MAR 19950002: IRONCAP GOLD

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19950002

REPORT ON THE IRONCAP GOLD PROPERTY
PEACE RIVER AREA, ALBERTA
Metallic and Industrial Minerals Permits No. 9390100001 to 9390100008

prepared by
Marum Resources Inc
4606 5th St S.W.
Calgary, AB, T2S 2E5

April 21, 1995

NOTICE

This report is the property of Marum Resources Inc. It represents a reference and assessment document for Metallic and Industrial Minerals Permits No. 9390100001 to 9390100008. Exploration work on the permits will continue throughout 1995.

The subject permits are primarily viewed as areas for gold exploration. However, they were also considered to have diamond exploration merit and a number of samples were investigated for diamond indicator minerals.

MARUM RESOURCES INC.

[redacted]

Richard A. Boulay, B.Sc.(Geology)
President

April 21, 1995

Project Overview

This compilation and assessment work report summarizes the results of three years of exploration activities by several exploration teams. The work was performed during the period January 1, 1992 to December 31, 1994.

Initially, the work consisted of prospecting activities to collect samples and exploratory laboratory work intended to identify the presence of gold and platinum group elements within the target formation, the upper Cretaceous Bad Heart formation.

Two conclusions were reached in the initial stages of exploration. First, that particles of free gold occur in most crushed samples at magnification of 80 power or higher. Second, the distribution and measurement of gold within the Bad Heart formation is subject to a "nugget effect" which renders measurement of gold content expensive. It should be noted that the gold occurs as bright yellow particles of native gold in an iron silicate (chamosite) matrix and responds well to normal fire assay procedures. However, the distribution of the gold within the formation remains undetermined and the selection of any particular 28 gram sample (one assay-ton) may not contain any gold or may contain a large amount of gold. The solution to acquiring a reliable estimate of commercial gold content is to perform hundreds of thousands of fire assays or to significantly increase the raw sample size. The first solution is not economically feasible. The second solution requires leaching of gold from crushed samples and the subsequent measurement of gold contained in the leach liquor with this amount being pro-rated back to the original sample weight, taking into account the amount of leach liquid employed in the procedure. This can be achieved by precipitating the gold from the leach liquor and assaying the precipitate or alternatively, by subjecting a representative sample of the leach liquor to neutron activation analysis.

During 1992, 1993 and 1994, eleven field expeditions were mounted to prospect the surface occurrences of the Bad Heart formation and large samples were collected for investigation in processing laboratories maintained by the prospecting teams. These initial laboratory investigations resulted in the determination that fine, particulate native gold occurred in most samples of the Bad Heart formation rocks. These same investigations outlined the difficulties which would be encountered in estimating the gold content of the formation for commercial purposes.

During 1994, the holders of the Metallic and Industrial Minerals Permits, entered into an option agreement with Marum Resources Inc. of Calgary. A compilation of geological information and geochemical results was undertaken in during 1994.

Two additional exploration expeditions were carried out during 1994 and sufficient samples were collected to further investigate the mineralogical characteristics of the Bad Heart formation. Some of the initial samples were contaminated with small grains of igneous rock which gave rise to speculation about the diamond bearing potential of this sedimentary formation, but the grains were identified as contaminants relatively quickly and no further diamond-related processing was undertaken.

Marum's exploration work during 1994 consisted of collecting and processing surface samples in order to determine the nature of the Bad Heart formation and the geological mechanisms which control the distribution of gold within the rocks. Optical inspection of raw samples, crushed samples and thin sections was undertaken by Marum's principal consultant, Mr. Richard T. Walker. Numerous concentration and leaching experiments were carried out by Marum staff with the concentrates and precipitates being visually investigated or the leach liquors being subjected to neutron activation analysis. Additional studies were undertaken by two other petrographic consultants. Consultations were held with representatives of various laboratories and with members of the Geological Survey of Canada concerning possible controls on gold mineralization. Leach tests were carried out in commercial laboratories. Additionally, a pressurized sodium bromide leach test was performed on four samples of material and encouraging qualitative results were obtained.

The results of the exploration work performed to date are positive in that they identify the Bad Heart formation as a potential gold host. The distribution of gold within the formation will be the focus of the next round of exploration which will be designed to investigate the stratigraphic and facies controls, if any, leading to commercial concentrations of the yellow metal.

Structure of this report

This report is a compilation of relevant technical material bearing on the exploration of the subject permits, assembled as a working data record and for permit assessment purposes. A general description of the regional and gross stratigraphic geology is provided by the Appendix 8. Moreover, the results of recent work, including petrographic studies are represented by the complete reproduction of the appropriate reports in the Appendices.

The appendices include:

1 **Photocopies of Metallic Mineral Exploration Permits No. 9390100001 to 9390100008, including a permit location map.**

2 **Ironcap Property (Bad Heart Formation) Outcrop Location, Sample Collection and Sample Processing Program.**

This appendix contains the descriptions of 717 samples collected and analyzed during the three year period extending from January 1, 1992 to December 31, 1994. The collection, study, analysis and compilation of sample material contained in this Appendix represents most of the quantitative data available for the Bad Heart formation in the project area.

3 **Petrographic Analysis of Outcrop Sample, Upper Cretaceous Bad heart formation, Peace River Area; prepared for Marum Resources by Graham Davies Geological Consultants, 1994.**

This report describes three thin sections of Bad Heart formation rock. The petrographer was asked to search for volcaniclastic evidence and reported none.

4 **Petrography of Sample RB#1 from NW Alberta, Report No. SSP-94-5/2, prepared for Monopros Limited by Scott-Smith Petrology, 1994.**

This report was prepared in cooperation with Monopros Limited. Two thin sections and four polished sections were prepared for analysis. A complete petrographic analysis is rendered in the report. Again, the petrographer was alerted to search for evidence of volcanogenic affinity and found none.

5 **Thin section description of three samples; prepared for Marum Resources Inc. by Dynamic Geological Consulting, 1994.**

A petrographic description of three thin sections.

6 **Report of two samples of Ironcap formation material; prepared for Marum Resources Inc. by Dynamic Geological Consulting, 1994.**

A discussion of two processed samples of Bad Heart formation rock.

7 **Neutron Activation Analysis; correspondence and summary information.**

Neutron activation analysis was performed on approximately 20 samples of leach liquor. Results ranged from trace amounts of gold and platinum group elements to upwards of three ounces. The Neutron Activation Analysis component of the exploration program has to date been qualitative rather than quantitative. The emphasis has, so far, been on validating the method for quantitative work during 1995 with precise measurement controls on the raw sample, the leaching process and the leach liquor sampling process. In general, the qualitative work performed so far has been successful with the generalized conclusion that the Bad Heart formation does contain geochemically significant but erratically occurring gold.

8 **Peace River Iron Deposits, Information Series 75, Alberta Research Council, 1975.**

This Appendix does not form part of this assessment report but is included for general reference. This report is an excellent description of the project area and its geology. The report infers in excess of 1.1 billion tons of iron-rich rock grading between 32 and 36 percent total iron. Most of this "reserve" lies within the subject permits.

Exploration Results

A three year program of exploration, sampling and laboratory analysis of the Bad Heart formation oolitic, ferruginous sandstone has produced the following results.

1. The Bad Heart formation is conclusively diagnosed as a marine, stable shelf, glauconitic, oolitic, ferruginous clastic rock deposited with a low sedimentation rate in a quiet marine environment.

2. The Bad Heart formation contains anomalous, even spectacular amounts of gold. The gold occurs as very fine particles of native metal which can be observed visually at about 100 power magnification.

3. Gold values vary dramatically, from traces to loosely extrapolated values of several ounces per ton. Work to date on bulk samples has been designed to qualitatively establish the physical, identifiable presence of gold in samples taken from numerous locations. This has been achieved by visual examination of crushed raw rock, by gravity concentration, by direct fire assay, by visual inspection of leach precipitates, and by neutron activation methods.

4. The distribution of gold within the Bad Heart formation has not been defined. Gold values are extremely erratic, even when comparing one ounce aliquots from the same sample. Current exploration tends towards the leaching of large, +20KG, samples in order to overcome the small scale variation in values.

5. Due to the preliminary nature of the sampling and analysis procedures performed over three years and the initial thrust of the exploration program to physically define the nature of the gold mineralization, there is a lack of quantitative assay information, even though the results of over 700 detailed samples analyses are represented by this report. This is partly due to the fact that the exploration teams have been performing pioneer work in order to determine the most feasible method to quantify the gold content of the Bad Heart target host. An informal overall average of 1 gm/Tonne gold content can be inferred over the sample base processed so far.

6. The Bad Heart formation contains anomalous amounts of platinum group metals, primarily osmium and iridium. These are also distributed erratically in the sandstone.

7. The exploration programs carried out so far have not included any drilling. Drill cores from drilling undertaken in the 1950's and 1960's cannot be located. Consequently, the exploration efforts to date have not included any detailed stratigraphic information which would shed light on stratigraphic or facies related mineralization controls.

8. The Bad Heart formation does not contain any material which demonstrates a volcaniclastic origin. Consequently, the formation is not currently considered to be a diamond exploration target.

9. There are sufficient indications of gold mineralization in the Bad Heart formation to justify continued exploration.

Recommended 1995 Exploration Program

The 1995 exploration program has two principal objectives:

1. To establish stratigraphic control over the data so far collected and to collect new samples with precise stratigraphic and facies definition. This will require a drill program of at least 12 holes.
2. To establish a quantitative geochemical database over the new sample collection. This database will consist of results from fire assay of raw samples as well as the results of quantified leach tests.

1995 Ironcap Project Exploration Budget.

Field Operations	$20,000
Leaching Tests	$25,000
Drilling (12 holes to 200 feet)	$25,000
Core & cutting processing	$20,000
Contingency	$10,000

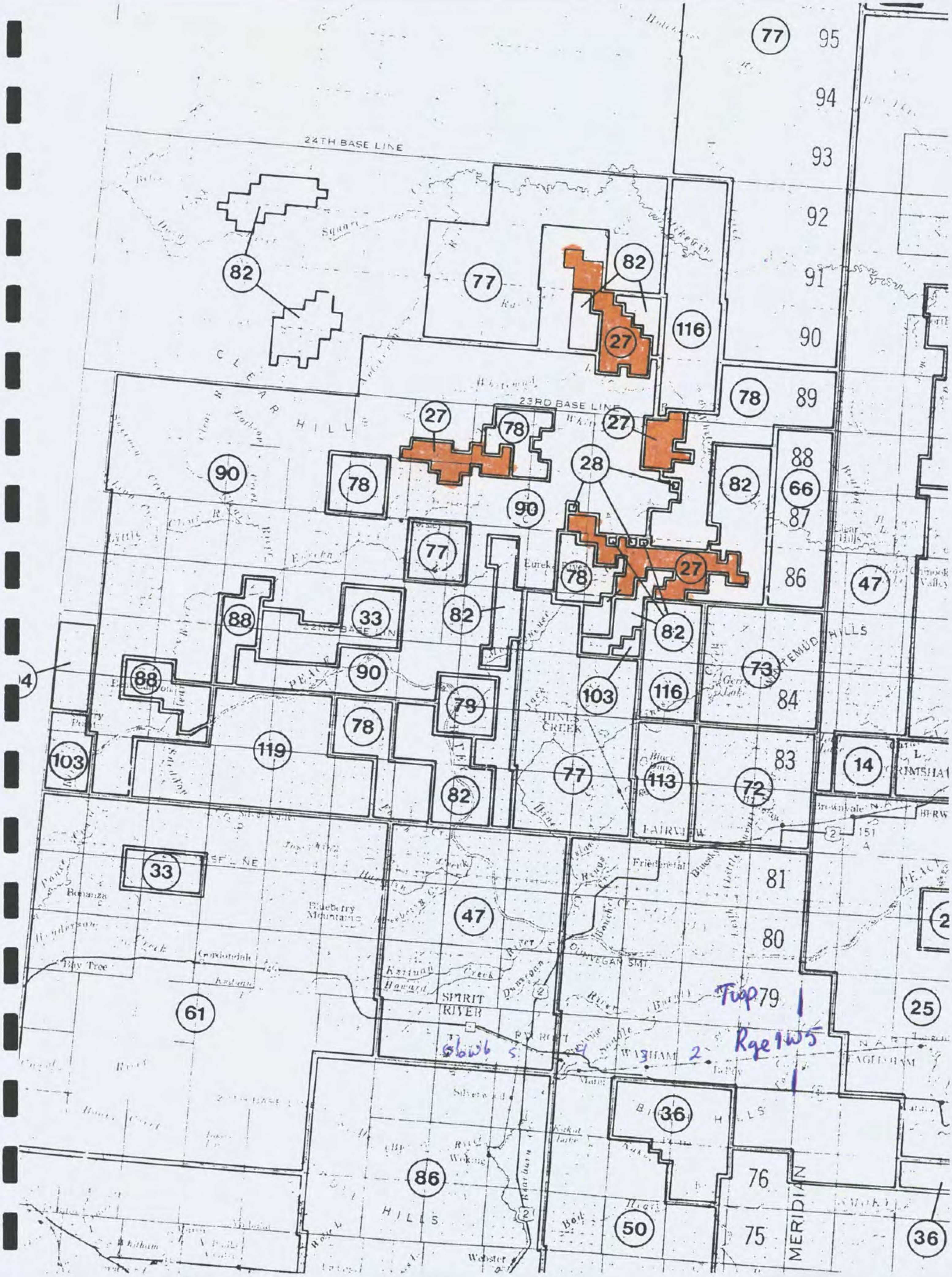
Total	$100,000

Marum Resources Inc.

[redacted]

Richard A. Boulay
President
April 21, 1995

APPENDIX 1



24TH BASE LINE
23RD BASE LINE
22ND BASE LINE
CLEAR HILLS
WHITEMUD HILLS
HINES CREEK
FAIRVIEW
SPIRIT RIVER
RYCROFT
WANHAM
DUNVEGAN SMT.
Eureka River
Peace
Brownvale
Grimshaw
Berwyn
Bonanza
Blueberry Mountain
Gordondale
Bay Tree
Silverwood
Woking
Webster
Friedenstal
Eaglesham
Tangent
Chinook Valley
Clear Hills
Cherry Point
Moonshine
Dunvegan
Kakut Lake
Saddle
Burnt
Whitemud
Hotchkiss
Square
Jackson
Clear R.
Little
Ksituan Creek
Howard
Henderson Creek
Pouce Coupe
Heart
Boit
Hines Creek
Leith
Boucher
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Josephine
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Alberta
ENERGY/MINERAL RESOURCES DIVISION

Petroleum Plaza – North Tower
9945 - 108 Street
Edmonton, Alberta
Canada T5K 2G6

Phone: (403) 427-7707
Fax: (403) 422-3044

File No. 6890100002 to 6890100009

February 7, 1994

423771 Alberta Ltd.
223 Creston Place
EDMONTON AB T5A 1X4

Dear Sir,

Re: Metallic Mineral Exploration Permit Nos. 6890100002 to 6890100009

The Metallic & Industrial Minerals Regulation (AR 66/93) provides for the conversion of the older Metallic Minerals Exploration Permits to the newer Metallic and Industrial Minerals Permits. An existing permit may be cancelled and a new permit issued, with a term commencement date of the existing permit. The advantage of the conversion is a longer term with reduced overall work requirements.

The above permits reached the end of the Initial renewal year on October 2, 1993 and October 19, 1993. The Department has reviewed your permits and has converted the permits as follows:

Existing Exploration Permit Nos.		New Permit Nos.		Work Assessment Period (Years)	Established Credit
6890100002		9390100001		Second (3/4)	nil
	to		to		
6890100009		9390100008		Second (3/4)	nil

I am enclosing your copy of the Metallic & Industrial Minerals Permits which conveys the rights to explore for Metallic & Industrial Minerals within the locations described therein.

Kindly pay particular attention to Section 14 of the Regulation, since your second period assessment work will be required by October 2, 1994 and October 19, 1994.

If you have any questions regarding the above, contact me at the above number.

Yours truly,

Brian Hudson

Brian Hudson
Manager
Mineral Agreements

/le
enclosures

Alberta
ENERGY
Mineral Resources Division

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100001

Date of Issue: 1994 February 7

Term Commencement Date: 1990 October 2

In this Permit:

(a) "Date of Issue" means the date shown above as the Date of Issue;

(b) "Location" means the tract or tracts of land described under the heading "Description of Location" in the Appendix to this Permit;

(c) "Metallic and Industrial Minerals" means the minerals described under the heading "Permitted Substances" in the Appendix to this Permit;

(d) "Permit Holder" means 423771 Alberta Ltd.

(e) "Term Commencement Date" means the date shown above as the Term Commencement Date.

(f) a reference in this Permit to the Mines and Minerals Act or to any other Act of the Legislature of Alberta shall be construed as a reference to

(i) that Act, as amended from time to time,

(ii) any replacement of all or part of that Act from time to time enacted by the Legislature, as amended from time to time, and

(iii) any regulations, orders, directives, by-laws or subordinate legislation from time to time made under any enactment referred to in clause (a) or (b), as amended from time to time.

This Permit grants to the Permit Holder the right to explore for Metallic and Industrial Minerals that are the property of the Crown in right of Alberta in the Location subject to the following terms and conditions:

APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100001

COMMENCEMENT OF TERM:

1990 OCTOBER 2

AGGREGATE AREA:

4 248 HECTARES

DESCRIPTION OF LOCATION:

6-06-087: 32NE,L11,L14;33L13-L16;34L13NW
6-06-088: 3W,L7N,L7SW,L8NW,L9W,L10,L15,L16;4;5;6N,L1NE, L3NW,L4-L8;7S,NW,L9,L10,L15,L16SW;10L1S,L1NW,L2-L4
6-07-087: 26L13N,L14N,L15N;27L14N;33NE,L7E,L8NW,L14E;34N, L1N,L1SE,L2N,L2SW,L3,L4SE,L6-L8;35N,SW,L1N,L2,L7,L8;36NW, L3NW,L4N,L5,L6W,L7N,L9W,L10,L15,L16W
6-07-088: 1;2SE,L3-L5,L6S,L9SE;3;4N,L1,L2,L3E,L6SE,L7S,L8; 5N,L2W,L3N,L3SE,L5-L7,L8NW;6NW,L5,L6W,L8N,L8SE,L9,L10N,L15, L16;7S,L9S,L10,L11;8S,L9-L11,L12S,L15SE,L16S;9S,L9-L12,L13S, L14S,L15S,L16;10S,L9SW,L10-L13,L14S
6-08-088: 1L2,L3,L6SE,L7-L10,L11E,L16

PERMITTED SUBSTANCES:

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL

Alberta
ENERGY
Mineral Resources Division

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100002

Date of Issue: 1994 February 7

Term Commencement Date: 1990 October 2

In this Permit:

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(c) "Metallic and Industrial Minerals" means the minerals described under the heading "Permitted Substances" in the Appendix to this Permit;

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(e) "Term Commencement Date" means the date shown above as the Term Commencement Date.

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This Permit grants to the Permit Holder the right to explore for Metallic and Industrial Minerals that are the property of the Crown in right of Alberta in the Location subject to the following terms and conditions:

APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100002

COMMENCEMENT OF TERM:

1990 OCTOBER 2

AGGREGATE AREA:

7 832 HECTARES

DESCRIPTION OF LOCATION:

6-04-089: 26N,L5-L8;27N,L5-L8;29N,L5-L8;30L8,L9,L16;31L1,
L8,L9,L16;32-35
6-04-090: 2W,L1,L2,L7;3-5;6L1,L8,L9,L15E,L16;7NE,L1,L2E,L7,
L8;8-10;11L3W,L4,L5,L12SW;15W,L1W,L2,L7,L10W;16;17;18E,L3E,
L6,L11,L13,L14;19E,L3,L4,L6,L14NE;20;21S,L9-L13;29L1S,L2-L5;
30SE,NW,L3,L5,L6,L9,L10,L15,L16W;31L3-L5,L12,L13
6-05-090: 25L9,L14-L16;36
6-05-091: 1;2;3L1E,L8,L9,L15,L16;10L1,L8,L9,L15,L16;11;
12L1S,L2S,L3-L5,L6W,L12,L13;13L4;14SW,L1,L2,L7,L8S,L8NW,
L10S,L10NW,L11-L13,L14S,L14NW;15N,SE,L3,L4,L5E,L6;16NE,L11N,
L12N,L13,L14;21S,L9-L12;22SW,L1,L2,L7S,L7NW,L10W,L11,L12

PERMITTED SUBSTANCES:

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL

BM

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Alberta
ENERGY
Mineral Resources Division

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100003

Date of Issue: 1994 February 7

Term Commencement Date: 1990 October 2

In this Permit:

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- (ii) any replacement of all or part of that Act from time to time enacted by the Legislature, as amended from time to time, and
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APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100003

COMMENCEMENT OF TERM:

1990 OCTOBER 2

AGGREGATE AREA:

3 448 HECTARES

DESCRIPTION OF LOCATION:

6-03-088: 7;8L5W,L13NW,L14N;15L3W,L4,L5,L6SW;16L1N,L2N,L4N,
L5-L8,L11SW,L12,L13SW;17N,SW,L1N,L2,L7,L8;18;19;20L2W,L3,L4,
L5S,L6S,L7SW,L13NW;28L13NW;29NW,L4,L5,L6W,L10N,L15,L16;30;
31S,NE,L11,L14SE;32;33NW,L4,L5,L6W
6-03-089: 4L4;5L1-L4,L5S,L6S,L7S,L8S
6-04-088: 12;13;24;25;36L1,L8,L9,L10E,L15E,L16

PERMITTED SUBSTANCES:

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL

BM

MA-1

Alberta
ENERGY
Mineral Resources Division

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100004

Date of Issue: 1994 February 7

Term Commencement Date: 1990 October 2

In this Permit:

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APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100004

COMMENCEMENT OF TERM:

1990 OCTOBER 2

AGGREGATE AREA:

6 296 HECTARES

DESCRIPTION OF LOCATION:

6-03-086: 19N,L1,L2N,L3N,L4N,L5-L8;20;21;22W;26L12,L13S;
27N,SW;28-30
6-04-085: 16;17L1N,L2N,L6E,L7-L9,L10S,L16E;18L16N;19L1,L2N,
L7E,L8,L9,L10E,L15NE,L16N;20;21;28W,L2,L7W,L10W,L15W;29L1N,
L2,L3,L4E,L5E,L6-L9,L10S,L11S,L16E;30L1,L2SE;33L1N,L2,L3,
L4E,L5E,L6-L9,L10S,L11S,L16E
6-04-086: 2L4NW,L5,L6W,L11,L12,L13W;3L1-L4,L5SE,L6S,L7S,L8,
L9SE,L16;10L1,L2NE,L7SE,L8S,L8NE,L9W,L16SE;11L3W,L4-L7,L8W,
L9W,L10-L12,L13S,L14E,L15;13L5W,L12,L13;14SE,L3E,L9,L10E,
L15E,L16;20L16N;21L13N;23L1,L2E,L8S,L8NE,L9,L10N,L15E,L16;
24N,SW,L1N,L2N,L2SW,L7,L8;25S,L9-L12,L13S,L14S,L16;26NW,L1,
L2E,L5-L10,L15SW;27SW,NE,L2W,L7,L11S,L11NE;28L1N,L2N,L3N,
L3SW,L4-L8,L11SW,L12,L13SW;29NE,L1,L2,L8,L11E,L14E;31N,L1,
L8;32NW,L1W,L2,L3E,L4N,L5-L10,L15,L16S;34L1,L2SE;35L3W,L4
6-04-087: 6S,NW,L10,L15;7L2,L3,L4SE
6-05-086: 36L9E,L16E
6-05-087: 1NE,L2N,L5E,L6N,L7,L8NW,L11,L12N,L12SE,L13,L14;
11NE,L1,L6N,L6SE,L7,L8,L11,L12NE,L13E,L14;12N,SW,L2,L7,L8W

PERMITTED SUBSTANCES:

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL

Alberta
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Mineral Resources Division

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100005

Date of Issue: **1994 February 7**

Term Commencement Date: **1990 October 2**

In this Permit:

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(c) "Metallic and Industrial Minerals" means the minerals described under the heading "Permitted Substances" in the Appendix to this Permit;

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(i) that Act, as amended from time to time,

(ii) any replacement of all or part of that Act from time to time enacted by the Legislature, as amended from time to time, and

(iii) any regulations, orders, directives, by-laws or subordinate legislation from time to time made under any enactment referred to in clause (a) or (b), as amended from time to time.

This Permit grants to the Permit Holder the right to explore for Metallic and Industrial Minerals that are the property of the Crown in right of Alberta in the Location subject to the following terms and conditions:

APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100005

COMMENCEMENT OF TERM:

1990 OCTOBER 2

AGGREGATE AREA:

2 872 HECTARES

DESCRIPTION OF LOCATION:

6-02-086: 15W,L2W,L7N,L7SW,L8N,L9,L10,L15;16E,L3,L4,L5S,L6,L11,L12NE,L13,L14;19L1N,L2N,L3NE,L6-L8,L9SW,L10SE,L11S,L11NE,L12N,L12SE,L13,L14N,L14SW;20L5-L8;21;22SW,L2S;28S,L9-L12;30SW,L2W,L7

6-03-086: 3NW,L5,L6W,L9NW,L10N,L15,L16;4NE,L7,L8,L11,L14;5L1-L5;9SE,L3,L9E,L16E;10;11L8N,L9,L10E,L13N,L13SW,L15,L16;12L12W,L13W;13L4,L5,L12SW;14S,NW,L9,L10,L15,L16SW;15L1,L2S,L3,L4,L8,L9,L10N,L15,L16;22E;23L2SW,L3S,L3NW,L4,L5,L12-L14,L15N,L16N;24L10NW,L11NE,L13,L14,L15W;25SW,L1N,L2,L7,L8,L10S,L11S,L12

PERMITTED SUBSTANCES:

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL

BM

Alberta
ENERGY
Mineral Resources Division

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100006

Date of Issue: 1994 February 7

Term Commencement Date: 1990 October 19

In this Permit:

(a) "Date of Issue" means the date shown above as the Date of Issue;

(b) "Location" means the tract or tracts of land described under the heading "Description of Location" in the Appendix to this Permit;

(c) "Metallic and Industrial Minerals" means the minerals described under the heading "Permitted Substances" in the Appendix to this Permit;

(d) "Permit Holder" means 423771 Alberta Ltd. 75%
Estabrook Construction Ltd. 25%

(e) "Term Commencement Date" means the date shown above as the Term Commencement Date.

(f) a reference in this Permit to the Mines and Minerals Act or to any other Act of the Legislature of Alberta shall be construed as a reference to

(i) that Act, as amended from time to time,

(ii) any replacement of all or part of that Act from time to time enacted by the Legislature, as amended from time to time, and

(iii) any regulations, orders, directives, by-laws or subordinate legislation from time to time made under any enactment referred to in clause (a) or (b), as amended from time to time.

This Permit grants to the Permit Holder the right to explore for Metallic and Industrial Minerals that are the property of the Crown in right of Alberta in the Location subject to the following terms and conditions:

APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100006

COMMENCEMENT OF TERM:

1990 OCTOBER 19

AGGREGATE AREA:

16 HECTARES

DESCRIPTION OF LOCATION:

6-03-087: 33L2

PERMITTED SUBSTANCES:

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL

BM

Alberta
ENERGY
Mineral Resources Division

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100007

Date of Issue: 1994 February 7

Term Commencement Date: 1990 October 19

In this Permit:

(a) "Date of Issue" means the date shown above as the Date of Issue;

(b) "Location" means the tract or tracts of land described under the heading "Description of Location" in the Appendix to this Permit;

(c) "Metallic and Industrial Minerals" means the minerals described under the heading "Permitted Substances" in the Appendix to this Permit;

(d) "Permit Holder" means 423771 Alberta Ltd. 75%
Estabrook Construction Ltd. 25%

(e) "Term Commencement Date" means the date shown above as the Term Commencement Date.

(f) a reference in this Permit to the Mines and Minerals Act or to any other Act of the Legislature of Alberta shall be construed as a reference to

- (i) that Act, as amended from time to time,
- (ii) any replacement of all or part of that Act from time to time enacted by the Legislature, as amended from time to time, and
- (iii) any regulations, orders, directives, by-laws or subordinate legislation from time to time made under any enactment referred to in clause (a) or (b), as amended from time to time.

This Permit grants to the Permit Holder the right to explore for Metallic and Industrial Minerals that are the property of the Crown in right of Alberta in the Location subject to the following terms and conditions:

APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100007

COMMENCEMENT OF TERM:

1990 OCTOBER 19

AGGREGATE AREA:

16 HECTARES

DESCRIPTION OF LOCATION:

6-04-086: 35L5

PERMITTED SUBSTANCES:

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL

Alberta
ENERGY
Mineral Resources Division

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100008

Date of Issue: **1994 February 7**

Term Commencement Date: **1990 October 19**

In this Permit:

(a) "Date of Issue" means the date shown above as the Date of Issue;

(b) "Location" means the tract or tracts of land described under the heading "Descriptio Location" in the Appendix to this Permit;

(c) "Metallic and Industrial Minerals" means the minerals described under the head "Permitted Substances" in the Appendix to this Permit;

(d) "Permit Holder" means **423771 Alberta Ltd. 75%**
Estabrook Construction Ltd. 25%

(e) "Term Commencement Date" means the date shown above as the Term Commencem Date.

(f) a reference in this Permit to the Mines and Minerals Act or to any other Act of t Legislature of Alberta shall be construed as a reference to

- (i) that Act, as amended from time to time,
- (ii) any replacement of all or part of that Act from time to time enacted by t Legislature, as amended from time to time, and
- (iii) any regulations, orders, directives, by-laws or subordinate legislation from tir to time made under any enactment referred to in clause (a) or (b), as amend from time to time.

This Permit grants to the Permit Holder the right to explore for Metallic and Industri Minerals that are the property of the Crown in right of Alberta in the Location subject to tl following terms and conditions:

APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9390100008

COMMENCEMENT OF TERM:

1990 OCTOBER 19

AGGREGATE AREA:

16 HECTARES

DESCRIPTION OF LOCATION:

6-05-087: 14L11

PERMITTED SUBSTANCES:

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL

BM

Ironcap Property (Bad Heart Formation)
Outcrop Location, Sample Collection
and Sample Processing Program.
(717 samples)

Results of the Regional Outcrop Mapping Project

Due to the nature of the terrain, locating outcrops over such a large property consumed a considerable number of man days. The initial, and most extensive sampling was carried out on easily accessible materials found along existing road cuts or in pre-existing pits. The regional outcrop mapping project resulted in the collection of small representative samples from scattered locations and established locations for the collection of more comprehensive samples in the future.. This program may be continued as required since the area is widely covered with seismic lines which likely contain numerous outcrop opportunities.

Due to the flat-lying character of the Bad Heart formation, field teams were able to more efficiently locate outcrops by concentrating in areas where the current ground surface occurred between 2,500 and 2,600 feet above sea level (ASL), as determined by a portable altimeter. This technique was used on roadways and also on trails, cut lines and overgrown seismic lines. Several new outcrop locations were identified. Additionally, a number of locations within the appropriate altitude zone were noted as having red, rusty looking soil and were designated as possible outcrop locations.

The weak grain cementation of the Bad Heart formation causes the exposed rock to crumble upon exposure making outcrop identification by shape next to impossible. Some success in identifying outcrop locations was achieved by looking for rusty blooms along the roadways within the pre-defined altitude zone.

Generally, the Bad Heart formation outcrops have been uniformly and heavily weathered to a light red, rusty material that is very friable and can be crumbled into clumps and grains by hand. The red stain at surface is usually the first indicator of exposure, except in the more northerly exposures along Rambling Creek where weathering is less intense and the outcrops are dark grey brown in colour. Small exposures in this area are very hard to identify. Over the entire area, there are also small outcrop exposures that are covered in a grey white coating, probably a calcite or salt crust. These are difficult to notice and their identification is made easier by narrowing the search focus to the altimeter range within which the formation is expected to occur.

Assay Data

The gold assay part of this project has been a source of great encouragement and great frustration. Initial assay results yielded high values and high expectations. As the assay data base increased it became evident that the quantification of gold in this target host would not be as easy as indicated by the initial results. Assay values proved to be extremely variable and the establishment of a consistent grade baseline proved impossible. As testing progressed, there developed a suspicion that the "ore" was complexing gold and thwarting normal fire assay methods. Consequently, project testing was then focused on the refractory nature of the rock and in time more consistent results were obtained. With further work, a pattern began to develop that led to the suspicion that the extreme variability in gold grades could be due to a nugget effect caused by erratic distribution of high single-point values throughout a more or less homogeneous rock matrix. More assays from many samples were processed but this proved only moderately successful and it was decided that the cost of such a sustained program would be unacceptable. Shortly thereafter, a program to investigate effective methods of producing concentrates for assay was undertaken. Several gravity concentration tests were performed to determine the most effective methods. So far, elutriation procedures and centrifugal concentrators have yielded the best results. Experiments with vibrating tables failed to yield acceptable results mainly due to the very clayey nature of the finely crushed rock. The clay tended to clog the riffles and to generally interfere with recovery. In general, pre-concentration was successful in that it tended to reduce the nugget effect.

Pre-concentration of rock samples was adopted as a standard analytical procedure and lead to the investigation of various crush sizes in order to maximize the liberation of gold particles. It was found through successive crushing tests on sample fractions that crush sizes of minus 100 mesh were needed with even finer crush sizes being desirable. However, given the attendant difficulty experienced with fine crush materials in a gravity concentration circuit, crushes of minus 150 mesh were not advantageous.

With the higher analytical result consistency found in pre-concentrated samples, further work addressing the refractory nature of the rock was undertaken. Several approaches were evaluated. These included specialized fluxing in fire assays, neutron activation, acid digestion, and roasting of the rock. Acid digestion and roasting were found to be of benefit. Neutron activation was considered accurate but with the necessarily small sample size that this technique requires the nugget effect reduces the applicability neutron activation as a primary analytical tool for this project. Some work was performed on the amalgamation of raw and treated ores in order to detect free gold.

Assay Data (cont'd)

Allowing for the routine pre-concentration of raw samples using gravity methods, standard gold fire assay techniques have proved to be the most effective in determining gold content. This is no doubt because the gold appears to occur as discrete, very fine particles of native gold. One indicated course of action, to optimize gold recovery, would be to evaluate very large samples of one tonne or more through optimal crush and pre-concentration to be followed by assay of the concentrates. The concentrates may or may not need roasting and/or acid digestion and further work will be performed to assess the need for more extensive assay procedures. Some preliminary bottle roll leach tests of both raw and concentrated ore have been completed with encouraging results

MAP REFERENCE NUMBER

These are the locations and sample reference codes, indicated on Map 2 of this Appendix, where multiple samples of Bad Heart Formation rock was collected. See next page for a description of the sample locations.

✳# - Bad Heart Formation Multiple Sample Location

✳ 1 INCP, INCPS, WP-E, WPET, WPEM, WPEB, PF WPF, WPNT, WPNM
✳ 2 INCPR
✳ 3 WRS, SCB,SCM, SCT,
✳ 4 RCT, RCM, RCB
✳ 5 HC
✳ 6 SL1B, SL1M, SL1T
✳ 7 SL2B, SL2M, SL2T
✳ 8 NT1, NT2
✳ 9 NS1, NS2, NS3

SAMPLE LOCATION CODES AND SITE DESCRIPTIONS

INCP-	Sample from Worsley pit
INCPR-	Sample from seam of ore exposed along Worsley road near pit
INCPS-	Sample from south wall of Worsley pit
WP-E-	Sample from south east wall of Worsley pit
WRS-	Sample from road cut north west of Worsley pit
WPET-	Sample from east wall of Worsley pit- top of exposure
WPEM-	Sample from east wall of Worsley pit- middle of exposure
WPEB-	Sample from east wall of Worsley pit- bottom of exposure
WPF-	Sample from floor of Worsley pit
WPNT-	Sample from north face of Worsley pit- top of exposure
WPNM-	Sample from north face of Worsley pit- middle of exposure
HC-	Sample from test pit dug next to Rambling Creek by ARC
SCB-	Sample from Running Lake Road exposure- bottom
SCM-	Sample from Running Lake Road exposure- middle
SCT-	Sample from Running Lake Road exposure- top
SL1B-	Sample from first Stony Lake Road exposure- bottom
SL1M-	Sample from first Stony Lake Road exposure- middle
SL1T-	Sample from first Stony Lake Road exposure- top
SL2B-	Sample from second Stony Lake Road exposure- bottom
SL2M-	Sample from second Stony Lake Road exposure- middle
SL2T-	Sample from second Stony Lake Road exposure- top
RCT-	Sample from exposure along Rambling Creek- top
RCM-	Sample from exposure along Rambling Creek- middle
RCB-	Sample from exposure along Rambling Creek- bottom
NT1	Sample from Notikewin Tower Road
NT2	Sample from Notikewin Tower Road
NS1	Sample from Notikewin Tower Road drainage crossing
NS2	Sample from Notikewin Tower Road drainage crossing
NS3	Sample from Notikewin Tower Road drainage crossing
DI	Diamond indicator sample site
WM	Sample from Whitemud River drainage
RC	Sample from Rambling Creek drainage
RC_DI	Re-test of RC for diamond indicator minerals
WM_DI	Re-test of WM for diamond indicator minerals
NS_DI	Re-test of NS for diamond indicator minerals

SAMPLE PROCESSING CODES

CODE	
FAR	Standard fire assay of raw ore
FAPT	Fire assay of pre-treated ore
FAS	Fire assay using sieved fractions of raw ore - used to reduce "nugget effect".
SCR	Scorification assay of raw ore
SCPT	Scorification assay of pre-treated ore
SCS	Scorification assay of sieved fractions of raw ore to reduce "nugget effect".
N	Neutron Activation
LT	Bottle roll leach test using thiourea
LC	Bottle roll leach test using cyanide
LAR	Bottle roll leach test using aqua regia
SPA	Small plate amalgamation used for amalgamation of lab samples of less than five assay tons. Mercury coated copper plate is used to gather free gold from slurried sample manually applied to plate.
A	Bottle roll amalgamation of larger samples.
ADH	Sample digested in Hydrochloric Acid
ADF	Sample digested in HydrofluoricAcid
ADS	Sample digested in Sulphuric Acid
ADN	Sample digested in Nitric Acid
ADAR	Sample digested in Aqua Regia
GCP	Gravity concentration by panning
GCT	Gravity concentration by vibrating table
GCE	Gravity concentration by elutriation tower.
ME	Microscopic examination
OC	Optimal crush size
RT	Roast
SED	Sediment diamond indicator test
T	Till diamond indicator test
G	Garnet
SP	Spinel
CR	Cromite
CRD	Chrome Diopside

SAMPLE ANALYSIS SHEET
(including cost allocation per sample in dollars)

SAMPLE ANALYSIS SHEET (including cost allocation per sample in dollars)

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
100	INCP-1	YG	GCP-ME	Visible gold	
100	INCP-2	YG	GCP-ME	Visible gold	
100	INCP-3	YG	GCP-ME	Visible gold	
100	INCPR-1	YG	GCP-ME	Visible gold	
100	INCPR-2	YG	GCP-ME	Visible gold	
100	INCPR-3	YG	GCP-ME	Visible gold	- one flake bigger than 20 mesh
100	INCPS-1	YG	GCP-ME	Visible gold	- one silver white flake
100	INCPR-2	YG	GCP-ME	Visible gold	
100	INCPR-3	YG	GCP-ME	Visible gold	
30	WP-E1	A	FAR	.1 OZ/T AU	
30	WP-E2	A	FAR	.12 OZ/T AU	
30	WP-E3	A	FAR	.03 OZ/T AU	
30	WP-E4	A	FAR	.16 OZ/T AU	
30	WP-E5	A	FAR	.04 OZ/T AU	
50	WP-E6	A	SPA	.3 OZ/T AU	Two flakes larger than 20 mesh.
30	WP-E7	A	FAR	.08 OZ/T AU	
30	SCM-1	A	FAR	.09 OZ/T AU	
30	SCM-2	A	FAR	.02 OZ/T AU	
30	SCM-3	A	FAR	.11 OZ/T AU	
30	SCM-4	A	FAR	.09 OZ/T AU	
30	SCM-5	A	FAR	.07 OZ/T AU	
30	SCM-6	A	FAR	.13 OZ/T AU	
50	SCM-7	A	SPA	.1 OZ/T AU	
30	SCT-1	A	FAR	.12 OZ/T AU	
30	SCT-2	A	FAR	.1 OZ/T AU	
30	SCT-3	A	FAR	.07 OZ/T AU	
30	SCT-4	A	FAR	.03OZ/T AU	
30	SCT-5	A	FAR	.04 OZ/T AU	
50	SCT-6	A	SPA	.18 OZ/T AU	
30	SCB-1	A	FAR	.02 OZ/T AU	
30	SCB-2	A	FAR	.08 OZ/T AU	
30	SCB-3	A	FAR	.11 OZ/T AU	
30	SCB-4	A	FAR	.08 OZ/T AU	
30	SCB-5	A	FAR	.73 OZ/T AU	
50	SCB-6	A	SPA	.2 OZ/T AU	
30	HC-1	A	FAR	.05 OZ/T AU	Sample from material left at rail head from previous sample program.
30	HC-2	A	FAR	.14 OZ/T AU	
30	HC-3	A	FAR	.11 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
30	HC-4	A	FAR	.03 OZ/T AU	
30	HC-5	A	SPA	.04 OZ/T AU	
30	WRS -1	A	FAR	.12 OZ/T AU	
30	WRS-2	A	FAR	.04 OZ/T AU	
30	WRS-3	A	FAR	.08 OZ/T AU	
30	WRS-4	A	FAR	.02 OZ/T AU	
50	WRS-5	A	SPA	.1 OZ/T AU	
30	WPET-1	A	FAR	.06 OZ/T AU	
30	WPET-2	A	FAR	.11 OZ/T AU	
30	WPET-3	A	FAR	.02 OZ/T AU	
50	WPET-4	A	SPA	.09 OZ/T AU	
30	WPEM-1	A	FAR	.02 OZ/T AU	
30	WPEM-2	A	FAR	.07 OZ/T AU	
30	WPEM-3	A	FAR	.14 OZ/T AU	
50	WPEM-4	A	SPA	.2 OZ/T AU	
30	WPEB-1	A	FAR	.09 OZ/T AU	
30	WPEB-2	A	FAR	.12 OZ/T AU	
30	WPEB-3	A	FAR	.04 OZ/T AU	
50	WPEB-4	A	SPA	.07 OZ/T AU	
30	WPF-1	A	FAR	.02 OZ/T AU	
30	WPF-2	A	FAR	.08 OZ/T AU	
30	WPF-3	A	FAR	.08 OZ/T AU	
30	WPF-4	A	FAR	.04 OZ/T AU	
50	WPF-5	A	SPA	.09 OZ/T AU	
12	WPET-5	L	FAR	TRACE	
12	WPET-6	L	FAR	.02 OZ/T AU	
12	WPET-7	L	FAR	TRACE	
12	WPEM-5	L	FAR	.03 OZ/T AU	
12	WPEM-6	L	FAR	.02 OZ/T AU	
12	WPEM-7	L	FAR	TRACE	
12	WPEB-5	L	FAR	TRACE	
12	WPEB-6	L	FAR	TRACE	
12	WPEB-7	L	FAR	.06 OZ/T AU	
12	SCM-8	L	FAR	.02 OZ/T AU	
12	SCM-9	L	FAR	.02 OZ/T AU	
12	SCM-10	L	FAR	TRACE	
12	SCB-7	L	FAR	.02 OZ/T AU	
12	SCB-8	L	FAR	.09 OZ/T AU	
12	SCB-9	L	FAR	TRACE	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
12	SCT-7	L	FAR	TRACE	
12	SCT-8	L	FAR	.03 OZ/T AU	
12	SCT-9	L	FAR	.02 OZ/T AU	
12	SCM-11	L	FAS	.06 OZ/T AU	
12	SCM-12	L	FAS	.03 OZ/T AU	
12	SCT-10	L	FAS	.05 OZ/T AU	
12	SCT-11	L	FAS	.04 OZ/T AU	
12	SCB-10	L	FAS	.04 OZ/T AU	
12	SCB-11	L	FAS	.08 OZ/T AU	
12	WPEB-8	L	FAS	TRACE	
12	WPEB-9	L	FAS	.04 OZ/T AU	
12	WPEB-10	L	FAS	.03 OZ/T AU	
12	WPEM-5	L	FAS	.05 OZ/T AU	
12	WPEM-6	L	FAS	TRACE	
12	WPEM-7	L	FAS	.07 OZ/T AU	
12	WPEB-11	BC	FAS	TRACE	
12	WPEB-12	BC	FAS	TRACE	
12	WPEM-8	BC	FAS	TRACE	
12	WPEM-9	BC	FAS	.03 OZ/T AU	
12	SCB-12	BC	FAS	.02 OZ/T AU	
12	SCB-13	BC	FAS	TRACE	
100	SCB-14	YG	GCP-ME	Visible gold	
100	SCB-15	YG	GCP-ME	Visible gold	
40	WPEM-10	YG	GCP	Visible gold	
100	WPEM-11	A	GCP-ME	Visible gold with heavy iron coat	
120	WPEM-11a	A	ADH-ME	Acid clean of WPEM-11 over twice as much visible gold	
100	WPEM-11b	A	ME	Detailed examination of visible gold	
100	WPNT-1	YG	GCP-ME	Visible gold	
100	WPNT-2	YG	GCP-ME	Visible gold	
100	WPNM-1	YG	GCP-ME	Visible gold	
100	WPNM-2	YG	GCP-ME	Visible gold	
100	WPEM-12	YG	GCP-ME	100% passes 50 mesh one flake AU	
100	WPEM-12a	YG	GCP-ME	Recrush to 100% pass 80 mesh - 7 1 flakes visible	
100	WPEM-12b	YG	GCP-ME f	Recrush to 100% pass 100 mesh - 15 lakes visible	
120	WPEM-12b1	YG	ADH-ME	Acid clean of 12b - 27 flakes visible	
16	WPEM-13	YG	SCR	.04 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
16	WPEM-14	YG	SCR	.06 OZ/T AU	
16	WPEM-15	YG	SCR	.06 OZ/T AU	
16	WPEM-16	YG	SCR	<.025 OZ/T AU	
16	WPEM-17	YG	SCR	.11 OZ/T AU	
16	HC-6	YG	SCR	.07 OZ/T AU	
16	HC-7	YG	SCR	.03 OZ/T AU	
16	HC-8	YG	SCR	.05 OZ/T AU	
16	HC-9	YG	SCR	<.025 OZ/T AU	
16	HC-10	YG	SCR	.05 OZ/T AU	
50	WPEM-18	YG	SPA	BLANK	
100	WPEM-19	YG	ADH-SPA	Visible gold	
16	WPEM-19a	YG	SCPT	Scorify of above - .08 oz/t AU	
200	WPEM-20	B	LC	TRACE	Bottle roll-cyanide
200	WPEM-21	B	LC	BLANK	
200	WPEM-22	B	LC	TRACE	
40	WPEM-23	YK	A	.18 OZ/T AU	Amalgamation of
40	WPEM-24	YK	A	.21 OZ/T AU	five assay ton samples.
40	WPEM-25	YK	A	.13 OZ/T AU	
40	WPEM-26	YK	A	.44 OZ/T AU	
40	WPEM-27	YK	A	.62 OZ/T AU	
25	WPEM-28	YK	N	TRACE	Neutron activation.
25	WPEM-29	YK	N	TRACE	
40	WPEM-30	YG	A	.3 OZ/T AU	Amalgamation of
40	WPEM-31	YG	A	.27 OZ/T AU	ten assay ton samples.
40	WPEM-32	YG	A	.7 OZ/T AU	
200	WPEM-33	YG	LT	<.025 OZ/T AU	Bottle roll
200	WPEM-34	YG	LT	<.025 OZ/T AU	thio-urea
200	WPEM-35	YG	LT	<.025 OZ/T AU	
230	WPEM-36	YG	ADH-LT	.06 OZ/T AU	Pre-treat and bottle roll
230	WPEM-37	YG	ADH-LT	.06 OZ/T AU	thio-urea leach.
230	WPEM-38	YG	ADH-LT	.04 OZ/T AU	
50	WPEM-39	YG	ADS-A	.03 OZ/T AU	Pre-treat and amalgamate
50	WPEM-40	YG	ADS-A	.07 OZ/T AU	
50	WPEM-41	YG	ADS-A	.05 OZ/T AU	
50	WPEM-42	YG	ADS-A	.1 OZ/T AU	
50	HC-11	YG	ADS-A	.06 OZ/T AU	Pre-treat and amalgamate
50	HC-12	YG	ADS-A	.14 OZ/T AU	
50	HC-13	YG	ADS-A	<.025 OZ/T AU	
50	HC-14	YG	ADS-A	.04 OZ/T AU	
50	SCT-12	YG	ADS-A	.04 OZ/T AU	Pre-treat-amalgamate

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
50	SCT-13	YG	ADS-A	.07 OZ/T AU	Acid pre-treat and
50	SCT-14	YG	ADS-A	.04 OZ/T AU	amalgamate.
50	SCT-15	YG	ADS-A	.04 OZ/T AU	
50	SCB-16	YG	ADS-A	.11 OZ/T AU	Acid pre-treat and
50	SCB-17	YG	ADS-A	.47 OZ/T AU	amalgamate.
50	SCB-18	YG	ADS-A	.09 OZ/T AU	
50	SCB-19	YG	ADS-A	.07 OZ/T AU	
50	SCB-20	YK	ADS-A	.09 OZ/T AU	Series of acid pre-treat
50	SCB-21	YK	ADS-A	.23 OZ/T AU	and amalgamate. Five
50	SCB-22	YK	ADS-A	.18 OZ/T AU	assay ton samples.
	SCB-23	YK	LOST TO LAB ACCIDENT		
50	SCB-24	YK	ADS-A	.14 OZ/T AU	
50	SCM-13	YK	ADS-A	.08 OZ/T AU	
50	SCM-14	YK	ADS-A	.08 OZ/T AU	
50	SCM-15	YK	ADS-A	.1 OZ/T AU	
50	SCM-16	YK	ADS-A	.07 OZ/T AU	
120	WPEM-43	TM	GCT-ME	Visible gold-some white metal flakes	
100	WPEM-44	A	ME	Crushed sample washed and examined- visible gold-white flakes - lumpy grey white metalic nicknamed "pudding". Individual particles pulled for SEM. Gold flakes hackly and semi crystaline as well as some more worn that had probably been transported in a placer environment. The white flakes and the "pudding" were both put through a hydrochloric acid treatment. White flakes dissolved as did the white grey metallic of the "pudding". The "pudding" left behind small isometric crystals of gold which were likely the "lumps in the pudding". Directed lab to pull more of the two questioned metalics for microprobe but no other examples found in this sample.	
100	WPEM-45	YG	ME	Attempt to duplicate above- same particles seen - visible gold with attached carbon - white flakes that were probed were metallic aluminum. Operator thought were contaminated sample but examination showed matrix of iron intimately associated with white flake. No "pudding" seen. Two flakes of copper with some gold edges.	
40	WPEM-46	A-X	ADH - FAPT	320 PPB AU	Assay ton acid leached
40	WPEM-47	A-X	ADH-FAPT	280 PPB AU	and difference made up
40	WPEM-48	A-X	ADH-FAPT	160 PPB AU	with barren fullers earth.
12	WPEM-49	A-X	FAR	30 PPB AU	No pre-treatment for 49-51
12	WPEM-50	A-X	FAR	22 PPB AU	
12	WPEM-51	A-X	FAR	43 PPB AU	
40	WPEM-52	YG	ADH-FAPT	.22 OZ/T AU	Series of pre-treat and
40	WPEM-54	YG	ADH-FAPT	.19 OZ/T AU	assay.
40	WPEM-55	YG	ADH-FAPT	.28 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	WPEB-13	YG	ADH-FAPT	.07 OZ/T AU	
40	WPEB-14	YG	ADH-FAPT	.17 OZ/T AU	
40	WPEB-15	YG	ADH-FAPT	.03 OZ/T AU	
40	WPET-5	YG	ADH-FAPT	.28 OZ/T AU	
40	WPET-6	YG	ADH-FAPT	<.025 OZ/T AU	
40	WPET-7	YG	ADH-FAPT	.14 OZ/T AU	
40	WPET-8	YG	ADH-FAPT	.07 OZ/T AU	
40	WPNT-3	YG	ADH-FAPT	.05 OZ/T AU	
40	WPNT-4	YG	ADH-FAPT	.18 OZ/T AU	
40	WPNT-5	YG	ADH-FAPT	.05 OZ/T AU	
40	WPNM-3	YG	ADH-FAPT	.03 OZ/T AU	
40	WPNM-4	YG	ADH-FAPT	.03 OZ/T AU	
40	WPNM-5	YG	ADH-FAPT	<.025 OZ/T AU	
40	WPNM-6	YG	ADH-FAPT	.04 OZ/T AU	
40	HC-15	YG	ADH-FAPT	.04 OZ/T AU	
40	HC-16	YG	ADH-FAPT	.03 OZ/T AU	
40	HC-17	YG	ADH-FAPT	.18 OZ/T AU	
40	HC-18	YG	ADH-FAPT	.04 OZ/T AU	
40	HC-19	YG	ADH-FAPT	.05 OZ/T AU	
40	HC-20	YG	ADH-FAPT	.13 OZ/T AU	
220	WPEM-56	YK	ADF-ADH-ME-FAPT	.11 OZ/T AU	Visible gold after digest
220	WPEM-57	YK	ADF-ADH-ME-FAPT	.14 OZ/T AU	Visible gold
180	WPEM-58	TM-L	ADF-ADH-FAPT	.1 OZ/T AU	
180	WPEM-59	TM-L	ADF-ADH-FAPT	.04 OZ/T AU	
40	SCT-16	YG	ADH-FAPT	.06 OZ/T AU	
40	SCT-17	YG	ADH-FAPT	.04 OZ/T AU	
40	SCT-18	YG	ADH-FAPT	.1 OZ/T AU	
40	SCT-19	YG	ADH-FAPT	.06 OZ/T AU	
40	SCT-20	YG	ADH-FAPT	.13 OZ/T AU	
40	SCM-17	YG	ADH-FAPT	.2 OZ/T AU	
40	SCM-18	YG	ADH-FAPT	.04 OZ/T AU	
40	SCM-19	YG	ADH-FAPT	.15 OZ/T AU	
40	SCM-20	YG	ADH-FAPT	.09 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	SCM-21	YG	ADH-FAPT	.03 OZ/T AU	
40	SCB-25	YG	ADH-FAPT	.07 OZ/T AU	
40	SCB-26	YG	ADH-FAPT	.04 OZ/T AU	
40	SCB-27	YG	ADH-FAPT	.025 OZ/T AU	
40	SCB-28	YG	ADH-FAPT	.41 OZ/T AU	
40	SCB-29	YG	ADH-FAPT	.06 OZ/T AU	
50	WPEM-60	YG	GCE-FAR	.18 OZ/T AU	
50	WPEM-61	YG	GCE-FAR	.14 OZ/T AU	
50	WPEM-62	YG	GCE-FAR	.33 OZ/T AU	
50	WPEM-63	YG	GCE-FAR	.05 OZ/T AU	
50	WPEM-64	YG	GCE-FAR	.16 OZ/T AU	
50	WPEM-65	YG	GCE-FAR	.14 OZ/T AU	
50	WPET-9	YG	GCE-FAR	.12 OZ/T AU	
50	WPET-10	YG	GCE-FAR	.06 OZ/T AU	
50	WPET-11	YG	GCE-FAR	.08 OZ/T AU	
50	WPET-12	YG	GCE-FAR	.1 OZ/T AU	
50	WPET-13	YG	GCE-FAR	.03 OZ/T AU	
50	WPEB-16	YG	GCE-FAR	.05 OZ/T AU	
50	WPEB-17	YG	GCE-FAR	.22 OZ/T AU	
50	WPEB-18	YG	GCE-FAR	.03 OZ/T AU	
50	WPEB-19	YG	GCE-FAR	.11 OZ/T AU	
50	WPEB-20	YG	GCE-FAR	.17 OZ/T AU	
50	WPEB-21	YG	GCE-FAR	.05 OZ/T Au	
60	WPEB-22	YG	GCT-FAR	.03 OZ/T AU	
60	WPEB-23	YG	GCT-FAR	<.025 OZ/T AU	
60	WPEB-24	YG	GCT-FAR	.03 OZ/T AU	
60	WPEB-25	YG	GCT-FAR	.05 OZ/T AU	
60	WPEB-26	YG	GCT-FAR	.04 OZ/T AU	
60	WPET-14	YG	GCT-FAR	.03 OZ/T AU	
60	WPET-15	YG	GCT-FAR	.03 OZ/T AU	
60	WPET-16	YG	GCT-FAR	.04 OZ/T AU	
60	WPET-17	YG	GCT-FAR	<.025 OZ/T AU	
60	WPET-18	YG	GCT-FAR	.03 OZ/T AU	
60	WPEM-66	YG	GCT-FAR	.06 OZ/T AU	
60	WPEM-67	YG	GCT-FAR	.03 OZ/T AU	
60	WPEM-68	YG	GCT-FAR	.04 OZ/T AU	
60	WPEM-69	YG	GCT-FAR	.04 OZ/T AU	
60	WPEM-70	YG	GCT-FAR	.03 OZ/T AU	
40	WPET-19	YG	GCE-SCR	.07 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
50	WPET-20	YG	GCE-SCR	.05 OZ/T AU	
50	WPET-21	YG	GCE-SCR	.05 OZ/T AU	
50	WPET-22	YG	GCE-SCR	.1 OZ/T AU	
50	WPET-23	YG	GCE-SCR	.04 OZ/T AU	
50	WPET-24	YG	GCE-SCR	.07 OZ/T AU	
200	WPET-25	YG	GCE-ME-SCR	.05 OZ/T AU	Visible gold
200	WPET-26	YG	GCE-ADH-ME-SCR	.06 OZ/T AU	Visible gold
200	WPET-27	YG	GCE-ADH-ME-SCR	.04 OZ/T AU	Visible gold
200	WPEM-71	YG	GCE-ADH-ME-SCR	.06 OZ/T AU	Visible gold on carbon
200	WPEM-72	YG	GCE-ADH-ME-SCR	.04 OZ/T AU	Visible gold some crystaline
180	WPEM-73	YG	GCE-ADH-SCR	.14 OZ/T AU	
200	WPEM-74	YG	GCE-ADH-ME-SCR	.04 OZ/T AU	Crystaline, hackly, placer exsamples of gold.
100	WPEM-75 ME	YG	OC-ADH-	Crush to minus 20 mesh-acid clean and examine for AU. One flake of hackly gold. Looks like copper is zoned in the flake.	
100	WPEM-76 ME	YG	OC-ADH	Crush to minus 30 mesh - acid clean 7 flakes AU. -four placer - two hackly one of those half copper - one semi-crystaline and much smaller than 30 mesh. One placer flake	
100	WPEM-77	YG	OC-ADH ME	Crush to minus 50 mesh - acid clean -two flakes all placer.	
100	WPEM-78	YG	OC-ADH ME	Crush to minus 80 mesh - acid clean -5 flakes - three placer and two hackly. Three flakes have a striated appearance which may be caused by grinder.	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
100	WPEM-79	YG ME	OC-ADH	Crush to minus 100 mesh - acid clean - 13 flakes - 8 are placer . Three seem to be torn from larger pieces show torn and crusher(?) smeared edges -two hackly. Some of the hackly appearance may be enhanced by acid digestion of copper or other metal.	
100	WPEM-80	YG	OC-ADH ME	Crush to minus 150 mesh- acid clean Nine flakes - much torn and/or smeared. all look placer but two with obvious copper inclusion.	
100	WPEM-81a	YG ME	OC-ADH	Crush to minus 20 mesh -three flakes removed. All hackly.	
100	WPEM-81b ME	YG	OC-ADH	Re-crush to minus thirty mesh - no flakes found.	
100	WPEM-81c ME	YG	OC-ADH	Re-crush to minus 50 mesh - three flakes two placer one hackly -all removed	
100	WPEM-81d	YG ME	OC-ADH	Re-crush to minus 80 mesh - two flakes both placer- removed.	
100	WPEM-81e ME	YG	OC-ADH	Re-crush to minus 100 mesh - four flakes removed -two others seen but attempt to recover lost. Seem to be covered with iron on one side. Flip during recovery attempt and can't find.	
100	SCT-21a ME	YG	OC-ADH-	Crush to minus 20 mesh - no flakes found .	
100	SCT-21b	YG ME	OC-ADH-	Crush to minus 30 mesh - one flake torn but looks placer-removed.	
100	SCT-21c	YG ME	OC-ADH-	Crush to minus 50 mesh - 3 flakes found and removed but one gold coloured flake lost . Not sure if it was gold. All flakes look placer one somewhat rough.	
100	SCT-21d ME	YG	OC-ADH-	Crush to minus 80 mesh - no flakes recovered but three extreamly fine gold coloured particles look more like pyrite. Unable to recover.	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
100	SCT-21e	YG ME	OC-ADH-	Re-crush to minus 100 mesh- 19 flakes seen-also some pyrite looking particles. 15 of 19 recovered-8 are placer-4 are semi-placer or partially hackly- 3 are hackly.	
120	SCT-22	YG	OC-ADH-ME-FAPT	.27 OZ/T AU	Crush= minus 100 mesh. Two flakes AU seen but acid wash was only one hour.
25	SCT-23	YG	OC-FAR	.13 OZ/T AU	Crush=minus 100 mesh
40	SCT-24	YG	OC-ADH-FAPT	.19 OZ/T AU	" "
25	SCT-25	YG	OC-FAR	.09 OZ/T AU	" "
40	SCT-26	YG	OC-ADH-FAPT	.18 OZ/T AU	" "
25	SCT-27	YG	OC-FAR	.1 OZ/T AU	" "
40	SCT-28	YG	OC-ADH-FAPT	.21 OZ/T AU	" "
25	SCT-29	YG	OC-FAR	.04 OZ/T AU	" "
40	SCT-30	YG	OC-ADS-FAPT	.18 OZ/T AU	" "
25	SCT-31	YG	OC-FAR	.11 OZ/T AU	" "
40	SCT-32	YG	OC-ADS-FAPT	.16 OZ/T AU	" "
25	SCT-33	YG	OC-FAR	.08 OZ/T AU	" "
40	SCT-34	YG	OC-ADS-FAPT	.22 OZ/T AU	" "
25	SCT-35	YG	OC-FAR	.09 OZ/T AU	" "
16	WPEM-82	YG	OC-SCR	Bead looks like corral-submitted for analysis =4.7% AG, 64.5% AU, 29.2% PT, 0.4% IR, 0.1%CU, 0.1% PB.	
40	WPEM-83	YG	OC-ADS FAPT	.17 OZ/T AU	
40	RCT-1	YG	OC-ADS FAPT	.08 OZ/T AU	
40	RCT-2	YG	OC-ADS FAPT	.14 OZ/T AU	
40	RCT-3	YG	OC-ADS FAPT	..14 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	RCT-4	YG	OC-ADS FAPT	.11 OZ/T AU	
40	RCT-5	YG	OC-ADS FAPT	.4 OZ/T AU	
40	RCT-6	YG	OC-ADS FAPT	.16 OZ/T AU	
40	RCT-7	YG	OC-ADS FAPT	.09 OZ/T AU	
40	RCT-8	YG	OC-ADS FAPT	.13 OZ/T AU	
40	RCT-9	YG	OC-ADS FAPT	.1 OZ/T AU	
40	RCT-10	YG	OC-ADS FAPT	.2 OZ/T AU	
40	RCT-11	YG	OC-ADS FAPT	.04 OZ/T AU	
40	RCT-12	YG	OC-ADS FAPT	.06 OZ/T AU	
40	RCT-13	YG	OC-ADS FAPT	.14 OZ/T AU	
40	RCT-14	YG	OC-ADS FAPT	.1 OZ/T AU	
40	RCT-15	YG	OC-ADS FAPT	.08 OZ/T AU	
40	RCM-1	YG	OC-ADS FAPT	.17 OZ/T AU	
40	RCM-2	YG	OC-ADS FAPT	.06 OZ/T AU	
40	RCM-3	YG	OC-ADS FAPT	.1 OZ/T AU	
40	RCM-4	YG	OC-ADS FAPT	.09 OZ/T AU	
40	RCM-5	YG	OC-ADS FAPT	.12 OZ/T AU	
40	RCM-6	YG	OC-ADS FAPT	<.025 OZ/T AU	
40	RCM-7	YG	OC-ADS FAPT	.11 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	RCM-8	YG	OC-ADS FAPT	.12 OZ/T AU	
40	RCM-9	YG	OC-ADS FAPT	.03 OZ/T AU	
40	RCM-10	YG	OC-ADS FAPT	.07 OZ/T AU	
40	RCM-11	YG	OC-ADS FAPT	.03 OZ/T AU	
40	RCM-12	YG	OC-ADS FAPT	.18 OZ/T AU	
40	RCM-13	YG	OC-ADS FAPT	.08 OZ/T AU	
40	RCM-14	YG	OC-ADS FAPT	.12 OZ/T AU	
40	RCM-15	YG	OC-ADS FAPT	.09 OZ/T AU	
40	RCB-1	YG	OC-ADS FAPT	.11 OZ/T AU	
40	RCB-2	YG	OC-ADS FAPT	.04 OZ/T AU	
40	RCB-3	YG	OC-ADS FAPT	.07 OZ/T AU	
40	RCB-4	YG	OC-ADS FAPT	.07 OZ/T AU	
40	RCB-5	YG	OC-ADS FAPT	.28 OZ/T AU	
40	RCB-6	YG	OC-ADS FAPT	.09 OZ/T AU	
40	RCB-7	YG	OC-ADS FAPT	.13 OZ/T AU	
40	RCB-8	YG	OC-ADS FAPT	.08 OZ/T AU	
40	RCB-9	YG	OC-ADS FAPT	.15 OZ/T AU	
40	RCB-10	YG	OC-ADS FAPT	.05 OZ/T AU	
40	RCB-11	YG	OC-ADS FAPT	.1 OZ/T AU	
40	RCB-12	YG	OC-ADS FAPT	.08 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	RCB-13	YG	OC-ADS FAPT	.11 OZ/T AU	
40	RCB-14	YG	OC-ADS FAPT	<.025 OZ/T AU	
40	RCB-15	YG	OC-ADS FAPT	.09 OZ/T AU	
200	RCB-16	YG	OC-GCE ME	Visible AU - some pyrite- AU mostly placer -some torn that could be hackly 9 placer with two of those smeared by crusher - 3 torn flakes that could be placer- two hackly that could be from one hackly flake - one other flake that was a gold colour but looked like gilded iron.	
200	RCM-17	YG	OC-GCE ME	Two visible flakes both hackly- one flake looks like crystal trying to grow at one end.	
200	RCT-18	YG	OC-GCE ME	Six flakes visible - two placer- two placer with torn edges - one piece that looks like one of the torn off pieces- one hackly.	
40	SL1B-1	YG	OC-ADS FAPT	.03 OZ/T AU	
40	SL1B-2	YG	OC-ADS FAPT	.03 OZ/T AU	
40	SL1B-3	YG	OC-ADS FAPT	.07 OZ/T AU	
40	SL1B-4	YG	OC-ADS FAPT	.05 OZ/T AU	
40	SL1B-5	YG	OC-ADS FAPT	.17 OZ/T AU	
40	SL1B-6	YG	OC-ADS FAPT	LOST-BROKEN CRUCIBLE	
40	SL1B-7	YG	OC-ADS FAPT	LOST-BROKEN CRUCIBLE	
40	SL1B-8	YG	OC-ADS FAPT	LOST-BROKEN CRUCIBLE	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	SL1B-9	YG	OC-ADS FAPT	.13 OZ/T AU	
40	SL1B-10	YG	OC-ADS FAPT	.1 OZ/T AU	
40	SL1B-11	YG	OC-ADS FAPT	.05 OZ/T AU	
40	SL1B-12	YG	OC-ADS FAPT	.06 OZ/T AU	
40	SL1B-13	YG	OC-ADS FAPT	<.025 OZ/T AU	
40	SL1B-14	YG	OC-ADS FAPT	.06 OZ/T AU	
40	SL1B-15	YG	OC-ADS FAPT	.13 OZ/T AU	
40	SL1B-16	YG	OC-ADS FAPT	.08 OZ/T AU	
40	SL1B-17	YG	OC-ADS FAPT	.05 OZ/T AU	
40	SL1B-18	YG	OC-ADS FAPT	.16 OZ/T AU	
40	SL1B-19	YG	OC-ADS FAPT	.11 OZ/T AU	
40	SL1M-1	YG	OC-ADS FAPT	.09 OZ/T AU	
40	SL1M-2	YG	OC-ADS FAPT	.14 OZ/T AU	
40	SL1M-3	YG	OC-ADS FAPT	.09 OZ/T AU	
40	SL1M-4	YG	OC-ADS FAPT	.03 OZ/T AU	
40	SL1M-5	YG	OC-ADS FAPT	.07 OZ/T AU	
40	SL1M-6	YG	OC-ADS FAPT	.22 OZ/T AU	
40	SL1M-7	YG	OC-ADS FAPT	.13 OZ/T AU	
40	SL1M-8	YG	OC-ADS FAPT	.08 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	SL1M-9	YG	OC-ADS FAPT	.12 OZ/T AU	
40	SL1M-10	YG	OC-ADS FAPT	.18 OZ/T AU	
40	SL1M-11	YG	OC-ADS FAPT	.06 OZ/T AU	
40	SL1M-12	YG	OC-ADS FAPT	.09 OZ/T AU	
40	SL1M-13	YG	OC-ADS FAPT	.12 OZ/T AU	
40	SL1M-14	YG	OC-ADS FAPT	.08 OZ/T AU	
40	SL1M-15	YG	OC-ADS FAPT	.11 OZ/T AU	
40	SL1T-1	YG	OC-ADS FAPT	<.025 OZ/T AU	
40	SL1T-2	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL1T-3	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL1T-4	YG	OC-ADS FAPT	.03 OZ/T AU	
40	SL1T-5	YG	OC-ADS FAPT	<.025 OZ/T AU	
40	SL1T-6	YG	OC-ADS FAPT	.08 OZ/T AU	
40	SL1T-7	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL1T-8	YG	OC-ADS FAPT	.11 OZ/T AU	
40	SL1T-9	YG	OC-ADS FAPT	<.025 OZ/T AU	
40	SL1T-10	YG	OC-ADS FAPT	.03 OZ/T AU	
40	SL1T-11	YG	OC-ADS FAPT	.07 OZ/T AU	
40	SL1T-12	YG	OC-ADS FAPT	.04 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	SL1T-13	YG	OC-ADS FAPT	.1 OZ/T AU	
40	SL1T-14	YG	OC-ADS FAPT	.05 OZ/T AU	
40	SL1T-15	YG	OC-ADS FAPT	.09 OZ/T AU	
100	SL1B-20	YG	OC-GCE ME	No visible AU	
100	SL1B-21	YG	OC-GCE ME	7 Visible flakes- 5 placer-two hackly	
180	SL1M-16	YG	OC-GCE ME	4 Visible flakes - two hackly - one placer -one white flake with hackly look - microprobe = crusher pollution	
100	SL1T-17	YG ME	OC-GCE	2 flakes- both placer one other flake but lost in attempt to recover	
100	SL1B-21a	YG FAPT	ADS-ME	TRACE	Acid clean of tailings from gravity cons - no visible gold -assay of insol.
100	SL1M-16a	YG	ADS-ME FAPT	TRACE	" "
100	SL1T-17a	YG	ADS-ME FAPT	TRACE	" "
40	SL1T-17c	YG	ADS-FAPT	.06 OZ/T AU	Assay of cons.
40	SL1M-16c	YG	ADS-FAPT	.14 OZ/T AU	" "
40	SL1B-22c	YG	ADS-FAPT	.09 OZ/T AU	
40	SL2B-1	YG	OC-ADS FAPT	.06 OZ/T AU	
40	SL2B-2	YG	OC-ADS FAPT	.1 OZ/T AU	
40	SL2B-3	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL2B-4	YG	OC-ADS FAPT	.09 OZ/T AU	
40	SL2B-5	YG	OC-ADS FAPT	.24 OZ/T AU	
40	SL2B-6	YG	OC-ADS FAPT	.06 OZ/T AU	
40	SL2B-7	YG	OC-ADS FAPT	.03 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	SL2B-8	YG	OC-ADS FAPT	.11 OZ/T AU	
40	SL2B-9	YG	OC-ADS FAPT	.03 OZ/T AU	
40	SL2B-10	YG	OC-ADS FAPT	.07 OZ/T AU	
40	SL2B-11	YG	OC-ADS FAPT	.15 OZ/T AU	
40	SL2B-12	YG	OC-ADS FAPT	.05 OZ/T AU	
40	SL2B-13	YG	OC-ADS FAPT	.08 OZ/T AU	
40	SL2B-14	YG	OC-ADS FAPT	.05 OZ/T AU	
40	SL2B-15	YG	OC-ADS FAPT	.O3 OZ/T AU	
40	SL2M-1	YG	OC-ADS FAPT	.1 OZ/T AU	
40	SL2M-2	YG	OC-ADS FAPT	<.025 OZ/T AU	
40	SL2M-3	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL2M-4	YG	OC-ADS FAPT	.07 OZ/T AU	
40	SL2M-5	YG	OC-ADS FAPT	.06 OZ/T AU	
40	SL2M-6	YG	OC-ADS FAPT	.03 0Z/T AU	
40	SL2M-7	YG	OC-ADS FAPT	.09 OZ/T AU	
40	SL2M-8	YG	OC-ADS FAPT	LOST- CUPEL FLAW	
40	SL2M-9	YG	OC-ADS FAPT	.38 OZ/T AU	
40	SL2M-10	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL2M-11	YG	OC-ADS FAPT	.08 OZ/T AU	
40	SL2M-12	YG	OC-ADS FAPT	.08 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
40	SL2M-13	YG	OC-ADS FAPT	<.025 OZ/T AU	
40	SL2M-14	YG	OC-ADS FAPT	.07 OZ/T AU	
40	SL2M-15	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL2M-16	YG	OC-ADS FAPT	.13 OZ/T AU	
40	SL2T-1	YG	OC-ADS FAPT	.17 OZ/T AU	
40	SL2T-2	YG	OC-ADS FAPT	.1 OZ/T AU	
40	SL2T-3	YG	OC-ADS FAPT	.11 OZ/T AU	
40	SL2T-4	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL2T-5	YG	OC-ADS FAPT	.06 OZ/T AU	
40	SL2T-6	YG	OC-ADS FAPT	.03 OZ/T AU	
40	SL2T-7	YG	OC-ADS FAPT	.13 OZ/T AU	
40	SL2T-8	YG	OC-ADS FAPT	.1 OZ/T AU	
40	SL2T-9	YG	OC-ADS FAPT	.<.025 OZ/T AU	
40	SL2T-10	YG	OC-ADS FAPT	.04 OZ/T AU	
40	SL2T-11	YG	OC-ADS FAPT	.03 OZ/T AU	
40	SL2T-12	YG	OC-ADS FAPT	.14 OZ/T AU	
40	SL2T-13	YG	OC-ADS FAPT	.09 OZ/T AU	
40	SL2T-14	YG	OC-ADS FAPT	.05 OZ/T AU	
40	SL2T-15	YG	OC-ADS FAPT	.<.025 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
200	SL2T-16	YG	OC-GCE ME-ADS FAPT	.05 OZ/T AU	Three flakes of hackly gold - one torn or smeared on corner- one has copper edge
200	SL2M-17	YG	OC-GCE ME-ADS FAPR	.13 OZ/T AU	11 flakes AU- 9 placer with 2 of those smeared 2 flakes hackly with one having striations or linear crystaline structure need better magnification-maybe SEM.
200	SL2B-16	YG	OC-GCE ME-ADS FAPR	.08 OZ/T AU	14 flakes AU - two flakes white metalic- 7 hackly AU- four of those smeared two torn pieces from placer(?) and 5 placer. White flakes dissolve in AND.
40	HC-21	YG-L	OC-ADS FAPT	.06 OZ/T AU	
40	HC-22	YG-L	OC-ADS FAPT	.03 OZ/T AU	
40	HC-23	YG-L	OC-ADS FAPT	.04 OZ/T AU	
40	HC-24	YG-L	OC-ADS FAPT	.09 OZ/T AU	
40	HC-25	YG-L	OC-ADS FAPT	.04 OZ/T AU	
100	WPC-1	YG	OC-ADH ADF-SCPT	.11 OZ/T AU	
100	WPC-2	YG	OC-ADH ADF-SCPT	.08 OZ/T AU	
100	WPC-3	YG	OC-ADH ADF-SCPT	.1 OZ/T AU	
100	WPC-4	YG	OC-ADH ADF-SCPT	.04 OZ/T AU	
100	WPC-5	YG	OC-ADH ADF-SCPT	.07 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
100	WPC-6	YG-M	OC-ADH ADF-SCPT	.03 OZ/T AU	
100	WPC-7	YG-M	OC-ADH ADF-SCPT	.03 OZ/T AU	
100	WPC-8	YG-M	OC-ADH ADF-SCPT	.09 OZ/T AU	
100	WPC-9	YG-M	OC-ADH ADF-SCPT	.04 OZ/T AU	
100	WPC-10	YG-M	OC-ADH ADF-SCPT	.06 OZ/T AU	
100	WPC-11	YG-M	OC-ADH ADF-SCPT	TRACE	
100	WPC-12	YG-M	OC-ADH ADF-SCPT	.1 OZ/T AU	
100	WPC-12	YG-M	OC-ADH ADF-SCPT	.04 OZ/T AU	
100	WPC-13	YG-M	OC-ADH ADF-SCPT	.05 OZ/T AU	
100	WPC-14	YG-M	OC-ADH ADF-SCPT	.04 OZ/T AU	
100	WPC-15	YG-M	OC-ADH ADF-SCPT	.04 OZ/T AU	
500	WPC-16a	YG	OC-GCE RT-ADS-FAPT	.09 OZ/T AU	30 Kg. sample raw = .5 Kg. con - split for assay
120	WPC-16b	YG	OC-GCE RT-ADS-FAPT	.07 OZ/T AU	
120	WPC-16c	YG	OC-GCE RT-ADS-FAPT	.07 OZ/T AU	
120	WPC-16e	YG	OC-GCE RT-ADS-FAPT	.1 OZ/T AU	
120	WPC-16f	YG	OC-GCE RT-ADS FAPT	.09 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
120	WPC-17	YG	OC-RT GCE-ADS FAPT	..09 OZ/T AU	
40	WPC-17a	YG	ADS-FAPT	TRACE	GCE-TAILS
120	WPC-18	YG	OC-RT GCE-ADS FAPT	.42 OZ/T AU	
40	WPC-18a	YG	ADS-FAPT	TRACE	GCE-TAILS
120	WPC-19	YG	OC-RT GCE-ADS FAPT	.21 OZ/T AU	
40	WPC-19a	YG	ADS-FAPT	TRACE	GCE-TAILS
120	WPC-20	YG	OC-RT GCE-ADS FAPT	.25 OZ/T AU	
40	WPC-20a	YG	ADS-FAPT	<.025	GCE-TAILS
120	WPC-21	YG	OC-RT GCE-ADS FAPT	.19 OZ/T AU	
40	WPC-21a	YG	ADS-FAPT	TRACE	GCE-TAILS
120	WPC-22	YG	OC-RT GCE-ADS FAPT	.32 OZ/T AU	
40	WPC-22a	YG	ADS-FAPT	<.025	GCE-TAILS
120	WPC-23	YG	OC-RT GCE-ADS FAPT	.23 OZ/T AU	
40	WPC-23a	YG	ADS-FAPT	TRACE	GCE-TAILS
120	RCM-18	YG-L	OC-RT GCE-ADS FAPT	.18 OZ/T AU	
40	RCM-18a	YG	ADS-FAPT	TRACE	GCE-TAILS
120	RCM-19	YG-L	OC-RT GCE-ADS FAPT	.22 OZ/T AU	
40	RCM-19a	YG	ADS-FAPT	TRACE	GCE-TAILS

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
120	RCM-20	YG-L	OC-RT GCE-ADS FAPT	.22 OZ/T AU	
40	RCM-20a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCM-21	YG-L	OC-RT GCE-ADS FAPT	.13 OZ/T AU	
40	RCM-21a	YG	ADS-FAPT	TRACE	TAILINGS
120	SL2M-18	YG-L	OC-RT GCE-ADS FAPT	.07 OZ/T AU	
40	SL2M-18a	YG	ADS-FAPT	TRACE	TAILINGS
120	SL2M-19	YG	OC-RT GCE-ADS FAPT	.09 OZ/T AU	
40	SL2M-19a	YG	ADS-FAPT	TRACE	TAILINGS
120	SL2M-20	YG	OC-RT GCE-ADS FAPT	.09 OZ/T AU	
40	SL2M-20a	YG	ADS-FAPT	TRACE	TAILINGS
120	SL2M-21	YG-L	OC-RT GCE-ADS FAPT	.06 OZ/T AU	
40	SL2M-21a	YG	ADS-FAPT	TRACE	TAILINGS
120	SL2M-22	YG-L	OC-RT GCE-ADS FAPT	.07 OZ/T AU	
40	SL2M-22a	YG	ADS-FAPT	TRACE	TAILINGS
120	HC-26	YG-L	OC-RT GCE-ADS FAPT	.07 OZ/T AU	
40	HC-26a	YG	ADS-FAPT	TRACE	TAILINGS
120	HC-27	YG	OC-RT GCE-ADS FAPT	.09 OZ/T AU	
40	HC-27a	YG	ADS-FAPT	TRACE	TAILINGS

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
120	HC-28	YG	OC-RT GCE-ADS FAPT	.09 OZ/T AU	
40	HC-28a	YG	ADS-FAPT	TRACE	TAILINGS
120	HC-29	YG	OC-RT GCE-ADS FAPT	.08 OZ/T AU	
40	HC-29a	YG	ADS-FAPT	TRACE	TAILINGS
120	HC-30	YG	OC-RT GCE-ADS FAPT	.1 OZ/T AU	
40	HC-30a	YG	ADS-FAPT	TRACE	TAILINGS
120	HC-31	YG	OC-RT GCE-ADS FAPT	.6 OZ/T AU	
40	HC-31a	YG	ADS-FAPT	TRACE	TAILINGS
120	HC-32	YG	OC-RT GCE-ADS FAPT	.1 OZ/T AU	
40	HC-32a	YG	ADS-RT	TRACE	TAILINGS
120	HC-33	YG	OC-RT GCE-ADS FAPT	.08 OZ/T AU	
40	HC-33a	YG	ADS-FAPT	<.025 OZ/T AU	TAILINGS
120	HC-34	YG	OC-RT GCE-ADS FAPT	.09 OZ/T AU	
40	HC-34a	YG	ADS-FAPT	TRACE	TAILINGS
120	HC-35	YG	OC-RT GCE-ADS FAPT	.14 OZ/T AU	
40	HC-35a	YG	ADS-FAPT	TRACE	TAILINGS
120	HC-36	YG	OC-RT GCE-ADS FAPT	.08 OZ/T AU	
40	HC-36a	YG	ADS-FAPT	TRACE	TAILINGS

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
120	HC-37	YG	OC-RT GCE-ADS FAPT	.08 OZ/T AU	
40	HC-37a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-19	YG	OC-RT GCE-ADS FAPT	.03 OZ/T AU	
40	RCT-19a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-20	YG	OC-RT GCE-ADS FAPT	.09 OZ/T AU	
40	RCT-20a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-21	YG	OC-RT GCE-ADS FAPT	.3 OZ/T AU	
40	RCT-21a	YG	ADS-FAPT	<.025 OZ/T AU	TAILINGS
120	RCT-22	YG	OC-RT GCE-ADS FAPT	.11 OZ/T AU	
40	RCT-22a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-23	YG	OC-RT GCE-ADS FAPT	.1 OZ/T AU	
40	RCT-23a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-24	YG	OC-RT GCE-ADS FAPT	.1 OZ/T AU	
40	RCT-24a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-25	YG	OC-RT GCE-ADS FAPT	.08 OZ/T AU	
40	RCT-25a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-26	YG	OC-RT GCE-ADS FAPT	.11 OZ/T AU	
40	RCT-26a	YG	ADS-FAPT	TRACE	TAILINGS

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
120	RCT-27	YG	OC-RT GCE-ADS FAPT	.1 OZ/T AU	
40	RCT-27a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-28	YG	OC-RT GCE-ADS FAPT	.09 OZ/T AU	
40	RCT-28a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-29	YG	OC-RT GCE-ADS FAPT	.14 OZ/T AU	
40	RCT-29a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-30	YG	OC-RT GCE-ADS FAPT	.11 OZ/T AU	
40	RCT-30a	YG	ADS-FAPT	,.025 OZ/T AU	TAILINGS
120	RCT-31	YG	OC-RT GCE-ADS FAPT	.11 OZ/T AU	
40	RCT-31a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-32	YG	OC-RT GCE-ADS FAPT	.13 OZ/T AU	
40	RCT-32a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-33	YG	OC-RT GCE-ADS FAPT	.22 OZ/T AU	
40	RCT-33a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-34	YG	OC-RT GCE-ADS FAPT	.11 OZ/T AU	
40	RCT-34a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-35	YG	OC-RT GCE-ADS FAPT	.09 OZ/T AU	
40	RCT-35a	YG	ADS-FAPT	TRACE	TAILINGS

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
120	RCT-36	YG	OC-RT GCE-ADS FAPT	.12 OZ/T AU	
40	RCT-36a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-37	YG	OC-RT GCE-ADS FAPT	.1 OZ/T AU	
40	RCT-37a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-38	YG	OC-RT GCE-ADS FAPT	.14 OZ/T AU	
40	RCT-38a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-39	YG	OC-RT GCE-ADS FAPT	.11 OZ/T AU	
40	RCT-39a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-40	YG	OC-RT GCE-ADS FAPT	.08 OZ/T AU	
40	RCT-40a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-41	YG	OC-RT GCE-ADS FAPT	.11 OZ/T AU	
40	RCT-41a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-42	YG	OC-RT GCE-ADS FAPT	.14 OZ/T AU	
40	RCT-42a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-43	YG	OC-RT GCE-ADS FAPT	.12 OZ/T AU	
40	RCT-43a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-44	YG	OC-RT GCE-ADS FAPT	.1 OZ/T AU	
40	RCT-44a	YG	ADS-FAPT	LOST - BROKEN CRUCIBLE	
40	RCT-44b	YG	ADS-FAPT	TRACE	TAILINGS

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
EVALUATION OF VIBRATING TABLE AS CONCENTRATOR					
120	RCT-45	YG	OC-RT GCT-ADS FAPT	.03 OZ/T AU	
40	RCT-45a	YG	ADS-FAPT	.025 OZ/T AU	TAILINGS
120	RCT-46	YG	OC-RT GCT-ADS FAPT	.05 OZ/T AU	
40	RCT-46a	YG	ADS-FAPT	.05 OZ/T AU	TAILINGS
120	RCT-47	YG	OC-RT GCT-ADS FAPT	.03 OZ/T AU	
40	RCT-47a	YG	ADS-FAPT	<.025 OZ/T AU	TAILINGS
120	RCT-48	YG	OC-RT GCT-ADS FAPT	.04 OZ/T AU	
40	RCT-48a	YG	ADS-FAPT	.03 OZ/T AU	TAILINGS
120	RCT-50	YG	OC-RT GCT-ADS FAPT	.04 OZ/T AU	
40	RCT-50a	YG	ADS-FAPT	<.025 OZ/T AU	TAILINGS
120	RCT-51	YG	OC-RT GCT-ADS FAPT	.28 OZ/T AU	
40	RCT-51a	YG	ADS-FAPT	.03 OZ/T AU	TAILINGS
120	RCT-52	YG	OC-RT GCT-ADS FAPT	.04 OZ/T AU	
40	RCT-52a	YG	ADS-FAPT	TRACE	TAILINGS
120	RCT-53	YG	OC-RT GCT-ADS FAPT	.12 OZ/T AU	
40	RCT-53a	YG	ADS-FAPT	.04 OZ/T AU	TAILINGS
120	RCT-54	YG	OC-RT GCT-ADS FAPT	.03 OZ/T AU	
40	RCT-54a	YG	ADS-FAPT	<.025 OZ/T AU	TAILINGS

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
50	NT1-1	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NT1-2	YG	OC-RT ADS-FAPT	<.025 OZ/T AU	
50	NT1-3	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NT1-4	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NT1-5	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NT1-6	YG	OC-RT ADS-FAPT	<.025 OZ/T AU	
50	NT1-7	YG	OC-RT ADS-FAPT	<.025 OZ/T AU	
50	NT1-8	YG	OC-RT ADS-FAPT	<.025 OZ/T AU	
25	NT1-9	YG	OC-SCR	.03 OZ/T AU	
25	NT1-10	YG	OC-SCR	.03 OZ/T AU	
25	NT1-11	YG	OC-SCR	<.025 OZ/T AU	
50	NT2-1	YG	OC-RT ADS-FAPT	<.025 OZ/T AU	
50	NT2-2	YG	OC-RT ADS-FAPT	.04 OZ/T AU	
50	NT2-3	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NT2-4	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NT2-5	YG	OC-RT ADS-FAPT	<.025 OZ/T AU	
50	NT2-6	YG	OC-RT ADS-FAPT	<.025 OZ/T AU	
50	NS1-1	YG	OC-RT ADS-FAPT	.04 OZ/T AU	
50	NS1-2	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NS1-3	YG	OC-RT ADS-FAPT	.07 OZ/T AU	
50	NS1-3	YG	OC-RT ADS-FAPT	.05 OZ/T AU	

SAMPLE ANALYSIS SHEET

COST	NUMBER	LAB	ANALYSIS	RESULT	COMMENTS
50	NS1-4	YG	OC-RT ADS-FAPT	.05 OZ/T AU	
50	NS2-1	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NS2-2	YG	OC-RT ADS-FAPT	.04 OZ/T AU	
50	NS2-3	YG	OC-RT ADS-FAPT	.05 OZ/T AU	
50	NS2-4	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NS2-5	YG	OC-RT ADS-FAPT	.04 OZ/T AU	
50	NS2-6	YG	OC-RT ADS-FAPT	.04 OZ/T AU	
50	NS3-1	YG	OC-RT ADS-FAPT	.04 OZ/T AU	
50	NS3-2	YG	OC-RT ADS-FAPT	.05 OZ/T AU	
50	NS3-3	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NS3-4	YG	OC-RT ADS-FAPT	.03 OZ/T AU	
50	NS3-5	YG	OC-RT ADS-FAPT	.04 OZ/T AU	
50	NS3-6	YG	OC-RT ADS-FAPT	<.025 OZ/T AU	
30	RC1	YG	SED	NO AU	
30	RC2	YG	SED	1 VIsible FLAKE	
30	RC3	YG	SED	NO AU	
30	RC4	YG	SED	4 FLAKES	
30	RC5	YG	SED	1 POSSIBLE FLAKE - COPPER?	
30	RC6	YG	SED	NO AU	
30	RC7	YG	SED	2 FLAKES	
30	RC8	YG	SED	NO AU	
30	RC9	YG	SED	NO AU	
30	WM1	YG	SED	NO AU	
30	WM2	YG	SED	NO AU	
30	WM3	YG	SED	1 FLAKE	
30	WM4	YG	SED	1 FLAKE	
30	WM5	YG	SED	NO AU	
30	WM6	YG	SED	1 FLAKE AU ONE WHITE FLAKE	
30	WM7	YG	SED	NO AU	

DIAMOND INDICATOR MINERAL SEARCH
COST TILL AND SEDIMENT HEAVY MINERAL INVESTIGATION

500	DI1	YG-M T	NIL
500	DI2	YG-M T	NIL
500	DI3	YG-M T	CR-G
500	DI4	YG-M T	G
500	DI5	YG-M T	G-CR
500	DI6	YG-M T	G-CR
500	DI7	YG-M T	NIL
500	DI8	YG-M T	NIL
500	DI9	YG-M T	NIL
500	DI10	YG-M T	G
500	DI11	YG-M T	NIL
500	DI12	YG-M T	G-CR
500	DI13	YG-M T	NIL
500	DI14	YG-M T	CR
500	DI15	YG-M T	G
500	DI16	YG-M T	NIL
500	DI17	YG-M T	NIL
500	DI18	YG-M T	NIL
500	DI19	YG-M T	G
500	DI20	YG-M T	NIL
500	DI21	YG-M T	NIL
500	DI22	YG-M T	NIL
500	DI23	YG-M T	NIL
500	DI24	YG-M T	NIL
500	DI25	YG-M T	NIL
500	DI26	YG-M T	CR
500	DI27	YG-M T	G
500	DI28	YG-M T	G-CR
500	DI29	YG-M T	NIL
500	DI30	YG-M T	NIL
500	DI31	YG-M T	NIL
500	DI32	YG-M T	G
500	DI33	YG-M T	NIL
500	DI34	YG-M T	NIL
500	DI35	YG-M T	NIL
500	DI36	YG-M T	NIL
500	DI37	YG-M T	NIL
500	DI38	YG-M T	NIL
500	DI39	YG-M T	NIL
500	DI40	YG-M T	G

DIAMOND INDICATOR MINERAL SEARCH

COST	TILL AND SEDIMENT HEAVY MINERAL INVESTIGATION		
	DI41	YG-M T	NIL
500	DI42	YG-M T	NIL
500	DI43	YG-M T	NIL
500	DI44	YG-M T	NIL
500	RC1DI	YG-M SED	RE-EXAMINE HEAVY MINERAL TESTS
500	RC2DI	YG-M SED	G
500	RC3DI	YG-M SED	G
500	RC4DI	YG-M SED	G
500	RC5DI	YG-M SED	G-SP
500	RC6DI	YG-M SED	G
500	RC7DI	YG-M SED	G-SP
500	RC8DI	YG-M SED	G
500	RC9DI	YG-M SED	G
500	WM1DI	YG-M SED	SP
500	WM2DI	YG-M SED	G-SP
500	WM3DI	YG-M SED	SP
500	WM4DI	YG-M SED	G
500	WM5DI	YG-M SED	G
500	WM6DI	YG-M SED	SP
500	WM7DI	YG-M SED	G-SP2

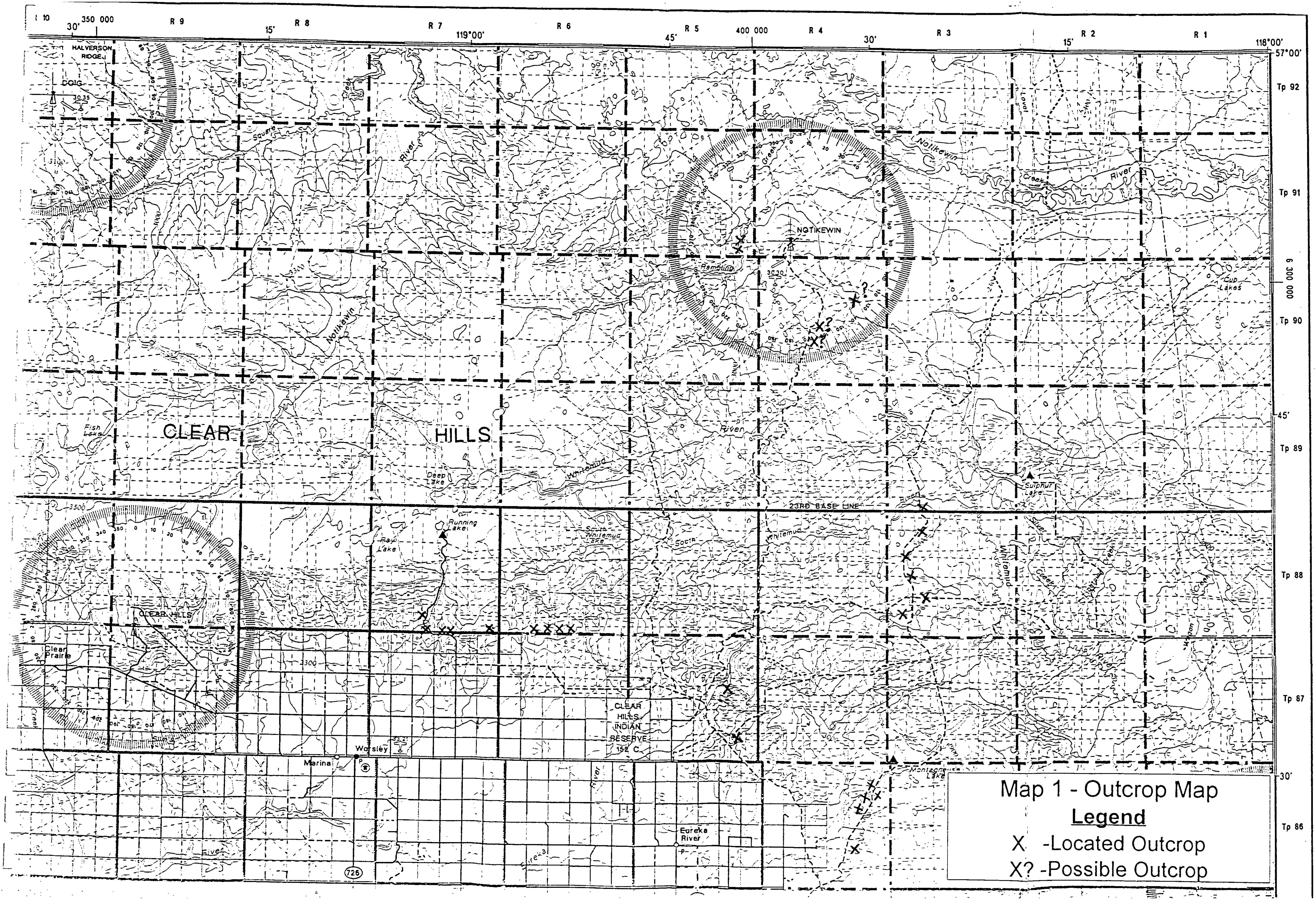
TOTAL $69,080

Marum Resources Inc.
REPORT ON THE IRONCAP
GOLD PROPERTY
PEACE RIVER AREA, ALBERTA
Metallic and Industrial Minerals Permits
No. 9390100001 to 93901000008

Clear Hills 1:250,000 (NTS 84D)

Map 1 - Outcrop Map

Legend
X -Located Outcrop
X? -Possible Outcrop



Map 1 - Outcrop Map

Legend

X -Located Outcrop

X? -Possible Outcrop

Marum Resources Inc.

REPORT ON THE IRONCAP GOLD PROPERTY

PEACE RIVER AREA, ALBERTA
Metallic and Industrial Minerals Permits
No. 9390100001 to 93901000008

Clear Hills 1:250,000 (NTS 84D)

Map 2

Bad Heart Formation Multiple Sample Locations and Diamond Indicator Mineral Sample Locations

Legend

DI# - Diamond Indicator Sample Location

✳# - Bad Heart Formation Multiple Sample Location

✳1 INCP, INCPS, WP-E, WPET, WPEM, WPEB, PF, WPNT, WPNM
✳2 INCPR
✳3 WRS, SCB,SCM, SCT,
✳4 RCT, RCM, RCB
✳5 HC
✳6 SL1B, SL1M, SL1T
✳7 SL2B, SL2M, SL2T
✳8 NT1, NT2
✳9 NS1, NS2, NS3

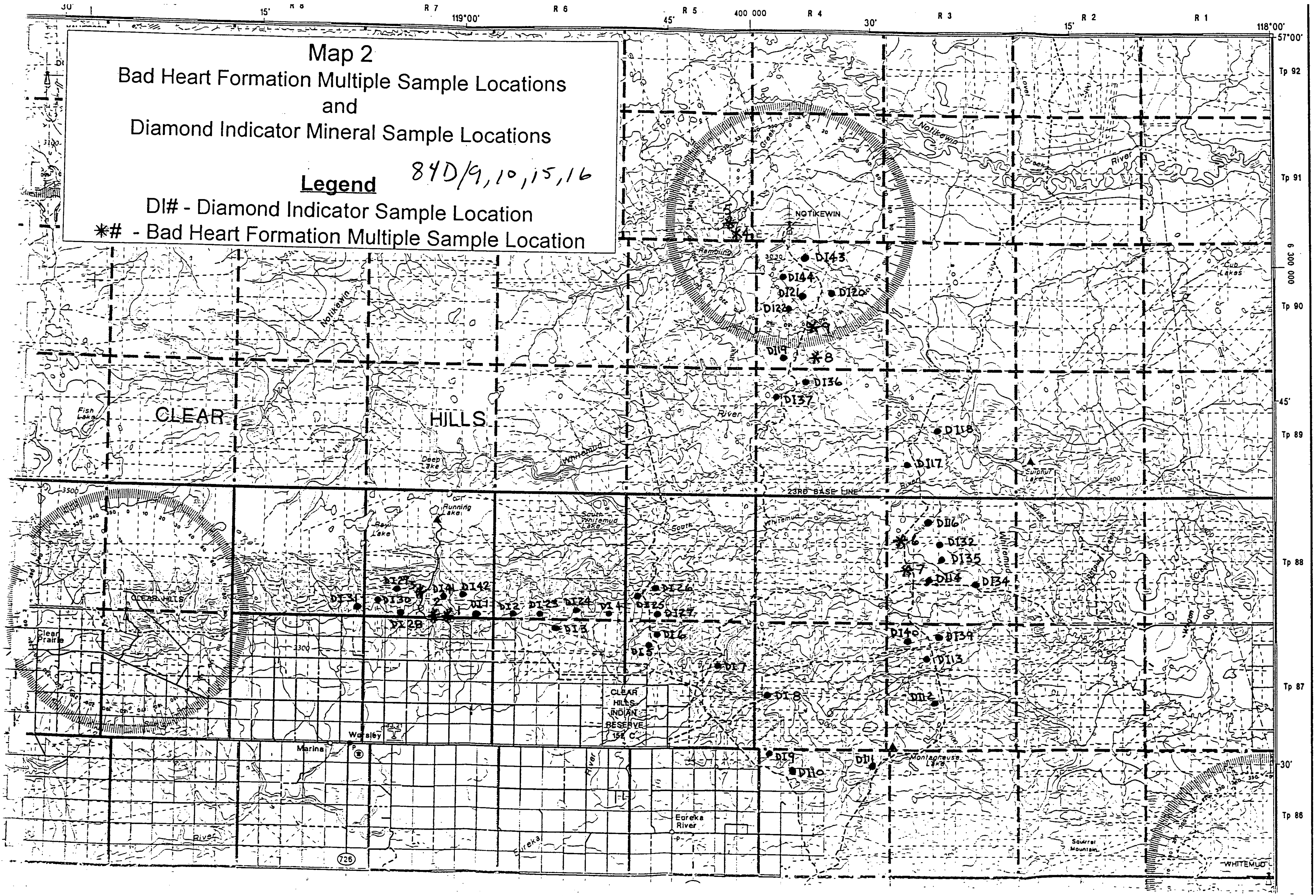
Map 2
Bad Heart Formation Multiple Sample Locations and Diamond Indicator Mineral Sample Locations

84D/9,10,15,16

Legend

DI# - Diamond Indicator Sample Location

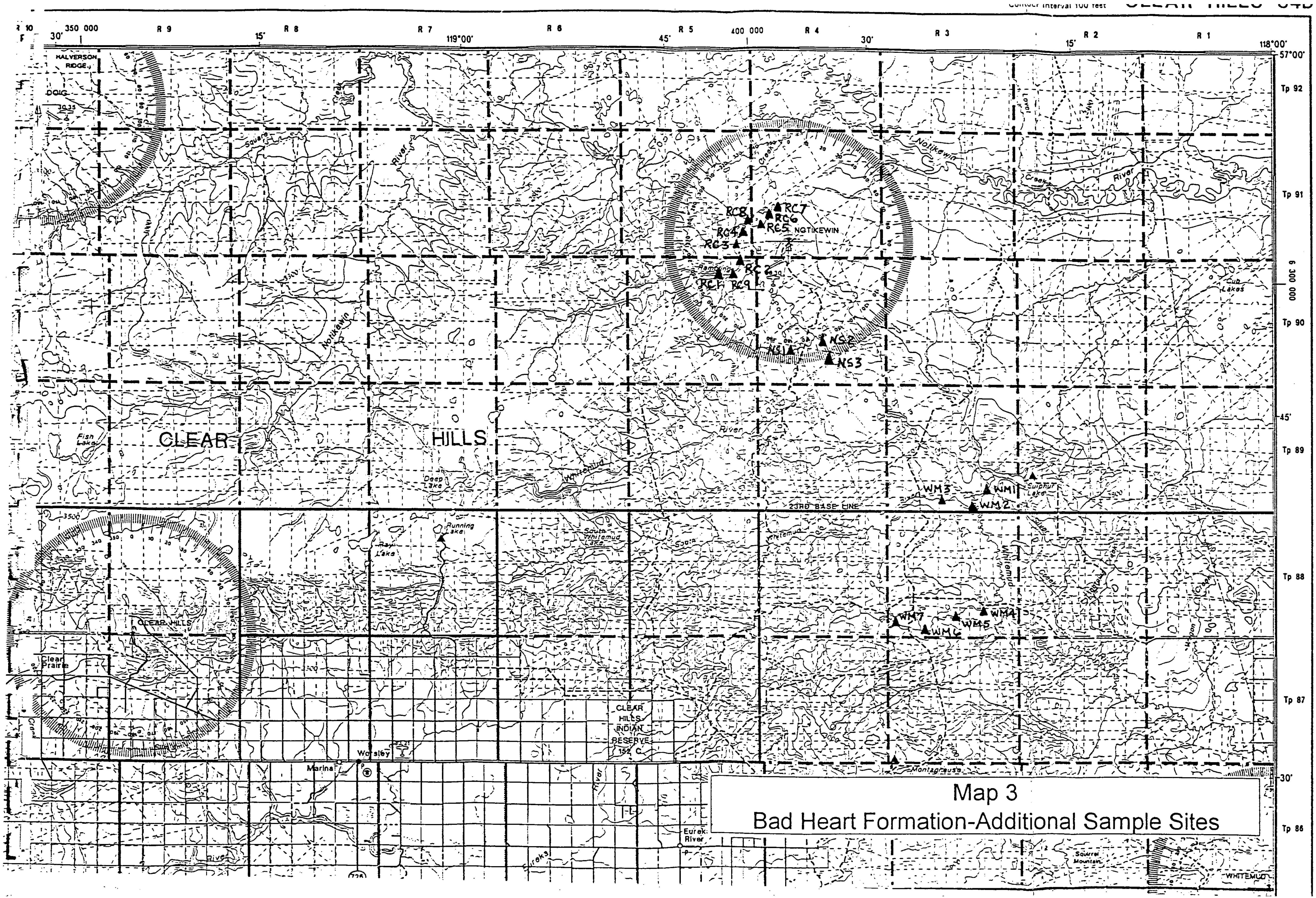
✳# - Bad Heart Formation Multiple Sample Location



Marum Resources Inc.
REPORT ON THE IRONCAP GOLD PROPERTY
PEACE RIVER AREA, ALBERTA
Metallic and Industrial Minerals Permits
No. 9390100001 to 93901000008

Clear Hills 1:250,000 (NTS 84D)

Map 3
Bad Heart Formation-Additional Sample Sites



Map 3

Bad Heart Formation-Additional Sample Sites

APPENDIX 3

PETROGRAPHIC ANALYSIS OF OUTCROP SAMPLE, UPPER CRETACEOUS BAD HEART FORMATION PEACE RIVER AREA

Prepared for Marum Resources Ltd.

by

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April, 1994

PETROGRAPHIC ANALYSIS OF OUTCROP SAMPLE, BAD HEART FORMATION

PETROGRAPHIC SUMMARY

Three thin-sections from a single outcrop sample were submitted for petrographic examination. Because of swelling clay problems, requiring preparation of thin-sections using oil-lubricated abrasive, the sections generally were over-thick except at the margins. This reduces the quality of the photomicrographs used in the report.

The sample is an oxidized chamosite ooid, glauconite peloid "ironstone" with a water-sensitive swelling-clay matrix (not analyzed - would require XRD). The nuclei of most of the chamosite ooids are smaller chamosite fragments, but about 10 per cent of the ooids are nucleated on detrital quartz grains (both monocrystalline and polycrystalline types). Detritol felspars, mainly of orthoclase type, also form a few ooid nuclei. Quartz grains lacking chamosite envelopes also are present.

Chamosite is a complex hydrated Fe-Mg aluminosilicate that has precipitated at the sea floor directly on free, wave-agitated nuclei. Later oxidation has altered much of the chamosite to iron oxides, probably including goethite and other varieties. During early diagenesis, chamosite ooids characteristically undergo mineralogical conversion and shrinkage. The latter is particularly apparent if the surrounding matrix has become cemented prior to shrinkage, so that it outlines a cast of the original grains. The newly-created pore space formed by shrinkage commonly is infilled by calcite cement (this sample), or by other digenetic minerals including authigenic clays.

Glauconite peloids, a common accessory of chamosite grainstones, form a small percentage of the present sample. They are recognized by their ovoid shape, desiccation fabrics, and microcrystalline clay texture. Glauconite peloids generally are a reliable indicator of a depositional environment with marine influence, either fully marine or estuarine-like. It should be noted, however, that berthierine peloids, very similar in texture to glauconite peloids, may be misidentified as glauconite, and are indicators of more brackish-water environments. Recrystallization and oxidation of peloids often obscures identification as originally glauconite or berthierine. The matrix of the chamosite ooids is a water-sensitive swelling clay impregnated with iron oxides, and containing a high percentage of oxidized siderite crystals in fusiform to microspheroidal or microrosette habit. Locally, where the matrix is absent or has been replaced, patches of zoned iron oxide cements are present. In thin-section, the cements appear bright red in transmitted light; they may be haematite or related crystalline iron oxides.

The chamosite ooid ironstone facies identified in thin-section from the Bad Heart Formation (note: spelling as two words, not Badheart, is based on usage in the CSPG Lexicon of Canadian Stratigraphy, Vol. 4, by D.J. Glass, 1990) is developed characteristically north of Hines Creek in the Clear Hills region of the Peace River area of west-central Alberta. Although references have not been examined, there apparently are several papers on the geochemistry and other aspects of the Bad Heart ironstones by G.B. Mellon in the 1960's; the GSC library may be able to locate these reports if required. In the set of illustrative photomicrographs, two examples of sideritic chamosite ooid ironstones from the Triassic of Alaska, overlying the main Prudhoe Bay reservoir section, have been included for comparison. These chamosite-rich rocks also contain glauconite peloids, and show similar diagenetic fabrics to the Bad Heart ironstones.

Environmentally, the chamosite ooid-glauconite peloid facies is interpreted to be the product of precipitation of Fe, Mg and K-bearing hydrous aluminosilicates at the seafloor or sediment-water interface in an overall marine setting (possible seasonally variable) under conditions of low sedimentation rates/low dilution by external siliciclastic sources. Modern analogues have been documented on the Holocene shelf in front of the Niger Delta of the north-eastern South Atlantic, with glauconite-dominant facies in deeper and colder outer shelf settings, and chamosite-rich facies in shallower and warmer shelf settings. In the Western Canada Sedimentary Basin setting for the Bad Heart ironstones, a similar intermediate shelf setting with condensed or low-sedimentation rate conditions is suggested, shelfward of a source of fine detrital clays and associated Fe oxides (deltaic source to the east).

Chamosite ooid ironstones in other basinal settings (Sverdrup Basin, Canadian Arctic; Jurasic-Cretaceous, offshore east coast of Canada) commonly overlie unconformities, recording transgressive systems with low sedimentation rates (condensed section) -- whether there is a similar relationship to an unconformity in the Bad Heart formation is undefined.

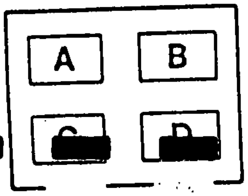
Examination of the sections reveals no recognizable evidence for a volcaniclastic influence or source. The detrital siliciclastic grains are dominated by quartz, with only a few feldspars. Swelling clay matrix may reflect an altered ash fall, but there is no specific geological reason to support this possibility.

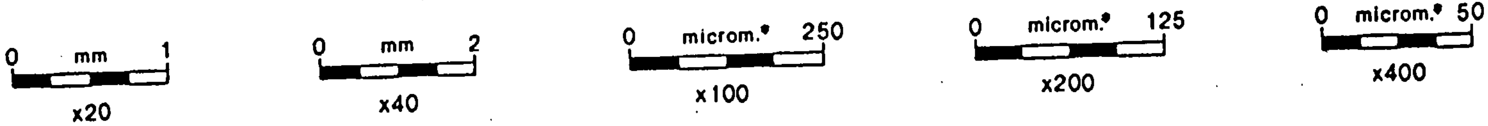
SELECTED PHOTOMICROGRAPHS

1A. Chamosite ooids (red arrows) enclosed in water-sensitive clay matrix (yellow in transmitted light) with abundant oxidized fine crystalline siderite (green arrows). Some of the ooids have been leached or have been washed out during the sample preparation process, and now are impregnated by blue epoxy. x 20.

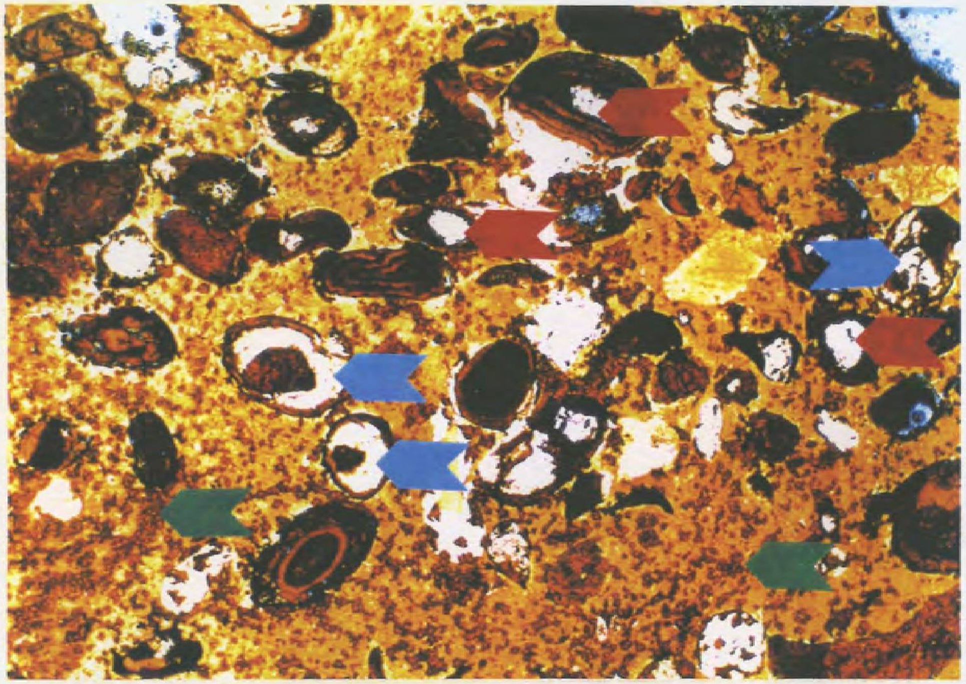
1B. Same as 1A at higher magnification showing dominance of chamosite ooids, some of which have detrital siliciclastic (mainly quartz) nuclei (red arrows). Many of the ooids show typical "shrinkage" fabrics of early diagenetic origin, with intragranular shrinkage fractures filled by calcite (blue arrows). Note that because the thin-section was difficult to make due to of swelling clays, it is overthick -- this causes overexposure of optically-clear quartz during photomicroscopy (losing internal textural detail of these components). Note the pervasive siderite crystals in the clay matrix (green arrows). x 40.

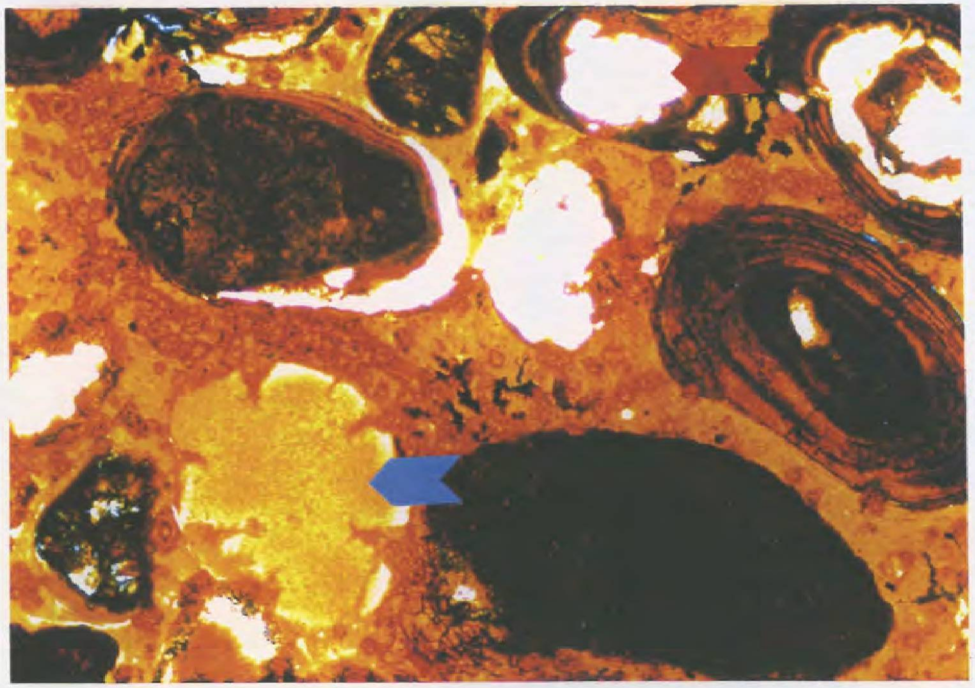
1C. +D. Two examples of oxidized chamosite ooids (now mainly goethite or related iron oxides), some with quartz nuclei (red arrows), with associated altered glauconite peloids (blue arrows). The glauconite and chamosite are common associates in this type of environmental setting. x 100.

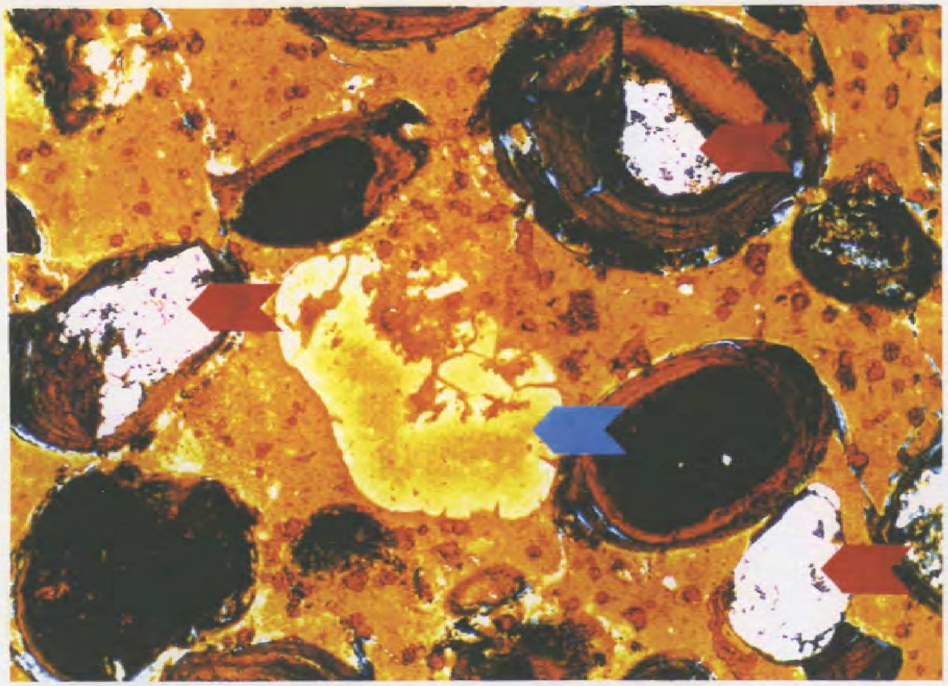




* microm. = micrometres (microns)





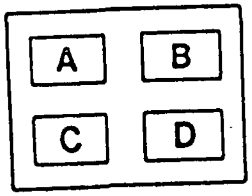


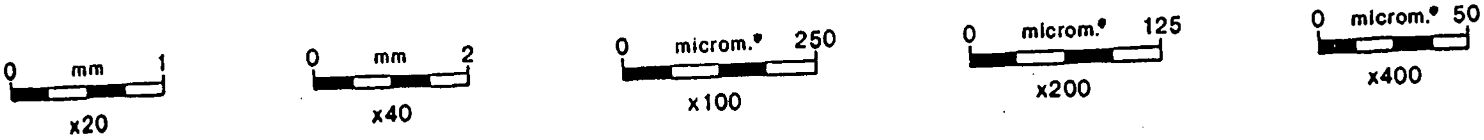
SELECTED PHOTOMICROGRAPHS

2A. +B. Two examples of monocrystalline and polycrystalline quartz grains (red arrows), some as nuclei of chamosite ooids, same as uncoated detrital grains. Although a few feldspars, probably orthoclase in composition, were noted, most of the siliciclastic grains in this sample are quartz. Note the red stained siderite crystals in the enclosing clay matrix, which appears yellow in transmitted light due to iron oxide impregnation. x 100.

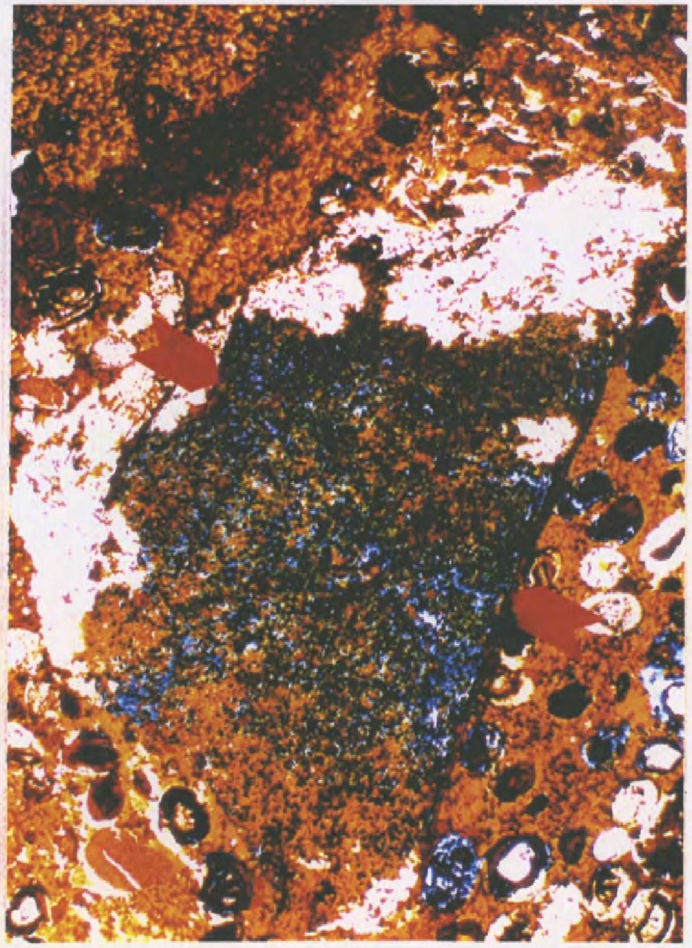
2C. Larger microporous (blue epoxy impregnation) iron oxide clast (red arrows) in chamosite ooid host. x 20.

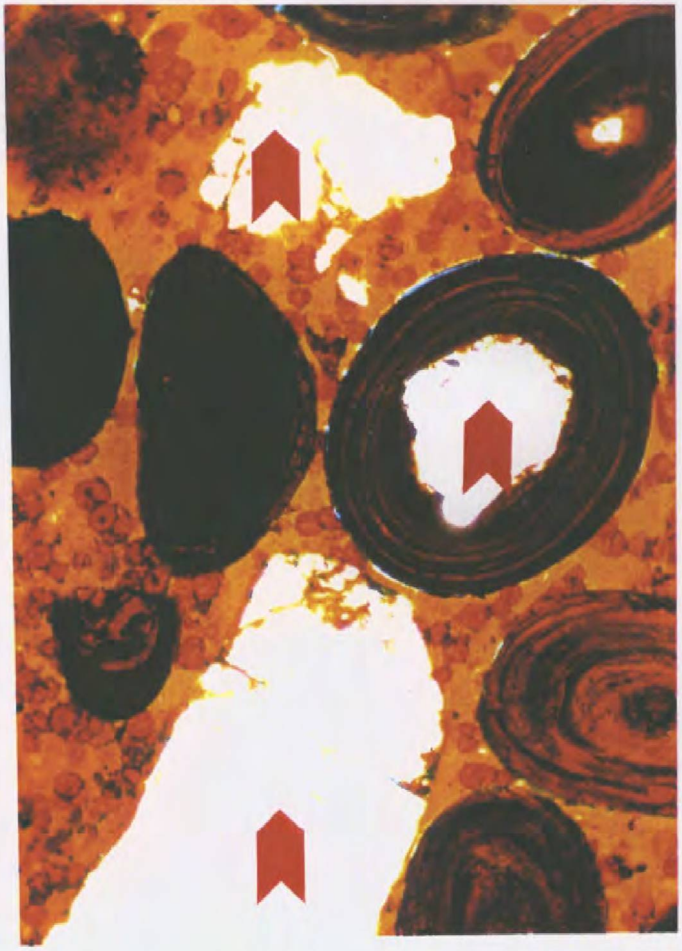
2D. Siderite crystals, probably of early diagenetic origin, enclosed in clay matrix. Crystals show microrosette or microspheroidal fabric typical of many early diagenetic siderite fabrics. x 200.

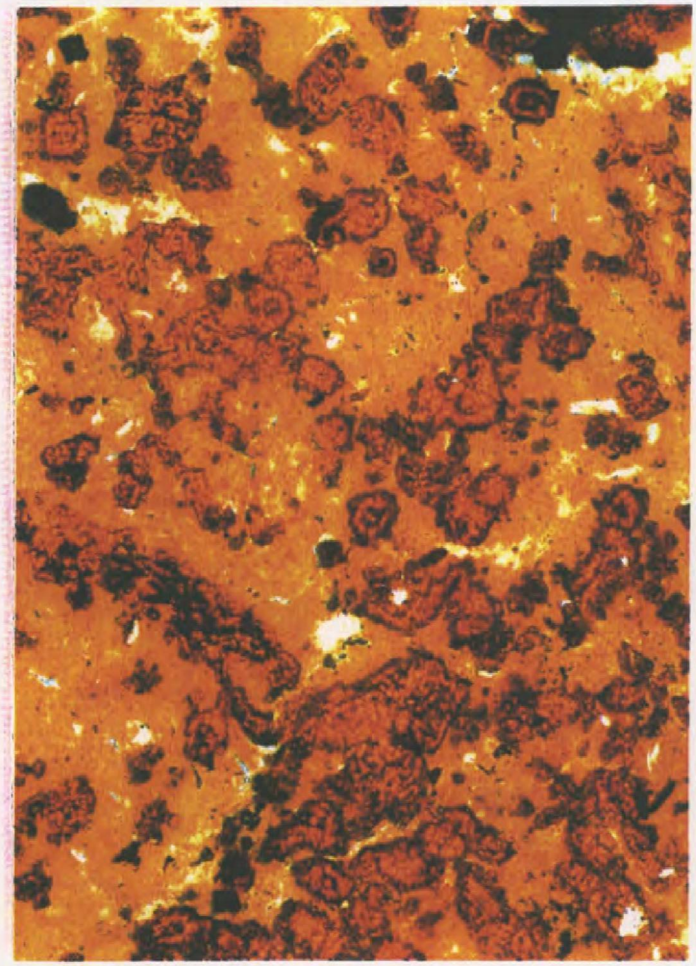




* microm.=micrometres (microns)



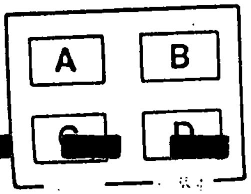


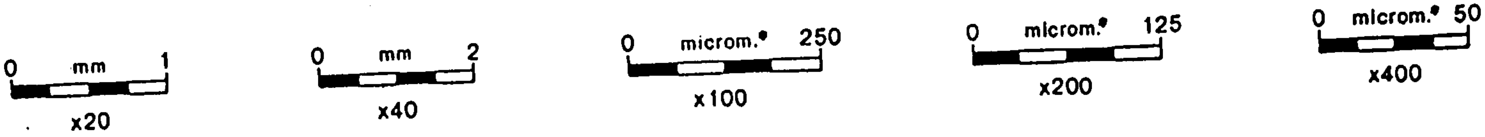


SELECTED PHOTOMICROGRAPHS

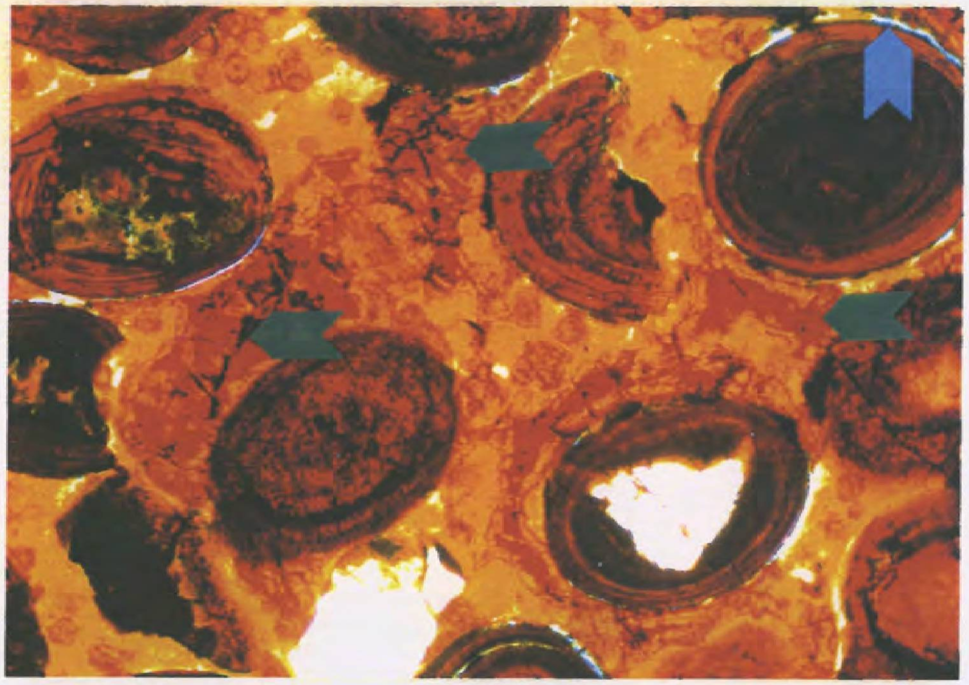
3A. +B. Two examples of chamosite ooid fabrics showing localized intergranular cement or replacement (green arrows), with some indication of crystal growth zoning within the cement. Strong red colour of the crystals under transmitted light indicates dominance of an iron oxide composition -- the mineral may be haematite or a derivative. Note the incipient circumgranular shrinkage cracks or micro fractures around several of the chamosite ooids (blue arrows). x 100.

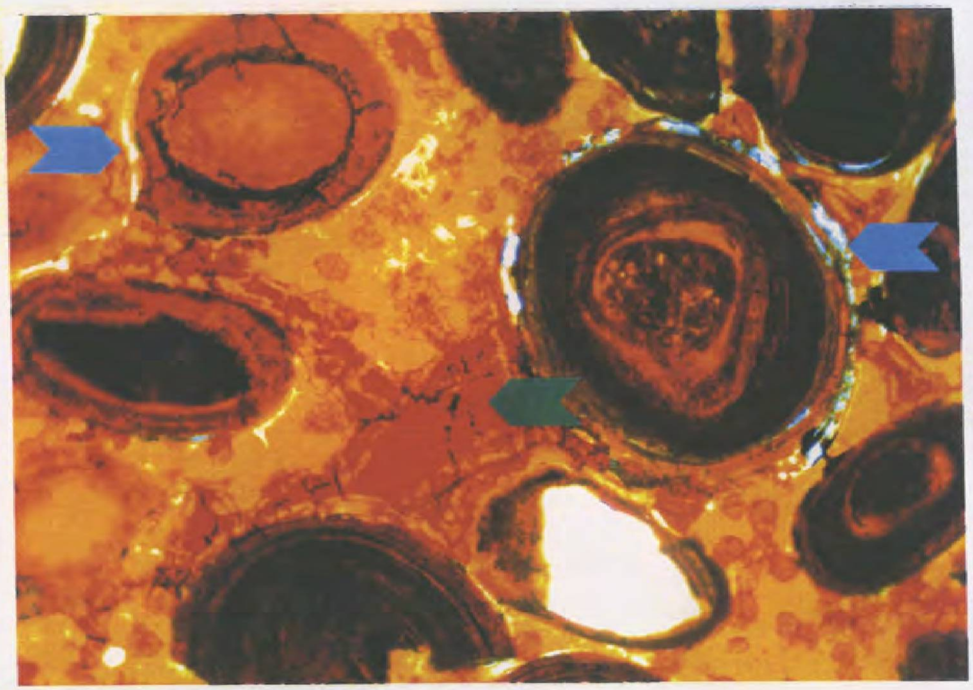
3C. +D. Two examples of highly altered and oxidized chamosite-glauconite peloid samples from the Triassic of Alaska, overlying in the main Prudhoe Bay oilfield section, showing similarity in some features to the submitted sample. Similarities include sideritic matrix (green arrows), but also with blue-stained ferroan calcite cement, and shrinkage fabrics with infill of shrinkage pore space by calcite and authigenic clays (red arrows). x 40.

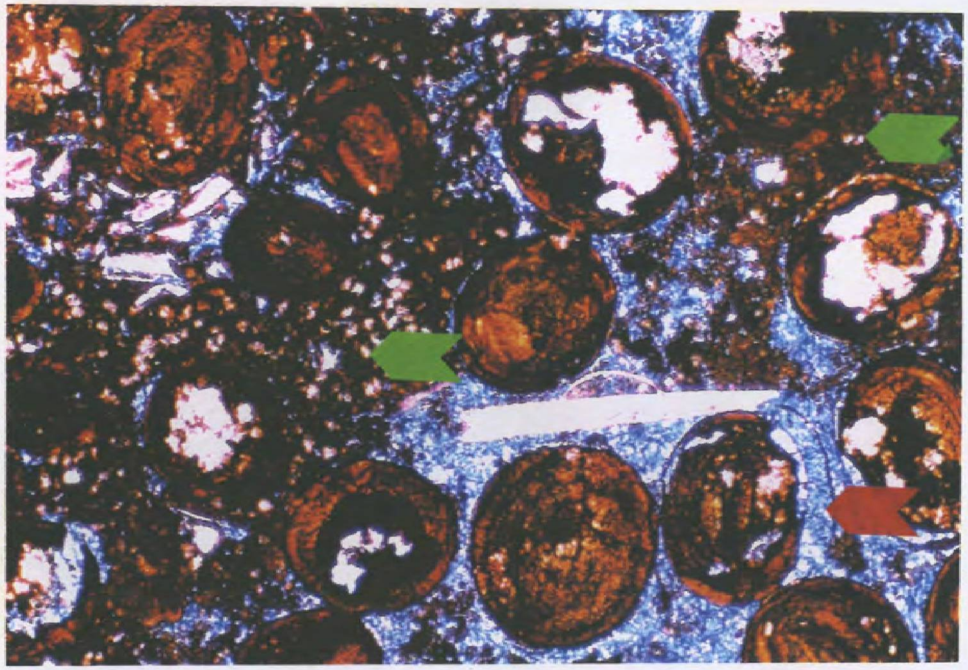


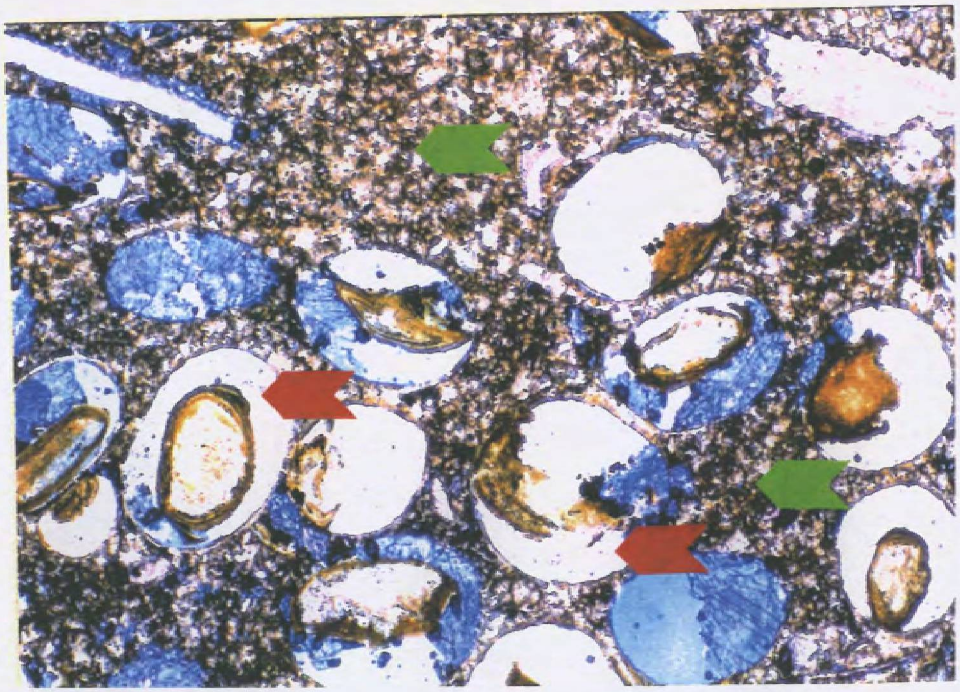


* microm.=micrometres=microns









PERMIT TO PRACTICE
GRAHAM DAVIES GEOLOGICAL CONSULTANTS LTD.
Signature
Date April 26, 1994
PERMIT NUMBER: P 4229
The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

G.R. DAVIES

APPENDIX 4

Scott-Smith Petrology

PETROGRAPHY OF SAMPLE RB#1 FROM NW ALBERTA

Report No. SSP-94-5/2

Confidential

Prepared for

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Canada

Prepared by

Scott-Smith Petrology
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North Vancouver
B.C. V7R 2M9
Canada

3rd June 1994

PETROGRAPHY OF SAMPLE RB#1 FROM NW ALBERTA

Abstract

The sample comprises one large hand specimen and five very small chips. The large rock and two of the chips are different sedimentary rocks in which there is no evidence for a volcanic origin. One constituent, which is present but not common, in the large specimen may represent glassy ash, among other possibilities. The three other very small chips are composed of hypabyssal sanidine-clinopyroxene-phlogopite minette but do not appear to relate to the other parts of this sample. No features were observed to suggest that any of these rocks are lamproites (or kimberlites).

1.0 INTRODUCTION

This sample was given by a prospector to Brad Wood of Monopros in Grande Prairie who then submitted to Scott-Smith Petrology for a petrographic investigation. The sample was apparently collected from near Peace River in NW Alberta. It is reported that the sample is of volcanic origin and that it contains lamproite fragments. No other information was supplied.

2.0 PETROGRAPHY

Macroscopic examination

The sample comprises one fairly large hand specimen and five very small (<0.5mm) chips which were submitted separately in a small vial.

The large sample (A) was examined prior to sample preparation. It has an overall orangy brown colour. The rock appears altered. The sample is mainly fine grained with most constituents less than 0.25mm in size. The rock appears to be finely laminated. The sample does contain the occasional coarser pebble like clast which range in size up to 1.5cm. These clasts are not common and their nature is difficult to discern. They appear to comprise similar fine grained altered material to the host but individual constituents are difficult to discern. The host rock appears to contain abundant clay minerals which may form the matrix to the coarser constituents. Quartz appears to be an important constituent of the rock. Other white and black grains must represent other minerals. No olivine or its pseudomorphs or any other mantle-derived minerals were observed. Some areas of the sample appeared to contain abundant ovoid oolith-like structures about 0.5mm in size. No mica or possible lamproitic fragments were observed. There is no evidence to suggest that this sample is of volcanic origin. It seems more likely that it is of sedimentary origin.

This large rock sample (A) was submitted to Vancouver Petrographics for the preparation of a series of polished slabs through the sample which were to be cut perpendicular to the lamination

Two thin sections were also prepared. It was considered that further thin sections should be made of carefully selected areas of any volcanic constituents that were observed on the polished slab.

A total of four polished slabs about 1cm thick were prepared. Both cut surfaces of these slabs were polished. The polish of these slabs could be improved but in the interests of time the samples were not re-submitted. It was considered that this did not mask the presence of any constituents. The main constituent of the rock appears to be well sorted fine (<0.2mm) grains of quartz which appear to have a fairly uniform distribution through most of the rock. The quartz grains may be clast supported but they are not closely packed. The matrix to the quartz appears to be composed predominantly of orangy brown coloured clayey material which disintegrates when wetted making the macroscopic examination difficult. Fine stringers of rusty brown probable iron oxides occur in the rock. These parallel and may define the lamination observed in the rock prior to sample preparation. This lamination is not so evident on the polished slabs. Some of the areas where the stringers occur appear to be finer grained and composed of more abundant clay minerals and less quartz. The rock resembles an iron oxide-rich sediment. The occasional rounded to well rounded pebble-like clast occurs in this rock (<1 or 2 per polished slab). They are generally more grey and less orangy brown in colour than the host rock. Some of them appear to be composed of quartz and resemble sandstone. Other finer examples may be finer grained sediments. Another example appears to contain common ooliths. There is no evidence for any other clast being present. No constituents of this rock suggest a volcanic derivation for this rock. Also no inclusions resembling the small mica-bearing chips submitted in the vial were observed.

Accompanying the main rock sample was a small vial containing five very small (<6mm) rock chips. One of the chips (chip C) has an orangy brown colour and resembles the main sample and it contained some of the oolith-like structures. Another chip (chip D) appear to be composed of fine grains or poorly sorted quartz grains which are cemented by dirty looking black-brown material. Neither of these chips appears to be of volcanic origin. Three of the small chips (chips E, F and G) have an overall grey colour. They are likely to be small pieces of an igneous rock. They contain abundant grains of very dark brown mica. The matrix to the mica is mainly light coloured but it appears to include some pale green grains which could represent a mafic mineral such as clinopyroxene. The remainder of the matrix is very light in colour but its nature cannot be discerned. These fragments resemble a lamprophyre but no classification can be made based on such small pieces of rock. Some phlogopite lamproites might be termed lamprophyre but there is no reason to suggest that these chips are lamproite rather than much more common mica-bearing lamprophyres, such as minettes. The very leucocratic matrix to the mica may suggest that they are not lamproite.

All the small chips were submitted to Vancouver Petrographics for sample preparation. It was requested that a thin section of the small chips be attempted although it was realised that this may not be successful.

Microscopic examination

Two thin sections of the large rock sample were prepared. They are numbered A and B. Thin section A is described first. This rock is composed mainly of colourless grains set in an orangy brown matrix (Plate 1). Most of these grains are <0.2mm in size although a few coarser grains are present. These grains, therefore, appear to be relatively well sorted. Most of the grains are very angular but some rounded grains are present. Most of the grains appear to be clear monocrystalline quartz (Plates 3 and 4). Most of these grains display non-uniform or undulose extinction suggesting that the quartz has been deformed. Less abundant fine polycrystalline grains of probable quartz are also present (Plate 4). Common, but less abundant than the quartz described so far, are grains which have slightly turbid appearance (Plate 3). These grains are finely poly- to crypto-crystalline and are probably composed of quartz (Plate 4). Other non-colourless grains similar in size and shape to those already described occur throughout the rock but are not abundant. Some of these are turbid and pale grey to yellowy in colour (Plate 3). They are often isotropic and they could represent fine grains of glassy ash. This is, however, difficult to confirm in grains which are so small. On the other hand these grains could be some other material such as collophane. Other grains are composed of cryptocrystalline material which could represent altered glass or secondary material after another primary constituent. Rare grains of feldspar with polysynthetic twinning are present. Rare grains of mica are also present. These constituents are clast supported but not closely packed.

Frequent but not common ooliths occur in this rock (Plate 2). They are mostly <0.5mm. They typically have a thin rim which is now composed of rusty brown iron oxides. These rims enclose a variety of material most of which have been replaced by secondary iron oxides. Some of the cores to these ooliths appear to be grain aggregates. Rarely the ooliths enclose a grain of quartz similar to that found in the host rock.

The matrix to the constituents described so far is composed mainly of browny and rust red brown material (Plate 3). The former is cryptocrystalline and appears to be composed of clay minerals (Plate 4). Although the quartz and associated grains have a fairly uniform distribution throughout the rock, there are patches which appear to be devoid of these grains and composed mainly of the probable clay minerals. Some of these patches may represent concentrations of the matrix material while others could be ill defined lithic fragments. One patch contains an inhomogeneous distribution of quartz grains as found in the host rock as well as more common ooliths and one of the pebble-like clasts. This sub-rounded pebble is composed of a slightly darker brown coloured clay mineral and a non-uniform distribution of quartz and other grains which are different from the host rock.

The other main matrix constituent of the main rock is bright orangy brown coloured clear material which is presumably composed of iron oxides (Plate 3). This material appears to totally replace a few grains which form some of the quartz-like grains as well as forming part of the inter-grain matrix together with the clay-like material just described. Fine granules(<0.1mm) of this material can occur in the clay-rich patches. This material also partly to totally replaces some of the ooliths. In addition this material occurs as vein-like stringers which occur in discontinuous zones throughout the rock (Plates 1 and 2). These stringers have a sub-parallel orientation in the samples. There is no apparent systematic change in grain size in this rock so there is no suggestion of bedding. The lamination observed macroscopically appears to derive only from the vein-like stringers of secondary iron oxide material.

Only one other well defined pebble-like clast occur in this thin section. It is 3.5mm in length, well rounded with an ovoid shape (Plate 5). It is composed of very fine grained quartz set in abundant clayey matrix. There may be a concentration of quartz in one layer which suggests that this material may be bedded. This clast is transected by a series of the iron oxide stringers.

Thin section B of the same rock is obviously very similar to that just described. No other noteworthy features were observed.

The third thin section comprises the five small chips which were submitted in the small vial along with the main rock sample. The thin sectioning of this material was successful. The orange brown chip (C) is composed of common iron oxides as found in the large rock sample. It contains some concentrically zoned ooliths which are composed mainly of iron oxides (Plate 6). No quartz is present which clearly distinguishes this chip from the large rock sample (A). Apart from the ooliths, the other constituents are poorly sorted and often finer grained than found in the main rock sample. These grains are totally replaced by iron oxides but have elongate, cuspate and other shapes (Plate 6). The nature of these grains is not understood but they are very different from the main rock sample. Some of the cuspate fragments could represent fragmented ooliths. They could equally be organic in origin. The matrix to these constituents described so far is relatively clean or clear carbonate (Plate 6). The latter also distinguishes this chip from the rock sample. No clay minerals occur in the matrix.

As observed macroscopically, chip D is different from rock sample A and chip C. It is composed of very poorly sorted grains of quartz ranging in size up to 0.5mm in size (Plate 7). The sorting is quite different from the main rock sample A. The occasional grain of polysynthetically twinned feldspar is present. The larger grains are mainly sub-rounded to rounded. Many of the smaller grains are angular in shape. The quartz mainly shows non-uniform extinction. Some polycrystalline grains are present. A few very altered grains of probable mica are present. Some of the constituents which are similar in size to the quartz grains appear to be composed of cryptocrystalline material. Other brown altered indiscernible constituents are present and they are mainly fine grained. All these constituents are set in a dirty looking darkish brown matrix which probably contains clay minerals (Plate 7). This matrix is different from that observed in rock sample A.

As observed macroscopically, chips E, F and G are very similar to each other. These chips are composed of a fairly fresh porphyritic igneous rock composed of three main constituents: mica, clinopyroxene and feldspar (Plates 8 and 9). Mica and clinopyroxene occur as phenocrysts as well as somewhat smaller probable groundmass grain and they occur in approximately equal amounts (perhaps 40 and 30 modal % respectively). The mica ranges in size up to 1mm. The larger grains occur as stubby laths, have sieve textures in their cores, can contain common inclusions of very fine grained opaque cubic grains of probable spinel and can be altered to a greeny brown material (Plate 8). The grains of 0.5mm and less occur as more slender lath-like grains which have a pale brown colour (Plates 8, 9 and 11). The rims are pleochroic to a darker brown mica. None of the mica is twinned. The large clinopyroxene grains appear to be equant and range in size up to 1mm in size (Plate 9). They are often intergrown with or replaced by mica which is similar to that occurring as phenocrysts (Plate 9). These grains are twinned and probably zoned. Some of the smaller clinopyroxene grains have more lath-like shapes. Some of these grains are clearly zoned.

The mica and clinopyroxene grains are set in a matrix which is composed mainly of clear fresh colourless feldspar (Plates 8, 9 and 11). The feldspar occurs as a mosaic of intergrown grains which are interstitial to the other minerals. Although many of the grains are anhedral, some of the grains approach a euhedral shape and they usually have lath-like shapes. Some of these grains show simple Carlsbad twinning. No polysynthetic twinning was observed (Plate 10). These features strongly suggest that the feldspar is sanidine. Some very fine grained spinels occur within the interstitial feldspar (Plate 11). A few grains of interstitial carbonate are also present. It is notoriously difficult to establish if carbonate is primary but its mode of occurrence in one chip suggests that it is primary. Rare grains of a greeny-rosy brown pleochroic mineral have a basal 60° cleavage to show that they are amphibole. Minor interstitial areas are composed of cryptocrystalline material which are more likely to represent secondary alteration than devitrified glass.

3.0 SUMMARY AND DISCUSSION

The large rock sample (A) appears to be a sedimentary rock composed of well sorted predominantly angular grains of quartz, possible grains of glassy ash, rare feldspar and mica set in a matrix which appears to be dominated by clay minerals and iron oxides (Plates 1 to 4). The latter also replaces primary constituents in the rock as well as occurring as discontinuous sub-parallel secondary vein-like stringers throughout the rock. The latter probably give the sample its laminated appearance. There is no suggestion of sedimentary bedding. The rock is clast supported but not closely packed. This rock is an immature matrix-rich fine sandstone which contains ooliths and abundant iron oxides and the occasional rounded pebble. Iron oxides may be sufficiently abundant to term this rock an ironstone. The pebbles appear to be sedimentary lithic clasts (Plate 5). The main rock may contain some common, but not abundant grains, of possible glassy ash (Plates 3 and 4). This interpretation is difficult to confirm in such small grains, particularly as no vesicles were observed. These could equally represent other constituents that could include collophane or others which have been replaced by secondary minerals. There is no evidence or reason to suggest that these grains, if volcanic, are of lamproitic or even lamprophyric origin. Basaltic (sensu lato) and other ash types are much more common and may well occur in the sediments found in NW Alberta.

Chip C shows certain similarities to the main rock sample in the presence of abundant iron oxides and ooliths. The absence of quartz and the presence other constituents, although totally replaced, are both very different from the main rock sample A (Plate 6). This shows that this chip may have undergone similar alteration to the main rock sample A but that it is not directly related to, or derived from, the large rock sample A. There is no evidence that can be used to suggest a volcanic origin of any of the constituents of this rock. It is possible that some of the altered cuspate fragments could be glass shards but there is no real reason to make this suggestion as there are other more likely options. If they were glass shards they are unlikely to be of lamproitic origin. Such constituents have not been observed in lamproitic pyroclastic material by this author.

Chip D is a poorly sorted immature medium sandstone (Plate 7). This chip contains abundant quartz but it is poorly sorted and the presence of rounded grains show that it is different to rock sample A. The nature of the matrix is also different and no iron oxides or ooliths are present. With both the primary and secondary nature of this rock being different to that of rock sample A and chips C and D, this sample is not obviously related to any of them. Also there is no evidence that suggests that any of the constituents in this very small chip have a volcanic origin.

In stark contrast to the rock sample and chips described so far, chips E, F and G are all similar relatively fresh porphyritic igneous rocks which are very likely to have derived from the same source. They are composed of phenocrysts of clinopyroxene and phlogopite set in a relatively coarse grained groundmass composed of similar clinopyroxene, phlogopite, probable sanidine, rare amphibole and minor amounts of another, possibly secondary, material (Plates 8 to 11). The latter is unlikely to be glass. The rosy colour of the amphibole is somewhat reminiscent of that found in lamproites. The zoning in the clinopyroxene, the colour and lack of twinning in the phlogopite, the twinning in the sanidine, the presence of probable spinel and the absence of leucite and priderite distinguishes this rock from lamproites. All these features, however, are typical of hypabyssal minettes. There is no reason to suggest that this rock is a lamproite rather than the much more common rock type minette. In the very unlikely event of this rock sample being a lamproite it should be noted that it would be classified as a sanidine-clinopyroxene phlogopite lamproite and that it contains no olivine. Such rocks, to date, have not been shown to contain economic quantities of diamonds or to carry significant 'kimberlitic' indicator minerals. Lamproites with such mineralogies are rare. Even those which are somewhat similar (e.g. Leucite Hills) show significant differences.

4.0 CONCLUSIONS

The large rock sample and two of the small chips appear to comprise different sedimentary rock types. The alteration of one chip is similar to the large rock sample, but otherwise there is no evidence to show that these rocks are related. No observed features can confirm that any of the constituents of these rocks are volcanic in origin. Some minor constituents in the large rock samples could be of volcanic origin but other possibilities also exist. Even if these grains were shown to be volcanic ash, there is no reason to suggest that they are related to any lamproite rather than much more common volcanic rock types.

In stark contrast to the main rock sample and the two chips described above, the other three chips are different coloured fresh porphyritic igneous rocks. They are classified as hypabyssal minette. There is no evidence to suggest that they have any lamproitic affinities. There is also no reason to suggest that this sample is related to either the main rock sample or either of the other chips.

5.0 FURTHER WORK

Although the results of this investigation do not suggest any lamproitic affinities to any of the rocks examined, some additional work could be undertaken to support the conclusions of this report.

(1) Treat a large amount of this material for "kimberlitic" indicator minerals. It should be noted that even if this rock were a lamproite it is unlikely that abundant or any high interest grains would be found.

(2) Sedimentary rocks are not within the expertise of this author. These samples and thin sections could be examined by another geologist who is experienced in such rock types.

(3) The classification of the igneous fragments could be verified by obtaining compositions of the primary minerals in this rock. If undertaken, this must include grains of the different generations as well as determinations of their compositional zoning.

(4) Only two thin sections of the main rock sample were initially prepared as it was considered that any further sections should be made from carefully selected areas of the potential lamproitic material encountered in the polished slabs. This has not been undertaken as no such material could be identified. Further random thin sections could be cut and examined.

(5) Examination of further samples of the igneous material with more detailed background information should ideally be undertaken to provide support for the classification based on three very small chips.

(6) More background information or an examination of the field relations of the different components of this sample, the general geology of the area and the nature of the country rocks is required to both understand their relationship and to allow further comment.

6.0 NOTE

This report presents the best professional opinion of the author based on the limited information at the time. There may be other information not available to the author which may change this opinion.

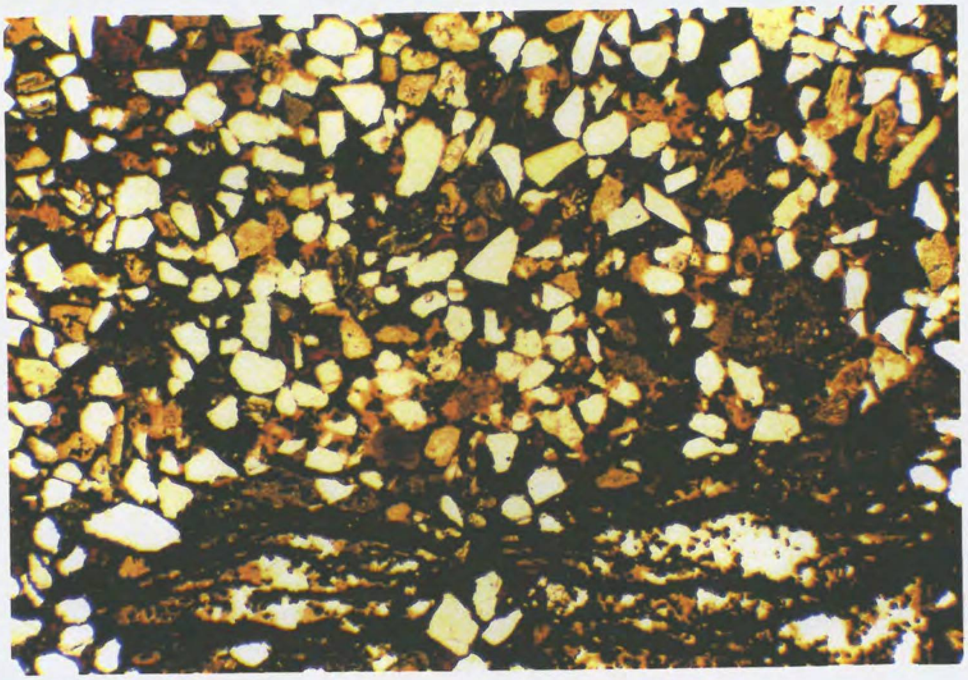

Plate 1

Large rock sample - A. Field of view =.4mm. This photomicrograph illustrates the main features of this rock. The sample is composed of well sorted fine colourless grains. Many of these grains have angular shapes. Other more coloured grains are also present. These constituents are set in a browny matrix. The sample is cut but sub-parallel discontinuous veins of browny iron oxides.

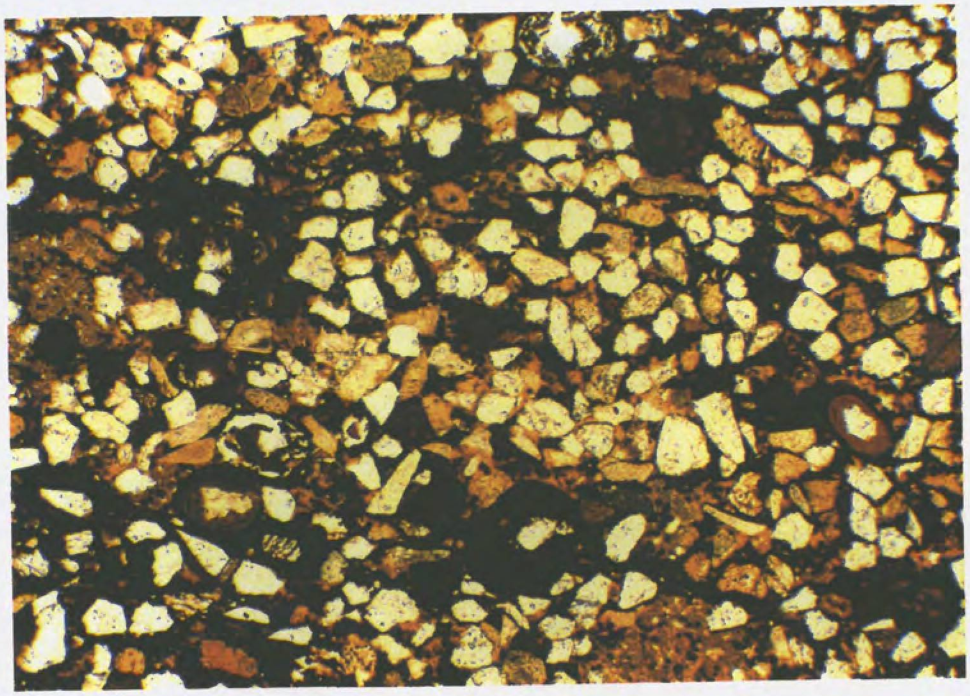

Plate 2

As Plate 1. Field of view = 4mm. This area of the sample includes some ooliths which are composed of brown iron oxides.

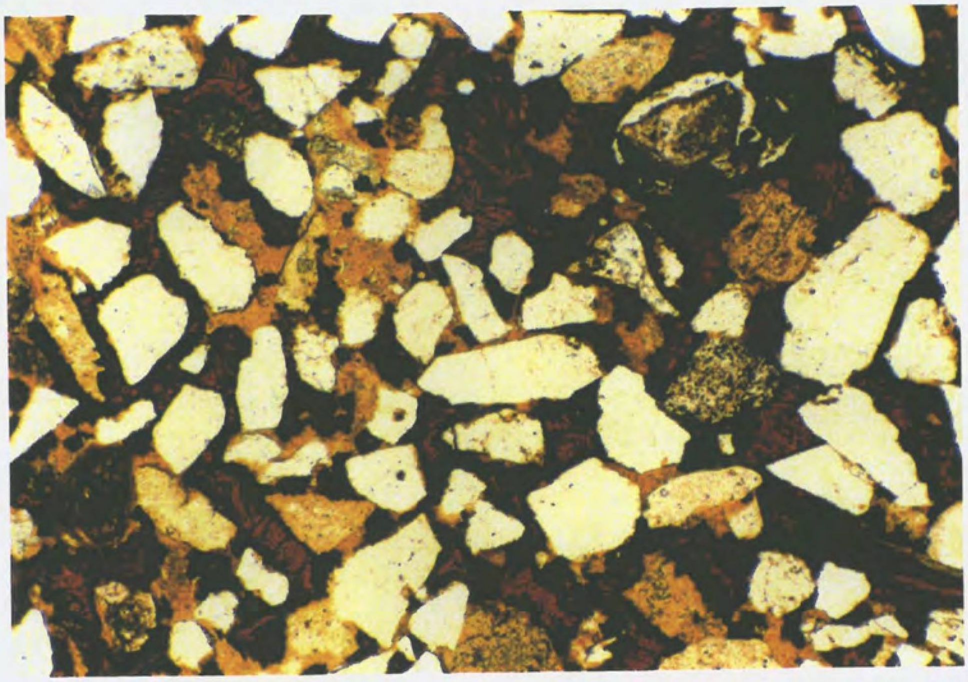

Plate 3

Large rock sample A. Field of view = 1.6mm. PPL. A typical area of one of the thin sections which shows that it is composed mainly of colourless angular grains. Some other coloured grains are also present. The matrix to the grains is composed of two main constituents. The darker brown material appears to represent secondary iron oxides while the lighter brown material appears to contain clay minerals.

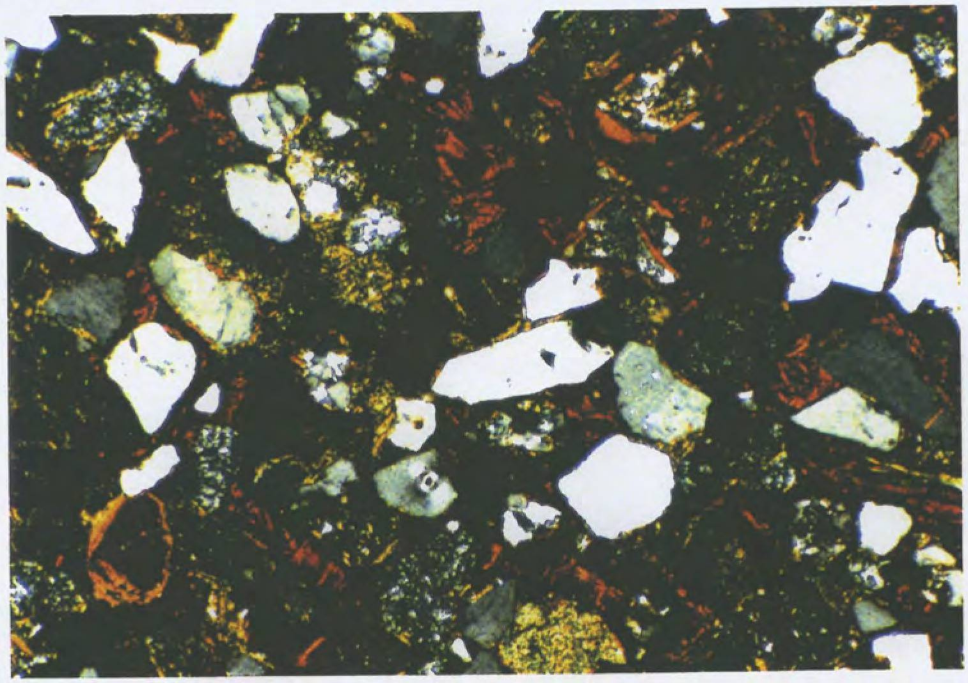

Plate 4

As Plate 3. Crossed nicols. It can be seen here that most of the grains are composed of quartz. Non-uniform extinction can be observed in some of these grains. Other grains are polycrystalline or cryptocrystalline while a few are virtually isotropic. Some of these grains could be glassy ash although this cannot be confirmed in these thin sections.The contrasting nature of the different consitituents of the inter-clast matrix can also be observed.

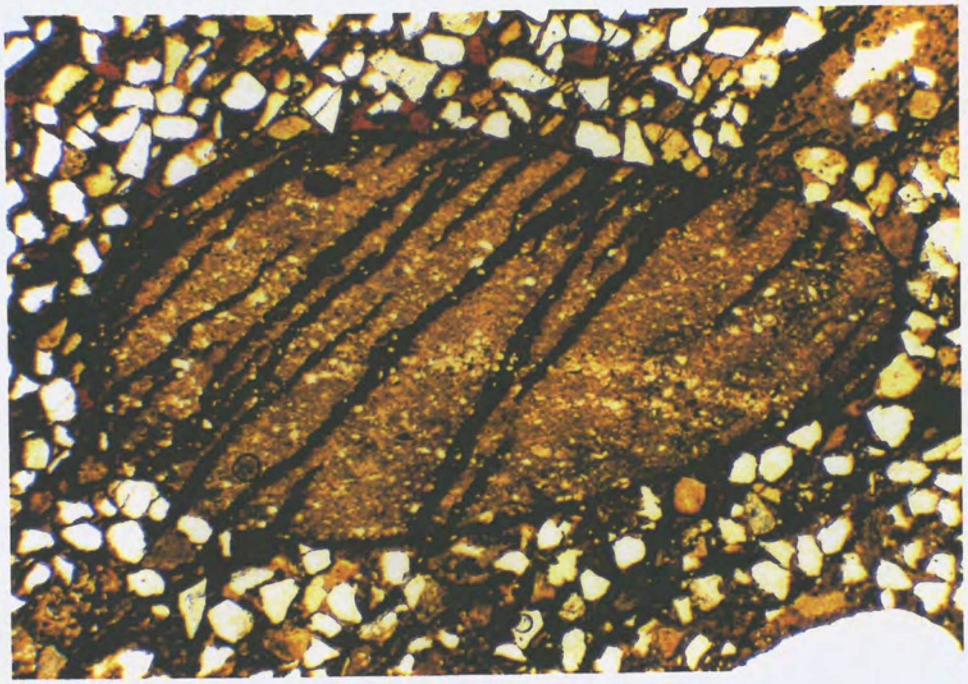

Plate 5

Main rock sample A. Field of view = 4mm. Here the main rock (as in Plates 1 to 4) contains a rounded pebble which is translected by secondary veins of iron oxides. The pebble is composed of very fine quartz in a clayey matrix. Some of the quartz appears to be concentrated in a layer which may represent a bed. The pebble is most likely to be a sedimentary rock.

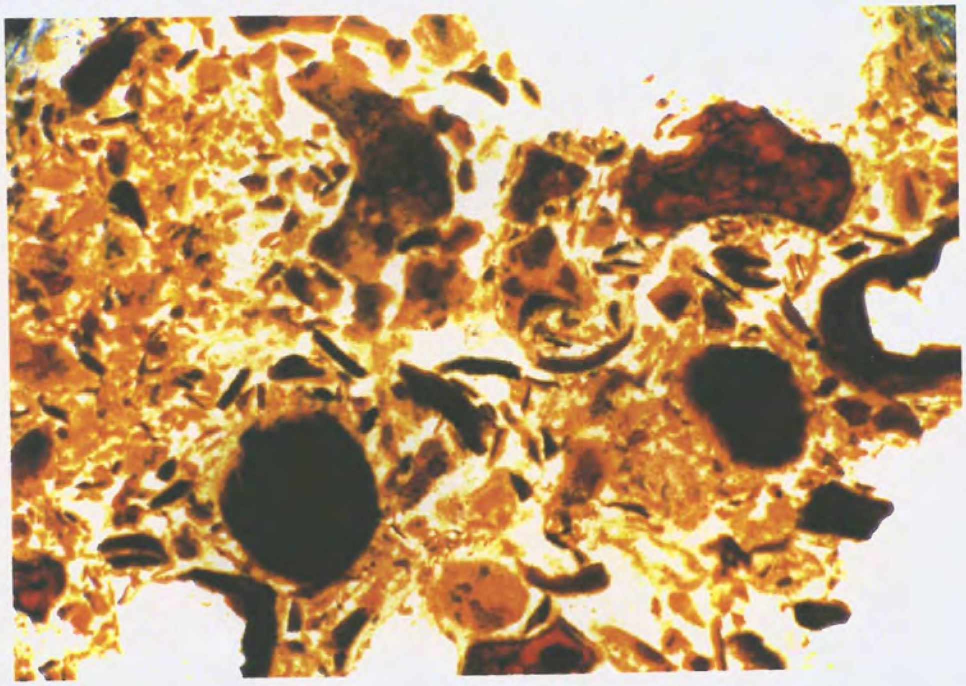

Plate 6

The orange brown chip C. Field of view = 1.6mm. This photomicrogrpah was taken with condensed light. This chip is composed of poorly sorted fine constituents which have all been replaced by iron oxides. Nine of these consitituents appears to have been quartz but they do include ooliths similar to those observed in the main rock sample. These constituents are set in a colourless matrix of carbonate. The nature of the clasts and the inter-clast matrix clearly shows that this chip is different from the main rock sample shown in Plates 1 to 4.

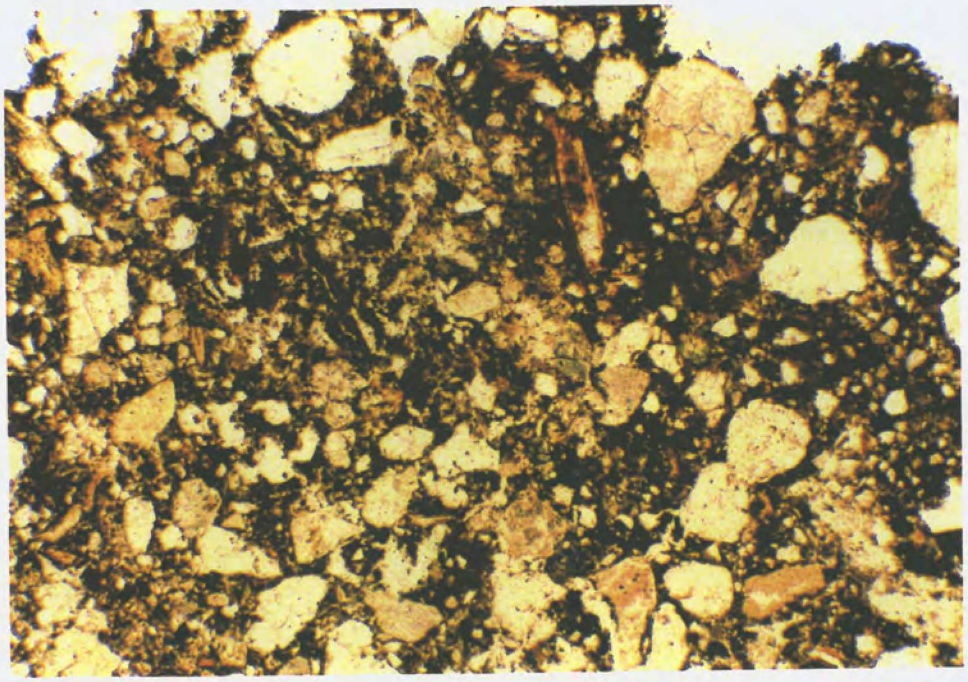

Plate 7

The dark brown chip C. This chip is composed of poorly sorted grains of quartz as well as the occasional feldspar and mica grains. Some of the quartz grains are more rounded than foun in the main rock sample. The matrix appears to contain clay minerals which have a dark brown colour in contrast the the matrix of the main rock sample A. This photomicrogrpah clearly shows that this chip is different from the main rock sample A shown in Plates 1 to 4.

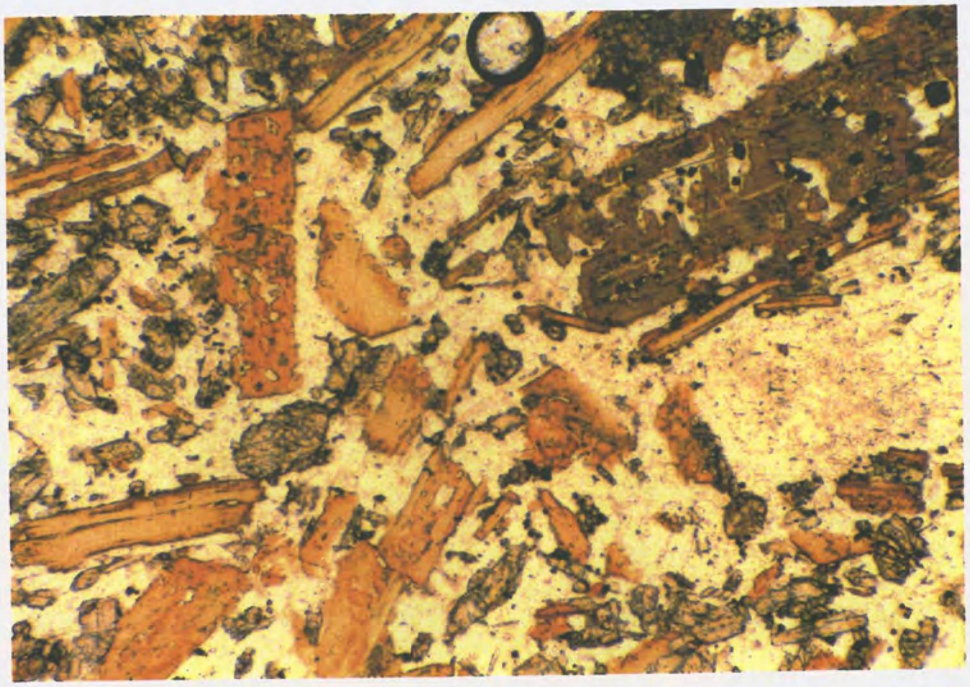

Plate 8

Chips D to F. Field of view = 1.6mm. These chips are contain phenocrysts of mica which enclose some fine grained spinel. The latter is coarser than that found in the groundmass. These micas are greeny in colour which shows that they are partly altered. These micas also appear to have sieve textured cores. The rest of the rock is composed of laths of phlogopite, clinopyroxene and colourless feldspar.

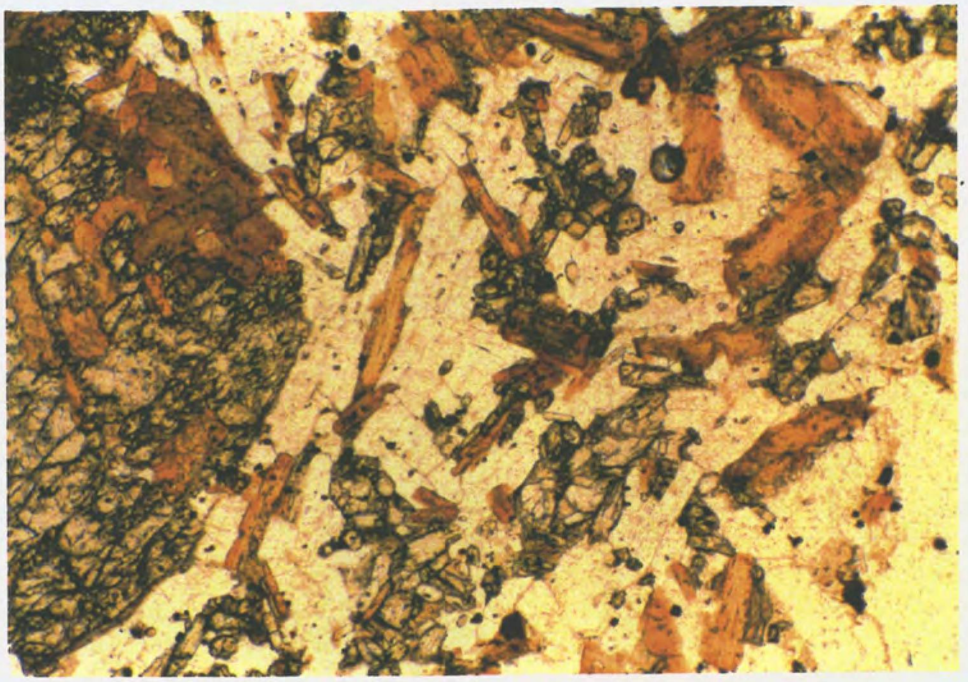

Plate 9

Chips D to F. Field of view = 1.6mm This photomicrograph shows part of one of the clinopyroxene phencrysts. It is either intergrown with or partly replaced by phlogopite. The rest od the rock is composed of laths of phlogopite, clinopyroxene and colourless feldspar.

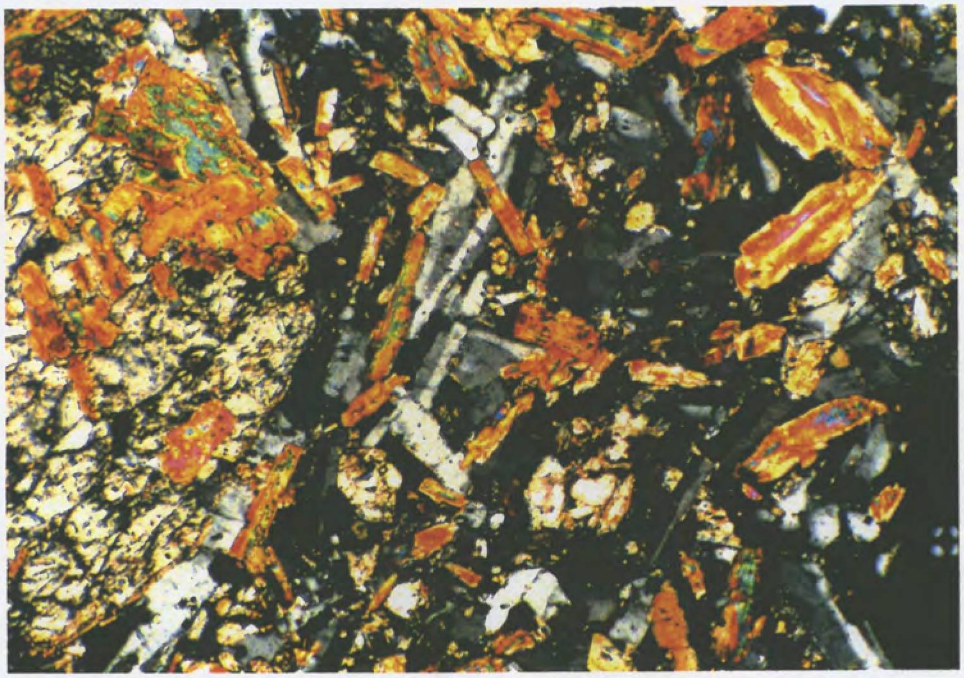

Plate 10

As Plate 9. Crossed nicols. This photomicrogrpah illustrates the simple Carlsbad twinning in the groundmass feldspar laths.

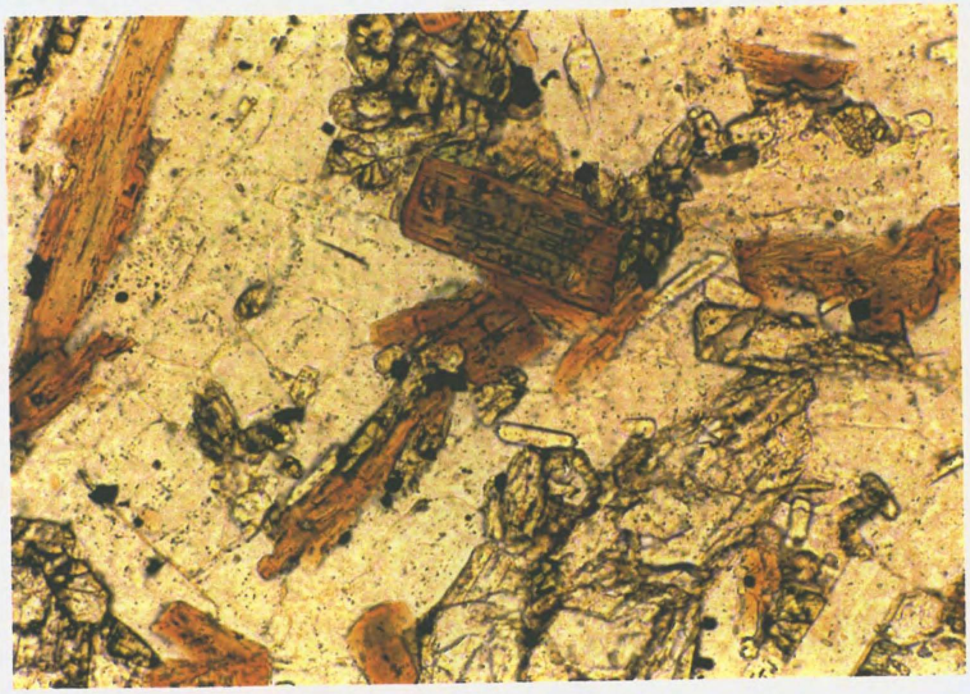

Plate 11

Chips D to F. Field of view = 0.6mm. This plate illustrates the nature of the groundmass which is composed of brown phlogopite, clinopyroxene ans colourless feldspar with minor amounts of very fine grained cubic probable groundmass feldspar. The green core to one grain of mica shows that it is partially altered and zoned.

APPENDIX 5

Dynamic Geological Consulting

Fax Memo

From: Rick Walker

Dynamic Exploration Ltd.
1916 - 5th Street South
Cranbrook, BC V1C 1K4

Phone: (604) 489 - 2255
Fax: (604) 426 - 8755

To: Marum Resources Inc.

Date: April 11, 1994

Attention: Rick Boulay

Time: 12:15 pm

Total Pages (with cover page): 5

As requested, a composite description of three thin sections supplied to Dynamic Exploration Ltd. by Marum Resources Inc.

The material was described as coming from an oolitic sedimentary unit, having a small proportion of enigmatic granitoid clasts. The thin sections supplied support the interpretation of a oolitic lithology in which the majority of the ooliths are cored by alkali feldspar grains. This observation, coupled with lamprophyric/lamproitic inclusions supports the possibility that there may be a proximal source of igneous material.

PROFESSIONAL GEOLOGIST ALBERTA
RICHARD T. WALKER

PROFESSIONAL GEOSCIENTIST
PROVINCE OF BRITISH COLUMBIA
R. T. WALKER

Rick Walker
Dynamic Exploration Ltd.
1916 - 5th Street South
Cranbrook, BC V1C 1K4

Phone: (604) 489 - 2255
Fax: (604) 426 - 8755

April 11, 1994

Rick Boulay
4606 - 5th Street S.W.
Calgary, Alberta
T2S 2E5

Re: Three thin sections of Clear Hills material

Upon examining the thin sections supplied I would have to agree with the interpretation that they are oolitic in origin. In hand sample, the lithology is comprised of fine (<1 mm), reddish coloured, spherical grains in an orange brown matrix. This observation is evident in thin section. The grains consist of a nucleus, generally comprised of a limited variety of silicate grains, with finely laminated, concentric layers. The concentric layers are now almost exclusively comprised of an iron-rich material, tentatively identified as haematite. The oolite has a bimodal population consisting of subequal proportions of spherical and elliptical ooliths. All the silicate minerals comprising the nuclei of the ooliths are angular to sub-angular, excepting the tentatively identified olivine grains which appear to have a relict euhedral, aggregate morphology.

The vast majority of the ooliths have a silicate nucleus, consisting of (in order of abundance): alkali feldspar and quartz ± olivine ± Ca-pyroxene (diopside). The alkali feldspar grains are tentatively identified on the basis of low interference colours (first order gray to yellow), undulose extinction, weakly defined cleavage (may or may not be present), weakly defined zoning (may or may not be present), twinning (may or may not be present) and ubiquitous weak to moderate alteration. Cleavage, zoning and twinning are features which would not occur in quartz. Furthermore, alteration effects would not be expected in quartz.

Twinning is weakly defined but instances of tartan twinning and lamellar twinning were observed. In addition, several grains had parallel cleavage in evidence. Finally, grains having a stinctly lath-like crystal morphology were observed. All of the above observations suggest alkali feldspar is present and ely comprises the predominant population of the silicates ing the ooliths.

eration of the alkali feldspar imparts a patchy appearance to grains in both plain and polarized light. In plain polarized ight interference colours range from gray to reddish brown in ccessively altered areas while in crossed polarized light the ered patches range from gray to black. The alteration product too small to identify in thin section but is interpreted to be sericite (white mica), a common alteration product of alkali dspars.

artz grains are present, characterized by equant grains having y to yellow (first order) interference colours and straight to ulose extinction. In a subordinate number of grains, lycrystalline, strained quartz is present.

ighly subordinate population of ooliths have an unaltered bonate nucleus, around which a concentric haematitic rind has eveloped. In addition, in some instances, a carbonate mantle is dent surrounding silicate grains within a concentric matitic rind.

highly altered olivine grains are tentatively identified on basis of 2^{nd} order interference colours, lack of cleavage and ict grain morphology.

matrix is composed of green, amorphous material in plane arized light. In crossed polarized light, however, very fine ained laths or plates appear to be present, probably of a yey material. It is very difficult to identify and is erpreted as chamosite "a monoclinic mineral of the kaolinite oup, $(Fe^{2+},Mg,Al,Fe^{3+},)_6(AlSi_3)O_{10}(OH)_8$. An important onstituent of many oolitic ironstones" (paraphrased from the tionary of Geologic Terms). In addition, there are orange- wn, irregular grains suspended in the matrix and in small ggregates, which are translucent and apparently isotropic in ssed polarized light.

TERPRETATION

contrast to the material provided previously, this material is t described as an oolite. However, the predominance of alkali eldspar identified coring the majority of the ooliths is consistent with proximity to an igneous source. It is curious that the possible lamprophyric to lamproitic material identified in the concentrate was not present, or at least not identified in the thin sections.

The angular to sub-angular texture of the grains comprising the nuclei of the ooliths suggests very little transport, again consistent with a proximal source. The great predominance of alkali feldspar is also consistent with an alkaline igneous source (including lamprophyre and lamproite). Larger grains (pisoliths) present in the hand samples may represent the igneous material described in the raw fractions previously supplied. However, positive identification was not possible, possibly due to haematitic rinds present on the grains.

Breakdown of lamproitic and/or lamprophyric igneous material could supply the alkali feldspar grains coring the ooliths. One problem with this interpretation is the lack of ooliths cored by biotite-phlogopite grains but this may be a function of specific gravity in the environment in which the ooliths formed.

RECOMMENDATIONS

The source of the igneous material must be addressed before much additional work is carried out on the deposit. The concentrate previously supplied has undeniable igneous material, recovered with very little processing of the bulk sample (treatment with HCl and HF). The thin section examined contain no lamprophyric and/or lamproitic inclusions. However, the ooliths are cored predominantly by tentatively identified alkali feldspar. While I feel relatively confident of this interpretation I cannot get optic axial figures to verify a biaxial (vs. uniaxial - quartz) nature. One relatively easy procedure to verify the presence or absence of alkali feldspar would be to stain the thin sections or a slab of rock with potassium cobaltinitrate, which would stain the feldspar yellow. Alternatively, or in addition, descriptions of the thin sections by unbiased third parties has been suggested by Rick Boulay, President of Marum Resources Ltd., might verify the presence of alkali feldspar.

It is further recommended by the author that outcrop exposures be examined for inclusions and/or clasts of igneous material from the proposed source. Such examination can wait or be subject to independent third party verification of an igneous component. Finally, one large, complete sample of the material should be processed for recovery and verification of the lamprophyric/ lamproitic inclusions, to specifically address the possibility of contamination. The author has been informed that the issue of possible contamination has already been addressed by Rick Boulay and that the concentrate previously supplied is free of contamination.

CONCLUSIONS

It is the authors opinion that the concentrate and thin sections supplied by Marum Resources Ltd. to date represent samples of an oolite, comprised of numerous ooliths having predominantly alkali feldspar nuclei. Larger grains (pisoliths), which may also have a concentric rind of haematite, are present consisting of a matrix having biotite-phlogopite phenocrysts.

There is sufficient evidence to support the original interpretation proposed by the author proposing a proximal source of alkaline igneous material. This possibility should be pursued to determine its validity. If igneous material is confirmed by independent sources, then the oolite should be examined in the field in an attempt to determine the position of the proposed source for the igneous material. In addition, the oolite should be evaluated for Rare earth Elements, Platinum Group Elements, base and other precious metals, as well as possible diamonds.

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RICHARD T. WALKER

PROFESSIONAL GEOSCIENTIST
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R. T. WALKER

APPENDIX 6

Dynamic Geological Consulting

Fax Memo

From: Rick Walker

Dynamic Exploration Ltd.
1916 - 5th Street South
Cranbrook, BC V1C 1K4

Phone: (604) 489 - 2255
Fax: (604) 426 - 8755

To: **Marum Resources Inc.**

Date: **March 29, 1994**

Attention: **Rick Boulay**

Time: **2:15 pm**

Total Pages (with cover page): **1**

As requested, a discussion of material examined in two samples supplied to Dynamic Exploration Ltd. by Marum Resources Inc. The first sample is identified as CH-1 (HCl and HF) and consists of approximately one teaspoon of concentrate. The second sample is identified as CH-1 (HCl) Coarse and consists of approximately one tablespoon.

The material was described as coming from an oolitic sedimentary unit, having a small proportion of enigmatic granitoid clasts. The following interpretation documents my reasoning for considering oolite to be a misnomer. I believe the sample represents up to three separate and identifiable alkaline igneous phases, possible associated with (a) diatreme(s) of lamprophyric or lamproitic affinity.

PROFESSIONAL GEOLOGIST ALBERTA
RICHARD T. WALKER

R. T. WALKER

Rick Walker
Dynamic Geological Consulting
1916 - 5th Street South
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Phone: (604) 489 - 2255
Fax: (604) 426 - 8755

March 29, 1994

Rick Boulay
4606 - 5th Street S.W.
Calgary, Alberta
T2S 2E5

Re: Samples CH-1 (HCl) Coarse and CH-1 (HCl/HF)

I have examined both samples supplied and interpret them to be hypabyssal intrusive to extrusive igneous material of lamprophyric to lamproitic composition.

Sample CH-1 (HCl) Coarse consists of approximately one tablespoon of concentrate while sample CH-1 (HCl/HF) consists of approximately one teaspoon of concentrate. Therefore, the interpretations based upon the following observations must be considered in the context of the outcrop from which they were derived.

<u>CH-1 (HCl/HF)</u>
The sample consists predominantly of individual mineral grains and fragments with subordinate brown coloured (Fe- stained) aggregate material. There are also partial relict moulds consisting of disaggregated rinds of haematitic (?) material, which elsewhere coat grains and fragments. Diopside (possibly low to moderate chrome content) are present as fragments and rare columnar crystals. Rounded to sub-rounded spinels (non-magnetic - possibly chromite), glassy black magnetite fragments and black ilmenite grains are evident. Many rounded, red-brown haematite(?) coated pellets are also present. There are a variety of glassy, vitreous minerals that may include: quartz, plagioclase and/or nepheline. In addition, white, translucent minerals may be alkali feldspar grains and fragments. Glassy moderately orange coloured grains may be rutile but are more likely garnet fragments. Finally, numerous euhedral biotite-phlogopite grains are present, up to 2 mm in diameter across their basal section.

CH-1 (HCl) Coarse
The coarse fraction examined is essentially bimodal in composition, comprised of dirty yellow coloured aggregates and grey coloured, hypabyssal to extrusive igneous material.

The dirty yellow portion, upon closer examination, consists of two phases, namely the "oolitic" fraction and a matrix fraction. The "oolitic" fraction is a misnomer as it is certainly not oolitic. Treatment with HCl has not dissolved the sample, therefore it is not calcareous in composition and there are very few instances of concentric structure to the grains. The "oolites" are actually rounded to sub-rounded pellets comprised of a nucleation site (a pre-existing grain or mineral fragment) and a haematite(?) rind. The matrix containing the pellets contains fine-grained, euhedral biotite. The second phase (arbitrary identification) of dirty yellow material consists of fine-grained (microphenocrysts?) biotite-phlogopite in dirty yellow matrix (composition currently unknown). No phenocrysts are present in the several small samples identified.

The yellow colouration appears to be a result of alteration of haematite into goethite and/or limonite. The matrix contains minerals identified above in the previous sample, implying a genetic link between the three phases identified in the sample.

The gray material contains euhedral biotite-phlogopite and subhedral to euhedral (green) diopside. Biotite-phlogopite crystals are predominant, with diopside crystals slightly subordinate. Biotite-phlogopite is also present as a matrix phase. The matrix consists of clear, vitreous silicates which may include some or all of the following: quartz, plagioclase and/or nepheline.

One large phenocryst of columnar, euhedral diopside (probably low chrome) was identified in this fraction.

INTERPRETATION

The fact that matrix is still evident after treatment with HCl indicates that the matrix is comprised largely of silicates, carbonate is either absent or sub-ordinate. This is inconsistent with an "oolitic" origin unless substantial replacement has occurred. This possibility is considered remote due to the lack of any indication of concentricity in the vast majority of the pellets examined. In addition, the abundant occurrence of igneous minerals suggests an igneous origin for this sample. Furthermore, the euhedral nature of biotite-phlogopite crystals as phenocrysts and in the matrix, and euhedral diopsides suggests a proximal source. The predominance of biotite-phlogopite crystals with slightly subordinate diopside suggests an alkalic composition similar to a lamprophyre or possibly a lamproite. The presence of two phases of biotite-phlogopite (phenocrysts and in groundmass) suggests the possibility of a madupitic lamproite.

Such an interpretation is consistent with the information available, both observable and reproducible in the concentrate and the reported presence of granitoid clasts. Such granitoid clasts would be difficult to reconcile with an oolitic package, as would the abundance of igneous material.

Furthermore, the pellets may represent igneous material re-worked in a sub-aqueous environment of limited extent. One possibility would be within a water filled crater associated with a diatreme. An iron-rich brine is the probable source of the haematitic rind developed on the mineral grains and fragments. In order for the extensive haematitic rinds to be precipitated, a restricted volume of iron-rich brine is required. Alternatively, the samples may represent portions of a pyroclastic apron associated with a proximal vent or vents, again deposited within a restricted basin. Finally, the igneous material may have been altered in the subsurface by an iron-rich brine.

RECOMMENDATION

This deposit should be evaluated for diamond potential. Furthermore, with the possibility of a proximal source, Platinum Group Element and Rare Earth Element potential should be considered. In addition, base and precious metals may be present.

Information available to the author indicates potential as an iron deposit, currently sub-economic. It may be that if this igneous material was sourced proximally then potential may exist for multiple commodities, making a mine feasible.

PROFESSIONAL GEOLOGIST ALBERTA
RICHARD T. WALKER

PROFESSIONAL
PROVINCE OF BRITISH COLUMBIA
R. T. WALKER
GEOSCIENTIST

APPENDIX 7

Marum Resources Inc.
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May 24, 1994

Dr. John Duke
SLOWPOKE Reactor Facility
3118 Dentistry Pharmacy Building
Univ of Alberta T6G 2N8

Dear Dr. Duke:

Please find enclosed two sealed centrifuge tubes, each labelled "IC-100 Aqua Regia", and a plastic bottle of sediment labelled "IC-100 Solids". The tubes contain Aqua Regia (3 HCL to 1 HNO3) and represent the leach liquor from a 300 gram samples of ironstone material. The solids represent the residue from the leaching process and have been thoroughly washed with water. Acid precautions should be used with the Aqua Regia, no precautions are necessary with the solids.

The materials were prepared as follows:

Solid chunks of ironstone were crushed in a plastic bag with a hammer.

300 grams was measured into a large contained and mixed. The material was distributed into 10 beakers and covered with Aqua Regia.

The beakers were placed on a rotary shaker and shaken for 36 hours at medium speed. Every 12 hours the material was hand stirred.

After 36 hours the material was poured into six centrifuge tubes and centrifuged at high speed for 20 minutes. The liquid was poured off into two clean centrifuge tubes and centrifuged again at high speed for 10 minutes. The liquid was then decanted into the two tubes labelled "IC-100 Aqua Regia", then sealed.

The solids were collected in a container and rinsed thoroughly with distilled water twice and with tap water three times.

I did not recombine the liquids from the two sealed tubes and suggest that you do so before extracting a sample for INAA. I would also like to run a sample of the solids for reference. Please use your discretion as to how many samples of the liquid and the solids should be run.

Yours truly,
Marum Resources Inc.

Richard A. Boulay, President

To: John Duke

From: Rick Boulay, Marum Resources

Handling: Tube #11 contains HF, all others contain either Aqua Regia or HCL.

Ironcap fines curshed in ball mill for 8 hours. Samples treated in acid for 30 hours.

IC-101-2
30 gms Ironcap fines +100ml HCl

IC-101-5
5 gms brushings from rods + 100ml Aqua Regia

IC-101-6
50 gms hard residue from rod mill, crushed by hammer + 100ml Aqua Regia

IC-101-7
30 gms Ironcap fines + 100ml Aqua Regia

IC-101-8
5 gms Ironcap fines + 100ml Aqua Regia

IC-01-11
30 gms Ironcap fines + 150ml HF

M. John M. Duke (1992)

Neutron Activation Analysis

Neutron activation analysis (NAA) involves the production of radioisotopes from stable nuclei for the purpose of elemental analysis. The principles of the technique were developed and tested by von Hevesy and Levi some fifty years ago. However it was not until the development of the nuclear reactor that the technique could be used in a routine manner. Over the last four decades the increased availability of research-type nuclear reactors (together with the development of semiconductor detectors and complementary solid-state electronics capable of collecting and reducing complex spectra) has made NAA an extremely attractive method of elemental analysis. At present the sensitivity, precision, generally non-destructive, and multi-element nature of NAA makes it a competitive means of analysis when access to a nuclear reactor is available. The following is a brief introduction to the theory of NAA. For a more complete coverage of the technique and its applications see Rakovic (1970), Kruger (1971), De Soete *et al.*, (1972), Muecke *et al.*, (1980), Amiel *et al.*, (1981), Erdtmann and Petri (1986), and Parry (1991).

Unlike many techniques commonly used for elemental analysis, NAA is based on the modification of the nucleus and not the orbiting electrons of the atom. Nuclei of stable atoms (making-up the sample to be analyzed) are irradiated with neutrons and some of the nuclei absorb or capture neutrons producing radionuclides (equation 1).

$$ {}^{N}_{Z}X + {}^{1}_{0}n = {}^{N+1}_{Z}X \xrightarrow{\beta^-} {}^{N+1}_{Z+1}Y \quad \text{..(1)} $$

e.g.,

$$ {}^{27}_{13}Al + {}^{1}_{0}n = {}^{28}_{13}Al \xrightarrow[T½ = 2.24\ min]{\beta^-} {}^{28}_{14}Si $$

These radionuclides decay according to a well-defined time constant (termed the half-life, T½) with the emission of high energy beta particles (β^-). In addition, the decay of many such radionuclides is accompanied by the emission of gamma-rays characteristic of the radionuclides. Detection and counting these gamma-rays affords the means of elemental analysis; the energy of the gamma photons being used to identify the radionuclide, and the intensity or number of detected gammas being directly proportional to the mass (and hence concentration) of the parent element.

A supply of neutrons is obviously essential for neutron activation analysis. Invariably, a nuclear reactor is used to generate the high neutron flux necessary for practical analyses. The University of Alberta has a small research-type pool nuclear reactor called the SLOWPOKE capable of producing a maximum thermal neutron flux of 1 x 10^{12} n cm^{-2} s^{-1}. In comparison to many other nuclear reactors the SLOWPOKE produces both a very stable and reproducible neutron flux which are important features for the most precise analyses.

NAA has several advantages over many other analytical techniques including, for example :-

- high sensitivity (using a SLOWPOKE reactor sensitivities for some 70 elements range from 10^{-4} to 10^{-11} g)
- multi-elemental in nature (*e.g.*, some 35 - 40 elements are routinely determined in geological materials)
- simple sample preparation
- low contamination risk
- generally matrix independent
- ease of calibration (very wide dynamic range)
- most analyses can be performed non-destructively
- nuclear reaction (therefore independent of chemical state)

No technique is without its disadvantages for NAA examples include:

- cost (nuclear reactor and fully equipped laboratory *c.* $1.0 M)
- not all elements have isotopes that readily become radioactive
- extra precautions are necessary for handling radioactive materials

APPENDIX 8

(2)

Information Series 75

PEACE RIVER IRON DEPOSITS

E. F. Bertram and G. B. Mellon

Alberta Research Council
1975

PART ONE: GEOLOGY, COMPOSITION, AND RESOURCES

Location and Access

The Peace River iron formation is located in the Clear Hills district of northwestern Alberta, about 300 air miles northwest of Edmonton (Fig. 1). The southern margin of the deposits is about 35 miles from a spur line of the Northern Alberta Railway which extends from the town of Peace River to Hines Creek. These deposits are within 5 to 20 miles of an all-weather gravelled road which extends northwestward from Hines Creek along the southern margin of the Clear Hills to Fort St. John, British Columbia.

A small-scale map showing the precise location of assessed areas is given in figure 2.

Geology and Terrain

The Clear Hills form a gently sloping upland which extends between the Peace River on the south and east and the British Columbia border on the west. The hills rise gradually from the surrounding wooded plains, and attain a maximum elevation of about 3,600 feet near their southwestern margin. Local relief is in the order of 1000 feet along the southern margin of the hills; to the north and east the hills slope gradually into the wide glaciated valleys of the Notikewin and Whitemud Rivers and their tributaries (Fig. 2).

The Clear Hills region is underlain by nearly flat-lying sandstone and shale formations of Cretaceous age, covered in most places by unconsolidated glacial deposits of variable thickness (Kidd, 1959; Green and Mellon, 1962). Bedrock exposures are scarce and discontinuous, being confined to some of the small streams which form a radial drainage pattern about the hills. The upper surface of the hills, beneath the glacial deposits, is capped by the Upper Cretaceous Wapiti Formation, which consists of sandstone and shale with thin coal (lignite) and bentonite interbeds. The iron bed is intercalated among dark grey marine shales of the Smoky Group which underlie the lower slopes of the hills and the surrounding lowlands (Fig. 3).

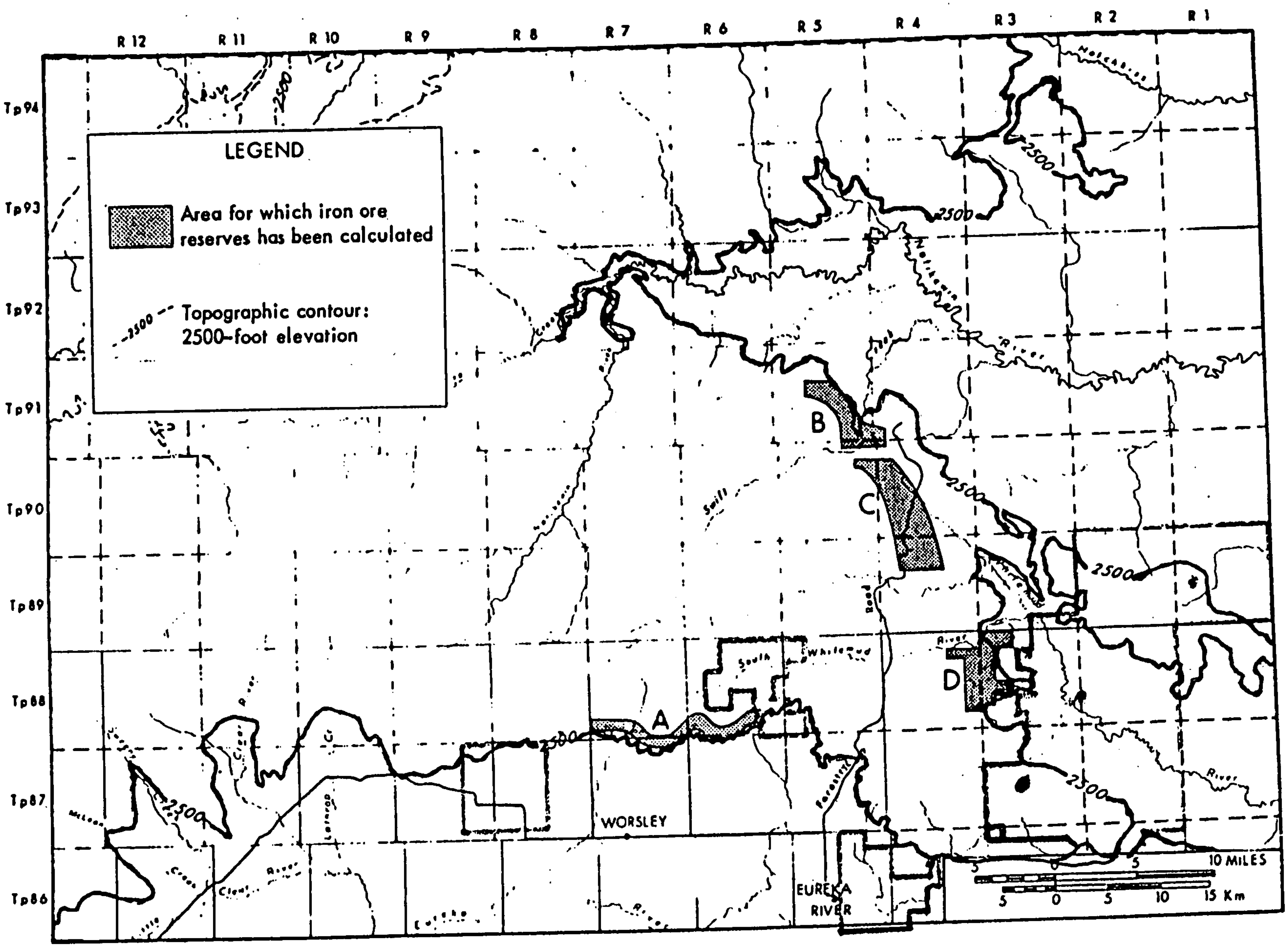


FIGURE 2. Location of assessed iron ore resources, Clear Hills district.

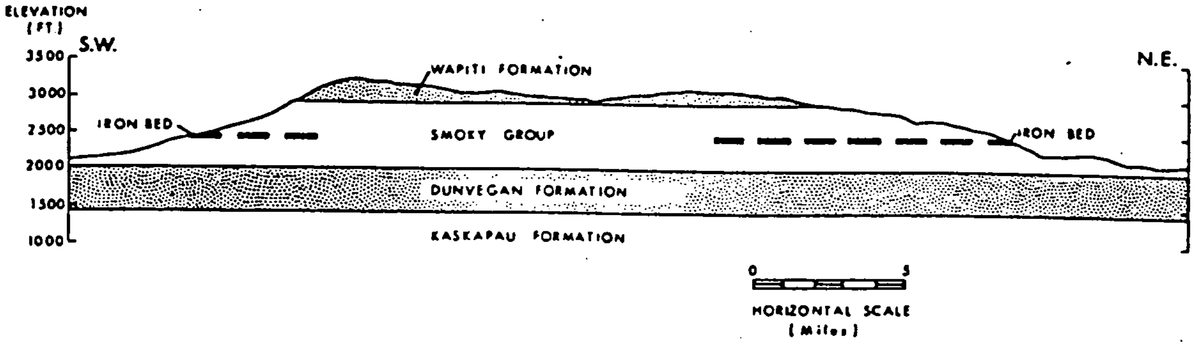


FIGURE 3. Schematic cross section through the Clear Hills showing the stratigraphic position of the oolitic iron formation.

The iron formation consists of dark brown to black oolitic sandstone with thin lenses and interbeds of hard sideritic ($FeCO_3$) "ironstone" and greenish grey mudstone. Near the outcrop margin the sandstone has been oxidized to form a soft, compact, reddish brown aggregate with harder carbonate-cemented lenses. Where present, the formation ranges in thickness up to 30 feet and forms a series of northwest-trending sandstone bodies which are exposed in places along the flanks of the hills at elevations between 2500 and 2700 feet. The mineable deposits are restricted to those areas near the outcrop margin where overburden is thinnest. The thickest and most widespread deposits underlie the northeast slopes of the hills, and thinner less extensive deposits have been found along the southern slopes north of Worsley (Fig. 2).

Scattered showings of oolitic sandstone also have been found in the northern, less accessible part of the Clear Hills, but these have not been explored in detail (Green and Mellon, 1962).

Composition

The Peace River iron deposit is an oolitic sandstone grossly comparable in mineral composition and texture to certain sedimentary iron formations in other parts of the world. The sandstone consists of densely packed oolites 0.5 to 1 mm in diameter, large nodular rock fragments, and angular quartz grains in a finely crystalline "matrix" composed of hydrated silica

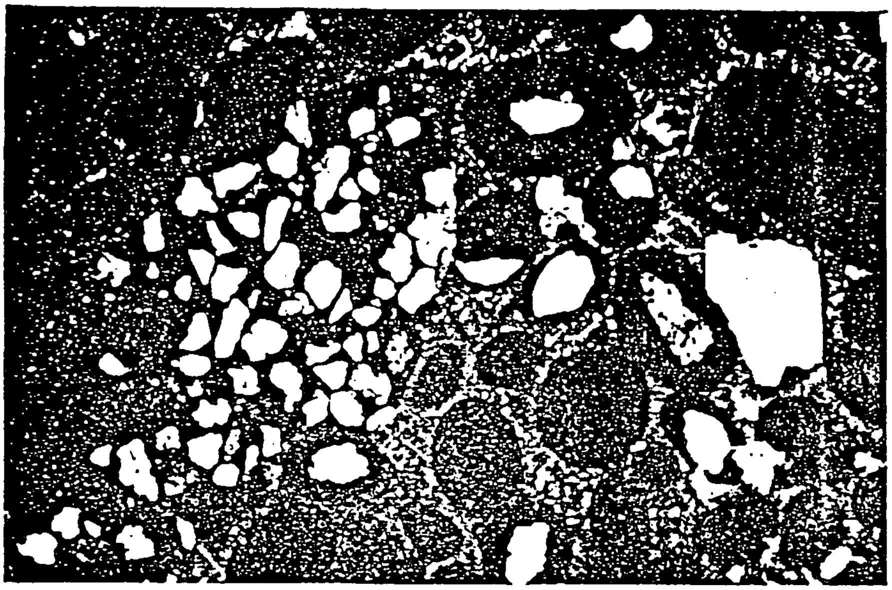


PLATE 1. *Peace River iron ore (Swift Creek deposit), transmitted light, magnification approximately 25. Ore consists of dark brown* ooliths *and large silty* rock fragments *in a greenish-brown* opaline *(siliceous)* matrix. *Quartz grains (white) are present as nuclei in some of the ooliths and as smaller silt grains in rock fragments.*

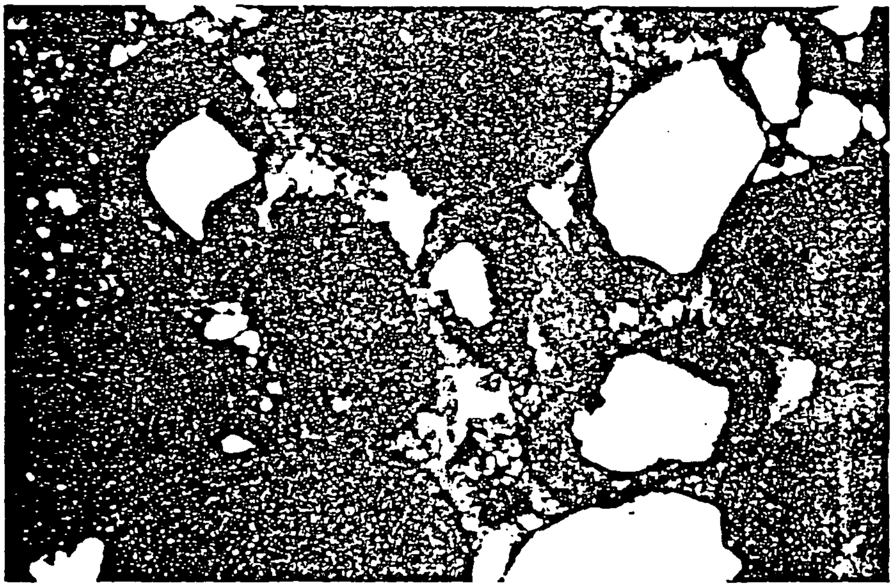


PLATE 2. *Peace River iron ore (Swift Creek deposit), reflected light, magnification approximately [illegible]. Ooliths consist of a nucleus (whitish quartz grains or dark brown to black rock fragments) about which concentric [illegible] shells of* goethite *($Fe_2O_3 \cdot H_2O$) and* opal *(hydrous silica) have been deposited. The greenish intergranular matrix [illegible] mixed with patches of "clay". Most [illegible] concentric outer shells of the ooliths.*

(opal), siderite (iron carbonate), and "clay" (Mellon, 1962). The oolite content (and hence the iron content) is highest in the upper part of the bed, decreasing progressively towards the base of the sandstone which grades into underlying dark grey shale.

The major iron-bearing minerals are *goethite* ($Fe_2O_3 \cdot H_2O$) and *siderite* ($FeCO_3$); small amounts of *pyrite* (FeS_2) and *glauconite* (Fe silicate) are found in some samples. Silica (SiO_2) is present as discrete quartz grains and as an amorphous opaline substance which forms part of the intergranular "matrix". This opaline substance (or "cement") is also a constituent of the iron-bearing oolites, having been co-deposited with goethite to form the outer concentric shells of the oolites (Plates 1 and 2).

Chemical analyses show that the various deposits are relatively uniform in average composition (Table 1). The salient features revealed by the analytical data are:

(1) Total iron (Fe) content averages between 32 and 36 percent. The Worsley deposits contain lower iron contents than the thicker deposits to the northeast (Swift Creek, Whitemud River, see Fig. 2).

(2) The silica content is relatively high, and the alumina content is correspondingly low.

(3) The phosphorus content is higher than desirable for a conventional iron ore. However, the sulfur content appears to be consistently low.

(4) The lime (CaO) content of the Swift Creek deposit is lower than that of the Worsley deposits. This may be caused by partial oxidation of the Worsley deposits in which siderite ($FeCO_3$) has reacted with groundwater solutions to form goethite ($Fe_2O_3 \cdot H_2O$) and calcite ($CaCO_3$).

(5) The water content is unusually high due to abundant opaline "cement".

Table 1. Chemical analyses of Peace River iron deposits

Constituent		Deposit		
		Worsley[1]	Swift Creek[2]	Swift Creek-[3] Whitemud River
Iron	Fe	32.65	35.44	32.98
Silica	SiO_2	25.67	26.49	29.26
Alumina	Al_2O_3	5.53	4.95	5.47
Manganese	MnO	0.16	0.16	N.A.
Magnesia	MgO	1.25	1.02	1.60
Lime	CaO	3.25	1.90	N.A.
Phosphorus	P	0.69	0.67	0.45
Sulfur	S	0.11	0.07	N.A.
Ignition loss	H_2O CO_2	14.36	13.78	11.91

N.A. = not available.

[1] Weighted averages of borehole samples (block "A", Fig. 2). Unpublished report by N.S. Edgar on Iron Prospecting Permit No. 17.

[2] Weighted averages of borehole samples (block "B", Fig. 2). Unpublished report by N.S. Edgar on Iron Prospecting Permit No. 16.

[3] Weighted averages of borehole samples (blocks "B" and "C", Fig. 2). Given in Kidd, 1959 (Res. Coun. Alberta Prelim. Rept. 59-3).

In summary, the Peace River oolitic deposits can be described as a low grade highly siliceous iron ore with complex mineral composition and texture. Because of the complex intergrowth relationships of the different mineral constituents, the deposits are difficult to upgrade by conventional beneficiation procedures.

Resources

Estimated resources and grades for the Peace River deposits are summarized in table 2. The estimates are based on the results of drilling programs carried out between 1959 and 1965 on four areas explored under iron prospecting permits held by Peace River Mining and Smelting Ltd., Edmonton, Alberta. The programs were supervised by N. S. Edgar, consulting mining engineer, whose reports subsequently were submitted to the Alberta Energy and Natural Resources. Copies of the reports are now kept in the Industrial Minerals Files, Alberta Research Council (Edgar, 1961, 1962, 1964, 1965).

The distribution of areas for which resources have been calculated is shown in figures 2 and 4. The areas are situated along the southern flank of the Clear Hills 5 to 6 miles north of Worsley (block A), and along the southeast margin adjacent to the Notikewin-Eureka River forestry access road (blocks B, C, D).

The degree of precision associated with the resource estimates varies substantially among the four areas: the resources for blocks A and B have been calculated from more than 100 borehole intersections in each area, whereas those for blocks C and D are based on only 8 and 2 borehole intersections respectively. Consequently, the resource estimates in table 2 are classified as "proven", "probable", and "possible" according to the data available for each area.

The total resources of iron ore inferred to be present in the four blocks are in excess of 1.1 billion tons grading between 32 and 36 percent total iron (Fe). About 227 million tons of this are considered "proven" and underlie blocks A (Worsley) and B (Swift Creek). The remaining 897 million tons are classed as "probable-possible" and underlie blocks C and D. Additional drilling is necessary to confirm the extent and grade of the iron bed in blocks C and D and to determine the exact thicknesses and composition of overburden deposits.

Table 2. Reserves and grades of sedimentary iron ore, Clear Hills district, northwestern Alberta

Block	Reserves (tons)			No. of Drillholes	Average Thickness Iron Bed (ft)	Grade (% Fe)	Maximum Overburden Thickness (ft)
	Proven	Probable	Possible				
A	25,750,000	8,225,000	-	120	8	33	65
B	201,000,000	-	-	115	22	34	130
C	-	684,000,000	-	8	17	-	200
D	-	-	205,000,000	2	11	-	200
Total	226,750,000	692,225,000	205,000,000				

Table 1. Succession of Strata in the Clear Hills Area, (from Green and Mellon, 1962).

ROCK UNIT			THICKNESS (m)	LITHOLOGY
Wapiti Formation			0-120	soft, whitish sandstone; grey, blocky, carbonaceous shale; thin coal seams (continental)
Smoky Group	Puskwaskau Formation		90-180	dark grey, fissile shale (marine)
	Bad Heart Sandstone		0-9	green, ferruginous, oolitic sandstone and mudstone (marine)
	Kaskapau Formation	upper member	45-125	dark grey, fissile shale (marine)
		lower member	12-47	whitish sandstone; grey, sandy shale; oolitic siderite (marine)
Dunvegan Formation			150-235	soft, grey sandstone with calc. concretions; grey, silty, carbonaceous shale (deltaic)
Shaftesbury Formation		upper member	90-170	grey, silty shale; thin, laminated siltstone (marine)
		lower member	180-320	black, fissile shale; numerous fish scales (marine)

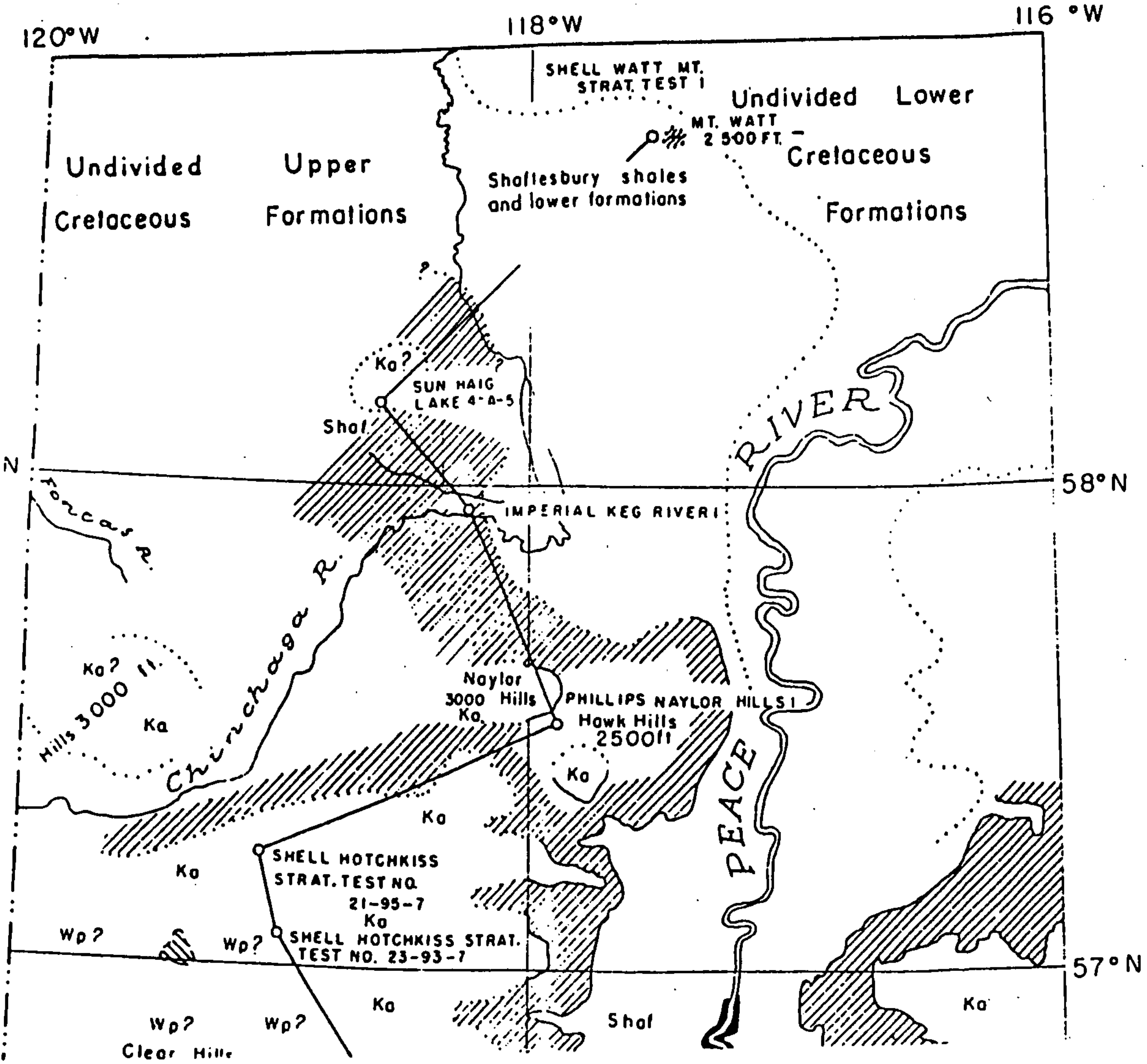


FIGURE 4

GEOLOGICAL MAP OF NORTHWESTERN
ALBERTA

Scale in Miles

20 10 0 20 40

LEGEND

UPPER CRETACEOUS

Wapiti formation ▨

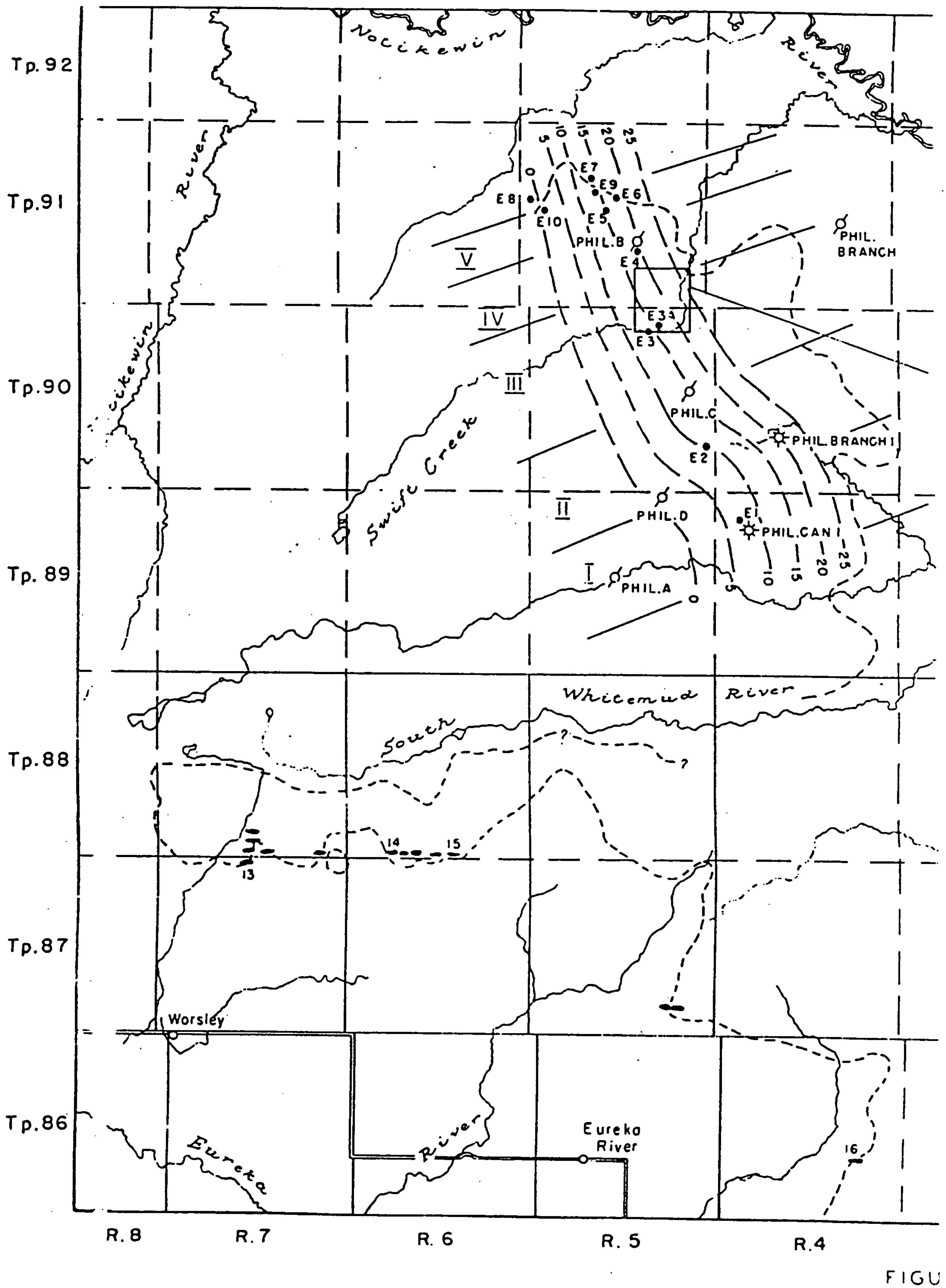
Wapiabi formation Wp

Bad Heart member -·-·-

Cardium formation - - -

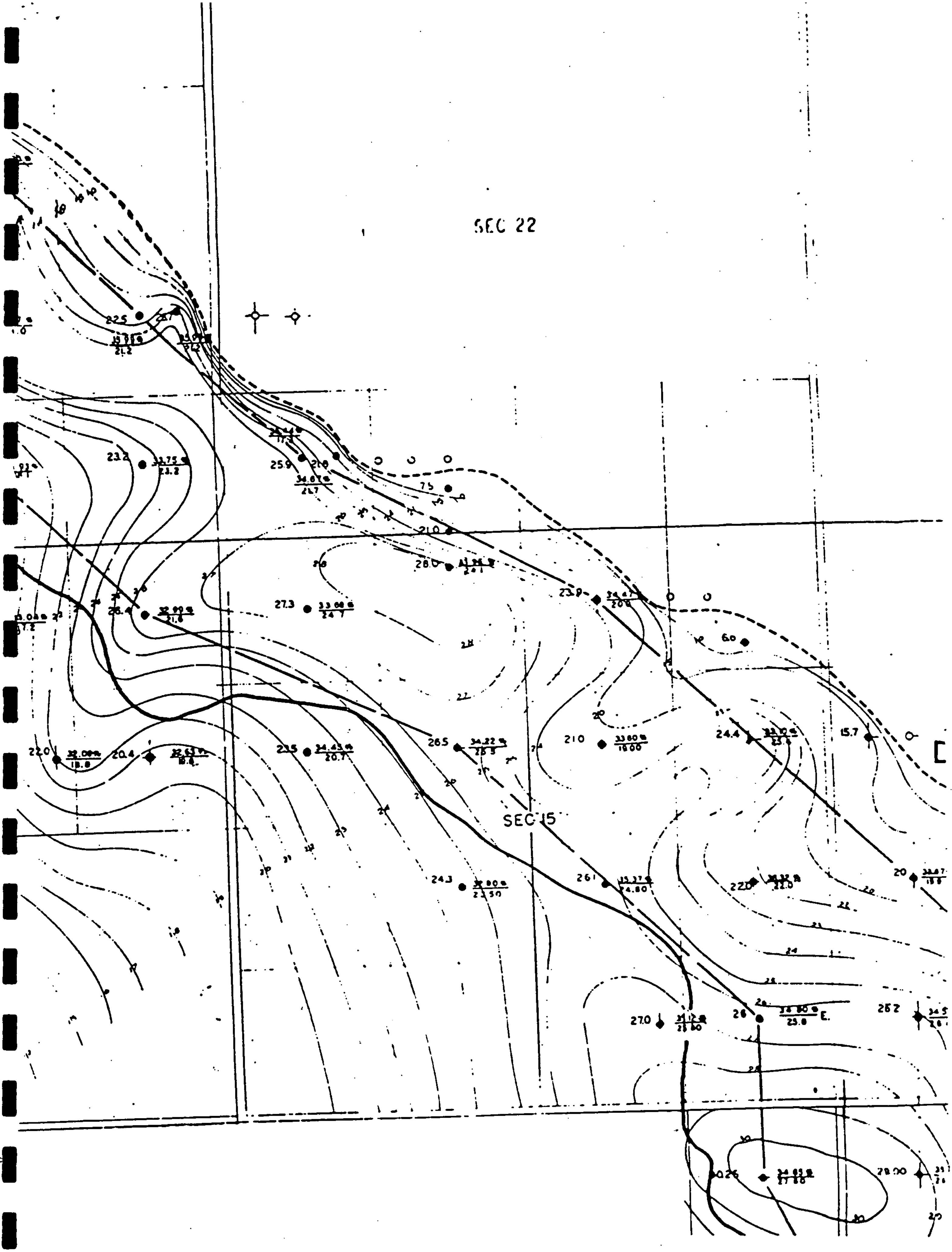
Kaskapau formation Ka

▨



FIGU

IRON DEPOSITS IN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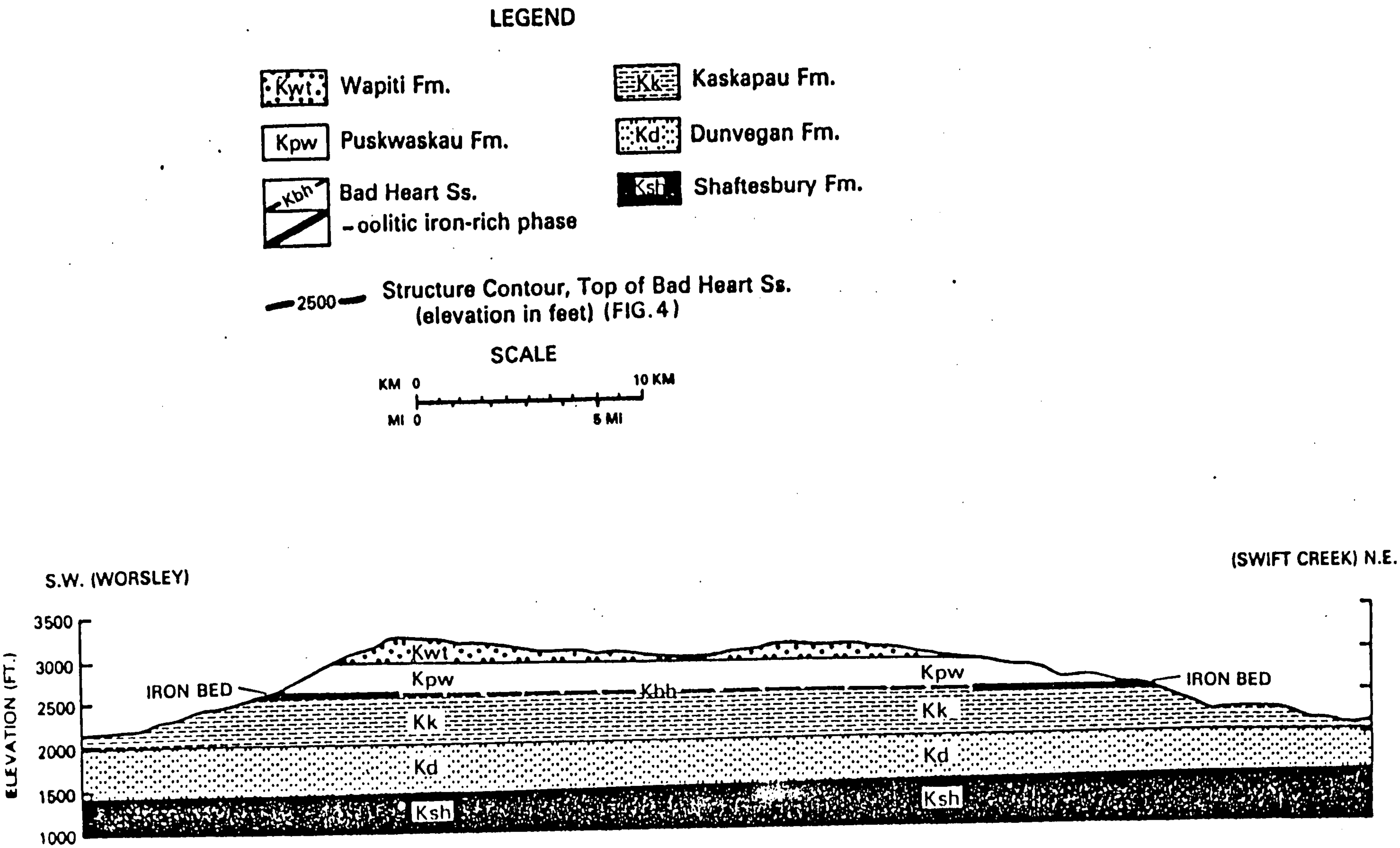


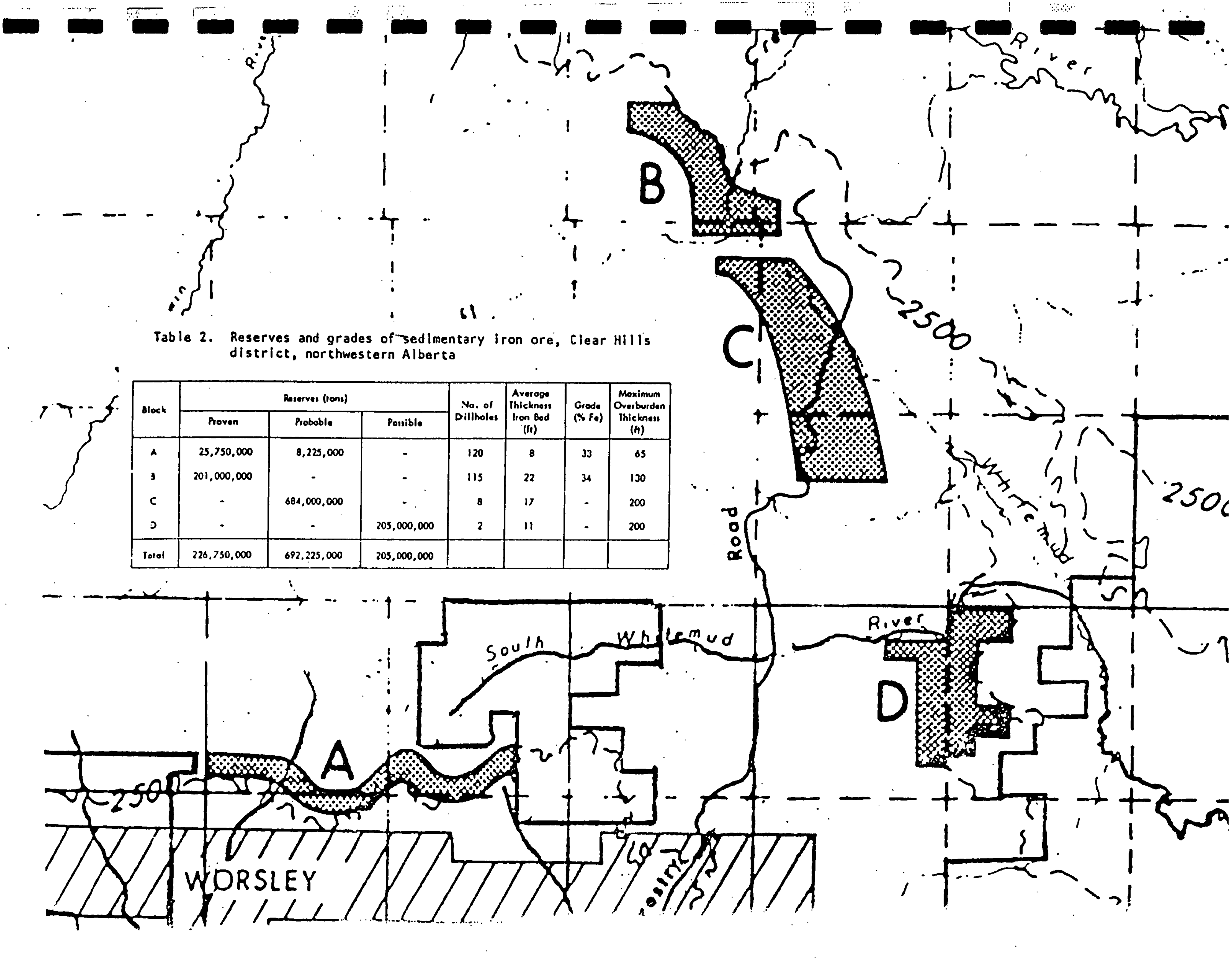
FIGURE 3. Schematic cross-section through the Clear Hills, showing stratigraphic setting of the iron formation.

Table VI

Typical Direct-Shipping and Concentrating Iron Ores

Type of Deposit and Location	Ore Minerals	Age	Associated Rocks	Chemical Composition per cent								Annual Production (Long Tons)	Reserves (Long Tons)	
				Fe	Mn	P	S	SiO_2	Al_2O_3	CaO	Moisture			
Sedimentary														
Oolitic														
Clear Hills, Alberta (1) Swift Creek	goethite siderite chamosite	Late Cretaceous	sandstone shale	31.55	0.18	0.45	0 - 0.7	25	6	1.5	10 - 12	nil	1.5 billion	#6.
(2) Worsley	goethite siderite chamosite	Late Cretaceous	sandstone shale	30	0.22	0.3	0.013	35	6	3	4 - 8	nil	100 million	
Birmingham, Alabama	hematite	Silurian	limestone shale	32 - 45	0.25	0.25 - 1.5	0.05	2 - 25	2 - 5	5 - 20	0.5 - 3.0	5 to 6 million	several billion	⑤
Wabana, Newfoundland	hematite siderite chamosite	Ordovician	sandstone shale	51	0.13	0.88	0.04	12	5	3	1.5	2 to 3 million	4 to 10 million	③
Central England	siderite chamosite	Jurassic	shale	28	2.24	0.07 - 1.2	0.04 - 0.74	2.10 - 32.7	2.81 - 16.8	1.9 - 33.85	15	12 to 20 million	3 billion	④
Lorraine "Minette" France, Luxembourg and West Germany	goethite hematite siderite	Jurassic	shale sandstone limestone	30	0.3	0.5 - 1.8	0.2	7 - 20	5	5 - 12	13 - 19	32 to 50 million	5 billion	②
Salzgitter, West Germany	siderite	Early Cretaceous	sandstone shale	25 - 33	0.2	0.4	-	21 - 30	7 - 8	4 - 7	-	3 million	1 billion	
Siderite														
Algoma, Ontario	siderite pyrite	Precambrian	banded chert and pyrite volcanic rocks	35	3	0.022	2 - 6	3 - 12	1.82	3 - 4	0.74	1 to 1.5 million	300 million	
Taconite														
Lake Superior region	magnetite	Precambrian	taconite	27.7 - 36.7	0.03 - 0.9	0.013 - 0.056	-	35 - 56	0.10 - 1.42	0.01 - 1.07	0.13 - 11.0	2 to 4 million	many billion	①
Other														
Choteau, Montana	titaniferous magnetite	Cretaceous	sandstone	44	0.5	0.02	0.05	17	5.2	1.6	-	nil	2 to 10 million	
Residual														
Lake Superior region	hematite goethite magnetite	Late Precambrian	banded chert	50 - 62	5	0.03 - 0.25	low	7 - 12	2	0.5	11	25 to 50 million	almost exhausted	
Labrador and Ungava, Quebec	hematite goethite	Late Precambrian	banded chert dolomite	50 - 61	0.08 - 8.0	0.057 - 0.13	0.01 - 0.03	3 - 8	0.22 1.5		10.0	12 million	over 600 million	
Steep Rock, Ontario	hematite goethite	Late Precambrian	dolomite iron formation volcanic rocks	53	0.18	0.28	0.3 - 0.4	6.5 - 8.1	1.4	-	9.4 - 9.7	2 to 3 million	over 300 million	
Cuba	hematite limonite magnetite		serpentine laterite	54	0.5 - 0.9	0.01	0.4	5.7	10 - 12	-	25	variable 0.2 million (1953)	several hundred million	
Replacement														
Adirondacks, New York	magnetite	Early Paleozoic?	granite gneiss	22 - 53	-	0.01 - 0.2	0.03 - 0.9	1 - 37	0.5 - 7	1.4 - 5.8	-	4 to 5 million	possibly 1.5 billion	
Cornwall, Pennsylvania	magnetite	Post-Cambrian	limestone skarn quartz diabase	29 - 43	-	0.016	2.00	16	5	4	-	1 million	not known	
Texada Island, British Columbia	magnetite	Jurassic	limestone skarn	41	-	0.05	1.44	4 - 8	2	1 - 4	-	0.2 to 0.5 million	not known	
Vancouver Island, British Columbia	magnetite	Jurassic	limestone skarn	50 - 65	-	0.004 - 0.121	0 - 3	3 - 12	-	-	-	0.4 to 1.3 million	not known	
Marmora, Ontario	magnetite hematite	Precambrian	gneisses marble	25 - 47	-	0.13	0.04 - 0.05	21 - 4	-	-	-	one million	20 million	

Compiled from many sources.



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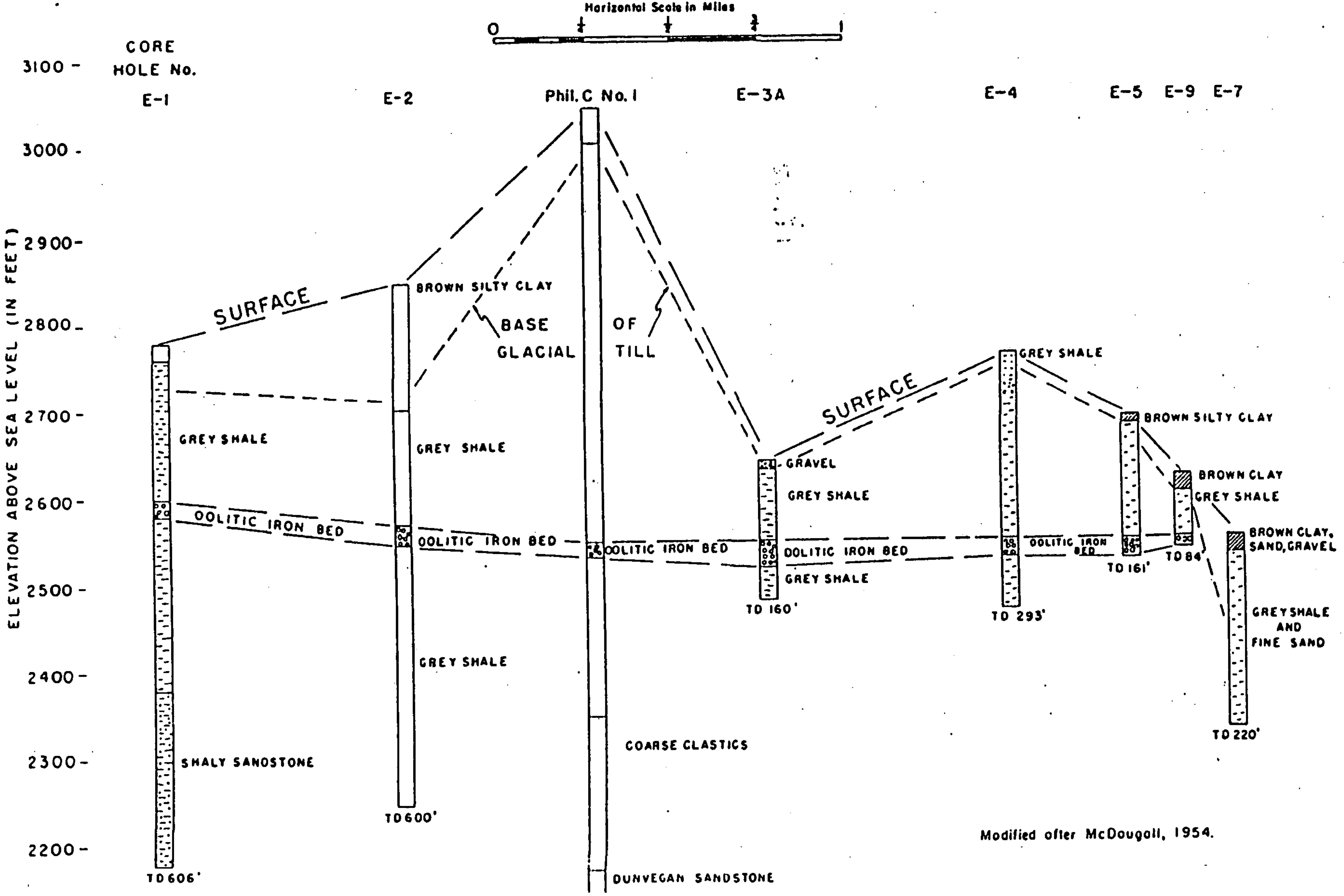
B	201,000,000	-	-	115	22	34	130
C	-	684,000,000	-	8	17	-	200
D	-	-	205,000,000	2	11	-	200
Total	226,750,000	692,225,000	205,000,000				

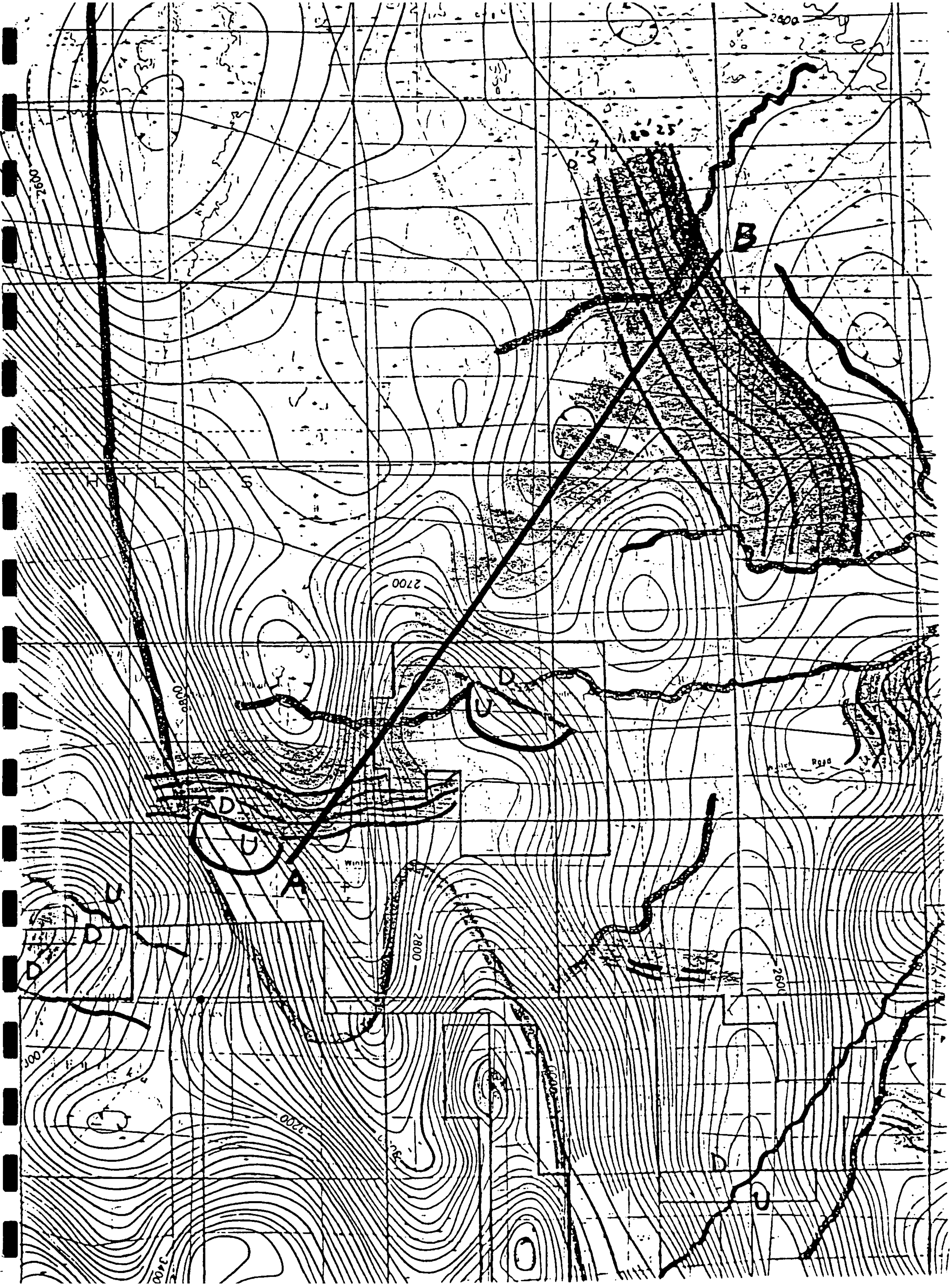
FIGURE 6

CORRELATION OF McDOUGALL'S CORE HOLES AND PHILLIPS' C NO.1 WELL

SWIFT CREEK AREA, CLEAR HILLS, ALBERTA



Modified after McDougall, 1954.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APPENDIX ~~11~~

9

SSN: A Powerful but Friendly Leach

by Walter Lashley
American Society for Applied Technology

A leach that is fast, powerful, inorganic, safe, and cheap—what more could a miner ask for?

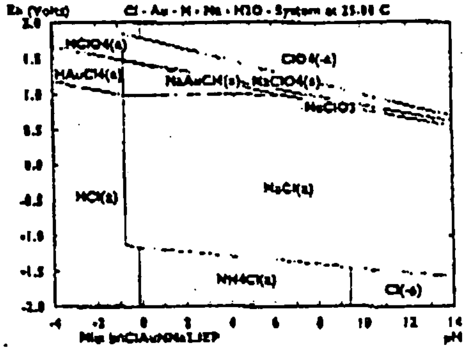
It started with a computer program from Finland that allows the user to do years of chemical mathematics in a matter of minutes. At the speed of light it flashes through thousands of chemical species in the database, selects the appropriate figures and fits them into the equation. In capable hands this program will calculate: reaction equations; heat and material balances; equilibrium balances; electrochemical cell equilibrium; formula weights; phase stability diagrams; and Pourbaix diagrams.

From the previous list the Pourbaix diagram is the most helpful, for it gives a visual picture of what happens and at what point it takes place chemically. Without the help of computers it takes months for a person to calculate and then draw one of these diagrams. ASAT is using a 386-SX with a math coprocessor and it takes the computer from ten to thirty minutes to calculate some of the diagrams that we will use in explaining how this leach works.

The Starting Point

Simplicity seems to be a concept that is difficult for the human mind to accept. If we cannot determine exactly what is happening in nature we automatically start looking for the complex and/or difficult. A common thread seems to move through the chemistry of gold and that is the use of salt to stabilize reactions. What happens if we start with salt alone?

Three hundred fifty grams per liter (2.92 lbs./gal.) of rock salt will do the job. Now let's hit it with some nitric acid, toss in a piece of gold, and see what the computer says.



When reading a Pourbaix the (a) indicates that the complex is in solution and (-a) states that the ion is negative. When there is no notation at all following the formula it states that the compound is in solid state. This diagram was drawn with chlorine as the elemental behavior sought and any reaction with gold is our prime interest.

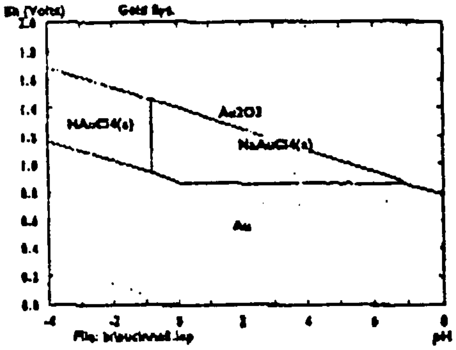
Unlike most Pourbaix diagrams the ones that we have requested do not stop at a pH of 0; they continue as negative numbers representing one mole acidic per number. In looking at the diagram it is apparent that there is little need for the solution to be over 1.5 Molar acid and the reduction/oxidation need not exceed 1.00 volts.. Our product will be sodium chloroaurate which will remain in solution until the pH of 6.2 or higher has been reached.

There is one important part that the computer program cannot as yet calculate: that is the dynamics of the chemical reactions. The next step is to check on those dynamics—at 25 degrees centigrade we have a pH of 1.2 and an ORP of 450 millivolts which is not enough to do it, or should I say that it does not look like enough to do it. Nitric acid slowly oxidizes the salt water and, as the loosely formed bond breaks, the chlorine is momentarily nascent. This "newborn" chlorine is, for a small fraction of a second, 100 times more powerful than elemental chlorine gas. In aqua regia the chlorine soon finds a second chlorine and becomes elemental chlorine, losing its power. Within the saltwater complex the chlorine combines with whatever is available and, if nothing is available, it reunites with sodium. In this way the chlorine is still there and can be triggered again and again. Couple this phenomenon with the fact that the reaction of chlorine with gold is exothermic and suddenly we have a self-sustaining chemical engine pumping heat directly into the spot where it is needed.

At this point we knew that the solution would leach gold but whether it was a valid and useful method had yet to be proven. We performed ten tests using a measured gold plate and setting the time at thirty minutes. As the tests progressed it was noted that the quantity of gold going into solution increased with each time the solution was used. The only variables that we were not controlling was a slight increase in temperature and the increasing gold content within the solution. We noted this fact and graphed the function. As we had already decided upon the first series of tests we continued, this time using 18K gold to represent 750 fine. The same curve appeared for the total metal removed with the gold being proportionate. This suggested that temperature was the cause.

Back to the Computer

Computers can be very cooperative if you know how to pose your question, so let's ask for the same chemistry at 80 degrees centigrade with the printout only involving the gold reactions. To keep it clean and simple, let's use only the positive voltages and pH no higher than pH 8 and down to 4 molar acid (the last is just for printing room). This gives us the upper left quadrant where the reactions of interest lie.



Required redox voltage dropped to just below 900 millivolts and the point of wasted chemistry begins at pH 0. In fact, the diagram implies that any pH less than pH 6.2 will dissolve gold. We tried it with the pH at 1.3 and 80 degrees C. Our test plate was 1.4 grams of 750 fine gold. Ken watched in fascination as the gold plate vanished in a matter of minutes. When he reported this, some larger pieces of pure gold were quickly chosen and inserted in the solution. They, too, vanished in minutes. Seven milliliters of solution dissolved a total of 4.5 grams of gold in fifty minutes. The solution was by no means saturated with gold but taking it to an end point would not gain information of great value.

Metallic copper is very slightly soluble in hydrochloric acid but it dissolved readily in the chlorates and perchlorates that are present in this leach. By the rules the solubility of gold in the presence of metallic copper should be nil but when both gold and copper are present in the same beaker neither metal seems to suffer a loss of lixiviation. Another observation during the test series was that regardless of how violent the reaction at the surface of the gold the odor of emitted chlorine was absent. This suggests that it re-combines with sodium rather than forming chlorine gas.

All eighteen minerals of gold are insoluble in both aqua regia and alkali cyanide which means that they escape recovery in many situations. Of these minerals the two most troublesome are aurocuprite and cupoaurite, both of which are compounds of gold and copper. SSN will leach both of these minerals. By the time this article has gone to press we will have checked the remaining sixteen minerals of gold. For the time being lets have a look at palladium, platinum and rhodium.

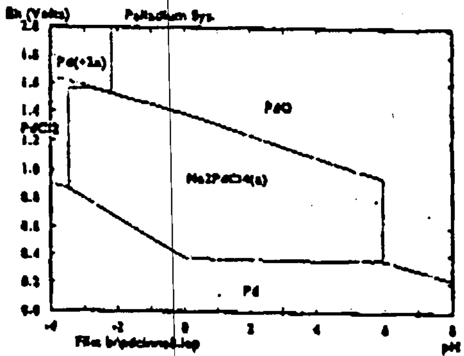
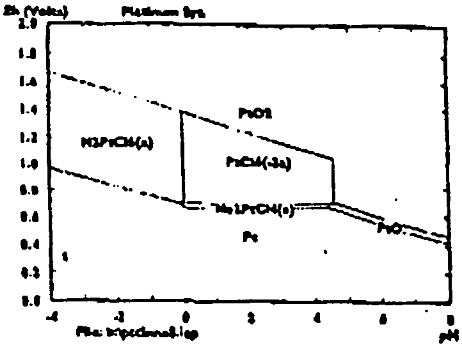
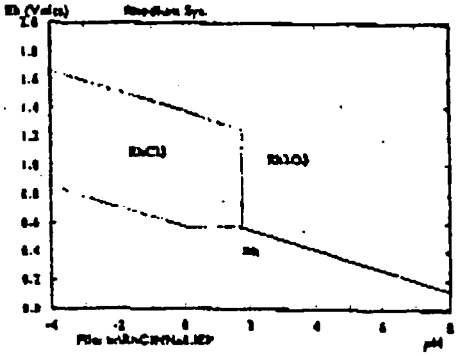


Diagram #3 suggests that palladium will leach at any redox above 400 millivolts and at any pH between pH 0 to pH 6. When fired alumina with palladium bonded to the surface was placed in SSN leach the reaction was immediate and quantitative. Massive palladium went into solution as rapidly as silver would in nitric acid. SSN is an excellent solvent for this metal. Palladium is the least noble of the PGM family so let's move on to platinum.

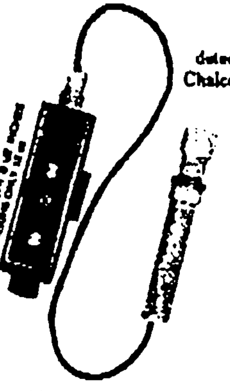


Platinum is more noble than palladium and Pourbaix diagram #4 shows that the window of solubility has begun to close. Redox is up to 650 millivolts and pH has narrowed to 4.5 or greater.

In an effort to check reality against theory, our tests involved both massive platinum and finely divided platinum. In both cases the lixiviation time was equal to that of gold.



With a raised eyebrow we ask the program for the Pourbaix diagram of



rhodium in SSN liquor. In all honesty, we felt that this was pressing our luck a little far. It takes about 60 seconds for the computer to respond for a "no go" situation. Sixty seconds later the crunch continued and we waited for another twenty minutes before the screen cleared and began to write. As you can see, we have a diagram stating that rhodium will dissolve in the SSN leach. The window has closed to pH 2 but it is still there.

Finely divided rhodium dissolved as easily as gold but the larger particles were a little slower. It is rare in nature that these metals would be found in a pure state and for that reason we produced a pea-sized bead of gold, palladium, platinum and rhodium equally proportioned. The solubility was total and the time was rapid.

Without running the Pourbaix diagrams we compounded a bead with all six PGEs present and tried again. This one was a failure, just as we anticipated. The insolubility of osmium, ruthenium and iridium blocked off the reaction with only the surface metals becoming involved.

Leaching Recovery

Flexibility is one of the virtues of this leach. SSN may be used for a weep type heap leach, flooded pit leach, or batch leach. The reaction time may be controlled by the temperature and/or the amount of nitric acid used. When the acid content is at its maximum efficiency the solution will not harm the skin, making the handling of the solution quite safe.

When used with pyrite and arsenopyrites the free gold dissolves before the pyrites have totally digested. In the case of entrapped gold the pyrites may be totally digested.

> ***There is no secret formula, no proprietary information, just a simple straight-forward leach...***

Recovery of the metals from solution posed no problem, for we used Butyl Diglyme to recover 999.99 gold and zinc cementation for the palladium, platinum and rhodium. We should add that we have a member on the East Coast that is developing a resin structured from thiourea for use in low level leach situations involving SSN leaching.

SSN has proven to be an excellent method of assay when the filters are folded in test lead and cupelled. Their results for both gold and PGEs are not only proven and weighable but a method of recovery demonstrated simultaneously. These assays may be of any size required from one to ten assay ton.

There is no secret formula, no proprietary information, just a simple straightforward leach; saturated salt water triggered with a small amount of nitric acid. Without the cooperation and financial support of the membership, ASAT would not be able to provide this information for the industry at large. If you find this information interesting and useful we could use your support as well. Call or write ASAT, P.O. Box 1705, Silver City, NM 88062-1705, phone (505) 388-5654.

BLM Extends Comment Period on Desert Management Plan

The Bureau of Land Management (BLM) has extended the comment period for the Northern and Eastern California Desert Coordinated Management Plan and environmental impact statement (EIS) to June 11, 1994.

This comprehensive multi-agency planning effort is designed to protect threatened and endangered species and their habitats within a 5.5 million-acre area in eastern San Bernardino, Riverside, and Imperial Counties. The BLM, U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game, and Joshua Tree National Monument are seeking the involvement of local, state, and federal agencies, private organizations, interest groups, and the public to identify issues and management actions that should be addressed in the draft management plan and EIS.

The management plan will direct future public land use decisions and the activities of cooperating local, state, and federal agencies. When completed and approved, it will provide specific guidelines for such uses as recreation, grazing, mining, and wilderness. The plan also will serve as the regional guidance document in the implementation of the USFWS' Desert Tortoise Recovery Plan.

Public comments will be accepted through June 11, 1994, at BLM's California Desert District Office, 6221 Box Springs Blvd., Riverside, CA 92507. For more information contact Dick Crowe at (909) 697-5216.

1.2 BULK LEACH EXTRACTABLE GOLD
(BLEG)
OR
BULK CYANIDE METHOD

The method is based on the selective dissolution of gold, silver and some of their compounds by dilute aerated solutions of sodium, calcium or potassium cyanide. Gold and silver are precipitated from the cyanide solution by either zinc dust or activated carbon. Once the gold has been concentrated by precipitation its concentration is determined by AAS after zinc or carbon is removed by fire assay or other chemical means.

The method was designed to try to overcome the gold population effects that occurs in low level gold samples by being able to treat very large samples and extract all the gold from the sample. The normal sample weight is approximately 5kgs and the only preparation necessary is to screen the sample to about 2mm before submitting to the laboratory for analysis. However, like all methods there are advantages and disadvantages with this method. Before we consider these let us look at the various stages in a BLEG analysis.

(A) Dissolution

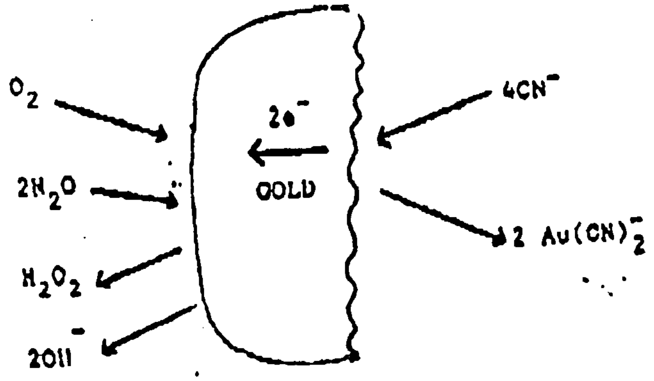
If the dissolution is regarded as an electrochemical corrosion process, then the gold may be considered to be going into solution at the anodic areas of the gold particle, while oxygen is reduced at the cathodic areas, and electrons are transferred through the metal from the anodic to the cathodic sites

i.e. at anodic:

$$2\ Au + 4\ CN^- \rightarrow 2\ Au(CN_2)^- + 2e$$

at cathodic:

$$O_2 + H_2O + 2e^- \rightarrow H_2O_2 + 2OH^-$$



Considering the above equations, it can be seen that a number of factors are important in ensuring that the gold present in the samples goes into solution.

(1) OXYGEN IN SOLUTION

Oxygen in solution is essential for the dissolution of gold in aqueous solutions at ordinary temperatures. The samples are normally made up to 50% solids with tap water as the first stage in the operation. Tap water contains between 5-10ppm dissolved oxygen and this concentration is all that is required to ensure dissolution. During the dissolution stage it is usual to agitate the sample, this not only ensures that the solution remains saturated with oxygen, but also that gold particles come in contact with the cyanide and oxygen. No attempt need be made to increase the partial pressure of oxygen over the solution e.g. by using high pressure air on oxygen, in enclosed vessels, since once the concentration of dissolved oxygen exceeds 25ppm the dissolution rate decreases.

....

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MINERALS EXPLORATION GEOLOGIST
11540 W. 27TH PL.
LAKEWOOD, CO 80215

(2) C ANIDE IN SOLUTION

The samples are made up to 50% solids with tap water and the cyanide is
added. A concentration of between 0.10 - 0.20% CN is used in most laboratories.
Cyanide is consumed or lost during the dissolution in a number of ways.
(a) If the pH is allowed to drop the NaCN is hydrolysed to HCN which is
volatile and poisonous. For this reason a pH of about 10.5 is required
throughout the operation to prevent hydrolysis:
(b) Iron sulphides, pyrrhotite and to a sser extent pyrite form ferrocyanides.
c) Copper minerals are readily soluble in cyanide solutions, with copper
rbonates e.g. malachite and azurite ca g the largest cyanide consumption.
(d) Arsenic and antimony minerals form c de complexes and reduce the
dissolution rates.
Because of the above here will be cyanide consumption during the dissolution
and so it is necess [illegible] the laboratory to closely monitor the cyanide
strength in solutior [illegible] st the concentration when necessary.

(3) PARTICLE SIZE

If a solution rate 3mg/cm^2 hr is taken as a rough avarage of the solution
rates met with in practice, it may be shown that a spherical particle 44um
diameter (325#) would take 14 hours to dissolve while a 149um sphere (150#)
would take 48 hours. This emphasises the importance of not using this method
if visible gold can be seen in the sample when collecting it.
After the sample has been in contact with the cyanide for a set time, usually
between 12-24 hours depending on the laboratory, floculating agents are added
to assist in clarifying the solution. A set weight of liquor is then extracted
and the process then proceeds to the precipitation stage.

(4) PRECIPITATION

As mentioned earlier several methods are available for precipitation gold
and silver from cyanide solutions. At present precipitation with zinc dust is
by far the most common technique used by laboratories doing BLEG work and so
we will consider this technique in more detail.
Gold and silver are quickly and completely cemented from cyanide solutions by
zinc according to following equation:

$$Zn + 2Au(CN)_2^- + 2\ Au + Zn(CN)_2^-$$

Copper is partly precipitated, numerous side reactions occur which lead to
consumption of zinc and or contamination of the precipitate. Zinc dissolves
readily in cyanide solution in the presence of oxygen so the solutions are
deaerated before precipitation.
Lead, in small amounts, improves precipitation by forming a lead - zinc couple,
and for this reason lead acetate or lead mitrate is usually added to very slow
and so 1 - 5ppm lead in solution is the maximum used.
When precipitation is complete, usually 30 - 60 minutes the vacuum is removed
and the sample is then filtered and the precipitate containing gold and silver
on zinc is recovered.

(5) DETERMINATION OF AU CONCENTRATION

Laboratories that utilize a fire assay finish then dry the precipitate, mix
with suitable fluxes and then go through the fire assay process as discussed
earlies. As the amount of gold in the final prill is likely to be very low
all laboratories do the gold concentration determination by AAS.

Laboratories using a wet chemical means dissolve the zinc in hydrochloric acid. After the zinc is dissloved aqua regia is added to dissolve the gold and this is then extracted into an organic solvent usually M.I.B.K. and read on an AAS.

This then is briefly the outling of the method. Let us now consider the advantages and disadvantages of the method.

(A) ADVANTAGES

(1) Because very large samples can be treated and all the gold extracted from the sample, very low detection limits can be obtained. Most laboratories quote a detection limit of about 0.05ppb on 50 ppt, compared with 5ppb by fire assay.
(2) Because the method treats the whole sample, the problem of obtaining a laboratory representative subsample is not encountered. As a result, accuracies such that one or two gold particles in the 5Kg sample should be detected. The method therefore overcomes the "gold population effects" in low level samples.
(3) Since no sample preparation is required, the only cost involved is that of the analysis. Most laboratories charge around $30.00 for this type of analysis.

(B) DISAVANTAGES

(1) The method is designed for grass roots stage exploration. It should be used to define target areas after which conventional exploration techniques i.e. pan concentrates and sieve analyses are employed. It is not designed for the evaluation of known exploration targets since the gold value obtained is not total gold as obtained by fire assay, but rather cyanide extractable gold.
(2) If visible gold is present in the sample, the method should not be used since not all the gold will be dissolved in the extraction time.
(3) Since each laboratory doing the method has different operation parameters e.g. extraction time, precipitating method etc. results from one laboratory will not be comparable with those from another laboratory. For this reason if you start a program with one laboratory you should maintain using that laboratory throughout the program.

10

APPENDIX ~~8~~

Not in this Report

Ron Evans

RESEARCH COUNCIL OF ALBERTA

Information Series No. 40

THE REDUCTION OF CLEAR HILLS IRON ORE BY THE R-N PROCESS

by

C.S. Samis and J. Gregory

Price 50 cents

RESEARCH COUNCIL OF ALBERTA

Information Series No. 40

THE REDUCTION OF CLEAR HILLS IRON ORE BY THE R-N PROCESS

by

C. S. Samis and J. Gregory

Research Council of Alberta
87th Avenue and 114th Street
Edmonton, Alberta
1962

CONTENTS

TABLES

THE REDUCTION OF CLEAR HILLS IRON ORE BY THE R-N PROCESS

I. INTRODUCTION

The development of an iron and steel industry is of prime consideration in the industrial growth of any nation or area. This statement is no less true for Alberta, and as a consequence the Research Council of Alberta has throughout its entire history been actively interested in the development of this vital basic industry. Indeed, the Research Council was established as a consequence of geological investigations on iron ore deposits in Alberta by Dr. J. A. Allan during the First World War. The interest and activity of the Research Council in this field has been particularly marked in recent years culminating in its participation in the semicommercial demonstration plant tests on the reduction of Peace River iron ore by the R-N process at Birmingham, Alabama.

This report traces the developments leading to the R-N testing program, and also offers a description of the tests and an analysis of the results.

II. HISTORY OF THE DEVELOPMENT OF THE PEACE RIVER IRON ORE DEPOSIT

In 1953 geologists of the Phillips Petroleum Company and of the Oil and Gas Conservation Board noted the presence of iron during the examination of core from a Phillips Petroleum Company well (Phil C No. 1 well). Subsequently the iron-bearing materials were found in three other Phillips wells.

In May, 1954, D. B. McDougall obtained an iron prospecting permit covering 100,000 acres in the Clear Hills area. He drilled 11 holes in the Swift Creek deposit and a report was written on the results of this work. For this investigation the chemical analyses were performed by W. E. Harris and K. B. Newbound at the University of Alberta, and the mineralogical analysis by C. P. Gravenor of the Research Council of Alberta. A bulk sample was sent to the Mines Branch of the Department of Mines and Technical Surveys. Later in 1954 a surface geological party was sent in by McDougall and a report was prepared by H. S. McColl of his staff. This report carries the first mention of outcrops along Swift Creek.

In 1956 mineralogical and age dating reports were prepared by A. C. Lenz at the University of Alberta under the direction of C. P. Gravenor. This was the first comprehensive report on the constituents of the iron-bearing material. In the same year the Research Council of Alberta sent R. Green and D. J. Kidd up to examine the Swift Creek deposit. Also in 1956, Premier Steel Mills Ltd. obtained a report from McDougall on his findings and took out several permits on the Swift Creek deposit.

In 1957, Premier Steel Mills Ltd. continued their investigations, working southwards, and along with a local farmer (Anderson) located the southern Clear Hills deposit. Also in 1957, G. L. Colborne, graduate student at the University of Alberta, examined the Swift Creek occurrence for Cleveland Cliffs Iron Company and wrote a thesis on this material.

In 1958, D. J. Kidd of the Research Council mapped all the outcrops along the southern Clear Hills indicating the best areas for further prospecting. Kidd made an estimate of 130 million tons available for strip-mining operations. At the same time, Premier Steel Mills Ltd. continued their operation in an examination of the Worsely occurrence by stripping operations.

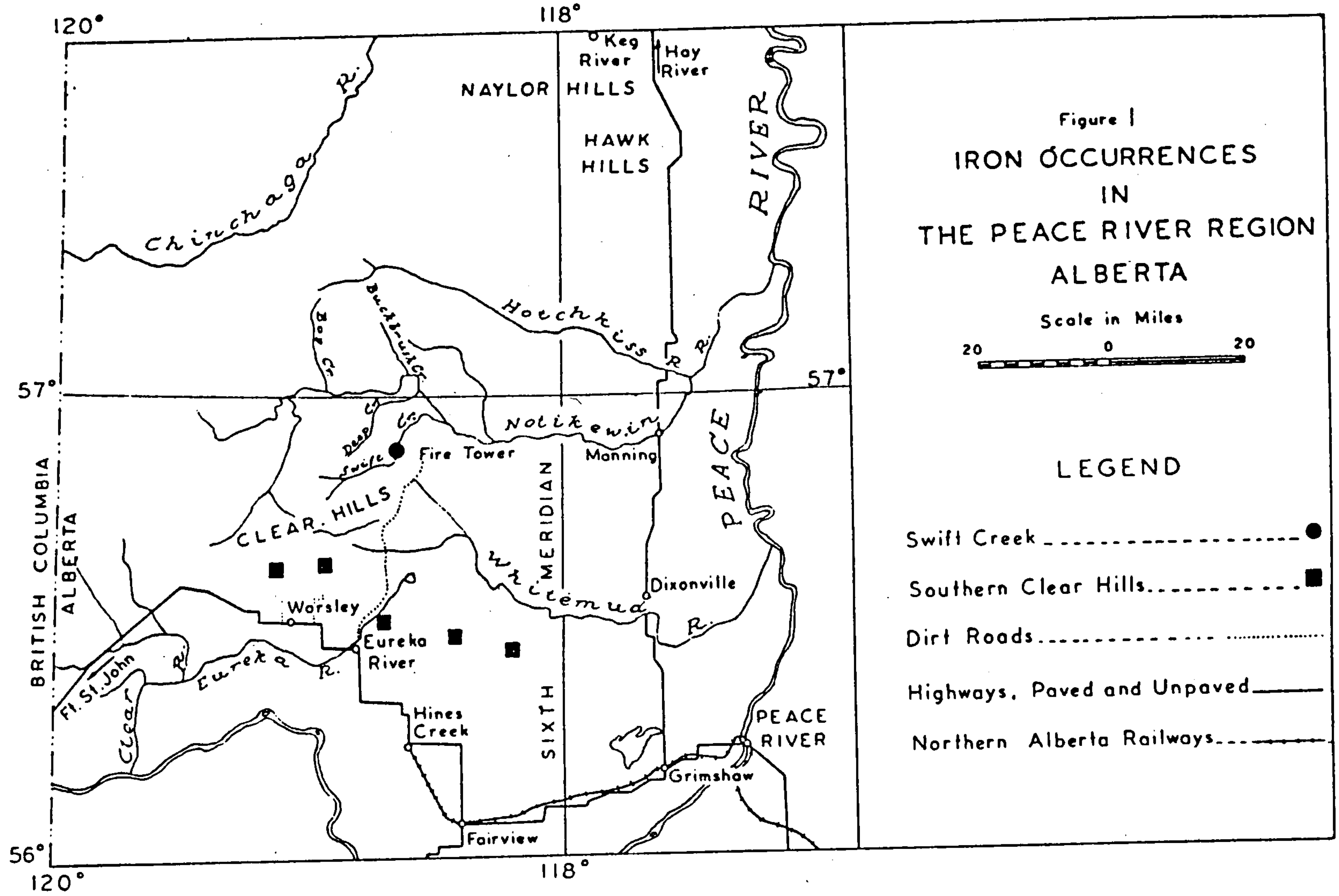

Figure 1
IRON OCCURRENCES IN THE PEACE RIVER REGION ALBERTA

Table 2. Chemical analyses of iron-rich samples, southern Clear Hills (after Kidd, 1959)

	Weight per cent				
	13	14	15	16	17
Total Fe	27.33	41.47	38.10	20.90	18.49
Mn Manganese	0.25	0.29	0.29	0.18	0.16
SiO_2 Silica	41.74	18.84	25.32	39.46	55.68
Al_2O_3 Aluminum	5.94	6.63	6.02	3.97	5.10
CaO Calcium	0.63	0.52	0.95	9.19	3.40
MgO Magnesium	0.83	0.82	0.48	1.05	0.90
TiO_2 Titanium	0.24	0.34	0.23	0.17	0.27
P Phosphorus	0.377	0.353	0.536	0.278	0.120
S Sulphur	0.007	0.012	0.008	0.032	0.015
C Carbon	0.65	0.66	0.58	2.55	1.10
Combined water	6.84	8.79	7.60	5.37	3.27

Sulphur content ranges from zero to 0.03 per cent (Kidd, 1959). The five analyses of the samples from the southern Clear Hills show an average of 29.2 per cent iron.

The silica and phosphorus content would appear to be high for long-established North American smelting methods but apparently a concentrate can be prepared which is suitable for blast furnace operation (Kidd, 1959). The percentages of other constituents such as sulphur are within metallurgically acceptable limits.

In the absence of a detailed drilling program it is difficult to give an accurate assessment of reserves. Based on available data, Kidd (1959) has suggested 1.5 billion tons for the Swift Creek deposit and 136 million for the southern Clear Hills deposit. In terms of strippable reserves the Swift Creek estimate might have to be reduced due to the heavy overburden on certain parts of the deposit.

Other ferruginous Cretaceous sandstone deposits in the Peace River region have been reported from the Dunvegan area, Spirit River Town, and the Smoky River (Kidd, 1959). Some of these deposits are similar petrographically and chemically to those described from Swift Creek but very little is known about their extent.

that steel plants totalling a capacity of 400,000 tons per year have been established in the four western provinces. In addition, the centrifugal casting plants of Anthes-Imperial at Calgary and Griffin Wheel Company in Winnipeg require an additional 40,000 tons of iron per year. Recent years have witnessed the amazing growth of pipe mills and their combined capacity is in excess of 1,000,000 tons per year. With the exception of the Saskatchewan plant the skelp for remaining plants is imported into Western Canada.

While the iron needs of the present rolling mills have been met by scrap supplies, the future expansion of the iron and steel industry together with the requirements for the pipe mills is raising the question of a basic source of supply of iron. The Consolidated Mining and Smelting Company of Canada Ltd. are already producing pig iron from their iron-rich tailings. Interest is also being shown by various groups in the Kelsey Lake deposits of Saskatchewan, the Peace River deposits, the Burmis magnetic sands, and the magnetites of Dillon, Montana.

V. STEPS LEADING TO R-N TESTS

Metallurgical Investigations

It was early apparent to Premier Steel Mills Ltd. that the Peace River iron ore was unsuitable as a blast furnace feed and the company began investigating various methods of processing low-grade ores.

At Watenstedt, Germany, a plant was in operation on a large scale utilizing low grade ores. The process in use was the Krupp-Renn process, a rotary kiln method using low-grade coal for reduction and oil or powdered coal for fuel. In 1956, samples of the ore and of Alberta coal were sent to Germany for pilot plant tests. Following satisfactory results on the test, Premier Steel Mills Ltd. sent a technical team to Germany to observe the commercial operation at Watenstedt. The basic conclusion arrived at by the team was that the process was satisfactory but that the product was unsuitable for anything but blast furnace charge material.

It was then recommended by Dr. Colclough of the British Iron and Steel Research Association, W. Voice of the British Iron and Steel Research Association, and P. E. Cavanagh of the Ontario Research Foundation that further work be done toward concentration of the ore. As a result, Cavanagh of the Ontario Research Foundation was commissioned to carry out a program of investigation involving flash roasting and magnetic concentration. Preliminary tests indicated that a concentrate running 54 - 56 per cent iron which was suitable charging material for a blast furnace could be produced.

Following these laboratory test results which indicated that the Peace River ore could be concentrated up to a grade of 54 - 56 per cent iron, it was decided that further work should be done on the geological and mining end of the project, and in 1958 a program of development was initiated calling for the drilling of closely spaced holes to definitely prove tonnage, grade, and overburden. Unfortunately, great difficulty was encountered in recovering reliable samples by standard drilling techniques and the program was abandoned until a suitable technique could be developed. In the meantime, some large bulldozer cuts were made into the deposit and bulk samples were taken for further metallurgical work. In late 1959, a dry drilling technique using an air blast to bring up the sample was tested and found to work successfully, and by March 1960 25,750,000 tons averaging 32.65 per cent iron had been proven.

below the melting point of the materials, and with subsequent concentration and briquetting of the metallic iron. The process had been successfully demonstrated during five years' operation of the R-N pilot plant, Birmingham, Alabama, on a great variety of ores and concentrates with iron contents from about 30 per cent iron to 70 per cent iron, and with ore particle sizes ranging from about 20 mesh to about 1 inch. Even very fine-grained ores and concentrates with particle size less than 200 mesh have been successfully treated after pelletizing the material before processing. As the process is carried out below the melting temperature of the materials, the process is suitable to basic as well as acidic ores. Thus the versatility of the process as regards ore grade and ore particle size has been thoroughly established.

A similar versatility has been established with respect to the fuel requirements of the process. The fuel requirements consist of:

1. Solid carbon for reducing agent

The solid carbonaceous matter is mixed with the ore and acts as reducing agent for the iron oxides, forming CO which is combusted above the ore bed in the rotary kiln. A wide variety of carbonaceous matter as, for instance, coke breeze, anthracite and char with low as well as high sulfur and ash contents, have been used successfully for this purpose.

2. Additional gaseous fuel for heating the kiln load

For this purpose, it has been established that natural gas, mineral oils (heavy as well as light), coal char gases, and other industrial gases of similar composition can be used. An extremely important development in this respect is the development of special processes for charring coking as well as noncoking coal - processes which can be integrated with the R-N reduction kiln, producing char for reducing agent and hot char gas as fuel for the kiln. Thus, coal, coking or noncoking, can be used as the sole source of fuel required for the process. The possibilities of the R-N process are thereby greatly enhanced and expanded, especially for locations and countries which lack coking coals for conventional steel production or where gaseous fuel is costly.

Description of the R-N Pilot Plant

The R-N plant consists primarily of a large, rotary kiln similar to a cement kiln. Ore mixed with a solid reductant such as coke breeze or coal char is fed into the kiln which is fired by oil or hot combustible gases as, for instance, char gas or partially combusted natural gas. The material travels through the kiln, is heated up and reduced to metallic iron progressively in counter-current to the kiln gases. The discharge from the kiln is cooled, separated from excess coke, ground and magnetically separated for removal of gangue, leaving a high-grade metallic iron concentrate which is pressed into briquettes suitable for steel melting stock.

The rotary kiln is 150 feet long with 9 feet OD and 7 1/2 feet ID. Spaced along the length of the kiln and penetrating the kiln wall are 6-foot-long, open-end air inlet tubes, extending to the axis of the kiln. Through these tubes regulated amounts of air are introduced for progressive combustion of the combustible gases in the kiln. Each tube acts as an inverted burner, admitting air into a stream of combustible gas. Instead of one strong, high-temperature flame, as in the case of only one burner at the end of the kiln, there are as many smaller flames as there are air tubes. This system of heating provides very precise control of the temperature profile over a major portion of the kiln, with corresponding increase of capacity and with relatively low flame temperatures in the kiln, minimizing the danger of clinkering.

For temperature control, ten thermocouples are mounted in the kiln. Thermocouple No. 1 measures the temperature in the stationary precombustion chamber at the discharge end of

Natural Gas

The heat value of the gas was 1,042 B.t.u. per cu. ft. Its analysis was:

CH_4	93.8 %
C_2H_6	2.6 %
C_3H_8	0.6 %
C_4H_{10}	0.25%
C_nH_n	0.25%

In the combustion chamber of the kiln, the gas is partially combusted and the resulting hot combustible gases are passed into the kiln.

Limestone

Limestone is normally mixed with the feed to effectively minimize the sulfur content of the R-N product which usually contains less than 0.05 per cent sulfur, even when relatively high sulfur content ores and fuels are used. In the first part of the test, a locally available limestone with particle size minus 3/16 was used. Later the addition of limestone was discontinued as the amount of lime in the ore itself seemed to be sufficient for sulfur removal.

Water

Water is used for cooling the kiln bearings, for indirect cooling of the kiln discharge, and for wet grinding, classification, and separation.

Operation

During the period from August 1 to October 9, 1960, two tests were made in the R-N pilot plant on 5,285.60 net tons of Clear Hills ore, supplied by Premier Steel Mill Ltd., Edmonton, Alberta, Canada. The first test was made on 3,486.05 net tons of ore from August 1 through September 2, and the second test on 1779.55 net tons of ore from September 17 through October 9.

The purpose of the tests was to demonstrate the amenability of the Peace River ore to treatment by the R-N process under conditions to allow realistic, economic projection to commercial scale. For any ore tested in the pilot plant, a "run-in" period is required to reach the optimum conditions, before a so-called "steady state" period can be established, during which complete operational data and heat and material balances are obtained as a basis for the commercial projection.

In the first test run, the ore "as received" was crushed to 5/8 inch prior to feeding to the kiln. The amount of fines in the ore "as received" and as created by crushing and handling was considerable - at times, the ore, as fed to the kiln, contained as much as 70 per cent minus 6 mesh. As the amount of fines varied, it was difficult to maintain an even load in the kiln. Besides, the presence of the fines necessitated a very close temperature control on the kiln in order to avoid sintering when operating so close to the softening temperature of the ore fines. Although sintering deposits on the walls were not formed, considerable difficulties were experienced with loose sinter deposits of fine particles on the thermocouple protection tubes requiring constant exchange and cleaning of thermocouples. In the latter part of the test run, some of the ore fines

As further research on the concentration circuit seemed to be needed, four one-thousand-pound samples of concentrate were shipped to the following laboratories for study:

Department of Mines and Technical Surveys, Ottawa
Ontario Research Foundation
Department of Mining and Metallurgy, University of Alberta
Wright Engineering, Vancouver, B.C.

Test II was carried out from September 16 to October 9, 1960. An additional 1800 tons were received and treated in this period, with the procedures evolved towards the close of the previous period. The ore for Test II had been exposed to heavy rains in transit and on the stock pile and presented more feeding problems due to sticking in the bins and passages. However, the last fourteen days of operation were satisfactory and gave an average metallization of 90 per cent. The "steady state" period ran from October 3 through October 7 and is presented as basis for commercial projection.

Observation

The R-N Corporation welcomes observers representing their clients. The supervisory personnel of the corporation were most cooperative and willing to discuss all aspects of the operation and to answer any questions. Photostatic copies of daily data sheets were made available to all observers. All observers were impressed with the complete openness and objectivity with which the R-N personnel discussed all matters. The following observers were present during various phases of the tests:

Dr. C. S. Samis, Professor of Metallurgy, University of British Columbia, representing Premier Steel Mills, Ltd., Edmonton.
Mr. L. R. Cunningham, Premier Steel Mills, Ltd., Edmonton.
Mr. John Gregory, Research Council of Alberta, Edmonton.
Mr. George Sibakin, Metallurgist, Steel Company of Canada, Ltd. Hamilton.
Mr. George Viens, Head, Pyro-metallurgical Section, Department of Mines and Technical Surveys, Ottawa.
Dr. John Dartnell, representing Stewarts and Lloyds, England.
Mr. G. G. Ridley, representing Stewarts and Lloyds, England.
Mr. P. Audette, Steel Company of Canada Ltd., Hamilton.
Mr. D. K. Pickett, Department of Mines and Technical Surveys, Ottawa.

VII. R-N CORPORATION TEST RESULTS

The test results were compiled by the R-N Corporation and presented to Premier Steel Mills in reports entitled:

(1) Spaulding Pilot Plant Test Report, Premier Steel Mill Ltd., Canada, August 1 to October 9, 1960
(2) R-N Report No. 179, R-N Commercial Facility Projection of Premier Steel Mills Ltd. Peace River Ore, Cases 1 & 2

Summary

The "steady state" period from October 3 through October 7 is representative of stable, controlled operations of the pilot plant on this ore. The results and data obtained during

Table 4.

R-N SPAULDING PILOT PLANT

Peace River Ore

2nd Test - Steady State

Oct. 3 - Oct. 7, 1960

Metallization 90.86% Recovery 74.22% actual, 83.17% corrected

Item	Natural Tons	% Water	Dry Tons	% Iron	Tons Iron	% Silica	Tons Silica	% Carbon	Tons Carbon	% Ash	% Met.	% Al_2O_3	% CaO	% P
						RAW MATERIALS								
Ore (plus Pellets)	527.89	14.51	451.28	40.17	185.28	18.50	83.48	1.65	7.43	-	-	7.45*	3.66*	0.69*
Fresh Coke	110.35	13.45	95.51	3.53	3.37	9.23	8.82	76.34	72.91	21.04	-	-	-	-
Recycle Coke	177.91	19.53	143.17	5.35	7.66	9.79	14.01	73.53	105.27	25.52	34.77	-	-	-
Limestone	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL IN	816.15	15.46	689.96	28.45	196.31	15.41	106.31	26.90	185.61	-	-	-	-	-
						CONCENTRATE								
Final Concentrate	121.21	7.84	111.71	90.00	100.54	3.56	3.98	0.25	0.28	-	94.10	2.31	0.76	0.29
Special Sample	4.05	37.45	2.53	50.43	1.28	26.28	0.66	2.19	0.06	-	-	-	-	-
Filter Cake to Pellets	92.52	15.38	78.29	62.00	48.54	14.65	11.47	3.46	2.71	-	76.74	-	-	-
						WASTES								
First Stage Tailings	5420.00	97.01	162.12	21.18	34.34	39.68	64.32	7.78	12.62	-	46.51	-	-	-
Second Stage Tailings	5001.00	99.43	28.35	18.10	5.13	39.26	11.13	0.53	0.15	-	28.86	-	-	-
Kiln Tailings	6329.00	99.73	17.09	19.78	3.38	19.02	3.25	38.15	6.52	-	36.13	-	-	-
Stack Loss (Est.)	9.55	-	9.55	23.88	2.30	15.71	1.50	23.12	2.20	-	-	-	-	-
Spillage	1.22	13.94	1.05	50.48	0.53	10.48	0.11	4.76	0.05	-	-	-	-	-
Total Waste	-	-	218.16	20.94	45.68	36.81	80.31	9.87	21.54	-	-	-	-	-
Recycle Coke	177.91	19.53	143.17	5.35	7.66	9.79	14.01	73.53	105.27	25.52	34.77	-	-	-
TOTAL OUT	-	-	553.86	-	203.70	-	110.43	-	129.86	-	-	-	-	-

Gas MCF	Power KWH	Recycle Coke Ratio	Kiln Gas - Average Analysis - % By Volume CO	CO_2	CH_4	O_2	H_2
2119	116,000	1.50	3.0	15.5	1.9	0.7	1.2

KILN TEMPERATURES, DEGREES F.

	Kiln Speed MPR	#1	#2	#3	#3A	#4	#5	#6	#7	#8	#9	F.E.H.	Stack	Kiln Disc.	Cooler Disc.	WEATHER Avg. Temp. °F	Avg. Hum. %
Avg. Gas	5:39	1885	1964	1976	1962	1960	1943	1936	1915	1910	-	904	507	1169	-	73	82
Avg. Bed	-	-	1907	1895	1886	1880	1869	1864	1817	1568	-	-	-	-	288		

*For ore included only - for composition of ore plus pellet feed, see following page.

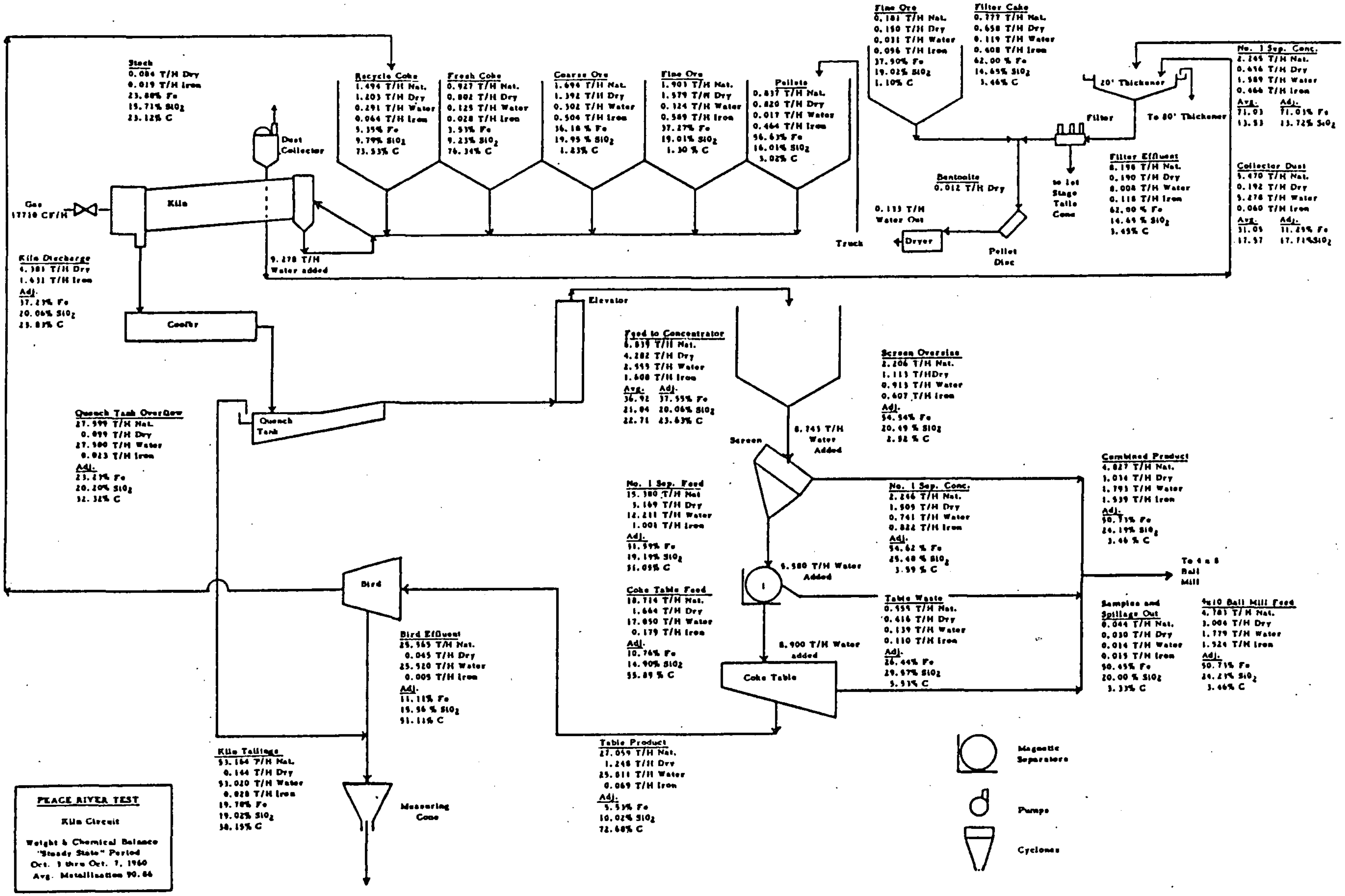

Figure 2. Peace River test - kiln circuit

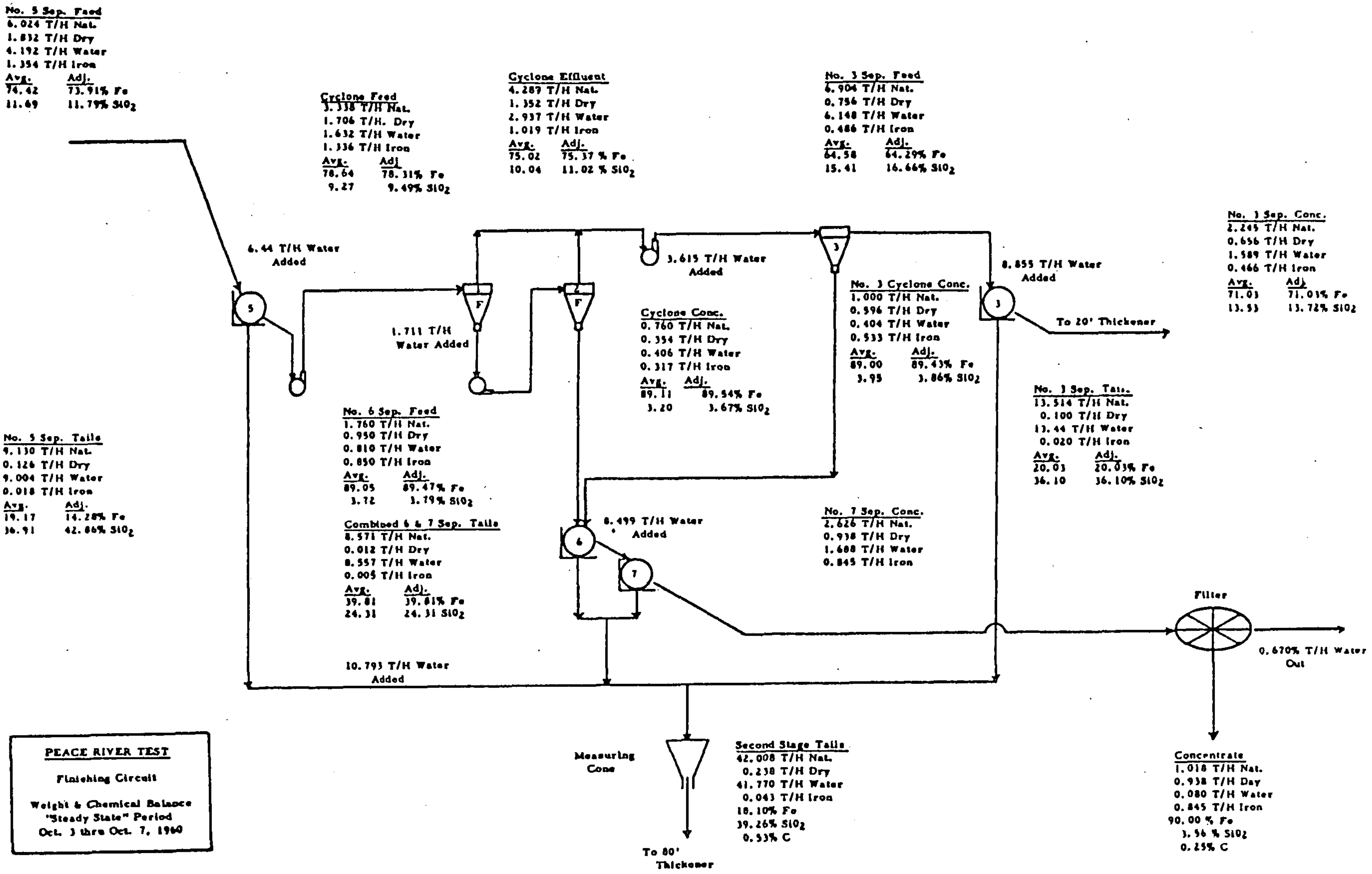

Figure 4. Peace River test - finishing circuit

Footnotes:

(1) The moisture content of the ore, as processed during the test, was higher than expected for commercial conditions.

(2) This lower value of heat in the unburned gases is approximately one million B.t.u. per ton of concentrate more than was actually obtained from the heat balance calculations of the period August 3 to August 10 and is equivalent to 3.5 per cent combustibles in the exhaust gas. The per cent combustibles for this period was just over 2 per cent as compared to over 6 per cent for the "steady state" period. During the "steady state" period no particular effort was made to reduce the combustibles in the exhaust gas since the reduction of iron was of prime importance.

(3) During the latter part of the test it was necessary to borrow a magnetic separator from the location in the circuit where the initial separation is made. Single separation instead of the usual double separation was thus employed. Consequently, more carbon was carried into the milling circuit and thus lost in the first stage tailings. These units of carbon would have normally been reclaimed with the recycle coke. This condition increased the physical carbon loss. It is estimated that the pelletizing of all the fine ore will further reduce the physical carbon loss to approximately 2.0 million B.t.u. per ton of concentrate.

(4) The heat input needed to balance with the reduced heat requirements (output) is made up with coke and gas at the same ratio as actually used during the "steady state" period.

Iron Recovery Calculations

Actual Iron Recovery

The actual iron recovery, as determined for the daily and period summaries in this report, are based on the amount of iron in the final concentrate yielded from the amount of iron in the ore only. The calculation is made as follows:

$$\frac{\text{Tons of Fe in Concentrate}}{\begin{matrix}\text{Tons Fe in Ore} \\ \text{Including Pellets*}\end{matrix} - \begin{matrix}\text{Tons Fe in} \\ \text{Filter Cake*}\end{matrix}} \times 100 = \%\ \text{Fe Recovery}$$

*Pellets included ore and filter cake. The filter cake is composed of kiln collector dust and recirculated milling circuit material, and therefore does not contribute new units of iron.

For this "steady state" period this method of calculation gives:

$$\frac{100.54}{185.28 - 48.54 - 1.28^{*}} \times 100 = 74.22\ \%$$

*Units of iron removed from circuit for special 4 x 10 ball feed sample.

Spillage Free Recovery

Another method for expressing iron recovery is by assuming a spillage free operation. This value is practical in commercial projection since large scale continuous operations would have

Plate 1. R-N briquettes

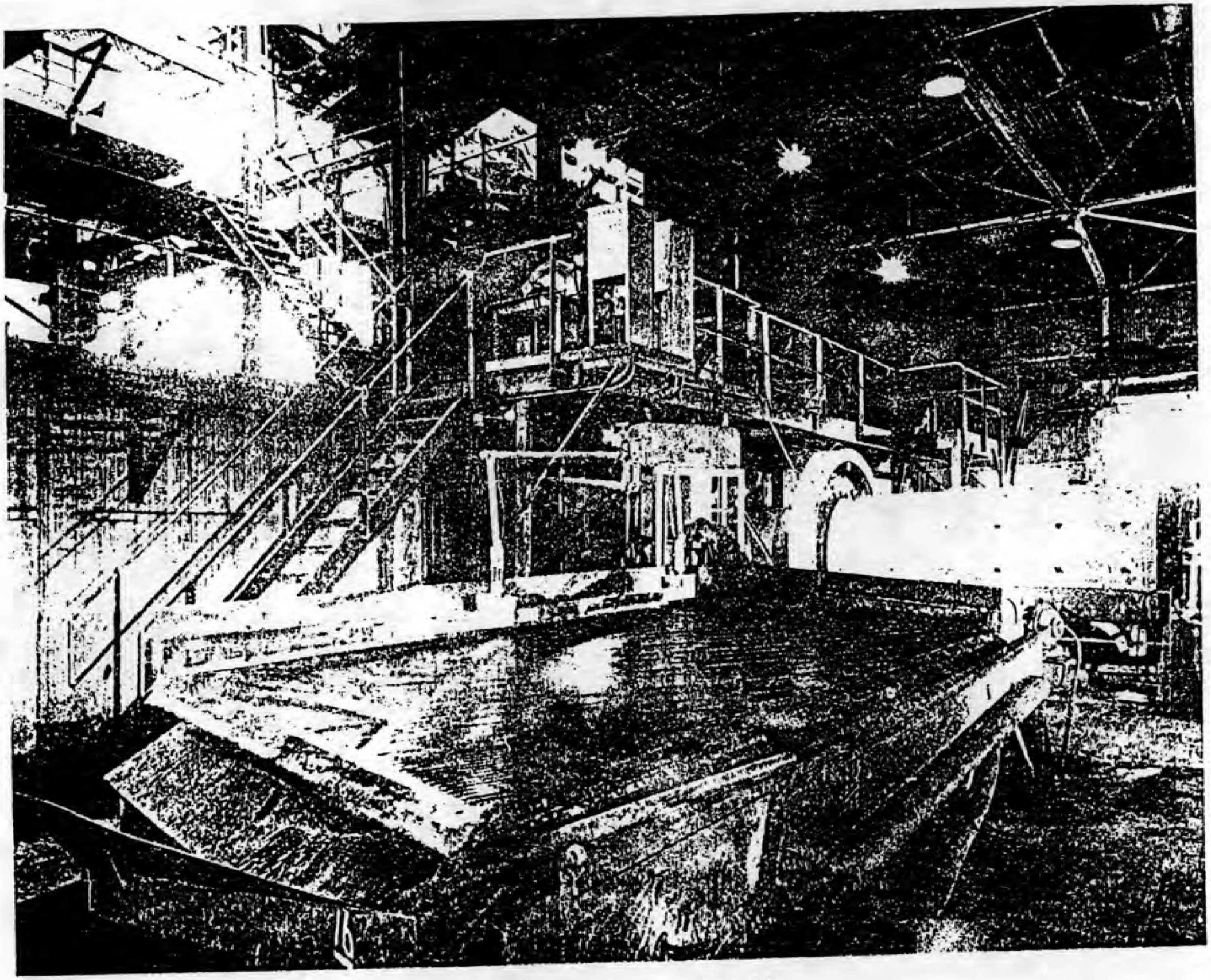

Plate 3. Excess coke recovery table

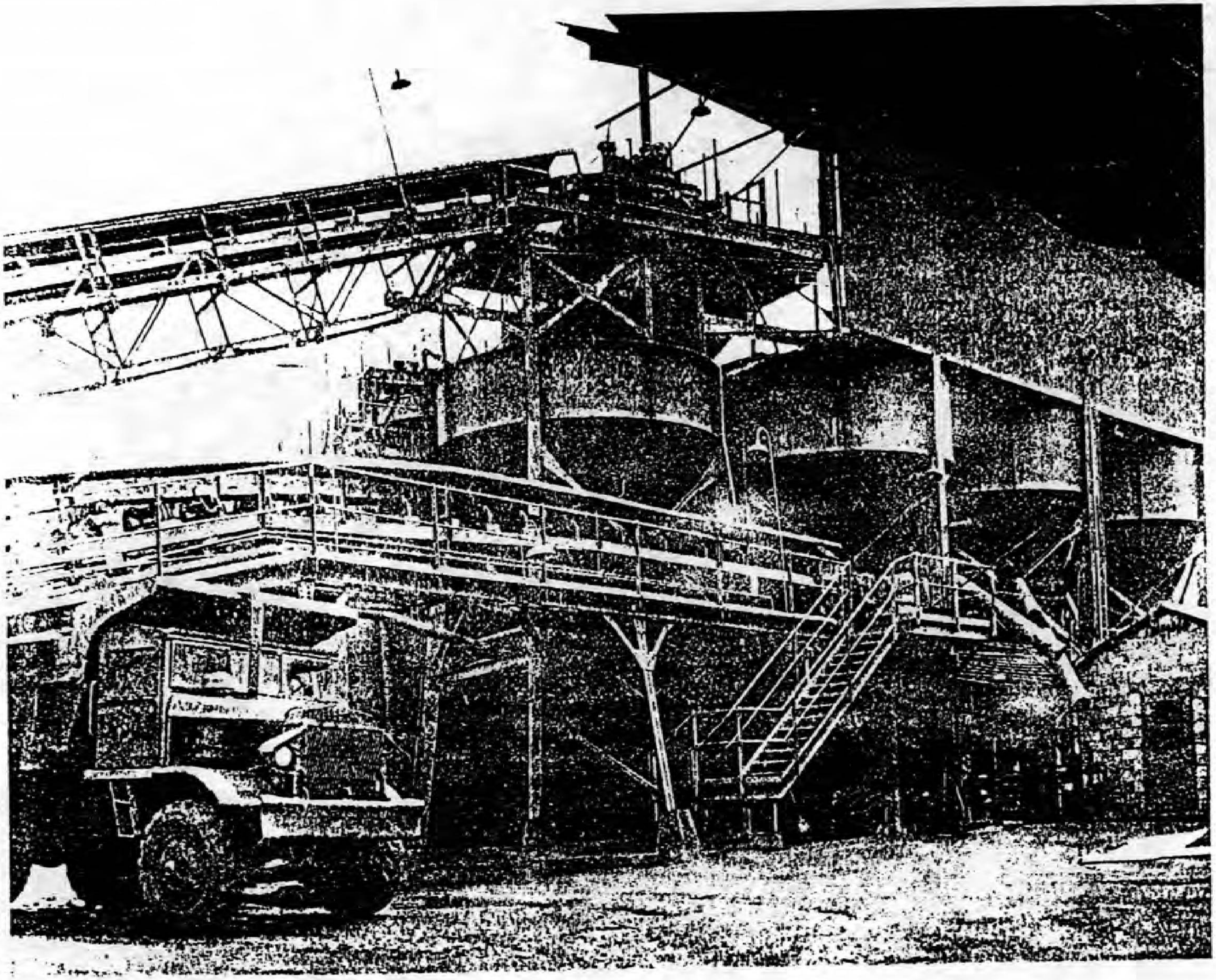

Plate 5. Recycle coke, ore, coke and limestone kiln feed hoppers

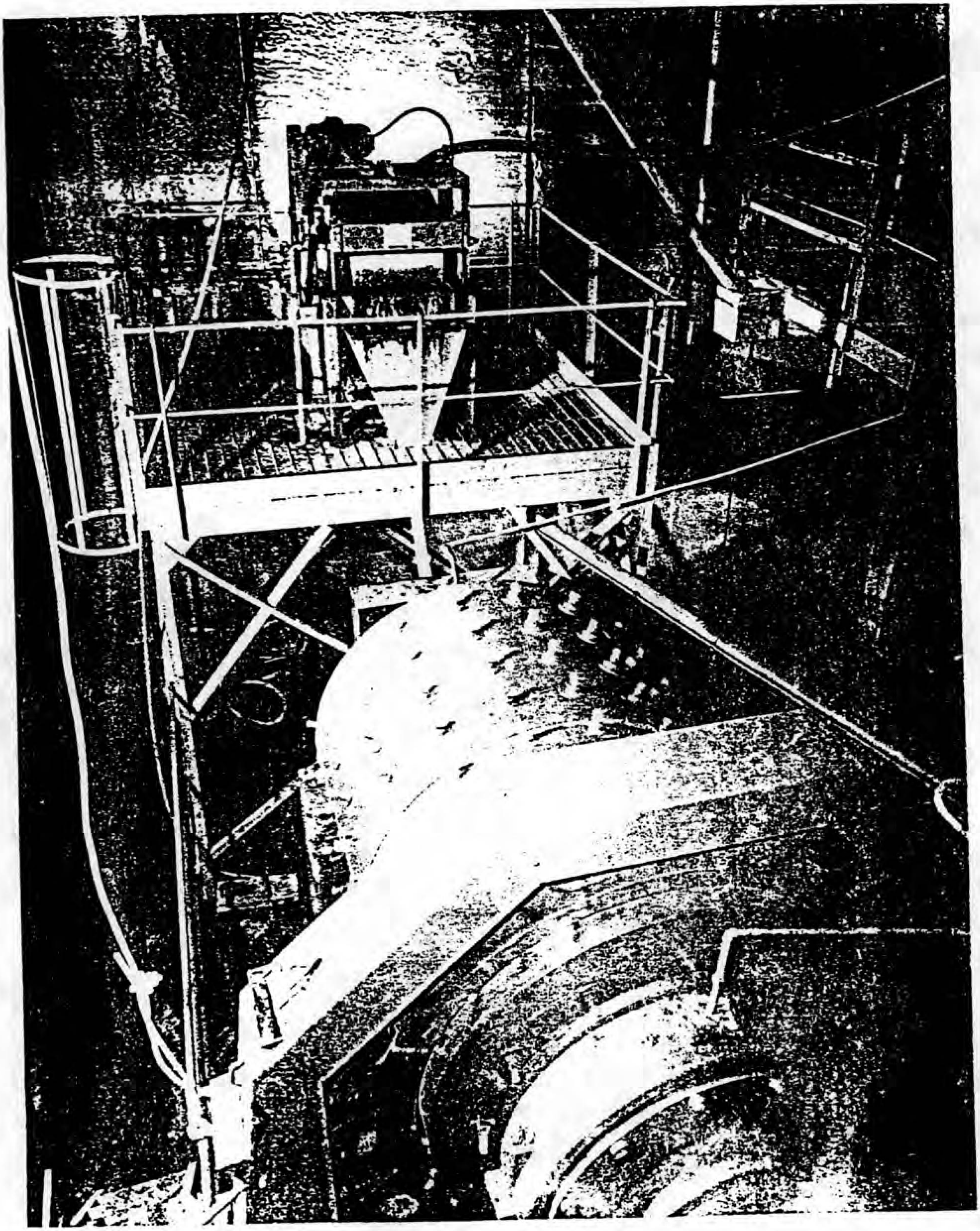

Plate 7. Ball mill and magnetic separator

able 1. Summary of alteration and mineralization in the four different rock units from Fort MacKay, Alberta, Canada

ck type	lithologic sequence	alteration	metallic minerals	Au related metallic phases
ltered granitoids	Proterozoic basement	epidote, chlorite, $CePO_4$, $CeCO_3$, calcite quartz veining native sulfur, and (K,Na)Cl	hematite, Fe, Ti, and Cr oxides, pyrite, Fe-chloride and minor PbS	Au, Au+Si, and Ag, Ag silicate, AgCl Pb, $PbCl_2$, $PbCO_3$, PbSb, and, Cu $CaWO_4$, Sb_2O_3, SnO_2
ranite Wash" and d-bed sandstone-aporite sequence	Paleosols and red sandstone, reddish-green siltstone, and gypsum thin bed Middle Devonian	$CeCO_3$, $CePO_4$, (K,Na)Cl biotite, native sulfur	hematite, Fe, Ti, and Cr-oxide, Ni oxide Fe-Chloride	Ag, Cu, AgCl, $PbCl_2$, Pb, $(Cu, Zn)Cl_2$, Cu-Zn alloy trace Au, Sb_2O_3, SnO_2, PbSb, (Cu,Fe)S, $CaWO_4$
averhill Lake rmation nestones	argillaceous limestone, fossiliferous limestone dolostone Upper Devonian	calcite, quartz, illite, chlorite, $CePO_4$, $CeCO_3$, NaCl, KCl, barite, native sulfur, biotite	hematite, pyrite, Ni-oxide, ilmite	Au+Ca, Au+Al, Au+Si, Au, Au+Ag, Au+Cd, Au+Cu+Zn, Au+Fe+Ni, Au-chlorides Cu, Cu+Zn, Fe+Cu+Zn, Cd+Zn. Zn,Pb, $PbCl_2$, $PbCO_3$ Ag, AgCl, Sb_2O_3, SnO_2, Bi-chloride
aver River ndstone	quartz cemented sandstone Lower Cretaceous	calcite, $CePO_4$, $CeCo_3$, NaCl, KCl, chlorite	hematite, Ni oxide, pyrite, ilmite	Cu, Cu+Zn, Zn, Pb, Sb_2O_3, SbS, Sn, Au Au+Cd, Au+Si, Ag

APPENDIX 12

Disseminated Au-Ag-Cu mineralization in the Western Canadian Sedimentary basin, Fort MacKay, Northeast Alberta

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Abstract

Disseminated Au-Ag-Cu mineralization has been discovered in the Western Canadian Sedimentary Basin (WCSB) at Fort MacKay, Alberta, Canada. The host rocks for the Au-Ag-Cu mineralization range from Proterozoic basement granitoids (~300 m underground), through to Devonian limestones and Cretaceous Beaver River sandstones at surface. The dominant gold forms, as detected by SEM backscatter imaging and energy dispersion X-ray spectrometer, are Au+Si and native Au alloys in the granitoids, and Au+Ca, Au+Al, Au, Au+Ag, Au+Cd, Au+Si, and Au+salts mixtures in the sediments. The Au-bearing minerals range in size from <0.2 to 400 µm, but are dominantly 1-2 µm. Associated alterations include calcite, quartz, salts, clay, and Ce-bearing minerals with abundant hematite and little pyrite. Other metallic elements, including Cu, Zn, Pb, Ag, Cd, Sb, Sn, Bi, and Ni, occur as (1) alloys (e.g. Cu and Ag); (2) oxides (e.g. Sb_2O_3); (3) chlorides (e.g. AgCl), and (4) carbonates (e.g. Pb-carbonate). The occurrence of Au-Ag-Cu mineralization in the area is explained by a genetic model in which oxidized brines leach metals from the basal red-bed sandstone-evaporite sequences and basement rocks, which are later precipitated by reducing agents in host rocks and by brine mixing. The discovery of the Au-Ag-Cu mineralization signifies a great opportunity for Au and other metal exploration in the WCSB.

INTRODUCTION

The Western Canadian Sedimentary Basin (WCSB), especially the Alberta portion of the basin, contains abundant petroleum resources and is the largest petroleum producing province of Canada. However, excepting the Pine Point Pb-Zn deposits (Anderson and Macqueen, 1982), and Ca, Li, and Mg potential from high salinity brines, there is no report of metallic mineral deposits in the basin (Edwards, 1988). Gold has been recovered from rivers in Alberta and Saskatchewan for over a century (Giusti, 1986; Edwards, 1988). The lack of known large-scale metallic mineralization in the basin may indicate an underdeveloped opportunity rather than a lack of geological potential because most geological studies in the WCSB have focused on energy resources.

Recently, elevated Au, Ag, and platinum group elements (PGE) abundances have been reported for the Phanerozoic sedimentary rocks of the WCSB from Fort MacKay, Northeast Alberta, indicating possible mineralization. However, different assay methods have produced contrasting Au results, and there has been confusion over the existence of significant Au mineralization in the area (see for example, a series reports in the Northern Miner, 1993; Abercrombie and Feng 1994). In this study, 32 rock chips, polished thin sections and rock slabs from (1) altered basement granitoids, (2) red-bed sandstone, and (3) Beaverhill Lake Formation (drill core and surface) near Fort MacKay have been examined by SEM using a backscatter image and energy dispersion X-ray spectrometer (EDS). More than half of the samples examined contain various amounts of Au and other metallic phases. This paper reports these results.

GEOLOGICAL BACKGROUND

Fort MacKay, Alberta, lies near the southwest edge of the Proterozoic trans-Hudson basement outcrop. (Figs. 1 and 2). Three broad rock sequences identified are: 1) basement; 2) a Devonian sequence dominated by red-bed sandstone, evaporite, and carbonate formations; and 3) a Cretaceous sequence of predominantly sandstones containing heavy oils (Carrigy, 1959; Figs. 1 and 2). Basement rocks buried underneath the Fort MacKay are Proterozoic granitoids that form part of a 2.0-1.8 Ma magmatic belt (e.g. Ross et al., 1991). Paleosols developed on the basement granitoids are preserved and are called "Granite Wash" (Fig. 2). The northwest striking Middle Devonian sequences, the Lower and Upper Elk Point Groups, in this region unconformably overlie basement. The Lower Elk Point Group comprises basal units of interbedded red sandstone, reddish-green mudstone, and evaporites which change upward into limestone and evaporites, forming a typical red-bed sequence (Meijer Drees, 1986; Fig. 2). The Upper Elk Point Group includes Winnipegosis Formation carbonates and Prairie Formation salt-evaporates. The edge or "solution front" of the Prairie Formation salts parallels the basin-basement boundary (Hamilton 1971; Fig. 2). The Beaverhill Lake Formation is the basal unit of the Upper Devonian and consists of a sequence of alternating limestones and shales (Fig. 1). Other Upper Devonian rocks, including the Woodbend and Nisku carbonate formations are absent in the study area (Fig. 2).

The Cretaceous Mannville Group (sandstones) was deposited on eroded Devonian rocks and contains the largest reserve of heavy-oil in the world (Fig. 2). Between the contact of Devonian and Cretaceous rocks there is a unique sequence of quartz cemented sandstones (Beaver River sandstones) which also outcrops in the area (Carrigy, 1959; Martin and Jamin, 1963). A northwest-southeast fault (Sewetakun fault) that may have affected rock units as young as

Devonian in age, was identified by Hackbarth and Nastasa (1979) based on geological, geophysical, and hydrogeological evidence (e.g. Fig. 2).

The regional hydrology of the formation waters in the northeastern Alberta basin has been documented by Bachu and Underschultz (1993). The pre-Prairie Formation aquifers, beneath the regionally extensive impermeable Prairie salt aquiclude, are characterized by regional topographically-driven flow along stratigraphic layers and updip migration (Fig.2). At the edge of the Prairie Formation salt, along the trace of the Sewetakun fault, vertical cross formational flow occurs (Fig. 2). The post-Prairie Formation aquifers are characterized by transitional flow regimes between regional and localized flow (Fig.2).

Figure 1. Bedrock geology of Fort MacKay area, Alberta, Canada (After Carrigy, 1959). The Sewetakun fault was identified by Hackbarth and Nastasa (1979), the Muskeg River fault was inferred from topographic features and offset of magnetic anomalies.

Figure 2. Schematic stratigraphic cross section of the Fort MacKay area, Alberta, Canada (after Carrigy, 1959)

ANALYTICAL RESULTS

Figure 3. (A) Association of $PbCl_2$ and AgCl grains on a fresh broken surface of an altered granitoid sample (B-1, core); (B) Disseminated AgCl grains on a fresh broken surface of a granitoid sample (number of AgCl grains >1000; B-1); (C) Enlargement of AgCl crystals in (B); (D) Ag+Si (Ag+Si EDS peaks) grains occur inside of Fe-epidote nodule in the altered granitoids (WS-1, core); (E) An aggregate of Au and Au+Si grains on a newly sawed granitoid surface, more than five such aggregate and >100 Au grains were found in the sample (A31028); (F) A hexagonal Au+Si core is rimed by pure Au (A31028). All photomicrographs shown are backscattered electron images. The element sequence is arranged in declining EDS peak intensity in all the figures.

Figure 4. (A) A native Au grain on a freshly broken surface of a red-bed sandstone sample (A1-RR). (B) Intergrowth of Au-bearing grains with salts (NaCl+KCl), calcite, and clay on the edge of the thin section (not in-situ). EDS peaks are Au+minor Cl+K+Al+Na for Au (T4-312.5, core). (C) Cd+Au+Zn+Pd alloys (1) grow on top of (2), a mixture of quartz+(Na,K)Cl+Au+Ag+Zn (EDS peaks: Si+Cl+Na+K+minor Au+Ag+Zn) (T4-312.5, core). (D) A group of fine Au grains (<2 μm bright spots) in the fresh broken surface of limestone, EDS peaks include Au+minor Ca+Al (number of Au grains >200; F20). (E) A large Au+Ag (9:1) grain (~400 μm), dark inclusion is mixture of clay and calcite. More than 30 grains of Au between 0.5-400 μm were found in the sample (T2-25.75). (F) A tongue shaped Au grain on the fresh surface of limestone. EDS peaks include Au+minor Al+Ca (F20).

Figure 5. (A) Association of Au and Cu-Zn grains on the fresh broken surface of limestone (F20). (B) A group of Au-bearing grains: (1) Ag+Ca+Au; (2) Au; (3) Ag+Au; (4) Si+Au+Ca; and (5) Au+Cd in a polished thin section of limestone (Au grains >15; RR-40). (C) Au & Au-Fe-Cd-Cu-Cr-Ni alloys occurs near cavity in the limestone and in fractures (T2-25.75, core). The

left corner shows Au scratch mark during polishing. (D) Zoned Au-bearing grain. At the two ends, the shaded parts are Au+Si, the bright centre is Au+Al (RR-40). (E) Au-bearing aggregate consisting of two parts on a polished limestone surface. Less bright part (1) is Ca+Al+Si+K+Cl+Au (less Au) and bright part (2) is Au+Ca+Al+Si+K+Cl (more Au) (Au grains >200; F18). (F) A zoned Au-bearing grain in limestone; the less bright rim (1) is Ca+Au, the bright core is Au+Ca (Au grains >200; F02).

Figure 6. (A) Au+Cd micro-grain, chlorite+illite, and calcite+clay aggregates occur within the same pore system in limestone, implying a genetic relationship (F02). (B) An Au+Ca grain occurs in the calcite veining network in the limestone (F02). (C) An Au+minor Cl+K grain and a cluster of KCl cubes embedded in a NaCl+KCl+calcite mixture matrix (Au grains >10, AgCl grains >200; RR-43A). (D) Au+Ag alloys occur on top of matrix material with O+Na+S+Cl+Ca+C EDS peaks (gypsum+salt+organic matter). The gypsum+salt+organic matter aggregates have erupted out of a flat surface (WK-14, limestone). (E) AgCl micro-grains in limestone (RR-43A). (F) Native Cu in limestone (sample A)

Fig. 7. Represent EDS peak patterns for Au- and Ag-bearing phases in the rocks from Fort MacKay area, Alberta, Canada.

DISCUSSION

Similarities of mineralization in the different rock units

The alteration and metallic mineralization of the four different rock units show some similarities (Table 1). They all contain Ce-bearing minerals, salts (NaCl and KCl), calcite, quartz, and clay. A unique metallic element association, including Au, Ag, Cu, Zn, Pb, Sb, Sn, Cd, Bi, and W, occurs in finely disseminated form in all four rock units. All rock units lack sulfide except for some pyrite. Metallic minerals mainly occur as (1) alloys (e.g. Cu and Cu+Zn); (2) oxides (e.g. Sb_2O_3); (3) chlorides (e.g. AgCl and $PbCl_2$), and (4) carbonates (e.g. Pb-carbonate). Au, Ag, and Cu mineralization is related to calcite, clay, quartz, hematite, and salt alteration. All these features suggest that the alteration and mineralization in the different rock units may have been caused by similar fluid processes.

The slight difference in the degree of alteration and mineralization between the different rock units may reflect different physical-chemical conditions in the different host rocks. Pb and Ag chlorides and pyrite are relatively more abundant in the altered granitoids near the "Granite Wash" than in the sedimentary rocks above. The form of Au minerals is also slightly different among the different rock units. In the altered granitoids, Au+Si associated with native Au is observed, but in the limestone, Au+Ca and Au+Al associated with native Au are present, a probable reflection of host rock composition.

The forms of Au-bearing minerals

Detailed EDS study indicates that Au+Ca, Au+Al, and Al+Si grains in granitoids and sediments have little or no oxygen, which rules out the possibility that these mixtures are oxides or carbonates. Instead, Au may alloy with Ca, Al, and Si. These types of Au alloys do not appear to have been reported in the literature before, and their chemical properties are unknown. Another important Au form is related to halide salts. Au in the sediments shows associations with salts, and Au-bearing grains were identified to have Au+Cl+K+Na EDS peaks, suggesting that these Au-bearing grains may be in the form of chlorides. However, it is unclear what the proportion of Au-chlorides to the total Au is, since some of the Au-chlorides may be sub-micron in size and not detected by SEM. Au-chlorides are soluble even in cold water and may be volatile at <300 °C. This form of Au could easily be lost because of inapproprite assay methods. The combined effects of novel forms of Au mineralization, and the presence of hydrocarbons and salts in the sediments may in part account for the non-reproducible assay results for gold.

Physical-chemical conditions of ore-forming solution

A unique feature of the alteration is widespread Ce-bearing minerals in all rocks. Ce can only be decoupled from the rest of rare earth elements (REE) under relatively oxidizing conditions when Ce is removed as Ce^{4+}. This is consistent with abundant hematite and Fe-Ni-Cr oxide minerals, both of which are indicators of high Eh conditions. Calcite, salt, clay, and quartz as the main alteration minerals suggests that the ore-forming solution were enriched in Cl, CO_3^{-2}, Si, Na, and K. The presence of Au-, Ag-, Pb-, Bi-, Cu-, and Fe-chlorides, and the Au-salt association indicate that Cl is a major agent in the ore-forming solutions, indicating Cl-rich formation waters or brines as the mineralizing solution. The fact that most metallic minerals do not occur as sulfides, except some for pyrite, indicates that either S was not abundant in the ore-forming solution or the ore-forming conditions were oxidized so that S existed in forms other than sulfide, or a combination of both. This is supported by the occurrence of a small amount of native S and barite.

The small grain size of the metallic and alteration minerals, their disseminated distribution, the alteration mineral associations, the wide distribution of soluble bitumen within the host rocks, and burial reconstruction together indicate that the temperature of mineralization was probably not >120°C. In the altered granitoids, the alteration minerals associated with Ag, Pb, and probably Au mineralization are larger in size, probably indicating somewhat higher temperatures in the basement. The timing of the mineralization may be Cretaceous or younger, since the Cretaceous Beaver River sandstone and quartzites were also mineralized, but conditions for transportation of metals by oxidized Cl-rich brines may have existed since the Middle Devonian and continue to the present day.

Au-Ag-Cu transportation and precipitation in the WCSB

Au, Ag, and Cu must have been enriched by some process to form a deposit. Therefore, the source of the metals, their mobility, transport, and precipitation mechanisms have to be addressed. The solubility of these metals in natural waters is mainly a function of Eh and fluid compositions (e.g. Maynard, 1983; Jaireth, 1992; Thornber, 1992, and references therein). According to these authors, Au, Ag, and Cu chloride, bromide, and iodide complexes are the most stable species in oxidized, neutral to acidic waters at low temperature. In the northeast Alberta basin, the formation waters contain abundant Cl, Br, and I, but relatively little or no H_2S (Hitchon et al., 1971; Hitchon, 1993). This makes Cl, Br, and I the most likely complexing agents to mobilize and transfer gold and other precious metals. However, these brines have relatively low Eh (e.g. Sverjensky, 1987; Hitchon 1993), therefore, Cl, Br, and I may not form soluble complexes with Au, Ag, and Cu (e.g. Maynard, 1983; Jaireth, 1992; Thornber, 1992). Sverjensky (1987) and Bloom et al. (1992) have calculated the chemical evolution of a saline brine during migration. If reducing formation waters react first with sulfate-rich evaporates and then with a typical red-bed assemblage, oxygen fugacities well into the hematite (jarosite) field can be attained. Under these conditions, Au, Ag, Cu and other metals are soluble as chloride complexes, and therefore may be leached out from the red-bed units or from basement rocks beneath (e.g. Fig. 8; Jaireth, 1992; Thorner, 1992). This is supported by the fact that formation waters from the "Granite Wash" have higher Fe and Mn contents than those from other aquifers (Hitchon, 1993). The metals would precipitate out from the solutions when encountering organic-rich layers, or mixing with brines with different Eh, pH or salinities.

In the context of the regional hydrogeology of the formation waters in the northeastern Alberta (Fig. 9), the generation of Au-Ag-Cu mineralization can be explained as follows. The formation waters or brines in the aquifers beneath the Prairie Formation were oxidized during their up-dip migration through the redbeds and "Granite Wash" (Fig. 9). The resulting oxidized brine then leached out gold and other metals from these rock units. The oxidized brines may also have circulated into basement and leached gold there, subsequently circulating back to the basin through faults (Fig. 9). *Owing to the impermeability of the Prairie Formation aquiclude, the ore-*bearing brines could not flow vertically through the Prairie Formation salts, but rather flowed up-dip along the base of the Prairie Formation (Fig. 9). At the solution front of the Prairie Formation salts, vertical upward cross formational flow became possible. Faults in the rocks further facilitated the upward cross formation flow (Fig. 9). When these ore-bearing, oxidized brines reached reducing environments in the overlying limestones and shales containing abundant organic metter, or when the brines mixed with other brines of different salinities and Eh-pH conditions, Au and other related metals precipitated and local mineralization took place.

In conclusion, the general geochemical environments and the possible genetic mechanism for the Au-Ag-Cu mineralization described here are very similar to those of so-called red-bed Cu deposits and the unconformity-related Au-PGE-U mineralization in the South Alligator mineral field, Australia (e.g. Sverjensky, 1987; Eugster, 1989; Bloom et al., 1992). The discovery of Au-Ag-Cu mineralization signifies a great opportunity for extensive exploration of metallic minerals in the WCSB basin, which has been overlooked for almost one hundred years.

ACKNOWLEDGEMENT

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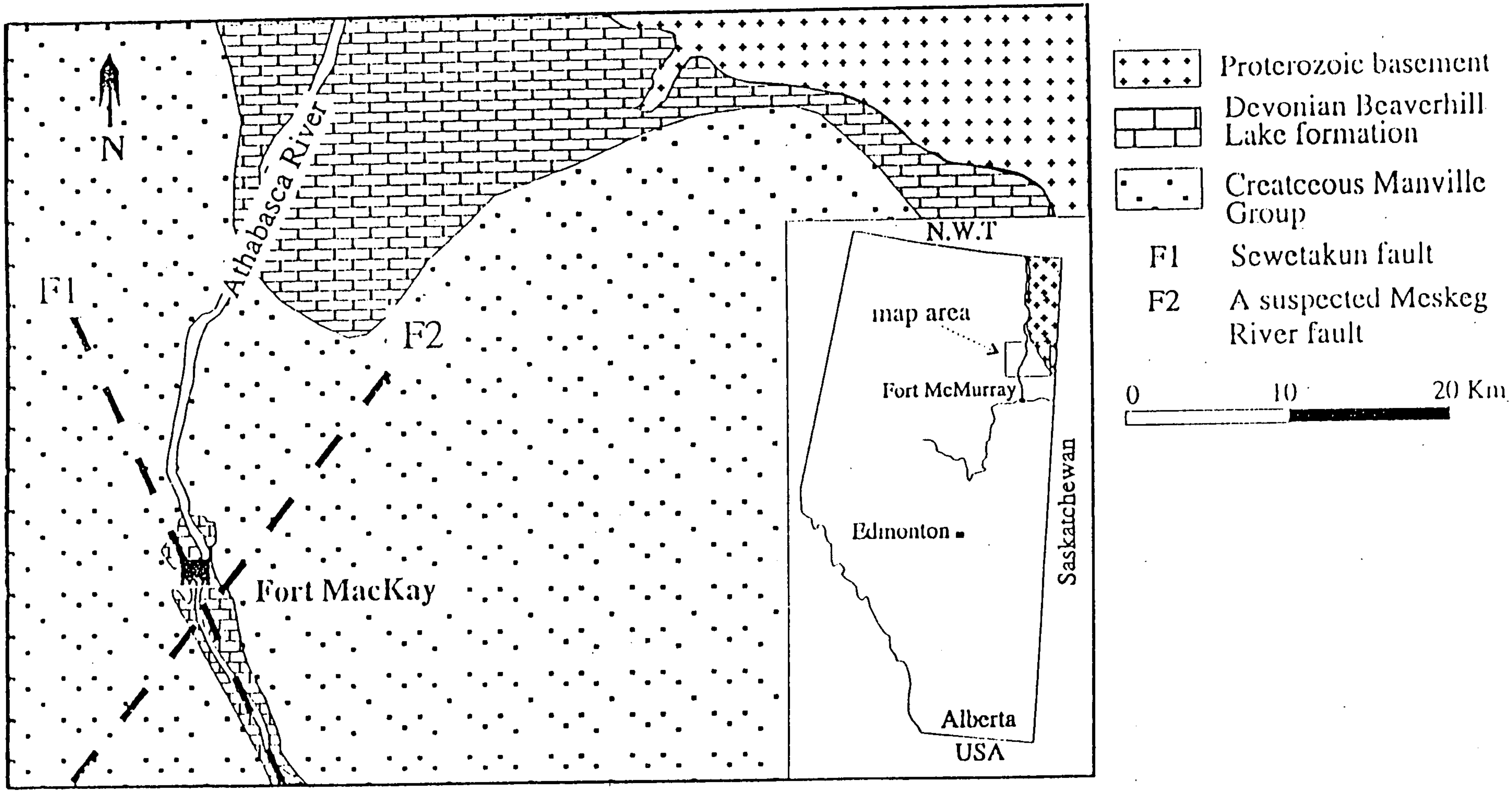


N
F1
F2
Athabasca River
Fort MacKay
N.W.T
map area
Fort McMurray
Edmonton
Saskatchewan
Alberta
USA
Proterozoic basement
Devonian Beaverhill Lake formation
Createceous Manville Group
F1 Sewetakun fault
F2 A suspected Meskeg River fault
0
10
20 Km

Figure 1

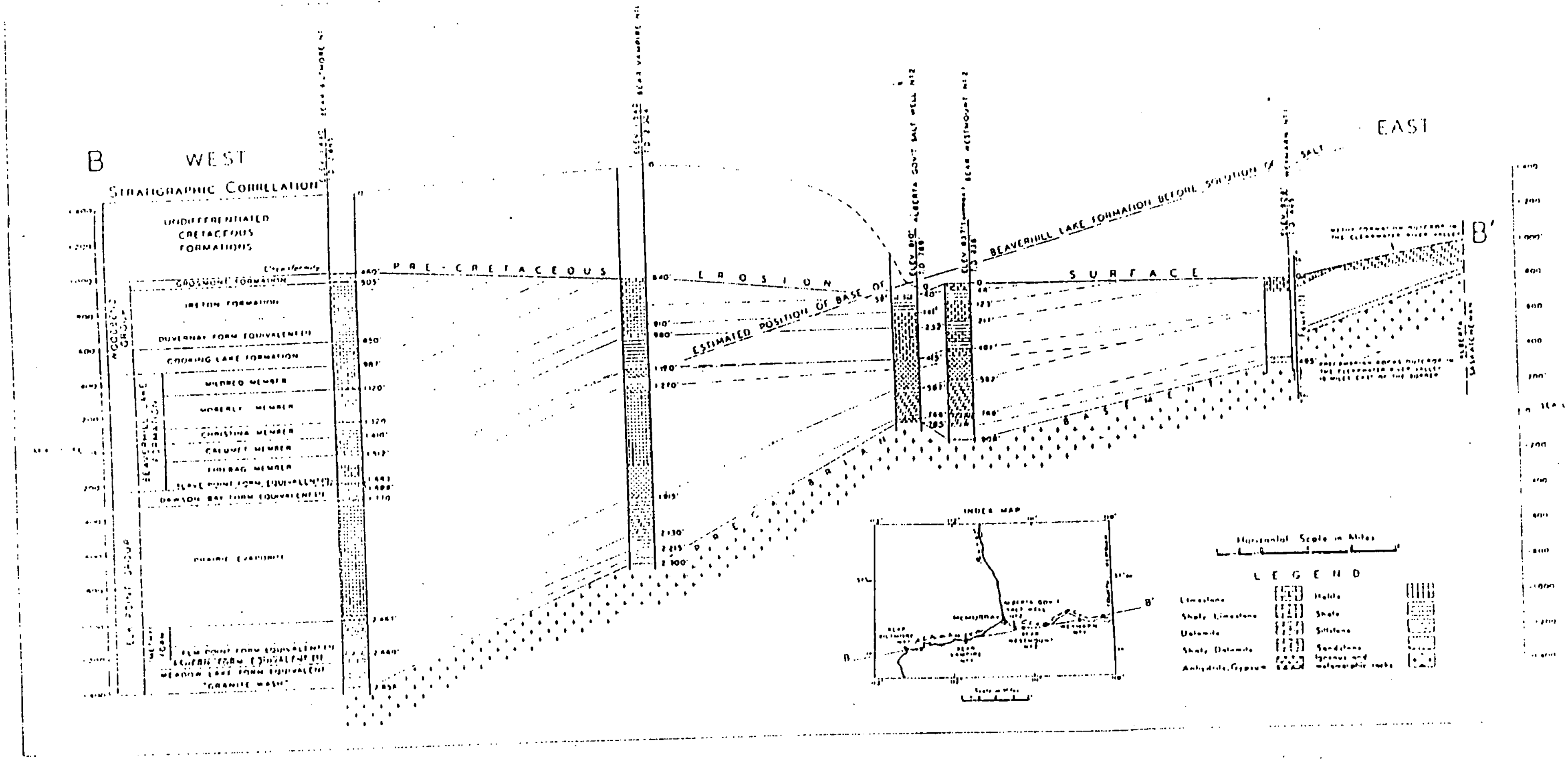
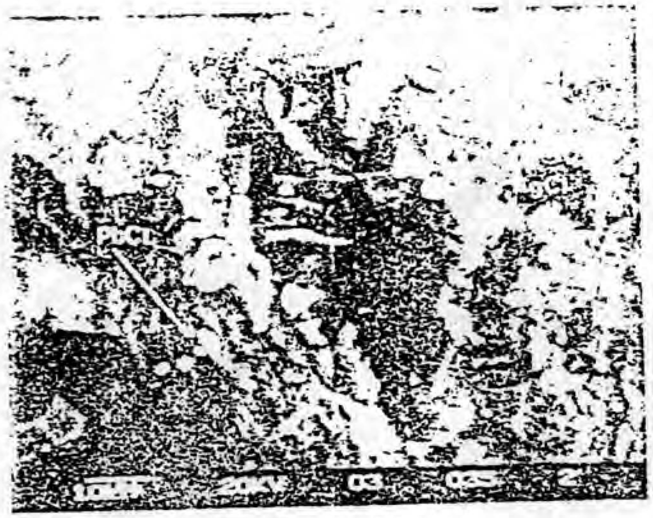
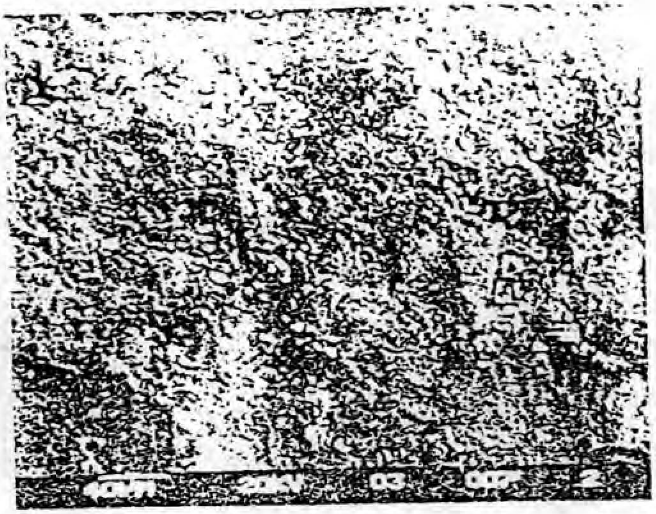


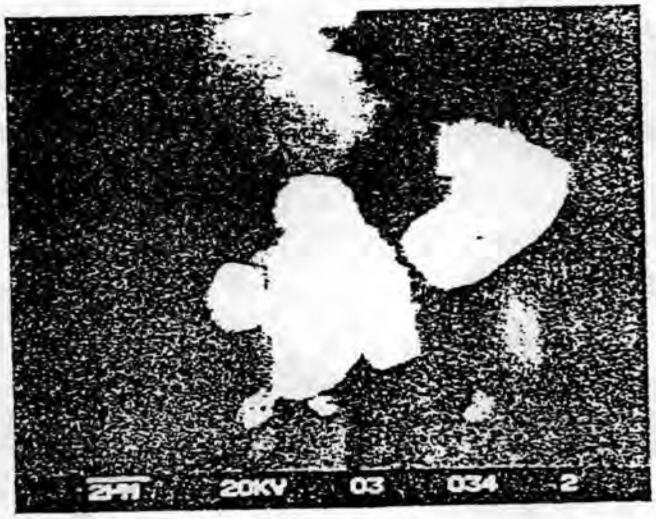
FIGURE 6 Geological Cross Section B-B' of Paleozoic Strata


PbCl
10MM 20KV 03 035 2

A


40MM 20KV 03 007 2

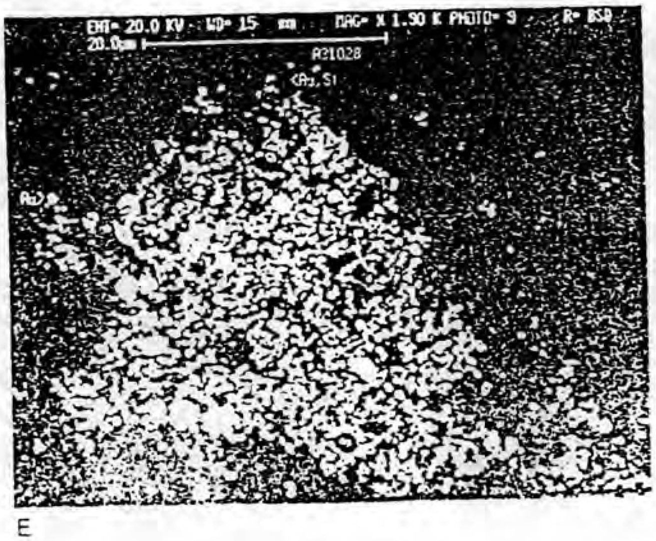
B


2MM 20KV 03 034 2

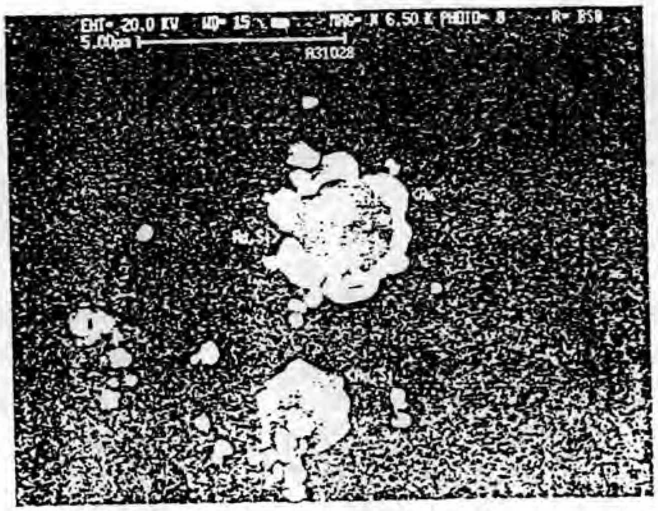
C


40MM 20KV 01 023 2

D


EHT= 20.0 KV WD= 15 mm MAG= X 1.90 K PHOTO= 9 R= BSD
20.0µm
R31028
(Al,Si

E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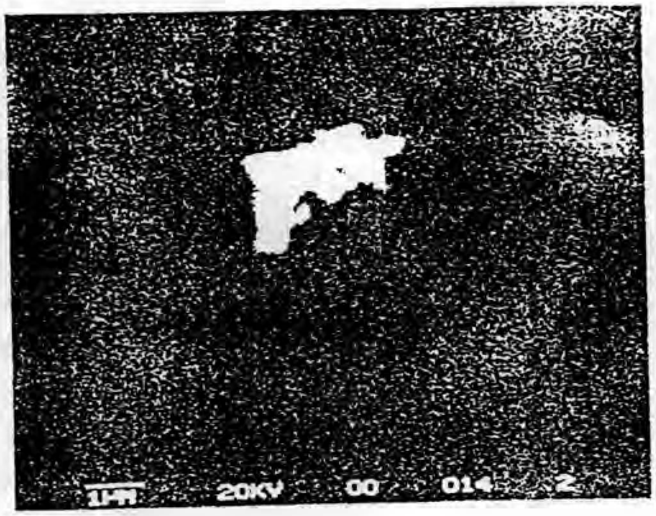
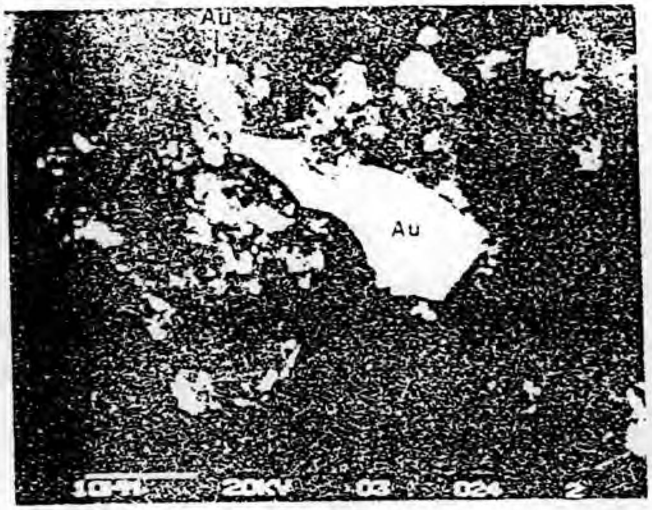
5.00µm
R31028

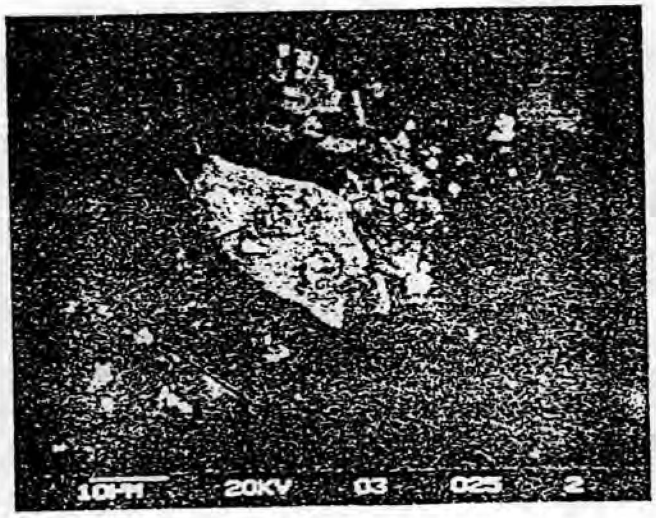
F


1µm 20KV 00 014 2

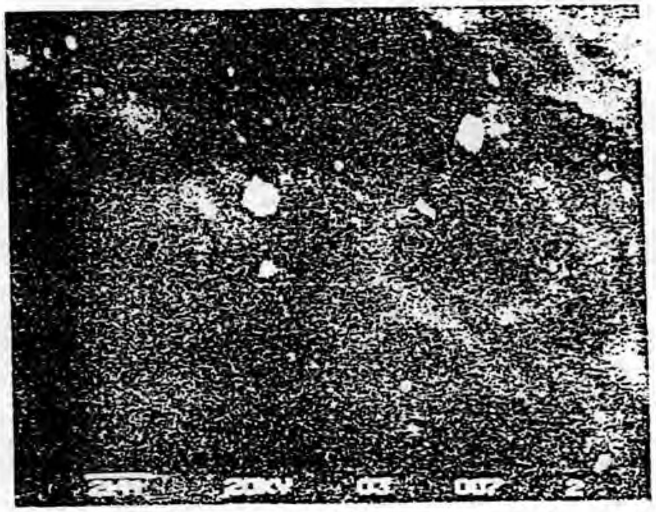
A


Au
Au
10µm 20KV 03 024 2

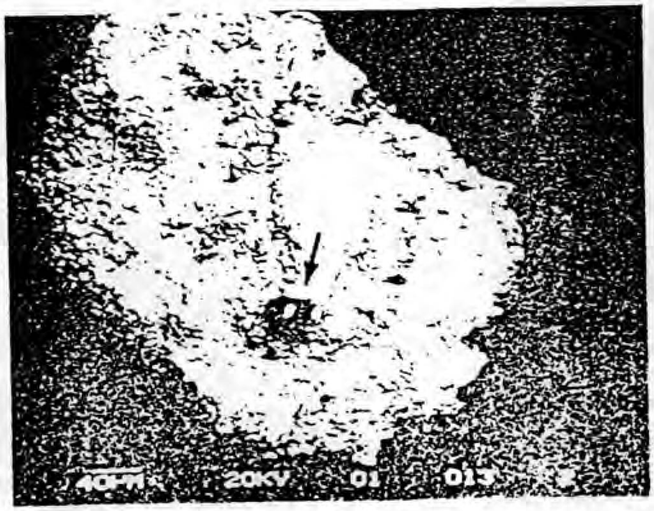
B


10µm 20KV 03 025 2

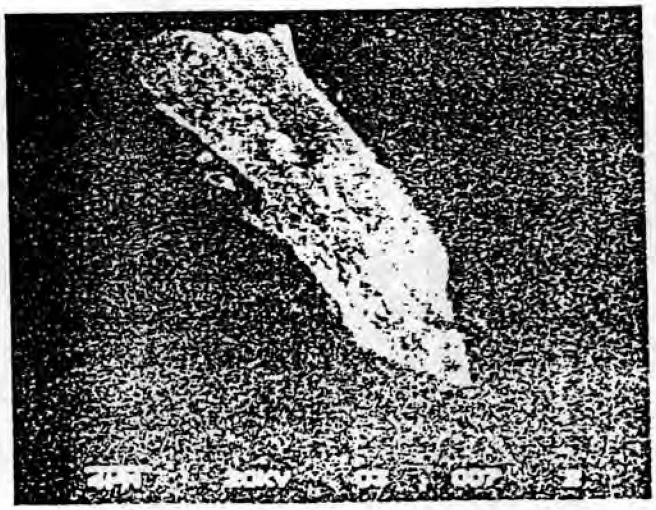
C


2µm 20KV 03 007 2

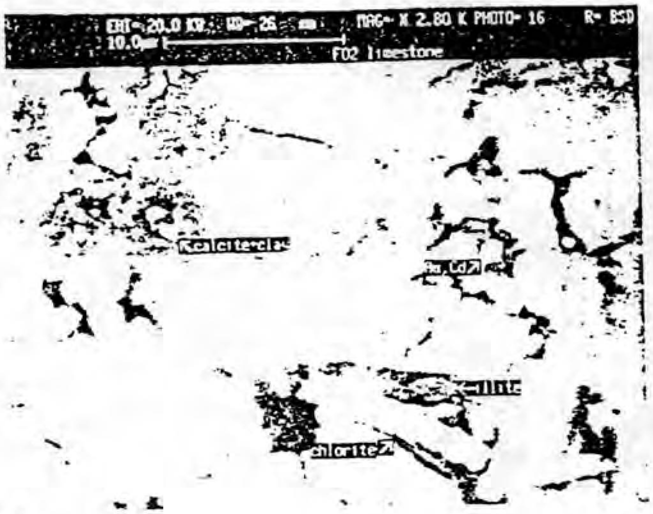
D


40µm 20KV 01 013 2

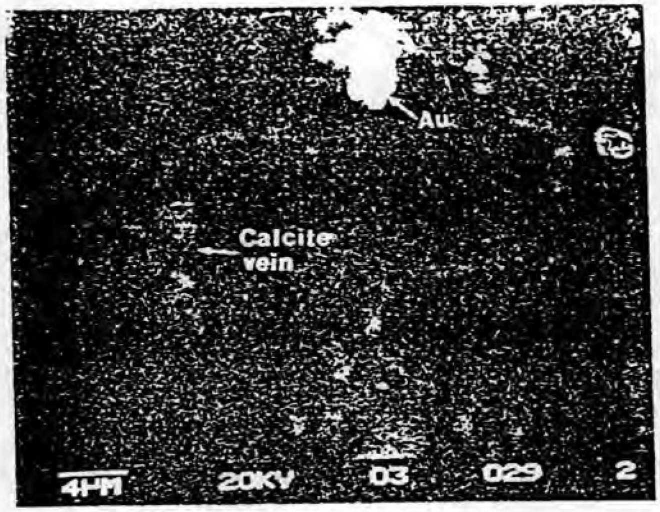
E


20KV 007

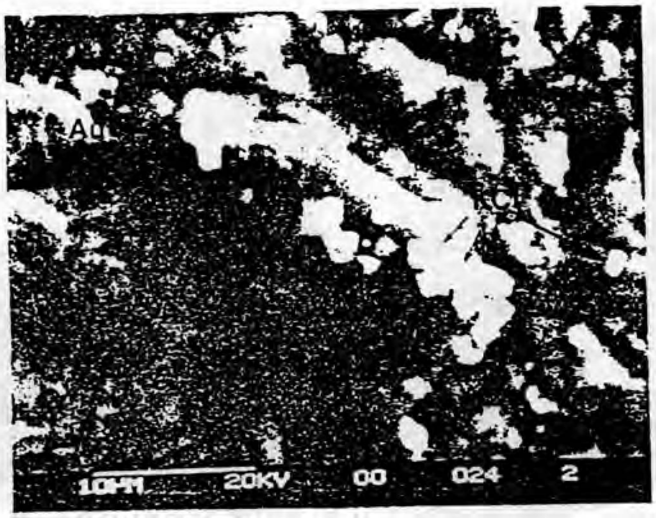
F


EHT= 20.0 KV WD= 26 mm MAG= X 2.80 K PHOTO= 16 R= BSD
10.0μm
F02 limestone
calcite+clay
Au,Cd
illite
chlorite

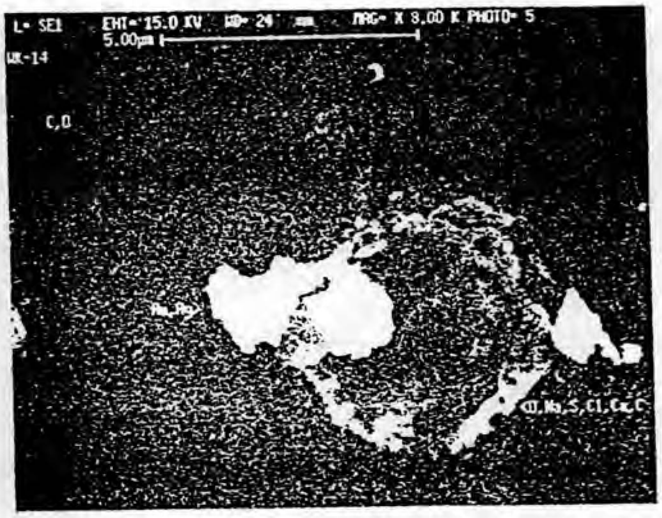
A


Au
Calcite vein
4μm 20KV 03 029 2

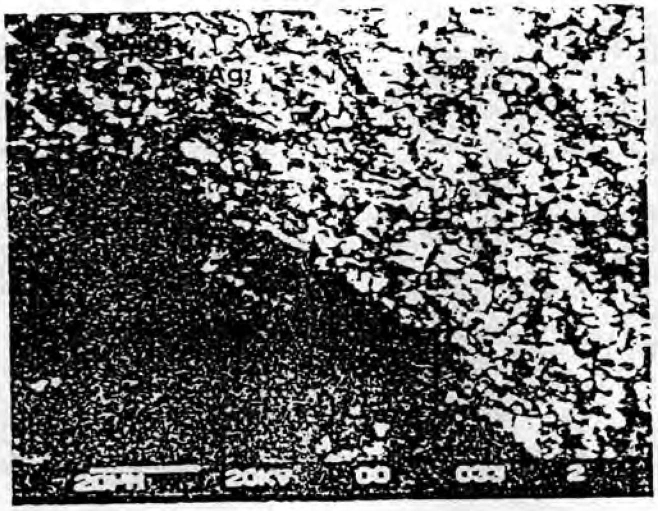
B


Au
C
10μm 20KV 00 024 2

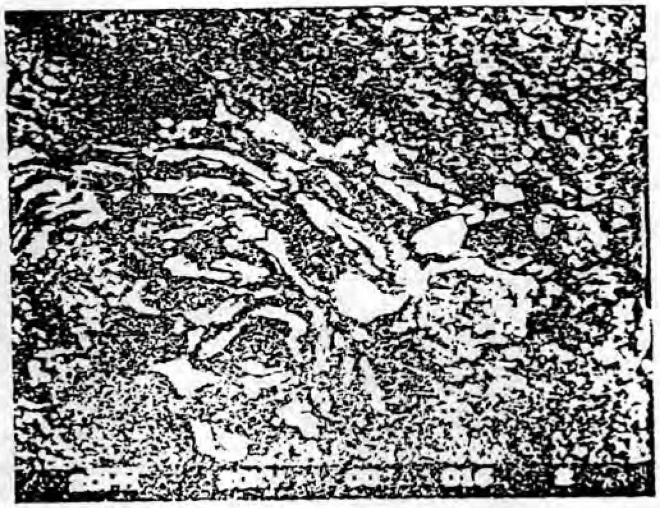
C


L= SE1 EHT= 15.0 KV WD= 24 mm MAG= X 8.00 K PHOTO= 5
5.00μm
WK-14
C,O
Au,Ag
O,Na,S,Cl,Ca,C

D


Ag
20μm 20KV 00 033 2

E


20μm 20KV 00 016 2

F

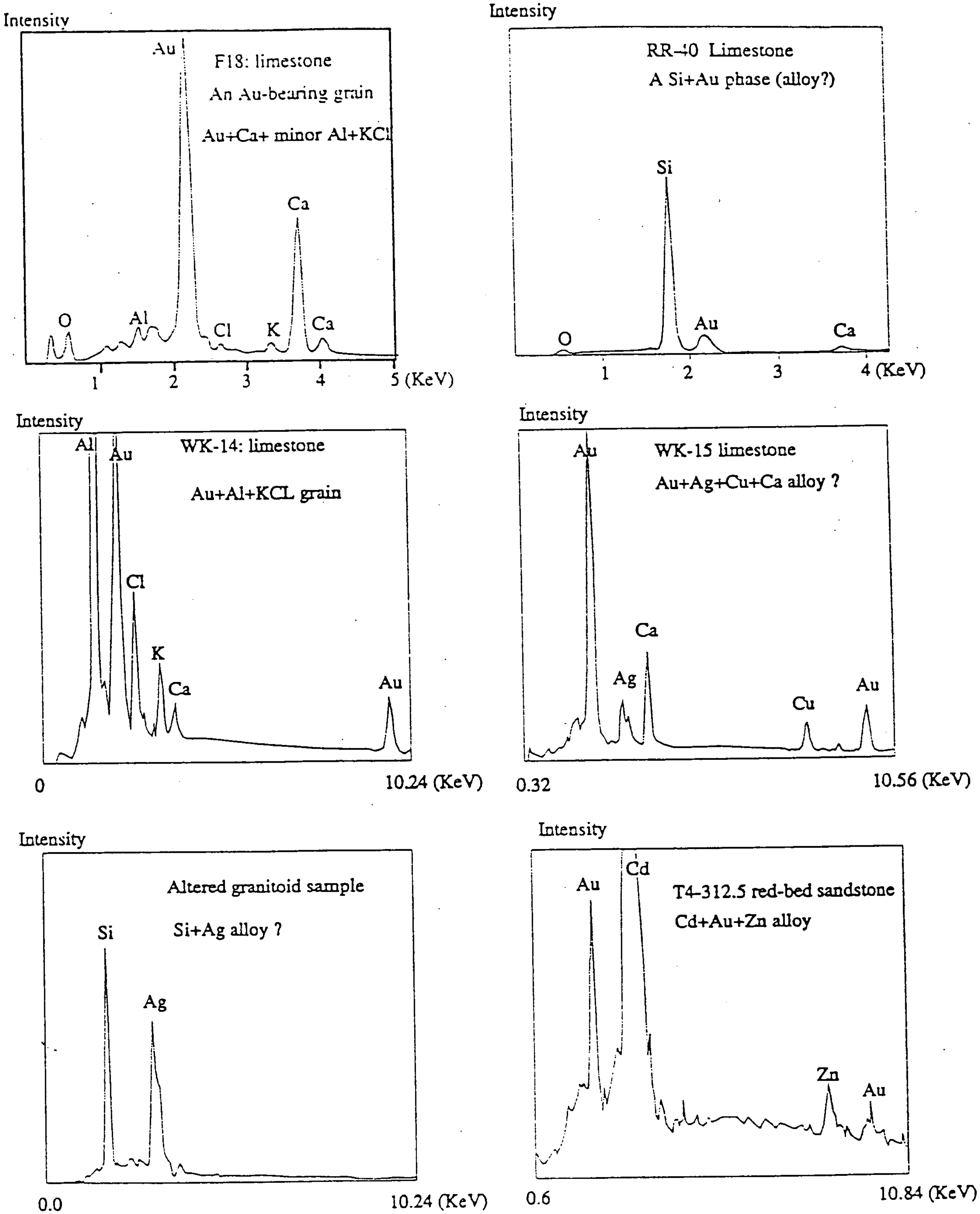


Fig. 7. Represent EDS peak patterns for Au- and Ag-bearing phases in rocks from Fort MacKay area, Alberta, Canada

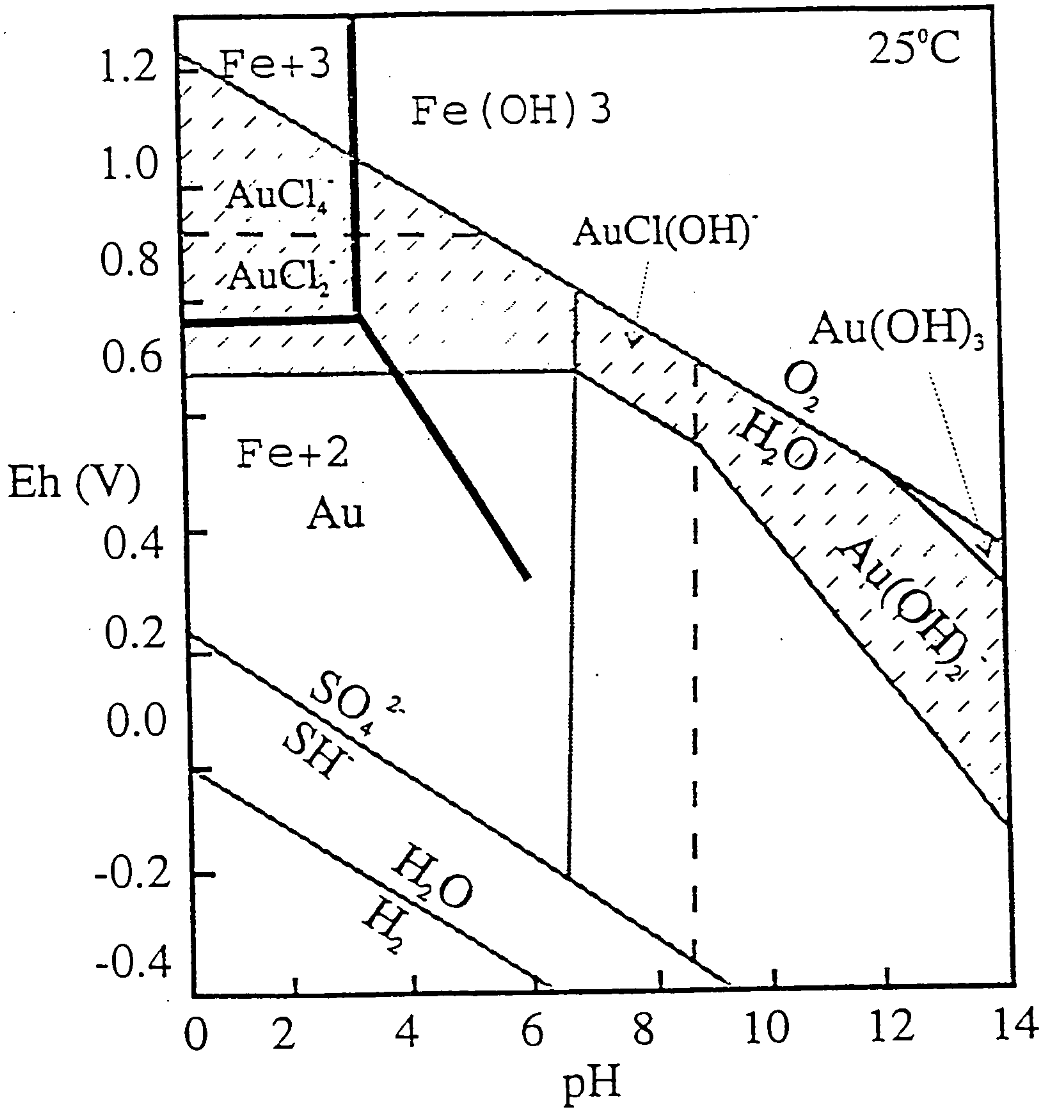


Fig. 8. Eh-pH diagram for Au (10^{-8} M) in a 1 M (35 g/L) Cl solution (thin lines) and Fe-H2O system (thick lines)

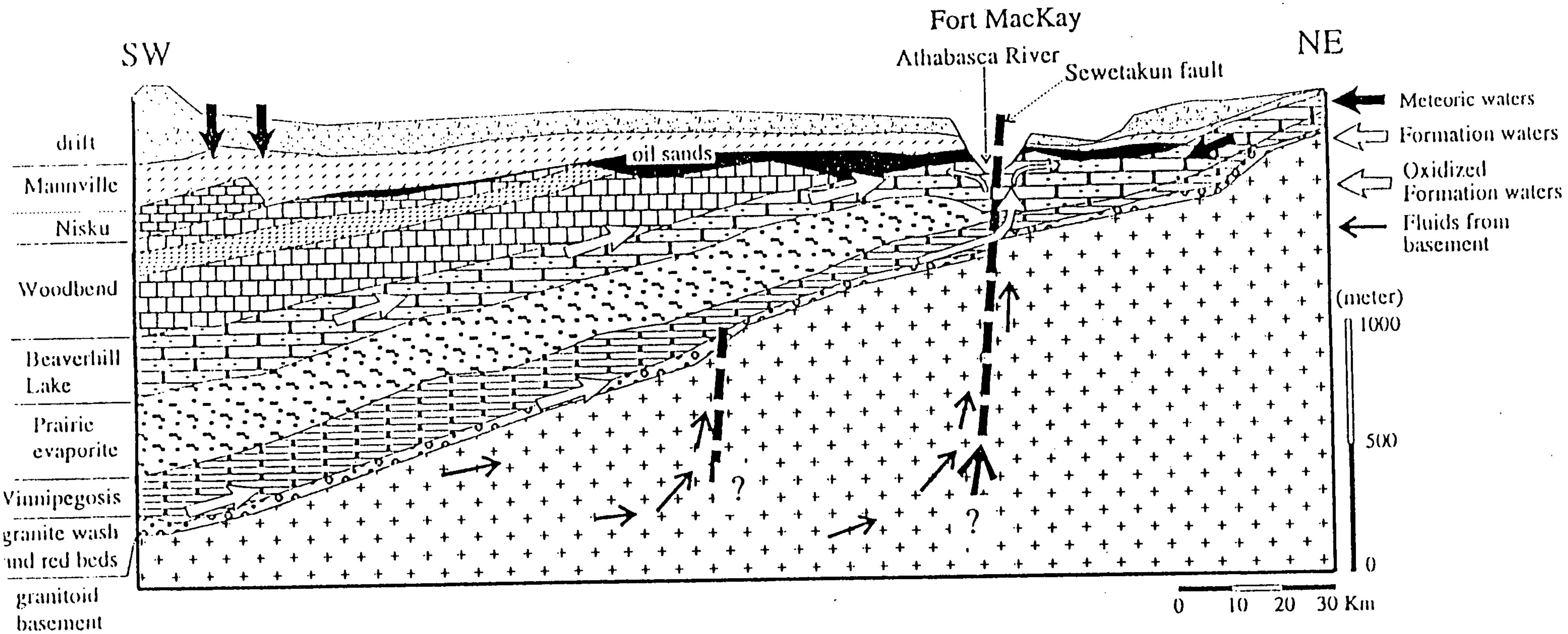

Fort MacKay
SW
NE
Athabasca River
Sewetakun fault
oil sands
drift
Mannville
Nisku
Woodbend
Beaverhill Lake
Prairie evaporite
Winnipegosis
granite wash and red beds
granitoid basement
Meteoric waters
Formation waters
Oxidized Formation waters
Fluids from basement
(meter)
1000
500
0
0
10
20
30 Km
?
?

Figure 9

APPENDIX

11

THE UNIVERSITY OF ALBERTA

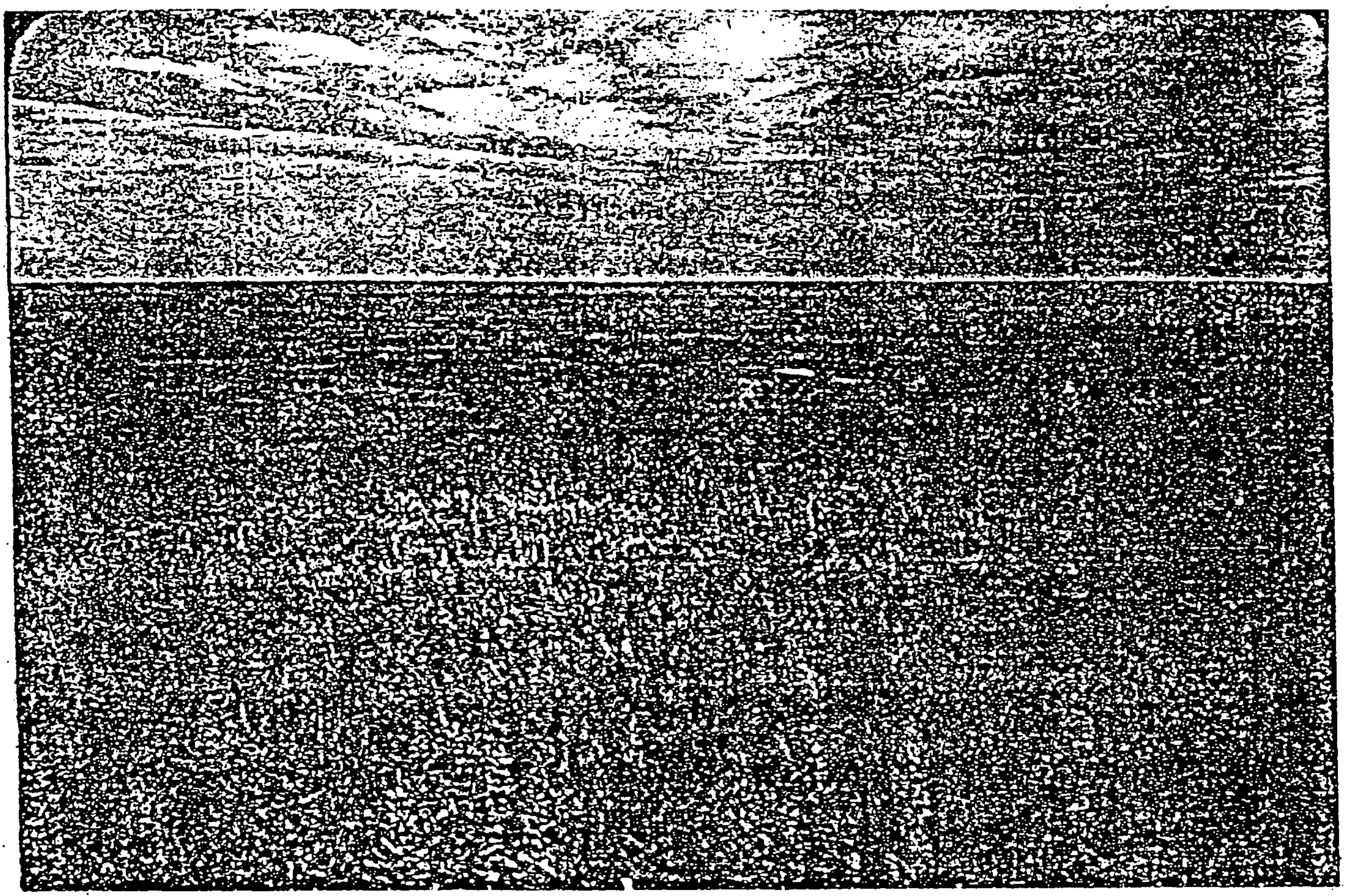
SEDIMENTARY IRON IN THE CRETACEOUS OF THE CLEAR HILLS AREA, ALBERTA

A DISSERTATION
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY
FACULTY OF ARTS AND SCIENCE
by
GERALD LAVERNE COLBORNE, B.Sc.

EDMONTON, ALBERTA

September, 1958



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Dr. W.L.C. Greer and the management of Cliffs of Canada, Ltd., who were responsible for the initiation of the field work which lead to the writing of this thesis; Mr. G.H. Findland and staff of the Alberta and Northwest Chamber of Mines for their timely advice in many field matters; L. Gustafson and R. Hall for their able assistance in the field; G.M. Hughes for his very important contribution in the laboratory.

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The writer is indebted to Dr. R.E. Folinsbee, under whose supervision this thesis was written, for his direction and assistance in many problems and especially for his part in the initiation of the field work in conjunction with Dr. W.L.C. Greer.

The writer would like to thank his wife, Elva Colborne, and Miss Dingman, department secretary, for their tolerance in the editing and typing of this thesis.

Frontispiece

Aerial view from Notikewin forestry tower, Clear Hills, Alberta. Looking northwest to the Notikewin River.

ABSTRACT

The wealth of oil and gas found in Alberta since 1947 has resulted in a greatly expanded economy. This has produced a growing market for iron and it's alloys in the western provinces, and has aroused the interest of several large international steel producers. Consequently all known occurrences of iron in Alberta have undergone investigation of varying intensity during the past few years.

This thesis sets forth the results of a study, from many approaches, of one of the more promising possible commercial deposits, located in the Clear Hills area of northwestern Alberta. This is a fine example of an oolitic iron deposit comparable, mineralogically, to many of the well known sedimentary deposits of iron throughout Europe and the United States of America.

The field and laboratory evidence appears to substantiate the assumption that the oolitic iron in the Clear Hills has definite commercial possibilities as a low grade iron ore. The prospective (but not proven) tonnage appears to be capable of supporting a large economical open pit operation.

TABLE OF CONTENTS

PLATES

CHAPTER I

INTRODUCTION

General Statement

There has been considerable interest shown in low-grade iron occurrences in Alberta during the past four years. This interest, although blunted by the recessional period in 1957-58, still has sufficient promise to be kept alive for future investigation and development.

The iron occurrences in question range from a low-grade commercial deposit to mere traces in some sedimentary rocks. Geographically, the known occurrences are confined to the foothill belts of the Rockies and the Clear Hills of the Peace River district; geologically, they appear to be most prevalent in the Upper Cretaceous marine sediments.

The writer, under the sponsorship of Cliffs of Canada Ltd. (Canadian Exploration Company of Cleveland Cliffs, U.S.A.), was commissioned to examine all possible iron occurrences in the Province of Alberta, so far as time allowed during the summer of 1957. Several areas were visited but final emphasis was placed on the Clear Hills deposit.

The Clear Hills deposit presented the best commercial possibilities and a problem in diagenesis and environment of deposition. The Clear Hills deposit is of the oolitic type and probably comparable to similar deposits throughout the world. The writer will attempt to show this relationship along with possible determination of source area, age and environment of deposition.

The nature of oolitic iron of the Clear Hills area, both in grade and quantity, gives it priority over all other known occurrences in Alberta. The other areas examined will be treated briefly as a means of correlation with conditions of possible contemporaneous deposition.

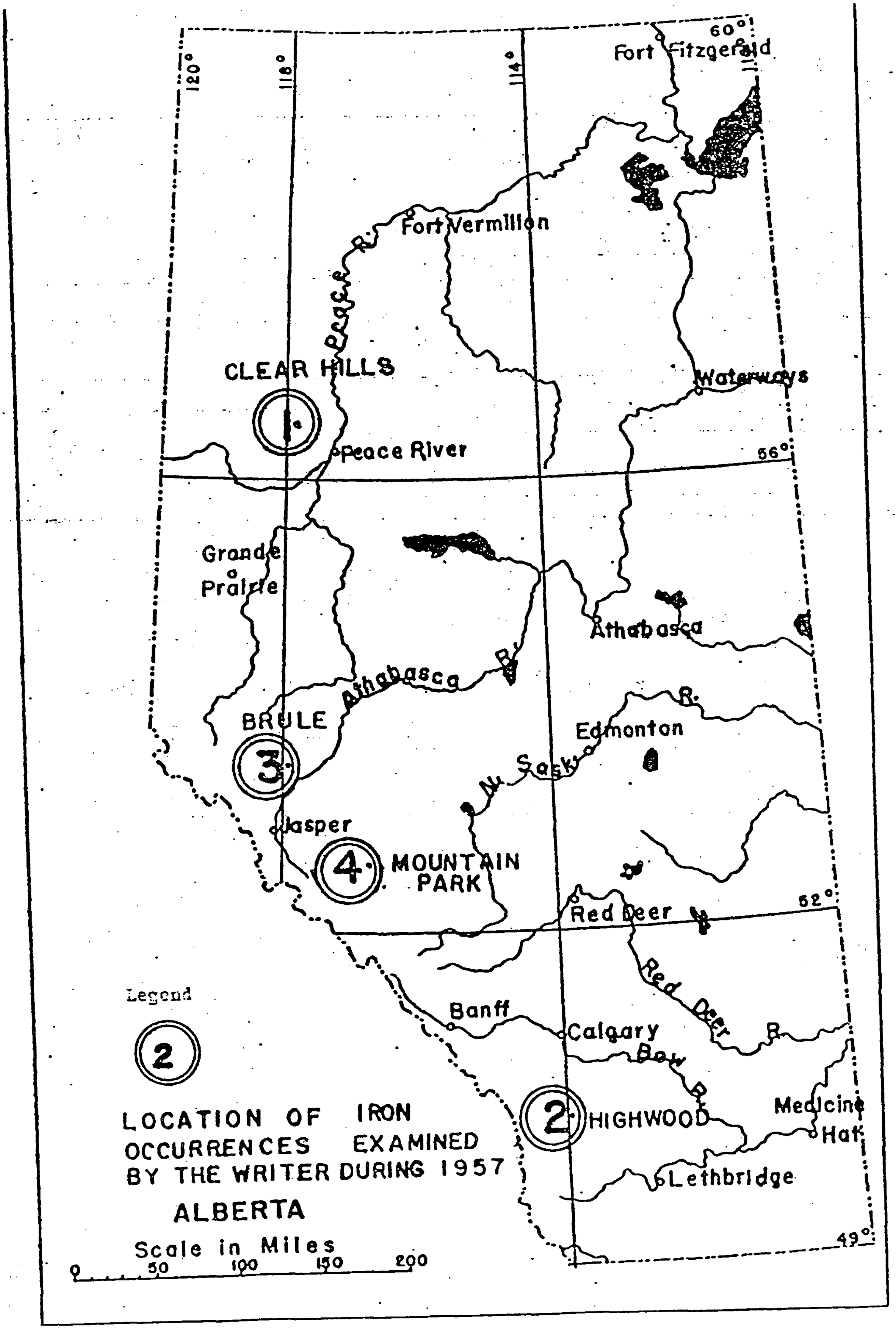
Location of Areas and Accessibility

All the areas investigated are located in the Province of Alberta, and are accessible by roads of highway calibre at least to their perimeters. The locations themselves can be reached by Alberta Forestry roads. The areas are located on the index map of Alberta (Fig. 1, p. 3) and the following is a more detailed description of location of each area in order of decreasing importance.

1.	Clear Hills	Twps. 87, 88, 89, 90, 91, 92 Rges. 4, 5, 6, 7	W6
2.	Highwood River	Twp. 16 Rge. 5	W5
3.	Brule	Twps. 50, 51 Rge. 27	W5
4.	Mountain Park	Twps. 45, 46, 47 Rges. 22, 23	W5

The Clear Hills area on which emphasis is being placed is located 300 air miles northwest of Edmonton (Fig. 1, p. 3). The east and south boundaries are accessible by road and rail, by the Grimshaw highway on the east and Hines Creek, the railhead, on the south.

The area lies between meridians of longitude 118° 30' W and 119° 00' W, and is bounded on the north and south by parallels of



LOCATION OF IRON OCCURRENCES EXAMINED BY THE WRITER DURING 1957

ALBERTA

57° 00' N and 56° 30' N respectively. This quadrangle includes all or parts of Townships 87 to 92 and Ranges 4 to 7 west of the sixth meridian (Fig. 2 in envelope on back cover).

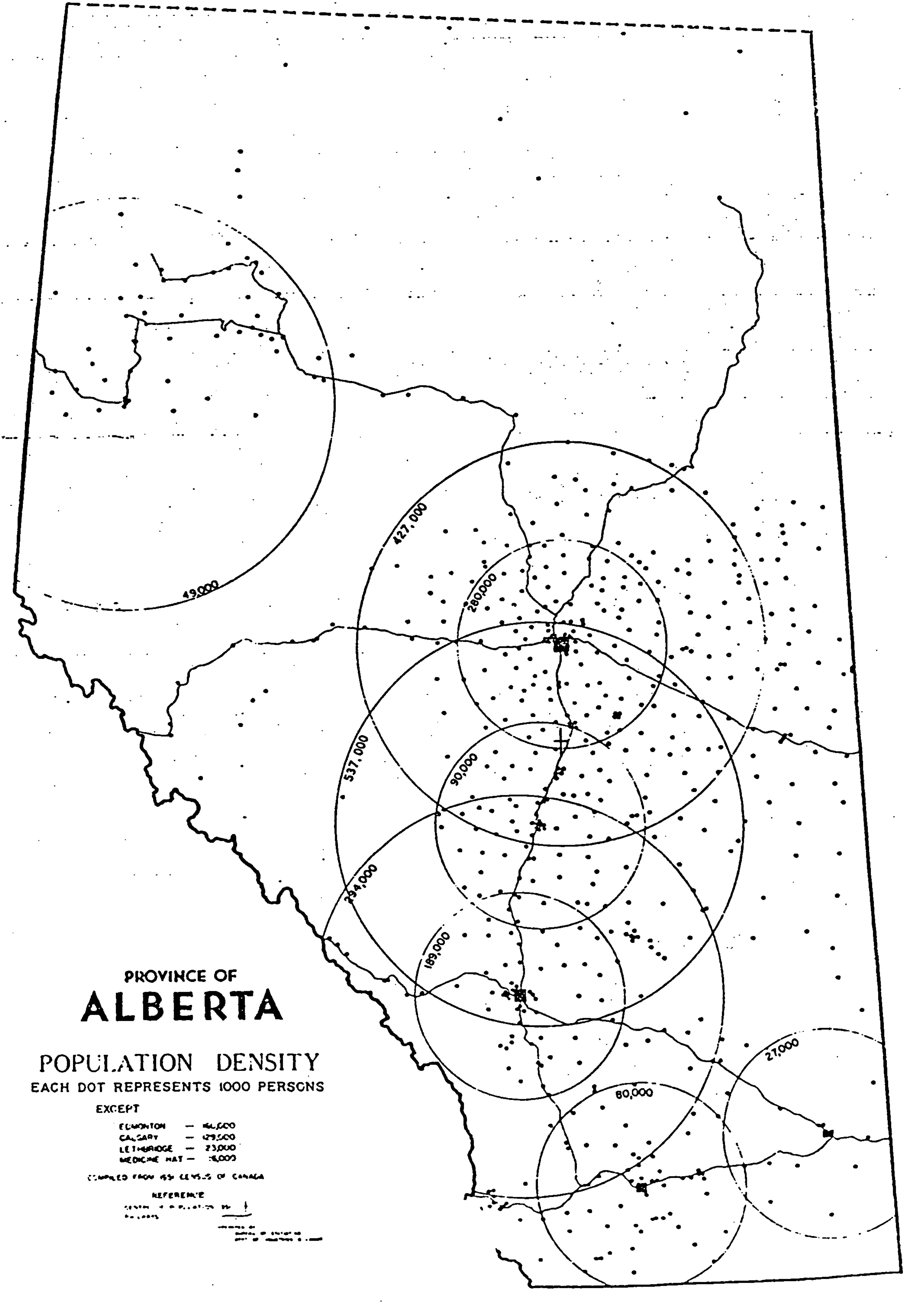
Culture

The chief occupations of the population in this area are similar to those of the entire Peace River Block - agriculture, subsidiary lumbering, and the usual winter trapping. The farming areas are confined to the perimeters of the Clear Hills and the remainder of the area in question is still a veritable wilderness, inhabited by a fairly large big-game population.

The area in recent years has been literally gridded with seismic exploration cut-lines and roads, which are only passable when the ground is frozen. The Clear Hills proper are devoid of human inhabitents, except for rangers of the Alberta Department of Lands and Forests during the "fire" season and trappers during the winter.

Economics is an important aspect of this thesis and it is therefore necessary to consider the population and density of population for the entire Peace River Block of Alberta. This would assume some importance as to local labor supply if and when a basic industry is developed. There are some 13 incorporated towns and villages in this area of approximately 34,000 square miles and the total population as shown by the 1951 census consisted of 54,102 persons (Table I, p. 6). At the time of the census this number was approximately 5.75 per cent of Alberta's total population (Istvanffy, 1954).

FIGURE 3.


PROVINCE OF
ALBERTA
POPULATION DENSITY
EACH DOT REPRESENTS 1000 PERSONS
EXCEPT
EDMONTON — 160,000
CALGARY — 129,500
LETHBRIDGE — 23,000
MEDICINE HAT — 16,000
COMPILED FROM 1951 CENSUS OF CANADA
REFERENCE
49,000
427,000
280,000
537,000
90,000
394,000
189,000
80,000
27,000

The rate of increase in Alberta's population (Table I) has accelerated since 1941. This is also an important factor in consideration of steel markets in the western provinces and should be related to density of population, as shown in Figure 3, page 5.

TABLE I

DENSITY OF POPULATION & AREA

	Area	Density
CENSUS DIV. 15	22,845 sq. miles	0.95
CENSUS DIV. 16	11,100 sq. miles	2.92
	33,945 sq. miles	

POPULATION (as of 1951)

Peace River Block, Alberta

Census Div. 15 - 21,663
Census Div. 16 - 32,439
54,102

5.75% of Alberta's total in 1951.

Population of incorporated cities, towns, and villages as of 1951:

Beaverlodge	514	Fairview	929
Falher	575	Grande Prairie	2664
Grimshaw	564	High Prairie	1141
Hythe	342	Kinuso	238
McLennan	1074	Peace River	1672
Rycroft	372	Spirit River	553
Wembly	251		

Population Alberta	1941	796,169
Population Alberta	1951	939,501
Population Alberta	1953	1,002,000
Population Alberta	1957	1,200,000

Population increase 66% since 1941.

Present Work

The writer, employed by Cliffs of Canada, Ltd., under the direction of Dr. W.L.C.Greer in Port Arthur carried out field investigation of reported iron occurrences in Alberta during the field season of 1957, as complete as time would permit.

Sections of Cretaceous sediments with showings of iron were examined in the Highwood River, Mountain Park, Brule and Clear Hills areas (Fig. 1, p. 3).

Two areas showed some promise of grade and quantity: the Highwood area of southern Alberta and the Clear Hills area of northwestern Alberta. The emphasis was placed on the Clear Hills deposits and most of the detailed work in the field and laboratory was carried out on this material.

Samples were collected from all areas previously mentioned, with careful sampling of the two areas that were assessed to be actual prospective deposits. The Clear Hills and the Highwood River areas appeared to present the best possibilities. Thin sections of samples from exposures examined, including sections of the Clear Hills and Highwood samples, and key sections of samples from other areas of lesser importance to be used in possible correlation, were prepared by a commercial laboratory. Crushed mounts were also prepared from the Clear Hills samples. Complete quantitative analyses were carried out on the Clear Hills samples and sanidine feldspar was separated for A^{40}/K^{40} age determination. Further details of methods and results are described in their respective chapters.

Previous Work

The Peace River has been a historic trade route across this part of northwest Canada, and today the famous Alaska Highway passes through the area.

Earliest observations on the geology were generally confined to the banks of the Peace River and its tributaries. The generally open character of the country made it possible for some early explorers to carry out reconnaissance surveys overland.

The earliest report containing reference to the geology of the Peace River Block is that of Selwyn (1875-76) in a reconnaissance survey of areas in northeastern British Columbia and east along the Peace River. A later survey by Dawson (1879-80) covered the Peace River area in more detail. He subdivided the Cretaceous of this area and assigned formational names, some of which are still retained.

McLearn (1917-19) made a more systematic survey and study of the Cretaceous formations exposed along the Peace and Smoky Rivers.

A general report on the geology of the Mackenzie River basin (Camsell et al, 1919) contains a summary of the geology along the Peace and Smoky Rivers on a small scale map and in very little detail.

J.A. Allan examined the Cretaceous section along the Peace in 1921 and at some points along the Smoky River at a later date. The results of his observations appear in the Research Council of Alberta Reports for 1921 and 1924.

In 1929 a detailed survey of the geology and water resources was carried out in parts of the Peace River and Grande Prairie districts.

This report contained detailed descriptions of formations examined (Rutherford, 1940). Additional work was carried out by J.A. Allan and C.R. Stelck (1940) and again by C.R. Stelck (1941). These reports were concerned with the Pouce Coupe area but since there are formational correlations with the Peace River area they have been included as references. The advent of the province-wide oil and gas exploration was mainly responsible for the opening up of this particular area.

In 1951 Phillips Petroleum Co. Ltd. drilled a wildcat well in the Clear Hills area, located in Legal Subdivision 12, Section 29, Township 89, Range 4, west of the 6th principal meridian. The oolitic iron member was encountered after passing through 50 feet of glacial debris and 420 feet of the Kaskapau (Upper Cretaceous) formation. This was the first indication, to the best knowledge of the writer, that an oolitic iron bed of this thickness was present in the Cretaceous (Istvánffy, 1954).

In 1954 the Alberta Government issued four exploration permits covering iron occurrences in the Clear Hills area.

The McDougall-Segan Syndicate, formed in 1954, reported that diamond drilling of their deposit on the east flank of the Clear Hills in Townships 84 to 95, Ranges 3 to 6, west of the 6th meridian, had indicated a flat-lying bed of oolitic iron averaging 10 feet in thickness over an area 13 miles by 3 miles. A potential reserve of one billion tons of "ore" averaging about 34% iron was reported (Janes, 1957).

Concentration tests carried out by the Mines Branch, Ottawa, indicated certain problems. In 1956 the Research Council of Alberta undertook research into the benefication of the iron, with special attention to mineralogy and chemistry of the deposit (Grace, 1956). A reconnaissance of the Clear Hills area made by Research Council geologists under the supervision of Dr. D.J. Kidd, during the summer of 1956, disclosed that the arenaceous oolitic iron of Upper Cretaceous age outcropped along the valley walls of Swift Creek in the Clear Hills. The outcrop area straddles the boundary between Townships 90 and 91, Range 3, west of the 6th meridian, and is roughly forty miles north of the railhead at Hines Creek. In July, 1956, Premier Steel Co. Ltd., Edmonton, took over iron permits that had been dropped by the McDougall-Segan Syndicate. During the fall of 1957 the writer carried out a field investigation of the Swift Creek areas.

CHAPTER II

GENERAL CHARACTER OF THE AREA

Geological Succession

The consolidated strata underlying the area shown on the map, Figure 2, are all of Cretaceous age. Only the oolitic iron member of the Kaskapau formation is exposed and forms the valley walls of some of the streams. The Dunvegan and older formations are exposed outside the immediate map area (Rutherford, 1930, p. 19), in the valley of the Peace River and near Grimshaw on the Mackenzie highway. A mantle of superficial Pleistocene and Recent deposits, varying in thickness from a few feet to approximately 100 feet, covers most of the area. The Pleistocene deposits are thickest in the preglacial valleys, where the continental ice sheet deposited most of its debris load. In general the strata dip to the south and regional slope, as indicated by the drainage, is to the north.

The general character of the formations in the area, names assigned to them and thicknesses as noted in the well log of Phillips "C" No. 1, are as follows:

TABLE - 2 -

TABLE OF FORMATIONS

Era	Period or epoch	Formations and thickness (feet)	Lithology
Cenozoic	Pleistocene	0-100 feet	Till; lake and stream deposits of boulders, gravel sand, silt and clay.
Mesozoic	Upper Cretaceous	Kaskapau 560 feet	Dark to black shales of marine deposition; some fine-grained sandstones and oolitic iron.
		Dunvegan 833 feet	Alternating sandstones and shales, brackish water deposition; some sandstones up to 50 feet thick.
		Shaftesbury 644 feet	Dark blue to grey friable marine shales; ironstone concretions.
	Lower Cretaceous	Peace River 251 feet	Massive sandstones, with a lower shale and alternating sandstone members.

Physiography

The Clear Hills area is part of the Great Plains region of western Canada. The area under discussion has been modified by glaciation and post-glacial laking (Pl. I, B., p. 85) from a maturely dissected topography to a youthful topography broken by the highland expression of the former uplands.

This area of low rolling hills, with a maximum elevation above sea level of approximately 3000 feet (local relief of 300 to 400 feet), lies on the northeastern edge of the Alberta syncline. Post-Cretaceous monadnocks are responsible for the hills, in pronounced contrast to the Eureka plain to the south. The surface expression is due mainly to accumulation of glacial debris in the form of end moraines and proglacial lacustrine deposits. The area appeared as a definite high during the Pleistocene and was probably responsible for the stagnation of the continental ice sheet in this area. The ice sheet contributed to the formation of many of the landforms present today.

Drainage

The waters of the entire Peace River area drain to the Arctic Ocean, by way of the Mackenzie River system.

The Clear Hills area is drained by streams flowing into the Peace River, which flows along the southern and eastern boundaries of the map sheet. The main streams flow across the area from west to east to the Peace River. Locally the drainage pattern is dendritic and youthful in stage.

The majority of the streams are underfit (too small to be responsible for the valley they flow in) and flow in glacial debris-choked preglacial valleys. The Notikewin River, largest in the area, forms the northern boundary of the area examined by the writer. It exhibits many splendid examples of ox-bow lakes, meander scars, meander scrolls and cyclic terraces. There is good evidence here of successive lowering of the meltwater during the final wasting of the continental ice sheet.

Some of the streams occupy proglacial spillways in part and preglacial valleys throughout the remainder of their course; while others have cut through the unconsolidated debris and are actively cutting the underlying Cretaceous bedrock. Summer rainfall ranges from 30 to 40 inches, consequently the dendritic drainage pattern in the unconsolidated glacial debris is very dense (Fig. 2). Springs are abundant on all slopes, indicating a very shallow water-table. The majority of springs carry iron in solution.

Preglacial Topography

Prior to glaciation this area is considered to have been a maturely dissected upland. The present topography has been modified to some extent by the erosive action of the continental ice sheet; the deep preglacial valleys have been filled with glacial debris and proglacial lacustrine deposits. The existing streams are presently eroding down to preglacial base level and are flowing in the same direction as preglacial streams.

The drainage pattern indicates a strong east-west lineation of ridges and hills. The hills are preglacial, modified by glacial action and masked with a veneer of glacial debris. Proglacial spillways have provided additional stream channels and are used in part by some of the present streams.

Terminal moraines in many localities occur on the preglacial ridges, restoring some of the relief that was destroyed by the continental ice sheet.

Forests and Woods

The uplands are the most heavily wooded (Pl. I, A., p. 85) and have not suffered fire damage in recent years. Spruce and poplar are most abundant and are sufficient in size and quantity to support several small lumber mills. There are several permanent planing mills in Hines Creek and many portable mills were noted, well into the map area. The stands of spruce would serve a mining operation's needs for timber.

The flat areas to the south, which include most of the settled districts, are in part open and in part wooded with poplar and shrubbery. This is gradually being removed as the cultivation of the land progresses.

It is also noted that spruce are found mainly on the north slopes and the aspen, poplar and birch groves are confined to the south. There appears to be very little mixing of coniferous and deciduous types. Forest reserves play an important part in the economy of this region.

CHAPTER III

DESCRIPTIVE GEOLOGY

Structure

The Clear Hills area is situated on the east limb of the "Alberta Syncline". Late Cretaceous and early Tertiary formations infilling the syncline are best developed in the southern half of Alberta. The distribution of these formations indicates that the trend of the synclinal axis is to the northwest. The axis extends northwest and crosses the Peace River near the west boundary of Alberta (Rutherford, 1930, p. 13).

Inclination of the strata forming the east limb of this syncline is generally small throughout the province. This holds true for the Clear Hills area, where the beds are flat-lying or dipping gently to the south.

The Clear Hills area has few outcrops. The only Upper Cretaceous bedrock examined in the field was the massive oolitic iron member of the Kaskapau formation. Any detailed study of structure from outcrop investigation is impractical. It is felt that the general structural features of the Peace River area as noted by previous workers (Rutherford, 1930, p. 14) holds for this area as well. Dips of low inclination to the south were observed in the oolitic iron member; but further evidence of structure was lacking. The overlying shales had been eroded off and underlying shales are not exposed.

Stratigraphy

The names assigned to the formations occurring within this area are tabulated in Chapter II. Most of these formations belong to the Upper Cretaceous. Correlation of these formations has been restricted to the Peace River and Athabasca River areas and is based on early work of McLearn (1917) and more recent microfaunal studies by C.R. Stelck and J.H. Wall (1954 and 1955).

None of the formations tabulated, with exception of the oolitic iron member, were examined in the field, but all were encountered in the discovery well. Descriptions of these formations are included in this thesis as a useful reference.

All of the formations described outcrop immediately outside the map-area. The following are detailed descriptions of the important formations of the Cretaceous of this area:

Peace River formation, Fort St. John group, Lower Cretaceous

Author: McConnell (1893)

Type locality: The Peace River sandstones ..... appear from beneath the latter (Shaftesbury formation) in descending the river immediately below the Smoky River forks, and are then exposed in the banks of the valley down to about three or four miles below Battle River (now Notikewin River).

Lithologic characteristics: McConnell - The Peace River sandstone consists of heavy massive beds of yellowish and greyish soft coarse sandstones, alternating with bands of thin-bedded sandstones and shales. The massive beds have an occasional thickness of fifty feet or more, and weather into a series of steep cliffs separated by sloping terraces cut out of the shaly bands. Lignite seams occur occasionally, and hard sandstone concretions ranging from a few inches to ten to fifteen feet in diameter form a prominent feature of the formation. In descending Peace River, the Peace River sandstones become more argillaceous, decrease gradually in thickness and at length disappear a few miles below the mouth of Battle River. In 1951 Wickenden described the Peace River formation as consisting of the following:

Continental member
Cadotte member
Middle shale member
Basal member

In 1952 a study group of the A.S.P.G., under the chairmanship of L.E. Workman (1954), restricted the Peace River formation and redefined it so that it contained the following:

Paddy member - 0-130 feet, average 60
Cadotte member - 40-170 feet, average 70
Harmon member - 40-110 feet, average 60

Thickness and distribution: As redefined, the Peace River formation averages 190 feet in thickness and in the cross-section accompanying the A.S.P.G. study group report the formation is recognized in subsurface from the Alberta-British Columbia boundary eastward to the south shore of Lesser Slave Lake.

Relation to other units: The formation is underlain by the siltstones and sandstones of the Notikewin member of the Falher formation and is in turn overlain by the dark marine shales of the Shaftesbury formation.

Shaftesbury formation, Fort St. John group, Lower Cretaceous

Author: McLearn and Henderson (1944)

Type locality: Lower Peace River, Alberta

History: The name "Fort St. John shale", originally used by Dawson (1880), applied to dark shales below the Dunvegan formation. Base defined by McConnell (1893) as shales between Peace River sandstones and Dunvegan formation. McLearn (1917) shortened name to "St. John" and used in the same manner as McConnell. Wickenden and Shaw (1943) raised Fort St. John to group status. McLearn and Henderson (1944) introduced Shaftesbury for shales formerly called Fort St. John and St. John in the lower Peace River area.

Lithologic characteristics: McLearn (1917) describes the formation as a sequence of dark blue to grey friable marine shales with occasional rounded or banded ironstone concretions.

Thickness and distribution: At type section 70 feet is exposed but it is estimated that at least 560 feet is present. In the Cache Creek area 1,300 feet has been measured.

Relation to other units: The contacts with the overlying Dunvegan formation and the underlying Peace River formation are conformable and gradational. The Shaftesbury is equivalent to the Cruiser, Goodrich, and Hasler formations of the Pine River area, British Columbia, and to lower Blackstone where the Dunvegan pinches out to the southeast. Wickenden and Shaw (1943) show a direct correlation with the "Dark Marine Shale" of the Lone Mountain area, British Columbia.

Paleontology: The Fish Scale zone is a prominent horizon within the Shaftesbury. The following fossils have been identified from the formation: *Neogastroplites*, *Posidonomya nahwisi* in British Columbia.

Dunvegan formation, Upper Cretaceous

Author: Dawson (1880)

Type locality: Near Dunvegan Trading Post, Peace River, northwestern Alberta

Lithologic characteristics: Consists of marine and non-marine sandstone, light grey to yellowish buff in color. Beds are massive and show crossbedding. Zones of thin-bedded sandstone and shale, shelly limestone and coal are present. Freshwater and marine fossils occur in the sands. The Dunvegan forms conspicuous light brown weathering mesas and buttes.

Thickness and distribution: 500' to 600' in the Peace River area thinning to the south and east. The Dunvegan extends from the Peace River area north to Fort Nelson and the Liard River, and in the foothills belt as far south as Jasper.

Relation to other units: The Dunvegan is overlain conformably by the Blackstone formation in central Alberta and by the Smoky River formation in the Peace River area of northeastern British Columbia. It is underlain by the Shaftesbury formation of the Fort St. John group. Both contacts are gradational. The Dunvegan is correlated with the Fort Nelson formation of northeastern British Columbia and the Liard River formation.

Paleontology: Non-marine fossils: *Unio dowlingi*; *Melania*; *Unio* sulfuriensis; Corbula pyriformis var. dunveganensis.

Marine fossils: Corbula cf. nematophora; Inoceramus dunveganensis; Inoceramus mcconnelli; Inoceramus rutherfordi; Inoceramus athabaskensis; Barbatia micronema; Ostrea anomioides.

Kaskapau formation, Smoky River group, Upper Cretaceous

Author: McLearn (1926)

Type locality: On the Peace River, vicinity of Dunvegan, the base outcrops at the top of the Dunvegan cliffs. On the Smoky River below Puskwaskau River to about 12 miles below Racing Creek, this member is exposed on the valley sides.

History: The Smoky River group was first used by Dawson in 1879 for shale strata exposed on the Smoky River. This unit was subdivided in 1918 by McLearn into the following members: Upper Shale, Bad Heart sandstone and Lower Shale. In 1926 he assigned the name Kaskapau to the lower shale member. The name Kaskapau is apparently derived from the term "Ka-ska-pa-te-si-pi", Cree for Smoky River. Gleddie (1948) proposed formational status for the Kaskapau shale within the Smoky River group.

Lithologic characteristics: Predominantly dark grey fissile carbonaceous shale, friable near the base, with varying amounts of ironstone concretions throughout. Sandstone lenses occur near the top and thin fine-grained sandstone beds are found near the base.

Thickness and distribution: The Kaskapau formation is about 520 feet thick on the Smoky River, and about 550 feet thick in the Sturgeon Lake area. At Wembly the formation is either thickened by lenses or it interfingers with a late Dunvegan sandstone series. Warren and

A COMPARISON BETWEEN OOLITIC ORE DEPOSITS

Geographic location		Clinton hard ore, U.S.A.	Lorraine Minette ore, France	Cleveland-Hill ore, England	Wabana ore, Newfoundland	Salzgitter ore, Germany		Clear Hills ore, Alberta, Canada
						High grade	Low grade	
Mineralogical composition		Hematite	Limonite Siderite Hematite	Chamosite Siderite	Hematite Chamosite Siderite	Siderite	Siderite	Limonite-goethite Siderite-chamosite?
Geological age		Silurian	Jurassic	Jurassic	Ordovician	Cretaceous	Cretaceous	Cretaceous
Associated rocks		Limestone Shale	Shales, sand-stone, marl	Shale	Sandstone Shale	Sandstone Shale	Sandstone Shale	Sandstone Shale
Chemical composition	Fe	37.0	30.0	36.0	20-57	32.60	29.70	30.15
	Mn	0.23	----	----	----	0.22	0.12	0.15
	P	0.30	0.5-1.8	0.55	0.7-2.0	0.37	0.48	0.58
	SiO_2	7.14	7.2	8.51	6.50	27.00	27.80	25.36
	Al_2O_3	3.81	----	6.12	3-6	10.17	5.60	6.24
	CaO	19.20	12.0	5.74	1.30	0.16	3.95	* ----
	H_2O	----	----	3.75	----	1.65	1.48	----
	S	0.08	----	0.05	----	0.16	0.05	+ 0.701

* Sometimes present

\+ Not always present

Stelck (1940) include the Pouce Coupe sandstone in the Kaskapau formation.

Relation to other units: Succeeds the Dunvegan sandstone and precedes the Bad Heart sandstone. The corresponding unit of the central Plains occurs about 180 feet below the First White Specks to below the Second White Specks.

Pleistocene Deposits and Recent Deposits

Some reference to these deposits has already been made in Chapter II.

Pleistocene deposits, including those formed immediately following glaciation, are prevalent throughout most of the area.

The recent deposits, consisting chiefly of river gravels and sands, are of no special significance.

The deposits due to glaciation are chiefly derived from areas to the northeast, since ice from the Keewatin centre covered the area.

The Pleistocene deposits are two main types: unsorted materials derived from melting ice, boulder clays and gravels, and the semi-stratified glacio-lacustrine deposits of finer silt-like material (Pl. I, B., p. 85).

Lithology

This thesis is concerned with the study of the oolitic member of the Kaskapau formation. Therefore this section will deal with the lithology of the Kaskapau underlying and overlying the oolitic iron member.

The following well log of Phillips "C" No. 1, as described by Richard Procter (Procter first noticed the iron in the discovery well), gives a fairly detailed lithologic description of the bedrock encountered under the drift.

TABLE 3

LITHOLOGIC DESCRIPTION
Well log of Phil. "C" No. 1 - after Richard M. Procter.

Rock type	Description	Footage
Sand, gravel	Glacial drift	10-50
	Kaskapau formation	
Shale	light grey to grey-green, finely micaceous, slightly calcareous, bentonitic and silty. Lignite occurs as laminae in the shale.	50-120
Sandstone	light grey-brown, fine-grained. Sand grains in the rock are subrounded, well sorted, and mostly clear to pink quartz.	120-160
Sandstone with shale	Sandstone is generally shaly, and very calcareous at base of the section. Shale is grey to grey-buff, finely micaceous in part, and also slightly calcareous. The amount of the shale increases downward.	160-210
Shale	grey to light grey-green, fissile but soft, silty and bentonitic in part; small amounts of ironstone. Coal and sandstone are present in some places.	210-310
Sandstone with shale	shale is grey and yellowish brown, fissile but soft; bentonitic, silty and finely micaceous in part. Sandstone is buff to brown, fine-grained, quartzose, glauconitic, calcareous, carbonaceous, siliceous, and micaceous, and grading to argillaceous limestone in part.	310-400

Rock type	Description	Footage
Shale	grey, grey-green to buff; finely micaceous, bentonitic and silty in part. Pelecypod shell fragments are abundant. Sandstone beds are present in some places.	400-470
Iron-bearing oolitic bed	yellowish brown to red oolites are embedded in a dark brown to black matrix. The average size of oolites is less than 0.5 mm. in diameter. Some pyrite and bentonitic shale is present in various places.	470-610
Shale	grey, bentonitic, finely micaceous. Some pyrite and oolitic cavings are present in various horizons.	
	Top of Dunvegan formation.	

Age and correlation of the Kaskapau formation and its included oolitic iron member

The oolitic iron bed is associated with the shales and sandstones of the "lower" Kaskapau formation. Evidence elaborated below indicates the iron is upper Cenomanian in age. This places it in the lower portion of the *Gaudryina irenensis* microfaunal zone and the upper portion of the *Dunveganoceras* megafaunal zone and makes it approximately equivalent to the Doe Creek sandstone of the Pouce Coupe area. Stelck and Wall (1955, p. 20) outline a zonation based on foraminiferal faunistic changes from the upper part of the Cenomanian strata into lower Turonian stage as follows:

TABLE 4

FOSSIL ZONES IN THE KASKAPAU

Turonian	"Central" Kaskapau	Pelagic microfaunal zone (lower or second white speckled shale) *Haplophragmoides spiritense* zone (includes white chalcedony bed)
Cenomanian		*Ammobaculites pocalis* zone (includes Howard Creek sand)
	Lower Kaskapau	*Gaudryina irenensis* zone (includes Pouce Coupe sand at top and Doe Creek member near base) *Ammobaculites gravenori* zone
	Dunvegan restricted	Unnamed microfaunal zone

Stelck and Wall (1955, p. 7) presented a succession of lithologic markers from the lower Turonian to Cenomanian stage from the Pouce Coupe area (thicknesses are approximate).

TABLE 5

LITHOLOGIC HORIZON MARKERS

Formation		Members and markers
"Central" Kaskapau		Second white speckled shale member
		"White chalcedonic bed" or "white nodular member"
	50'	shale
		Cenomanian-Turonian contact
	20'	shale
		Howard Creek sand top
	130'	sandy and tuffaceous shales
"Lower" Kaskapau	30'	Pouce Coupe sandstone
	74'	shale with ironstone
	6'	Doe Creek sandstone
	190'	sandy shales

Dunvegan formation - sandstones and shales.

The terms "Central" and "Lower" were introduced by Stelck and Wall (1955, p. 7). Locally the "Central" and "Lower" Kaskapau portions have been correlated from Pouce Coupe to Spirit River (Stelck and Wall, 1954, pp.9-14). Regionally the Kaskapau has been correlated with many areas in the United States and Canada (Stelck and Wall, 1954, pp. 14-16).

A study of the microfaunal assemblages received from two core holes, Eureka No. 1 and No. 2 (McDougall, 1954) was carried out by Lenz (1956). The microfauna in the shales underlying the iron bed were found in both core holes, establishing a horizon for the iron bed.

Lenz (1956, p. 16) reported that all of the foraminifera were arenaceous forms and divided the fauna into two zones based on the Ammobaculites gravenori and Gaudryina irenensis of the Peace River area (Stelck and Wall, 1955, p. 21-22). Apparently neither of these species was present in this locality and Lenz (1956) based his zonation on the faunal assemblage and on the presence of Proteonina alexanderi. This placed the section in the Upper Cenomanian stage. Lenz (1956) concludes that the iron bed overlying the shales would be within the lower part of the Gaudryina irenensis zone. This would be equivalent to the Doe Creek sand (Stelck, personal communication), a thin sandstone member in the lower part of the Kaskapau formation of the Peace River area. Stelck and Wall (1955, p. 27) and Lenz (1956, p. 18) believe the environment to be near-shore, probably brackish or lagoonal, based on shallow-water arenaceous fauna present. Stelck and Wall (1955, p. 28) believe that the depth of water was slowly increasing, with a change from almost fresh water to normal salinity and with normal deposition from lowered source areas accompanied by the deepening of the late Cenomanian seas.

CHAPTER IV

GENERAL CHARACTER OF THE "ORE"

General Statement

The oolitic iron "ore" was examined in place, outcropping along the valley of Swift Creek (Fig. 2 - in envelope at back of thesis). The exposure varied in thickness at the surface from a few feet to over 25 feet. This variation was due mainly to slumping of superficial glacial deposits covering the outcrop wherever the angle of valley slope was low enough to support this material. The thickest sections were not examined in detail because the straight walls made them inaccessible (Pl. II, B., p. 86). However, the general character and appearance of the "ore" along several miles of the valley bottom was uniform and massive. There did not appear to be any variation so far as could be seen.

The only exception to this was the color change in the outcrop from water level up for several feet - the "ore" was definitely greyish green in color and graded into the brown and reddish brown. This variation in color can be seen in Plate VII, A., page 91; and Plate IV, A. and B., page 88. This color variation has definite chemical implications.

The oolitic iron weathers very easily because of its soft and friable nature. The well weathered surface takes on the appearance of a clay bank (Pl. III, A., p. 87) and could easily escape detection. Farther upstream the outcrop had been subjected to recent frost action and fresh "ore" was exposed (Pl. V, A. and B., p. 89). In Plate III, B., page 87, close examination revealed a hint of weak bedding but the most noticeable feature was the large-scale polygonal pattern to the "ore", almost "honeycomb" in effect. This would seem to indicate post-depositional ground-water action with concentration of iron oxide along planes of weakness.

A typical exposure was chosen in excess of 24 feet and trenched to the fresh material (Pl. III, A., p. 87). This exposure was carefully measured and composite samples were taken from each two-foot interval. The exposure was sampled from the bottom up, since this was the simplest method.

Petrology

Megascopic description: DeFord and Waldschmidt (1946) presented the following definitions of oolite and oolith: ..... "An oolite is a rock made up of an aggregate of small spheroidal bodies called ooliths, held together by interstitial cementing material. The normal diameter of an oolith is less than one millimeter. The name oolith comes from the resemblance to fish roe .....". The recommended size range for the ooliths is 0.1 - 1.0 millimeters in diameter. The term ooid was recently proposed by P.E. Cloud (DeFord and Waldschmidt, 1946, p. 1588) to be used in preference to the term oolith by some authors to avoid confusion with oolite and oolitic. In this thesis the writer will use the terms oolite and oolith as elaborated by DeFord and Waldschmidt (1946).

The Clear Hills ferruginous oolite does not appear to have definite bedding planes. It is quite probable that if any existed they were destroyed by the post-depositional compaction of the material or by mechanical redeposition.

The oolite in outcrop and hand specimen presents a variety of colors ranging through grey-green (Pl. VII, A., p. 91), greenish grey, yellow-brown to reddish brown (Pl. VI, A., p. 90) with bluish black iron oxides concentrated along post-depositional fracture planes in the section. The oolite from a distance appears to be a rusty nodular sandstone. On closer inspection it is apparent that the material is sandsize but appears as uniform spheroids similar to very fine pellets, having a submetallic luster, embedded in an earthy matrix varying in color from greenish grey to reddish brown. Examination by hand lens and binocular microscope revealed fine sandsized angular quartz, false ooliths formed from rock fragments and irregular-shaped concretions of grey-green mudstone possibly chamositic or sideritic in composition.

The oolite exposure varied in hardness from the bottom of the exposure to the top. The softer friable material was found at the top of the bed. This may have been due to surface leaching and exposure but it was also noticed that the density of ooliths increased upwards and therefore the matrix volume decreased.

The oolite outcrop, where exposed to weathering for any length of time, disintegrated easily, presenting a yellowish brown earthy appearance (Pl. III, A., p. 87) which could easily be confused with subsoil overburden. A portion of sample CH-10 (Appendix, p. 73) was subjected to several freeze-thaw cycles, having first been saturated with water. It disaggregated with facility and produced a very fine sand composed of the ooliths (Pl. VI, B., p. 90).

Samples from the upper beds, dark reddish brown in color, were extremely friable and could be broken up by squeezing between the fingers. Under the binocular microscope the material consisted largely of dark brown spherical, subspherical, and oblate spheroidal accretionary bodies displaying a submetallic luster, with common sizes less than 0.25 mm. The ooliths are loosely held in clay-like light greenish-colored matrix in the basal beds but as the percentage of ooliths becomes greater the matrix decreases and merely fills the interstices of the ooliths in contact.

Most of the broken ooliths exhibit fresh-looking angular quartz nuclei, concentrically surrounded by a dark brown limonite-like material. HCl (1:1 Solñ) was applied on a polished surface of a sample and observed under the binocular microscope. It is noticed that an accelerated reaction takes place in or around the nuclei and sparsely in the matrix. It was found that the polished surface was extensively etched. The remains from the etching were quartz sands and concentric rings of limonite-like material.

The surface exposures of the oolite present a definite nodular appearance (Pl. III, B., p. 87); and (Pl. IV, A., p. 88) and in fact individual nodules are quite common. Fossil wood (Pl. VII, B., p. 91) and bone were discovered in the oolitic iron bed and identified as such by C.R. Stelck (personal communication).

Microscopic description: Two series of thin sections were prepared and examined. This included 16 from the Clear Hills samples and 15 from the Highwood samples (Appendix, pp. 77-78). The Highwood thin sections were included for possible correlation of environment of deposition, source material and source area. Since variation in the material of the Clear Hills oolite was not great a general description is given, supplemented by mention of particular features characteristic of certain horizons. Outstanding examples of diagnostic features and mineralogy are depicted in the color plates included in this thesis.

The soft nature of the oolite prevented the production of thin sections of standard thickness. This was a disadvantage in that it was impractical to obtain optic figures or use birefringence in most cases in determining the minerals present. This was overcome to some extent by correlating results of other chemical and physical tests, to arrive at a reasonable determination of the mineral character of the oolite.

Because of the thicknees of the thin sections it was necessary to utilize maximum light with the aid of the converging lens and without use of the analyser nicol.

The basal beds of the exposure, greyish green in the hand specimen (Pl. IX, A., p. 93), under the microscope appeared as a mass of uniform-sized spherulites or rhombs of grey-green siderite with the occasional fragment of clean angular quartz. The ooliths were a minor constituent, probably less than 10 per cent.

Nodules removed from the deposit indicated the possibility of erosion and redeposition of the primary oolite. These nodules appeared to be composed of a microcrystalline sideritic (chamositic?) mudstone, with included individual ooliths and rock fragments containing ooliths (Pl. VIII, A. and B., p. 92). Fossil wood (Pl. XI, A. and B., p. 95) and bone is liberally distributed throughout the exposure and is indicative of near-shore environment.

The character of the oolite changes rapidly upward in the exposure. The color change is due to increase in the percentage of ooliths (Pl. VI, A., p. 90) and the increase in the amount of limonite-goethite present in the shells of the ooliths.

The ooliths show little evidence of distortion through compaction and the variable shapes can be related to the odd shapes of the nuclei (Pl. IX, B., p. 93 and Pl. XII, B., p. 96).

The ooliths vary in arrangement from being "suspended" in the matrix in the basal beds to being very closely packed. At points of contact there is little if any indentation. There are two possible reasons for this: either the ooliths were deposited in an indurated state or the matrix was soft and acted as a cushion until they were sufficiently indurated.

The nuclei of the ooliths consist of a variety of media (Pl. IX, B., p. 93). The clear subangular grains of quartz are by far the most abundant. In most cases the quartz is clear and unchanged but examples of replacement are not uncommon (Pl. X, B., p. 94). Nuclei of the ooliths consist of the following: quartz, from 15 to 40 per cent, fragments of ironstone nodules, rock fragments, and subrounded feldspar grains (orthoclase clear and fresh). No fossil foraminifera appear to be present in any of the thin sections examined. The total volume of the ooliths in the section examined varies from 10 per cent at the base to over 50 per cent in the upper beds.

The matrix is composed of the same minerals found in the ooliths: siderite, chamosite (glauconite?), limonite-goethite after siderite, quartz, feldspar, rock fragments, with the occurrence in some samples of secondary calcite, and chert fragments. In thin section No. 3080 there is evidence of chalcedonic replacement of calcite. Plate XIII, A., page 97 presents a good example of secondery calcite probably replacing siderite; all vestiges of concentric oolith structure have been destroyed.

Sideritic-chamositic (glauconitic?) mudstone forms the major portion of the matrix and varies from 10 to 50 per cent of the total volume of matrix. It varies in color from a dirty greyish green yellowish green to dirty brown, poorly translucent and is in thin section characteristically splotchy and non-uniform. Absolute determination of chamosite in the matrix was not possible. The siderite exhibits a spherulitic texture and occasionally shows good rhombic form (Pl. IX, A., p. 93).

Within the matrix are loose angular grains of quartz, occasional grains of clear subangular feldspar (commonly orthoclase), pseudo-ooliths formed of rounded fragments of ironstone and fragments of wood and bone (Pl. XI, A., and B., p. 95).

Chemistry

Quantitative chemical analyses were carried out on a series of 12 oolitic iron samples, CH to CH-12 inclusive (Appendix, p. 73).

This work was supervised by H. Baadsgaard and the analytical work done by G.M. Hughes and the writer. This analytical work was primarily carried out to determine the per cent weight of ferrous iron and ferric iron in the Clear Hills oolitic iron. The results were used to advantage in substantiating the presence of siderite ($FeCO_3$) in this deposit. One complete analysis was carried out at the University by C.E. Noble, Provincial Analyst, one by Cliffs of Canada Ltd. (p. 36) and several by the Research Council of Alberta for McDougall (1954) (Appendix, p. 76).

The iron in the basal beds is almost completely ferrous iron. This corroborates the large percentage of siderite determined in the thin sections as occurring in the lower beds. The ferrous iron content decreased from the base upwards, in the uppermost sample it is in negligible amounts.

The complete analysis revealed minor amounts of calcium oxide, magnesium oxide, and manganese. Sulphur occurred in a few samples; the sulphur may have been released by the decomposition of pyrite. Pyrite was present in small amounts as microgranular crystals in the basal beds. Calcium, sodium, minor amounts of tin and possibly chromium were found in the McDougall samples in a spectrographic analysis (Appendix, p. 76).

The complete analysis also indicates that there is sufficient silica, alumina, magnesia and phosphorus present to account for the presence of chamosite.

The chemical analysis has confirmed identifications which had been made by petrographic methods and established the presence of other minerals not indicated by microscopic examination.

The petrographic and chemical examinations indicate the presence of three principal iron-bearing minerals which include a complex oxide, a silicate and a carbonate. Shell matter probably accounts for the phosphorus content, the minor amounts of magnesia and lime indicated by the analysis, and some of the secondary calcite as revealed by petrographic examinations.

The ore and accompanying rocks appear to be free from any original lime content outside the small amounts indicated by the complete analysis.

All of the constituents of the "ore" vary somewhat from layer to layer and a representative mineral assemblage with limiting percentages is as follows:

Limonite-goethite ($2Fe_2O_3.3H_2O$ - $Fe_2O_3.H_2O$)	5-25%
Siderite ($FeCO_3$)	5-25%
Chamosite $15(Fe,Mg)O.5Al_2O_3.11SiO_2.16H_2O$	5-10%
Quartz (SiO_2)	15-20%
Collophanite? ($Ca_3P_2O_8$)	1-2%
Orthoclase ($KAlSi_3O_8$)	3-5%
Pyrite (FeS_2)	0-1%
Carbonaceous matter (C)	0-5%

Chemically the average sample from the middle of the deposit is approximately as follows:

Iron	30.15%
Silica	25.36%
Alumina	6.24%
Sulphur	0.70%
Phosphorus	0.58%
Manganese	0.15%

(The above analysis was run by Cleveland Cliffs Ltd., Ishpeming, Michigan, in core from Phillips "Cen" No. 1).

Geochronology

Age dating was undertaken to establish an age for the oolitic iron in the Kaskapau formation. The presence of sanidine feldspar, presumably of volcanic origin, provided an opportunity to obtain an age by the potassium-argon method.

Sample: A composite sample, collected from location "A" on Swift Creek (Fig. 2), representing the 16-foot to 28-foot interval (depths from surface on exposure) was used in the determination.

Preparation of sample: The composite sample of oolitic iron "ore" was mechanically crushed and pulverized. The disaggregated sample was put through a series of sieves consisting of the following screen sizes: 35, 60, 80, 100, 140, and 200 meshes to the inch (U.S. Sieve Series). The sample retained on the 140 mesh appeared to present the best size. The sieving was carried out twice, once wet and once dry.

The sample was then separated into light and heavy fractions using heavy liquid tetrabromoethane (sp. gr. was reduced to 2.54 by addition of acetone and checked with feldspar chip at 20° C). The light fraction was then run through the Frantz magnetic separator at all amperage settings and two final passes at maximum of 1.5 amps. The material in the non-magnetic fraction was then subjected to further heavy liquid separation, using tetrabromoethane (at specific gravity 2.54) and the light fraction with specific gravity less than 2.54 obtained from this operation amounted to about 6 grams. The sample appeared to be mainly feldspar with some quartz contamination.

A mount of the material was made up in Canada Balsam. This mount was examined under the petrographic microscope. The writer concluded that the feldspar present was mainly sanidine.

Potassium-Argon method: This sample was run by H. Baadsgaard after a series of washings with HCl to remove all traces of iron. The following information was obtained:

AK No. 14	Slide No. 3224
K mineral	Sanidine (?)
Oolitic member	Kaskapau formation (Upper Cretaceous)
Run No. 13	A^{40}/gm. sample 1.53×10^{-5} cc. STP
% K_2O - 2.63 (F-23)	$A^{40}/K^{40} = 0.0103$
%K - 2.18	Calculated age = 169×10^6 years.

Conclusions: It is quite apparent that the sanidine does not date the time of deposition of the iron. Feldspar in the matrix is detrital; it could possibly provide some indication of the source material.

The age places the sanidine formation in Jurassic, at about the time of the Topley batholith. Detritus from the erosion of this intrusive might possibly be the source of the iron and its associated detrital material.

Conditions of Deposition of the Iron

Castano and Garrels (1950, p. 770) based on their "experimental sea" reported that rivers of moderately low pH draining into the sea might well contain considerable quantities of ferrous iron. It has been shown that river water pH varies considerably, but some river waters have values of 7.0 or lower (Rankama and Sahama, 1950, p. 228). On reaching the sea the river would drop its clastic load. If the river entered an area of open circulation the iron would probably be precipitated immediately and be diluted with the clastic material. If, however, the area of deposition was a lagoonal or restricted basin type, the river waters would very likely keep the lagoon or basin waters fairly fresh or at most brackish. If this were the case the clastics would be left behind and the iron carried to a place where there was sufficient ocean water in equilibrium with calcium carbonate to oxidize and precipitate the iron. In sediments and sedimentary rocks ferric iron precipitates as the common valence state.

As a general rule, siderite rarely occurs in ores. It must depend for its formation on the activity of the ferrous ion and the activity of the carbonate ion. Conditions for $FeCO_3$ formation would be fairly high pH, where ferrous ion activity is maximum and the hydroxyl ion is relatively low. Both hydroxyl and carbonate increase with increasing pH and ferric iron predominates.

Where organic debris such as has been found in the Clear Hills oolite and stagnant water coexist, oxygen is rapidly removed. Iron moving into such an environment might be expected to precipitate as ferrous compounds. Therefore, formation of siderite and chamosite would be expected.

It can be stated that iron-bearing solutions moving into aerated ocean waters containing calcium carbonate will precipitate ferric oxide (Rankama and Sahama, 1950, p. 666). With the addition of silt and slight lowering of pH, chamosite might possibly be formed. If, however, iron-bearing solutions move into an area of stagnant water where organic debris tends to accumulate, the minerals formed might well be chamosite (if silt present) or siderite and pyrite.

Such conditions would not be expected to last very long; movements of the strand line might well put a given basin beyond the range of iron, and calcium carbonate deposition might be resumed. A change in river volume or silting up of a clastic-trapping basin might result in the common precipitation of the iron along with the clastic deposition. This appears to be the case at the time of iron deposition in the Clear Hills area. The thickness of the iron bed does not exceed 30 feet (McDougall, 1954) and is on the average approximately 15 feet. This would indicate a relatively short period of deposition. The environmental pH varied from time to time due to alternating periods of deposition of organic material, stagnant water conditions, and periodic re-entrance of normal sea water.

The ferrous to ferric iron ratio decreases from the base of the examined section and the upper beds contain only minor amounts of siderite and chamosite. There is sufficient Al_2O_3 present to account for the presence of chamosite or chamositic mudstone. Chamosite (hydrated Fe, Mg, Al, Silicate), known to form only in a marine environment, may be a secondary replacement of quartz and feldspar, and probably forms when the basin of deposition is subjected to an inflow of silt carried by the streams.

Ferrous bicarbonate may be formed by the action of CO_2-bearing waters on ferrous minerals in the absence of oxygen. The supposition that iron is carried in solution, principally as the bicarbonate or soluble carbonate, is fairly well founded (Harden, 1919, pp. 64-84). Iron will remain in solution if CO_2 is in excess; when CO_2 is decreased precipitation results. If oxygen is present in normal amounts ferric hydroxide will be precipitated and if oxygen is scarce ferrous carbonate will come out of solution.

In areas of brackish water in marine swamps and marshes iron is deposited in the presence of plants. Decaying vegetation inhibits oxidation as stated above, and iron is deposited as ferrous carbonate. Even if ferric hydroxide were precipitated, it could be reduced and the formation of ferrous carbonate could take place.

The aforementioned environment is very similar to that favoring coal accumulation and presence of carbonaceous material would indicate that conditions were almost right for this to occur as well. In many parts of the world siderite is associated with coal.

Low gradient sluggish streams have a very low suspended load capacity. The major iron load of this type of stream is in solution as a bicarbonate or a ferric colloid. This would account for the lack of common sediments mixed with the iron. If these streams debouched into brackish waters having an above normal content of humic acid, the ferric compounds might be reduced to the ferrous state and deposited as carbonate. The occurrence of brackish water microfaunas in the underlying shales substantiates the belief that the zone of deposition was a lagoon, a barred basin, or an estuarine delta area.

Formation and Deposition of Ooliths

The writer believes that the Clear Hills deposit is comparable to Wabana iron ore of Newfoundland in some aspects. Hayes (1915, p. 93) notes a total lack of limestone or igneous rock in the Ordovician series of sedimentary rocks of Newfoundland. This also applies to the iron member of the Kaskapau formation and the underlying and overlying Cretaceous sediments. The phosphate indicated in the analysis on page 37 could very well be derived from fossil shell remains. There is no evidence that transformation from an original oolitic limestone to oolitic siderite-limonite has taken place.

Hayes (1915, p. 82) also contends that the siderite of Wabana formed at the sea bottom or just below the surface of deposition at the expense of chamosite and hematite in the presence of organic debris undergoing decomposition. Hayes finds siderite at the base of the Newfoundland bed, a noteworthy comparison since the siderite of the Clear Hills oolite is most abundant at the base of the bed and decreases upwards. It has been shown that it tends to replace quartz and limonite-goethite.

The formation of Florida and Bahama oolites is said to be dependent on bacteria active in shoal waters precipitating enormous quantities of calcium carbonate (Illing, 1954, p. 41) under definite temperature conditions and salinity. The chemically precipitated calcite may form spherulites which in turn form ooliths by accretion aided by wave action in the shallows. Similar physical methods might have been operative for the formation of the siderite-chamosite-limonite-goethite ooliths.

Krumbein and Garrels (1952, p. 28) believe that siderite precipitation takes place in barred basins or stagnant lagoons or estuaries at a pH of 7.0 to 7.8 and an Eh of approximately -0.2.

The writer believes that the Clear Hills ooliths are primary in origin, because of the following observations:

(1) There is no evidence of primary calcite ooliths

(2) In near-shore marine waters the redox potential and pH tend to favor the formation of siderite

(3) There are no limestones of note in the Cretaceous

lithologic sequence involved, and least of all oolitic limestones

(4) The siderite is for the most part amorphous and there is little evidence of secondary crystallization

(5) The carbonate content of the waters of deposition was not in excess or limestone would have been precipitated

(6) The carrier water would have to be carbonated to carry sufficient iron to account for the deposit

(7) The carbonated iron-bearing fresh waters, on reaching the marine or brackish water of higher pH, would tend to precipitate iron out as a carbonate.

That the formation of ooliths is due to precipitation caused by physio-chemical reactions has been conclusively established (Bucher, 1918). The environment of oolith deposition was a controversial subject for many years. Hayes, Gruner, Illing, Kelly and many others working in this field have concluded that ooliths are formed in relatively shallow water of estuaries, lagoons or very shallow seas, where the turbulent action of current or waves served to suspend suitable nuclei for subsequent accretion of oolith shells. This concept is now generally accepted.

Oolitic iron deposits are almost entirely within marine beds but it has been reported (Kelly, 1951, p. 2222) that ferruginous ooliths are now forming in certain Swedish lakes. It is also known (Twenhofel, 1939, p. 573) that oolites form under subaerial conditions in certain soils and of course these oolites might be eroded and deposited in the sea. Furthermore, it has been recognized that oolites formed one place in the sea probably have been reworked by currents and deposited in their final burial place wholly by mechanical means. There is considerable evidence to support the theory that this is the case with the Clear Hills oolitic iron deposit. There do not appear to be any gradations in the Kaskapau, contacts are sharp chemically, lithologically, and faunal-wise. Nodules (Pl. VIII, A. and B., p. 92) are common in the deposit containing a mixture of sideritic chamositic matrix, individual ooliths and rock fragments with included ooliths. Oolith fragments are not uncommon, together with fragments of chert, secondary calcite after ooliths (Pl. XIII, A., p. 97), calcite veins, pseudo-ooliths of rounded rock fragments (Bastin, 1950, p. 67) and ironstone nodule fragments. Lack of fossils of marine origin in the deposit also points to possible mechanical deposition of the primary material.

Iron mineral oolites may develop by either: (1) accretionary growth about a nucleus before burial (Pl. XII, A., p. 96); (2) concretionary crystallization from a hydrogel of amorphous solid; (3) pseudomorphous replacement in sea water of an earlier non-iron oolite (Brown, 1914, p. 770); (4) oolitic replacement in sea water of a non-oolitic substance; (5) crystallization in oolitic form of finely divided crystals and amorphous materials after burial; and (6) replacement by salts in pore-space (connate) water after burial.

The writer believes that the Clear Hills oolite falls into the first division of the above summary of types of oolitic development.

Despite the various ways that deposits of iron can be formed it would appear from the findings of Moore and Maynard (1929, p. 301) that the dominant manner of deposition of iron minerals is by coagulation of hydrosols and hardening of hydrogels.

Source of the "Ore"

Van Hise and Leith (1911, p. 499) concluded that all the important Lake Superior iron-bearing formations are similar in origin. They believe that a very large part of the iron and silica was contributed to the ocean directly, either by magmatic emanations from igneous rocks in the ocean floor or rapid decomposition of basic igneous rocks in contact with sea water while still very hot. This theory was expanded by Collins, Quirke and Thomson (1926, pp. 1-141) and by many others working in this field.

The average river water today contains less than one part per million of iron (Gruner, 1922, p. 421). This suggests that these waters are inadequate as a source for the deposition of iron formation as defined by James (1954, p. 239). James defined iron-formation as follows: ....."a chemical sediment typically thin-bedded or laminated, containing 15 per cent or more iron of sedimentary origin, commonly but not necessarily containing layers of chert". Rivers in tropical climates such as the Amazon of Brazil, however, carry 2 to 7 parts per million of Fe_2O_3. Van Hise and Leith based their work on studies of temperate weathering cycles. James (1954, p. 276) points out that vulcanism, though not uncommon during periods of iron deposition, is not necessary or always contemporaneous.

It has been established that the Clear Hills oolith is a sedimentary formation. There has been no evidence that vulcanism played any part in supplying source material. It appears that the environment of deposition resembles that of the Lake Superior region (James, 1954, p. 280), with the exception that there was apparently no tectonic activity associated with the period of deposition. Iron is a common component in the Cretaceous sediments of all ages and often forms enriched zones of nodules or replacement beds such as in the Blackstone-Cardium zone in the Highwood area (Pl. XV, B., p. 99, and Pl. XVI, B., p. 100).

The analysis of the Highwood samples (Appendix, p. 78) indicates that the iron content can be substantial. Therefore it does not seem unlikely that the Clear Hills oolite could be deposited during periods of optimum conditions. The original material appears to have come from a western granitic source, as indicated by the fresh quartz and feldspar, both transport resistant, and only the odd fragment of chert. The intrusion of the Topley granite and related intrusions in Jurassic time, subsequent deep weathering under tropical conditions, and alternating wet and dry seasons provided a low lying source area and sluggish rivers (Alling, 1947, p. 1011) to transport iron in solution to the lagoons or estuaries marginal to the Kaskapau sea.

Occurrences of Similar Ore

Clinton iron ore beds: The Clinton iron ore beds rank next in importance to the Lake Superior deposits (Bateman, 1942, p. 568). These beds outcrop across Wisconsin and New York and south to Alabama.

The ore occurs as sedimentary beds intercalated with shale, limestone, and sandstone of Clinton (Silurian) age. The types of ore are: (1) oolitic ore composed of round oolites of hematite, 1 to 2 mm. in diameter, enclosed in a matrix of hematite and calcite; (2) fossil fragments partly replaced by limonite and enclosed in amorphous oolitic hematite; (3) flaxseed ore composed of flattened concretions of hematite surrounded by hematite mud and replaced fossil fragments. Alling (1947, p. 1015) believes the Clinton ores to be primary due to the diagenesis of marine limestones in the presence of solutions well supplied with iron compounds. He also believes that the original iron compounds could have been ferrous and have become oxidized to the ferric state.

Wabana iron ores of Newfoundland: The oolitic iron ore with ferruginous shales and sandstones forms part of a series of sedimentary rocks of lower Ordovician age. Siderite occurs in smaller quantity than chamosite or hematite but is locally abundant. It replaces hematite and chamosite and in some instances detrital quartz. The siderite was chemically precipitated according to Hayes (1915, p. 93), probably under the cover of overlying sediments. This could also be the case with the Clear Hills ore deposit. Hayes also believes (1915, p. 94) that the Wabana iron ore is primary and is mined today in essentially the same conditions as deposited, except for induration, faulting, and minor additions of secondary calcite and quartz.

Minette ores of Luxemburg and Lorraine: These ore deposits resemble the Wabana ores in their oolitic character and the content of green ferrous silicate. It is believed that they were deposited on the bottom of a shallow coastal sea. Formerly these deposits and many similar deposits were considered to be metasomatic replacements of limestones. The primary character of the deposition is now fully recognized (Tyrrell, 1937, p. 230).

Oolitic ores of Bohemia and Thuringia, Germany: Oolitic hematite-chamosite-siderite ores occur in these regions of Germany in rocks of lower Silurian age. This ore also resembles the Wabana deposit. The fact that limestone is entirely lacking in this lithologic sequence is noteworthy.

Cleveland iron ores of England: The most important ores of England, the Jurassic ores of the Cleveland Hills in North Yorkshire, are comprehensively reviewed by Bastin (1950, p. 69) in a summary of the work of A.F. Hallimond (1925, p. 10) in a paper written for the Geological Society of Great Britain. These deposits are characteristically oolitic and all evidence points to them as being primary in nature. They differ from most other oolitic iron ores in that the iron is largely in a ferrous state as chamosite and siderite. Ferric oxides are rare and if present occur as products of recent weathering. In the Cleveland ores the ooliths average about one-sixteenth of an inch in diameter and are composed of chamosite and siderite. The chamosite is fine-grained and concentrically banded. Siderite is granular and usually replacing chamosite. Some ooliths are wholly chamosite but rarely wholly siderite. Many ooliths have no recognizable nucleus but others contain shell or oolith fragments. The matrix consists of siderite rhombs in a groundmass of fine chamosite. The Cleveland oolitic iron ore appears to bear a close resemblance to the Clear Hills oolitic iron "ore" in structural and mineralogical characteristics.

CHAPTER V

ECONOMIC GEOLOGY

General Statement

The oolitic iron "ore" may have a significant place in the future development of the province of Alberta. The deposits do not approach the "Mesabi type" in grade and purity but past history has shown that man can make good use of the material at his disposal. Therefore it is necessary that a summary of the pertinent features of the economic background of the province be presented. It will be seen that all of these factors are interdependent and probably hold the key to the development of this low grade iron.

The Clear Hills area is located within the area designated as the "Canadian North Pacific" (Camsell et al, 1947). This area was so named for study purposes by the Canadian section of the North Pacific Planning Project, headed by Charles Camsell, and initiated in 1943. The main purpose of this project was defense study of the northern areas of North America but the analysts also produced a report on the future economic possibilities of this vast region.

The region comprises approximately 1,000,000 square miles, more than one-quarter the area of Canada. Prior to World War II there were less than 1000 miles of usable roads in the entire area. The Peace River district, which includes the Clear Hills, was the only part of this region that had a sizable population and transportation facilities.

Land Transportation

Hines Creek is located at the end of steel, on the edge of the iron deposits. The Northern Alberta Railroad reached this trading centre in 1930. The area is accessible by two all-weather highways of the Alberta Highway System, to Hines Creek on the south and the eastern boundary is readily accessible by way of the Mackenzie Highway, which begins at Grimshaw, a few miles west of the town of Peace River. There is a possibility of the road to Hines Creek being extended westward by direct route to Fort St. John in British Columbia, where the Pacific Great Eastern Railway has recently been extended, providing the Peace River district with an outlet to the Pacific coast. Forestry Department roads and oil-company exploration trails and roads make practically all parts of the area open to travel at various times of the year, dependent on seasonal conditions.

Agriculture

Hines Creek is an important trading centre, in the heart of a rich mixed farming and lumbering district. The area was originally ranching country, supporting thousands of sheep and cattle. Ranching has been superseded but not replaced by one of the best mixed farming areas in the north. Hines Creek is a trading centre for about 4,000 settlers from the surrounding area. Hundreds of carloads of cattle, sheep, hogs and dairy products are shipped from this centre each year. Forecasts of the settling of 1,000,000 acres of 3,000,000 acres available have been made for the very near future.

Forests

Only rough estimates of the timber resources of northern Alberta lying within the North Pacific region are possible. The northern portion of the province, lying between the 55th parallel of latitude and the northern boundary and between 114th and 120th meridians, has been estimated to contain about five and one-half billion board feet of merchantable timber (Camsell etal, 1947, p. 55-57). This figure considers the conifers only and since the Forestry Department of Alberta believes that the poplar and birch growth is probably three times greater it can easily be seen that the timber reserve is spectacular.

Considering the Clear Hills area as a unit, estimates of 790 million board feet of timber have been given. During 1957 Hines Creek planing mills shipped more than 26 million board feet. In addition to this production approximately 60 carloads of pulpwood are shipped annually from this centre.

Water-Power Resources

The Peace River drains an area of 119,000 square miles and is the largest tributary of the Mackenzie drainage system. The headwaters are located in a great intermontane valley, west of the main range of the Rocky Mountains. One half of the drainage area is in the Cordilleran region and the remainder forms part of the Great Central Plain. The Peace River is navigable by river-type steamers from its mouth to Hudson Hope in British Columbia, apart from the obstruction at Vermilion Chutes.

Water supply: The flow of the Peace River varies considerably because of the distinct physiographic divisions in its drainage basin. The greater part of the run-off comes from the mountain section dependent on temperature and precipitation. The records at Peace River town show a maximum discharge of 375,000 c.f.s. in June, 1922, and minimum discharge of 6,350 c.f.s. in December, 1916. The average annual flow is approximately 62,000 c.f.s. (Camsell et al, 1947, p. 77).

Power resources: No power development had been made in the Peace River basin prior to 1947. Studies for development on the Nation River, for supply at Pinchi Lake, were being made at this time. Several possible power sites have been investigated on the Peace River, with estimated potential horsepower available ranging from 25,000 to 500,000.

Power possibilities are indicated on a number of the tributaries of the Peace but information is insufficient to give any estimates of their potentialities. The power sites appear to be available but large power-consuming industries would be required to warrant their development. The province of Alberta in its entirety has a potential of only 2.5 million kilowatts of hydro-electric power on all of its rivers. Therefore power resources in British

Columbia adjacent to this area must be considered.

Mineral Resources

The Clear Hills area, underlain by sediments, does not offer any possibility for metallic mineral deposits, apart from the oolitic iron occurrences. Non-metallics and hydrocarbons are of great importance in the Peace River district of Alberta and British Columbia.

Coal: The coal deposits of the Peace River district (British Columbia) are among the most important undeveloped coal reserves in the west. They are known to occur over an area of several thousand square miles. A recent compilation of mineable coal reserves has placed these at over one billion short tons (Camsell, 1947, p. 35). The coal available would provide the economic fuel required for the smelting of the iron "ore".

Peace River district, Alberta: The coals of Alberta are classified according to the classification of coals by Rank A.S.T.M., Designation D388-38. Allan (1943, p. 166) reported that there was no anthracite coal or lignite, with the exception of one seam in the Pakowki area. In the Peace River area of Alberta three general coal areas have been located (Fig. 4, p. 57) where coal has either been discovered or produced (Allan, 1943, p. 167).

TABLE 6

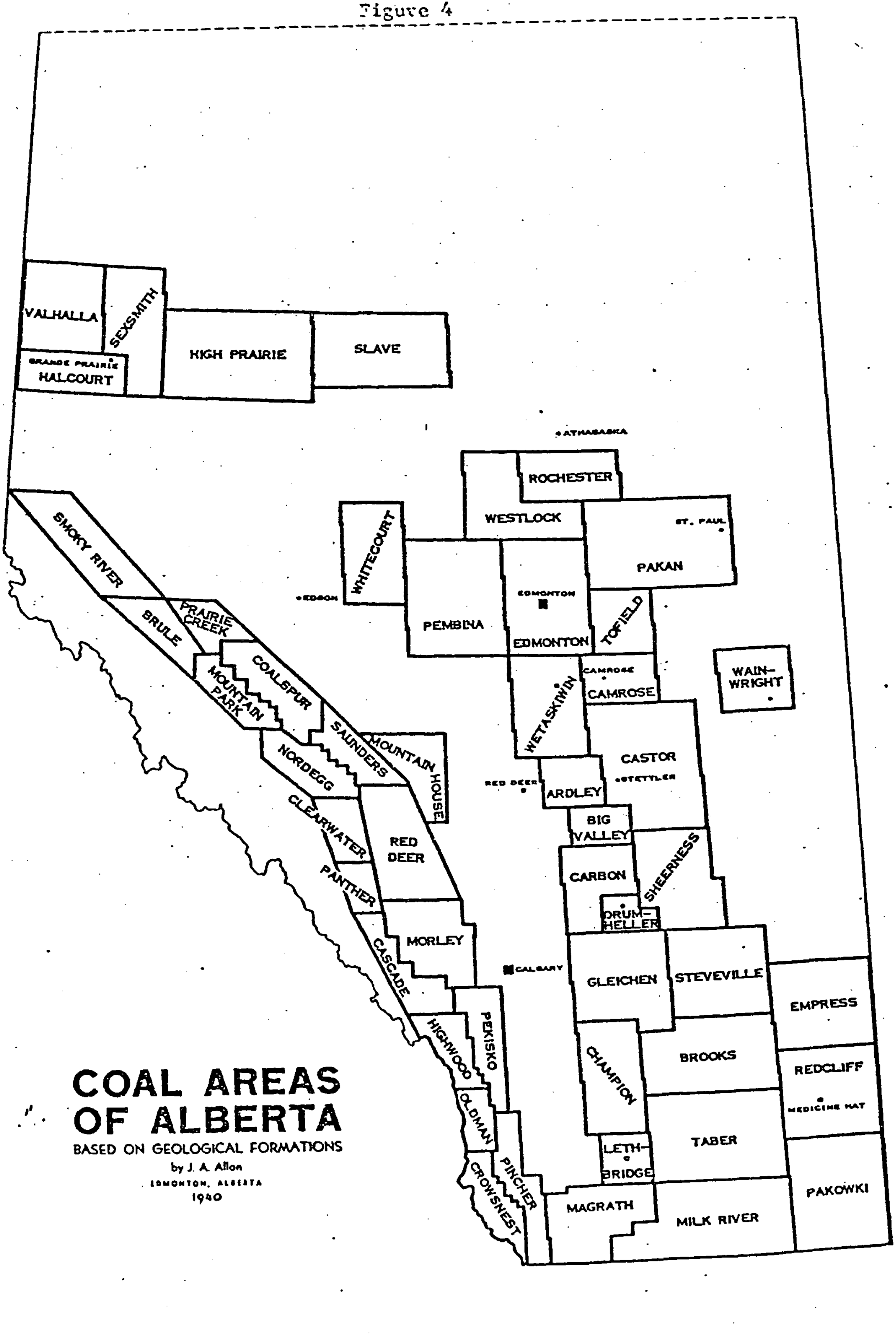
PEACE RIVER, ALBERTA COALS

Area	Thickness of seam (feet)	Depth of cover (feet)	Dip	Rank
Halcourt	1.5-2.3	0-150	---	high volatile C bituminous and sub-bituminous B
Sexsmith	3	30-40	---	sub-bituminous C
High Prairie	---	---	---	sub-bituminous C

The principal coal producing section of the Peace River district is the Halcourt coal area which occupies Townships 69-71, Ranges 5-13, west of the 5th meridian (Fig. 4, p. 57). Production from the rest of the Peace River district has been negligible up to the present.

Allan and Carr (1944, p. 40) reported the results of the survey in the Wapiti-Cutbank area as follows: ..... "it appears unlikely that thick coal seams will be discovered north of the Wapiti River". The known thin seams in this area have been mined with some success in the past (Allan and Carr, 1944, p. 26), but mining operations today are at their lowest ebb. Some occurrences on Pinto Creek and the lower part of the Cutbank River show some promise but there is no evidence to show that they would be economic deposits. The above evidence would indicate that deposits other than these would have to be discovered to provide adequate fuel supply for an iron industry.

Figure 4



COAL AREAS OF ALBERTA

BASED ON GEOLOGICAL FORMATIONS

by J. A. Allan

EDMONTON, ALBERTA

1940

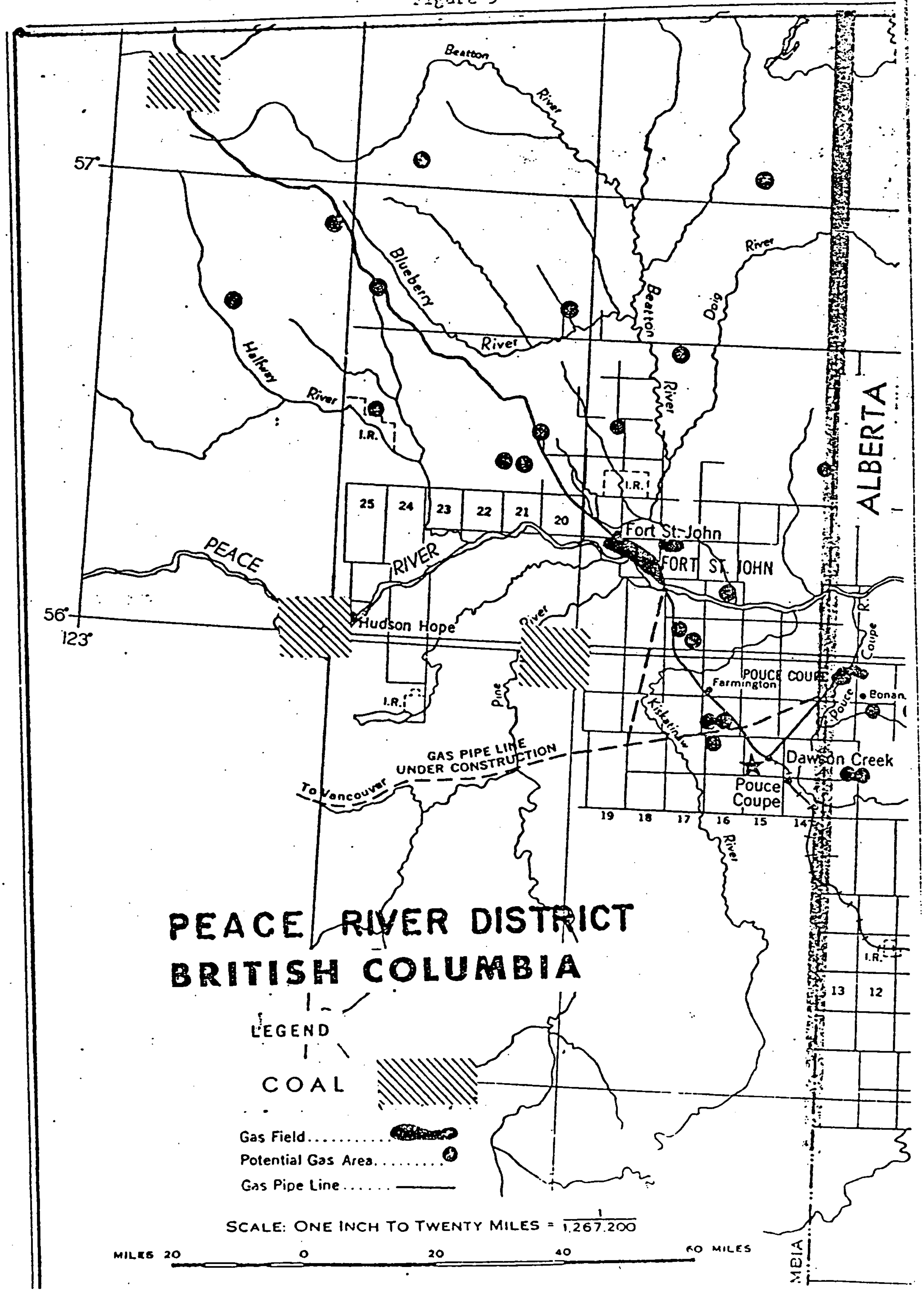
This assumption is based on the possibility that the initial concentration of iron would be carried out close to the source.

Peace River district, British Columbia: It has been known for some time that the Cretaceous rocks of this area had associated coal seams of fairly high rank and thickness (Dawson, 1879-80, p. 115B).

In the Peace River area coal deposits are found in the Gething formation of the Bullhead group, Lower Cretaceous in age. The Gething is correlated with the Luscar formation and the lower part of the Blairmore group on the basis of flora found in the following localities: (Fig. 5, p. 59) - Peace River Canyon coal area, Dunlevy Creek-Cust Creek-Butler Ridge area, Carbon Creek coal basin area, Fisher Creek-Pine River area, Hasler Creek coal area, and Halfway Sikanni Chief River area (McLearn and Kindle, 1950, p. 150). The Peace River canyon coal field is the best known of these; several small mines have operated from time to time during the past 25 years. The combined coal reserves of the six areas has been estimated by the Royal Commission on Coal (McKay, 1947) as 467,040,000 tons of probably mineable coal and with 573,440,000 tons of possible additional mineable coal.

The coals of the Peace River district, British Columbia, have low ash content and a high calorific value for a majority of the seams (Mathews, 1946, p. 20). According to the A.S.T.M. classification by rank, all of the coal seams in the Peace River foothills are either low volatile bituminous or medium volatile bituminous.

Figure 5


PEACE RIVER DISTRICT
BRITISH COLUMBIA
LEGEND
COAL
Gas Field
Potential Gas Area
Gas Pipe Line
SCALE: ONE INCH TO TWENTY MILES = 1/1,267,200
MILES 20
0
20
40
60 MILES
57°
56°
123°
Beatton River
Blueberry River
Halfway River
Beatton River
Doig River
PEACE RIVER
Pine River
Kiskatinaw River
Pouce Coupe R.
I.R.
25
24
23
22
21
20
19
18
17
16
15
14
13
12
Fort St. John
FORT ST. JOHN
Hudson Hope
POUCE COUPE
Farmington
Bonan.
Dawson Creek
Pouce Coupe
GAS PIPE LINE UNDER CONSTRUCTION
To Vancouver
ALBERTA
MBIA

The structure of this area varies, from the Plains areas flat structure through Foothills structures to the typical Cordilleran folded and faulted structural features. All coal seams are within economic depth and none exceed 1000 feet according to McLearn and Kindle (1930). The main factor in the lack of development of these coal areas is the absence of a large market in the area.

In the event that the Clear Hills iron is developed the logical source of coal is the Peace River Canyon and Pine Pass areas of British Columbia. It has already been shown that the coal areas of northwestern Alberta are inadequate.

Mileages on existing transportation routes (Northern Alberta Railways and Pacific Great Eastern Railroad) and also the direct lines distances from the railhead at Hines Creek to the coal areas of Alberta and British Columbia are as follows:

TABLE 7

MILEAGE TO COAL AREAS

Coal Areas	Distance from Hines Creek, Alberta	
	Line distance (miles)	Rail distance (miles - apprex.)
Edmonton, Alberta	280	360
Grande Prairie, Alberta	75	225
Spirit River, Alberta	35	100
High Prairie, Alberta	100	130
Peace River, Alberta	50	60
Dawson Creek, British Columbia	75	300
Fort St. John, British Columbia	85	350
Hudson Hope area, British Columbia	130	400
Pine Pass area, British Columbia	175	400

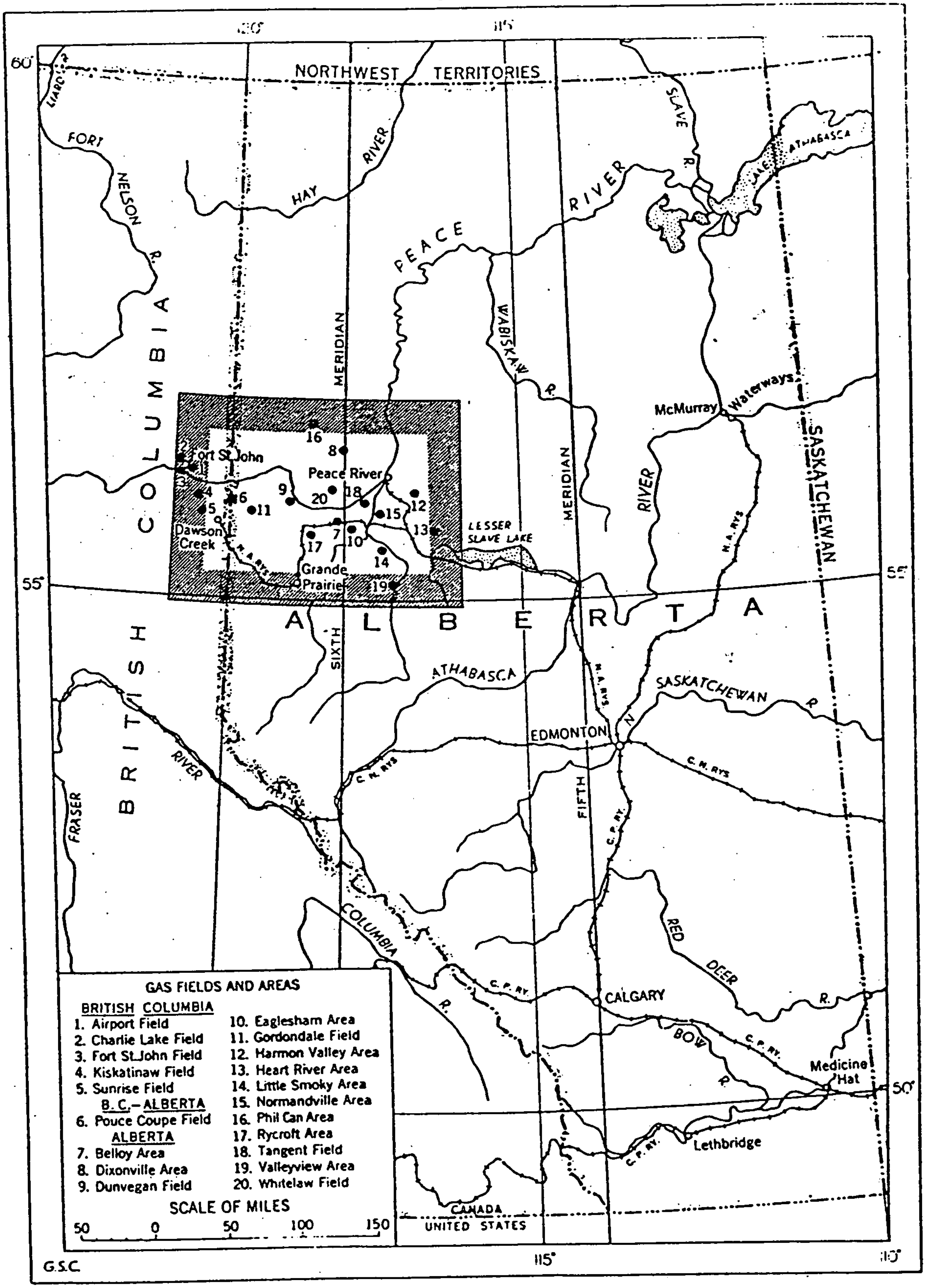
The table shows that the existing railroads, with their indirect routes, provide uneconomical haulage distances. The line distances to the British Columbia coal deposits are well within economic limits. If the iron or the coal is to be developed in this area it would be necessary to construct shorter, more direct railroads.

Limestone: The mountainous areas of the Peace River district of British Columbia afford an abundant supply of Triassic and Paleozoic limestones that might be suitable for use in a steel industry. Williams (1934) has pointed out that raw materials and fuel for the manufacture of Portland cement are available in close proximity in the Peace River district.

Limestone may be obtained 15 miles up Peace River above the mouth of the Nabescha. A plant site on the Pine River situated between the mouths of Le Moray and Mountain Creeks could obtain limestone within a radius of ten miles and coal on Pyramid Mountain within three miles.

Petroleum and Natural gas: The Peace River block and Hines Creek area in particular contains a large number of gas producing fields and wells (Fig. 6, p. 63). Natural gas and crude petroleum are produced or reserves are established throughout the area. Natural gas is by far the most abundant (Hume and Ignatieff, 1952). Here again is the possibility of a fuel source available on the site of the iron "ore" that could be used in the reduction and concentration of the iron, if additional gas reserves were made available for the

Figure 6



INDEX MAP SHOWING GAS FIELDS AND AREAS IN THE PEACE RIVER AREA OF ALBERTA AND BRITISH COLUMBIA

Peace River district. At the present time the reserves for this market are inadequate.

Iron: The preceding sections of this chapter have served as background information on the economic geology involved in the utilization of the low grade oolitic iron of the Clear Hills. This type iron deposit is not new to the steel industry of the world, especially in Europe. The North American steel industry, in the eastern portion of the continent, has been and still is fortunate in having extensive high grade deposits. The Clear Hills type of deposit presents many familiar problems in benefication and reduction and this has resulted in a general lack of interest by those capable of developing this low grade iron deposit in Alberta. The high silica content does not lend itself too well to the standard smelting procedures. Phosphorus content presents a problem though it might be eliminated or utilized. Sulphur does not appear to be present in all samples and may not be a problem. The silica could be eliminated by magnetic separation and flotation and is not present in more than the expected amounts for this type of "ore".

There are, however, many factors in favor of this deposit. A recent economic survey report by J.T. Donald & Co. (Economic Research Consultants), produced for Calgary Power Ltd., revealed a 123 million-dollar steel market in Alberta. At the present time 87 per cent of Alberta's steel is shipped into the province. It is mentioned in the survey that a steel industry using indigenous ores may be started in the province, opening the door for coke production from available coal resources on a large scale.

The Peace River area of northeastern British Columbia is served by the Pacific Great Eastern Railroad, which now extends from Vancouver to Taylor, British Columbia, half way between Fort St. John and Dawson Creek, British Columbia. It seems possible that this railway, which passes through the coal area of Peace River Canyon, could be extended into Alberta and the Clear Hills iron deposits by a more direct route than now exists.

Preliminary work by the McDougall-Segan Syndicate has proven a reserve of a billion tons. Their area of investigation was relatively small and it is felt that more extensive surveys will reveal billions of tons of low grade iron. Recent investigations by Premier Steel Co. Ltd. of Edmonton have disclosed a more accessible deposit near Worsley, 30 miles southwest of the original location, containing a favorable calcium carbonate content.

Fuel should be no problem because of large coal reserves less than 150 miles from the deposit. Natural gas on the location could possibly be used in the pelletizing process but the present reserves of natural gas are insufficient for the present Peace River market. This might be alleviated by further discoveries but the possibilities remain in doubt. Hydro power sites are available in British Columbia's Peace River Canyon, where 400,000 horsepower could be developed to provide the power required (Camsell, 1947, p. 77). The recently completed Royal Commission Report on Canada's Economic Prospects (November, 1957) gives hydro power remaining to be developed on the Peace River in northeastern British Columbia as 3 million kilowatts (Gordon, 1957, p. 141).

A recent news release (June 17, 1958, Edmonton) reported that the British firm of Thomson-Houston is investigating five possible hydro-power sites in the Peace River Canyon of northeastern British Columbia.

Mining of the material would not present any difficulty. In most locations the overburden is light and the "ore" itself could be removed by standard open pit methods.

The Clear Hills is not a "Mesabi" or a "Labrador" but does compare favorably with the Minette ore of France of the Salzgitter of Germany in character and composition, and, with the sizable existing steel market and the possibility of over 2 million people in Alberta by 1975, this deposit may be competitive with steel from eastern sources.

CHAPTER VI

CONCLUSIONS

The oolitic iron of the Clear Hills in its present location appears to be a reworked sedimentary iron deposit. The oolitic iron was initially laid down as a primary material in a brackish marine lagoon in an environment which was favorable to the deposition of iron carried in solution by rivers from the source areas. As the deposition progressed, changes in pH, the abundance or lack of oxygen, variable amounts of organic debris, allowed the precipitation of the limonite-goethite to alternate with the Fe carbonate facies. This could take place as indicated above or it could be a simple replacement of primary siderite.

It is believed that the "ore" is of marine or marginal marine to brackish-water origin. The oolitic structure is characteristic of marine environment and the presence of chamosite, considered to be exclusively a marine environment mineral, substantiates this theory. The oolites were probably formed by colloidal processes and if not, as siderite directly. The oxides were reduced on the bottom or slightly beneath the surface of deposition. Variations in composition of the deposit suggest a gradual change to conditions more favorable to the oxide facies. Probably deepening of the water by influx of the sea resulted in turbulent flow aerating the waters and produced normal oxygen content. The presence of fragmentary ooliths, chert fragments, secondary calcite and rock fragments containing ooliths gives the deposit all the appearance of a primary deposit eroded and redeposited mechanically. The source of the original primary iron is believed to be to the west. The mineralogy indicates an igneous source, possibly the Topley batholith undergoing deep tropical erosion. Iron was probably carried as a colloid by large sluggish streams incapable of carrying large suspended loads.

Any clastic material would probably be dropped before the zone of iron deposition was reached. The microscopic appearance of the oolith shells suggests colloidal conditions and this would mean that iron (colloids) in solution would have to come in contact with the saline sea waters to be precipitated. This would carry the iron beyond the clastic trap basin. The general scarcity of clastic material in the deposit suggests that it has not been transported very far from the original bed of deposition. Quite probably the deposit was merely ripped to pieces by wave action as the sea level rose.

The Clear Hills oolitic iron "ore" compares favorably with most of the known oolitic iron ore deposits of the world. Considering the well known deposits of this type it appears that the Cleveland Hill deposits of England present the most interesting comparison. The histories of deposition of both the Clear Hills and the Cleveland Hill deposits from the evidence at hand have much in common.

There is a substantial market for steel in Western Canada. The possibilities of this market expending are very good. There are large tonnages of low grade iron in the Clear Hills deposit.

A minimum estimate is approximately one billion tons (McDougall, 1954). Fuel in the form of coal, and hydro-electric power resources are available for development in the Peace River Canyon area of British Columbia within economic line distance of the iron deposit.

LIST OF THIN SECTIONS - CLEAR HILLS

Field Number	Thin Section Number	Location	* Interval (feet)
CH-1	3076	Swift Creek - A	26'-28'
CH-2	3077	" " - A	24'-26'
CH-3	3078	" " - A	22'-24'
CH-4	3079	" " - A	20'-22'
CH-5	3080	" " - A	18'-20'
CH-6	3081	" " - A	16'-18'
CH-7	3082	" " - A	14'-16'
CH-9	3083	" " - A	10'-12'
CH-11	3084	" " - A	6'-8'
CH-16	3085	" " - A Nodule	14'-16'
CH-15	3086	" " - B	6'-8'
CH-17	3087	" " - A Nodule	16'-18'
CH-21	3088	" " - A	10'-12'
CH-20	3089	" " - A Fossil wood	14'-16'
CH-22	3090	" " - A	-17'-
CH-23	3091	" " - B	-16'-

* All depths from surface (Till 4 feet).

CHEMICAL ANALYSES OF OOLITIC IRON
(SWIFT CREEK, CLEAR HILLS)

Sample No.	Thin Section No.	Footage (from surface)	Percent by weight		
			Fe^{++}	Fe^{+++}	Total Iron
TILL		0'-4'			
CH-12	* No thin section	4'-6'	0.27	33.19	33.46
CH-11	3084	6'-8'	1.52	30.56	32.08
CH-10	* No thin section	8'-10'	0.50	31.93	32.08
CH-9	3083	10'-12'	1.53	30.12	31.65
CH-8	* No thin section	12'-14'	2.12	34.03	36.15
CH-7	3082	14'-16'	10.58	16.58	27.20
CH-6	3081	16'-18'	6.12	21.12	27.24
CH-5	3080	18'-20'	10.54	13.11	23.65
CH-4	3079	20'-22'	10.35	13.46	23.81
CH-3	3078	22'-24'	7.92	13.88	21.80
CH-2	3077	24'-26'	21.92	3.18	25.10
CH-1	3076	26'-28'	19.00	0.14	19.14

* Material too soft and friable for thin section

(Chemical analyses done by G.M. Hughes and G.L. Colborne)

ANALYSES OF SWIFT CREEK OOLITIC IRON SAMPLES FOR CLIFFS OF CANADA*

Lab. No.	Sample No.	Total Iron	Loss on Ignition	Interval (in feet)
30-716	CH-1	27.26	17.35	0-2 Location A
717	CH-2	26.94	22.31	2-4 " "
718	CH-3	28.94	18.92	4-6 " "
719	CH-4	27.98	13.67	6-8 " "
720	CH-5	27.90	13.36	8-10 " "
721	CH-6	27.42	13.49	10-12 " "
722	CH-7	30.05	13.47	12-14 " "
723	CH-8	30.77	12.57	14-16 " "
724	CH-9	34.77	11.73	16-18 " "
725	CH-10	33.97	12.91	18-20 " "
726	CH-11	33.73	11.74	20-22 " "
727	CH-12	35.73	12.74	22-24 " "
728	CH-13	27.26	13.81	0-12 Comp.
729	CH-14	33.65	12.05	12-24 Comp.
730	CH-15	31.49	13.69	Location B Type sample
731	CH-16	30.37	20.94	Location A
732	CH-17	35.41	22.65	Nodule at A
733	CH-18	11.91	14.27	Band in till

* Analyses carried out by Steep Rock Iron Mines Ltd., Steep Rock, Ontario, (1957).

ANALYSES OF CORE HOLE SAMPLES
(McDougall, 1954, p. 10)

- 5 foot intervals -

Sample No.	E-1A[+]	E-3B	E-3C	E-4C	E-4D
L.O.I.	13.64	12.57	12.52	12.98	12.63
SiO_2	27.49	27.34	48.46	34.05	37.89
Fe_2O_3	50.10	50.58	28.02	41.55	35.47
Al_2O_3	6.11	5.95	6.00	6.55	7.70
MgO	2.62	2.34	2.68	2.63	3.30
CaO	0.00	0.19	0.00	0.00	0.00

Sample No.	E-1B	E-2A	E-2B	E-3A	E-4A
L.O.I.	16.32	12.80	16.37	15.35	14.56
SiO_2	23.18	31.68	19.93	21.52	23.80
Fe_2O_3	46.40	43.84	52.94	51.98	52.46
Al_2O_3	7.25	7.40	6.55	6.30	5.80
* MgO + CaO	4.68	2.53	2.87	1.31	1.60

Sample No.	E-4B	E-5A	E-5B	E-5C	E-5D
L.O.I.	13.75	12.93	16.37	15.24	13.76
SiO_2	27.34	26.14	25.57	24.70	27.36
Fe_2O_3	49.47	48.88	48.88	46.67	45.98
Al_2O_3	6.50	7.40	6.50	8.05	7.45
* MgO + CaO	2.60	2.64	1.66	3.32	2.95

* Calculated as MgO

[+] E-1A - E = Eureka - 1 = hole number - A = interval

POSSIBLE TOTAL IRON FROM MCDOUGALL ANALYSES

(McDougall, 1954, p. 11)

Sample No.	Percent Iron
E-1A	40.5
E-1B	38.8
E-2A	35.1
E-2B	44.3
E-3A	42.9
E-3B	40.4
E-3C	22.4
E-4A	42.9
E-4B	40.1
E-4C	33.4
E-4D	28.4
E-5A	39.2
E-5B	40.8
E-5C	38.4
E-5D	37.3

Spectrographic Analyses of McDougall Samples by K.B. Newbound, Physics Department, University of Alberta. (McDougall, 1954, p. 12).

Iron - major constituent
Magnesium - less than 10 percent
Silicon - lines weak, element difficult to excite
Sodium - less than 1 percent
Calcium - less than 1 percent
Chromium - presence not definitely established but possible
Sample 5D - contained some tin.

LIST OF THIN SECTIONS - HIGHWOOD RIVER AREA

Field Number	Thin Section Number	Location	* Interval (feet)
HW-1	3092	Contact Creek Pit-1	Blackstone-Cardium contact
HW-2	3093	" " " "	0'-1'
HW-3	3094	" " " "	1'-3'
HW-5	3095	" " " "	3'-5'
HW-6	3096	" " " "	5'-7'
HW-7	3097	" " " "	7'
HW-9	3098	" " " "	7'-10'
HW-10	3099	" " " "	10'-12'
HW-11	3100	" " " "	12'-15'
HW-12	3101	" " " "	15'-20'
HW-13	3102	" " " "	20'-25'
HW-14	3103	" " " "	Nodules 15'-25'
HW-15	3104	" " Pit-2	Basal bed
HW-16	3105	" " " "	Middle bed
HW-17	3106	" " " "	Top beds

* Footage reads from Blackstone-Cardium contact upwards.

* ANALYSES OF FERRUGINOUS SANDY SHALE - BLACKSTONE-CARDIUM CONTACT, CONTACT CREEK-HIGHWOOD RIVER AREA FOR CLIFFS OF CANADA

Lab No.	Sample No.	Total Iron	Silica	Loss on Ignition	Interval
28-889	HW-1	23.15	25.39	19.62	Blackstone-Cardium contact
890	2	23.47	28.32	10.95	Pit-1 0'-1'
891	3	26.60	16.17	21.18	1'-3'
892	4	28.29	21.45	14.39	Oxidized at 3'
893	5	31.51	16.45	17.59	3'-5'
894	6	27.65	15.34	20.77	5'-7'
895	7	34.40	11.22	20.07	Base oxidized zone at 7'
896	8	42.68	11.23	19.86	Oxidized zone 7'
897	9	23.71	16.37	24.48	7'-10'
898	10	15.75	19.50	22.50	10'-12'
899	11	11.73	30.07	17.77	12'-15'
900	12	2.57	33.78	20.00	15'-20'
901	13	1.93	57.18	15.73	20'-25'
902	14	6.27	80.20	4.90	Nodules 15'-25'
903	15	39.06	12.27	18.00	Pit-2 Basal bed
904	16	35.28	13.28	16.99	Middle bed
905	17	31.10	12.72	17.78	Top beds
906	18	1.61	93.40	1.98	Overlying sandstone

* Analyses carried out by Steep Rock Iron Mines, Ltd., Steep Rock, Ontario (1957).

A COMPARISON BETWEEN OOLITIC ORE DEPOSITS

Geographic location		Clinton hard ore, U.S.A.	Lorraine Minette ore, France	Cleveland-Hill ore, England	Wabana ore, Newfoundland	Salzgitter ore, Germany		Clear Hills ore, Alberta, Canada
						High grade	Low grade	
Mineralogical composition		Hematite	Limonite Siderite Hematite	Chamosite Siderite	Hematite Chamosite Siderite	Siderite	Siderite	Limonite-goethite Siderite-chamosite?
Geological age		Silurian	Jurassic	Jurassic	Ordovician	Cretaceous	Cretaceous	Cretaceous
Associated rocks		Limestone Shale	Shales, sandstone, marl	Shale	Sandstone Shale	Sandstone Shale	Sandstone Shale	Sandstone Shale
Chemical composition	Fe	37.0	30.0	36.0	20-57	32.60	29.70	30.15
	Mn	0.23	----	----	----	0.22	0.12	0.15
	P	0.30	0.5-1.8	0.55	0.7-2.0	0.37	0.48	0.58
	SiO_2	7.14	7.2	8.51	6.50	27.00	27.80	25.36
	Al_2O_3	3.81	----	6.12	3-6	10.17	5.60	6.24
	CaO	19.20	12.0	5.74	1.30	0.16	3.95	* ----
	H_2O	----	----	3.75	----	1.65	1.48	----
	S	0.08	----	0.05	----	0.16	0.05	+ 0.701

* Sometimes present

\+ Not always present

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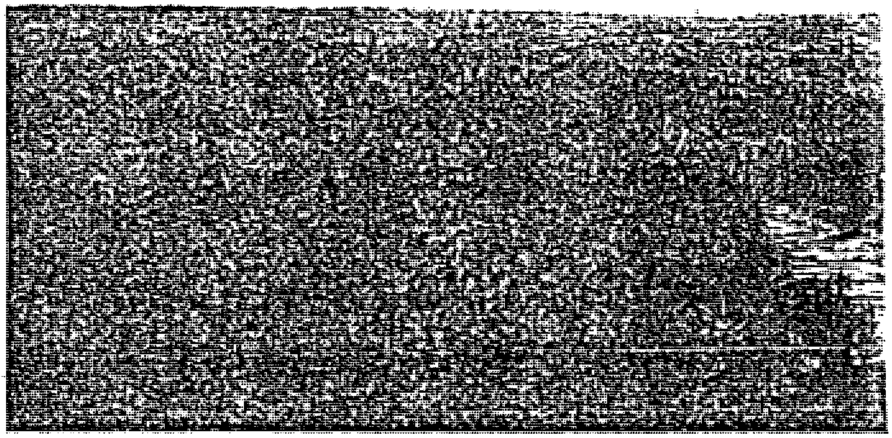
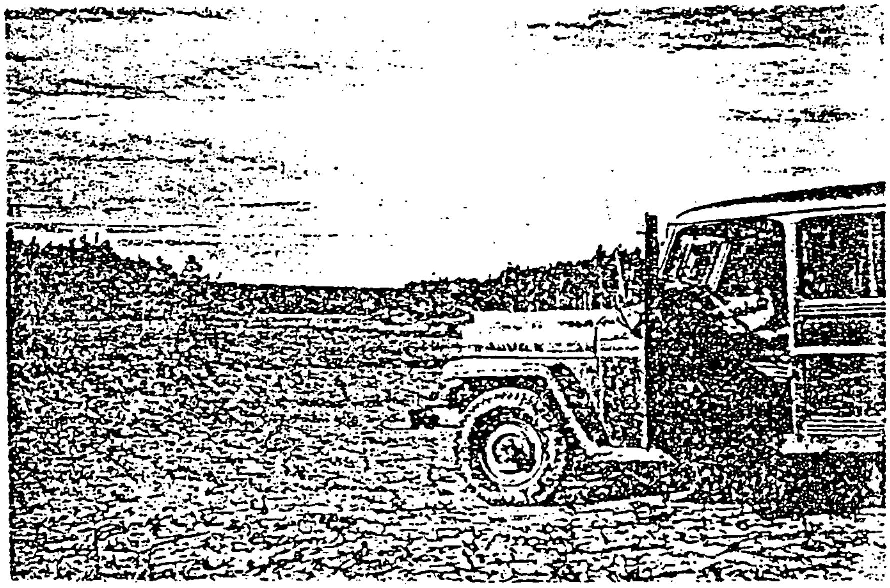
Plate I

A. - View looking southwest from Notikewin forestry tower, Clear Hills, Alberta

B. - Emergency landing strip one mile south of Notikewin forestry tower, built on glaciolacustrine silt





APPENDIX ~~B~~
12

TUL PETROLEUMS LTD.

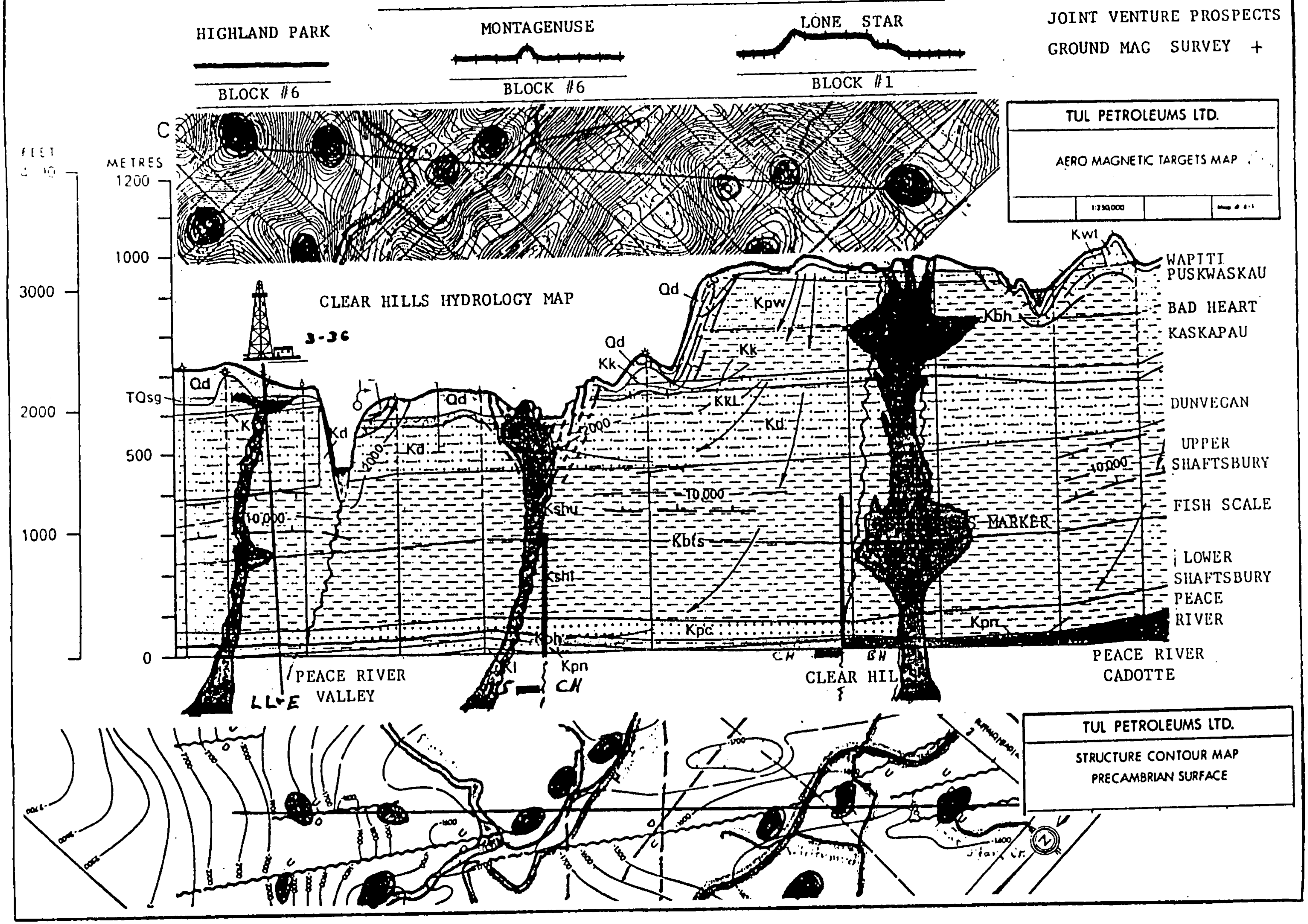
THE PEACE RIVER DIAMOND EXPLORATION PROJECT

extracts from....

1993 YEAR END EXPLORATION AND PROPERTY REPORT

with the permission of
TUL Petroleums Ltd.

TUL PEACE DIAMOND PROJECT - YEAR END OCTOBER '93 REPORT



1.0 INTRODUCTION

DIAMONDS IN ALBERTA

At least twenty diamond finds have been made in Alberta. Diamond finds in the N.W.T have been associated with the Archean North American Craton and margins, and sutures between assembledges of sub-cratons.

Diamonds in Alberta are believed to originate from classic kimberlite pipe intrusions, modelled after those in South Africa, or from the more lucrative but elusive lamproite deposits. Alluvial diamond finds are also possible.

The Peace River Arch in north west Alberta is a region where diamonds have apparently been found. Heavy mineral diamond indicators are being used to point the way to their sources. Aeromagnetic surveys and drilling activities are planned by permit holders in Alberta. Monopros - DeBeers of South Africa and Diamet have large tracts of land in the Peace River region. Monopros' activities of several years, in the area, have been kept secret. However, we have located and photographed their Grande Prairie facility and their wash plant equipment. The Peace River Arch diamond play is quietly developing and has not yet become well known.

The Peace River Arch, is a significant structural feature. It is an anticline underlaying twenty thousand square miles in Alberta. The basement rock is comprised of three major sub-cratons which vary in age of formation. They are made up of granitic material and vary from one another in formation, age, density and magnetic character.

Successive uplift,collapse and downwarping of parts of the arch have created reefal and structural traps for oil and gas; therefore, geologic information from several thousand exploration holes is available.

The mechanics of the Peace River Arch are not well understood. Migration of the building blocks which form today's continents, the northwesterly movement of the North American Craton and accretion of new material from the west, have created a complex geological dynamic in this region.

Crustal thickening, cratonic transverse movement, uplift and collapse, have resulted in fault systems and regional grabens; or failed rifts; which have created conditions believed to be suitable for kimberlite or lamproitic emplacement.

TUL Petroleums Ltd is a small private oil and gas company owned by the undersigned. Tri Union Resources Ltd is a petroleum and natural gas industry land service company.

TUL Petroleums Ltd has applied for and has received Metallic and Industrial Minerals Permits covering about twenty townships. Some of these were applied for in the name of Tri Union Resources Ltd, in early stages of the play for strategic reasons. Some of the lands were applied for 100% for TUL, while other lands were applied for on behalf of TUL and silent partners, under trust conditions.

TUL Petroleums Ltd has prepared maps of basement and structural geology and has obtained aero magnetic data for the prospect lands.

The lands have been divided into blocks, based on a combination of; the time acquired, geological prospects, and/or partnership interests. Each Permit Application was named according to its geographical area. Additional data has been acquired for the Monopros lands for play development and comparison purposes.

Geological basement and structural isopach maps of the Precambrian surface indicate several interesting features. Faults, suites of faults and suture zones, represent linaments of crustal weakness and movement. Crustal rock character, age, density and history of movement, together with knowledge of overlaying geophysical/aeromagnetic data, lead us to identify target areas for exploration.

Prospect areas and targets were picked, based on differing geological concepts; therefore, a number of exploration philosophies and techniques are required during exploration.

With this and previous reports, we have informed the TUL PEACE DIAMOND JOINT VENTURE partners and other prospective investors of the known facts about the Peace River Arch diamond play. We have layed out the agreements in place and the understandings that we have at this time. We have formed a team, adopted an exploration philosophy and raised additional capital, and we have designed exploration programs to evaluate the properties and advance the Peace River diamond play. We have met our objective of adding value to the Project lands and enhanced the likelyhood of finding diamonds on some of our properties. Finding other valuable stone and minerals is also possible.

THE PEACE RIVER DIAMOND EXPLORATION CAMP

2.0 Location and Access

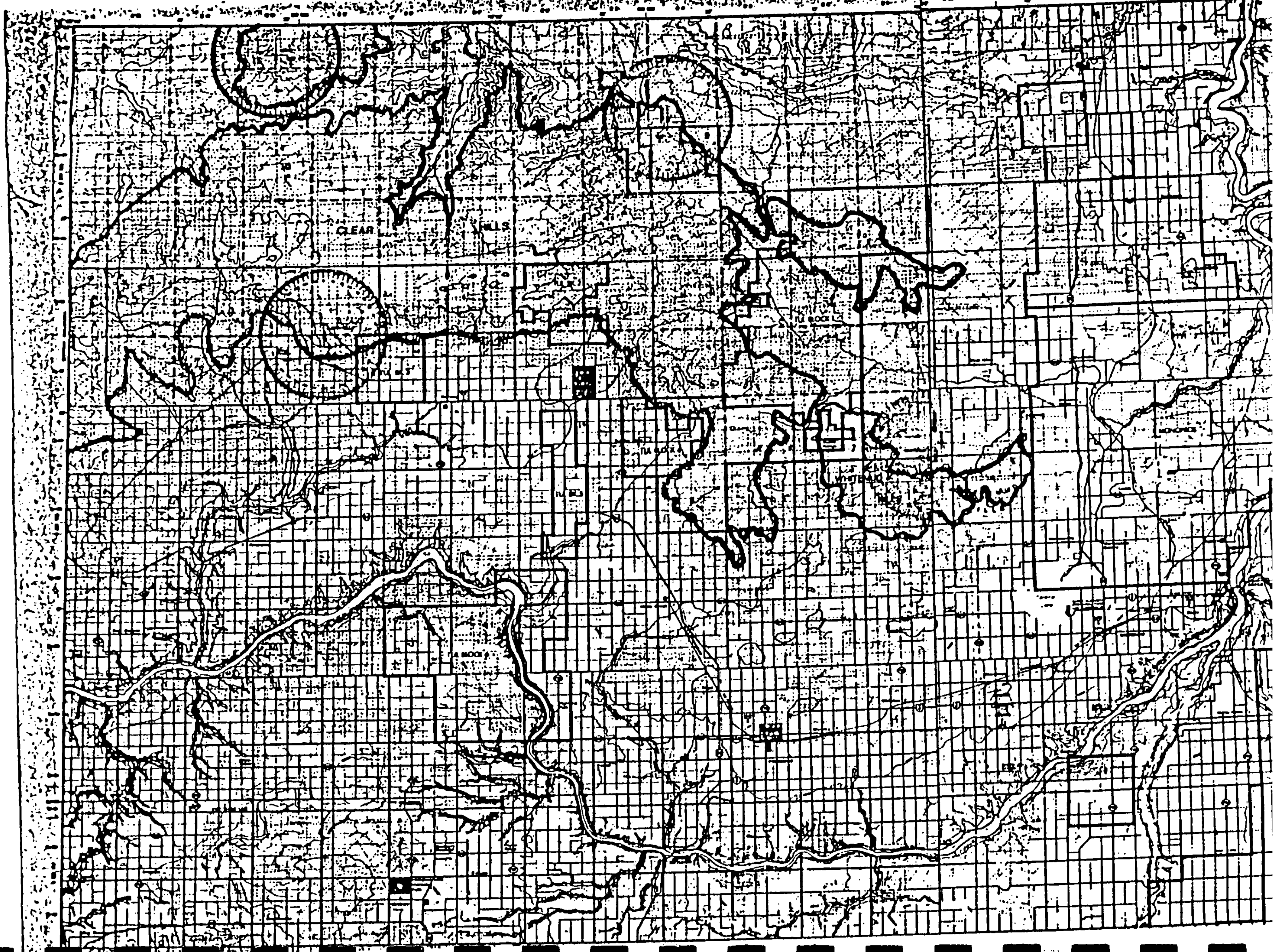
The Peace River Arch underlies the Clear Hills in north western Alberta, the Peace River Lowlands west of the Town of Peace River, and extends south under the Wapiti Plain to Grande Prairie and to Dawson Creek in British Columbia.

The Peace River diamond play centers around the Town of Peace River and covers parts of the Municipal Districts of Smoky River # 130, # 133, Peace # 135 and Fairview # 136. It also covers parts of Improvement Districts: Slave Lake # 17, Wanham # 19, Woking # 20, Worsley # 21 and Grimshaw # 22. It covers most of the four National Topographic Series (NTS) 1:250,000 scale maps in NTS "C", "D", "N" and "M", an area of 21,000 square miles.

The TUL prospects are west of the Town of Peace River; along the river and on the Lowlands; north of the Town of Fairview, in the Whitemud Hills and in the Clear Hills.

The lands west of the Town of Peace River are transected by the Peace River and contain four townships. These lands are accessible from the lowlands terrace accross privately owned lands. These Peace River Lowlands are largely farmlands and and ranchlands situated at an elevation of around 2100 feet ASL. They slope toward the steep walled valley of the Peace River - some 1000 feet below and are cut by several tributary streams.

The lands in the river valley itself are important from a geological and exploration point of view. The river valley lands are accessible by jet-boat sixty miles west of Peace River. The valley walls are steep, slumped and block slumped. These exposures and outcrops make it possible to do an effective soil and rock sampling program. In this westerly area, the river has eroded through the Cretaceous - Kaskapau, Dunvegan and into the Cretaceous Upper Shaftsbury Formation. Further to the east, north of Peace River, it has eroded below the Shaftsbury Fish Scales Marker.


CLEAR HILLS

Stream channel development and morphology are important to the TUL project.

The development and location of the Peace River channel reveals facts about the underlaying structure and tectonics. River gradient and flow data aids us in designing and timing exploration programs. River sediment sampling is one our best exploration methods. Channel form and morphology; island, sand bar and point bar sampling; discharge data and fluctuations; and timing of fieldwork, according to periods of least flow, are important in terms of access to the best data.

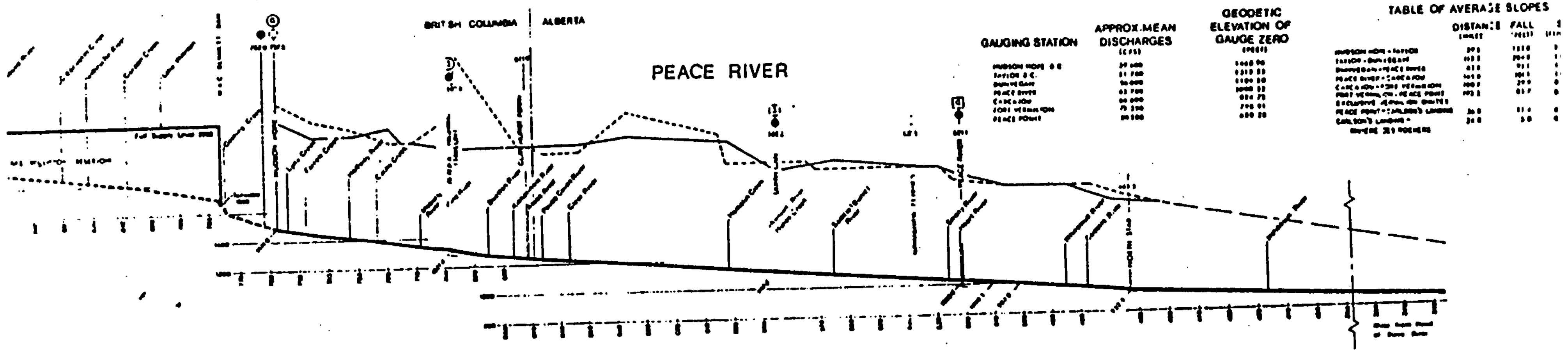
Most of the TUL lands are in the Clear Hills and Whitemud Hills, or on their side slopes. These hills are a part of a physiographic region known as the Clear Hills Uplands. Elevations reach three thousand, five hundred feet in the Clear Hills summits and plateaus. The Whitemud Hills reach two thousand, seven hundred feet. There is over a thousand feet of relief between some of these hills and the Peace River Lowlands terrace and over twenty-five hundred feet from the Peace River Valley bottom at Dunvegan Bridge.

The Clear Hills are well treed and are presently being logged by a number of companies. The entire area has been explored at one time or another by oil and gas companies using siesmic. Grids of cut-lines are common. Many areas have been explored for oil and gas and remanents of roads exist in many parts of the hills.

There are three Alberta forestry fire towers in the Clear Hills. There is one fire tower in the Whitemud Hills. These towers have access routes which provide reasonable four wheel drive road access to most of the TUL lands.

Some areas have been developed as oil and gas fields. These areas have well developed oil and gas field wellsite roads held under Licences of Occupation. There is at least one compressor station and connecting gathering system existing in the Clear/Whitemud Hills. Use of existing roads and negotiation for the use of these roads is a priority in our exploration program.

Generally, the TUL lands are accessible under most conditions. That is, you can drive to them; however, much of the field work has to be done by walking or using low pressure tired all terrain-type vehicles.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ALBERTA
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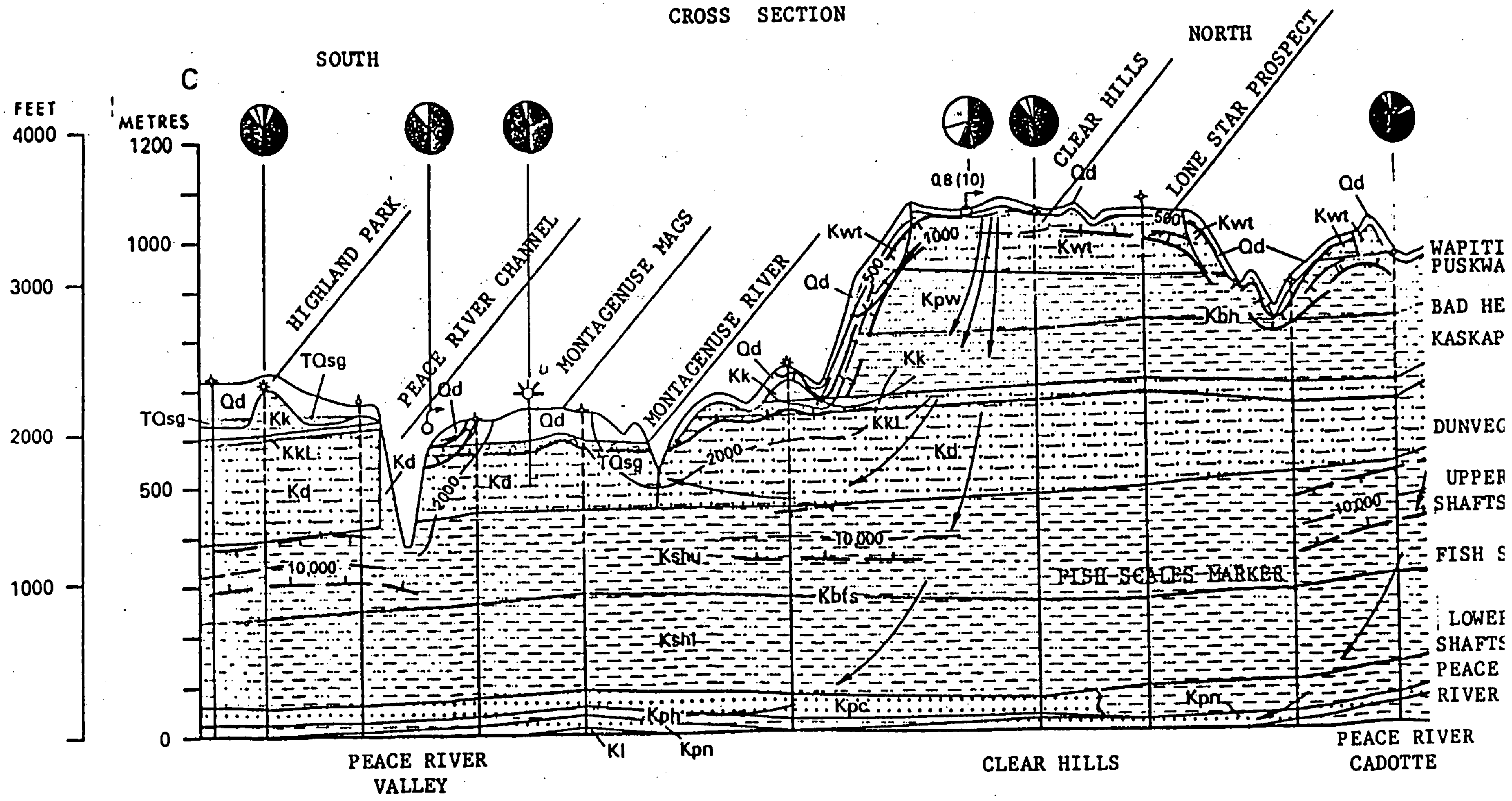
GEODETIC ELEVATION OF GAUGE ZERO
TABLE OF AVERAGE SLOPES
DISTANCE
FALL

CLEAR HILLS HYDROLOGY

CROSS SECTION



2.1 Physiography

The physiographic region known as the Clear Hills Uplands has a severe climate, 350 to 450 mm of annual precipitation and fewer than eighty frost free days per year. Most of the precipitation probably occurs during the spring and early summer. This is a problem for access where there are benonitic sandstones, shales and clays. The area is covered with Grey Wooded soils interspersed with wetlands; peatlands, bogs and muskegs.

The physiographic region known as the Peace River Lowlands also has a severe climate and 400 mm of annual precipitation. Since these lands are flatter, access is less of a mobility problem. However,time and money is required to obtain access, because most of the area is patented land. There is farming and ranching on these, the Dark Grey soils and the Dark Grey Wooded soils.

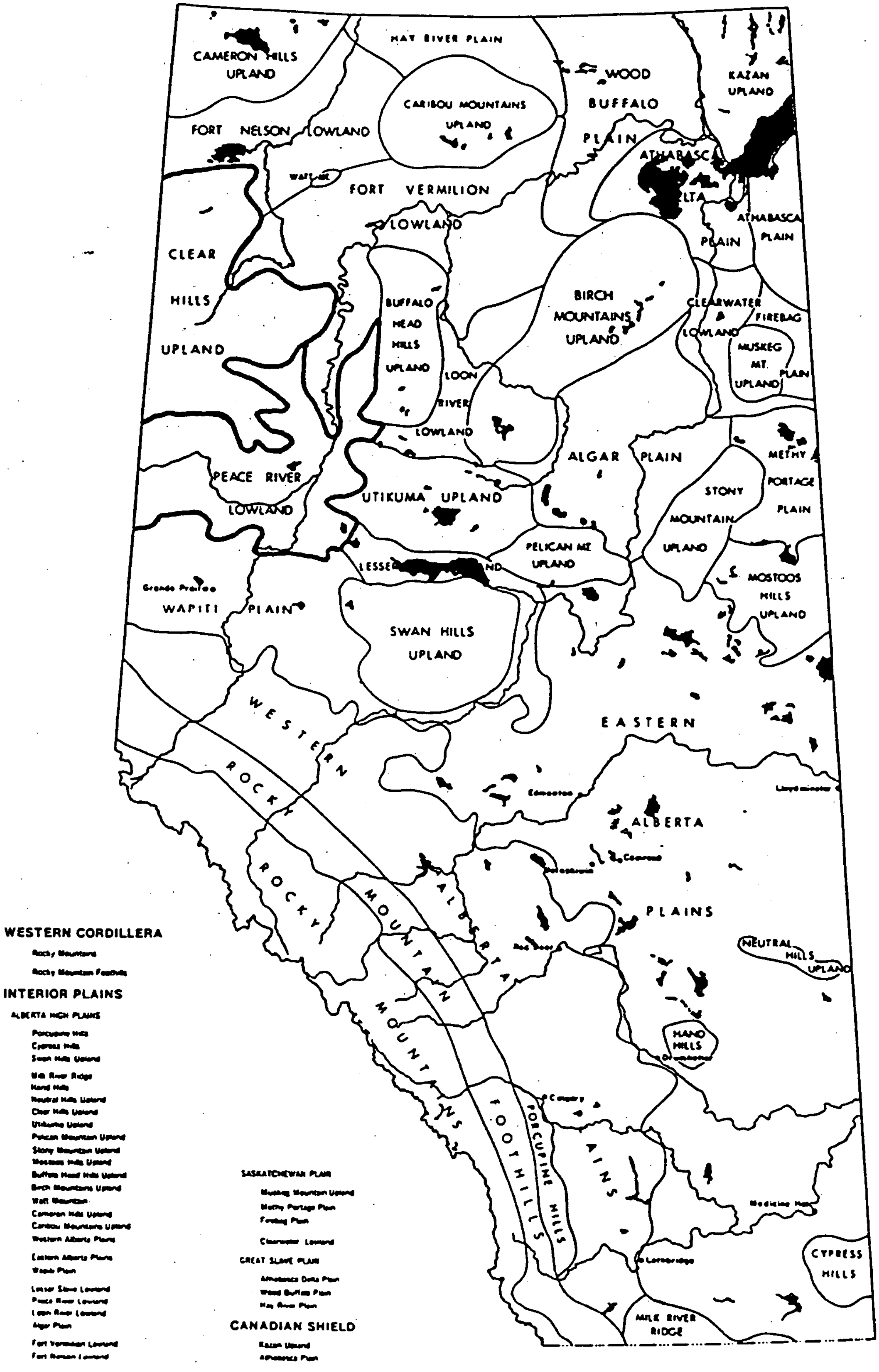
2.2 Environmental Concerns

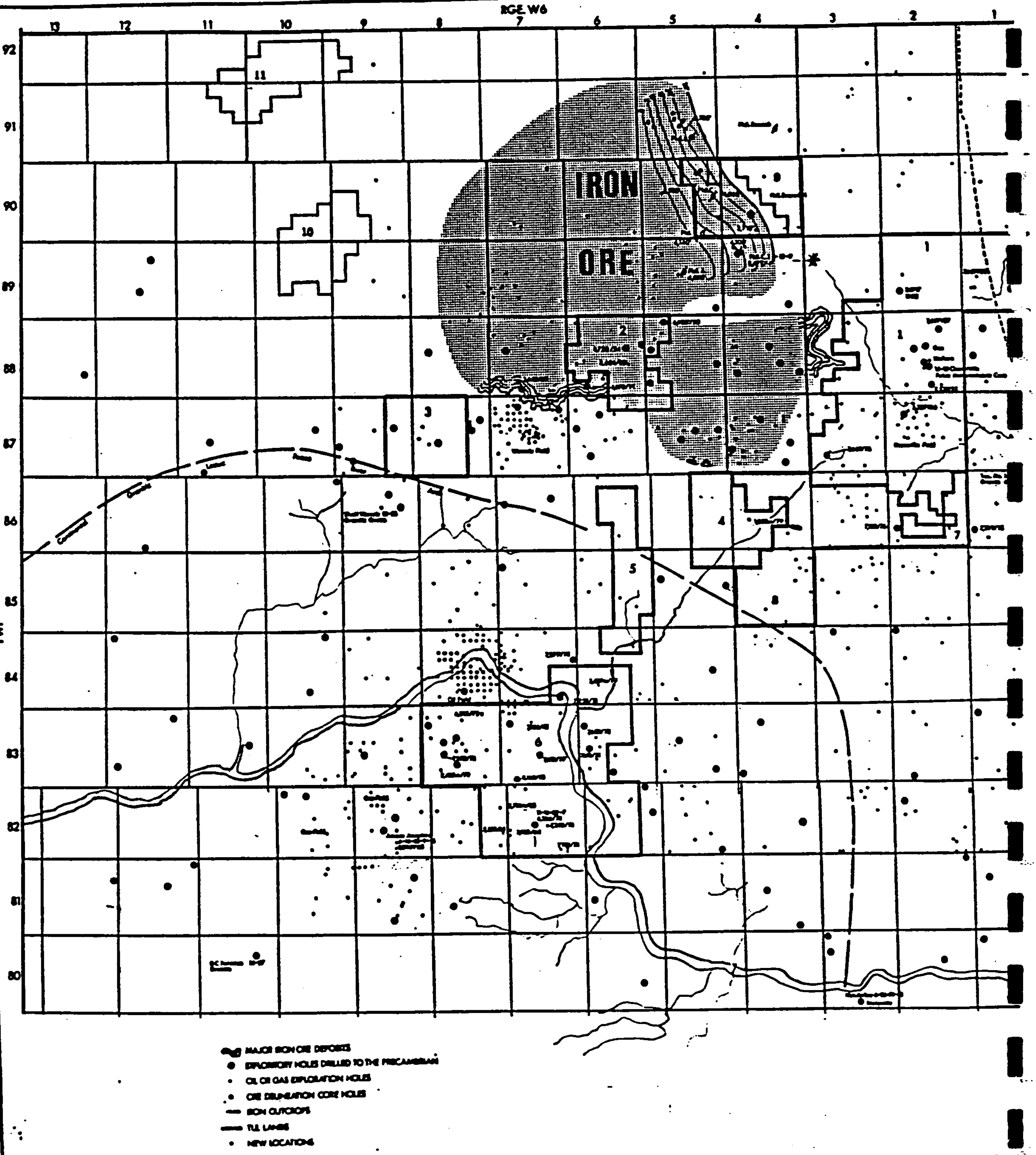
There are environmental concerns for some of the lands that make up our permits. Our discussions with Alberta Forestry and Alberta Environment have encouraged us in that these departments have been most accomodating; since it is in eveyone's interest to explore and creat jobs; however, proper permitting and responsible field practices are required. An exploration permit is required by a company and a form of program plan must be submitted to Alberta Energy. We have extensive experience in doing this and understand the specific concerns and requirements of Alberta Culture (archaeology), Environment, Lands and Forests, Wildlife, Fisheries, etc.

2.3 History

Exploration of the Clears Hills dates back to the early part of this century and has been written about in a report by the Alberta Research Council. Attention first came to the Clears Hills when prospectors observed outcrops of ironstone and oolitic iron in ten to twenty foot thick beds exposed in the Clear Hills and Whitemud Hills. Claims were staked for minerals early on, but the potential of these iron beds was not recognized for some time. The heavy mineral exploration centered around the Clear Hills Iron Deposits and culminated in Alberta Research Council studies, core hole drilling, volumetric estimations and economic evaluations during the Seventies. These iron deposits are known world-class iron deposits and compare in size with the Allsace-Lorraine deposits of north eastern France and Germany. There is at least 1.5 billion tons of 37% iron in this region. This area would probably be under development through the Western Diversification Program if it were not for the present recession and an abundance of iron in eastern North America.

PHYSIOGRAPHIC MAP OF ALBERTA





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TILL LAKES
NEW LOCATIONS

Information Series 75

PEACE RIVER IRON DEPOSITS

E. F. Bertram and G. B. Mellon

Alberta Research Council
1975

PART ONE: GEOLOGY, COMPOSITION, AND RESOURCES

Location and Access

The Peace River iron formation is located in the Clear Hills district of northwestern Alberta, about 300 air miles northwest of Edmonton (Fig. 1). The southern margin of the deposits is about 35 miles from a spur line of the Northern Alberta Railway which extends from the town of Peace River to Hines Creek. These deposits are within 5 to 20 miles of an all-weather gravelled road which extends northwestward from Hines Creek along the southern margin of the Clear Hills to Fort St. John, British Columbia.

A small-scale map showing the precise location of assessed areas is given in figure 2.

Geology and Terrain

The Clear Hills form a gently sloping upland which extends between the Peace River on the south and east and the British Columbia border on the west. The hills rise gradually from the surrounding wooded plains, and attain a maximum elevation of about 3,600 feet near their southwestern margin. Local relief is in the order of 1000 feet along the southern margin of the hills; to the north and east the hills slope gradually into the wide glaciated valleys of the Notikewin and Whitemud Rivers and their tributaries (Fig. 2).

The Clear Hills region is underlain by nearly flat-lying sandstone and shale formations of Cretaceous age, covered in most places by unconsolidated glacial deposits of variable thickness (Kidd, 1959; Green and Mellon, 1962). Bedrock exposures are scarce and discontinuous, being confined to some of the small streams which form a radial drainage pattern about the hills. The upper surface of the hills, beneath the glacial deposits, is capped by the Upper Cretaceous Wapiti Formation, which consists of sandstone and shale with thin coal (lignite) and bentonite interbeds. The iron bed is intercalated among dark grey marine shales of the Smoky Group which underlie the lower slopes of the hills and the surrounding lowlands (Fig. 3).

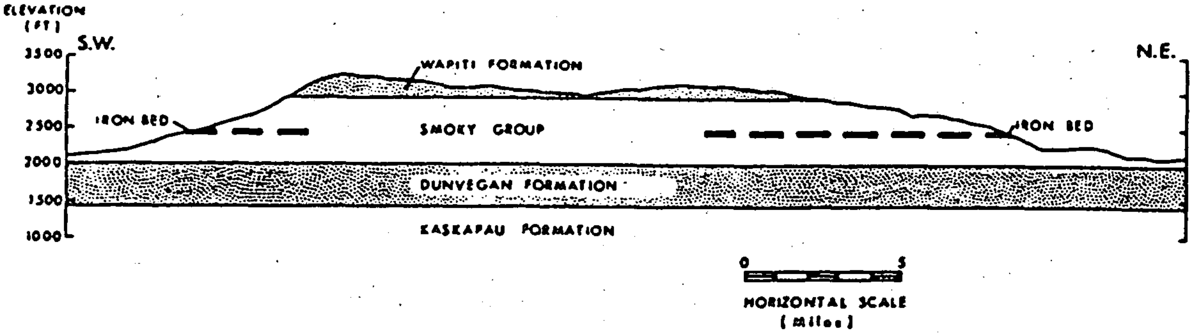


FIGURE 3. Schematic cross section through the Clear Hills showing the stratigraphic position of the oolitic iron formation.

The iron formation consists of dark brown to black oolitic sandstone with thin lenses and interbeds of hard sideritic ($FeCO_3$) "ironstone" and greenish grey mudstone. Near the outcrop margin the sandstone has been oxidized to form a soft, compact, reddish brown aggregate with harder carbonate-cemented lenses. Where present, the formation ranges in thickness up to 30 feet and forms a series of northwest-trending sandstone bodies which are exposed in places along the flanks of the hills at elevations between 2500 and 2700 feet. The mineable deposits are restricted to those areas near the outcrop margin where overburden is thinnest. The thickest and most widespread deposits underlie the northeast slopes of the hills, and thinner less extensive deposits have been found along the southern slopes north of Worsley (Fig. 2).

Scattered showings of oolitic sandstone also have been found in the northern, less accessible part of the Clear Hills, but these have not been explored in detail (Green and Mellon, 1962).

Composition

The Peace River iron deposit is an oolitic sandstone grossly comparable in mineral composition and texture to certain sedimentary iron formations in other parts of the world. The sandstone consists of densely packed oolites 0.5 to 1 mm in diameter, large nodular rock fragments, and angular quartz grains in a finely crystalline "matrix" composed of hydrated silica (opal), siderite (iron carbonate), and "clay" (Mellon, 1962). The oolite content (and hence the iron content) is highest in the upper part of the bed, decreasing progressively towards the base of the sandstone which grades into underlying dark grey shale.

The major iron-bearing minerals are *goethite* ($Fe_2O_3 \cdot H_2O$) and *siderite* ($FeCO_3$); small amounts of *pyrite* (FeS_2) and *glauconite* (Fe silicate) are found in some samples. Silica (SiO_2) is present as discrete quartz grains and as an amorphous opaline substance which forms part of the intergranular "matrix". This opaline substance (or "cement") is also a constituent of the iron-bearing oolites, having been co-deposited with goethite to form the outer concentric shells of the oolites (Plates 1 and 2).

Chemical analyses show that the various deposits are relatively uniform in average composition (Table 1). The salient features revealed by the analytical data are:

(1) Total iron (Fe) content averages between 32 and 36 percent. The Worsley deposits contain lower iron contents than the thicker deposits to the northeast (Swift Creek, Whitemud River, see Fig. 2).

(2) The silica content is relatively high, and the alumina content is correspondingly low.

(3) The phosphorus content is higher than desirable for a conventional iron ore. However, the sulfur content appears to be consistently low.

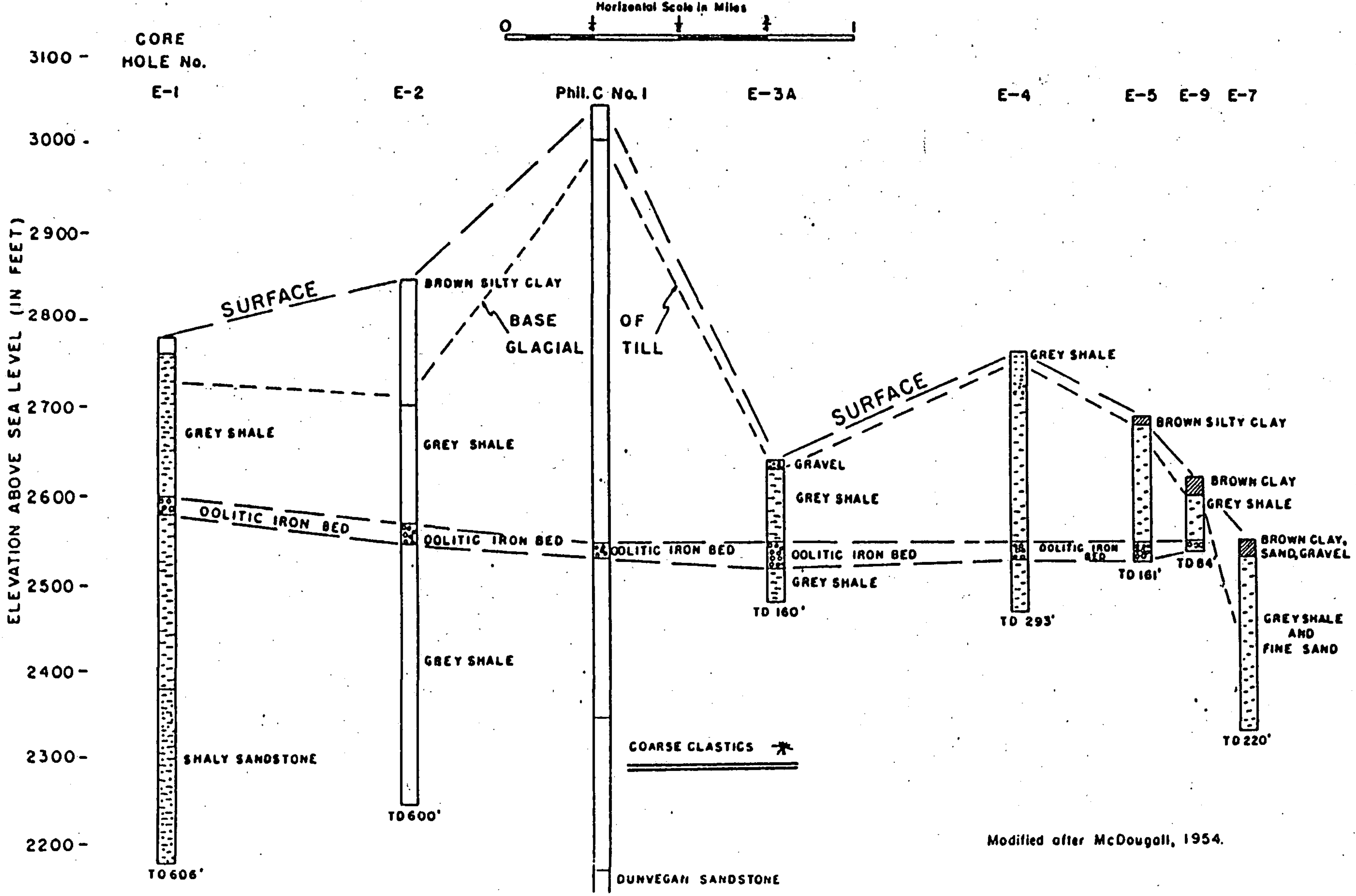
(4) The lime (CaO) content of the Swift Creek deposit is lower than that of the Worsley deposits. This may be caused by partial oxidation of the Worsley deposits in which siderite ($FeCO_3$) has reacted with groundwater solutions to form goethite ($Fe_2O_3 \cdot H_2O$) and calcite ($CaCO_3$).

(5) The water content is unusually high due to abundant opaline "cement".

FIGURE 6

CORRELATION OF McDOUGALL'S CORE HOLES AND PHILLIPS' C NO.1 WELL

SWIFT CREEK AREA, CLEAR HILLS, ALBERTA



Modified after McDougall, 1954.

Table 1. Succession of Strata in the Clear Hills Area, (from Green and Mellon, 1962).

	ROCK UNIT		THICKNESS (m)	LITHOLOGY
	Wapiti Formation		0-120	soft, whitish sandstone; grey, blocky, carbonaceous shale; thin coal seams (continental)
Smoky Group	Puskwaskau Formation		90-180	dark grey, fissile shale (marine)
	Bad Heart Sandstone		*Probably 0-9	Glauconite* green, ferruginous, oolitic sandstone and mudstone (marine) Some Bentonites - from volcanic ash
	Kaskapau Formation	upper member	45-125	dark grey, fissile shale (marine)
		lower member	12-47	whitish sandstone; grey, sandy shale; oolitic siderite (marine)
	Dunvegan Formation		150-235	soft, grey sandstone with calc. concretions; grey, silty, carbonaceous shale (deltaic)
	Shaftesbury Formation	upper member	90-170	grey, silty shale; thin, laminated siltstone (marine)
		lower member	180-320	black, fissile shale; numerous fish scales (marine)

* There also some interesting Titanium values.

GEOLOGY

4.0 Geology of the Peace River Arch

The TUL Peace River Arch play was initially founded on the simple principle; "Stake close to someone who knows what they are doing."

Since Monopros has spent an estimated 6.5 million dollars exploring their sixty-nine townships, or $4.50 per acre on 1,407,000 acres, we assume that they put a high value on the Peace River properties. Since Diamet has substantial acreage in the N.W.T. and have discovered a world class diamond pipe, we assume that they also feel that the play has good potential.

MONOPROS/DeBEERS has 16 Townships close to the east boundary of the TUL acreage. They also have fifty-three Townships on trend to the southeast of the TUL lands. DIAMET has twenty-nine townships on the same sub-craton, but sixty miles south of the TUL lands.

(Note Permits Map # 26 and # 17 respectively)

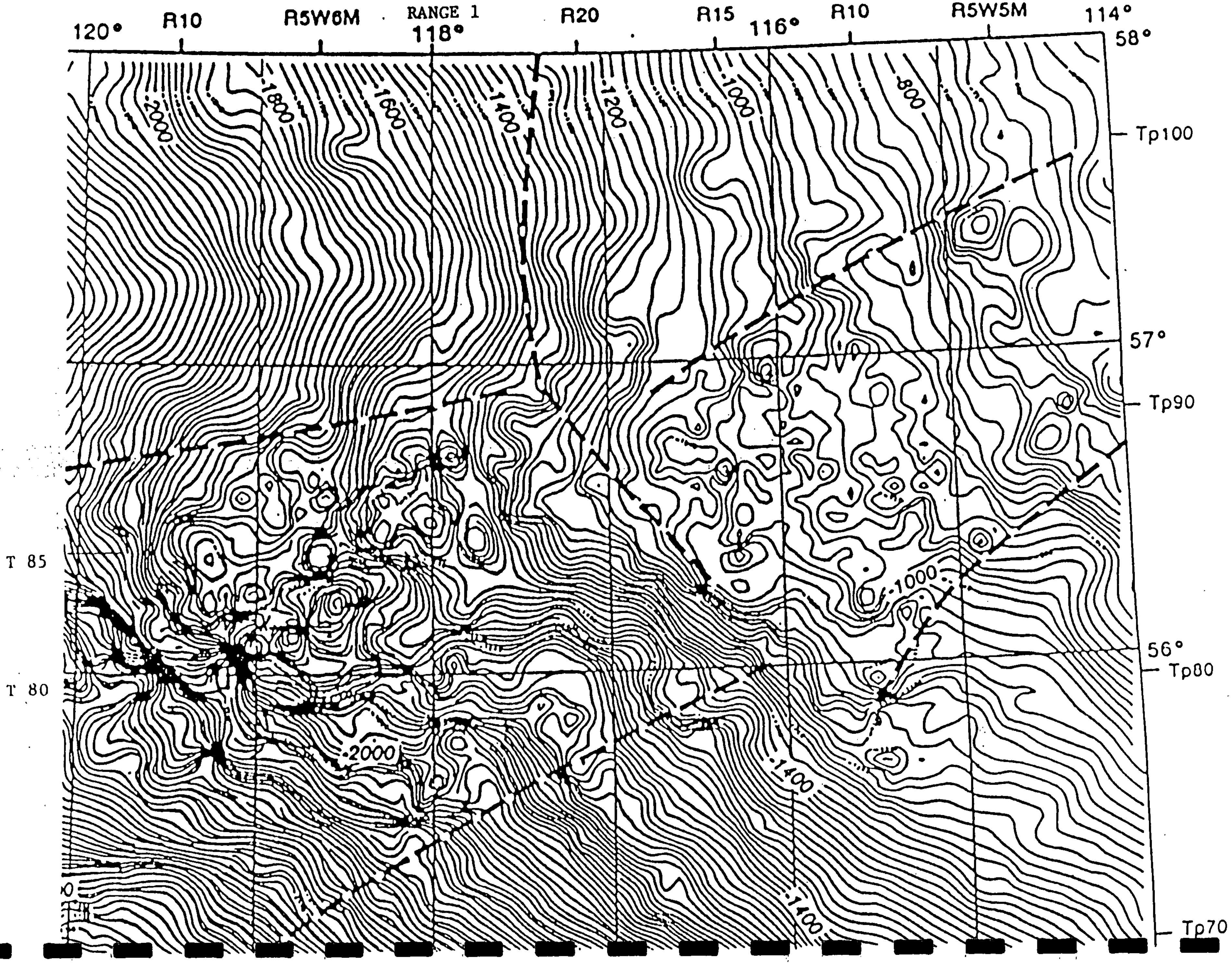
The Peace River Arch is a significant anticlinal structure. This structure is granitic. The granites have large crystals due to slow cooling. These granites cooled below the surface of the earth or the sea floor. The granites are resistive and brittle. The Peace River Arch is made up of an assembleage of cratonic Precambrain granites, which rose above sea level at the beginning of the Devonian Period,. four hundred million years ago. Arching of the anticline has resulted in fracturing. The material that protected these basement rocks from quick cooling has been eroded away and the remaining Precambrian Granites remain as an ancient erosional surface.

(See Cross-Section of the Peace River Arch Anticline)

The present surface of the Precambrian Peace River Arch now lies,on average, about seven thousand feet below the surface in the Peace River area. The Precamrian erosional surface rises in elevation, gently in most areas, toward the north and east, at a rate of about 50 feet per mile, but in the Peace River Area, two regions associated with the arch, have a "busy" uneven surface. This could be do to erosional features, fracturing and displacement, vertical movements such as collapses and/or intrusions.

The material covering the arch is made up of a succession of sediments known as the Phanerzoic (visible life). These are comprised of limestones and dolomites, mudstones and shales. These sediments have been layed down as a result of deposition, rising sea levels; and in response to the collapse of the anticline and further down-warping of the arch under the weight of the phanerzoic. Some of the Phanerzoic sediments are reefal, shallow sea deposition, lagoonal, deltaic, etc.

(See - Stratigraphy - Peace River Arch Region)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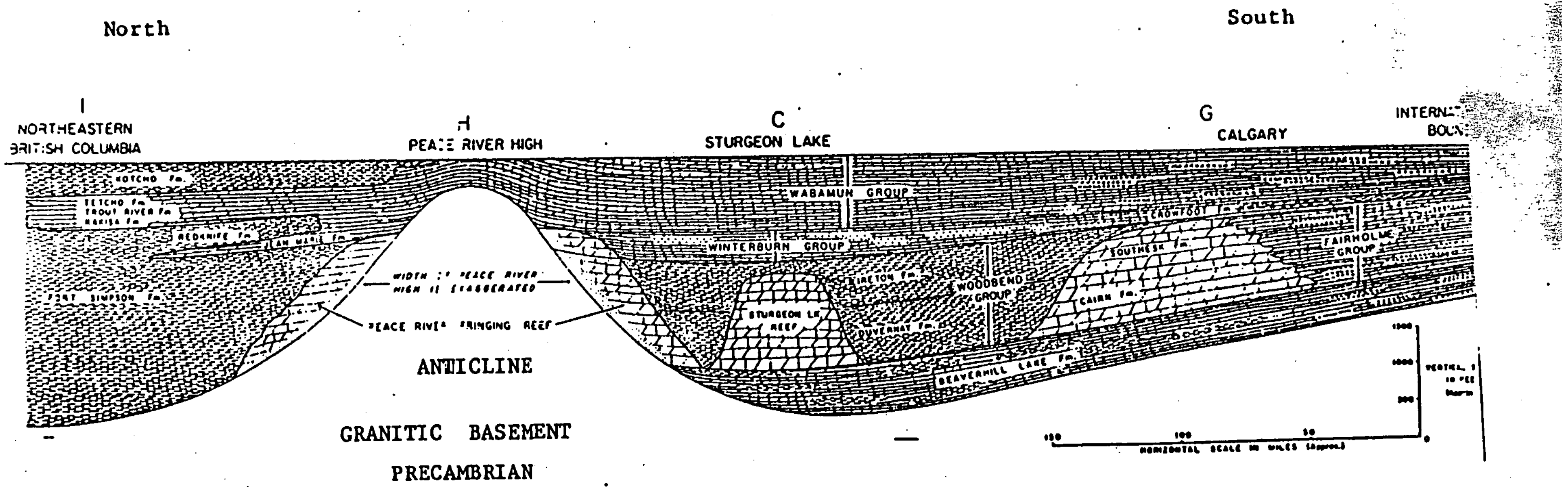
PEACE RIVER ARCH AREA



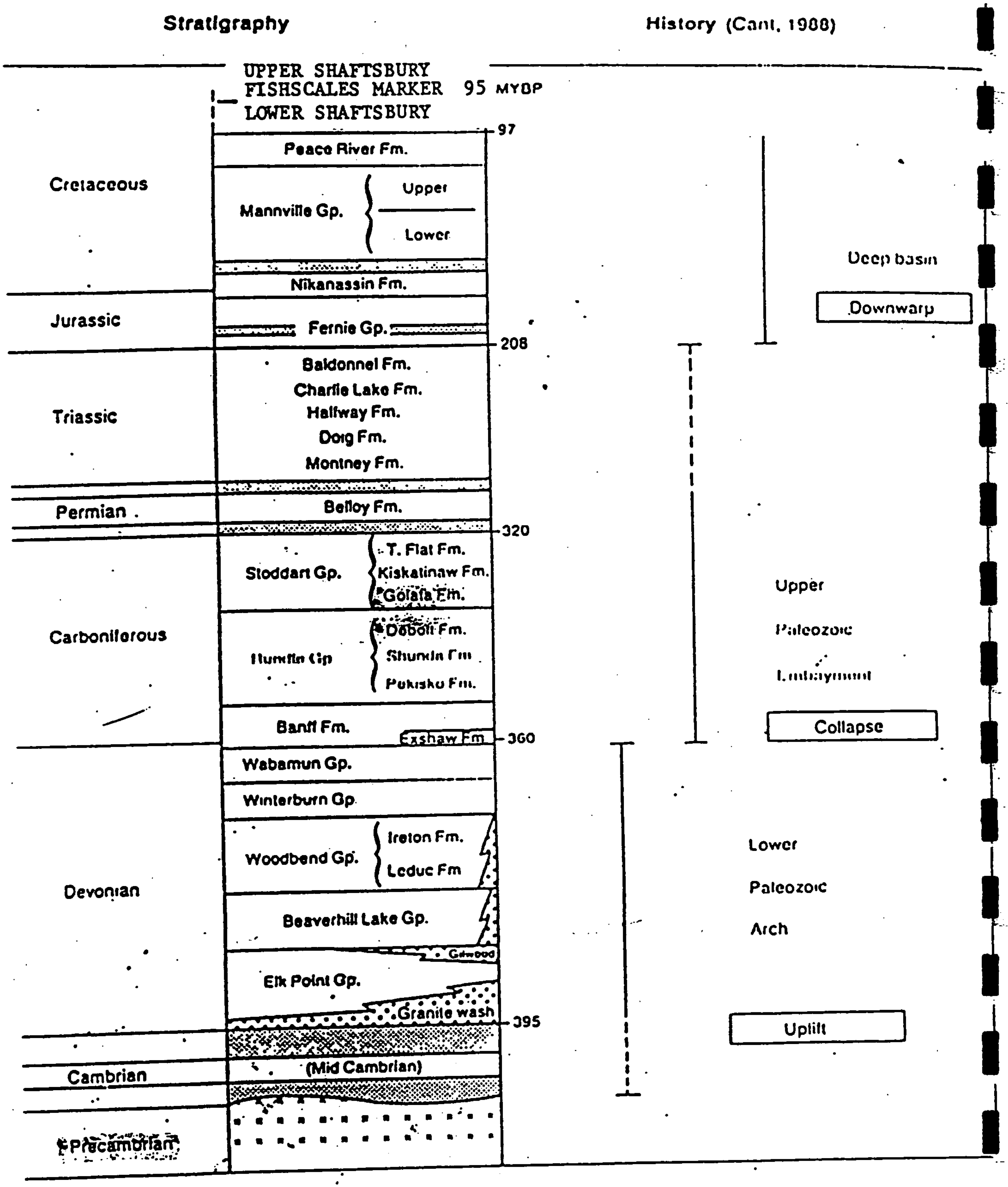


Fig. 2. Table of formations of the Peace River region, with

About 2,500 oil and gas exploration holes and some core holes and research holes have been drilled in the Peace River Arch area.

(See Drill Core Data Map)

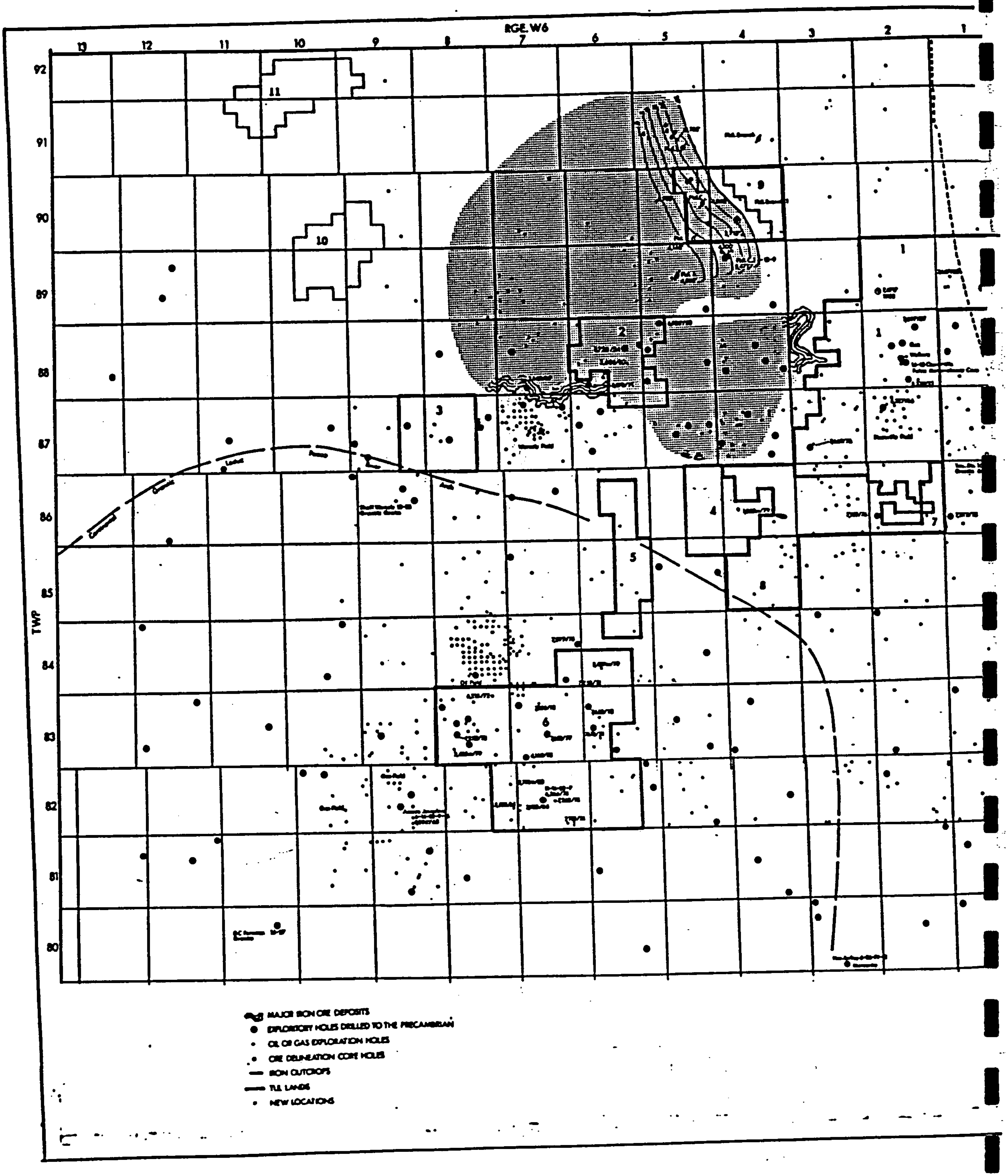
About one hundred of these holes were drilled to the Precambrian. The Structure contour map of the Precambrian is an isopach map showing the present topography of the Precambrian surface. Whether the topography of this surface is the result of erosion or warping or both is unknown.

(See Structure - Contour Map - Precambrian Surface)

This map area includes 169 townships. A cross-section of this area from north-east to south-west, through a number of exploration holes, shows the present Precambrian surface to be topographically; a hill, a terrace and a gentle slope.

The difference in elevation between the summit of the topographical high on the Precambrian surface and the relatively level terrace area to the west is in the order of 1000 feet.

The difference in elevation between the terrace and the bottom of the south west slope is in the order of 3000 feet.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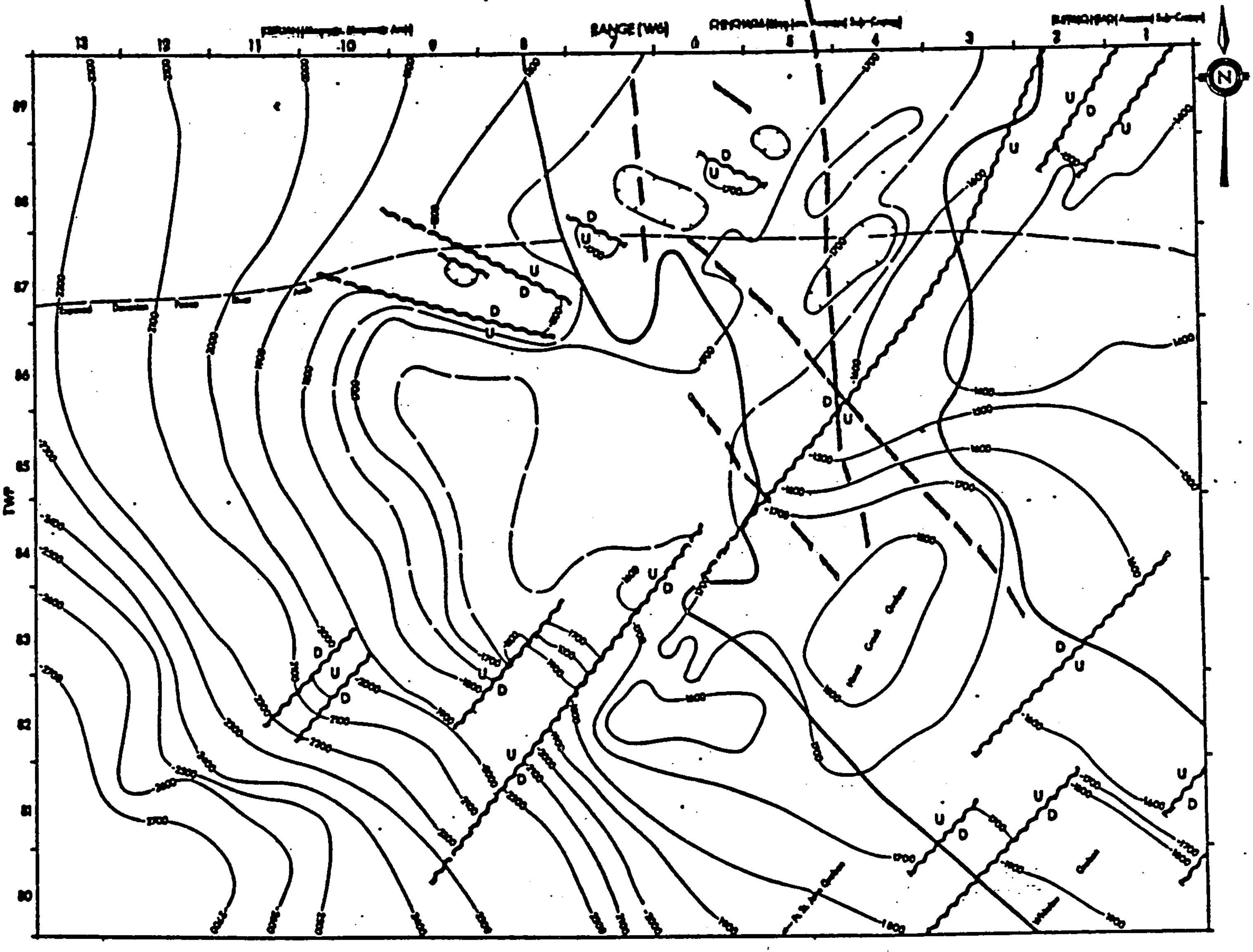
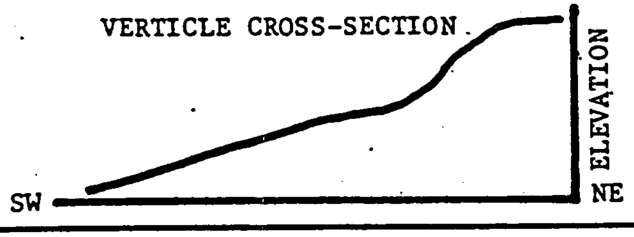
NEW LOCATIONS



DEEP STRUCTURAL FAULTING

[illegible] CROSS-CUT FAULTS



TUL PETROLEUMS LTD.

STRUCTURE CONTOUR MAP
PRECAMBRIAN SURFACE

1:250,000

BASEMENT FEATURES

Further exploration and more accurate deliniation of the surface reveals a number of anomalous localized topographic structures. Often these structures seem to protrude from the Precambrian surface up to three hundred feet, about the height of the Calgary Tower. They might look like fence posts protruding from the basement.

FAULTING

Exploration has established a number of deep basement faults in the region.

One main central fault runs from southwest to north east, discontinues or transforms, continues and the curves to the north. Seven thousand feet above, on the surface, the Peace River turns abruptly to the south at the point of transformation. There is a degree of surficial expression of the basement.

The central main fault is significant. The difference in elevation between topographic high side slope, perhaps the footwall, and the topogrphically lower side, perhaps the hanging wall, is 300 to 700 feet.

GRABENS

There are complexes of grabens, possible intrusions and areas of subsidence curving around the north part of the anticline.

The Hines Creek Graben bottoms at about -1600 meters, 1500 feet below the summit, about the same elevation as the main fault hanging wall. The Graben is flanked by NE/SW trending faults believed to propagate from deep basement to at least the Taylor Flats Formation and possibly above the Belloy Formation; Dolomites, Sandstones and Cherts; and these flanking faults are, according to Barklay et al, arcuate in their propagation from the basement.

The -1600 meter plateau southwest of the Hines Creek Graben sits around 700 feet above the base of the graben and seems to have resisted collapse, which seems unusual, since it sits between the massive Fort St. John Graben and the feeder or minor Hines Greek Graben.

REGIONAL COLLAPSE

Studies show that parts of the arch and a region to the south west began to collapse near the end of the Devonian.

A series of parallel faults indicate that this collapse, presently called the Ft.St. John Graben and the Dawson Creek Graben, center in an area one hundred miles to the southwest. Depths of collapse reach nearly a kilometer.

Collapse continued for a hundred million years and is evidenced into the Belloy Formation and to the base of the Triassic. This collapse extends in a minor way into the Peace River area in the form of the Hines Creek, Whitelaw and Cindy satelite or minor grabens. These faults originate in the basement and propagate in an arcurate or curvalinear way to near surface.

Other systems of faults and other successions of faults extend to various depths through the Phanerzoic as well. The region is highly fractured.

Granite is understood to be hard and brittle. This basement rock has fractured as a result of uplift and collapse. Some of the faults can be dated by plotting their extension into various horizontal Phanerzoic sediments of known dates.

It is possible to associate the anomalous features evident on the basement with faults which propagate from the basement and through the Phanerzoic. They may be intrusions.

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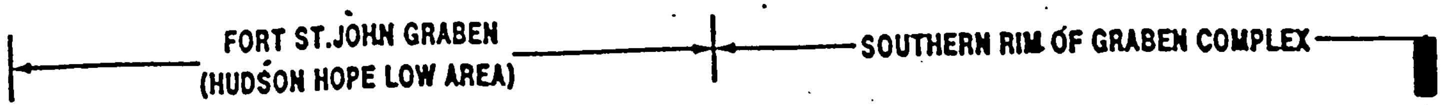


Fig. 8d. "EW1" East-West section, Twps 79-81, Rges 1-26 W6. L
North-South sections (Fig. 8 a,b,c).

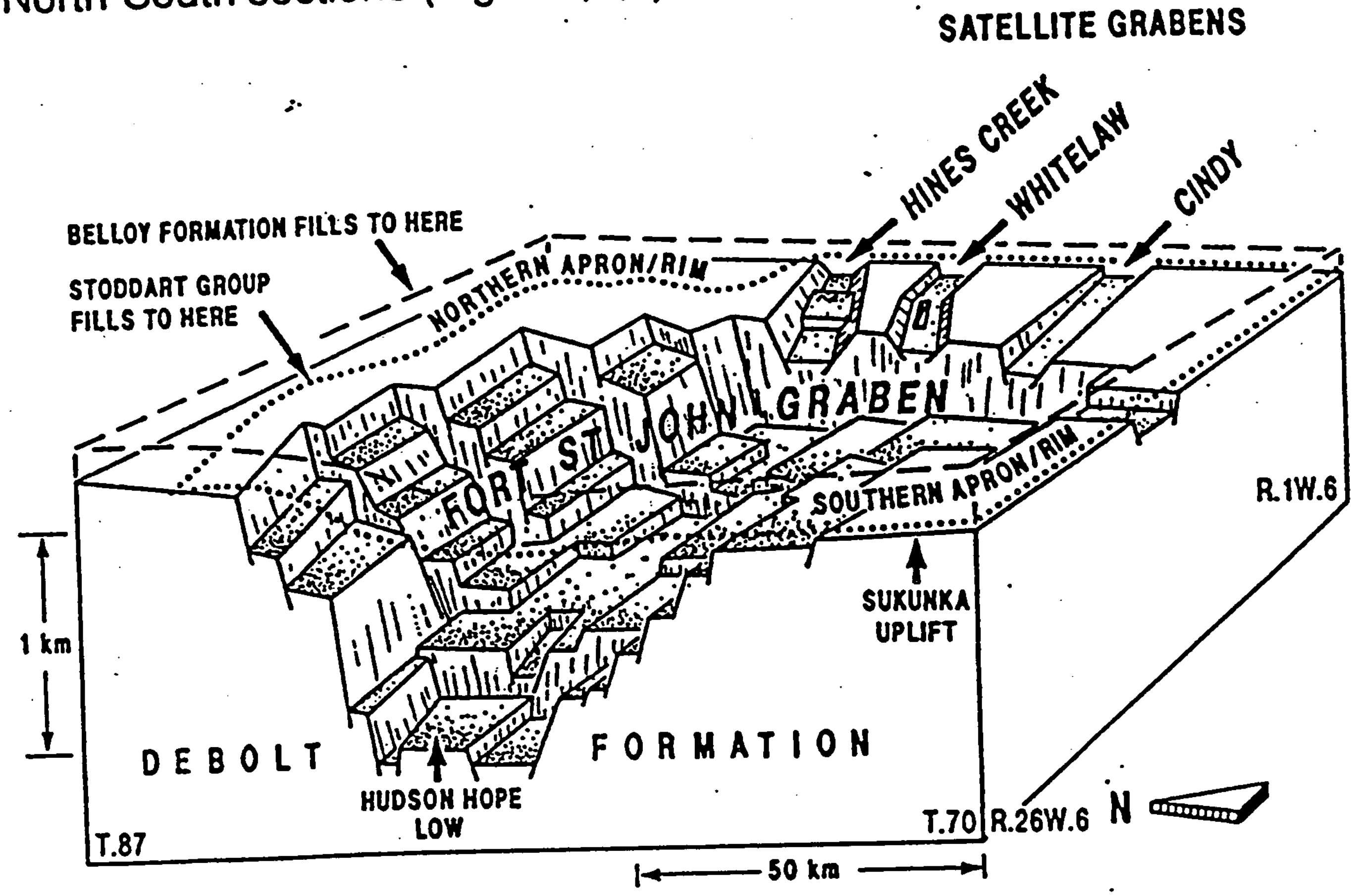


Fig. 9. Sketch of Carboniferous-Permian Dawson Creek Graben Complex. Golata, Kiskatinaw, Taylor Flat, and Belloy formations successively filled the graben complex as it developed. The reconstruction shows arcuate shape, wedge-like westward deepening, and interna and satellite grabens and horsts. Sketch is based on cross-sections, and on isopach and structure maps.

Lithology and Internal Stratification

Three mappable, lithological subdivisions of the Golat Formation can be made and are identified as G1, G2, and G3 (Figs. 8, 12).

4.1 Plate Tectonics

The origin of the Basement rocks and the behavior of the Peace River Arch is associated with continental drift and plate tectonics.

Reconstructing the history of the continents with plate tectonics is complex, but we know that the continents are made up of stable blocks or cratons. The ancient stable cratons are the Archeons.

Continental stable cratons move in response to subcrustal currents. They also move from areas of crustal creation or sea floor speading toward areas of crustal subduction and remelt.

North America is made up partly of the North American Craton. This craton has possibly travelled from the present location of Tasmania to its' present position over the last billion years or so.

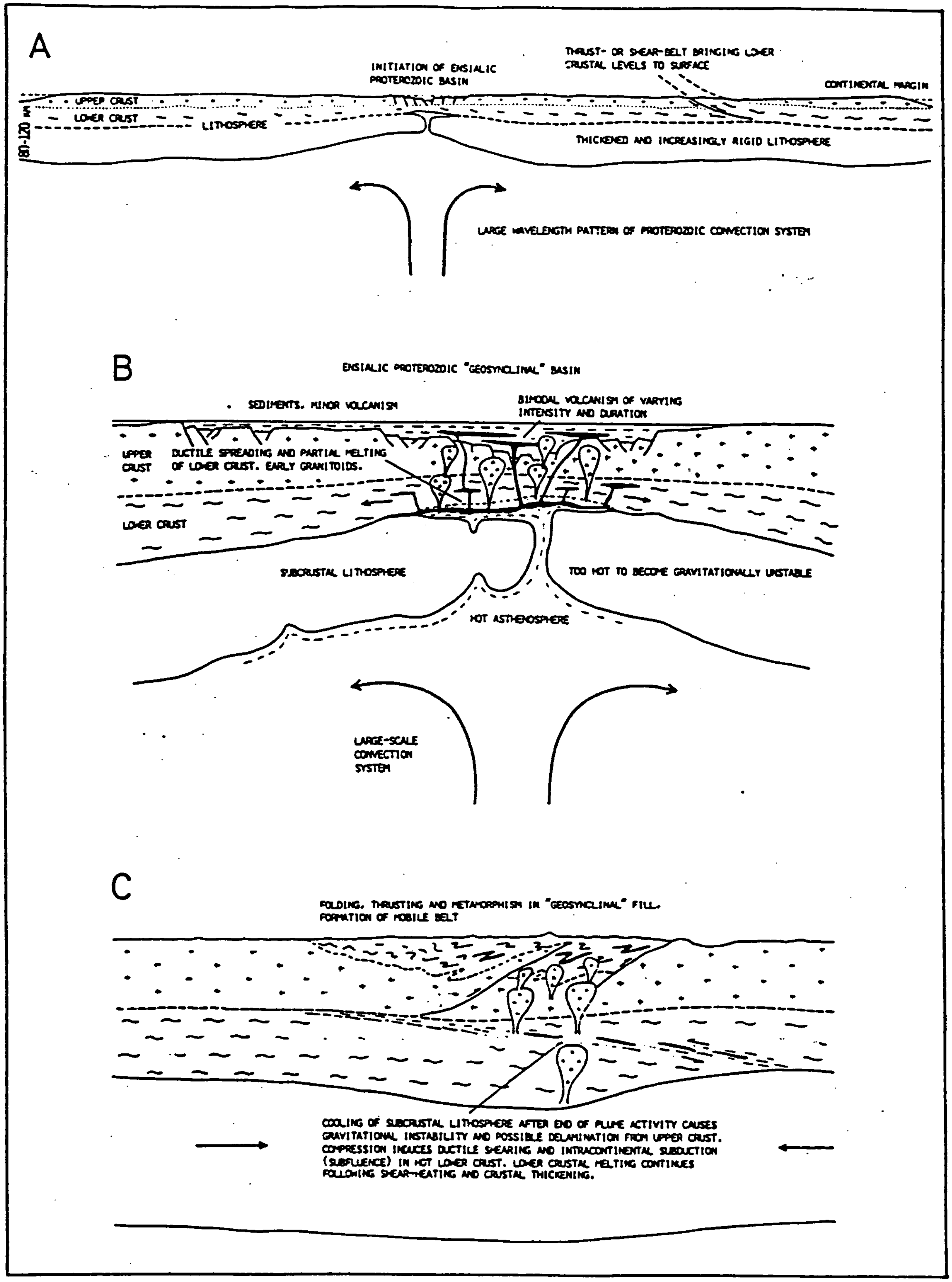
Kroner's schematic on the next page gives an illustration of some of the dynamics involved in crustal formation, magmatic currents, uplift and collapse. In effect, this schematic exemplifies some of the dynamics of the Peace River Arch.

Uplift of the Peace River area Precambrian basement, over a long period of time, is associated with it's movement accross the globe, as a part of the North American Craton and it's assembleage of sub-cratons.

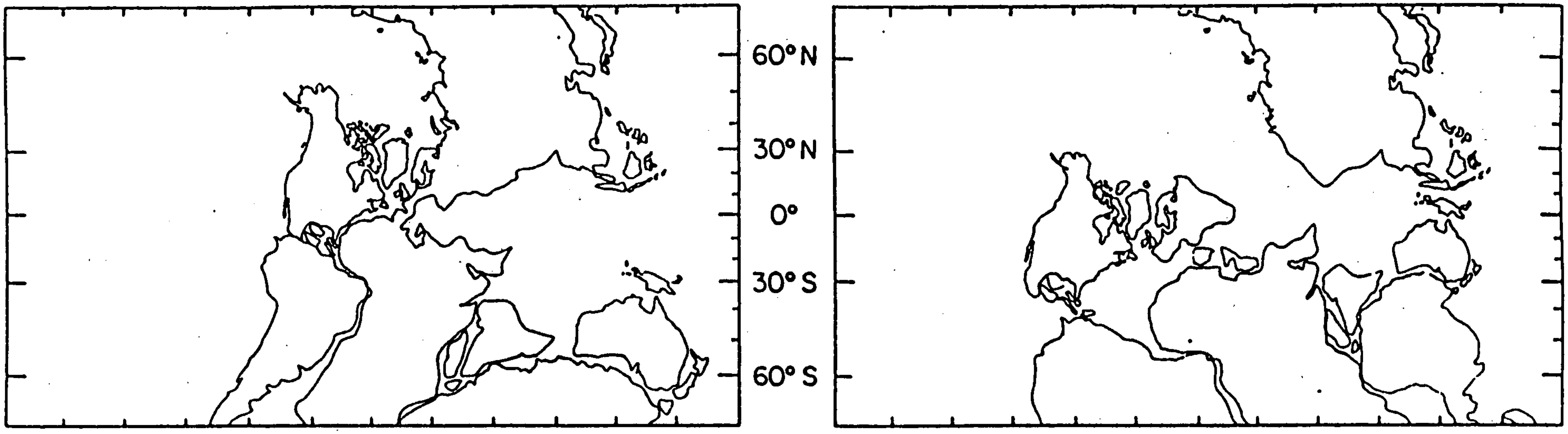
(See simplified illustration of continental drift.)

Intrusions which may host diamonds are connected with stable platforms like the North American Craton. They seem to be associated with the type of mantle that preserves subcrustal diamond formation. These are the eclogites and the peridotites. The area of preservation is the diamond stability field.

Once formed and preserved, crustal anticlines such as the Peace River Arch provide the driving force; crustal movement, subduction, crustal heating; and the opportunity; faults, rifts and collapse systems like grabens, for explosive emplacement of diamondiferous minerals such as kimberlites and lamproites.

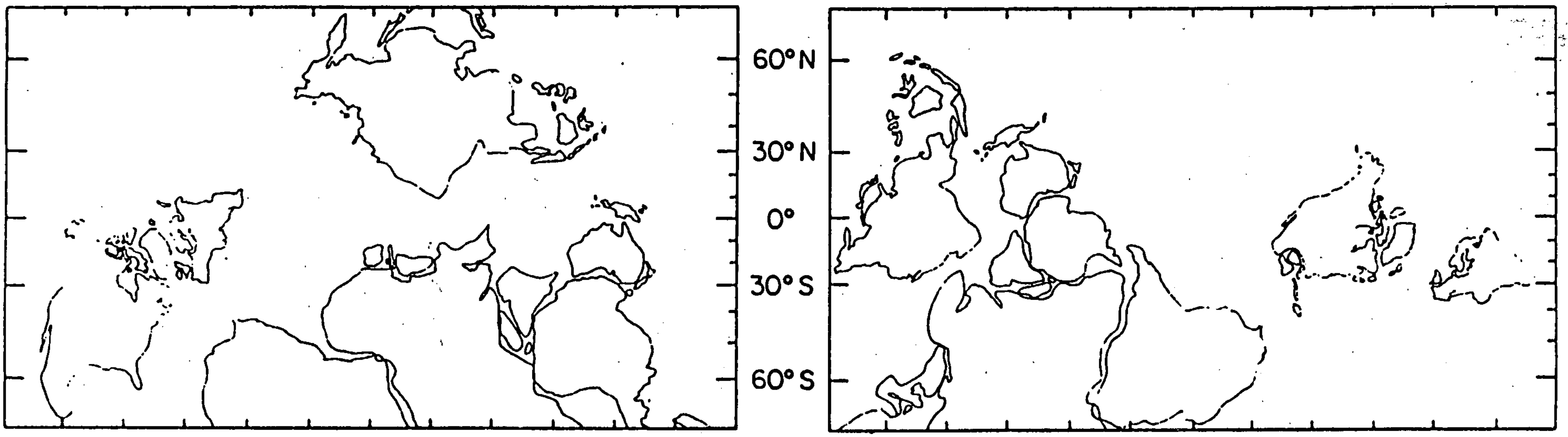


10.21. Schematic sections showing the development of early Proterozoic ensialic mobile belts (from Kröner, 1981).



(e) Permian, 250 my ago

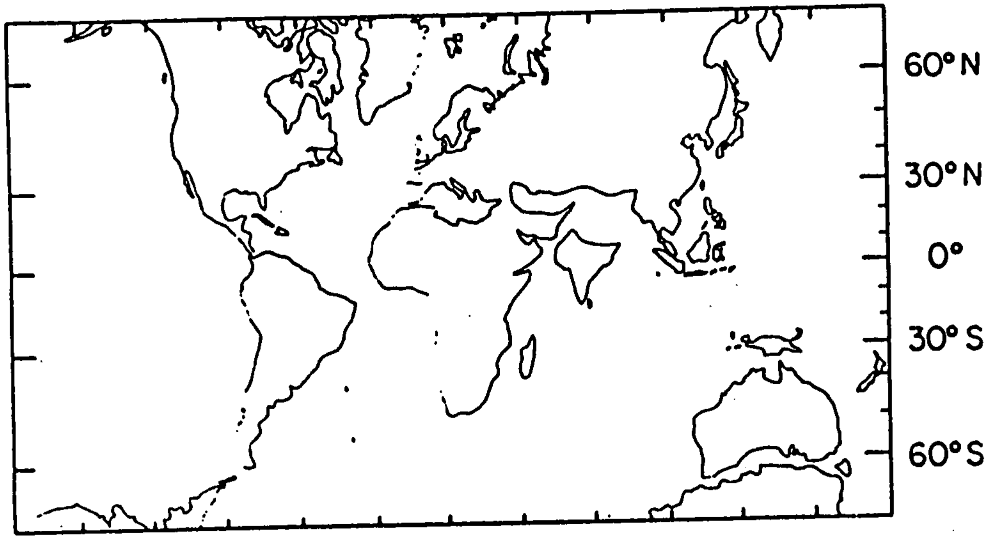
(f) Lower Carboniferous, 340 my ago



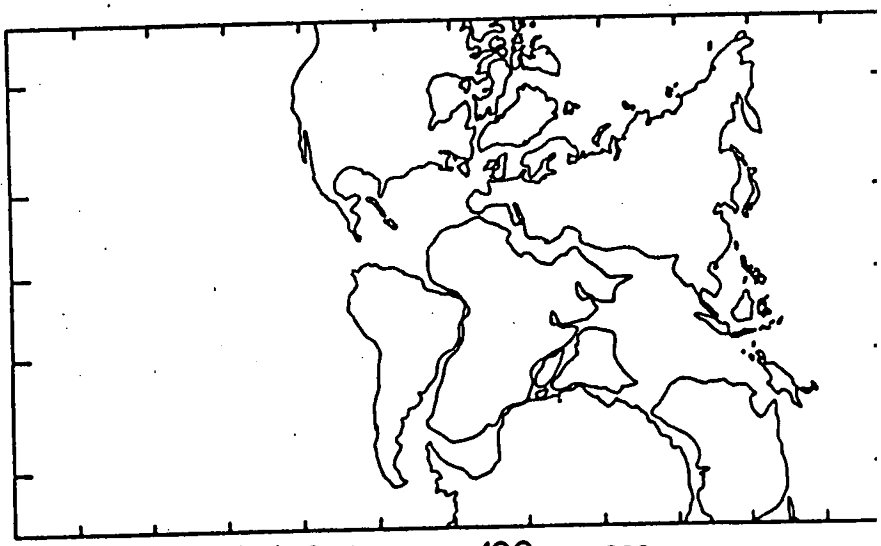
(g) Lower Devonian, 380 my ago

(h) Cambrian / Lower Ordovician, 510 my ago

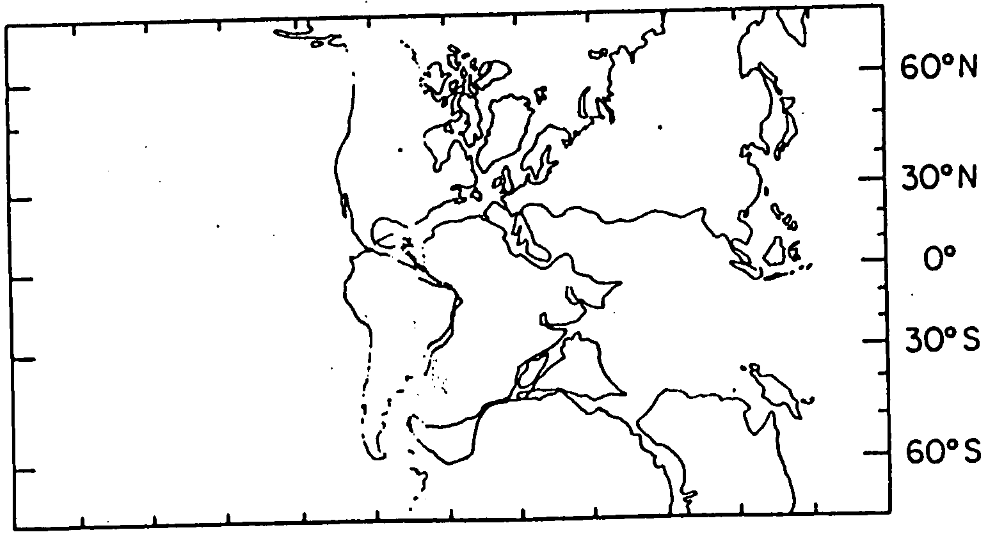
Fig. 9.3. Continental drift from the Cambrian to the Tertiary illustrating the formation and break-up of Pangaea. (Maps based on Smith, Briden and Drewry, 1973; reproduced by permission of The Palaeontological Association)



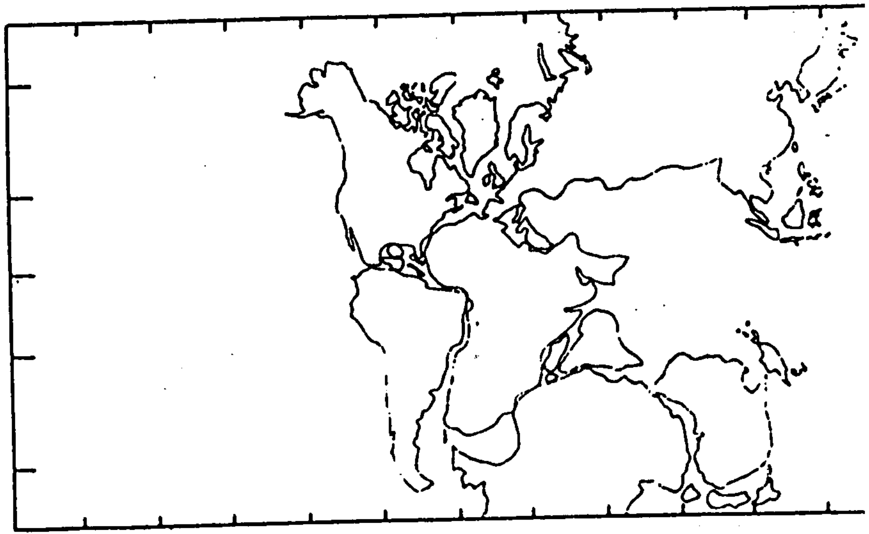
(a) Tertiary, 50 my ago



(b) Cretaceous, 100 my ago



(c) Jurassic, 170 my ago



(d) Triassic, 220 my ago

4.2 Craton Assembleage

The North American Craton is a stable platform which is made up of a number of sub-cratons.

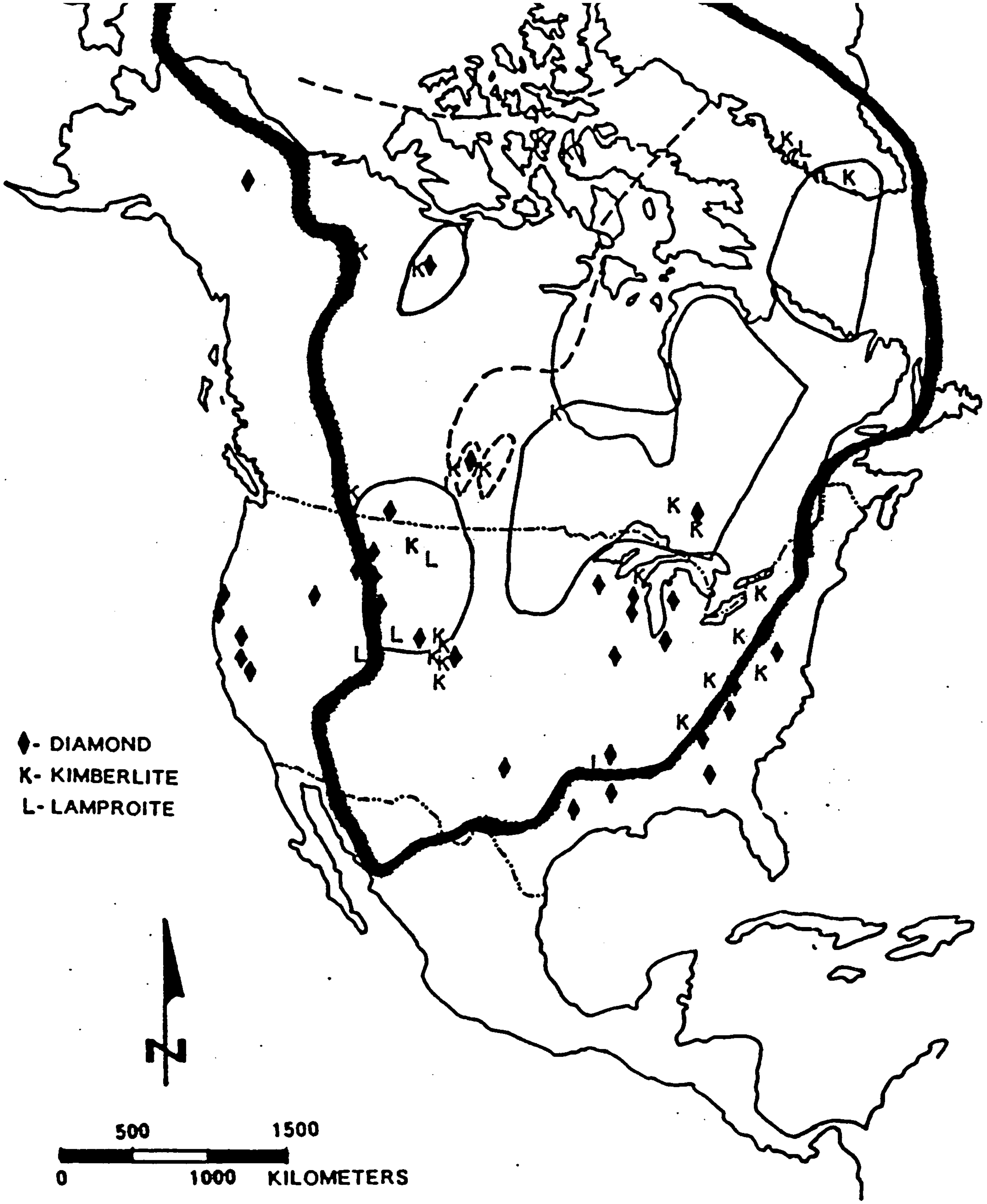
(see North American Craton)

The Theriault and Ross schematic shows the sub-cratons as being underlain by archeon domains. The black verticle lines represent suture zones where sub-cratons have collided or joined.

(see schematic tectonic model from Theriault and Ross, 1990.)

The sub-cratons in the Peace River Arch are (east to west) the Buffalo Head, the Chinchaga and the Ksituan. These have been dated as to formation at around 2.0, 1.9, 1.8 billion years (Ga.) respectively.

(see Domains, Arcs, Terranes from the Alberta Lithoprobe Study.)



NORTH AMERICAN CRATON

FIGURE 2

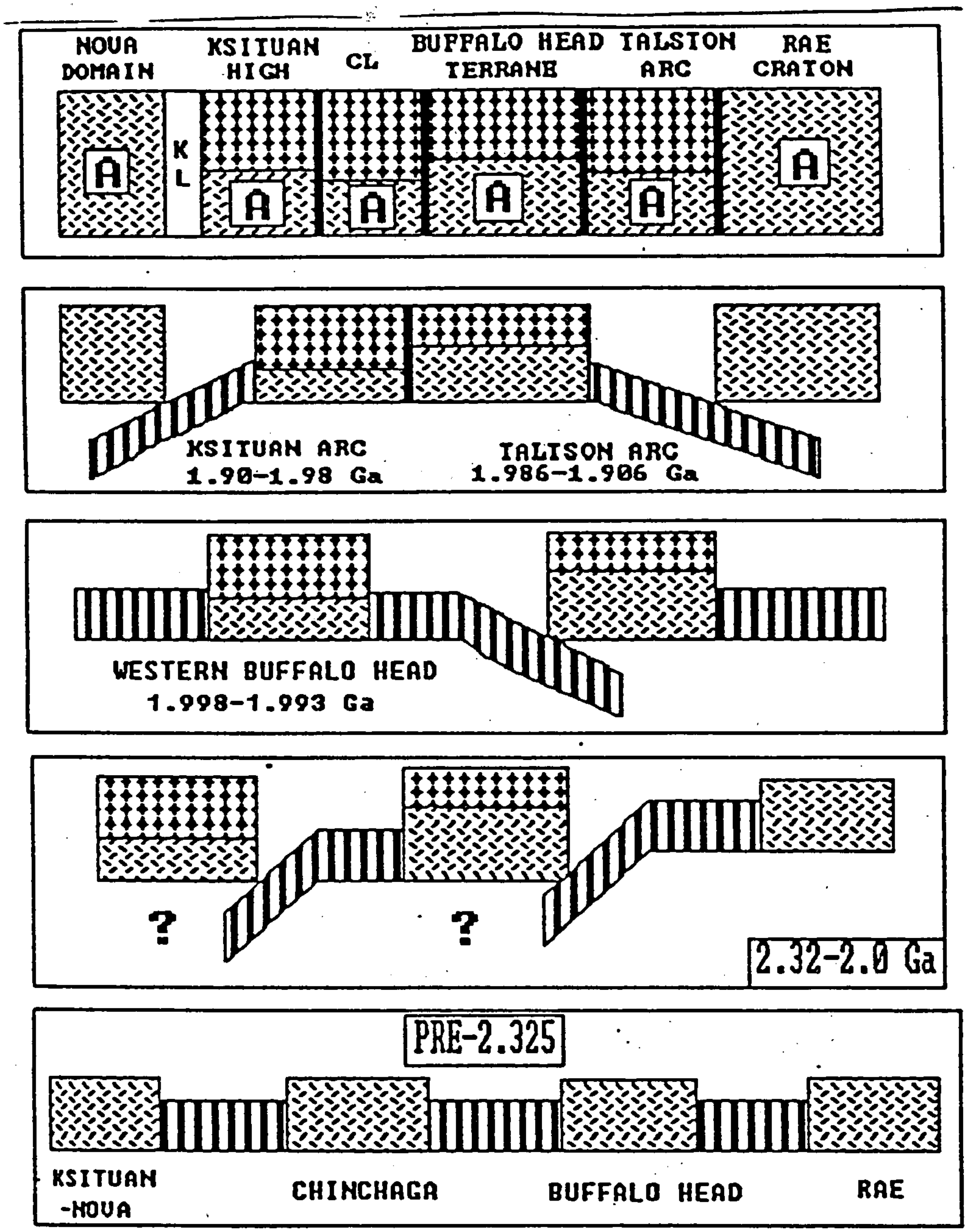


Fig. 4. Schematic tectonic models for the Proterozoic assembly and growth of continental crust in northern Alberta. The upper panel shows the inferred present cross-section (corresponding to about 56°N) of Archean and Early Proterozoic domains, the latter built on a foundation of Archean crust, as inferred from Sm-Nd isotopes (Theriault and Ross, 1990). CL, Chinchaga Low; KL, Kiskatinaw Low. The bold vertical lines between domains are inferred sutures based on breaks in geophysical characteristics and/or geochronology. Prior to 2.32 Ga (the oldest rock in the Buffalo Head Terrane), the crust was composed of Archean continental blocks separated by oceanic lithosphere (vertical stripes). Progressive convergence and subduction of oceanic crust led to the formation of Lower Proterozoic magmatic rocks (Ksituan, Taltson, and western Buffalo Head). The polarity of the subduction zones is highly speculative, especially before about 2.0 Ga.

4.3 TERRANES

The point of this paper is to ascertain whether there are diamonds in the Peace River Region, and if so, then where are the best places to look. Does TUL have properties with good prospects and where on those prospective lands are the best targets?

The GSC Terrane Map of the Canadian Cordillera shows the history of the accretion of land masses from the west colliding with North American Craton.

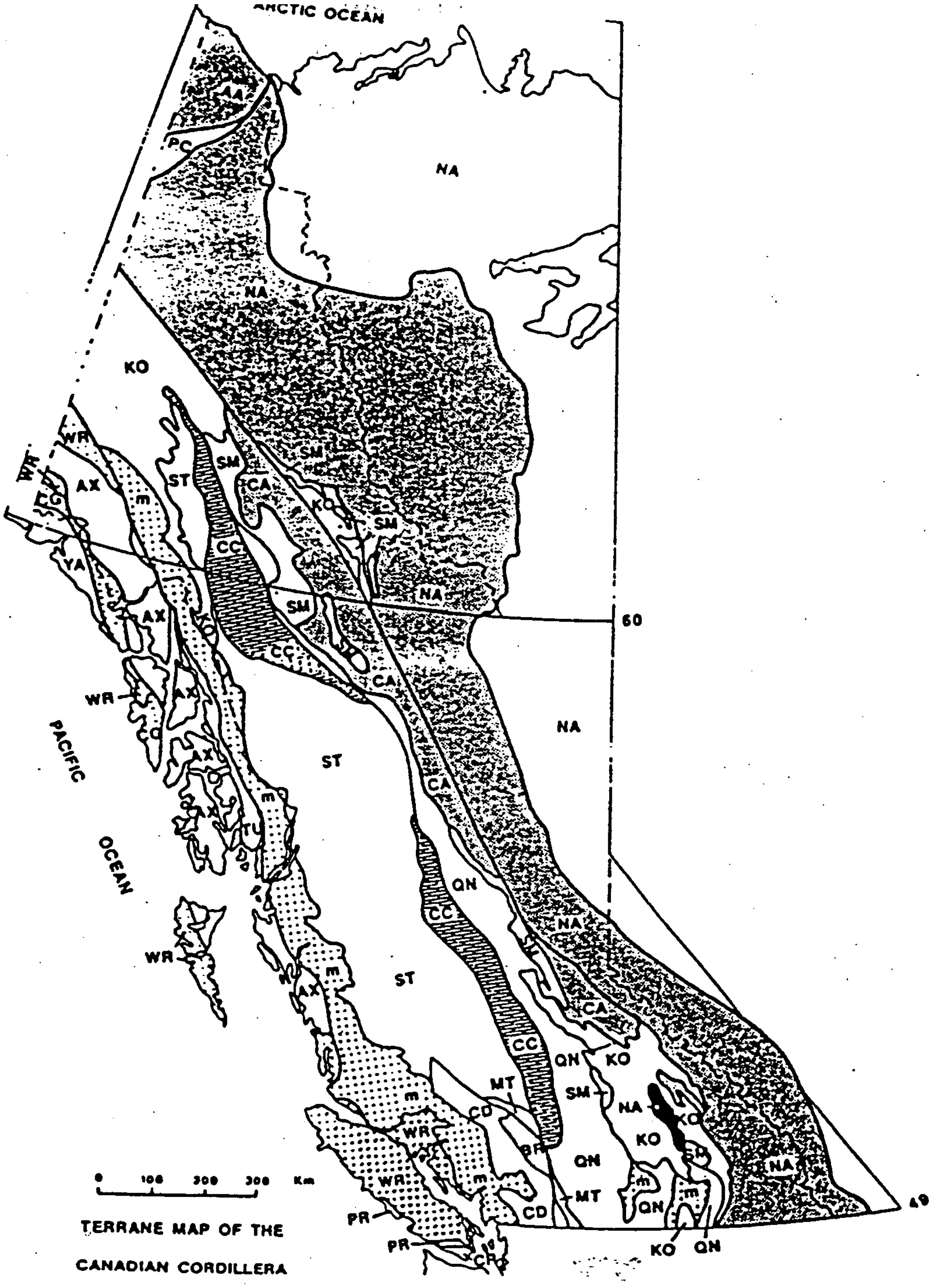
(see G.S.C. Terrane Map of the Canadian Cordillera)

"Where Terranes Collide" tells the story of the dynamics and the timing for Western Canadian accretion of terranes and substantiates the proposition that the Peace River Region cratonic blocks have been pressured by a series of west southwesterly collisions.

According to Yorath, the Cassiar Terrane collided with the North American Craton, the North American Interior 160 million years ago, near the end of the Jurassic. A crustal failure may have occurred in the Peace River Arch at that time. In terms of Arch history, this would be at the end of the post Devonian Collapse. Regardless, there is reason to believe that a rift or failed rift occured on or near part of the Peace River Arch. This indicates that the North American Craton is a stable craton, but that collisional and thermal forces have fractured the Peace River Arch. If a diamond stability field exists, under the Baffalo Head Sub-craton, then there have been opportunities for diamond emplacement in the way of fractures and instabilities.

If there are diamonds in the Peace River Region and there have been opportunities for diamond emplacement, then in order to estimate the depth to target exploration, we need to date the events responsible for diamond emplacement. Dating events directs our search to particular lithologic horizons and or sedimentary layers of known dates.

Our estimation for the dates of diamond emplacement in the Peace River Region are given later in this report.



TERRANE MAP OF THE CANADIAN CORDILLERA

LEGEND

A. ANCIENT CONTINENTAL NORTH AMERICA

1. NA CONTINENTAL INTERIOR (CRATON)

2. CONTINENTAL MARGIN

(a) NA CORDILLERAN MIOGEOCLINE

(b) CA CASSIAR TERRANE

(c) AA ARCTIC ALASKA TERRANE

(d) ■ PRECAMBRIAN CYSTALLINE BASEMENT ROCKS

B. EXOTIC TERRANES OF THE CORDILLERA

1. KO KOOTENAY

2. PC PORCUPINE

3. INTERMONTANE SUPERTERRANE

(a) ST Stikinia (b) QN Quesnellia

(c) SM Slide Mountain

(d) CC Cache Creek

4. INSULAR SUPERTERRANE

(a) WR Wrangellia (b) AX Alexander

C. TERRANES OF THE COAST BELT

(a) TU Taku (b) CD Cadwallader etc. (c) MT Methow

D. PACIFIC TERRANES

(a) CG Chugach (b) YA Yakutat

(c) PR Pacific Rim (d) CR Crescent

E. m Metamorphic rocks of unknown affinity.

4.4 LITHOPROBE STUDIES

The Alberta Basement Transects Study Group conducts ongoing crustal research and continues to published their findings, based partly on deep penetrating siesmic and magnetic surveys.

The Lithoprobe has identified and dated the subcratons of Northwest Alberta and describes the relative motion of subcratons that underlay Peace River.

(See Domains,Magmatic Arcs, Magmatic Lows, Accreted Terranes map of Alberta)

There was a point in time at which the early earth's crust reached a critical bouyancy state. Continental building blocks became fairly mobile. This is thought to have occurred about one billion years ago.

According to plate tectonics and continental drift, the North American Craton moved thousands of miles in a northwesterly direction from the central latitudes during the Devonian (400 million B.P.) to the northern latitudes by the end of the Cretaceous. (65 million B.P.)

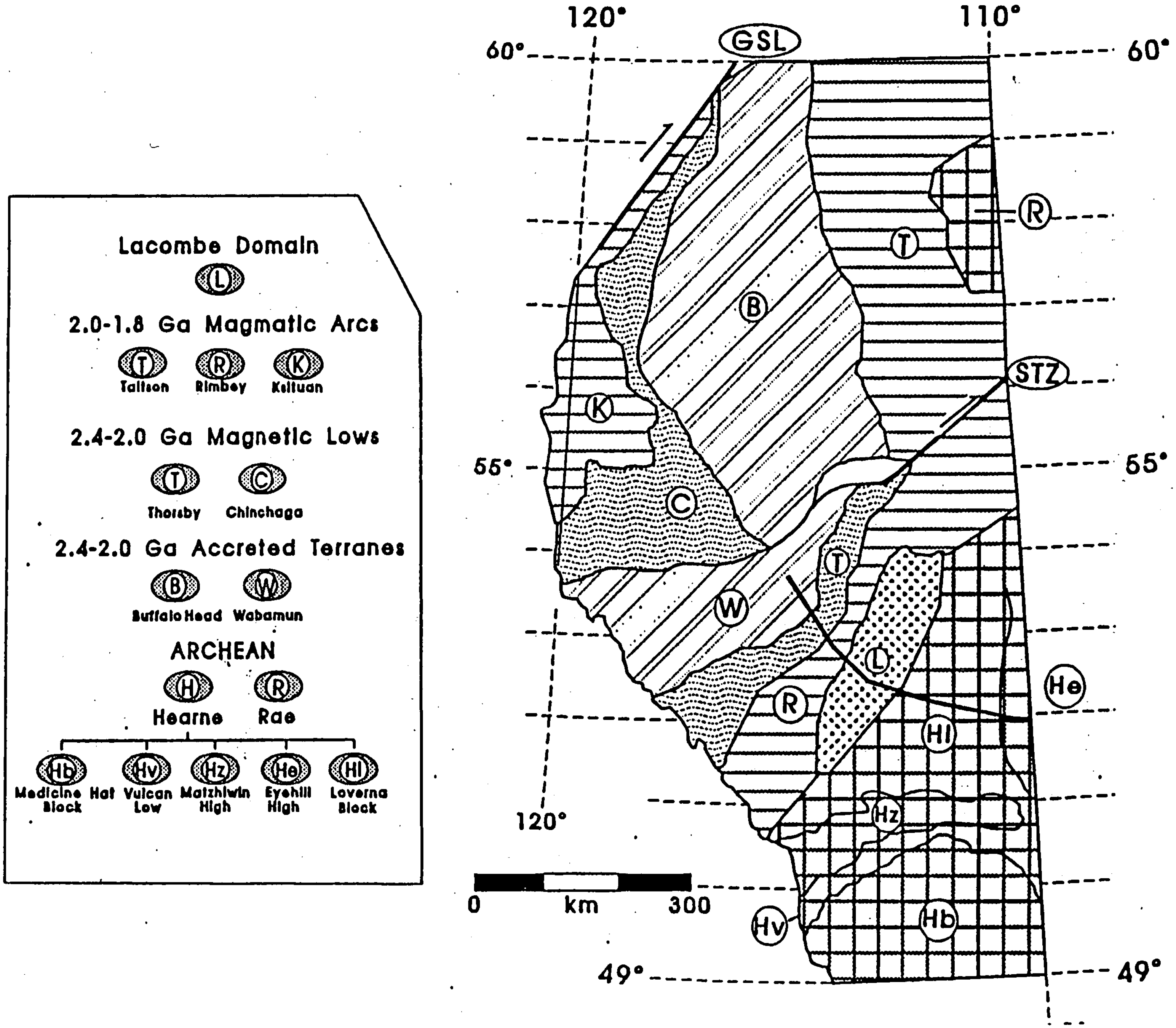
The three sub-cratons underlaying the area west of Peace River moved in an easterly direction and were accreted to the North American Craton, colliding with the Buffalo Head Sub-craton.

The Buffalo Head is an accreted sub-craton which is comparitively magnetic. The Chinchaga is an accreted sub-craton which is not very magnetic. The Ksituan is a magmatic arc, which is the next accretion to the North American Craton, and is relatively magnetic.

The Suture Zones, where it is believed that the three Peace River sub-cratons meet, are shown on the Precambrian Structure Contour Map and on the Craton Assembleage Map.

We look at the suture zones as areas of crustal weakness, especially where they are cross-cut by known deep basement faults. The suture zones are the regions we examine to determine whether there is reason to believe that one sub-craton is subducted by another.

Craton subductions may be likely places for intrusions, but they may not be the opportunity for intrusions,which provide the thermal protection required to allow diamonds to reach the surface without being destroyed.


Lacombe Domain
L
2.0-1.8 Ga Magmatic Arcs
T Taltson
R Rimbey
K Ksituan
2.4-2.0 Ga Magnetic Lows
T Thorsby
C Chinchaga
2.4-2.0 Ga Accreted Terranes
B Buffalo Head
W Wabamun
ARCHEAN
H Hearne
R Rae
Hb Medicine Hat Block
Hv Vulcan Low
Hz Matzhiwin High
He Eyehill High
Hl Loverna Block
120°
110°
60°
60°
55°
55°
49°
49°
120°
GSL
STZ
T
R
B
K
C
T
W
L
R
He
Hl
Hz
Hv
Hb
0
km
300

FIGUR.

4.5 SUB-CRATON DYNAMICS

The Buffalo Head Sub-craton is a logical place to look for diamonds. There are a number of sub-regions on the Buffalo Head that meet our criteria for being places where faulting, cross-faulting and magnetics indicate there may be intrusions; intursions that host diamonds.

The Buffalo Head Sub-craton has characterisics in common with the Slave Sub-craton in the Northwest Territories. The Slave is a stable craton probably has undergone a turning moment imparted to it by collision with other sub-cratons. The Slave is fractured by deep basement faults. The Slave Craton holds one of the world's richest diamond kimberlite pipes, near La Des Gras.

The Bauffalo Head Sub-craton seems to have been halted in it's northwest drift, partly by collision with northeasterly travelling sub-cratons, which were accreted.

Our contour map showing the Precambrian erosional surface shows a series of faults and horsts and grabens. The faults are thought to be fractures and fracture systems which occurred at various times when the arch was active.

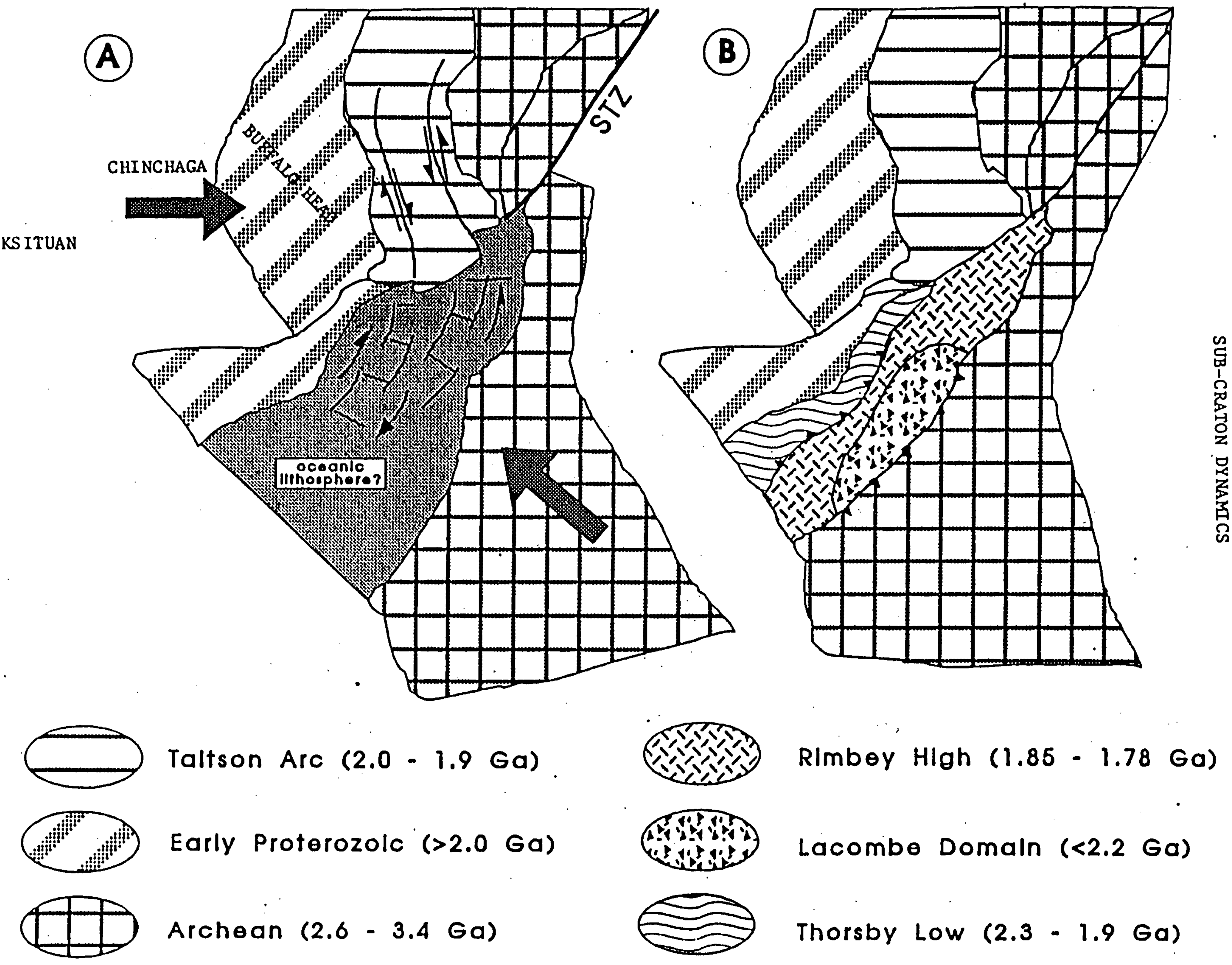
Horsts occur when a rock unit rises above the surrounding rock, as between a pair of faults. Grabens can occur when a unit or units of rock fall or collapse relative to surrounding rock, as a unit vertically falls, sided by two parallel faults.

The main deep basement fault that runs northeast, transforms, and continues to run northeast accross our Structure Contour Map has be named by ourselves, the "The Montagenuse Fault." This fault exhibits a posative curve in Township 88, Range 3, W6M.

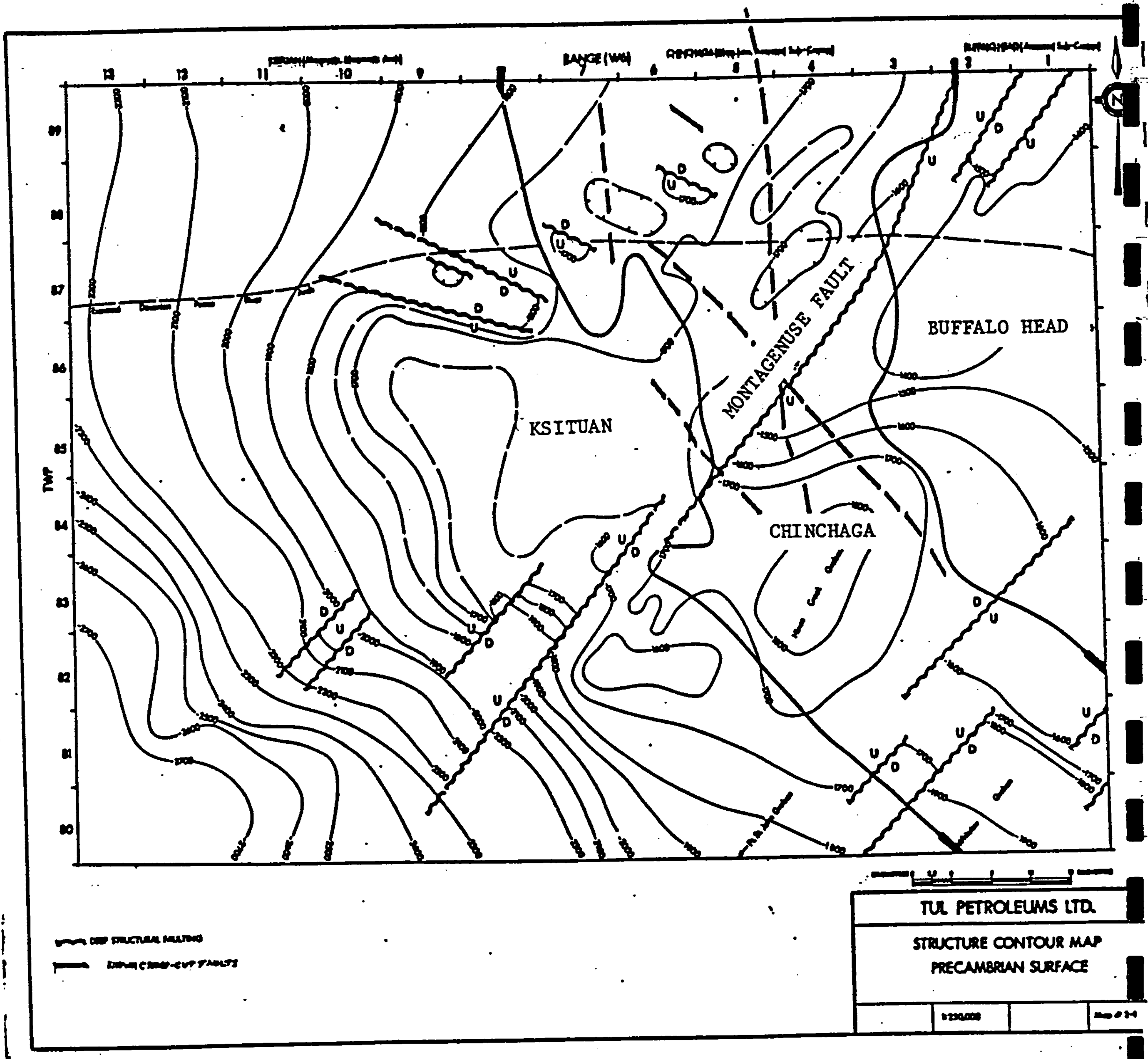
There seems to historic-dynamic evidence that the Buffalo Head-Chinchaga -Ksituan assemblege has undergone a turning moment. As a pattern, there is evidence from the Precambrian Structure Map that the assemblege has undergone a turning moment.

There are known kimberlite intrusives along a northeast-southwest linament south of the Town of Peace River. Monopros has drilled their lands on and parallelling this linament. Our problem is to determine whether there are similar targets for kimberlite intrusives on trend but further north, along the Buffalo Head-Chinchaga-Ksituan assemblege. Is it like the Slave?

From a deep basement faulting and a cross-cut faulting point of view and from a dynamic point of view, TUL has targets where kimberlite (or lamproite) pipes may have intruded.


A
B
CHINCHAGA
KSITUAN
BUFFALO HEAD
STZ
oceanic lithosphere?
Taltson Arc (2.0 - 1.9 Ga)
Early Proterozoic (>2.0 Ga)
Archean (2.6 - 3.4 Ga)
Rimbey High (1.85 - 1.78 Ga)
Lacombe Domain (<2.2 Ga)
Thorsby Low (2.3 - 1.9 Ga)

SUB-CRATON DYNAMICS



4.6 CHINCHAGA SUBDUCTION

The shape of the eastern edge of the Chinchaga sub-craton, as it fits into the cratonic assemblage, leads us to conclusions about the dynamics of the Peace River Arch and possible subduction of the Chinchaga.

The Chinchaga is magnetically low. It appears to be pinched out to the south. There is coincidence between suture zones and the faulting systems. It is reasonable to conclude that craton movement in a north-westerly direction meeting and accreting sub-cratons moving in an easterly direction resulted in major fracturing, some subduction of one or more of the sub-cratons and probably a hinge/turning moment being induced for a period of time into the structure, as (see residual pressure map) evidenced by the transform fault through the deep basement and the curvalinear aspect to the north-east part of this same fault. All of this acitivity; accretion, turning, arching and fracturing has resulted in identifiable minor grabens and graben complexes, horsts and suites of faults which set conditions for intursions of magma into the area. (See structure and Contour Map)

There is also some correlation between the orientation of basement features; the topographic highs and lows; which appear as a linament in Townships 87,88 and 89, Ranges 7,8,9, W6M and are parallel to the major fault accross the map area.

Horsts,grabens,faulting and alteration; and perhaps subduction; as evidenced in the isopach map; as well as the arching history of the Peace River anticline,suggest a lot of movement and many opportunities for kimberlite or lamproite intrusions. "Faulting is the opportunity and dyanamics are the driving force for emplacement."

The Suture Zones, where it is believed the three Peace River area sub-cratons meet, are shown on Precambrian Structure Contour map and on the craton assembleage maps.

The Ksituan sub-craton is a magmatic arc. It covers a large region in the south. The Ksituan is probably less dense than the Buffalo Head. Granitic Gneiss is found in well cores in the west. The large south region seems to have collapsed from the end of the Devonian to the beginning of the Triassic.

An area which resists displacement; erosion or subduction; underlies Townships 84, 85 and 86, Range 6, W6M. There are embayments to the Ksituan to the north and south.

This areal protrusion in the Ksituan, coincident with three magnetic highs, is anomalous and nothing like it appears on any of the other suture zones in Alberta. The only outlier similar, but opposite, is that on the Buffalo Head, fifteen miles to the east. Together, the Ksituan and the Buffalo Head appear to squeeze the Chinchaga; the Chinchaga likely being subducted, and Montagenuse Fault, a major beep basement fault, transects both. The magnetic anomalies probably represent intrusives. On the Buffalo Head side, core data reveals Felsic Volcanic basement rock which indicates that volcanism occured there at some time.

Table 2. S_{Hmin}/depth gradients calculated for 7 areas in the Peace River Arch region. Also shown are estimated S_{Hmin} magnitudes at 2 km depth in each area. The locations of areas 1 to 7 are indicated on Figure 4.

Area	Gradient assuming $S_{Hmin} = 0$ at surface in kPa/m (no. of measurements)		Possible gradient in kPa/m if $S_{Hmin} > 0$ at surface (S_{Hmin} at surface in MPa)	S_{Hmin} in Mpa at 2 km (Standard deviatio	
1) T.77-84, R.10-18W6	19.0	(4)	13.8 (7.0)	34.8-38.0	(4.8)
2) T.68-71, R.09-13W6	16.7	(16)	—	33.4	(3.4)
3) T.58-67, R.04-08W6	17.0-25.0	(14)	17.0 (8.0)	42.0-44.0	(7.1)
4) T.62-63, R.19-26W5	14.9	(4)	—	29.8	(1.5)
5) T.91-97, R.06-10W5	?15.9 or less	(4)	—	?30.0	(7.0)
6) T.78-81, R.03-08W5	17.0	(4)	—	34.0	(2.6)
7) T.71-72, R.03-08W5	15.4	(10)	—	30.8	(2.0)

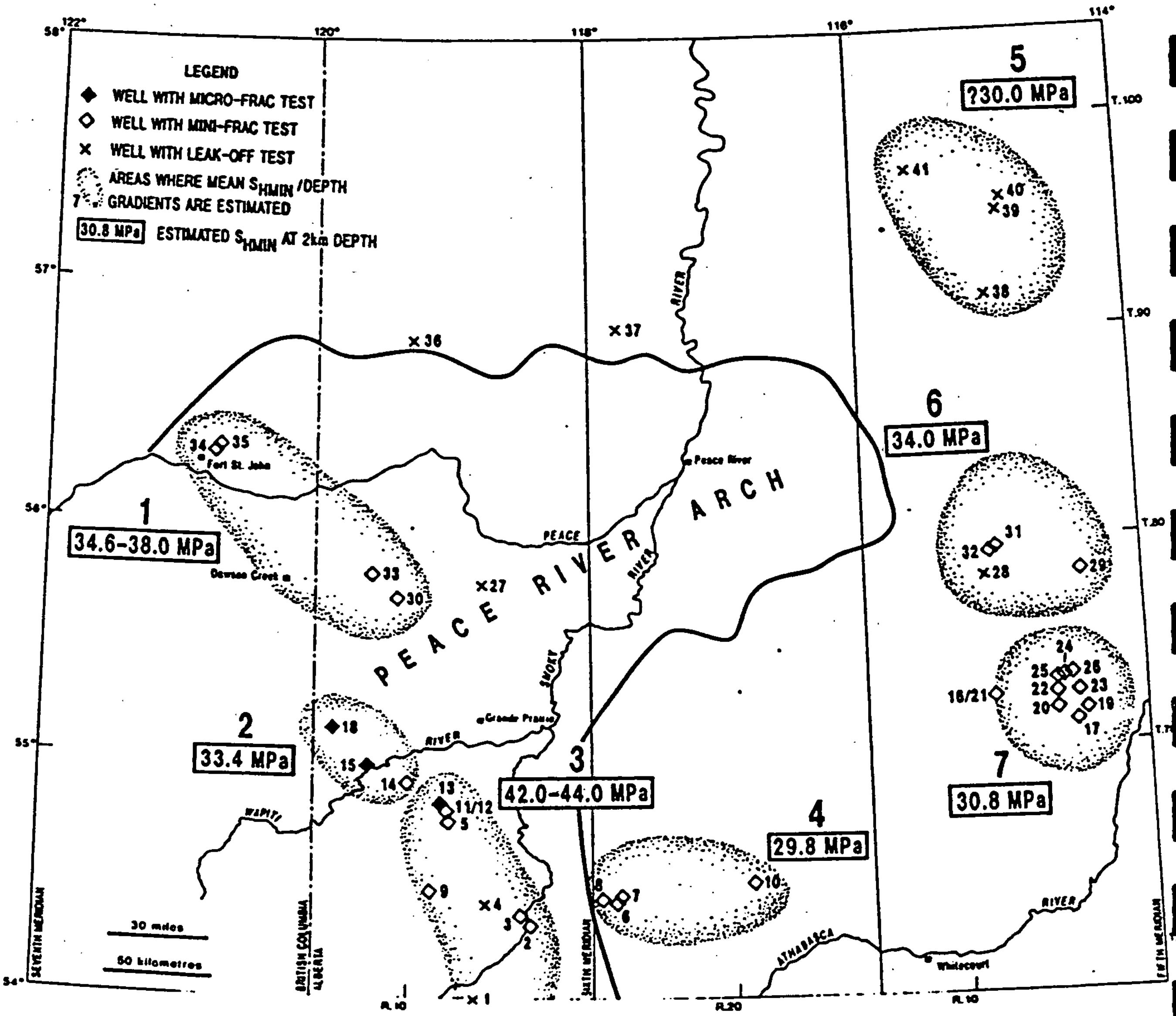
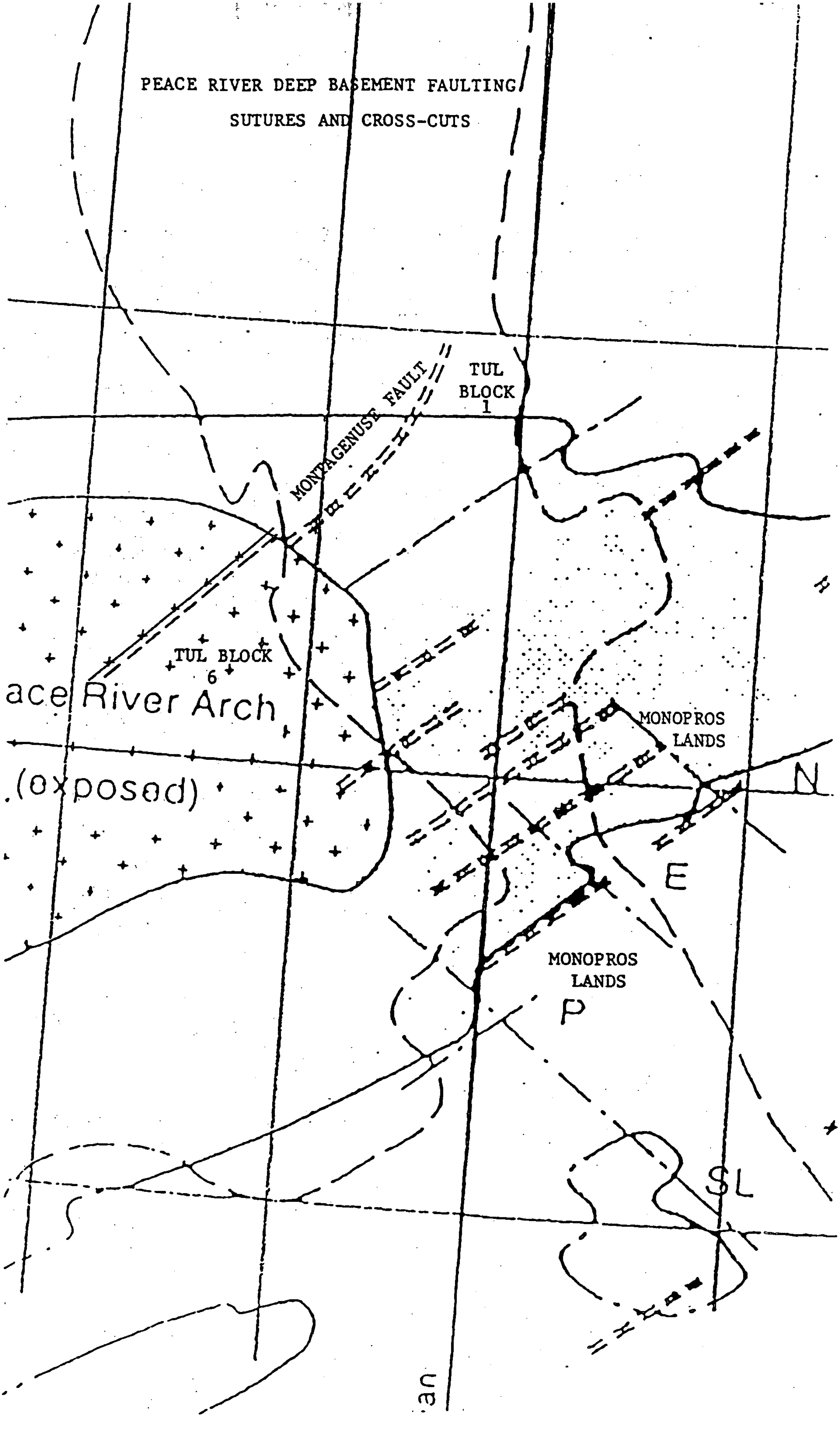


Fig. 4. Location of wells in the Peace River Arch area for which S_{Hmin} magnitude data are available. The wells have been assigned to sev areal groupings for estimating mean S_{Hmin}/depth gradients.

PEACE RIVER DEEP BASEMENT FAULTING
SUTURES AND CROSS-CUTS



4.7 THE PEACE RIVER ARCH ANTICLINE

The map on the next page shows the western Canadian Craton and Archean Sub-Cratons.

The Peace River Arch straddles the Ksituan Magmatic Arc, the subducted Chinchaga sub-craton and the archean Buffalo Head Sub-craton.

The dividing lines between the sub-cratons are the suture zones; zones of crustal weakness.

Diamonds have been discovered at Yamba Lake and at Lac Des Arch; three hundred and two hundred miles north of Yellowknife, N.W.T., respectively. These are some of the world's richest diamond pipes. They lie within the Slave archean sub-craton, along the faulting system shown on the map. The Slave Sub-Craton appears to have undergone a turning motion - like the Buffalo Head Sub-Craton and the Peace River Arch region.

The Buffalo Head has a number of north/south fractures or sub-sutures not displayed on the map. The TUL lands strattle the Peace River Arch and the three underlaying sub-cratons and are situated on and around the most significant northeast/southwest trending fault in the region.

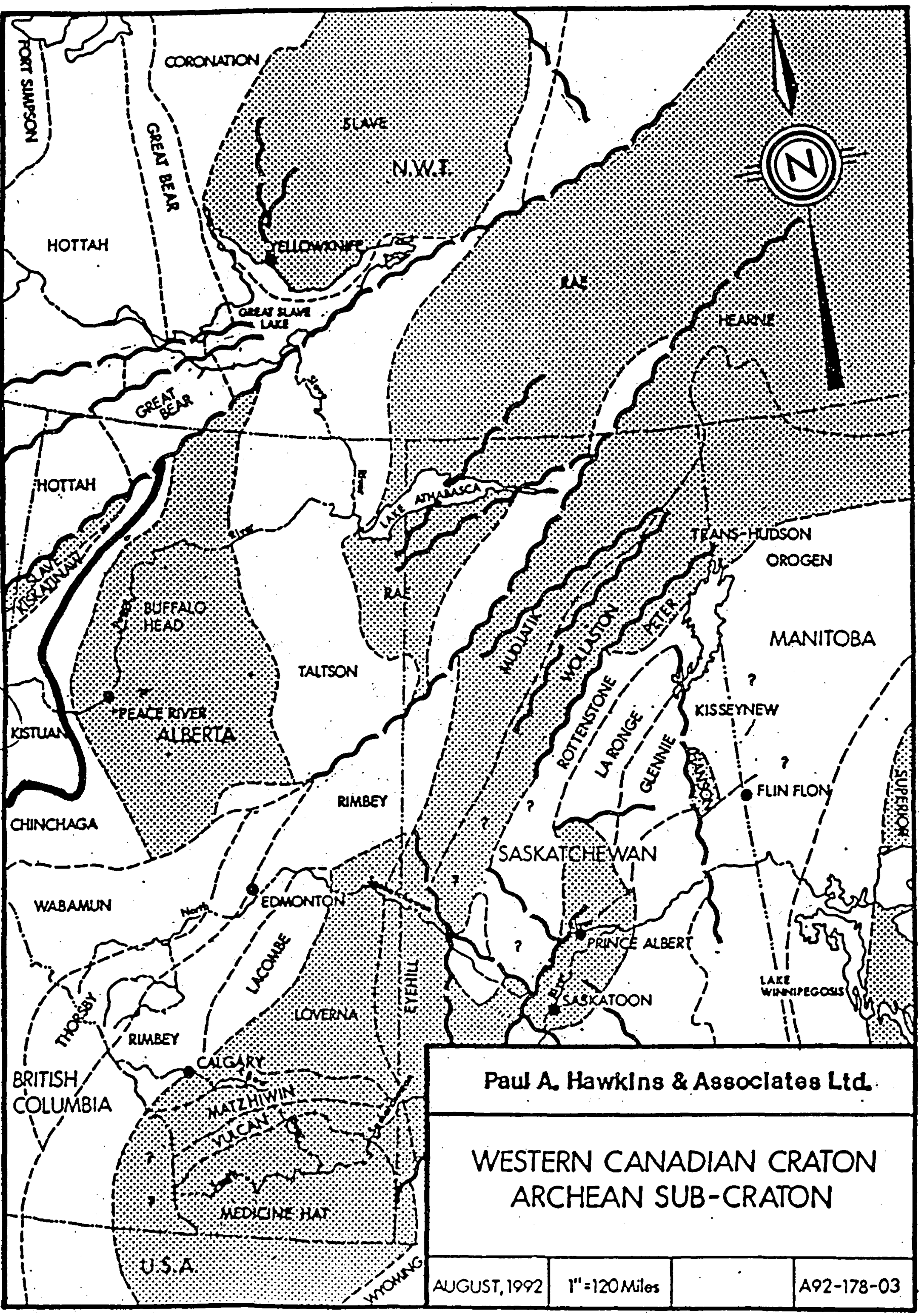
Monopros' diamond play is similar in that they have a regionally weak section of the Precambrian basement. They have additional northwest/southeast intersecting faults, as do the TUL lands.

There is a comparison to be made between the Slave Sub-craton pipes and Peace River geology.

Lithoprobe, Alberta Basement Transects has done recent work and is presently planning a program to study the Peace River Area basement. To date, their studies have been helpfull in allowing us to speculate about the subduction of the Chinchaga and model it.

The Ksituan/Chinchaga suture zone and the subduction of the Chinchaga are important pieces to a puzzle that explains the existence of three magnetic anomalies on the TUL lands near the Ksituan Embayment.

Ks



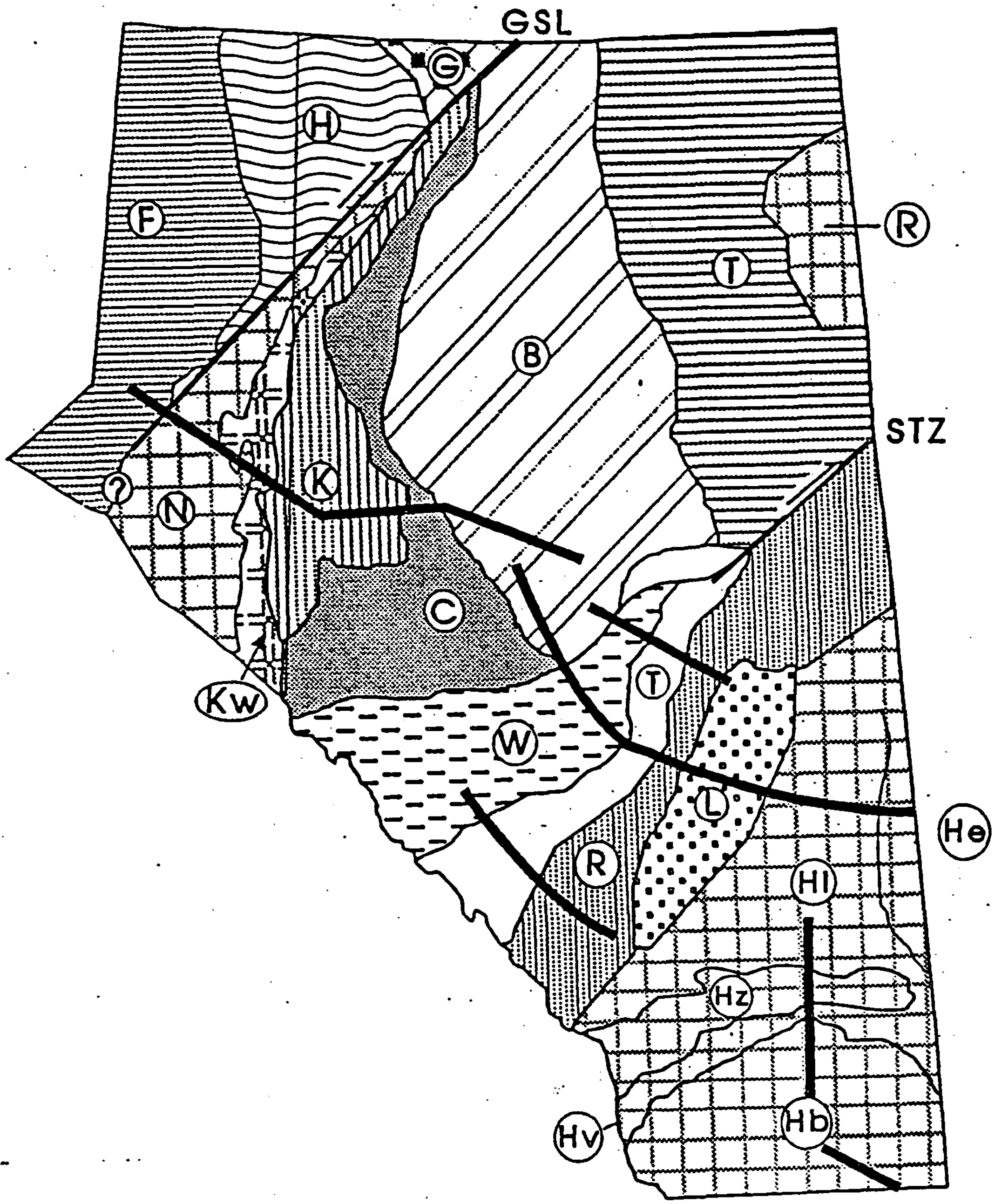
Paul A. Hawkins & Associates Ltd.

WESTERN CANADIAN CRATON
ARCHEAN SUB-CRATON

AUGUST, 1992	1" = 120 Miles		A92-178-03

LITHOPROBE

ALBERTA BASEMENT TRANSECTS



REPORT OF TRANSECT WORKSHOP
MARCH 4-5, 1992
HUSKY OIL CONFERENCE CENTRE

BERTA BASEMENT TRANSECTS REPORT #28

been a point of detachment and underthrusting of mantle lithosphere. Alternatively, the ramp may only represent the transition from weaker to stronger lower crust (as discussed in the next section), or it may have been inherited from the rifted margin of western North American. We need to know the provenance of the lower crust beneath the Intermontane Terrane to distinguish among these possibilities.

Model 5: Lateral Change in Crustal Properties

Model 5 (Figure 11) shows how a lateral increase in the shear strength of the retroward mid-crustal detachment pins the toe of the model 2 (Figure 4) low angle critical wedge. Deformation is transferred to a new step-up shear zone which roots on the detachment at the point where the strength increases. Pinning reduces the velocities in the external retrowedge and increases the rate of shear thickening as the wedge builds between the pin point and the basal singularity.

Similar step-up shears zones will form wherever detachments are pinned and they result in the same transfer of deformation from one crustal level to another as the singularity driven step-up shear zones. It is not easy to distinguish which process is responsible for a given shear zone. In simple cases the mechanics of stress transfer requires the topography to be asymmetric above a velocity singularity because the sense of shear reverses at the singularity. For crust pushed against a pinned ramp or barrier the average topographic slope must be up throughout the distance from the pinning point to the source of the push because the sense of shear remains the same. Topography is not always diagnostic, however. For example, the thrust deformation on the Alpine fault in New Zealand may be pinned by Indo-Australian plate crust that is stronger than Pacific plate crust (Beaumont *et al.*, 1992). The Grenville Front and Monashee ramp may also have been pinned.

Model 6: Compression of a Multilayer Crust and the Response to Erosion

Model 6 (Figure 12) shows four stages of the growth when the model crust has three layers. The upper 20km and underlying 15km have laboratory based wet quartz and wet properties.

Figure 5: Model 3. Log$_{10}$ (Deviatoric strain rate) (grey tones, see scale bar) an instantaneous velocity distribution with respect to the velocity singularity (lines Model materials, temperature and growth are the same as model 2 (Figure 4) but t basal boundary condition has been modified proward of the singularity to force pa of the lower layer to detach and underthrust as though attached to the underlyi substrate. This process corresponds to subduction of the lower crust. Note th the velocity singularity is in the interior of the model and that the shear planes a similar to those of the prototype. The weak mid-crustal detachment again results the exterior low taper angle wedges but no lower crust is uplifted to upper crust levels.

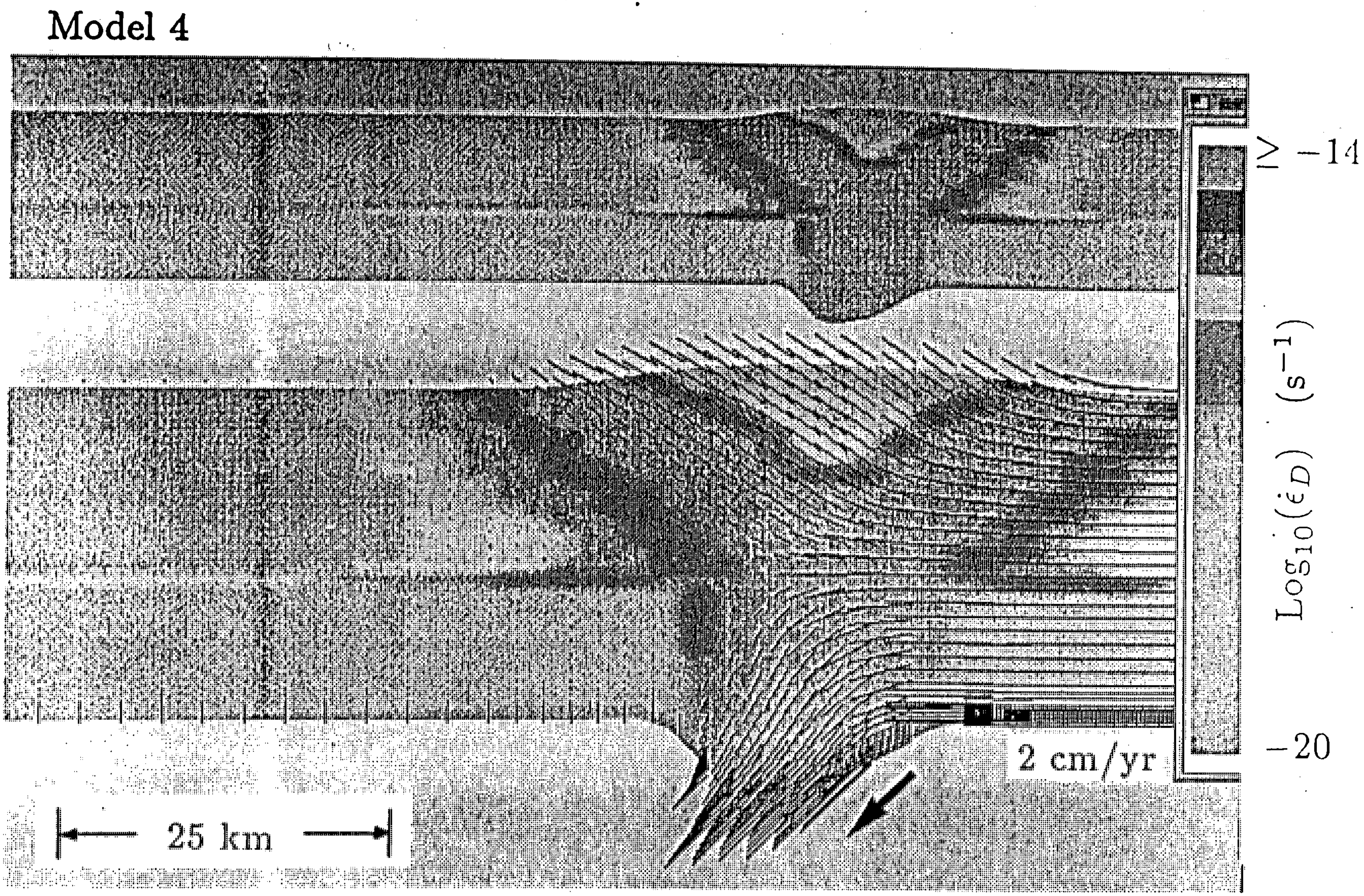
Figure 6: Model 4. Log$_{10}$ (Deviatoric strain rate) (grey tones, see scale bar) a instantaneous velocity distribution with respect to the velocity singularity (lin Model boundary conditions, growth and materials are the same as model 3 (Fig 5) but the temperature at the mid crust has been lowered to increase the sh strength of the mid-crustal detachment so that it is not significantly weaker than basal detachment. Step-up shear zones above the mid-crustal singularity are no smaller scale version of those of model 1 (Figure 3).

Figure 7: Velocity distributions for models 2 and 3 with low strength mid-crus detachments. Note the significant difference between 'step-up' and 'step-dow the lower crust.

Figure 8: Velocity distributions for models 1 and 4 with no significant mid-crustal w zone. Note how the width of the plug wedge can be used to estimate the approxi depth to the singularity when the model growth is small.

Figure 9: Crustal scale seismic reflection line drawings and interpretation from Grenville Province. a) and d) are GLIMPCE data (from Green *et al.*, 1988). panel shows the Grenville Front Tectonic Zone (GFTZ) and bottom panel shows w is interpreted by us to be the seismic character of the Superior Province crust b

Fig 6



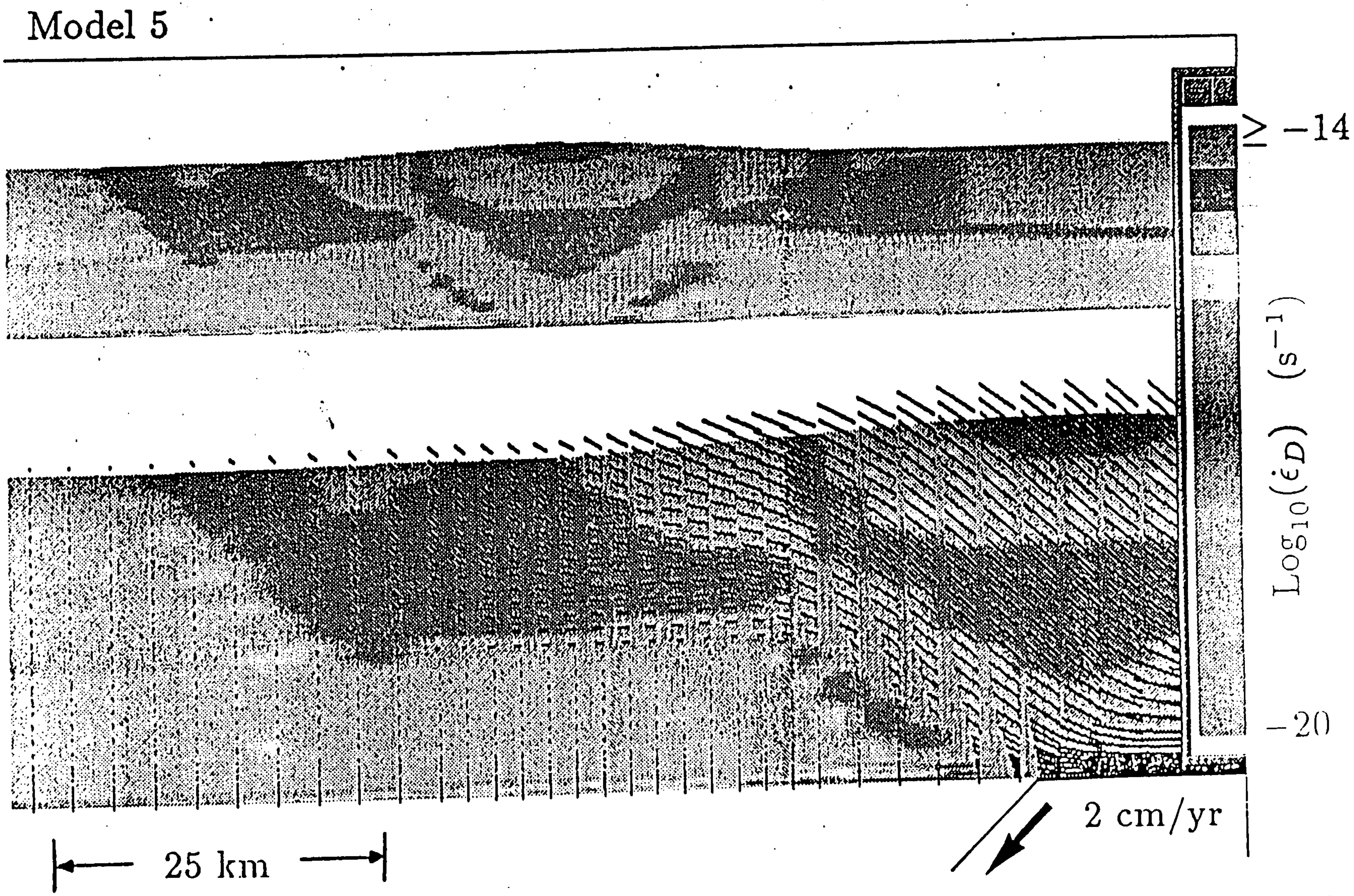


Fig 11

4.8 THE PHANEROZOIC

The Early Phanerozoic is the succession of marine limestones, mudstones and shales that lay over the Precambrian granitic basement. Discontinuities can be seen in a cross-section of the Phanerozoic at the sub-craton suture zones.

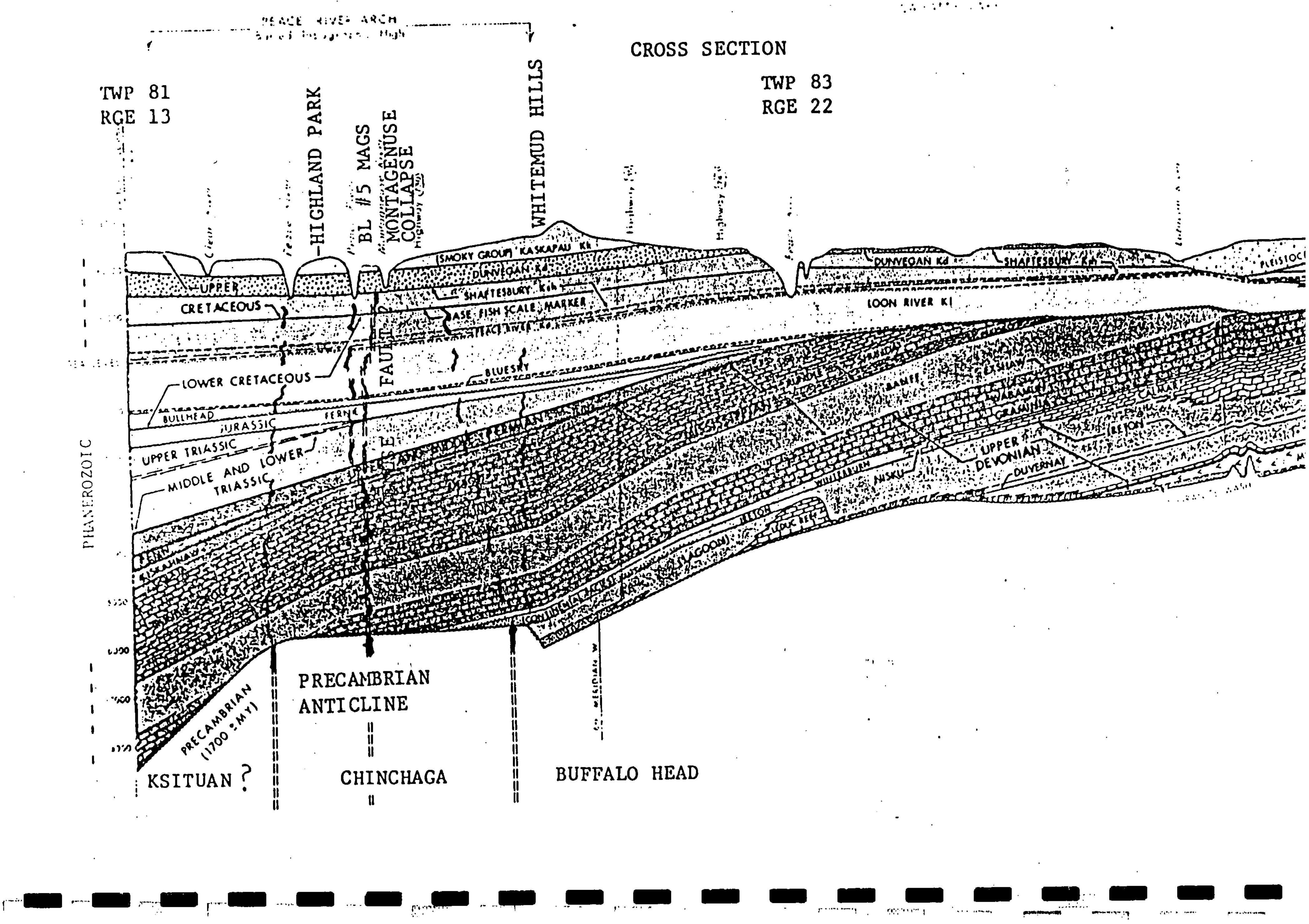
Oil and gas drilling has delineated many faults and faulting systems that exist in the Phanerozoic in the Peace River Arch area. The business of the basement is not just erosinal topography,it is a result of massive movements and, in some cases, probably intrusions.

For the TUL PEACE DIAMOND PROJECT, the location, shape, direction and distance of propagation is important to our interpretation. These faults are the conduits for kimberlite and lamproite emplacement.

Early Phanerozoic sediments responded to known movements of the Peace River Arch. As the Precambrian land mass rose, granitic sediments eroded from the land mass and were deposited as the Granite Wash. Reefs grew up around the continental Devonian Peace River Arch. Early Phanerozoic deposition responded to the collapse of the arch in the southwest by filling developing grabens with sediments. Therefore, the Phanerozic masks some of the dynamics of the arch. Dated sedimentary layers make dating of faults possible, as they propagate from basement through Phanerozoic layers.

We are also extrapolating information about known faults in the basement to predict where we should look for faulting in the Phanerozoic and especially the Cretaceous, where we expect to discover Late Cretaceous to early Tertiary pipes.

Our maps of faults and faulting systems has been found to be accurate, according to our observations, sitting oil and gas drill rigs, and according to airphoto interpretation and field work.


PEACE RIVER ARCH
CROSS SECTION
TWP 81
RGE 13
TWP 83
RGE 22
HIGHLAND PARK
BL #5 MAGS
MONTAGENUSE COLLAPSE
WHITEMUD HILLS
SMOKY GROUP KASKAPAU Kk
DUNVEGAN Kd
SHAFTESBURY Ksh
BASE FISH SCALE MARKER
PEACE RIVER Kp
LOON RIVER Kl
PLEISTOC
UPPER
CRETACEOUS
LOWER CRETACEOUS
FAULT ?
BLUESKY
BULLHEAD
JURASSIC
FERNIE
UPPER TRIASSIC
MIDDLE AND LOWER TRIASSIC
PERMIAN
BANFF
EXSHAW
WABAMUN
GRAMINIA
CALMAR
IRETON
UPPER DEVONIAN
DUVERNAY
NISKU
LEDUC REEF
LAGOON
CONTINENTAL CLASTICS
PHANEROZOIC
PRECAMBRIAN (1700 ± MY)
PRECAMBRIAN ANTICLINE
KSITUAN ?
CHINCHAGA
BUFFALO HEAD

4.9 QUARTERNARY/PLEISTOCENE GEOLOGY

Most of Alberta is a glacial landscape. The northern third of the Province has not been mapped in any detail, either by the provincial government or by the federal government.

The surficial landscape of Alberta is made up of a series of till sheets and glacial landforms overlaying eroded bedrock.

Continental glaciers a thousand feet thick advanced from the Baffin Island region and scoured the bedrocks mainly in a southeasterly direction. The western margin of ice advance is thought to be a line from Pincher Creek to Grande Prairie.

Alpine glaciers advanced from the west and the Rocky Mountains as valley ice trains. Between these two opposing ice advances there is thought to be an area called the ice free corridor. That is, there may have been a region just east of the Rockies which was not greatly glaciated and may have been clear of ice during much of the Pleistocene; at least a million years.

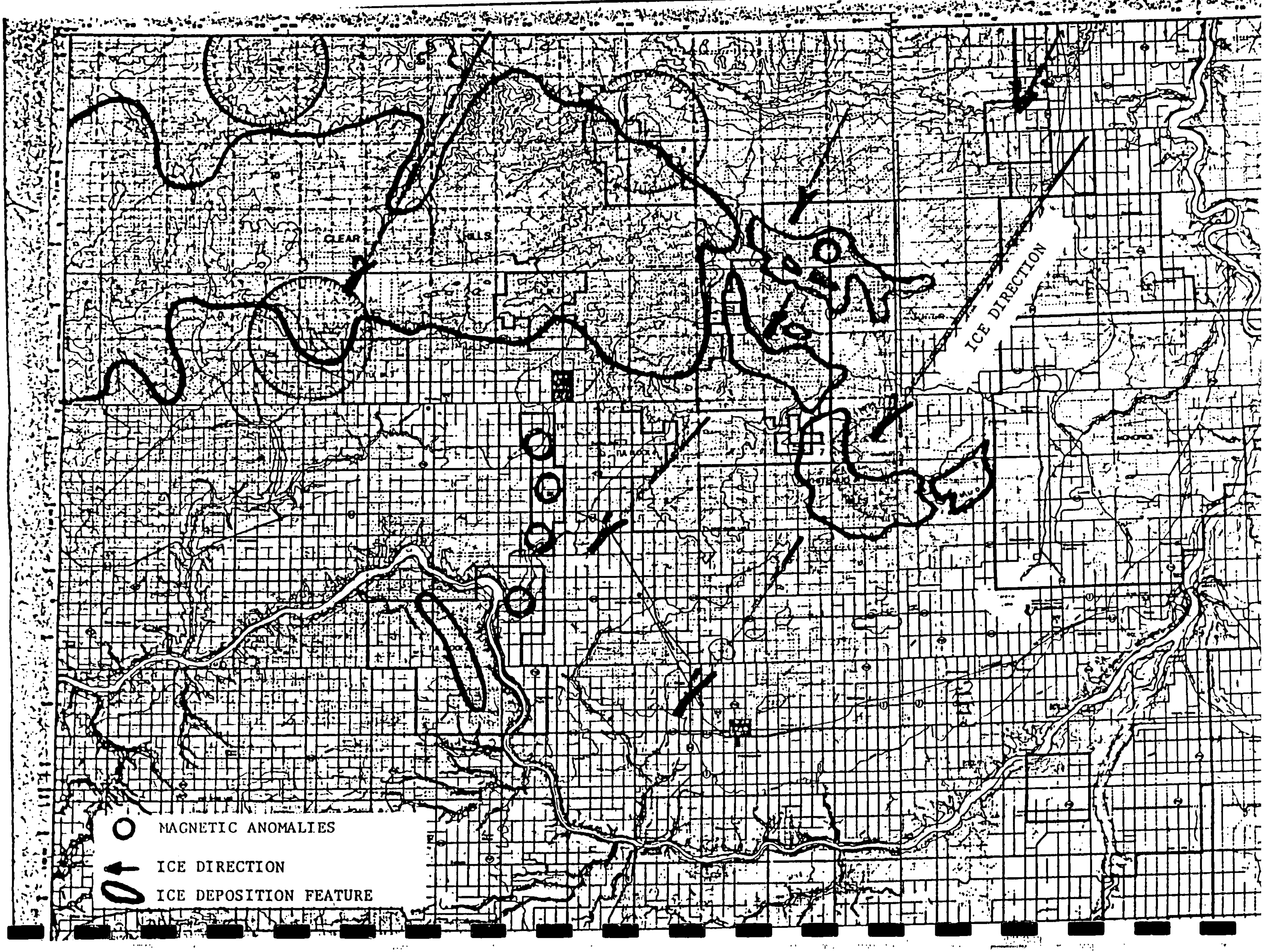
Glaciers moved massive amounts of materials. They are driven by gravity. At their base is a plastic zone that is impregnated with debris,which acts like sandpaper to scour and gather more material. The shear weight of glacial ice was responsible for much of the effect that glaciation had on the landscape.

Northeastern Alberta has been eroded all the way down to the lower Phanerozoic at Fort McMurray and even to the Precambrian at Lake Athabasca. Lake Athabasca now has an elevation of under a thousand feet.

South western Alberta has been eroded much less than the rest of the Province. Late Cretaceous sandstones such as the Paskapoo remain. This formation lays at an elevation of over three thousand feet around Calgary.

Some upland areas of the province have hardly been glaciated at all. The Porcupine Hills in the southwest, the Hand Hills near Hanna, the Cypress Hills in the south and probably the Clear Hills have been spared much glacial erosion. They remain at a height of up to 3500 feet. The Wapiti bedrock is late Cretaceous.

The western landscapes of Alberta, due to the modifying effect of glaciation, are said to be much the same as they were preglacially, except that the general topography is smoother, after levelling of higher landforms and the filling of the lower valley terrains.


CLEAR
HILLS
ICE DIRECTION
MAGNETIC ANOMALIES
ICE DIRECTION
ICE DEPOSITION FEATURE

Many of the river valleys that now exist have been filled with glacial materials and re-eroded in the same place. The Peace River District contains several thalwegs, preglacial channels which were filled with material, but were not re-eroded out and remain as hidden subsurface channels.

The glaciated regions of the Province, about ninety percent of the Province, exhibit numerous glacial landforms, characterized as third order relief features: 1. kettle and moraine covered plateaus and peneplains; moraines, kettles, eskers; hummocky moraine regions; prairie mounds and crevasse fillings; 2. string fens, fen and bog plateaus; 3. ice thrust ridges; 4.drumlinesque, ice flow ridge and striated topography; 5. glaciofluvial; spillway coulees, outwash plains, kame terraces, glacial deltas and lacustrine basins. And the river valleys which were filled with glacial debris and which have not been re-eroded to form river and stream channels, the thalwegs.

The Quarternary geology of the Peace River District is important to the TUL Joint Venture fieldwork. Soil, stream and down-hole sample locations are picked with history and landscape modification in mind. When a discovery of a diamond or diamond indicators is made, we need to be able to relate that sample to a proximal source. Following a glacial dispersal train is a big job, but it paid off in the Lac De Gras, N.W.T. diamondiferous kimberlite discoveries.

For the Clear Hills, there is little published information available and no high quality maps.

For Peace River, there is work being carried out by the Alberta Research Council.

For the west Peace River Lowlands there is limited information available.

A lot more Quarternary work has to be done for the region and more particularily for the TUL lands. Unfortunately, Quarternary work is time consuming and expensive. We will limit our Quarternary mapping and interpretation to LanSat and air photo work until more detailed mapping is required. Our Quarternary work will probably begin with the investigation of the numerous gravel pits scattered around the Peace River District.

4.10 SURFICIAL EXPRESSION OF UNDERLAYING STRUCTURE

Our geological mapping comes from a number of sources; E.R.C.B. maps, G.S.C. published reports and from work done by our consulting geologist.

Our maps show known faults delineated by oil and gas drilling and suspected faults taken from LandSat and air photo mosaics.

In diamond exploration, the geologist looks for faults, linear weaknesses in the crust that can be conduits for diamond emplacement and for evidence of intrusives themselves.

The cheapest and easiest way to identify targets for exploration is by doing air photo interpretation. The second way to identify targets is to observe faults and pipe features on the ground. If all goes well, diamond indicators will be found at these locations and magnetic surveys will direct drilling to diamond bearing host pipes.

We have been successful in confirming that the fault mapping at Highland Park is accurate from experience sitting an oil drilling rig on that property.

We have confirmed the "Montagenuse Fault" location and the transform region to our own satisfaction,by surface observation in the field. We have studied the massive Montagenuse Collapse at the transform location.

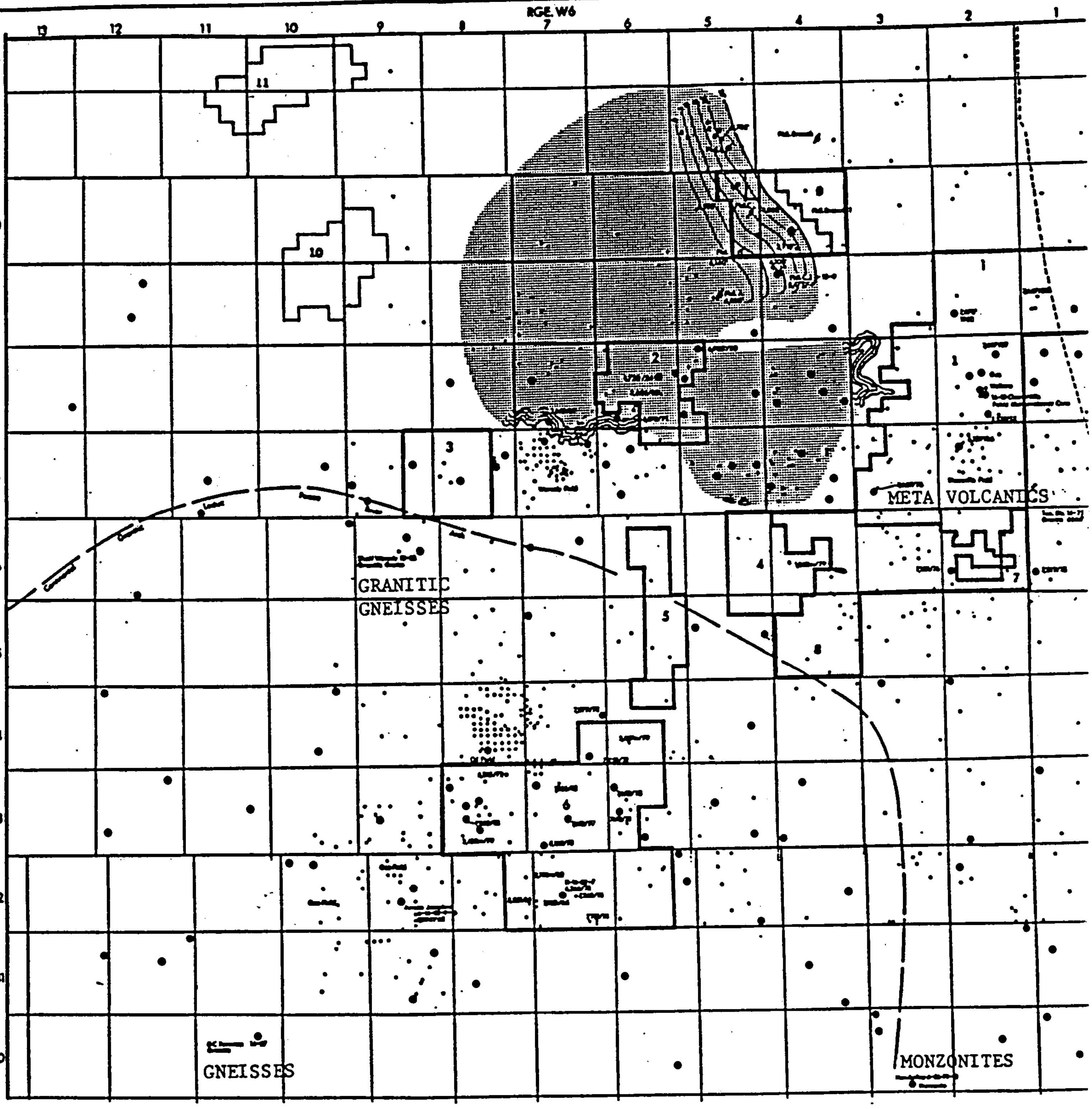
We have observed from LandSat, a number of pipe features on the Monopros and Larken properties at Peace River.

We have plotted the Block 5 magnetic anomalies and we have observed by airplane and ground search that there are circular surficial features at one location, Mag Target #2 and near a second location, Mag Target #1.

The Lone Star magnetic anomaly drew us to conduct three field trips to that property. There are a number of surficial features that could be related to intrusives.

There are also so many siesmic cut lines accross the prospect together with two dry and abandoned oil drilling locations, that oil companies have obviously seen sturcture in that one square mile area. The known faults associated with the Lone Star Graben Complex can be seen as subtle valleys and drainage linaments crossing the property. It is common knowledge among sedimentary geologists that faults can be observed in the surficial patterns of central northwest Alberta.

Even deep basements faults can sometimes be seen in surficial patterns. The evidence is stacking up to say that intrusive pipes exist, that they intrude the sedimentary layers that are now bedrock at Peace River and that these structures may be observable as surficial features veilled by glacial tills.

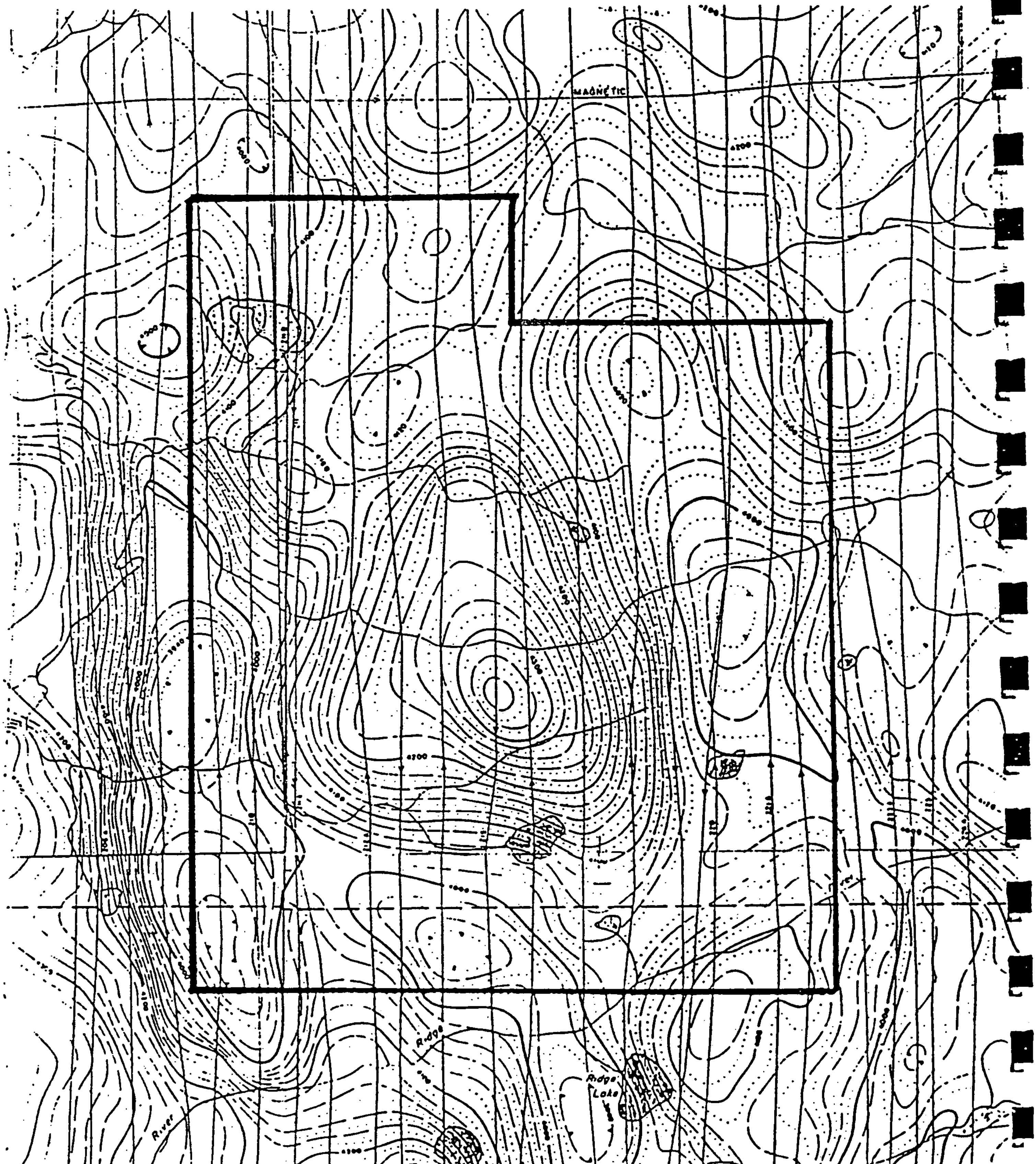


- MAJOR IRON ORE DEPOSITS
- ● EXPLORATORY HOLES DRILLED TO THE PRECAMBRIAN
- • OIL OR GAS EXPLORATION HOLES
- • ORE DELINEATION CORE HOLES
- — IRON OUTCROPS
- — TLL LANDS
- ○ NEW LOCATIONS

DRILL CORE DATA MAP

FIGURE 1, DETAIL AREA B, TOTAL FIELD MAGNETOMETER SURVEY, SENSOR HEIGHT - 300 METRES, LINE SPACING - 800 METRES

FROM GEOLOGICAL SURVEY OF CANADA GEOPHYSICS PAPERS: 3937, 42J/5; 3938, 42J/12; 3960, 42J/6; AND 3961, 42J/11



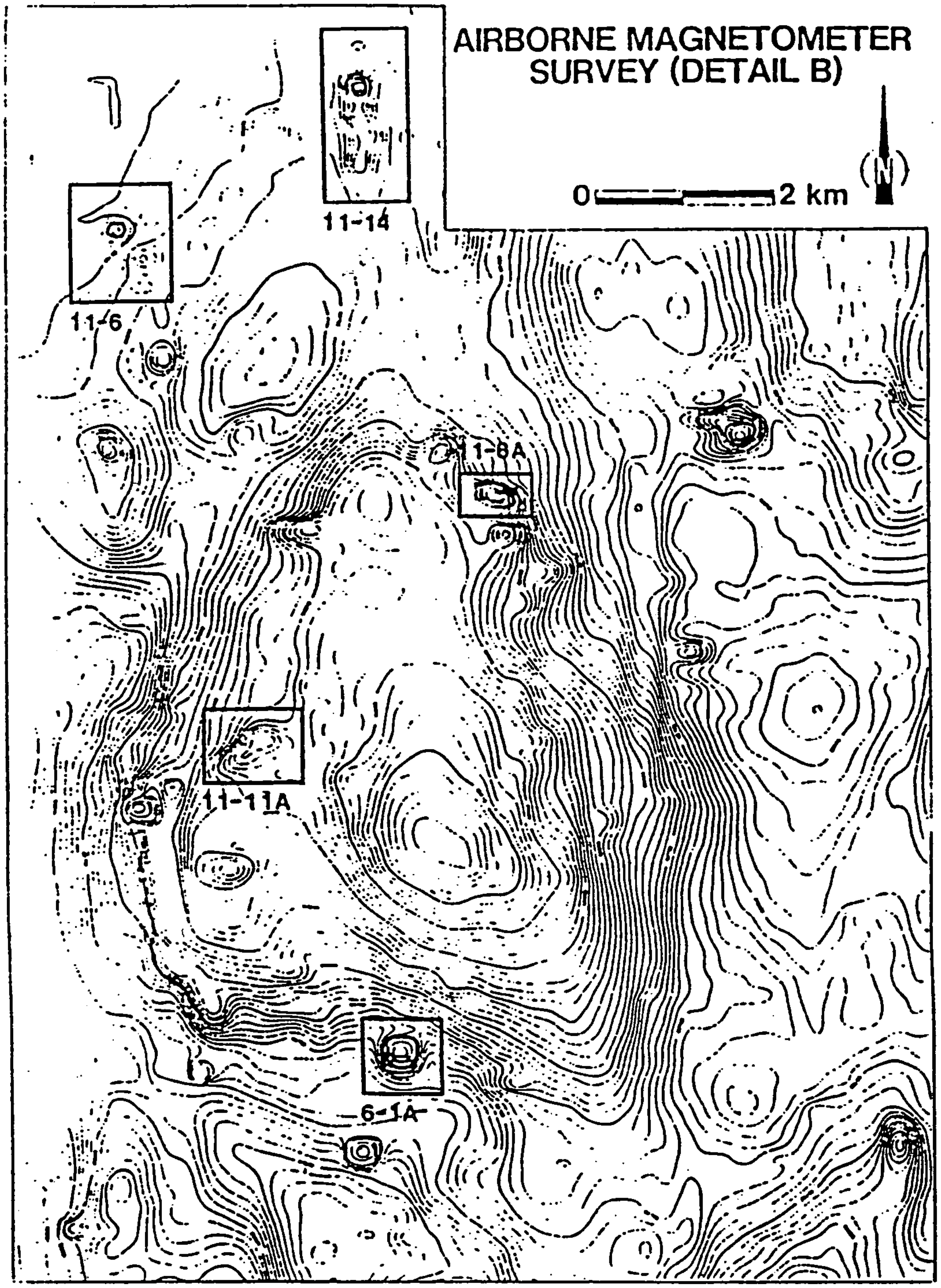


FIGURE 2, HIGH RESOLUTION TOTAL FIELD MAGNETOMETER SURVEY
SENSOR HEIGHT - 60 METRES, LINE SPACING - 250 METRES

FROM REED AND SINCLAIR, THE SEARCH FOR KIMBERLITE IN THE JAMES B LOWLANDS OF ONTARIO. THERE IS A MAJOR INCREASE IN THE RESOLUTION THE MAGNETIC FIELD FROM FIGURE 1 (THE REGIONAL SURVEY), AND TH DETAIL SURVEY. THIS IS ACCOMPLISHED BOTH BY FLYING CLOSER TO T GROUND AND ESPECIALLY BY FLYING A SMALLER LINE SPACING.

AT LEAST 25 MAGNETIC BODIES RESIDING ABOVE BASEMENT, CAN BE SEEN I THIS AREA OF ABOUT 150 SQUARE KILOMETRES.

GEOPHYSICAL

8.1 AERO MAGNETIC SURVEYS

Aero magnetic surveys have met with success as an exploration tool for finding kimberlite pipes. There are numerous reports and papers on the subject.

The Government of Canada Energy, Mines and Resources Aero Magnetic Maps are usefull. They have been flown at about 1,500 feet AGL and are on a one mile flight line spacing. We have successfully used these aero mag maps in picking areas for soil testing.

At Highland Park, we recovered Clinopyroxenes from rat-hole samples near a magnetic anomaly.

At Lone Star, we recovered good garnet populations near our aero magnetic target.

At Montagenuse - Block #5, we identified a surficial feature which corresponds to the location of magnetic target M-2.

It is well known that aero magnetic surveys can help to close in on targets especially if they are flow at low level and close spacing.

The cost of airplane aero magnetic surveys is between $ 9.00 and $ 15.00 per kilometer.

8.2 VERY LOW FREQUENCY

VERY LOW FREQUENCY receiving equipment records data when VLF wave generators in the United States, used for submarine navigation, energize an ore body in the earth's crust.

The VLF receivers are of some use in identifying kimberlites, but we have not tried this method at Peace River yet.

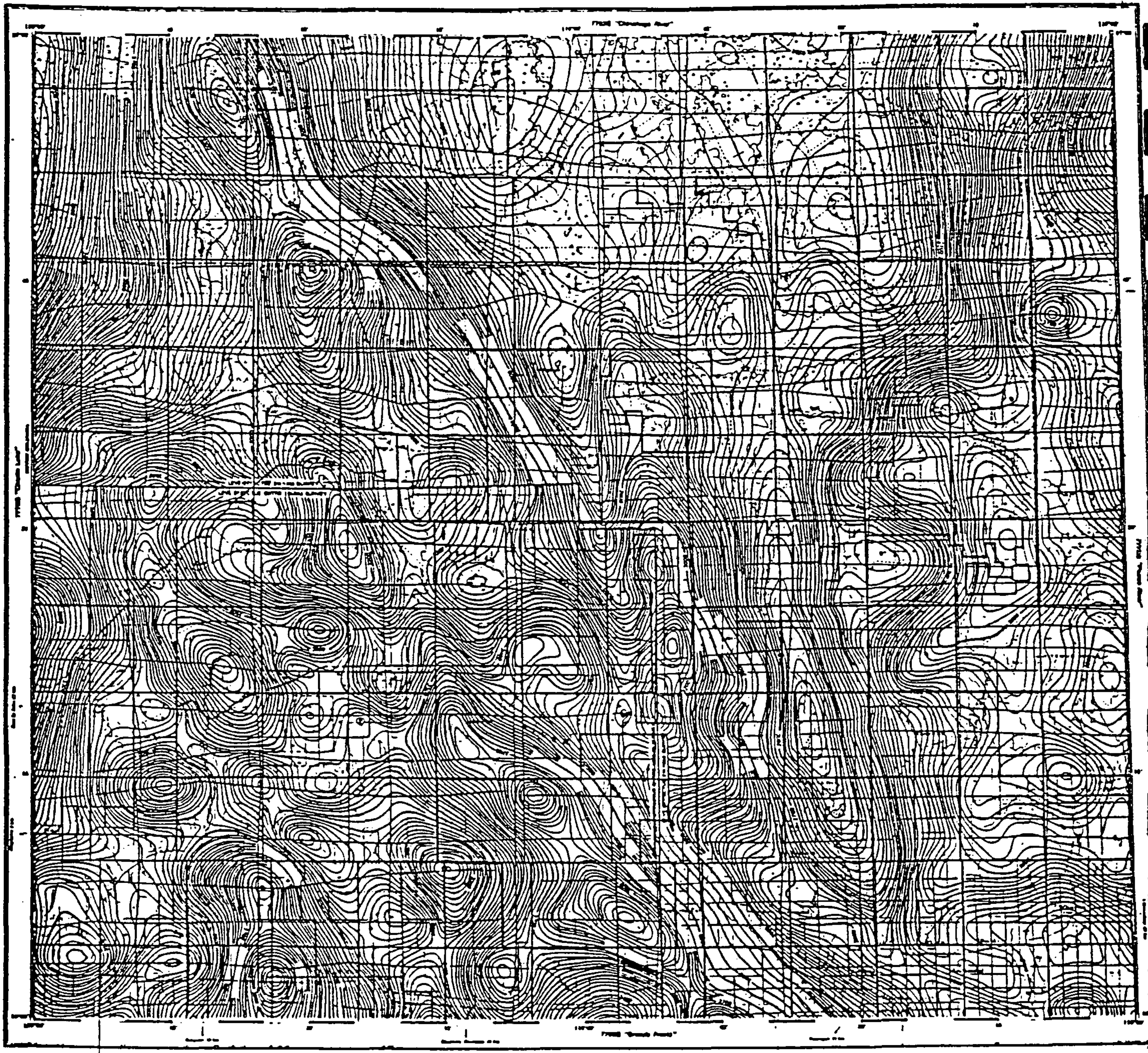
8.3 GRAVITY SURVEYS

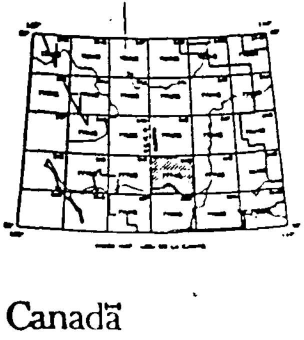
Gravity measuring devices gather data on the relative gavitational field of a prospect. Gravity surveys are useful in searching for kimberlites, but we have not tried it yet.

Energy, Mines and Resources Canada / Énergie, Mines et Ressources Canada

GEOPHYSICAL SERIES (AEROMAGNETIC)
SÉRIE DES CARTES GÉOPHYSIQUES (AÉROMAGNÉTIQUES)

Geological Survey of Canada / Commission géologique du Canada





MAP-CARTE
7774G

CLEAR HILLS

ALBERTA

Scale 1:250 000 - Échelle 1/250 000

KILOMETRES 5 2.5 0 5 10 15 KILOMETRES

TUL PETROLEUMS LTD.

AERO MAGNETIC TARGETS MAP

	1:250,000		Map # 4-1

—— TUL HEAVY METAL PERMITS

Canada

8.4 GROUND MAGNETIC SURVEYS

Ground magnetic surveys are similar to aero magnetic surveys. Ground mag equipment is more versitile and cheaper, than aero mag equipment and flying a survey.

We have lease/purchased a SCINTREX ENVI-MAG Magnetometer and Gradiometer.

Ground tests of this equipment at Lone Star confirm that it is versitile, light and easy to operate, and is good for doing quick checks and tests of new ground to be explored.

With the Scintrex, we have field test proven the Energy, Mines and Resources Canada, Geophysical Series (Aeromagnetic) maps for Montagenuse and Lone Star. They are reliable, but not very detailed.

Use of magnetic surveys have proven to be successfull in locating kimberlite pipes. About half of kimberlite mineral emplacements are magnetic enough to be located with this methodology.

Kimberlites are often iron rich. Weathering of the iron minerals are probably responsible for the colour of the "Yellow Ground" associated with diamonds in South Africa. This strata is probably less magnetic than the unweathered strata below, the "Blue Ground," found deeper in the kimberlitic diatreme.

Lamproites are a different mineral, but are emplaced in a similar way to kimberlites. Since their iron content is usually less than kimberlites and their geometry is usually different, more dispered, aeromagentic work is less usefull for finding lamproites. This seems to be proving the case at the Lower Montagenuse Prospect.

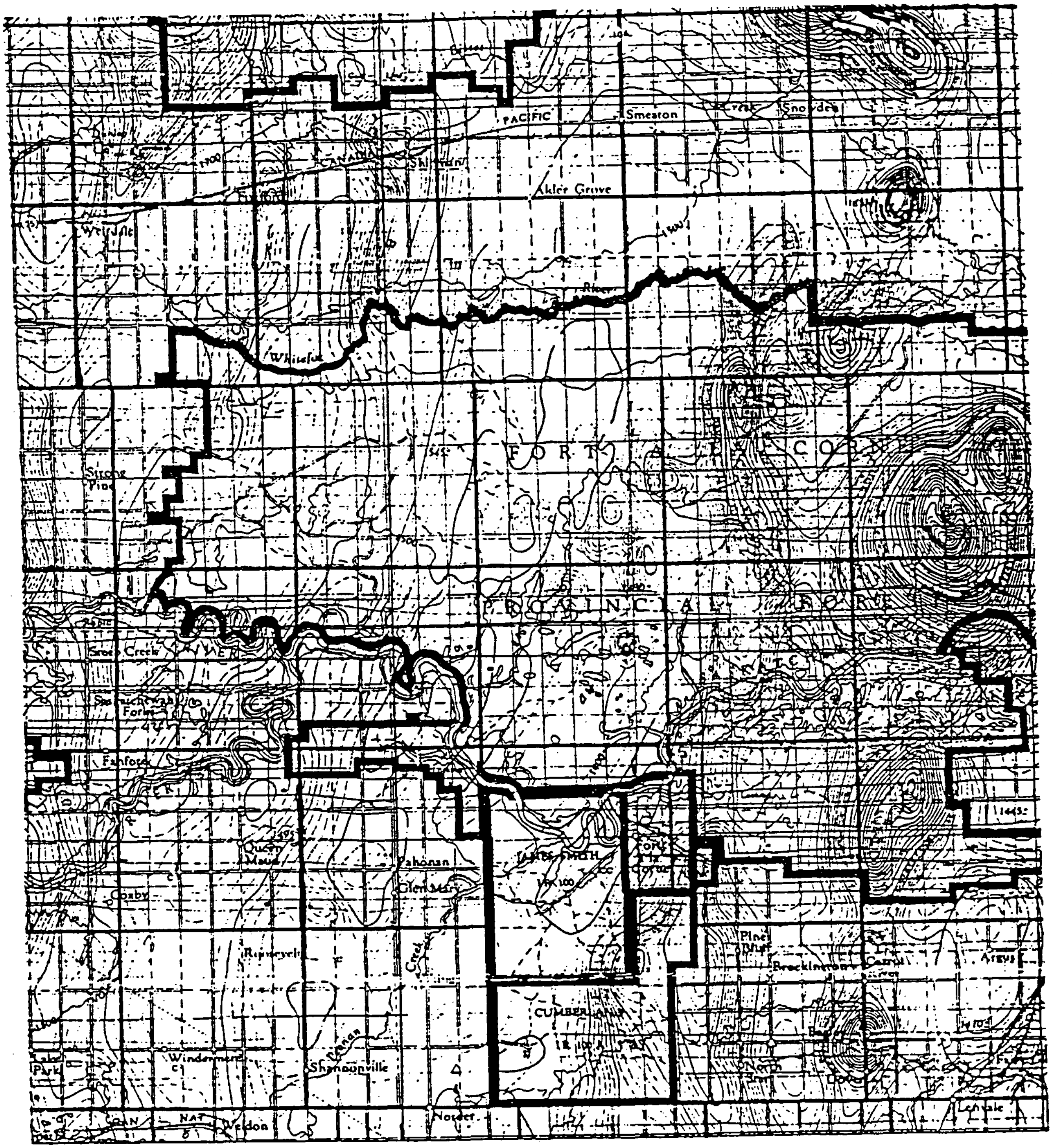
The magnetic signature of a magnetometer reacting to a kimberlitic intrusion should be like the "Bulls-eye" we see at Lone Star on a magnetic contour map.

(Note the Lone Star magnetic contour map)

The FORT A LA CORNE kimberlites are proving to be diamondiferous and do have the "bulls-eye" signiture.

(See FORT A LA CORNE magnetic contour map)

MAGNETIC SURVEY IN FORT A LA CORNE AREA



8.5 SIESMIC SURVEYS

Saskatchewan Energy and Mines and the Saskatchewan Geological Survey Open File Report 92-2 "Diamonds and Precious Gems of the Phanerzoic Basin, Saskatchewan: Preliminary Investigations by M.R. Gent describes an example where siesmic, shot by oil companies exploring for oil and gas in Southern Saskatchewan, found the diatreme now known as the "Maple Creek Intrisive."

Note the cross-section of the sedimentary layers from the Shaunavon to the Bearpaw on the next page. Also note the geometry of Belly River, Lea Park and Milk River after uplift and collapse.

Siesmic surveys over this diatreme,show that it is possible to see intrusives with siesmic.

Notice the evident uplifting of the reflectors in the left center of the following page and the disturbed areas above on either side.

On the Lone Star Prospect, oil companies have shot about twenty-five miles of siesmic over eight square miles of land. Two dry holes attest to the fact that they saw some kind of structure there, but they didn't find oil or gas.

Their objective was probably the Mississippian Debolt gas bearing formation, which is mapped by the Alberta E.R.C.B. on the Structure Contour of the top of the Paleozoic - Map Number Eleven.

Note on the next page, the Prospex plot of most of the siesmic lines available over the TUL Joint Venture lands.

Some of these siesmic lines should be purchased by the TUL Joint Venture and reprocessed. If the surface features on the prospect do indicate diatremes, then they may show on siesmic.

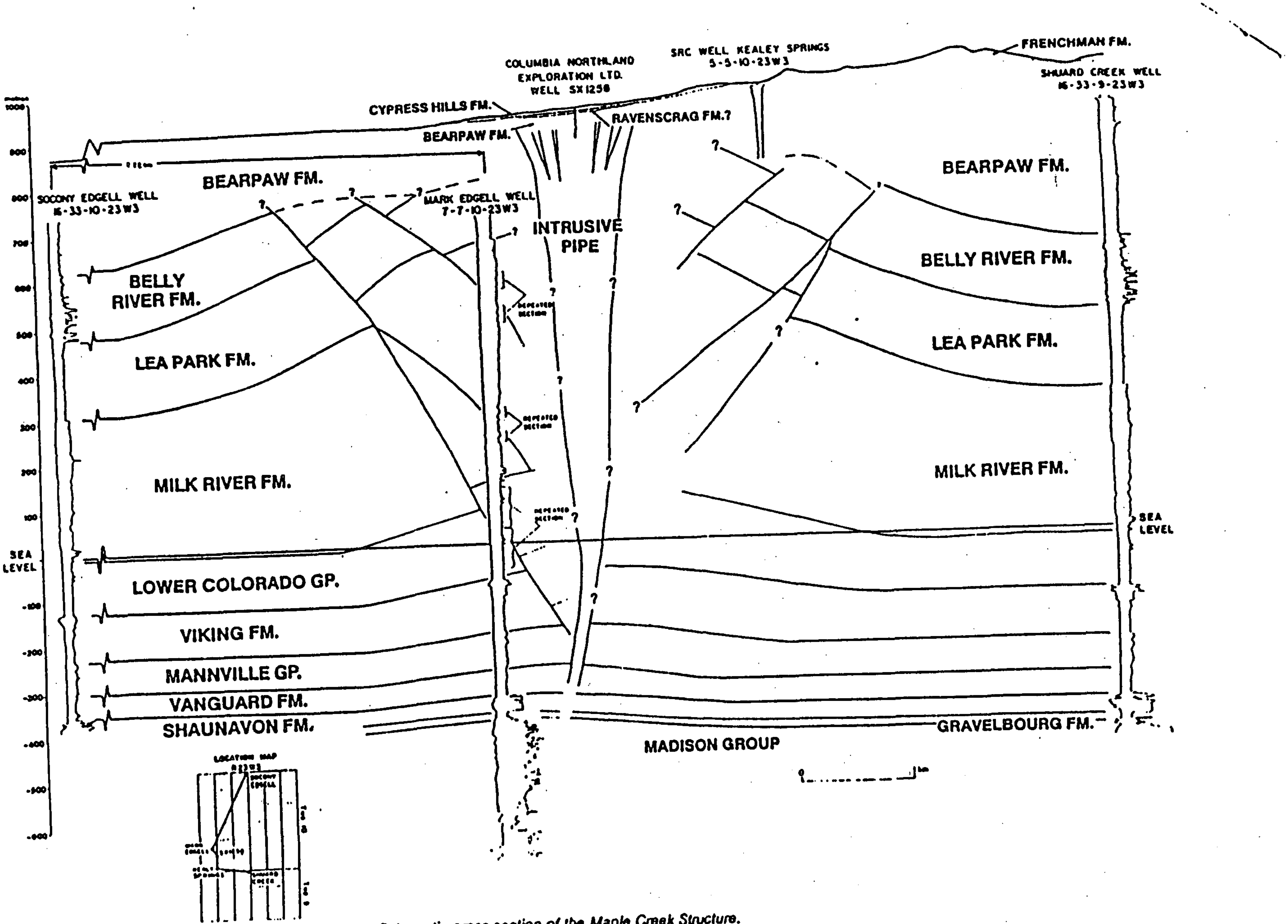


Figure 15 - Schematic cross-section of the Maple Creek Structure.

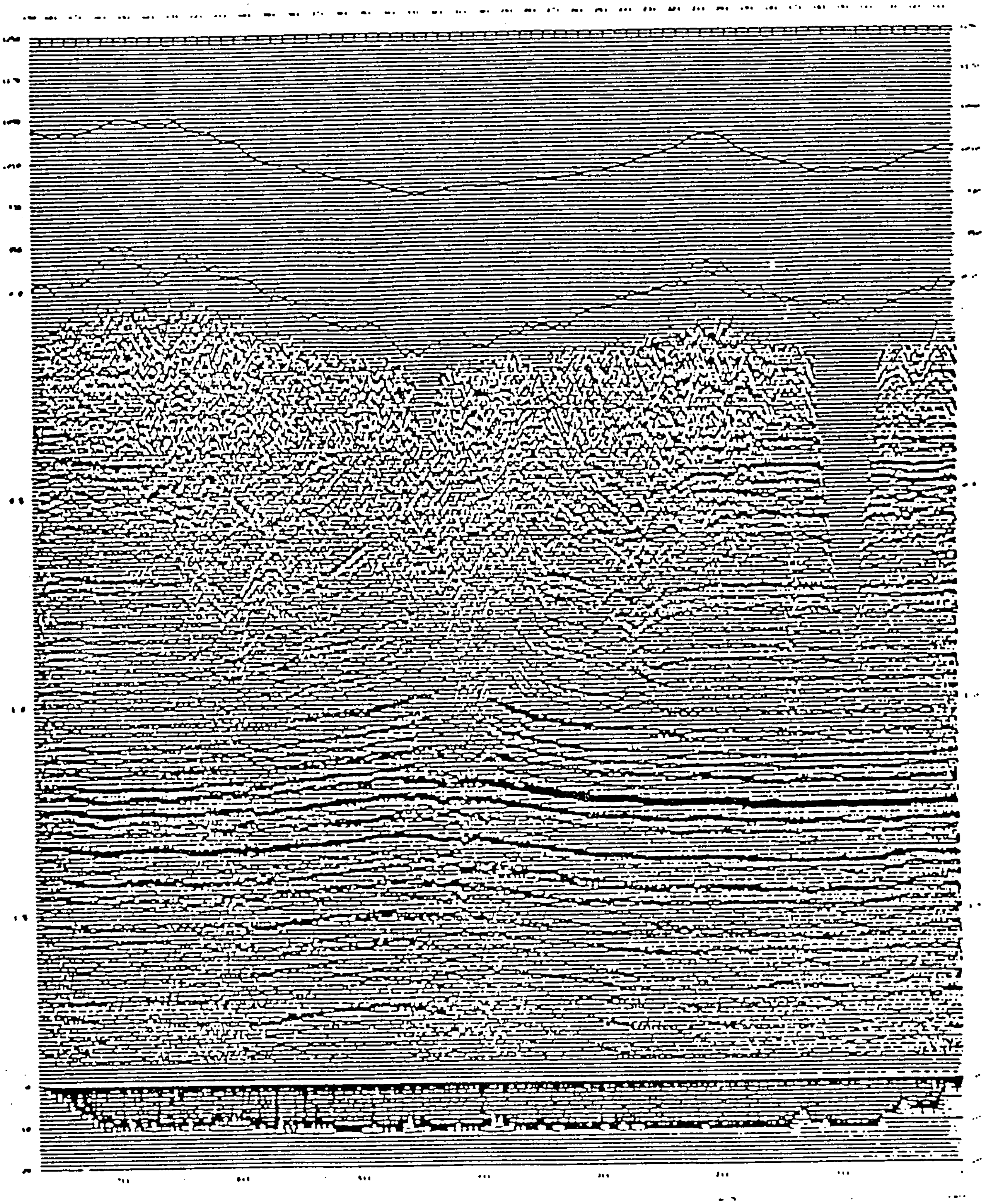
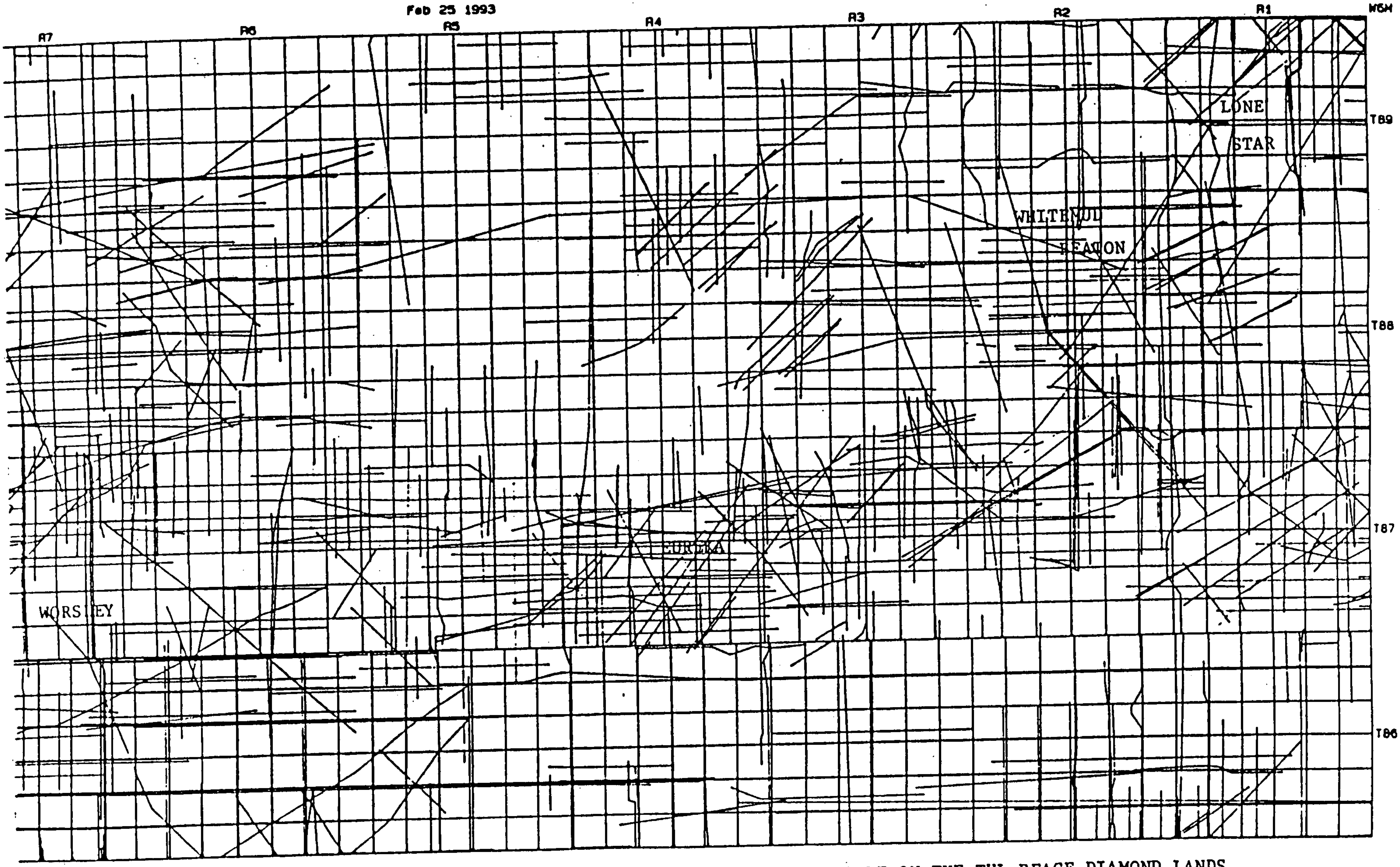


Figure 14 - Seismic section of the Maple Creek Structure (courtesy of Mark Resources Inc.).



COMPOSITE SIESMIC SURVEYS AVAILABLE ON THE TUL PEACE DIAMOND LANDS

[redacted] [redacted] [redacted] [redacted] 1: 12[redacted] Th[redacted] Trade[redacted] [redacted] Inc[redacted] 198[redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted]

9.0 DATA STACKING.

No one or two exploration methods consistently lead to the discovery of diamond pipes.

Finding diamond bearing pipes is a matter of mixing and matching data and refining techniques.

Using overlays and light tables, TUL has stacked up the data successfully. TUL prospects have been "built up" as conceptual models, using data stacking and from those, targets have been picked.

Computer mapping has the potential to make the mixing and matching of data easier statistically more analytical.

9.1 OIL AND GAS DRILLING

Oil and gas companies have drilled over twenty-five hundred holes on the Peace River Arch. A hundred or so holes have gone to the Precambrian.

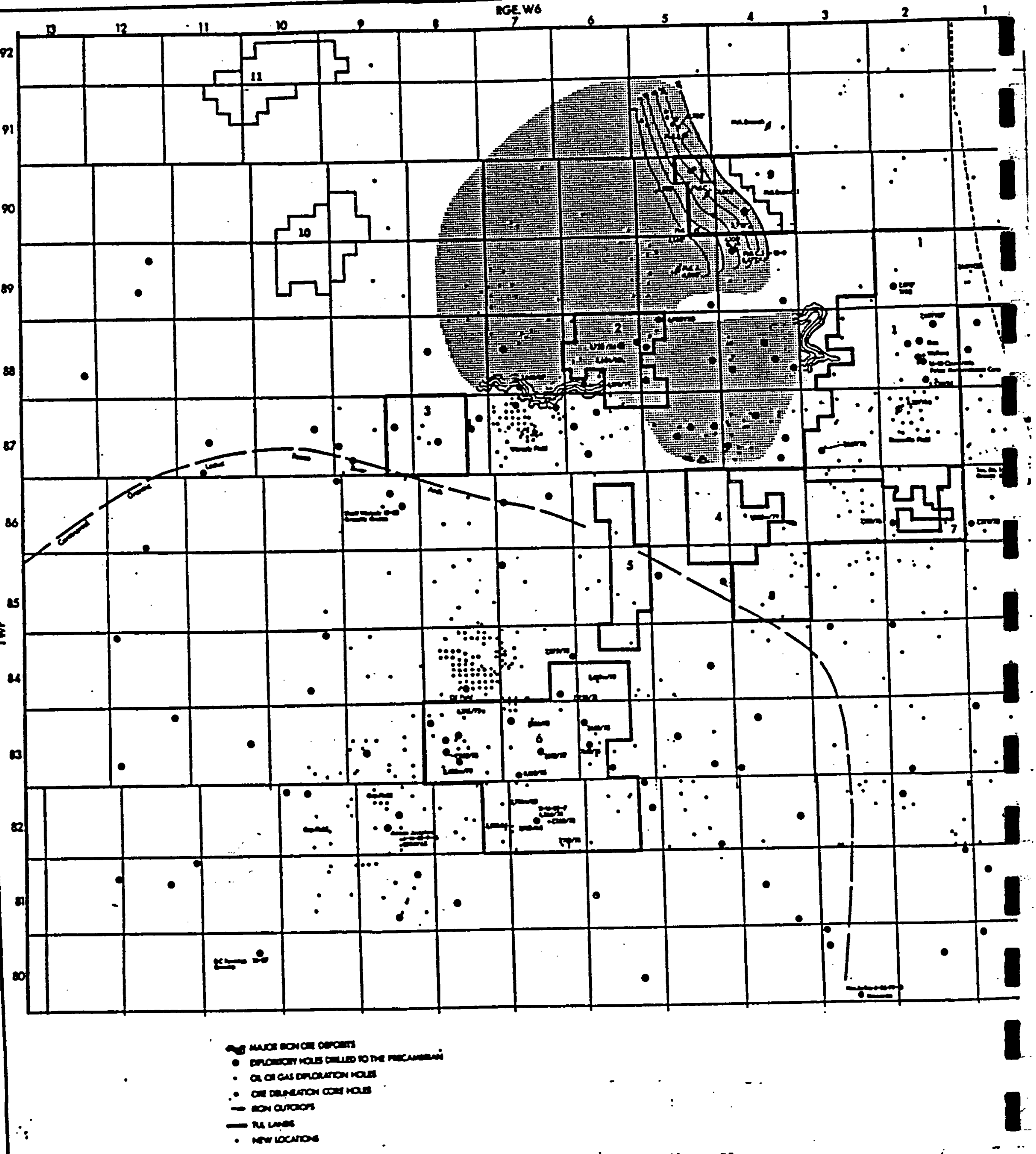
The first layer of data is the kind of rock that makes up the Precambrian. The second layer of data is the elevation of the surface of the Precambrian erosional surface.

Each and every formation shown of the formations table can is mapped as to the top of the formation and the thickness of the formation. There are around forty designated formations from the Precambrian to the surface.

The Fish Scales Shale is one of the easily identified "Marker" formations used to identify the beginning of an expected sequence on a drill rig.

Stratigraphy, lithology and elevations provide the information required to correlate with other holes and creat a description about the history of that time period when a particular formation was laid down.

OIL AND GAS DRILLING LOCATIONS



We have maps of the surface of the Precambrian,it's lithology,cratons,suture zones, faulting, displacement and topography.

After drafting the Precambrian information at a 1:250,000 scale, we learned what we could from this and began to map other formations and data at 1:250.

9.2 PHANEROZOIC OVER PRECAMBRIAN

Corelation of logs and published articles provided the data required to see how far faults propagated from one depth to surface. Air photos and Landsat imagery confirmed that some faults propagated all the way to surface. Faults, verticle and horizontal displacements were studied until we could see patterns of events. There are dated systems of faults and displacements.

9.3 AERO MAGNETIC MAPS

The aero magnetic maps show individuals, groups and linaments of magnetic highs on the Buffalo Head. The Chinchaga contains a series of subtle lows. The Ksituan Magmatic Arc appears to boil with highs in contrast to deep lows.

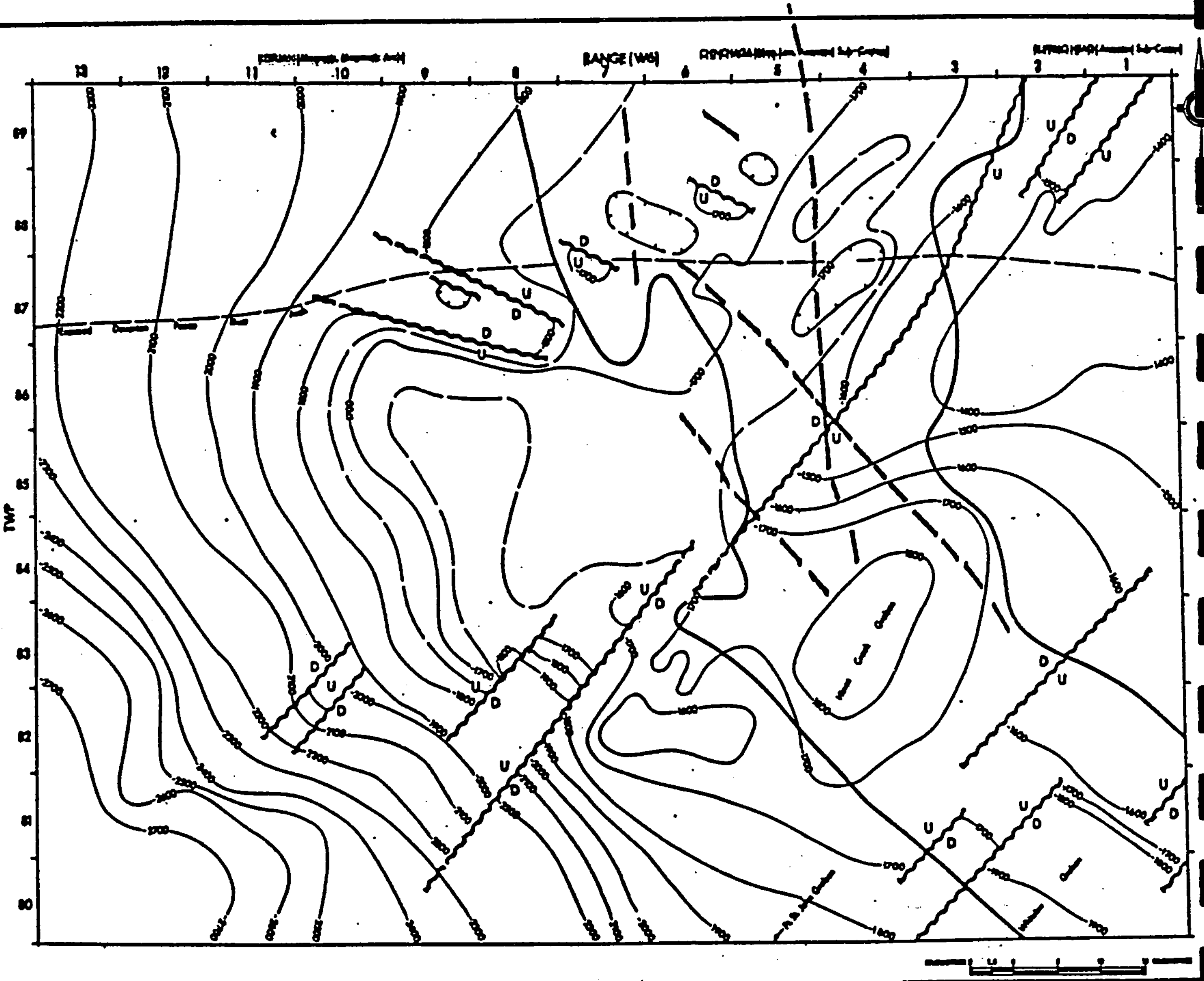
From the aero magnetic maps, it is impossible for us to differentiate between regional low responses and anomalous low responses or regional highs and target highs. We can't distinquish between basement anomalies or intrusive pipe anomalies.

9.4 MAGNETICS OVER PRECAMBRIAN

When we laid the aero magnetics map over Precambrian geology, faulting and suture zones, the coincidence was startling. Magnetic anomalies are related to the edges of sub-cratons and to sutures. Some magnetic anomalies are related to faults and graben complexes. Magnetic anomalies are not related to topographic highs, that look like intrusives on the basement.

9.5 FAULTING OVER TOPOGRAPHY

Paul Hawkins and Ass. Ltd. prepared a faulting map of the Peace River Region.



DEEP STRUCTURAL FAULTING

[illegible]

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STRUCTURE CONTOUR MAP
PRECAMBRIAN SURFACE

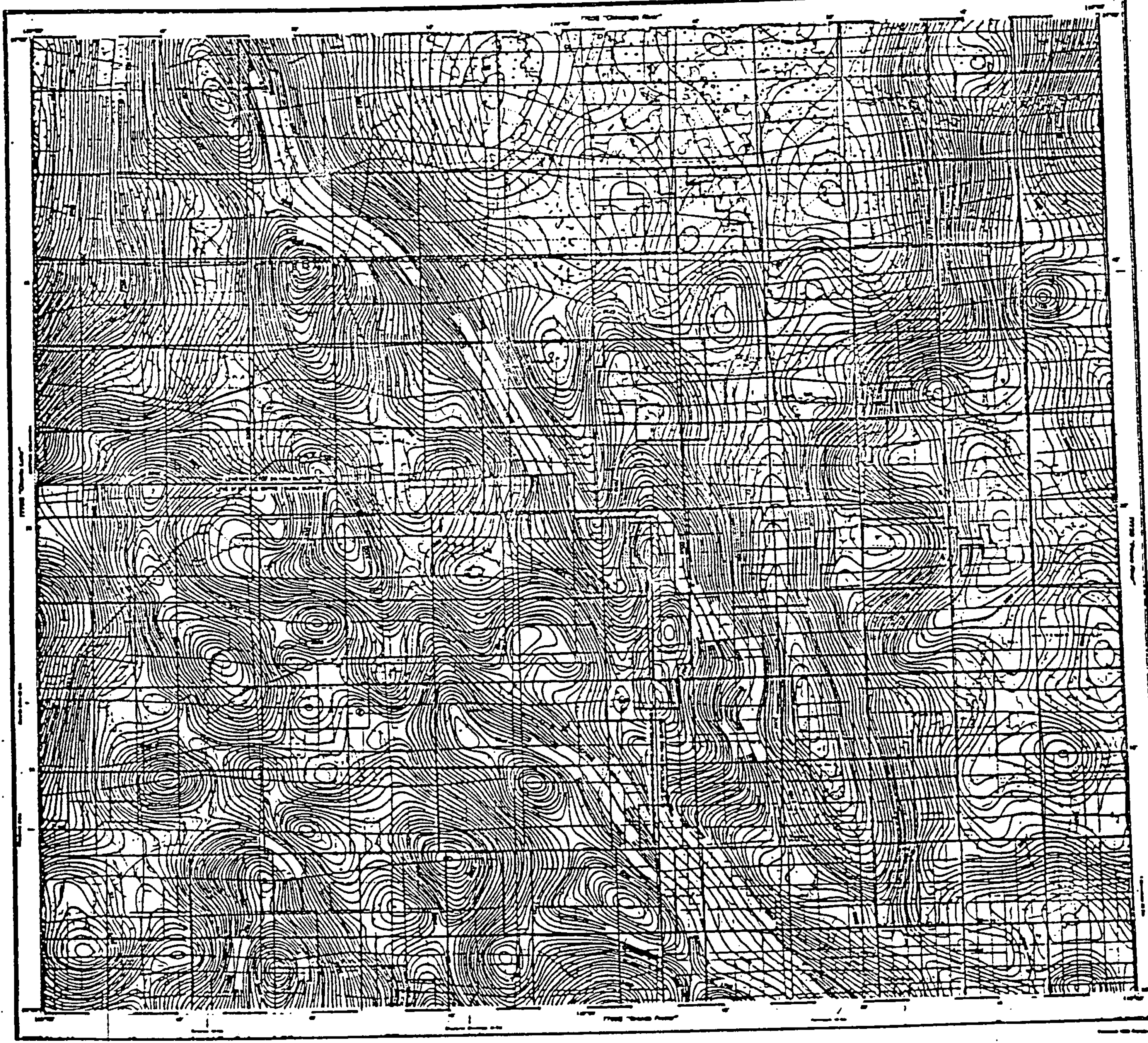
1:250,000

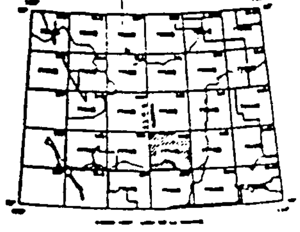
07

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

GEOPHYSICAL SERIES (AEROMAGNETIC)
SÉRIE DES CARTES GÉOPHYSIQUES (AÉROMAGNÉTIQUES)

Geological Survey of Canada
Commission géologique du Canada





MAP-CARTE
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CLEAR HILLS

ALBERTA

Scale 1:250 000 - Échelle 1/250 000

TUL PETROLEUMS LTD.

AERO MAGNETIC TARGETS MAP

1:250,000

Map # 6-1

TUL HEAVY METAL PERMITS

Canada

Patterns of sub-cratonic sutures can be loosely associated with topographic patterns, such as drainage. Faults which propagate to the upper Carbonates affect topography. Rivers like the Peace and Smoky sometimes deviate around or follow faults and linaments.

There are systems of northwest trending faults and systems of northeast trending faults. There tend to be mag highs and/or surficial features where a system of faults intersect with a suture zone.

9.6 MAGNETICS OVER TOPOGRAPHY

There is some correlation between magnetic highs and the location of rivers, but we don't understand that association.

9.7 MAGNETICS OVER FAULTING OVER BASEMENT

When aero magnetics is stacked over basement geology and faulting, the data is confusing; but, where there is a deep basement weakness, particularily where a suite of faults interects, or butts against a suture zone, that is a likely place for an intrusion and often a magnetic anomaly is identifiable near that location, as if an intrusion started at the basement and followed a fault toward the surface.

Based on all kinds of information known about the Peace River map area, the above description qualifies about fourteen townships, which should have intrusions. From my information, some of those targets have already produced encouraging results for diamond exploration.

9.8 SURFACE MOSAICS for STACKED DATA TARGETS

Where data stacking tells us that we should see suficial expression of an event, often we do. We have targeted locations and then studied the air photos. It is possible to see through a veil of glacial material and identify possible intrusives.

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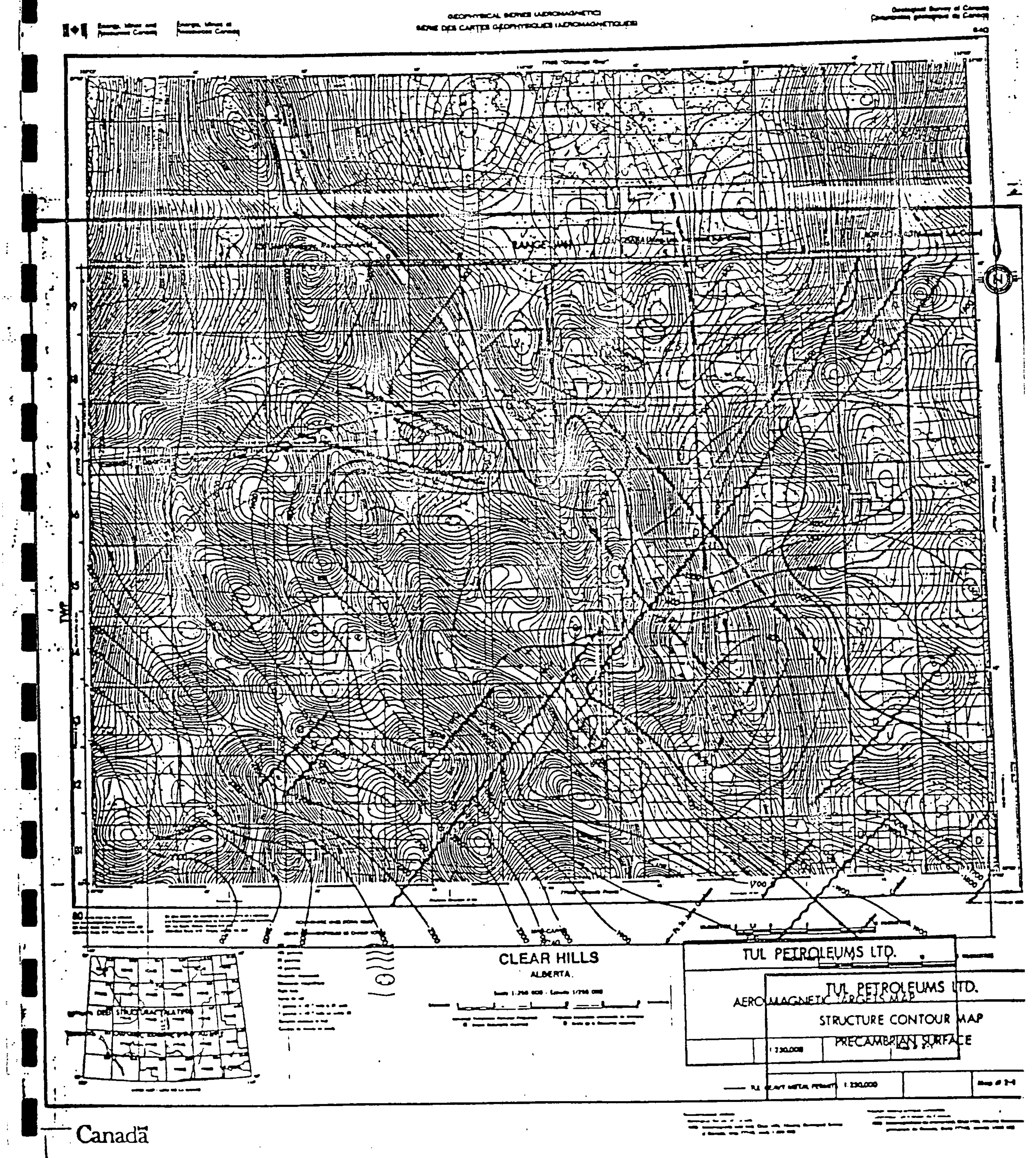
FAULTING OVER BASEMENT, OVER AERO MAGNETIC PLUS CROSS-CUTS & SUTURES.



9.9 SOIL TESTING AND DIAMOND INDICATORS

We have taken about three thousand pounds of soil samples and processed around one thousand pounds of material. We have tested soils on five magnetic targets and one collapse feature. The targets that met our criteria for intrusions most completely, returned the highest number of garnets.

Pyrope garnets and Chrome Diopside populations seem to be numerically assocaited with surficial features suspected to be diatremes at Lone Star.

Pryrope garnets and Clinopyroxenes, which have been classified by microprobe ananlysis as diamond indicators, seem to have dispersal trains and origins which indicate an eclogitic diamond source near Montagenuse.

Other diamond indicators in the field samples, like the illmenites, have not yet been analysed.

9.10 SIESMIC DATA

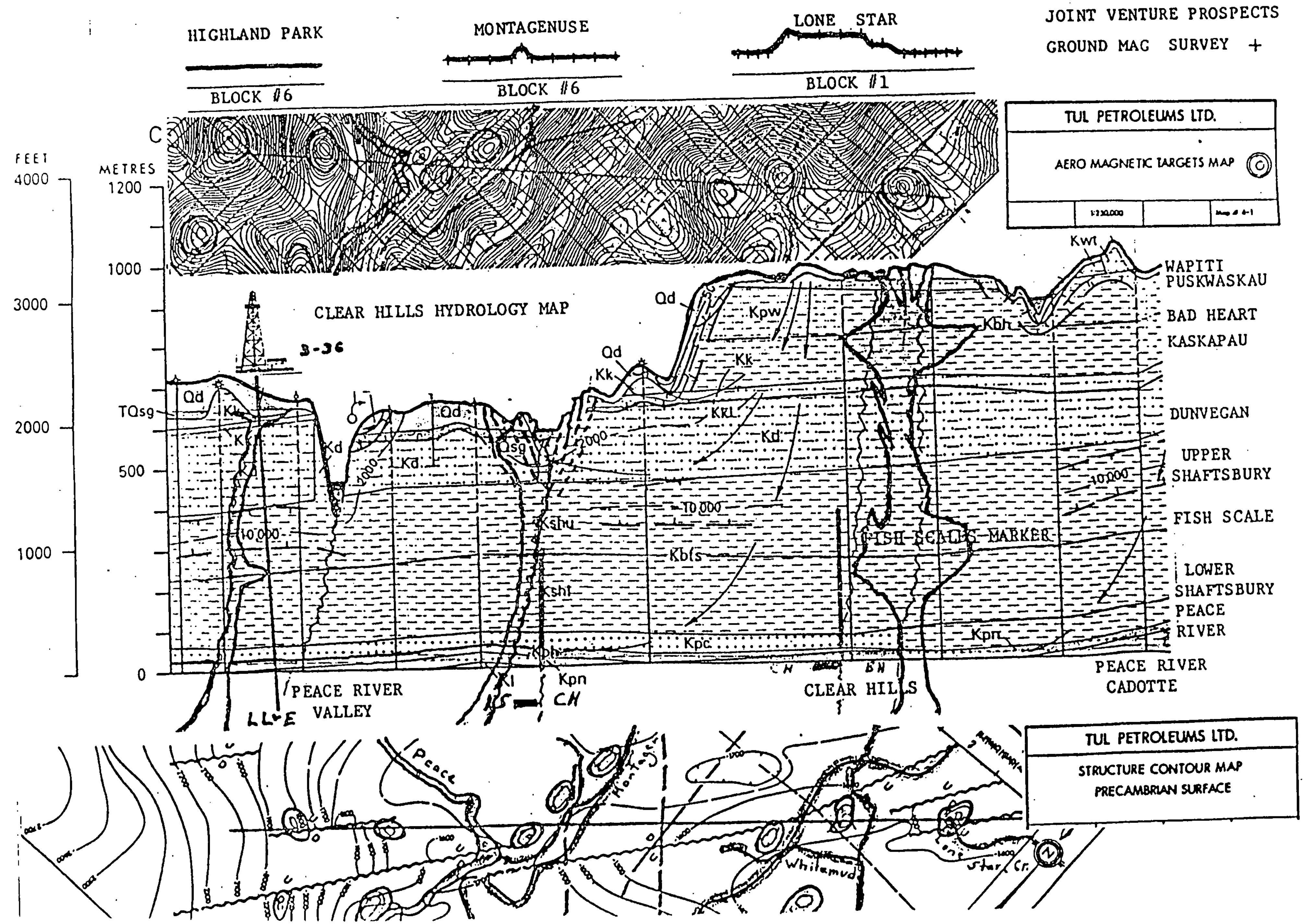
One of our top priorities for next season should be to acquire siesmic data and stack it onto our present data.

9.11 CONCLUSION

The Lone Star Prospect is near the first drilling stage, based on data stack -ing. We suspect that Lone Star contains one or more intrusions.

The Montagenuse Prospect has produced encouraging geochemical results, but we have not been able to determine where a diatreme exists.

A CONCEPTUAL VIEW - AFTER DATA STACKING - OF THE PEACE RIVER DIATREMES AS THEY MAY INTRUDE INTO TUL LANDS.



APPENDIX

Color Photography

Color photographs of the outcrop and the area and color photomicrographs of thin sections contribute much to the description of this iron "ore". It can be readily seen that color was practically essential in the descriptions and black-and-white photographs would be of little value except in visualizing texture and structure of the material. The thickness of the oolitic thin sections prohibited the use of the Nicol prism in most cases.

Considerable time and money were expended in preparation of the color plates but it is felt that the expenditure was necessary and rewarding. The following information is given as an aid to anyone doing this type of work in the future.

Field photography: This particular aspect is the simplest of the two projects and the essentials are a good camera and daylight film (color) to suit the individual's purpose. The field color plates in this thesis were procured using a Zeiss Contaflex "C" 35 mm. camera, with a built-in exposure meter. The film used was Kodak Ectochrome daylight - A.S.A. No. 32. This film was used mainly because of past success, economy, and the fact that it can be developed locally. The exposures used were governed by the light meter readings. The results are almost always good. All hand specimen photographs were taken using the above equipment and available light.

Color photomicrographs: This work was carried out using the Geology Department's equipment, which is described below.

Microscope - Leitz polarizing, Model KM-L, No. 502442

Eyepiece lens - 8 magnifications

Objective lens - low power 3.2 - 10 diameter
medium power 10.1 - 30 diameter

Attachments - Leitz photomicrograph apparatus with bellows extension (40 cm.)

Camera - Leitz Leica 1 f., 35 mm., No. 682345

Filter - White or light blue in light source attachment on microscope

Light - Full scale light - pin point at light source in combination with convergent lens

Film - Ansco - Super Anscochrome
Tungsten 35 mm., A.S.A. No. 100 - 20 exposures

Exposure time - Several test runs were made on time exposure and the best exposure times using the magnification and light conditions described are as follows:

for low power 10 diameter 1 sec.
for medium power 30 diameter 1/2 sec.

Prints - All photographs were developed as transparencies and the better ones selected for printing. These were printed and enlarged (6 diameters) by Pix-a-Color Ltd. of Edmonton. The results were good. Even though it is still impossible to get exact color duplication the resulting colors were very close to the originals, considering that this was a first attempt with this very fast film.