# THICKNESS AND FACIES VARIATION OF THE CARBONIFEROUS SYDNEY MINES FORMATION IN THE MORIEN SYNCLINE, CAPE BRETON ISLAND

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## ABSTRACT

Sixty-three drill holes (Cape Breton Development Corporation 'A' series, 1905-1928; Nova Scotia Department of Mines 'PM' series, 1978-1980) from the Morien Syncline, Cape Breton Island have been analyzed to study the thickness and facies variation of the lower Sydney Mines Formation (Westphalian D). This project marks the first time the information contained in these holes has been compiled and used to infer changes in sedimentary strata over the syncline in its entirety. Two sections along the Morien coastline provide additional information on facies and paleoflow.

Coal seams and strata within the Morien Syncline are divided into six stratal packages each tens of metres thick: the Backpit Stratal Package from the top of the Backpit Seam to the top of the Phalen Seam; the Phalen Stratal Package from the top of the Phalen Seam to the top of the Seam 'A'; the 'A' Stratal Package from the top of Seam 'A' to Seam 'B'; the 'B' Stratal Package from the top of Seam 'B' to Seam 'C'; and the 'C' Stratal Package from the top of Seam 'C' to a lowermost Seam 'D'. The packages correspond to basinwide cyclothems that probably reflect relative sea-level change in equatorial latitudes linked to Gondwanan glaciation.

Stratal thickness and facies variation, along with paleoflow data from coastal sections, suggest that the syncline was a paleotopographic low during deposition of the lower Sydney Mines Formation. This is indicated on isopach maps by northward thinning from the syncline axis for most seams and stratal packages. Local thickening southward at some levels suggests that the location of the paleodepocentre may have been centered south of the present syncline axis during some periods. Sandstone and red shale isolith maps show relatively high proportions of these facies south of the syncline axis; this suggests the presence of a more elevated area with well-drained conditions on the southern flank of the syncline. Support for the existence of a local depocentre is provided by paleoflow patterns, which run mainly parallel to and transverse to the syncline axis. A strong northerly paleoflow mode suggests that some infill was supplied from basement (pre-mid-Devonian) sources south of the study area. Deformation during the Permian (?) later accentuated the synform and generated steep dips on the northern limb.

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## ACKNOWLEDGMENTS

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# Chapter 1: INTRODUCTION

## *1.1 General Statement*

The Port Morien coal district of Northeastern Cape Breton has been an area of geological and economic interest for well over three centuries. Although smugglers and bootleggers mined coal since initial colonization, the French Military first officially mined coal from the Morien Syncline in 1720, when it was found necessary to obtain a supply of fuel for the labor force constructing the Fortress of Louisburg (Gregory, 1978). Since then, provincial records suggest five mines have operated within the Port Morien district, with mining being conducted on the Harbour and Phalen seams, by the Dominion Coal Company and the Nova Scotia Steel Company. By 1930, the last operating mine had ceased production, ending a district industry which lasted over 65 years (Gregory, 1978).

This project focuses on the stratigraphic characteristics of the Upper Carboniferous Sydney Mines Formation within the Morien Syncline (Figs. 1.1 - 1.3). Analysis of drill hole information is used to investigate the cyclicity of the sedimentary record and the stratal-tectonic relationships of the Morien Syncline, shedding light on how sedimentation varied spatially through time. The project also examines the areal extent and thickness of individual coal seams, some of which have not been mined systematically to date. Additionally, we investigate the extent of sandstone and shale lenses that locally split some seams, thus reducing their mining potential in some parts of the Morien Syncline. The use of elevation data to create accurate structural contour maps for some seams can potentially allow the outcrop distribution of individual seams to be refined and current geological maps to be updated.

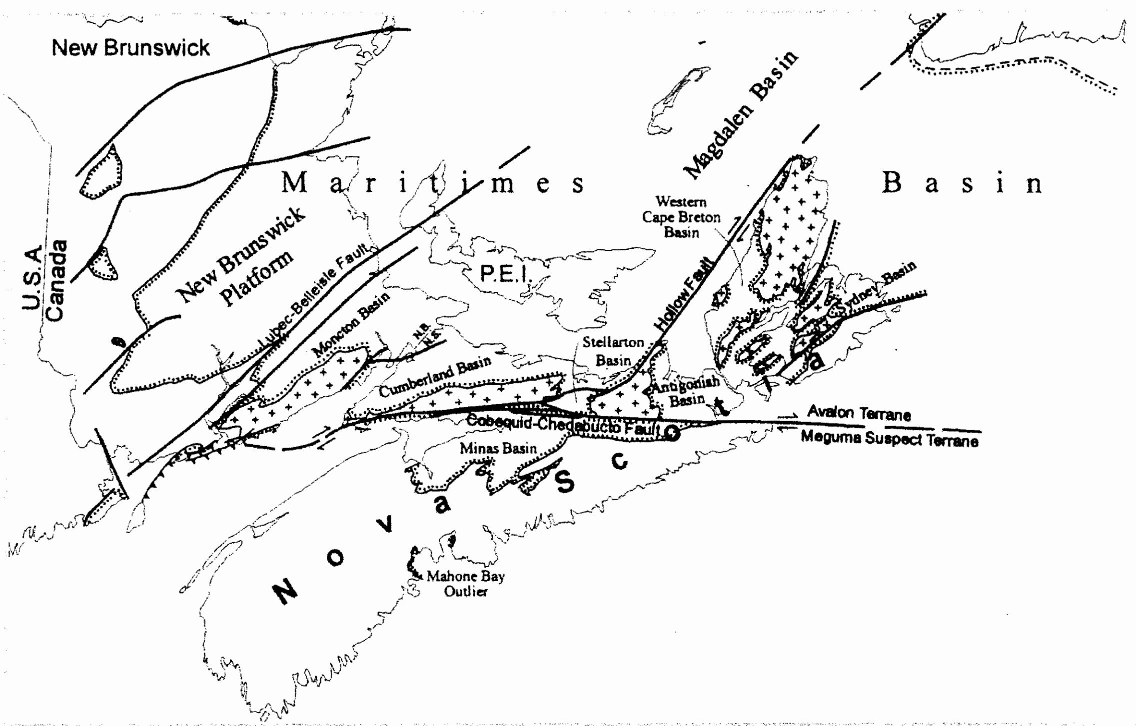



**Figure 1.1:** Areas underlain by Middle Devonian – Permo-Carboniferous strata of the southern Maritimes Basin in Nova Scotia, with component depositional basins and intrabasinal massifs. Project area is of the Sydney Basin, North-East Cape Breton. From Calder, 1998.

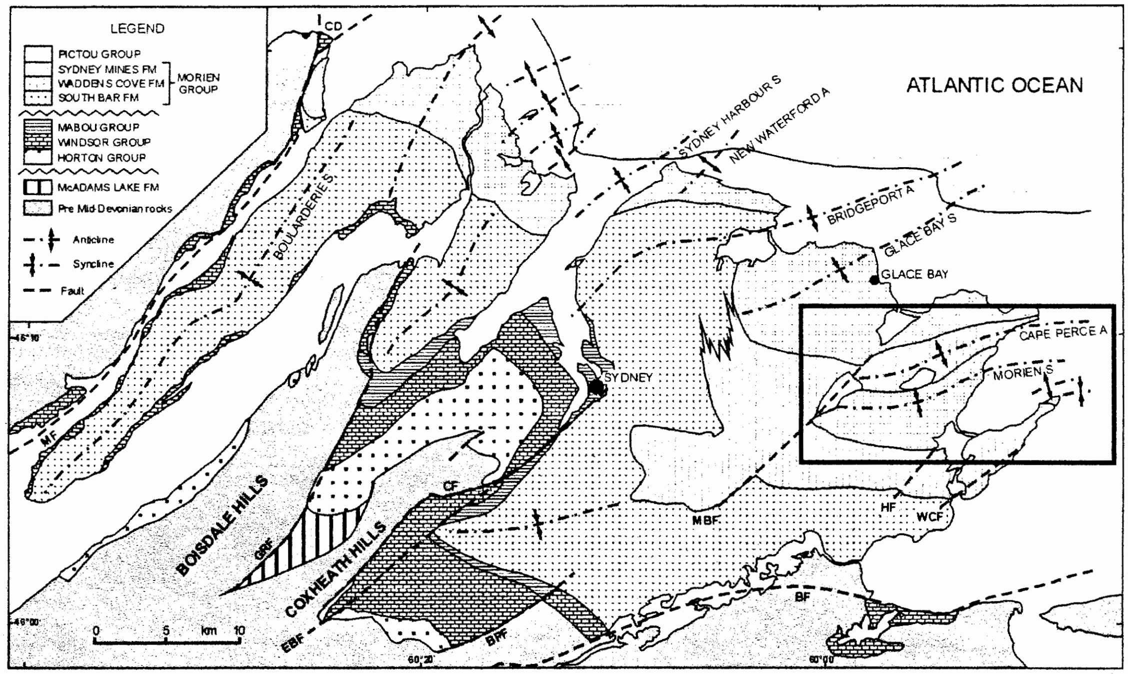
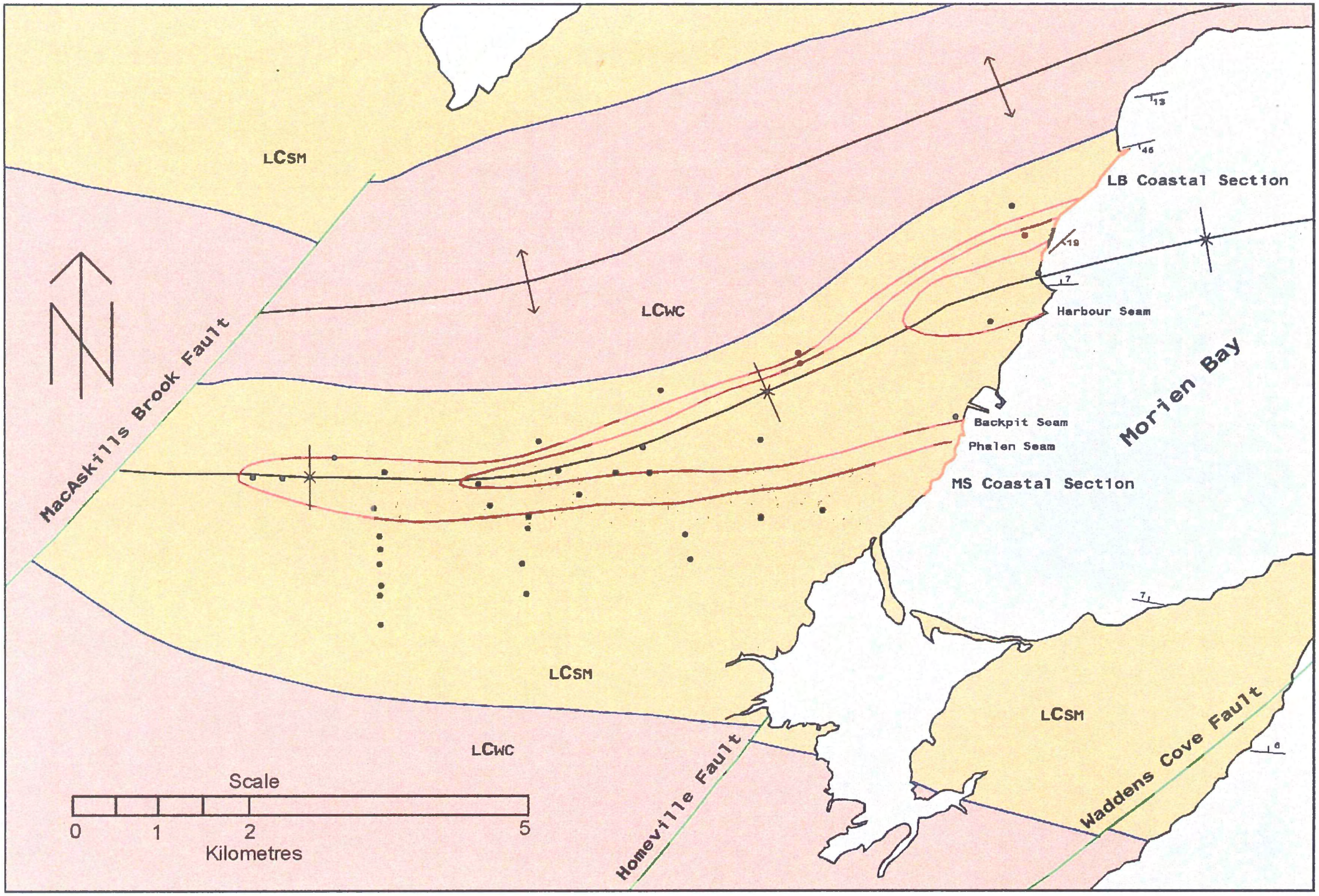



**Figure 1.2:** Geological map of the onshore Sydney Basin, showing the location of the Morien Syncline in relation to Northeastern Cape Breton. Boxed section represents study area. Modified from Pascucci *et al.*, 2000.

*(Figure 1.3: Diagram on following page)*

**Figure 1.3:** A geological map of the Morien Syncline showing syncline axis location and major fault systems. *LCWC* denotes areas of the Waddens Cove Formation (Westphalian B to Westphalian C). *LCSM* denotes areas of the Sydney Mines Formation (Westphalian D to Stephanian). Black dots represent A-series drill hole locations used in this study. Coastal sections used for study are represented as orange lines and are referred to as the Long Beach coastal section (LB; LB-00) and the Morien South coastal section (MS; MS-00). Steeps dips associated with the northern limb of the syncline are expected to have been generated by deformation of the Donkin Episode (Pascucci *et al.*, 2000; Gibling *et al.*, submitted). Map based on Boehner and Giles, 1986.


LCSM
LCWC
LB Coastal Section
Harbour Seam
Morien Bay
Backpit Seam
Phalen Seam
MS Coastal Section
MacAskills Brook Fault
LCSM
LCWC
LCSM
Homeville Fault
Waddens Cove Fault
Scale
0
1
2
5
Kilometres

Sixty-three drill hole records compiled from drilling along the Morien Syncline (1908 to 1928, DEVCO A-series; 1978 to 1980, NS Dept of Mines PM-series) have been analyzed using *RockWorks99*, a spreadsheet-based computer program that yields correlation diagrams and isopach maps. Correlations are compared to transects along coastal cliff sections of Morien Bay using data collected from June to August 2000 by H. L. MacDonald (M.Sc., in progress) and the author.

*1.2 Objective and Scope of Project*

The objective of this project is to examine the available drill holes of a selected region of the Sydney Basin to determine the stratigraphic variation within the area and to see how it relates to the regional tectonic setting. Previous research has suggested that there is a relation between stratal thickness of the Sydney Mines Formation and its location within folds across the outcrop belt (Haites, 1951; Hacquebard, 1983; Tibert and Gibling, 1999; Pascucci *et al.*, 2000; Gibling *et al.*, submitted). For example, the Phalen and Harbour Seams in the Glace Bay district are thicker in the Glace Bay Syncline than over the adjacent Bridgeport Anticline (Haites, 1951). Research suggests that a similar relationship could exist within the project area, with the thickness of strata, including coal seams, increasing towards the axis of the Morien Syncline, as in the Glace Bay district. Previous research has also recognized cyclicity of coal seams and intervening clastic sediments (cyclothems) across the basin (Haites, 1951; Gibling and Bird, 1994). This project addresses this cyclicity within the Morien Syncline, where cyclothems have received little attention.

It has been suggested that tectonic activity accompanied and affected deposition within the Sydney Mines Formation (Haites, 1951; Hacquebard, 1983;

Pascucci *et al.*, 2000). Indicative of this relationship is the fact that several thin seams have been economically feasible to mine in synclinal areas only (Haites, 1951). This thickening of seams in synclinal areas is attributed to elevated subsidence rates in synclinal areas of the basin. Additionally, the variation of sediment accumulation in particular areas of the Sydney Mines Formation outcrop belt may have influenced fold relationships that developed after deposition.

Despite the length of time since it was first recognized that strata are thicker in synclinal areas, most of the documentation has been in the form of brief, generalized statements and observations of thin stratal intervals. No systematic spatial analysis of this phenomenon has yet been published for the Sydney Basin. This study provides such a documentation using a dense drill hole array in a synclinal area.

The cyclic stratal succession of the Sydney Mines Formation was first documented comprehensively by Gibling and Bird (1994). The formation comprises sandstone and grey and red mudstone, with limestone and economic coal, and includes alluvial and restricted marine facies (Rust *et al.*, 1987), all of which are systematically developed within cyclothems (Gibling and Bird, 1994). Cyclothems have been ascribed to relative sea level fluctuations, tectonism, climatic changes, or to some combination of these factors (Gibling and Bird, 1994).

The Sydney coalfield has drawn the attention of geologists for many years, and several main periods of systematic geological research can be distinguished. The first period, 1872 to 1900, is covered by the studies of Ch. Robb and H. Fletcher (Haites, 1951), which set the main stratigraphic framework for the basin. Work completed during this period was of high quality and is still consulted. Following this, studies were continued by A. O. Hayes and W. A. Bell from 1917 – 1938 (Haites, 1951), which, as a result of paleobotanical studies, positioned the Sydney coalfield in its appropriate place in the stratigraphic column. The work of Hayes and Bell (1923) is still considered the main base for any geologic work in the Morien area. A third period of study is a result of the Geological Survey of Canada and Nova Scotia Department of Natural Resources, starting in 1948 and continuing throughout the 1980's (Haites, 1951; 1952; Hacquebard, 1983; and many others). Work during this period focused generally on the nature and continuity of the major coal seams, in particular the Mullins, Gardiner, Emery, Phalen, and Harbour seams. A fourth period of study has developed over the past 20 years, including work at Nova Scotia Department of Natural Resources, and by M. Gibling and co-workers principally at Dalhousie University, where the study has focused mainly on sediment cyclicity and sequence stratigraphy.

# Chapter 2: BACKGROUND GEOLOGY

## *2.1 Geological Setting of the Maritimes Basin*

### *2.1.1 Maritimes Basin*

Upper Paleozoic rocks of the Maritimes Basin are widely distributed in Quebec and the Atlantic Provinces (Fig. 1.1) (Bell and Howie, 1990; Calder, 1998), with deposits of Mid Devonian and Carboniferous successor basins resting unconformably on rocks deformed during the Acadian Orogeny (Pascucci *et al.*, 2000; Gibling *et al.*, submitted). The major Late Paleozoic depocentre is the western Maritimes Basin (Bell and Howie, 1990), which occupies the southern half of the Gulf of St Lawrence and extends into adjacent areas of Quebec and the Atlantic Provinces. The Upper Paleozoic strata of the Maritimes Basin span the Middle Devonian to Early Permian (Calder, 1998), and its history included several periods of subsidence following the Acadian Orogeny (Bell and Howie, 1990; Gibling *et al.*, 1992; Calder, 1998; Pascucci *et al.*, 2000). The Maritimes Basin is a complex of predominantly northeasterly trending basins originally interconnected and currently separated by intervening massifs of the Avalon, Grenville, and Meguma terranes (Calder, 1998). The Devonian and Early Carboniferous basin fill comprises alluvial and lacustrine deposits of the Horton and Mabou groups and marine deposits of the Windsor Group (Bell and Howie, 1990; Gibling *et al.*, 1992; Calder, 1998).

### *2.1.2 Sydney Basin*

The Sydney Basin forms part of the regional Maritimes Basin, with strata exposed onshore in Cape Breton and extending offshore towards Newfoundland (Fig. 2.1). The eastward extent of the basin fill has not been established, however is known to

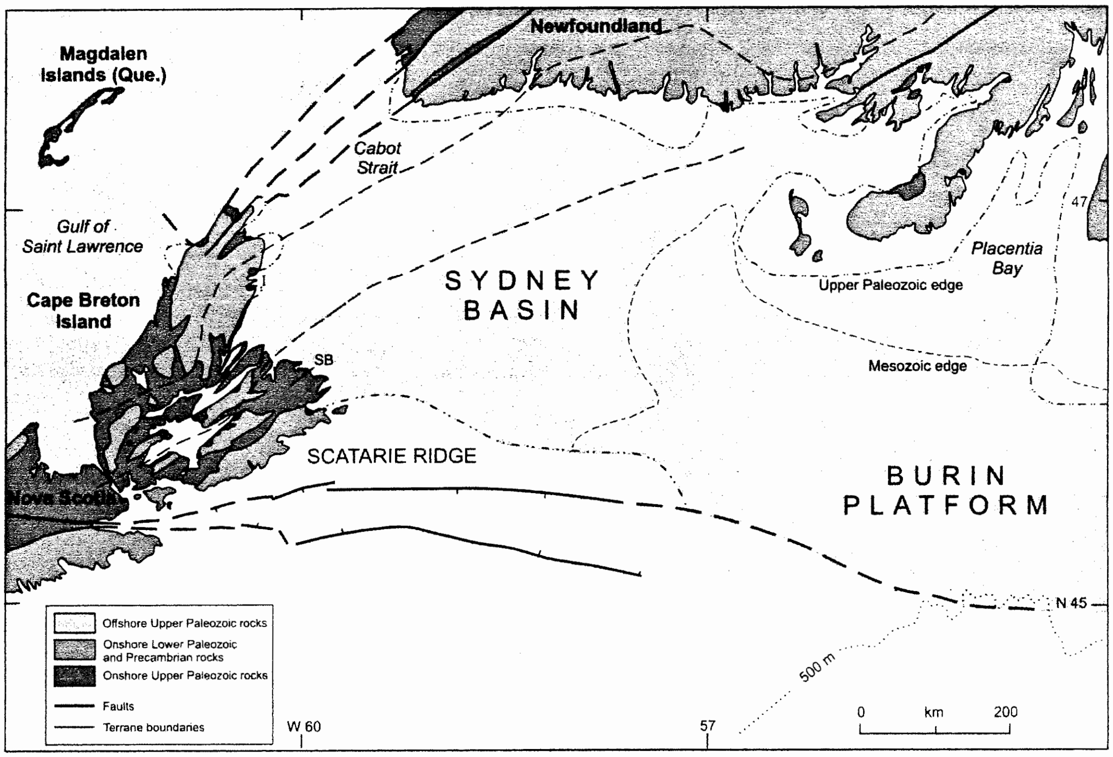



**Figure 2.1:** Areal extent of the Sydney Basin. Strata extend offshore towards Newfoundland and are exposed onshore in Cape Breton. Eastward, the Sydney Basin is known to extend beneath the Burin Platform, but its boundary has not been established. SB denotes onshore and nearshore strata of the Sydney Basin. Dotted line running through the Sydney Basin represents the boundary between the Mira and Bras d'Or terranes. Modified from Pascucci *et al.*, 2000.

extend under the Burin Platform (Pascucci *et al.*, 2000). Northward, fault zones in the Cabot Strait associated with small depocentres that include Upper Paleozoic strata border the basin. Such faults separate the Sydney Basin from the central part of the Maritimes Basin beneath the Gulf of St. Lawrence. Southward, the basin is bordered by Proterozoic rocks of Scatarie Ridge (Fig. 2.1) (Pascucci *et al.*, 2000). Geological and geophysical assessments made by Sheridan and Drake (1968) and King and MacLean (1976) characterize the Sydney Basin as 4-5 km thick and saucer-shaped, with beds dipping towards a deeper central area under the Atlantic Ocean. For a detailed description of the Sydney Basin, the reader is referred to Bell and Howie (1990), Calder (1998), and Pascucci *et al.* (2000). A brief summary of these papers is now presented, focusing on basinal stratigraphy.

## *2.2 Stratigraphy of the Sydney Basin*

### *2.2.1 Basement*

The Sydney Basin fill lies unconformably above Precambrian and Lower Paleozoic rocks that amalgamated prior to or during the Acadian Orogeny (Mid-Devonian), which records the final closure of the Iapetus Ocean (Barr *et al.*, 1995, 1998; Calder, 1998). Calder (1998) and Pascucci *et al.* (2000) suggest that the Upper Paleozoic depocentre of the Gulf of St. Lawrence originated by extension on southeast-dipping surfaces at lower crustal levels, interpreted as thrusts formed during earlier tectonic episodes. An inferred detachment under the Sydney Basin may have originated in a similar manner, as an Acadian thrust front lies in western Newfoundland north of the Sydney Basin (Pascucci *et al.*, 2000).

*2.2.2 McAdams Lake Formation*

The Sydney Basin is subdivided into several groups and formations (Figs. 1.2; 2.2). The McAdams Lake Formation (Mid-Devonian) is the earliest basin fill, with strata deposited in a half-graben during postorogenic extension along the Mira-Bras d'Or terrane boundary. This formation comprises coarse siliciclastic strata, organic-rich shale, and coal, of lacustrine and alluvial origin.

*2.2.3 Horton Group*

The overlying Horton Group (Fig. 2.2), ranging from Tournaisian to early Viséan (Gibling *et al.*, submitted), rests on an angular unconformity and occupies grabens across Atlantic Canada. Thickness varies from up to 600 m in the Minas Basin to as much as 3000 m in western Cape Breton. The Horton Group includes thick polymictic conglomerates and has a tripartite basinal stratigraphy of alluvial strata with intervening organic-rich lacustrine beds.

*2.2.4 Windsor Group*

Overlying the Horton Group with apparent concordance in the Sydney Basin are the marine deposits of the Windsor Group (Viséan) (Fig. 2.2), varying up to 1000 m in thickness. The Windsor Group records transgression by a shallow sea in which marine carbonates and evaporite deposits accumulated. The type section near Windsor, Nova Scotia includes at least 473 m of red sandstone, red and grey siltstone, and limestone, with dolomite and gypsum. Thick halite sections (up to 327 m) are present in the Windsor Group, although evaporites may not be prominent throughout the entire basin.

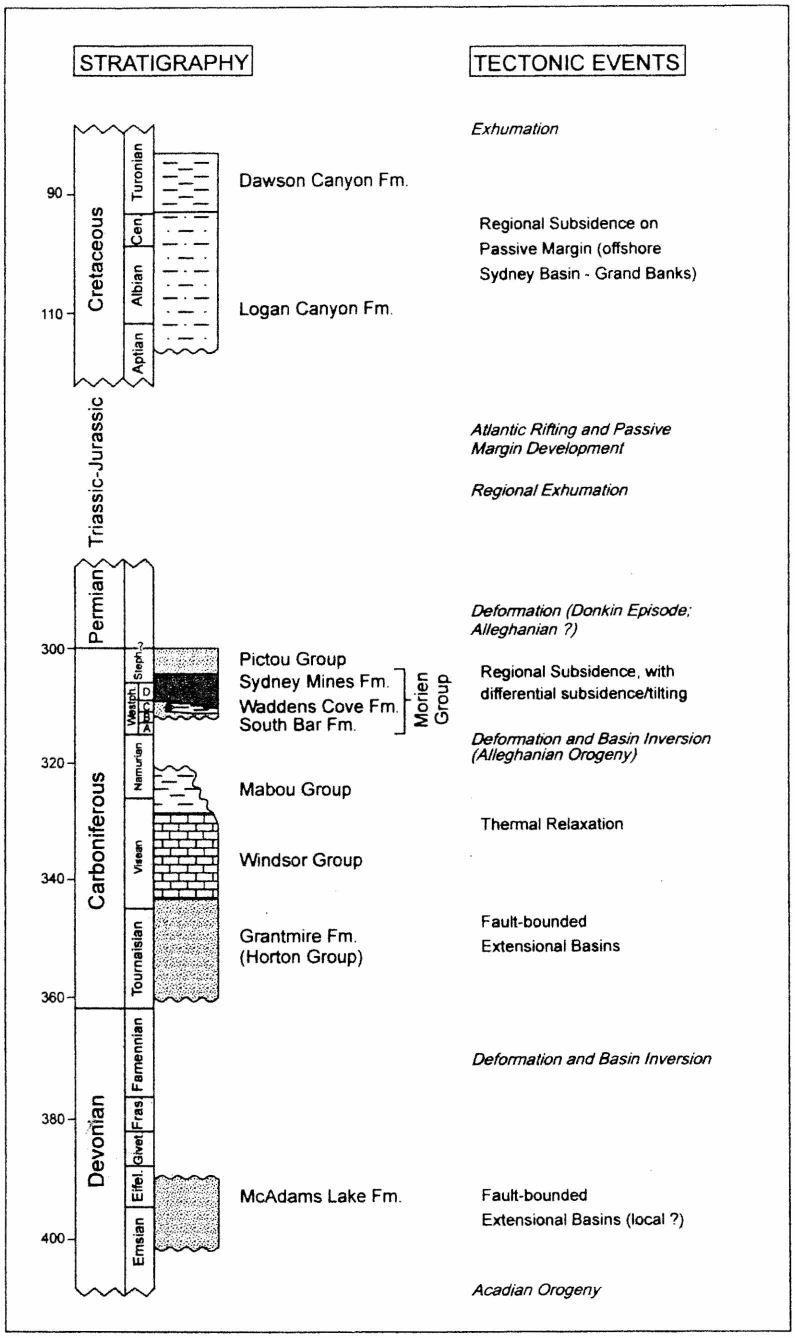



**Figure 2.2:** Stratigraphic column of the onshore section of the Sydney Basin. Numbers to the far left of the diagram represent absolute age dates (m.y.). Tectonic events known to have affected the Sydney Basin are listed as well. Modified from Gibling *et al.*, submitted.

*2.2.5 Mabou Group*

Following withdrawal of the Windsor Sea, a semiarid climate persisted through the late Viséan as lake margins of the basal portion of the Mabou Group (late Viséan to Namurian) contracted and desiccated, depositing cyclic carbonate and red beds (Calder, 1998). The group attains a thickness of 3000 m in Nova Scotia and consists of sandstone, siltstone, shale, limestone, and sulphate evaporites, with some thick dark shales (Bell and Howie 1990; Calder 1998; Pascucci *et al.* 2000).

*2.2.6 Morien Group*

Ranging in age from Westphalian B to Stephanian and attaining a thickness of up to 1966 m, the Morien Group lies unconformably above the Mabou and Windsor groups (Fig. 2.2) (Tibert and Gibling, 1999). The basal South Bar Formation consists mainly of braided-fluvial sandstones with minor coal, at least 860 m thick (Rust and Gibling, 1990). Sandstone, pebbly sandstone and conglomerate predominate, with mudrocks and coals forming less than 10% of the aggregate thickness (Tibert and Gibling, 1999). At more easterly localities, the upper portion of the South Bar Formation is equivalent to sinuous channel deposits incised into well-indurated siliceous paleosols of the Waddens Cove Formation (Tibert and Gibling, 1999).

The Sydney Mines Formation overlies the South Bar and Waddens Cove formations and is approximately 1000 m thick (Hacquebard, 1983; Tibert and Gibling, 1999; Gibling *et al.*, submitted). The formation, containing eastern Canada's main economic coal seams, is dated as Westphalian D to Stephanian (Tandon and Gibling, 1994; Tibert and Gibling, 1999), and is well exposed along the northeast coast of Cape Breton Island. The deposition of the coals and associated strata has long been attributed to a fluvial setting, an interpretation supported by an apparent absence of cephalopods, conodonts, and other marine fossils combined with an abundance of ostracods, bivalves, gastropods, and fresh-water shark teeth (Wightman *et al.*, 1993). However, the presence of agglutinated foraminifera in shales associated with the coals suggests that deposition of parts of the Sydney Mines Formation took place on an extensive coastal platform during relative highstands of sea level (Wightman *et al.*, 1993; Tandon and Gibling, 1994). Gibling and Bird (1994) elaborate, stating that the formation is a meandering fluvial to restricted-marine unit that consists of cyclic deposits of sandstone, mudstone, limestone, and economic coal. The cyclothems are thought to record high-frequency (Milankovitch-band) eustatic events associated with Gondwanan glaciation (Tibert and Gibling, 1999).

*2.3 Tectonics Affecting the Sydney Basin*

Work relating to the structural characteristics of the Sydney Basin (Fig. 2.2) has recently been carried out by Pascucci *et al.* (2000) and Gibling *et al.* (submitted). The following overview is a brief summary of these papers, to which the reader is referred for a more extensive presentation.

Lower and Upper Carboniferous strata of the Sydney Basin dip gently (5-20°) and the Morien Group exhibits broad northeast- to east- trending folds. Folding was likely initiated by warping during deposition, as suggested by greater coal seam thicknesses in synclines than on anticlines (Hacquebard 1983). Stratal thickness (Robb, 1876; Hacquebard, 1983) and facies evidence (Gibling and Bird, 1994; Tandon and Gibling, 1997; Tibert and Gibling, 1999) indicate that some synclines were paleotopographic lows during Morien deposition, suggesting Late Carboniferous fault movement and compactional draping over the faulted blocks, or some combination of the two.

Northeast-striking faults cut pre-Morien strata onshore in the Sydney Basin. Regional faults show a combination of dip-slip and strike-slip motion, with up to 18 km of known stratal offset. Most such faults cannot be traced across the basal Morien unconformity, implying that they were inactive during or before the mid-Carboniferous, linked to Alleghanian deformation (Gibling *et al.*, submitted).

Low-angle reverse faults with northwest strikes and throws of up to 120 m have been documented in coal mines in the Sydney Mines Formation (Haites, 1951, 1952). Some of the most prominent faults lie in the Donkin area, just north of the Morien Syncline. Generally, displacement of such faults increases with depth. Normal faults and thrust faults are also present in the Sydney Mines Formation, as documented in coal mines (Haites, 1951, 1952) and Morien Bay (Hacquebard, 1983).

Fault surfaces recently observed by Gibling *et al* (submitted) directly offshore on the New Waterford Anticline (Fig. 1.2) are non-planar and generally dip northeast with reverse separations of 1-10 m. Several observations based on these surfaces indicate that faulting pre-dated folding: fault curvature coincides in general location and sense with the folds in bedding; the structure contours on the fault surface are more strongly curved than the bedding-fault intersection lines, which matches well with information from mining operations; and the interlimb angles of folds in bedding (10-15°) are comparable with the orientation difference between different parts of the fault (Gibling *et al.*, submitted).

Such observations on fault surfaces distinguish two generations of structures responsible for shortening of strata in the Sydney Mines Formation in the New Waterford area (approximately 20-25 km NNW from the Morien Syncline) (Fig. 1.2). An earlier episode generated localized northwest-striking and southwest-vergent faults. Subsequent northwest-southeast shortening produced the fold system of which the Morien Syncline is a part. Further analysis along the Cape Perce Anticline suggests structural features similar to those at New Waterford (Gibling *et al.*, submitted). Pascucci *et al.* (2000) referred to both the areal faulting and folding as the Donkin Episode.

Major coal seam distribution near the Glace Bay Syncline (10 km NNW of Morien Syncline) and sedimentary evidence indicates that some synclines between prominent anticlines onshore were paleotopographic lows and sites of preferential sediment accumulation during Morien deposition. The Sydney Mines Formation is thick in the Glace Bay Syncline and contains a high proportion of poorly drained facies such as grey mudstone and limestone. Relatively thick coals are also prominent. It is inferred that relief during deposition was modest as major coal seams cover both anticlinal and synclinal areas (Gibling *et al.*, submitted). Some paleotopographic lows may overlie Early Carboniferous extensional basins and faulted basement with irregular relief (Pascucci *et al.*, 2000).

Evidence suggests that the Donkin Episode represents compressional or transpressional events during the latest Permian stage of Pangean assembly. Deformation during this time period correlates with the final stages of the Alleghanian Orogeny (Pascucci *et al.*, 2000; Gibling *et al.*, submitted).

*2.4 Timing of Deformation of the Sydney Mines Formation*

Onshore strata of the Morien Group typically dip gently (5-15°), but can dip as much as 50° along the Bridgeport Anticline and the Cape Perce Anticline (Fig. 1.3) (Hayes and Bell, 1923). Cleat sets in coals along directions of 065° and 335° suggest development synchronous with folding (Haites, 1951).

Gibling *et al.* (submitted) studied 10 coal samples orientated with respect to local dip and strike from the McRury, Emery, Phalen, and Harbour seams (Fig 2.3). Of these 10 samples, three were collected from the area being referred to as the Long Beach coastal section for the purpose of this project (Fig. 1.3). The purpose of this study was to determine the orientation of the seams during coalification using vitrinite reflectance values of each sample (Gibling *et al.*, submitted). Thermal experiments on coals have shown that anisotropy develops during coalification, indicating that vitrinite has directional properties.

The minimum reflection axis ($R_{min}$) of uniaxial negative ellipsoids is orientated near-perpendicular to bedding in undeformed sedimentary basins. Essentially, this indicates that compression during sediment burial is assumed to have been vertical (Levine and Davis, 1989). In this situation, reflectance values should fan across fold axes if the coal-bearing strata were deformed after coalification (Levine and Davis, 1984). Coals with biaxial reflectance patterns are reported from strongly folded or faulted strata, suggesting that tectonic stresses are responsible for the biaxial anisotropy (Levine and Davis, 1984; 1989; among others).

With the exception of sample 10 (McRury Seam), all samples exhibited uniaxial negative reflectance patterns with reflectance axes essentially orthogonal with

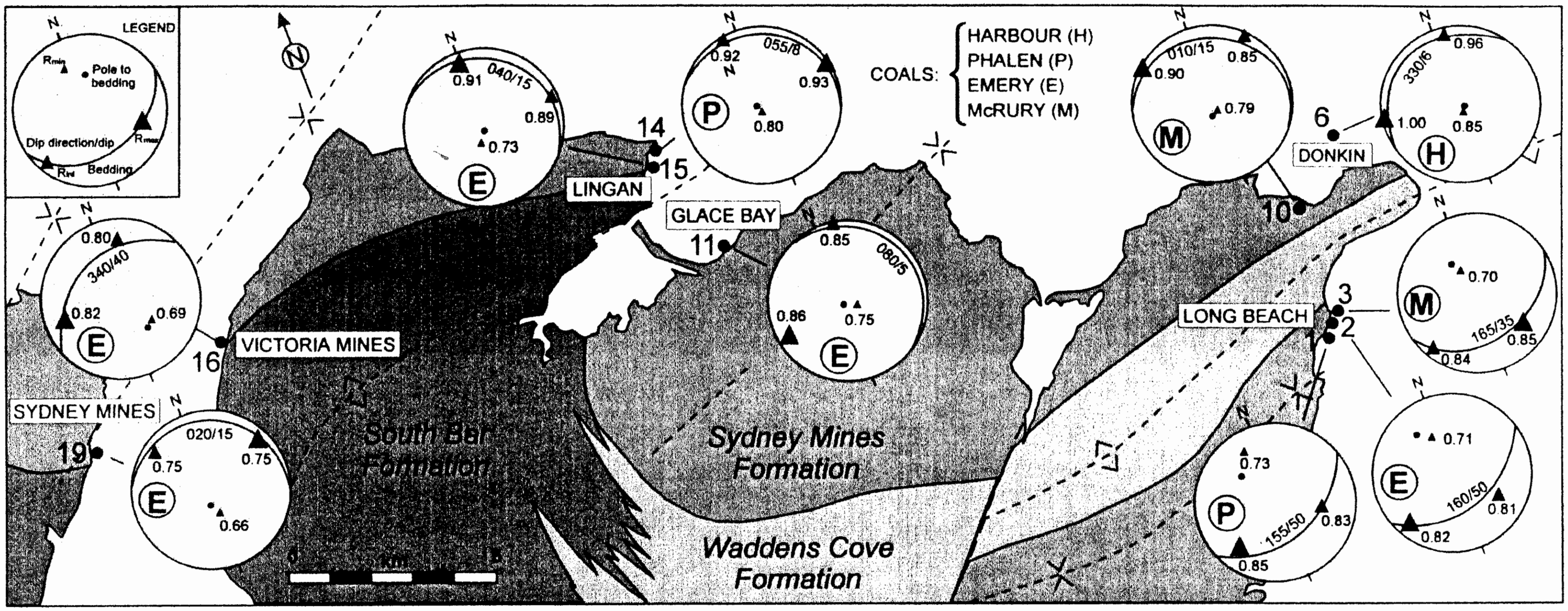



**Figure 2.3:** Locations of 10 coal seam samples studied by Gibling *et al.* (submitted). All samples were orientated with respect to local dip and strike. Circled letters in stereo projections represent which seam each sample came from. With the exception of sample 10, all samples exhibited uniaxial negative reflectance patterns. Sample 10 showed evidence of biaxial negative anisotropy. Such a predominant uniaxial reflectance pattern provides strong indication that the bulk of coalification within the onland portion of the Sydney Mines Formation took place during burial-related compaction while the beds were flat-lying without significant directed horizontal stress (Gibling *et al.*, submitted). Samples 1-3 are from the Long Beach coastal section. From Gibling *et al.* (submitted).

the bedding, even where the beds dip steeply (Gibling *et al.*, submitted). Such a predominant uniaxial reflectance pattern provides strong indication that the bulk of coalification within the onland portion of the Sydney Mines Formation took place during burial-related compaction while the beds were flat-lying without significant directed horizontal stress (Gibling *et al.*, submitted). It is expected that coalification was essentially complete before deformation of the Donkin Episode generated steep dips on the limbs of the Cape Perce (Fig. 1.2, 1.3) and Bridgeport anticlines (Fig 1.2).

Sample 10, which shows evidence of biaxial negative anisotropy, suggests that some coals in some locations may have been tilted before or during the main phase of coalification. Slight tilting is consistent with differential subsidence during Morien group deposition, which is supported by geological (facies) evidence (Hacquebard and Donaldson, 1970). It is also consistent with minor tilting during early stages of the Donkin Episode, perhaps associated with southwest-vergent thrust faults such as those documented near New Waterford (Gibling *et al.*, submitted).

Although no absolute means of dating the coal-measures deformation is apparent, deformation of the Sydney Mines Formation can be dated as Stephanian or later (Gibling *et al.*, submitted), since the youngest Sydney Mines strata are Stephanian in age. The oldest Mesozoic strata that overlie the Sydney Basin Paleozoic succession are Early Cretaceous in age and appear relatively flat-lying in seismic profiles on the Burin Platform (MacLean and Wade, 1992; Pascucci *et al.*, 2000).

Fission-track modeling results for detrital apatite from the Sydney Basin (Grist *et al.*, 1995; Grist and Gibling, 1999) help to constrain the timing of coalification and thus of the deformational episode that post-dates coalification. Such results imply that coalification at Sydney was largely complete by the Middle to Upper Triassic (Gibling *et al.*, submitted).

# Chapter 3: DATA AND METHODS

## *3.1 Overview of Data Set*

### *3.1.1 'A' series drill holes of the Morien Syncline*

Data consist of 37 holes drilled from 1905 to 1928 for use by the Dominion Coal Company, which subsequently became the Cape Breton Development Corporation (CBDC). Labeled as the 'A' series, drilling was completed by the Dominion Iron and Steel Company, Nova Scotia Department of Mines, Smith & Traverse Company, and the North Atlantic Collieries Company. Copies of the drilling information sheets were provided to M. R. Gibling by the Cape Breton Development Corporation and by D. J. MacNeil of the Nova Scotia Department of Natural Resources.

The 'A' series drill holes (Fig. 3.1) have been drawn upon for analysis for few other studies. Hayes and Bell (1923) presented 'A' series drill logs and compared them to coastal exposures to infer small-scale variations from the modern coast. As property of CBDC, the data have been used for inland stratigraphic information in the Morien Syncline area (Haites, 1952), and have proved to be a primary source of information for such purposes. This project marks the first time 'A' series drill hole information has been compiled as a whole to infer changes in sedimentary strata over the Morien Syncline in its entirety.

### *3.1.2 'PM' series drill holes of the Morien Syncline*

Data also consist of 26 holes drilled from 1978 to 1980 by the Nova Scotia Department of Mines, currently a sector of the Nova Scotia Department of Natural Resources (NSDNR). The 'PM' series drill holes (Fig. 3.2) were put down in the Port Morien district to determine the availability of what was interpreted as potential

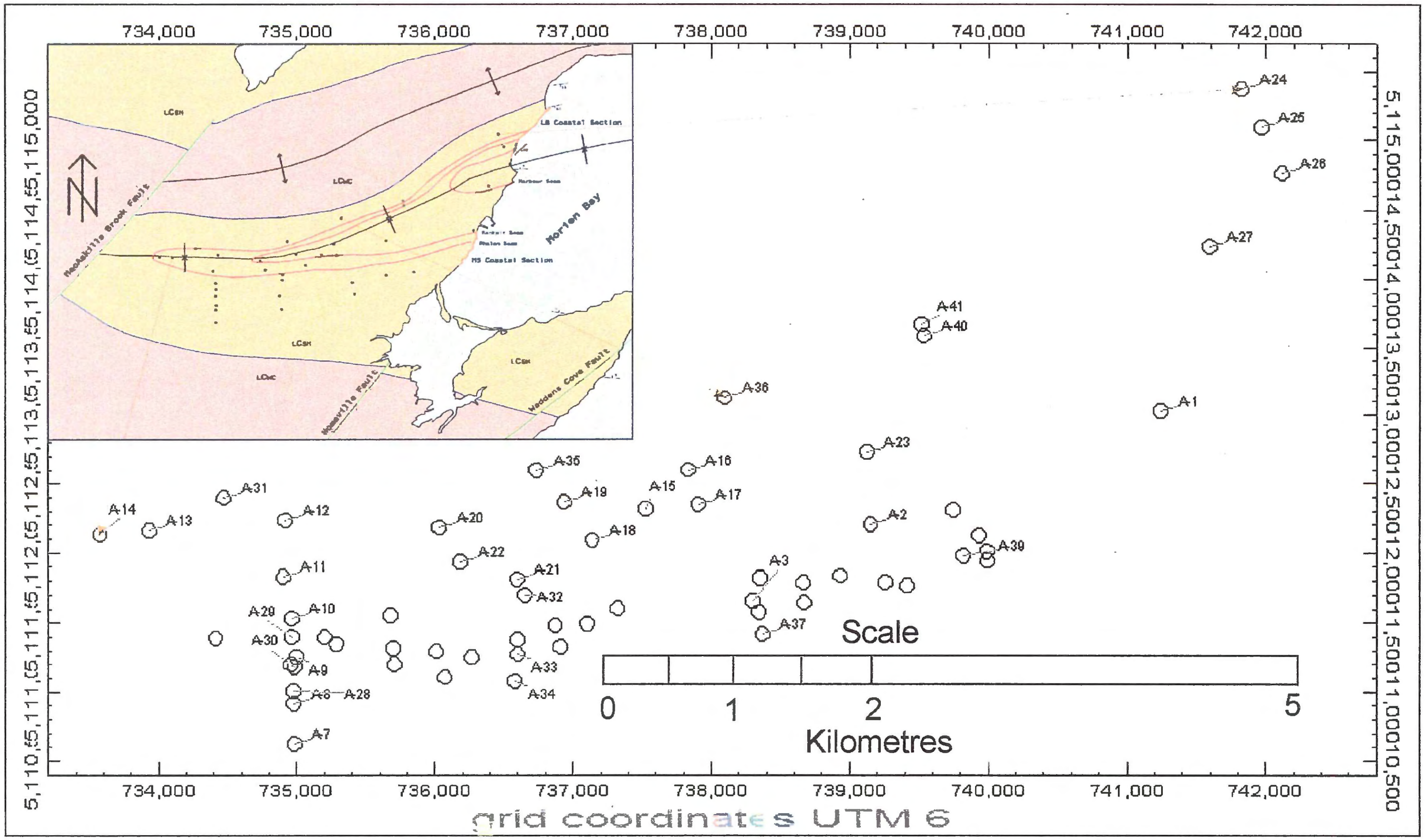



**Figure 3.1:** Locations of the 'A' series drill holes used in study. Inset is a simplified geologic map showing the drill hole locations in relation to upper coal seams and syncline axis. See Figure 1.3 for an expanded version. Orange lines are lines of similarity to show which locations coincide. Inset based on Boehner and Giles (1986).

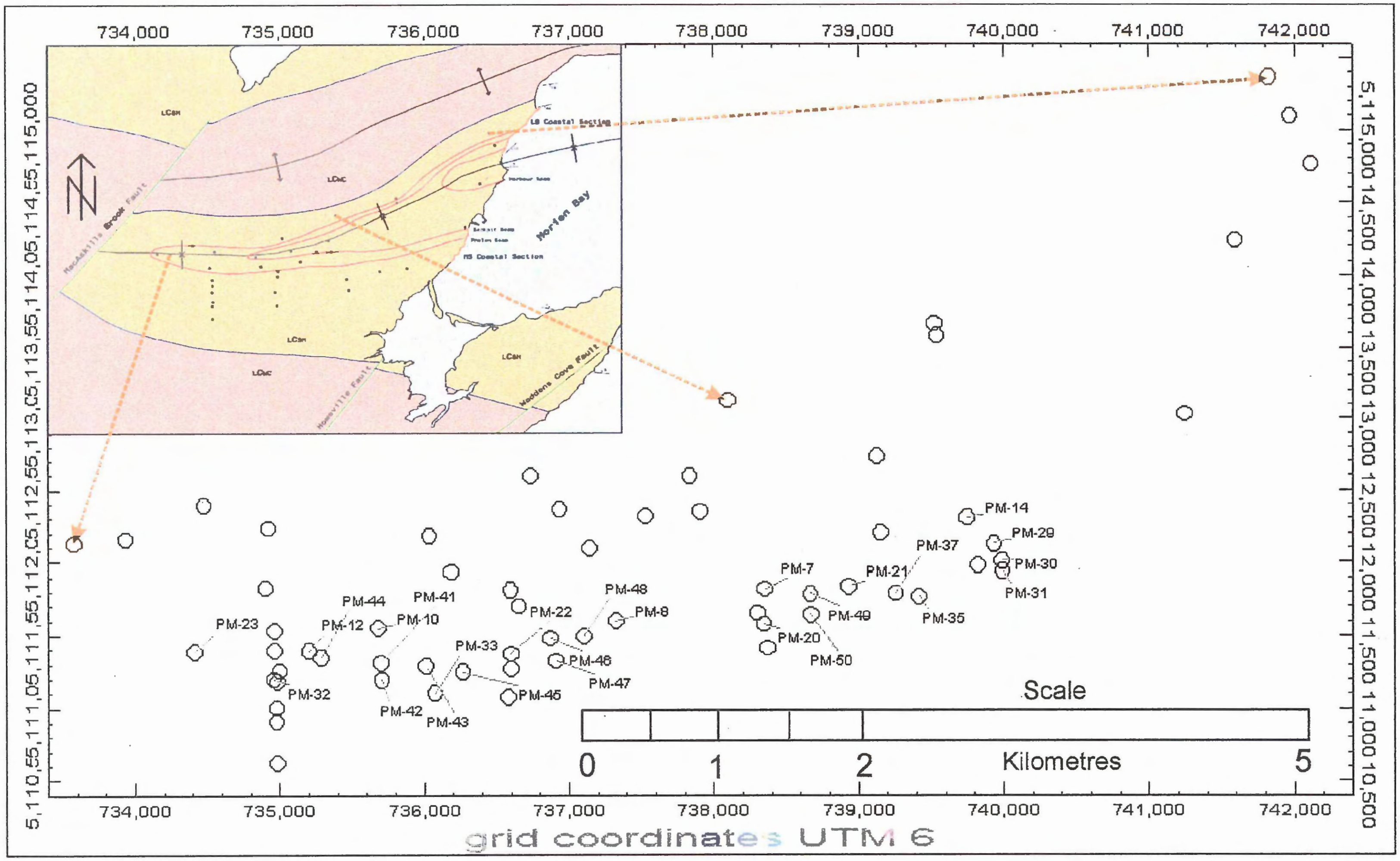



**Figure 3.2:** Locations of the 'PM' series drill holes used in study. Inset is a simplified geologic map showing the drill hole locations in relation to coal seams and syncline axis. See Figure 1.3 for an expanded version. Orange lines are lines of similarity to show which locations coincide. Inset based on Boehner and Giles (1986).

strippable Emery (Spencer) Seam coal resources (Gillis, 1981). Consequently, the 'PM' series generally penetrates seam interval 'B' as referred to in this study, however whether this seam correlates with the basin wide Emery Seam is questionable.

Copies of 'PM' drilling information sheets were provided to M. R. Gibling by R. D. Naylor of NSDNR. D. J. Hughes of the Geological Survey of Canada in Calgary provided further information relating to drill hole locations for both the 'A' and the 'PM' series. The 'PM' series drill holes to provide information relating to strata below the Phalen Seam along the southern limb of the syncline axis. Most 'PM' series holes have proven too short to encompass complete stratal packages, however, will provide solid information in relation to seam interval 'B' and somewhat to seam interval 'A'.

*3.1.3 Coastal sections*

Coastal exposures near Port Morien were measured by H. L. McDonald and the author from June to August 2000. Data collected are used here to relate the inland stratigraphy to coastal exposures. The coastal exposures also provide detailed facies and paleoflow information that could not be obtained from drill hole information sheets and very limited inland exposures. It is expected that coastal exposures will provide a 'set standard' with which inland drill holes can be compared (Figs. 3.3, 3.4) (H. L. McDonald, M.Sc. in progress).

*3.2 Stratigraphic Information*

Drill hole information is presented as isopach and isolith maps. By presenting strata delineated by marker beds in the form of isopach and isolith maps, spatial variation in thickness and facies can be examined, which may provide insight into tectonically induced subsidence.

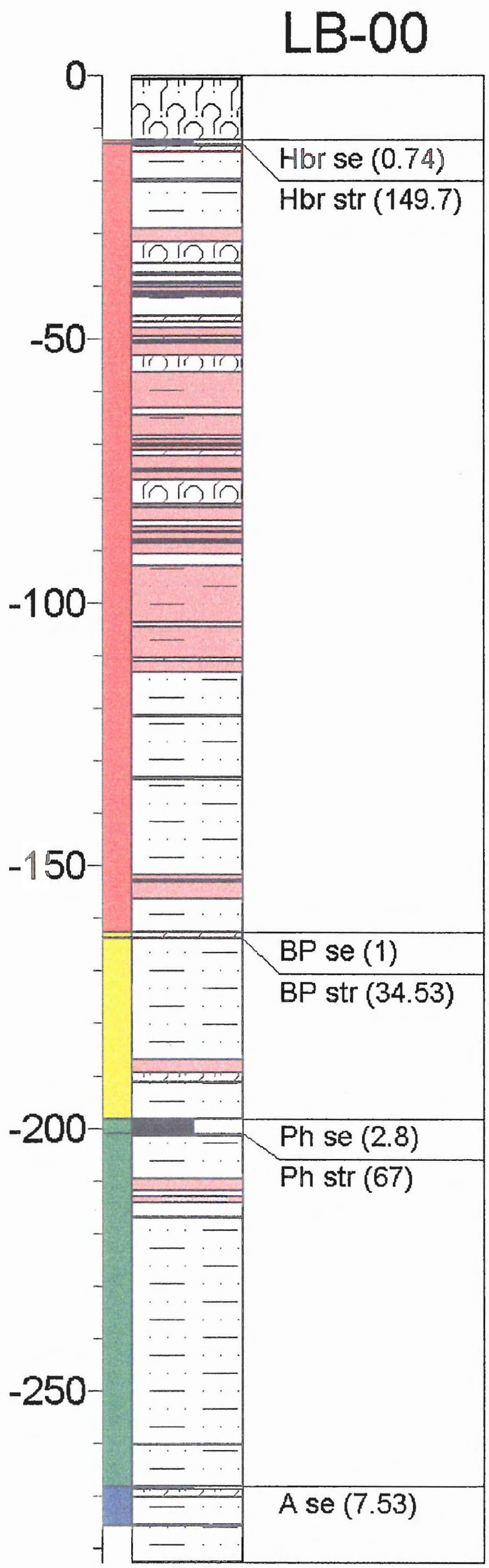



**Figure 3.3:** Stratigraphic succession of the Long Beach (LB) coastal section (Fig 1.3). Information collected from this coastal exposure provides a standard with which to compare inland 'A' and 'PM' series drill holes. Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black; concealed or non-recoverable strata represented as pattern containing question marks (?). Major coal seams are labeled as such, with stratal thickness values presented in metres. Harbour Seam (Hbr se); Backpit Seam (BP se); Phalen Seam (Ph se); Seam 'A' (A se).

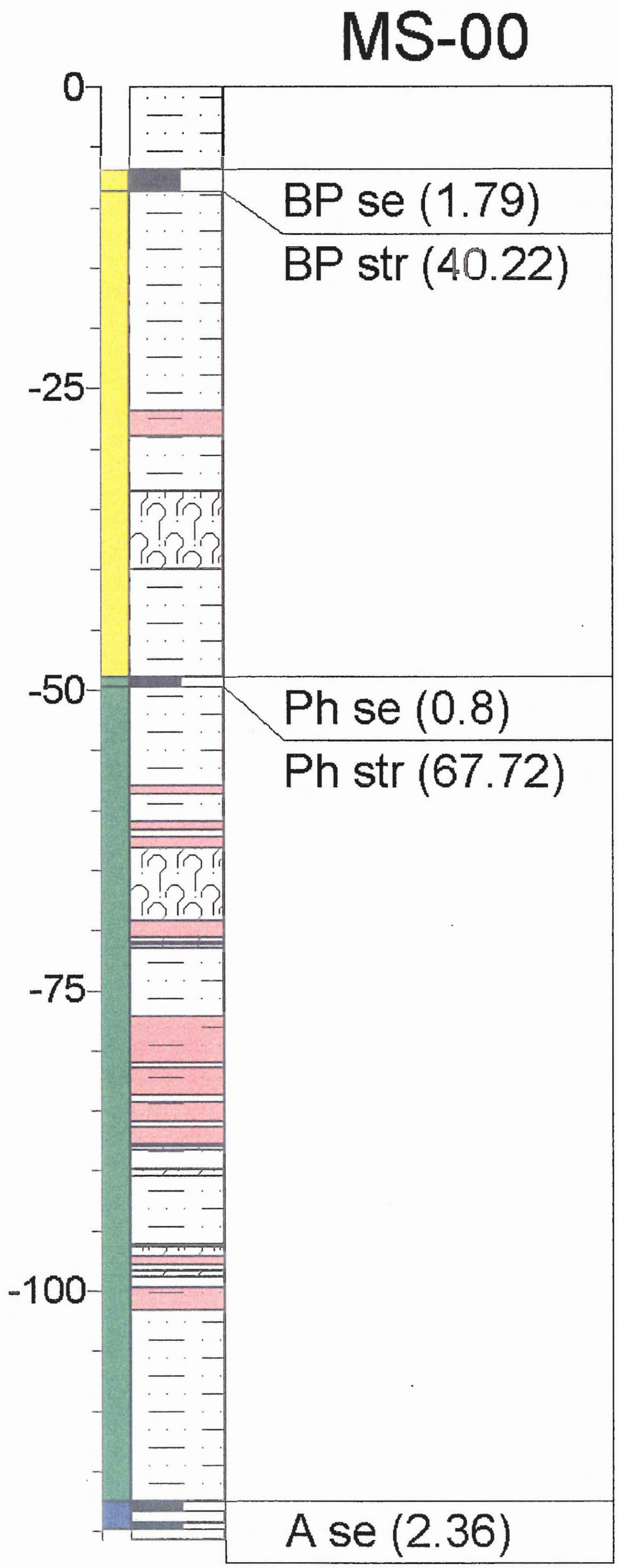



**Figure 3.4:** Stratigraphic succession of the Morien South (MS) coastal section. Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black; concealed or non-recoverable strata represented as pattern containing question marks (?). Major coal seams are labeled as such, with stratal thickness values presented in metres. Backpit Seam (BP se); Phalen Seam (Ph se); Seam 'A' (A se).

Cross section correlations have been constructed running roughly parallel and perpendicular to the Morien Syncline axis (Appendix A), using defined stratal packages (Fig. 3.5). Strata of the syncline can be subdivided in relation to extensive coal seams, and variations relating to the units as a whole can be observed (Fig. 3.6). By comparing these thickness variations with those of other stratal packages, a picture of subsurface geology arises. Isopach and isolith maps of these stratal units provide an estimate of areal thickness and facies variations. By deciphering the spatial variation in grain size, drainage patterns within the Morien Syncline may emerge, which can then be compared to paleoflow measurements from coastal sections.

By correlating drill holes along section lines perpendicular to the Morien Syncline axis, evidence of syn-depositional subsidence variation due to tectonic processes may become apparent. From earlier work (e.g. Haites, 1951), it is expected that strata will generally be thicker closer to the axis and thin with distance from the axis.

## *3.3 Analytical Methods*

### *3.3.1 Data input into computer*

The data set was processed and analyzed using *RockWorks99*, a spreadsheet-based computer program that can be used to create correlations and stratigraphic maps. Drill holes were entered in spreadsheet form, with each drill hole as a unique spreadsheet row (Appendix B). Such input values included northing, easting, surface elevation, and stratigraphic dip. The depths to the boundaries of each major coal seam were entered as computed values relative to surface elevation of each hole. As well, all measurements presented in drill hole logs were converted from imperial to metric form.

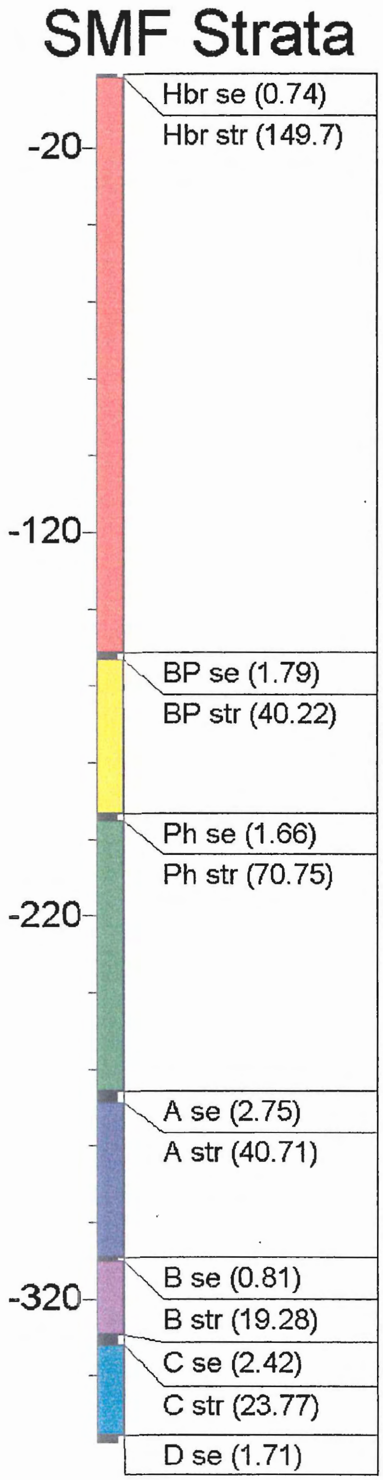



**Figure 3.5:** A composite representation of the Sydney Mines Formation (SMF) strata present in the Morien Syncline. Strata can be subdivided into six main stratal packages, each containing a seam interval and all underlying strata above the seam interval below. Stratal packages are as follows: Harbour Stratal Package (red), containing the Harbour Seam interval and underlying strata above the Backpit Seam interval; Backpit Stratal Package (yellow); Phalen Stratal Package (green); Seam 'A' Stratal Package (blue); Seam 'B' Stratal Package (purple); Seam 'C' Stratal Package (turquoise). Thickness value for Harbour Stratal Package from Long Beach coastal section; Backpit Stratal Package from Morien South coastal section; Phalen and 'A' stratal packages from drill hole A-1; 'B' and 'C' stratal packages and seam interval 'D' from drill hole A-2.

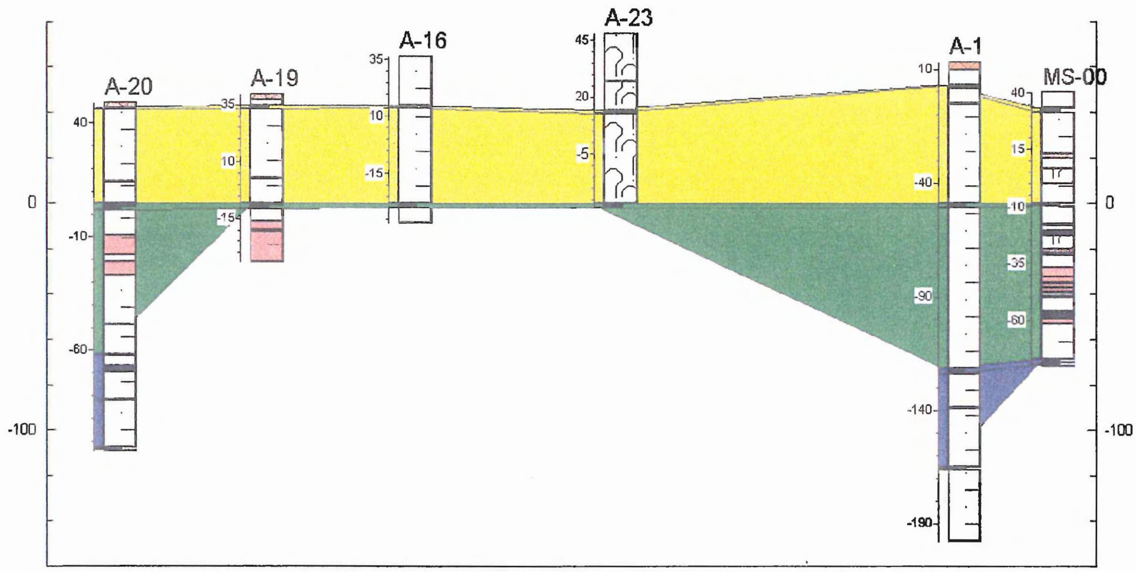



**Figure 3.6:** An example of stratal package correlation. By comparing the stratal packages that exist between coal seams, variations in overall stratal thickness become apparent. This example shows stratal thickness variation between the Backpit and the Phalen seams and runs from inland on the syncline (A-20) towards the Morien South coastal section (MS-01). Refer to Fig 3.1 for reference. Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black; concealed or non-recoverable strata represented as pattern containing question marks (?).

Strata of each unit recognized by the drillers in each drill hole were added in a separate spreadsheet (Appendix C), which was attached in file form to the main sheets. By attaching such data as separate sheets, the program was able to generate correlations and display each drill hole lithology file as components of images. Also added to main spreadsheets were thickness values for each coal seam and coal-to-coal stratal intervals. In total, approximately 78 spreadsheets were constructed and used to analyze the drill holes and coastal sections.

#### *3.3.2 Construction of maps*

Correlations and maps were generated in *RockWorks99*. *Paint Shop Pro 6.0*, *CorelDraw Version 7.0* (with *Corel Photo-Paint 7.0*), and *CorelDraw Version 8.0* (with *Corel Photo-Paint 8.0*) were used to modify figures and to add features such as scale bars and north arrows to maps. *Adobe PhotoShop 6.0* was also used for modification of some diagrams.

Establishing lithostratigraphic correlation within the Sydney Mines Formation is generally quite complex. The definition of marker beds aids correlation, assuming good marker beds are chosen. Coals were selected as marker beds for this project because they represent long time periods and are areally extensive.

### *3.4 Limitations of Data*

#### *3.4.1 Combination of lithologies*

Common to the 'A' series drill holes is the combination of lithologies, where individual lithologies are grouped together and labeled as an overall segment. For example, in many instances where 5 m of strata was drilled containing sandstone and shale, it was recorded as such, with individual stratal beds not distinguished. The resolution of non-coaly strata was not considered important during the creation of such log sheets, which were created primarily in the interest of evaluating coal seams and splits. Furthermore, mining operations were not interested in a detailed presentation of bed lithologies between coals. This summary of lithologies does not permit the interpreter to know precisely what is present, and places significant constraints on correlation of local rock units. As well, no geophysical logs are available to correct for lithological imprecision. Hence, when units are recorded as 'sst and shale', each lithology has been assigned 50% of the unit thickness for constructing sandstone abundance isolith maps. Furthermore, non-coal strata have not been distinguished in correlations unless redbeds are evident.

### *3.4.2 Facies change*

A facies change can cause one lithology to change gradually into another, and the boundary between them must be arbitrary. Sometimes facies change causes units to merge or split, causing the scheme of stratigraphic cutoffs to be even more arbitrary and complex (Prothero and Schwab, 1996). In addition, channel bodies can be of limited extent, incising through associated strata. For these reasons, no attempt was made in this study to correlate individual lithological units, apart from major coals, and correlations were restricted to stratal packages on a scale of tens of metres.

### *3.4.3 Drill hole locations*

A problem particularly with the 'A' series drill holes is establishing their locations accurately. Originally, drill hole locations were recorded in relation to local mine sites or local roads (Appendix C). For example, the location of drill hole A-9 (drilled in 1908) was originally recorded on the log sheet as '2600 ft south of No. 21

Colliery'. A second example, the location of drill hole A-37 (drilled in 1928) was originally recorded as '5000 ft south of Morien Jct. Crossing and 3000 ft east of Main Line S & L Rly, near old Wash Plant'. At a later unknown date, approximate southings and eastings for each drill hole were written on the data sheets. These coordinates were based on the CBDC company grid, and are expected to be quite reliable (D. J. MacNeil, written communication, 2000). A conversion of these coordinates to UTM (Universal Transverse Mercator) by D. J. Hughes in the 1980's was used in this study. Hughes' conversion of 'PM' series coordinates were also used in this study, and are expected to be quite reliable as well.

Nevertheless, the reliability of locations that have been converted (at least) twice at separate dates must be questioned. Evidence which supports questioning the reliability of drill hole locations is apparent by comparing locations on Map 86-1 of the Nova Scotia Department of Mines and Energy (Fig 3.7) with locations in Figure 3.1. In this example, the most extreme case of location discrepancy is presented, where Boehner and Giles (1986) show drill hole A-30 1.8 km due north of its location according to coordinates based on the CBDC company grid and the conversions completed by D. J. Hughes. Such location discrepancies hinder the validity of this study, which relies heavily on drill hole locations.

*3.4.4 Dips of beds*

An issue that could introduce errors to this study is the stratigraphic dip for each drill hole. Of the complete set of drill holes used for this study, 56% had dip measurements recorded. For other drill holes, dip had to be estimated using the closest hole(s) of known dip. Stratal thicknesses recorded on drill logs are apparent thicknesses,

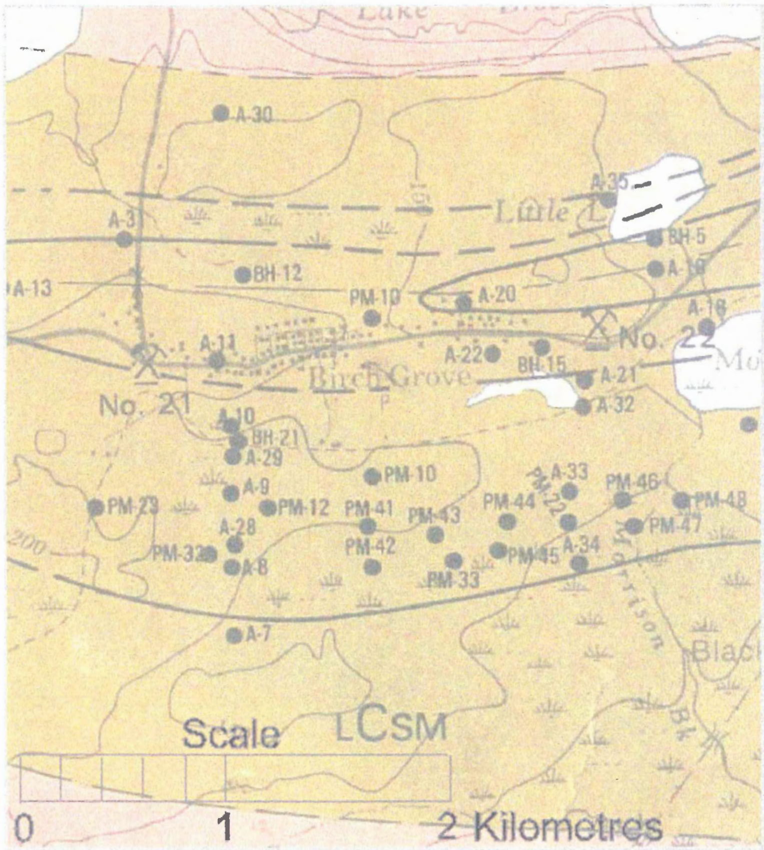



**Figure 3.7:** A portion of Map 86-1 (Boehner and Giles, 1986), showing several drill hole locations. Based on the coordinates of drill hole locations used for this study, hole A-30 should be located between holes A-9 and A-28, approximately 1.8 km due south of where it is shown. Width of diagram is 3.45 km. *LCSM* denotes Sydney Mines Formation strata.

showing true distance below surface, suitable for mine evaluation. True thickness values in this study have been calculated assuming vertical drilling unless otherwise noted. (For example, holes A-24 and A-25 both note that they were drilled with the 'hole angling 47° to horizontal, northerly direction', essentially normal to bedding in an area where dips are unusually steep.) Without accurate dip measurements, it is difficult to calculate accurate stratal thickness values. With 44% of drill holes having estimated dip values, considerable true thickness errors are possible if drill hole locations are incorrect.

A column of true thickness values was constructed for each lithological unit on the spreadsheets. Most dips recorded are less than 10°, and dip correction to this amount reduces apparent thickness by approximately 1-2%. As noted in Chapter 4, this percentage change is not enough to account for the changes of thickness noted for some stratal packages within the syncline area.

*3.4.5 Seam splits and identification*

Coal seams are good marker beds to study thickness variation of thin, successive stratal intervals because they have a wide areal extent. As well, based on the compaction rate (perhaps as much as 10x) of peat in coal formation (Haites, 1951; Gibling and Bird, 1994), small changes in coal thickness may be equivalent to originally large changes in peat thickness. If syndepositional subsidence varied locally, coal beds might be expected to be thicker along the hinge of the Morien Syncline and might decrease in thickness with distance from this axis, as suggested in Chapter 2.

For major coals on drill hole logs, drillers have usually identified the seam. Generally, the drillers knew where they were drilling in relation to the nearest coal seam, and could deduce what each subsequent seam would be, based on a standard set of major, mineable seams in the area. Many times, drillers would write two names if unable to determine which one applied. By studying the driller's picks and comparing them to outcrop traces and neighboring holes or coastal sections, it is apparent that the driller's picks are reliable in nearly all cases, and are used in this study.

*3.5 Overview of Data Quality*

Aside from the problems associated particularly with the 'A' series drill holes, they prove to be an adequate component to the data set. Of the 'A' series drill holes, almost 70% record complete stratal units from at least one coal-to-coal unit. Many contain more than one complete coal unit, and can be drawn upon for several correlations. The use of coastal sections as 'standards' sheds light into the relation between shales and sandstones in drillers' logs, and what they represent in an environmental framework. Although there are sources of error associated with the 'A' series data set, they enable correlations to be made within the Morien Syncline area to a first approximation. These correlations are suitable for evaluating substantial changes in seam and interseam thickness and facies across the area, and no attempt has been made to evaluate metre-scale variations.

# Chapter 4: DATA ANALYSIS AND RESULTS

## *4.1 Facies*

Lithologies common to the 'A' series drill holes can be grouped into facies units as described in Table 4.1. Facies interpretation below is based on Long Beach and Morien South coastal sections (H. L. McDonald, M.Sc. thesis in progress), as well as Gibling and Bird (1994) and Tandon and Gibling (1994, 1997), who studied the Sydney Mines Formation across the basin.

The Sydney Mines Formation consists of alluvial and coastal plain deposits with economic coal (Gibling and Bird, 1994). Peats formed on an extensive coastal plain during transgression and highstand of sea level (Wightman *et al*, 1993).

Several drill core facies presented in Table 4.1 represent poorly drained floodplains and bayfills with hydromorphic paleosols (Gibling and Bird, 1994; Tandon and Gibling, 1994; 1997). Coals formed as rheotrophic peats (Tandon and Gibling, 1994), and are commonly present as thin bands with shale partings. Coastal sections show rooted lithologies below seams and at many other levels, generally grey claystones and less commonly grey siltstones. Such units most likely formed as hydromorphic paleosols in poorly drained settings (Tandon and Gibling, 1997). Other grey fine-grained strata in the outcrops are platy, lacking roots, and formed in shallow standing water (bays or lakes). All these facies are grouped in drill hole descriptions as grey shale and assemblages of sandstone intermixed with grey shale (Table 4.1).

Red shales (and assemblages of sandstone and red shale intermixed) are common in the 'A' series drill holes (Table 4.1). Similar strata are observed in coastal sections to be generally rooted, with carbonate nodules locally present, and include vertic paleosols indicative of seasonal wetting and drying (Tandon and Gibling, 1997). Such facies are indicative of well-drained flood plains (Gibling and Bird, 1994). Meter-scale calcretes, which are prominent in outcrops, were not noted separately in drill hole logs.

**Table 4.1:** Facies common to the 'A' series drill holes, based on information in original drill hole logs.

| Facies | Description |
|---|---|
| **Coal** | Generally little description; distinguished as clean, split, as coal mixture, or as coal and splint, or coal with partings. Sulphur and ash content is commonly noted for larger seams. **Ex**: A-2, A-9 |
| **Shale (grey)** | Dark, grey, green, blue, broken, hard, and/or soft. Presence of fossils uncommonly noted (types of fossils not distinguished). If a unit is labeled shale with no descriptive word(s) attached, it is presumed to be grey shale. Rarely labeled as sandy. **Ex**: A-2, A-9 |
| **Shale (red)** | Dark, purple, red, reddish, chocolate red, broken, hard, and/or soft. Sometimes noted as mixed with grey shale or with bands of clay. Rarely labeled as sandy. **Ex**: A-2, A-31. |
| **Sandstone** | Broken, fine grained, very fine grained, hard, blue, green, light brown, and/or grey. Sometimes denoted to be present with bands of shale or clay. Commonly referred to as sandstone, with no descriptive word(s) attached. **Ex**: A-1, A-2, A-9. |
| **Sst/shale (grey)** | Generally no descriptive attributes attached. Sometimes denoted as sandstone and blue or grey shale. **Ex**: A-7. |
| **Sst/shale (red)** | Generally no descriptive attributes attached. Usually denoted as sandstone and red shale. **Ex**: A-7. |
| **Conglomerate** | Hard and/or grey. Associated with sandstone facies. Located above or under sandstones, or labeled as sandstone with conglomerate. **Ex**: A-1 |

Sandstones and minor conglomerates are common in all stratal packages represented in 'A' series drill holes and coastal sections. Based on coastal section analysis, sandstone and associated conglomerate facies inland most likely represent channel deposits cut through bay-fill, lacustrine, and flood plain deposits. Sandstones also represent splays or bay-fill sheet deposits (Gibling and Bird, 1994).

*4.2 Stratal Packages*

Strata of the Sydney Mines Formation within the Morien Syncline can be subdivided into stratal packages according to encompassing coal seams. Six packages have been determined within the drill holes and transects along coastal sections (Fig. 3.4).

The uppermost (Harbour) package starts at the top of the Harbour Seam and includes strata to the underlying Backpit Seam. Two 'A' series drill holes record the Harbour Seam (A-26, 27), but the complete Harbour Stratal Package is only represented in the Long Beach coastal section, where it obtains a thickness of approximately 150 m. Due to insufficient data, no interpretations are made based on the Harbour Stratal Package.

The Backpit Stratal Package begins with the Backpit Seam and continues down to the top of the Phalen Seam. The complete Backpit Stratal Package is recorded in six 'A' series drill holes (A-1, 16, 19, 20, 23, 25), and exposed within both coastal transects.

The Phalen Stratal Package extends from the top of Phalen Seam to the top of an underlying seam interval (Seam 'A') that may or may not be associated with the Emery Seam. Seam 'A' is completely penetrated in nine of the studied drill holes (A-1, 2, 12, 18, 20, 21, 25, 35, 40). The Phalen Stratal Package is also exposed along both coastal transects.

The 'A' Stratal Package begins at the top of seam interval 'A' and extends down to the top of an underlying Seam 'B'. The 'A' Stratal Package is recorded in 19 of the studied drill holes (A-1, 2, 3, 10, 12, 18, 20, 29, 30, 31, 32, 39, 40, 41; PM-7, 8, 10, 12, 14). Although not present in the Morien South coastal section, the 'A' stratal package may be present in the Long Beach coastal section, but has not yet been analyzed.

The 'B' Stratal Package begins at the top of Seam 'B' and extends down to the top of Seam 'C'. This stratal package is recorded in 12 drill holes studied (A-2, 3, 8, 12, 18, 28, 29, 31, 32, 33, 37, 39), and is stratigraphically below coastal exposures studied.

Sufficient data exist to define a lowermost 'C' Stratal Package that contains strata from the top of Seam 'C' to the top of an underlying Seam 'D'. The 'C' Stratal Package is represented in 5 drill holes studied (A-2, 8, 12, 28, 31).

The following isopach and isolith maps show the stratal packages in stratigraphic order (from base to top) and in relation to the syncline axis. The Morien Syncline axis trace is defined from inland seam mapping and coastal exposure. For the purpose of this study, syncline axis position is determined as defined by Boehner and Giles (1986).

*4.3 Seam 'D'*

Seam 'D' is represented in six drill holes used in this study (A-2, 7, 8, 12, 28, 31). A structural contour map of the upper surface of Seam 'D' shows that the seam is deeper towards the syncline axis and much shallower along the southern limb of the syncline (Fig. 4.1). This contour map also provides strong evidence in favor of seam picks and correlation.

Isopach representation of Seam 'D' (Fig. 4.2) shows thickness variation within the syncline in relation to the upper and lower bounding surfaces of Seam 'D'. This representation shows coal seam thickness variation, including the thickness of any splits present. In comparison, Figure 4.3 is an isolith representation of the total coal thickness of Seam 'D', excluding any non-coaly strata which reside between the upper and lower bounding surfaces of the seam. It is to the reader's benefit to understand the difference between these two styles of seam depiction.

Isopach representation of Seam 'D' (Fig. 4.2) suggests thickness increase towards the present-day coast at least along the southern limb. A maximum seam thickness is present in drill hole A-2 (1.7 m), which is due to a seam split. Total thickness of actual coal in the Seam 'D' interval of A-2 is 0.5 m (Fig. 4.3). In comparison, inland drill hole A-31 contains a total actual coal thickness of 0.6 m, with an absence of any split development. Comparison of Figures 4.2 and 4.3 suggests split development towards the present-day coast, and total coal diminishing inland and to the south. Lack of split, and a maximum thickness at drill hole A-31, may suggest a maximum coal thickness along the northern limb, or perhaps localized far inland.

*4.4 'C' Stratal Package ('C'SP)*

The complete 'C'SP is represented in five drill holes (Fig. 4.4). Due to the positioning of such drill holes, little could be done in the way of generating an isopach map displaying thickness variation. Drill holes A-8 and A-28 positioned inland on the southern limb suggest stratal package thickness values of 24.5 m and 18.0 m,

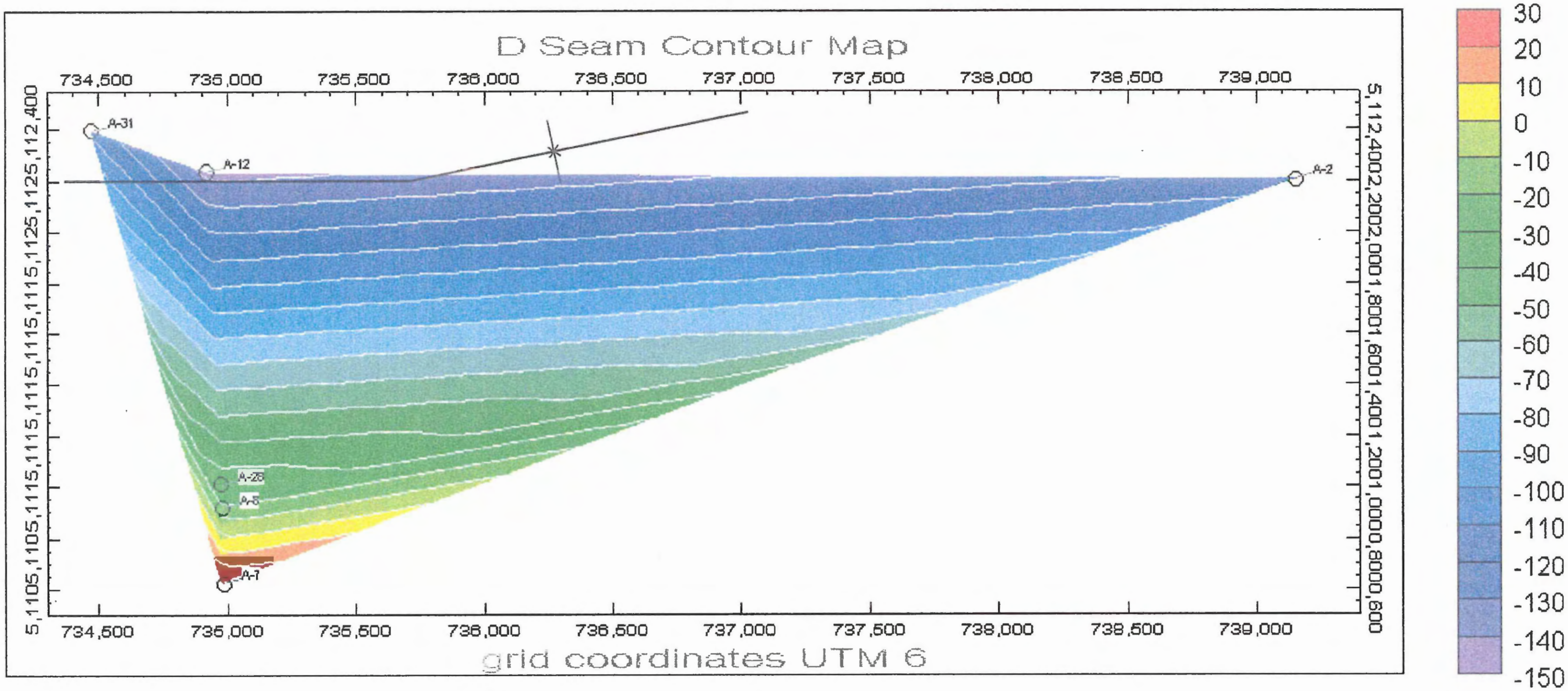



**Figure 4.1:** Structural contour map of the upper bounding surface of Seam 'D', based on available drill hole information. Scale to the right is elevation in metres, relative to sea level (0 m). Diagram shows the synform relation of Seam 'D', which is deepest near the axis trace. Diagram also provides evidence in favor of seam picks and correlation between drill holes. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

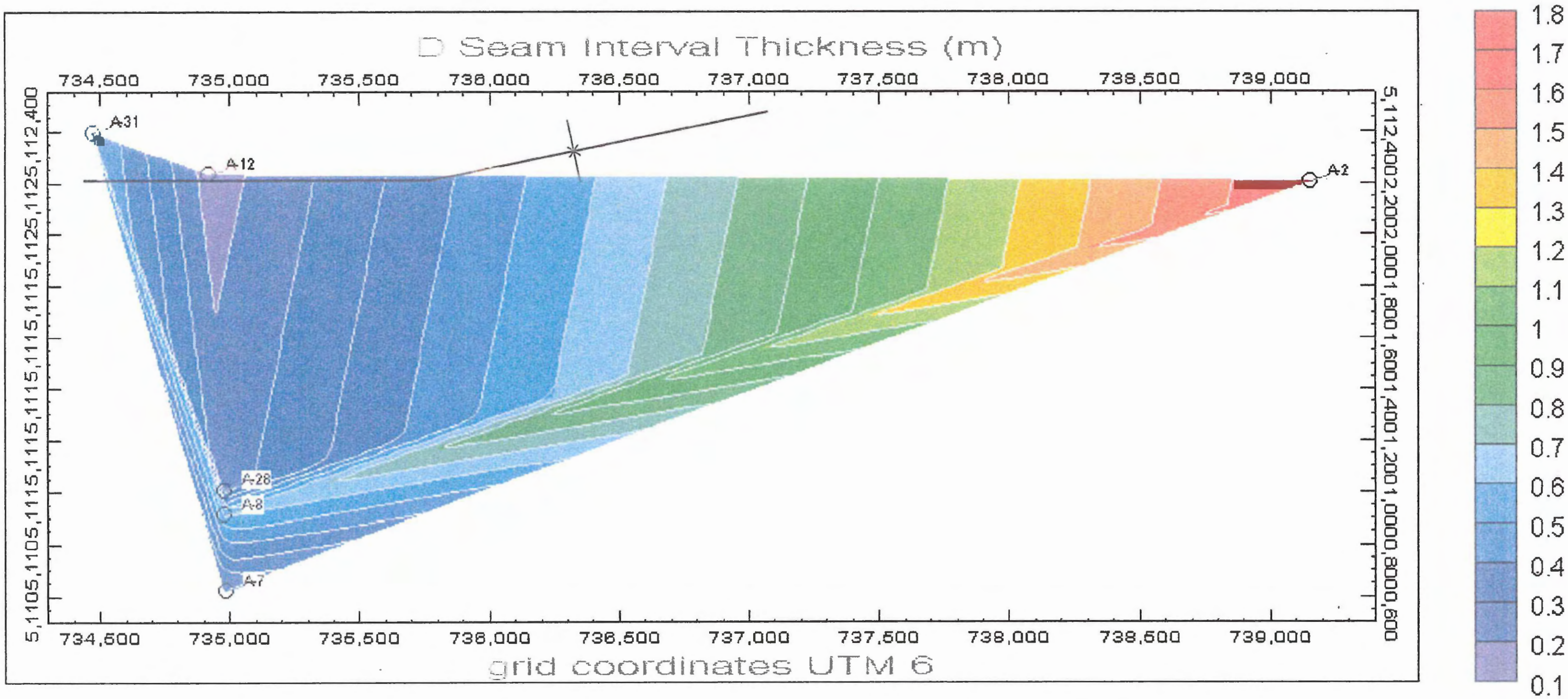



**Figure 4.2:** Isopach representation of Seam 'D' interval thickness based on available drill hole information. This diagram includes coaly and non-coaly strata between the upper and lower bounding surfaces of Seam 'D'. Extensive thickness increase in drill hole A-2 (1.7 m) is due to a Seam 'D' split, separated by over 1 m of non-coaly strata. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

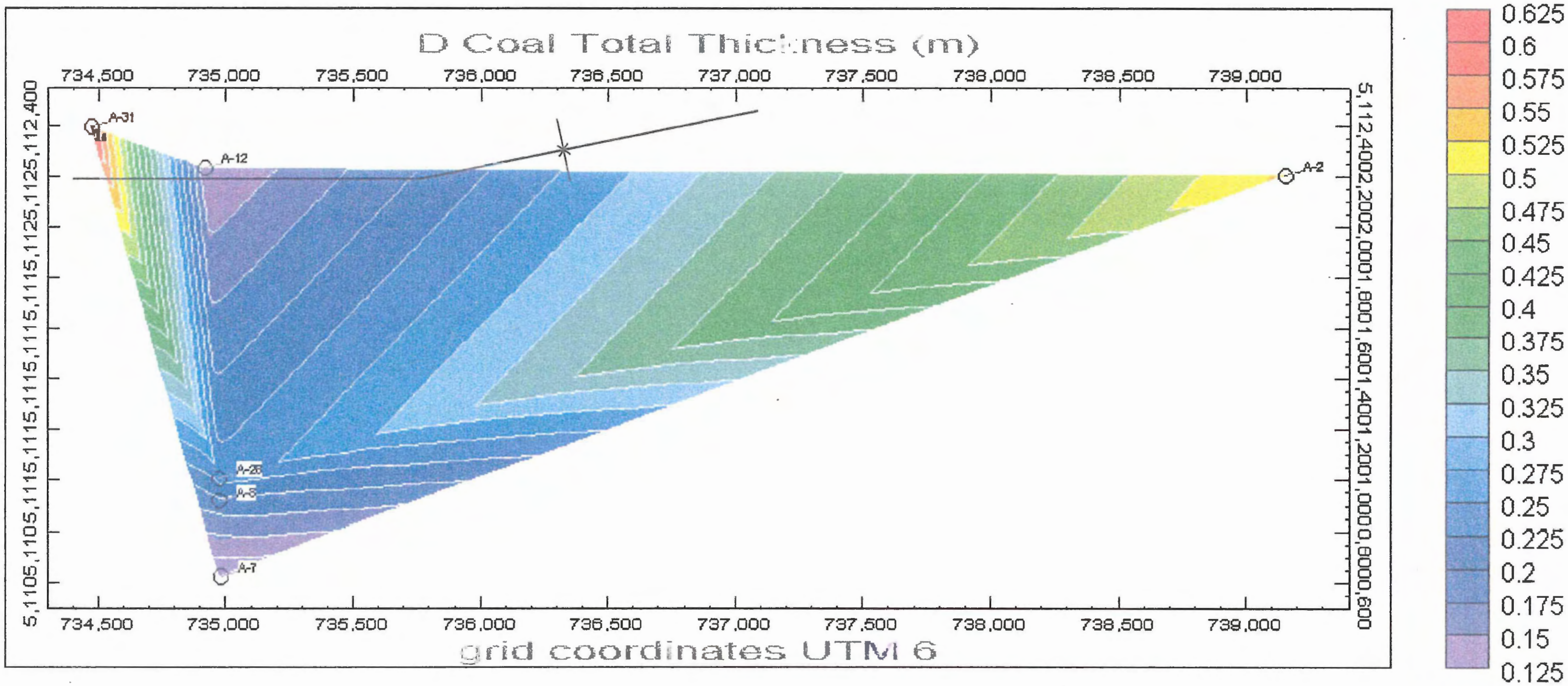



**Figure 4.3:** Isolith representation of total Seam 'D' coal thickness based on available drill hole information. This diagram is comparable to that above, except does not include thickness values for non-coaly strata present within the seam interval. Comparison of figures 4.2 and 4.3 suggests split development towards the present-day coast, and total coal diminishing towards inland and to the south. Lack of split, and a maximum thickness at drill hole A-31 may suggest a maximum coal thickness along the northern limb, or perhaps localized far inland. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

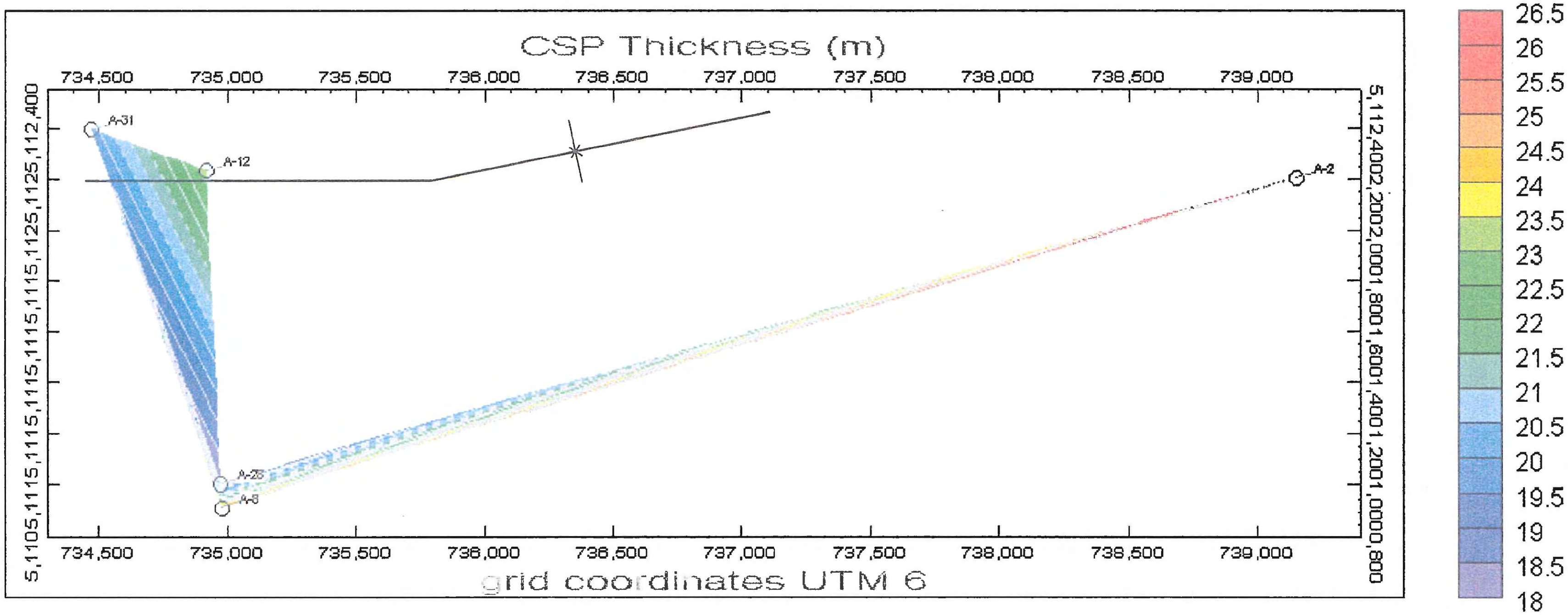



**Figure 4.4:** Isopach representation of 'C'SP thickness variation based on available drill hole information. Drill holes A-8 (24.5 m) and A-28 (18.0 m) positioned inland on the southern limb may suggest thickness increase towards the southern limb, but this is uncertain. Inland values north of the axis may suggest increase towards the syncline axis. A thickness maximum of 26.2 m is present in drill hole A-2, located towards the present-day coast on the southern limb of the syncline. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

respectively, for that area. The strong contrast in these thickness values between A-8 and A-28 may suggest thickness increase towards the southern limb over a short distance, but this is uncertain. Inland values north of the axis may suggest increase towards the syncline axis, or a decrease far inland, going from 19.8 m (A-31) to 23.3 m (A-12) in just over 0.5 km. A thickness maximum of 26.2 m is present in drill hole A-2, located towards the present-day coast on the southern limb of the syncline. The five thickness values for the 'C'SP suggest an average stratal package thickness of approximately 23 m.

Sandstone abundance may vary spatially within the 'C'SP (Fig. 4.5). Sandstone abundance is highest in the vicinity of A-31 (72%), and appears to be higher inland and to the north, overall. A sandstone abundance minimum is recorded by drill hole A-2 (11%), which may be indicative of low sandstone abundance towards the present-day coast, but insufficient evidence exists to support this inference. Abundance values ranging from 25-35% are present inland on the southern limb.

Data relating to redbed abundance within the 'C'SP are rare (Fig. 4.6). Drill hole information suggests that 30% of the strata of the 'C'SP in drill hole A-28 contains redbeds. Of the five drill holes which recorded the 'C'SP, no others showed evidence of redbed development, which could be indicative of totally grey, hydromorphic conditions, depending on the reliability of drilling records. Certainly, it is evident that strata containing redbeds are present inland on the southern limb.

*4.5 Seam 'C'*

Seam 'C' is represented in 12 drill holes used in this study (A-2, 3, 8, 12, 18, 28, 29, 31, 32, 33, 37, 39). A structural contour map of the upper surface of Seam 'C'

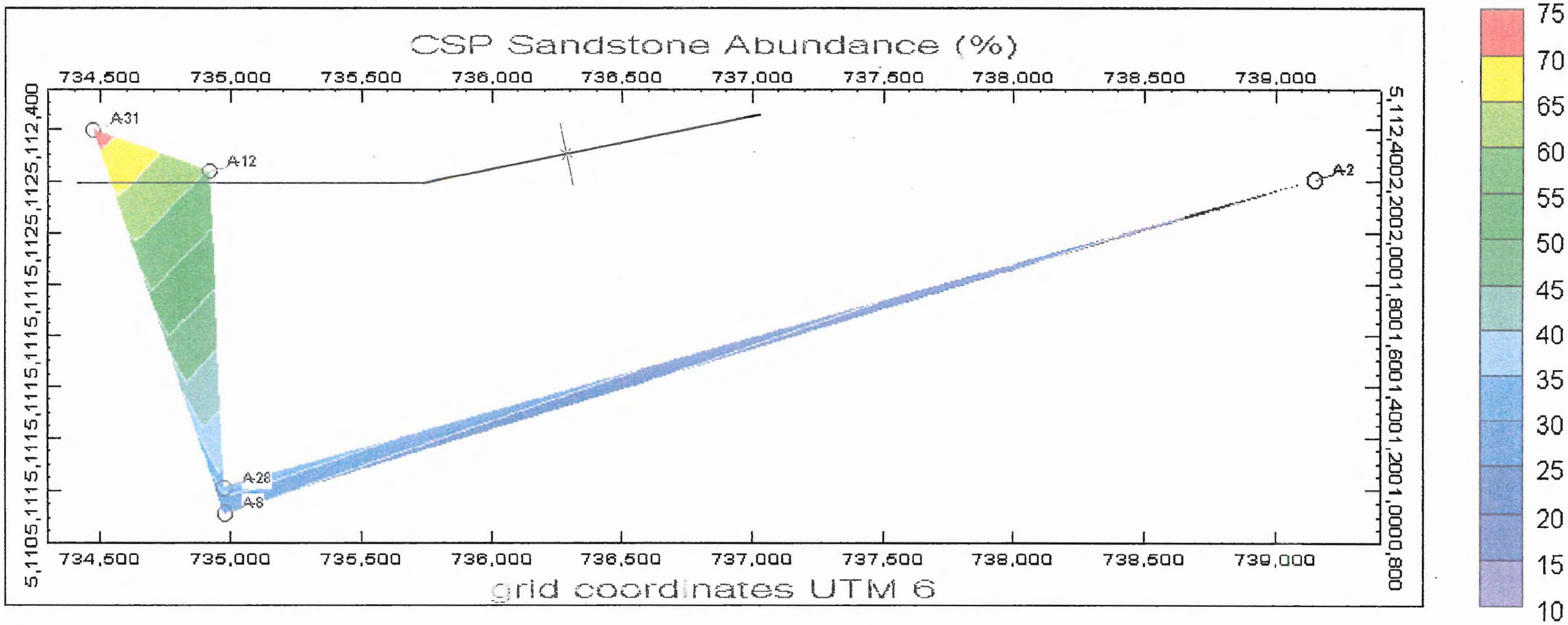



**Figure 4.5:** Isolith representation of sandstone abundance variation within the 'C'SP based on available drill hole information. Sandstone abundance is highest in the vicinity of A-31 (72%), and appears to be higher inland and to the north, overall. A sandstone abundance minimum is recorded by drill hole A-2 (11%), which may be indicative of low sandstone abundance towards the present-day coast. Abundance values ranging from 25-35% are present on the southern limb, inland. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

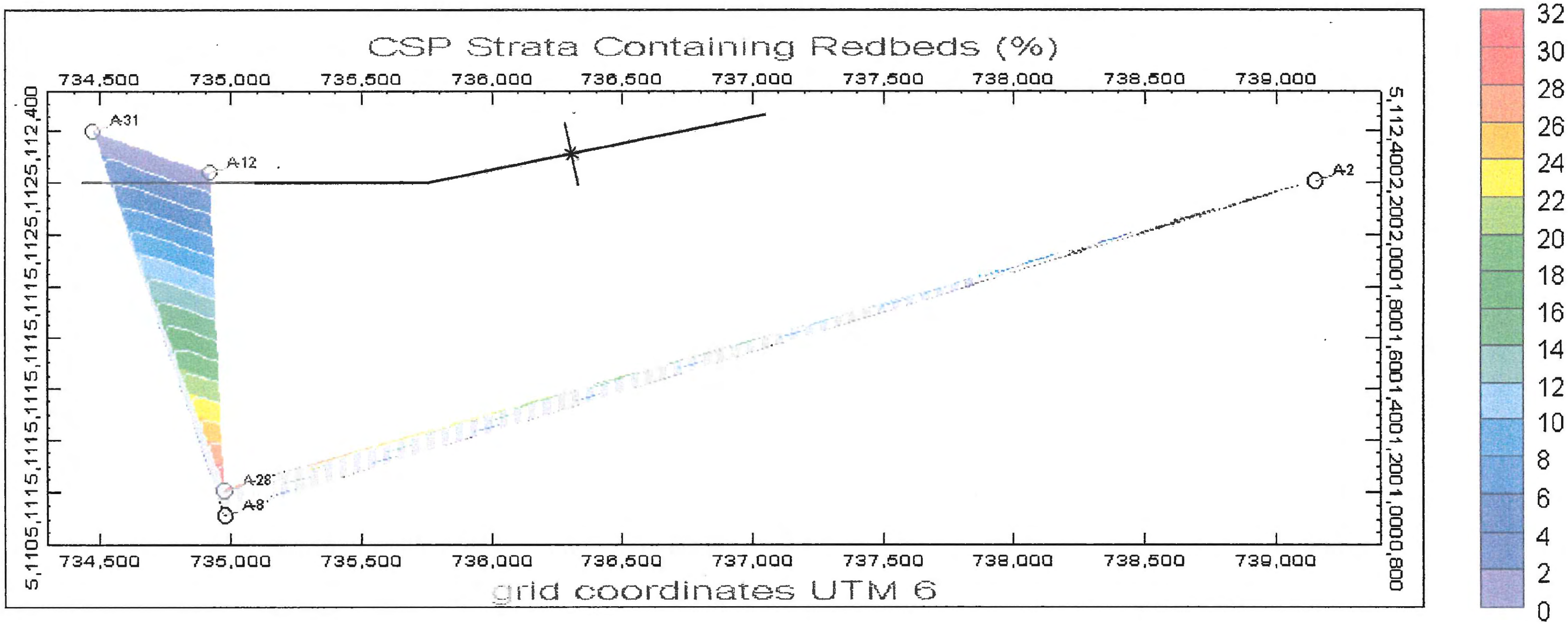



**Figure 4.6:** Isolith representation of strata containing redbeds within the 'C'SP based on available drill hole information. Drill hole information suggests that 30% of the strata of the 'C'SP in drill hole A-28 may contain redbeds. Of the 5 drill holes which recorded the 'C'SP, no others showed evidence of redbed development. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

shows that the seam is much deeper towards the syncline axis and shallower along the southern limb of the syncline (Fig. 4.7).

Seam 'C' interval thickness roughly mirrors patterns evident in the 'C'SP (Fig. 4.8). Seam interval thickness decreases inland and is higher locally on the southern limb of the syncline, approximately 2 km from the coast, where a split occurs. Not much information exists for the northern limb of the syncline; the pattern visible along the southern limb may or may not be mirrored to the north. The most inland drill holes suggest seam interval thinning from the syncline axis to the southern limb.

Total coal thickness of Seam 'C' appears to be maximal inland along the syncline axis (Fig. 4.9). This trend is displayed relatively well in isolith form, where a total coal thickness maximum is displayed in drill hole A-12 (1.2 m), where no seam splitting is evident. Drill hole A-18 (0.7 m) also has a relatively high total coal thickness and is located relatively close to the syncline axis, east of drill hole A-12. Due to the positioning of this series of drill holes, no information exists relating to the area close to the present-day coast and very little information is known relating to the northern limb.

*4.6 'B' Stratal Package ('B'SP)*

The complete 'B'SP is represented in 12 drill holes (A-2, 3, 8, 12, 18, 28, 29, 31, 32, 33, 37, 39). The isopach map for 'B'SP thickness variation shows evidence of stratal thickening inland and on the southern limb of the Morien Syncline (Fig. 4.10). Maximum stratal thickness occurs at drill holes A-33 (27.6 m), A-28 (27.4 m) and A-8 (27.3 m), all located inland on the southern limb. As with the underlying Seam 'C', very little information exists relating to the northern limb of the syncline, particularly towards the present-day coast. Drill holes A-12 (23.9 m) and A-31 (24.9 m) may suggest

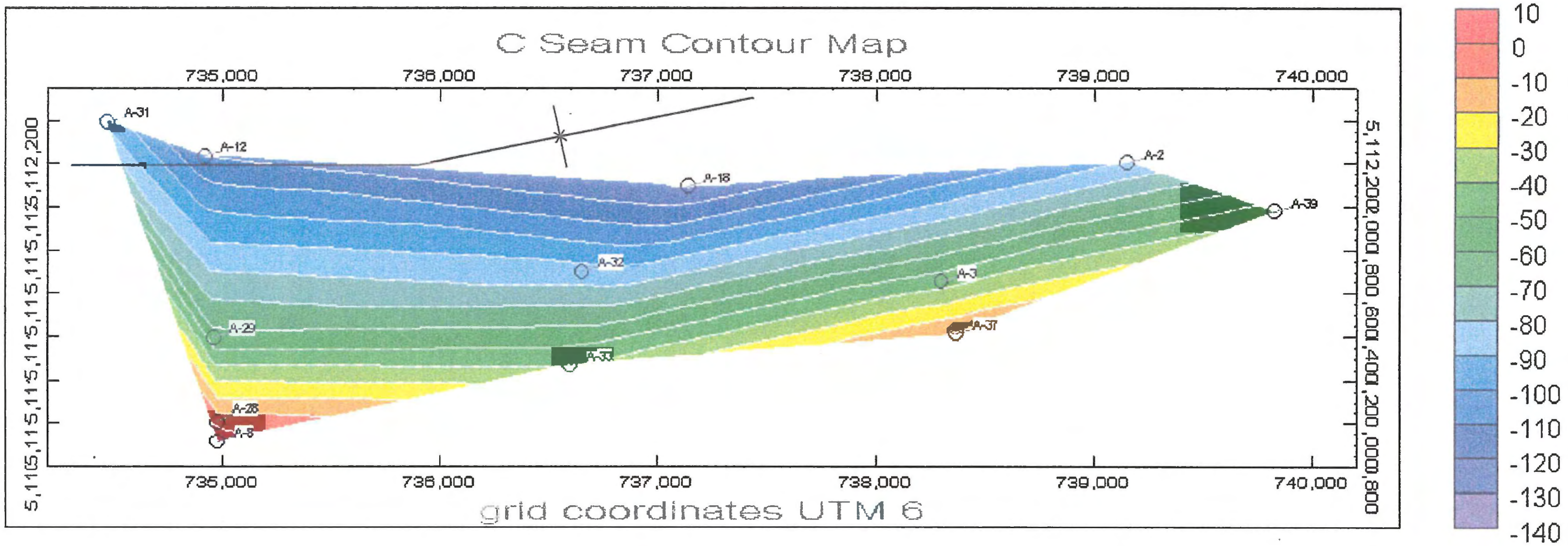



**Figure 4.7:** Structural contour map of the upper bounding surface of Seam 'C' based on available drill hole information. Scale to the right is elevation in metres, relative to sea level (0 m). Diagram shows the synform relation of Seam 'C', which is deepest near the axis trace. Computer-simulated correlation between inland drill holes A-29 (-57 m) and A-31 (-93 m) is most likely not accurate, as it is expected that depth should increase slightly in conjunction with the axis trace. A more accurate elevation along the axis would be comparable to that of drill hole A-12 (-120 m). Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

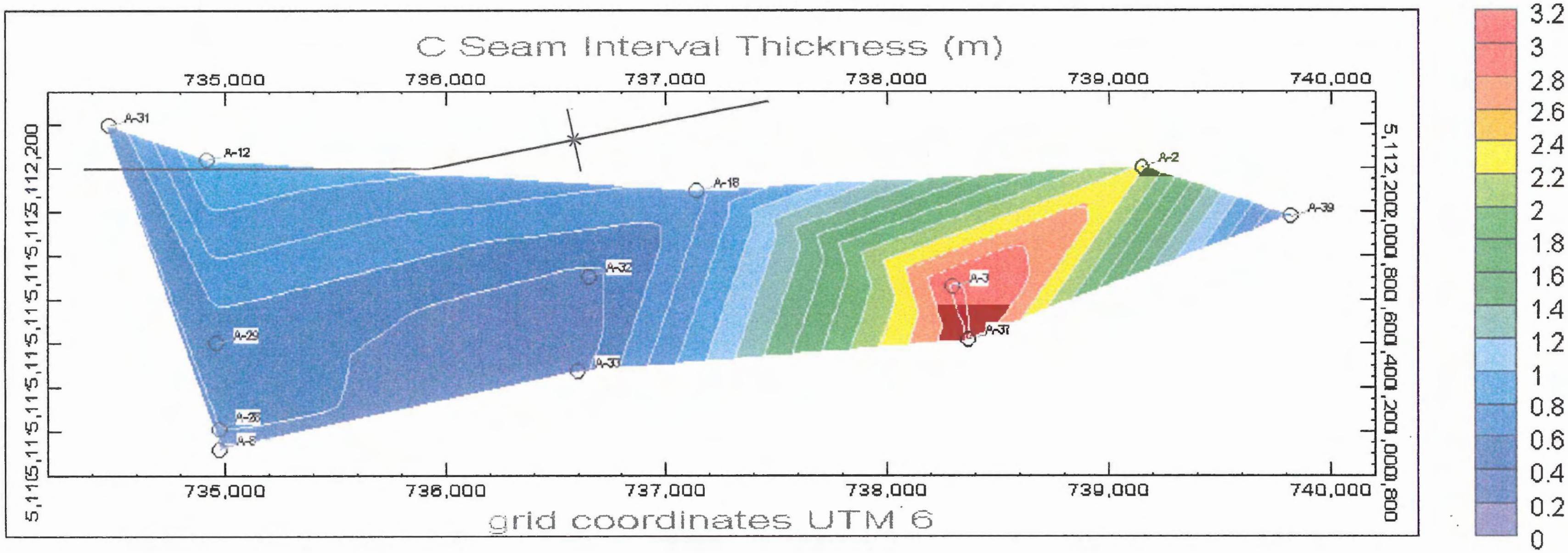



**Figure 4.8:** Isopach representation of Seam 'C' interval thickness based on available drill hole information. This diagram includes coaly and non-coaly strata between the upper and lower bounding surfaces of Seam 'C'. Seam interval thickness decreases inland and is higher locally on the southern limb of the syncline, approximately 2 km from the coast, due to a split. The pattern visible along the southern limb may or may not be mirrored to the north. The most inland drill holes suggest seam interval thinning from the syncline axis to the southern limb. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

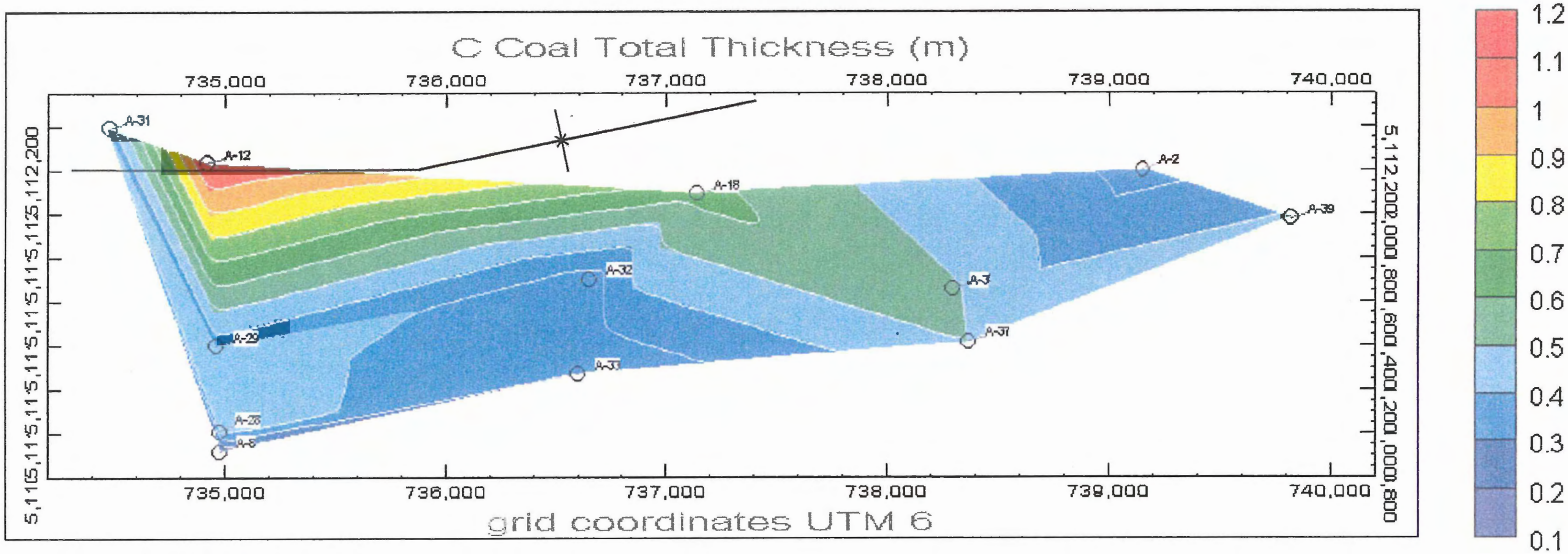



**Figure 4.9:** Isolith representation of total Seam 'C' coal thickness based on available drill hole information. This diagram is comparable to that above, except does not include thickness values for non-coaly strata present within the seam interval. Total coal thickness of Seam 'C' appears to be maximum inland in proximity to the syncline axis. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

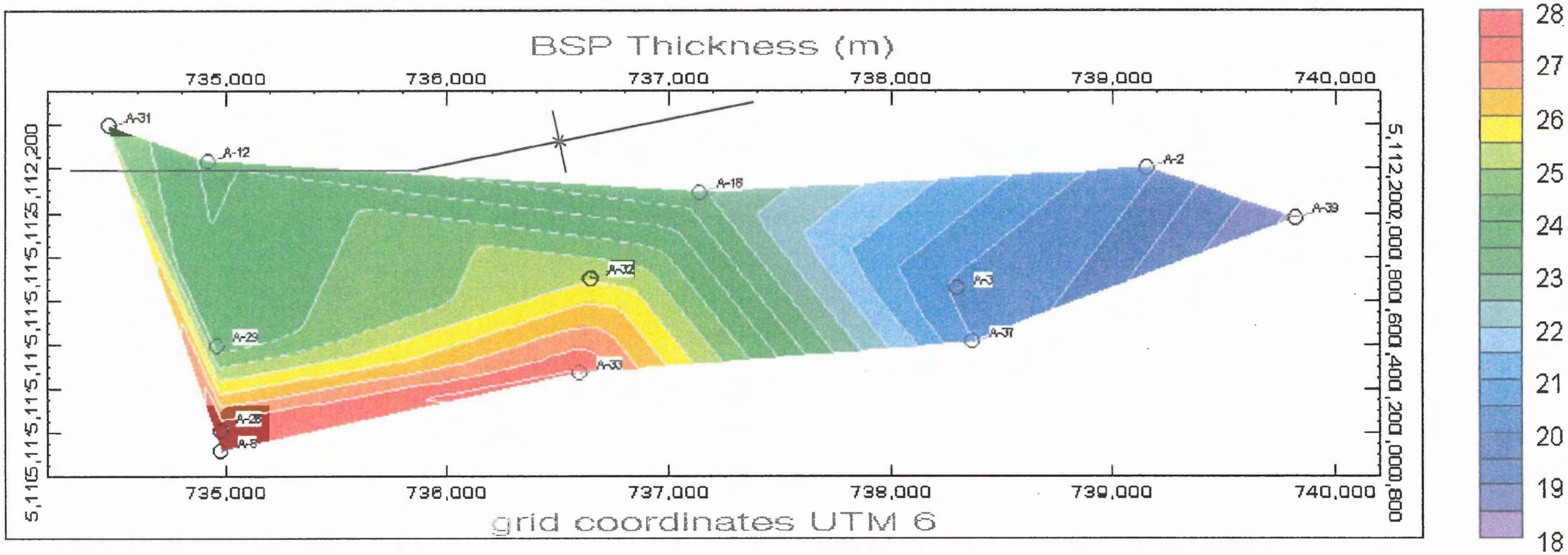



**Figure 4.10:** Isopach representation of 'B'SP thickness variation based on available drill hole information. Stratal thickening inland and on the southern limb of the Morien Syncline is evident. Very little information exists relating to the northern limb of the syncline, particularly towards the present-day coast. Drill holes A-12 (23.9 m) and A-31 (24.9 m) may or may not suggest thickness increase away from the present-day coast along the northern limb. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

thickness increase away from the present-day coast along the northern limb, however not enough data exist for firm findings relating to this region of the study area at this stratigraphic depth.

Sandstone abundance within the 'B'SP varies within the Morien Syncline (Fig. 4.11). Sandstone abundance trends relating to the 'B'SP may suggest a high sandstone concentration along the southern limb of the syncline, increasing towards the present-day coast. Maximum abundance values are evident around A-29 (30%), A-18 (29%), A-3 (35%), and A-2 (29%). Due to an absence of data relating to the coastward area and northern limb of the syncline, it is difficult to interpret abundance variation relating to that area. However, Figure 4.11 suggests that sandstone abundance is most likely concentrated along the southern limb of the syncline, possibly increasing towards the present-day coast.

Strata containing redbeds within the 'B'SP broadly mirror sandstone abundance in distribution. Figure 4.12 suggests that strata containing redbeds may be focused along the southern limb of the syncline, with maximum values attained at drill holes A-8 (38%), A-33 (21%), A-18 (26%), and A-3 (28%). Trends present in Figure 4.12 may suggest an increase in redbeds towards the present-day coast, however insufficient data coastward and to the north exist to make any firm decisions.

*4.7 Seam 'B'*

A structural contour map of the upper surface of Seam 'B' shows a synformal pattern, suggesting that seam correlation between drill holes is accurate (Fig. 4.13). As is evident, Seam 'B' increases in depth towards the syncline axis and is shallow along the southern limb of the syncline. Seam 'B' is represented in 39 drill holes used in

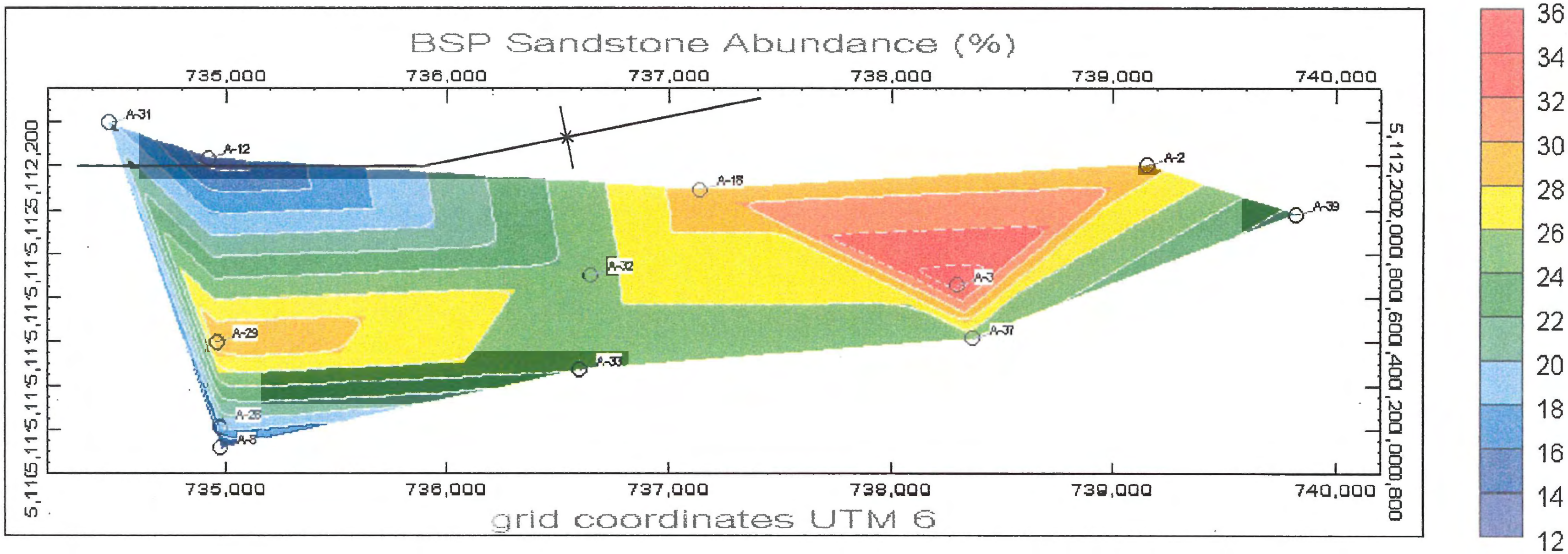



**Figure 4.11:** Isolith representation of sandstone abundance variation within the 'B'SP based on available drill hole information. Trends may suggest an increase in sandstone concentration along the southern limb of the syncline, increasing towards the present-day coast. Due to an absence of data relating to the coastward area and northern limb of the syncline, it is difficult to interpret abundance variation relating to that area. This diagram suggests that sandstone abundance is most likely concentrated along the southern limb of the syncline, possibly increasing towards the present-day coast. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

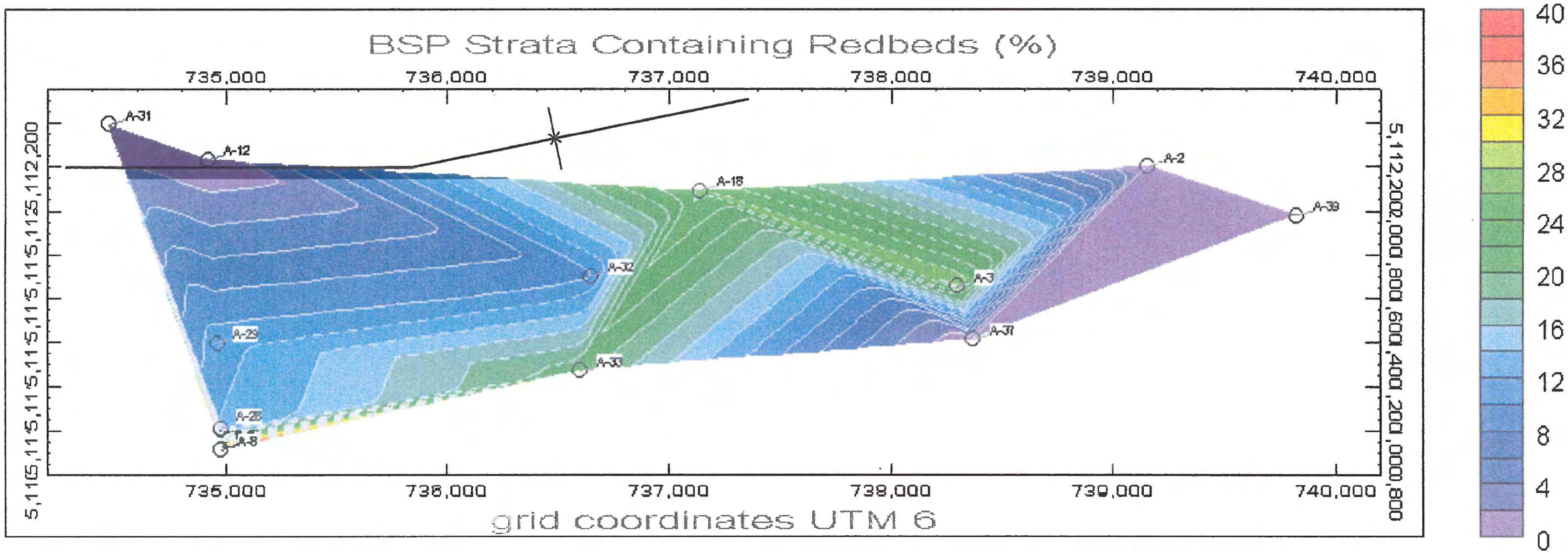



**Figure 4.12:** Isolith representation of strata containing redbeds within the 'B'SP based on available drill hole information. Strata containing redbeds within 'B'SP may roughly mirror sandstone abundance in distribution. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

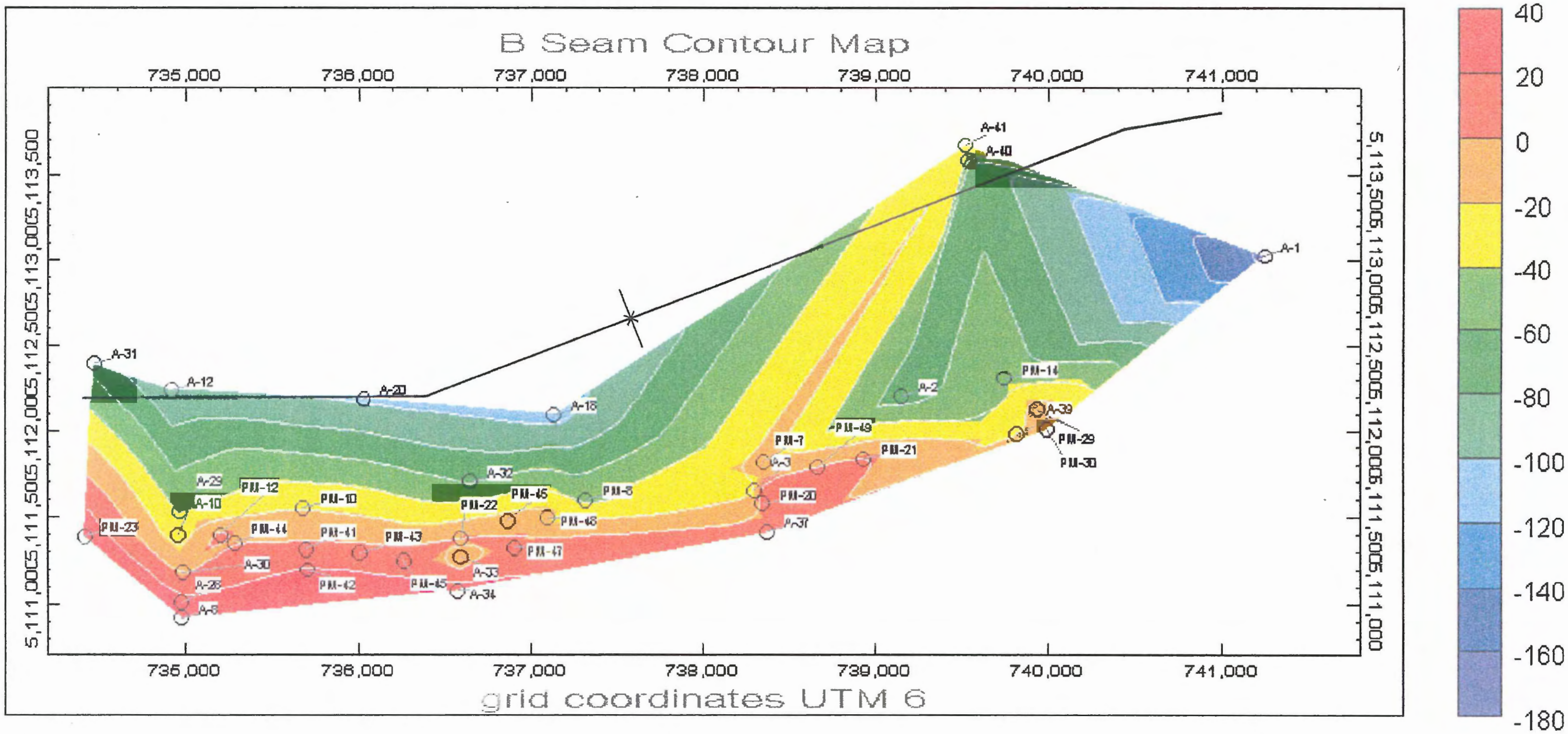



**Figure 4.13:** Structural contour map of the top of Seam 'B' based on available drill hole information. Scale to the right is elevation in metres, relative to sea level (0 m). Diagram shows the synform relation of Seam 'B', which is deepest near the axis trace. Computer-simulated correlation between drill holes PM-7 (-15m) and A-41 (-21m) is most likely not accurate, as it is expected that depth should increase slightly in conjunction with the axis trace. A more accurate elevation along the axis may be comparable to that of drill holes A-18 (-107m) or A-20 (-103 m). Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

this study (A-1, 2, 3, 8, 10, 12, 18, 20, 28, 29, 30, 31, 32, 33, 34, 37, 39, 40, 41; PM-7, 8, 10, 12, 14, 20, 21, 22, 23, 29, 30, 41, 42, 43, 44, 45, 46, 47, 48, 49), most of which are located along the southern limb of the Morien Syncline. In the case of drill hole PM-14, a Seam 'B' thickness of 0.2 m was recorded. Because this value is well below the average thickness, it was assumed to be in error and was not included in the data set.

Seam 'B' interval (Fig. 4.14) is on average, just under 1 m in thickness along the southern limb of the Morien Syncline. Inland along the southern limb, a seam split occurs, which is focused around drill holes A-8, 28, 30, PM-12, and A-10. Overall, Seam 'B' interval thickness appears very consistent within the syncline, aside from the mentioned split.

Total coal thickness in Seam 'B' is quite consistent as well (Fig. 4.15), averaging approximately 0.87 m. A slight increase of 0.5 m in total coal thickness occurs inland. Based on the trend apparent in Figure 4.15, total coal thickness may increase slightly away from the syncline axis, although very little data exists to support this inference, as most holes are focused on the southern limb.

*4.8 'A' Stratal Package ('A'SP)*

The complete 'A'SP is represented in 19 drill holes (A-1, 2, 3, 10, 12, 18, 20, 29, 30, 31, 32, 39, 40, 41; PM-7, 8, 10, 12, 14). Due to abnormal thickness values, drill hole PM-7 was not used in 'A'SP thickness isopach representation.

A thickness high located at drill hole PM-8 (53.5 m) may indicate an 'A'SP thickness increase focused on the southern limb (Fig. 4.16). Isopach representation suggests relatively low thickness values towards the present-day coast, and far inland to

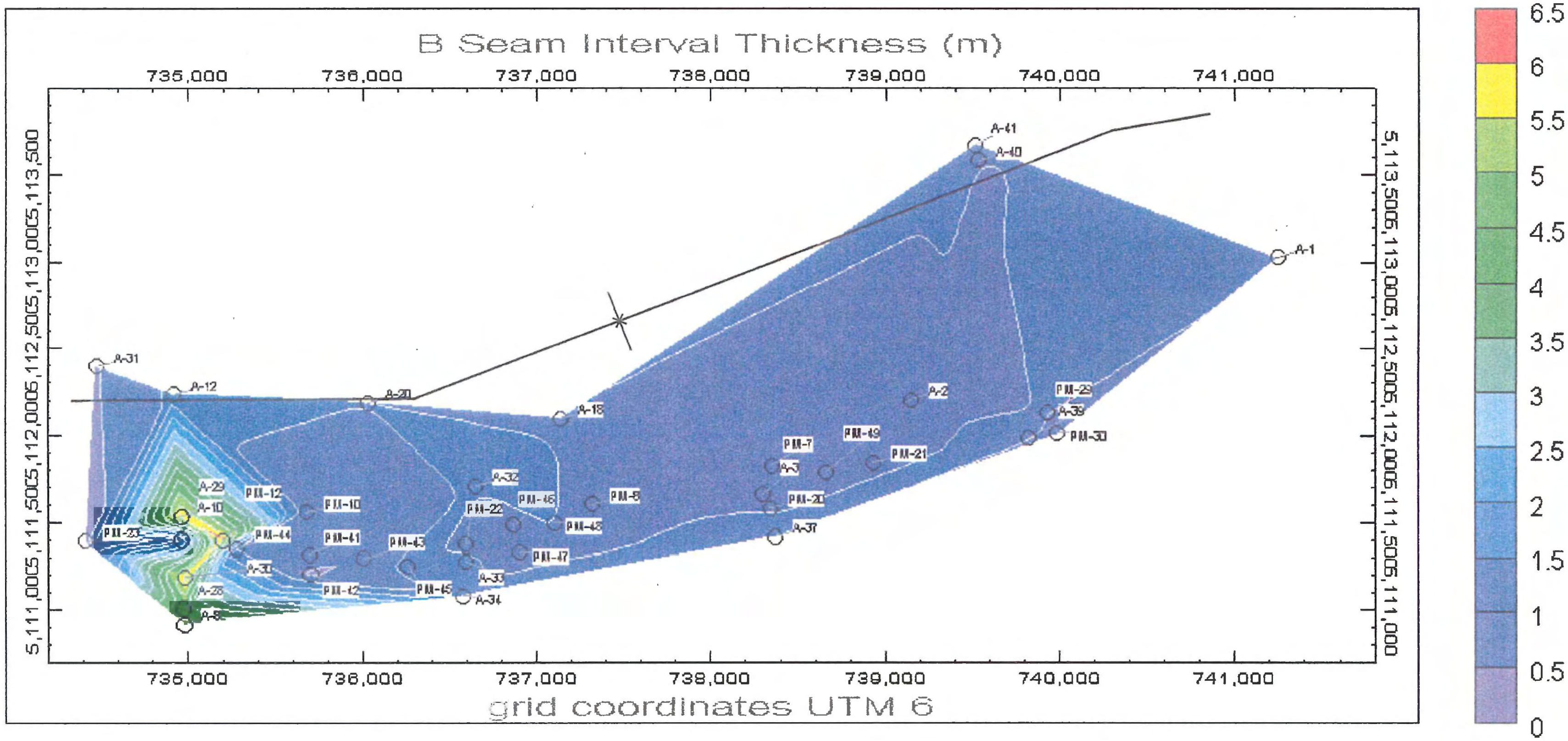



**Figure 4.14:** Isopach representation of Seam 'B' interval thickness based on available drill hole information. This diagram includes coaly and non-coaly strata between the upper and lower bounding surfaces of Seam 'B'. A seam split occurs inland along the southern limb, however, Seam 'B' interval thickness appears otherwise very consistent within the syncline. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

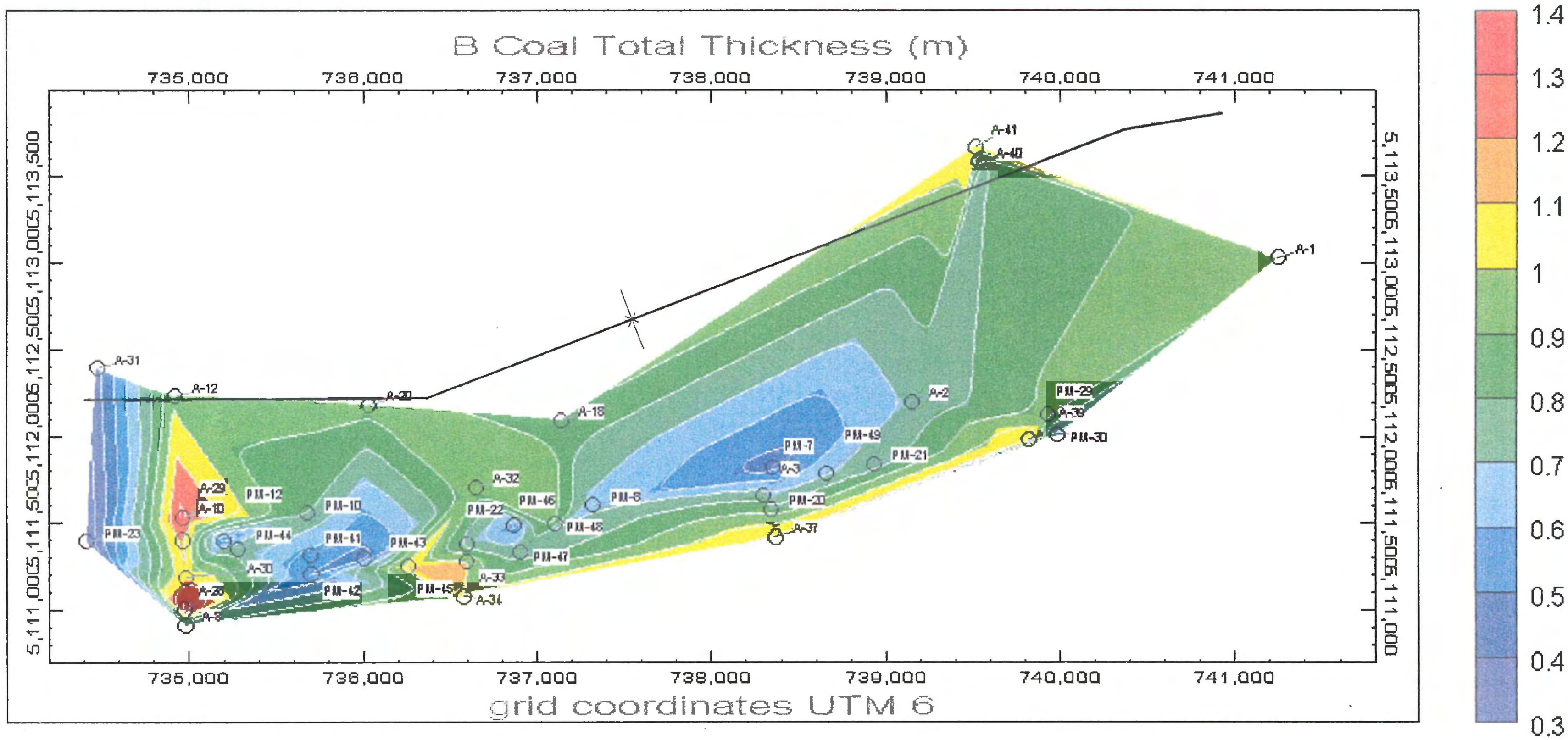



**Figure 4.15:** Isolith representation of total Seam 'B' coal thickness based on available drill hole information. This diagram does not include thickness values for non-coaly strata present within the seam interval. Total coal thickness in Seam 'B' is quite consistent, averaging approximately 0.87 m with a slight increase of 0.5 m in total coal thickness occurring inland. Total coal thickness may slightly increase away from the syncline axis, although very little data exists in support. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

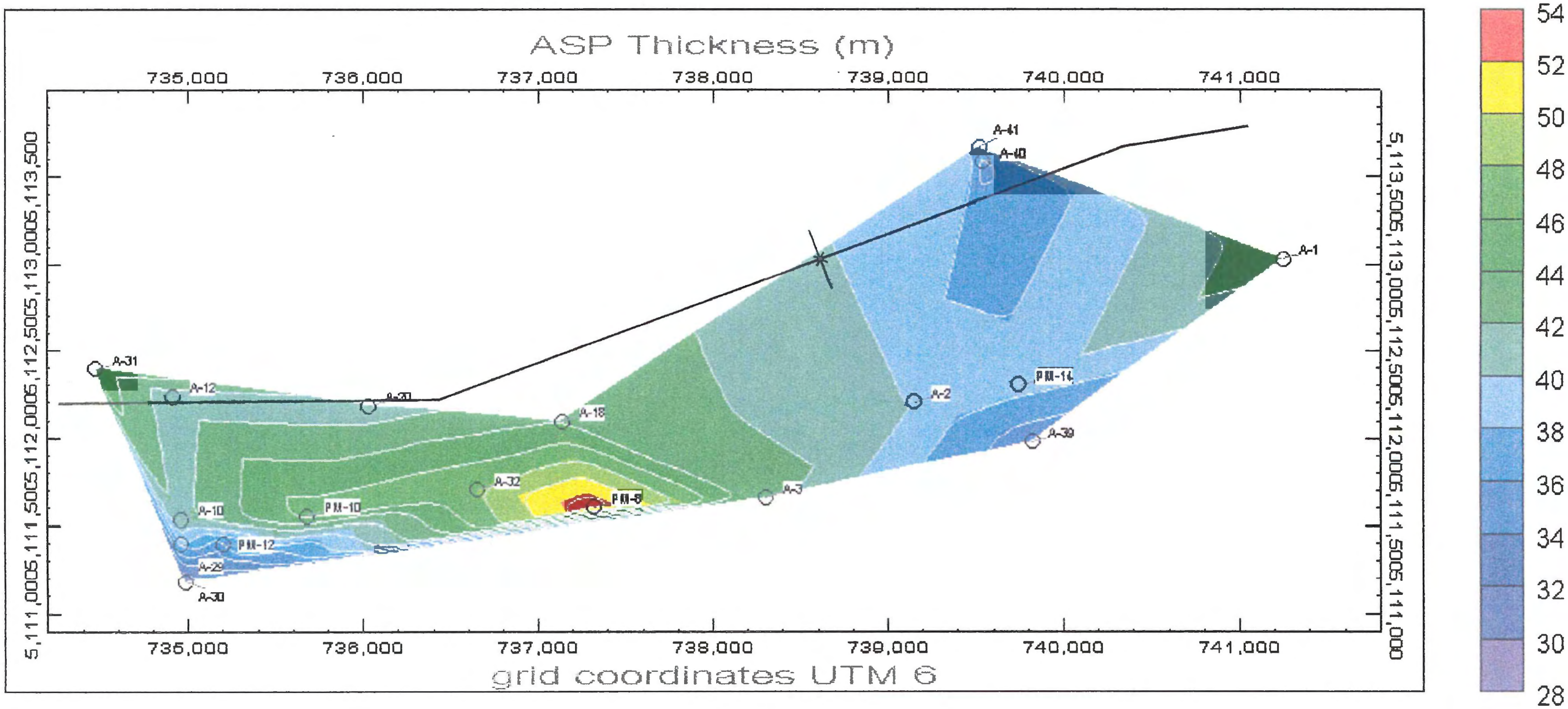



**Figure 4.16:** Isopach representation of 'A'SP thickness variation based on available drill hole information. Stratal package thickness appears to be greater on the southern limb. Generally, thickness appears to increase inland, with a maximum thickness attained south of the syncline axis. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

the south. Generally, thickness appears to increase inland, with a maximum thickness attained south of the syncline axis.

Sandstone abundance values within the 'A'SP do not lead to any discernible trends (Fig. 4.17). Inland, trends are masked by extreme sandstone abundance in drill hole A-12 (77%), which may or may not be an accurate representation. Figure 4.17 suggests that sandstone abundance is relatively high on the northern limb of the syncline. On the southern limb, sandstone abundance may be more variable. Coastward, although very few data exist, it seems as if sandstone abundance may be increasing. An established decrease in sandstone abundance is also noted far inland on the southern limb.

Three drill holes used in this study exhibit strata contain redbeds (Fig. 4.18). A-2 (47%) exhibits a relatively large lithologic unit that records evidence of redbeds, according to loggers. Drill holes A-32 (5%) and A-40 (6%) show evidence of redbed strata as well, acknowledging that strata containing redbeds may exist on both limbs of the syncline. All other drill hole logs lack any information which suggests the presence of strata containing redbeds within the 'A'SP. It is expected that only a very small portion of the lithological unit of drill hole A-2 is composed of actual redbed strata; Figure 4.18 suggests that redbeds are present within the 'A'SP, although in small quantities.

*4.9 Seam 'A'*

Confidence in Seam 'A' correlation between drill holes can be established by considering Figure 4.19, which shows the uppermost bounding surface at a shallow elevation along the southern limb of the syncline and gradually becoming deeper towards

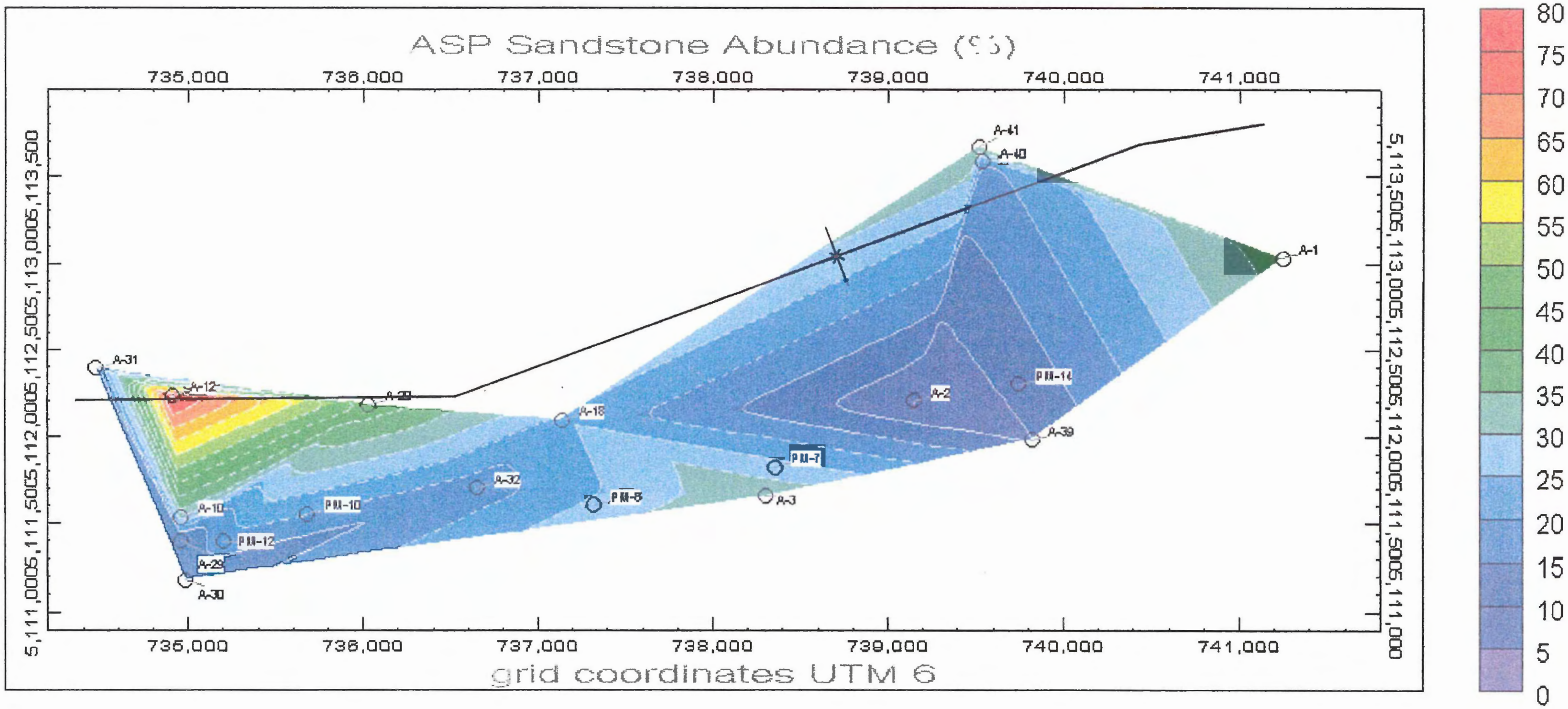



**Figure 4.17:** Isolith representation of sandstone abundance variation within the 'A'SP based on available drill hole information. Inland trends are masked by extreme sandstone abundance in drill hole A-12 (77 %), which may not be an accurate representation. Sandstone abundance appears relatively high on the northern limb of the syncline and variable to the south. An established decrease in sandstone abundance is noted far inland on the southern limb. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

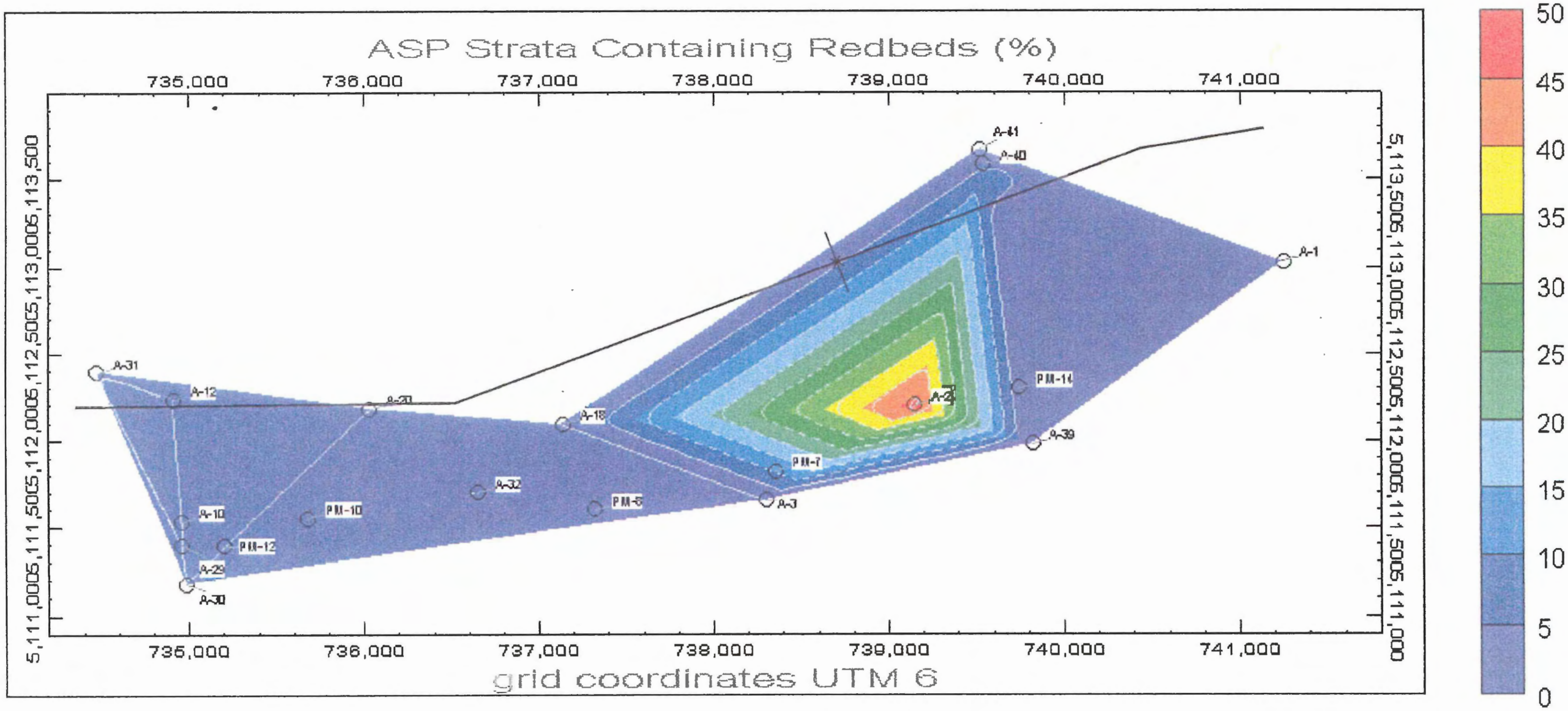



**Figure 4.18:** Isolith representation of strata containing redbeds within the 'A'SP based on available drill hole information. A-2 (47 %) exhibits a large lithologic unit that records evidence of redbeds, according to log sheets. Drill holes A-32 (5 %) and A-40 (6 %) show evidence of redbed strata as well, acknowledging that strata containing redbeds may exist on both limbs of the syncline. All other drill hole logs lack any information which suggests the presence of strata containing redbeds within the 'A'SP. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

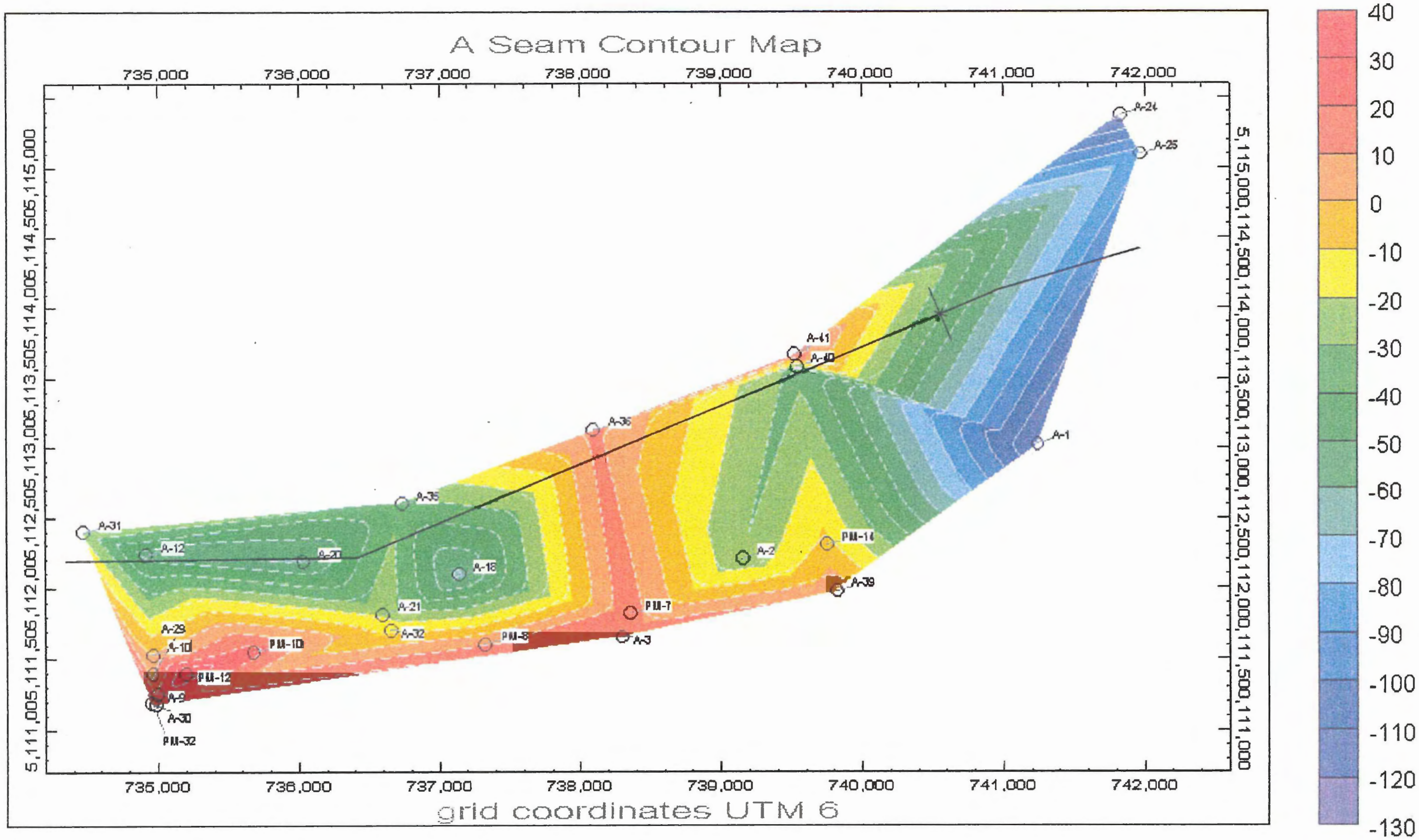



**Figure 4.19:** Structural contour map of the top of Seam 'A'. Scale to the right is elevation in metres, relative to sea level (0 m). Diagram shows synform relation, which is deepest near the axis trace. Computer-simulated correlation between drill holes PM-7 (16 m) and A-36 (13 m) is not accurate, as depth is expected to increase in conjunction with the axis trace. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

the axis and present-day coast. Such an orientation corresponds with the orientation of the Morien Syncline, as defined by inland seam mapping and coastal exposure.

Interval thickness of Seam 'A' varies considerably along the syncline (Fig. 4.20). Thickness increases gradually inland, from 2.4 m at the Morien South coastal section, to 24 m at drill hole A-31. The 'A' and 'PM' series drill holes portray the Seam 'A' interval as composed of 1, 2, or 3 'main' coal splits, with thin coaly strata sometimes present, and with accompanying non-coaly strata. By comparing drill holes along the syncline, it is apparent that Seam 'A' changes from a 1.8 m coal seam at drill holes A-24 and A-25 to a series of splits which encompass 24 m of stratal thickness at drill holes A-31.

From A-25 (and A-24) to A-41 (and A-40), Seam 'A' splits into two coal seams, separated by almost 11 m of strata. Drill hole A-36 shows the same coal split, separated by over 20 m of strata. Farther inland, drill hole A-35 shows two small coals and two larger coals (which most likely correlate with those of A-36) within a stratal thickness of almost 20 m. Inland thickness increase is common along the southern limb as well, although appears to be more intense to the north of the axis.

Analysis of total coal thickness within the Seam 'A' interval suggests an increase in coaly strata towards the coast (Fig. 4.21). Also common is a local abundance of coaly strata inland, focused just south of the syncline axis. In comparison with Seam 'A' interval thickness, it is apparent that the total thickness of coaly strata is inversely related to the interval thickness, particularly well seen in trends inland along the syncline axis. This relation suggests that overall 'A' coal (peat) accumulation is inversely related to splitting as well.

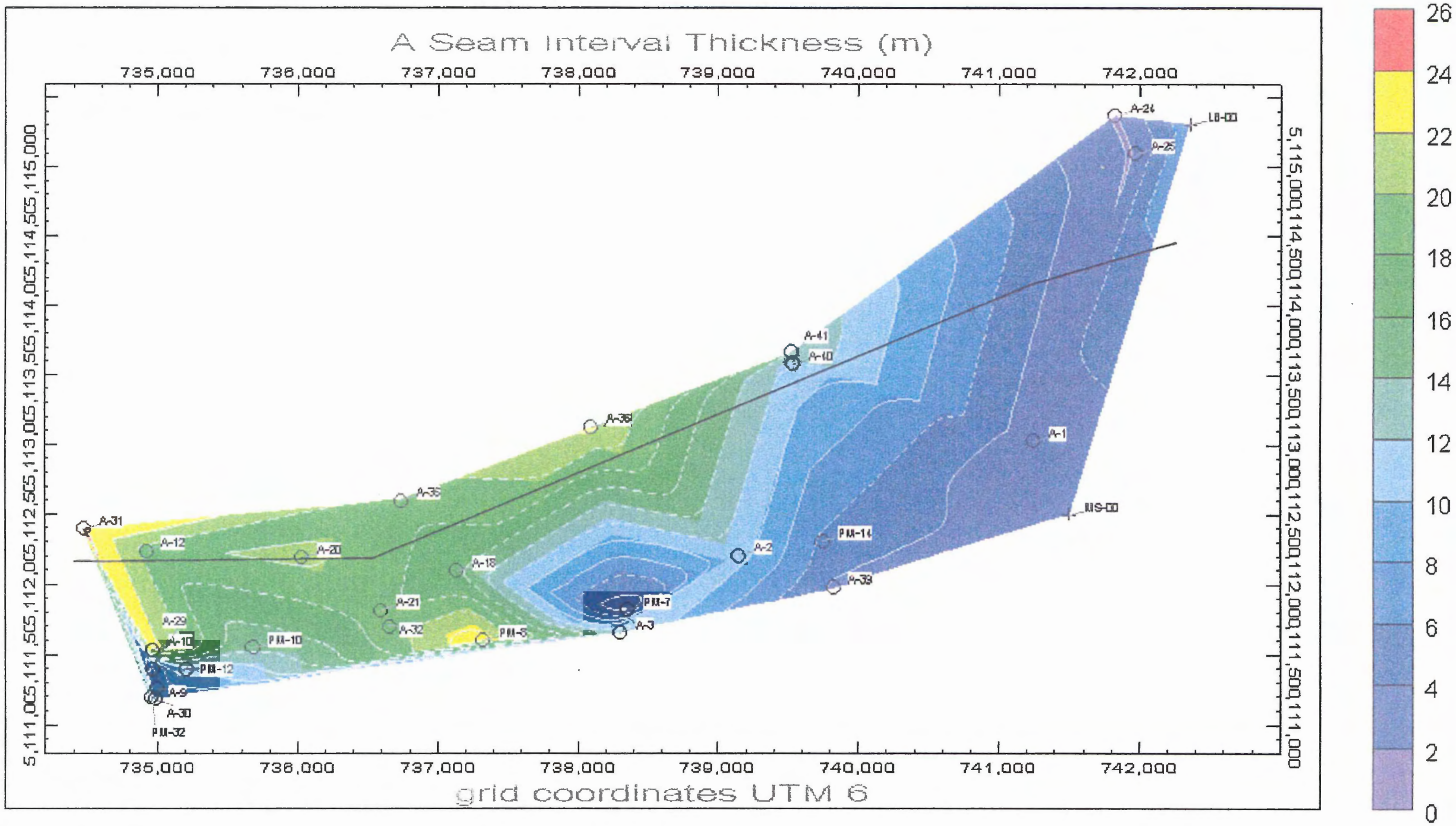



**Figure 4.20:** Isopach representation of Seam 'A' interval thickness based on available drill hole information. This diagram includes coaly and non-coaly strata within the upper and lower bounding surfaces of Seam 'A'. Thickness increases inland, from 2.36 m at the Morien South coastal section, to 24 m at drill hole A-31. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

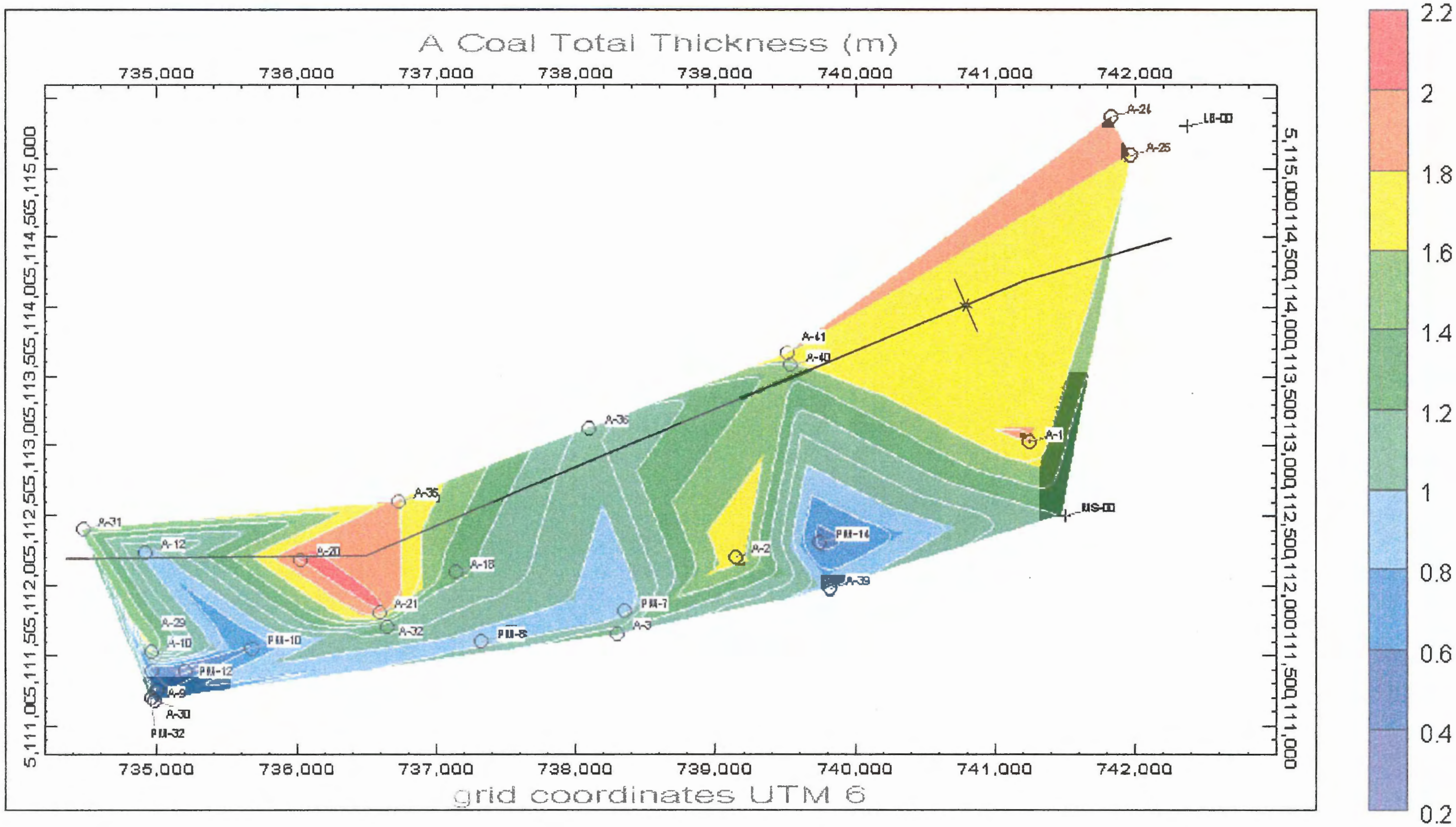



**Figure 4.21:** Isolith representation of total Seam 'A' coal thickness. This diagram may suggest an increase in coaly strata towards to coast. Also common is a local increase in coaly strata inland, focused just south of the syncline axis. In comparison with Seam 'A' interval thickness, it is apparent that the total thickness of coaly strata is inversely related to the interval thickness, particularly parallel to the syncline axis. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

Because of the nature of the Seam 'A' interval and thus the 'A'SP, an additional isopach map is added, showing thickness variation of 'A'SP strata below the lower bounding surface of the Seam 'A' interval (Fig. 4.22). As expected due to the relatively stable thickness of the 'A'SP (Fig. 4.16) and the thickness trend of the Seam 'A' interval (Fig. 4.20), the 'A'SP below-seam stratal thickness appears to be an inverse of the Seam 'A' interval. Thickness increase occurs to the present-day coast and is focused along the southern limb of the Morien Syncline.

*4.10 Phalen Stratal Package (PSP)*

The complete PSP is represented in nine drill holes (A-1, 2, 12, 18, 20, 24, 25, 35, 40) and both coastal sections. Drill hole information suggests that PSP thickness within the Morien Syncline varies from 62 m to 73 m (Fig. 4.23). Due to a thickness value that is severely off in comparison to its surroundings (39 m), drill hole A-25 was not used in isopach representation of the PSP.

The isopach map for PSP thickness variation shows good evidence of stratal thickening towards the present-day coast, and possibly to the south of the syncline axis as suggested by drill hole A-1 (72.4 m). Stratal thickness appears to decrease inland, with a minimum thickness attained near drill holes A-18 (62.3 m) and A-35 (63.6 m). Due to a lack of information along the syncline axis, it is difficult to determine if stratal thinning occurs towards the syncline limbs. Drill holes A-12 (68.4 m) and A-20 (66.4 m), located inland along the syncline axis, in comparison with A-18 (towards the southern limb) and A-35 (towards the northern limb) may suggest such thinning, however more data points within the region of the axis would firm up (or challenge) this observation.

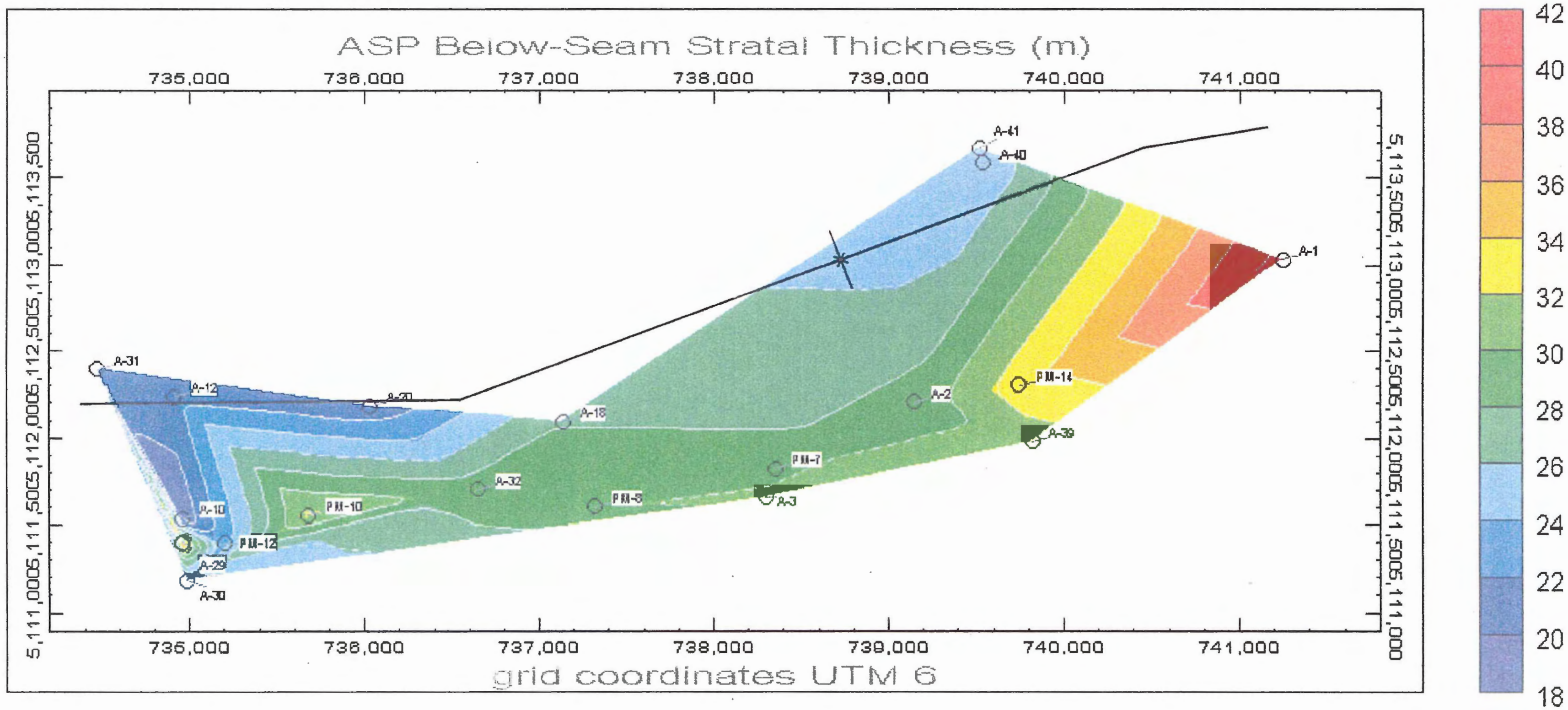



**Figure 4.22:** Isopach representation showing thickness variation of 'A'SP strata below the lower bounding surface of the Seam 'A' interval. 'A'SP below-seam stratal thickness appears to be an inverse of the Seam 'A' interval (Fig. 4.20). Thickness increase occurs to the present-day coast and appears focused along the southern limb of the Morien Syncline. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986). Compare with Figures 4.16 and 4.20.

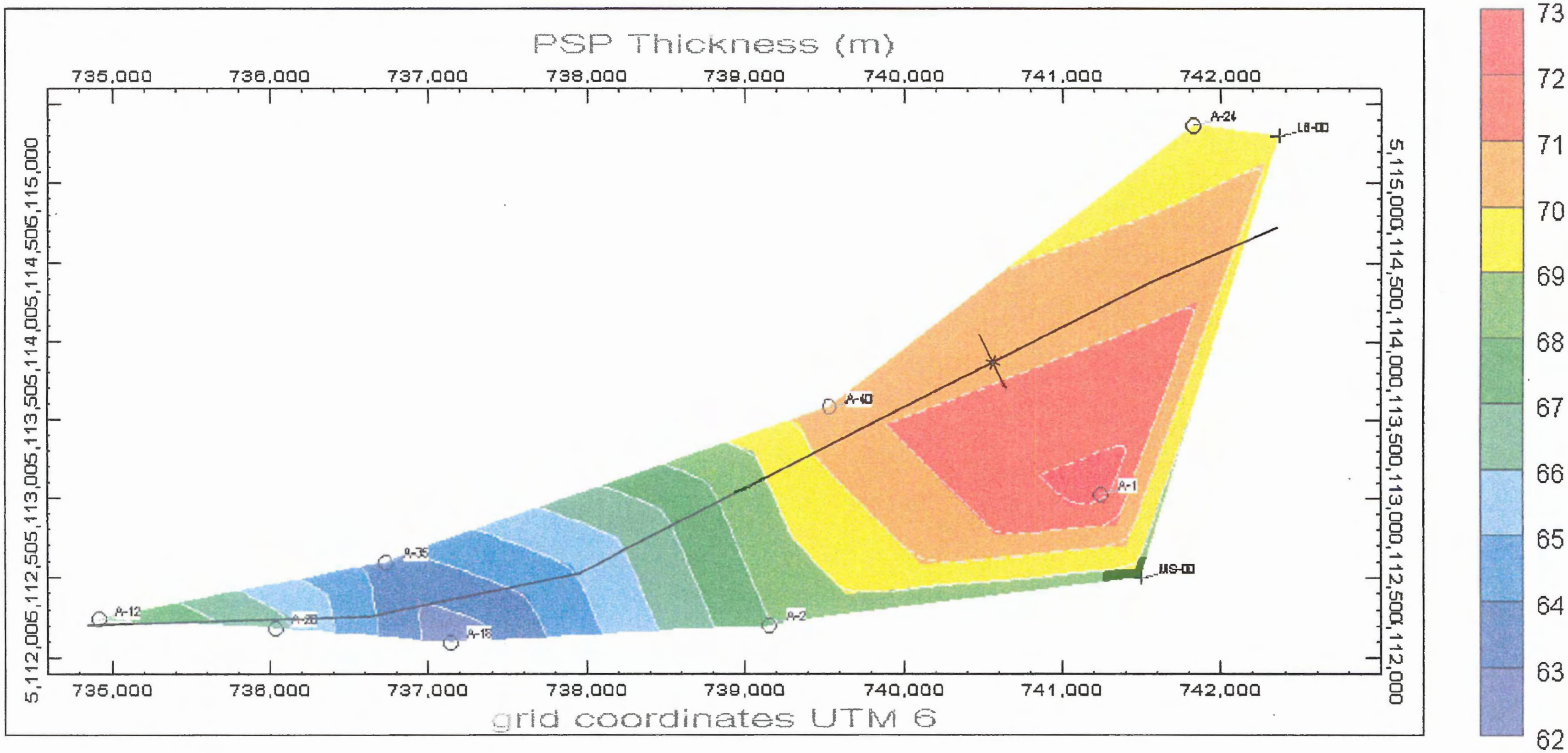



**Figure 4.23:** Isopach representation of PSP thickness variation based on available drill hole information. Stratal thickening towards the present-day coast and on the southern limb of the Morien Syncline is evident. Due to a lack of information along the syncline axis, it is difficult to determine if stratal thinning occurs towards the syncline limbs. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

Sandstone abundance varies within the PSP as well (Fig. 4.24). Excluding drill hole A-12 (80%), which has an extremely high sandstone abundance that may be inaccurate, sandstone abundance varies from 17% (A-24) to 38% (A-1). High sandstone abundances seem to be focused towards the present-day coast and on the southern limb. Although limited data exist along the syncline axis, it is apparent that sandstone abundances are higher along the southern limb of the syncline in comparison with the northern limb.

Strata containing redbeds within the PSP seem to be concentrated on the inland portion of the syncline (Fig. 4.25). This is well established along the southern limb by the increasing trend from drill holes A-1 (0%), to A-2 (35%), to A-18 (57%). This is also visible along the northern limb, by comparing drill holes A-25 (17%), to A-40 (7%), to A-35 (45%). Similar to thickness variation for the PSP, inland drill holes can be used to investigate how strata containing redbeds vary towards the syncline limbs. By comparing drill holes A-12 (15%) and A-20 (22%), which lie along the syncline axis, with drill holes farther towards the limbs such as A-35 (to the north; 45%) and A-18 (to the south; 57%), it may be that strata containing redbeds are less common along the axis and more concentrated along the limbs. Again, more data along the axis would aid in such analysis.

*4.11 Phalen Seam*

A structural contour map of the upper surface of the Phalen Seam shows good synform relation, confirming that seam correlation between drill holes is accurate (Fig. 4.26). As is evident, Seam 'B' increases in depth towards the syncline axis and is shallow along the northern and southern limbs of the syncline.

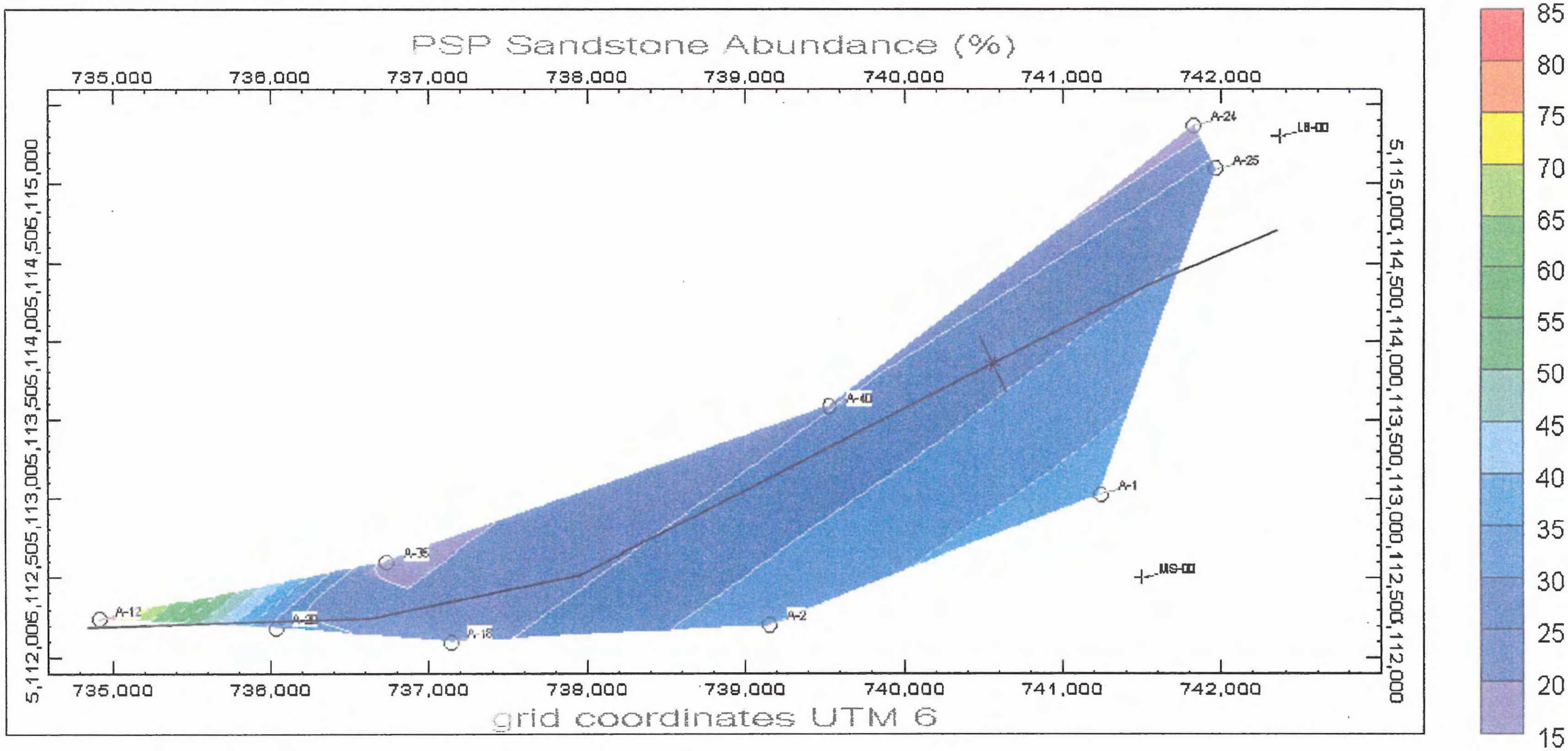



**Figure 4.24:** Isolith representation of sandstone abundance variation within the PSP based on available drill hole information. Excluding drill hole A-12, which has an extremely high sandstone abundance (80 %) that may be inaccurate, sandstone abundance varies from 17 % (A-24) to 38 % (A-1). High sandstone abundances seem to be focused towards the present-day coast and on the southern limb. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

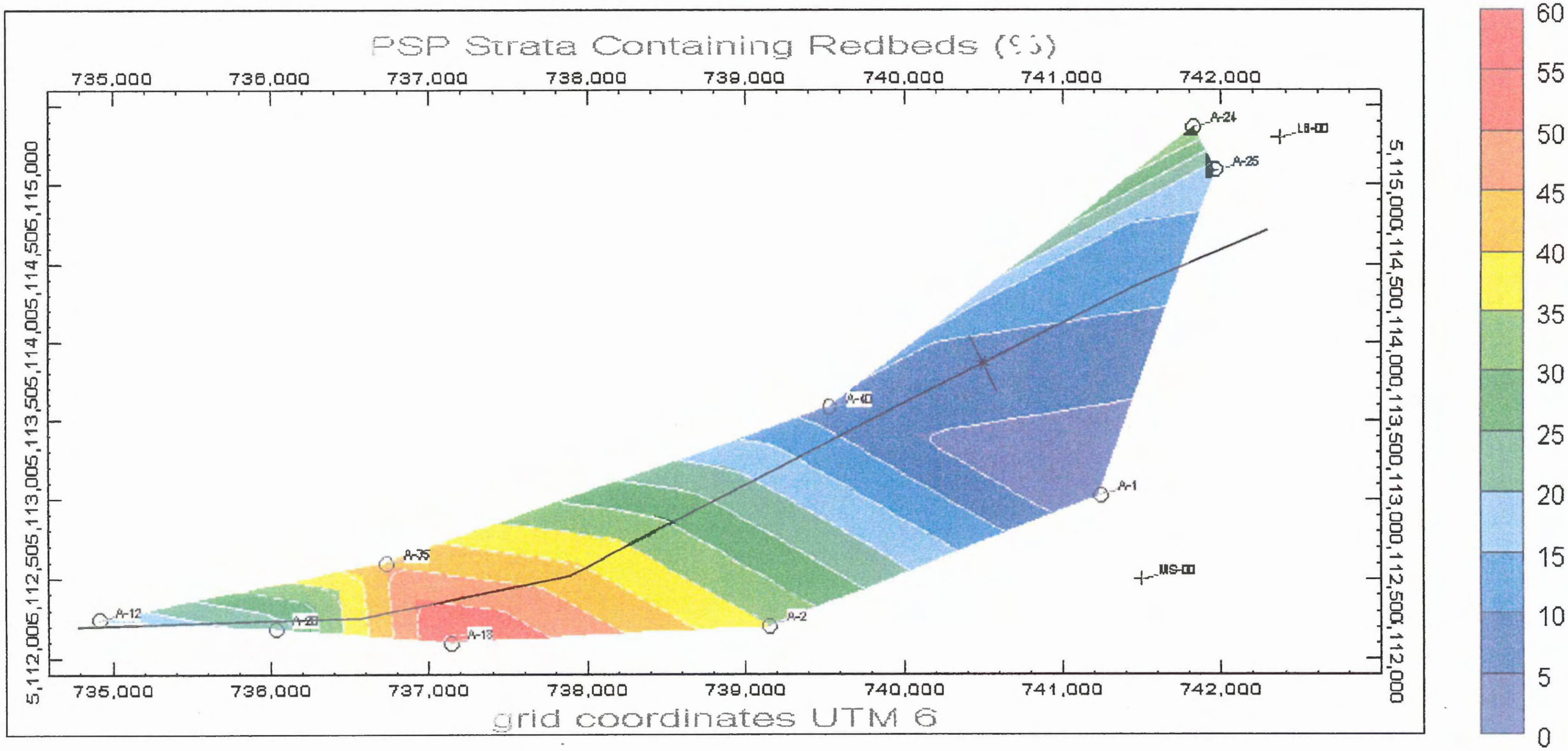



**Figure 4.25:** Isolith representation of strata containing redbeds within the PSP based on available drill hole information. Strata containing redbeds within the PSP seem to be concentrated on the inland portion of the syncline. It may also be that strata containing redbeds are less common along the axis and more concentrated along the limbs. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

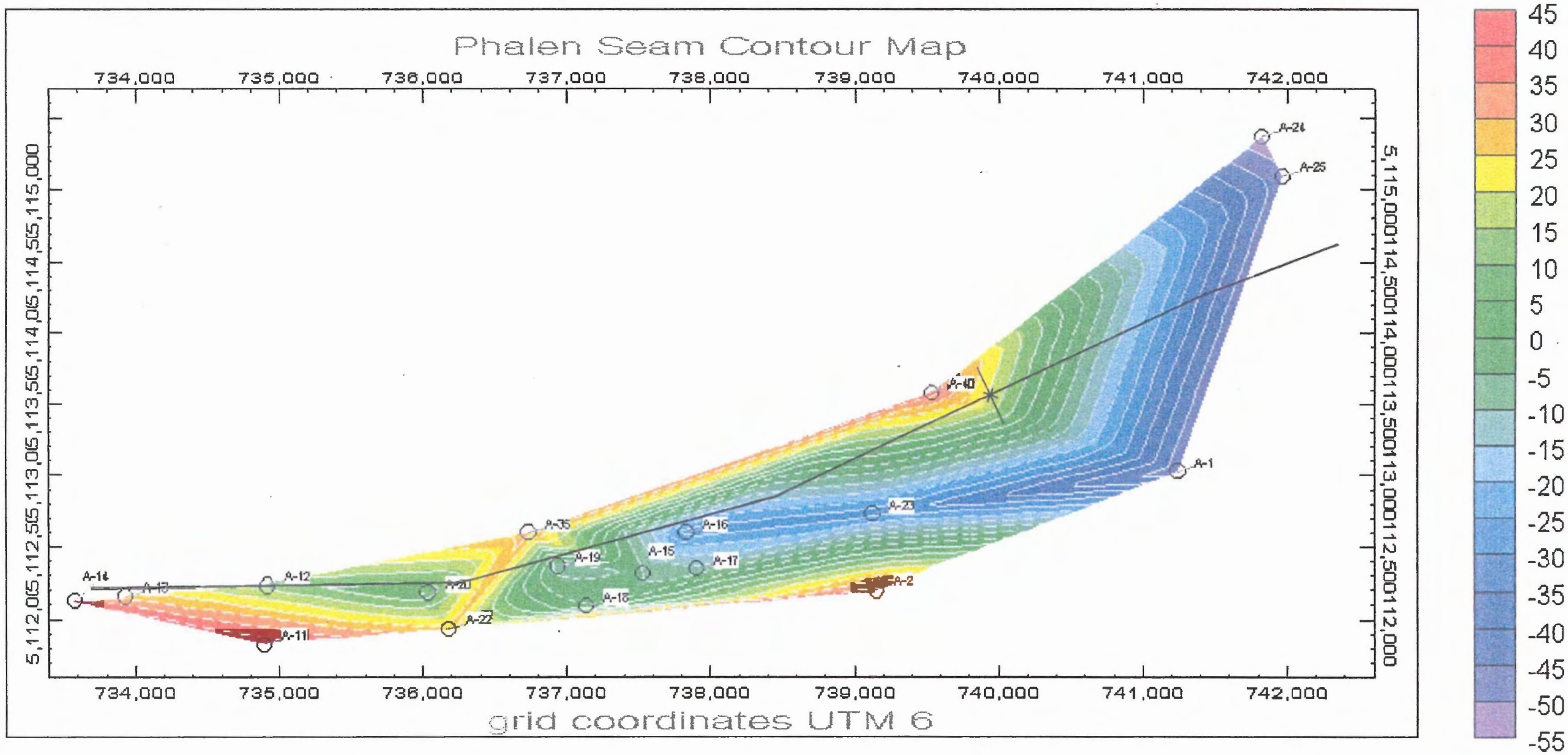



**Figure 4.26:** Structural contour map of the top of the Phalen Seam based on available drill hole information. Scale to the right is elevation in metres, relative to sea level (0 m). Diagram shows the synform relation of the Phalen, which is deepest near the axis trace. Computer-simulated correlation between drill holes A-22 (26 m) and A-35 (31 m) is most likely not accurate, as it is expected that depth should increase slightly in conjunction with the axis trace. A more accurate elevation along the axis may be comparable to that of drill holes A-20 (5 m) or A-19 (-8 m). Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

The Phalen Seam is represented in 18 drill holes (A-1, 2, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 35, 40), and both coastal sections used in this study. The Phalen Seam interval (Fig. 4.27) varies from 0.6 m (A-2) to 3.1 m (A-22) in thickness along the Morien Syncline. Interval thickness increases inland from the present-day coast, and appears to reach a minimum thickness coastward along the southern limb, as suggested by drill hole A-2 (0.6 m) and the Morien South coastal section (0.8 m). Maximum thickness is attained around drill hole A-22 (3.1 m), but appears to remain relatively high inland, particularly along the southern limb.

Total Phalen Seam coal thickness (Fig. 4.28) is quite consistent with the interval thickness, as expected for a seam with minimal splitting. Total coal thickness increases inland from the present-day coast, and appears to reach a minimum thickness coastward along the southern limb, as suggested by the Morien South coastal section (0.8 m). Maximum total coal thickness is attained around drill hole A-22 (3.1 m), and remains relatively high inland. It appears as well that coal is more abundant along the northern limb of the syncline, in comparison to the south. Accuracy of the interval seam thickness (Fig. 4.27) and the total coal thickness (Fig. 4.28) of drill hole A-25 (1.46 m) is questioned; PSP thickness was concluded to be most likely inaccurate for this hole, as its Phalen Seam thickness does not conform well with thickness values in nearby holes.

*4.12 Backpit Stratal Package (BSP)*

The complete BSP is represented in six drill holes (A-1, A-16, 19, 20, 23, 25) and both coastal sections (Fig. 4.29). Because of their proximity to drill hole A-16, drill holes A-15 and A-17 were added to the data set and given BSP values equal to that of A-16 (43 m). This was done to allow better isopach representation inland, where

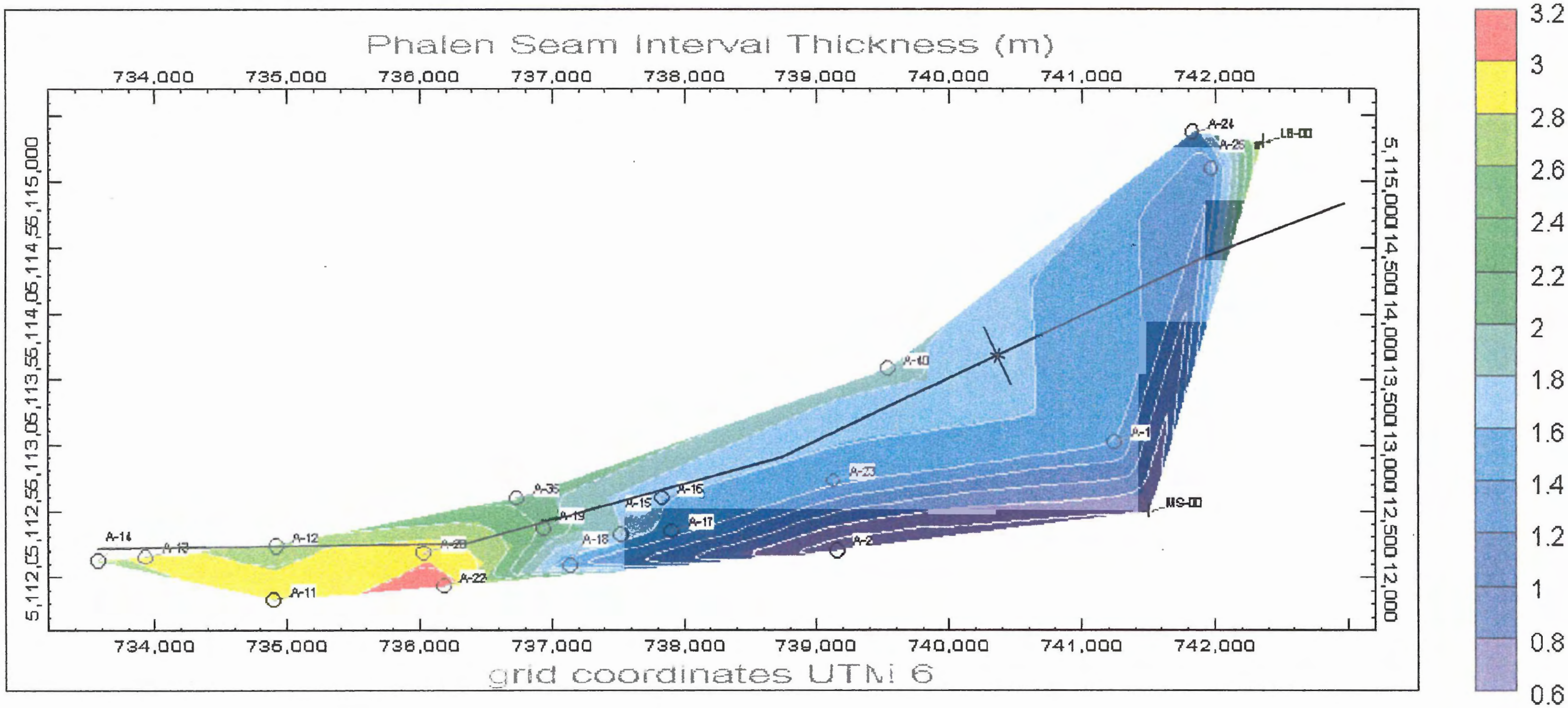



**Figure 4.27:** Isopach representation of the Phalen Seam interval thickness. Interval thickness decreases towards the present-day coast and appears to reach a minimum thickness coastward along the southern limb as suggested by drill hole A-2 (0.6 m) and the Morien South coastal section (0.8 m). Maximum thickness is attained around drill hole A-22 (3.1 m) and appears to remain relatively high inland, particularly along the southern limb. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

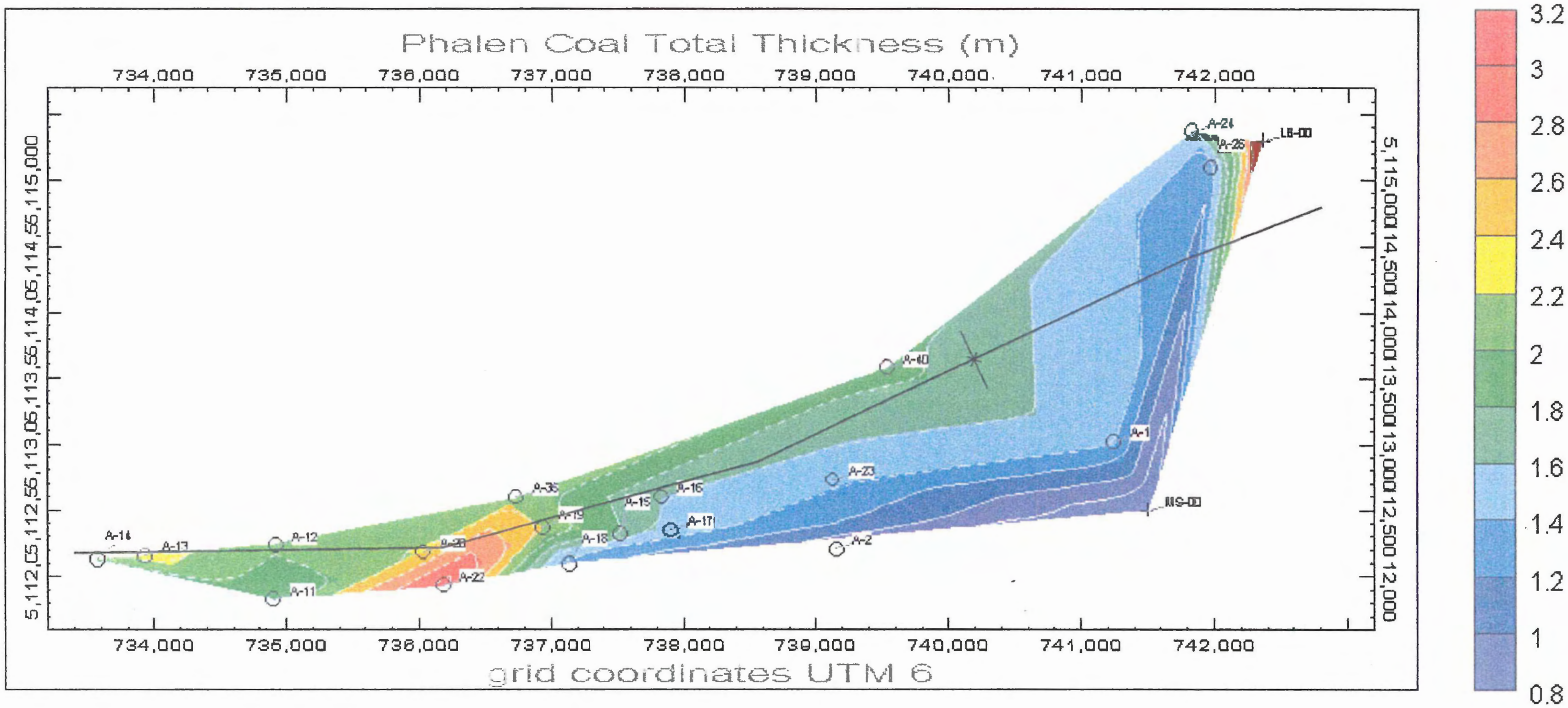



**Figure 4.28:** Isolith representation of total Phalen coal thickness based on available drill hole information. This diagram does not include thickness values for non-coaly strata present within the seam interval. Coal appears more abundant (overall) along the northern limb of the syncline, in comparison to the south. Accuracy of the interval seam thickness and the total coal thickness of drill hole A-25 (1.46 m) is questioned; PSP thickness was concluded most likely inaccurate for this hole, as its' seam thickness does not conform well to those surrounding it. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

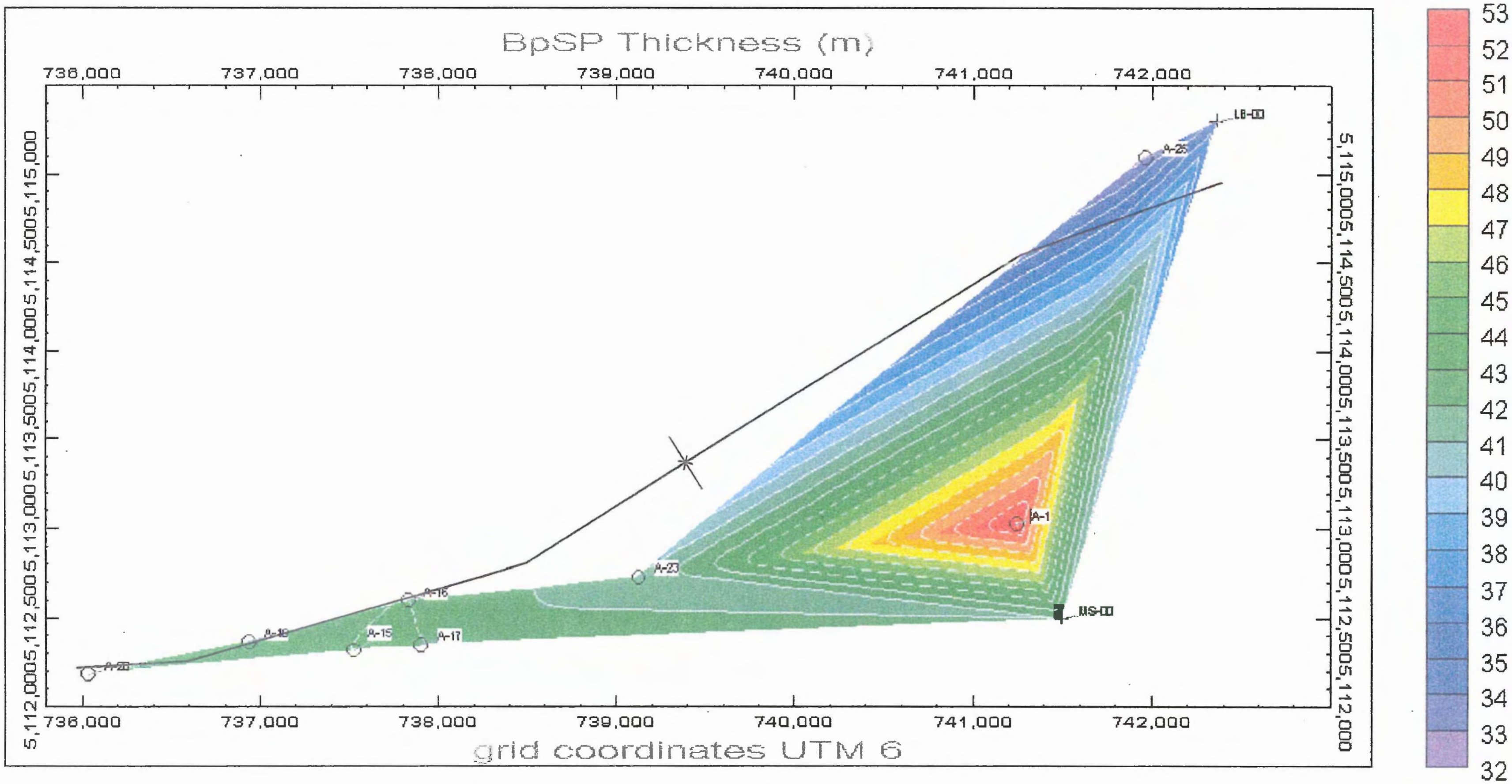



**Figure 4.29:** Isopach representation of BSP thickness variation based on drill hole information. In comparison to drill hole A-1, stratal thickness appears to decrease inland, and is greatest south of the axis towards the coast. Stratal thinning towards the northern limb from the synclinal axis is apparent. Stratal thickness from inland towards the Morien South coastal section appears relatively constant, averaging approximately 42 m. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

information is limited. It is expected that thickness values for drill holes A-15 and A-17 are comparable to that of A-16. Maximum BSP thickness is attained around drill hole A-1 (52 m), located south of the syncline axis, near the present-day coast. Located north of the axis and near the present-day coast, drill hole A-25 exhibits a minimum stratal thickness (33 m). A-23 (40 m), A-16 (43 m), and A-19 (44 m) represent the inland extent of the BSP.

Stratal variation patterns are difficult to discern due to the small size of the data set. In comparison to drill hole A-1, stratal thickness appears to decrease inland, and is greatest south of the axis towards the coast. Information from A-25 suggests stratal thinning towards the northern limb from the synclinal axis. Stratal thickness from inland towards the Morien South coastal section appears relatively constant, averaging approximately 42 m. Ignoring drill hole A-1 (Fig. 4.30), trends appear quite different; stratal thickness increases inland, but is still concentrated along the southern limb of the syncline. Due to the small size of the data set, it is difficult to discern the nature of thickness variation within the BSP, particularly along the syncline axis. It can be said with relative certainty, however, that BSP thickness is greater along the southern limb than in the region of the syncline axis and areas just north of the axis.

Sandstone abundance patterns within the BSP are difficult to discern as well, particularly since drill hole A-23 did not have lithologies recorded (in this particular hole, non-coaly strata were not labeled). Sandstone abundance for drill hole A-1 (65%) seemed abnormally high in comparison with the other four, which averaged less than 24% (Fig. 4.31). Due to the lack of data, inferences relating to abundance variation cannot be made with confidence. Ignoring drill hole A-1, values may suggest that

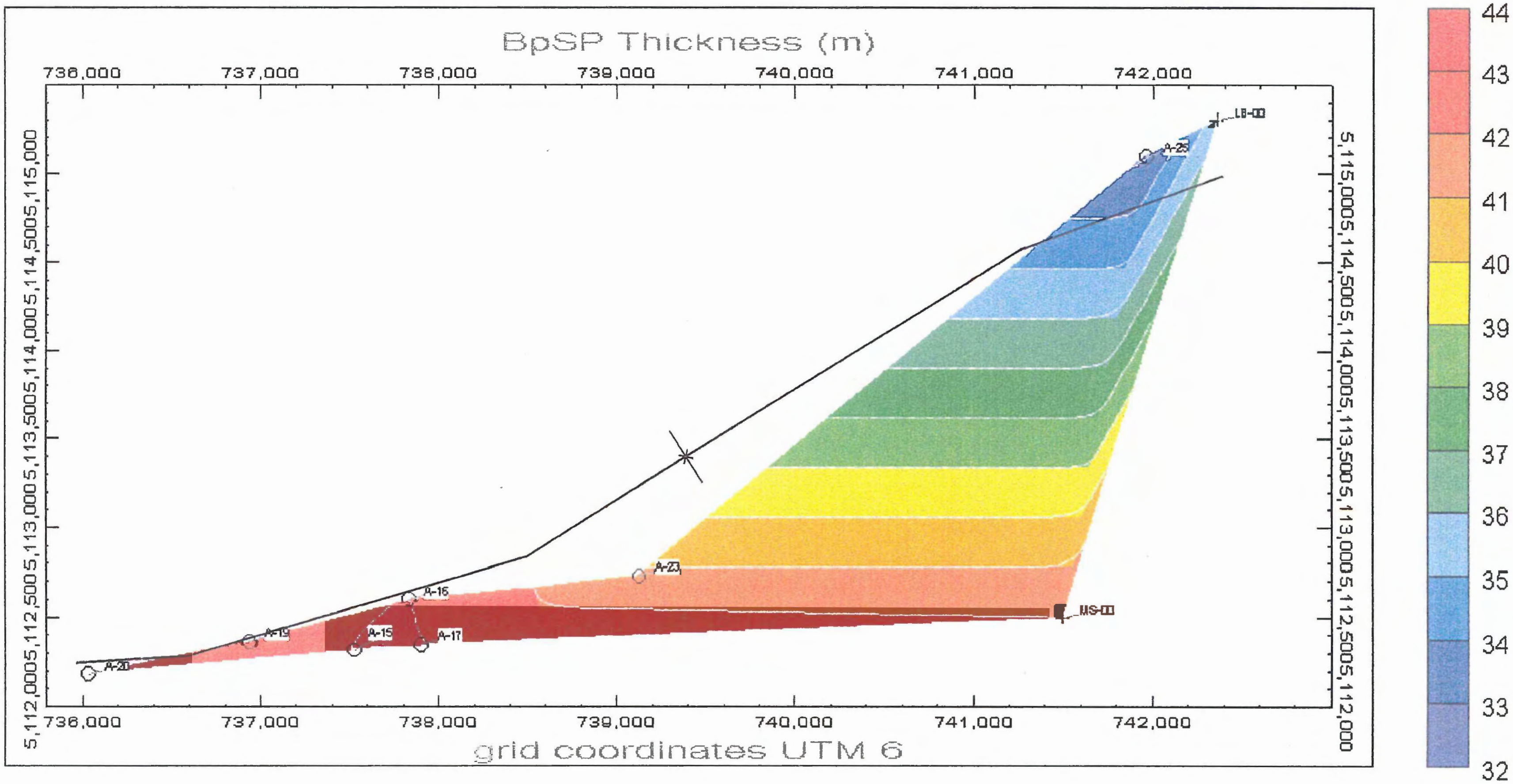



**Figure 4.30:** Isopach representation of BSP thickness variation, not accounting for drill hole A-1 (52 m). Ignoring A-1, trends appear quite different; stratal thickness appears to slightly increase inland, but is still concentrated along the southern limb of the syncline. Compare with Figure 4.29.

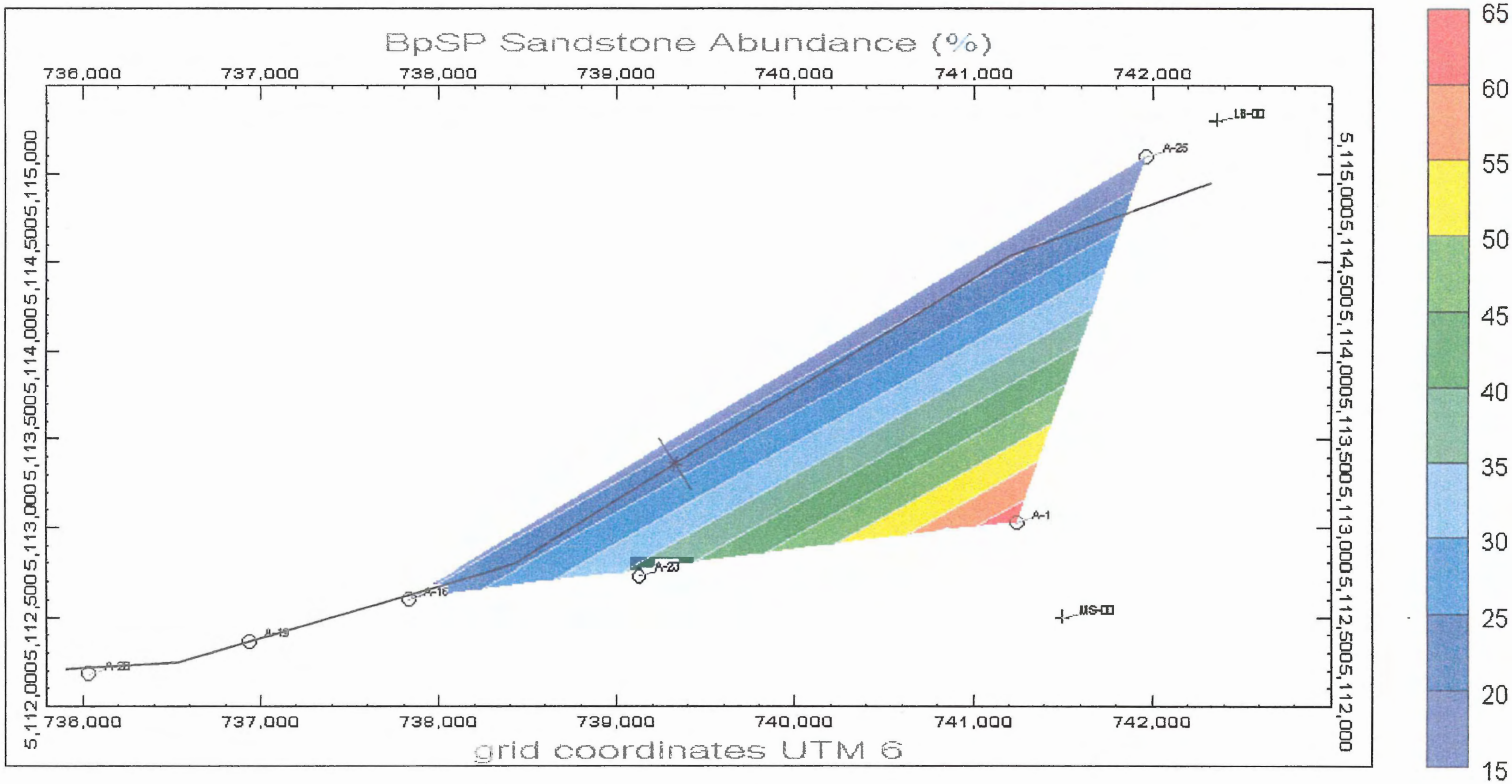



**Figure 4.31:** Isolith representation of sandstone abundance variation within the BSP based on available drill hole information. Excluding drill hole A-1, which has an extremely high sandstone abundance (65 %) that may be inaccurate, sandstone abundance averages approximately 24 %. Due to the lack of data, inferences relating to abundance variation cannot be made with confidence. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

sandstone abundance is greater inland, but insufficient data exist to base observations. In comparison to underlying stratal packages, the BSP may contain a relatively low overall sandstone abundance (24%). In comparison, the PSP and 'A'SP both display similar overall sandstone abundances of 26%, although the 'A'SP is much more erratic. However, the lowermost stratal package studied, the 'C'SP, displays a higher overall sandstone abundance (40%), which may or may not suggest a shift in grainsize deposition through time.

Strata containing redbeds within the BSP of the Morien Syncline may be uncommon (Fig. 4.32). Of the five drill holes, four (A-1, 16, 19, 20) recorded no strata containing redbeds. Drill hole A-25 (10%) suggests the presence of strata containing redbeds on the northern limb of the syncline in close proximity to the present-day coast. No patterns are evident relating to redbed distribution throughout the BSP due to insufficient data.

*4.13 Backpit Seam*

Backpit Seam interval thickness variations (Fig. 4.33) are difficult to discern due to limitations of the data set. Maximum interval thickness is recorded along the Morien South coastal section (1.8 m), and at drill hole A-23 (1.7 m). A high thickness value is also evident in A-19 (1.4 m). Minimum thickness values may reside along the northern limb of the syncline as represented by drill hole A-25 (0.3 m), which may suggest seam thinning just north of the syncline axis. High seam values present in A-16 (1.2 m) and A-19 (1.4 m) imply slight thinning inland in relation to the Morien South coastal thickness. A-23 (1.7 m) resides south of the syncline axis, and may suggest seam thickening towards the southern limb away from the axis. The high thickness value

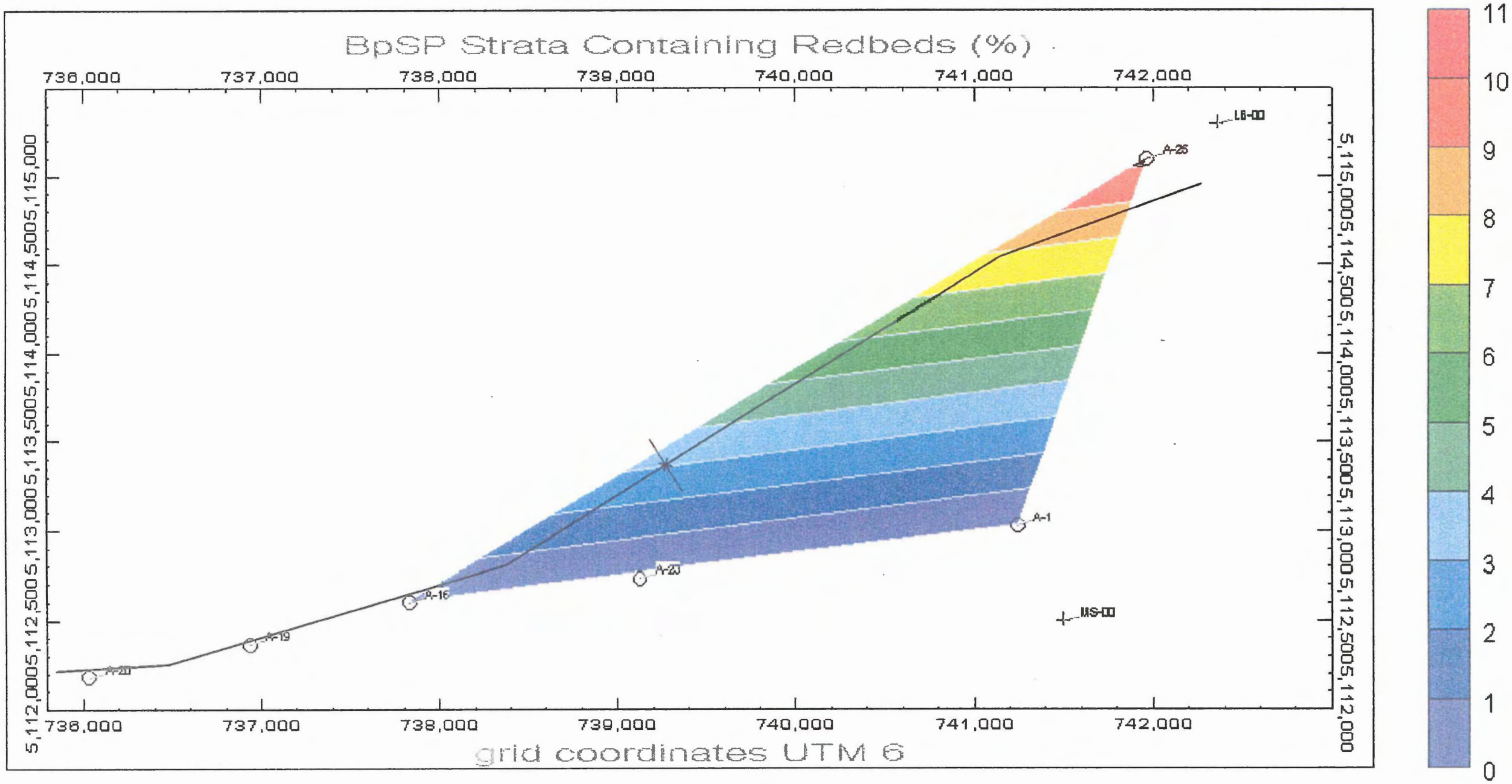



**Figure 4.32:** Isolith representation of strata containing redbeds within the BSP based on available drill hole information. No patterns are evident relating to redbed distribution throughout the BSP due to insufficient data. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

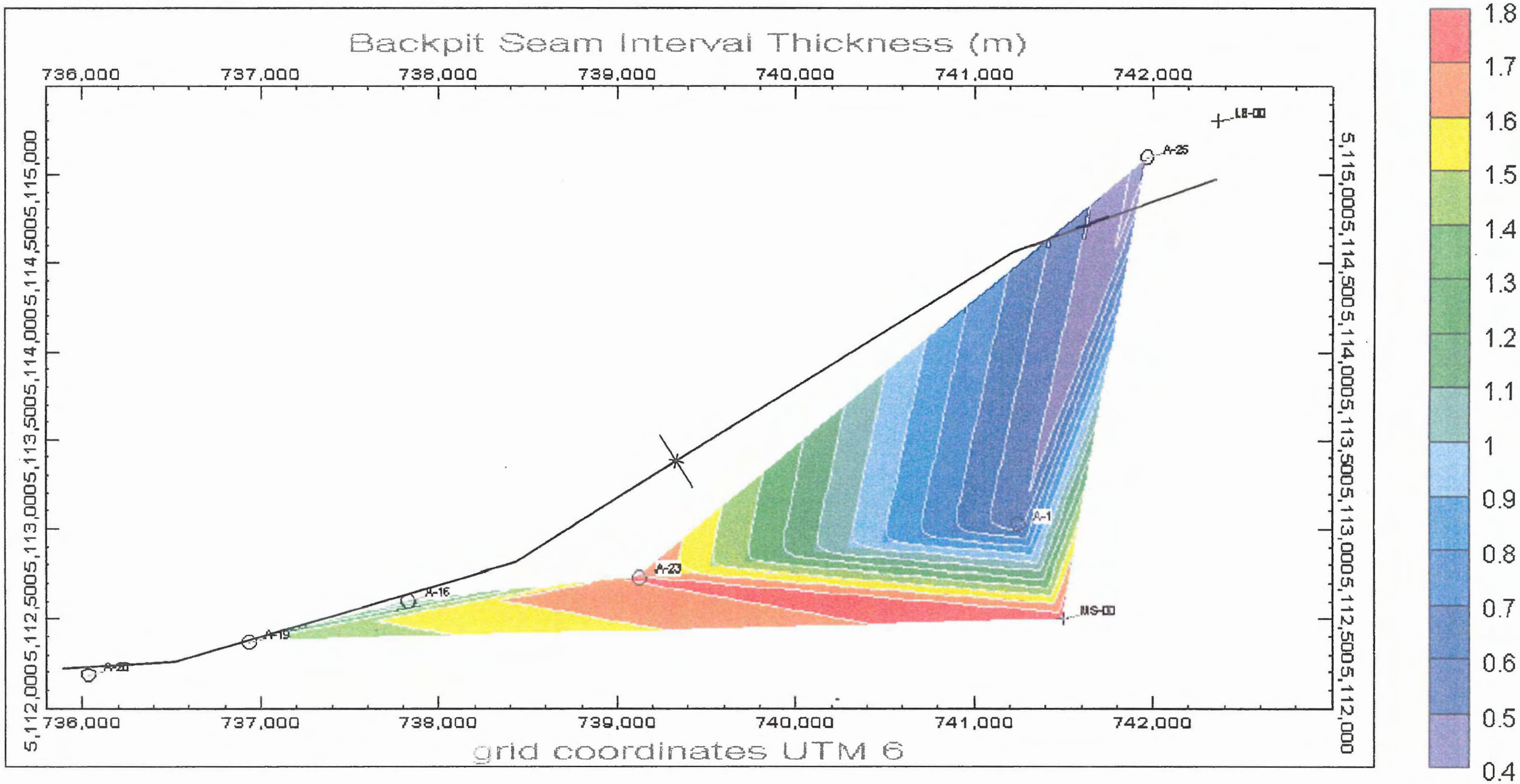



**Figure 4.33:** Isopach representation of the Backpit Seam interval thickness. High seam values present in A-16 (1.2 m) and A-19 (1.4 m) imply slight thinning inland in relation to the Morien South coastal thickness. A-23 (1.7 m) resides south of the syncline axis, and may suggest seam thickening towards the southern limb away from the axis. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

represented in the Morien South coastal section suggests increasing seam thickness either towards the coast or localized along portions of the southern limb.

An isolith map comparing total Backpit coal thickness (Fig. 4.34) appears very similar to the seam interval isopach. An exception is drill hole A-23 (0.65 m). Total Backpit coal thickness may be greater along the southern limb of the syncline, in comparison to the north. Insufficient data makes it difficult to infer variation within the Backpit Seam and Stratal Package.

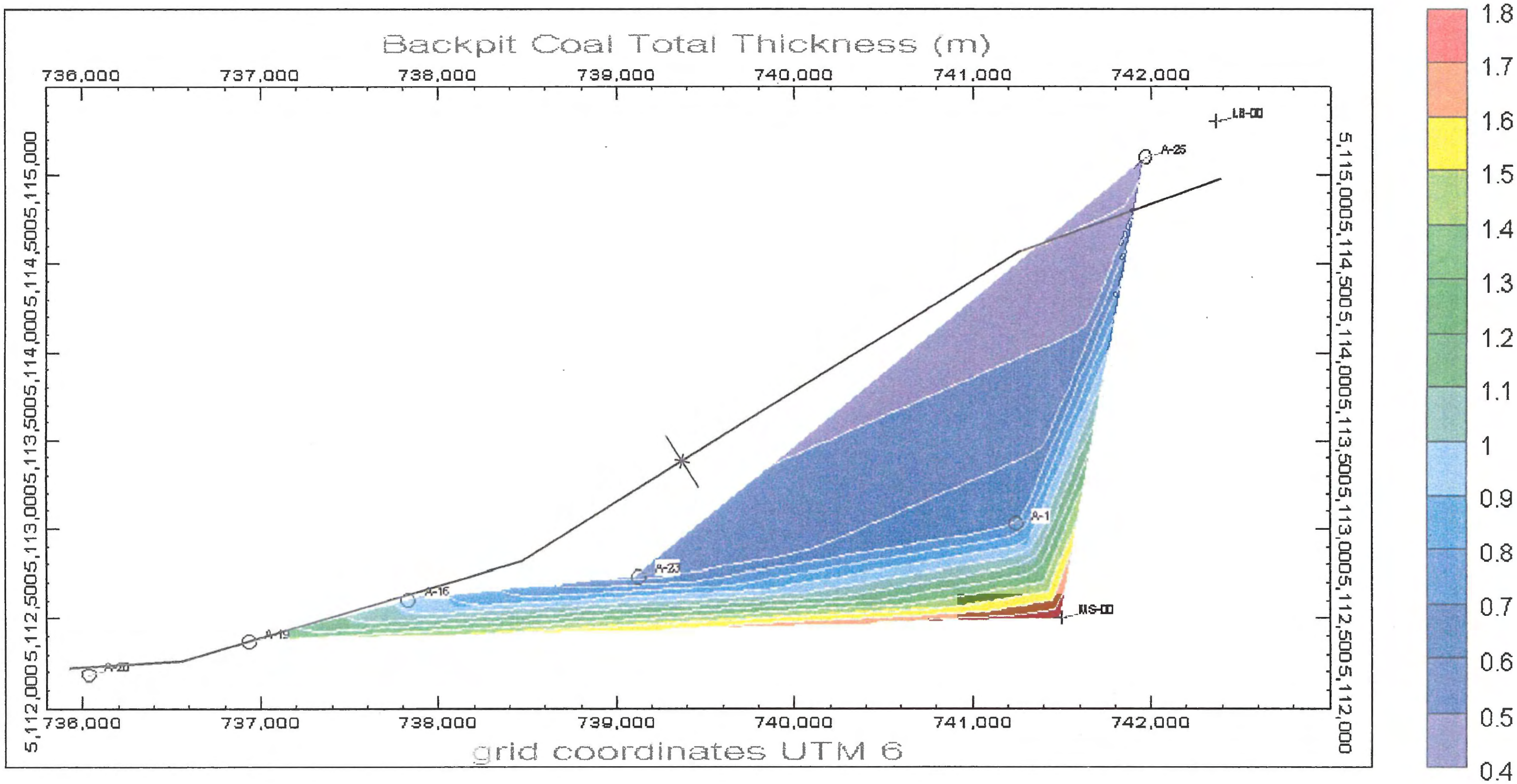



**Figure 4.34:** Isolith representation of total Backpit coal thickness based on available drill hole information. Total Backpit coal thickness may be greater along the southern limb of the syncline, in comparison to the north. Insufficient data makes it difficult to infer variation of the Backpit Seam. Black line refers to approximate syncline axis location, based on Boehner and Giles (1986).

# Chapter 5: DISCUSSION

## *5.1 Coal Seams and Stratal Packages*

### *5.1.1 Differential subsidence*

Stratal Package thickness values for the Sydney Mines Formation of the Morien Syncline can be compared to equivalent thicknesses across the onshore portion of the Sydney Mines Formation. Table 5.1 presents stratal package thickness values for three coastal sections and one mine record, each located within 25 km of the Morien Syncline. Thickness values show that stratal packages within the Morien Syncline are thicker than in these areas, suggesting that differential subsidence took place across the Sydney Mines Formation outcrop area. The three coastal sections are located in the vicinity of the Bridgeport Anticline, towards the margin of the Sydney Harbour Syncline (Victoria Mines) and the Glace Bay Syncline (Dominion). The Donkin Tunnel is located just north of the Cape Perce Anticline (Fig. 1.2).

**Table 5.1:** Thickness values of stratal intervals in sections located north and northwest of the Morien Syncline for the Sydney Mines Formation, Sydney Harbour area. Coastal sections, unpublished data, M. R. Gibling. Donkin Tunnel section logged by S. Lamb for DEVCO, completed 1984. Morien Syncline data from this study.

| Coastal Section | Typical PSP Thickness (m) | Typical BSP Thickness (m) |
|---|---|---|
| *Victoria Mines*, ~ 25 km from Morien Syncline | 42 m | 35 m |
| *Lingan*, ~ 19 km from Morien Syncline | 32 m | 28 m |
| *Dominion*, ~ 15 km from Morien Syncline | 38 m | 23 m |
| *Donkin Tunnel*, 5 km N of Morien Syncline | 63 m | 36 m |
| Morien Syncline Thickness | 62-72 m | 32-43 m |

A cyclic relation between coal seams and sedimentary strata is evident in the Sydney Mines Formation of the Morien Syncline, suggesting recurring peat formation through time. Detailed facies information that would have allowed paleoenvironmental and sequence stratigraphic analysis of such cyclothems, was not recorded on 'A' series log sheets. Thus, although the cyclic relation between coal seams and strata is recognized in the study area, no discussion will be presented. Cyclothemic relations within the Morien Syncline area will be discussed in detail by H. L. McDonald (M.Sc. in progress).

*5.1.2 Seam interval variation*

Several trends are evident in studied seam intervals of the Morien Syncline (Table 5.2). With the exception of the lowest two seam intervals (Seam 'D', Seam 'C'), all show thickness increase inland. Splitting is also common inland. Of the four seams that display evidence of splitting, three suggest split development inland. An exception to this is seam interval 'C'; this interval displays the least developed splitting of the four, which only occurs in a localized region of the southern limb.

Although data are very limited, thinning northward from the Morien Syncline axis appears to be common in most seam intervals. Two exceptions to this may be seam interval 'D', thickening northward in the inland area, and the Phalen Seam, thickening northward in the coastal area. Although maximum thickness values are locally attained south of the syncline axis, several seam intervals with considerable data suggest thickness decrease toward the southern limb. An example of such a trend is the inland portion of seam interval 'C'. Seam interval 'A' displays a similar trend, although with localized high thickness values on the southern limb. Thus, in general, trends are weakly developed in seam interval thickness, with an overall tendency for thinning both north and south of the syncline axis.

**Table 5.2:** Data trends relating to seam interval thickness variation. Terms *coastal* and *inland* refer to modern geography of the Port Morien area. '*Σ Coal*' denotes Total Coal. Symbol '<' denotes thickness increase coastward. Symbol '>' denotes thickness increase inland. Red color signifies evidence of seam splitting. 'nd' denotes no data. '?' denotes uncertainty in trend evaluation. '??' denotes considerably uncertainty in trend evaluation.

| **Seam Interval/ Total Coal** | **Trends** | | | | |
|---|---|---|---|---|---|
| | **Overall** | **Inland** | | **Coastal** | |
| | | **Axis to N** | **Axis to S** | **Axis to N** | **Axis to S** |
| **Seam 'D' (Fig. 4.2)** < | Increases to coast; max south of axis (?) | Increases (??) | Increases (?) | nd | nd |
| **Seam 'C' (Fig. 4.8)** < | Increases to coast; max south of axis (?) | Decreases (??) | Decreases | nd | Increases (?) |
| **Seam 'B' (Fig. 4.14)** > | Relatively constant, with a local high inland; south of axis | nd | Increases (??) | nd | Constant |
| **Seam 'A' (Fig 4.20)** > | Increases inland; max south of or along axis; local high at PM-8 | Constant (?) | Decreases (overall) | Decreases (?) | Decreases (?) |
| **Phalen Seam (Fig 4.27)** > | Increases inland; max south of axis | Decreases | Increases (?) | Increases (?) | Decreases |
| **Backpit Seam (Fig. 4.33)** > | Increases inland (?); max south of axis (?) | nd | Increases (??) | Decreases (??) | Increases (?) |

### *5.1.3 Total coal variation*

Trends exist in total coal thickness variation for individual seams (Table 5.3). Trends in total coal thickness variation north and south of the syncline axis for individual seams generally correspond to seam interval thickness variation. This is evident, as thickness trends between the two conform in most instances, although the trends in total coal thickness are perhaps less prominent. An interesting trend is the overall thickness variation of the total coal within a seam interval, in relation to underlying and overlying seams; generally, the six coal seams studied have alternating total coal thickness trends (Table 5.4).

**Table 5.3:** Data trends relating to total coal thickness variation. Terms *coastal* and *inland* refer to modern geography of the Port Morien area. '*Σ Coal*' denotes Total Coal. Symbol '<' denotes thickness increase coastward. Symbol '>' denotes thickness increase inland. 'nd' denotes no data. '?' denotes uncertainty in trend evaluation. '??' denotes considerably uncertainty in trend evaluation.

| **Seam Interval/ Total Coal** | **Trends** | | | | |
|---|---|---|---|---|---|
| | **Overall** | **Inland** | | **Coastal** | |
| | | **Axis to N** | **Axis to S** | **Axis to N** | **Axis to S** |
| **Σ Coal 'D' (Fig. 4.3)**<br>< | Increases to coast (?); max south of axis (?) | Increases (?) | Increases | nd | nd |
| **Σ Coal 'C' (Fig. 4.9)**<br>> | Increases inland along axis; max at A-12 | Decreases (??) | Decreases | nd | nd |
| **Σ Coal 'B' (Fig. 4.15)**<br>> | Increases inland; max south of axis | Decreases (??) | Increases | Increases (??) | Increases |
| **Σ Coal 'A' (Fig. 4.21)**<br>< | Increases to coast; max south of or along axis | Decreases (?) | Decreases | Increases (?) | Decreases (?) |
| **Σ Phalen Coal (Fig. 4.28)**<br>> | Increases inland; max south of axis | Decreases | Increases | Increases (?) | Decreases |
| **Σ Backpit Coal (Fig. 4.34)**<br>< | Increases to coast; max south of axis (?) | nd | Increases (??) | Decreases (??) | Increases |

It is also interesting to note that with the exception of seam interval 'B', all split seams show a total coal thickness variation inversely related to the seam interval thickness variation as a whole. In other words, total coal abundance decreases with splitting. This observation is in accordance with splitting, as it can usually result in the eventual disappearance of a seam.

**Table 5.4:** Trends of thickness apparent in total coal of seam intervals studied. Generally, thickness trends alternate with each subsequent coal. An exception to this is seam interval 'B', which is generally uniform in thickness across the study area (0.88 m). Inland thickness variation of seam interval 'B' results in a total coal thickness increase of 30-40 cm.

| Total Coal | Increases Inland | Increases Coastward |
|---|---|---|
| Σ 'D' | | * |
| Σ 'C' | * | |
| Σ 'B' | * | |
| Σ 'A' | | * |
| Σ Ph | * | |
| Σ BP | | * |

*5.1.4 Stratal package variation*

Stratal packages prove slightly more variable than seams, and clear trends are less evident (Table 5.5). Of the five stratal packages, three tend to thicken to some degree inland, although the 'C'SP and the PSP tend to thin inland from the present-day coast. Nearly all stratal packages show evidence of thinning towards the northern limb of the syncline, both in inland and coastal areas. Southward thickening from the syncline axis is noted at several levels, which may suggest that the present syncline axis does not correspond precisely with the original depocentre axis.

**Table 5.5:** Data trends relating to stratal package thickness variation. Terms *coastal* and *inland* refer to modern geography of the Port Morien area. Symbol '<' denotes thickness increase coastward. Symbol '>' denotes thickness increase inland. 'nd' denotes no data. '?' denotes uncertainty in trend evaluation. '??' denotes considerably uncertainty in trend evaluation.

| **Stratal Package** | **Trends** | | | | |
|---|---|---|---|---|---|
| | **Overall** | **Inland** | | **Coastal** | |
| | | **Axis to N** | **Axis to S** | **Axis to N** | **Axis to S** |
| **'C'SP (Fig. 4.4) <** | Increases to coast (?); max south of axis (?) | Decreases (?) | (?) | nd | nd |
| **'B'SP (Fig. 4.10) >** | Increases inland; max south of axis | Decreases (??) | Increases | nd | Decreases (?) |
| **'A'SP (Fig. 4.16) >** | Increases inland; max south of axis | Increases (??) | Increases | Decreases (??) | Variable (?) |
| **PSP (Fig. 4.23) <** | Increases to coast; max south of axis | Decreases (?) | Decreases | Decreases (?) | Increases (?) |
| **BSP (Figs. 4.29-30) >** | Increases inland (ignoring A-1); max south of axis | nd | Constant | Decreases (?) | Increases (?) |

*5.2 Sandstone Abundance Variation*

Sandstone distribution trends are evident in stratal packages studied (Table 5.6). Although precise sandstone proportions are uncertain where lithologies are combined in drillers' logs, some distinctive trends are apparent. The four uppermost stratal packages generally exhibit high sandstone abundance focused along the southern limb of the syncline. A general trend of decreasing sandstone abundance northward is shown for these four stratal packages. The exception to such trends is the 'C'SP, which is defined by five drill holes of poor positioning. Trends apparent to the 'C'SP may not be reliable.

**Table 5.6:** Percent sandstone (%) trends. Terms *coastal* and *inland* refer to modern geography of the Port Morien area. 'nd' denotes no data. '?' denotes uncertainty in trend evaluation. '??' denotes considerably uncertainty in trend evaluation.

| **Stratal Package Sandstone Abundance** | **Trends** | | | | |
|---|---|---|---|---|---|
| | **Overall** | **Inland** | | **Coastal** | |
| | | **Axis to N** | **Axis to S** | **Axis to N** | **Axis to S** |
| **'C'SP Fig. 4.5** | Increases inland (?), max north of axis (?) | Increases (?) | Decreases | nd | nd |
| **'B'SP Fig. 4.11** | Increases to coast, max south of axis (?) | Decreases (??) | Increases | nd | Increases (??) |
| **'A'SP Fig. 4.17** | Increases inland overall; max south of axis (?) | Decreases (??) | Decreases (?) | Increases (??) | Variable |
| **PSP Fig. 4.24** | Increases to coast (?), local high at A-12; max south of axis (?) | Decreases (?) | Increases (?) | Decreases (?) | Increases (?) |
| **BSP Fig. 4.31** | Increases to coast, local high at A-1 (?); max south of axis (?) | nd | nd | Decreases (?) | Increases (?) |

Evidence may suggest a greater degree of variation of sandstone abundance in lower stratal packages. Drill holes containing the 'C'SP range in percent sandstone from approximately 11-72%. For the 'B'SP, percent sandstone decreases and is less variable, with a range of approximately 12-35%. The 'A'SP exhibits a percent range of approximately 5-44%, ignoring a very high value of 77% at drill hole A-12. For the Phalen Stratal Package, values range roughly from 17-34%, ignoring a high value again, at drill hole A-12 (80%). The uppermost Backpit Stratal Package exhibits percent values of 15-31%, ignoring a high value of 63% at drill hole A-1.

Trends in overall sandstone abundance are poorly defined, with a tendency to higher values in lower stratal packages. If so, it may hold true that drainage systems were more extensive in lower stratal packages. Higher sandstone percents in stratal units reflect extensive channel drainage systems, with associated splays and bay-fill sheet deposits, comprising a larger proportion of the strata (Gibling and Bird, 1994).

A possible decrease in sandstone abundance upwards through the stratal packages suggests a decrease in aggregate grain size. The Sydney Mines Formation along the Morien Syncline shows possible evidence of an environmental shift through time away from an extensive drainage system and toward a more poorly drained environment with an increase in floodplain fines and hydromorphic paleosols. The limited facies assemblage recorded throughout the 'A' series drill holes does not permit facies change to be studied more definitively. However, the Backpit Coal level, with a basin-wide capping limestone, has been taken to indicate the maximum transgressive level within the lower Sydney Mines Formation (Gibling and Bird, 1994), and the upward decrease in sandstone proportion is in accord with this suggestion. Alternatively, controlling factors for sediment transport in the Sydney Mines Formation may include proximity to sediment supply in combination with orogenic movements in the sediment-supplying hinterland (Haites, 1951).

*5.3 Strata Containing Redbeds*

Redbed abundance trends are not pronounced throughout the stratal packages present in the Morien Syncline (Table. 5.7). Precise redbed stratal proportions (i.e., 'red' lithological units in comparison to 'grey' lithological units) are uncertain where lithologies are combined in drillers' logs; hence actual redbed abundance trends are difficult to decipher. Instead, the abundance of stratal units which have recorded evidence of redbeds has been compared. Such a comparison method represents a conservative evaluation highly dependent on the logging techniques of original drillers. Abundance values proved highly erratic, although nevertheless, some trends are apparent.

The 'B'SP and PSP exhibit an increase in red shale inland. This may apply to the 'C'SP as well, although insufficient data exist for this package. The 'A'SP exhibits an overall low abundance of strata containing redbeds, however such strata do exist in the vicinity of drill hole A-2 for this stratal package. Inland to coastal trends relating to redbeds in the BSP could not be established due to insufficient data. However, the BSP does have evidence of red shale on the northern limb. Redbed abundances generally decrease toward the northern limb in the inland areas of all stratal packages, but trends are less consistent in coastal areas. Strata containing redbeds are concentrated along the southern limb of the axis, or are relatively constant, in the four lowermost packages. The BSP may actually conform to such a trend as well, although insufficient data exist for this stratal package.

Trends relating to the abundance of redbed strata within successive stratal packages are not strongly developed, although there is a slight tendency for general redbed abundance to decrease upsection. Redbeds of the Sydney Mines Formation are indicative of mature paleosols and well-drained flood plains where the water table was low (Gibling and Bird, 1994). In conjunction with sandstone abundance variations presented above, the presence of redbeds in lower stratal packages may be evidence that the Sydney Mines Formation in the Morien Syncline represents an environmental shift from extensive channel drainage systems with well-drained floodplains to an environment of poor drainage where water retention was more common.

**Table 5.7:** Abundance variation of strata containing redbeds (rb). Terms *coastal* and *inland* refer to modern geography of the Port Morien area. 'nd' denotes no data. '?' denotes uncertainty in trend evaluation. '??' denotes considerably uncertainty in trend evaluation.

| Strata containing redbeds | Trends | | | | |
|---|---|---|---|---|---|
| | Overall | Inland | | Coastal | |
| | | Axis to N | Axis to S | Axis to N | Axis to S |
| **'C'SP Fig. 4.6** | Evidence of rb inland, south of axis | nd | Increases (?) | nd | nd |
| **'B'SP Fig. 4.12** | Variable; may be highest south of axis, inland (?) | Decreases (??) | Increases (?) | Variable | Variable |
| **'A'SP Fig. 4.18** | Evidence of rb near coast (A-2), on southern limb | Constant (??) | Constant (?) | Decreases (?) | Increases (?) |
| **PSP Fig. 4.25** | Increases inland; highest south of axis | Decreases (?) | Increases | Increases (?) | Decreases (??) |
| **BSP Fig. 4.32** | Evidence of rb near coast (A-25), on northern limb | nd | nd | Increases (??) | Decreases (?) |

*5.4 Link to Paleoflow*

Paleoflow data were collected from coastal sections during fieldwork by H. L. McDonald (M.Sc. in progress) and the author. Paleoflow measurements were obtained from unipolar indicators such as trough cross strata, ripple marks, and flute casts, and bipolar indicators such as current lineations and groove casts. Overall, strata of the coastal sections exhibit relatively high flow-direction variability, which is consistent with the meandering-fluvial origin of much of the Sydney Mines Formation (Gibling *et al.*, 1992). Although paleoflow data will be thoroughly presented and analyzed by H. L. McDonald, a brief overview of unipolar indicators was compiled and made available for use in this study.

Three paleoflow measurements from the 'A'SP of the Long Beach coastal section indicate a northeasterly flow orientation. This orientation is in accordance with a study completed for the area by Gibling *et al.* (1992). Thirty-four PSP paleoflow measurements from both coastal sections convey generally a range of NW-N-NE in flow direction. Six BSP paleoflow measurements from the Long Beach coastal section convey a flow direction ranging from west to north. Overall, paleoflow measurements from the coastal sections suggest NW, N, and NE modes in flow direction, especially N and NE. This implies sediment sources to the south (transverse to the syncline axis) and to the southwest (along the syncline axis).

A possible sediment source for northward paleofluvial transport is pre-Mid-Devonian rocks located approximately 20 km due south of the Morien Syncline axis (Boehner and Giles, 1986; Pascucci *et al.*, 2000). Such rocks were most likely affected and uplifted due to accretionary forces of the Acadian Orogeny. Areal uplift of pre-Mid-Devonian basement rocks would provide an adequate sediment source for deposition within the Morien Syncline area. Elsewhere in the basin, NE paleoflow along synclinal axes is prominent (Gibling *et al.*, 1992) and appears to be the regional paleoflow pattern.

Paleoflow from the south aids in understanding the sandstone distribution observed within the Morien Syncline. Sandstone abundance is highest on the southern limb of the axis, and decreases across the syncline. The generally high proportion of red shale to the south also implies the presence of a well-drained upland. The northeasterly paleoflow directions present in the 'A'SP of the Long Beach coastal section suggest original flow directions sub-parallel with the synform.

This flow relation with synform orientation suggests that the syncline broadly corresponds to a local depocentre. Pre-existing topography such as a basement block in the proximity of the northern limb would have bordered this depocentre. It is probable that paleoflow directions were initially guided by a progressively buried paleotopography.

The presence of a paleotopographic high under the Cape Perce Anticline is possible. However, recent work by Pascucci *et al.* (2000) studying basement structures did not provide strong support for a pre-Morien high. In spite of this, good evidence in favor of a paleotopographic high arises from this study. Generally, all seam and stratal thickness variations presented strongly suggest thinning toward the northern limb of the Morien Syncline.

*5.5 Stratal Compaction and Differential Subsidence in the Morien Syncline*

Stratal package thickness is related to the compaction factor of each lithology present. Typically in sedimentary basins, shales can undergo compaction such that their compacted thickness is approximately half their original sediment thickness (Prothero and Schwab, 1996). Similarly, during coalification, peats undergo compaction to achieve thickness values only 10 % of what they originally were (Haites, 1951). In contrast, sandstone undergoes relatively little compaction during burial.

Drill hole A-1 suggests a relation between stratal package thickness and sandstone abundance. For the three uppermost stratal packages studied, A-1 represents a point of localized high sandstone abundance (Figs. 4.17; 4.24; 4.31), while at the same time representing a relatively thick stratal succession in each stratal package (Figs. 4.16; 4.23; 4.29). This suggests that thickness variation is not always attributable to position within the syncline, but may be related in some areas to sandstone abundance.

However, evidence for differential subsidence exists with the study area. Relatively high thickness values exist within stratal packages along the southern limb of the syncline, even in locations where sandstone abundance is low. For example, in the 'A'SP (Figs. 4.16; 4.17), drill holes PM-10 and A-32 exhibit average thickness values, with relatively low sandstone abundances. Similarly, drill hole A-12, located on the syncline axis, contains a thickness value below average, while having a sandstone abundance approaching 80%. Although sandstone proportion correlates locally with package thickness, systematic trends in package thickness mainly appear unrelated to lithology. Further analysis is required to explore links to compaction.

*5.6 Limitations of Data*

Several limitations exist within the data set used for this study. The simplicity of drillers' notes set limitations to the degree of facies interpretation and comparison that could be made. A study of the cyclicity of the Sydney Mines Formation within the Morien Syncline would depend on the identification of paleosols and limestones, which unfortunately were not the priority of the drillers.

More confidence in thickness values would exist if stratigraphic dips were provided for each drill hole. Since a significant percentage of dips had to be estimated, some uncertainty in thickness values is attributed to a considerable part of the data set.

It is expected that the coastal sections provide data that could be used to interpret changes and characteristics of the inland data set. Although coastal exposures aided greatly in the present analysis, additional data will become available through work by H. L. McDonald (M.Sc. in progress). Forthcoming details relating to facies assemblage, paleoflow, and grain size in particular will further constrain the results of the present study.

## Chapter 6: CONCLUSIONS

### *6.1 Key Points of Interpretation*

Several conclusions are drawn relating to the thickness and facies variation of the Sydney Mines Formation in the Morien Syncline area:

1. In comparison to thickness values in some onshore portions of synclines of the Sydney Mines Formation, interseam stratal packages studied are slightly thicker within the Morien Syncline. This suggests that differential subsidence took place across the Sydney Mines Formation outcrop area.
2. All six seam intervals studied attain maximum thickness just south of and along the Morien Syncline axis. The four uppermost seam intervals studied ('B', 'A', Phalen, Backpit) thicken inland. Seam intervals 'D' and 'C' tend to thicken toward the coast. Seam intervals generally thin towards the northern limb of the syncline, and to some degree towards the southern limb, although there may be many local variations.
3. Of four seam intervals that display splitting ('C', 'B', 'A', Backpit), three ('C', 'A', Backpit) show steady splits that become more pronounced the farther they progress. Within these seam intervals, total coal thickness is inversely related to seam interval thickness, suggesting that total coal diminishes as seam splits become more pronounced.
4. Total coal within intervals variably increases or decreases inland from the modern coastal area, with a tendency for successive seams to alternate from inland and coastward thickening. Total coal trends generally accord with seam interval trends, with modest north and southward thinning from the axis.

5. Interseam stratal packages (~20 to 70 m thick) studied generally thicken inland, with the exception of the Seam 'C' Stratal Package (Seam 'D' to Seam 'C') and the Phalen Stratal Package (Seam 'A' to Phalen Seam), which show evidence of thinning inland. With one local exception, the five stratal packages thin north of the syncline axis. There is a common tendency for thickness to increase south of the syncline axis, and attain maximum thickness just south of and along the Morien Syncline axis.
6. There is a pronounced tendency for high sandstone and red shale abundances along the southern limb of the Morien Syncline, possibly with the exception of the 'C'SP. The increased proportion of red shale may suggest that the southern limb of the syncline bordered a well-drained region close to the present Sydney Basin margin. In the Backpit Stratal Package, the presence of red shales on the northern limb suggests that the Cape Perce Anticline may have been relatively elevated.
7. Sandstone and red shale abundance values may suggest a slight progressive decrease from older to younger packages, which in turn suggests an environmental shift through time from extensive channel drainage systems with associated splays and bay-fill sheet deposits, towards a more poorly-drained environment with an increase in floodplain fines and hydromorphic paleosols. This may reflect progressive transgression through time from seam interval 'C' to the Backpit Seam level.
8. Unipolar indicators from channel bodies and associated strata in coastal sections indicate NW, N, and NE modes in flow direction, particularly N and NE. Although these provisional data require further analysis, these modes suggest

sediment sources lay to the south and southwest of the Morien Syncline area. Pre-Mid-Devonian rocks presently lie approximately 20 km south of the Morien Syncline axis, across the fault bounded basin margin, and may have been an important local source area, in accord with the general southward increase in red shale and sandstone abundance.

9. Substantial flow correspondence with synform orientation, parallel and transverse to the axis, suggests that the syncline area constituted a local depocentre during lower Sydney Mines Formation deposition.
10. Stratal package thickness locally correlates with the abundance of sandstone, which undergoes little compaction. However, relatively high thickness values exist within stratal packages along the southern limb of the syncline, even in locations where sandstone abundance is low. Thus, package thickness distribution provides evidence in support of differential subsidence.
11. The systematic distribution of stratal thickness, facies, and paleoflow within the Morien Syncline area suggests that the syncline may have been a paleotopographic low during lower Sydney Mines Formation deposition. This in turn suggests the syncline may have originated as a syndepositional feature. Subsequent deformation, possibly during the Permian (Pascucci *et al.*, 2000), enhanced an initial topography of relative highs and lows, generating dips of up to 50° on the northern limb of the syncline. Southward thickening from the syncline axis at several levels suggests that the present syncline axis does not correspond precisely with the original depocentre axis.

*6.2 Economic Implications*

The Port Morien coal district has been an area of mining interest for well over three centuries. Surface mining of coal by smugglers and local residents most likely occurred well before its official beginning in 1720. Provincial records show five mines that have operated within the Morien Syncline, focusing on the Harbour and Phalen seams. When the last operating mine had ceased production in 1930, at least 6,285,560 metric tonnes had been mined from such seams (Gregory, 1978). 'PM' series drilling completed in 1980 along the southern syncline limb confirms total coal thickness values of 0.96 m on average for what is referred to as the Spencer (Emery) Seam, which has not been mined. Shallow dips along the southern limb of less than 10° result in an overburden of approximately 30 m a kilometre down dip of the estimated seam trace, towards the axis.

Optimistic estimates of 'Spencer' (Seam 'B') coal abundance suggest that up to 9,360,000 $m^3$ of coal may exist along the onland portion of the southern limb of the syncline, assuming an average total coal thickness of 0.96 m. Such a figure arises when an area of 6.5 km by 1.5 km is assumed for the southern limb of the syncline (Fig. 1.3). Average analyses for ash and sulphur in the seam yield 8.14% and 3.41%, respectively with a calorific value of just over 13,380 Btu/lb (Gillis, 1980).

If 'Spencer' coal mining were to become feasible along the southern Morien limb, several factors exist which place constraints on overall mining procedures. Birch Grove is a suburban community located inland just south of the Morien Syncline axis. Although its current extent is unknown, its location and size (demographically and regionally) most likely would have to be considered. Furthermore, areal infrastructure may need consideration, particularly water reservoirs and possibly septic systems and related drainage systems. Boehner and Giles (1986) categorize the southern limb as a marsh environment, which suggests a waterlogged area. It is unknown how mining procedures would affect areal groundwater systems, however infrastructure and marsh environments could possibly become contaminated. Furthermore, such a waterlogged environment may hinder surface (?) or longwall (?) mining procedures, as additional costs of groundwater pumping would diminish the overall productivity of such an operation.

Aside from complications associated with the Morien Syncline southern limb, 'Spencer' Seam mining may eventually prove economically feasible in the future. As mining techniques improve, associated costs will most likely diminish. Fuel costs will always fluctuate in price, and the market for such a reservoir may develop with relatively short notice. For reasons such as this, an understanding alone of such a natural resource is an investment in itself.

*6.3 Future Recommendations*

Although none of the mines located within the Morien Syncline are currently operational, data relating to each (if attainable) could greatly add to our knowledge of inland strata. New data on inland strata could allow the presentation of an elaborate facies assemblage, which would most likely allow a more thorough understanding of the environmental shifts through time.

Boehner and Giles (1986) also show an offshore drill hole (H-3), approximately 9 km NE of Port Morien. Incorporation of this core into the data set might allow inferences to be made relating to stratal thickness variation on a much larger scale than can presently be done.

Also beneficial would be to view any stored remnants of the data set, particularly of the 'A' series drill holes. By viewing the actual cores, it may be possible to better interpret lithological descriptions as recorded by drillers, allowing more inland facies interpretation. It would also assist in lithological correlation with coastal sections, and may allow some degree of cyclothemic study to be conducted inland. Particularly useful would be the identification of limestones, paleosols, or any unit that may shed light on the sequence stratigraphic framework of the syncline.

Finally, information to be presented by H. L. McDonald (M.Sc. in progress) will shed more light on such factors as grain size variation though time, paleoflow variation, and stratal cyclicity in the Sydney Mines Formation of the Morien Syncline. When combined with the present analysis and other previous work, a thorough understanding of stratal thickness and facies variation within the Sydney Mines Formation of the Morien Syncline should emerge.

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**APPENDIX A:** Cross section correlations constructed running roughly parallel and perpendicular to the Morien Syncline axis, using defined stratal packages. Compare with isopach and isolith maps of Chapter 4. For location reference, refer to Figures 3.1 and 3.2.

**APPENDIX B:** Main spreadsheet used to analyze 'A' and 'PM' series drill holes in *RockWorks99*. 'Strat Dip' column records the stratigraphic dip of the strata at each drill hole location. If a stratigraphic dip was not presented on the original drill hole log sheet, an approximate dip value was interpolated based on those of the surrounding holes. 'Northing' and 'Easting' coordinates in UTM, as provided by D. J. Hughes of the Geological Survey of Canada in Calgary. 'Collar' column refers to surface elevation of drill holes (in metres). 'Lith' column (lithology) lists accompanying files that contain drill hole log sheets in spreadsheet form. 'Se' and 'Str' columns to the right of 'Lith' express depths in metres to each such horizon. Columns to the right of 'se' and 'str' columns present seam interval, total coal, and stratal package thicknesses based on information provided in each of the drill hole log sheets. Also recorded is the abundance of strata containing redbeds within each stratal package (rs/s %).

**APPENDIX C:** Drill hole log sheet information in spreadsheet form. 'Start' and 'End' measurements have been converted from imperial measurements on log sheets to metric. Such measurements refer to the depth to which each boundary was found. Descriptive sections incorporate any extra information that was provided on log sheets.

**APPENDIX D:** Two examples of actual drill hole information sheets (A-9, A-32). Evident on each sheet is the drill hole name, original description of location, and the company that conducted hole recovery. Also present is coordinates for a CBDC grid system, which were added at a later unknown date (top left corner). Present as well on the log sheet for drill hole A-32 is a stratigraphic dip measurement. Such a dip measurement is not presented for drill hole A-9, which had to be estimated based on those of the surrounding drill holes.

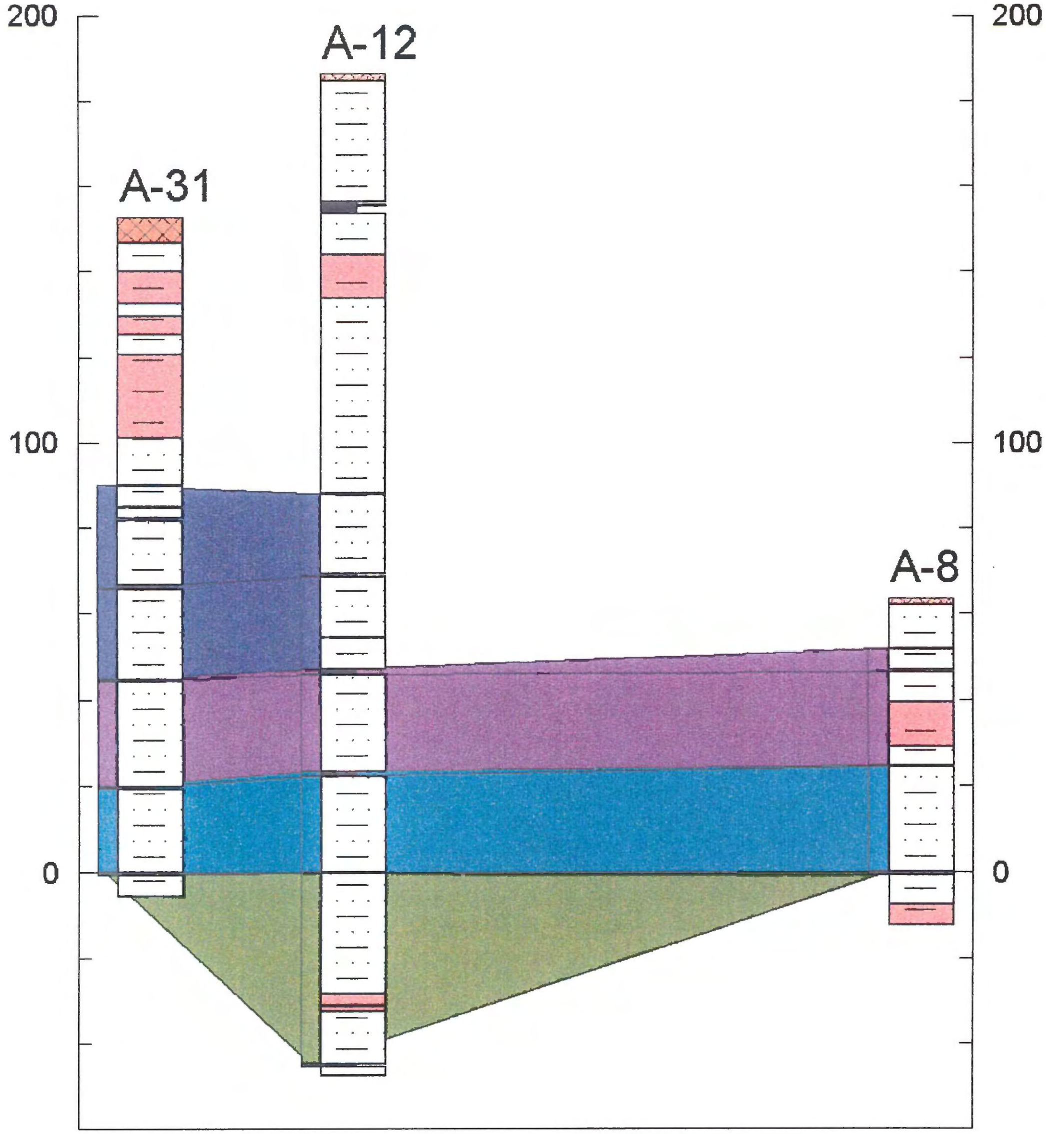



**Figure A-1:** Stratigraphic correlation of drill holes containing strata of the lowermost 'C' Stratal Package (highlighted turquoise). Also present is strata of the 'B' Stratal Package (purple) and strata of the 'A' Stratal Package (blue). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'D' used as correlation datum.

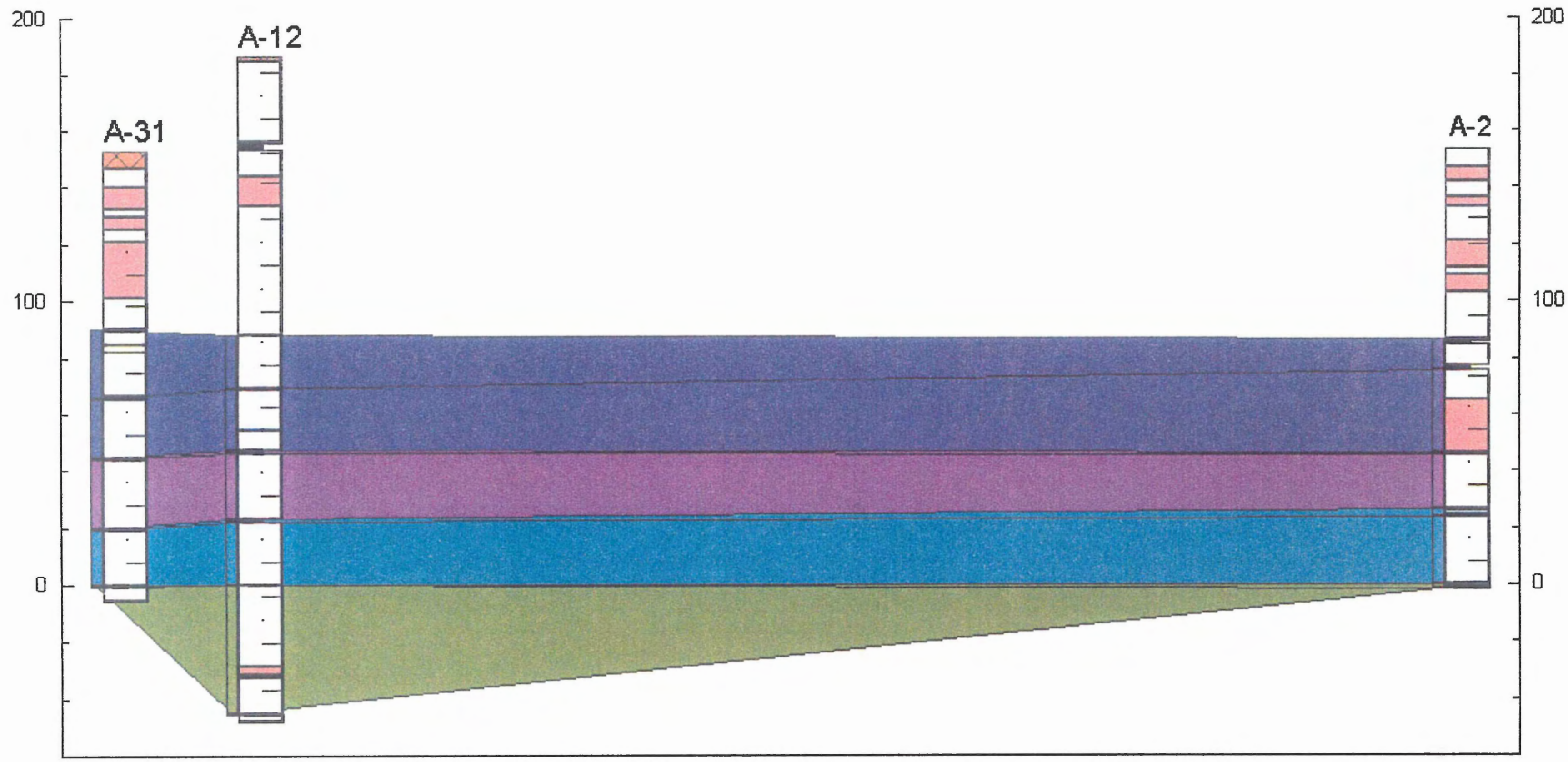



**Figure A-2:** Stratigraphic correlation of drill holes containing strata of the lowermost 'C' Stratal Package (highlighted turquoise). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'D' used as correlation datum.

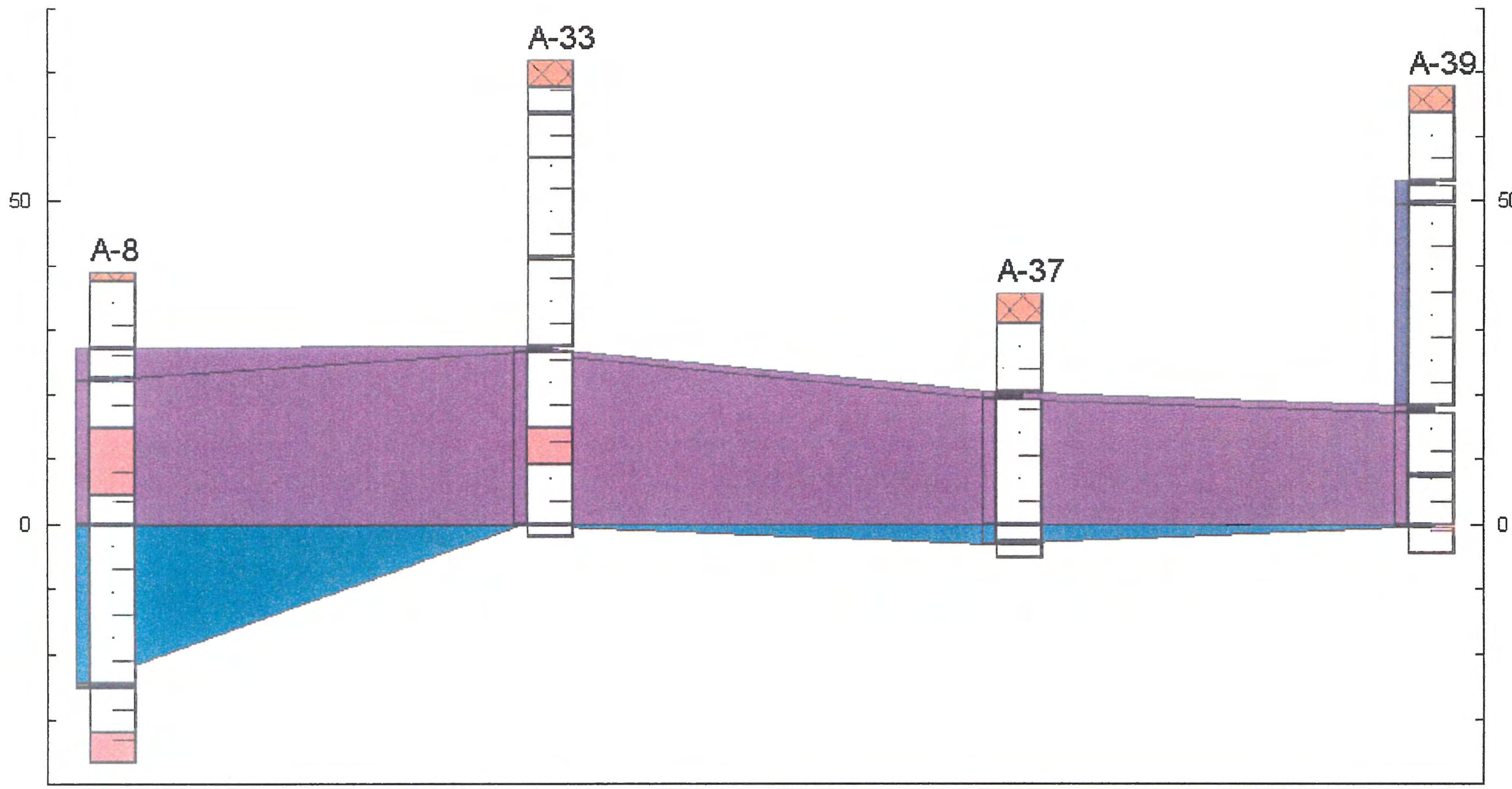



**Figure A-3:** Stratigraphic correlation of drill holes containing strata of the 'B' Stratal Package (highlighted purple). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'C' used as correlation datum.

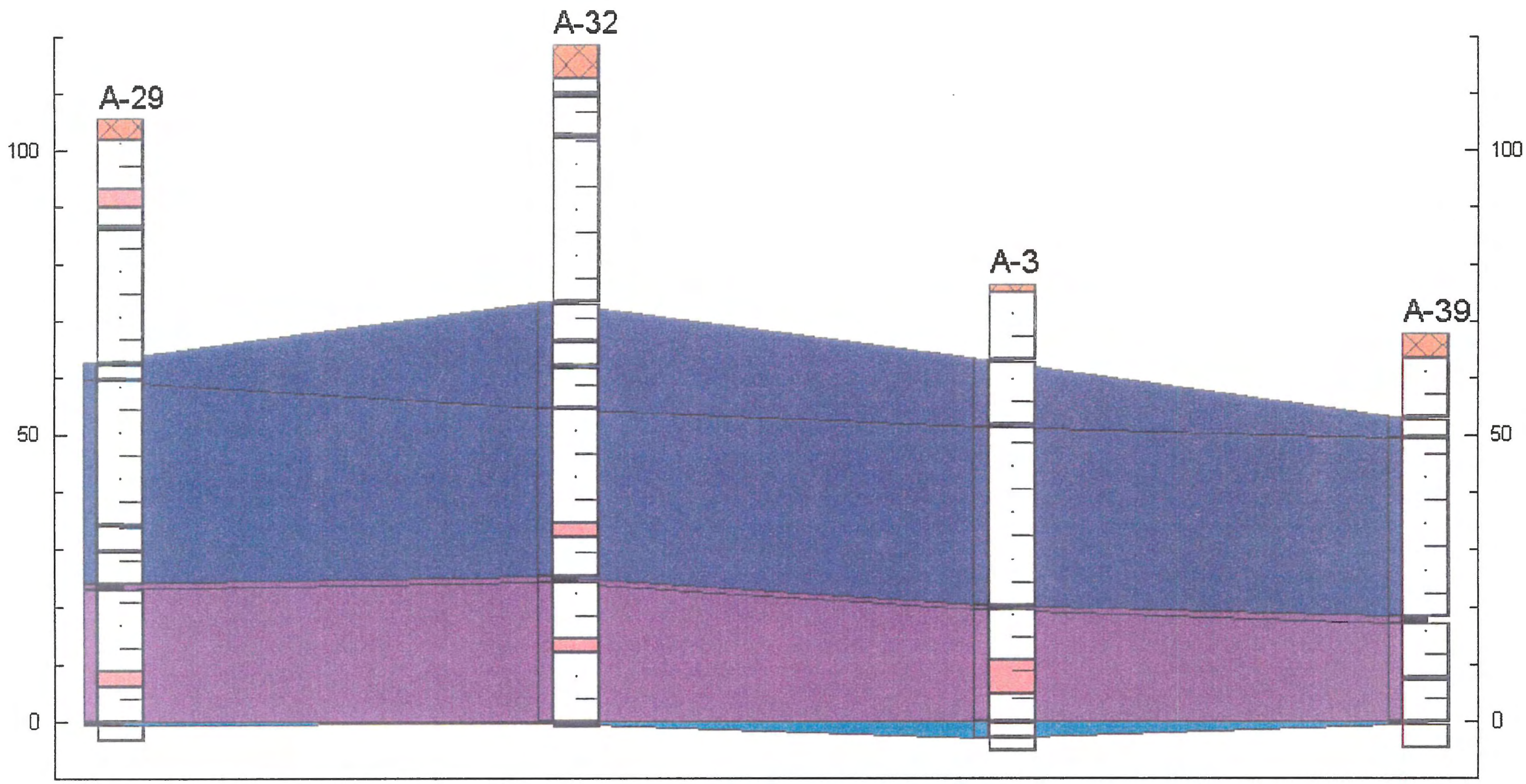



**Figure A-4:** Stratigraphic correlation of drill holes containing strata of the 'B' Stratal Package (highlighted purple). Also present is strata of the 'A' Stratal Package, highlighted blue. Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'C' used as correlation datum.

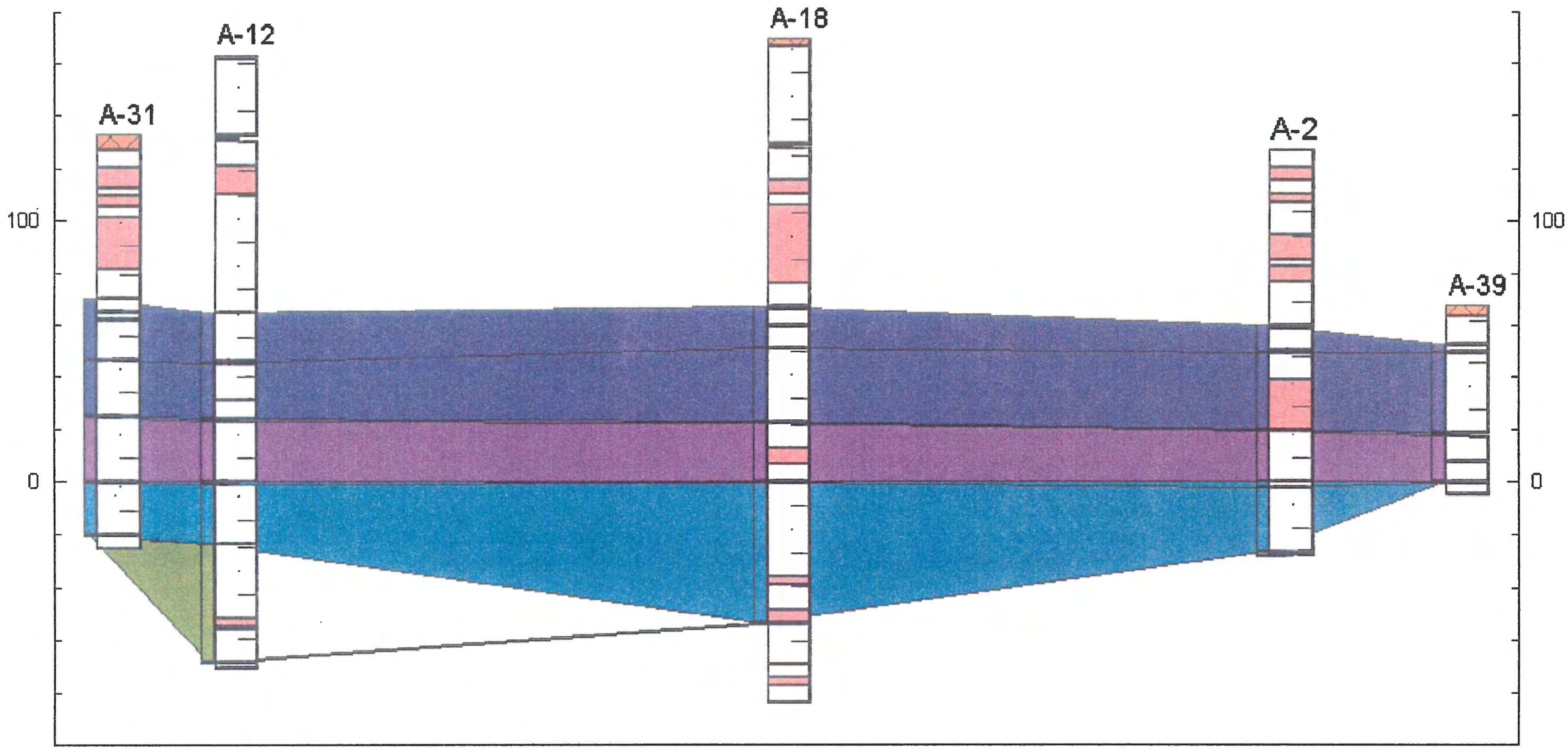



**Figure A-5:** Stratigraphic correlation of drill holes containing strata of the 'B' Stratal Package (highlighted purple). Also present is strata of the 'A' Stratal Package, highlighted blue. Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'C' used as correlation datum.

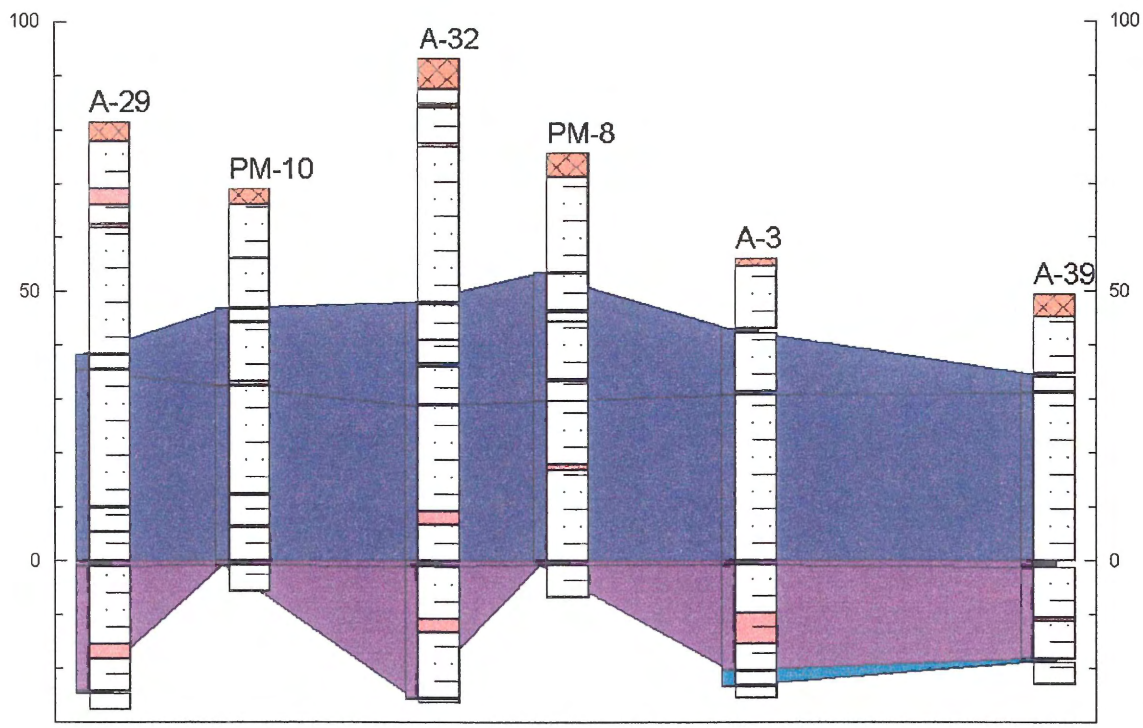



**Figure A-6:** Stratigraphic correlation of drill holes containing strata of the 'A' Stratal Package (highlighted blue). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'B' used as correlation datum.

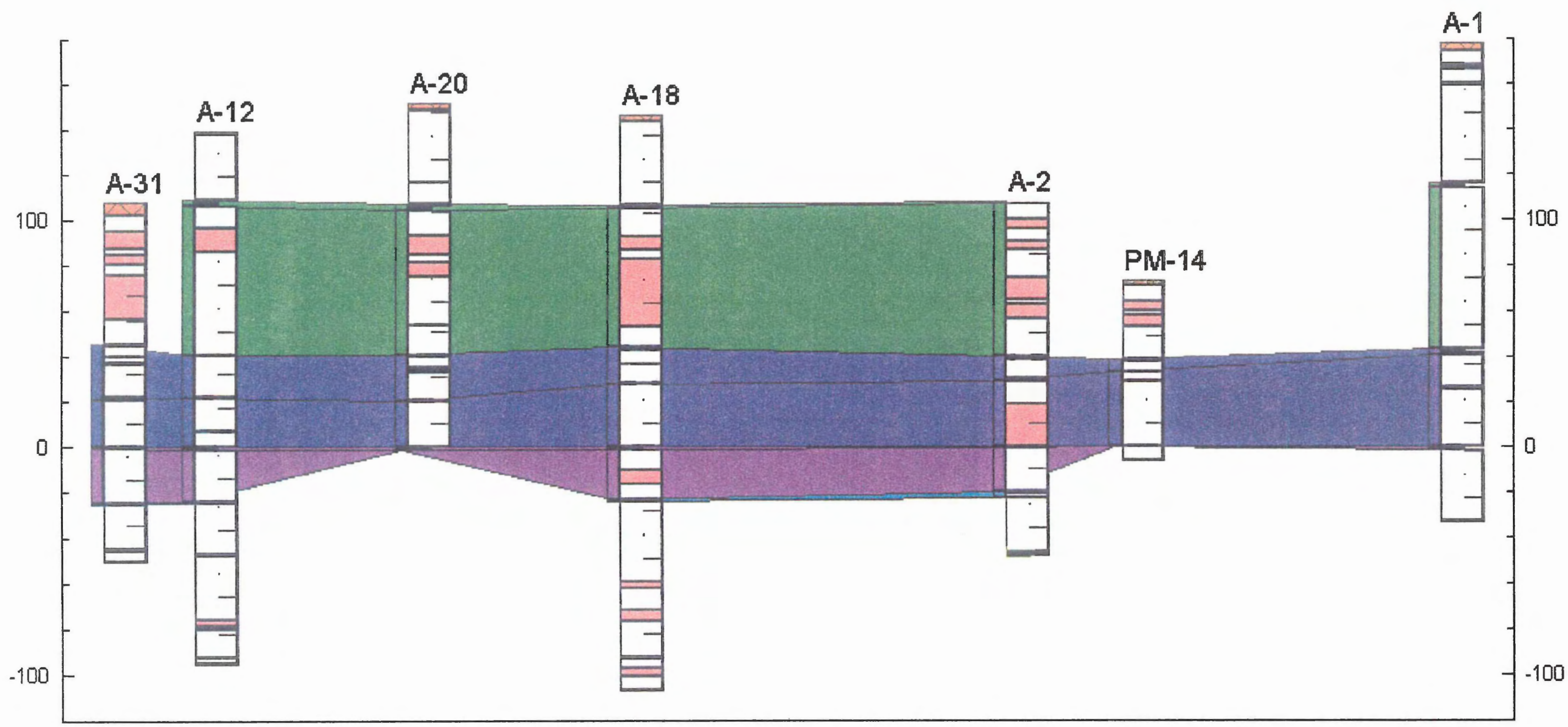



**Figure A-7:** Stratigraphic correlation of drill holes containing strata of the 'A' Stratal Package (highlighted blue). Also present is strata of the Phalen Stratal Package (highlighted green). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'B' used as correlation datum.

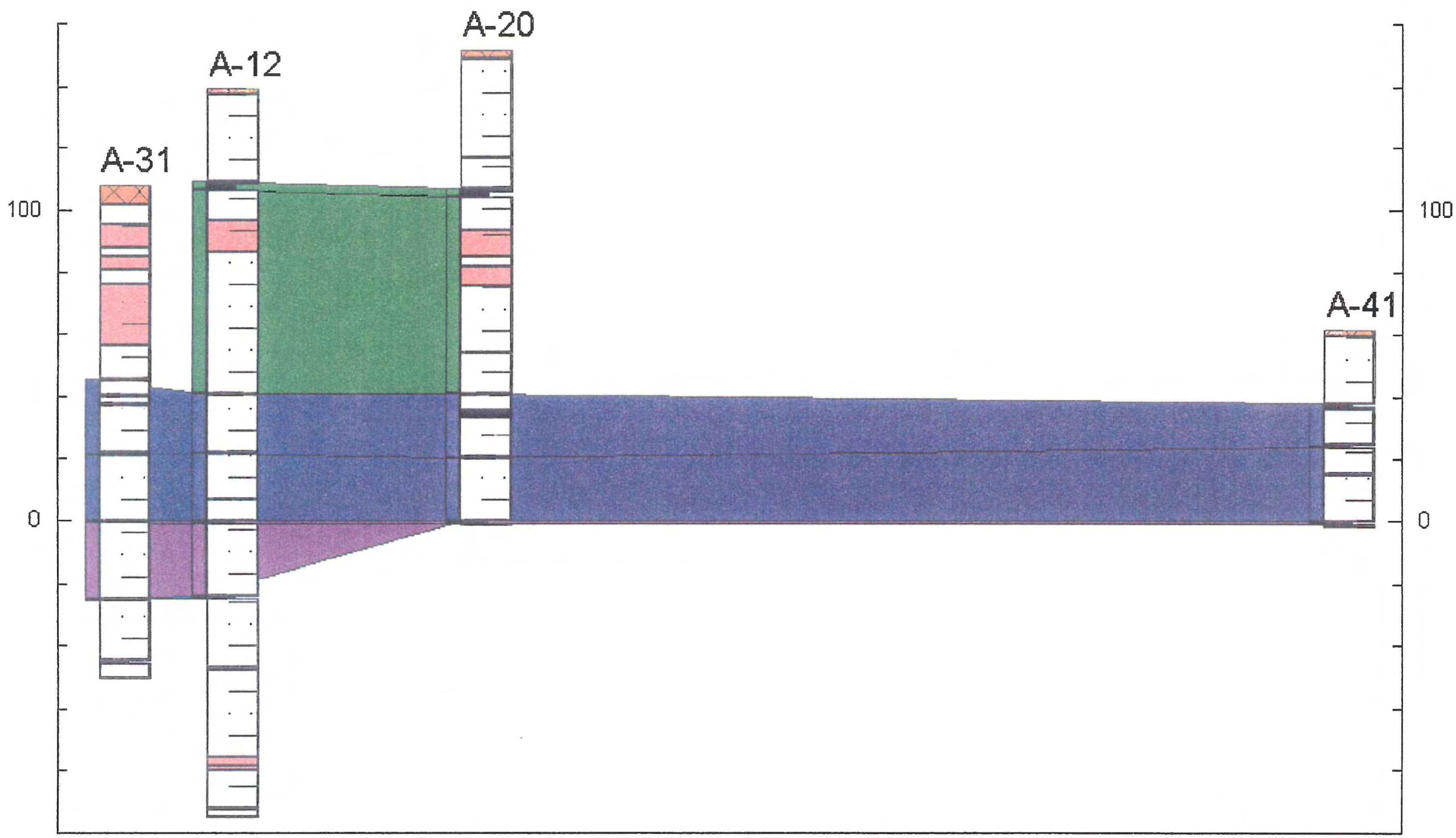



**Figure A-8:** Stratigraphic correlation of drill holes containing strata of the 'A' Stratal Package (highlighted blue). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'B' used as correlation datum.

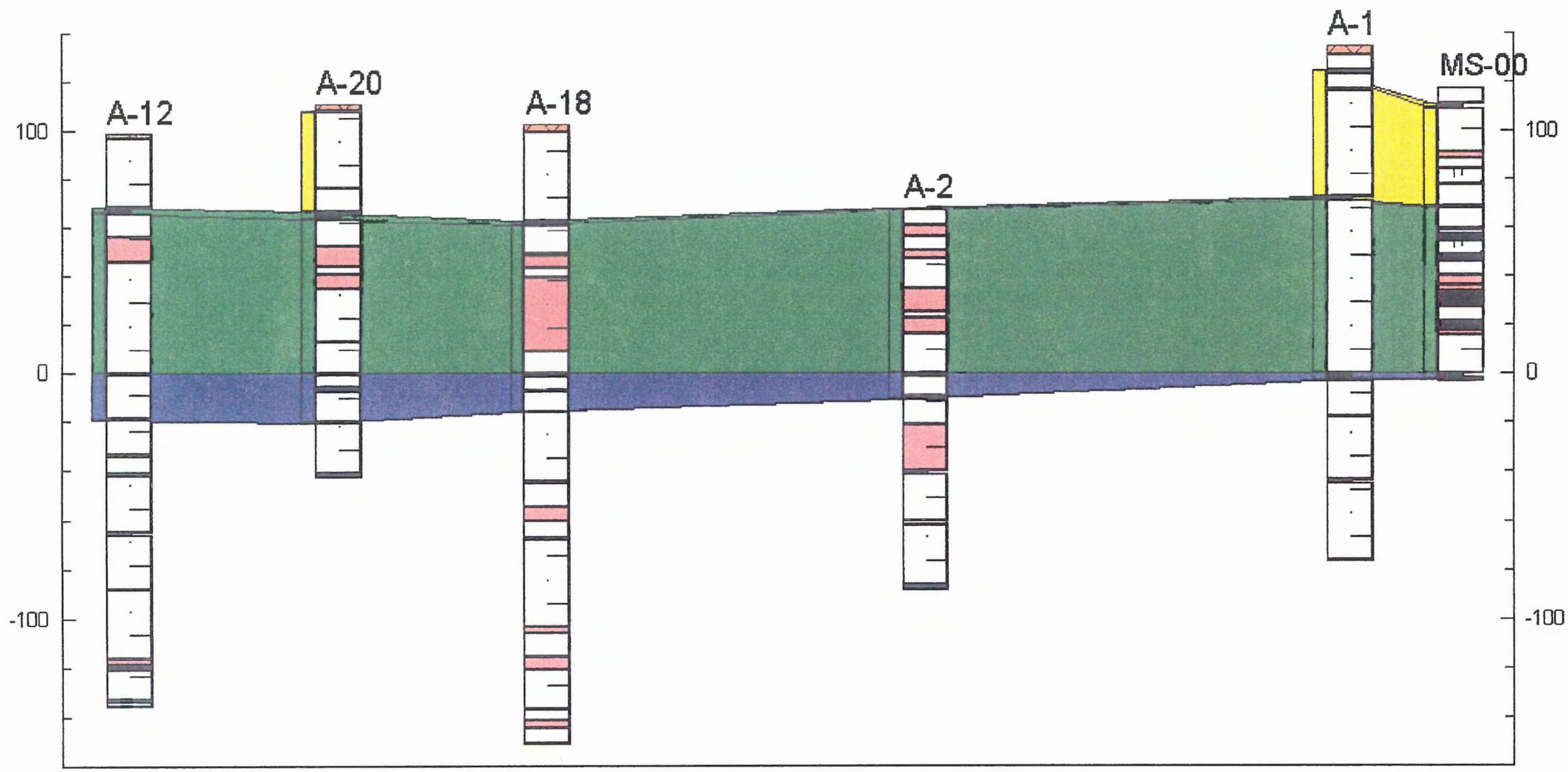



**Figure A-9:** Stratigraphic correlation of drill holes containing strata of the Phalen Stratal Package (highlighted green). Present as well is strata of the Backpit Stratal Package (highlighted yellow). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'A' used as correlation datum.

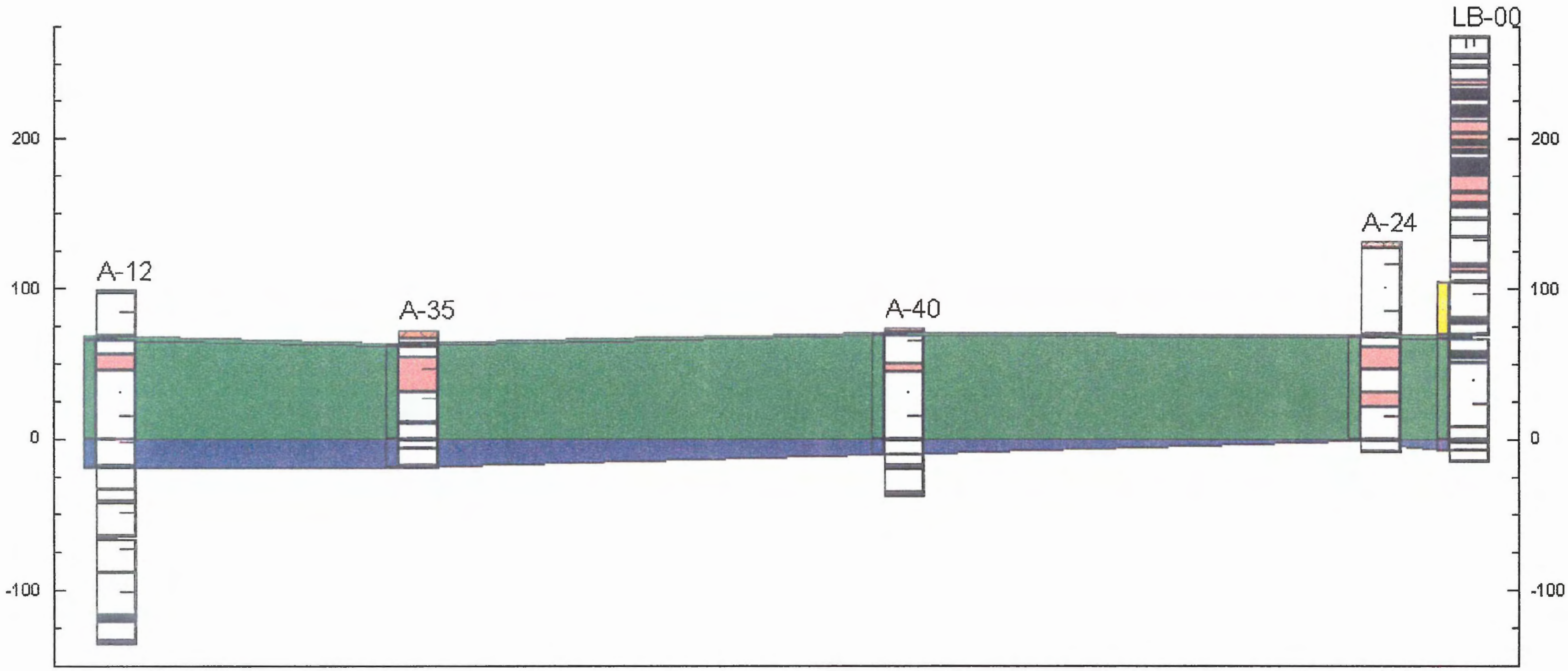



**Figure A-10:** Stratigraphic correlation of drill holes containing strata of the Phalen Stratal Package (highlighted green). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black. Upper bounding surface of Seam 'A' used as correlation datum.

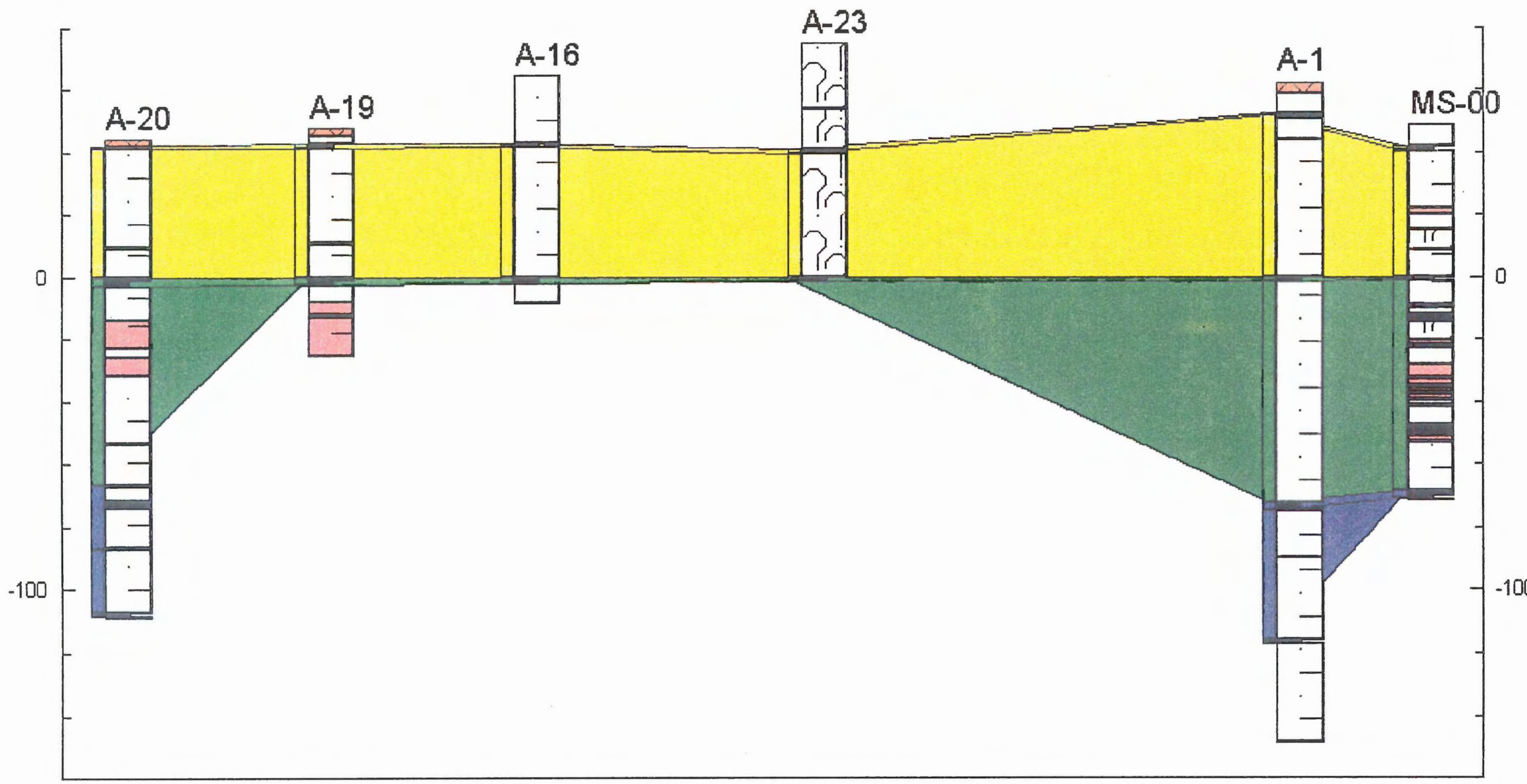



**Figure A-11:** Stratigraphic correlation of drill holes containing strata of the Backpit Stratal Package (highlighted yellow). Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black; question mark pattern (A-23) denotes unknown strata. Upper bounding surface of the Phalen Seam used as correlation datum.

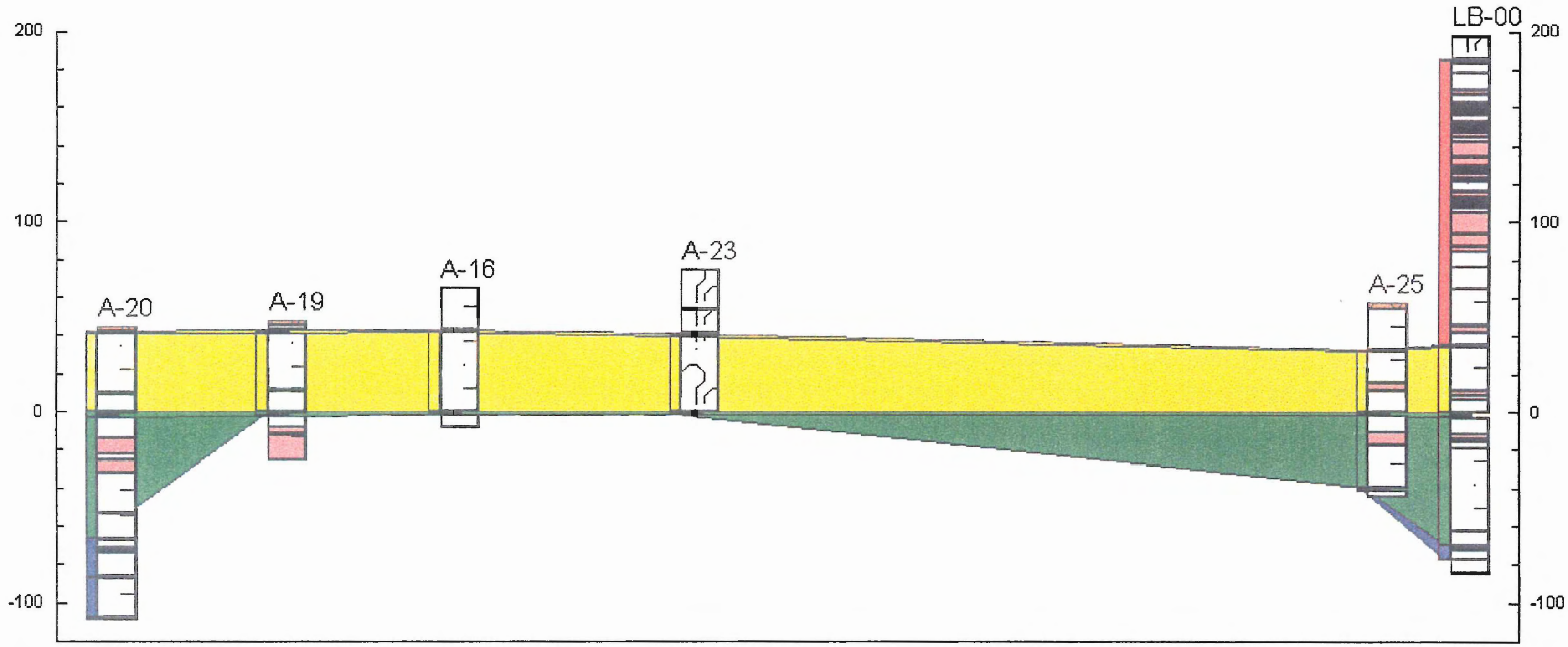



**Figure A-12:** Stratigraphic correlation of drill holes containing strata of Backpit Stratal Package (highlighted turquoise). Also present is the Long Beach (LB-00) record of the uppermost Harbour Stratal Package (red), which is not present in any other drill hole or coastal section used in this study. Grey bed strata represented as unshaded; strata containing redbeds represented as shaded; coal and coaly strata represented as indented black; question marks denote unknown strata. Upper bounding surface of the Phalen Seam used as correlation datum.

| Well ID | Strat Dip | Easting | Northing | Collar | Lith | Hbr Se | Hbr Str | BP Se | BP Str | Ph Se | Ph Str | A Se | A Str | B Se | B Str | C Se | C Str |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1 | 8 giv | 741244 | 5113030 | 13.11 | A-1.lit | | | 3.35 | 2.74 | -48.88 | -50.54 | -121.29 | -124.04 | -164.75 | -165.85 | | |
| A-2 | 7.2 giv | 739151 | 5112204 | 37.80 | A-2.Lit | | | | | 38.41 | 37.80 | -29.53 | -40.59 | -69.41 | -70.22 | -89.50 | -91.92 |
| A-3 | 8 giv | 738299 | 5111656 | 31.55 | A-3.Lit | | | | | | | 18.42 | 6.19 | -24.61 | -25.51 | -44.98 | -48.01 |
| A-7 | 14 est | 734983 | 5110624 | 38.68 | A-7.Lit | | | | | | | | | | | | |
| A-8 | 12 giv | 734978 | 5110916 | 44.23 | A-8.Lit | | | | | | | | | 32.60 | 27.23 | 5.26 | 5.08 |
| A-9 | 6.8 est | 734996 | 5111259 | 51.42 | A-9.Lit | | | | | | | 20.92 | 13.61 | | | | |
| A-10 | 5 giv | 734961 | 5111533 | 47.40 | A-10.Lit | | | | | | | 0.07 | -22.96 | -41.43 | -47.36 | | |
| A-11 | 3.5 est | 734899 | 5111829 | 51.45 | A-11.Lit | | | | | 43.84 | 40.93 | | | | | | |
| A-12 | 4 giv | 734917 | 5112236 | 42.79 | A-12.Lit | | | | | 12.70 | 9.99 | -55.67 | -75.09 | -96.45 | -97.52 | -120.33 | -121.55 |
| A-13 | 3.5 est | 733931 | 5112160 | 45.81 | A-13.Lit | | | | | 29.38 | 26.51 | | | | | | |
| A-14 | 3.5 est | 733575 | 5112132 | 50.44 | A-14.Lit | | | | | 39.48 | 36.78 | | | | | | |
| A-15 | 4 est | 737526 | 5112318 | 42.17 | A-15.Lit | | | | | -4.72 | -6.74 | | | | | | |
| A-16 | 3.5 est | 737831 | 5112602 | 36.42 | A-16.Lit | | | 14.74 | 13.59 | -28.27 | -30.08 | | | | | | |
| A-17 | 4.5 est | 737903 | 5112351 | 38.34 | A-17.Lit | | | | | -9.68 | -11.41 | | | | | | |
| A-18 | 3.5 giv | 737138 | 5112095 | 38.92 | A-18.Lit | | | | | -1.10 | -2.72 | -63.41 | -79.48 | -107.38 | -108.36 | -130.48 | -131.21 |
| A-19 | 3.5 giv | 736933 | 5112368 | 39.72 | A-19.Lit | | | 34.70 | 33.30 | -8.21 | -10.60 | | | | | | |
| A-20 | 3.5 giv | 736032 | 5112185 | 49.16 | A-20.Lit | | | 46.72 | 46.12 | 4.73 | 1.76 | -61.71 | -82.25 | -102.52 | -103.52 | | |
| A-21 | 5.8 giv | 736593 | 5111815 | 33.53 | A-21.Lit | | | | | | | -22.44 | -41.09 | | | | |
| A-22 | 4.5 est | 736184 | 5111935 | 38.56 | A-22.Lit | | | | | 25.60 | 22.51 | | | | | | |
| A-23 | 8.5 giv | 739126 | 5112733 | 48.16 | A-23.Lit | | | 14.39 | 12.68 | -26.77 | -28.43 | | | | | | |
| A-24 | 4 cal | 741822 | 5115371 | 7.62 | A-24.Lit | | | | | -54.12 | -55.82 | -123.46 | -125.29 | | | | |
| A-25 | 4 cal | 741965 | 5115097 | 10.27 | A-25.Lit | | | -14.82 | -15.28 | -47.58 | -49.04 | -86.59 | -88.42 | | | | |
| A-26 | 3.5 est | 742113 | 5114763 | 11.28 | A-26.Lit | -26.68 | -29.64 | | | | | | | | | | |
| A-27 | 7.5 est | 741590 | 5114240 | 10.97 | A-27.Lit | -35.63 | -38.42 | | | | | | | | | | |
| A-28 | 6.8 giv | 734975 | 5111008 | 48.74 | A-28.Lit | | | | | | | | | 22.10 | 17.40 | -5.30 | -5.75 |
| A-29 | 6.8 giv | 734960 | 5111398 | 49.01 | A-29.Lit | | | | | | | 6.02 | 2.92 | -32.42 | -33.49 | -56.64 | -57.10 |
| A-30 | 6.8 giv | 734983 | 5111185 | 51.45 | A-30.Lit | | | | | | | 25.12 | 19.36 | -4.26 | -10.20 | | |
| A-31 | 3 cal | 734472 | 5112396 | 40.23 | A-31.Lit | | | | | | | -22.43 | -46.76 | -67.74 | -68.20 | -92.68 | -93.13 |
| A-32 | 6 giv | 736651 | 5111703 | 31.97 | A-32.Lit | | | | | | | -13.21 | -32.26 | -61.12 | -62.18 | -86.59 | -86.94 |
| A-33 | 6 giv | 736599 | 5111272 | 30.48 | A-33.Lit | | | | | | | | | -13.79 | -14.90 | -41.38 | -41.68 |
| A-34 | 9 est | 736578 | 5111079 | 39.59 | A-34.Lit | | | | | | | | | 23.63 | 22.52 | | |
| A-35 | 16 cal | 736734 | 5112601 | 39.56 | A-35.Lit | | | | | 31.06 | 28.72 | -32.53 | -51.44 | | | | |
| A-36 | 35 giv | 738096 | 5113129 | 32.37 | A-36.Lit | | | | | | | 12.64 | -9.71 | | | | |
| A-37 | 8.2 giv | 738370 | 5111416 | 26.53 | A-37.Lit | | | | | | | | | 11.45 | 10.24 | -9.08 | -12.09 |
| A-39 | 8.8 giv | 739821 | 5111980 | 22.69 | A-39.Lit | | | | | | | 7.93 | 4.31 | -26.73 | -27.93 | -45.11 | -45.62 |
| A-40 | 32.3 giv | 739536 | 5113585 | 40.68 | A-40.Lit | | | | | 37.59 | 35.52 | -33.03 | -44.40 | -68.59 | -69.58 | | |

| Well ID | D Se | D Str | BP se (m) | BP co (m) | BSP (m) | BSP rs/s | Ph se (m) | Ph co (m) | PSP (m) | PSP rs/s | A se (m) | A co (m) | ASP (m) | ASP rs/s | B se (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1 | | | 0.61 | 0.76 | 52.23 | 0.00 | 1.66 | 1.66 | 72.41 | 0.00 | 2.75 | 2.01 | 43.46 | 0.00 | 1.10 |
| A-2 | -115.69 | -117.40 | | | | | 0.61 | | 67.94 | 35.20 | 11.06 | 1.96 | 39.88 | 47.00 | 0.81 |
| A-3 | | | | | | | | | | | 12.23 | 1.35 | 43.03 | 0.00 | 0.90 |
| A-7 | 28.23 | 28.01 | | | | | | | | | | | | | |
| A-8 | -19.26 | -19.97 | | | | | | | | | | | | | 5.37 |
| A-9 | | | | | | | | | | | 7.31 | 0.93 | | | |
| A-10 | | | | | | | | | | | 23.03 | 1.85 | 41.50 | 0.00 | 5.93 |
| A-11 | | | | | | | 2.91 | 2.03 | | | | | | | |
| A-12 | -143.62 | -143.77 | | | | | 2.71 | 2.24 | 68.37 | 15.20 | 19.42 | 0.90 | 40.78 | 0.00 | 1.07 |
| A-13 | | | | | | | 2.87 | 2.50 | | | | | | | |
| A-14 | | | | | | | 2.70 | 2.19 | | | | | | | |
| A-15 | | | | | | | 2.02 | 2.02 | | | | | | | |
| A-16 | | | 1.15 | 1.07 | 43.01 | 0.00 | 1.81 | 1.81 | | | | | | | |
| A-17 | | | | | | | 1.73 | 1.73 | | | | | | | |
| A-18 | | | | | | | 1.62 | 1.47 | 62.31 | 56.70 | 16.07 | 1.47 | 43.97 | 0.00 | 0.98 |
| A-19 | | | 1.40 | 1.40 | 42.91 | 0.00 | 2.39 | 2.39 | | | | | | | |
| A-20 | | | 0.60 | 0.60 | 41.99 | 0.00 | 2.97 | 2.42 | 66.44 | 21.70 | 20.54 | 2.23 | 40.81 | 0.00 | 1.00 |
| A-21 | | | | | | | | | | | 18.65 | 2.22 | | | |
| A-22 | | | | | | | 3.09 | 3.09 | | | | | | | |
| A-23 | | | 1.71 | | 41.16 | | 1.66 | 1.66 | | | | | | | |
| A-24 | | | | | | | 1.70 | 1.70 | 69.34 | 34.70 | 1.83 | 1.83 | | | |
| A-25 | | | 0.46 | 0.46 | 32.76 | 10.20 | 1.46 | 1.46 | 39.01 | 17.20 | 1.83 | 1.83 | | | |
| A-26 | | | | | | | | | | | | | | | |
| A-27 | | | | | | | | | | | | | | | |
| A-28 | -23.31 | -23.57 | | | | | | | | | | | | | 4.70 |
| A-29 | | | | | | | | | | | 3.10 | 0.53 | 38.44 | 0.00 | 1.07 |
| A-30 | | | | | | | | | | | 5.76 | 0.70 | 29.38 | 0.00 | 5.94 |
| A-31 | -112.45 | -113.06 | | | | | | | | | 24.33 | 1.68 | 45.31 | 0.00 | 0.46 |
| A-32 | | | | | | | | | | | 19.05 | 1.31 | 47.91 | 5.10 | 1.06 |
| A-33 | | | | | | | | | | | | | | | 1.11 |
| A-34 | | | | | | | | | | | | | | | 1.11 |
| A-35 | | | | | | | 2.34 | 2.34 | 63.59 | 44.50 | 18.91 | 2.03 | | 0.00 | |
| A-36 | | | | | | | | | | | 22.35 | 1.13 | | | |
| A-37 | | | | | | | | | | | | | | | 1.21 |
| A-39 | | | | | | | | | | | 3.62 | 0.91 | 34.66 | 0.00 | 1.20 |
| A-40 | | | | | | | 2.07 | 2.07 | 70.62 | 7.30 | 11.37 | 1.66 | 35.56 | 5.80 | 0.99 |

| Well ID | B co (m) | BSP (m) | BSP rs/s | C se (m) | C co (m) | D se (m) | D co (m) |
|---|---|---|---|---|---|---|---|
| A-1 | 1.10 | | | | | | |
| A-2 | 0.81 | 20.09 | 0.00 | 2.42 | 0.36 | 1.71 | 0.53 |
| A-3 | 0.90 | 20.37 | 28.20 | 3.03 | 0.61 | | |
| A-7 | | | | | | 0.22 | 0.13 |
| A-8 | 0.90 | 27.34 | 38.10 | 0.18 | 0.18 | 0.71 | 0.22 |
| A-9 | | | | | | | |
| A-10 | 1.33 | | | | | | |
| A-11 | | | | | | | |
| A-12 | 1.07 | 23.88 | 0.00 | 1.22 | 1.22 | 0.15 | 0.15 |
| A-13 | | | | | | | |
| A-14 | | | | | | | |
| A-15 | | | | | | | |
| A-16 | | | | | | | |
| A-17 | | | | | | | |
| A-18 | 0.98 | 23.10 | 26.30 | 0.73 | 0.73 | | |
| A-19 | | | | | | | |
| A-20 | 1.02 | | | | | | |
| A-21 | | | | | | | |
| A-22 | | | | | | | |
| A-23 | | | | | | | |
| A-24 | | | | | | | |
| A-25 | | | | | | | |
| A-26 | | | | | | | |
| A-27 | | | | | | | |
| A-28 | 1.38 | 27.40 | 12.20 | 0.45 | 0.45 | 0.26 | 0.26 |
| A-29 | 1.23 | 24.22 | 11.20 | 0.46 | 0.46 | | |
| A-30 | 1.19 | | | | | | |
| A-31 | 0.46 | 24.94 | 0.00 | 0.45 | 0.45 | 0.61 | 0.61 |
| A-32 | 1.06 | 25.47 | 9.50 | 0.35 | 0.35 | | |
| A-33 | 1.11 | 27.59 | 20.90 | 0.30 | 0.30 | | |
| A-34 | 1.11 | | | | | | |
| A-35 | | | | | | | |
| A-36 | | | | | | | |
| A-37 | 1.21 | 20.53 | 0.00 | 3.01 | 0.60 | | |
| A-39 | 1.20 | 18.38 | 0.00 | 0.51 | 0.51 | | |
| A-40 | 0.89 | | | | | | |

| Well ID | Strat Dip | Easting | Northing | Collar | Lith | Hbr Se | Hbr Str | BP Se | BP Str | Ph Se | Ph Str | A Se | A Str | B Se | B Str | C Se | C Str |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-41 | 32.3 giv | 739519 | 5113671 | 40.48 | A-41.Lit | | | | | | | 16.77 | 2.86 | -21.11 | -22.27 | | |
| LB-00 | n/a | 742360 | 5115300 | 60.99 | LB-00.Lit | 48.74 | 48.00 | -101.70 | -102.70 | -137.23 | -140.03 | -207.03 | -214.56 | | | | |
| MS-00 | n/a | 741500 | 5112500 | 40.20 | MS-00.Lit | | | 33.29 | 31.50 | -8.72 | -9.52 | -77.24 | -79.60 | | | | |
| PM-7 | 10 giv | 738352 | 5111821 | 29.08 | PM-07.Lit | | | | | | | 15.70 | 14.06 | -14.51 | -15.06 | | |
| PM-8 | 8 giv | 737322 | 5111601 | 30.40 | PM-08.Lit | | | | | | | 8.26 | -15.52 | -45.21 | -45.98 | | |
| PM-10 | 6 giv | 735678 | 5111553 | 47.37 | PM-10.Lit | | | | | | | 25.21 | 10.68 | -21.76 | -22.67 | | |
| PM-12 | 7 giv | 735200 | 5111397 | 50.47 | PM-12.Lit | | | | | | | 38.97 | 27.12 | 4.02 | -2.06 | | |
| PM-14 | 8 giv | 739747 | 5112307 | 27.04 | PM-14.Lit | | | | | | | -7.50 | -13.24 | -46.45 | -46.66 | | |
| PM-20 | 9 giv | 738345 | 5111577 | 25.24 | PM-20.Lit | | | | | | | | | 19.82 | 18.92 | | |
| PM-21 | 8 giv | 738932 | 5111838 | 38.25 | PM-21.Lit | | | | | | | | | 3.78 | 2.95 | | |
| PM-22 | 9 giv | 736597 | 5111377 | 26.24 | PM-22.Lit | | | | | | | | | 0.90 | 0.07 | | |
| PM-23 | 12 giv | 734412 | 5111391 | 60.99 | PM-23.Lit | | | | | | | | | 36.81 | 36.49 | | |
| PM-29 | 9 est | 739933 | 5112126 | 16.86 | PM-29.Lit | | | | | | | | | -9.04 | -10.06 | | |
| PM-30 | 9 est | 739989 | 5112011 | 12.04 | PM-30.Lit | | | | fault | | zone? | | | -4.05 | -4.82 | | fault |
| PM-31 | 9 est | 739993 | 5111943 | 9.66 | PM-31.Lit | | | | | | | | | | | | |
| PM-32 | 9 est | 734956 | 5111200 | 50.26 | PM-32.Lit | | | | | | | 35.68 | 22.10 | | | | |
| PM-33 | 10 est | 736071 | 5111108 | 30.66 | PM-33.Lit | | | | | | | | | | | | |
| PM-35 | 9 est | 739416 | 5111768 | 18.47 | PM-35.Lit | | | | | | | | | | | | |
| PM-37 | 9 est | 739256 | 5111790 | 24.41 | PM-37.Lit | | | | fault | | zone? | | | | | | fault |
| PM-41 | 8 est | 735697 | 5111315 | 40.20 | PM-41.Lit | | | | | | | | | 5.81 | 4.95 | | |
| PM-42 | 12 est | 735703 | 5111199 | 35.00 | PM-42.Lit | | | | | | | | | 21.05 | 20.64 | | |
| PM-43 | 10 est | 736010 | 5111293 | 35.20 | PM-43.Lit | | | | | | | | | 8.39 | 7.85 | | |
| PM-44 | 8 est | 735284 | 5111352 | 32.70 | PM-44.Lit | | | | | | | | | -0.99 | -1.85 | | |
| PM-45 | 9 est | 736264 | 5111252 | 28.10 | PM-45.Lit | | | | | | | | | 13.58 | 12.40 | | |
| PM-46 | 10 giv | 736869 | 5111482 | 25.80 | PM-46.Lit | | | | | | | | | -9.89 | -10.54 | | |
| PM-47 | 9.5 est | 736908 | 5111326 | 20.80 | PM-47.Lit | | | | | | | | | 8.03 | 7.20 | | |
| PM-48 | 10 est | 737101 | 5111496 | 26.40 | PM-48.Lit | | | | | | | | | -8.71 | -9.75 | | |
| PM-49 | 9.5 est | 738664 | 5111787 | 34.20 | PM-49.Lit | | | | | | | | | 0.37 | -0.42 | | |
| PM-50 | 8.2 est | 738669 | 5111644 | 55.99 | PM-50.Lit | | | | | | | | | | | | |

| Well ID | D Se | D Str | BP se (m) | BP co (m) | BSP (m) | BSP rs/s | Ph se (m) | Ph co (m) | PSP (m) | PSP rs/s | A se (m) | A co (m) | ASP (m) | ASP rs/s | B se (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-41 | | | | | | | | | | | 13.91 | 1.94 | 37.88 | 0.00 | 1.16 |
| LB-00 | | | | | 35.53 | | 2.80 | 3.05 | 69.80 | | 7.53 | | | | |
| MS-00 | | | 1.79 | 1.79 | 42.01 | | 0.80 | 0.80 | 68.52 | | 2.36 | | | | |
| PM-7 | | | | | | | | | | | 1.64 | 0.81 | 30.21 | | 0.55 |
| PM-8 | | | | | | | | | | | 23.78 | 0.89 | 53.47 | | 0.77 |
| PM-10 | | | | | | | | | | | 14.53 | 0.58 | 46.97 | | 0.91 |
| PM-12 | | | | | | | | | | | 11.85 | 0.23 | 34.95 | | 6.08 |
| PM-14 | | | | | | | | | | | 5.74 | 0.48 | 38.95 | | 0.21 |
| PM-20 | | | | | | | | | | | | | | | 0.90 |
| PM-21 | | | | | | | | | | | | | | | 0.83 |
| PM-22 | | | | | | | | | | | | | | | 0.83 |
| PM-23 | | | | | | | | | | | | | | | 0.32 |
| PM-29 | | | | | | | | | | | | | | | 1.02 |
| PM-30 | | zone? | | | | | | | | | | | | | 0.77 |
| PM-31 | | | | | | | | | | | | | | | |
| PM-32 | | | | | | | | | | | 13.58 | 1.14 | | | |
| PM-33 | | | | | | | | | | | | | | | |
| PM-35 | | | | | | | | | | | | | | | |
| PM-37 | | zone? | | | | | | | | | | | | | |
| PM-41 | | | | | | | | | | | | | | | 0.86 |
| PM-42 | | | | | | | | | | | | | | | 0.41 |
| PM-43 | | | | | | | | | | | | | | | 0.54 |
| PM-44 | | | | | | | | | | | | | | | 0.86 |
| PM-45 | | | | | | | | | | | | | | | 1.18 |
| PM-46 | | | | | | | | | | | | | | | 0.65 |
| PM-47 | | | | | | | | | | | | | | | 0.83 |
| PM-48 | | | | | | | | | | | | | | | 1.04 |
| PM-49 | | | | | | | | | | | | | | | 0.79 |
| PM-50 | | | | | | | | | | | | | | | |

| Well ID | B co (m) | BSP (m) | BSP rs/s | C se (m) | C co (m) | D se (m) | D co (m) |
|---|---|---|---|---|---|---|---|
| A-41 | 1.16 | | | | | | |
| LB-00 | | | | | | | |
| MS-00 | | | | | | | |
| PM-7 | 0.55 | | | | | | |
| PM-8 | 0.77 | | | | | | |
| PM-10 | 0.91 | | | | | | |
| PM-12 | 0.61 | | | | | | |
| PM-14 | 0.21 | | | | | | |
| PM-20 | 0.90 | | | | | | |
| PM-21 | 0.83 | | | | | | |
| PM-22 | 0.83 | | | | | | |
| PM-23 | 0.32 | | | | | | |
| PM-29 | 1.02 | | | | | | |
| PM-30 | 0.77 | | | | | | |
| PM-31 | | | | | | | |
| PM-32 | | | | | | | |
| PM-33 | | | | | | | |
| PM-35 | | | | | | | |
| PM-37 | | | | | | | |
| PM-41 | 0.66 | | | | | | |
| PM-42 | 0.60 | | | | | | |
| PM-43 | 0.54 | | | | | | |
| PM-44 | 0.86 | | | | | | |
| PM-45 | 1.18 | | | | | | |
| PM-46 | 0.65 | | | | | | |
| PM-47 | 0.83 | | | | | | |
| PM-48 | 1.04 | | | | | | |
| PM-49 | 0.79 | | | | | | |
| PM-50 | | | | | | | |

A-1

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.32 | Overburden | |
| 3.32 | 9.76 | Strata | |
| 9.76 | 10.37 | Coal | 2'0" |
| 10.37 | 11.27 | Strata | |
| 11.27 | 11.42 | Coal | 0'6" |
| 11.42 | 18.06 | Strata | |
| 18.06 | 18.27 | Coal | 0'8" |
| 18.27 | 61.99 | Strata | |
| 61.99 | 63.65 | Coal | 5'6" |
| 63.65 | 134.40 | Strata | |
| 134.40 | 135.88 | Coal | 4'10 3/4" |
| 135.88 | 136.62 | Strata | |
| 136.62 | 137.15 | Coal | 1'9 3/4" |
| 137.15 | 151.90 | Strata | |
| 151.90 | 152.07 | Coal | 0'7" |
| 152.07 | 177.86 | Strata | |
| 177.86 | 178.96 | Coal | 3'8" |
| 178.96 | 210.69 | Strata | |

A-2

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 6.84 | Strata | |
| 6.84 | 11.49 | with rb Strata | |
| 11.49 | 16.94 | Strata | |
| 16.94 | 20.26 | with rb Strata | |
| 20.26 | 32.67 | Strata | |
| 32.67 | 42.04 | with rb Strata | |
| 42.04 | 44.47 | Strata | |
| 44.47 | 50.82 | with rb Strata | |
| 50.82 | 67.33 | Strata | |
| 67.33 | 67.53 | Coal | |
| 67.53 | 67.78 | Strata | |
| 67.78 | 68.57 | Coal | |
| 68.57 | 76.69 | Strata | 2'6" |
| 76.69 | 77.44 | Coal | |
| 77.44 | 78.17 | Strata | 0'9" |
| 78.17 | 78.39 | Coal | |
| 78.39 | 88.48 | Strata | |
| 88.48 | 107.21 | with rb Strata | 2'8" |
| 107.21 | 108.02 | Coal | |
| 108.02 | 127.30 | Strata | 0'8" |
| 127.30 | 127.51 | Coal | |
| 127.51 | 129.57 | Strata | 0'6" |
| 129.57 | 129.72 | Coal | |
| 129.72 | 153.49 | Strata | 1'4" |
| 153.49 | 153.90 | Coal | |
| 153.90 | 155.08 | Strata | 0'5" |
| 155.08 | 155.20 | Coal | |

A-3

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 1.51 | Overburden | |
| 1.51 | 13.13 | Strata | |
| 13.13 | 13.88 | Coal | 2'6" |
| 13.88 | 24.76 | Strata | |
| 24.76 | 25.36 | Coal | 2'0" |
| 25.36 | 56.16 | Strata | |
| 56.16 | 57.06 | Coal | 3'0" |
| 57.06 | 65.94 | Strata | |
| 65.94 | 71.69 | with rb Strata | |
| 71.69 | 76.53 | Strata | |
| 76.53 | 76.83 | Coal | 1'0" |
| 76.83 | 79.25 | Strata | |
| 79.25 | 79.56 | Coal | 1'0" |
| 79.56 | 81.67 | Strata | |

A-7

| Start | End | Keyword |
|---|---|---|
| 0.00 | 3.41 | Overburden |
| 3.41 | 10.45 | Strata |
| 10.45 | 10.53 | Coal |
| 10.53 | 10.62 | Strata |
| 10.62 | 10.67 | Coal |
| 10.67 | 19.52 | Strata |
| 19.52 | 46.22 | with rb Strata |
| 46.22 | 54.21 | Strata |
| 54.21 | 59.53 | with rb Strata |

A-8

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 1.49 | Overburden | |
| 1.49 | 11.63 | Strata | |
| 11.63 | 11.93 | Coal | 1'0" |
| 11.93 | 16.40 | Strata | |
| 16.40 | 17.00 | Coal | 2'0" |
| 17.00 | 24.16 | Strata | |
| 24.16 | 34.59 | with rb Strata | |
| 34.59 | 38.97 | Strata | |
| 38.97 | 39.15 | Coal | |
| 39.15 | 63.49 | Strata | |
| 63.49 | 63.60 | Coal | |
| 63.60 | 64.09 | Strata | |
| 64.09 | 64.20 | Coal | |
| 64.20 | 70.97 | Strata | |
| 70.97 | 75.75 | with rb Strata | |

A-9

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.27 | Overburden | |
| 2.27 | 16.65 | Strata | |
| 16.65 | 16.72 | Coal | 0'3" |
| 16.72 | 25.25 | Strata | |
| 25.25 | 25.56 | Coal | |
| 25.56 | 30.50 | Strata | |
| 30.50 | 30.57 | Coal | |
| 30.57 | 30.70 | Strata | |
| 30.70 | 30.98 | Coal | |
| 30.98 | 37.54 | Strata | |
| 37.54 | 37.81 | Coal | 0'11" |
| 37.81 | 53.51 | Strata | |
| 53.51 | 53.61 | Coal | |
| 53.61 | 62.06 | Strata | |

A-10

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 1.51 | Overburden | |
| 1.51 | 1.82 | Strata | |
| 1.82 | 8.50 | with rb Strata | |
| 8.50 | 9.42 | Strata | |
| 9.42 | 17.62 | with rb Strata | |
| 17.62 | 20.96 | Strata | |
| 20.96 | 33.11 | with rb Strata | |
| 33.11 | 47.33 | Strata | |
| 47.33 | 47.66 | Coal | |
| 47.66 | 47.73 | Strata | |
| 47.73 | 47.81 | Coal | |
| 47.81 | 49.81 | Strata | |
| 49.81 | 50.26 | Coal | mixture |
| 50.26 | 57.55 | Strata | |
| 57.55 | 57.68 | Coal | |
| 57.68 | 59.22 | Strata | |
| 59.22 | 59.83 | Coal | mixture |
| 59.83 | 70.11 | Strata | |
| 70.11 | 70.36 | Coal | 0'10" |
| 70.36 | 88.83 | Strata | |
| 88.83 | 89.04 | Coal | mixture |
| 89.04 | 93.64 | Strata | |
| 93.64 | 94.76 | Coal | 3'8" |
| 94.76 | 95.37 | Strata | |

A-11

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.65 | Overburden | |
| 3.65 | 7.61 | Strata | |
| 7.61 | 7.99 | Coal | 1'3" |
| 7.99 | 8.87 | Strata | |
| 8.87 | 10.52 | Coal | 5'5" |
| 10.52 | 10.68 | Strata | |

A-12

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 1.52 | Overburden | |
| 1.52 | 30.09 | Strata | |
| 30.09 | 30.54 | Coal | 1'6" |
| 30.54 | 31.01 | Strata | |
| 31.01 | 32.80 | Coal | 5'10" |
| 32.80 | 42.33 | Strata | |
| 42.33 | 52.69 | with rb Strata | |
| 52.69 | 98.46 | Strata | |
| 98.46 | 98.67 | Coal | 0'8" |
| 98.67 | 117.09 | Strata | |
| 117.09 | 117.55 | Coal | dirty 1'6" |
| 117.55 | 117.65 | Strata | |
| 117.65 | 117.88 | Coal | dirty 0'9" |
| 117.88 | 132.00 | Strata | |
| 132.00 | 132.15 | Coal | dirty 0'6" |
| 132.15 | 139.24 | Strata | |
| 139.24 | 140.31 | Coal | 3'6" |
| 140.31 | 163.12 | Strata | |
| 163.12 | 164.34 | Coal | dirty 4'0" |
| 164.34 | 186.41 | Strata | |
| 186.41 | 186.56 | Coal | 0'6" |
| 186.56 | 214.80 | Strata | |
| 214.80 | 217.53 | with rb Strata | |
| 217.53 | 217.76 | Strata | |
| 217.76 | 218.98 | with rb Strata | |
| 218.98 | 231.33 | Strata | |
| 231.33 | 231.88 | Coal | 1'10" |
| 231.88 | 234.04 | Strata | |

A-13

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.13 | Overburden | |
| 2.13 | 16.43 | Strata | |
| 16.43 | 16.85 | Coal | 1'4" |
| 16.85 | 17.22 | Strata | |
| 17.22 | 19.30 | Coal | clay streamers |

A-14

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.44 | Overburden | |
| 2.44 | 10.96 | Strata | |
| 10.96 | 11.45 | Coal | 1'7" |
| 11.45 | 11.50 | Strata | |
| 11.50 | 12.02 | Coal | 1'9" |
| 12.02 | 12.48 | Strata | |
| 12.48 | 13.66 | Coal | 3'11" |
| 13.66 | 14.43 | Strata | |

A-15

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 6.38 | Overburden | (coal above) |
| 6.38 | 35.28 | Strata | |
| 35.28 | 35.58 | Coal | & shale |
| 35.58 | 46.89 | Strata | |
| 46.89 | 48.91 | Coal | 6'8" |
| 48.91 | 57.79 | Strata | |

A-16

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 21.68 | Strata | |
| 21.68 | 21.73 | Coal | |
| 21.73 | 21.81 | Strata | |
| 21.81 | 22.83 | Coal | 2'9" |
| 22.83 | 64.69 | Strata | |
| 64.69 | 66.50 | Coal | 5'11" |
| 66.50 | 73.03 | Strata | |

A-17

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 8.51 | Overburden | |
| 8.51 | 14.88 | with rb Strata | |
| 14.88 | 16.41 | Strata | |
| 16.41 | 33.44 | with rb Strata | |
| 33.44 | 33.64 | Coal | 0'8" |
| 33.64 | 48.02 | Strata | |
| 48.02 | 49.75 | Coal | 5'8" |
| 49.75 | 54.40 | Strata | |

A-18

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.04 | Overburden | |
| 3.04 | 40.02 | Strata | |
| 40.02 | 40.42 | Coal | 1'4" |
| 40.42 | 40.57 | Strata | |
| 40.57 | 41.64 | Coal | 3'6" |
| 41.64 | 53.56 | Strata | |
| 53.56 | 53.71 | Coal | & shale |
| 53.71 | 59.04 | with rb Strata | |
| 59.04 | 63.14 | Strata | |
| 63.14 | 93.12 | with rb Strata | |
| 93.12 | 102.33 | Strata | |
| 102.33 | 103.09 | Coal | 2'6" |
| 103.09 | 103.32 | Strata | |
| 103.32 | 103.37 | Coal | 0'2" |
| 103.37 | 109.51 | Strata | |
| 109.51 | 109.95 | Coal | 1'6" |
| 109.95 | 118.18 | Strata | |
| 118.18 | 118.40 | Coal | 0'9" |
| 118.40 | 146.30 | Strata | |
| 146.30 | 147.28 | Coal | 3'3 1/4" |
| 147.28 | 156.52 | Strata | |
| 156.52 | 162.60 | with rb Strata | |
| 162.60 | 169.40 | Strata | |
| 169.40 | 170.13 | Coal | dirty 2'5 1/2" |
| 170.13 | 205.56 | Strata | |
| 205.56 | 208.30 | with rb Strata | |
| 208.30 | 217.73 | Strata | |
| 217.73 | 222.78 | with rb Strata | |
| 222.78 | 222.96 | Coal | 0'2" |
| 222.96 | 238.93 | Strata | |
| 238.93 | 239.03 | Coal | 0'4" |
| 239.03 | 243.60 | Strata | |
| 243.60 | 246.80 | with rb Strata | |
| 246.80 | 253.16 | Strata | |

A-19

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.59 | Overburden | |
| 2.59 | 5.02 | Strata | |
| 5.02 | 6.42 | Coal | 4'7" |
| 6.42 | 36.74 | Strata | |
| 36.74 | 37.07 | Coal | mixture |
| 37.07 | 47.93 | Strata | |
| 47.93 | 49.07 | Strata | w coal |
| 49.07 | 50.32 | Coal | 4'1" |
| 50.32 | 56.00 | Strata | |
| 56.00 | 59.65 | with rb Strata | |
| 59.65 | 60.56 | Strata | |
| 60.56 | 73.34 | with rb Strata | |

A-20

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.44 | Overburden | |
| 2.44 | 3.04 | Coal | & clay |
| 3.04 | 34.70 | Strata | |
| 34.70 | 34.99 | Coal | mixture |
| 34.99 | 44.43 | Strata | |
| 44.43 | 45.04 | Coal | 2'0" |
| 45.04 | 45.59 | Strata | |
| 45.59 | 47.40 | Coal | 5'10" |
| 47.40 | 58.43 | Strata | |
| 58.43 | 66.94 | with rb Strata | |
| 66.94 | 69.99 | Strata | |
| 69.99 | 76.08 | with rb Strata | |
| 76.08 | 97.81 | Strata | |
| 97.81 | 97.91 | Coal | 0'4" |
| 97.91 | 110.87 | Strata | |
| 110.87 | 111.53 | Coal | 2'2" |
| 111.53 | 116.19 | Strata | |
| 116.19 | 116.42 | Coal | 0'9" |
| 116.42 | 117.54 | Strata | |
| 117.54 | 117.79 | Coal | 0'10" |
| 117.79 | 117.89 | Strata | |
| 117.89 | 118.40 | Coal | 1'8" |
| 118.40 | 130.83 | Strata | |
| 130.83 | 131.41 | Coal | 1'11" |
| 131.41 | 151.68 | Strata | |
| 151.68 | 152.68 | Coal | 3'4" |
| 152.68 | 153.27 | Strata | |

A-21

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.89 | Overburden | |
| 2.89 | 18.50 | Strata | |
| 18.50 | 25.18 | with rb Strata | |
| 25.18 | 27.76 | Strata | |
| 27.76 | 31.85 | with rb Strata | |
| 31.85 | 55.97 | Strata | |
| 55.97 | 56.30 | Coal | 1'1" |
| 56.30 | 65.70 | Strata | |
| 65.70 | 66.48 | Coal | 2'7" |
| 66.48 | 71.62 | Strata | |
| 71.62 | 71.92 | Coal | 1'0" |
| 71.92 | 73.59 | Strata | |
| 73.59 | 73.82 | Coal | 0'9" |
| 73.82 | 74.04 | Strata | |
| 74.04 | 74.62 | Coal | 1'10" |
| 74.62 | 75.84 | Strata | |

A-22

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.43 | Overburden | |
| 2.43 | 12.96 | Strata | |
| 12.96 | 14.25 | Coal | w clay & shale |
| 14.25 | 16.05 | Coal | 5'11" |

A-23

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 21.11 | No Recover | |
| 21.11 | 21.20 | Coal | 0'4" |
| 21.20 | 33.77 | No Recover | |
| 33.77 | 33.92 | Coal | 0'6" |
| 33.92 | 34.98 | No Recover | |
| 34.98 | 35.48 | Coal | 1'8" |
| 35.48 | 74.93 | No Recover | |
| 74.93 | 76.59 | Coal | 5'6" |

A-24

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.26 | Overburden | |
| 4.26 | 61.74 | Strata | |
| 61.74 | 63.44 | Coal | 5'6" |
| 63.44 | 69.95 | Strata | |
| 69.95 | 84.55 | with rb Strata | |
| 84.55 | 100.36 | Strata | |
| 100.36 | 109.79 | with rb Strata | |
| 109.79 | 131.08 | Strata | |
| 131.08 | 132.91 | Coal | 6'0" |
| 132.91 | 139.90 | Strata | |

A-25

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.34 | Overburden | |
| 3.34 | 25.09 | Strata | |
| 25.09 | 25.55 | Coal | 1'6" |
| 25.55 | 42.58 | Strata | |
| 42.58 | 45.93 | with rb Strata | |
| 45.93 | 57.85 | Strata | |
| 57.85 | 59.31 | Coal | 4'6" |
| 59.31 | 68.43 | Strata | |
| 68.43 | 75.13 | with rb Strata | |
| 75.13 | 96.86 | Strata | |
| 96.86 | 98.69 | Coal | 6'0" |
| 98.69 | 102.19 | Strata | |

A-26

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 37.96 | Strata | |
| 37.96 | 40.92 | Coal | 9'9" |

A-27

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 7.55 | Overburden | |
| 7.55 | 17.43 | Strata | |
| 17.43 | 17.58 | Coal | 0'6" |
| 17.58 | 18.19 | Strata | |
| 18.19 | 24.23 | with rb Strata | |
| 24.23 | 46.60 | Strata | |
| 46.60 | 49.39 | Coal | 9'3" |
| 49.39 | 50.00 | Strata | |

A-28

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 5.75 | Overburden | |
| 5.75 | 26.64 | Strata | |
| 26.64 | 27.25 | Coal | 2'0" |
| 27.25 | 30.57 | Strata | |
| 30.57 | 31.34 | Coal | 2'6" |
| 31.34 | 37.84 | Strata | |
| 37.84 | 39.36 | with rb Strata | |
| 39.36 | 43.90 | Strata | |
| 43.90 | 45.71 | with rb Strata | |
| 45.71 | 54.04 | Strata | |
| 54.04 | 54.49 | Coal | 1'6" |
| 54.49 | 60.85 | Strata | |
| 60.85 | 66.30 | with rb Strata | |
| 66.30 | 72.05 | Strata | |
| 72.05 | 72.31 | Coal | 0'10" |
| 72.30 | 83.56 | Strata | |

A-29

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.63 | Overburden | |
| 3.63 | 12.41 | Strata | |
| 12.41 | 15.44 | with rb Strata | |
| 15.44 | 19.07 | Strata | |
| 19.07 | 19.68 | with rb Strata | |
| 19.68 | 42.99 | Strata | |
| 42.99 | 43.08 | Coal | 0'4" |
| 43.08 | 43.29 | Strata | |
| 43.29 | 43.36 | Coal | 0'3" |
| 43.36 | 45.72 | Strata | |
| 45.72 | 46.09 | Coal | 1'2" |
| 46.09 | 71.44 | Strata | |
| 71.44 | 71.59 | Coal | 0'6" |
| 71.59 | 75.98 | Strata | |
| 75.98 | 76.14 | Coal | 0'6" |
| 76.14 | 81.43 | Strata | |
| 81.43 | 82.50 | Coal | 3'6" |
| 82.50 | 96.88 | Strata | |
| 96.88 | 99.60 | with rb Strata | |
| 99.60 | 105.65 | Strata | |
| 105.65 | 106.11 | Coal | 1'6" |
| 106.11 | 108.99 | Strata | |

A-30

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.33 | Overburden | |
| 3.33 | 10.30 | Strata | |
| 10.30 | 10.40 | Coal | 0'4" |
| 10.40 | 26.33 | Strata | |
| 26.33 | 26.72 | Coal | 1'3" |
| 26.72 | 31.78 | Strata | |
| 31.78 | 32.09 | Coal | 1'0" |
| 32.09 | 49.96 | Strata | |
| 49.96 | 50.11 | Coal | 0'6" |
| 50.11 | 55.71 | Strata | |
| 55.71 | 56.10 | Coal | & splint 1'4" |
| 56.10 | 60.85 | Strata | |
| 60.85 | 61.65 | Coal | 2'8" |
| 61.65 | 63.57 | Strata | |

A-31

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 6.09 | Overburden | |
| 6.09 | 12.47 | Strata | |
| 12.47 | 20.07 | with rb Strata | |
| 20.07 | 23.11 | Strata | |
| 23.11 | 27.37 | with rb Strata | |
| 27.37 | 31.93 | Strata | |
| 31.93 | 51.60 | with rb Strata | |
| 51.60 | 62.66 | Strata | |
| 62.66 | 62.96 | Coal | & splint 1'0" |
| 62.96 | 67.82 | Strata | |
| 67.82 | 68.12 | Coal | & splint 1'0" |
| 68.12 | 70.56 | Strata | |
| 70.56 | 71.02 | Coal | 1'6" |
| 71.02 | 86.07 | Strata | |
| 86.07 | 86.48 | Coal | dirty 1'4" |
| 86.48 | 86.78 | Strata | splint |
| 86.78 | 86.99 | Coal | 0'8" |
| 86.99 | 107.97 | Strata | |
| 107.97 | 108.43 | Coal | 1'6" |
| 108.43 | 132.91 | Strata | |
| 132.91 | 133.36 | Coal | & splint 1'6" |
| 133.36 | 152.68 | Strata | |
| 152.68 | 153.29 | Coal | 2'0" |
| 153.29 | 158.15 | Strata | |

A-32

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 5.76 | Overburden | |
| 5.76 | 8.49 | Strata | |
| 8.49 | 9.10 | with rb Strata | |
| 9.10 | 15.77 | Strata | |
| 15.77 | 16.37 | with rb Strata | |
| 16.37 | 45.18 | Strata | |
| 45.18 | 45.53 | Coal | 1'2" |
| 45.53 | 52.15 | Strata | |
| 52.15 | 52.25 | Coal | 0'4" |
| 52.25 | 56.40 | Strata | |
| 56.40 | 57.01 | Coal | 2'0" |
| 57.01 | 63.98 | Strata | |
| 63.98 | 64.23 | Coal | 0'10" |
| 64.23 | 83.99 | Strata | |
| 83.99 | 86.41 | with rb Strata | |
| 86.41 | 93.09 | Strata | |
| 93.09 | 94.15 | Coal | 3'6" |
| 94.15 | 104.00 | Strata | |
| 104.00 | 106.43 | with rb Strata | |
| 106.43 | 118.56 | Strata | |
| 118.56 | 118.91 | Coal | 1'2" |
| 118.91 | 119.46 | Strata | |

A-33

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.25 | Overburden | |
| 4.25 | 8.18 | Strata | |
| 8.18 | 8.49 | Coal | 1'0" |
| 8.49 | 15.16 | Strata | |
| 15.16 | 15.32 | Coal | 0'6" |
| 15.32 | 30.62 | Strata | |
| 30.62 | 30.93 | Coal | 1'0" |
| 30.93 | 44.27 | Strata | |
| 44.27 | 45.38 | Coal | 3'8" |
| 45.38 | 57.00 | Strata | |
| 57.00 | 62.76 | with rb Strata | |
| 62.76 | 71.86 | Strata | |
| 71.86 | 72.16 | Coal | 1'0" |
| 72.16 | 73.68 | Strata | |

A-34

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 6.32 | Overburden | |
| 6.32 | 15.96 | Strata | |
| 15.96 | 17.07 | Coal | 3'8" |
| 17.07 | 18.06 | Strata | |

A-35

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 5.28 | Overburden | |
| 5.28 | 8.50 | Strata | |
| 8.50 | 10.84 | Coal | 8'0" |
| 10.84 | 17.87 | Strata | |
| 17.87 | 41.32 | with rb Strata | |
| 41.32 | 61.25 | Strata | |
| 61.25 | 61.54 | Coal | 1'0" |
| 61.54 | 72.09 | Strata | |
| 72.09 | 72.68 | Coal | 2'0" |
| 72.68 | 72.78 | Strata | |
| 72.78 | 73.08 | Coal | 1'0" |
| 73.08 | 78.72 | Strata | |
| 78.72 | 78.83 | Coal | 0'5" |
| 78.83 | 89.97 | Strata | |
| 89.97 | 91.00 | Coal | 3'6" |
| 91.00 | 91.16 | Strata | |

A-36

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.24 | Overburden | |
| 2.24 | 9.74 | Strata | |
| 9.74 | 9.99 | with rb Strata | |
| 9.99 | 19.73 | Strata | |
| 19.73 | 20.48 | Coal | 3'0" |
| 20.48 | 41.70 | Strata | |
| 41.70 | 42.08 | Coal | 1'6" |
| 42.08 | 44.96 | Strata | |

A-37

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.52 | Overburden | |
| 4.52 | 4.68 | Coal | 0'6" (?) |
| 4.68 | 15.08 | Strata | |
| 15.08 | 16.29 | Coal | 4'0" |
| 16.29 | 35.61 | Strata | |
| 35.61 | 35.91 | Coal | 1'0" |
| 35.91 | 38.32 | Strata | |
| 38.32 | 38.62 | Coal | 1'0" |
| 38.62 | 40.74 | Strata | |

A-39

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.22 | Overburden | |
| 4.22 | 14.76 | Strata | |
| 14.76 | 15.37 | Coal | 2'0" |
| 15.37 | 18.08 | Strata | |
| 18.08 | 18.38 | Coal | 1'0" |
| 18.38 | 49.42 | Strata | |
| 49.42 | 50.62 | Coal | 4'0" |
| 50.62 | 59.96 | Strata | |
| 59.96 | 60.57 | with rb Strata | |
| 60.57 | 67.80 | Strata | |
| 67.80 | 68.31 | Coal | 1'8" |
| 68.31 | 72.32 | Strata | |

A-40

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.09 | Overburden | |
| 3.09 | 5.16 | Coal | 8'0" |
| 5.16 | 23.96 | Strata | |
| 23.96 | 29.12 | with rb Strata | |
| 29.12 | 73.71 | Strata | |
| 73.71 | 74.35 | Coal | 2'6" |
| 74.35 | 74.74 | Strata | |
| 74.74 | 74.86 | Coal | 0'6" |
| 74.86 | 84.18 | Strata | |
| 84.18 | 85.08 | Coal | 3'6" |
| 85.08 | 91.48 | Strata | |
| 91.48 | 93.55 | with rb Strata | |
| 93.55 | 109.27 | Strata | |
| 109.27 | 109.66 | Coal | 1'6" |
| 109.66 | 109.76 | Strata | |
| 109.76 | 110.26 | Coal | 1'11" |
| 110.26 | 112.10 | Strata | |

A-41

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.06 | Overburden | |
| 2.06 | 23.71 | Strata | |
| 23.71 | 24.61 | Coal | 3'6" |
| 24.61 | 24.99 | Strata | |
| 24.99 | 25.26 | Coal | 1'0" |
| 25.26 | 36.85 | Strata | |
| 36.85 | 37.62 | Coal | 3'0" |
| 37.62 | 45.87 | Strata | |
| 45.87 | 46.39 | with rb Strata | |
| 46.39 | 61.59 | Strata | |
| 61.59 | 62.75 | Coal | 4'6" |
| 62.75 | 63.39 | Strata | |

PM-07

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.00 | Overburden | |
| 3.00 | 13.38 | Strata | |
| 13.38 | 14.11 | Coal | |
| 14.11 | 14.94 | Strata | |
| 14.94 | 15.02 | Coal | |
| 15.02 | 24.93 | Strata | |
| 24.93 | 25.22 | with rb Strata | |
| 25.22 | 26.80 | Strata | |
| 26.80 | 26.88 | with rb Strata | |
| 26.88 | 29.12 | Strata | |
| 29.12 | 35.28 | with rb Strata | |
| 35.28 | 43.59 | Strata | |
| 43.59 | 43.83 | Coal | coaly shale |
| 43.83 | 44.14 | Coal | |
| 44.14 | 48.94 | Strata | |

PM-08

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.53 | Overburden | |
| 4.53 | 22.14 | Strata | |
| 22.14 | 22.32 | Coal | |
| 22.32 | 29.23 | Strata | |
| 29.23 | 29.54 | Coal | |
| 29.54 | 31.19 | Strata | |
| 31.19 | 31.27 | Coal | dirty |
| 31.27 | 42.02 | Strata | |
| 42.02 | 42.31 | Coal | |
| 42.31 | 45.89 | Strata | |
| 45.89 | 45.92 | Coal | 0'1" |
| 45.92 | 57.66 | Strata | |
| 57.66 | 58.74 | with rb Strata | |
| 58.74 | 75.61 | Strata | |
| 75.61 | 76.38 | Coal | |
| 76.38 | 82.42 | Strata | |

PM-10

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.03 | Overburden | |
| 3.03 | 13.01 | Strata | |
| 13.01 | 13.14 | Coal | coaly shale |
| 13.14 | 22.16 | Strata | |
| 22.16 | 22.39 | Coal | shaly |
| 22.39 | 24.86 | Strata | |
| 24.86 | 25.01 | Coal | coaly shale |
| 25.01 | 35.78 | Strata | |
| 35.78 | 35.88 | Coal | shaly |
| 35.88 | 36.59 | Strata | |
| 36.59 | 36.69 | Coal | |
| 36.69 | 56.82 | Strata | |
| 56.82 | 56.93 | Coal | coaly shale |
| 56.93 | 62.79 | Strata | |
| 62.79 | 62.89 | Coal | shaly |
| 62.89 | 69.13 | Strata | |
| 69.13 | 70.04 | Coal | |
| 70.04 | 74.90 | Strata | |

PM-12

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.24 | Overburden | |
| 4.24 | 11.50 | Strata | |
| 11.50 | 11.55 | Coal | |
| 11.55 | 17.45 | Strata | |
| 17.45 | 17.58 | Coal | shaly |
| 17.58 | 23.30 | Strata | |
| 23.30 | 23.35 | Coal | |
| 23.35 | 46.45 | Strata | |
| 46.45 | 46.60 | Coal | shaly |
| 46.60 | 52.07 | Strata | |
| 52.07 | 52.53 | Coal | |
| 52.53 | 58.40 | Strata | |

PM-14

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.11 | Overburden | |
| 2.11 | 9.36 | Strata | |
| 9.36 | 13.69 | with rb Strata | |
| 13.69 | 15.63 | Strata | |
| 15.63 | 20.05 | with rb Strata | |
| 20.05 | 34.54 | Strata | |
| 34.54 | 34.59 | Coal | coaly shale |
| 34.59 | 34.70 | Strata | |
| 34.70 | 34.75 | Coal | |
| 34.75 | 35.14 | Strata | |
| 35.14 | 35.17 | Coal | |
| 35.17 | 40.03 | Strata | |
| 40.03 | 40.28 | Coal | shaly |
| 40.28 | 44.68 | Strata | |
| 44.68 | 44.78 | Coal | shaly |
| 44.78 | 73.49 | Strata | |
| 73.49 | 73.70 | Coal | |
| 73.70 | 79.40 | Strata | |

PM-20

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.91 | Overburden | |
| 3.91 | 5.42 | Strata | |
| 5.42 | 6.32 | Coal | |
| 6.32 | 12.64 | Strata | |

PM-21

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.53 | Overburden | |
| 4.53 | 13.13 | Strata | |
| 13.13 | 13.88 | with rb Strata | |
| 13.88 | 17.96 | Strata | |
| 17.96 | 18.57 | with rb Strata | |
| 18.57 | 24.76 | Strata | |
| 24.76 | 25.31 | with rb Strata | |
| 25.31 | 34.47 | Strata | |
| 34.47 | 35.30 | Coal | |
| 35.30 | 42.57 | Strata | |

PM-22

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.71 | Overburden | |
| 2.71 | 11.84 | Strata | |
| 11.84 | 11.99 | Coal | shaly |
| 11.99 | 25.34 | Strata | |
| 25.34 | 26.17 | Coal | |
| 26.17 | 31.32 | Strata | |

PM-23

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 1.79 | Overburden | |
| 1.79 | 14.84 | Strata | |
| 14.84 | 15.03 | Coal | |
| 15.03 | 15.81 | Strata | |
| 15.81 | 15.95 | Coal | |
| 15.95 | 24.18 | Strata | |
| 24.18 | 24.50 | Coal | |
| 24.50 | 30.71 | Strata | |

PM-29

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.07 | Overburden | |
| 4.07 | 25.90 | Strata | |
| 25.90 | 26.92 | Coal | |
| 26.92 | 31.92 | Strata | |

PM-30

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.61 | Overburden | |
| 3.61 | 16.09 | Strata | |
| 16.09 | 16.86 | Coal | top 5" shaly |
| 16.86 | 19.87 | Strata | |
| 19.87 | 21.68 | with rb Strata | possibly faulted |

PM-31

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.61 | Overburden | |
| 3.61 | 4.22 | Strata | |
| 4.22 | 7.23 | No Recover | coal frags |
| 7.23 | 8.66 | Strata | |
| 8.66 | 9.64 | with rb Strata | |

PM-32

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.61 | Overburden | |
| 3.61 | 14.58 | Strata | |
| 14.58 | 14.63 | Coal | |
| 14.63 | 20.05 | Strata | |
| 20.05 | 20.73 | Coal | (coaly shale) |
| 20.73 | 27.75 | Strata | |
| 27.75 | 28.16 | Coal | shaly |
| 28.16 | 30.72 | Strata | |

PM-33

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.21 | Overburden | |
| 4.21 | 5.60 | Strata | |
| 5.60 | 5.80 | Coal | |
| 5.80 | 12.61 | Strata | |

PM-35

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.51 | Overburden | |
| 4.51 | 4.97 | Coal | |
| 4.97 | 6.40 | Strata | |
| 6.40 | 9.14 | with rb Strata | |
| 9.14 | 9.64 | No Recover | |
| 9.64 | 15.05 | Strata | |
| 15.05 | 21.68 | with rb Strata | |

PM-37

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.22 | Overburden | |
| 4.22 | 8.45 | Strata | |
| 8.45 | 10.84 | with rb Strata | faulted (?) |
| 10.84 | 27.70 | Strata | fault zone? |

PM-41

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 6.44 | Overburden | |
| 6.44 | 23.24 | Strata | |
| 23.24 | 23.47 | Coal | dirty |
| 23.47 | 28.97 | Strata | |
| 28.97 | 29.31 | Coal | shaly |
| 29.31 | 34.39 | Strata | |
| 34.39 | 34.76 | Coal | |
| 34.76 | 34.96 | Strata | coaly |
| 34.96 | 35.25 | Coal | |
| 35.25 | 40.60 | Strata | |

PM-42

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.89 | Overburden | |
| 4.89 | 7.83 | Strata | |
| 7.83 | 8.02 | Coal | coaly |
| 8.02 | 13.95 | Strata | |
| 13.95 | 14.36 | Coal | |
| 14.36 | 21.32 | Strata | |

PM-43

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.94 | Overburden | |
| 3.94 | 14.64 | Strata | |
| 14.64 | 14.84 | Coal | dirty |
| 14.84 | 19.40 | Strata | |
| 19.40 | 19.53 | Coal | shaly |
| 19.53 | 26.81 | Strata | |
| 26.81 | 27.35 | Coal | |
| 27.35 | 33.48 | Strata | |

PM-44

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.95 | Overburden | |
| 4.95 | 20.50 | Strata | |
| 20.50 | 20.60 | Coal | |
| 20.60 | 28.56 | Strata | |
| 28.56 | 28.62 | Coal | coaly shale |
| 28.62 | 33.69 | Strata | |
| 33.69 | 34.52 | Coal | |
| 34.52 | 34.55 | Coal | shaly |
| 34.55 | 39.61 | Strata | |

PM-45

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.95 | Overburden | |
| 3.95 | 14.52 | Strata | |
| 14.52 | 15.70 | Coal | |
| 15.70 | 21.73 | Strata | |

PM-46

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 3.94 | Overburden | |
| 3.94 | 24.52 | Strata | |
| 24.52 | 24.64 | Coal | |
| 24.64 | 35.69 | Strata | |
| 35.69 | 36.34 | Coal | |
| 36.34 | 42.15 | Strata | |

PM-47

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.93 | Overburden | |
| 4.93 | 12.77 | Strata | |
| 12.77 | 13.60 | Coal | |
| 13.60 | 21.50 | Strata | |

PM-48

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.43 | Overburden | |
| 4.43 | 21.67 | Strata | |
| 21.67 | 21.74 | Coal | shaly |
| 21.74 | 21.91 | Strata | |
| 21.91 | 22.11 | Coal | |
| 22.11 | 35.11 | Strata | |
| 35.11 | 36.15 | Coal | |
| 36.15 | 42.35 | Strata | |

PM-49

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 2.66 | Overburden | |
| 2.66 | 2.96 | Strata | |
| 2.96 | 3.45 | Coal | triconed |
| 3.45 | 16.27 | Strata | |
| 16.27 | 16.37 | with rb Strata | |
| 16.37 | 17.56 | Strata | |
| 17.56 | 17.65 | with rb Strata | |
| 17.65 | 33.83 | Strata | |
| 33.83 | 34.62 | Coal | |
| 34.62 | 39.75 | Strata | |

PM-50

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 4.55 | Overburden | |
| 4.55 | 5.10 | Strata | |
| 5.10 | 5.13 | Coal | |
| 5.13 | 7.92 | No Recover | |
| 7.92 | 17.82 | Strata | |

LB-00

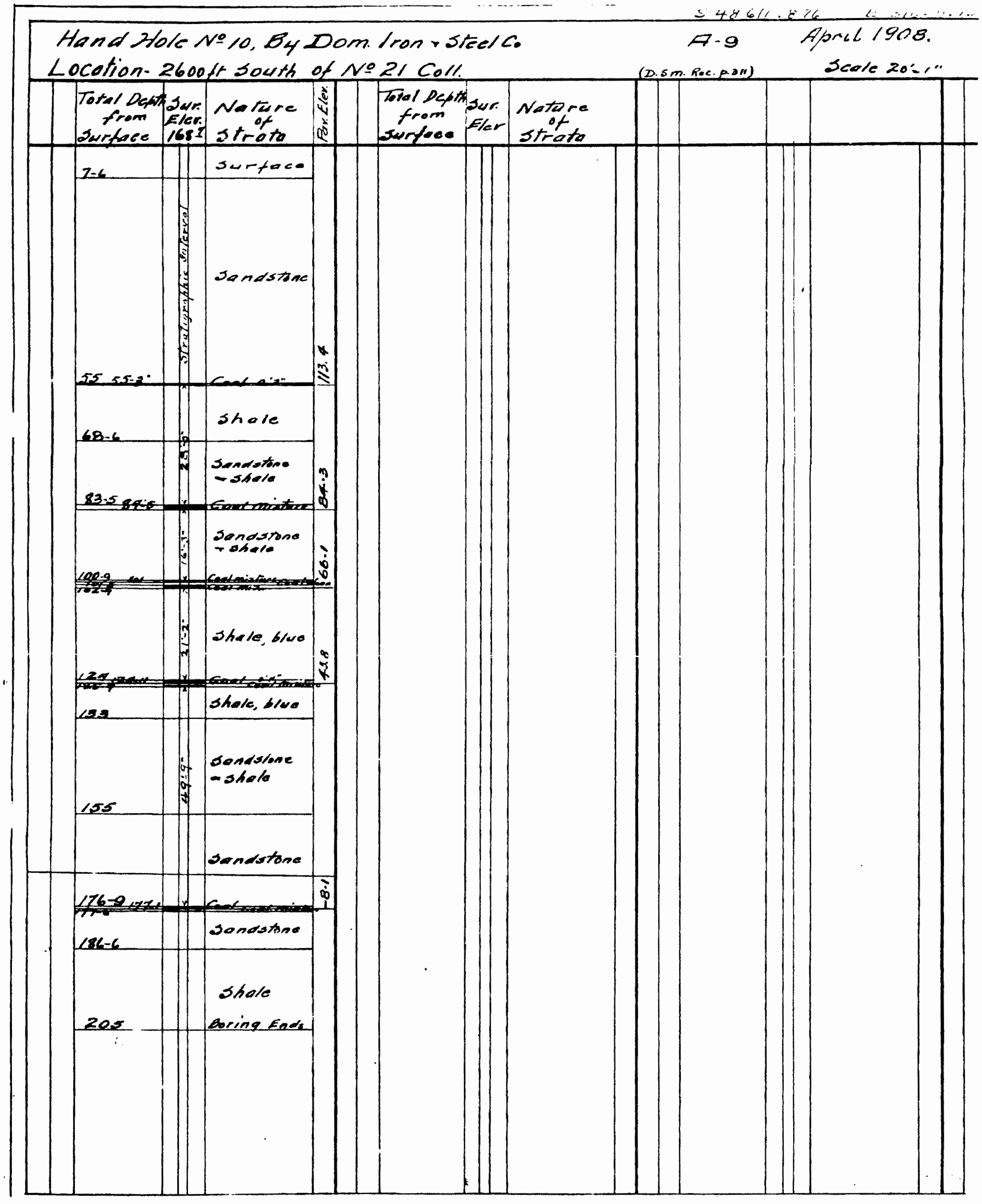
| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 0.75 | Strata | |
| 0.75 | 12.25 | No Recover | |
| 12.25 | 12.99 | Coal | Harbour se (0.74m) |
| 12.99 | 13.44 | Strata | |
| 13.44 | 14.64 | No Recover | |
| 14.64 | 19.81 | Strata | |
| 19.81 | 20.11 | No Recover | |
| 20.11 | 29.12 | Strata | l-m grey |
| 29.12 | 31.62 | with rb Strata | red |
| 31.62 | 35.62 | No Recover | |
| 35.62 | 37.42 | Strata | |
| 37.42 | 38.02 | with rb Strata | red |
| 38.02 | 39.20 | Strata | |
| 39.20 | 39.53 | with rb Strata | red |
| 39.53 | 40.23 | No Recover | |
| 40.23 | 40.98 | with rb Strata | red |
| 40.98 | 41.18 | No Recover | |
| 41.18 | 41.57 | Strata | |
| 41.57 | 41.95 | with rb Strata | red |
| 41.95 | 45.55 | Strata | |
| 45.55 | 46.75 | No Recover | |
| 46.75 | 47.98 | Strata | |
| 47.98 | 49.48 | with rb Strata | red |
| 49.48 | 50.08 | No Recover | |
| 50.08 | 50.47 | with rb Strata | red |
| 50.47 | 50.75 | No Recover | |
| 50.75 | 53.18 | with rb Strata | red |
| 53.18 | 56.18 | No Recover | |
| 56.18 | 62.98 | with rb Strata | w red |
| 62.98 | 64.38 | Strata | |
| 64.38 | 68.41 | with rb Strata | red |
| 68.41 | 69.03 | Strata | |
| 69.03 | 69.91 | with rb Strata | red |
| 69.91 | 70.32 | Strata | |
| 70.32 | 71.07 | with rb Strata | red |
| 71.07 | 72.07 | No Recover | |
| 72.07 | 74.75 | with rb Strata | |
| 74.75 | 75.20 | Strata | |
| 75.20 | 76.68 | with rb Strata | red |
| 76.68 | 81.13 | No Recover | |
| 81.13 | 81.80 | with rb Strata | red |
| 81.80 | 81.96 | Strata | |
| 81.96 | 84.39 | with rb Strata | red |
| 84.39 | 85.63 | Strata | |
| 85.63 | 86.47 | with rb Strata | red |
| 86.47 | 86.67 | No Recover | |
| 86.67 | 87.98 | with rb Strata | |
| 87.98 | 88.43 | No Recover | |
| 88.43 | 88.77 | Strata | |
| 88.77 | 90.77 | with rb Strata | red |

(LB-00)

| Start | End | Keyword | |
|---|---|---|---|
| 90.77 | 93.07 | Strata | brnish drk grey |
| 93.07 | 103.60 | with rb Strata | red |
| 103.60 | 104.65 | Strata | grey |
| 104.65 | 110.42 | with rb Strata | red paleosol w roots |
| 110.42 | 111.12 | No Recover | |
| 111.12 | 113.27 | with rb Strata | |
| 113.27 | 121.47 | Strata | |
| 121.47 | 121.70 | Coal | Bouthillier se (?) (0.23m) |
| 121.70 | 133.27 | Strata | |
| 133.27 | 133.55 | Coal | Backpit Se ? (no) |
| 133.55 | 151.75 | Strata | |
| 151.75 | 152.70 | with rb Strata | red & grey |
| 152.70 | 153.12 | Strata | |
| 153.12 | 156.37 | with rb Strata | red clay --> grey siltst |
| 156.37 | 162.69 | Strata | |
| 162.69 | 163.69 | No Recover | Backpit Se (mined out?) |
| 163.69 | 186.82 | Strata | black organic siltst |
| 186.82 | 189.32 | with rb Strata | d red |
| 189.32 | 191.32 | No Recover | covered |
| 191.32 | 198.22 | Strata | |
| 198.22 | 201.02 | Coal | Phalen seam (2.8m) |
| 201.02 | 201.27 | Strata | organic shale |
| 201.27 | 201.52 | Coal | coal (0.25m) |
| 201.52 | 209.61 | Strata | organic shale |
| 209.61 | 211.91 | with rb Strata | drk red & grey |
| 211.91 | 213.03 | Strata | |
| 213.03 | 214.19 | with rb Strata | drk red & grey |
| 214.19 | 216.80 | Strata | |
| 216.80 | 217.10 | with rb Strata | chippy; red & grey |
| 217.10 | 260.26 | Strata | |
| 260.26 | 260.27 | Coal | |
| 260.27 | 268.02 | Strata | d grey |
| 268.02 | 268.67 | Coal | Emery Se (0.65m) |
| 268.67 | 270.15 | No Recover | |
| 270.15 | 275.35 | Strata | d grey |
| 275.35 | 275.55 | Coal | lwr leaf of Emery se (?) |
| 275.55 | 282.63 | Strata | l grey |

MS-00

| Start | End | Keyword | |
|---|---|---|---|
| 0.00 | 6.91 | Strata | |
| 6.91 | 8.70 | Coal | Backpit seam (1.79m) |
| 8.70 | 26.84 | Strata | |
| 26.84 | 28.92 | with rb Strata | red --> grey |
| 28.92 | 33.48 | strata | |
| 33.48 | 39.99 | No Recover | |
| 39.99 | 48.92 | Strata | |
| 48.92 | 49.72 | Coal | Phalen seam (0.8m) |
| 49.72 | 57.94 | strata | |
| 57.94 | 58.64 | with rb Strata | d red |
| 58.64 | 60.94 | strata | |
| 60.94 | 61.64 | with rb Strata | d grey & red |
| 61.64 | 62.20 | strata | |
| 62.20 | 63.15 | with rb Strata | red & m grey |
| 63.15 | 69.14 | No Recover | |
| 69.14 | 70.54 | with rb Strata | m grey & red tint |
| 70.54 | 70.94 | No Recover | |
| 70.94 | 71.21 | strata | |
| 71.21 | 71.51 | No Recover | |
| 71.51 | 77.09 | strata | |
| 77.09 | 80.96 | with rb Strata | red & m grey |
| 80.96 | 81.36 | strata | |
| 81.36 | 83.68 | with rb Strata | m grey & red |
| 83.68 | 84.31 | strata | |
| 84.31 | 85.91 | with rb Strata | red |
| 85.91 | 86.40 | strata | |
| 86.40 | 87.74 | with rb Strata | red clay --> siltst |
| 87.74 | 87.94 | strata | |
| 87.94 | 88.29 | No Recover | |
| 88.29 | 89.81 | strata | |
| 89.81 | 90.41 | No Recover | |
| 90.41 | 96.14 | strata | |
| 96.14 | 96.34 | with rb Strata | red & grey |
| 96.34 | 97.06 | No Recover | |
| 97.06 | 97.76 | with rb Strata | d grey & red |
| 97.76 | 98.28 | Strata | |
| 98.28 | 98.83 | No Recover | |
| 98.83 | 99.73 | Strata | |
| 99.73 | 101.60 | with rb Strata | m grey & red |
| 101.60 | 117.44 | Strata | |
| 117.44 | 118.30 | Coal | Emery seam (0.86m) |
| 118.30 | 119.25 | Strata | m grey |
| 119.25 | 119.80 | Coal | coal-rich shale, S-rich |
| 119.80 | 120.70 | Strata | m grey |



Hand Hole No 10, By Dom. Iron + Steel Co. A-9 April 1908.

Location- 2600 ft South of No 21 Coll. (D.S.m. Rec. p.311) Scale 20' = 1"

| Total Depth from Surface | Sur. Elev. 168 | Nature of Strata | Par. Elev. |
|---|---|---|---|
| 7-6 | | Surface | |
| 55 55-3" | Stratigraphic Interval | Sandstone | 113.4 |
| | | Coal [illegible] | |
| 68-6 | | Shale | |
| 83-5 84-6 | 25'-5" | Sandstone + shale | 84.3 |
| | | Coal mixture | |
| 100-9 [illegible] 102-4 | 16'-3" | Sandstone + shale | 66.1 |
| | | Coal mixture, coal [illegible] Coal mix. | |
| 124 [illegible] | 21'-2" | Shale, blue | 43.8 |
| | | Coal [illegible] coal mixture | |
| 133 | | Shale, blue | |
| 155 | 49'-9" | Sandstone + shale | |
| | | Sandstone | |
| 176-9 177 | | Coal [illegible] | -8.1 |
| 186-6 | | Sandstone | |
| 205 | | Shale | |
| | | Boring Ends | |

**Figure D-1:** Log sheet for drill hole A-9. Drill sheet contains such information as when drilling was completed and by whom; description of drill hole location (top right, under label); collar elevation; total strata recovered with a brief description; DEVCO coordinates written in at a later unknown date (top left).

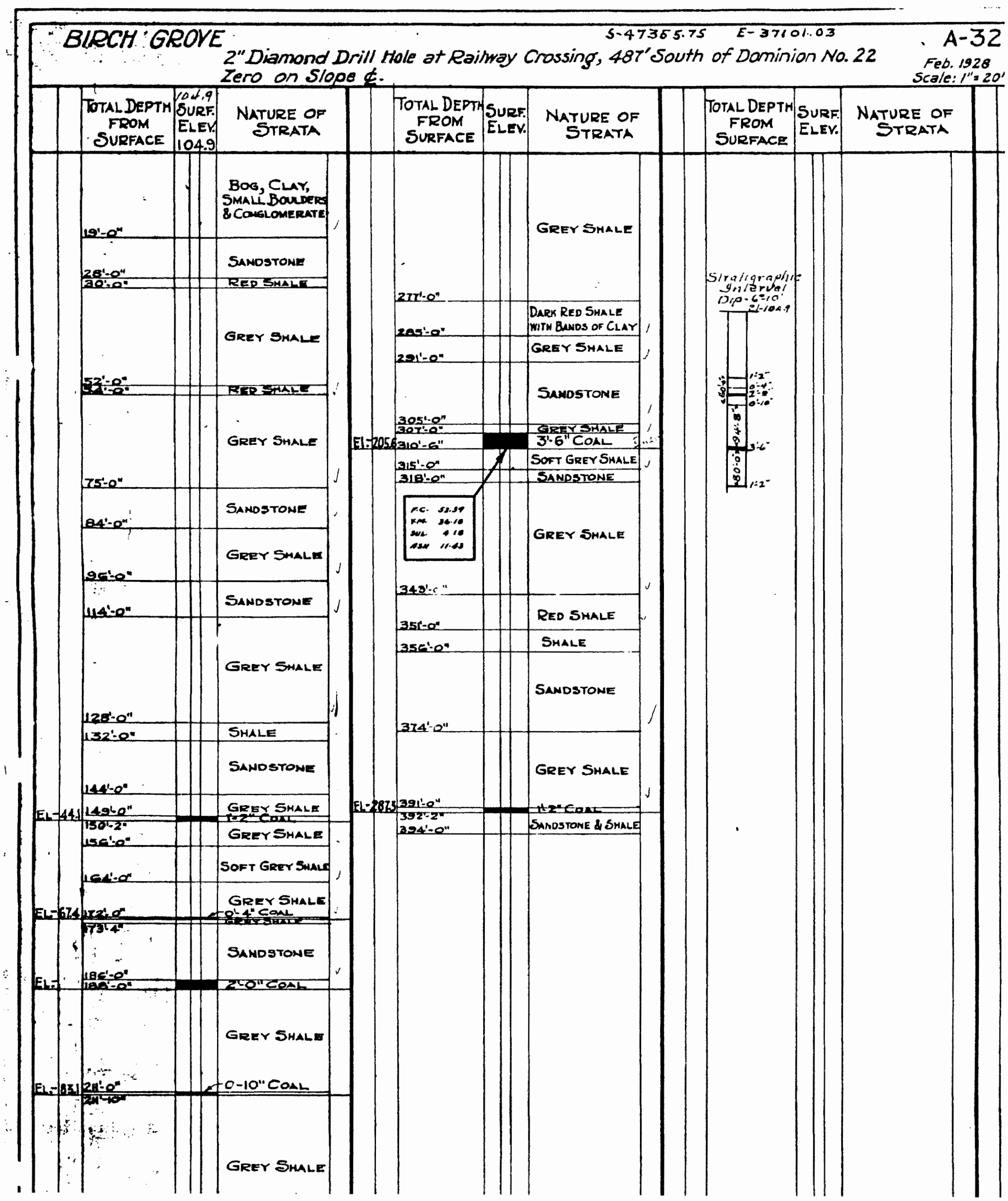



**Figure D-2:** Log sheet for drill hole A-32. Drill sheet contains such information as when drilling was completed and by whom; description of drill hole location (top right, under label); collar elevation; total strata recovered with a brief description; stratigraphic dip; characteristics of larger coals; DEVCO coordinates written in at a later unknown date (top left).