INTRODUCTION

This report gives a brief summary of work carried out during 1991 on the Olden Township wollastonite property of Ram Petroleums Limited. The great majority of the work consisted of beneficiation studies, which are described in a separate report by J. Kriens of IMD Laboratories Ltd.

PROPERTY, LOCATION AND ACCESS

The property consists of two unpatented claims, SO 748449 and 748450, covering the north-east and north-west quarters respectively of lot 4, Concession III, Olden Township, Frontenac County, Southern Ontario Mining Division. The claims have a nominal area of 50 acres each.

The property lies about 6 km south of the village of Mountain Grove, which is 2 km south of Highway 7, 51 km west of Perth and about 280 km east of Toronto. A township road which links the hamlets of Long Lake and McLean runs across the property and provides access.
HISTORY, PREVIOUS WORK, GEOLOGY

The history and geology of the property are described in a previous report (Ram Petroleums Limited, Report on 1990 Diamond Drilling Programme, Hawley Wollastonite Property, Olden Township, Frontenac County, South-Eastern Ontario, by C. R. Bowdidge, December 1990). This information will not be repeated here.

WOLLASTONITE DEPOSIT

On the basis of surface geological mapping and 1,500 metres of diamond drilling, a wollastonite deposit has been defined. It consists of an irregular lens 250 metres long, up to 55 metres thick, with a dip of approximately 40° to the north. It has been traced to a maximum depth of 120 metres vertically below surface.

Reserves are estimated at 2,517,055 tonnes with an estimated content of material containing approximately 32% wollastonite. The remainder of the rock consists of calcite with minor diopside and accessory amounts of quartz, feldspar, and garnet.

BENEFICIATION STUDIES

Laboratory work in 1991 was carried out on two types of material: (1) split core from the 1990 diamond drilling programme, and (2) a bulk sample taken from a trench in 1989. The split core was made into a number of composite samples with a view to subjecting each to a consistent beneficiation process to assess variations in grade and quality of the wollastonite through the deposit. A composite of all split core samples (excluding some lower grade material from the extremities of the deposit) was also made. Sample numbers in J. Kriens' report are the same as those in drill logs presented in the 1990 drilling report (Bowdidge, op cit).
Bulk material from the trench was used where larger quantities of material were required, as for testing grinding techniques, or where unproven flotation agents were being tested.

At one point in the laboratory programme, the writer was requested to re-examine the drill core because certain composite samples gave wollastonite contents with anomalously high alumina contents. It became apparent that haloes of feldspathization are present in the wollastonite-calcite ore for up to 50 cm around granitic dykes which cut the deposit, although many such dykes are very narrow (as little as 1 cm thick). Further refinements of the flotation technique by Mr. Kriens resulted in a lowering of the alumina content, and it was concluded that this, in combination with one or more of (a) selective rejection of feldspatic material during mining, (b) a picking belt between primary and secondary crushing, and (c) grade control by blending ore from different parts of the deposit, would result in an acceptable commercial product.

RECONNAISSANCE FOR ADDITIONAL WOLLASTONITE OCCURRENCES

The writer and A.J. Menard spent several days examining carbonate rocks exposed on roadsides and in road cuts throughout Olden and Oso Townships, with a view to locating additional occurrences of wollastonite. The restriction to roads was imposed because most land in these townships is patented, and therefore inaccessible to casual exploration. Mr. Menard also made a few traverses across lots where mineral rights are vested in the Crown, and over patented land with the permission of the owners.
Only one new occurrence of wollastonite mineralization was located by this work. It consists of a band of calcite-wollastonite marble which varies in thickness from 0.5 to 2 metres, and carries an estimated 15% of wollastonite. The location is not being made public, because the mineralized zone lies on two patented lots, and agreements to explore it have not yet been reached with the property owners.

Respectfully submitted,

C. R. Bowdidge, M.A., Ph.D.

DEVELOPMENT OF A BENEFICIATION PROCESS FOR SEPARATING WOLLASTONITE FROM CALCITE, DIOPSIDE & OTHER TRACE MINERALS

I.M.D. PROJECT # 90254
I.M.D. REPORT # 90254-3

Prepared for:
Ram Petroleums

Prepared by:
I.M.D. Laboratories Ltd.

December, 1991
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1.0 SUMMARY

* A composite prepared from wollastonite-rich sections of drill cores, representing the deposit being explored, can be processed by a special grinding process to produce wollastonite of high aspect ratio.

* This confirms that all of the ore in the deposit is amenable to the selected grinding process.

* Flotation tests, conducted on either the bulk sample or on the core-composite ground in a high speed hammer mill, confirms that a good quality high-aspect-ratio wollastonite product can be produced.

* Several reagent systems have been identified and are capable of facilitating effective separation. Further work is required to establish optimum process conditions and cost effectiveness of the various reagent systems.

* Wollastonite products produced by flotation are sufficiently low in iron content to require no further treatment by magnetic separation. Residual diopside remaining in wollastonite concentrates may be removed at a lower capital cost with flotation than with high intensity magnetic separation. Work in this area is recommended.

* The calcite fraction obtained by flotation of the drill core composite is not as clean as from the bulk surface sample. Additional processing is required to achieve a calcite product of commercially acceptable quality.

* No significant progress has been made in reducing the residual feldspar in the wollastonite product. The amount of feldspar remaining in the wollastonite is small and may not be a factor in product acceptance. Work to be conducted with a mixture of a phosphoric acid mono and diester of alkyl polyglycol ethers may result in further improvements.

2.0 INTRODUCTION

This report is a continuation of reporting results obtained in processing the Ram Petroleums' wollastonite ore.

The report outlines results from a number of flotation tests, using different chemical reagents or approaches, to the beneficiation process as well as results of grinding tests on a bulk composite prepared from drill core samples.

Results as reported are for work completed prior to December 31, 1991.
3.0 MINERAL SEPARATION BY DRY PROCESSING

Distinct differences in the particle shape of the various minerals contained in the ore present an opportunity for achieving mineral separation by taking advantage of these differences. The highly developed acicular structure of the wollastonite, as compared to the cubical shape of the calcite and rounded grain shape of diopside, not only means significant differences in particle shape but also in particle size.

Two processing methods dependant on differences in particle size and/or shape (in order to achieve separation) are screening and air classification. A third method, electrostatic separation, depends on electro-physical properties of the minerals to achieve mineral separation.

It was considered prudent to at least conduct exploratory tests to determine if any of these techniques have a chance of succeeding or at least resulting in concentrating the wollastonite.

3.1 Air Classification

In air classification, the separation of minerals is based on particle size for materials consisting of a single mineral. For materials containing several minerals, separation is based on particle mass i.e. a small particle of magnetite will behave similarly to a larger particle of quartz with the same mass. If air classification is 100% efficient then theoretically the coarse fraction from the classifier should contain only particles of greater unit mass and the fine fraction only particles of a lower mass, irrespective of particle size. The separation point is controlled by centrifugal- and air-drag forces.

Other factors that play a significant role are the surface area of a particle and particle shape. A large flat particle with a given unit mass will thermodynamically behave differently than a perfect sphere of the same material and identical mass.

It was felt that with differences in specific gravity, particle shape and surface areas separation of wollastonite from the other minerals could be achieved.

To determine this tests were conducted at Progressive Industries Ltd. in Sylacauga, Alabama, a manufacturer of a high efficiency air classifier. A total of fifteen tests were conducted using part of the bulk sample ground in a high speed hammer mill. The wollastonite has a high aspect ratio and needles are generally very thin.

Tests conducted under a broad range of classifier settings showed that the shape difference was less of a factor than had been anticipated. Very thin but long wollastonite particles were collected in the same classifier fraction as the fine diopside and calcite. Short but thick and long but thicker wollastonite was concentrated with coarser calcite and diopside particles. While it was not possible to make effective separation it is clear that the bulk of the very high aspect ratio wollastonite is concentrated in the fine fraction from the classifier. This by itself is of interest in that it provides a means of separating "very high" aspect ratio wollastonite from coarser "lower aspect" ratio wollastonite. It further suggests that air classification combined with screening may be worth investigating as a means of separating wollastonite on the basis of aspect ratio.

From these results it was concluded that with the material used in the testwork it was not possible to make an acceptable separation of the minerals contained in the sample.
3.2 Dry Screening

As noted, there is a very distinct shape difference in the various minerals contained in the ore following grinding in a high speed hammer mill. In general, the wollastonite consists of thin needles with lengths 5 to 20 times greater than the diameter. By comparison the calcium carbonate has the characteristic hexagonal crystal shape i.e. looks like a small cube. The diopside tends to be more of a sugary, rounded grain.

Microscopic examination clearly shows that the length of wollastonite needles is many times greater than the largest dimensions of the calcite or diopside particles. Hence it should theoretically be possible to achieve a separation by screening. Practically it is much more complex as it requires that the wollastonite be oriented parallel to the screen surface. If the wollastonite is randomly oriented or subjected to a constant change in orientation it is quite possible for the wollastonite to pass through the screen opening if its orientation is at or near right angles to this opening.

Most commercial screens are of the vibratory-type which tends to cause particles to bounce rather than slide across the screen. This was confirmed by tests at I.M.D. Laboratories in which vibratory screening was compared with a more gentle sliding motion over a screenscraper.

It was found that significant amounts of calcite and diopside could be removed by screening if the screen motion had only a minimal vibratory action, allowing material to slide over the screen rather than bounce on it.

A screening test was arranged with Sweco of Canada Ltd. This test was conducted using material ground in the high speed hammer mill.

Results of these tests were encouraging in that it was possible to achieve a significant increase in the concentration of wollastonite in the fraction passing over the screen and removal of a large portion of the calcite and diopside with the material passing through the screen.

A test conducted at 120 mesh showed that 52.4% of the material passed over the screen and 47.6% passed through the screen.

From microscopic examination of the two fractions it was estimated that the coarse fraction contains approximately 60 - 65% wollastonite by volume and the fine fraction is estimated to contain 10 - 15% wollastonite.

Of importance is that losses of high aspect ratio wollastonite in the fine fraction were surprisingly low. Most of the wollastonite in the fine fraction tends to be the shorter, fine needles and shards of wollastonite rather than high aspect ratio particles.

While losses of wollastonite are not acceptable at this level, it is indicated that this may be improved by additional screening. Dry screening should be given consideration in further development work.
3.3 Electrostatic Separation

Separation of wollastonite from the other mineral constituents by electrostatics was considered as a possibility. This was discussed with Dr. Grandy, Research Director for Carpco Incorporated, Jacksonville, Florida.

Dr. Grandy indicated that they had made separations of wollastonite and diopside from calcite followed by removal of diopside by magnetic separation. A sample of hammer mill ground material was forwarded to Carpco. However, they were not able to make a separation at the particle size of the submitted sample.

Dr. Grandy indicated that separation would be more likely on coarser feed material. Based on the lack of success no further consideration should be given to electrostatic separation.

4.0 SEPAEATION BY FLOTATION OF HIGH ASPECT RATIO WOLLASTONITE FROM OTHER MINERALS

All previous flotation work was conducted on conventionally ground core samples which served to provide data on wollastonite content, quality recovery and in essence providing information on ore grade product recovery.

Conventional grinding methods unfortunately cause the acicular structure of the wollastonite to be damaged, producing mostly wollastonite with low aspect ratio. For separation it is necessary that all the minerals are physically separated from each other by grinding to the liberation point.

While conventional grinding was satisfactory for providing an assessment of ore grade, for commercial development it is necessary to grind the ore with specialized equipment that will maintain the structural integrity of and produce wollastonite with a highly acicular particle shape and a resulting aspect ratio of up to 20:1.

An appropriate grinding process has been successfully developed for the ore contained in the Ram Petroleums deposit, producing a wollastonite product with aspect ratios comparable to the best available commercial products.

Wollastonite ground in this manner has a high surface area and low bulk density. This imposes a different set of conditions on the flotation process. The fine particles size, high surface area and acicular nature of the wollastonite combine to change operational conditions in the flotation process.

For this reason exploratory flotation tests were conducted using a bulk sample ground with a high speed hammer mill and subsequently on material produced by grinding a drill core composite in the same mill. These flotation tests explored several reagent combinations, depressants for calcite, reverse flotation and other process variables such as pulp density, reagents, rate of addition, pH and process sequence.

Most of the flotation work on drill core samples successfully used a quaternary amine as collector in flotation. Use of this reagent was continued on material ground in the hammer mill. Initial tests concentrated on using various depressants for calcite and/or diopside during flotation.
4.1 **Flotation Using Quaternary Amines**

Initial tests consisted of testing various chemical additives for their effectiveness as a diopside depressant. These were compared with a control test, not using a depressant and only amine as collector. Wollastonite and calcite products were tested for loss on ignition and acid insoluble residue.

Flotation feed was from the hammer mill ground bulk sample. Process yields, loss on ignition and acid solubles are shown on table #1

<table>
<thead>
<tr>
<th>Flotation Reagent System</th>
<th>% Wollastonite Yield</th>
<th>% Calcite Yield</th>
<th>% L.O.I. Wollastonite</th>
<th>% Acid Insol. Calcite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary Amine #1</td>
<td>43.80</td>
<td>34.00</td>
<td>1.86</td>
<td>1.24</td>
</tr>
<tr>
<td>Quaternary Amine #1 + Starch</td>
<td>45.60</td>
<td>33.80</td>
<td>1.45</td>
<td>1.16</td>
</tr>
<tr>
<td>Quaternary Amine #1 + Citric Acid</td>
<td>46.10</td>
<td>31.70</td>
<td>2.18</td>
<td>3.32</td>
</tr>
<tr>
<td>Quaternary Amine #1 + Acetic Acid</td>
<td>44.60</td>
<td>31.70</td>
<td>1.65</td>
<td>3.33</td>
</tr>
</tbody>
</table>

**OBSERVATIONS:**

Of the three depressants, starch appears to give the best overall results relative to product yield, loss on ignition of wollastonite and lower acid insolubles in the calcite.
4.2 **Flotation With Fatty Acids**

In all of the flotation tests the practise has been to float the wollastonite away from the calcite and other minerals. A single exploratory test was conducted to float calcite from wollastonite.

This test used an emulsion prepared from a fatty acid and sodium hydroxide as the collector for calcite. No other reagent was used. The objective was to achieve a clean wollastonite concentrate, low in calcite and with a good white colour after firing at 1000\(^0\) C.

Observations during the test indicated losses of wollastonite in the calcite fraction. Following filtering of the calcite and wollastonite concentrates it was noted that most of the diopside was contained in the wollastonite while significant amounts of wollastonite were lost to the calcite concentrate. The conclusion was that fatty acid is neither a particularly effective nor selective collector.

The wollastonite product had a high ignition loss (2.67%), indicative of carbonates. The colour of the fired wollastonite was grey indicating presence of iron-bearing minerals in the wollastonite.

Despite lack of success the concept of floating the calcite has merit. It eliminates the potential problem of chemical reagent residues in the wollastonite particles. Reverse flotation should be given further consideration, using other reagents such as petroleum sulphonates or di-ester amines of phosphoric acid.

4.3 **Flotation With Other Reagents**

Following a literature search and discussions with reagent manufacturers other potential reagents for flotation of wollastonite from calcite or calcite from wollastonite were considered. Several of these reagents were obtained and preliminary tests were conducted.

The reagents tested were other quaternary amines, an imadozoline and a complex di-ester amine of phosphoric acid.

Each test was conducted using the bulk surface sample as feed material and consisted of a rougher and three (3) cleaner floats. Resulting wollastonite products were tested for loss on ignition and fired colour. Products with low loss on ignition and good fired colour also analyzed for their chemical composition.

Table # 2 gives process details on each of the tests, loss on ignition and fired colour. Table # 3 gives the chemical composition of these analyzed samples.
### TABLE # 2

**PRELIMINARY TESTS WITH OTHER COLLECTORS**

<table>
<thead>
<tr>
<th>Process Fraction</th>
<th>%</th>
<th>Imadozaline</th>
<th>Imadozaline + Sodium Silicate</th>
<th>Quaternary Amine #2</th>
<th>Quaternary Amine #2 + Starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rougher (Calcite) Tailings</td>
<td>39.0</td>
<td>47.5</td>
<td>25.7</td>
<td>23.8</td>
<td></td>
</tr>
<tr>
<td>1st. Cleaner Tailings</td>
<td>8.4</td>
<td>6.4</td>
<td>15.1</td>
<td>16.5</td>
<td></td>
</tr>
<tr>
<td>2nd. Cleaner Tailings</td>
<td>3.2</td>
<td>2.5</td>
<td>9.0</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>3rd. Cleaner Tailings</td>
<td>1.5</td>
<td>1.0</td>
<td>5.6</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>Magnetics-Wollastonite</td>
<td>0.3</td>
<td>1.8</td>
<td>0.6</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Magnetics-Calcite</td>
<td>---</td>
<td>---</td>
<td>0.3</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Wollastonite Product</td>
<td>47.6</td>
<td>40.7</td>
<td>43.8</td>
<td>47.7</td>
<td></td>
</tr>
<tr>
<td>Loss on Ignition</td>
<td>0.39%</td>
<td>0.83%</td>
<td>1.90%</td>
<td>2.74%</td>
<td></td>
</tr>
<tr>
<td>Fired Colour</td>
<td>White</td>
<td>White</td>
<td>Grey/Purple</td>
<td>Grey/Purple</td>
<td></td>
</tr>
</tbody>
</table>

**Comments:**

The new quaternary amine is not selective. Co-flotation of calcite was more prominent than with quaternary amine #1. Only the two concentrates produced with the imadozaline were analyzed. The test in which only imadozaline was used produced a clean concentrate with low loss on ignition and a very white fired colour.

* Imadozoline is a short name for 1) hydroxyethyl - 2) alkylimadozaline
### TABLE # 3
CHEMICAL COMPOSITION OF IMADOZOLINE TEST PRODUCTS

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>IMADOZOLINE</th>
<th>IMADOZOLINE + SODIUM SILICATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>SiO₂</td>
<td>53.00</td>
<td>54.30</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.21</td>
<td>0.26</td>
</tr>
<tr>
<td>CaO</td>
<td>45.40</td>
<td>44.20</td>
</tr>
<tr>
<td>MgO</td>
<td>0.12</td>
<td>0.22</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.11</td>
<td>0.44</td>
</tr>
<tr>
<td>MnO</td>
<td>0.042</td>
<td>0.44</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.021</td>
<td>0.026</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>L.O.I.</td>
<td>0.54</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Comments:
Both products contain small amounts of residual diopside and feldspar but are otherwise of excellent quality. Results are fully comparable with the standard quaternary amine collector and based on these tests further work with this reagent is warranted. The lower feldspar and diopside content of the wollastonite is highly encouraging.
One other reagent, a mixture of a phosphoric acid mono and diester of alkyl-polyglycol ethers, is being evaluated. Based on initial observations this chemical is capable of floating calcite at neutral or basic conditions and quartz, feldspar and other silicates at acidic conditions. This reagent will be referred to as the new reagent.

With the particular mineralogical composition of the Ram Petroleums "wollastonite-calcite" ore such a reagent may be very effective in first floating off all of the calcite, followed by acidification and flotation of other silicate minerals.

A test using hammer mill "ground material" was conducted using the new reagent and compared with a test using the "standard" quaternary amine #1 procedure i.e. floating wollastonite from the other minerals. The ground material was from the drill core composite.

The new reagent, a product of Hoechst Chemical, is made in Germany. The cost is significantly higher than the quaternary amine #1 but lower amounts may be required. Its effectiveness as a reagent must be better defined before its cost effectiveness can be established.

The initial test worked very well. Calcite was floated first, followed by a single cleaner float on the calcite concentrate. The two sink portions (wollastonite) were combined, acidified with sulphuric acid and silicate minerals floated off.

Table # 4 shows a comparison in product yield and quality with the comparative quaternary amine #1 test.
### TABLE # 4

<table>
<thead>
<tr>
<th>PROCESS FRACTION</th>
<th>NEW REAGENT</th>
<th>QUATERNARY AMINE #1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Calcite Tailings</td>
<td>59.60</td>
<td>55.20</td>
</tr>
<tr>
<td>1st. Cleaner Tailings</td>
<td>10.00</td>
<td>11.70</td>
</tr>
<tr>
<td>2nd. Cleaner Tailings</td>
<td>----</td>
<td>3.50</td>
</tr>
<tr>
<td>3rd. Cleaner Tailings</td>
<td>----</td>
<td>1.30</td>
</tr>
<tr>
<td>Wollastonite Product</td>
<td>30.30</td>
<td>28.30</td>
</tr>
</tbody>
</table>

### CHEMICAL COMPOSITION

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>T-13</th>
<th>T-14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NEW REAGENT</td>
<td>QUATERNARY AMINE #1</td>
</tr>
<tr>
<td>SiO₂⁻</td>
<td>52.10 %</td>
<td>52.20 %</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.74</td>
<td>0.75</td>
</tr>
<tr>
<td>CaO</td>
<td>44.00</td>
<td>44.00</td>
</tr>
<tr>
<td>MgO</td>
<td>0.68</td>
<td>0.66</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.12</td>
<td>0.11</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.34</td>
<td>0.33</td>
</tr>
<tr>
<td>Fe₂O₃⁻</td>
<td>0.16</td>
<td>0.20</td>
</tr>
<tr>
<td>MnO</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.003</td>
<td>0.004</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>L.O.I.</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>L.O.I. (IMD)</td>
<td>0.59</td>
<td>0.87</td>
</tr>
<tr>
<td>Fired Colour</td>
<td>White</td>
<td>White</td>
</tr>
</tbody>
</table>
Comments:

The new reagent system is simple to operate and requires less flotation equipment. Recovery is good and product quality is identical with the quaternary amine product. Neither of the two products were processed by magnetic separation in order to facilitate comparison of the flotation process.

Magnetic separation will result in reducing the diopside content of the products. Obviously magnetic separation is not required to reduce the iron content since it is already very low. For this reason, removal of residual diopside by flotation is considered an option that must be investigated. The test with the new reagent was no more successful than amine #1 with respect to reducing the feldspar content of the wollastonite product. Since only a single test has been performed it is premature to presume that this reagent will not be effective for feldspar reduction. More testing is obviously required.

5.0 MAGNETIC SEPARATION OF DIOPSIDE FROM GROUND ORE OR FROM WOLLASTONITE-CALCITE CONCENTRATES

Diopside is present in the ore in various quantities and type. It ranges from an almost colourless to yellow shading into an apple green variety which is likely hedenbergite, an iron rich variety with iron substituting for magnesia.

It has been observed during flotation (using the quaternary amine #1 process) that the darker varieties remain mostly in the flotation tailings, while the clearer transparent variety tends to report with the wollastonite concentrate.

This in effect means that, based on our the current knowledge of processing this type of ore, diopside remaining in the wollastonite product must be removed by high intensity magnetic separation. The same is true for the calcite concentrate. Diopside would have to be removed by magnetic separation if the calcite product is to be marketed.

There are two options relative to magnetic separation. They are:

A) Magnetic separation of the ore after grinding but before flotation

B) Magnetic separation of the wollastonite concentrate after flotation

Option A) is only of interest if both the wollastonite and calcite products are to be marketed while option B) is used if only the wollastonite is marketed.

While high intensity magnetic separation is an effective processing tool, capital cost are significant. It is for this reason that further effort be directed towards removing diopside by flotation.
5.1 Removal of Diopside By Flotation

Recent work with a different flotation reagent indicates that it may be possible to integrate diopside removal with the wollastonite-calcite flotation process. It is further indicated that this may also reduce residual feldspar and quartz.

Only limited work has been done but results are sufficiently encouraging to warrant further work.

6.0 GRINDING OF A COMPOSITE PREPARED FROM DRILL CORE SAMPLES

As noted, wollastonite must be ground using a special grinding technique to maintain and enhance the acicular particle shape. This results in a wollastonite product with a high aspect ratio.

In previous work a bulk surface sample was used for grinding tests. This test was very successful in obtaining a wollastonite product with high aspect ratio.

A second series of grinding tests were conducted using a composite prepared from all of the "wollastonite rich" ore sections identified in drill cores.

The composite made up from drill core sections differs from the bulk surface sample in that some ore sections are richer in diopside and in some cases also contain feldspar and quartz in small amounts as well as traces of sulphide minerals.

All grinding tests were performed with the high speed hammer mill equipped with ceramic liners and deflector bars. A total of four separate tests were made.

6.1 Evaluation of Results

Ground products show that the wollastonite has an excellent "aspect ratio" as was the case with the ground bulk surface sample. This confirms that the wollastonite rich ore, as identified in the drill core and other testing, responds well to the grinding process and results in wollastonite with the desired high aspect ratio.

It must be noted that in this latest series of grinding tests the hammer mill was equipped with deflector bars as well as ceramic liners. The function of the deflector bars is to assure the material stays in the grinding zone, reducing risk of wear on the rotor.

In evaluating the ground products it was observed that the products were generally finer than the previous tests without deflector bars. This however may also be due to the fact that the drill core composite is of a different mineralogical composition (with respect to associated minerals) than the bulk surface sample.

Results from the four (4) grinding tests are shown on table # 5
### TABLE # 5

**A.C.M. GRINDING TEST**

<table>
<thead>
<tr>
<th>Test #</th>
<th>Rotor Speed</th>
<th>Classifier Speed</th>
<th>Airflow M³/Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-1</td>
<td>5500 R.P.M.</td>
<td>2000 R.P.M.</td>
<td>18 M³/Min.</td>
</tr>
<tr>
<td>R-2</td>
<td>5500 R.P.M.</td>
<td>2000 R.P.M.</td>
<td>20 M³/Min.</td>
</tr>
<tr>
<td>R-3</td>
<td>5500 R.P.M.</td>
<td>1500 R.P.M.</td>
<td>20 M³/Min.</td>
</tr>
<tr>
<td>R-4</td>
<td>5500 R.P.M.</td>
<td>1750 R.P.M.</td>
<td>20 M³/Min.</td>
</tr>
</tbody>
</table>

### PRODUCT ANALYSIS

<table>
<thead>
<tr>
<th>Test # 7</th>
<th>% Retained on 100 mesh</th>
<th>% -100 + 200 m.</th>
<th>% -200 + 325 m.</th>
<th>% -325 m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-1</td>
<td>4.04</td>
<td>21.70</td>
<td>32.40</td>
<td>41.90</td>
</tr>
<tr>
<td>R-2</td>
<td>4.59</td>
<td>15.77</td>
<td>38.70</td>
<td>40.90</td>
</tr>
<tr>
<td>R-3</td>
<td>6.40</td>
<td>17.29</td>
<td>26.80</td>
<td>49.50</td>
</tr>
<tr>
<td>R-4</td>
<td>1.53</td>
<td>18.60</td>
<td>29.20</td>
<td>50.70</td>
</tr>
</tbody>
</table>
7.0 CONCLUSIONS AND RECOMMENDATION

7.1 Conclusions

From all of the work done - on drill core, bulk samples and composites - it is clear that:

* the wollastonite ore responds well to the selected grinding process

* high aspect ratio wollastonite can be produced by froth flotation from the ground products

* pre-screening of ground product may be a cost effective method of achieving wollastonite concentration thereby reducing capital and operating cost in the "downstream" part of a plant.

7.2 Recommendations

7.2.1 Short Term Objectives

The following work is recommended with respect to additional processing work using hammer mill ground material

* continue work on the use of the new flotation chemical primarily because of its simplicity and anticipated lower capital and operating costs. The same comments apply to further work with the imadozaline type reagent.

* Investigate separation of residual diopside by flotation (integrated with the primary flotation process) rather than by capital cost-intensive high intensity magnetic separation.

* Continue to search for a processing method that will result in a further reduction of the feldspar content in the wollastonite concentrate. The reagent imadozaline type of chemical appears to offer the best prospect.
7.2.2 Medium Term Objectives

* Finalize the beneficiation process

* Identify all process variables and conduct "timed" flotation tests for scale up data - commercial plant or pilot plant testing.

* Conduct vacuum and pressure filtration tests and determine final moisture content of wollastonite concentrates.

* Identify methods of drying wollastonite concentrates that will not damage particle structure.

* Determine the need for air classifying the flotation product following drying.

* Evaluate the settling rates of process tailings and need for flocculants.

* Evaluate recycling of water from tailings ponds to the flotation process.

* Prepare a conceptual flow sheet.

* Conduct a "pre-feasibility" study based on the conceptual flow sheet, product-volume and mix.

* Obtain a bulk sample for pilot plant test.

* Conduct pilot plant testing

* Prepare pilot plant products for market testing

* Conduct a more detailed and specific market survey