EVALUATION OF LEONARDITE (HUMALITE)

RESOURCES OF ALBERTA

by

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EXECUTIVE SUMMARY

Leonardite, humalite and humate are similar naturally occurring materials that are enriched in humic and other organic acids. These materials are of interest as a source of humic acids. Their major uses are as a soil amendment in agriculture and reclamation, and as a drilling fluid additive.

Deposits of these materials occur in Alberta, Saskatchewan, and possibly in British Columbia, but little has been compiled or published about their extent, quality and economic significance. This report attempts to summarize the available information for Alberta.

Leonardite is defined as a naturally occurring oxidized form of lignite coal that is rich in humic acids. Mineable deposits of leonardite exist in the Estevan, Saskatchewan area. In Alberta the term humalite (from "humic" and "Alberta") has been used informally for the material from Battle River (Forestburg) and Sheerness coalfields. Humalite is the weathered product of subbituminous coals and carbonaceous shales.

In Alberta commercial production occurred between 1957 and 1983, when Dresser Industries (Magcobar) produced about 47,000 tonnes of humalite from their own pits and from a nearby coal mine in the Forestburg area. That material was used as a drilling fluid additive, but the operation closed due to the decline of oilfield drilling activity.

While the traditional oilfield markets for humic acid products shrank in North America, new opportunities were opening up in agriculture, horticulture and reclamation. Research since the mid-1960s has demonstrated that humic acids are effective as soil conditioners, especially in saline and alkaline soils, and in soils that are depleted in organic matter. They also appear to be effective against certain types of soil contamination.
We estimate the value of humic acid products currently being sold in Alberta to be under $500,000 for agriculture/horticulture/environmental applications and about $140,000 for oilfield applications.

Alberta's known speculative resources are upward of 2 million tonnes. Indicated resources are about 272,000 tonnes and measured resources are about 118,000 tonnes.

We estimate that humalite could be processed and sold in Alberta for less than $62.00/tonne or about 30¢/kg which is less than half the current cost of imported products. Given the extensive agricultural activities in Alberta and the growing need for reclamation (about 200 hectares of mining lands and 1,500 hectares of well sites are being reclaimed annually in Alberta), humalite could capture a market of 45,000 tonnes per year or more.

There are no apparent infrastructural, environmental, social or legal barriers to the development of Alberta's humalite resources. However, development of market demand and product awareness are needed. A strategic approach to demand development is proposed that involves agricultural and reclamation research and testing, better definition of the resource base, studies of market trends, and evaluation of potential export markets in the Pacific northwest, so that Canadian business can be made more aware of this existing opportunity.
1. **INTRODUCTION**

Leonardite, humalite and humate are similar naturally occurring materials that are enriched in humic and other organic acids. They are formed by the natural weathering or oxidation of lignite, subbituminous coal and carbonaceous sediments (carbonaceous shales, mudstones and claystones). These materials are of interest as a source of humic acids. Their major uses are as a soil amendment in agriculture and reclamation, and as a drilling fluid additive. They have also used as binders for iron ore pellets and lignite briquets, as a stabilizer for ion exchange resins in water treatment, and as a water-soluble stain for wood finishing (Roybal and Barker, 1987).

Deposits of these materials occur in Alberta, Saskatchewan, and possibly in British Columbia, but little has been compiled or published about their extent, quality and economic significance. This report attempts to summarize the available information for Alberta.

In the United States leonardite, humate and "weathered coal" have been produced commercially from deposits in North Dakota and New Mexico, often as a by-product of lignite or coal mining. In Canada commercial production occurred in Alberta between 1957 and 1983, when Dresser Industries (Magcobar) produced about 47,000 tonnes of humalite from their own pits and from a nearby coal mine in the Forestburg area. That material was used as a drilling fluid additive; the operation closed due to the decline of local oilfield drilling activity. Various organizations currently
market imported material for oilfield and for agricultural and horticultural applications.

The potential uses in agricultural, horticultural, and environmental applications have grown substantially both in extent and scope during recent years. Current concerns about the environmental impact of inorganic fertilizers have sparked a renewed interest in organic soil conditioners like leonardite, humate and humalite. The need to reclaim and restore land disturbed by petroleum drilling, mining and other industrial activities is also creating a demand for products of this type.
2. **TERMINOLOGY AND CHEMISTRY**

Leonardite was named for Dr. A.G. Leonard, first director of the North Dakota State Geological Survey, in recognition of his pioneering work on this resource in the early 1900s (Kohanowski, 1957). Leonardite is defined as a naturally occurring oxidized form of lignite coal that is rich in humic acids (Kohanowski, 1970). It is a natural lithology or rock type, and as such it can include a variety of minerals, elements and compounds, while still falling within the original definition.

The terminology has been complicated by the fact that the original definition specifies an origin from lignite, effectively excluding similar materials that are derived from subbituminous coals and carbonaceous or coaly sediments. All of these materials are similar in that they are all natural lithologies that are enriched in humic acid. However, differences that arise from such factors as coal rank, texture, mineral matter content and weathering history affect their quality and thus their potential uses. Thus while some geologists have informally expanded the use of the term leonardite to include all of these materials, others have sought new terms.

In New Mexico, for example, the term humate is sometimes used (Section 3.2). In Alberta the term humalite (from "humic" and "Alberta") has been used informally. This report will continue to use that term, for reasons discussed in Section 3.3, defining it as Alberta lithologies that are enriched in organic acids, especially humic acids, and are formed by the natural weathering or oxidation of coal or carbonaceous sediment.

Roybal and Barker (1987) reviewed the terminology used to describe humic materials. As they stated, "Humic material is not a pure substance, so an
ambiguous and complex terminology is in use by geologists, chemists, soil scientists, agronomists, and producers. Material mined for its humic acid content is an extremely variable mixture of base-soluble humic, fulvic and ulvic acids and their salts, formed during the partial or complete decay of organic matter. This decay releases a high molecular-weight organic material that is darkly coloured, partly colloidal, and weakly acidic" (Roybal and Barker, 1987, p. 2105). Their list of terms and definitions is presented in Table 1.

The humic acid content is the major factor of economic interest, and it is the chemistry of humic acids that governs many of their uses. Important chemical properties include cation exchange capacity, buffering properties, and ability to chelate metal ions (Freeman, 1970).

Humic acids have an average molecular weight between 5,000 and 50,000, are amorphous, and have large cation exchange capacities ranging from 200-500 meq/g (Senn and Kingman, 1973). They include in their structure alcoholic and phenolic hydroxyl (OH) groups and carboxyl (COOH) groups (Cooley et al., 1970), which comprise more than 20% of the molecule (Berkowitz et al., 1963; O'Donnell, 1970a; Broughton, 1972a). This is reflected in the increased oxygen content of humic acid-enriched lithologies. Humic acids are alkali soluble, due to the presence of the carboxyl and hydroxyl groups, but are water insoluble (Moschopedis and Kay, 1969; Broughton, 1972a). Humates (salts of humic acids) can be extracted by solution in alkaline (high pH) solutions, and humic acids can then be reprecipitated by lowering the pH (Figure 1).
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Carbonaceous Mudstone/Shale</td>
<td>Called humate by geologists if it contains base-soluble humic acids (Siemers and Wadell, 1977)</td>
</tr>
<tr>
<td>Fulvate</td>
<td>Salt of fulvic acid (Siemers and Wadell, 1977)</td>
</tr>
<tr>
<td>Fulvic Acid</td>
<td>Base-soluble and acid-soluble fraction of humate (Martin et al., 1962)</td>
</tr>
<tr>
<td>Humate (Singular)</td>
<td>Geologically a carbonaceous claystone/mudstone/shale rich in humic matter (Siemers and Wadell, 1977)</td>
</tr>
<tr>
<td>Humate (Plural)</td>
<td>Salts of humic acids (Siemers and Wadell, 1977)</td>
</tr>
<tr>
<td>Humate Acids (Singular)</td>
<td>Base-soluble organic material insoluble in acid then insoluble in alcohol (Martin et al., 1962)</td>
</tr>
<tr>
<td>Humate Acids (Plural)</td>
<td>Humic and fulvic and ulmic acids (Siemers and Wadell, 1977)</td>
</tr>
<tr>
<td></td>
<td>Hydrogen ion in exchange sites (Senn and Kingman, 1973)</td>
</tr>
<tr>
<td></td>
<td>Base-soluble organic material insoluble in alcohol (Martin et al., 1962)</td>
</tr>
<tr>
<td>Humic Material (Matter, Substances, Deposits)</td>
<td>Completely decomposed organic matter containing humic acid (Siemers and Wadell, 1977)</td>
</tr>
<tr>
<td>Humin(s)</td>
<td>Derived from plants; carbonaceous (Thrush, 1968)</td>
</tr>
<tr>
<td></td>
<td>Chemical an alkali-insoluble fraction of humate (Martin et al, 1962)</td>
</tr>
<tr>
<td>Humus</td>
<td>Decomposed vegetable substances insoluble in alkali carbonates, water and bensol (Thrush, 1968)</td>
</tr>
<tr>
<td></td>
<td>Chemically an alkali-soluble fraction of humate (Martin et al, 1962)</td>
</tr>
<tr>
<td></td>
<td>Lithologically a carbonaceous mudstone or shale (Siemers and Wadell, 1977)</td>
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<tr>
<td></td>
<td>Oxidized (weathered) lignite or coal, rich in organic matter (Siemers and Wadell, 1977)</td>
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<tr>
<td></td>
<td>Dark, organic, well-decomposed soil material consisting of plant, and animal residues and various inorganic elements (Thrush, 1968)</td>
</tr>
<tr>
<td>Leonardite</td>
<td>Oxidized (weathered) lignite (Kohanowski, 1970; Siemers and Wadell, 1977; Fowkes and Frost, 1960)</td>
</tr>
<tr>
<td></td>
<td>Sometimes includes oxidized (weathered) subbituminous coal (Siemers and Wadell, 1977)</td>
</tr>
<tr>
<td>Lignite</td>
<td>Drilling-fluid additive rich in base-soluble humic acids made from lignite (Miles and Blair, 1983)</td>
</tr>
<tr>
<td>Ulimate</td>
<td>Salt of ulmic acid</td>
</tr>
<tr>
<td>Ulmic Acid</td>
<td>Base-soluble organic material that is acid insoluble then alcohol soluble (Martin et al., 1962)</td>
</tr>
<tr>
<td>Weathered (Oxidized) Coal</td>
<td>Often called leonardite and typically derived from subbituminous coal (Siemers and Wadell, 1977)</td>
</tr>
<tr>
<td>Weathered (Oxidized)Lignite</td>
<td>True leonardite (Siemers and Wadell, 1977) and called &quot;slack&quot; in the past (Fowkes and Frost, 1960)</td>
</tr>
</tbody>
</table>
Fig. 1 - General analytical flowchart for determining the various components of humate (from Roybal and Barker, 1987)
3. MINEABLE DEPOSITS

In Canada, leonardite deposits are associated with the lignite deposits of the Estevan, Saskatchewan area. Humalite occurs with the subbituminous coals of the Battle River and Sheerness coalfields of Alberta. It is possible that deposits exist in British Columbia, associated with some of the low-rank subbituminous coal and lignite deposits, but none have yet been reported in the literature.

In the United States mineable deposits include leonardite in North Dakota, and humate and weathered coal in New Mexico (Hoffman and Austin, in press). Humic acid-rich deposits also exist in Arkansas, Florida, Louisiana, Michigan, Minnesota, New York, Texas and Wyoming (Burdick, 1965).

3.1 Leonardite in North Dakota and Saskatchewan

Leonardite is a soft, medium-brown, coal-like substance associated with lignite outcrops in North Dakota, Saskatchewan and Texas. It is "essentially salts of humic acids admixed with mineral matter such as gypsum, silica and clay" (Fowkes and Frost, 1973). Leonardite differs from lignite in its higher oxygen content and greater cation exchange capacity. The oxygen content of lignite is about 19-20%, while that of leonardite is higher (due to the carboxyl groups) at about 28-29% (Fowkes and Frost, 1960).

Three types of leonardite were described from North Dakota by Kohanowski (1957):

Type I resembles the material referred to as native humus acid in early literature. It is a black colloidal material that swells to several times its original volume in water. It dissolves in alkali hydroxides
leaving no residue and producing a dark brown solution. It may be precipitated as a light brown colloid at pH of 4 or lower (Fowkes and Frost, 1960).

Type II is a mixture of Type I material and lignite found where the lignite is overlain by a very thin (less then 8 feet) layer of permeable sediment (Fowkes and Frost, 1960).

Type III resembles the laboratory-precipitated product described for Type I. It is fine-grained, colloidal, and intimately intergrown with gypsum (Fowkes and Frost, 1960). Most commercially mined leonardite in North Dakota has been Type III.

A wide range of compositions has been reported for leonardite, as might be expected for a naturally occurring rock type. For example, fixed carbon content (d.a.f.) can range from 38 to 46%, volatile matter (d.a.f.) from 61 to 54%, oxygen from 28.4 to 19.5% and ash from 7.0 to 8.4% (as received) (Fowkes and Frost, 1960). The humic acid content, which is the most important factor in determining potential use, also varies widely. For example, Fowkes and Frost (1960) report data from three samples, two from North Dakota and one from Texas. Soluble humic acids (as received) in 1 normal NaOH solution ranged from 32.8 to 42.2% for the North Dakota samples and was 28.1% for the Texas sample.

The lignite deposits of North Dakota and the associated leonardite occurrences are correlative with those of the Ravenscrag Formation of southern Saskatchewan. Using samples from the Utility Mine near Estevan, Broughton (1972a,b) reported that the oxygen content of leonardite was variable, ranging from 25-60%, while that of lignite was less
than 25%. He reported the extractable humic acid content of a representative sample of leonardite as 84%, while that of the lignite was 5%. Whitaker (1977) described the distribution of leonardite within the Poplar River Mine.

3.2 Humate and Weathered Coal in New Mexico

The term humate has both chemical and geological definitions. As noted by Siemers and Wadell (1977), "In the purest sense (chemically), humate is the salt or ester of humic acid; however, in geologic use the term "humate" commonly refers to a rock type containing abundant humic acid along with other components such as silt and clay mineral matter." Thus the term is used to describe carbonaceous claystone/mudstone/shale that is rich in humic matter (Table 1).

In New Mexico humate is associated with the subbituminous coal seams of the San Juan Basin. Petrographic examination has shown that it is comprised mainly of detrital clay minerals that have been stained by humic matter. Some humic matter is also present as finely disseminated debris (Siemers and Wadell, 1977). It is mined and sold under the name humate, and is being used for agricultural purposes and as a drilling fluid additive, depending on its grade (Roybal and Barker, 1987).

Compositions for New Mexico humate are reported by Siemers and Wadell (1977) and Roybal and Barker (1987). Typical ranges are fixed carbon 2-17%, volatile matter 9-34%, and ash 4-25%, although ash can reach up to 75% in run-of-mine samples. Humic acid content ranges between 2-56%, averaging 16.6%.
New Mexico also produces "weathered coals" (Table 1). These are distinguished from leonardite in that they are derived from subbituminous coals rather than from lignite. Their humic acid content ranges between 60-75%, ash 14-30% and fixed carbon 22-39%. Their average humic acid content (about 66%) is greater than that of humate (about 17%) and fresh coal (about 10%) (Siemers and Wadell, 1977).

3.3 Humalite in Alberta

In Alberta the term humalite (from "humic" and "Alberta") has been used informally for the material from the Battle River and Sheerness coalfields (J. Carter, pers. comm., 1993). Despite the fact that the term has not previously been formally defined and is not widely recognized outside of Alberta, this report will continue to use it.

There are a number of reasons for continuing to use the term humalite. The term leonardite is not appropriate because the material is not derived from lignite. Humalite is associated with weathered subbituminous coal seams and carbonaceous shales, so the terms humate and "weathered coal" might be applicable. However, this might imply that the Alberta deposits are analogous, geologically and in terms of quality, with those of New Mexico. This may or may not be the case. Very little is known about the origin, lithology and quality of the Alberta material, and it needs further study. In addition, the term humate is open to confusion, being originally a chemical term that has been extended to describe a lithology. The term weathered coal is worse, because the weathering or oxidation of coal does not always increase the extractable humic acid content; in fact, in most cases it does not. By using the term humalite, as defined in Section 2, specifically for the Alberta material, we can avoid possible confusion when comparing it with other materials from other localities.
3.3.1 Quality
Like leonardite and humate, Alberta humalite is enriched in organic acids, especially humic acids. Proximate analyses are not available for humalite, but the humic acid content ranges from 15 to 80%, averaging 60% (J. Carter, 1982). The sulphur content is usually quite low (less than 1%) as it is in the original coaly material. Most the humalite produced in Alberta seems to have been more closely related to carbonaceous shale than to coal.

3.3.2 Geology
Humalite occurs with the coals of the Horseshoe Canyon Formation of Alberta. These coals originated from poorly drained swamps and mires that were part of near-shore or deltaic and fluvial sequences (McCabe et al., 1988). The humalite likely formed by weathering reactions in which oxygen-bearing water acted upon the coal and coaly sediments. The zones of weathering are usually shallow (1 to 10 m deep) and often underlie permeable materials.

In the case of highly weathered coal, the coal beds themselves (0.3 to 1.2 m thick) are affected, usually from the top of the bed to the first substantial (>10 cm) impermeable parting. In the case of carbonaceous shales, the shales are usually in direct contact with the coal seams, or separated only by thin partings. The beds are essentially flat-lying. The weathering surfaces appear to be controlled by the preglacial topography. Variations in paleotopography combined with variations in permeable cover produce an often spotty and discontinuous distribution. Unlike the situation in North Dakota the Alberta materials are not associated with gypsum (J. Carter, pers. comm., 1993). The low initial sulfur content of the Alberta
coal seams is probably responsible for the low sulphur content of Alberta humalite (usually <1%).

3.3.3 Past Production, Exploration and Reserves

Production of humalite began in 1957 in the Forestburg area, where the humalite occurred in beds 0.3 to 1.2 m thick overlying the coal seams (J. Carter, 1982). Magcobar Drilling Fluid Services, a division of Dresser Industries, operated a small open-pit mine until 1979, and subsequently purchased a large quantity of humalite from the Forestburg Collieries' (Luscar Limited) Diplomat Mine, which has subsequently closed. Magcobar built up a considerable stockpile, a remnant of which (about 15,000 tonnes) is still in the yard at the Magcobar Plant site near Rosalind.

John Carter, then with Dresser Industries, described the humalite at Forestburg Collieries in an internal report to Dresser, using the term leonardite to describe the material:

"The Leonardite occurred in beds 1 - 4 feet thick overlying the coal seam in the "D" area SE of the tipple.

A contract was arranged between Dresser Industries Inc. and Forestburg Collieries Ltd. to mine and stockpile this material.

In June 1980 Dresser Minerals commenced hauling leonardite from the Forestburg mine and to date has removed 36,640 tons of crude leonardite to the Rosalind Plant stockpile for processing."
Presently it is estimated that approximately 15,000 - 20,000 tons of crude leonardite can be obtained from the Forestburg "D" zone. This is sufficient for the year 1982 only and no further known reserves have been sampled from the Forestburg Mine area." (J. Carter, 1982, p. 1).

At that time sales of humalite-based products for drilling fluids were strong and the assured supplies of raw feed to the Rosalind Plant were limited, so Dresser continued to mount an aggressive exploration program. Carter and his associates became interested in the Sheerness area south of Hanna (about 160 km southeast of the Rosalind Plant). His 1982 report states:

"Outcrops were examined in 1980 and a few samples analyzed for old holes cored for coal.

**Drilling:**
In past years the drilling to outline the coal seams at Sheerness unfortunately did not provide sufficient samples of Leonardite for evaluation.

As this material is soft, part soluble, and most difficult to core, a sample barrel was invented by Lexco Ltd. to obtain uncontaminated samples. This tool has proved to be excellent for the evaluation of leonardite under shallow overburden.

In November, 1981 the Lexco drill was used for overburden evaluation under the supervision of Bob Logan. Some 23 holes were drilled over the area. Six of these holes sampled Leonardite of variable quality.
At the same time the drill was used to sample an area on SE 1/4 Sec. 25-23-W4M [sic]. This area lies in the far north east boundary of the Mining Permit and closest to the railroad.

**Reserves:**

a) In the eastern portion of the quarter 22 drill holes indicated probable reserves under 33 acres of approx. 130,000 Tons under an average of 4.8 feet of overburden. The average thickness of the seam is 3.55 feet with an average colour index of 560*.

b) On the west boundary of SE 1/4 Sec. 25-29-13-W4M five widely spaced drill holes indicated potential reserves of approximately 300,000 Tons of Leonardite." (J. Carter, 1982, p. 2).

* The "colour index" refers to a test for humic acid content developed by Dresser Industries. The humic acid is extracted from the sample in a 1 Normal NaOH solution. This produces a brownish liquid, the density of which is measured using a standard colorimeter. A reading of 700 is calibrated to equal 70% humic acid by comparison with a Dresser Industries standard.

The reserve terminology used by Carter above is no longer standard for either coal or coal-related materials. According to the classification of Hughes et al. (1989), those in Part (a) would be classified as an In Place Measured Resource of Immediate Interest, since the economic criteria
needed for the term Reserve have not been demonstrated. Those in Part (b) would be called an Indicated Resource of Immediate Interest.

The Carter report concluded that:

1) more detailed work would be required to formulate a mining plan for the Measured Resources;
2) more exploration is required in the lesser known areas;
3) an "estimated potential" resource "of possibly commercial Leonardite may amount to approx. 2 million tons in the Sheerness coal measures." (J. Carter, 1982, p. 3).

Unfortunately, Magcobar effectively closed its Rosalind operation in 1983 following the substantial decline in Alberta oilfield activities. The sales envisioned in 1980 never materialized.

The Sheerness deposit remains the major resource available at present. Luscar's Diplomat Mine has closed, and Luscar reports that mining at the nearby Paintearth Mine (which replaced Diplomat) has progressed away from the favourable subcrop where the humalite occurs, and that no additional resources of humalite are available at the Paintearth Mine (R. Engler, Luscar Ltd., pers. comm., 1993). Manalta Coal Ltd. indicated that no known humalite resources occur at any of the mines that they currently operate. (P. Graham, Manalta Coal Ltd., pers. comm., 1993).

At Sheerness, Luscar holds a mining permit covering a number of sections. The recovery of humalite could be coordinated with the recovery of the coal. The coal is dedicated to the Sheerness Power Station, and mining of the area of interest is currently scheduled to commence in 1996.
<table>
<thead>
<tr>
<th>Location</th>
<th>Quantity</th>
<th>Assurance</th>
<th>Geologic Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheerness East 1/2 of SE 1/4 Sec. 25-23-13 W4M</td>
<td>118,000 tonnes</td>
<td>Measured Resource of Indicated Interest</td>
<td>under an area of about 33 acres and ± 5 feet of cover</td>
</tr>
<tr>
<td>Sheerness West portion of SE 1/4 Sec. 25-19-13 W4M</td>
<td>372,000 tonnes</td>
<td>Indicated Resources of Immediate Interest</td>
<td>more definition is required</td>
</tr>
<tr>
<td>Sheerness subcrop areas of coal deposits</td>
<td>&gt; 2 million tonnes</td>
<td>Speculative Resources</td>
<td>requires much more geology and drilling</td>
</tr>
<tr>
<td>Forestburg Area (vicinity of old Rosalind plant)</td>
<td>50,000 tonnes</td>
<td>Speculative Resources</td>
<td>In discontinuous seams under shallow cover on local farm properties not associated with active coal mining</td>
</tr>
</tbody>
</table>
Fig. 2 - North American Leonardite and Humalite Resource Locations
Fig. 3 - Western Canadian Humalite and Leonardite areas
4. CURRENT PRODUCTION AND MARKETING

4.1 United States
The production and distribution of leonardite, humate and humic acid is relatively well established in the United States. These materials have been produced in North Dakota since the 1920s and in New Mexico since the mid-1960s. The industry is stable and apparently growing. At present U.S. production appears to be split about equally between two major uses, agriculture and oilfield drilling.

In the United States, humic acid is classified as both a fertilizer and soil conditioner. Its application in agriculture has been growing steadily over the past 15 years (Sec. 5.1).

The use of humic substances as drilling fluid conditioners is well documented (Section 5.2). Production for this purpose is highly variable and dependent on petroleum exploration and development drilling, activities that have been declining in North America over the past decade.

According to Hoffman and Austin (in press) and G.K. Hoffman (pers. comm., 1993), three mines are currently producing humate and weathered coal in New Mexico, with an estimated total production of about 36,000 tonnes. The material sells for $55 US to $165 US per tonne, depending on humic acid content. Production of leonardite in North Dakota is estimated at about 31,000 tonnes per year.

4.2 Western Canada
Although there are known deposits of leonardite in Saskatchewan and humalite in Alberta, there is no active production of humic acid-bearing
materials in Canada at present. However, imported humic acid products (from humate, leonardite and weathered coal) from the United States are available here.

In Canada, humic acid-products are classified as soil conditioners. The importers serving agricultural and horticultural markets in Alberta include several small firms handling volumes of a few hundred tonnes per year. Most of the product is sold as a soil conditioner and is called humate. It comes in 100 lb. bags. The two humate suppliers contacted declined to provide exact figures on imports for the past few years, but volumes do not appear to be large. We estimate that the value of sales must be under $500,000 per year.

A number of oilfield drilling supply and service companies import humic acid products as drilling fluid amendments. The tonnages vary greatly depending on oilfield drilling activity. No accurate figures are available for this industry either. However, during years of relatively high drilling rates (late 1970s and early 1980s) Alberta-produced humalite was used by the local oil industry and exported at rates approaching 20,000 tonnes per year (J. Carter, pers. comm., 1993).
5. USES

The material with the greatest humic acid content is sold as a drilling fluid additive. Lower grade material is used in agriculture, horticulture and reclamation. Minor uses include as a binder for iron ore pellets and lignite briquets; as a stabilizer for ion exchange resins in water treatment; and as a water-soluble stain for wood finishing (Roybal and Barker, 1987).

To be of economic interest, the raw material must provide sufficient humic acid if being used in a more or less natural state, or must contain enough humic acid to make extraction economic. For agricultural purposes New Mexico humate generally contains 12 to 18% humic acid; it is generally dried and crushed to -50 mesh. Higher grade material (usually weathered coal or leonardite) is used as a drilling fluid additive. That material must contain 65% humic acid; it is also dried and crushed. When used in an extraction process the raw grade required is highly dependent on the economics of the process but higher grades are most desirable.

For agricultural purposes the natural material must have minimal concentrations of potentially harmful trace elements. Elements of concern include mercury, arsenic, selenium, cadmium, barium, lead, zinc and radioactive nuclides.

5.1 Agriculture, Horticulture and Reclamation

Uses in agriculture, horticulture and reclamation share the objectives of improving soil conditions and plant growth by addition of organic matter in the form of humic acids. Some of the applications involve naturally occurring problem soils, such as saline and alkaline soils, and natural clay-rich or sandy soils that are depleted in organic matter. Others involve soils
that have been depleted in organic matter by intensive cultivation. Unconsolidated sediments that have been used to backfill mined areas are usually extremely poor in organic matter, and may also be saline or alkaline. The worst-case scenarios involve soils that have been contaminated, either as a result of agricultural activities, with excess fertilizers, pesticides and herbicides, or as a result of industrial activities such as the production and processing of petroleum and natural gas.

Organic matter content is essential to healthy, productive soils. As explained by Moschopedis, "The main component of soil organic matter is humic acids. Soil organic matter serves many purposes and provides desirable physical properties in soils. Without it, soils would bake and crack in summer, would compact easily when wet, would erode seriously during heavy rains, would have poor water retention properties and reduced ability to retain plant nutrients. The nature of the interaction between organic and inorganic matter in soils is mainly due to hydrogen bonding between the hydrogens in clay and the carbonyl groups in the organic matter. As a result of this interaction, pronounced differences in physical properties exist among soils with various amounts of organic matter." (Moschopedis, 1966, p.2).

As Freeman explained it, "Most soil scientists and agronomists agree that humus serves important functions in the soil. ... Humus in the soil has a three-fold function:

(1) physical modification of soil structure and texture enabling increased moisture retention and aeration;
chemical fixation of soil minerals and their retention in an
exchangeable form available for plant growth, increasing the
buffering properties of the soil, and chelating of metal ions
under alkaline conditions; and

biological stimulation of growth by serving as a substrate for
micro-organisms... (Freeman, 1970, p. 150).

The role described in (2) above has been particularly well documented.
O'Donnell found that, in saline soils, humic acid increased the uptake of
nitrogen and phosphate, and improved the Na/Mg ratio (Mg is essential to
the formation of chlorophyll), thus diminishing the effects of excess sodium.
In alkaline soils iron is depleted by precipitation as a carbonate, but
Freeman and Fowkes (1968) found that coal-derived humate promotes
plant uptake of iron by serving as a metal chelate. McKenzie (1970) found
that, in acid soils that contained toxic levels of soluble aluminum, humates
improved plant growth, probably by chelation or fixation of soluble
aluminum. The role of soluble aluminum released by acid rain in killing
trees is currently under study in central Canada (D. Stephenson, G.S.C,
pers. comm., 1993).

The above benefits of humic acids, and thus of leonardite, humalite and
humate, have been reasonably well substantiated. Other benefits that have
been proposed remain controversial. For example, Freeman felt that
humus stimulated plant growth directly, "by supplying a slow release of
O'Donnell felt that his work had demonstrated auxin-like properties
(O'Donnell, 1973b). On the other hand, in an earlier project McKenzie
(1970, p. 71) failed to find any "special growth benefits to plants, other than
supplying necessary chemical nutrients."
Another suggested role for humic acids is in soils that are contaminated by pesticides and excess nitrogen fertilizers. McKenzie found "no evidence to support claims that coal humates ... reduced toxicity effects of excess fertilizers" (McKenzie, 1970, p. 71). However, Beran and Guth (1965), quoted by Cooley et al. (1970, p. 160), found that the persistence of organic pesticides (DDT, Lindane, Aldrin and parathion) was lessened by the presence of humic acids in the soils. M. Schnitzer (Agriculture Canada, pers. comm., 1993) pointed out that some of the research being done by chemical companies in Europe is aimed at reducing the impact of humic acids on pesticides and herbicides! Given the growing problem of soils contaminated by all manner of chemicals, this aspect of humic substances warrants more research. Barbara McCord, an Alberta reclamation consultant with the Good Earth Organization Inc., in a 1993 interview with the authors, stated that humic acid products seem to be beneficial to soils contaminated by hydrocarbons. She has used them in her work with positive results.

5.1.1 An Agricultural Example
An Alberta farmer, Mr. Allen Graff of Vulcan, used humalite from the Rosalind Plant for several years. In a 1993 interview with the authors, he explained that his soil conditions and crops are amenable to benefit from humic acids. He uses a loading rate of about 200 lbs/acre. He has used humalite from the Rosalind Plant (now owned by M.I. Industries, successor to Magcobar) because it contains more than twice as much humic acid as the imported humate from New Mexico or leonardite from North Dakota, thus his loading rate was much lower than those recommended in American literature.
Mr. Graff's results are impressive. For example, last year his land produced a wheat crop of 23 bushels/acre at 57 lbs/bushel, while his neighbour, with the same soil and moisture conditions, obtained 3 bushels/acre at 27 lbs/bushel. The neighbour uses chemical fertilizer and herbicides. Mr. Graff uses humalite and other organic products such as manure. Because it is high-quality Canada #1, and has an "organically" grown certification, his wheat sells in the United States for 2.5 times more than the current Canadian wheat board rate. Mr. Graff is quite concerned that he will not be able to find a source of supply now that the Rosalind Plant has closed.

A major trend that is developing in North America is the movement toward "natural" things. People are willing to pay extra for the "peace of mind" that is associated with natural things like food. The term "organically grown" is now widely used (and probably misused, too) in relation to food grown without chemical fertilizers, pesticides and herbicides. A large market is growing in California and the Pacific northwest for organic products. Humalite could easily win a share of that market now being served by New Mexico and North Dakota production.

"Americans spent $4.2 billion on natural foods in 1990, more than 30% above what they spent in 1979. The figures include sales at the nation's 7,253 health food stores and in the health food sections of supermarkets. Sales of health foods in supermarkets increased by 10% to $679 million, compared with an increase of only 3% in 1986." (Celente and Milton, 1991).

5.1.2 Older Research and Testing in Saskatchewan
Research on the use of leonardite as a modifying medium for saline and alkaline soils was done at the Saskatchewan Research Council in the early
1970s (O'Donnell, 1970-1973). In southern Alberta and Saskatchewan, many acres of potentially productive farmland are lost due to conditions of high salinity. O'Donnell found that the humic acids improved the uptake of nitrogen, phosphate, iron and magnesium, and diminished the effects of excess sodium. He also found that leonardite improved root initiation and growth, which indicated possible auxin-like (hormone-like) properties (O'Donnell, 1973a,b).

5.1.3 Older Research and Testing in Alberta
As Cooley et al. (1970) noted, much of the world literature on the use of humic acids from coals relates to materials made by chemically oxidizing unweathered coals (e.g., van der Watt et al., 1991). Reviewing all of those artificial products is beyond the scope of this report, but it is worth describing Western Canada's contribution: the Alberta Research Council developed a sulfomethylation process to extract humic acids from lignites and low-rank coals (Moschopedis et al., 1966-1975). The process used both naturally oxidized lignites and coals, and those manufactured from coals by any of several known conventional oxidation processes. The objective of was to render the humic acids soluble in water so that they could be filtered and purified, removing deleterious materials and mineral matter. The resulting products were intended for both drilling fluid and agricultural use.

As explained by Moschopedis and Kay, "Sulfomethylation involves replacement of active hydrogen atoms within the humic acid molecule by the sulfomethyl group (-CH₂SO₃M, where M is a cation such as hydrogen, sodium, potassium, calcium or ammonium) and sulfonation involves introduction of the sulfonic group (-SO₃M) by the sulfite and/or bisulfite
moleules to quinonoid or other carboxyl groups within the humic acid molecule." (Moschopedis and Kay, 1969, p.1).

Moschopedis and others conducted a series of experiments using sulfomethylated low-rank Alberta coals from Wabamun, Egg Lake, Tofield, Dodds and Sheerness. The products were evaluated as drilling fluid thinners, fertilizers and soil conditioners (e.g., Moschopedis, 1966b; Moschopedis and Kay, 1969; Moschopedis, 1970; McKenzie, 1970; Moschopedis, 1973a,b; etc.). Several patents were issued as a result of that work (e.g., Canadian Patent No. 722,720, Nov. 30, 1965; No. 83705, April 21, 1970).

The work included a series of studies of the effects of the sulfomethylated products on plant growth in various types of soils (Moschopedis and Kay, 1969; McKenzie, 1970). Greenhouse tests were done by the University of Alberta Department of Soil Science, followed by larger scale field tests by the Department of Soil Science and the Solonetzic Soil Station at Vegreville. Some of the results were encouraging, but others were not. Some of the negative results appeared to be related to the addition of bisulfate during the processing (Cairns and Moschopedis, 1971, p. 62). Discussions may be found in McKenzie (1970), and Cairns and Moschopedis (1971).

5.2 Oilfield Drilling Fluids

In drilling a well of any type, a fluid is circulated to the cutting bit and back to the surface to remove the cuttings, and to cool and lubricate the bit. The fluid, called drilling fluid or drilling mud, must have a controlled viscosity and pH, it must resist flow into permeable strata, it must have a gel structure that is strong enough to suspend and transport the cuttings, and it must be sufficiently dense to provide the pressure needed to prevent
collapse of the borehole walls and to resist invasion of the hole by overpressured oil, gas or water contained in the surrounding rock strata.

Water-based drilling fluids normally include water and finely ground inorganic materials such as clays (especially bentonite), and weighting materials such as barium sulfate, iron oxide, amorphous silica and calcium carbonate. Additives are used to control fluid loss, viscosity, yield point and gel strength.

As the amount of solids in the drilling fluid increases, the viscosity of the system increases rapidly. In bentonitic drilling fluids, the critical change in viscosity occurs at a solids content of about 8-9% (Moschopedis and Kay, 1969). Additives known as drilling mud thinners are used to accommodate higher solids contents while maintaining an acceptable viscosity and pH.

High-grade leonardite, humate and humalite (often sold under the name "lignite" in this market) have been found to be effective as drilling fluid thinners (Odenbaugh and Ellman, 1967; Moschopedis and Kay, 1969; Miles and Blair, 1983). They disperse and stabilize solid suspensions in the fluid, decreasing the viscosity and gel strength, without affecting the filtration properties (Broughton, 1973a).

5.3 Other Uses
Humic acid compounds have been shown to be useful in the formulation of iron ore pellets, and coal and lignite briquets. They are combustible, leaving behind minimal ash. Sodium humate solutions have high viscosities and an ability to gel at high concentrations, with excellent binding properties for granular materials (e.g., Fine and Wahl, 1964;
Wen et al., 1986; Sastry & Fuerstenau; 1982). Humic acid is also used in the stabilization of foundry sand molds.

The buffering effect, colloidal properties and cation exchange capacity of humic acids are relevant to the treatment of water and effluents. Humate has occasionally been used as a stabilizer for ion-exchange resins in water treatment (Roybal and Barker, 1987).

Other uses proposed or patented for humic acid products include wood stains and preservatives, tanning agents, chemical feed stock, and ionic metal capture agents.
6. POTENTIAL MARKETS

Agriculture, horticulture and reclamation are markets with the largest potential for growth. Oilfield drilling fluid additives has been an attractive market in the past, but as drilling has been decreasing steadily in North America that market has become much weaker. The other uses described above represent very minor markets at present.

6.1 Agriculture

There are three areas of opportunity in agriculture to which humalite and leonardite products can be targeted: treatment of naturally occurring problem soils; treatment of soils depleted in organic matter by intensive cultivation; and production of crops for "natural" food markets. Many acres of potentially productive farmland in southern Alberta and Saskatchewan are lost to conditions of high salinity and alkalinity, and very low concentrations of organic matter. Organic matter is further reduced by intensive cultivation, and practices such as crop rotation and the plowing under of cover crops do not always fully replenish the humic acid content. Further, concerns about the environmental impact of chemical fertilizers, herbicides and insecticides, coupled with consumer desires for more "natural" organically-grown foods, have created a growing and profitable market niche in North America (Section 5.1.1).

The current price of humate in bags (imported from New Mexico) f.o.b. Calgary $1.00/lb or $2.20/kg. That price would likely be moderated somewhat if volumes were larger and if local competition were to arise. We estimate that local humalite in a dry, screened, bulk form (including a 50% margin) would cost about $34.50/tonne or $0.18/kg f.o.b. Sheerness. Our estimate does not include packaging, marketing or research. We estimate
that packaging would not add more than 50% to the price. Marketing and research would not be more than $10.00/tonne. This would produce a sale price of about $61.75/tonne or $0.31/kg. Even if our estimates are low by 100%, the price would be substantially below that of New Mexico humate. The humic acid content of humalite is about twice that of the New Mexico product. If one considers humic acid units (one unit = 1% by weight at constant moisture), the price of humalite would be considerably below that of the New Mexico material. Mr. Graff's experience (Section 5.1.1) suggests that this is correct. The humalite he was buying from Rosalind contained 2 to 2.5 times more humic acid units than the imported materials from New Mexico or North Dakota.

6.2 Horticulture
Horticulture includes small-scale consumers such as greenhouses, golf courses and home gardeners. These potential customers would be attracted to humalite and leonardite products for reasons similar to those of agricultural consumers, and would be particularly interested in the "environmentally friendly" and "natural" aspects. They would purchase smaller quantities, at higher prices.

6.3 Reclamation
Reclamation represents a major and growing area of need, both within Alberta and elsewhere.

6.3.1 Mined Lands
As many as 200 hectares of disturbed land are being reclaimed annually at mines (primarily coal and oilsands mines) in Alberta each year. Equally large areas are reclaimed at mine sites in Saskatchewan and British Columbia. The soils involved are often clay-rich and/or salt-laden, soil
types that have been found to benefit from applications of humic acid-enriched materials (Section 5). If only 25% of the total area (50 hectares) would benefit from humalite or leonardite at a loading rate of about 900 tonnes/hectare, the required material would amount to 45,000 tonnes. Even at lower rates of application the annual market potential is still substantial.

6.3.2 Petroleum Extraction Sites
Over 170,000 wells have been drilled in Alberta to date, about 90,000 of them are still active, and more are being drilled every year. These wells will require some form of reclamation, which represents a large potential market. Between 1,500 and 2,000 well sites are reclaimed each year. This number is expected to rise over the next decade. Many of these sites are contaminated with spilled hydrocarbons and brines. Humalite and related products are beneficial soil amendments for these conditions, as indicated by a growing body of evidence that is being amassed by reclamation companies in Alberta.

6.3.3 Other Industrial Sites
Other potential sites include abandoned oil and gas production battery facilities; pipeline, seismic, and power-line rights of way; and other industrial locations. For example, abandoned battery sites often include hydrocarbon-contaminated soils that require treatment by harsh means such as soil washing. This process, while successful in contamination removal, leaves the soil devoid of necessary organic matter and destroys beneficial soil microbes. Application of humic acid-bearing materials helps to restore the organic matter and provide a suitable environment for soil microbes.
6.4 Drilling Fluid Products

In the past this was an attractive market for the highest grade material, but
with the decline of oilfield drilling in North America it has shrunk
substantially and will likely remain unstable for the next few years.
Magcobar closed their Rosalind Plant in 1983 because Canadian oilfield
demand alone (about 600 tonnes/year) was insufficient to justify operating
costs. However, this market could be served as a sideline by an operation
that was aimed mainly at agriculture and horticulture.

Leonardite, often called "lignite" by the drilling industry, is usually supplied
from North Dakota and currently costs about $0.14/lb US or $0.31/kg US
landed in Calgary. Using an exchange rate of 1.2 this would be $0.17/lb
or $0.37/kg. It is sold in 50 lb or 22.8 kg bags. That material has been
crushed, screened and partially dried. The current Canadian industry
requirements are for between 300 to 600 short tons (270-544 tonnes)
depending on activity. The old Magcobar Plant at Rosalind is now sitting
idle, with an unused stockpile of about 15,000 tonnes of unprocessed
material. Some local interest has been shown in purchasing the pile for
agricultural purposes. The Plant could be reactivated and the stockpile
marketed, but the demands of the drilling industry alone would not be
sufficient to sustain production. Agricultural markets would also have to
be developed. The Alberta humalite has an advantage over the North
Dakota leonardite in that it contains significantly less gypsum. Gypsum
tends to retard the thixotropic properties of the drilling fluids.
7. INFRASTRUCTURE

The infrastructure required to bring humalite to market is essentially already in place. The most significant humalite deposit known is located near Sheerness in southeastern Alberta. A good network of roads and rail links exists in that area. In fact, part of the Measured Resource noted in Section 5.3.1 lies along a CPR rail line. Highway 36, within a few kilometres of the deposit, connects with the Trans-Canada Highway near Brooks, less the 100 km to the south. Alberta has sufficient haulage capacity in the trucking industry to accommodate substantial tonnages of humalite.

The Sheerness deposit lies approximately 200 km east of Calgary and 350 km southeast of Edmonton by road. Two of the largest potential markets for humalite in Alberta are in the treatment of various types of agricultural soils and in the reclamation/restoration of oil and gas well sites. Thousands of hectares of potential market opportunities lies within a 200 km radius of Sheerness for those two uses alone.

Processing facilities would be needed. As in coal mining, a mine-site tipple would be required. For primary treatment the tipple material would be fed into a drying or humic acid extraction plant. A drying/handling plant with capacity of 100,000 tonnes per year would cost about $1.6 million to construct. The operating cost (mining through processing and loading) would be about $23.00/tonne or $34.50 with a 50% margin added which would translate to a sale price of 31¢/kg.
Fig. 4 - Road and Rail Network in Alberta
8. IMPACT

8.1 Environmental Impact
The impact of humic acid products on soil and water are not at issue, except where impurities such as heavy metals are present in the raw material. Humic acids are major components of natural, healthy soils, and in some areas occur naturally in groundwater. In fact, some people feel that humic acids are beneficial to human health and have used them in folk remedies.

The major concern would involve the mining of the raw material. Potential mining of humalite at Sheerness or leonardite at Estevan would be associated with active coal mines, and would be covered by existing regulations. Given the excellent record of achievement by regulators and mining companies, problems would not be anticipated.

The overall impact of production of humalite and/or leonardite would probably be beneficial, providing better, more natural, products for agriculture and reclamation.

8.2 Social Impact
The only issue seems to relate to the creation of employment in an area that is traditionally short of jobs. If a processing plant were to be set up at Sheerness, about 15 full time jobs could be created in managing, handling and processing the product. Marketing and sales could generate another 5 to 15 jobs. It is assumed that mining would be handled by existing coal operations. The trucking industry would also likely benefit by the additional sales from the Alberta area.
9. DEVELOPMENT OF DEMAND

The current imported supply is more than adequate to handle the current demand. However, if demand were to grow, large quantities of material could be competitively produced locally in Alberta. A possible strategic approach to developing greater demand for humalite and/or leonardite products is outlined below.

1) Agricultural and reclamation research and testing. Appropriate government agencies should conduct field tests involving a variety of plant species and soil types. The existing distribution industry, small as it is, should be offered participation. Organizations such as coal and petroleum associations should also be sought as supporters and participants. The agricultural industry should be represented by appropriate groups. The use of humic acids to restore soils contaminated by hydrocarbons is one particularly interesting area for research and field testing.

2) The resource base in Alberta, Saskatchewan and British Columbia should be more rigorously defined. This includes the testing of materials for quality and trace elements.

3) Canadian business should be made more aware of this existing opportunity. Perhaps the chemical fertilizer industry should be encouraged to take up this approach as a business opportunity that is complementary, not competitive, with their current products. Some writers, such as Siemers and Wadell (1977), have suggested that humic acid products could be
combined with chemical fertilizers, to the benefit of both agriculture and the fertilizer industry.

4) The trend toward organically produced food is growing in Canada, but needs to be better quantified so that information can be made available to growers with a sufficient lead time for them to act.

5) The export potential and growing markets in the Pacific northwest should be better quantified. The appropriate private sector participants should be brought into this process.
10. CONCLUSIONS

Alberta and Saskatchewan have significant mineable deposits of humalite and leonardite. Agricultural, horticultural and reclamation markets are the key focus areas to stimulate production and processing of humic acid products from these materials. Markets for "environmentally friendly" agricultural products like leonardite and humalite are growing, as is the demand for natural foods that are grown with such products. The need to reclaim and restore disturbed and contaminated soils is also a growing market opportunity. Alberta has more than sufficient resources in the ground (>2 million tonnes speculative resources), and a real need for the product, as well as a need for the jobs that would be created. Opportunities for export markets are favourable, especially to the Pacific northwest.
11. SELECTED BIBLIOGRAPHY


