

INCISED SHOREFACE SEDIMENTS OF THE
BURNSTICK MEMBER, CARDIUM FORMATION,
BRAZEAU RIVER GASFIELD, ALBERTA.

INCISED SHOREFACE SEDIMENTS OF THE
BURNSTICK MEMBER, CARDIUM FORMATION,
BRAZEAU RIVER GASFIELD, ALBERTA

BY

SUSAN MARGOT BURBIDGE

A Thesis

Submitted to the Department of Geology
in Partial Fulfilment of the Requirements
for the Degree
Honours Bachelor of Science

McMaster University

April, 1989

Bachelor of Science
(Geology)

McMaster University
Hamilton, Ontario

Title: Incised Shoreface Sediments of the Burnstick
Member, Cardium Formation, Brazeau River
Gasfield, Alberta.

Author: Susan Margot Burbidge

Supervisor: Dr. R.G. Walker

Number of Pages: x, 106.

ABSTRACT

The Burnstick Member of the Cardium Formation (Turonian, Late Cretaceous) occurs in the subsurface of southern Alberta and is sandwiched between the Hornbeck Member and the Raven River Member. These sediments were deposited in the Alberta Foreland Basin along the eastern margin of the rising Canadian Cordillera.

The Burnstick Member sediments appear to have been deposited tens of kilometers east of the closest known paleoshoreline which presents a major problem with respect to sediment transport in an offshore environment. Two possibilities exist for the deposition of the Burnstick Member sediments including, direct emplacement into an offshore environment by storm related currents ("offshore bars") or deposition in a shoreface environment during a rapid lowering of sea level (incised shoreface deposits).

Approximately 130 electrical logs and 23 cores were used to determine the sedimentology and sand body geometry of the Burnstick Member in the Brazeau River area. Well log cross sections and core cross sections show that the Burnstick Member rests on a major erosional surface (E4) that outlines a sigmoidal step which is open towards the northeast. The steps are between 4-6 m deep and are interpreted to have developed in shoreface environments.

In off-fields areas the E4 surface merges with the T4 surface (Burnstick- Raven River Member contact) and forms the E4/T4 surface. The E4/T4 surface is flat relative to a

horizontal lower marker.

The Hornbeck Member sediments, which underlie the Burnstick Member, is composed of bioturbated shallow marine mudstones. The Burnstick Member is composed of a coarsening upward sequence which passes from bioturbated muddy siltstones up into clean conglomeratic sandstones. The Burnstick reaches a maximum thickness of 8 metres. The Raven River Member overlying the Burnstick is composed of massive black mudstone referred to as the "Black Blanket".

The Burnstick Member sediments are concentrated in long, linear sand bodies, which strike NW-SE. The sand bodies rest on the incised step in the E4 surface. They are interpreted to be incised shoreface deposits that were localized on the shelf during sea level fluctuations. A rapid fall in relative sea level is proposed to have initiated lowstand shoreface development on the shelf. Stillstand caused the shoreface to retreat towards the southwest and become incised into the underlying Hornbeck Member. A transgression is proposed to have followed, which planed off the upper shoreface and evidence of subaerial erosion to the southwest. This transgression eventually buried the Burnstick Member sediments in marine muds.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Dr. Roger Walker for his excellent supervision and his unending encouragement. It was only through his support that I was able to complete my B.Sc. thesis.

I would also like to thank Unocal Canada Limited, Calgary for the use of their facilities for collecting well log data. In particular, I would like to thank Bill Haskett and Owen Neal for supplying me with maps and core listings and taking good care of me while I was at Unocal Canada Ltd. The author also appreciated the kind and helpful staff of the Energy and Resources Conservation Board, Core Research Center in Calgary.

I wish to thank Jack Whorwood (McMaster University) for the reproduction of the drafting and photographs and for his helpful advice on presentation of the figures. Also I would like to thank Dr. P.M. Clifford for his help in solving the structural problems encountered in the study area.

I would like to thank Dr. Walker's graduate students, Simon Pattison, Jenifer Wadsworth, Scott Hadley, Steve Davies, Tom Boreen, Bruce Power, Jeremy Bartlett and Tony Reynolds, their help and advice was greatly appreciated. In particular, I would like to express special thanks to Simon for his all help in getting me started, to Scott, who shared his core table and to Jenifer for writing computer programs for data manipulation.

My friends and classmates have been very important to me. Their moral support has sustained me through a very tough final year. I would especially like to thank Doug Neilson for his friendship and support.

Finally, I would like to thank the people who mean the most to me, my family. I could not have completed my B.Sc if it hadn't been for the patience, understanding and support of Mar and Gorgeous.

Table of Contents

	Page
ABSTRACT	iii
ACKNOWLEDGEMENTS	v
TABLE OF CONTENTS	vii
LIST OF FIGURES	ix
 CHAPTER 1 - Introduction	
1.1 The Geological Problem	1
1.2 Previous Work on the Cardium Formation	4
CHAPTER 2 - Regional Setting and Stratigraphy	
2.1 Introduction	8
2.2 Stratigraphy	8
2.3 Regional Setting	11
2.4 Data Base	12
CHAPTER 3 - Facies	
3.1 Introduction	15
3.2 Facies Description	15
Facies 1 - Massive Dark Mudstone	16
Facies 3 - Dark Bioturbated Muddy Siltstone	16
Facies 4 - Pervasively Bioturbated Muddy Siltstone	18
Facies 5 - Bioturbated Sandstone	21
Facies 7 - Nonbioturbated Sandstone	24
Facies 8 - Conglomerate	26
3.3 Vertical Facies Sequences	28

CHAPTER 4 - Cross Sections	
4.1 Introduction	36
4.2 Cross Sections	36
CHAPTER 5 - Geometry	
5.1 Introduction	57
5.2 Isopach Maps and Mesh Disgrams	57
5.3 Profiles	64
CHAPTER 6 - Interpretations	
6.1 Introduction	68
6.2 The E4 Surface	68
6.3 The Facies Sequence	71
6.4 The T4 Surface	72
6.5 Sequence of Events	72
6.6 Problems	73
CHAPTER 7 - Conclusions	76
References	77
Appendix 1 - Data File of Wireline Log picks	82
Appendix 2 - Core Logs	85

List of Figures

Figure	Page
1.1 Location of Cardium oil and gas fields	2
2.1 Stratigraphy of the Alberta Group	9
2.2 Stratigraphy of the Cardium Formation	10
2.3 Location Map of the core and well log data	13
3.1 (A) Facies 1P; (B) Facies 3; (C) Facies 1/3; (D) Facies 1P/3P	17
3.2 "Black Blanket" Comparison	19
3.3 (A) & (B) Facies 4; (C) Facies 4G; (D) Facies 4P	20
3.4 (A) & (B) Facies 5; (C) Facies 5G; (D) Facies 5P	22
3.5 (A) <u>Terebellina</u> and <u>Rhizocorallium</u> (B) <u>Teichichnus</u>	23
3.6 (A), (B) & (C) Facies 7; (D) Facies 5-7-GS	25
3.7 (A) Facies 7P; (B) & (C) Facies 8; (D) Facies 8-GS	27
3.8 Composite vertical facies sequence	29
3.9 A muddy on-field vertical sequence	30
3.10 A sandy on-field vertical sequence	32
3.11 (A) & (B) sharp E4 erosion surfaces (C) & (D) gradational E4 erosion surfaces	33
3.12 An off-field vertical sequence	35
4.1 Location map of well log and core cross sections	37
4.2 Isopach map of the LM to UM interval	38
4.3 Legend of symbols used in the core diagrams	40
4.4 Well log cross section A-A'	41
4.5 Schematic of a blind thrust	43

Figure	Page
4.6 Well log cross section B-B'	44
4.7 Core cross section B-B'	45
4.8 Well log cross section C-C'	47
4.9 Core cross section C-C'	48
4.10 Well log cross section D-D'	49
4.11 Core cross section D-D'	50
4.12 Well log cross section E-E'	52
4.13 Core cross section E-E'	53
4.14 Well log cross section F-F'	54
4.15 Well log cross section S-S'	55
4.16 Core cross section S-S'	56
5.1 Isopach map of the LM to E4 interval	58
5.2 Mesh diagram of the E4 surface	59
5.3 Isopach map of the E4 to T4 interval	61
5.4 Isopach map of the LM to T4 interval	62
5.5 Mesh diagram of the T4 surface	63
5.6 Profile of the Burnstick Member along X-X'	65
5.7 Profile of the Burnstick Member along Y-Y'	66
5.8 Profile of the Burnstick Member along Z-Z'	67
6.1 Schematic of interpreted sequence of events	74

CHAPTER 1: Introduction

1.1 The Geological Problem

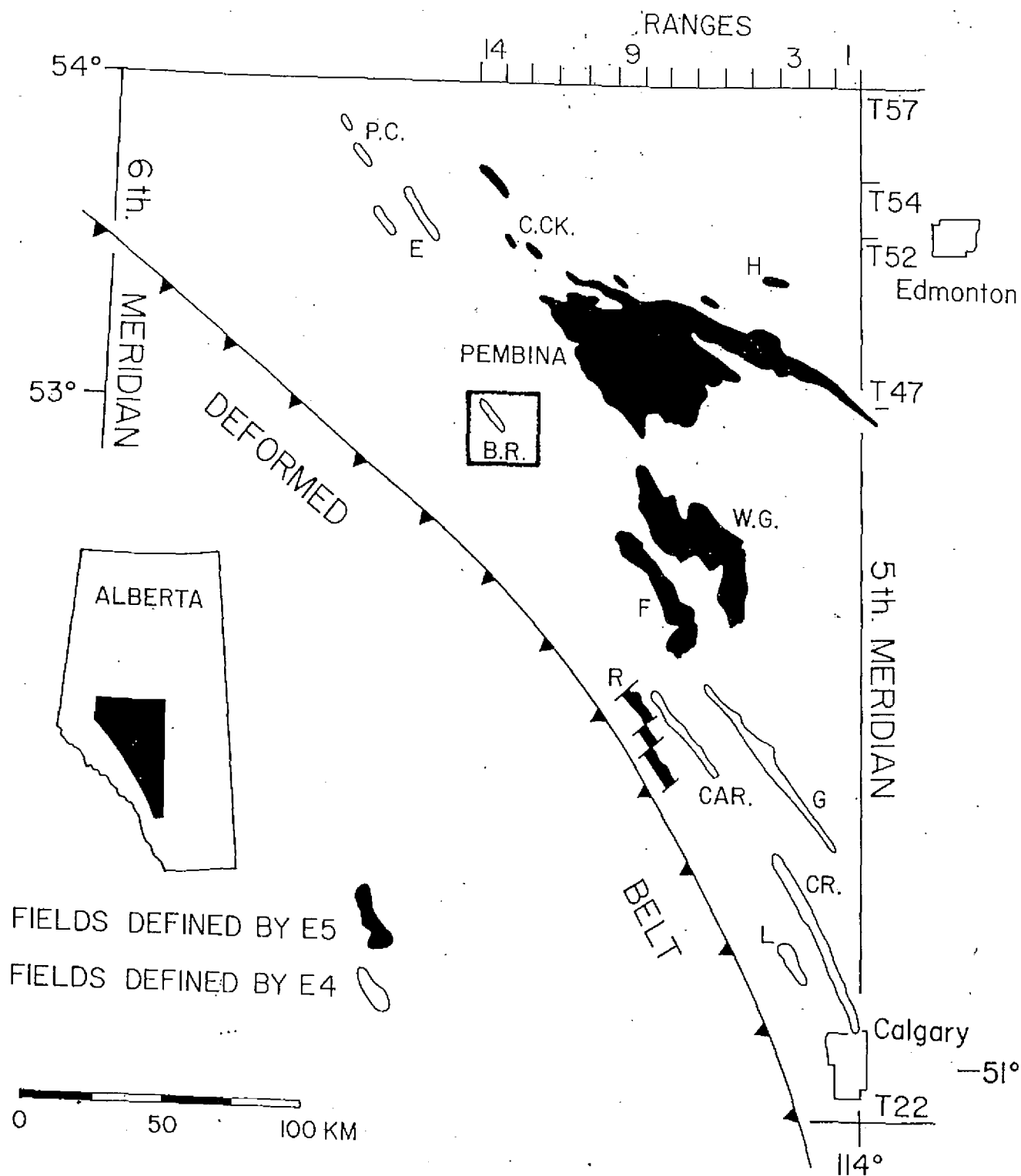
This thesis is a subsurface study of the Burnstick Member of the Cardium Formation in the Brazeau River area of southern Alberta. The purpose of the study is to determine the environment of deposition of this coarse sediment package.

The Burnstick Member fields, including the Brazeau River area, are long linear sand bodies ("offshore bars") (Fig. 1.1) that are encased in marine mudstones. This at first implies that they were deposited below wave base, in relatively deep water, many kilometers from the nearest paleoshoreline.

There are two problems associated with the formation of these "offshore bars". First, how were the coarse sediments transported out across the shelf to be deposited onto marine muds, and second, how were the sediments focussed or concentrated into long linear bars or ridges. Storm currents, such as storm surge currents, density currents and turbidity currents have been proposed as ways of moving the coarse sediment out onto the shelf.

The second problem of how the sediments were focussed into long linear ridges is more difficult to deal with. The theoretical model proposed by Swift and Rice (1984) suggests that sediment is focussed on topographic highs due

Figure 1.1 The location of Cardium oil and gas fields in southwestern Alberta. The area of this study is enclosed in the box labelled B.R.(Brazeau River). Note that the Brazeau River Field is on line with G (Garrington) to the south. (E - Edson; P.C.- Pine Creek; C.CK.- Carrot Creek; H - Highvale; W.G.- Willesden Green; F - Ferrier; R - Ricinus; CAR.- Caroline; CR.- Crossfield; L - Lochend). (Walker, pers. comm, 1989)



to deceleration of the sediment-carrying current over the high. This model does not address the problem of how the long linear topographic high develops in the first place, nor does it explain why the sand body has a sharp top. Also, in the modern examples discussed by Slatt (1984), the sand bodies are bank-like deposits rather than long linear bars like those observed in the Burnstick Member.

An alternate interpretation is that the sand bodies were not the result of sediment transported across the shelf but instead were deposited in the shoreface. To deposit shoreface sediment onto marine mud it is necessary for the shoreface to migrate basinward onto the shelf. This could occur in response to a relative drop in sea level. The relative drop in sea level would result in the formation of a basin wide erosion surface overlain by a coarsening upward shallow marine sequence. Seven basin wide erosion surfaces and associated coarsening upward sequences have been recognized in the Cardium Formation (Plint et al., 1986; Fig. 2.2). Bergman and Walker (1987) proposed that the conglomeratic sequences were deposited in incised shorefaces formed during stillstand then buried by marine muds during transgression.

The Burnstick Member fields that have been studied so far have been interpreted as "offshore bars" (Berven, 1966) or more recently as incised shoreface deposits (Pattison,

1987). The aim of this thesis is to determine if the Burnstick Member sediments at Brazeau River can be interpreted as "offshore bars" or incised shoreface deposits. This will be established by studying the sand body geometry and sedimentology of the Burnstick Member in the Brazeau River area. In particular, the basal contact of the Burnstick Member will be mapped in plan view and cross section to determine how the stratigraphic position of the Burnstick Member changes.

1.2 Previous Work on the Cardium Formation

The purpose of this section is to briefly outline the development of ideas concerning the deposition of the Cardium Formation. The present understanding of the Cardium Formation is the result of both outcrop and subsurface studies. This discussion will first deal with the Cardium in general then focus in on previous studies of the Burnstick Member. A more comprehensive review of the history of ideas concerning the deposition of the Cardium Formation is given by Stott (1963) and Walker (1983a).

Ideas about the deposition of the Cardium Formation since the early fifties include a wide range of environments. Beach (1955) interpreted the Cardium Formation as turbidity current deposits based on the continuity of the pebble horizons (Walker, 1983a). This

idea was not well received and was quickly replaced by concepts involving shallow marine sedimentation. These interpretations were made on the basis of sedimentary structures and sand body geometries and ranged from barrier island to deltaic. The shallow water origin of the Cardium Formation was supported by the classic outcrop work of Stott (1963) who interpreted the Cardium Formation as varying from shallow water to transitional environment deposits (Walker, 1983a).

The concept of storm emplaced sands was introduced by Michaelis and Dixon (1969). This stimulated an influx of new ideas about the origin of the Cardium Formation. Various interpretations followed in the 1970's and early 1980's which involved the deposition of the coarse clastic material by storm induced currents including storm generated turbidity currents (Walker 1983a).

The most recent phase in the evolution of ideas about the deposition of the Cardium Formation is incised shoreface deposits. This interpretation hinges on the recognition of seven basin wide erosion surfaces, implying that the deposition of the Cardium Formation is related to fluctuations of relative sea level. Recent research interprets the main Cardium Formation sand bodies as shoreface deposits on the basis of sand body and erosion surface geometry (Bergman and Walker, 1987; Pattison,

1987).

The most important oil and gas producing Cardium sand bodies are the E5 and E4 fields (Fig. 1.1). The E5 fields are made up of the Raven River and Carrot Creek Members while the E4 fields are made up of the Burnstick Member. Most of the research on the Cardium Formation so far has dealt with the E5 fields. The only recent studies to involve the Burnstick Member are that of Berven, 1966; Walker, 1983b; Walker, 1983c; Plint et al., 1986 and Pattison, 1987.

The early study by Berven (1966) concluded that the rocks now assigned to the Burnstick Member were deposited as "offshore bars" tens of kilometers east of the nearest paleoshoreline; no transporting or focussing mechanism was proposed. The two papers by Walker (1983b, 1983c) discussed the stratigraphy and facies and proposed the formal names for the Cardium Members. Walker (1983c) concluded that the sediments of the southern fields were deposited at least 100 kilometers from the paleoshoreline by turbidity currents. (Walker no longer believes the Cardium sand bodies were deposited by turbidity currents Walker, pers. comm., 1989).

The Burnstick Member overlies the E4, erosion surface (Plint et al., 1986) and most recently has been interpreted as an incised shoreface deposit

(Pattison, 1987).

CHAPTER 2: Stratigraphy and Regional Setting

2.1 Introduction

The purpose of this chapter is to outline the stratigraphy of the Cardium Formation as developed by Stott (1963), Walker (1983c) and Plint et al. (1986). A brief discussion of the regional setting of the Cardium Formation is also included. Finally, this chapter covers the data base on which this study is based.

2.2 Stratigraphy

The Cardium Formation was deposited during the Turonian Stage of the Late Cretaceous. According to Haq et al. (1987) the Turonian covers the absolute time span from 92 to 89 million years ago. The Cardium occupies only the late Turonian and is believed to have been deposited in approximately one million years (Walker, 1986).

The Cardium Formation is made up of coarse clastic sediment that was deposited into the Alberta Foreland Basin from the rising Cordillera in the west. It is one of the three formations that make up the Alberta Group (Fig. 2.1) which is time equivalent to the Colorado Group in the United States (Walker, 1986).

The subsurface stratigraphic sequence of the Cardium Formation (Fig. 2.2) is divided into members on the basis of the seven basin wide erosion surfaces (labelled E1 to

Figure 2.1 The stratigraphy of the Alberta Group (Modified from Walker, 1986 with absolute ages from Haq et al, 1987). The Cardium Formation is Upper Turonian in age and rests stratigraphically between the Wapiabi and Blackstone Formations.

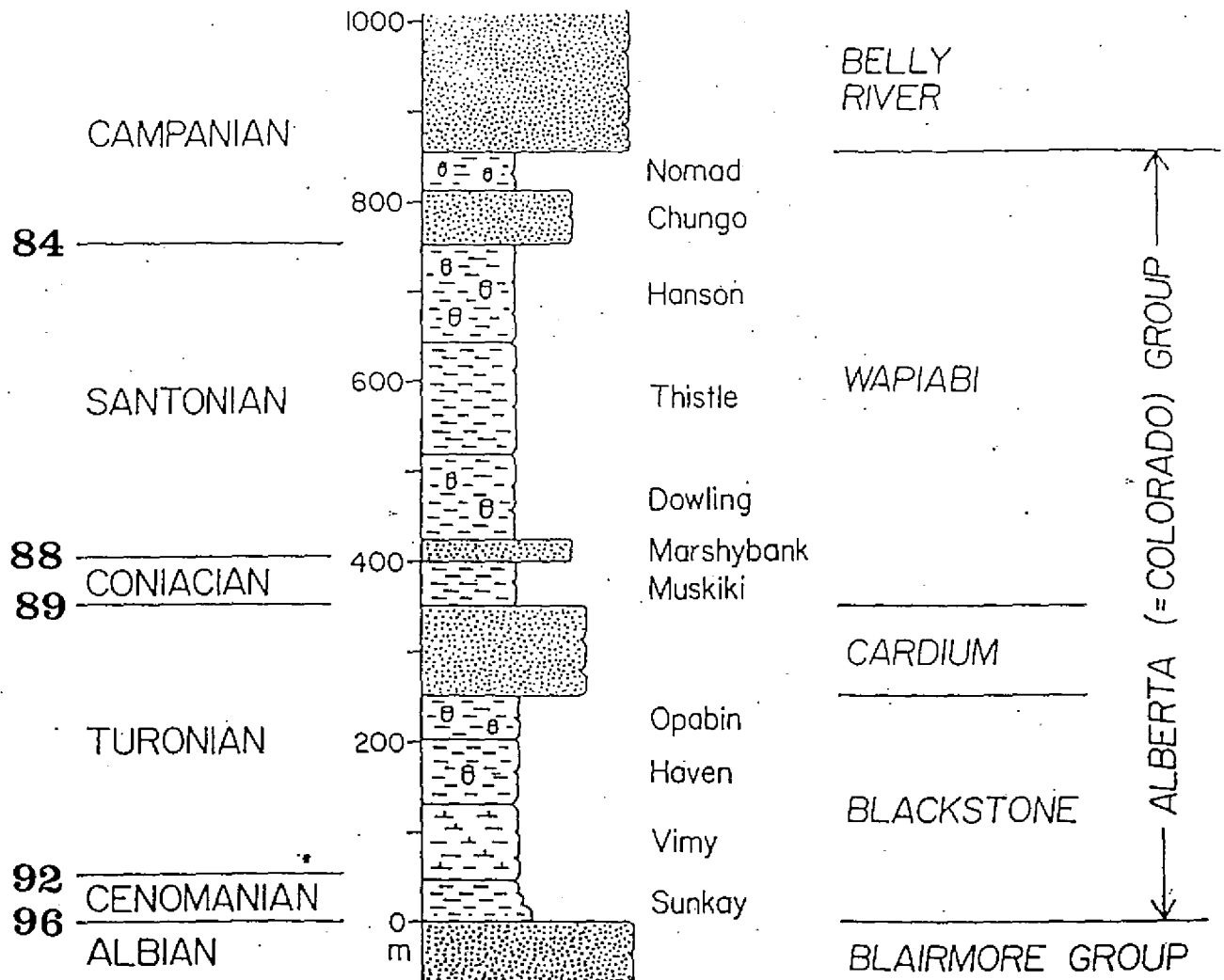
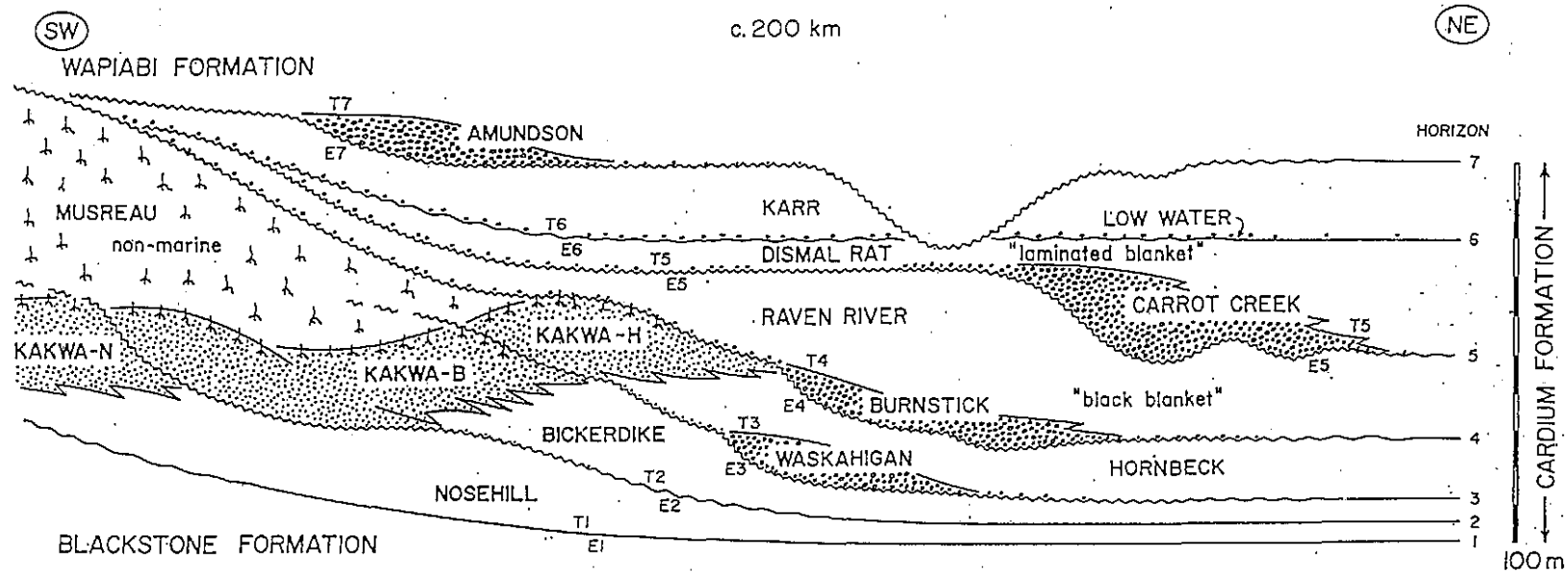


Figure 2.2 The subsurface stratigraphy of the Cardium Formation in southwestern Alberta (from Walker and Eyles, 1988, modified from Plint et al., 1986). The seven basin wide erosion surfaces are labelled E1 to E7 and the overlying transgressive surfaces are labelled T1 to T7. The Burnstick Member occurs at a stratigraphic interval midway through the Cardium Formation above the E4 erosion surface.



E7) identified by Plint et al. (1986). These erosional surfaces are unconformities that divide the Cardium Formation into allostratigraphic units bounded above and below by erosional surfaces. These allostratigraphic units comprise the members of the Cardium Formation.

The Burnstick Member is located midway through the Cardium Formation between the E4 erosion surface and the T4 transgressive surface. Where the surface is designated E4/T4 the E4 and T4 surfaces are coplanar. In core the E4/T4 surface is represented by, at most, a thin veneer of conglomerate. In the west the E4/T4 surface truncates the Kakwa Member. The Kakwa Member represents the closest possible paleoshoreface sandstone to the Burnstick Member (Plint et al., 1986). To the east the E4/T4 surface fades into marine mudstones.

2.3 Regional Setting

The Cardium Formation oil and gas fields are located in the tectonically undisturbed Alberta Foreland Basin (Fig. 1.1), on the western edge of the Western Interior Seaway of North America. During the Late Turonian a major global regression occurred which caused the sea level to drop in the Western Interior Seaway (Haq et al., 1987). It appears that the regression may be related to the deposition of the Cardium Formation.

The regional dip of the Cardium sediments in the subsurfaces ranges from 0.36°W in the northeastern corner of Pembina (Leggitt, 1987) to 0.72°W in the southwestern part of Lochend (Pattison, 1987). Thus it appears that the dip increases westward across the Alberta Basin.

The strike of the structure contours on top of the Burnstick Member sandstone is approximately NW-SE (Berven, 1966). A similar strike of 319° is shown by the Brazeau River Field (Burnstick Member).

2.4 Data Base

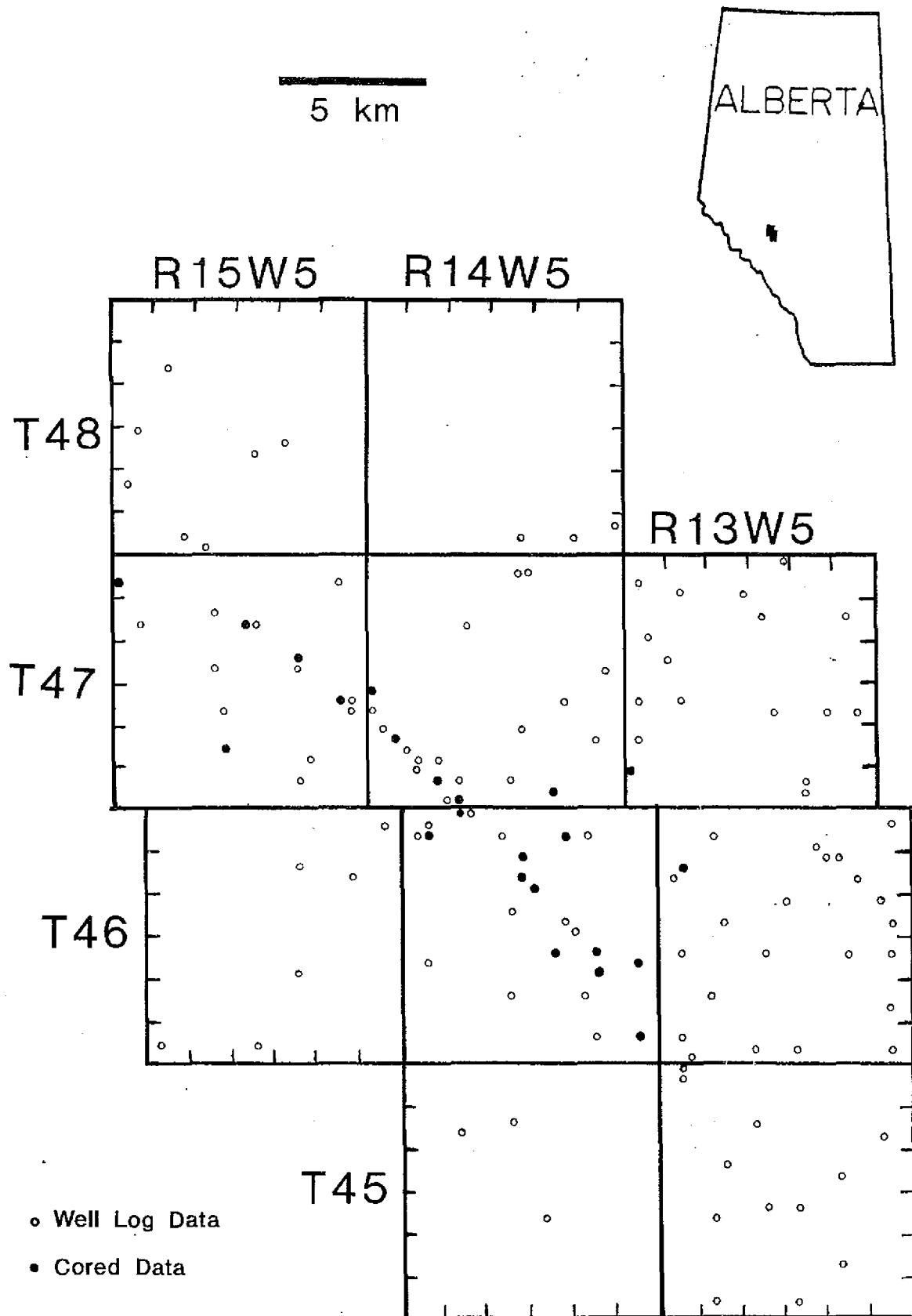
The Brazeau River oil and gas field lies west of Pembina (Fig. 1.1). This study includes T 45-48 R 13-15 (Fig. 2.3) and covers an area of approximately 1000 km².

Two types of data were collected for this study; drill core and electrical well logs. The drill core consists of 23 (3½ inch and 4 inch diameter) cores most of which were confined to the field area. These were logged to determine sand or silt content and trends, grain size trends, sedimentary structures and trace fossils. The sediments were divided into facies on the basis of their lithology, sedimentary structures and trace fossil content. These facies and the vertical facies sequences are described in Chapter 3.

The drill core data was augmented by approximately 130

Figure 2.3 The location of the core and well log data.

The core data is concentrated in a linear trend which follows the trend of the field.



resistivity wireline logs. Resistivity logs were chosen over other logs because they were available for all the wells and they gave the best response for correlation. A prominent rightwards deflection (high resistivity) on a resistivity log is characteristic of the Burnstick Member in on-field areas. The well log responses were first calibrated to the lithology using the existing core data. Then the lithology and position of the E4 surface was estimated in uncored wells allowing the construction of cross sections.

CHAPTER 3: Facies

3.1 Introduction

Six different facies have been identified in the cores that penetrate the Burnstick Member of Brazeau River Field. These facies are based on the Cardium facies scheme set up by Walker (1983c). Of the six facies, two occur largely in the Raven River Member and the remaining five occur in the Burnstick and Hornbeck Members.

Additional facies are denoted by the modifying letters G and P. G signifies that the facies includes scattered grit. This grit ranges in size from sand to granules (0.5 mm - 2 mm). P signifies that the facies contains "pebbles". The pebble size ranges from 2 mm to 10 mm but normally in the Burnstick Member the average clast size is 4.5 mm. In places the observed facies falls between two existing facies categories. In this case the unit is described by listing both facies with a slash between them (ie. F 4/5 means intermediate between F 4 and F 5). In some cases facies are interbedded, designated by dashes (-) between the facies (ie. F 5-7 means facies 5 and 7 are interbedded).

3.2 Facies Description

The following is a description of the facies observed in the cores of the study area. The facies are

distinguished by their lithology, sedimentological characteristics, sedimentary structures and biological (trace fossil) characteristics. Only those facies seen in the study area will be described below, consequently some of Walker's (1983c) facies will not appear.

Facies 1: Massive Dark Mudstone

This facies consists of dark grey to black massive mudstones with no fissility. There are no visible burrow traces. There is no discernible silt in this facies.

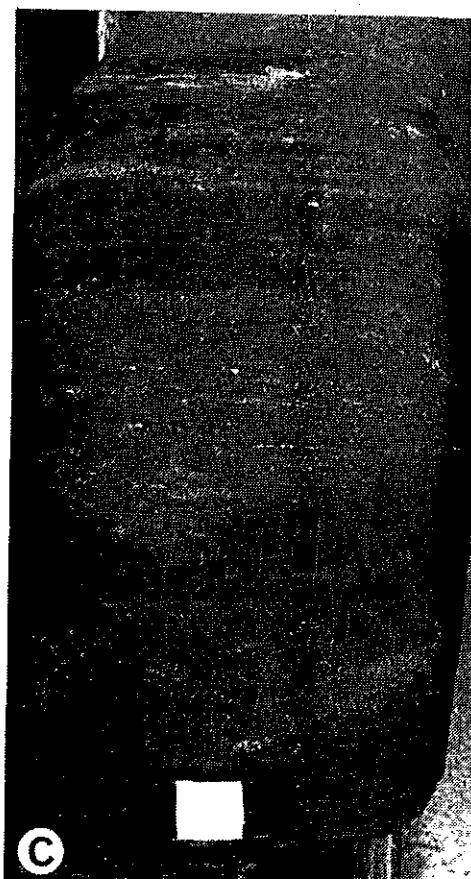
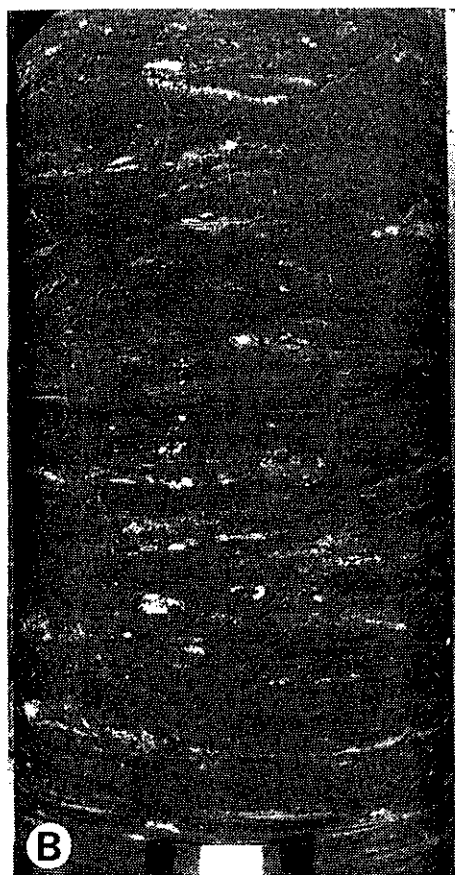
Facies 1 forms the "Black Blanket" (Walker, 1983) that overlies the Burnstick Member in most Cardium fields. However there is only one occurrence of Facies 1 within the study area; in most cores the "Black Blanket" is somewhat siltier than Facies 1. In this one instance Facies 1P occurs as a transitional facies between the upper contact of the Burnstick Member and Facies 1 (Fig. 3.1A).

Facies 3: Dark Bioturbated Muddy Siltstones

This facies consists of dark grey, massive, muddy siltstone with patches of silt (Fig. 3.1B). The patches, which reach a maximum size of 3 cm in width and 1 cm in thickness, occasionally show faint lamination. There is no lamination observed in the background facies. The observed burrow traces include Terebellina and (rarely)

Figure 3.1 The scale bars are 3 centimeters in length.

- (A) Facies 1P above the T4 surface from 14-32-46-14W5 at 2416.6 metres.
- (B) Facies 3 from 10-1-46-14W5 at 2427.8 metres.
- (C) Facies 1/3 from 8-28-46-14W5 at 2370 metres.
- (D) Facies 1P/3P from 5-31-47-15W5 at 2483.6 metres.



side-packed burrows.

An intermediate facies 1/3 (Fig. 3.1C) is commonly observed overlying the Burnstick Member. This facies is contains more dispersed silt than Facies 1 but the patches of silt observed in Facies 3 are rare. It appears dark grey rather than black. Terebellina is the only recognizable trace in this facies.

Facies 3 and 1/3 occur as "P" facies (Fig. 3.1D). The clasts fine and become less abundant upwards. They range in size from 10 mm to coarse sand. The average clast size is 5 mm. These "P" facies are sometimes partially sideritized.

Facies 1P/3P or 3P overlies the Burnstick Member and is a transition facies to the "Black Blanket". Facies 3, Facies 1/3 and Facies 1 comprise the "Black Blanket" in the Brazeau River area. Often the "Black Blanket" is observed to become siltier upwards from facies 1/3 into facies 3. The amount of silt in the "Black Blanket" varies over the study area. A comparison of three cores is shown in Figure 3.2.

Facies 4: Pervasively Bioturbated Muddy Siltstones

This facies consists of silt and fine sand which has been mixed into black mud by burrowing organisms (Figs. 3.3A, 3.3B). Patches of silt are often preserved as beds

Figure 3.2 Comparison of the Raven River Member from three Brazeau River Wells (8-28-46-14W5, 14-32-46-14W5 and 5-31-47-15W5). The "Black Blanket" (Raven River Member) is designated by "B". The sleeves are approximately 8 centimeters wide and 75 centimeters long.

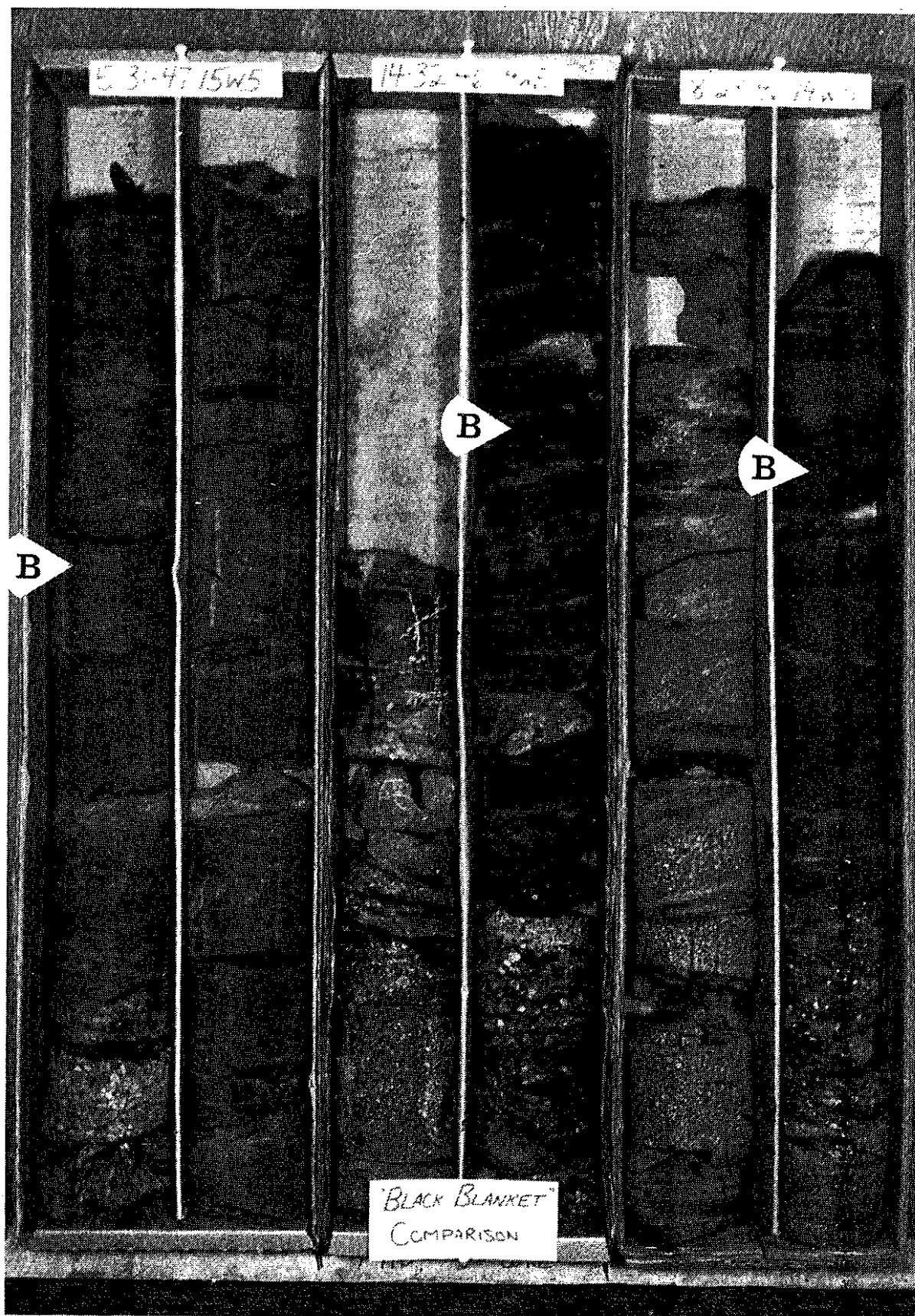


Figure 3.3 The scale bars are 3 centimeters in length.

- (A) Facies 4 showing non-laminated patches of silt from 02/10-14C-46-14W5 at 2370 metres.
- (B) Facies 4 showing laminated silt from 10-1-46-14W5 at 2431.65 metres.
- (C) Facies 4G from 10-1-46-14W5 at 2426.15 metres.
- (D) Facies 4P from 7-14-46-15W5 at 2328.8 metres.



or lenses which can be up to 5 cm thick. The patches usually show planar or low angle lamination with low angle truncations. The boundaries of these patches often show traces of burrowing. Traces observed in Facies 4 include Terebellina, Helminthopsis, Planolites, Teichichnus, and Chondrites(?).

Facies 4 has a corresponding "G" and "P" facies. Facies 4G (Fig. 3.3C) contains grit from coarse sand up to granules. The grit occurs in concentrated zones or spread throughout the facies. In general the patches of silt tend to contain the coarser grit. Facies 4P (Fig. 3.3D) is similar to Facies 4G but the clasts range from coarse sand up to pebbles (<1 mm - 10 mm). Facies 4G and 4P contain fewer recognizable traces.

Facies 5: Pervasively Bioturbated Sandstones

Facies 5 consists of bioturbated muddy sandstone (Fig. 3.4A). It is somewhat sandier than Facies 4 and more bioturbated. Laminated patches are rare in Facies 5 but those observed usually exhibit low angle truncations (Fig. 3.4B). The recognizable traces include Terebellina (Fig. 3.5A), Planolites, Helminthopsis, Teichichnus (Fig. 3.5B) and Rhizocorallium (Fig. 3.5A) or Zoophycos.

Facies 5 also occurs as "G" or "P" facies (Figs. 3.4C, 3.4D). Facies 5G contains grit from coarse sand up to

Figure 3.4 The scale bars are 3 centimeters in length.

- (A) Facies 5 from 10-5-47-14W5 at 2510.2 metres.
- (B) Facies 5 showing low angle truncations in a patch of laminated sand from 102/10-14C-46-14W5 at 2361.75 metres.
- (C) Facies 5G from 10-1-46-14W5 at 2424.95 metres.
- (D) Facies 5P from 102/10-14C-46-14W5 at 2364.3 metres.

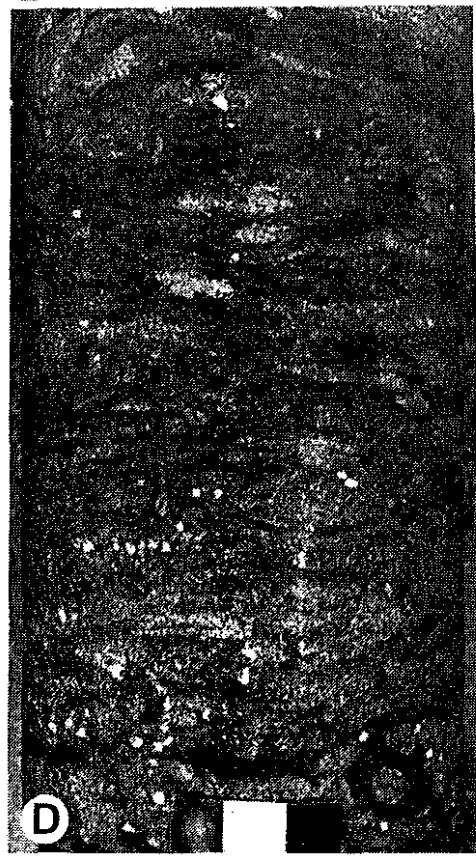
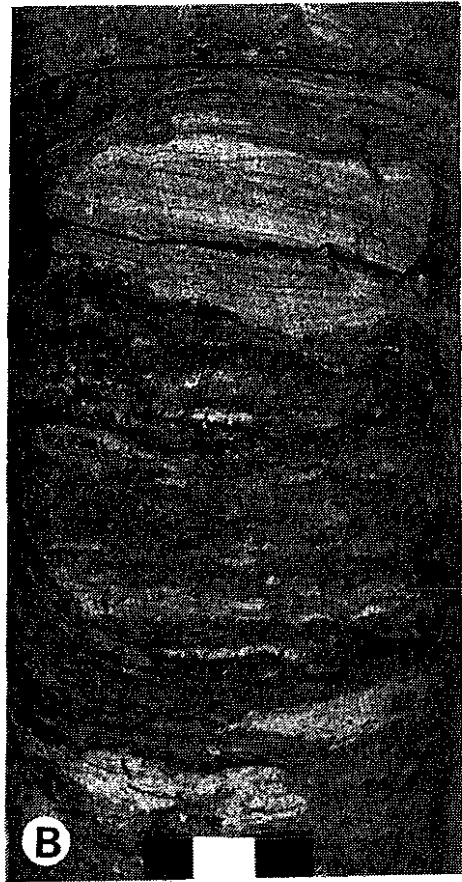
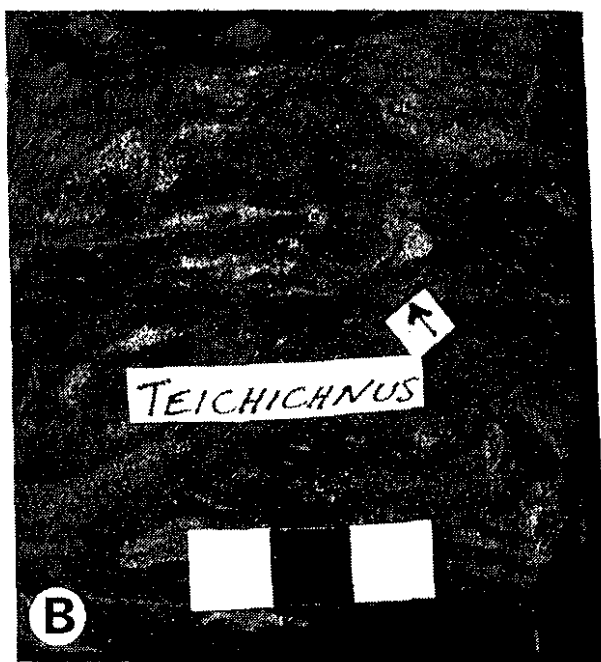
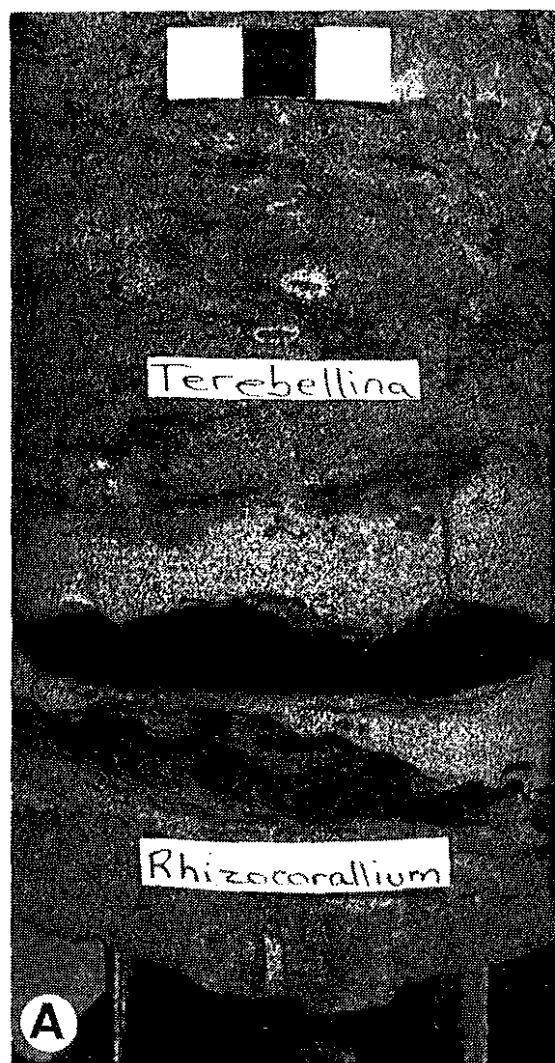


Figure 3.5 The scale bars are 3 centimeters in length.

- (A) Examples of Terebellina and Rhizocorallium in Facies 5 from 10-7-47-14W5 at 2434.6 metres.
- (B) An example of Teichichnus in Facies 4/5 from 7-13-46-14W5 at 2332 metres.



granules (0.5 mm - 2 mm). The grit is distributed evenly throughout giving the facies a speckled appearance. Facies 5P is similar to Facies 5G but the clasts range from coarse sand up to pebbles (<1 mm - 10 mm).

Transitional facies between Facies 4 and Facies 5 occur as do the corresponding "G" and "P" facies.

Facies 7: Nonbioturbated Sandstones

Facies 7 consists of nonbioturbated sandstones. The sandstones are well sorted quartz sands which range from 0.25 mm to 1.50 mm. Black mud laminae or beds are sometimes observed. These do not exceed 3 cm in thickness and usually have sharp bases and burrowed tops (Fig. 3.6C).

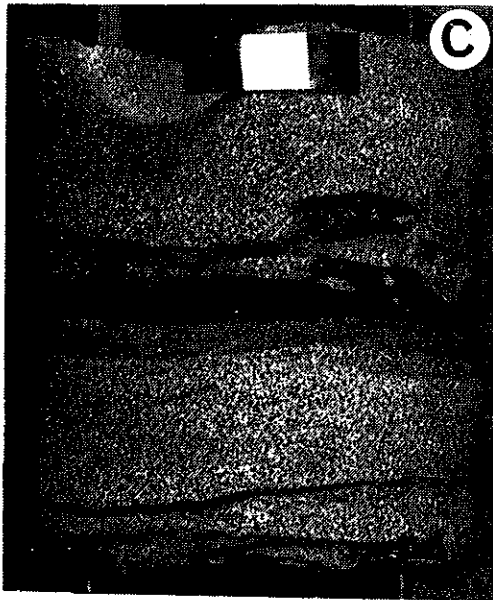
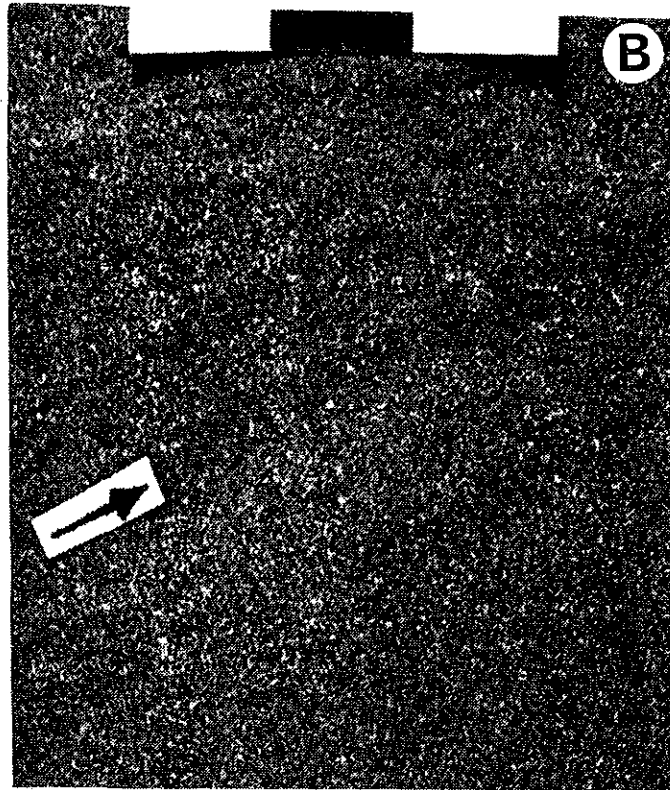
Other common features of Facies 7 are ripped up mud clasts. The mud clasts are 0.5 cm to 8 cm and can be rounded or angular. These clasts are frequently sideritized. The ripped up clasts tend to occur in zones and these zones are commonly found in the lower two-thirds of Facies 7.

The principal sedimentary structure of Facies 7 is cross lamination. This cross-lamination is highlighted by mud clasts or slight colour variation (Figs. 3.6A, 3.6B). The angles range from 15° - 27°.

Few trace fossils are recognized in Facies 7 except for Planolites (usually associated with the tops of mud

Figure 3.6 The scale bars are 3 centimeters in length.

- (A) Facies 7 showing cross lamination highlighted by mud clasts in 11-23-47-15W5 at 2472 metres.
- (B) Facies 7 showing cross lamination highlighted by colour variation in 10-15-46-14W5 at 2960 metres.
- (C) Facies 7 showing black mud laminae with sharp bases and burrowed tops in 14-32-46-14W5 at 2419.6 metres.
- (D) Facies 5-7-GS in 102/10-14C-46-14W5 at 2365 metres.



laminae) and very rare occurrences of Ophiomorpha.

Facies 7 often occurs interbedded with Facies 5 and zones of gritty siderite (GS) (Fig. 3.6D). The individual beds are usually 2 to 10 cm and have sharp or gradational contacts. The interbedded facies is designated by Facies 5-7-GS.

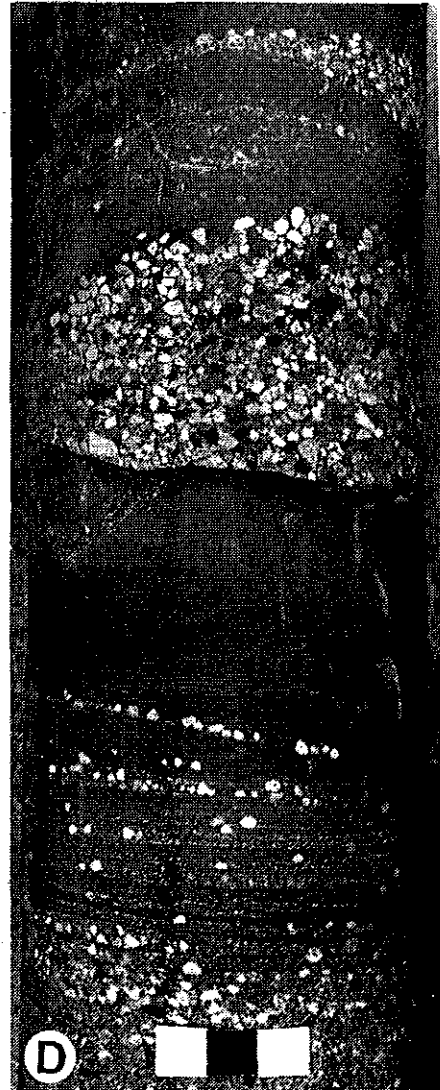
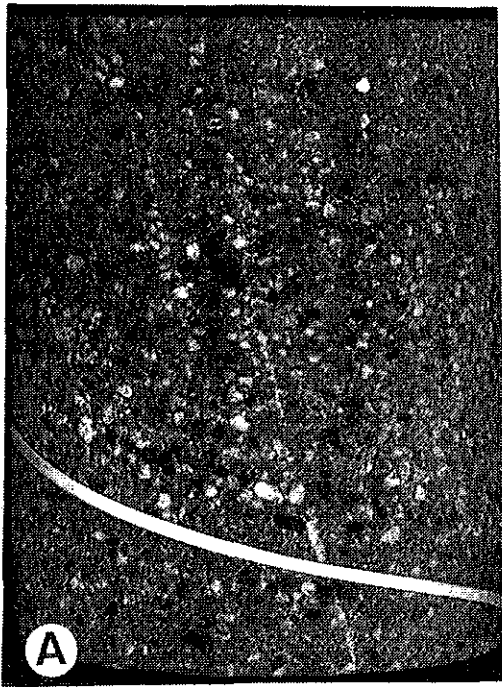
Facies 7P is similar to Facies 7 but it contains granules and/or pebbles. These pebbles reach a maximum size of about 10 mm. Mud clasts and mud laminae are not common in Facies 7P but a crude cross stratification is sometimes observed (Fig. 3.7A). Facies 7P often grades into a conglomerate as the pebbles increase upwards.

Facies 8: Conglomerate

Facies 8 consists granules and pebbles which are clast supported. The maximum pebble size ranges from 2 to 15 mm (Fig. 3.7B). The number and size of pebbles increases upwards (Fig. 3.7C). Sedimentary structures are not clear but cross lamination is suggested by mud clasts and sideritized zones. Facies 8 is often interbedded with thick siderite zones containing pebble or gritty stringers, Facies 8-GS (Fig. 3.7D). No trace fossils were observed in Facies 8.

Figure 3.7 The scale bars are 3 centimeters in length.

- (A) Facies 7P showing crude cross stratification in 16-28-46-14W5 at 2410.8 metres.
- (B) Facies 8 showing the maximum pebble size reached in the conglomerate from 14-32-46-14W5 at 2417 metres.
- (C) Facies 8 showing coarsening upwards trend from 11-23-47-15W5 at 2474 metres.
- (D) Facies 8-GS from 10-7-47-14W5 at 2532.4 metres.



3.3 Vertical Facies Sequence

The facies described above are superimposed to form a vertical facies sequence (Figs. 3.8, 3.9, 3.10). The sequence begins with the Hornbeck Member, which is composed of Facies 4, Facies 4/5 and Facies 4-4/5. This member lacks a consistent coarsening upward sequence; instead the facies grade back and forth into one another.

The Hornbeck Member is overlain by the Burnstick Member. The contact between the Hornbeck Member and the Burnstick Member is marked by an influx of coarse grit and/or pebbles. It can appear sharp (Figs. 3.11A, 3.11B) or gradational (Figs. 3.11C, 3.11D). The gradational contacts are due to bioturbation and can be restricted to a zone of 10 cm or less.

The Burnstick Member is a coarse sediment package that coarsens and cleans upwards. Facies 4G, Facies 4P, Facies 4G/5G or Facies 4P/5P forms the base of the Burnstick Member. Commonly the only difference between the Hornbeck and the Burnstick is that the Burnstick contains grit and/or pebbles.

The gritty bioturbated muddy siltstones pass upwards into cleaner sands of Facies 5G and/or Facies 5P. Usually the grit and pebbles decrease upwards and the "P" facies grades into Facies 5. Facies 5 then passes upwards into Facies 7. This transition from Facies 5 to Facies 7 is

Figure 3.8 A composite vertical sequence compiled from the on-field cores of the Brazeau River Area. The legend of symbols used in core logs is given in Figure 4.3.

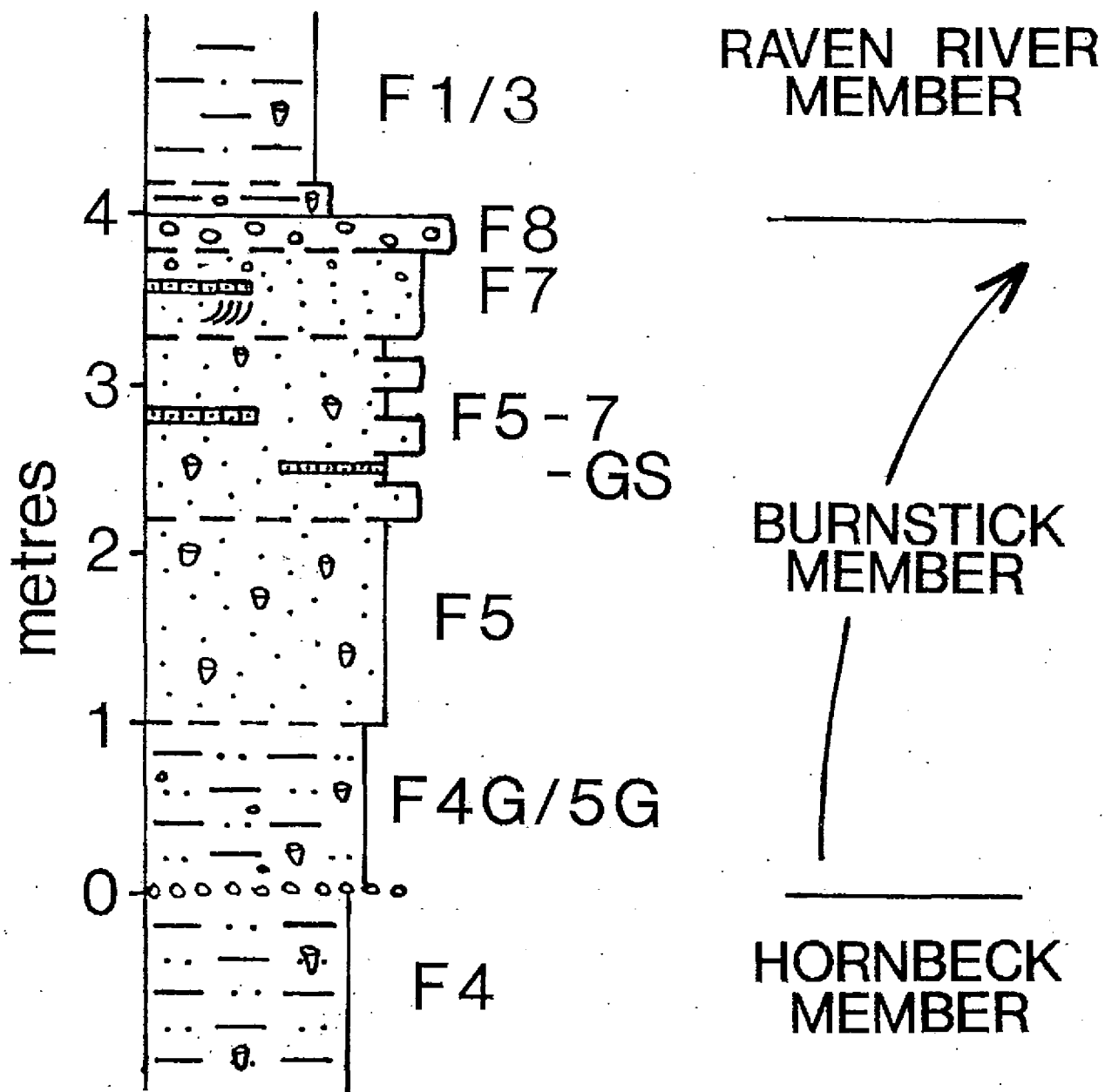


Figure 3.9 The next two pages show a typical vertical sequence for a muddy on-field core. The core is 14-32-46-14w5 (2424.4-2416.1 metres). The E4 erosion surface is marked by E and the T4 transgressive surface is marked by T. The other labels delineate the contacts between units and indicate the facies stratigraphically above the marker. "I" corresponds to the interbedded facies F5-7-GS. The sleeves are approximately 8 centimeters wide and 75 centimeters long and the top is to the top right.



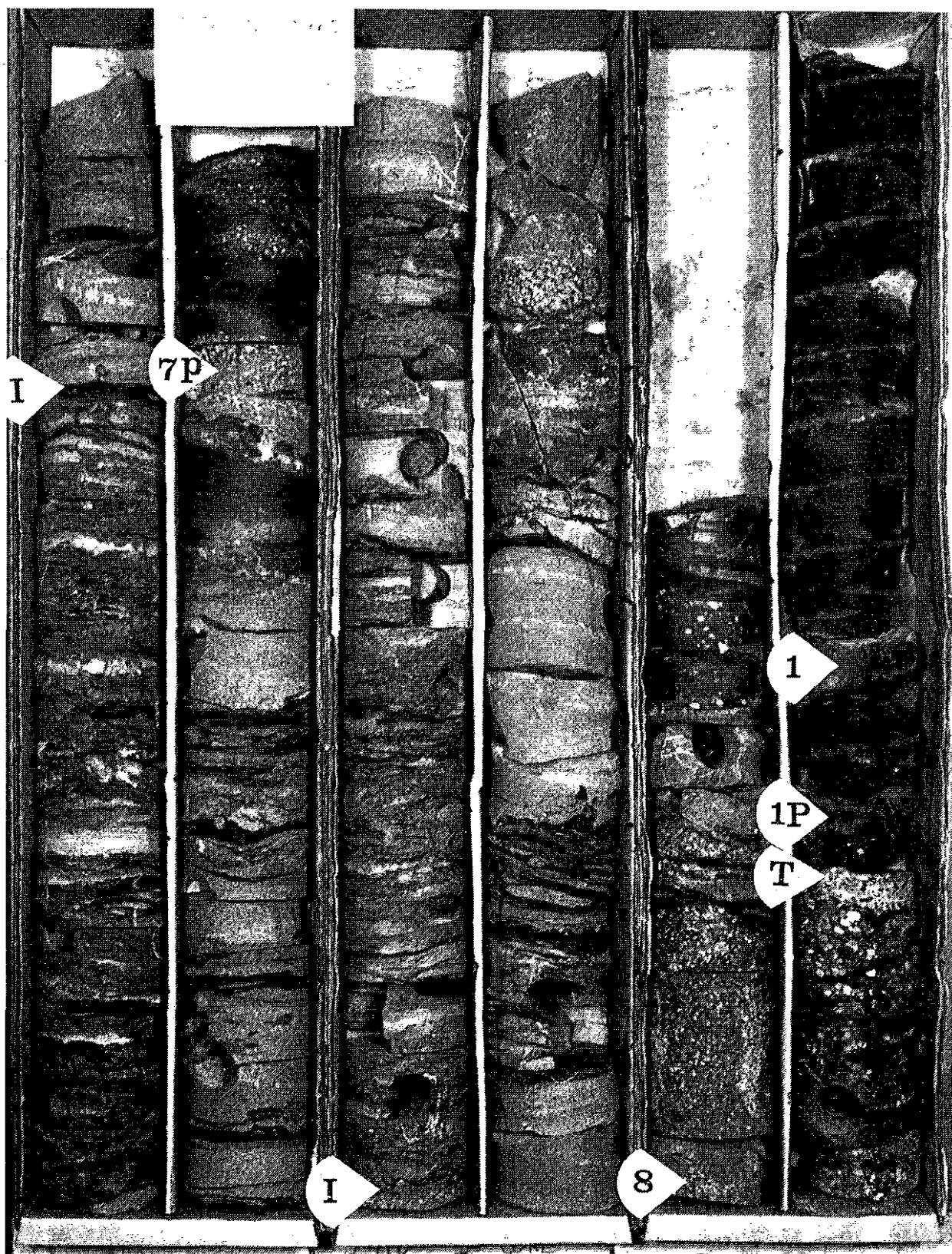


Figure 3.10 A typical vertical sequence for a sandy on-field core. The core is 10-15-46-14w5 (2427.25-2431.50 metres). The E4 erosion surface is marked by E and the T4 transgressive surface is marked by T. The other labels delineate the contacts between units and indicate the facies stratigraphically above the marker. The sleeves are approximately 8 centimeters wide and 75 centimeters long and the top is to the top right.

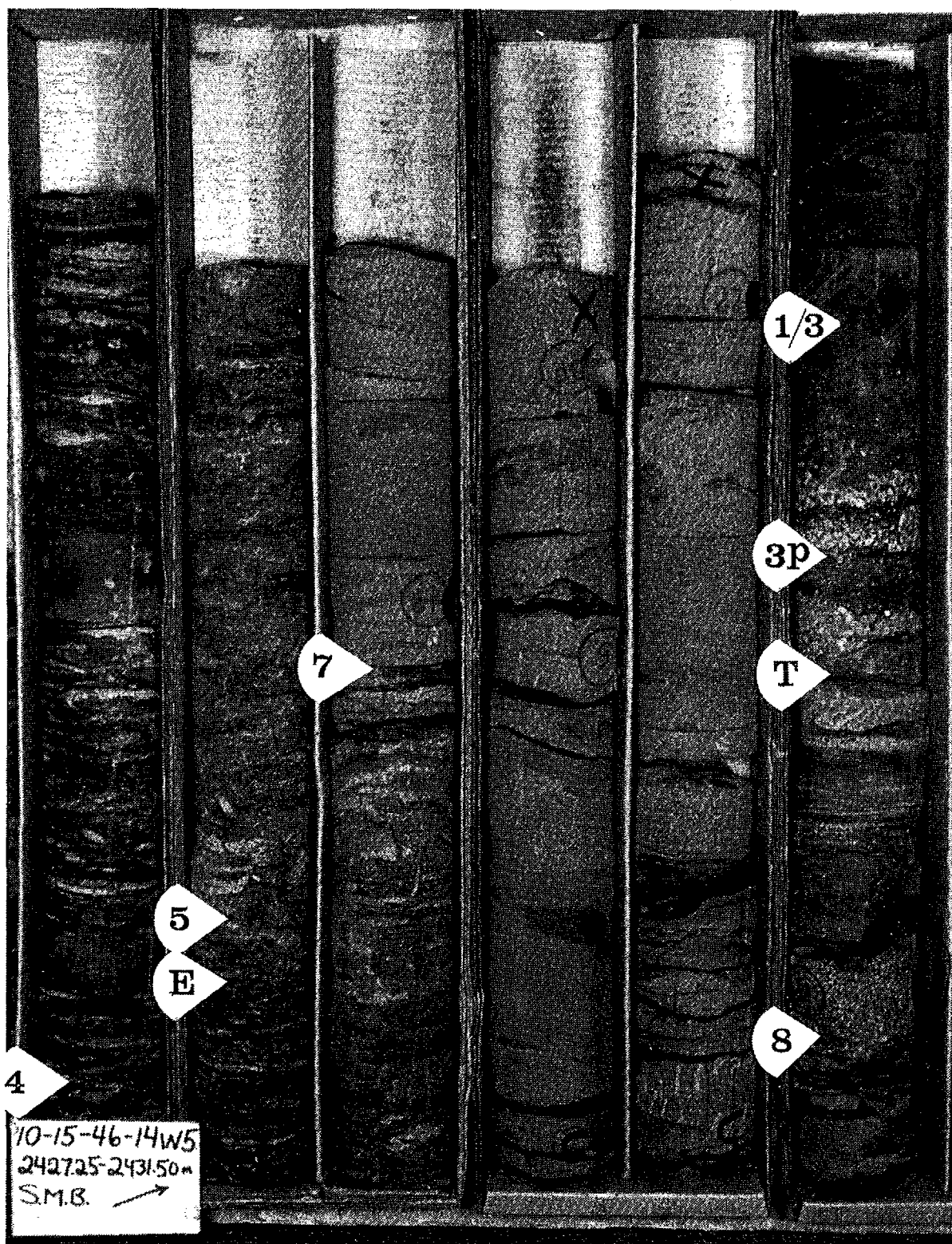
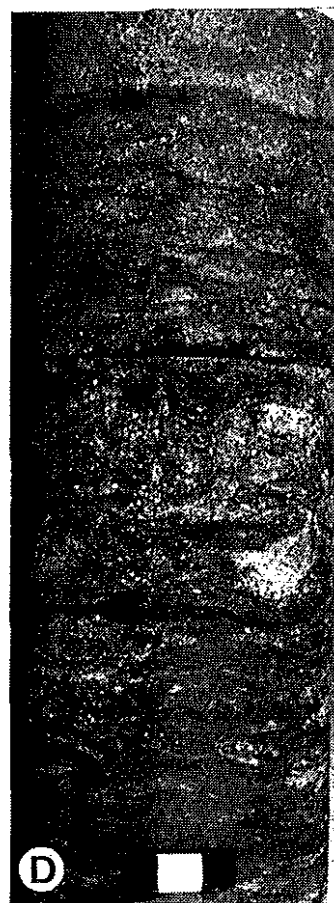
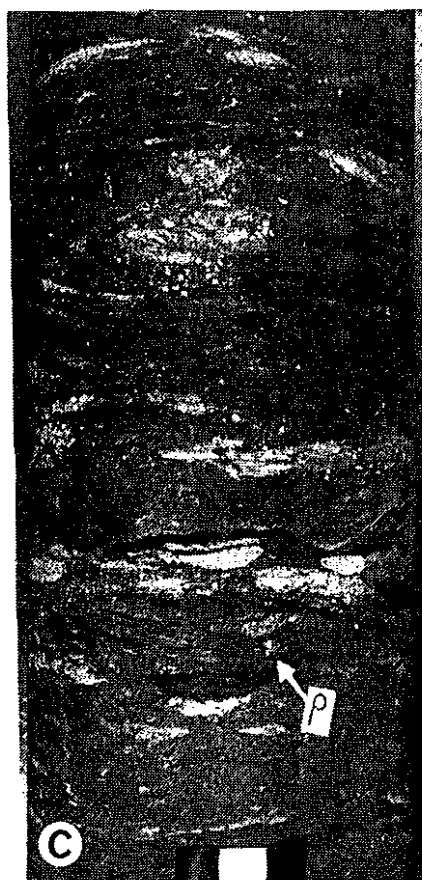
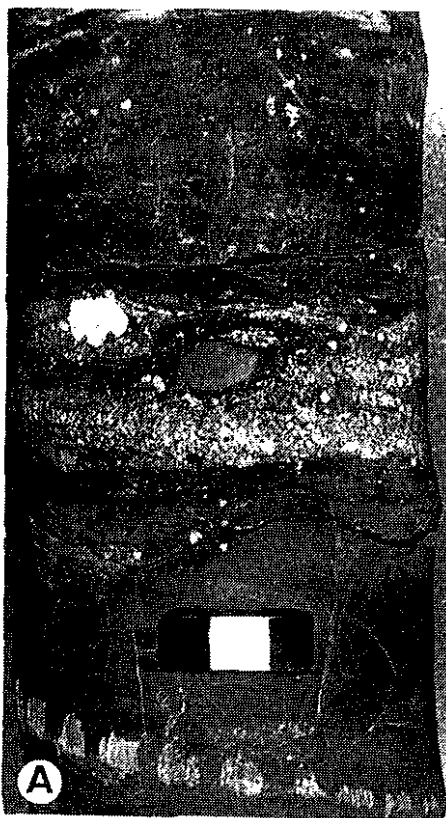


Figure 3.11 The scale bars are 3 centimeters in length.

- (A) A sharp E4 erosion surface from 14-32-46-14W5 at 2412.7 metres.
- (B) A fairly sharp E4 erosion surface (highlighted by the arrow) from 13-18-47-14W5 at 2517 metres.
- (C) A more gradational E4 erosion surface from 12-4-47-15W5 at 2484 metres. The erosion surface is taken as the first occurrence of pebbles or grit (marked by P).
- (D) A gradational E4 erosion surface from 8-28-46-14W5 at 2376.6 metres. The amount of grit and pebbles increase gradually upwards. The erosion surface is taken as the first occurrence of grit or pebbles.

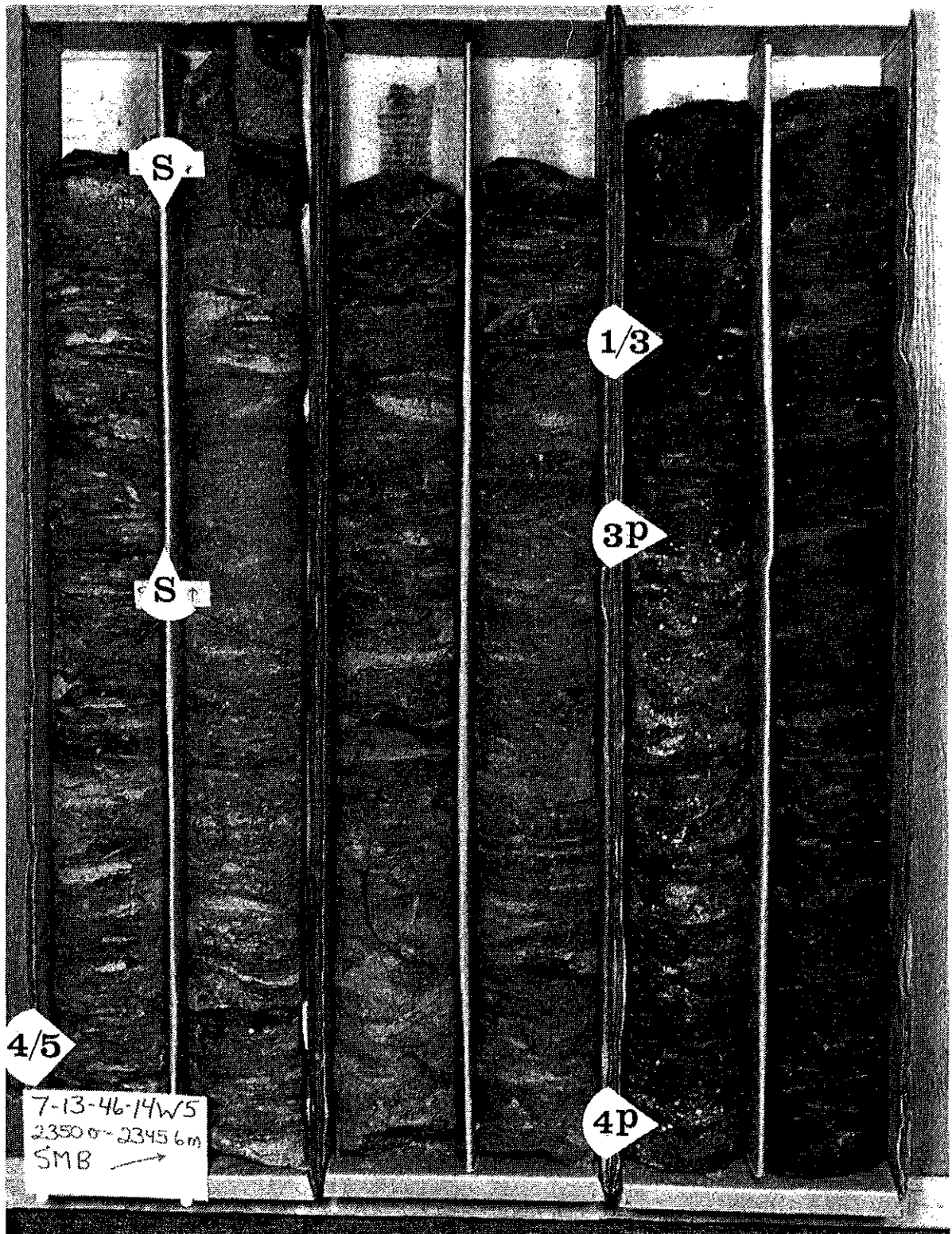


often through an interbedded unit of Facies 5-7-GS. The cleaning upward trend continues and the interbedded facies passes gradationally into Facies 7 and Facies 8. Facies 8 is overlain sharply by the Raven River Member.

The base of the Raven River Member consists of Facies 3P, Facies 1P/3P or Facies 1P. The "P" facies is transitional to the "Black Blanket". The "Black Blanket" in the study area consists of Facies 3, Facies 1/3 or Facies 1. Commonly, in wells containing long intervals of the Raven River Member, the "Black Blanket" is observed to become siltier upwards.

In cores from off-field, the Raven River Member sits directly on Facies 4G, Facies 4P, Facies 4G/5G or Facies 4P/5P (Fig. 3.12). Occasionally the contact between the Burnstick Member and the Raven River Member is represented by a pebble lag.

Figure 3.12 A typical vertical sequence for an off-field core. The core is 7-13-46-14w5 (2345.6-2350 metres). The labels delineate the contacts between units and indicate the facies stratigraphically above the marker. The "S" markers bracket a thick sideritized zone. The sleeves are approximately 8 centimeters wide and 75 centimeters long and the top is to the top right.



CHAPTER 4: Cross Sections

4.1 Introduction

In order to understand the lateral variations and two dimensional geometry of the Burnstick Member it was necessary to construct cross sections across the study area. Six well log cross sections and four core sections were constructed perpendicular to the strike of the field and one well log section and its corresponding core section was constructed parallel to the field. The location of these sections is shown in Figure 4.1.

4.2 Cross Sections

The purpose of the well log cross sections is to trace the E4 and T4 surfaces across the study area in order to reveal any changes in their stratigraphic position.

The datum used for the well log cross sections is the lower marker (LM) below the Burnstick Member (Fig. 4.4). It is a rightward deflection in the resistivity log. An upper marker (UM) was also picked; it is recognised as the broad "M"-shaped marker above the Cardium Formation (Fig. 4.4). To determine the topography on the datum UM to LM was isopached (Fig. 4.2). This isopach reveals that there is very little topography on the datum, however UM and LM are divergent. LM dips 0.03° to the east with respect to UM. The strike of the contours is north. The divergence

Figure 4.1 The base map showing the locations of the well log and core cross sections. The open circles represent well log data and the filled circles represent core and well log data.

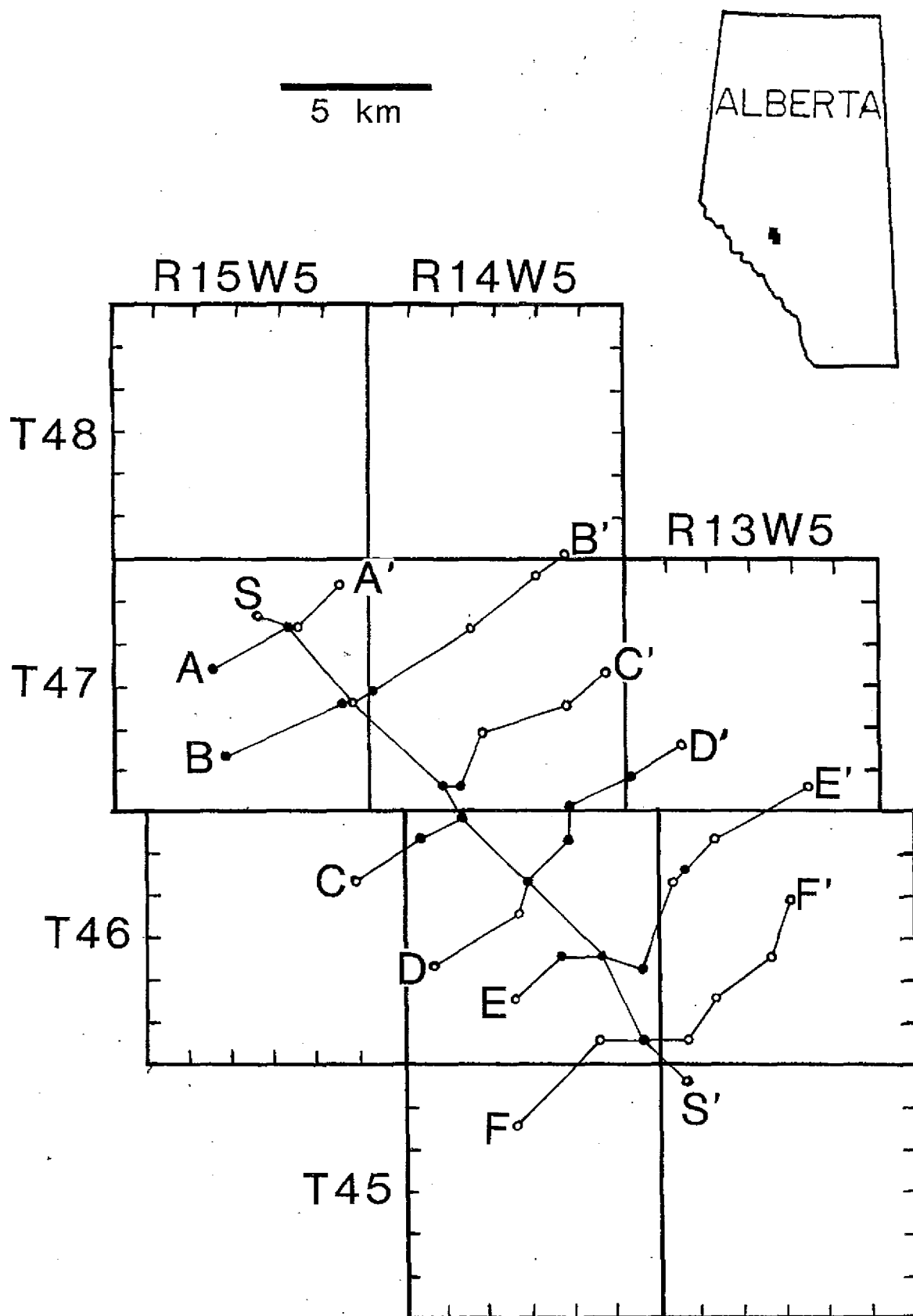
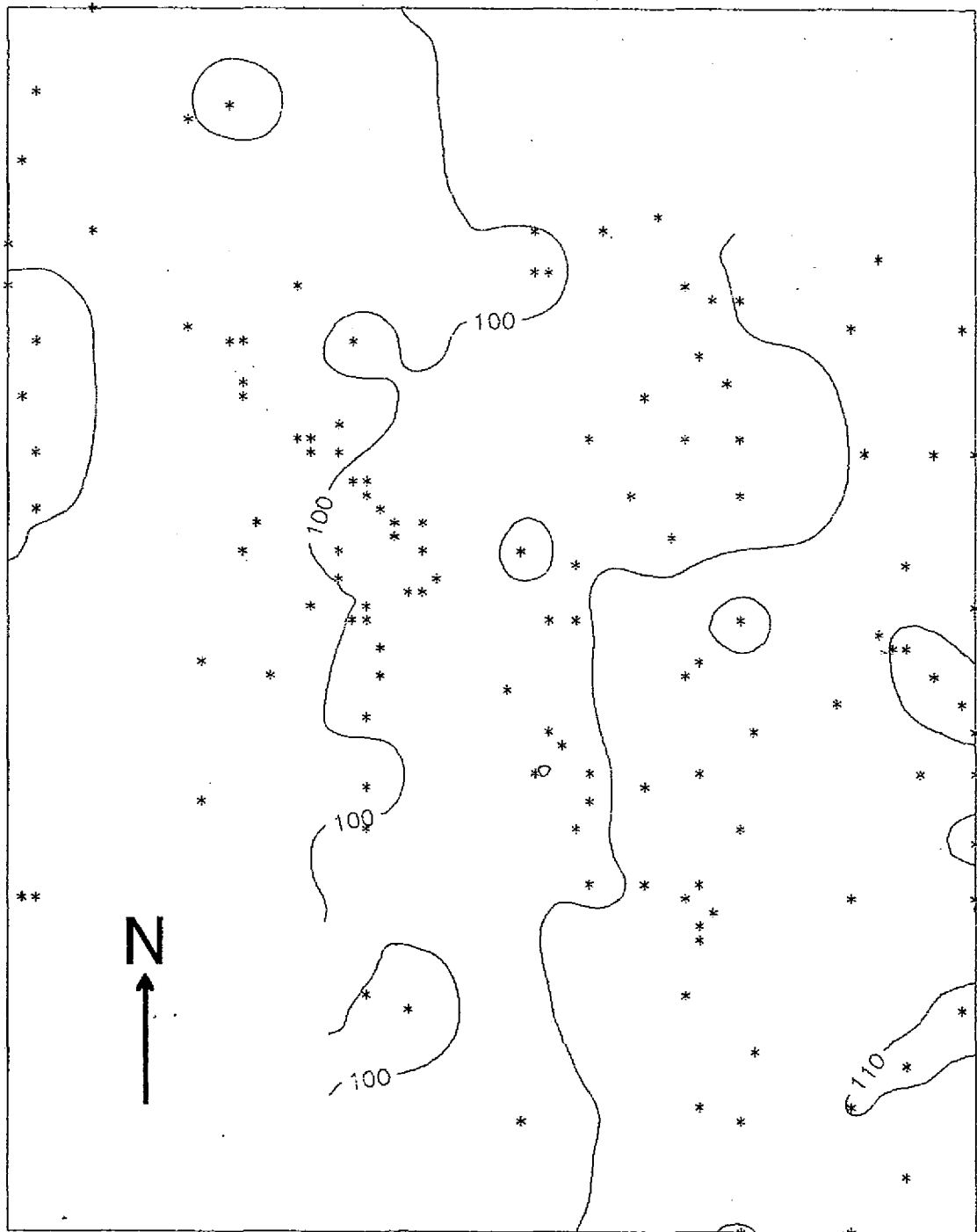


Figure 4.2 Isopach map of lower marker (LM) to upper marker (UM) interval. The contour values are in metres.. Data points are represented by *.



5 km

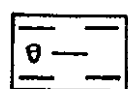
between LM and UM is not obvious in the cross sections because they trend southwest to northeast and therefore the apparent divergence will be much less.

Five other markers were picked, E7, E5, T4, E4 and E1. The picks at Brazeau River were compared with those at Pembina and are based on Plint et al. (1986). These correlations with Pembina and within the Brazeau River area are further strengthened by the distinctive and ubiquitous "Black Blanket" that overlies the Burnstick Member. The characteristic log signatures are evident from the cross sections (Figs. 4.4, 4.6, 4.8, 4.10, 4.12, 4.14, 4.15). The location of cored intervals are marked on the well logs by a heavy black bar. The E4 surface is represented by a zigzag correlation line while the T4 surface is represented by the straight line labeled E4/T4.

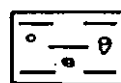
Five core cross sections were constructed to help trace the E4 and T4 surfaces across the study area and to reveal and lateral facies changes. These core sections are hung on the lower datum used for the well log cross sections. The core sections contain the same wells as those used in the well log sections. Only the interval of core containing the Burnstick Member was used for the cross sections. The legend for the core sections is shown in Figure 4.3.

The first of the cross section is A-A' (Fig. 4.4).

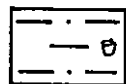
Figure 4.3 Legend of symbols used in the core cross sections.



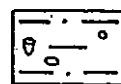
Facies 1



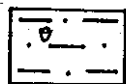
Facies 1P



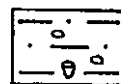
Facies 1/3



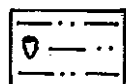
Facies 1P/3P



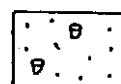
Facies 3



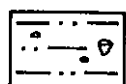
Facies 3P



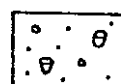
Facies 4



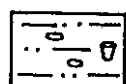
Facies 5



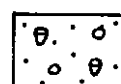
Facies 4G



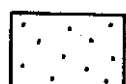
Facies 5G



Facies 4P



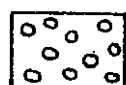
Facies 5P



Facies 7



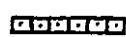
Facies 7P



Facies 8



Facies 5-7-GS



Siderite



Siderite Nodules



Mud Ripups



Coaly Fragment



Cross Lamination

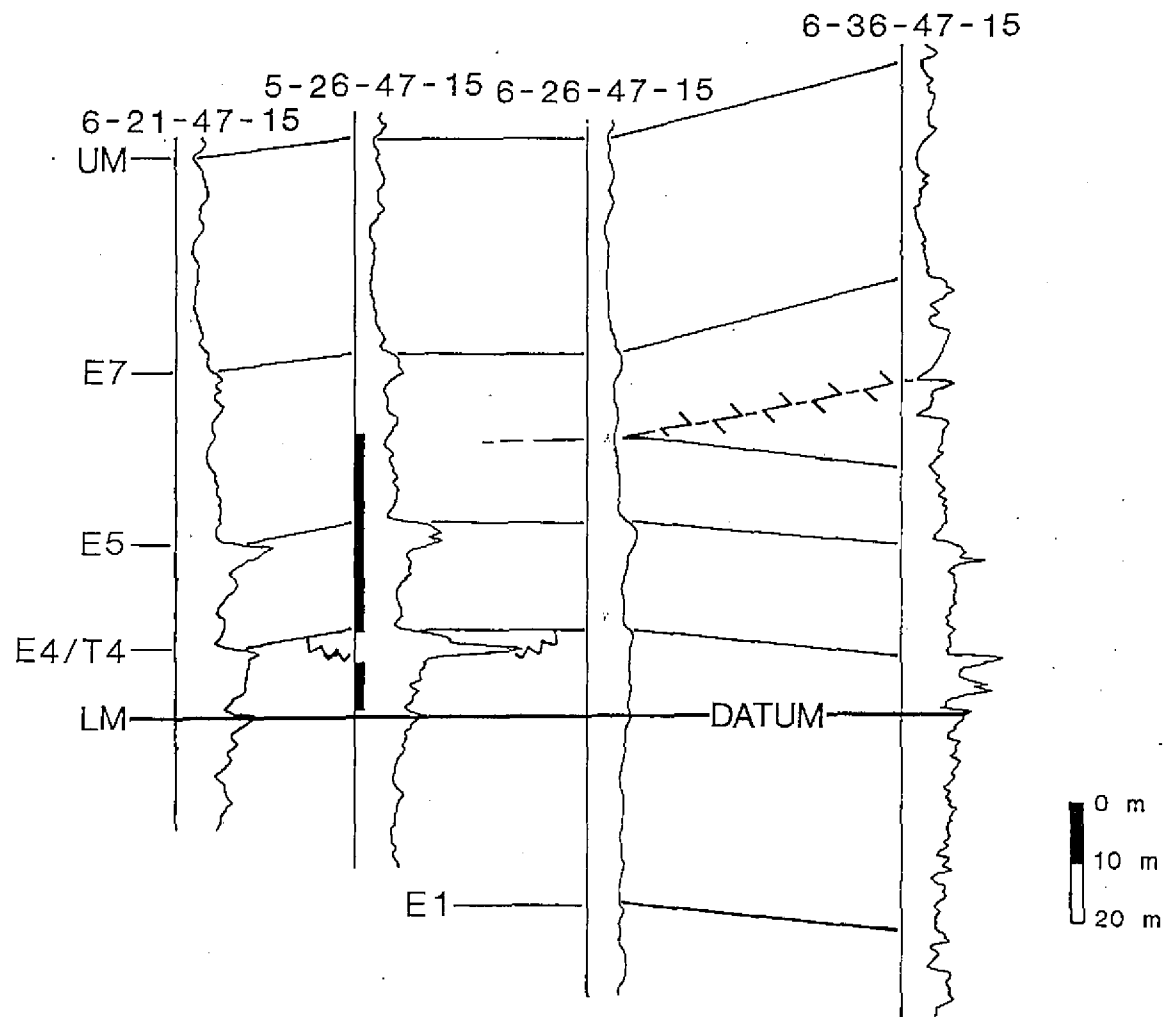


Pebble Stringers

Figure 4.4 Cross section A-A'. Location shown on Fig. 4.1. Horizontal distance covered is approximately 6 km. The "inclined Z" represents a thrust fault slip plane. (UM -Upper Marker; LM - Lower Marker.)

A

A'



SW

NE

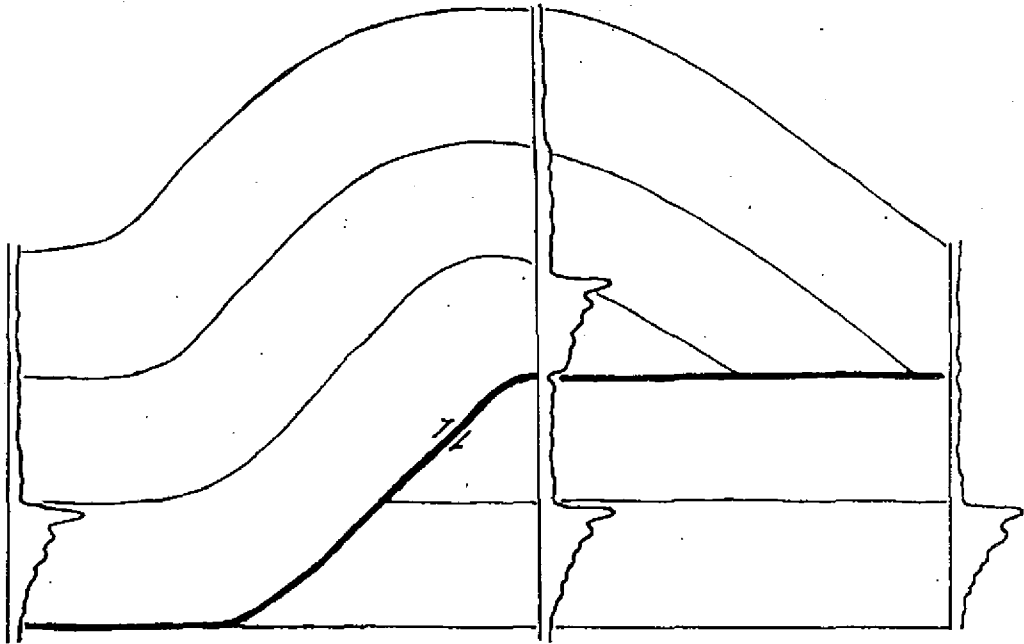
There is no corresponding core section for A-A'. The correlations in this cross section are straight forward, however UM and LM diverge towards the northeast. This is attributed to small scale blind thrust faults (Fig. 4.5). The general location of the thrust fault is recognized by divergence of the correlation lines. For example, in cross section A-A' (Fig. 4.4) it is obvious that there is a thrust fault between E7 and E5 because the correlation lines diverge. The correlation lines above the fault remain parallel as do those below the fault. The exact location of the fault is determined by comparing the log signatures of the faulted well and an unfaulted well (Fig. 4.5B). The fault plane is recognised as the place where the log signature departs from the unfaulted signature when the signatures are traced both down and up the log. The thickness of the fault is determined by deciding how much of the log signature is repeated above the fault plane. The fault-repeated section in 6-36-47-15W5 is approximately 15 metres. These thrust faults occur throughout the study area but were never cored. The faults are generally too small to trace from one well to the next.

In cross section B-B' (Figs. 4.6, 4.7) the parallel nature of the correlation lines is disrupted by thickening of the section due to thrust faults. In this case the section is thickened by approximately 12 metres. All the

Figure 4.5 (A) A schematic diagram of a blind thrust fault. The resistivity response is repeated through the faulted section. No scale is implied here. (Clifford, P.M., pers. comm., 1989)

(B) Showing the comparison of well logs. "F" delineates the fault plane, where the log responses depart from the normal response. The fault repeat is shaded.

A



B

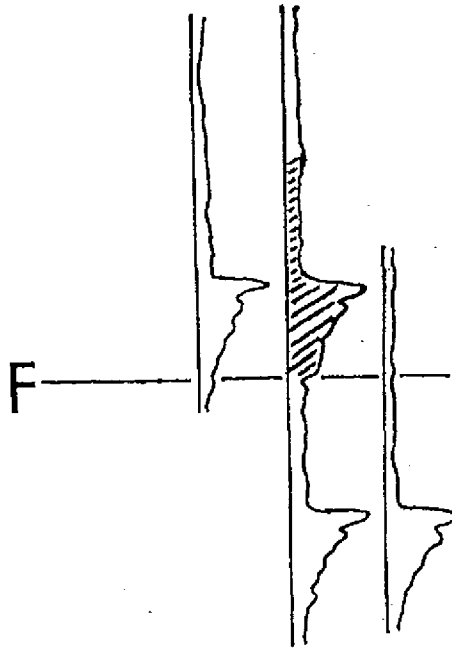


Figure 4.6 Cross section B-B'. Location shown on Fig. 4.1. Horizontal distance covered is approximately 13 km. The "inclined Z" represents a thrust fault slip plane. (UM -Upper Marker; LM - Lower Marker.)

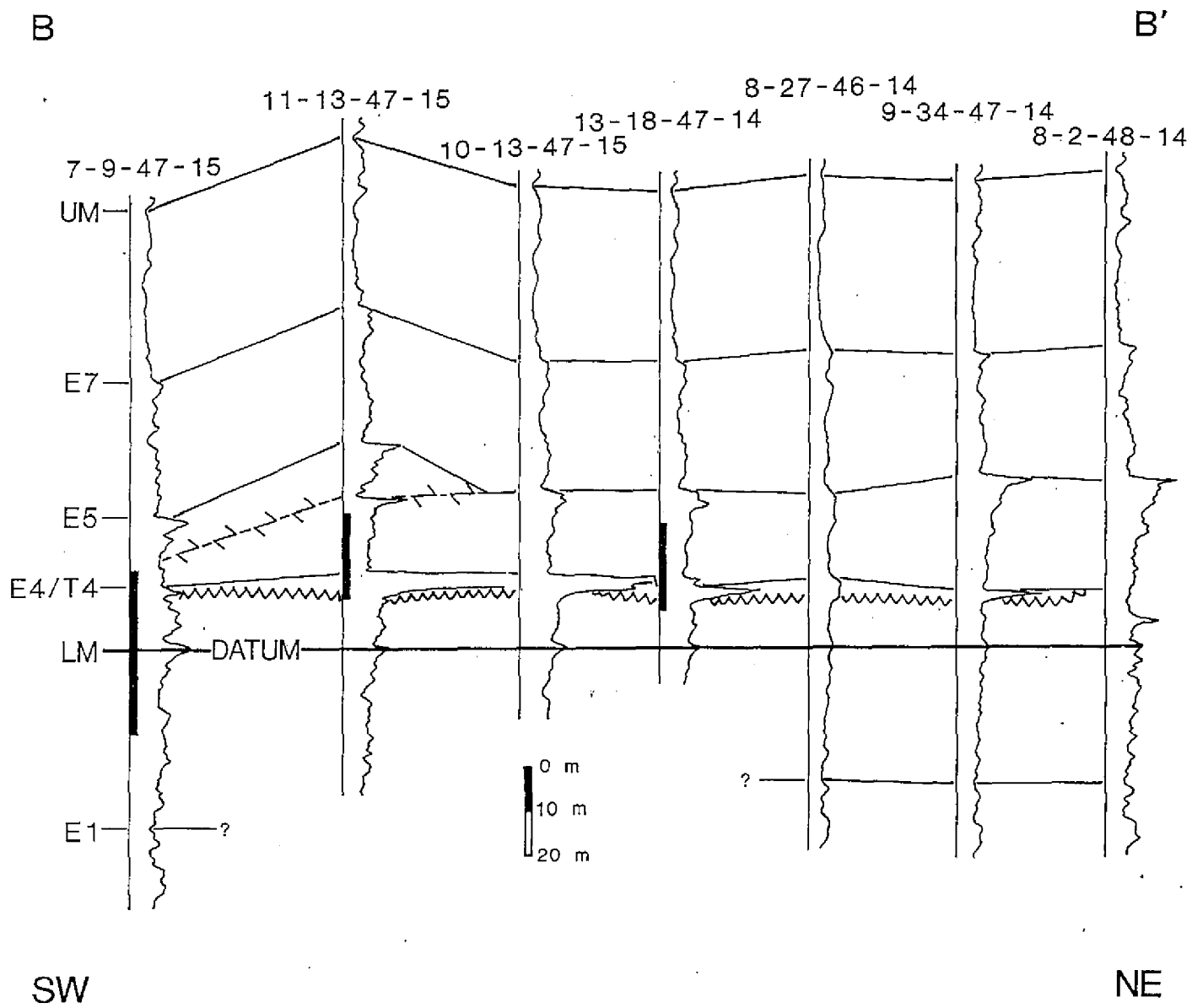


Figure 4.7 Core cross section B-B'. The location is shown on Fig. 4.1 and the legend is shown in Fig. 4.3. The horizontal distance is approximately 5 km.

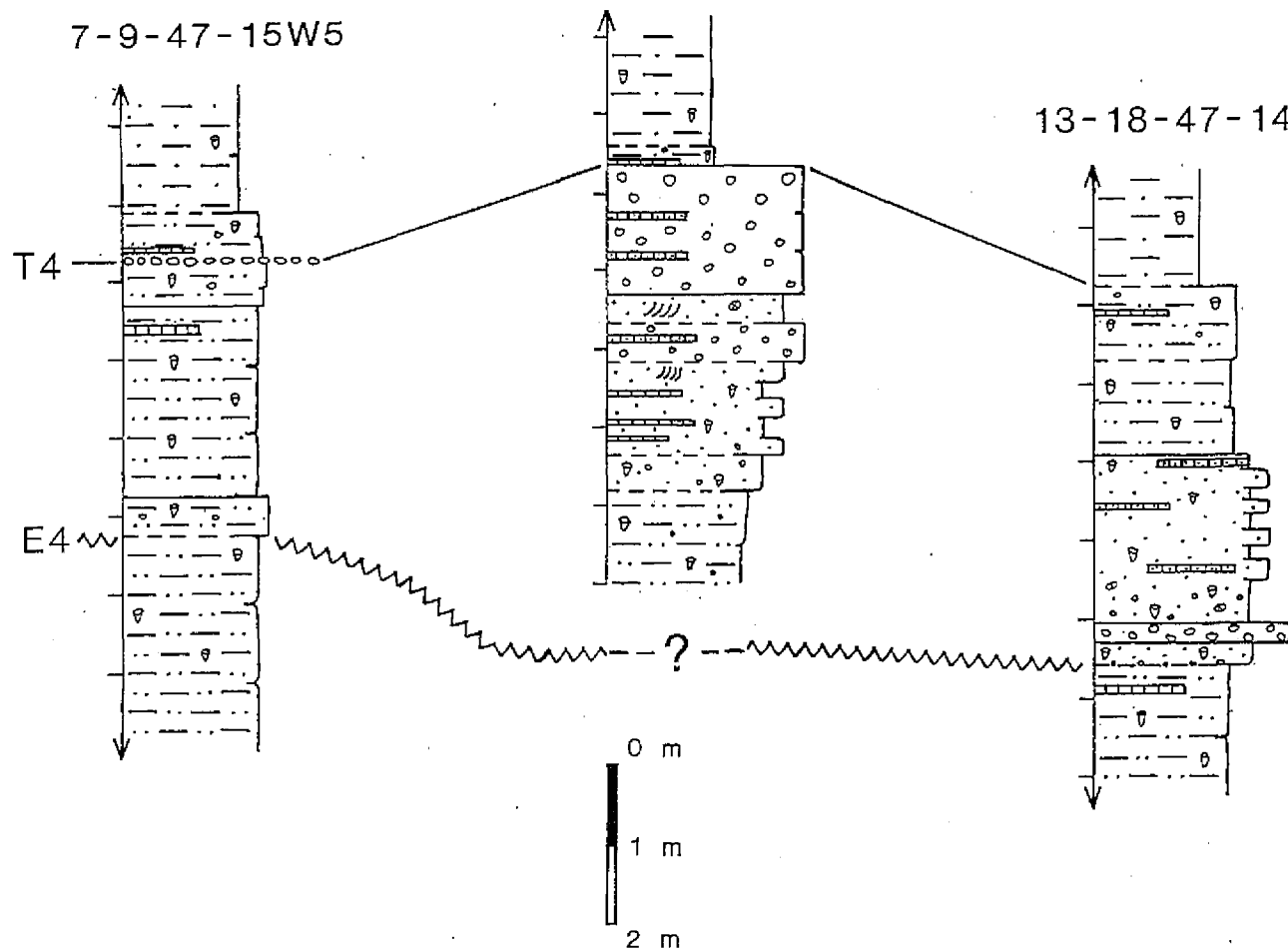
B

B'

11-13-47-15W5

7-9-47-15W5

13-18-47-14W5



SW

NE

correlations were straight forward except for E4/T4. Where core was available the correlations were based on the core. If core was not available as in 10-13-47-15W5, the correlation was based on the similar log signatures along the cross section and on strike. To the northeast the Burnstick signature completely disappears. In this case the correlation was made by carefully matching the log signatures between E5 and LM. The lower spike was not correlated to E4/T4 because comparison with other wells along strike indicate that the lower spike is a new coarsening upward sequence that developed above LM.

The well log section, and particularly the core section, shows the erosion surface steps down about 1.5 metres (Fig.4.7) towards the northeast. The core section also shows a lateral facies change with the cores getting muddier towards the northeast.

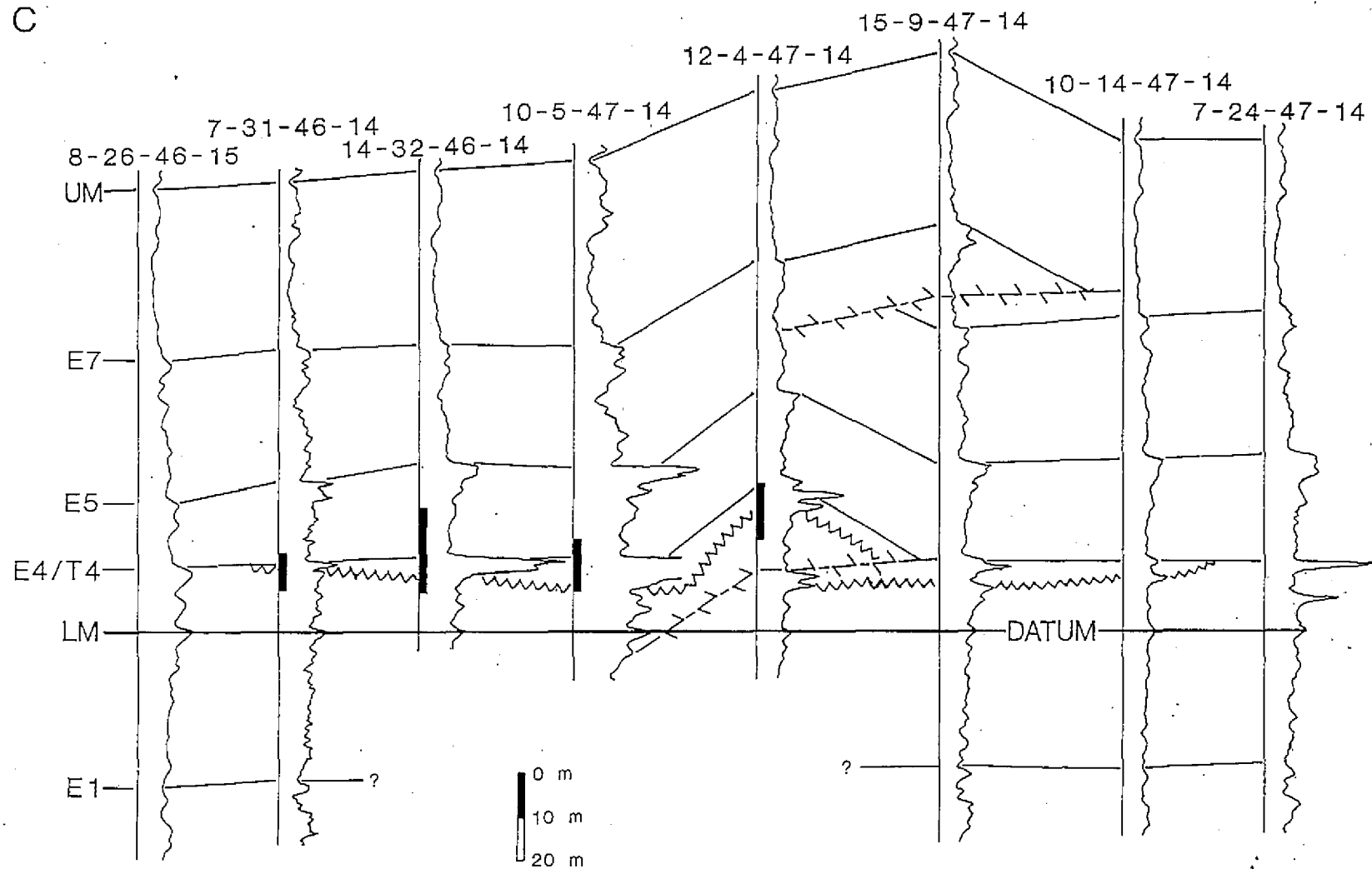
The correlations in C-C' (Figs. 4.8, 4.9) are disrupted by two thrust faults, the lower fault has repeated the Burnstick Member. Once again all the correlations are straight forward. The core section (Fig. 4.9) shows that E4 drops about 2.5 metres. Also the cores get muddier towards the northeast.

The correlations in D-D' (Figs. 4.10, 4.11) were straight forward except that the E4/T4 response fades out towards the northeast as discussed above. Also the

Figure 4.8 Cross section C-C'. Location shown on Fig. 4.1. Horizontal distance covered is approximately 12 km. The "inclined Z" represents a thrust fault slip plane. (UM -Upper Marker; LM - Lower Marker.)

C

C'



SW

NE

Figure 4.9 Core cross section C-C'. The location is shown on Fig. 4.1 and the legend is shown in Fig. 4.3. The horizontal distance is approximately 4 km. The unusual correlation between 10-5-47-14W5 and 12-4-47-14W5 is due to thrust faulting of the Burnstick Member in well 12-4-47-14W5 (Fig. 4.8). The fault repeated section is approximately 17 metres thick.

C

C'

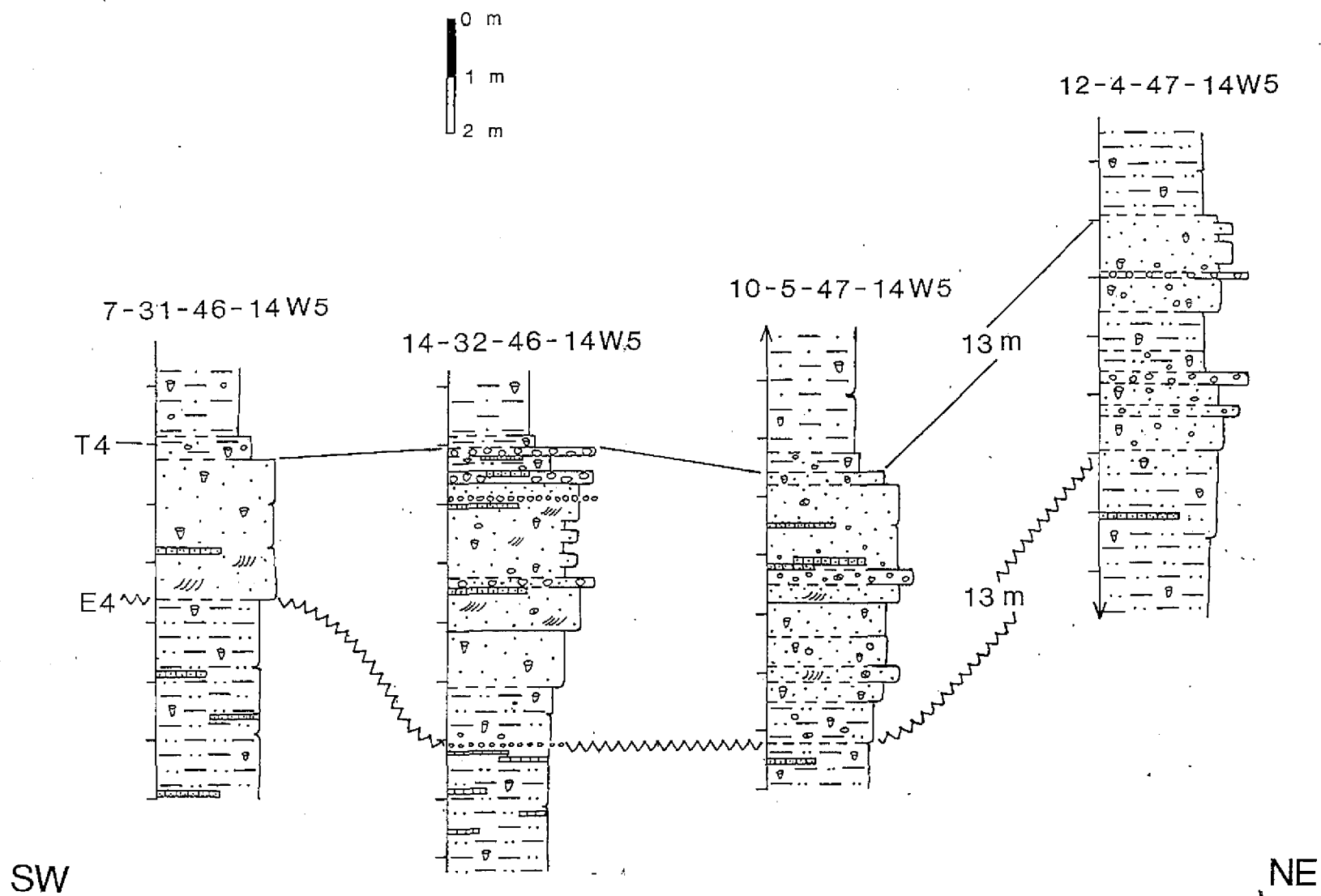


Figure 4.10 Cross section D-D'. Location shown on Fig. 4.1. Horizontal distance covered is approximately 12 km. The "inclined Z" represents a thrust fault slip plane. (UM -Upper Marker; LM - Lower Marker.)

D'



Figure 4.11 Core cross section D-D'. The location is shown on Fig. 4.1 and the legend is shown in Fig. 4.3. The horizontal distance is approximately 5 km.

D'

NE

0 m
1 m
2 m

8-34-46-14W5

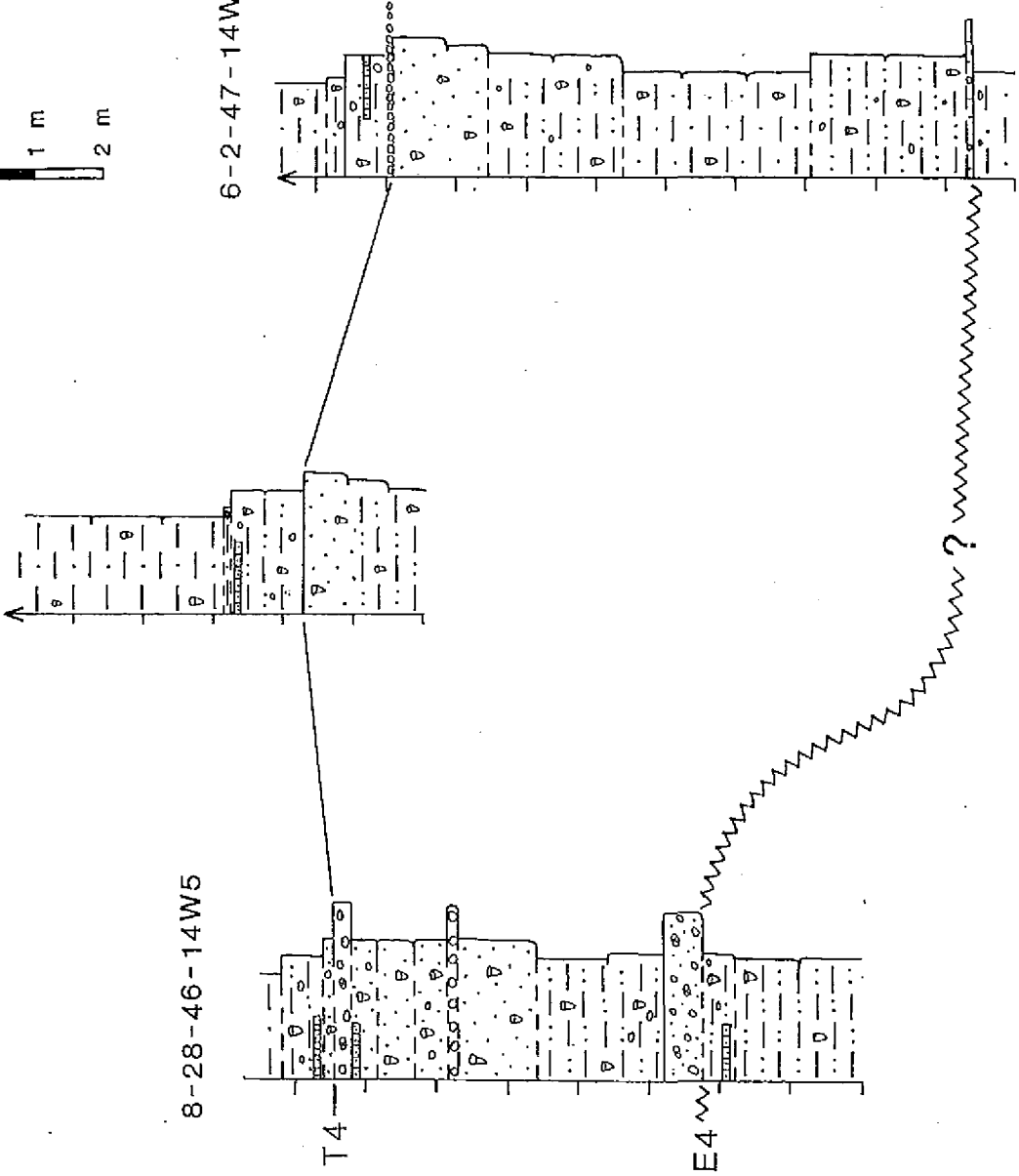
6-2-47-14W5

8-28-46-14W5

T4

E4

SW



correlation lines are disrupted by thrust faults. The stratigraphic drop in E4 towards the northeast is nearly 4 metres (Fig. 4.11).

In cross section E-E' (Figs. 4.12, 4.13) the correlations are disrupted by thrust fault however in this case the fault correlates from one well to the next. The stratigraphic drop in E4 towards the northeast is a little over 2.5 metres (Fig. 4.13).

The southern most cross section F-F' (Fig. 4.14) has no corresponding core section. The correlations show the usual problem of the E4/T4 response fading out towards the northeast but otherwise the correlations are straight forward. This cross section shows no evidence of thrust faulting.

There were no problems with the correlations in the strike section, S-S' (Figs. 4.15, 4.16).

In general, the cross sections show a well defined E4/T4 surface to the southwest that fades out towards the northeast. The E4 surface drops down stratigraphically towards the northeast to form a shallow step. This is shown in the well log cross sections and the core cross sections. It appears from the strike sections that the Burnstick Member thins towards the northwest. The core sections reveal a lateral facies change in which the cores get muddier towards the northeast.

Figure 4.12 Cross section E-E'. Location shown on Fig. 4.1. Horizontal distance covered is approximately 14 km. The "inclined Z" represents a thrust fault slip plane. (UM -Upper Marker; LM - Lower Marker.)

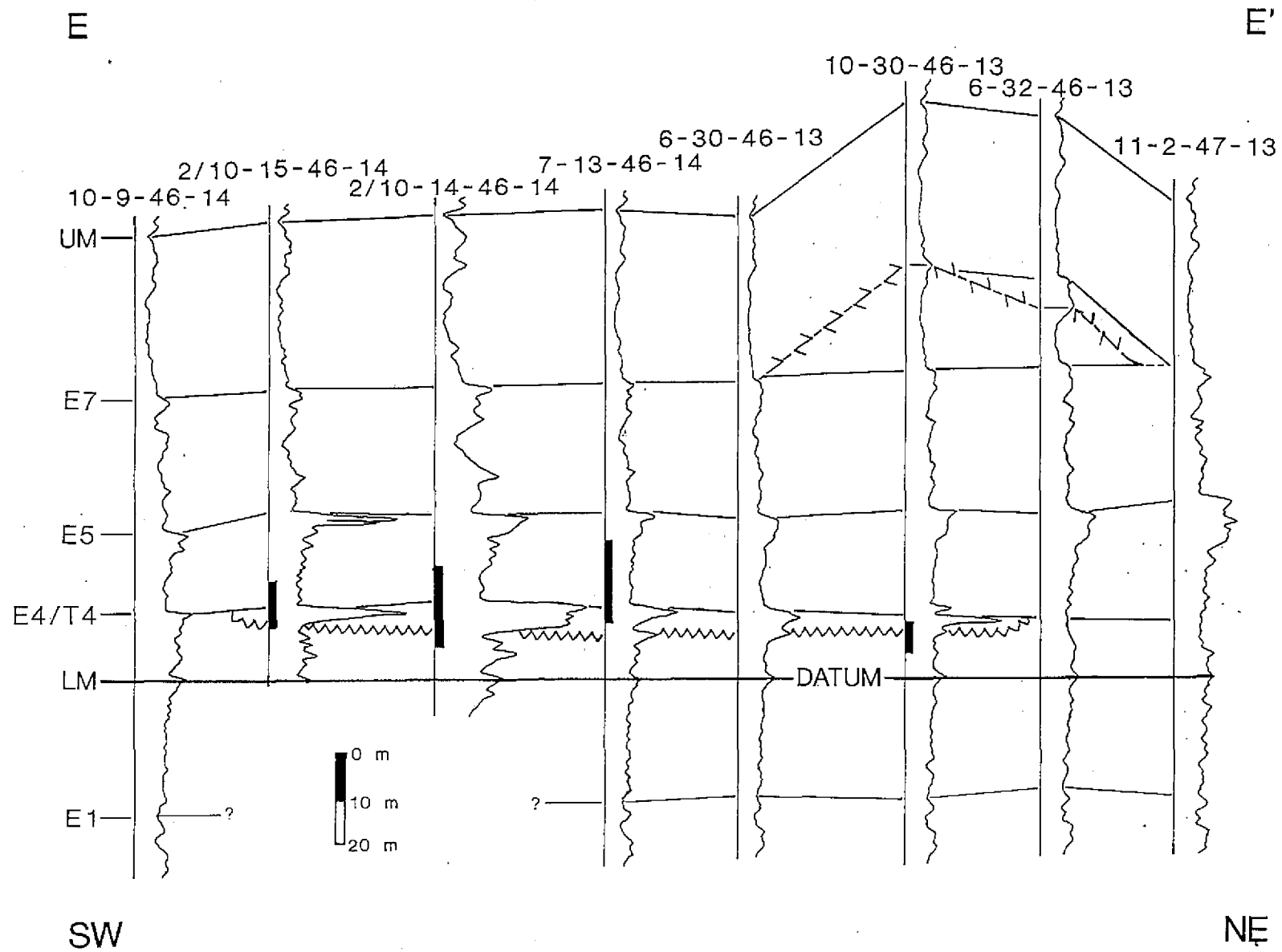


Figure 4.13 Core cross section E-E'. The location is shown on Fig. 4.1 and the legend is shown in Fig. 4.3. The horizontal distance is approximately 3 km.

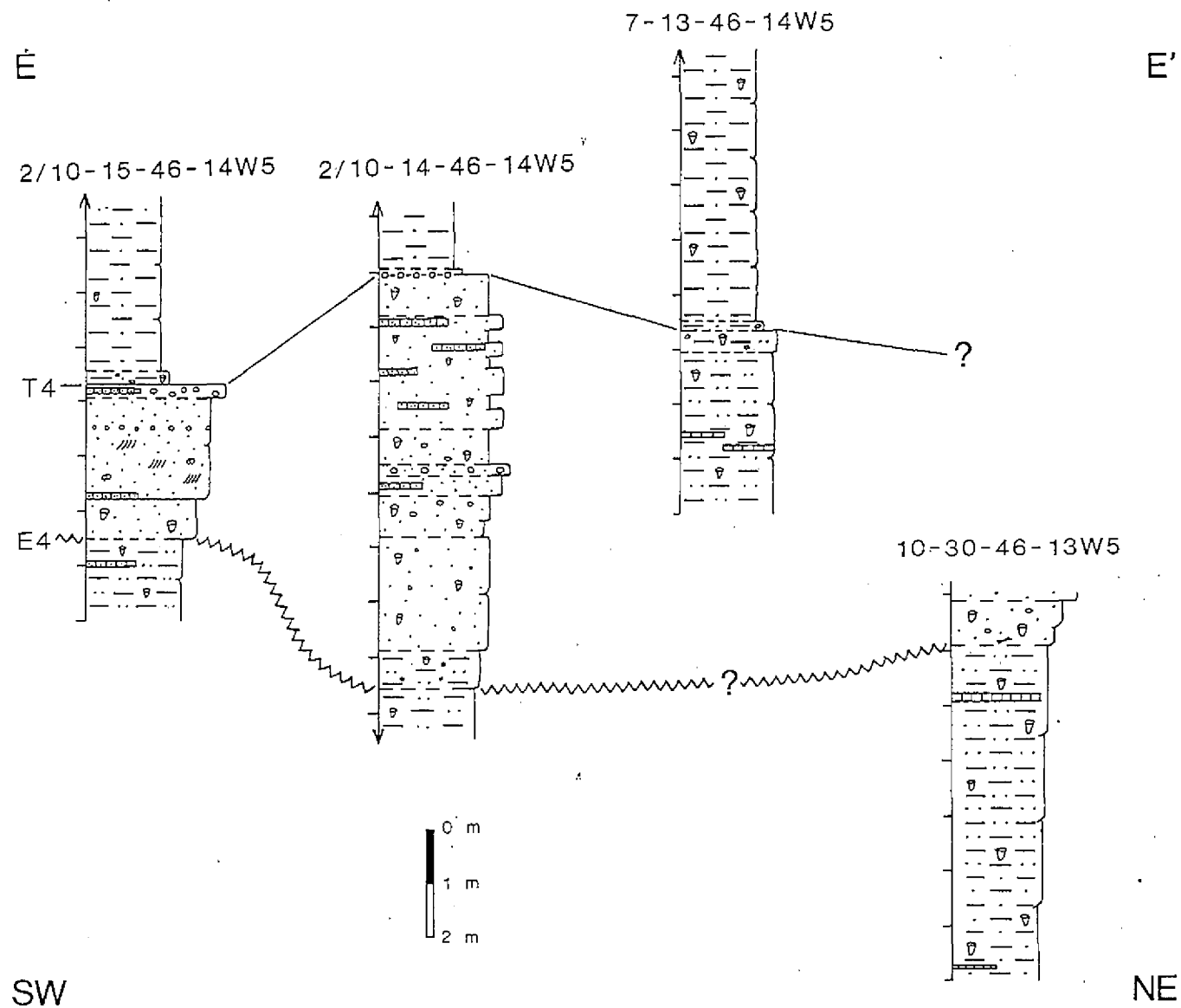
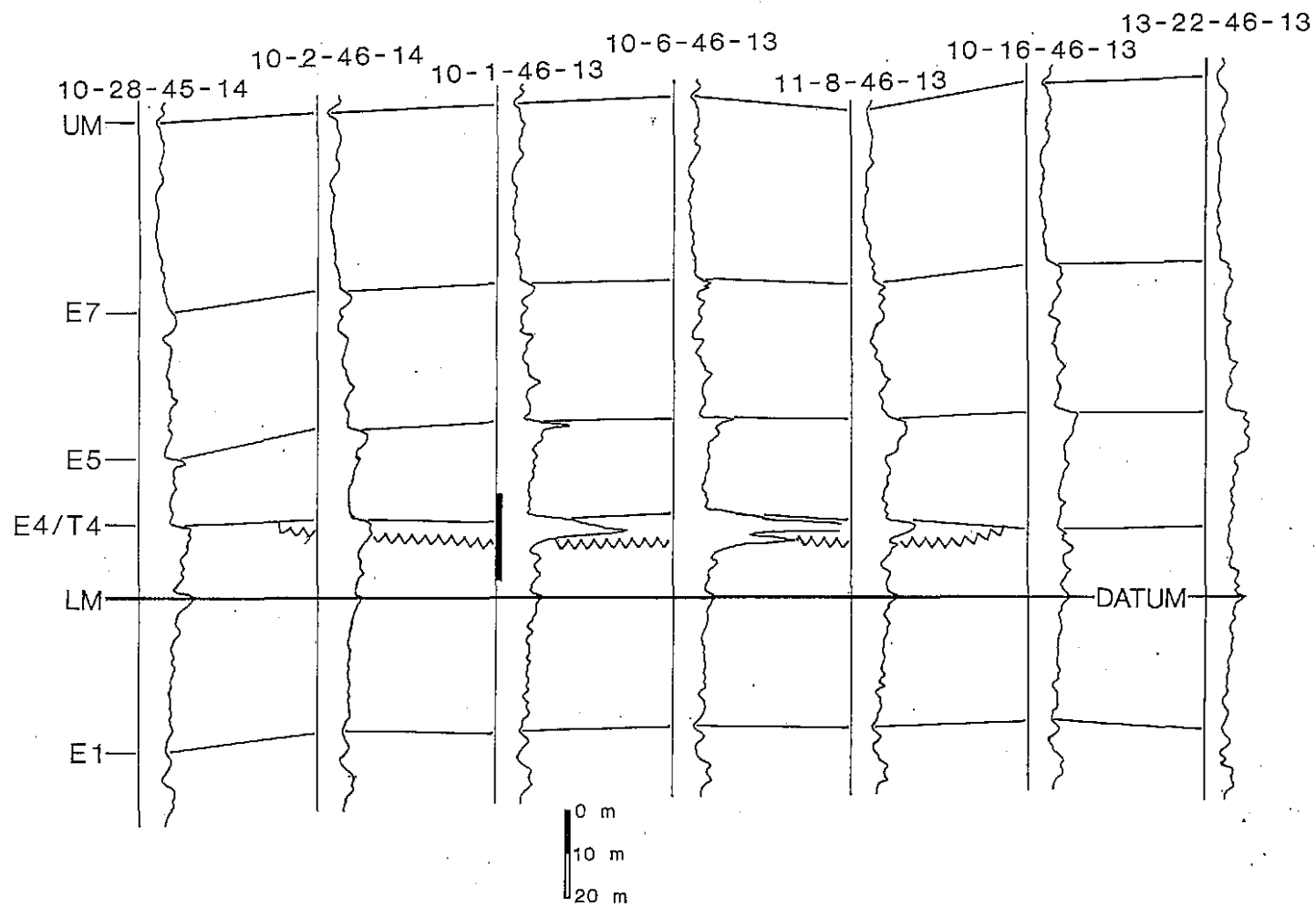


Figure 4.14 Cross section F-F'. Location shown on Fig.
4.1. Horizontal distance covered is
approximately 13 km. (UM -Upper Marker; LM-
Lower Marker.)

F

F'



54

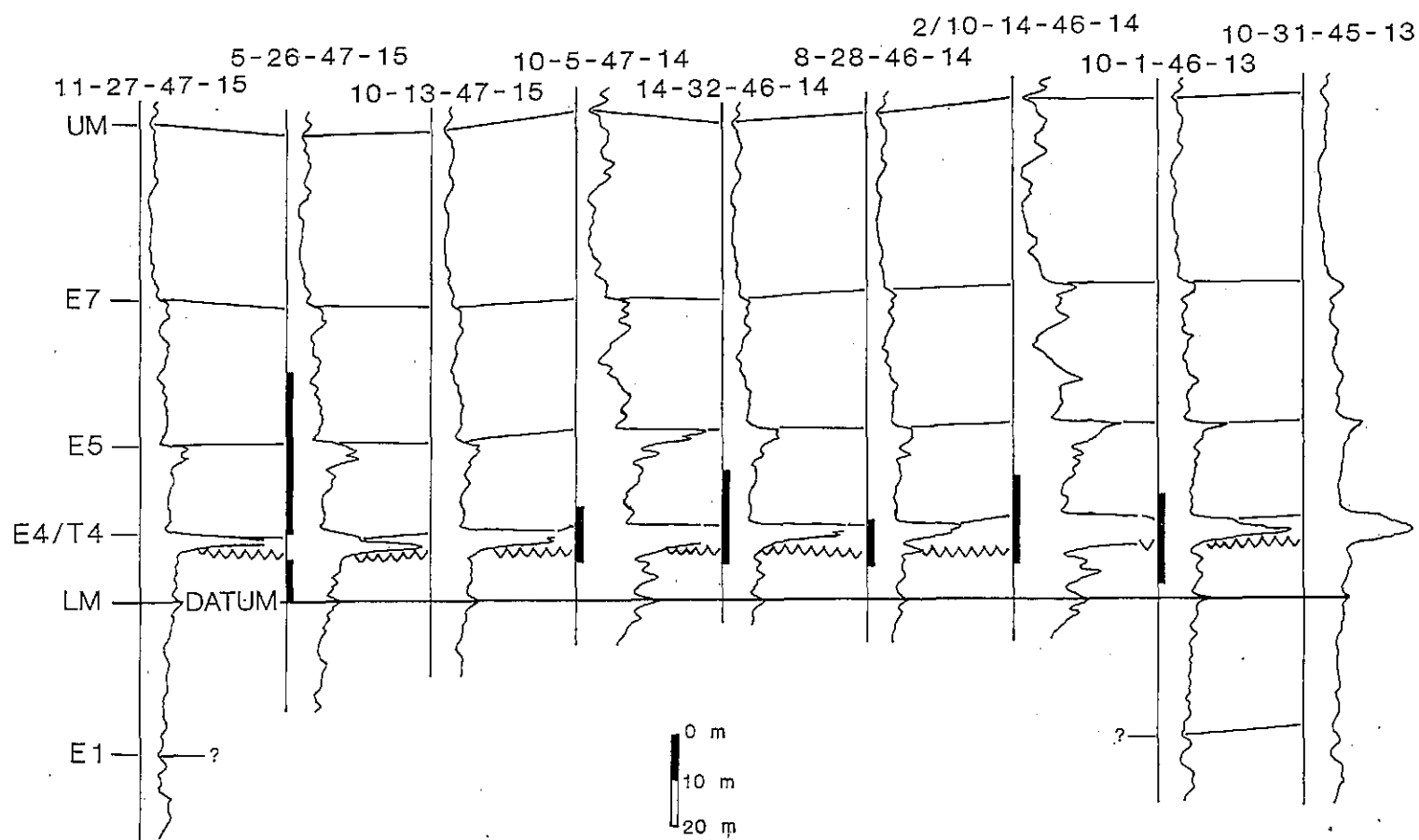
SW

NE

Figure 4.15 Cross section S-S'. Location shown on Fig.
4.1. Horizontal distance covered is
approximately 20 km. (UM -Upper Marker; LM-
Lower Marker.)

S

S'



55

NW

SE

Figure 4.16 Core cross section S-S'. The location is shown on Fig. 4.1 and the legend is shown in Fig. 4.3. The horizontal distance is approximately 17 km.

S

S'

2/10-14-46-14W5

10-1-46-14W5

14-32-46-14W5

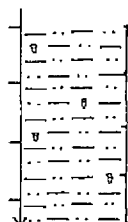
8-28-46-14W5

10-5-47-14W5

5-26-47-15W5

T4 — ?

E4 ~~~~~ ?



0 m
1 m
2 m

NW

SE

CHAPTER 5: Geometry of the Burnstick Member

5.1 Introduction

The purpose of this chapter is to develop a better understanding of the geometry of the Burnstick Member by studying it in three dimensions. This is accomplished by constructing isopach maps, profiles and 3-D mesh diagrams.

In order to construct the maps and diagrams, a data file of well log picks was compiled. The picks were made from all available well logs and were based on the well log and core cross sections presented in chapter 4. Where necessary the data was corrected for the occurrence of thrust faults by subtracting the thickness of the fault repeated section from the depth values for the picks that are stratigraphically below the fault. The file, which includes E1, LM, E4, T4, E5, E7 and UM, is provided in Appendix 1.

5.2 Isopach Maps and Mesh Diagrams

Isopach maps and mesh diagrams were generated using the Surfer Software package. The first map generated was an isopach map of the lower marker to E4 interval (Fig. 5.1). The corresponding mesh diagram was also generated (Fig. 5.2). These two diagrams display the shape of the E4 surface. In general, the E4 surface forms a platform in the southwest that drops down towards the northeast. The

Figure 5.1 Isopach map of the lower marker (LM) to E4 interval. The contour interval is 2 metres. Data points are represented by *. The heavy black arrow shows the direction of view for the mesh diagram (Fig 5.2).

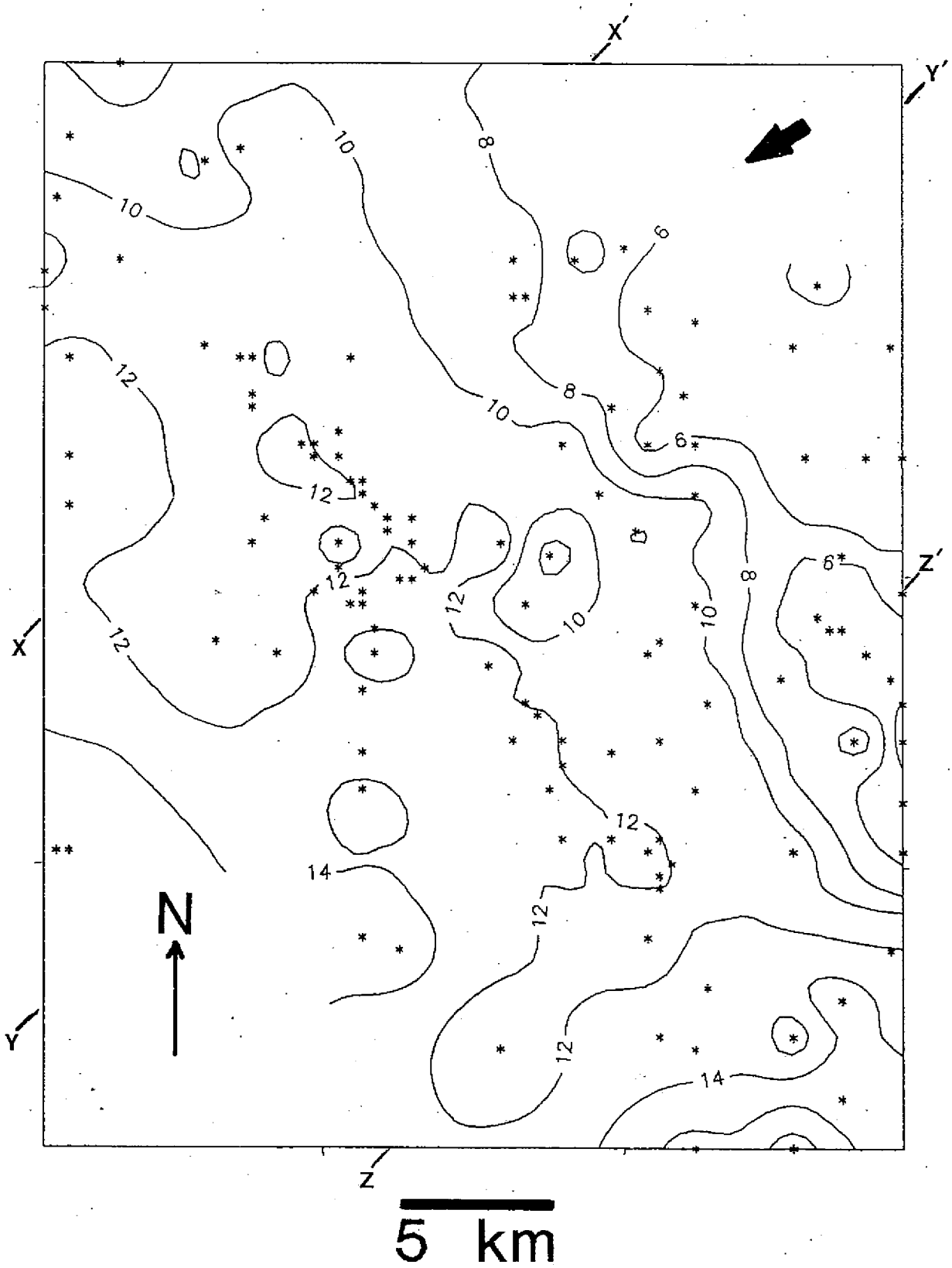
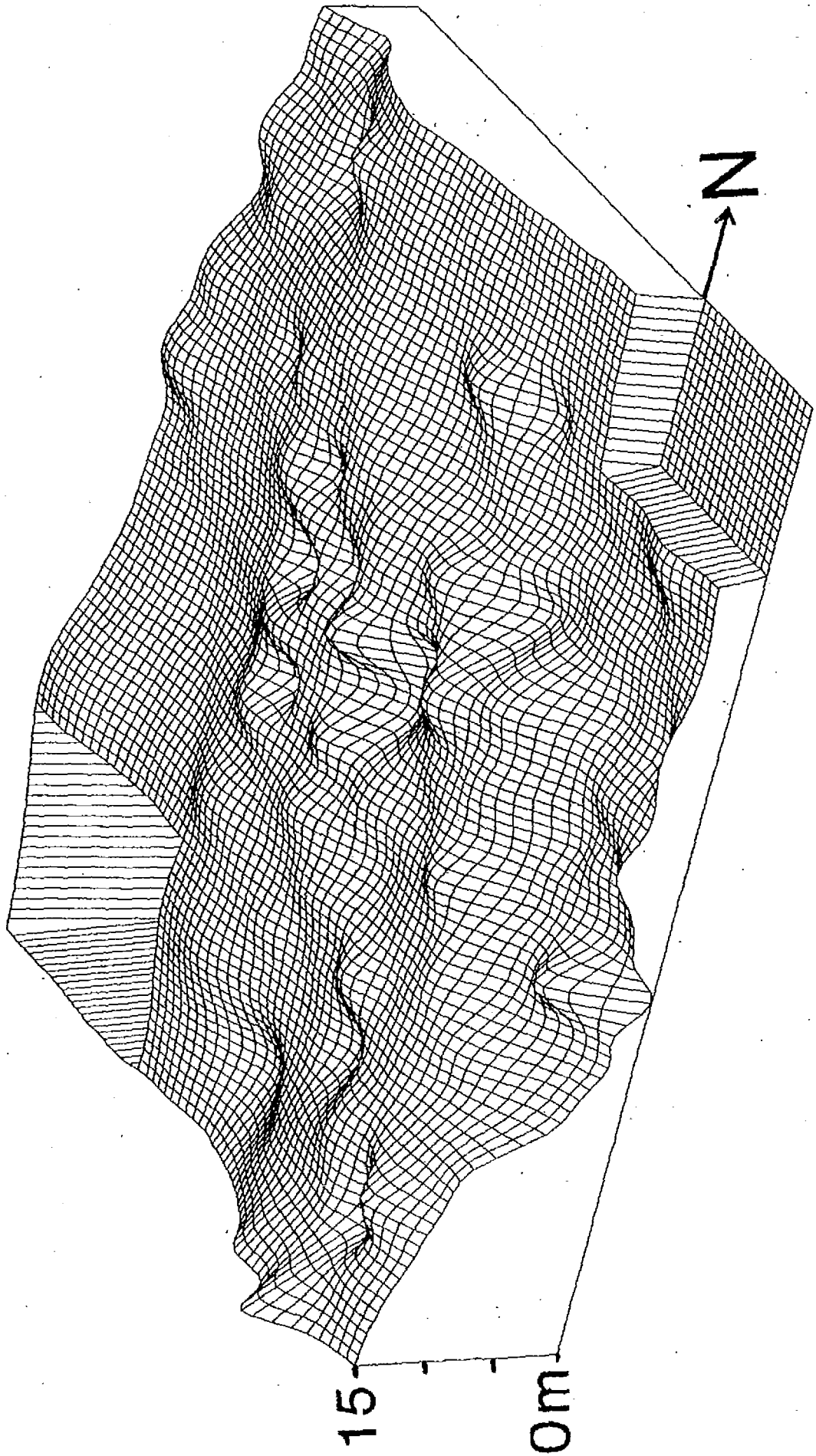


Figure 5.2 Mesh diagram showing the topography of the E4 surface. The diagram is a perspective view. The corresponding isopach map is presented in Figure 5.1.

VE=600



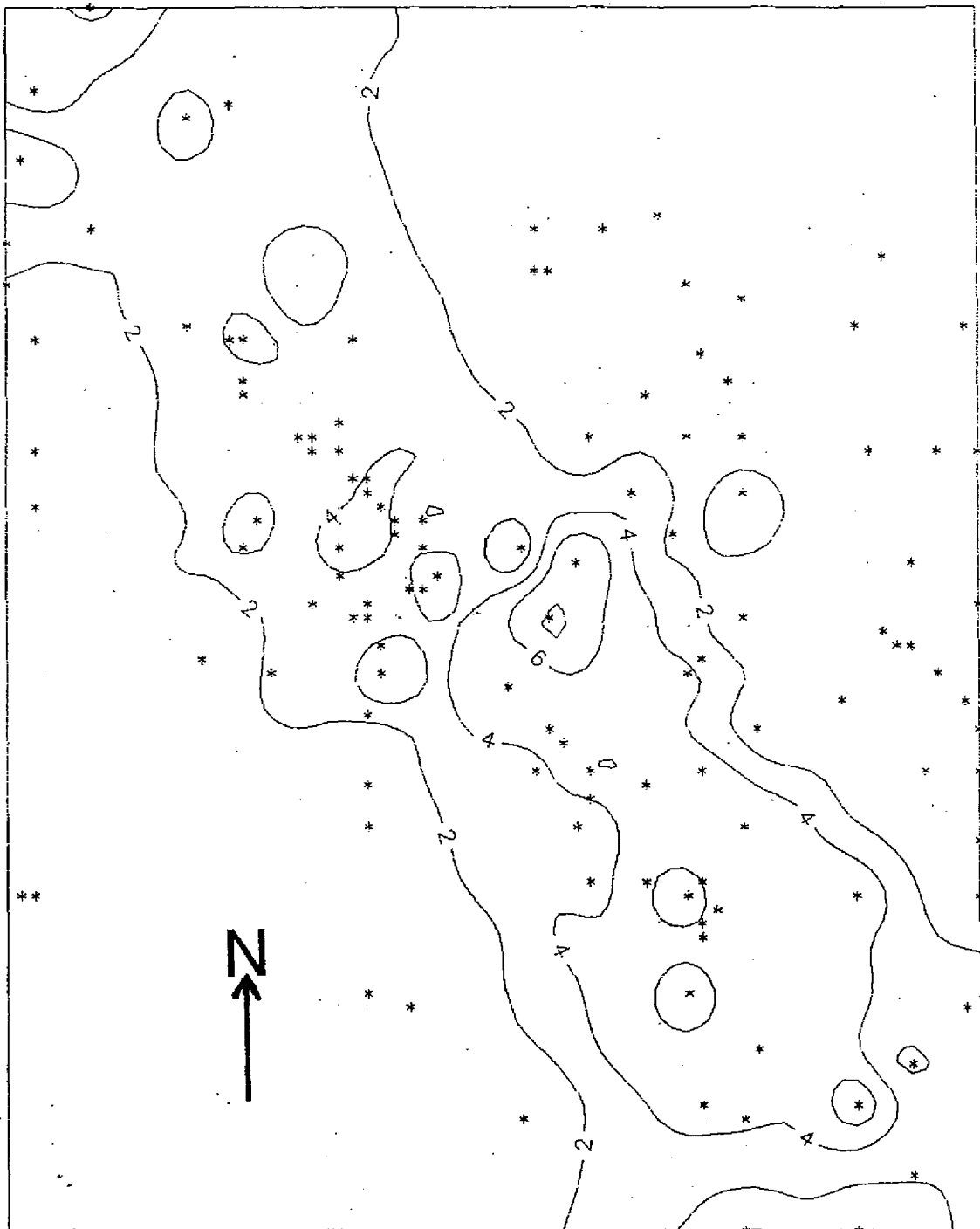
relief on the platform is 12 to 14 metres, while the relief in the northeast is approximately 6 metres.

To show the thickness of the Burnstick Member a second isopach map was generated of the E4 to T4 interval (Fig. 5.3). The maximum thickness of the Burnstick Member is approximately 8 metres. The contours of this map emphasize the linear nature of the Burnstick Member sand body. The strike of this linear sand body is parallel to the step.

A third isopach map was generated to show the topography of the T4 surface. The map, and its corresponding mesh diagram, is an isopach of the LM to T4 interval (Figs. 5.4, 5.5). These diagrams are similar to the E4 diagrams in that they both show a platform in the southwest that steps down towards the northeast. The relief on the platform is approximately 14 metres while the relief over the sand body reaches a maximum of 18 metres.

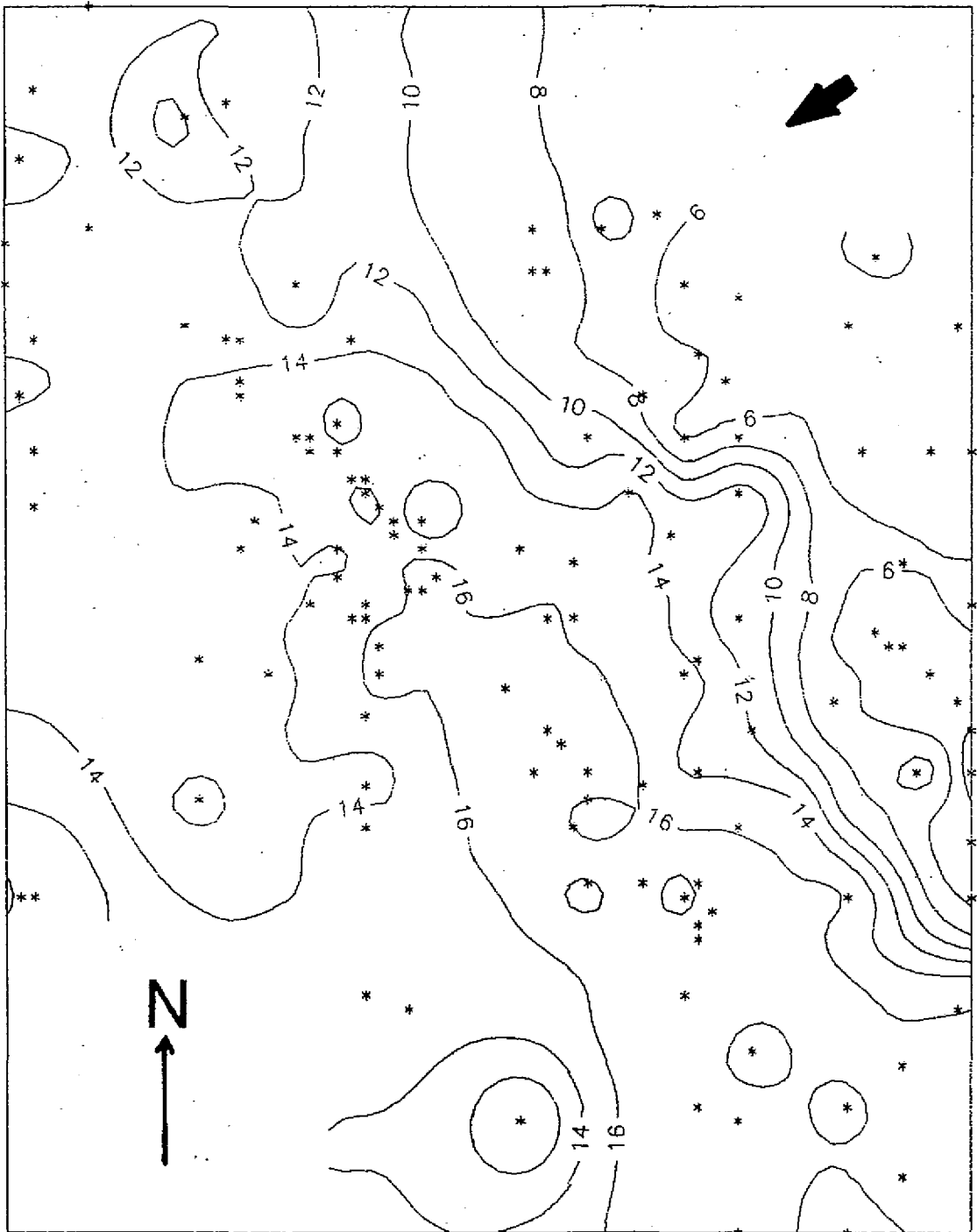
Comparison of the E4 and T4 mesh diagrams (Figs 5.2, 5.5) reveals that the E4 surface is more rugged than the T4 surface. The mounds and depressions observed on the T4 surface are often inherited from the E4 surface. This inheritance is more pronounced away from the step and towards the northwest. The areas of least inheritance are those where the Burnstick Member is its thickest.

Figure 5.3 Isopach map of the E4 to T4 interval. The contour interval is 2 metres. Data points are represented by *.



5 km

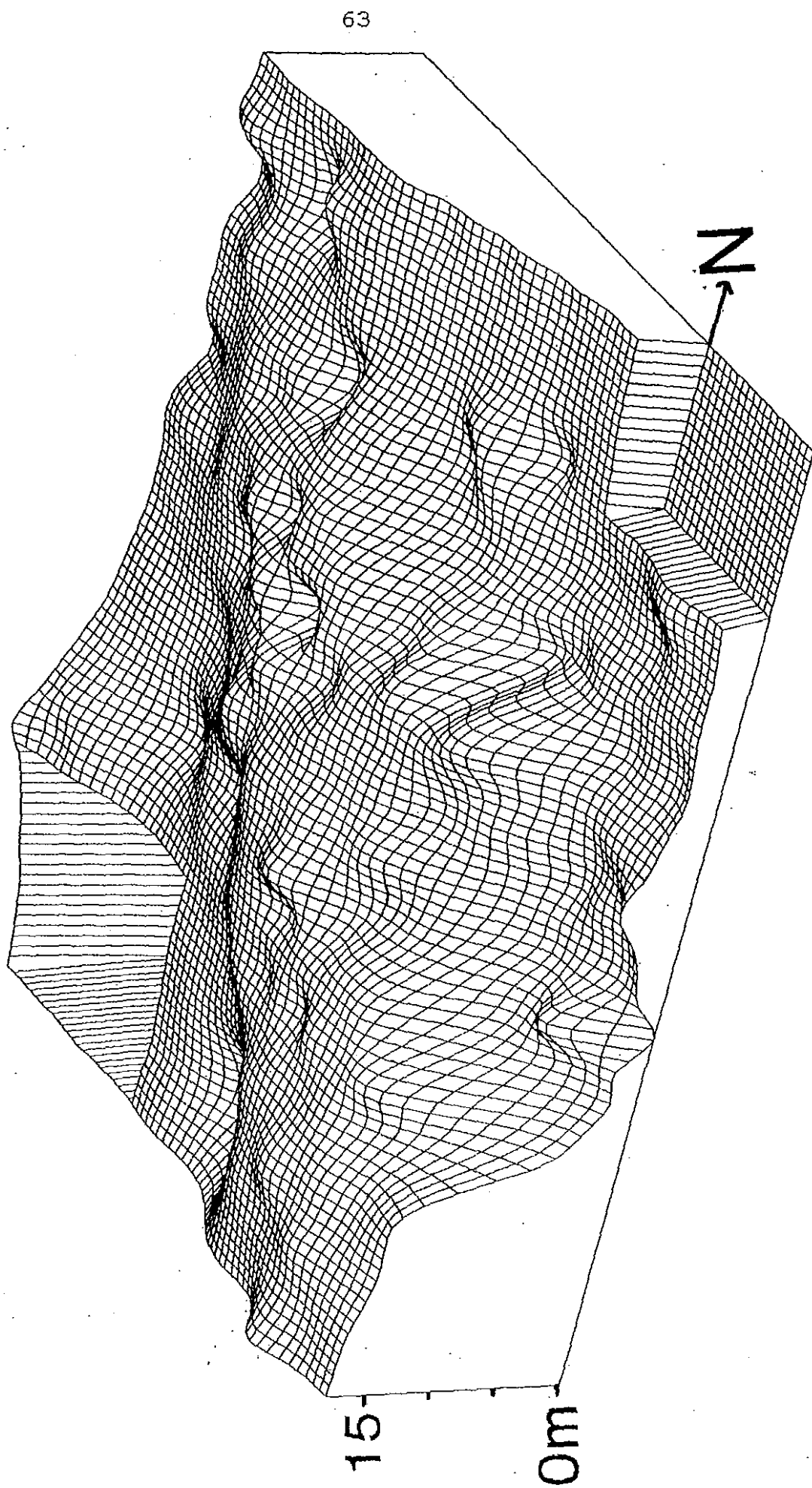
Figure 5.4 Isopach map of the lower marker (LM) to T4 interval. The contour interval is 2 metres. Data points are represented by *. The heavy black arrow shows the direction of view for the mesh diagram (Fig 5.5).



5 km

Figure 5.5 Mesh diagram showing the topography of the T4 surface. The diagram is a perspective view. The corresponding isopach map is presented in Figure 5.4.

VE=600



5.3 Profiles

Three profiles were constructed perpendicular to the strike of the field to show how the Burnstick Member sediments rests on the erosion surface (Figs. 5.6, 5.7, 5.8). The profiles indicate that the Burnstick Member sediments sit asymmetrically on the edge of the step. The shape of the sediment package changes from the northwest to the southeast. In the northwest the Burnstick Member sand body is broad and thin whereas in the southeast the sediment package is thick and has a highly arched top surface. The step in the E4 surface is much steeper in the southeast than northwest.

Figure 5.6 Profile of the Burnstick Member along X-X'.

The location of the profile is shown in Figure 5.1. The Burnstick Member is designated by the stipled pattern.

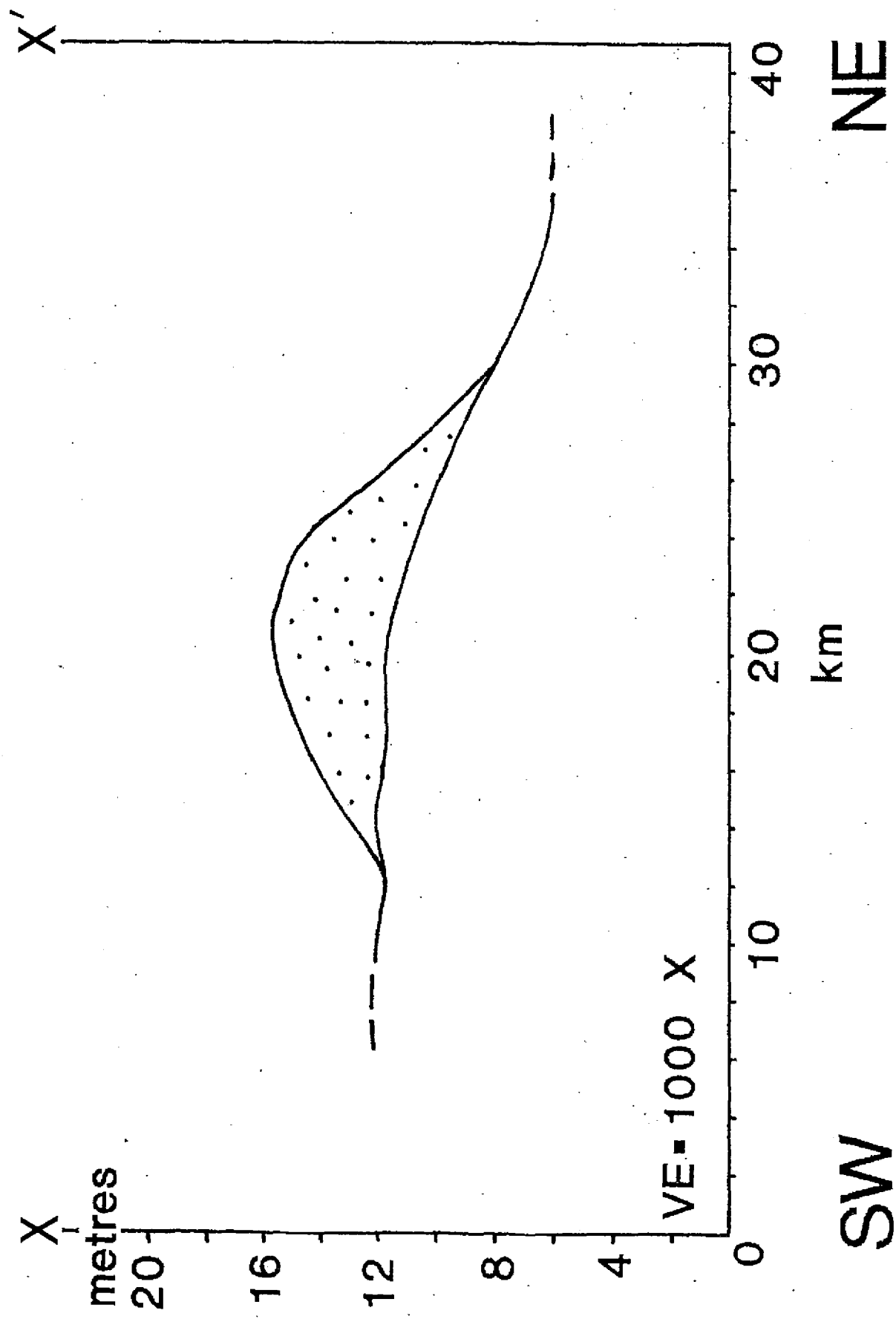


Figure 5.7 Profile of the Burnstick Member along Y-Y'.

The location of the profile is shown in Figure 5.1. The Burnstick Member is designated by the stipled pattern.

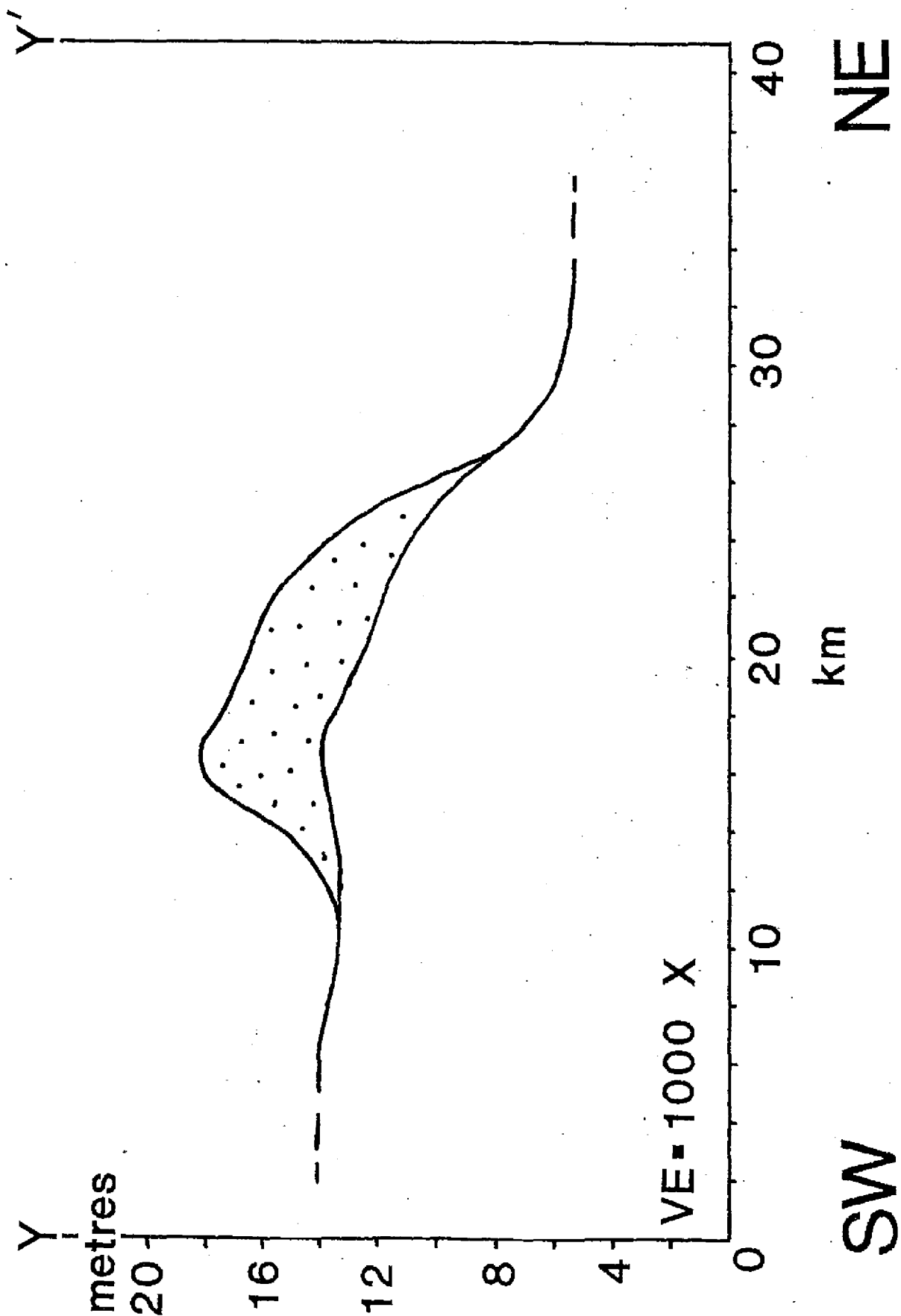
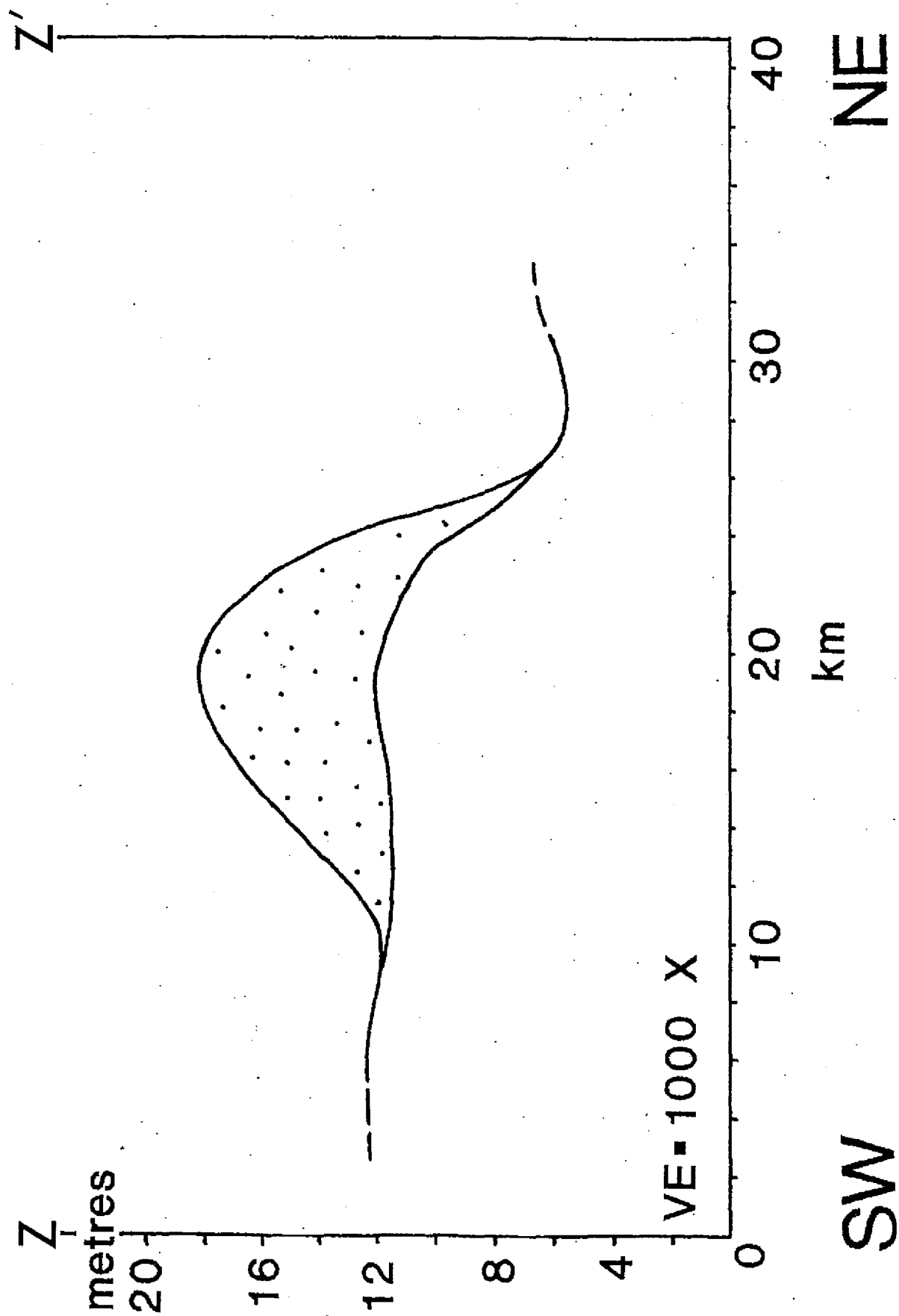


Figure 5.8 Profile of the Burnstick Member along Z-Z'.

The location of the profile is shown in Figure 5.1. The Burnstick Member is designated by the stipled pattern.



CHAPTER 6: Interpretations

6.1 Introduction

The purpose of this chapter is to interpret the environment of deposition of the Burnstick Member. These interpretations are based on the previously discussed cross sections, isopach maps, mesh diagrams and profiles.

6.2 The E4 Surface

The E4 surface is the contact between the Hornbeck Member and the Burnstick Member. Unfortunately, the Hornbeck Member lacks a distinct vertical facies sequences but instead is made up of a series of gradational pervasively bioturbated muddy siltstones. This makes it difficult to determine if the overlying E4 surface cut erosively into the Hornbeck Member because missing sequences cannot be identified.

The contact, when observed in core, is generally sharp (sometimes it is bioturbated but it is always distinct). This implies a change in the sedimentation which, although it does not prove erosion occurred on the E4 surface, does not disprove it either.

The shape of the E4 surface, which was mapped in chapter 5 with respect to a lower marker, is consistently observed to step down towards the northeast. It is a distinct step and not simply a progressive thinning from

southwest to northeast (Fig. 5.2). This produces a sigmoidal geometry to the E4 surface. As a result the Hornbeck Member is thinner towards the northeast than it is towards the southwest. This implies that the E4 surface has eroded the Hornbeck Member to the northeast. It appears that on the basis of the mapping presented in chapter 5 there was 4 to 6 metres of erosion on the E4 surface in the Brazeau River area.

There are three possible environments for the formation of the E4 erosion surface; fully subaerial, fully submarine (on the shelf) or in between at the shoreface (Bergman and Walker, 1987). If the environment of formation of the E4 surface were fully subaerial the E4 surface would have been cut by fluvial processes. This interpretation is the least likely in that the topography of the E4 surface (Figs. 5.1, 5.2) does not resemble the topography that would result from incised rivers. Subaerial erosion fails to explain the one-sided step in the E4 surface which runs parallel to the strike of the Brazeau River Field. Also subaerial erosion fails to explain how the sediments are deposited asymmetrically on the step. Finally, there is no evidence of subaerial exposure (such as roots, paleosols or coal) found in the sediments of the Brazeau River area.

The second possible environment, shallow marine, is

also unlikely. One of the problems with shallow marine environment is that the geometry of the erosion surface is incompatible with storm wave scour or submarine channel erosion. Also the rather sharp step in the E4 surface indicates localized erosion which is inconsistent with our present understanding of erosional processes in the shallow marine environment.

The third environment for the development of the E4 erosion surface is the shoreface. According to Reinson (1984) a shoreface is defined as the area seaward from the low tide mark to fairweather wave base. Shorefaces are characterised by a sigmoidal geometry which "opens" towards the sea and has a strike parallel to the shoreline (Swift and Niedoroda, 1985). This is very similar to the cross sectional geometry of the E4 surface (Figs. 5.2, 5.6, 5.7, 5.8). Also the E4 step has a strike of approximately 310° which is roughly parallel to the strike of the paleoslope.

The sediments of the Burnstick Member consist of a coarsening upward sequence which rests asymmetrically on the step (Figs. 5.6, 5.7, 5.8). A gradual facies change in which the sediments get muddier to the northeast is also observed. These facts help support the idea that the E4 surface was formed in the shoreface because a coarsening upward sequence and a change towards muddier facies seaward would be expected in the shoreface.

6.3 The Facies Sequence

The Burnstick Member consists of a distinct coarsening upward sequence. The sequence passes from gritty pervasively bioturbated muddy siltstones up into clean cross bedded sands and finally into granule conglomerates. The average thickness of this sequence is 4 metres. The following trends are observed in the facies sequence: the facies get cleaner upwards, the sediments get coarser upwards, the bioturbation decreases upwards and the number of preserved sedimentary structures increases upwards.

The sequences and trends observed in the Burnstick Member are similar to those observed in the modern coastal environment from offshore to the beach. Howard and Reineck (1981) described modern sequences as consisting of bioturbated sandy silt in the offshore zone, interbedded sand and sandy silt in the transition zone and cross bedded sandstone in the shoreface zone. This suggests that the Burnstick Member is an offshore-transition zone sequence.

The thickness of the shoreface sequence in the modern coastal environment is 5 - 16 metres (Howard and Reineck, 1981). This is thicker than the average Burnstick Member sediments thus implying that the upper shoreface was not preserved in the Burnstick Member sequence. The facies sequence of the Burnstick Member also suggests that the upper shoreface was not preserved.

6.4 The T4 Surface

The T4 surface is the sharp contact between the Burnstick Member and the overlying Raven River Member. It marks a distinct change in sedimentation from the sandy, conglomeratic facies below to the muddy facies above. This change is interpreted to have occurred in response to a rise in sea level. During this transgression it is proposed that the upper shoreface sediments were eroded away. The upper preserved sediments were probably reworked during the transgression and perhaps this accounts for the "piling up" of the Burnstick Member sediments on the shoreface step (Fig. 5.7).

In off-field areas the E4 and T4 surface become coplanar and are represented by a thin layer of coarse clastic material. This layer is interpreted as a transgressive lag deposit.

6.5 Sequence of Events

Based on the evidence given above the E4 surface is interpreted to have developed in the shoreface. The erosion surface is incised 4 to 6 metres into the underlying Hornbeck Member. In order for a shoreface to become incised into the marine muds of the Hornbeck Member a relative drop in sea level must have occurred. The following order of events is proposed for the incision of

the E4 surface (Fig. 6.1): 1) a rapid relative drop in sea level caused the shoreline to migrate basinward. This allowed a lowstand shoreface to develop on shallow marine sediments. 2) the lowstand shoreface was incised by wave scour during a relative sea level stillstand. During stillstand the E4 surface retreated towards the southwest into the underlying Hornbeck Member. This was followed by deposition of sediment to the newly cut shoreface. 3) a relative rise in sea level caused a transgression. This transgression planed off the top of the shoreface, removing the upper shoreface sediments and the evidence of aerial exposure to the southwest. The transgression buried the remaining shoreface in marine muds.

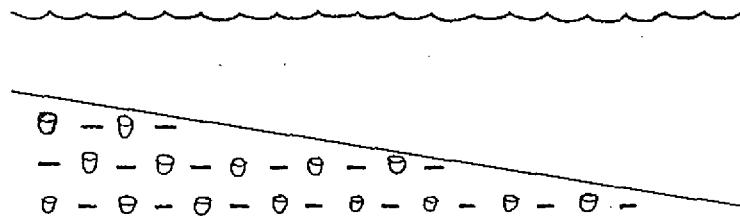
6.6 Problems

The original geologic problem approached in this thesis was to determine the environment of deposition of the Burnstick Member sediments in the Brazeau River area. The Burnstick Member sediments have been interpreted as incised shoreface deposits. One problem that lacks a satisfactory explanation is how the sediments were piled up on the shoreface step (Fig. 5.6, 5.7, 5.8). It was suggested above that perhaps the piling up was due to reworking during transgression but this is speculation. No mechanism has been discovered to account for this "piling

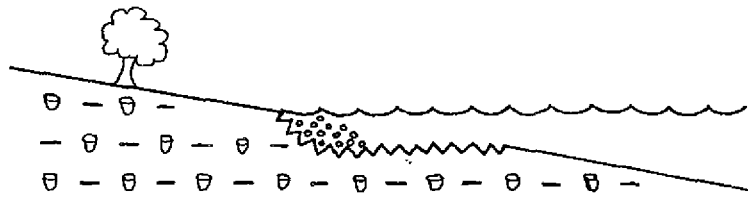
Figure 6.1 Schematic diagram representing the sequence of events responsible for the deposition of the Burnstick Member.

- (A) Before the relative drop in sea level. The shoreface is to the southwest out of the diagram. The symbols () represent bioturbated shelf mudstones.
- (B) A relative drop in sea level causes the shoreface to migrate basinwards (NE) and a lowstand shoreface to develop. Stillstand causes the shoreface to retreat towards the southwest. Sediment is deposited in the shoreface. The E4 surface is represented by the zigzag line. The tree indicates that subaerial erosion takes place to southwest of the shoreface.
- (C) A relative rise in sea level results in the drowning of the incised shoreface. Quiet deposition of marine will bury the shoreface sediments. The dashed line represents the previous subaerially exposed surface that was planed off during the transgression.

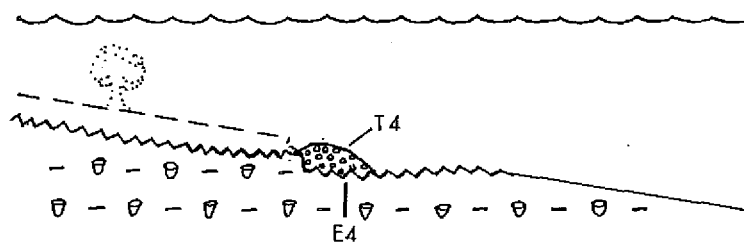
A



B



C



SW

NE

up".

Another problem involves the question of how the sediments were supplied to the shoreface. Presumably the sediments were transported to the shoreface by rivers and spread out by longshore drift. The rivers were eroded away during the transgression. Evidence for longshore drift should be preserved in the sediments as a decrease in grain size in the down current direction. However no distinct trend was detected in the Burnstick Member sediments of the Brazeau River area.

CHAPTER 7: Conclusions

- 1) The base of the Burnstick Member is defined by the E4 erosion surface. The E4 surface erodes 4 - 6 metres into the underlying shallow marine sediments of the Hornbeck Member and outlines a step. This surface is interpreted to have developed in a shoreface environment during a stillstand in relative sea level.
- 2) The Burnstick Member sediments are up to 7 metres thick and rest asymmetrically on the step in the E4 surface. These sediments are interpreted to be lower to middle shoreface sediments that were localized on the shelf during a lowering of sea level. The upper shoreface sediments were probably eroded during subsequent sea level rise.
- 3) The T4 surface defines the top of the Burnstick Member. This surface is interpreted to have developed due to a rise in sea level which "drowned" the shoreface and buried it in marine mudstones.
- 4) It is probable that other Burnstick Member fields would exist along strike. On strike fields do exist (Fig. 1.1) and these fields have been interpreted as incised shoreface deposits (Pattison, 1987).

REFERENCES

- BERGMAN, K.M., 1987. Erosion surfaces and gravel shoreface deposits: the influence of tectonics on the sedimentology of the Carrot Creek Member, Cardium Formation (Turonian, Upper Cretaceous), Alberta, Canada. Ph.D. Thesis, McMaster University, 404 p..
- BERGMAN, K.M. and WALKER, R.G., 1987. The importance of sea-level fluctuations in the formation of linear conglomeratic bodies; Carrot Creek Member of the Cardium Formation, Cretaceous Western Interior Seaway, Alberta, Canada. *Journal of Sedimentary Petrology*, v. 57, p. 651-665.
- BERGMAN, K.M. and WALKER, R.G., 1988. Formation of Cardium erosion surface E5, and associated deposition of conglomerate; Carrot Creek Field, Cretaceous Western Interior Seaway, Alberta. In: James, D.P. and Leckie, D.A. (eds.), *Sequences, Stratigraphy, Sedimentology: Surface and Subsurface*. Canadian Society of Petroleum Geologists, Memoir 15, p. 15-24.
- BREVEN, R.J., 1966. Cardium sandstone bodies, Crossfield-Garrington area, Alberta. *Bulletin of Canadian*

Petroleum Geology, v. 14, p. 208-240.

HAQ, B.V., HARDENBOL, J., and VAIL, P.R., 1987. Chronology of fluctuating sea levels since the Triassic. Science, v. 235, p. 1156-1167.

HOWARD, J.D., and REINECK, H.E., 1981. Depositional facies of high energy beach-to-offshore sequence: comparison with low energy sequence. AAPG Bulletin, v. 65, p. 807-830.

LEGGITT, S.M., 1987. Facies geometry and erosion surfaces on the Cardium Formation, Pembina field, Alberta, Canada. M.Sc. Thesis, McMaster University, 183 p.

MICHEALIS, E.W., and DIXON, G., 1969. Interpretation of depositional processes from sedimentary structures in the Cardium sand. Bulletin of Canadian Petroleum Geology, v. 17, p. 410-443.

PATTISON, S.A.J., 1987. Relative Sea Level Control of Incised Shoreface Sediments in the Burnstick Member, Cardium Formation, Upper Cretaceous, Alberta. M.Sc. Thesis, McMaster University, 206 p.

- PATTISON, S.A.J., 1988. Transgressive, incised shoreface deposits of the Burnstick Member (Cardium "B" Sandstone) at Caroline, Crossfield, Garrington and Lochend; Cretaceous Western Interior Seaway, Alberta, Canada. In: James, D.P. and Leckie, D.A. (eds.), Sequences, Stratigraphy, Sedimentology: Surface and Subsurface. Canadian Society of Petroleum Geologists, Memoir 15, p. 155-166.
- PLINT, A.G., WALKER, R.G., and BERGMAN, K.M., 1986. Cardium Formation 6: Stratigraphic framework of the Cardium in subsurface. Bulletin of Canadian Petroleum Geology, v. 34 (2), p. 213 -225.
- REINSON, G.E., 1984. Barrier-island and associated strand-plain systems. In: Walker, R.G., (ed.), Facies Models, Geoscience Canada Reprint Series 1 (Second Edition), p. 119-140.
- SLATT, R.M., 1984. Continental shelf topography: key to understanding distribution of shelf sand-ridge deposits from Cretaceous Western Interior Seaway. The AAPG Bulletin, v. 68 (9), p. 1107-1120.
- STOTT, D.F., 1963 The Cretaceous Alberta Group and

equivalent rocks, Rocky Mountain Foothills, Alberta.
Geological Survey of Canada, Memoir 317, 306 p.

SWIFT, D.J.P., and NIEDORODA, A.W., 1985. Fluid and sediment dynamics on continental shelves. In: R.W. Tillman et al. (eds.), Shelf Sands and Sandstone Reservoirs. SEPM Short Course No. 13, p. 47-134.

SWIFT, D.J.P., and RICE, D.D., 1984. Sand bodies on muddy shelves: a model for sedimentation in the Western Interior Cretaceous Seaway, North America. In: R.W. Tillman and C.T. Siemers (eds.), Siliciclastic Shelf Sediments, SEPM Special Publication 34, p. 43-62.

WALKER, R.G., 1983a. Cardium Formation 1. "Cardium a turbidity current deposit" (Beach, 1955): a brief history of ideas. Bulletin of Canadian Petroleum Geology, v. 31, p. 205-212.

WALKER, R.G., 1983b. Cardium Formation 2. Sand body geometry in the Garrington - Caroline - Ricinus area, Alberta -- the "the ragged blanket" model. Bulletin of Canadian Petroleum Geology, v. 31, p. 14-26.

WALKER, R.G., 1983c. Cardium Formation 3. Sedimentology

and stratigraphy in the Garrington - Caroline area, Alberta. Bulletin of Canadian Petrology, v.31, p. 213-230.

WALKER, R.G., 1986. Cardium Formation 7. Progress report compiling data from outcrop and subsurface in southern Alberta. McMaster University, Tech. Memo 86-3, 97 p.

WALKER, R.G. and EYLES, C.H., 1988. Geometry and facies of stacked shallow-marine sandier upward sequences dissected by erosion surface, Cardium Formation, Willesden Green, Alberta. AAPG Bulletin, v. 72 (12), p. 1469-1494.

APPENDIX 1: Wireline Log Picks Used for Isopach Maps

T&R	LSD	E1	LM	E4	T4	E5	E7	UM
4513	603	7808	7718	7655	7655	7594	7502	7361
4513	605	7861	7762	7707	7707	7655	0	7419
4513	611	7716	7630	7579	7573	7495	7406	7272
4513	1115	7719	7627	7590	7567	7494	7401	7266
4513	1016	7785	7694	7650	7636	7565	7472	7437
4513	617	7880	7786	7742	7729	7665	7572	7437
4513	1020	7786	7696	7650	7635	7570	7480	7351
4513	623	7625	7535	7485	7480	7396	7306	7173
4513	625	7618	7524	7484	7470	7387	7294	7161
4513	1128	7770	7681	7649	7624	7549	7455	7321
4513	1031	7977	7882	7842	7828	7861	7668	7534
4513	1531	0	2401.5	2389.0	2385.0	2364.0	2334.5	2294.5
4514	615	8184	8055	8022	8022	7946	0	7716
4514	1028	2523.0	2490.0	2475.5	2475.5	2462.0	2429.5	2389.5
4514	629	2543.5	2508.5	2494.0	2494.0	2481.0	2440.5	2411.0
4613	701	7398	7314	7296	7296	7175	7083	6954
4613	603	7667	7578	7543	7526	7451	7358	7227
4613	604	2348.5	2320.0	2307.0	2304.5	2283.0	2253.0	2211.0
4613	106	0	2382.5	2371.5	2365.5	2346.0	2313.0	2272.5
4613	1006	2402.0	2373.5	2362.5	2356.0	2335.5	2307.0	2266.5
4613	1108	7821	7730	7695	7677	7606	7515	7386
4613	712	2240.5	2208.0	2204.0	2204.0	2173.5	2145.0	2105.0
4613	1013	7314	7208	7200	7200	7100	6983	6857
4613	1014	7539	7456	7424	7424	7329	7236	7105
4613	1016	7575	7487	7454	7454	7360	7259	7130
4613	1018	7697	7608	7570	7554	7480	7389	7261
4613	720	2293.0	2265.0	2253.5	2253.5	2228.0	2197.0	2155.0
4613	1322	2290.0	2261.0	2254.5	2254.5	2220.5	2189.0	2150.0
4613	724	2252.5	2221.5	2217.5	2217.5	2186.5	2157.0	2118.0
4613	1424	2292.5	2262.5	2258.0	2258.0	2225.0	2197.0	2158.5
4613	826	2312.5	2282.0	2277.5	2277.5	2244.5	2216.0	2178.0
4613	1326	7608	7513	7492	7492	7386	7294	7168
4613	1426	2321.0	2290.5	2286.0	2286.0	2253.5	2225.0	2187.0
4613	630	7950	7861	7828	7812	7740	7642	7516
4613	1030	2386.0	2357.5	2346.5	2344.0	2320.5	2307.5	2246.5
4613	632	7699	7637	7604	7604	7505	7394	7270
4613	134	2327.5	2297.0	2292.5	2292.5	2259.5	2230.5	2192.5
4613	1036	2222.5	2196.0	2189.0	2189.0	2156.0	2127.0	2088.0
4614	1001	2464.5	2436.0	2424.0	2419.5	2399.0	2370.0	2330.5
4614	1002	8218	8122	8082	8070	8006	7911	7780
4614	1009	8435	8331	8282	8282	8221	8125	7999
4614	1111	2473.0	2443.0	2429.0	2426.5	2406.5	2378.5	2339.5
4614	713	2392.0	2363.0	2353.0	2347.0	2326.0	2296.0	2256.0
4614	214	0	2418.0	2406.5	2403.0	2381.0	2353.5	2313.5
4614	1014	0	2376.5	2365.0	2358.5	2334.5	2311.0	2272.0
4614	1015	0	2447.0	2432.5	2430.0	2408.0	2382.0	2342.0

T&R	LSD	E1	LM	E4	T4	E5	E7	UM
4614	718	2566.0	2532.5	2520.0	2520.0	2505.0	2473.5	2435.0
4614	1021	7933	7832	7787	7782	7715	7628	7502
4614	822	0	2388.5	2377.0	2372.0	2353.0	2323.5	2285.0
4614	423	0	2379.5	2367.0	2361.5	2341.5	2313.0	2273.5
4614	427	0	2384.5	2371.5	2367.5	2342.5	2319.5	2281.5
4614	828	0	2387.0	2377.0	2370.5	2350.0	2322.0	2284.5
4614	1628	0	2425.0	2412.5	2408.0	2388.0	2360.0	2321.0
4614	631	2457.0	2425.0	2411.0	2410.5	2392.5	2363.5	2326.5
4614	731	2457.5	2425.0	2411.0	2410.5	2393.0	2362.0	2326.5
4614	1031	8049	7945	7900	7897	7838	7744	7622
4614	1432	0	2432.5	2421.5	2417.0	2396.5	2370.0	2332.0
4614	1532	0	2420.0	2408.0	2403.0	2384.5	2356.5	2318.5
4614	633	8067	7967	7931	7918	7849	7755	7632
4614	834	0	2411.0	2403.5	2394.0	2373.5	2344.5	2306.5
4614	635	8032	7939	7998	7890	7815	7717	7582
4615	704	2663.0	2625.5	2609.5	2609.5	2592.0	0	2530.0
4615	606	0	2646.0	2630.0	2627.0	2612.0	2590.0	2546.5
4615	215	0	2581.5	2575.0	2570.0	2556.0	2527.0	2482.5
4615	826	2482.5	2454.0	2443.0	2441.0	2426.5	2391.0	2357.5
4615	1027	0	2480.0	2469.0	2468.0	2453.0	2423.0	2382.5
4615	1036	8337	8232	8193	8187	8126	8035	7911
4713	602	2246.5	2218.5	2212.0	2212.0	2178.0	2150.0	2112.0
4713	1102	7400	7298	7256	7256	7187	7098	6967
4713	1306	2453.5	2425.5	2412.5	2411.5	2384.5	2358.5	2322.0
4713	1108	7924	7824	7787	7774	7707	7613	7491
4713	713	7075	6989	6968	6968	6860	6772	6645
4713	814	2203.5	2177.0	2173.0	2173.0	2137.5	2109.5	2070.5
4713	715	7315	7228	7213	7213	7097	7013	6883
4713	1117	7618	7520	7503	7503	7407	7308	7184
4713	1118	7765	7677	7660	7660	7552	7458	7332
4713	1220	2275.0	2246.0	2240.5	2240.5	2208.0	2182.0	2144.0
4713	1125	6943	6862	6846	6846	6729	6640	6512
4713	1127	7213	7131	7116	7116	6998	6913	6785
4713	230	2271.0	2241.0	2235.0	2235.0	2204.5	2177.0	2138.0
4713	631	7465	7368	7350	7350	7248	7158	7025
4713	332	7292	7200	7184	7184	7070	6968	6842
4713	133	2189.0	2162.0	0	0	2123.5	2065.5	2059.5
4713	1634	2159.0	2134.5	2128.0	2128.0	2092.5	2065.5	2026.5
4714	602	8287	8194	8173	8144	8076	7976	7850
4714	1103	2508.0	2478.0	2464.0	2464.0	2443.0	2409.5	2372.0
4714	404	0	2443.5	2432.0	2428.5	2408.0	2380.0	2342.5
4714	1204	0	2491.5	2483.5	2478.0	2457.5	2428.0	2390.5
4714	105	0	2476.0	2462.5	2460.0	2438.5	2409.5	2372.0
4714	1005	0	2517.5	2506.0	2501.5	2481.5	2454.5	2414.5
4714	1305	2568.0	2537.5	2525.0	2521.0	2501.5	2474.5	2437.0
4714	807	0	2545.0	2533.5	2529.0	2512.5	2481.0	2444.0
4714	1007	0	2549.5	2537.0	2533.0	2512.5	2486.0	2449.0
4714	1407	0	2551.5	2539.0	2536.0	2517.0	2488.0	2451.5

T&R	LSD	E1	LM	E4	T4	E5	E7	UM
4714	208	0	2528.0	2518.5	2517.5	2493.0	2463.5	2425.5
4714	408	2561.0	2531.0	2519.0	2515.0	2493.5	2466.5	2428.0
4714	1509	2527.5	2499.0	2489.5	2484.0	2462.5	2432.5	2395.0
4714	1112	2498.0	2470.5	2459.5	2455.0	2433.0	2403.5	2367.0
4714	1014	8129	8038	8002	8002	7920	7821	7697
4714	518	0	2554.0	2542.0	2538.5	2520.0	2492.0	2454.5
4714	1318	0	2529.0	2519.0	2516.0	2496.0	2468.0	2431.5
4714	724	7825	7736	7710	7710	7615	7523	7393
4714	628	7912	7817	7780	7772	7710	7610	7483
4714	934	2262.0	2230.0	2221.5	2220.0	2195.5	2188.0	2195.0
4714	1034	7453	7340	7315	7315	7234	7148	7021
4715	1102	2628.5	2594.0	2583.0	2581.0	2564.0	2534.5	2497.0
4715	709	2663.0	2625.0	2613.0	2612.0	2597.5	2567.0	2530.0
4715	211	2617.5	2584.0	2572.5	2571.0	2553.5	2524.5	2487.0
4715	713	8460	8336	8291	8286	8230	8140	8018
4715	1013	0	2557.0	2545.5	2542.0	2523.5	2596.0	2457.5
4715	1113	0	2526.0	2513.5	2510.5	2495.0	2465.0	2428.5
4715	716	8690	8576	8530	8530	8497	8390	8268
4715	621	0	8271	8235	8235	8175	8080	7960
4715	623	2544.0	2512.5	2500.0	2498.0	2483.0	2452.0	2416.0
4715	1123	0	2486.0	2475.0	2471.0	2453.0	2425.0	2388.0
4715	526	0	8160	8126	8118	8050	7957	7838
4715	626	8236	8130	8088	8088	8022	7927	7810
4715	1127	8201	8108	8070	8062	8001	7906	7785
4715	730	2520.0	2485.5	2473.0	2473.0	2461.5	2428.5	2392.5
4715	531	2530.0	2494.5	2483.0	2482.0	2468.0	2438.0	2403.0
4715	636	2459.5	2423.5	2421.0	2414.5	2396.0	2365.0	2328.5
4814	901	2229.5	2204.0	2198.0	2198.0	2165.0	2137.5	2099.5
4814	802	2241.0	2211.5	2206.0	2206.0	2176.5	2148.0	2109.0
4814	703	7644	7545	7511	7511	7429	7341	7216
4815	404	0	2458.5	2449.5	2446.0	2426.0	2397.5	2360.5
4815	705	8241	8134	8098	8090	8030	7934	7818
4815	1107	0	8143	8108	8108	8042	7948	7830
4815	1214	7989	7888	7850	7843	7782	7679	7556
4815	615	8109	8006	7982	7977	7909	7803	7680
4815	1518	2466.5	2432.0	2423.5	2418.0	2397.5	2369.0	2333.5
4815	729	2415.5	2384.5	2378.0	2371.5	2356.0	2320.5	2287.0

Appendix 2

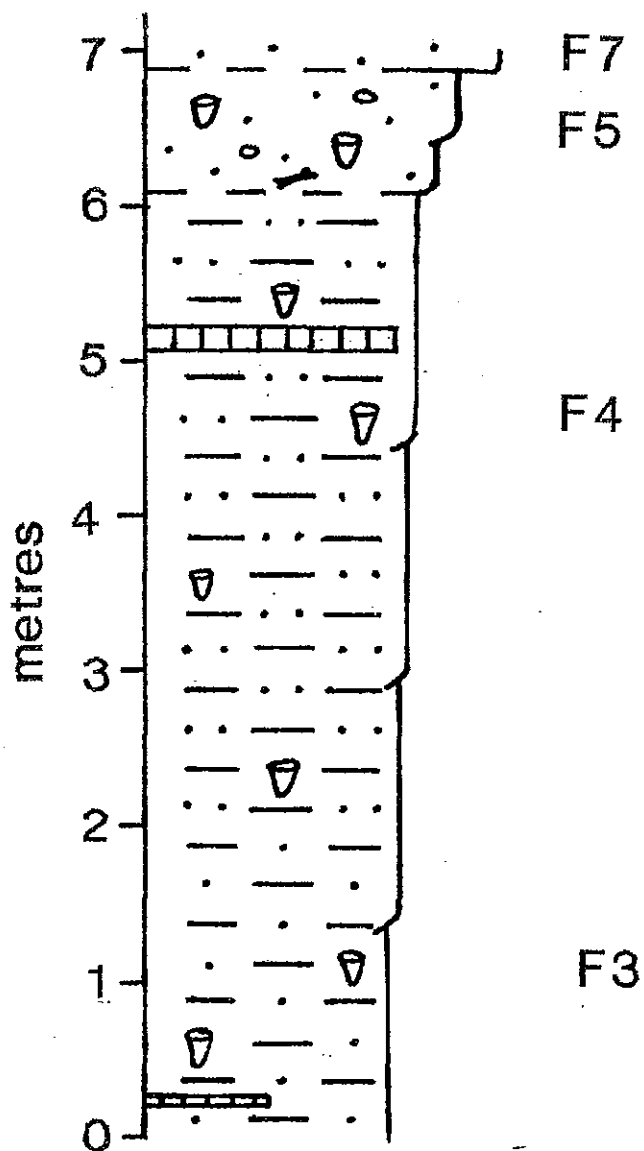
Core logs of the Burnstick Member interval. The legend of symbols used is found in Figure 4.3 (page 40).

10-30-46-14W5

Cored Interval: 2363.0-2370.0 m

(Corrected: 2365.0-2372.0 m)

Length of Core = 7.1 m

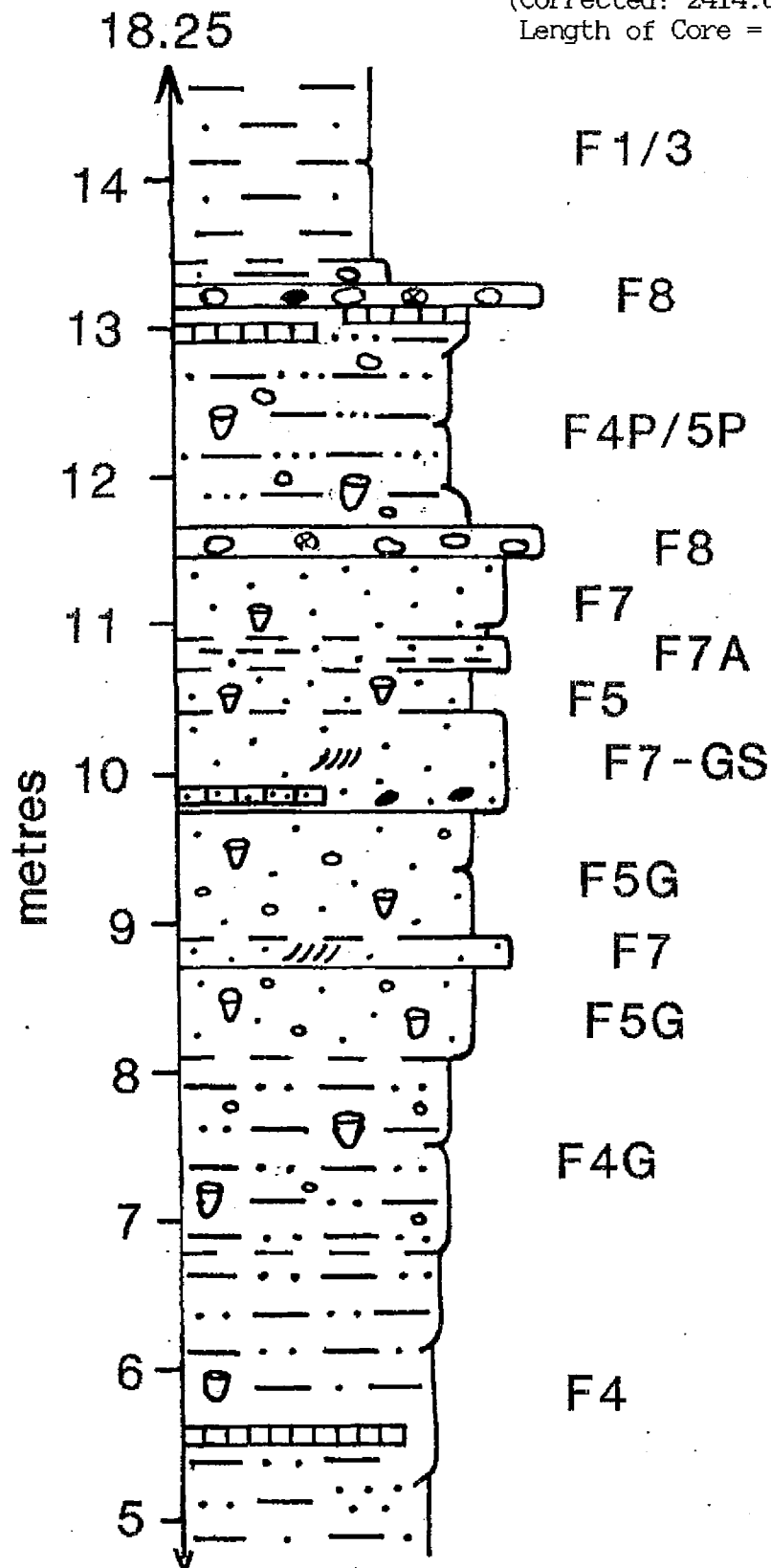


10-1-46-14W5

Cored Interval: 2415.0-2433.2 m

(Corrected: 2414.0-2432.25 m)

Length of Core = 18.25 m

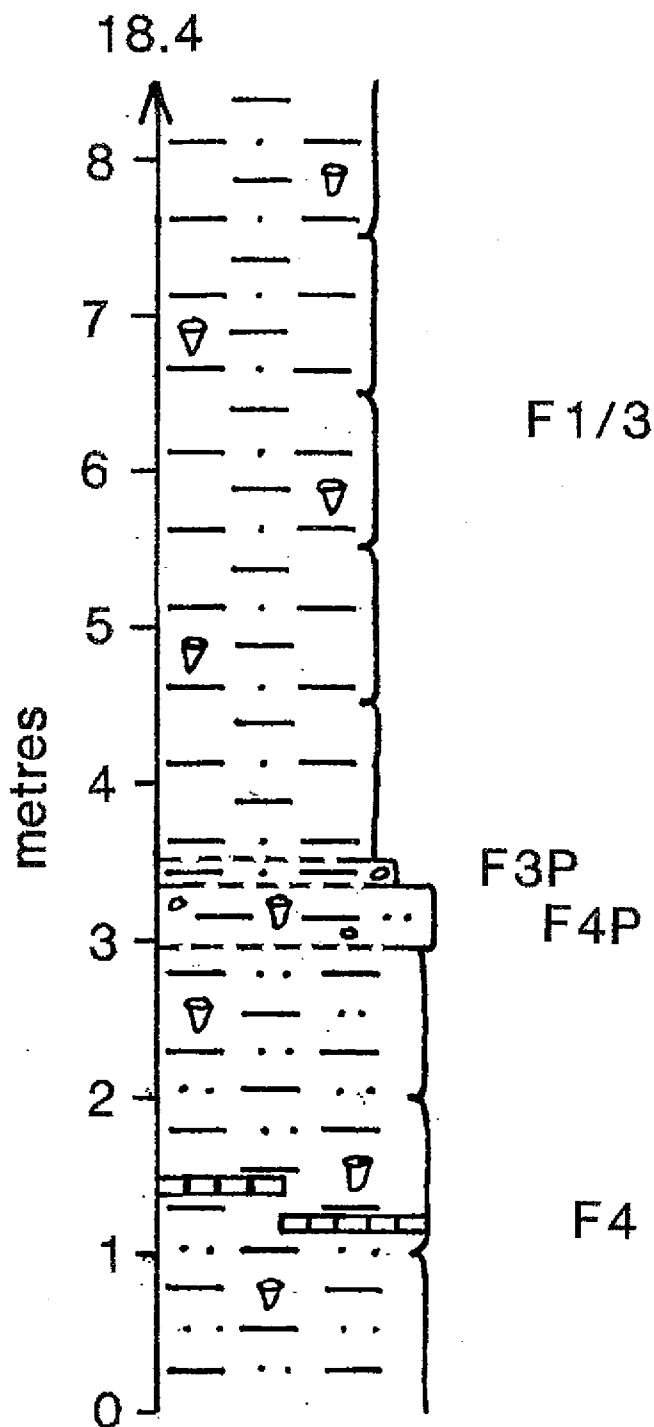


7-13-46-14W5

Cored Interval: 2333-2351.4 m

(Corrected: 2332-2350 m)

Length of Core = 18.40 m

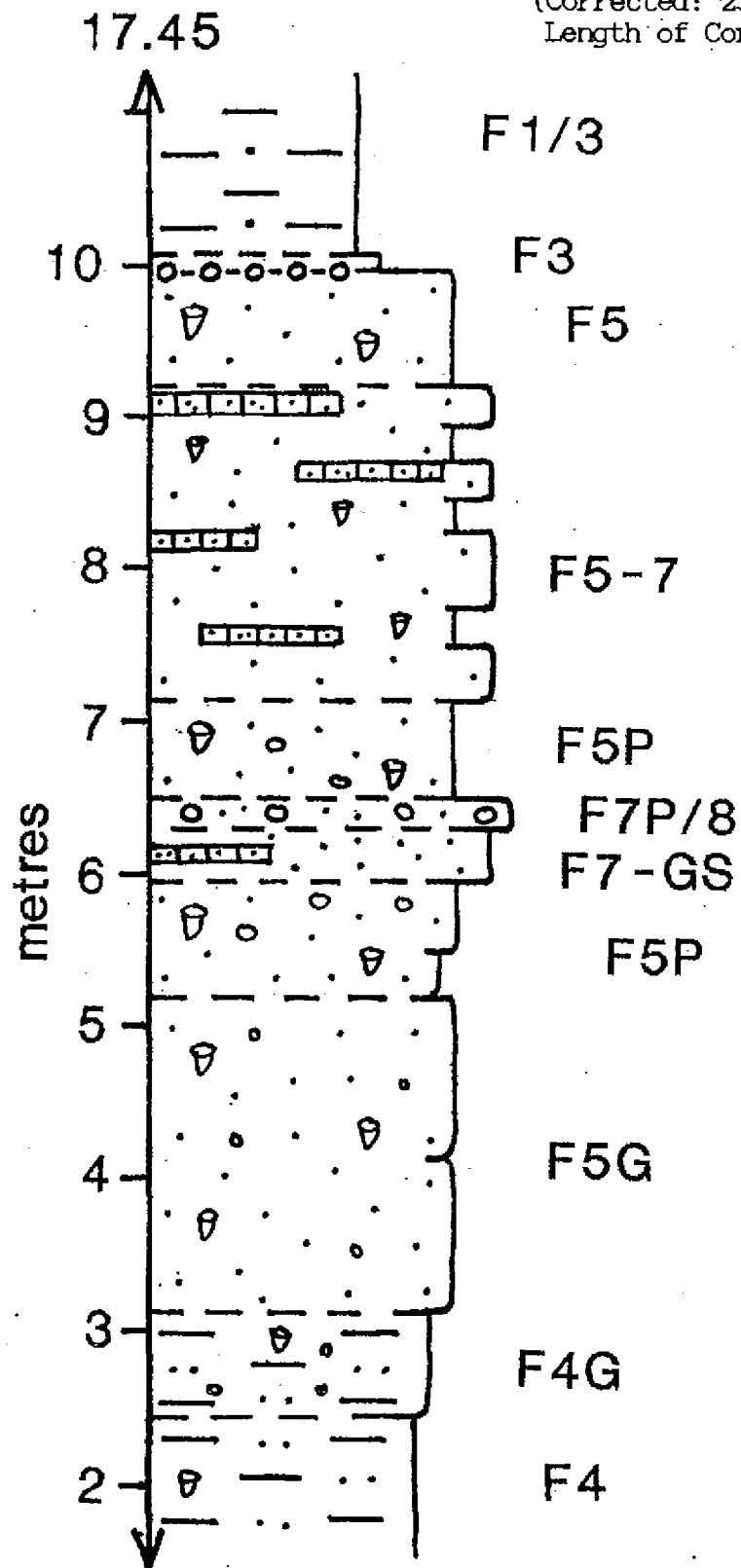


2/10-14-46-14W5

Cored Interval: 2353.0-2371.0 m

(Corrected: 2351.0-2369.0 m)

Length of Core = 17.45 m

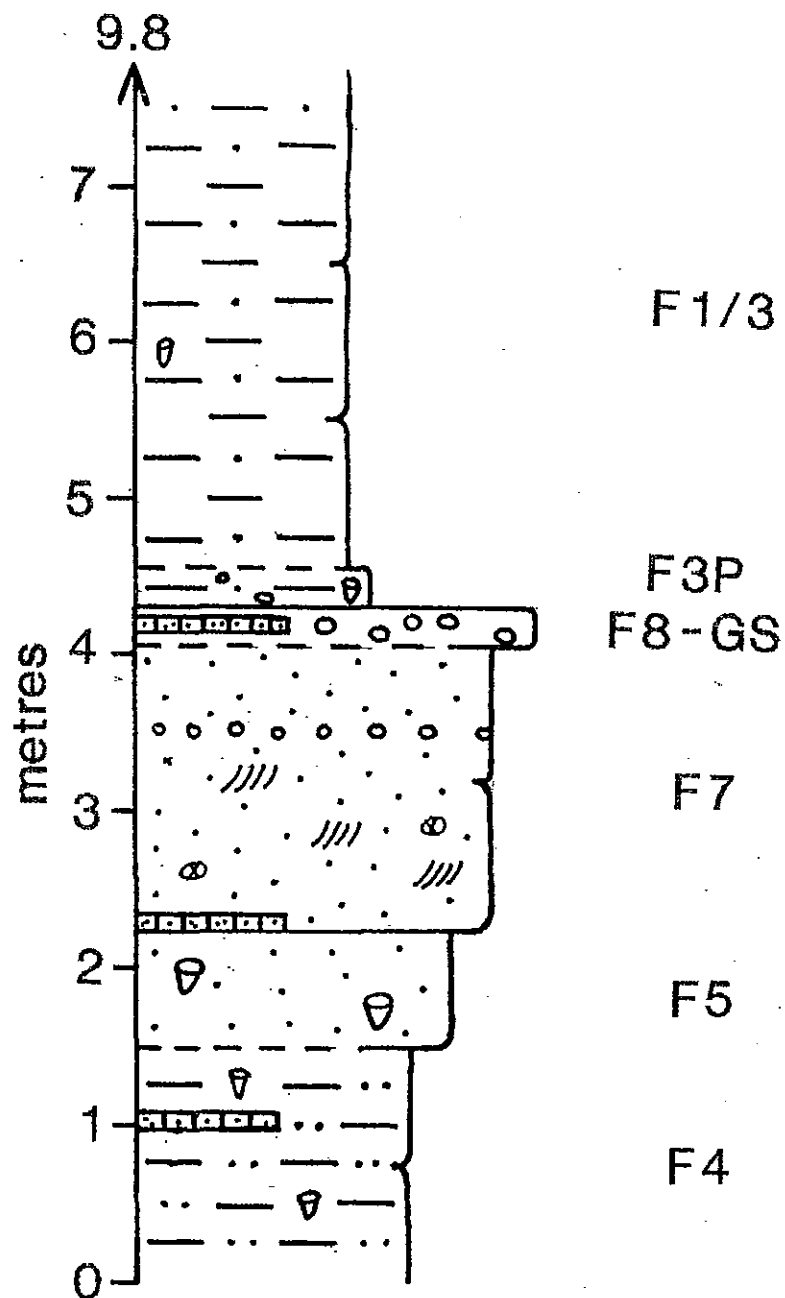


2/10-15-46-14W5

Cored Interval: 2422.0-2432.0 m

(Corrected: 2424.0-2434.0 m)

Length of Core = 9.8 m

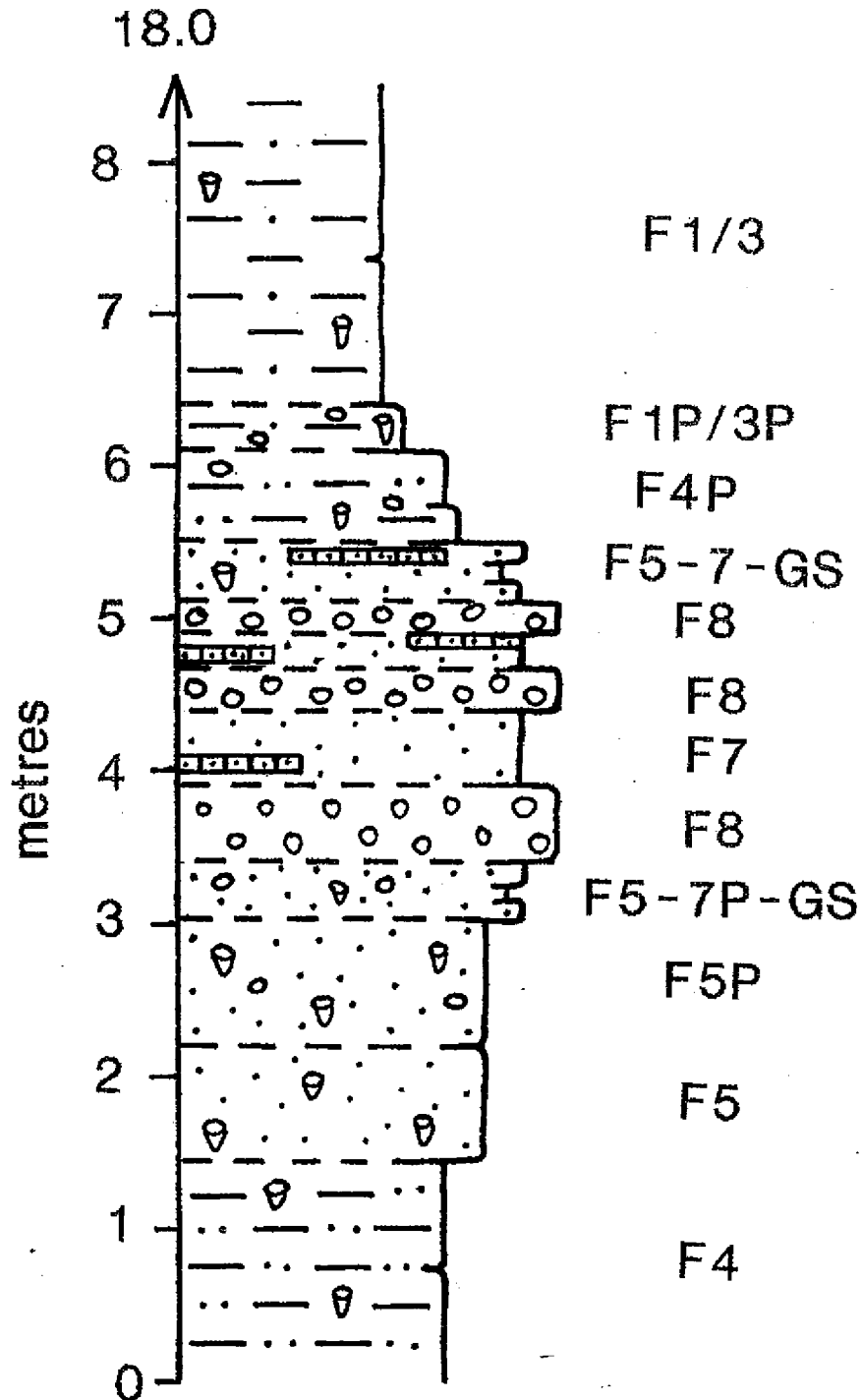


4-27-46-14W5

Cored Interval: 2350.0-2368.0 m

(Corrected: 2355.0-2373.0 m)

Core Length = 18.0 m

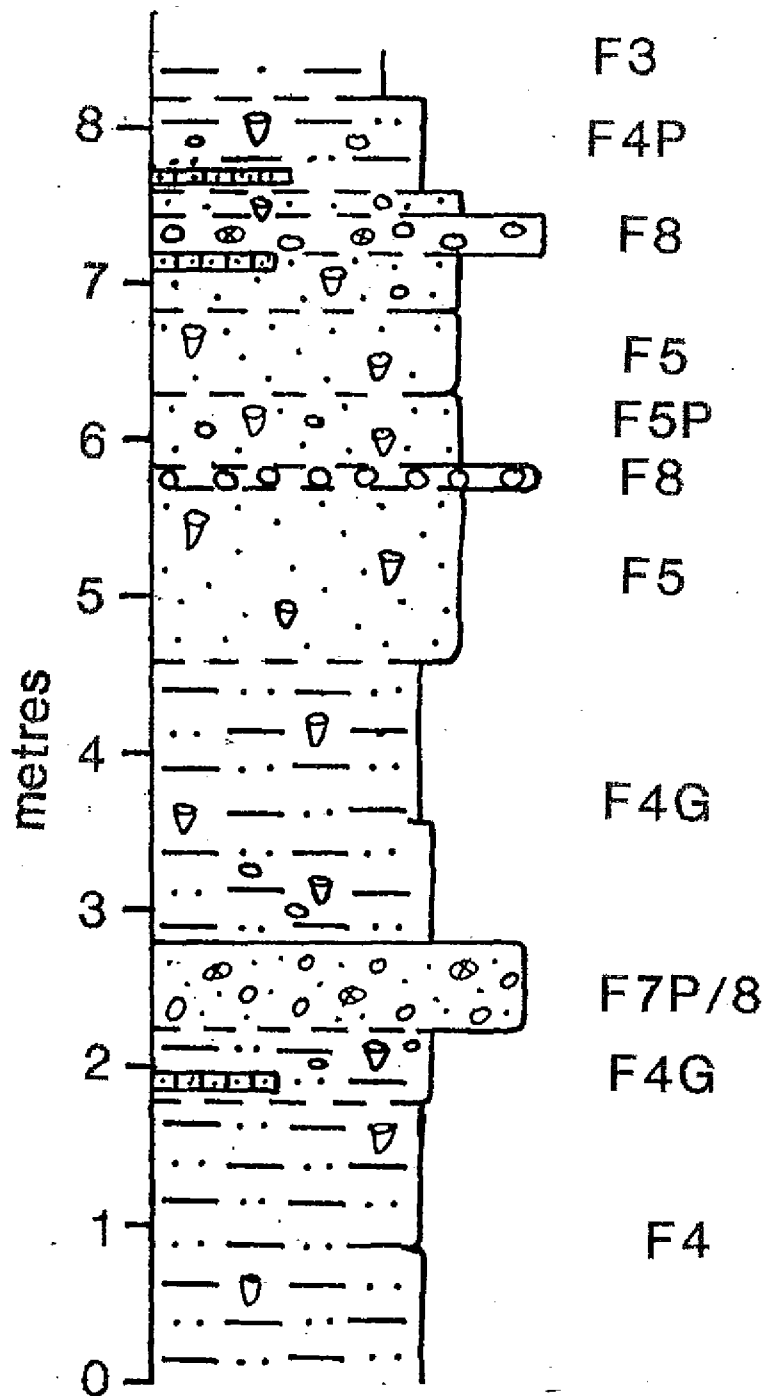


8-28-46-14W5

Cored Interval: 2370.0-2379.0 m

(Corrected: 2370.0-2379.0)

Length of Core = 8.50 m

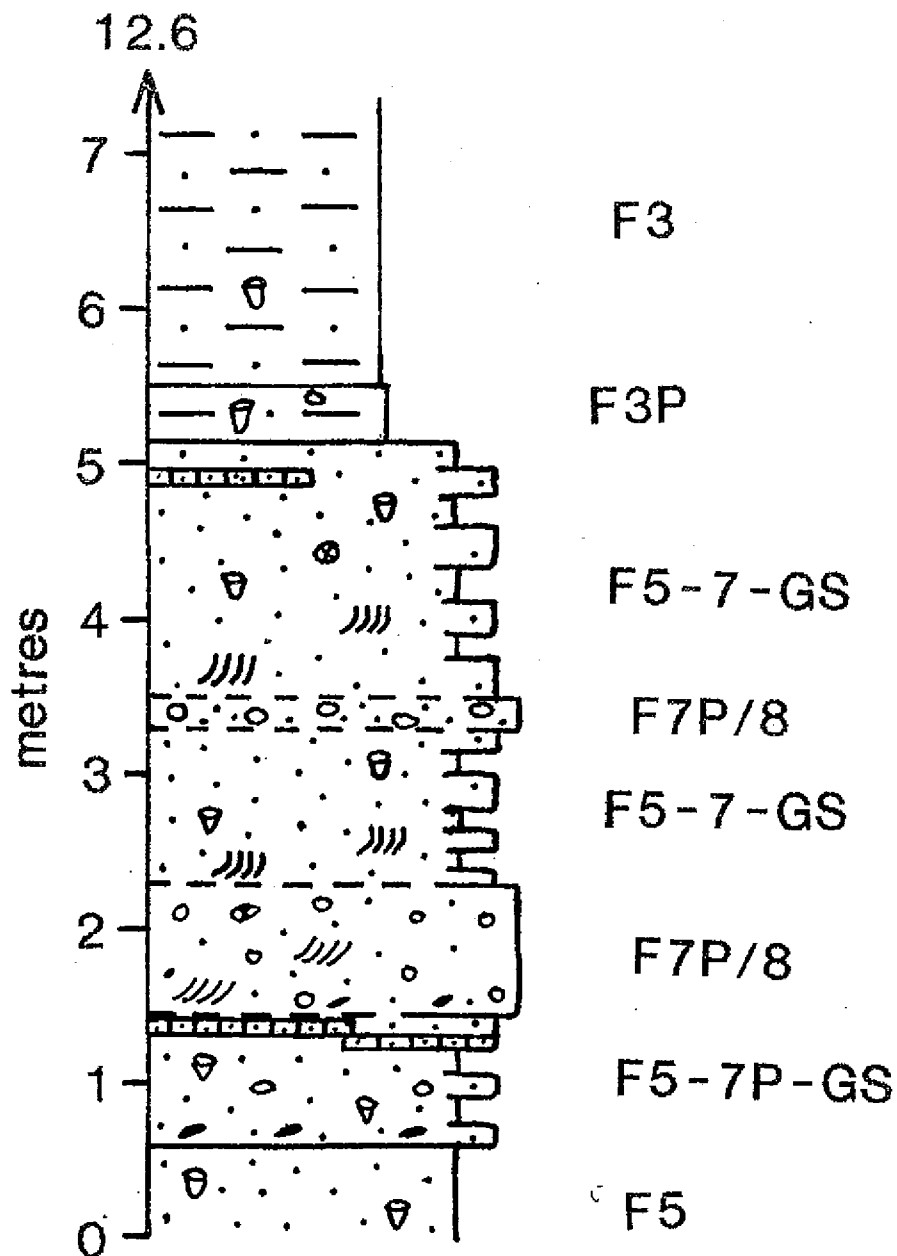


16-28-46-14W5

Cored Interval: 2401.0-2413.6 m

(Corrected: 2400.0-2412.6 m)

Length of Core = 12.6 m

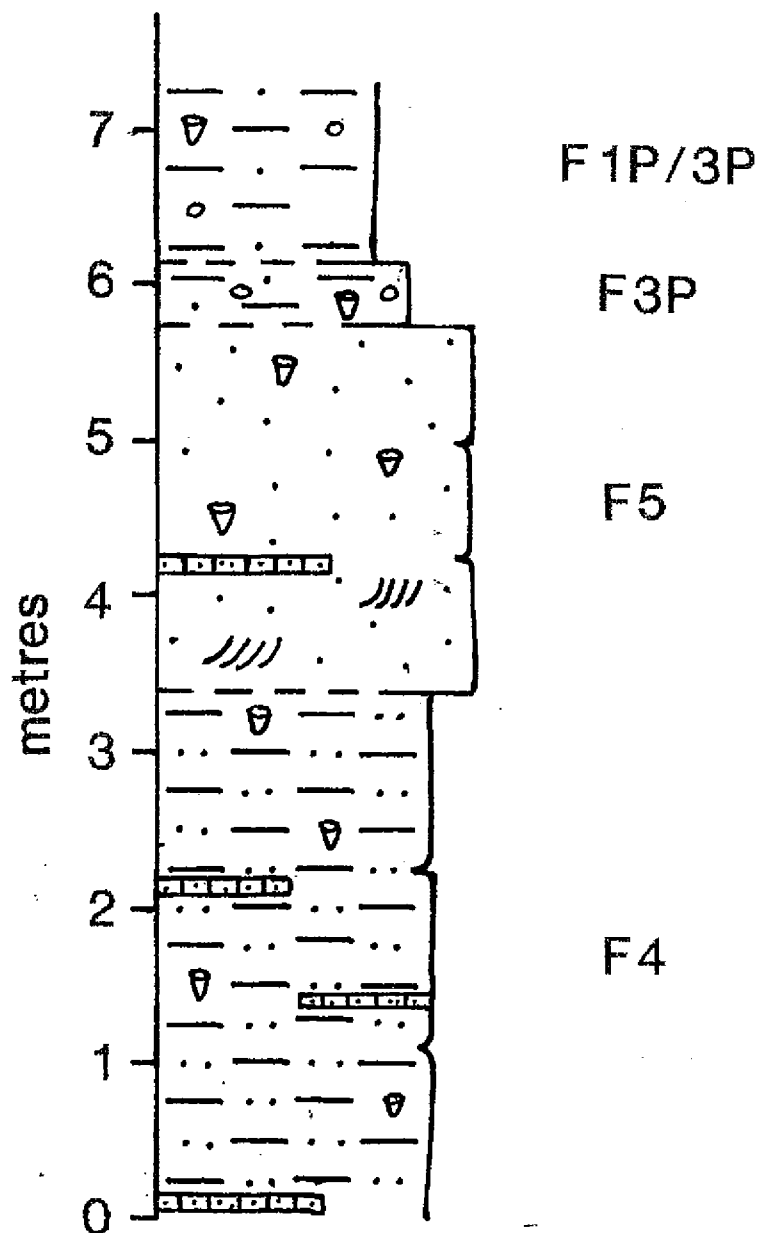


7-31-46-14W5

Cored Interval: 2404.0-2412.0 m

(Corrected: 2408.8-2416.0 m)

Length of Core = 7.9 m

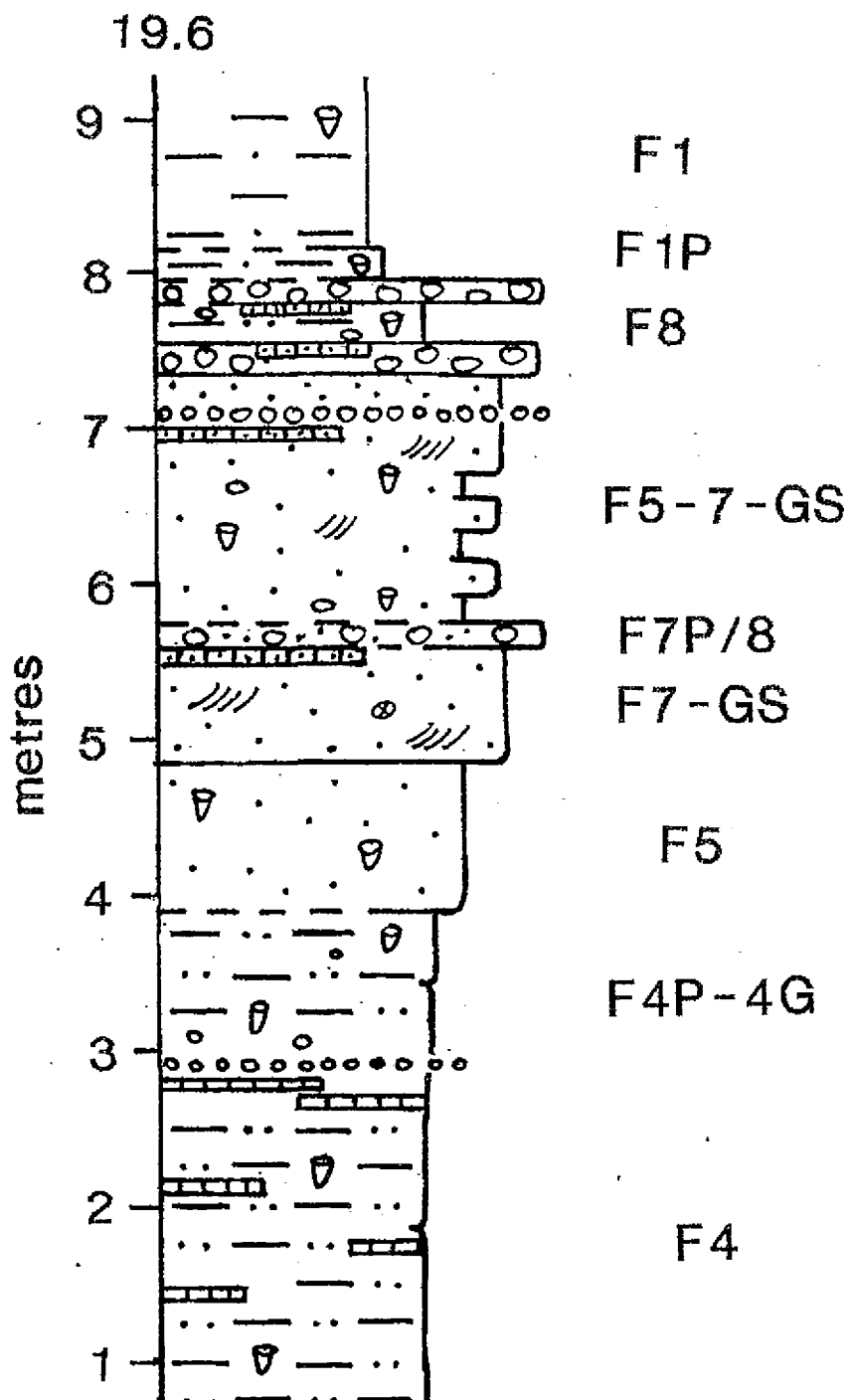


14-32-46-14W5

Cored Interval: 2405.0-2424.6 m

(Corrected: 2405.0-2424.6 m)

Length of Core = 19.6 m

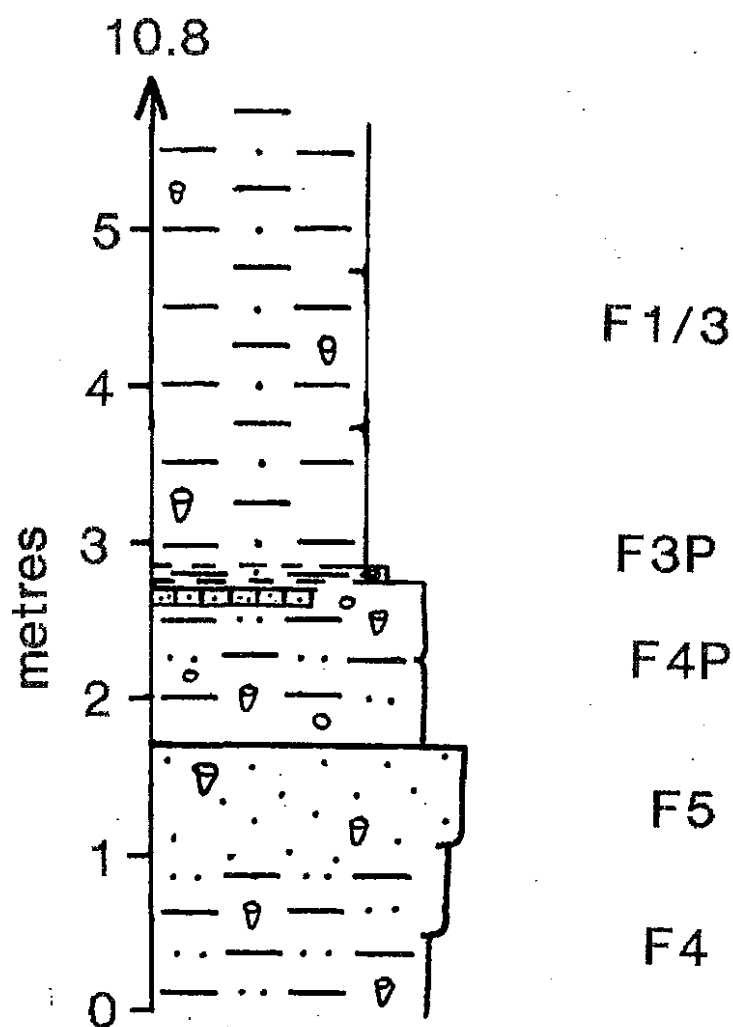


8-34-46-14W5

Cored Interval: 2395.0-2405.8 m

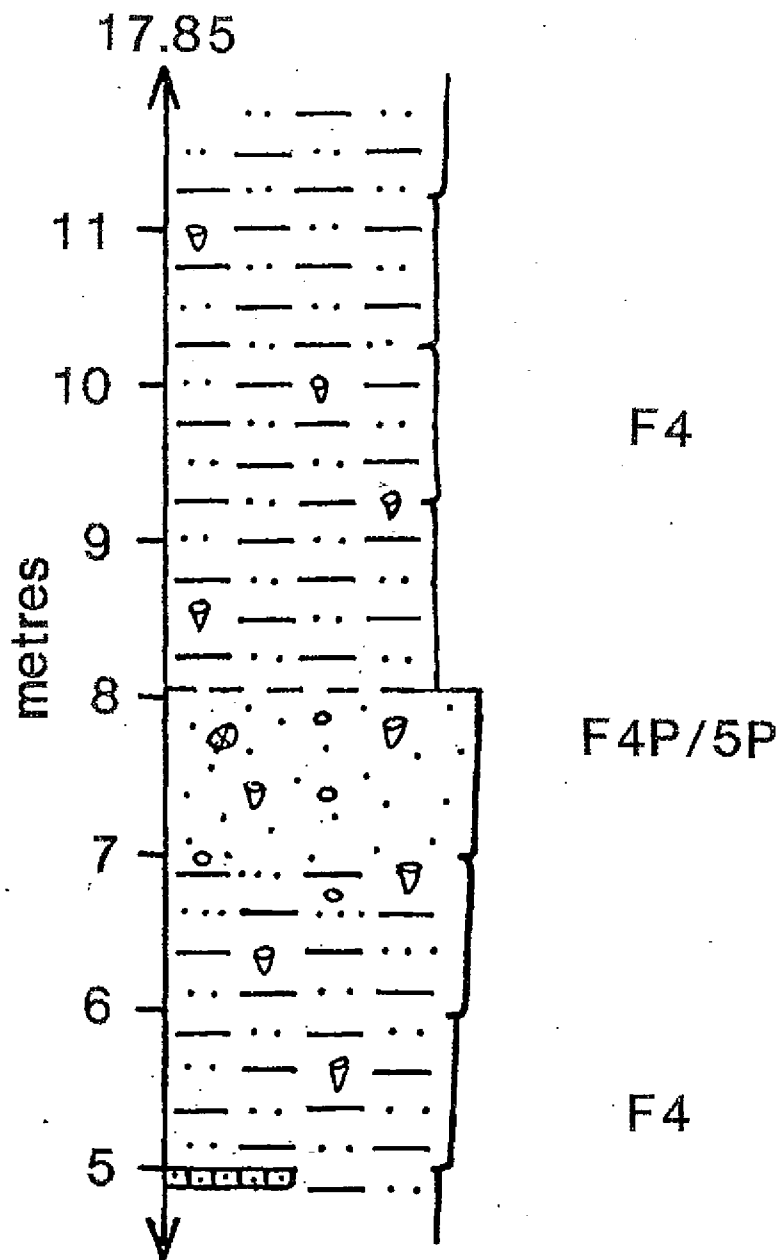
(Corrected: 2395.0-2405.8 m)

Length of Core = 10.80 m



13-6-47-13W5

Cored Interval: 2416.0-2434.2 m
(Corrected: 2417.0-2435.0 m)
Length of Core = 17.85 m

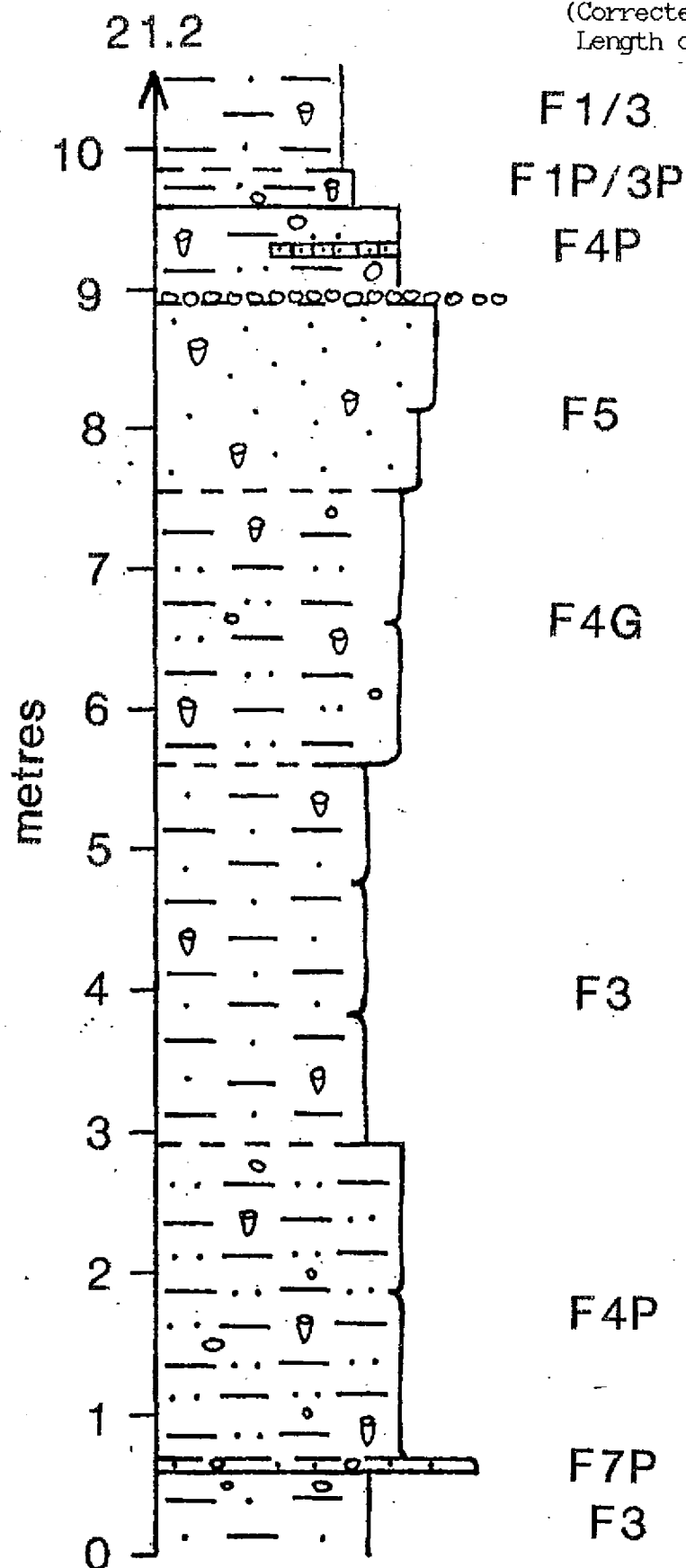


6-2-47-14W5

Cored Interval: 8080-8170'

(Corrected: 8082.5-8172.5')

Length of Core = 21.2 m

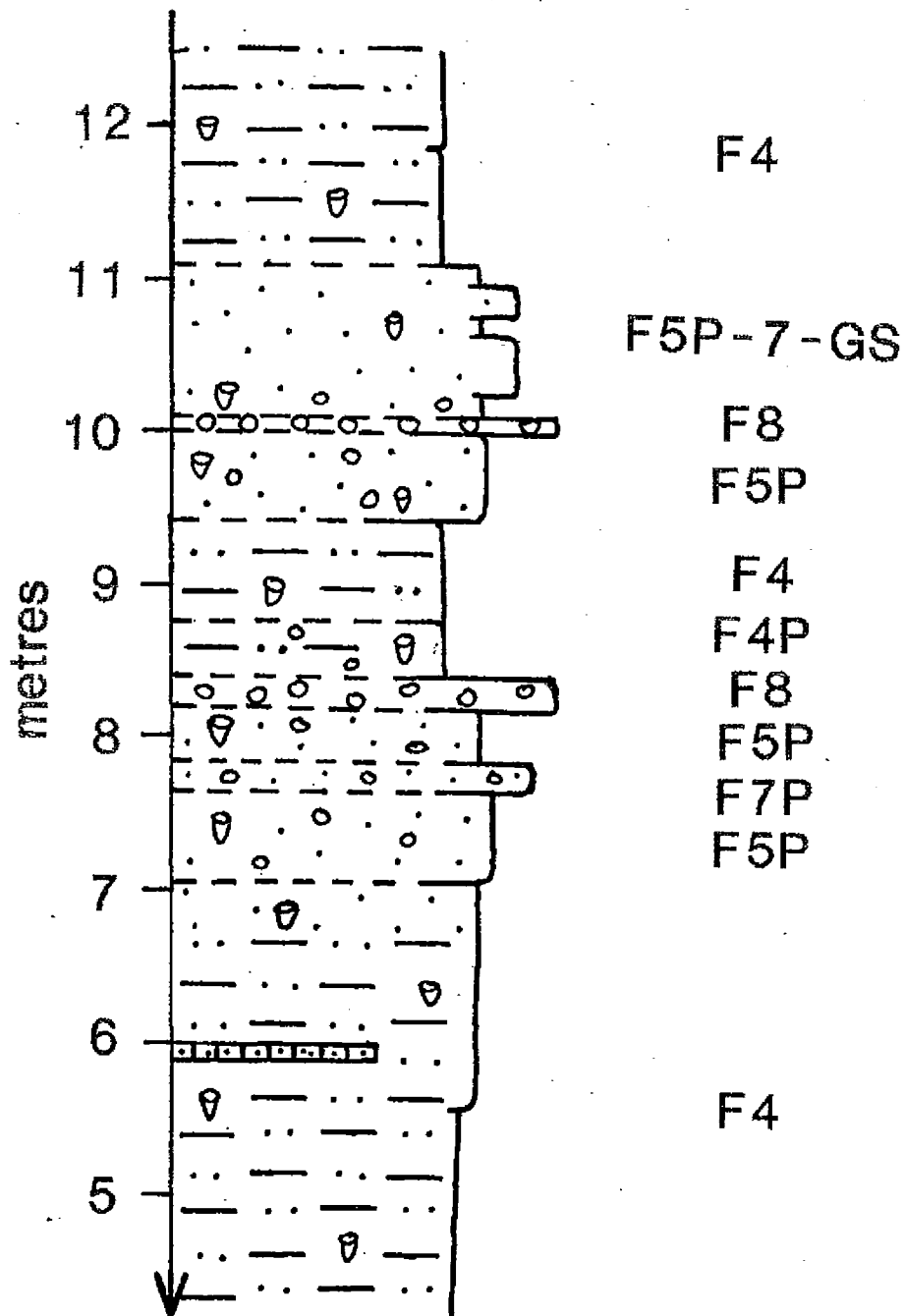


12-4-47-14W5

Cored Interval: 2477.0-2489.0 m

(Corrected: 2477.65-2489.65 m)

Length of Core = 12.5 m

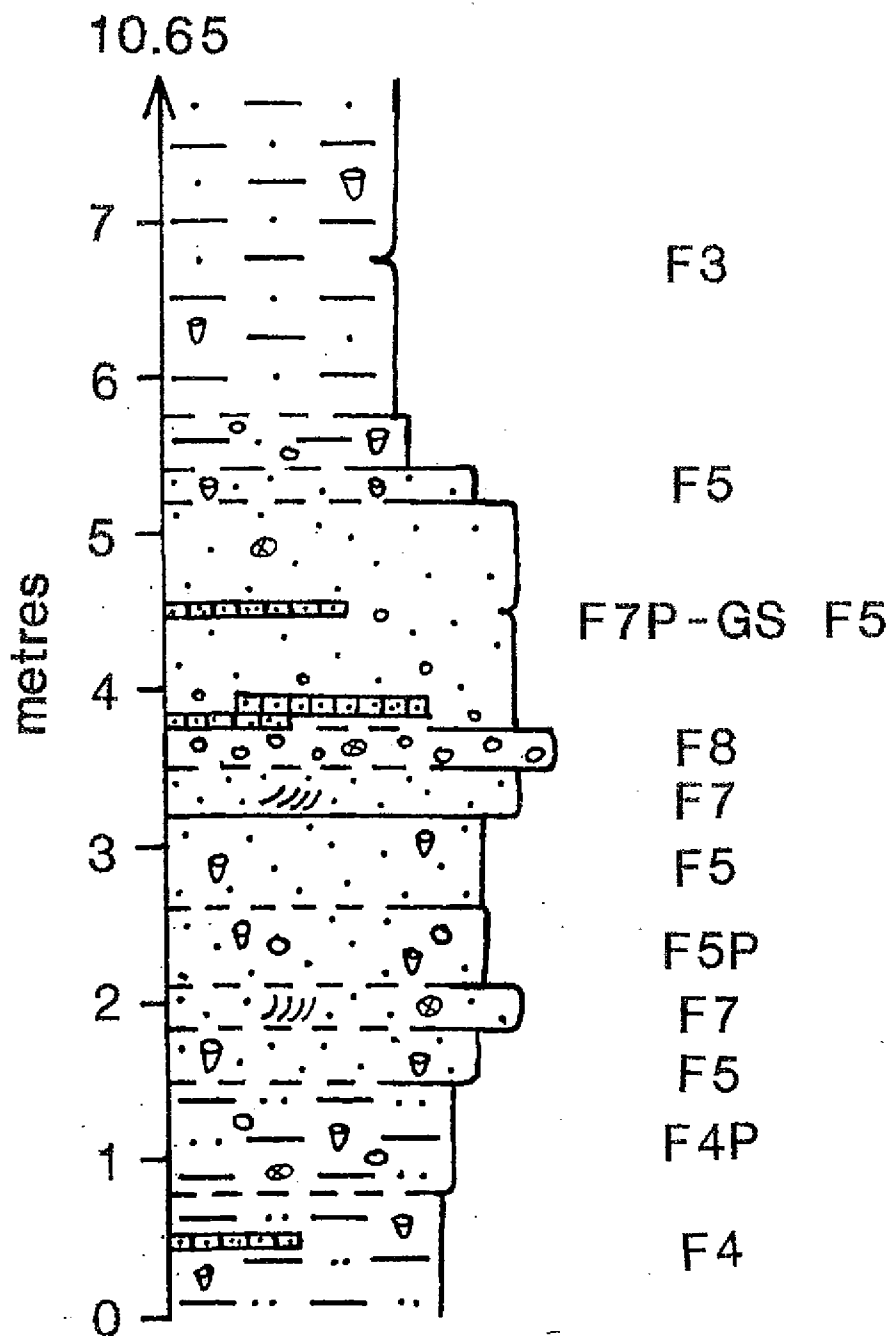


10-5-47-14W5

Cored Interval: 2502.0-2512.7 m

(Corrected: 2497.5-2508.25 m)

Length of Core = 10.65 m

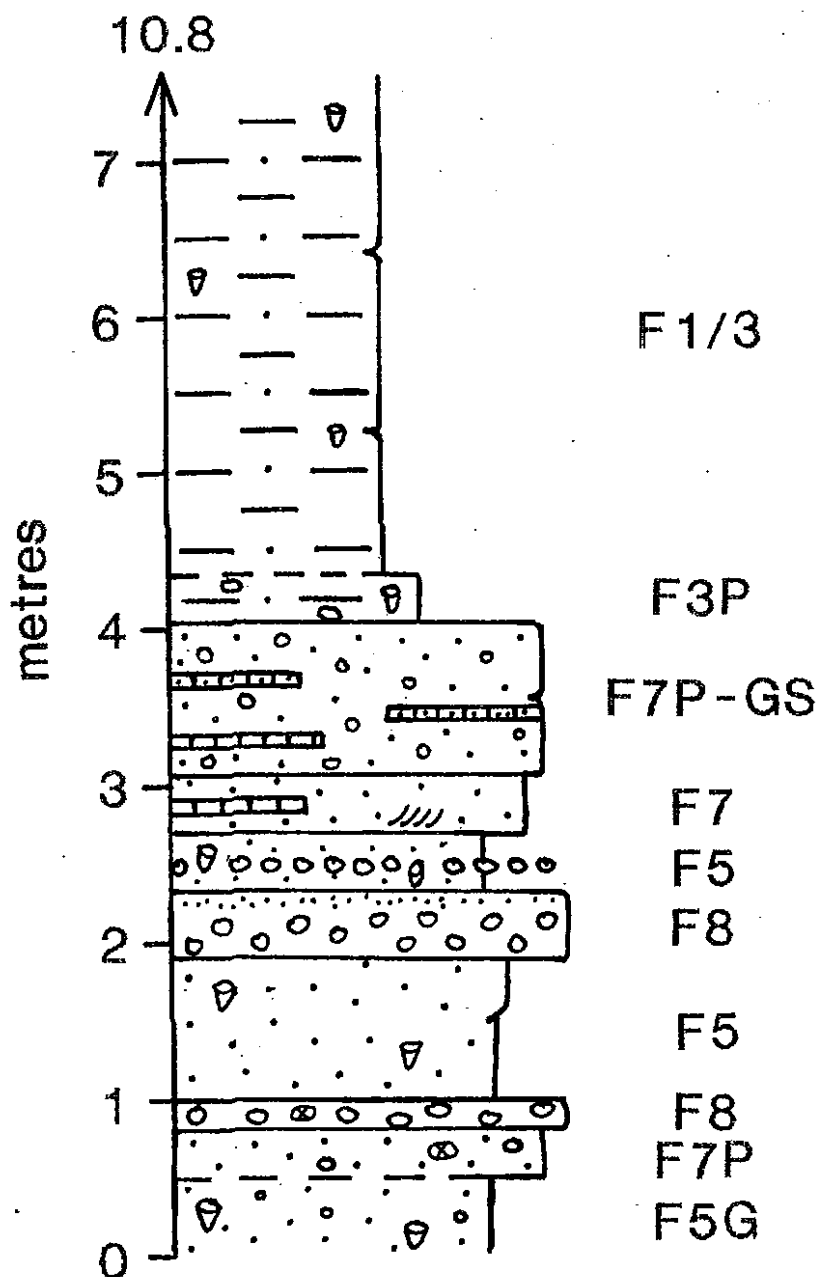


10-7-47-14W5

Cored Interval: 2525.0-2536.0 m

(Corrected: 2526.0-2538.0 m)

Length of Core = 10.80 m

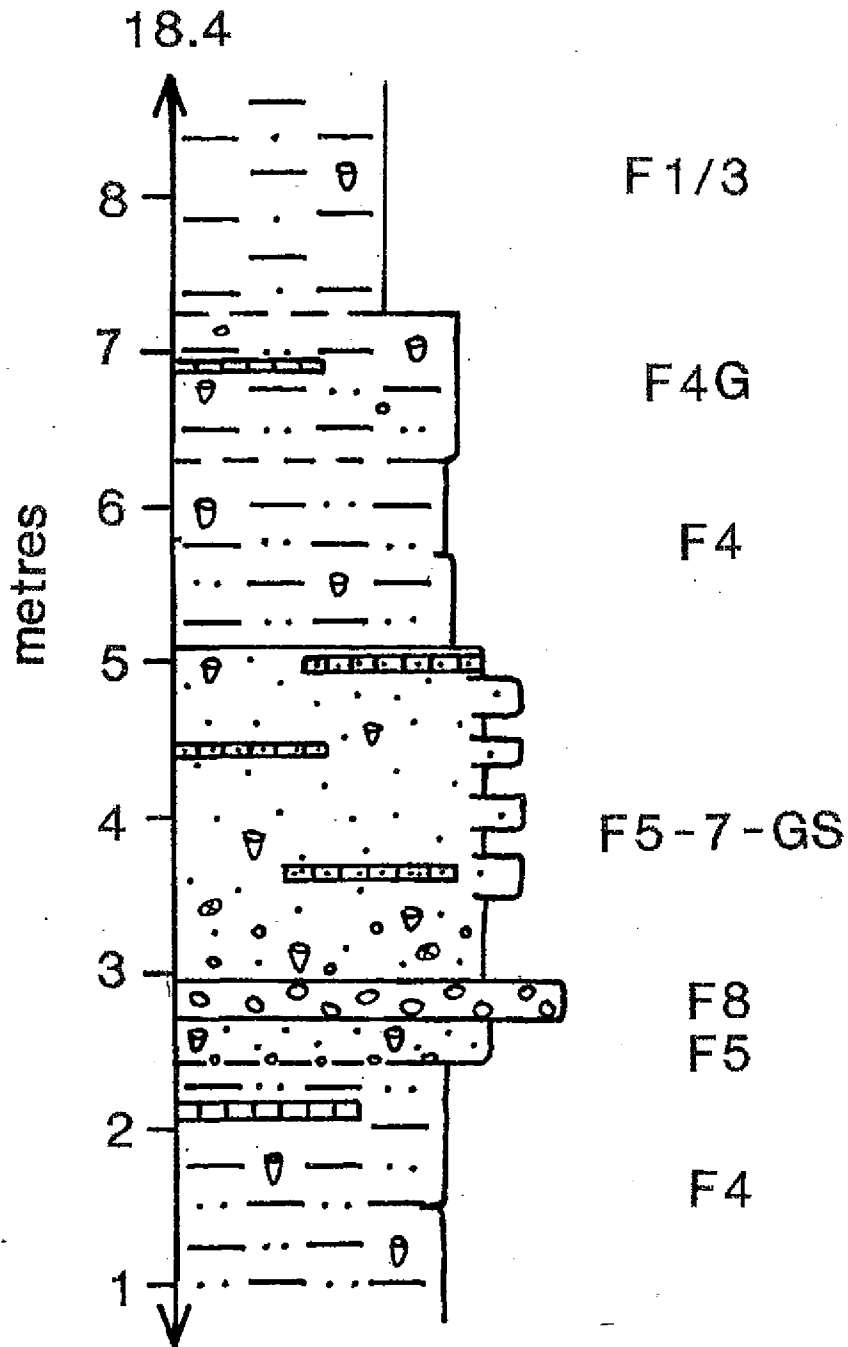


13-18-47-14W5

Cored Interval: 2501.0-2521.4 m

(Corrected: 2503.0-2521.4 m)

Length of Core = 18.4 m

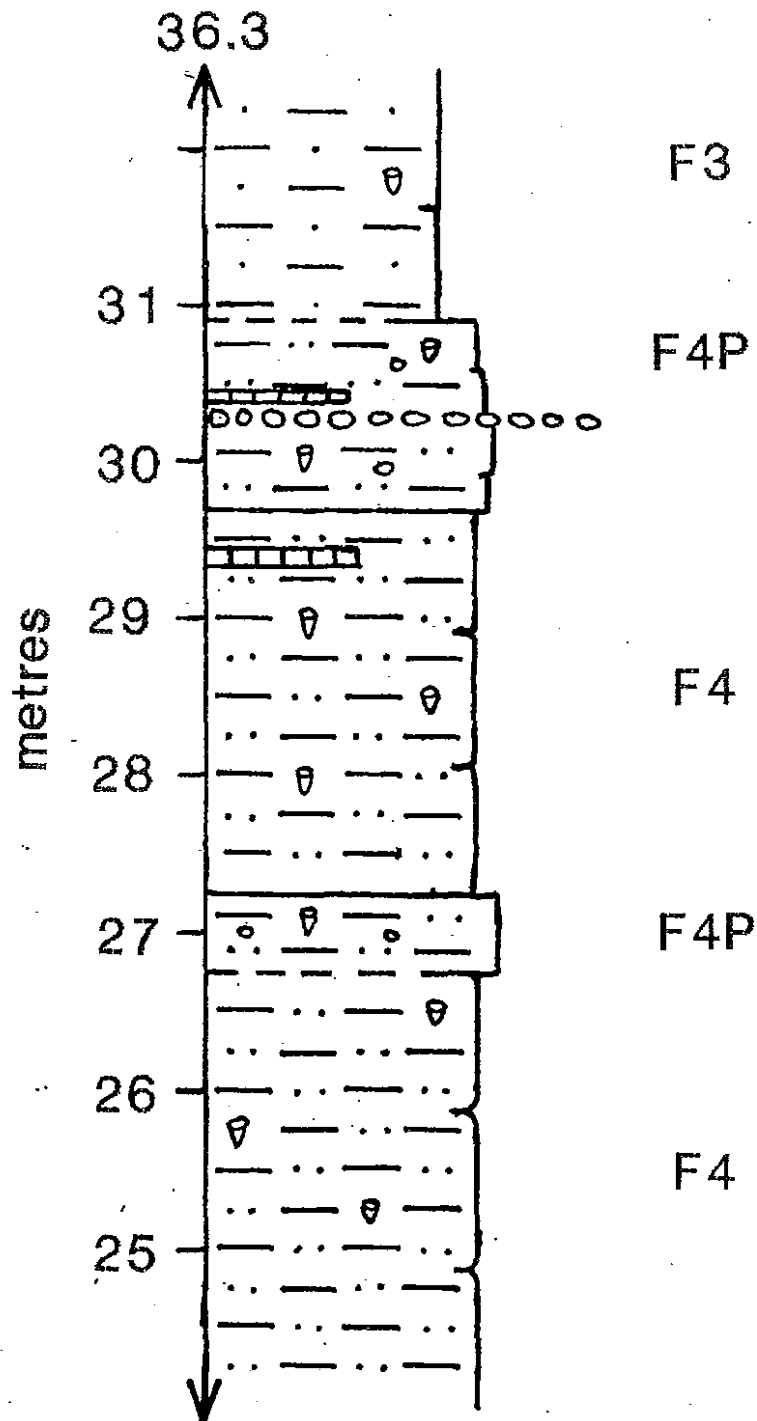


7-9-47-15W5

Cored Interval: 2614.4-2650.0 m

(Corrected: 2619.0-2654.5)

Length of Core = 36.3 m

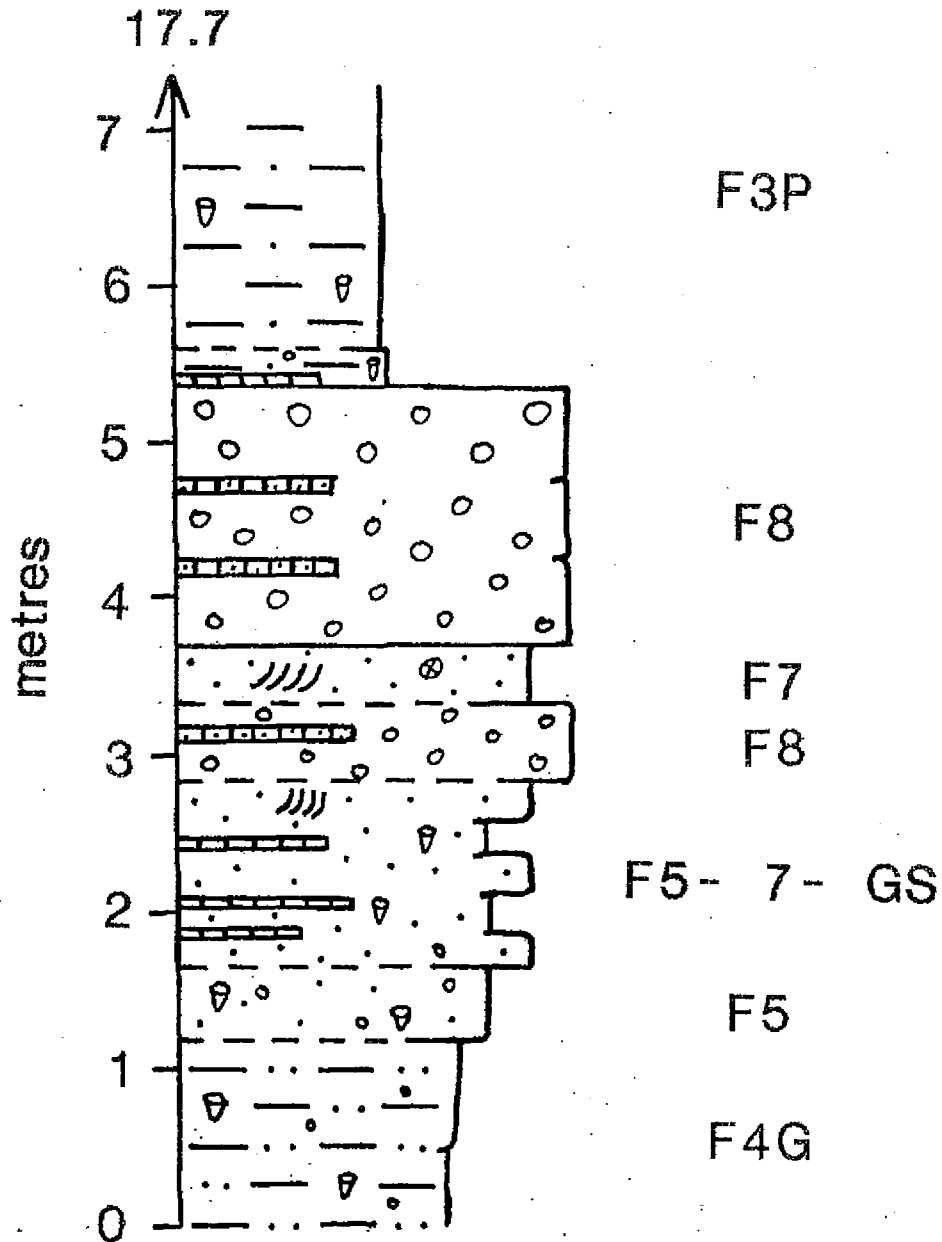


11-13-47-15W5

Cored Interval: 2511.8-2529.8 m

(Corrected: 2509.8-2527.5 m)

Length of Core = 17.7 m

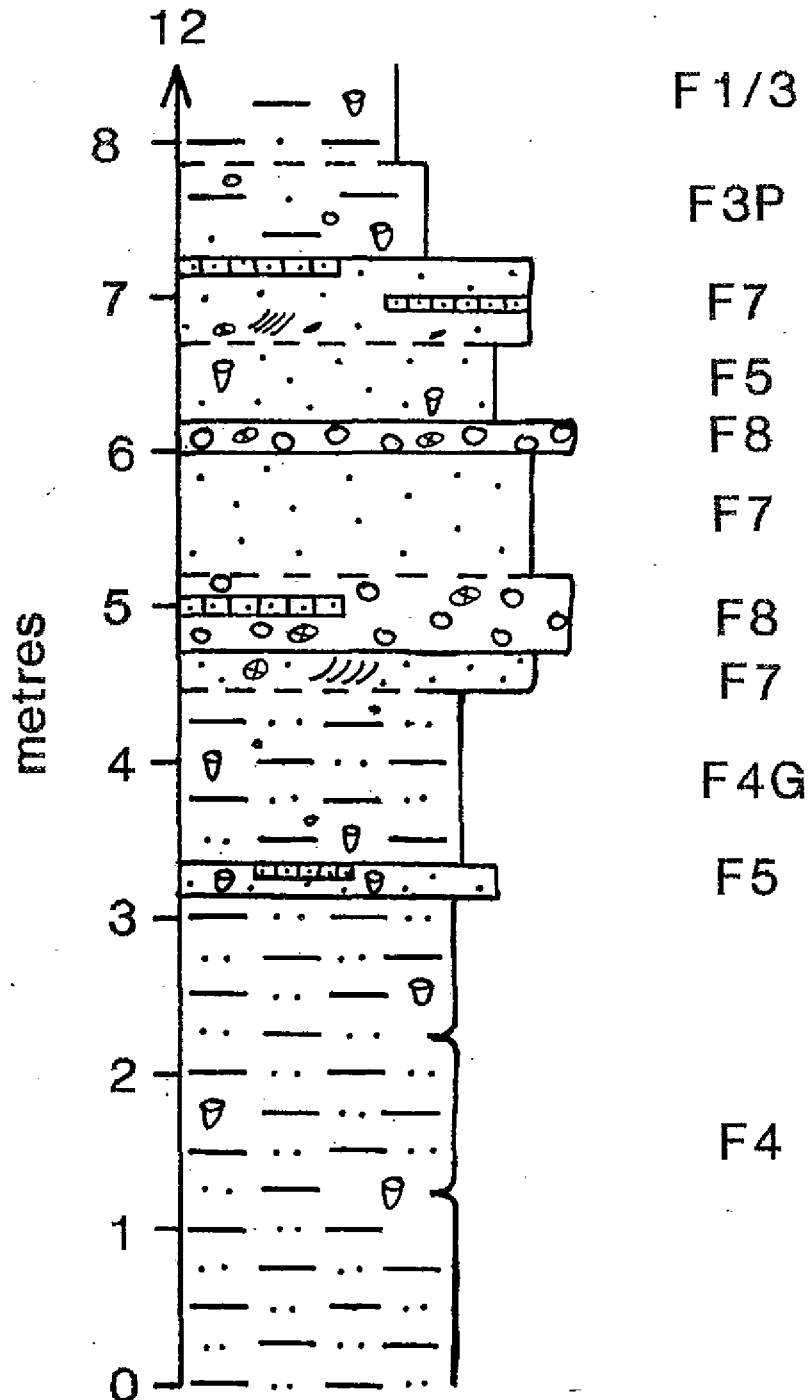


11-23-47-15W5

Cored Interval: 2468.0-2480.0 m

(Corrected: 2466.0-2478.0 m)

Length of Core = 12 m



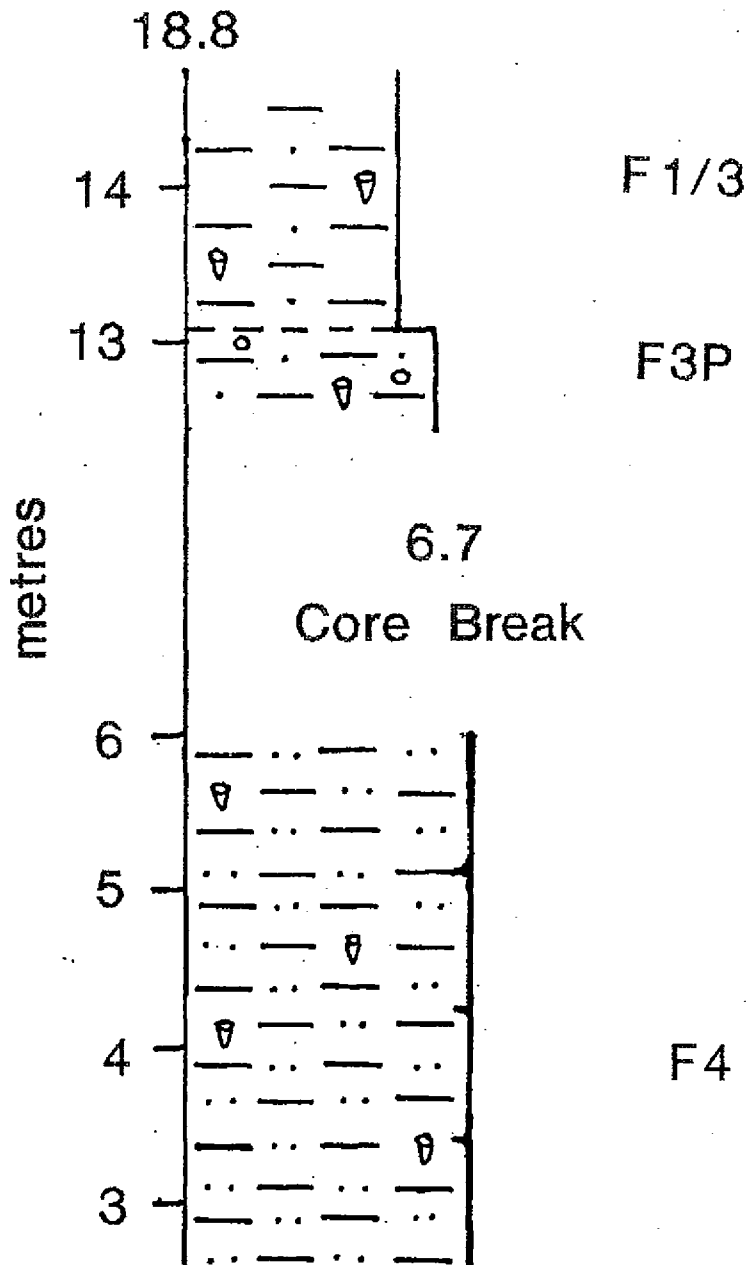
5-26-47-15W5

Cored Interval: 8089.9-8109.9'

8131.9-8156.8'

Length of Core = 6.10 m

6.0 m

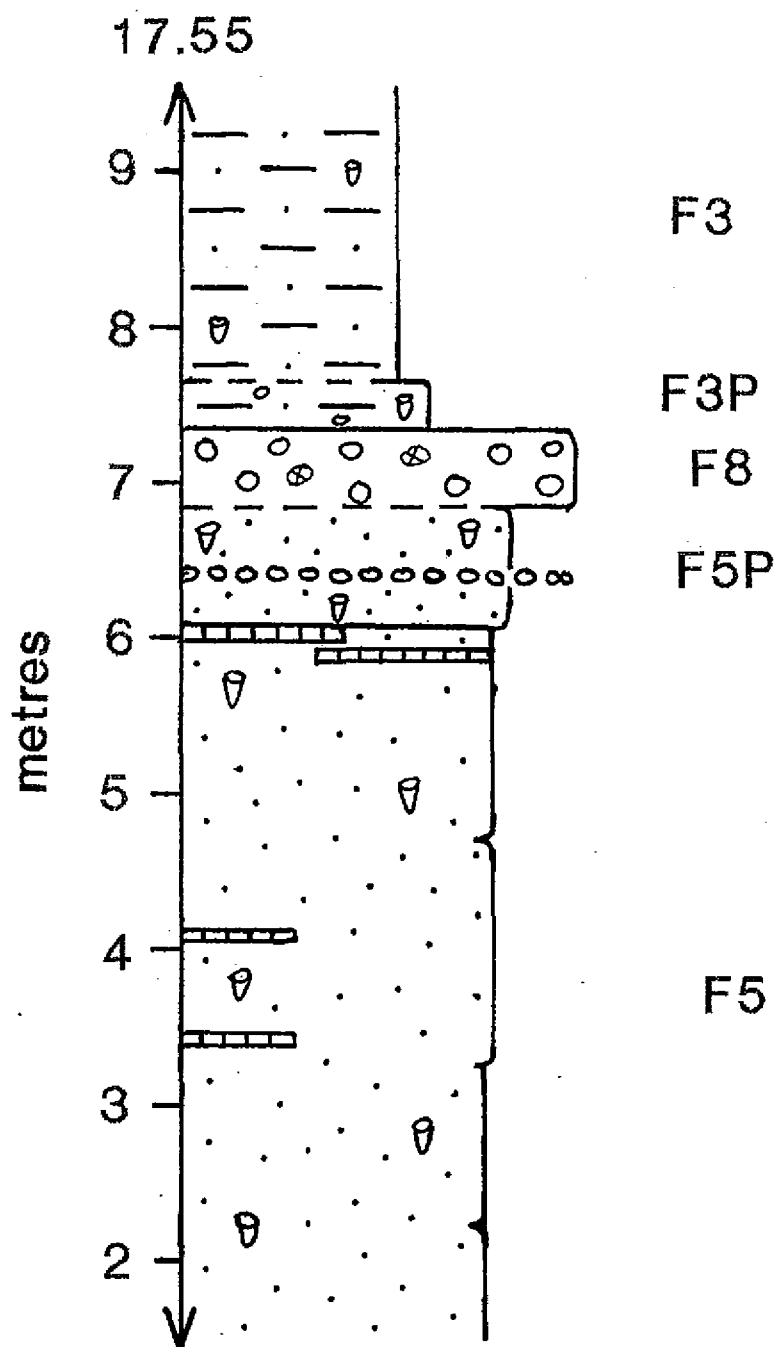


5-31-47-15W5

Cored Interval: 2472.0-2491.0 m

(Corrected: 2471.0-2471.5 m)

Length of Core= 17.5 m



2-14-46-14W5

Cored Interval: 2396.0-2408.4 m

(Corrected: 2396.0-2408.4 m)

Length of Core = 12.35 m

