Tasmania Department of Mines – Unpublished Report 1988/29

Industrial minerals in Tasmania – wollastonite.

by C. A. Bacon and R. S. Bottrill

Abstract

A small, low-grade deposit of wollastonite exists in the vicinity of the Kara scheelite mine near Hampshire in northern Tasmania. Interest has recently been expressed in investigating the potential uses of this resource, and metallurgical testing has shown concentrates of 70% wollastonite can be obtained from feedstock ore containing 42–59% wollastonite.

Wollastonite is used extensively as a filling and reinforcing agent in plastic, paint, ceramics, and tiles, and as a partial substitute for both fibreglass and asbestos. No wollastonite is currently produced in Australia. All local consumption uses imported products, which sell for around $550–650/tonne.

INTRODUCTION

Wollastonite ($CaSiO_3$) is ideally composed of 48.3% CaO and 51.7% SiO_2, and is a triclinic mineral found in contact metamorphosed limestones, usually in the form of cleavable masses, crystals being rare. Even small, crushed fragments of wollastonite retain their cleavage, with the result that when crushed the mineral fragments are needle-shaped, commonly seven to eight times long as wide. This property makes wollastonite a useful reinforcing agent, and being chemically inert, a useful filler in a variety of different products.

Wollastonite was named after the English chemist William Wollaston (1766–1828), who discovered the elements palladium and rhodium. In recent years wollastonite has become important as a potential replacement for asbestos, the use of which is declining due to problems with health and safety of workers involved in the mining and handling of some forms of asbestos. All wollastonite used in Australia is imported, there being none produced here. Tonnages consumed are very small.

CHEMICAL AND PHYSICAL PROPERTIES

Wollastonite is a calcium silicate ($CaSiO_3$) of the pyroxenoid family and occurs in three structural modifications: wollastonite proper; parawollastonite; and pseudowollastonite. The first two minerals are both forms of (low temperature) α-$CaSiO_3$, while pseudowollastonite is the high temperature form (β-$CaSiO_3$, stable above 1120°C). Wollastonite is a triclinic mineral, and is moderately common in metamorphosed siliceous limestones. Parawollastonite is monoclinic and is rarer but of the same paragenesis, and pseudowollastonite is triclinic and a rare mineral in some pyrometamorphic rocks.

Wollastonite is usually massive to fibrous, and is colourless to brilliant white, or various pale tints when impure. Although the mineral is normally fairly pure, small amounts of Mn and Fe may substitute in the structure. Masses pure enough to mine are uncommon.

Typical physical properties of wollastonite products are:

Brightness:	90% (compared to MgO)
Oil absorption (rub out):	35 lbs/100 lbs
Hardness (Mohs):	4.5
Specific gravity:	2.9
Density:	24 lbs/solid gallon
Coefficient of expansion:	5×10^{-6} mm/mm/°C
pH of 10% slurry:	9.9
Solubility in water:	0.0095 g/100 cc
Chemical activity:	Largely inert, except concentrated acids.
Refractive Index:	1.63
Melting Point:	1540°C

Pure wollastonite contains 48.3% CaO and 51.7% SiO_2. Typical analyses are shown in Tables 1, 2 and 5.

USES

The prime use of wollastonite is in the manufacture of plastic, where the inert, acicular fibres are a valuable reinforcing material. In paint (house paints, etc.) wollastonite is used as a pH stabiliser, to help prevent can and lid corrosion and to keep the pigments in suspension.

Wollastonite can be used as a partial substitute for fibreglass and asbestos, and is used in the ceramic and refractory industries. In ceramic use, wollastonite improves the mechanical properties of ceramic ware and reduces warping or cracking of rapidly-fired materials. Tiles especially are stronger with the inclusion of wollastonite. This is because wollastonite contains virtually no moisture, and so can reduce thermal expansion and cracking associated with moisture in ceramics. As wollastonite contains both calcium and silica, traditional raw materials such as flint, quartz, sand, feldspar, marble, limestone, talc, etc. can be wholly or at least partially replaced with just one mineral. Shrinkage is minimised by the acicular nature of wollastonite particles, and tiles containing 55% wollastonite have been shown to have a firing shrinkage as low as 0.1–0.2%

Minor uses of wollastonite are in the manufacture of fluxes, match-heads, abrasives, and metal casting plastics. As an abrasive, wollastonite is used in making wheels, stones and industrial pumice.

KNOWN DEPOSITS

The United States of America is the largest producer and consumer of wollastonite. During the 1930's small quantities were mined in California and made into mineral wool, however, this was largely experimental and proper mining did not begin until the 1950's. Currently, most of the USA's supply comes from the states of New York and California. The deposit near New York (Willisboro) has reserves in excess of 10 million tonnes of 55–65% wollastonite. A number of small occurrences are worked in California.

Elsewhere, wollastonite is, or has been, produced from mines in Mexico, central Asia (USSR), south-west Finland, Kenya and Namibia. World reserves of proven wollastonite-bearing rocks exceed 90 million tonnes, with probable reserves being 270+ million tonnes.

SYNTHETIC WOLLASTONITE

Varieties of synthetic wollastonite are made in the USA and some European countries. The synthetic forms do not have the acicular crystal structure of the natural mineral, and are also more absorbent.

A synthetic variety 'synopal' is made in Denmark from chalk, sand and dolomite, while in Italy 'wollanita' is made from silica, chalk, sand and dolomite. This is used as a road material, an abrasive, and in ceramics. In the USA, synthetic wollastonite is manufactured as 'silene' (Pittsburgh Plate Glass Company) and as 'Micro-Cel' (Manville Products Corporation). The synthetic varieties cost around twice that of the natural product (Elevatorski, 1983).

CONSUMPTION

Production of wollastonite appears to be around 115,000 tonnes/year. The main producers are the USA, Finland and India. The following table of tonnages mined is taken from the *Australian Mining Review 1984.*

Country	1979	1980	1981	1982	1983
Finland	10,576	8,782	13,690	14,962	15,402
Kenya	200	-	-	-	
Mexico	11,892	20,905	14,602	15,599	-
USA	63,000	76,000	87,000	86,000	83,000
India	3,794	5,790	15,915	20,724	16,557

NOTE: In addition to the countries listed, Japan, Namibia and Turkey are also believed to produce wollastonite.

SPECIFICATIONS

Commercial products in the USA are classed as 'milled grades' (-200, -325 and -400 mesh, and -10 µm) and 'attrition grades' (a 20:1 length/diameter product).

PRICES

Prices (in 1981) of the milled grades were 2 cents–5 cents (US) per pound (i.e. $US40–$US100 per tonne) and 7 cents per lb ($150 per tonne) for the attrition grade (Elevatorski, 1983). In Australia, at the current time, processed wollastonite, known as 'kemolit', sells for $A550–650/tonne. The wollastonite is imported from either India or the USA (Industrial Minerals, pers. comm.).

TASMANIAN OCCURRENCES

Wollastonite has been recorded from the Shepherd and Murphy mine at Moina in a wollastonite-garnet rock; from some metamorphosed Permian calcareous mudstones around Hobart (Petterd, 1910); and from an area near Hampshire, in northern Tasmania. This latter occurrence, near the Kara mine, is the only known deposit having any possible economic importance. Wollastonite occurs in Ordovician sequences transitional between the Gordon Limestone and the Moina Sandstone, and metamorphosed by Devonian granite.

The occurrence has been examined by Thomas and Henderson (1943), Hughes (1950) and Longman (1961). Several outcrops of limestone in Limestone (now Wollastonite) Creek contain wollastonite in varying amounts. The geology of this area has been mapped by Baillie *et al.* (1986). Typical analyses are shown in Table 1.

Hughes (1950) noted that limestone and wollastonite-bearing rocks did occur in the area of Limestone Creek, but that the area of limestone was not substantial. The rocks in Limestone Creek were described (Longman, 1961) as consisting of "fine alternating bands of calcium silicate rocks containing wollastonite as a prominent constituent, recrystallised limestone and quartzite ranging in thickness from nine inches to two feet (0.23–0.60 m) and dipping towards the west at 10-15°" (Longman, 1961).

PETROLOGY

Recent mineral processing tests by the Department of Mines on Kara wollastonite have incorporated some petrological work, described in Appendix 1 and summarised below and in Tables 1 to 6. Results are similar to those of Longman (1961), although he calculated reserves assuming all MgO as dolomite (not observed in this study) rather than diopside.

The ores contain wollastonite intimately intergrown with varying amounts of diopside, calcite, quartz, feldspars, pyrrhotite and minor accessories. The wollastonite comprises between 20 and 70 vol% of various rocks, and has a prismatic to fibrous texture and a grain size between 0.05 and 1.0 mm. It is commonly poikiloblastic, with fine inclusions of calcite, diopside and other phases, between about 5 and 50 µm in size (Plate 1). The feldspars range from An_1 to An_{100}, and diopside may contain a few % of Al_2O_3 and FeO. Accessories include pyrite, sphene, chalcopyrite, epidote, leucoxene, zircon and amphibole.

There is little or no quartz co-existing with calcite, indicating complete reaction to wollastonite. The diopside indicates some original dolomite; pyrrhotite original pyrite; and the feldspars probably some original kaolinitic layers. The textures and mineralogies are compatible with an origin by hornfelsing of mixed carbonate and siliciclastic sediments by a nearby granite intrusion.

MINERAL PROCESSING TESTS

The Department of Mines has carried out some test work on the wollastonite ores at the request of Kara mine leaseholders Tasmania Mines Pty Ltd. This work encompassed magnetic separation and flotation, and is summarised in Appendix 1.

A wollastonite concentrate with about 73% wollastonite was produced from a 25 kg sample of feed containing about 45% wollastonite. The principal contaminants in the feed were calcite and diopside, and in the concentrate diopside and feldspar. Petrographic studies indicate that crushing to <10 µm would be necessary to liberate all wollastonite from included phases but the proportion of impurities may be low enough for some uses

CONCLUSIONS

While wollastonite is known to occur in this limestone, Thomas and Henderson (1943) observed that the beds containing the mineral were very thin, and even these beds were not pure wollastonite. Extensive sampling of the various bands by Longman (1961) showed that the average content of wollastonite was around 30%, and this could be increased to 37% by 'selective quarrying' and leaving out the chert bands. Reserves were estimated at 1,000,000 tonnes of wollastonite.

To be usable, the Tasmanian wollastonite would first have to be extracted from the chert and limestone with which it occurs, and, as the most useful feature of wollastonite is the acicular nature of the small particles, removal would have to be done without destruction of the small particles. This is likely to be quite difficult. Wollastonite deposits which are currently mined commercially are of quite high grade, compared to the local 30% grade, and are also large enough to support sizeable mining operations which can effect economies of scale.

Nonetheless, despite the small size and relatively poor grade of wollastonite, there may be some potential for this mineral to be mined and used. Recent mineral processing tests (Appendix 1) have shown that a feedstock containing 42% wollastonite can be upgraded by wet magnetic separation and flotation to produce a 70% wollastonite concentrate.

REFERENCES

BAILLIE, P.W.; WILLIAMS, P. R.; SEYMOUR, D. B.; *et al.*. 1986. Geological atlas 1:50 000 series. Sheet 36 (8015S). St Valentines. *Department of Mines, Tasmania.*

ELEVATORSKI, E. A. 1983. Wollastonite; *in:* LEFOND, S. J. (ed.). *Industrial minerals and rocks (Vol. 2).* 1383–1390. American Institute of Mining, Metallurgical and Petroleum Engineers : New York.

HUGHES, T. D. 1950. Limestone at Hampshire. *Unpubl. Rep. Dep. Mines Tasm.* 1950:160.

LONGMAN, M. J. 1962. Wollastonite at Limestone Creek near Hampshire. *Tech. Rep. Dep. Mines Tasm.* 6:10–15.

PETTERD, W. F. 1910. *Catalogue of the minerals of Tasmania.* Department of Mines, Tasmania.

[14 October 1988]

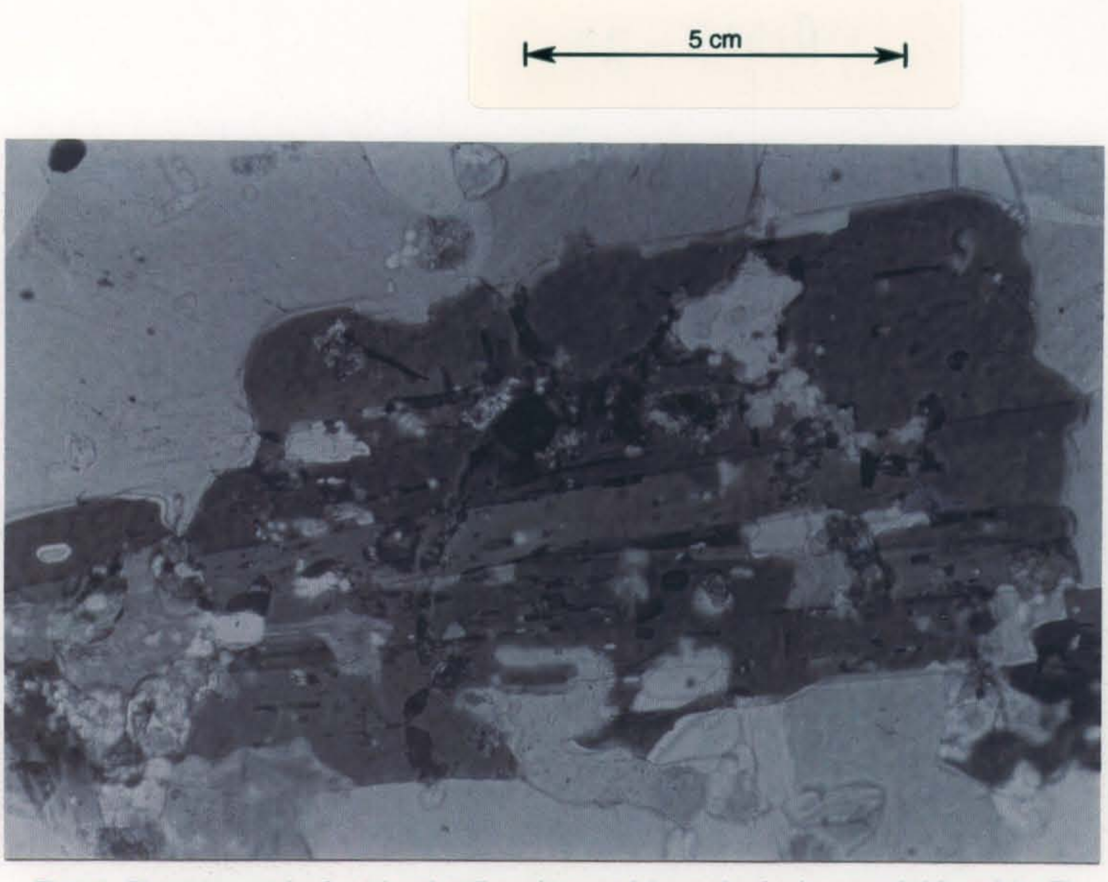

Plate 1. *Photomicrograph of a twinned wollastonite crystal (crossed polars) surrounded by calcite. The wollastonite is richly poikiloblastic with inclusions of calcite and diopside. Field of view 690×460 µm.*

Table 1: Whole rock analyses (Wt. %).

Sample	Si02	Al2O3	Fe2O3	MgO	CaO	CO2	SO3	total
R886/A1	41.44	2.30	1.32	3.47	39.51	8.97	0.10	97.11
T&H1	29.20	3.11	0.72	3.42	44.46	18.62	2.50	102.03
" 3	68.00	4.50	2.20	0.40	21.60	2.60	nd	99.30
851468	46.60	1.70	1.40	4.30	40.70	3.80	0.40	98.90
R886/A8	52.08	2.37	0.78	2.67	41.14	0.62	0.03	99.69
Comm.Mins.	48.77	0.66	0.43	0.06	48.02	1.68	nd	99.62

Table 2. Average Mineral Compositions (Wt. %) from table 5.

	SiO2	Al2O3	Fe2O3	MgO	CaO	CO2	SO3	total
Wollastonite	52.01	0.00	0.00	0.00	47.99	0.00	0.00	100.00
Diopside	54.39	1.75	2.96	15.62	25.63	0.00	0.00	100.35
Calcite	0.00	0.00	0.00	0.00	56.00	44.00	0.00	100.00
Feldspar (An)	55.27	28.17	0.00	0.00	12.38	0.00	0.00	95.82
Quartz	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
Pyrrhotite	0.00	0.00	90.70	0.00	0.00	0.00	91.20	181.90

Table 3: Calculated mineral constitution (from Tables 1 & 2).

Sample	Wollastonite	Diopside	Calcite	Feldspar (An)	Quartz	Pyrrhotite	Haematite	Total
R886/A1	44.93	22.21	20.39	6.78	2.24	0.11	1.21	97.87
T&H 1	29.08	21.89	42.32	9.68	-3.18	2.74	-2.02	97.02
" 3	32.67	2.56	5.91	15.81	40.88	0.00	2.20	97.97
851468	58.92	27.52	8.64	4.32	-1.40	0.44	0.96	96.57
R886/A8	73.06	17.09	1.41	7.35	0.73	0.03	0.75	96.57
Comm. Mins.	94.80	0.38	3.82	2.32	-2.03	0.00	0.43	99.73

Table 4: Sample Descriptions

R886/A1	Bulk ore sample.
T&H 1	Wollastonite-bearing band (Thomas & Henderson, 1943).
" 3	Siliceous band (Thomas & Henderson, 1943).
851468	Bulk ore sample.
R886/A8	Wollastonite concentrate produced from R886/A1.
Comm. Mins.	Commercial wollastonite product (Commercial Minerals).

Table 5: Probe analyses of various minerals from the Kara deposits.

	Woll1	Woll2	Woll3	Av. Woll.	Sphene
SiO2	52.46	53.35	51.32	52.38	31.14
TiO2	bld*	bld	bld	bld	34.9
Al2O3	bld	bld	bld	bld	2.29
Fe2O3	bld	bld	bld	bld	bld
MgO	bld	bld	bld	bld	0.54
CaO	48.89	47.60	48.50	48.33	29.03
Total	101.35	100.95	99.82	100.71	97.90

	Di1	Di2	Di3	Av. Di	Calcite
SiO2	53.89	53.83	56.60	54.77	bld
Al2O3	0.40	4.89	bld	1.76	bld
Fe2O3	3.06	3.45	2.43	2.98	bld
MgO	16.02	13.97	17.21	15.73	bld
CaO	25.44	25.54	26.44	25.81	55.33
Total	98.81	101.68	102.68	101.06	

	Fsp1	Fsp2	Fsp3	Fsp4	Fsp5	Fsp6	Fsp6	Average
SiO2	61.10	59.90	53.50	70.34	49.53	47.74	46.76	55.55
Al2O3	23.80	26.00	28.90	19.93	31.31	33.27	35.01	28.32
CaO	10.00	4.60	16.10	0.10	18.80	18.80	18.70	12.44
K2O	0.40	0.50	0.60	0.10	bld	bld	0.60	0.31
Na2O	4.70	9.00	0.90	11.90	0.40	0.30	bld	3.89
Total	100.00	100.00	100.00	102.37	100.04	100.11	101.07	100.51

* bld: below level of detection

Sample Details:

Mineral No.	Reg. rock No.	Description
Woll1	G400326A	Wollastonite
Woll2	G400326A	Wollastonite
Woll3	G400326A	Wollastonite
Sphene	G400326B	Sphene
Di1	G400326A	Diopside (Di91)
Di2	G400326A	Diopside (Di89)
Di3	G400326B	Diopside (Di93)
Calcite	G400326A	Calcite
Fsp1	G400326A	Bytownite (An70)
Fsp2	G400326A	Andesine (An36)
Fsp3	G400326A	Anorthite (An95)
Fsp4	G400326A	Albite (An1)
Fsp5	G400326B	Anorthite (An96)
Fsp6	G400326B	Anorthite (An96)
Fsp6	G400326B	Anorthite (An100)

Table 6 : Mineralogy of Wollastonite ores (Qualitative).

Sample	Mineral	Approx %	Size range (µm)	Av. size (µm)
400325				
	Wollastonite	60	200-1000	600
	Calcite	30	100-1000	400
	Diopside	5	10-200	100
	Feldspars*	2	20-200	100
	Pyrrhotite	1	20-200	100
	Others*	1	10-100	50
400326A				
	Wollastonite	30	200-2000	1000
	Calcite	60	100-600	300
	Diopside	5	10-200	100
	Feldspars*	5	20-200	100
	Sulphides*	1	10-200	100
	Others*	1	10-100	50
400326B				
	Quartz	30	10-200	50
	Wollastonite	20	10-100	50
	Calcite	5	10-100	50
	Diopside	<1	10-50	20
	Feldspars*	40	2-50	10
	Sulphides*	2	10-200	50
	Others*	1	10-100	50
400335				
	Wollastonite	69	100-1000	300
	Calcite	8	50-500	150
	Diopside	20	10-100	60
	Feldspars*	3	10-60	40
	Sulphides*	1	10-100	40
	Others*	1	10-100	40

* Others include sphene, leucoxene, zircon, epidote, amphiboles and possibly vesuvianite.
Sulphides include pyrrhotite, pyrite and rare chalcopyrite.
Feldspars include plagioclase and potash feldspars.

APPENDIX 1

Treatment of wollastonite ore

INTRODUCTION

A 25 kg sample of wollastonite ore from the Tasmania Mines Kara deposit was treated at the Department of Mines Laboratory at Launceston, with the aim of producing a high-grade wollastonite product.

Some sixteen products from the metallurgical tests were examined by R. S. Bottrill to determine their mineralogical constitution. The results of both the metallurgical and mineralogical investigations are outlined in this appendix.

Metallurgical Investigation

K. J. Austin
P. L. James

The 25 kg sample was processed as follows:

1. The as-received ore was jaw crushed to 4 mm, mixed, then riffled to produce:
   (a) A head sample for chemical analysis.
   (b) Ten one-kilogram samples for test work.

2. Each of the one-kilogram test samples was separately ground in a laboratory ball mill at 40% solids for 25 minutes. Any +600 µm material remaining was reduced to -600 µm by mortar and pestle.

3. One kilogram of ground ore was wet then dry screened to provide a description of grind.

4. Two of the one-kilogram ball mill ground samples were combined (test N1) and fed to a Jones Wet Magnetic Separator using the following conditions:
   (a) Maximum magnetic strength (i.e. 40 amp current)
   (b) Feed rate 250 g/minute
   (c) Wash water 3 litres/minute

5. The Jones magnetic product was fed to a Davis Tube for ball mill iron removal.

6. The Jones non-magnetic product was subjected to calcite froth flotation in a Denver laboratory flotation cell using the following reagents and conditions:
   (a) Sodium carbonate (regulator) — 0.6 kg/tonne
   (b) Oleic acid (collection) — 3.3 kg/tonne
   (c) Aero frother 77 (frother)
   (d) Flotation time — 5 minutes
   (e) Cleaner flotation time — 5 minutes

7. The flotation tailing product (wollastonite concentrate) was subjected to silica froth flotation in a Denver laboratory flotation cell using the following conditions and reagents:
   (a) Aeromine 3037 (collector) — 4 kg/tonne
   (b) Fuel oil (collector) — 1.5 kg/tonne
   (c) Aerofrother 77 (frother)
   (d) Flotation time — 5 minutes
   (e) Cleaner flotation time — 5 minutes

8. Except for the Davis Tube magnetics or ball mill iron product, all N1 products were assayed for Loss on Ignition, CaO, MgO, Fe_2O_3, Al_2O_3, and SiO_2.

9. A further Jones Magnetic separation test was performed on six kilograms of sample, with the non-magnetic product being subject to rougher calcite froth flotation only. All conditions used were those as previously described. This test was termed N2, and only the rougher flotation tail or wollastonite concentrate was analysed.

The results obtained from the metallurgical tests are shown in Tables 7–9.

Fusion Point Determination of Concentrate

The fusion point of the test N2 wollastonite concentrate 1400°C, with the softening point being 1280°C.

Firing Tests of N2 Concentration

Small test pieces were made (using the wollastonite concentrate) and fired in an electric furnace for six hours at 1000°C. The surfaces of the fired test pieces showed a slight pink tinge, probably due to the oxidation of the contained iron (0.9% Fe_2O_3). Superficial fritting occurred and the test pieces were quite fragile.

Table 7. *SIZING ANALYSES — 25 MINUTE BALL MILL GRIND*

Particle size (µm)	Percent mass	Cumulative Percent mass
-4000 + 2360	0.4	0.4
-2360 + 1180	0.1	0.5
-1180 + 600	0.1	0.6
-600 + 300	0.1	0.7
-300 + 150	2.7	3.4
-150 + 75	3.7	7.1
-75 + 38	0.3	7.4
(-38)	(92.6)	(100.0)
C/S 1	19.8	27.2
C/S 2	21.6	48.8
C/S 3	12.8	61.6
C/S 4	13.2	74.8
C/S 5	6.0	80.8
O/F	(19.2)	100.0
Head	100.0	--

C/S at 24oC

Table 8. *OVERALL TEST RESULTS*

Product	% Mass	% LOI	% CaO	% SiO_2	% MgO	% Fe_2O_3	% Al_2O_3	% CaCO from LOI
+ 600 µm	0.6	-	-	-	-	-	-	-
Davis tube M/A (Tramp iron)	0.3	-	-	-	-	-	-	-
Davis tube Non Mag	4.6	3.5	29.7	44.5	7.3	10.1	3.5	8.0
=Jones Magnetics Diopside, Augite etc.	4.9	3.5	29.7	-	-	-	-	-
Jones M/S Washings =Middlings	11.1	5.4	37.9	45.1	5.5	1.5	2.7	12.3
Cleaner FC (Calcite Conc)	23.7	25.5	44.2	21.0	3.5	0.9	1.5	58.0
Cleaner FT (Middling)	7.9	1.2	36.7	49.5	5.6	1.5	2.7	2.7
Rougher FC (mainly cal) =Sum of CFC & CFT above	31.6	(19.4)	(42.3)	(28.1)	(4.0)	(1.1)	(1.8)	(44.1)
*Rougher FT (Wollastonite Conc)	51.8	0.62	41.1	52.1	2.7	0.8	2.4	1.4
Jones Non Mags =Sum of FC & FT above	83.4	(7.7)	(41.6)	(43.0)	(3.2)	(0.9)	(2.2)	(17.5)
Calc H/D	100.0	(7.2)	(40.2)	(42.9)	(3.6)	(1.4)	(2.3)	(16.4)
Head assays	-	9.0	39.5	41.4	3.5	1.3	-	(20.5)

+ *Test N2*

Product	% Mass	% LOI	% CaO	% SiO_2	% MgO	% Fe_2O_3	% Al_2O_3
F1T (Wollastonite Conc)	55.0	0.9	40.8	51.9	2.8	0.9	2.3
F1C (Calcite Conc)	29.1	-	-	-	-	-	-
Jones M/S N	84.1	-	-	-	-	-	-
Jones M/S W (washings)	11.8	-	-	-	-	-	-
Jones M/S M/A	4.1	-	-	-	-	-	-
Head	100.0	-	-	-	-	-	-

* The calculated wollastonite content of the Rougher FT (wollastonite concentrate) was found to be approximately 70.5 % in a mass of 51.8 % overall.

+ The yield and chemical composition of the wollastonite product from test N2 was very similar to that of test N1. Test N2 was only performed such that a quantity of wollastonite concentrate would be available for commercial evaluation.

Table 9. *SILICA FLOTATION OF ROUGHER FT (WOLLASTONITE CONCENTRATE)*

Product	% Mass	% LOI	% CaO	% SiO_2	% MgO	% Fe_2O_3	% Al_2O_3
CFC	34.3	0.77	41.7	51.8	2.2	0.90	2.2
CFC	2.4	0.75	39.8	51.5	3.5	0.87	3.1
F1C	36.7	(0.77)	(41.6)	(51.8)	(2.3)	(0.90)	(2.3)
F1T	15.1	0.70	39.6	51.3	3.5	0.70	2.3
FT	51.8	(0.75)	(41.1)	(51.6)	(2.6)	(0.84)	(2.3)

Whilst it is readily apparent that the wollastonite concentrate contains an excess of SiO_2, conventional silica flotation did not achieve any SiO_2 removal or concentration.

Mineralogical Investigation

R. S. Bottrill

Sixteen products from metallurgical tests on wollastonite ores from the Kara area were submitted for determination of their mineralogical constitution. Sample details are summarised in Table 10.

The samples were all run on the X-ray diffractometer, calibrated externally with pure and weighed mixes of minerals similar to the constituent phases (calcite, wollastonite, diopside, and feldspar). Calibration was difficult due to the mixture of several minerals with complete X-ray patterns and indefinite compositions. The results are shown in Table 10.

The measured whole-rock analyses (Table 11, by XRF) were used to estimate compositions for constituent phases (Table 12), and thus calculate the expected whole-rock composition (Table 13). The measured and calculated compositions are not in particularly good agreement: CaO, SiO_2 and CO_2 are generally comparable (A2 would be better if an iron-bearing phase could have been measured) but the minor components Al_2O_3, MgO and Fe_2O_3 correlate poorly. This suggests that the calibrating samples may have been inappropriate in composition for these products, and/or the minerals have greater compositional variability than expected. The results in Table 10 are thus more precise than accurate, and may only be taken to indicate relative compositional trends.

The XRF analyses (Table 11) were converted into mineralogical constitutions (Table 14) using the estimated mineral compositions in Table 12. These figures may be more accurate than those in Table 10 but should still be used with caution, as accurate mineral compositions are not available. Quartz and hematite were not detected but are represented in Table 14 to indicate excess silica and Fe_2O_3 from the calculations, which could be corrected to zero by manipulation of mineral compositions. Na and K in the XRF analyses could indicate some albite and alkali feldspars.

The calculated mineralogy of the feed (A1 in Table 14) is about 42% wollastonite, 23% diopside, 20% calcite and 9% feldspar. This indicates a little more diopside than expected from preliminary studies. The ore samples examined to date indicate ranges in mineralogy of about 30–70% wollastonite, 5–60% calcite, 1–20% diopside, 2–40% feldspar and 1–2% sulphides. The ore is obviously very variable, and more selective mining may be necessary to maximise the wollastonite in the feed.

Table 10. Mineral Constitution by XRD (Wt. %, semi-quantitative), and sample descriptions.

No.	Description	Woll. *	Di	Calcite	Fsp
A1	Head	-	-	-	-
A2	Jones M/S, M/A	65	30	4	1
A3	1st M/S test,+600	81	17	1	1
A5	Jones washings	69	18	12	1
A6	CFC (Calcite Con)	19	11	68	2
A7	CFT (Middling)	76	18	4	2
A8	FT (Woll. Con)	92	7	0	1
A9	C/S 1	74	13	11	2
A10	C/S 2	79	7	13	1
A11	C/S 3	77	10	12	1
A12	C/S 4	79	10	10	1
A13	C/S 5	77	9	13	1
A14	-4000+150μm	83	11	5	1
A15	-150+38μm	83	10	6	1
A17	F1T	91	8	0	1
A18	F2T	92	5	1	2
A19	F2C	94	4	0	2

*Abbreviations in table 15.

Table 11: Whole rock analyses -XRF (Wt. %).

No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	CO_2	SO_3	total
A1	41.44	2.30	1.32	3.47	39.51	8.97	0.10	97.11
A2	44.51	3.47	10.06	7.27	29.67	3.52	1.12	99.62
A5	45.05	2.71	1.49	5.47	37.90	5.35	0.08	98.05
A6	20.96	1.46	0.90	3.53	44.24	25.51	0.02	96.62
A7	49.47	2.69	1.52	5.61	36.72	1.23	0.04	97.28
A8	52.08	2.37	0.78	2.67	41.14	0.62	0.03	99.69

Table 12. Estimated Mineral Compositions (Wt. %)

No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	CO_2	SO_3	total
Woll.	51.7	0	0	0	48.3	0	0	100
Di	53	2.5	3.6	15	25.9	0	0	100
Calcite	0	0	0	0	56	44	0	100
Fsp (An)	64.8	18.3	0	0	17	0	0	100.1
Qtz	100	0	0	0	0	0	0	100
Po	0	0	90.7	0	0	0	91.2	181.9

Table 13: Whole rock analyses calculated from Tables 10 and 12.

No.	SiO2	Al2O3	Fe2O3	MgO	CaO	CO2	total
A2	50.15	0.93	1.08	4.50	41.58	1.76	100.00
A3	51.54	0.61	0.61	2.55	44.26	0.44	100.00
A5	45.86	0.63	0.65	2.70	44.88	5.28	100.00
A6	16.95	0.64	0.40	1.65	50.45	29.92	100.00
A7	50.13	0.82	0.65	2.70	43.95	1.76	100.00
A8	51.92	0.36	0.25	1.05	46.42	0.00	100.00

Table 14: Calculated mineral constitution (from Table 11).

No.	Woll	Di	Calcite	Fsp(An)	Qtz	Po	Hem	Total
A1	42.46	23.1	20.4	9.4	1.13	0.11	0.39	97.02
A2	21.61	48.5	8.0	12.3	-0.35	1.23	7.20	98.51
A5	41.34	36.5	12.2	9.8	-2.02	0.09	0.10	97.97
A6	10.01	23.5	58.0	4.8	0.22	0.02	0.03	96.57
A7	49.40	37.4	2.8	9.6	-2.11	0.04	0.13	97.26
A8	70.45	17.8	1.4	10.5	-0.59	0.03	0.11	99.73

Table 15: Abbreviations

Woll.	Wollastonite ($CaSiO_3$)
Di	Diopside ($CaMgSi_2O_6$)
Fsp (An)	Feldspar (anorthite: $CaAl_2Si_2O_8$)
Qtz	Quartz (SiO_2)
Po	Pyrrhotite (FeS)