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JADE IN CANADA

S.F. LEAMING

1978

Cover: Nephrite jade, Provencher Lake area, British Columbia.

Slab of carving-grade material cut from a five ton boulder and photographed using transmitted light. The black spots are composite grains of chromite and garnet.

M. Coyne.

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Yu, CHINESE CHARACTER FOR JADE
Brush-painted by Mr. Wah Quan Seto, Vancouver

JADE IN CANADA

INTRODUCTION

Jade, which by popular definition, includes two minerals, jadeite and nephrite, is represented only by nephrite in Canadian deposits. In Canada nephrite occurs mainly in the Cordillera and most known deposits are in British Columbia. A few deposits are known from Yukon Territory where more discoveries may be anticipated. An additional occurrence is reported from Rae River, Northwest Territories. It is possible that jade may be found in Ontario and Quebec.

Jade, particularly the nephrite variety, is present on all continents but most occurrences are found at irregular intervals along the length of the Cordillera from California to Alaska. Jadeite, the rarer, more valuable variety is found in Central America, California, Japan and Europe, but the greatest quantity of the highest quality still comes from Burma. There is a possibility that jadeite may be found in the Canadian Cordillera. Jadeitic pyroxene in microscopic amount is known in a few places but so far no monomineralic masses of jadeite have been found.

Nephrite was used by the native peoples of British Columbia as long ago as about 2000 B.C. The main and probably the only centre of manufacture was the Lillooet-Lytton area where alluvial nephrite in suitable initial shapes and sizes was found in abundance on the bars along the Fraser and Bridge rivers. With the growth of amateur lapidary hobby in the 1950's many "rockhounds" were attracted to these rivers. Prospectors soon realized the economic value of the material to the lapidary trade and began to look outside the Lillooet area and discoveries were made in Omineca and Cassiar districts in central and northern British Columbia, and in the Yukon Territory. Little has been published on Canadian jade and this report was prepared in response to a need for a comprehensive account with special reference to Canadian occurrences. As well as the necessary field and laboratory work on the specimens collected, an intensive library search was made for pertinent information on occurrences elsewhere in the world.

Results of this study include a more precise definition of jade, an explanation of the origin of the nephritic texture, chemical analyses of Canadian nephrite, a radiometric age of one Canadian nephrite specimen, an estimate of reserves and suggestions for further discoveries.

Many "rockhounds" and jade producers have contributed to this report by supplying information on the history of jade in British Columbia, the locations of deposits, hospitality in their field camps, and countless specimens. The author would like to acknowledge the many contributions by the following: L. Barr, R. Bouvette, G. Davis, C. Ebner, W. Ellert, E. Floyd, C. Hubbell, A. Jensen, V. Kesjer, W. Laut, O. Messerer, C. McEwen, L. Owen, F. Plut, R. Purvis, W. Robertson, B. Seywerd, R.J. Smith, E. Sowden, H.N. Street, W. Zacharias.

HISTORY OF JADE

The earliest use of jade is lost in antiquity. Jade artifacts have been found in Neolithic culture sites in Europe, Asia, and in North and Central America. One of the oldest sites is that at Yakut, U.S.S.R. (Siberia) where nephrite artifacts were associated with organic matter giving a radiocarbon date of 4880 B.C. (Semyontsov et al., 1972). The artifacts included nephrite adzes and white nephrite rings. It may be postulated that the aesthetic value attached to the material was a later development in the evolution from primitive tool and weapon making to artistic expression thereby implying a long prior knowledge and use of the material. If this is true, the earliest use of jade may well extend back beyond 5000 B.C.

Jade has long been prized in China. Until the mid-eighteenth century all Chinese jade was the nephrite variety but then Burmese jadeite became widely used and because of its general superiority in lapidary qualities the misconception arose that Chinese jade is jadeite. There are reports that jadeite does or did occur in China but this cannot be confirmed. Certainly nephrite has been found in China but the original sources are now exhausted except for those of Turkestan, which supplied large blocks of raw material brought by arduous and slow transportation to the carving centres of eastern China. The Chinese character for jade, Yu, is shown in the frontispiece. It means precious stones in general. When Burmese jadeite was first introduced into China, the carvers recognized its distinctive lapidary qualities and called it fei-ts'ui, which according to Ruff (1962) meant false or non-yu. This word is commonly said to mean the colour of the kingfisher's feathers - a beautiful green, called Imperial green and a colour not found in nephrite. Meen (1963) stated that jade has been worked in Burma for 3000 years, and he implied that trade with China extends back this far. The statement is not documented and seems contrary to general opinion.

In any event jade carving in China goes back to the earliest dynasties and even at the outset of Chinese civilization carvings of great beauty and intricacy were sculptured for the use of the emperors. Few if any strictly utilitarian objects are found in China. Most are ceremonial and ritual objects; few tools or weapons have been found, a fact cited by Laufer (1912) as evidence that the Chinese never passed through an epoch equivalent to a stone age or Neolithic culture. Laufer attributed the few utilitarian artifacts that have been found to non-Chinese civilization. There can be no doubt that nephrite was in fact used in Neolithic times in China. Details are of more interest to the archeologist than the geologist. It is sufficient to record that jade was used in China as long ago as 1500 B.C. and probably much longer. During the Chou Dynasty (1122 B.C. to 231 B.C.) and the Han Dynasty (206 B.C. to A.D. 220) carving of jade reached an artistic level which has not been exceeded since.

In Central America jade carving was highly advanced in the Olmec and Mayan civilizations as long ago as 1000 B.C. When the Spanish conquistadores landed in 1519 they found that the Aztecs prized jade more than gold. The Aztecs called their jade chalchihuitl. The Spaniards used the expression piedra de yjada meaning stone of the loins, in allusion to a supposed efficacy in curing intestinal disorders. The English word jade appears to have been derived from the Spanish word indirectly. Most authorities suggested the Spanish word was translated into French "pierre de l'ejade" and via grammatical error to "le jade". The latinized version of piedra de yjada was rendered lapis nephriticus and hence the English - nephrite.

The French chemist A. Damour was the first to show the essential difference between the two varieties of jade and it was he who named jadeite in 1863. Jade artifacts, mainly jadeite axes, have been found in many parts of the British Isles. No source for the raw material is known and consequently it is assumed that these articles were imported as trade goods from continental Europe where both artifacts and sources of raw material are known. Many of the artifacts from Britain have been recovered from Neolithic tombs. Piggott and Powell (1951) associated the artifacts with migration and trade along the west coasts of England and Scotland at the beginning of the second millenium B.C.

Both jadeite and nephrite artifacts and deposits are known from Europe, in France, Switzerland, Italy, Germany and Poland. Probably the most important deposits are those discovered in Poland by Herman Traube in 1884 and 1886. These were the first recorded occurrences of in situ nephrite from Europe. The discovery of workshop activity nearby showed that the deposits had been worked in prehistoric time.

Jade has been used by the Maoris of New Zealand since their discovery of the Islands probably about A.D. 1000. When Captain Cook came to New Zealand in 1769 he found a fairly advanced jade culture that seems to require a much longer period of time than 700-800 years to develop. Thus it might be concluded that the Maoris brought some knowledge of the material with them from other Polynesian sources. Jade is found in New Caledonia and New Guinea so possibly the full extent of the antiquity of jade in the South Pacific has not been established.

The first announcement of the discovery of jade in Australia dates from only a few years ago. It has been reported from New South Wales and South Australia.

The first reference to jade in Canada seems to have been made by Sir John Richardson (1851). Dawson (1887) commented on the use of jade by the Salish people along Fraser and Thompson rivers of southern British Columbia and noted that in situ deposits were known. He hazarded the guess that the material would eventually be found in volcanic rocks of the Carboniferous and Triassic periods.

In the Fraser Valley from Lillooet to Vancouver, numerous cultural sites of Salish people have yielded nephrite artifacts dating to the third millenium B.C. Baker (1970) stated that upper middle period (1500 B.C. to A.D. 1) artifacts near Lillooet include nephrite celts (edged implements). Calvert (1970) obtained a radiocarbon date of 2360 ± 110 B.C. from organic matter at the base of the St. Mungo cannery cultural site on the south arm of the Fraser River opposite New Westminster. Artifacts from this site include adze blades of nephrite from a stratigraphic unit above the base and hence somewhat younger than 2360 B.C. Stryd (1972), excavating near Lillooet, found ground nephrite artifacts in component 3 of the Fountain site, provisionally estimated to represent an interval between 2000 B.C. and 1500 B.C. He believed that this may represent the earliest occurrence of worked nephrite in the southern interior of British Columbia.

The use of nephrite in Canada clearly has a history that must approach 4000 years. It is recorded (Holland, 1962) that Chinese placer miners recognized nephrite in their diggings and shipped back to China an unknown and, in fact, unsubstantiated quantity of jade boulders in the years 1850 to 1900.

The next episode of the jade story in British Columbia was the discovery of nephrite jade by W.J. Storie on Wheaton Creek in the Cassiar District in 1938. This district has since become a major source of nephrite but did not displace Lillooet as the jade capital of British Columbia until about 1974. Revival of interest in Fraser River jade is attributed to the late C.J. Halsey and the late Captain Duncan who began collecting jade from the Fraser bars near Lillooet about 25 years ago. With the rise in popularity of the hobby of "rockhounding" many local residents around Lillooet became adept in finding jade boulders along Fraser and Bridge rivers. Some boulders were very large. In Marshall Creek, and along the lower part of the Bridge River, boulders of 10 tonnes or more were found. These quantities were more than any "rockhound" or his whole club could use and consequently a commercial enterprise developed with buyers from Germany, Hong Kong and the United States obtaining most of the material. Discoveries of individual boulders and deposits in situ continued in the Lillooet-Bridge River area in the 1960's and 1970's with increasing numbers of deposits being found in situ in Shulaps and Cadwallader mountains, but with fewer discoveries of alluvial material. Small boulders and cobbles are, however, still found on the Fraser bars after each annual run-off and reworked material is eagerly combed by individuals and rock clubs.

Jade discoveries in British Columbia have been due to the efforts of a few enthusiastic and enterprising individuals. The late Ed Osterlund found a substantial deposit of nephrite at the head of Hell Creek in the Shulaps Mountains in 1960. Harry Street was active in the Lillooet area and found numerous boulders in Bridge River, Marshall Creek, Jim Creek and Noel Creek, and discovered deposits in situ along Noel Creek. His wife, Nellie, is credited with the discovery of nephrite near D'Arcy on the eastern end of the Cadwallader Range; R.J. Smith, prospecting along Brett Creek, found boulders leading to the discovery of an in situ deposit which was not exposed but had to be uncovered by bulldozer. C. McEwen found jade at the head of Jim Creek near Shulaps Peak in 1974.

Omineca jade discoveries were initiated by the discovery of boulders on Vital Creek by J.B. Thurber and H.M. Kindrat in 1962 and Bruce Russell in 1963. The team of L. Owen and S. Porayko found jade boulders along Ogden Creek which lead to the discovery of deposits in situ on Mount Ogden in 1968.

Mrs. W. Robertson discovered nephrite at the head of O'Ne-ell Creek on Mount Sidney Williams in 1967; deposits were found in place along with talus material mixed with much serpentinite. Earlier (1964) prospecting on Mount Sidney Williams by R. Purvis, W. Erichsen and A. Bell resulted in the discovery of minor amounts of alluvial material.

Little production in the Wheaton Creek jade field followed W.J. Stories' 1938 discovery until about 1957 when G. Davis produced 1000 pounds from placer leases on Wheaton (Boulder) Creek. Intermittent production has continued and a few hundred pounds were taken out in 1975. Jade was found in situ by Walter Ellert in 1970 on Wheaton Creek, a short distance south of its junction with Alice Shea Creek. Numerous boulders were also discovered on the property and small amounts of jade removed.

In Cassiar district Andy Jensen discovered jade near Provencher Lake in 1969. This is a major source of nephrite with many hundreds of boulders along the valley floor and at least twenty in situ deposits in the mountains to the east of the lake.

In 1965 Ben Seywerd discovered jade in situ at the north end of Dease Lake after several years experience in finding boulders along the tributaries of Thibert Creek and near the north end of Dease Lake.

In 1967 Clancy Hubbell recognized nephrite in the serpentine being mined at Cassiar Asbestos mine at Cassiar, B.C. For some time prior to this some unknown quantity had been removed with the rest of the waste rock in the mining process and is now lost in the waste dump. Some effort is now being made to save nephrite found in mining the asbestos.

Nephrite has been found in a few places in the Yukon Territory mainly as rare cobbles or small boulders along the Yukon River. In 1969 Roy Sowden found nephrite in situ in the Frances Lake area. The occurrences are in the Campbell Range north of Watson Lake. Serpentinite is visible from the

Campbell Highway west of milepost 84, the location of the southernmost occurrence of two found by Sowden. Production has so far been limited to a few tons, partly due to transportation difficulties, but continued production is likely.

DEFINITIONS

Jade

Jade and the related terms, jadeite, chloromelanite and nephrite are variously defined in the literature. Some of the definitions are rather imprecise but in general the meaning is clear enough. Jade is the name applied to aggregates of either of two different minerals. One, a variety of amphibole, is called nephrite, the other a variety of pyroxene is called jadeite. It is unfortunate that the same name is applied to two different materials. Hardinge (1961) proposed using the name jade as a collective noun to include both nephrite and jadeite. It is used in this generic sense by many archeologists and art historians, who regard the distinction as academic. Most authorities agree that the work may be applied to either material. This results in an ambiguity which may be resolved by use of the binomial appelations, amphibole jade (nephrite) and pyroxene jade (jadeite). The ambiguity could be eliminated by using the mineralogical names but it is unlikely that the general public will ever give up the name jade in spite of the attendant confusion. Nephrite is defined as a tough, fine grained tremolite (or actinolite) breaking with a splintery fracture and a glistening lustre (Ford, 1932). Other definitions are less precise, e.g. Deer et al. (1962) simply say that nephrite is either tremolite or actinolite. Kraus and Slawson (1947) call nephrite a monoclinic variety of amphibole. These definitions are unsatisfactory for more than one reason. Although nephrite may be tremolite, the converse is not necessarily true. The essential feature of nephrite is the texture, called nephritic by Turner (1935) of the principal ingredient, fibrous tremolite. This texture is characterized by randomly-oriented bundles, tufts and sheaf-like groups of felted and twisted fibers. Definitions which fail to mention this texture must be considered unsatisfactory because otherwise any fine grained mass of tremolite could be called nephrite. Nephrite may grade into tremolite rock by the progressive replacement of the nephritic tremolite by coarse prismatic tremolite, as noted by Turner (1935) and Kolesnik (1970) and this is also seen in Canadian deposits.

Jadeite is a mineral species belonging in the pyroxene group. Chemically, it is sodium aluminum silicate ($NaAlSi_2O_8$) and crystallizes in the monoclinic system.

Jade composed of the mineral jadeite may be called pyroxene jade, jadeite jade or simply jadeite.

According to Rogers (1942) jadeite occurs exclusively in jadeite rock (jadeitite), a monominerallic rock. The term jadeitite however has fallen into disuse.

Although jadeite from Burma may approach the ideal composition for this mineral, much of the Central American jade is characterized by large amounts of diopside; some specimens were found by Washington (1922) to contain 50 per cent or more. He proposed the name tuxtlite for such materials. He found further that albite was also abundant in some specimens and thought that there was a continuous series from diopside-jadeite to albite. He proposed the name mayaite for this series. The concept of a series and the need for a special name may be questioned. Apart from this it is clear that pyroxene jade may not be entirely jadeite. It follows that definitions that define jade in terms of jadeite would exclude many specimens containing diopside and albite and which historically were among the first material to be called jade.

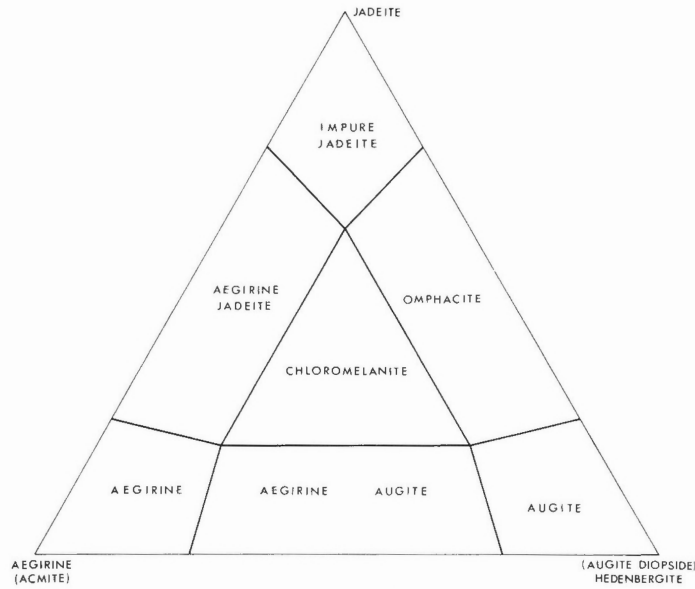


Figure 1. Classification of sodic pyroxenes (after Essene and Fyfe, 1967).

Chloromelanite is defined as a monoclinic pyroxene intermediate in composition between the end members, augite (diopside)-acmite-jadeite (Essene and Fyfe, 1967; Fig. 1). As chloromelanite may contain 20 to 60 per cent jadeite, some specimens may be considered jade, others may be excluded. This poses a dilemma resolved by Desautels (1972) in this manner: "whether the sample is jadeite, diopside-jadeite or chloromelanite, all are unquestionably identifiable as pyroxenes and are close enough to jadeite to be recognized as slight variant kinds of the same species".

Perhaps it is best not to attempt to define jade for clearly it may grade imperceptibly into non-jade and any arbitrary boundary would merely divide material into two classes with insignificant differences at that boundary.

Jade has been defined mainly by mineralogists who describe the mineralogy of the principal constituents, tremolite or jadeite in terms of crystal structure, cell dimensions, chemistry, optical constants etc.

Petrographers are apt to view jade as the common name of two monominerallic rocks, one a variety of amphibolite, the other a variety of pyroxenite and study the texture, associated minerals and field relationships; it is in this petrographic sense that jade is treated in this report.

Jade-Like Materials

Many substances have been called jade; these are mainly greenish, generally hard rocks or minerals which may superficially resemble jade but because they are neither nephrite nor jadeite they cannot be called jade, even though some may have lapidary qualities of merit. Some materials may have an appreciable jade content but if it is less than 50 per cent the material is not jade although it may qualify for the title "near-jade". In this category are many pyroxenites with jadeite components making up less than 50 per cent of the sample as in some Central American artifacts in which the pyroxene is jadeitic diopside. Some nephritic rocks containing much prismatic tremolite may also fall in this category.

The term is useful because it recognizes a jade content in those borderline cases where the material would not be acceptable to the lapidary trade. Jade is primarily a lapidary material.

Serpentine is commonly used as a substitute for jade. Many of the less expensive carvings originating in the Orient may be this material. It has been described as Soochow jade or Korea jade. Other varieties of serpentine such as williamsite, bowenite and verde antique may also be labelled jade. A simple hardness test or the measurement of specific gravity would suffice to show that they are not jade.

Some hard and heavy minerals called jade in error or on purpose may be harder to identify. Vesuvianite for example may be confused with jadeite which, in some varieties it resembles rather closely in colour, hardness and specific gravity. The index of refraction of vesuvianite is somewhat higher and a refractometer reading of 1.70 to 1.73 would be diagnostic. Vesuvianite, also called idocrase, is called californite or California jade when used in the lapidary trade.

Green grossularite garnet from South Africa has been sold as Transvaal jade. It may be distinguished from nephrite or jadeite by its superior hardness and specific gravity. Because it is isometric, grossularite could be distinguished by the use of a polariscope.

Pectolite has been mistaken for jade in some Alaskan localities. It is commonly found in compact greenish masses with a hardness about 6. It is easily fusible and decomposes in warm hydrochloric acid.

A few other greenish minerals such as aventurine (quartz) amazonstone (feldspar) and green jasper have been incorrectly identified as jade.

Boulders of a fine grained whitish rock found along the Fraser River in the vicinity of Hope have been called mutton-fat jade by some "rockhounds" in British Columbia. The rock is a quartzite having accessory dumortierite (blue) and numerous very fine sillimanite needles.

While some materials may be called jade in error others may well be a deliberate deception. Glass imitations and such appelations as Suchow, California or Transvaal jade, may be an attempt to capitalize on the esteem held for true jade. Such materials may be called pseudojade, a term meant to cast disparagement on such deception.

JADEITE

Identification in Hand Specimens

Jadeite or pyroxene jade as defined here includes mineral aggregates whose monoclinic pyroxenes range from pure jadeite to jadeitic pyroxenes. It is therefore variable in composition and hence in physical appearance. Visual inspection augmented by a few simple physical tests is not likely to facilitate more than a tentative identification.

In general jadeite jade will be a tough, hard, heavy, equigranular aggregate of prismatic pyroxene crystals.

It is commonly light in colour, whitish or mottled with tints of green, blue or lavender. Some specimens may be bright green, others may be dark green to almost black. Plane surfaces such as those produced by a diamond saw cut may reveal colour changes better than a natural surface and may also show the granular nature by reflection of light from prismatic cleavage planes.

Specimens of whitish, stream worn boulders from Burma exhibit a surface similar to quartzite but boulders from residual deposits may have a dark brown to yellowish brown crust. Boulders from other climates may have different surface features.

The specific gravity of jadeite is near 3.3 and should be between 3.24 and 3.43. Some albite-jadeite and diopside-jadeite specimens from Central America may be as low as 3.2.

Jadeite has a hardness of 6 1/2 to 7 on Mohs' scale.

Table 1

Chemical Analyses of 'jadeite' taken from various sources

	1	2	3	4	5	6	7	8	9	10
SiO_2	59.45	58.12	59.51	59.38	57.39	58.02	58.1	58.28	58.3	59.35
Al_2O_3	25.21	20.32	24.31	25.82	18.93	22.96	18.5	21.86	20.4	22.18
Fe_2O_3		2.49	0.35	0.45	4.45	0.77	4.2		2.6	1.15
FeO		0.77	0.30	Tr	0.81	0.18	0.8	2.42	0.6	0.32
MgO		2.16	0.58	0.12	1.93	1.70	1.7	1.99	1.3	1.77
CaO		3.13	0.77	0.13	2.74	1.58	3.0	2.53	2.4	2.57
Na_2O	15.34	12.43	14.37	13.40	12.46	12.38	13.4	12.97	14.5	12.20
K_2O		0.10	0.20	0.02	0.11	0.16	0.0	-	0.2	0.20
MnO		0.07	0.01	-	0.09	0.01	0.03	0.22	Tr	0.01
TiO_2		0.31	0.01	0.04	0.44	0.04	0.2	-	nil	0.18
CR_2O_3		-	-	-	-	-	-	-	-	-
H_2O+		0.61	0.06	0.22	0.54	0.87	-	-	-	0.20
H_2O^-				0.16		0.61	-			-
	100.00	100.51	100.47	99.74	99.88	99.28	99.9	100.27	100.3	100.13

1. Theoretical $NaAlSi_2O_6$
2. Jadeite celt, Guatemala (Foshag, 1955)
3. Jadeite-Burma (Yoder, 1950)
4. Jadeite-California (Coleman, 1961)
5. Chloromelanite-Guatemala (Foshag, 1955)
6. Jadeite-Japan (Kawano, 1939)
7. Jadeitic pyroxene, Pinchi Lake, B.C. (Patterson, 1973)
8. Jadeite-Axe from Switzerland (Smith, 1963)
9. Jadeite from Axe, Scotland (Smith, 1963)
10. "Blue jade" Mexico (Foshag, 1955)

Toughness means the resistance to breakage. There is no scale of toughness equivalent to Mohs' scale of hardness. Rocks are judged to be tough when a great deal of energy must be expanded to break off a sample with a hammer. In this qualitative test jadeite is very tough. Toughness may be stated in a quantitative way by measurement of certain mechanical properties which allow the calculation of fracture toughness and fracture surface energy. Bradt et al. (1973) gave the following values for jadeite, nephrite and quartzite:

Fracture	Nephrite	Quartzite	Jadeite
surface energy (erg/cm^2)	226000	4320	121000
Fracture toughness ($dynes/cm^{-3}/^2$)	7.7×10^8	7×10^7	7.1×10^8

In thick sections jadeite is opaque but some gem material may be translucent. When polished, jadeite has a vitreous to pearly lustre but natural surfaces are dull. Jadeite breaks with an even fracture reflecting the granular texture.

Jadeite is fusible (2 1/2) to a transparent glass at the same time colouring the flame yellow.

Identification by Mineralogical Methods

Positive identification of minerals involves techniques and instruments designed to determine the crystal structure i.e., the kinds of, and special arrangements of the constituent atoms. This involves the use of X-ray diffraction equipment and is the ultimate authority in mineral identification. Some minerals may be identified by less sophisticated apparatus such as the petrographic microscope by which characteristic optical properties are determined. Some minerals may be identified by chemical analysis, but this technique does not distinguish between paramorphs. The mineralogy of jadeite may be found in textbooks and no attempt will be made to duplicate this information here.

Chemistry

Jadeite is a silicate mineral with the formula $NaAlSi_2O_6$. Rarely is it pure; small amounts of other elements may be detected on chemical analysis. Burmese jade is close to the ideal formula and may contain less than 2 per cent of elements other than sodium, aluminum, silicon and oxygen. Some of the Central American jadeites however may contain appreciable amounts of calcium and iron. A comparison of chemical analyses taken from the literature is shown in Table 1. The additional elements found by chemical analysis are not necessarily impurities but represent the presence of other, closely related minerals in solid solution. These include diopside and acmite, the proportions of which may be included from the chemical analyses. Examples of the results of such calculations are shown in Table 2.

From this table it is apparent that some specimens nominally called jade or jadeite, actually contain a greater proportion of diopside.

The colour of jadeite is commonly attributed to the presence of chromium in the crystal lattice. This may be so in some cases but iron also is known as a colouring agent and some green jadeite specimens contain iron but no chromium. Rossman (1974) studying the optical spectra of green, white and lavender coloured jadeite, showed that green jadeite was

Table 2

Proportions of Components in Various "Jadeite" Specimens

	AUTHORS DESIGNATION	%Jd*	%Ac+	%Di†	REFERENCES	
1	White jadeite (California)	96.5	2.4	1.1	Coleman	1961
2	Green jadeite (California)	74.3	15.1	10.7 (1)	Coleman	1961
3	Jadeite (Burma)	96.5		1.5 (2)	Foshag	1957
4	Blue Jade (Mexico)	89	1	10	Foshag	1957
5	Jadeite (Guatemala)	89		13 (2)	Foshag	1957
6	Diopside-Jadeite (Guatemala)	45	2	53 (2)	Foshag	1957
7	Chloromelanite (Guatemala)	77	12	11	Foshag	1957
8	"Tuxtlite" (Mexico)	45.15		51.51	Washington	1922
9	"Jadeite" (Mexico)	64.45		5.60	Washington	1922
10	"Mayaite" (Central America)	81.69	11.54		Washington	1922
11	Jadeitic pyroxene	77.9	11.3	10.8	Patterson	1973
12	Acmite jadeite	57.5	38.5	4.0	Patterson	1973

(1) Di + He (Hedenbergite)
(2) Di + Others
(3) Specimen has 30% albite
* jadeite
\+ acmite
† diopside

produced by ferric iron. Microprobe analyses of the two samples of green jadeite showed only 0.20% CR_2O_3 in one and nil in the other. Clearly the common belief that chromium is the sole colouring agent in jadeite is not correct.

Petrography

Although jadeite is a mineral and is described in mineralogical terms in textbooks on mineralogy, masses of natural jadeite may be considered a monomineralic rock with properties due to the texture, and chemical variations due to the presence of other minerals.

As seen in thin section, jadeite rock is a fine to medium grained aggregate of anhedral to subhedral pyroxene crystals with a granular interlocking texture. The pyroxene may be nearly pure jadeite and the specimen may be entirely monomineralic, but specimens from other localities, also called jade or even jadeite, may be composed of pyroxene with less than 50 per cent jadeite. Other minerals may be present in amounts varying from a few to many per cent. Albite is commonly present as an accessory mineral and has been noted in specimens from Burma, Central America and California. Coleman et al. (1968) found that zeolites are present in jadeite from California and Foshag (1955) mentioned the presence of muscovite, titanite, hornblende, actinolite, zoisite and chromite in Guatemalan jadeite. Plate 1 shows a photomicrograph of typical Burmese jadeite with prismatic fibrous crystals.

Plate 1. Photomicrograph of Burmese jadeite showing prismatic habit. x 63 crossed nicols. GSC 202783-0

Petrogenesis

Jadeite is typically a mineral of metamorphic rocks in which it may be one of many components occurring with lawsonite, crossite, albite, glaucophane, quartz, nepheline, etc. It belongs in the blueschist facies of metamorphism; i.e. it is formed under conditions of low temperature and high pressure. Most monomineralic masses of jadeite occur in or near serpentinite associated with these low-temperature, high pressure rocks. Commonly the jadeite is associated with tectonic inclusions within serpentinite masses where it occurs as vein-like bodies cutting the inclusions and within the serpentinite as irregular pods of jadeite or jadeite and albite. Coleman (1961) in studying the jadeite deposits of the Clear Creek area of California, came to the conclusion that the jadeite-albite veins arose from mobilized fluids rich in jadeite molecule and deficient in water in a silica undersaturated environment. According to Coleman and Clark (1968) temperature-pressure conditions of blueschist metamorphism are probably in the range 200° to 300°C and pressure 6 to 9 kilobars.

A pressure of 9 kb corresponds to a burial load of about 30 km. A normal geothermal gradient of 30° km would produce a temperature of about 900°C at this depth. Very rapid burial to this depth may be postulated as a mechanism to produce the high pressure without allowing time for the rocks to heat up to the high temperature.

An alternative to the deep burial theory is the development of the needed pressure by a combination of moderate depth of burial and a 'tectonic overpressure' produced by thrust faulting (Blake et al., 1969).

This theory, developed from a study of the Franciscan Group in California, has been applied to similar blueschist metamorphism in other parts of the world.

Occurrences of Jadeite

Jadeite, the mineral, is widely distributed and is probably commoner than was once thought, mainly because it may be found as a rather inconspicuous component of rocks in the blueschist metamorphic facies which is now more widely recognized. Large masses of jadeite are much less common.

The principal source of gem quality jadeite is Burma but even there the finest grade, the so-called Imperial jade, is relatively rare.

Alluvial jadeite in Central America was used by the Olmec, Maya and Aztec artisans, but it appears the supply was not great and some years after the Spanish conquest little remained. Deposits of jadeite in place are reported from Guatemala but are of no great size.

Recently it has been shown that jadeite occurs with other minerals in a large tract of Franciscan rocks in California with locally, some rarer occurrences of monomineralic masses.

Jadeite as a chemical component of the mineral omphacite is known from a number of localities in Europe, South America, New Zealand and North America. Omphacite occurs with garnet in the rock eclogite. Occurrences in Canada are known from the Yukon (Tempelman-Kluit, 1970) and central British Columbia (Patterson, 1973). Rocks approaching this metamorphic grade occur west of Dease Lake in northern British Columbia (Monger, 1975).

The best chances of discovering jadeite in British Columbia are in the Pinchi Lake area. Figure 2 shows the area worth searching. Success would seem to depend on finding inclusions of blueschist rocks within adjacent serpentinite where by analogy to Burma and California monomineralic masses might be expected.

The Pinchi Lake area contains glaucophane – lawsonite-bearing rocks derived from basic rocks, dolomites, limestones, chert greywacke and argillaceous sediments, with chert, schist and greywacke making up 95 per cent of the total. Acmitic jadeite occurs with lawsonite, titanite, chlorite, white mica, aragonite and glaucophane in some of the rocks but no occurrences of macroscopic jadeite are known.

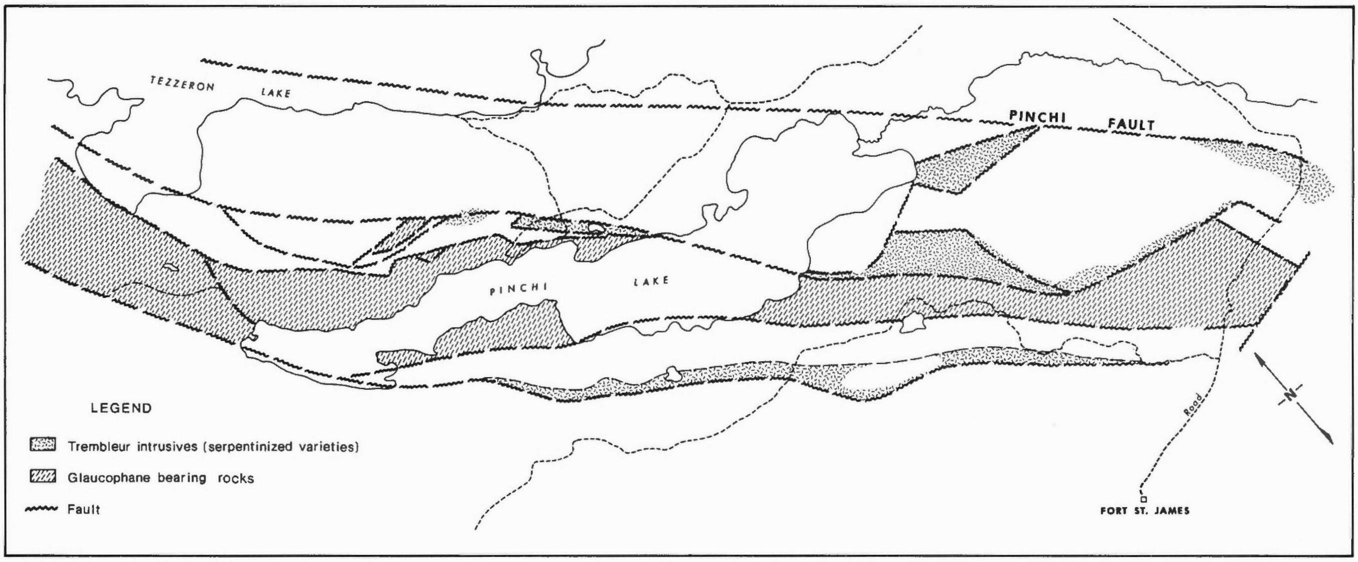


Figure 2. Glaucophane bearing rocks in Pinchi Lake area after Patterson (1973).

In California pure jadeite occurs in serpentinite and jadeitic pyroxene occurs in metagreywacke in somewhat analogous situations. The best chance of finding masses of pure jadeite lie in silica-deficient rocks, e.g. serpentinites. Coleman and Clark (1968) show that jadeite in California occurrences is found in two distinct environments.

(1) tectonic inclusions of albite-crossite pyroxene schist containing jadeite as an accessory mineral;

(2) pod-like bodies with a central core of jadeitic pyroxene. Veins in the schist contain pure white jadeite; the pods contain dark green jadeitic pyroxene.

NEPHRITE

Identification in Hand Specimens

Positive identification of a nephrite specimen requires confirmation that the main component is the mineral tremolite with a nephritic texture. This is only possible through microscopic study of thin sections. Distinction between nephrite and tremolite by chemical analyses and X-ray diffraction studies is at best indirect and may be inconclusive.

Nephrite may be tentatively identified by determination of a few physical properties by simple tests and visual inspection.

Although green is the usual colour of nephrite it may range from white to nearly black through various tints and shades of green. Other colours although mentioned in the literature are rare. Some specimens are mottled due to mineralogical and chemical variations. Colour names applied to nephrite include emerald, spinach, leek, light or dark green etc. These designations are subjective. A better method of describing the colour is to compare the specimens to colour standards as those of the Munsell system which arranges colours according to three parameters, hue, value and chroma. Forty-seven specimens of nephrite from British Columbia were matched against the standard colour in the Munsell colour chart. Sixteen colour designations were needed to describe all the variations in this group. The colours were all in the yellow-green hue. Some specimens of so-called black nephrite were included in the test and these too were yellow-green but because of the low value and chroma parameters, they appear almost black.

The colour of minerals is not easily explained and will not be attempted here. The interested reader is referred to Nassau (1975). It suffices to say that the colour of nephrite as is the case for many green minerals is related to the presence of iron in the crystal structure and probably depends on the ratio of the two valency states in which it may exist.

Specific gravity measurements on 23 specimens of Canadian nephrite ranged from 2.95 to 3.01 and averaged 2.99. This means that one cubic foot of nephrite weighs about 186 pounds and one ton of nephrite occupies a volume of 10.75 cubic feet.

The hardness of nephrite is commonly stated as 6 1/2 or slightly harder than steel. This is a useful field test to eliminate many greenish rocks such as serpentine or talc. Care must be taken to ensure that the test is not applied to softer minerals within or adjacent to the nephrite. Fraser (1972) found that the hardness of 14 polished specimens of nephrite from British Columbia fell in the range 6 1/2 to more than 7. The tests were made on polished surfaces, probably accounting for a slightly greater hardness than that obtained from fracture faces. In the first case, the hardness is due to the difficulty in disrupting the crystal bonds. In the second, the hardness is a measure of the difficulty in breaking the protruding crystals; it is essentially a test of strength not a criterion of hardness.

Nephrite is a very tough rock. It resists breakage to such an extent that it may be impossible to take a sample from a large boulder by blows with an ordinary 1 1/2 lb. rock hammer and may resist breakage even by an 8 lb. sledge hammer. This is particularly true of most rounded stream boulders. Poor quality nephrite, or angular blocks such as may be found on talus slopes or at outcrops, may fracture more readily, but the relative toughness will be apparent. The crushing strength of nephrite is greater than steel. Kolesnik (1970) gives a figure of 7759 kg/cm^2 for Russian nephrite (110000 lb./in.^{2}) and Belyk et al. (1973) in tests on Canadian nephrite from Mount Ogden found that direct compressive crushing strengths varied from 4.6 to 61.2 thousands of pounds per square inch. The wide range in results was due to the presence of natural fractures in some of the specimens.

A useful field test for nephrite is the translucency shown on thin edges of broken specimens or through thin slabs sawn from a specimen. Some light will be transmitted through nephrite slabs up to 10 to 15 mm thick; very thin slabs will be nearly transparent and colourless. The translucency test permits the appraisal of the quality of the rock by revealing the presence of opaque inclusions, fractures and colour variations.

Lustre of natural surfaces is dull but polished surfaces are greasy or oily.

Identification by Mineralogical Methods

As nephrite is composed essentially of tremolite, mineralogical methods of identification, including X-ray diffraction, index of refraction determinations and chemical analyses will not distinguish nephrite from common tremolite.

Nephrite is identified by petrographic examination of a thin section in which both the identity of the tremolite may be determined and the nephritic texture may be observed. Mineralogists might consider the petrographic microscope to be one of their tools and object to the exclusion of its use from mineralogical methods. Nevertheless the description of the texture of an aggregation of minerals is not usually included in textbooks on mineralogy.

The mineralogy of nephrite is that of tremolite and may be found in many good textbooks.

Chemistry

The main constituent in nephrite is the mineral tremolite, and chemical analyses approach those of that mineral. Departures from the ideal composition reflect the presence of other minerals as well as minor variations due to atomic substitutions normally occurring in tremolite.

Tremolite is an amphibole mineral in the tremolite-ferroactinolite series. Amphiboles in general are characterized by double chains of silica tetrahedra of composition (Si_4O_{11}) linked by cations in various sites in the structure (Fig. 3). This structure is such that a wide range of substitution of ions may occur, hence the amphibole group may have a wide range of chemical compositions which may be generalized as:

$$X_{2-3}Y_5Z_8O_{22}(OH,F,Cl,)_2$$

where

X = Calcium, sodium, potassium

Y = Ferrous iron, manganese, magnesium, chromium, titanium, aluminum, ferric iron, lithium, zinc

Z = silicon, aluminum.

The structure of tremolite is shown on Figure 3C where a number of sites available for ion occupancy are denoted by M_1, M_2, M_3, M_4 and 'A'. Normally the 'A' sites are vacant in tremolite. X ions occupy the M_4 sites, Y ions occupy the M_1, M_2, M_3 sites. The Z ions are the centres of the silicon tetrahedra. Hydroxyl ions, essential to all amphiboles, are located over the double chain holes. Tremolite is ideally:

$$Ca_2Mg_5Si_8O_{22}(OH)_2$$

with increasing substitution of iron for the magnesium, the formula becomes:

$$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$$

and with complete substitution:

$$Ca_2Fe_5Si_8O_{22}(OH)_2$$

which is ferroactinolite. The amphibole with incomplete Mg:Fe substitution is actinolite.

The above is a continuous series and pure end members may be rare or nonexistent. It is customary to divide the range of composition so that the tremolite may contain a small percentage of ferroactinolite. Ferroactinolite may contain an equally small amount of tremolite. In this report, the divisions of Deer et al. (1963) are accepted giving the following classification:

tremolite,	80 - 100 per cent tremolite	0 - 20 per cent ferroactinolite
actinolite,	20 - 80 per cent tremolite	80 - 20 per cent ferroactinolite.
ferroactinolite,	0 - 20 per cent tremolite	80 - 100 per cent ferroactinolite

with change in composition, a gradual change in physical properties occurs as shown in Figure 4.

Twenty mol per cent $Ca_2Fe_5Si_8O_{22}(OH)_2$ in the tremolite structures corresponds to a FeO content of about 8 per cent. This is higher than the total iron content shown in published analyses of nephrite from world wide sources. Even if the lower limit (10 mol per cent) set by Winchell (1945) is used, most nephrite specimens fall within the tremolite field.

Most definitions of nephrite equate it with tremolite (or actinolite) and assume therefore a chemical equality. Kolesnik (1970) however goes to some length to show that there is (at least to his satisfaction) a significant chemical difference between nephrite and tremolite.

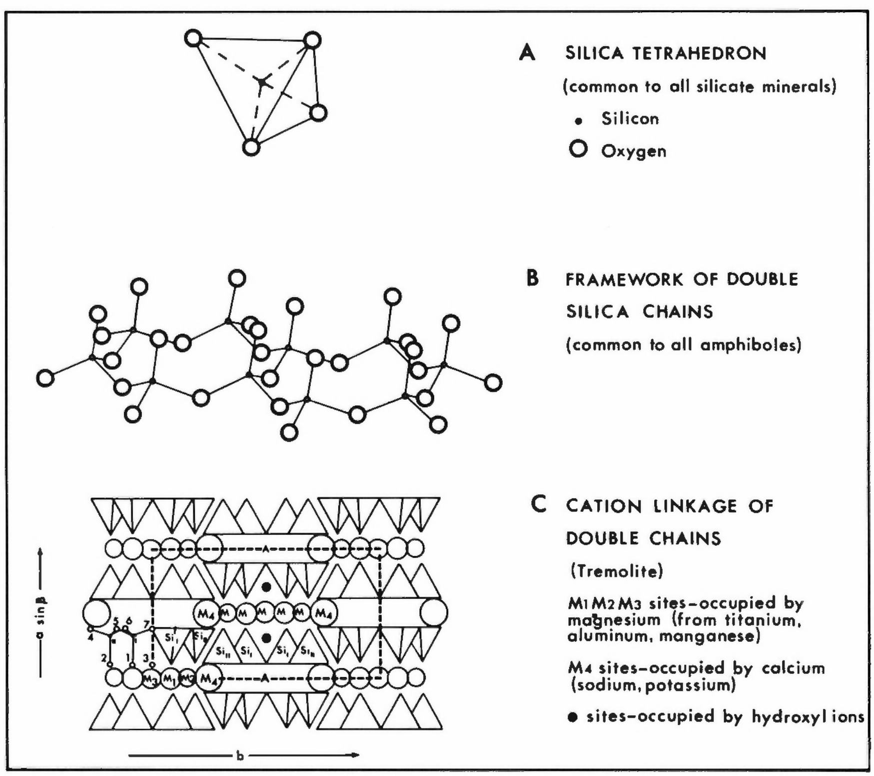


Figure 3. Crystal structure of tremolite from Ernst (1968).

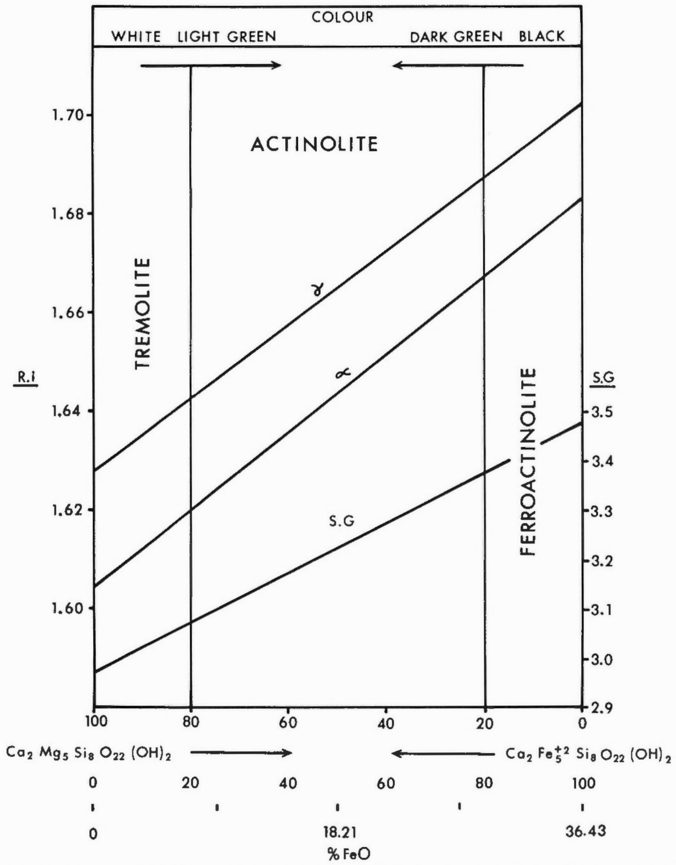


Figure 4. Relation between chemical composition and refractive indices. Density and colour for the tremolite-ferroactinolite series. Deer, Howie, Zussman (1963).

He presents the crystallochemical formulae for the average of 72 tremolite and 57 nephrite specimens as follows:

(1) Tremolite

$$(Ca_{1.83}Mg_{0.15}K_{0.03}Na_{0.12})_{2.11}\ (Mg_{4.31}Fe^{+3}_{0.10}Fe^{+2}_{0.54}Al_{0.05})_{5.0}\ (Si_{7.75}Al_{0.25})_{8}\ (O_{22})\ (OH)_{1.93}O_{0.07}$$

(2) Nephrite

$$(Ca_{1.91}Na_{0.12}K_{0.03}Mg_{0.05})_{2.11}\ (Mg_{4.53}Fe^{+2}_{0.36}Fe^{+3}_{0.11})_{5.00}\ (Si_{7.77}Al_{0.20})_{7.97}\ O_{22}\ (OH)_{2}\ (H_{2}O)_{0.47}$$

The principal differences in these two formulae are the higher content of calcium and lower value of magnesium in the X position for nephrite.

These are statistical differences and assuming the accuracy of the analyses they do show that on the average there is a small chemical difference between nephrite and tremolite, i.e. that nephrite is a variety of tremolite.

This contention however rests on the assumption that no impurities are present in the material analyzed, and that all the analyses meet a high standard of precision. Although Kolesnik claims he took care to include only reliable analyses some doubt may be cast on the number and precision of the nephrite analyses.

Of interest in Kolesnik's comparison of nephrite and tremolite is the question of the role of magnesium in the two materials. By maintaining the precise atomic proportion of 5.00 for the Y position, excess magnesium is assigned to the X position; in tremolite a large amount of magnesium must be accommodated there, but in nephrite the amount is very small. Kolesnik attributes the excess magnesium in tremolite to mechanical admixtures of anthophyllite $(MgFe)_7(Si_8O_{22})(OHF)_2$.

It is not clear why the Y position must be filled by precisely 5 ions except to satisfy the ideal theoretical structure. It would appear that the Y position can accommodate somewhat more than 5 ions.

Leake (1968) has shown that many good analyses of amphiboles contain appreciably more than 5 ions in the Y position, and there may be less. He sets the limits from 4.75 to 5.25. Kolesnik's example (the crystallochemical formulae for nephrite) could as well be written to include all the magnesium in the Y position and there would be no need to postulate (as he does) a mechanical addition of anthophyllite to explain the high magnesium content.

Chemical analyses of eight specimens of Canadian nephrite are shown in Tables 3A, 3B.

The material is thought to be typical of the average quality nephrite from each locality. They are not however representative samples and cannot be considered to represent the average chemical composition of each deposit. Unfortunately, the specimen from Dease Lake turned out to be of inferior grade compared to the other specimens in that it contains appreciable talc. None of the specimens are purified tremolite; some spinel group minerals, chrome garnet, chlorite and possibly serpentine may be present in small but variable amounts. In calculating the half unit cell contents, these minerals were assumed to be absent. In so far as the results are compared to analyses of pure tremolite, these assumptions are unwarranted but as a means of comparing nephrite analyses, the assumption probably is acceptable. The nature of nephrite is such that in most published analyses the elimination of minor impurities is incomplete at best and probably in many cases, not attempted. For mineralogical purposes it is important that all the impurities are eliminated; for petrographic purposes the significance of contributions by other minerals may be important. Thus the chemical characteristics of Cassiar nephrite as shown in Table 3 would probably disappear if the chrome garnet were eliminated from the sample before analysis was begun. Chemical analyses of pure nephritic tremolite may be expected to converge towards the ideal composition of tremolite (with say 4% FeO) but analyses of unpurified nephrite might be expected to cover a wider range in composition. Not enough analyses of nephrite from a single deposit have been made to be able to demonstrate that chemical analyses can be used as a means of identifying the source area. Crystallochemical (structural) formulae derived by Pyrend computer program developed by Dr. E. Essene and Dr. P.B. Read from the chemical analyses in Table 3A are shown in Table 4.

The third example (Dease Lake nephrite) does not meet the criteria laid down by Leake (1968) for good amphibole analyses. This may be attributed to the high percentage of talc in the specimen. The second example (Cassiar nephrite) shows a slight excess of atoms in the Y position and this may be due to the presence of chrome garnet as an impurity.

The average value for calcium, 1.89, is close to what Kolesnik has shown to be the average value for the 57 nephrite analyses used in his study. Two of the analyses (No. 1, No. 7) are close to the average values for 72 tremolite analyses.

Table 3A

Analyses of Canadian Nephrite

MnO	TiO_2	CaO	K_2O	SiO_2	Al_2O_3	MgO	FeO	Fe_2O_3	Na_2O	Cr_2O_3*	NiO*	F†	H_2O^+	H_2O^-	Cl^+	F=0	Cl=0	Total	Total -F = 0
0.41	0.01	12.20	0.03	52.78	2.72	21.20	4.74	1.12	0.05	0.32	0.20	0.05	3.94	0.22	0.004	0.02		99.99	99.97
0.10	0.01	10.40	0.02	53.24	3.04	23.20	3.31	1.11	0.03	0.26	0.17	0.06	4.82	0.26	0.004	0.03		100.03	100.00
0.08	0.01	12.10	0.10	55.12	1.92	21.80	3.31	0.95	0.14	0.18	0.12	0.03	3.84	0.32	0.01	0.01	0.002	100.03	100.02
0.09	0.01	12.90	0.06	56.32	1.76	21.40	3.02	0.63	0.10	0.19	0.14	0.03	3.22	0.26	0.001	0.01		100.13	100.12
0.18	0.01	13.00	0.05	56.64	1.12	21.40	3.16	0.80	0.06	0.16	0.11	0.02	3.20	0.18	0.01	0.01	0.002	100.10	100.09
0.13	0.01	13.20	0.04	56.50	1.28	21.80	3.31	0.55	0.06	0.16	0.08	0.02	2.88	0.06	0.004	0.01		100.08	100.07
0.08	0.02	12.00	0.03	54.96	2.64	21.20	3.45	1.04	0.05	0.28	0.18	0.03	3.50	0.60	0.01	0.01	0.002	100.07	100.06
0.10	0.02	12.64	0.03	56.18	1.88	21.40	3.16	0.72	0.05	0.20	0.14	0.03	2.98	0.46	0.01	0.01	0.002	100.00	99.99
0.15	0.01	12.31	0.04	55.22	2.04	21.67	3.43	0.86	0.07	0.22	0.14	0.03	3.55	0.30	0.01	0.01	=	100.16	

Analysts: Geological Survey of Canada
J.G. Sen Gupta
†R.J. Guillas
*P.G. Belanger and K.A. Church

Table 3B

Spectrochemical Analyses of Canadian Nephrite
Minor Elements

No.	Ti	Ba	Co	Sc	Sr	V	Cu	Be	Cr	Mn	Ni
1	.0039	.0027	.0054	.0011	NF	.0051	.005	.0002	.22	.39	.16
2	.0014	.0014	.0058	.00077	.0017	.0038	"	"	.18	.068	.13
3	.0042	.0035	.0042	.00062	.0030	.0033	"	"	.12	.054	.094
4	.0023	.0043	.0033	.00067	.0021	.0030	"	"	.13	.072	.11
5	.0047	.0018	.0035	.00055	.0050	.0043	"	"	.11	.15	.085
6	.0040	.0018	.0024	.00060	.0027	.0029	"	"	.11	.091	.060
7	.0043	.0047	.0054	.00079	.0017	.0035	"	"	.19	.060	.14
8	.0073	.0044	.0039	.00063	.0019	.0032	"	"	.14	.068	.11

No.	Locality	No.	Locality
1	Cassiar Asbestos Mine - Cassiar B.C.	5	Birkenhead Jade - Hell Creek, B.C.
2	Seyward Claim - Dease Lake, B.C.	6	Greenbay Mining - Breet Creek, B.C.
3	Ellert Claim - Alice Shea Creek, B.C.	7	Street Claim - Noel Creek, B.C.
4	New World Jade - Mount Ogden, B.C.	8	Ebner Claim - Frances Lake area, Y.T.

Analysts - Geological Survey of Canada
P.G. Belanger and K.A. Church

Table 4

Structural Formulae* of Canadian Nephrite

1.	$(Ca_{1.8251}\ Na_{0.0382}\ K_{0.0180})_{1.8633}\ (Mg_{4.5743}\ Fe^{2+}_{0.3897}\ Fe^{2+}_{0.1006}\ Mn_{0.0095}\ Ti_{0.0011}\ Cr_{0.0200})_{5.1733}\ (Si_{7.7596}\ Al_{0.2404})_{8.0000}$
2.	$(Ca_{1.8674}\ Na_{0.0138}\ K_{0.0055})_{1.8867}\ (Mg_{4.5142}\ Fe^{2+}_{0.5663}\ Fe^{3+}_{0.1204}\ Mn_{0.0496}\ Ti_{0.0496}\ Cr_{0.0361})_{5.2877}\ (Si_{7.5401}\ Al_{0.4580})_{7.9981}$
3.	$(Ca_{1.5825}\ Na_{0.0083}\ K_{0.0036})_{1.5944}\ (Mg_{4.9109}\ Fe^{2+}_{0.3931}\ Fe^{3+}_{0.1186}\ Mn_{0.0120}\ Ti_{0.0011}\ Cr_{0.0292})_{5.5347}\ (Si_{7.5609}\ Al_{0.4391})_{8.0000}$
4.	$(Ca_{1.9253}\ Na_{0.0270}\ K_{0.0107})_{1.9630}\ (Mg_{4.4433}\ Fe^{2+}_{0.3518}\ Fe^{3+}_{0.0660}\ Mn_{0.0106}\ Ti_{0.0010}\ Cr_{0.0209})_{5.0279}\ (Si_{7.8454}\ Al_{0.1546})_{8.0000}$
5.	$(Ca_{1.9637}\ Na_{0.0162}\ K_{0.0071})_{1.9870}\ (Mg_{4.5115}\ Fe^{2+}_{0.3843}\ Fe^{3+}_{0.0575}\ Mn_{0.0153}\ Ti_{0.0010}\ Cr_{0.0176})_{5.0412}\ (Si_{7.8446}\ Al_{0.1554})_{8.0000}$
6.	$(Ca_{1.9410}\ Na_{0.0162}\ K_{0.0089})_{1.9661}\ (Mg_{4.4450}\ Fe^{2+}_{0.3683}\ Fe^{3+}_{0.0839}\ Mn_{0.0212}\ Ti_{0.0010}\ Cr_{0.0176})_{5.0140}\ (Si_{7.8930}\ Al_{0.1070})_{8.0000}$
7.	$(Ca_{1.8081}\ Na_{0.0136}\ K_{0.0054})_{1.8271}\ (Mg_{4.4437}\ Fe^{2+}_{0.4057}\ Fe^{3+}_{0.161}\ Mn_{0.0095}\ Ti_{0.0021}\ Cr_{0.0311})_{5.1686}\ (Si_{7.7289}\ Al_{0.2711})_{8.0000}$
8.	$(Ca_{1.8884}\ Na_{0.0135}\ K_{0.0053})_{1.9072}\ (Mg_{4.4476}\ Fe^{2+}_{0.3685}\ Fe^{3+}_{0.0755}\ Mn_{0.0118}\ Ti_{0.0021}\ Cr_{0.0220})_{5.0699}\ (Si_{7.8355}\ Al_{0.1665})_{8.0000}$

1. Alice Shea Creek	2. Cassiar Asbestos Mine	3. Dease Lake	4. Mount Ogden
5. Brett Creek	6. Hell Creek	7. Noel Creek	8. Frances Lake, Y.T.

* anhydrous basis by Pyrend computer program developed by Drs. E. Essene and P.B. Read and written by the latter.

Petrography

Nephrite is essentially monominerallic and is characterized by a peculiar texture in which microfibrous tremolite occurs as twisted and felted bundles, tufts and sheaf-like aggregates in interlocking random orientation. Chlorite, talc, diopside, garnet and spinel group minerals may be present in minor amounts. In some specimens patches of coarse prismatic tremolite may replace the nephritic tremolite (Pl. 2A). Both Turner (1935) and Kolesnik (1970) noted that nephrite may grade into tremolite rock and this is also seen in Canadian occurrences.

Individual crystal groups in nephrite vary in size and shape. Commonly they are elongated bundles with a length to width ratio of 2:1 to 5:1 and some may also be wider than long with ratios from 2:3 to 1:6. These are exceptional however and most groups have an average length to width ratio of about 3:1. Groups with lengths greater than 0.3 mm are uncommon, but some coarse tremolite patches may be up to 1 to 2 mm in length. Noteworthy in all nephrite is the manner of extinction. Under crossed nicols groups made up of parallel microfibres do not extinguish at the same angle. This is interpreted to mean that the microfibres are twisted and not optically parallel.

The most common impurity in Canadian nephrite, and probably in nephrite from elsewhere, is a mineral of the spinel group, either chromite, magnetite or picotite. These are commonly fractured and the fragments slightly displaced as shown in Plate 2B.

Emerald-green garnet, uvarovite or chrome grossular, in irregular anhedral patches partly replaced by chlorite or nephritic tremolite is found in some specimens from most British Columbia localities and is particularly abundant in nephrite from the Cassiar Asbestos Mine (Pl. 3A, 3B).

Chlorite is a common alteration product and develops from the tremolite or garnet but is rarely more than 2 - 3 per cent.

Diopside is reported in Canadian nephrite by Holland (1962) and Fraser (1972) but it was not seen in any thin sections examined by the author nor was it found in X-ray diffractometer tracings of 8 specimens submitted to the X-ray laboratory of the Geological Survey of Canada.

Talc is present in some specimens and some low quality nephrite may contain serpentine minerals as well.

Petrogenesis of Nephrite

Review of world literature reveals a long list of theories on the petrogenesis of nephrite. These are briefly outlined below. Finlayson (1909) suggested the following possible origins for New Zealand nephrites:

1. Uralitization of pyroxene.
2. Contact-action of peridotite on limestone.
3. Replacement of olivine by tremolite.
4. Deep-seated metamorphism of serpentine-talc-carbonate rocks.

Turner (1935), also considering New Zealand nephrite, discounts (2) and (4) above but adds:

5. Tremolitization of hornblende.
6. Shearing of tremolitized rocks with concomitant growth of fresh fibres.
7. Intense shearing and mechanical breakdown of parent rock (pyroxenite, hornblende, etc.) with concomitant chemical reconstitution and growth of fresh crystals.

Grubenmann (1910):

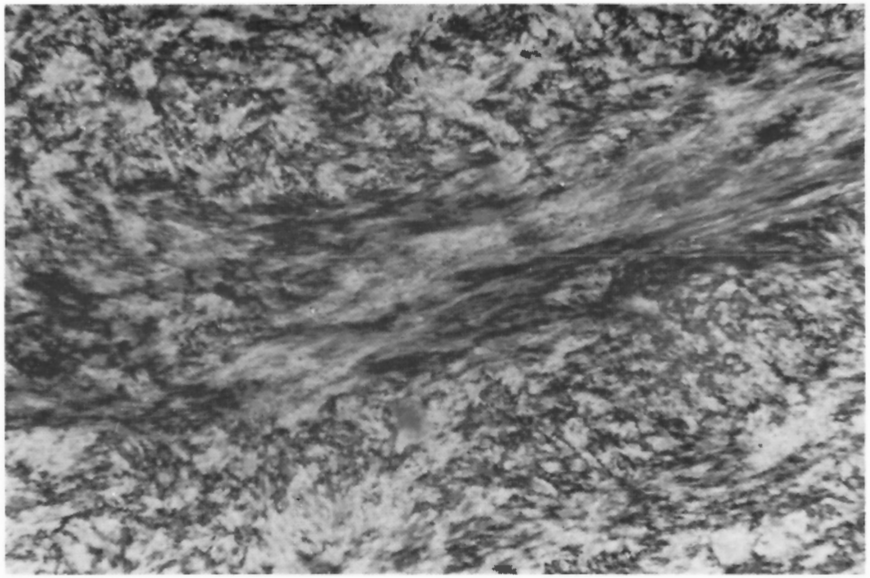
8. Placed nephrite deposits with hornblende and actinolite schists in the meso zone of dynamo-thermal metamorphism of magnesian rocks.

Bloomfield (1958) in studying nephrite in Nyasaland (now Malawi) came to the conclusion that:

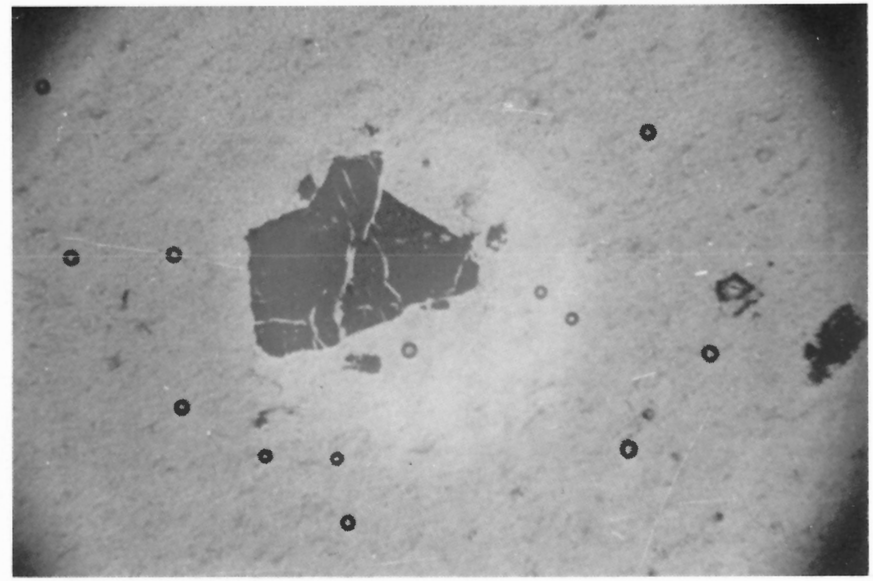
9. Nephrite originated by autometasomatism of ultrabasic intrusion aided by tectonic movement.

Chesterman (1951), describing Marin County, California nephrite, considers:

10. The nephrite as a vein deposit from solutions arising from serpentinite.

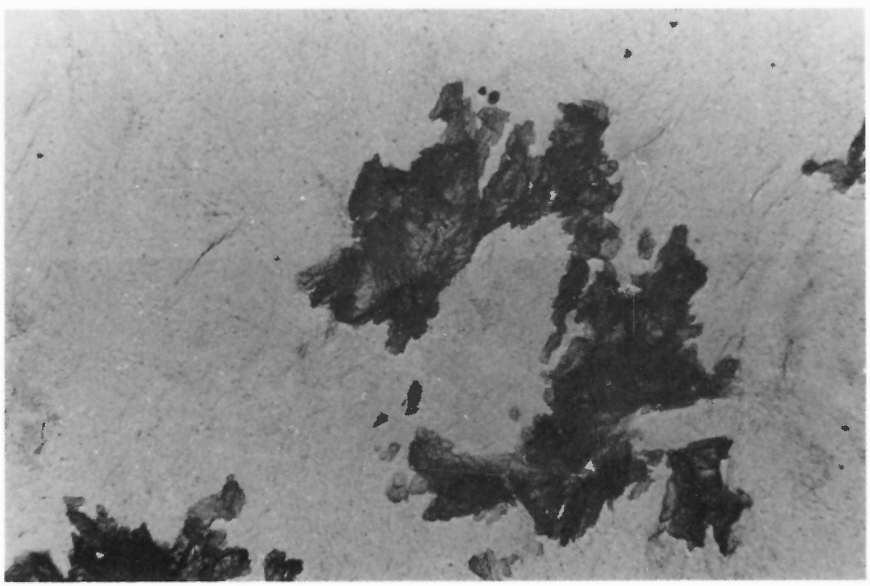


A. Nephrite from Shulaps Range showing coarse prismatic tremolite. x 63 crossed nicols. GSC 202783-J

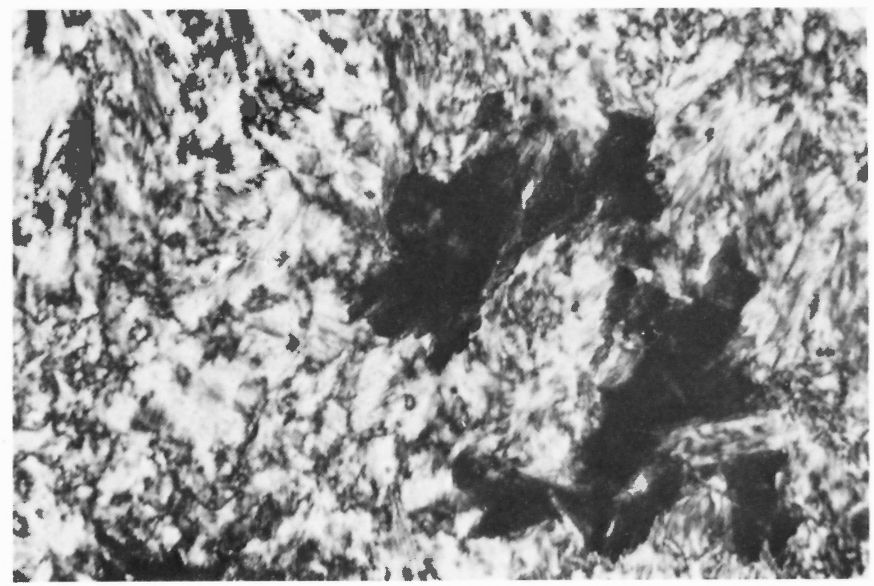


B. Fractured picotite in Cassiar nephrite x 63; plain light. GSC 202885-P

Plate 2. Photomicrographs of Canadian Nephrite



A. Chrome garnet in nephrite x 63 plain light. GSC 202783-B



B. Same photomicrograph as in A, but with crossed nicols. GSC 202783-C

Plate 3. Photomicrographs of Cassiar nephrite

Crippen (1951) studying nephrite at Cape Marten, California stated that:

11. Nephrite is a replacement of lenticular bodies of pulverized greywacke with magnesium metasomatism from serpentine.

Holland (1962) in regard to nephrite in British Columbia stated that:

12. The tremolite rocks are the recrystallization products of thermal and cataclastic metamorphism of basic rocks.

Kolesnik (1970), reviewing the literature summarizes work of other authors of the U.S.S.R. and other countries, contributed the following data:

Bogdanovich on an East Sayan deposit:

13. Nephrite originated by the replacement of amphibole or pyroxene rocks of a fine tremolite aggregate, with fibrous texture...the result of pressure (schistosity).

Shestopalov on nephrite in Ospenisk massif:

14. Nephrite originated by contact-reaction processes at the quartzite-serpentine boundary under stress.

Mamurovsky on a deposit at Mount Bikilyar, South Urals:

15. "Nephrite of the Bikilyary deposit originated by tremolitization of diopside rock from the effect of solutions from a younger granitic intrusion".

Kalkowsky, studying nephrite in Apennine deposits thought:

16. Nephrite originated in serpentine as a result of tectonic movements.

Steinman also studied the Apennine deposits and came to a different conclusion namely:

17. Nephrite was formed, along with the serpentinization of hot peridotites, by solutions from gabbro. The matted fibrous texture was a result of pressure created by the serpentinization of peridotite.

Kolesnik views the origin of nephrite as follows:

18. Nephrite is a metasomatic formation originating at a definite temperature, pressure, and chemical characteristic of the mineralizing medium in ultrabasic rocks at their contact with basic rocks that are albitized at the same time.

19. Coleman (1966) regarded nephrite as a contact reaction zone mineral developed at serpentine – country rock contacts by metasomatic alteration. The process is seen as coeval with the serpentinization of ultramafic rocks whereby calcium is released to combine with migrating silica from the country rocks forming tremolite along the contact.

20. Nicol (1974) describing nephrite deposits in south Australia stated that, "The nephrite jade formed by metamorphism of impure dolomite to tremolitite with later tectonic recrystallization of tremolite grains to fine grained, felted nephrite".

Some of these theories require the presence of serpentinite but others do not. These theories are here divided into two categories (1) metamorphic nephrite (non-serpentine type) and (2) metasomatic nephrite (serpentine type).

Metamorphic Nephrite

Metamorphic nephrite has received little attention other than the identification of the process by Nichol (1974) for some Australian nephrite and by the Wyoming Geological Survey for deposits in that state. A possible example of metamorphic nephrite is reported by Kindle (1952) from Yukon Territory but details are lacking.

The Australian deposits reported by Nichol (op. cit.) consist of irregular, lenticular and pod-shaped bodies, the largest of which is 65 m long on the surface and 3 m wide; the third dimension is unknown. These bodies have developed:

- enclosed in dolomitic limestone.
- enclosed in calc-silicate rock (tremolite, diopside, talc schist).
- between dolomitic marble and calc-silicate rock.
- at attenuated culminations of dolomitic marble and calc-silicate rock lenses.
- between incompetent dolomitic marble or calc-silicate rock and competent quartzfeldspathic gneiss, migmatite granite or meta-aplogranite.
- enclosed in quartzfeldspathic gneiss but along the strike of a dolomitic marble or calc-silicate zone.

According to Nichol, nephrite is developed where dolomitic marble or calc-silicate rocks display locally more intense deformation. Contacts between nephrite and calc-silicate rocks are usually sharp but may be transitional where the adjacent calc-silicate rock is tremolitite or talc schist. The texture of this nephrite is similar to the texture of metasomatic nephrite. Nichol recognized four variations:

(1) Microcrystalline tremolite with felted fibres up to 0.1 mm in length (average 0.04 mm) disposed in sheaves, rosettes, and subparallel schistose alignment.

(2) Vaguely defined, irregular relict tremolite up to 5 mm in diameter (average 2.0 mm). These relict grains consist of areas of groundmass tremolite with common extinction positions with random distribution. Margins may grade into the groundmass.

(3) Relatively well defined fibro-lamellar tremolite prisms and lozenges, between 0.1 - 0.3 mm long and 0.05 - 0.025 mm wide which occur in minor groups with random orientation; accessory epidote is common.

(4) Coarse grained tremolite developed in compound veins between 3 and 4 mm wide.

It appears that only the first category constitutes true nephrite according to the definition used in this report. The other varieties would be near-nephrite, semi-nephrite or tremolite rock (tremolitite).

Accessory minerals include goethite, pyrite, quartz, mica/talc, epidote, apatite, chlorite and sphene.

According to Nichol, regional metamorphism of impure dolomite produces tremolite by the reaction:

$$5CaMg\,(CO_3)_2 + 8SiO_2 + H_2O$$
$$= Ca_2Mg_5Si_8O_{22}\,(OH)_2 + 3CaCO_3 + 7CO_2$$

and he regards the formation of nephrite as due to sudden release of pressure and consequent recrystallization of tremolite bodies saturated with H_2O under high pressure.

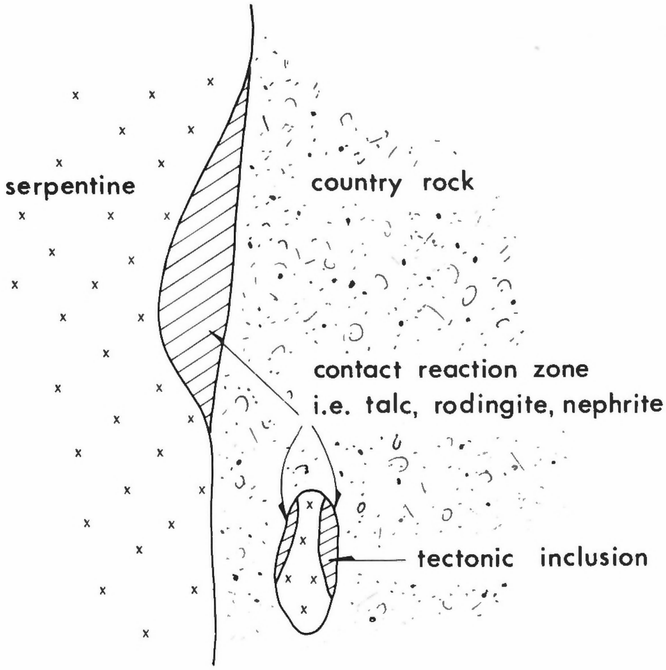


Figure 5. Development of contact reaction zones.

Metasomatic Nephrite

The concept of metasomatic alteration along the contact between serpentinite and other rocks of diverse chemistry has been in the literature since Eskola (1932) wrote about metamorphic differentiation and included metasomatism in the term. Phillips and Hess (1936) outlined the principles in this way:

"Where two solid rocks are in contact with each other, the one serpentine and the other a siliceous sediment or its metamorphosed equivalent, perhaps a quartz-mica schist, there is a strong contrast in chemical compositions. The permeation of hydrothermal solutions along such a contact results in an interchange of material between them as well as the recrystallization of both rocks to form minerals stable under the conditions obtaining. The alterations thus formed on either side of the contact will be called contact reaction zone" (Fig. 5).

Phillips and Hess (1936) in studying the serpentinite occurrences in the Appalachians from Vermont to southern Quebec pointed out that where hydrothermal solutions attack serpentinite along a contact with country rock, zones of talc, chlorite and nephrite may develop. In regard to the latter, they say that "less commonly actinolite is found in the chlorite zone. Thin sections of serpentinite - country rock contacts sometimes show a mass of interlocking tremolite or actinolite fibres. Such masses have been called nephrite". A number of examples of the development of tremolite in contact reaction zones are given including a sketch of a cross-section of the Federal Mine in Quebec. Although no mention of nephritic texture is made in these examples it may be assumed that conditions for the formation of nephritic tremolite i.e. nephrite jade, may exist in Quebec and Vermont and diligent search may well be rewarded.

Coleman (1966), studying the serpentinites in New Zealand, noted many contact reaction zones between serpentinite and argillite, greywacke, gabbro, basalt, and limestone, with the development of many thin nephrite and semi-nephrite (Turner, 1935) masses.

According to Coleman, the nephrite is a product of the desilication and calcium metasomatism produced by the enclosing serpentinites on the contact rocks, i.e. by the addition of silica and calcium to the serpentine to produce tremolite. He does not account for the nephritic texture other than to relate it to high-grade metamorphism, in the absence of which only low quality seminephrites develop.

On the basis of experimental evidence serpentinization requires water and silica and temperatures below 500°C. The calcium released during serpentinization is available for the formation of carbonates and calc-silicate rocks. Thus:

$$5(3MgO.2SiO_2.2H_2O) + 14SiO_2 + 6CaO$$
Serpentine

$$= 3(2CaO.5MgO.8SiO_2.H_2O) + 7H_2O$$
Tremolite

According to Coleman, P-T conditions during metasomatism are estimated at 280°C to 500°C and 4 to 9 Kb, an unusual combination of geological conditions.

Coleman (1967) added further information on contact reaction zones from his study of ultramafic rocks in California, Washington and Oregon. He related the process of metasomatism to the serpentinization and tectonics of ultramafic intrusion. He pointed out that hydrogarnet is a predominant mineral in contact reaction zones, but idocrase, diopside, prehnite, xonotlite, chlorite and nephrite also are characteristic. Estimates of P-T conditions indicate that alteration occurred under high pressure approaching that of blueschist metamorphic facies in many areas. He suggested that the reaction zones develop at a time when larger masses of ultramafic mantle are tectonically emplaced into the base of the crust or moved tectonically higher into it. Serpentinization, alteration and tectonism are contemporaneous. Kolesnik (1970) in studying the nephrite deposits of Siberia emphasized the role of metasomatism in the origin of these rocks at gabbro-serpentine contacts and came to the conclusion that nephrite is a metasomatic formation originating within strictly definite temperature, pressure and chemical conditions characteristic of the mineralizing solution in ultrabasic rocks at their contact with basic rocks. Other products of the same metasomatic process are garnet-diopside-vesuvianite-wollastonite rocks (garnetites, rodingites) and albitites with alkalic amphiboles and pyroxenes.

All nephrite deposits visited in the course of field work for this report are metasomatic alterations along serpentinite-country rock contacts. Most have associated contact reaction zones of "whiterocks" (rodingite) or similar calc-silicate rocks, and talc. All evidence points to tectonic emplacement of serpentinite and the associated nephrite as manifested by faulting, fracturing and preferred orientation of the fibre groups and in some semi-nephrites, ptygmatic folding of light coloured layers. On a microscopic scale dynamic activity is shown by fracturing of chromite/picotite grains and microfractures through the rock. No doubt the petrogenesis of nephrite is a long and complex process, intimately associated with the genesis and intrusion of the serpentinite.

The characteristic texture of nephrite requires explanation. The intertwining and felting of the microfibres seemingly requires a dynamic environment best produced by tectonic activity associated with the faulting and intrusion of the parent serpentinite. The ubiquitous shearing of associated serpentinite and fracturing of nephrite suggest that the formation of the nephrite took place during the emplacement of the serpentinite so that a dynamic environment of changing pressure, temperature and supply of reactants precluded the development or preservation of large scale deposits. Nephrite lodes are characteristically small, lenticular, fault-bounded and variable in structure. The right conditions did not persist long in any one place. This could only happen in a rapidly changing environment. This also accounts for the development of "whiterock" bodies and talc fringes along with nephrite where physicochemical changes rapidly cross stability fields. Thus a tectonic inclusion within an upward moving mass of serpentinite is at one time in an environment favourable to the development of contact reaction zones but shortly after it has moved into an area of different pressure and temperature where further reaction cannot be sustained. The general increase in density of rocks in the contact reaction zone suggests that the total pressure is very high and may be largely water pressure. With rapid elevation of the contact along active faults the water escapes and this rapid lowing of the high confining pressure allows the tremolite formed in the reaction zone to expand violently, in fact to explode and thoroughly shatter the mass from which recrystallization of the microfibres in random orientation then takes place. The hypothesis is rather tenuous but the fractured chromite/picotite grains inevitably found in nephrite deposits are evidence that fragmentation does happen (See Pl. 2B).

As nephrite is never found in metasomatic association with unserpentinized ultramafic rocks, the formation is assumed to have occurred at a temperature below the breakdown of olivine to serpentine. This has been determined experimentally to be somewhat below 500°C and may be as low as 290°C (Coleman, 1966). Pressure conditions for the formation of contact reaction zones is estimated (Coleman, 1967) to be in the vicinity of 4 to 8 Kb under conditions where the water pressure was nearly equal to the total pressure.

If we assume that tremolite forms at this pressure, it implies very deep burial or else if formed at moderate depth then some additional pressure must be supplied by tectonic over-pressure in the manner of Blake et al. (1969) or as a gas over-pressure in the manner of Brothers (1970). Whatever the cause of the high pressure, the rapid release requires some drastic tectonic event such as very rapid uplift along fault zones similar to those that are always found along serpentinized alpine ultramafic bodies. During this activity, blocks of the country rock may be detached from the contact zone and be emplaced within the mass of the serpentinite. Such blocks, called tectonic inclusions, are common in most nephrite occurrences. This relationship is shown diagrammatically in Figure 5.

An alternative theory for the origin of nephrite is suggested from study of thin sections of serpentine which reveals that a texture similar to that of nephrite is commonly found in masses of serpentine - group minerals, particularly antigorite, but also in chrysotile and lizardite. Faust and Fahey (1962) illustrate this with several photomicrographs one of which is almost identical to that shown on Plate 4. It may be postulated from this, that metasomatic replacement occurs within the serpentine adjacent to the contact with other rocks and across which the reactants enter the serpentine minerals altering them to tremolite. It is assumed that the processes occur in a dynamic environment which is responsible for the fracturing of the chromite, the partial destruction of the mesh structure commonly found in serpentines, and the deformation so typical of the nephrite and the enclosing rocks.

It is possible to extend the concept of metasomatic alteration to the metamorphic deposits by invoking an intermediate stage so that instead of the direct production of tremolite from dolomite, olivine is first produced by reaction with silica:

$$2CaMg(CO_3)_2 + SiO_2 = 2CaCO_3 + Mg_2SiO_4 + 2CO_2$$

dolomite — olivine (forsterite)

The forsterite may then be serpentinized and the metasomatic alteration of this to tremolite may be effected.

(1) Forsterite + water = serpentine

(2) Serpentine + silica + water + lime = tremolite

Classification

Nephrite varies widely in colour, texture, structure and alteration. These variations produce an infinite variety of types which may be reduced to a few groups with common petrographic characteristics.

Two classifications of nephrite have been proposed. Kolkowsky (1906) who studied the deposits in northern Italy recognized seven types:

(1) Matted fibrous (nephritic) with individual very fine fibres or tufts closely intertwined with a simultaneous extinction.

(2) Radial with tufts reminiscent of a cockscomb.

(3) Spherulitic.

(4) Fibrous - a long tuft of nearly parallel fibres.

(5) Wavy, with parallel fibres in regularly alternating bands locally visible with the naked eye.

(6) Fluffy, with the fibres indistinguishable even at the highest magnification. The entire mass is reminiscent of coarse fluff with gradually changing interference colours.

(7) Coarse grained (mosaic). The grains (2-3 mm) consist of short and extremely fine fibres with a nearly simultaneous extinction.

The second classification is that Turner (1935) derived from a study of New Zealand greenstone, a term which included nephrite, tremolite amphibole and serpentine. In this classification of nephrite and related rocks he recognized five divisions of which only the first three apply to true nephrite.

(a) Non-schistose nephrite - characterized by uniformly small sized unoriented arrangement of the component tufts of fine tremolite fibres. The tufts usually vary from 0.02 mm to 0.3 mm in length reaching 0.05 mm in rather rare instances. Occasionally well defined stout prisms or acicular crystals (up to 1.5 mm by 0.03 mm) of coarse tremolite may be present in small amount; these contrast sharply with the exceedingly slender tufted fibres of the surrounding nephritic base, and indicate transition to semi-nephrites.

Plate 4. Photomicrograph of serpentinite showing texture resembling that of nephrite. x 63 crossed nicols GSC 202783-L

A. Alluvial deposit. Boulder from Fraser River near Lillooet. GSC 203173-G.

B. Colluvial deposits. Talus blocks from in situ deposit in Provencher Mountains. GSC 203173-D

C. In situ deposit. Provencher Mountains. GSC 203173-F

Plate 5. Types of nephrite occurrence

(b) Schistose nephrites; the distinctive feature is the presence of plentiful parallel tufts of tremolite fibres set in a base composed of finely felted, unoriented tufts which in some cases make up only a small percentage of the total.

(c) Semi-nephrites; consist of abundant relatively coarsely crystalline tremolite which takes the form of well defined acicular prisms or relatively large sheafs of parallel, unfelted fibres, with interstitial nephritic tufts.

The classification proposed in this report combines some of the term and usage of both Kolowsky (1906) and Turner (1935).

- True nephrite - composed of unoriented tufts, bundles or sheaf-like groups of tremolite micro-fibres set in a matrix of much finer, but similar texture.
- Foliated nephrite - composed of tufts, bundles and sheaf-like groups with a preferred orientation which imparts a weak grain to the rock.
- Semi-nephrite - composed of nephrite partly replaced by coarse prismatic tremolite which imparts a strong foliation or schistosity to the rock.
- Botryoidal nephrite - composed of microfibres in groups arranged in radial fashion giving roughly spherical surfaces up to about 25 mm in diameter.
- Chatoyant nephrite - composed of microfibres in more or less parallel arrangement in alternating bands.

Mineralogical varieties occur when appreciable content of other minerals make their presence known by visual inspection. These may be attached to the various class as adjectival modifiers as talcy jade, when talc is noticeable; chrome jade, a popular designation for jade with noticeable amounts of chrome garnet; intestinal jade in which diopside is abundant in sinuous bands; and spinel jade for specimens with abundant spinel group minerals (chromite, magnetite or picotite).

Types of Occurrence

Nephrite occurs in three types of deposits.

Alluvial Deposits

These are deposits associated with flowing water, i.e. placer deposits. These may be Pleistocene glaciofluvial deposits such as those along with valley of Provencher Lake in the Cassiar Mountains or recent deposits such as those along modern Fraser River bars. Alluvial deposits may be either active, in which the flowing water continues to scour the material so that a smooth skin is produced (Pl. 5A), aiding in identification, or inactive, so that a rough weathered skin develops. This skin is variable in colour and texture rendering sight identification difficult.

Inactive alluvial deposits commonly lie along fluvial or glaciofluvial terraces and a few may be found in eskers.

Colluvial Deposits

These are angular, generally large (several tonnes) talus blocks lying down slope from bedrock occurrences (Pl. 5B). Most in situ occurrences have some associated talus deposits. Talus deposits may be expected to form a continuum with alluvial deposits. Tracing alluvial boulders upstream has led to the discovery of talus blocks and in situ occurrences in the Shulaps, Mount Ogden and Provencher areas in British Columbia.

In situ Deposits

These are the bedrock occurrences which give rise to the first two types through the processes of erosion and transport. They are typically lenticular bodies less than 10 m wide, up to 100 m long and perhaps 50 m deep (Pl. 5C). A few nephrite lodes are tabular bodies, less than 1 m wide, and 20 to 30 m in the other dimensions. In situ nephrite deposits are invariably associated with serpentinites in contact with country rock or with tectonic inclusions with the serpentinite.

In situ deposits may range in size from a few tonnes to perhaps 4500 tonnes. The largest known deposit in British Columbia is that on the property of Cry Lake Jade Mines east of Provencher Lake. Minimum dimensions of this deposit indicate a probable reserve of 3600 tonnes and possible reserves may be several times this. Probably this represents close to the maximum size that may be expected in metasomatic nephrite deposits because of the isolating effect of the reaction zone on the chemical dissimilarities which give rise to these deposits. Less is known about the ultimate size of metamorphic nephrite deposits, but probably they are similarly limited in ultimate size.

Grades of Nephrite

Grade of nephrite means the degree of suitability of the material for commercial purpose. This is distinct from the classification of nephrite as set out in the preceding chapter. It is applicable only to cut blocks as normally produced during the operations of jade properties. It cannot be applied to outcrops or large boulders without extensive core drilling or sawing.

Nephrite varies widely in lapidary qualities mainly on the basis of colour, impurities, fractures and structure. The trade preference is for 'lively' green shades although jet black material is sold. The off-white, "mutton fat" jade of some Chinese carvings is highly prized but this variety has not been found in Canada. Uniform colour is preferred to mottled or variegated colour in jewellery although for carving the latter defect is tolerated. The main impurity in most nepherite is a mineral of the spinel group, i.e. chromite, magnetite or picotite, which form black spots and streaks and may under-cut and cause pitting in the finished articles. Some nephrite may contain streaks of talc, or chlorite which are also undesirable. Chrome garnet is present in some Canadian nephrite but whether or not this is undesirable depends on the personal taste of the user. Many think that bright emerald green spots and splashes, for example material from the Cassiar Asbestos open pit, are attractive.

Fractures are a serious defect in nephrite. They are unsightly and if present in carving stone or gemstone there is a danger of breaking where the fractures are only weakly healed. A few widely spaced fractures may not be serious, but microfractures may be so closely spaced that even a small cabochon cannot be cut from the material.

Structure refers to the grain imparted by preferred orientation of the component fibre groups. These affect the way the material behaves during polishing – sawing must be in the right direction to give the best polished surfaces. The best material will be structurally isotopic, that is it will have little or no grain; the worst may be structurally anisotopic and in fact be a tremolite schist.

Commercial nephrite may be divided into a superior class, gem grade, and an inferior class, the carving grade. Lower grade gem class material merges with higher grade carving class, and the division is arbitrary. Grade C therefore includes material from which gem quality material may be cut. It should be noted that some of the properties listed under the highest grade (Grade A, Fig. 6) may persist through all the grades, but none of the properties listed under "F" may persist past the carving grade "C".

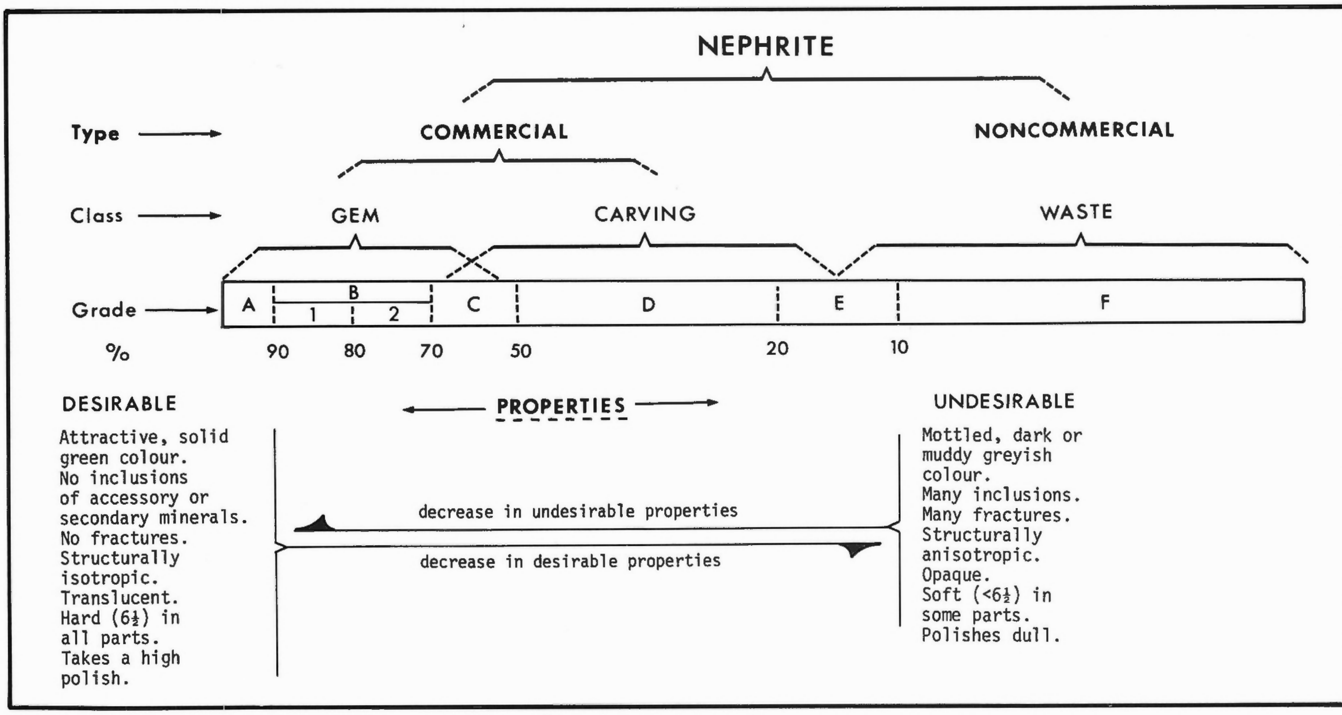


Figure 6. Grades of nephrite.

There is no generally accepted grade scale in use in the industry in British Columbia. Commonly there may be a three-fold grading using such designations as no. 1, 2 or 3, or A, B, C, and descriptive terms such as select, choice, average, may be used without any stated specifications other than vague colour designations.

In order to give some quantitative basis to the grades shown on Figure 6, the percentage scale shown below the grade scale assumes that desirable and undesirable properties are progressive. This is a gross oversimplification as both the desirable and undesirable properties may persist from one grade to the other. Thus, sound green material may be so badly fractured that it cannot be used for commercial purposes and would therefore be noncommercial.

The price of nephrite of course is a function of the grade, but the grade is independent of the price which is a matter of negotiation between buyer and seller. Over the years, the price of nephrite has increased, but the grade of any particular piece of nephrite has remained unchanged.

NEPHRITE DEPOSITS IN CANADA

Most deposits of nephrite in Canada occur in British Columbia. On the simplified geological map of British Columbia (Fig. 7) nephrite deposits occur along a median belt of major faults and serpentinites trending northwesterly from the International Boundary near Hope to the Yukon border north of Dease Lake. Three principal areas are, from south to north, the Lillooet segment, the Omineca segment and the Cassiar segment. The nephrite deposits lie mainly between the Coast Mountains on the west and the Rocky Mountains on the east. The belt is not strictly parallel with the structural grain, however, because in the south it lies along the eastern margin of the Coast Mountains, farther north the deposits lie in the Omineca Mountains, and in the north they are largely in the Cassiar Mountains or along the eastern margin of the adjacent Stikine Plateau. The association of nephrite with faults, serpentinites, and mainly Permo-Triassic rocks, implies relationships compatible with plate tectonic theory. The deposits are all associated with middle Paleozoic to Triassic rocks which are thought to have been part of the oceanic crust but which are now found as large allochthonous slabs thrust over continental rocks.

All deposits of nephrite are associated with serpentinites intrusive into or in fault contact with suites of greenstone, chert, pelite and limestone. These rocks range in age from Late Devonian to Late Triassic although most are of Late Paleozoic age.

One of the most important of these rock assemblages is the Cache Creek Group, which in northern British Columbia has a basal part considered by Monger (pers. comm., 1976) to be an ophiolitic complex of Late Devonian or Early Mississippian age. Stratigraphically higher is a ribbon chert and argillite sequence forming a matrix containing pods of volcanics and shallow-water limestone. Monger views the ophiolitic rocks as oceanic crust which opened up to allow formation of volcanic island arcs. On the flanks of these volcanoes, marine organisms built up deposits of chert and limestone, the latter forming atolls. Later submarine slumping and subaerial erosion produced breccias of mixed volcanic and sedimentary origin. The original site of the island arc was offshore from the margin of the craton or core of the North American continent. Subsequent tectonic events led to the obduction or over-thrusting of these rocks onto the continental rocks in Mesozoic time. The nephrite deposits are believed to have formed when the serpentinites were intruded or very shortly thereafter. One radiometric age of nephrite from Ogden Mountain in the Omineca segment was reported by Lanphere (pers. comm., 1976) as 315 million years or mid-Pennsylvanian. This age is plausible although it is believed that serpentinite with accompanying nephrite lodes was mobilized along faults at later times. Final disposition of nephrite deposits probably rarely corresponds to the place of origin.

Southern British Columbia; Lillooet Segment

Nephrite occurrences in southern British Columbia are most numerous in the Shulaps Range; a few have been found in adjacent areas in the Cadwallader range and along Bridge

River. Alluvial deposits along Fraser and Coquihalla rivers are attributed to in situ occurrences in the serpentine belt which extends from the International border east of Hope, northwesterly to Lillooet (Fig. 8). For descriptive purposes all the occurrences of nephrite in southern British Columbia are grouped under the Lillooet segment of the serpentinite belt. A number of separate structures within these segments have yielded or are expected to yield nephrite occurrences.

Coquihalla River Deposits

Small boulders of nephrite have been found in and along Coquihalla River from time to time but in no great amount. This may be attributed to a paucity of in situ deposits as a source.

Hozameen Area

The Hozameen area includes fault bounded serpentinites extending in a north-northwesterly direction across Coquihalla River to Fraser River south of Boston Bar. Reports of in situ deposits are not confirmed but reported alluvial deposits along Coquihalla River appear to be authentic. Much of this area is in rugged terrain and has not been extensively prospected. Contact reaction zones producing talc along the serpentinite contact are known on the former Aurum mine now held by Carolin Mines, and Cairnes (1930) mentioned "whiterock" alteration of serpentinite in several places adjacent to Coquihalla River; these are important clues in nephrite prospecting and support the belief that in situ deposits will be found in this part of the Lillooet Segment.

Fraser River Deposits

Under this heading are included, not only the alluvial deposits of the Fraser River but a number of deposits associated with areas of serpentinite related to the Fraser fault system.

Boulder of nephrite are found each year on the many bars along Fraser River from Lillooet to Chilliwack. They are not abundant nor very large but because they are commonly free from any surface rind, the green colour makes

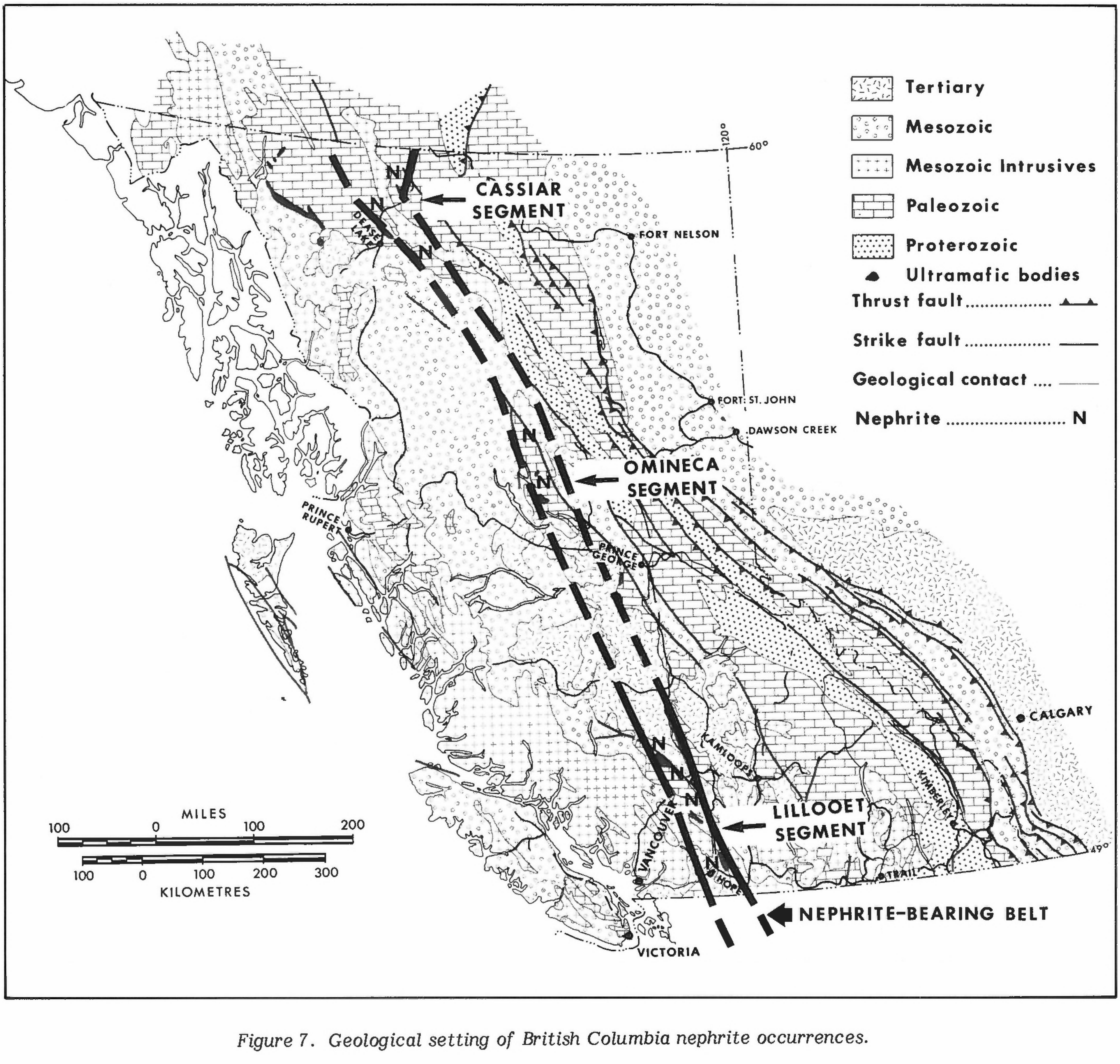


Figure 7. Geological setting of British Columbia nephrite occurrences.

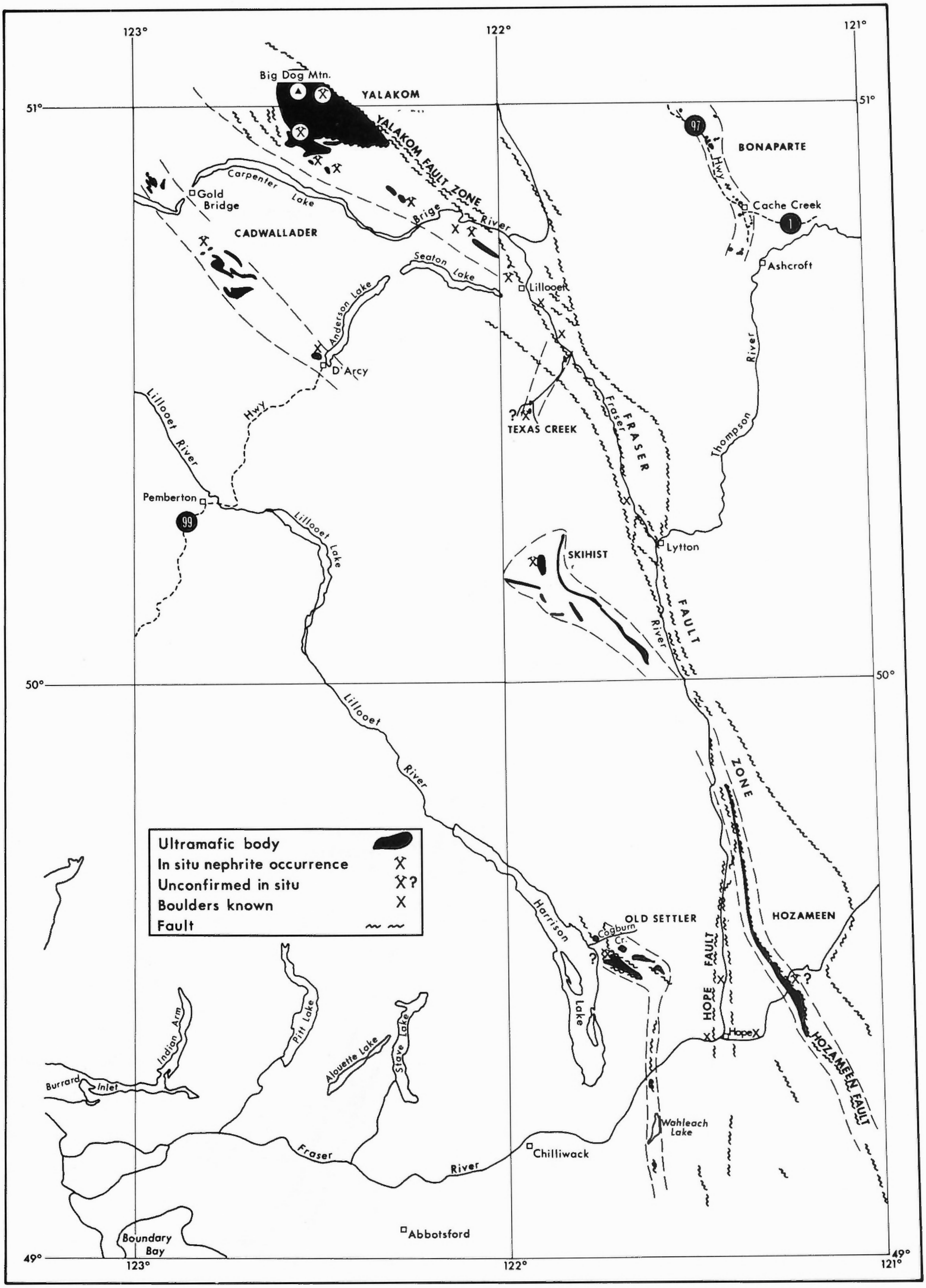


Figure 8. Nephrite deposits Lillooet segment.

recognition easy. Plate 5A illustrates one such boulder found along the Fraser south of Lillooet. Generally, the smallest boulders are found farthest from Lillooet. The boulder in the illustration weighs about 10 kg.

Old Settler

This area appears to be a continuation of a belt of serpentinites extending north from the International Boundary to the vicinity of Old Settler Mountain where an abrupt change in strike to a northwesterly direction occurs. Reports of nephrite along Talc Creek, which flows westerly, have not been confirmed but are believed to be reliable. The area is readily accessible by logging roads along the east side of Harrison Lake.

Skihist

The Skihist locality appears to be a continuation of the Hozemeen structure (Fig. 8) although the continuity is disrupted by the Fraser fault zone. A large deposit of vesuvianite with minor nephrite on Skihist Mountain has produced at least 45 tonnes of lapidary material. Probably much of the vesuvianite float found along the Fraser, originated there. The amount of nephrite associated with the vesuvianite is unknown but is presumably minor. The deposit has not been seen by the author, who is indebted to Mr. Ron Purvis for the information.

Texas Creek

A few small outcrops of serpentinite appear to lie in a north-northeasterly trending zone extending from the head of Texas Creek to its mouth on Fraser River.

Reports of nephrite near the head of the creek have not been confirmed but contact reaction zones with some nephritic selvages were seen on lot 237 along the lower reaches of the creek above the Texas Creek Road.

Bridge River Deposits

Alluvial boulders along Bridge River were once both large and numerous but over the years most of them have been removed. Much of Bridge River flows through Indian

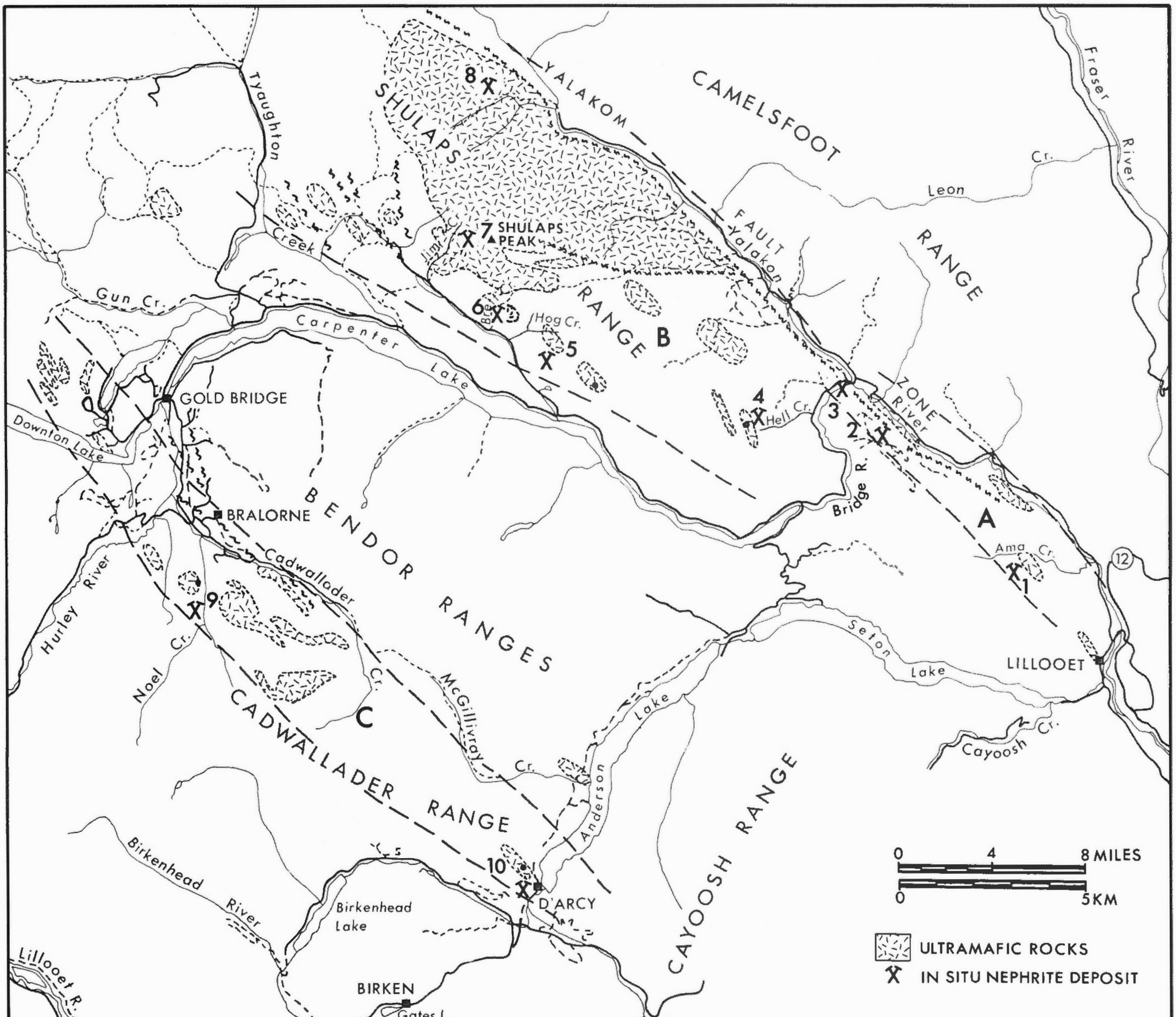


Figure 9. Nephrite deposits in the Bridge River (A), Yalakom (B) and Cadwallader (C) areas.

Reserve lands which effectively remove the remaining boulders (if any) from exploitation except through co-operation with the local band. A number of small and low quality deposits occur in place adjacent to the river from its mouth upstream for about 48 km. Some of these may have contributed to the alluvial deposits but many boulders are believed to have been glacially transported from the Shulaps Range where large in place deposits are known.

Ama Creek

Serpentinites near the head of Ama Creek (Fig. 9, No. 1) contain a number of contact reaction zones with nephrite but little or no material of commercial grade has been found. The area is accessible using the powerline road which leaves the Bralorne road at the south end of the bridge over Bridge River, 6 km north of Lillooet.

At a point on the access road 14 km from the Bralorne road an outcrop of "whiterock" in serpentine contains two irregular veinlike bands of nephrite. Along the west side of the outcrop, the "whiterock" consists mainly of albite with minor diopside, in fault contact with serpentinite. Serpentine outcrops east of the "whiterock" suggesting that it is a tectonic inclusion. The mineralogy indicates that the inclusion was a block of gabbroic rock in which the calcic plagioclase has been albitized.

Applespring Creek

This deposit (Fig. 9, No. 2) lies on the westside of Bridge River about 450 m south of the cable ferry downstream from the mouth of Applespring Creek. Holland (1962) described it as being 45 cm to 60 cm wide and consisting of nodules, sheared lenses and layers of pale greenish grey waxy nephrite enclosed in sheared tremolite in a pronounced fault in serpentinite. The deposit was not seen by the author, but it is evidently a seminephrite or noncommercial type.

Horseshoe Bend

A contact reaction zone in serpentinite occurs in the west wall of the horseshoe bend of Bridge River 0.4 km downstream from the confluence with Yalakom River (Fig. 9, No. 3). Several nephrite boulders up to a few hundred kilograms in weight were seen in the river but no nephrite was actually found in place in the contact reaction zones. Three irregular masses of "whiterock" occur within sheared serpentinite as tectonic inclusions.

Shulaps Range Deposits

Included here are those deposits associated with the main mass of the Shulaps Range and a number of satellite bodies associated with it (Fig. 9). Most of the nephrite produced from in situ deposits has come from this region. The northerly part of the Shulaps Range consists of a large mass of ultramafic rock, mainly harzburgite, with lesser amounts of dunite and pyroxenite. These rocks are now intensely serpentinized in at least ten separate occurrences southeast of the main mass, a number of smaller satellite bodies of serpentinite with contact reaction zones include nephrite deposits.

The Shulaps ultramafic bodies are in fault contact with Upper Triassic sedimentary rocks. Tectonic inclusions within the serpentinite are numerous; that the body was intruded as a cold solid is proven by the complete lack of thermal effects, even in limestone, and the pervasive shearing, fracturing and faulting of the serpentine and its contacts with the invaded rock.

All of the known nephrite occurrences in the Shulaps area occur near the margins of the main ultramafic mass or minor satellitic bodies which probably represent faulted slices from small apophyses. Some of these marginal occurrences are associated with tectonic inclusions within the main mass. Figure 10 is a diagrammatic representation of the relationships exhibited by some of the Shulaps occurrences.

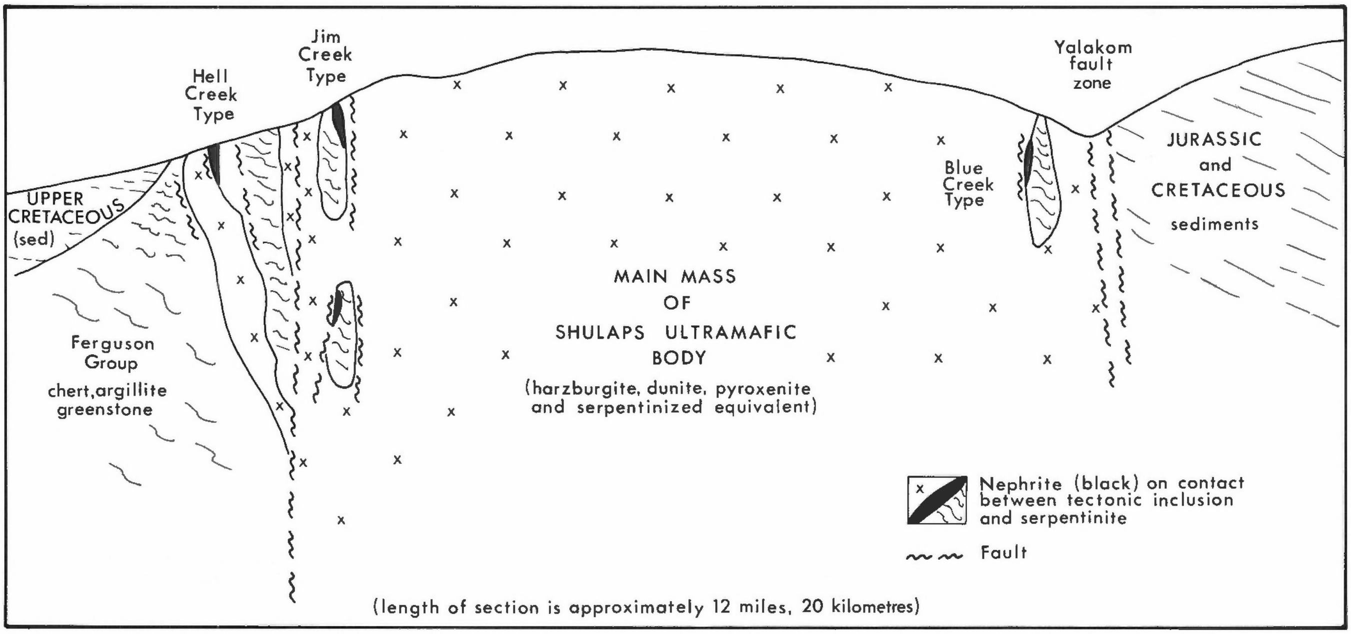


Figure 10. Diagrammatic cross-section through Shulaps ultramafic body looking northwest, adapted from Leech (1953).

Hell Creek

This deposit (Fig. 9, No. 4) was found in 1966 by the late E. Osterland who took out a few hundred kilograms by packhorse prior to selling the property to B.C. Gem Supply Limited in 1968. B.C. Gem removed about 100 tonnes (Pl. 6A). Some nephrite remains on the property but mining is becoming difficult and expensive. Probably little further work on the main deposit will be attempted, but possibilities of new discoveries remain. The Hell Creek deposit, located at the head of Hell Creek at an elevation of about 2000 m, consists of a faulted mass of nephrite 2.4 m wide in places, with a talc border about 0.3 m wide lying between serpentinite and Ferguson Group sediments (Pl. 6B). Both contacts are faults and the faults combined with cross fractures striking N65E facilitated mining by making it possible to extract, by hydraulic jacks, blocks up to 20 tonnes in weight for further reduction by 1 m diamond saws (Pl. 7A). During the first year of operation cut blocks of 40 to 45 kg were removed by helicopter from the mine to the Yalakom Valley road. In 1969 an access road was constructed to reduce transportation costs.

The nephrite zone, which strikes N50°W and dips 75°SE, can be traced by intermittent outcrops of nephrite and talcy nephrite for 900 m but all production has come from a small part of the zone where a wide part was well exposed over a length of about 15 m, and a vertical extent of about 6 m. The calculated production was 300 tonnes, of which about 50 per cent was commercial.

The fractures striking N65°E and dipping 70°SE are widely spaced. A weak foliation striking parallel with the fractures dips 20°N. Along the east side of the nephrite body a band of talc 0.3 m wide has developed in fault contact with the Ferguson Group sediments; on the west side, the nephrite is in contact with serpentinite. Lack of "whiterock" alteration of country rock and the presence of faults on both sides of the body indicate it has been tectonically transported to the present position.

Nephrite from the Hell Creek deposit varies in quality from good to fair. The deterioration in quality is mainly due to the increase in coarse tremolite patches, talc and opaque minerals. Plate 6C is a photomicrograph of good average nephrite in which the typical nephritic texture is well developed.

Hog Creek

Hog Creek nephrite deposits (Fig. 9, No. 5) include at least two small separate occurrences in satellite serpentinite bodies south of the main Shulaps ultramafic intrusive about 2.4 km east of Rex Peak. A bulldozer road leads to the deposits from the Marshall Lake Road about 400 m east of Hog Creek.

The higher deposit at the end of the road is badly caved and little excavation was done originally. Green serpentinite with small patches of schistose talc, nephrite and minor "whiterock" are present but contact relationships are difficult to determine. Presumably little good quality nephrite was found. At the lower deposit, serpentinite is in contact with schist. A few boulders of serpentinite with contact reaction zones were seen. Some nephrite was found by the developers in small lodes but most were of poor quality. The claims were subsequently acquired by Greenbay Mining as part of the Brett Creek holdings but no further work has been done.

Brett Creek

The Brett Creek nephrite lode (Fig. 9, No. 6) was found by Robert Smith in 1967 by tracing boulders to, and digging along, the contact between serpentine and cherty sediments. The original lode was blind in that it was covered by overburden. Total production to date has been about 800 tonnes according to Mr. Smith. Of this about 150 tonnes remain unsold mainly because of poor quality. All this production came from one deposit which still contains nephrite although the pit is now in a dangerous condition and removal of a large amount of waste will be required before further production is possible.

The principle feature of this deposit is the presence of a large tectonic inclusion of chert within a mass of serpentinite. This inclusion is in fault contact with serpentinite on the north side of a major fault striking N75°E. Metasomatic alteration of the inclusion resulted in the development of "whiterock", that is lime silicates, mainly hydrogarnet, and clinozoisite, with nephrite and talc. The talc occurs as a skin up to 15 cm wide on the fault side of the nephrite. In places, lenses or vein-like selvages of nephrite as shown diagrammatically in Figure 12, occur along the "whiterock"-serpentinite contact. In 1969 nephrite was exposed on both sides of the chert in irregular lenses or pods up to several tonnes in weight. All of the lenses had been removed prior to 1975 when operators enlarged the pit by removing the serpentinite thereby exposing a wall of nephrite about 18 m long, 9 m high and 45-60 cm thick (Pl. 7A) against the contact reaction zone. This vein was detached by shaking the structure with explosives placed in holes drilled into the "whiterock" along the bottom of the pit. About 80 tonnes were removed.

The nephrite in this part of the deposit is of poorer quality than much of the material in the lenses and pods in the upper part. The low grade results from poor colour; some is olive green (10GY 2/1) but most is greyish green (10GY 3/4). Fractures are noticeable in some specimens. Possibly some of the fractures were induced by the use of explosives. In addition to these defects there is a slight foliation due to preferred orientation of bundles of nephritic tremolite and a few shreds of prismatic tremolite parallel with the strike direction (N75°E).

Plate 7 comprises two photomicrographs of typical Brett Creek nephrite. The average size of the bundles is 0.063 mm long by 0.018 mm wide. Plate 7B shows a fractured picotite grain, the principal opaque mineral. A little chlorite occurs with the fractures.

A prominent feature in the whiterock or contact reaction zones is the presence of small masses and irregular patches of pink thulite. This mineral has not been reported from other nephrite deposits in British Columbia.

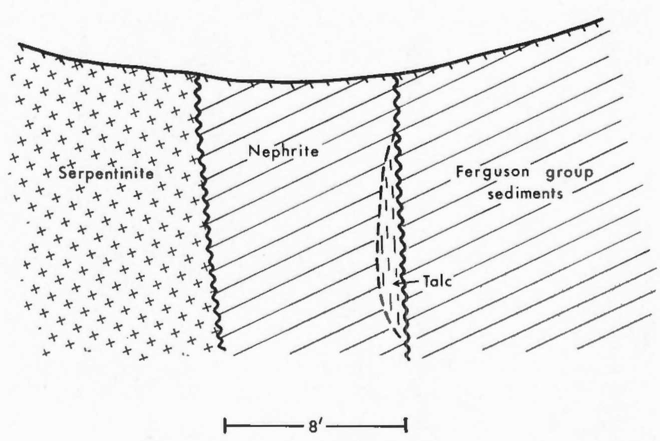
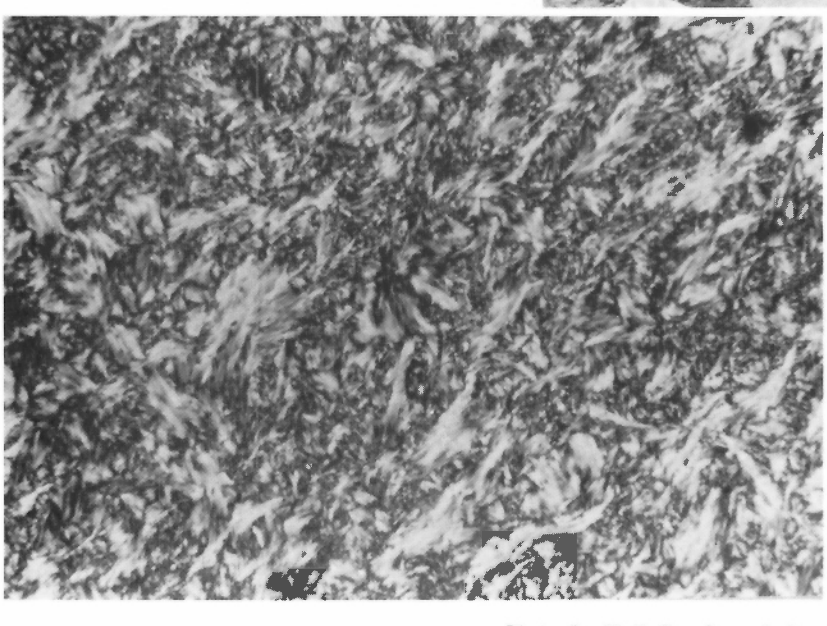


Figure 11. Diagrammatic cross-section, Hell Creek nephrite deposit (Birkenhead Jade Mines Ltd.).

A. Production of commercial blocks of nephrite. GSC 154035

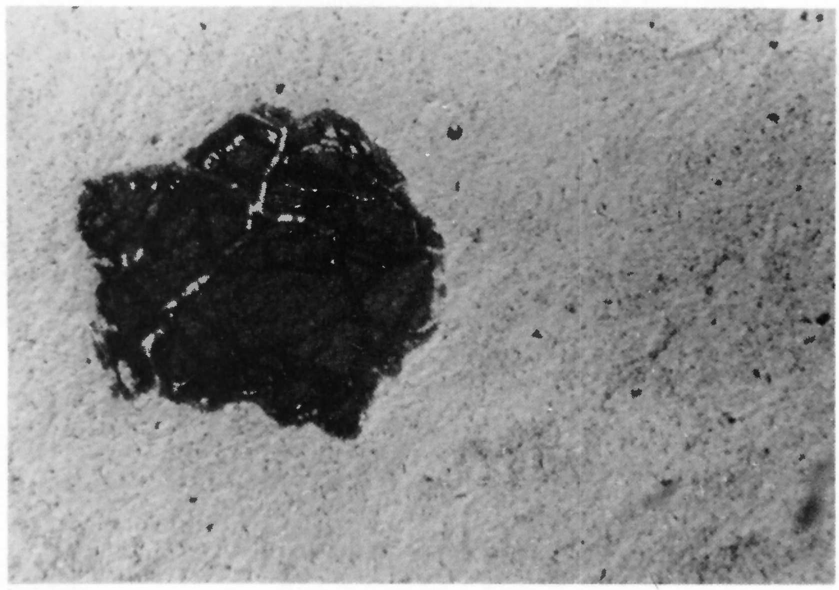
B. In situ deposit 2.4 m in width. GSC 154036



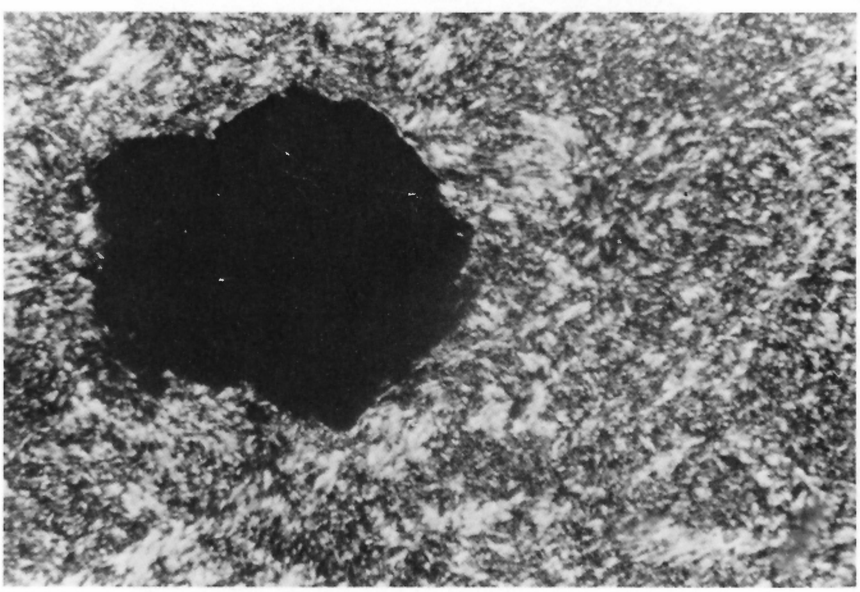
C. Photomicrograph of nephrite. x 63 crossed nicols. GSC 202783-K

Plate 6. Hell Creek nephrite deposit

A. Nephrite "vein" between serpentinite (left) and "whiterock" (right) GSC 203173-B



B. Photomicrograph of nephrite showing picotite in nephrite base. x 63 plain light GSC 202783-S



C. Same photomicrograph as in B. x 63 crossed nicols GSC 202783-T

Plate 7. Brett Creek nephrite deposit

A. Lens or nodule in serpentinite GSC 164458

B. "Whiterock" alteration with botryoidal nephrite in serpentinite GSC 164457

Plate 8. Jim Creek nephrite deposit

Plate 9. Noel Creek nephrite deposit. GSC 154044

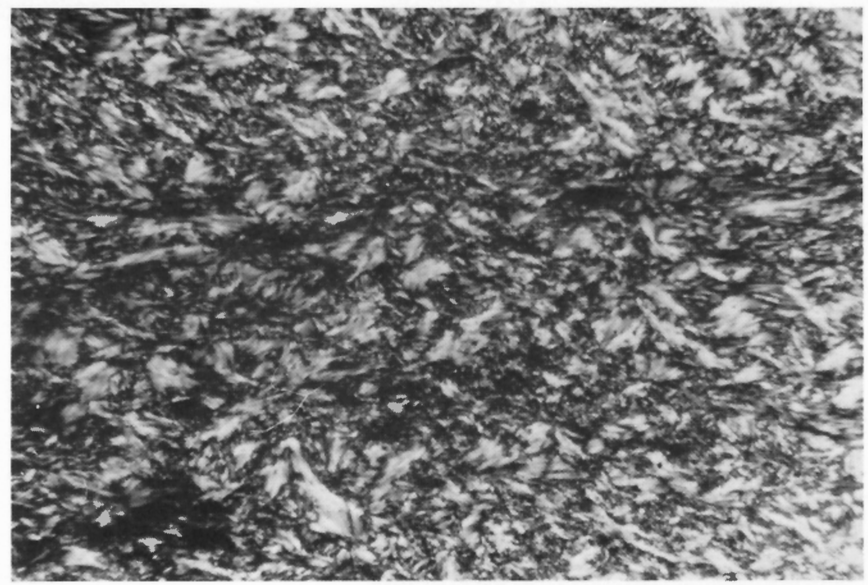


Plate 10. Photomicrograph of nephrite from O'ne-ell Creek, Mount Sidney Williams. x 63 crossed nicols GSC 202783-G

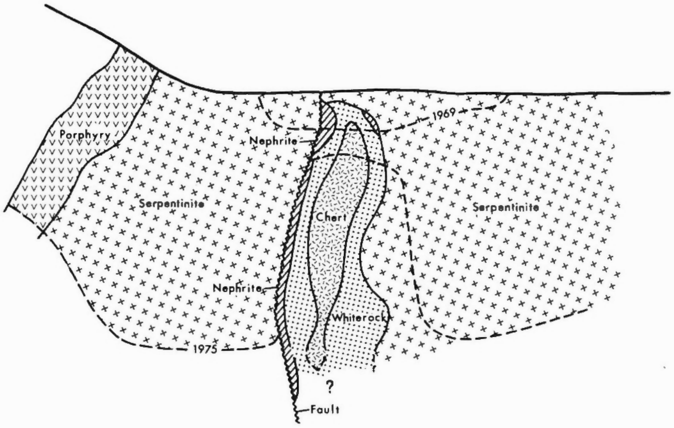


Figure 12. Diagrammatic cross-section, Brett Creek nephrite deposit (Greenbay Mining and Exploration Ltd.).

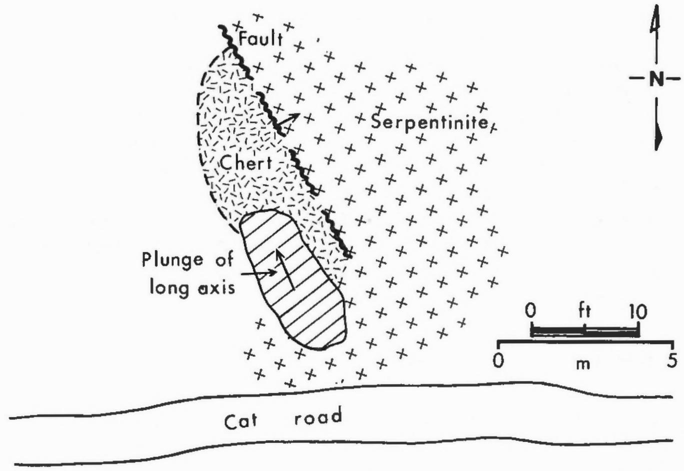


Figure 13. Diagrammatic plan, Jim Creek nephrite deposit (Capp Claims).

Jim Creek

Alluvial boulders of nephrite have been found along Jim Creek (Fig. 9, No. 7) since the early days of activity in Bridge River area. In 1974, C. McEwen, prospecting at the head of Jim Creek, about 8 km by access road from Marshall Lake, found nephrite in an alteration zone associated with chert. In addition, minor botryoidal nephrite was found as thin, vein-like ribbons within serpentinite. The botryoidal nephrite is mainly of interest as specimens; no significant amount of commercial, massive nephrite occurs with the botryoidal type. The principal lode on this property as exposed by bulldozer, is a mass of nephrite 1m by 1m by 4m which seems to be larger because the cigar-shaped nodule could not be moved with a HD9 tractor. The exposed dimensions indicate a 10-tonne mass but it may be double or triple this weight. The deposit is largely surrounded by serpentinite but chert is in contact with the nephrite along the north side of the exposure (Fig. 8A). The deposit does not seem large enough to have supplied all the alluvial material which has been found along Jim Creek and there may have been, or may still be other occurrences at lower elevations.

Botryoidal nephrite occurs in 30 to 60 cm, flat-lying bands within serpentinite 150 m above the main deposit. These bands are partly schistose talc-bearing nephrite and partly "whiterock". They are of no commercial importance (Pl. 8B). The chert in thin section reveals that the original rock was an impure siliceous sediment mainly quartz but with nests of albite and clinozoisite; there is minor chlorite, stilpnomelane and carbonate. Small alteration zones with botryoidal nephrite were seen in the serpentinite along the ridge running west from Shulaps Peak. No commercial grade nephrite was found but the area was only given a cursory examination; the possibilities for further discoveries must be considered good. Unfortunately most of the favourable area is above 2100 m elevation resulting in a short season, arduous working conditions, and in many places, shortage of water for cutting.

Blue Creek

The Blue Creek nephrite deposit (Fig. 9, No. 8) is located in the northern Shulaps Mountains north of Blue Creek and about 0.8 km east of the camp of the now abandoned Elizabeth Mine. Access to the mine is provided by a narrow road up Yalakom Valley to a crossing above the confluence of Blue Creek and Yalakom River. The 6-mile Blue Creek part has not been maintained for many years and is only passable on foot, horse or motorcycle.

The nephrite occurrences lie in a long zone of "whiterock" with small pods of botryoidal nephrite, a pinkish mineral identified by X-ray diffraction as clinoamphibole, and some greenish minerals thought to be vesuvianite. The zone strikes N30°W and is up to 8 m wide. Contacts are not clearly exposed; the zone lies within a serpentine mass and is believed to represent a line of tectonic inclusions. No large masses of commercial nephrite were found but the possibilities have not been exhausted. There has been no commercial production from this deposit.

Cadwallader Range Deposits

The Cadwallader area includes all the nephrite deposits associated with the ultramafic deposits in the Cadwallader Range from Noel Creek to D'Arcy. Nephrite has only been found at the extreme ends of this belt. This may be due in part to lack of prospecting in the difficult terrain in the central part where ultramafic bodies have been mapped. The ultramafic rocks intrude the Bridge River Group, which consists of chert, argillite, volcanic rocks and minor limestone. Fossils in limestone at Tyaughton Creek indicate a Middle Triassic age but the oldest rocks in the group could be much older (Cameron and Monger, 1971). The emplacement of the ultramafic bodies cannot be older than Middle Triassic.

Noel Creek

Prospecting along Cadwallader and Noel creeks (Fig. 9, No. 9) revealed nephrite boulders which led Mr. H. Street to the discovery of in situ deposits.

Two in situ occurrences are known. They are about 300 m up the slope on the west side of Noel Creek a short distance from the confluence with Cadwallader Creek. The serpentinite with which they are associated is plotted on Figure 9. Mr. H. Street put in a bulldozer road to the showings and recovered several tonnes of nephrite but after cutting and selling the easily recovered material, little work has been done since 1969. At the time of the visit about 45 tonnes of low grade and rejected nephritic rock in boulders and cuttings were seen on the property. Several large, 13.5-tonne, uncut and therefore unappraised blocks were also seen. Although most of the easily obtained boulders and talus blocks have been found and tested, some good possibilities for further production remain. A possible reserve of some 450 tonnes is reasonable. Probable reserves might be conservatively set at 45 tonnes. No. 1 Deposit, the most southerly of the two seen, appears to be associated with listwanite (quartz-carbonate). The nephrite is best classified as seminephrite, because it is mainly shreds of tremolite with clinozoisite and titanite. No. 2 Deposit (Pl. 9) about 300 m north of No. 1, consists of a south-dipping band of seminephrite between listwanite on the hanging wall and clinozoisite-carbonate contact reaction zone on the footwall. Serpentinite is not directly associated with the nephrite and it is therefore probably a detached tectonic inclusion. These occurrences are difficult to assess because much of the rock is covered by talus or overburden.

D'Arcy Nephrite

Nephrite occurs as small lenses within serpentinite north of the settlement of D'Arcy at the western end of Anderson Lake (Fig. 9, No. 10). The deposit is just off the powerline road at a point about a mile north of D'Arcy where the road, after running directly uphill, abruptly turns east. The zone extends for about 150 m southerly from an outcrop of serpentinite on the north side of the road. Four outcrops along a N45°W trend marks the zone with the widest nephrite band, about 50 cm. The relationship appears to be a contact zone between andesite and serpentinite. From the dimensions observed the zone may contain about 300 tonnes in the probable category, but no quality can be considered proved.

On the basis of a study of thin sections, the material would be classified as seminephrite; it contains much shreddy tremolite in addition to the nephritic base. Fractured chromite grains, in part replaced by chlorite, are present. Gem quality material was obtained from some parts of the deposit by Mrs. Nellie Street, the discoverer. The alteration zone associated with the serpentinite is mainly clinozoisite which appears to be a replacement or angular fragments, i.e. a breccia. In addition, minor amounts of prismatic tremolite and diopside were seen.

Central British Columbia; Omineca Segment

Included in this segment of the nephrite-bearing belt are occurrences from Mount Sidney Williams to the Axelgold Range. Deposits have been found only near the extremities of the segment. Some alluvial boulders have been found at a considerable distance from any known outcrops of serpentinite. In part, this may be attributed to glacial transport; in part, to undiscovered or concealed serpentinite outcrops along the Pinchi fault zone (see Fig. 14).

Mount Sidney Williams

The principal nephrite deposit is on the Jade Queen property at the head of O'ne-ell Creek. It was discovered by Mrs. W. Robertson in 1969. The property did not live up to initial expectations and no production has been recorded since 1970. Fraser (1972) studied the occurrence and much of the following information may be credited to him.

The Mount Sidney Williams ultramafic body is part of the Trembleur intrusions of Armstrong (1949). It consists of peridotite and dunite, partly to completely serpentinized. A number of reaction zones were noted by Armstrong at the contact of the ultramafic mass along the southwest face of Mount Sidney Williams, along the southwestern contact of the peridotite in the southern part of Mitchell Mountains, and along the borders of some of the sill that outcrops between Mount Sidney Williams and Tsitsutl Mountain. Armstrong noted that in the southern part of the Mitchell Mountains, peridotite stocks cut cherty and argillaceous rocks and in many places zones of tremolite schist have developed. Contact reaction zones were noted in xenoliths of siliceous and argillaceous rocks. Further discoveries of nephrite in this area are likely.

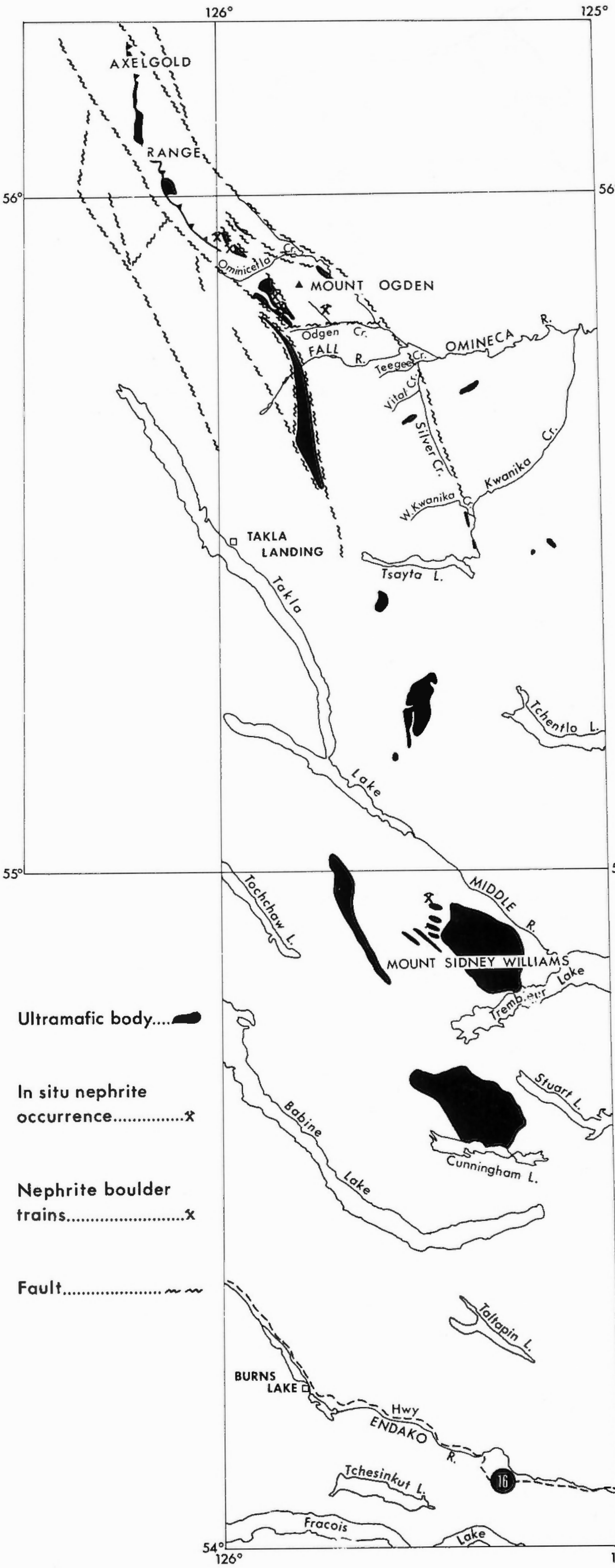


Figure 14. Nephrite deposits in Omineca segment.

The Trembleur intrusions are considered to be partly or wholly of pre-Late Triassic age, and are confined to areas of Cache Creek Group rocks of Late Paleozoic age. Much faulting, shearing and fracturing of the ultramafic masses was noted by Armstrong and alteration is present along many contacts. Some is of carbonate-quartz-mariposite type which as Patterson (1973) noted, probably formed in Eocene time during late stage activity on the Pinchi fault zone. This type of alteration is not associated with the formation of nephrite.

A deposit of nephrite was found by Mrs. W. Robertson on the north side of O'ne-ell Creek 5.6 km from its confluence with Middle River and about 8 km northwest of the summit of Mount Sidney Williams. The property is known as the Jade Queen. In a study of the deposit Fraser (1972) stated, "The nephrite in this deposit occurs as veins and lenses in a zone of foliated tremolite-chlorite rock developed at the contact between serpentinite of the Trembleur intrusions, and cherts, quartzites and argillites of the Cache Creek Group".

The largest mass of nephrite, and the only one exposed at the surface, is on the north side of the creek. It is 7 m wide and has an average true thickness of 1.5 m. Information from a drillhole indicates that the nephrite extends for at least 9 m, but that its thickness decreases to 0.45 m. Using these figures, a maximum of about 200 tonnes may be calculated. Fraser described a slab of nephrite at the base of the in situ deposit as weighing approximately 150 tonnes.

Two other nephritic lenses were intersected in drillholes, one was 15 cm thick, the other about 1 m but both were described as seminephrite. No estimate of reserves in boulder form was made. In view of lack of production since 1969 it may be concluded that some published estimates must be revised downward. The diagrammatic section through the main lode shown on Figure 15, is derived from a map accompanying Fraser (1972).

The interesting feature of this deposit is the tremolite-chlorite alteration zone developed between the serpentinite and the Cache Creek sedimentary rocks. These are greenish grey in contrast to the usual whitish contact reaction zones or "whiterock" of most nephrite occurrences. They are mainly tremolite in fibrous form approaching a nephritic texture in places and it seems possible that some of the material could have been mistakenly included in estimates of nephrite reserves. According to Fraser (1972), the Jade Queen nephrite includes true nephrite of Turner's classification. The tufts in the nephritic base range from 0.01 to 0.20 mm in length. In schistose nephrite, aggregates are 0.02 to 0.10 mm wide by 0.10 to 1.30 mm long and the semi-nephrites may include groups up to 1.90 mm by 5.40 mm.

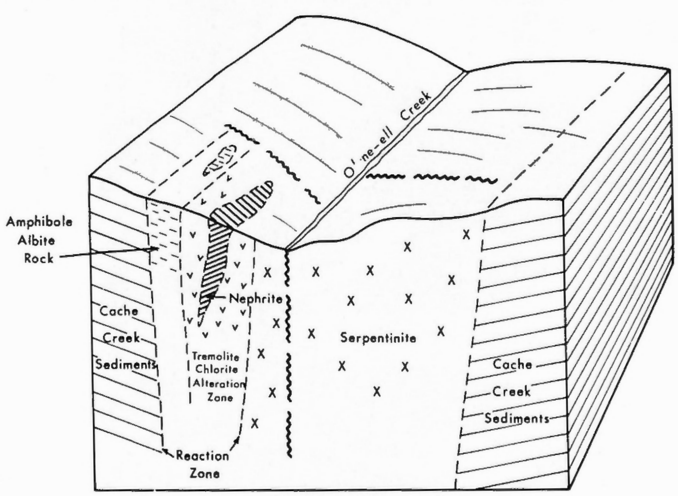


Figure 15. Jade Queen Mines Ltd. O'ne-ell Creek Nephrite deposit from Fraser (1972).

A spinel-group mineral, commonly picotite, is always present and forms crystal up to 1.3 by 0.90 mm. Rounded and fractured chromite is also noted in crystals up to 0.5 mm in diameter or as rims on picotite.

According to Fraser, diopside is present in subhedral crystals or corroded remnants in some thin sections. Uvarovite garnet was found in several thin sections, usually as replacement rims on corroded picotite, but also as discrete grains in elongated aggregates parallel to the schistosity. Chlorite occurs as aggregates of tiny flakes in irregular patches generally elongated in the direction of schistosity and comprises up to 10 per cent of the rock. Titanite is present as brownish microlites in almost all thin sections. Minor amounts of carbonate, talc, pyrite and phlogopite were noted in some specimens.

Plate 10 shows a photomicrograph of typical nephrite from this deposit.

Mount Ogden

On Mount Ogden a number of sill-like serpentinite bodies with associated faults and contact reaction zones occur in Cache Creek Group sediments along the western slope of the mountain. The productive ground is held by two separate companies, Far North Jade Limited and Continental Jade Limited. The discovery of in situ nephrite at the head of Lee Creek, a tributary of Odgen Creek, was made by L. Owen and S. Poryko in 1969.

Production of cut blocks of nephrite was continued by New World Jade until 1974 when the assets were acquired by B.C. Gem (H.K.) Limited. Since 1976 claims have been held by Continental Jade Limited.

Following the success of Owen and Porayko, boulders and large blocks of nephrite close to the bedrock source were found to the northwest of the Owen-Porayko deposit. The ground was staked by L. Barr for Far North Jade Limited, and intermittent production began in 1970, when L. Barr cut high quality nephrite into small blocks and flew them out from Ogden Lake. About the same time alluvial boulders were found on the creek immediately east of Ogden Creek. A large block of claims was staked by Kwan Yin Limited and preparations were made for large scale production. Apparently the quality and/or quantity did not meet expectations and the property is now in other hands. Examination of aeromagnetic map 5286G (published by the Geological Survey of Canada in 1970) offers an explanation for the lack of in situ nephrite. The area is underlain by a large magnetic low, indicative of Cache Creek Group sediments lacking significant areas of mafic or ultramafic rocks. The boulders may have been glacially transported from the B.C. Gem property, or if they are derived from in situ deposits along the creek, such deposits must be very small.

The initial nephrite discovery on Mount Ogden was made at the head of Lee Creek along a contact zone between serpentinite and Cache Creek metasediments. Most of the production has come from the locality covered by mineral claims Lee No. 1, 2, 3 and 4 (Pl. 11). On the main showing initial production was from colluvial blocks detached from the main lode and nearby loose blocks that were transported by Pleistocene ice. At increasing distances from the lode, the colluvial blocks were modified by stream action to form boulders of various sizes ranging from a few kilograms to several tonnes.

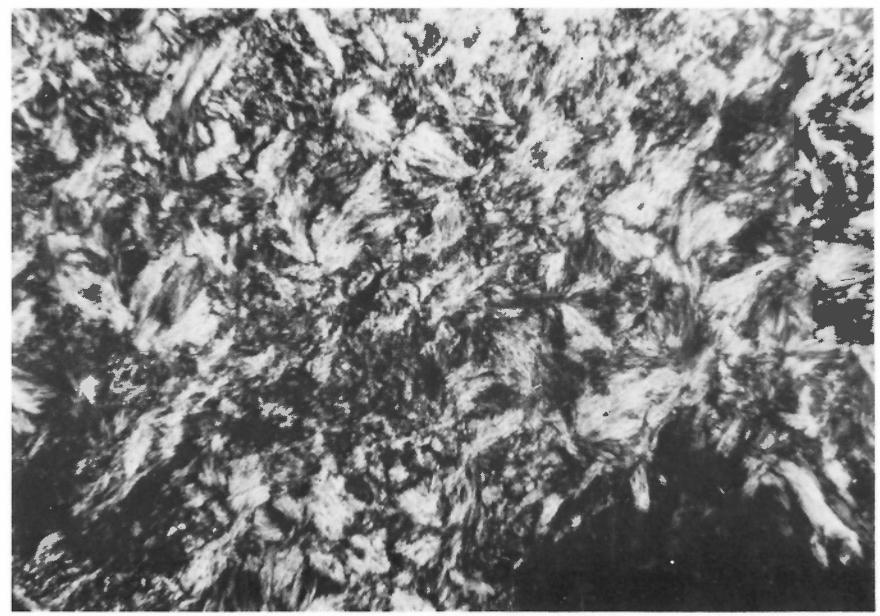
The contact reaction zone which may be up to 30 m wide, consists of talc, schist, "whiterock" bodies, inclusions of Cache Creek sedimentary rocks and nephrite lenses (Fig. 16A).

A. Wire saw for cutting large blocks. GSC 164461

B. General view of camp. GSC 164462

Plate 11. Nephrite production on Mount Ogden

A. Fractured picotite. x 16 plain light. GSC 203173



B. Typical nephrite. x 63 crossed nicols. GSC 203173-A

Plate 12. Photomicrographs of nephrite from Mount Ogden

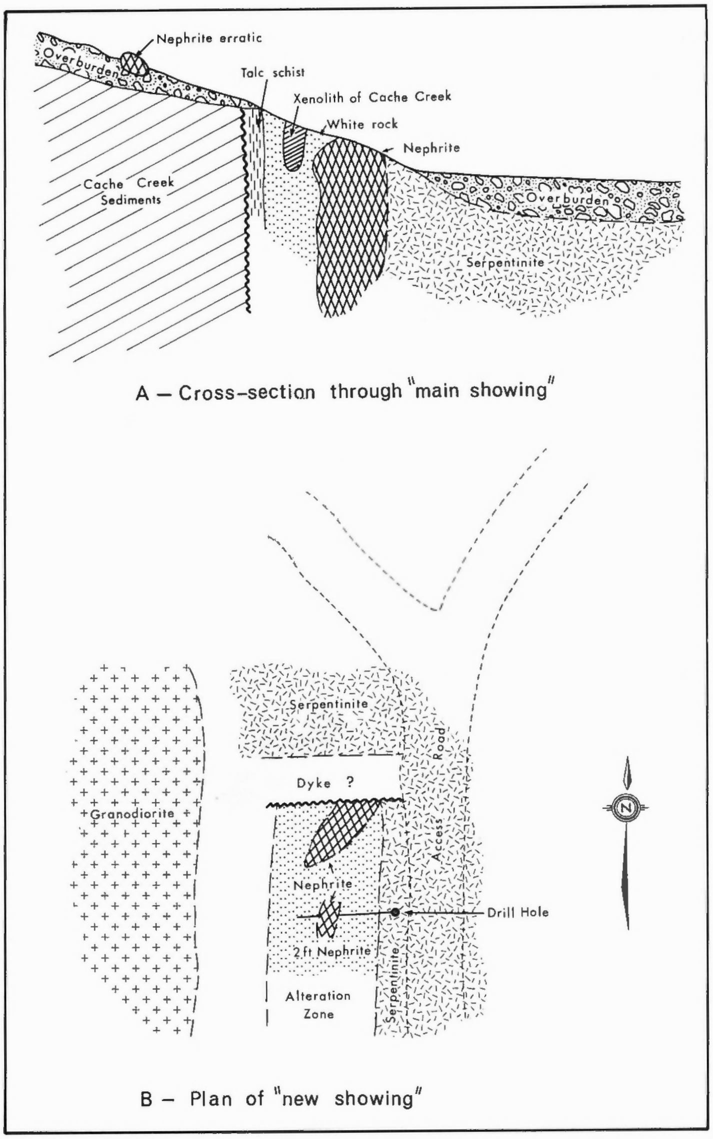


Figure 16. Diagrammatic sketches of nephrite deposits on Mount Ogden.

The nephrite, which may be up to 3 m thick, is fractured or faulted into blocks as much as 70 to 100 tonnes in weight. When first examined in 1970, the nephrite lens appeared to be about 50 m long, 3 m wide and 5 m high giving a volume of 750 m^3 or about 2250 tonnes. Some of the material was not commercial grade, and much of it was low grade. However, in places the nephrite was the finest quality found anywhere in British Columbia. Nephrite of various grades has been found in place elsewhere on the property in four other apparently small occurrences. At the most important, "the new showing", 600 m southwest of the main showing, serpentinite is close to a body of granodiorite and may be in contact with it. At one point along this contact, nephrite in small lenses lies within an alteration zone within the serpentinite (Fig. 16B). A band of nephrite 0.6 m thick was intersected in a short horizontal drillhole ten feet south of the nephrite outcrop. It appears that a contact reaction zone has developed in a tectonic inclusion and that the later intrusion of the granodiorite has obscured the original relationship. The granodiorite included in the Omineca intrusives of Cretaceous age is probably not relevant to the formation of the nephrite.

Appraisal of the potential is difficult. Possible reserves may be from 500 to 1000 tonnes. Probable reserves from an exposed lode and some talus blocks may yield about 50 tonnes.

Typical nephrite shows microfibres 0.05 mm long with an average width of 0.02 mm (Pl. 12). Minor chlorite and picotite can be seen in the thin section.

Another company, Far North Jade Limited, has worked jade claims on Mount Ogden intermittently since 1969. Initial production came from large slabs and blocks of residual or talus material obviously close to the bedrock source. One large block, estimated to weigh 70 tonnes (Pl. 13), has been about 25 per cent reduced by diamond sawing. Blocks this size are not conveniently handled by even 36-inch diamond saw blades, but Mr. L. Barr succeeded in extracting about 20 tonnes, most of which has been removed from the property. The nephrite in the remaining block shows patches of good colour but there is considerable fracturing which reduces the quality.

Other slabs and blocks were seen on the property and according to Mr. L. Barr (pers. comm., 1976) in situ deposits have been found. Estimates of reserves are speculative but are as high as 200 tonnes with probable reserves of perhaps 500. Inspection of the sawn faces on the 70-tonne blocks suggests that 50 tonnes could be considered proven.

Axelgold Range

Nephrite has been found in the southern end of the Axelgold Range, along the trend of the Mount Ogden occurrences (Fig. 14). The deposit consists of large alluvial boulders or colluvial blocks. The property has not been seen by the writer. The owner, Mr. Frank Plut reported a production of one tonne of high quality nephrite. His estimates of reserves is 200 tonnes. From the reported size of some of the blocks it is probable that they are very close to the bedrock source. The area is underlain by serpentinite, Cache Creek Group rocks and some granitic intrusives. Further prospecting can be expected to reveal contact reaction zones with nephrite occurrences.

Northern British Columbia; Cassiar Segment

The Cassiar segment (Fig. 17) of the nephrite bearing belt of British Columbia follows the southern margin of the Atlin Terrane as defined by Monger (1975). A smaller but still important branch (in terms of nephrite possibilities) diverges from the main belt north of Cry Lake and continues in a north-northwest direction into Yukon Territory. All the nephrite deposits in the Atlin Terrane occur in the eastern part of the belt. Most are in the Cry Lake map-area (104 J).

Cry Lake Map-Area

Nephrite in the Cry Lake map-area are associated with fault-bounded ultramafic bodies extending diagonally across the map-area (Fig. 18). The ultramafics are mainly serpentinized pyroxenite, wehrlite with small bodies of dunite, pyroxenite, and gabbro. Nephrite occurrences are distributed along the whole length of the serpentinite belt with a concentration towards the eastern end. The quality of many of these however is very low, some best described as tremolite rock. For this reason Figure 18 is titled nephritic rocks in the Cry Lake map-area.

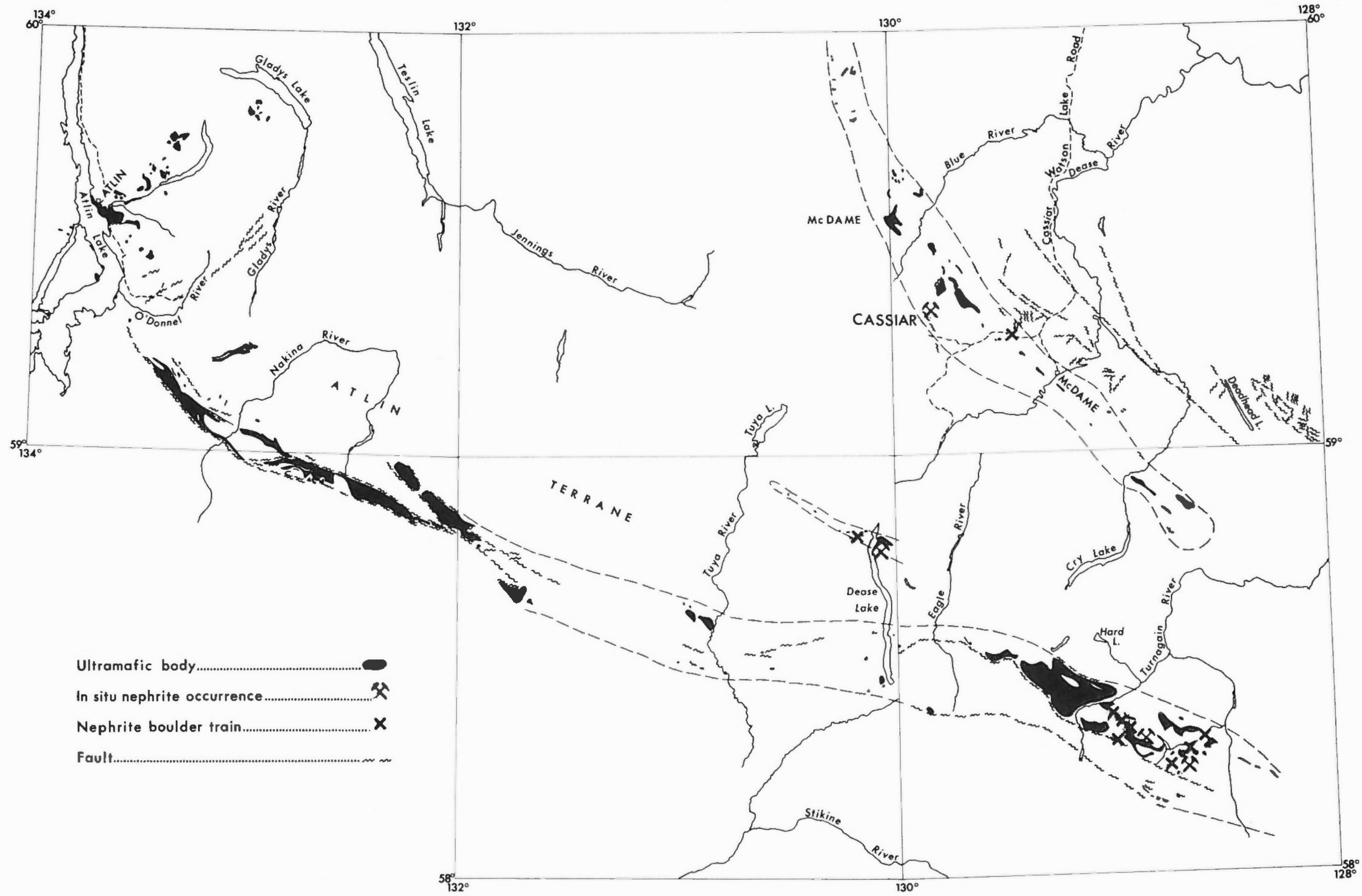


Figure 17. Nephrite deposits in Cassiar segment.

Wheaton Creek

Wheaton Creek, probably from its mouth, but particularly on placer leases 0.8 km upstream from Turnagain River to the upper reaches south of the junction with Alice Shea Creek, is the locale of alluvial deposits consisting of large nephrite boulders (up to 15 tonnes). Intermittent production of cut blocks by various prospectors, has continued since 1965. A traverse up the creek in 1977 revealed many boulders, some of which have been tested by diamond saw cuts and found noncommercial. Many commercial grade boulders have already been removed and total production is unknown. G. Davis who holds mineral leases here estimates that 2000 to 3000 tonnes of nephrite in boulder form lie along the creek from Alice Shea Creek north to Turnagain River. A few boulders were seen by the author along the creek south of Alice Shea. Moreover, alluvial and in situ deposits were seen in the uplands both east and west of Wheaton Creek Valley. Some of the alluvial boulders along Wheaton Creek may have been the result of glacial contact reaction zones in the valley bottom. About 0.4 km south of the confluence with Alice Shea Creek an outcrop of talcy nephrite was tested by sawing. The material appears to be noncommercial but it should be noted that the full extent of this lens has not been delineated and some commercial nephrite might be present. The whole area is largely drift covered.

Plate 13. Production of nephrite from 70-tonne boulder. Mount Ogden GSC 203173-J

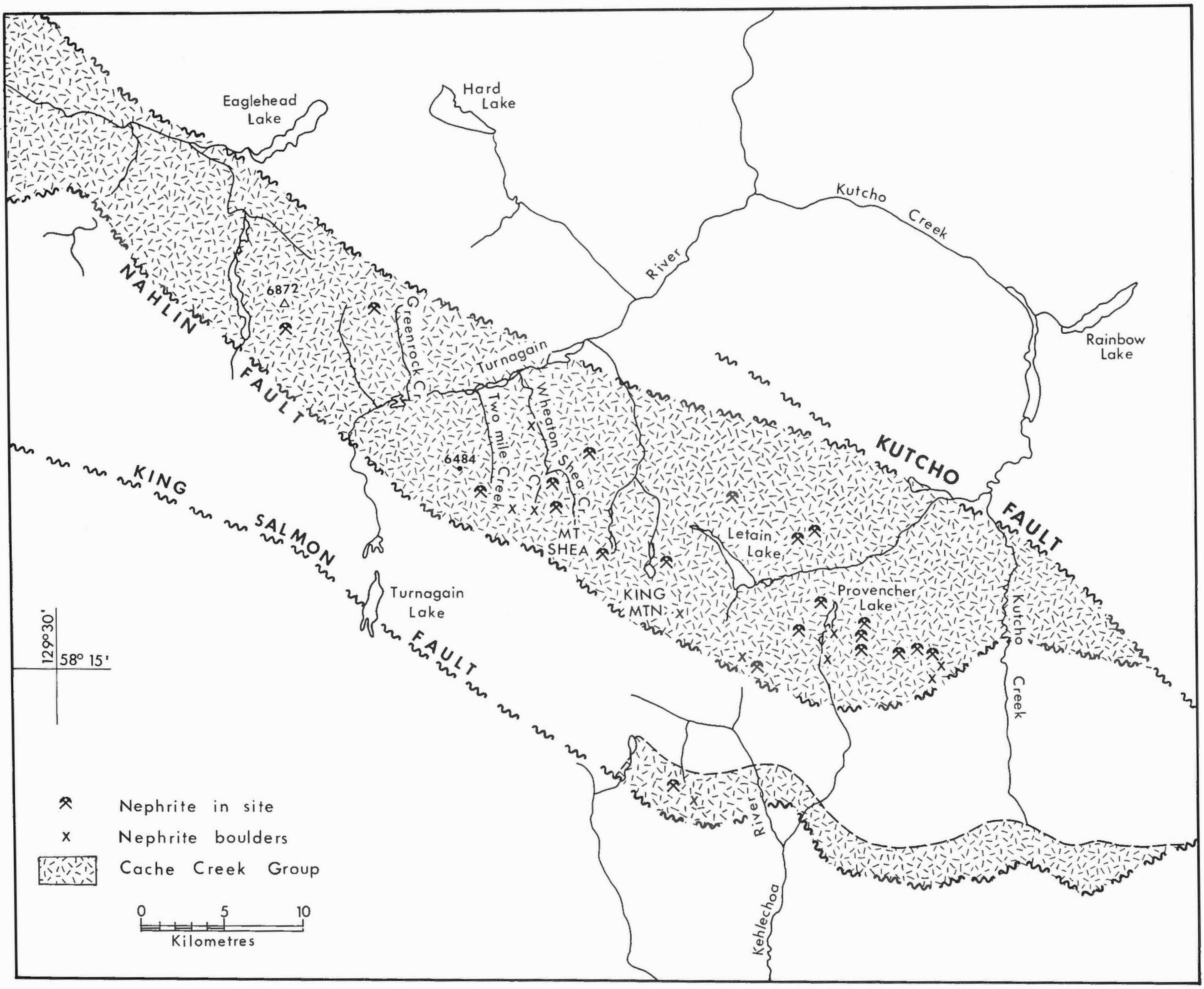


Figure 18. Nephritic deposits in Cry Lake map-area.

King Mountain

Several nephrite veins occur on King Mountain the prominent landmark known in the central part of the Cry Lake map-area. Little commercial nephrite has been produced and most of the deposits do not appear to be commercial because of the schistose structure exhibited to varying degrees.

Nephrite in serpentinite occurs on a long spur extending northeast from the east side of the main mass of the mountain. The deposit was covered by two mineral claims, King Kong 1 and 2.

A lens about 30 m long and 2 m wide is exposed over a vertical height of about 2 m to give a mass of about 100 tonnes. Quality seems to be low because of strong foliation but some commercial material could be present. Nephrite is also associated with a large mass of white quartz which contains diopside and vesuvianite.

Three small lenses also occur in a saddle adjacent to the most westerly peak of the chain of peaks that make up King Mountain. These deposits lie in sheared serpentinites that form small tectonic inclusions. They do not appear to be of commercial grade.

About 0.8 km east of the easternmost peak of King Mountain, a train of nephrite boulders extends in a northerly direction. The boulders are mostly small and probably noncommercial. No nearby in situ deposit was found. The boulders had been discovered and marked by flagging by a prospector but there was no sign of any testing of the material by either core drill or diamond saw.

Provencher Lake

Until 1976 production of nephrite in the Provencher Lake area was entirely from the alluvial deposits along the valley floor adjacent to Provencher Lake. In situ deposits in the adjacent mountains were discovered mainly by Mr. A. Jensen but owing to their difficult location and the greater supply of easily obtained alluvial material in the valley, no attempt has been made to exploit them. Since then, some of these deposits have been commercially exploited.

Nephro-Jade Canada Limited Initial production by Nephro-Jade Limited on leases along Provencher Lake entailed testing of boulders by core drilling. From inspection of these cores, boulders are marked so that those containing commercial grades may be found in the winter when a tractor train comes in from Dease Lake via a winter road that is more or less impassable during the summer. The cost of transportation by this method is about 40 cents a pound. From Dease Lake, the blocks are trucked to Vancouver at a further cost of about 10 cents a pound. In Vancouver the boulders are cut into rectangular blocks, graded, and shipped to markets, mainly in Taiwan.

Many lenses of nephrite have been found in the mountains east of Provencher Lake. Not all are large, commercial deposits; some are only a few tonnes in size and may be sheared and fractured to such an extent that no commercial blocks could be cut from them. Others are large; one lens is about 8 to 10 m wide. Most of the deposits are held as mineral claims by various individuals or companies. Ownership is likely to change hands as deposits are worked out, sold, or prove noncommercial.

A number of claims and leases have been held by Nephro-Jade Canada Limited along the valley of Provencher Lake and in the mountains to the east. Alluvial boulders have been tested by drilling and removed during the winter for the past several years. The company also holds or did hold mineral claims where lenses of nephrite occur in the mountains east of the lake. Some, or all of these claim groups may now be held by others.

Nephrite occurs on a mineral claim in the N.C.W. Group, 3.2 km east of the midpoint of Provencher Lake. There, a contact alteration zone composed of diopside, grossular and chlorite lies between serpentinite and metasediments. The nephrite was seen mainly as talus blocks in an area of much pinkish garnet alteration. In the same place green diopside crystals and pisolitic thomsonite were found in the alteration zone.

An occurrence of nephrite on the X mineral claim lies at the head of the valley which runs southeast from the north end of Provencher Lake. It can be seen from the camp site by looking in a southeast direction just below the skyline. Most of the nephrite occurs as talus blocks. Some in situ bands with contact reaction zone material occurs as small lenses in the serpentine.

Nephrite on the C.W.A. Claims, lying east of the south end of Provencher Lake At this locality, nephrite occurs as lenses along a contact reaction zone between serpentinite on the north and metasediments on the south. The structure can be seen striking easterly for over a thousand feet along the steep cirque wall where it is largely inaccessible, but plainly marked by the light coloured alteration zone. The serpentinite is black and dense near the contact but 25 m north, there is a change in which a band of serpentinized harzburgite forms a 15 m wide band followed by bright green serpentinite. The metasediments are mainly chert or chert argillite. The serpentine visible from the saddle where the nephrite occurs, appears to form the core of an anticlinal fold in the metasediments. Six slabs of talus nephrite on the west-facing slopes range up to about 10 tonnes. The smallest is about one ton. In all about 22 tonnes lie exposed on the slopes, but no doubt more lies further downhill.

This occurrence is in a difficult location and much of the eastern extension may not be economically recoverable due to the precipitous character of the mountain. A specimen of good quality nephrite from this location was compared with standard colours in the Munsell chart. The colour formula was 5GY3/1, thus it is dark greenish yellow.

On the "Jade Claims" one quarter mile west of the north end of Provencher Lake, nephrite occurs as sheared talc-rich lenses in a contact zone between metavolcanics on the south and serpentinized peridotite on the north. The exposure is small and details were not obtained. The nephrite appears to be noncommercial.

King Mountain Jade Four claims held by W. Ellert of Dease Lake under the name King Mountain Jade were staked in 1976 along with places leases on the southeastern side of Provencher Mountains overlooking Kutcho Creek. Six separate occurrences were seen on a visit to the property in 1976.

The first deposit consists of talus blocks and in situ lodes closely clustered in a small area between serpentinite on the west and thin bedded cherty sediments on the east. Total tonnage in 14 separate blocks is estimated to be 240 tonnes. Only one small saw cut had been made at the time of my visit and the proportion of commercial nephrite could not be estimated. None of the contacts could be determined but there did not appear to be any significant contact reaction zone; the nephrite appeared to be a tectonic emplacement of nephrite, stripped from its place of origin (Pl. 14).

A second deposit lies 1800 feet southeast of No. 1 deposit and consists of a nephrite lode 2 to 3 m wide and about 35 m long, lying between serpentinite on the north and cherty sediments on the south. Calculations of minimum dimensions indicated a body of some 1000 tonnes but as this lode was untested, the proportion of commercial nephrite is unknown.

About 120 m west of the second deposit, a block of nephrite stands out on the south slope of the mountain. Calculation of minimum dimensions indicate that a body of some 2000 tonnes of unclassified nephrite may be expected in this deposit. Contacts were not seen but serpentinite outcrops 100 m to the west and greenstone outcrops within 8 m of the south side.

A fourth occurrence of nephrite on the claim group consists of a narrow, 1 m band of nephrite, 15 m long lying about 30 m north of the No. 1 deposit. It seems to lie entirely within serpentinite but contacts were not seen.

In the fifth deposit, a small irregular lode developed with "whiterock" alteration between limestone and serpentinite 90 m northwest of No. 1 deposit. The nephrite is sheared and talcose and noncommerical in the visible part but the full extent of the lode could not be determined due to snow cover.

Lastly, the property contains a nodular or botryoidal occurrence of noncommercial nephrite 180 m southeast of No. 1 deposit.

Cry Lake Jade Mines Limited This company holds mineral claims covering several lodes and colluvial blocks of nephrite derived from these lodes in the Provencher Mountains east of Provencher Lake. In 1976 employees were core drilling some of these blocks (Pl. 5B). Subsequently 39 tonnes were removed from the property and sold.

The main lode consists of a lens of nephrite exposed across a width of 8 to 10 m, 20 m along the strike length and exposed through a vertical distance of about 10 m. These dimensions indicate a body of at least 2500 tonnes, and possibly closer to 4000 tonnes or even more. Although nothing can be said about the quality much of the deposit will no doubt be of noncommercial grade. A deposit of this size presents some mining problems. It is not possible to use circular diamond blades of the usual size. Cry Lake Jade Mining began mining by extracting large blocks by the use of hydraulic wedges along natural fractures in drillholes. The method worked, but was slow. Later in the season, explosives were used in an attempt to speed up production. This practice is considered by most jade producers to be unacceptable because it may produce extensive fractures in the material rendering it unfit for commercial use. The operators of the Cry Lake property however believe that light charges may be used and any damage is compensated for by increased production.

Plate 14. In situ nephrite on property of King Mountain Jade. GSC 203173-G

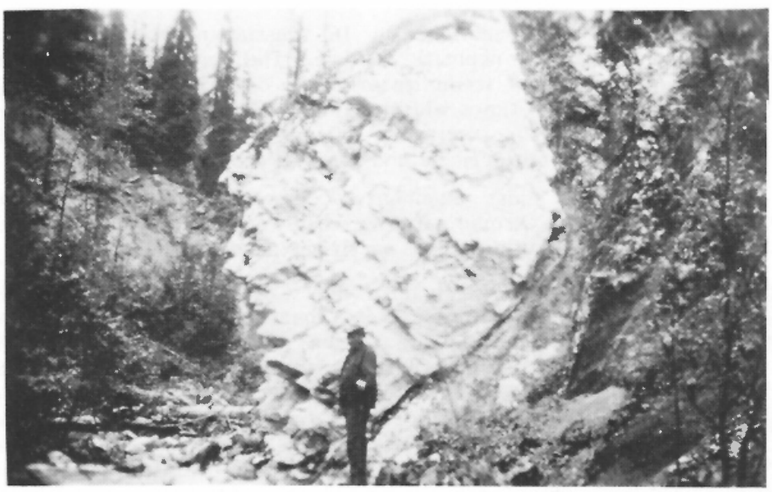


Plate 15. Delure Creek "whiterock" in fault contact with serpentinite. GSC 203173-E

The large blocks produced on this property by wedging and explosives are taken to an airstrip in the valley of Kutcho Creek where the blocks are further reduced and flown to Dease Lake airport for trans-shipment by truck to Vancouver for grading and sale.

In 1976 the adjoining property of King Mountain Jade was leased with the objective of securing a further source of supply of nephrite.

Overton claims Nephrite in talus blocks and in place in an area covered by mineral claims were seen in a small serpentinite mass 4 miles south of Letain Lake. In all about 100 tonnes in talus blocks ranging in size from 3 to 30 tonnes. The property has not been adequately tested, consequently no estimate of the percentage of commercial grade can be determined.

There is a small contact reaction zone on an upland near the blocks in which some low grade nephrite occurs in place but presumably few of the talus blocks were derived from this zone. This deposit is held by mineral claims registered in the name of Gene Overton of Cassiar, B.C.

Kehlechoa River Area

A small belt of serpentinite pods extends across the head of Kehlechoa River. On one of these pods, about 14 km south of King Mountain, a narrow contact reaction zone in serpentinite contains nephrite of good quality but not in great quantity. About 1.5 km east of this deposit, alluvial boulders ranging in size from one to twenty tonnes were found by the author in 1977. Eight of these boulders, aggregating about 60 tonnes were judged to contain some commercial grades but because they are untested by drill or saw no estimate of the percentage can be stated.

Dease Lake Area

Nephrite deposits, both alluvial and in place have been found near the north end of Dease Lake. Alluvial boulders occur along Thibert and Delure creeks on the west side of the lake, and along Seywerd Creek.

Serpentinite occurs along and adjacent to the Thibert Creek fault. Small nephrite boulders of 100 to 200 km were seen along Delure Creek by the author. One tectonically emplaced mass of rodingite (Pl. 15) was found in the canyon along Delure Creek near the confluence with Thibert Creek. Although no nephrite was seen in place the traverse through the canyon was not completed.

Alluvial nephrite along Seywerd Creek at Sawmill point at the north end of Dease Lake was traced to a bedrock source south of Seywerd Creek about 0.4 km east of the Stewart-Cassiar Highway. The in situ deposit was found in 1965 by Mr. Ben Seywerd but has not been extensively worked because of the ready availability of alluvial material nearby. The nephrite lode lies between cherty sediments of the Cache Creek Group and serpentinite (Fig. 19). The lode is cut off by a vertical fault at the northwest end of the exposure but the extension in the opposite direction is open, although largely concealed by overburden. The deposit has been worked by wedging off blocks between diamond saw cuts so that a pit about 1 m deep has been excavated in the best parts.

McDame Area

A belt of serpentinite lying in Sylvester Group rocks runs from Cry Lake to McDame and continues beyond to the Yukon border. In this belt, nephrite occurs in the Cassiar Asbestos Mine. It is unlikely that this is the only occurrence in this belt. The serpentinites in the Blue River area northwest of Cassiar are considered worthy of further prospecting because of the contact reaction zones known to exist there (Wolfe, 1965).

Nephrite lenses occur in the open pit of Cassiar Asbestos Mine. Many tonnes of nephrite were extracted during mining operations and hauled to the waste dump before it was identified by Mr. Clancy Hubbell. Due to his efforts about 300 tonnes were salvaged and stockpiled at the mill site. Most of the material has now been sold. Future mining may uncover more nephrite and no doubt much of this will be salvaged.

The nephrite occurs with a "whiterock" alteration zone between the hanging wall argillite and greenstone of the Sylvester Group of Late Devonian – Early Mississippian age and serpentinite intrusive into these rocks. At least 20 "whiterock" bodies were noted in the mine and probably nephrite was associated with more than one of these, but passed unnoticed in previous mining. The origin of "whiterock" bodies is regarded by Gabrielse (1963) as a metasomatic alteration of diabasic dykes which were at the same time ruptured and dislocated during the tectonic emplacement of the serpentinite. The mineral content of the "whiterock" bodies is varied; garnet (grossularite or hydrogrossular) is dominant but albite, prehnite, zoisite, ilmenite, sphene and vesuvianite may be present in varying amounts.

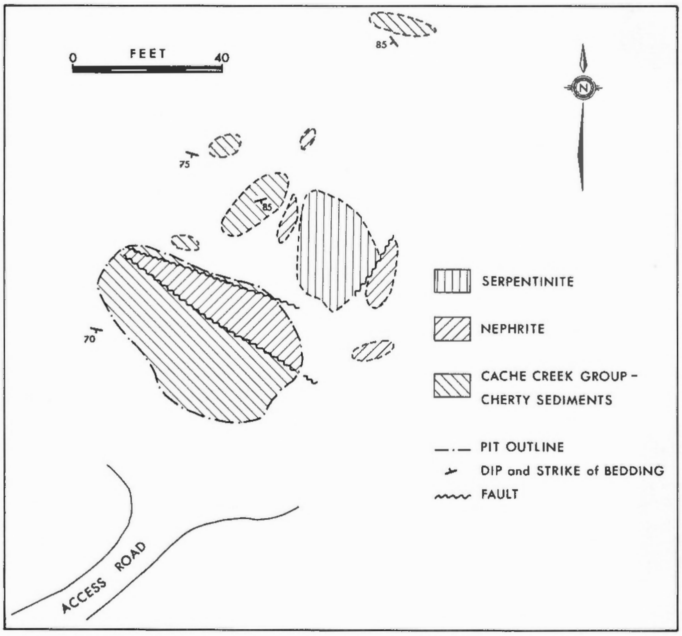


Figure 19. Seyward Creek nephrite deposit, Dease Lake.

Many of the dyke-like bodies are entirely within serpentinite, and show evidence of magmatic intrusion with chilled borders and relict ophitic textures. The alteration zone, which is known to have yielded nephrite, lies between serpentinite and the overlying argillites and it appears to be a contact reaction zone between these two rock types. However, it could also be considered an alteration of a diabase dyke intruded between serpentinite and argillite.

Gabrielse noted true contact reaction zones between serpentinite and greenstone with gradational contacts along the upper contact of the ultramafic body at Cassiar. In this zone tremolite, vesuvianite, pyroxene, zoisite and talc are present. It seems likely that some of the contact reaction zones have become detached from their place of origin and moved into new locations. Nephrite from Cassiar Mine is atypical compared to nephrite from other British Columbia deposits. There is a noticeable abundance of chrome garnet in specks, blocks and irregular patches which make up to 5 per cent of the volume of some specimens. The matrix is commonly darker green than most specimens from elsewhere in British Columbia but the presence of much chrome garnet can mask this aspect. Five specimens matched to Munsell colour chips gave the following values; 5 GY 4/4, 10 GY 4/4, 10 GY 3/4, 10 GY 2/2 and 10 GY 2/1.

In thin section (Pl. 16) Cassiar nephrite shows the characteristic nephritic texture. The bundles and groups of microfibres of tremolite exhibit a disparity of size, varying from (length times width) .018 by .007 mm to .034 to .016 as determined by counts on 100 groups in each of two slides representing the finest and coarsest grained specimens.

The most abundant accessory mineral in Cassiar nephrite is chrome garnet (possibly uvarovite). It occurs as ragged anhedral patches partly replaced by chlorite (Pl. 3A).

Much of the Cassiar nephrite is highly fractured. It is a matter of debate how much of this is due to the mining operation in which heavy explosive charges are used, and how much is natural. Some specimens collected at the mine show sets of curved fracture planes clearly indicative of tectonic origin. Most specimens show some foliation due to preferred orientation of the component microfibre groups. Cassiar nephrite is somewhat atypical in fracture which is more even than the hackly or splintery fracture of other occurrences in British Columbia.

As has been already noted, the nephrite is chemically distinguishable from other Canadian nephrite. The higher chromium content is a reflection of the high chrome garnet; chromite is only a minor component in three thin sections.

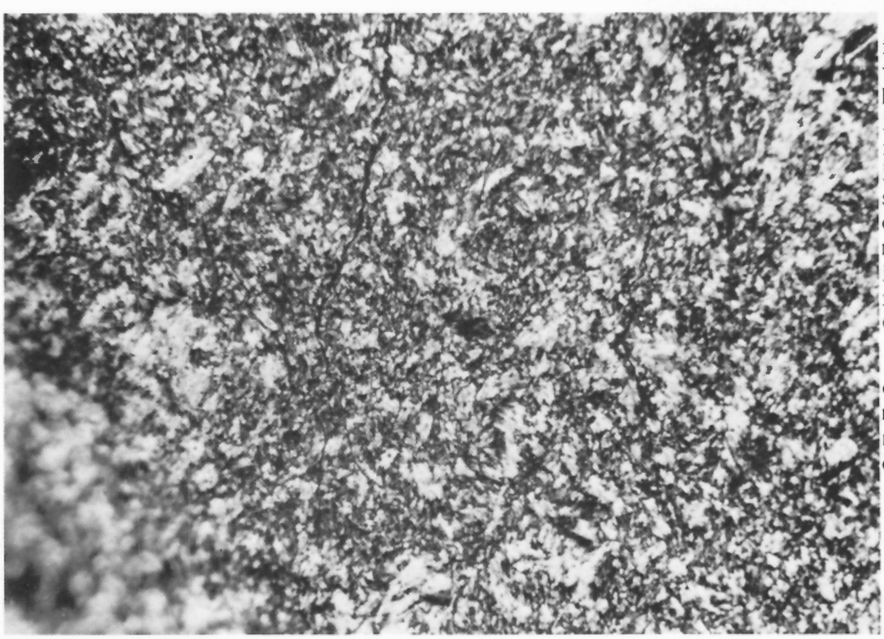


Plate 16. Photomicrograph of fine grained variety of Cassiar nephrite. x 63 crossed nicols GSC 202783-H

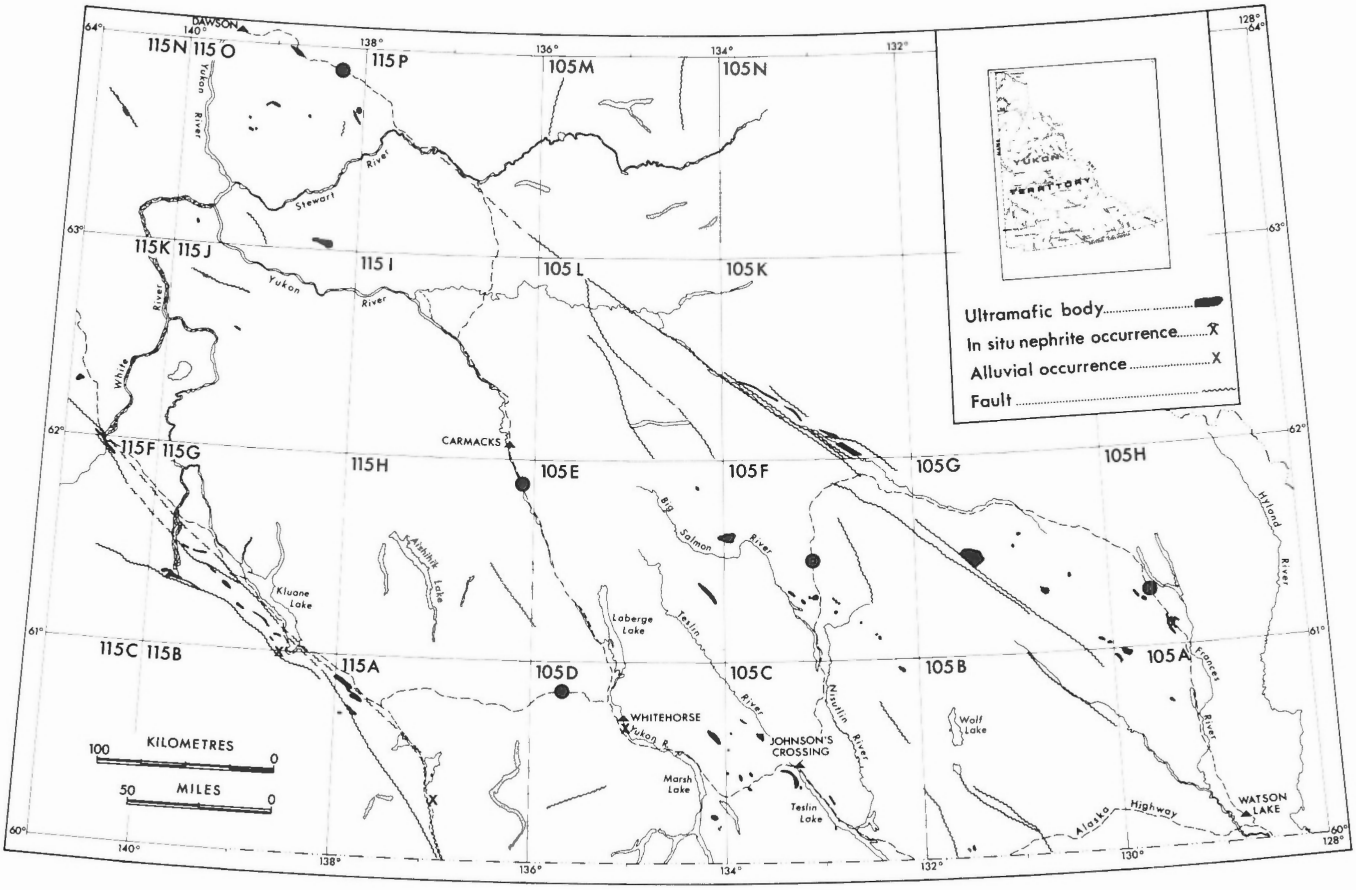


Figure 20. Yukon ultramafic intrusions.

Yukon Territory

Few nephrite occurrences have been reported from the Yukon Territory in spite of geological conditions similar to those in adjacent British Columbia. Two locations in Frances Lake map-area (105 H) contain in situ deposits and talus blocks but there are no known placer deposits. A few alluvial boulders have been found in the Yukon River near Whitehorse. Reports of nephrite from Klukshu Mountain near the Haines road are probably authentic and likely represent very minor in situ occurrences. A nephrite pebble in the Bishop collection at the Metropolitan Museum in New York City is said to have come from Sulphur Creek in the Klondike gold fields. Reports of alluvial nephrite near Kluane Lake have not been substantiated. These few examples seem to be all that is known of Yukon nephrite occurrences and except for the Frances Lake deposits, all seem to be insignificant.

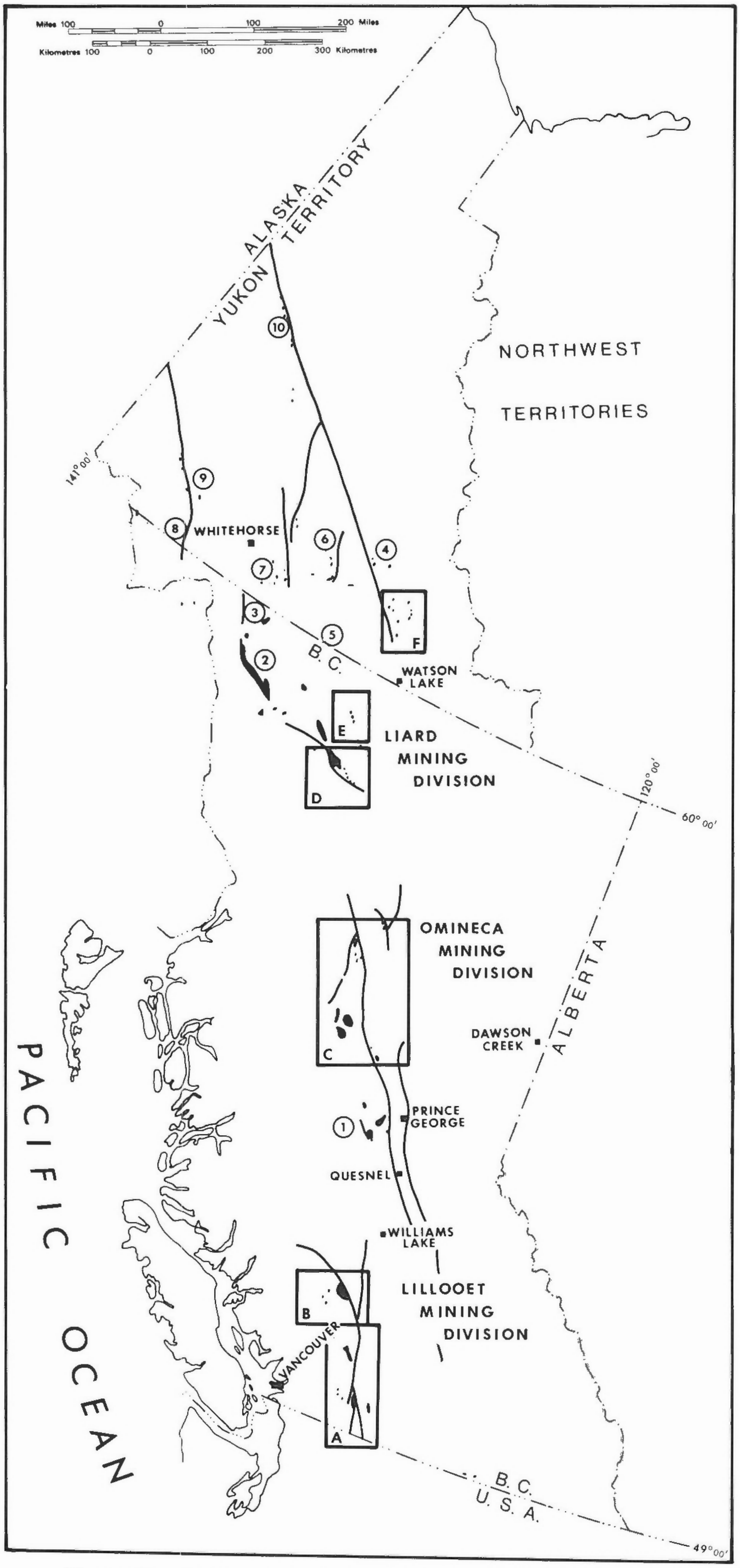
The estimate of possible reserves in the Yukon (Fig. 21) accounts for only 6.2 per cent of the total Cordilleran reserve. Probable reserves amount to only 2 per cent. Perhaps these figures are too low but from a study of Geological Survey reports on the geology of the Yukon, there is no reason to assume that these figures could be significantly increased. The discovery of one or two major deposits, however, would do much to change these estimates. Prospecting is recommended in the more favourable parts of the Yukon although the Cassiar segment of the Cordilleran nephrite belt appears to be a better place to look for nephrite.

Frances Lake Map-Area

In situ nephrite deposits were found by Earl Sowden in the mountains west of Mile 84 on the Campbell Highway in Frances Lake map-area (105 H). The serpentinites with which the deposits are associated are clearly visible from the highway. In the area, Mississippian and Devonian sediments are intruded by serpentinites in narrow bands parallel with the regional strike and conformable with the bedding planes, i.e. they are sill-like bodies.

Five "whiterock" bodies or contact reaction zones were seen within the serpentinites or near the serpentinite-sediment contact. One of these "whiterock" or rodingite bodies is a thick sill 1.5 m wide striking N30°W and dipping 25° northeast. The southeast end is dissected and parts are dispersed throughout the serpentine. On one of these parts an irregular nephrite lens has formed. The nephrite is schistose and largely noncommercial. Some of the "whiterock" zones lack nephrite. The "whiterock" is mainly diopside and hydrogarnet with brownish opaque patches of sphene and spinel. A chemical analysis of the nephrite (Table 3) shows similarity with most nephrite and is noteworthy only in the amount of TiO_2 which is about twice the average or normal amount found in other Canadian nephrite.

A few tonnes of nephrite have been removed by helicopter from the property. Attempts to put in a road were thwarted by permafrost which turned roads into a quagmire of mud and water. According to Karl Ebner, an associate of Earl Sowden, a 90 tonne boulder was found on the property.



	AREA	TONNES Proved	Prob.	Poss.
A	FRASER	—	200	500
B	YALAKOM	—	1,000	2,000
C	OMINECA	—	2,000	10,000
D	CRY LAKE	100	20,000	50,000
E	CASSIAR	—	1,000	10,000
F	FRANCES	—	500	1,500
	TOTALS	100	24,700	74,000

ADDITIONAL POSSIBILITIES FROM ULTRAMAFIC BODIES WITH NO KNOWN OCCURRENCES

(1)	Prince George			300
(2)	Nahlin ultramafic body			700
(3)	Atlin			500
(4)	Pelly mountain			1,000
(5)	Teslin			500
(6)	Quiet lake			500
(7)	Whitehorse			200
(8)	Dezadeash			500
(9)	Kluane a			500
(10)	Dawson			200
	TOTALS			4,900
	GRAND TOTALS	100	24,700	78,900
	COMMERCIAL GRADES	100	2,470	7,890

Inventory of Nephrite in storage at Vancouver, Chilliwack and Lillooet, probably 400 tons; Dec.1, 1976

Fault

Ultramafic bodies

A — Areas with known occurrences

(1) — Areas with no known occurrences but where discovery may be postulated from favourable geological indications.

Figure 21. Preliminary estimates of nephrite reserves in Canadian Cordillera; British Columbia and Yukon.

Probable reserves are placed at 500 tonnes and possible reserves may be three times this. The quality of this nephrite is usually low but some good material has been found. Production has been sporadic since 1970. In 1976 Leox Jade took an option on the property.

Klukshu Lake Area

Kindle (1952) reported the presence of apple-green jade on the slopes of the mountain east of Klukshu Lake close to the Haines Road about 58 km south of Haines Junction. The location is shown on Figure 20. According to Kindle the specimens were thought to be nephrite but no petrographic data were given. The writer spent two days in the area searching for sources of specimens or additional specimens of the alluvial material but none were found. The area is underlain by schist, gneiss, amphibolite and limestone of the Yukon Group. There is no serpentinite in the vicinity. The formation of the nephrite, if indeed it is authentic, must be considered to have been a metamorphic reaction in which magnesian limestones were converted into amphibolites in the manner described by Nicol for Australian nephrite. This would be the only metamorphic nephrite that has been found so far in Canada.

The area is readily accessible from the Haines road which passes just south of the south end of Klukshu Lake. The favourable prospecting ground lies near the 1200 m contour due east of the south end of the lake. Outcrops are concealed near the lower slopes of the mountain by deep overburden but there are enough exposures to warrant a careful search for more alluvial and in situ deposits which may be present.

Potential Nephrite Areas in the Yukon Territory

Figure 20 shows the location of most of the major ultramafic bodies in Yukon Territory some of which may be expected to contain nephrite deposits. In certain areas the serpentinites have small contact reaction zones and specimens of alluvial nephrite indicate a nearby bedrock source. Most of the alluvial occurrences, however, are represented by only a few small pebbles or boulders indicating extensive transport. Study of reports on Yukon geology, mainly from Geological Survey of Canada publications, suggests that the number and size of nephrite deposits in the Yukon is likely to be significantly less than those from British Columbia. Perhaps detailed mapping of serpentinite bodies will reveal more contact reaction zones in Yukon ultramafic areas. The following notes on the map-areas making up the southern half of the Yukon summarizes the potential for nephrite discovery in terms of serpentinization, contact reaction zone development and the presence of alluvial or in situ deposits.

In the Watson Lake map-area (105 A) a few outcrops of steatized peridotite, serpentinite, gabbro and pyroxenite are shown on Map 19-1966 (Gabrielse, 1967). Most lie within areas of Mississippian rock but one outcrop is shown in an area with Hadrynian sediments. According to Gabrielse (pers. comm., 1976) these ultramafic rocks do not include many highly serpentinized members and the probability of finding contact zones is low. Recent work by Tempelman-Kluit (1977) has shown that the large ultramafic bodies in the northwestern part of the map-area are parts of an allochthonous sheet.

Ultramafic rocks in Wolf Lake map-area (105 B) are not extensive. Three outcrops of ultramafic rocks shown in the southwest corner of Map 10-1960 (Poole et al., 1960) are described in the legend as olivine-bearing pyroxenite dunite and serpentized and metamorphosed equivalents. These rocks are cut by Jurassic and Cretaceous intrusives but are not otherwise dated. They are not part of a recognizable belt but occur as isolated blocks in Devonian-Mississippian meta-sediments. Nothing is known of their relationship with the invaded rocks viz. whether or not any contact reaction zones have developed or how much serpentinization has occurred. The possibility of finding nephrite here is low.

In Teslin map-area (105 C), twenty outcrops of peridotite, pyroxenite and serpentinite are shown on Map 1125A (Mulligan, 1963) but many more, too small to be mapped on this scale, are known. Serpentinization is extensive, parts of all bodies and all of some are serpentinized but no mention is made of contact reaction zones. Thus it is assumed that these are rare or absent and accordingly the possibility of nephrite development is likewise rare or absent.

Serpentinized ultramafic rocks in Quiet Lake map-area lie in a belt running diagonally through the southern half of the map-area. A number of outcrops near Tower Peak were examined and although there are some contact reaction zones with development of talc, no nephrite was found. However, the examination was too brief to evaluate the possibilities of finding nephrite. The area is one of the more favourable and further search is recommended.

A number of outcrops of ultramafic bodies and their serpentinized equivalents lie north of the Tintina Trench in Finlayson map-area. Some have contact reaction zones but no nephrite has been reported nor was any found during a brief search made in 1976. However the possibilities for the discovery of nephrite appear moderately high.

A few outcrops of serpentinized ultramafic rocks occur in the Snag map-area but brief descriptions by Tempelman-Kluit (1974) do not report any contact reaction zones. That fact, together with the dearth of outcrops suggests that the possibilities for nephrite discoveries here is very low.

The pebble of nephrite reported to have come from Sulphur Creek near Dawson and now in the Bishop collection in the Metropolitan Museum of Art in New York City, lends support to the postulate that in situ nephrite deposits may be associated with the ultramafic bodies in the vicinity. The nearest ultramafic body to Sulphur Creek lies along the valley of Indian River about 8 km to the south. It seems unlikely that it could contribute alluvium to Sulphur Creek.

A single pebble cannot be considered conclusive proof that the source is nearby unless more and eventually larger specimens can be found. A single pebble may be an artifact lost by the owner.

Three outcrops of serpentinite along the eastern margin of Laberge map-area are briefly described by Bostock and Lees (1938). No mention is made of contact reaction zones and little can be stated in regard to the possibility of nephrite occurrence. It seems unlikely that any obvious alteration zone would be disregarded and therefore it is assumed that none was seen. If this is so, then the possibilities of nephrite occurrences must be very low.

Ultramafic bodies including peridotite, dunite, serpentinite and pyroxenite occur in five parts of the Whitehorse map-area. Alteration is mainly steatitization but one contact reaction zone of the rodingite type was seen in serpentinite west of Lake Laberge (Wheeler, 1961). No in situ serpentinite is known in the vicinity of Miles Canyon where alluvial nephrite has been reported. Direction of ice movement suggests that the ultramafic bodies on Jubilee Mountain may have contributed alluvial debris to the channel now occupied by Marsh Lake and Yukon River where glaciofluvial action may have moved the nephrite boulders to the Miles Canyon area. This is highly speculative but suggests that the ultramafic bodies on Jubilee Mountain should be carefully prospected in view of Wheeler's statement that these rocks are steatitized and converted to rocks containing abundant tremolite.

Kindle (1952) noted several bodies of peridotite, dunite and serpentized equivalents in the Dezadeash map-area. Most are unserpentinized but the mass of ultramafic rock along the mountain front between Jarvis and Dezadeash rivers contains all gradations from dark peridotite to green serpentinite. No mention is made of contact reaction zones and it seems likely that they are rare if not absent. The map-area contains the Klukshu occurrence of metamorphic nephrite so the area is interesting even if the possibilities are not great.

Northwest Territories

Nephrite artifacts have been found over much of the Arctic Coast and on the Arctics Islands. Workshop activity is absent, however, and as only one in situ occurrence is known it seems that most if not all the nephrite artifacts were trade goods or family heirlooms brought from an original culture probably in Alaska.

The reference to the one in situ occurrence is brief and unsupported by any mineralogical data and there does not seem to be any corroboration of the occurrence by later explorers. Sir John Richardson (1851) wrote ..."At a cascade in Rae River, ten miles above its mouth, walls from eight to twenty feet high of bluish-grey quartz rock, layers of asparagus stone or apatite, thin beds of soapstone and some nephrite or jade – a group of minerals which belong to primitive formations".

This occurrence may be authentic, but in view of the state of science in those days and the lack of documentation it may be best considered an unconfirmed locality.

Other Provinces

There are few references to the occurrence of nephrite in eastern Canada in spite of some possibilities of contact reaction zones in serpentinites in Ontario and Quebec. Greenlee (1962) claimed that jade (nephrite) had been found on the northern shore of Lake Huron near Kettle Point, Ontario. The pebbles were confirmed as nephrite by members of the Cranbrook Institute of Science. The evidence offered however did not seem conclusive as a petrographic description was not given.

Of considerable interest is the paper by Phillips and Hess (1936) in which a contact reaction zone between serpentine and phyllite at the Federal Mine in the Thetford Asbestos district of Quebec is described. In it, the development of talc, actinolite and chlorite is characteristic of the contact reaction phenomenon and although nephrite was not mentioned, the authors were aware of the possibility of its development in this environment.

Of interest too, is the analysis given by Maxwell et al. (1958) for jadeite, from the Bell pit at Thetford Mines, Quebec. The analysis clearly shows that the specimen cannot be jadeite:

SiO_2	57.82
Fe_t	4.42
MgO	21.60
CaO	14.55
H_2O	1.10

It is close to the usual analysis for tremolite. The accompanying description ..."a fine-grained light grey material like chert occurring over a width of one inch to two inches along the edge of a feldspathic dyke some 5 or 6 feet thick which intrudes the serpentine ..." is highly suggestive of a metasomatically altered and albitized gabbro dyke with minor development of nephrite.

Cooke (1950) noted the alteration of serpentinized ultramafic rocks to talcified tremolite in the Eastern Townships of Quebec.

The possibility of finding nephrite occurrences among the many serpentinite bodies in Eastern Canada should not be discounted before a complete search has taken place. The material is not as rare as commonly believed, but deposits may be small and easily overlooked.

ECONOMICS OF THE CANADIAN NEPHRITE INDUSTRY

The price of nephrite in 1977 varied from less than 50 cents to more than $40.00 per pound depending on the quality and the amount purchased in a single sale. Most companies sell on a sliding scale depending on the quantity purchased. This is illustrated by the following 1976 wholesale price list of one company in British Columbia.

'A' Grade	Price per pound ($)
Up to 600 lb.	15.00
600 - 2200 lb.	12.75
2200 - 11,000 lb.	10.00
over 11,000 lb.	9.10
'B' Grade	
Up to 600 lb.	8.20
600 - 2200 lb.	6.40
2200 - 11,000 lb.	5.00
11,000 - 22,000 lb.	4.55
22,000 - 44,000 lb.	4.10
over 44,000 lb.	3.90
'C' Grade	
Up to 11,000 lb.	2.75
11,000 - 22,000 lb.	2.50
over 22,000 lb.	2.30

These are asking prices and may not be firm for the gross value of 100 tons of B grade at $3.90 per pound amounts to $780,000. Such a sum allows considerable room for negotiation.

The domestic market for nephrite is very small, and although statistics are not available, the total annual sales to rockhounds, carvers and collectors is probably only a few tons. Consequently the existence of a nephrite industry depends on the demands of foreign buyers.

The world demand for nephrite in 1977 may be about 800 tons distributed as follows:

500 tons - Taiwan
200 tons - People's Republic of China
50 tons - Hong Kong
12-15 tons - Germany
2 tons - New Zealand
10 tons - United States of America

This estimate of demand is not the same as the consumption, for it is likely that the supply has fallen short of the demand for some time, especially for the better grades.

Production comes from Canada, Alaska, Taiwan, Russia, Australia and although no statistics are available it is estimated that the production may be as little as 50 per cent of the demand.

There are many tonnes of low quality nephrite available, but high quality material is apparently scarce. Buyers from Taiwan often cannot find suitable material from Canadian sources, and presumably from other countries as well. It might be thought that this scarcity would cause a great increase in price.

Although jade jewellery and carvings are prized and may be expensive to buy in some forms and styles, most of the inexpensive tourist or souvenir type ornaments do not have a great intrinsic value so there is a limit on the selling price which in turn limits the cost of the raw materials. Except for inflationary increases, the cost of nephrite ($4.00 to $8.00) is probably now at a peak in terms of today's costs of production. In considering the profitability of a nephrite industry, therefore, the maximum wholesale price may be considered to be $8.00 or $10.00 a pound. Retail prices may be as high as $40.00 a pound, or higher if sold by slabs or small cut blocks of the finest quality. Commonly producers sell at both retail and wholesale levels and prices are apt to be extremely variable depending on quality and quantity purchased.

The profitability of a nephrite industry depends mainly on the size and quality of the deposit. The costs of exploration, testing and transportation are generally less than one half the gross wholesale value of the nephrite. Thus the cost of production is not likely to be a factor in the success of a venture unless the amount of nephrite found amounts to only a few hundred pounds.

Appraisal of the quality of boulders, talus blocks or outcrops is made using a diamond drill or saw. The diamond drill provides a solid core which may be inspected or otherwise tested for quality. This core is relatively small, however, and may pass through the only good part of a boulder, and hence an exaggeration in gross value may occur. In large boulders more than one hole is necessary to give a fair estimate of quality for the whole boulder. Drilling with diamond-drill core bits is slow and many drillers consider 1.5 m in an 8-hour period is a good average. Improved technique may double the amount. The practice of using portable drills with X-ray bits (3/4 inch) with or without extra pressure but using a lever technique commonly polishes the diamonds so they no longer cut effectively after about 1.5 m. The diamonds are not otherwise harmed and may be recovered and reset in new bases for a relatively small cost. Thus a bit costing $60.00, may be returned to the manufacturer for a credit of about $40.00. In general bit costs might be considered to be a maximum of $5.00 per foot of core. If the 5-foot core is considered to sample 5 cubic feet, then bit costs amount to only $0.02 a pound. Wages for a driller are probably $50.00 with an equal amount for camp costs, so that drilling costs might then be averaged at $0.25-0.30 a pound. Sawing costs by custom sawing in Vancouver using a combination of a wire saw and circular diamond saws to reduce large boulders (in excess of 20 tons) to suitable sizes for export, can be done for $0.30-$0.45 per pound. In the field, sawing costs are higher but this is partly offset by lower transportation charges as only commercial grades will be removed from the property.

Transportation costs are variable from as little as $0.05 per pound to perhaps $0.60 per pound. The lowest costs are provided by truck and low-bed trailer units hauling a minimum of 20 tons. Loads from Dease Lake to Vancouver may be transported for less than 10 cents a pound.

'Cat' trains, consisting of several crawler tractors with trailers, have been used to haul large boulders out of the Provencher Lake area to Dease Lake at a cost of about 50 cents per pound. This is the only way very large boulders can be brought out of remote locations. The method is slow and because it is best done under winter conditions, extra equipment is needed there by adding to the cost.

While 50 cents a pound is not an unreasonable cost, this applies to all the material removed from the property. If only half can be sold, the cost per pound is effectively doubled. It is therefore important that the boulders or blocks be tested to such an extent, that transportation of noncommercial material is kept as low as possible.

Air freighting can be done at reasonable costs of $0.10 per pound or less on contracts of 80 to 100 tons using Twin Otter or equivalent aircraft. The use of aircraft necessitates cutting the nephrite into blocks suitable for manual loading.

Helicopters have been used in a few places to sling out blocks from the site of production in high mountains to a road in the nearby valley. Costs can be as low as 5 cents a pound if optimum quantities are available and if high ferrying charges can be eliminated or spread over large quantities. High capacity helicopters may be an economically feasible means of transportation over longer distances provided that only commercial grades are carried.

Estimate of costs shows that in most cases, production costs may be less than $1.50 a pound consisting of:

	($)
Discovery cost	0.05
Testing	0.30
Sawing	0.50
Transportation	0.60
	$1.45

Production costs therefore are relatively unimportant in the nephrite industry because most good quality nephrite sells for more than $4.00 a pound and may be closer to $8.00.

Before 1970 most nephrite in British Columbia was obtained from alluvial deposits in which boulders of a few hundred pounds to a few tons were found and cut on the spot, or in some cases removed to the finders premises for further reduction and sale. With the depletion of many alluvial deposits, the search for in situ occurrences has been rewarded by the discovery of many deposits which required more effort and expense to exploit. A quarrying technique is required to loosen blocks from the lode and place them in position for further sawing or removal. The removal of nephrite from its places of origin is commonly a matter of digging away the serpentine usually found on one contact at least, and loosening the naturally fractured blocks into the space provided by the removal of the serpentine. As some blocks are large, a large crawler tractor is commonly employed. Operating costs for these machines run to $60-$80 an hour, but for most in situ deposits they are almost indispensable. Operating costs in terms of dollars per pound may vary from $0.10 to $1.00 a pound but based on 50-ton production over a 3-month season using a 'cat' at $60 an hour, costs of about 50 cents a pound may be calculated. These costs may be added to the production costs of alluvial boulders to give a total production cost of about $2.00 for in situ nephrite.

Mining nephrite is sometimes expedited by blasting. This may, and probably always does harm by producing fractures in the nephrite. Some claim that the use of small charges of dynamite along natural fractures, or in drillholes spaced along them or in the wall rocks adjacent to the nephrite is acceptable even if some nephrite may be ruined for commercial purposes, the increased efficiency justifies the practice. Most producers insist that the use of explosives is detrimental. It may be that the blasting merely open incipient fractures, and would have little effect on sound nephrite, but it seems likely that the risk is not worth taking and the use of explosives should be restricted to large bodies which cannot be mined by conventional sawing.

Wire sawing has been used on one property in British Columbia but mechanical difficulties with this system have discouraged wider use. Attempts to mine nephrite on a large scale is unlikely to be very successful because of the high percentage of non-commercial grades in most deposits, and because of their small size. The high operating costs attending exploitation in remote parts of British Columbia has already defeated several attempts by mining companies to establish successful ventures.

In spite of this jade mining can be a successful operation for two or three compatible persons who are prepared to work hard during a short season testing boulders or outcrops and sawing the product into manageable blocks of commercial grade on the property. The production of only a few tonnes could be used to sustain a retail business for the balance of the year by selling small quantities at premium prices, or it would be sold in a single wholesale transaction at a lower price.

PRODUCTION OF NEPHRITE IN CANADA

Production of nephrite in Canada is largely from British Columbia; only a few tonnes have come from the Yukon Territory.

Table 5 lists the production from the three mining divisions from which all provincial production has come. The latest figures at the time of writing (late 1977) are for 1975. Unofficial estimates for the following years are believed to be reliable but are probably low. The figures clearly show the large increase in production that began in 1970 with the discoveries of nephrite in Omineca and Cassiar Mining divisions. The Cry Lake area of British Columbia contains some large in situ deposits as well as numerous smaller ones and their associated alluvial or colluvial deposits, so that continued production at a rate of several hundred tonnes a year is possible if the grade of these deposits proves to be high enough.

RESERVES OF NEPHRITE IN CANADA

The estimate of reserves of nephrite in Canada is essentially that of the total quantity of all commercial grades of nephrite likely to be found in British Columbia and the Yukon Territory (Fig. 21).

In common with estimates of reserves of other mineral commodities a three-fold classification is used to indicate the degree of uncertainty of the estimates.

(1) Proved reserves are those which have been measured to establish quantity and have been sufficiently sampled by sawing or drilling sufficiently to preclude noncommercial material being included in the estimate. Proved reserves are small because they are mainly included in producers stockpiles and are soon sold.

(2) Probable reserves include those boulders, talus blocks and in situ occurrences which can be measured for volume but which have not been sampled sufficiently to determine the percentage of commercial nephrite beyond that empirically derived from experience in the field. Probable reserves are generally large compared to proved reserves. They may include those extensions of known deposits in which the volume of material may be equal to or as much as two or three times greater than the visible part.

(3) Possible reserves include undiscovered deposits which may be reasonably expected in geologically favourable areas, viz. alpine ultramafic rocks showing contact reaction zones and perhaps some alluvial nephrite nearby. This category is subject to large error as both the quantity and quality are unknown. Possible reserves should not be considered as part of the assets of a nephrite property.

The estimates shown in Figure 21 are based on the author's personal knowledge of nearly all of the known deposits, the mode of occurrence and genesis of nephrite and a survey of the literature on Canadian occurrences of ultramafic rocks with contact reaction zones. The estimates are considered to be of the right order of magnitude and somewhat conservative.

The 10 per cent factor used to assign commercial quantities to the total quantity is arbitrary and may be optimistic; it may be low in some deposits but is known to be too high in others. The table indicates that at an annual depletion rate of 300 tonnes the probable reserves will last 8 years. If during this time half the possible reserves are transferred to the probable category then at the same rate of depletion a further 13 years supply will be available. Thus it appears that the supplies of nephrite should last 21 years. In the meantime the cost of production can be expected to increase above average inflationary rises because of the depletion of the more easily found, alluvial deposits and the need to mine in situ lodes. The increased cost will continue to the point where buyer resistance will limit the ultimate price. Thus bulk commercial sales will diminish and eventually cease because the cost of production will have exceeded the intrinsic value of the material. The supply will therefore diminish and eventually only small sales of high cost nephrite will be made to a few collectors or "rockhounds" who will find that the small quantity purchased makes the investment minimal. It seems likely that there will always be available small quantities of nephrite for future amateur needs, but it will almost certainly be at inflated prices.

SUGGESTIONS TO PROSPECTORS

Prospecting for nephrite in Canada has been largely a search in the alpine-type serpentinite bodies of the Cordilleran region embracing most of the British Columbia and Yukon Territory. It should not be assumed however, that nephrite does not occur elsewhere. There is some indication that nephrite may yet be found in eastern Canada where serpentinite bodies with contact reaction zones have been reported. Cooke (1950) noted serpentinized ultramafic dykes altered to calcified tremolite in the Eastern Townships of Quebec, and the work of Phillips and Hess (1936) suggests that nephrite may yet be found in eastern Canada.

At present, however, British Columbia must be considered the most favourable part of Canada for further discoveries of nephrite. During the past ten years, activity has shifted northward from the Lillooet area in southern British Columbia, first to the Omineca district in the middle of the province, and now to the Cassiar district in the far north where most of the production of nephrite is coming from.

It must not be assumed that all the nephrite has been found in the more southern districts. There remain areas in the Shulaps and Cadwallader ranges that have not been completely searched. The map by Roddick et al. (1973) shows the extent of the ultramafic rocks in the east half of Pemberton map-area where further search is recommended.

The Hozameen, Old Settler, Skihist and Bonaparte areas shown on Figure 8 offer possibilities for nephrite discoveries with relatively convenient access.

The Omineca Segment of the nephrite belt of British Columbia (Fig. 14), contains some large bodies of ultramafic rock which have not been thoroughly searched. Most production in this area has come from the vicinity of Mount Ogden, with a small amount from Mount Sidney Williams. The area must be considered favourable for further discoveries but access is difficult; much of the area is best reached by aircraft.

Table 5

Nephrite Production in British Columbia
From Annual Reports – Minister of Mines & Petroleum Resources

Year	Mining Division	Quantity (lb.)	Value ($)	$/lb.	Total to Quantity (lb.)	Date Value ($)	$/lb.
1962 and before	Lillooet	56935	20760	0.36			
1963	Lillooet	16000	15529	0.97	207986	72490	0.35
1964	Lillooet	10337	11404	1.10	218323	83894	0.38
	Omineca	1200	2400	2.00	1200	2400	2.00
1965	Liard	2000	2000	1.00	2000	2000	1.00
	Lillooet	4129	5249	1.27	222452	89143	0.40
	Omineca	1000	2000	2.00	2200	4000	2.00
1966	Liard	8493	8648	1.02	10493	10648	1.01
	Lillooet	3140	4577	1.46	225592	93720	0.41
1967	Liard	14920	19714	1.32	25413	30362	1.19
	Lillooet	5240	4627	0.88	230832	98347	0.43
1968	Liard	1810	2125	1.17	27223	32487	1.19
	Lillooet	42095	83899	1.99	272927	182246	0.67
	Omineca	5110	19646	3.84	7310	24046	3.29
1969	Liard	5825	11960	2.05	33048	44447	1.34
	Lillooet	6060	5237	0.86	278987	187483	0.67
	Omineca	14447	25438	1.76	21757	49484	2.27
1970	Liard	5322	9099	1.70	38370	53546	1.39
	Lillooet	14280	27583	1.93	293267	215066	0.73
	Omineca	243000	213574	0.88	264757	263058	0.99
1971	Liard	3993	7772	1.95	43363	61318	1.45
	Lillooet	44867	102900	2.29	338134	317966	0.94
	Omineca	118900	85660	0.72	383657	348718	0.91
1972	Liard	2934	3689	1.26	45297	65007	1.43
	Lillooet	192450	142450	0.74	530584	460766	1.15
	Omineca	48341	88729	1.83	431998	437447	1.01
1973	Liard	3444	4793	1.39	48741	69800	1.43
	Lillooet	28050	7200	0.26	558634	467966	0.84
	Omineca	122757	294815	2.40	554755	732262	1.32
1974	Liard	1838	3211	1.75	50579	73011	1.44
	Lillooet	-	-		558634	467966	0.83
	Omineca	5900	15402	2.61	560655	747664	1.33
1975	Liard	3214	8590	2.67	59169	81601	1.38
	Lillooet	-	-	-	558634	467966	0.83
	Omineca	240255	405553	1.68	800910	1153217	1.43
	* latest official figures						
1976	Unofficial estimates by author						
	Liard	200 tonnes					
	Lillooet	80 tonnes					
	Omineca	20 tonnes					
1977	Liard	200 tonnes					
	Omineca	15 tonnes					

In the far north, current interest centres in the Cry Lake map-area (Fig. 18) where some nephrite deposits are being mined. A number of unclaimed boulder trains and in situ occurrences were seen by the writer during the summer of 1977. One of the most important is a boulder field shown on Figure 18 west of Kehlechoa River, and 11 km south of King Mountain. The deposits west of Greenrock Creek and that south of peak 6872 are worth further investigation.

All that part of the Atlin Terrane between Tuya River and Atlin is virtually virgin territory for nephrite prospectors.

North of Cassiar Asbestos mine, serpentinized ultramafic rocks at the head of Blue River with contact reaction zones are reported by Wolfe (1965). He did not report nephrite, but "whiterock" and tremolite reminiscent of typical nephrite occurrences were noted. The implication is that nephrite occurrences are likely to be found there.

Yukon Territory contains many ultramafic bodies in geological environments similar to those of British Columbia, but so far only a few occurrences of nephrite have been reported. In part, this may be due to adequate search by only a few people with a knowledge of nephrite occurrences and the ability to recognize the material in weathered outcrops and boulders.

The presence of in situ nephrite in Frances Lake map-area (105H) suggests that prospecting in the serpentinite areas of Yukon should be considered the primary guide to potential nephrite occurrences. All contact reaction zones associated with these rocks should be examined closely for nephrite.

All nephrite deposits seen by the writer in British Columbia are of metasomatic origin, but the possibility of nephrite occurrences of the metamorphic type cannot be ignored.

Nephrite from the high-grade metamorphic rocks of the Shuswap Terrane east of Sicamous is reported but unconfirmed. The sketchy reference to jade near Klukshu Lake in Yukon Territory adds to the belief that there may be deposits of this type in the Cordillera.

Jadeite may also occur wherever blueschist metamorphism is found. Prospectors in the Pinchi Lake area in central British Columbia should be aware of the existence of such rocks.

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APPENDIX I

ANALYSES OF FOREIGN NEPHRITE

	1	2	3	4	5	6	7	8
MnO			Tr.	0.19	0.10		0.15	0.20
TiO_2				0.04	0.23		0.10	0.10
CaO	13.805	13.19	12.01	11.8	12.52	12.4	13.10	10.30
K_2O		0.27		0.20	0.06	0.16	Tr.	0.20
SiO_2	59.169	57.00	58.11	55.0	59.79	56.0	57.58	54.10
Al_2O_3		1.42	0.24	0.90	0.88	0.78	1.35	3.30
MgO	24.808	21.39	21.79	21.8	24.31	20.3	20.65	20.30
FeO		1.89	0.38	3.8	0.96		4.02	
						(7.91)		(12.30)
Fe_2O_3		1.76	5.44	1.6	0.33		0.15	
Na_2O		0.75		0.20	0.35	0.067	0.12	
Cr_2O_3		-			0.0		-	
NiO								
F					n.d.			
H_2O+	2.218	2.72		3.16	2.10			
							2.61	
H_2O-			1.78	1.16	0.32	1.89		
C								
Total	100.000	100.39	99.75	99.85	101.95	99.6	99.83	100.80

1- theoretical tremolite $Ca_2 Mg_5 Si_8O_{22} (OH)_2$
2- average of 32 specimens from U.S.S.R. Kolesnik (1970)
3- Alaskan Nephrite, Smith (1913)
4- New Zealand Nephrite, Coleman (1967)
5- Brazil, nephrite celt, Washington (1922)
6- Cowell, Australia, Nichol (1974)
7- Poland, Heflik (1968)
8- Wyoming, Sherer (1969)

APPENDIX II

PRINCIPAL REFERENCES OF CORDILLERAN GEOLOGY IN REGARD TO SERPENTINITE ZONES

NTS Sheet	
92 H	Cairnes (1937), (1943) Monger (1970)
92 I	Duffell and McTaggart (1952)
92 J	Drysdale (1916) Cairnes (1937) McCann (1922) Leech (1953) Roddick and Hutchison (1973)
93 B	Tipper (1959)
93 G	Tipper (1961)
93 K.L.	Armstrong (1949)
94 C	Roots (1954) Irvine (1976)
94 D	Lord (1948) Irvine (1976) Irvine (1975)
104 I	Gabrielse et al. (1962)
104 J	Gabrielse and Souther (1962) Monger (1975) Monger (1969)
104 K	Souther (1971)
104 N	Aitken (1959)

NTS Sheet	
104 O	Gabrielse (1969)
104 P	Gabrielse (1963) Wolfe (1965)
105 A	Gabrielse (1967)
105 B	Poole et al. (1960)
105 C	Mulligan (1963)
105 D	Wheeler (1961)
105 E	Bostock and Lee (1938)
105 F	Tempelman-Kluit (1974)
105 G	Wheeler et al. (1960)
105 H	Blusson et al. (1966)
106 D	Green (1972)
115 A	Kindle (1952)
115 B	Wheeler et al. (196)
115 F-G	Mueller (1967)
115 H	Tempelman-Kluit (1974)
115 J-K	Tempelman-Kluit (1974)
115 N-O	Tempelman-Kluit (1974)
116 A-B	Green (1972)

APPENDIX III
GLOSSARY OF TECHNICAL TERMS USED IN THIS REPORT

Acmite	-	Mineral – member of monoclinic pyroxene family $Na\ Fe^{+3}\ Si_2O_6$.
Actinolite	-	Mineral – member of monoclinic tremolite-ferroactinolite series $Ca_2(MgFe)_5\ Si_8O_{22}\ (OH)_2$.
Acicular	-	Needle-like crystals.
Albite	-	Mineral – member of triclinic feldspar group $Na\ Al\ Si_3O_8$.
Albitite	-	Rock – composed mainly of the mineral albite.
Allochthonous	-	A term applied to rocks which have not been formed where they are now found.
Alluvial	-	Pertaining to sediments laid down by running water in river beds, bars, flood plains, fans and deltas.
Amphibole	-	Mineral group with general formula: $A_2B_5(Si,\ Al)_8O_{22}(OH,F)_2$ A = Na, Ca, K B = Mg $Fe^{+2}Fe^{+3}$Al Ti, Li, Mn, common amphiboles are hornblende, actinolite, tremolite.
Argillite	-	An argillaceous rock without noticeable bedding or secondary foliation.
Argillaceous	-	Applied to rocks composed of clay minerals – e.g. shale, argillite.
Blastoporphyritic	-	A term applied to metamorphic rocks in which evidence of porphyritic texture has been preserved.
Blueschist	-	Metamorphic rocks characterized by presence of blue soda amphiboles and pyroxenes.
Botryoidal	-	A mineral habit resembling the appearance of a bunch of grapes.
Breccia	-	A fragmental rock composed of angular fragments of diverse origin.
Calc-Silicate	-	General term for lime silicates such as wollastonite, tremolite.
Cation	-	An ion bearing a positive charge, e.g. $Fe^{+2}\ Mg^{+2}\ Na^{+1}$.
Chert	-	Rock – siliceous sediment, consisting of fine grained crypto-crystalline quartz.
Chlorite	-	Soft, green, foliated mineral. A hydrous silicate of aluminium and magnesium with Al and Fe substituting for Mg.
Chrome	-	A chemical term for chromium oxide Cr_2O_3 commonly misused as a modifier in description of green-spotted nephrite.
Chromite	-	Mineral of spinel group $Fe\ Cr_2\ O_4$ forms much of the black opaque mineral in nephrite.
Clinopyroxene	-	A monoclinic member of the pyroxene group.
Clinozoisite	-	Mineral – member of epidote group. $Ca_2\ Al_3\ Si_3\ O_{12}\ (OH)$.
Colluvial	-	Pertaining to loose, incoherent deposits developed by gravity sliding as talus blocks at base of cliff or on steep slopes.
Cretaceous	-	The latest period in the Mesozoic era lasting from 65 to 136 million years ago.
Desilication	-	Removal of silica (SiO_2) by breakdown of silicate minerals or removal of silica from magma by reaction with wall rocks to form silicates.
Diopside	-	Mineral monoclinic pyroxene $Ca\ Mg\ Si_2\ O_6$.
Dolomite	-	Mineral – a double carbonate $Ca\ Mg\ (CO_3)_2$. Rock masses of dolomite are also called dolomite, dolomitic limestone or magnesium limestone.
Dunite	-	An ultramafic rock consisting mainly of olivine, but may have accessory pyroxene, plagioclase and chromite.
Fault	-	A fracture in rocks along which some displacement of the adjacent parts has taken place.
Ferroactinolite	-	Mineral – end member in the tremolite-ferroactinolite series of the amphibole group. $Ca_2Fe_5^{+2}(Si_8O_{22})\ (OH,F)_2$
Ferric	-	Pertaining to iron ions having a valence of 3, or three charges on the atom, Fe^{+3}.
Ferrous	-	Pertaining to iron ions having a valence of 2, or two positive charges on the atom Fe^{+2}.
Foliated	-	Pertaining to rocks with a layered or laminated structure resulting from segregation of minerals through igneous or metamorphic processes.

Fracture	- A break in rocks produced by application of force, producing surfaces other than cleavage or parting surfaces, e.g. hackly fracture.
Gabbro	- A basic rock composed essentially of clinopyroxene and calcic plagioclase in coarse grained plutonic bodies.
Garnet	- A mineral group of general formula A_3 B_2 $(SiO_4)_3$ A = Ca Mg Fe^{+2} Mn B = Fe^{+3} Al, Cr, V, Ti, Zr
Gneiss	- A coarse grained metamorphic rock composed of alternating bands of different mineralogical composition.
Greenstone	- A general field term for fine grained, chloritic, altered volcanic rocks. The appelation for nephrite in New Zealand.
Harzburgite	- An ultramafic rock composed of olivine and orthopyroxene. A variety of peridotite.
Hydrogarnet	- Mineral – member of garnet group with $Si\ O_4$ partly replaced by $(OH)_4$.
Hydrothermal	- Pertaining to hot water in the earth and the solutions, alteration and deposits attributed to it.
Hydroxyl	- The anion produced by the hydrolysis of water H_2O H^+ $+OH^-$
Index of refraction	- The ratio of the velocity of light in air to the velocity of light in another medium. A diagnostic property of non-opaque minerals.
In Situ	- In place, or in its place of origin.
Intrusive	- A rock which in liquid form penetrated other rocks and solidified without reaching the surface.
Jadeite	- A pyroxene mineral with composition Na (Al, Fe^{+3}) Si_2O_6 one of the two jade minerals.
Jurassic	- The second period in the Mesozoic era, lasting from 190 to 136 million years ago.
Listwanite	- (Holmes, A., 1928) – a schistose rock of yellowish green colour composed of various combinations of quartz, dolomite, magnesite, talc and limonite – commonly called quartz-carbonate rock with distinctive features due to addition of mariposite.
Lode	- A mineral deposit in solid rock, as opposed to placer deposits.
Lustre	- The surface appearance of a mineral produced by reflected light. A diagnostic property in some minerals, and an aid in identification.
Magna	- The hot, mobile rock material generated within the earth from which igneous rocks form on cooling and consolidation.
Mesozoic	- The geological era between the Paleozoic and Cenozoic eras. It lasted from 65 to 225 million years before present.
Metamorphism	- The process by which solid rocks are altered in mineral composition, texture and structure by response to new conditions of temperature and pressure.
Metasediment	- Metamorphosed sediments.
Metasomatic	- Pertaining to metasomatism, the process of solution and deposition by which new minerals develop in the place of other minerals under the influence of chemical potentials in different temperature – pressure environments.
Microcrystalline	- Crystalline aggregate in which the individual grains can be distinguished with a microscope.
Mineral	- A naturally occurring inorganic chemical substance with an orderly internal atomic arrangement.
Mississippian	- The oldest period in the Paleozoic era and extending from 325 to 345 million years ago.
Monoclinic System	- One of six crystal systems having three crystallographic axes of unequal length with one inclined axis.
Monominerallic	- Pertaining to rocks containing one essential mineral e.g. Marble - Calcite Sandstone - Quartz Dunite - Olivine Serpentinite - Serpentine
Nephrite	- A fine grained form of tremolite in which microfibres of tremolite are aggregated into bundles, group and sheaf-like aggregates set in a similar but finer grained matrix. A variety of Jade.

Nicol prism - A device fashioned from optically clear calcite (Iceland Spar) for producing plane-polarized light for use in optical instruments, principally the petrographic microscope.
NOTE: Sheet polaroid does the same thing, and is referred to as a Nicol.

Ophiolite - An assemblage of mafic and ultramafic igneous rocks ranging from spilite to basalt with gabbro, peridotite, serpentinite and considered as typical oceanic crust material.

Ophitic - A textural term applied to diabase in which euhedral plagioclase crystals are embedded in a large pyroxene crystal.

Ore - A mineral or aggregate of minerals from which metals may be recovered at a profit. In broader terms, a mineral deposit which may be exploited profitably.

Oxidation - In chemistry (1) combining with oxygen; (2) the change from lower to higher positive valence.
Fe^{+2} Fe^{+3} + 1e hence removal of 1 or more electrons.

Paleozoic - First era in Phaneroxoic eon. Lasting from about 600 to 200 million years ago.

Pennsylvanian - The sixth period of the Paleozoic era, lasting from 325 to 280 million years ago.

Peridotite - A coarse grained ultramafic rock consisting mainly of olivine and minor pyroxene.

Permian - The youngest period of the Paleozoic era, lasting from 280 to 225 million years ago.

Petrogenesis - The study of the origins of rocks particularly in regard to the physico-chemical environment.

Petrography - The description and classification of rocks mainly by microscopic examination.

Picotite - A chromian spinel $(Mg, Fe)(Al, Cr)_2 O_4$.

Placer Deposits - Surficial or unconsolidated deposits – commonly gravel in which minerals accumulate largely by gravity separations; especially said of gold, and stream tin.

Pleistocene - The earlier of the two epochs of the Quaternary Period of the Cenozoic Era. Commonly equated with Ice Age, particularly in Canada.

Prehnite - Mineral commonly associated with zeolites, generally greenish in colour. H = 6-6.5 has been mistaken for jade (nephrite). $Ca_2 Al_2 Si_3 O_{10} (OH)_2$

Pyroxenite - A monominerallic rock composed essentially of pyroxene.

Radiometric age - The absolute age of rocks as determined by decay or radioactive elements in the constituent minerals.

Rock - An aggregate of one or more minerals making up an appreciable volume of material on or in the earth.

Rodingite - "Whiterock" or calc-silicate formed by alteration of gabbro in contact with serpentinite with concurrent albitization and development of nephrite.

Serpentine - Mineral group consisting of several varieties including: anigorite, chrysotile, lizardite. $(Mg, Fe^{+2})_3 Si_2 O_5 (OH)_4$

Serpentinite - A rock mass composed essentially of serpentine minerals.

Shear zone - A tabular sheeted structure in which rocks have been crushed, faulted and brecciated over a width of several or many feet.

Specific gravity - The ratio of weight of a substance to that of an equal volume of water at 4°C.

Sphene - Synonym of titanite.

Spherulitic - Pertaining to spherulites – small, radiating, concentrically arranged aggregations of minerals of spherical shape.

Spinel - Mineral group $AB_2 O_4$
A = Mg, Fe^{+2}, Zn, Mn, Ni, Cu, Ti, Ge, Si
B = Al, Fe^{+2}, Fe^{+3}, Cr, V
Spinel sp. $Mg Al_2 O_4$

Steatite - Essentially talc rock or soapstone.

Stilpnomelane - Mineral – $K(Fe^{+2}, Fe^{+3}, Al)_{10} Si_{12} O_{30} (OH)_{12}$

Talc - Mineral, $Mg_3 Si_4 O_{10} (OH)_2$

Talus - Fallen rock material at base of cliff or steep hillside commonly of large, angular blocks.

Tectonic - Pertaining to rock structures resulting from deformation of the earth's crust.

Titanite - Mineral – $Ca Ti Si O_5$ also called sphene.

Thomsonite	- Mineral – member zeolite group. Na Ca_2 $(Al_5\ Si_5)\ O_{20}.6H_2O$.
Triassic	- The earliest period of the Mesozoic era lasting from 225 to 190 million years ago.
Ultrabasic	- A chemical term applied to igneous rocks with less than 45 per cent silica.
Ultramafic	- Igneous rocks rich in magnesian and iron minerals and no quartz, little feldspar.
Uralite	- Fibrous or acicular variety of hornblende occurring in altered rocks.
Uvarovite	- Chrome garnet $Ca_3\ Cr_2\ (SiO_4)_3$
Vesuvianite	- Mineral – also called idocrase. Complex hydrous silicate resembling jadeite in specific gravity, hardness and colour. $Ca_{10}\ Mg_2\ Al_4\ (SiO_4)_5\ (Si_2O_3)_2\ (OH)_4$
Whiterock	- Calc-silicate rock, rodingite or contact reaction zone with development of hydrogarnet, diopside, wollastonite, tremolite, etc.
Wollastonite	- Mineral – Ca SiO_3
X-ray diffraction	- The reflection (diffraction) of X-rays from atomic planes in a crystalline substance including minerals at definite angles related to the wave length of the X-rays and the spacing of the atomic planes.
Zeolite	- Mineral group of hydrous alumino silicates of sodium calcium, barium, strontium, and potassium with compositions somewhat to feldspars with water.

APPENDIX IV

SURVEY OF FOREIGN JADE OCCURRENCES

North America (United States)

Jade occurs elsewhere in North America as nephrite in the western Cordillera, from California to Alaska, where contact reaction zones between serpentine and country rocks give rise to lime silicates and magnesium hydrous silicates through chemical diffusion processes. Nephrite deposits in Wyoming are presumably of the metamorphic types similar to those in New South Wales and Turkestan.

Washington State

Nephrite is reported from a number of localities in Washington. One of these is on the lower eastern slope of Mount Higgins east of Mount Vernon where serpentinite is in contact with Darrington Schist. The contact is not clearly exposed but pieces of nephrite and rodingite alteration were found in the debris covering the contact which follows a small water course.

Nephrite in botryoidal form is reported from the southeast end of Cultus Mountain (L. Ream, pers. comm., 1974). A number of other localities associated with known serpentinite localities have yielded nephrite but production from Washington seems to have been sporadic, and of low quality.

Oregon

At least one nephrite occurrence is known in Oregon. It is Curry County in the southwest corner of the state (Sinkankas, 1959). Several more might be expected and even predicted on the basis of Coleman's (1967) work on contact reaction zones. His work in Oregon included investigation of four areas near Myers Creek, Ingersoll Peak, Myrtle Creek and Baldy Mountain where contact reaction zones between serpentinite and other rocks resulted in development of rodingite and chlorite/nephrite boulders.

California

Jade has been found in twelve counties in California. The first in situ jadeite was found in 1936 in San Benito County. Since then numerous occurrences have been discovered. These are distributed along almost the whole length of the state from just south of the Oregon boundary to just north of the Mexican boundary. Most of the occurrences are in the Coast Ranges and are associated with serpentinite. In some localities only alluvial boulders are found. Most jade is nephrite; jadeite has been found in four localities.

The basic information for each occurrence is summarized in Table A 4.1, "Jade Occurrences of California", most of the information being from Bulletin 189, California Division of Mines.

Two references to jade in El Dorado and Centra Coster countries are not included because no details could be found. It should be noted that jadeite occurs with nephrite in the Leech Lake Mountain occurrence. This is unusual.

Alaska

Nephrite occurs principally in the Upper Kobuk River, and its tributaries, Dahl, Cosmos and Jade creeks, and along the Shungnak River in northwestern Alaska.

Artifacts of nephrite attracted the attention of Lt. George Stoney, U.S.N. on a visit to the Arctic Coast in 1883. In the following year he explored along the Kobuk River looking for the source of the alluvial boulders but the material he brought out proved to be serpentine. In the winter of 1885-86, he was successful in finding the source of the nephrite on Jade Mountain. According to Anderson (1945) nephrite is abundant as alluvial boulders and in situ deposits but no estimate of reserves has been made. Apparently most of this nephrite is inferior in quality and unsuitable for lapidary purposes. Some gem quality material is found, however, and a few tons was produced in the years following 1970.

Wyoming

Alluvial jade was abundant in south-central Wyoming but apparently it is now very scarce. Many of the boulders were exposed to sand blasting by desert winds which aided considerably in recognition of the material by removing surface incrustations of weathering products, lichens or dirt. Some Wyoming jade is of highest quality and commands premium prices, but like jade everywhere colour and quality varies over a great range. The best quality gem material is relatively rare.

In situ deposits of jade have been found in a few places in Wyoming but no details are available. Brief mention of these occurrences state the nephrite is associated with metamorphic rocks of Precambrian age. The presence of serpentinite does not seem to be a prerequisite. The association with high grade metamorphic rocks suggests that Wyoming nephrite is the metamorphic type.

Wisconsin

Nephrite is reported from Wisconsin where it occurs in situ in an area of dolomitic rocks. Identification as nephrite seems to rest on the presence of actinolite-tremolite as a replacement of volcanic rocks. A nephritic texture is not confirmed and it may be that the rock merely resembles nephrite in some aspects.

Michigan

Greenlee (1962) claimed to have found alluvial nephrite in Michigan in gravel pits, and along the shore of Lake Huron. Verification, however, is not available. Similar "jade" is reported by Greenlee from Illinois, Indiana, Iowa, Minnesota and Ohio.

Vermont

Nephrite is not known to occur in Vermont but the work of Phillips and Hess (1936) suggested that the many contact reaction zones associated with the serpentinite belt extending from Vermont to southern Quebec may well contain some nephrite bodies in some localities. Actinolite bodies are numerous so it is possible that the nephrite may have developed somewhere in this belt.

Central America

The jade of Central America seems to be entirely jadeite. It is found mainly as alluvial boulders in Guatemala and Costa Rica, Honduras and elsewhere but the bedrock source seems to have eluded discovery. The in situ deposits may have been small, and scattered from Guerrero in Mexico to Panama or even to Venezuela. The material was so highly prized by the Aztecs at the time of the Spanish conquest (about 1520 A.D.) that they preferred it to gold. Presumably it was then in very short supply.

Table 6

Jade Deposits in California

Locality No.	County	Location	Type	Geology	
1	Siskiyou	Chan Jade Mine, Indian Creek near Happy Camp.	nephrite		Bull. 189
2	Trinity	North Fork, Eel River	jadeite nephrite	Alluvial boulders	Bull. 189
3	Mendocino	Williams Creek, 6 miles east of Covelo	nephrite	alluvial	Bull. 189
4	Mendocino	North Fork, Eel River, Leech Lake Mt.	nephrite jadeite	alluvial	Chesterman (1963)
5	Sonoma	Valley Ford	jadeite	in schist	Bull. 189
6	Marin	Massa Hill, 5 miles south of Petulama	nephrite	veins and lenses in sheared and blocky serpentine intruding Upper Jurassic Franciscan formation	Chesterman (1951)
7	Monterey	Cape San Martin and Jade Cove	nephrite	Replacement of Franciscan (Upper Jurassic) metasediments near serpentinite	Crippen (1950)
8	San Benito	Clear Creek	jadeite	alluvial	Bull. 189
9	Mariposa	David Gulch, 1 1/2 miles north-north-west of Bagby and north toward Coulterville	nephrite		Evans (1966)
10	TuLare	Lewis Hill, 2 miles north of Porterville	nephrite	in serpentine	Bull. 189
11	San Luis Obispo	near Paso Robles	nephrite	alluvial	Bull. 189
12	Santa Barbara	near Los Olwos in creek bed on south slope of Figueroa Mt. Woodhouse	nephrite	alluvial	Bull. 189
13	Riverside	Eagle Mt.	nephrite	in contact zone between dolomite and quartz monzonite porphyry	Bull. 189
14	Riverside	Storm Jade Mine, Chiriaco Summit, near Indio	nephrite	associated with serpentine in colomite	Bull. 189

South America

In contrast to Central America, the jade of South America is mainly nephrite but no great amount is known either as artifacts or deposits. The main source of nephrite is the state of Bahia in Brazil where nephrite celts (stone axe leads) have been found in some number and where alluvial and in situ deposits have been discovered. According to Washington (1922), the nephrite lies within a belt of gneiss. Serpentinite is not mentioned although pyroxenite and hornblendite are present. The association with high grade metamorphic rocks suggests that the nephrite is of similar origin.

Jadeitic pyroxene in eclogite is common in Venezuela. Segregation into monomineurallic masses may be postulated to account for discoveries of jadeite in Venezuela and neighbouring Central America.

Europe

The first reported in situ occurrence of jade in Europe was discovered in Silesia in 1884. Deposits in northern Italy were found in 1906. Jade from Neolithic sites and alluvial boulders have been reported over a wide range from Brittany, Ural Mountains, the Alps, and the eastern Mediterranean.

Early writers on gemstones were probably describing jade in some cases at least, under varieties of jasper. Thus, Agricola in 1556 used the term 'jaspis' for which he had fourteen varieties. It seems certain that one of these was jade.

Poland

Poland now includes the former German district of Silesia. In 1884 Herman Traube first found nephrite in a quarry near Jordansmuhl and two years later located another occurrence near Reichinbach. These towns are a few tens of kilometres south of Breslau (now Wroclaw). The Jordansmuhl deposit is much larger, and it is reported by Ruff (1963) that in 1958 the deposit was again being worked for nephrite. Kolesnik (1970) reviewed the literature which includes the work of Traube.

The nephrite occurs between serpentine and a "whiterock" which Traube calls granulite, and which Kolesnik considers a metasomatic alteration of gabbro. It is variable in mineralogy; albite, hornblende, garnet, epidote, zoisite, quartz, prehnite and biotite have been identified.

Italy

Deposits of nephrite in northern Italy occur in the Apennine Mountains between Sestri Levante and Monterosso. According to Kolesnik (1970) the first investigator was Kalkowsky in 1906. Twelve outcrops of nephrite occur over a distance of 23 km. The nephrite lies mainly in the contact zone between serpentinite and gabbro.

Switzerland

Small deposits of nephrite are known from several places in the Swiss Alps. They include two occurrences near the village of Salux, a few more near Val de Faller, a vein deposit at Poschiavo and another in the Gottard Range, and two small outcrops of nephrite in the Handuas area. This information is given in brief by Kolesnik (1970) who quoted references which the writer has not seen.

Germany

Kolesnik (1970) quoted various authors in reference to nephrite in various parts of Germany. One example given was ascribed to Rimann (1938) for an in situ deposit in Thuringia, East Germany where nephrite has formed in serpentinites. In Harz area, nephrite has formed along peridotite-gabbro contacts according to Uhlig (1910). Alluvial deposits are present near Leipzig and Potsdam in Bavaria, West Germany.

Finland

Kolesnik (1970) refers to an occurrence of "anthophyllite nephrite" near Usimaki. The information, paraphrased from Rimann (1936), is sketchy.

United Kingdom

Jade is reported to occur in the United Kingdom. Ruff (1963) says that Professor Matthew F. Heddle gave several localities in Scotland, but some at least have been discredited. Probably most are serpentine.

Greece

According to Ruff (1963) jade occurs on the Island of Syros on the tip of the mainland south of Athens.

Artifacts have been found by archeological expeditions on the mainland as well as on the islands of Crete and Syra. It is a question of how much jade was the result of trade with Asia, and how much may have been produced from local sources. According to Gabrielse (pers. comm., 1977), ultramafic rocks including serpentinites and tectonic melanges are abundant in Greece and discoveries of nephrite deposits might be expected.

Africa

Malawi Nephrite Deposits

Nephrite is reported from Chimwadzulu Hill near the Mozambique border in western Malawi. When the geology was described by Bloomfield (1958), the country was called Nyasaland.

The nephrite occurs as tremolite-nephrite-actinolite rocks and, as described by Bloomfield, seem to be of the metamorphic type as they occur in high-grade metamorphic rocks and not as contact reaction zones between serpentinite and country rocks. Serpentine and other ultramafic rocks underlie part of the Chimadzulu Hill, but are not in contact with the nephrite-tremolite rocks.

Nephrite is said to occur as the groundmass between broad prisms of tremolite. The identification of the nephrite rests on X-ray examination. Bloomfield's description of schistose varieties of the tremolite-nephrite rocks is interesting. The schistose rocks usually consist of thin blades of white tremolite forming a felted aggregate and enclosing small porphyroblasts of amorphous jade-green nephrite.

From some of the terminology used in the description of these rocks one might question whether these are true nephrites. Perhaps they are really only tremolite rocks. Bloomfield does not discuss the definition of nephrite, nor does he describe the material.

Rhodesia

Nephrite is reported (Anderson, 1961) from a locality west of Fort Victoria in an environment of Precambrian serpentinites that have been altered to talc schists and listwanite. Further details are not known.

Asia

China

The country most famous for jade is undoubtedly China where the art of carving jade reached high levels of artistic expression more than 3000 years ago. The earliest artifacts of China were made from nephrite, probably from local sources which have long since been depleted. In ancient times the large deposits in Turkestan supplied most of the requirements and continued to do so long after the deposits in Shensi, Honan and Kuang-Si provinces were depleted. Much of the white nephrite used in some of the larger carvings, came from the Kuen Lun Mountains of Turkestan, now a part of China. The occurrences there were described by Stoliczka (1874). Apparently the nephrite lies in veins in mica and hornblende schist. No serpentinite is mentioned and it appears that these deposits must be of the metamorphic type.

Nephrite deposits on the island of Taiwan are typical metasomatic or contact reaction zones developed between serpentinite and schist. The deposits may have been extensive but they have not been able to supply the demand for high quality nephrite. Factories in Taiwan seem to require nephrite from Canada or Australia to supplement whatever local production is possible. Probably little or no jadeite has been found in China. The so-called Chinese jade is invariably Burmese jadeite.

Burma

The jade of Burma is jadeite. Most of the production comes from alluvial or residual deposits in northern Burma where it is associated with ultrabasic rocks, mainly serpentinite, containing vein- or dyke-like bodies of albite-jadeite-glaucophane and actinolite. Some of these are large; Yoder (1950) suggested that one deposit was 600 feet wide and 1500 feet long. If it is assumed that the third dimension is 500 feet, the deposit would contain about 4.5 million tons. Some of the material is mixed albite and jadeite, and schistose inclusions which may amount to half the volume. Nonetheless, such a vast reserve explains why mining has gone on so long in one restricted area and why it continues to be the main supply of this valuable commodity. If the estimate is correct, it probably means that jadeitite is not rarer than nephrite in world reserves because total reserves of nephrite are probably less than a few hundred thousand tons.

India

Jade carvings have been produced by lapidary artisans in India for several centuries; the Mogul jades of the sixteenth and seventeenth centuries were particularly skilfully made from nephrite whose source is not known. Possibly it came from Turkestan, although Butler (1963) stated that Washington claims the carvings are not made from nephrite from Turkestan, Burma or other known localities, but comes from a locality in India (now in Pakistan). Butler found two pebbles of good quality nephrite in the gravel bed of the Teri Toric River in the Kohat District of West Pakistan, thereby giving rise to speculation that an indigenous source was at hand. However, the small size pebbles weighed 191 and 379 grams, and the absence of any great number of pebbles suggest they were a long way in both time and space from their place of origin.

Japan

Jadeite is found in Japan in glaucophane schists and as monomineralic masses associated with serpentinites in the Kotaki area on the west side of Honshu Island. The identification was confirmed by optical, chemical and X-ray methods. However, the presence of nephrite has also been claimed (Meen, 1966) because of amphibole-type X-ray powder patterns from some acicular minerals associated with the jadeite.

The evidence is not conclusive and the mineral may be common tremolite, an accessory noted in some of the specimens from these rocks. Nephrite texture was not confirmed and the identification may be questioned.

Union of Soviet Socialist Republics

The main source of nephrite from the U.S.S.R. is the East Sayan district, west of Lake Baikal and just north of the Mongolian border in Siberia. The first studies on the area were made in 1852. Further discoveries were made at the turn of the century. Kolesnik (1970) did a detailed study mainly on one deposit, the Opinsk-Kitoy ultramafic massif.

The ultramafic Kitoy massif is a lenticular body trending parallel with the regional structure of the enclosing Proterozoic rocks. The age of the intrusion is considered Lower to Middle Cambrian and is spatially related to major faults. The bulk of the ultramafic rocks are harzburgite, dunite and peridotite, with serpentinized lenses, borders and offshoots along the periphery of the main body.

Talc-carbonate rocks (listwanites) are extensively developed in the serpentinite. Talc-carbonate zones largely occur at contact between ultramafics and crystalline schist and limestone. Listwanite occurs around granitic and gabbroic borders near serpentinite or in serpentine as veins and irregular zones. The main component is ferromagnesian carbonate and quartz; minor talc and fuchsite are usually present.

Two nephrite deposits are known from the East Sayan ultramafic belt. Kolesnik (1970) delas mainly with the larger which is similar in structure and geology to the smaller. The larger deposit was discovered in 1938 by a Russian geologist. Ultramafic rocks enclose gabbrodiorite bodies, completely replaced by metasomatic alteration products, garnetite, rodingite and albitite. Nephrite occurs with the alteration products in the contact zone between serpentine and gabbro.

Australasia

New Zealand

Jade has long been prixed by the Maoris in the New Zealand for the manufacture of implements, weapons and ornaments. Most, if not all of the raw material came from alluvial deposits in the Otago, Westland and Canterbury districts of South Island. The source of the nephrite was believed by Turner (1935) to be serpentinites of these districts but few in situ deposits were known prior to 1963 when large in situ deposits and loose blocks were found in abundance at the headwaters of the Arhura River in Westland district. An account of the discovery is given by Dalziel (1963). The occurrence seems to be in the vicinity of the Griffith Range ultramafics studied by Coleman (1966) who pointed out that minor nephritic lenses were present in contact reaction zones between serpentinite and alpine schists, and implied that in situ nephrite would be found in large quantity.

Serpentinites extend along the length of South Island in association with the Alpine Fault. In most localities studied by Coleman reaction zones between the serpentinite and country rock are present and in many, nephrite or seminephrite has developed. The country rock may be argillite, greywacke, limestone, dolerite schist, gabbro or basalt. In most places nephrite is a minor part of the contact reaction zone and may be absent.

The deposit of the head of Arahura River is said to be exceptionally large. It should be pointed out, however, that in the writer's experience, jade prospectors are generally optimistic; most jade deposits contain more inferior jade, talc, serpentine, rodingite than is first realized by their discoverers.

On the North Island of Piopio and North Aukland districts, serpentinites intrude Teritiary and Mesozoic sediments. Gabbro-peridotite complexes at North Cape are only partly serpentinized. Nephrite apparently does not occur in the North Island, although minor reaction zones have developed in some localities.

It appears that nephrite in New Zealand is much more abundant than commonly thought and with active prospecting many in situ deposits are likely to be found. As there is a ban on export of raw nephrite, the amount already discovered may well exceed the requirements of local industry for a long time and consequently there is probably little incentive for further discoveries.

Australia

Nephrite has only recently been discovered in Australia; there is no history of its use by the aborigines. The first discovery was made in 1960 in the Great Serpentine Belt of New South Wales. The locality however yielded only 39 tons. According to Chalmers (1970) the material was typical nephrite although less translucent than the best New Zealand specimens. The geology of the occurrence was not described but only the brief statement that the nephrite was recovered from weathered serpentine was made.

A second occurrence of nephrite in New South Wales consisted of poor quality greenish grey nephrite in serpentinite at a gold mine at Lucknow in the Central Highlands. No details of the geology or size of deposit were provided by Chalmers.

Apparently no further discoveries of nephrite have been made from the area or have not generally been reported. The serpentine belt is 350 km long and may not have been carefully prospected for nephrite. It seems reasonable to assume that further discoveries will be made.

The most important discovery of nephrite in Australia is that made in South Australia, north of Cowell where according to Nicol (1974) metamorphic nephrite deposits contain 45,000 tons of what can be classed as probable reserves. Possible reserves are considered to be in excess of this figure.

Oceania

Nephrite is said to occur in the serpentinite of New Caledonia but no references are available.

Jadeite is well known in New Guinea and the Celebes in metamorphic rocks of the low grade glaucophane schist facies. Pure monominerallic masses of lapidary quality are however rare.