JURASSIC ROCK CREEK MEMBER IN THE SUBSURFACE OF THE EDSON AREA (WEST-CENTRAL ALBERTA)

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Table of Contents

Page

PREFACE

This study is focussed on the Rock Creek Member, a widespread Middle Jurassic clastic unit in west-central Alberta, and is a part of the Regional Subsurface Geology Program jointly sponsored by the Alberta Energy and Natural Resources (AENR) and the Alberta Research Council (ARC).

Interest in the Rock Creek Member dates from the late 1970's when sandstones of this unit were recognized as important reservoir rocks extending over an area of more than 20 000 km^2 in the west-central Plains and adjacent Foothills. However, despite hundreds of wells drilled through the Rock Creek, its hydrocarbon reservoirs were frequently by-passed and the unit itself was often misidentified. In addition, local names (for example, Niton, Granada) have been used to denote sandstones of the Rock Creek unit and added to the confusion about its stratigraphic position and age.

Besides insufficient paleontological dating of strata at the Jurassic-Lower Cretaceous boundary, many of the questions relating to Rock Creek stratigraphy stem from the complex inter-relationship with overlying, and also often hydrocarbon-bearing, Lower Cretaceous sediments including Lower Mannville Ellerslie ("Basal Quartz") Member and Cadomin Formation. This is especially true for areas where intervening "Upper Fernie" and Lower Cretaceous shales are missing and where Ellerslie or Cadomin sandstones rest directly on Rock Creek sandstones. In such areas hydrocarbon reservoirs in Rock Creek and Ellerslie (or Cadomin) sandstones may be in communication; this often leads to exploration and production problems and also creates difficulties related to definition of individual hydrocarbon reservoirs and productive zones for legal purposes, such as lease continuation and deeper rights reversion.

ACKNOWLEDGMENTS

This study was undertaken during the period from February to October, 1984, during which time the author was seconded to the Alberta Geological Survey Department of the Alberta Research Council.

I would like to thank Dr. R. Harrison, Project Co-ordinator of the Regional Subsurface Geology Program for his patience, advice and organization of meetings with industry representatives.

My thanks are also due to Dr. D. Cant who critically commented on the cross-sections and gave valuable advice on various aspects of evaluation of sedimentary sequences, and to B. Rottenfusser both for technical advice concerning computer generation of maps and discussion of various topics relating to sedimentary rocks.

Dr. C. Singh provided palynological and micropaleontological analyses of Jurassic and Cretaceous rocks from several cored wells in and east of the study area, and L. Jones performed the computer-related technical work. Drafting was supervised by L. Bradley.

My special thanks go to geological staff of several Calgary-based companies including Esso Resources (Dr. D. James), Shell Canada Resources (D. Marion), Chevron (D. Organ, A. Graham), PetroCanada (A. Williams) and to G.E. Chin, presently with Jacor Holdings Ltd. in Calgary. Their advice and discussions regarding the Rock Creek problems in the early stages of the project were very valuable.

INTRODUCTION

AREA OF STUDY

The study area is approximately 5500 km^2 in size, is located in west-central Alberta and is bounded by Townships 48 to 57, Ranges 14 to E1/2 19, W5M. Edson lies nearly in the centre of the study area (Figure 1).

A number of oil and gas fields have been defined in the study area and to date some 420 wells have been drilled to explore for hydrocarbon reservoirs found in Devonian, Mississippian, Triassic, Jurassic and Lower and Upper Cretaceous formations. Four hundred and six of these wells penetrated the Rock Creek Member in the mapped area while most of the shallower wells were only drilled to the Glauconitic/Bluesky or Cardium Formations.

Well coverage for the Rock Creek in the study area is relatively good (Figures 9 to 14) although the wells are not regularly distributed and only a few wells were cored in the Rock Creek and adjacent intervals including Nordegg, Poker Chip, "Upper Fernie", Lower Mannville and Cadomin. However, numerous wells immediately east and southeast of the mapped area (particularly in the Niton, Carrot Creek, Cynthia-Pembina and West Pembina fields) were cored in the critical Rock Creek-Lower Mannville interval (Marion 1982, 1983, 1984) and provided valuable material for log calibration.

PREVIOUS WORK

Although a number of oil companies have been producing or exploring for Rock Creek hydrocarbons in and adjacent to the study area for almost two decades, little has been published about this unit. The only important exception to this is a recent M Sc thesis (1982) and subsequent publications (1983, 1984) by D. Marion, all devoted to Rock Creek geology and petrography in Townships 48 to 54, Ranges 9 to 13, W5M.

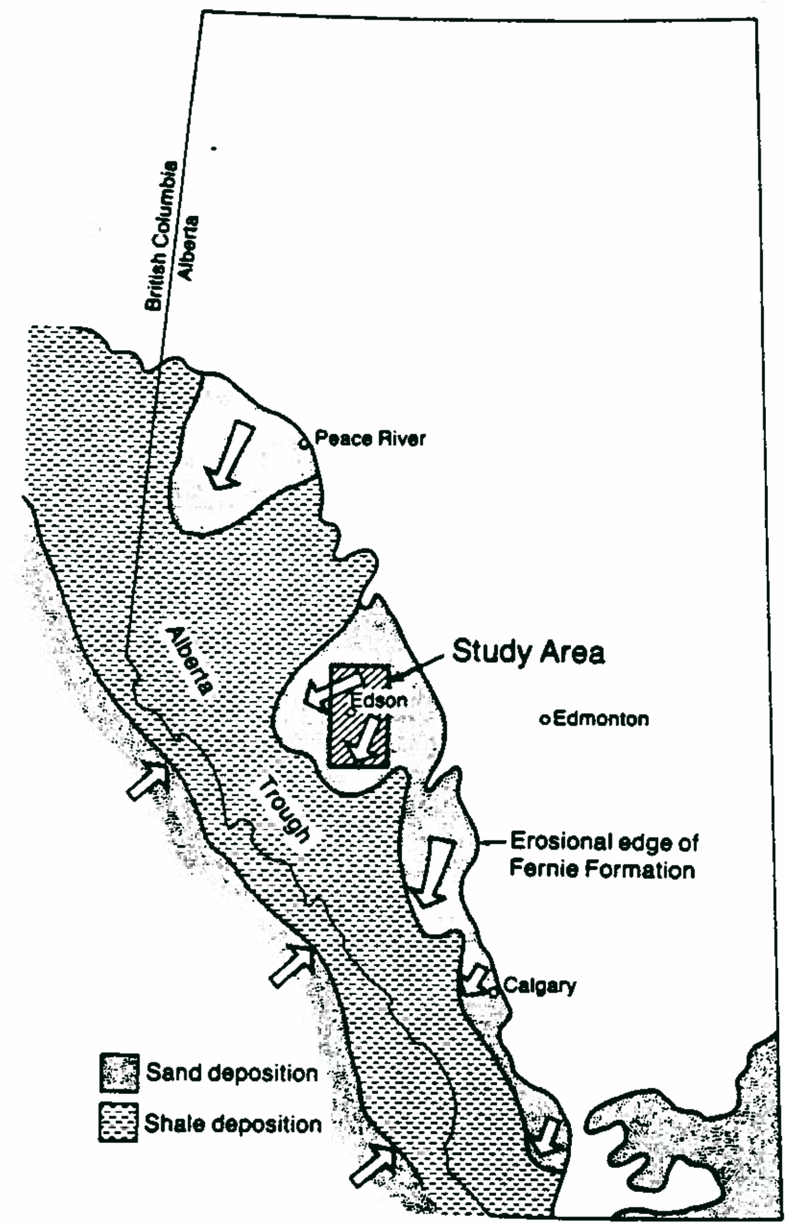


Figure 1. Location of Study Area

Another recent M Sc thesis (Harris, 1981), dedicated chiefly to Cadomin Formation, deals briefly with Rock Creek and illustrates the unit on two regional cross-sections entering the western part of the present study area. Also extending into the latter is a regional cross-section of J.H. Lackie (1958) but it shows only one well in the study area, with Rock Creek included in Lower Mannville.

To the author's knowledge, no recent detailed maps of Rock Creek have been published for the study area, although an extensive lobe of Lower to Middle Jurassic sandstone extending southwestward into the Fernie basin was mapped by Ziegler (1969, p.20) in his large-scale paleogeographic map of Lower and Middle Jurassic of Western and Arctic Canada, and by Springer et al (1964) and Carlson (1968).

A recent study of the Jurassic-Lower Mannville boundary sequence by Horne et al (1982) was undertaken in the Niton field immediately east of the study area, but only a short abstract summarizing the results has been published.

Preliminary results of the present study in the Edson area have been previously summarized by J. Losert (1985).

OBJECTIVES

The present study was directed towards obtaining a better understanding of the geology of the Rock Creek Member and its relationships with overlying and underlying stratigraphic units. The primary goal of the study was to delineate the distribution, geometry, continuity and internal subdivision of the Rock Creek Member.

The second purpose of the study was to characterize relationships between the Rock Creek Member and associated units in places where pre-Ellerslie erosion reached the Rock Creek level and where subsequently-deposited arenites of Lower Cretaceous age are in direct contact with Rock Creek sandstones.

A third goal was paleontological dating of Upper Jurassic-Lower Cretaceous boundary strata in several key wells located outside the immediate study area in the Niton field. This part of the study is still in progress and a separate report will be published in cooperation with Dr. C. Singh of the Alberta Research Council.

The final goal of the present study was to provide additional data and documents (cross-sections, isopach and structure maps, formation tops picks) to both those interested in the hydrocarbon exploration of the Rock Creek Member and associated units, and to those concerned with legal problems related to hydrocarbon reservoirs within the Rock Creek Member and associated formations.

METHODS

A review of the limited published literature was followed by examination of unpublished maps, cross-sections, and paleontological age-determinations provided by some of the previously-acknowledged petroleum companies, and supplemented by discussions with the previously-mentioned individuals.

Typical cores encompassing the Rock Creek Member and associated units were selected from the ERCB core file and used for calibration of petrophysical logs. Cores from 20 wells were examined, mainly from the area studied by Marion (1982), but additional cores from the Niton field and also a few cores from the study area itself were also used. Also examined were Cadomin and Rock Creek bit cuttings from several uncored wells in the western part of the study area.

Prominent shaly and silty breaks within, above and below the Rock Creek were sampled for palynological and micropaleontological examination by Dr. C. Singh, with the sampled interval including Poker Chip Shale, Rock Creek Member, "Upper Fernie" and Lower Mannville.

A grid consisting of four north-south and seven east-west regional stratigraphic cross-sections extending through and beyond the mapped area

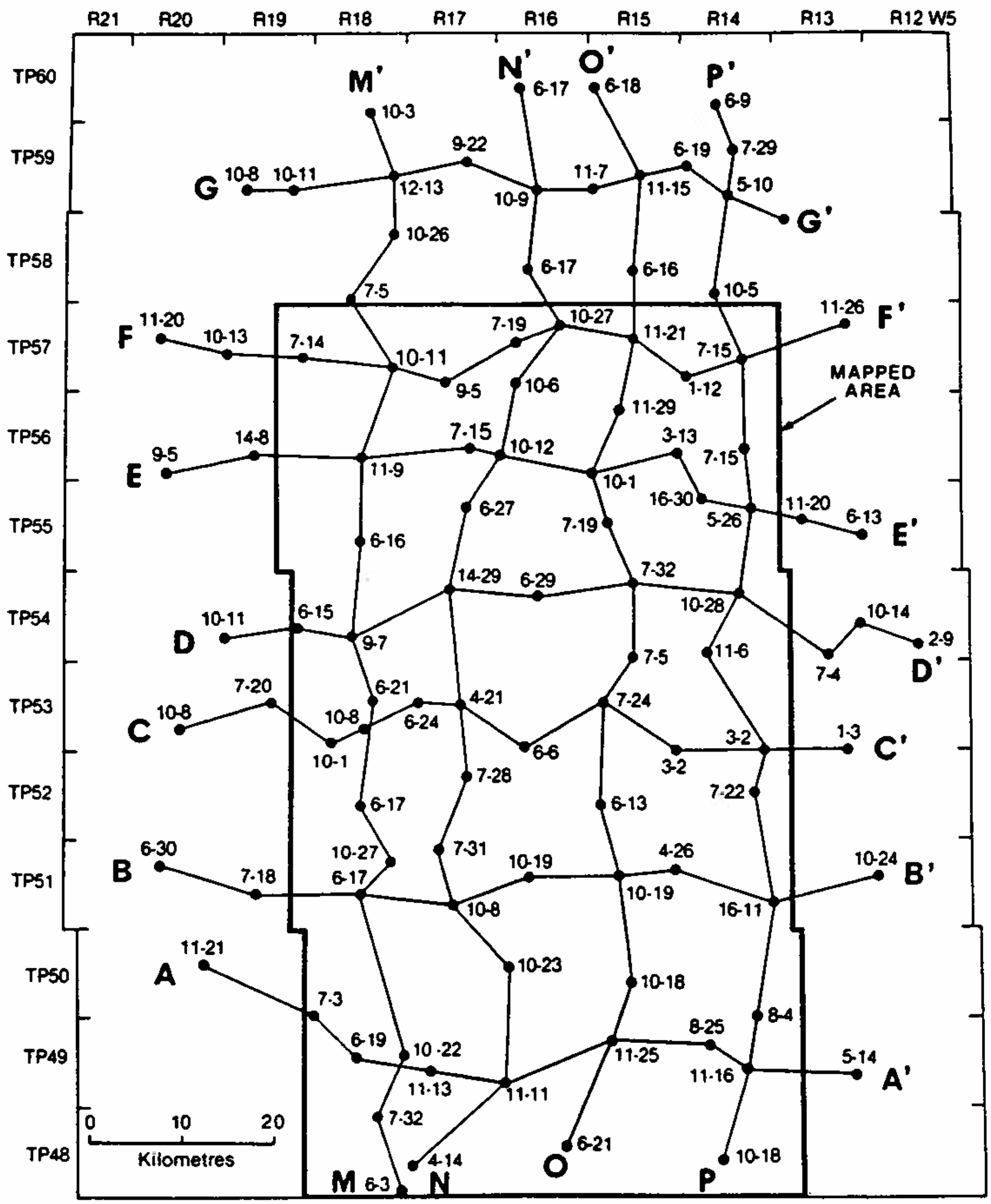


Figure 2. Location of Cross-Sections

(Figure 2) was constructed to establish the distribution of and relationships between the stratigraphic units of interest. In the southeast, four of the east-west cross-sections (A-A' to D-D' were tied into those published by Marion (1983, 1984). Although the spacing of cross-sections was only one to two townships apart and well frequency was one to two wells per township, this density proved insufficient in some areas and additional local "working" cross-sections were developed in order to elucidate the geology in such areas.

Gamma ray-sonic logs are available for most wells and were used, together with electric logs, in the construction of cross-sections. The top of the Glauconitic/Bluesky was used as the datum and local markers were combined to substitute for that datum where the top of this unit was difficult to pick.

Formation tops for the Mannville, Glauconitic/Bluesky, Lower Mannville, Cadomin, "Upper Fernie", Rock Creek, Poker Chip and Nordegg were picked for 406 wells penetrating the Rock Creek and were fed into a computer data base. For the purpose of this study, the individual Mississippian and Triassic formations underlying the Nordegg were not differentiated and were mapped collectively as a Mississippian/Triassic unit, with its top defining the sub-Jurassic unconformity. These tops picks were used to generate isopach and structure maps of the Rock Creek member and associated formations (Figures 5 to 14) using the Surface II contouring package employed by the Alberta Research Council.

STRATIGRAPHY AND STRUCTURE

STRATIGRAPHY

In industry reports, well information cards, and ERCB well data the stratigraphic terminology used for the study area corresponds to Central Plains (eastern part of the area) and to Northwest Plains (western part of the area), as shown in the ERCB Table of Formations for Alberta. Figures 3 and 4 illustrate the correlation of the two suites of terminologies. Figure 3 schematically shows the geological setting of

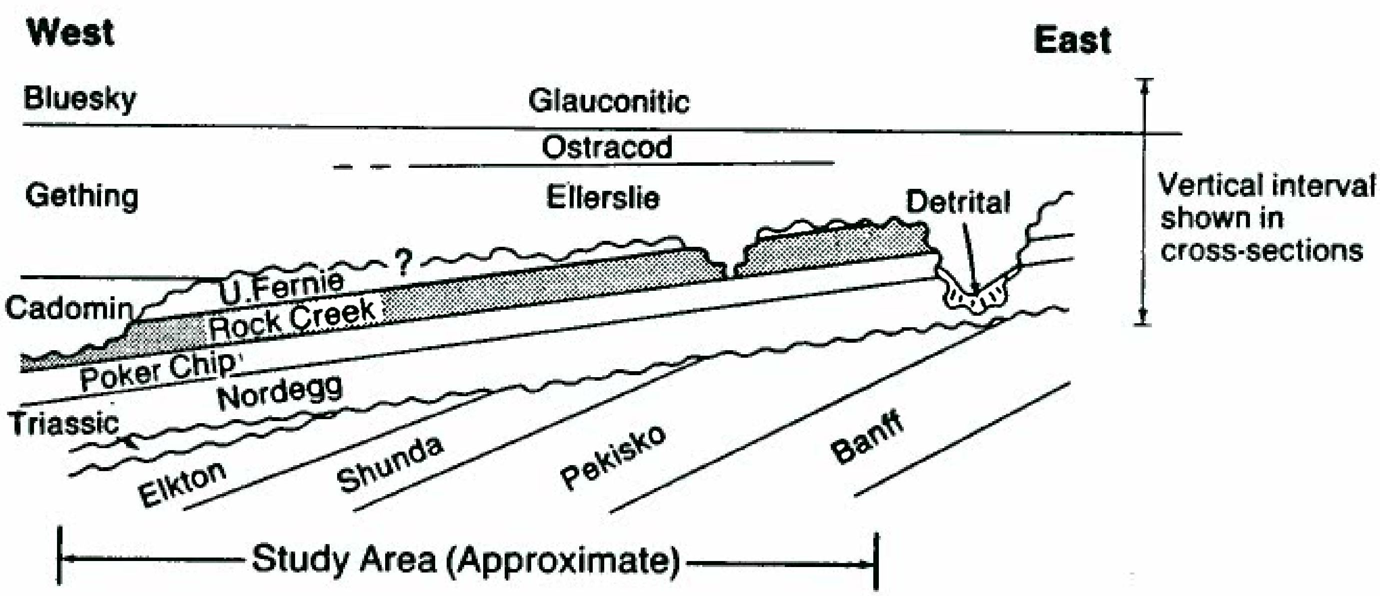


Figure 3. Schematic Geological Cross-Section

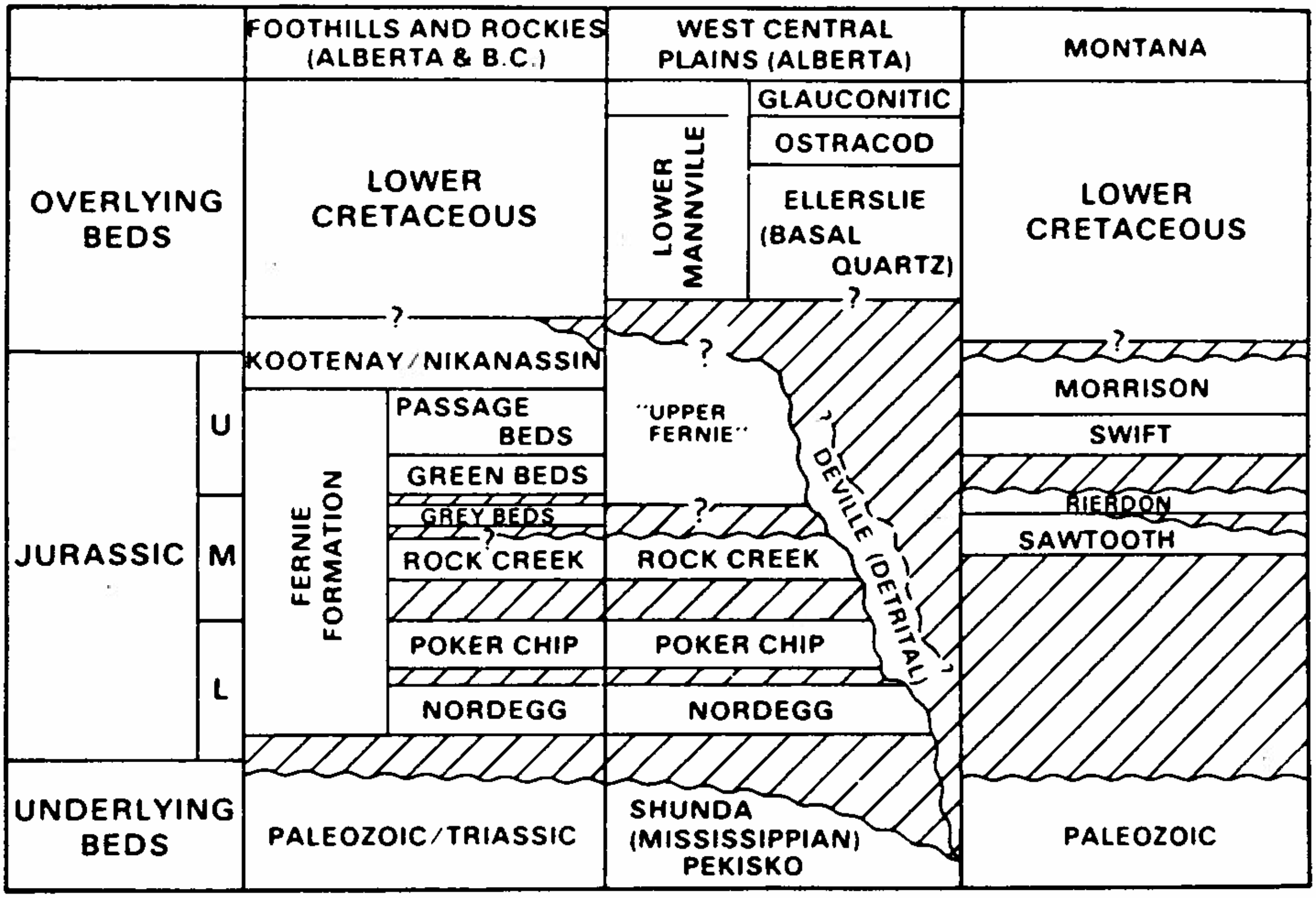


Figure 4. Scheme of Stratigraphy

Rock Creek in the Edson area and also indicates the vertical stratigraphical interval displayed in the cross-sections enclosed with this report.

The Lower Jurassic Nordegg Member is the oldest Jurassic unit present and is 40 to 70 metres thick in the mapped area (Figure 5). Cherty dolomites and limestones, cherts, sandstones and mudstones together with phosphatic rocks and shales are the main constituents of the unit which is present throughout and east of the study area (Bovell, 1979).

From east to west, carbonates and shales of progressively younger Mississippian formations (Banff, Pekisko, Shunda, Elkton) unconformably subcrop against Nordegg, and an unconformity-bound, easterly thinning wedge of Triassic (Montney ?) separates Mississippian from Nordegg in the western part of the study area, along the Triassic erosional edge (Figure 3).

Overlying the Nordegg and present virtually throughout the area is the Poker Chip Shale, a Lower Jurassic unit built up predominantly of dark shales interbedded with thin layers of siltstones and sandstones and up to 25 m thick (Figure 6). This horizon however was absent from some localities in Tp 53, R 18, W 5.

Sandstones (quartzarenites), locally glauconite-bearing and typically bioturbated, together with siltstones, coquinoid sandstones and subordinate shales are the main constituents of the Middle Jurassic Rock Creek Member. Two cycles were recognized by Marion (1982) in the Granada area (east of the study area), with a prominent siltstone unit sandwiched between two sub-units consisting of sandstones with coquinoid bases (for example the westernmost part of cross-section B-B') but this pattern tends to disappear towards the west. Figure 7 indicates a conspicuous thickening of the unit from NW towards SE.

The Rock Creek is overlain by Upper Jurassic marine shales or by Lower Cretaceous (Ellerslie Member, Gething Formation, Cadomin Formation)

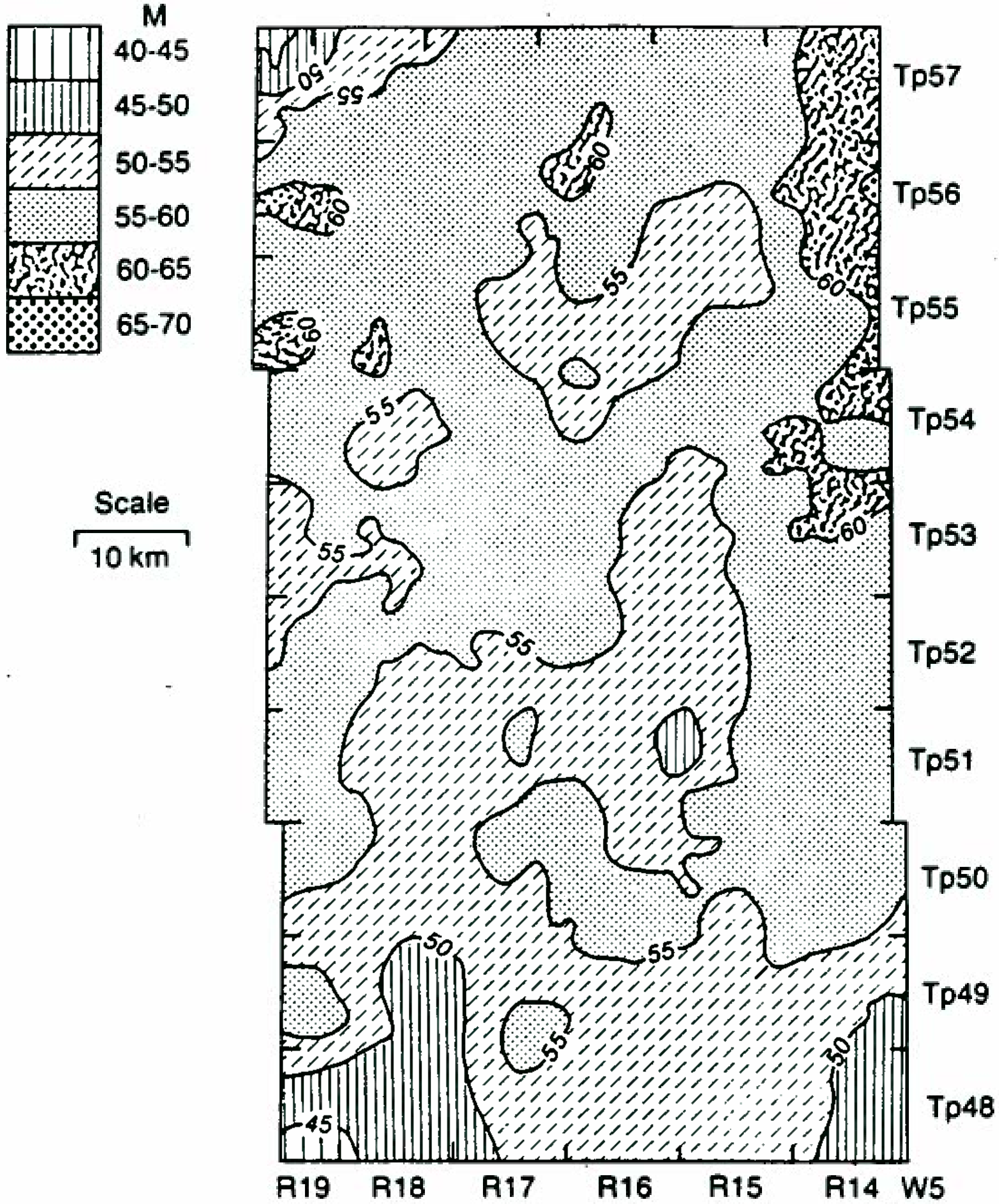


Figure 5. Isopach Nordegg Mbr.

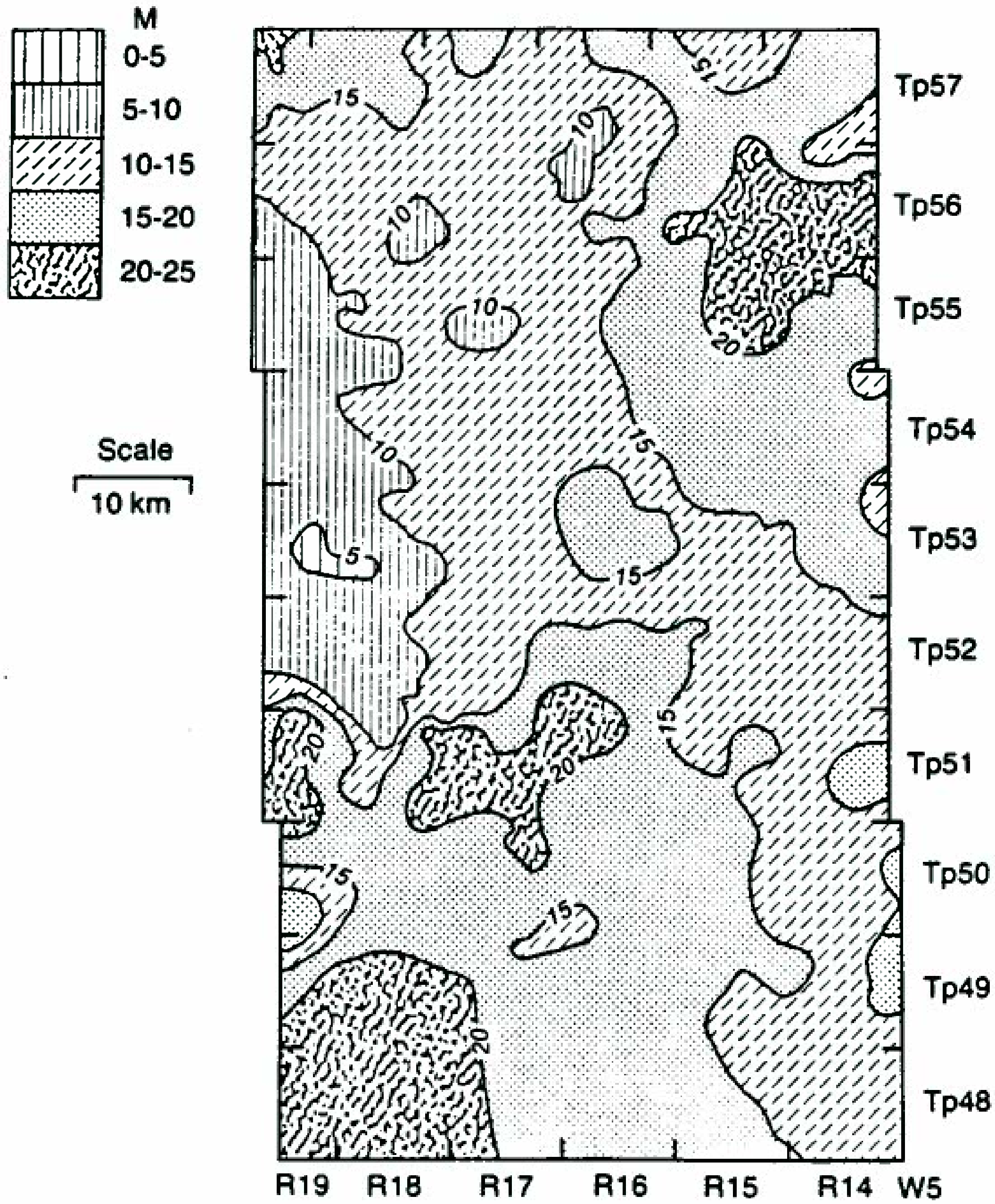


Figure 6. Isopach Poker Chip Shale

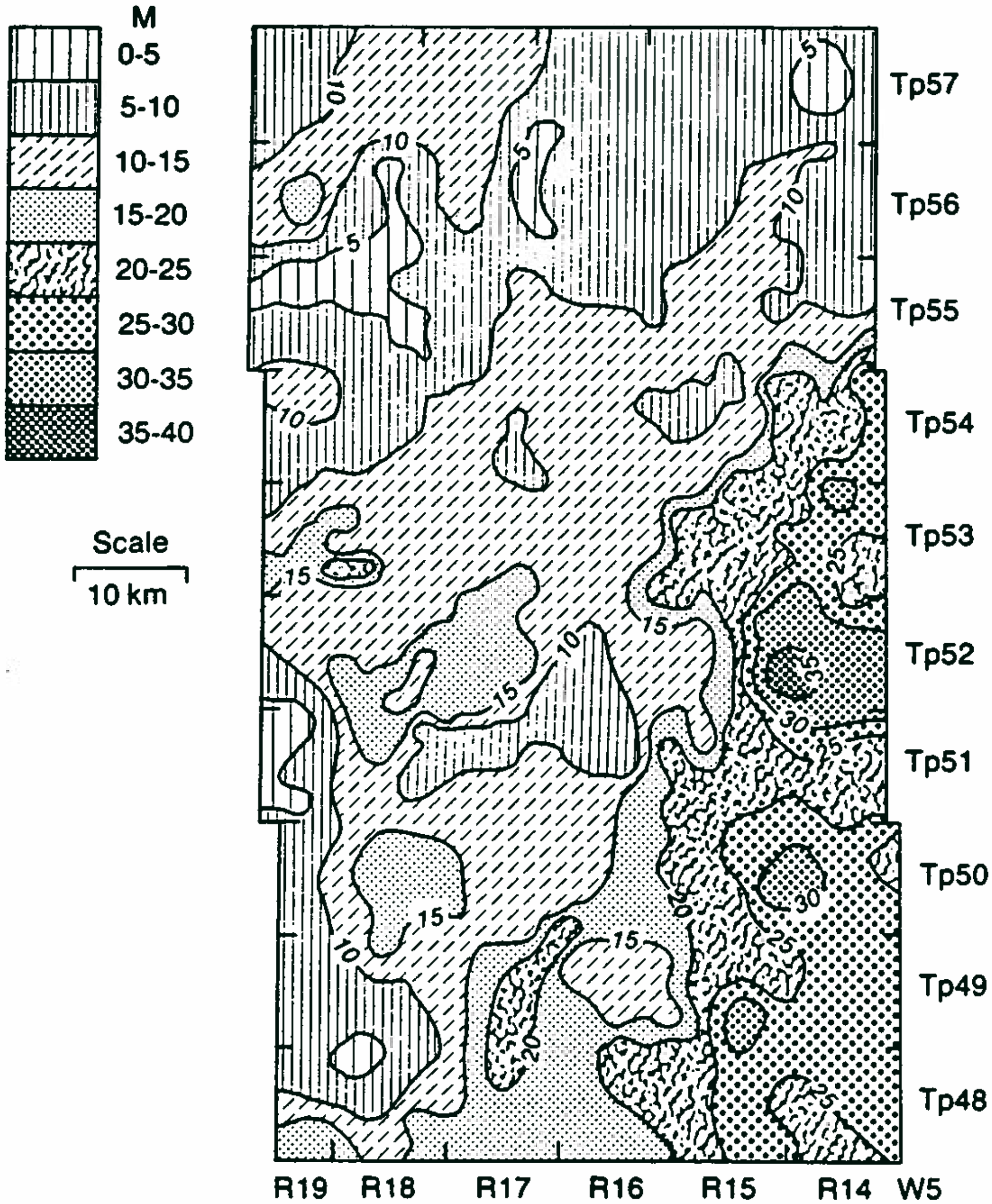


Figure 7. Isopach Rock Creek Mbr.

sandstones, conglomerates, siltstones and shales deposited in transitional to continental settings. Shaly beds (with subordinate siltstones and sandstones) immediately above Rock Creek are sometimes informally termed "Upper Fernie" or Passage Beds, or simply "Fernie" in company reports and well information tickets. In the present work, the rather descriptive term "Upper Fernie" is used but it is realized that despite a Late Jurassic-Early Cretaceous age of "Upper Fernie" (as determined by paleontological analyses provided by D. Marion), its precise age is still unknown, as is the nature of its contact with overlying Lower Mannville strata. While the lower boundary of "Upper Fernie" (contact with the Rock Creek Member) is assumed to represent a break in sedimentation (unconformity; Marion, 1982) its upper contact with Lower Cretaceous strata is difficult to establish, especially where the "Upper Fernie" is overlain with lithologically similar "ribbon" or "lenticular" shale-siltstone-sandstone sequences of Ellerslie or Gething age. As the critical interval is usually not cored and logs alone are not sufficient to define the contact, the latter (and the location of the "sub-Cretaceous" unconformity) is often picked in a somewhat inconsistent manner (see later text).

In the eastern part of the study area, the lower section of Lower Mannville is represented by the Ellerslie Member, a shale-siltstone series 25 to 60 metres thick, with several prominent though discontinuous sandstone layers up to 15 metres thick ("Basal Quartz"). The lowermost (continental-fluvial) part of this unit covers irregularities in the pre-Ellerslie paleotopography and locally infills valleys incised into Jurassic strata, but the upper portions of the Ellerslie section may blanket larger areas.

Sandstones, fossiliferous shales and calcareous mudstones above the Ellerslie Member are the main constituents of the Ostracod zone ("Calcareous Member"). This is generally about 10 to 15 metres thick and can be traced throughout much of the eastern part of the study area as an useful marker.

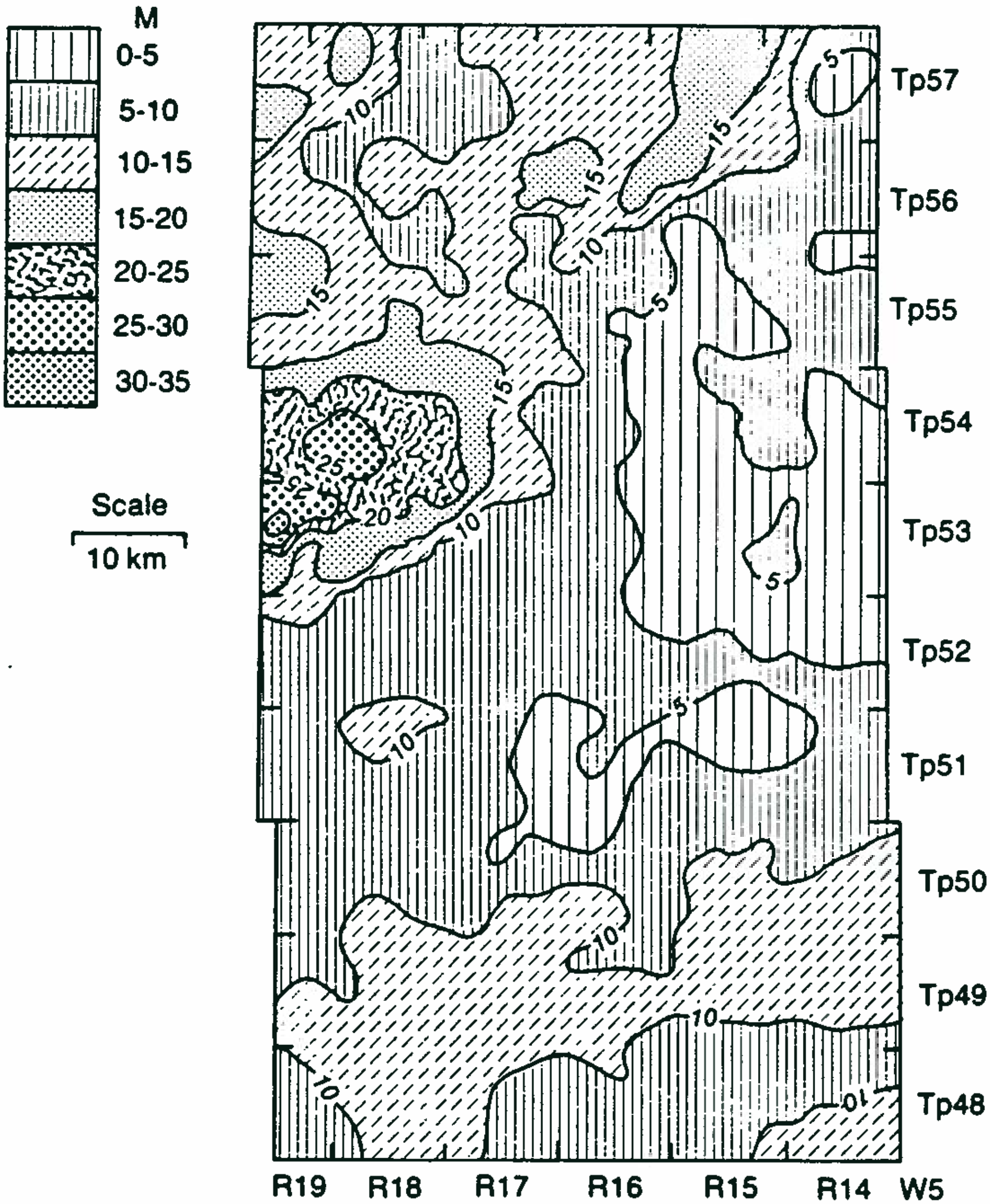


Figure 8. Isopach Glauconitic SS./Bluesky Fm.

In the western and southern portions of the study area the thickness of the Lower Mannville gradually increases to 60 to 100 metres and the monotonous shale-sand series of Gething Formation becomes equivalent to the Ellerslie Member and Ostracod zone (Figure 3). Important sandstone bodies known under local names such as "Kaybob sands" or "Fox Creek sands" occur as discontinuous layers within the Gething Formation. At the base of the Gething (Figure 3) the Cadomin Formation is 18 to 40 metres thick and consists of dark, cherty sandstones and subordinated conglomerates unconformably overlying "Upper Fernie" shales or resting directly on Rock Creek sandstones (cross-sections A-A', B-B'). An alluvial-fan and alluvial-plain origin has been repeatedly invoked to explain the geometry and facies changes within the Cadomin and the characteristic flat-base and upward-fining Gamma ray well-log signature.

Sandstones (with minor conglomerates), siltstones and shales constituting the typically coarsening-upwards sedimentary pattern of the Glauconitic Sandstone Formation (in the east), and its Bluesky equivalent (in the west), mark the beginning of Upper Mannville marine sedimentation and blanket the entire area. Typical occurrence is as northeast-southwest trending marine and offshore bars with clean sandstones attaining thicknesses of up to 25 metres (Figure 8 and all cross-sections), with some channelling indicated on logs.

Overlying the Glauconitic/Bluesky Formation is the Upper Mannville series (Spirit River equivalent) consisting of several coarsening-upward shale-sandstone sequences capped with coals and shales. The lowest, laterally persistent coal is usually some 50 to 70 metres above the top of Glauconitic/Bluesky and was used as a local marker in places where the top of Glauconitic/Bluesky is difficult to pick.

STRUCTURE

Structure contour maps (Figures 9 to 14) illustrate the northwest to southeast strike and monoclinal southwesterly dip of the Nordegg, Poker Chip, Rock Creek, Glauconitic/Bluesky and Mannville strata and also of

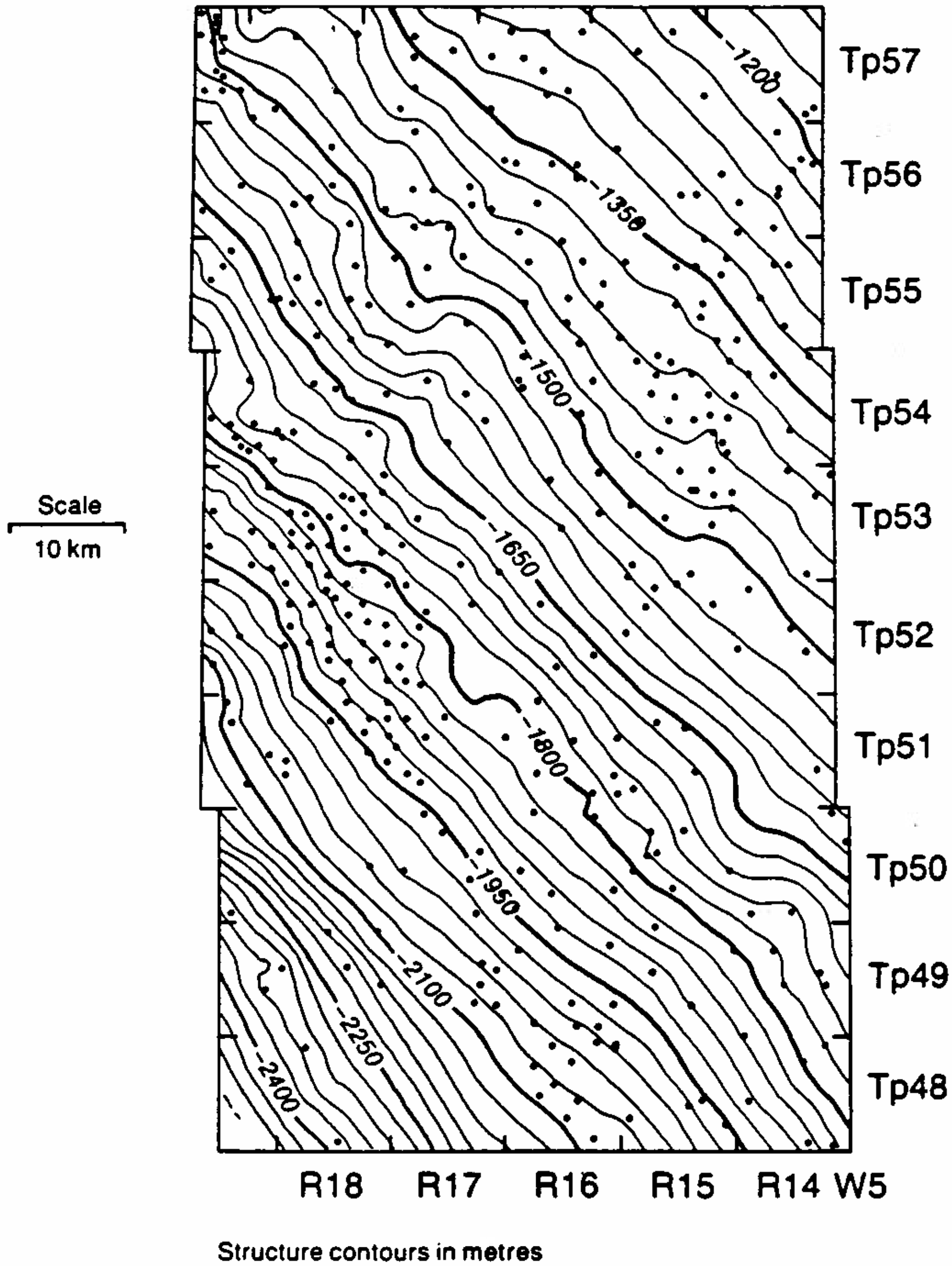


Figure 9. Structure of Sub-Jurassic Unconformity

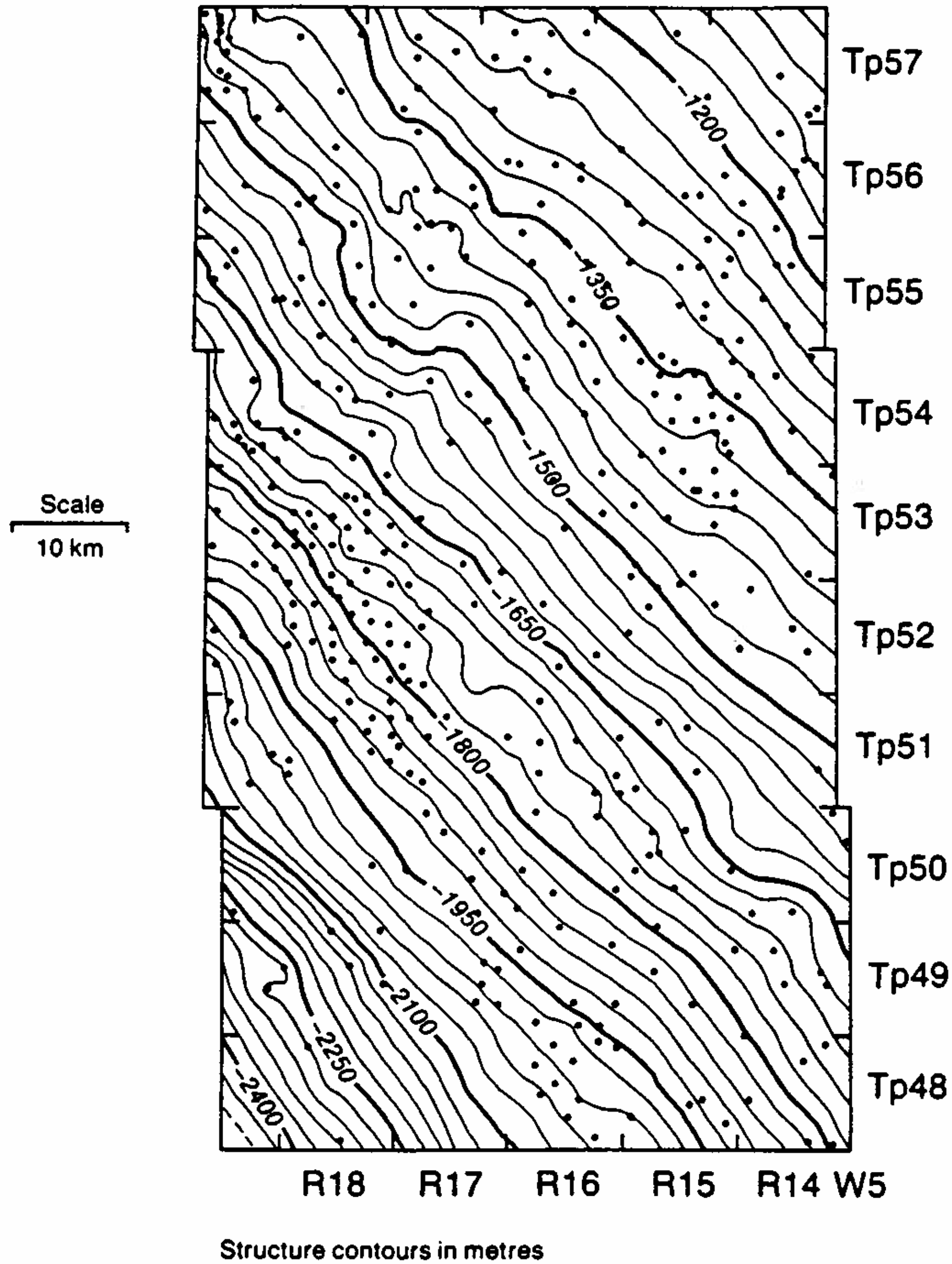


Figure 10. Structure of Nordegg Mbr.

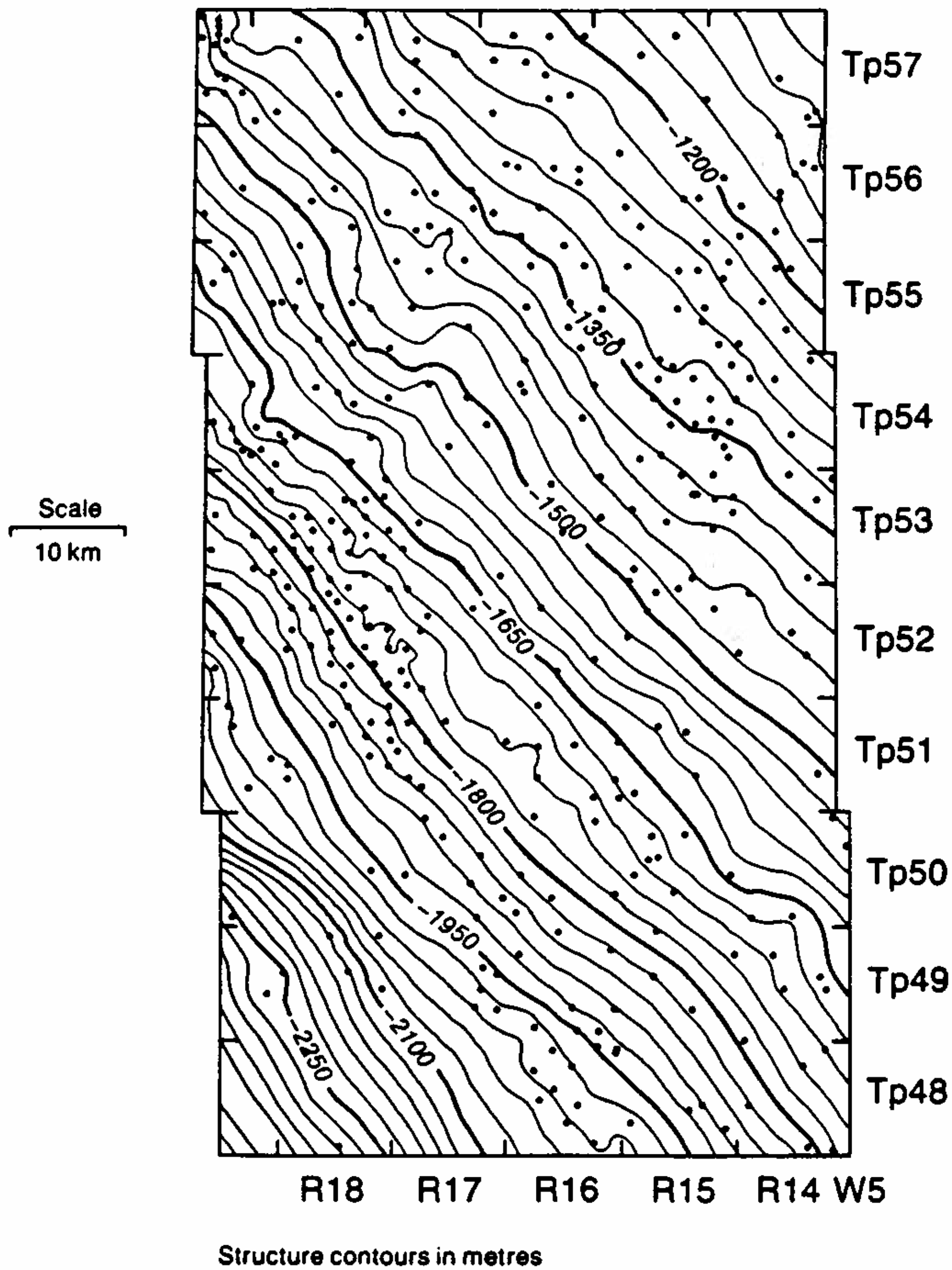


Figure 11. Structure of Poker Chip Shale

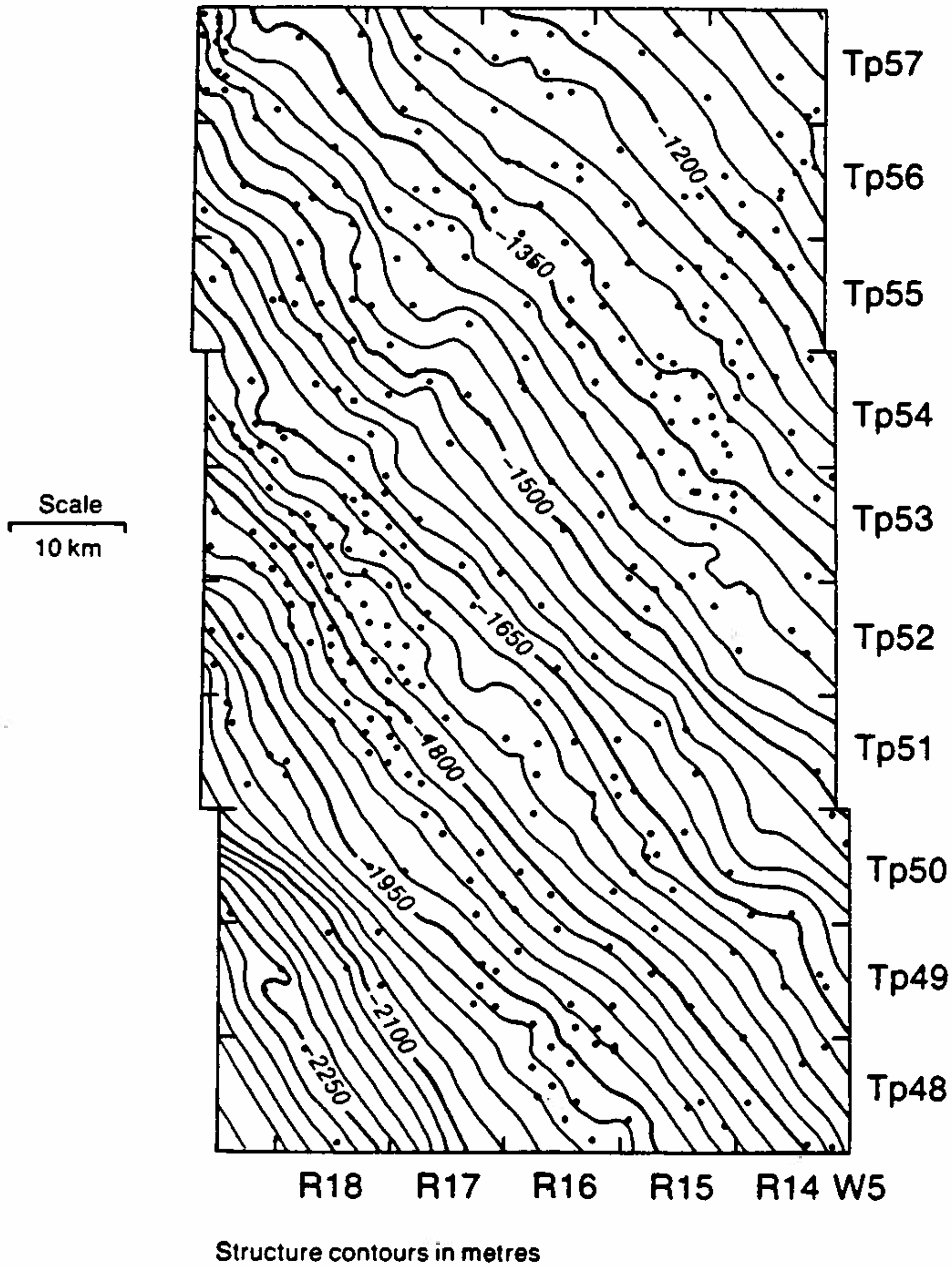


Figure 12 Structure of Rock Creek Mbr.

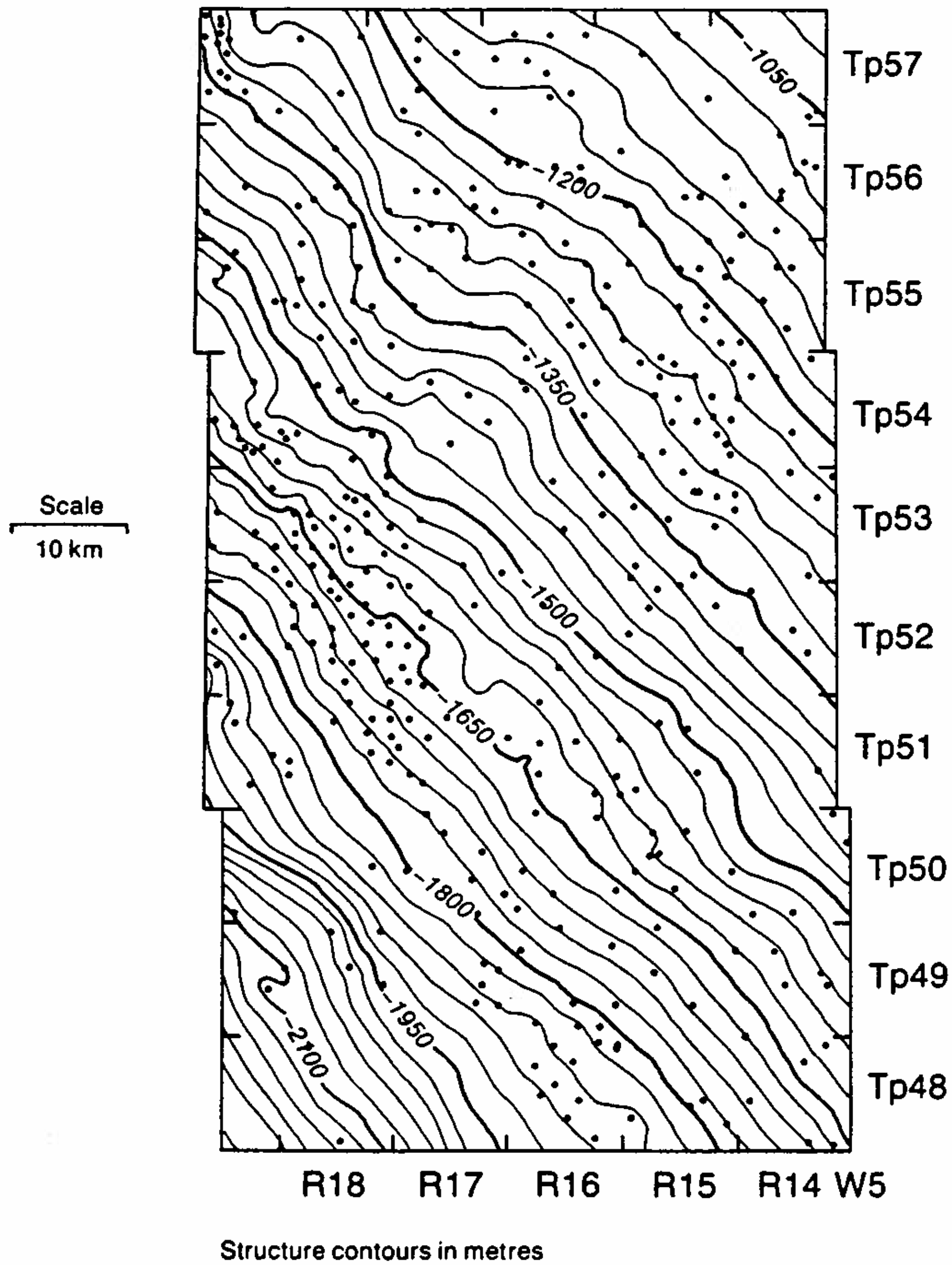
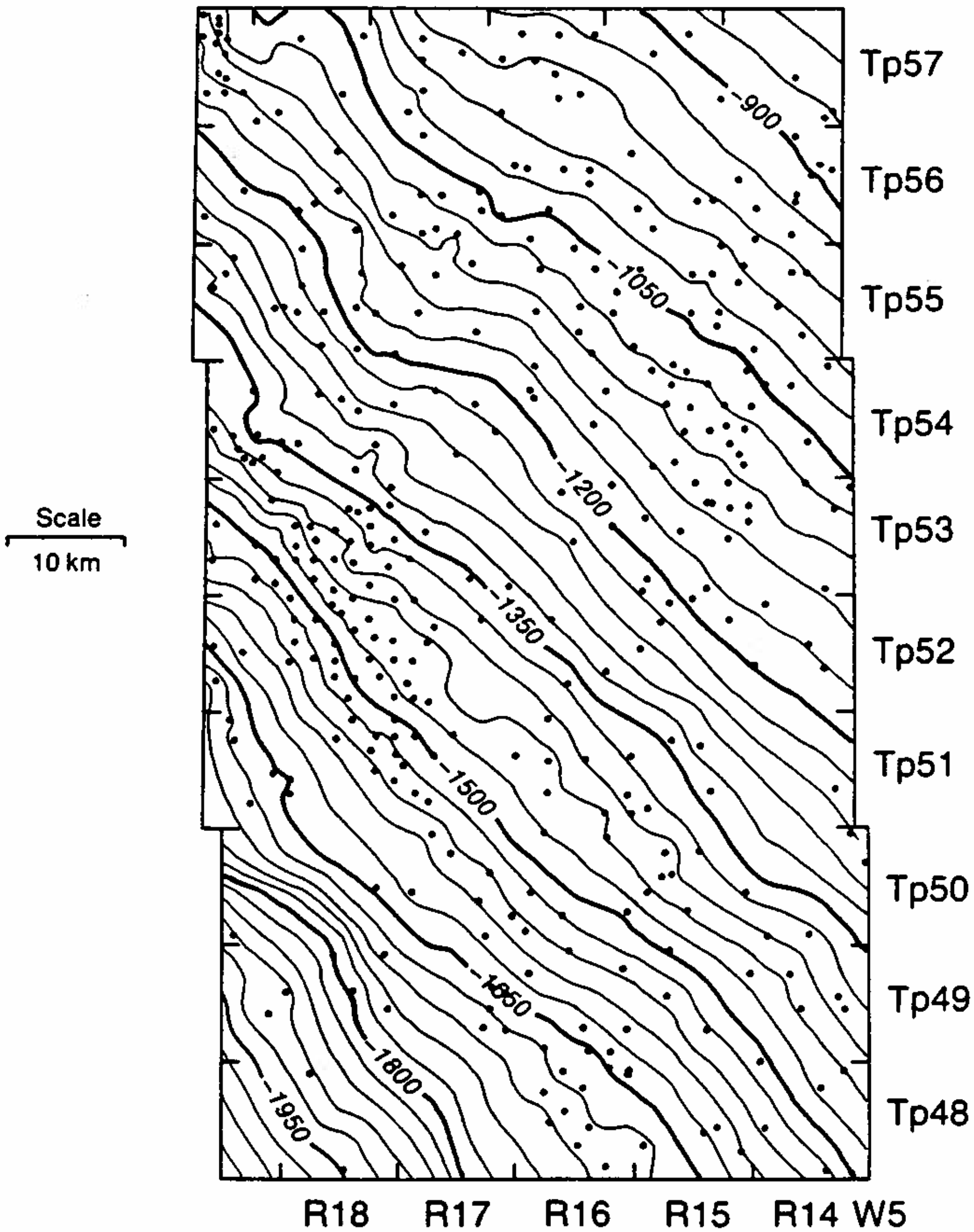


Figure 13 Structure of Glauconitic Sandstone/Bluesky Fm.



Structure contours in metres

Figure 14 Structure of Mannville Grp.

the sub-Jurassic unconformity (top of the Mississippian plus Triassic interval). No structural closures are apparent when using the 30 metre contour interval.

As expected from the position of the study area on the northeast flank of the Western Canadian sedimentary basin, a gradual steepening of the dip can be observed from northeast to southwest in all of the formations as well as in the sub-Jurassic unconformity. For example, the dip of Rock Creek Member (notwithstanding its westerly thinning) increases from approximately 0.5 to 0.6 degrees in the northeast to approximately 0.8 to 0.9 degrees in the southwest part of the study area. Similar values were obtained for the other formations.

DISCUSSION OF RESULTS

ROCK CREEK MEMBER

The cross-sections and isopach map (Figure 7) indicate that the Rock Creek Member is essentially a continuous, mappable unit throughout the entire study area (Tp 48 to 57, R 14 to E1/2 19, W 5 M). Neither a depositional nor an erosional edge of the unit was observed in the mapped area, although pinching out of the Rock Creek and/or its complete erosion can be inferred from several cross-sections to the north of the study area.

Maximum thicknesses of the Rock Creek (25 to 30 metres) are confined to the southeast part of the study area and are similar to those found by Marion (1984, Figure 10) in the Granada area to the east. A conspicuous regional thickness trend can be established from the general, mostly gradual thinning trend of the Rock Creek from east to west (cross-sections A-A' to F-F') and from south to north (cross-sections M-M' to P-P'; see also Figure 7). This regional pattern is evidently of primary (depositional) origin and is consistent with an easterly derivation of Jurassic marine sands prograding westwards and southwestwards into the Fernie basin, as illustrated by Ziegler (1969;

see Figure 1 of this report).

The relatively simple depositional thickness pattern emerging from the cross-sections and the isopach map (Figure 7) is complicated by local channelling which is responsible for a sudden increase in Rock Creek thickness observed in Tp 53, R 18, W 5 M (for example, in well 10-8-53-18W5 shown on cross-section C-C'), with less than 5 metres of Poker Chip Shale (Figure 6) complementing the local Rock Creek thickness high. Also complicating the Rock Creek depositional pattern is an interpreted splitting of the unit into two subunits in Tp 56 to 57, R 17 to 19, W 5 M, as shown on cross-sections F-F' and M-M'.

A conspicuous depositional thinning and pinching out of the Rock Creek has been detected on cross-sections M-M', F-F' and G-G' immediately beyond the northwest corner of the mapped area. Here, a thin sand equivalent to the Rock Creek is found capping, and constituting an inseparable part of, the coarsening-upward sequence of Poker Chip Shale (compare cross-section M-M', wells 10-26-58-18W5 and 12-13-59-18W5; cross-section N-N', well 6-17-60-16W5; cross-section F-F', well 10-13-57-20W5; cross-section G-G', wells 12-13-59-18W5 and 10-11-59-19W5).

As can be seen in the cross-sections, the primary (depositional) pattern of Rock Creek was modified by "pre-Cretaceous" erosion. However, in contrast to Niton, Carrot Creek, Cynthia-Pembina and West Pembina fields where erosion on the "pre-Cretaceous" unconformity locally reached Nordegg to Mississippian levels (Marion, 1982) the Rock Creek appears to be the deepest zone affected by this erosion in the mapped area.

Although continuity of the Rock Creek in the mapped area was not interrupted by "pre-Cretaceous" erosion, log cross-sections indicate a partial to complete removal of the unit in erosional valleys carved through "Upper Fernie" into the upper part of the Nordegg immediately to the north of the study area. These pre-Ellerslie valleys apparently represent tributaries of the regional Mannville drainage system mapped by Williams (1963), and are now infilled with continental Ellerslie deposits.

In the southwest part of the study area effects of "pre-Cretaceous" erosion can be inferred from sudden changes in Rock Creek thickness in a northwest-southeast trending Cadomin-filled low delineated, on the northeast side, by an approximately 30 to 40 metre rise in pre-Cadomin relief possibly corresponding to or parallel with what has been vaguely called the Fox Creek Escarpment. Here, much or all of the "Upper Fernie" and locally also part of the Rock Creek was removed, so that Rock Creek sandstones may be directly overlain by sandstones and conglomerates of Cadomin age (cross-sections A-A', B-B', M-M'), as observed in Tp 49, R 18, W 5 M.

Logs and core study indicate that the Rock Creek Member, although occurring as a continuous stratigraphic unit throughout the study area, is far from being homogeneous and uniform in lithology. The inhomogeneity of the unit is "graphically" illustrated by variable geophysical log motifs, especially those seen on the gamma ray response curve. "Boxy" (flat-top, flat, abrupt base) motif typical, in conjunction with the presence of glauconite and coquinoid facies, of marine shelf deposits such as tidal sand bodies, migrating sand waves and ridges with local channelling, is fairly common and corresponds to a major clean sand body usually interrupted by one or more siltstone or shale breaks. A major siltstone break up to 10 metres thick and correlative with the "Siltstone Unit" of Marion (1982) in the Granada area is also developed in the eastern part of the study area (cross-section B-B'). However, the "Siltstone Unit" rapidly thins (or splits) towards the west and is no longer mappable, although an analogous, "two-prong" pattern (with two sandstone bodies separated by a thin intervening siltstone to shale layer) can be traced in many wells and over a considerable distance (compare cross-sections D-D' and E-E').

In most of the study area, however, the "boxy" log motif shows gradational variations towards more complex patterns involving almost separate sand sheets and minor fining-upward sequences atop or within the main sand body: in particular, an upward-coarsening sequence frequently observed at the base of the main (or lowermost) sand body and gradually evolving from the underlying Poker Chip Shale. The latter is of particular importance and will be discussed later.

The vertical and lateral lithological variability and inhomogeneity of the Rock Creek Member, together with the tendency of Rock Creek sandstones to develop a tight "facies" by diagenetic recrystallization, (and cementation) are responsible for the reservoir-quality clean sands occurring as discontinuous bodies with unpredictable incoherent domains of good porosity and permeability, and also make the whole unit somewhat unpredictable from the exploration and production point of view. As a result, the extent and continuity of hydrocarbon reservoirs in the Rock Creek is not readily predictable. In rare cases, two or more stacked, but vertically separated reservoirs may occur within the Rock Creek due to reduced vertical permeability. On the other hand, examples are known where vertical communication exists between hydrocarbon reservoirs in the Rock Creek and those located in directly overlying Lower Mannville sandstones, although even in such cases low permeability barriers may interrupt the communication.

ROCK CREEK-POKER CHIP SHALE RELATIONSHIP

Except in three wells in Tp 53, R 18, W 5 M where Rock Creek rests directly on Nordegg (as exemplified by well 10-8-53-18W5 on cross-section C-C'), Rock Creek is everywhere underlain by Poker Chip Shale. It is not clear whether the absence of Poker Chip in the above case is due to non-deposition or erosion, but channeling of Rock Creek (interpreted from gamma ray log pattern) may be one possible explanation.

Poker Chip Shale is typically a shaly unit, with minor siltstone and sandstone layers occurring throughout the unit but mainly concentrated in its upper part. Some of these are lenticular and of local importance, but some siltstone or sandstone beds within the Poker Chip Shale, although only 1 to 3 metres thick, are of broad areal extent and can be correlated for dozens of kilometres (cross-sections A-A', D-D', E-E', F-F', G-G').

Despite irregular variations in sand content that can be observed across the Poker Chip Shale interval, gamma ray logs from numerous wells in and beyond the study area indicate that as a whole the Poker Chip Shale is a continuous, coarsening-upward sequence with sand content generally increasing towards its top. In many cases, such as those illustrated by wells 7-28-52-17W5, 10-8-51-7W5 and 14-29-54-17W5 (all on cross-section N-N'), or 11-6-54-14W5 (cross-section P-P') and 10-19-51-15W5 (cross-section B-B'), the basal sandstone beds of the Rock Creek can be regarded as a direct continuation and an integral part of the Poker Chip sequence. Such gradual transition between these two units makes the placing of the contact between the two on logs rather arbitrary.

The same conclusion - interpretation of Poker Chip and Rock Creek as inseparable parts of one single sequence - is reached when thick Rock Creek sandstones are traced westwards and northwards into areas where thinning of the sandstones occurs and where thin Rock Creek sand equivalents caps, and is part of, the coarsening-upward sequence of Poker Chip Shale (cross-sections F-F', G-G'). Such a conclusion is in good agreement with the gradational contact between Poker Chip Shale and Rock Creek Member observed in Rocky Mountain outcrops by Stronach (1981, 1984) and Hall (1984).

The observation of a gradual transition between Poker Chip Shale and Rock Creek Member does not support the assumption of an unconformity separating Poker Chip and Rock Creek, as inferred (in Granada area) from the presence of scattered shale clasts in the base of Rock Creek and from frequent sharp contact between the two on gamma ray logs (Marion, 1982, p. 36, 37; 1984). It has been shown in the previous discussion that local channelling of the Rock Creek into underlying, already-compacted Poker Chip sediments during the migration of shallow-marine sand bodies can be responsible for the flat-base gamma ray motif of the Rock Creek base, and it is thought that the same mechanism can account for the presence of shale clasts in basal Rock Creek sandstones.

ROCK CREEK-"UPPER FERNIE"-L. CRETACEOUS RELATIONSHIPS

In most parts of the study area the Rock Creek is overlain by a rather monotonous sequence, up to several dozen metres thick, which consists of shales interlayered with minor siltstone and sandstone bodies. Similar to the Granada area, the contact is usually abrupt in both logs and cores (although some aberrations were found in the study area) and together with the presence of phosphatic nodules in basal shales immediately above the Rock Creek sandstones may be indicative of an unconformity (Marion, 1982).

Clean shales frequently occurring at the base of the above sequence have been informally termed "Upper Fernie" and considered Passage Beds - Kootenay equivalent in the Granada area (Marion, 1982), and were interpreted as Passage Beds in the west (Harris, 1981), whereas interbedded "lenticular" shales, siltstones and sandstones above them were referred to as Lower Mannville by both of these authors. However, differentiation of, and locating the contact between, the "Upper Fernie" shales and Lower Mannville where developed as a shaly facies is extremely difficult and the contact has therefore been arbitrarily set "...at the point where interbedded sandy shales of Mannville Group meet the more homogeneous, fine-grained shales of the Fernie Group..." (Harris, 1981, p. 18), or "...at the first median value that occurs in the shale sequence..." (Marion, 1982, p. 36).

In the absence of other criteria this approach was applied on a trial basis in the present study (shown on cross-sections as dashed lines) but it was soon realized that if strictly adhered to it would inevitably lead to "artificial" contacts. Close inspection of gamma ray logs reveals that in many instances the clean shales corresponding to "Upper Fernie" or Passage beds represent the lowermost, but integral part of a continuous upwards-coarsening sequence in which it is impossible to locate the Upper Jurassic-Lower Cretaceous contact. In other cases, placing the boundary between the two according to the above criteria would mean illogically locating the contact in the middle of a continuous upward-coarsening sequence.

This and other considerations (unknown precise stratigraphic position of basal clean shales and of the whole coarsening-upward "Upper Fernie"-Lower Mannville boundary sequence; inability to precisely correlate subsurface Jurassic and Lower Cretaceous with Rocky Mountain outcrops; lack of cores in the critical interval) make the contacts (as shown on the cross-sections by dashed lines) only of schematic value and indicate that further study is needed to elucidate the location of the contact and the nature of a "sub-Cretaceous" unconformity.

NORDEGG MEMBER-POKER CHIP SHALE RELATIONSHIP

The Nordegg Member is a ubiquitous unit throughout the mapped area and has a fairly constant thickness varying between 40 and 60 metres. Although thinning to 28 to 30 metres was detected adjacent to the northwestern part of the study area (cross-section G-G') the unit was apparently not exposed at the pre-Ellerslie surface and was not affected by the pre-Ellerslie erosion in the study area.

The top of the Nordegg Member and its contact with Poker Chip Shale are generally well-defined and easily picked on gamma ray logs, although difficulties arise when the Nordegg top displays a step-like pattern on gamma ray logs in some wells in the east. However, in the western part of the study area, and especially to the northwest of it, doubts arise as to the location of the Nordegg-Poker Chip contact.

As best illustrated on logs of the three westernmost wells in cross-sections F-F' and G-G', a thin but regionally extensive, strongly radioactive zone occurs less than 10 metres above the flat gamma ray curve deflection which is usually picked as Nordegg top. The nature of the intervening interval (between the radioactive zone and the flat gamma ray deflection), which generally thins eastwards (as the radioactive zone approaches the flat deflection) is unknown, as is its precise age.

Although a traditional approach was followed (due to lack of core) in the present work and the flat gamma ray curve deflection was picked as the Nordegg top, it seems possible that it is the conspicuous radioactive zone that may represent the top of the Nordegg. For this reason, log depth of the radioactive zone was also picked in all cases where the latter is identifiable on logs and reconstruction of a different Nordegg top is thus possible from the computer-stored data.

Where present and well-developed, the radioactive zone has a resistivity within the 1 to 50 ohm range and is easily correlative over thousands of square kilometres in the western part of the study area and west of it. The cause of this increased radioactivity (which evidently occurs at a well-defined stratigraphic level) is unknown, but an unconformity-associated (?) phosphatic layer containing radioactive compounds may be a logical explanation. As such, the zone may be indicative of a hiatus or unconformity at or close to the Nordegg-Poker Chip Shale boundary.

CADOMIN FORMATION

Confined to the extreme southwest part of the study area and extending for hundreds of kilometres beyond, the Cadomin Formation is built up of a lithologically-distinct, 20 to 35 metre thick clastic sequence at the base of the Gething Formation, and is underlain by "Upper Fernie" shales or directly by the Rock Creek Member (cross-sections M-M', N-N', A-A' to F-F').

The Cadomin Formation is recognized on gamma ray logs as a motif typically involving a "blocky" to upward-fining sequence with abrupt base, and fills a prominent paleotopographic low delimited, on the northeast side, by a moderate rise in Jurassic subcrop. Cross-sections A-A', B-B' and N-N' demonstrate that the relief on the rise (which may possibly correspond to what is called the "Fox Creek Escarpment") is between 20 and 35 metres and also that the Cadomin thins rapidly as the western face of the rise is approached.

Although existing isopach maps of the Cadomin (McLean, 1977; Harris 1981) depict a sharp and relatively straight northeastern depositional edge of this unit, the east-west cross-sections A-A' and C-C' indicate that Cadomin, in a lateral less-clean (silty) lithofacies may extend farther east than previously mapped. Also, log characteristics (not confirmed in this study by core or cutting) in the Lower Cretaceous section in several wells in the southeast corner of Tp 54, R 18, W 5 M and in the extreme western part of Tp 53, R 17, W 5 M indicate that a separate (?) Cadomin outlier may occur in the study area, beyond the main Cadomin body mapped by McLean and Harris.

Study of a few Cadomin cores (from 7-3-50-19W5) reveal that in contrast to clean quartzarenites of the Rock Creek Member, Cadomin lithology is characterized by a "salt-and-pepper" type sandstone containing grains of black, bluish and white chert and fine conglomerates with pebbles up to 2.5 cm in size and of identical composition.

ROCK CREEK MEMBER - CADOMIN FORMATION AND ROCK CREEK MEMBER - ELLERSLIE MEMBER RELATIONSHIP

One of the most intriguing features observed in the study area is the vertical juxtaposition of the Rock Creek Member sandstones with Lower Cretaceous (Ellerslie and Cadomin) sandstones in places where intervening shales of "Upper Fernie" and Lower Cretaceous are absent due to non-deposition or erosion. Responsible for possible vertical communication of hydrocarbon reservoirs, such direct contacts are restricted to the westernmost part of the study area (Cadomin-Rock Creek contacts) and to its easternmost part adjoining the Niton, Carrot Creek, Cynthia-Pembina and West Pembina fields (Rock Creek-Ellerslie contacts).

In the west and southwest, Cadomin is usually separated from Rock Creek by shales of "Upper Fernie" that may be up to 30 metres thick, but locally the two units are in a direct contact (sandstone on sandstone). Although such contacts cannot be definitively interpreted solely with the aid of logs, and very few wells were cored in the critical interval, bit cuttings can be used to locate the contact based on the distinctly different lithologies of the Rock Creek and Cadomin sandstones.

Using this approach, a conspicuous thickening of Cadomin (complemented by lows in Rock Creek isopach) was detected on some of the cross-sections (B-B', M-M') along the Fox Creek Escarpment, suggesting that prior to Cadomin deposition the Rock Creek sandstones were locally exposed along the escarpment and were subject to extensive "pre-Cretaceous" erosion. The latter, coupled with primary (depositional) westward thinning and pinching out of the Rock Creek makes the identification of Rock Creek in logs, and mapping of its western depositional and erosional edges, a difficult task.

In the easternmost part of the mapped area an analogous situation exists where Rock Creek, possibly partly eroded, is directly overlain by sandstones present in the basal section of the continental Ellerslie series. On logs and in cores such situations are characterized by a thick (up to 40 metres), multiple sandstone sequence (irregularly interrupted by minor shaly and silty breaks) at the Jurassic-Lower Cretaceous boundary and has been previously recognized east of the study area, particularly in the Niton field. Here, in the absence of paleontological evidence, individual sands in this boundary sequence have been described using local names such as Niton "A", "B", "C" sands, as exemplified by the well 10-14-54-13W5M in cross-section D-D'.

Although Horne and others (1982) considered the Niton "A", "B", "C" sands as being all Lower Cretaceous ("Basal Quartz") in age, Marion (1982) was able to discriminate Rock Creek sandstones from Ellerslie sandstones and showed that the lowermost Niton sandstone ("C") correlates lithologically, petrographically and paleontologically with the Middle Jurassic Rock Creek Member. While most workers now agree that the Niton "C" sand corresponds to the Rock Creek Member and the Niton "A" sand belongs to Ellerslie Member, opinions regarding the origin and age of the Niton "B" sand are not uniform, with Jurassic and Ellerslie being proposed as alternatives.

In order to obtain more accurate data relative to the Niton "B" sand, (which is an important oil and gas producer) a core study of the Jurassic-Lower Cretaceous boundary sandstone package was undertaken by the author and a micropaleontological (mainly palynological) analysis of shales and siltstones, interlayered with the individual sands was performed by Dr. C. Singh of the Alberta Research Council. Although this study is still in progress some important results have already emerged, the details of which are as follows.

Cores from five wells in the Niton field (10-14-53-13W5, 4-30-54-12W5, 6-32-54-12W5, 6-5-55-12W5 and 6-13-55-12W5) were selected for the study because in all of them the "B" sand can be easily correlated and is invariably overlain by a coarsening-upwards sequence topped by Niton "A" sand. In all of the above wells the "B" sand is 4 to 6 metres thick and is marked by a double peak on gamma ray logs. It is characterized by a small amount of glauconite (locally with pyrite), bioturbation and also by high porosity, especially when compared with the rather tight "C" sand. Judging from its composition and structures, a marine origin of the "B" sand can be suggested.

Palynological examination of shales and silty shales within and immediately below the "B" sand revealed the presence of abundant Jurassic dinoflagellates (along with an acritarch species), which are indicative of an open marine environment during the deposition of the "B" sand. The following species were identified: Apteodinium nuciforme (Deflandre) Stover and Evitt, 1978; Egmontodinium torynum (Cookson and Eisenack) Davey, 1979; Gonyaulacysta jurassica var. longicornis (Deflandre) Sarjeant, 1982; Hystrichogonyaulax cladophora (Deflandre) Stover and Evitt, 1978; Jansonia jurassica Pocock, 1972; Glomodinium evittii (Pocock) Davies, 1983; Pareodinia ceratophora Deflandre, 1947; Senoniasphaera jurassica (Gitmez and Sarjeant) Lentin and Williams, 1976; Sentusidinium sp.A; Sentusidinium sp.B; Sentusidinium sp.C; Veryhachium sortehatense Fensome, 1979.

A major palynofloral and paleoenvironmental change at the top of the "B" sand points to the onset of continental, fresh-water sedimentation producing the coarsening-upward Ellerslie sequence (including the "A" sand) followed by the deposition of Ostracod Zone sediments (with a characteristic early Albian dinoflagellate Muderongia spp.) originating in a very low-saline, brackish environment. True marine sediments are represented by overlying deposits of the Glauconitic Bluesky Formation.

CONCLUSIONS

1. Shallow-marine sediments of the Jurassic Rock Creek member (mainly quartzarenites and siltstones with subordinate shales and coquinas) are present throughout the entire study area (Tp 48 to 57, R 14 to E1/2 19, W 5 M). Neither a depositional nor an erosional edge of the unit was detected in the area, but thinning and/or partial to complete erosion of Rock Creek member was observed immediately to the northwest.

2. Log cross-sections and isopach maps based on 406 wells from an area of approximately 5500 km^2 indicate a depositional thinning of Rock Creek from east to west and northwest suggesting an easterly derivation of the Rock Creek clastic sediments.

3. Although mappable over large areas, the Rock Creek Member is not a lithologically homogeneous unit and reservoir-quality clean sands within it occur as discontinuous, separate bodies. This, together with porosity reduction due to diagenetic recrystall-ization, means that the areal extent and lateral as well as vertical continuity of hydrocarbon reservoirs in Rock Creek may be much less than commonly assumed.

4. With rare exceptions the Rock Creek Member is underlain in the mapped area by, and gradually develops from, the shale-siltstone-sandstone sequence representing the Poker Chip Shale. The two units are interpreted as a single, coarsening-upwards sequence with no intervening unconformity. However, local channelling in the Rock Creek may be responsible for local removal of the Poker Chip Shale (detected in a few wells), for the flat (abrupt) base of basal Rock Creek sandstone observed on gamma ray logs, and also for the presence of shale clasts in basal Rock Creek sandstone beds.

5. Dark marine shales underlying the Rock Creek and usually interpreted as "Upper Fernie" often represent the lowermost part

of a vertically-continuous, coarsening-upwards sequence in which the Jurassic-Lower Cretaceous contact (and the "sub-Cretaceous" unconformity) are impossible to define solely on the basis of logs. In the absence of cores and accurate paleontological dating the stratigraphic span of "Upper Fernie" and its relationship to Lower Cretaceous is still open to question, and requires further study.

6. In contrast to the Niton, Carrot Creek, Cynthia-Pembina and West Pembina field areas, the Rock Creek Member is the deepest (oldest) unit affected by pre-Ellerslie erosion in the study area. Within the latter the continuity of the Rock Creek Member has not been interrupted, but to the north the Rock Creek sediments were completely removed in pre-Ellerslie valley(s) carved into the Jurassic (as a part of the Lower Mannville drainage system) and subsequently filled with continental Ellerslie sediments.

7. In the southwest corner of the study area, and adjacent to it, effects of "sub-Cretaceous" erosion are reflected by sudden changes in the thickness of the Rock Creek, and also by its partial to almost complete erosion in an extensive, northwest-southeast trending, Cadomin-filled low. Upper parts of the continental Cadomin clastic wedge, developed as a "less clean" silty to shaly lithofacies, may extend beyond the northeast boundary of the low (which is emphasized by a rise in Jurassic subcrop possibly corresponding to the "Fox Creek Escarpment").

8. Locally, "sub-Cretaceous" erosion of "Upper Fernie" followed by subsequent infilling of paleotopographic lows by Ellerslie (or Cadomin) resulted in the deposition of Ellerslie (or Cadomin) sandstones directly on sandstones of the Rock Creek Member. In such stacked sandstone sequences the contact of Rock Creek sandstones with Lower Cretaceous sandstones cannot be delineated solely on the basis of geophysical logs. Core study, especially

when complemented with palynological examination, is the only reliable tool for distinguishing between the Jurassic and Lower Cretaceous sandstones.

9. Palynological dating of the multiple, hydrocarbon-bearing sandstone sequence developed at the Jurassic-Lower Cretaceous boundary in the Niton field indicates that both Niton "C" and "B" sands are of shallow-marine origin and Jurassic in age, whereas Niton "A" sand is a part of the continental, Lower Cretaceous Ellerslie sequence.

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FIGURE CAPTIONS

Stratigraphic Cross Sections, Rock Creek Mbr. Edson Area, West Central Alberta

A-A′, B-B′, C-C′

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Alberta Energy and Natural Resources

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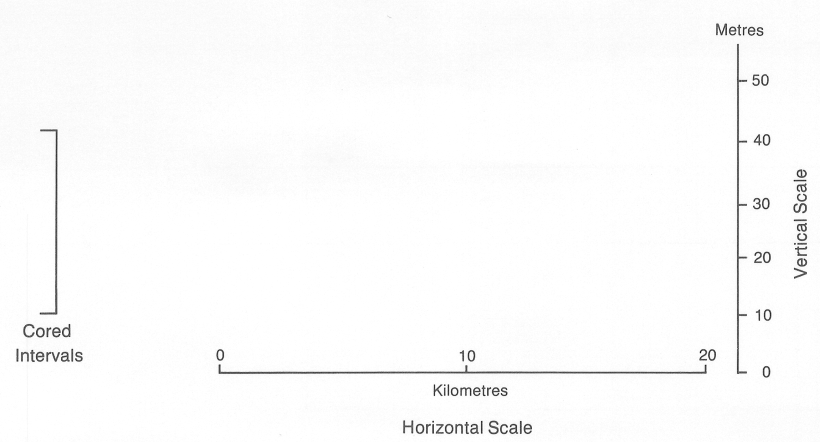
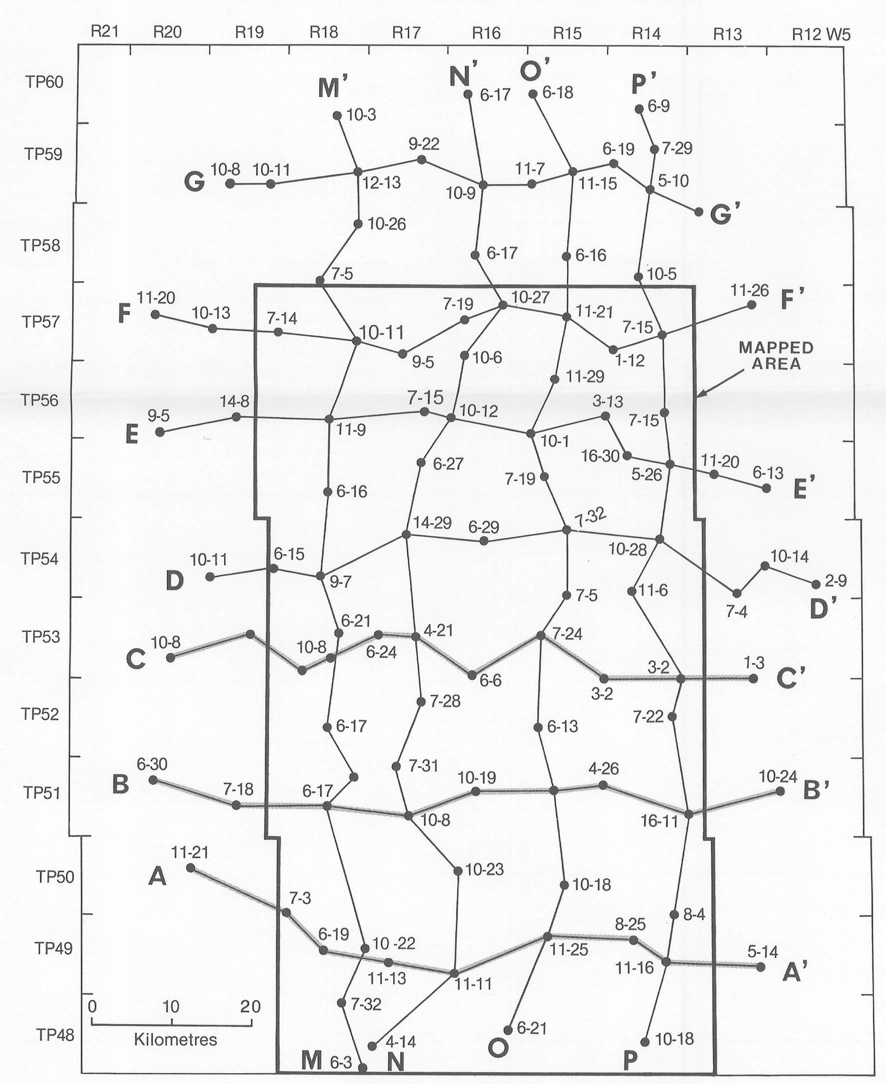
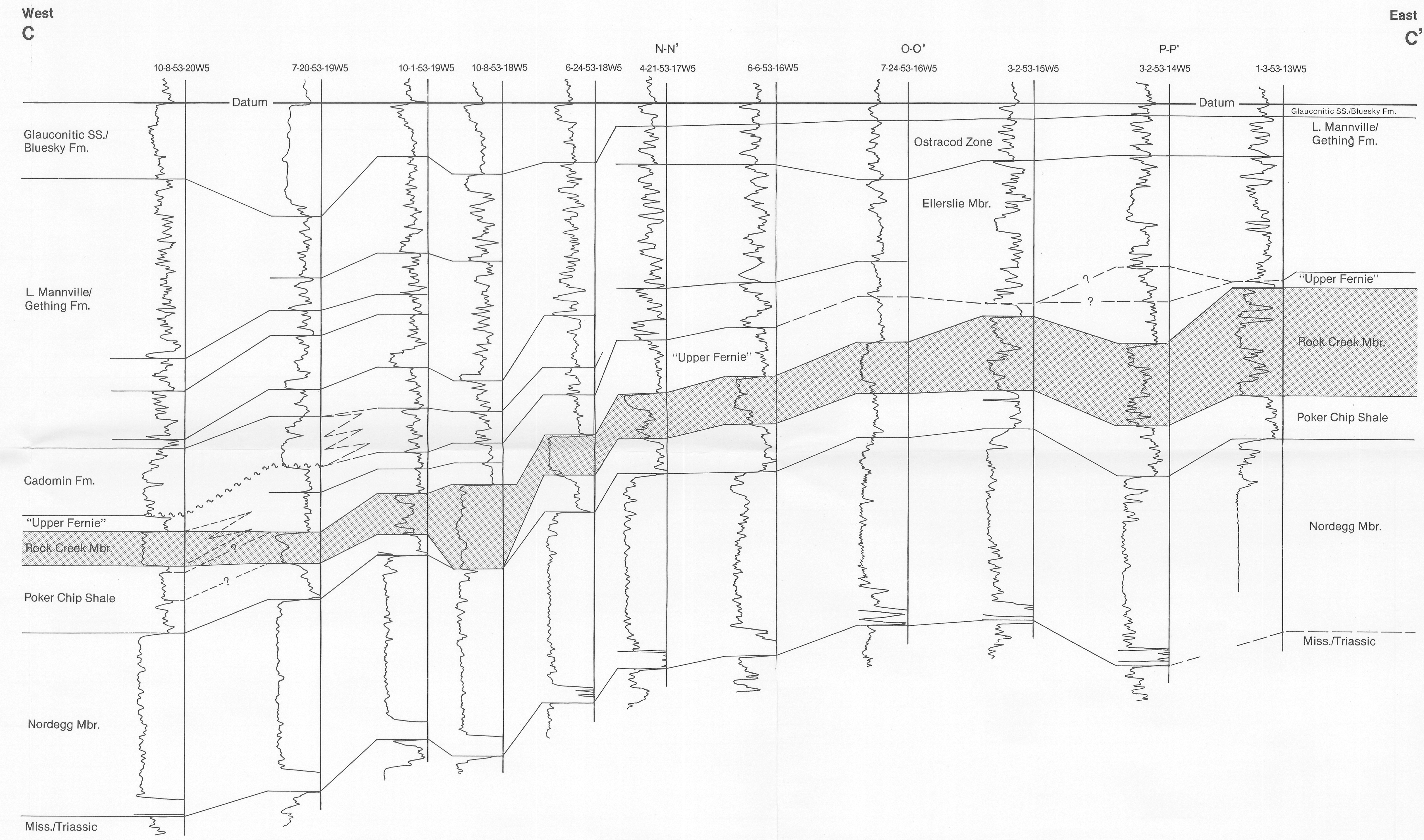
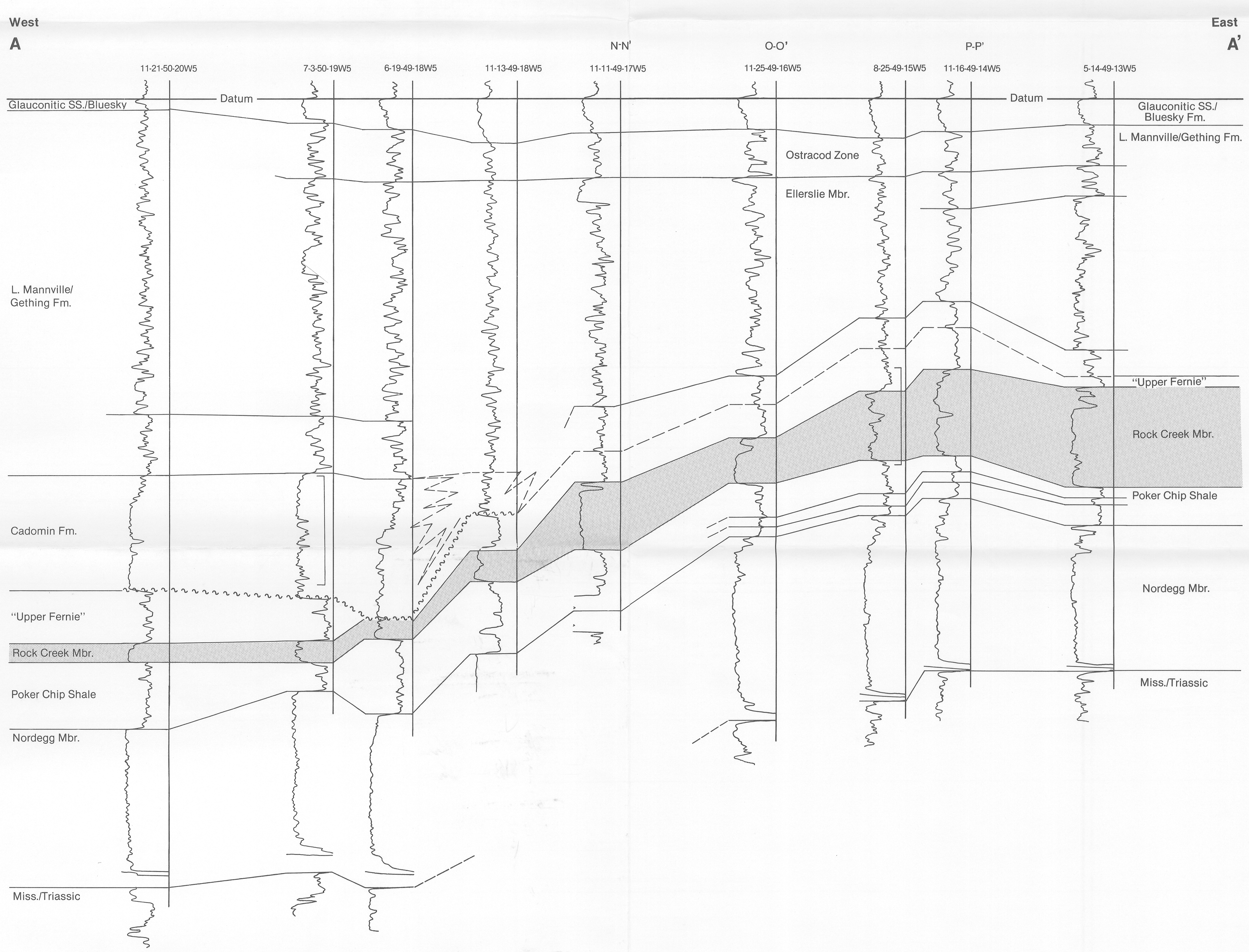
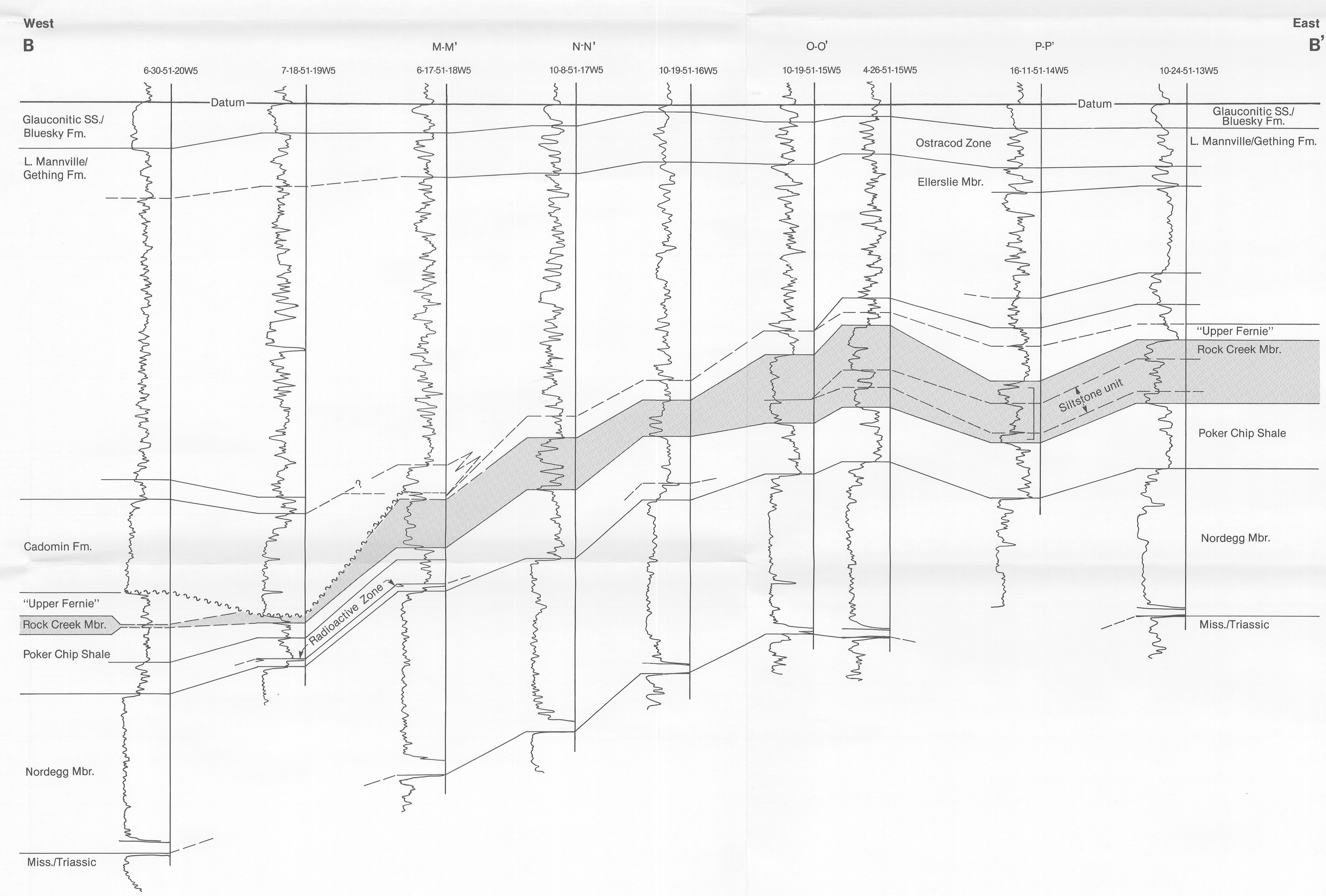


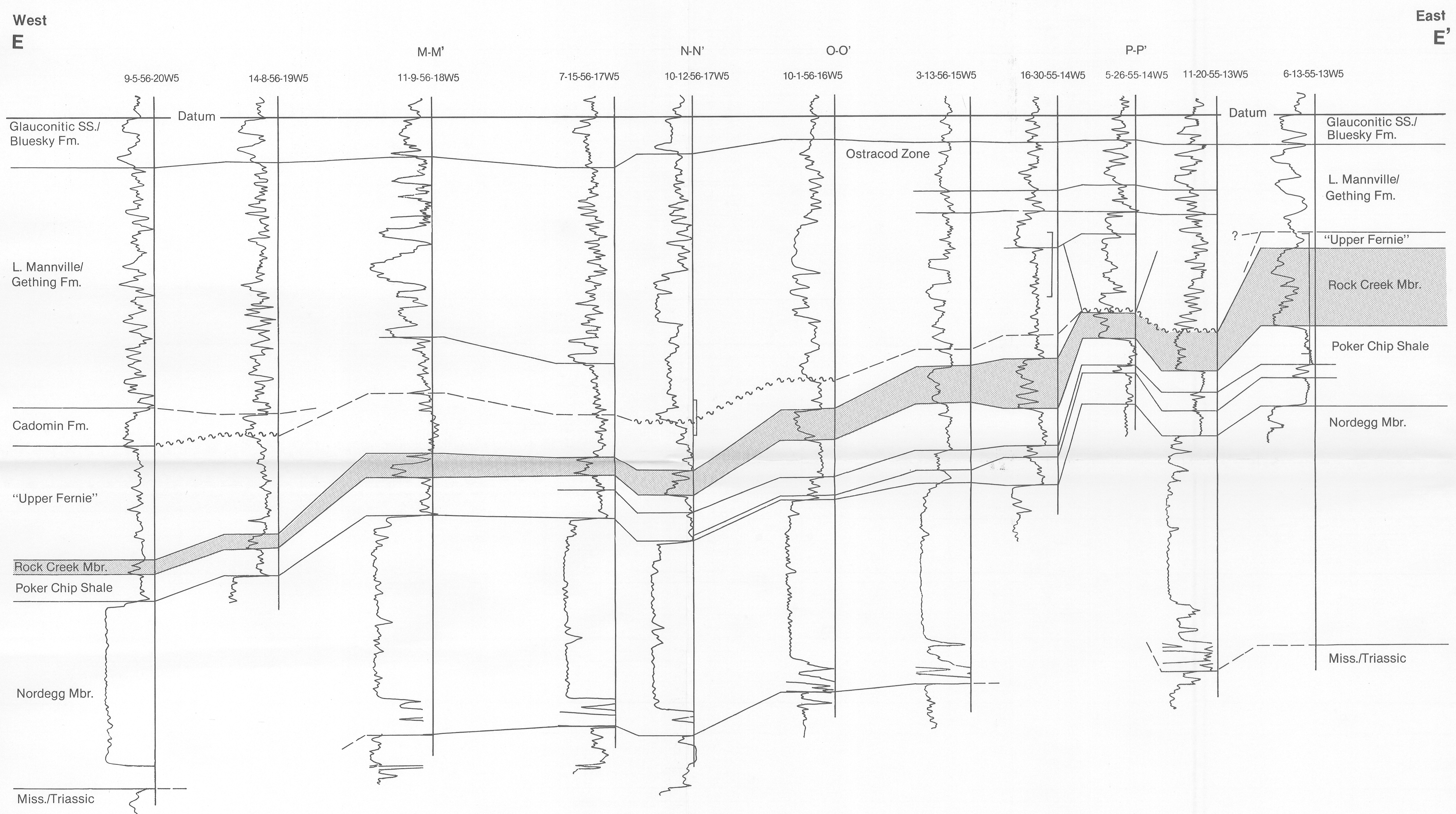
Location of Cross Sections

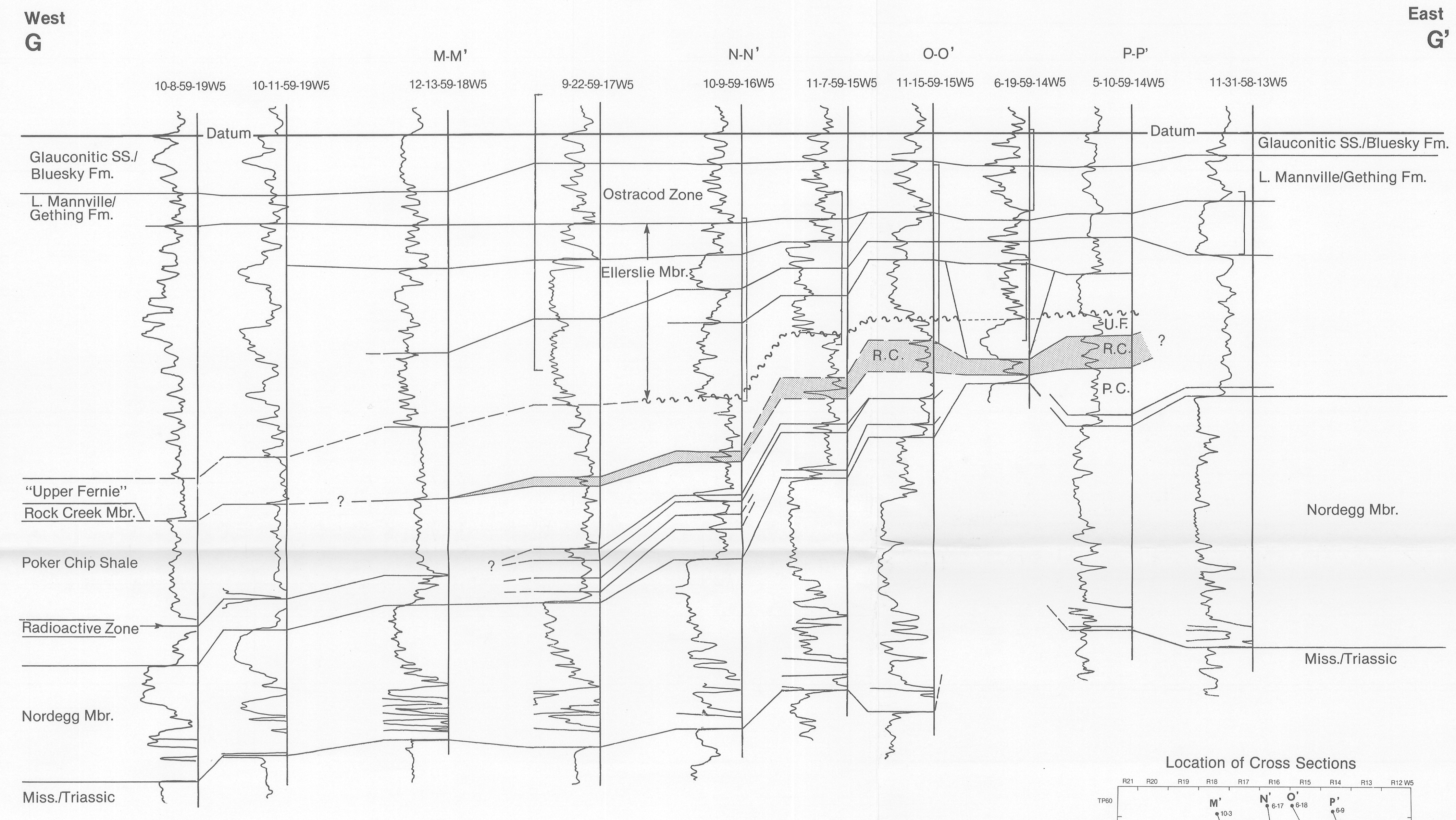


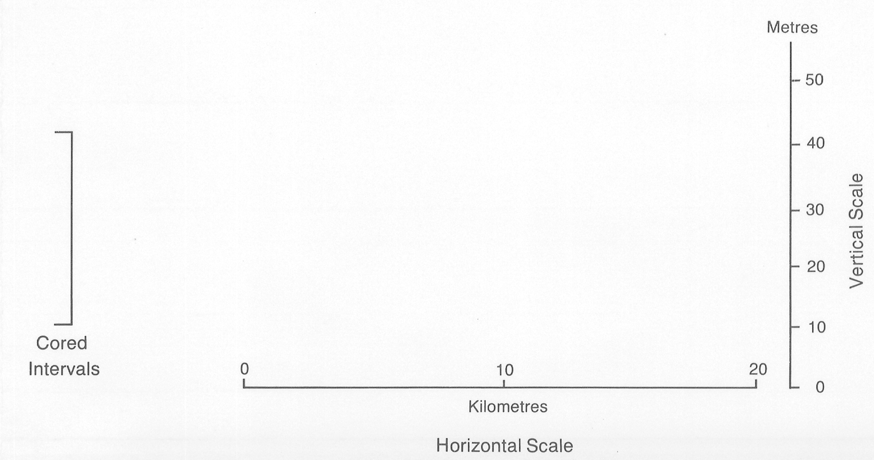


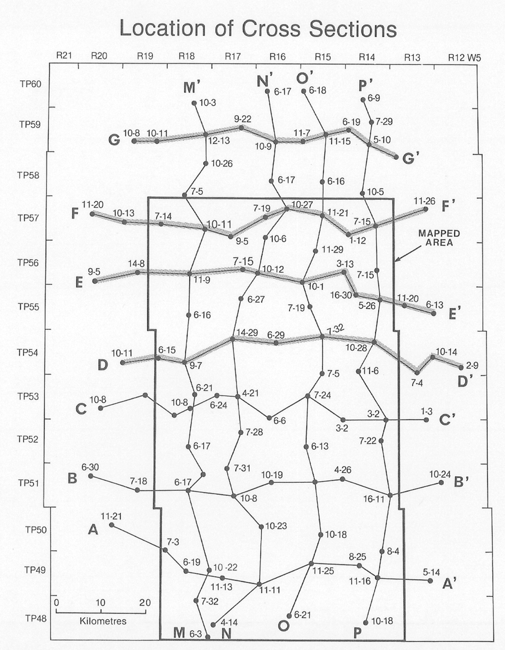


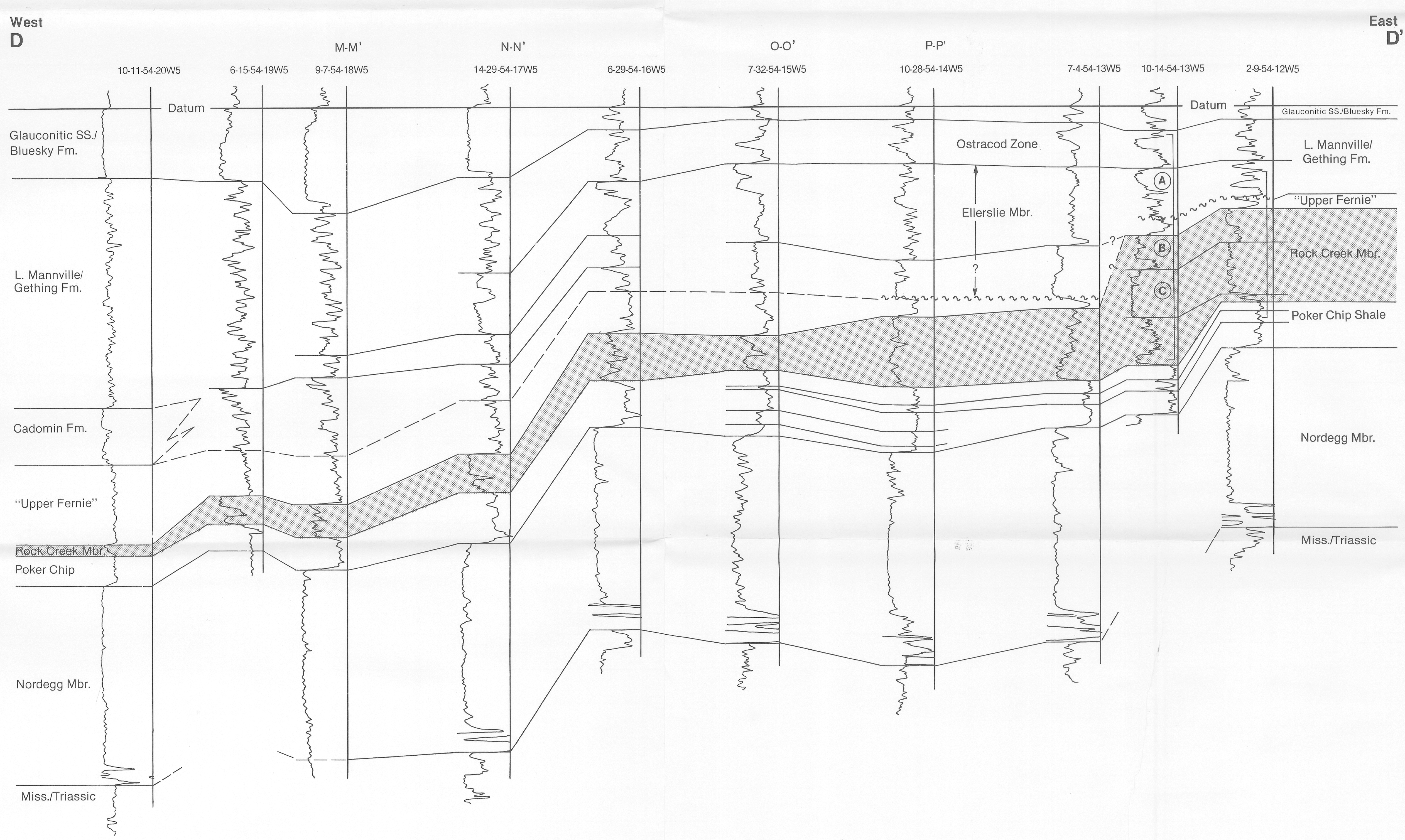


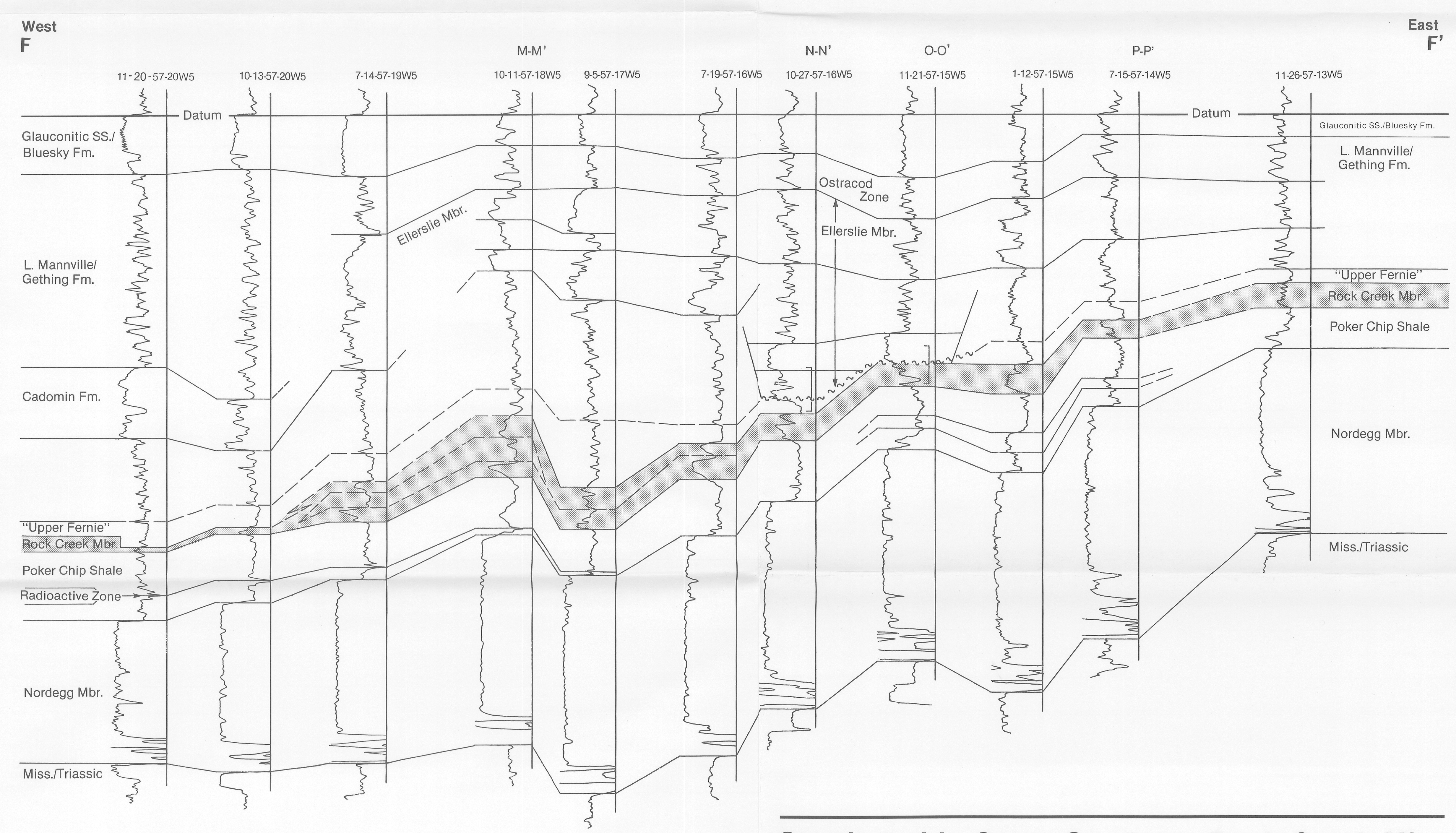












Stratigraphic Cross Sections, Rock Creek Mbr. Edson Area, West Central Alberta

D-D′, E-E′, F-F′, G-G′

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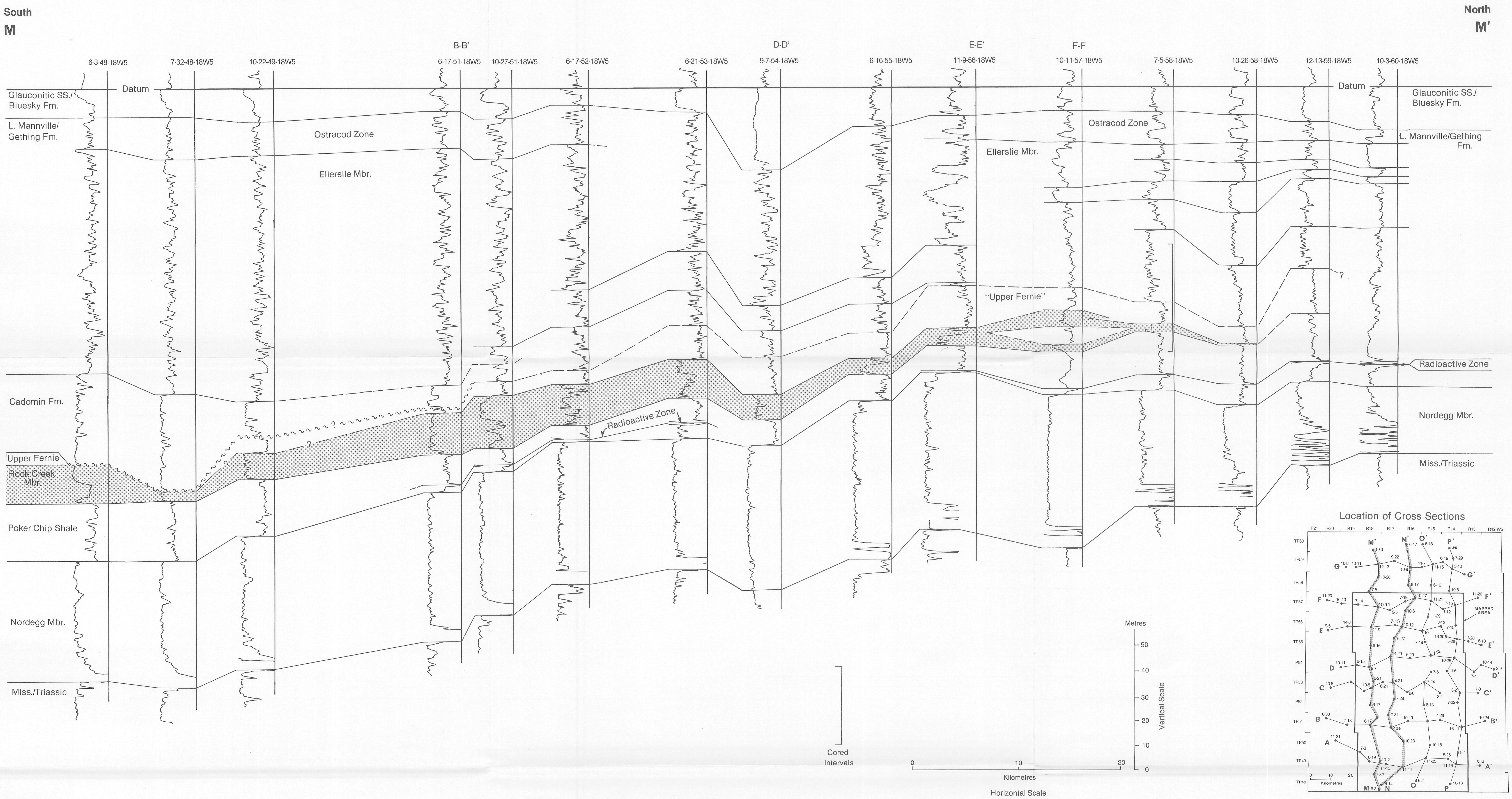

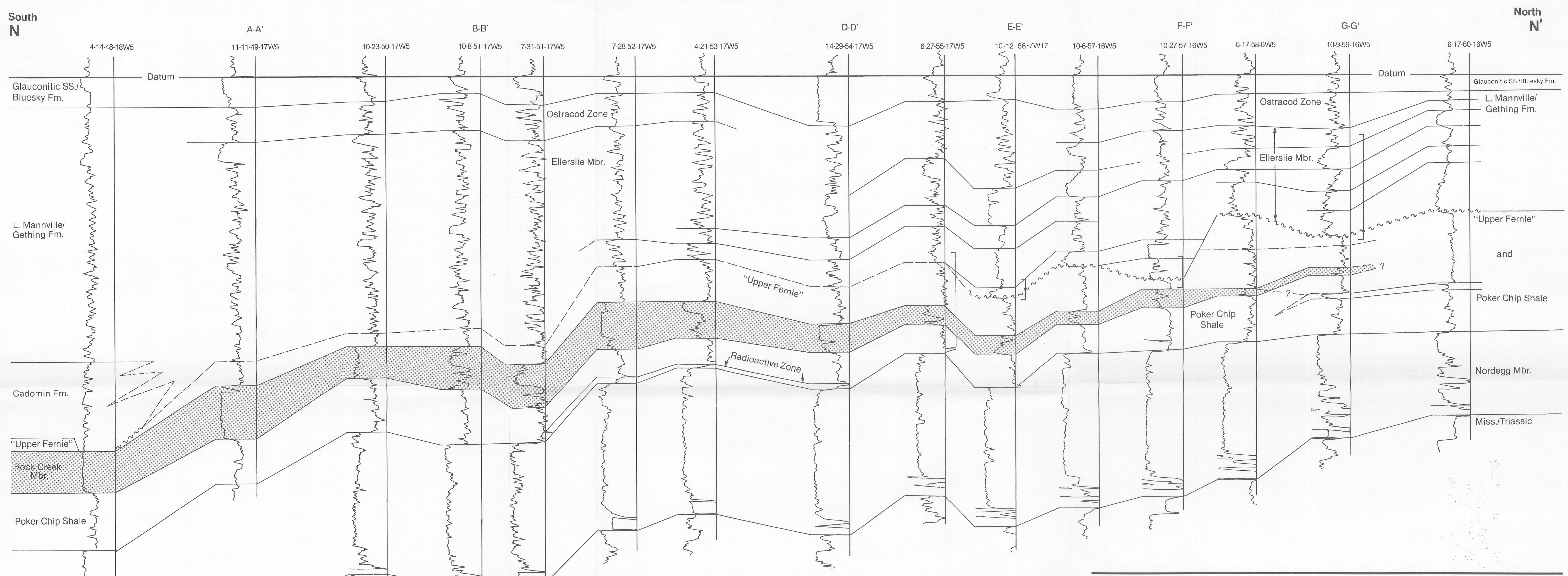

Stratigraphic Cross Sections, Rock Creek Mbr. Edson Area, West Central Alberta

M-M′, N-N′

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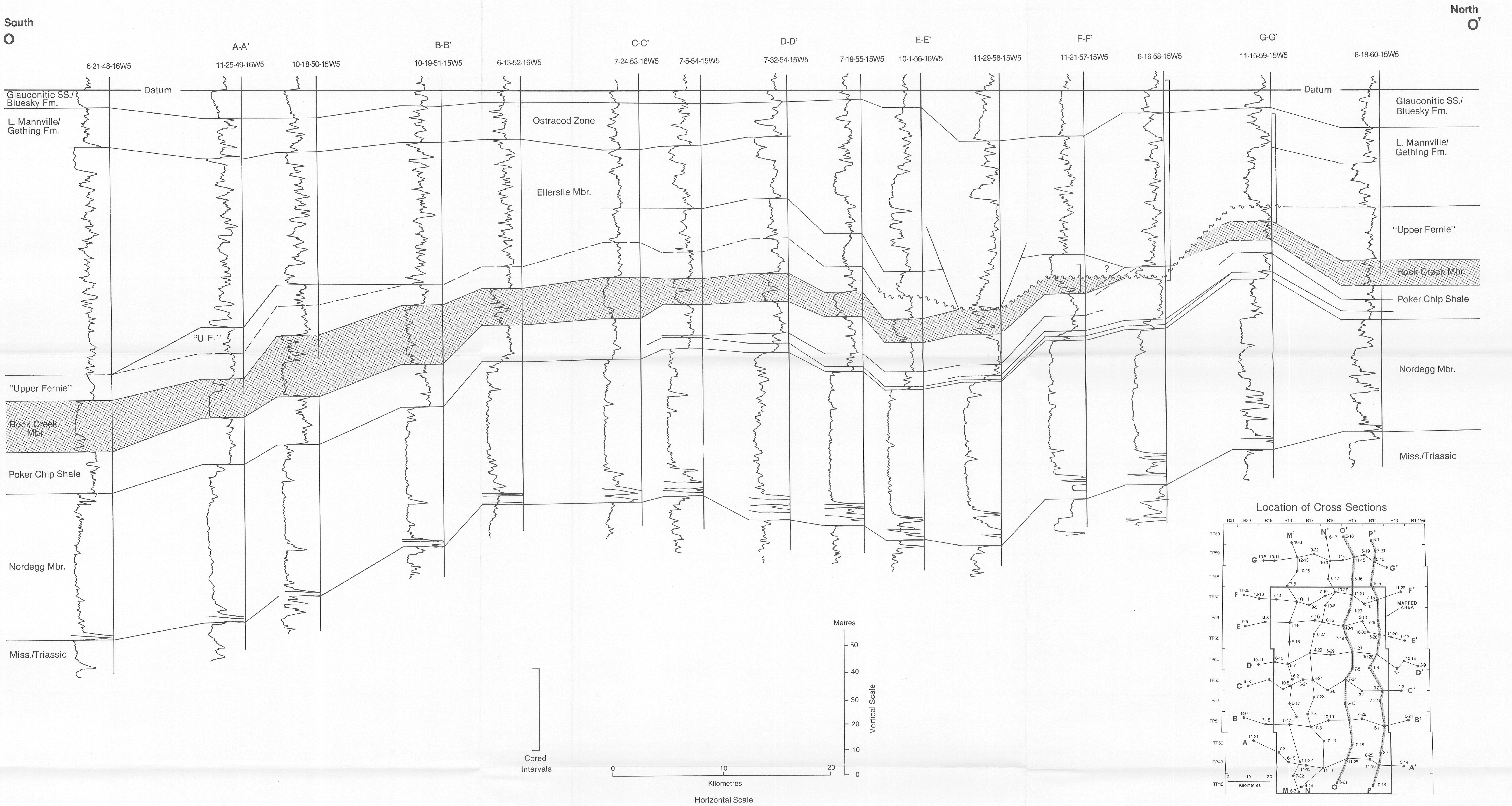

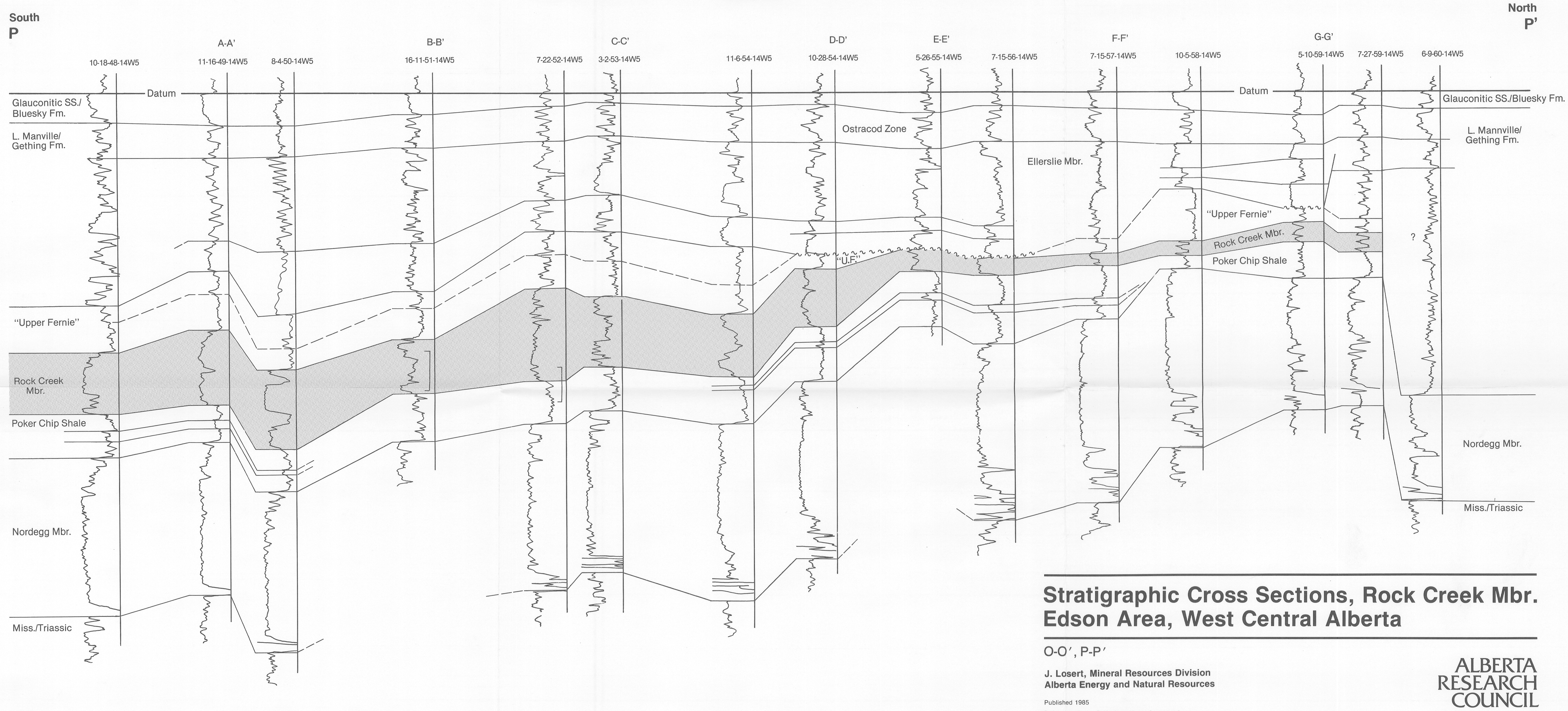

Stratigraphic Cross Sections, Rock Creek Mbr. Edson Area, West Central Alberta

O-O′, P-P′

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