ORKUSTOFNUN
Energy Analysis Division

British Mining Consultants Limited

PRELIMINARY ASSESSMENT of ECONOMIC FEASIBILITY OF LIGNITE MINING IN ICELAND

OS-85003/OBD-01
Reykjavík, January 1985

ORKUSTOFNUN
Grensásvegi 9, 108 Reykjavík

Verknúmer 963

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Iðnaðarráðuneytið
Arnarhvoli
101 Reykjavík

Varðar: Frummat á hagkvæmni surtarbrandsvinnslu á Íslandi

Hjálagt sendist hinu háa ráðuneyti skýrsla sem breska námuvinnsluráðgjafafyrirtækið British Mining Consultants Ltd hefur samið fyrir Orkustofnun um "frummat á hagkvæmni surtarbrandsvinnslu á Íslandi". Skýrsla þessi er liður í rannsóknum Orkustofnunar á surtarbrandi sem unnar eru í samræmi við ályktun Alþingis frá 22. febrúar 1983, sem send var stofnuninni með bréfi ráðuneytisins frá 25. maí það ár. Í ályktun Alþingis er kveðið á um að "ríkisstjórnin skuli fela Orkustofnun og Rannsóknaráði ríkisins rannsókn á surtarbrandi á Vestfjörðum og könnun leiða til nýtingar hans til orkuframleiðslu og iðnaðar".

Í viðræðum milli orkumálastjóra og framkvæmdastjóra Rannsóknarráðs varð að ráði að Orkustofnun og Rannsóknaráð skiptu þannig með sér verkum í meginatriðum í verkefni þessu, að Orkustofnun annaðist rannsókn á námunum sjálfum, hagkvæmni surtarbrandsvinnslu og á nýtingarmöguleikum surtarbrands til orkuvinnslu, en Rannsóknaráð sæi um rannsókn á nýtingarmöguleikum hans til iðnaðar. Í framhaldi af þeim viðræðum var saminn listi sá yfir verkliði sem fylgir með bréfi þessu sem fylgiskjal 1.

Þessir rannsóknarþættir Orkustofnunar hafa verið undir stjórn Jóns Vilhjálmssonar deildarstjóra Orkubúskapardeildar.

Nú er lokið við 5 fyrstu liðina. Um fyrstu þrjá kom skýrsla vorið 1984 eftir Kristján Sæmundsson og Freystein Sigurðsson jarðfræðinga á Orkustofnun, sem nefnist "Surtarbrandur á Vestfjörðum".

8

Varðandi 5. liðinn, frumúttekt á markaði hérlendis fyrir surtarbrand, var niðurstaðan sú, að sem orkugjafi kæmi hann helst til álita í kyntum hitaveitum í stað olíu og raforku, og þá fyrst og fremst á Vestfjörðum (Ísafirði, Bolungarvík og Patreksfirði), þ.e. sem næst vinnslustað, en einnig í Sementsverksmiðjunni á Akranesi í stað innfluttra kola. Til iðnaðar kæmi surtarbrandur helst til álita sem kolefnisgjafi fyrir Járnblendiverksmiðjuna á Grundartanga, einnig í stað innflutts kolefnis. Skilyrði þess að surtarbrandur gæti náð þessum markaði er vitaskuld í öllum tilvikum það, að hann standist sæmilega samanburð við innflutt kol hvað verð snertir, og helst að hann sé ódýrari, kominn til notanda, því notkun hans hefur yfirleitt í för með sér aukakostnað fyrir notandann umfram það að nota steinkol.

Talið var, að kyntu hitaveiturnar þyrftu um 1990 orku sem samsvarar um 25 000 tonnum á ári af góðum surtarbrandi, og Sementsverkdsmiðjan um 40 000 tonn á ári.

Með hliðsjón af því var ákveðið að miða athugunina á vinnsluhagkvæmni við þrennskonar magnforsendur, þ.e.

25 000 t/ári
65 000 t/ári
100 000 t/ári

Meðfylgjandi skýrsla hefur að geyma niðurstöður úr 4. lið, frumúttekt á vinnsluhagkvæmni surtarbrands á Vestfjörðum.

Valdir voru alls 5 staðir á Vestfjörðum til þessarar úttektar á grundvelli skýrslu þeirra Kristjáns og Freysteins. Þeir eru:

- Straumnesfjall
- Gil (nálægt Bolugnarvík)
- Botn í Súgandafirði
- Dufansdalur og Þernudalur í Arnarfirði
- Stálfjall.

Sérfræðingar frá Britisth Mining Consultans Ltd (BMCL), þeir Mr. K. Lumsdon námuverkfræðingur og Mr. R. Goossens, yfirmaður Könnunardeildar breska kolaráðsins (NCB), komu hingað til lands í ágústmánuði 1984 og ferðuðust til þessara staða ásamt þeim Kristjáni Sæmundssyni og Birgi Jónssyni jarðfræðingum frá Orkustofnun. Voru þá m.a. tekin sýni af surtarbrandinum sem rannsökuð voru í Bretlandi.

Við skoðun töldu bresku sérfræðingarnir surtarbrandslögin við Gil vera svo þunn og þykkt þeirra svo óregluleg að vinnsla þeirra með nútíma vinnsluaðferðum væri ekki raunhæfur möguleiki. Var Gili því sleppt í frekara vinnslumati.

Fyrir hina staðina 4 gerðu sérfræðingar BMCL lauslega áætlun um tilhögun surtarbrandsvinnslu, þar á meðal um fyrirkomulag á námum á hverjum stað; vinnsluaðferð, hreinsun á surtarbrandinum og flutning hans, útskipun og flutning með skipum. Út frá þeirri áætlun og reynslutölum frá Bretlandi um vinnsluafköst, svo og út frá tölum sem Orkustofnun lét í té um launakostnað á Íslandi; kostnað við vinnubúðir og uppihald og annan slíkan kostnað, var áætlaður vinnslukostnaður á hvert tonn af hreinsuðum surtarbrandi. Stofnkostnaður námu með tilheyrandi vélum og mannvirkjum var áætlaður út frá reynslu í Bretlandi. Gert var ráð fyrir 20 ára afskriftartíma stofnkostnaðar og 8% raunvöxtum.

Á tveimur staðanna, Stálfjalli og Dufansdal-Þernudal, var ekki talið gerlegt að hreinsa surtarbrandinn vegna þess að eðlisþyngd leir- og grjótlaga í og í kringum hann er svo lík eðlisþyngd brandsins sjálfs. Þar er því gert ráð fyrir að selja brandinn eins og hann er unninn, og er hitagildi hans fyrir þá sök m.a. lægra þar en brandsins frá Botni og úr Straumnesfjalli, sem gert er ráð fyrir að hreinsa. Bæði hitagildi og eðlisþyngd eru metin út frá niðurstöðum rannsókna á þeim sýnum sem tekin voru á stöðunum fjórum sumarið 1984.

Niðurstöður skýrslunnar eru dregnar saman á meðfylgjandi fylgiskjali 2, sem sýnir áætlaðan vinnslukostnað á hvert tonn, hitagildi og vinnslukostnað á orkueiningu á stöðunum fjórum. Reiknuð eru tvö tilvik varðandi surtarbrandsvinnsluna; annað þar sem tollar og aðflutningsgjöld af vélum og búnaði til vinnslunnar eru eftirgefin; hitt þar sem þau eru ekki eftirgefin. Fyrra tilvikið er sambærilegt við það sem tíðkast hefur varðandi innfluttan búnað til raforkuvinnslu úr vatnsafli, þar sem þessi gjöld hafa verið gefin eftir. Til samanburðar er verð á innfluttum steinkolum. Verðlag miðast við október 1984.

Tölurnar sýna meðalverð hjá notanda, þ.e. þær fela í sér vegið meðaltal flutningskostnaðar, auk vinnslukostnaðar. Vægistölur í mati á flutningskostnaði er hlutfallslegt magn þess eldsneytis sem flutt er til hvers um sig þeirra staða sem taldir eru hér að neðan. Þær hlutfallstölur eru sem hér segir:

	Heildarmagn		
	25 000 t/a	65 000 t/a	100 000 t/a
Ísafjörður	44,0 %	16,9 %	11,0 %
Bolungarvík	30,0 -	11,5 -	7,5 -
Patreksfjörður	26,0 -	10,0 -	6,5 -
Akranes	0,0 -	61,0 -	75,0 -
	100,0 %	100,0 %	100,0 %

Á hverjum um sig hinna fjögurra hugsanlegu vinnslusvæða á Vestfjörðum eru tiltækar upplýsingar um surtarbrand fyrst og fremst frá einum eða örfáum stöðum á hverju svæði. Vitað er að þykkt surtarbrandslaga er mjög misjöfn. Af þessum sökum töldu hinir bresku sérfræðingar ekki varlegt að gera ráð fyrir að hver staður gæti talist fulltrúi nema fyrir næsta nágrenni sitt, og "næsta nágrenni" þótti þeim hæfilega metið 2 km^2. Þar sem þykkt surtarbrandslagsins í þessum 2 km^2 leyfir ekki 100 000 tonna vinnslu í 20 ár var þeirri magntölu sleppt í áætluninni, en það var alls staðar nema í Stálfjalli, þar sem lagþykktin er nægjanleg til að vinna megi 100 000 tonn á ári í 20 ár úr 2 km^2. Tölurnar þaðan benda hins vegar til að áhrif vinnslumagnsins á vinnslukostnaðinn séu lítil eftir að komið er upp í 65 000 t/a og þar yfir.

Af töflunni sést, að Botn ætti að geta gefið ódýrastan surtarbrand, reiknað á orkueiningu, fyrst og fremst vegna hærra hitagildis á brandinum þar en annars staðar. Raunar munar ekki miklu á hitagildinu í Botni og Straumnesfjalli, en vegna erfiðra aðstæðna þar, óbyggðar o.fl. verður vinnsluksotnaður á tonn mun hærri, og þess vegna einnig á orkueiningu.

Samanburðurinn við innflutt steinkol sýnir að frá besta staðnum, Botni, myndi surtarbrandur verða um þrisvar sinnum dýrari á orkueiningu en innflutt kol, komin til notenda, jafnvel þótt tollar og aðflutningsgjöld af vélum og búnaði til vinnslunnar séu ekki reiknuð.

Til að yfirlit fáist yfir lengra tímabil er á fylgiskjali 3 sýnt raunverð á kolum undanfarin 10 ár í samanburði við áætlaðan kostnað surtarbrands frá Botni, án tolla og aðflutningsgjalda af vélum og búnaði til námuvinnslu.

Í skýrslu BMCL eru gerðar tillögur um frekari rannsóknir á stöðunum fjórum ef menn vilja kanna þá nánar, en með tilliti til lélegra gæða surtarbrandsins annars staðar, erfiðleika við vinnslu þar og erfiðleika við að hreinsa brandinn eftir vinnslu, svo og flutningserfiðleika, er lagt til að ef farið verður út í frekari rannsóknir á vettvangi verði þær takmarkaðar við Botn. Þær rannsóknir, sem þar er talið að gera þyrfti í fyrstu eru fólgnar í því að hreinsa skriður og önnur laus jarðefni á tveimur stöðum, ca. 500 og 1000 m vestan við gömlu námuna í Botni og grafa sig þar að surtarbrandinum (ef hann er þar fyrir hendi), og að bora tvær holur 500 og 1000 m austan við námuna, meðfram þjóðveginum til Ísafjarðar. Tilgangur þessarar könnunar er að ganga úr skugga um frekari útbreiðslu og þykkt surtarbrandslaganna á þessum stöðum.

Með tilliti til hins mikla verðmunar á surtarbrandi frá Botni og innfluttum kolum og tilliti til þess, að verðlag á þeim hefur verið nokkuð stöðugt að raungildi undanfarin 10 ár leggur Orkustofnun til að slíkar rannsóknir verði látnar bíða þar til raunverðlag á kolum hefur um nokkurt árabil hækkað verulega, þannig að ætla megi að surtarbrandur verði innan fárra ára samkeppnisfær við innflutt kol.

Heildarniðurstaðan af þeim rannsóknum sem þegar hafa farið fram innan ramma áðurnefndrar ályktunar Alþingis frá 22. mars 1983 (liðir 1-5 á fylgiskjali 1) er því sú, að íslenskur surtarbrandur sé sem stendur langt frá því að vera samkeppnisfær við innflutt steinkol og hafi ekki verið það a.m.k. síðustu tíu ár. Þetta gildir hvort heldur brandurinn er notaður sem eldsneyti eða sem iðnaðarhráefni. Með hliðsjón af því telur Orkustofnun ekki vera rök til þess frá því sjónarmiði að afla ódýrs eldsneytis eða hráefnis til iðnaðar að halda áfram síðari hluta surtarbrandsrannsóknanna, þ.e. liðum 6-10 á fylgiskjali 1 fyrr en þróun kolaverðs gefur til kynna að surtarbrandur kunni að verða samkeppnisfær við innflutt steinkol á næstu fimm árum eða svo þar á eftir.

Að endingu er rétt að minna á að þetta er í fyrsta skipti sem alvarleg tilraun er gerð til að meta íslenskt eldsneyti sem orkugjafa eða iðnaðarhráefni út frá nútímalegum viðhorfum og tækni. Miklar rannsóknir hafa sem kunnugt er farið fram á öðrum íslenskum orkulindum. Ýmsir hafa lengi velt því fyrir sér hvort nýting á íslensku eldsneyti eins og surtarbrandi gæti einnig verið vænleg. Um önnur svör hefur ekki verið að ræða en huglægt mat hvers og eins. Þessi athugun er því fyllilega tímabær og málið ætti nú að liggja mun ljósar fyrir en áður.

Allra virðingarfyllst,

Jakob Björnsson

Jakob Björnsson

ORKUSTOFNUN

1984 01 09

Verkliðir í athugun á hagkvæmni surtarbrandsvinnslu á Vestfjörðum
JB/sg

1. Söfnun eldri upplýsinga um surtarbrand á Vestfjörðum og vinnslu hans.

2. Skoðun jarðfræðinga á helstu surtarbrandsstöðum á Vestfjörðum; taka sýnishorna og rannsókn á þeim.

3. Samning skýrslu, með ítarlegum útdrætti á ensku, þar sem dregnar eru saman upplýsingar úr liðum 1 og 2. Þessi skýrsla felur í sér þær upplýsingar sem ráðunautum í vinnslutækni surtarbrands eru fengnar í hendur.

4. Frumúttekt á vinnsluhagkvæmni surtarbrands á þeim stöðum á Vestfjörðum þar sem vinnsla þykir vænlegust á grundvelli upplýsinga í skýrslunni og að undanfenginni skoðun vinnslutækniráðunauta á aðstæðum á mismunandi stöðum. Úttektin er unnin af breska ráðgjafafyrirtækinu British Mining Consultants, en menn frá því fara í skoðunargerð um Vestfirði sumarið 1984, og skila skýrslu sinni 2-3 mánuðum eftir þá för. Úttektin miðast við 25000, 65000 og 100 000 tonna vinnslumagn á ári.

5. Frumúttekt á hugsanlegum markaði hér á landi fyrir surtarbrand sem orkugjafa.

6. Úttekt á brennslutækni sem hæfir notkun surtarbrands og hugsanlegum markaði fyrir hann hérlendis. Samanburður á kostnaði þeirrar tækni við brennslutækni fyrir kol og olíu; mat á reynslu af henni annars staðar.

7. Frumúttekt á iðngreinum sem nýtt gætu surtarbrand sem hráefni og hugsanlegt væri að starfrækja hér á landi.

8. Nánari athugun á hagkvæmni surtarbrands sem orkugjafa, á grundvelli 4, 5 og 6, með áherslu á þeim sviðum þar sem líklegt þykir að hagkvæmni surtarbrandsnotkunar verði mest.

9. Nánari athugun á hagkvæmni iðnaðar sem nýtir surtarbrand sem hráefni, á grundvelli liða 4 og 7, með áherslu á vænlegustu iðngreinunum.

10. Lokaskýrsla um hagkvæmni surtarbrandsvinnslu til orkuvinnslu og iðnaðar.

Liðum 1 og 2 er lokið, og lið 3 lýkur á útmánuðum 1984. Liður 4 verður unninn sumarið 1984 og lýkur um haustið. Lið 5 lýkur vorið 1984. Liðir 6, 7, 8, 9 og 10 bíða niðurstöðu úr lið 4.

Orkustofnun vinnur liði 1,2, 3 og 5. Breska ráðgjafafyrirtækið British Mining Consultants annast um lið 4, í samvinnu við Orkustofnun og Orkubú Vestfjarða, sem einnig aðstoðaði við lið 2. Iðntæknistofnun Íslands vinnur lið 7 í samvinnu við Rannsóknarráð ríkisins. Ráðstöfun annara liða bíður niðurstöðu úr 4.

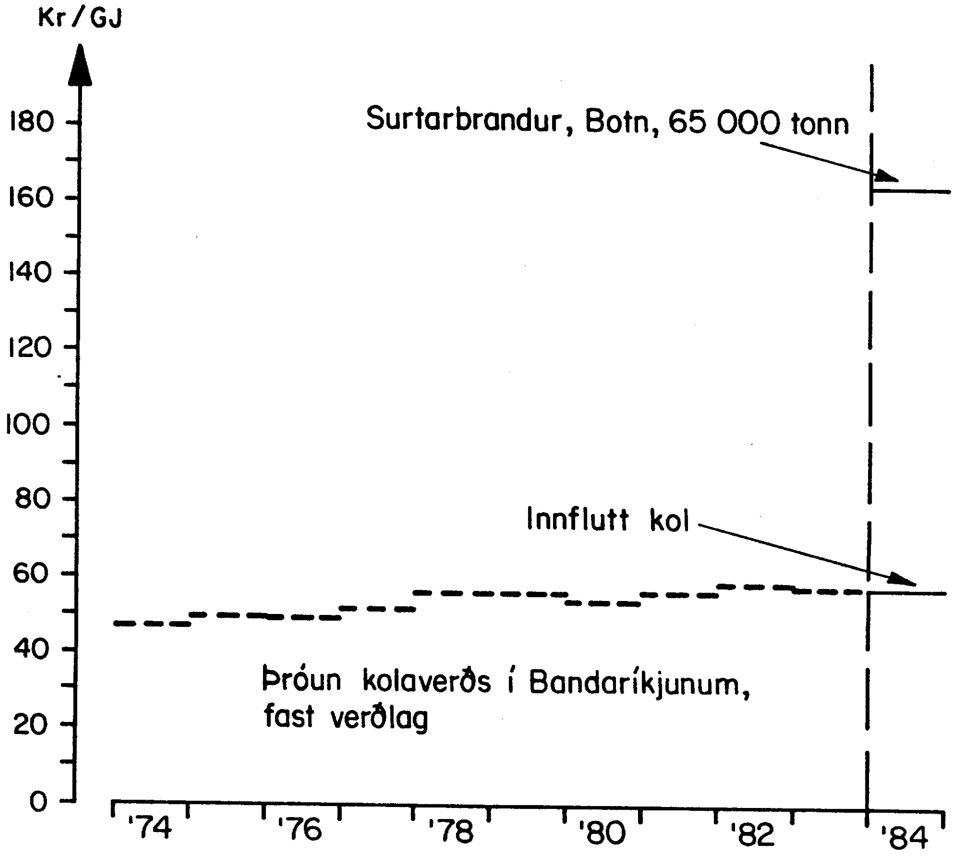
Fylgiskjal 2

Vinnslukostnaður surtarbrands á nokkrum stöðum á Vestfjörðum
Verðlag í okt. 1984

	Án tolla og aðfl.gjalda af vélum og búnaði til vinnslunnar			Með tollum og aðfl.gjöldum af vélum og búnaði til vinnslunnar		
Árlegt vinnslumagn, t	25 000	65 000	100 000	25 000	65 000	100 000
Staður						
Botn						
Kostnaður á tonn, kr/t	3027	2282	-	3736	2821	-
Hitagildi, GJ/t	13,86	13,86	-	13,86	13,86	-
Kostnaður á GJ, kr/GJ	218	165	-	270	204	-
Dufansdalur og Þernudalur						
Kostnaður á tonn, kr/t	3060	1601	-	3719	1976	-
Hitagildi, GJ/t	7,70	7,70	-	7,70	7,70	-
Kostnaður á GJ, kr/GJ	397	208	-	483	257	-
Straumnesfjall						
Kostnaður á tonn, kr/t	4617	3013	-	5317	3542	-
Hitagildi, GJ/t	11,50	11,50	-	11,50	11,50	-
Kostnaður á GJ, kr/GJ	401	262	-	462	308	-
Stálfjall						
Kostnaður á tonn, kr/t	3788	1876	1777	4456	2251	2151
Hitagildi, GJ/t	8,43	8,43	8,43	8,43	8,43	8,43
Kostnaður á GJ, kr/GJ	449	223	211	529	267	255
Innflutt steinkol						
Kostnaður á tonn, kr/t	1590	1535	1523	1590	1535	1523
Hitagildi, GJ/t	26,58	26,58	26,58	26,58	26,58	26,58
Kostnaður á GJ, kr/GJ	60	58	57	60	58	57

Fylgiskjal 3

VOD-OB-963-JV
84.12.1634-GSJ



Verð á innfluttum kolum, þróun kolaverðs í Bandaríkjunum og áætlaður kostnaður við vinnslu surtarbrands. Verðlag á 3. ársfjórðungi 1984

British Mining Consultants Limited

Preliminary Assessment

of

Economic Feasibility of Lignite Mining in Iceland

to

National Energy Authority

October 1984

CONTENTS

CHAPTER V continued

CHAPTER V (continued)

CHAPTER VI continued

LIST OF APPENDICES

LIST OF TABLES

LIST OF PLATES

EXECUTIVE SUMMARY

1. The limited geological data show that mineable seams at three sites are less than 1 m thick and, at the fourth, 1.2 m thick. The lateral extent of the reserves has not been proven, and the available data regarding reserves are only sufficient for designing a hypothetical mine layout and undertaking a preliminary outline costing.

2. The sampling of the lignite shows that it is of low calorific value, with a high ash and moisture content. At some of the localities it is of very poor quality.

3. The initial capital estimates range from approximately IKr124 million at Botn, to approximately IKr523 million at Straumnesfjall. These estimates exclude interest charges and possible taxes and tariffs.

4. The total capital and operating costs, per tonne of lignite, for the four sites range from IKr1,601 to IKr4,617. (These include interest charges but exclude possible tariffs and taxes.)

5. Allowing for differences in heat value, the lowest total cost per tonne (achievable at Botn) is three times more expensive than imported coal.

6. It is therefore considered that, on the grounds of the poor quality of the lignite, the difficulty of cleaning the material and the high total costs of mining and transportation, any further work should be confined to limited exploration at Botn. When this is carried out, a more detailed study of the deposit there could be made.

CHAPTER I

INTRODUCTION

BACKGROUND

1. The National Energy Authority (NEA) of Iceland wishes to determine the economic feasibility of producing lignite from deposits in north-west Iceland. Arising from an initial contact between its Director General, Mr Jakob Bjornsson, and Mr R B Dunn, then Director General of Mining, National Coal Board (NCB), an outline Terms of Reference was passed to British Mining Consultants Limited (BMCL), the overseas consultancy arm of the NCB. A proposal in response to Mr Bjornsson's letter to Mr Dunn, dated 19th May 1983, was submitted by BMCL to the NEA in June 1983.

2. The geological information regarding the lignite deposits in north-west Iceland is limited, and insufficient reserves have been identified on which to base a formal mine plan in the localities suggested to BMCL for evaluation.

3. Because the history of mining lignite in the north-west peninsula is confined to periods during the last two world wars, there is a limited amount of previous mining experience.

4. Because of the high cost of exploration the client has decided to commission a preliminary assessment of the economic feasibility of lignite mining. A number of assumptions on the geometry, distribution and quality of the lignite will have to be made on which conceptual mine plans and preliminary cost estimates can be based.

TERMS OF REFERENCE

5. The Terms of Reference of BMCL's proposal, dated 17th June 1983, and given in Appendix "A" of this report, were accepted by the NEA on 6th June 1984.

6. The following scope of work was proposed:-

(i) Study the existing geological information on the lignite deposits.

(ii) Examine the available information on previous mining, eg plans, methods, etc.

(iii) Visit the site locations on the north-west peninsula.

(iv) Carry out geological examinations and collect samples if appropriate.

(v) Examine sites for evidence of previous mining.

(vi) Interview any personnel who participated in previous mining activities.

(vii) Examine the transportation routes from the mine sites to the appropriate vessel loading points.

(viii) Identify the mining and transportation problems.

(ix) Develop conceptual plans to solve or minimise these problems.

(x) Develop rough estimates for mining and transportation costs.

(xi) Evaluate the alternative plans using qualitative and quantitive criteria.

(xii) Using the best alternatives, make assessments of the economic feasibility for the three tonnage levels of 25,000 tonnes per annum (tpa), 65,000 tpa and 100,000 tpa.

(xiii) Develop a programme for further exploration if appropriate.

7. With regard to the collection of samples referred to in (iv) above, 55 samples were collected during the study. It was agreed with Mr Bjornsson, on Friday 24th August 1984 that the BMCL team would transport these samples to the UK for testing purposes. Of the samples, 31 were lignite measures/mudstones, and 24 tuff and mudstone with some lignite. The tests to be carried out on all the samples would be for specific gravity, ash content, and moisture. Further analysis was carried out on some of the 31 lignite material samples, together with lignite from some of the remaining 24, including tests for volatile matter, calorific value, carbon, hydrogen, sulphur and chlorine, ash fusion temperature and ash analysis. Not all of these tests were carried out on every sample.

8. It was agreed with Mr Bjornsson on 24th August 1984 that the charges for these tests, estimated to amount to £3,800, would be in addition to the charges for the original study.

OBJECTIVES

9. The object of the study was therefore to assess the feasibility of mining lignite from the most promising sites, using the most appropriate mining technology, and transporting the lignite to a place where it might be loaded on vessels. The delivered cost of the lignite was compared with that of imported hard coal and, since viability can be a function of quantity, three levels of output were assessed, namely 25,000 tpa, 65,000 tpa, and 100,000 tpa.

PERSONNEL

10. The project was carried out under the direction of Dr R K Dunham, Executive Director - Mining, BMCL. The project team, which visited Iceland between 11th August and 25th August 1984, comprised the following:-

Mr K Lumsdon, Senior Mining Engineer, BMCL.
Mr R F Goossens, Deputy Chief Geologist, NCB.

UNITS

11. SI measurements (millimetres and metres) have been used in the report, except in the case of seam sections and the related appendix (Appendix "B") where centimetres have been used throughout.

12. Cost data are given in Icelandic Krona, valid for the third quarter of 1984. Where costs have been factored from other cost data an exchange rate of £1 = IKr40.9 has been used.

DATA BASE

13. A study of the lignite deposits in the north-west peninsula is available in a report written by Mr Freysteinn Sigurosson and Dr Kristjan Saemundsson of the NEA, dated April 1984. This report includes a summary in English. Other parts of the text were translated during the BMCL visit by Dr Saemundsson.

14. Lignite quality data are based on analyses carried out by the NCB laboratories at Wath-upon-Dearne, South Yorkshire.

15. A considerable amount of the cost data has been obtained from the NEA.

16. The sites are covered by topographic maps at the scale of 1:50,000 and 1:100,000. Geological maps of the area, at a scale of 1:250,000, are also available.

ACKNOWLEDGEMENTS

17. The assistance of Mr Jakob Bjornsson and his staff at the NEA is gratefully acknowledged. Special thanks are due to Mr Jon Vilhjalmsson, Dr Kristjan Saemundsson and Mr Birgir Jonsson.

CHAPTER II

REGIONAL SETTING

INTRODUCTION

1. Lignite occurs in many localities in Iceland, mainly within the Tertiary plateau basalt series. It is most common in the north-west peninsula and most of the information on lignite in Iceland relates to occurrences in this peninsula.

2. The north-west peninsula lies between latitudes 65°20' and 66°40' N and longitude 23° and 24° W some 220 km north of Iceland's capital, Reykjavik. The main town and seaport of the north-west peninsula is at Isafjordur (see Plate 1).

3. There is no mining of lignite taking place in Iceland at the present time. It has only been during periods of import crisis during the world wars that its exploration was necessary. A number of mines were started during the First World War. Only one deposit at Botn was mined during the Second World War.

4. Within the north-west peninsula, seam sampling and the investigations of the lignite deposits have been concentrated at the following locations (see Plate 2):-

(i) Botn - approximately 10 km west of Isafjordur.

(ii) Gil - approximately 10 km west-north-west of Isafjordur.

(iii) Dufansdalur and Thernudalur - approximately 55 km south-west of Isafjordur.

(iv) Straumnesfjall - approximately 36 km north of Isafjordur.

(v) Stalfjall - approximately 80 km south-west of Isafjordur.

The distances quoted in the above from Isafjordur are direct and not overland or sea distances.

COAL IMPORTS

5. Coal imports to Iceland at present are mainly for the ferrosilicon smelting plant at Grundartanga (30,000 to 40,000 tpa) and for the cement works at Akranes, (20,000 tpa). The cement works coal has a thermal value of 6,300 to 6,400 kcal/kg and the price is IKr1,500/tonne (US$50) at the factory gate. The coal for the ferrosilicon factory is washed and sieved and costs about IKr2,000/tonne (US$65). BMCL understands that the contract for the imported coal expires at the end of the year.

PRIMARY ENERGY CONSUMPTION

6. Primary energy consumption in 1983 was as follows:-

	Tonnes of Oil Equivalent
Hydro	840,000
Geothermal	520,000
Oil	490,000
Coal	30,000
Total	1,880,000

ELECTRICITY GENERATION

7. Electricity generation in 1983 was as follows:-

	Giga Watt hour
Hydro	3,588
Geothermal	172
Oil	6
Total	3,766

Installed capacity is 908 MW.

ENERGY FOR HEATING

8. Energy for heating in Iceland was estimated to be around 4,000 GWh (used energy) in the year 1983. Energy sources for heating were:-

Electricity	15%
Geothermal	80%
Oil	5%

In 1983 two district heating systems in the north-west peninsula used 39 GWh of electricity and two in the east used 29 GWh.

PHYSICAL GEOGRAPHY AND CLIMATIC CONDITIONS

9. The terrain in the north-west is rugged, with mountains generally rising steeply from the coast to heights of between 500 and 800 m above mean sea level (amsl).

10. The snow line in the north-west peninsula is approximately 600 m amsl.

11. The annual precipitation in the region of the possible mine sites is estimated to range between 1,200 and 1,600 mm per year. The temperature can be expected to vary from -20^{0}C in the winter to +20^{0}C in the summer months at sea level. The temperature is estimated to decrease by 1^{0}C for every 100 m of altitude.

DEPOSITS - LOCATION, ACCESS AND SERVICES

Botn

12. The lignite exposure and former workings at Botn is at the head of the Suganda Fiordur, approximately 13 km from Isafjordur and 10 km from Sudureyri.

The lignite has been exposed on a steep mountain side approximately 140 m amsl, where a waterfall has washed away debris and clay from the vertical faces of the upper layers.

13. The access from the main road to the former mine workings is by a steep stone road/track which is in a very bad state of repair. Access along the road to the fishing village of Sudureyri is via a good unmettalled road approximately 10 km long along the floor of the valley and which should not create special problems in winter. The road from the mine to Isafjordur is approximately 13 km long, very steep and over a mountain top (540 m elevation) and it is estimated that this road could be closed for four months during the winter.

14. Water for the mine would be available from the waterfall adjacent to the mine entrance. Environmentally, consideration would have to be given to the fish farming ponds at the head of the fiord which could be affected by polluted water from the mine. To connect an electric power supply to the mine site would involve 5 km of transmission lines.

Gil

15. The lignite deposits at Gil are approximately 5.5 km from Bolungarvik, a prosperous fishing village approximately 15 km from Isafjordur. The former workings are reached by walking over heathland approximately 1 km from the end of an unmettalled road. An access road to the mine from the existing road would be fairly difficult to construct and maintain. Water would be available from the swiftly flowing streams nearby. There is no electricity power supply at the site. Accessibility of the mine from Bolungarvik and Isafjordur is reasonable.

Dufansdalur and Thernudalur

16. Two former lignite mines are sited approximately 13 km from Bilduldalur near the Fossfjordur. One mine was sited at the nose of the mountain, the Dufansdalsnupur, at approximately 160 m amsl. The surface area available at the mine entrance is virtually nil and there would be a danger from falls of material from the steep basalt rocks above the exposure. It would be difficult to lay on a water supply to this site.

17. The former workings at Thernudalur are situated at the head of the valley in the vicinity of a very fast flowing stream, which could be used to supply water to the mine. There is no electric power to either site of the former workings at Dufansdalur and Thernudalur and to connect a power supply would involve approximately 6 km of transmission lines.

18. It would require approximately 1 km of road to be constructed from the mine site at Thernudalur to the existing road and a new pier would need to be constructed at the Fossfjordur. The Fossfjordur is deep and does not freeze over in winter. There is a community of 350 people at Bilduldalur approximately 13 km away, with a good access road along the valley floor. There is a small airport adjacent to this road, and this road is usually kept open in winter. Because of the terrain at the valley head at Thernudalur, the surface heapstead would be difficult to construct.

Straumnesfjall

19. The lignite in two layers outcrops at approximately 180 m amsl on the very steep cliffs at Straumnesfjall. The area is uninhabited and has to be reached by a three hour boat trip from Isafjordur. Landing below the cliffs is possible only in calm weather; alternatively the outcrops can be reached on foot from Latrar (three to four hours walk).

20. During the First World War, some limited amount of pickings from the lignite exposure took place. The lignite was loaded into sacks, lowered down the cliff and transported by sea in rowing boats to Isafjordur. There has been no other mining of the lignite in this area.

21. There are no electric transmission lines to the area and a power supply would have to be by submarine cable or by diesel generators. Pier facilities could be constructed in the sheltered area at Latrar.

22. An old road to the top of Straumnesfjall also exists and could be used to give access to a mine site at the top of Straumnesfjall (approximately 400 m amsl). The road rises over 300 m in a short distance and would be a difficult access. There are no settlements in the area and a camp site for the mine would have to be provided. There is no obvious supply of water for the mine but it is possible that it could be supplied from a local tarn in the general area. No borehole information regarding lignite exists in the area. The general area is very isolated.

Stalfjall

23. A mine was established during the First World War at Stalfjall. The lignite exposures were accessed at approximately sea level, with access to the mine site from the sea. Landings could only be made in very calm weather. The alternative access is a short road journey from Melanes, at the southern end of Baejarvadall, and then a two hour walk to the top of the cliffs above the exposure. The cliffs in the area are very steep and are up to 650 m amsl. Access down the cliffs is difficult. At the former mine site, there is only a very limited surface area available, with a risk of rock falls from the steep basalt cliffs above.

24. There is no electric power supply or water supply to the existing site. There are no harbour facilities near to the existing mine site and new facilities here would be very difficult and costly to construct. New harbour facilities would have to be made at Vatneyri, approximately 35 km north-west and extensive new road facilities from a conceptual mine site to existing roads would also be required. The area is sparsely inhabited and a camp site is likely to be necessary in the first instance.

CHAPTER III

GEOLOGY

GENERAL GEOLOGY

Stratigraphy

1. The geological sequence of the north-west peninsula comprises a series of volcanic rocks, mainly basalt lava flows, totalling over 3,000 m in thickness and of Upper Miocene age. Within this sequence Dr Saemundsson has identified four short sedimentary intercalations. These are widely spaced in the volcanic series, varying from a few millimetres up to 10 m in thickness, and have quite wide lateral extents. It is within these sedimentary deposits that the lignite layers occur, together with beds of dark carbon-rich mudstones and numerous streaks and bands of tuff.

2. Since the sedimentary rocks are softer than the enclosing basalts, the outcrops are frequently expressed as topographic "slacks" in the steep mountain slopes with overlying and underlying crags of basalt.

Structure

3. The volcanic sequence and the enclosed sedimentary beds dip gently to the south-east. The dip is almost flat in the extreme north-west of the peninsula and increases slowly to the south-east to about 10°. The exposures visited show local fluctuations of dip and several small faults. These could be the result of compactional structures associated with the irregularities of the upper and lower surfaces of the nearby basaltic rocks. There is no evidence of large faults.

4. Near-vertical igneous dykes could be seen cutting through the volcanic rocks and also the sedimentary beds at some localities. The frequency of the dykes is variable and they show some tendency to occur in groups. The dykes have mainly a north-east to south-west trend.

SITES EXAMINED

Botn

5. The lignite seam is exposed high on the valley side at the old mine entrances. The mine tunnels were not accessible because of water but the seam was available for sampling at the sides of the right-hand tunnel. The overlying basalt is hard with joints about 0.3 to 0.5 m apart and over 6 m is well-exposed. Beneath the basalt lies 2.15 m of grey and dark grey mudstone with bands of tuff. This strata was friable and would not give a stable roof if mining without supports. At the left-hand side of the right-hand tunnel these mudstones, etc have a thickness of 0.85 m because they are cut diagonally by a 1.3 m fault. The fault had an east to west strike and a downthrow to the south. The seam section at the left-hand side of the right-hand tunnel was as follows:-

Lignite with five or six thin tuff layers, totalling about 3 cm	42 cm)
Light grey tuff	2 cm)
Lignite with tuff streaks	10 cm)

Light grey tuff, variable thickness	1 to	4 cm)	
Lignite		6 cm)	
Light grey tuff, variable thickness	2 to	3cm)	77 to 79 cm
Lignite		8 cm)	
Alternating lignite and tuff		4 cm)	
Dark grey mudstone		-	

6. At the right-hand side of the right-hand tunnel, the seam was measured and sampled as follows:-

Dark grey mudstone with tuff bands and ochre staining	30 cm	
Shaly lignite with many thin tuff layers and streaks	50 cm)	
Pale brown-grey tuff with plant impressions	5 cm)	100 cm
Lignite and fossil wood with two pale brown tuff bands, 2 cm at 5 to 7 cm from the top, and 5 cm at 9 to 14 cm from the top	45 cm)	
Dark mudstone with tuff layers and fossil wood	30 cm	

7. Information from various sources indicates that this section is unusually thick and that the section at the left-hand side of the tunnel is more representative of the mine. The proportion of lignite to tuff is the same at both sides.

<u>Gil</u>

8. The lignite at this location was considered by Dr Saemundsson to be the same as that at Botn and could be seen in the isolated old mine. The overlying basaltic rock is a massive hyaloclastite at least 6 m thick with a few widely spaced joints (6 to 8 m apart). This forms the roof of the mine tunnels. At the end of the longest tunnel the section sampled and measured was as follows:-

Interbedded tuff and mudstone, friable	70 cm
Lignite and fossil wood with tuff layers and streaks	61 cm
Dark mudstone with tuff bands	30 cm

9. In a small side tunnel the seam was only 40 cm thick. At about 10 m from the mine entrance further samples were taken and the section was as follows:-

Interbedded tuff and mudstone	40 to 50 cm
Lignite and fossil wood with tuff wedges and nodules	50, 52, 54 & 55 cm
Dark mudstone with tuff bands	approx 80 cm
Fossil wood	approx 30 cm

10. In a small tunnel adjacent to the waterfall and some 20 m from the mine the seam was measured at 40 cm. Just outside the main mine entrance a strong basalt dyke was well-exposed and was about 3 m wide.

11. Although the seam at Gil is the same as the one mined at Botn, the thinner and very variable sections indicate a much poorer development which offers little possibility for modern mining.

Dufansdalur and Thernudalur

12. The lignite seam at this locality is younger than that of Botn and Gil and is exposed at two points: at Dufansdalur high on the steep mountain slope below very steep basalt crags where a single tunnel has been driven into the mountain, and about 1.5 km to the south-west where two small mine tunnels had been made near the waterfall at Thernudalur. There was evidence of another tunnel entrance nearby.

13. The tunnel in the nose of the mountain at Dufansdalur was driven beneath massive jointed basalts. About 1.1 m of strata separated the basalt from the seam and floor measures had been excavated in the tunnel. Two samples were obtained with difficulty. The higher sample, taken about 0.5 m below the basalt was a carbonaceous mudstone with tuff bands, and the lower one, 1.1 m below the basalt was a coarse-grained tuff with some fossil wood. The mine tunnel exposed 2.2 m of seam and floor measures, of which the lowest 20 cm was below water level. The tunnel had a very slight falling gradient into the mountain and was therefore inaccessible except near the entrance where the sequence was well-exposed, sampled and measured and was as follows:-

Inferior lignite with tuff bands	28 cm)	
Interbedded, very inferior lignite with carbonaceous mudstone and tuff bands	39 cm)	
Interbedded, very inferior lignite and carbonaceous mudstone and tuff bands	44 cm)	154 cm
Inferior shaly lignite with some tuff bands	8 cm)	
Very carbonaceous mudstone with tuff bands	27 cm)	
Very inferior shaly lignite	8 cm)	
Dark brown blocky carbonaceous mudstone with some pale brown tuff bands	46 cm	
Stained brown mudstone with lignite bands	20 cm	

14. The tunnel had stood well since mining 67 years ago and the roof was strong and even.

15. At Thernudalur the seam was sampled at the entrance to the small cave-like mine. The basaltic strata was a massive hyaloclastite breccia separated from the lignite seam by 0.45 m of siltstone with a little fossil wood. The section of the seam and floor measures was as follows:-

Inferior shaly lignite with thin tuff and carbonaceous mudstone bands	58 cm)

Dark brown mudstone with grey tuff bands	120 cm	
Inferior shaly lignite with green tuff bands	55 cm	
Interbanded tuff, mudstone and lignite up to 3 cm thick (25% lignite)	150 cm	
Shaly lignite	18 cm	
Carbonaceous mudstone and tuff with some fossil wood	11 cm	
Shaly lignite with tuff bands	9 cm	
Coarse light grey tuff with bands of shaly lignite 2 to 6 cm thick	45 cm	
Very inferior lignite with thin tuff bands	30 cm)	
Inferior shaly lignite with thin tuff bands	30 cm)	
Inferior shaly lignite with pale brown tuff bands	30 cm)	120 cm*
Inferior lignite with pale brown tuff bands	30 cm)	
Pale brown coarse-grained tuff, carbonaceous in parts	50 cm	
Tuff and strong mudstone	300 cm	

* This seam was sampled in four 30 cm subsections because of little visual variation.

HYDROGEOLOGY

22. At all the sites the overlying strata is essentially a sequence of basalts of considerable thickness. These rocks have virtually no primary porosity or permeability. However, they are often well-jointed and, because they contain very little clay material, would give rise to open joint systems when undermined. This would give a high joint permeability and would provide easy passage for ground water into mine workings. Where these open joint systems occur below streams, then considerable quantities of water could flow into the mine. It is with these factors in mind that the conceptual mine layouts take advantage of the low strata dips to obtain self-draining conditions.

SEAM THICKNESS AND CONTINUITY

23. The various localities show sections of lignitic material up to 1.8 m thick, but when looked at from a mining and quality point of view the most attractive sections are in the 75 to 120 cm range. At this thickness range the continuity of seams is particularly important for mining. At Botn the old tunnels indicate a continuity of 100 m, but at Gil very rapid changes in thickness are evident. At the other localities the continuity is also suspect and therefore further exploration is essential before any mining takes place. The conceptual mine plans call for seam continuity at workable thickness for up to 2 km^2. This calls for seam provings over this distance at intervals of not more than 500 m.

ASSOCIATED STRATA

24. The lignite sequences always contain sedimentary material in the form of mudstone and tuff. The mudstone at some localities is carbonaceous and contains

woody lignite. The overlying and underlying mudstones usually contain a high proportion of tuff bands. Where this is the case, the roof and floor measures (when mining takes place) should hold reasonably well and at the same time should cave satisfactorily on longwall faces. The basalts would behave in mining conditions according to their joint frequency ie, the well-jointed basalts should cave satisfactorily whilst the poorly jointed hyaloclastites could give rise to difficult roof control and abnormal and uneven roof collapse. The tuff bands, layers and streaks within the seams are considered sufficiently weak to mine with the lignite without giving problems. However, when the mined product is washed, the thin layers and streaks will be difficult to remove. In some cases the specific gravity of the tuff is not sufficiently different from the inferior lignites to achieve separation. In such cases the whole mined product would have to be marketed untreated and would be a very low quality product as a result.

SEAM QUALITY

25. The analyses of the seams and associated strata are set out in Appendix "B". It will be seen that the degree of analytical work has been varied according to the type of material. It should be noted that the samples were all air dried at 106^{0}C before analysis. This gave a standard material but the moisture contents shown are less than those that will occur in mining, particularly when washing takes place.

26. All the samples were notably low in sulphur content and also in chlorine content.

RESOURCES AND PRODUCT QUALITY

27. Because of the lack of proved continuity of the lignite bands at workable thicknesses the resources at the various locations can only be assumed to be present. Further exploration could prove that the continuity is inadequate and consequently the resources assumed to be present to carry out conceptual mine planning and financial assessment may be severely overstated. In each case a workable area of 2 km^2 has been assumed and the most appropriate seam thickness taken to arrive at the resources in each case.

28. From the analytical data it is possible to estimate the main quality features of the product of mining (and preparation where applicable). These are as follows:-

Botn

29. When the run-of-mine material is washed to remove the main tuff bands, the product, with an assumed moisture content of 30%, would have an ash content of 20.5% and a calorific value of 13,860 kJ/kg.

Gil

30. The main bed of 40 to 60 cm could yield a product with a 30% moisture content (assumed), a 27% ash content, and a calorific value of 10,600 kJ/kg.

Dufansdalur

31. The whole seam would give an untreated product with a 30% moisture content, a 44.3% ash content and a calorific value of 6,410 kJ/kg.

Thernudalur

32. When the 26 cm of tuff is removed the product would have a 30% moisture content, a 36% ash content and a calorific value of 9,050 kJ/kg. If the large cave exposures are more representative then the untreated product would have a 30% moisture content, a 35% ash content and a calorific value of 8,610 kJ/kg.

Straumnesfjall

33. When the mudstone and tuff are removed by washing, the product would have a 30% moisture content, a 23.4% ash content, and a calorific value of 11,500 kJ/kg. These figures would be slightly poorer if the 28 cm top leaf is excluded.

Stalfjall

34. It is not considered economic to attempt to wash the product to remove the tuff bands because of their thinness. The untreated product would have a moisture content of 30%, an ash content of 37% and a calorific value of 8,430 kJ/kg.

CHAPTER IV

EXAMINATION OF AVAILABLE INFORMATION ON PREVIOUS MINING

INTRODUCTION

1. Information on previous mining in the form of papers and reports had been collected by Dr Kristjan Saemundsson of the NEA and these were made available to the BMCL team. The translations into English were made by Dr Saemundsson and Mr Birgir Jonsson. Dr Saemundsson had also obtained names of individuals who could supply some information regarding past mining and these people were met and discussions took place.

2. It must be borne in mind that mining of lignite (on a very limited scale) had taken place at Botn during both world wars and at Dufansdalur, Thernudalur, Gil and Stalfjall during the First World War. As a consequence, the information obtained was often second-hand. There was only one miner still alive, aged 90 years, who had worked in the mine at Stalfjall in 1917.

3. In discussions with Mr Bjornsson, at Reykjavik on 13th August 1984, the question of past mining records, plans, etc was discussed. Dr Saemundsson has not been able to trace any plans of previous mining operations.

4. Most of the information collected from papers, reports and interviews with miners is given in Appendix "C" and is summarised briefly below.

Botn

5. The information is as follows:-

(i) Report by Mr Sigurdar Thorarinsson for Icelandic Government, dated October 1938. One lignite layer, 70 cm thick, topmost part woody. Two tunnels driven in 1917. Reference to much water in the mine.

(ii) Report by Mr F Sigurosson and Dr K Saemundsson, dated April 1984. Thickness of lignite said to be 90 cm but reference to a measurement of the lignite in the tunnel by a geologist of 62 to 75 cm. Workings took place during the First World War and the Second World War. Tunnels go in over 100 m and at present are flooded.

(iii) Interview with Mr Fridberts Peturssoner, Farmer, August 1984. First workings in First World War. Faeroes miners started work in mine in 1941 and finished in spring 1943. They lowered height of tunnels to less than 1 m. He had been informed that the thickness of lignite varied between 70 to 90 cm. Lignite transported over the mountain to Isafjordur by 2.5 tonne lorries during four months of summer only.

BMCL Comment

6. Lignite, 70 to 90 cm thick. Slight mining difficulties with water and weak roof. Reasonable access to main road from mine entrance. Workings took place for about two years in Second World War.

Gil

7. The information is as follows:-

(i) Report by Mr Sigurdar Thorarinsson for Icelandic Government, dated October 1938. Lignite in two layers, thickness, 53 and 55 cm, and 30 cm and 40 cm. Mudstones between the layers approximately 1 m thick. Workings took place during First World War and tunnel advanced 30 m. No large reserves and the deposit gets thinner further inbye.

(ii) Report by Mr F Sigurosson and Dr K Saemundsson, dated April 1984. Thickness of main lignite bed, 50 to 60 cm. The lignite was regarded as very poor burning material.

BMCL Comment

8. Lignite bed very thin, and poor quality. Limited reserves. Workings in First World War for short period only.

Dufansdalur and Thernudalur

9. The information is as follows:-

(i) Report by Mr Sigurdar Thorarinsson for Icelandic Government, dated October 1938. Aggregate thickness at Dufansdalur is 75 cm and at Thernudalur, 90 cm. Workings during First World War. Mining started at Thernudalur because people did not like coal from Dufansdalur.

(ii) Report by Mr F Sigurosson and Dr K Saemundsson, dated April 1984. At Dufansdalur, thickness of lignite, 80 cm. Tunnel 80 to 100 m long. At Thernudalur the lignite entrance is at 100 m amsl. Worked during First World War only.

(iii) Interview with Mr B Olafsson, Farmer, August 1984. Headings at Thernudalur advanced 20 m. Quality of material at Dufansdalur and Thernudalur all bad. Referred to difficulty of access to Dufansdalur mine at nose of mountain. Water experienced in headings at both sites.

BMCL Comment

10. Lignite bed estimated at 75 to 90 cm. Poor quality material. Difficulty of access at Dufansdalur.

Straumnesfjall

11. The information is as follows:-

(i) Report by Mr F Sigurosson and Dr K Saemundsson, dated April 1984. Thickness of lignite observed at outcrop at three localities was as follows:-.

(a) 70 cm of lignite in a total of 4 m of sedimentary layer.

(b) Two beds, one 70 cm thick and 90 cm.

(c) Total of 3 m of lignite but layers are thin and separated by mudstone and ash.

BMCL Comment

12. One exposure is of good thickness but very doubtful quality. No previous mining in the past other than pickings during First World War, hence limited information.

Stalfjall

13. The information is as follows:-

(i) Report by Mr Ivan Svedberg, Swedish Mining Engineer, dated 1916. Lignite thickness, 1.3 m. Reference to difficulty in differentiating between lignite and mudstones. No exact data on aerial extent of lignite layers. Ash percentages of 21.7% and 25% mentioned but also reference to high ash and low thermal value. Three tunnels driven up to 30 m in length. Water did not cause any difficulties. Roof stable. Because there is no port and a difficult wind situation, it was not possible to remove the lignite mined. He refers to the difficulty of setting up mining operations on steep cliff.

(ii) Report on "Coal Mining In Iceland" by Mr H H Eiriksson, Trans of I Min E, Great Britain, Vol LIX, Part I (1919-20). Reference is made to an Icelandic/Danish Company working at Stalfjall, which always "worked at a loss".

(iii) Report by Mr Sigurdar Thorarinsson for the Icelandic Government, dated October 1938. No reference to thickness. Lignite seems to contain a lot of ash. Longest tunnel, 80 m. Cliffs, 650 m high. Reference to very inaccessible location. Mining did not pay and company went bankrupt.

(iv) Tape recording made in 1979 of conversation with former miners of Stalfjall. Workings in 1917. Very difficult to gain access from the sea. Working by drilling, blasting and hand loading. Very little space at entrance to tunnels. No supports in tunnels, roof was very stable. Quality of material did not improve as mine went further in. No lignite was taken from the site.

(v) Interview with Mr H Kristinsson, aged 90, former miner at Stalfjall, August 1984. For every tub of lignite, there were two tubs of waste. The material had poorish heat value. Very difficult access from sea.

BMCL Comment

14. Deposit, approximately 1.3 m thick. No particular mining problems. Poor quality material. Very restricted mine location and difficult access. Previous mining operations worked at a loss. No lignite ever removed from site.

CHAPTER V

PAST AND ALTERNATIVE METHODS OF WORKING

PAST MINING

1. From the available information, lignite mining in Iceland has been confined to:-

(i) Pickings from outcrops on the steep slopes, generally where the lignite has been exposed by water washing away the scree. The pickings have been very limited because the outcrops are usually covered in scree.

(ii) Underground mining. This has usually taken the form of single headings driven from the outcrop into the mountain side. Laterals off the main heading were driven at Botn and Gil. A room and pillar system was developed to a limited extent at Stalfjall. A sketch plan of the workings at Stalfjall is shown on Plate 3.

2. Information from old miners and an examination of the headings at Gil, Dufansdalur and Stalfjall show that the headings were worked without setting supports and these headings are still standing satisfactorily today after over 60 years. When worked, there was no evidence to suggest any occurrence of dangerous mine gases. Water appears to have been encountered in all of the mines but it is not recorded as causing undue difficulties in driving the tunnels. The lignite bed was usually worked with the associated mudstone to a working height of approximately 2 m. At Botn, this practice was changed by the Faeroes miners in the Second World War to a working height of 70 to 90 cm using wooden supports. The method of loosening the lignite at Botn and Stalfjall was by the use of explosives. The lignite was hand loaded. The lignite was transported from the heading to the surface in small tubs, wheelbarrows and sacks. Hand sorting of the mined material to remove bands of tuff and mudstone was required.

3. The mines employed about eight men (maximum) underground.

MINING CONDITIONS

Seam Floor

4. The lignite seam is usually underlain by mudstones and tuff layers. Inspections in 1984 at Gil and Stalfjall showed that the floor of the headings had remained stable.

Seam Roof

5. The lignite seam is usually overlain by a mudstone, but at Thernudalur, above a 58 cm bed of lignite is a 45 cm thick siltstone roof, containing a few pieces of lignite.

6. Above the mudstones/siltstones lie thick deposits of basalt, sometimes columnar and often well jointed. Disturbances of this layer in tunnels would be minimal and therefore the joints would not yield large quantities of water. Disturbance by longwall mining could greatly increase the water yield from the joint system. The overlying basalt beds are strong and although usually well jointed there may be possible caving problems with longwall working.

Lignite

7. The lignite material is present as:-

(i) "fossil wood" forming strong flat lying slabs;

(ii) shaley lignite which can be weak and friable; and

(iii) more blocky material often with a rather canneloid appearance.

8. Associated with these are streaks and bands of tuff of variable thickness and also layers of black mudstone with a low carbon content.

9. The sides of the tunnels seen had stood well suggesting a reasonably competent material.

Seam Gradient

10. At all the localities observed the full dip of the lignite beds was very low. There were local, steeper dips near faults and a regional dip of 7° has been recorded at Stalfjall.

Cover

11. The thickness of cover over the proposed mining areas ranges from outcrop up to 600 m. The cover increases rapidly with an average thickness of 300 m, because of the very steep mountain terrain.

Presence of Water

12. Water was encountered in the underground roadways when lignite was worked in the past. The annual precipitation for the north-west peninsula ranges between 1,200 and 1,600 mm per year. There is insufficient information to enable a reasonable estimate to be made of the water inflow to the mine workings.

Geological Faulting and Dykes

13. The basalts and clastic intercalations are cut by near vertical dykes (common thickness 1 to 4 m). Dyke density is believed to be low. Examination at Gil showed that small faulting had occurred. In discussions regarding past workings at Botn, BMCL was informed that a small fault had been encountered.

ALTERNATIVE MINING SYSTEMS AND WINNING METHODS

Opencast Mining

Introduction

14. The extremely large ratio of overburden to the small, low grade mineral deposits, would render opencast operations extremely expensive. For this reason such an operation would not normally be considered further as a commercial venture.

15. Five areas containing lignite beds were examined. Generally, the geographical and geological circumstances are fairly similar. As an example, the Dufansdalur site was considered in more detail and the following comments are based on examination of this area.

Equipment

16. The bulk of the strata overlying the lignite beds is basalt of high compressive strength. The topography is steep and hard rock outcrops. Such conditions preclude the use of bucket wheel excavator systems, motor scrapers or front end loading shovels or any other methods which rely on easy digging.

17. The only plant suitable for such conditions are heavy duty face shovels equipped with rock buckets. The harsh environment dictates that rope shovels as opposed to hydraulic shovels would give a better availability. Electric drive would normally be cheaper but, because of power supply difficulties, diesel drive would be a more realistic option. Dozer assistance would be imperative.

18. Dragline plant could only be considered if further drilling proved sufficient reserves in relatively flat continuous seams. The initial capital investment would be substantial and, in any case, it would only be realistic to consider a relatively small portion of the overburden for working by such plant.

19. Use of dumptrucks for transporting the overburden is the only realistic method. Any conveyor system would require a very powerful crusher. The capital investment required could not be justified on the low mineral outputs or limited payback periods postulated.

Mining Methods

20. The main lignite bed rises from an elevation of about 140 m on the south-east of the peninsula, to the north-north-west. The ridge and plateau are about 350 m amsl. Side slopes are of the order of 30^0, and are steeper in the exposed basalt. Thus, up to 200 m of burden overlies a relatively thin lignite bearing sedimentary tabular deposit.

21. Such a configuration precludes the use of a simple strip mining technique. Open pit mining is not applicable. Winning of any significant tonnages by contour mining is not possible by virtue of the existing gradients. The only possible method applicable is multi-bench terrace mining entailing progressive mountain top removal from the nose of the promontory into the massif of the mountain range.

22. Benches generally range from 8 to 18 m. A typical bench height applicable here would be 10 to 12 m. Thus, 15 to 20 benches would be required. Each would need to be levelled for blasting.

23. The only realistic and cost effective method of depositing the initial overburden is to fill the valley and fiord area on one side, below the lignite horizon. After a bench is established down to each viable lignite seam, the material arising from progressive advance of the overburden benches could be dumped behind in the worked out areas. This would be cheaper for some of the material, and would mean a less pronounced change to the character of the landscape.

24. Initially, dozing and isolated drilling and blasting would be required at the surface to prepare the top bench. Thereafter, the use of heavy duty, tracked, rotary blast hole drill rigs would be required on each bench, drilling down to the base of the bench. Close burden and spacing and heavy charges would be required in basalt. Excavation by shovel and dumptruck would follow. Dozer assistance on the bench would be required, because of large hard lumps and variations in the floor hindering the traffic of both trucks and drill rigs preparing the next bench.

Mineral Recovery

25. Opencasting permits the winning of thin seams and the careful separation of roof and floor, as well as removal of dirt bands, from the lignite.

26. The cleaning of roof material would be done initially by dozer or grader, followed by a backhoe with a flat blade standing on the "bat" above the lignite carefully cleaning off down to the material to be lifted. Similar plant, or hand labour, could be used to win the bottom of the seam from the floor.

27. Lifting of a thin lignite band should be done by a fully revolving forward shovel fitted with a coal bucket viz: a flat bottomed rear discharge bucket having a large base area and long fine angled teeth flush with the base.

28. It might be possible to win some additional lignite by augering from the final highwall, or even directly into the mountainside without significant excavation. This method, however, would only be feasible if the seam horizon were relatively constant in the direction of augering. Hence, detailed and accurate drilling would be needed to prove such circumstances before investment in an auger system were undertaken. Further, only limited reserves could be extracted by this method. The limited auger size required by the thin seam would only allow a very limited penetration depth. This, allied to the thin seam available, would preclude the winning of large tonnages by this method.

Haul Roads and Services

29. Constant maintenance of haul roads by grader would be required. Grader assistance, tip end face maintenance and ramp cutting would require the use of powerful tracked dozers. A fuel distribution service by bowser would be required. Explosive distribution by truck would be necessary and drainage arrangements might need to be made.

30. Additional work might be required for the mine environment or because of ecological constraints. Lagoons for settlement and treatment of pumped water might be needed. Similarly, water bowsers for dust suppression during dusty dry conditions might be needed.

31. These main constraints would involve additional cost. Independent workshops and a high stock of spares would be required and general logistics in the north-west would entail stocking of food, reservoir construction for water supply, treatment plant, sewage disposal plant, explosives, stores, etc.

32. As opencast mining is not practised currently in Iceland, such a project would require substantial training. Difficulties with manpower, skills and climate might all lead to a relatively low level of machine production being anticipated during the early years.

Financial Viability

33. The biggest single cost would be overburden removal. This would be of the order of IKr25 to 40/m^3, including depreciation and interest charges.

34. Overburden preparation, mostly heavy blasting, would cost a further IKr15 to 25/m^3. Thus, blasting and excavation would cost, by the methods outlined above, IKr40 to 65/m^3.

35. Discounting any additional, unproven, leaves of lignite, for a bed 0.7 m thick, overlain by 200 m of overburden, the cost of exposing the lignite would be of the order of IKr8,000 to 13,000/m^3 of lignite. About 1 m^2 x 0.7 m of lignite, if virtually all won, at a specific gravity of 1.45, yields approximately one tonne. The overburden costs would thus be IKr8,000 to 13,000/tonne.

36. Overall mining costs and transport to preparation plant usually fall within a range of 1.5 to 2 times the costs of working the overburden. As there is a heavy weighting to the overburden task, for budget purposes it would be reasonable to assume all these other operations would cost approximately 50% of this task.

37. From the above assumptions, it can be seen that the overall costs of the scheme, apart from preparation and transport to market, would be in the range IKr12,000 to 20,000/tonne produced. This is greatly in excess of current rates applicable to lignite on the world markets.

Conclusions

38. Considered as a purely commercial venture, opencasting of the lignite beds of the north-west peninsula, while being technically feasible, is not viable in isolation from other projects.

Underground Mining

39. There are a number of systems available for underground mining of coal, and a wide variety of machines and methods for winning the in situ coal from the solid. A glossary of mining terms is given in Appendix "E".

40. The systems which require consideration for the mining conditions in Iceland are room and pillar, room and pillar with pillar extraction, longwall and augering.

41. Winning methods requiring consideration may be subdivided into hand-got, blasting off the solid, cut and blast and machine-mined.

Underground Gasification

42. This system involves drilling access boreholes into the seam, setting fire to the seam at one point, feeding the fire by means of the borehole with oxygen in some form and exhausting the product gases through another borehole. The product gases are then cleaned.

43. This method of energy extraction is only in a very experimental stage in the western world. The systems envisaged call for near level topography with easy access to bring in large drilling equipment. Clearly the topography of the north-west peninsula would appear to be completely incompatible with the requirements for underground gasification.

BRIEF DESCRIPTION OF UNDERGROUND MINING SYSTEMS

Room and Pillar Mining

44. In the room and pillar system the mineral is extracted from a series of narrow entries and the strata above the working panel are supported by pillars between the roads. (See Plate 4).

Pillar Extraction

45. Where pillar extraction is practised, panels are developed using the room and pillar system, and subsequently the pillars are extracted systematically, allowing the roof to cave. Support for the pillaring operation is usually in the form of individual timber posts or hydraulic jacks, which provide temporary roof support only. In addition, temporary supports are used to control the waste edge.

46. Frequently, during pillar extraction operations, the roof collapses prematurely causing portions of pillars or whole pillars to be left behind in the waste. In normal conditions, 10% to 15% of the plan area within a panel is lost owing to roof control problems.

Longwall

47. In the longwall system the mineral is extracted from a long face or wall, up to about 300 m in length in thin seams. The roof adjacent to the wall is supported and as the wall is worked, the supports are moved forward and the area behind is allowed to cave. In some special cases, generally to reduce the effect of strata movement or surface subsidence, the waste area may be packed or stowed, but there is still some lowering of the roof.

Advancing Longwall

48. In the advancing system the access roadways, termed the gates, are formed at each end of the mined-out area. There are normally only two entries per face, one at each end, and the area between the roads is usually allowed to cave behind the longwall face. (See Plate 5).

Retreating Longwall

49. Retreat faces are operated in a similar manner to advancing faces but differ in that the access roadways are pre-formed (see Plate 5). The access roads are driven to a predetermined boundary and a face line established between the two roads. Face equipment is then installed and the wall retreated between the pre-developed roadways, so extracting the panel of coal. In thin seam mining there is a higher cost for the access roadways caused by mining more rock above the thin seam to create necessary roadway height.

Augering

50. Using this method the mineral is won by boring either circular holes or narrow slots from a pre-developed roadway. Owing to the very short roof span of the hole or slot, the excavations are self-supporting. Parallel holes or headings are driven from the development entry, leaving ribs of coal between the holes to provide support. The ribs themselves can be designed wide enough to provide general support, or the holes can be bored in groups, leaving wider ribs between the groups of holes, so allowing a measure of crush to occur between individual holes.

WINNING METHODS

51. The mineral may be broken from the solid in a variety of ways: by hand or with pneumatic picks, blasted from the solid, undercut and blasted, or machine mined. A variety of equipment is available for winning the coal, from simple ploughs to power loading machines of the continuous miner and shearer loader type.

52. After the mineral has been broken it must be loaded on to the haulage system. In the case of hand-got operations the coal is normally loaded by shovels into small cars, or on to a low-capacity portable conveyor.

53. Where the mineral has been broken by explosives or has been cut and blasted, it can be loaded by hand or by machine. Where the mineral is wholly machine mined, it is loaded by the machine into cars or on to a conveyor system.

COMPARISON OF UNDERGROUND MINING SYSTEMS AND WINNING METHODS

Safety

54. The safety rating of hand-got workings, where a miner works at the coal face with hydraulic or wood props and bars can be regarded as low. "In-seam miner" layouts, where the men work behind the machine and supports are set immediately behind the machine, have a higher safety rating.

Minimum Heights

55. Minimum heights are dependent on local strata conditions and ground movement. With longwall advancing using an undercutter, the minimum height is the height of the coal cutter plus a minimum clearance under the supports. With the room and pillar system using an in-seam miner, the minimum height is 0.86 m. Normally, a thickness slightly in excess of the minimum thicknesses quoted is more practicable.

Normal Working Gradient

56. Nearly all mining systems work most efficiently in flat conditions. Gradient is not so critical with longwall systems. The maximum practical gradient for mechanised room and pillar workings is about 10° to 12°.

Maximum Depth

57. Strata pressures normally increase with depth. In room and pillar systems, this effect is minimised by progressively increasing the size of the pillars. A maximum depth of cover for normal working is often quoted as 305 m to give acceptable recoveries. Advancing longwall workings have operated at depths of almost 1,200 m.

Effect of Weak Roof

58. Room and pillar workings can be badly affected by weak roof conditions necessitating a narrowing of the working place in order to maintain the integrity of the roof. In longwall mining also, weak roofs can require narrower widths of working and closer setting of supports both on the face and in the roadways.

59. In thin seams, a weak roof stratum is often cut out in the mining operation and this can produce material preparation problems and consequently adversely affect the economics of this operation.

Effect of Weak Floor

60. In room and pillar workings, large pillars may be required to reduce floor heave. Floor heave can be more of a problem with longwall advancing faces and can result in gate roadways having to be enlarged a second time. With longwall, bases or soles to the props may be necessary to reduce floor penetration.

Effect of Methane

61. Longwall workings are easier to ventilate than room and pillar, and therefore better able to deal with high methane percentages. Methane drainage systems are easier with longwall layouts.

Spontaneous Combustion Risk

62. The longwall system generally offers better protection from the risk of spontaneous combustion.

Extraction Ratio

63. The extraction or recovery ratio is low in augering systems, as it is in room and pillar, when no secondary mining of pillars takes place. Longwall systems offer the best extraction ratio, particularly a layout that adopts the re-use of gate roads by extracting continuous panels. Thin seams offer the best conditions for this technique.

Production

64. Productivity increases with the degree of mechanisation and, hence, all the hand-got combinations are low in productivity.

Capital Cost

65. The capital cost varies with the degree of mechanisation. Longwall advancing faces can be started early in a project thus enabling initial capital costs of new mine development to be defrayed more quickly.

Operating Costs

66. Operating costs consist mainly of labour and materials; thus operating costs for all the hand-got methods are relatively high. Both labour and material costs tend to be higher in thin seams, owing to the lower tonnage of coal extracted per unit of advance.

PREFERRED MINING SYSTEM AND WINNING METHOD

67. The longwall system, described below is preferred. However, this method has not been proved in the existing geological conditions, and it is therefore thought necessary to include an alternative system of room and pillar mining.

Longwall Mining

68. The methods of mining which are at present considered suitable for the conditions in Iceland are those which, initially, will not require a high degree of mechanisation. It must be recognised that the training of skilled engineers and technicians takes a considerable time and can only really be acquired through experience.

69. Therefore based on these premises, it is not proposed to recommend at this stage a system of mining involving the use of powered chock supports on the longwall face. Semi-mechanised systems involving the use of coal cutters used with wooden or hydraulic props and bars, and wood chocks as a waste edge support, are considered more practical.

70. However, it would be advisable that, before risking substantial capital expenditure and the risks associated with longwall mining, trial mining should be carried out using the longwall system. The reasons for this approach are:-

(i) There is no previous experience of longwall mining in Iceland.

(ii) The overlying basalt may be difficult to cave satisfactorily.

(iii) There is a potential for subsidence inducing breaks to the surface allowing passage for water. Mining methods such as longwall, which induce severe disruption of the overlying strata, may further aggravate water inflow to the mining areas.

71. There have been numerous systems using what is termed "conventional" support for longwall faces throughout the UK coal industry. In the conceptual plan it is proposed to use in the first instance, the following systems:-

(i) Trial face - hand-filled. Hydraulic props and bars and waste edge supports with belt conveyor and floor-mounted coal cutter. If successful on the trial face, this would be followed immediately by (ii).

(ii) Semi-mechanised face with the undercutter adapted to load the lignite on to the conveyor.

Trial Face - Hand-Filled Method

72. A trial advancing longwall face supported by hydraulic props and bars should have a width of approximately 100 m and a minimum run of approximately 300 m. A typical support system, together with the equipment layout is illustrated on Plate 6.

73. This conventional system of longwall mining has been used for many decades in the UK mining industry. The system is cyclic, giving one cut advance in 24 hours. The sequence of operations is decribed as follows:-

(i) The whole width (100 m) of face is undercut to a depth of about 1.4 m by a floor-mounted cutting machine, which rope hauls itself along the face. After the machine has passed, "cutter nogs" are placed in the cut to support the overhanging material.

(ii) The face is then drilled to a depth of 1.45 m.

(iii) The drilled holes are progressively charged with explosive, stemmed with clay material and the lignite blasted down. With the top holes drilled correctly, the lignite should fall away at the roof parting near to the top of the seam.

(iv) The lignite is hand-filled on to the face belt conveyor and, when the floor area is sufficiently cleared, a further row of props and bars are set. During the lignite filling operation it is usual to set temporary props under the newly exposed roof.

(v) The face conveyor is advanced by dismantling and reconstructing in the forward track.

(vi) The waste side wooden chocks are released using chock releases built with the chock and they are rebuilt in the next track.

(vii) The maingate caunch is then advanced "in line" with the face. The manpower required to operate such a face is shown in Table I.

Semi-Mechanised Face with Flight Loading

74. This method is a progression from the hand-filled system. After undercutting, the machine is fitted with special loading flights. The lignite loading machine then moves to the maingate, loading the lignite on to the bottom belt conveyor. The main advantage of this method is that the physical work of hand-filling the material is reduced with some saving in manpower (see Table II).

Semi-Mechanised Face with Multi-Jibs

75. In this method the lignite cutting machine is fitted with more than one jib and the whole seam is cut and loaded on to the bottom belt conveyor. Multi-jib cutter loaders have been used extensively in the past in the UK mining industry. They are another convenient stage on the way to full mechanisation as they can be directly used on what was formerly a handloaded longwall face. The machine is compatible with bottom belt conveyors and the system of support proposed for the hand-filled trial face.

Mechanised Longwall Method

76. Four main types of power loader are in use in thin seams; these are the trepanner, the plough, the floor based shearer and the conventional conveyor mounted shearer. A floor based trepanner has been designed for 0.86 m thick and above seams. The principle is that a circular drum rotates in the vertical plane and, as it is driven along the buttock of the coal face, it trepans the coal and loads it on to the face conveyor through gaps in its cylindrical walls. This machine gives a higher proportion of larger sized coal. Ploughs can operate in any seam section from which coal can be satisfactorily conveyed. On faces with armoured face conveyors and powered supports, 0.81 m is the minimum seam section recommended. A severe limitation of the plough system is the inability to control its cutting horizon. In Iceland, the lignite is usually hard and the cleat poorly developed, and, in these circumstances, ploughing would not be recommended.

77. Where the coal is too hard for the plough, the shearer is the most popular machine. Acceptable results have been obtained from seams of 0.76 m, using a single drum machine, conveyor mounted, cutting bi-directionally, with remote haulage. The decline in thin seam mining in the UK has halted further developments of this machine.

78. Improvements to the shearer loader have concentrated on the thicker seam models, resulting in large horsepower, double ended, ranging drum machines. These can only be used in seams thicker than 1.3 m.

79. An in-web or buttock shearer, which does not sit on the conveyor, can operate in seams down to 0.87 m. Approximately, 50 machines of this type are presently operating in the UK in seams ranging between 0.9 and 1.2 m. This would appear to be the basis for future developments.

80. The breakdown of equipment in thin seams and its subsequent repair and replacement is often more inconvenient and costly than in a thicker seam.

81. Because the geology of the lignite areas in Iceland is relatively unknown, and the longwall mining system has not been proven, the introduction of mechanised longwall mining systems is not recommended at this stage.

Room and Pillar Mining

82. There are many variations of room and pillar mining. Because of the thin section of the lignite, a layout using long rectangular pillars rather than square pillars is recommended. Because of the thin section it will be necessary to load the material on to a conveyor.

83. A method considered as suitable for the conditions is as follows.

Heading Machine With Conveyors Working in Long Rooms

84. A machine that could be used, having regard to the thickness of the lignite varying between 0.75 and 1.2 m is the Dosco/NCB in-seam miner. This

machine is well proven in the UK. However, the minimum viable thickness for this machine is 0.86 m. At Botn and Straumnesfjall, assuming that the floor stone could be cut, some extra height would need to be made, resulting in contamination of the run-of-mine (rom) material.

85. For the in-seam miner system to be successful, fairly strong roof and floor strata are required.

86. It should be pointed out that the level of technology with the in-seam miner is fairly high and this is not ideal in a new mine situation with "green" labour.

87. Because of the low output requirements and fairly sophisticated infrastructure required, the in-seam miner is not preferred for the 25,000 tpa scenario. The alternative cyclic mining system referred to in paragraph 98 would be recommended.

Description of Equipment and Operation

88. Plate 7 shows a general arrangement of an in-seam miner.

89. The material is cut from the whole of the face by cutterpicks which traverse the face from end to end. The picks are mounted on pick carrying plates which, in turn, are mounted on a chain. The chain runs in a rigid jib guide which extends the full width of the face and carries the bottom and top race for the chain. At each end of the jib, the chain is hauled around a toothed sprocket which can be either electrically or hydraulically powered.

90. Loading buckets, attached to the chain, pick up the cut material when travelling along the bottom race of the jib. The material is discharged via a chute on to a delivery conveyor when the buckets have been elevated around the delivery-end drive sprocket.

91. The chain jib is pivot-mounted on to a base frame which allows the jib to be raised or lowered hydraulically to control the vertical cutting horizon of the machine. The mechanism is effective in vertical steering.

92. The machine is advanced into the face by hydraulic pushing rams attached to the base frame and staked on to anchor units.

93. The development of the panels could be carried out by a heading machine such as the Dosco Dintheader, or by conventional drill and blast methods and loading by Eimco shovel. Because the lignite is thin in section, the amount of development drivage required would be high. Development drivages must be completed on schedule if production from the headings is not to be affected.

94. After the panel has been blocked out, the in-seam miner would be used to drive roadways approximately 300 m in length until it holed into the pre-driven roadway on the other side of the panel. The machine would then be flitted back to the next heading entrance, and used to drive a second roadway for 300 m. The use of the in-seam miner to drive roadways between the panels would be repeated until the whole panel was extracted.

95. The headings can be supported by wood bars, steel bars or rolled steel joists supported by wood props. Hydraulic props can be set during the production shift and replaced in the non-production shift by wood props.

96. When the drivage of the heading is completed, supports are salvaged ready for use in the next heading.

97. The manpower required per heading, based on the experience in the UK, is shown in Table III.

Alternative Room and Pillar Mining Equipment

98. Gathering arm loading machines are available for working in thin seams. The method of working is cyclic. The lignite would be prepared for loading by undercutting using a separate cutting machine. This would be followed by drilling the lignite either using a boom or hand-held machines. The material would then be fired and loaded on to a conveyor using the gathering arm loader. There are examples of this type of working in the USA.

Auger Type Continuous Miner

99. The Wilcox miner is a thin seam continuous miner which uses the auger principle. Wilcox miners are advertised for coal seams between 0.66 m and 1.25 m. The cutting mechanism consists of two augers which are sumped axially into the face. The machine is then traversed across the face of the heading, using ropes. The augers have picks mounted on the periphery of the auger scrolls and these cut the coal during the traversing operation. There are no machines of this type operating in the UK, but good results are being obtained in the USA.

AUGERS

Simple Augers

100. Simple augers are used extensively in the USA, on the surface, for extending mining operations under the highwall of open pit operations.

101. Development work has been carried out in the USA to extend the simple auger method underground. The work involved modifying the equipment to make it fit into the restricted space available underground.

102. There is no practical limit on the minimum hole diameter that may be bored: the limitation is an economic one. Despite the expectation of faster drilling speeds in smaller holes, the relationship between hole diameter and output is that the latter varies as the square of the diameter.

103. One of the serious limitations is the problem of deviation of the line cut by the auger in both the horizontal and vertical planes. Deviation is dependent on the cutting characteristics of both the seam and the host rock and on the rigidity of the auger sections. In boring small diameter holes, the auger scroll sections have a lower degree of rigidity than in larger holes. Thus, deviation problems are likely to be greater in thin seams. Deviation tends to limit the length of the hole and aggravate the time spent on repositioning the auger for the next hole. The limitation in hole length would increase the amount of roadway development necessary for the exploitation of a block of coal.

104. The likely high strength of the lignite seam in Iceland suggests that augering would be difficult.

105. These factors, together with the inherent lack of production capacity, preclude the viable use of a single hole auger in a thin seam underground.

106. There are no underground augering operations in the UK.

RECOMMENDED SYSTEM

107. If the results of the trial longwall face workings indicate that the caving of the strata and the control of the roof can be successfully accomplished, then the longwall system is recommended. In the first stages, semi-mechanised methods of working the longwall faces are proposed. After experience is gained with the intermediate level of technology proposed and more information is available regarding the mining geology and reserves available, then fully mechanised methods can be tried. The longwall system has a high output potential if fully mechanised systems can be introduced.

108. The room and pillar mining system has a fairly high degree of flexibility, and is better able to deal with faults and geological disturbances than the longwall system. If the longwall system does not work satisfactorily, then a room and pillar system, using either a continuous mining system or a cyclic system with gathering arm loader type machine could be tried.

CHAPTER VI

MINE PLANNING

ASSUMPTIONS

1. Information obtained from outcrop studies and some limited mining gives the geologist and the mining engineer few proven data on which to make firm plans for mines. However, in order to provide a basis for assessing the feasibility of establishing mines at Botn, Dufansdalur and Thernudalur, Straumnesfjall and Stalfjall, assumptions have been made and conceptual mine plans drawn up.

2. At Gil mine, insufficient reserves with a workable thickness of lignite were identified and therefore no further work has been done.

3. The assumptions that have been made for mine planning are:-

(i) In all the scenarios, despite the lack of information, the seam, as proven by the outcrop sampling, extends for approximately 2 km^2 from the outcrop. This assumption was agreed with Mr Bjornsson.

(ii) Variations in seam thickness that have been predicted are not so great as to make underground mining impractical.

(iii) Because of the limited information no account has been taken in the conceptual mine plan of dykes or faults. If the proposals for a mine do go ahead, then further exploration will be required to generate a more reliable geological data base.

(iv) Exploration boreholes at each of the sites would be difficult because of the terrain.

LEVELS OF OUTPUT

4. Three levels of saleable output have been assessed, namely 25,000 tpa, 65,000 tpa and 100,000 tpa. At Botn, Dufansdalur and Thernudalur, and Straumnesfjall insufficient reserves were identified in the 2 km^2 area, to produce a conceptual plan for a 100,000 tpa mine.

BOTN

Mining Geology and Reserves

5. These are as follows:-

Lignite Thickness

6. Two sections of lignite at the entrance to Botn mine measured 77 and 100 cm. The variation in thickness over the short distance between sections must be noted. Information from past workings suggests that the lignite bed was usually about 70 to 80 cm thick. An average thickness of 0.75 m was taken, of which, 12 cm was waste (ie tuff).

Near Seam Rocks

7. The roof is taken as 2 m of mudstone overlain by a strong basalt, which is jointed every 30 to 50 cm. The mudstone appeared soft, and may be difficult to support. Any water in the roof would soften the mudstone. The mudstone floor appeared hard.

Dirt Bands

8. The tuff bands in the lignite at the mine entrance showed signs of weathering, ie the tuff is not too hard and would not present difficulties in mining.

Faulting

9. A fault of 1.3 m throw was measured between the two entrances to the mine.

Seam Gradient

10. Existing mine entrance dipping very slightly into the hillside. Seam gradients were estimated to be low and in a south-easterly direction.

Reserves

11. Earlier total tunnel drivage was believed to have advanced approximately 300 m, with short laterals off the main tunnel. No other exposures or borehole information were found. Reserves are likely to extend up the valley head and under the mountain in a south-westerly direction but borehole information will be required to confirm thickness and presence of the lignite.

12. Reserves have been assumed to be present over a 2 km^2 area, to the rise side of the main tunnel.

13. In situ reserves are calculated as 2 km^2 x 0.75 m thickness x 1.45 SG, yielding 2,175,000, say 2.2 million tonnes of lignite.

14. A survey carried out by the NCB on 24 representative collieries in the UK, indicated that approximately half the coal in the seams now being worked is extracted. Coal is left in situ in pillars, between headings due to faulting, in odd shaped areas, for surface support, in roof or floor and in barriers.

15. Assuming that 50% of the in situ reserves are recoverable, then recoverable reserves would equal 1.1 million tonnes.

Access and Mining Method

Existing Access

16. There are two adit entrances in the lignite approximately 4 m apart. Both are now flooded and could not be inspected. The tunnel heights are estimated at 1.8 m. No supports were observed in the old tunnels. These old entrances should be pumped out, examined and the main tunnel considered for re-use as part of the new mine.

17. There are no buildings or other structures at the site. An access road, used in the 1940s, connects the mine entrance with the road below. Extensive repair and reconstruction of this access road would be necessary before it could be re-used for large vehicles. There are large quantities of scree which could be used for road base material. A snow removal vehicle would be required to keep the access road open in winter. The site area available for surface buildings is very small. Because of the steep terrain, construction of a large surface site would be

difficult. There is no electricity supply line to the mine site or valley head and a connection would involve 5 km of transmission lines.

Proposed Access

18. In the conceptual mine plan, it is proposed to refurbish one of the existing tunnels and use it as a main intake. This would reduce costs and assist exploration as it is believed to run 300 m into the mountain. A second tunnel entrance to act as the main return would be required.

Mining Method

19. The mining method and mine layout would need to be flexible to accommodate expected changes in lignite thickness. The preferred mining method is therefore based on the advancing longwall method, with extraction heights ranging between 0.75 and possibly 1 m.

General Underground Mine Layout

20. The access to the mine would be in the lignite outcrop at 140 m amsl. The normal mine surface facilities, such as a fan, amenity buildings, lamp room, workshops and preparation plant would be situated at the surface near to the mine entrance.

21. The underground mine design (see Plate 8) is based on two main trunk roadways driven along the strike in a south-westerly direction to the extent of the mineable reserves (estimated at 2 km^2). The main trunk roadways would be 3.66 m x 3.05 m supported by arched girders. The final choice of support would depend on further information concerning strength of roof and floor but, for the basis of analysis, arches are used. The roadways would be driven by drilling and blasting and loading the material on to a stage loader using an Eimco track mounted shovel. The drill boom would be mounted on the stage loader.

22. One longwall advancing face operating to the rise from the main trunk roadways would produce an annual saleable output of 25,000 tpa. Two faces would be required to produce an output of 65,000 tpa. After longwall working experience had been gained, it might be considered necessary to provide for a standby longwall face.

District Layout and Development

23. Initially, one district would be developed with one or two faces being worked from that district, this being preferable for provision of services and supervision.

Panel Layout

24. Advance faces would be used and each panel would be on average 100 m wide and a maximum of 1,000 m long depending on the continuity of the mineable seam section. Faces would be equipped with hydraulic props, bottom belt conveyor and a coal cutter/flight loader. The face would be worked on a 24 hour cycle, advancing 1.45 m per day, with a face life of approximately 2½ years. When one face finished, face equipment transfer would be done over a weekend.

25. Gate roadways to the face would be driven 3.66 x 2.44 m in the maingate and 3.05 x 2.44 m in the tailgate. The strata above the seam would be drilled and fired and the broken material used to form a pack on the waste side of the gate.

Production Calculations

26. Output 25,000 tpa: Lignite production would come from one advancing face, operating on a 24 hour cycle. In addition, there would be some lignite produced from the development drivages. Production has been calculated on a five day week, 240 days total per annum.

25,000 tpa

	ROM tonnes
Face (85 m wide)	32,150
Development drivage	3,800
ROM delivered to preparation plant	35,950

About 36,000 tonnes of rom product delivered to the mineral preparation plant would on washing (estimated 70% recovery) produce just over 25,000 tonnes of lignite with approximately 20.5% ash, 30% moisture and have a calorific value of 13,860 kJ/kg (3,310 kcal/kg).

65,000 tpa

	ROM tonnes
Face 1 (115 m wide)	43,500
Face 2 (115 m wide)	43,500
Development drivage (2 developments/face)	7,600
Total	94,600

About 95,000 tonnes of rom product delivered to the mineral preparation plant would on washing produce just over 66,000 tonnes of lignite of similar analysis to the 25,000 tpa case.

Underground Transport

27. Lignite transport within the mine would be entirely by conveyor. The face belt conveyor would feed on to a scraper chain conveyor, acting as a stage loader, on to the maingate belt. A higher capacity belt would be used in the main intake trunk roadway feeding to the surface. Endless rope haulages would be installed for men and materials. Manriding haulage would not be required for some considerable time. Purpose-built materials cars would be used.

Ventilation

28. The fan size would depend upon the level of output. Each face would be ventilated by approximately 5 m^3/s of air, with a further 3 m^3/s of air for the developments, allowing two developments per longwall face. As an example, allowing for, say, a maximum of two longwall faces, a total of 30 m^3/s would give some spare capacity. Assuming a 50% ventilation efficiency, an electrically driven fan of 60 m^3/s would be installed at the surface, together with a spare fan of half the capacity driven by a diesel generator. This overall quantity is considered adequate, consistent with a good working environment, predicted methane emission and dust suppression requirements. Development headings would be ventilated by small electrically driven auxiliary fans and tubing.

Mine Services

Surface Buildings

29. These would include conveyor drive house, endless haulage house, main and standby ventilation fan, bath unit, lamp room, workshops, stores and mine office. In addition, a small reservoir would be included as well as pumping facilities to supply water to the mineral preparation plant, to the mine for machine cooling and dust suppression and for the baths and potable water supply. Further, a substation would be included as well as a small sewage treatment plant, mineral preparation plant and storage bunkers, for rom and clean lignite, explosives magazine, first aid and rescue equipment house.

Power Distribution

30. All face plant, conveyors, haulages, pumps, etc would be electrically operated at 550 V. The 19 kV high tension supply would be brought to the surface substation and transformed to a 3.3 kV supply system. An underground transformer would convert this supply to 550 V. A diesel driven generator would be provided as a standby to drive the fan and pumps and allow some spare capacity. The underground electrical equipment should be flameproof.

Water Supply

31. This would be obtained from the waterfall running in the vicinity of the mine entrance. Water used for the mineral preparation should always be available and not be allowed to freeze in winter. Effluent water from the mine and preparation plant should be treated in settling ponds.

Lignite Preparation Plant

32. This would consist of a dense media cyclone washer housed in the usual type of surface building. The plant would have a capacity of 50 tonnes per hour. Therefore it might be advisable to wash the material intermittently and allow the rom material to build up until a run of about eight hours could be put through the plant.

Waste Disposal

33. Waste material after washing could be deposited on the surface and used to increase the available level surface area.

Manpower

34. The mine would operate on a three shift basis, of eight hours per shift, five days a week, for 240 days per annum. The number of jobs at the mine site is estimated at:-

(i) 25,000 tpa

Face (Flight loading)	28
Developments	6
Underground transport	5
Miscellaneous underground labour	4
Management (Deputies included in face manpower)	5
Surface	5
Total	53

The total number of jobs has been multiplied by 1.1 to allow for an absenteeism rate (NCB figure in 1983/84 was 10.6%). Total 58.

Management includes a Manager, Undermanager, Engineer, Surveyor and Wages Clerk.

(ii) 65,000 tpa

Faces (two)	62
Developments	12
Underground transport	9
Miscellaneous underground labour	8
Management (Deputies included in face manpower)	5
Surface	5
Total	101

Allowing for absenteeism, the total number of men required is 111.

Productivity

35. This is estimated as follows:-

(i) 25,000 tpa. Mine productivity (all employed) would be 1.8 saleable tonnes/manshift.

(ii) 65,000 tpa. Mine productivity would be about 2.4 saleable tonnes/manshift.

Surface Transportation Route

36. The following route for the Botn lignite is projected:-

(i) 11,000 tpa by road to Isafjordur.

(ii) 7,500 tpa by road to Bolungarvik.

(iii) 6,500 tpa by road to Isafjordur and shipped to Vatneyri.

The above situation assumes a mine output of 25,000 tpa. In the event of the 65,000 tpa scenario being selected, it is envisaged that a quay would be built at Sudureyri, shipping the 6,500 tonnes to Vatneyri and the remaining 40,000 tonnes (the supply to Isafjordur and Bolungarvik by road would remain unchanged) to the cement works at Akranes.

37. Regarding road transport to Isafjordur and Bolungarvik, the market requirement would be transported during those months of the year when the roads should be relatively unaffected by adverse weather. The lignite would be stockpiled during the remaining months.

38. The access road from the existing mine site at Botn to the main road would need extensive reconstruction.

39. Extensive harbour improvements would be required at Sudureyri before lignite could be shipped to Vatneyri and Akranes. The road from the mine to Sudureyri runs along the valley floor and should not cause undue problems in winter.

DUFANSDALUR AND THERNUDALUR

Mining Geology and Reserves

40. These are as follows:-

Lignite Thickness

41. A possible working section of lignite is estimated at 90 cm including some tuff. At Thernudalur, the working section of lignite is split by a 3 to 4 cm tuff layer.

Near Seam Rocks

42. At Thernudalur the immediate roof is a siltstone and the floor a tuff bed. At Dufansdalur, a strong dark mudstone and tuff form the roof and floor.

Dykes and Faults

43. Dykes were observed in the mountain side, but because of the limited information no account has been taken of them in drawing up the conceptual mine plan.

Reserves

44. The tunnel at the nose of the mountain at Dufansdalur advanced about 100 m in lignite. The lignite was also worked at Thernudalur, one of the tunnels being 16.5 m long. For the purpose of the conceptual mine plan reserves have been projected within the mountain at Dufansdalur and Thernudalur as follows (see also Plate 9):-

In situ reserves, based on a 2 km^2 area, amount to 2 km^2 x 0.9 m thickness x 1.7 SG = 3.06 million tonnes.

Assuming that 50% of the in situ reserves are recoverable, then recoverable reserves = 1.5 million tonnes.

Quality of Lignite

45. Samples taken at the former sites of mining show that the specific gravities of the lignite and associated mudstones do not vary greatly. As a consequence it is not considered efficient to treat the material by washing. The estimate of the ash in the rom material is 38%. The rom product is therefore the same as the saleable product.

Access and Mining Method

Existing Access

46. The existing access at Dufansdalur has been advanced an estimated 100 m. No supports were observed. The existing heading is flooded but appeared to be in good condition. There would be a number of disadvantages in using the existing tunnel, including: (a) very restricted surface area and steep mountain slope; (b) danger of rock falls above site; (c) no water supply; (d) access for men to mine entrance would be difficult.

Proposed Access

47. In the conceptual mine plan, access to the lignite would be by two headings into the outcrop at a point up the valley at about 160 m amsl. The mine surface buildings would be at a lower level, with the difference in height used for bunkerage of rom material. A new mine access road would be required to link up with the existing road and proposed pier at the Fossfjordur.

Mining Method

48. The proposed mining method is based on the advancing longwall method, with an extraction height of 0.9 m.

General Underground Mine Layout

49. The underground mine design is based on two main trunk roadways driven approximately along the strike in a south-westerly to north-easterly direction to the limit of the estimated area of reserves. Roadway drivage details are as described for Botn.

50. One longwall advancing face, approximately 45 m wide, operating to the rise from the main trunk roadways, together with the associated developments, would produce an annual saleable output of 25,000 tpa. One longwall face 115 m wide, together with developments, would be required to produce an output of 65,000 tpa.

District Layout and Development

51. The outcrop evidence indicates that the regional dip of the seams is low and to the south-east. The trunk roadways would be initially developed in a westerly direction. A longwall advancing face would be developed and worked to the rise as early as possible to test the longwall system.

Panel Layout

52. The panel layout would be similar to that described for Botn. Because of the mine layout configuration the life of the faces would vary between one and 3.5 years.

Production Calculations

53. Output 25,000 tpa: Lignite production would come from one advancing face, operating on a 24 hour cycle, plus lignite produced from development drivages. Production has been based on a five day week, 240 days total per annum.

25,000 tpa

	ROM tonnes
Face (45 m wide)	22,500
Development drivage	4,500
Total	27,000

The rom material is estimated to have an ash content of 38%, a calorific value of 7,700 kJ/kg (1,840 kcal/kg) and a moisture content of 30%.

65,000 tpa

	ROM tonnes
Face (115 m wide)	61,000
Development drivage (2 developments/face)	4,500
Total	65,500

Underground Transport and Ventilation

54. Similar arrangements are as described for Botn in paragraphs 27 and 28.

Mine Services

55. Surface buildings and power distribution would be as for Botn. Approximately 6 km of transmission lines would be required to connect the mine surface site. The water supply would be obtained from the stream at the head of the valley.

Manpower

56. The manpower estimates are similar to those for Botn, but have been adjusted for the differences in face length, and take into account the fact that a preparation plant is not necessary.

Productivity

57. This is estimated as follows:-

(i) 25,000 tpa. Mine productivity would be 1.9 rom tonnes/manshift.

(ii) 65,000 tpa. Mine productivity would be 3.9 rom tonnes/manshift.

In these cases rom production is the same as saleable production.

Surface Transportation Route

58. The lignite would be transported down the valley to a new pier to be constructed at the Fossfjordur. Ships would be used to transport 11,000 tonnes to Isafjordur, 7,500 to Bolungarvik, 6,500 to Vatneyri with the remaining 40,000 tonnes to the cement works at Akranes. This assumes an annual output of 65,000 tonnes. In the event of an output of only 25,000 tonnes, there would be no shipment to Akranes.

59. The road up the valley would be approximately 1 km long, and would be difficult to construct but should not be adversely affected by winter weather. The fiord is deep, does not freeze in winter and is well sheltered.

STRAUMNESFJALL

Mining Geology and Reserves

60. These are as follows:-

Lignite Thickness

61. Two beds of lignite were identified. The upper bed comprises 1.8 m of lignite with mudstone and tuff beds. The low overall quality of this bed and the low quality of the lignite within it indicates that this is unlikely to be a workable proposition. The lower bed consisted of 85 cm of lignite with 12 cm of tuff lenses within the lignite. About 2.6 m of strata with a small amount of lignite separate the two beds.

Near Seam Rocks

62. The roof and floor of the upper bed are mudstone. About 4 m of mudstones overlay the upper bed with a very strong basalt above. The roof and

floor of the lower bed are mudstones, the floor being a strong grey brown mudstone.

Seam Gradient

63. This is estimated at 2° in a south-easterly direction.

Reserves

64. There is very little information to enable an estimate of the reserves to be made. There has been no previous underground mining, excavations being confined to pickings at the outcrop.

65. The conceptual plan is based on reserves of the lower lignite bed, 85 cm thick over an area of 2 km^2. It must be noted, that for the site to be considered further, at least four more good provings are required. In this connection the surface topography could be suitable for drilling.

66. In situ reserves amount to 2 km^2 x 0.85 m thickness x 1.45 SG = 2.465 million tonnes.

67. Assuming that 50% of the in situ reserves are recoverable, then recoverable reserves would equal 1.23 million tonnes.

Quality of Lignite

68. The specific gravity of the lignite averages 1.5 and that of the associated mudstones, 1.9 to 2. The difference is considered enough for efficient separation to be carried out in a dense media cyclone. The recovery of the lignite from the rom material is estimated at 70%.

Access and Mining Method

Proposed Access

69. Access from the outcrop on the very steep cliffs is almost impossible. A pier for transport of the lignite would have to be constructed at Latrar, which is more sheltered. Access to the lignite could be by two vertical shafts, sited at the top of Straumnesfjall at about 400 m amsl. One shaft would be equipped with a skip, the other would be a service shaft. The mineral, after treatment, would be transported via the existing road approximately 4 km to the new pier at Latrar. This would involve a steep section with a fall of around 300 m.

70. Water to the site would have to be pumped from nearby tarns.

71. There is no electricity on site and a submarine cable would be required to transmit electricity from the grid. This is considered uneconomic, and electricity would have to be generated on site using diesel generators.

Mining Method

72. The preferred mining method is the longwall advancing method.

General Underground Mine Layout

73. The preferred access to the mine would be by two shafts situated at about 400 m amsl. The normal mine facilities such as fan, amenity buildings, lamp room, workshops, and mineral preparation plant would be sited at the surface near to the entrance to the mine. A camp for the men working at the mine would be constructed at Latrar, near the pier, where the climatic conditions are more favourable. The camp would require its own power generator, a supply of potable water and the necessary sewage arrangements.

74. The underground mine layout (see Plate 10) is based on driving two main trunk roadways in a north-westerly direction, with cross-laterals at intervals of approximately 1,000 m. The layout would allow longwall advancing panels to be driven to the rise. One of the cross-laterals could be driven through to the cliffs to form a drainage channel for water, thus saving pumping costs up the shaft. The size of the trunk roadways and cross-laterals and method of drivage would be similar to that described at Botn.

75. The number of faces required to produce tonnages of 25,000 tpa and 65,000 tpa is similar to Botn.

District Layout and Development

76. Initially, one district would be developed with one or two faces being worked in that district.

Panel Layout

77. Advance faces would be used and each panel would be 75 m or 100 m wide with a run of 900 m, depending on continuity of the mineable seam section and the level of output required. Face equipment, cycle, and gate roadways are as described at Botn.

Production Calculations

78. These are as follows:-

25,000 tpa

	ROM tonnes
Face (75 m wide)	32,100
Development drivage	4,300
ROM delivered to preparation plant	36,400

79. About 36,400 tonnes of rom product delivered to the mineral preparation plant would on washing (estimated 70% recovery) produce just over 25,000 tonnes of lignite with 23.4% ash. The calorific value of the saleable product is estimated at 11,500 kJ/kg (2,747 kcal/kg), with a moisture content of 30%.

65,000 tpa

	ROM tonnes
Face 1 (100 m wide)	43,000
Face 2 (100 m wide)	43,000
Development drivage (2 developments/face)	8,600
Total	94,600

80. About 95,000 tonnes of rom product delivered to the mineral preparation plant would on washing (estimated 70% recovery) produce just over 66,000 tonnes of saleable lignite.

Underground Transport

81. The transport system would be similar to Botn other than that the lignite would be loaded into a skip at the shaft bottom and then raised to the surface.

82. Men and materials would be lowered down the service shaft.

Ventilation

83. Similar to Botn other than that one shaft would be used as an intake and one as a return. An exhausting fan would be situated near the mouth of the upcast shaft.

Mine Services

84. Similar to Botn other than that winding engine houses and winding gear would have to be provided. As there is no electric power supply, diesel driven generators would be used. Camp facilities would have to be provided at Latrar, with a supply of potable water, necessary sewage arrangements and power generator. Water to the mine site at the top of the cliffs would require approximately 1 km of pipeline and pumping facilities to negotiate a 500 m difference in level.

Manpower

85. The manpower estimates are similar to those for Botn, with adjustments made where necessary.

Productivity

86. This is estimated as follows:-

(i) 25,000 tpa. Mine productivity would be about 1.8 saleable tonnes/manshift.

(ii) 65,000 tpa. Mine productivity would be about 2.5 saleable tonnes/manshift.

Surface Transportation Route

87. The following route for the Straumnesfjall lignite is projected:-

(i) From the mineral preparation plant near to the shafts at the top of Straumnesfjall to the pier loading facilities at Latrar, along 4 km of road, of which 2.5 km are along the mountain top, with a difference in level of 300 m to the new pier to be constructed at Latrar.

(ii) All material would be transported by sea, during the summer months only, to Isafjordur, Bolungarvik and Vatneyri in the case of a 25,000 tpa output, with the further 40,000 tonnes going to Akranes in the event of a 65,000 tpa output.

STALFJALL

Mining Geology and Reserves

88. These are as follows:-

Lignite Thickness

89. One workable bed of lignite was identified, 1.2 m thick with some tuff bands.

Near Seam Rocks

90. The roof of the 1.2 m bed is a mudstone and the floor a shaley sandstone. Both appeared strong. Above the sedimentary layer is a 30 m plus thick columnar basalt.

Seam Gradient

91. This is estimated at 7^0 in a south-easterly direction.

Reserves

92. There is little information on which to estimate the reserves. Only a 100 m lateral extent can be confidently predicted. Observations of the deposit at Holt, approximately 13 km east, showed only 1 cm thickness of lignite. The conceptual plan is based on reserves within an area of 2 km^2. In situ reserves amount to 2 km^2 x 1.2 m thickness x 1.55 SG = 3.72 million tonnes. Assuming that 50% of the in situ reserves are recoverable, then recoverable reserves amount to 1.86 million tonnes.

Quality of Lignite

93. The specific gravity of the lignite varied between 1.54 to 1.68 with that of the near seam rocks between 1.92 and 2.06. Of the lignite bed, approximately 75% of the material contained 35% ash and the remaining 25% contained 68% ash. Because the differences in the specific gravity are small and the tuff bands are thin, washing is not considered efficient. Therefore the rom material would not be washed and it is estimated that the saleable material would have an average ash content of 37%.

Access and Mining Method

Existing Access

94. The access made in 1917 into the lignite at approximately sea level is considered to have insufficient surface area to site the necessary surface buildings.

Proposed Access

95. Therefore, access is planned by two adits into the lignite at about 100 m amsl. This is in the vicinity of the site of the living accommodation of the former miners of Stalfjall. At this point a considerable amount of scree would have to be removed to expose the lignite.

Mining Method

96. Evidence suggests that the lignite may vary in thickness over short distances. The preferred method is based on longwall advancing with a maximum extraction height of 1.2 m.

General Underground Mine Layout

97. The access to the mine would be at 100 m amsl with mine surface facilities such as fan, amenity buildings, lamp room, and workshops sited at the surface near to the mine entrance.

98. The underground mine design (see Plate 11) is based on two main trunk roadways driven in an east to west direction. The size of roadways and method of working are similar to those for the Botn conceptual mine plan.

99. Longwall advancing faces would be laid out so that they advance to the rise, to minimise any problems from water entering the workings.

Panel Layout

100. The longwall face would be equipped as for Botn with the width of face varying with the output required.

Production Calculations

101. These are as follows:-

(i) Because the lignite is not being washed and because the specific gravity of the material has been taken as 1.55, slightly higher than for most of the other deposits, the output of 25,000 tpa could be achieved by one longwall face approximately 60 m wide, together with developments, working on a 48 hour cycle.

(ii) Thus, 65,000 tpa could be achieved by a 90 m wide face operating on a 24 hour cycle.

(iii) The 100,000 tpa output could be achieved by two 70 m wide faces operating on a 24 hour cycle.

25,000 tpa

	ROM tonnes
Face (60 m wide)	19,000
Development drivage	6,500
Total	25,500

The saleable output would have an ash content of about 37% with a calorific value of 8,430 kJ/kg (2,013 kcal/kg) and a moisture content of 30%.

65,000 tpa

	ROM tonnes
Face (90 m wide)	58,250
Development drivage	6,500
Total	64,750

100,000 tpa

	ROM tonnes
Face 1 (70 m wide)	45,000
Face 2 (70 m wide)	45,000
Development drivage	13,000
Total	103,000

Underground Transport, Ventilation and Mine Services

102. These are similar to those for Botn. Electricity transmission lines would have to be brought a distance of 15 km. Water for the site could be obtained from a nearby source using approximately 1 km of pipeline.

Manpower

103. Similar to Botn with adjustments made for face widths, in the 25,000 tpa scenario, working a 48 hour cycle and with no mineral preparation plant.

Productivity

104. This is estimated as follows:-

(i) 25,000 tpa. Mine productivity would be 1.8 rom tonnes/manshift.

(ii) 65,000 tpa. Mine productivity would be 4.0 rom tonnes/manshift.

(iii) 100,000 tpa. Mine productivity would be 4.0 rom tonnes/manshift.

Surface Transportation Route

105. For the purposes of the study it was agreed that the route would be as follows:-

(i) From the mine site a new road would have to be constructed adjacent to the cliffs, through a 500 m long tunnel through the mountain and then to the existing main road, a distance of approximately 6 km.

(ii) 6,500 tonnes of the material would go by road to Vatneyri, a distance of 40 km.

(iii) The remaining mineral would be transported by road from the mine to a new pier to be constructed at the southern part of the Patreksfjordur. The total distance by road would be 20 km. Approximately, 11,000 tonnes of the lignite would be shipped to Isafjordur and 7,500 tonnes to Bolungarvik with, in the case of the 65,000 tpa output, the additional 40,000 tonnes being shipped to Akranes. In the event of the 100,000 tpa output, the further 35,000 tpa would go to the ferrosilicon plant at Grundartanga.

CHAPTER VII

COMMERCIAL LIGNITE PREPARATION PROCESSES

POSSIBLE PROCESSES

1. There are three main methods which are worth considering. They are presented below in decreasing order of complexity.

Dense Media Washers

2. Dense media processes use a suspension of solids in water to provide an artificial liquid "dense media" that has a density between lignite and dirt, so that lignite will float and dirt will sink. The material used in modern plants treating coal is magnetite and use is made of its magnetic properties to recover it for re-use. Magnetite costs approximately £50/tonne in the UK and consumption is 1 to 2 kg of magnetite in a well run plant for every tonne of lignite treated.

3. Dense media systems are very efficient, but there are several disadvantages:-

(i) The relative density of the dense media suspension has to be accurately controlled, and sophisticated control systems are necessary.

(ii) If all the raw lignite is required to be washed, then it would be necessary to use two separate processes, a dense media bath to handle the large sizes and a dense media cyclone to handle the fines. This split is necessary because of the longer settling times required by the smaller particles. The cut-point between the two systems is normally within the range 12 to 25 mm.

(iii) If dense media suspensions are left unused for any length of time, the magnetite settles out and is difficult to get back into suspension. This could be a problem for this type of plant if it is only to be operated for a few hours at a time.

(iv) Magnetite suspensions are very abrasive and plants have to be designed to withstand this abrasion.

4. These factors mean that dense media systems are normally only used for large plants (say, with the range 100 to 500 tonnes/h). This is above the tonnage required for even the largest operating scenario. However, manufacturers could be prepared to make a "package unit" dense media bath with a rated capacity of about 50 tonnes/h.

5. As it is envisaged that only a single market is to be supplied, lignite material could be crushed to -15 mm, and the 15 to 0 5 mm treated in a cyclone plant and the -0.5 mm disposed of in the settling pond. This would eliminate the need for a dense media bath.

Baum Jig Washer

6. The Baum jig washer is the most commonly used process in the UK. In this process the coal is washed over a grid fitted within a box, through which there is an upward and downward pulsing surge of water. This action stratifies the raw coal with the heaviest, and therefore the dirtiest, particles at the bottom and the

lightest and cleanest particles at the top. The clean coal is carried forward by the flow of water through the box and is discharged on to classifying and dewatering screens. The heavier material in the box moves along the grid and falls into the boot of a bucket elevator which lifts it out of the box, after which it is discarded.

7. Simple automatic controls can be fitted to control the removal of dirt and to ensure a consistent quality of clean product.

8. Baum jigs could treat unsized lignite up to about 100 mm. If there is a high proportion of -12 mm raw lignite, some manufacturers recommend using a false bed of feldspar on the grid of the box. This bed opens up on the pulsation (upward) strokes and allows the fine dirt to fall through the bed. However, on the suction (downward) stroke the feldspar bed closes up and prevents losses of clean material.

9. Whilst most Baum jigs handle 100 tonnes/h or more it is possible to buy a small package unit designed for 50 tonnes/h. This could theoretically handle the output of the largest mine scenario (420 tpd) by working 8 h/day.

10. In the UK, the specific gravity of the coal may be half that of the associated dirt. This is of advantage in the Baum jig washing process. When the densities of the two materials are much closer, as identified with the lignite deposits in Iceland, then the process is not so efficient.

Barrel Washer

11. The barrel washer (originally the Blackett washer) is cheap, simple in design, and is currently being used to wash anthracite at small private mines in the UK, and also to recover coal from spoil heaps.

12. The barrel washer consists of a tube, up to 2 m in diameter and up to 15 m in length, fitted inside with three to five fixed "scrolls", the depth of which varies with the size of coal to be washed. The tube is supported at an angle of about 9^0 and is rotated around the longitudinal axis at 5 to 10 rev/min. The bottom 1 to 2 m of the tube is perforated, the size of the holes depending on the size of the coal being washed, and also on the sizes of clean material required. The raw material is fed in at a point about 1 to 2 m from the top of the tube and is washed down the tube by a stream of water. The stone and dirt, being heavier than coal, are caught in the scrolls which spiral them upwards and they are then discharged from the top of the tube. The lighter coal is washed over the scrolls and is carried to the bottom of the tube where the bottom portion acts as a dewatering screen.

13. This type of washer could be used to clean lignite sized up to 150 mm. It used to be considered necessary to pre-size the raw material into separated sizes and wash each size in a separate barrel. There are now plants treating 75 to 0.0 mm raw material in one barrel.

14. Such a unit would have a capacity of about 25 tonnes/h. In the UK the specific gravities of the coal and dirt treated in the barrel washer vary substantially and this adds to the efficiency of the process. Where the densities of the materials are closer, then the process is less effective.

OTHER FACTORS

15. There are a number of other factors which must be recognised in the design and operation of any preparation plant. These are:-

Treatment of Fines

16. None of the methods above is effective for cleaning coal of less than 0.5 mm. The only efficient process for this type of material is froth flotation. The use of a spiral concentration for the treatment of fines is being tested in the UK, but there are no working installations at the moment in the NCB. However, the tonnages involved in this instance do not justify the addition of these forms of treatment process.

17. These fines would therefore be discharged in a slurry form into a settling lagoon. After several months the material would have dried sufficiently to be handled with a front-end loader for sale as a low grade industrial fuel. Such a system obviously requires the availability of two lagoons, one being filled and the other reclaimed.

Dewatering of Clean Products

18. All the washed lignite would include surplus moisture which would have to be reduced before sale. In practice all the sizes suitable for, say, the domestic market would be very free draining. The smaller (say, -12 mm) material could be treated in a centrifuge, and this is the normal method in a large plant; however, in this instance, it would normally be stocked for a period before sale and this would allow it to reach an equilibrium moisture content.

Disposal of Refuse

19. It is assumed that local planning regulations would allow refuse to be tipped near to the mine site, however, some cost provision should be allowed for the eventual restoration of the tipping area.

PREFERRED SOLUTION

20. The density of the lignite material is about 1.5 SG and that of the associated tuff, roof and floor measures about 2 SG. To separate the materials, a sophisticated method of cleaning is required. It is considered that the Baum jig and barrel washer would not be effective, because the densities of the materials are too close. The only satisfactory way would be to use the dense media process with separation at about 1.8 SG. As referred to in paragraph 5, the lignite material could be crushed to -15 mm and all treated in a dense media cyclone.

21. At Dufansdalur and Thernudalur, and at Stalfjall where the densities of the lignite and associated mudstones are much closer, consideration should be given to selling the lignite without treatment.

PLANT CAPITAL COSTS

Dense Media Cyclone

22. A 50 tonnes/h dense media cyclone is estimated to cost about £150,000 (IKr6,135,000), excluding civil works in the UK. This estimate must be regarded as being of "order of magnitude" accuracy. The estimate does not include lagoons and dumps. Product storage bunkers are also excluded, since it is assumed that these would be required even without a mineral preparation plant.

CHAPTER VIII

OUTLINE COSTING AND FINANCIAL ANALYSIS

INTRODUCTION

1. The technical factors which influence the production costs of lignite have been discussed in earlier chapters. In view of the complexity of production cost estimating, a detailed feasibility study is the best way to determine the economic viability of any proposed mining venture. Such a detailed study is costly and time consuming and could not be undertaken in respect of the sites as some essential data were not available.

2. It was agreed with NEA that the preliminary assessment of the economic feasibility of the different areas would be based on a number of "scenarios" relating to possible mine configurations, cleaning methods and transport routes, the object being to produce "order of magnitude" guidelines for the feasibility of mining lignite at possible sites so that comparison could be made with imported hard coal.

SOURCES OF INFORMATION

3. Sources of information which have been used to provide the basic data may be placed in one or other of the following categories:-

(i) Data provided by NEA, Iceland.

(ii) UK NCB costs and information.

(iii) Mining machinery costs from UK manufacturers.

(iv) Shaft sinking costs from UK contractors.

(v) BMCL "in house" knowledge.

4. Available relevant cost data relating to UK machinery have been adjusted by inflation indices to obtain estimates valid for the third quarter of 1984. The costing of the mine includes a 10% contingency. Other cost items contain a contingency, varying from 0 to 10%, depending on the quality of the estimate and the anticipated conditions in Iceland.

5. UK manufacturers' ex-works costs have been multiplied by 110% to give cif prices.

CAPITAL COSTS

6. Details of the estimated initial capital expenditure are provided in Tables IV, V, VI and VII and are summarised in Table VIII.

7. Land acquisition costs have been excluded because of lack of information.

8. With regard to cost estimates for surface and mine equipment using UK manufacturers' prices, the client requested that two cases should be computed:-

(i) No taxes and tariffs on imported materials and equipment.

(ii) Taxes and tariffs (which would double the price of imported materials and equipment).

9. Costs for a camp site have been included for the Straumnesfjall and Stalfjall sites. The cost estimates are based on IKr200,000 per person to set up the camp and include sleeping facilities, kitchen, bathrooms and lounge. Washing facilities have also been provided at the Straumnesfjall mine site.

Financing and Capital Recovery Charges

10. The cost of capital is assumed to have a real rate of interest of 8% per annum.

11. The useful life of the mine is taken as a maximum of 20 years. In some scenarios reserves would remain available for working after this period. In some scenarios, the life of the mine is less than 20 years.

12. Capital costs would be repaid over the life of the project in equal annual payments. The capital costs include interest calculated on a compound basis. This is used to arrive at a capital cost per tonne and is considered to give a fairer treatment than trying to apportion depreciation and interest charges.

OPERATING COSTS

Production and Productivity

13. Production and productivity estimates are given in Chapter VI of the report.

14. The number of working days per annum for each mine used for production calculations is 240. The days not worked are assumed to be:-

(i) Saturdays and Sundays, 104.

(ii) Annual and public holidays, 21.

15. The absentee rate for employees is assumed to average 10% (NCB figure in 1983/84 was 10.6%).

Wage Levels and Wage Related Charges

16. The information regarding wage levels in Iceland was supplied by the NEA under the following categories of workers:-

(i) Labourers.

(ii) Equipment workers.

(iii) Craftsmen.

17. These categories have been fitted into the projected underground manpower requirements.

18. The wage levels are based on eight hours of work, three shifts, five days per week. Included in the total figure are:-

(i) Wages.

(ii) Pay while travelling to and from work.

(iii) Bonus at 25%.

(iv) Taxes.

(v) Food and cleaning.

Materials

19. A wide variety of materials is used in the mining industry, the chief items of consumption comprising:-

- timber for roof support, sleepers, etc;
- steel for roof support, rails, chutes, cutter picks, etc;
- explosives and detonators;
- oils and greases;
- electricity cables;
- plastic water pipes;
- safety and protective clothing;
- conveyor belting;
- ventilation tubing.

20. An estimation of the consumption of these items is time consuming and tends to be inaccurate and, as there are no underground lignite mines operating in the UK and Iceland, estimates have been based on information relating to comparable NCB collieries with a machine cut/flight loaded method of mining at £4.20/tonne (IKr172/tonne).

Repairs to Equipment

21. The estimated costs of repairs to equipment are based on the assumption that repairs to plant are a function of the initial capital cost and of the conditions under which it operates. For this study, the following rates have been applied:-

(i) Surface equipment - 10% of initial capital equipment/annum.

(ii) Underground equipment - 15% of initial capital equipment/annum. The estimated cost of repairs has allowed for the replacement of those capital items which do not have an operating life equivalent to that of the mine.

Power, Heat and Light

22. This item comprises electricity and lignite consumption. However, the cost of lignite used for heating is generally small compared with electricity charges and is ignored in this study.

23. A study of the electricity consumed at a number of NCB collieries shows that the units per tonne of coal produced vary widely. Taking into account the comparatively small ventilation loads and the degree of mechanisation proposed, a

figure of 30 units per tonne produced has been adopted. A fixed charge has also been included.

General Expenses

24. These costs include all the miscellaneous administrative, legal, sales and colliery charges incurred in operating a colliery. An allowance of 10% of the wages plus wages charges costs is considered to be realistic.

COMPARATIVE COSTS

25. Hard coal imported to Iceland at present is mainly for the ferrosilicon factory at Grundartanga (30,000 to 40,000 tpa) and for the cement works at Akranes (20,000 tpa). The cement works uses coal with a thermal value of 6,300 to 6,400 kcal/kg and the price is IKr1,500/tonne at the factory gate. (Reference Report by Mr Freysteinn Sigurosson and Dr Kristjan Saemundsson, Orkustofnun, April 1984). The coal for the ferrosilicon factory is washed and sieved and costs approximately IKr2,000/tonne.

26. Taking into account the calorific values of the lignite material relating to a cost of IKr1,500/tonne, then:-

(i) for the 3,310 kcal/kg lignite expected at Botn, the above price is equivalent to IKr782/tonne;

(ii) for the 1,840 kcal/kg lignite expected at Dufansdalur and Thernudalur, the above price is equivalent to IKr435/tonne;

(iii) for the 2,747 kcal/kg lignite expected at Straumnesfjall, the above price is equivalent to IKr649/tonne;

(iv) for the 2,013 kcal/kg lignite expected at Stalfjall, the above price is equivalent to IKr476/tonne.

27. The lignite mined in Iceland would be from three times to over seven times more expensive than the cost of currently imported coal, allowing for the different heat values. No possible tariffs and taxes have been included in these comparisons. If tariffs and taxes were included, the lignite would cost four to nine times more (see Table IX).

28. Informal discussions with the NCB who are supplying the coal to the cement works and ferrosilicon factory, indicate that current prices of coal may increase by 10% on fob prices.

CHAPTER IX

FURTHER EXPLORATION

1. The provings examined at the various sites in the north-west peninsula were of an isolated nature and offered little opportunity to establish whether the sections examined had a really useful extent. At best BMCL has the knowledge that tunnels were driven for 100 m at Botn and that, whilst the seam was variable, it did not appear to thin below 70 cm. The exposures at Gil showed significant lateral changes in thickness and section and the two provings at Dufansdalur, 1.5 km apart, showed little resemblance to one another.

2. The terrain would make any future exploration difficult and expensive, indeed, in some cases, access for drilling would involve transport of drilling equipment by helicopter. It might be possible to expose the lignite seams at other localities along the mountain sides and this might have to be carried out by hand-digging.

3. At Straumnesfjall it is suggested that any further exploration takes the form, initially, of about four boreholes through the basalt from the cliff top. These holes should be spaced about 500 m apart with two of the provings located about 500 m away from the cliff outcrop where samples were taken. Water supply for drilling these holes could prove difficult.

4. At Botn it is advised that four provings be made; two at 500 and 1,000 m west along the outcrop from the existing mine entrances. These provings would call for the removal of the scree and adequate exposures made to obtain reliable measurements and samples. Two further provings should be made at approximately 500 and 1,000 m to the east by short boreholes which could be located alongside the road to Isafjordur. A supply of water is available here. The drilling should be by diamond coring, possibly supported by geophysical logging of the boreholes.

5. At Stalfjall the first step towards further exploration should be to expose the seam inland from the cliff exposure. Three or four excavations could be made at localities around 500 m apart so as to satisfactorily expose the seam for measuring and sampling, then a more reliable picture of seam variation would be obtained. It should be remembered that, when an attempt was made to locate the seam east of Stalfjall, near Holt, the only lignite that could be found was a seam of 1 cm.

6. It is not recommended to carry out further work at Gil and whilst further exploration should be carried out at Dufansdalur before any mine were established (this would involve mountain top drilling through the basalt) the first steps could be to seek exposures on either side of the mountain. These exposures would be difficult to obtain or make in view of the very steep slopes.

CHAPTER X

CONCLUSIONS AND RECOMMENDATIONS

SEAM AND QUALITY

Botn

1. The seam is around 75 cm in thickness and would yield moderate quality lignite of about half the calorific value of imported coal.

Gil

2. The seam is of moderate quality, and is poorer than Botn, but the thickness variations over very short distances indicate that a mine cannot be considered.

Dufansdalur and Thernudalur

3. The seam appears to be around 90 cm thick, and is essentially poor quality lignite with thin included dirt bands which cannot be readily removed by mineral preparation. The product is therefore particularly poor in quality and has a low calorific value even for lignite.

Straumnesfjall

4. The exposures here show two seams, the upper one of very poor quality and the lower one of moderate quality, the most likely workable section within this seam is 85 cm thick.

Stalfjall

5. Two seams are present, an upper one of 55 cm considered too thin to be worked and a lower seam of 120 cm of poor quality lignite, again with thin included dirt bands which would be very difficult to remove economically.

RESERVES

6. Within the data available it has not been possible to estimate reliably the reserves at any of the locations. Exploration needs to be carried out and, in most cases, this will prove expensive. For the purpose of this report it was agreed that an area of 2 km^2 of workable coal was to be assumed to be present. From the limited information available this assumption is very much open to question. Nevertheless, in the absence of the assumption, no comparisons could be made as to the probable costs of the end product.

SITES

7. All the sites visited were in difficult terrain where any mines established would inevitably carry abnormally high costs. Some call for new harbours to be built and power lines to be constructed. Additional roadworks were required at all locations and camp sites would need to be built at two. The remoteness of the Straumnesfjall site seriously offsets the slightly better quality of the lignite there.

LIGNITE CLEANING

8. The lack of preparation knowledge of the likely mine products to be produced means that the selection of a cleaning process is difficult. At two of the locations, the material does not appear to lend itself to any useful beneficiation.

ECONOMIC ASSESSMENT

9. The evaluation of the different factors affecting each location lead to three important conclusions:-

(i) The possible mine site at Botn has advantages over the others, even so the best anticipated total cost is calculated at IKr2,282/tonne, excluding taxes and tariffs. This is three times greater than imported hard coal after allowing for differences of heat value.

(ii) At Straumnesfjall, although the seam quality is not greatly different from that at Botn, the additional capital costs of shaft sinking, camp site, harbour, etc have resulted in a total mine cost of IKr3,013/tonne, 4.6 times more expensive than imported hard coal. Again this is the lowest anticipated mine cost achievable at this site.

(iii) At Dufansdalur and Thernudalur, and also Stalfjall, the lignite seam is of particularly low quality which, together with other factors (harbour, roads, etc) gives total costs for each as being 3.7 times more expensive than equivalent heat coal at the optimum mine outputs. It is very likely that lignite from these locations would be unacceptable for the ferrosilicon factory.

RECOMMENDATIONS

10. Whilst it would appear to be very unlikely that any of the possible mines could offer acceptable options, it can be recommended that limited exploration in the Botn locality would establish whether there are sufficient reserves to establish a mine.

APPENDICES

APPENDIX "A"

TERMS OF REFERENCE

APPENDIX "A"

TERMS OF REFERENCE

1. The NEA envisages a two-man consultancy team to inspect the sites of the lignite deposits, discuss the feasibility of exploiting them with NEA geologists and others and report on its findings.

2. The object of the study is to "assess the feasibility of mining lignite from the most promising sites, using the most appropriate modern mining technology, and transporting it to a place where it may be loaded on vessels". The delivered cost of the lignite should be compared with that of imported hard coal and, since viability can be a function of quantity, three levels of output should be assessed, namely 25,000 tonnes, 65,000 tonnes and 100,000 tonnes per year (tpa).

SCOPE OF WORK

3. The following scope of work is suggested:-

(i) Study the existing geological information on the lignite deposits.

(ii) Examine the available information on previous mining, eg plans, methods, etc.

(iii) Visit the site locations on the north-west peninsula.

(iv) Carry out geological examinations and collect samples if appropriate.

(v) Examine sites for evidence of previous mining.

(vi) Interview any personnel who participated in previous mining activities.

(vii) Examine the transportation routes from the mine sites to the appropriate vessel loading points.

(viii) Identify the mining and transportation problems.

(ix) Develop conceptual plans to solve or minimise these problems.

(x) Develop rough estimates for mining and transportation costs.

(xi) Evaluate the alternative plans using qualitative and quantitive criteria.

(xii) Using the best alternatives, make assessments of the economic feasibility for the three tonnage levels of 25,000 tpa, 65,000 tpa and 100,000 tpa.

(xiii) Develop a programme for further exploration if appropriate.

APPENDIX "B"

DESCRIPTION AND ANALYSES OF SAMPLES

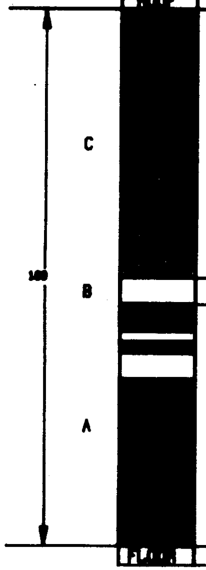
TAKEN, AUGUST 1984

LOCATION: BOTN

Combined field and laboratory description

ANALYSIS (AIR DRIED)

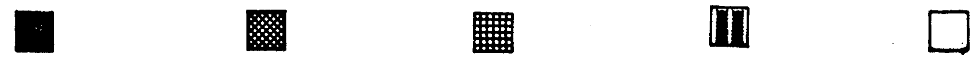
UNIT	Th cm	SP.GR	ASH %	MOISTURE %	Combined field and laboratory description
ROOF	-	2.15	74.0	17.70	Dark mudstone with tuff bands (ochre staining).
C	50	1.53	28.5	17.00	Shaly lignite with many thin tuff layers and streaks (15% by weight).
B	5	2.38	87.5	7.80	Brown-grey tuff with plant impressions.
A	45	1.54	24.6	14.30	Lignite and fossil wood with two pale brown tuff bands. (2cm band from 5-7 cm and 5 cm band from 9-14 cm).
FLOOR	30+	1.65	55.7	14.00	Dark mudstone with tuff layers and fossil wood.



	Th cm	SP.GR	ASH %	MOISTURE %
A+C	100	1.58	31.7	15.18

Remarks: Other section measured but not sampled 3 m away had an overall section of 77 cm including similar proportions of tuff bands.

Scale 1:15



LOCATION: BOTN

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

		Floor Lig*	Floor Tuff*	A Lignite*	A Tuff*	B	C	Roof	Comp
	SUBSECTIONS	Floor Lig*	Floor Tuff*	A Lignite*	A Tuff*	B	C	Roof	Comp
	SAMPLE NO.	11	11	12	12	13	14	15	A Lig + C
	THICKNESS cm	12.5	17.5	38	7	5	50	-	91
	Specific Gravity	1.46	2.14	1.44	2.25	2.39	1.53	2.15	1.49
Air Dried	Moisture %	15.5	13.2	15.1	9.4	7.8	17.0	17.7	16.2
	Ash %	16.6	75.4	15.8	82.4	87.5	29.5	74.0	23.5
	Volatile Matter %			41.7			36.0		38.5
	Fixed Carbon %			27.4			17.5		21.8
	Total Sulphur %			0.53		0.04	0.54		0.54
	Chlorine %			0.02		0.02	0.02		0.02
	Carbon Dioxide %								0.2
	Phosphorus %					0.138			0.228
	Carbon %								40.2
	Hydrogen %								3.50
	Calorific Value KJ/K			18,440			13,490		15,900
Dry Ash	Volatile Matter %			60.3			67.3		63.8
Free	Calorific Value KJ/K			26,680			26,060		26,360
Ash	Initial Deformation °C								1,260**
Fusion	Hemisphere °C								1,310
Temp.	Flow °C								1,330
Red. Atm.									

*Segregated by hand ** Shrinkage at 1130°C For the ash analysis on Sub sections B and A lig + C see over

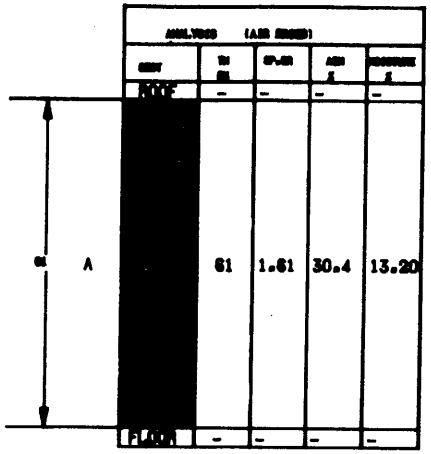
LOCATION: BOTN

Ash Analysis

SUBSECTION	B TUFF	COMPOSITE A LIG + C
THICKNESS ANALYSED cm	5	88
ASH e.d. %	87.5	23.5
	%	%
SiO_2	53.5	43.7
Fe_2O_3	10.1	8.0
MgO	1.4	2.0
CaO	5.1	10.4
Al_2O_3	21.4	25.1
TiO_2	4.5	3.4
Na_2O	2.6	1.0
K_2O	0.4	0.3
SO_3	0.2	4.1

LOCATION: GIL (End of tunnel)

Combined field and laboratory descriptions



Interbedded tuff and mudstone.

Lignite and fossil wood with tuff layers and streaks.

Dark mudstone with tuff bands.

A	61	1.61	30.4	13.20

Scale 1:15

ASH %   <25   25.1 - 40   40.1 - 50   50.1 - 60   60 >

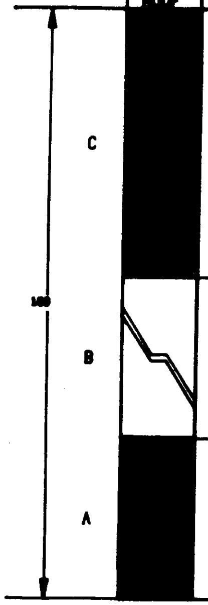
LOCATION: GIL (End of tunnel)

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		A
	SAMPLE NO.		21
	THICKNESS	cm	61
	Specific Gravity		1.61
Air Dried	Moisture	%	13.2
	Ash	%	30.4
	Volatile Matter	%	49.0
	Fixed Carbon	%	7.4
	Total Sulphur	%	0.12
	Chlorine	%	0.02
	Carbon Dioxide	%	
	Phosphorus	%	0.132
	Carbon	%	
	Hydrogen	%	
	Calorific Value	KJ/K	13.480
Dry Ash Free	Volatile Matter	%	86.9
	Calorific Value	KJ/K	23,900
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C	
	Hemisphere	°C	
	Flow	°C	

LOCATION: GIL (tunnel, 10 m inbye)



ANALYSES (AIR DRIED)				
SEAM	TH MM	SP.GR	ASH %	MOISTURE %
ROOF	-	2.18	[illegible]	[illegible]
C	30	1.65	36.6	12.80
B	80	2.18	71.7	16.50
A	30	1.45	8.8	11.40

	TH MM	SP.GR	ASH %	MOISTURE %
A+C	160	1.65	32.6	14.72

Scale 1:15

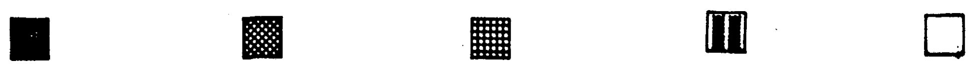
Combined field and laboratory descriptions

Interbedded tuff and mudstone.

Lignite and fossil wood with tuff wedges and nodules.

Dark mudstone with tuff bands.

Fossil wood.



ASH %. <25 | 25.1 - 40 | 40.1 - 50 | 50.1 - 60 | 60 >

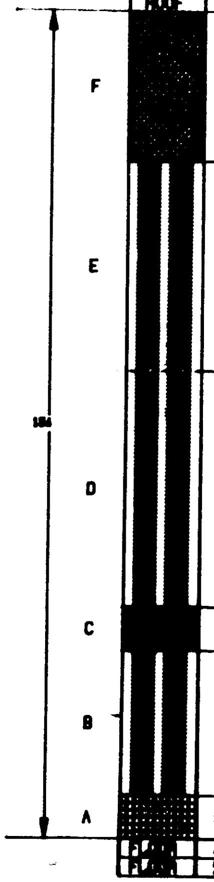
LOCATION: GIL (10 m INBYE)

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

			A	B	C	ROOF	
	SUBSECTIONS		A	B	C	ROOF	
	SAMPLE NO.		20	22	23	24	
	THICKNESS	cm	30	40	50	-	
	Specific Gravity		1.45	2.12	1.65	2.18	
Air Dried	Moisture	%	11.4	16.5	12.8	13.6	
	Ash	%	8.8	71.7	36.6	79.8	
	Volatile Matter	%			47.8		
	Fixed Carbon	%			2.8		
	Total Sulphur	%			0.13		
	Chlorine	%			0.02		
	Carbon Dioxide	%					
	Phosphorus	%			0.075		
	Carbon	%					
	Hydrogen	%					
	Calorific Value	KJ/K			11,660		
Dry Ash Free	Volatile Matter	%			94.5		
	Calorific Value	KJ/K			23,040		
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C					
	Hemisphere	°C					
	Flow	°C					

LOCATION: DUFANSDALSNUPUR (At old mine)



ANALYSIS (AIR DRIED)				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ROOF	50	1.[illegible]	[illegible]	14.20
ROOF	110	2.44	[illegible]	5.[illegible]
F	28	1.63	39.8	16.40
E	38	1.76	50.4	18.60
D	44	1.86	57.7	16.20
C	8	1.61	38.0	16.10
B	27	1.82	55.4	17.20
A	8	1.73	44.5	17.00
[illegible]	[illegible]	[illegible]	[illegible]	21.10
[illegible]	[illegible]	[illegible]	[illegible]	16.70

	[illegible]	[illegible]	[illegible]	[illegible]
A:F	154	1.77	50.8	17.06

Scale 1:15

Combined field and laboratory descriptions

Carbonaceous mudstone with tuff bands.
Coarse-grained tuff with some fossil wood.

Inferior lignite with tuff bands (16.5%).

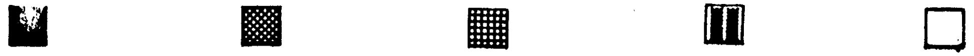
Interbedded very inferior lignite with carbonaceous mudstone and tuff bands.

Interbedded very inferior lignite (52%) with carbonaceous mudstone and tuff bands.

Inferior shaly lignite with some tuff streaks.

Very carbonaceous mudstone with tuff bands (18%).

Very inferior shaly lignite.
Dark brown blocky carbonaceous mudstone with some pale brown tuff bands.
Stained brown mudstone with lignite bands (below water level).



ASH % | <25 | 25·1 - 40 | 40·1 - 50 | 50·1 - 60 | 60 >

LOCATION: DUFANSDALSNUPUR (At old mine)

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		FLOOR 2	FLOOR 1* LIGNITE	FLOOR 1* TUFF	A	B LIGNITE*	B TUFF*	C	D LIGNITE*	D TU[illegible]
	SAMPLE NO.		41	42	42	43	44	44	45	46	46
	THICKNESS	cm	20	18.5	27.5	8	22	5	8	23	21
	Specific Gravity		1.93	1.83	1.98	1.73	1.76	2.07	1.61	1.73	2.0[illegible]
Air Dried	Moisture	%	18.7	20.8	21.3	17.0	17.9	14.8	16.1	16.9	15.5
	Ash	%	63.0	60.2	65.7	44.5	50.8	72.6	39.0	48.0	66.9
	Volatile Matter	%									
	Fixed Carbon	%									
	Total Sulphur	%									
	Chlorine	%									
	Carbon Dioxide	%									
	Phosphorus	%									
	Carbon	%									
	Hydrogen	%									
	Calorific Value	KJ/K									
Dry Ash Free	Volatile Matter	%									
	Calorific Value	KJ/K									
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C									
	Hemisphere	°C									
	Flow	°C									

* Segregated by hand

Continued/....

LOCATION: DUFANSDALSNUPUR (At old mine)

ANALYSIS OF SUBSECTIONS

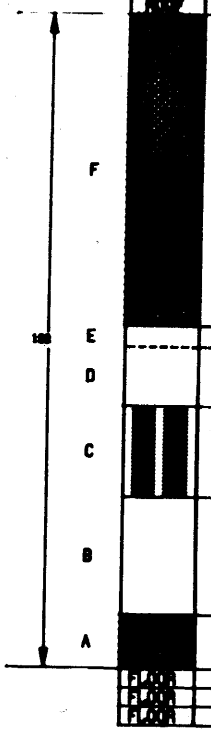
Sample Type: Channel

	SUBSECTIONS		E	F LIGNITE*	F TUFF	COMP. C;D LIG; E; F LIG;	ROOF 1* LIGNITE	ROOF 1* TUFF	ROOF 2	
	SAMPLE NO.		47	48	48		49A	49A	49B	
	THICKNESS	cm	39	23.5	4.5	93.5	38.5	71.5	50	
	Specific Gravity		1.76	1.55	2.04	1.61	1.56	2.92	1.88	
Air Dried	Moisture	%	18.6	16.8	15.0	17.6	16.0	2.8	14.2	
	Ash	%	50.4	32.0	71.2	46.1	32.6	79.0	59.0	
	Volatile Matter	%				26.8				
	Fixed Carbon	%				9.5				
	Total Sulphur	%				0.42				
	Chlorine	%				0.04				
	Carbon Dioxide	%								
	Phosphorus	%								
	Carbon	%								
	Hydrogen	%								
	Calorific Value	KJ/K				9,060				
Dry Ash Free	Volatile Matter	%				73.8				
	Calorific Value	KJ/K				24,960				
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C								
	Hemisphere	°C								
	Flow	°C								

* Segregated by hand

LOCATION: DUFANSDALUR/THERNUDALUR (Entrance of Small Cave)

Combined field and laboratory descriptions



Unit	[illegible]	[illegible]	[illegible]	[illegible]	Description
ROOF	-	1.84	[illegible]	[illegible]	Mudstone with plant remains and fossil wood fragments.
F	38	1.38	37.3	15.30	Inferior shaly lignite with thin tuff and carbonaceous mudstone bands (11%).
E	4	2.18	67.4	5.10	Pale brown tuff with plant impressions.
D	11	1.81	63.4	10.00	Interbedded dark mudstone and tuff with lignite streaks.
C	17	1.65	50.4	12.80	Carbonaceous mudstone with tuff bands and fossil wood.
B	22	2.32	84.6	8.10	Pale brown tuff with plant impressions.
A	10	1.38	34.2	16.20	Inferior lignite with some fossil wood.
FLOOR	10	1.75	51.4	17.70	Carbonaceous mudstone with plant remains.
FLOOR	30	2.00	[illegible]	[illegible]	Black and brown mudstone with tuff layers and fossil wood.
FLOOR	30	[illegible]	73.4	7.80	Interbedded dark mudstone and tuff with plant remains and fossil wood.

	[illegible]	[illegible]	[illegible]	[illegible]
A+F	122	1.81	54.4	12.51

Scale 1:15

ASH %	<25	25·1 - 40	40·1 - 50	50·1 - 60	60 >

LOCATION: DUFANSDALUR/THERNUDALUR (Entrance of Small Cave)

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

			Floor 3	Floor 2	Floor 1	A	B	C	D	Comp	E
	SAMPLE NO.		31	32	33	34	35	36	37	C + D	38
	THICKNESS	cm	30	30	10	10	22	17	11	28	4
	Specific Gravity		2.39	2.00	1.75	1.58	2.32	1.85	1.91	1.87	2.19
Air Dried	Moisture	%	7.8	14.2	17.7	16.2	8.1	12.8	10.0	11.7	5.1
	Ash	%	72.4	66.0	51.4	34.2	84.6	50.4	63.4	55.6	87.4
	Volatile Matter	%								23.9	
	Fixed Carbon	%								8.8	
	Total Sulphur	%								0.22	0.02
	Chlorine	%								0.04	0.02
	Carbon Dioxide	%									
	Phosphorus	%									
	Carbon	%									
	Hydrogen	%									
	Calorific Value	KJ/K								7,160	
Dry Ash Free	Volatile Matter	%								73.1	
	Calorific Value	KJ/K								21,900	
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C									
	Hemisphere	°C									
	Flow	°C									

Continued...

LOCATION: DUFANSDALUR/THERNUDALUR (Entrance of Small Cave)

ANALYSIS OF SUBSECTIONS

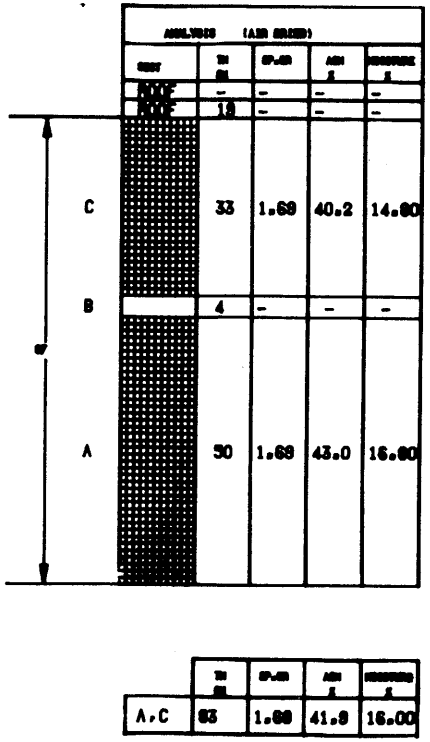
Sample Type: Channel

	SUBSECTIONS		F Lig *	F Tuff *	Roof
	SAMPLE NO.		39	39	310
	THICKNESS cm		52	6	—
	Specific Gravity		1.56	1.87	1.94
Air Dried	Moisture	%	15.7	13.7	11.2
	Ash	%	34.1	60.8	63.0
	Volatile Matter	%	35.5		
	Fixed Carbon	%	14.7		
	Total Sulphur	%	0.41		
	Chlorine	%	0.02		
	Carbon Dioxide	%			
	Phosphorus	%			
	Carbon	%			
	Hydrogen	%			
	Calorific Value	KJ/K	12,820		
Dry Ash Free	Volatile Matter	%	70.7		
	Calorific Value	KJ/K	25,540		
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C			
	Hemisphere	°C			
	Flow	°C			

* Segregated by Hand

LOCATION: DUFANSDALUR/THERNUDALUR (Large Cave)

Combined field and laboratory description



Pale brown tuff band.

Inferior lignite with tuff bands and fossil wood.

Pale brown tuff band.

Inferior lignite with some carbonaceous mudstone bands.

Remarks: Measurement in two adjacent localities indicate variability in thickness, the seam being 94 and 72 cm respectively.

Scale 1:15

LOCATION: DUFANSDALUR/THERNUDALUR (Large Cave)

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		A	C	
	SAMPLE NO.		311	312	
	THICKNESS	cm	50	33	
	Specific Gravity		1.69	1.69	
Air Dried	Moisture	%	16.8	14.8	
	Ash	%	43.0	40.2	
	Volatile Matter	%	30.1	36.3	
	Fixed Carbon	%	10.1	8.7	
	Total Sulphur	%	0.30	0.30	
	Chlorine	%	0.04	0.02	
	Carbon Dioxide	%	1.2	1.6	
	Phosphorus	%	0.078	0.078	
	Carbon	%	25.0	28.6	
	Hydrogen	%	4.58	2.91	
	Calorific Value	KJ/K	9,860	11,100	
Dry Ash Free	Volatile Matter	%	74.9	80.7	
	Calorific Value	KJ/K	24,520	24,660	
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C			
	Hemisphere	°C			
	Flow	°C			

LOCATION: STRAUMNESFJALL

Combined field and laboratory description

Unit	Th cm	Sp.Gr	Ash %	Moisture %	Combined field and laboratory description
					Analyses (air dried)
ROOF	210	-	-	-	
	30	-	-	-	Woody Lignite
	160	-	-	-	Mainly mudstone with some tuff bands and thin lignite layers.
F'	30	1.54	30.0	18.20	Inferior lignite, shaly in places with fossil wood.
E'	30	1.76	52.6	18.30	Carbonaceous mudstone with fossil wood (29%).
D'	30	1.57	33.8	18.30	Inferior shaly lignite and fossil wood.
C'	30	1.64	43.6	18.80	Inferior shaly lignite with brown mudstone bands.
B'	30	1.65	43.7	18.40	Fossil wood with carbonaceous mudstone (25%).
A'	30	1.64	40.6	16.40	Inferior lignite with mudstone and thin tuff bands.
	200	-	-	-	Alternating tuff, mudstone and thin bands of fossil wood.
E	28	1.37	6.9	15.90	Lignite with fossil wood.
D	35	1.96	68.7	12.40	Brown tuff and mudstone with a little fossil wood.
C	30	1.36	34.3	16.50	Lignite with fossil wood and tuff layers, and 8cm thick tuff wedge near base (tuff 23%).
B	25	1.41	10.4	15.30	Lignite with fossil wood.
A	30	1.62	44.6	20.20	Inferior lignite with a 3cm tuff band (10-13cm from top) and also mudstone and tuff streaks.
FLOOR	30+	1.92	67.5	18.10	Strong pale brown tuff and mudstone.

Scale 1:20

	Th cm	Sp.Gr	Ash %	Moisture %
A-E	148	1.61	38.4	15.80

	Th cm	Sp.Gr	Ash %	Moisture %
A'-F'	180	1.63	41.0	18.36

LOCATION: **STRAUMNESFJALL**

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		Floor	A	B	C LIGNITE	C TUFF	D	E	A'LIGNITE*	A' TUFF
	SAMPLE NO.		51	52	53	54	54	55	56	57A	57A
	THICKNESS cm		+ 50	30	25	23	7	35	28	23	7
	Specific Gravity		1.92	1.62	1.41	1.43	2.00	1.96	1.37	1.57	1.86
Air Dried	Moisture	%	18.1	20.2	15.3	17.6	14.0	12.4	15.9	17.0	14.8
	Ash	%	67.5	44.6	10.4	17.6	73.4	68.7	6.9	33.1	61.4
	Volatile Matter	%		24.8	46.1	39.8			48.5		
	Fixed Carbon	%		10.4	28.2	25.0			28.7		
	Total Sulphur	%		0.36	0.46	0.43	0.04		0.31		
	Chlorine	%		0.04	0.04	0.04	0.04		0.02		
	Carbon Dioxide	%			0.1						
	Phosphorus	%			0.011						
	Carbon	%			47.2						
	Hydrogen	%			4.16						
	Calorific Value	KJ/K		8,320	18,760	16,600			19,700		
Dry Ash	Volatile Matter	%		70.5	62.0	61.4			62.8		
Free	Calorific Value	KJ/K		23,640	25,240	25,620			25,520		
Ash	Initial Deformation	°C									
Fusion	Hemisphere	°C									
Temp.	Flow	°C									
Red. Atm.											

*Segregated by Hand

Continued/.....

LOCATION: **STRAUMNESFJALL**

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		B' LIGNITE*	B' TUFF*	C' LIGNITE*	C' TUFF*	D'	E' LIGNITE*	E' TUFF*	F'
	SAMPLE NO.		57B	57B	57C	57C	57D	57E	57E	57F
	THICKNESS	cm	7.5	22.5	13	17	30	8.5	21.5	30
	Specific Gravity		1.39	1.74	1.54	1.72	1.57	1.42	1.90	1.54
Air Dried	Moisture	%	15.3	19.2	19.6	19.6	19.3	15.4	19.1	18.2
	Ash	%	12.0	52.2	28.2	54.2	33.8	13.6	64.1	30.0
	Volatile Matter	%								
	Fixed Carbon	%								
	Total Sulphur	%								
	Chlorine	%								
	Carbon Dioxide	%								
	Phosphorus	%								
	Carbon	%								
	Hydrogen	%								
	Calorific Value	KJ/K								
Dry Ash Free	Volatile Matter	%								
	Calorific Value	KJ/K								
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C								
	Hemisphere	°C								
	Flow	°C								

*Segregated by hand

Continued/...

LOCATION: STRAUMNESFJALL

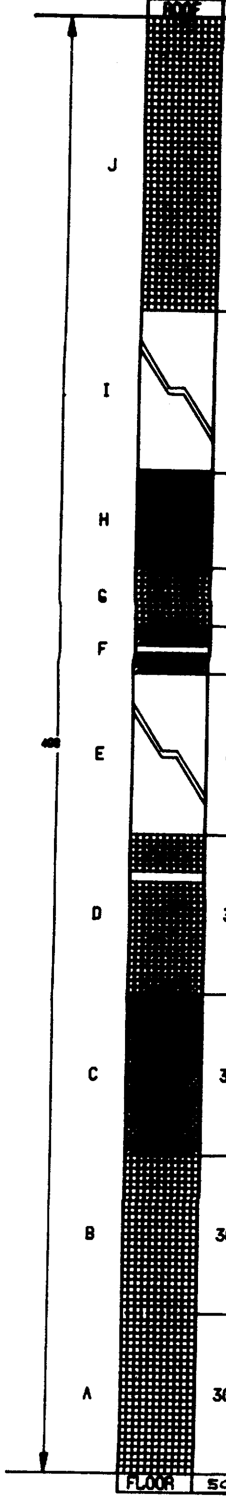
ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		COMP. LIGNITE
	SAMPLE NO.		A'–F'
	THICKNESS	cm	112
	Specific Gravity		1.54
Air Dried	Moisture	%	18.0
	Ash	%	29.2
	Volatile Matter	%	34.8
	Fixed Carbon	%	18.0
	Total Sulphur	%	0.48
	Chlorine	%	0.04
	Carbon Dioxide	%	0.2
	Phosphorus	%	0.032
	Carbon	%	33.2
	Hydrogen	%	3.12
	Calorific Value	KJ/K	13,000
Dry Ash Free	Volatile Matter	%	65.9
	Calorific Value	KJ/K	24,620
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C	
	Hemisphere	°C	
	Flow	°C	

LOCATION: STALFJALL

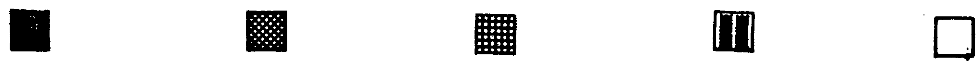
Combined field and laboratory descriptions



ANALYSIS (AIR DRIED)					
UNIT	TH CM	SP.GR	ASH %	MOISTURE %	Description
ROOF	120	–	–	–	Dark brown mudstone with grey tuff bands.
J	55	1.62	41.3	17.20	Inferior shaly lignite with green tuff bands (19%).
I	150	1.87	62.6	13.30	Interbanded tuff with some mudstone and lignite (25%) (1-3 cm bands).
H	18	1.48	24.4	15.40	Shaly lignite.
G	11	1.71	45.6	13.80	Carbonaceous mudstone and tuff with some fossil wood.
F	9	1.51	25.2	15.00	Shaly lignite with a tuff band.
E	45	1.86	60.9	14.50	Coarse light grey tuff with bands of shaly lignite (2-6 cm thick).
D	30	1.81	51.2	12.70	Very inferior lignite with mudstone and thin tuff bands.
C	30	1.62	40.2	15.50	Inferior shaly lignite with thin tuff bands.
B	30	1.63	42.5	15.40	Inferior shaly lignite with pale brown tuff bands.
A	30	1.68	44.0	13.90	Inferior lignite with pale brown tuff bands.
FLOOR	50+	2.11	69.0	10.20	Pale brown coarse tuff, carbonaceous in parts.

	TH CM	SP.GR	ASH %	MOISTURE %
A-J	408	1.79	52.3	14.32

Scale 1:15



ASH % | <25 | 25.1 - 40 | 40.1 - 50 | 50.1 60 | 60 >

LOCATION: STALFJALL

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		Floor	A LIGNITE*	A TUFF*	B LIGNITE*	B TUFF*	C LIGNITE*	C TUFF*	D LIGNITE*
	SAMPLE NO.		61	62	62	63	63	64	64	65
	THICKNESS	cm	+50	23.5	6.5	23	7	25.5	4.5	20
	Specific Gravity		2.11	1.58	2.06	1.54	1.92	1.55	1.99	1.68
Air Dried	Moisture	%	10.2	14.5	12.2	15.7	14.7	16.3	11.8	13.8
	Ash	%	69.0	36.1	66.0	32.9	67.8	33.9	68.1	40.3
	Volatile Matter	%								
	Fixed Carbon	%								
	Total Sulphur	%								
	Chlorine	%								
	Carbon Dioxide	%								
	Phosphorus	%								
	Carbon	%								
	Hydrogen	%								
	Calorific Value	KJ/K								
Dry Ash Free	Volatile Matter	%								
	Calorific Value	KJ/K								
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C								
	Hemisphere	°C								
	Flow	°C								

* Segregated by hand

Continued/....

LOCATION: STALFJALL

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		D TUFF*	COMP. LIGNITE A – D	COMP TUFF A – D	COMP A – D	E LIGNITE*	E TUFF*	F LIGNITE*	F TUFF*
	SAMPLE NO.		65				66	66	67	67
	THICKNESS	cm	10	92	28	120	17.5	27.5	8.5	0.5
	Specific Gravity		2.06	1.58	2.01	1.80	1.60	2.03	1.48	2.09
Air Dried	Moisture	%	10.8	15.1	12.2	14.3	15.5	14.0	15.2	12.9
	Ash	%	69.0	35.7	67.9	44.7	37.5	72.6	21.0	75.9
	Volatile Matter	%		33.9			28.3			
	Fixed Carbon	%		15.3			18.7			
	Total Sulphur	%		0.44	0.17	0.36	0.36			
	Chlorine	%		0.06	0.05	0.06	0.04			
	Carbon Dioxide	%		0.8						
	Phosphorus	%		0.040						
	Carbon	%		32.3						
	Hydrogen	%		2.98						
	Calorific Value	KJ/K		12,720						
Dry Ash Free	Volatile Matter	%		68.9			60.2			
	Calorific Value	KJ/K		25,860						
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C		1,190						
	Hemisphere	°C		1,310						
	Flow	°C		1,380						

* Segregated by hand

Continued/.....

LOCATION: STALFJALL

ANALYSIS OF SUBSECTIONS

Sample Type: Channel

	SUBSECTIONS		COMP.	G	H	I	J LIGNITE*	J TUFF*
	SAMPLE NO.		F	68	69	610	611	611
	THICKNESS	cm	9	11	18	150	45	10
	Specific Gravity		1.51	1.71	1.48	1.97	1.56	1.88
Air Dried	Moisture	%	15.0	13.8	15.4	13.3	17.4	16.3
	Ash	%	25.2	45.6	24.4	62.6	34.2	67.8
	Volatile Matter	%			36.2		30.5	
	Fixed Carbon	%			24.0		17.9	
	Total Sulphur	%	0.44	0.22	0.48		0.32	
	Chlorine	%	0.04	0.02	0.02		0.04	
	Carbon Dioxide	%						
	Phosphorus	%						
	Carbon	%			40.7			
	Hydrogen	%			3.70			
	Calorific Value	KJ/K			16,500			
Dry Ash Free	Volatile Matter	%			60.1		63.0	
	Calorific Value	KJ/K			27,400			
Ash Fusion Temp. Red. Atm.	Initial Deformation	°C						
	Hemisphere	°C						
	Flow	°C						

*Segregated by hand

APPENDIX "C"

INFORMATION ON PAPERS, DOCUMENTS, AND INTERVIEWS RELATING TO PAST LIGNITE MINING

APPENDIX "C"

INFORMATION ON PAPERS, DOCUMENTS AND INTERVIEWS RELATING TO PAST LIGNITE MINING

1. The information has been compiled in date order:-

Report on Stalfjall by Swedish Engineer, Mr Ivan Svedberg, dated 26th November 1916, translated by Dr K Saemundsson.

2. The total thickness of the stone coal should have been 5 to 6 m. In reality the total thickness of the whole layer of lignite and mudstones is 3.9 m of which 1.3 m is lignite. The reason for this discrepancy is the difficulty in differentiating between the dark mudstone and the real lignite.

3. Experimental work started in an old digging and a tunnel of about 30 m length was driven in following the bottom of the lignite bearing sequence. Another tunnel parallel to this one 18 m long was driven following the upper boundary of the lignite strata in layers they would not reach in first place. A third tunnel was made to the west 8 m long. The roof appeared stable and its composition should not hinder or obstruct further tunnelling. The deposit between the layers could be used for backfill. Water did not cause any difficulties. Conditions look equal to those mines on southern tip of Sweden. After some training the workers should be able to produce 1.2 to 1.5 t of coal per man per day. Finally, due to there being no port and difficult wind situation it would not be possible to get away the lignite mined.

4. It must not be overlooked that although lignite thickness is considerable there are very great difficulties in setting up a mining operation because of the lignite outcropping on a steep cliff.

5. According to the profiles, the layers numbered 3, 4, 5, 6 and 7* which have a total thickness of 2 m 10 cm, of which 110 cm is lignite, will be most suitable for mining. The rubbish between the layers is used for back filling to keep up the roof. However, the stability of the roof will depend upon how the yellow shale layers will behave. Only a longer experience will show how this will work out.

* No diagrams were attached to the report to identify the individual thicknesses and nature of the layers.

6. Provided that the lignite is worth mining, that the layer No 2 in the column will support itself (be good for a roof), can the layers 3 to 7 be considered for mining then the conditions are likely to be no worse than the mines in southern Sweden.

7. Regarding the thickness and type of the coal, it seems likely that the lignite under the mountain should be better quality and thicker. According to the state testing station in Copenhagen, the analysis should be Moisture 18.9% and 17%, Ash 21.7% and 25%, Thermal Value 3,506 kJ/kg and 3,407 kJ/kg. Also the Swedish State Railway Testing Laboratory carried out some analysis of small samples and the results are Moisture 18.93%, 18.55%, Ash 20.18% and 35.22% and Thermal Value 3,845 kJ/kg and 2,750 kJ/kg.

Uses

8. I would say, based on my experience, lignite of the quality that can be mined at Stalfjall and of the composition, can be used for most of the purposes in Iceland but these lignites are too high in ash and far too low in Thermal Value for shipping or for export to Denmark. However, in an emergency situation, the coal in Quality 1 could be used for shipping but because of the low thermal value the effective voyage length of the ship would be less.

The Coal Reserves

9. No exact data exists on the aerial extent of the lignite layer so it is not possible to calculate the reserves with any confidence.

10. The only fact is that the profile offers mining a 110 cm layer ($1\frac{1}{2}$ t/m^2) and this would be 1.5 million t/km^2. Stalfjall as it is now from N-S is 12 km and as the coal occurrence is constant over that distance, every kilometre across the mountain should contain 18 million tonnes. However, this is an estimate which is not at all very improbable.

11. He anticipated, 50,000 t/a mining, that the lignite reserves of Stalfjall in all probability for the mining of 50,000 t/a, the reserves can be considered inexhaustible.

Paper "Coal Mining in Iceland and the Spar Mine at Helgustadir, Iceland" by H H Eiriksson, Transactions of Institution of Mining Engineers, Great Britain, Vol LIX, Part I (1919-1920)

12. A copy of this paper is enclosed as Appendix "D".

13. Page 1, Paragraph 1 "the weathered and half-hidden outcrops do not give a favourable impression of the quality and size of the seams, and nothing was therefore done to investigate the possibilities of working any of these deposits until 1915. Then a private man, owning one of the best and thickest seams in the West of Iceland, namely the Stalfjall Seam, formed an Icelandic-Danish Company to work it. The company has been in operation since 1916, but has always worked at a loss".

14. "The opening out of these seams, together with the scarcity of fuel due to the restrictions placed on coal imports to Iceland by the war, drew attention to several of the other seams. Lignite was actually taken from a few of them, but only to a small extent and without any proper appliances, and consequently the lignite did not even pay for the labour expended in getting it".

15. A table on page 4 of the paper shows the Stalfjall coal as having a calorific value in calories of 5,100, a moisture content of 18% and an ash content of 18%. The author states "the analyses, although only proximate, show clearly that none of the Icelandic coals is of much commercial value".

Report by Sigurdar Thorarinsson for the Icelandic Government, dated 6th October 1938, "On the Main Lignite Localities of Iceland, Accessibility and Possibility of Mining"

Gil Mine

16. Mined 1916-1918. I measured the section in the mine and the following is a mean of many measurements. These are two lignite layers.

Guomundur Bardarson measured 53 cm and 55 cm, Thorarinsson measured 30 and 40 cm. Between the layers there is a mudstone, carbon rich, 80 to 100 cm thick. These thicknesses make it possible to work the two layers as one with tunnel height of the height of a man. The lignite has been mined in such a way that the breccia forms the roof and the mudstone below the lower lignite, the floor. According to the farmer at Gil, the miners got 1.5 t of coal out of each m^2. The main tunnel is 30 m long.

17. West of the river quite some lignite has been worked as well. Layers are as thick as main mine.

18. I have very little faith in the possibility of large scale mining both because the mine is not good enough and it is not possible to see large reserves and the deposit gets thinner as they go inbye.

Botn

19. Lignite 140 m above sea level. The work started on Botn mine in 1917. There are two openings but there is very much water in the mine. It was equally deep at the entrance as at the end. There is only one lignite layer nearly 70 cm thick. The topmost part of it is woody, otherwise most of it is proper lignite. Stein Eirtkssonn, foreman of the team in 1917, said that the lignite was a good fuelling material. The amount of lignite per worker was about one tonne of coal for three men.

20. I think the possibilities are better than Gil. Access is better. There is only one seam, as thick as the two layers at Gil. At times of high coal prices I think coal could be worked here profitably.

Dufansdalur and Thernudalur

21. On the nose of Dufansdalur mountain there are layers of lignite and mudstone 170 m above sea level and they dip south-east. They appear again at Thernudalur 110 m above sea level. Obviously they are the same layers as the basalt is recognised.

22. Both on the nose of the mountain and in the valley lignite was mined during the First World War. The layering of these mines shows the lignite layers at Dufansdalur to be many but mainly thin beds. At Thernudalur there are fewer layers but they are thicker. The aggregate thickness of the lignite at Dufansdalur is 75 cm, and at Thernudalur, 90 cm. In both localities the lignite can be classified as proper lignites. Nowhere have I seen a lignite as "fat", a silky lustre can be seen and they burnt with a multi-coloured flame. I assume that there is very much ash in the deposit but hope CV is high because of the lustre. (As far as can be ascertained samples were never taken).

23. If the lignite from here turns out to be good fuelling material, I think that this is probably the best I have seen, especially Thernudalur at the head of the valley. I consider accessibility is better at nose of mountain, and let the coal down the mountain on a rope. I am worried that the lignite layers are so thin and because they are so thin they may crumple and get lost on sorting.

24. I did not see any thicker deposits at the end of the mine at Dufansdalur which was 35 m in. Also work at the Thernudalur mine was started because people did not like coal from Dufansdalur.

Stalfjall

25. He refers to location and cliffs being 650 m high. At the base of these cliffs there are lignite and mudstone layers about 5 m thick. The layers above them are a very thick columnar basalt. The dip is 7^0 to the east (it is actually 7^0 SSE). About 300 m further west the lignite layers become covered by screes. To get there, you must go down alone on a path for one person which goes down the cliffs and screes. Just west of the lignite there is a grass bench where the mine houses stood. Although it seems there could be a danger of rock avalanches and snow. The shore consists of coarse rock and usually there is some surf and you can only land there in a calm north wind. At this apparently very inaccessible location there was the largest attempt to mine lignite on a grand scale. It was during the First World War that a consortium was formed and the lignite was mined 1915-1918. On the grass west of the mine, two large wooden houses for the miners were built and there were as many as 40 men working there. A big steam engine was brought in to drive the drilling tools. That engine is still up in the scree but soon it will fall into it. In the tunnels, the longest 80 m with offshoots and connecting tunnels, you can still see the rusty steel rails, and tubs.

26. The mining itself did not pay well off and the company went bankrupt. The main reason would have been the very difficult access. Rumours said the steam engine used up most of the coal. Much of the coal stocked on the beach was washed away during a heavy storm. Very little of the mine coal found itself on the market.

27. The lignite here is only proper lignite. They seem to contain a lot of ash but there are streaks of glossy coal which seems to be a very good fuelling material and also that type was considered just as good as imported coal. The difficulty of access is such that I do not consider it advisable to start work here. (There is no mention of the thickness of the layers).

Iceland, July 1942, by British Naval Intelligence Division - Extract Referring to Fuel

Fuel

28. Beds of coal (lignite) are not uncommon in the older rocks, but the seams are thin and of inferior quality. Since 1916 sporadic attempts have been made to work them, apparently always at a loss, although they are very often dug in a small way for local use. Black lustrous volcanic glass has been mistaken for coal. Coal has been worked at Stalfjall, on the northern shore of Breioifjorour, and on the coast at Tjornes, 10 km north-north-east of Husavik. At Tungunamur, Tjornes, three seams (of Pliocene age), 10, 40 and 70 cm thick respectively, are separated by mudstone; the coal is very sandy and gives a strong sulphurous smell when burnt; the mine has been abandoned. Lignite is being mined on a small scale in Sugandafjorour. (Botn). Peat is widespread in the lowlands and valleys and has been extensively dug for fuel. Thicknesses seldom reach 4 m, and the deposits in the volcanic districts commonly contain ash and blown sand.

Report by Freysteinn Sigurosson and Dr Kristjan Saemundsson, Orkustofnun, April 1984

29. The following extracts relating to past mining sites are taken from the above report:-

Botn

30. The lignite mine at Botn has always been considered an attractive proposition. During the Second World War it was the only mining of lignite in

Iceland. According to press reports, the lignite thickness is said to be 90 cm. According to a geologist who measured the thickness in the tunnel during the First World War it was 62 to 75 cm and keeps its thickness in the main tunnel and laterals. In the Second World War, 7 to 8 men from the Faeroe Islands, worked the mine for two years. They lowered the tunnel height to one metre (previously it was a man's height) and worked in on their knees. The main tunnel goes in just over 100 m into the mountain. With side drivages the aggregate amount of tunnelling is 300 m. There is a brook flowing down and near the side of the tunnel entrances. The water is diverted into the tunnel, a dam has been constructed, and the water is used by the farmer for making electricity. The tunnel is therefore inaccessible. The mine entrance is 140 m amsl. The lignite is nowhere to be seen on the slopes because it is covered in scree. The thickness of the interbed is 4 to 5 m. The thickness of the lignite is 80 cm. Under the main layer is 70 cm of carbon rich mudstone.

Gil

31. The lignite occurs alongside Gika river about 180 m amsl. It is not known of any other outcrop of the sedimentary layer elsewhere in the valley except at Trolla, 1 km south but there is no lignite in it here. The lignite of the Gil mine was mined in the First World War but the work was extremely difficult as can be seen from press reports and that was why the enterprise stopped. Also the lignite was very poor burning material.

32. There are two openings south of the mine and one under the waterfall. The lower opening (western most) is almost closed by scree falling over it. By removing the scree it was possible to creep in. There was a small cave which reached 8 m into the mountain alongside a dyke. Obviously the dyke had created some problem in the lignite mine. The roof is an hyaloclastite breccia, probably formed by lava flowing into a lake. The thickness of the lignite bearing section was mentioned. The main lignite seam was 50 to 60 cm with most of the lignite near the top of the bed. Below was a clayey lignite. Gudmundur G Bardarson (1918) mentioned two lignite layers in the Gil mine, one 35 to 53 cm, the second 40 to 55 cm separated by 1 m of material.

33. The main mine is about 60 m up the stream and is easily accessible. The dyke mentioned is adjacent to the entrance but does not disturb the working. Beyond the entrance there is a large room with pillars of natural rock. The mine reached about 50 m in, but is very irregular. The greatest height to the roof is about 3 m but most of the workings are much lower. The lignite is well exposed in the walls. The findings are similar to the report of 1938. There are two lignite layers, the lower looks better for burning. Between them there is a mudstone. It is possible to get about 120 m of the lignite bearing strata in the gorge but much scree has to be removed between the entrances to get to the layer. The lignite can be seen across the river but only very little. Some lignite has been taken there. The roof of the mine consists of a hyaloclastite breccia which is very stable. However, the mudstone between the lignite and the hyaloclastite breccia does not hold and falls down.

Dufansdalur

34. Site entrance 170 m amsl. Tunnel entrance almost closed. Tunnel is 1.8 m high. Tunnel is dipping inbye. Tunnel is 80 to 100 m long. Section shows very many layers, aggregate thickness 75 cm. The old miners are all dead.

Thernudalur

35. Entrance approximately 100 m amsl. Worked during the First World War.

Straumnesfjall

36. At the first locality, at the nose above the lighthouse, the total thickness of the layer is 10 m, with the lignite found in the uppermost 4 m, the thickest layer is about 20 cm. In total the lignite is 70 cm of the total of 4 m.

37. Following the sedimentary sequence around the nose, there comes a very broad scree slope, beyond which is an exposure. Above the shipwreck, the lignite was examined. There the total thickness of the sedimentary is 12 m. The lignite occurs in the layer mainly in two beds. About 70 cm near the top, and three layers totalling 90 cm in lower part.

38. The third profile was about 200 to 300 m further from the lighthouse (inspected by BMCL team). The total thickness was 12 m, the lowermost 5 m are scree covered but obviously do not contain any lignite. This profile contained more lignite than the others. In the uppermost 6 m there was a total of 3 m of lignite but the layers are thin and separated by mudstone and ash.

INTERVIEWS

Botn

Wednesday, 15th August 1984, Fridberts Peturssoner, Farmer. Interpreter, Dr Kristjan Saemundsson.

39. The farmer had not worked in the mine, but had farmed the land on which the mine is situated, during the period of the mine operations in the Second World War. He gave the following information:-

(i) Two main roads driven, pillars between were very small.

(ii) Length of the tunnels, 300 m directly in (but not confident of this distance).

(iii) The Icelanders worked the mine in the First World War and 1941.

(iv) The Faroes miners, who came in 1941, lowered the height of working, and filled the old openings with waste. Tunnels were very low, about 1 m high.

(v) They worked off mainly to the right with small tunnels.

(vi) They used iron rails, small wagons. No mechanised haulage.

(vii) Thickness of the lignite was about 90 cm with two clay layers. Bottom of the seam not even. Where you had undulations the lignite was thinner, down to 50 cm.

(viii) Upper layer was more persistant.

(ix) Foreman of the mine said thickness was more often 70 cm.

(x) Height of main tunnel, 2.5 m maximum.

(xi) Tuff layers did not cause problems of working but light grey tuff had to be picked out. Also dirt from roof and floor.

(xii) Compressed air was used to drill holes in the lignite and blasted down. Hand picks were also used.

(xiii) Mine was selling two types of lignite:-

(a) Unsorted.

(b) Hand cleaned.

(xiv) Working for 10 hours, 6 men at mine, $^{2}/_{3}$ t of lignite for each man per day, ie 4 t/day.

(xv) Essentially dry mining, some local "drops".

(xvi) General slope was dipping inbye with a trench at the side for water to run out - depth of the trench at the tunnel entrance was maximum of 1 m.

(xvii) The farmer had no knowledge as to whether the "make" of water changed with the seasons.

(xviii) Waterfall did not affect mining.

(xix) Icelanders allowed 2 m of mudstone to fall and no supports were set.

(xx) Both tunnel and headings were made lower by the Faeroes miners and wood timber and props were set. Width of main heading 3 m. Height 1 m 50 cm. Width of tunnels 3 to 4 m.

(xxi) Height of tub 80 cm (estimate).

(xxii) Layer near the roof was hand picked off to make a 50 cm overcut. Then drilled and blasted from the top. Mudstone easier to work than the lignite.

(xxiii) The farmer did not burn lignite, he burned peat.

(xxiv) The mine was operated by a company who bought the tools. The mine was not subsidised. They stopped working because coal price went down.

(xxv) Coal was tipped along a chute into a lorry. The lorry took 2½ t and the lignite was used in three local villages.

(xxvi) Preparations to work the mine started in 1939. In 1940 the Faeroes foreman took over. In spring 1941 the mine started working properly. Worked all of 1942. In spring 1943 the Faeroes miners stopped working. No Icelanders would work it.

(xxvii) The men were using carbide lights.

(xxviii) A small fault approximately 1 m down throw had been encountered about 250 m in. Main heading encountered a dyke at about half way in. It was 1 m thick. Very hard. No water or gas encountered with the dyke.

(xxix) Headings stopped because they were having roof problems but he could not say what these problems were.

(xxx) He thought the mine could be worked 12 months per year but you would need a caterpillar vehicle to remove the snow.

(xxxi) There were no pumps in the mine to pump out water.

(xxxii) The mine worked two headings at a time with one man per heading. The foreman did the blasting. Two men were employed on hand clearing, one on haulage and one on general work such as salvaging.

(xxxiii) As far as he was aware, there were no special problems in the mine. The biggest problem was accommodation for the workers.

(xxxiv) The floor of the workings was mostly dry, but in some places, wet and slippery.

(xxxv) The mine transported the lignite by $2\frac{1}{2}$ t lorries over the mountain to Isafjordur. Worked this way for four months in summer, doing three journeys per day. Loaded from stocks, each journey taking two hours including loading and unloading.

Gil

40. There was no known person to give any information regarding the former workings.

Dufansdalur and Thernudalur

41. Monday, 20th August 1984. Benedidit Beneditsson, aged about 55. He was curious to inspect the mine. In 1974 he had waded down the tunnel (he removed all his clothing). He counted about 100 steps. At the end of the tunnel a large cave had been made. The road had been widened to 6 m and the roof fall was observed about 4 m above the road (probably up to basalt). The water went up to his chest. No tunnels off the main heading, but there had been some widening at intervals (probably to make sumps for water).

42. Monday, 20th August 1984, Bjorn Olafsson. Aged 64, he had lived 50 years on the farm near the mine. The headings in the valley were 20 m in. Dufansdalur was by far the longest. The material from each was all equally bad. It was easier in the valley to go at various headings. Only one at nose of mountain because of difficulty of access. The men had small oil lamps. They used explosives to loosen the rock and then hand tools to get the lignite. The poor material was hand picked out. No supports were set. The material from the head of the valley was transported by horse and cart and he thinks there may have been a cable arrangement from the mouth of the mine. The headings were not dry. Where the widening took place, the floor was excavated to $1\frac{1}{2}$ to 2 m to collect water during the day and were emptied at night using buckets. There was no power to the site and no ventilation fan.

43. Telephone conversation between Olafir Gislasson, and Dr Kristjan Saemundsson. Mr Olafir Gislasson, who it was thought may be helpful, thought the headings in the valley were the deepest. He had no other information.

Straumnesfjall

44. No previous mining at this site other than "pickings" from the outcrop.

Stalfjall

45. Tuesday, 21st August 1984. The team were guided to the site by Bragi Ivarsson, who had worked the farm near where the mine is situated, for 20 years. He had no information.

46. Wednesday, 22nd August 1984. Dr Kristjan Saemundsson and Birgir Jonsson translated a tape recording of a conversation of old miners of Stalfjall. The recording was made in 1979. The following points were noted:-

(i) The recording was made because people are interested in energy matters.

(ii) In 1917, the men came to the site by sea with a ship that brought the machines from Sweden. It took two weeks to get everything on shore. Provisions taken for whole season. It was impossible to get anything on shore unless it was absolutely calm.

(iii) Drilled 1 m before blasting. We started to drill four holes at the bottom and then additional holes in the top. Compressed air was used and this helped the ventilation, particularly clearing the fumes after blasting.

(iv) They did the least work in the upper layer in the third tunnel, furthest west. Most of the work done in the lower layers in the other two tunnels.

(v) Ventilation was difficult before compressed air was introduced.

(vi) The company operating the mine was the Danish Icelandic Coal Company.

(vii) Tunnel of about 10 to 15 m was made in June 1916. They started tunnelling properly in 1917. Everyone was optimistic that coal would get better as mine went further in. The two first tunnels were the eastern tunnels. In 1917 they opened the tunnel to the west. Rails were only used on the beach, they could not get rails up to the tunnel.

(viii) Near the entrance of the mine they built a small compressor house with two small compressors. They had no air receiver. The compressors were powered by the steam engine. They had three drills and three chisels. They worked at the bottom and at the same time drilled in the top.

(xi) They did not work Sundays.

(x) Number of men in tunnels 6 to 7. Some men outside sorting the material. Also men on transport, carpenters.

(xi) On the lowest tide of the summer, they were trying to insert a high pole in the sea to take a cable from the mine to tip into a boat.

(xii) At the outside of the mine they broke up the material and the mudstone was thrown away.

(xiii) There was very little space at the mine entrance to do anything. At high tide and bad weather the waste was washed away immediately and often the coal also.

(xiv) There was a lot of rock falls down the cliff, particularly in bad weather.

(xv) There was no electricity. It was thought that soon after starting, the mine had a doubtful future, and the owner did not bring in electricity.

(xvi) It was a good day if they blasted once per day.

(xvii) They did not need any support in the tunnels.

(xviii) They opened connecting tunnels between the main tunnels for safety purposes and ventilation.

(xix) The rock was not hard, but it was real rock, like basalt.

(xx) No investigations took place for other lignite exposure in the mountain.

(xxi) The quality of the material did not improve as the mine went further in.

(xxii) Could it have been used for ships? Yes, but it would have been a lot of work, though the ash was easy to remove and it fell through the bars.

(xxiii) The cook did not complain about the lignite she used for cooking.

(xxiv) The dynamite was nitro nobel. They had powder fuse. They were always afraid of rock falls as the moutain shook when they blasted.

(xxv) The best layer was about 0.3 m thick, bluish when broken, very good to fire in the steam engine. This layer was lignite, then there was a whitish layer above it. The lignite used for the steam engine was always from a particular layer.

(xxvi) They worked from 7 am till 6 pm.

(xxvii) Approximately 20 people worked at the mine, including the women.

(xxviii) No lignite was actually taken away from the site. The quality of the material did not get better under the mountain.

(xxix) The roof was very stable. There was never any roof collapse. The men did not wear hard hats.

47. Friday, 24th August 1984. Interview at Reykjavik Hospital with Mr Hannes Kristinsson, aged 90. Former miner at Stalfjall. Interview and translation assisted by Dr Kristjan Saemundsson and Birgir Jonsson:-

(i) The miners considered that the mine was exploratory only.

(ii) For every tub of lignite, there were two tubs of waste.

(iii) The material had poorish heat value.

(iv) Used dynamite and air drills.

(v) Lot of surf and high waves badly affected "landings" from the sea.

(vi) Best lignite went for cook, smithy and steam engine.

(vii) They did have rails but most of it run out by wheel barrow.

(viii) He left in autumn before work was over.

(ix) They were trying to erect a tripod on the low tide, but always it was broken down by the sea.

(x) They worked shifts, 6 am to 2 pm, 2 pm to 10 pm.

APPENDIX "D"

COAL MINING IN ICELAND

AND

THE SPAR MINE AT HELGUSTADIR

ICELAND

By Helgi H Eiriksson

COAL-MINING IN ICELAND.

By HELGI H. EIRIKSSON, B.Sc.

Coal of Tertiary formation has been found extensively in North-East and West Iceland. In historic times, or during and after the period of emigration to Iceland, the Icelanders made charcoal on a large scale by burning wood in specially-made hollows or holes, but it was not until recent times that the natural deposits of coal were discovered. Prof. T. Thoroddsen, when travelling in Iceland (1882-1898), found coals and lignites* in many places where they were previously unknown; but the weathered and half-hidden outcrops do not give a favourable impression of the quality and size of the seams, and nothing was therefore done to investigate the possibilities of working any of these deposits until 1915. Then a private man, owning one of the best and thickest seams in the West of Iceland, namely, the Stálfjall Seam (No. 2, Fig. 1, Plate I.), formed an Icelandic-Danish Company to work it. The company has been in operation since 1916, but has always worked at a loss. Another seam was also started in 1915 in Tjörnes (No. 3, Fig. 1, Plate I.) in the North of Iceland, but was not worked regularly until 1917, when it was taken over by the Icelandic Government. The opening-out of these seams, together with the scarcity of fuel due to the restrictions placed on coal imports to Iceland by the war, drew attention to several of the other seams. Coal was actually taken from a few of them, but only to a small extent and without any proper appliances, and consequently the coal did not even pay for the labour expended in getting it.

Most of the coals in Iceland are lignites, and are all of Tertiary formation. Their actual geological horizon has not yet been finally determined, but they belong most probably to the Oligocene Period.

During my stay in Iceland I had an opportunity of examining roughly two of the seams in East Iceland. One of these,

* Thoroddsen, T., Ferdabók, Kaupmannahöfn, vols. i. to iv., 1913-1915.

the coal-seam in Jökulbotnar (No. 4, Fig. 1, Plate I.), Reydarfjörd, is 6 feet 4 inches thick, but of which only about 1 foot 10 inches is real coal, the rest being either claystone or a mixture of clay-material and coal (Fig. 4, Plate I.). The seam lies about 1,000 feet above sea-level. It has been opened out in two places, one on each side of a normal fault along the line of which a stream flows that has worked a kind of hollow or valley in the mountain. These openings, although not worked so far, expose the seam quite well. The fault has a down-throw of about 16 feet to the west, and the gradient of the seam is approximately 1 in 10 in a south-westerly direction.

This seam has been traced through the greater part of the mountain where it occurs, and also in the headland on the north side of the firth, where it lies a good deal higher, indicating that the inclination is fairly uniform. But *débris* and clay falling for centuries from the vertical faces of the upper layers of the lavas have nearly everywhere completely covered the out-crop, thus making it rather difficult to follow or discover it again.

The extent and uniformity of thickness of the seam indicate that it has been formed *in situ*. The loose, powdery volcanic ash, however, together with fragmental products of the weathering of the scoriaceous surfaces of the lavas, have found shelter in the vegetation when carried about by the wind,* and thus helped to swell up the seam, but the amount of this ash and clay-material mixed with and embedded in the coal must have depended not only on the loose material present on the plateau, but also on the wind and weather at the time of deposition of each layer of coal.

The other seam, or rather deposit, because it does not form a continuous seam, that I visited during the summer is in Skálanes (No. 5, Fig. 1, Plate I.) in Seydisfjörd. There the coal occurs as lenticular patches, thickest in the centre and thinning out in all directions, the thickness varying from 1 inch to 6 inches. The size of the patches might be from a few yards to perhaps half-a-mile in diameter, it being difficult to follow the outcrop, as it appears in a precipice, about 45 feet above sea-level, on the top of a basalt sheet which protrudes just sufficiently to allow a man to walk along it. The deposit forms part of the parting between two basalt sheets, the top and bottom of the thickest coal being considerably burnt, but the centre portion is very lustrous, and in appearance is similar to ordinary bituminous coal. The thinner patches are usually burnt quite through. The cracks and joints in the coal are nearly completely filled with lime and iron oxide, which have

* "The Building up of the North Atlantic Tertiary Volcanic Plateau," by Leonard Hawkes, *Geol. Mag.*, 1916, vol. iii., page 389.

evidently been deposited by waters percolating long after the formation of the coal. These mineral deposits, however, decrease the value of the coal, and increase considerably the percentage of ash and the specific gravity.

In this case the evidence is strongest for a drift formation. It is possible that the patches are due to small oases near the edge of a main forest, and in that case the bulk of the coal ought to be either under the mountains or completely washed away, according to the position of the wood from which it was formed.

The difficulty in getting at the patches and also their thinness cause the profitable working of them to be out of the question, but a few hundred yards from the outcrop, and farther up the firth, the mountain side extends into a narrow strip of lowland, and there I would suggest that a few boreholes should be put down in order to ascertain the extent of the coal in that direction.

The possibilities of coal of older formation than Tertiary in Iceland can be ascertained only by boring. And it is doubtful even whether boring could be carried out so far as to get through the volcanic series. The thickness of these volcanic series cannot be definitely estimated. Quoting from Hawkes (*loc. cit.*, page 385), "The observable thickness is 11,000 feet, and how much has to be added on to this, top and bottom, it is impossible to state." But no further knowledge of the composition of the Icelandic mountains and their foundations can be obtained without investigation, and for that purpose a few boreholes are absolutely necessary. Below are given approximate analyses of coal from five different places in Iceland, together with those of a Continental lignite and a Scottish non-caking coal, for the sake of comparison:—

Locality of mine.	Carbon.	Calorific value.		Evaporating power.	Specific gravity.	Sulphur.	Combustible volatile matter.	Moisture.	Ash.
		Calories.	British thermal units.						
	Per cent.					Per cent.	Per cent.	Per cent.	Per cent.
Jökulbotnar ...	21·40	2,923	5,310	5·45	1·65	3·678	22·90	11·35	40·5
Skálanes	33·00	3,444	6,210	6·41	{1·71 1·43	4·520	20·45	9·00	33·0
Tjörnes	36·45	4,030	7,270	7·50	1·42	6·452	33·25	12·25	21.5
Skardströnd ...	34·82	4,421	7,970	8·22	1·42	8·930	28·00	13·25	15·0
Stálfjall	—	5,100	9,190	9·48	—	—	—	18·00	18·00
Continental lignite	59	5,300	9,550	9·85	1·18	—	24·70	10·30	6·00
Scottish coal ...	89	8,000	14,400	14 90	1·30	1·0	7·50	—	4·50

The above analyses, although only proximate, show clearly that none of the Icelandic coals is of much commercial value.

The samples from the mines in Tjörnes and Skardströnd were given to me for analysis, but I did not see the places from which they were taken. The analysis of the coal from Stálfjali is taken from a report on that mine by a mining engineer in Sweden, as I did not get a sample from that mine myself.

None of the samples analysed here can be considered properly representative of its respective seam, as all were obtained very near to the outcrop and have since been kept under the influence of the atmosphere for several months. The sample from Skálanes was taken across the whole thickness of the seam, the burnt and unburnt parts being kept in proper proportions. But the specific gravity was estimated for each part separately; the specific gravity of the burnt portions (laden with CaO and Fe_2O_3) being 1·71, and that of the central part 1·43.

The sample from Jökulbotnar is from the poorest part of the seam, the lower 9-inch layer, and therefore gives a worse result than the average might do.

These remarks are merely a rough outline of the position regarding the occurrence and mining of coal in Iceland. No thorough prospecting or examination has as yet been carried out in that respect, and until this has been done further information cannot be given.

In conclusion, I wish to express my thanks to Prof. D. Burns for guiding me in the preparation of this paper; also to Mr. W. J. Buchanan, who estimated the calorific values of my coal samples, the only bomb-calorimeter in Scotland being in his charge in the Chemistry Laboratory of the Royal Technical College, Glasgow.

To il[lust]rate Mr. Helgi H. Eiríksson's Papers on "The [Spa]r-mine at Helgustadir, Iceland," and "Coal-mining in Iceland."

Fig. 1.—Map of Iceland.

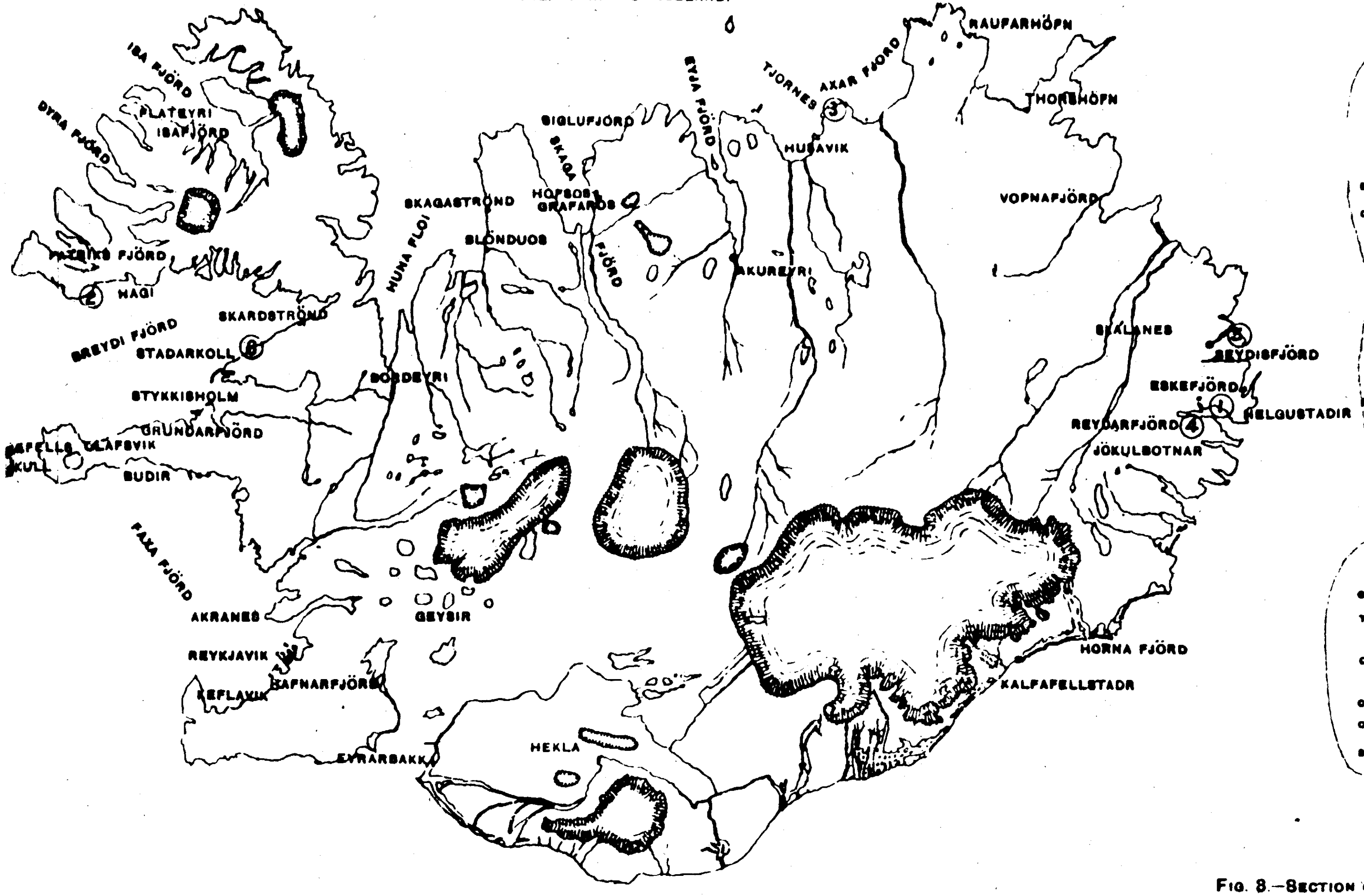


Fig. 4.—Section of Seam in Jökulbotnar.

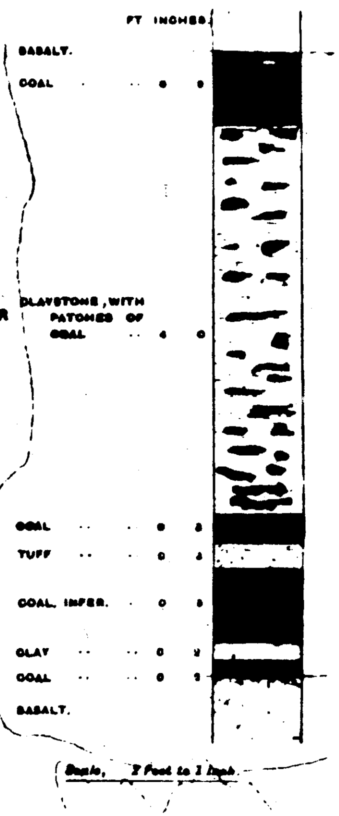


Fig. 2.—Section of Mountain Side and Iceland Spar-mine.

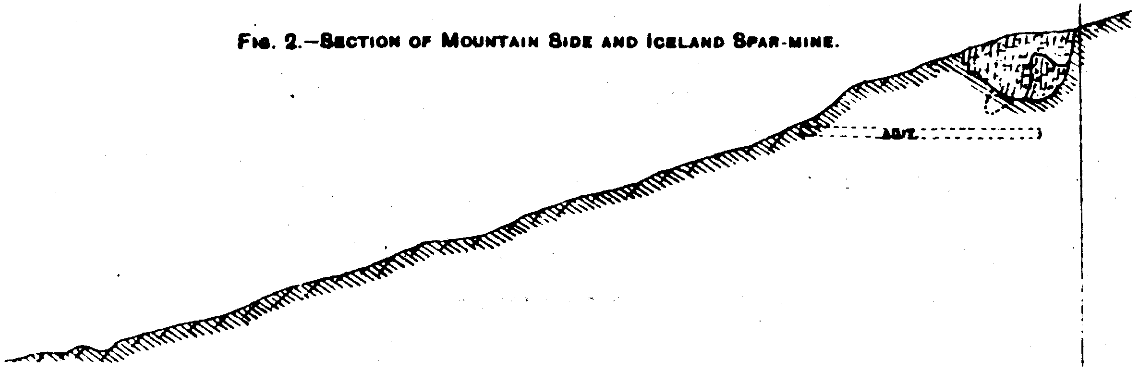
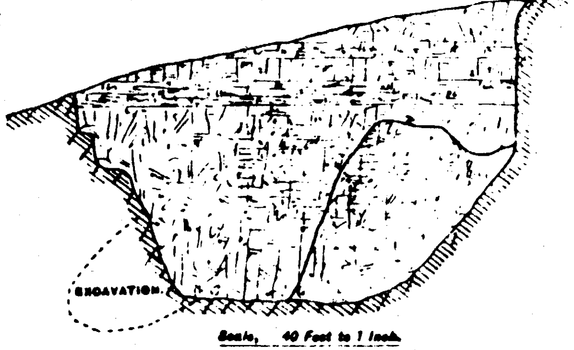


Fig. 3.—Section of Iceland Spar-mine.



APPENDIX "E"

GLOSSARY OF MINING TERMS

APPENDIX "E"

GLOSSARY OF MINING TERMS

Term	Definition
adit	A nearly horizontal drivage from the surface to the mine workings. Used for drainage or other purposes.
bat	A carbonaceous shaly material often with thin layers of coal, occurring within a coal seam.
caunch	The breaking down of the roof in the mine roadways to increase the headroom for transport and ventilation.
cleat	Coal seams are usually intersected by a series of inclined joints which have received distinctive names such as "cleat" or "slips". Usually, there are two distinct systems of joints coursing roughly at right angles to each other. The term "face cleat" is applied to the major joint and "end cleat" to the minor joint.
cutter	A machine which draws itself by rope haulage along the longwall face, cutting a thin strip of mineral from the bottom of the seam in preparation for shot-firing and loading.
cutter nogs	Wooden pieces used to support the undercut coal.
drift	An inclined tunnel from the surface to the mineral serving the same purpose as a shaft. It may be driven in lignite or stone.
duff	Fine dry mineral obtained from a coal preparation plant.
goaf/gob/waste	The worked-out area in a mine.
gummings	The small mineral or dirt produced by the picks of a coal cutter.
heading	A roadway driven in the lignite seam.
jib	The arm carrying the cutter chain of a cutter which extends into the lignite at approximately right angles to the body of the machine.
pack	A pillar, constructed from loose stones and dirt, built in the waste area or roadside to support the roof.
plough	A cutter-loader with knives to slice the mineral off the face, usually drawn along by means of chain haulage.
retreat mining	A method of extracting coal by driving narrow headings to the boundary then opening out faces and working the deposit backwards towards the shaft, drift or main entry.
shearer	A machine which cuts and loads coal on a longwall face. The cutting is normally done by means of picks secured to a disc or drum which is rotated by an electric drive. The coal is loaded either by a plough drawn along behind the machine or by spiral vanes on the disc which lifts the coal on to the face conveyor.
trepanner	A machine which cuts and loads coal on a longwall face. It operates by cutting an annulus of large diameter. A core is formed in the centre and this is then cracked by heavy duty breaker picks in the trepan head.

TABLES

TABLE I

MANPOWER PER FACE - LONGWALL ADVANCING FACE, 100 m LONG, HAND-FILLING

24 hour cycle of working
Three shifts of eight hours per shift
Method of working: undercutting, drilling and firing and hand-filling

	No of Men	
No 1 Shift (Preparation)		
Lignite cutter operator	1	Depth of web cut 1.45 m
Lignite cutter cable handler	1	
Driller	1	
Shotfirer	1	
Deputy (supervisor)	1	
Subtotal	5	
No 2 Shift (Lignite Production)		
Fillers	15	(Load approximately 7 m/man)
Maingate caunch	4	
Tailgate caunch	3	
Fitter	1	
Electrician	1	
Deputy (supervisor)	1	
Subtotal	25	
No 3 Shift (Advancing Conveyor, Supports and Chocks)		
Advancing conveyor, supports and chocks	7	
Deputy	1	
Subtotal	8	
Total face manpower	38	

Note: The above manpower is based on the waste being totally caved, using wood chocks at the waste edge. If the waste does not cave satisfactorily it may be necessary for face packs to be constructed, which would require extra manpower (estimated at an additional 10 men/day who would do their work on the No 3 shift).

TABLE II

MANPOWER PER FACE - LONGWALL ADVANCING FACE, 100 m LONG, SEMI-MECHANISED

24 hour cycle of working
Three shifts of eight hours per shift
Method of working: undercutting, drilling and firing, and flight loading

No 1 Shift (Preparation)	No of Men	
Lignite cutter operator	1	Depth of web cut 1.4 m
Lignite cutter cable handler	1	
Driller	1	
Making stall for machine at tailgate	2	
Shotfirer	1	
Deputy (supervisor)	1	
Subtotal	7	
No 2 Shift (Lignite Production)		
Flight loader operators	2)	Operate as "team" of six
Moving props and bars	4)	
Maingate caunch	4	
Tailgate caunch	3	
Fitter	1	
Electrician	1	
Deputy (supervisor)	1	
Subtotal	16	
No 3 Shift (Advancing Conveyor and Chocks)		
Advancing conveyor and chocks	5	
Deputy	1	
Subtotal	6	
Total face manpower	29	

Note: The above manpower is based on the waste being totally caved, using wood chocks at the waste edge. If the waste does not cave satisfactorily it may be necessary for face packs to be constructed, which would require extra manpower (estimated at an additional 10 men/day who would do their work on the No 3 shift).

TABLE III

MANPOWER PER HEADING - DOSCO/NCB IN-SEAM MINER

	No of Men	
Machine team	3	1 driver, 2 assistants. Support setting, advancing ventilation tubes, advancing conveyor return end
Back up	3	Transferring all supplies from mouth of heading. Installing conveyor structure
Conveyor/haulage operator	1	
Fitter	1	General maintenance
Electrician	1	Advancing telephone, tannoy and conveyor signals
Deputy	1	

TABLE IV

CAPITAL COST OF SURFACE BUILDINGS

Construction - Steel Framed, Concrete Floor, Insulated and Heated

Item	25,000 tpa		65,000 tpa		100,000 tpa	
	Size m	Cost Kr	Size m	Cost Kr	Size m	Cost Kr
Mine offices	6 x 10	320,000	6 x 10	320,000	6 x 10	320,000
Workshops, inc sawmill	10 x 15	600,000	10 x 15	600.000	20 x 20	1,600,000
Stores	6 x 10	320,000	10 x 15	600,000	10 x 15	600,000
Vehicle garage	6 x 10	320,000	6 x 10	320,000	10 x 15	600,000
Explosive store	-	200,000	-	200,000	-	200,000
Electrical substation	6 x 10	320,000	6 x 10	320,000	6 x 10	320,000
Fan house	-	200,000	-	200,000	-	200,000
Lamp room	-	200,000	-	200,000	-	200,000
Baths and canteen	6 x 10	320,000	6 x 10	320,000	10 x 15	600,000
Hauler house	6 x 10	320,000	6 x 10	320,000	6 x 10	320,000
Conveyor house	6 x 10	320,000	6 x 10	320,000	6 x 10	320,000
Weigh house	-	100,000	-	100,000	-	100,000
Stockyards	-	200,000	-	200,000	-	200,000
ROM Bunker (100 t)	-	1,600,000	-	1,600,000	-	1,600,000
Contingencies 10%	-	534,000	-	562,000	-	718,000
Total		5,874,000		6,182,000		7,898,000

<u>TABLE V</u>

<u>CAPITAL COST OF SURFACE EQUIPMENT</u>

Item	UK Ex-works £	Kr	25,000 tonnes		65,000 tonnes		100,000 tonnes	
			CIF	x 2 to Allow for Tariffs & Taxes	CIF	x 2 to Allow for Tariffs & Taxes	CIF	x 2 to Allow for Tariffs & Taxes
Office furniture & equipment	3,600	147,240	162,000	324,000	162,000	324,000	162,000	324,000
Workshops equipment	30,000	1,227,000	1,350,000	2,700,000	2,025,000	4,050,000	2,025,000	4,050,000
Stores binning	3,600	147,240	162,000	324,000	210,500	421,000	243,000	486,000
Lorry for general duties	-	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Explosives store shelving	1,000	40,900	45,000	90,000	45,000	90,000	45,000	90,000
Substation transformers, switchgear, cable & distribution board	110,000	4,500,000	4,950,000	9,900,000	6,190,000	12,375,000	6,190,000	12,375,000
Diesel generator (standby) 400 kW	-	1,700,000	1,700,000	1,700,000	1,700,000	1,700,000	1,700,000	1,700,000
Main fan & spare fan	-	490,800	540,000	1,080,000	540,000	1,080,000	540,000	1,080,000
Lamps & charging equipment	9,600	392,600	432,000	864,000	518,000	1,036,000	518,000	1,036,000
Showers, lockers & canteen furniture	24,000	981,600	1,080,000	2,160,000	1,350,000	2,700.000	1,350,000	2,700,000
Weighing machine	48,000	1,963,000	2,160,000	4,320,000	2,160,000	4,320,000	2,160,000	4,320,000
Contingencies 10%	-	-	1,358,000	2,446,000	1,590,050	2,909,600	1,593,300	2,916,100
Total	-	-	14,939,000	26,908,000	17,490,550	32,005,600	17,526,300	32,077,100

Note: At Straumnesfjall the winding engines and winding houses are included in the capital cost estimate for shaft sinking and shaft furnishings.

TABLE VI

CAPITAL COST OF UNDERGROUND EQUIPMENT

Item	UK Price £	CIF	Kr	No Required	Total Kr	
Longwall Face						
Thin seam cutter	55,000	60,500	2,474,450	2	4,948,900	
Face belt complete (100 m)	9,180	10,100	413,090	1	413,090	
Drilling machines	560	616	25,194	4	100,778	
Gate end switches	4,180	4,600	188,140	4	752,560	
Stage loader	28,180	31,000	1,267,900	1	1,267,900	
Props	105	116	4,744	500	2,372,200	
Bars (2 m long) & brackets	63	69	2,822	250	705,500	
Miscellaneous (face signalling, etc) 10%					1,056,093	
					11,617,021	
Development Heading 2/Face						
Drilling machines	560	616	25,194	4	100,778	
Electric ventilating fans	780	860	35,174	2	70,348	
Electric pump	1,300	1,430	58,487	2	116,974	
Gate end switches	4,180	4,600	188,140	4	752,560	
Eimco track loading shovel	15,000	16,500	674,850	2	1,349,700	
Belt	9,180	10,100	413,090	2	826,180	
Stage loader	28,180	31,000	1,267,900	2	2,535,800	
Miscellaneous 10%					575,234	
					6,327,574	
Transport						
Maingate belt (1,000 m)	51,800	57,000	2,331,300	1	2,331,300	
Trunk belt (2,000 m)	89,000	98,000	4,008,200	1	4,008,200	
Belting	131,800	145,000	5,930,500	1	5,930,500	
Maingate hoists & rope	14,000	15,400	629,860	1	629,860	
Tailgate hoists & rope	14,000	15,400	629,860	1	629,860	
Development hoists & rope	9,500	10,450	427,405	2	854,810	
Tubs & material bogies	500	550	22,495	30	674,850	
Gate end switches	4,180	4,600	188,140	4	752,560	
Miscellaneous 10%					1,581,194	
					17,393,134	
General Underground						
Main pump with motor & switchgear	12,000	13,200	539,880	1	539,880	
Section switches	4,180	4,600	188,140	2	376,280	
Transformer	20,000	22,000	899,800	1	899,800	
Miscellaneous (telephones, rails, pipes, etc)	10,000	11,000	449,900		449,900	
Total					2,265,860	
Grand total					37,603,589	say 37,604.000
2 Face Situation, Additional to above						
1 Extra face equipment					11,617 021	
1 Gate belt					2,331,300	
Extra conveyor belt					1,840 500	
Development equipment for 2 extra headings					6,327,574	
Extra maingate hoist					629,860	
Extra tailgate hoist					629,860	
Extra development hoists					854,810	
Extra tubs & material bogies					674.850	
Extra gate end switches					376,280	
Extra transformer					899,800	
Additional miscellaneous					449,900	
					64,235,344	say 64,235,000

TABLE VII

MINERAL TREATMENT CAPITAL COST ESTIMATES

(a) With Cyclone

ROM bunker
↓
Screen
↓
Crusher
↓
Cyclone plant (includes screens)
↓
Product bunker

(b) Without Cyclone

ROM bunker
↓
Screen
↓
Crusher
↓
Product bunker

(a) With Cyclone

Item	UK Cost £	Kr	CIF	With Tariffs & Taxes
Screen) Crusher)	50,000	2,045,000	2,249,500	4,499,000
Cyclone plant	150,000	6,135,000	6,748,500	13,497,000
Product bunker	-	1,636,000	1,636,000	1,636,000
Cyclone building	-	320,000	320,000	320,000
Total	-	10,136,000	10,954,000	19,952,000

(b) Without Cyclone

Item	UK Cost £	Kr	CIF	With Tariffs & Taxes
Screen) Crusher)	50,000	2,045,000	2,249,500	4,499,000
Product bunker	-	1,636,000	1,636,000	1,636,000
Total	-	3,681,000	3,885,500	6,135,000

TABLE VIII

SUMMARY OF CAPITAL AND OPERATING COSTS

MINE		BOTN				DUFANSDALUR & THERNUDALUR				STRAUMNESFJALL				STALFJALL					
Item	Source of Information	25,000 tpa	25,000 tpa Tariffs & Taxes Inc	65,000 tpa	65,000 tpa Tariffs & Taxes Inc	25,000 tpa	25,000 tpa Tariffs & Taxes Inc	65,000 tpa	65,000 tpa Tariffs & Taxes Inc	25,000 tpa	25,000 tpa Tariffs & Taxes Inc	65,000 tpa	65,000 tpa Tariffs & Taxes Inc	25,000 tpa	25,000 tpa Tariffs & Taxes Inc	65,000 tpa	65,000 tpa Tariffs & Taxes Inc	100,000 tpa	100,000 tpa Tariffs & Taxes Inc
CAPITAL COSTS																			
Site																			
Land acquisition costs have been excluded		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mine planning & consultancy fees	E	2,000,000	2,000,000	3,000,000	3,000,000	2,000,000	2,000,000	3,000,000	3,000,000	2,000,000	2,000,000	3,000,000	3,000,000	2,000,000	2,000,000	3,000,000	3,000,000	4,000,000	4,000,000
Site preparation	E	16,000,000	16,000,000	16,000,000	16,000,000	16,000,000	16,000,000	16,000,000	16,000,000	10,000,000	10,000,000	10,000,000	10,000,000	16,000,000	16,000,000	16,000,000	16,000,000	16,000,000	16,000,000
Surface																			
Surface buildings	A	5,874,000	5,874,000	6,182,000	6,182,000	5,874,000	5,874,000	6,182,000	6,182,000	5,234,000	5,234,000	5,542,000	5,542,000	5,874,000	5,874,000	6,182,000	6,182,000	7,898,000	7,898,000
Surface equipment	B, E	14,939,000	26,908,000	17,491,000	32,006,000	14,939,000	26,908,000	17,491,000	32,006,000	14,939,000	26,908,000	17,491,000	32,006,000	14,939,000	26,908,000	17,491,000	32,006,000	17,526,000	32,077,000
Preparation plant	B	10,954,000	19,952,000	10,954,000	19,952,000	3,886,000	6,135,000	3,886,000	6,135,000	10,954,000	19,952,000	10,954,000	19,952,000	3,886,000	6,135,000	3,886,000	6,135,000	3,886,000	6,135,000
Mine Capital Costs																			
Exploratory work	B	1,432,000	1,432,000	1,432,000	1,432,000	20,450,000	20,450,000	20,450,000	20,450,000	20,450,000	20,450,000	20,450,000	20,450,000	12,270,000	12,270,000	12,270,000	12,270,000	12,270,000	12,270,000
Mine access	B, D, E	7,500,000	7,500,000	7,500,000	7,500,000	9,000,000	9,000,000	9,000,000	9,000,000	245,000,000	245,000,000	245,000,000	245,000,000	9,000,000	9,000,000	9,000,000	9,000,000	9,000,000	9,000,000
Development drivage	E	6,000,000	6,000,000	8,500,000	8,500,000	5,500,000	5,500,000	8,000,000	8,000,000	5,000,000	5,000,000	7,500,000	7,500,000	4,500,000	4,500,000	7,000,000	7,000,000	9,500,000	9,500,000
Mine equipment	C, E	37,604,000	75,208,000	64,235,080	128,470,000	35,862,000	71,724,000	37,604,000	75,208,000	36,733,000	73,466,000	64,235,000	128,470,000	36,733,000	73,466,000	37,604,000	75,208,000	62,493,000	124,986,000
Services																			
Connecting electricity	A	2,000,000	2,000,000	2,000,000	2,000,000	2,400,000	2,400,000	2,400,000	2,400,000	3,400,000	3,400,000	5,100,000	5,100,000	6,000,000	6,000,000	6,000,000	6,000,000	6,000,000	6,000,000
Connecting water	A	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
Transport																			
Access roads	A	6,000,000	6,000,000	6,000,000	6,000,000	6,000,000	6,000,000	6,000,000	6,000,000	12,000,000	12,000,000	12,000,000	12,000,000	80,000,000	80,000,000	80,000,000	80,000,000	80,000,000	80,000,000
Port facilities	A	-	-	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	50,000,000	50,000,000	50,000,000	50,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000	30,000,000
Camp Site		-	-	-	-	-	-	-	-	12,000,000	12,000,000	22,000,000	22,000,000	12,000,000	12,000,000	14,000,000	14,000,000	22,000,000	22,000,000
General Expenses	E	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
SUBTOTAL		112,403,000	170,974,000	175,394,000	263,142,000	154,011,000	204,091,000	162,113,000	216,481,000	430,210,000	487,910,000	475,772,000	563,520,000	235,702,000	286,653,000	244,933,000	299,301,000	283,073,000	362,366,000
Contingency 10%		11,240,000	17,097,000	17,539,000	26,314,000	15,401,000	20,409,000	16,211,000	21,648,000	43,021,000	48,791,000	47,577,000	56,352,000	23,570,000	28,665,000	24,493,000	29,930,000	28,307,000	36,237,000
TOTAL		123,643,000	188,071,000	192,933,000	289,456,000	169,412,000	224,500,000	178,324,000	238,129,000	473,231,000	536,701,000	523,349,000	619,872,000	259,272,000	315,318,000	269,426,000	329,231,000	311,380,000	398,603,000
Operating life of mine (to maximum of 20 years)		20	20	12	12	20	20	20	20	20	20	13	13	20	20	20	20	18	18
Interest at 8% pa for life of mine		128,341,000	195,218,000	114,294,000	171,474,000	175,850,000	233,031,000	185,096,000	247,178,000	491,214,000	557,096,000	337,298,000	399,508,000	269,124,000	327,300,000	279,664,000	341,742,000	286,656,000	366,954,000
TOTAL CAPITAL COST		251,984,000	383,289,000	307,227,000	460,930,000	345,262,000	457,531,000	363,420,000	485,307,000	964,445,000	1,093,797,000	860,647,000	1,019,380,000	528,396,000	642,618,000	549,090,000	670,973,000	598,036,000	765,557,000
TOTAL LIGNITE PRODUCTION (tonnes)		500,000	500,000	780,000	780,000	500,000	500,000	1,300,000	1,300,000	500,000	500,000	845,000	845,000	500,000	500,000	1,300,000	1,300,000	1,800,000	1,800,000
CAPITAL COST/TONNE		504 Kr	767 Kr	394 Kr	591 Kr	691 Kr	915 Kr	280 Kr	373 Kr	1,929 Kr	2,188 Kr	1,019 Kr	1,206 Kr	1,057 Kr	1,285 Kr	422 Kr	516 Kr	332 Kr	425 Kr
OPERATING COSTS - ANNUAL																			
Mine Site																			
Labour (salaries, wages & wages charges)	A	39,696,000	39,696,000	75,984,000	75,984,000	37,836,000	37,836,000	47,184,000	47,184,000	44,568,000	44,568,000	82,140,000	82,140,000	44,568,000	44,568,000	51,396,000	51,396,000	79,236,000	79,236,000
Materials	B, E	4,300,000	8,600,000	11,180,000	22,360,000	4,300,000	8,600,000	11,180,000	22,360,000	4,300,000	8,600,000	11,180,000	22,360,000	4,300,000	8,600,000	11,180,000	22,360,000	17,200,000	34,400,000
Maintenance, repairs & stores	B, E	7,135,000	13,972,000	11,384,000	22,471,000	6,873,000	13,449,000	7,390,000	14,482,000	7,004,000	13,711,000	11,384,000	22,471,000	7,004,000	13,711,000	7,390,000	14,482,000	11,127,000	21,956,000
Power	A, B	3,637,000	3,637,000	6,825,000	6,825,000	3,637,000	3,637,000	6,825,000	6,825,000	3,637,000	3,637,000	6,825,000	6,825,000	3,637,000	3,637,000	6,825,000	6,825,000	9,246,000	9,246,000
Transport	A	4,346,000	4,346,000	9,735,000	9,735,000	2,790,000	2,790,000	8,592,000	8,592,000	3,240,000	3,240,000	9,852,000	9,852,000	4,307,000	4,307,000	12,569,000	12,569,000	19,798,000	19,798,000
Miscellaneous	B	3,970,000	3,970,000	7,600,000	7,600,000	3,780,000	3,780,000	4,720,000	4,720,000	4,457,000	4,457,000	8,214,000	8,214,000	4,457,000	4,457,000	5,140,000	5,140,000	7,924,000	7,924,000
SUBTOTAL		63,084,000	74,221,000	122,708,000	144,975,000	59,216,000	70,092,000	85,891,000	104,163,000	67,206,000	78,213,000	129,595,000	151,862,000	68,273,000	79,280,000	94,500,000	112,772,000	144,531,000	172,560,000
OPERATING COSTS/TONNE		2,523 Kr	2,969 Kr	1,888 Kr	2,230 Kr	2,369 Kr	2,804 Kr	1,321 Kr	1,603 Kr	2,688 Kr	3,129 Kr	1,994 Kr	2,336 Kr	2,731 Kr	3,171 Kr	1,454 Kr	1,735 Kr	1,445 Kr	1,726 Kr
TOTAL COST/TONNE		3,027 Kr	3,736 Kr	2,282 Kr	2,821 Kr	3,060 Kr	3,719 Kr	1,601 Kr	1,976 Kr	4,617 Kr	5,317 Kr	3,013 Kr	3,542 Kr	3,788 Kr	4,456 Kr	1,876 Kr	2,251 Kr	1,777 Kr	2,151 Kr

Notes:

1. Figures are in Icelandic Krona except where otherwise indicated.
2. Sources of Information:-

   A - NEA, Iceland
   B - NCB, UK
   C - UK Manufacturers
   D - Shaft Sinking Costs from UK Contractors
   E - BMCL "In-House"

TABLE IX

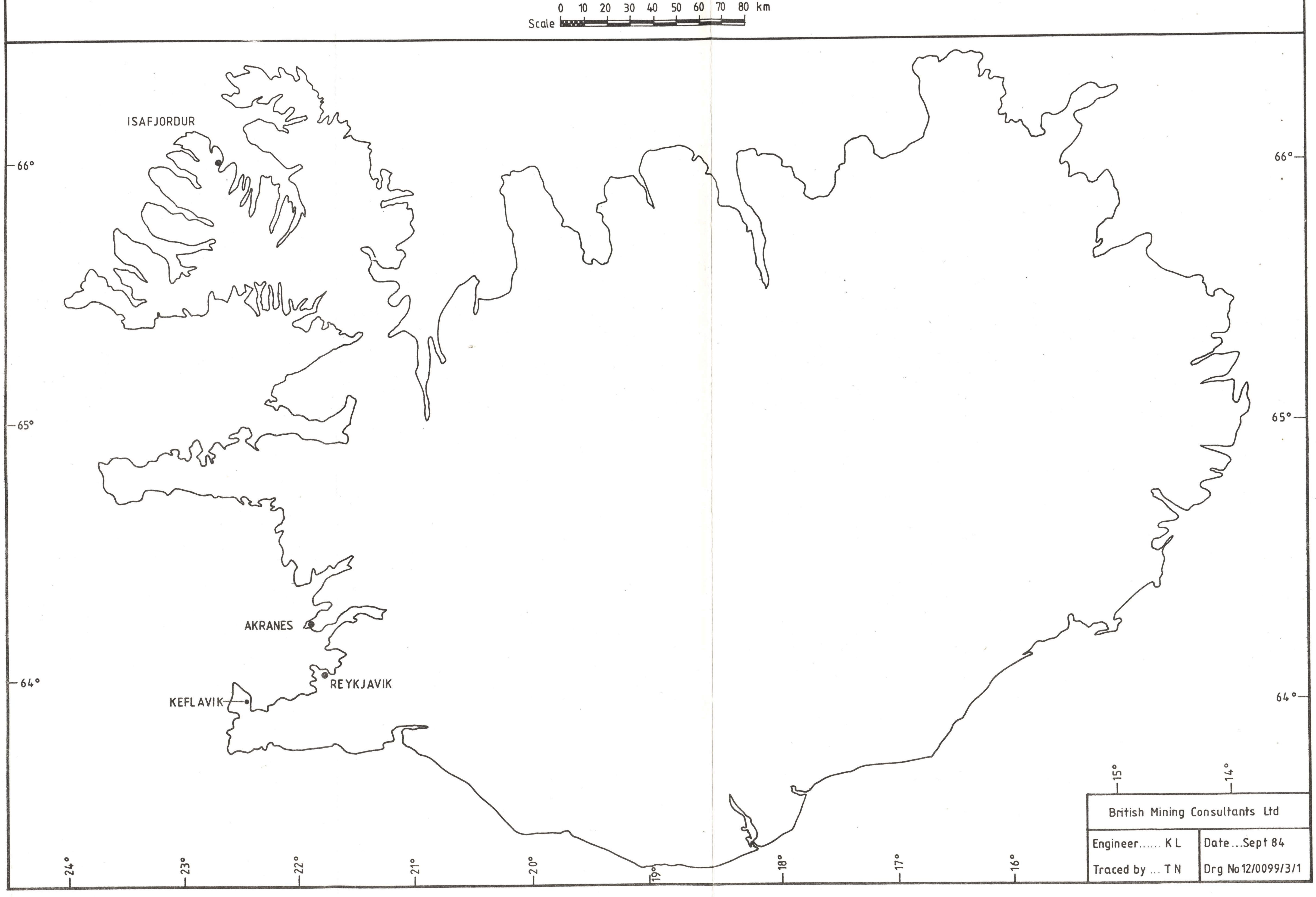
TOTAL COST PER GJ

	Without tariffs and taxes			With tariffs and taxes		
Quantity, tpa	25,000	65,000	100,000	25,000	65,000	100,000
Botn						
Total cost per tonne	3,027	2,282	-	3,736	2,821	-
Calorific value, GJ/tonne	13.86	13.86	-	13.86	13.86	-
Total cost per GJ	218	165	-	270	204	-
Dufansdalur & Thernudalur						
Total cost per tonne	3,060	1,601	-	3,719	1,976	-
Calorific value, GJ/tonne	7.70	7.70	-	7.70	7.70	-
Total cost per GJ	397	208	-	483	257	-
Straumnesfjall						
Total cost per tonne	4,617	3,013	-	5,317	3,542	-
Calorific value, GJ/tonne	11.50	11.50	-	11.50	11.50	-
Total cost per GJ	401	262	-	462	308	-
Stalfjall						
Total cost per tonne	3,788	1,876	1,777	4,456	2,251	2,151
Calorific value, GJ/tonne	8.43	8.43	8.43	8.43	8.43	8.43
Total cost per GJ	449	223	211	529	267	255
Imported Hard Coal						
Total cost per tonne	1,590	1,535	1,523	1,590	1,535	1,523
Calorific value, GJ/tonne	26.58	26.58	26.58	26.58	26.58	26.58
Total cost per GJ	60	58	57	60	58	57

Note: Figures are in Icelandic Krona except where otherwise stated.

PLATES

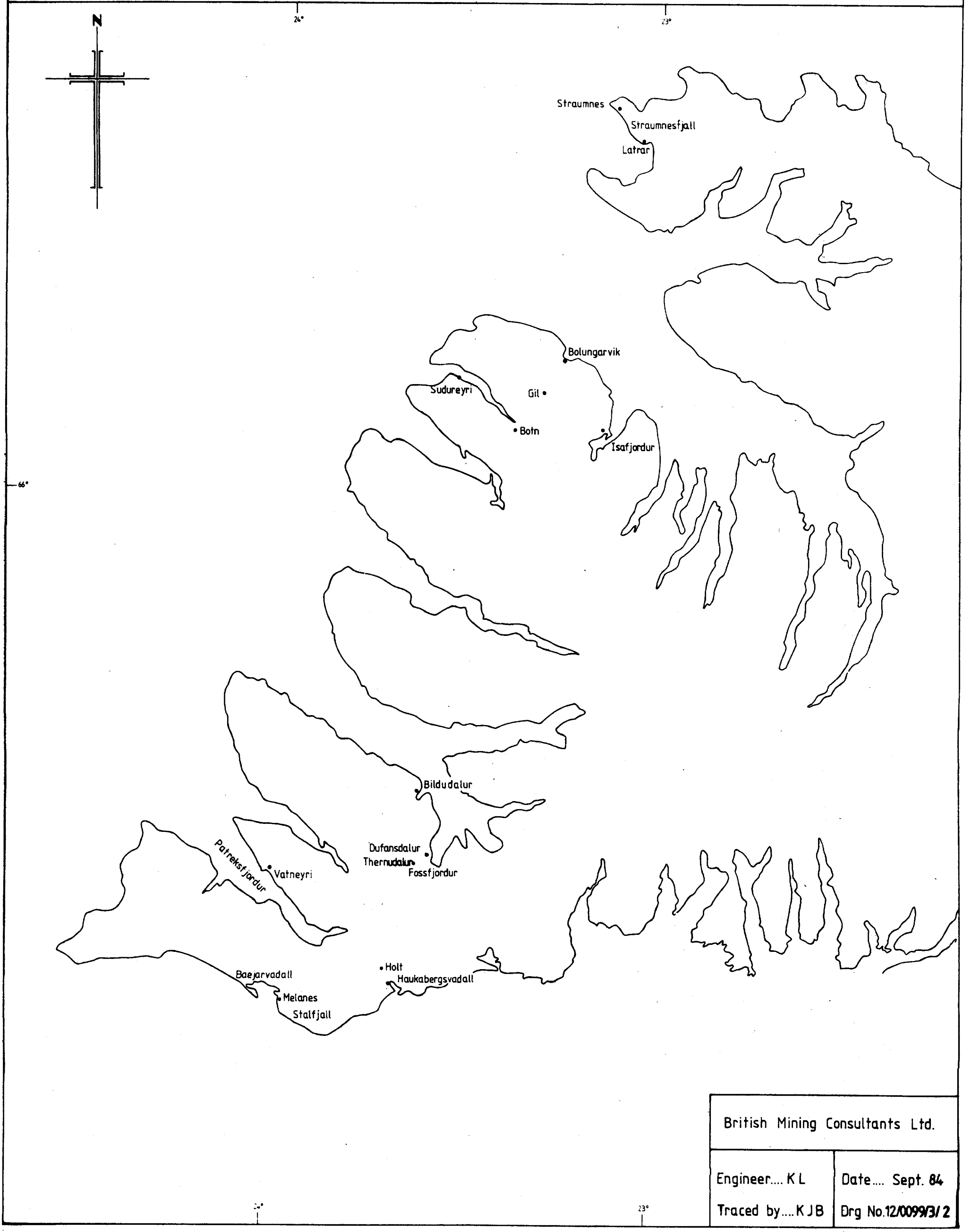
GENERAL LOCATION PLAN



British Mining Consultants Ltd	
Engineer...... K L	Date ...Sept 84
Traced by ... T N	Drg No 12/0099/3/1

LOCATIONS IN NORTH WEST PENINSULA, ICELAND

Scale 0 — 160 — 320 — 480 km



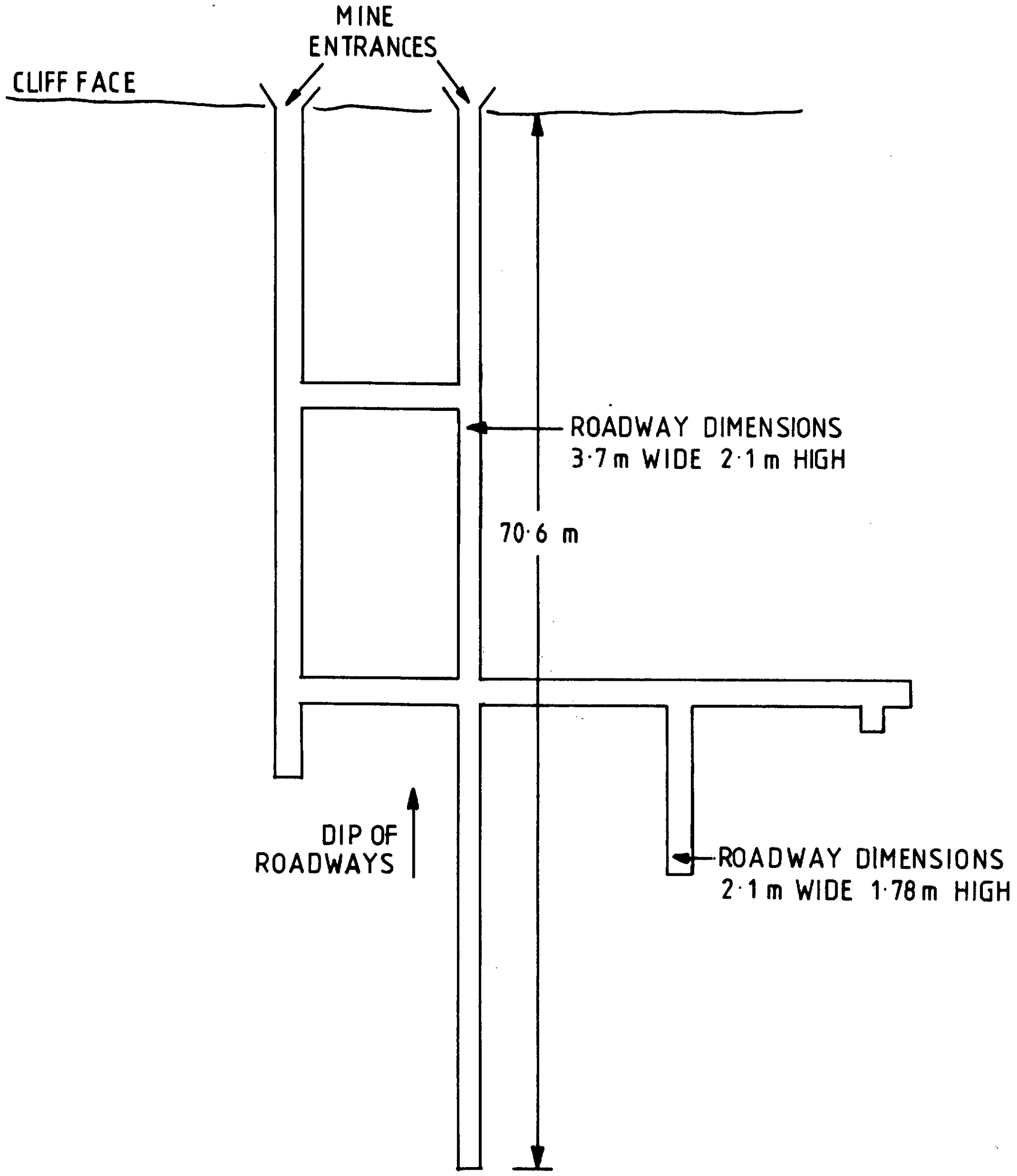
British Mining Consultants Ltd.

Engineer.... K L	Date.... Sept. 84
Traced by.... K J B	Drg No.12/0099/3/2

STALFJALL MINE

SKETCH PLAN OF FORMER WORKINGS

Scale 1:500



British Mining Consultants Ltd.	
Engineer.... K L	Date....October 84
Traced by.... T L	Drg No. 12/0099/3/3

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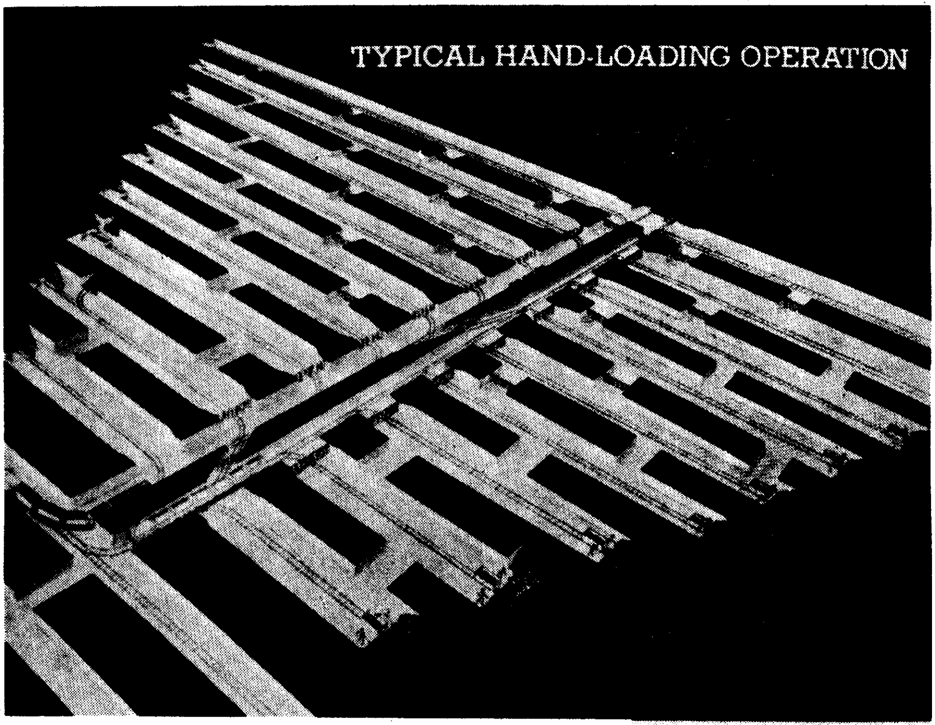
ROOM AND PILLAR WORKINGS



(Joy Manufacturing Company.)

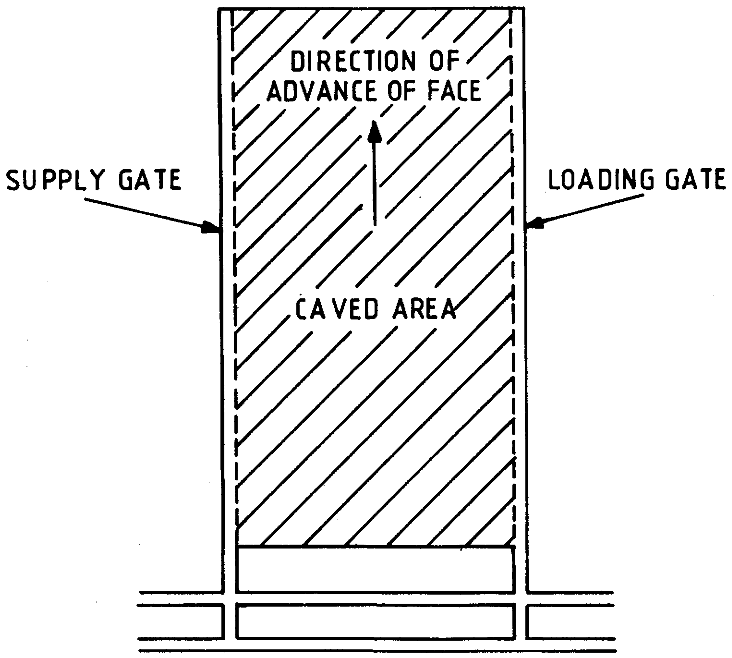
British Mining Consultants Ltd.	
Engineer.... K L	Date....October 84
Traced by.... T N	Drg No..12/0099/3/4

POS 841472

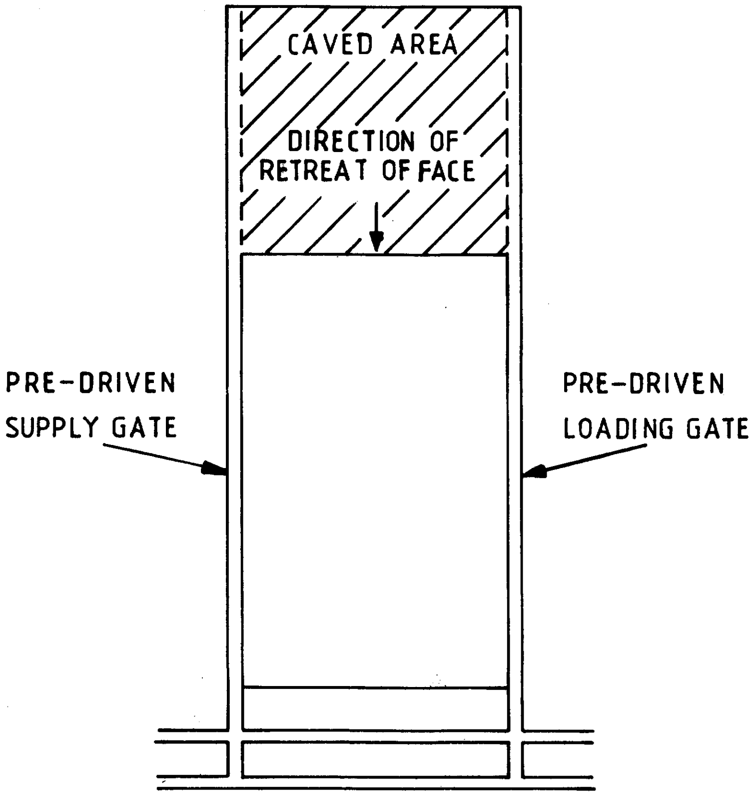
LONGWALL FACES

ADVANCING AND RETREATING SYSTEMS

LONGWALL ADVANCING



LONGWALL RETREATING

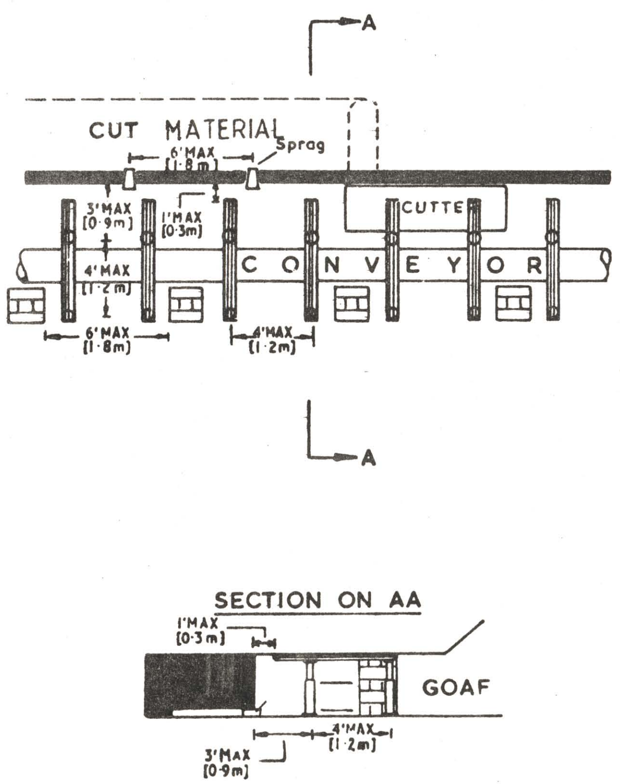


British Mining Consultants Ltd.	
Engineer.... KL	Date....October 84
Traced by.... TN	Drg No...12/0099/3/5

METHOD OF SUPPORT ON LONGWALL CONVEYOR FACES

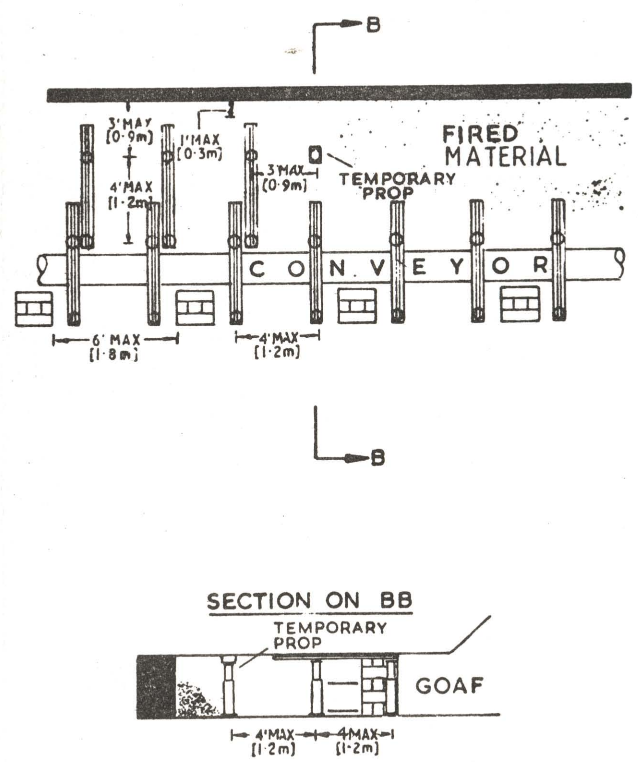
FOR 4'-9" (1·4 m) ADVANCE

1_CUTTING OPERATION.



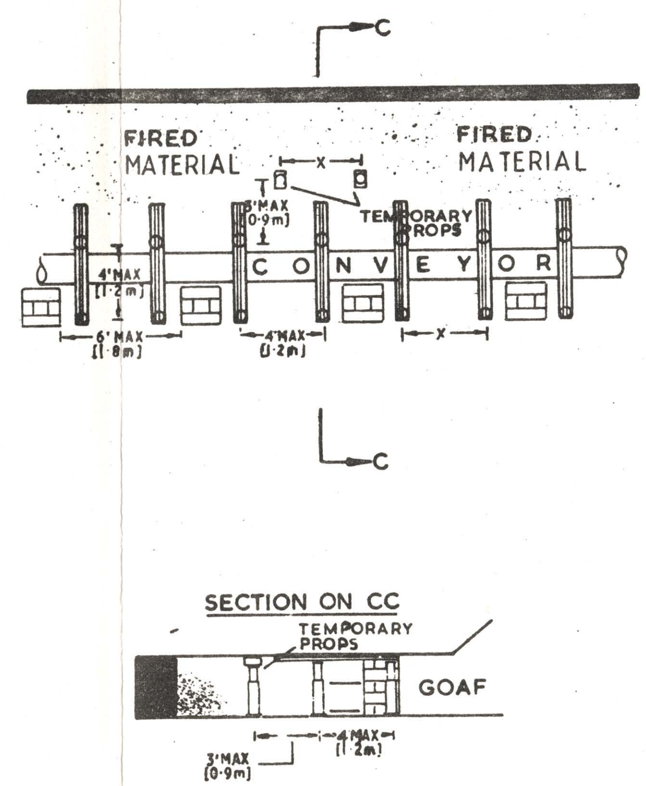
2_FILLING OPERATION.

(i)_COAL WORKED ON THE BUTTOCK



(ii)_TEMPORARY SUPPORTS DURING 'BREAKING-IN' OPERATION.

'X' shows that the distance between temporary props is the same as the distance between props in a row and must not exceed 4' [1·2m]



3_DRAWING OPERATION.

DRAWING SEQUENCE

1_Chains are attached to the props under Bar 1.

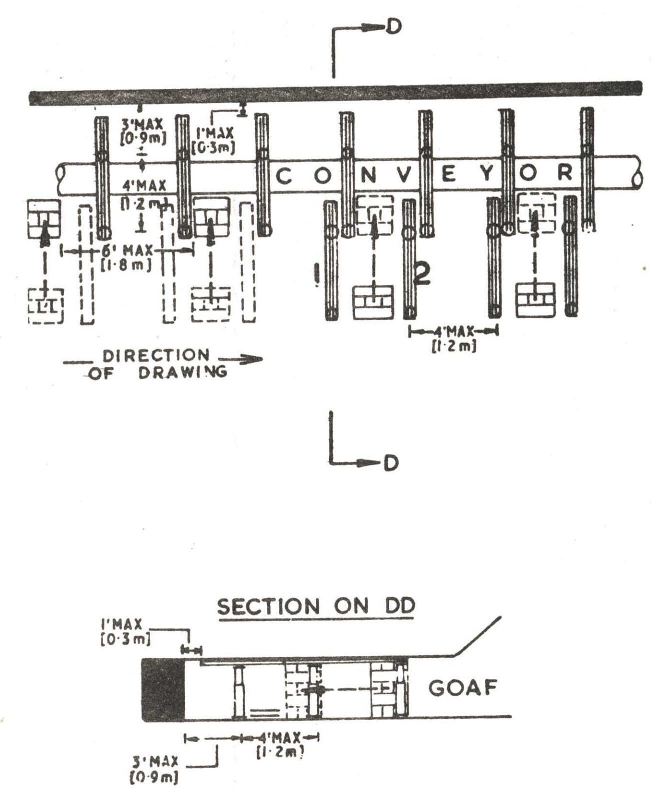
2_Chock now drawn and re-built in new position.

3_Props under Bar 1 now released and along with bar are withdrawn from a place of safety.

4_Chains are attached to the props under Bar 2.

5_Props under Bar 2 now released and along with bar are withdrawn from a place of safety.

6_This procedure to be repeated along face in the direction of drawing.

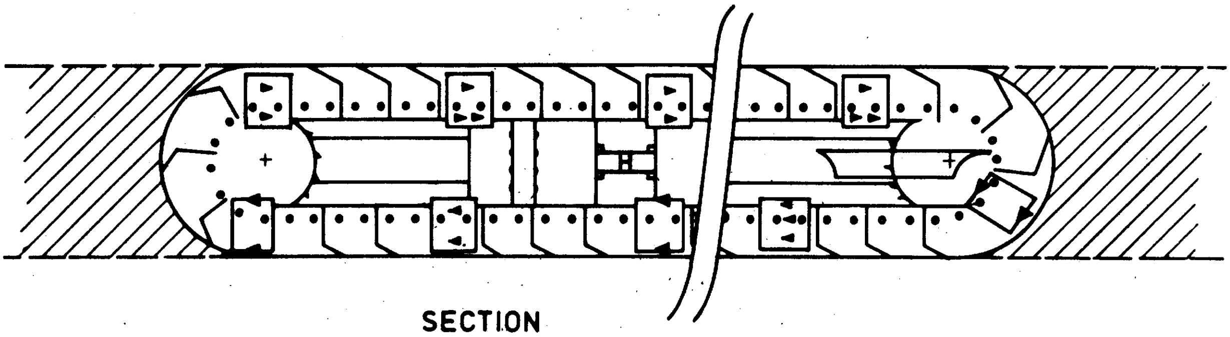


DISTANCES SHOWN IN FEET WITH METRIC EQUIVALENT IN BRACKETS.

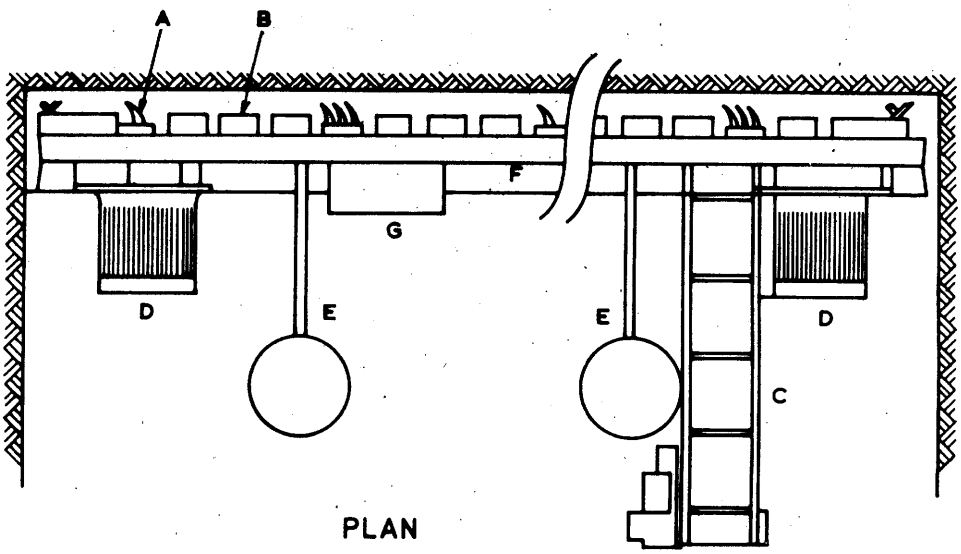
British Mining Consultants Ltd.	
Engineer.... K L	Date.... Sept 84
Traced by.... —	Drg No 12/0099/3/6

IN-SEAM MINER

GENERAL ARRANGEMENT



SECTION



PLAN

LEGEND

Cutters	A
Conveyor scoops	B
Discharge conveyor	C
Power units	D
(electric or hydraulic)	
Thrust rams	E
Main frame	F
Control position	G
Chain tension unit	H

British Mining Consultants Ltd.

Engineer.... KL	Date....October 84
Traced by.... —	Drg No...12/0099/3/7

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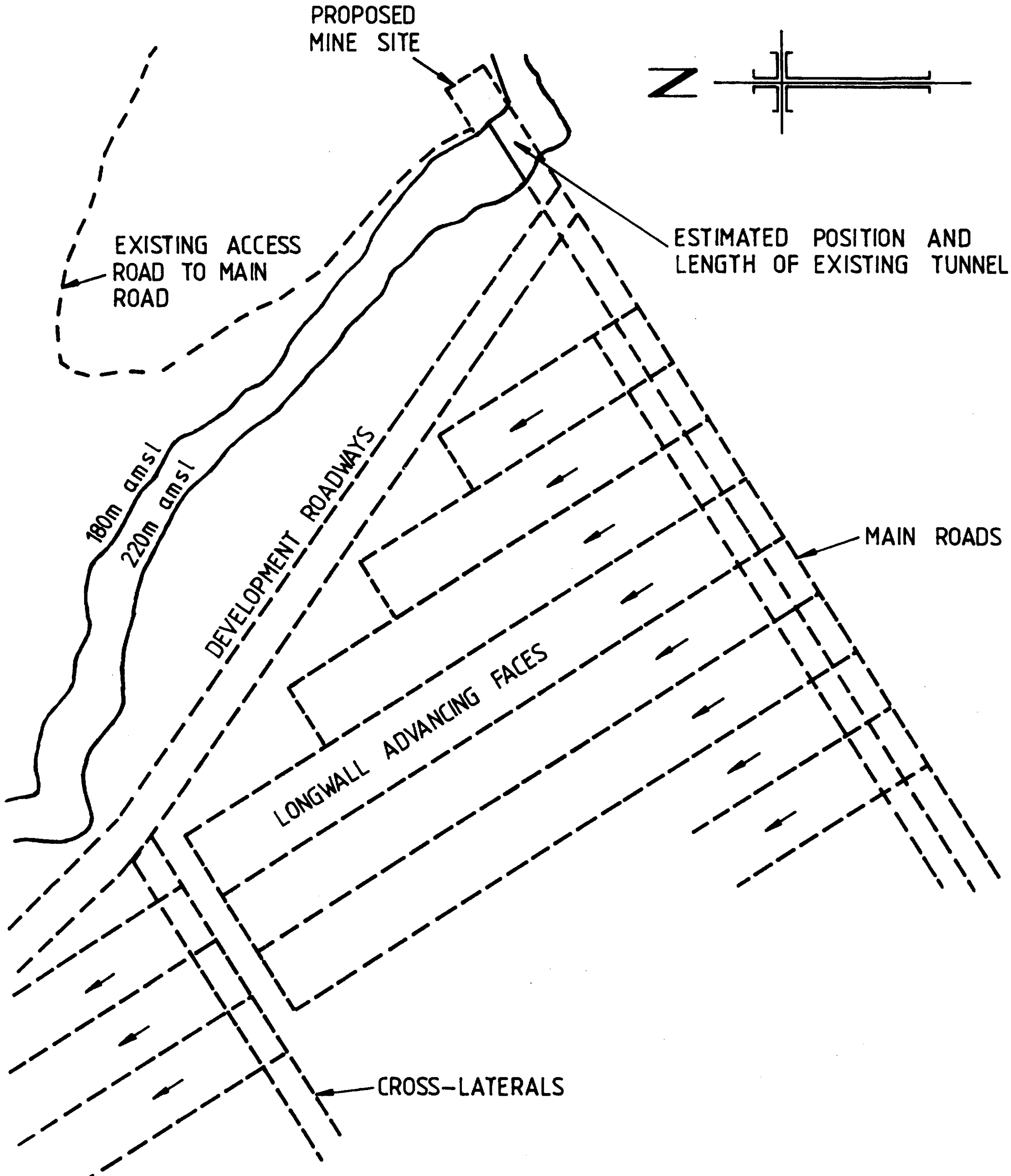
CONCEPTUAL MINE PLAN - BOTN

1000 500 0 1000 Metres

1 : 10,000



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Engineer....KL	Date....October 84
Traced by.... KJB	Drg No.12/0099/3/8

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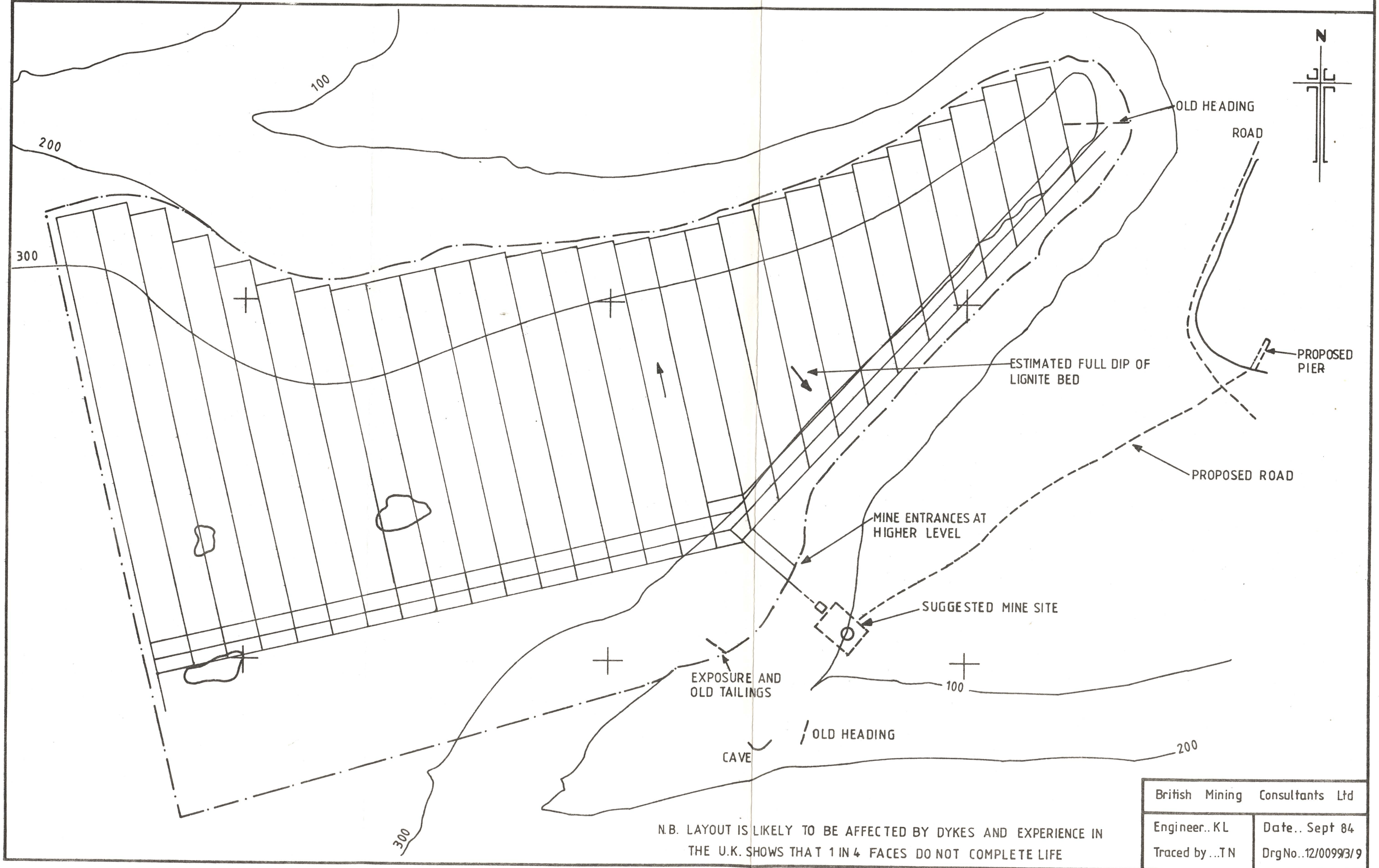
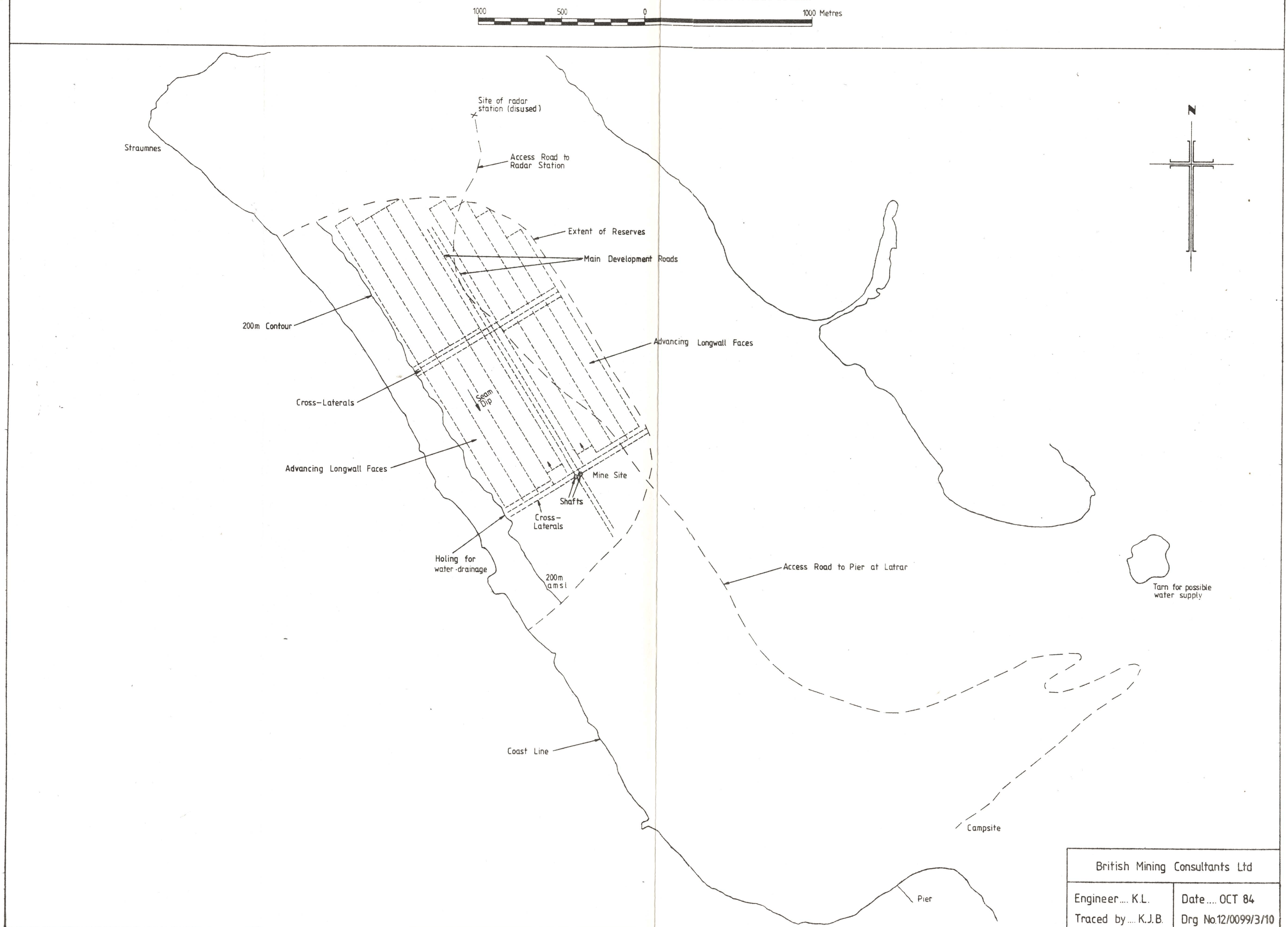
DUFANSDALUR AND THERNUDALUR
CONCEPTUAL MINE PLAN – LIGNITE SEAM

Scale 1: 10,000



CONCEPTUAL MINE PLAN - STRAUMNESFJALL



CONCEPTUAL MINE PLAN - STALFJALL