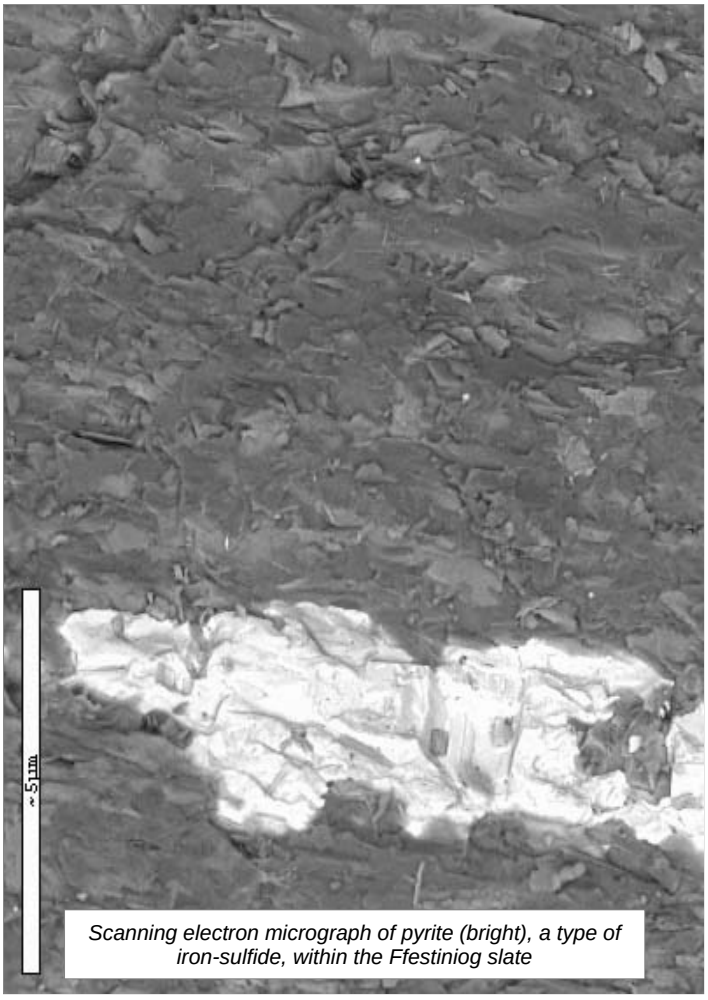
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Comparison of Natural Roofing Slates

IBIS Report 1214/P-001, July 2005



Scanning electron micrograph of pyrite (bright), a type of iron-sulfide, within the Ffestiniog slate

TABLE OF CONTENTS

DOCUMENT CONTROL 3

EXECUTIVE SUMMARY 4

1 INTRODUCTION 5

2 INVESTIGATION METHODS AND RESULTS 6

2.1 Introduction 6
2.2 Scanning Electron Microscopy and Micro-Analysis 6

3 SUMMARY OF FINDINGS 7

4 DISCUSSION OF FINDINGS 8

4.1 General 8
4.2 Comparing the Ffestiniog and Glendyne Slates 8
4.3 Other Information 9

5 SUMMARY CONCLUSIONS 11

6 REMARKS 12

Tables

1.1 Schedule of Samples 5

Figures

3.1 Summary of Scanning Electron Micro-Analysis Results 7

Appendices

A Scanning Electron Microscopy and Micro-Analysis Results, 5 pages

Comparison of Natural Roofing Slates

IBIS Report 1214/P-001, July 2005

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For IBIS Limited

Barry J Hunt
BSc MSc MASI MCIOB CSci CGeol EurGeol FGS MRICS FRMS
Director

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Comparison of Natural Roofing Slates

Executive Summary

At the request of Glendyne Inc, IBIS has carried out a comparative investigation into the properties of two natural roofing slates. The principal purpose was to provide comment on the potential substitution of Ffestiniog slate from Wales with Glendyne slate from Canada.

The investigation drew on information and results previously determined by IBIS and others for the submitted materials, some historical documentation concerning the use of the Glendyne slate, and the geological formation of the slates. In summary the following was concluded:

- The majority of slates exhibit similar elemental composition with similar mineral assemblages. The Ffestiniog and Glendyne slates were no exception and were very similar in this respect.
- The Ffestiniog and Glendyne slates are visual matches and geologically similar, exhibiting comparable properties, being top quality roofing slates.
- The Ffestiniog slate may be substituted with the Glendyne slate, thus providing the customer with greater choice without fear of compromise.
- Both current and historic data for the two slates suggests that they exhibit similar physical and mechanical characteristics.

In those circumstances where there is a belief that only Welsh slate must be used, the geological history of Canadian slate should be taken into perspective. In particular, the Glendyne slate deposit formed in the same sea as the Ffestiniog slate deposit and it is only the opening of the Atlantic Ocean and political history that have separated them.

NOTE: This executive summary is provided for initial briefing purposes only and should not be substituted for the main body of the report and the detailed conclusions and recommendations provided therein.

Comparison of Natural Roofing Slates

1 INTRODUCTION

At the request of Glendyne Inc., IBIS has carried out a comparative investigation in to the properties of two natural roofing slates. The slates were sampled from the store yard of the Client; the details of the samples are provided in **Table 1.1** below.

The principal issue to be investigated was whether Glendyne slate from Canada was a close match for Ffestiniog slate from Wales.

This report describes the investigation carried out and then provides and discusses the findings. Conclusions are then provided concerning the similarities and differences of the slates. A number of standard remarks conclude the report.

Table 1.1: Schedule of Samples

IBIS Reference	Sample Details
1214/X1	Advised Ffestiniog natural roofing slate from Ffestiniog, Wales, with nominal dimensions of 500x250x4-6mm
1214/X2	Advised Glendyne natural roofing slate from St Marc du Lac Long, Quebec, Canada with nominal dimensions of 508x254x4-5mm

2 INVESTIGATION METHODS AND RESULTS

2.1 Introduction

The Glendyne slate has recently been investigated by IBIS, the full current and new British (and European) Standard tests[1, 2] being carried out. The findings of this investigation have been provided in a separate IBIS report but the information obtained has been applied to the current investigation to provide better interpretation of the results.

The Ffestiniog slate is well known within the UK and has a long and successful history of use. This slate has not been tested by IBIS to the new British Standard although we have longstanding experience of this material and there is a wealth of information readily available to assist with the interpretation of the results of the current investigation.

2.2 Scanning Electron Microscopy and Micro-Analysis

The two samples of roofing slate were each examined and analysed using a scanning electron microscope using both energy dispersive and back-scattered electron modes. Both area and spot analyses were carried out using a micro-analytical attachment to measure the electron energy dispersion, to assist the observations and provide quantitative elemental data.

The equipment used is able to analyse all elements of atomic mass 8 (oxygen) and above. The test was carried out by a presently unaccredited laboratory. However, the laboratory is considered by IBIS to achieve equivalent standards.

The detailed scanning electron micro-analysis results are provided in **Appendix A** as Certificates of Examination and Analysis Nos. 1592/1214 and 1593/1214. A comparative summary of the results is provided in **Section 3** of this report, whilst the findings are discussed in **Section 4**.

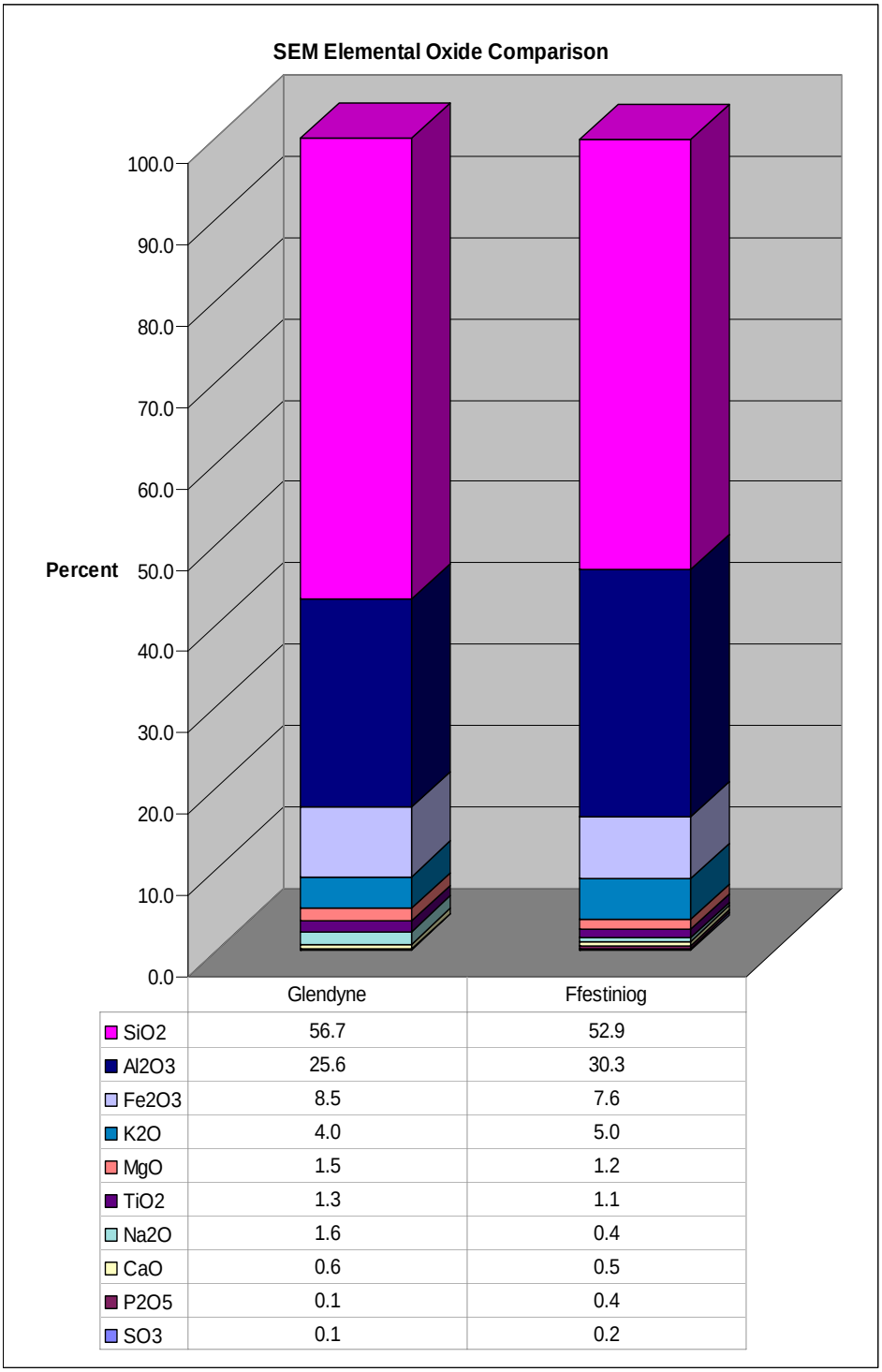
1 BS EN 12326-1: 2004, Slate and stone products for discontinuous roofing and cladding – Part 1: Product Specification. Published by the British Standards Institution, London, England.

2 BS EN 12326-2: 2000, Slate and stone products for discontinuous roofing and cladding – Part 2: Methods of test. Published by the British Standards Institution, London, England.

3 SUMMARY OF FINDINGS

The scanning electron micro-analytical data presented in Appendix A has been summarised and compared below in **Figure 3.1**. The data is normalised to 100% for the calculated elemental oxide equivalents.

Figure 3.1: Summary of Scanning Electron Micro-Analysis Results



	Glendyne	Ffestiniog
SiO2	56.7	52.9
Al2O3	25.6	30.3
Fe2O3	8.5	7.6
K2O	4.0	5.0
MgO	1.5	1.2
TiO2	1.3	1.1
Na2O	1.6	0.4
CaO	0.6	0.5
P2O5	0.1	0.4
SO3	0.1	0.2

4 DISCUSSION OF FINDINGS

4.1 General

Most slates are formed from the metamorphism of deep sea muds that, by the nature of their formation, are all similar. Therefore, the analyses demonstrate immediately that the Ffestiniog and Glendyne slates exhibit very similar elemental compositions.

Most deep sea muds comprise the minerals that are resistant to the various weathering and alteration processes that occur at the Earth's surface. These minerals are the phyllosilicates such as micas and clays, quartz and various iron and aluminium oxide and hydroxide weathering products. The muds are also extremely fine grained by virtue of larger particles being deposited closer to shore or within rivers and lakes.

The exceptions to the general rule include the Cumbrian slates that are formed from muds that contain extremely fine volcanic dust falls, and carbonate slates derived from lime muds typically formed in more shallow marine environments.

In the following sections the two slates are more closely scrutinised with respect to how they are geologically related. Historical comment is then provided.

It must be understood that much of the geological information provided in the following sections is greatly simplified. Furthermore, the information relies on interpretation that is constantly changing as more is learnt about the Earth's geological history. However, it is hoped that the information provided is a reasonable guide to the materials in question.

4.2 Comparing the Ffestiniog and Glendyne Slates

Visually the two slates are similar, as is their performance in both the current and former[3] British Standard tests and the American ASTM[4] tests. However, what makes the Ffestiniog and Glendyne slates particularly similar to one another is the fact that the original muds both appear to be formed as a result of turbidity currents giving rise to greywacke sequences[5].

The outcome of this depositional environment is a series of layered muds of variable grain size and proportion of quartz to phyllosilicates. These variations are still present in both slates giving rise to their slightly rippled surfaces due to the changing competency of the relict laminations that cut the cleaved surface at an angle. In both slates the cleavage direction is independent of the original bedding laminations.

For most of the last 600 million years, North Wales was actually attached to the mass that now forms Newfoundland in a micro-continent sometimes referred to as Avalonia. This micro-continent also contained parts of Belgium, North Germany, New Brunswick and other parts of eastern maritime North America. This was separated from the remainder of North America (often referred to as Laurentia) by the Iapetus Ocean.

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3 BS 680: 1971. Specification for Roofing Slates. Part 2, Metric Units. Published by the British Standards Institution, London, England.

4 American Society for Testing Materials (ASTM), Test Designation C406-96, Standard Specification for Roofing Slate. Published by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA.

5 Turbidity currents occur when there are sub-marine sediment slips. The dislodged sediment races down into the deep ocean basin with finer particles deposited at lower depths. Variations in successive currents give rise to laminated sequences with variations in particle size and mineral proportions. Most rocks formed from such sediments are found to be greywackes.

Geologically the slates formed apparently on opposite sides of the Iapetus Ocean and also at different times. The Ffestiniog muds were produced during the Ordovician Period on the Avalonian side of the Iapetus Ocean whilst the Glendyne muds were produced during the following Silurian Period on the Laurentian side of the Iapetus Ocean.

Through the course of the Ordovician and Silurian Periods the Iapetus Ocean shrank as Avalonia and Laurentia moved toward each other finally colliding around 400 million years ago. This uplifted, folded and, in the process, metamorphosed the mudrocks, transforming them into slate. This period of mountain building is referred to as the Caledonian orogen, the range extending from Norway, through Scotland, Wales, Ireland, Newfoundland and on into the North-Eastern United States as the Appalachians.

When comparing the elemental analyses of the two slates there is very little difference between them although there are two notable, albeit slight variations. One variation is the slightly higher silica and lower aluminium content of the Glendyne slate, suggesting that a little more quartz is present for similar reasons and with similar consequences as described for the Trinity slate previously. The other variation is the sodium:potassium ratio, the Glendyne slate containing higher sodium to the detriment of potassium suggesting a greater proportion of possible smectite type clay minerals instead of muscovite and/or possible illite clay minerals.

If no further geological activity had taken place, the Welsh, Newfoundland and North-East American slate deposits would have remained in one long continuous band. However, at the end of the Cretaceous Period 65 million years ago, North America split from Europe, the drifting apart forming the Atlantic Ocean that we know today and which now separates the deposits by 2,000 or so miles.

4.3 Other Information

In a 1909 report by Murray and Howley[6], Howley, who was then the head of the Geological Survey of Newfoundland, notes the following:

> *"The superior quality and quantity of the Newfoundland Slate beds is the surprise of all that visit them. They are of the same formation as the Welsh Slates."*

In the same report it is stated that between 1865 and 1909, 153,702 squares of finished roofing slate were produced, the bulk of which was shipped to England.

A Newfoundland Governmental report[7] of 1912 noted that various geological surveys had identified the potential wealth of the undeveloped slate beds of Newfoundland. An idea of the immense wealth lying dormant in these beds is given in the notes made by Mr. 0.J. Owen, a practical quarry engineer who had 41 years' experience in the slate trade both in Wales and Newfoundland. He is cited as follows:

> *"Providing capital be found to work the same, the resources of Newfoundland in Slate are such that they can supply all the demand for roofing and other kinds of slates required in the English and other markets."*

Later in the report the following is noted:

6 Murray, Alexander, and Howley, James P. Geological Survey of Newfoundland Reports, 1881-1909. St. John's: Robinson and Company Limited Press, 1918.

7 Newfoundland's Slate Quarries: One of the British Empire's Undeveloped Sources of Wealth. Newfoundland Governmental Report, Dated 30 June, 1912.

"the total output of Slate per year from Newfoundland is now only about 600 tons, all of which is readily bought in England. This small output is due to the fact that only recently have Geologists and Mineral experts called attention to the beds. Owing to the decline of the output from the Welsh quarries, an ever-increasing number of engineers and quarry-owners are seeking new fields….. The product of these quarries has been marketed in England, and buyers bear striking testimony to the excellent quality of the Slate."

5 SUMMARY CONCLUSIONS

The Welsh Ffestiniog and Canadian Glendyne slates are closely related, being originally formed under similar conditions in the same sea adjacent to each other. Both slates were then subjected to similar metamorphic processes.

The deposit containing the Ffestiniog and Glendyne slates was torn apart as the Atlantic Ocean formed, separating the slates by thousands of miles. However, today's location and political boundaries should not get in the way of the fact that the slates essentially are almost identical.

The Ffestiniog and Glendyne slates look the same and perform similarly in tests, and experience has proven both slates to be durable over centuries rather than decades.

There is a history of export of Newfoundland slate to the UK to provide alternative and matching supplies to Welsh slate at times when it appears that slate production in Wales was unable to cope with demand.

There appear to be no reasons why Glendyne slate ought not to be used as a replacement or alternative to Ffestiniog slate, even in politically sensitive areas.

6 REMARKS

An investigation into the properties of the Welsh Ffestiniog slate compared to the Canadian Glendyne has been carried out. The slates are similar because of their historical geological mode of formation, regardless of their current geographical location.

These remarks conclude the work so far requested and should be taken as being applicable only to materials properly represented by these samples. Natural roofing slate resources may be expected to exhibit both lateral and vertical variations in composition and properties and single or small samples may not necessarily be reliably representative of a resource or even specific locations within that resource.

Any samples taken for laboratory investigation will be retained for a period of one month from the date of this report. After this time the samples will be disposed of unless otherwise instructed. On request the samples may be either returned or stored, either action incurring a small administration charge.

If you require any further assistance in this matter please do not hesitate to contact us.

Comparison of Natural Roofing Slates

Appendix A
Scanning Electron Microscopy and Micro-Analysis Results

Contents

Certificate No. 1592/1214: Scanning Electron Microscopy and Micro-Analysis
Certificate No. 1593/1214: Scanning Electron Microscopy and Micro-Analysis

Certificate of Examination & Analysis
Scanning Electron Microscopy and Micro-Analysis

Client and Sample Details			
Client	Glendyne Inc.		
IBIS Ref. No	1214-X1	**Client Ref**	Ffestiniog
Site	Not applicable		
Sample Details	500mm by 250mm Ffestiniog slate		
Sampled by	BJH/IBIS	**Date Sampled**	Not advised
Tested by	ME/GMRS	**Date Tested**	02.05.05

Methods of Examination and Analysis	
Method	The sample was examined using a scanning electron microscope using both energy dispersive and back-scattered electron modes. Both area and spot analyses were carried out using a micro-analytical attachment to measure the electron energy dispersion to assist both the observations but also to provide quantitative elemental data.
Comments	The equipment used is able to analyse all elements of atomic mass 8 (oxygen) and above.
Accreditation	The test was carried out by a presently un-accredited laboratory. However, the laboratory is considered by IBIS to achieve equivalent standards.

Results			
General Observations	The slate principally comprised silicon and aluminium with minor iron, magnesium, potassium and titanium. The main minerals appeared to be silica and various phyllosilicates including chlorite and white mica. Significant pyrite and rutile were identified.		
Type of Analysis		3mm Square	Spot Analysis
Calculated Percentages of Mineral Oxides	SiO_2	52.9	6.4
	TiO_2	1.1	0.4
	Al_2O_3	30.3	5.4
	Fe_2O_3	7.6	43.6
	MgO	1.2	0.3
	MnO	0.3	0.0
	CaO	0.5	0.1
	Na_2O	0.4	-0.4
	K_2O	5.0	0.6
	SO_3	0.2	43.8
	P_2O_5	0.4	-0.6
	NiO	-0.1	0.2
	CuO	0.1	0.1

Remarks

The information given in this certificate was obtained with all due care and attention. Opinions and interpretations expressed are the consultants view based solely on their assessment of the sample presented for analysis.

Issue Date: 12/05/2005

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Director, IBIS Limited

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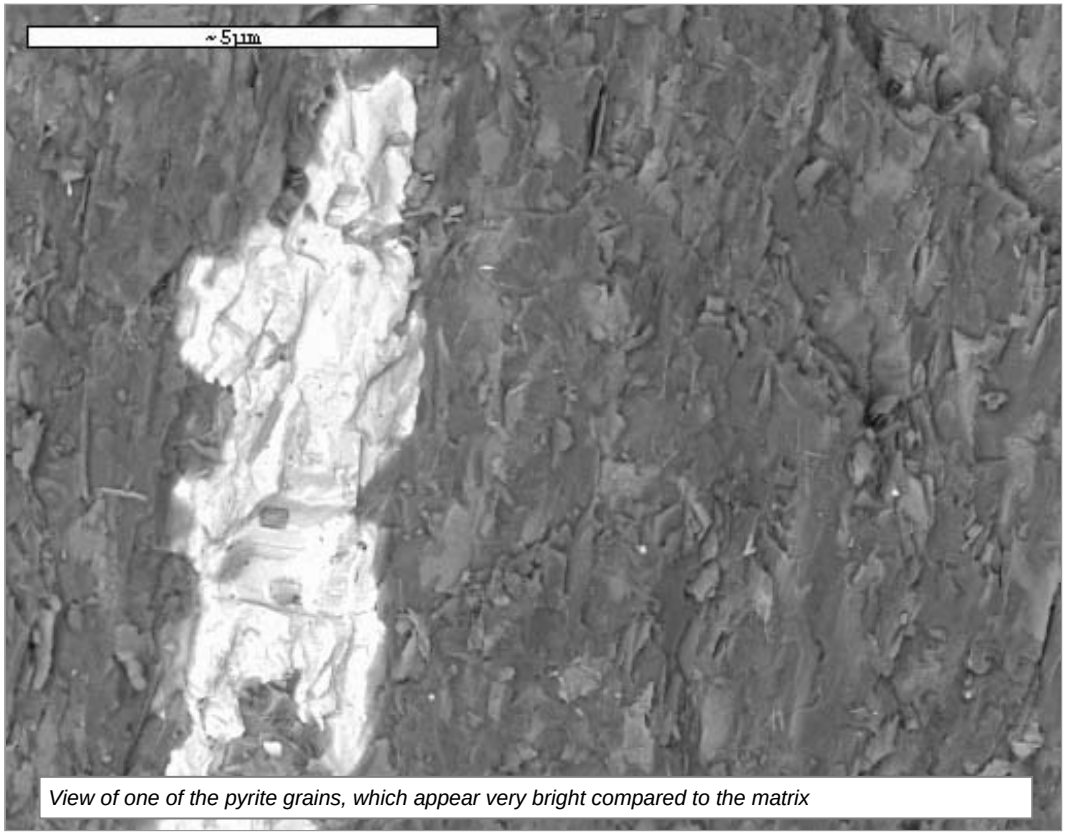
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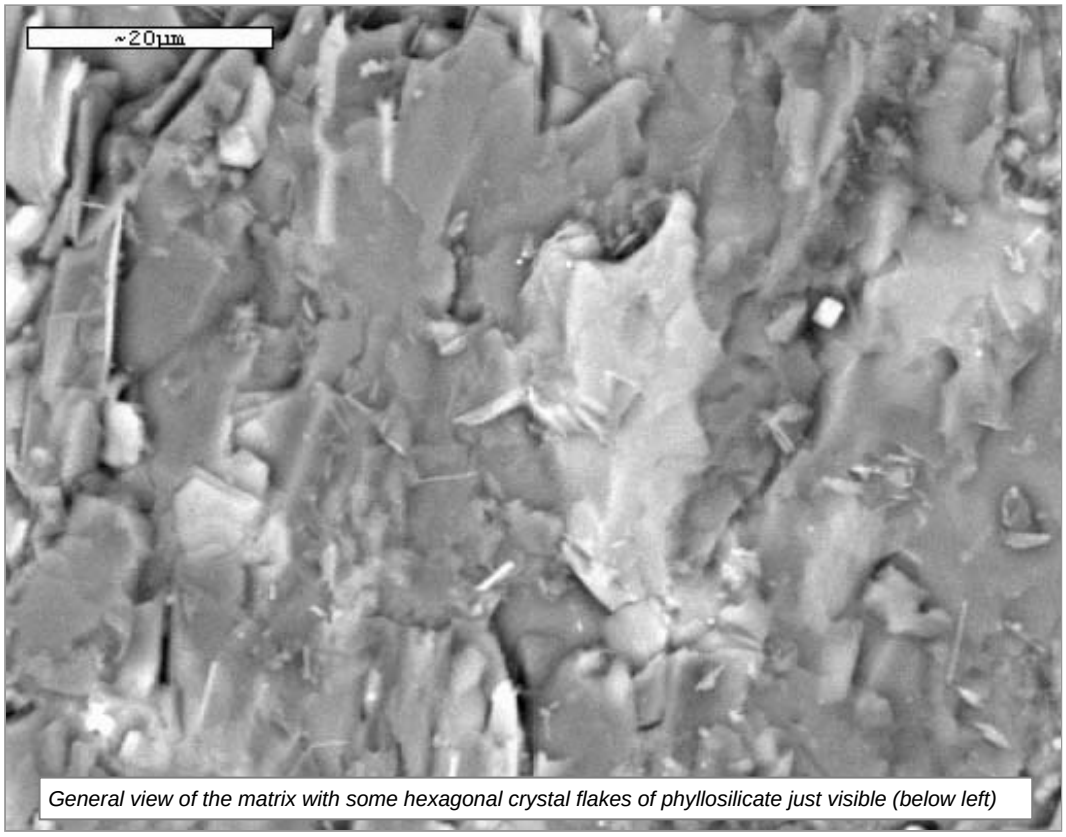
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Certificate of Examination & Analysis
Scanning Electron Microscopy and Micro-Analysis

Electron Micrographs



View of one of the pyrite grains, which appear very bright compared to the matrix



General view of the matrix with some hexagonal crystal flakes of phyllosilicate just visible (below left)

Certificate of Examination & Analysis
Scanning Electron Microscopy and Micro-Analysis

Client and Sample Details			
Client	Glendyne Inc.		
IBIS Ref. No	1214-X2	**Client Ref**	Glendyne
Site	Not applicable		
Sample Details	508mm by 254mm Glendyne slate		
Sampled by	BJH/IBIS	**Date Sampled**	Not advised
Tested by	ME/GMRS	**Date Tested**	02.05.05

Methods of Examination and Analysis	
Method	The sample was examined using a scanning electron microscope using both energy dispersive and back-scattered electron modes. Both area and spot analyses were carried out using a micro-analytical attachment to measure the electron energy dispersion to assist both the observations but also to provide quantitative elemental data.
Comments	The equipment used is able to analyse all elements of atomic mass 8 (oxygen) and above.
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Results			
General Observations	The slate principally comprised silicon and aluminium with minor iron, magnesium, potassium and sodium. The main minerals appeared to be silica and various phyllosilicates including chlorite and white mica. Traces of pyrite, rutile and haematite were identified.		
Type of Analysis		3mm Square	Spot Analysis
Calculated Percentages of Mineral Oxides	SiO_2	56.7	20.9
	TiO_2	1.3	1.2
	Al_2O_3	25.6	12.3
	Fe_2O_3	8.5	64.7
	MgO	1.5	0.8
	MnO	0.2	0.1
	CaO	0.6	0.2
	Na_2O	1.6	-1.2
	K_2O	4.0	1.2
	SO_3	0.1	-0.1
	P_2O_5	0.1	0.2
	NiO	0.0	-0.1
	CuO	0.0	-0.2

Remarks

The information given in this certificate was obtained with all due care and attention. Opinions and interpretations expressed are the consultants view based solely on their assessment of the sample presented for analysis.

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microscopy
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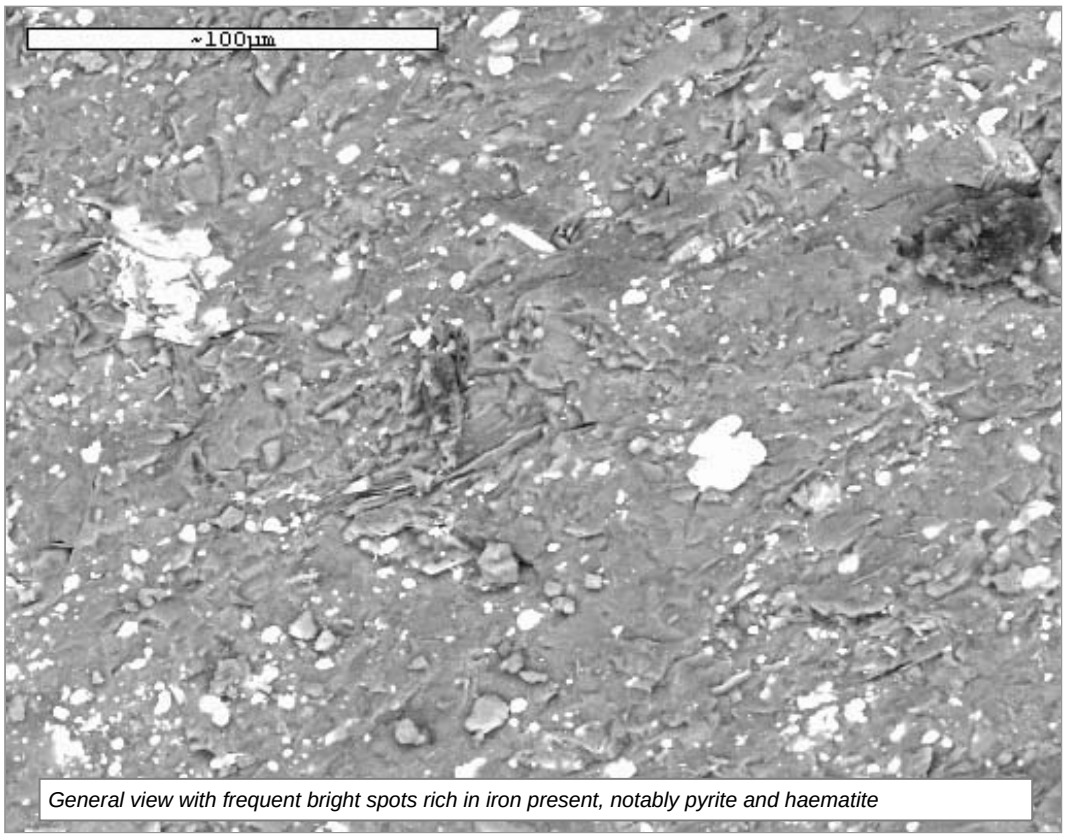
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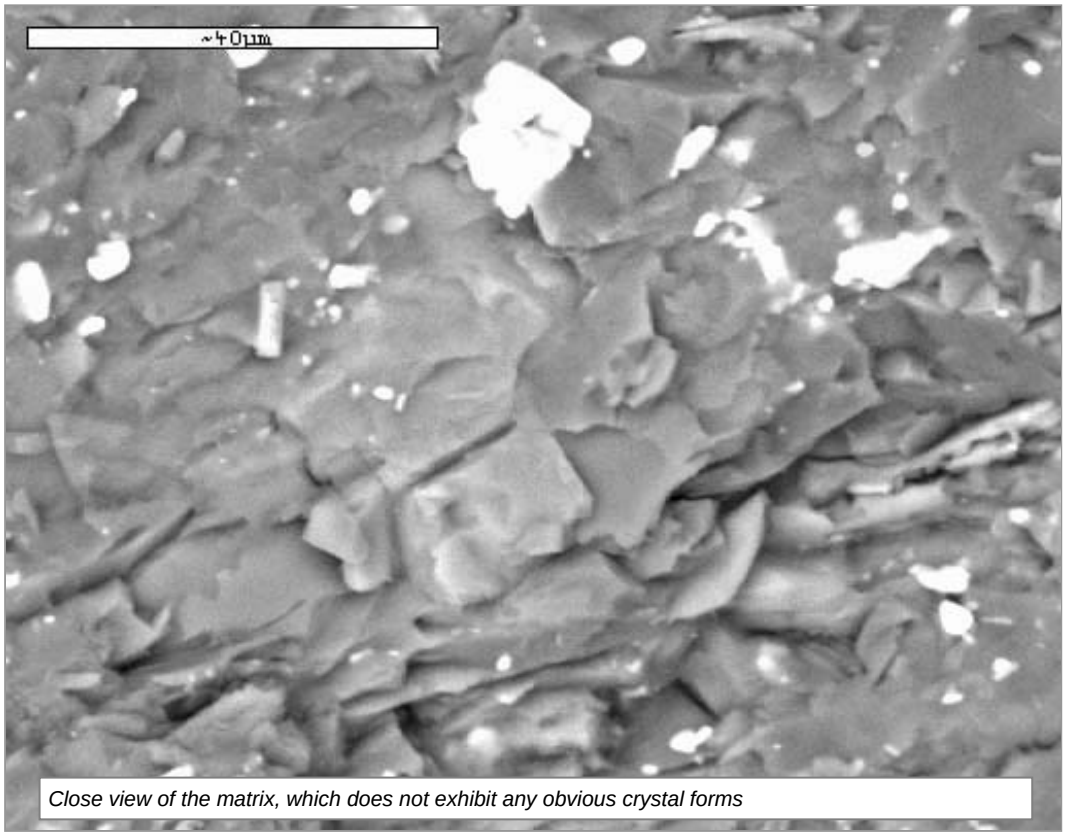
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Certificate of Examination & Analysis
Scanning Electron Microscopy and Micro-Analysis

Electron Micrographs



General view with frequent bright spots rich in iron present, notably pyrite and haematite



Close view of the matrix, which does not exhibit any obvious crystal forms