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ROYMAC HOLDINGS LTD.

MAGNETITE SAMPLING AND RESEARCH - 1983

BURMIS, ALBERTA

Trigg, Woollett Consulting Ltd.

December 1983

A. H. Grant
C. M. Trigg

ROYMAC HOLDINGS LTD.

MAGNETITE SAMPLING AND RESEARCH - 1983

BURMIS, ALBERTA

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SECTION I

ROYMAC HOLDINGS LTD.

SUMMARY OF MAGNETITE SAMPLING AND RESEARCH - 1983

BURMIS, ALBERTA

Trigg, Woollett Consulting Ltd.

December 1983

A. H. Grant
C. M. Trigg

ROYMAC HOLDINGS LTD.

SUMMARY OF MAGNETITE SAMPLING AND RESEARCH - 1983

BURMIS, ALBERTA

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ROYMAC HOLDINGS LTD.

SUMMARY OF
MAGNETITE SAMPLING AND RESEARCH - 1983

BURMIS, ALBERTA

INTRODUCTION

This section summarizes the report on 1983 field exploration that is contained in section II and the reports on magnetite research that are contained in sections III and IV. Conclusions based on the results of the three reports, and recommendations for future work are presented at the end of this section.

MAGNETITE SAMPLING - 1983, SOUTH BURMIS, ALBERTA (SECTION II)

Exploration, consisting of one or more of geological examinations, geological mapping, trenching, trench sampling and chip sampling, was performed at magnetite occurrences at three locations near Burmis, southwestern Alberta. Magnetite at South Burmis, North Burmis, and Dungarvan Creek occurrences exists as paleo-placer concentrations in folded and faulted Upper Cretaceous Belly River Formation sandstone. Locally, magnetite constitutes as much as 60 per cent of the volume of rock. Trenching, drilling and bulk sampling of some occurrences have been performed in the past.

At South Burmis magnetite occurrences two bulk samples of magnetite-rich sandstone were collected from a trench excavated in 1983; the samples were submitted to the Coal Mining Research Centre, Edmonton, Alberta for determination of magnetite content and to determine the suitability of the magnetite as a gravimetric separating medium in coal cleaning processes. Ultimately, tests were performed on only one sample (059) that had been hand-trimmed to remove most secondary iron oxide minerals. The Coal Mining Research Centre has issued reports to Trigg, Woollett Consulting Ltd. summarizing test results and recommendations.

Portions of the test product material produced by the Coal Mining Research Centre were submitted for analysis of silver, cadmium, cobalt, copper, molybdenum, nickel, zinc, tungsten, lead, bismuth, antimony, barium, chromium, niobium, thorium, titanium, tin, uranium, vanadium, zirconium, cerium, tantalum and yttrium - elements which commonly exist in heavy minerals that may occur as placer concentrations. Concentrations of most of the elements are low; high concentrations of titanium, vanadium, zirconium and cerium do not constitute economically significant grades.

At South Burmis magnetite occurrences, eleven rock chip samples were collected from the trench excavated during 1983 exploration and from two trenches excavated in the late 1950's. Three rock chip samples were collected from outcrop at Dungarvan Creek magnetite occurrences. The fourteen chip samples were analyzed for gold, platinum and palladium, which may be concentrated as placer deposits. The fourteen chip samples contain maximum concentrations of 125 parts per billion gold, less than 50 parts per billion platinum, and 15 parts per billion palladium; these concentrations are not of economic importance.

The report concludes that results of magnetite content and quality tests performed by the Coal Mining Research Centre will determine if further exploration is warranted at South Burmis magnetite occurrences. Further exploration at North Burmis magnetite occurrences should be performed only in conjunction with future exploration, if warranted, at South Burmis occurrences.

EVALUATION OF MAGNETITE, RESEARCH TASK 83/76 (SECTION III)

Many coal cleaning processes utilize a slurry of high specific gravity to separate fine grained coal, which floats on the slurry, from denser waste material, which sinks. Magnetite is a preferred separating medium because it has high specific gravity and because it can be recovered from waste material by magnetic separators, and reused. Because of its high specific gravity, magnetite must be of very fine grain size to remain in suspension in a separating medium; typical commercial coal preparation magnetite concentrate contains at least 85 weight per cent grains of less than 0.045 mm (325 mesh) diameter. Magnetite-bearing rock must usually be milled to achieve the fine grain size. Magnetite grains and magnetite concentrate must be of high purity to ensure high specific gravity of the separating medium and to enhance magnetite recovery from waste material. Commercial coal preparation magnetite concentrate typically has a specific gravity of 4.6 to 4.8 (relative to 5.18 for pure magnetite); magnetite concentrate typically contains less than 10 per cent non-magnetic impurities.

The Coal Preparation Division of the Coal Mining Research Centre was awarded a contract to determine the magnetite content, or grade, of southwestern Alberta magnetite occurrences and the suitability of the magnetite as a coal preparation medium. The Coal Mining Research Centre evaluated data from previous studies and performed tests on magnetite-rich sandstone supplied by Trigg, Woollett Consulting Ltd.

Based on published data for sixty iron-rich sandstone samples collected in southwestern Alberta, the Coal Mining Research Centre suggests that the mean magnetite content of the sandstone is less than 15 per cent by weight (less than 13.5 per cent by volume). Approximately 94 per cent of magnetite grains are coarser than the desired 0.045 mm diameter, and magnetite-bearing sandstone must, therefore, be very finely ground to liberate magnetite of the required diameter. Impurities that exist as inclusions of other minerals in magnetite or as oxidation products of magnetite will not adversely affect magnetite specific gravity, degree of magnetite recovery from waste material, or the quality of cleaned coal. Results of previous concentration tests that used laboratory-scale magnetic separators indicate that a suitable magnetite concentrate can be produced from low grade southwestern Alberta magnetite-bearing sandstone.

Tests performed by the Coal Mining Research Centre on sample 059, which was provided by Trigg, Woollett Consulting Ltd., consisted of crushing, milling and magnetic separation. Crushing of the initial sample was accomplished by a jaw crusher, milling to a fine grain size was accomplished by ball milling, hammer and/or by mortar and pestle milling, magnetic separation was accomplished with a Davis Tube Wet Magnetic Separator - a highly efficient laboratory-scale separator. Wet ball-milling and mortar and pestle milling produced sub-samples consisting entirely of grains less than 0.045 mm in diameter; other milling techniques did not produce the size of material required for coal preparation.

Results of Davis Tube magnetic concentration tests on milled sub-samples show that the percentage of magnetic material recovered from crushed rock decreases with decreasing grain size of test material, consistent with published data. This decrease in recovery is desirable since it indicates that magnetic material is being more efficiently separated from non-magnetic material at finer grain sizes and that the concentrate will, therefore, contain a greater percentage of magnetite. Milled sub-sample 059A, which was slightly coarser than desired, produced a magnetite concentrate weighing approximately 55 per cent of the original milled sample and had a specific gravity of 4.5. Milled sub-sample 059E, which was too fine for coal preparation, produced a magnetite concentrate weighing approximately 45 per cent of the original milled sample. The ideal size of material should be between the sizes of sub-samples 059A and 059E and should presumably produce a magnetite concentrate weighing approximately 50 per cent of the original sample.

Based on iron analyses performed by an independent laboratory, sample 059 contains approximately 40 per cent magnetite by weight; sample 059E contains approximately 91 per cent magnetite by weight. Sample 059A has an estimated magnetite content of 72 per cent by weight and would, therefore, have an acceptable specific gravity of 4.5.

The results of tests performed on sample 059 indicate that the sample will produce a magnetite concentrate suitable for coal preparation. Weight per cent recovery would be approximately 50 per cent from sandstone containing 40 per cent magnetite by weight; the concentrate would presumably have a magnetite content between 91 per cent and 72 per cent, and a specific gravity greater than 4.5.

The report recommends that two 50 kg samples, one containing approximately 40 per cent magnetite by weight and one containing approximately 15 per cent magnetite by weight, be processed using small scale commercial equipment. The testing was estimated to require approximately four weeks to complete at an estimated cost of $2,500. Important properties such as specific gravity, recoverability and magnetite content of test product material produced by the recommended processing should be compared with those of magnetite concentrate currently being used for coal preparation in western Canada. This comparison testing was estimated to require approximately two weeks to complete at an estimated cost of $2,000.

EVALUATION OF MAGNETITE: PHASE TWO (SECTION IV)

In Section III, Coal Mining Research Centre concluded that magnetite-bearing sandstone from southwestern Alberta can be processed to yield a magnetite concentrate suitable as a gravimetric separating medium for coal cleaning. The conclusion was based on results of evaluation of published data and on results of laboratory tests performed on high grade magnetite-bearing sample 059, which was collected in 1983 by Trigg, Woollett Consulting Ltd. Further evaluation using small scale commercial processing equipment, and comparison of the processed magnetite concentrate with concentrate currently in use in western Canada, were recommended.

The recommended further evaluation was performed using sample 059, which contains approximately 40 weight per cent magnetite. Coal Mining Research Centre submitted approximately 45 kg of a crushed portion of sample 059 to Eriez Magnetics Ltd., Erie, Pennsylvania, for feasibility tests. The objective of the tests was to determine if commercial milling and magnetic separation equipment could produce a coal preparation medium containing at least 96 per cent grains, by weight, of less than 0.045 mm diameter and at least 91 per cent, by weight, magnetic material. The specifications correspond to Foote Grade E magnetite, which is a high quality magnetite commonly used in coal preparation.

Feasibility tests produced a concentrate containing 99.5 weight per cent grains finer than 0.045 mm diameter and 93.5 weight per cent magnetic material; the concentrate has a specific gravity of 4.5. Results of the feasibility tests indicate that a high grade magnetite concentrate can be produced from magnetite-rich sandstone from southwestern Alberta using conventional processing techniques.

Magnetite concentrate produced from sample 059 is finer grained and has lower specific gravity than magnetite concentrates from Wesfrob and Craigmont, both of which are currently in use in Western Canada. Because sample 059 magnetite concentrate was prepared in a laboratory, it is probable that a commercially produced concentrate would be coarser and of lower specific gravity, however, the decrease in specific gravity would not be significant.

The percentage of magnetic material in sample 059 magnetite concentrate is slightly higher than in the Wesfrob and Craigmont magnetite concentrates. However, recoverability of magnetic material from sample 059 concentrate, based on a non-standard test devised by the Coal Mining Research Centre, is lower, probably due to lower purity of the magnetite. In high intensity magnetic fields associated with large commercial magnetic separators it is felt that the recovery of magnetic material from sample 059 concentrate would, at worst, be only marginally lower than recoverability from the Wesfrob and Craigmont magnetite concentrates.

Magnetite concentrate produced commercially from southwestern Alberta magnetite-bearing sandstone would probably be inferior to magnetite concentrates currently in use, but would still be acceptable as a coal preparation medium.

The report recommends that results of tests performed on sample 059 should be applied to material of the grade that would be mined in southwestern Alberta in order to determine the economic feasibility of mining the deposits. If this testing is positive and if mining of the deposits is economically feasible, then it is recommended that approximately 2 tonnes of typical grade material should be subjected to a more comprehensive feasibility study on full scale magnetic separators.

CONCLUSIONS

Laboratory testing of a selected magnetite sample (059) from the South Burmis deposit has shown that a magnetite concentrate acceptable as a coal preparation medium can be produced. However, the magnetite concentrate could be inferior, because of lower specific gravity and poorer recoverability, to magnetite concentrates from Wesfrob and Craigmont that are presently in use in western Canadian coal cleaning plants.

Because the South Burmis magnetite deposit is well positioned relative to producing coal mines, is within a few kilometres of highway 3, is within a few kilometres of Canadian Pacific Railways Crowsnest line and because the property is not subject to other than government production royalties, further evaluation is warranted. However, further evaluation of South Burmis magnetite deposit should be performed in conjunction with evaluation of other magnetite deposits in Western Canada.

RECOMMENDATIONS

Discussions should be held with representatives of Coal Mining Research Centre in order to determine the exact nature and costs of the recommendations which they present in "Evaluation of Magnetite: Phase Two".

Prior to instituting any recommendations proposed by the Coal Mining Research Centre, the results of the literature research on western Canadian magnetite deposits should be evaluated and priorities placed upon which deposits, including the Burmis, Alberta deposits, warrant further attention.

Trigg, Woollett Consulting Ltd.

[redacted]

A. H. Grant, M.Sc., P.Geol.

[redacted]

C. M. Trigg, Ph.D., P.Eng.

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF ALBERTA
PERMIT NUMBER
P 2374
TRIGG, WOOLLETT CONSULTING LTD.

December 20, 1983
Edmonton, Alberta

CERTIFICATION

I, C. M. TRIGG OF [redacted] EDMONTON, ALBERTA CERTIFY AND DECLARE THAT I AM A GRADUATE OF THE UNIVERSITY OF BRITISH COLUMBIA WITH A B.A.SC. DEGREE IN GEOLOGICAL ENGINEERING (1954) AND A GRADUATE OF MCGILL UNIVERSITY WITH A PH.D. DEGREE IN GEOLOGY (1964). I AM REGISTERED AS A PROFESSIONAL GEOLOGIST AND A PROFESSIONAL ENGINEER WITH THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS AND GEOPHYSICISTS OF ALBERTA AND I AM LICENSED TO PRACTISE AS A PROFESSIONAL ENGINEER WITH THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF ONTARIO AND SASKATCHEWAN.

MY EXPERIENCE INCLUDES SERVICE AS A MINE GEOLOGIST, ELDORADO NUCLEAR LIMITED, GREAT BEAR LAKE, N.W.T., CHIEF MINE GEOLOGIST AND CHIEF GEOLOGIST IN CHARGE OF EXPLORATION, ELDORADO NUCLEAR LIMITED, BEAVERLODGE, SASKATCHEWAN; MANAGER, EXPLORATION, J. FOSTER IRWIN ENGINEERING & MANAGEMENT SERVICES LTD., EDMONTON, ALBERTA. SINCE 1968 I HAVE CONDUCTED AND DIRECTED PROPERTY EXAMINATIONS, PROPERTY EVALUATIONS AND EXPLORATION PROGRAMS ON BEHALF OF COMPANIES AS PRINCIPAL OFFICER OF TRIGG, WOOLLETT & ASSOCIATES LTD. AND TRIGG, WOOLLETT CONSULTING LTD.

I HAVE NO DIRECT OR INDIRECT INTEREST IN ROYMAC HOLDINGS LTD., NOR DO I EXPECT TO RECEIVE SUCH INTEREST.

THE REPORT ENTITLED "SUMMARY, MAGNETITE SAMPLING AND RESEARCH - 1983, BURMIS, ALBERTA" IS BASED UPON STUDY OF PUBLISHED AND UNPUBLISHED DATA.

[redacted]

C. M. TRIGG, PH.D., P.ENG.

DECEMBER 1983
EDMONTON, ALBERTA

SECTION II

NTS 82G/9, 82H/4

ROYMAC HOLDINGS LTD.

MAGNETITE SAMPLING - 1983

SOUTH BURMIS, ALBERTA

Trigg, Woollett Consulting Ltd.

June 1983

R. K. Johnston
C. M. Trigg

ROYMAC HOLDINGS LTD.

MAGNETITE SAMPLING - 1983

SOUTH BURMIS, ALBERTA

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MAGNETITE SAMPLING - 1983

SOUTH BURMIS, ALBERTA

SUMMARY

Trenching, trench sampling, chip sampling and/or geological mapping were performed at magnetite occurrences in southwestern Alberta. Two samples of Belly River Formation magnetite-rich sandstone were collected at South Burmis occurrences and submitted to the Coal Mining Research Centre for determination of magnetite content and to determine the suitability of the magnetite as a gravimetric separating medium in coal cleaning processes. The submitted samples are visually estimated to contain 50 to 60 per cent magnetite by volume. Test product material prepared by the Coal Mining Research Centre does not contain important concentrations of silver, cadmium, cobalt, copper, molybdenum, nickel, zinc, tungsten, lead, bismuth, antimony, barium, chromium, niobium, thorium, titanium, tin, uranium, vanadium, zirconium, cerium, tantalum or yttrium. Chip samples collected from magnetite-rich and magnetite-poor sandstone in trenches at South Burmis occurrences contain only low concentrations of gold, platinum and palladium.

A geological examination of North Burmis magnetite occurrences was performed. The occurrences are similar to South Burmis magnetite occurrences and have a visually estimated magnetite content of 40 to 50 per cent by volume.

Geological examination and chip sampling were performed at Dungarvan Creek magnetite occurrences. The occurrences are geologically similar to those at South Burmis and contain visually estimated 30 to 40 per cent magnetite by volume. Chip samples contain only low concentrations of gold, platinum and palladium.

Results of magnetite content and quality tests on submitted samples and recommendations by the Coal Mining Research Centre will determine if further sampling or exploration is required at South Burmis magnetite occurrences. Further exploration at North Burmis magnetite occurrences should be performed only in conjunction with further sampling and exploration, if warranted, at South Burmis occurrences.

INTRODUCTION

Location and Access

South Burmis magnetite occurrences are in the Rocky Mountain Foothills approximately 5 km east of Crowsnest Pass, Alberta, and are within the area designated National Topographic System (NTS) 82G/9 (Dwg. 3202-1). Trench samples were collected at occurrences that exist from 2 to 3 km north of Burmis, Alberta. Access to the occurrences is by private, four-wheel drive road leading north from Highway 3. The Canadian Pacific Railway main line and Highway 3 pass through Burmis.

North Burmis magnetite occurrences are approximately 13 km north of Burmis within the area designated NTS 82G/9 (Dwg. 3202-1). The occurrences are accessible by private four-wheel drive road leading west from the North Burmis municipal road. Previous exploration in the area comprised road-building, trenching, drilling and driving of an adit for removal of bulk samples. North Burmis magnetite occurrences are within an area classified as Forestry Reserve.

Dungarvan Creek magnetite occurrences are approximately 29 km south of Pincher Creek, Alberta, within the area designated NTS 82H/4 (Dwg. 3202-1). The occurrences examined are 5 km west of Highway 6 and are accessible by municipal road leading west from the highway, 7 km south of Twin Butte, Alberta. Mineral rights to Dungarvan Creek magnetite occurrences are held by Cunningham Creek Mines Ltd., Calgary, Alberta.

1983 Sampling, Geological Evaluations

Trenching, trench sampling, chip sampling, and geological mapping of trenches were performed at the South Burmis magnetite occurrences from May 8 to 14, 1983. Geological examination of the North Burmis magnetite occurrences was performed May 10, 1983. Chip sampling and geological examination of the Dungarvan Creek magnetite occurrences were performed May 15, 1983. Table I compares South Burmis, North Burmis and Dungarvan Creek magnetite occurrences.

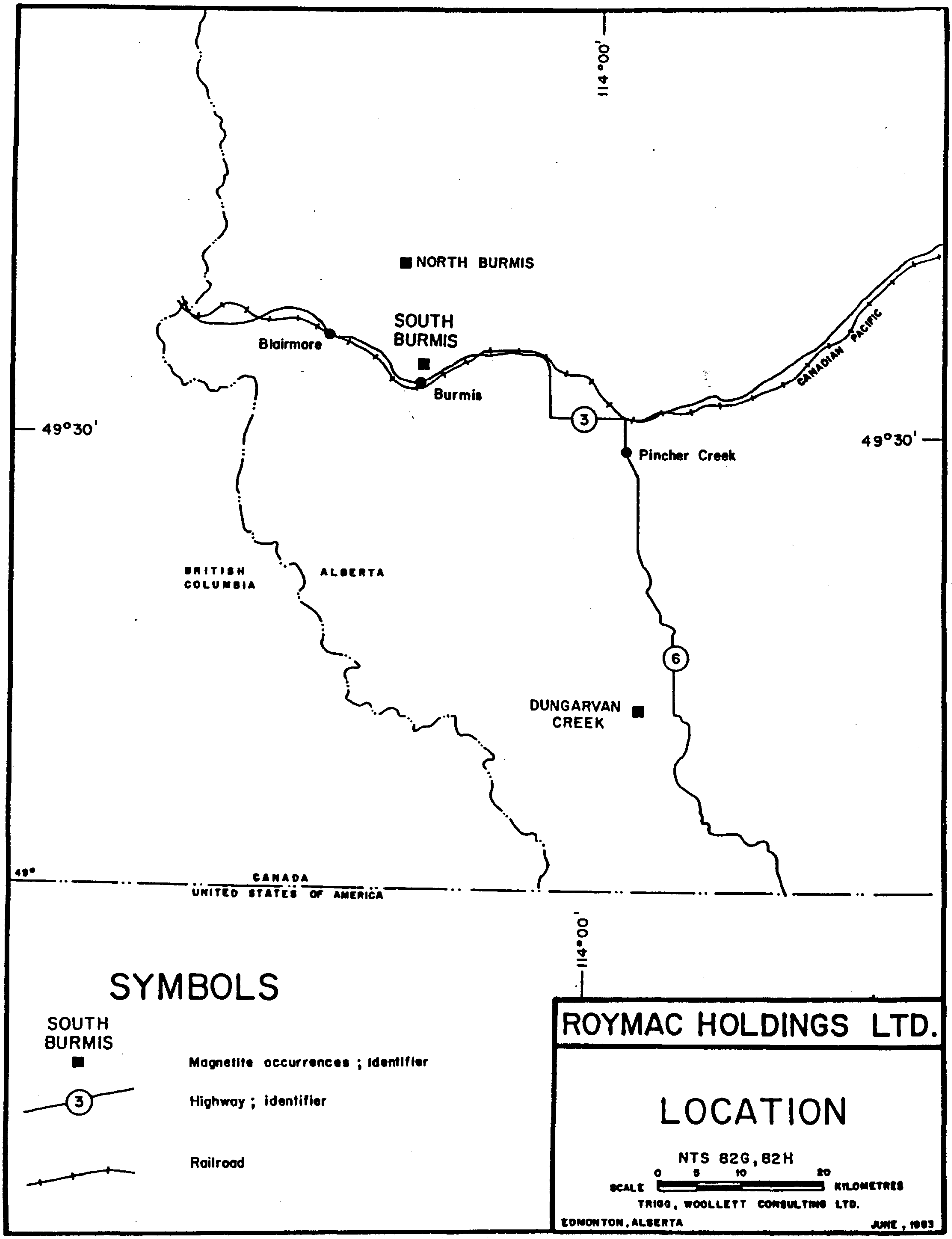
Magnetite-rich samples were collected at South Burmis magnetite occurrences for testing to determine magnetite content and suitability of the magnetite as a gravimetric separating medium for coal cleaning processes.

SOUTH BURMIS MAGNETITE OCCURRENCES

Geology

Regional geology has been compiled at 1:126,720 scale by the Geological Survey of Canada (Price, 1961).

The South Burmis magnetite occurrences are hosted by the basal sandstone member of the Belly River Formation, of late Cretaceous age. Mellon (1961) postulates that the magnetite-bearing sandstone beds were concentrated as placer deposits along the margin of the late Cretaceous Colorado sea. The basal member of the Belly River Formation consists of cream weathering, cross-bedded, fine- to medium-grained, poorly indurated sandstone (Figure 1, Appendix I).


114°00'
NORTH BURMIS
SOUTH BURMIS
Blairmore
Burmis
CANADIAN PACIFIC
49°30'
3
Pincher Creek
49°30'
BRITISH COLUMBIA
ALBERTA
6
DUNGARVAN CREEK
49°
CANADA
UNITED STATES OF AMERICA
114°00'
SYMBOLS
SOUTH BURMIS
Magnetite occurrences ; identifier
3
Highway ; identifier
Railroad
ROYMAC HOLDINGS LTD.
LOCATION
NTS 82G, 82H
0 5 10 20
SCALE KILOMETRES
TRIGG, WOOLLETT CONSULTING LTD.
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JUNE, 1983

DWG.3202-1

Magnetite-bearing sandstone outcrops along a narrow, north-trending zone over an approximately 5 km strike length extending north from Burmis. Upper Cretaceous rocks have been folded into a broad, north-plunging anticline which is cut by numerous north-striking, west-dipping thrust faults. Magnetite-bearing sandstone occurs on the west limb of the anticline, forming a series of north-striking, subparallel ridges. High magnetite content, with resulting dark color, high magnetism and resistance to weathering make the magnetite-bearing beds a distinct sedimentary horizon.

The South Burmis magnetite-bearing sandstones are divided into two units based on visual estimates of magnetite content. Magnetite-rich beds are dark grey-blue, massive, very fine grained and strongly magnetic and have considerably greater specific gravity than barren host-rock sandstone. Magnetite-rich sandstone is estimated to contain 50 to 60 per cent magnetite by volume. Mafic rock fragments and chlorite, and lesser amounts of hematite, quartz and calcite, make up 40 to 50 per cent of rock volume.

Magnetite-poor sandstone beds are olive-green weathering to dark green weathering, massive, very fine- to fine-grained, and weakly to moderately magnetic and have specific gravity only slightly greater than barren host-rock sandstone. The majority of magnetite-poor sandstone is estimated to contain 5 to 10 per cent magnetite by volume. Quartz, mafic rock fragments, chlorite, biotite, hematite and calcite cement, in order of decreasing abundance, make up the remaining rock volume. Sandstone containing 2 to 5 per cent magnetite by volume is olive-green; magnetite occurs as laminae and small lenses of magnetite-rich sandstone. Organic material in the form of black, brittle bitumen and a coal-like substance, occurs in small (less than 5 cm across), planar, matted forms, usually in association with lenses of magnetite-rich material.

Magnetite-rich and magnetite-poor sandstone are interbedded; individual beds are in the order of 1 m or less thick. Results of geological mapping of trenched magnetite-bearing sandstone indicate a complex history of small-scale faulting and folding accompanied by pervasive fracturing. Fractured pieces of rock are rarely greater than 20 cm in any dimension.

Oxidation of magnetite to hematite and limonite along fractures has produced a weathered rind averaging 1 cm thick (Figure 3, Appendix I). Weathering has occurred to at least 1.0 m depth as indicated by trenching.

Trenching and Sampling

Trench 1 (Dwgs. 3202-2, 3202-3; Appendix I, Figures 3 and 4) was excavated during 1983 exploration. Trench 2 (Dwgs. 3202-2, 3202-4) and Trench 3 (Dwgs. 3202-2 and 3202-5) were excavated during exploration performed in 1956 and 1957 by West Canadian Magnetic Ores Ltd. (Mellon, 1961).

Two samples, 059 and 123, each weighing about 150 kg and each comprising about 0.068 m^3 of magnetite-rich sandstone, were collected from Trench 1. Sample 059 consists of hand-picked magnetite-rich sandstone with a maximum estimated secondary iron oxide content of 0.5 per cent. As much as possible of the oxidized rind was removed by hand-trimming in order to obtain a sample as rich in magnetite and as low in oxidized iron as possible. Sample 123 consists of hand-picked magnetite-rich sandstone with an estimated secondary iron oxide content of 5 per cent. Oxidized rind was not trimmed from fragments constituting this sample. Both samples were submitted to the Coal Mining Research Centre, Coal Preparation Division, Edmonton, Alberta for testing to determine magnetite content and suitability of the magnetite as a gravimetric separating medium for coal cleaning processes; tests were performed only on sample 059. The Coal Mining Research Centre has issued reports to Trigg, Woollett Consulting Ltd. summarizing test results and recommendations; see sections III and IV which follow this report.

A portion of the test product material prepared by the Coal Mining Research Centre was submitted to Bondar-Clegg & Company Ltd., Ottawa, Ontario for analysis by atomic absorption spectroscopy technique for silver, cadmium, cobalt, copper, molybdenum, nickel, zinc, tungsten, lead and bismuth. A second portion was submitted to Bondar-Clegg & Company Ltd., Vancouver, British Columbia for analysis by X-ray fluorescence technique for antimony, barium, chromium, niobium, thorium, titanium, tin, uranium, vanadium, zirconium, cerium, tantalum and yttrium. These elements exist within heavy minerals that occur as paleo-placer deposits and as heavy mineral beach sands forming at present. The test product material contains approximately 72 per cent magnetite and 28 per cent non-magnetic grains (section III, p.15). Analytical results are in Appendix II.

Six chip samples were collected from magnetite-rich and magnetite-poor sandstone at Trench 1 (Dwg. 3202-3), one chip sample was collected from magnetite-poor sandstone at Trench 2 (Dwg. 3202-4), four chip samples were collected from magnetite-rich and magnetite-poor sandstone at Trench 3 (Dwg. 3202-5). The samples were analyzed for gold, platinum and palladium by combined fire assay and atomic absorption technique by Bondar-Clegg & Company Ltd., Vancouver, British Columbia; analytical results are in Appendix II.

Test product material from sample 059 contains 0.2 parts per million (ppm) silver, less than 0.2 ppm cadmium, 32 ppm cobalt, 15 ppm copper, 4 ppm molybdenum, 41 ppm nickel, 485 ppm zinc, 138 ppm tungsten, 62 ppm lead, less than 2 ppm bismuth, less than 1 ppm antimony, 43 ppm barium, 154 ppm chromium, 70 ppm niobium, 71 ppm thorium, 4.48 per cent titanium, 22 ppm tin, 16 ppm uranium, 1,675 ppm vanadium, 1,583 ppm zirconium, 1,052 ppm cerium, 8 ppm tantalum and 41 ppm yttrium.

Concentrations of gold in the chip samples range from less than 5 to 125 parts per billion; concentrations of platinum are all less than 50 parts per billion and concentrations of palladium range from less than 5 to 15 parts per billion.

NORTH BURMIS MAGNETITE OCCURRENCES

Geology

North Burmis magnetite occurrences, which are northerly strike extensions of South Burmis occurrences, outcrop as sharp, north-trending ridges. Topographic relief is in the order of 200 m to 300 m. Thrust faulting and folding have produced at least four stacked repetitions of the magnetite-bearing horizon (Mellon, 1961). Magnetite occurs in the Belly River Formation basal sandstone in alternating magnetite-rich and magnetite-poor beds which are 1 m or less thick, as at South Burmis. Visual estimates of magnetite content are 40 to 50 per cent by volume; chlorite content is significantly greater than in similar rocks at South Burmis magnetite occurrences. Fracturing of magnetite-bearing sandstone is much less intense at North Burmis than at South Burmis, probably as a result of less intense small scale faulting.

DUNGARVAN CREEK MAGNETITE OCCURRENCES

Geology

Dungarvan Creek magnetite occurrences are hosted by basal Belly River Formation sandstone in a geological setting similar to that at South Burmis (Mellon, 1961; Dwg. 3202-6). Outcrops examined on the north bank of Dungarvan Creek are nearly flat-lying and are cut by a complex system of faults. In general, structural and stratigraphic features of Dungaravan Creek magnetite occurrences are consistent with those at South Burmis occurrences. Magnetite-rich sandstone contains an estimated 30 to 40 per cent magnetite by volume; interlaminated barren sandstone makes up 20 to 30 per cent rock volume.

Sampling

Three chip samples were collected perpendicular to bedding across magnetite-rich and magnetite-poor sandstone outcrops at two locales (Dwg. 3202-6). The samples were analyzed for gold, platinum and palladium by Bondar-Clegg & Company Ltd., Vancouver, British Columbia (Appendix II).

Concentrations of gold in the chip samples range from 5 to 20 parts per billion (ppb), concentrations of platinum are less than 50 ppb and concentrations of palladium are 5 ppb or less.

CONCLUSIONS

Magnetite-rich sandstone at South Burmis occurrences contains visually estimated 50 to 60 per cent magnetite by volume.

Results of magnetite content and quality tests on samples collected at South Burmis occurrences and submitted to the Coal Mining Research Centre will determine if further sampling or exploration is warranted at South Burmis magnetite occurrences.

Concentrations of silver, cadmium, cobalt, copper, molybdenum, nickel, zinc, tungsten, lead, bismuth, antimony, barium, chromium, niobium, thorium, tin, uranium, tantalum and yttrium are low in test product material prepared by the Coal Mining Research Centre. Although high concentrations of titanium (4.48 per cent), vanadium (1,675 ppm), zirconium (1,583 ppm) and cerium (1,052 ppm) exist in the sample, they do not constitute economically important concentrations.

Chip samples from magnetite-rich and magnetite-poor sandstone at South Burmis contain only low concentrations of gold, platinum and palladium.

North Burmis magnetite occurrences are strike extensions of, and are similar to, South Burmis magnetite occurrences. North Burmis magnetite-rich sandstone is visually estimated to contain 40 to 50 per cent magnetite by volume.

Chip samples collected from magnetite-rich and magnetite-poor sandstone at Dungarvan Creek contain low concentrations of gold, platinum and palladium. These magnetite occurrences are geologically similar to those at South Burmis although visual estimates of magnetite content are lower; magnetite comprises 30 to 40 per cent magnetite by volume.

RECOMMENDATIONS

Results of magnetite content and quality tests on submitted samples, and recommendations by the Coal Mining Research Centre will determine if further sampling or exploration should be performed at South Burmis magnetite occurrences. Further exploration at North Burmis magnetite occurrences is recommended only if performed in conjunction with further sampling and exploration at South Burmis magnetite occurrences, if warranted.

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS,
GEOLOGISTS and GEOPHYSICISTS
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P 2374
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CONSULTING LTD.

Trigg, Woollett Consulting Ltd.

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R. K. Johnston, B.Sc.

[redacted]

C. M. Trigg, Ph.D., P.Eng.

June 1983
Edmonton, Alberta

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Price, R. A. (1961) Geology: Fernie (east half), British Columbia - Alberta, 1:126,720; Geol. Surv., Canada, Map 35-1961.

CERTIFICATION

I, C. M. TRIGG OF [redacted]EDMONTON, ALBERTA CERTIFY AND DECLARE THAT I AM A GRADUATE OF THE UNIVERSITY OF BRITISH COLUMBIA WITH A B.A.SC. DEGREE IN GEOLOGICAL ENGINEERING (1954) AND A GRADUATE OF MCGILL UNIVERSITY WITH A PH.D. DEGREE IN GEOLOGY (1964). I AM REGISTERED AS A PROFESSIONAL GEOLOGIST AND A PROFESSIONAL ENGINEER WITH THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS AND GEOPHYSICISTS OF ALBERTA AND I AM LICENSED TO PRACTISE AS A PROFESSIONAL ENGINEER WITH THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF ONTARIO AND SASKATCHEWAN.

MY EXPERIENCE INCLUDES SERVICE AS A MINE GEOLOGIST, ELDORADO NUCLEAR LIMITED, GREAT BEAR LAKE, N.W.T., CHIEF MINE GEOLOGIST AND CHIEF GEOLOGIST IN CHARGE OF EXPLORATION, ELDORADO NUCLEAR LIMITED, BEAVERLODGE, SASKATCHEWAN; MANAGER, EXPLORATION, J. FOSTER IRWIN ENGINEERING & MANAGEMENT SERVICES LTD., EDMONTON, ALBERTA. SINCE 1968 I HAVE CONDUCTED AND DIRECTED PROPERTY EXAMINATIONS, PROPERTY EVALUATIONS AND EXPLORATION PROGRAMS ON BEHALF OF COMPANIES AS PRINCIPAL OFFICER OF TRIGG, WOOLLETT & ASSOCIATES LTD. AND TRIGG, WOOLLETT CONSULTING LTD.

I HAVE NO DIRECT OR INDIRECT INTEREST IN ROYMAC HOLDINGS LTD., NOR DO I EXPECT TO RECEIVE SUCH INTEREST.

R.K. JOHNSTON'S REPORT ENTITLED "MAGNETITE SAMPLING - 1983, SOUTH BURMIS, ALBERTA" IS BASED UPON FIELD WORK AND UPON STUDY OF PUBLISHED AND UNPUBLISHED DATA.

[redacted]

C. M. TRIGG, PH.D., P.ENG.

JUNE, 1983

EDMONTON, ALBERTA

TABLE I

SOUTH BURMIS, NORTH BURMIS, DUNGARVAN CREEK

MAGNETITE OCCURRENCE COMPARISONS

Features	South Burmis Occurrences	North Burmis Occurrences	Dungarvan Creek Occurrences
Topography	Prominent north-south ridges: relief 100 m to 200 m	Prominent north-south ridges in steps rising to the west: relief 300 m or greater	Flat to gently rolling hills: relief 20 m or less
Outcrops	Sharp, north trending ridges, outcrops dipping westward, faulted, badly fractured	Sharp, north trending ridges, folded, thrust faulted and repeated	Low, soil covered ridges. Flat-lying, faulted
Host rock: Belly River Formation basal sandstone	Cream weathering, thinly cross-bedded, fine grained, poorly indurated sand-stone	Cream weathering, thinly cross-bedded, fine grained, poorly indurated sandstone	Cream weathering, thin- to medium bedded, fine grained, poorly- to well-indurated sandstone
Magnetite-rich sandstone texture	Massive, granular	Massive, granular	Inter-laminated magnetite-rich and barren sandstone
Visually estimated magnetite content	50 to 60 per cent	40 to 50 per cent	30 to 40 per cent
Estimated reserves	1,384,000 tonnes	139,200 tonnes	5,828,800 tonnes
Land status	Private land; mineral rights held by Trigg, Woollett Consulting Ltd. on behalf of Roymac Holdings Ltd.	Crown land; Forestry Reserve. Mineral rights held by Trigg, Woollett Consulting Ltd. on behalf of Roymac Holdings Ltd.	Private land

APPENDIX I

SOUTH BURMIS PHOTOGRAPHS

APPENDIX I

LIST OF FIGURES

Figure 1. Belly River Formation basal sandstone at Trench 2, South Burmis.

Figure 2. Belly River Formation: barren sandstone overlain by magnetite-rich sandstone. Photograph taken near Trench 3, South Burmis.

Figure 3. Fractured magnetite-rich sandstone with concentric oxidation rinds. Photograph of south wall of Trench 1, South Burmis.

Figure 4. Trench 1, looking west-southwest.

APPENDIX II

GEOCHEMICAL LAB REPORTS

Bondar-Clegg & Company Ltd.
130 Pemberton Ave.
North Vancouver, B.C.
Canada V7P 2R5
Phone: (604) 985-0681
Telex: 04-352667

BONDAR-CLEGG

Geochemical Lab Report

EPORT: 123-0782

ROM: TRIGG, WOOLLETT CONSULTING LTD. SUBMITTED BY: R JOHNSTON
ATE: 14-JUN-83 PROJECT: 3202

LEMENT	LOWER DETECTION LIMIT	EXTRACTION	METHOD	SIZE FRACTION	SAMPLE TYPE	SAMPLE PREPARATIONS
Au	5 PPB	AQUA REGIA	Fire Assay AA	-100	ROCKS	CRUSH,PULVERIZE -100
Pt	15 PPB	AQUA REGIA	Fire Assay AA	-100		RETENTION OF REJECTS
~~Pd~~	~~2~~			~~-100~~		

EPORT COPIES TO: TRIGG WOOLLETT CONSULT. INVOICE TO: MR. R. JOHNSTON
MR. R. JOHNSTON

EMARKS:

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130 Pemberton Ave.
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Canada V7P 2R5
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Telex: 04-352667

BONDAR-CLEGG

Geochemical Lab Report

ˌEPORT: 123-0782 PROJECT: 3202

AMPLE UMBER	ELEMENT UNITS	Au PPB	Pt PPB	Pd PPB	NOTES
3RJ0001		<5	<50	<5	
3RJ0002		<5	<50	<5	
R 3RJ0003		10	<50	15	
P 3RJ0004		15	<50	10	
3RJ0005		<5	<50	<5	
R 3RJ0006		10	<50	<5	
3RJ0007		<5	<50	15	
3RJ0008		<5	<50	<5	
R 3RJ0009		25	<50	<5	
3RJ0010		<5	<50	<5	
R 3RJ0011		125	<50	<5	
R 3RJ0012		5	<50	<5	
3RJ0013		20	<50	<5	
3RJ0014		20	<50	<5	

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764 Belfast Road
Ottawa, Ontario
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Telex: 053-4455

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Geochemical Lab Report

[illegible]: 013-1309

[illegible]: TRIGG-WOOLLETT CONSULTING LTD. SUBMITTED BY: F. WYNNE
[illegible]: 29-JUN-83 PROJECT: 3202

[illegible]	ELEMENT	LOWER DETECTION LIMIT	EXTRACTION	METHOD	SIZE FRACTION	SAMPLE TYPE	SAMPLE PREPARATIONS
01	Cu	1 PPM	MULT ACID TOT DIG	DC Plasma		PREPARED PULP	AS RECEIVED, NO SP
	Pb	2 PPM	MULT ACID TOT DIG	DC Plasma			
	Zn	1 PPM	MULT ACID TOT DIG	DC Plasma			
04	Mo	1 PPM	MULT ACID TOT DIG	DC Plasma			
	Co	1 PPM	MULT ACID TOT DIG	DC Plasma			
	Ni	1 PPM	MULT ACID TOT DIG	DC Plasma			
07	Cd	.5 PPM	MULT ACID TOT DIG	DC Plasma			
08	Ag	.2 PPM	MULT ACID TOT DIG	DC Plasma			
	Bi	2 PPM	MULT ACID TOT DIG	DC Plasma			
	W	1 PPM	MULT ACID TOT DIG	DC Plasma			

[illegible]RT COPIES TO: DR. C.M. TRIGG INVOICE TO: DR. C.M. TRIGG

[illegible]RKS: < MEANS LESS THAN

W-

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Geochemical Lab Report

REPORT: 013-1309 PROJECT: 3202 PAGE 1

SAMPLE NUMBER	ELEMENT UNITS	Cu PPM	Pb PPM	Zn PPM	Mo PPM	Co PPM	Ni PPM	Cd PPM	As PPM	Bi PPM	W PPM	NOTES
D5[illegible]		15	62	485	4	32	41	<0.2	0.2	<2	138	

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Ottawa, Ontario
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Telex: 053-4455

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Geochemical Lab Report

R ORT: 013-1363

FROM: TRIGG-WOOLLETT CONSULTING LTD. SUBMITTED BY: BCC VANC
D : 11-JUL-83 PROJECT: 3202

ORDER	ELEMENT	LOWER DETECTION LIMIT	EXTRACTION	METHOD	SIZE FRACTION	SAMPLE TYPE	SAMPLE PREPARATIONS
01	Ta	3 PPM		X-RAY Fluorescence		PREPARED PULP	AS RECEIVED, NO SP
2	Y	1 PPM		X-RAY Fluorescence			
3	Ce	10 PPM		X-RAY Fluorescence			

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R ARKS: YOUR REPORT NO. 123-1086

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BONDAR-CLEGG

Geochemical Lab Report

RE[illegible]ORT: 013-1363

PROJECT: 3202 PAGE 1

S[illegible]PLE N[illegible]BER	ELEMENT UNITS	Ta PPM	Y PPM	Ce PPM	NOTES
[illegible]		8	41	1052	

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764 Belfast Road
Ottawa, Ontario
Canada K1G 0Z5
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Telex: 053-4455

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Geochemical Lab Report

RE..RT: 113-1363

FR.. : TRIGG-WOOLLETT CONSULTING LTD. SUBMITTED BY: BCC VANC
DA.. : 15-AUG-83 PROJECT: 3202

OR..R	ELEMENT	LOWER DETECTION LIMIT	EXTRACTION	METHOD	SIZE FRACTION	SAMPLE TYPE	SAMPLE PREPARATIONS
01	Cr	2 PPM		X-RAY Fluorescence		PREPARED PULP	AS RECEIVED, NO SP
	V	2 PPM		X-RAY Fluorescence			
	[illegible]	1 PPM		X-RAY Fluorescence			
04	Ba	15 PPM		X-RAY Fluorescence			
[illegible]	Nb	1 PPM		X-RAY Fluorescence			
	Sb	1 PPM		X-RAY Fluorescence			
07	Sn	1 PPM		X-RAY Fluorescence			
08	Th	1 PPM		X-RAY Fluorescence			
	Z[illegible]	1 PPM		X-RAY Fluorescence			
[illegible]	Ti	.01 PCT		X-RAY Fluorescence			

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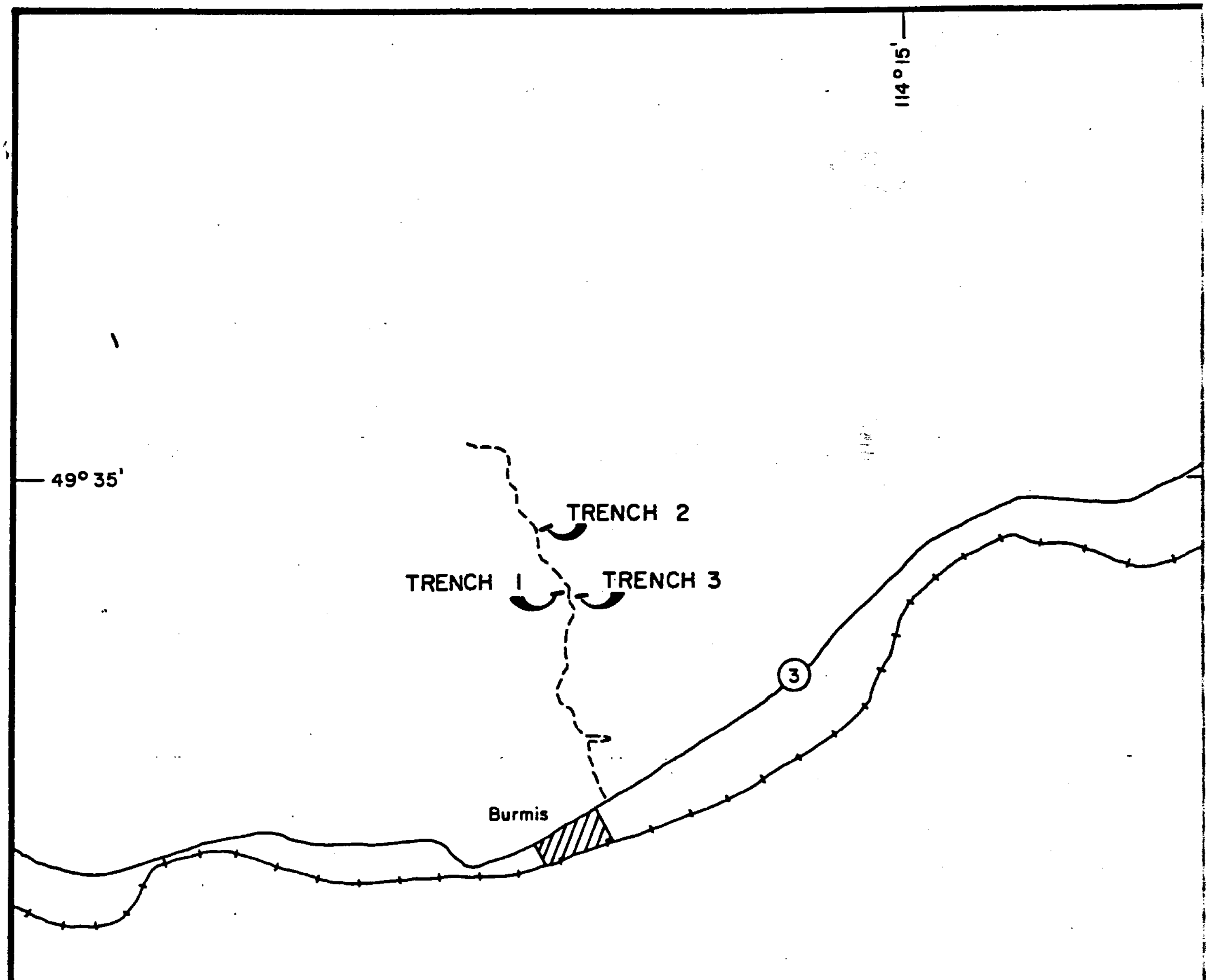
Geochemical Lab Report

REPORT: 113-1363 | PROJECT: 3202 | PAGE 1

SAMPLE NUMBER	ELEMENT UNITS	Cr PPM	V PPM	U PPM	Ba PPM	Nb PPM	Sb PPM	Sn PPM	Th PPM	Zr PPM	Ti PCT	NOTES
[illegible]		154	1675	16	43	70	<1	22	71	1583	4.48	



PROFESSIONAL ENGINEER
C. M. TRIGG
ALBERTA

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS,
GEOLOGISTS and GEOPHYSICISTS
OF ALBERTA
PERMIT NUMBER
P 2374.
TRIGG, WOOLLETT
CONSULTING LTD.

SYMBOLS

TRENCH 2	Trench; identifier
(3)	Highway; identifier
	Private, four-wheel drive road
	Canadian Pacific Railway
Burmis	Community; identifier

ROYMAC HOLDINGS LTD.

SOUTH BURMIS

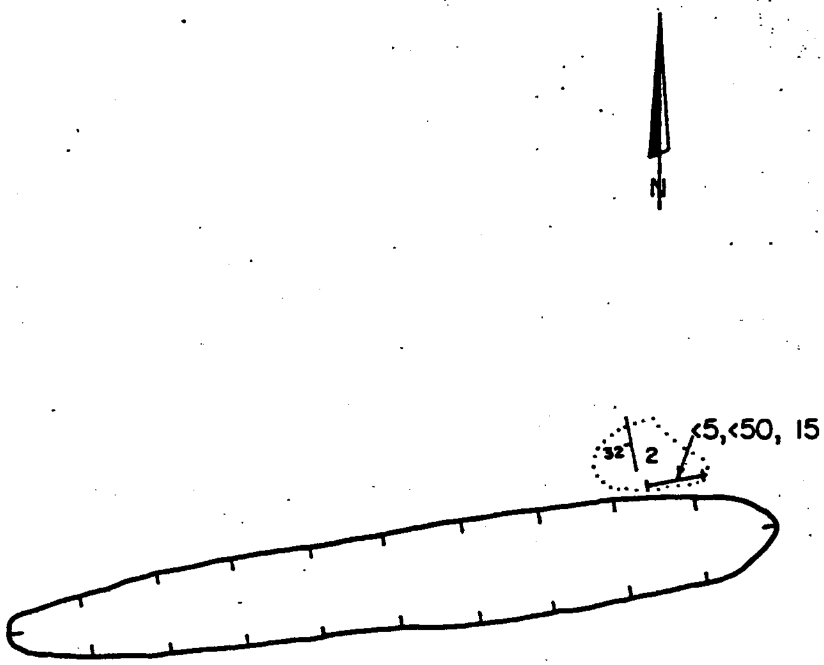
TRENCH LOCATIONS

NTS 82G/9

SCALE 0 0.5 1.0 2.0 KILOMETRES

TRIGG, WOOLLETT CONSULTING LTD.

EDMONTON, ALBERTA JUNE, 1983



LEGEND

UPPER CRETACEOUS
BELLY RIVER FORMATION

2	MAGNETITE-RICH SANDSTONE Olive-green, massive siliceous sandstone, minor black brittle bitumen: 5 to 10 per cent magnetite by volume

SYMBOLS

	Outcrop
32	Bedding; inclined
	Trench outline
<5,<50, 15	Assay interval: gold in parts per billion, platinum in parts per billion, palladium in parts per billion

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TRENCH 2

GEOLOGY, CHIP SAMPLING

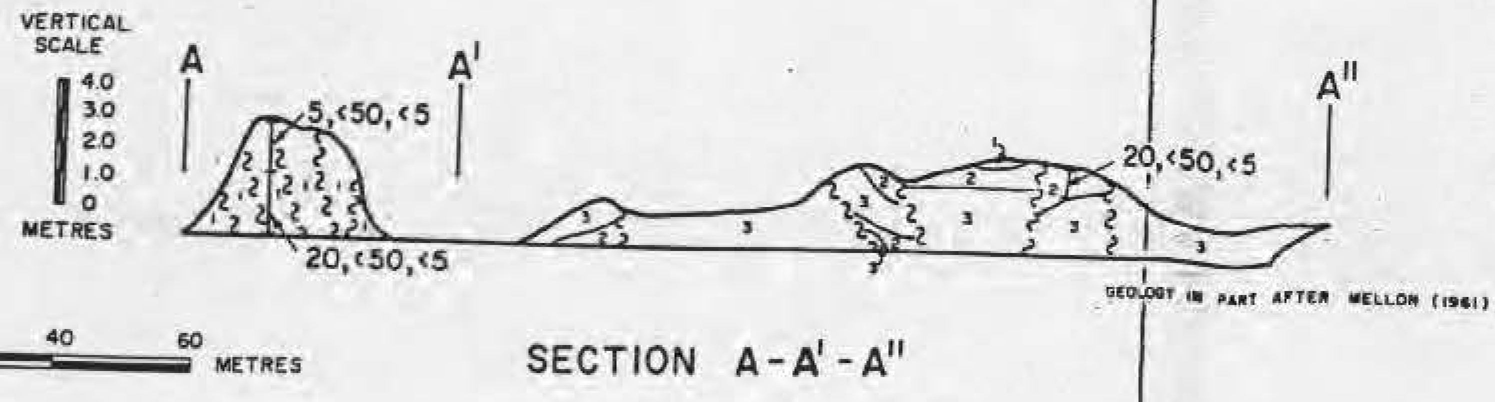
NTS 82G/9
SOUTH BURMIS, ALBERTA

SCALE 0 1.0 2.0 3.0 4.0 METRES

TRIGG, WOOLLETT CONSULTING LTD.
EDMONTON, ALBERTA
JUNE, 1983

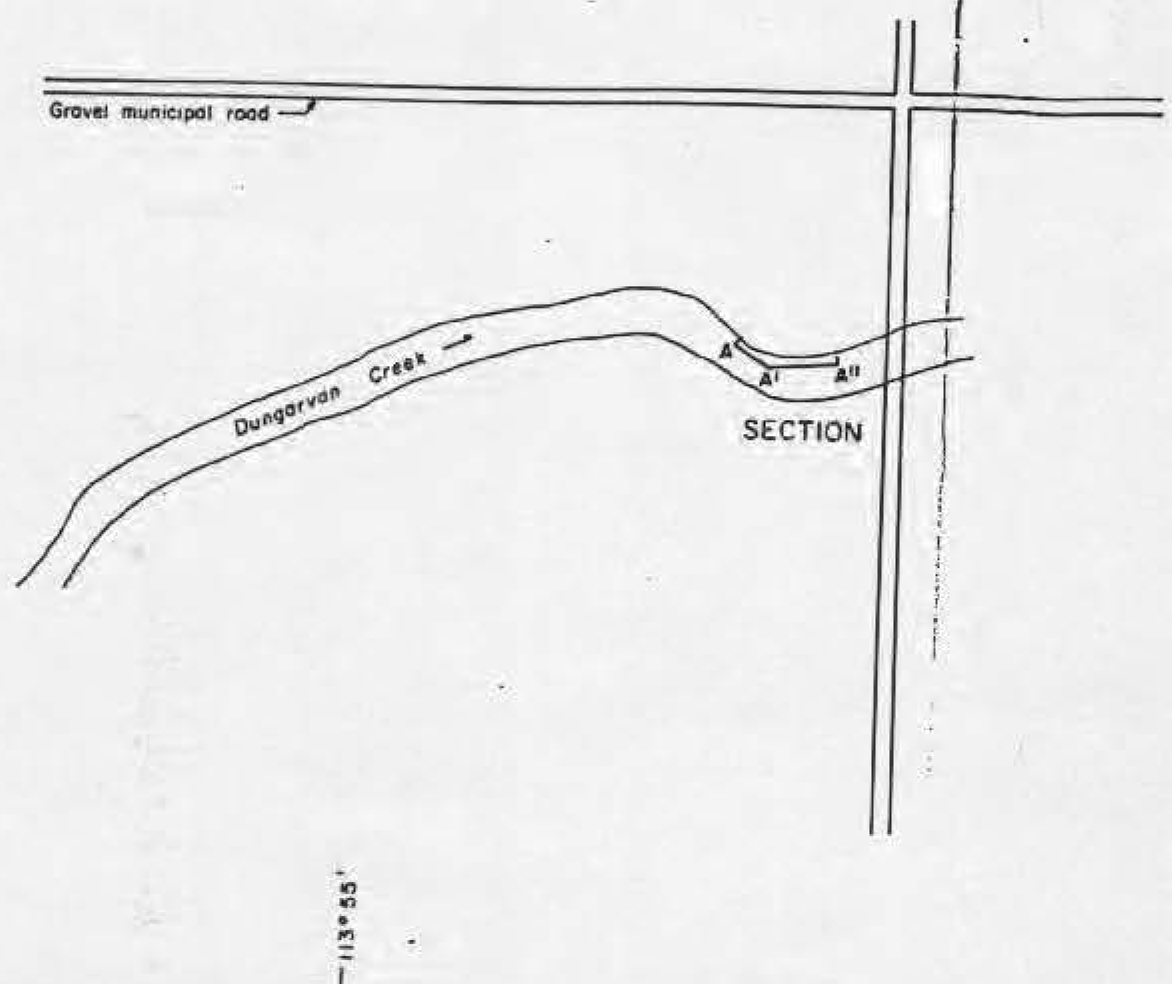
DWG. 3202-4

GEOLOGY, CHIP SAMPLING



SECTION A-A'-A''

LOCATION



LEGEND

UPPER CRETACEOUS
- BELLY RIVER FORMATION

[1] MAGNETITE-RICH SANDSTONE
Black to dark grey-blue, very fine- to fine-grained magnetite sandstone with laminations of barren sandstone: 30 to 40 percent magnetite by volume

[2] MAGNETITE-POOR SANDSTONE
Light to dark green, fine grained, thinly bedded sandstone: 5 to 10 percent magnetite by volume

[3] BARREN SANDSTONE
Cream to tan weathering thin- to medium-bedded arkosic sandstone

SYMBOLS

Geological contact

Fault: approximate

20,<50,<5 Chip sampled interval: gold in parts per billion, platinum in parts per billion, palladium in parts per billion

PROFESSIONAL ENGINEER ALBERTA
G. M. TRIGG

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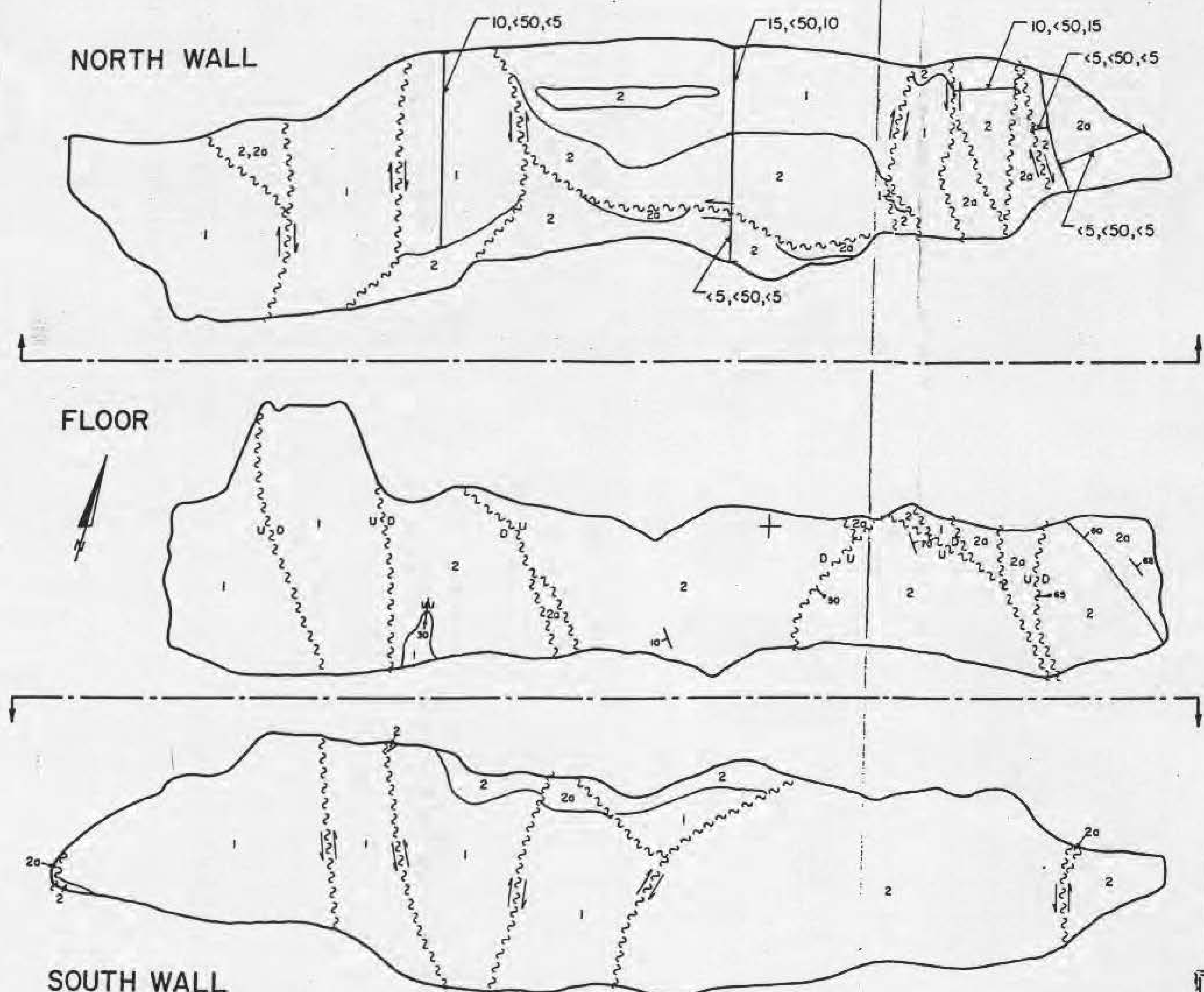
ROYMAC HOLDINGS LTD.

LOCATION, GEOLOGY, CHIP SAMPLING

NTS 82H/4
DUNGARVAN CREEK, ALBERTA
SCALE 0 100 250 500 METRES
TRIGG, WOOLLETT CONSULTING LTD.
EDMONTON, ALBERTA
JUNE, 1983

DWG. 3202-6



LEGEND

UPPER CRETACEOUS
BELLY RIVER FORMATION

1	MAGNETITE-RICH SANDSTONE
1:	Dark grey-blue, massive, very fine grained magnetite sandstone: 50 to 60 percent magnetite by volume

2,2a	MAGNETITE-POOR SANDSTONE
2:	Dark green, massive, very fine- to fine-grained, siliceous sandstone: 5 to 10 percent magnetite by volume
2a:	**Olive-green, fine-grained sandstone with laminae, small lenses of magnetite-rich sandstone and black, brittle bitumen: 2 to 5 per cent magnetite by volume**

SYMBOLS

Geological contact

Bedding; inclined, horizontal

Minor fold: plunge indicated

Fault: relative movement, dip, up- and down thrown blocks indicated

15,<50,10 Chip sampled interval: gold in parts per billion, platinum in parts per billion, palladium in parts per billion

PROFESSIONAL ENGINEER ALBERTA
C. M. TRIGG

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TRENCH I

GEOLOGY, CHIP SAMPLING

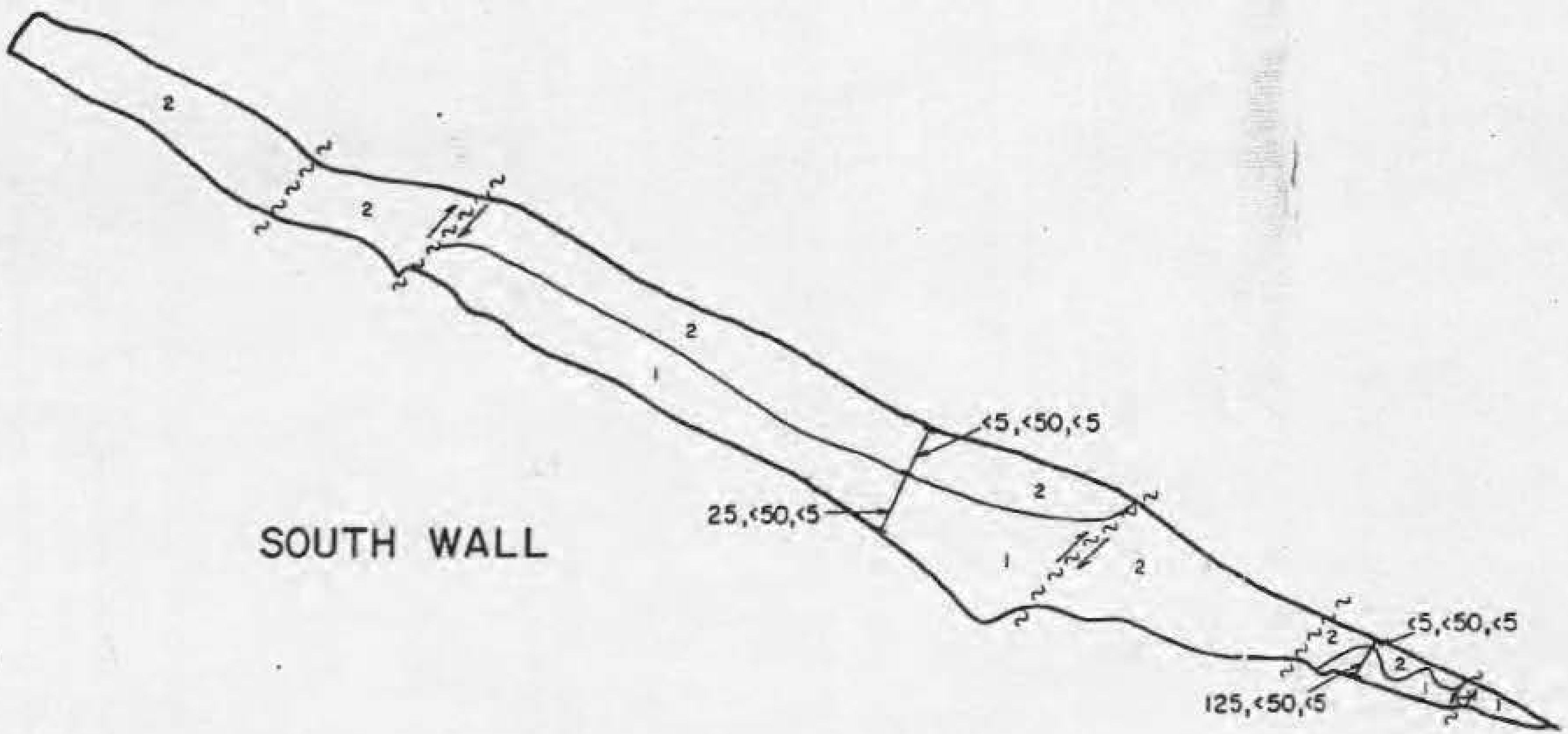
NTS 82G/9
SOUTH BURMIS, ALBERTA

SCALE 0 0.25 0.50 1.0 METRES

TRIGG, WOOLLETT CONSULTING LTD.

EDMONTON, ALBERTA JUNE, 1983

DWG. 3202 - 3



LEGEND

UPPER CRETACEOUS
BELLY RIVER FORMATION

[1] MAGNETITE-RICH SANDSTONE
Dark grey-blue, massive, very fine grained magnetite sandstone: 50 to 60 per cent magnetite by volume

[2] MAGNETITE-POOR SANDSTONE
Dark green, massive, very fine- to fine-grained, siliceous sandstone: 5 to 10 per cent magnetite by volume

SYMBOLS

Geological contact

Fault: relative movement indicated

125,<50,<5 Chip sampled interval: gold in parts per billion, platinum in parts per billion, palladium in parts per billion

PROFESSIONAL ENGINEER C. M. TRIGG ALBERTA

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ROYMAC HOLDINGS LTD.
TRENCH 3
GEOLOGY, CHIP SAMPLING
NTS 82G/9
SOUTH BURMIS, ALBERTA
SCALE 0 0.5 1.0 2.0 METRES
TRIGG, WOOLLETT CONSULTING LTD.
EDMONTON, ALBERTA JUNE, 1983

DWG. 3202-5

CMRC

EVALUATION OF MAGNETITE RESEARCH TASK 83/76

by

R.J. Germain

CMRC Report 83/39-C July 1983

CONTENTS

CMRC

SUMMARY

This report presents CMRC's preliminary evaluation of Blairmore magnetite bearing sandstone with respect to its suitability as a coal preparation magnetite. CMRC's evaluation consisted of a review of data from previous studies done by other agencies and of testing a sample of Blairmore magnetite bearing sandstone using a Davis Tube Wet Magnetic Separator. We conclude that an acceptable coal preparation magnetite can be produced and we recommend that additional testwork be done.

CONCLUSIONS

The information contained in the literature and the results of our Davis Tube tests indicate that a coal preparation magnetite of suitable purity and density can be produced from Blairmore magnetite bearing sandstone using efficient laboratory scale equipment. It is technically feasible to produce an acceptable magnetite product on a commercial scale from any grade of Blairmore magnetite bearing sandstone. The grade at which production becomes economic can be established only through additional testing.

RECOMMENDATIONS

Based on the conclusion that it is technically feasible to produce an acceptable coal preparation magnetite from Blairmore magnetite bearing sandstone, we recommend that:

1. Two 50kg samples, one of approximately 40 weight % magnetite such as sample 059 used in this study and one of approximately 15 weight % magnetite, should be processed using small scale commercial equipment. This processing will produce concentrates of similar quality to a full scale plant product and will also provide an indication of the process scheme, and production costs of a commercial plant. We recommend that this work be done by Eriez Magnetics Ltd. The testing should take about four weeks, inclusive of sample shipment time. Costs should be about $2,500 Canadian.

2. The products from recommendation #1 should be compared to the two magnetites currently used in western Canada. Comparing properties such as bulk density, recoverability, and weathering characteristics will indicate the relative quality of a Blairmore magnetite product. For instance, the ease with which a magnetite is magnetically recoverable is an important property that varies from one magnetite to another. This testwork would require only a few kilograms of each magnetite product and could be completed within two weeks of receiving the concentrates from Eriez Magnetics. The estimated costs for this testwork, including procurement of magnetite samples from several mines, is $2,000.00.

INTRODUCTION

Objective

The Coal Preparation Division of the Coal Mining Research Centre (CMRC) was awarded a contract by Trigg, Woollett Consulting Ltd. (TWC) to do a preliminary evaluation of Blairmore magnetite bearing sandstone with respect to its suitability as a source for coal preparation magnetite. Specifically, the study was to establish whether Blairmore magnetite bearing sandstone has sufficient potential to warrant a more extensive evaluation. Blairmore magnetite bearing sandstone had previously been judged unsuitable as a steelmaking ore.

Scope

The scope of this study included:

i) An evaluation of previously published information regarding Blairmore magnetite bearing sandstone with respect to its suitability for use in coal preparation

ii) Determination of the magnetics content of a sample of Blairmore magnetite bearing sandstone

iii) Recommendations regarding further evaluation.

Properties of Coal Preparation Magnetites

In general, coal particles coarser than about 0.6mm are separated from similarly sized non-coal particles (rock, shale, clay) by utilizing the difference in specific gravity of the two. When placed in a water suspension of specific gravity intermediate to the coal and non-coal, the coal floats and the non-coal sinks. In coal preparation, finely ground magnetite is slurried in water to produce the suspension or heavy medium of desired specific gravity, typically between 1.3 and 1.8. Other solids, such as sand, can be used to produce the heavy medium; however, magnetite is preferred primarily because of its high specific gravity and because it is easily recovered using magnetic separators.

The high specific gravity of magnetite is advantageous because, on a volume basis, the quantity of magnetite required is small. Thus, suspension viscosity is kept to a minimum. On the other hand, the high specific gravity reduces the suspension's stability. The use of very fine magnetite helps to maintain stability and to maintain uniform specific gravity.

Since few coal preparation plants have grinding facilities magnetite must be supplied already ground. Magnetite is often marketed on the basis of size consist, with the percent minus 45 microns (325 mesh) being the governing criteria. The magnetite grades of one U.S. supplier are provided in Table 1. Table 2 gives typical size distributions of magnetites used in coal preparation.

Table 1: Foote Mineral Co. Typical Magnetite Grades

Weight % Minus 45 microns	Grade
55-70	A
90	B
96	E
98	F

Table 2: Typical Magnetite Size Distributions

Particle Size, (microns)	Weight % Minus Stated Size Grade B	Grade E
90	97 - 99	98 - 100
75	95 - 98	97 - 100
60	92 - 97	97 - 100
45	85 - 90	96 - 98
30	67 - 74	84 - 87
20	53 - 62	66 - 75
10	21 - 36	37 - 45
5	7 - 8	11 - 12

Magnetite purity should be as high as possible. The greater the amount of impurities, the lower will be the magnetite specific gravity, with the subsequent negative effect on suspension viscosity and positive effect on stability. The specific gravity of pure magnetite is 5.18. The specific gravity of a coal preparation magnetite is typically about 4.6 - 4.8.

Magnetite impurities that are liberated from the magnetite grains are less desirable than the impurities that have not been liberated. At the coal preparation plant, the liberated impurities will eventually be lost. These losses are recorded as magnetite losses. Table 3 provides some typical quantities of liberated non-magnetic impurities associated with commercial coal magnetites.

Table 3: Liberated Non-Magnetics in Commercial Magnetites

Magnetite Source	% Non-Magnetics (Davis Tube Analysis)
Eastern U.S.A.	9
Eastern U.S.A.	7
Western Canada	3

The magnetite content ($Fe_3 O_4$) of magnetites is not normally provided. Instead, either the iron content (Fe) or ferric oxide content ($Fe_2 O_3$) is provided. This is due to the relative ease of determining Fe or $Fe_2 O_3$ as compared to $Fe_3 O_4$. The Fe_3O_4 content is calculated from the reported Fe or Fe_2O_3 content by multiplying either the Fe content by 1.382 or the Fe_2O_3 content by 0.967. These calculations assume that Fe or Fe_2O_3 is actually present as Fe_3O_4. For example, the first magnetite of Table 3 is 63.3 weight % Fe, which converts to 87.5 weight % Fe_3O_4. The other major component of commercial coal preparation magnetite is usually silica.

EVALUATION OF PREVIOUS STUDIES OF BLAIRMORE MAGNETITE BEARING SANDSTONE

Literature Sources

Several previous studies have been done to evaluate Blairmore magnetite bearing sandstone as a potential steelmaking ore. The information they provide is very useful for evaluating Blairmore magnetite bearing sandstone as a potential coal preparation magnetite.

The information sources provided by Trigg, Woollett Consulting and that were reviewed by CMRC were:

Ref. 1. "Sedimentary Magnetite Deposits of the Crowsnest Pass Region, Southwestern Alberta" by G.B. Mellon, Research Council of Alberta, Bulletin 9, 1961.

Sources 2 - 6 were published by the Mineral Dressing and Process Metallurgy Division of the Department of Mines and Technical Surveys of the Federal Government of Canada.

Ref. 2. Report MD-995, 1941

Ref. 3. Report MD-507-0D, 1951

Ref. 4. Report MD-3034, 1954

Ref. 5. Report MD-3187, 1957 (plus supporting progress reports)

Ref. 6. Report MD-913-OD, 1957

Discussion

In the following discussion, whenever reference is made to a specific information source, the numbering system of above will be used. For example (Ref. 1 pp. 50-52) indicates that the information in question comes from ARC Bulletin 9, pages 50 to 52. Similarly, (Ref. 4 p.3) refers to Report MD-3034, page 3.

Magnetite Content

It should be noted that, on average, the deposit is low grade. The mean Fe_2O_3 content of sixty samples was 29.34 weight % (Ref. 1 p. 27) which corresponds to a mean magnetite content of 15.47 volume % and of 17.17 weight % (Ref. 1 pp. 61-63, 65-69). Magnetite was determined by counting grains in thin sections. All black opaque grains were classified as magnetite; however, this method overestimates the volume % magnetite due to inclusion of opaque non-magnetite minerals such as ilmenite (Ref. 1 pp. 29-31), such that the magnetite contents should be reduced by a factor of 10-20%. Thus, the mean magnetite content of the samples evaluated in Ref. 1 is probably less than 15 weight %.

The samples tended to be either low or high in magnetite content - 44 samples contained less than 15 volume % magnetite, 9 contained more than 50 volume %, and 7 contained between 15 and 50 volume % magnetite.

Magnetite Liberation Size

Table 4 (Ref. 1 pp. 52-55) indicates that the magnetite grains are finer than either quartz, feldspar, or clastic carbonate. Also, about 94% of the magnetite and 96-100 % of the other three minerals are coarser than 0.045mm (325 mesh). Table 4 suggests that no extremely fine magnetite exists, yet some samples did have fines as small as .001 mm (Ref. 3 pp. 2-3). Table 4 suggests that most of the magnetite should be liberated below 0.100mm (150 mesh). The optical technique used in Ref.1 to determine grain size underestimates the actual grain size as would be determined by screening. Multiplying the optically determined grain sizes by 1.32 gives a better indication of actual grain size (Ref.1 p.71). As indicated in Table 1, commercial coal preparation magnetites are finer than the mean grain size of the magnetite in Blairmore magnetite bearing sandstone. In order to meet the size criteria for coal preparation magnetite Blairmore magnetite bearing sandstone must be ground finer than its magnetite liberation size. Thus, with respect to the three minerals listed above, pure magnetite grains should be produced if breakage occurs preferentially along grain boundaries.

Table 4: Grain Sizes of Magnetite and Three Other Minerals

Mineral	Grain Size (mm) Mean	Range	Number % Greater Than 0.045 mm
Quartz	0.204	0.707-0.031	97
Feldspar	0.203	0.707-0.063	100
Clastic Carbonate	0.178	0.500-0.031	96
Magnetite	0.100	0.250-0.022	94

The grain sizes of quartz, feldspar, and clastic carbonate were determined from mangetite-poor samples and the magnetite grain sizes were determined from magnetite-rich samples; however, there is no reason to suspect a significant change in the grain sizes of the first three minerals when present in magnetite rich sandstone (Ref. 4 p. 3).

No grain size analysis is provided for authigenic chlorite; however, its grain size is definitely smaller than the magnetite grain size. This is evident from a photo of a thin section of magnetite - rich sandstone (Ref. 1 p. 95). The authigenic chlorite fills all the pores amongst the magnetite grains and acts much like a cement to hold the grains together. Authigenic chlorite should be the principal source of non-magnetic impurity associated with any magnetite product from Blairmore magnetite. This is so not only because the chlorite has a finer size consist, but also because it is the only non-magnetic mineral of consequence whose quantity does not decrease as the quantity of magnetite increases (Ref. 1. pp. 44-45). Chlorite has a specific gravity of from 2.6 to 3.3 and as such will decrease the specific gravity of the magnetite product. No analyses of magnetic concentrates were done to determine chlorite content. Most of the chlorite should report to the non-magnetic tailings (Ref. 1 p. 73). From iron and titanium analyses of magnetic concentrates (Ref. 1. p. 72) one can estimate that the maximum chlorite content would be about 10%, assuming that all iron is present as Fe_3O_4 and that all non-Fe_3O_4 and non-TiO_2 is chlorite.

Product Purity

The purity of a Blairmore coal preparation magnetite will be affected by the chemical purity of the magnetite as well as by the quantity of non-liberated minerals such as quartz, chlorite, etc. Both hematite, $Fe_2 O_3$, and ilmenite, $Fe\ TiO_3$, are associated with the magnetite grains as intergrowths (magnetite-ilmenite) or as surface oxidation (magnetite-hematite); however, this was not the case for all the samples investigated (Ref. 4. p. 3). About 12% of the magnetite had at least 10% alteration to hematite and about 6% of the magnetite had ilmenite associated with it (Ref. 1 p. 30). These impurities are not a problem since they do not affect the magnetite recovery and, in themselves, they have high specific gravities (hematite sp. gr. is 5.26 and ilmenite sp. gr. is about 4.7).

It should be noted that the Blairmore magnetite was considered unacceptable as a steelmaking ore largely because of the high titanium content, of which 35 to 50% is present in the magnetic fraction of the ore (Ref. 1 p. 72), possibly as a solid solution in the magnetite (Ref. 1 p. 31). This high titanium content will not be a problem if a coal preparation magnetite is produced even though much of this magnetite will be used for cleaning coking coals. The maximum amount of titanium ($Ti\ O_2$) that will be added to the coal due to magnetite losses will be 0.01% and a typical coking coal contains 0.12% $Ti\ O_2$.

Magnetic Beneficiation

Several Blairmore magnetite bearing sandstone samples were subjected to magnetic concentration tests using a Davis Tube or some other magnetic concentrator. The results of the Davis Tube tests are summarized in Table 5. Table 5 shows that the iron content of the magnetic concentrate increases as the particle size decreases, which is to be expected. Note that despite the wide range of iron content in the feed (16.7 to 53.5%), the -200 mesh concentrates are all quite similar in iron content (60.2 to 66.5%). This suggests that an acceptable concentrate should be produced from both low and high grade feeds; however, due to the quantity of material that must be rejected from low grade feeds, there is no doubt that product purity will be poorer when low grade feeds are processed with commercial scale equipment. The iron contents of the -200 mesh concentrates compare very favourably with the 63.3% iron content of the first commercial magnetite listed in Table 3.

Table 5: Davis Tube Magnetic Concentration Tests
Results of Previous Studies

Sample	Particle Top Size (mesh)	Iron Content (wt. % Fe) Feed	Concentrate	Wt. % Recovery	Reference
A	100	16.7	61.4	7.0	2 pp. 4-5
	200	16.7	62.4	7.0	
B	100	53.5	64.4	71.0	
	200	53.4	66.5	68.0	
C	100	22.5	62.4	19.0	
	200	23.2	64.4	19.0	
D	100	52.0	60.8	77.0	
	200	51.6	64.3	70.0	
E	100	35.2	59.1	40.0	3 pp. 2-3
F	65	39.7	56.3	62.5	5 pp. 19-20
	100	39.7	58.2	56.1	
	150	39.7	60.5	51.9	
	200	39.7	62.3	49.6	
G	65	47.1	58.0	72.2	
	100	47.1	60.2	67.0	
	150	47.1	62.4	64.8	
	200	47.1	63.4	60.4	
H	65	34.6	54.2	52.9	
	100	34.6	56.8	47.4	
	150	34.6	59.0	46.2	
	200	34.6	60.8	44.0	

The Davis Tube is an analytical apparatus designed to determine the % magnetics content of solids. As such, it rejects non-magnetic particles with greater efficiency than commercial magnetic separators and it also recovers magnetic particles with greater efficiency. The iron contents of the Davis Tube concentrates of Table 5 are probably higher than would be achieved commercially. A better indication of potentially commercially produced concentrates is provided in Table 6, which summarizes tests done with other laboratory scale magnetic separators. The concentrate iron contents of the -150 and -200 mesh fractions of Table 6 suggest that a suitable magnetite product should be attainable. It should be noted that the feed iron contents of Table 6 are at least double the 20.5% mean Fe content of the samples analysed in Ref. 1.

Table 6: Concentration Tests Using Small Scale Magnetic Separators - Results of Previous Studies

Separators	Particle Top Size (mesh)	Iron Content (wt.% Fe) Feed	Concentrate	Wt. % Recovery	Reference
Crockett (wet belt)	10	49.8	55.5	83.0	4 p. 19
	20	49.3	56.8	77.2	
	48	47.3	59.1	65.6	
	100	47.4	62.1	59.2	
	150	48.8	62.6	59.8	
	200	48.5	61.9	54.6	
Jeffrey-Steffensen (double drum)	100	49.4	62.4	51.3	4 pp. 21-22
	200	51.3	65.7	48.9	
Jeffrey-Steffensen	150	39.7	62.4	36.7	5 p. 21

Gravity Concentration tests also produced concentrates high in iron content (Ref. 4 pp. 23-25); however, gravity concentration is not acceptable as a benefication method because all dense iron bearing minerals, such as hematite and ilmenite, report to the concentrate. These non-magnetic minerals will be lost to the tailings at the coal preparation plant where magnetic recovery methods are used.

Conclusions

The information contained in the previous studies of other agencies suggests that a suitable coal preparation magnetite can be produced from Blairmore magnetite bearing sandstone, particularly from the higher grade deposits. The typical deposits are low grade and thus, recoveries will also be low.

CMRC MAGNETIC CONCENTRATION TESTWORK

Introduction

CMRC performed magnetic concentration tests, using a Davis Tube, on a sample of Blairmore magnetite bearing sandstone in an attempt to confirm the published data discussed in the prior section and to provide new data at a finer size consist.

Details of the testing procedure and conditions are provided in Appendix I. Briefly, of two approximately 150 Kg samples received, one sample was crushed, milled, and sub-sampled to produce several samples of varying size consist. These samples were analysed for percent mangetics using a Davis Tube Wet Magnetic Separator.

Table 7 provides size analyses of the samples tested in the Davis Tube.

Table 7: Davis Tube Samples - Size Analyses

Particle Size		Wt. % Passing Stated Size Sample Designation				
(mesh)	(mm)	059A[1]	059B[2]	059C[3]	059D[4]	059E[5]
30	0.600				87.6	
50	0.300				67.2	
65	0.212				56.3	
100	0.150	97.6	94.6		48.3	
150	0.106	95.4	90.1		39.8	
200	0.075	90.5	82.1		31.6	
270	0.053	85.4	74.6		24.6	
325	0.045	82.1	70.7	100	20.0	100.0

1 059A was produced by dry ball milling. Wet sieve analysis

2 059B was produced by dry ball milling. Wet sieve analysis

3 059C was produced by dry ball milling to about 059A consist, then wet mortar and pestle of +325 mesh. Wet sieve analysis

4 059D was produced by dry pulverizing in hammer mill. Dry sieve analysis

5 059E was produced by wet ball milling. Wet sieve analysis.

Test Results and Discussion

Results from the Davis Tube magnetic concentration tests are provided in Table 8. Recoveries are calculated on a reconstituted feed basis (magnetics plus non-magnetics = 100%) since for the slurry feeds, samples 059C and 059E, the actual dry weight of feed could not be determined. Recoveries for 059A, 059B, and 059D were about 2% less based on the known dry feed weight as compared to the reconstituted feed weight. Each sample was tested twice.

Table 8: Results of CMRC Davis Tube Tests

Sample	Approximate Top Size (mm)	% Recovery (Magnetics) Run #1	Run#2
059D	2.000	84.7	84.7
059B	0.212	70.9	71.0
059A	0.150	55.5	55.9
059C	0.045	62.2	64.6
059E	0.045	44.5	44.4

These results agree with the literature data, Tables 5 and 6, in that solids recovery decreases as particle size decreases. Recovery decreases because the non-magnetics are being liberated from the magnetics. This, of course, is desirable since the quality of the recovered magnetics increases with respect to magnetite purity. Figure 1 illustrates this fact more clearly. The results of this study, samples 059A-059E, show more scatter and a less definite trend in Figure 1. We believe this is due to the problems encountered in grinding the samples (cf. Appendix I). The mortar and pestle method used to reduce sample 059C to -325 mesh might well have caused significant smearing of non-magnetic gangue onto the magnetite grains. The gangue would then report to the magnetics product along with the magnetite.

Sample 059B also seems to have a high recovery, but it is possible that the high recovery is correct. An "~" shaped curve is to be expected since, over the coarse size ranges, only very small amounts of pure non-magnetics will be released as size decreases and over the very fine size ranges essentially all the non-magnetics

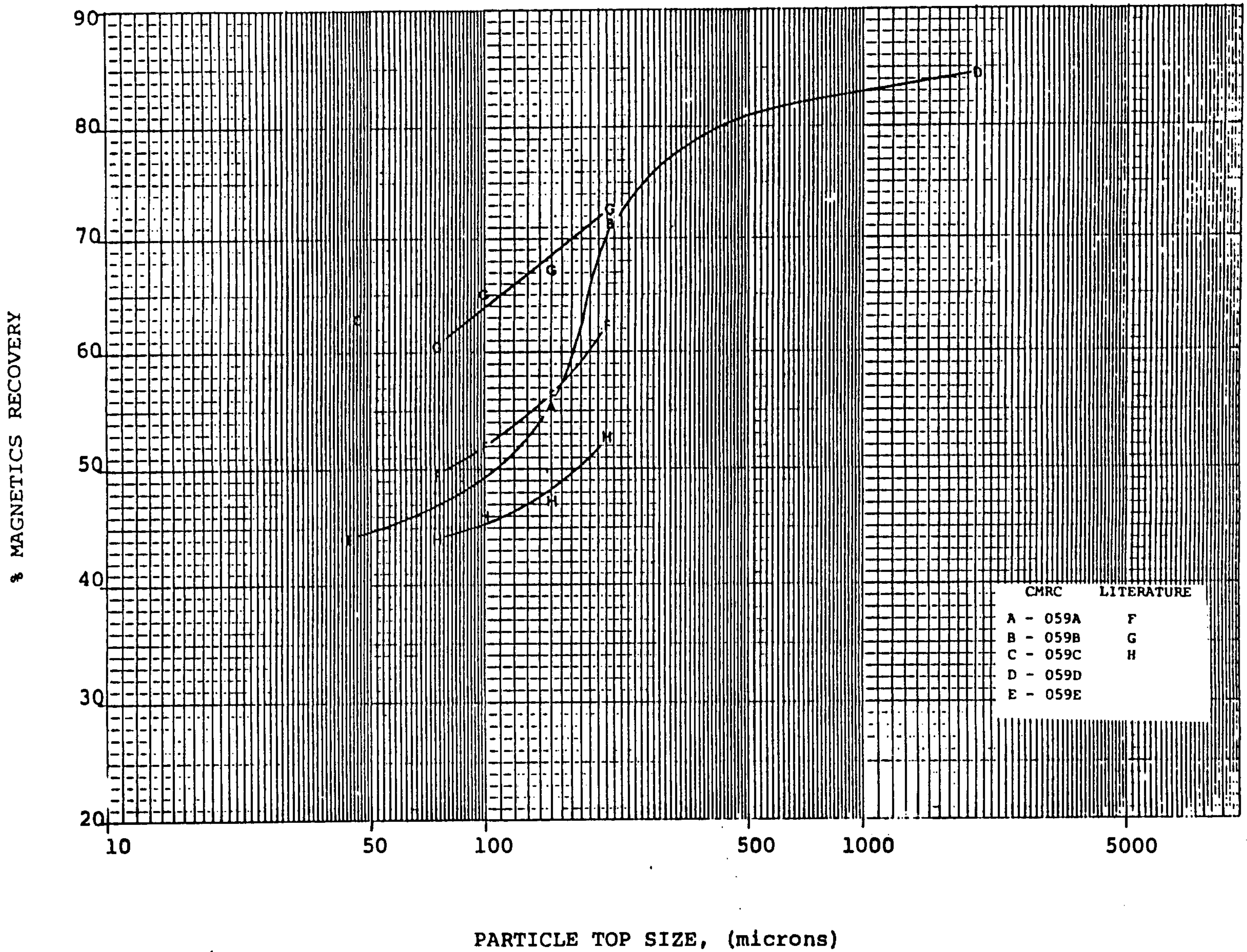


Figure 1: Davis Tube Test Results - CMRC and Literature Data

should be released so that further size reduction should not decrease recovery. The maximum change in recovery per size reduction change should occur as the magnetite liberation size is approached, which for this magnetite is in the 150 mesh size range. Note that the maximum drop in recovery for all samples of Figure 1 occurs between 65 and 100 mesh.

The bulk of sample 059A was returned to Trigg, Woollett Consulting Ltd; however, a small sample was sent to an independent laboratory for an iron assay (Appendix II:Feed). Sample 059A assayed 49.0% Fe by weight. Bulk density determinations were done on small 059 sample fragments in the same manner as done in Ref. 1 p. 65. The average bulk density of 14 determinations was 3.65, with a range from 2.83 to 4.05. Using the regression Y = 50.95 X - 128.62 (Ref. 1, pp. 66), where Y is % Fe_2O_3 by weight and X is bulk density, the average Fe_2O_3 content is 56.84%. This converts to 39.8% Fe, which is significantly less than the 49.0% laboratory assay.

Since the 49.0% iron content of the 059 feed is similar to the 47.1% of sample G, then their magnetic recoveries should also be similar. The much lower recoveries for the 059 samples (Figure 1) could be due to a greater proportion of the iron being present as non-magnetic iron. The magnetic concentrate of 059E was assayed at 65.9 weight % Fe (Appendix II:MAG). Assuming that the Davis Tube recovers all the magnetic iron, then the magnetic iron content of the 059 feed is 29.3 weight % (0.659 X 44.5). Thus, the non-magnetic iron content of sample 059 is 19.7 weight % (49.0% - 29.3%), whereas Ref. 1 indicates that the non-magnetic iron content of Blairmore magnetite bearing sandstone averages 8.5 weight %. The higher non-magnetic iron content of the 059 sample is probably due to oxidation.

The assayed 65.9% Fe by weight of the 059E concentrate converts to 91.0% magnetite by weight, assuming that all the iron in the concentrate is present as magnetic iron. The 059E concentrate would definitely be an acceptable coal preparation magnetite.

If we assume that all the magnetite of 059E was recovered in the 059A concentrate, then the 059A concentrate would contain about 72% magnetite, or about 28% non-magnetics by weight. If the non-magnetics have a specific gravity of 2.7, then the 059A concentrate would have a specific gravity of 4.5, which is acceptable for a coal preparation magnetite.

Sample 059A would be too coarse and 059E too fine for a coal preparation magnetite. The ideal size lies between the two. Thus, if a magnetic beneficiation process of equal efficiency to the Davis Tube were used, an acceptable coal preparation magnetite could be produced at about 50 weight % recovery.

Conclusions

The Davis Tube test results of this study agree with the results presented in the literature sources. The results confirm the expected trend of decreasing magnetics recovery with decreasing particle size, and that significant magnetite liberation occurs below a top size of about 0.2mm. When ground to and beneficiated at the size consist required for a coal preparation magnetite, the magnetite sample used for these tests would produce an acceptable magnetite in terms of purity and specific gravity. Weight % recovery would probably be about 50 % from an ore containing about 40 weight % magnetite.

APPENDIX I
TESTWORK DETAILS

Samples

Two samples, each of approximately 150 Kg, were delivered to CMRC by Trigg Woollett Consulting (TWC) personnel. CMRC was directed by TWC to use the sample in barrel 059 for all testwork. The remaining sample, barrel 123, was left untouched.

Sample Preparation

Crushing and Grinding

The test sample was spread onto a plastic sheet and allowed to equilibrate with the laboratory air for three days. The entire sample was then crushed to less than 19mm in a small jaw crusher. The -19mm material was sub-sampled to about 40 Kg by riffling. The entire 40 Kg was pulverized in a hammer mill to minus 2mm and then riffled into two half-samples. One half was retained as sample 059D. The second half was further pulverized in a hammer mill to minus 0.6mm (sample Y for reference purposes).

Two sub-samples of Y were obtained by riffling. These sub-samples were ground dry in a rubber-lined laboratory ball mill using steel balls as the grinding medium. The two ball-milled samples were designated 059A and 059B. The bulk of sample 059A was eventually returned to TWC.

The dry ball-milling created problems. The ground ore tended to coat the balls, which were irregular in shape, thus reducing the grinding efficiency and making complete recovery of the ground samples very difficult since the coating adhered to the balls. Scraping was necessary to remove the coating, which tended to come off as small flakes rather than as a powder.

In an attempt to solve this problem, new spherical balls were obtained and a riffled sample from sample 059D was used. The results were the same as before. This new sample was wet screened on a 325 mesh sieve and the plus 325 mesh solids were wet-ground to minus 325 mesh using a ceramic mortar and pestle. This sample was designated sample 059C.

A second riffled sample from 059D was ground with the new balls, but this time the grinding was done wet. No problems were noticed with this sample which was designated sample 059E.

Size Analyses

The size analyses of the samples 059A, 059B, 059C, 059D and 059E are provided in Table AI. Standard laboratory stainless-steel sieves were used. Samples 059A, 059B, 059C and 059E were wet sieved by hand. Sample 059D was dry sieved using a Ro-Tap Sieve Shaker.

Table AI: Davis Tube Samples - Size Analyses

Particle Size		Wt. % Passing Stated Size Sample Designation				
(mesh)	(mm)	059A[1]	059B[2]	059C[3]	059D[4]	059E[5]
30	0.600				87.6	
50	0.300				67.2	
65	0.212				56.3	
100	0.150	97.6	94.6		48.3	
150	0.106	95.4	90.1		39.8	
200	0.075	90.5	82.1		31.6	
270	0.053	85.4	74.6		24.6	
325	0.045	82.1	70.7	100	20.0	100.0

1 059A was produced by dry ball milling. Wet sieve analysis

2 059B was produced by dry ball milling. Wet sieve analysis

3 059C was produced by dry ball milling to about 059A consist, then wet mortar and pestle of +325 mesh. Wet sieve analysis

4 059D was produced by dry pulverizing in hammer mill. Dry sieve analysis

5 059E was produced by wet ball milling. Wet sieve analysis.

Davis Tube Tests

The Davis Tube Wet Magnetic Separator is a piece of laboratory apparatus used to determine the quantity of magnetic material present in fine solids. The magnetic solids remain trapped inside a tube which rotates back-and-forth between the poles of an electromagnet. The tube is filled with water and a slow flow of water washes over the trapped magnetics during the test. The rotating and reciprocating action of the tube forces non-magnetic solids through the trapped bed of magnetic solids. The non-magnetics pass out of the tube and can be discarded or captured for further analysis or for material balance calculations.

Several operating variables exist such as magnet strength, water flow rate, tube angle, tube stroke rate, and test duration. For these tests, the conditions were:

Power to Magnet	: 1.5 amps
Water Flow Rate	: 0.4 liter/min
Tube Stroke Rate	: 90/min
Tube Angle	: 45 degrees
Test Duration	: 18 minutes

Setting of the conditions is somewhat arbitrary and meaningfull results can be obtained only if the conditions remain the same for all tests, which was the case in this study. The non-magnetic tailings were collected in 10 liter plastic buckets and allowed to stand for 24 hours. The clear liquid was then either decanted or siphoned off. The remaining solids were washed into beakers and then dried at 104°C. The dry cake was scraped from the beakers. Similarly, the magnetic concentrate was also dried at 104°C. Each sample (059A-059E) was tested twice in the Davis Tube to provide some degree of confidence. Table AII indicates that the tests were highly reproducible and that the method of collecting the tailings does not produce significant error. Samples 059C and 059E were added to the Davis Tube in slurry form, so the true feed weight was not obtainable.

Table AII: Davis Tube Test Results

Sample	Test Number	Feed Weights (g) Actual	Feed Weights (g) Calculated[1]	Product Weights (g) Magnetics	Product Weights (g) Non-Magnetics
059A	1	8.368	7.971	4.425	3.546
	2	11.802	11.424	6.388	5.036
059B	1	10.743	10.423	7.385	3.038
	2	6.208	5.987	4.254	1.733
059C	1	-	6.552	4.078	2.474
	2	-	28.308	18.276	10.032
059D	1	10.858	10.718	9.076	1.642
	2	12.145	11.993	10.163	1.830
059E	1	-	10.740	4.783	5.957
	2	-	20.633	9.170	11.463

[1]Calculated = Weight of magnetics plus weight of non-magnetics

General Observations

The following observations were made during sample preparation and testing.

1. Dry ball milling was extremely difficult in comparison to wet ball milling.

2. The dry finely ground magnetite had a steep angle of repose and did not flow readily. It tended to bridge over the riffle slots.

3. The Davis Tube magnetic concentrates had the characteristic black color of magnetite.

4. The Davis Tube effluent water was rusty in color.

5. The magnetite was distributed throughout the sample. Each of 25 coarse fragments (19mm x 6mm) was attracted to and held by CMRC's dry drum magnetic separator.

APPENDIX II

COAL MINING RESEARCH CENTRE

SAMPLES: Two - MAG - FEED

SAMPLE	% FE	C.E.S. #
Feed	48.96	42
Mag	65.88	43

CYCLONE ENGINEERING SALES LTD.

File: S1-327

Date: August 4, 1983

Confidential

EVALUATION OF MAGNETITE: PHASE TWO

By R.J. Germain

CMRC Report No. 83/78-C November 1983

Prepared for: Trigg, Woollett Consulting Ltd.

CONTENTS

SUMMARY

Feasibility tests of a high grade sample of Blairmore magnetite bearing sandstone indicated that a Grade E coal preparation magnetite (size distribution of 96 wt. % passing 325 mesh and a minimum magnetics content of 91 wt. %) could be produced at a yield slightly greater than the quantity of -325 mesh magnetics present in the raw feed. Laboratory scale comparative tests with magnetites currently in use in western Canada suggest that a commercially produced Blairmore magnetite would be comparable in terms of size consist and magnetics content but would be inferior, though acceptable, in terms of specific gravity and recoverability.

It is recommended that the economics be established for producing a Grade E magnetite from a feed typical of the magnetite bearing sandstone that will be mined. If the economics are favourable, then pilot plant scale recoverability tests should be done using a magnetite produced from such a typical feed.

CONCLUSIONS

1) Eriez Magnetics Ltd. concluded that conventional processing could produce a Grade E magnetite from a magnetite bearing feed equivalent to that tested. Product yield would be slightly greater than the quantity of -325 mesh magnetics present in the feed.

2) Relative to currently available western Canadian magnetites, a Blairmore magnetite would be:

   - comparable in size distribution
   - comparable in magnetics content
   - inferior in specific gravity
   - inferior in purity
   - inferior in recoverability

   Thus, a Blairmore magnetite would be less marketable relative to the two magnetites currently used in western Canada; however, the Blairmore magnetite would still be an acceptable magnetite, particularly if it could be marketed at a discount.

RECOMMENDATIONS

1) Apply the data from the Eriez feasibility tests to a Blairmore raw feed typical of the grade that will be mined. Determine the economic feasibility of producing a competitively priced magnetite product from this typical grade of feed.

2) If the economic feasibility results are positive, mine sufficient typical grade feed for a more comprehensive feasibility study. Sufficient magnetite should be produced to enable comparative recoverability tests on full scale magnetic separators. Pilot plant testing would require about 2 tonnes of magnetite product.

INTRODUCTION

Trigg, Woollett Consulting Ltd. (TWC) contracted the Coal Mining Research Centre (CMRC) to aid in evaluating Blairmore magnetite bearing sandstone as a potential coal preparation magnetite. CMRC reported its original evaluation in CMRC Report 83/39-C. Briefly, the conclusions and recommendations of CMRC Report 83/39-C were:

(i) It is technically feasible to produce an acceptable coal preparation magnetite from Blairmore magnetite bearing sandstone.

(ii) Samples of high and low grade magnetite bearing sandstone should be processed using small scale commercial equipment.

(iii) Important coal preparation magnetite properties, such as specific gravity, recoverability, and magnetics content, should be compared for the laboratory produced Blairmore magnetite products and for the two magnetites currently available in western Canada.

At TWC's request, CMRC continued its evaluation, as per ii and iii above, using sample 059, a high grade sample of Blairmore magnetite bearing sandstone. This report presents CMRC's evaluation.

FEASIBILITY STUDY

Approximately 45 Kg of the original 059 sample was hammer milled to pass 20 mesh (0.85 mm) and sent to Eriez Magnetics Ltd., Erie, Pennsylvania. Eriez Magnetics Ltd. performed a feasibility test on the 059 sample using laboratory scale equipment. The objective of the Eriez test was to produce a magnetite equivalent to Foote Grade E magnetite, which is a typical commercial magnetite supplied by the Foote Mineral Company of Exton, Pennsylvania. Coal preparation magnetites are designated by Grades. The specifications for a Grade E magnetite are: a size distribution of not less than 96 wt. % passing 325 mesh (44 microns) and a magnetics content of not less than 91 wt. %. The magnetics content is measured using a Davis Tube, which is a laboratory apparatus that measures the magnetics content of slurried fine particles by trapping the magnetic particles between the poles of its electromagnet.

Eriez conclusion was:

> A high grade magnetite concentrate can be produced following a conventional process using wet drum magnetic separators.

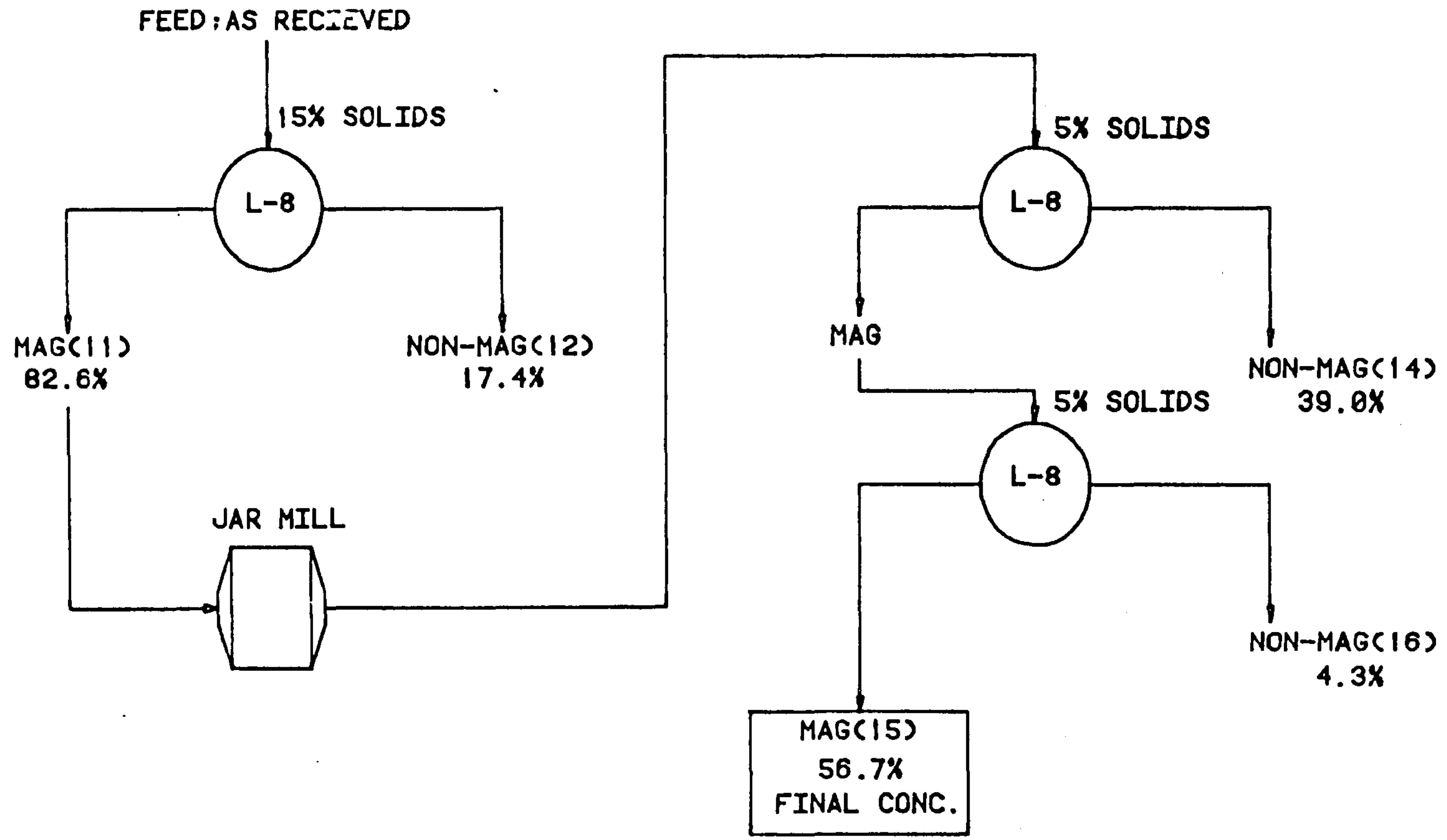
In a phone conversation, Eriez personnel made the following observations:

(i) Blairmore magnetite bearing sandstone posed no difficulties in beneficiating, behaving as a typical magnetite bearing feed.

(ii) The processing required was typical for producing Grade E magnetite.

The flowsheet of the Eriez test is shown in Figure 1. Table 1 summarizes the data and results of the tests. The Eriez report forms Appendix 1.

RR#83-373



CONCENTRATE SPECIFICATIONS

93.5% DT MAG
99.5% -325 MESH
4.5 SPECIFIC GRAVITY

FRACTION	%WT	%DT MAG	UNITS	DIST.
MAG(15)	56.7	93.5	53.015	96.9
NMAG(16)	4.3	11.1	0.477	0.9
NMAG(14)	39.0	3.1	1.209	2.2
CALC. HEAD		54.7		

WET DRUM FIELD INTENSITY.500 GAUSS EQUIVALENT

ERIEZ MAGNETICS
TEST FLOWSHEET
FOR
COAL MINING RESEARCH CENTER
FIG. #1

Table 1: Calculated Data From Eriez Test[1]

Fraction	Size	Wt. %	Magnetics Content[2] Wt. % in Fraction	Magnetics Content[2] As % of Feed
Non-Mag (12)	-20 mesh	17.4	7.4	2.8
Non-Mag (14)	-325 mesh	32.2	3.1	2.1
Non-Mag (16)	-325 mesh	3.6	11.1	0.9
Final conc. Mag (15)	-325 mesh	46.8	93.5	94.3
Feed	-20 mesh	100.0	46.5	100.0

[1] Calculations provided in Appendix 2

[2] Magnetics Content defined as - 325 mesh solids recoverable by Davis Tube

Table 1 indicates that processing a -20 mesh feed containing 46.5 wt. % magnetic particles produced a -325 mesh magnetite concentrate, Mag. (15), containing 93.5 wt. % magnetics. The processing recovered 94.3 wt. % of the feed magnetics with a product yield of 46.8 wt. %. CMRC Report 83/59-C predicted a product yield of about 50 wt. % from a feed containing about 40 wt. % magnetite.

Eriez returned the magnetic products and non-magnetic tails to CMRC for subsequent analysis and evaluation.

COMPARATIVE EVALUATION

The size distribution, specific gravity, Davis Tube magnetics content, and recoverability of the 059 magnetic concentrate, 059MC (Mag (15) in Figure 1), were compared to the same properties of Wesfrob magnetite and Craigmont magnetite, both of which are currently being used in western Canadian coal preparation plants. CMRC performed these comparative tests to determine whether a Blairmore magnetite would be competitive in the western Canadian coalfields.

CMRC personnel collected the Wesfrob sample from a coal preparation plant's magnetite stockpile: the Craigmont sample was collected by minesite personnel and shipped to CMRC.

Size Distribution

Table 2 provides size analyses for sample 059MC, Wesfrob, and Craigmont magnetite. As stated previously, the 059MC sample was laboratory prepared and thus is not necessarily representative of a commercially produced magnetite. Table 2 shows that 059MC is finer than the other two magnetites, neither of which meets the Grade E specification of 96% passing 325 mesh.

A commercially produced Blairmore magnetite will probably be coarser than the 059MC product produced by Eriez.

Table 2: Size Analyses[1]

Size Fraction (mesh)	Wt. % in Size Fraction					
	059MC[2]		Wesfrob		Craigmont	
	#1	#2	#1	#2	#1	#2
+ 100	0.0	0.0	0.1	0.2	0.2	0.4
100 x 200	0.0	0.0	0.5	0.5	0.5	0.5
200 x 270	0.2	0.3	3.0	2.2	2.2	1.7
270 x 325	0.7	0.6	2.4	3.5	4.5	3.1
-325	99.1	99.1	94.0	93.6	92.6	94.3

[1] Determined by wet sieving

[2] Eriez value: 99.5% - 325 mesh

SPECIFIC GRAVITY

Table 3 shows that the 059MC magnetite has a lower specific gravity than the Wesfrob and Craigmont magnetites. Thus, relative to western Canadian magnetites, a commercial Blairmore magnetite would not be as acceptable in terms of specific gravity. Typically, coal preparation magnetites are about 4.6 specific gravity. Thus, the 059MC magnetite is acceptable with respect to specific gravity.

The lower specific gravity of the 059MC magnetite is probably due to poorer magnetite purity resulting from unliberated impurities (see next section: Davis Tube Magnetics).

Commercially produced Blairmore magnetite would not have a higher specific gravity than the 059MC sample. The commercial product would, in all probability, be somewhat coarser in size and consequently contain a higher proportion of unliberated impurities. This would tend to decrease specific gravity; however, the decrease would not be significant.

Table 3: Specific Gravities[1]

Determination	059MC[2]	Wesfrob	Craigmont
1	4.6	5.1	5.0
2	4.6	5.0	5.1

[1] Determined by Displacement of water

[2] Eriez value: 4.5

DAVIS TUBE MAGNETICS

Table 4 shows that the 059MC magnetite has a Davis Tube magnetics content comparable to the other two magnetites. A commercially produced Blairmore magnetite should also be comparable.

Table 4 indicates that all three magnetite products have essentially the same amounts of liberated impurities, yet the specific gravity of the 059MC magnetite was lower than that of the other two magnetites. This suggests that the 059MC magnetite still has low specific gravity unliberated impurities associated with it.

The 059MC Davis Tube magnetics content determined by CMRC is much higher than that determined by Eriez. Eriez personnel stated that they regularly get lower Davis Tube results than other laboratories. The CMRC values may be high but this does not affect the comparative evaluation/conclusion that a Blairmore magnetite would be equivalent to Wesfrob and Craigmont magnetites in terms of magnetics content.

Table 4: Davis Tube Magnetics Analyses

	Wt. % Magnetics in Sample		
Determination	059MC	Wesfrob	Craigmont
1	97.9	97.6	97.4
2	97.8	97.5	97.4

Eriez Value: 93.5%

RECOVERABILITY

An important property of a coal preparation magnetite is the ease with which it can be recovered from preparation plant process streams. This property varies from one magnetite to another and is affected by such variables as magnetite purity, particle size, particle shape, magnetic field strength, etc.

There are no standard tests, ASTM or otherwise, for evaluating magnetite recoverability. Thus, CMRC devised a non-standard test to compare the recoverability of the 059MC magnetite to that of Wesfrob and Craigmont magnetite. The basic procedure for this test is provided with Figure 2.

Table 5 provides the results of the recoverability tests. Figures 3 and 4 are plots of the data for recoverability test #5.

Table 5: Magnetite Recoverability Test Results

Test #	Time Period# (30 sec.)	Wt. % Magnetite Recovered					
		059MC		Wesfrob		Craigmont	
		% of Initial	% of Remaining[1]	% of Initial	% of Remaining[1]	% of Initial	% of Remaining[1]
1	1	16.2	16.2	21.6	21.6	23.2	23.2
	2	12.6	15.1	20.1	25.6	16.5	21.5
2	1	14.6	14.6	23.1	23.1	23.6	23.6
	2	12.2	14.3	17.4	22.7	16.4	21.5
3	1	15.7	15.7	22.3	22.3	22.1	22.1
	2	12.9	16.0	18.4	23.7	16.6	21.3
4	1	17.6	17.6	24.0	24.0	22.3	22.3
	2	13.0	15.8	16.3	21.4	16.3	21.0
5	1	15.8	15.8	25.9	25.9	22.1	22.1
	2	12.8	15.2	16.1	21.8	15.3	19.6
	3	10.3	14.5	10.9	18.8	11.5	18.4
	4	7.9	12.9	8.2	17.4	8.7	17.0
	5	6.8	12.8	6.4	16.5	6.4	15.1
	6	5.0	10.7	4.7	14.4	4.9	13.5
	7	3.9	9.4	3.4	12.2	3.6	11.6
	8	3.1	8.3	2.5	10.4	2.7	9.9
	9	2.9	8.5	2.1	9.8	2.3	9.4
	10	2.4	7.7	1.7	8.9	1.8	7.8

[1]% of Remaining: Wt. % magnetite recovered during the period x relative to weight of magnetite remaining in suspension at beginning of time period x.

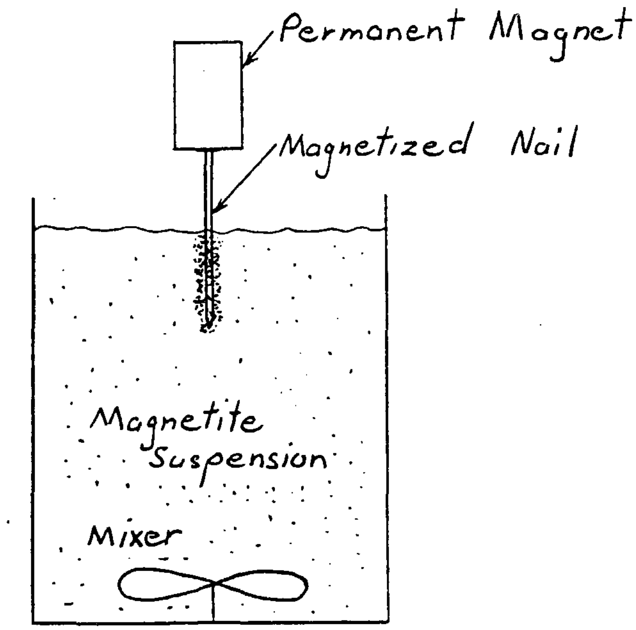


Figure 2: Recoverability Arrangement

(i) Mix a known weight of magnetite (approx. 1 gm) in 1.25ℓ of water at set mixing conditions (i.e. mixing speed: a household food blender was used).

(ii) Insert magnetized nail into stirred magnetite suspension for set time period (30 seconds)

(iii) De-magnetize nail by removing from permanent magnet, wash solids from nail, dry and weigh solids

(iv) Repeat (ii) and (iii) for subsequent time periods.

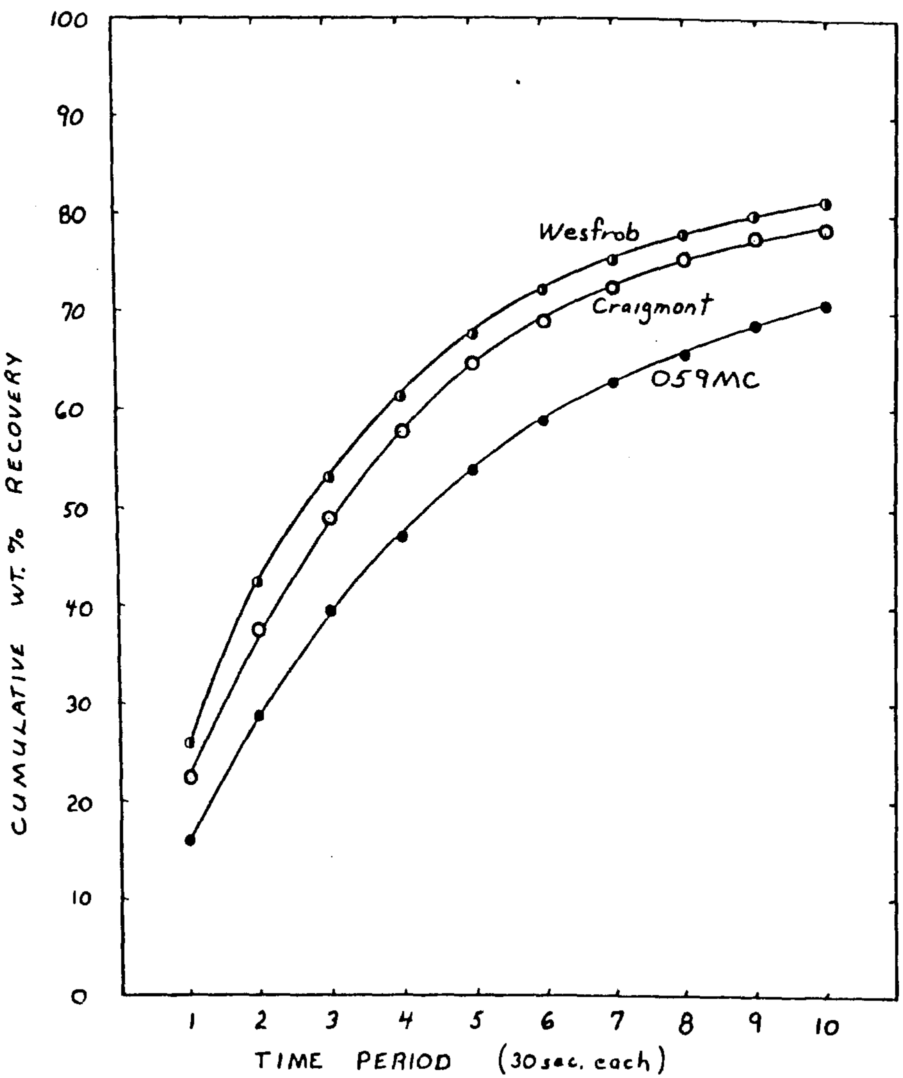


Figure 3: Cummulative Recovery for Successive Time Intervals

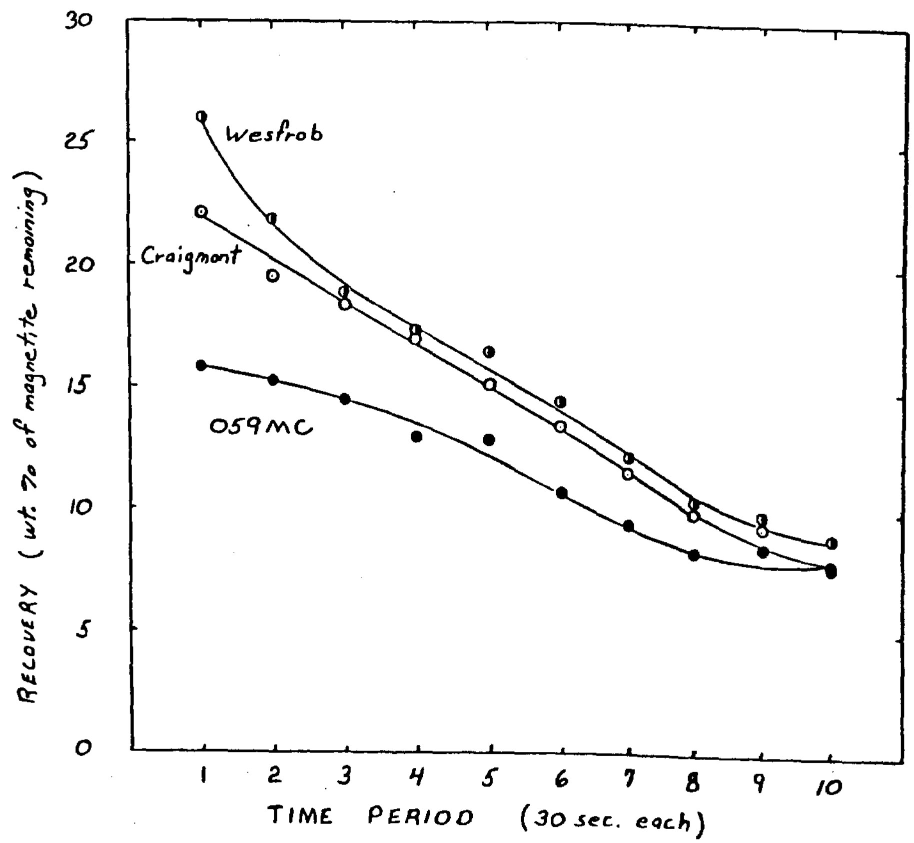


Figure 4: Recovery during Successive Time Intervals Based on Quantity of Magnetite Present at start of Interval

Table 5 and Figures 3 and 4 indicate that the 059MC magnetite has lower recoverability than the other two magnetites. The recoverability of Wesfrob magnetite has been reported by others as being very good. The lower relative recoverability of the 059MC magnetite is in agreement with its lower specific gravity and inferred lower purity. Recoverability should be proportional to magnetic susceptibility which, in turn, is proportional to magnetite purity.

Although the 059MC recoverability in the comparative tests is significantly lower than that of the other two magnetites, this difference would not necessarily mean significantly lower recoverability at the coal preparation plant. Magnetic susceptibility is proportional to magnetic field intensity. In the higher intensity fields of commercial separators the magnetic susceptibilities, and hence relative recoverabilities, of the three magnetites might be more similar. For example, the Davis Tube operates at a high magnetic field intensity and the Davis Tube "recoverabilities" suggest that 059MC magnetite is equal, if not superior, in recoverability to Wesfrob and Craigmont magnetites.

It can be argued that the finer size distribution of the 059MC magnetite has a negative effect on its recoverability. This is due to viscosity/drag forces which make it more difficult for the finest particles to move through the water to the magnetized nail. The negative contribution of the 059MC size distribution to its lower relative recoverability is probably not significant.

Although our relative recoverability tests are difficult to extrapolate to the recoverabilities that would occur in a coal preparation plant we feel there is a high probability that a commercially produced Blairmore magnetite will be marginally less recoverable than either Wesfrob or Craigmont magnetite. A marginal decrease in recoverability could be compensated for by a nominal decrease in magnetite price.

APPENDIX 1

WET MAGNETIC BENEFICIATION
OF MAGNETITE
FOR
COAL MINING RESEARCH CENTER
RR #83-373

ERIEZ
ERIE, PENNSYLVANIA
U.S.A.

CONTENTS

ERIEZ MAGNETICS®

Central Test Laboratory
REPORT OF TEST

Date: OCTOBER 13, 1983 Research Request: #83-373

Test Made For: COAL MINING RESEARCH CENTER

Address

City State

1.0 TITLE: Wet Magnetic Beneficiation of Magnetite

2.0 INTRODUCTION: The Coal Mining Research Center is investigating a magnetite source for its suitability as heavy medium. Approximately 100 lbs. of -20 mesh ore was received for testing. The objective being to produce a magnetite of equivalent to Foote Grade E.

2.1 Equipment Used -- Eriez Laboratory Model L-8 Wet Drum Separator was used for all tests.

3.0 DISCUSSION:

3.1 Test Procedures -- One test flowsheet was followed as shown on the attached Figure #1. The entire sample as received was slurried at 15% solids and pumped to the L-8. Field intensity for this pass and all subsequent passes was set at 500 gauss high gradient equivalent. The magnetic concentrate (11) was then taken for Davis Tube Magnetics determination. A D.T. mag content of 85.0% was reduced to 53.1% after milling to 325 mesh. Non-magnetics (12) assayed 11.9% D.T. mag in an as-received condition.

Approximately one-half of the concentrate was reduced to 95% -325 mesh using steel jar mills.

This fraction was then slurried to approximately 5% solids and pumped through the L-8. The concentrate obtained here was immediately repulped and again passed through the L-8.

All test fractions were filtered and dried for return to the client.

3.2 Evaluation -- Overall 46.8 weight percent was recovered as a magnetic concentrate. This concentrate assayed 93.5% D.T. magnetics, 99.5% -325 mesh, and 4.5 specific gravity --all meeting or exceeding the nominal specifications for Foote Grade E magnetite.

Recovery of magnetics in the last two stages was 96.9%.

It is recommended that solids concentration not exceed 15% in the first stage. Higher solids concentration in the last two stages may be possible but would probably contribute to a lower grade final concentrate.

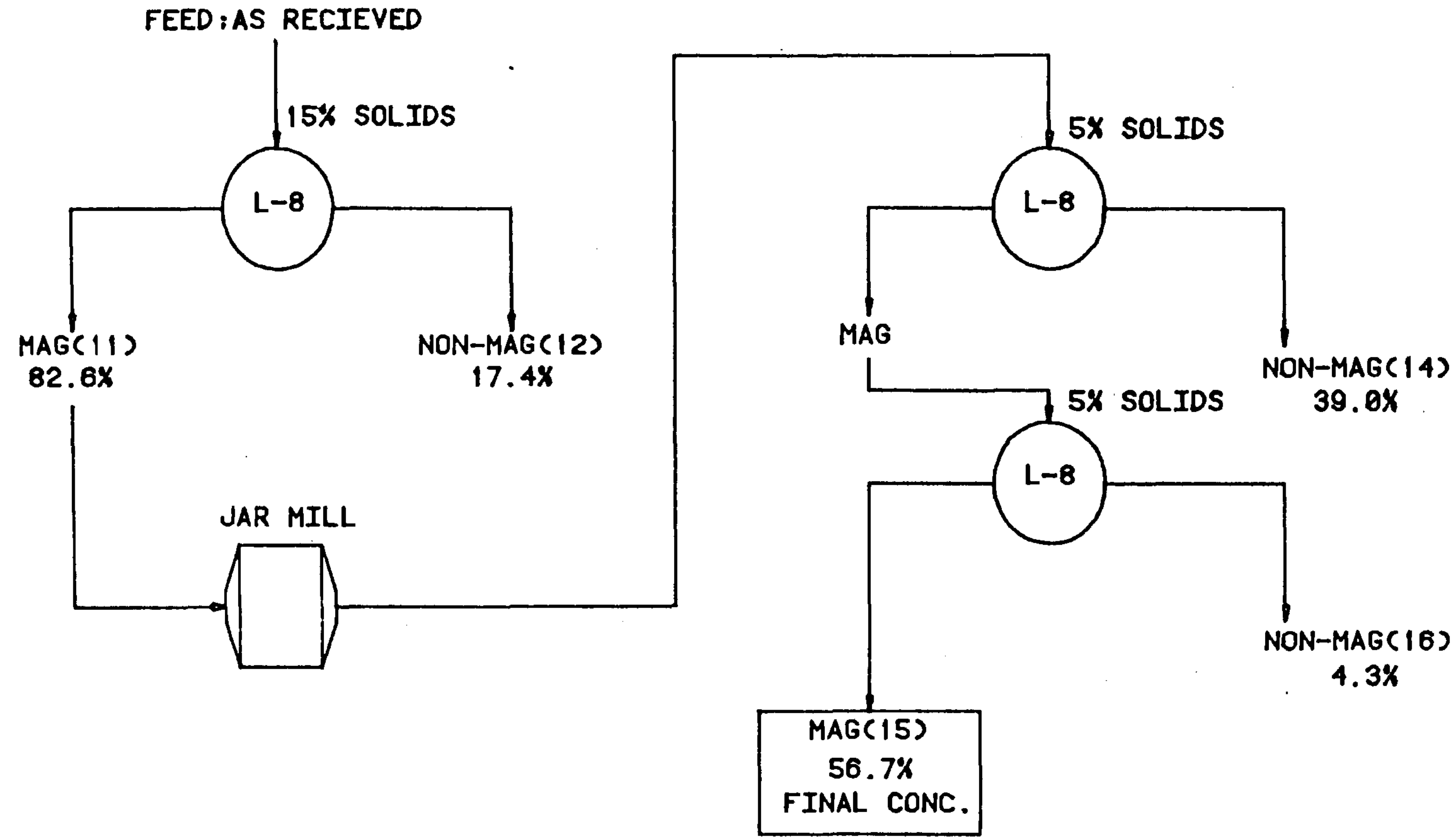
4.0 CONCLUSION: A high grade magnetite concentrate can be produced following a conventional process using wet drum magnetic separators.

[redacted]

Michael J. Ross
Mineral Processing Engineer

MJR/jaj

RR#83-373



CONCENTRATE SPECIFICATIONS

93.5% DT MAG
99.5% -325 MESH
4.5 SPECIFIC GRAVITY

FRACTION	%WT	%DT MAG	UNITS	DIST.
MAG(15)	56.7	93.5	53.015	96.9
NMAG(16)	4.3	11.1	0.477	0.9
NMAG(14)	39.0	3.1	1.209	2.2
CALC. HEAD		54.7		

WET DRUM FIELD INTENSITY:500 GAUSS EQUIVALENT

ERIEZ MAGNETICS
TEST FLOWSHEET
FOR
COAL MINING RESEARCH CENTER

FIG. #1

Appendix 2

CALCULATIONS FOR TABLE 1

Eriez separated the as received -20 mesh feed into magnetic concentrate (Mag (11) and non-magnetic tails (Non-Mag (12)). The magnetic concentrate was then split into two sub-samples. One sub-sample was milled to -325 mesh. This -325 mesh Mag (11) sample was used as the feed for two subsequent separations. Eriez calculated yields for these two subsequent separations assuming the -325 mesh feed equalled 100%; however, the -325 mesh feed was equivalent to 82.6% of the initial -20 mesh feed. The following calculations convert the Eriez values to values based on the -20 mesh feed. The calculations also compute a feed magnetite content. It is assumed that -325 mesh solids recovered in the Davis Tube are magnetite.

Calculations

Mag (15) 56.7 wt% x 0.826 = 46.8 wt.% of initial -20 mesh feed
46.8 wt.% x 0.935 D.T. magnetics = 43.8 wt.% magnetite

Non-Mag (16) 4.3 wt.% x 0.826 = 3.6 wt.% of initial -20 mesh feed
3.6 wt.% x 0.111 D.T. magnetics = 0.4 wt.% magnetite

Non-Mag (14) 39.0 wt.% x 0.826 = 32.2 wt.% of initial -20 mesh feed
32.2 wt.% x 0.031 D.T. magnetics = 1.0 wt.% magnetite

Non-Mag (12) 17.4 wt.% x 1.000 = 17.4 wt.% of initial -20 mesh feed
At -20 mesh Mag (11) assayed 85.0% D.T. magnetics
At -325 mesh Mag (11) assayed 53.1% D.T. magnetics
Assume same proportions for Non-Mag (12)
-325 mesh D.T. magnetics = -20 mesh D.T. magnetics x 53.1/85.0
= 11.9 x 53.1/85.0
= 7.4%
17.4 wt% x 0.074 D.T. magnetics = 1.3 wt.% magnetite

Feed Magnetite = Mag (15) + Non-Mags (16), (14), (12)
= 46.5 wt.%