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# JURASSIC LITHOLOGIES AND SOME FACTORS AFFECTING SEDIMENT DISTRIBUTION IN NORTHWESTERN ALBERTA

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## Abstract

The Lower Jurassic strata of northwestern Alberta consist of basal, highly radioactive marlstones (Pliensbachian?) overlain by green or brown (Toarcian to Aalenian) Poker Chip Shales. Both were deposited on a passive cratonic margin, although a brief erosional or non-depositional period may have intervened between the two.

A regional unconformity (probably erosional) separates these sediments from the overlying Late Jurassic or Upper Fernie shale/sandstone package. These marine clastics (mainly shale) were deposited in and adjacent to a subsiding foreland basin which developed in response to the onset and continued activity of the Columbian orogeny to the west.

A highly to moderately glauconitic transgressive unit at the base of the Upper Fernie package (Early Oxfordian to Late Callovian 'Green beds' equivalent) is present throughout the study area, and in the region coincident with the ancient Peace River Arch, is expressed by relatively thick quartz sands. To the west, thick marine Nikanassin sand and shale deposition extended into Late Jurassic and possibly Early Cretaceous times in response to rapid subsidence of the foreland basin.

A Lower Cretaceous (Hauterivian) erosional event subsequently bevelled increasingly older Jurassic sediments eastward.

Re-initiation of Cordilleran uplift in Early Cretaceous (Barremian) times produced a fresh sediment supply in the west and continued subsidence of the Alberta foredeep trough. A major trunk fluvial system developed in the trough (Spirit River Channel), and received sediment from the Cordillera to the west, and from a broad highland to the east. This highland, including the western Fox Creek Escarpment, was a relief feature which exposed mainly Jurassic sediments to erosion in the Early Cretaceous. Continued subsidence and further accumulation of Gething fluvial and delta plain deposits eventually buried these highlands in late Aptian time.

## Introduction

The purpose of this paper is to reiterate and provide more detail to lithologic descriptions discussed in a previous paper co-authoured by Poulton, Tittemore and Dolby (1990). The intra- and interrelationships of Jurassic units will be summarized, and the effects of Lower Cretaceous erosion on the current subsurface distribution of Jurassic sediments will be discussed.

The area of study is shown in Figure 1, and shows the location of the stratigraphic cross sections utilized by Poulton et al (1990), and in this report. These sections have been slightly modified by the author subsequent to detailed sample examination.

The Jurassic section in northern Alberta is a complex, eastward tapering wedge of clastics and minor carbonates that represent the dynamic pre-orogenic events and onset of the Columbian Orogeny in the early Late Jurassic. The complexity arises from the numerous unconformities that occur within the section, and by its substantial structural modification in pre-Lower Cretaceous and Lower Cretaceous times. The dynamics are expressed by relatively quiescent periods that are interrupted by these widespread erosional events. Figure 2 is a table of formations reflecting current thoughts on Jurassic stratigraphy.

From the standpoint of an oil and gas explorationist, there are three major considerations that lend support to the examination a generally non-producing collection of deposits. Firstly, the development of a Nordegg carbonate bank in west central Alberta probably influenced the accumulation of major Cretaceous and Jurassic oil and gas deposits in this area. Secondly, the high organic content of Jurassic shales and marls were important source rock contributors for many Cretaceous and Triassic clastic plays found throughout Alberta and in British Columbia [Jackson (1984), Riediger (1990), Masters (1984)]. Thirdly, an understanding of Jurassic lithologies and their distributions has a bearing on the delineation of Lower Cretaceous clastics.

The figures in the Appendix 2 of this report contain lithologic descriptions which incorporate core and chip sample examinations. Cores were sampled by the author and dated palynologically by G. Dolby (Poulton et al,1990). Although they are essential for understanding the stratigraphic relationships, they are less than representative of the total Jurassic section north of Township 55. Most cores include only thin Upper Fernie representatives below Cretaceous sands or above

Rock Creek sands, Poker Chip Shale below Rock Creek sands or above Nordegg carbonates, or Nordegg clastics above the Triassic formations of interest. To get a complete lithologic picture, these cores were thus supplemented by chip sample descriptions. Because there are no cores in the wells of Section C-C'(Fig. 6), chip samples were examined in selected wells, although these descriptions are not included in this report.

It should be noted that in Appendix 2, the Triassic has quotation marks ("Triassic") in the lithologic descriptions. Since the Triassic is a period, and the column heading indicates formations or members, these quotations are meant simply to mark this exception.

Five cores were described and sampled south of Township 60 (secondary study area of Figure 1), but these wells are not described in detail here because several comprehensive studies have been published regarding the Jurassic in west central Alberta. [Losert (1986,1990), Marion (1984), Rosenthal (1988)]. Summaries of core data are included in Appendix 1.

This report basically divides the Jurassic into 5 units. The lowest four are members of the Fernie Formation. The basal, oldest member is the Lower Fernie shelf limestone/clastic unit (Plienbachian?), or Nordegg Member. As discussed in Poulton et al (1990), descriptions of the Nordegg Member in Alberta encompass more than one rock type and age. While at its type area at Nordegg, Alberta it is a black, cherty limestone (Early Sinemurian or older) (Spivak, 1949; Frebold, 1957), in west central Alberta it is a carbonate bank (undated - Sinemurian?)

(Poulton et al, 1990) and is a series of dolomites and sandstones (undated) on the eastern Jurassic subcrop edge of the same area (Bovell, 1979). In the study area of this report, the marlstones have been interpreted as being a younger stable shelf facies north of the carbonate bank of west central Alberta, and will be referred to as Lower Fernie shelf facies or limestone/clastic unit, or simply Nordegg Member.

This unit lies unconformably on Late Carboniferous carbonates in the south, and on Triassic carbonates and clastics in the study area. The Poker Chip Shale rests unconformably on the Nordegg, and while overlain by Rock Creek sands south of the study area, it is blanketed by the Upper Fernie shale/sandstone unit in northwestern Alberta. In some areas, it may be entirely missing due to erosion. The Nikanassin Formation, a sandstone package, is in part, syndepositional with Upper Fernie shales and sandstones, but has not been examined by the author, and will only be touched on briefly in this report.

## Acknowledgments

This paper draws on information contained in a previous paper by Poulton et al (1990). The sections (Figs. 4 to 8) are taken directly from this paper, with slight modifications. Some of these wells, in turn, were taken from more detailed sections correlated by Jiri Losert (Alberta Department of Energy) and Shaun O'Connell (Alberta Geological Survey). All of the information regarding Lower Cretaceous geology was gleaned from studies presented by Paul Jackson; David Smith, Carl Zorn, and Robert Sneider; and Robert Gies in A.A.P.G. Memoir 38 on the Elmworth deep basin (see references). The geology of Figure 3 is copied, with slight modifications, from Paul Jackson's study of Lower Cretaceous paleogeography in the aforementioned memoir. However, the interpretations and data provided in this study are entirely the reponsibility of the author. The Jurassic portion of the correlation chart (Fig. 2) is after Poulton et al (1990), and the Cretaceous part is modified from Smith et al (1984) and Rosenthal (1988). Cores were examined at the core storage facility of the Energy Resources Conservation Board, and samples were provided by the sample repository at the Institute of Sedimentary and Petroleum Geology. Financial support for this study, which is a contribution to the Peace River Arch and Western Canada Atlas projects of the Geological Survey of Canada and the Alberta Geological Survey, was provided by S. Bell and R. McQueen (Institute of Sedimentary and Petroleum Geology). A special thanks to Terry Poulton (I.S.P.G.) for providing opportunities, guidance, and valuable information and insights.

## Lithologic Descriptions of Units

### NORDEGG MEMBER

Described in the Lexicon of Canadian Stratigraphy - Western Canada (1990) and by Spivak (1949) and Frebold (1957) as "a black, cherty limestone" . Springer et al. (1964) add that "in the subsurface it extends eastward to a line from Pincher Creek through Calgary to the Gilby area southwest of Edmonton and consists of speckled dark brown shale of bituminous appearance, with thin beds of shaly limestone."

In the study area, the Nordegg just south of Township 54 is a calcareous multi-coloured chert varying to a cherty banded limestone. These beds are 45 to 60 m. thick, thinning northward and eastward, and are generally massively-bedded in the middle and lower portions. The upper two to three meters (noted in cores from wells 10-12-57-19W5M and 14-8-56-19W5M) are brecciated to varying degrees, and abundant collapse structures, stylolitic sutures and shale intraclasts were observed. These features would indicate a period of emergence, and the contact with the overlying Poker Chip Shale is therefore probably erosional. As discussed in Poulton et al (1990), the Nordegg carbonate bank is undated, but regarded as Sinemurian in age. Extensive sampling of the Nordegg in the subsurface have produced no conclusive dates due to the poor quality of diagnostic fossils. They are either too thermally altered, too far-ranging or too few in number for practical dating purposes.

Between Townships 59 and 60, this chert/limestone sequence changes northward to interbedded dark marlstones and highly calcareous dark shales with abundant calcareous white specks and fish remains. Thin, argillaceous limestone stringers are not uncommon. Figs. 4 and 5 demonstrate this lithologic change from the carbonate bank facies to northward thinning shelf shales and marls. As discussed in Poulton et al (1990), these sediments are perhaps younger (Pliensbachian) than the Sinemurian(?) carbonate bank of central Alberta.

The gamma ray log signature of the Nordegg north of Township 60 shows a high radioactive count, and can be similarly seen in two well-known marker beds in Alberta; the Base of Fish Scales, with it's high concentration of fish remains, and the Second White Specks, which contains abundant calcareous white specks.

Average thickness of this carbonate/clastic facies is 30 to 40 meters, and is maintained northward to Twp. 85, then thins to the erosional zero-edge at Township 91.

East to west relationships seem to be less dramatic north of Township 60, and do not show the lithologic transitions apparent in the northwest/southeast direction on strike with the Alberta Trough. The thickness increases from 10 to 15 meters at the Alberta/B.C. border, to 30 meters just east of the Sixth Meridian, then tapers down to the zero edge eastward beyond that.

## POKER CHIP SHALE MEMBER

Described in the Lexicon of Canadian Stratigraphy (1990) as typically black, platy, fissile shale. In north central Alberta, it can also be dark green, dark brown, and greyish-green, and is variously silty and/or pyritic. Average thickness is 10 to 25 meters (thinning southward), and thin, clean sandstone stringers are not uncommon. In well 14-8-56-19W5M, the Poker Chip Shale contains a thin limestone bed. The Poker Chip Shale unconformably overlies the Nordegg in the subsurface of north central Alberta.

North of Township 60, these shales are generally green or brown, and are variably bentonitic, silty, arenaceous and pyritic, and often contain siderite stringers. Thicknesses range from one or two meters to over 60 meters in well 15-34-77-1W6M (Fig. 5). This unusually thick Poker Chip accumulation also yielded the first documented Aalenian age found in Western Canada, whereas Toarcian dates are given for Poker Chip Shales in the rest of the province. The nature of the contact with the Lower Fernie shelf facies north of Twp. 60 is less clear than that further south.

## ROCK CREEK MEMBER

Described in the Lexicon (1990) as quartzose siltstones and sandstones with calcite cement. They can be heavily bioturbated. Marion (1984) reports that in west central Alberta, they are basal coquinoid sandstones overlain by burrowed, silty sandstone with clean flaser and cross-bedded, and planar-laminated to wave rippled sandstones at the top.

The Rock Creek sand is not found north of Township 55, and its northern erosional edge in north central Alberta can be seen in Figure 4. The core in well 10-14-54-13W5M was dated by C. Singh for Losert (1986), and confirms the presence of Niton 'B' and Rock Creek as far north as Twp. 54. By log correlation alone, wells 14-8-56-19W5M (Fig. 5) and 7-5-58-18W5M (Fig. 4) could easily be assigned to the Rock Creek Member. However, cores were sampled and described by the author, and on the basis of resultant dates and lithologies, these sands have been assigned to the Poker Chip Shale and Green Beds, respectively (see Appendix 1 for sample depths and dates). This also points out the importance of core examination for the delineation of sometimes subtle but often significant lateral variations in Jurassic sands.

Lackie (1958) described Rock Creek sands in northwestern Alberta and northeastern British Columbia. However,re-examination of these sands has led to the conclusion that they can easily be placed in the Upper Fernie shale/sandstone package (Poulton et al., 1990). Poulton (1984) noted that no Middle Jurassic fossils have been documented north of 54°N latitude (Twp. 58). However, Aalenian sediments have been found in three wells sampled in this study (wells 14-8-56-19W5M, 4-32-69-19W5M and 15-34-77-1W5M). Based on lithologies and correlations, these sediments (predominantly shales) have been designated as Poker Chip Shale Members.

## UPPER FERNIE SHALE/SANDSTONE UNIT

The upper parts of the Fernie Formation are described in the Lexicon (1990) as "glauconitic sands, concretionary bands and brown weathering siltstones and sandstones". They include the Green Beds ("dark to bright green glauconitic sandstone or siltstone with calcareous concretions weathering yellowish-brown"). Upper Fernie shales in northwestern Alberta are not described in the Lexicon, but in the south they are included in the poorly defined Ribbon Creek Member as dark grey, silty or clayey shales. The Passage Beds in the south are described as dark grey shales with yellow-brown weathering concretions.

In the south end of the study area, the cored sands in the Upper Fernie package were dated as Late Callovian to Early Oxfordian, and are therefore probably Green Beds equivalents (see well 6-27-60-19W5M; Appendix 1 and 2). They are represented by thin (up to 5 meters thick), highly to moderately glauconitic and often argillaceous sandstones. Small-scale, low angle ripple cross bedding was observed in these sands. Shale interbeds are dark grey, greenish-grey and black, and are also often highly glauconitic. Siderite stringers are common, as are arenaceous and/or argillaceous siltstone stringers. These sands are equivalent to the "Niton B" sands of north central Alberta, which are prolific hydrocarbon producers (Losert, 1990).

Northward, from Twps. 60 to 74, basal Green Beds equivalents persist, but are much thinner and less discernable on logs. The top of this argillaceous sand unit is marked by a deflection on the gamma ray log which reflects a highly glauconitic black shale and siderite interval with minor sideritic quartz sand, and probably represents the maximum transgressive episode in Green Beds deposition (Poulton et al, 1990). Interbedded shales are grey, and green or brown with a greyish cast, and are variably glauconitic, arenaceous and silty.

North of Twp. 74, very well-developed, thick (10 to 50 meters) quartz sands appear at the same interval. Lackie (1958) named them Rock Creek, but the glauconitic and sideritic nature of these sands, which often have thin bands of black, glauconitic shales, argues for their affinity to the Green Beds equivalents further south.

Deposition of interbedded sand, shale and siltstone continued into at least Late Kimmeridgian times (as in well 6-35-64-21W5M). The shales grade from grey to green, and are silty and arenaceous. The grey, quartzose sands are occasionally glauconitic and cemented with clay. Siltstones are most often very arenaceous and/or argillaceous. The thickness of the Upper Fernie package ranges from 10 to 75 meters.

## Summary of Jurassic Unit Relationships

In the study area, the Lower Fernie shelf facies is probably Pliensbachian in age (Poulton et al, 1990). Being perhaps younger than the Sinemurian(?) carbonate bank in central Alberta, it may have been deposited on the stable shelf while an erosional event occurred over the carbonate bank. While the contact of the carbonate bank with the overlying Poker Chip Shale is therefore erosional in central Alberta, the contact between the Pliensbachian(?) shelf marls and the Toarcian to Aalenian Poker Chip Shales of northwestern Alberta is less clear. It may well be conformable, but for purposes of consistency with outcrop data to the west (Poulton et al, 1990), and because there is no evidence to the contrary, the contact is shown in this report as an unconformity.

A probable unconformity exists between the Toarcian/Aalenian Poker Chip Shales and the youngest (Late Callovian or Early Oxfordian) beds of the Upper Fernie shale/sandstone unit. Whether this is a period of non-deposition or erosion is debatable, but Poulton (1984) and Davies and Poulton (1986) suggested that uplift in northwestern Alberta and northeastern British Columbia may have taken place prior to Upper Jurassic sedimentation. Erosion is further indicated by substantial thickness variations and local absence (well 10-9-74-20W5M) of the underlying Poker Chip Shale. Whether erosional or non-depositional, the contact on geophysical logs is expressed subtly, and without sufficient core control, the uncertainty of the exact contact position is indicated on the sections and lithologic descriptions by a dashed unconformity line.

The varying and relative thickness of the basal Green Beds sand north of Twp. 74 may well be related to the movement of fault blocks over the Peace River Arch. It is possible that local Arch related tectonism occurred with the onset of the Columbian orogeny to the west and the associated development of the Alberta Trough foredeep east of it. The collapse or downwarping phase of the Arch took place in the Late Paleozoic. Cant (1988) found evidence of further collapse in Lower Cretaceous sediments, demonstrated principally by positive thickness anomalies. The possibility cannot be ruled out that similar developments may have occurred in the early Late Jurassic while orogenic activity was initiated westward, and while the Green Beds (interpreted to be a transgressive basal sand unit- Poulton, 1984) were being deposited in the newly developing foredeep.

Uninterrupted deposition of shales, siltstones, and minor sandstones continued from the Late Callovian into at least Late Kimmeridgian times in the east part of the study area, and in the west part, may have carried on into the Early Cretaceous as thick Nikanassin sands and shales accumulated in the rapidly subsiding foreland basin.

## Lower Cretaceous Erosional Influence on Jurassic Sediment Distribution

The present day distribution of Jurassic strata in the subsurface was influenced considerably by Lower Cretaceous erosional events. The basic information regarding the geologic setting of the Lower Cretaceous in this report is distilled from comprehensive studies by Jackson; Smith, Zorn and Sneider; and Gies (1984 - see references).

The sub-Cretaceous unconformity represents an erosional event developed during Hauterivian (Early Cretaceous) time. It was the result of a brief cessation of Cordilleran orogenic activity in the west which reduced sediment supply and minimized tectonic movements in the Alberta basin (Smith et al, 1984). Consequently, pre-Cretaceous strata were truncated to produce a subcrop of Jurassic sediments in the west, Devonian carbonates roughly east of the Fifth Meridian (the 'Axial High' ancient highland marked 'Y' in Figure 3 was mainly composed of these sediments), and a thin subcrop of Mississippian shales and carbonates in between the two.

A strong re-initiation of Cordilleran uplift in Barremian time resulted in the deposition of eastward prograding Cadomin alluvial fan conglomerates. These, in turn, contributed coarse clastic sediment to a developing northwest/southeast trending fluvial braid plain (Spirit River Channel) along the west edge of the basin. The eastern edge of these re-worked Cadomin fluvial sediments is marked by the Fox Creek Escarpment. This was the western edge of a broad positive feature which divided, and in part, supplied sediment to the developing Spirit River Channel system in western Alberta and the Edmonton Channel system of central Alberta. The Spirit River Channel system became a broad valley incised into Jurassic sands and shales (Jackson, 1984).

Figure 3 is a lithofacies map showing the major Lower Mannville fluvial systems and highland areas. Most of the highlands (depicted on the map as white or hatched areas) were exposed Upper Jurassic and uppermost Poker Chip Shale sediments in southern, central and western Alberta, and were underlain by lowermost Poker Chip Shales and the Nordegg Member. The hatched areas were extreme relief features, probably consisting of relatively thick Upper and Middle Jurassic, and thin Poker Chip Shales. These would seem to have been the last areas that were inundated during maximum flooding of the southeasterly transgressing Boreal Sea in Late Gething times, and are therefore overlain by relatively thin accumulations of Lower Mannville sediments. Locally, these high areas are unconformably overlain by post-Aptian deposits, thus indicating a period of exposure extending through Lower Mannville and early Middle Mannville deposition.

The Alberta Trough or Basin east of the Cordilleran uplift continued to subside during Aptian time, resulting in further accumulation of fluvial, and eventually, of delta plain sediments of the Upper Gething formation in northern Alberta. Rivers flowed eastward from the Cordilleran uplands into the Spirit River braid plain, then were re-distributed northward along this trunk river system to the Boreal Sea. Smith et al (1984) note that fluvial Gething sandstones of the Spirit River Channel are mainly restricted to the Lower Gething, and Jackson

(1984) adds that they were deposited eastward to the position of the Fox Creek Escarpment over the Cadomin Formation. In Late Gething time, the Fox Creek Escarpment and highlands were buried due to a significant change in drainage patterns which expanded river drainage flow eastward over the ancient highland. The highland thus became a low-lying, swampy drainage basin, with river flow meandering randomly across this plain from west to east (Smith et al, 1984). Jackson (1984) submits that this area subsequently became a marine basin with the transgression of the Boreal Sea. However, he states that the outline of marine areas is quite speculative because "marine upper Gething or Ostracod equivalents cannot be distinguished from younger marine Bluesky or Wabiskaw Formations". As mentioned previously, some areas of the 'extreme relief' highlands (X, Y and Z - Fig. 3) were still subaerially exposed.

The study area of this report demonstrates some of these paleogeographic features; the Fox Creek Escarpment and highlands, the Spirit River Channel, the Peace River Channel, and the eastern approach to the western Cordilleran uplands (see Figure 3 for locations of these features with superimposed stratigraphic cross section locations).

Section A - A' (Figure 4) cuts diagonally (southwest to northeast) across the highlands of Barremian time, from the western Fox Creek Escarpment edge to the northern edge of the highlands and into the Peace River Channel.

It is interesting to note that the 'Pembina High' (indicated by an 'X' on Figure 3) roughly coincides with the position of the Sinemurian(?) carbonate bank of Poulton et al (1990). It reflects an area of thin to non-deposition of Lower Cretaceous strata, but also represents a relatively thick accumulation of Middle and Upper Jurassic sands discussed by Losert (1986, 1990), Marion (1984) and Rosenthal (1988) among others (see also well 10-14-54-13W5M: Figure 4). Hypothetically, the carbonate bank may have acted as a structural repository for shoaling Jurassic sands which were relatively resistant to erosion (compared to 'Fernie Shales') during the Early Cretaceous. Subsequent burial by Gething/ Ellerslie continental deposits completed a scenario for hydrocarbon accumulation including: structural relief, proximity to source beds, stratigraphic/structural trapping mechanisms, and unconformities which may have acted as conduits for the migration of oil and/or gas.

Moving northward from the Pembina High on the same section (Figure 4), the apparent erosional truncation of the Poker Chip Shale between wells 4-32-69-19W5M and 10-9-74-20W5M argues for an erosional event pre-dating Upper Fernie deposition. Section D - D' (Figure 8) shows a similar relationship. Figure 4 also indicates that the northern edge of the ancient highlands sloped gently into the Peace River Channel.

Section B - B' (Fig. 5), on the other hand, demonstrates relief of up to 25 meters (80 ft.) as you come off the Fox Creek Escarpment (well 11-12-69-22W5M) into the Spirit River Channel (well 7-33-73-1W6M), and then back onto the escarpment (well 15-34-77-1W6M). As suggested by Smith et al. (1984), relatively thin (less than 60 m.) Upper Gething sediments overlie a relatively thickly preserved Jurassic sequence over the highlands area. This study shows that this Jurassic sequence consists of Upper Fernie shales and sandstones, and in some cases, uppermost Poker Chip Shales. Vertically thick Gething deposits, on the other hand, infill areas where the Jurassic is thinly preserved (lowermost Poker Chip Shale and Lower Fernie shelf facies only - see Figs. 4 and 5).

Section C - C' (Fig. 6) shows Cadomin alluvial fan and braid deposits overlying, in the south end, a wedge of basal Nikanassin marine sands and shales probably derived from the craton (Stott, 1984). They are Late Jurassic sediments infilling the rapidly subsiding Alberta foreland basin which were subsequently truncated by pre-Cadomin (Hauterivian) erosion. This bevelling, as indicated in Section C - C', removed successively older Jurassic units northward, and in the northern highland area (Figure 3 - white), Lower Fernie marlstones were probably exposed to erosion. It is interesting to note that the relatively thick sands of the basal Upper Fernie unit (Green Beds) in this section coincide with the location of the Peace River Arch (Cant, 1988) between Twps. 75 and 85 near the B.C. border.

The east-west cross sections (Figs. 7 and 8) both demonstrate the thick Upper Jurassic section in the west resulting from rapid subsidence and infilling of the foreland basin. The resulting wedge tapers eastward due to depositional thinning, and later, to truncation of successively older units by sub-Cretaceous (Hauterivian) erosion.

Section A - A'' (Fig. 7) shows the expression of the ancient northern highlands (well 10-1-82-6W6M), where Mannville strata are relatively thin. Mannville deposits increase vertically as you move into the Peace River Channel to the east and the Spirit River Channel to the west. Once again, thick quartzose sands at the base of the Upper Fernie are coincident with the location of the Peace River Arch.

Section D - D' (Figure 8) illustrates the abutment of Cadomin sands against the Fox Creek Escarpment (well 10-9-74-20W5M), the thick accumulation of Upper Jurassic sediments in the foreland basin, and eastward tapering due to depositional thinning and Hauterivian truncation.

## Conclusions

This report is an attempt to characterize Jurassic sediments which, for the most part, have been considered non-descript 'Fernie shales' situated between more economically interesting Cretaceous and Triassic or Paleozoic deposits.

As can be seen, the Jurassic sequences in northwestern Alberta are unique in their own right, and not simple northward extensions of their 'counterparts' further south.

That they represent a fundamental tectonic change from a passive epicratonic margin to an orogenic belt and foredeep make them worth study on an academic level. From an economic standpoint, Jurassic reservoirs in Alberta, Saskatchewan and Manitoba "are hosts for about 4 per cent of western Canada's total initial reserves of oil, and 1.4 per cent of its marketable natural gas" (Poulton, 1989). In addition, they served as watersheds which supplied sediments to major Lower Mannville fluvial deposits. As mentioned earlier, they also made significant hydrocarbon contributions to Paleozoic and Lower Cretaceous oil and gas reservoirs.

This report, then, contains previously unavailable data which contributes to a better understanding of Jurassic strata. Some of the ideas put forth here are speculative, but highlight the need for further study.

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## FIGURES:

Fig. 1 - Location of study area and index map of subsurface sections.

Fig. 2 - Correlation chart

Fig. 3 - Lower Mannville fluvial systems

Fig. 4 - North-south stratigraphic section A-A'

Fig. 5 - North-south stratigraphic section B-B'

Fig. 6 - North-south stratigraphic section C-C'

Fig. 7 - East-west stratigraphic section A-A''

Fig. 8 - East-west stratigraphic section D-D'

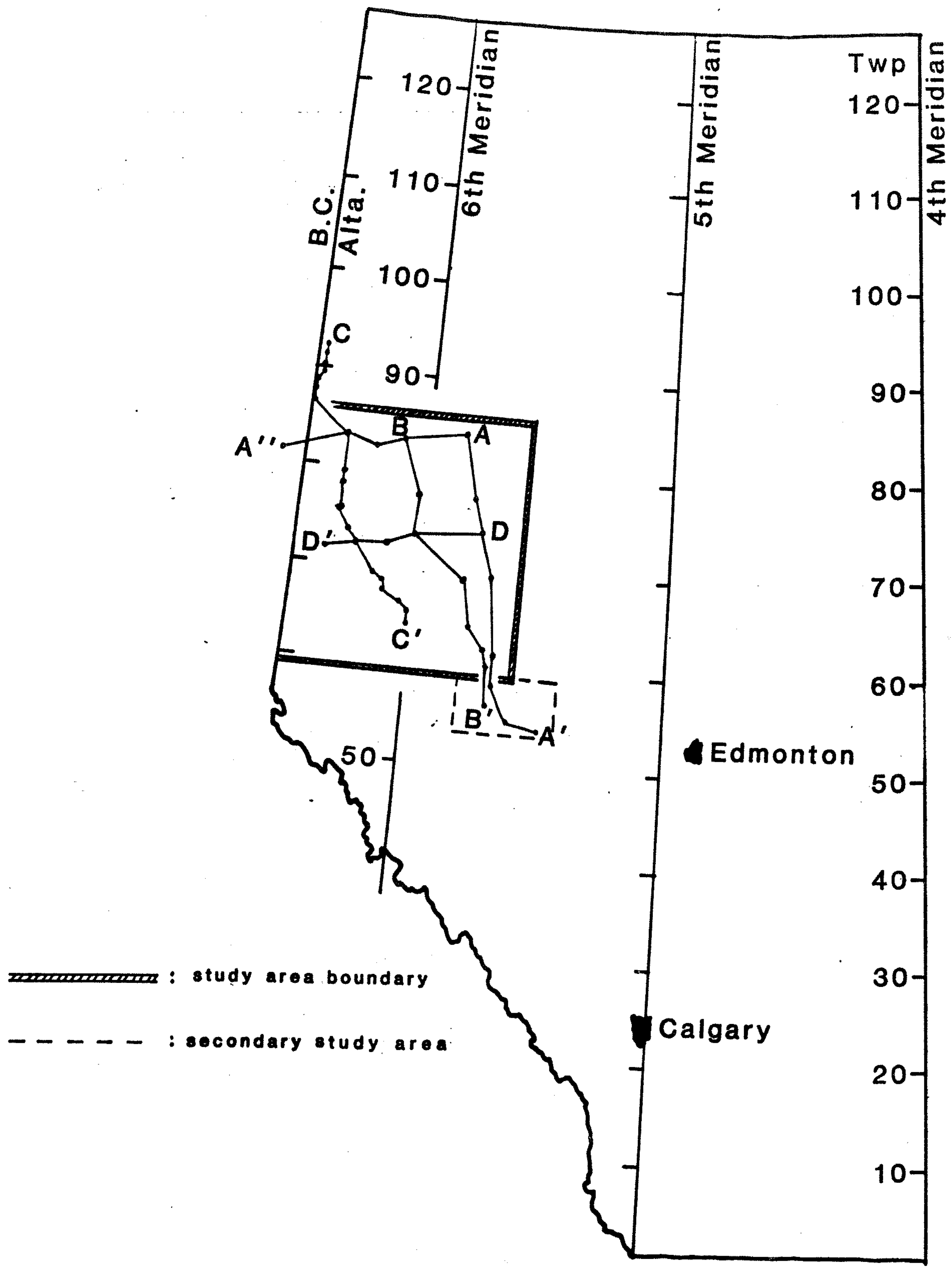



Figure 1 : study area and cross section index map

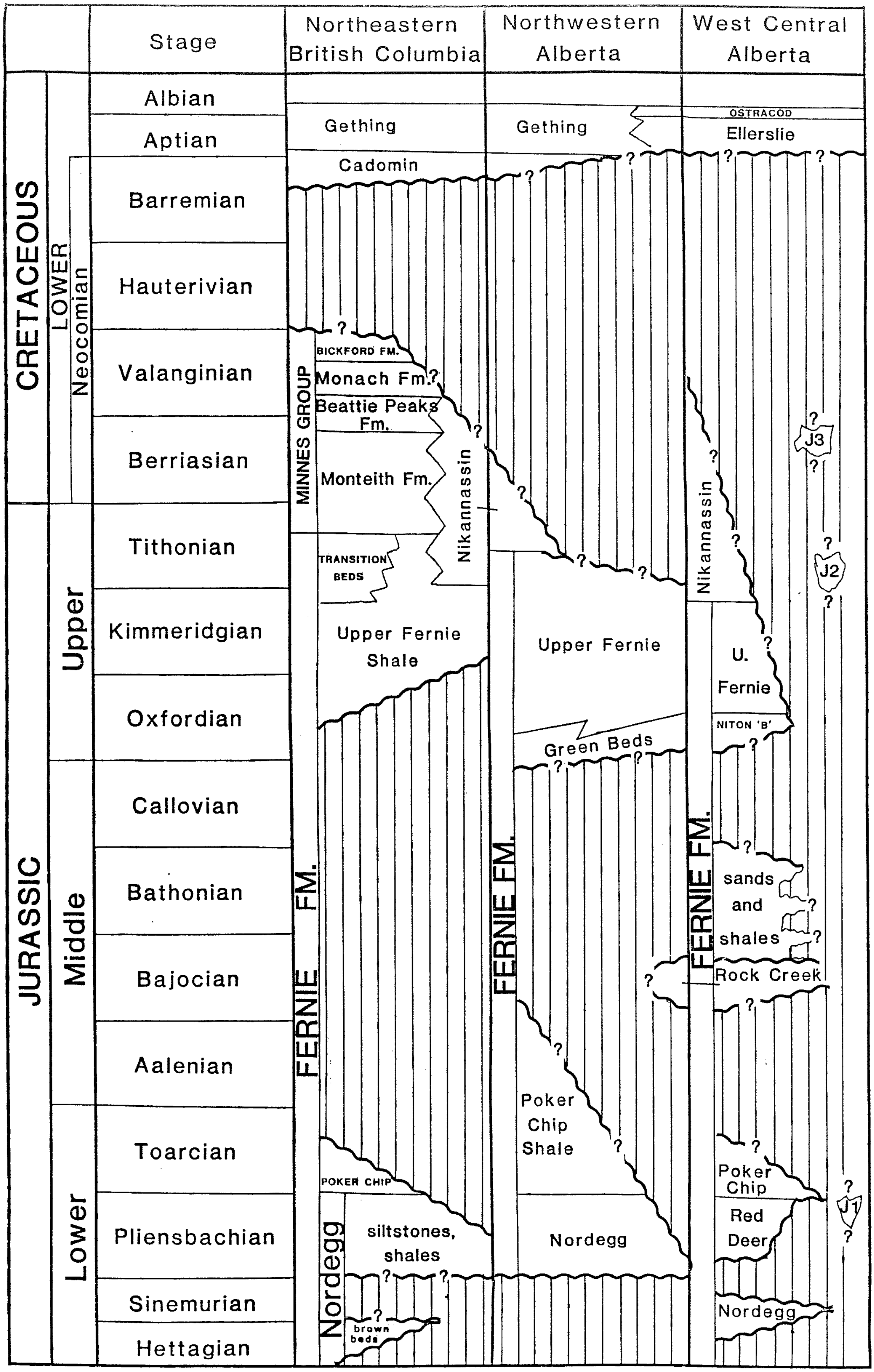



Figure 2 : Correlation chart

FIGURE #3: Lower Mannville Fluvial Systems

**1** - Spirit River Channel

**2** - Peace River Channel

**3** - Edmonton/Bellshill Lake Channel

**F** - Fox Creek Escarpment/highlands

**V** - Cadomin alluvial fans

**X** - Pembina High

**Y** - Axial High

**Z** - Southern highlands

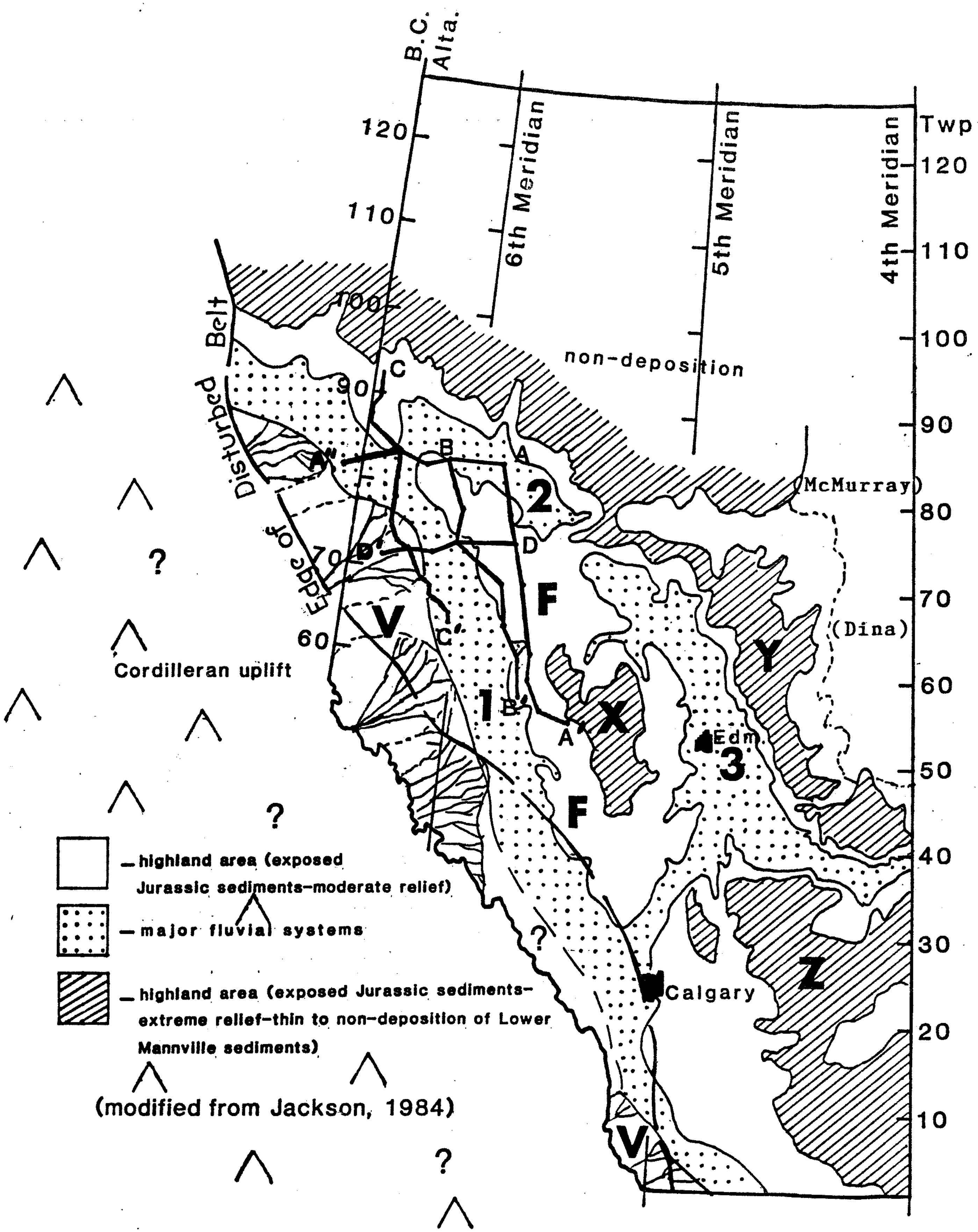



Figure 3 : Lower Mannville Fluvial Systems

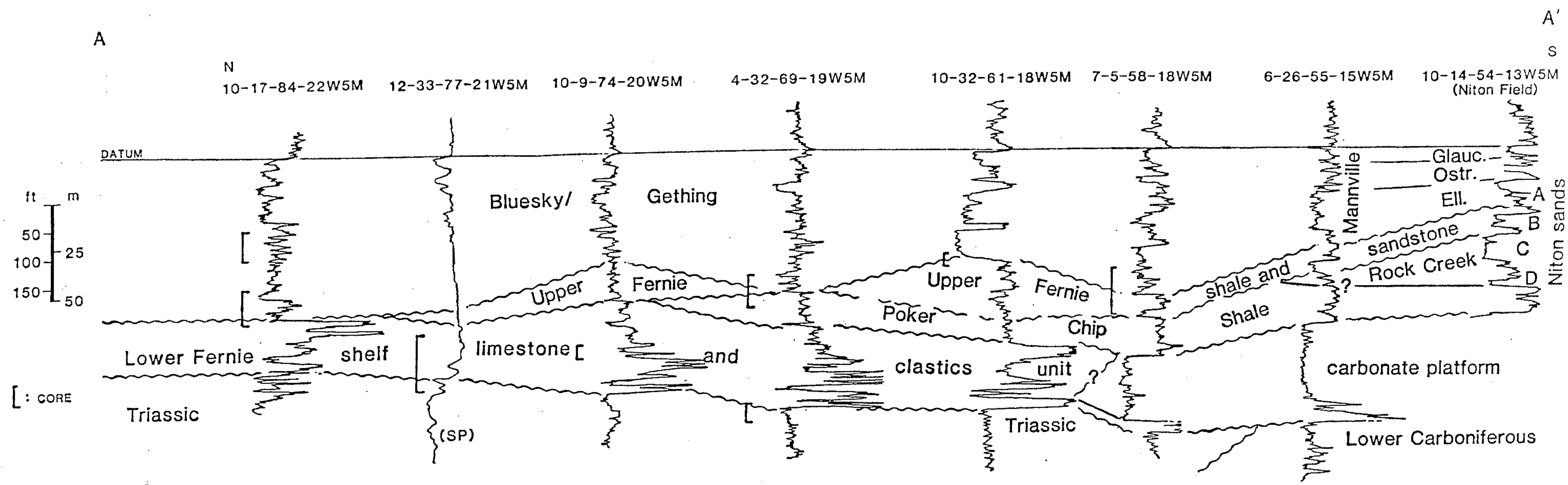



Figure 4 : Stratigraphic section A–A'

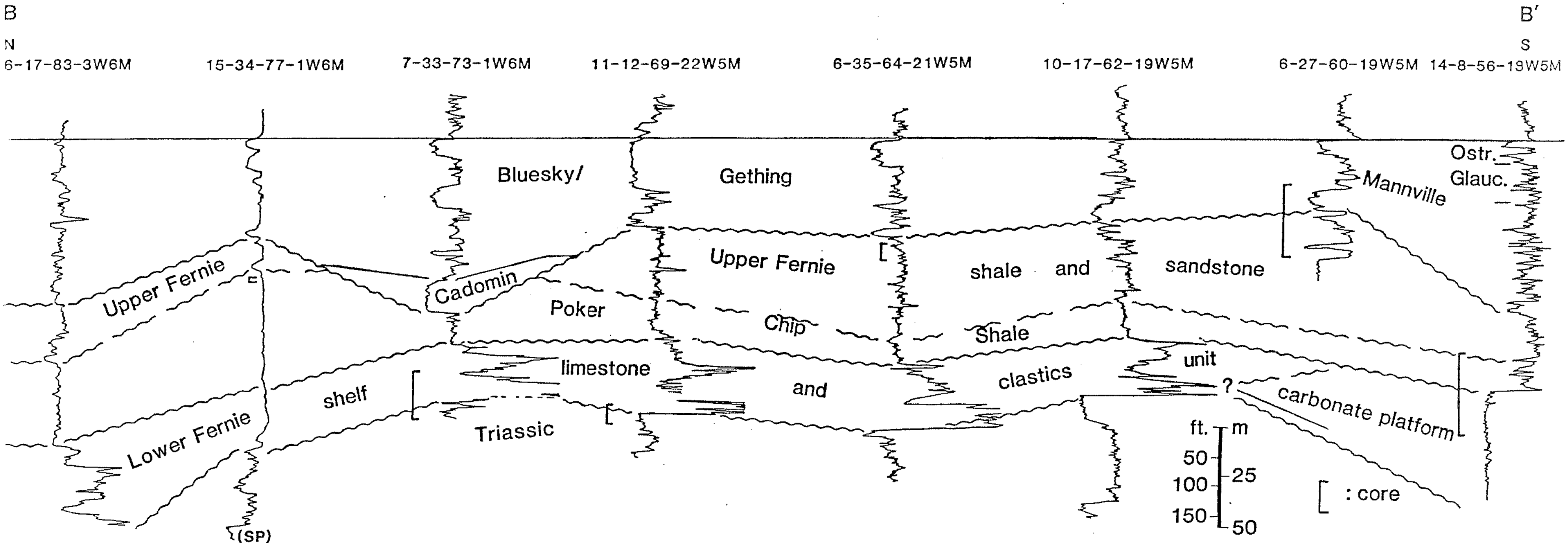



Figure 5 : Stratigraphic section B–B′

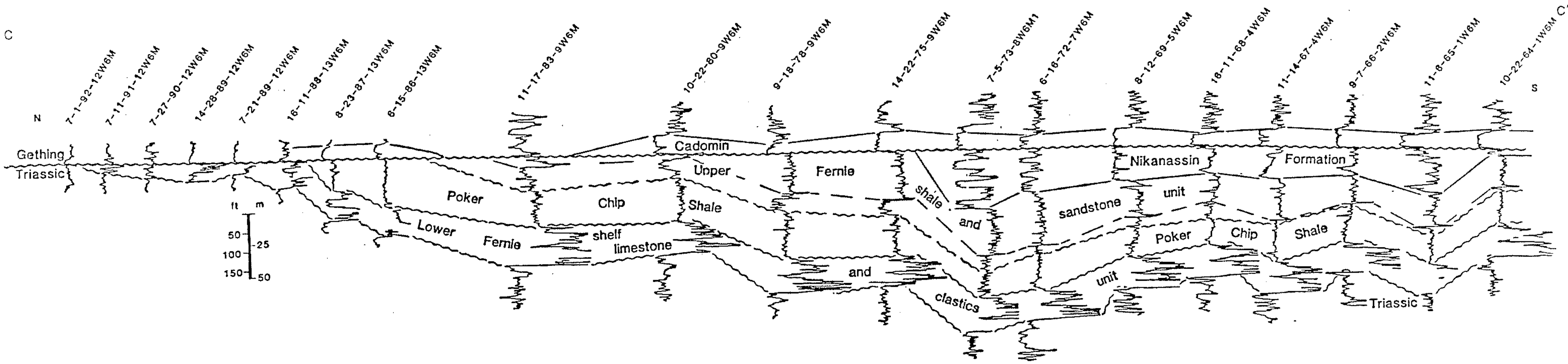



Figure 6 : Stratigraphic section C–C'

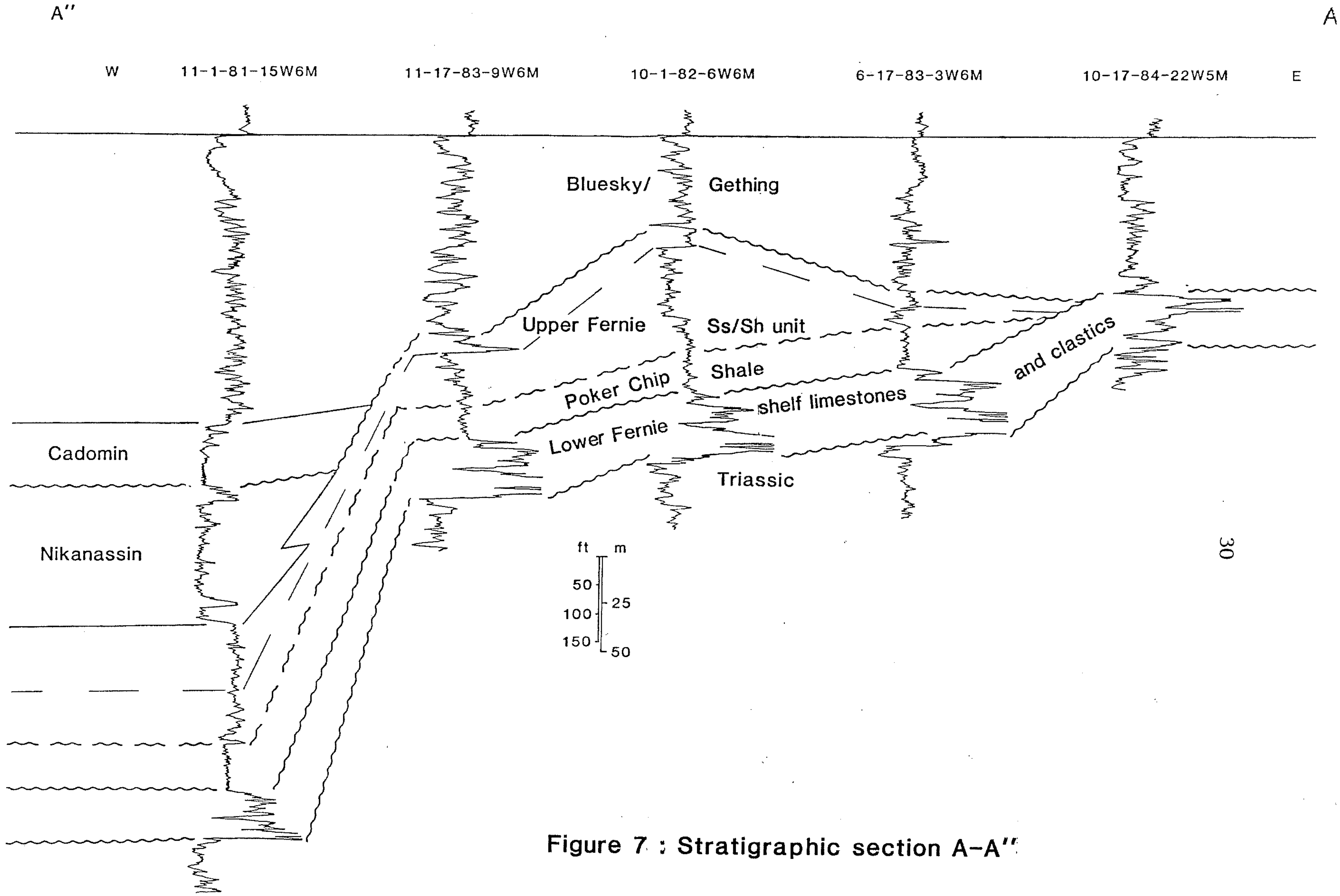



Figure 7 : Stratigraphic section A-A''

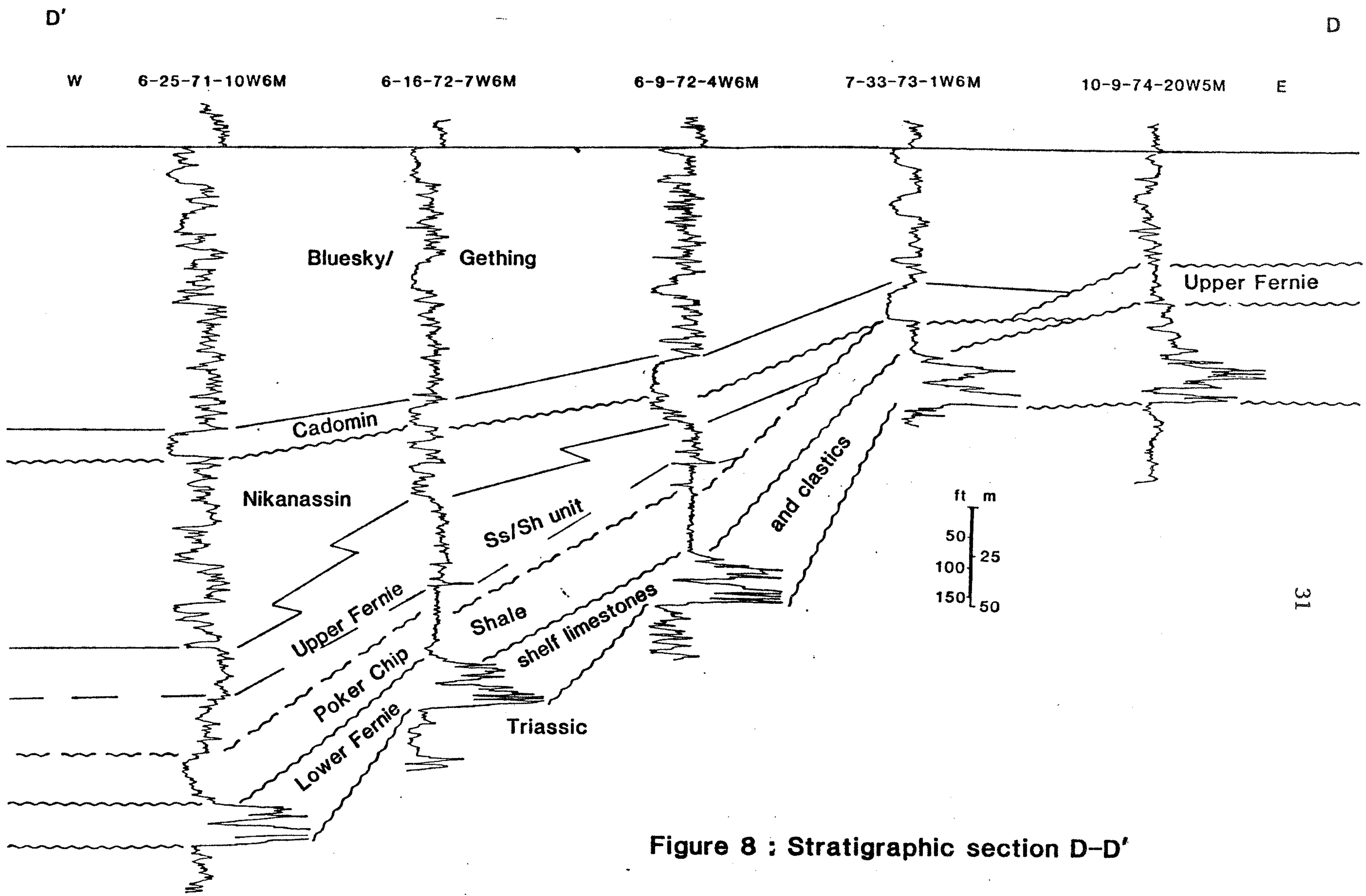



**Figure 8 : Stratigraphic section D–D'**

## APPENDIX 1: CORES AND PALYNOLOGICAL SAMPLES EXAMINED

## APPENDIX 1: CORES AND PALYNOLOGICAL SAMPLES EXAMINED

Location: 14-6-56-13 W5M
Interval: 1906.5 - 1920.1 m.
cut: 13.6 ; rec. 13.6 m.
Formation: Green Beds
sample 1: GSC loc. no. C-171160
depth: 1907.5 m.
age: Middle Oxfordian
2: GSC loc. no. C-171161
depth: 1910.9 m.
age: Middle Oxfordian
3: GSC loc no. C-171162
depth: 1916.3 m.
age: Middle Oxfordian

Location: 14-8-56-19 W5M
Interval: Core #1: 2829.2 - 2847.0 m.
cut: 17.8; rec. 17.8 m.
#2: 2847.6 - 2865.6 m.
cut: 18.0; rec. 4.0 m.
#3: 2865.8 - 2866.6 m.
cut: 0.8; rec. 0.7 m.
#4: 2866.6 - 2872.4 m.
cut: 5.8; rec. 3.8 m.
Formation: Poker Chip Shale to Nordegg
Sample 1: GSC loc. no. C-171166
depth: 2829.2 m.
age: Jurassic undifferentiated
2: GSC loc. no. C-171167
depth: 2830.8 m.
age: Jurassic undifferentiated
3: GSC loc. no. C-171168
depth: 2831.8 m.
age: Jurassic undifferentiated
4: GSC loc. no. C-171169
depth: 2834.8 m.
age: Aalenian to Toarcian
Sample 5: GSC loc. no C-171170
depth: 2836.3 m.
age: Aalenian to Toarcian
6: GSC loc. no. C-171171
depth: 2839.1 m.
age: Aalenian to Toarcian
7: GSC loc. no. C-171172
depth: 2841.3 m.
age: Aalenian to Toarcian
8: GSC loc. no. C-171173
depth: 2843.8 m.
age: Aalenian to Toarcian
9: GSC loc. no. C-171174
depth: 2846.8 m.
age: Aalenian to Toarcian
10: GSC loc. no. C-171175
depth: 2847.8 m.
age: Indeterminable

Location: 12-26-57-15 W5M
Interval: 2351.5 - 2362.7 m.
cut: 11.6; rec. 11.2 m.
Formation: Ellerslie (Cretaceous)
Sample 1: GSC loc. no. C-171164
depth: 2354.35 m.
age: Cretaceous
2: GSC loc. no. C-171165
depth: 2359.25 m.
age: Cretaceous

Location: 10-12-57-19 W5M
Interval: Core #3: 2780.0 - 2787.0 m.
cut: 7.0; rec. 7.0 m.
#4: 2787.0 - 2788.2 m.
cut: 1.2; rec. 1.2 m.
Formation: Poker Chip (Red Deer?) to Nordegg
Sample 1: GSC loc. no. C-171177
depth: 2780.0 m.
age: Early Toarcian to Late Pliensbachian
2: GSC loc. no. C-171178
depth: 2781.0 m.
age: Early Toarcian to Late Pliensbachian

Location: 7-5-58-18 W5M
Interval: Core #1: 2399.0 - 2417.0 m.
cut: 18.0; rec. 17.4 m.
#2: 2417.0 - 2435.0 m.
cut: 18.0; rec. 6.0 m.
Formation: Cretaceous to Green Beds
Sample 1: GSC loc. no C-171181
depth: 2406.0 m.
age: Early Oxfordian to Latest Callovian
2: GSC loc. no. C-171184
depth: 2414.5 m.
age: as above
3: GSC loc. no. C-171185
depth: 2416.0 m.
age: as above
4: GSC loc. no. C-171186
depth: 2417.0 m.
age: as above
5: GSC loc. no. C-171187
depth: 2419.0 m.
age: as above
Sample 6: GSC loc. no. C-171188
depth: 2421.0 m.
age: Early Oxfordian to Latest Callovian
7: GSC loc. no. C-171189
depth: 2421.4 m.
age: as above

Location: 6-27-60-19 W5M
Interval: Core #2: 2204.0 - 2222.25 m.
cut: 18.25; rec. 18.25
#3: 2222.5 - 2240.5 m.
cut: 18.0; rec. 18.0 m.
Formation: Gething to Upper Fernie/Green Beds
Sample 1: GSC loc. no. C-171190
depth: 2204.9 m.
age: Indeterminable
2: GSC loc. no. C-171192
depth: 2217.35 m.
age: Jurassic undifferentiated
3: GSC loc. no. C-171193
depth: 2219.0 m.
age: as above
4: GSC loc. no. C-171195
depth: 2224.25 m.
age: as above
5: GSC loc. no. C-171196
depth: 2225.25 m.
age: as above
6: GSC loc. no. C-171197
depth: 2226.5 m.
age: as above
7: GSC loc. no. C-171198
depth: 2229.5 m.
age: Early Oxfordian to Latest Callovian

Sample 8: GSC loc. no. C-171199
depth: 2232.0 m.
age: Early Oxfordian to Latest Oxfordian
9: GSC loc. no. C-171200
depth: 2232.5 m.
age: as above
10: GSC loc. no. C-187101
depth: 2235.75 m.
age: as above
11: GSC loc. no. C-187102
depth: 2237.0 m.
age: as above
12: GSC loc. no. C-187103
depth: 2238.0 m.
age: as above
13: GSC loc. no. C-187104
depth: 2240.0 m.
age: as above

Location: 10-32-61-18 W5M
Interval: 6515 - 6540 ft.
cut: 25'; rec. 25'
Formation: Gething to Green Beds
Sample 1: GSC loc. no. C-187105
depth: 6527.5'
age: Early Oxfordian to Latest Callovian
2: GSC loc. no. C-187106
depth: 6532'
age: as above
3: GSC loc. no. C-187107
depth: 6535'
age: as above
4: GSC loc. no. C-187108
depth: 6536'
age: as above
Sample 5: GSC loc. no. C-187109
depth: 6537'
age: as above

Location: 6-35-64-21 W5M
Interval: Core #2: 5914 - 5941 ft.
cut: 27'; rec. 27'
#3: 6200 - 6261 ft.
cut: 61'; rec. 61'
Formation: Upper Fernie to Upper Fernie Nordegg to Triassic
Sample 1: GSC loc. no. C-187110
depth: 5914'
age: Late Kimmeridgian
2: GSC loc. no. C-187111
depth: 5922'
age: as above
3: GSC loc. no. C-187112
depth: 5928'
age: as above
4: GSC loc. no. C-187113
depth: 5934'
age: as above
5: GSC loc. no. C-187114
depth: 5940'
age: as above
6: GSC loc. no. C-187116
depth: 6202'
age: Indeterminable
7: GSC loc. no. C-187119
depth: 6220'
age: as above
8: GSC loc. no. C-187121
depth: 6224'
age: as above

Location: 4-32-69-19 W5M
Interval: Core #1: 4509 - 4567 ft.
cut: 58'; rec. 55'
#2: 4734 - 4769 ft.
cut: 35'; rec. 35'
Formation: Gething to Poker Chip Shale
Nordegg to Triassic
Sample 1: GSC loc. no. C-187122
depth: 4512'
age: Cretaceous
2: GSC loc. no. C-187123
depth: 4531'
age: as above
3: GSC loc. no. C-187124
depth: 4545'
age: Aalenian to Toarcian
4: GSC loc. no. C-187125
depth: 4552'
age: as above
5: GSC loc. no. C-187126
depth: 4559'
age: as above
6: GSC loc. no. C-187127
depth: 4564'
age: as above
7: GSC loc. no. C-187128
depth: 4734'
age: Indeterminable
8: GSC loc. no. 187129
depth: 4736'
age: as above
9: GSC loc. no. C-187130
depth: 4738'
age: as above
Sample 10: GSC loc. no. C-187131
depth: 4740'
age: Indeterminable

Location: 11-12-69-22 W5M
Interval: 1498.0 - 1508.0 m.
cut: 10; rec. 9.5 m.
Formation: Nordegg to Triassic
Sample 1: GSC loc. no. C-187132
depth: 1498.0 m.
age: Indeterminable
2: GSC loc. no. C-187133
depth: 1499.5m
age: as above
3: GSC loc. no. C-187135
depth: 1502.75 m.
age: as above

Location: 7-33-73-1 W6M
Interval: 4693 - 4753 ft.
cut: 60'; rec. 60'
Formation: Nordegg to Triassic
Sample 1: GSC loc. no. C-187149
depth: 4693'
age: Indeterminable
2: GSC loc. no. C-187150
depth: 4698'
age: as above

Location: 10-9-74-20 W5M
Interval: 3510 - 3533 ft.
cut: 23'; rec. 23'
Formation: Nordegg
Sample 1: GSC loc. no. C-187136
depth: 3510'
age: Indeterminable

Sample 2: GSC loc. no. C-187137
depth: 3519'
age: Indeterminable
3: GSC loc. no. C-187138
depth: 3523'
age: as above
4: GSC loc. no. C-187139
depth: 3528'
age: as above
5: GSC loc. no. C-187140
depth: 3532'
age: as above

Location: 12-33-77-21 W5M
Interval: 2964 - 3042 ft.
cut: 78'; rec. 51'
Formation: Nordegg to Triassic
Sample 1: GSC loc. no. C-187141
depth: 2965'
age: Indeterminable
2: GSC loc. no. C-187143
depth: 2975'
age: as above
3: GSC loc. no. C-187146
depth: 3008'
age: as above

Location: 15-34-77-1 W6M
Interval: 3370 - 3377 ft.
cut: 7'; rec. 7'
Formation: Poker Chip Shale
Sample 1: GSC loc. no. C-187151
depth: 3370'
age: Aalenian

Sample 2: GSC loc. no. C-187152
depth: 3375'
age: as above
3: GSC loc. no. C-187153
depth: 3376'
age: as above

Location: 10-17-84-22 W5M
Interval: Core #2: 2206 - 2256 ft.
cut: 50'; rec. 50'
#3: 2305 - 2362 ft.
cut: 57'; rec. 48'
Formation: Gething
Gething to Nordegg
Sample 1: GSC loc. no. C-187154
depth: 2207.5 '
age: Cretaceous
2: GSC loc. no. C-187155
depth: 2218'
age: as above
3: GSC loc. no. C-187156
depth: 2226'
age: as above
4: GSC loc. no. C-187158
depth: 2241'
age: as above
5: GSC loc. no. C-187159
depth: 2253'
age: as above
6: GSC loc. no. C-187160
depth: 2256'
age: as above
7: GSC loc. no. C-187161
depth: 2314'
age: as above

Sample 8: GSC loc. no. C-187162
depth: 2319'
age: Cretaceous

9: GSC loc. no. C-187163
depth: 2322'
age: as above

10: GSC loc. no. C-187164
depth: 2326'
age: as above

11: GSC loc. no. C-187165
depth: 2333'
age: as above

12: GSC loc. no. C-187166
depth: 2340.5'
age: as above

13: GSC loc. no. C-187167
depth: 2343'
age: Indeterminable

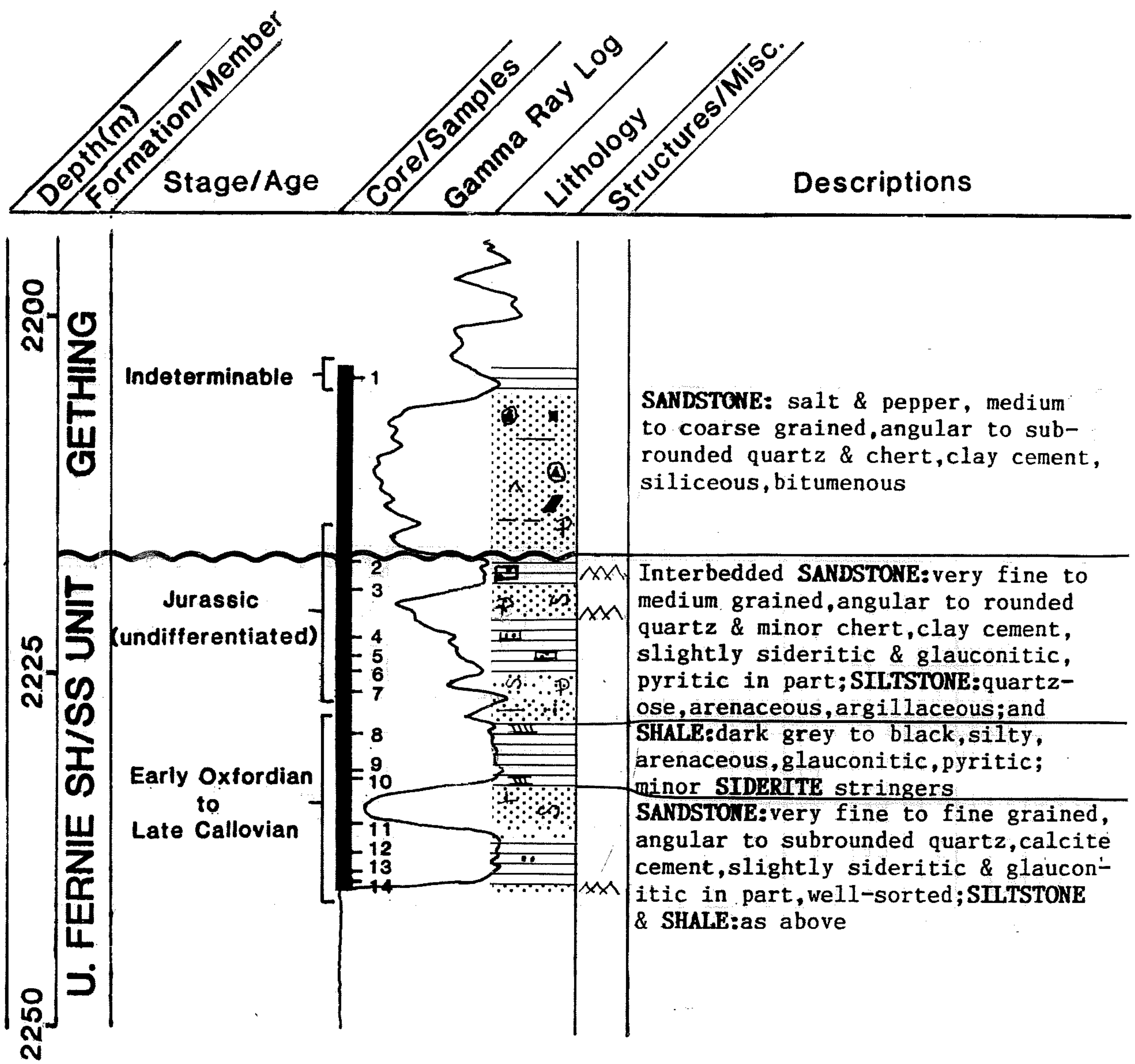
14: GSC loc. no. C-187168
depth: 2345'
age: as above

15: GSC loc. no. C-187169
depth: 2352'
age: as above

# APPENDIX #2: DETAILED LITHOLOGIC DESCRIPTIONS

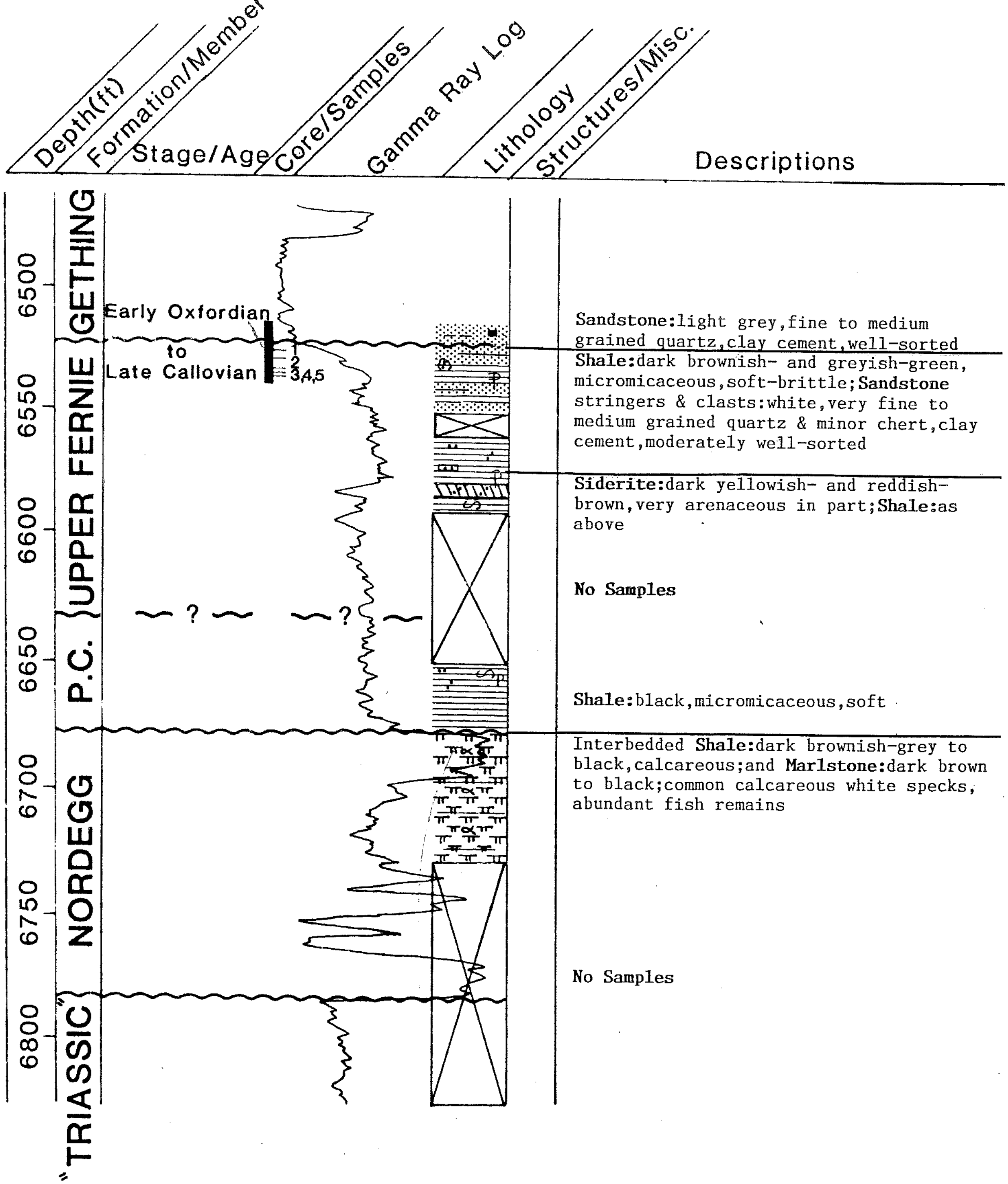
# LEGEND

- Sandstone
- Shale
- Siltstone
- Limestone
- Marlstone
- Bedded Chert (light,dark)
- Clay (stone)
- Siderite (bedded,itic)
- Argillaceous
- Silty/stringers
- Arenaceous/stringers
- Chert grains/pebbles
- Pyritic
- Calcareous
- Ripple cross-bedding
- Bioturbated
- Deformed bedding planes
- Clast
- Bentonite
- Ammonite
- No sample
- Plant remains
- Coal/carbonaceous
- Glauconitic
- Siliceous
- Bitumenous
- Fish remains

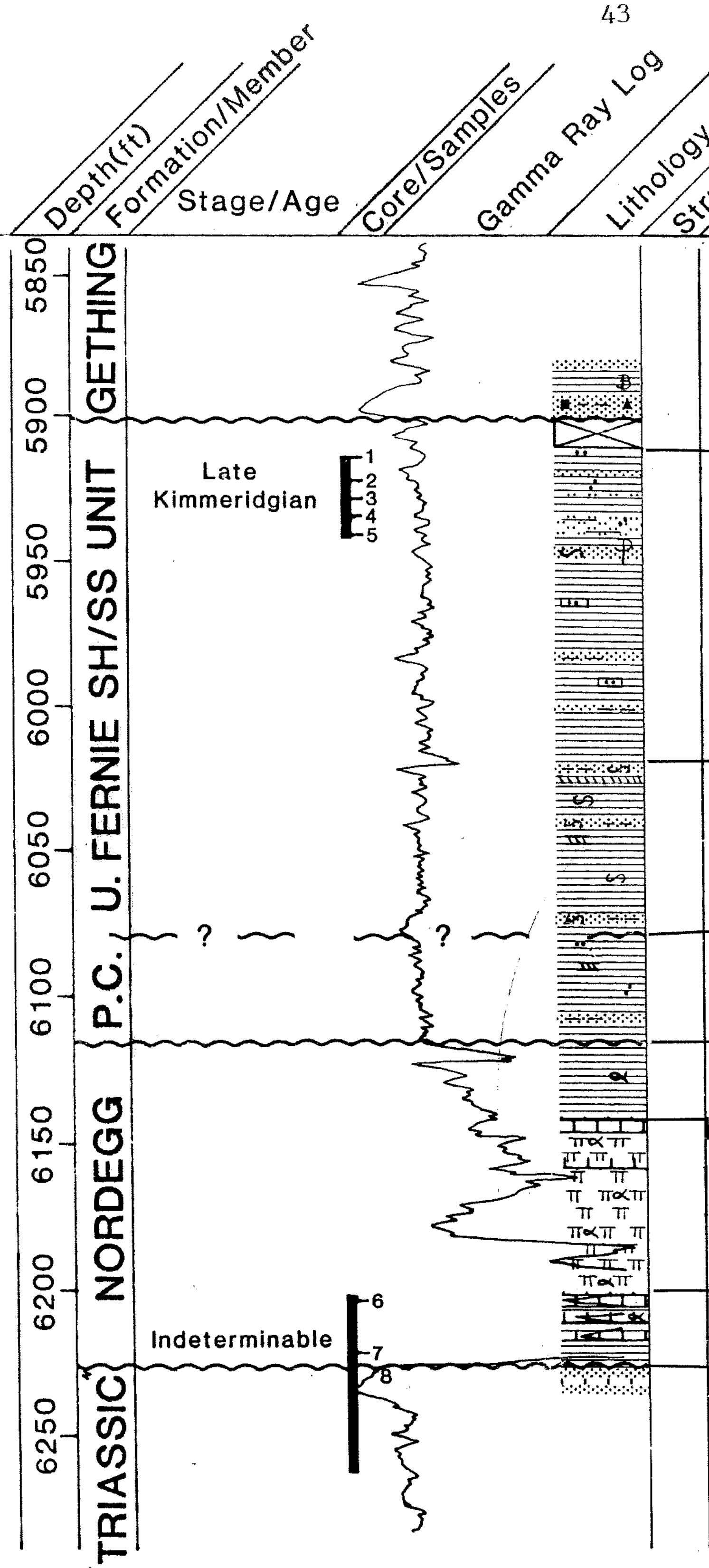


Depth(m)
Formation/Member
Stage/Age
Core/Samples
Gamma Ray Log
Lithology
Structures/Misc.
Descriptions
2200
2225
2250
GETHING
U. FERNIE SH/SS UNIT
Indeterminable
Jurassic (undifferentiated)
Early Oxfordian to Late Callovian
1
2
3
4
5
6
7
8
9
10
11
12
13
14
SANDSTONE: salt & pepper, medium to coarse grained,angular to subrounded quartz & chert,clay cement, siliceous,bitumenous
Interbedded SANDSTONE:very fine to medium grained,angular to rounded quartz & minor chert,clay cement, slightly sideritic & glauconitic, pyritic in part;SILTSTONE:quartzose,arenaceous,argillaceous;and
SHALE:dark grey to black,silty, arenaceous,glauconitic,pyritic; minor SIDERITE stringers
SANDSTONE:very fine to fine grained, angular to subrounded quartz,calcite cement,slightly sideritic & glauconitic in part,well-sorted;SILTSTONE & SHALE:as above


6 - 27 - 60 - 19W5M




10 - 32 - 61 - 18W5M




Descriptions

Interbedded **SANDSTONE:** light grey, very fine to fine grained quartz & minor chert, clay cement, mod. well-sorted; and **SHALE:** dark grey, micromicaceous; common **BENTONITE** stringers

**SHALE:** medium to dark grey and greenish-grey, micromicaceous, silty &/or arenaceous in part; **SANDSTONE** stringers: light to dark grey, very fine to fine grained quartz & minor chert, occasionally glauconitic, clay cement, mod. well-sorted; **SILTSTONE** stringers: light to medium grey, quartzose, argillaceous &/or arenaceous in part; minor **SIDERITE** stringers: dark yellowish-brown

**SHALE:** dark greenish-brown, micromicaceous, with common medium to coarse, rounded glauconite pellets, very arenaceous in part; **SIDERITE** stringers: medium to dark yellowish-brown; minor very argillaceous, glauconitic **SANDSTONE** stringers

**SHALE:** dark brownish grey and green, micromicaceous, silty &/or arenaceous in part; minor **SIDERITE** stringers: medium to dark yellowish-brown

**SHALE:** dark brown & greyish-brown, slightly to very calcareous &/or micromicaceous, with scattered calcareous white specks & fish remains

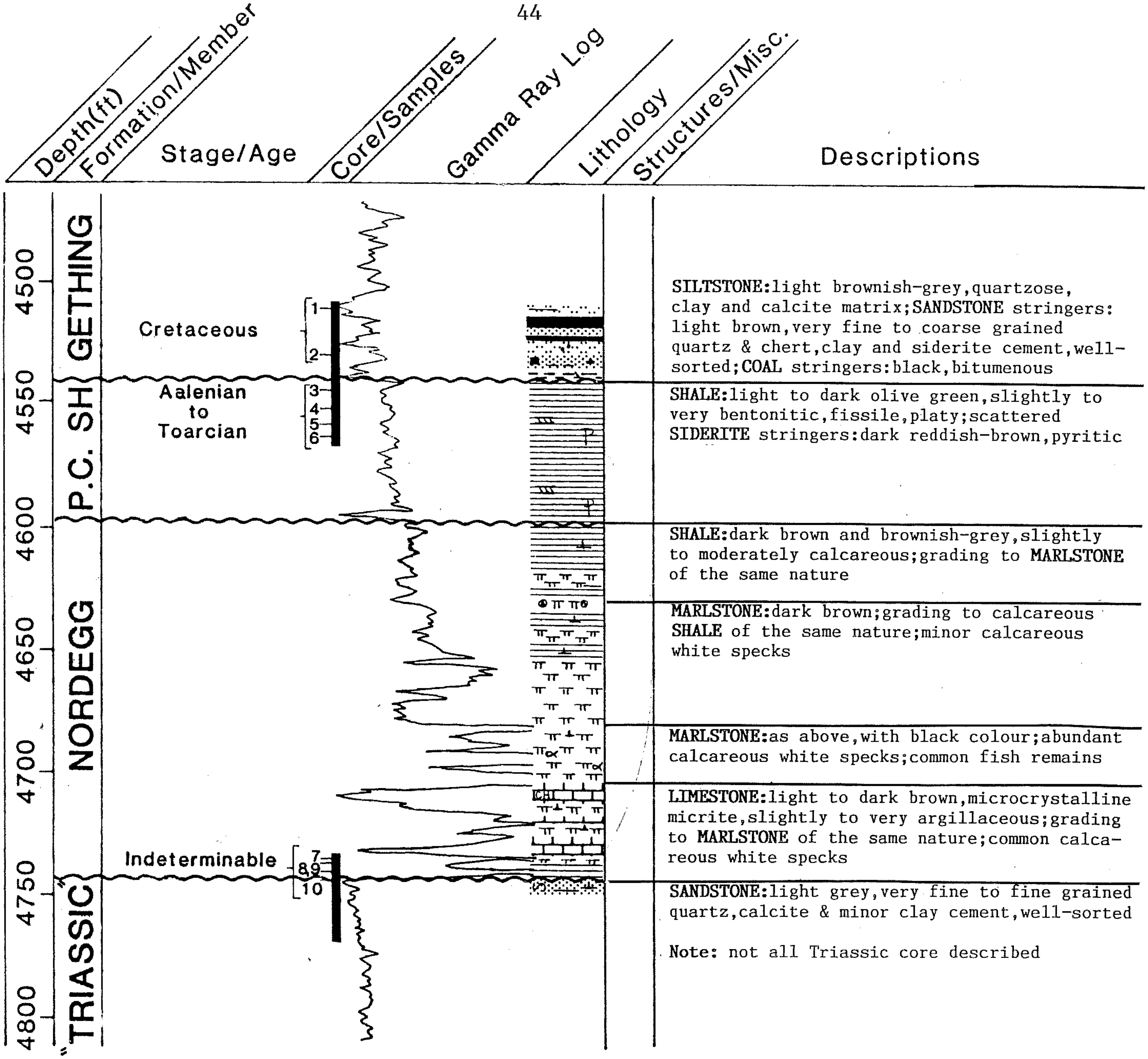
Interbedded **MARLSTONE:** dark brown & greyish-brown; and **LIMESTONE:** white to dark brown, microcrystalline, very argillaceous; common calcareous white specks and fish remains

**SHALE:** dark grey to black, very calcareous with abundant white specks, scattered fish remains; grading to **LIMESTONE:** micro to cryptocrystalline micrite, very argillaceous

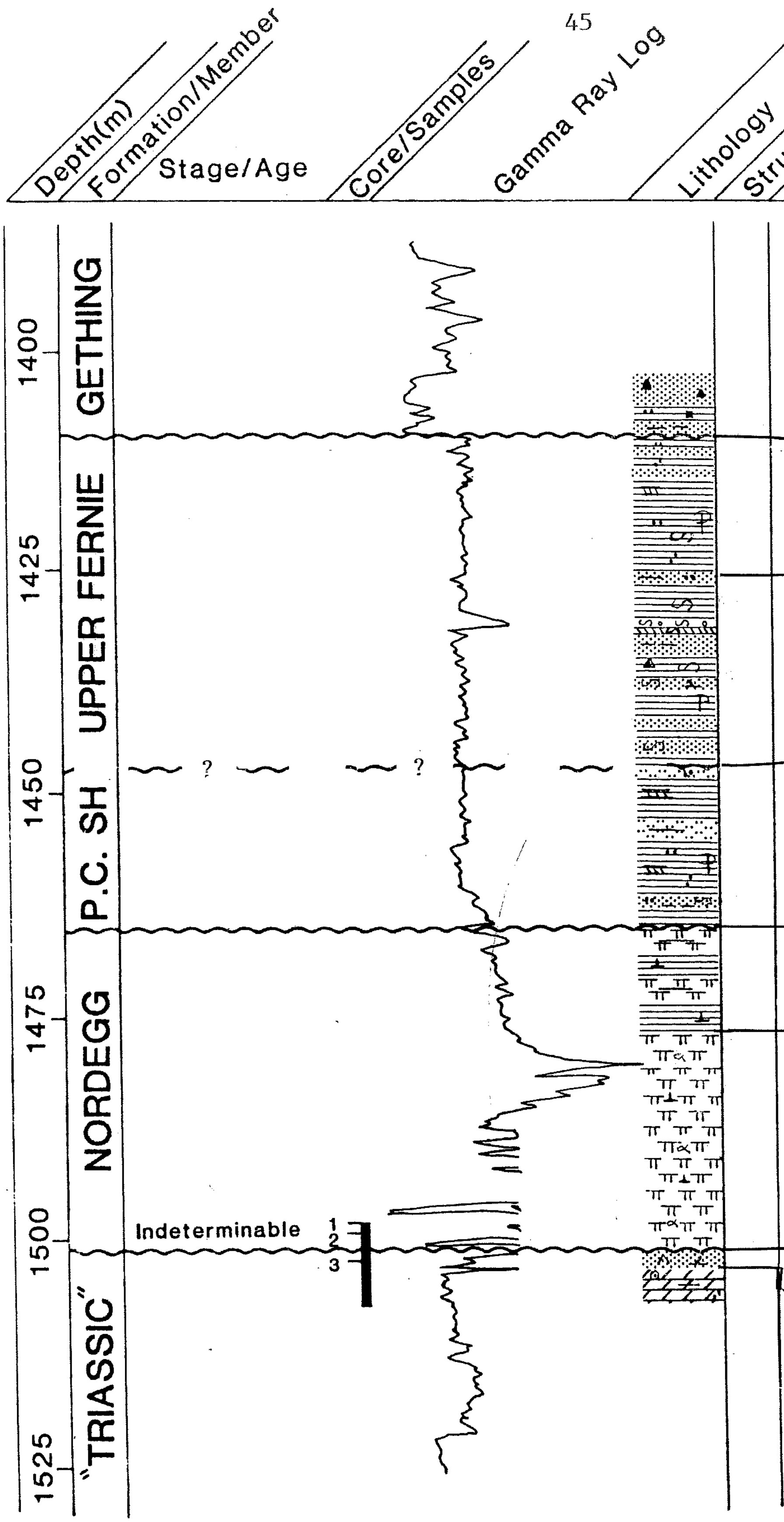
**SANDSTONE:** white to light grey, very fine to fine grained quartz, abundant calcite matrix, glauconitic in part, well-sorted; grading to **ARENACEOUS LIMESTONE** of the same nature, dolomitic in part

**Note:** not all Triassic core described

6 - 35 - 64 - 21W5M


Depth(ft)
Formation/Member
Stage/Age
Core/Samples
Gamma Ray Log
Lithology
Structures/Misc.
Descriptions
4500
4550
4600
4650
4700
4750
4800
GETHING
P.C. SH
NORDEGG
TRIASSIC
Cretaceous
Aalenian
to
Toarcian
Indeterminable
1
2
3
4
5
6
7
8
9
10
SILTSTONE:light brownish-grey,quartzose, clay and calcite matrix;SANDSTONE stringers: light brown,very fine to coarse grained quartz & chert,clay and siderite cement,well-sorted;COAL stringers:black,bitumenous
SHALE:light to dark olive green,slightly to very bentonitic,fissile,platy;scattered SIDERITE stringers:dark reddish-brown,pyritic
SHALE:dark brown and brownish-grey,slightly to moderately calcareous;grading to MARLSTONE of the same nature
MARLSTONE:dark brown;grading to calcareous SHALE of the same nature;minor calcareous white specks
MARLSTONE:as above,with black colour;abundant calcareous white specks;common fish remains
LIMESTONE:light to dark brown,microcrystalline micrite,slightly to very argillaceous;grading to MARLSTONE of the same nature;common calcareous white specks
SANDSTONE:light grey,very fine to fine grained quartz,calcite & minor clay cement,well-sorted
Note: not all Triassic core described

4 - 32 - 69 - 19W5M




## Descriptions

**SANDSTONE:** salt & pepper, fine to coarse grained (fining downward) quartz and chert, clay cement, well-sorted; **SHALE** stringers: dark greenish-grey, micromicaceous, silty in part, brittle to waxy

**SHALE:** medium to dark green and olive green, micromicaceous; minor **SIDERITE** stringers: dark reddish-brown; trace of glauconite pellets

**SHALE:** as above/**SHALE:** black, glauconitic, soft; **SANDSTONE** stringers: light to medium grey, very fine to fine grained quartz and chert, clay cement; **SIDERITE** stringers: very glauconitic in part, as above.

**SHALE:** medium to dark greenish-grey, micromicaceous; **SANDSTONE** stringers: light grey, very fine to fine grained quartz & minor chert, clay cement, mod. well-sorted; minor **SIDERITE** stringers: as above; common pyrite; trace of glauconite grains

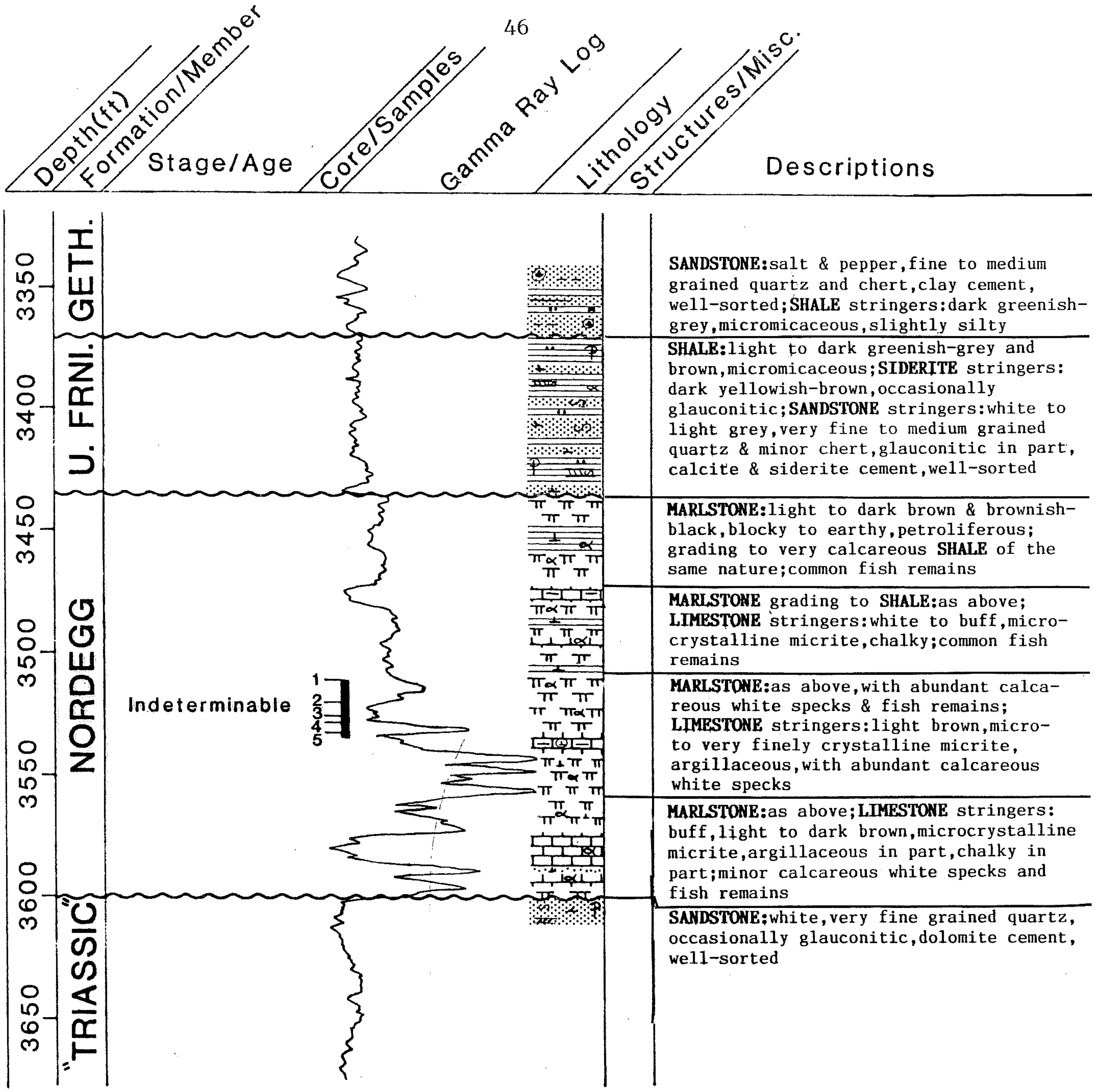
**SHALE:** medium to dark brown, very calcareous, sideritic; grading to **MARLSTONE** of the same nature

**MARLSTONE:** medium to dark brown, blackish-brown, petroliferous, very argillacoeus in part, with common calcareous white specks, minor fish remains

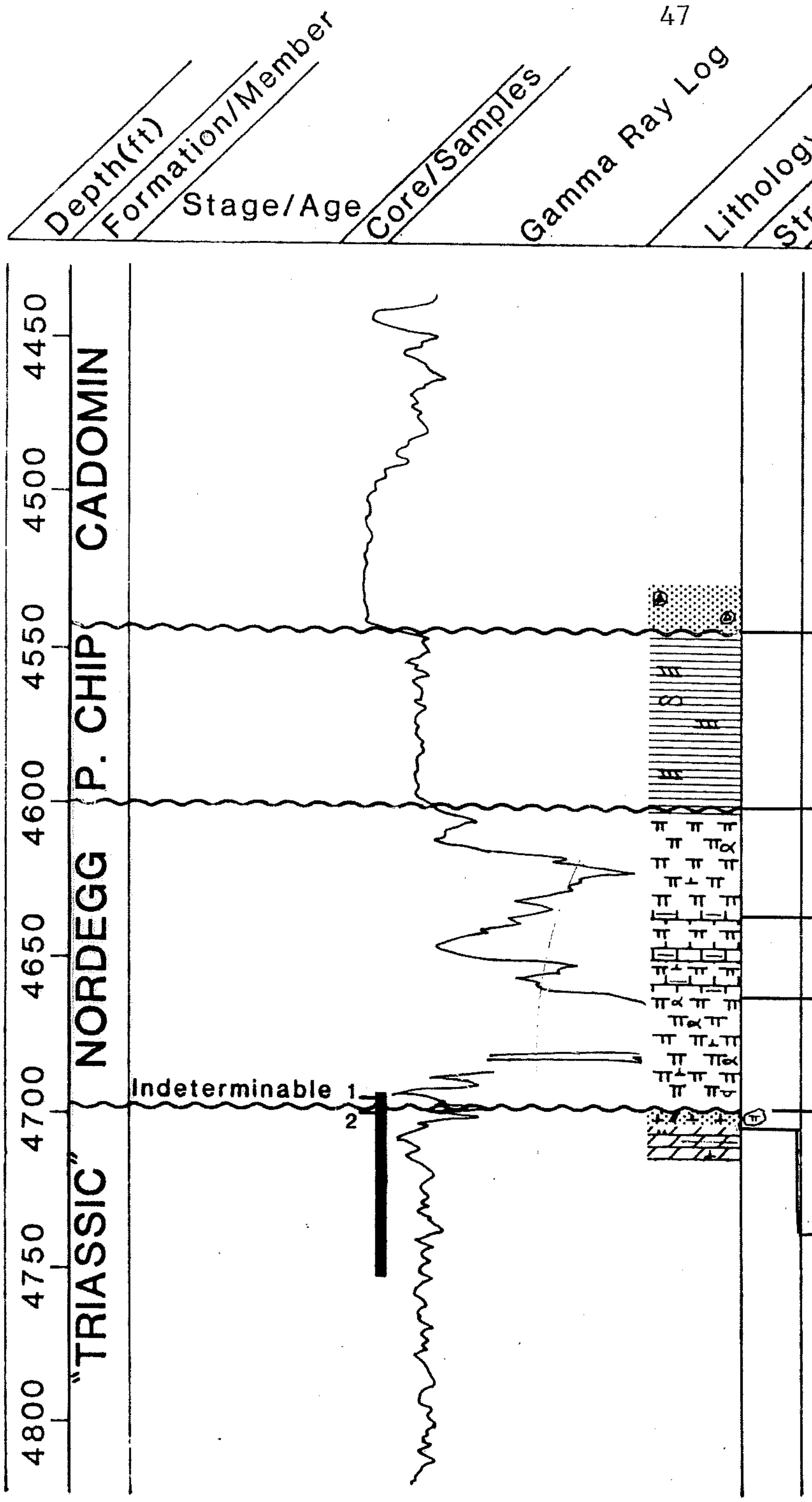
**SANDSTONE:** light grey, fine to medium grained quartz, dolomitic, siliceous in part

**DOLOMITE:** white, light to dark brown & grey, microcrystalline to finely crystalline, slightly argillaceous &/or arenaceous in part; scattered <u>Crinoid</u>(?) fragments

11 - 12 - 69 - 22W5M


Depth(ft)
Formation/Member
Stage/Age
Core/Samples
Gamma Ray Log
Lithology
Structures/Misc.
Descriptions
3350
3400
3450
3500
3550
3600
3650
GETH.
U. FRNI.
NORDEGG
"TRIASSIC"
Indeterminable
1
2
3
4
5
SANDSTONE:salt & pepper,fine to medium grained quartz and chert,clay cement, well-sorted;SHALE stringers:dark greenish-grey,micromicaceous,slightly silty
SHALE:light to dark greenish-grey and brown,micromicaceous;SIDERITE stringers: dark yellowish-brown,occasionally glauconitic;SANDSTONE stringers:white to light grey,very fine to medium grained quartz & minor chert,glauconitic in part, calcite & siderite cement,well-sorted
MARLSTONE:light to dark brown & brownish-black,blocky to earthy,petroliferous; grading to very calcareous SHALE of the same nature;common fish remains
MARLSTONE grading to SHALE:as above; LIMESTONE stringers:white to buff,micro-crystalline micrite,chalky;common fish remains
MARLSTONE:as above,with abundant calca-reous white specks & fish remains; LIMESTONE stringers:light brown,micro- to very finely crystalline micrite, argillaceous,with abundant calcareous white specks
MARLSTONE:as above;LIMESTONE stringers: buff,light to dark brown,microcrystalline micrite,argillaceous in part,chalky in part;minor calcareous white specks and fish remains
SANDSTONE:white,very fine grained quartz, occasionally glauconitic,dolomite cement, well-sorted

10 - 9 - 74 - 20W5M




Descriptions

**SANDSTONE:** unconsolidated, conglomeratic, medium to very coarse grained quartz and chert, minor clay cement

**SHALE:** dark brown, micromicaceous, waxy, occasionally glauconitic; scattered to common **SIDERITE** stringers: light to dark yellowish-brown, dark orangish-yellow

**MARLSTONE:** dark to light brown, beige, brownish-black, petroliferous, soft, earthy to chalky, minor calcareous white specks, trace of fish remains

**MARLSTONE:** as above; grading to very argillaceous **LIMESTONE** of the same nature; common white specks, fish remains

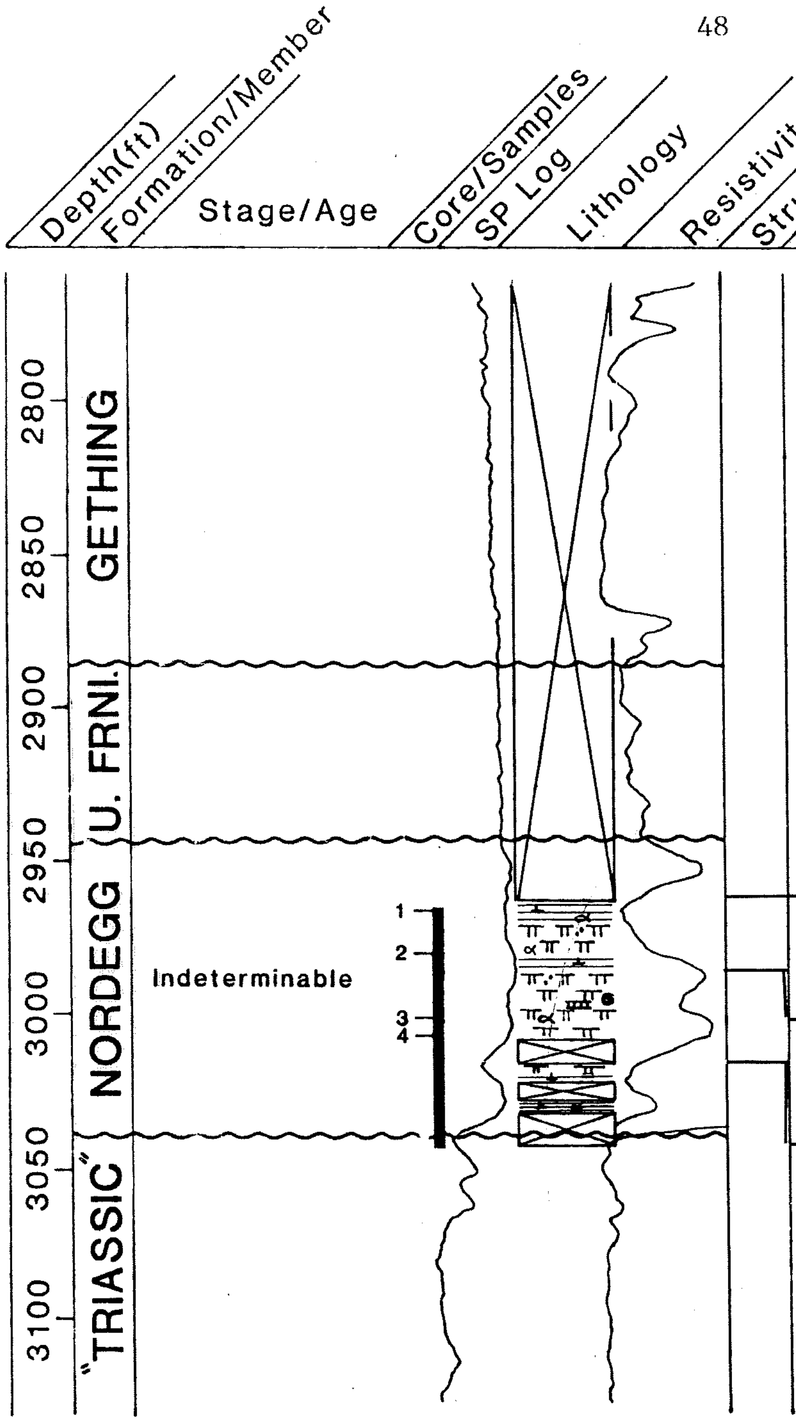
**MARLSTONE:** dark brown & brownish-black, petroliferous, earthy to brittle, common calcareous white specks, minor fish remains

**CALCARENITE:** fine to medium grained dolomitic limestone grains, bitumen & minor calcite cement; scattered Marl-stone clasts

**DOLOMITE:** white to light grey, micro- to very finely crystalline, argillaceous in part, massive; scattered dark greenish-grey **SHALE** stringers

**Note:** not all Triassic core described

7 - 33 - 73 - 1W6M




**Descriptions**

NO SAMPLES

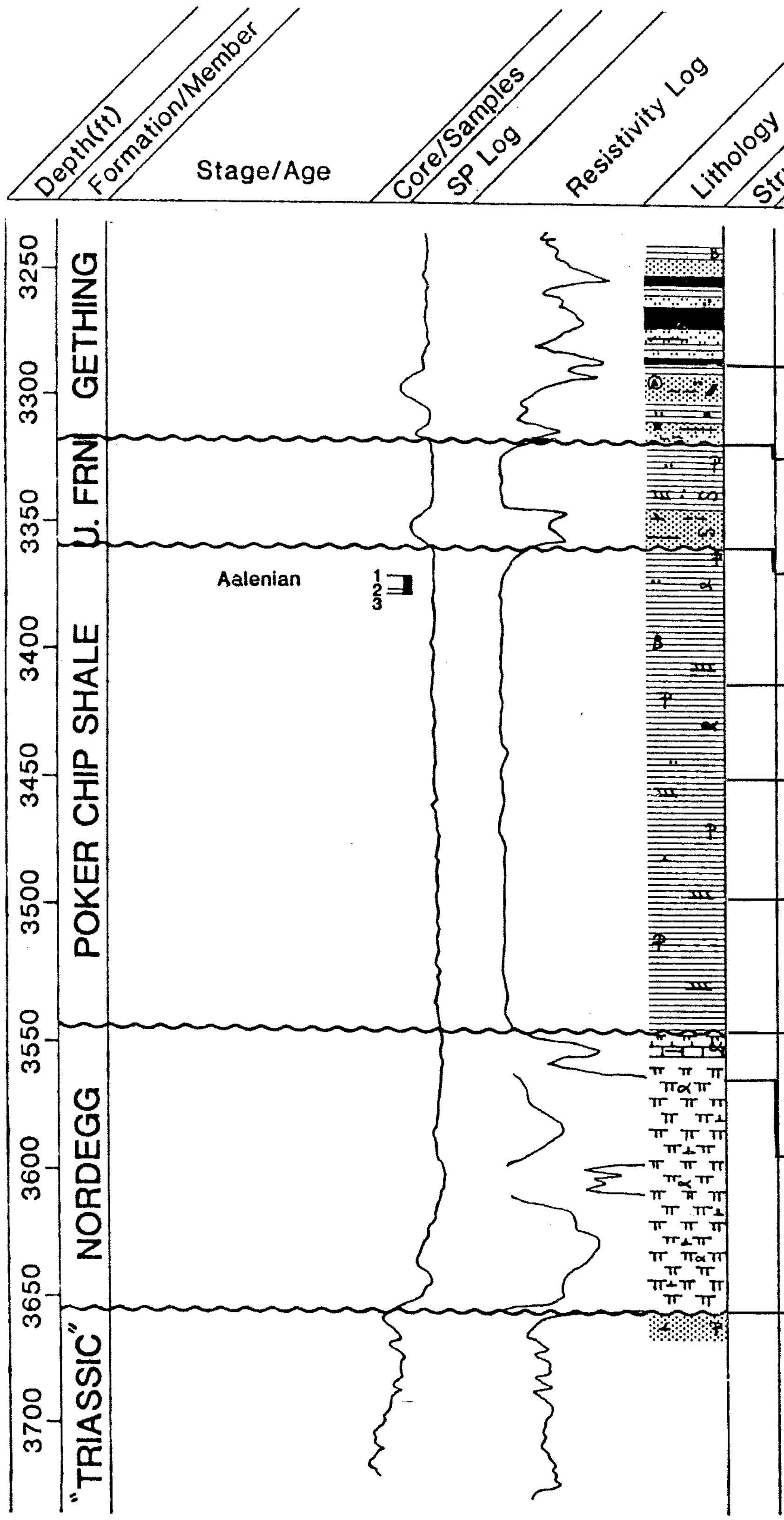
**MARLSTONE:**medium to dark brownish-grey,light to dark brown,arenaceous in part,common to abundant calcareous white specks and fish remains;grading to very calcareous **SHALE** of the same nature,hard,brittle

**MARLSTONE:**as above;**LIMESTONE** stringers:white to light brown,microcrystalline to finely crystalline micrite,argillaceous in part; scattered to common Pelecypod fragments,fish remains and calcareous white specks

**MARLSTONE:**light brown,earthy;grading to calcareous **SHALE:**dark brownish-grey,micro-micaceous in part;scattered to common fish remains

**Note:** only samples available: 4050 - 7740 ft.

12 - 33 - 77 - 21W5M




**Descriptions**

Interbedded **SHALE:**light to dark grey,greenish- and brownish-grey,micromicaceous;**SILTSTONE:** white to light grey,quartzose;**SANDSTONE:**white, light to dark brown,very fine to medium grained, quartz & minor chert,clay cement,mod. well-sorted;and **COAL:**black,bituminous

**SANDSTONE:**salt & pepper,mainly unconsolidated, coarse to very coarse grained quartz and minor chert,minor bitumenous cement,mod. well-sorted; **SHALE** and **SILTSTONE** stringers:as above

SHALE:dark grey,micromicaceous,glauconitic in part;SANDSTONE:white-light brown,very fine to medium grained quartz,glauconitic in part,clay and siderite cement,mod. well-sorted;SIDERITE stringers:dark yellowish-brown,glauconitic

**SHALE:**medium to dark brown & brownish-grey, micromicaceous and/or bentonitic,pyritic, slightly silty and/or arenaceous,with scattered to common fish remains,soft,fissile,occasionally glauconitic

**SHALE:**dark greyish-green,micromicaceous,slightly silty,bentonitic and/or pyritic in part;minor **SIDERITE** stringers:light to dark yellowish-brown;scattered fish remains

**SHALE:**light to dark greyish-green,very slightly calcareous in part,as above;minor **SIDERITE** stringers:medium to dark yellowish-brown

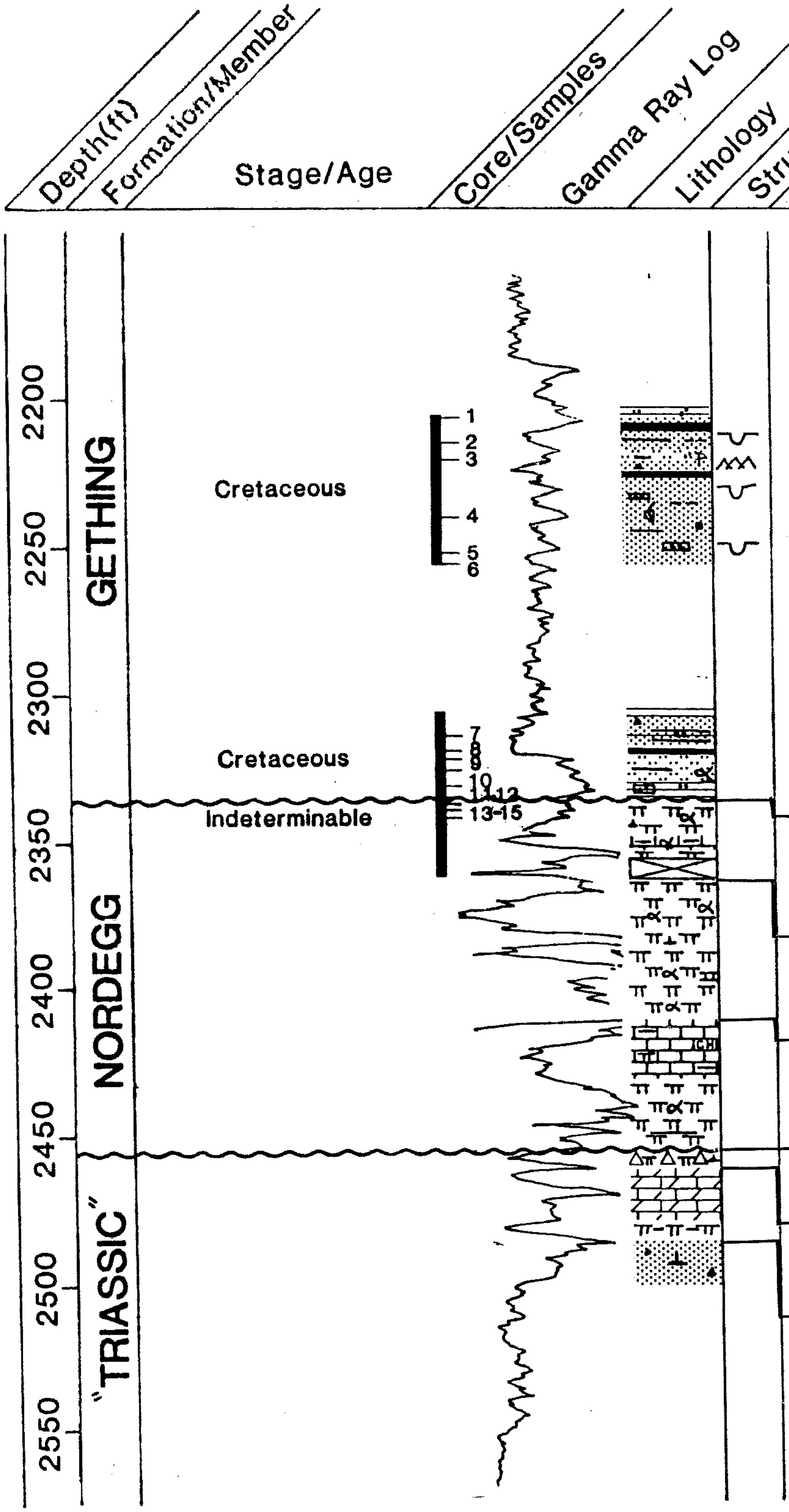
**SHALE:**mainly dark greyish-green,as above; minor **SIDERITE** stringers:as above

**MARLSTONE:**dark yellowish-brown,earthy,petroliferous;**LIMESTONE** stringers:white,light to dark brown,microcrystalline micrite,argillaceous in part,chalky in part;common fish remains

**MARLSTONE:**light to dark brown,brownish-black, chalky to earthy in part,petroliferous,with common calcareous white specks,minor fish remains

**SANDSTONE:**white to light brown,very fine to fine grained quartz,abundant dolomite cement, well-sorted

15 - 34 - 77 - 1W6M




**Description**

**SANDSTONE:**light to medium brown,very fine to medium,occ. coarse grained quartz & chert, clay cement,very friable in part,poorly to well-sorted;**SILTSTONE** stringers:light grey & brown,quartzose,argillaceous,arenaceous;**SHALE** stringers:light to dark greenish-grey,micro-micaceous,silty,carbonaceous,arenaceous;**COAL** stringers:black,sub-bituminous

**Samples not described**

**SANDSTONE:**light to dark grey,very fine to coarse grained quartz and chert,very argillaceous(matrix),well-sorted;grading downward to argillaceous,arenaceous **SILTSTONE** and silty, arenaceous **SHALE**;minor **COAL**:as above

**MARLSTONE:**dark greenish-grey,with abundant white specks and fish remains;**LIMESTONE** stringers:light to medium brown,microcrystalline micrite,with scattered to common fish remains

**MARLSTONE:**light to dark brown,brownish-black, earthy to chalky in part,petroliferous in part,minor fish remains,common calcareous white specks

**LIMESTONE:**light to dark brown,microcrystalline micrite,chalky in part,argillaceous in part; **MARLSTONE** stringers & beds:as above

Interbedded **CHERT:**mottled light to dark grey, white,tripolitic;and **MARLSTONE:**light brown, chalky to earthy

**DOLOMITIC LIMESTONE:**white to light brown,very finely crystalline to microcrystalline, sucrosic;grading to **CALCAREOUS DOLOMITE** of the same nature;**MARLSTONE:**dark brown

**SANDSTONE:**salt and pepper,fine to coarse grained quartz and chert,calcite cement,mod. well-sorted

10 - 17 - 84 - 22W5M