71-36

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 71-36

AGE OF THE CONTACT METASOMATIC COPPER AND IRON DEPOSITS, VANCOUVER AND TEXADA ISLANDS, BRITISH COLUMBIA

(Report and 1 figure)

D. J. T. Carson, J. E. Muller,
R. K. Wanless, and R. D. Stevens

Price, 75 cents

1971

GEOLOGICAL SURVEY

OF CANADA

CANADA

PAPER 71-36

AGE OF THE CONTACT METASOMATIC COPPER AND IRON DEPOSITS, VANCOUVER AND TEXADA ISLANDS, BRITISH COLUMBIA

D. J. T. Carson, J. E. Muller,
R. K. Wanless, and R. D. Stevens

DEPARTMENT OF ENERGY, MINES AND RESOURCES

Available by mail from *Information Canada*, Ottawa

from the Geological Survey of Canada
601 Booth St., Ottawa

and

Information Canada bookshops in

HALIFAX - 1735 Barrington Street
MONTREAL - 1182 St. Catherine Street West
OTTAWA - 171 Slater Street
TORONTO - 221 Yonge Street
WINNIPEG - 499 Portage Avenue
VANCOUVER - 657 Granville Street

or through your bookseller

Price: .75 Catalogue No. M44-71-36

Price subject to change without notice

Information Canada
Ottawa
1971

CONTENTS

Illustration

ABSTRACT

The results of several previous geological investigations strongly suggest that all of the important contact metasomatic iron and copper deposits of Vancouver and Texada Islands are younger than the Triassic, but are pre-Tertiary. Potassium-argon age determinations made by the Geological Survey of Canada support this contention and further indicate that a very large majority of the deposits of this class, probably including all those of economic importance, were emplaced at intervals throughout much of the Jurassic period.

RÉSUMÉ

Les résultats de plusieurs recherches géologiques préalables suggèrent fortement que tous les gîtes importants de fer et de cuivre des îles Vancouver et Texada, formés par métasomatose de contact, sont plus récents que le Trias, mais antérieurs au Tertiaire. Les datations par la méthode potassium-argon, effectuées par la Commission géologique du Canada, confirment cette hypothèse et de plus elles indiquent que la très grande majorité de ces gisements de cette catégorie, englobant probablement tous ceux qui revêtent une importance économique, ont été mis en place pendant plusieurs intervalles échelonnés sur une bonne partie de la période du Jurassique.

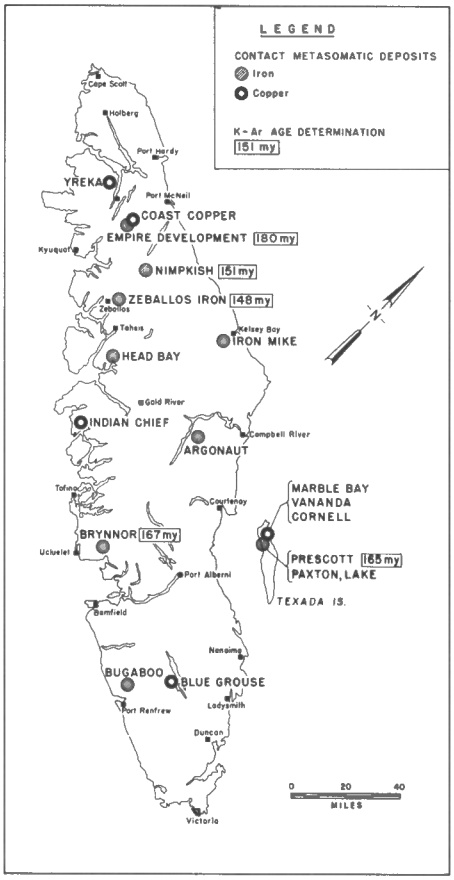

Figure 1. Major contact metasomatic iron and copper deposits of Vancouver and Texada Islands.

AGE OF THE CONTACT METASOMATIC COPPER AND IRON DEPOSITS OF VANCOUVER AND TEXADA ISLANDS, BRITISH COLUMBIA

INTRODUCTION

This paper interprets the presently available data relating to the geological age of the contact metasomatic iron and copper deposits of Vancouver and Texada Islands. Included are several previously unpublished potassium-argon age determinations. Contact metasomatic deposits, commonly referred to as skarn deposits, are abundant on the two islands. Several have been profitably exploited in recent years, but only Coast Copper and Texada Iron Mines are producing at present. The largest and most important of the known deposits, including those discussed in this paper, are shown in Figure 1.

Appreciation is expressed to W.D. McCartney, G.E.P. Eastwood, and W.I. Nelson Jr. for advice and aid in the collection of samples, and to H. Gabrielse and K.E. Northcote who critically read the manuscript and offered many suggestions.

GEOLOGY

The geology of the contact metasomatic deposits has been the subject of several studies. A compilation of the characteristics of these deposits taken largely from previous work is given in Table 1.

Although early Permian limestone of the Sicker Group is widespread on Vancouver Island, all the important contact metasomatic iron and copper deposits are exclusively at or near the contacts between granitic intrusions and limestone of the late Triassic Quatsino Formation. To explain this limited association, Sangster (1969) and Eastwood (1965) suggested that rising intrusions obtained excess iron from basic volcanic rocks of the Karmutsen Formation which occurs between the two limestones, so that only upon reaching the Quatsino Formation did they have sufficient iron to form magnetite deposits.[1] Carson (1968) noted an abundance of granitic bodies near the Quatsino Formation as compared with the Sicker limestone, and also observed that many of these bodies are concordant or semiconcordant. He proposed that due to lithostatic pressure, most Jurassic intrusions did not halt their ascent, spread laterally, and crystallize, until they had breached the top of the Karmutsen Formation.[2] Such a process would result in an accumulation

[1] In many localities the Karmutsen Formation is anomalously high in syngenetic copper. It may also have been the original source for copper in the skarn deposits.

[2] This mechanism of intrusion was proposed by Gunning (1932) for the Nimpkish "batholith" of northern Vancouver Island.

Manuscript approved for publication July 19, 1971.
D.J.T. Carson is a member of the staff of Noranda Exploration Co. Ltd., the other authors are officers of the Geological Survey of Canada.

Table 1. Characteristics of the Contact Metasomatic Iron and Copper Deposits of Vancouver and Texada Islands

Type	Main metals, tenor	Ore mineralogy, common textures	Skarn mineralogy and textures	Host rocks and associated formations	Physical forms of deposits	Structural controls
Contact Metasomatic Iron Deposits	40 - 60% Fe Concentrates 55% - 64% Fe and relatively free from impurities.	Magnetite. Minor pyrrhotite, specularite, pyrite, chalcopyrite, sphalerite. Rare marcasite, cobaltite, safflorite, smaltite. Magnetite occurs as fracture-fillings, vug-filling, replacements of skarn and country rocks. Locally it is banded, colloform, massive, brecciated.	Abundant zoned garnet (andradite-grossularite). epidote (pistacite), pyroxene (diopside-hedenbergite). Less abundant actinolite, quartz, prehnite. Rare vesuvianite, wollastonite, axinite, chloritic phlogopite. Calcite, chlorite, amphibole, serpentine are common in the host rocks. Garnet and pyroxene intergrown and disseminated in one another. Epidote veins and patches in both. Earlier spidote is deuteric, later is of skarnification process.	Known deposits are in Quatsino or other Upper Triassic limestone or adjacent volcanic rocks and (rarely) intrusions. Mesozonal-epizonal intrusions ranging in composition from gabbro to quartz monzonite are nearby.	All sizes of magnetite bodies from a few feet to more than 100 feet across, generally in cluster. Bodies are tabular, lens-like, spherical, pipe-like, cylindrical, but mainly irregular in shape. Largest production, Texada Iron Mines - 15,000,000 tons.	Local folds, generally synclines. Fractured rock in folds. Stratigraphic contacts. Intrusive contacts, especially at tongues or cupolas. Faults, zones of brecciated rock. Local post-ore faults control limits of some bodies.
Contact Metasomatic Copper Deposits	Cu 1.5% - 2% in economic deposits Fe, Au, Ag may also be recovered.	Chalcopyrite; bornite common at some deposits. Pyrrhotite, pyrite, magnetite common. Minor sphalerite, galena, specularite, marcasite. Rare ilvaite, molybdenite. Fibrous intergrowths of actinolite and sulphides common. Chalcopyrite disseminated, in veinlets. Colloform pyrite, pyrrhotite.	As in iron skarns but more variable; actinolite common, rare sillimanite. Many garnets unzoned.	As for iron skarns except: 1) host rocks are more varied and rarely pure limestone. 2) many deposits are further from major intrusions though dykes may be present.	All sizes of ore bodies up to >500,000 tons (Coast Copper). Physical forms similar to iron skarns but massive bodies less common, tabular bodies parallel to bedding more common.	As for magnetite skarns. Contacts of dykes and sills with bedding may be more important.

of crystallizing magma at this level, and could explain the almost exclusive development of both metalliferous and non-metalliferous skarn near the overlying Quatsino Formation.

There is a very close association between intrusion of granitic magma, development of skarn (Sangster, 1969), and the iron and copper mineralization. Eastwood (1965, 1966) believed that these were related processes that occurred over a time interval of less than two million years. In such a case, the difference in the ages of an intrusion and its associated skarn could not be resolved using K-Ar techniques.

Available isotopic ages and stratigraphic information indicate that the granitic intrusions of Vancouver Island are Jurassic and Tertiary, and those of Texada Island are Jurassic and early Cretaceous (Wanless et al., 1966, 1967, 1968; Muller and Carson, 1969; this paper). The Tertiary plutonic phase of Vancouver Island was accompanied by copper and gold mineralization. This phase has not been recognized on Texada Island. It should be noted that a very large number of granitic intrusions, particularly those along the west coast of Vancouver Island, remain to be dated.

EXPERIMENTAL PROCEDURE FOR POTASSIUM-ARGON AGE DETERMINATIONS

Mineral concentrates were prepared from crushed rock samples by standard magnetic and heavy liquid separation techniques. Argon was extracted from the samples by fusion in vacuo. Released gases were purified by passage through hot CuO, liquid nitrogen cooled traps, and over a titanium sponge getter. During the fusion of each sample a calibrated quantity of ^{38}Ar tracer (spike) was equilibrated with the gas evolved.

Isotopic analysis of the argon was performed in a modified A.E.I. MS-10 mass spectrometer operated in the static mode, and having a sensitivity of 1×10^{-8} cc STP/mv. Mass discrimination factors were determined for analyses of atmospheric argon. Ion currents were selected by rapidly switching the source voltage, and the vibrating reed electrometer amplifier output was measured with an integrating digital voltmeter and recorded on paper tape. Corrections for instrumental memory effects were made, when necessary, by extrapolating the data to zero time, the standard deviation of the average for typical analyses is less than $\pm$ 0.1%.

Potassium content of mica concentrates was determined by X-ray fluorescence techniques, whereas isotope dilution mass spectrometry was employed for the potassium determination of hornblende concentrates.

INTERPRETATION OF POTASSIUM-ARGON DATA

Empire Development and Coast Copper

The Empire Development magnetite-skarn, the Coast Copper deposit, and several other skarn occurrences are genetically related to the Coast Copper gabbro-diorite stock (Jeffery, 1961a). The sample collected for a K-Ar age determination (Table 2) is a medium-grained layered intergrowth of plagioclase, pyroxene, phlogopite, and olivine, with very minor alteration products, from a skarn zone in the Merry Widow pit of the Empire

Table 2. Potassium-Argon Age Determinations Relating to Contact Metasomatic Deposits of Vancouver and Texada Islands

Sample No.	Related deposit(s)	Rock	Mineral dated	%K	$\%Ar^{40}$	% Chlorite	% Biotite in Hornblende	Age m.y.
K-Ar-1652*	Empire Development and Coast Copper	Skarn	Phlogopite	7.29	85	7	-	181±8
K-Ar-1652*	Empire Development and Coast Copper	duplicate run	Phlogopite	7.29	89	7	-	178±8
GSC-64-2	Brynnor	Granodiorite	Biotite	6.13	65	30	-	167±10
GSC-64-3	Brynnor	Post-ore andesite porphyry-dyke; sample from two localities	Biotite	4.29	35	30	-	121±35
K-Ar-1716*	Brynnor	Same dyke as above but sample from one locality	Biotite	6.49	54	20	-	47±3
GSC-65-14	Nimpkish Iron	Granodiorite	Biotite	5.23	74	30	-	151±14
GSC-65-15	Nimpkish Iron	Same sample as 65-14	Hornblende	0.36	24	0	3	143±60
GSC-66-28	Zeballos Iron	Skarn	Phlogopite	5.47	84	35	-	148±8
K-Ar-1698*	Texada Mines Prescott Pit Gillies Stock	Granodiorite	Hornblende	0.56	57	-	0	165±9
GSC-67-39	Texada Island Pocahontas Stock	Granodiorite	Biotite	7.38	90	5	-	120±6
K-Ar-1541(2)*	Texada Island Pocahontas Stock	Duplicate run	Biotite	7.38	84	5	-	110±5
K-Ar 1541A*	Texada Island Pocahontas Stock	Same rock as 1541	Hornblende	1.15	64	-	10-15	114±15
K-Ar-1778A*	East Stock	Granodiorite	Biotite	6.90	94	18	-	111±6
K-Ar 1778*	East Stock	Duplicate run, same rock as 1778A	Biotite	6.67	93	25	-	106±4
K-Ar-1777*	East Stock		Hornblende	0.44	78	-	2	155±8

*Unpublished determination

Development Mine. Contact relationships are not known but this rock may originally have been a mafic tuff. The ages of 181 ± 8 and 178 ± 8 m.y. for the phlogopite represent the time of crystallization of the skarn and also the approximate age of the magnetite. The Empire Development and Coast Copper ores and the Coast Copper stock are probably, therefore of early Jurassic age.[1]

The age of 181 ± 8 m.y. is the oldest yet obtained on Vancouver Island and perhaps significantly, the Coast Copper stock is the most mafic intrusion for which K-Ar age data has been obtained.

Brynnor Mine

Pre-ore granodiorite collected by G.E.P. Eastwood of the British Columbia Department of Mines and Petroleum Resources, yielded a K-Ar age of 167 ± 10 m.y. for biotite (Wanless et al., 1966).

Two K-Ar ages are available for biotite from post-ore andesite porphyry dyke-rock. The first, from material collected by G.E.P. Eastwood in 1964, gives a K-Ar age of 121 ± 35 m.y. The determination was made on a composite sample taken from two exposures of similar-appearing andesite porphyry, apparently along strike from one another, but a few hundred feet apart. Eastwood believed that the two exposures were parts of the same dyke. A second sample was collected in 1969 by W.I. Nelson Jr. of Noranda Exploration Company, Limited at one of Eastwood's localities and has a much younger age of 47 ± 3 m.y. Other dykes of possible Tertiary age[2] occur within 20 to 60 feet of the dyke sampled by Nelson which also comprises part of Eastwood's composite sample. Assuming that both age determinations are analytically valid, there are at least two possibilities to explain the age discrepancy:

(a) Eastwood's composite sample is from two post-ore dykes of different ages.

(b) The samples are from the same Mesozoic dyke but updating has occurred at one locality by a Tertiary thermal event such as the intrusion nearby of dykes.

Neither of the above considerations precludes the conclusion that the minimum age of a post-ore dyke at Brynnor is 121 ± 35 m.y. and that the magnetite ore is older than 121 ± 35 m.y. but younger than 167 ± 10 m.y.

Eastwood (1965) believed that although the granitic intrusive complex at Brynnor varies somewhat in composition, all its phases are probably closely related and were emplaced during the same intrusive episode. Formation of skarn and deposition of magnetite followed magmatic intrusion

---

[1] According to the Geological Society of London time scale, the Jurassic period extended from 135 to 190-195 m.y., and the middle Jurassic from 162 to 172 m.y.

[2] A potassium-argon age of 59 ± 3 m.y. was obtained on biotite from quartz monzonite at Paradise Creek which is three miles south of Brynnor Mine (GSC 66-32, Wanless et al., 1968). This intrusion may extend northward to within one mile of the Brynnor deposit (Muller and Carson, 1969).

closely. Therefore, the age of 167 ± 10 m.y., or middle Jurassic, which represents the time of crystallization of the Brynnor granodiorite, is probably also the approximate age of the magnetite ore.

Nimpkish Iron Mine

A sample of the relatively potassic Nimpkish batholith which is believed to be the immediate source of iron for the magnetite deposit of the Nimpkish Iron Mine (Sangster, 1969) yields K-Ar ages of 151 ± 14 m.y. on biotite and 143 ± 60 m.y. on hornblende. The low K and ^{40}Ar content and impurity of the hornblende, which contains numerous inclusions of plagioclase, make the latter age less reliable as indicated by the large error limits of ± 60 m.y. Further, the nearby Bonanza batholith which is petrographically similar to much of the Nimpkish batholith and may be connected to it at depth, yields two K-Ar ages on the same biotite sample of 150 ± 8 and 152±7 m.y. (Wanless et al., 1968 – GSC 66-27).

Thus the magnetite ore at Nimpkish Iron Mine was probably emplaced about 150 m.y. ago during the late Jurassic.

Zeballos Iron Mine

A sample of coarse phlogopite from skarn adjacent to the FL orebody of Zeballos Iron Mine yields a K-Ar age of 148 ± 8 m.y. Megascopically, the phlogopite appears to be very pure. It has a greenish brown colour but X-ray analysis indicates that 35 per cent chlorite is present, probably as a primary crystallographic intergrowth. The late Jurassic K-Ar age represents the time of formation of the skarn and the approximate age of the magnetite.

Prescott Deposit of Texada Iron Mines Limited

The Prescott orebody is one of several iron-copper skarn deposits on Texada Island. It is at the contact of Marble Bay (= Quatsino) limestone, Karmutsen volcanic rocks and the Gillies Stock. A sample of granodiorite from this stock was dated in addition to samples from two other granitic plutons exposed along the northeast coast of the island, one mile east of Pocahontas Bay ("Pocahontas Stock") and from a logging road 6 miles south-southeast of Northeast Point ("East Stock").

The Gillies Stock sample is relatively fine-grained (< 3 mm) biotite-hornblende granodiorite containing some pyroxene as nuclei of hornblende. Only hornblende could be extracted and yielded an age of 165 ± 9 m.y., in close agreement with that of granodiorite associated with the Brynnor orebody and many other Middle Jurassic intrusions of Vancouver Island (Muller and Carson, 1969). As the orebodies and skarn replace country rock as well as the Gillies Stock (Sutherland Brown, 1965), the ore appears to have been deposited during a final stage of the intrusive episode.

The East Stock, on the east coast of Texada Island, is biotite-hornblende granodiorite, very similar to that of the Gillies Stock. It yielded ages of 155 ± 8 m.y. on hornblende and 106 ± 6, 111 ± 6 m.y. on duplicate

analyses of the associated biotite. It is suggested that the original age of intrusion was the same as that of the Gillies Stock, but a more recent event at about 110 m.y. ago completely updated the biotite and had only a slight rejuvenating effect on the hornblende. This explanation is supported by the more or less concordant dates on the 'Pocahontas stock', a hornblende-biotite granodiorite, coarser grained and more quartz-rich (30% versus 10%) than the Gillies Stock. Hornblende from the 'Pocahontas stock' yielded 114 ± 15 m.y., and biotite duplicate ages of 110 ± 6 m.y. and 120 ± 6 m.y. Thus it seems probable that two intrusive pulses are represented on Texada Island and that the older pulse was responsible for the formation of the Prescott orebody. During the younger pulse, some small magnetite lenses were deposited near the 'Pocahontas stock' (McConnell, 1914). Further age-determinations on post-ore dykes and on the smaller intrusive bodies associated with the worked-out copper-skarn deposits near Vananda are required to determine if there was more than one distinct pulse of mineralization of economic importance on Texada Island.

DISCUSSION AND CONCLUSIONS

With the exception of the imprecise age of 143 ± 60 m.y. for hornblende of the Nimpkish batholith (above), the oldest and youngest K-Ar ages relating directly to the economic iron-copper skarn deposits of Vancouver and Texada Islands have been obtained for phlogopite from the Empire Development and Zeballos Iron magnetite mines. These are 181 ± 8 and 148 ± 8 m.y., respectively. Further, the six economic deposits for which K-Ar age data are available are related to intrusions that span the entire compositional range (gabbro to quartz monzonite) of the intrusions associated with all the contact metasomatic deposits of Vancouver Island (Carson, 1968). The most mafic and oldest known of these intrusions is the Coast Copper stock, and one of the most salic and youngest is the Nimpkish batholith. The six dated deposits should, therefore, provide a good cross-section of all the contact metasomatic deposits.

There are additional, though less definitive data relating to the age of many other contact metasomatic deposits. Only a few small skarn-type metalliferous occurrences are known to be associated with the epizonal Tertiary intrusions which are genetically related to porphyry coppers and gold-quartz veins (Carson, 1969). On the other hand, the Argonaut mine and several skarn prospects along the eastern side of Vancouver Island are associated with intrusions that, although not dated, are unconformably overlain by late Cretaceous sedimentary rocks. The intrusions are granodiorites and are petrographically similar to the Nimpkish, Bonanza, and Saanich granodiorites which are known to be Jurassic.

It is concluded that most of the contact metasomatic iron and copper deposits of Vancouver and Texada Islands, probably including all those of economic importance, were derived from intrusions emplaced at various times during the Jurassic period. Very weak and apparently uneconomic skarn-type mineralization occurred during emplacement of early Cretaceous and early Tertiary plutons.

SELECTED REFERENCES

Bacon, W. R.
1957: Iron deposits in coastal and southern British Columbia; Minister Mines, B. C.; Ann. Rept., 1956, p. 125.

Black, J. M.
1953: Iron Hill (The Argonaut Co. Ltd.); Minister Mines, B. C.; Ann. Rept., 1952, pp. A221-228.

Carson, D. J. T.
1968: Metallogenic study of Vancouver Island with emphasis on the relationships of mineral deposits to plutonic rocks; unpublished PhD thesis, Carleton Univ., Ottawa.

Carson, D. J. T.
1969: Tertiary mineral deposits of Vancouver Island; Can. Mining Met. Bull., vol. LXXII, pp. 116-125.

Eastwood, G. E. P.
1963: Geology of the Kennedy Lake area; Minister Mines Petrol. Resources, B. C.; Ann. Rept., 1962, pp. 111-124.

1964: Tofino Inlet; Minister Mines Petrol. Resources, B. C.; Ann. Rept., 1963, pp. 111-121.

1965: Replacement magnetite on Vancouver Island, British Columbia; Econ. Geol., vol. 60, pp. 124-148.

1966: Iron deposits of British Columbia; Can. Inst. Mining Met., Spec. vol. No. 8; pp. 329-333.

Gunning, H. C.
1930: Geology and mineral deposits of Quatsino-Nimpkish area, Vancouver Island; Geol. Surv. Can., Sum. Rept., 1929, Pt. A, pp. 94-143.

1932: Form and mechanism of intrusion of the Nimpkish "batholith"; Trans. Roy. Soc. Can., 3rd ser., sec. 4, vol. 26, pp. 289-304.

Hoadley, J. W.
1953: Geology and mineral deposits of the Zeballos-Nimpkish area, Vancouver Island, British Columbia; Geol. Surv. Can., Mem. 272.

Jeffery, W. G.
1961a: Benson Lake; Minister Mines Petrol. Resources, B. C.; Ann. Rept., 1960, pp. 90-101.

1961b: Nimpkish Lake; Minister Mines Petrol. Resources, B. C.; Ann. Rept., 1060, pp. 101-103.

McConnell, R. G.
1914: Texada Island, B. C.; Geol. Surv. Can., Mem. 58.

McKechnie, N. D.
1957: Blue Grouse (Cowichan Copper Co. Ltd.); Minister Mines, B. C.; Ann. Rept. 1956, pp. 120-122.

Muller, J. E., and Carson, D. J. T.
1969: Geology and deposits of the Alberni area, British Columbia; Geol. Surv. Can., Paper 68-50.

Sangster, D. F.
1969: The contact-metasomatic magnetite deposits of southwestern British Columbia; Geol. Surv. Can., Bull. 172.

Stevenson, J. S.
1950: Geology and mineral deposits of the Zeballos mining camp, B. C.; B. C. Dept. Mines, Bull. 27.

Sutherland Brown, A.
1962: Pyrometasomatic iron-copper deposits on the west coast; Western Miner, vol. 35, pp. 44-45.

1965: Texada Mines Ltd.; Minister Mines Petrol. Resources, B. C.; Ann. Rept. 1964, pp. 146-151.

Wanless, R. K., Stevens, R. D., Lachance, G. R., and Rimsaite, J. Y.
1965: Age determinations and geological studies, K-Ar isotopic ages, report 5; Geol. Surv. Can., Paper 64-17.

1966: Age determinations and geological studies, K-Ar isotopic ages, report 6; Geol. Surv. Can., Paper 65-17.

Wanless, R. K., Stevens, R. D., Lachance, G. R., and Edmonds, C. M.
1967: Age determinations and geological studies, K-Ar isotopic ages, report 7; Geol. Surv. Can., Paper 66-17.

1968: Age determinations and geological studies, K-Ar isotopic ages, report 8; Geol. Surv. Can. Paper 67-17.

Young, G. A., and Uglow, W. L.
1926: The iron ores of Canada, Volume I, British Columbia and Yukon; Geol. Surv. Can., Econ. Geol. Ser. No. 3, 1926.