringe on the albite-quartz contact is consistent with tantalum minerals collecting on this contact). The green colour which is most noticeable in the left part of the photo is due to the presence of the green lithian mica; (c) Tantalum mineralization in an albite-beryl-mica assemblage from the high-grade tantalum 511-Zone (Beryl Pit area); the scaling bar chisel end is 25.5 cm; (d) Scooptram close to one of the spodumene zone pillars illustrating the room and pillar method used at Tanco; (e) Custom designed aerial lifts.

Table ***3***
Zoning of the Tanco pegmatite*

Zone	*Main constituents*	*Characteristics subordinate (accessory) and rare minerals*	*Textural and structural characteristics*	*Geochemistry important major & minor elements*
Exomorphic unit	Biotite, tourmaline, holmquistite	Arsenopyrite	Fine-grained reaction rims and diffuse veins	K, Li, B (P, F)
(10) Border zone	Albite, quartz	Tourmaline, apatite, (biotite), beryl, triphylite	Fine-grained layers	Na, (B, P, Be, Li)
(20) wall zone	Albite, quartz	Beryl, (tourmaline), muscovite, Li-muscovite, microcline-perthite	Medium-grained, with giant K-feldspar crystals	K, Na, (Li, Be, F)
(30) aplitic albite zone	Albite, quartz, (muscovite)	Muscovite, Ta-oxides, beryl, (apatite, tourmaline, cassiterite), ilmenite, zircon, sulfides	Fine-grained undulating layers, fracture fillings, rounded blebs, diffuse veins	Na, (Be, Ta, Sn, Zr, Hf, Ti)
(40) lower intermediate zone	Microcline-perthite, albite, quartz, spodumene, amblygonite	Li-muscovite, lithiophilite, lepidolite, petalite, Ta-oxides	Medium- to coarse- grained; heterogeneous	K, Na, Li, P, F, (Ta)
(50) upper intermediate zone	Spodumene, quartz, amblygonite	Microcline-perthite, pollucite, lithiophilite, (albite, Li-muscovite), petalite, eucryptite, Ta-oxides	Giant crystal size of major and most of the subordinate minerals	Li, P, F, (K, Na, Cs, Ta)
(60) central intermediate zone	Microcline-perthite, quartz, albite, muscovite	Beryl, (Ta-oxides), zircon, ilmenite, spodumene, sulfides, lithiophilite, apatite, cassiterite	Medium- to coarse-grained	K, (Na, Be, Ta, Sn, Zr, Hf, Ti)
(70) quartz zone	quartz	Spodumene, amblygonite	monomineralic	Si, (Li)
(80) pollucite zone	pollucite	Quartz, spodumene, petalite, muscovite, lepidolite, albite, microcline, apatite	Almost monomineralic	Cs, (Li)
(90) lepidolite zone	Li-muscovite, lepidolite, microcline-perthite	Albite, quartz, beryl, (Ta-oxides, cassiterite), zircon	Fine-grained	Li, K, Rb, F, (Na, Be, Ta, Sn, Zr, Hf, Ga)

* From Černý, 2005.

B. Mineralogy

31. Mineralogy from Tanco is very diverse with more than 100 contained minerals listed in the literature (*e.g.* Černý *et al.*, 1996; 1998). Tanco has yielded four holotypes of new minerals: černýte (Kissin *et al*,. 1978), tancoite (Ramik *et al*,. 1980), diomignite (London *et al.*, 1987), titanowodginite (Ercit *et al.*, 1992), Ercitite (Fransolet *et al.*, 2000), Groatite (Cooper *et al.*, 2009). An updated listing of the mineral occurrences at Tanco can be found in Table 4: Mineral occurrences at Tanco (updated from Černý, 2005 and taking into account the current IMA-CNMMN nomenclature). Detailed descriptions of the different minerals, including mineral geochemistry and evolution, can be found in the previously mentioned publications and several others (*e.g.* Černý *et al.*, 1996; 1998; Černý, 2005).

Table ***4***
Mineral occurrences at Tanco*

Native elements		**Phosphates**	
Lead	Pb	Fluorapatite	$(Ca,Mn)_5(PO_4)_3(F)$
Bismuth	Bi	*Carbonate-hydroxylapatite*	$Ca_5(PO_4,CO_3)_3(OH)$ (after Burke, 2008)
Arsenic	As	Lithiophosphate	Li_3PO_4
Copper (?)	Cu	Lithiophilite	$Li(Mn>Fe)PO_4$
Antimony	(Sb>Bi)	Triphylite	$Li(Fe>Mn)PO_4$
Stibarsen	SbAs	Amblygonite	$LiAlPO_4(F,OH)$
		Montebrasite	$LiAlPO_4(OH,F)$
Sulfides and sulfosalts		Tancoite	$LiNa_2HAl(PO_4)_2(OH)$
Galena	PbS	Whitlockite	$Ca_3(PO_4)_2$
Sphalerite	(Zn,Cd)S	Fairfieldite	$Ca_2(Mn,Fe)(PO_4)_2.2H_2O$
Hawleyite	(Cd,Zn)S	Collinsite	$Ca_2(Mg,Fe)(PO_4)_2.2H_2O$
Pyrrhotite	$Fe_{1-x}S$	Crandallite	$CaAl_3H(PO_4)_2(OH)_6$
Pyrite	FeS_2	Overite	$Ca_3Al_3(PO_4)_8(OH)_6.15H_2O$
Marcasite	FeS_2	Dorfmanite	$Na_2HPO_4.2H_2O$
Arsenopyrite	FeAsS	Ercitite	$NaMnPO_4(OH).2H_2O$
Stibnite	Sb_2O_3	Switzerite	$(Mn,Fe)_3(PO_4)_2.7H_2O$
Molybdnite	MoS_2	Groatite	$NaCaMn^{2+}_2 (PO_4) [PO_3(OH)]_2$
Cosalite	$PbBiS_2$	**Carbonates**	
Gladite	$CuPbBi_5S_9$	Calcite	$CaCO_3$
Pekoite	$CuPbBi_{11}S_{18}$	Rhodochrosite	$MnCO_3$
Gustavite	$Pb_5Ag_3Bi_{11}S_{24}$	Dolomite	$CaMg(CO_3)_2$
Tetrahedrite	$(Cu,Fe,Ag)_{12}Sb_3S_{13}$	Zabuyelite	Li_2CO_3
Freibergite	$(Ag,Cu,Fe)_{12}Sb_3S_{13}$		
Bournonite	$PbCuSbS_3$	**Sulfates**	
Dyscrasite	Ag_3Sb	Baryte	$BaSO_4$
Pyrargyrite	Ag_3SbS_3		
Miargyrite	$AgSbS_2$	***Borates***	
Cubanite	$CuFe_2S_3$	Diomignite	$Li_2B_4O_7$
Chalcopyrite	$CuFeS_2$		
Stannite	Cu_2FeSnS_4	**Silicates**	
Kësterite	Cu_2ZnSnS_4	Quartz	SiO_2
Černýite	Cu_2CdSnS_4	Albite	$Na(AlSi_3O_8)$
		Microcline	$K(AlSi_3O_8)$
		Sanidine (Adularia)	$K(AlSi_3O_8)$
Halides		*Rb-feldspar*	$(Rb>K)(AlSi_3O_8)$
Fluorite	CaF_2	Biotite**	$K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$
		Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$

Oxides		*Lithian muscovite*	$K(Al,Li)_2(Al,Si)_4O_{10}(OH,F)_2$
Cassiterite	SnO_2	Lepidolite**	$(K,Rb)(Li,Al)_2(Al,Si)_4O_{10}(OH,F)_2$
Rutile	$(Ti,Fe,Ta,Nb)O_2$	Illite**	$(K,H_2O)Al_2(AlSi_3O_{10})(OH,H_2O)_2$
Tantite	Ta_2O_5	Montmorillonite	$(Na,Ca)(Mg,Al)_2(Si_4O_{10})(OH)_2.n(H_2O)$
Tapiolite-(Fe)	$Fe^{2+}Ta_2O_6$	Cookeite	$LiAl_4(AlSi_3O_{10})(OH)_8$
Columbite-(Fe)	$Fe^{2+}Nb_2O_6$	Eucryptite	$LiAl(SiO_4)$
Columbite-(Mn)	$Mn^{2+}Nb_2O_6$	Spodumene	$LiAl(Si_2O_6)$
Tantalite-(Mn)	$Mn^{2+}Ta_2O_6$	Petalite	$Li(AlSi_4O_{10})$
Wodginite	$Mn(Sn>Ta,Ti,Fe)(Ta>Nb)_2O_8$	Foitite	$\square Fe^{2+}_2AlAl_6(Si_6O_{18})(BO_3)_3(OH)_4$
Ferrowodginite	$(Fe>Mn)(Sn>Ta,Ti.Fe)(Ta>Nb)_2O_8$	Schorl	$NaFe^{2+}_3Al_6(Si_6O_{18})(BO_3)_3(OH)_4$
Titanowodginite	$(Mn>Fe)(Ti>Sn,Ta,Fe)(Ta>Nb)_2O_8$	Elbaite	$NaLi_{1.5}Al_{1.5}Al_6(Si_6O_{18})(BO_3)_3(OH)_4$
Ferrotitanowodginite	$(Fe>Mn)(Ti>Sn,Ta,Fe)(Ta>Nb)_2O_8$	Rossmanite	$\square LiAl_2Al_6(Si_6O_{18})(BO_3)_3(OH)_4$
Lithiowodginite	$LiTaTa_2O_8$	Feruvite	$CaFe^{2+}_3Al_5Mg(Si_6O_{18})(BO_3)_3(OH)_4$
Simpsonite	$Al_4Ta_3O_{13}(OH)$	Dravite	$NaMg_3Al_6(Si_6O_{18})(BO_3)_3(OH)_4$
Stibiotantalite (?)	$SbTaO_4$	Beryl	$Be_3Al_2(Si_6O_{18})$
Microlite *renamed fluorcalciomicrolite or oxycalciomicrolite*	$(Na,Ca)_2Ta_2O_6(O,OH,F)$ (see Atencio *et al.*, 2010 for details)	Topaz	$Al_2SiO_4(F>OH)_2$
Uranmicrolite (after Atencio *et al.* 2010)	$(Na,Ca,U)_2Ta_2O_6(O,OH,F)$	Pollucite	$(Cs,Na)(AlSi_2O_6).nH_2O$
Cesstibtantite *renamed Hydroxykenomicrolite*	$(Sb,Na)_2Ta_2(O,OH)_6(OH,Cs)_1$ (after Atencio *et al*. 2010)	*Cesian analcime*	$(Na,Cs)(AlSi_2O_6).nH_2O$
Calciotantite	$CaTa_4O_{11}$	Holmquistite	$Li_2Mg_3Al_2(Si_8O_{22})(OH)_2$
Rankamaite-Sosedkoite	$(Na,K)_{3-x}Al(Ta,Nb)_{10}(O,OH)_{30}$	Zircon	$(Zr,Hf)(SiO_4)$
Ilmenite	$(Fe,Mn)TiO_3$	Thorite	$ThSiO_4$
Uraninite	UO_2	Coffinite (?)	$U(SiO_4.(OH)_4)$
Manganite	$MnO(OH)$	Garnet (?)**	$(Mn,Fe)_3Al_2Si_3O_{12}$

* Updated from Černý, 2005 and taking into account the current IMA-CNMMN nomenclature.

Note:

** Refers to a series name.

Mineral names in italic: not approved by IMA.

□ represents a vacancy.

C. Geochemistry

32. The Tanco pegmatite is a mineralized, peraluminous pegmatite body, belonging to the LCT family, Rare-Element-Li subclass, complex type, subtype petalite (classification by Černý and Ercit, 2005). The most recent work on bulk geochemistry of Tanco was published by Stilling *et al.* (2006). In their work, a 3D CAD space model of the pegmatite was used to help with the calculation of volumes and compositions of individual zones and of the whole pegmatite. The 3D model was built using Auto Miner and Schreiber's Quick-Surf with Matrox Graphics real-time tools. The model includes information from 736 underground and 538 at surface drill-holes, underground observations, measured and estimated mineral modes of the zones, zone-specific compositions and mineral densities, and ore grades.

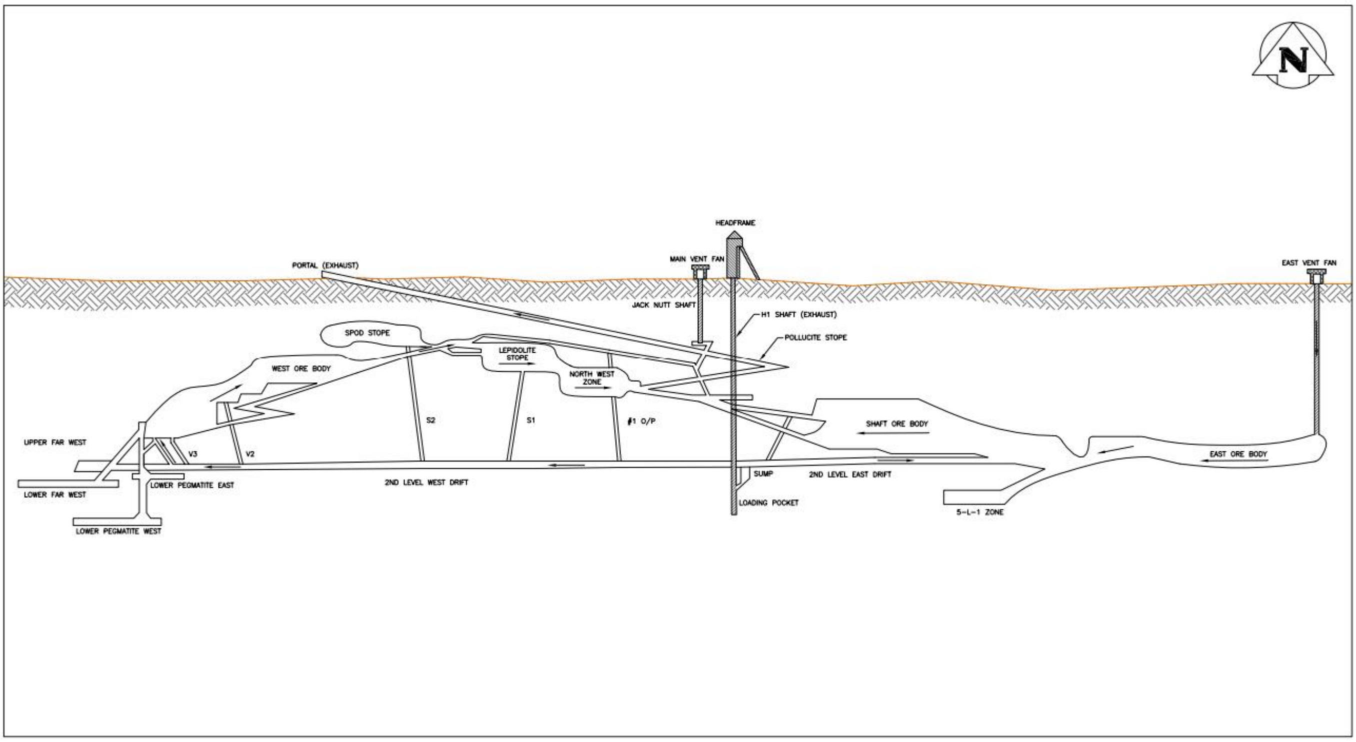
33. The bulk mode of Tanco is close to a muscovite granite, with the exception of 8 wt.% petalite, 2.8 wt.% lithian micas, and 1 wt.% primary spodumene. The contents of all other accessory silicates and phosphates are only in tenths of a wt.%, and minerals of the high-field-strength elements account for mere hundredths to thousandths of a wt.% each. Accordingly, the bulk chemical composition of the pegmatite corresponds to that of a peraluminous, moderately silicic, high-phosphorus, Na>K granite, with enrichment in Li, Rb, Cs and F; moderate contents of Tl, Be, B, Ga, Sn, Nb and Ta, and remarkable depletion in

Fe, Mn, Mg, Ca, Ba, Sc, Ti and Zr. A very high degree of fractionation is shown for the bulk pegmatite by the values K/Rb 4.7, K/Cs 9.3, Rb/Cs 2.0, Rb/Tl 137, Fe/Mn 0.63, Mg/Li 0.02, Al/Ga 917, Zr/Hf 2.6, Zr/Sn 0.21 and Nb/Ta 0.19 (Stilling *et al.*, 2006).

VI. Mining

34. The Tanco pegmatite is situated about 60 m below Bernic Lake and is accessible from surface either via a shaft or via a 400 m ramp with 20% decline (Figure V). Mining is carried out using the room and pillar method (Figure IVd) mainly because the mine is shallow (which contributes to lower inherent ground stresses and generally stable ground conditions), and its diverse mineralogy. The initial pillar design was to have 16 m square pillars, with mining rooms also at 16 m wide. As mining progressed, ongoing rock mechanics studies showed that the rooms could be increased to 22 m, without excessively loading the pillars. Pillar reduction has been completed successfully throughout the mine.

Figure V
Idealized mine cross-section looking south west*



* From Tetratech, 2013.

35. Two-boom hydraulic jumbos perform all drilling for drifts, slashes, benches and arches. During the initial top slice development, the roof is carefully arched, utilizing smooth blasting techniques. Rock bolting is rarely required because ground stress in the Tanco mine is considered low, relative to other hard rock mines. The roof arches allow residual ground stresses to be redirected to the post pillars.

36. At Tanco, the roof of mature mine workings average 20 m above the working levels below, and in places, may reach >30 m. These high backs are carefully monitored throughout mining operations, utilizing custom designed aerial lift devices (referred to as Giraffes, Figure IVe). Where suited, mining is carried out, utilizing a single boom Simba long-hole drill. The longhole method was the primary method by which the oversized pillars were reduced. The broken ore is transported utilizing different sizes load-haul-dumps, mobile, front-end loader units, and a 20-ton truck to various ore-passes, which are located throughout the mine.

37. The ore is broken on grizzlies (metal grates at the top of the ore pass), utilizing either mobile or stationary hydraulic rock breakers. The ore is then passed to an underlying tramming level where it is transported to the shaft by a train of 4-ton Granby style, side dump ore cars, and hoisted to surface coarse ore bins via 4-ton Kimberly style skips.

38. Tantalum and spodumene ores are stored in one of two loading pockets and skipped on a daily basis up the two-compartment shaft, into dedicated surface coarse ore bins. The mine however, must produce and provide three distinct ores to the mill. To overcome the limitation of the system, one loading pocket and associated coarse ore bin is emptied weekly and an appropriate tonnage of pollucite ore is batched through.

39. Mine ventilation air is downcast from surface through one of two vent raises, one being, in part, the Jack Nutt shaft from 1929/30 and the other, a 1.8 m diameter bore-hole raise. The exhaust mine air up-casts through the access decline. Total fresh air volume exceeds 5300 m^3 per minute and is appropriate for the operation of Tanco's fleet of diesel mining equipment. A fleet of personnel carriers and service trucks supports mining operations. Tanco maintains all of its mine equipment at its own on-site facilities.

A. Mineral processing

40. Due to limitations in usable land with the mine on a peninsula, the concentrator is constructed on a spit between two bays of Bernic Lake. The processing building is multi-floored, with equipment on a total of six levels. The major items of concentration equipment are on two levels, with feed preparation equipment, filters and driers, on the upper levels, with pumps on the lower levels.

41. The first stage of processing is crushing, where the coarse ore from underground (<300 mm in size) is broken down to <12 mm in size. The tantalum, spodumene and pollucite ores are crushed into separate fine-ore, storage bins.

42. Different processes are used to concentrate each product. Tantalum is processed by gravity concentration, a process that uses the density of tantalum minerals which are much heavier than the waste minerals quartz and feldspar. Spodumene, on the other hand, is primarily processed by flotation, which makes use of the different physical and chemical characteristics of the surfaces of the various minerals. Pollucite is ground and then subjected to acid leaching and other chemical processing to produce caesium chemicals.

1. Tantalum

43. The major uses for tantalum are in the electronics industry (*e.g.*, cell phones, computers) and for cutting tools. High quality capacitors are the major single application for tantalum. Other tantalum alloys are important constituents of aero engines, and for acid resistant pipes and tanks used in the chemical industry. In addition, tantalum's medical applications are also of importance (e.g., used for hip-joint replacements and dental implants).

44. For many years the Tanco Mine was the sole tantalum producer in Canada but it is currently not in production in part due to the abundance of low-cost production from Central Africa and Australia. Given an increasing emphasis on sourcing this product from a diversity of sources, it is expected that Ta production will be produced at Tanco in the coming years.

45. Textural and geochemical studies of the Nb-Ta oxides from the Tanco Lower pegmatite provided evidence for the tantalum mineralization being of magmatic origin. Interaction of fluids may have only had an indirect role in delivering minor elements such as Fe, Mn or Ca (van Lichtervelde *et al.* 2007). Van Lichtervelde *et al.* (2006) found that enclosed metagabbro rafts (part of Tanco's pegmatite country rock) had no evident chemical influence on the crystallisation of columbite-group minerals in the pegmatite. Abnormally high concentrations of tantalum are spatially associated with metagabbro rafts in the mine but the raft's influence on the tantalum mineralization is more physical than chemical. The authors concluded that these rafts might have separated distinct pegmatite cells that have evolved independently of the whole pegmatite body.

Tantalum processing

46. There are three main elements in the gravity concentration of Tanco's minerals: liberation of the commodities from the gangue or waste rock; feed preparation of the ground product into different size fractions; and concentration of the different fractions. At Tanco, the plant is split effectively into three fractions: grinding/spiral circuit, fine sand circuit and slime circuit.

47. The circuit is configured so that free tantalum is recovered ahead of primary grinding from feed material less than 2 mm by spirals. The grinding circuit is then closed at 0.30 mm by a Linatex hydrosizer with the underflow recirculating to the main grinding mill.

48. The fine sand product from the grinding circuit is dewatered by cyclones and then classified by Bartles-Stokes hydrosizers into five separate size fractions which are essential for satisfactory separation on conventional gravity equipment. The first three coarsest size fractions from the Bartley-Stokes hydrosizer are treated by spirals for tantalum recovery. A fourth finer-size fraction exceeds recoverable sizes on spirals and is treated by Holman shaking tables. The fifth size fraction, which are slimes, report to the slime circuit. The spirals each produce a low-grade concentrate, a recirculated middling, and a tailings product. Falcon continuous concentrators (Sepro) scavenge the fine-sand tailings products. When this system was installed, this 300 g-force centrifugal separator was one of the most advanced concentration devices available, confirming Tanco's commitment to "leading edge technology" in the pursuit of performance.

49. Rougher concentrates from all sections are collected in a storage tank from which feeds the cleaner section at a constant flowrate and density. The creation of size fractions which feed four cleaner tables is achieved by the use of hydrocyclones and a Dorr-Oliver hydrosizer. The cleaner tables produce a fine, 35% Ta_2O_5 concentrate, where table middlings, and tailings are recirculated back to the circuit for reprocessing.

50. Overflows from the various cyclones along with the Stokes hydrosizer overflow constitute the feed to the ultrafines circuit. These are thickened in another bank of 2" high-pressure cyclones and treated by a flotation process. Tantalum flotation concentrate then reports to a 450 g-force Falcon centrifuge (UF600) which was developed at Tanco specifically for treating a tantalum flotation product.

51. Overall recovery of tantalum ranges from 69-72%. During the summer months, accumulated tailings can be processed along with the ore; the same flowsheet being used. Recovery from the tailing portion of the feed is of the order of 30%, upgrading the feed from 0.05% to 30% Ta_2O_5. The specifications of a typical tantalum concentrate produced at Tanco are >28 wt.% of Ta_2O_5.

2. Lithium

52. Spodumene can be used either as a feedstock to produce lithium carbonate, hydroxide and metal, or directly, in its mineral form, in the glass and ceramics industries. Global estimates in early 2024 by the United States Geological Survey (USGS) for end-use markets suggests that 80% of lithium production is used in batteries. Currently, Li-Cs-Ta pegmatites account for the majority of the world's lithium production according to data from the USGS (2024).

Spodumene processing

53. After crushing to <12 mm, the 2.0 fraction is removed ahead of the dense medium separation circuit (DMS) Triflo which rejects minerals commonly known as feldspars utilizing a Condor 300 (Sepro). from the <12 mm >2.0 mm range DMS feed material. Ferrosilicon and magnetite with a 70:30 mixture is used to create a medium with an effective density of separation of 2.65 kg/l. The <2.0 mm fraction continues to the grinding circuit.

54. The sink product and the <2.0 mm fraction are ground in closed circuit with a Linatex hydrosizer to produce a grinding circuit product of 95% passing 212 µm. A 5 foot (~1.5 m), low intensity drum magnet (LIMS) within the grinding circuit removes ground steel produced during the grinding process.

55. Prior to 2009, the Tanco process was required to produce spodumene concentrates with Li_2O values exceeding 7.0 %Li_2O, along with specifications for P_2O_5, K_2O and Fe_2O_3. These specifications were all well below 0.5%. This required a process with multiple lithium cleaning flotation stages, an amblygonite flotation stage for the removal of P_2O_5, a mica removal stage for controlling K_2O, and selective mining combined with the use of wet high intensity magnetics (WHIMS) for controlling Fe_2O_3. The product was then filtered by a horizontal belt filter, and then dried by a propane-fired rotary drier so that it could be shipped by railcar dry.

56. The current spodumene product being produced at Tanco now has a lithium specification closer to 5.5% Li_2O, with relaxed specifications for the elements which previously required tight control. This has allowed the Tanco spodumene flotation process to be drastically simplified as the requirements only consider the lithium grades. The process consists of a rougher flotation and a scavenger flotation. The scavenger flotation retreats the rougher flotation rejects. There is also a cleaner flotation stage to upgrade the material recovered by the scavenger flotation stage. Flotation concentrate is then filtered to a moisture of approximately 10%, and then shipped from site in bulk using highway trucks. Tantalum is currently not being recovered from the spodumene ore fed to the mill with the same stringent specifications, as it was in the past. This has simplified the spodumene process from how it was handled pre-2009 at Tanco.

3. Caesium

57. Tanco produces caesium products from pollucite. Caesium can be used in magneto-hydrodynamic power generation, in aerospace applications, opto-electronics, in DNA separation and as a catalyst in chemical applications. Caesium formate is a clear, water-soluble fluid with a specific gravity of 2.3 g/cm^3 and a viscosity similar to water. The main use for the pollucite mined at Tanco is in the manufacture of caesium formate brine, a calibrated drilling lubricant for high temperature, high pressure oil wells. It is used where the properties of low viscosity, high specific gravity and complete solution confer significant benefits over traditional solids-based drilling fluids in deep wells greater than 4,575 m (Benton and Turner, 2000).

58. From an occupational health and safety perspective, there are considerable benefits to the use of caesium formate. It has low toxicity for mammals with a pH between 10 – 11. Skin contact is not desirable, but if it occurs, has no immediate consequences. The low environmental toxicity of caesium formate makes it the fluid of choice in areas where environmental sensitivities are particularly acute (Gilbert and Pessala, 2009).

Caesium Formate Plant

59. The caesium formate pilot plant was designed, built and commissioned in 1996/97 in response to a potential market for formate brines. The plant was designed to readily incorporate process changes and modifications enabling it to produce a wide variety of cesium-based products, thus allowing Tanco and Cabot Corporation to rapidly respond to these future markets. The original plant was designed to produce 500 barrels/month of 2.3 g/cm^3 specific gravity caesium formate. In 1999, expansion of the plant allowed for the production of 700 barrels/month. In 2001, the plant underwent a further expansion in order to accommodate the manufacturing of conventional caesium chemicals (Vanstone *et al.*, 2005).

B. Environmental-socio-economic requirements for the Tanco Mine

60. The basis to Manitoba's Environmental Assessment and Licensing Regime is under *The Environment Act (2015),* but the history of the how the legislative functions were developed is important to understanding how a resource can be classified on the E axis. The following summary is based on Manitoba Law Reform Commission Final Report, (2015).

61. In 1929, an agreement was signed between the Dominion of Canada and the provincial government of Manitoba to transfer the interest of all Crown lands, mines, minerals and royalties associated with them to the Province. When the Natural Resource Transfer

Agreement (NRTA) came into effect, it placed the provincial government in control of Manitoba's natural resources. The NRTA initiated the provincial government's responsibility of overseeing the use of natural resources in the province. The transfer of authority resulted in a flood of new legislation enacted to better manage Manitoba's resources including *The Mines and Natural Resources Act*, empowering the government department to be responsible for the administration and enforcement of the legislation. Although there had been significant damage done to Manitoba's environment during the years when the Dominion of Canada was in control, this new provincial legislation was largely focused on controlling resource rights and setting fees for the use of such materials.

62. Control of provincial water resources was also transferred to Manitoba in 1930, at which time the province enacted *The Water Rights Act* and *The Water Power Act*, giving the province the authority to license the diversion of water and other water uses. *The Water Rights Act* addresses domestic, industrial, municipal, irrigation and other water usages establishing requirements for the construction of licenced activities, expropriation, and enforcement of the Act.

63. *The Water Rights Act* gives all property owners equal access to water on a first come, first served basis. However, if the water is used for municipal or industrial purposes or more than 25,000 litres per day for other purposes, a permit must be obtained. The purpose of the Manitoba water rights licensing scheme is to ensure the sustainable allocation of the province's water resources under *The Water Rights Act* and regulations.

64. In 1935, Manitoba's pollution protection framework expanded to include restrictions on substances such as decaying matter, lime, chemical substances, drugs, poisonous matter and garbage as a result of *The Pollution of Water Prevention Act*. This pollution control legislation was passed partly because of a perceived need to reduce the pollution in Manitoba's river systems, particularly in the Red River. The *Pollution of Water Prevention Act* has been credited with reducing overall water pollution levels in Manitoba and getting some of the province's major water pollution issues under control. In 1968 it was repealed and replaced by *The Clean Environment Act* (CEA).

65. *The Clean Environment Act*, the predecessor of today's *The Environment Act*, was the first Act in the province to reflect the need to provide more comprehensive protection for the environment: air, water and land. On 31 March 1988, *The Environment Act* replaced CEA, 1972 and the environmental assessment process was introduced. The intent of *The Environment Act* is to "develop and maintain an environmental management system in Manitoba which will ensure that the environment is maintained in such a manner as to sustain high quality of life, including social and economic development, recreation and leisure for this and future generations." The Department of Environment and Workplace Safety and Health was the authority responsible for administrating the environmental assessment and licensing process when this legislation was enacted in 1988. Under *The Environment Act*, the scope of environmental protection was expanded with a new definition of environment that included "air, land, and water, or plant and animal life, including humans". *The Environment Act* formalized the role of the public in the environmental assessment and licensing process. The Clean Environment Commission continued to function under this new legislation, including to develop and maintain public participation in environmental matters.

66. Environmental assessment is the process by which the environmental implications of a proposed development are evaluated for consideration during approval and licensing decisions. Although commonly expressed as two separate terms, both assessment and licensing are considered to be part of the same continuous process in Manitoba. Environmental assessment is a process to predict environmental effects of proposed initiatives.

67. An environmental assessment:

- Identifies potential adverse environmental effects.
- Proposes measures to mitigate adverse environmental effects.
- Predicts whether there will be significant adverse environmental effects, after mitigation measures are implemented.
- Includes a follow-up programme to verify the accuracy of the environmental assessment and the effectiveness of the mitigation measures.

68. These activities identify environmental, social and economic factors that should be considered during the construction process.

69. While public input and participation in assessing prospective development proposals is an important step in the regulatory system, it should not be confused with the requirements to consult with Indigenous people. An important aspect of understanding both resource and environmental legislation throughout Canada is the role and place of the Indigenous people. The Manitoba Government is responsible for both Crown-Indigenous consultation and the engagement process required for federal and provincial environmental authorizations. As a proponent, the federal government requires the Manitoba Government to engage with potentially affected Indigenous groups when developments are proposed to assist in fulfilling the federal Crown constitutional obligations and to fulfil the regulatory requirements for developing a complete Environmental Impact Statement. This stems from the role of the Crown, which has a responsibility under Section 35 of Canada's constitution to consult with Indigenous groups or communities whose exercise of treaty or Aboriginal rights might be affected by a government decision or action related to the project.

70. The Manitoba Government recognizes that Indigenous groups and communities have the right to be informed about the impacts that a project may have on their rights and interests. They also have the right to express their views about the project and its impacts and have those views be given serious consideration and mitigated where appropriate.

71. The Tantalum Mining Corporation of Canada Ltd. currently operates the Tanco Mine under Manitoba Environment Act Licence No. 973 which was issued on February 4, 1983. Regulatory approvals for the operation date back to 1969 when approval for development of the East Tailings Management Area (TMA) was granted. In 1972, Tanco submitted an application to the Clean Environment Commission to prescribe limits in connection with the discharge of effluent into Bernic Lake. Order No. 396 was issued in 1974 and contained only one effluent quality limit on the discharge of contaminants from the mine and mill complex, which specified the pH was to be kept in the range of 6.0 to 8.5. Two subsequent proposals were filed with the department in 1980 and 1982. The first was for expansion of mill capacity from 163,000 tonnes to 226,750 tonnes per year. The second was for construction of the spodumene concentrate pilot plant and dam to provide impoundment for spodumene tailings in the North Bay of Bernic Lake. Effluent quality was regulated solely by the discharge limits set out in the Order until December 2002, when the mine became subject to the Metal Mining Effluent Regulations.

72. Since 1992, Manitoba Conservation has examined 36 alterations to this Licence. In 2013, a comprehensive Notice of Alteration, was submitted that fully describes the operation as it was at that point, as well as Tanco's plans to operate and develop the facility through to the end of the mine life, along with an assessment of the current environmental effects of the operation through to final close out. Since Bernic Lake is a headwater lake and therefore very susceptible to environmental damage, the plant design minimizes environmental impacts on the surrounding area. All areas of the plant are contained to capture any spilled material, and wastes are stored in a lined disposal cell, which eliminates the discharges to the lake. Water quality measurements are required as part of the permitting requirements for the operation collected quarterly from Bernic Lake and nearby Tulabi Lake. The analytical results are compared to Manitoba Water Quality Standards, Objectives and Guideline Tier II and Tier III guidelines for the protection of freshwater aquatic life (Williamson 2011) and the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life (CCME, 1999).

73. Currently, with a focus on the long-term remediation of the site, two new project proposals have been submitted for environmental review by the Department of Environment and Climate Change, the regulatory agency for development permits in Manitoba.

74. One proposal examines the West Tailings Management Area (WTMA). The WTMA is one of two tailings management areas on the mine site and is used to provide long-term storage of tantalum and spodumene tailings. In 2016, Tanco conducted an internal resource estimate on the tailings concluding that the WTMA tailings contained 2.86 million tonnes of tailings with approximately 1.06% Lithium Oxide, 0.54% Caesium Oxide, and 0.44% Rubidium Oxide (Tetratech 2023). In 2023, a proposal was submitted to initiate the environmental permitting process for the construction of a new 3,000 tonnes per day (tpd) processing plant that will reprocess approximately 3 million tonnes of existing tailings located within the WTMA over a five-year period to produce lithium concentrates. The new processing facility would require an increase in the licenced daily production rates from 1,000 tpd to 4,000 tpd overall, with the new mill capable of processing 3,000 tpd and the existing mill (running concurrently) capable of processing 1,000 tpd. An estimated 95% of the process water requirements is expected to be recycled water sources, which would require only a modest increase in the mine effluent discharge rate.

75. Test work and modelling are being completed to confirm treatment measures required to maintain or improve the mine effluent discharge into Bernic Lake. The fines and slimes in the tailings water carry reactive phosphorus and phosphorus that is biologically active, so the treatment options tested have focused on Total Suspended Solids treatment. Based on preliminary test work, and with a conservative 80 percent water recovery (recycling) rate, the phosphorus impact to Bernic Lake associated with the Project is expected to be an order of magnitude lower than current loading.

76. A second proposal has been submitted to examine the Eastern Tailings Management areas which holds the residues from the Caesium Product Facility (CPF) (Tanco 2023). Studies of the tailings and the residue leachate have demonstrated that the drystack capacity of the East TMA. The CPF residue functions as an essentially impervious cap and the residue drystack creates an isolated groundwater depression beneath the stack. Any migration of the residue leachate signature parameters away from the drystack is result of surface runoff and not groundwater transport. A plan to initiate residue drystacking through to the end of mine life is being developed.

VII. UNFC Classification of the Tanco deposit

77. The Tanco deposit demonstrates some of the challenges classifying multi product projects. In the Sinomine Resources 2022 Annual Report, the resources at the Tanco Mine are summarized but this summary is not to the disclosure level required to evaluate the quality of the estimate (Sinomine 2023).

78. The in-situ pegmatite deposit has a mineable resource (only an amalgamated value that includes measured, indicated and inferred is available) in current underground operations of:

- 2,324,400 tonnes with a Li_2O grade of 1.859% containing a Li_2O metal quantity of 43,206.78 tonnes.
- 3,709,570 tonnes with a Ta_2O_5 grade of 0.109% containing a Ta_2O_5 metal quantity of 4,037.52 tonnes.
- 116,400 tonnes with a Cs_2O grade of 13.83% containing a Cs_2O metal quantity of 16,100 tonnes.

79. This information was initially provided to meet the requirements of the Shenzhen Stock Exchange in Hong Kong for exploration and mining projects in China. The original estimate was classified according to the "New” system for categorizing mineral resources and ore reserves. The “Old” system has been phased out since 1999 and was based on the Soviet classification system which used categories A through F for resources, based on

decreasing levels of geological confidence. The new system is based on the standards of the United Nations Framework Classification for Resources.

80. In the case of Tanco, the reserve estimates in the public record demonstrate a variety of historical pre-CRIRSCO disclosure formats, that would be considered non-compliant with current Canadian National Instrument (NI43-101) requirements. This should not be misconstrued as a reflection of poor work, fraud or misrepresentation, as it is a reflection of the complex and extended history of this mine. Given the mine history, it is apparent that as the demand for the main mine products changed, the focus of the mine production also changed. What can not be determined is the degree to which the commodity prices were incorporated into some of the reported estimates, if reserves for non-produced commodities recalculated to reflect actual prices or were old estimates based on higher prices retained without the proper revision.

81. Classification for the E axis should be **E1** as the company's development and operation are confirmed to be environmentally-socially-economically viable by the Environmental Approvals Branch of the Department of Sustainable Development, of the Manitoba Government. Tanco has submitted the necessary reports to comply with the Environment Act, which regulates outlines the environmental assessment and licensing process. However, as there are three commodities that are subject to different market conditions the rating for Tantalum must be distinct from Lithium and Caesium. Instead of an E1 class, Tantalum must be rated either as a Development on Hold **E2** class or Development not Viable **E3**. Considering that the price has restricted mining for 15 years, **E3** seems to be the most appropriate classification for Tantalum.

82. Based on information from 2013 (Tetratech, 2013) and 2021 (Environment Act Proposal report, 2021), emissions to air produced by the Tanco facility are reported annually to the National Pollutant Release Inventor and are considered 'non-significant'. Water discharge is monitored at the West Discharge site (the primary discharge site from the mine) and its quality has been conducted since the discharge was first established in 1996. The water quality monitoring required under Environment Act License No. 973 is for quarterly measurements of pH and total suspended solids. These parameters are environmentally acceptable for the Tanco mine. The last update to the Tanco processing facilities was in 2021 as per Environment Act Proposal report requested by the Environmental Approvals Branch of the Department of Sustainable Development, part of Manitoba Government in order to update the Tanco Bernic Lake Mine's Environment Act License (Environment Act Proposal report, 2021). Detailed results for the environmental control over the years can be accessed for 2013 (Tetratech, 2013) and 2021 (Environment Act Proposal report, 2021).

83. Specifically, and using the subcategory system, we can classify the deposit as **E1.1.** as development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions. Tanco has been following all environmental regulations and has the environmental permits required to operate the mine and process plant in place. But the Tantalum project should be **E3.3** given the ongoing market conditions.

84. For potential proposed projects that involve the potential reprocessing of tailings, a classification of **E3.2** is suggested. The material is well-characterized and does not involve an increase of the mine's environmental footprint. The material has a consistent grade and should be comparatively inexpensive to move to a processing plant. The permit applications have been submitted and if the processing goes as planned could result in a reduction of the environmental impact of the site.

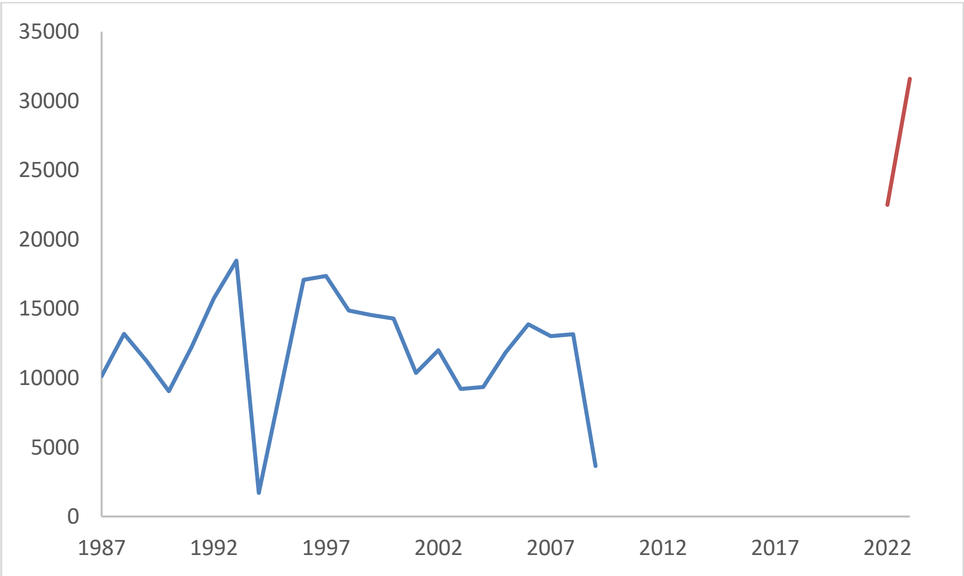
85. The classification of F axis should be **F1** because production is currently taking place and the technical feasibility of a development project has been confirmed. Because Tanco is a multi-commodity deposit and production at Tanco can fluctuate due to market demands, a subcategory in the classification of the F axis should be applied. Currently for lithium and caesium production, subcategory **F1.1** should be applicable. Table 5 shows historical lithium production at Tanco and Figure VI provide production numbers for historical production of lithium, demonstrating this fluctuation.

Table ***5***
Tanco lithium production history data

Year	*Li_2O Conc. grade*	*Conc. tonnes*
1987	7.32	10141
1988	7.29	13179
1989	7.29	11244
1990	7.26	9045
1991	7.23	12233
1992	7.30	15762
1993	7.30	18473
1994	7.31	1701
1996	7.24	17094
1997	7.20	17360
1998	7.24	14879
1999	7.21	14547
2000	7.19	14298
2001	7.16	10366
2002	7.19	11997
2003	7.18	9200
2004	7.16	9357
2005	7.17	11835
2006	7.19	13879
2007	7.08	13013
2008	7.11	13161
2009	7.03	3647
2022	5.00	22500
2023	4.82	31598

Note: Abbreviations: Conc., concentrate.

Figure VI
Lithium production at the Tanco mine*



* 1987-2009, blue and 2022-2023, orange.

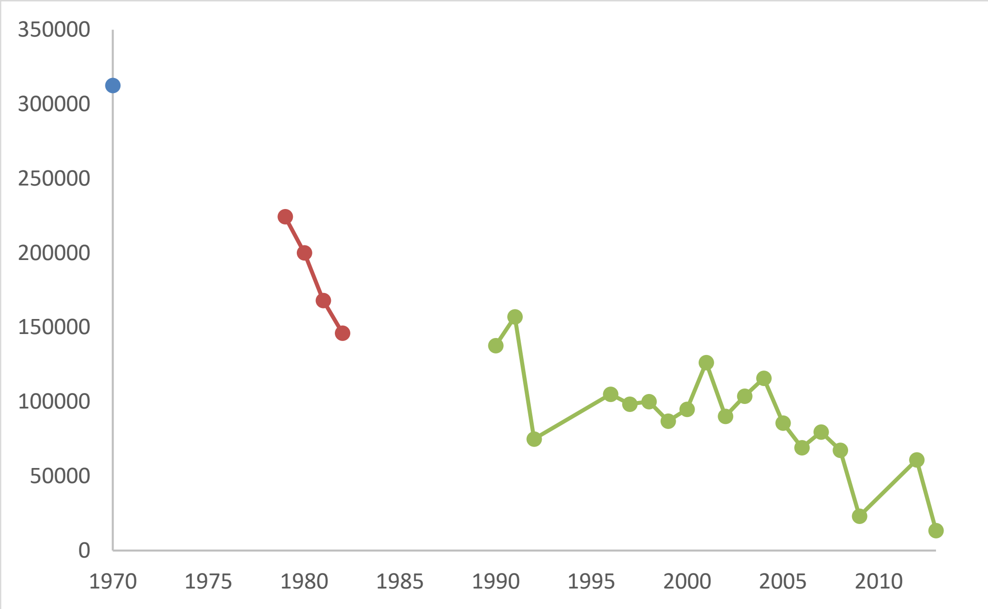
86. Because tantalum production is halted at the moment, subcategory **F2.3** should be applied to this commodity (Table ***6*** **Tanco tantalum production history data**Table 6, Figure VII). The main reasoning is that past production of tantalum clearly demonstrates that studies have been completed to prove the technical feasibility of development and operation and there is a reasonable expectation that all necessary approvals or contracts for the production of tantalum will be forthcoming. Table 6 and Figure VII show historical production numbers for tantalum and illustrate the fluctuation over the years.

Table ***6***
Tanco tantalum production history data

Year	*Ore quantity (tonnes)*	*Ta metal in the feed (Kg)*
1970	138326	312616
1979	163751	224339
1980	147156	200133
1981	137847	168173
1982	116900	146125
1990	155834	137799
1991	161571	157157
1992	80150	74990
1996	149648	105033
1997	122372	98380
1998	125785	100127
1999	124924	86925
2000	137492	95081
2001	183537	126440
2002	142513	90319
2003	146570	103840
2004	162541	115903
2005	145758	85763
2006	118148	69216
2007	117126	79616
2008	119273	67551
2009	43607	23108
2012	118851	60968
2013	36198	13537

Note: Abbreviations: Con., concentrate.

Figure VI
Production of contained Ta metal at the Tanco mine*



* 1970, blue; 1979-1982, red; and 1990-2013, green.

87. If there are proposed projects that involve the reprocessing of tailings, a classification of **F2.2** is suggested. The material has been processed previously and to some degree is a form of stockpiled rock. The material has a consistent grade and a uniform grain size already. No new technology is needed for the reprocessing but the re-mobilization of this material does present the opportunity to investigate different metallurgical processes to ensure that the recoveries are maximized. The permit applications have been submitted and if the processing goes as planned would result in a significant quantity of production with very little water usage.

88. While the classification for the G axis should be **G1**, the classification for Tanco depends on and the degree of compilation for each commodity. Current operations are reported to be producing Lithium Concentrate and Caesium Formate. The reserve estimates have been aggregated to include G1 and G2 and G3 resources and then for these commodities can then be classified as **E1 F1 G3**. In contrast, the classification for tantalum must be lower due to the lack of active production. The compiled resource estimates are shown in Table 7.

Table ***7***
Lithium, caesium and tantalum resource estimates

	Classification	*Type*	*Commodity*	*Quantity (tonnes)*	*Grade*	*Metal Content*	*Sub Class*	*E*	*F*	*G*
Caesium										
	113	Underground	Cs_2O	116,400	13.80%	16,100	In Production	1	1.1	3
Lithium										
	113	Underground	Li_2O	2,324,400	1.86%	43,206.78	In Production	1	1.1	3
Tantalum										
	333	Underground	Ta_2O_5	3,709,570	0.10%	4,037.52	Development Not Viable	3	2.3	3

VIII. Conclusions

89. This case study demonstrates that the classification of a mining project from public information is possible using the UNFC classification system. The classification is possible even when the estimates that are available are not disclosed to a level that would be compliant with standardised systems such as the Canadian National Instrument (NI) 43-101 or the Australian Joint Ore Reserve Committee (JORC) Code. However, the study does reveal a number of other interesting features. The studied mine has undergone quite a large number of transformations. Starting as a Tantalum mine, it has been a Caesium mine and now a Lithium mine as the main commodity has changed over the years. This change is not intrinsic to the mine itself but represents the changing price of the main commodities over time as shown below.

Commodity Prices (illustrative dates)

Lithium:	5.4 US$/kg Li in 2010	14.8 US$/kg Li in March 2024	Up 174%
Tantalum:	239 US$/kg Ta in 2012	190 US$/kg Ta in 2023	Down 21%
Caesium:	62,800 US$/kg Cs in 2009	117,000 US$/kg Cs in 2023	Up 86%

90. The Tanco mine presents an interesting case study as this is a multicommodity deposit and the commodities have been mined over an extended mine life while responding to various market conditions and economic demands. In some regards, the whole project should not be treated as one project but should be considered as three projects that are interrelated. There is the repeated situation where one or two of the commodities are profitable, that may be enough for the mine to operate. On the other hand, if only one of the commodities is being produced but it is not profitable, the mine might shut down.

Acknowledgements

91. The authors would like to acknowledge the support of the Manitoba Geological Survey and Tantalum Mining Corporation of Canada, Ltd (part of Sinomine Resource Group Co., Ltd.) in preparing this case study.

References

Anderson, S.D., Černý, P., Halden, N.M., Chapman, R. and Uher, P. 1998: The Yitt-B pegmatite swarm at Bernic Lake, Southeastern Manitoba: a geochemical and paragenetic anomaly; Canadian Mineralogist, v. 36, p. 283-301.

Atencio, D., Andrade, M.B., Christy, A.G., Gieré, R. and Kartashov, P.M. 2010: The pyrochlore supergroup of minerals: nomenclature; Canadian Mineralogist, v. 48, p. 673-698.

Baadsgaard, H. and Černý, P. 1993: Geochronological studies in the Winnipeg River pegmatite populations, southeastern Manitoba; Geological Association of Canada−Mineralogical Association of Canada, Joint Annual Meeting, Program with Abstracts, v. 18, p. A5.

Bannatyne, B.B. 1985: Industrial minerals in rare-element pegmatites of Manitoba; Manitoba Energy and Mines, Geological Services, Economic Geology Report ER84-1, 96 p.

Benton, W. and Turner, J. 2000: Cesium formate fluid succeeds in North Sea HPHT field trials; Drilling Contractor, p. 38-41.

Brown, J.A., Martins, T. & Černý, P. 2017: The Tanco Pegmatite at Bernic Lake, Manitoba. XVII. Mineralogy and Geochemistry of Alkali Feldspars. The Canadian Mineralogist; 55 (3), p. 483-500. https://doi.org/10.3749/canmin.1700008

Burke, E.A.J. 2008: Tidying up Mineral Names: an IMA-CNMNC Scheme for Suffixes, Hyphens and Diacritical marks; The Mineralogical Record v.39, p. 131-135.

Černý, P. 2005: The Tanco rare-element pegmatite deposit, Manitoba: Regional context, internal anatomy, and global comparisons; *in* Linnen, R.L., and Samson, I.M., *eds*., Rare-Element

Geochemistry and Mineral Deposits: Geological Association of Canada, GAC Short Course Notes 17, p. 127-158.

Černý, P. and Ercit, S. 2005: The classification of granitic pegmatites revisited; Canadian Mineralogist, v. 43, p. 2005-2026.

Černý, P., Ercit, T. and Vanstone, P. 1996: Petrology and mineralization of the Tanco rare-element pegmatite, Southeastern Manitoba (Field Trip A3). Geological Association of Canada – Mineralogical Association of Canada, 63p.

Černý, P., Ercit, T. and Vanstone, P. 1998: Mineralogy and Petrology of the Tanco rare-element pegmatite deposit, Southeastern Manitoba (Field trip Guidebook B6); International Mineralogical Association. 17th General Meeting, Toronto, 74 p.

Černý, P., Trueman, D.L., Ziehlke, D.V., Goad, B.E. and Paul, B.J. 1981: The Cat Lake-Winnipeg River and the Wekusko Lake pegmatite fields, Manitoba; Manitoba Energy and Mines, Manitoba Resources Division, Economic Geology Report ER80-1, 215 p.

Cooper, M.A., Hawthorne, F.C., Ball, N.A., Ramik R.A. and Roberts, A.C. 2009: Groatite, Na Ca Mn^{2+}_2 (PO_4) $[PO_3(OH)]_2$, a new mineral species of the alluaudite from the Tanco pegmatite, Bernic Lake, Manitoba, Canada: description and crystal structure; Canadian Mineralogist, v. 47, p. 1225-1235.

Dawson, K.R. 1974: Niobium (Columbium) and Tantalum in Canada; Econ Geol 29; Geological Survey of Canada p. 119-120; https://doi.org/10.4095/103996

Environment Act Proposal report, 2021: https://www.gov.mb.ca/sd/eal/registries/1906.4/eap.pdf

Ercit, T.S., Hawthorne, F.C. and Černý, P. 1992: The wodginite group. I. Structural crystallography. Canadian Mineralogist v. 30, 597-611.

Fransolet, A.-M., Cooper, M.A., Černý, P., Hawthorne, F.C., Chapman, R. and Grice, J.D. 2000: The Tanco pegmatite at Bernic Lake, southeastern Manitoba. XV. Ercitite, $Na,Mn^{3+}PO_4(OH)(H_2O)_2$, a new phosphate mineral species, Canadian Mineralogist v. 38, p.893-898.

Gilbert, H.P. 2005: Geological investigations in the Bird River area, southeastern Manitoba (parts of NTS 52L5N and 6N); *in* Report of Activities 2005, Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, p. 125-139.

Gilbert, H.P. 2006: Geological investigations in the Bird River area, southeastern Manitoba (parts of NTS 52L5N and 6); *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 184–205.

Gilbert, H.P. 2007: Stratigraphic investigations in the Bird River greenstone belt, Manitoba (part of NTS 52L5, 6); *in* Report of Activities 2007, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 129–143.

Gilbert, H.P., 2008: Stratigraphic investigations in the Bird River greenstone belt, Manitoba (part of NTS 52L5, 6); *in* Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 121−138.

Gilbert, H.P., Davis, W.D., Duguet, M., Kremer, P.D., Mealin, C.A. and MacDonald J. 2008: Geology of the Bird River Belt, southeastern Manitoba (parts of NTS 52L5, 6); Geoscientific Map MAP2008-1.

Gilbert, Y. and Pessala, P. 2009: Cesium formate and Zinc bromide: Comparative Hazard Assessment and HSE Profiles; Gaia Consulting OY, 48p.

Hutchinson, R.W. 1959: Geology of the Montgary Pegmatite [Manitoba]. Economic Geology, v. 54, p. 1525-1542.

Kissin, S.A., Owens, D.R. and Roberts, W.L. 1978: Černýite, a copper - cadmium - tin sulfide with the stannite structure; Canadian Mineralogist, v. 16, p. 139-146.

Kremer, P.D. and Lin, S. 2006: Structural geology of the Bernic Lake area, Bird River greenstone belt, southeastern Manitoba (NTS 52L6): implications for rare element pegmatite emplacement; *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 206–213.

Kremer, P.D. 2010: Structural geology and geochronology of the Bernic Lake area in the Bird River greenstone belt, Manitoba: Evidence for syn-deformational emplacement of the Bernic Lake pegmatite group; M.Sc. thesis, University of Waterloo 91pp.

Lenton, P.G. 1979: Mineralogy and petrology of the Buck Claim lithium pegmatite, Bernic Lake, Southeastern Manitoba; M.Sc. thesis, University of Manitoba, 164 p.

London, D. 1985: Origin and significance of inclusions in quartz: a cautionary example from the Tanco pegmatite; Manitoba, Economic Geology, v. 80, p. 1988-1995.

London, D., Zolensky, M.E. and Roedder, E. 1987: Diomignite: natural $Li_2B_4O_7$ from the Tanco pegmatite, Bernic Lake, Manitoba; Canadian Mineralogist, v. 25, p. 173-180.

Manitoba's Environmental Assessment and Licensing Regime under The Environment Act. 2015: http://www.manitobalawreform.ca/pubs/pdf/130-full_report.pdf

Percival, J.A., Sanborn-Barrie, M., Skulski, T., Stott, G.M., Helmstaedt, H. and White, D.J. 2006: Tectonic evolution of the western Superior Province from NATMAP and LITHOPROBE studies; Canadian Journal of Earth Sciences, v. 43, p. 1085−1117.

Ramik, R.A., Sturman, B.D., Dunn, P.J. and Povarennykh, A.S. 1980: Tancoite, a new lithium sodium aluminum phosphate from the Tanco pegmatite, Bernic Lake, Manitoba, Canadian Mineralogist, v.18, p. 185-190.

Scoates, J.S. and Scoates, R.F.J 2013: Age of the Bird River Sill, southeastern Manitoba, Canada, with implications for the secular variation of layered intrusion-hosted stratiform chromite mineralization; Economic Geology, v. 108, 13 p.

Sinomine 2021: Sinomine Tanco's Technical Renovation& Restoration for Spodumene Processing System Officially Put into Operation in Canada; http://en.sinomine.cn/xwdti/176.html

Sinomine 2023: 2022 Annual Report http://en.sinomine.cn/uploads/20230512/1683875390469986.pdf

SRK 2023: https://www.srk.com/en/publications/jorc-and-the-chinese-resource-classification-system-an-srk-view

Stilling, A., Černý, P. and Vanstone, P.J. 2006: The Tanco pegmatite at Bernic Lake, Manitoba. XVI. zonal and bulk composition and their petrogenetic significance; Canadian Mineralogist, v. 44, p. 599-623.

Stott, G.M., Corkery, M.T., Percival, J.A., Simard, M. and Goutier, J. 2010: Project units 98-006 and 98-007. A revised terrane subdivision of the Superior Province; in Summary of Field Work and Other Activities 2010, Ontario Geological Survey, Open File Report 6260, p. 20-1 - 20-10.

Tanco 2023 Tantalum Mining Corporation of Canada Bernic Lake Mine – Cesium Processing Facility Residue Reprocessing Project (2023) https://www.gov.mb.ca/sd/eal/registries/1906.2tanco/cesium_reprocessing_noa.pdf

Tetratech 2023 Tantalum Mining Corporation of Canada Ltd.: Tailings Reprocessing Facility Project Environment Act Proposal https://www.gov.mb.ca/sd/eal/registries/1906.5/eap.pdf

Tetratech, 2013: TANCO Mine Notice of Alteration, Tantalum Mining Corporation of Canada Limited. https://minedocs.com/23/Tantalum-Mining-Tanco-Project-Description-2013.pdf

Trueman, D.L. 1980: Stratigraphy, structure and metamorphic petrology of the Archean greenstone belt at Bird River, Manitoba; Ph.D. thesis, University of Manitoba, Winnipeg, Manitoba, 150 p.

United Nations Framework Classification for Resources, 2019: ECE ENERGY SERIES No. 61 https://unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/publ/UNFC_ES61_Update_2019.pdf

UNECE 2022. UNFC Guidance Europe – Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe, United Nations Economic Commission for Europe. Geneva 2022. https://unece.org/sites/default/files/2022-11/UNFC%20GUIDANCE%20EUROPE-FINAL_0.pdf

United Nations Framework Classification for Resources – A Case Study on Graphite (2022): https://unece.org/sites/default/files/2022-04/ECE_ENERGY_GE.3_2022_15.pdf

U.S. Geological Survey, Mineral Commodity Summaries, Lithium (2024): https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-lithium.pdf

van Lichtervelde, M., Linnen, R.L., Salvi, S. and Didier, B. 2006: Evaluating the role of metagabbro rafts on tantalum mineralization in the Tanco pegmatite; Manitoba; Canadian Mineralogist v. 44, p. 625-644.

van Lichtervelde, M., Salvi, S., Béziat, D. and Linnen, R.L. 2007: Textural Features and Chemical Evolution in Tantalum Oxides: Magmatic Versus Hydrothermal Origins for Ta Mineralization in the Tanco Lower Pegmatite, Manitoba, Canada; Economic Geology, v. 102, p. 257-276.

van Lichtervelde, M., Grégoire, M., Linnen, R.L., Béziat, D. and Salvi, S. 2008: Trace element geochemistry by laser ablation ICP-MS of micas associated with Ta mineralization in the Tanco pegmatite, Manitoba, Canada; Contributions to Mineralogy and Petrology, v. 155,p. 791-806.

Vanstone, P., Young, S., Galeschuk, C., Simard, R. and Gibb, A. 2005: The Tanco Rare-element pegmatite, Southeastern Manitoba; Tantalum Mining Corporation of Canada Limited, 22p.

Wang, X. 1993: U-Pb zircon geochronology study of the Bird River greenstone belt, southeastern Manitoba; M.Sc. thesis, University of Windsor, Windsor, Ontario, 96 p.