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THE STRATIGRAPHY, SEDIMENTOLOGY AND PETROGRAPHY OF THE JURASSIC-EARLY CRETACEOUS CLASTIC WEDGE IN WESTERN ALBERTA

By

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Submitted to the Faculty of Graduate Studies, University of Manitoba in partial fufillment of the requirements for a doctoral degree in Science

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CHAPTER 8 DIAGENESIS AND RESERVOIR POTENTIAL

The outcrop and core samples of Jurassic and Early Cretaceous sandstones examined in this thesis exhibit a wide range in porosity and authigenic mineral assemblages. To assess the reservoir potential of these sandstones, the composition and sequence of authigenic mineral phases present, and the amount and type of porosity retained were systematically studied.

When the samples were initially point-counted for framework mineralogy, the proportion of (blue-dyed) epoxy-impregnated pore space in each sample was also counted. The percentage of porosity in each sample is tabulated in Appendix 4 and compiled in Table 7. The porosity values determined by these point counts are probably higher than the actual porosity as extensive plucking occurred during thin section preparation and this imparted an artificially high porosity on many of the samples.

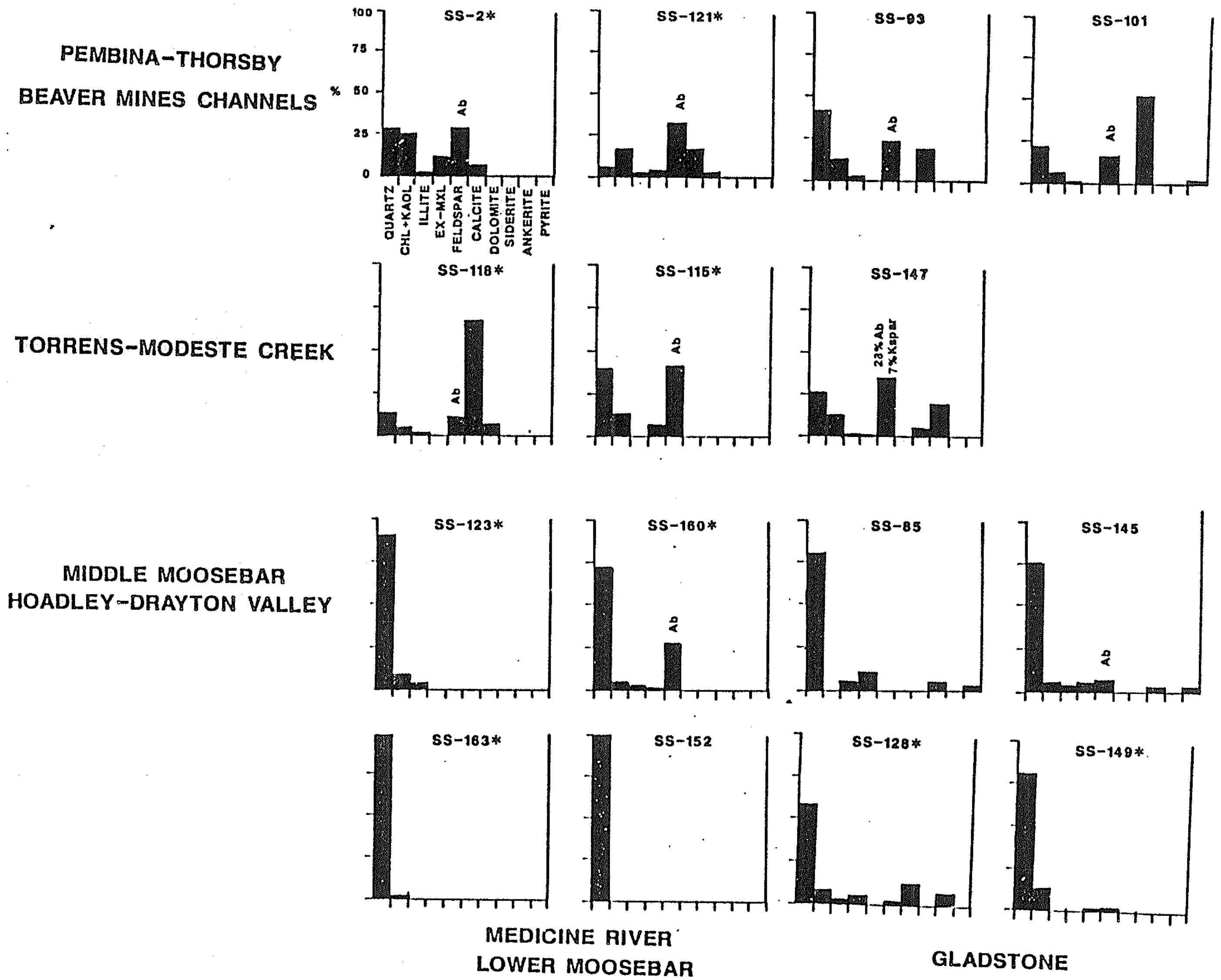
After this initial point count was complete, the relative proportions (absent, traces, common, or abundant) of the three dominant cement phases (quartz, carbonate, and clays) in each slide were estimated. Quantitative estimates of the various cement phases proved to be difficult to make for two reasons.

1) The relative abundance of quartz overgrowths was difficult to estimate as recognizable dust rims were rare and, in most cases, distinction between the overgrowth and the detrital grains was virtually impossible.

2) The very fine grained "cruddy" nature of the authigenic and detrital (matrix) clays precluded accurate identification, or differentiation, of this fraction using conventional petrographic techniques. To facilitate identification of the authigenic phases, the mineralogic composition of fifteen representative sandstone samples was established (Table 13, Fig. 50) by XRD analysis. These analyses were performed at the Geochemical laboratory at the

Sample #	Expandable Mixed/Layer Clays	Illite	Chlorite Kaolinite	Quartz	Feldspars	Calcite	Dolomite	Pyrite	Others
<u>Glauconite-Beaver Mines Channel SS</u> SS-2 Ram River	11	2	9 (Ch) 16(K)	28	28 (albite)	6	-	-	-
SS-93 (Thorsby)	-	2	13(K)	41	24 (albite)	-	20	trace	-
SS-101 (Pembina)	-	trace	7(K)	21	17 (albite)	-	52	3	-
*SS 121 (Burnt Timber)	4	3	16 (Ch) 19 (K)	6	32 (albite)	17	3	-	-
<u>Torrens-Modeste Creek</u>									
SS 118	-	trace	3	13	10-(albite)	67	7	-	-
*SS 115	6	-	14	40	40-(albite)	trace	-	-	-
SS 147	trace	1	14 (K) trace (Ch)	26	7 (K-spar) 28-(albite)	-	4	-	20-siderite
<u>Hoadley-Drayton Valley Middle Moosebar</u>									
SS 85	10	5	-	80	-	-	-	2	3-siderite
*SS 123	-	3	7 (K)	90	-	-	-	-	-
SS 160	5	4	5 (K)	76	6 (albite)	-	-	2	2-siderite
*SS 160	trace	2	4	72	17 (albite)	-	3	-	2-siderite
<u>Medicine River - Mbr</u> - SS 152	-	-	-	100	-	-	-	-	-
<u>Gladstone Formation</u>									
SS 128	5	3	9 (K)	59	-	4	14	-	6-ankerite
SS 149	-	trace	13 (K)	82	2	3	-	-	-

TABLE 13: Mineralogic composition of Blairmore-Mannville Sandstones based on XRD analysis   * outcrop sample



(50) Histogram plots showing the relative abundance of various mineral phases (based on XRD analysis) in Blairmore-Mannville sandstones, west central Alberta.

Geological Survey of Canada (Calgary) were integrated with petrographic data to provide constraints on the origin and age relationships of the various minerals present.

A strong stratigraphic control on porosity development and the degree and style of cementation was recognized in the samples. The authigenic mineralogy appears to be closely linked to the stratigraphically-controlled variations in framework composition described in the previous chapter. The diagenetic mineral assemblage, and reservoir potential, of each of these sandstone successions will be discussed in the following section.

(A) FERNIE SANDSTONES

The very fine-grained quartz arenites in the Rock Creek and Upper Fernie intervals are extensively cemented by syntaxial quartz overgrowths (Table 7). This cement appears to have been precipitated early as there is little evidence of deformation/squashing of the (rare) labile grains. Pore-filling isotropic clay (chlorite?) cements were also recognized in several samples although, in most cases, these were volumetrically much less important than the quartz overgrowths. Traces of carbonate cement are found in approximately 10% of the sandstones and bright green glauconite is also present as either discrete grains or early pore-filling cement in approximately 50% of the sandstones (e.g.,SS-87). None of the Fernie samples were analyzed by XRD and thus the specific mineralogy of the glauconite-clay cements could not be established. In most samples, the glauconite comprises the earliest (first) authigenic phase and this was followed by the quartz overgrowths and finally by the carbonate or clay phases.

The modal porosity in the Fernie sandstones ranges from 0-26 % (Appendix 4). No systematic variations in porosity could be discerned across the study area although this is difficult to assess with the limited number (n=14) of thin sections examined. Styolites were recognized in many cores although there is little evidence of pressure solution (i.e. embayed or interpenetrating grain contacts) in any of the thin sections examined. Most of the porosity in the Jurassic sandstones appears to be secondary in origin and related to either dissolution of detrital lithic grains and shrinkage and or dissolution of the authigenic (glauconite-chlorite-carbonate) cements.

(B) KOOTENAY-NIKANASSIN SANDSTONES

All of the outcrop samples of the Kootenay and Nikanassin sandstones were tightly cemented by quartz and/or carbonate cements (Table 7). The finer-grained, more quartzose Nikanassin sandstones contained extensive overgrowth development with prominent dust rings. Evidence of extensive pressure solution (e.g. sutured grains) was recognized in virtually all of the samples. The chert-rich Kootenay samples were more difficult to study as it was difficult to differentiate lithic fragments and/or matrix from authigenic phases. The mineralogical composition of the Kootenay-Nikanassin sandstones was not studied with XRD. Styolites were observed in one sample but pressure solution features were not as extensive as in the Nikanassin sandstones.

(C) GLADSTONE-ELLERSLIE SANDSTONES

The fine to medium-grained quartz and chert-rich litharenites of the Gladstone and Ellerslie Formations exhibit a simple authigenic assemblage which is dominated by syntaxial quartz overgrowths and varying amounts (trace to abundant) of late carbonate cement (Tables 7 and 13). A greenish-brown, non-isotropic clay cement is also present in most (80%) of the samples although these clays are volumetrically much less important than the carbonate and quartz cements described previously. X-ray diffraction analysis of two outcrop samples of Gladstone sandstones indicate that they are comprised primarily of quartz (59-82%) and contain minor kaolinite (9-13%) and dolomite (0-14%), and lesser amounts of calcite, ankerite, mixed-layer clays, illite and feldspar (Fig. 50, Table 13). The unidentifiable green-brown (pore-filling) clay cement is probably kaolinite as this is the only clay mineral in these samples which is comparable in abundance in the XRD analysis to the green brown mica seen in thin section. It is unclear whether this kaolinite has a detrital or authigenic origin. Since it generally exhibits a pore-filling texture, it is interpreted as a late (post-overgrowth) cement phase.

The distribution and proportion of carbonate cements in the samples are very erratic. There is a crude grain-size control on the authigenic mineralogy as the finer-grained (highly quartzose) samples are more extensively cemented with overgrowths whereas the coarser-grained (chert-rich) sandstones are more commonly cemented by carbonate or clays. The quartz cementation appears to have been early as there is little evidence of squashing/deformation of most of the lithic grains.

The Gladstone-Ellerslie sandstones exhibit a wide range in porosity. Both outcrop samples examined are tightly cemented (Appendix 4) whereas the equivalent sandstones in the subsurface retain porosities ranging up to 20%. Most of the porosity appears to be primary in origin although some the carbonate cement in some of the coarser samples (e.g. SS-47, Appendix 4) exhibits dissolution textures (Schmidt and Macdonald 1979). No other systematic spatial variations in porosity or authigenic mineral assemblages were recognized across the study area.

(D) MOOSEBAR-GLAUCONITE SANDSTONES

The Moosebar-Glauconite sandstones exhibit a wide range in authigenic mineral phases and porosity which is closely related to previously described stratigraphic variations in framework composition. These variations can be summarized as follows:

(i) LOWER MOOSEBAR-MEDICINE RIVER SANDSTONES

The very fine-grained quartz arenites in the Lower Moosebar-Medicine River sandstones are extensively cemented by quartz overgrowths. No porosity was preserved in the single sample of this sandstone from the outcrop belt (SS-163) whereas equivalent sandstones in the subsurface (SS-152) retained traces of primary porosity. Mineralogic analysis of the core sample (SS-152) confirmed petrographic observations that these samples consist almost entirely of quartz.

(ii) MIDDLE MOOSEBAR-HOADLEY-DRAYTON VALLEY SANDSTONES

The chert and quartz-rich litharenites of the Middle Moosebar-Hoadley-Drayton Valley members are also extensively cemented by syntaxial quartz overgrowths. However, these sandstones generally exhibit much better porosity than the quartzose sandstones of the underlying Lower Moosebar-Medicine River sandstones. Carbonate cements are virtually absent in these sandstones whereas clay cements are present in varying proportions (trace to common) in approximately 50% of the samples. Most of these sandstones also contain varying amounts (0-17%) of glauconite. The XRD analysis of four of these sandstones (SS-85, 123, 145, 160) indicate that they are dominated by quartz and contain variable amounts (0-17%) of albitic plagioclase (probably of diagenetic origin) and minor proportions of expandable/mixed layer clays (0-10%) and illite (2-5%).

In most samples, the earliest authigenic phase consists of bright green glauconite which forms discrete grains and encrusting and pore-filling cements. This glauconite phase is probably recorded as expandable/mixed layer clays on the XRD analysis as most glauconite consists of a partially disordered, potassium-rich smectite clay or mica (Odim and Matter 1981). Most of the porosity is occluded by an early quartz cement which forms syntaxial overgrowths on the detrital quartz and isopachous drusy quartz rims on the chert fragments. The albite recorded in the XRD analysis probably represents a diagenetic replacement of detrital feldspar as all recognizable feldspar in thin section appears to comprise part of the framework. The unidentified clay cement which comprises the youngest authigenic phases in most samples is probably kaolinite. Most of the cementation appears to have been early as there is little evidence of squashing/deformation of the labile lithic grains.

No systematic variations in mineralogy or porosity could be discerned across the study area. The amount of porosity retained in each sample is inversely related to the amount of quartz cement present and most of the porosity appears to be primary in origin. However, some of the clay-rich sandstones in this interval (e.g. SS-85) exhibit cement-dissolution fabrics (Schmidt and Macdonald 1979), suggesting a secondary origin. The porosity exhibits significant variations over short vertical intervals within one well (e.g. SS-53 and 54) or between wells spaced only a few kilometers apart (e.g. SS-80 and 85). Quartz cementation is generally more pervasive in sandstones with a quartz-rich framework (e.g. SS-88) although other more deeply buried quartzose samples from the same interval may retain high porosities (e.g. SS-79). It is unclear which factors control the degree of quartz cementation and consequent variations in porosity in this interval but it does not appear to be simply related to burial depth or framework mineralogy.

(iii) TORRENS-MODESTE CREEK-BEAVER MINES-THORSBY-PEMBINA SANDSTONES

The feldspathic Torrens-Modeste Creek marine sandstones and Beaver Mines-Thorsby-Pembina channel sandstones are extensively cemented by a "cruddy" clay-carbonate cement which has completely occluded most, or all, of the primary porosity. Most of the porosity reduction in these sandstones is the result of mechanical compaction (squashing of labile lithic grains) and it is very difficult to differentiate squashed lithic grains and detrital matrix from authigenic cements in most samples.

Mineralogical analysis of these sandstones (Table 13, SS-2, 93, 101, 115, 118, 121, 147) indicates that they are comprised of quartz (6-41%), albite (10-40%), chlorite+kaolinite (3-25%), expandable/mixed layer clays (trace-11%), illite (trace-3%) and carbonates (including calcite, dolomite and/or siderite) which comprise up to 74% of some samples (e.g., SS-115). Most of the quartz grains retain subangular (detrital) outlines and quartz overgrowths are rare to non-existant in most samples. The albite recorded on the XRD analysis is probably a diagenetic replacement of detrital plagioclase as all recognizable (stained) feldspar is present as discrete grains. The origin of the cruddy clay material (undifferentiated chlorite-kaolinite-illite-expandable/mixed layer clays) could not be established with the techniques employed in this study. The ubiquitous carbonate in these sandstones is a relatively late phase which has aggressively replaced portions of most of the detrital (quartz, feldspar and lithic fragment) grains and much of the clay matrix and cement.

All of the primary porosity in these sandstones has been completely occluded by either the cruddy clay cement-matrix or the late carbonate cements. The outcrop samples and most core samples are tight and most of the porosity described in the point counts was either artificially induced by plucking or is secondary in origin. In the Thorsby and Pembina fields, where these sandstones constitute the hydrocarbon reservoir, the porosity appears to be related to dissolution of both the carbonate and clay cement-matrix material.

(E) SUMMARY AND INTERPRETATION OF DIAGENETIC HISTORY

The diagenetic history and reservoir potential of the Jurassic and Early Cretaceous sandstones in western Alberta can be summarized in terms of seven major points.

(i) The abundance and type of authigenic (cement) phases present in these sandstones is clearly influenced by stratigraphically-controlled variations in framework composition and these relationships are summarized in Table 14. The quartz arenites in the lower part of the succession are extensively cemented by early quartz overgrowths and lesser amounts of late pore-filling kaolinite. The chert-rich sandstones in the Gladstone-Ellerslie and Hoadley-Drayton Valley intervals exhibit thin drusy quartz rims on the chert grains and variable proportions of syntaxial overgrowths on the quartz grains. The feldspathic litharenites and lithic arkoses in the upper part of the succession are generally tight and most primary porosity has been destroyed by extensive cementation and mechanical compaction of the labile lithic grains. These sandstones contain abundant replacement and pore-filling carbonate which, in certain areas (e.g. Thorsby-Pembina fields) has been partially dissolved to form reservoir-quality secondary porosity.

(ii)The general absence of pressure solution textures and abundance of early quartz overgrowths suggests that these sandstones acted as net importers of silica during diagenesis (Houseknecht 1988). Blatt (1979) used mass-balance equations to demonstrate that a non-local source of silica was required to

Stratigraphic Interval	Detrital Mineralogy	Porosity Reduction		Porosity Enhancement	Reservoir Potential
		Physical Compaction	Authigenic Phases (Replacement + Cement)		
Gates - Beaver Mines (Torrens & Modeste Creek)	Plag + VRF + Chert + Qtz	Extensive	Abdt Early Clays (CH + Kaol), Extensive Late Carbonatization of Plag. + VRF	Local Dissolution of Plag, VRF & Late Carbonate Cement	Overall V.P. Locally (eg) Thorsby Pembina, Fair ϕ with low K
Middle Moosebar-Hoadley - Drayton Valley	Chert + Qtz, Plag + VRF	Minor	Minor Early Glauconite, Overgrowths on Qtz Grains, Minor Drusy Qtz Rims on Chert	Minor Dissolution Of Glauconite	Fair-Good ϕ, Best ϕ in coarser, chert-rich sandstone and conglomerate
Lower Moosebar-Medicine River	Qtz	-	Minor Early Glauconite, Extensive Qtz Overgrowths	-	Poor-Fair ϕ, low K due to fine grain size
Gladstone-Ellerslie	Chert + Qtz	-	Minor Early Carbonate, in Coarser SS, Extensive Qtz overgrowths	Local Dissolution of Early Carbonate Cements	Poor-Excellent Best ϕ is secondary in coarser (chert-rich) sandstone
Kootenay-Nikanassin	Chert + Qtz	-	Extensive Qtz overgrowths	-	nil This interval is restricted to Foothills where it is tightly cemented
Fernie Formation (Rock Creek - Upper Fernie)	Qtz, traces Chert	-	Traces early Glauconite Extensive Qtz overgrowths	Local Dissolution of Early Glauconite Extensive Tripolisation of Detrital Chert	Nil to Good Best ϕ/K at Jurassic subcrop edge

Qtz - quartz, VRF- volcanic rock fragments, Plag - Plagioclase, Ch - Chlorite, Kaol - Kaolinite ϕ - porosity, K - permeability

TABLE 14 Summary of detrital and authigenic mineralogy and reservoir potential of Jurassic-Cretaceous sandstones examined in this study.

- indicates that this texture/process not recognized explain the ubiquitous presence overgrowths in most sandstones. He suggested that the silica was generated at great depths by pressure solution and clay mineral reactions (smectite-illite transformation) and was delivered to the shallow sandstones via vertically circulating groundwaters. Houseknecht's (1988) observation that quartz overgrowth cements generally predate pressure solution also supports a non-local source of silica. However, overgrowths are also observed in sandstones from sedimentary basins which have never been deeply buried (Smosna 1988) and shallow burial processes (e.g. dissolution of unstable mineral phases) must also be considered as a potential silica source. The source of the silica cement in the Jurassic-Early Cretaceous sandstone examined in this study could not be established.

(iii) The presence of albitic plagioclase in Mannville and Blairmore sandstones in Alberta has been reported by previous researchers (Ghent and Miller 1974; Putnam and Pedskalny 1983). These studies interpreted the albite as a replacement product of detrital plagioclase. Putnam and Pedskalny (1983) noted that the composition of the plagioclase population was highly erratic and that albitization is most prevalent in sandstones where diagenesis has not been arrested by the the presence of early cements or trapped oil. Siebert et al. (1984) documented that the albitization process acts as a source of dissolved Ca^{++} and Al^{+++} and a sink for Na^{+} and dissolved silica in the porewater. This could account for the close association of replacive and pore-filling carbonate with albitized feldspar, and the scarcity of quartz overgrowths, in the Gates, Beaver Mines and equivalent Glauconite sandstones.

(iv) The authigenic clay cements in the sandstones examined were generated by several different processes. The glauconite recognized in thin section, which is recorded as mixed layer/expandable clays on the XRD analysis, probably represents a very early (synsedimentary) authigenic phase. Glauconite precipitation is favoured by slow sedimentation rates in an open-marine system and commonly forms in semi-confined micro-environments where ionic exchange between the porewater and overlying water column is limited (Odom and Matter 1981).

The origin of the other clay phases in the sandstones is more problematical. Suttner and Dutta (1986) noted that the mineralogy of early authigenic phases is a function of groundwater chemistry which, in turn, is controlled by climate. They suggested that a kaolinite + quartz assemblage, similar to that observed in virtually all of the Early Cretaceous sandstones examined in this study, is indicative of dilute groundwaters characteristic of humid climates. The abundance of coals associated with these sandstones, which is also indicative of humid climates, supports this interpretation.

The chlorites probably have a more complex origin as they appear to be a late authigenic phase. Authigenic chlorite is commonly found in volcanically-derived sandstones where it is thought to have formed by the reaction of mafic minerals or unstable rock fragments with highly saline porewaters which exhibit elevated concentrations of Mg^{++} (Smosna 1988). This interpretation is supported by the fact that chlorite is only found in feldspathic sandstones in the upper part of the Mannville-Blairmore interval which are, in part, volcanically-derived. An alternative interpretation of late chlorite cements was proposed by Hutcheon et al. (1980) who suggested that authigenic chlorite + calcite was produced by a reaction between kaolinite and/or illite + dolomite + quartz . They suggested that this reaction occurs at burial depths of 5-6 km and that it acted as a sink for dissolved silica and a source of CO_2 which could have initiated mineral dissolution and formation of secondary porosity. This interpretation is supported by the association of chlorite-rich feldspathic sandstones with calcite (e.g. SS-2, 121, Table 13) and some non-chloritic feldspathic sandstones with dolomite (e.g. SS-93, 101, Table 13). More work is required to determine which of these processes is more likely to have generated the chlorite present in these sandstones.

The trace amounts of illite found in most samples and the presence of expandable/mixed layer clays in non-glauconitic fluvial sandstones (e.g. SS- 2, Table 13) are difficult to interpret. The origin of these clays could not be determined with the techniques employed in this study.

(v) The origin of the carbonate cements in the Early Cretaceous sandstones is difficult to assess as the thin sections were not stained for carbonate and thus the mineralogy is only known for the few samples which were analyzed by XRD. Most of the carbonate cements are probably late (burial) phases as they typically postdate the quartz overgrowths. These cements typically comprise aggressive carbonate phases (calcite, dolomite and siderite) which replace detrital feldspar, quartz and lithic fragments in the feldspathic Glauconite-Beaver Mines-Gates sandstones. The large amount of carbonate in some samples (e.g. SH-118 contains 74% combined calcite + dolomite) clearly requires an external (non-local) source of Ca^{++} and Mg^{++} cations. Some of these cations may have been derived from local alteration of the detrital plagioclase or mafic minerals. However, most cations were probably generated from the transformation of smectite to illite in the enclosing mudstones (Boles and Frank 1979). The mechanism controlling this pervasive carbonate replacement could not be established.

(vi) Most of the porosity in the Rock Creek and Upper Fernie sandstones is secondary and related to the dissolution of authigenic clays (glauconite and chlorite), and stable (chert) and unstable lithic grains. The presence of white tripolitic chert grains has previously been described in the Jurassic sandstones by Hopkins (1981) who used it as evidence that humid climates prevailed in the source area. However, this author considers that the tripolitic chert alteration was a post-depositional process which probably occurred when the sandstones were exposed to acidic meteoric waters in an exposed or near-surface environment, analogous to that described by Shanmugan and Higgins (1988). This alteration probably occurred during the uplift and exposure at the pre-Cretaceous unconformity.

(vii) Most of the porosity in the Early Cretaceous sandstones is primary in origin although minor amounts of secondary porosity are present in most samples (Table 14). The quartz arenites and chert litharenites in the Gladstone-Ellerslie interval are tightly cemented in the outcrop belt but retain poor to good porosity in the subsurface. The quartz arenites of the lower Moosebar-Medicine River interval are tight in the outcrop belt and retain poor to fair porosity in the subsurface. The chert litharenites (and associated conglomerates) of the Hoadley-Drayton Valley-middle Moosebar interval retain fair to good porosity in both the subsurface and the outcrop belt and comprise the best reservoir lithologies examined. In these sandstones, the quartz phase forms a thin drusy rim on the chert grains and syntaxial overgrowths are much less common than in the quartz arenites. Outcrop and subsurface samples of feldspathic litharenites and lithic arkoses in the upper part of the Mannville-Blairmore interval are generally tightly cemented. However, in the Pembina and Thorsby areas, significant secondary porosity is created by dissolution of both detrital aluminosilicates (plagioclase) and late carbonate cements. Early studies (e.g. Schmidt and McDonald 1979) suggested that most secondary porosity was related to the dissolution of carbonates. However, more recent studies (e.g. Siebert et al. 1984) have revealed that aluminosilicates such as plagioclase are also highly susceptible to dissolution by organic acids generated by kerogen maturation. This is an important concept as silicate dissolution exerts a strong control on the distribution of authigenic mineral phases and consequently of porosity, in the Jurassic-Early Cretaceous sandstones in the study area.

CHAPTER 9 PALEOCURRENTS

Paleocurrent data can be integrated with facies information to deduce the source area, paleoslope, and dispersal patterns within a sedimentary basin (Potter and Pettijohn 1977, p. 315). In each outcrop measured in this study, the orientation of any directional sedimentary structures (e.g., wave-ripple crests or cross-stratification) and the regional attitude of the bedding, were measured using a Brunton compass.These data were corrected for regional tilt using a stereonet technique outlined in Potter and Pettijohn (1977) and the corrected values are compiled in Table 14. For each stratigraphic unit within the outcrops, the mean orientation of these sedimentary structures was calculated using a Hewlett-Packer HP-51 calculator and a vector mean summary program proposed by Lindholm (1979). These corrected and mean values are tabulated in Table 14 and plotted in Fig. 51. Due to the recessive-weathering nature of the outcrops examined, only a limited number of paleocurrent data were collected during field work. Despite the paucity of data, several generalizations can be made concerning changing paleoslope and dispersal patterns during the Early Cretaceous and these will be discussed in the following section.

(A) CADOMIN AND GLADSTONE FORMATIONS

All directional sedimentary structures measured in the non-marine Cadomin and Gladstone Formations are plotted on a map from McLean's (1977) report which shows the location of the major Early Cretaceous channel trends in Alberta (Fig. 51). The Cadomin Formation is an alluvial fan-braided river sequence which was deposited by a series of coalescing alluvial fans or braided river systems which flanked the eastern margin of the thrust belt. A rapid eastward decrease in the thickness and grain-size of the Cadomin Formation has been cited as evidence of a east to

Location	Stratigraphic Unit	Sedimentary Structure	Orientation	n # Measurements	mean
McIntyre Mines	LM	GC	90°/270°	1	90°/270°
	LM	WRC	140°/320° 160°/340°	2	150°/330°
	CAD	PBIM	94° 131° 118° 82° 130°	5	111°/291°
	NIK	SLA	30°/210°	1	30°/210°
Ruby Creek	LM	GC	158°/338° 162°/342° 153°/333°	3	158°/338°
	LM	WRC	120°/300° 88°/268° 82°/262°	3	100°/280°
Crescent Falls	T	PL	10°/190° 28°/208°	2	19°/199°
	MM	WRC	100°/280° 88°/268°	2	94°/274°
	LM	WRC	050°/230° 72°/252° 059°/239° 70°/250°	4	060°/240°
	LM	GC	128°/308° 148°/328° 129°/309° 120°/300°	4	131°/311°
	GL	SLA	144°/324° 140°/320° 150°/330° 180°/360°	4	154°/334°
	GL	GC	130°/310° 151°/331°	2	141°/321°
Ram River	MM	FD	28° 10° 6°	3	15°
	MM	WRC	45°/225°	1	45°/225°
Tay River	MM	SLA	170°/350°	1	170°/350°
Burnt Timber Creek	BM	FD	31°/211° 117°/297°	2	74°/254°
	LM	WRC	50°/230°	1	50°/230°
Waiparous Creek	LM	WRC	113°/293° 70°/250°	2	92°/272°
	GL	LAL	42° 68° 66° 82°	4	65°/245°

Stratigraphic Interval

T - Torrens
MM - Middle Moosebar
LM - Lower Moosebar
GL - Gladstone
NIK - Nikanassin
CAD - Cadomin

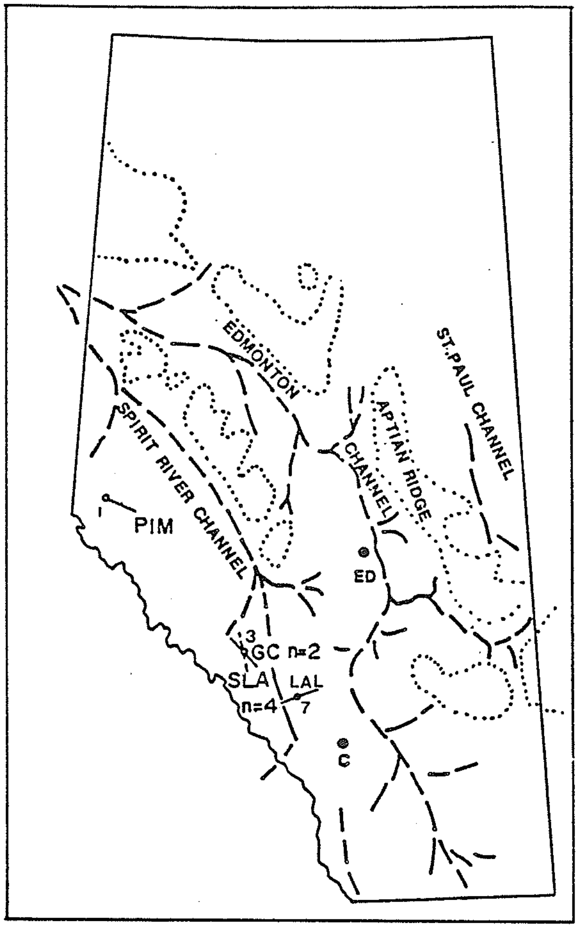
Sedimentary Structures

GC - Gutter Cast
WRC - Wave Ripple Crest
SLA - Strike of Lateral Accretion
PL - Parting Lineation
PBIM - Pebble Imbrication
FD - Foreset Dip DX
LAL Long axis log casts

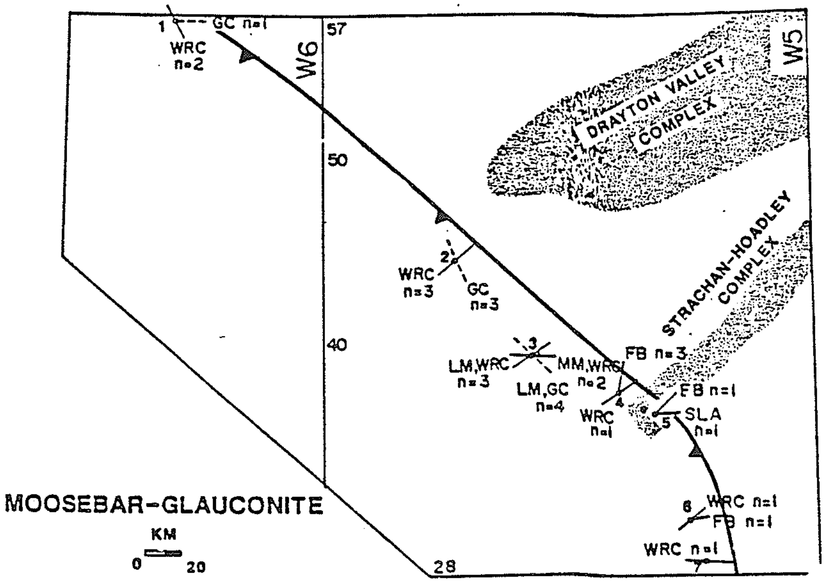
TABLE 15 Summary of paleocurrent data measured in outcrops of the Blairmore Group.

OUTCROP LOCALITIES

1 Grande Cache
2 Ruby Creek
3 Crescent Falls
4 Ram River
5 Tay River
6 Burnt Timber Creek
7 Waiparous Creek



CADOMIN-GLADSTONE-BASAL ELLERSLIE



(51) Paleogeographic maps of the Cadomin-Gladstone-Ellerslie and Glauconite-Moosebar intervals showing the location and orientation of paleocurrent indicators measured in various outcrops.

(For symbol legend see Table 15)

northeast-dipping paleoslope (McLean 1977; Schultheis and Mountjoy 1978). Assuming that imbricated pebbles in fluvial conglomerates dip upstream (Harms et al. 1975), the pebble imbrication data from the McIntyre Mines outcrop indicates an ESE-dipping paleoslope (mean 111° Az). Each of the values listed in Table 14 represents the interpreted flow direction based on the mean orientation of 50 pebbles measured at different levels within the Cadomin. This was the only Cadomin outcrop where pebble imbrication was measured as pebble orientations could not be measured in other, more highly indurated, exposures. No high angle cross-stratification was recognized in the Cadomin outcrops examined.

In the Gladstone Formation, the only directional sedimentary structures measured were gutter casts (at the base of sharp-based floodplain sandstones) and lateral accretion surfaces in point bar sandstones. The long axis of gutter casts approximates the flow direction for the eroding current (down local paleoslope) whereas the strike of lateral accretion surfaces is parallel to local channel trends (Taylor and Walker 1984). The orientation of these features yields a sense of direction only (e.g. NW-SE) and can not be used to determined vectorial flow direction (e.g. NW) unless incorporated with other paleocurrent data. In fluvial systems, these features typically display a high dispersion about the mean as local paleoslope is highly variable. However, they can provide useful paleoslope data if a large number of data points are compiled (Potter and Pettijohn 1977).

In the Crescent Falls section, the mean strike of the lateral accretion surfaces (154°/334°) and the mean long axis of the gutter casts (141°/321°) in the Gladstone Formation are oriented NW/SE. These measurements are consistent with Taylor and Walker's (1984) interpretation of a northwest-dipping paleoslope during Gladstone deposition. A northwest trend is also supported by subsurface data (Fig. 51A) which shows that major channel systems (e.g. Edmonton, Spirit River Channels) in the equivalent Ellerslie interval were oriented NW/SE. However, if the orientation of fossil logs in fluvial channels is used to infer flow direction, as described by Leckie and Walker (1982), the orientations measured in the Gladstone sandstone in the Waiparous Creek section indicate NE (mean 65° az) flow direction. The reason for this apparent discrepancy in flow directions in the Gladstone interval could not be established with the limited paleocurrent data collected in this study.

(B) GLAUCONITE-MOOSEBAR FORMATIONS

All of the paleocurrent data measured in outcrops of the brackish-marine Moosebar strata are plotted on a map (Fig. 51) showing the distribution of major sand complexes in the equivalent Glauconite Formation in the subsurface. Symmetrical wave ripple crests in the lower and middle Moosebar generally exhibited a ENE/WSW orientation in outcrops in the southern Foothills (e.g. Waiparous Creek, Burnt Timber Creek, Ram River, Crescent Falls and Ruby Creek) and a NW/SE orientation in outcrops in the the northern Foothills (e.g. McIntyre Mines) outcrop (Table 14, Fig. 51). The orientation of wave ripples in the lower and middle Moosebar are generally similar (Fig. 51 , Table 14) although the ripples capping the sandstone at the top of the lower Moosebar in the Crescent Fall section have a NW/SE elongation (Table 14, Fig. 51) which is almost normal to the prevailing trend.

The long axis of symmetrical wave ripple crests are typically oriented sub-parallel to shoreline trends, due to the refraction of waves as they propogate across a shallowing basin (Potter and Pettijohn 1977, p. 119-120; Leckie and Walker 1982). On this basis, the mean NE trend of wave ripple crests in the Moosebar in the Foothills and the NE elongation of the Hoadley-Strachan and Drayton Valley sandstones in the Plains is consistent with previous interpretations of a NW-dipping paleoslope in this area (McLean and Wall 1981; Taylor and Walker 1984). In the northern part of the study area, the orientation of the lower Moosebar-Bluesky shorelines could not be established. However, the NW trend of wave-ripple crests in this interval in the McIntyre Mines section (Fig. 51) indicates that they probably trend NW/SE.

The long axis of gutter casts exhibited a NW/SE trend in the Crescent Falls and Ruby Creek sections and a ESE/WNW trend in the McIntyre Mines section (Fig.51). If gutter casts are scoured by offshore-directed, bottom-hugging flows, as Taylor and Walker(1984) have suggested, then these trends suggest a northwest-dipping paleoslope in the southern part of the study area and an easterly-dipping paleoslope in the northern Foothills. This is consistent with the interpretations based on the orientation of wave ripple crests (described above).

In addition to the wave-ripple and gutter cast data described above, several other directional sedimentary structures were measured and these are plotted in Fig. 51 and listed in Table 14. In the Beaver Mines Formation in the southern Foothills high angle cross beds in fluvial sandstones indicate NE flow directions (e.g. Ram River and Burnt Timber Creek sections). In the Tay River section, lateral accretion surfaces in the middle Moosebar conglomerate dipped to the NE (mean 80°Az). These conglomerates were probably deposited in some type of north-trending channel system although their exact origin is obscure. Parting lineations which were measured in hummocky-cross stratified (HCS) sandstones at the base of the Torrens sandstone in the Bighorn River section (Table 14, Fig. 51B) exhibited a NE trend (mean 19°/199°). These lineations also probably indicate regional paleoslope as the storm currents which create these structures are typically oriented offshore (Leckie and Walker 1982).

CHAPTER 10 SOURCE ROCK POTENTIAL

To evaluate the source rock potential of the Jurassic and Early Cretaceous strata in the study area, ninety-five shale samples were analyzed using the Rock-Eval/TOC analyzer in the Geological Survey of Canada laboratory (Calgary). The location and stratigraphic interval represented by each sample is listed in Appendix 2C. One hundred mg samples were crushed, sieved (200 mesh) and treated with acid to dissolve the carbonate fraction. The raw data from these analyses are tabulated in Appendix 5.

The Rock-Eval/TOC system determines the richness and type of organic material present in, and the level of thermal maturity of, potential source rocks. The analysis involves heating each sample in an inert atmosphere (pyrolysis) and recording the amount of carbon-bearing compounds generated at different temperatures. This information is recorded as a pyrogram which generally exhibits three distinctive peaks (Tissot and Welte 1984, p. 509-510). The S1 peak is a measure of in situ (non-migrated) volatile hydrocarbons which are released at relatively low temperature (<300°C) and is expressed in terms of mg HC/g sample). The S2 value (also expressed in terms of mg HC/g sample), is a measure of the hydrocarbons liberated during the "artificial maturation" as the samples are progressively heated to 600°C . This represents the amount of hydrocarbons which could be generated if maturation of the sample had gone to completion. The S3 is a measure of the quantity of CO2 liberated (mg CO2/g sample) during the final (high temperature) stage of pyrolysis (Tissot and Welte 1984). The TOC is determined by heating the pyrolysis residue in a second oxidizing oven (600°C in air) and summing this with the carbon from the pyrolysis peaks. The hydrogen index (HI) is the ratio of the S2 value to the TOC and is expressed in mg HC/g TOC. The oxygen index is the ratio of the S3 peak to the TOC and is expressed in terms of mg CO2/g TOC.

The Tmax is a measure of the thermal maturity of the organic material and records the temperature at which the maximum amount of hydrocarbons are generated (apex of the S2 peak) during pyrolysis (Tissot and Welte 1984).

(A) INTERPRETATION OF THE ROCK-EVAL DATA The raw data generated by the Rock-Eval system can be interpreted in several different manners to determine the three basic source rock parameters (richness, type, and level of thermal maturity).

(i) RICHNESS

The most frequently cited measure of richness is the % TOC. Shales must have at least 0.5% TOC to be considered as potential source rocks and major source beds typically contain between 5 and 10% TOC (Tissot and Welte 1984). Peters (1986) proposed cutoff values of 0.5%, 1.0%, and 2.0% TOC to discriminate between poor, fair, and good potential source rocks. However, not all shales with high percentages of TOC are good source rocks because much of the OM can be (non-productive) oxidized inert matter (Tissot and Welte 1984). A more direct measure of richness is the genetic potential (S1+S2) as this records the amount of hydrocarbons evolved during pyrolysis. These values are expressed in mg HC/g sample (or equivalent kg HC/tonne) and cutoff values of 2 and 6 kg HC/tonne are used to differentiate between poor, moderate and good potential source rocks (Tissot and Welte 1984, p. 513).

(ii) ORGANIC TYPE

The characteristics (type) of organic matter present in potential source rocks is established by cross-plotting their hydrogen and oxygen indices on a Van Krevelen diagram. The position of the data points on this type of plot is then compared to "typical" kerogen evolution plots to determine if it is Type I (oil-prone), Type II (oil and gas-prone) or the gas-prone type III organic matter (Tissot and Welte 1984). Although this is a good technique for determining the approximate composition of the organic matter, it is difficult to compare samples numerically on these binary plots. An alternative system proposed by Peters (1986), considers only the hydrogen index (HI) and subdivides potential source rocks into oil-prone (HI > 300), oil and gas-prone (HI=150-300), and gas-prone (HI < 150) categories. A third system, also proposed by Peters (1986), employs the S1/S2 ratio and uses cutoff values of 3.0 and 5.0 to discriminate between gas, oil+gas, and gas-prone source rocks.

(iii) MATURATION

The level of thermal maturity of potential source rocks can be estimated in two different ways. The Tmax values increase with increasing thermal maturity. Although the upper and lower limits of the oil window varies with organic type, Peters (1986) suggested that the top and base of the oil window be assigned at Tmax values of 430°C and 465°C respectively.

A second measure of the thermal maturity is the transformation ratio or production index (PI). This value measures the ratio of volatile hydrocarbons (S1) to total producable hydrocarbons (S1+S2). This value increases with increasing maturation levels and Peters (1986) proposed that PI values of 0.1 and 0.5 be used to define the top and base of the oil window, respectively.

(B) RESULTS

The subsurface (core) samples were subdivided into three groups on the basis of stratigraphic position (Jurassic- undifferentiated, Ellerslie, and Glauconite). The outcrop samples, indicated with an asterisk in Appendix 5, were compiled with their interpreted subsurface equivalent. The range and mean

%TOC for each of the stratigraphic units, and the frequency distribution of samples within each of the richness, type and maturity classes described above, are compiled in Table 16 and plotted in Figs. 52-56. A cross-plot of the Tmax values and the PI was constructed to evaluate the maturity of the samples (Fig. 57). The source rock parameters and potential of the shales within each stratigraphic interval are discussed below.

(i) JURASSIC SHALES (UNDIFFERENTIATED)

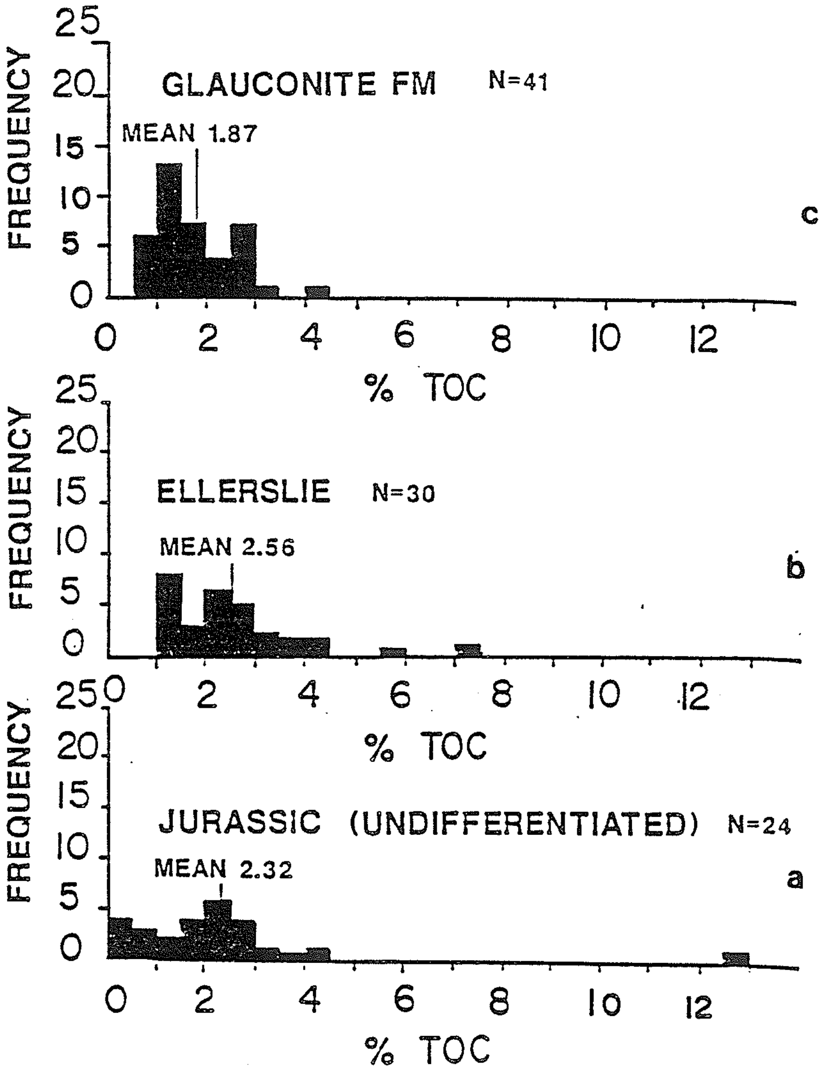
Twenty-four samples of Jurassic shales were analyzed and these data are summarized in Table 16. The TOC values for these shales ranged from 0.09% to 12.83% and averaged 2.32% (Fig. 52, Table 16). However, if the single, anomalously high sample was eliminated (i.e. SH-60), the mean would be decreased to 1.87%. This number appears to be a more representative average value, based on the frequency histogram of %TOC values (Fig. 52A). The %TOC values are highly erratic and different samples from the same well exhibit large differences in %TOC (e.g. SH-86, 87 and 88). No systematic spatial variations in TOC values can be discerned when the values are plotted on a map (Fig. 53A). In the Jurassic shales, the high variation in %TOC is related to the depositional facies sampled . In general, the dark ribbon facies shales contained much higher %TOC values than the light ribbon facies. On the basis of the richness limits proposed by Peters (1986) most (75%) of the Jurassic shales comprise good to very good source rocks (Table 16). Similarly, on the basis of genetic potential (S1/S1+S2), most (71%) of the shales have moderate to good potential (Table 16).

On the van Krevelen diagram (Fig. 54), the Jurassic shales plot as Type II and III organic matter. However, most samples plotted between the Type II and Type III kerogen paths which suggests that these shales are capable of

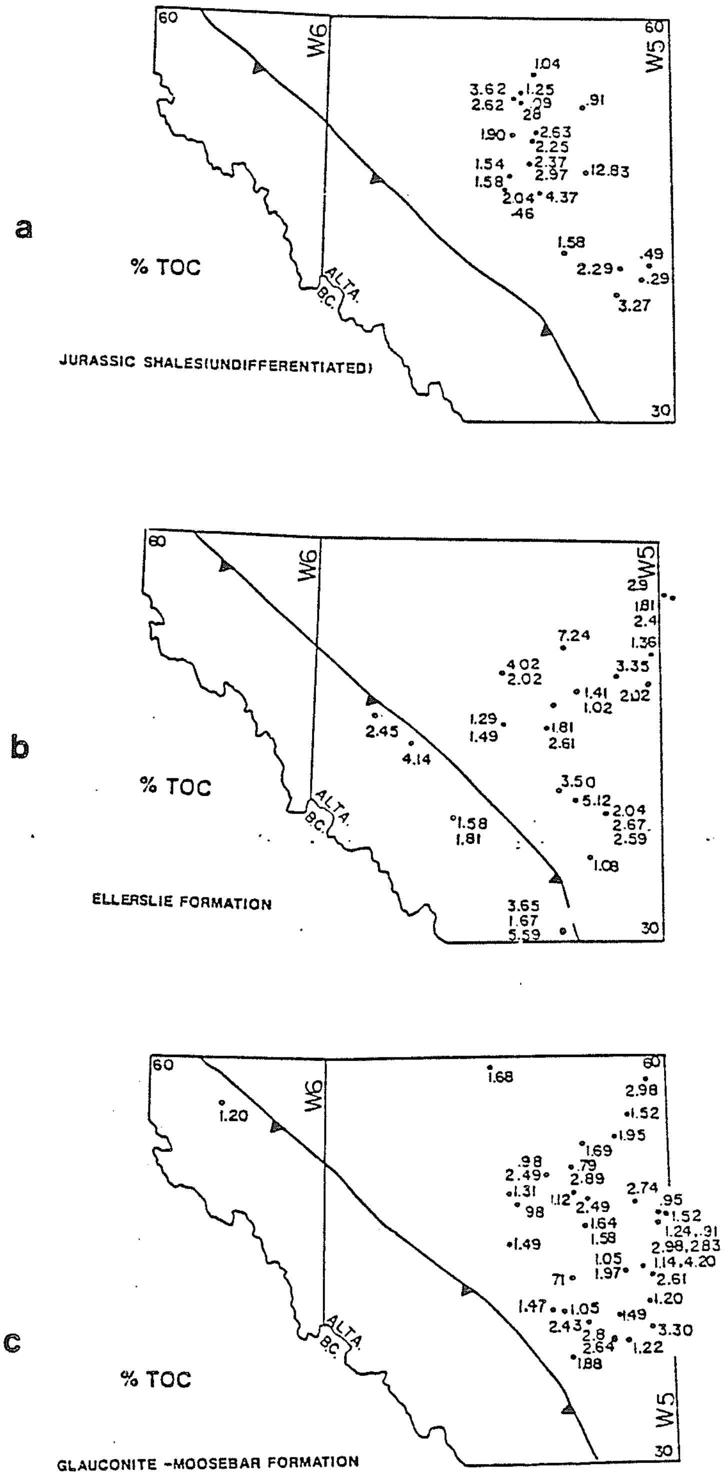
	AMOUNT								TYPE						MATURATION					
Stratigraphic Unit (# of) (Samples)	% TOC					$S_1 + S_2$ mg Hc/gm sample			S_2 / S_3			HI			PI $\frac{S_1}{S_1+S_2}$			Tmax(°C)		
	Range mean	Poor 0-0.5	Fair 0.5-1.0	Good 1.0-2.0	V. Good >2.0	Nil <2.0	Moderate 2-6.0	Good >6.0	Gas 0-3.0	Oil + Gas 3.0-5.0	Oil >5.0	Gas 0-150	Oil + Gas 150-300	Oil >300	<.1	0.1-0.4	>.4	<430°	430°-465°	>465°
Glauconite Shales (n = 41)	0.71 - 5.59 mean 1.82	0 (0%)	6 (15%)	21 (51%)	14 (34%)	16 39%	15 37%	10 24%	16 39%	5 12%	20 49%	22 54%	12 29%	7 17%	6 15%	35 85%	0 0	0 0	39 95%	2 5%
Ellerslie-Basal L. Moosebar (n = 30)	1.02-7.24 mean 2.56	0 0%	0 0%	11 37%	19 63%	7 23%	14 47%	9 30%	10 33%	2 7%	18 60%	12 40%	13 43%	5 17%	6 20%	23 77%	1 3%	2 6%	20 67%	8 27%
Jurassic (Undifferentiated) (n = 24)	0.09-12.83 mean 2.32 (1.87)	4 17%	2 8%	6 25%	12 50%	7 29%	11 46%	6 25%	7 29%	3 13%	14 58%	12 50%	10 42%	2 8%	6 25%	18 75%	0 0%	3 13%	18 74%	3 13%

Total n = 95

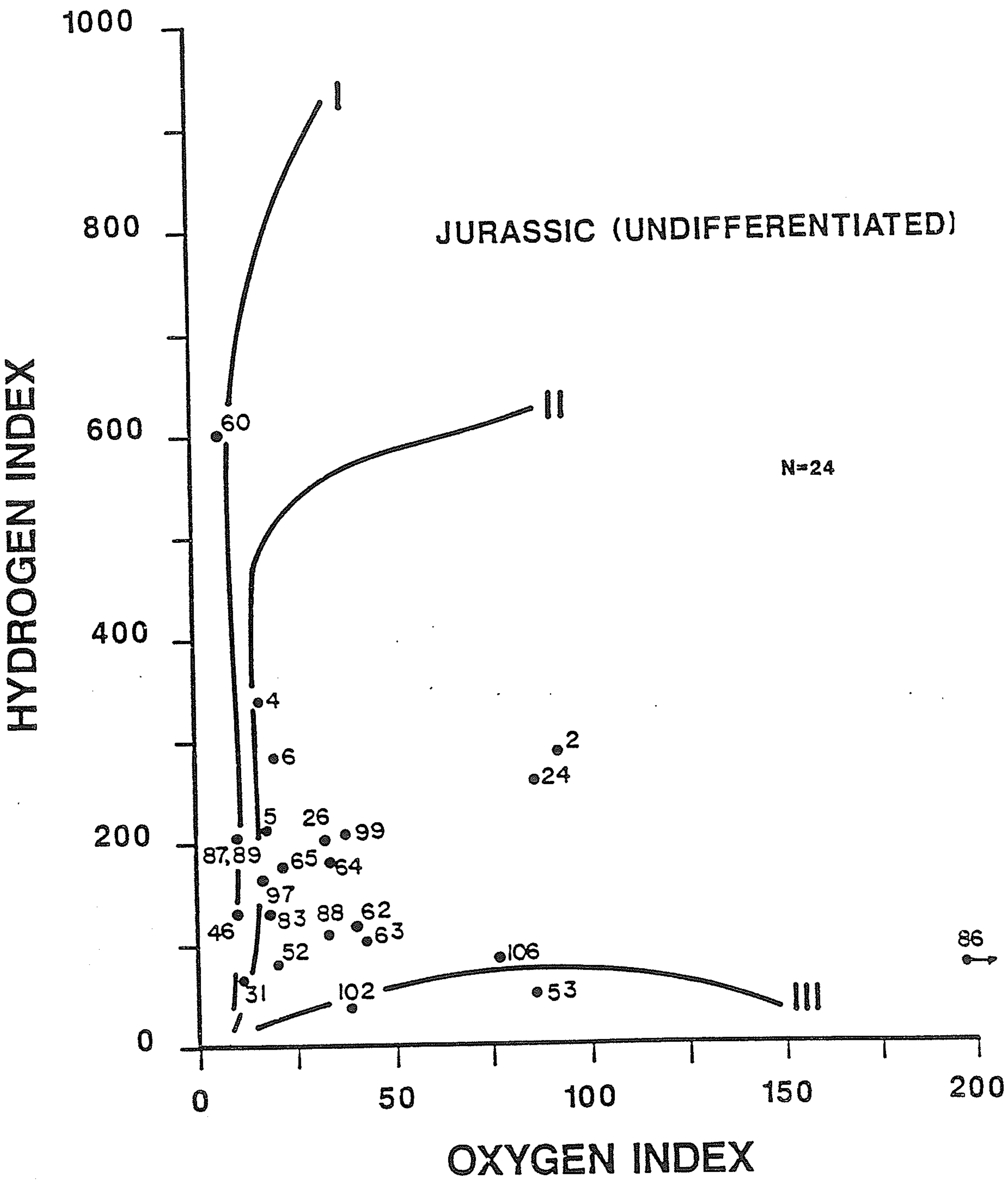
TABLE 16 Frequency Distribution of Major Source Rock Parameters For Glauconite, Ellerslie & Jurassic Shales



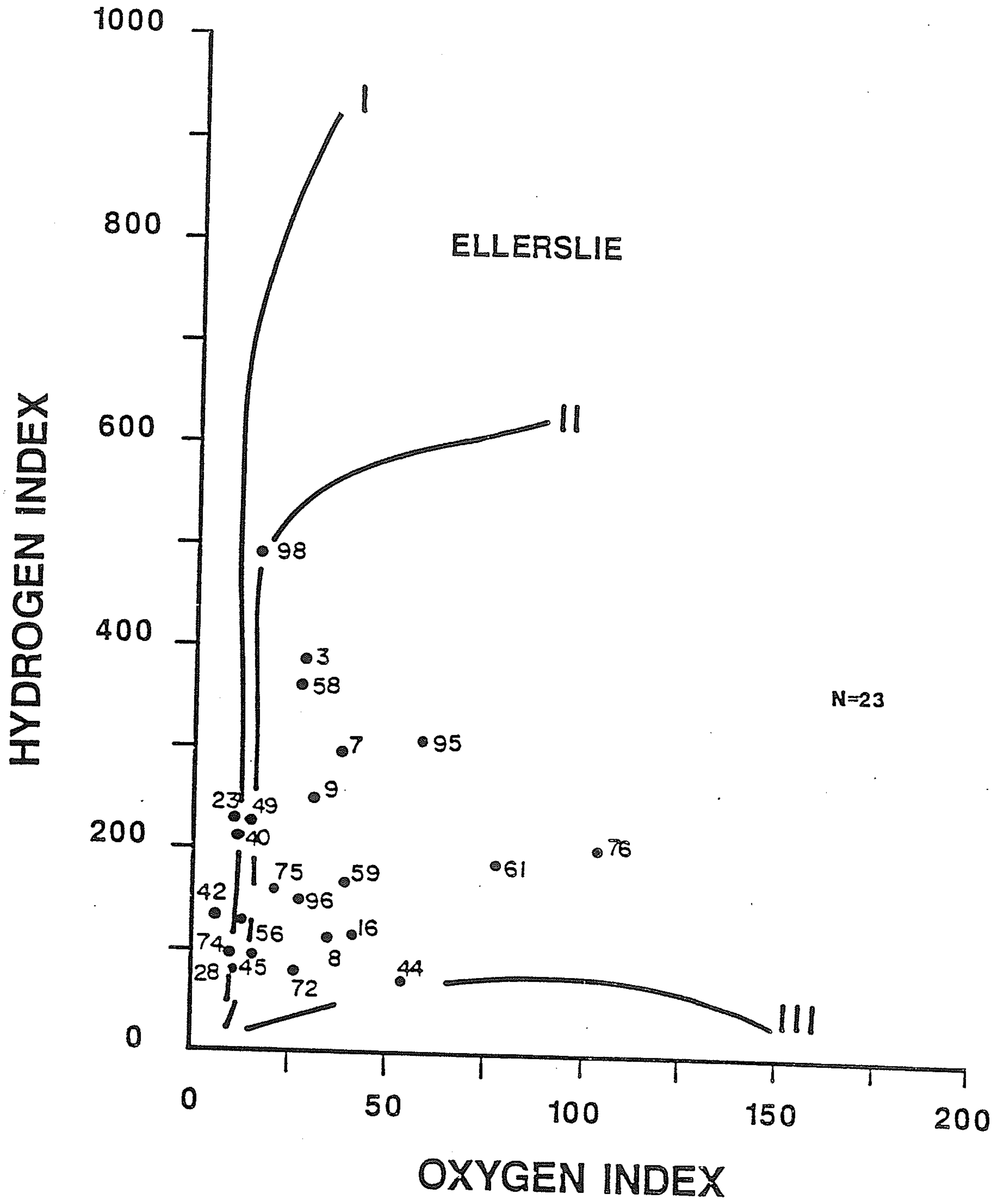
(52) Frequency histogram showing the range of, and mean, TOC values for the Jurassic, Lower Moosebar-Ellerslie and Glauconite shales.



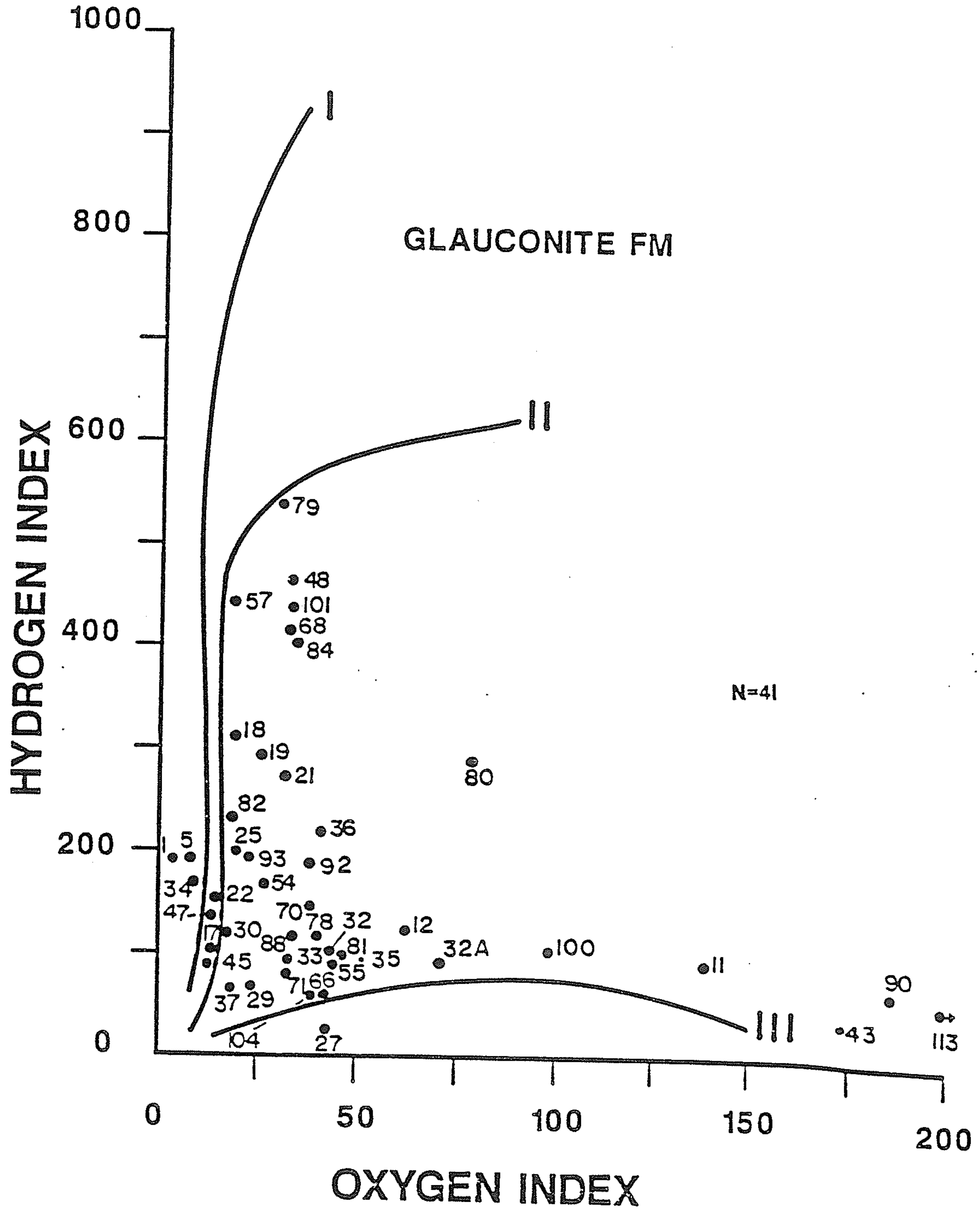
(53) Spatial distribution of TOC in (A) Fernie (B) Ellerslie-basal Lower Moosebar and (C) Glauconite-middle, upper Moosebar shales.



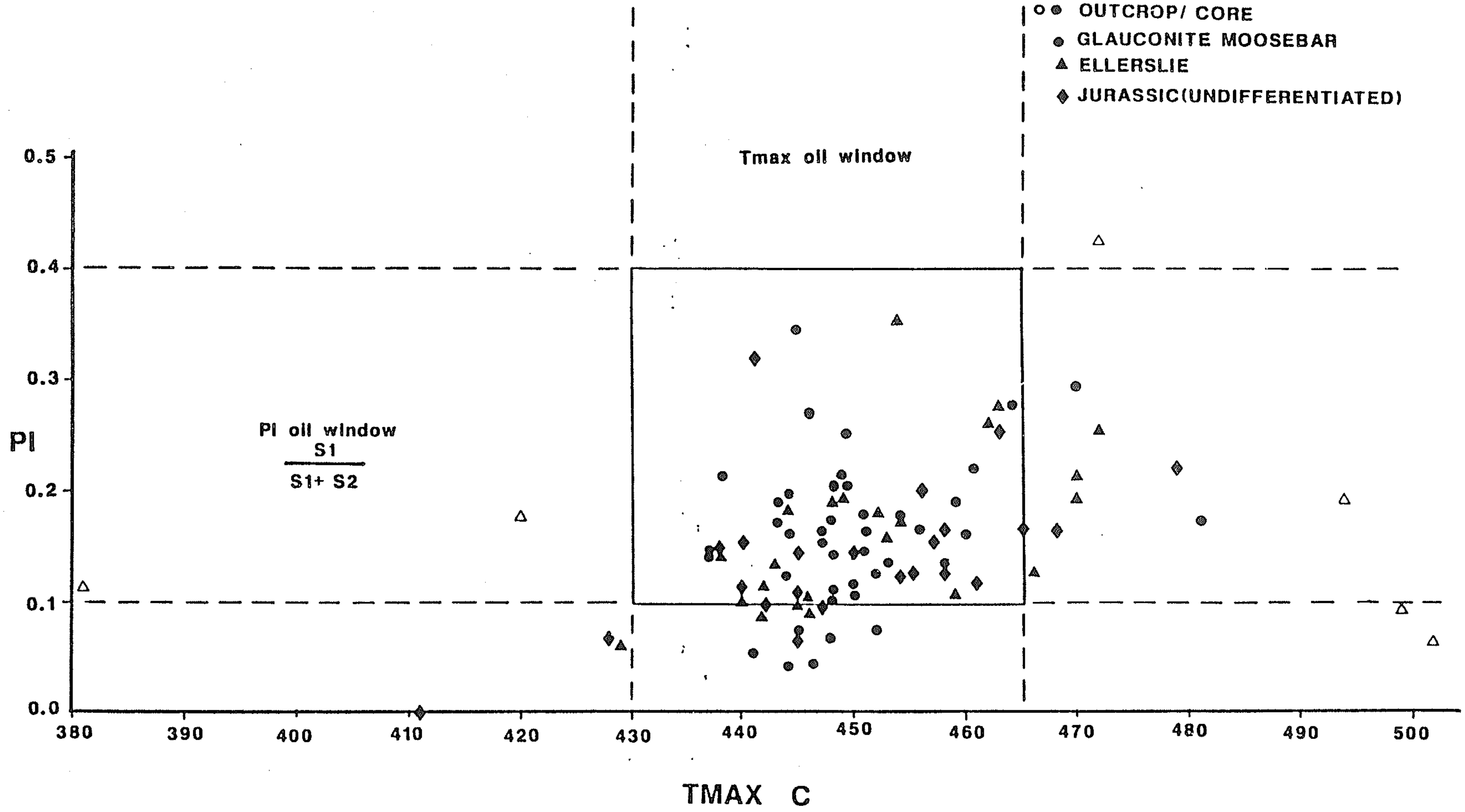
(54) Van Krevelen-type diagram, Jurassic shales.



(55) Van-Krevelen-type diagram, Ellerslie-basal lower Moosebar shales.



(56) Van Krevelen-type diagram Glauconite-middle, upper Moosebar shales.



(57) Plot of Tmax versus Production Index (PI) values of Jurassic and Early Cretaceous shales.

generating both gas and oil. On the basis of S2/S3 ratio cutoffs proposed by Peters (1986), most (71%) of the Jurassic shales are considered oil or oil+gas-prone. However, the HI values for these same shales suggest that only 50% are gas and oil-prone (Table 16).

On the basis of PI values (S1/S1+S2), most (79%) of the Jurassic shales are presently within the oil window (Table 16, Fig. 57). Similar maturation levels were indicated by the Tmax values as 75% of the samples were within the oil window limits described by Peters (1986). Only 3 samples (13%) had Tmax values which indicated that they were past the oil window. Only two samples (SH-86, 102) plotted above the oil window on the basis of both Tmax and PI values (Fig. 57). Both of these samples exhibited very low %TOC values. Since Peters (1986) has noted that low yield samples commonly generate anomalous pyrolysis data, these samples are considered to be unreliable indices of maturation levels.

(ii) ELLERSLIE SHALES

Thirty samples of Ellerslie and equivalent (basal Lower Moosebar) shales were analyzed and these data are summarized in Table 16. The %TOC values ranged from 1.02 to 7.24% and averaged 2.56% (Fig. 52B). Based on the richness cutoff values proposed by Peters (1986), all of these samples are good to very good potential source rocks. When these data were plotted on a map (Fig. 53B), no systematic pattern in %TOC could be discerned and different shale samples from the same well (e.g.,SH-72 and 74) typically exhibited higher variation than samples from adjacent wells. The control on TOC values within the Ellerslie could not be established. However, the shales sampled represented a wide range in depositional environments, including non-marine, brackish-lagoonal and open marine settings and this probably exerted a strong influence on their %TOC values. On the basis of S1+S2 yields, most (77%) of the samples have moderate to good potential (Table 16).

On the van Krevelen diagram (Fig. 55), most of the the Ellerslie shales plot between the Type II and Type III fields, indicating that they would probably generate gas and oil on maturation (Tissot and Welte 1984). On the basis of S2/S3 ratios, most (60%) of the samples fall into the oil-prone category (S2/S3 > 5.0) and another 7% fall within the oil+gas field (Table 16). On the basis of HI indices, most (60%) of the samples have some oil-generating capacity (HI>150) although only 17% fall into the oil-prone category (Table 16). Most (77%) of the samples plotted in the oil window on the basis of PI values and a similar proportion (70%) were within the oil window indicated by Tmax values (Table 16, Fig. 57). Thus, the Ellerslie shales are considered to be mature throughout the study area. Only one sample (SH-96) plotted outside (above) the oil window on the basis of both (Tmax and PI) parameters and was apparently immature. However, a second sample from the same well (SH-95) did plot in the oil window . The cause for this discrepancy in apparent maturation levels could not be determined.

(iii) GLAUCONITE SHALES

Forty-one core samples of shales from the Glauconite Formation were analyzed for source rock potential and these data are summarized in Table 16. The %TOC values ranged from 0.71 to 5.59 % and averaged 1.82 % (Fig. 52C). On the basis of the cutoff values proposed by Peters (1986), most (85%) of the samples have good to very good potential and the remaining 15% have fair potential (Table 16). No systematic variation in %TOC was recognized when the data was plotted on a map (Fig. 53C) and the factors controlling TOC distribution could not be determined. However, on the basis of S1+S2 yield, only 24% of the samples exhibit good potential and the remainder have nil to moderate potential as oil source rocks. The apparent discrepancy between richness estimates based on TOC and S1+S2 yields probably indicates that the Glauconite shales contain a large amount of inert (oxidized) organic matter. This material is included in the %TOC but does not yield hydrocarbons during pyrolysis (Peters 1986). The Glauconite shales are typically more highly bioturbated than the Ellerslie shales and this probably reflects a more oxygenated substrate during deposition of the Glauconite shales. This oxygenated substrate, in turn, could have resulted in degradation (oxidation) of much of the OM before burial, thus diminishing its hydrocarbon-generating potential (Tissot and Welte 1984).

On the van Krevelen diagram (Fig. 56), most of the Glauconite shales plot along, and between, the Type II and Type III curves, indicating that they are capable of generating gas and oil. On the basis of S2/S3 ratios, most (61%) have some oil-generating potential although a significant proportion (39%) are gas-prone only (Table 16). Similarly, on the basis of hydrogen indices, a significant proportion (54%) of the Glauconite shales are gas-prone only and only 17% are considered as oil-prone.

Most of the Glauconite shales fall within the oil window indicated by PI and Tmax values (Table 16, Fig. 57). As none of the samples plotted outside the oil window on the basis of both Tmax and PI values, the Glauconite shales are considered to be mature throughout the study area.

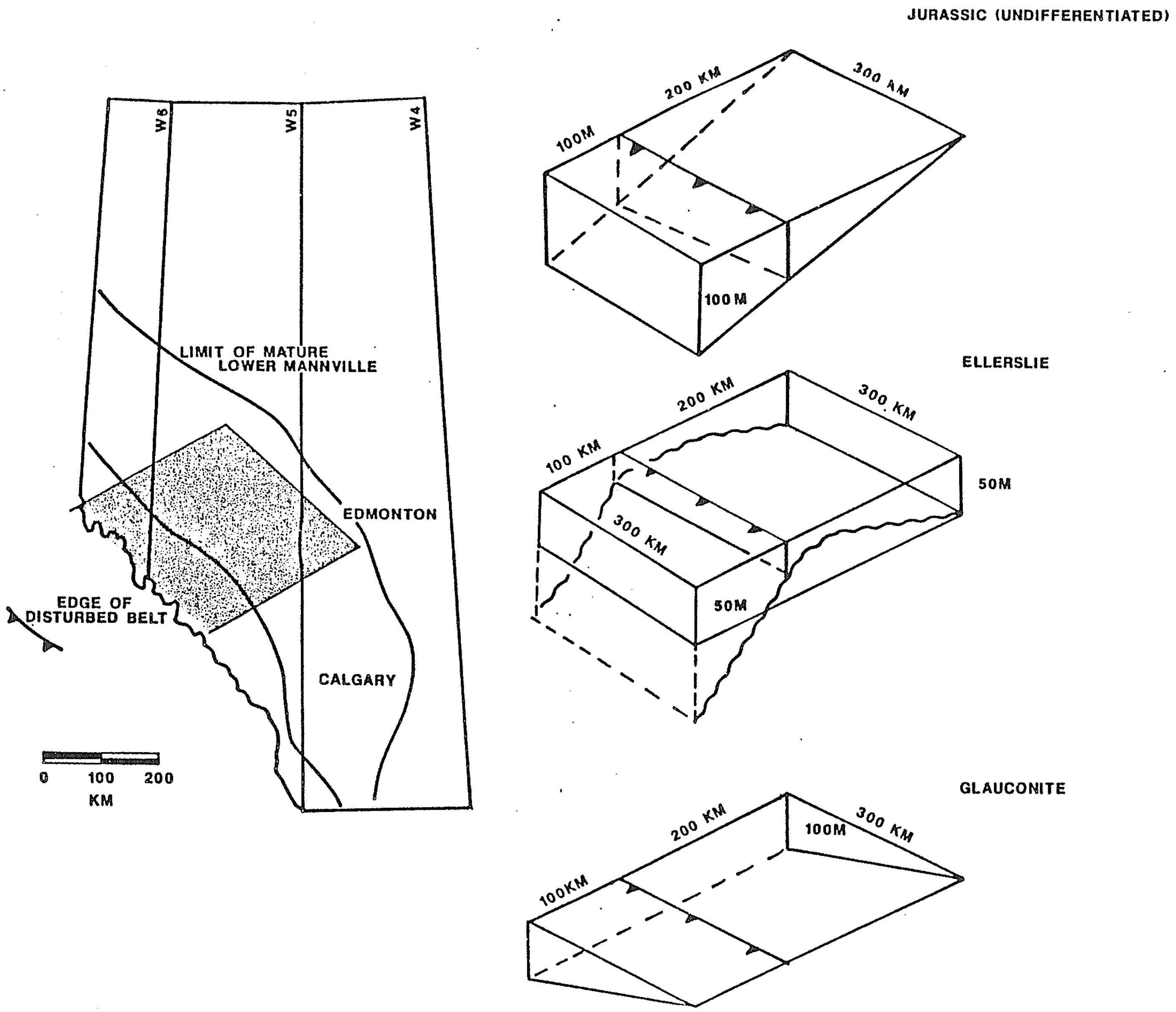
(C) CALCULATIONS ON THE OIL-GENERATING CAPACITY OF THE JURASSIC-EARLY CRETACEOUS SHALES

Several recent studies (Masters 1984; Moshier and Waples 1985) have modeled the source rock potential of the Jurassic-Early Cretaceous shales in

	Stratigraphic Interval	Volume Source rock	% SH	Volume Shale km^3 (mi)^3	TOC	HI	K (constant)	Go Generative Capacity [TOC x HI X K] million bbls/mi^3	f Maturity Coefficient *	Diagenetic Bitumen Index mg HC/gm TOC	DB Diagenetic Bitumen Volume (million bbls/mi^3)	Hcv Go + DB	Hex Hex (Hydrocarbons) (expelled) (Hcv-threshold)	Migration Transport Efficiency (% oil not lost) (in migration)	Total Trapped Hydrocarbons (barrels)
This Study	Glauconite	$\frac{300 \times 300 \times .10}{2}$ =4500 km^3	.50	2250 km^3 (539.5 mi^3)	1.82	187	0.7	238.2	1.0	31	39.5	278.7	228	35%	80 billion
	Ellerslie	$\frac{300 \times 300 \times .05}{2}$ = 2250 km^3	.80	1800 km^3 (431.6 mi^3)	2.56	183	0.7	327.9	1.0	33.6	60.2	388	338	35%	118 billion
	Jurassic (Undifferentiated)	$\frac{300 \times 300 \times .10}{2}$ = 4500 km^3	.80	3600 km^3 (863.2 mi^3)	2.32	182	0.7	295.6	1.0	33.5	54.4	350	300 $\sum$ 866 Total, This study	35%	105 billion 303 billion
	Moshier & Waples (1985)				1.3%	95.6	0.7	–	1.0	23					450 billion (total for all Alberta) Plains
	Masters (1984)				2.0 - 7.5%							20,000	7000	75%	5000 billion (total for all Alberta)

TABLE - 17 Source Rock Parameters & Volumetric Calculations Showing Potential Amount of Oil Generated By The Jurassic-Cretaceous Shales in central Alberta

* assuming section is 100% mature



(58) Schematic diagram showing location of the area evaluated for source rock potential and the geometry and dimensions of the stratigraphic slices evaluated for source rock potential.

western Alberta to determine whether they could have generated the massive reserves of heavy oil and tar sands which are hosted in equivalent strata in eastern Alberta. These studies employed different data, modelling techniques and volumetric formulae and arrived at markedly different conclusions concerning the source rock potential of these strata (Table 17).

Masters (1984) estimated that in excess of 7500 billion barrels could have been generated by the Jurassic-Early Cretaceous section in Alberta and considered that these strata comprised the principal source for both the heavy and conventional reserves. On the other hand, Moshier and Waples (1985) suggested that a maximum of 450 billion barrels could have been generated and concluded that the Jurassic-Early Cretaceous section could not be the primary source of these massive oil reserves. To reconcile these apparently contradictory conclusions, the hydrocarbon-generating capacity of the shales was calculated using the formulae employed by Moshier and Waples (1985), the isopach and Rock-Eval data collected in this thesis, and some regional data on maturation levels published by Masters (1984). The data and calculations are summarized in Table 17 and plotted in Fig. 58.

(i) METHODOLOGY

The study area selected encompassed most of the thesis area and was approximately 300 km long (parallel to the mountain front) and approximately 300 km wide (Fig. 58). The area extends from the western Plains into the disturbed belt where an unknown amount of tectonic shortening has occurred. In a regional sense, the amount of shortening in the disturbed belt ranges from 200 km in the southern Cordillera to less than 100 km further north (Price and Carmichael 1986). To be on the conservative side, an estimated 100 km of shortening is inferred in the study area and this westerly-thickening wedge is included as potential source rock. Based on the vitrinite reflectance data published by Masters (1984) and the Rock-Eval data in this report, virtually all of the shales in the study area are fully mature and capable of generating oil. The thickness and geometry of each stratigraphic unit studied (Jurassic, Ellerslie and Glauconite Formation) was estimated from the various isopach maps compiled in the thesis and the simplified "rock volume" diagrams for each of the three units is shown in Fig. 58. The percentage shale value for each of the three stratigraphic intervals was estimated by averaging the percentage of shale (based on 2/3 deflection on gamma-ray logs) in each of the three units in 100 (randomly selected) wells in the study area. The %TOC and HI values for each stratigraphic interval were averaged from the data collected in this study (Appendix 5) and the formulae and constants (e.g., K=0.7) were taken from Moshier and Waple´s (1985) paper.

(ii) DISCUSSION

The calculations presented in Table 17 suggest that approximately 866 billion barrels of oil could have been expelled from the Jurassic-Mannville shales in the study area. This value is nearly twice Moshier and Waple´s (1985) estimate (450 billion barrels) for the amount of oil generated by the Mannville strata across the entire Alberta Basin. This estimate is also nearly an order of magnitude lower than the Master´s (1984) estimate of 7000 billion barrels of oil expelled from the entire basin. The great discrepancies between these estimates probably reflects the different formulae and parameters (e.g., mean %TOC and HI values) that were employed in each study. It is beyond the scope of this thesis to resolve the problems and limitations of these two numerical techniques although a few comments can be made concerning the source rock parameters used by each study.

The Mannville shales examined in this thesis contained nearly twice as much TOC (Glauconite 1.82%, Ellerslie 2.56%) as the shales (mean 1.3%) sampled by Moshier and Waples (1985). In addition, the average hydrogen indices of the Glauconite and Ellerslie shales sampled in this study (mean 187 and 183 respectively) are nearly twice the average values (95.6) in the shales sampled by Moshier and Waples (1985). This difference probably results from different stratigraphic interval and study areas being investigated. In this thesis, outcrop and subsurface samples from the lower (Ellerslie) and middle (Glauconite) parts of the Mannville interval were examined. These are comprised of brackish to marine shales which contain a significant amount of Type II organic matter. Moshier and Waples (1985) only analyzed subsurface (core) samples and did not calculate the amount of oil which could have been generated in the Foothills. Moreover, they sampled the entire Mannville interval which included the upper (non-marine) strata. Most of the organic matter in these shales is probably Type III plant material with limited oil-generating potential.

The %TOC values employed in this study are significantly lower than the values outlined by Masters (1984). His study sampled the entire Mesozoic wedge and considered that the marine and marginal marine (coal-bearing) strata of the Gething, Nikanassin and Falher Formations in north-central Alberta comprised the most important source rocks. Although these shales contain very high %TOC (up to 7.5%), they are dominated by Type III organic matter (Masters 1984) and it is unlikely that they generated significant volumes of oil.

It is difficult to estimate what proportion of the oil was lost in migration or degraded by bacteria after migration. Moshier and Waples (1985) suggested that under optimal conditions, 35% of expelled oil could be trapped and the remaining 65% would be lost in the migration process. Masters (1984) suggested that only 25% of expelled oil would be lost during migration and that

75% could be preserved in hydrocarbon traps. In the calculations presented in Table 17, the more conservative (35%) migration efficiency coefficient was employed. On this basis, of the 866 billion barrels generated by the Jurassic and Early Cretaceous shales, at best only 303 billion barrels (35%) could have survived the migration process. This is nearly an order of magnitude smaller than the 2650 billion barrels of tar sands and heavy oils reserves currently in place.

The potential volume of Mannville-derived oils would be further reduced if corrections are applied for incomplete maturation or if significant proportions of the hydrocarbons were generated as gas, rather than oil (as would be predicted by examination of the van Krevelen diagrams). In addition, this large disparity would be further accentuated if the volume of the oil trapped in the heavy oil belt would corrected for volumetric losses due to bacterial degradation (Masters 1984; Moshier and Waples 1985). However, these corrections are difficult to quantify (Moshier and Waples 1985) and the volumetric estimates will not be corrected for these processes in this study.

(D) CONCLUSIONS

The Jurassic-Early Cretaceous shales sampled in this study exhibit fair to very good source potential. These shales are mature and within the oil window in most of the western Plains and near or within the gas window in the Foothills. Volumetric calculations indicate that these shales could have generated 866 billion barrels of oil and that under optimal conditions, 303 billion barrels could have survived the migration process. As these values are an order of magnitude lower than the existing in-place hydrocarbon reserves in the Early Cretaceous tar sands and heavy oil deposits in eastern Alberta and western Saskatchewan, it is highly unlikely that these shales could have comprised the source of these oil deposits.

CHAPTER 11 COLLISION OROGENY AND FORELAND BASIN SEDIMENTATION

Foreland basins are elongate structural depressions which flank fold/thrust belts associated with major collision orogens. The subsidence in these basins is a near-instantaneous lithospheric response to the emplacement of thrust sheets in the adjacent orogen (Turcotte and Schubert 1982). The rate of subsidence in these basins increases exponentially towards the edge of the disturbed belt, resulting in an elongate, asymmetric geometry. The thickness and facies distribution of clastic strata within foreland basins is controlled by the thickness, rigidity, and density of the lithosphere, as well as the rate and amount of crustal loading (Jordan 1981; Quinlan and Beaumont 1984). This chapter will review the relationship between collision orogeny and foreland basin sedimentation and will close with a revised interpretation of the Jurassic-Early Cretaceous tectonic history of the southern Cordillera.

(A) COLLISION OROGENY AND MOUNTAIN-BUILDING PROCESSES.

Collision orogens are complex zones of compressional structural deformation, metamorphism and uplift which are formed during the collision between two or more lithospheric plates (Spencer 1988). Although their origin is reasonably well understood, the timing and nature of the forces driving the uplift and compressional folding in collision orogens remain poorly understood. Part of the problem is that the complex, multi-stage tectonic history of most fold/thrust mountain belts has only been unravelled since the theory of accretionary tectonism was introduced in the last decade. Before introducing foreland basin sedimentation, a brief review of these mountain-building processes will be presented.

One of the most important observations concerning collision orogeny is that most vertical uplift in this type of mountain belt occurs after the compressional thrusting has ceased (Gansser 1982). This regional uplift is initiated by the thickening of the crust by A-type subduction and is aided by the buoyant effects of hot, relatively low-density magmatic rocks in the metamorphic core and by erosion (unloading) of the thrust sheets in the adjacent fold/thrust belt (Gansser 1982; Spencer 1988). Rates of tectonic uplift in modern mountain belts are, on average, eight times faster than rates of denudation in these same areas (Gansser 1982; Schumm 1963). It is this great difference between the rates of uplift and erosion which permits massive mountain ranges such as the Alps or Himalayas to be constructed in a relatively short period of time (Gansser 1982).

(i) CHARACTERISTICS AND ORIGIN OF LARGE SCALE CYCLICITY IN FORELAND BASIN SUCCESSIONS

Thick successions of marine and non-marine strata, locally dissected by basin-wide unconformities, have been described in foreland basins flanking the Alpine, Appalachian, Himalayan, and Cordilleran mountain chains (van Houten 1981; Quinlan and Beaumont 1984; Parkash et al. 1980; and Eisbacher et al. 1974). These successions typically contain one or more large (km) scale coarsening-upward megacycles comprised of a basal marine sequence overlain by coarse non-marine strata. The terms flysch and molasse were first introduced as formal stratigraphic terms in the central Alps to describe these marine and non-marine strata respectively (see Hsu 1970; and van Houten 1981 for reviews of these terms). Bertrand (1897) cited in van Houten (1974) later used these terms in a descriptive (facies) sense and suggested that they comprised part of a geosynclinal cycle which was somehow related to the mountain-building event. These terms have been adopted by geologists working in other sedimentary basins and are generally interpreted as syn and post-orogenic deposits respectively

(Miall 1978; van Houten 1981).

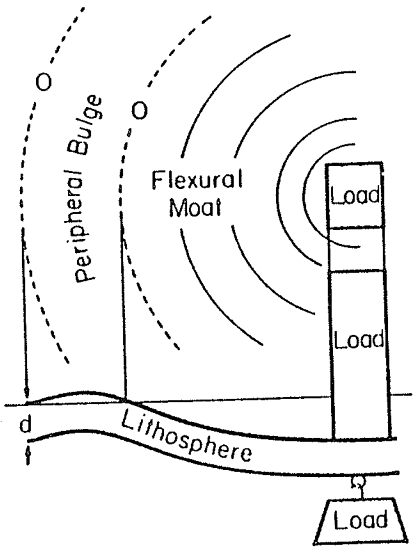
The clastic wedge flanking the Alps is comprised of several kilometers of Cretaceous-Eocene marine shales and sandstones (Flysch) which are overlain by 6-10 km of Oligocene-Miocene coarse clastics (Molasse). The Molasse contains several very thick, coarsening-upward megacycles, each of which is considered to represent a period of renewed uplift and denudation (van Houten 1974, 1981). In the Appalachians, three flysch-molasse successions are recognized and each is comprised a thick (1-3 km) basal marine shale sequence which is overlain by several km of coarse clastics. Quinlan and Beaumont (1984) interpret the three successions as the record of three major orogenies (Taconic, Acadian and Allegheny) which affected this area during the Paleozoic. In the Himalayas, two coarsening-upward successions are noted in the 5-km thick Siwalik molasse (Parkash et al. 1980). Likewise in the Western Canadian Sedimentary Basin, two (Eisbacher et al. 1974; Miall 1978) and possibly three (Stott 1984) megacycles are recognized (see Chapter 1).

Two schools of thought have emerged to explain the origin of these large scale megacycles. The first model interprets an influx of coarse clastic detritus into the basin as evidence of renewed faulting and tectonism in the source area. This relationship has been demonstrated in modern (Blair and Bilodeau 1988) and ancient rift basins (e.g. Gloppen and Steel 1981) and has been applied to foreland basin sucessions. Since most detritus in foreland basin successions is ultimately derived from the thrust sheets, the stratigraphic position of conglomerates has been used to estimate the timing of episodes of renewed thrusting and tectonic activity in the Cordillera (Schultheis and Mountjoy 1978; Jordan 1981; van Houten 1981).

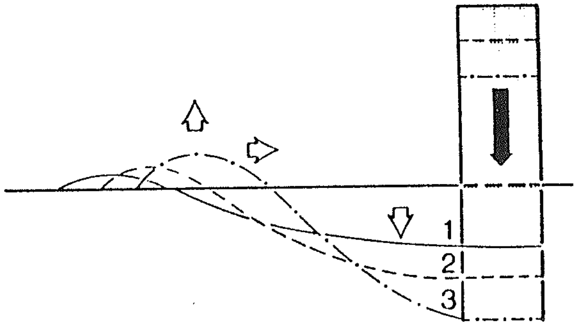
The second school considers that the influx of coarse clastics into the basin marks the end, rather than the inception of thrusting, and records a regional isostatic uplift of the fold/thrust belt, and the associated foreland basin Quinlan and Beaumont 1984; Heller et al. 1988; Blair and Bilodeau 1988). In this model, episodes of thrusting correspond with periods of rapid subsidence (and possibly marine transgression) in the adjacent foreland basin. This theory was first applied to strata in the Western Interior Basin by Kauffmann (1977) and Quinlan and Beaumont (1984) later expanded on the idea using data from the Appalachians. They suggested that the imposition of a thrust sheet load initiates rapid elastic flexure of the lithosphere, resulting in rapid subsidence in the basin flanking the fold belt and localized uplift along a peripheral bulge located farther away from the disturbed belt (Fig. 59A). As the load is removed, or redistributed, as the thrust sheets are bevelled by erosion, the basin deepens and becomes narrower and the forebulge migrates towards the edge of the disturbed belt, forming a regional unconformity (Fig. 59B).

The principal difference between these two models concerns the origin the increased topographic relief which causes the coarse clastic wedge to prograde out into the basin. In the first model, uplift is confined to the fold/thrust belt and the amount of relief is directly related to the amount of vertical displacement along the individual faults. In the second model, the uplift is a consequence of the isostatic rebound of the lithosphere which is initiated after the thrusting has either ceased or greatly slowed. As this flexure involves the entire lithosphere, a regional isostatic uplift of both the fold/thrust belt and the adjacent foreland basin is initiated.

Heller et al. (1988) have suggested that both models may apply during different stages of foreland basin evolution and this explains the differences in the types of conglomerates present in foreland basins. During their synorogenic phase when the thrust sheets are emplaced in the fold/thrust belt, a

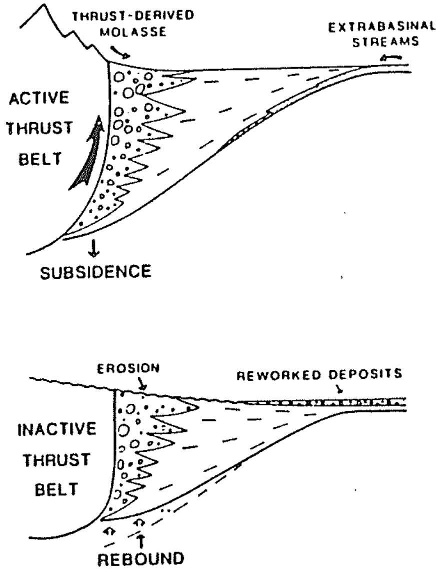


Cartoon illustrating initial deformation of a uniform lithosphere produced by a square load either deposited on the surface or intruded at depth. The upper panel depicts a plan view and the lower panel a cross-sectional view. Note that these figures are not drawn to scale and that the amplitude of the peripheral bulge is exaggerated.



Cross-sectional view of the surface deformation of a continuous viscoelastic lithosphere under a surface load. The initial response is the same as that of the elastic lithosphere of Fig. 2 (profile 1). As time progresses relaxation of stress makes the profile evolve through stages 2 and 3 as the response progresses toward local isostatic equilibrium.

b



Depositional models for synorogenic (A) and postorogenic (B) phases of foreland-basin evolution.

(59) Models of tectonism and sedimentation in an active foreland basin proposed by (A) Quinlan and Beaumont (1984) and (B) Heller et al. (1988).

basin subsidence is most rapid immediately adjacent to the edge of the fold belt. This results in deposition of a thick, narrow band of conglomerates which grade rapidly into thick, fine-grained marine or lacustrine shales) only a few km from the edge of the disturbed belt. During the subsequent post-orogenic phase (Fig. 59B), the lithosphere rebounds as the load is removed by erosion and a basin-wide unconformity, overlain by a thin sheet-like conglomerate is developed (Heller et al. 1988).

This relatively simple model is attractive as it provides an autocyclic mechanism for generating the large scale cyclicity and the basin-wide unconformities in foreland basin successions which are triggered by episodic thrusting in the adjacent fold belt.

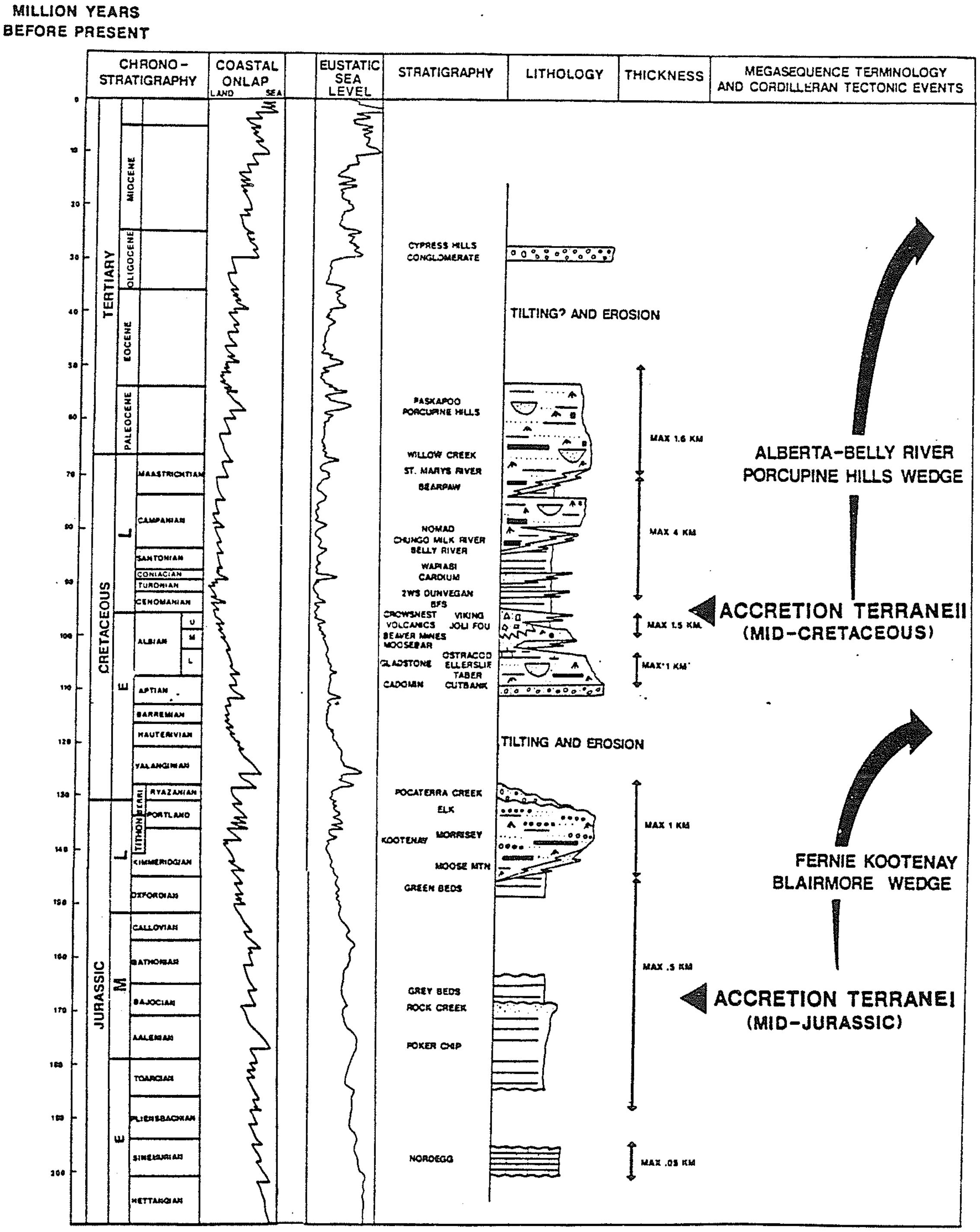
(ii) TECTONIC MEGACYCLES IN THE WESTERN CANADIAN SEDIMENTARY BASIN

The tectonic history of the southern Cordillera is extremely complex and recent studies have offered dramatically different tectonic interpretations of the same area (Monger et al. 1982; Lambert and Chamberlin 1988). Part of the problem is that the record of the initial Jurassic-Early Cretaceous (Columbian) orogeny within in the Cordillera has been obscured and overprinted by the younger Late Cretaceous-Tertiary (Laramide) orogeny. This section will evaluate these contrasting tectonic models by interpreting the stratigraphic record in the foreland basin in terms of the model proposed by Heller et al. (1988).

A composite geologic section was constructed showing the age and facies characteristics of the clastic wedge in the southern portion of the Western Canadian Sedimentary Basin (Fig. 60). The vertical time scale, and sea level curves plotted on this diagram were redrafted from Haq et al. (1987) and the the maximum thickness, age and facies characteristics was derived from a variety of sources including McCrossan and Glaister (1964), Stott (1984) and Poulton (1984). The two megacycles recognized by Eisbacher et al. (1974), are plotted on the right hand side of the diagram (Fig. 60). Each cycle represents a period of approximately 70 million years and is comprised two basic components which include a basal marine shale and an upper marginal to non-marine coarse clastic (molasse) interval (Eisbacher et al. 1974). The thickness of the basal marine shale varies from tens of meters (Fernie Formation) to more than 1 km (Alberta Group). Both of the upper (molasse) intervals are dissected by a major unconformity which is overlain by conglomerate (Cadomin-Cypress Hills Formations). In the lower megacycle, this conglomerate is overlain by a second km-thick succession of largely non-marine strata (Blairmore-Luscar Groups) and is locally capped by volcanics in the Crowsnest Pass area. In the upper cycle, any strata overlying the Cypress Hills conglomerate has been removed by post-Oligocene erosion.

(iii) INTERPRETATION OF MEGACYCLES IN THE CLASTIC WEDGE OF THE SOUTHERN CORDILLERA

To relate these depositional megacycles to tectonism in the Cordillera, the timing of the two collision events proposed by Monger et al. (1982) and the age of major episodes of magmatism, metamorphism and uplift in the orogen (according to Archibald et al. 1983) were plotted on the composite geologic section (Fig. 60). On this diagram, the inital (Mid-Jurassic) collision event appears to coincide with a period of rapid subsidence in the basin (recorded by the Fernie shales) and an intense, but brief, episode of magmatism, tectonic thickening and prograde metamorphism in the southern Cordillera (Archibald et al. 1983; Brown and Read 1983). This probably represents the synorogenic stage of basin evolution proposed by Heller et al. (1988) in which thrusting



(60) Tectonic megacycles in the Western Canadian Sedimentary Basin. Chronostratigraphic stage boundaries, coastal onlap and eustatic sea level curves from Haq et al. (1987), age of various stratigraphic units from Poulton (1984) and Stott (1984).

initiated by the collision event results in rapid subsidence, and marine transgression, in the foreland basin.

The coarse clastic wedge at the top of the lower megacycle (Kootenay-Blairmore Groups) was deposited during the following 40-60 million years in response to rapid uplift in the southern Cordillera (Archibald et al. 1983). This would represent the post-orogenic stage of basin evolution (Heller et al. 1988) during which time thrusting had probably ceased or slowed and erosion of the uplifting orogen led to a major influx of coarse clastics into the basin. The profound unconformity at the top of the Kootenay-Nikanassin interval, which is overlain by the Cadomin conglomerate, records the culmination of this regional uplift of the orogen and flanking foreland basin.

The origin of the Blairmore-Luscar wedge overlying the Cadomin conglomerate is problematical. The thick, largely non-marine section suggests that an episode of renewed thrusting had occurred in the fold/thrust belt which apparently records renewed tectonism along the active western margin of the craton. However, this event differed from the initial (collision) event as it was followed by volcanism along the margin of the basin (Crowsnest Volcanics), a swarm of late (post-tectonic) granitic plutons in the Kootenay Arc (Archibald et al.1983) and a flood of feldspathic detritus into the basin from an unknown (probably now-eroded) volcanic source which was centered in the southern Cordillera. A second unconformity is recorded by the abrupt contact of the volcanics and feldspathic sandstones at the top of the Blairmore with the deep marine shales of the Alberta Group. The Alberta Group shales at the base of the second megacycle apparently record an episode of renewed thrusting in the orogen which was probably initiated by the accretion of the second composite terrane to the craton. However, as this strata was not studied in this thesis, this megacycle will not be discussed in more detail.

(iv) IMPLICATIONS FOR TECTONIC EVOLUTION OF THE SOUTHERN CORDILLERA

The development of two km-thick megacycles in the Late Mesozoic-Tertiary clastic wedge flanking the Rocky Mountains supports the hypotheses that two separate collision events occurred along the active western margin of the North American craton. If the marine shales at the base of these successions do record the time at which the thrust sheets were emplaced, as Heller et al. (1988) have suggested, then these two collision events occurred during the Late Jurassic and Middle Cretaceous respectively. The stratigraphic record thus supports the two-collision model presented by Monger et al. (1982). The stratigraphic data from the foreland basin does not support Lambert and Chamberlin´s (1988) single-collsion model which suggests that the first interaction between the craton and the single large composite terrane (Cordilleria) occurred during the Albian (Middle Cretaceous). Much older, westerly-derived, clastics are found throughout the length of the Foothills (e.g.,Kootenay Group), indicating that a significant amount of uplift and erosion occurred in the Cordillera as early as the Late Jurassic.

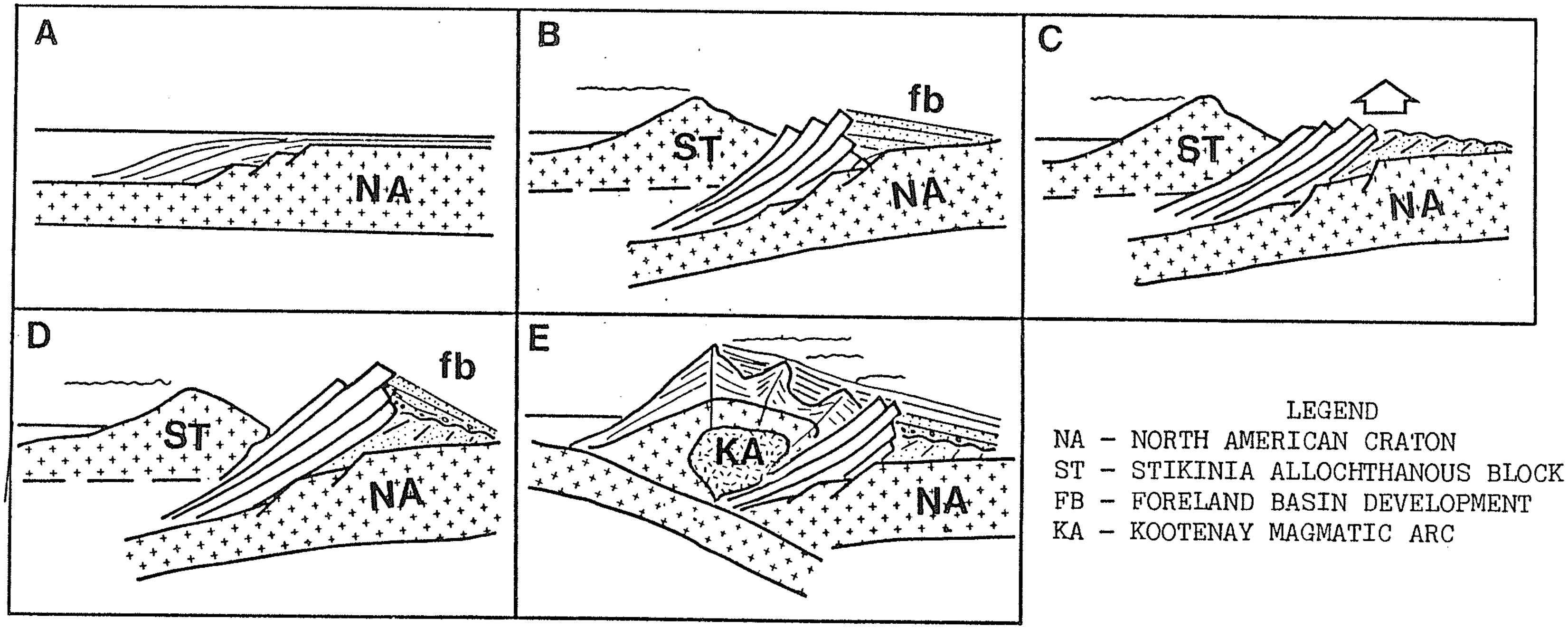
The tectonic model proposed by Monger et al. (1982) does require some modification, however, as the apparent displacement along major strike slip fault systems in the Cordillera is much less than the displacement indicated by paleontologic and paleomagnetic data (Price and Carmichael 1986). Lambert and Chamberlin´s (1988) model suggests that most of this north-south displacement is taken up by oblique subduction along a west-dipping suture zone which is presently marked by the Purcell Thrust. During this time, the craton was underthrusting the Cordilleria allochthon and thrust sheets would have been emplaced onto the under-riding craton, initiating rapid subsidence in the foreland basin developed east of the orogen. This accretion event was essentially complete by 105 Ma and further convergence in the southern Cordillera was taken up along an east-dipping subduction zone which developed on the west side of Cordilleria (Lambert and Chamberlin 1988). Magmas generated above this east-dipping subduction zone probably constructed a (now largely eroded) magmatic arc in the southern Cordillera which is is represented by the swarm of 100Ma plutons in the Kootenay Arc and the Crownest Volcanics in the southern Cordillera. The marine shales of the overlying Alberta group record a renewed episode of thrusting in the orogen which accompanied the second major collison along the active western margin of the ancestral Cordillera.

(vi) SUMMARY, TECTONIC HISTORY OF THE SOUTHERN CORDILLERA

Complex structural geology and overlapping magmatic and metamorphic events have obscured the Jurassic-Early Cretaceous tectonic history of the southern Canadian Cordillera. However, examination of the sedimentological and petrographic characteristics of clastic strata deposited in the foreland basin which flanked the orogen has yielded valuable information on the timing, nature and origin of the tectonic events which shaped the ancestral Cordillera. Six major stages are recognized in the evolution of the Cordillera during the Jurassic and Early Cretaceous.

(1) During the Early and Middle Jurassic, the western margin of North American Craton was a passive margin (Fig. 61A). A thin (condensed) shallow marine clastic and carbonate succession, dissected by several unconformities, was deposited at that time (i.e.,Nordegg, Poker Chip, and Rock Creek Members of the Fernie Formation). The sandstones were well-sorted and highly quartzose, reflecting their mature, recycled (cratonic) derivation .

2) During the Middle Jurassic, the western margin of the craton evolved into an



(61) Tectonic evolution of the southern Canadian Cordillera A) passive margin basin facing an open ocean during the Paleozoic and Early Mesozoic B) transition into a foreland basin in response to Middle Jurassic collision of an allochthoncus terrane along a west-dipping subduction zone C) cessation of thrusting, resulting in uplift and erosion of the orogen and adjacent basin, and formation of the basin-wide (pre-Cadomin unconformity) D) accelerated subduction along the west-dipping suture zone, resulting in subsidence and deposition of Cadomin-Gladstone and E) final accretion of the allochthanous block, resulting in reversal of subduction direction, and establishment of a magmatic arc in the southern Cordillera (Kootenay Arc). This arc served as source for the feldspathic sandstones of the Beaver Mines-Upper Mannville interval. The arc is now eroded although the swarm of post-tectonic 100Ma plutons in this area comprise the roots to this arc.

active (convergent) margin (Fig. 61B). An unknown amount of oceanic lithosphere was consumed in a west-dipping subduction zone and this resulted in the collision of a composite exotic terrane with the western margin of the North American Craton. This collision resulted in the emplacement of thrust sheets onto the underiding (cratonic) plate and initiated rapid subsidence in a foreland basin which developed between the fold belt and the craton. During this stage of basin evolution, a westward-thickening wedge of deep marine shales (Upper Fernie-Green Beds) was deposited.

3)As compressional folding ceased, or slowed, and the fold/thrust belt was bevelled by erosion, the collision orogen rebounded, introducing a rapid flux of coarse clastics into the basin (Kootenay Group, Fig. 61B). These sandstones are chert and quartz-rich and were reworked from uplifted Proterozoic and Paleozoic miogeoclinal successions in the ancestral fold/thrust belt. These strata are presently found only in the Foothills as they have been truncated by pre-Cretaceous erosion further east.

4) The regional crustal thickening resulting from this collision, coupled with continued erosion and redistribution of the thrust load, initiated a massive regional isostatic uplift of the fold/thrust belt and adjacent foreland basin (Fig. 61C The amount of uplift, and consequently the thickness of strata eroded, was greater in the east. In the extreme western part of the basin, a km-thick, near continuous section of Late Jurassic to Early Cretaceous Kootenay strata is preserved (Stott 1984). This fact that little, or no, stratigraphic hiatus exists below the pre-Cretaceous unconformity in the west and that the same unconformity cuts down into Paleozoic strata in the Plains suggests that differential uplift, possibly related to migration of a

forebulge, occurred across the basin.

5) The Blairmore strata overlying this unconformity probably records an episode of renewed subsidence in the basin which was probably initiated by continued thrusting in the orogen. During this time, the subduction zone was still dipping to the west (Fig. 61E) and the chert and quartz-rich sandstones were derived from uplifted Proterozoic and Paleozoic miogeoclinal strata in the ancestral fold/thrust belt. Theoverallfining-upward succession represented by the Cadomin-Gladstone and Moosebar Formations probably records an increase in subsidence rates which culminated with the advance of the Clearwater Sea into the basin.

6) The feldspathic sandstones in the upper part of the Blairmore (Beaver Mines-Gates Formation) record a major change in provenance which probably reflects a reversal in subduction zone polarity in the southern Cordillera. These sandstones were apparently derived from a magmatic arc centered in the southern Cordillera (Kootenay Arc) which developed over an east-dipping subduction zone (Fig. 61E). The swarm of post-tectonic (100Ma) plutons in the Kootenay Arc, and the Crowsnest Volcanics, are the only preserved record of this magmatic event. After an unknown amount of oceanic lithosphere was consumed in this subduction zone, a second composite exotic terrane was accreted to the western margin of the orogen. This collision "choked off" this subduction zone and initiated a second major episode of thrusting in the ancestral fold/thrust belt. This thrusting, in turn initiated rapid subsidence in the adjacent foreland basin and led to the deposition of the thick (Alberta Group) marine shales which comprise the base of the second tectonic megacycle.

(B) A DEPOSITIONAL MODEL FOR FORELAND BASIN SEDIMENTATION

In addition to the km-scale tectonic cycles previously described in the Mesozoic clastic wedge in Alberta, this interval also exhibits a smaller-scale cyclity. These sequences are typically meters or 10's of meters in thickness. The three transgressive-regressive cycles described in the Glauconite-Moosebar interval are examples of this order of cyclicity. Similar cyclicity has also been described in other stratigraphic units in the Western Canadian Sedimentary Basin (Leckie 1986b; Plint and Walker 1987) and in cyclothems of marginal to non-marine, coal-bearing strata of the Appalachians (Wanless and Weller 1932, quoted in Miall 1984, p. 348) and British Isles (e.g. Ramsbottom 1979).

This cyclicity has been attributed to various causes including the progradation and abandonment of deltaic lobes (Ferm 1975), eustatic sea-level fluctuations (Crowell 1978), and a combination of eustatic and tectonic mechanisms (Leckie 1986b). Before interpreting the cyclicity recognized in the Moosebar-Glauconite, a brief review of these processes will be presented.

(i) GROWTH AND ABANDONMENT OF DELTAIC LOBES

The cyclothemic nature of the Carboniferous strata in the foreland basin flanking the Appalachians has been attributed to the progressive growth and abandonment of distributary lobes in a river-dominated delta (Ferm 1975). The Mississippi Delta, which is cited as a modern analog for these sequences, is comprised of a series of thick distributary lobes which built out into the Gulf of Mexico in the past 6000 years. This model can not be invoked, however, for most of the Cretaceous marginal-marine sequences in the Western Interior Basin as most of these comprise sheet-like, wave-dominated marine sandstones which exhibit no evidence of lobe development (Leckie 1986b; Plint and Walker 1987; Rosenthal and Walker 1987). Coleman (1975) has also noted that lobe switching is not an important process in modern wave-dominated deltas.

(ii) EUSTATIC SEA LEVEL FLUCTUATIONS

In the past decade, a series of landmark papers published by Exxon researchers (e.g. Vail et al. 1977 and Haq et al. 1987) have suggested that eustatic sea level fluctuations exert a strong influence on clastic depositional systems. This group recently published a chronostratigraphic and sea level chart for the Mesozoic-Tertiary (Haq et al. 1987) in which they documented 119 globally synchronous sea level shifts over the past 250 million years (average cycle duration approximately 2.1 million years). To relate this chart to the foreland basin succession in Alberta, these curves were plotted beside the tectonic megacycle schematic (Fig. 60). A detailed chart focusing on the Cretaceous interval is shown in Fig. 62. Vail et al. (1977) recognized four levels of cyclicity on these sea level curves which include first order (100Ma duration), second order (10-100Ma duration), third order (1-10Ma duration), and fourth order (.01-.1 Ma duration). Vail et al. (1977) also proposed a model which could be used to predict the response, and record, of various depositional systems to these eustatic sea level fluctuations. In this model, a drop in relative sea level occurs when the eustatic sea level drops faster than the rate of subsidence. This results in a seaward shift of the shoreline, exposure of part, or all, of the shelf, and incision of river systems into previously deposited strata. A subsequent rise in eustatic sea level, which is accentuated by subsidence, leads to rapid coastal flooding (transgression) and aggradation of the previously incised channels (Vail et al. 1977).

While this model, and the associated curves, appear to be a panacea for explaining the cyclicity recognized in all Mesozoic stratigraphic sequences, there are several problems with it which have not yet been resolved. The first problem concerns the actual dating of the strata being evaluated. Several researchers (e. g. Jeletzky 1978) have criticized the bio- and chronostratigraphic framework upon which the eustatic model is based. These problems are best illustrated by comparing the age of the Cretaceous stage boundaries (Fig. 63) most recently published by the Exxon group (Haq et al. 1987) with the ages indicated in the recent Decade of North American Geology (DNAG) publication (Palmer et al. 1983). Although there is a close correspondance between Exxon and DNAG stage boundaries for the *Late* Cretaceous (average difference only .66 Ma), there is a major difference in the proposed boundaries for the Early Cretaceous interval (average difference 8.25 Ma). On this basis, it is difficult to accept their Early Cretaceous "globally synchronous" fluctuations as the discrepancies in the age of the strata (+/-8.25 Ma) far exceeds the average duration (2.1 Ma) of the individual cycles which they are correlating.

The second problem with the eustatic model concerns the proposed origin of the eustatic sea level fluctuations. While the first or second order cycles can be readily explained in terms of changes in the rate of sea floor spreading (Miall 1984, p. 357), the origin of the higher frequency (third or fourth order) cycles have not been resolved. Some of these rapid, large fluctuations (e.g. Holocene rise in sea level) can be attributed to deglaciation but this process can not be invoked in during the warmer Cretaceous period (Miall 1984). Since a mechanism for generating high frequency *eustatic* sea level fluctuations has not been established, the writer considers that alternative models should be considered to explain the *relative* sea level fluctuations which are recognized in the stratigraphic section.

(iii) TECTONIC CONTROLS ON SEDIMENTATION

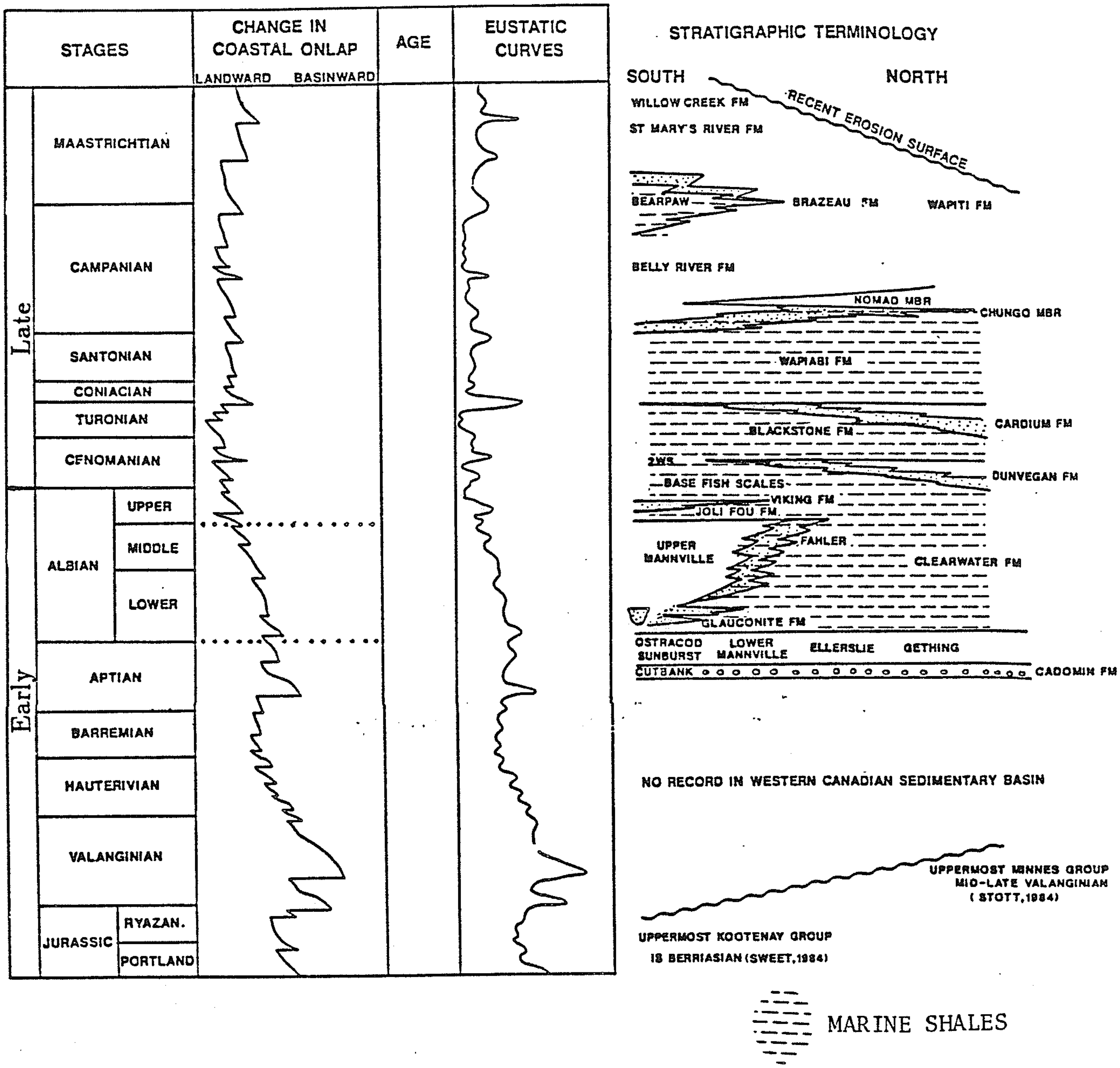
Foreland basins comprise a unique type of sediment depocenter in that their existence is tied directly to tectonism in a fold/thrust belt with which they are associated. On a long-term (million year) scale, foreland basins are clearly subjected to episodes of varying rates of subsidence which are separated by periods of uplift (see previous section).

On a shorter term, rates of uplift in modern collision orogens are also episodic and highly variable. The few detailed geodetic studies available indicate that short episodes of rapid uplift are separated by long periods of erosion (Blatt et al. 1980, p. 30, Gansser 1982). In the higher Himalayas, Pleistocene strata have been uplifted as much as 5 km in the past 1.6 million years. The discontinuous (episodic) nature of this uplift is recorded by series of topographic terraces within the Pleistocene strata, which are cut by very deep (1 km) river gorges. Assuming that crustal flexure in foreland basins is a near instantaneous (10^4 to 10^5 years) response to loading (or unloading) in the fold/thrust belt (Turcotte and Schubert 1982), then the alternating periods of uplift and erosion in the orogen should be accompanied by short-term (100,000's of years) fluctuations in the rates of subsidence (or uplift) in the adjacent basin. This is an important point as it is this scale of the cyclicity (100,000's of years duration) which are recognized in other stratigraphic units in the Western Interior Basin (Leckie 1986b) and in the cyclothems of the British Isles (Ramsbottom 1979).

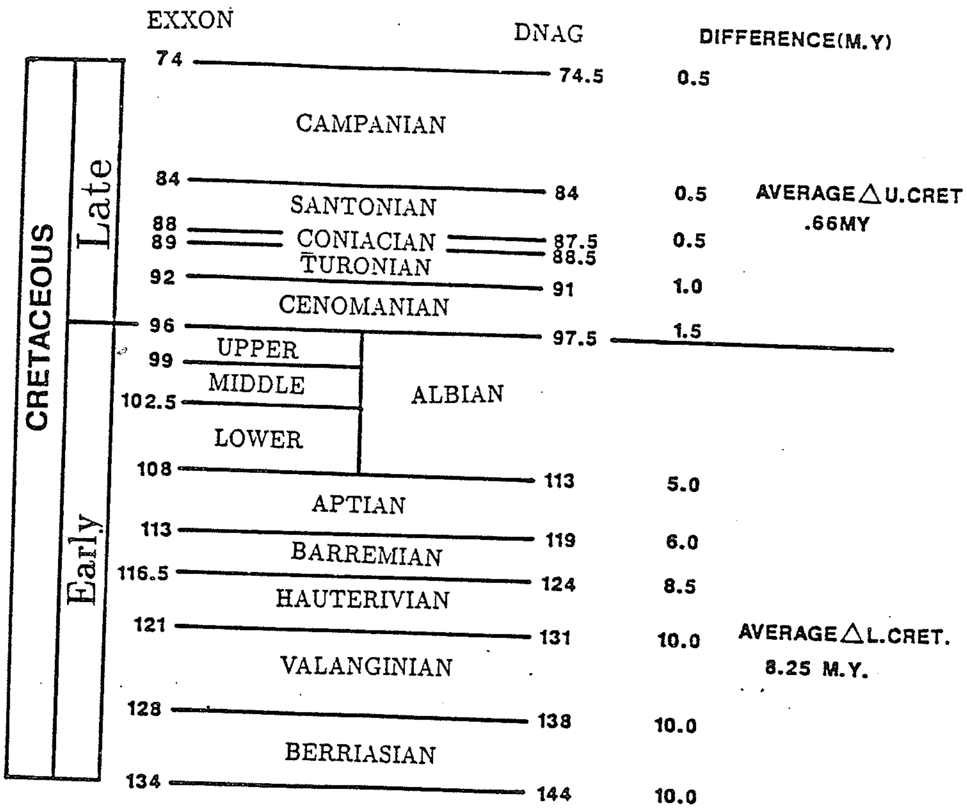
It is possible that even higher frequency tectonic events in the disturbed belt (i.e. individual earthquakes) are manifested in the stratigraphic section in the adjacent basin. In a forearc setting, a single earthquake in Alaska in 1964 uplifted a coastal area exceeding 150,000km ^{2} by as much as 11.3 m while adjacent coastal swamps were depressed as much as 2.3 m below sea level (Pflaker 1972). Although similar geodetic data from earthquakes in foreland setting was not available to the writer, the presence of numerous, high magnitude earthquakes in these settings (e.g. Iran, Pakistan, Turkey) would suggest that similar displacements would occur in these areas. When such large, virtually instantaneous displacements of this magnitude are compared with eustatic fluctuations of cm or meters per thousand years, it is clear in that tectonic influence is capable of overwhelming the eustatic imprint in tectonically active foreland basins.

(iv) CYCLICITY IN THE GLAUCONITE-MOOSEBAR INTERVAL: IMPLICATIONS FOR INTERPRETATION OF FORELAND BASIN SUCCESSIONS

The three transgressive-regressive successions recognized in the Early Albian Glauconite-Moosebar interval are interpreted as the record of recurrent fluctuations in relative sea level. On the eustatic sea level chart presented by Haq et al. (1987), three prominent fluctuations are noted during the Early Albian (Fig. 62). While this would appear to support the eustatic model, it is noted that large differences exist between the chronostratigraphic boundaries proposed for the Albian (Fig. 63). In addition, it is unclear where the contact of Early and Middle Albian is recorded in the stratigraphic succession (McLean 1982). For these reasons, it is unclear where the Moosebar-Glauconite succession should be plotted on the eustatic sea level chart. One possible way of resolving this problem is to group the Early and Middle Albian intervals together and analyze the cyclicity and eustatic sea level fluctuations across the entire interval. During the 9 million years represented by the Early and Middle Albian interval (Fig. 63), five deflections are noted on the eustatic sea level curve (Fig. 62) published by the Exxon group. However, during that same time, at least 10 regressive-transgressive successions are recognized in the Moosebar and Gates strata (7 in the Gates interval and 3 in the underlying



(62) Cretaceous eustatic sea level and coastal onlap curves plotted beside a schematic stratigraphic section of strata in Alberta Foothills. Chronostratigraphic time scale, and eustatic sea level and coastal onlap curves from Haq et.al. (1987) and information on the age of stratigraphic units from Poulton (1984); Stott (1984); and Rudkin (1964).



(63) Comparison of chronostratigraphic stage boundaries published by DNAG (Palmer et al. 1983) and the Exxon research group (Haq et al. 1987).

Moosebar) which represent that time period in the Foothills (Leckie 1986b; this thesis Chapter 6). These observations suggest that the cyclicity recognized in the foreland basin was of a higher frequency (less than a milllion years duration) than the eustatic fluctuations outlined on the chart (average duration 2.1 million years).

A tectonic mechanism for generating these relative sea level fluctuations in the Glauconite-Moosebar interval is supported by two independant lines of evidence. These fluctuations were accompanied by changes in sandstone composition (Chapter 7) and basin paleoslope (Chapter 6). As it is unlikely that simple eustatic sea level fluctuations could have resulted in changes in provenance and basin geometry, these observations are cited as evidence that the cyclicity was at least partly influenced by tectonism in the adjacent collision orogen. On this basis, transgressions would result during periods of accelerated thrusting when rapid basin subsidence was initiated by the emplacement of thrust sheets in the foreland fold/thrust belt. Regressive sequences and/or regional unconformities would be generated when thrusting ceased or slowed and the crust rebounded, resulting in accelerated uplift and erosion and a increased flux of detritus into the basin.

CHAPTER 12 CONCLUSIONS

(1) During the Jurassic to Early Cretaceous, the Western Canadian Sedimentary Basin evolved from a simple passive margin flanking a stable craton to a complex foreland basin flanking a major collision orogen. In west-central Alberta, this transition is recorded by clastic strata of the the Jurassic Fernie Formation and the Early Cretaceous Blairmore-Mannville Group. This change in tectonic setting resulted in pronounced changes in depositional style and basin geometry and had a major impact on the source rock and reservoir potential of the strata which were deposited in the basin during that time.

(2) The Early to Middle Jurassic is represented by the Nordegg, Poker Chip and Rock Creek Members of the Fernie Formation. These strata comprise a thin, condensed marine sequence of chert, shale, and highly quartzose marine sandstones which is dissected by several unconformities. The base of the Late Jurassic is represented by a thin, areally extensive succession of glauconitic marine shales which are locally interbedded with thin quartzose sandstones (Upper Fernie-Green Beds). In the western part of the study area, this basal shale is overlain by a westward-thickening wedge of marine and non-marine strata (Kootenay Group-Nikanassin Formation). These strata are truncated by a major unconformity which can be traced across the basin. A near complete Jurassic-Early Cretaceous section is preserved in the western Foothills whereas the (pre-Cretaceous) unconformity truncates progressively older strata towards the east. This suggests that more uplift and erosion occurred in the eastern (flat-lying) part of the basin than in the western part of the basin flanking the fold/thrust belt. This differential uplift may have resulted from the migration of a tectonic forebulge across the basin.

The Blairmore-Mannville interval overlying this unconformity is comprised of three units which include a basal non-marine to brackish interval (Cadomin-Gladstone-Ellerslie), a middle brackish to open marine shale/sandstone succession (Moosebar-Glauconite), and an upper non-marine interval (Beaver Mines-Gates Formation). Three depositional successions can be correlated across the study area in the middle Moosebar-Glauconite interval and each is comprised of a basal transgressive marine shales overlain by regressive marine sandstones which are locally dissected by incised fluvial channels. These transgressive-regressive sequences record recurrent fluctuations in relative sea level during the advance and subsequent retreat, of the boreal Clearwater Sea from central Alberta. The upper part of the Blairmore-Mannville interval is comprised of coarse feldspathic non-marine sandstones and mudstones which, in the central Foothills, contain thick interbedded coal beds.

(3) Several scales of cyclicity are recognized in the Late Mesozoic-Tertiary clastic wedge of the Western Canadian Sedimentary Basin. Two kilometer-thick tectonic megacycles are recognized and each represents approximately 70 million years. Each cycle is comprised of a basal marine shale which is overlain by a thick marginal to non-marine coarse clastic succession (molasse) which is truncated by a major unconformity which can be traced across the basin. The lower marine interval records an episode of rapid subsidence in the basin which accompanies emplacement of the thrust sheets in the adjacent orogen. The overlying coarse clastics record a massive influx of coarse clastics into the basin which were shed from the rising orogen. The unconformity near the top of the megacycle records a massive isostatic uplift of the orogen, and foreland basin, probably in response to tectonic thickening of the lithosphere in the adjacent orogen.

In addition to the large scale tectonic cycles described above, small-scale cyclicity is also recognized in the Jurassic-Early Cretaceous strata in the study area. In central Alberta, the Glauconite-Moosebar interval was deposited during a major Early Albian trangression of the boreal Clearwater Sea. This transgression probably records a rise in relative sea level which resulted from accelerated subsidence rates in the foreland basin in response to renewed thrusting in the orogen. The higher order cyclicity (meters to 10's of meters in thickness) within the Glauconite-Moosebar interval is also the result of fluctuations in relative sea level. The three sequences recognized in the Glauconite-Moosebar interval are accompanied by significant changes in provenance and basin geometry, suggesting that this scale of cyclicity is also tectonically-induced. In summary, it appears that most of the cyclicity recognized in the Late Jurassic-Early Cretaceous clastic wedge of the Western Canadian Sedimentary Basin is tectonically-induced. The signature of eustatic sea level fluctuations which may have occurred during this time was overwhelmed by the effects of changes in the rate of uplift or subsidence in the basin.

4) The petrographic composition of the Jurassic-Early Cretaceous sandstones in western Alberta is closely linked to the tectonic history of the ancestral Cordillera. Prior to the onset of orogeny in the Rocky Mountains (Early-Middle Jurassic), the sandstones were highly quartzose and very well sorted, reflecting their multicyclic, cratonic derivation. The petrography of the overlying Nikanassin sandstones was not investigated in detail in this thesis although previous researchers (e.g., Rapson 1965) noted that equivalent Kootenay sandstones in the south are chert and quartz-rich are probably derived from uplifted miogeoclinal strata in the Cordillera. Sandstones at the base of the Blairmore-Mannville interval are also chert and quartz-rich and were probably derived from uplifted Paleozoic and Proterozoic miogeoclinal strata in the

ancestral fold/thrust belt. Sandstones at the top of the interval contain abundant feldspar and volcanogenic detritus and were probably derived from a magmatic arc which was probably centered in the southern Cordillera. This change in sandstone composition is abrupt and typically occurs over a few meters of stratigraphic section at the top of the Glauconite-Moosebar interval. This suggests that the change in provenance was not the result of gradual unroofing of a collision orogen but rather the result of an abrupt change in the character of the source terrain in the southern Cordillera. This change in sedimentary provenance may record a reversal in the polarity of the subduction zone in the ancestral Cordillera, following accretion of the composite exotic terrane to the western margin of the craton.

(5) The differences in the framework composition of the Jurassic-Early Cretaceous sandstones resulted in differing degrees of cementation and porosity development. The fine-grained, highly quartzose Jurassic sandstones are tightly cemented by quartz overgrowths and generally comprise poor reservoirs, except where unstable detrital or early authigenic phases have been removed by secondary dissolution. The chert and quartz-rich sandstones at the base of the Early Cretaceous exhibit varying degrees of syntaxial and epitaxial quartz overgrowths but generally retain significant amounts of primary porosity. The feldspathic, volcanogenic sandstones at the top of the Blairmore-Mannville are typically plugged by authigenic clay-carbonate cements and form reservoirs only where extensive secondary dissolution has occurred. The framework control on authigenic mineral phases suggests that at least some of the cement was derived from local sources.

(6) The Jurassic-Early Cretaceous shales are fair to good source rocks which

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(6) The Jurassic-Early Cretaceous shales are fair to good source rocks which

are moderately rich in Type II and Type III organic matter. The Ellerslie shales contain more organic matter (average 2.56% TOC) than the Glauconite-Moosebar and Jurassic shales (average 1.87% and 2.32% respectively) because they were deposited under restricted marine and estuarine , rather than open-marine, conditions. The Jurassic and Early Cretaceous shales are mature across the eastern part of the study area (Plains) and overmature in the Foothills. Although these strata have probably generated significant volumes of gas and oil, volumetric calculations suggests that they could not comprise the principal source of the massive tar sand and heavy oil deposits located in equivalent strata in eastern Alberta.

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APPENDIX 1 LOCATION ACCESS TO OUTCROPS

SHEEP RIVER section 35 TWP 19 R5W5

From Turner Valley, drive approximately 30 km west on Hwy. 546. A short section of carbonaceous sandstone(Kootenay Formation) is exposed on the right (north) side of the road. From this point, drive another .5 km west, park the vehicle, and descend into the Sheep River valley. The outcrop is exposed on the north side of the river. A second section of the Blairmore is exposed on the Sheep River 10 km further west (section 19-TWP19-R5W5), immediately downstream of the bridge crossing the Sheep River. However, the river banks are very steep and this section is virtually inaccessible, except at very low water levels.

WAIPAROUS CREEK section 15, 16 TWP 28 R9W5

This section is located approximately 1 hours drive northwest of Calgary. From the junction of Hwys. 1A and 22, drive west along 1A for 13 km and then proceed north onto the Forestry Trunk Road for approximately 40 km. Turn west at the Mockingbird Fire Tower access road and park the vehicle approximately 2 km east of this turnoff. Outcrop is sporadically exposed along both banks of the creek starting several hundred meters upstream of the large gravel bar.

BURNT TIMBER CREEK sections 24, 25 TWP30 R9W5

From the junction of the Forestry Trunk Road and Highway 1A (see above), drive north for approximately 68 km to the outcrop where the road crosses Burnt Timber Creek. Park vehicle at the bridge and walk approximately 2 km east along an old access road to the end of a large meadow. Descend into the river valley and walk another .5 km downstream where the base of the section is marked at the base of the Cadomin conglomerate.

PRAIRIE CREEK sections 34, 35 TWP 36 R11W5

This outcrop is located approximately 45 minutes south of Rocky Mountain House. Follow Hwy. 752 south from the center of Rocky Mountain House, cross the Clearwater River, and continue another 2 km south before turning south onto the Strachan Gas Plant road. Follow this road for 50.3 km to the junction of the Fall Creek access road. The Cadomin and Upper Fernie is well exposed into the roadcut at the junction whereas the middle Moosebar conglomerate is accessed by driving up the road for 1.3 km and hiking northward approximately 300 m along an overgrown seismic line which intersects the road at a steep angle.

FALL CREEK SECTION section 31 TWP 37 R11, 12W5

This outcrop is exposed along both banks of Fall Creek and is accessed by driving up the Fall Creek road (see above) for approximately 10 km to the bridge which crosses Fall Creek. Park the vehicle and hike northeast 5 km along an old wellsite road which follows the creek. This outcrop is exposed on the east limb of the large anticline structure which is breached at the crest, forming the spectacular falls along the creek.

TAY RIVER section 9 TWP 36 R10W5

This outcrop is accessed from the Strachan Gas Plant road which links the Forestry Trunk Road with Hwy. 22. From this junction of the Fall Creek road (see above), drive approximately 5 km south to the bridge over Tay River. Park the vehicle and hike southeast along an overgrown game trail which follows the creek. The outcrop is located in a heavily wooded gorge, approximately 6 km from the forestry road. *Note* This is a very wet hike which involves wading a deep creek several times.

RAM RIVER section 4, 5 TWP 38 R12W5

This outcrop is very difficult to access at it is located about 1.5 hour driving time from Nordegg and another 4 hours of hiking (one way) from the closest road access. From the junction of the Forestry Trunk Road and the David Thompson Highway just west of Nordegg, drive south for approximately 30 km and turn east onto the North Ram River access road. Follow this road for approximately 13 km and park the vehicle at the east end of the large meadow where the main road turns north. Hike west along the abandoned road for another 12 km to the junction of the North Ram and the Ram River. Wade across the North Ram River (low water stages only) and hike along the west side of the Ram River gorge for approximately 3 km upstream.

CRESCENT FALLS sections 25, 26, 27 TWP 39 R17W5

This outcrop is exposed along in the gorge along both banks of the Bighorn River, just downstream of Crescent Falls. From Nordegg, follow Hwy. 11 for 16 km and turn west onto the access road to Crescent Falls. Follow this for approximately 4 km and park the vehicle just above the main falls. This Gladstone section is exposed in the gorge approximately 1 km south of the Main Falls and is accessed by following a hiking trail to the lower falls. To examine the Moosebar Formation, descend into the gorge immediately below the upper falls and hike along the river bed (low water stages only) for approximately 1.5 km. The sandstone ledge forming lip of the lower falls is approximately 30m above the base of the Moosebar.

SHUNDA CREEK section 1 TWP 41 R14W5

This outcrop is well exposed on the David Thompson Highway (#11) about 6 miles east of Nordegg. It is located beside the abandoned railroad bridge crossing the road and Shunda Creek. This outcrop is the type section of the Nordegg Member (Fernie Formation) which, with the uppermost Mississippian, is exposed in the roadcut approximately 100m west of the Cadomin conglomerate exposure.

RUBY CREEK sections 2, 11 TWP 45 R21W5 and 34, 35 TWP44 R21W5

The Ruby Creek sections are located approximately 100 km northwest of Nordegg and are accessed via the Forestray Trunk Road. Drive northwest from Nordegg for approximately 63.2 km to the turnoff to the Thunder Lake Reserve access road. Follow this road for approximately 33.4 km to the junction of Ruby Creek and the Cardinal River. Ford the river just upstream of the junction and follow the creek upstream to the second outcrop.

CADOMIN section 5 TWP 47 R23W5

This outcrop is the type section of the Cadomin and is poorly exposed along a railroad cut along the McLeod River on the west outskirts of the town of Cadomin. From the center of town, drive west approximately 1 km to the bridge traversing the river which leads to the Genstar Cement Plant (the gate at this bridge is locked on weekends and evenings). Cross the bridge and drive east along the railroad tracks for 1 km to the first outcrop of Nikanassin sandstones. The Gladstone and Moosebar interval is discontinuous and badly deformed and several repeats of the Cadomin can be observed in the next 500m of roadcut beside the railroad tracks.

GRANDE CACHE COMPOSITE section TWP 58 R8W6

The section shown in Appendix IV is a composite of three separate sections which are exposed along the banks of the Smoky River between the town of Grand Cache and the McIntyre Mine Coal Mine to the north. The lower part of the interval (McIntyre Mine outcrop, sections 3, 9 TWP 58 R8W5) is exposed on the east side of the river, approximately 500m south of the bridge which crosses the river immediately south of the minesite. The middle part of the section is accessed by walking across a second (railroad) bridge which crosses the river several km upstream of the mine and following the tracks for another 1.5 km north. The base of the section is exposed in a deep gorge, approximately 200m east of the tracks and the Torrens sandstone, and overlying coal is exposed at the top of the rock face. The uppermost part of the interval is exposed in the Gustav Flats section, on the west side of the river, and can be accessed by driving several km northwest along the Fire Tower access road.

APPENDIX 2A LIST OF CORES EXAMINED

LOCATION	DEPTH	STRATIGRAPHY
01-32-56-26W4	3934-4111	E-N
11-11-56-27W4	3795-3855	G-E
06-15-56-27W4	3881-3875	E
06-16-56-27W4	3730-3840	E
07-35-56-27W4	3765-3839	E
08-17-36-06W5	2706-2765M	UM-G-E
10-22-37-09W5	3124-3142M	G
10-04-38-02W5	6750-6810	UM-MR
07-15-38-02W5	6808-6904	G
13-32-38-04W5	2248-2488M	UM-MR-N
07-12-38-09W5	2943-2963M	G
	2995-3023M	E
07-13-38-09W5	2900-2340M	UM-G
02-19-39-04W5	7256-7296	UM-G
04-33-39-05W5	2284-2328M	UM-G-E-UF
10-19-40-02W5	6727-6858	G-E
10-28-40-03W5	6967-7066	E-UF-PC
08-33-40-03W5	2128-2149M	UF-PC
14-04-40-05W5	2284-2305M	G
	2314-2356M	E-UF-RC
06-07-40-05W5	2316-2359M	G
06-01-40-06W5	2328-2346M	G
10-09-40-06W5	2403-2423M	G
14-23-40-06W5	2353-2368M	UM-G
03-20-40-07W5	2463-2473M	G
16-31-40-07W5	2316-2336M	G-E-UF
10-35-40-07W5	2456-2468M	UM-G
	2496-2515M	G-E
04-36-40-08W5	2560-2587M	G-UF
16-06-41-01W5	1867-1885M	G
11-31-41-01W5	1839-1871M	UM-G
06-27-41-03W5	6942-7052	E-UF
08-05-41-04W5	2155-2170M	UM-G
11-12-41-04W5	6925-6975	G-UF-RC
10-23-41-05W5	2200-2227M	UM-G
08-26-41-05W5	2329-2384M	UM-G-UF
16-34-41-05W5	2235-2252M	G-E-UF-RC
08-08-41-06W5	2380-2411M	G
08-26-41-06W5	2329-2365M	UM-G
	2375-2384M	G-UF
06-02-41-07W5	2468-2492M	UM-G
11-11-41-07W5	2466-2487M	G
10-31-41-09W5	2742-2760M	G
10-34-41-10W5	2807-2817M	G
13-22-42-01W5	1782-1799M	G
11-21-42-04W5	2049-2082M	UM-G
07-08-42-05W5	2218-2236M	G
10-22-42-05W5	7100-7220	UM-G
06-17-42-07W5	8015-8135	UF-RC-PC
06-18-42-07W5	1903-1922M	UM-G
12-32-42-09W5	2635-2650M	UF
01-30-43-01W5	1756-1777M	UM-G
10-08-43-02W5	1823-1859M	G-E
11-07-43-03W5	2034-2052M	G
01-08-43-03W5	1986-2005M	G-E
10-34-43-03W5	1915-1951M	G
02-16-43-04W5	2030-2054M	G
07-34-43-04W5	2056-2071M	G
10-34-43-04W5	1915-1951M	G
06-35-43-07W5	2259-2282M	E-RC-N
06-35-43-07W5	2259-2282M	E-RC
08-13-43-10W5	2646-2664M	UF
07-05-44-02W5	1802-1833M	G
10-12-44-02W5	1773-1791M	G
13-17-44-02W5	1877-1932M	UM-G
06-10-44-03W5	1866-1902M	UM-G
08-21-44-03W5	2033-2044M	G-E
16-21-44-03W5	2006-2027M	G
11-33-44-03W5	1862-1887M	UM-G
16-16-44-04W5	2050-2077M	G-E
06-08-44-04W5	2300-2324M	UM-G
10-26-45-01W5	1638-1656M	UM-G
03-03-45-02W5	1767-1793M	UM-G
07-04-45-02W5	1768-1824M	UM
02-10-45-02W5	1786-1825M	G-E
11-26-45-02W5	1771-1802M	G
06-29-45-09W5	7721-7733	E-UF-RC
06-14-46-10W5	2331-2416M	G-E-UF-RC
10-32-46-10W5	2449-2489M	E-UF
06-30-46-13W5	9667-9732	G-E
10-09-46-14W5	10254-10304	E-UF-RC
10-14-46-14W5	9655-9689	E
06-18-47-06W5	6719-6846	E-UF-PC
07-06-47-10W5	2467-2519M	UF-RC
	2434-2459M	G-E
04-28-47-11W5	2446-2474M	UF
14-33-48-01W5	1492-1533M	G
16-30-48-01W5	1530-1548M	G
16-34-48-01W5	1472-1506M	G
03-17-48-02W5	1619-1637M	G
14-22-48-02W5	1592-1612M	G
14-23-48-02W5	1575-1592M	G
06-24-48-02W5	1587-1608M	G
08-24-48-02W5	1586-1604M	G
14-25-48-02W5	1552-1570M	G
16-36-48-02W5	1546-1564M	G
14-29-48-04W5	5760-5797	G-E
	5840-5335	E-PC
06-33-48-04W5	1780-1798M	G-E
09-06-48-06W5	1795-1820M	UM
06-07-48-07W5	6530-6572	G-E
08-23-48-07W5	1876-1686M	G
06-15-48-09W5	2108-2144M	E-UF-RC
08-32-48-11W5	2337-2356M	UF-RC-PC
05-34-48-12W5	2470-2526M	E-UF-RC
07-03-48-14W5	9439-9560	E-UF-RC
06-12-48-15W5	9625-9285	E
06-21-48-16W5	9910-10010	G-E
07-36-48-16W5	9680-9790	G-E
01-02-49-01W5	1552-1580M	G
14-03-49-01W5	1459-1493M	G
12-04-49-01W5	1480-1502M	G
08-05-49-01W5	1498-1516M	G
06-09-49-01W5	1470-1500M	G
14-14-49-01W5	1436-1454M	G
14-22-49-01W5	1448-1466M	G
16-35-49-01W5	1410-1428M	G
07-20-49-02W5	1471-1491M	G
07-24-49-02W5	1460-1478M	G
10-28-49-03W5	1566-1584M	G-E
06-32-49-03W5	1623-1656M	G-E-PC-N
06-33-49-03W5	1724-1736M	E
11-29-49-04W5	1722-1739M	E
10-25-49-06W5	5557-5617	G
06-35-49-06W5	5746-5810	G
14-07-49-07W5	1965-2010M	G-E-UF
07-03-49-09W5	2068-2102M	UF-RC
07-11-49-10W5	2200-2227M	UF-RC
06-13-49-11W5	2227-2263M	UF-RC
08-35-49-12W5	7535-7650	UF
05-06-49-13W5	2641-2657M	E-UF
10-35-49-13W5	2413-2453M	G-E
07-03-49-16W5	9820-9671	G-E
07-03-49-17W5	9665-9795	G
11-12-49-17W5	9852-9973	G-E
16-01-50-01W5	1384-1403M	G
16-11-50-02W5	1510-1528M	E
06-05-50-03W5	1584-1602M	G-E-PC
06-11-50-03W5	1557-1594M	G-E-PC-N
06-01-50-04W5	1532-1608M	G-E-PC
16-08-50-04W5	1585-1599M	G-E-PC
07-03-50-04W5	5206-5266	G
08-24-50-04W5	1526-1555M	G-E
07-11-50-05W5	5262-5314	G
05-12-50-05W5	1644-1673M	G-E-PC
06-02-50-06W5	5555-5705	UM-G
06-13-50-06W5	5260-5320	G
06-16-50-06W5	5385-5490	G-E
06-22-50-06W5	5361-5408	G
06-01-50-07W5	1717-1735M	UM-G
	1747-1765M	G
10-15-50-07W5	1832-1868M	G-E-N
11-25-50-07W5	1735-1762M	G
06-32-50-08W5	6117-6237	G-UF
06-11-50-09W5	1939-1968M	G
	1985-1997M	RC-PC
03-34-50-12W5	2282-2300M	G-E
08-30-50-13W5	2414-2450M	G-E-UF-RC
09-35-50-14W5	2425-2443M	G-E
04-04-51-04W5	5175-5230	E-PC-N
14-21-51-04W5	1607-1625M	E
06-05-51-06W5	1687-1737M	G-E-PC
06-07-51-07W5	1898-1910M	G-E-PC
07-12-51-08W5	1839-1888M	G-E-PC
07-20-51-10W5	2072-2113M	E-RC
06-33-51-10W5	2017-2062M	G-E-PC
10-03-51-11W5	2214-2248M	G-E-UF-RC
06-36-51-12W5	2212-2263M	E-UF-RC
02-20-51-13W5	2406-2418M	G-E
06-06-52-01W5	1437-1455M	E
06-03-52-04W5	1496-1514M	G-E
06-29-52-08W5	5805-5917	G-E
14-31-52-08W5	1813-1889M	G-E-N
06-36-52-08W5	1427-1446M	G-E
09-08-52-11W5	2072-2141M	G-E-UF
05-10-52-13W5	2275-2294M	E-UF
10-17-53-13W5	2144-2174M	G-E-UF-RC
07-19-53-18W5	8590-8645	E
11-11-53-20W5	2816-2853M	G-E
10-33-54-05W5	4668-4728	G
06-18-54-07W5	1617-1689M	G-E-PC-N
11-02-54-08W5	5430-5547	G-E-PC
11-25-54-12W5	1861-1898M	UF-PC
10-24-54-13W5	6392-6510	UF-RC-PC
06-19-55-05W5	1419-1467M	G-PC
10-08-55-12W5	6213-6315	G-E-UF-RC
10-18-55-12W5	1904-1959M	E-UF-RC
07-30-55-12W5	6237-6358	E
02-02-55-13W5	6435-6560	UF
06-30-56-03W5	1230-1259M	G
06-24-56-04W5	4125-4193	G
	4260-4335	E-PC-N
10-29-56-11W5	5974-6034	UF
02-14-56-14W5	1975-2008M	UM-G
10-25-58-04W5	3660-3717	G
06-16-58-15W5	2058-2130M	G-UF
11-31-58-15W5	2075-2128M	G-E
11-07-59-02W5	3500-3621	G-E
07-19-60-14W5	1707-1731M	G-E-UF

APPENDIX 2B LIST OF SANDSTONE SAMPLES

SAMPLE NUMBER	LOCATION	DEPTH	STRATIGRAPHIC UNIT
SS-2	RAM RIVER		UPPER MOOSEBAR
SS-3	WAIPAROUS		GLADSTONE
SS-4	RAM RIVER		GLADSTONE
SS-8	RAM RIVER		UPPER MOOSEBAR
SS-12	CRESCENT FALLS		LOWER MOOSEBAR
SS-14	RAM RIVER		LOWER MOOSEBAR
SS-16	05-34-46-12W5	2404 m	RC
SS-17	07-09-50-04W5	5230'(1594 m.)	G(DV)
SS-22	05-12-50-05W5	1657 m.	E
SS-23	07-36-48-16W5	9675'(2949 m.)	G(DV)
SS-25	10-22-42-05W5	7160'(2182 m.)	G(H)
SS-26	06-24-56-04W5	4140'	G(MC)
SS-29	05-12-50-05W5	1665 m.	N0RD
SS-34	11-07-59-02W5	3621'(1103 m.).	E
SS-35	07-36-48-16W5	9630'(2935 m.)	G(MC)
SS-36	10-29-56-11W5	6025'(1836 m.)	UF
SS-37	05-34-48-12W5	2472 m.	E
SS-39	02-02-55-13W5	6530'(1990 m.)	RC
SS-40	05-12-50-05W5	1647 m.	E
SS-42	06-18-42-2W5	1914 m.	G(H)
SS-44	02-14-56-14W5	1984 m.	G(MC)
SS-45	08-30-50-13W5	2443 m.	UF
SS-46	10-22-37-09W5	3138 m.	G(H)
SS-47	08-30-50-13W5	2417 m.	G
SS-49	08-17-36-06W5	2742 m.	G(C)
SS-50	•	2730 m.	G(C)
SS-51	11-26-45-02W5	1786 m.	G(H)
SS-53	07-12-38-09W5	2946 m.	G(H)
SS-54	•	2953 m.	G(H)
SS-55	11-26-45-02W5	1770 m	G(H)
SS-56	06-36-51-12W5	2235 m.	RC
SS-57	06-36-51-12W5	2227 m.	E
SS-58	14-21-51-4W5	1610 m.	E
SS-59	04-33-39-05W5	2317 m.	E
SS-60	•	2321 m.	UF
SS-61	14-21-51-04W5	1623 m.	E
SS-62	14-31-52-08W5	1842 m.	E
SS-63	10-28-40-03W5	7018'(2039 m.)	UF
SS-64	•	7058'(2151 m.)	UF?
SS-67	10-17-53-13W5	2159m	E?
SS-68	14-04-40-05W5	2338 m.	RC
SS-73	03-20-40-07W5	2464 m.	G(H)
SS-74	•	2468 m.	G(H)
SS-75	16-06-41-01W5	1880 m.	G(G)
SS-76	•	1871 m.	G(G)
SS-77	08-05-41-04W5	2159 m.	G(H)
SS-78	16-34-41-05W5	2241 m.	E
SS-79	08-08-41-06W5	2383 m.	G(H)
SS-80	01-30-43-01W5	1760 m.	G(H)
SS-81	01-08-43-03W5	1994 m.	G(MR)
SS-82	•	1986 m.	G(MR)
SS-83	11-17-43-05W5	2077 m.	UM
SS-84	10-12-44-02W5	1785 m.	G
SS-85	13-17-44-02W5	1914 m.	G(H)
SS-86	08-21-44-04W5	2032 m.	E
SS-87	07-06-47-10W5	2498 m.	RC
SS-88	16-30-48-01W5	1534 m.	G(MC)
SS-89	06-07-48-07W5	6630'(2021 m.)	E
SS-90	•	6635'(2022 m.)	E
SS-91	06-12-48-15W5	9655'(2943 m).	E
SS-92	06-09-49-01W5	1474 m.	G(TH)
SS-93	•	1478 m.	G(TH)
SS-94	•	1486 m.	G(TH)
SS-95	14-03-49-01W5	1486 m.	G(TH)
SS-96	•	1477 m.	•
SS-97	06-32-49-03W5	1640 m.	E
SS-98	08-35-49-12W5	7550'(2301 m.)	UF
SS-99	11-12-49-17W5	9860'(3005 m.)	G(DV)
SS-101	06-01-50-07W5	1757 m.	G(P)
SS-102	11-25-50-07W5	1756 m.	G(DV)
SS-103	•	1750 m.	G(P)
SS-105	06-11-50-09W5	1940 m.	G(P)
SS-106	•	1950 m.	G(DV)
SS-107	10-17-53-13W5	2174 m.	RC
SS-108	06-18-54-07W5	1625 m.	E
SS-109	•	1629 m.	E
SS-111	GRANDE CACHE	GF1	TORRENS
SS-113	RUBY CREEK	D	UPPER MOOSEBAR
SS-114	MCINTYRE MINES	1	NIKANASSIN
SS-115	RUBY CREEK	B	TORRENS
SS-116	PRAIRIE CREEK	A	ROCK CREEK
SS-118	BIGHORN	Z	TORRENS
SS-119	CRESCENT FALLS	CF10	UPPER MOOSEBAR
SS-121	BURNT TIMBER	BTCF	BEAVER MINES
SS-123	TAY RIVER	A	UPPER MOOSEBAR
SS-128	MCINTYRE MINES	5	GLADSTONE
SS-129	BIGHORN	Y	UPPER MOOSEBAR
SS-138	CADOMIN	B	TORRENS
SS-142	MCINTYRE MINES	7	GLADSTONE
SS-145	06-02-50-06W5	5658'(1724 m.)	G(DV)
SS-147	•	5590'(1703 m.)	G(MC)
SS-149	CRESCENT FALLS	CF2	GLADSTONE
SS-151	FALL CREEK		UPPER MOOSEBAR
SS-152	13-32-38-04W5	2254 m.	G(MR)
SS-153	10-04-38-02W5	6806'(2074 m.)	G(MR)
SS-154	07-19-53-18W5	6600'(2012 m.)	G(ED)
SS-155	07-15-38-02W5	6808'(2072 m.)	G(C)
SS-156	07-05-45-02W5	1809 m.	G(MR)
SS-157	•	1830 m.	•
SS-158	13-32-38-04W5	2270 m.	E
SS-160	FALL CREEK	E	UPPER MOOSEBAR
SS-161	CRESCENT FALLS	CF1	GLADSTONE
SS-163	•	CF8	LOWER MOOSEBAR

APPENDIX.2C LIST OF SHALE SAMPLES

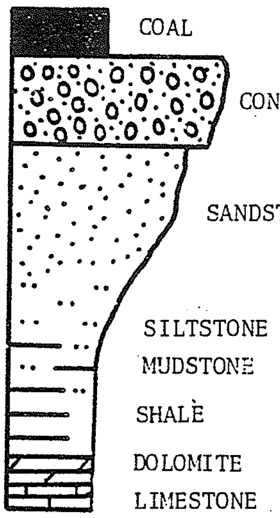
SH-1	13-17-44-02W5	1909m	G
SH-2	08-33-40-03W5	2128m	J
SH-3	06-15-56-27W4	3845'	E
SH-4	10-29-56-11W5	6032'	J
SH-5	10-18-55-12W5	1933m	J
SH-6	04-33-39-05W5	2337m	J
SH-7	"	2315m	E
SH-8	"	2306m	E
SH-9	"	2311m	E
SH-11	14-23-48-02W5	1588m	G
SH-12	"	1598m	G
SH-13	05-34-48-12W5	2492m	J
SH-14	Gladstone Creek		G
SH-15	Bighorn River		G
SH-16	08-17-36-06W5	2754m	E
SH-17	07-13-38-09W5	2909m	G
SH-18	02-19-39-04W5	7274'	G
SH-19	10-19-40-02W5	6275'	G
SH-20	14-04-40-05W5	2287m	G
SH-21	"	2314m	G
SH-22	16-31-40-07W5	2516m	G
SH-23	"	2535m	E
SH-25	10-23-41-01W5	2225m	G
SH-26	16-34-41-05W5	2250m	J
SH-27	10-31-41-09W5	2743m	G
SH-28	10-34-41-09W5	2760m	E
SH-29	10-34-41-10W5	2808m	G
SH-30	06-18-42-02W5	1904m	G
SH-31	12-32-42-09W5	2650m	J
SH-32	11-33-44-03W5	1864m	G
SH-33	"	1880m	G
SH-34	"	1888m	G
SH-35	16-21-44-04W5	2011m	G
SH-36	08-21-44-04W5	2030m	G
SH-37	06-08-44-08W5	2322m	G
SH-40	06-14-46-14W5	2392m	E
SH-42	"	2420m	E
SH-43	06-30-46-13W5	9680'	G
SH-44	"	9707'	E
SH-45	"	9720'	E
SH-46	04-28-47-11W5	2467m	J
SH-47	06-07-48-07W5	6550'	G
SH-48	"	6622'	G
SH-49	06-15-48-09W5	2117m	E
SH-52	07-03-48-14W5	9539'	J
SH-53	"	9560'	J
SH-54	08-05-49-01W5	1506m	G
SH-55	01-02-49-02W5	1566m	G
SH-56	"	1580m	E

SH-57	06-32-49-03W5	1636m	G
SH-58	"	1644m	E
SH-59	14-07-49-07W5	1989m	E
SH-60	"	2009m	J
SH-61	"	1967m	E
SH-62	05-06-49-13W5	2655m	J
SH-63	"	2648m	J
SH-64	08-35-49-13W5	7587'	J
SH-65	"	7640'	J
SH-66	10-35-49-13W5	2424m	G
SH-70	06-32-50-08W5	6130'	G
SH-71	08-30-50-13W5	2416m	G
SH-72	"	2426m	E
SH-74	"	2433m	E
SH-75	"	2450m	J
SH-76	06-06-52-01W5	1450m	E
SH-78	06-29-52-08W5	5835'	G
SH-79	"	5862'	G
SH-80	"	5902'	G
SH-81	09-08-52-11W5	2075m	G
SH-82	"	2088m	G
SH-83	"	2104m	J
SH-84	11-02-54-08W5	5430'	G
SH-86	10-24-54-13W5	6406'	J
SH-87	"	6460'	J
SH-88	"	6505'	J
SH-89	02-02-55-13W5	6475'	J
SH-90	06-24-56-04W5	4125'	G
SH-92	11-07-59-02W5	3548'	G
SH-93	07-19-60-14W5	1715m	G
SH-95	06-16-56-27W4	3790'	E
SH-96	"	3840'	E
SH-97	06-36-51-12W5	2233m	J
SH-98	14-31-52-08W5	1834m	E
SH-99	05-10-52-13W5	2238m	J
SH-100	10-33-54-05W5	4705'	G
SH-101	06-18-54-07W5	1622m	G
SH-102	"	1637m	J
SH-103	Burnt Timber Creek		LM
SH-106	02-02-55-13W5	6510'	J
SH-107	Crescent Falls		LM
SH-108	Burnt Timber Creek		LM
SH-109	"		LM
SH-110	Cadomin		LM
SH-111	Grande Cache		UM
SH-113	Ruby Creek		LM
SH-114	06-02-50-06W5	5655'	G
SH-115	06-02-50-06W5	5564'	G
SH-116	Fall Creek		LM

APPENDIX 3B CORE DESCRIPTIONS

LEGEND

LITHOLOGY



SEDIMENTARY STRUCTURES

TROUGH CROSS STRATIFICATION
PLANAR TABULAR CROS STRATIFICATION
PARALLEL LAMINATION
HUMMOCKY CROSS STRATIFICATION
SWALEY CROSS STRATIFICATION
CURRENT RIPPLE LAMINATION
WAVE RIPPLE LAMINATION
NORMAL GRADING
SOFT SEDIMENT DEFORMATION STRUCTURES
PALEOSOL PROFILE
SYNAERISIS CRACKS
BIOTURBATION
ROOTS

LOG TYPE

SP SPONTANEOUS POTENTIAL
GR GAMMA RAY

SEQUENCES

↗ COARSENING UPWARD
↖ FINING UPWARD

CONTACTS

GR GRADATIONAL
SH SHARP

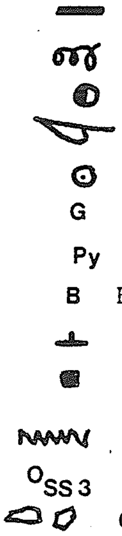
STRATIGRAPHIC TERMINOLOGY

E ELLERSLIE FORMATION
BS BLACKSTONE FORMATION
FERNIE FORMATION
UF UPPER FERNIE
RC ROCK CREEK
PC POKER CHIP
N NORDEGG
M MISSISSIPPIAN
W WABAMUN
UM UPPER MANNVILLE
M MANNVILLE
MRC MEDICINE RIVER COAL

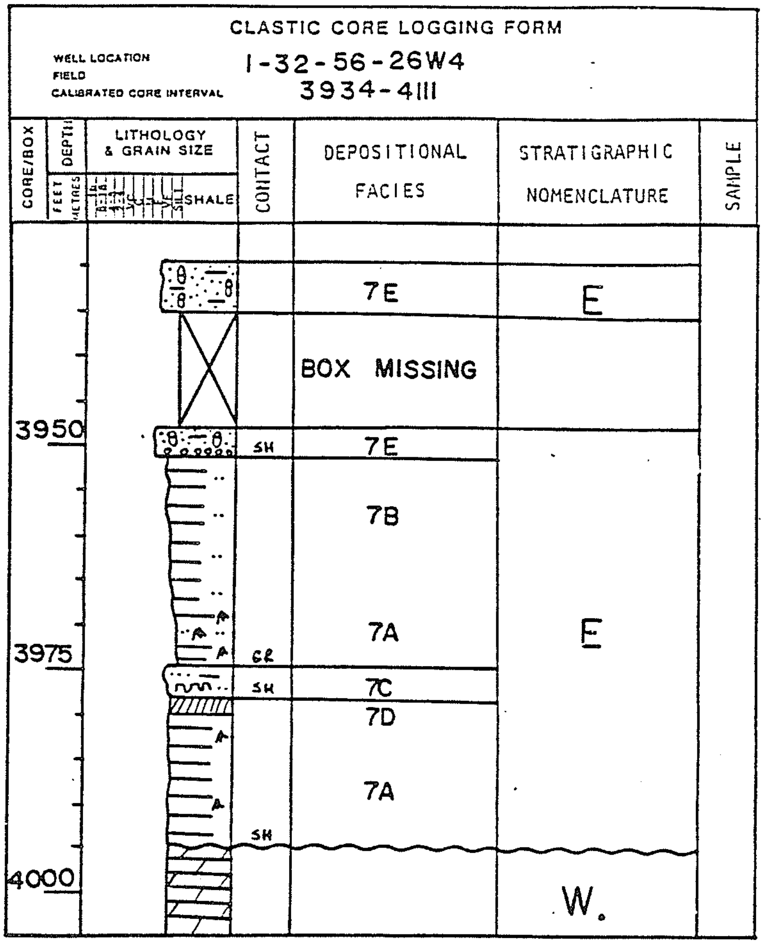
G GLAUCONITE FORMATION
MR MEDICINE RIVER
H HOADLEY
DV DRAYTON VALLEY
MC MODESTE CREEK
O OSTRACODE SHALE

B B-MARKER SHALE
A A-MARKER SHALE
C CAROLINE CHANNEL
P PEMBINA CHANNEL
TH THORSBY CHANNEL
E EDSON CHANNEL

ACCESSORIES



COAL LAMINAE
GASTROPODS
OSTRACODES
BELEMNITES
CRINOIDS
G GLAUCONITE
Py PYRITE
B BENTONITE
CALCAREOUS
CARBONACEOUS
STYOLITES
$^{O}SS3$ SAMPLE LOCATION
CLAY PEBBLE CLASTS

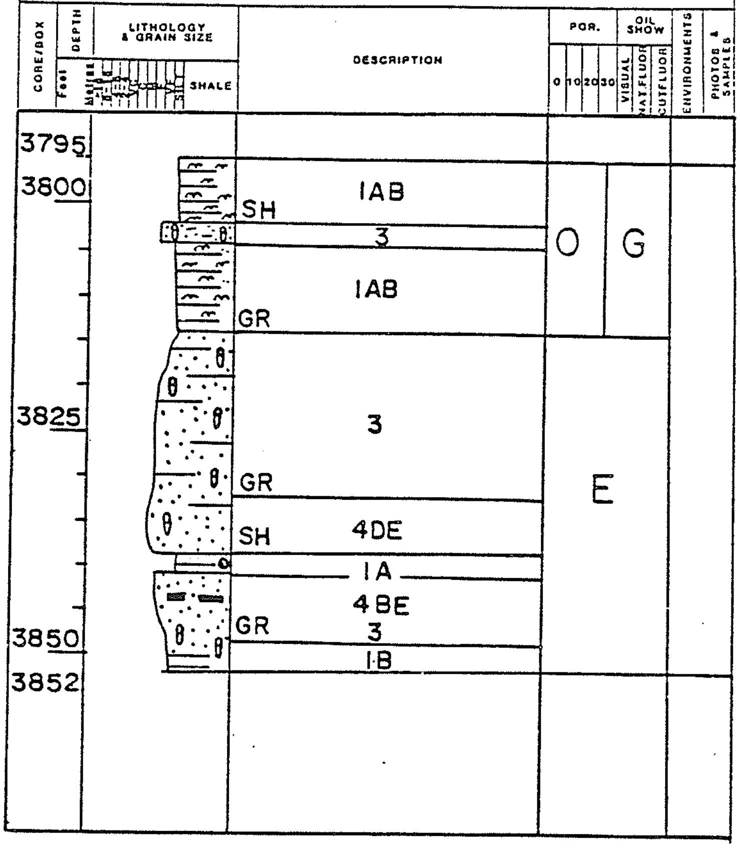

CLASTIC CORE LOGGING FORM

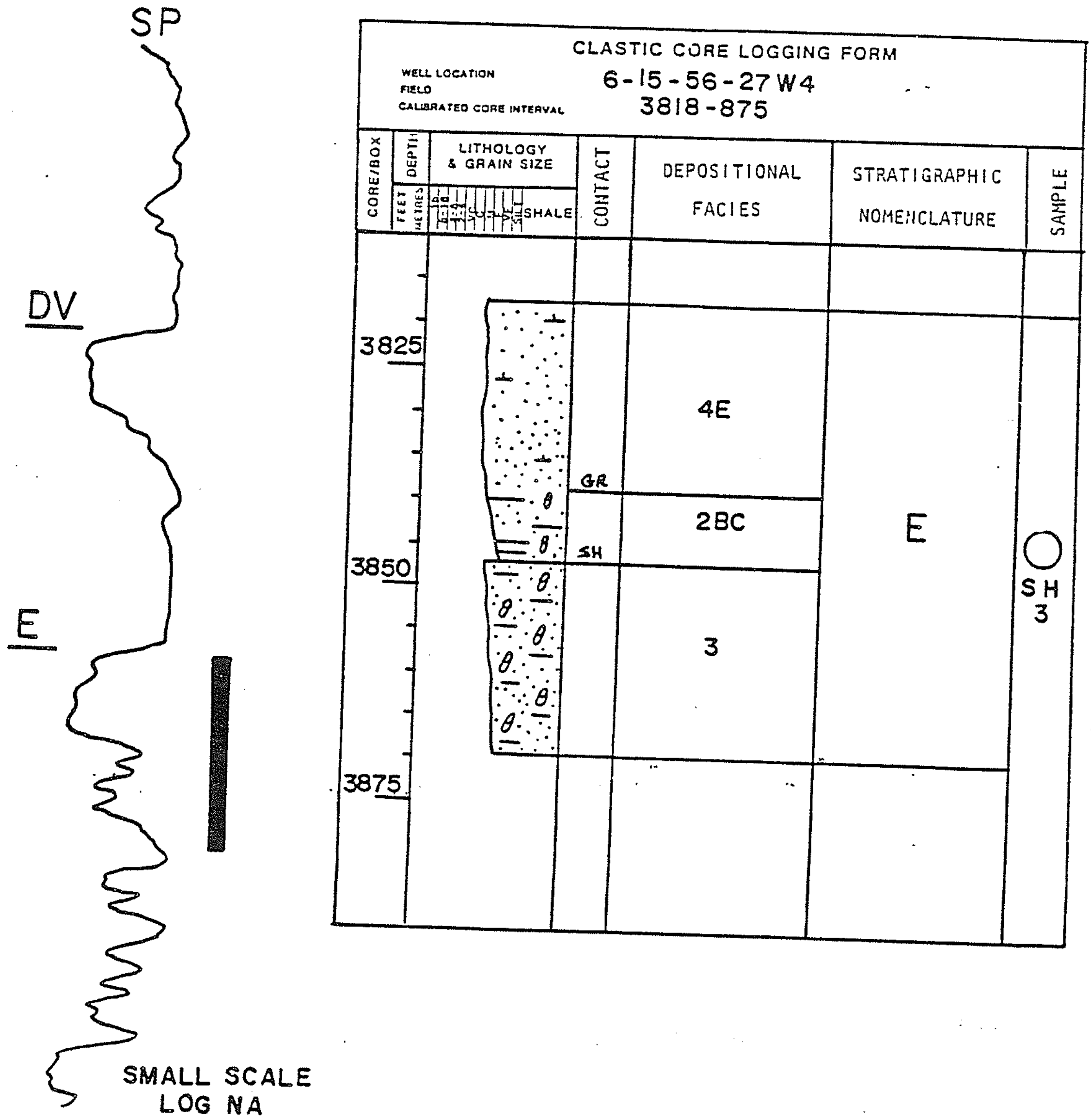
WELL LOCATION 1-32-56-26W4
FIELD
CALIBRATED CORE INTERVAL 3934-4111

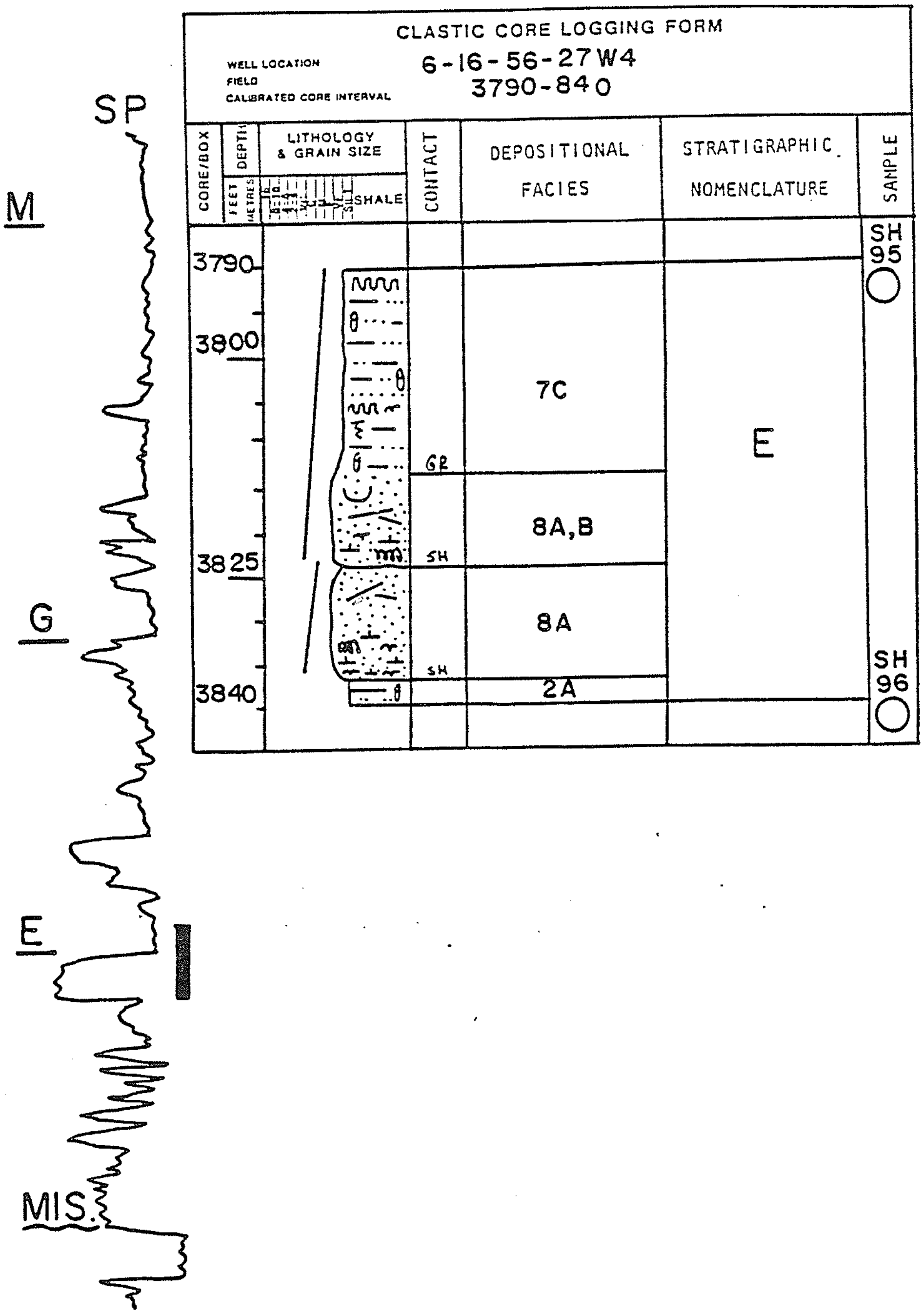
LOG NA

CLASTIC CORE LOGGING FORM

Well Location 11-11-56-27W1
Field
Calibrated Core Interval 3795-3850



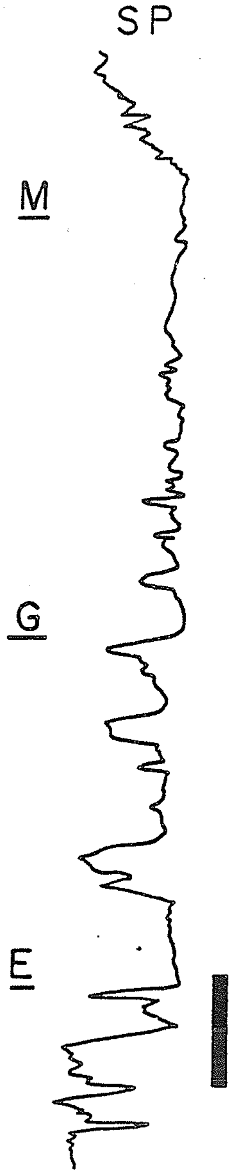

SP
DV
E
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-15-56-27W4
3818-875
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
3825
3850
3875
GR
SH
4E
2BC
3
E
SH 3
SMALL SCALE
LOG NA

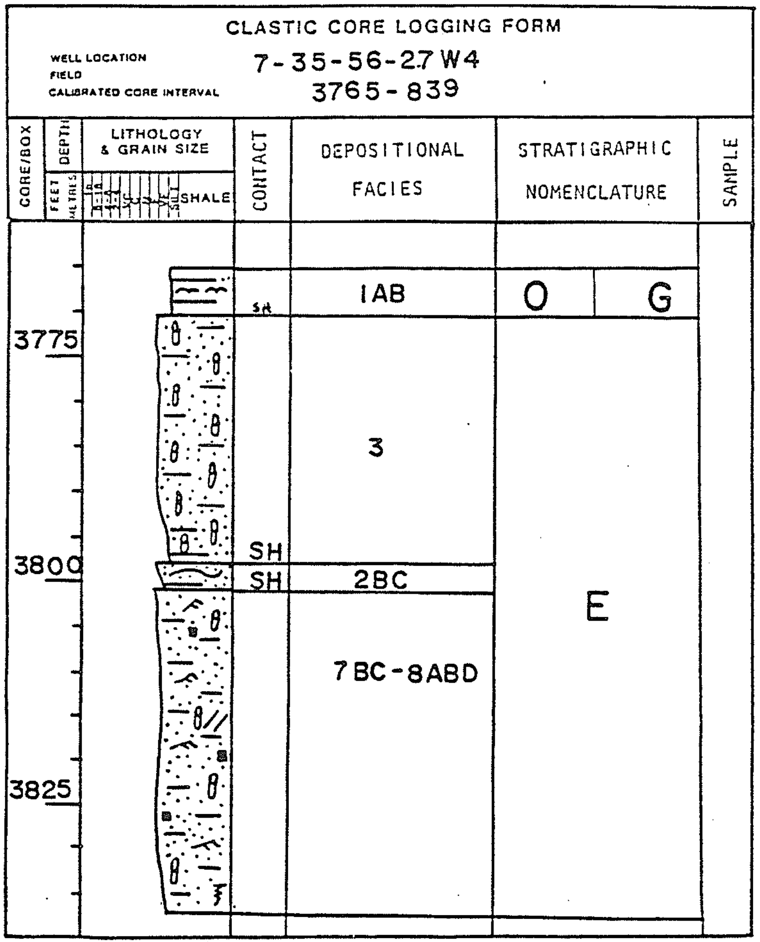


CLASTIC CORE LOGGING FORM

WELL LOCATION 6-16-56-27W4
FIELD
CALIBRATED CORE INTERVAL 3790-840

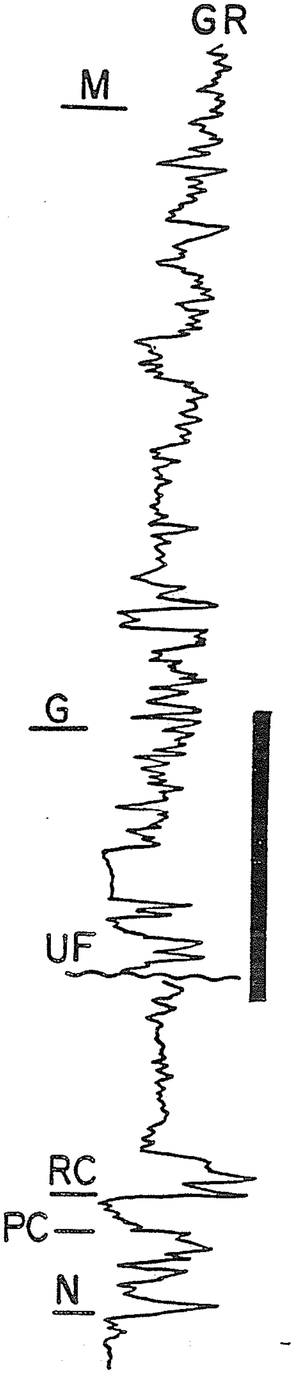
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	3790					SH 95
	3800		GR	7C	E	
	3825		SH	8A,B		
			SH	8A		
	3840			2A		SH 96

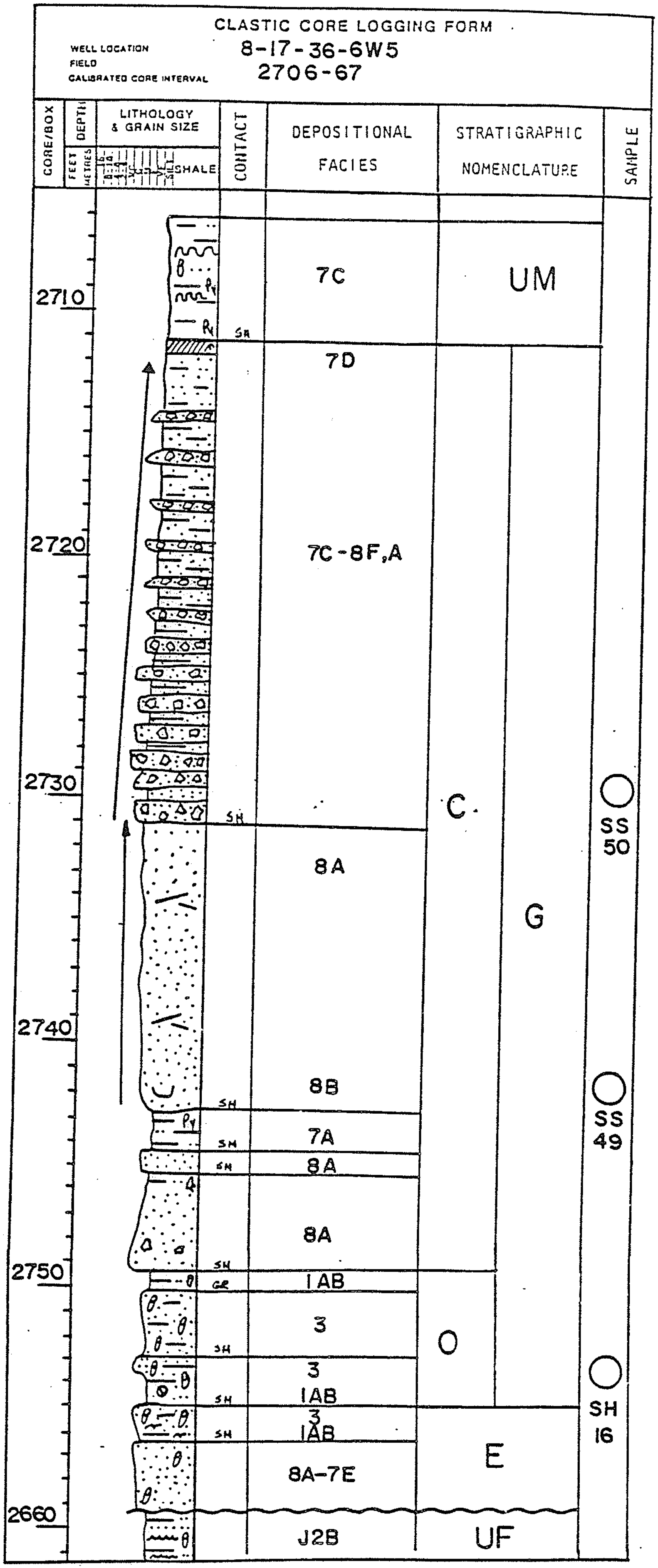



CLASTIC CORE LOGGING FORM

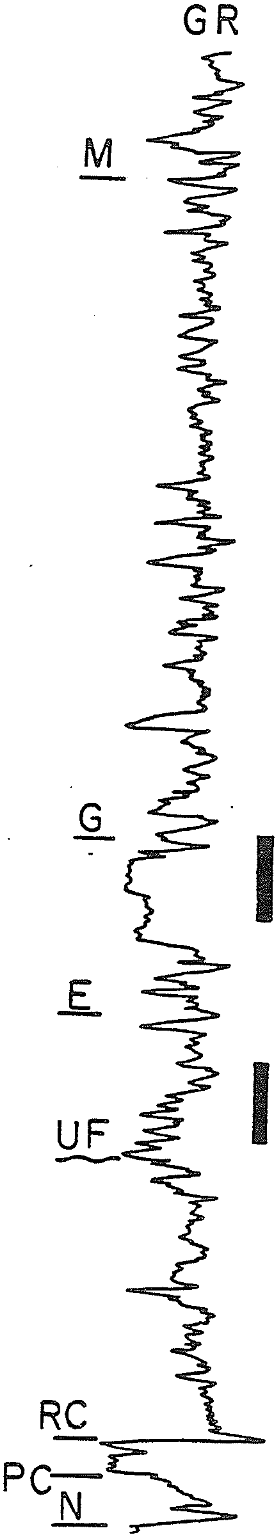
WELL LOCATION 7-35-56-27 W4
FIELD
CALIBRATED CORE INTERVAL 3765-839

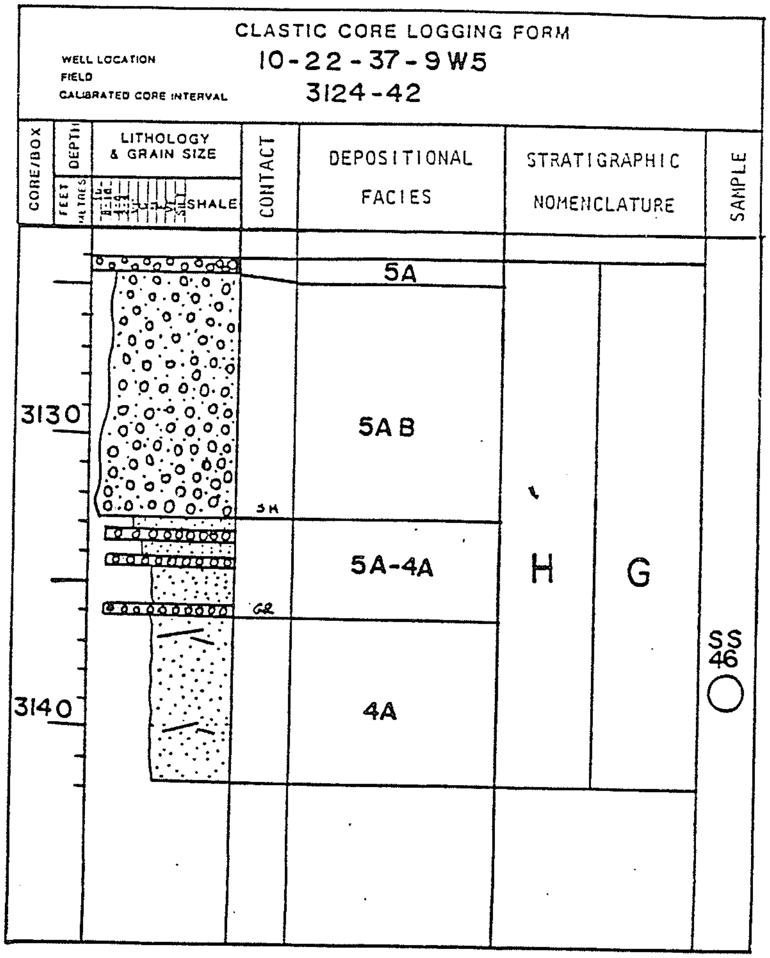
CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
			SH	1AB	O / G	
	3775		SH	3	E	
	3800		SH	2BC		
	3825			7BC-8ABD		



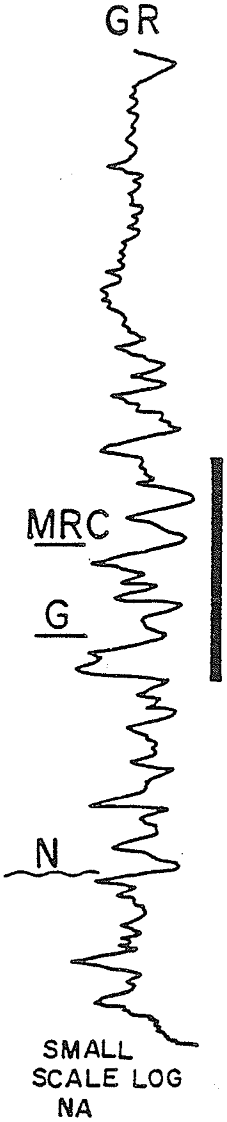

CLASTIC CORE LOGGING FORM

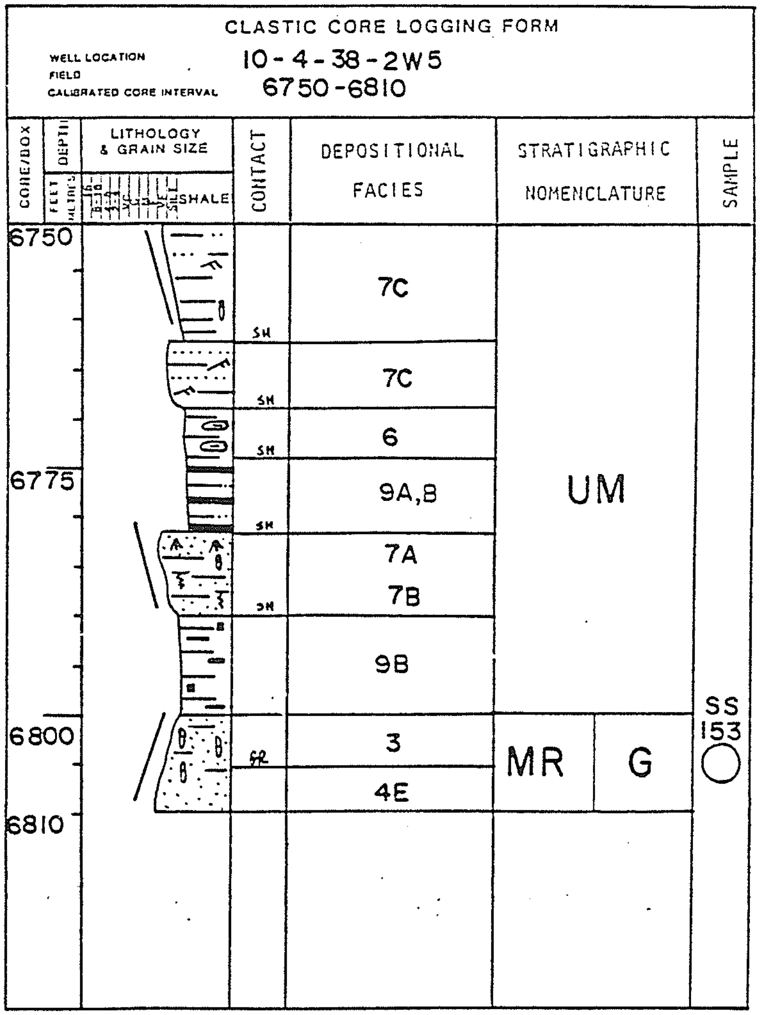
WELL LOCATION 8-17-36-6W5
FIELD
CALIBRATED CORE INTERVAL 2706-67




CLASTIC CORE LOGGING FORM

WELL LOCATION 10-22-37-9W5
FIELD
CALIBRATED CORE INTERVAL 3124-42

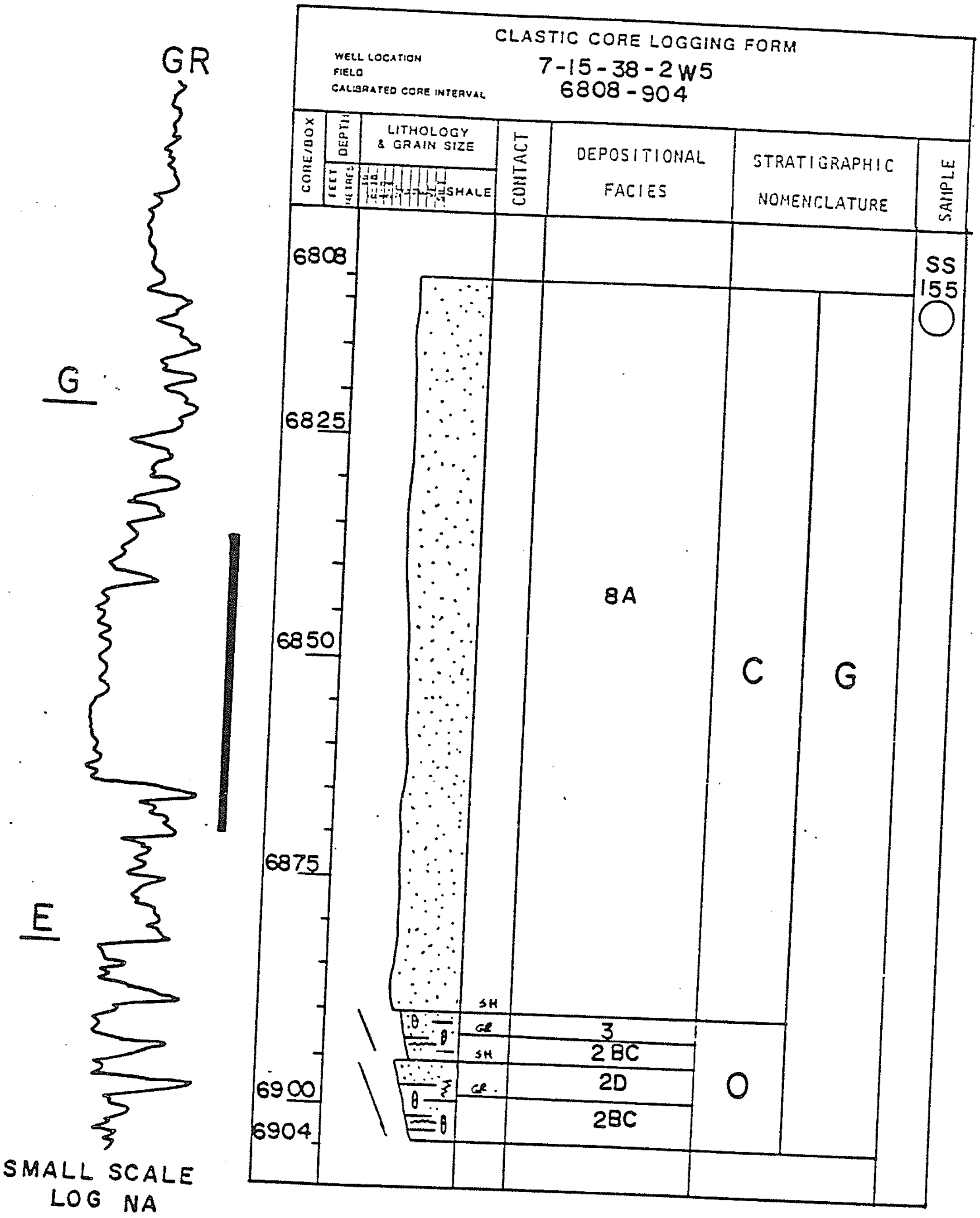


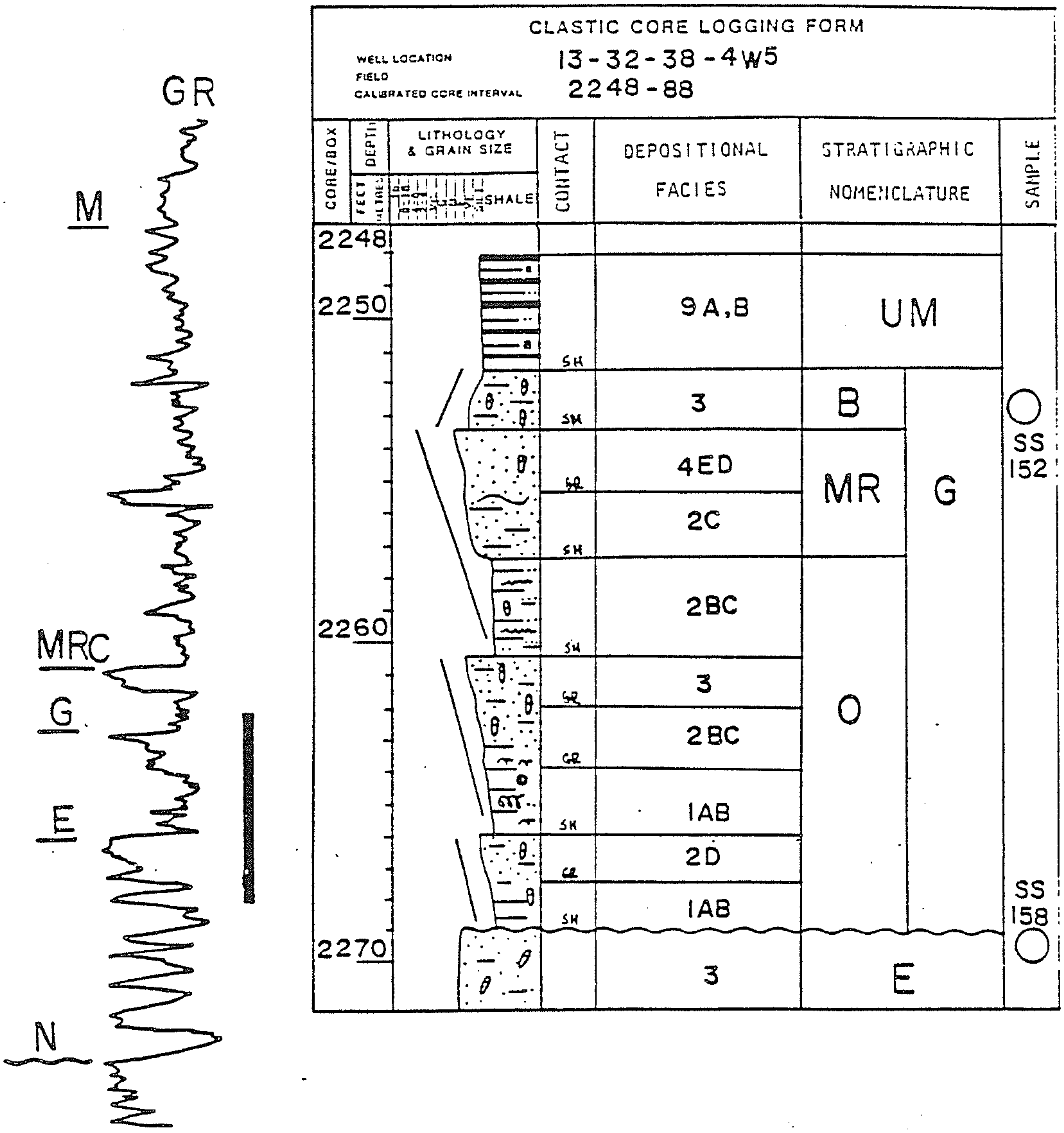


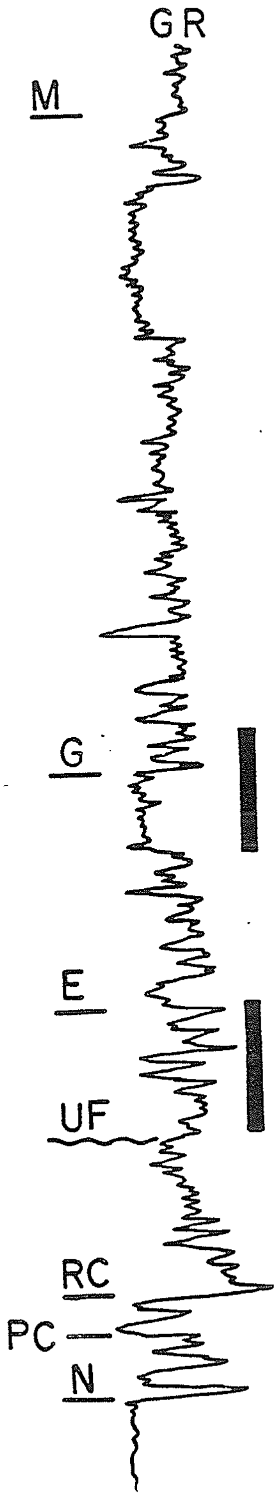
CLASTIC CORE LOGGING FORM

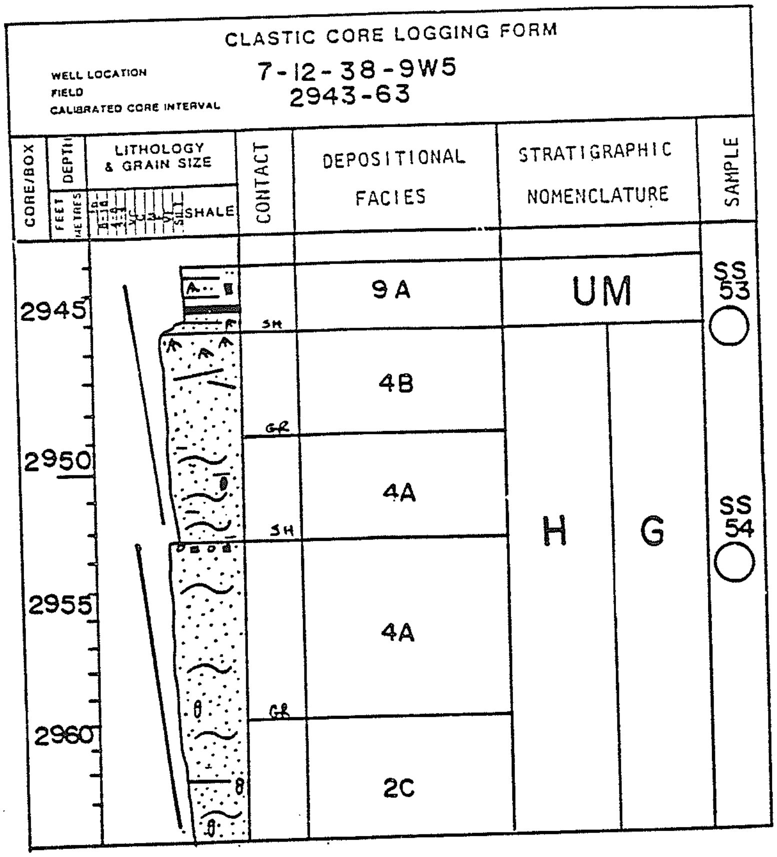
WELL LOCATION 10-4-38-2W5
FIELD
CALIBRATED CORE INTERVAL 6750-6810

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	6750		SH	7C	UM		
			SH	7C			
			SH	6			
	6775		SH	9A,B			
			SH	7A 7B			
				9B			
	6800		GR	3	MR	G	SS 153 ○
				4E			
	6810						


GR
G
E
SMALL SCALE LOG NA
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
7-15-38-2W5
6808-904
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
6808
6825
6850
6875
6900
6904
SS 155
8A
C
G
SH
GR
SH
GR
3
2BC
2D
2BC
O


GR
M
MRC
G
E
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
13-32-38-4W5
2248-88
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2248
2250
2260
2270
SH
GR
9A,B
3
4ED
2C
2BC
3
2BC
1AB
2D
1AB
3
UM
B
MR
G
O
E
SS 152
SS 158

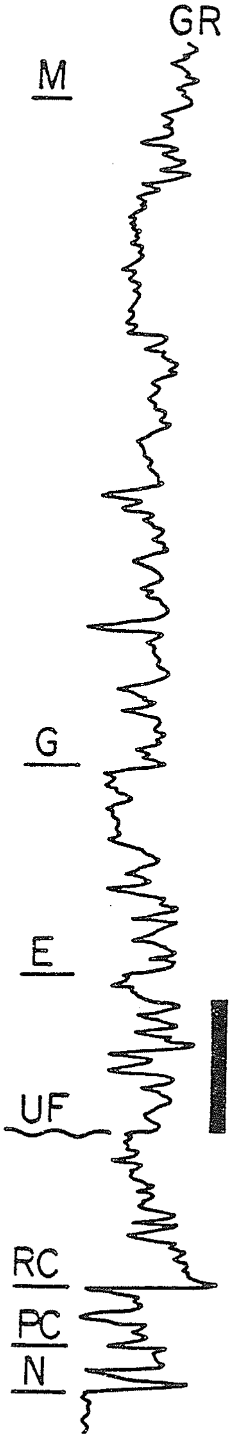


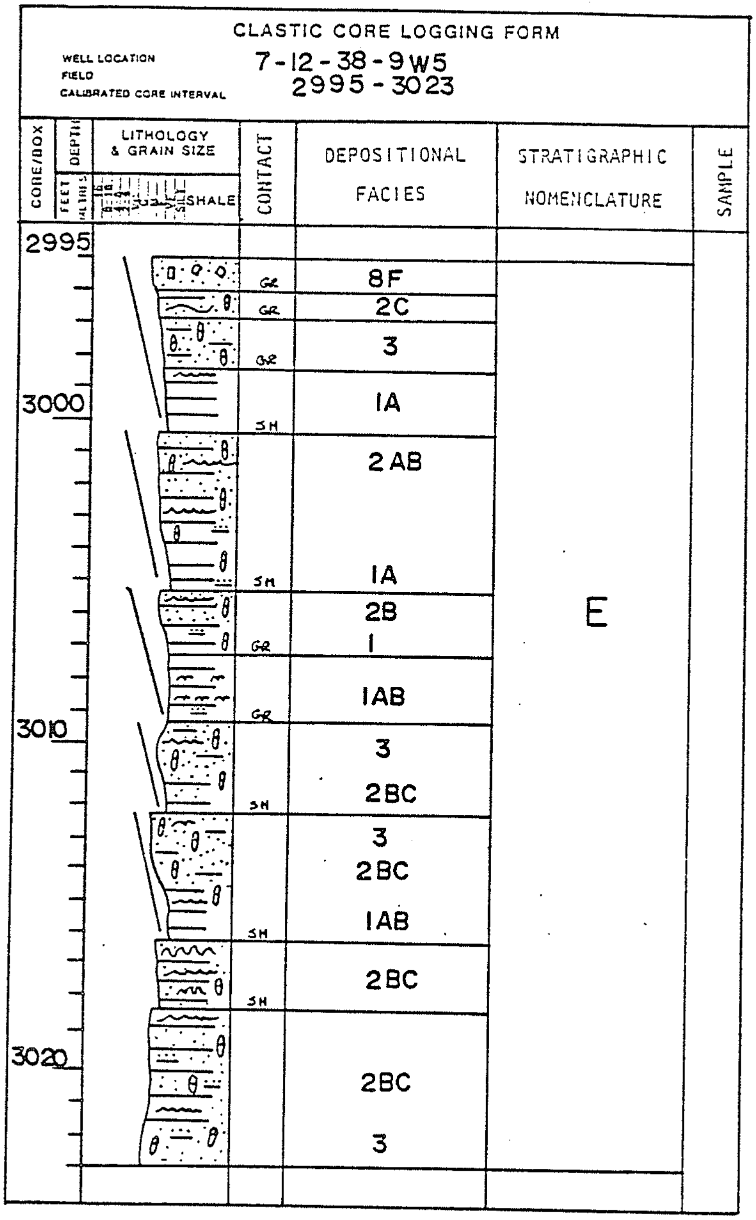


CLASTIC CORE LOGGING FORM

WELL LOCATION 7-12-38-9W5
FIELD
CALIBRATED CORE INTERVAL 2943-63

CORE/BOX	DEPTH FEET	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2945	SH	9A	UM		SS 53
		GR	4B	H	G	
	2950	SH	4A			SS 54
	2955	GR	4A			
	2960		2C			

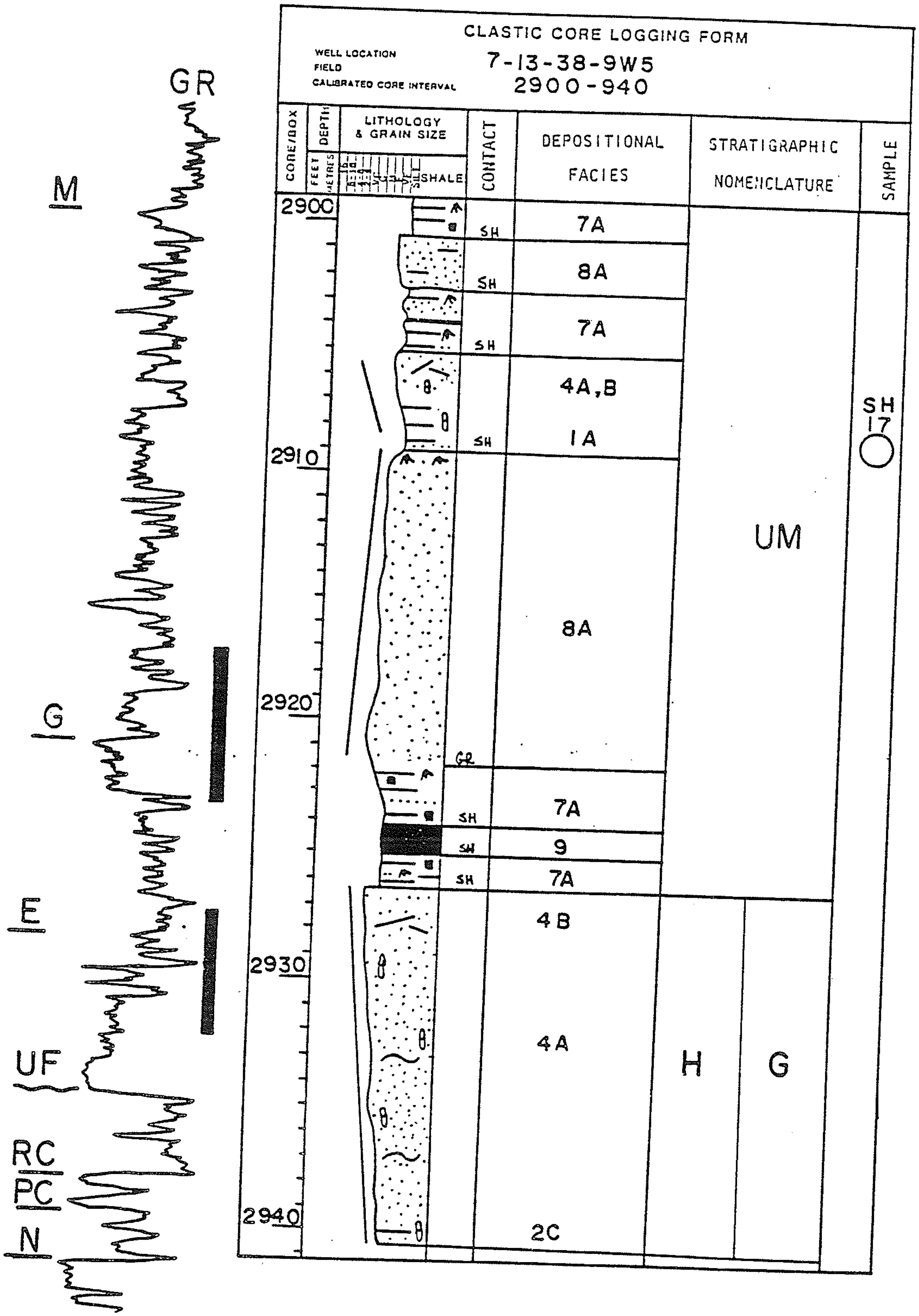




CLASTIC CORE LOGGING FORM

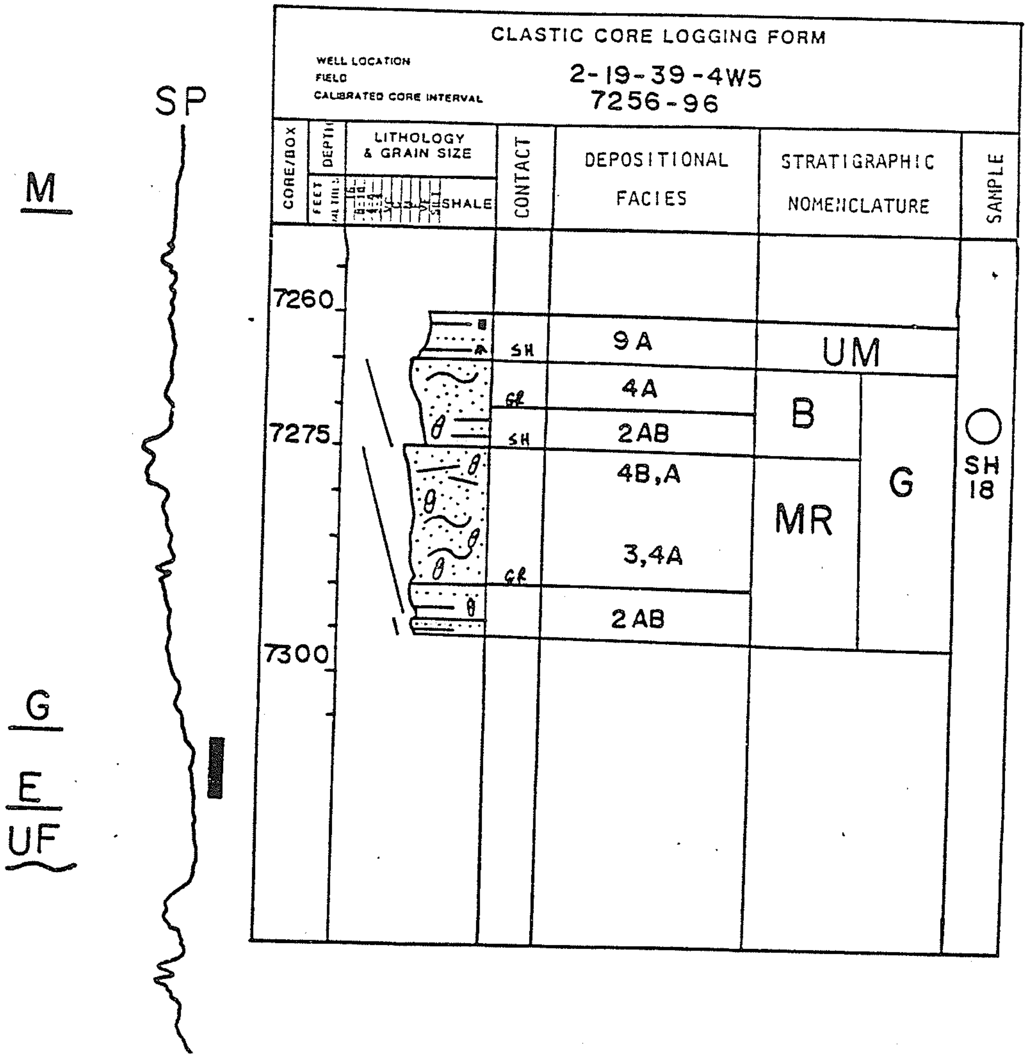
WELL LOCATION 7-12-38-9W5
FIELD
CALIBRATED CORE INTERVAL 2995 - 3023

CORE/BOX	DEPTH (FEET)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2995		GR	8F	E	
			GR	2C		
			GR	3		
	3000		SH	1A		
			SH	2 AB 1A		
			GR	2B 1		
			GR	1AB		
	3010		SH	3 2BC		
			SH	3 2BC 1AB		
			SH	2BC		
	3020			2BC 3		



CLASTIC CORE LOGGING FORM

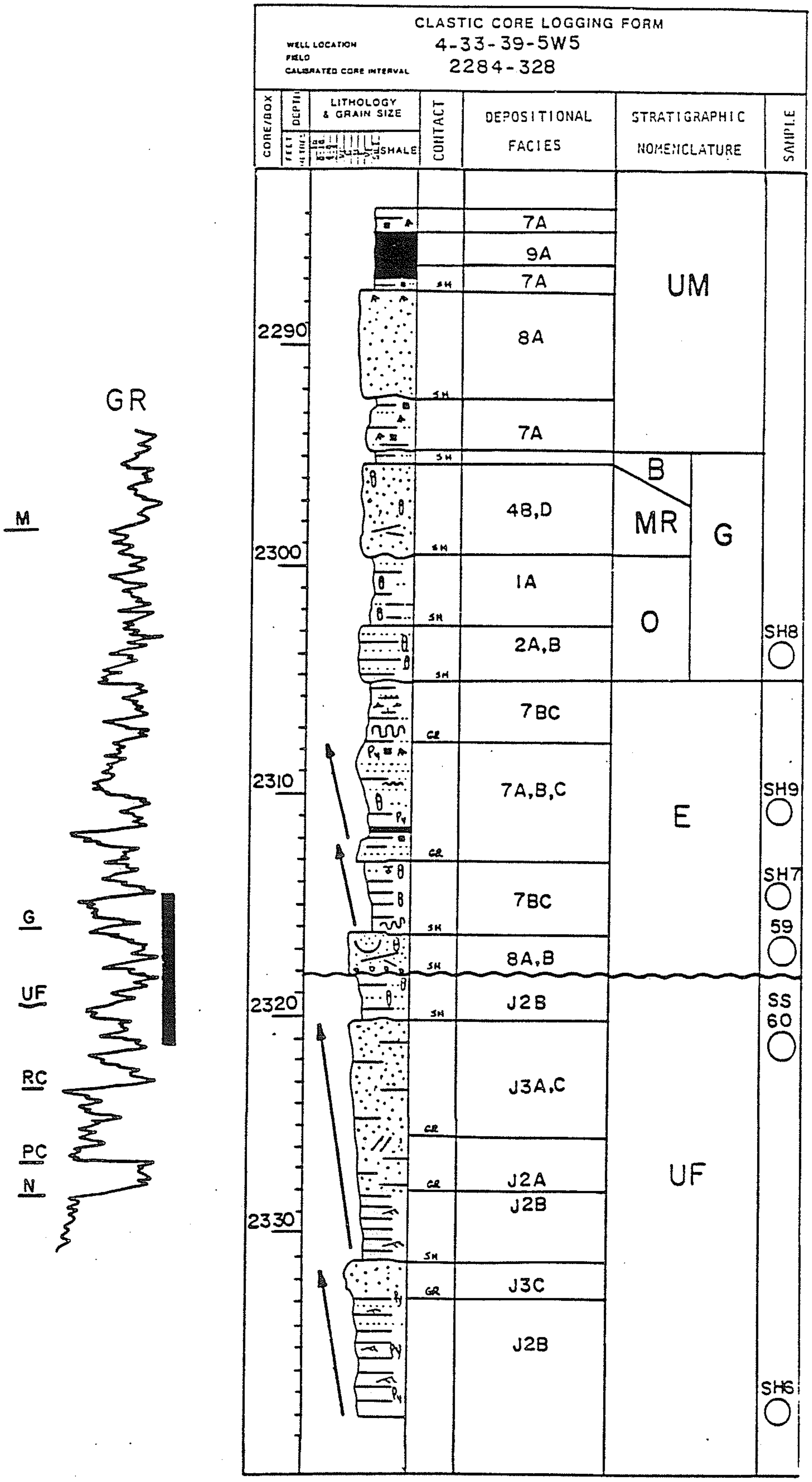
WELL LOCATION
FIELD 7-13-38-9W5
CALIBRATED CORE INTERVAL 2900-940

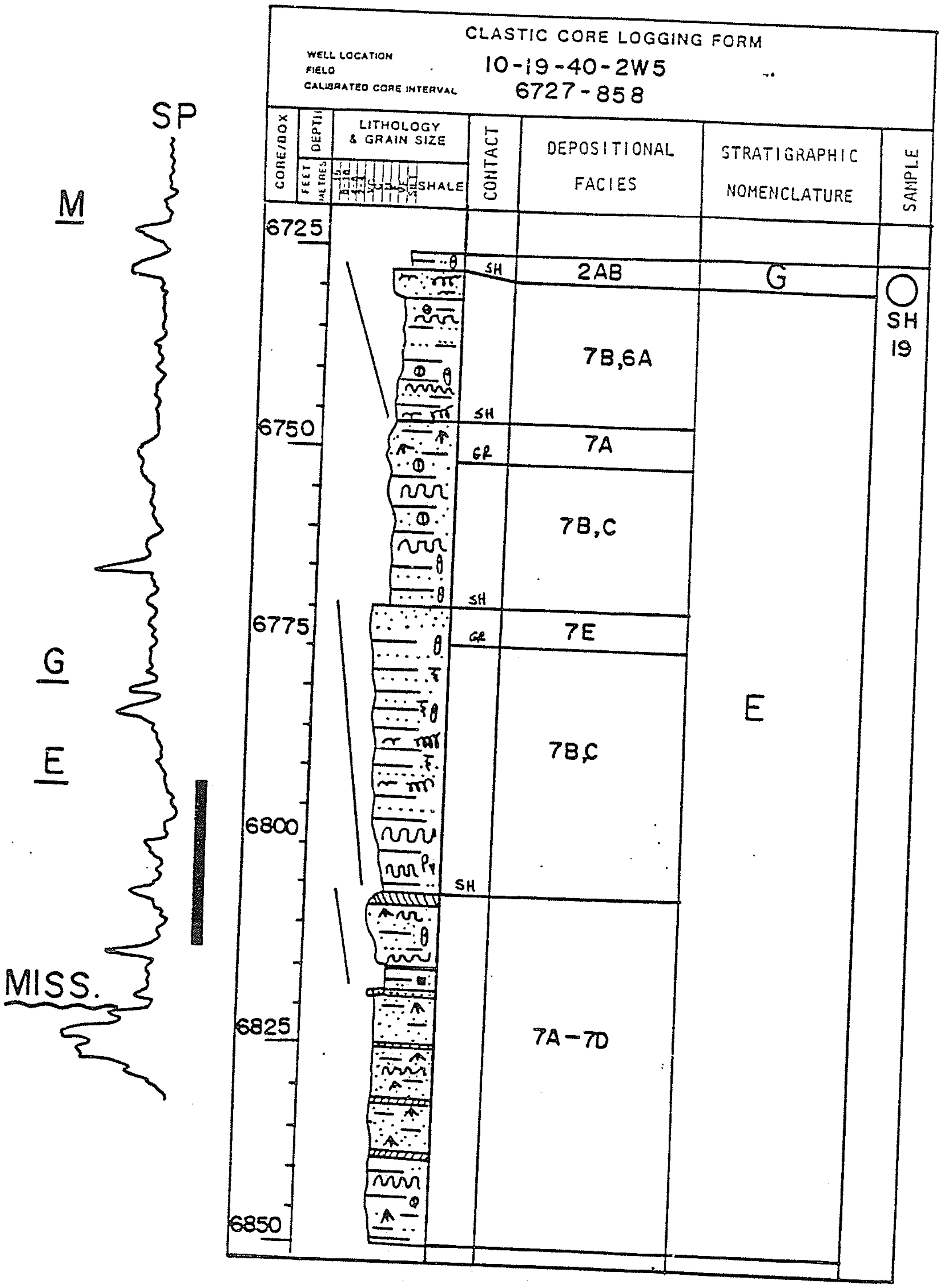


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

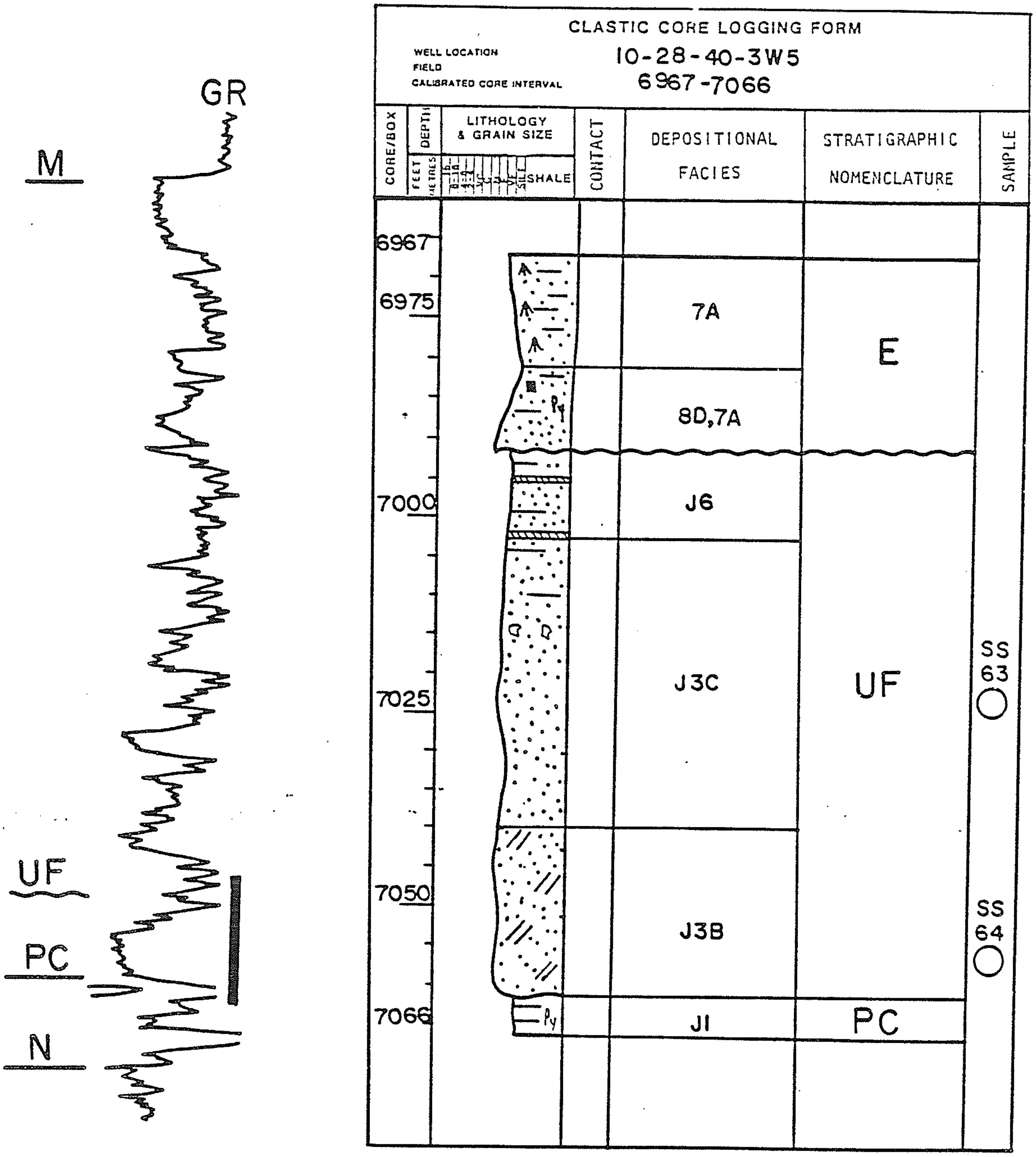
2-19-39-4W5
7256-96

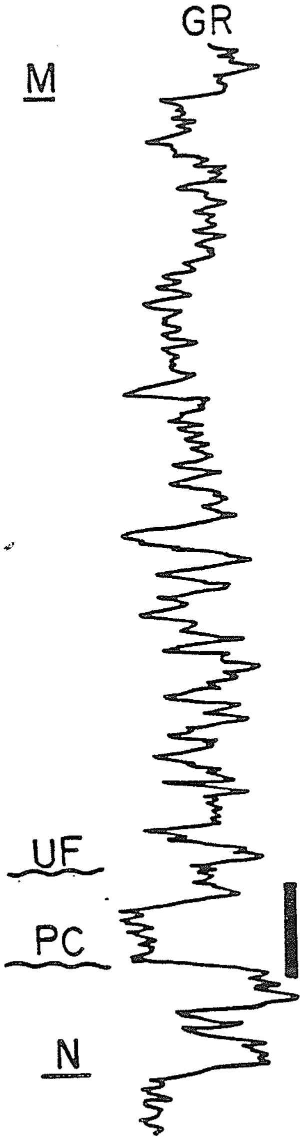

CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
4-33-39-5W5
2284-328
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2290
2300
2310
2320
2330
7A
9A
7A
8A
7A
4B,D
1A
2A,B
7BC
7A,B,C
7BC
8A,B
J2B
J3A,C
J2A
J2B
J3C
J2B
UM
B
MR
G
O
E
UF
SH8
SH9
SH7
59
SS 60
SH6
SH
GR
GR
M
G
UF
RC
PC
N

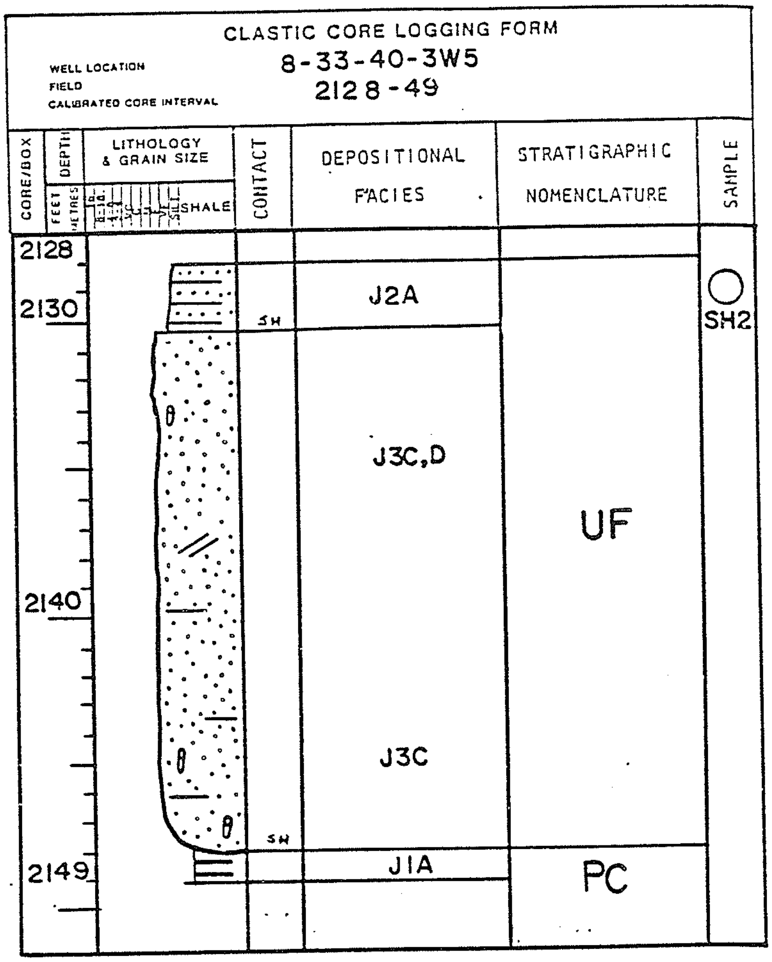


CLASTIC CORE LOGGING FORM

WELL LOCATION 10-19-40-2W5
FIELD
CALIBRATED CORE INTERVAL 6727-858


GR
M
UF
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
10-28-40-3W5
6967-7066
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
6967
6975
7000
7025
7050
7066
7A
8D,7A
J6
J3C
J3B
J1
E
UF
PC
SS 63
SS 64
Py

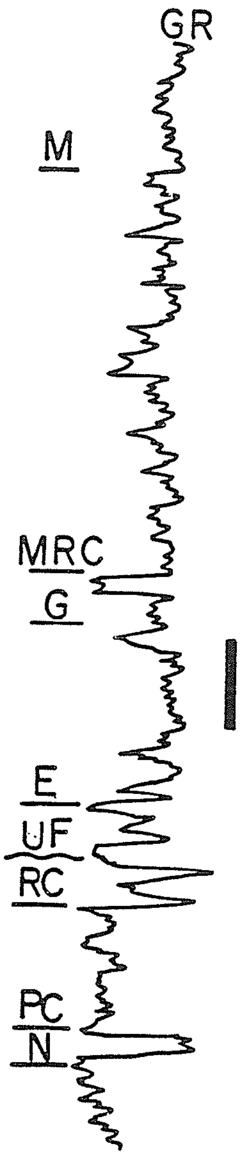


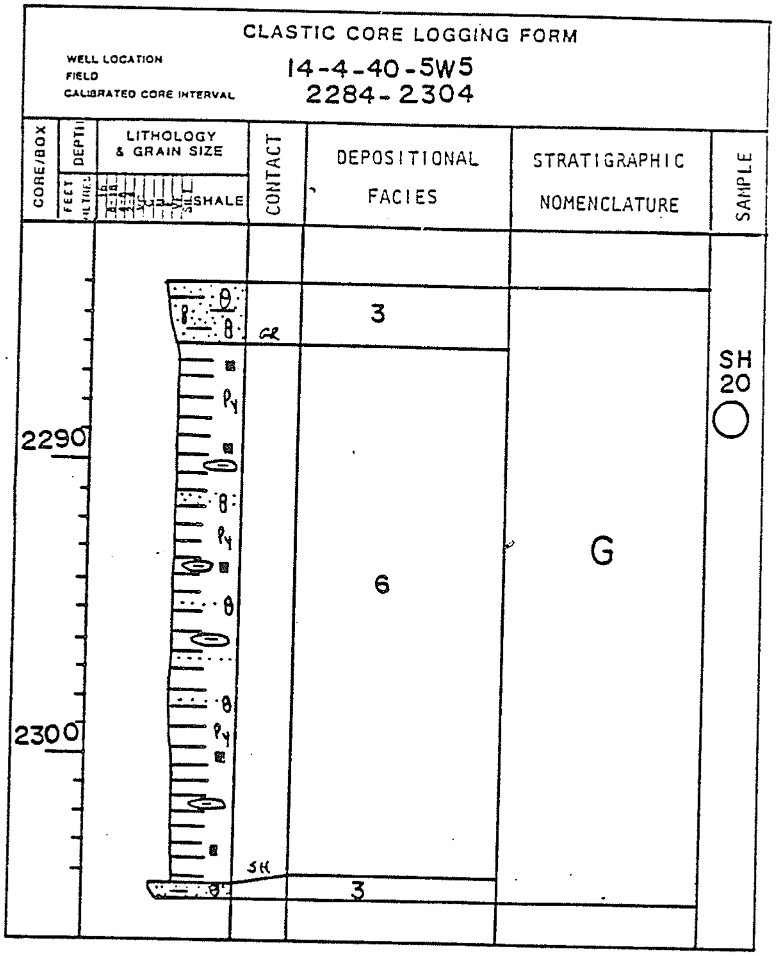


CLASTIC CORE LOGGING FORM

WELL LOCATION 8-33-40-3W5
FIELD
CALIBRATED CORE INTERVAL 2128-49

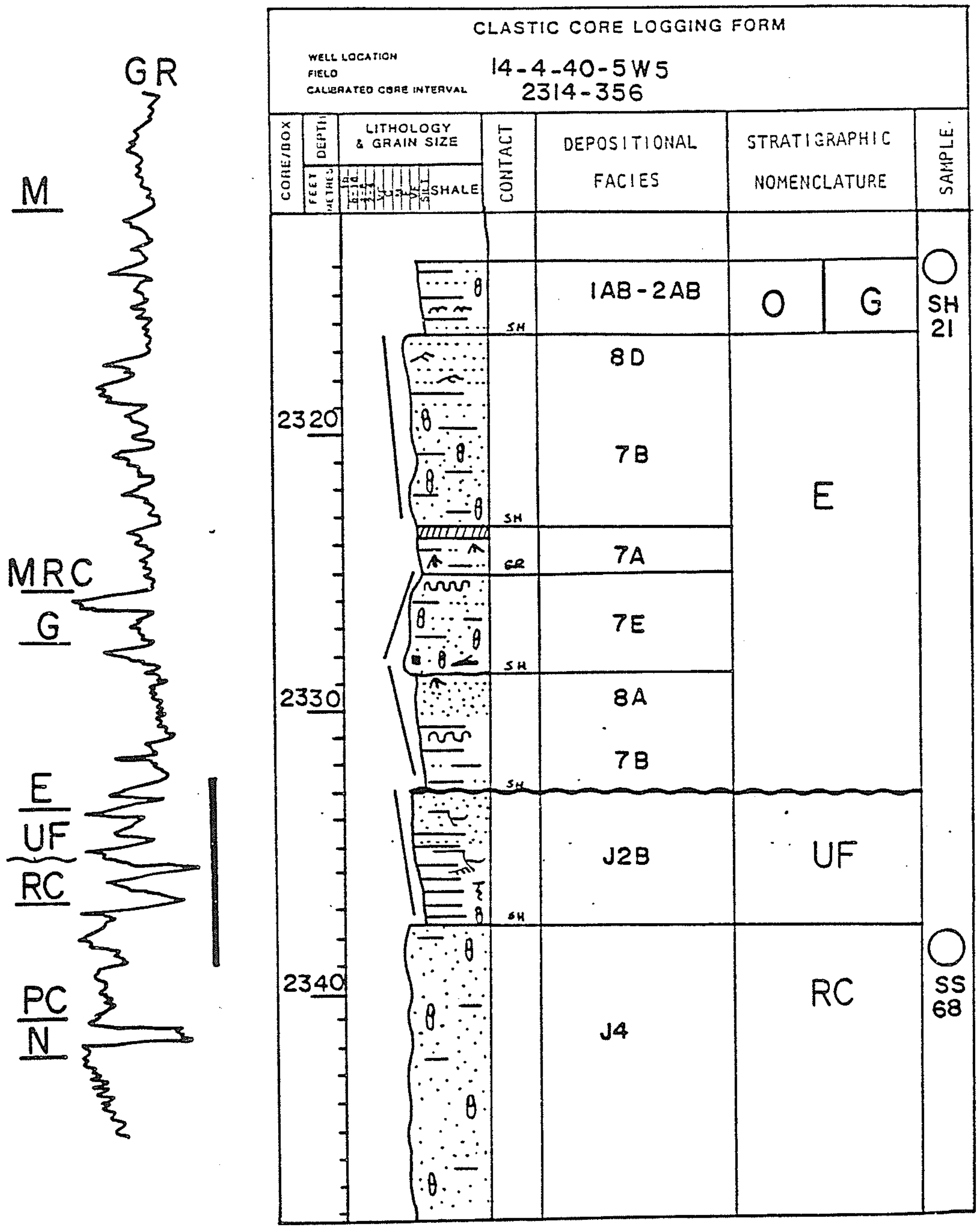
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2128					
	2130		SH	J2A		SH2
				J3C,D	UF	
	2140					
			SH	J3C		
	2149			J1A	PC	

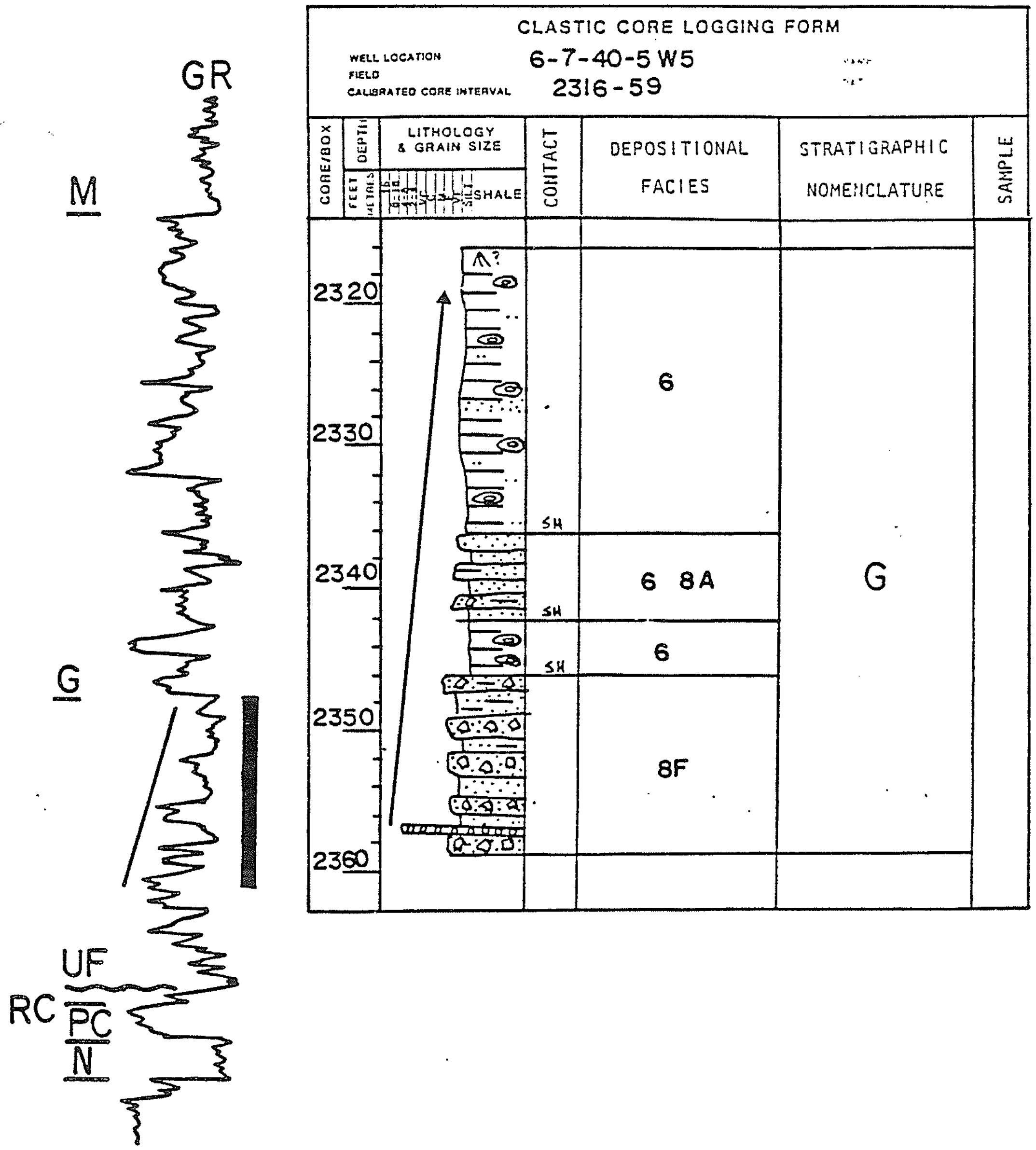


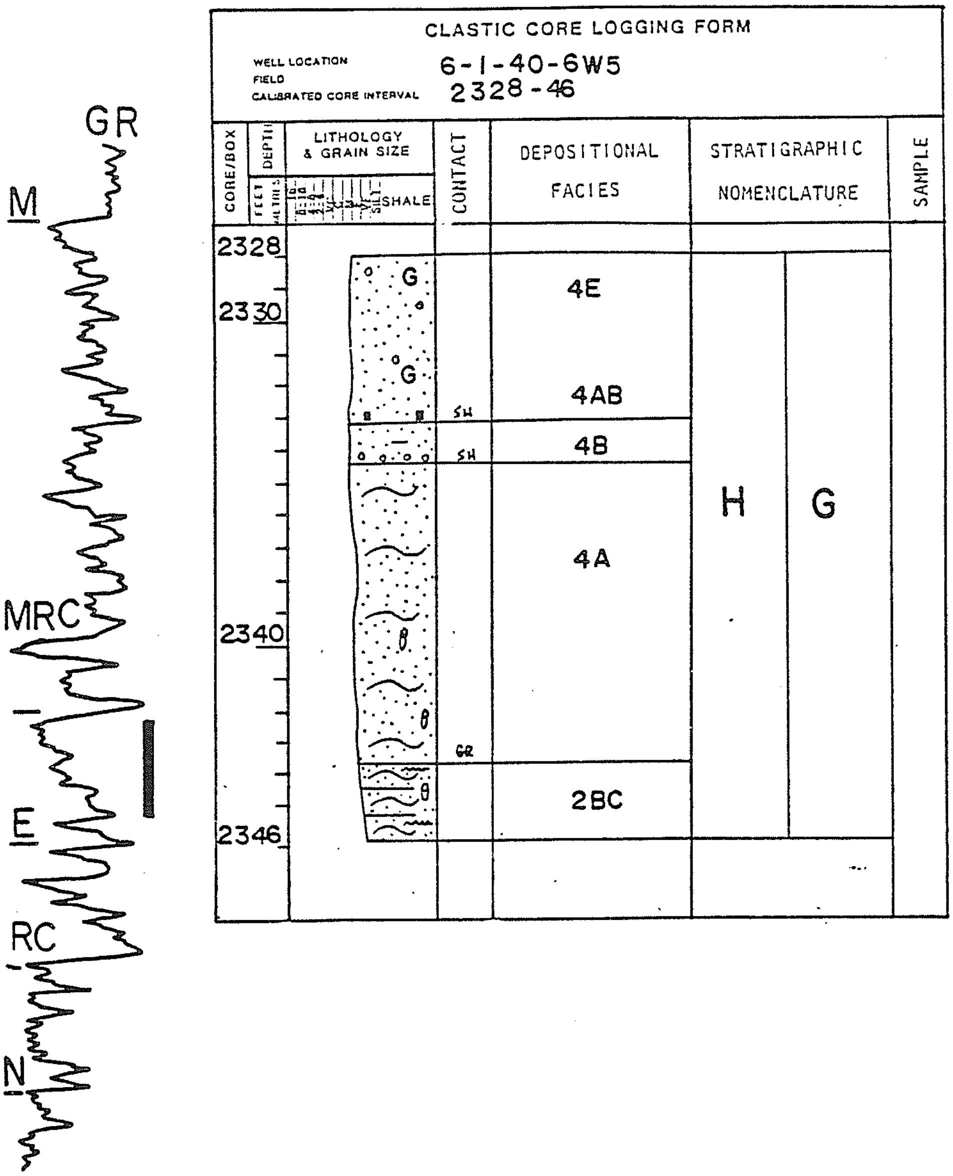


CLASTIC CORE LOGGING FORM

WELL LOCATION 14-4-40-5W5
FIELD
CALIBRATED CORE INTERVAL 2284-2304


GR
M
MRC
G
E
UF
RC
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
14-4-40-5W5
2314-356
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2320
2330
2340
SH
SH
GR
SH
SH
SH
1AB-2AB
8D
7B
7A
7E
8A
7B
J2B
J4
O
G
E
UF
RC
SH 21
SS 68


GR
M
G
UF
RC
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-7-40-5 W5
2316-59
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SILT
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2320
2330
2340
2350
2360
SH
SH
SH
6
6 8A
6
8F
G

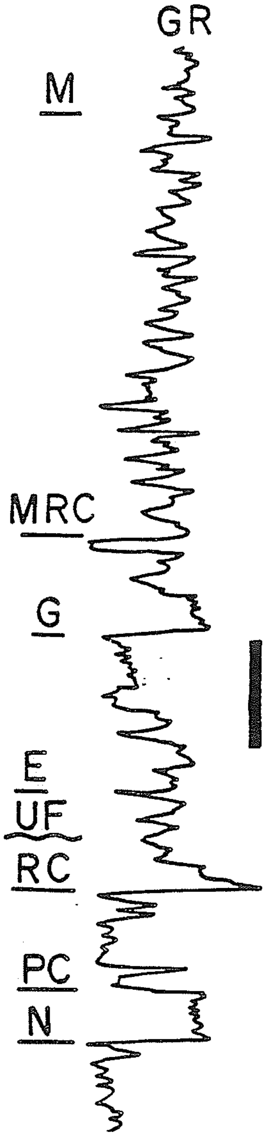


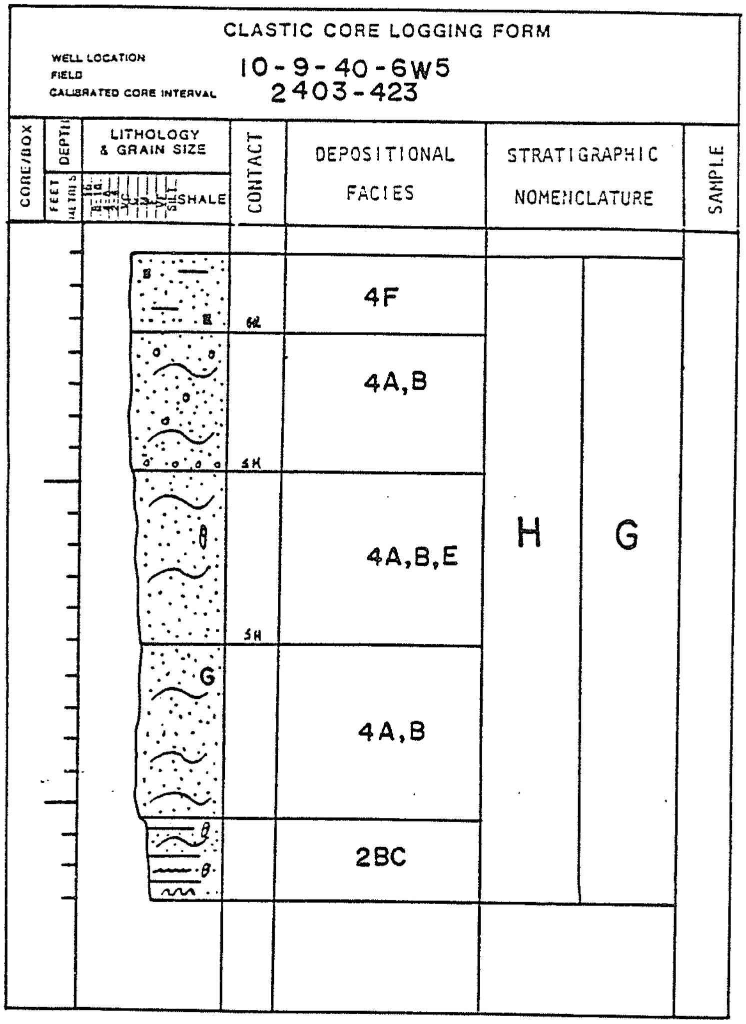
CLASTIC CORE LOGGING FORM

WELL LOCATION 6-1-40-6W5

FIELD

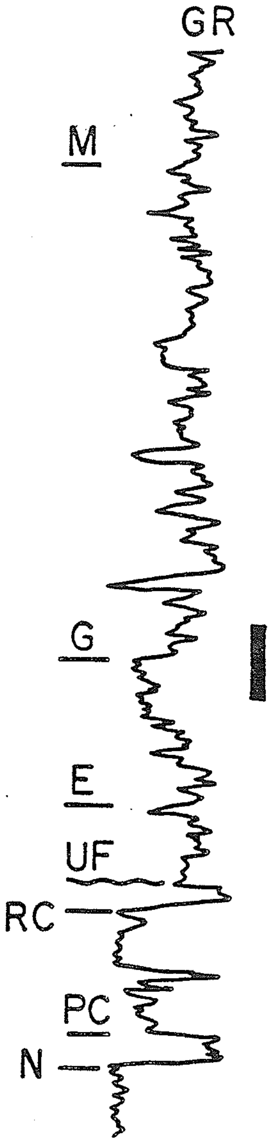
CALIBRATED CORE INTERVAL 2328-46

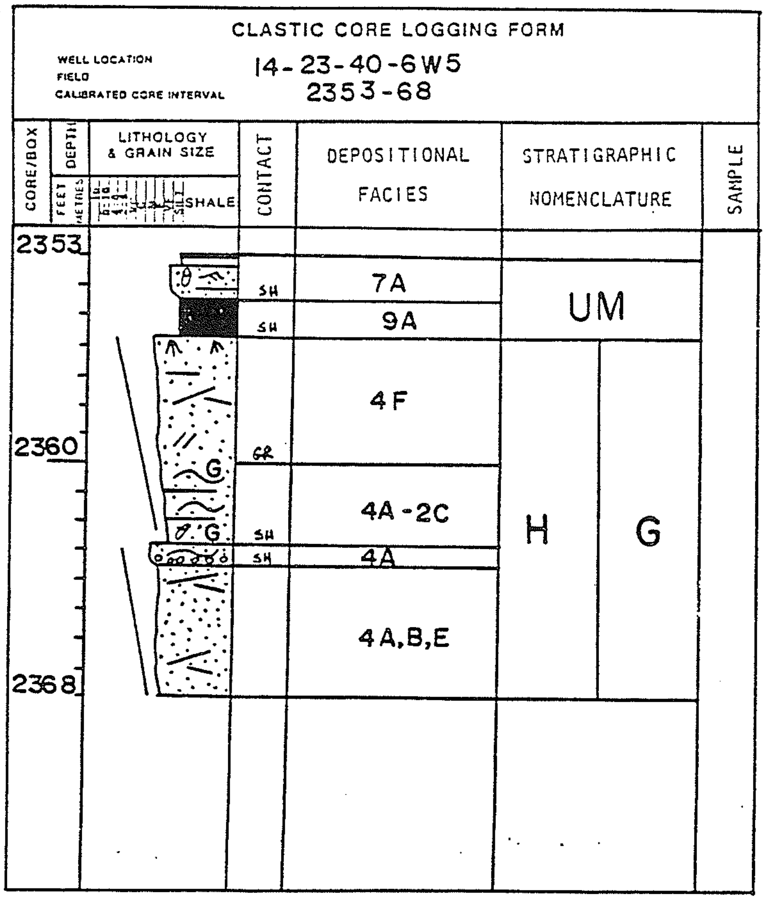



CLASTIC CORE LOGGING FORM

WELL LOCATION 10-9-40-6W5
FIELD
CALIBRATED CORE INTERVAL 2403-423

CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	
GR	4F	H	G
SH	4A,B		
SH	4A,B,E		
	4A,B		
	2BC		

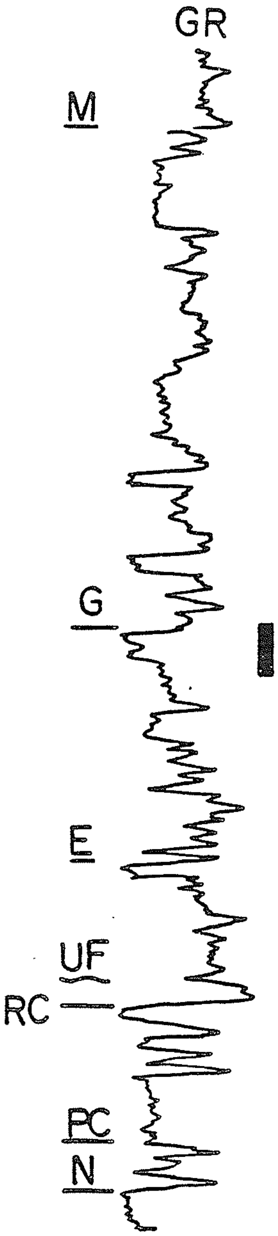


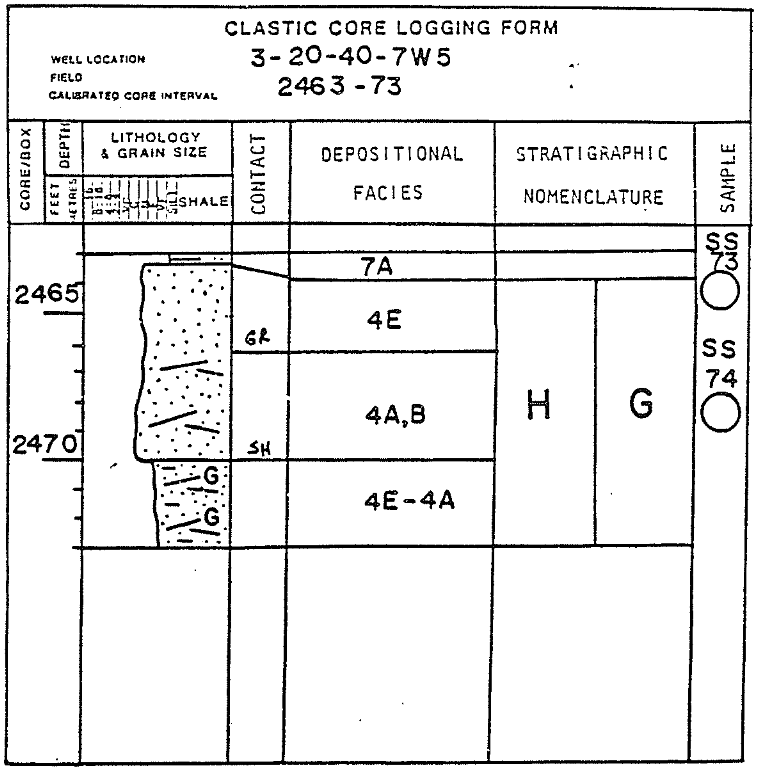


CLASTIC CORE LOGGING FORM

WELL LOCATION 14-23-40-6W5
FIELD
CALIBRATED CORE INTERVAL 2353-68

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2353		SH	7A	UM		
			SH	9A			
				4F	H	G	
	2360		GR	4A-2C			
			SH	4A			
			SH	4A,B,E			
	2368						

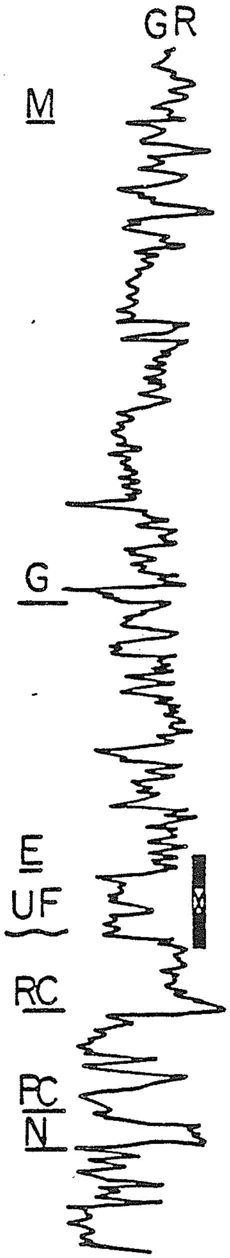


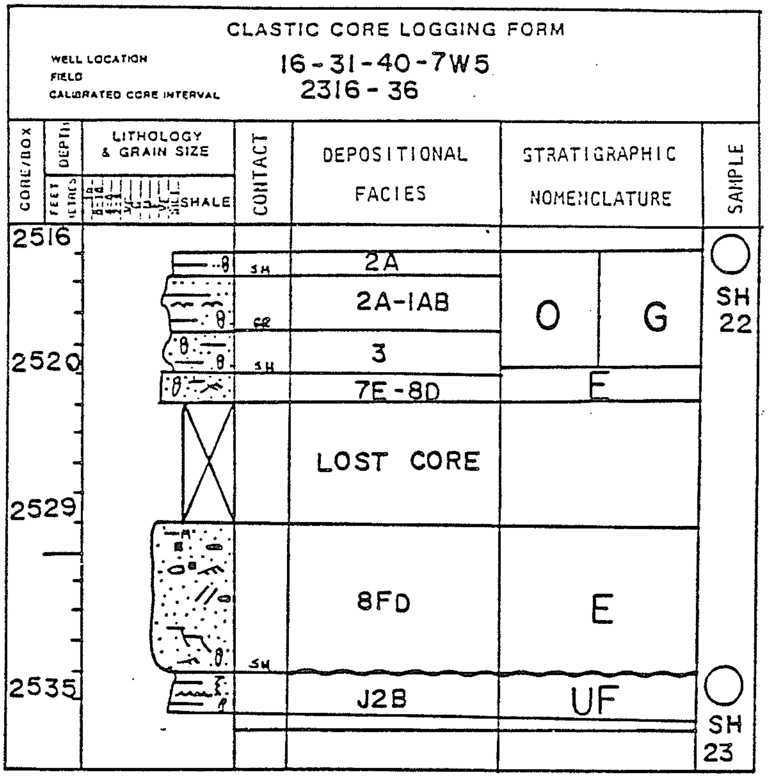


CLASTIC CORE LOGGING FORM

WELL LOCATION 3-20-40-7W5
FIELD
CALIBRATED CORE INTERVAL 2463-73

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
				7A			SS 73 ○
	2465		GR	4E	H	G	
				4A,B			SS 74 ○
	2470	G G	SH	4E-4A			

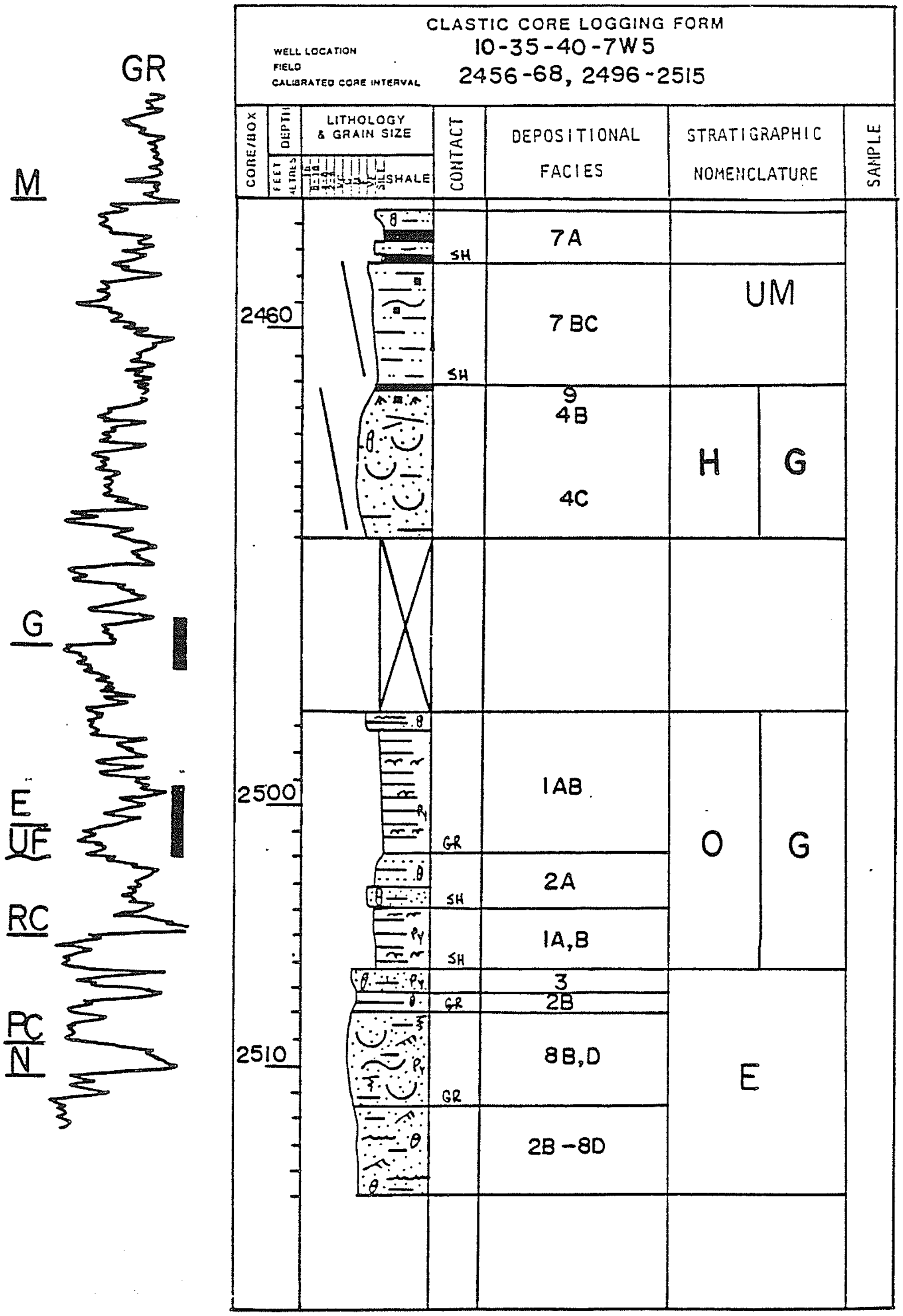




CLASTIC CORE LOGGING FORM

WELL LOCATION 16-31-40-7W5
FIELD
CALIBRATED CORE INTERVAL 2316 - 36

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2516					○ SH 22
			SH	2A	O G	
			GR	2A-1AB		
	2520		SH	3		
				7E-8D	E	
				LOST CORE		
	2529			8FD	E	
	2535		SH	J2B	UF	○ SH 23

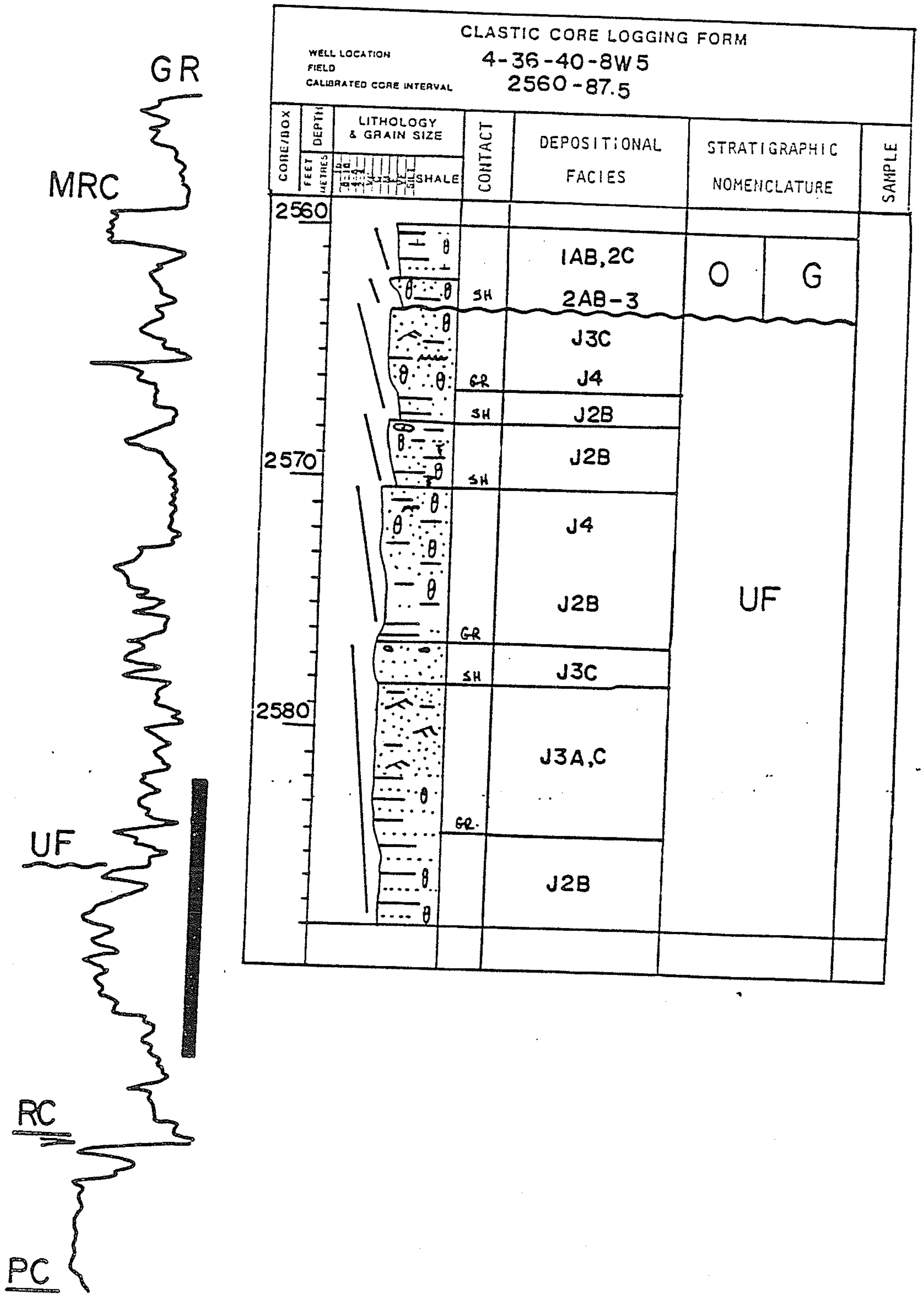


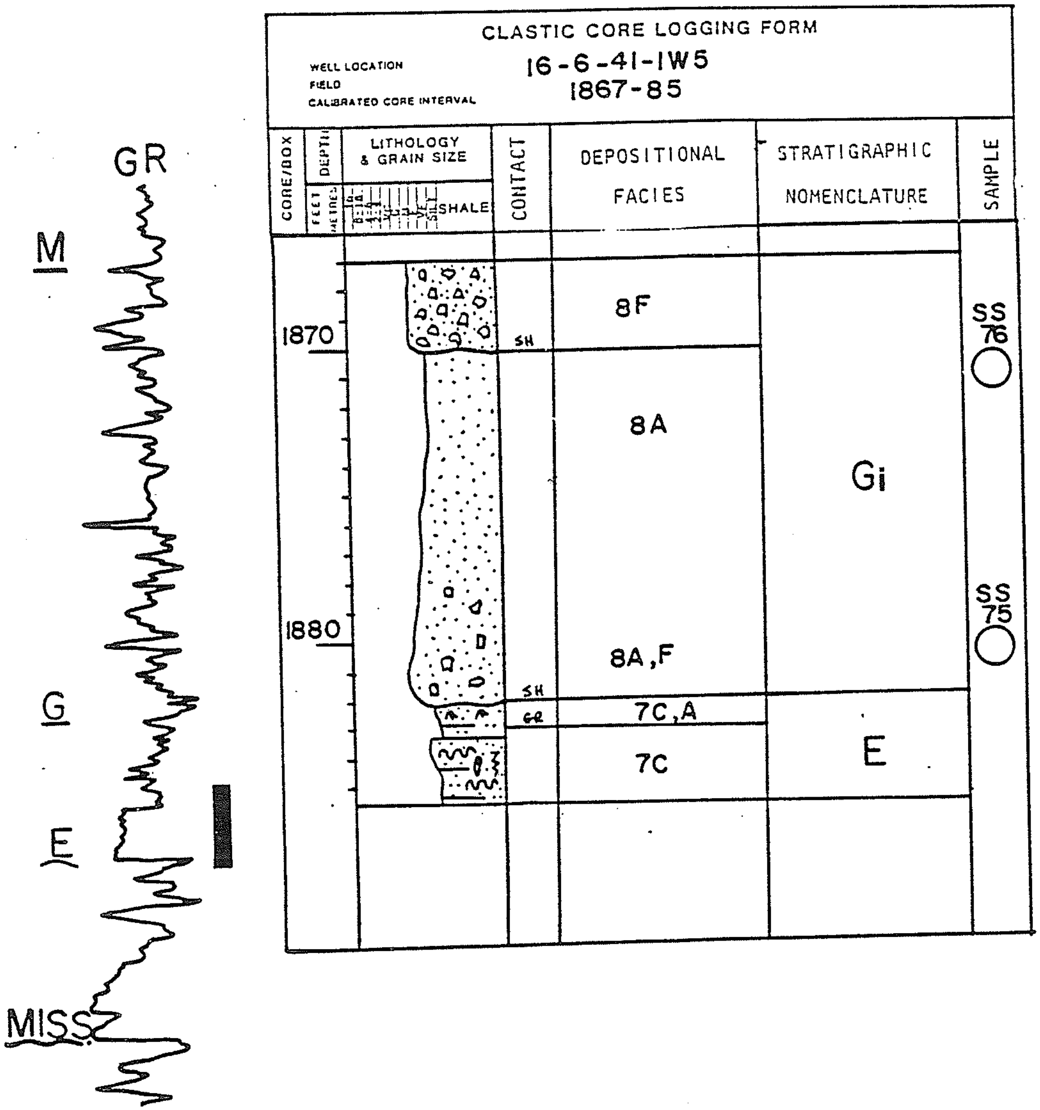
CLASTIC CORE LOGGING FORM

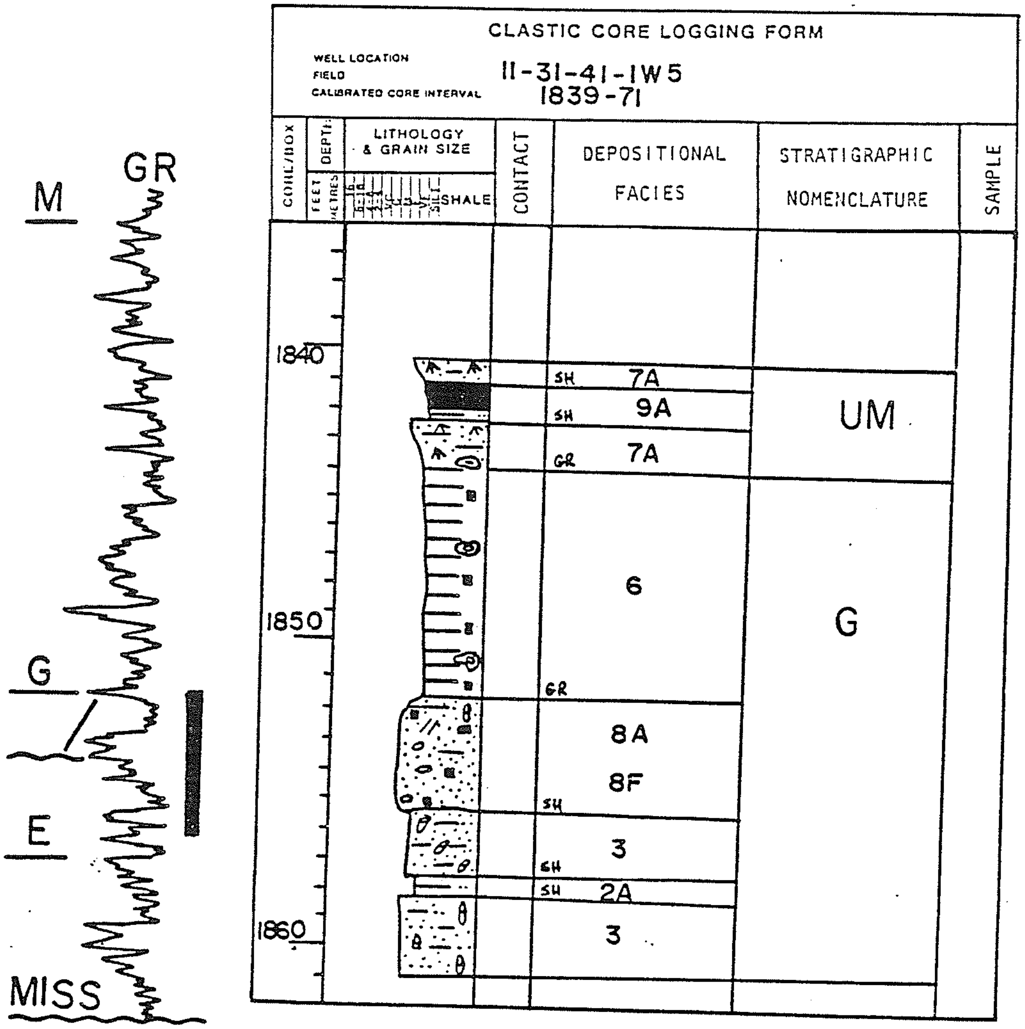
WELL LOCATION 10-35-40-7W5

FIELD

CALIBRATED CORE INTERVAL 2456-68, 2496-2515

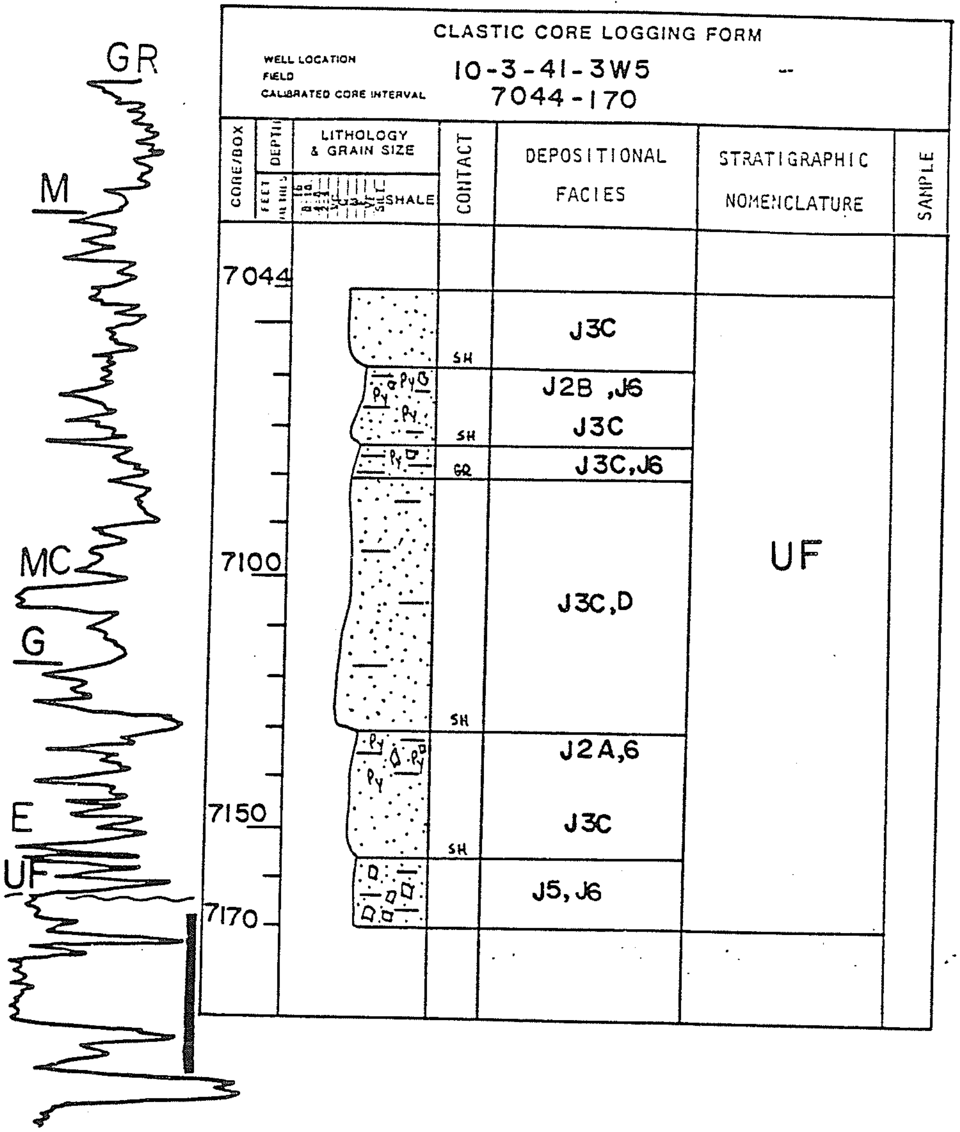

GR
MRC
UF
RC
PC
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
4-36-40-8W5
2560-87.5
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2560
2570
2580
SH
GR
1AB,2C
2AB-3
J3C
J4
J2B
J2B
J4
J2B
J3C
J3A,C
J2B
O
G
UF


GR
M
G
E
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
16-6-41-1W5
1867-85
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1870
1880
SH
SH
GR
8F
8A
8A,F
7C,A
7C
Gi
E
SS 76
SS 75



CLASTIC CORE LOGGING FORM

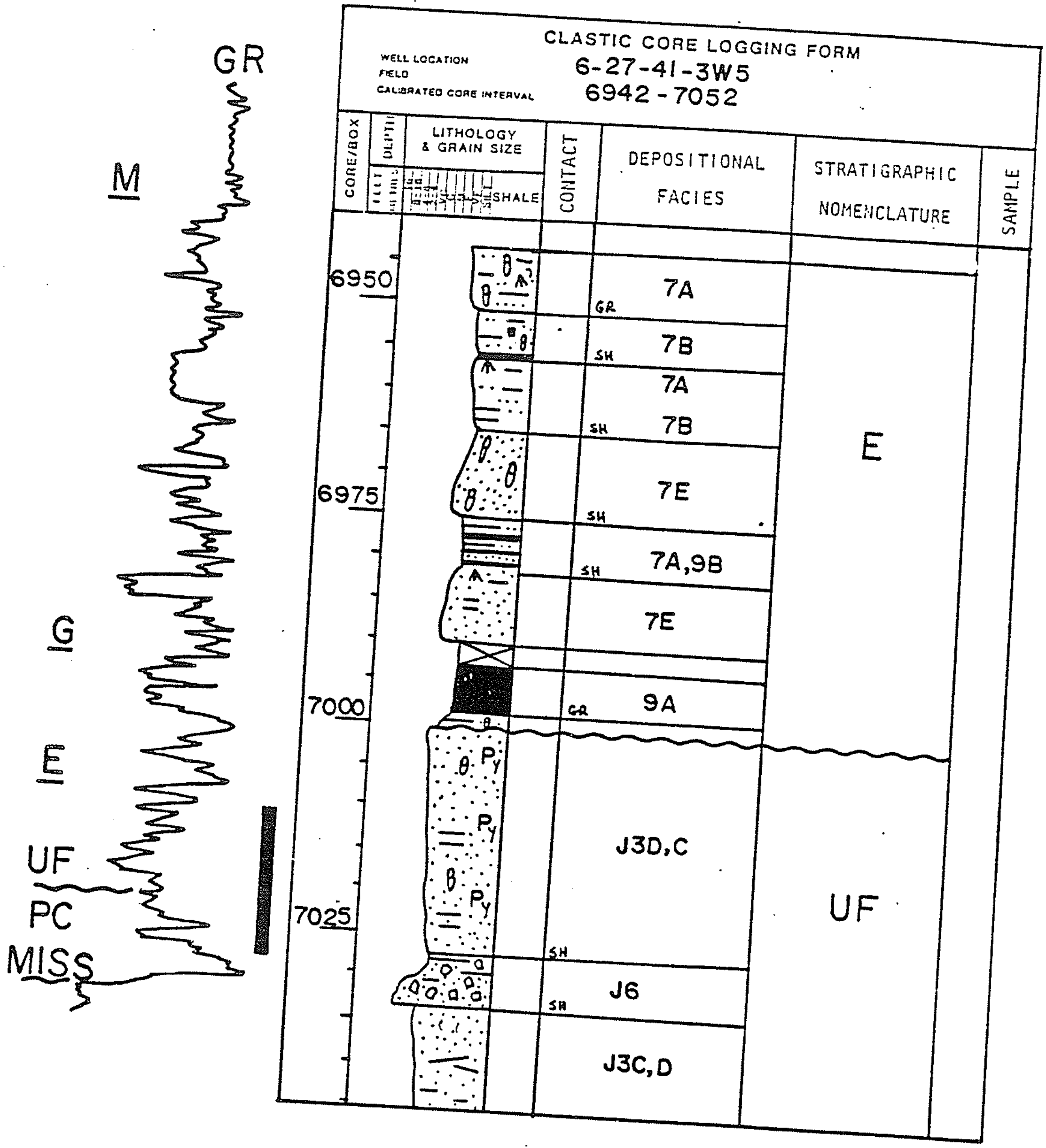
WELL LOCATION
FIELD 11-31-41-1W5
CALIBRATED CORE INTERVAL 1839-71



CLASTIC CORE LOGGING FORM

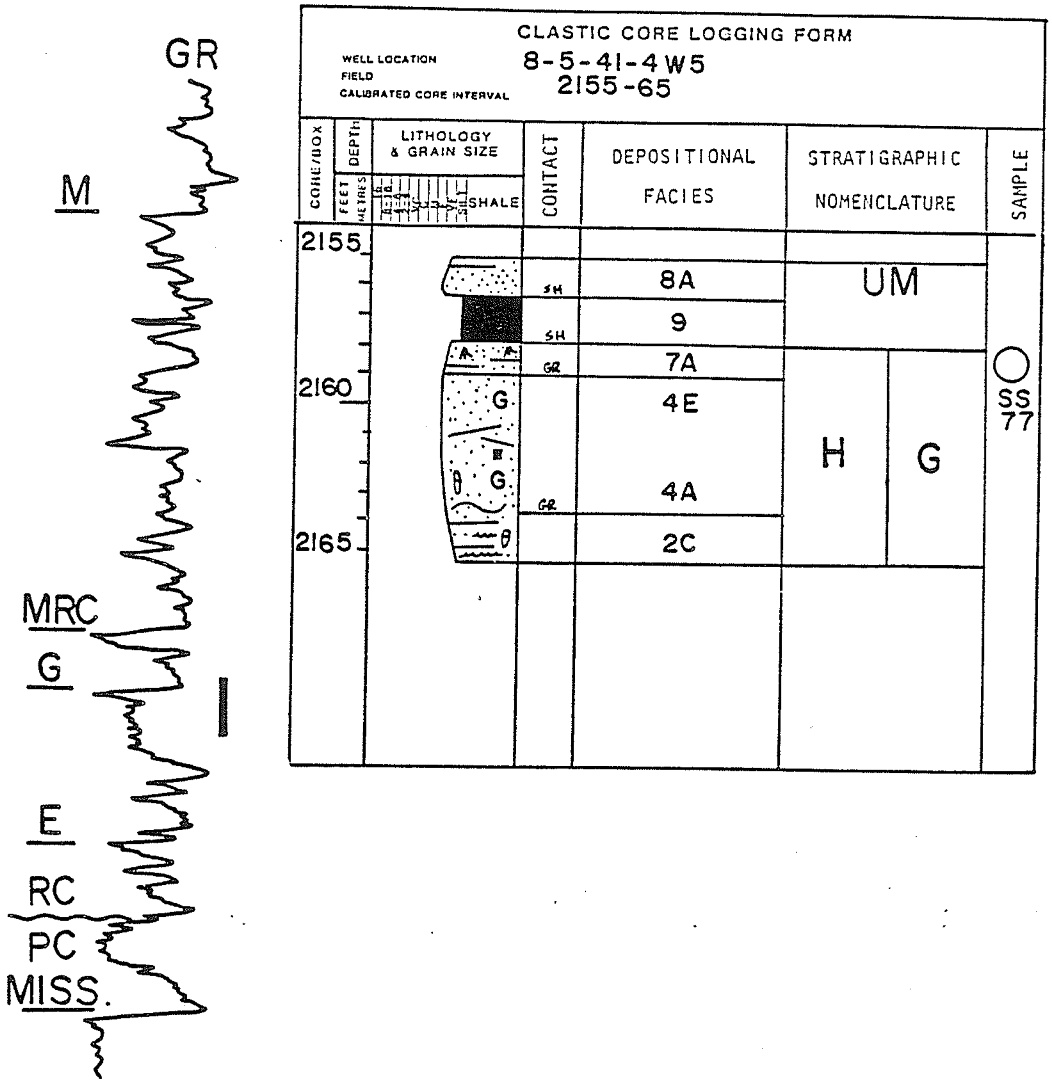
WELL LOCATION 10-3-41-3W5
FIELD --
CALIBRATED CORE INTERVAL 7044-170

CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	7044		SH	J3C	UF	
			SH	J2B ,J6 J3C		
			GR	J3C,J6		
	7100		SH	J3C,D		
	7150		SH	J2A,6 J3C		
	7170			J5, J6		



CLASTIC CORE LOGGING FORM

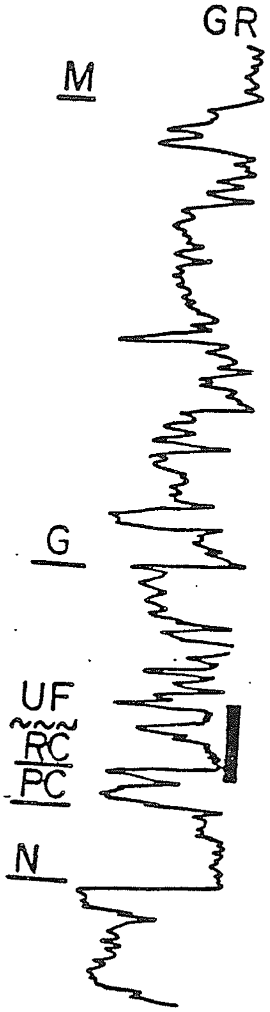
WELL LOCATION 6-27-41-3W5
FIELD
CALIBRATED CORE INTERVAL 6942 - 7052

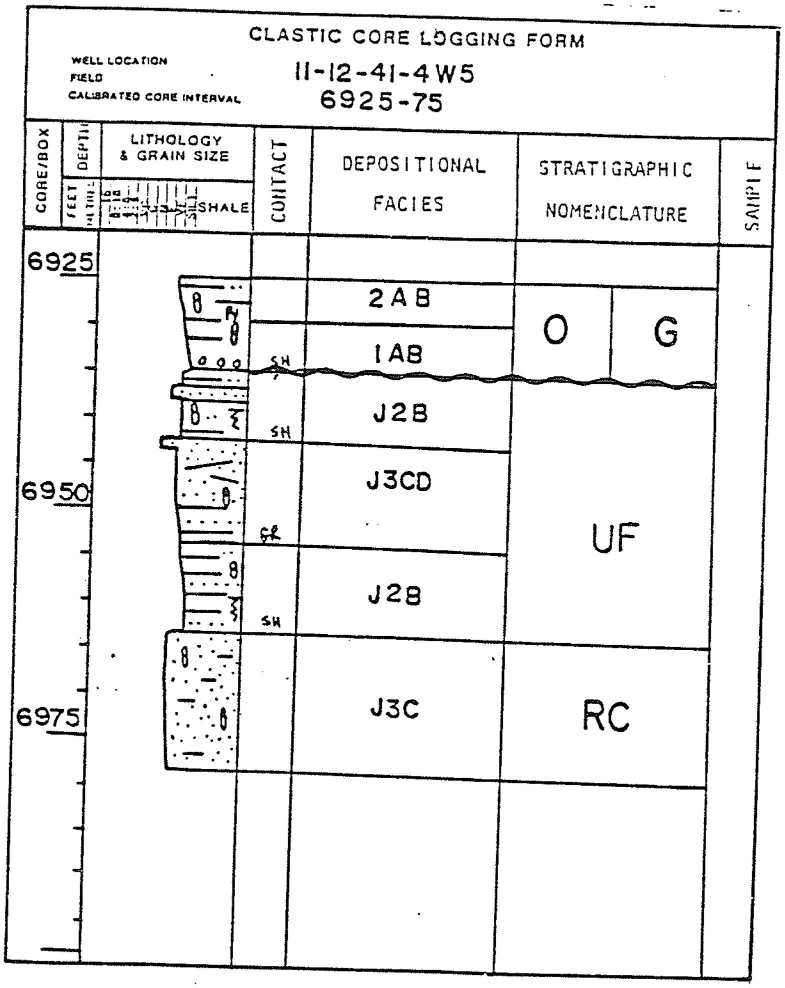


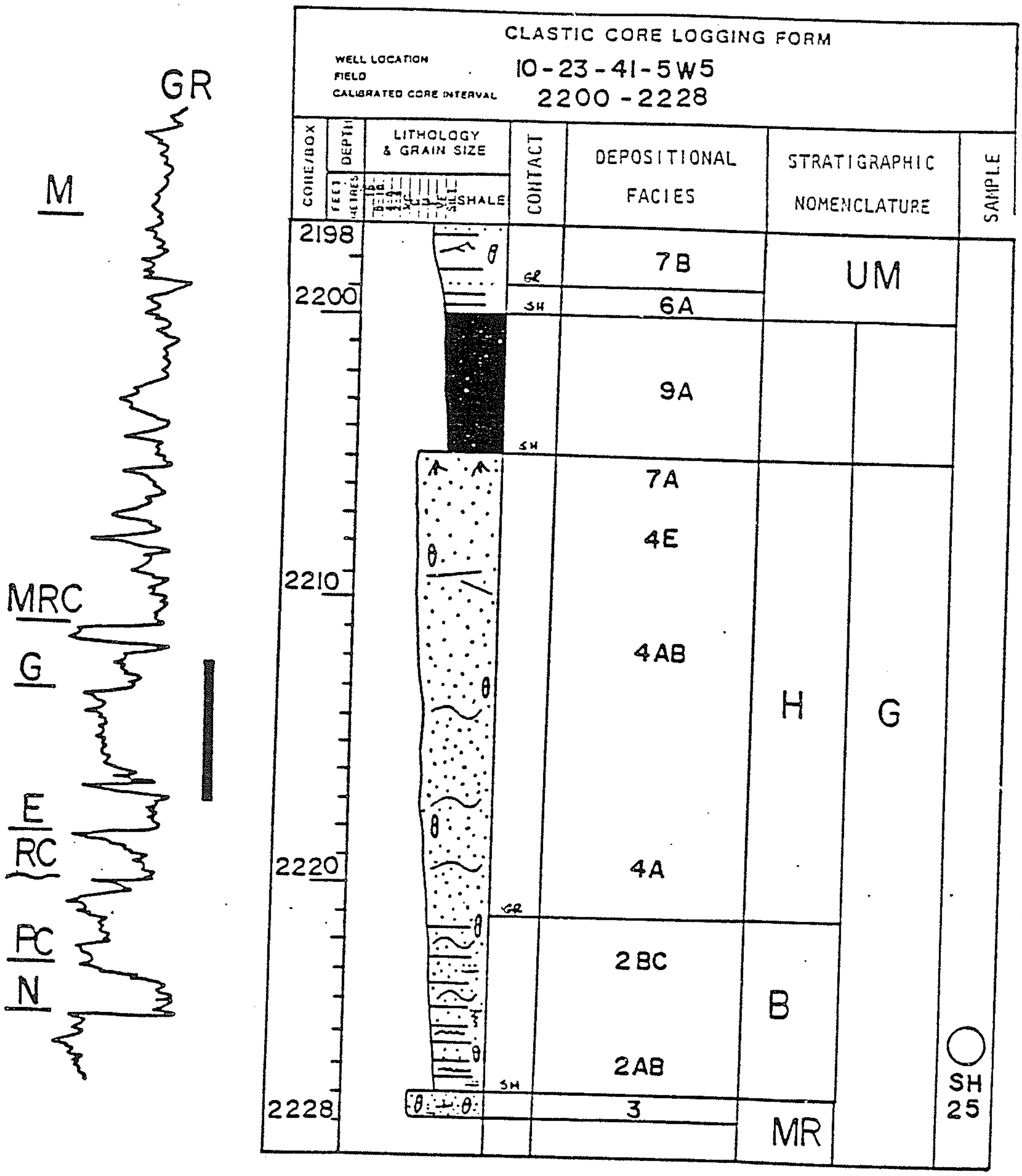
CLASTIC CORE LOGGING FORM

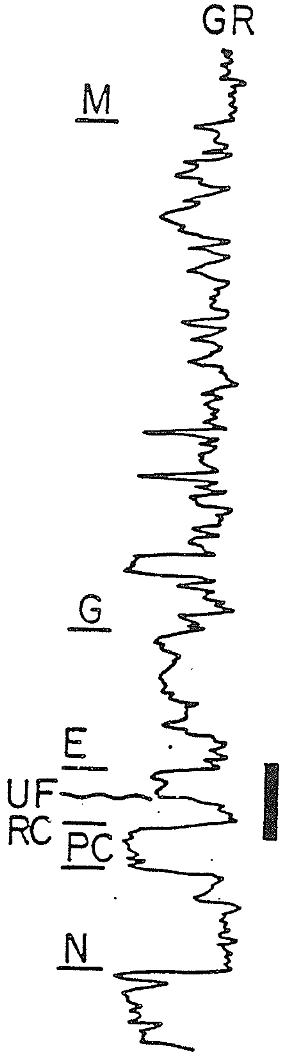
WELL LOCATION 8-5-41-4 W5
FIELD
CALIBRATED CORE INTERVAL 2155-65

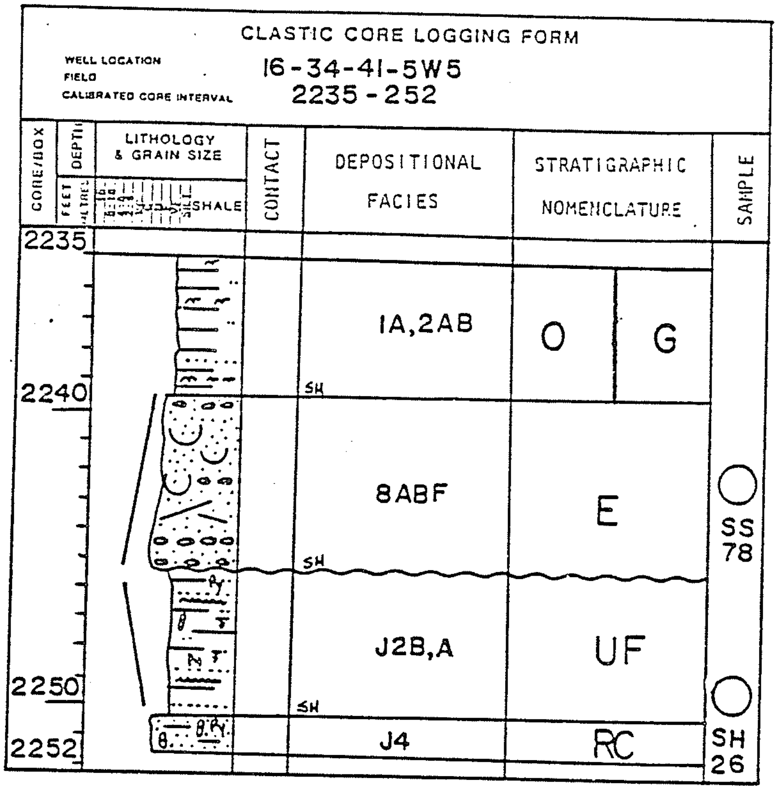
CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2155		SH	8A	UM		
			SH	9			
			GR	7A	H	G	○ SS 77
	2160			4E			
			GR	4A			
	2165			2C			


GR
M
G
UF
RC
PC
N


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
11-12-41-4W5
6925-75
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
6925
6950
6975
SH
SH
GR
SH
2AB
1AB
J2B
J3CD
J2B
J3C
O
G
UF
RC

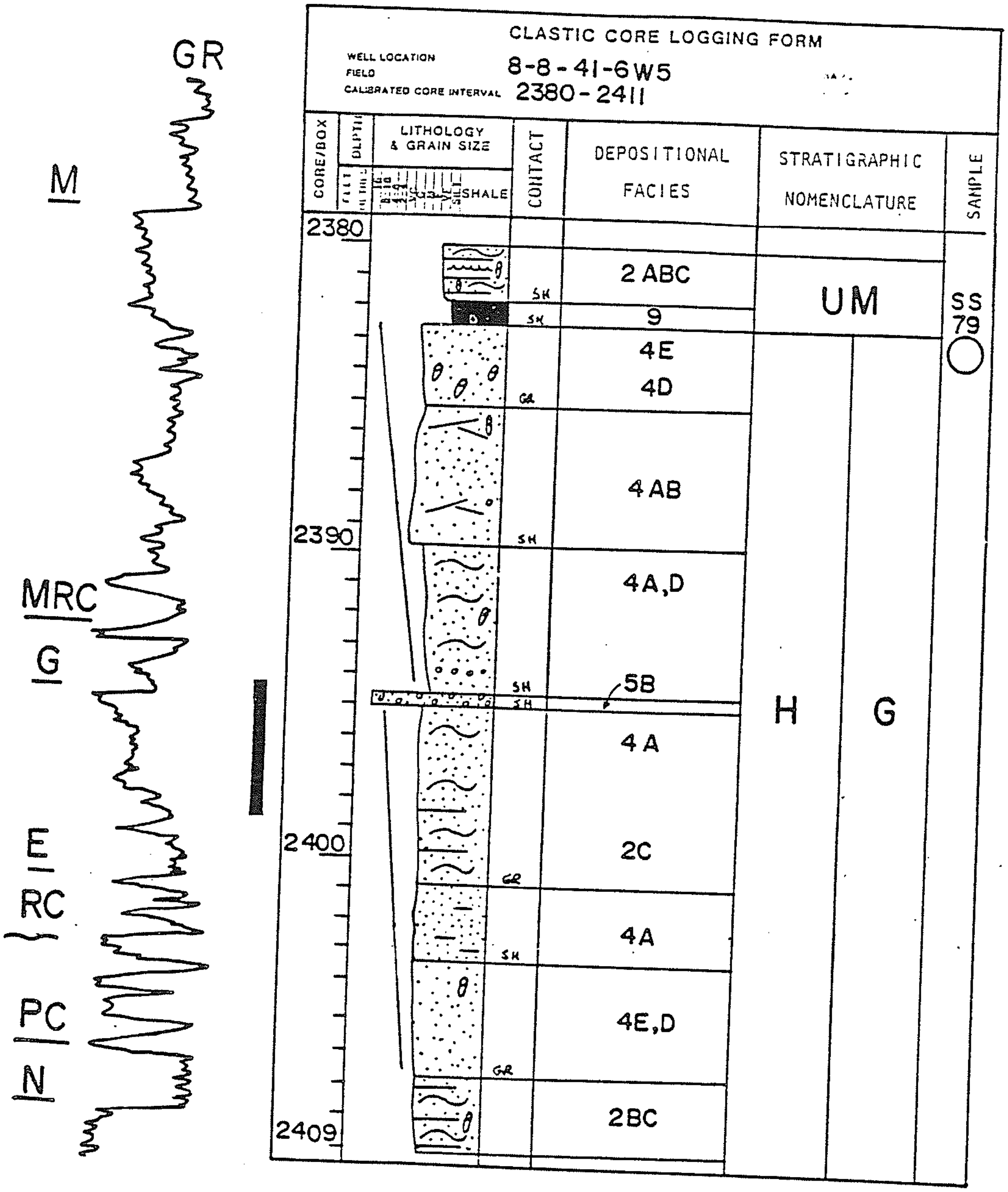

GR
M
MRC
G
E
RC
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
10-23-41-5W5
2200-2228
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2198
2200
2210
2220
2228
GR
SH
SH
GR
SH
7B
6A
9A
7A
4E
4AB
4A
2BC
2AB
3
UM
H
G
B
MR
SH
25

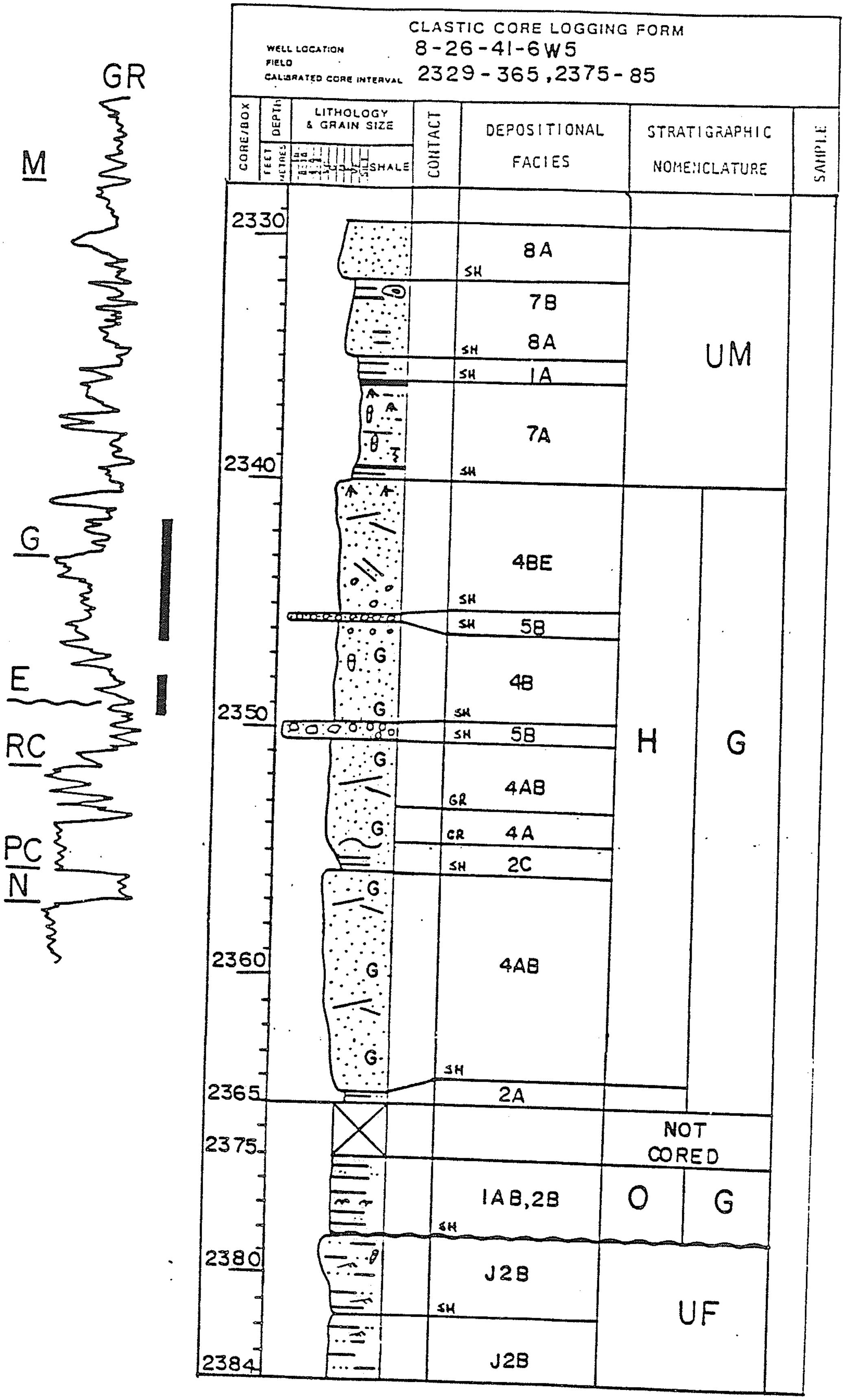



CLASTIC CORE LOGGING FORM

WELL LOCATION 16-34-41-5W5
FIELD
CALIBRATED CORE INTERVAL 2235 - 252

CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2235						
			SH	1A,2AB	O	G	
	2240		SH	8ABF	E		SS 78
			SH	J2B,A	UF		
	2250		SH	J4	RC		SH 26
	2252						


GR
M
MRC
G
E
RC
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
8-8-41-6W5
2380-2411
CORE/BOX
DEPTH
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2380
2390
2400
2409
SH
GR
2 ABC
9
4E
4D
4AB
4A,D
5B
4A
2C
4A
4E,D
2BC
UM
H
G
SS 79

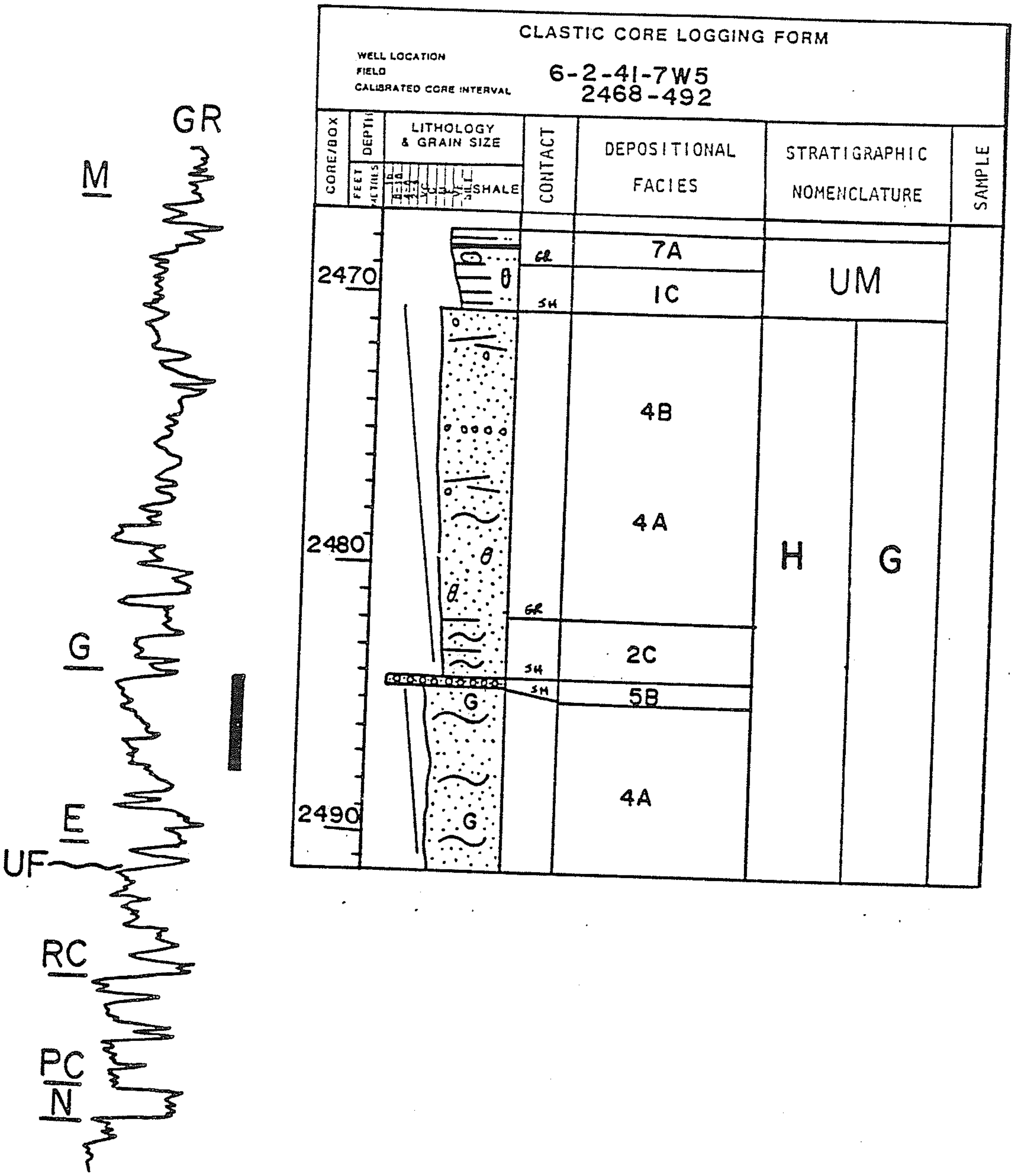


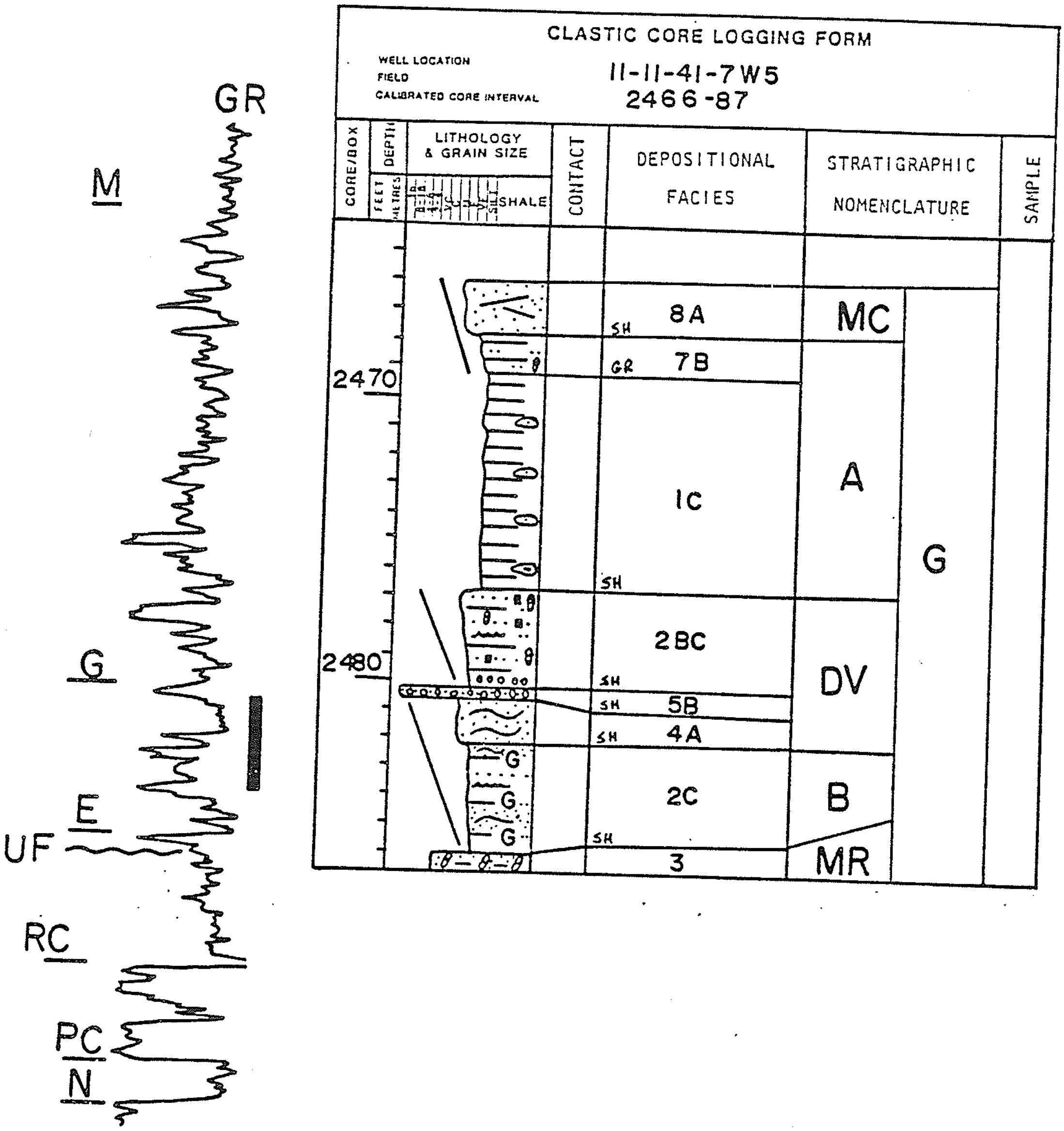
CLASTIC CORE LOGGING FORM

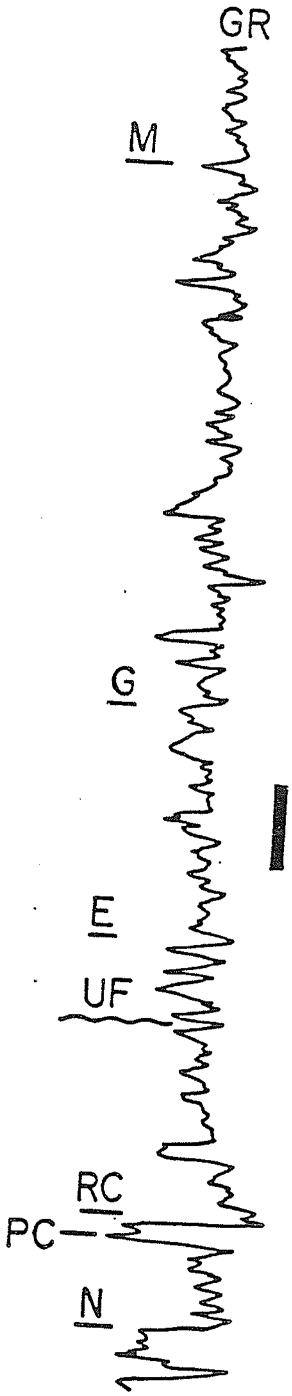
WELL LOCATION 8-26-41-6W5

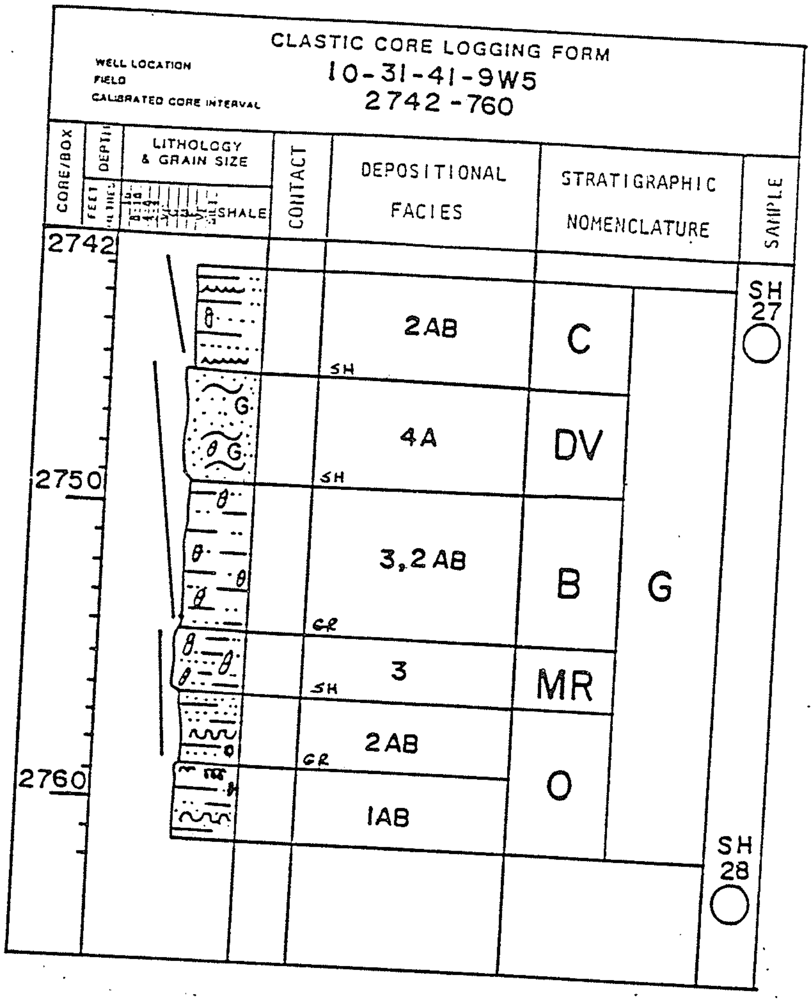
FIELD

CALIBRATED CORE INTERVAL 2329-365, 2375-85


GR
M
G
E
UF
RC
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-2-41-7W5
2468-492
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2470
2480
2490
GR
SH
GR
SH
SH
7A
1C
4B
4A
2C
5B
4A
UM
H
G


GR
M
G
E
UF
RC
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
11-11-41-7W5
2466-87
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2470
2480
SH
GR
SH
SH
SH
SH
SH
8A
7B
1C
2BC
5B
4A
2C
3
MC
A
DV
B
MR
G

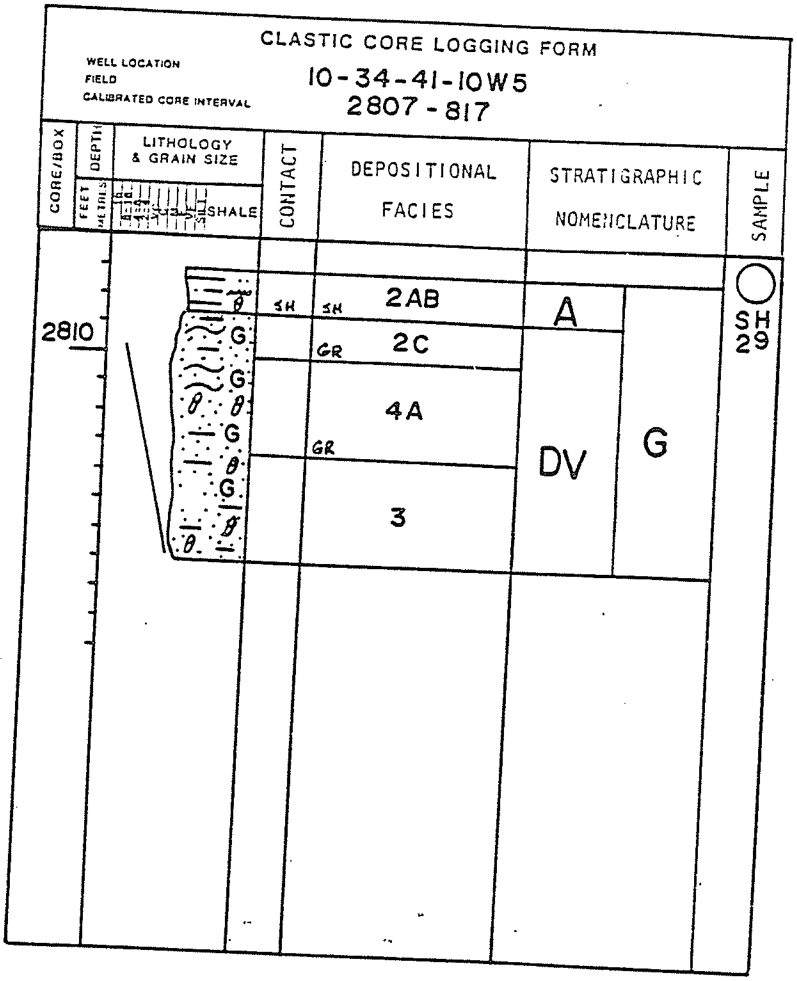




CLASTIC CORE LOGGING FORM

WELL LOCATION 10-31-41-9W5
FIELD
CALIBRATED CORE INTERVAL 2742-760

CORE/BOX	DEPTH (FEET, METRES)	LITHOLOGY & GRAIN SIZE (SHALE)	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2742						SH 27 ○
			SH	2AB	C	G	
			SH	4A	DV		
	2750		GR	3,2AB	B		
			SH	3	MR		
			GR	2AB	O		
	2760			1AB			SH 28 ○

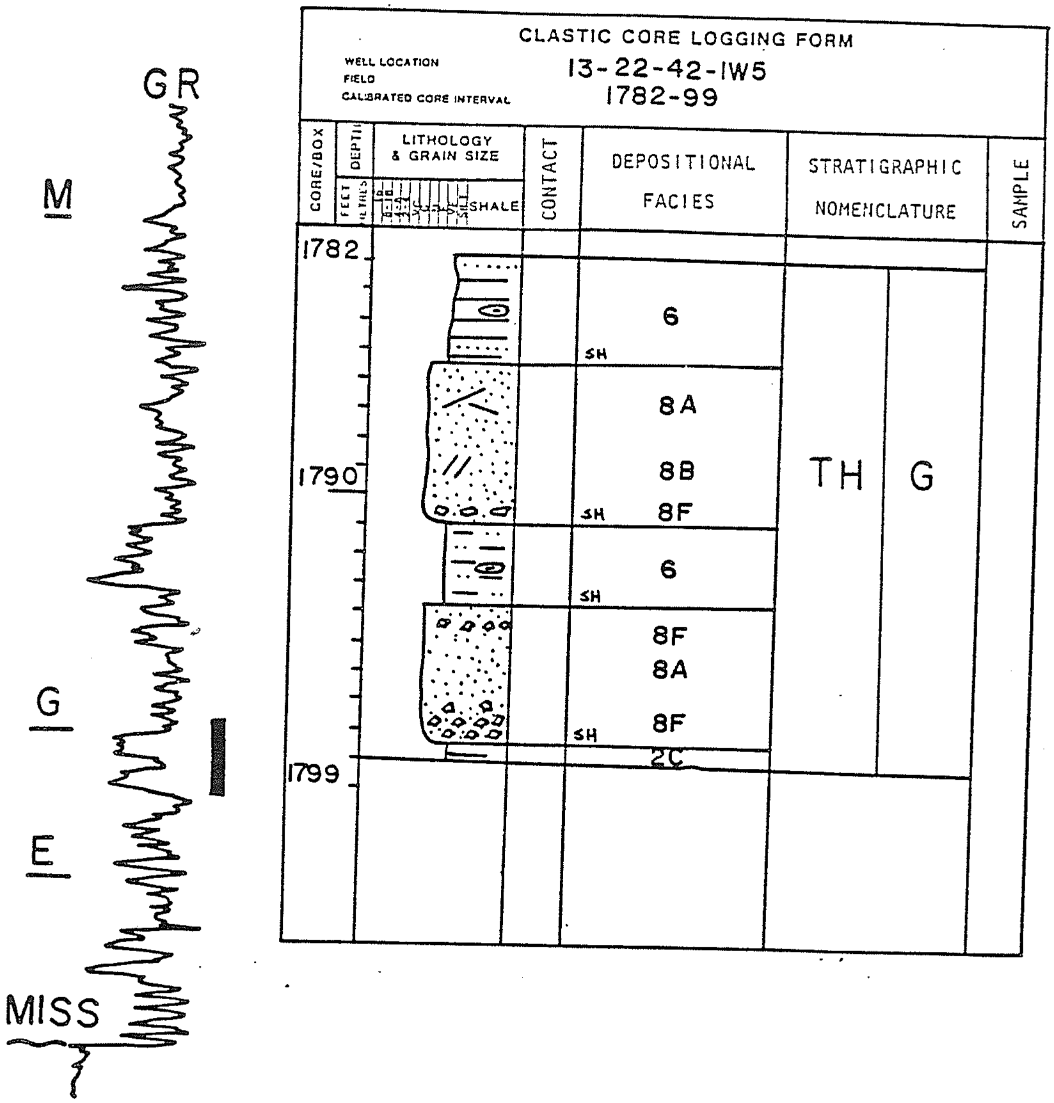


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

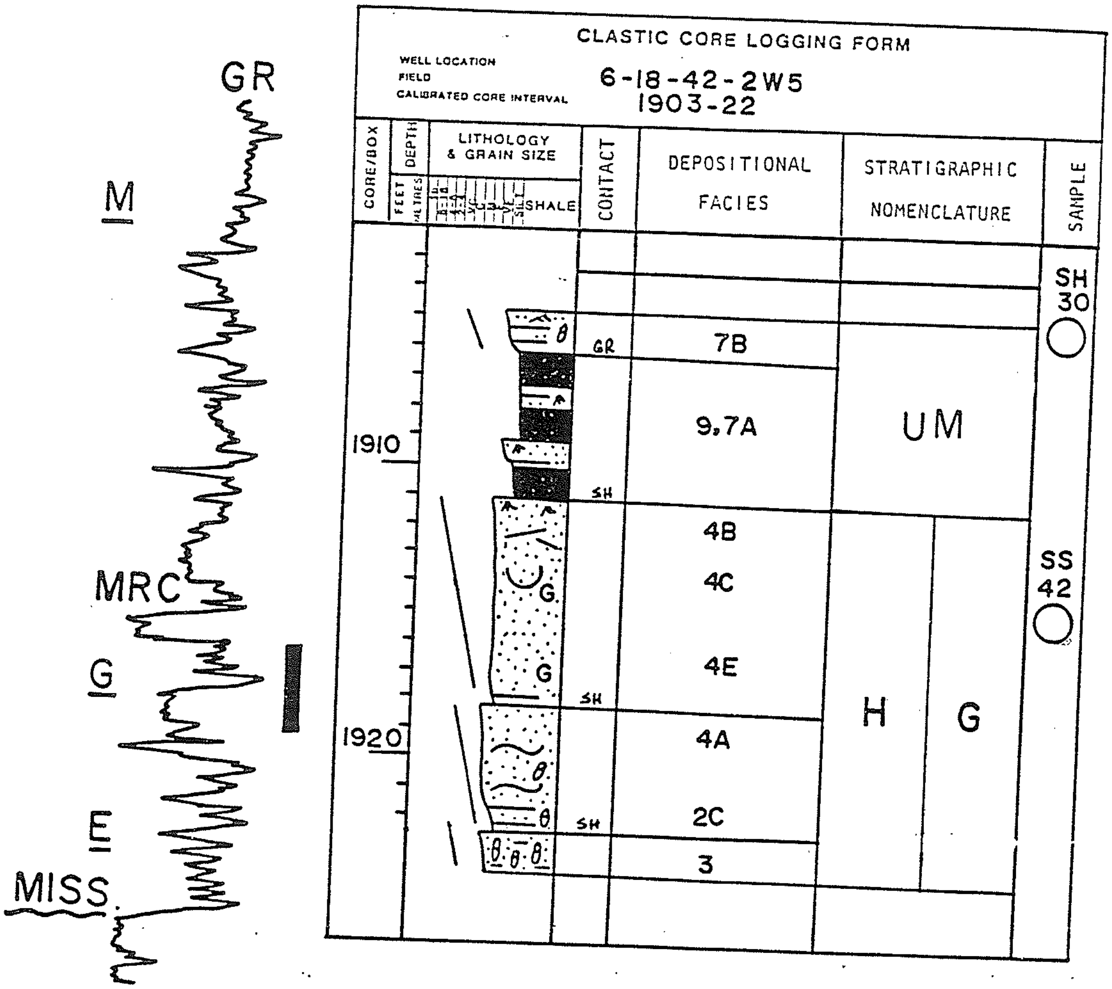
10-34-41-10W5
2807 - 817

CORE/BOX	DEPTH FEET / METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
			SH	2AB	A	G	SH 29
	2810		GR	2C	DV		
				4A			
			GR	3			



CLASTIC CORE LOGGING FORM

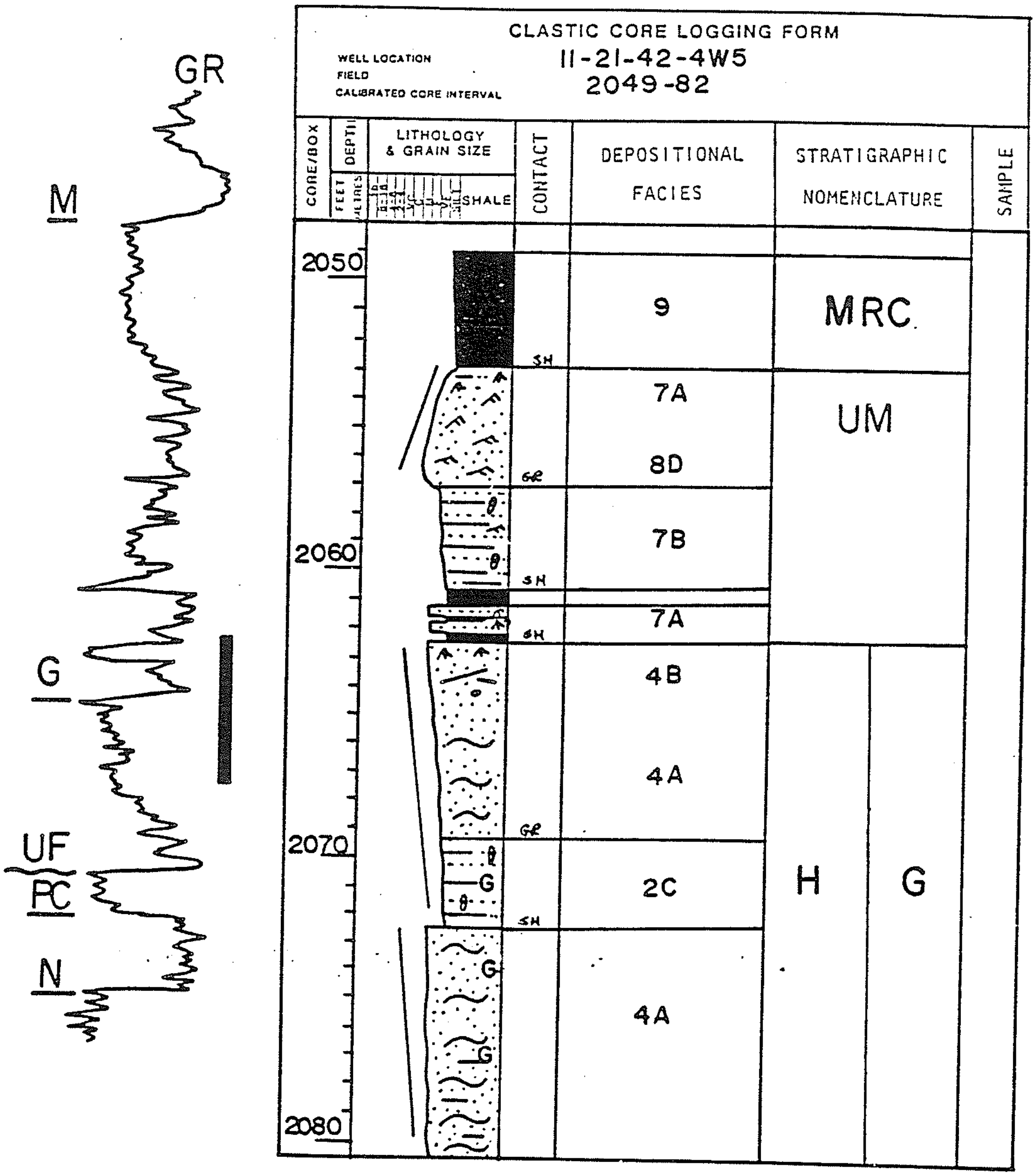
WELL LOCATION 13-22-42-IW5
FIELD
CALIBRATED CORE INTERVAL 1782-99

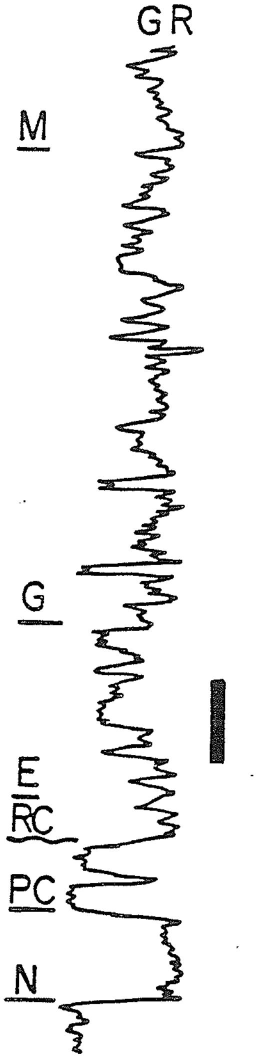


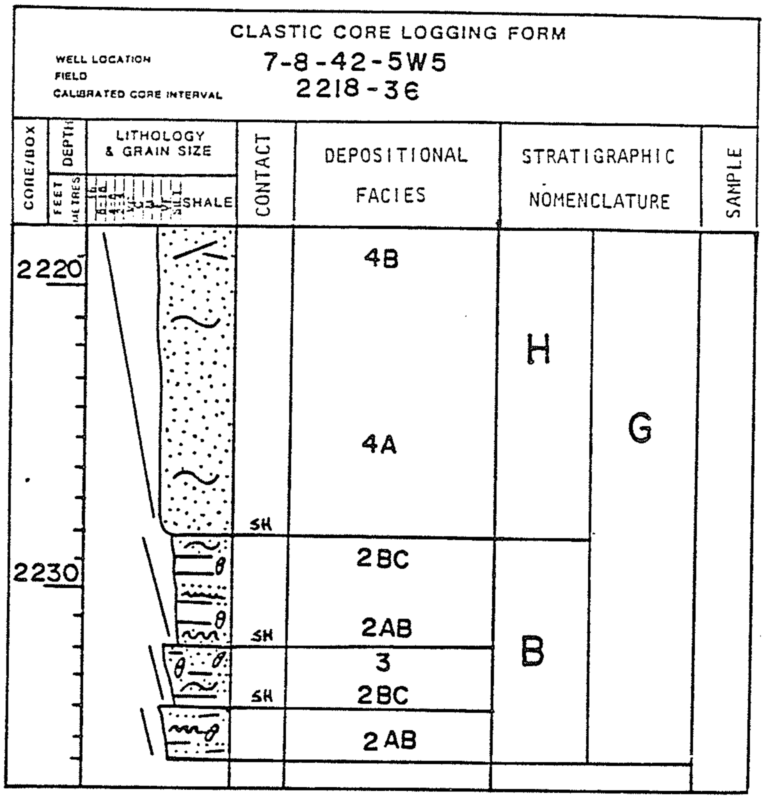
CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

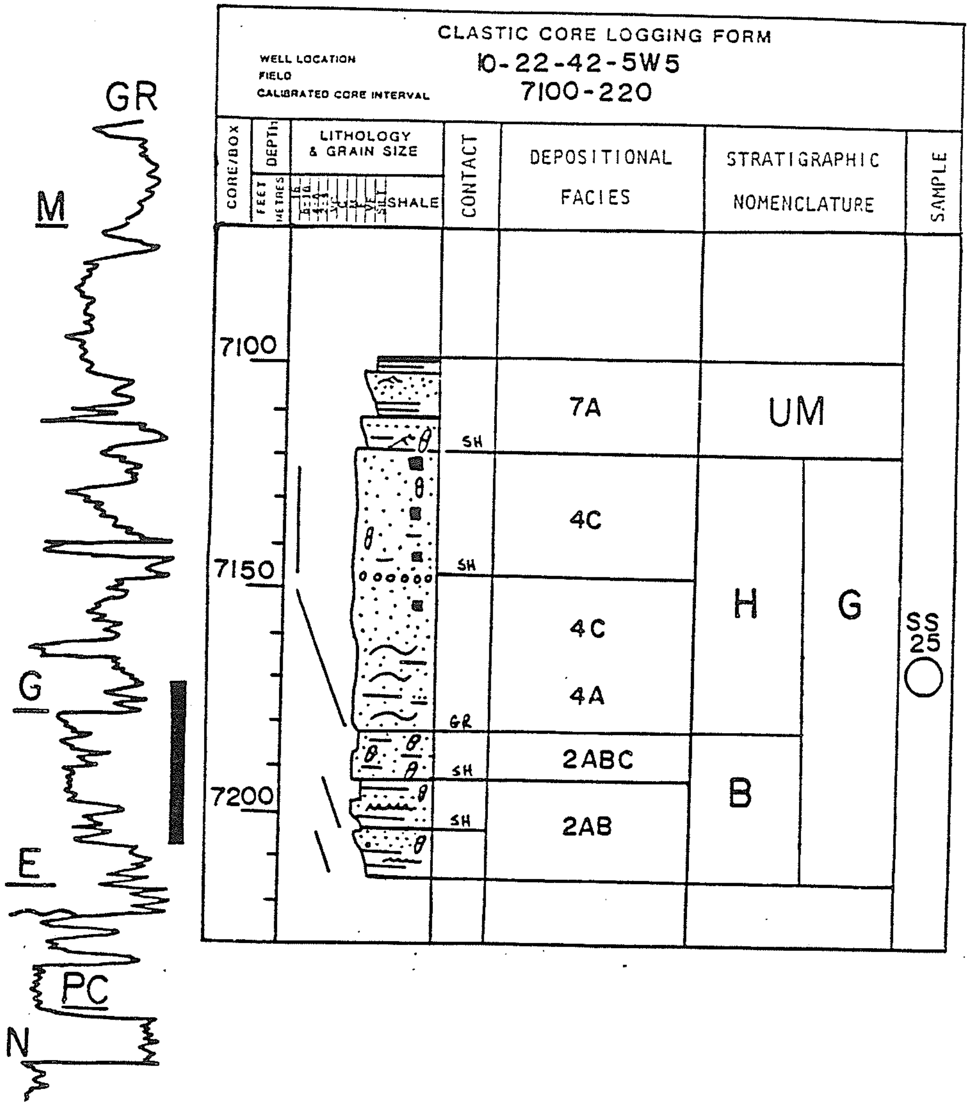
6-18-42-2W5
1903-22

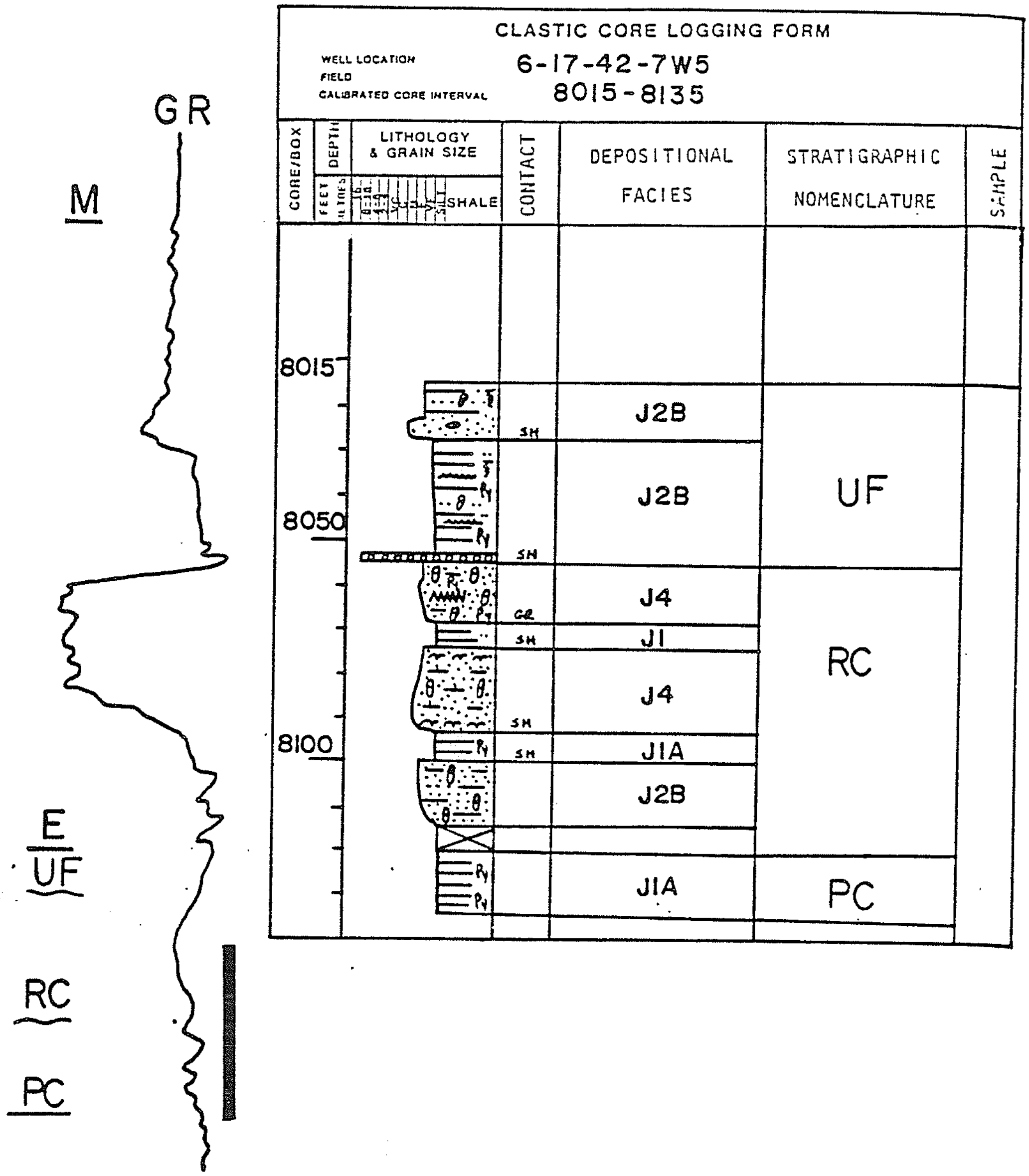

GR
M
G
UF
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
11-21-42-4W5
2049-82
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2050
2060
2070
2080
SH
GR
SH
SH
GR
SH
9
7A
8D
7B
7A
4B
4A
2C
4A
MRC
UM
H
G

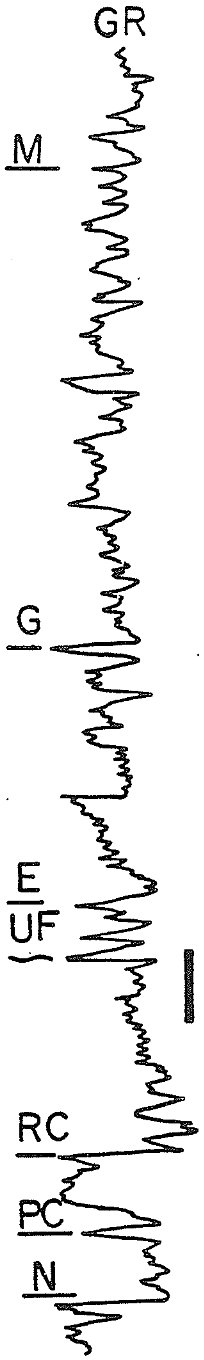


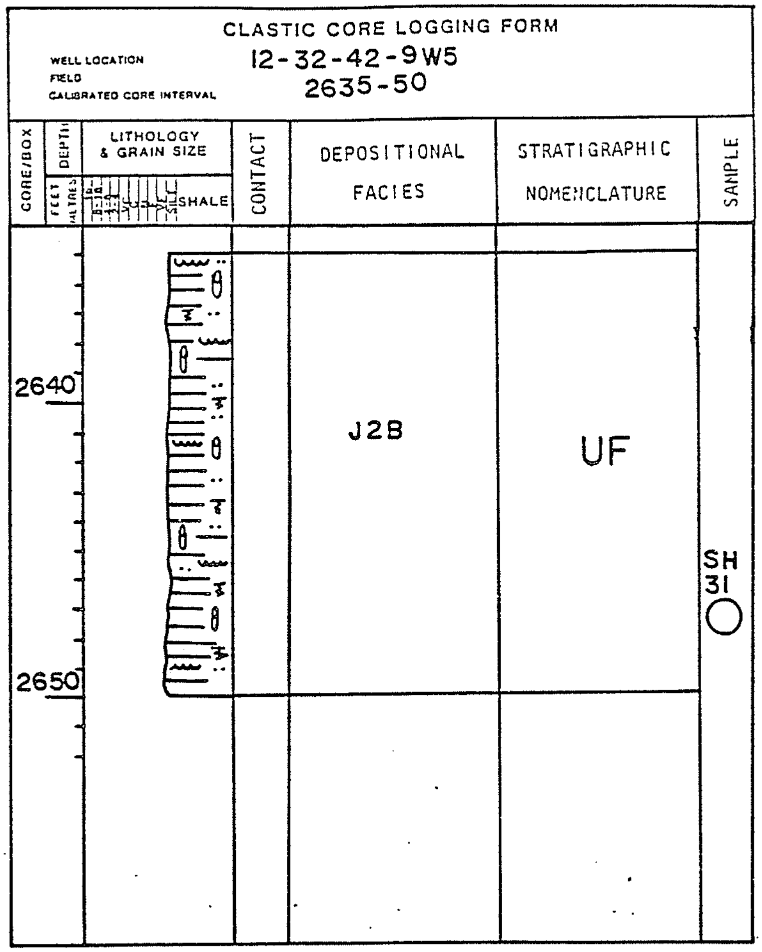

CLASTIC CORE LOGGING FORM

WELL LOCATION 7-8-42-5W5
FIELD
CALIBRATED CORE INTERVAL 2218-36


GR
M
G
E
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
10-22-42-5W5
7100-220
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
7100
7150
7200
SH
SH
GR
SH
SH
7A
4C
4C
4A
2ABC
2AB
UM
H
G
B
SS 25


GR
M
E
UF
RC
PC
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-17-42-7W5
8015-8135
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
8015
8050
8100
SH
SH
GR
SH
SH
SH
J2B
J2B
J4
J1
J4
J1A
J2B
J1A
UF
RC
PC

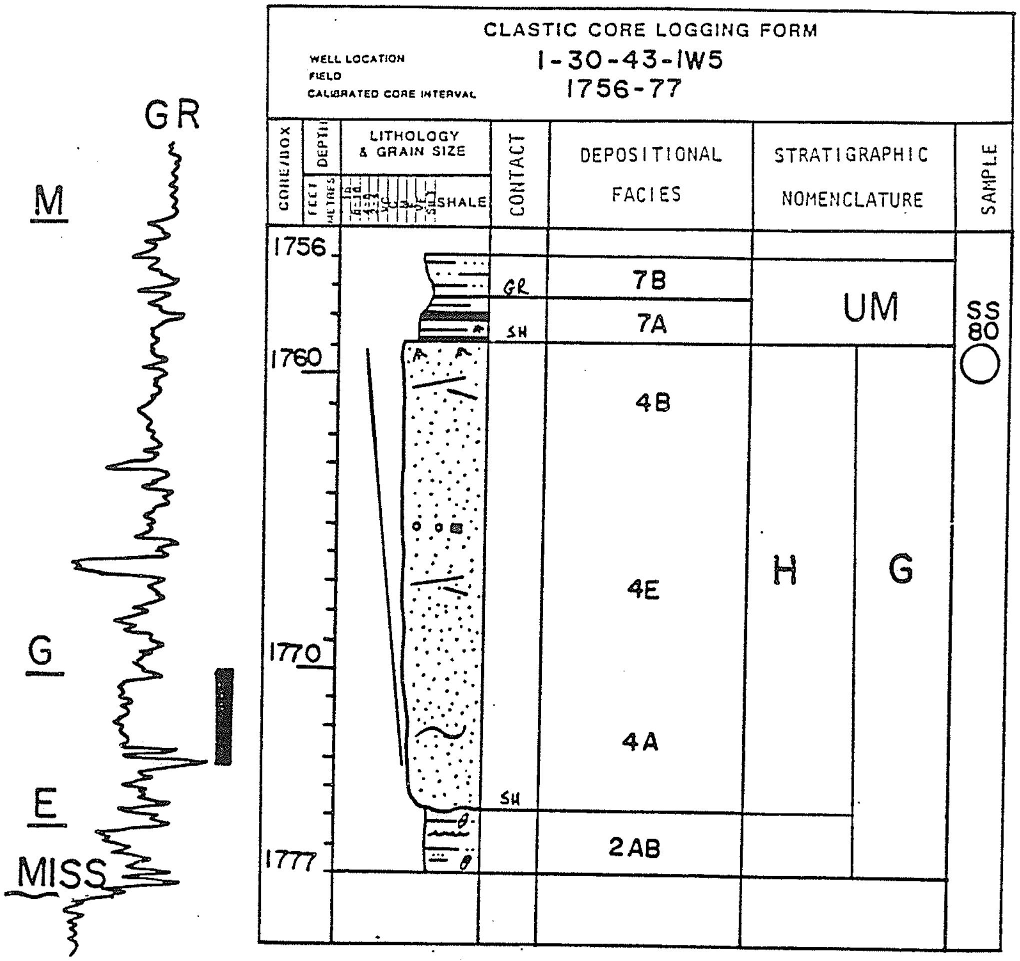


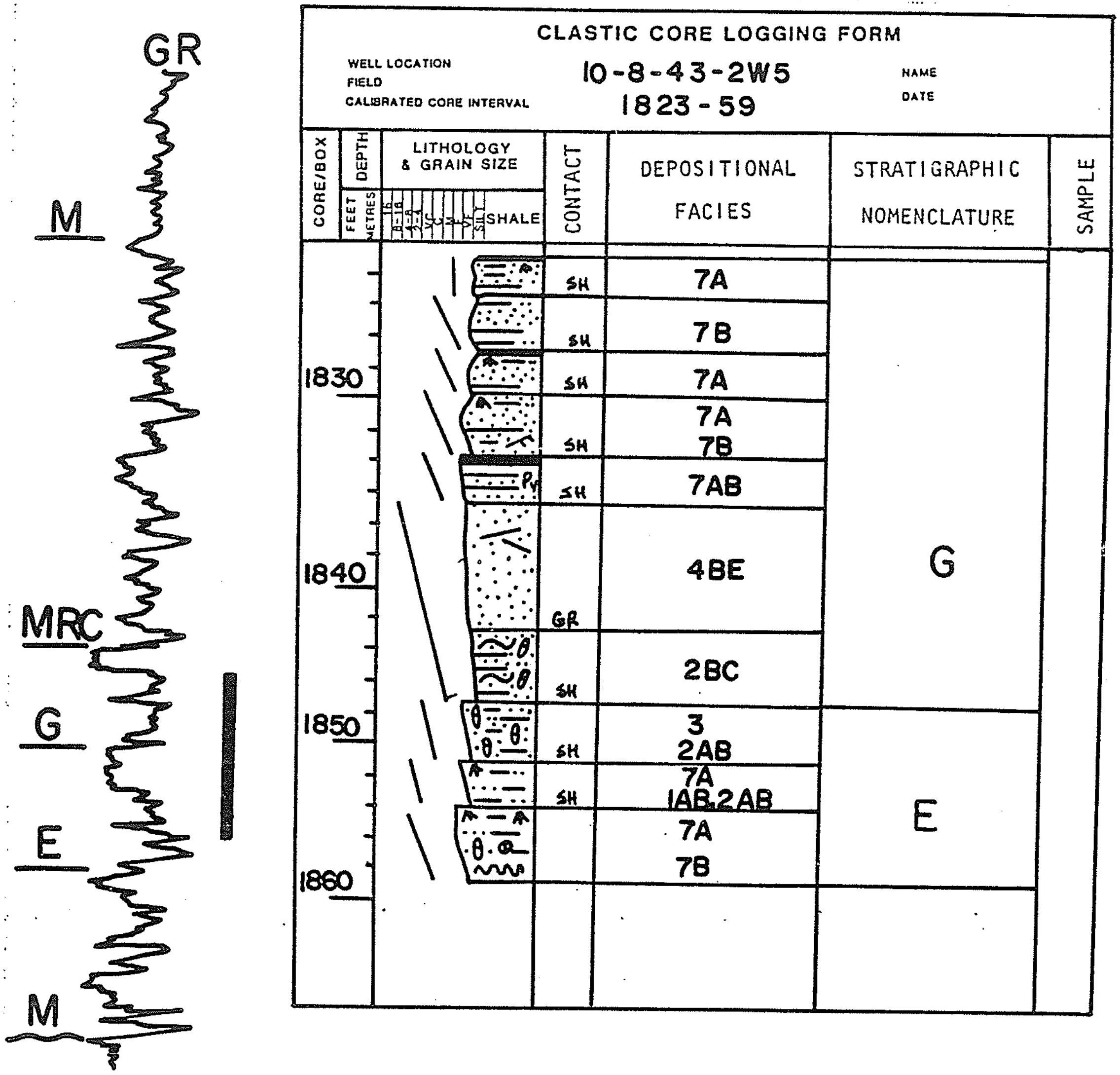


CLASTIC CORE LOGGING FORM

WELL LOCATION 12-32-42-9W5
FIELD
CALIBRATED CORE INTERVAL 2635-50

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2640 2650			J2B	UF	SH 31 ○

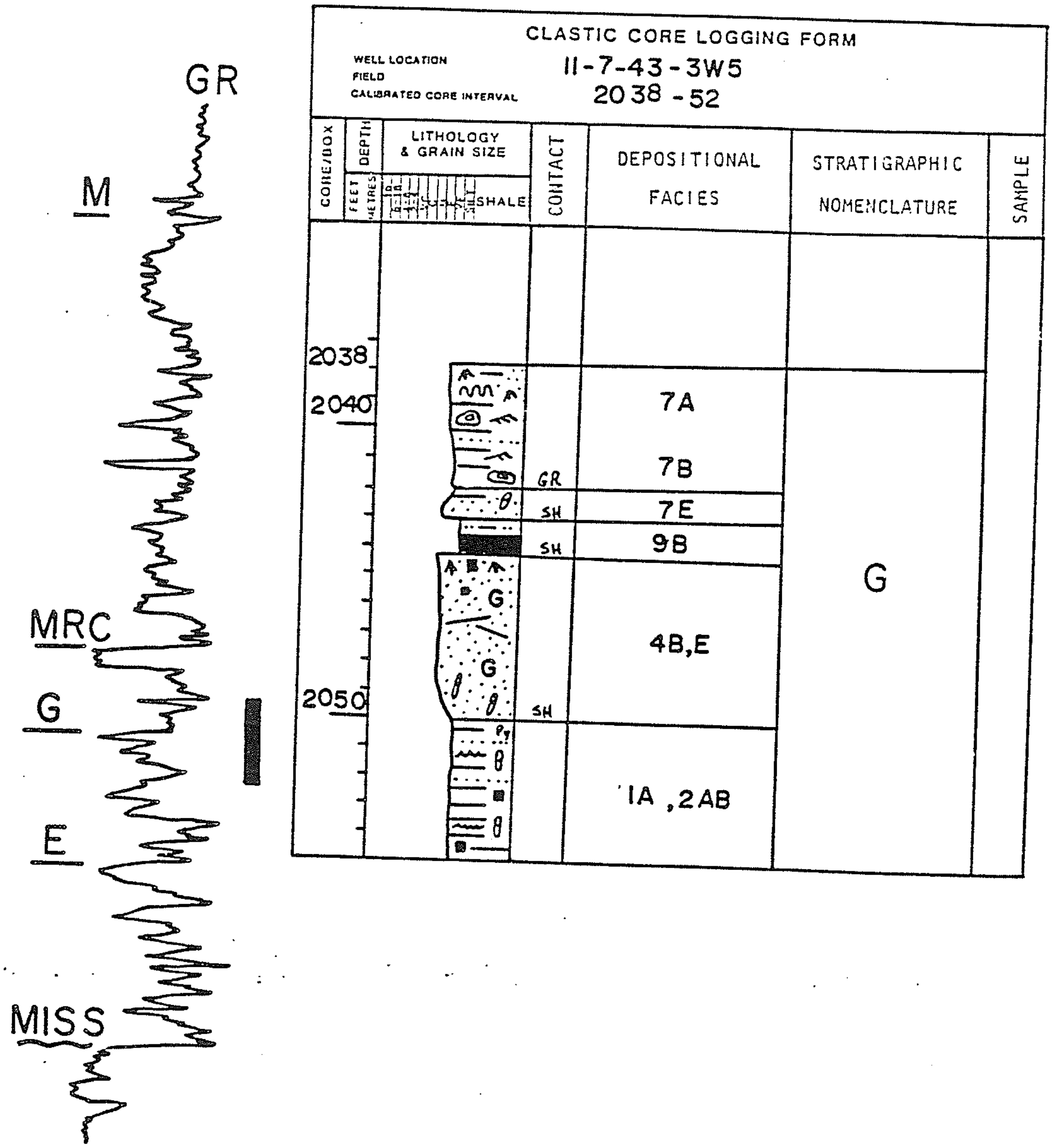

GR
M
G
E
MISS
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
1-30-43-1W5
1756-77
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1756
1760
1770
1777
GR
SH
SH
7B
7A
4B
4E
4A
2AB
UM
H
G
SS 80



CLASTIC CORE LOGGING FORM

WELL LOCATION 10-8-43-2W5
FIELD
CALIBRATED CORE INTERVAL 1823-59
NAME
DATE

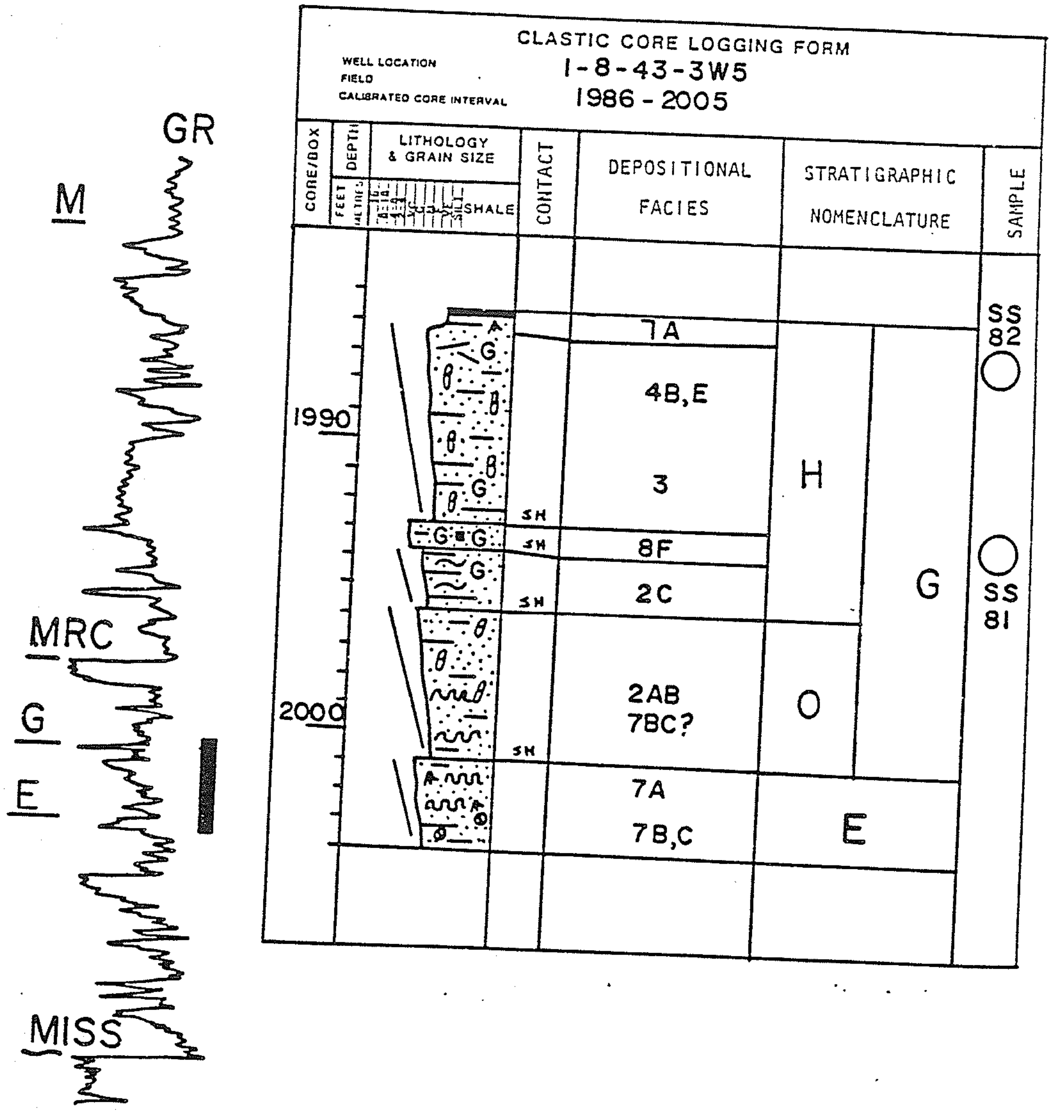
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
			SH	7A	G	
			SH	7B		
	1830		SH	7A		
			SH	7A 7B		
			SH	7AB		
	1840		GR	4BE		
			SH	2BC		
	1850		SH	3 2AB	E	
			SH	7A 1AB,2AB		
	1860			7A 7B		

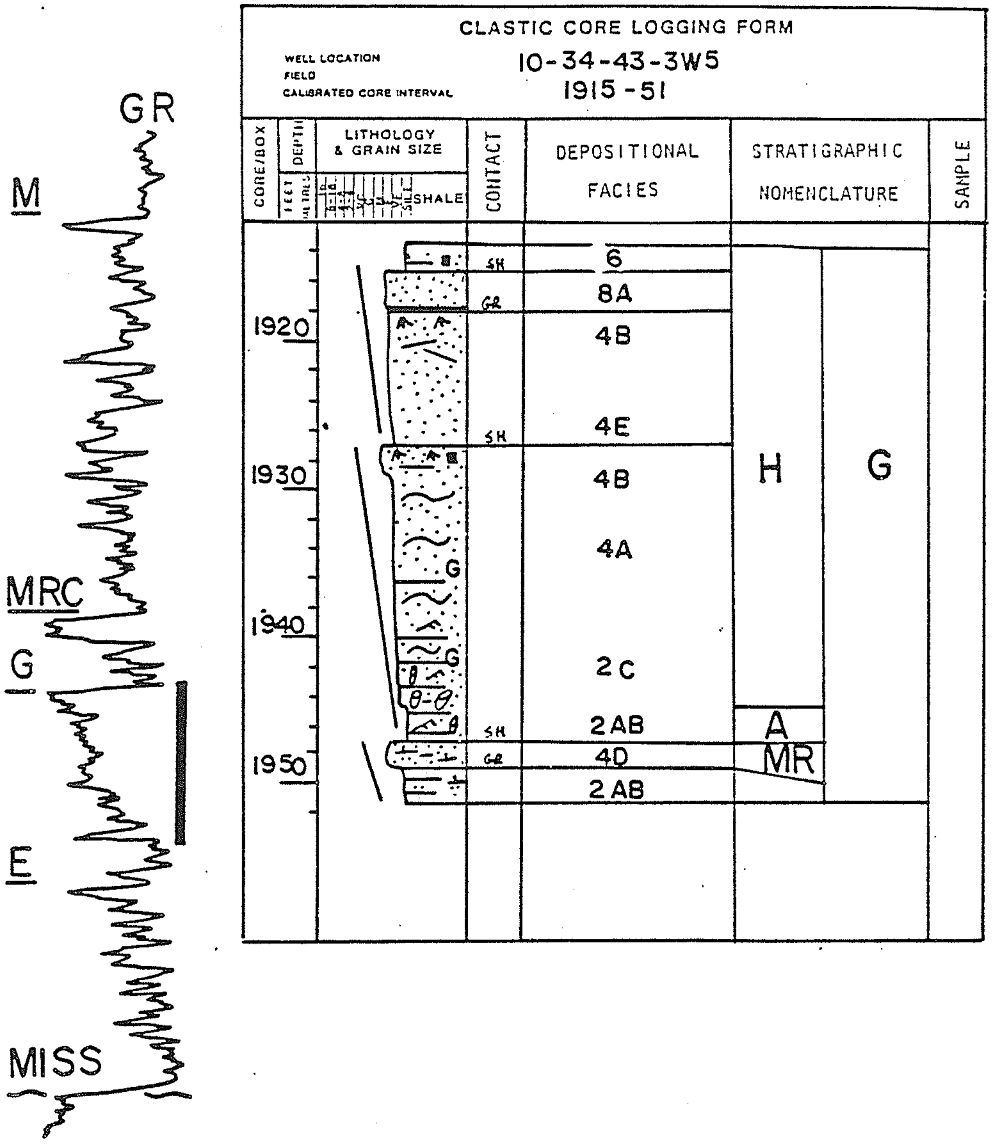


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 11-7-43-3W5
CALIBRATED CORE INTERVAL 2038 - 52

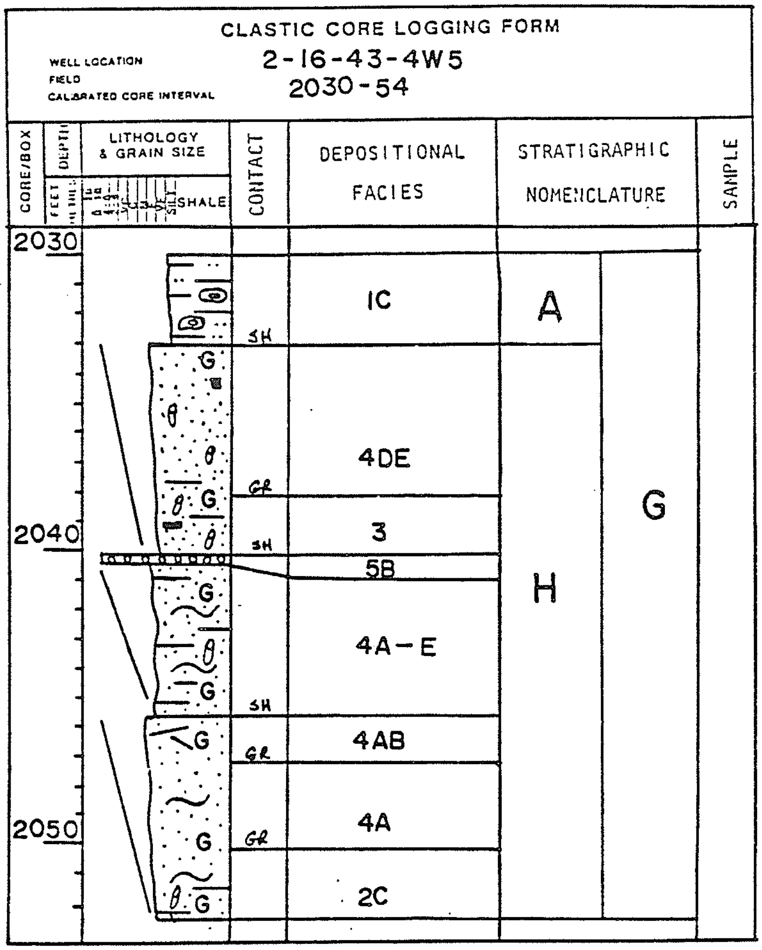
CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2038			7A	G	
	2040		GR	7B		
			SH	7E		
			SH	9B		
			SH	4B,E		
	2050			1A ,2AB		


GR
M
MRC
G
E
MISS
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
1-8-43-3W5
1986 - 2005
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1990
2000
SH
SH
SH
SH
7A
4B,E
3
8F
2C
2AB
7BC?
7A
7B,C
H
O
E
G
SS 82
SS 81



CLASTIC CORE LOGGING FORM

WELL LOCATION 10-34-43-3W5
FIELD
CALIBRATED CORE INTERVAL 1915-51

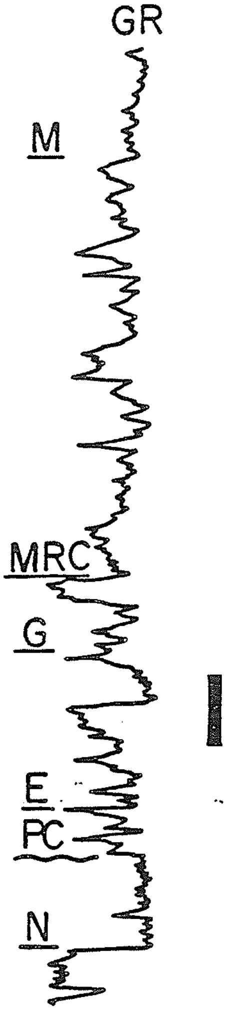


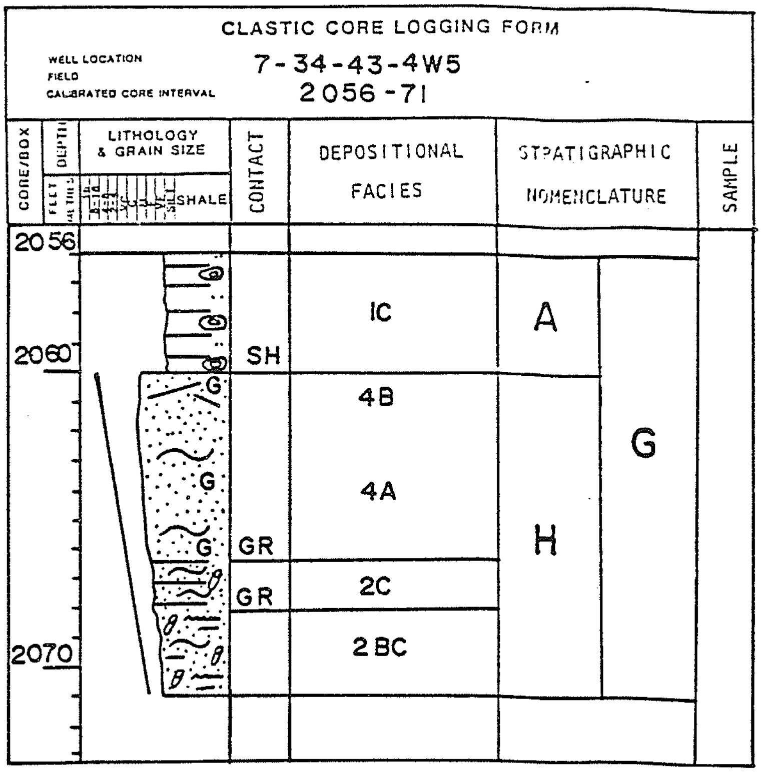
CLASTIC CORE LOGGING FORM

WELL LOCATION 2-16-43-4W5
FIELD
CALIBRATED CORE INTERVAL 2030-54

CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
SH	IC	A	G	
GR	4DE	H		
SH	3			
	5B			
SH	4A-E			
GR	4AB			
GR	4A			
	2C			

LOG
NA



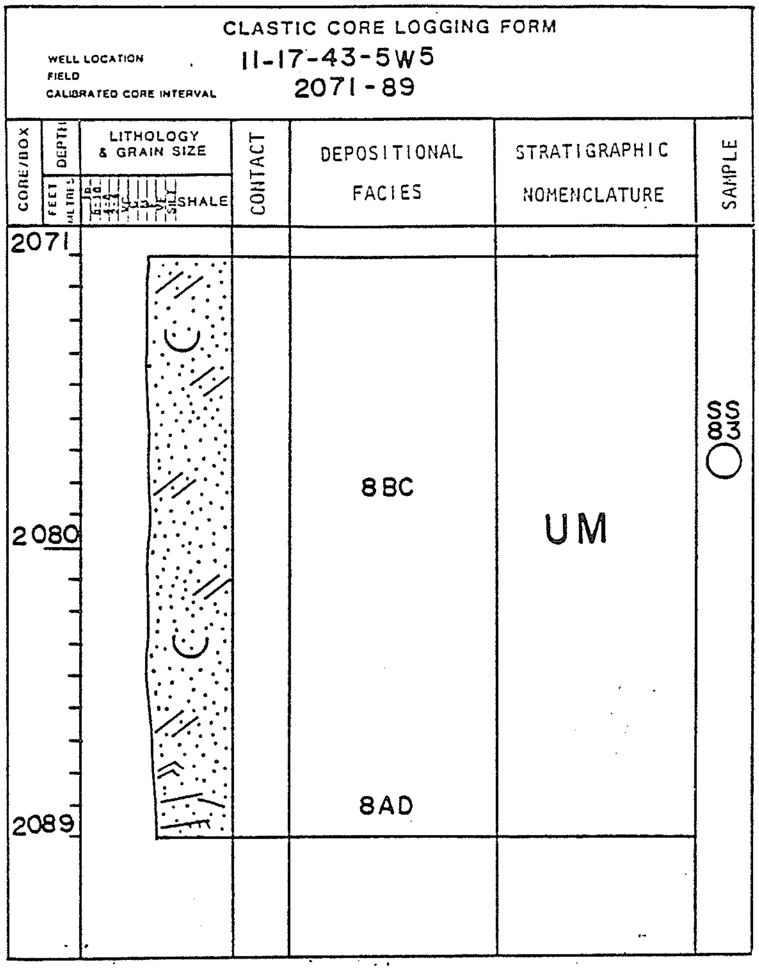

CLASTIC CORE LOGGING FORM

WELL LOCATION 7-34-43-4W5
FIELD
CALIBRATED CORE INTERVAL 2056-71

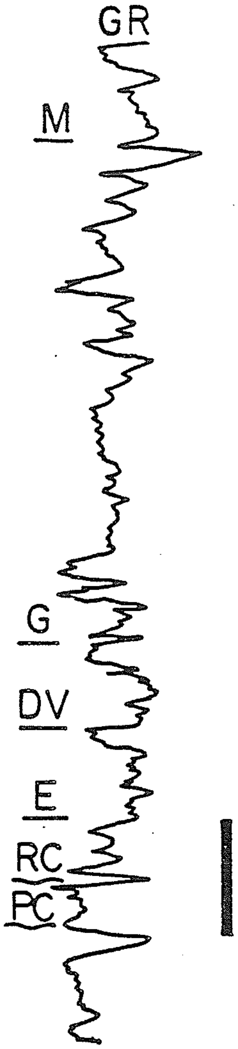
CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2056						
		@		IC	A	G	
	2060		SH				
		G		4B	H		
		G		4A			
		G	GR				
			GR	2C			
	2070			2BC			

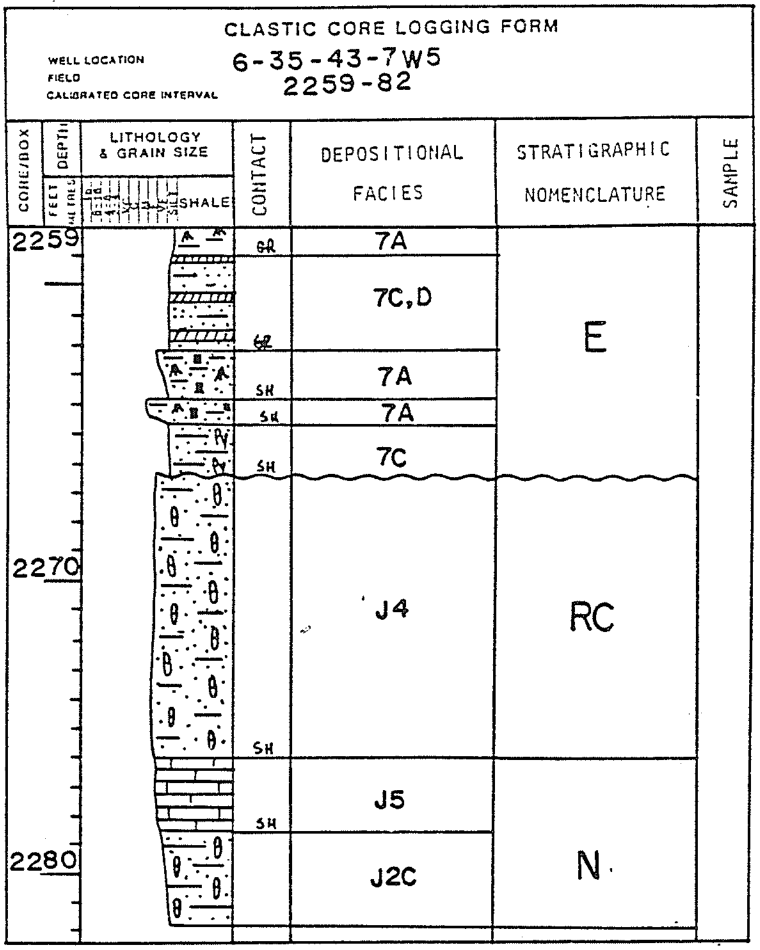
CLASTIC CORE LOGGING FORM

WELL LOCATION 11-17-43-5W5
FIELD
CALIBRATED CORE INTERVAL 2071-89



DEPTH (FEET)	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
2071			
			SS 83
2080	8BC	UM	
2089	8AD		

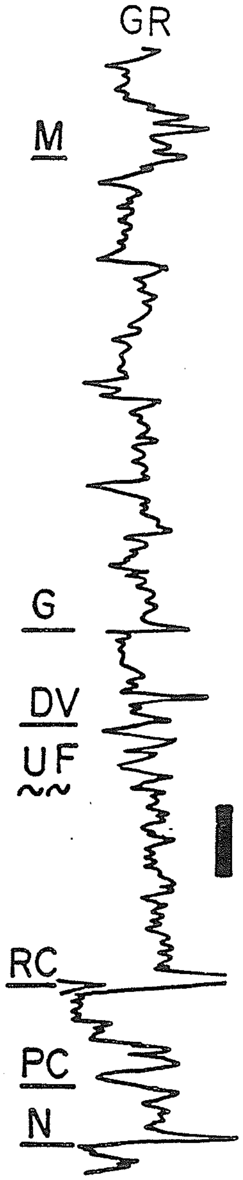


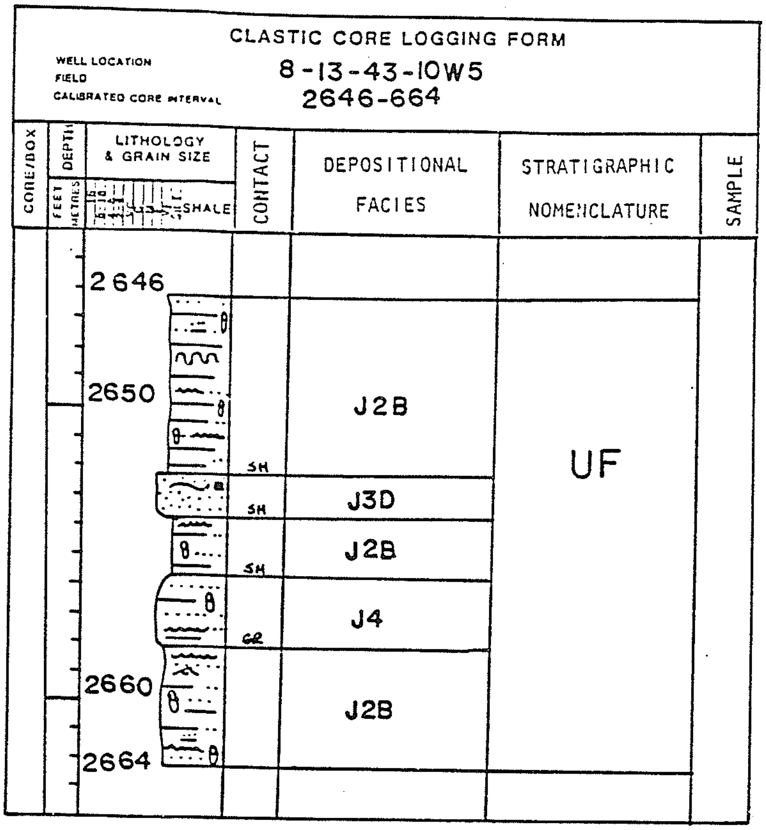


CLASTIC CORE LOGGING FORM

WELL LOCATION 6-35-43-7W5
FIELD
CALIBRATED CORE INTERVAL 2259-82

CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2259		GR	7A	E	
			GR	7C,D		
			SH	7A		
			SH	7A		
			SH	7C		
	2270		SH	J4	RC	
			SH	J5	N	
	2280			J2C		

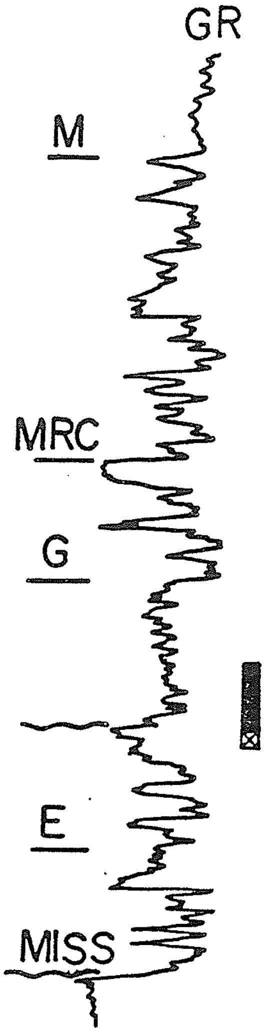


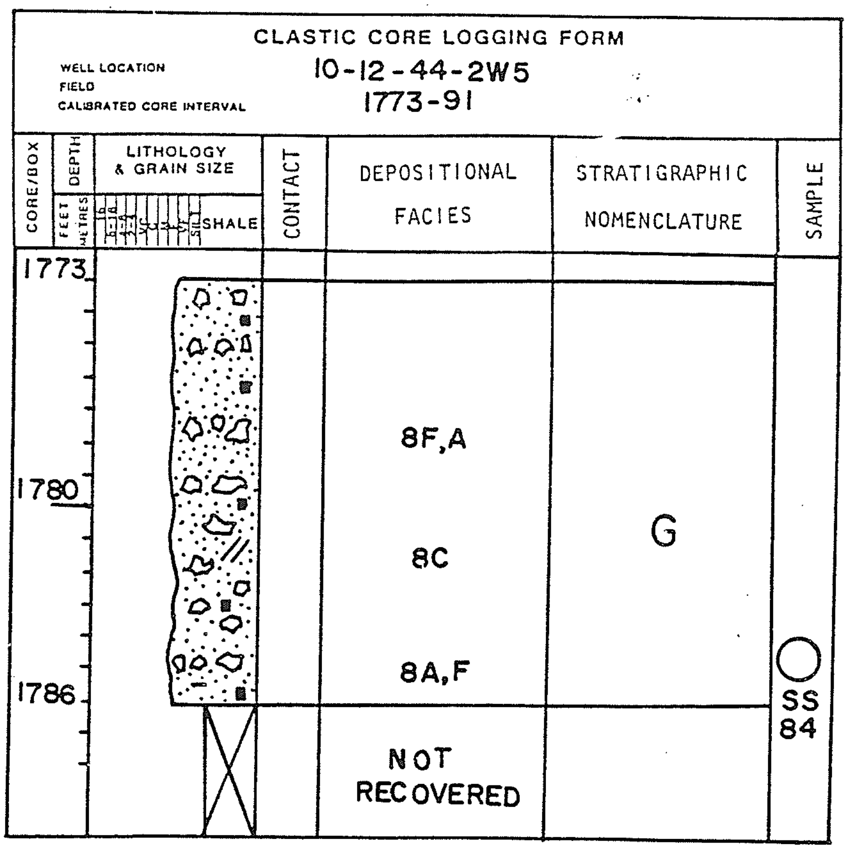


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 8-13-43-10W5
CALIBRATED CORE INTERVAL 2646-664

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2646 2650		SH	J2B	UF	
			SH	J3D		
			SH	J2B		
			GR	J4		
	2660 2664			J2B		

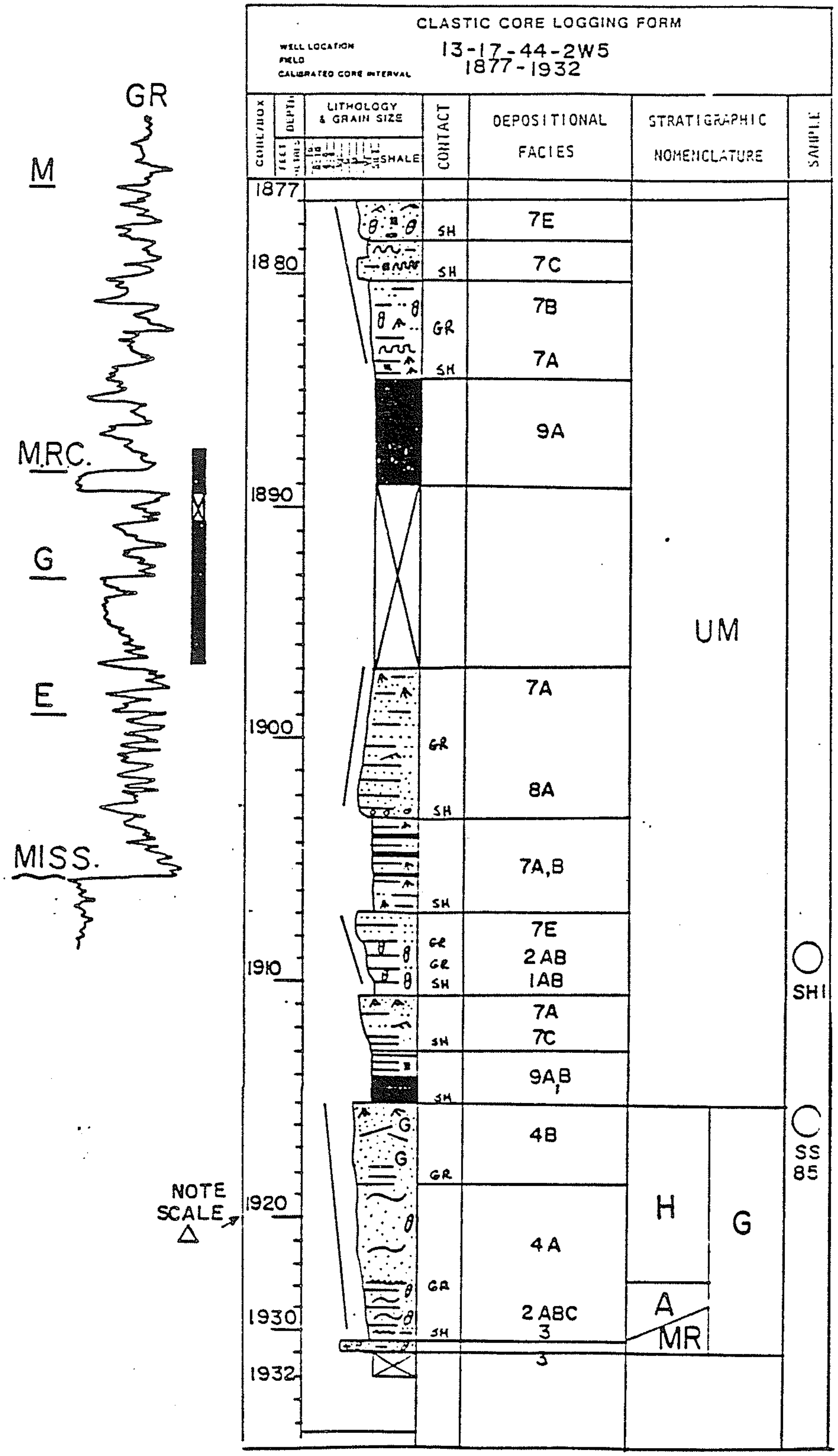


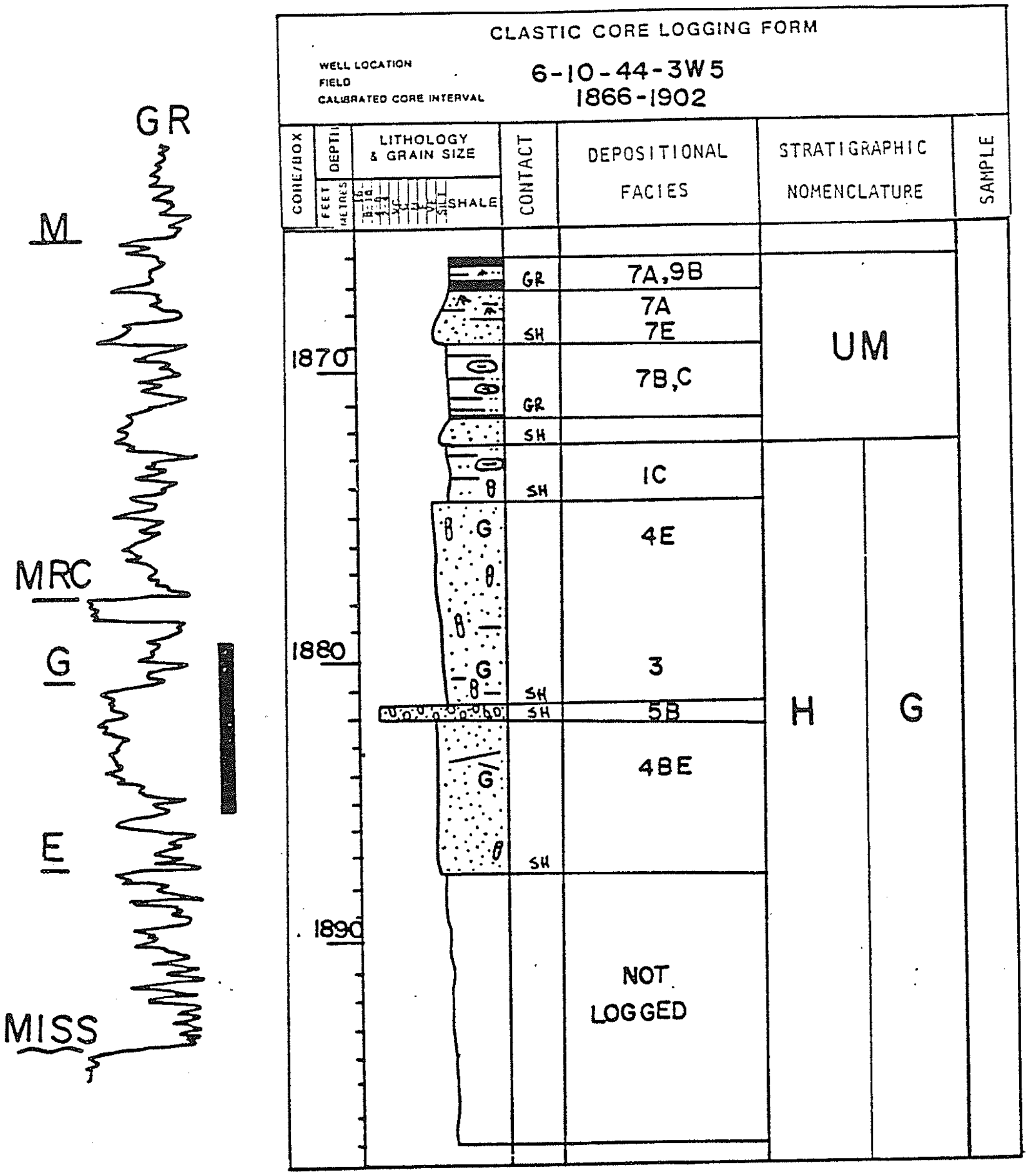


CLASTIC CORE LOGGING FORM

WELL LOCATION 10-12-44-2W5
FIELD
CALIBRATED CORE INTERVAL 1773-91

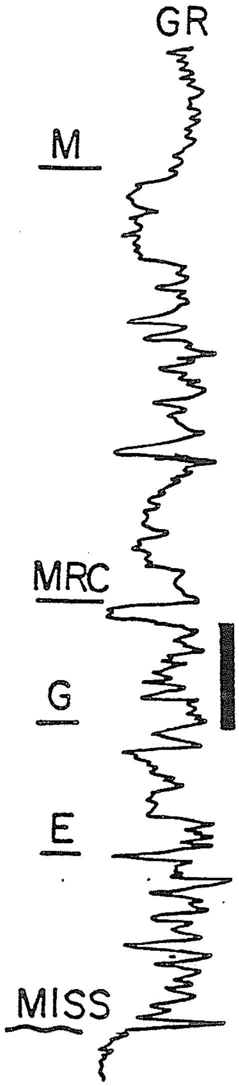
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE 16 8-16 4-8 2-4 VC C M F VF SILT SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	1773			8F,A	G	
	1780			8C		
	1786			8A,F		○ SS 84
				NOT RECOVERED		

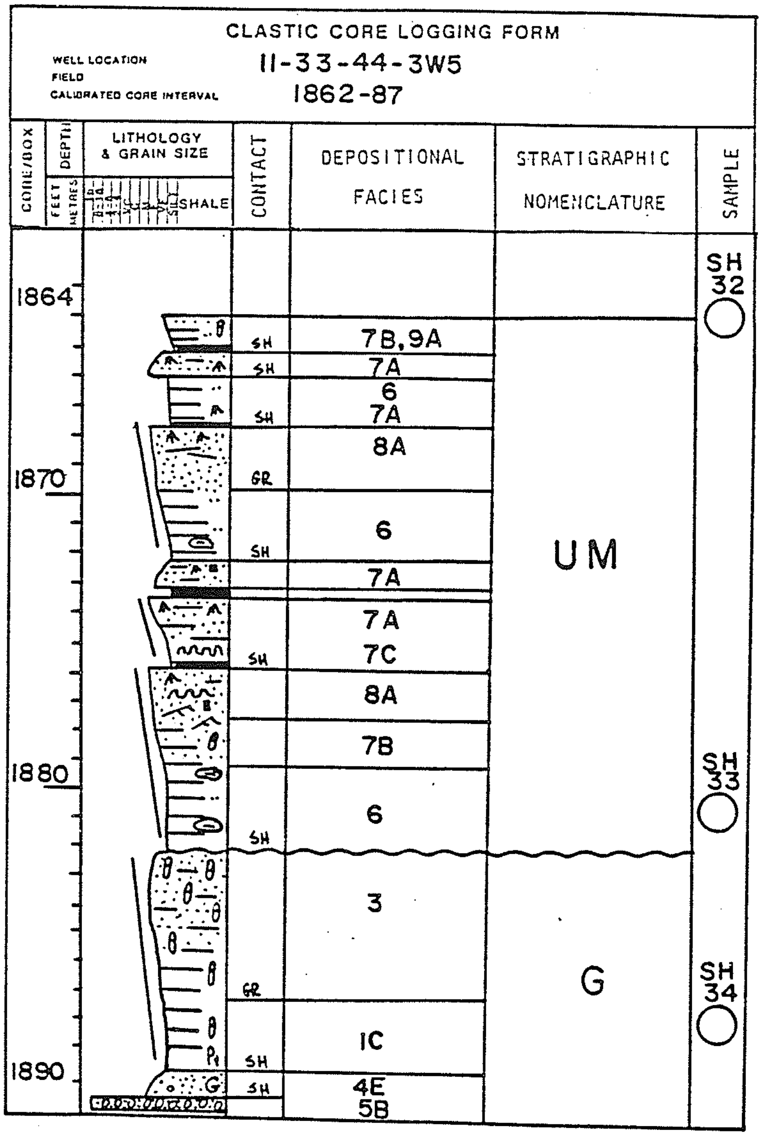

CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
13-17-44-2W5
1877-1932
CORE/BOX
FEET DEPTH METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
GR
M
MRC.
G
E
MISS.
NOTE SCALE
1877
1880
1890
1900
1910
1920
1930
1932
SH
SH
GR
SH
GR
SH
SH
SH
GR
GR
SH
SH
SH
GR
GR
SH
7E
7C
7B
7A
9A
7A
8A
7A,B
7E
2AB
1AB
7A
7C
9AB
4B
4A
2ABC
3
3
UM
H
A
MR
G
SH1
SS85



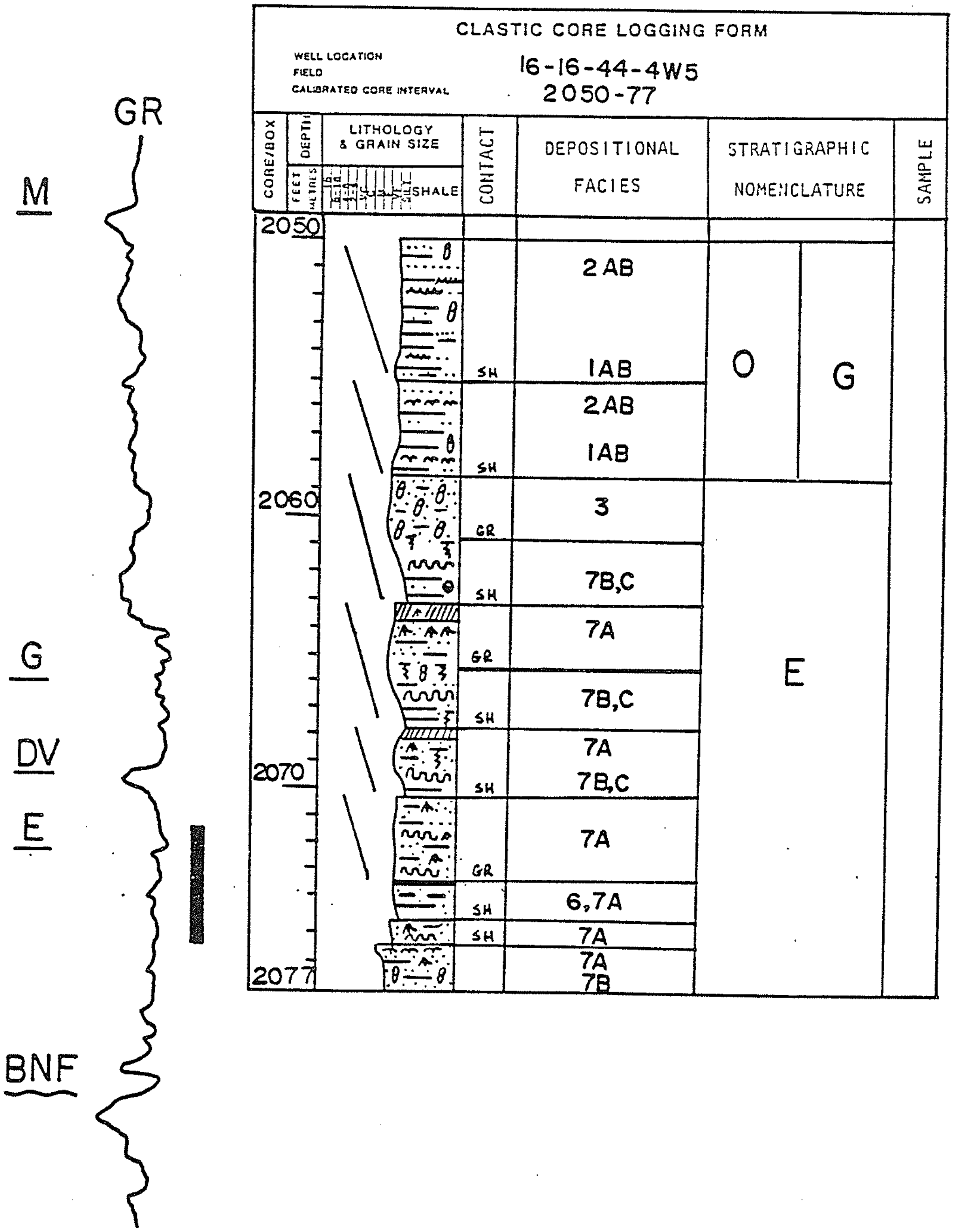
CLASTIC CORE LOGGING FORM

WELL LOCATION 6-10-44-3W5
FIELD
CALIBRATED CORE INTERVAL 1866-1902




CLASTIC CORE LOGGING FORM

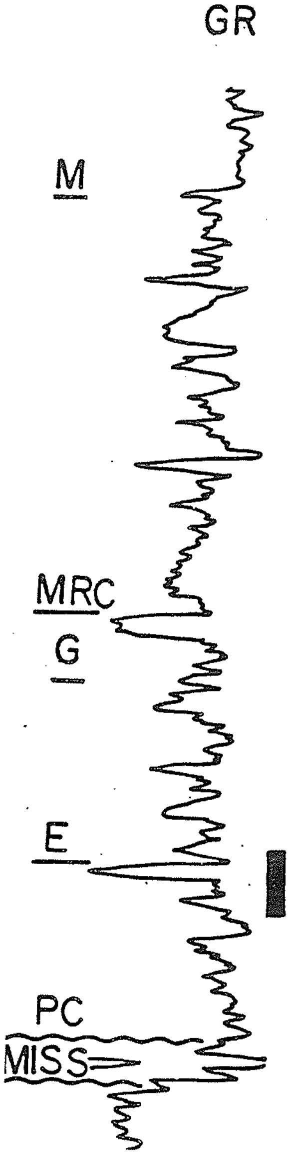
WELL LOCATION 11-33-44-3W5
FIELD
CALIBRATED CORE INTERVAL 1862-87

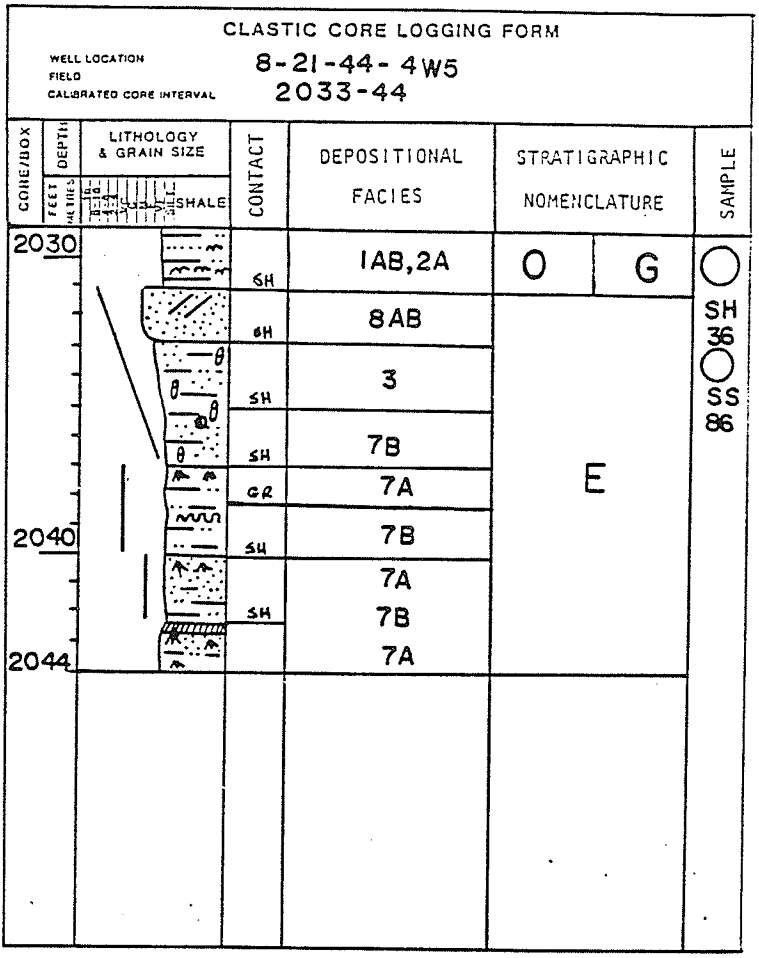


CLASTIC CORE LOGGING FORM

WELL LOCATION 16-16-44-4W5
FIELD
CALIBRATED CORE INTERVAL 2050-77

CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
SH	2 AB 1AB	O	G	
SH	2AB 1AB			
GR	3	E		
SH	7B,C			
GR	7A			
SH	7B,C			
SH	7A 7B,C			
GR	7A			
SH	6,7A			
SH	7A			
	7A 7B			

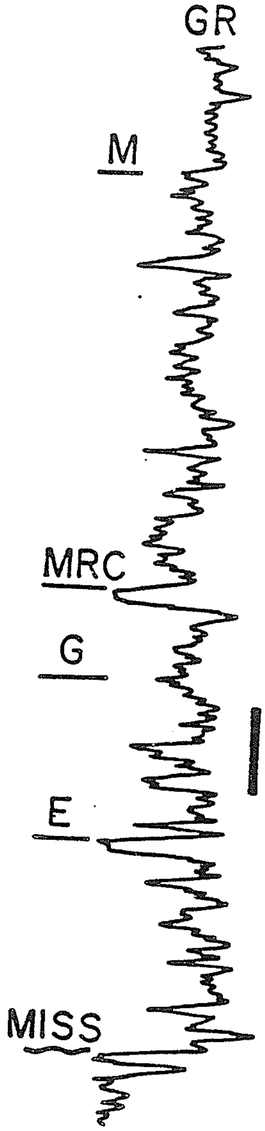


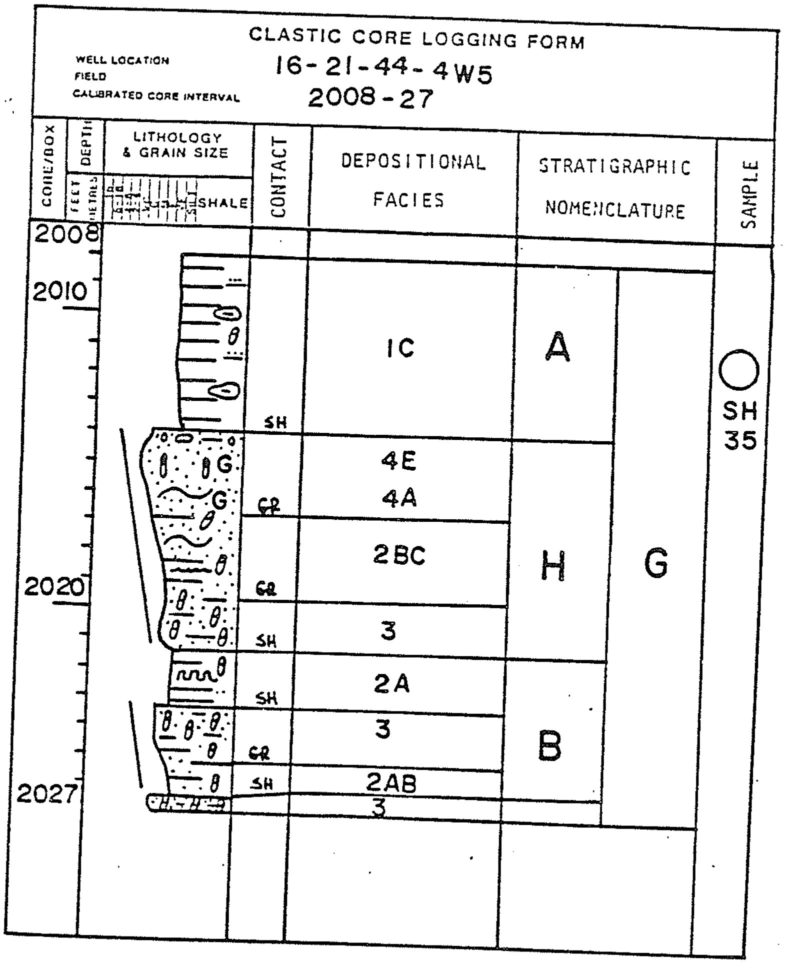


CLASTIC CORE LOGGING FORM

WELL LOCATION 8-21-44- 4W5
FIELD
CALIBRATED CORE INTERVAL 2033-44

CORE/BOX	DEPTH FEET / METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2030		SH	1AB,2A	O	G	○ SH 36
			SH	8AB	E		○ SS 86
			SH	3			
			SH	7B			
			GR	7A			
	2040		SH	7B			
				7A			
			SH	7B			
	2044			7A			

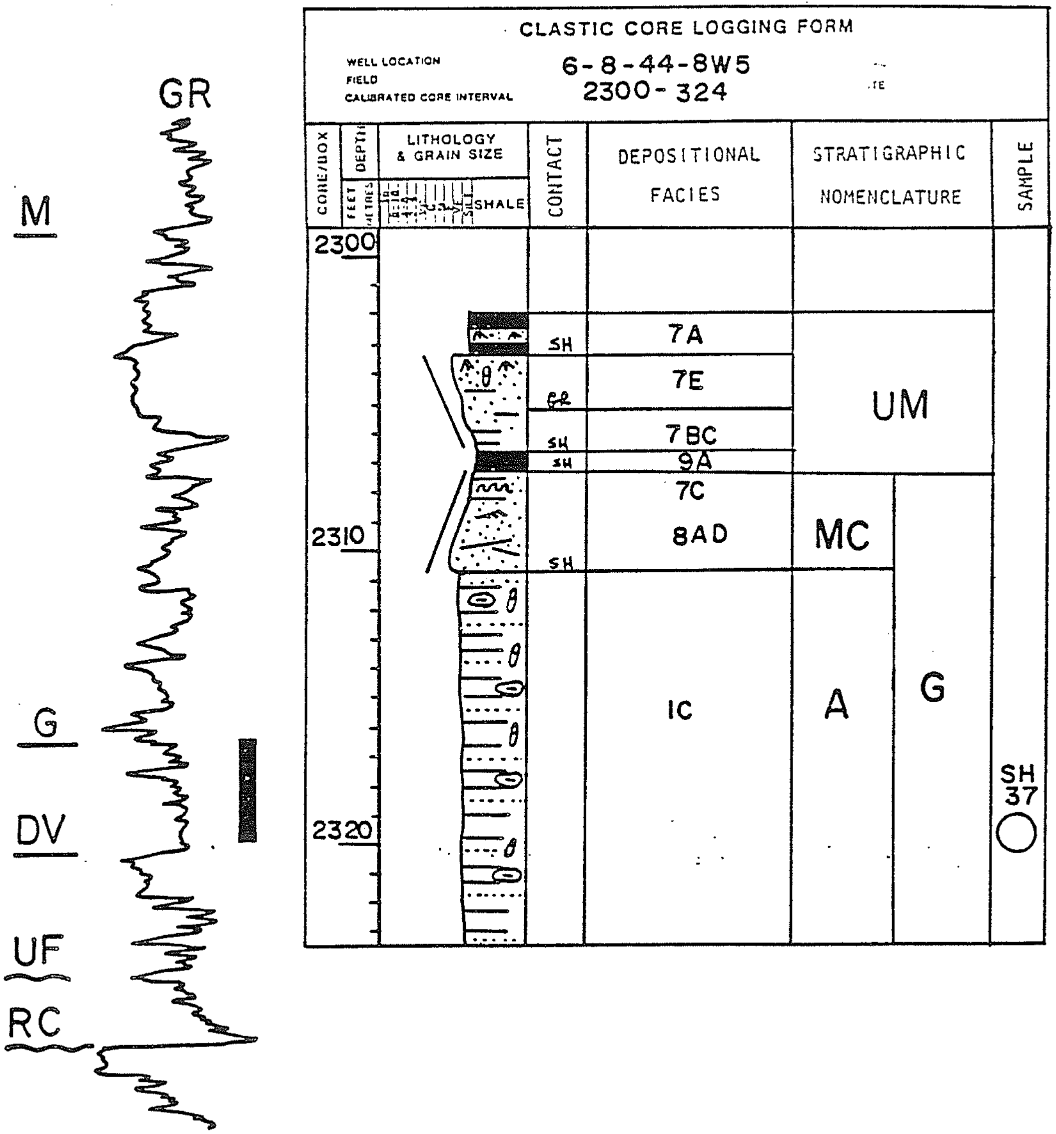


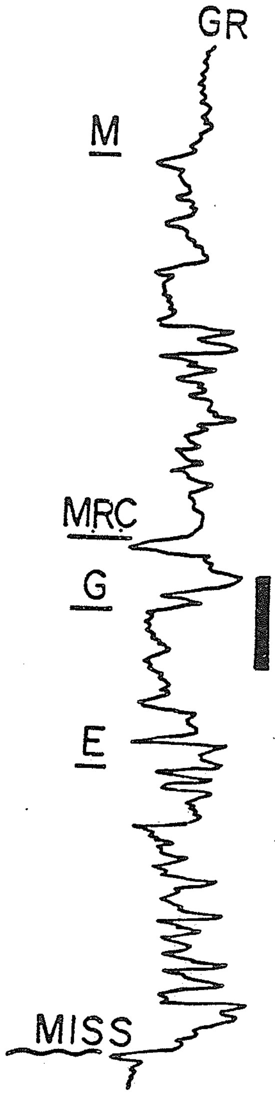


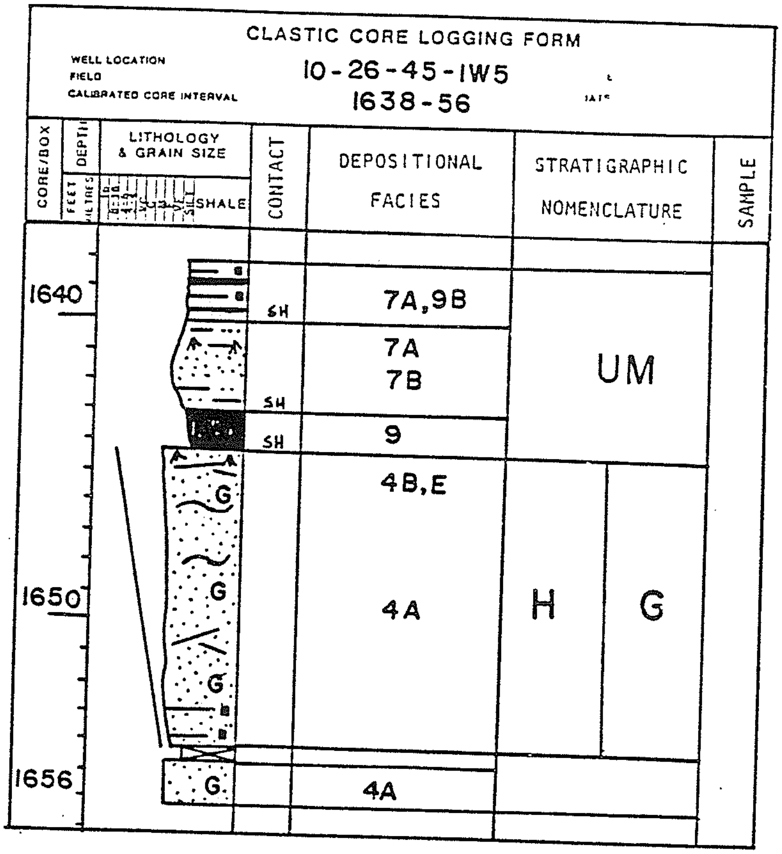
CLASTIC CORE LOGGING FORM

WELL LOCATION 16-21-44-4W5
FIELD
CALIBRATED CORE INTERVAL 2008-27

CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
SH	1C	A	G	SH 35
GR	4E 4A	H		
GR	2BC			
SH	3			
SH	2A	B		
GR	3			
SH	2AB			
	3			


GR
M
G
DV
UF
RC
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-8-44-8W5
2300-324
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2300
2310
2320
SH
GR
SH
SH
SH
7A
7E
7BC
9A
7C
8AD
IC
UM
MC
A
G
SH 37

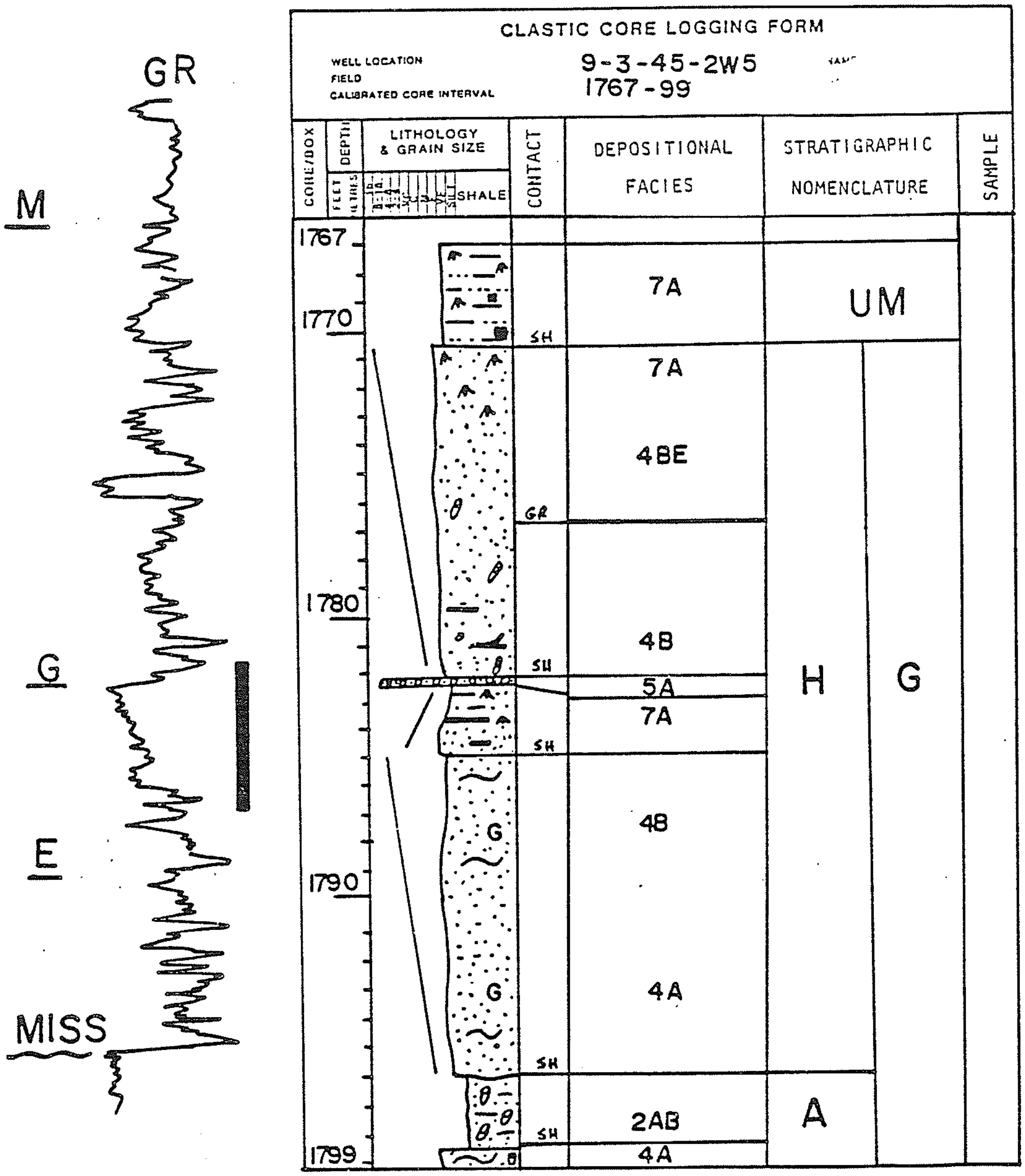




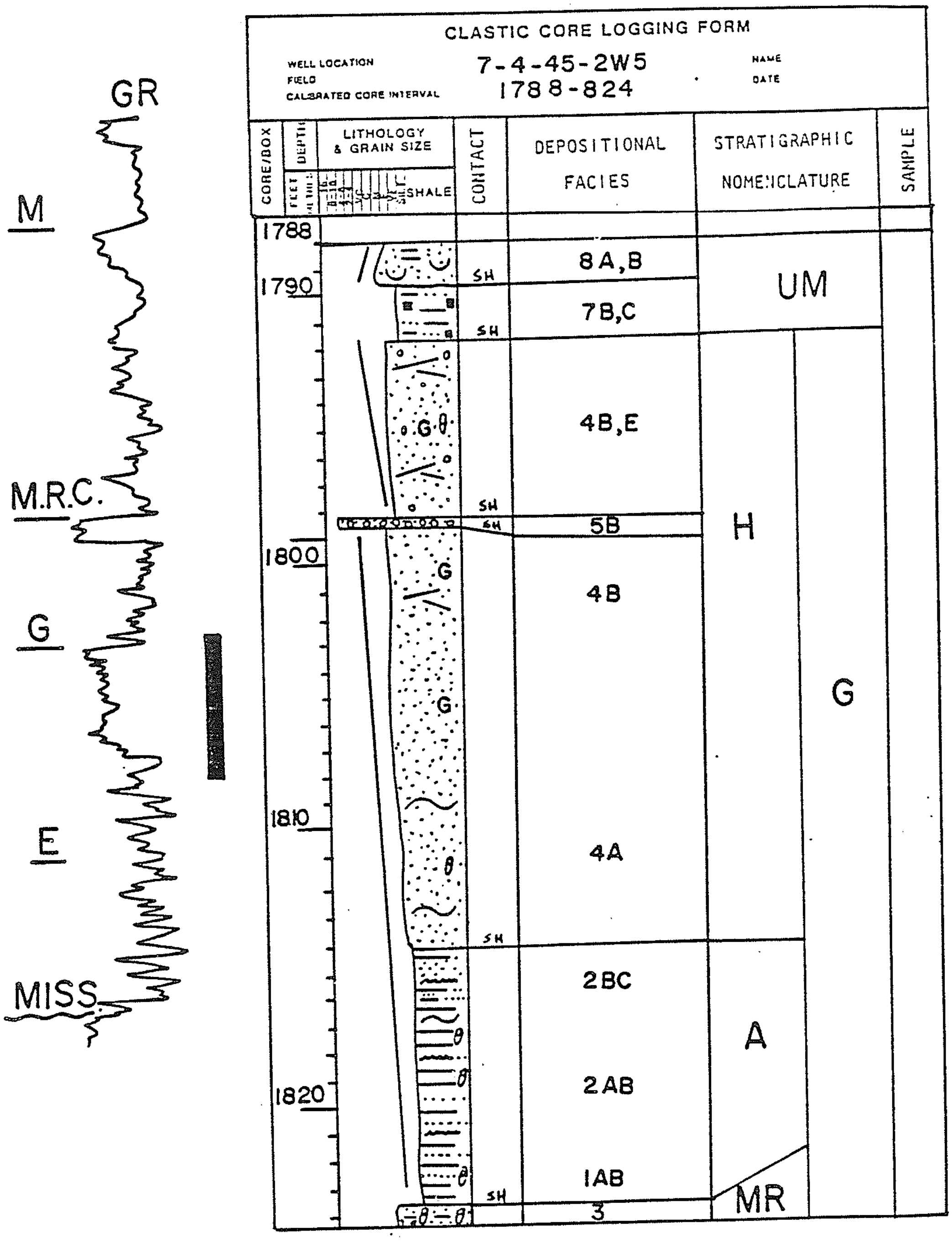
CLASTIC CORE LOGGING FORM

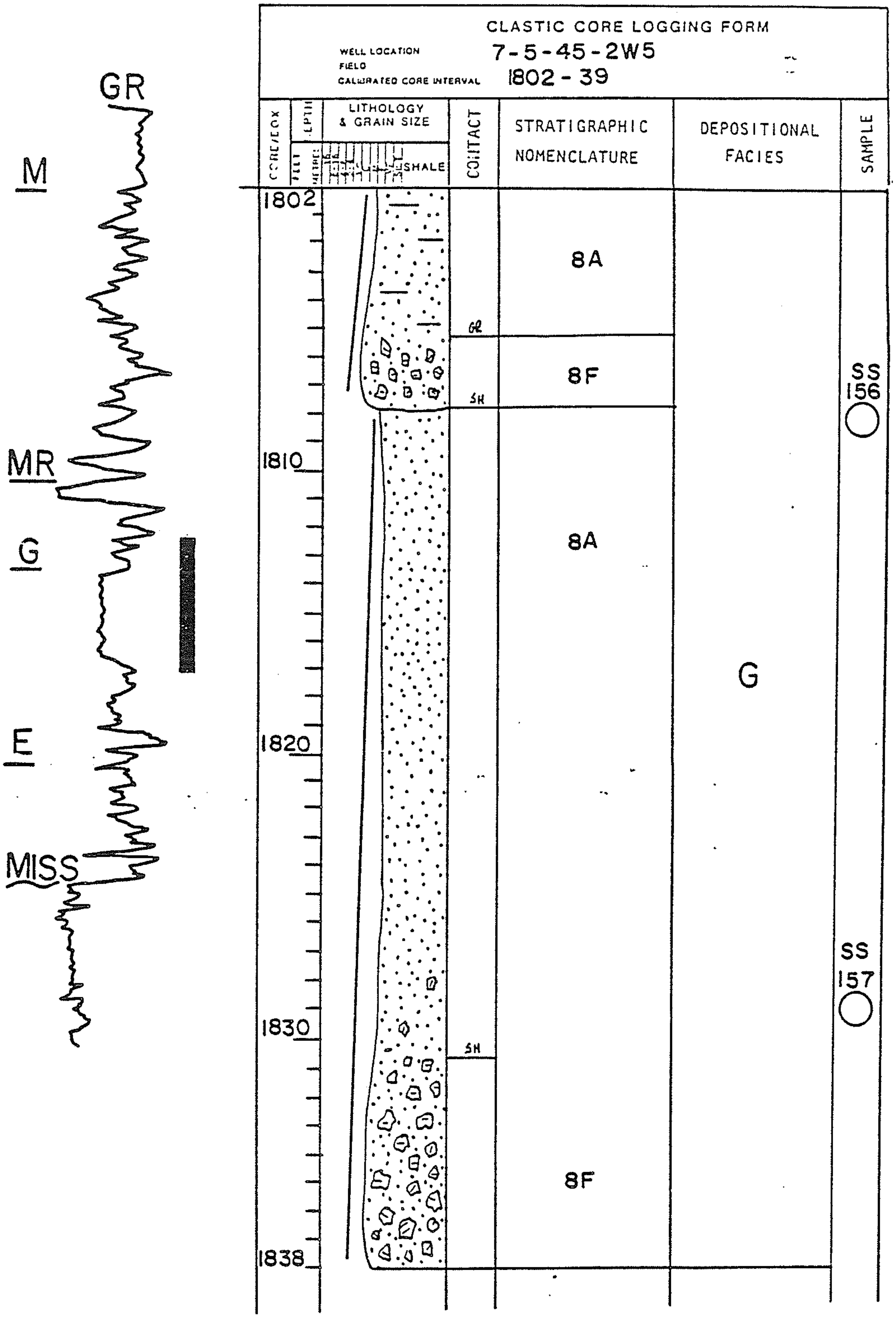
WELL LOCATION
FIELD 10-26-45-1W5
CALIBRATED CORE INTERVAL 1638-56

CORE/BOX	DEPTH FEET	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1640		SH	7A,9B	UM		
			SH	7A 7B			
			SH	9			
				4B,E	H	G	
	1650			4A			
	1656			4A			


CLASTIC CORE LOGGING FORM

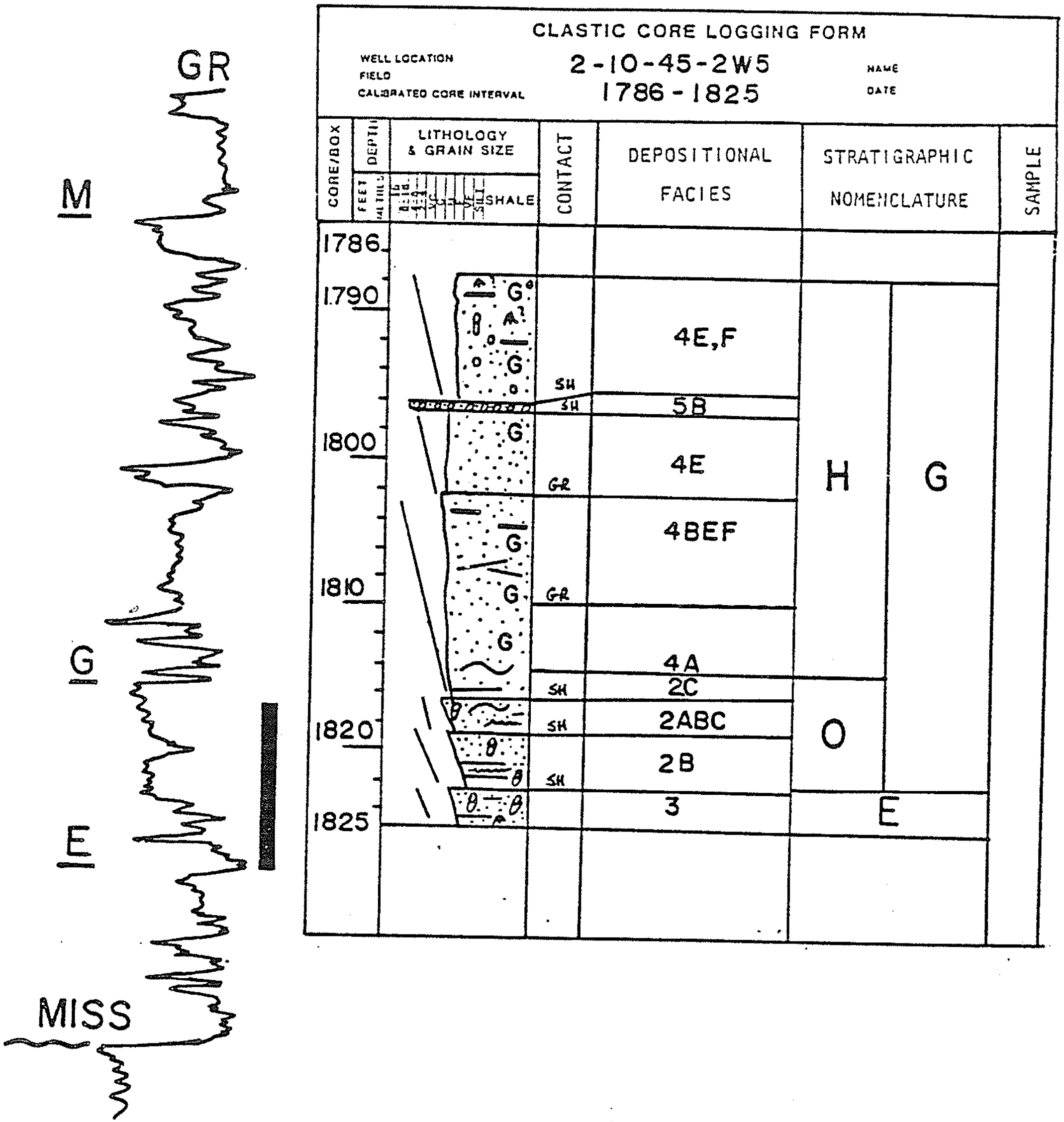
WELL LOCATION 9-3-45-2W5
FIELD
CALIBRATED CORE INTERVAL 1767-99

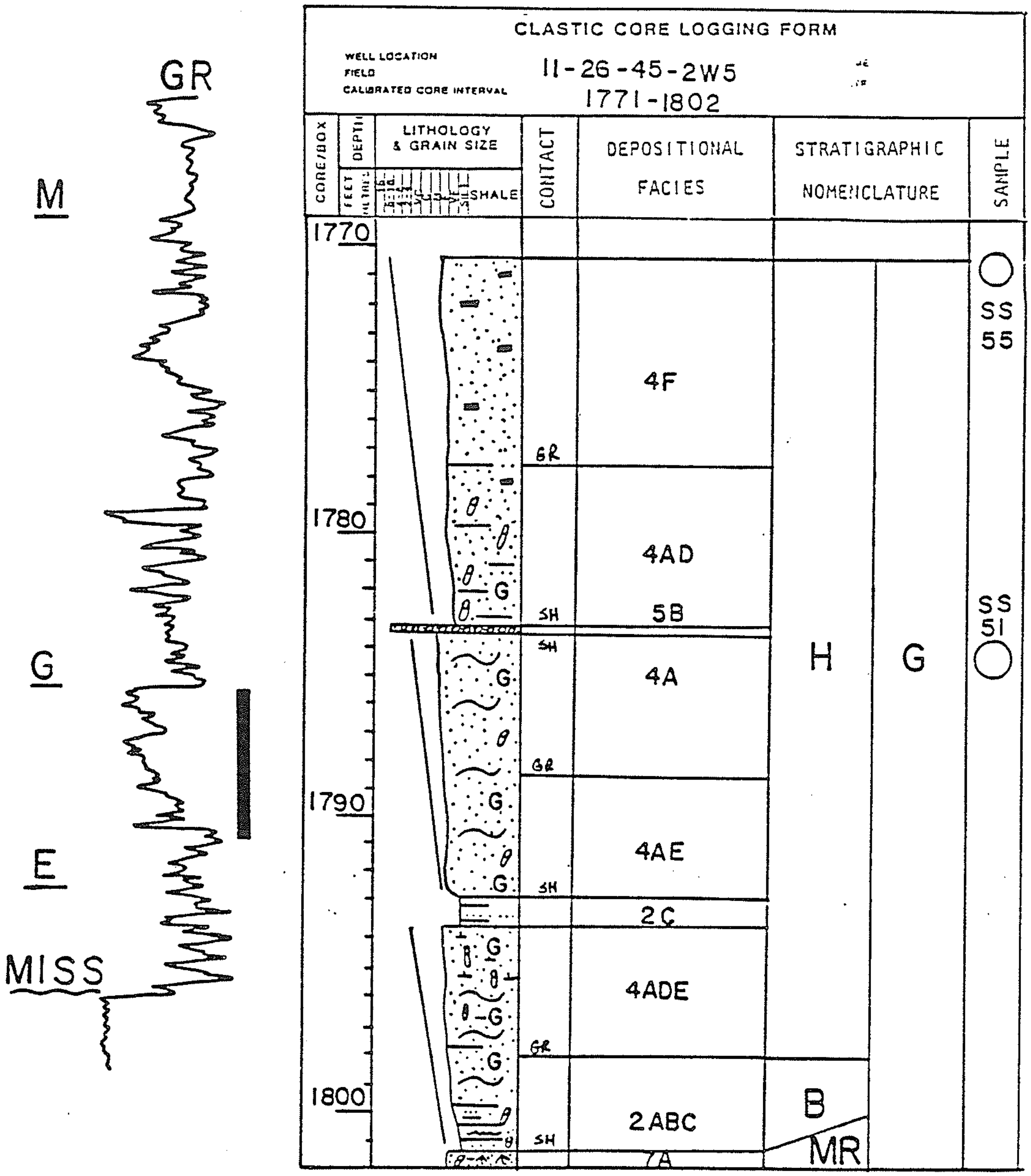

GR
M
M.R.C.
G
E
MISS
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
7-4-45-2W5
1788-824
NAME
DATE
CORE/BOX
DEPTH
FEET
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1788
1790
1800
1810
1820
SH
8 A,B
7B,C
4B,E
5B
4B
4A
2BC
2AB
1AB
3
UM
H
G
A
MR

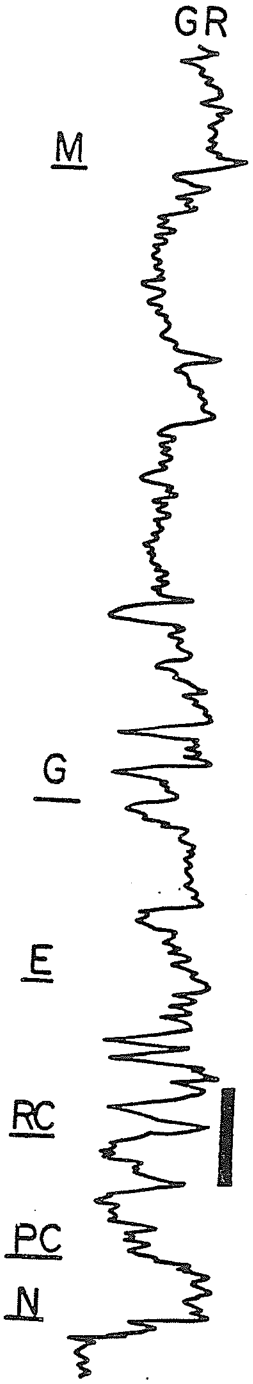


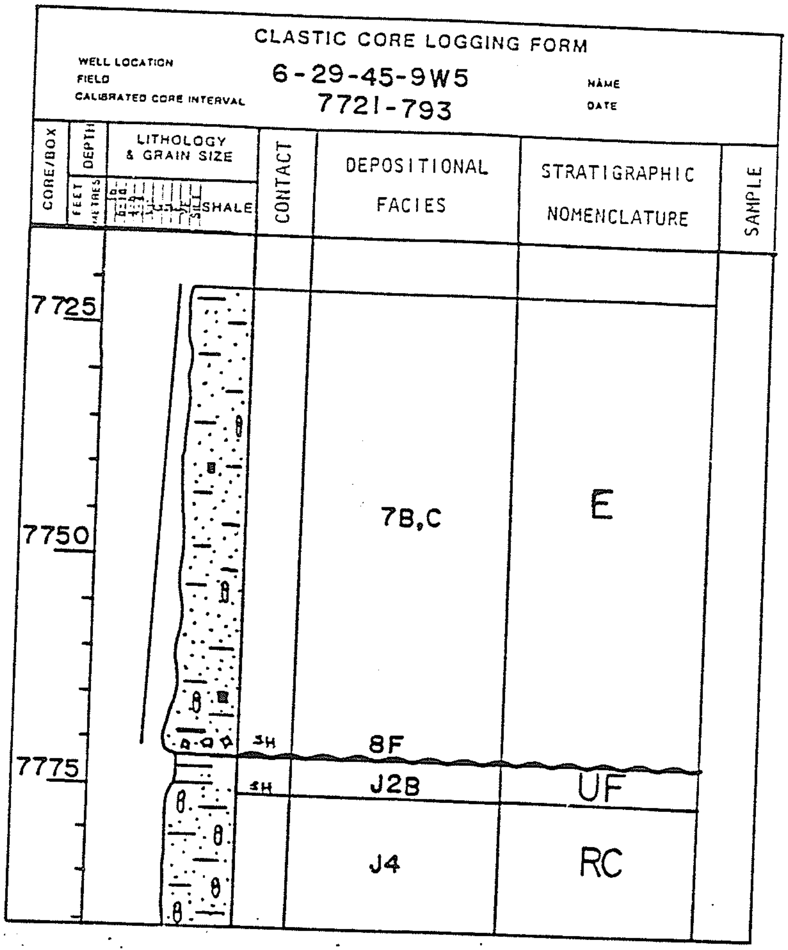
CLASTIC CORE LOGGING FORM

WELL LOCATION 7-5-45-2W5
FIELD
CALIBRATED CORE INTERVAL 1802 - 39


GR
M
G
E
MISS
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
2-10-45-2W5
1786 - 1825
NAME
DATE
CORE/BOX
DEPTH
FEET
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1786
1790
1800
1810
1820
1825
SH
GR
4E,F
5B
4E
4BEF
4A
2C
2ABC
2B
3
H
G
O
E

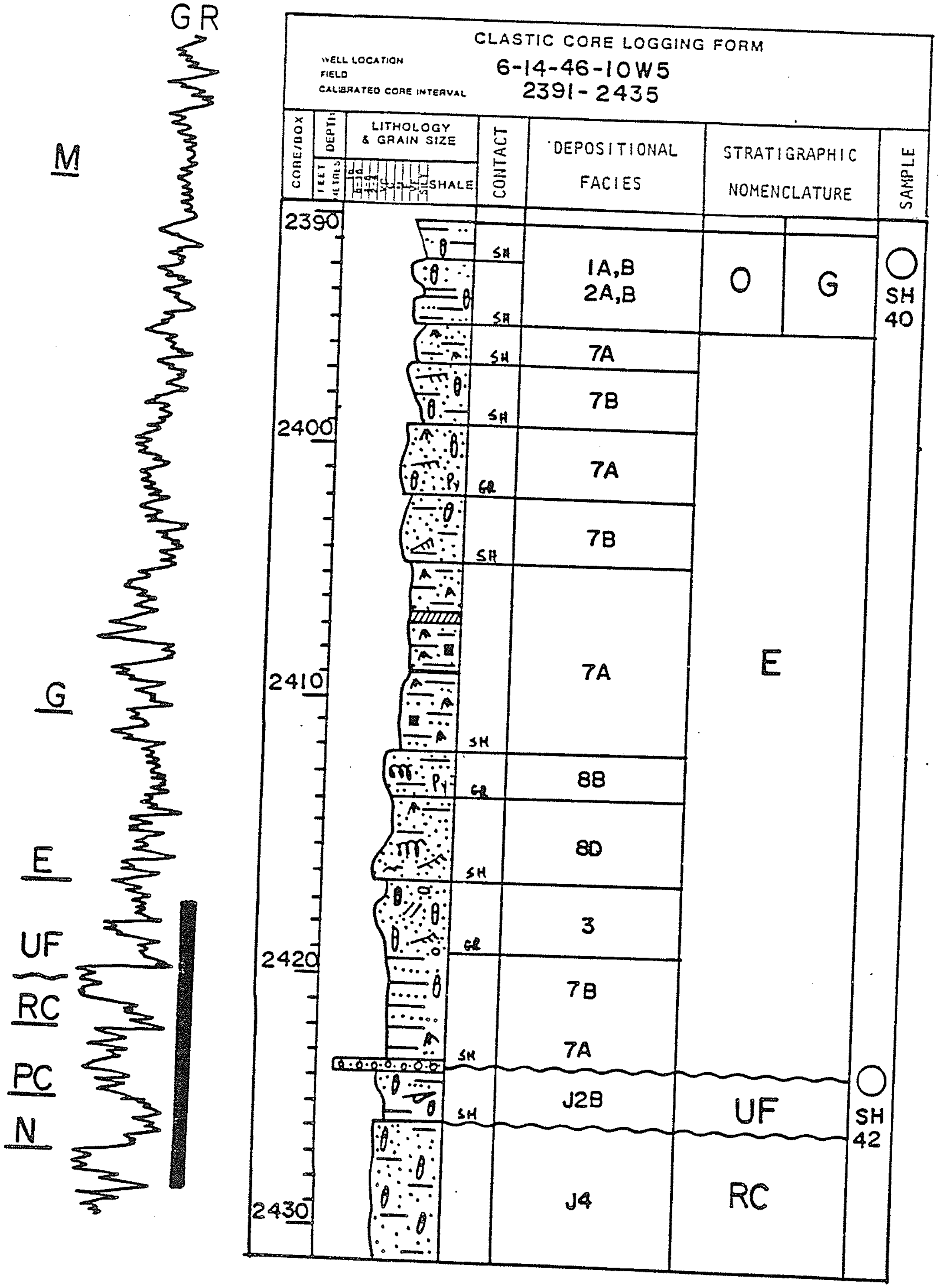

GR
M
G
E
MISS
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
11-26-45-2W5
1771-1802
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1770
1780
1790
1800
GR
SH
SH
GR
SH
GR
SH
4F
4AD
5B
4A
4AE
2C
4ADE
2ABC
7A
H
G
B
MR
SS 55
SS 51





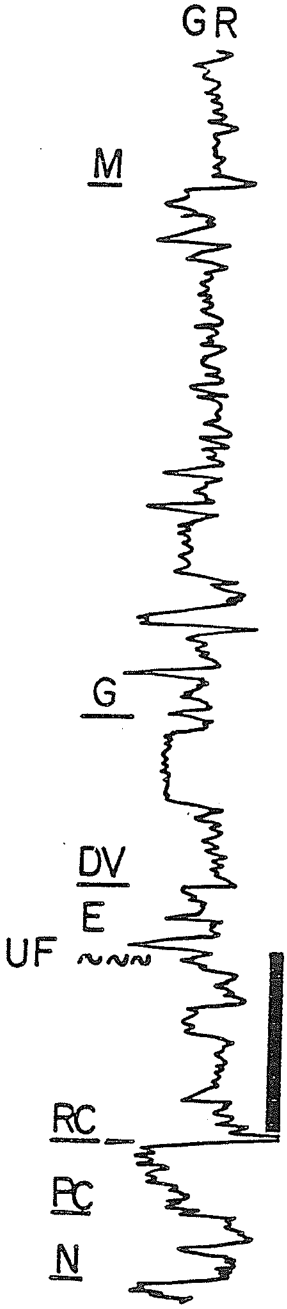
CLASSIC CORE LOGGING FORM

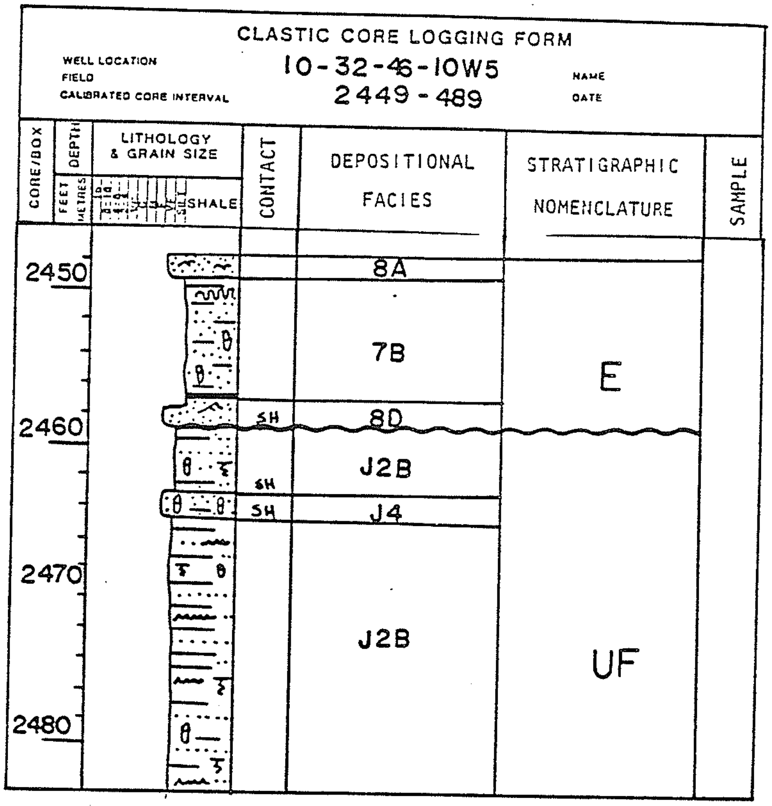
WELL LOCATION
FIELD 6-29-45-9W5
CALIBRATED CORE INTERVAL 7721-793
NAME
DATE



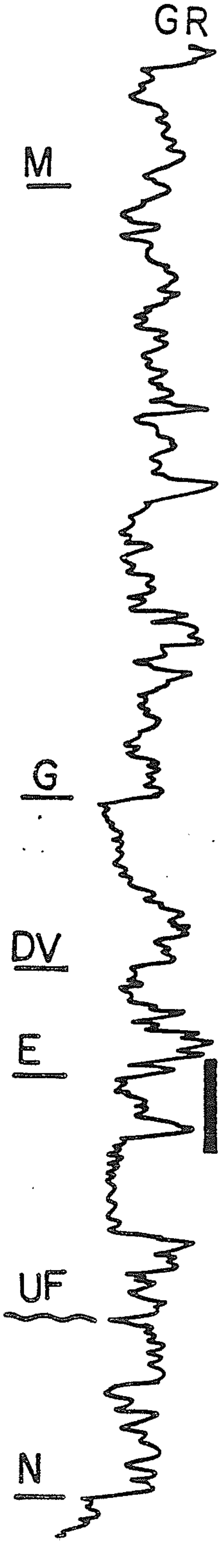
CLASTIC CORE LOGGING FORM

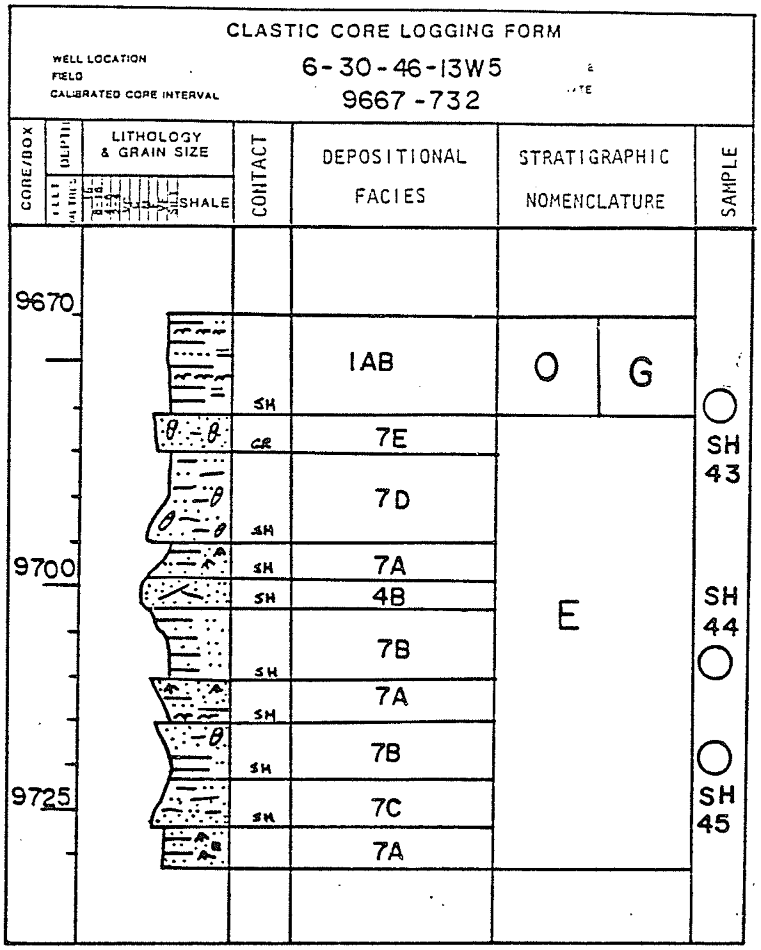
WELL LOCATION 6-14-46-10W5
FIELD
CALIBRATED CORE INTERVAL 2391-2435




CLASTIC CORE LOGGING FORM

WELL LOCATION 10-32-46-10W5
FIELD
CALIBRATED CORE INTERVAL 2449-489
NAME
DATE

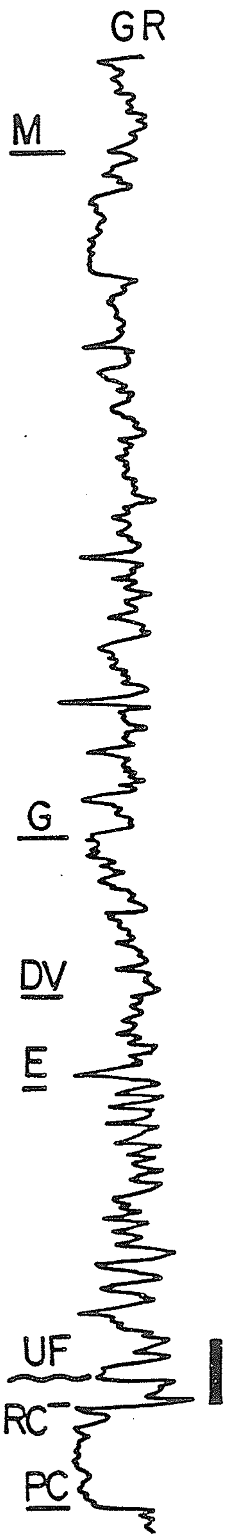


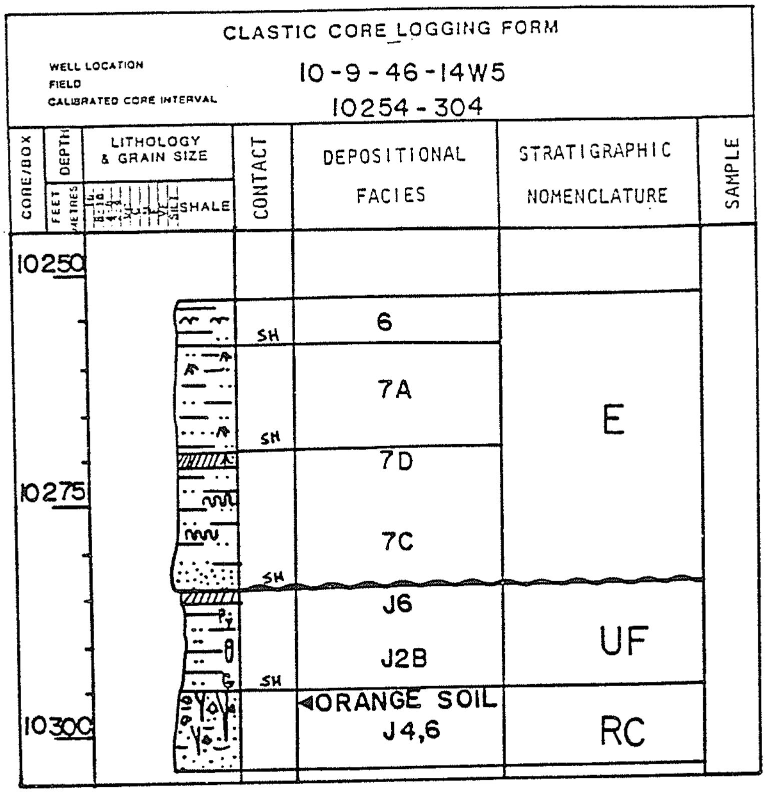


CLASTIC CORE LOGGING FORM

WELL LOCATION 6-30-46-13W5
FIELD
CALIBRATED CORE INTERVAL 9667-732

DEPTH	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
9670	SH	IAB	O	G	
	CR	7E	E		○ SH 43
	SH	7D			
9700	SH	7A			
	SH	4B			SH 44
	SH	7B			○
	SH	7A			
	SH	7B			○
9725	SH	7C			SH 45
		7A			

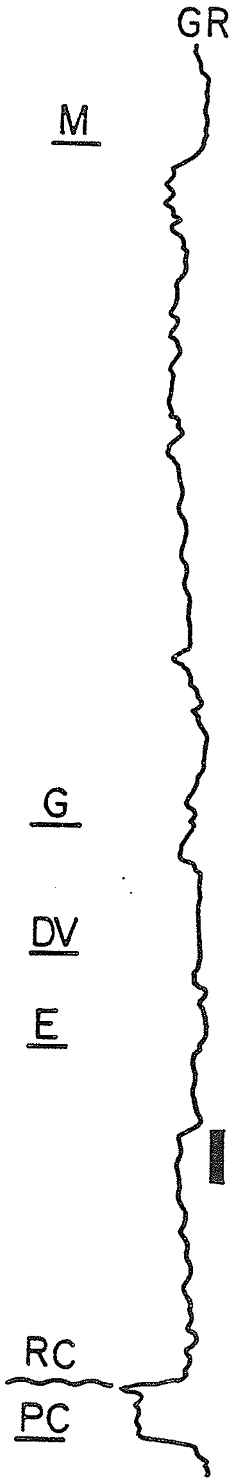


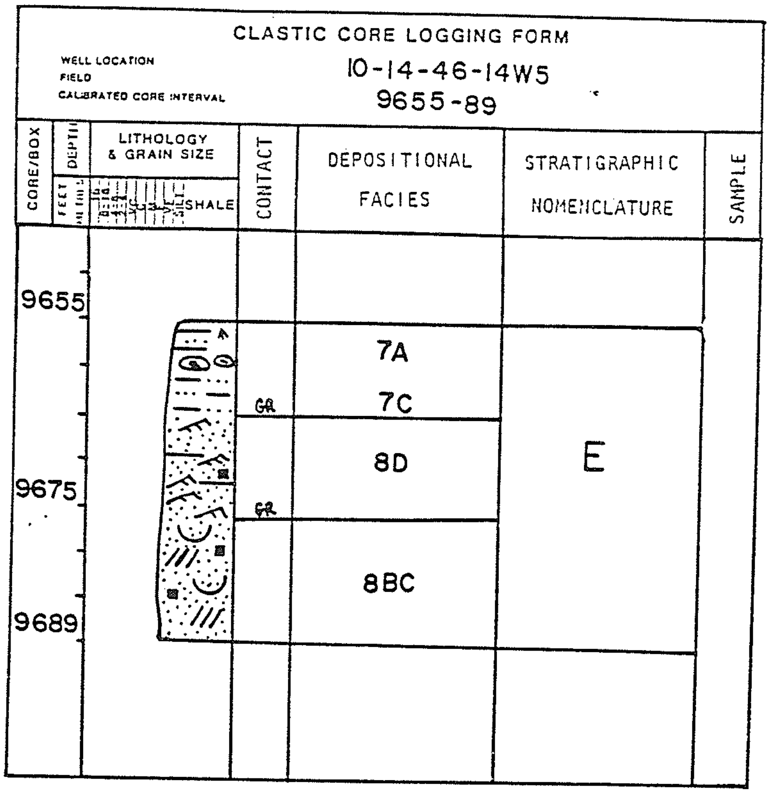


CLASTIC CORE LOGGING FORM

WELL LOCATION 10-9-46-14W5
FIELD
CALIBRATED CORE INTERVAL 10254-304

CORE/BOX	DEPTH FEET / METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
10250						
			SH	6	E	
			SH	7A		
				7D		
10275			SH	7C		
				J6	UF	
			SH	J2B		
10300				◀ORANGE SOIL J4,6	RC	



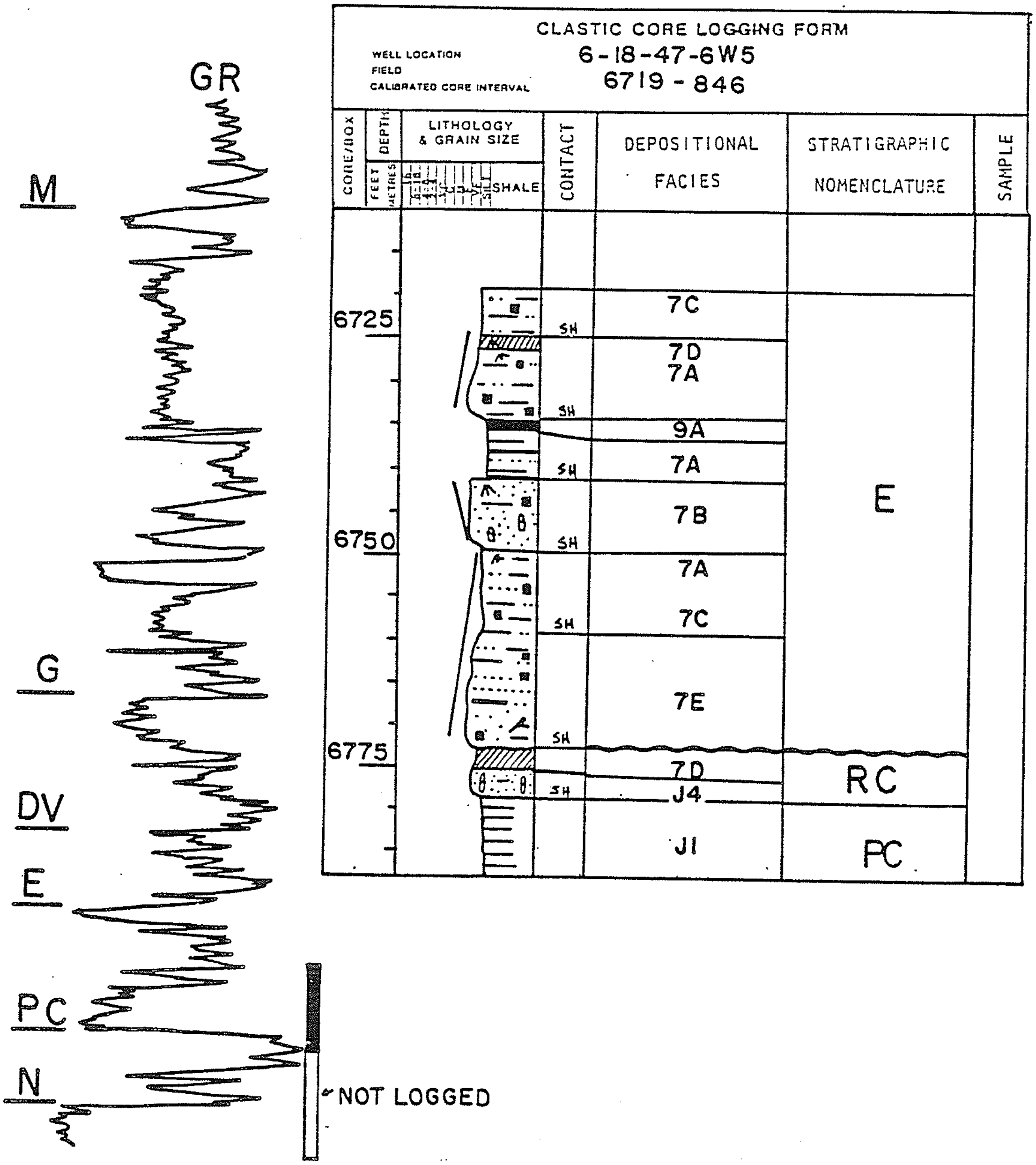


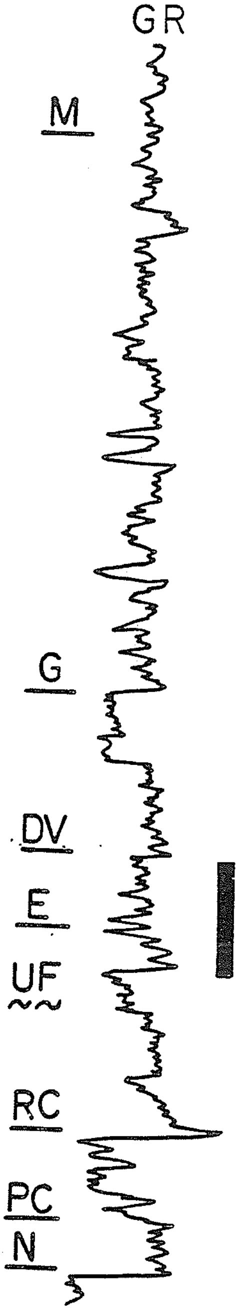
CLASTIC CORE LOGGING FORM

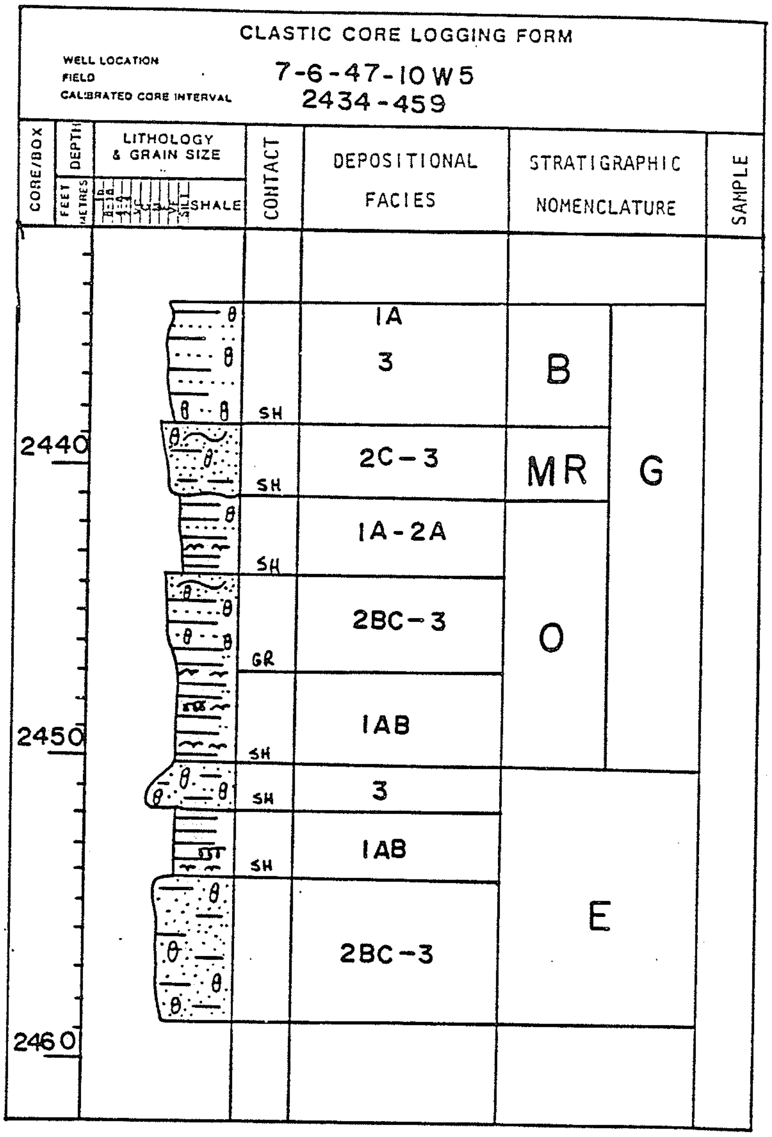
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

10-14-46-14W5
9655-89

CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE … SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
9655				7A	E	
			GR	7C		
				8D		
9675			GR			
				8BC		
9689						


GR
M
G
DV
E
PC
N
NOT LOGGED
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-18-47-6W5
6719 - 846
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
6725
6750
6775
SH
7C
7D
7A
9A
7A
7B
7A
7C
7E
7D
J4
J1
E
RC
PC

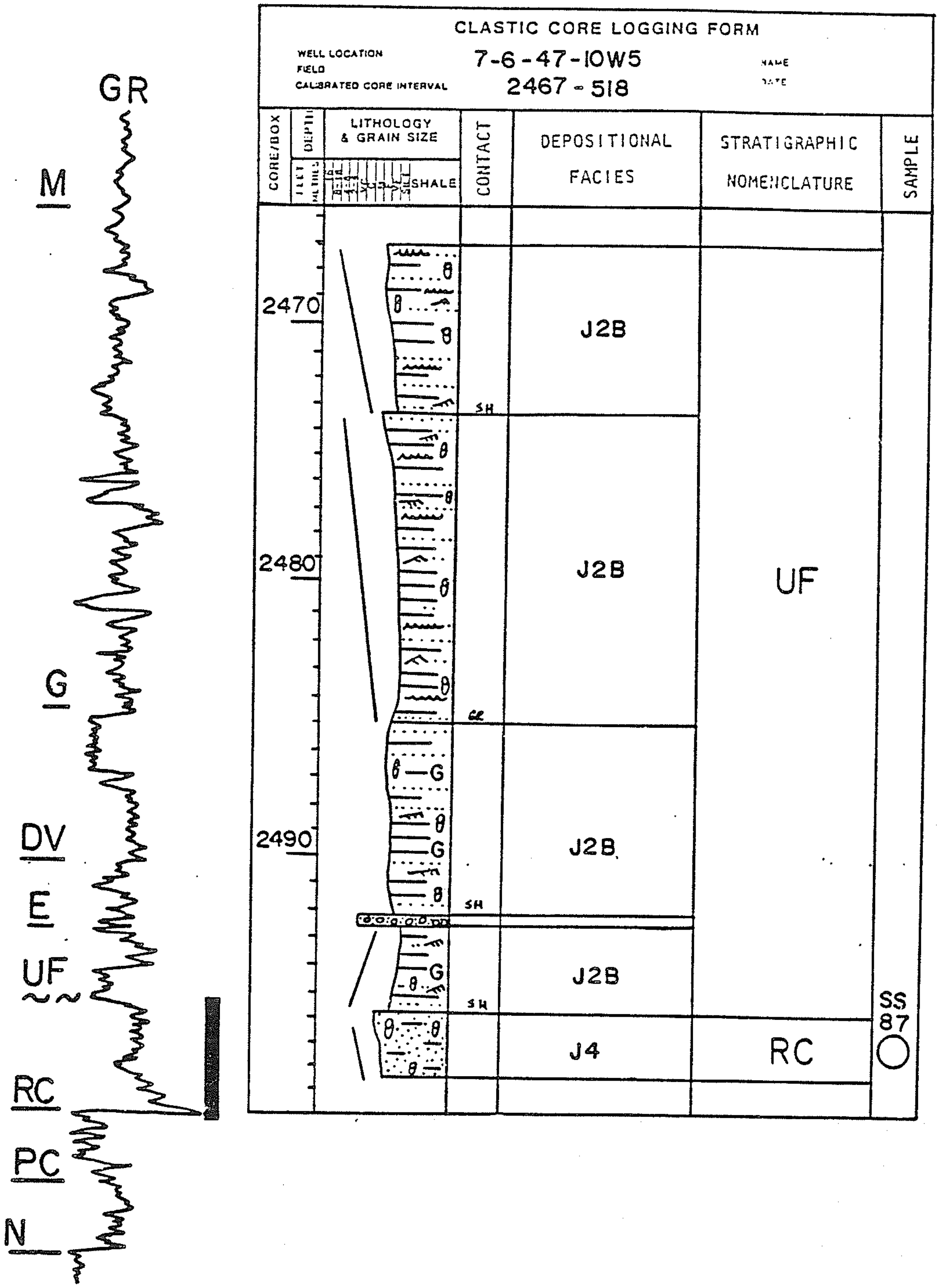




CLASTIC CORE LOGGING FORM

WELL LOCATION 7-6-47-10W5
FIELD
CALIBRATED CORE INTERVAL 2434-459

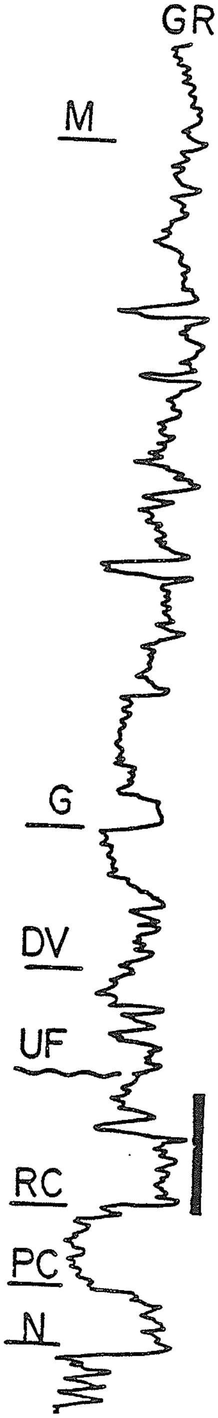
CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	
SH	IA 3	B	G
SH	2C-3	MR	
SH	IA-2A	O	
GR	2BC-3		
SH	IAB		
SH	3	E	
SH	IAB		
	2BC-3		

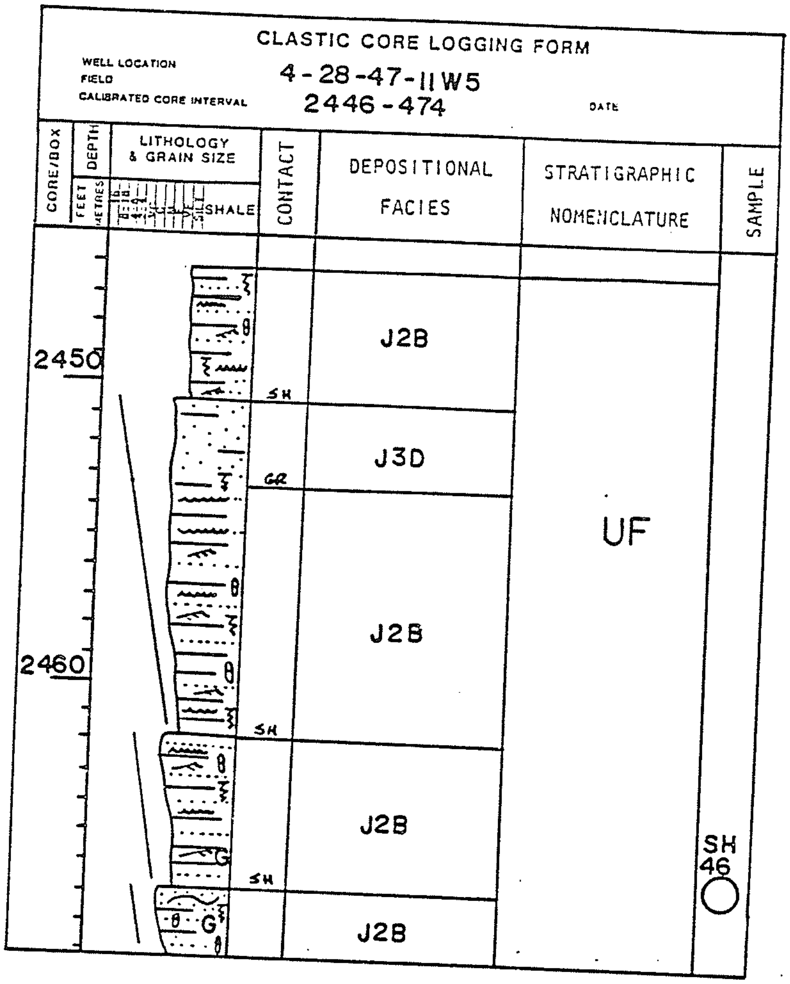


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 7-6-47-10W5
CALIBRATED CORE INTERVAL 2467 - 518
NAME
DATE

CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
SH	J2B	UF	
GR	J2B		
SH	J2B		
SH	J2B		
	J4	RC	SS 87 ○

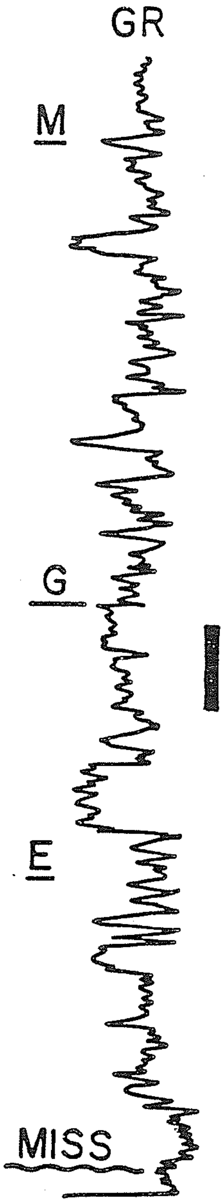


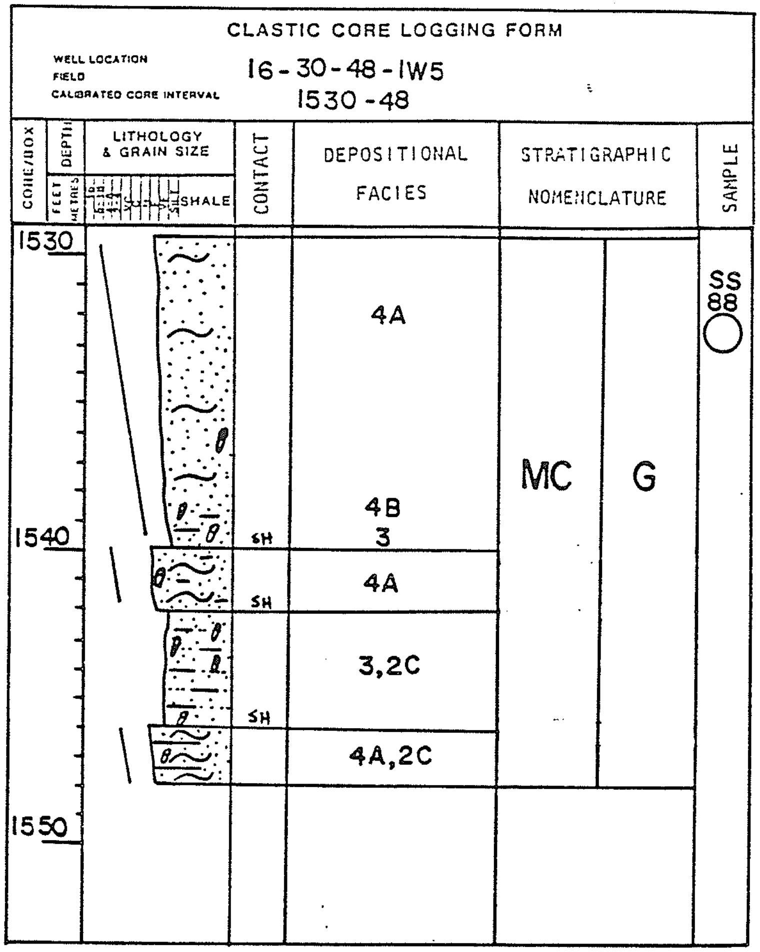


CLASTIC CORE LOGGING FORM

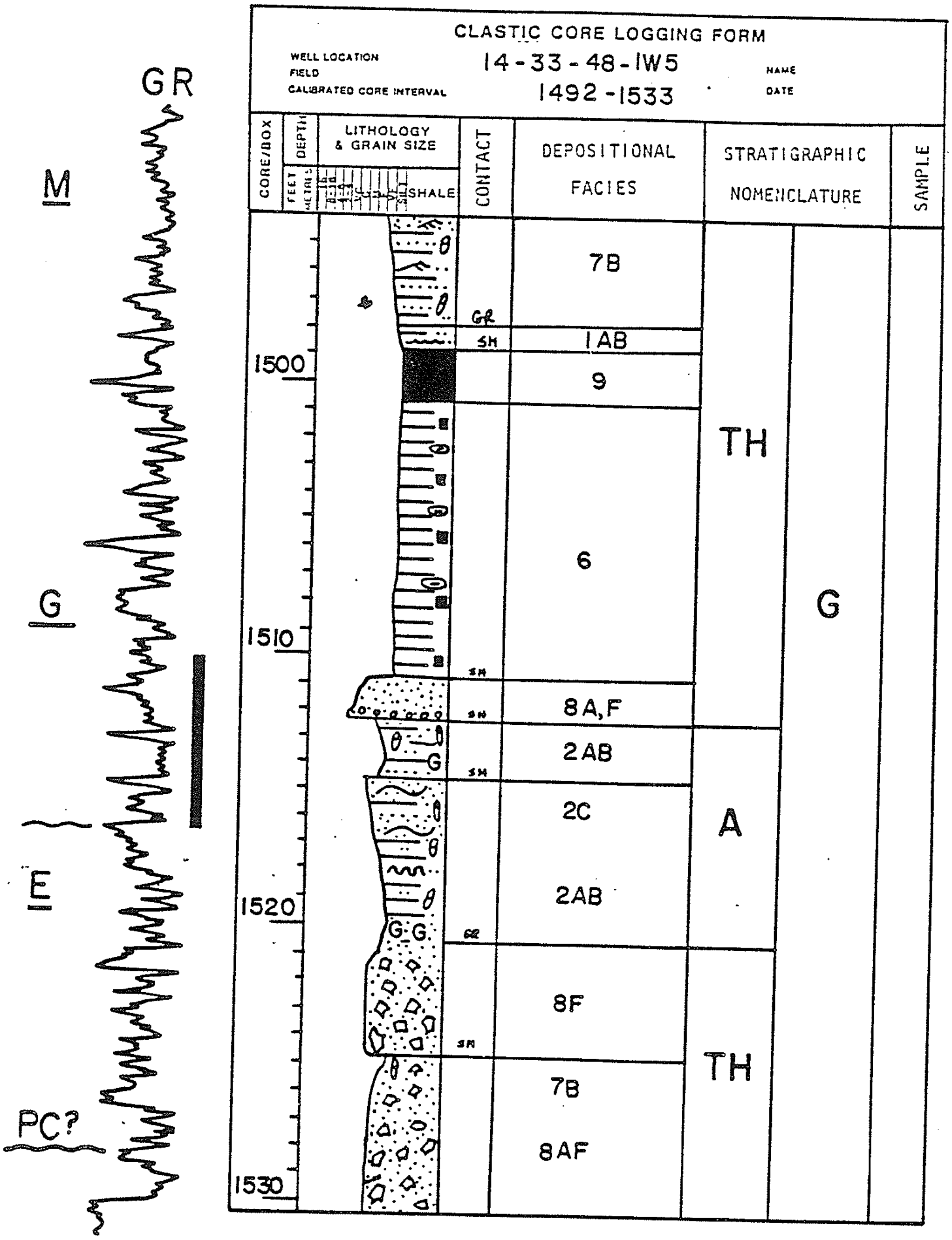
WELL LOCATION
FIELD 4-28-47-11W5
CALIBRATED CORE INTERVAL 2446-474
DATE

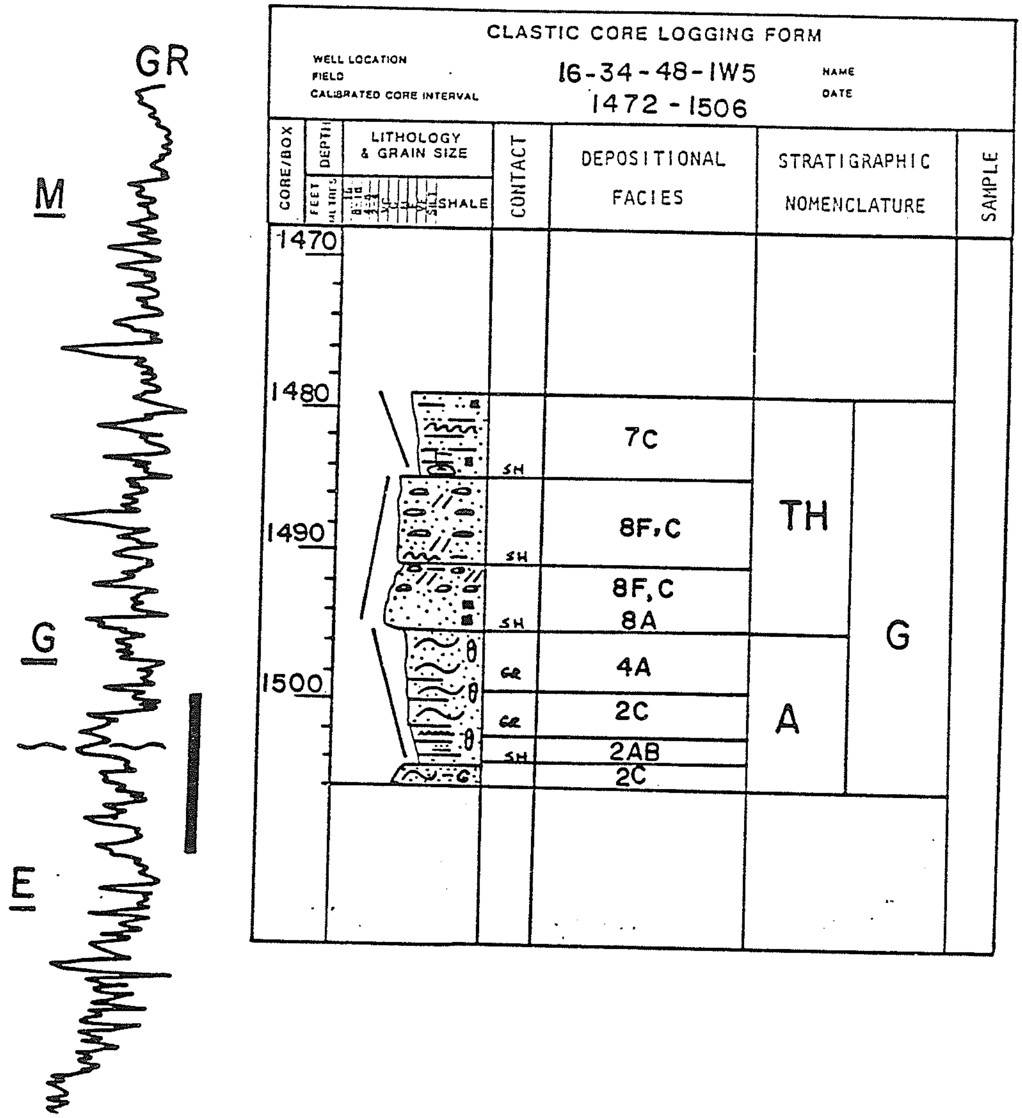
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
			SH	J2B	UF	
	2450		GR	J3D		
	2460		SH	J2B		
			SH	J2B		SH 46 ○
				J2B		




CLASTIC CORE LOGGING FORM

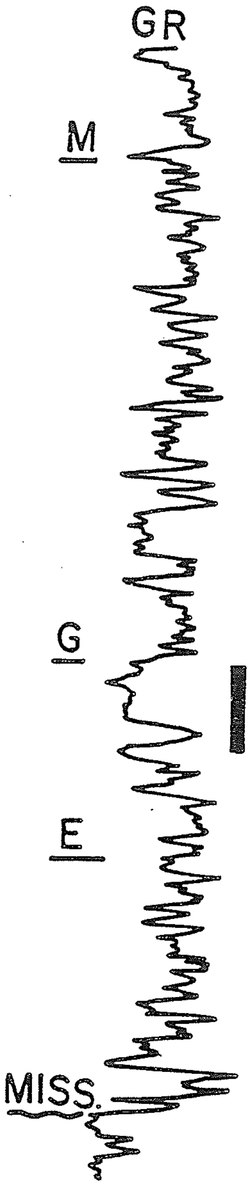
WELL LOCATION 16-30-48-1W5
FIELD
CALIBRATED CORE INTERVAL 1530-48

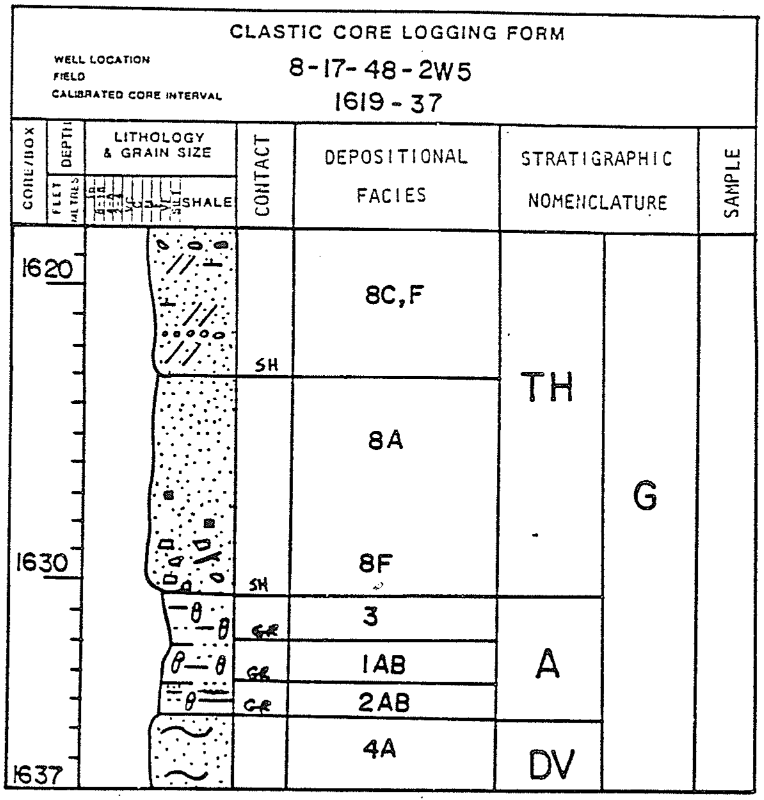

CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
14-33-48-1W5
1492-1533
NAME
DATE
GR
M
G
E
PC?
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1500
1510
1520
1530
GR
SH
SH
SH
SH
GR
SH
7B
1AB
9
6
8A,F
2AB
2C
2AB
8F
7B
8AF
TH
A
TH
G



CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 16-34-48-1W5
CALIBRATED CORE INTERVAL 1472 - 1506
NAME
DATE

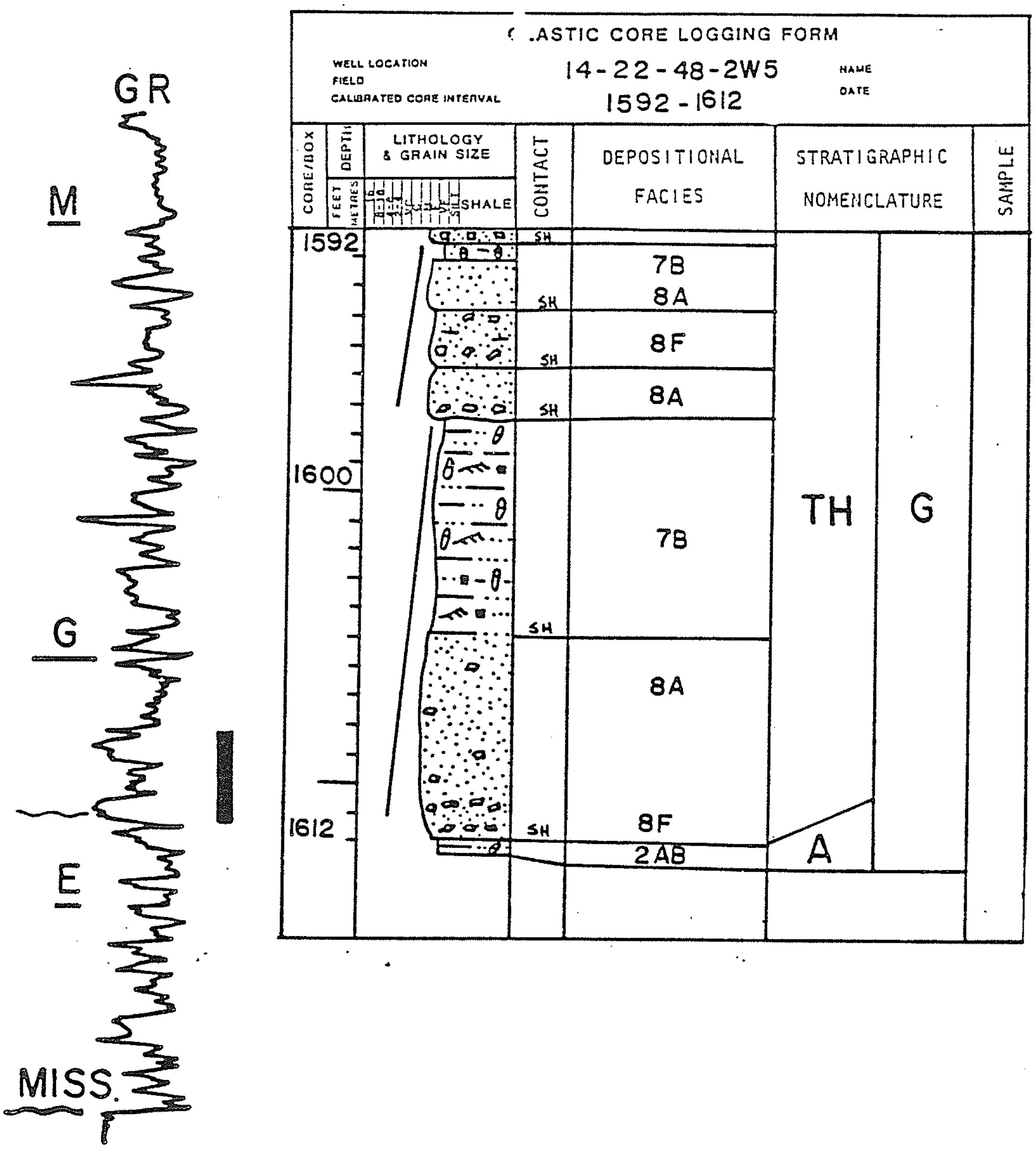




CLASTIC CORE LOGGING FORM

WELL LOCATION 8-17-48-2W5
FIELD
CALIBRATED CORE INTERVAL 1619 - 37

CORE/BOX	DEPTH FEET METRES	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1620	SH	8C,F	TH	G	
			8A			
	1630	SH	8F			
		GR	3	A		
		GR	1AB			
		GR	2AB			
	1637		4A	DV		



C .ASTIC CORE LOGGING FORM

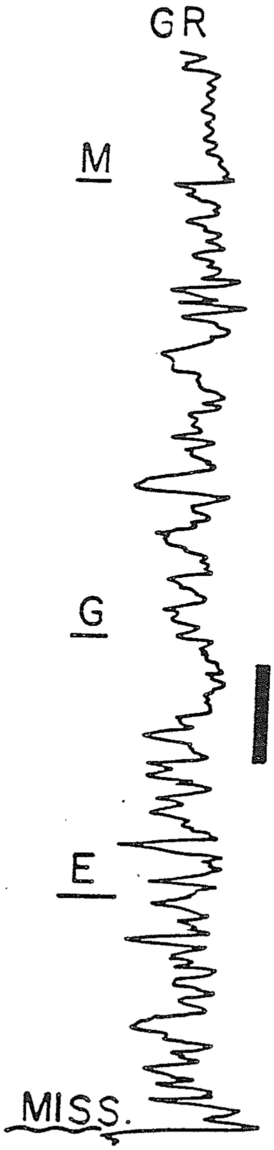
WELL LOCATION 14-22-48-2W5

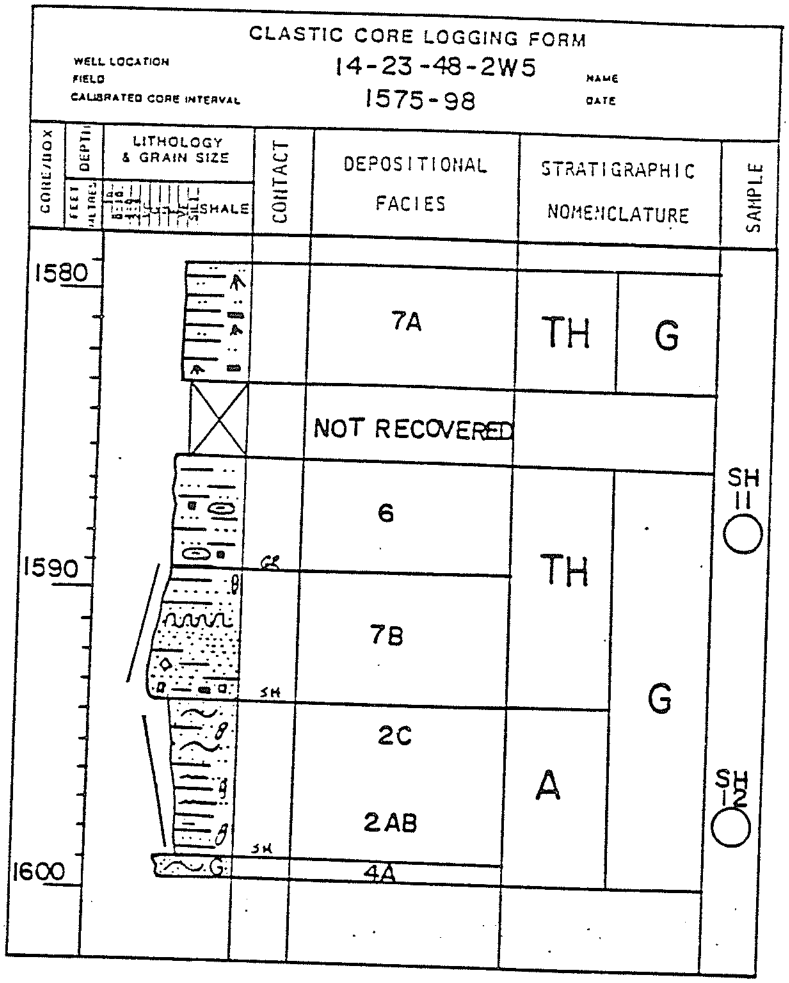
FIELD

CALIBRATED CORE INTERVAL 1592 - 1612

NAME

DATE

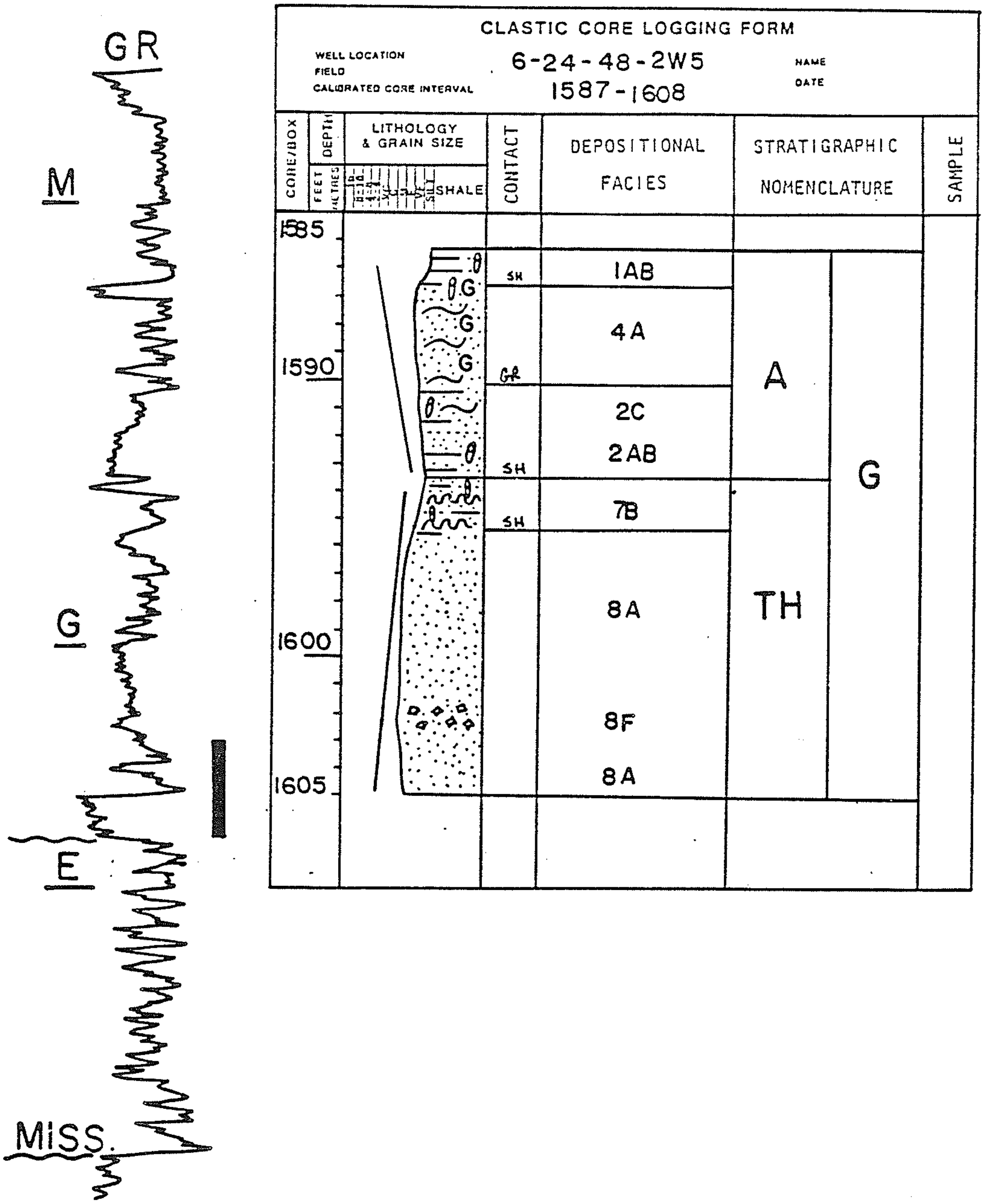




CLASTIC CORE LOGGING FORM

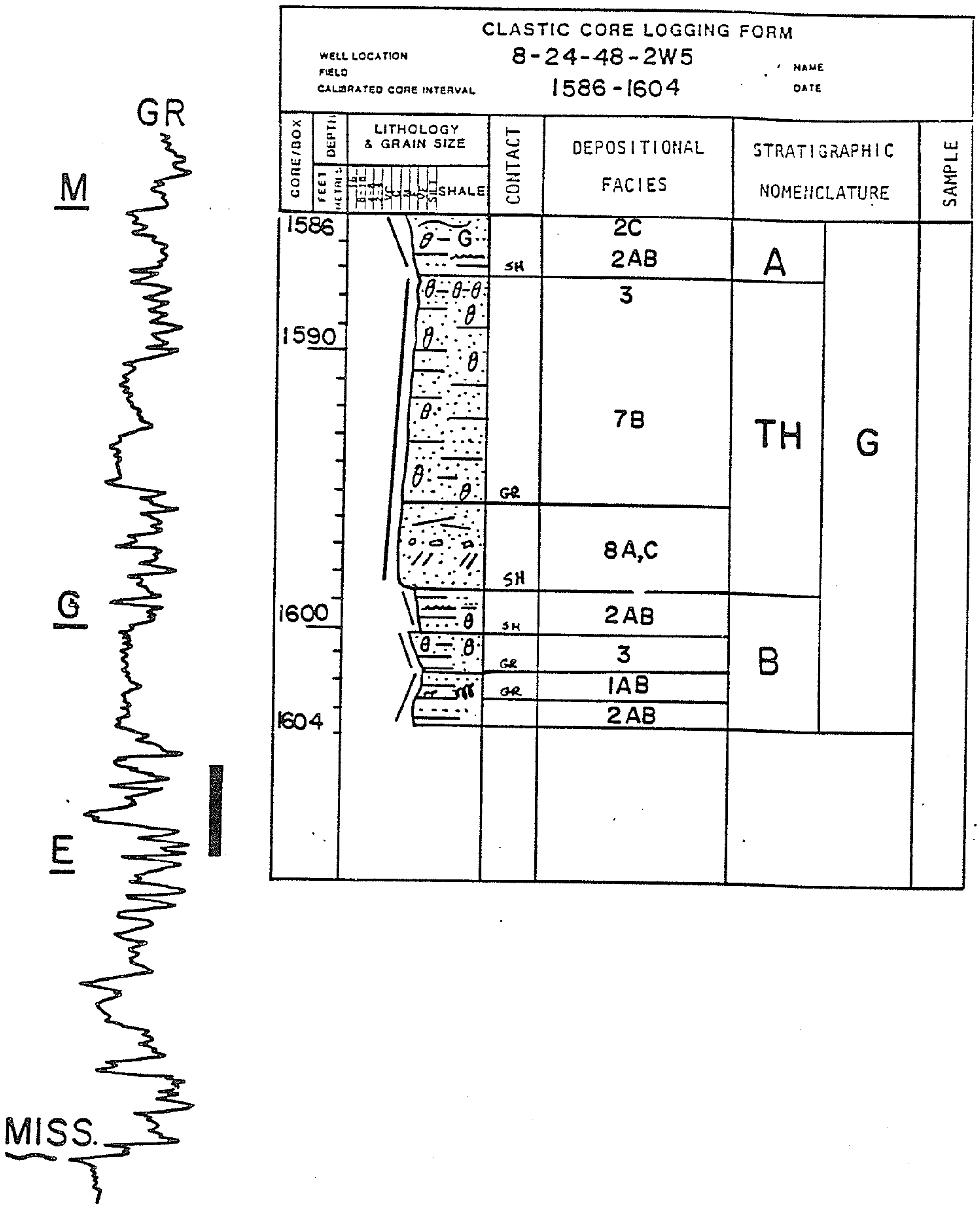
WELL LOCATION 14-23-48-2W5
FIELD
CALIBRATED CORE INTERVAL 1575-98
NAME
DATE

CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1580			7A	TH	G	
				NOT RECOVERED			
				6	TH	G	SH 11
	1590		SH	7B			
				2C	A		SH 12
			SH	2AB			
	1600			4A			



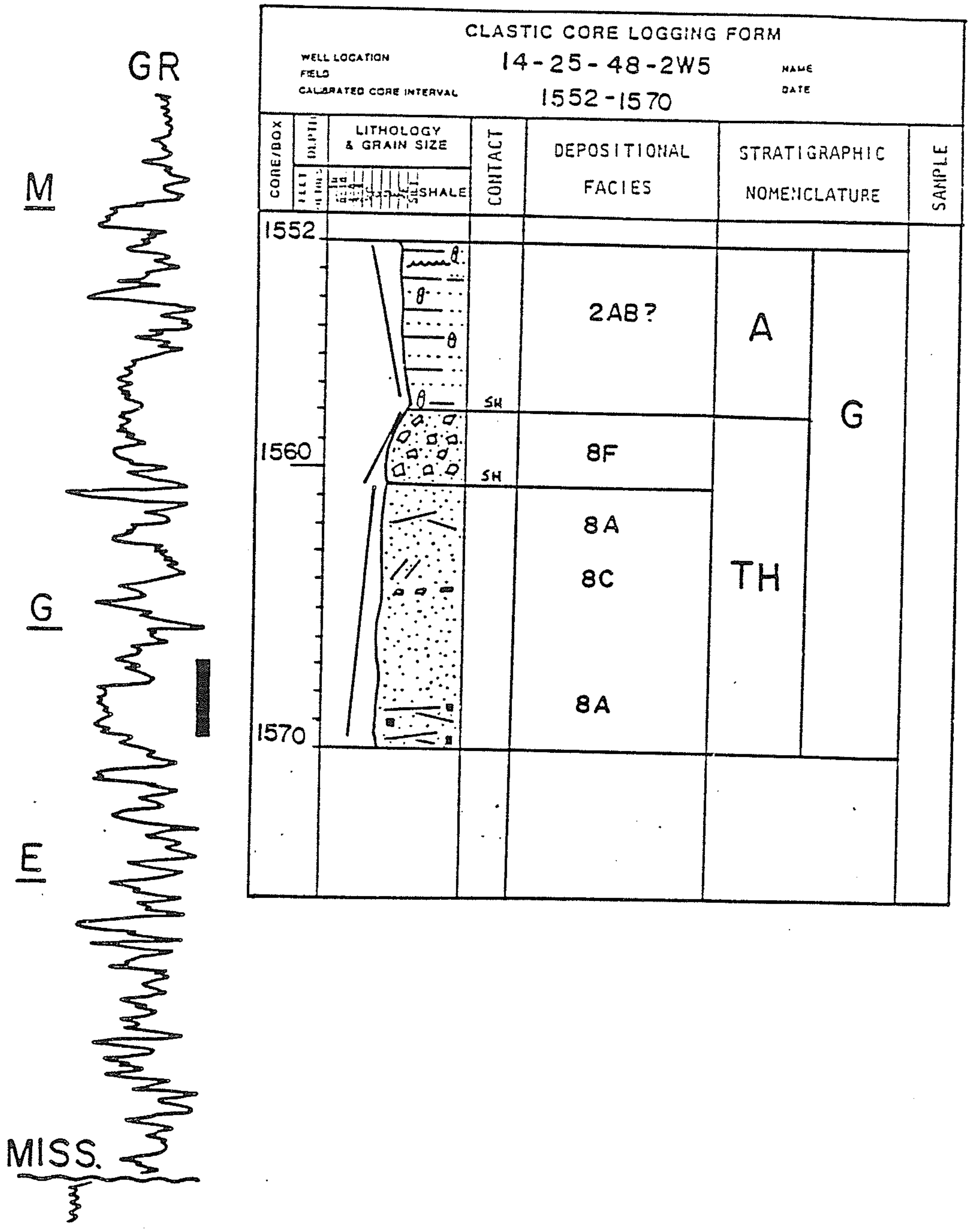
CLASTIC CORE LOGGING FORM

WELL LOCATION 6-24-48-2W5
FIELD
CALIBRATED CORE INTERVAL 1587-1608
NAME
DATE



CLASTIC CORE LOGGING FORM

WELL LOCATION 8-24-48-2W5
FIELD
CALIBRATED CORE INTERVAL 1586-1604
NAME
DATE



CLASTIC CORE LOGGING FORM

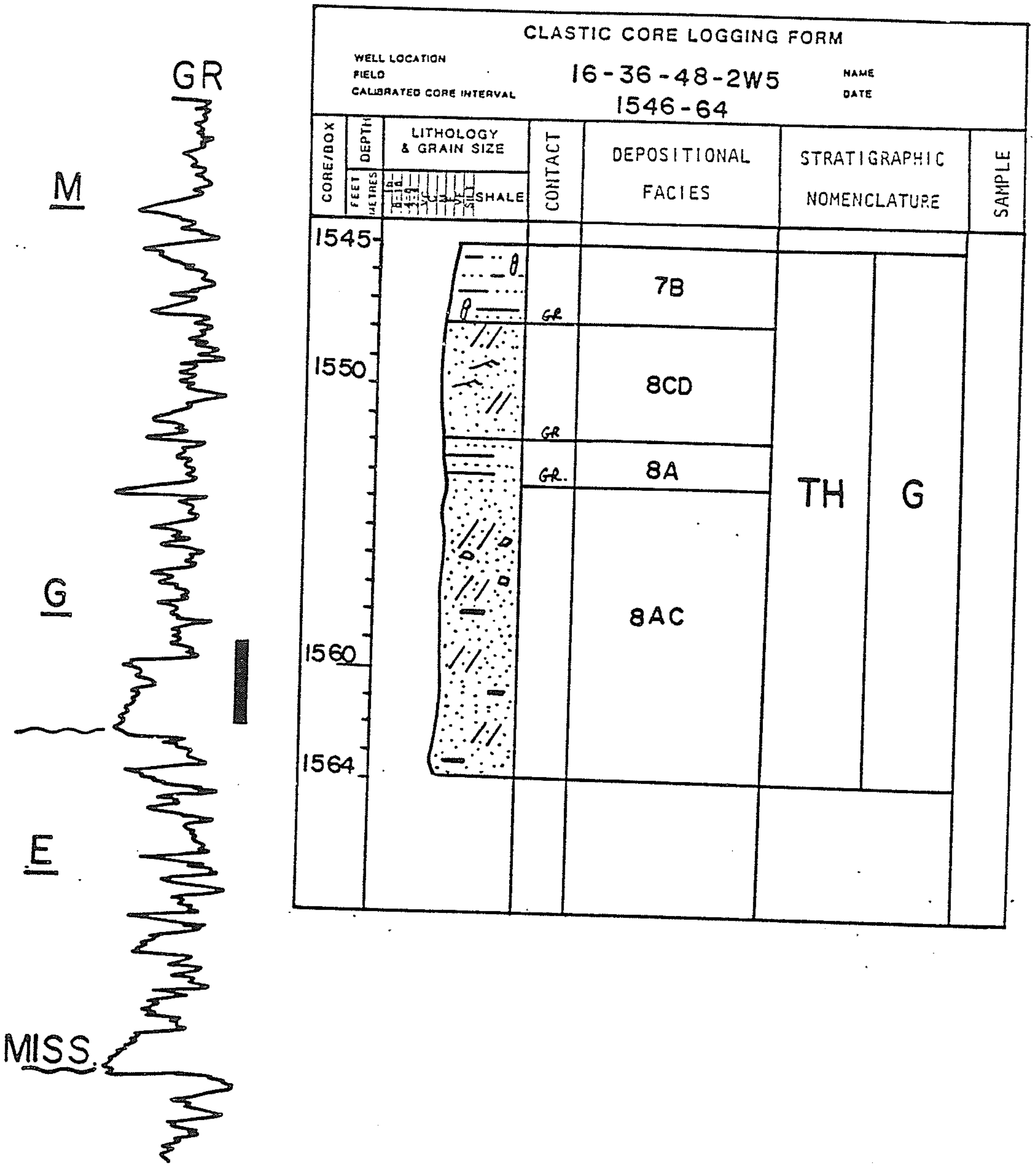
WELL LOCATION 14-25-48-2W5

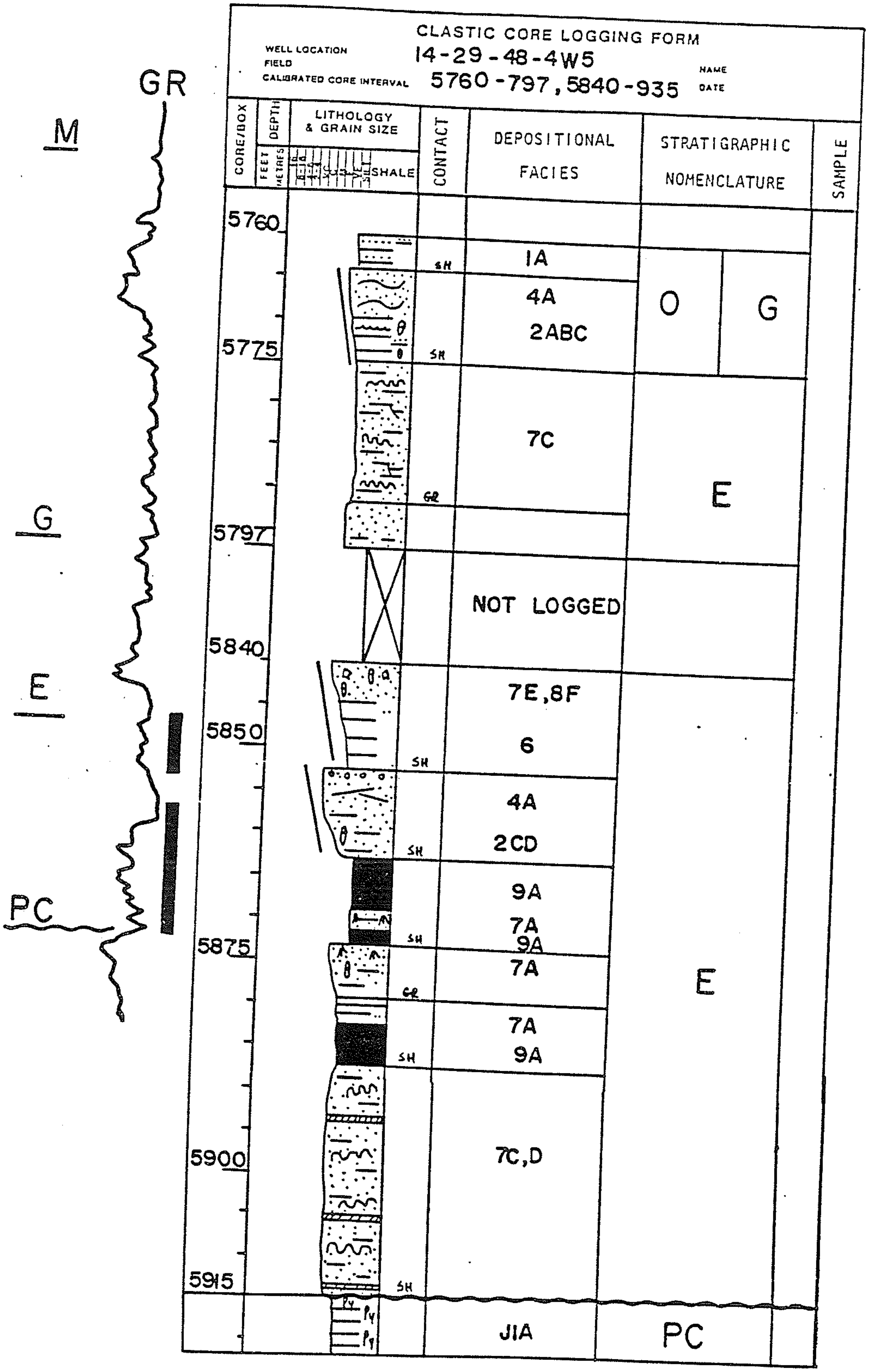
FIELD

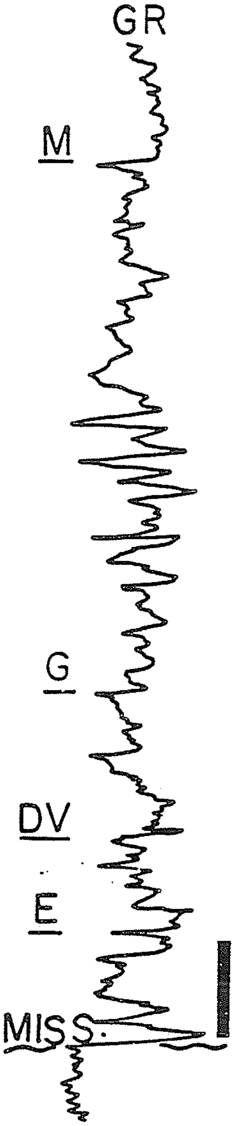
CALIBRATED CORE INTERVAL 1552-1570

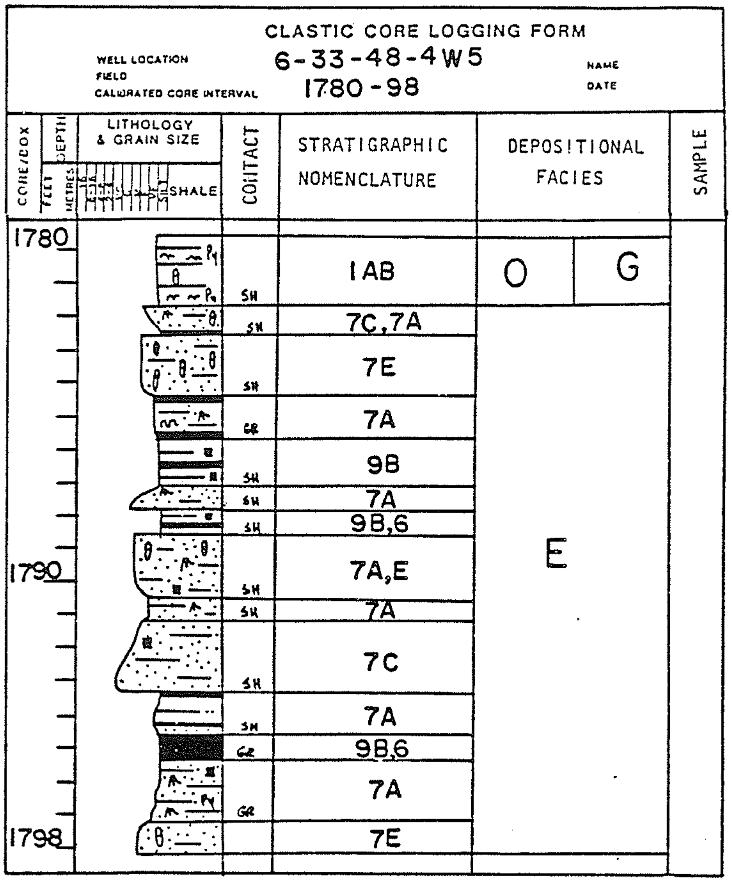
NAME

DATE


GR
M
G
E
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
16-36-48-2W5
1546-64
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1545
1550
1560
1564
GR
GR
GR.
7B
8CD
8A
8AC
TH
G


GR
M
G
E
PC
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
14-29-48-4W5
5760-797, 5840-935
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
5760
5775
5797
5840
5850
5875
5900
5915
SH
GR
1A
4A
2ABC
7C
NOT LOGGED
7E,8F
6
4A
2CD
9A
7A
9A
7A
7A
9A
7C,D
JIA
O
G
E
E
PC
Py

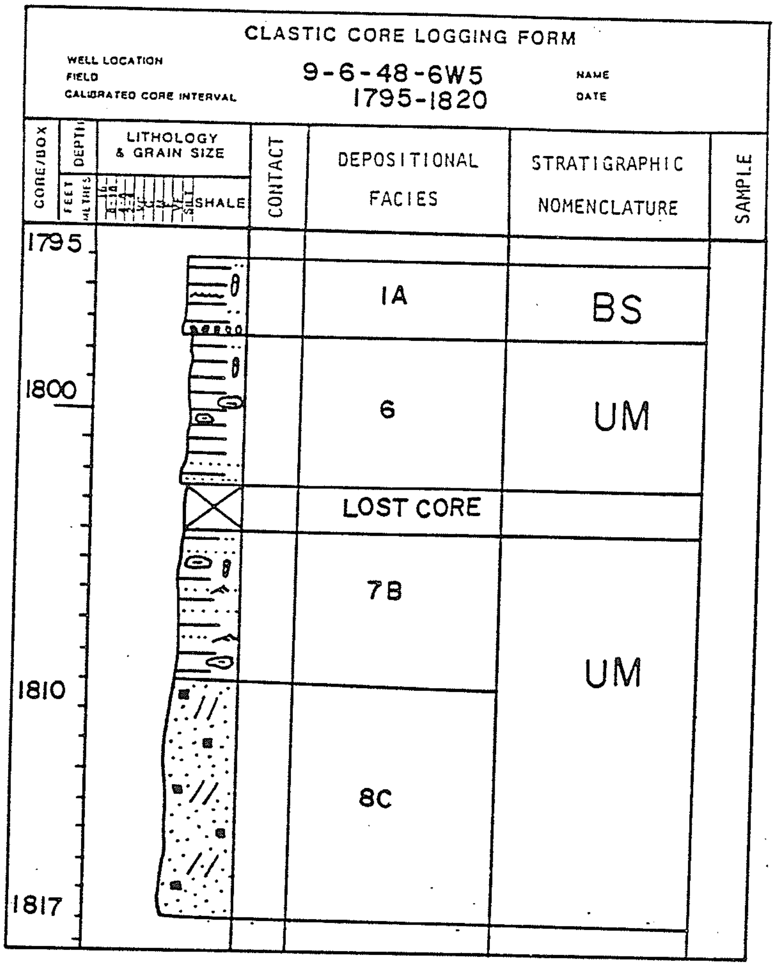



CLASTIC CORE LOGGING FORM

WELL LOCATION 6-33-48-4W5
FIELD
CALIBRATED CORE INTERVAL 1780-98
NAME
DATE

DEPTH (FEET)	CONTACT	STRATIGRAPHIC NOMENCLATURE	DEPOSITIONAL FACIES		SAMPLE
1780	SH	1AB	O	G	
	SH	7C,7A	E		
	SH	7E			
	GR	7A			
	SH	9B			
	SH	7A			
	SH	9B,6			
1790	SH	7A,E			
	SH	7A			
	SH	7C			
	SH	7A			
	GR	9B,6			
	GR	7A			
1798		7E			

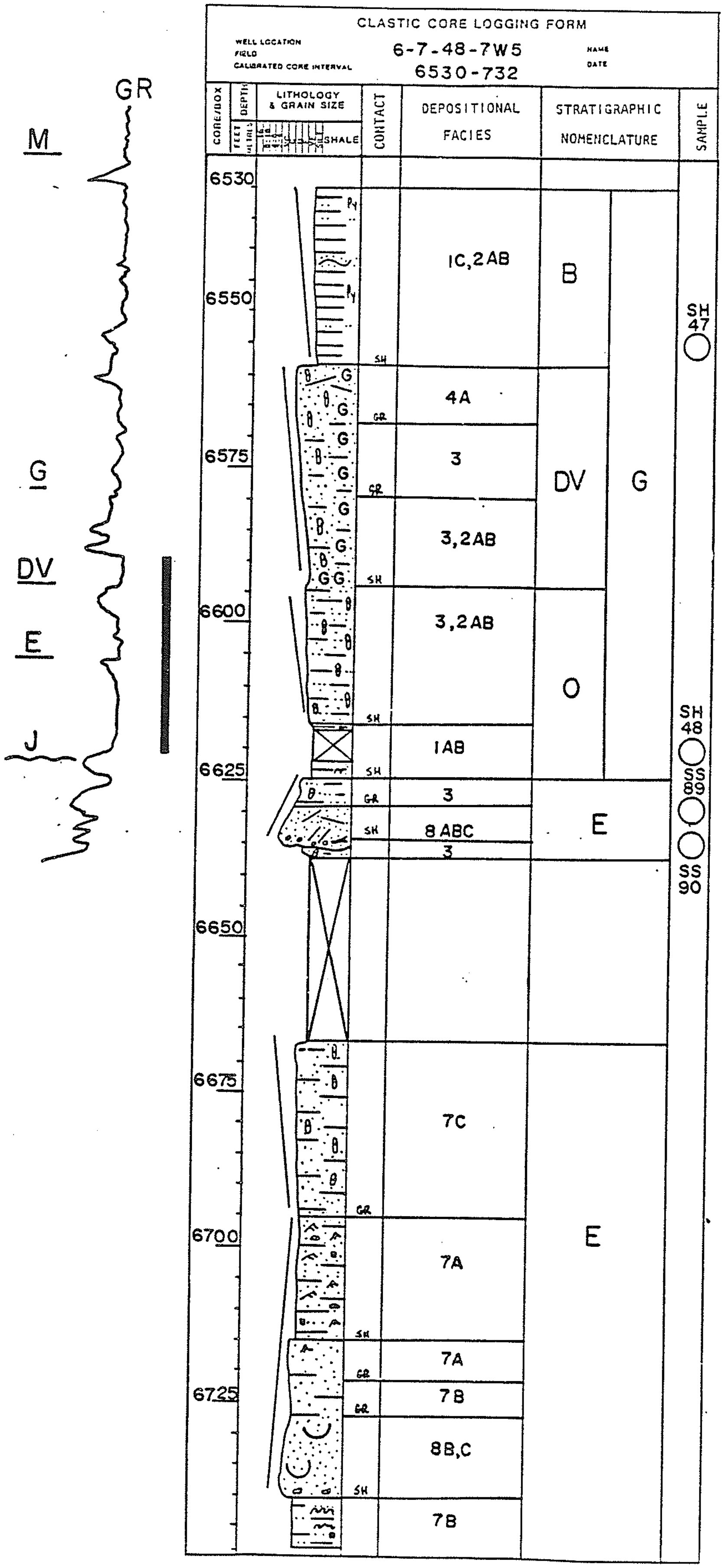
LOG NA

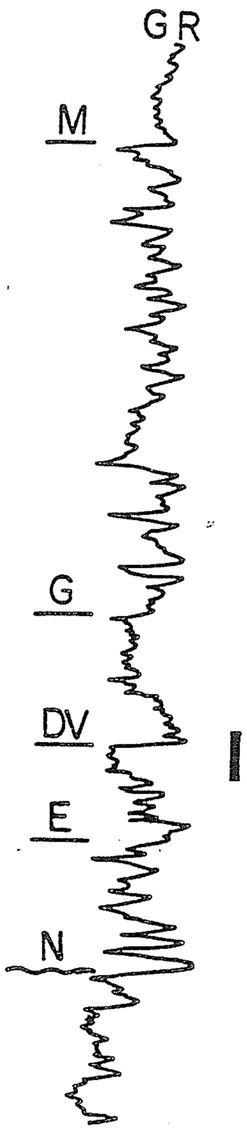


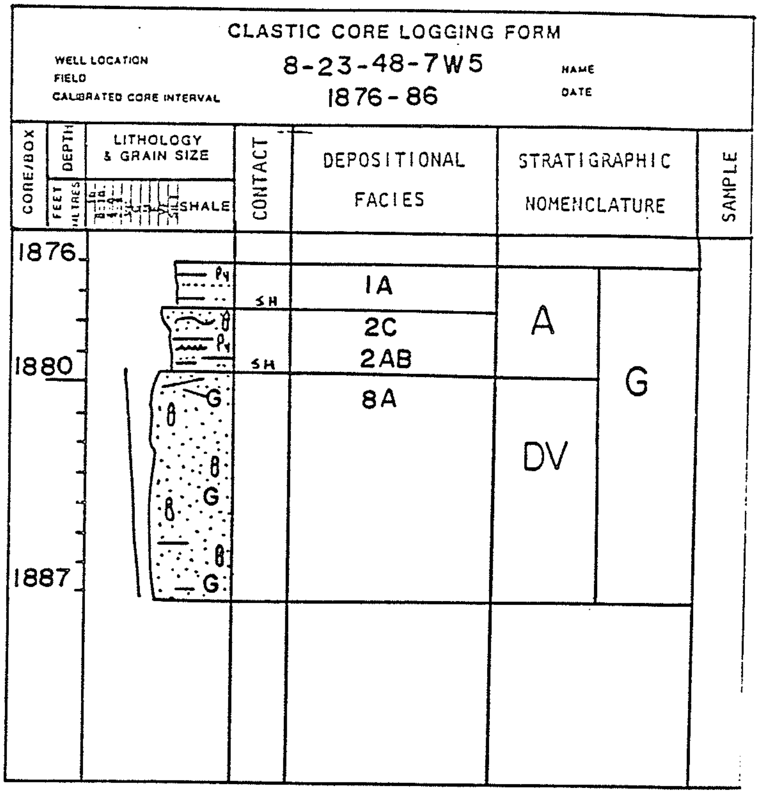
CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 9-6-48-6W5
CALIBRATED CORE INTERVAL 1795-1820
NAME
DATE

CORE/BOX	DEPTH FEET	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	1795			1A	BS	
	1800			6	UM	
				LOST CORE		
				7B	UM	
	1810			8C		
	1817					


GR
M
G
DV
E
J
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-7-48-7W5
6530-732
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
6530
6550
6575
6600
6625
6650
6675
6700
6725
Py
SH
GR
1C,2AB
4A
3
3,2AB
3,2AB
1AB
3
8 ABC
3
7C
7A
7A
7B
8B,C
7B
B
DV
G
O
E
E
SH 47
SH 48
SS 89
SS 90

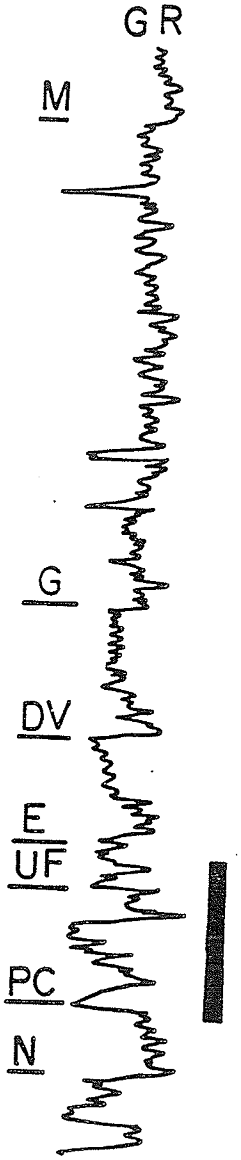


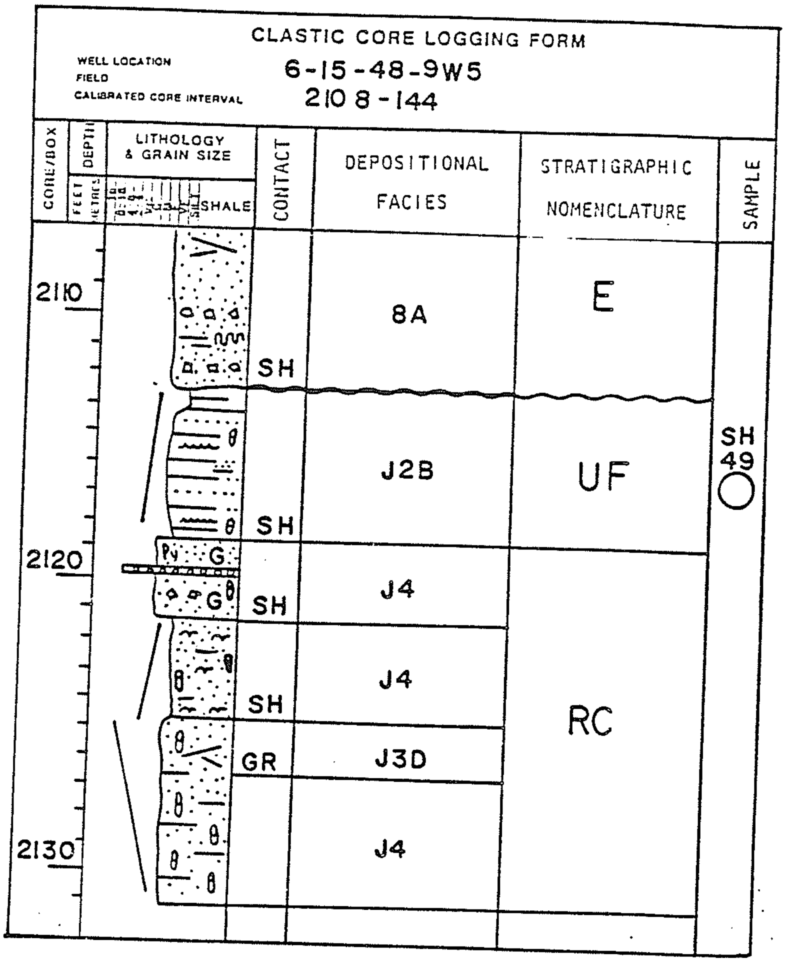


CLASTIC CORE LOGGING FORM

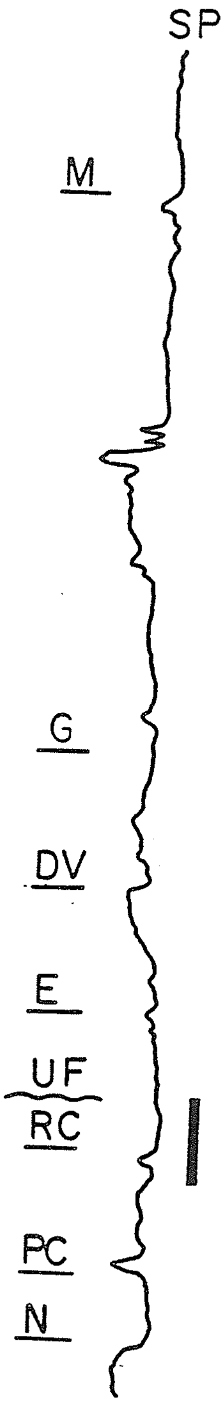
WELL LOCATION 8-23-48-7W5
FIELD
CALIBRATED CORE INTERVAL 1876-86
NAME
DATE

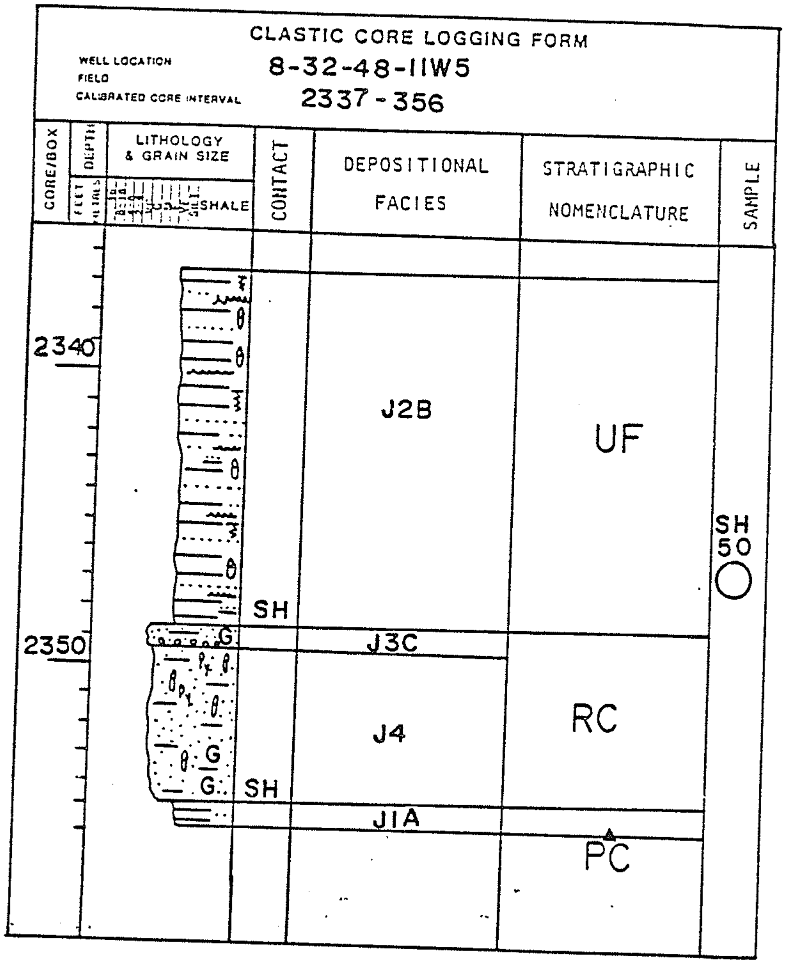
CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1876						
				1A	A	G	
			SH	2C			
				2AB			
	1880		SH	8A	DV		
	1887						



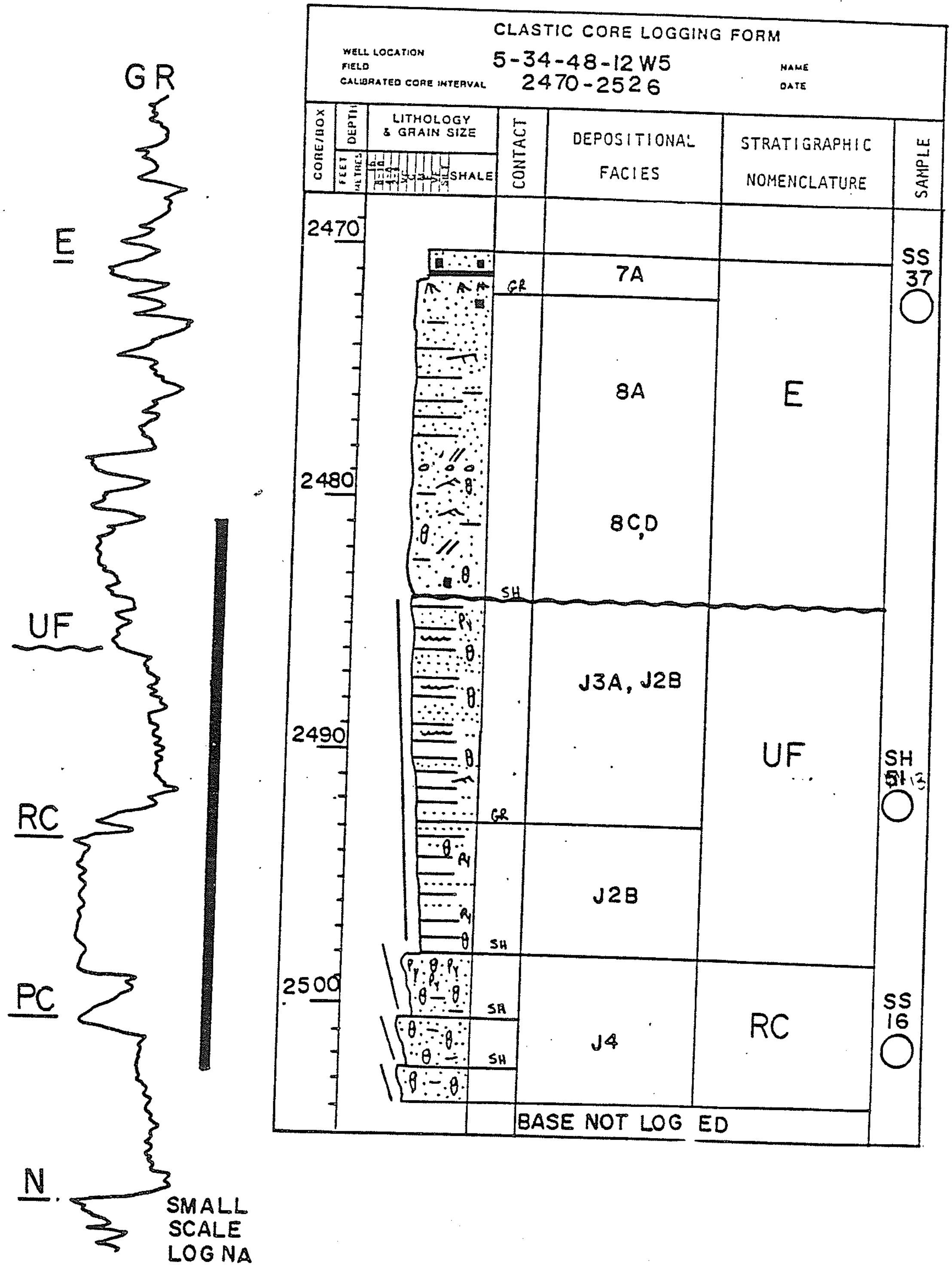

CLASTIC CORE LOGGING FORM

WELL LOCATION 6-15-48-9W5
FIELD
CALIBRATED CORE INTERVAL 2108-144




CLASTIC CORE LOGGING FORM

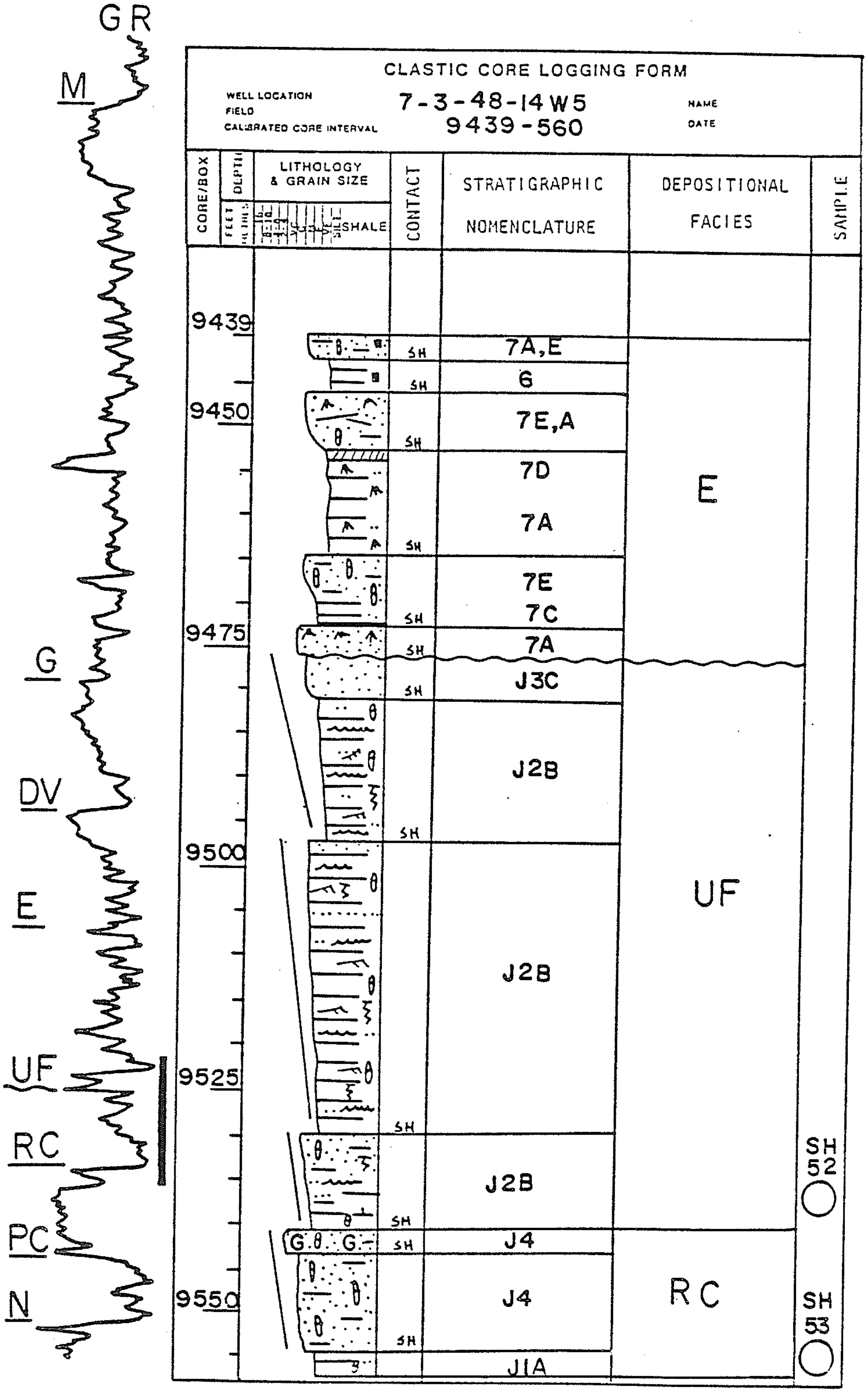
WELL LOCATION 8-32-48-11W5
FIELD
CALIBRATED CORE INTERVAL 2337-356



CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 5-34-48-12 W5
CALIBRATED CORE INTERVAL 2470-2526
NAME
DATE

CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
			GR	7A	E	SS 37
				8A		
			SH	8CD		
			GR	J3A, J2B	UF	SH 51
			SH	J2B		
			SH SH	J4	RC	SS 16
		BASE NOT LOGGED				



CLASTIC CORE LOGGING FORM

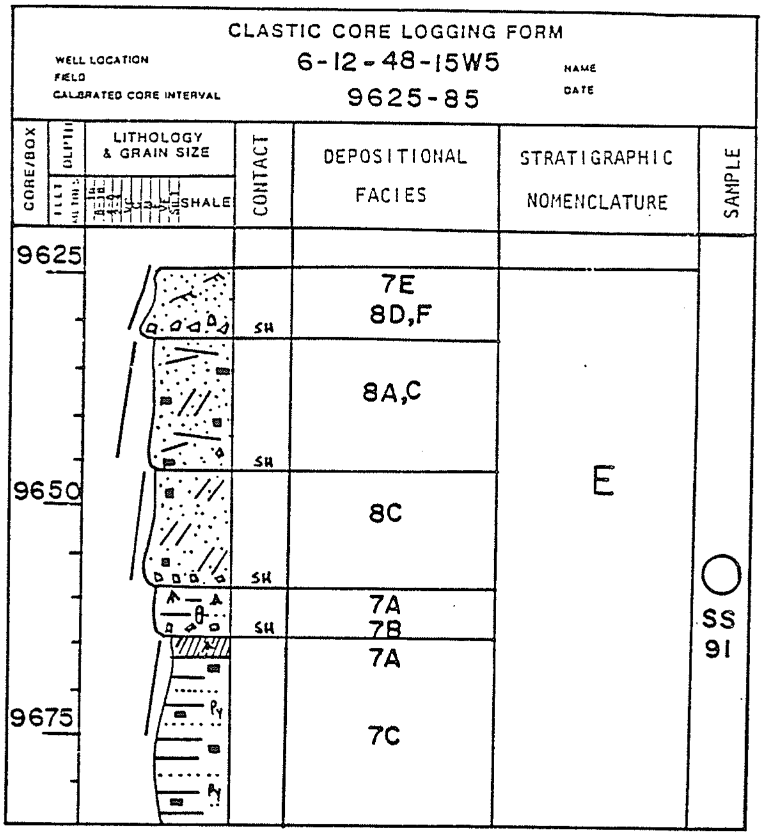
WELL LOCATION 7-3-48-14W5

FIELD

CALIBRATED CORE INTERVAL 9439-560

NAME

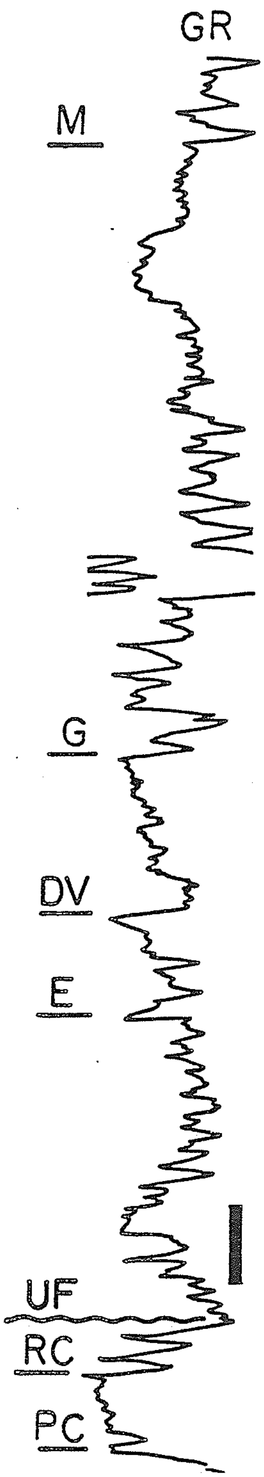
DATE

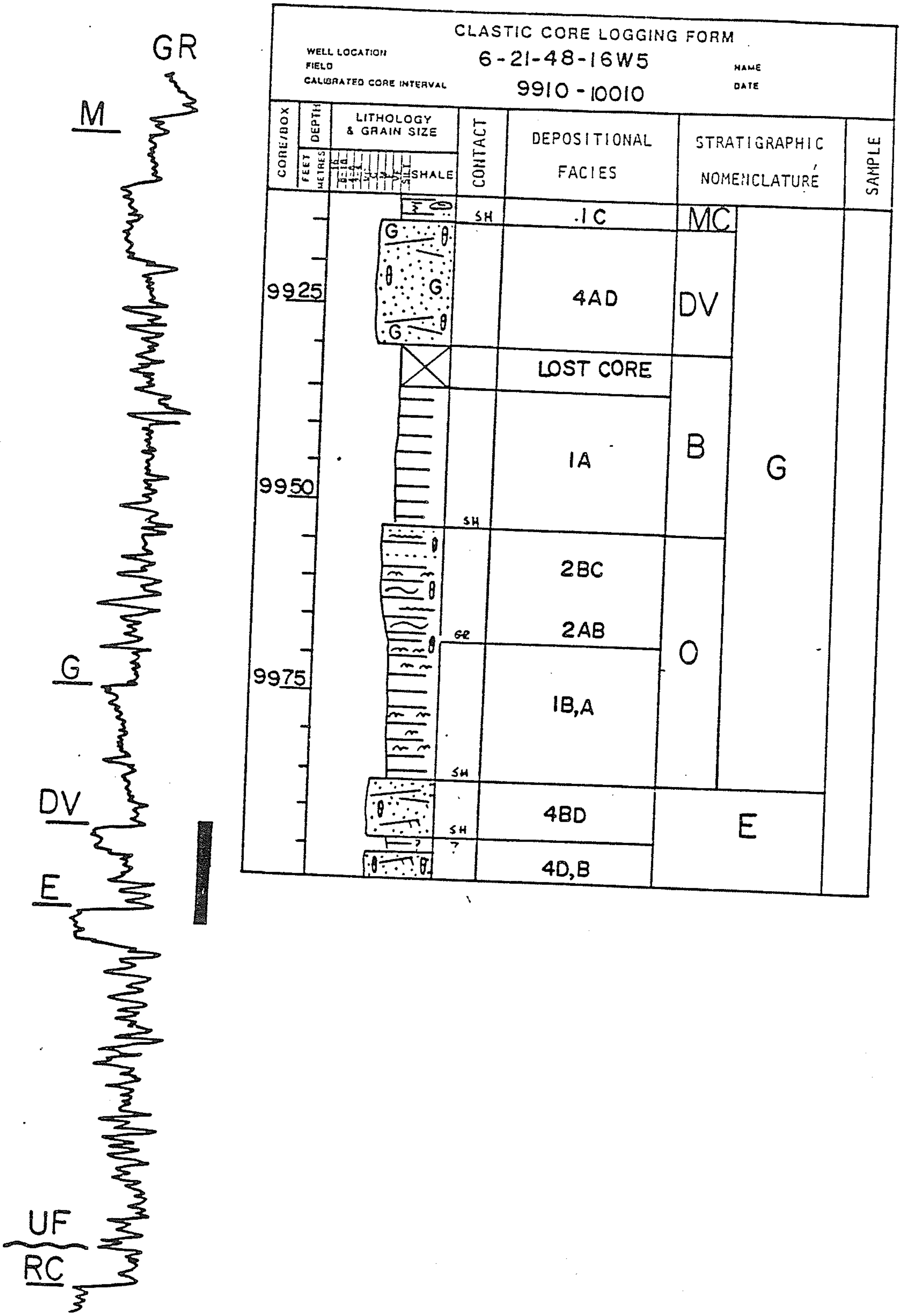


CLASTIC CORE LOGGING FORM

WELL LOCATION 6-12-48-15W5 NAME
FIELD
CALIBRATED CORE INTERVAL 9625-85 DATE

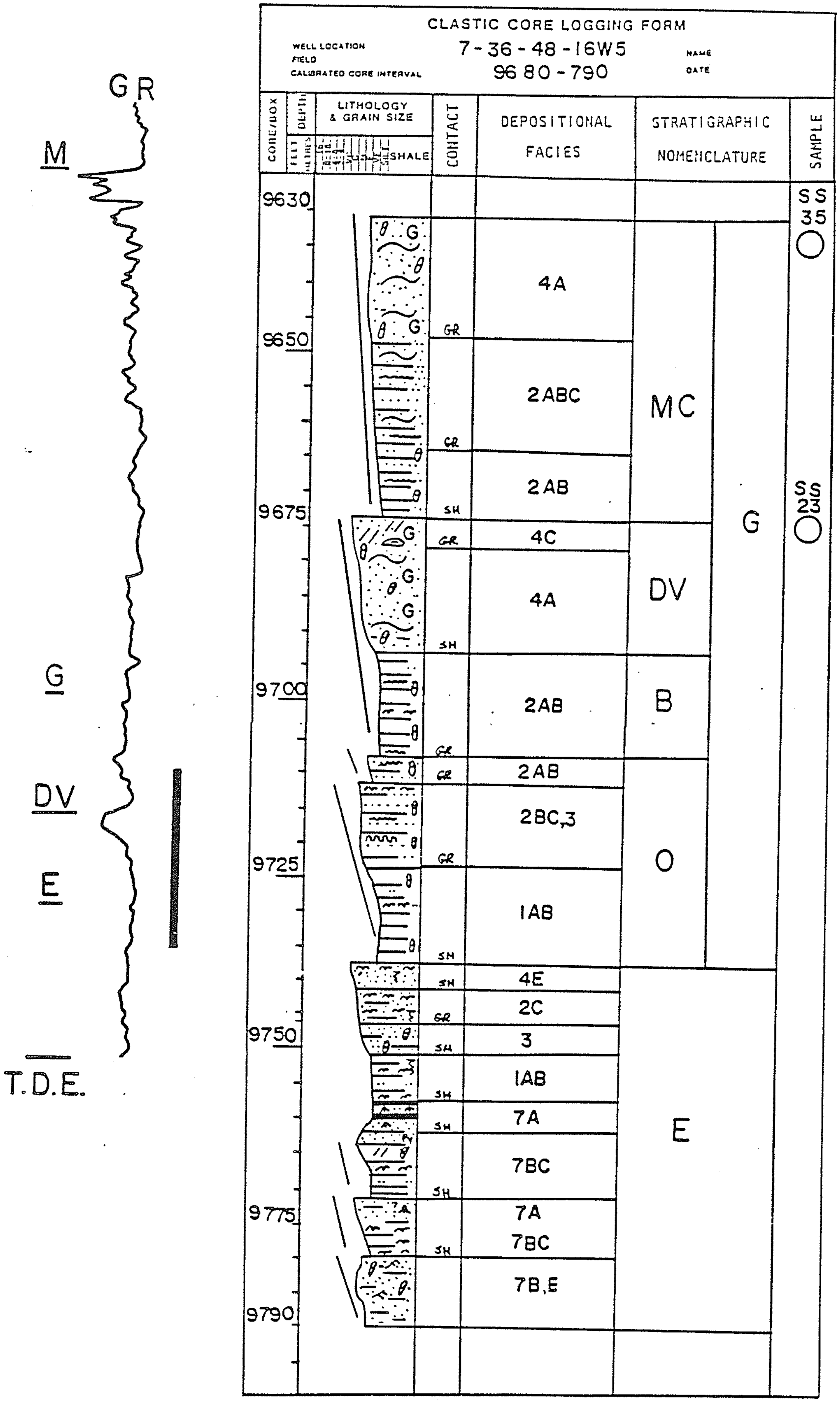
CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
9625			SH	7E 8D,F	E	
			SH	8A,C		
9650			SH	8C		○ SS 91
			SH	7A 7B		
				7A		
9675				7C		

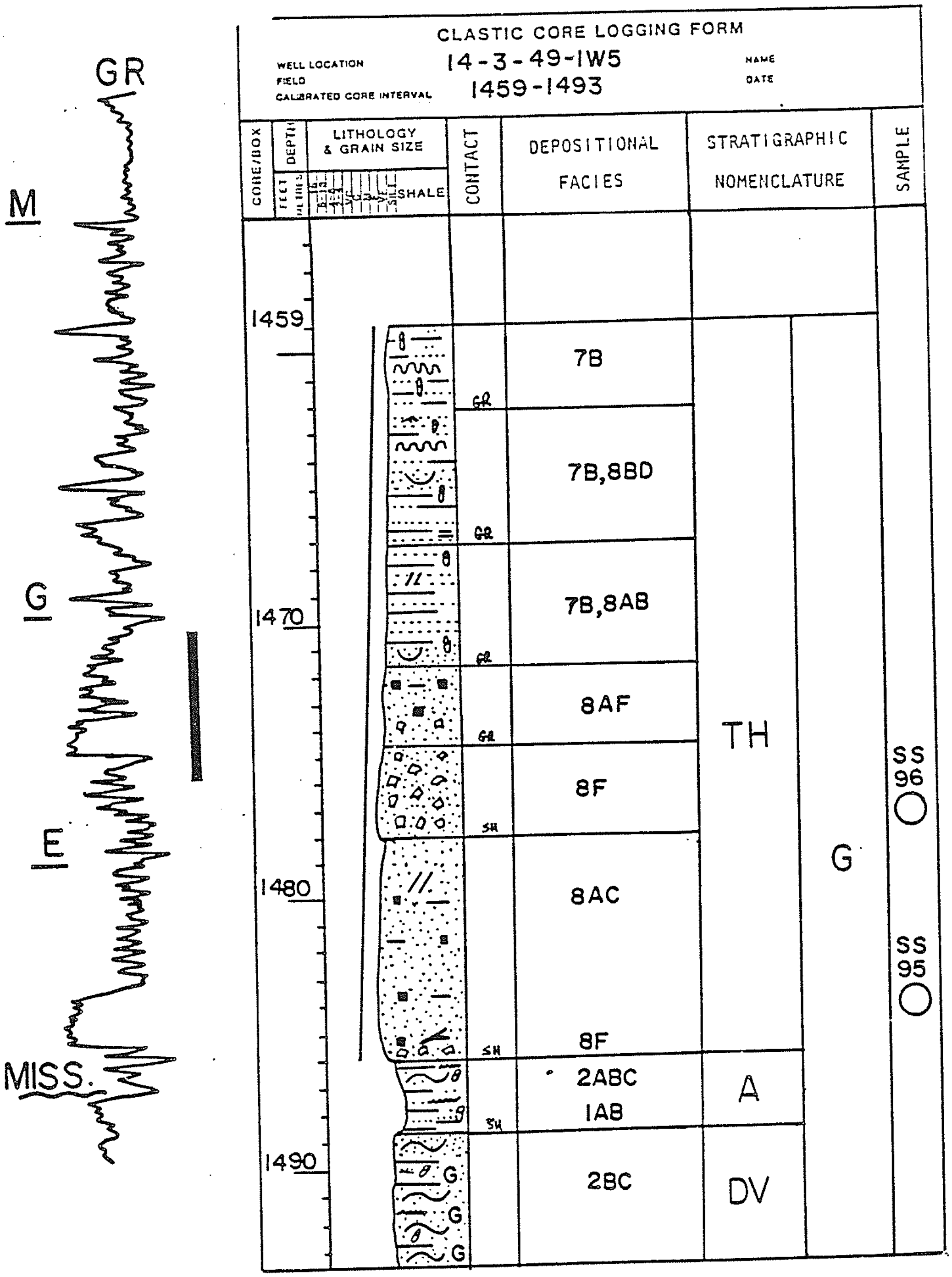




CLASTIC CORE LOGGING FORM

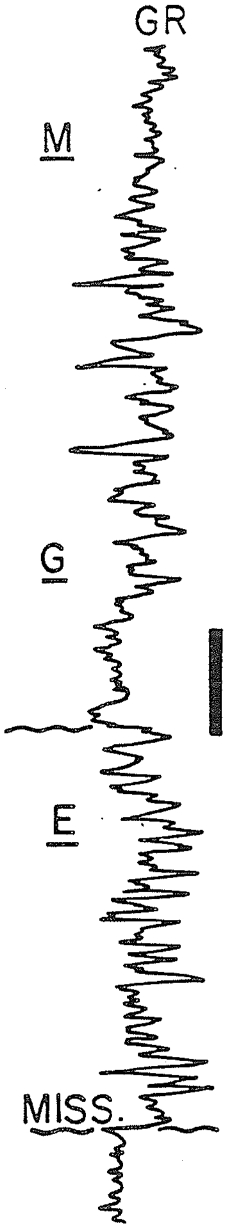
WELL LOCATION
FIELD 6-21-48-16W5
CALIBRATED CORE INTERVAL 9910 - 10010
NAME
DATE

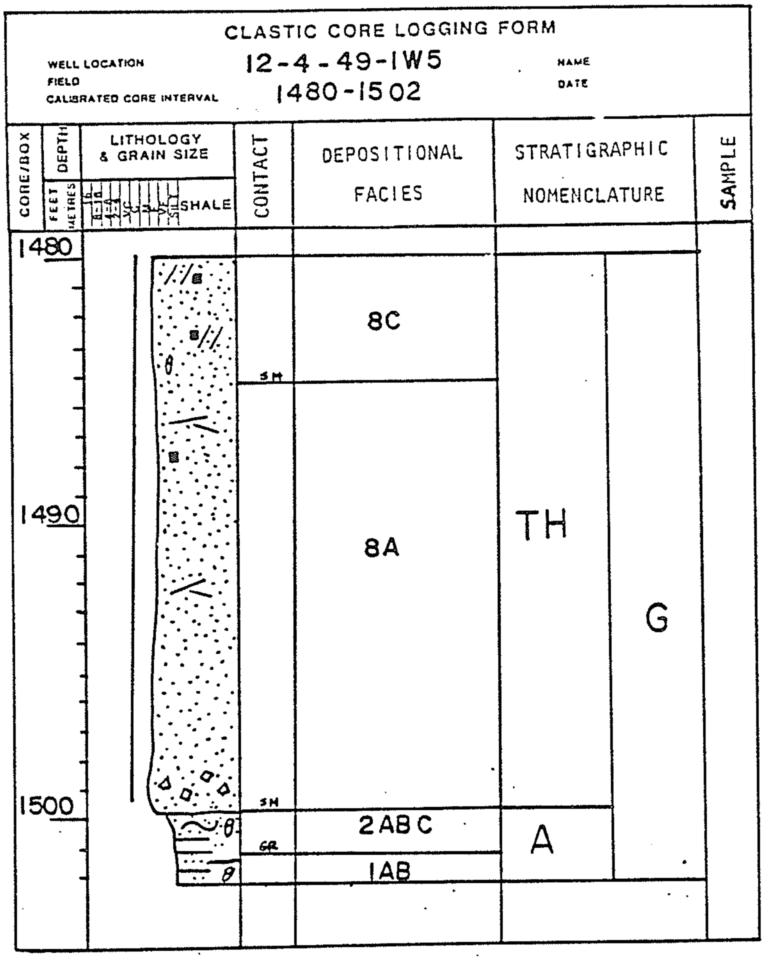

CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
7-36-48-16W5
9680-790
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
9630
9650
9675
9700
9725
9750
9775
9790
GR
SH
4A
2ABC
2AB
4C
4A
2AB
2AB
2BC,3
1AB
4E
2C
3
1AB
7A
7BC
7A
7BC
7B,E
MC
DV
B
O
G
E
SS 35
SS 23
GR
M
G
DV
E
T.D.E.



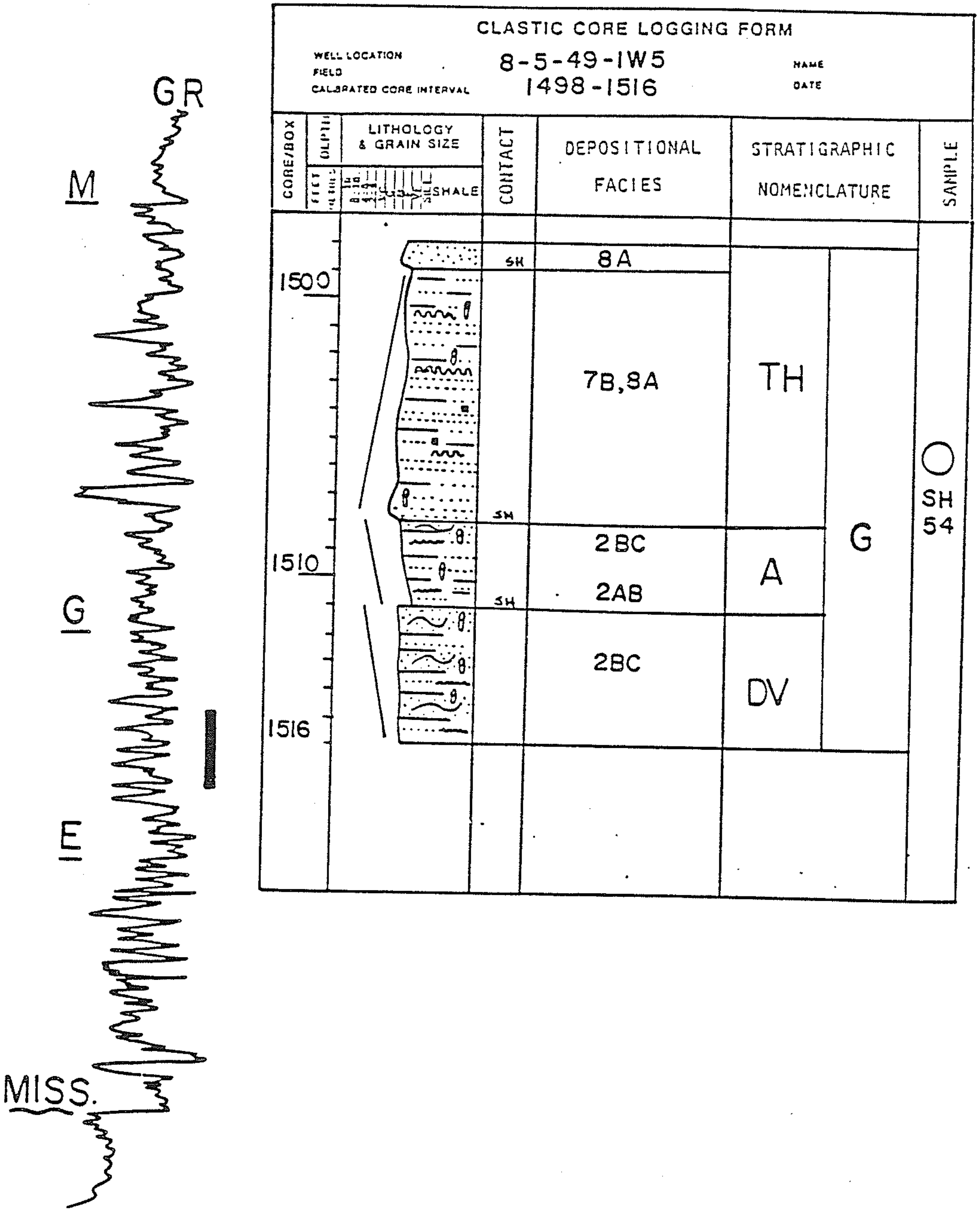
CLASTIC CORE LOGGING FORM

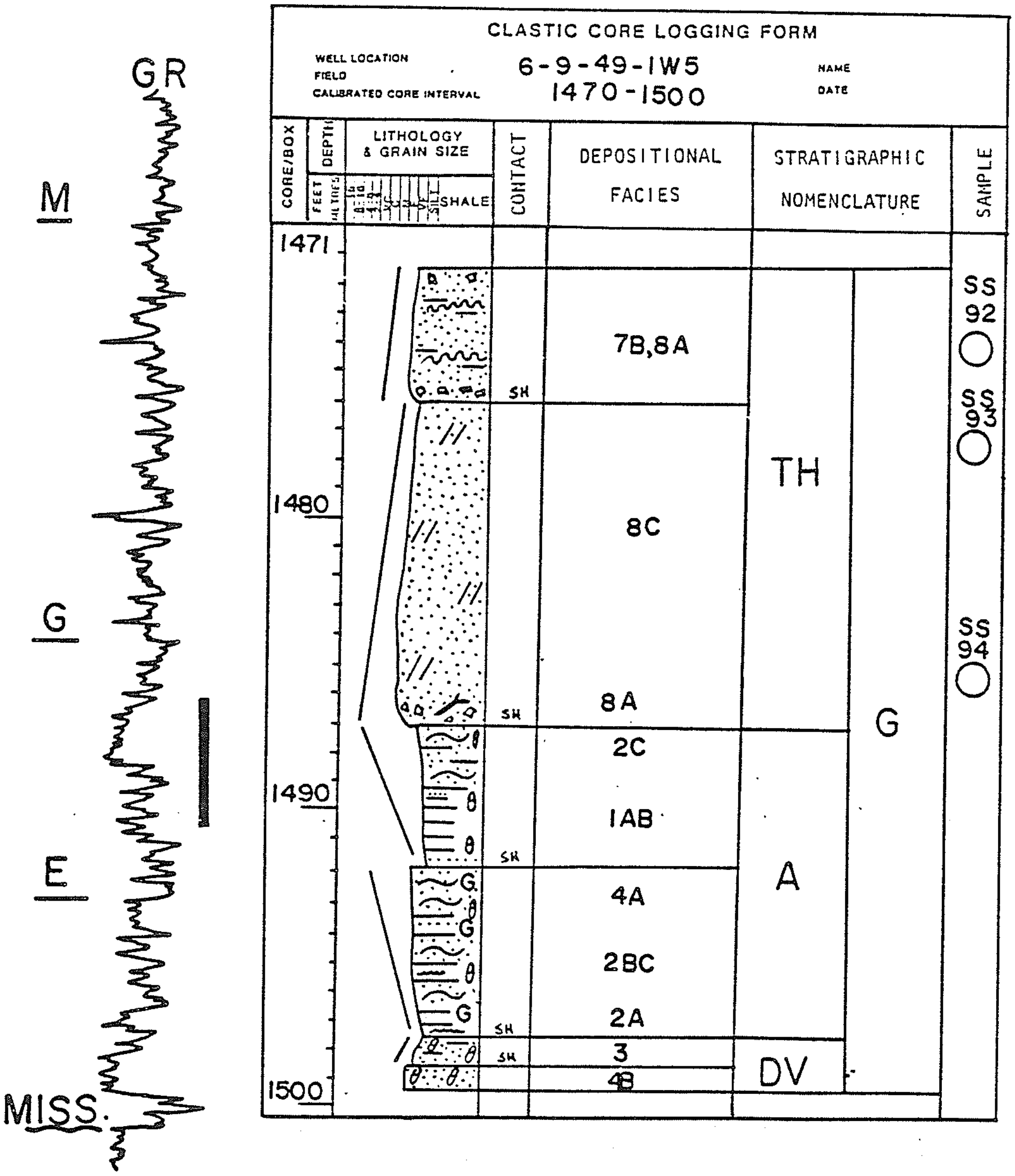
WELL LOCATION 14-3-49-1W5
FIELD
CALIBRATED CORE INTERVAL 1459-1493
NAME
DATE




CLASTIC CORE LOGGING FORM

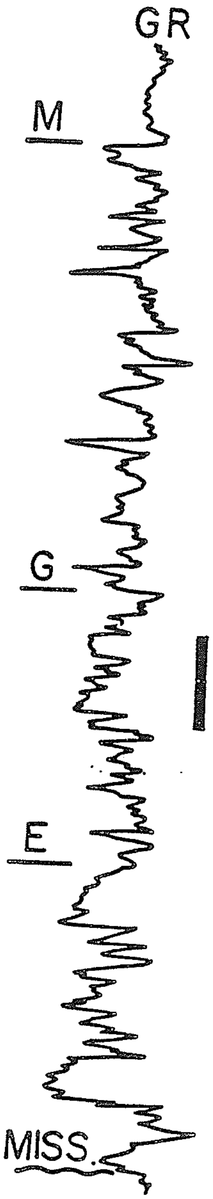
WELL LOCATION 12-4-49-1W5
FIELD
CALIBRATED CORE INTERVAL 1480-1502
NAME
DATE

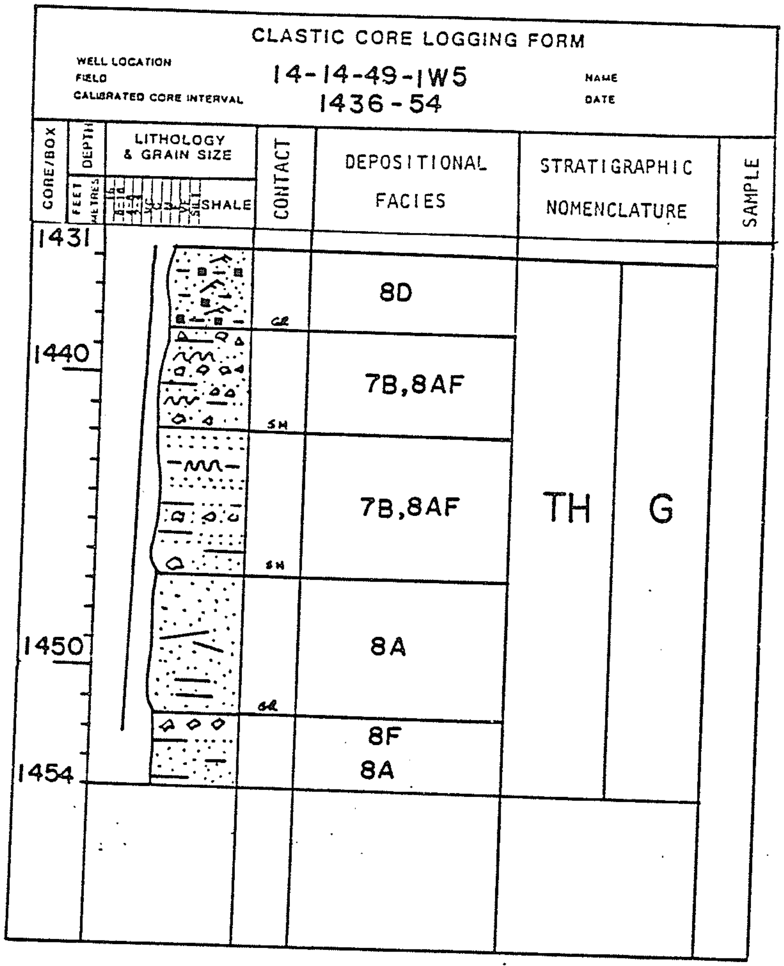

GR
M
G
E
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
8-5-49-1W5
1498-1516
NAME
DATE
CORE/BOX
FEET
DEPTH
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1500
1510
1516
SH
SH
SH
8A
7B,8A
2BC
2AB
2BC
TH
A
DV
G
SH 54



CLASTIC CORE LOGGING FORM

WELL LOCATION 6-9-49-1W5
FIELD
CALIBRATED CORE INTERVAL 1470-1500
NAME
DATE

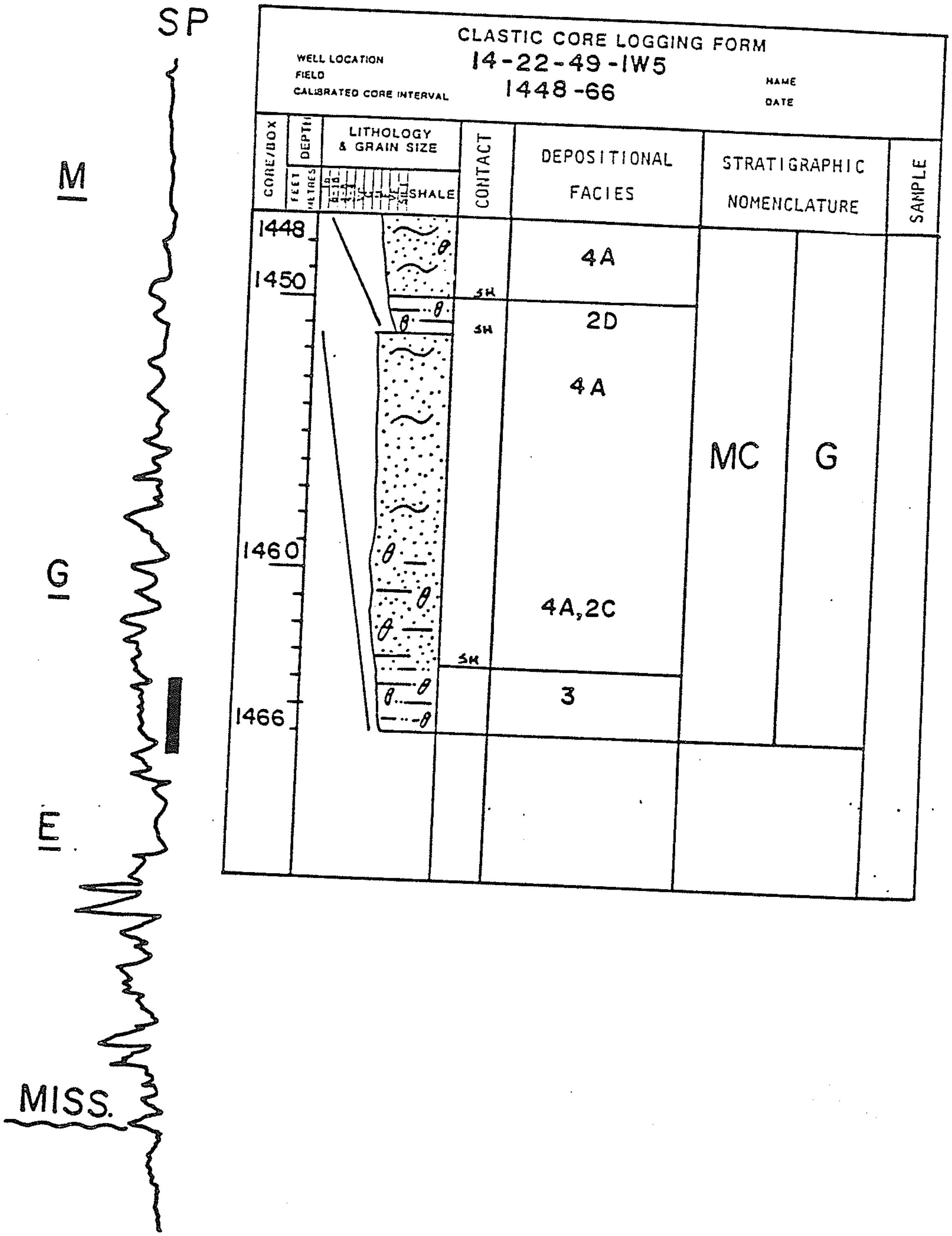


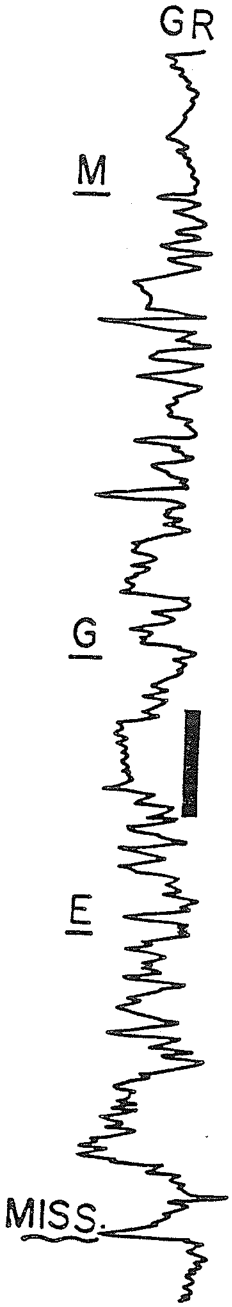


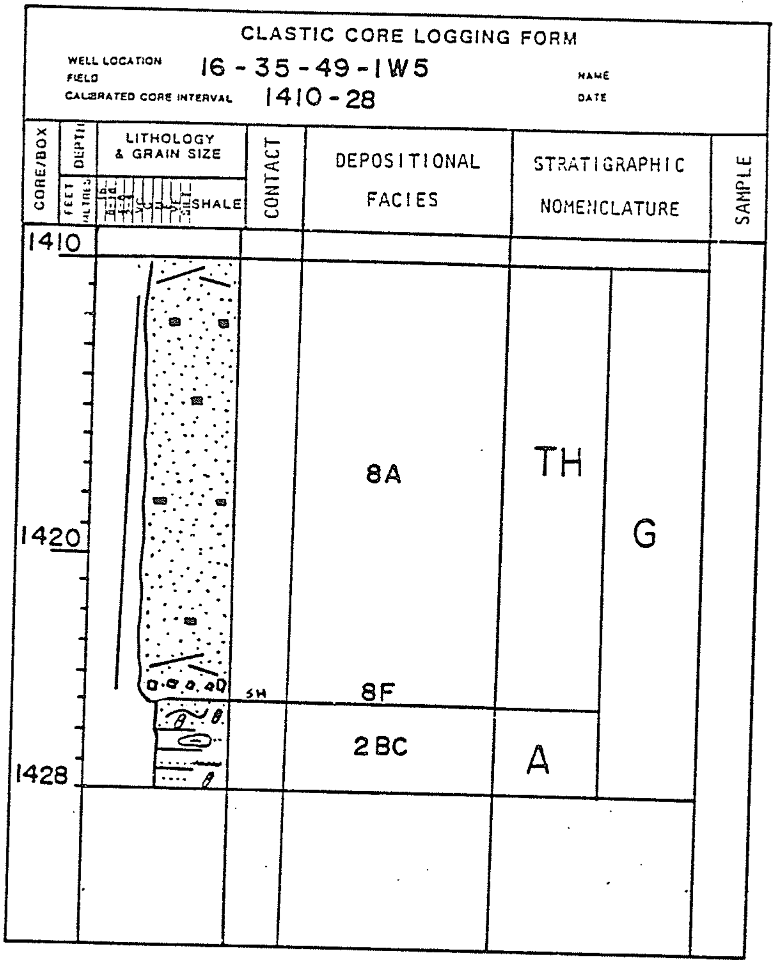
CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 14-14-49-1W5
CALIBRATED CORE INTERVAL 1436-54
NAME
DATE

CORE/BOX	DEPTH FEET / METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1431		GR	8D	TH	G	
	1440		SH	7B,8AF			
			SH	7B,8AF			
	1450		GR	8A			
	1454			8F 8A			


SP
M
G
E
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
14-22-49-1W5
1448-66
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1448
1450
1460
1466
SH
SH
SH
4A
2D
4A
4A,2C
3
MC
G

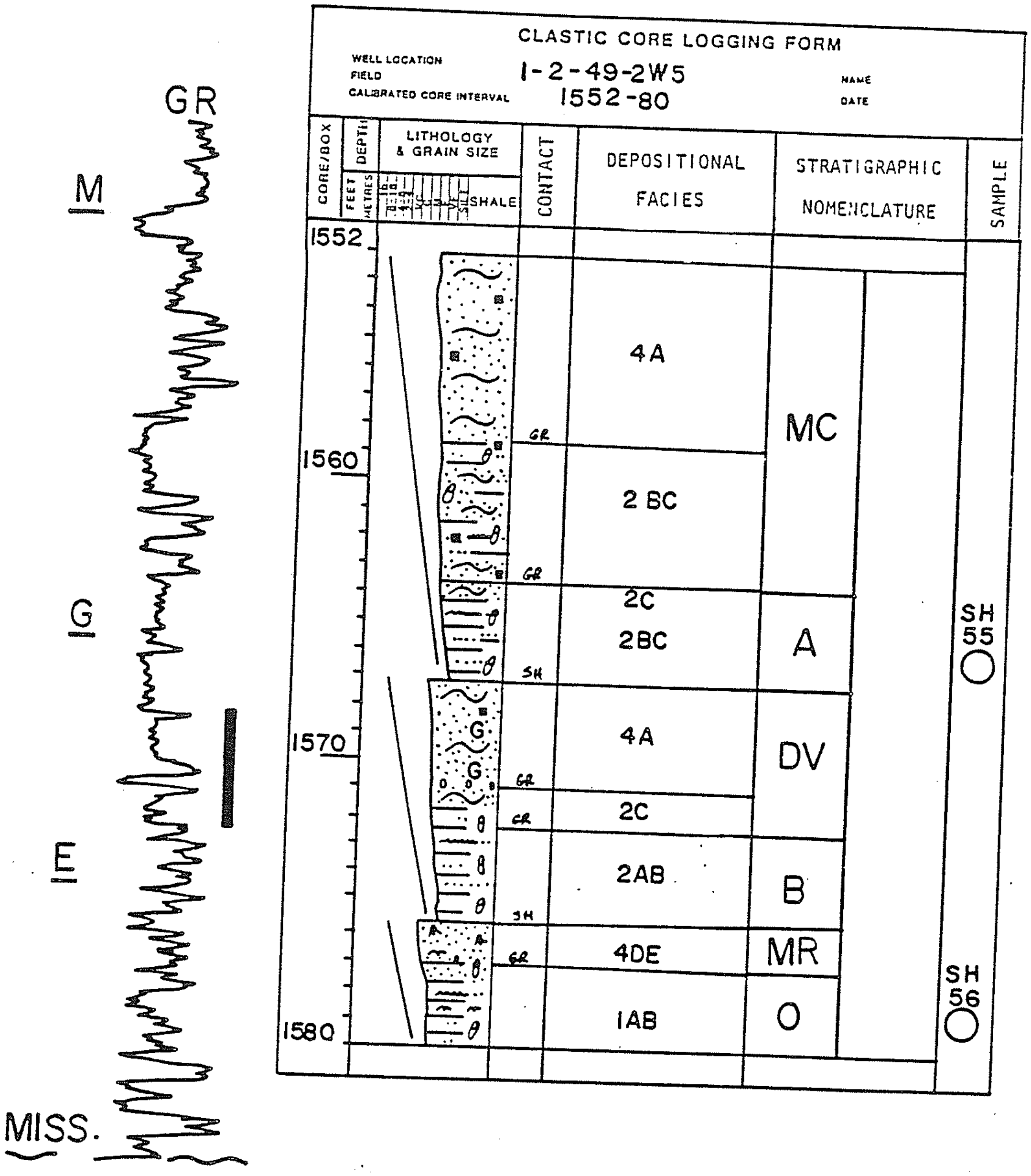




CLASTIC CORE LOGGING FORM

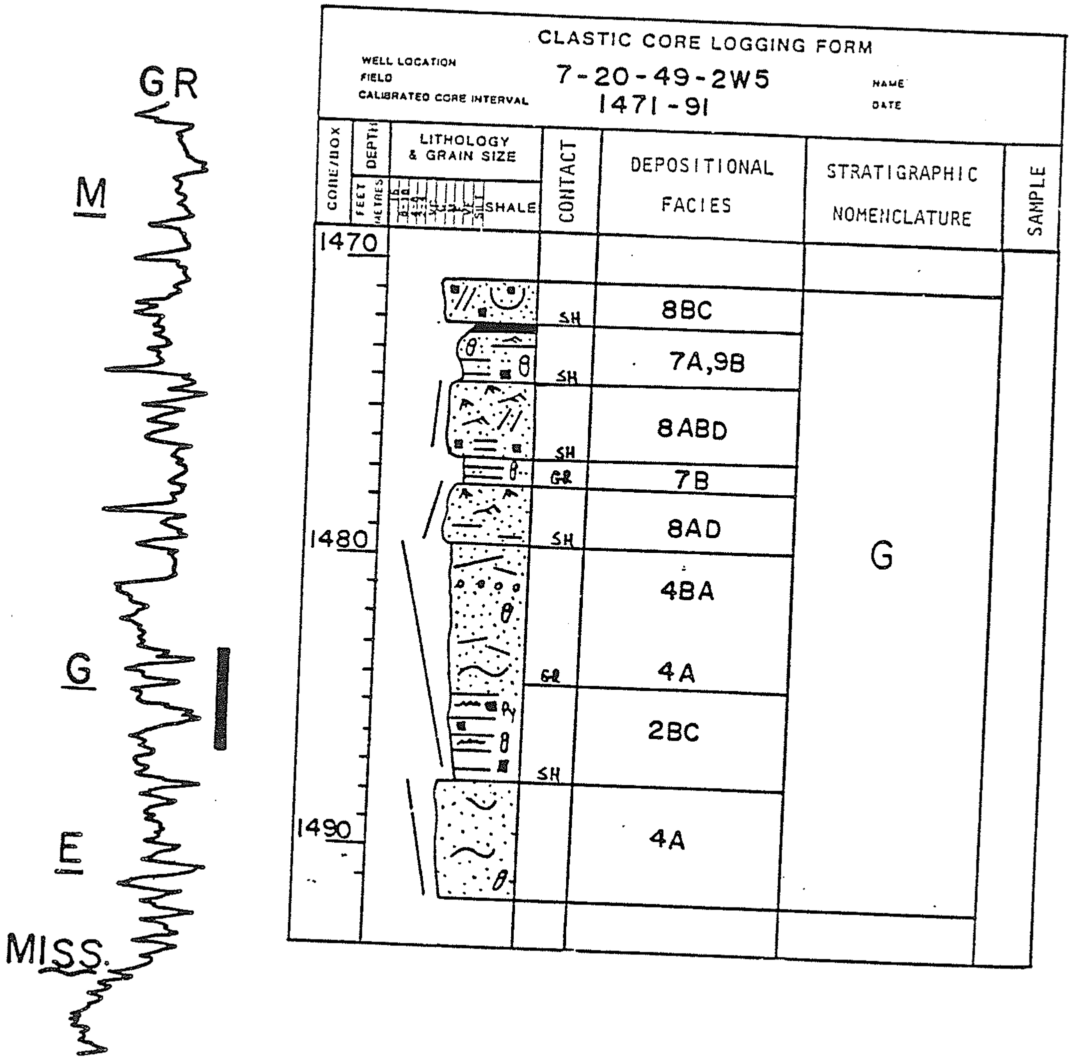
WELL LOCATION
FIELD 16-35-49-1W5
CALIBRATED CORE INTERVAL 1410-28
NAME
DATE

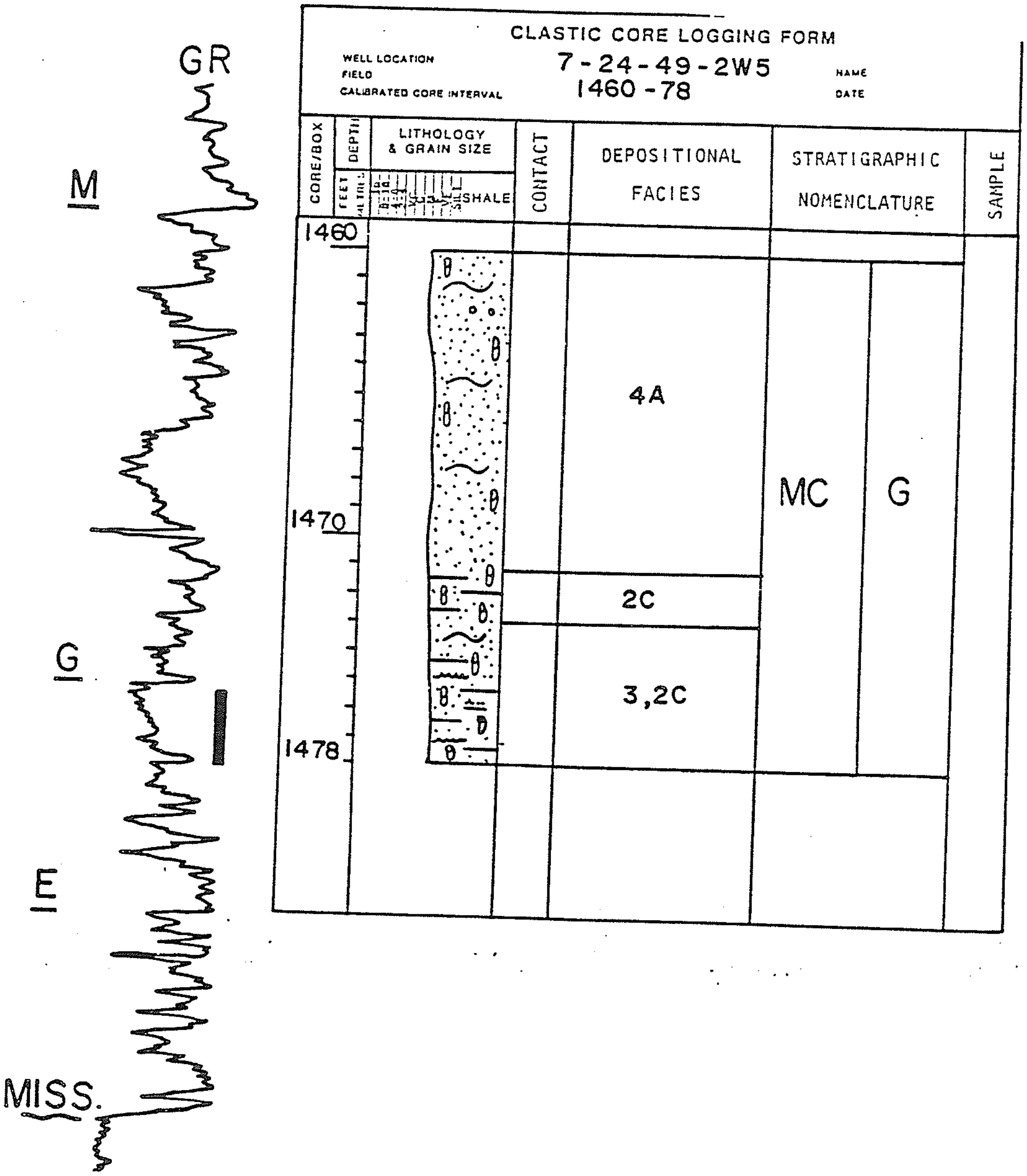
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
1410				8A	TH	G	
1420			SH	8F			
1428				2BC	A		



CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 1-2-49-2W5
CALIBRATED CORE INTERVAL 1552-80
NAME
DATE

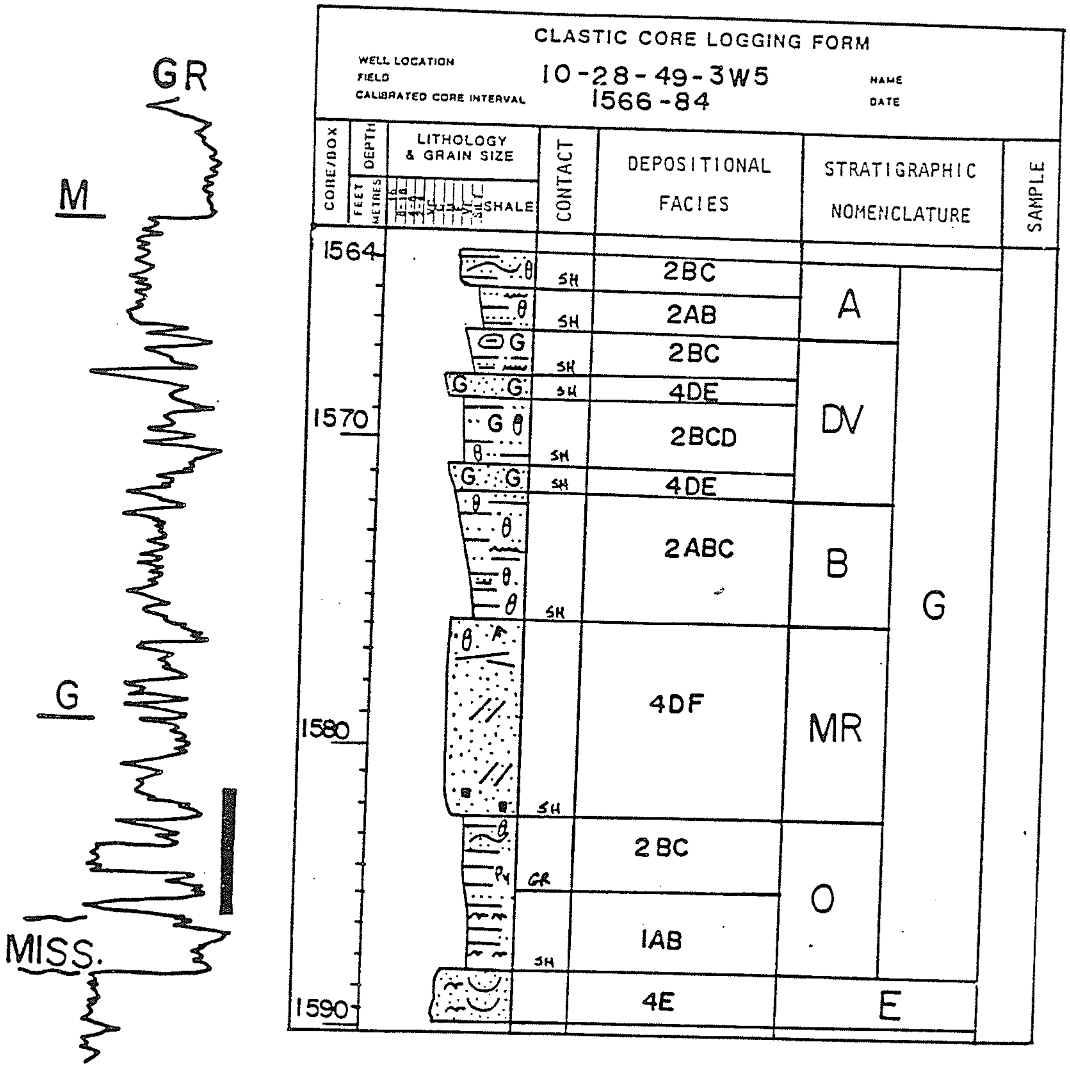

GR
M
G
E
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
7-20-49-2W5
1471-91
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1470
1480
1490
SH
8BC
SH
7A,9B
SH
8ABD
GR
7B
SH
8AD
4BA
GR
4A
2BC
SH
4A
G
Py



CLASTIC CORE LOGGING FORM

WELL LOCATION 7-24-49-2W5
FIELD
CALIBRATED CORE INTERVAL 1460-78
NAME
DATE

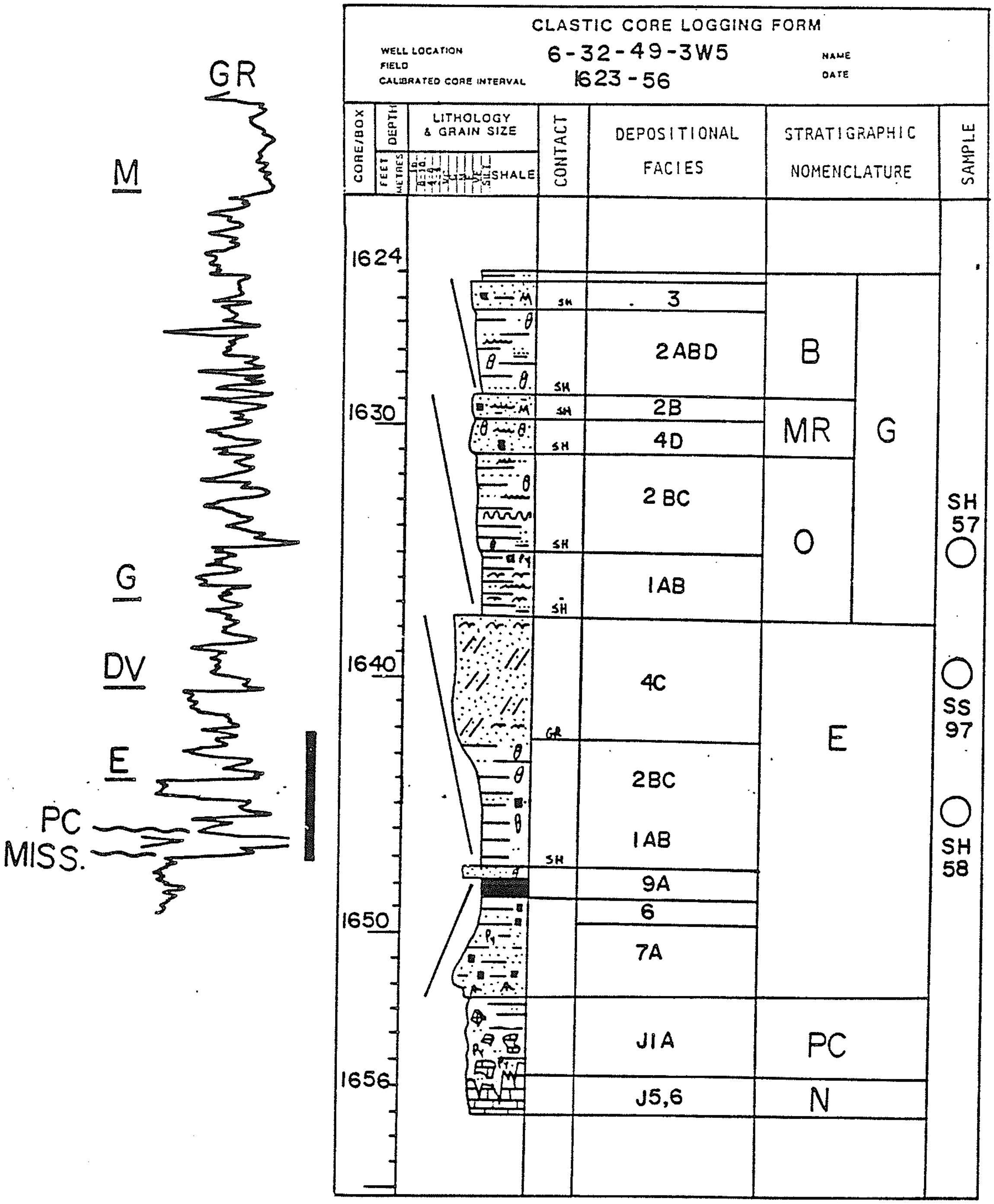
CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1460			4A	MC	G	
	1470			2C			
				3,2C			
	1478						

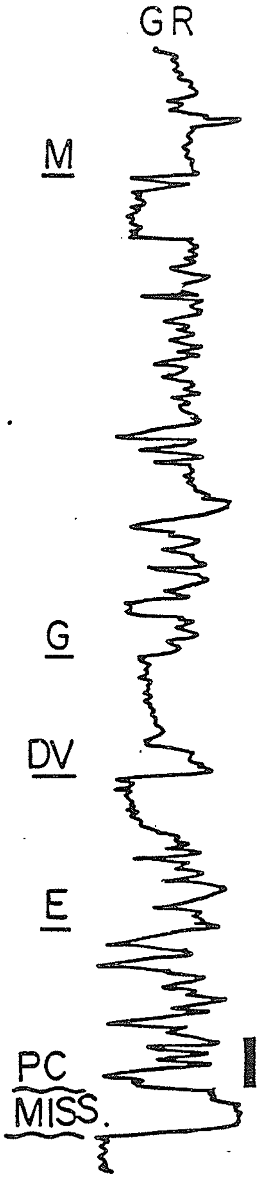


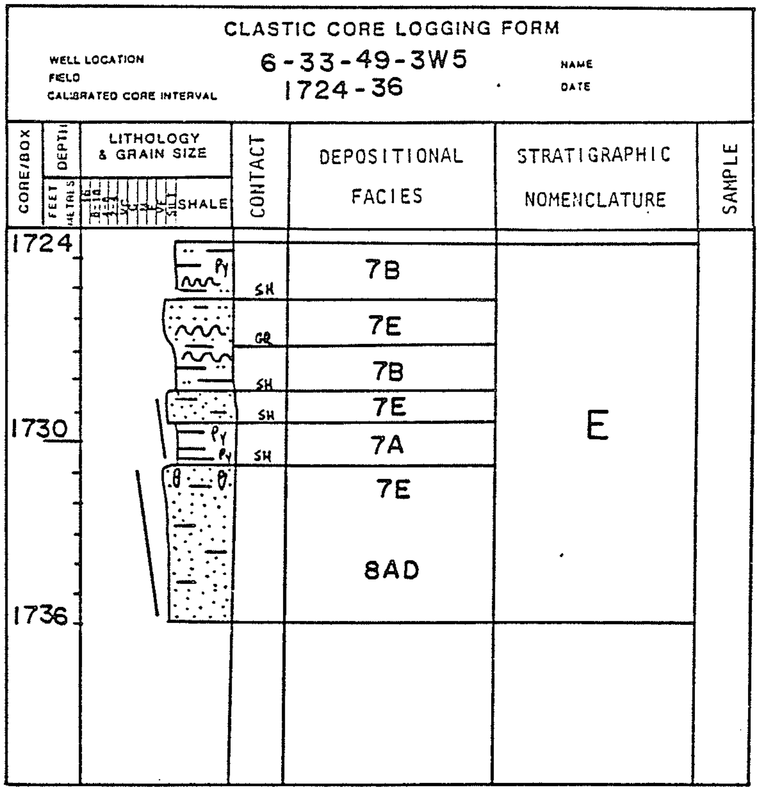
CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 10-28-49-3W5
CALIBRATED CORE INTERVAL 1566-84
NAME
DATE

CORE/BOX	DEPTH FEET METRES	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1564	SH	2BC			
		SH	2AB	A	G	
		SH	2BC	DV		
		SH	4DE			
	1570	SH	2BCD			
		SH	4DE			
		SH	2ABC	B		
	1580	SH	4DF	MR		
		GR	2 BC	O		
		SH	1AB			
	1590		4E	E		

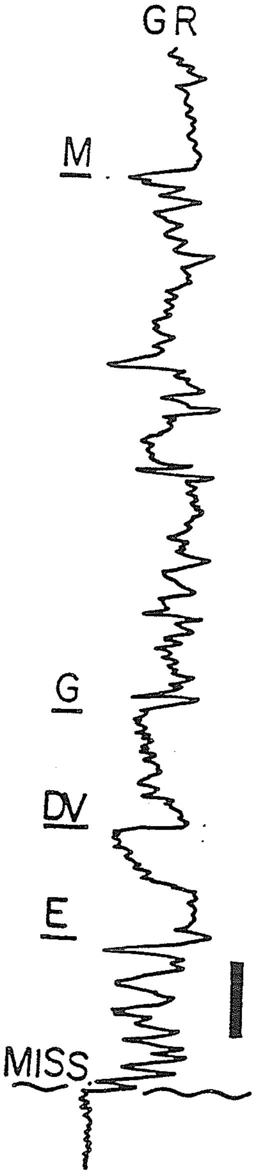

GR
M
G
DV
E
PC
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-32-49-3W5
1623-56
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1624
1630
1640
1650
1656
SH
GR
3
2ABD
2B
4D
2 BC
1AB
4C
2BC
1AB
9A
6
7A
J1A
J5,6
B
MR
O
G
E
PC
N
SH 57
SS 97
SH 58

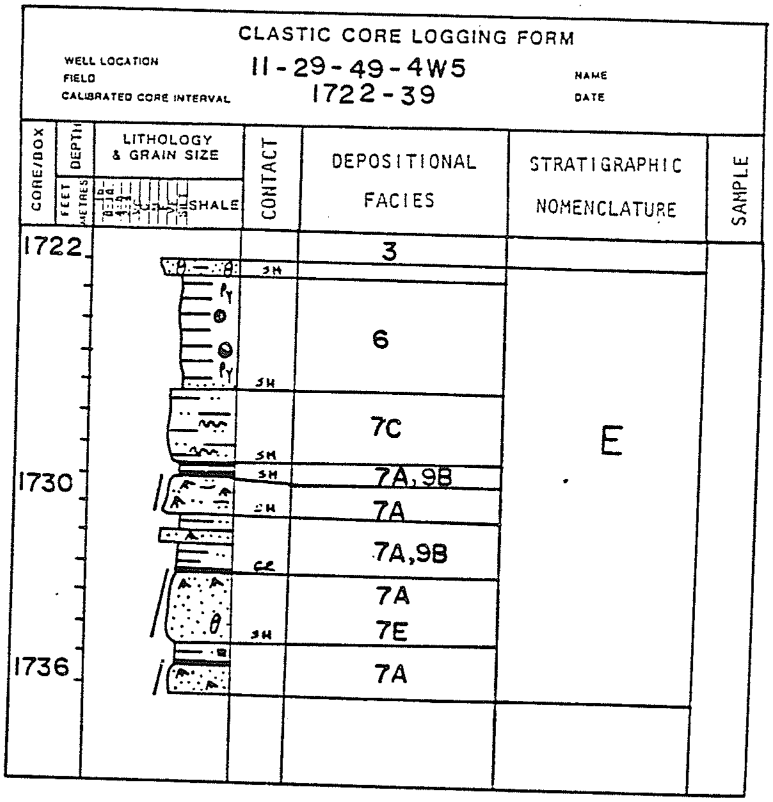



CLASTIC CORE LOGGING FORM

WELL LOCATION 6-33-49-3W5
FIELD
CALIBRATED CORE INTERVAL 1724-36
NAME
DATE

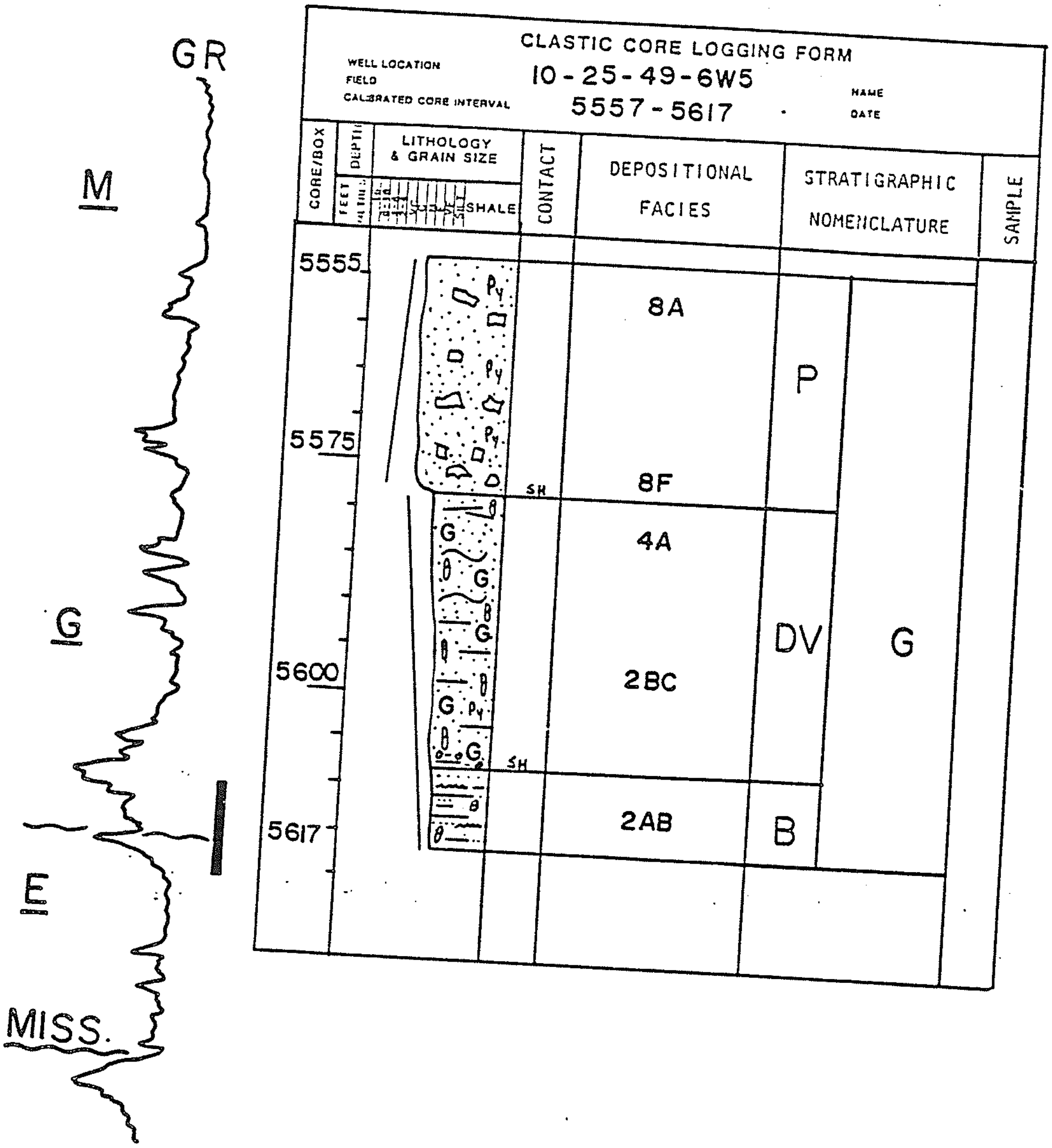
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
1724		Py	SH	7B	E	
			GR	7E		
			SH	7B		
			SH	7E		
1730		Py Py	SH	7A		
				7E 8AD		
1736						




CLASTIC CORE LOGGING FORM

WELL LOCATION 11-29-49-4W5
FIELD
CALIBRATED CORE INTERVAL 1722-39
NAME
DATE

CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	1722		SH	3		
			SH	6	E	
			SH	7C		
			SH	7A,9B		
	1730		SH	7A		
			CE	7A,9B		
				7A		
			SH	7E		
	1736			7A		



CLASTIC CORE LOGGING FORM

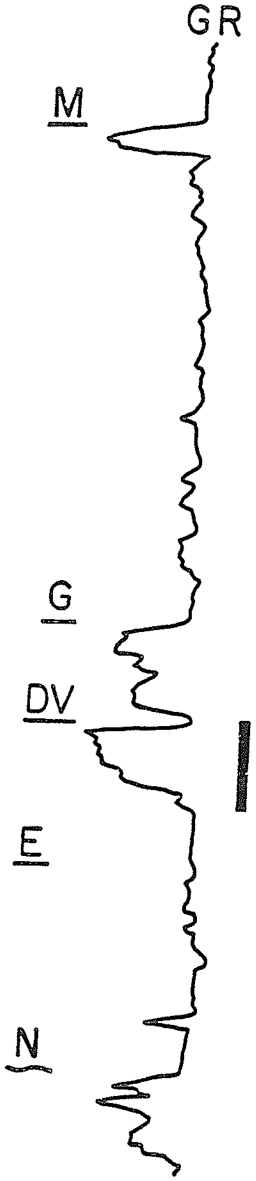
WELL LOCATION 10-25-49-6W5

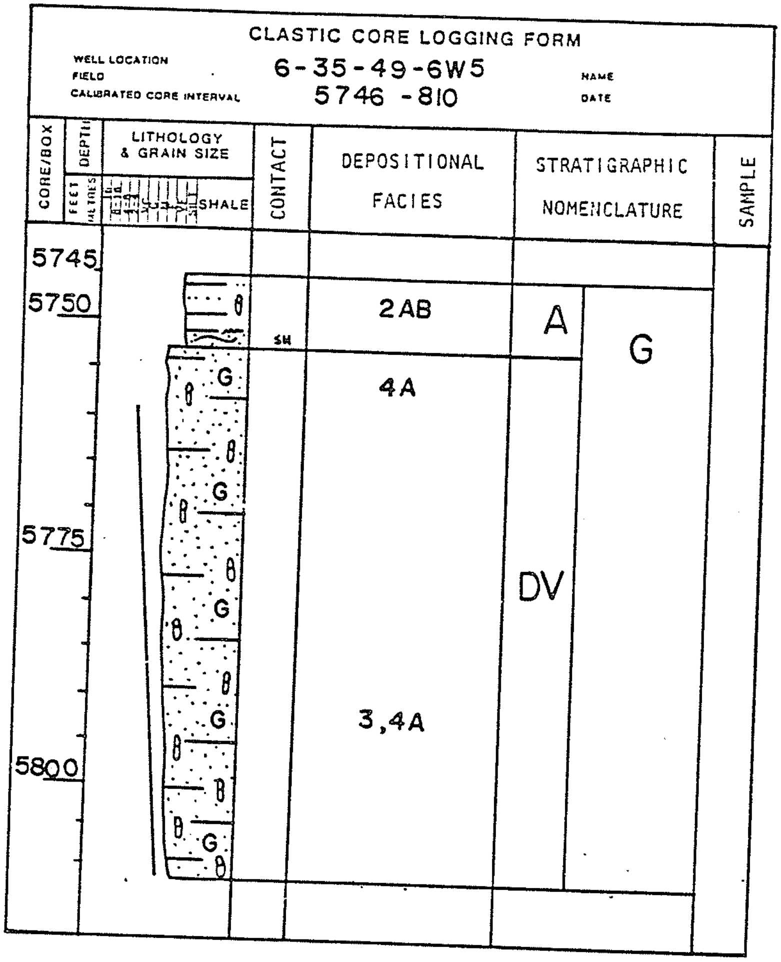
FIELD

CALIBRATED CORE INTERVAL 5557-5617

NAME

DATE

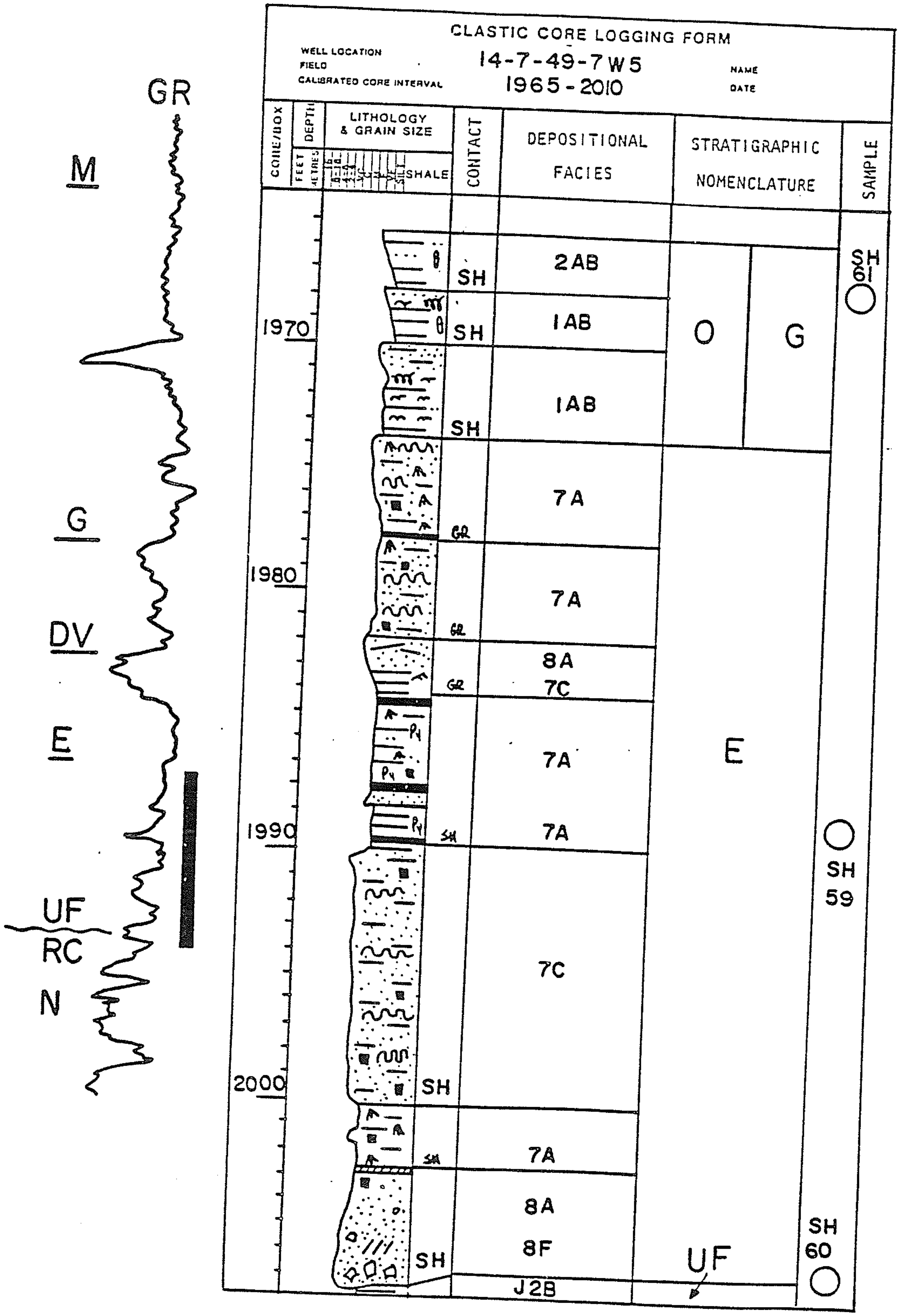


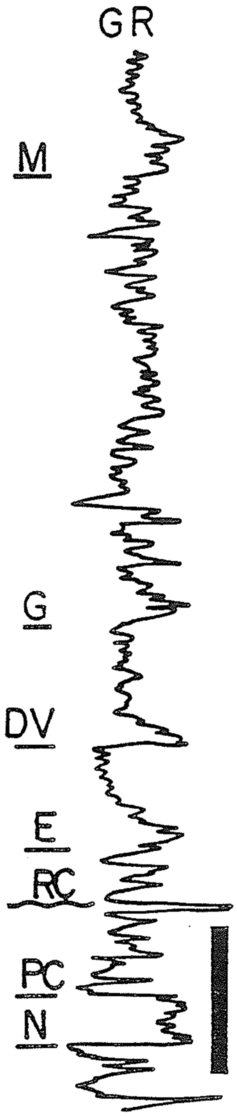


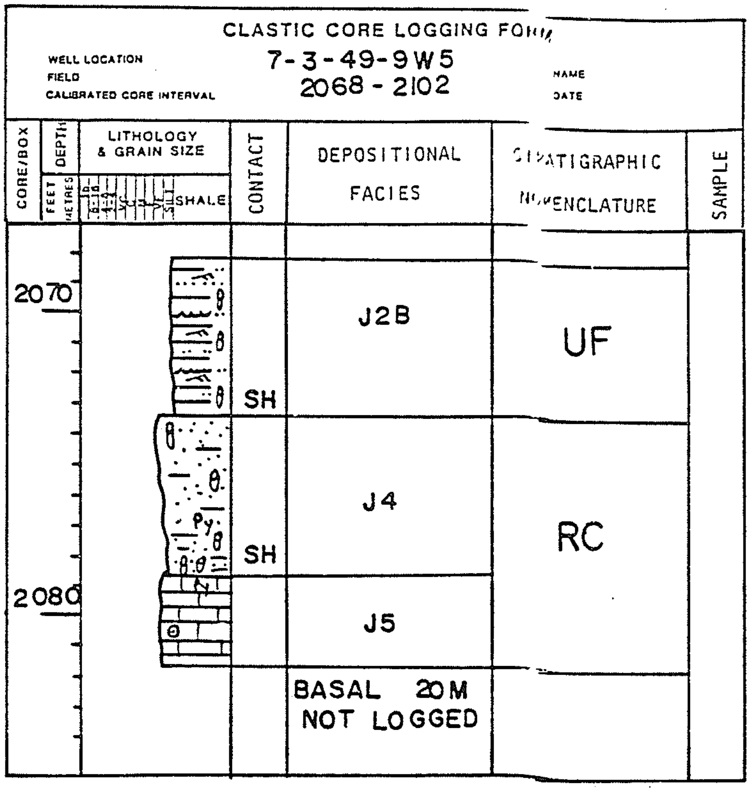
CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 6-35-49-6W5
CALIBRATED CORE INTERVAL 5746 -810
NAME
DATE

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	5745						
	5750		SH	2AB	A	G	
				4A	DV		
	5775						
	5800			3,4A			


GR
M
G
DV
E
UF
RC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
14-7-49-7W5
1965-2010
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1970
1980
1990
2000
SH
SH
SH
GR
GR
GR
SH
SH
SH
SH
2AB
1AB
1AB
7A
7A
8A
7C
7A
7A
7C
7A
8A
8F
J2B
O
G
E
UF
SH 61
SH 59
SH 60



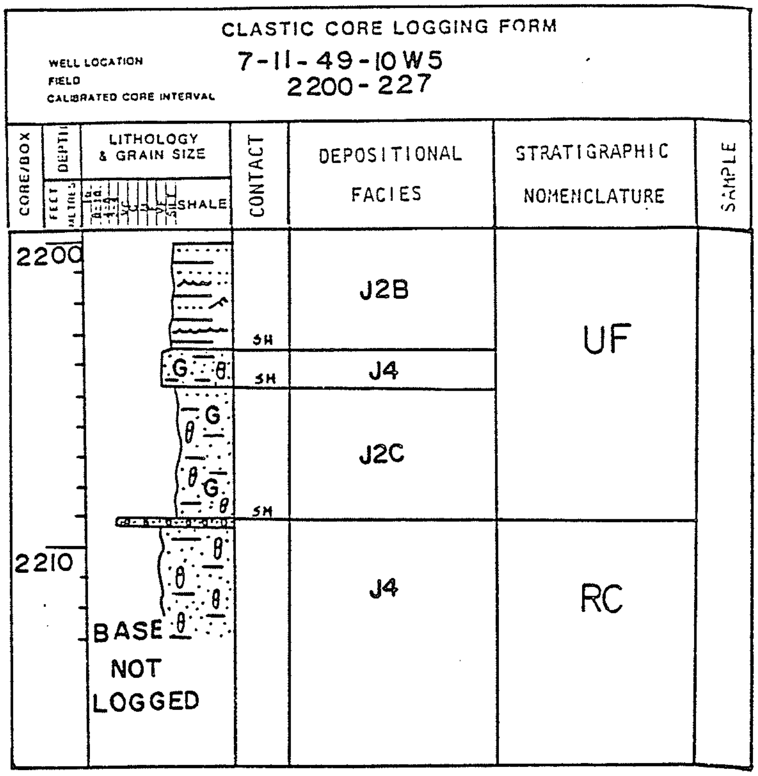


CLASTIC CORE LOGGING FOR

WELL LOCATION 7-3-49-9W5
FIELD
CALIBRATED CORE INTERVAL 2068 - 2102

NAME
DATE

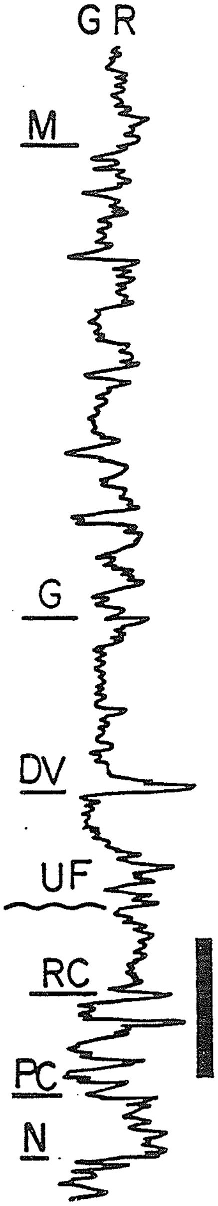
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2070		SH	J2B	UF	
			SH	J4	RC	
	2080			J5		
				BASAL 20M NOT LOGGED		

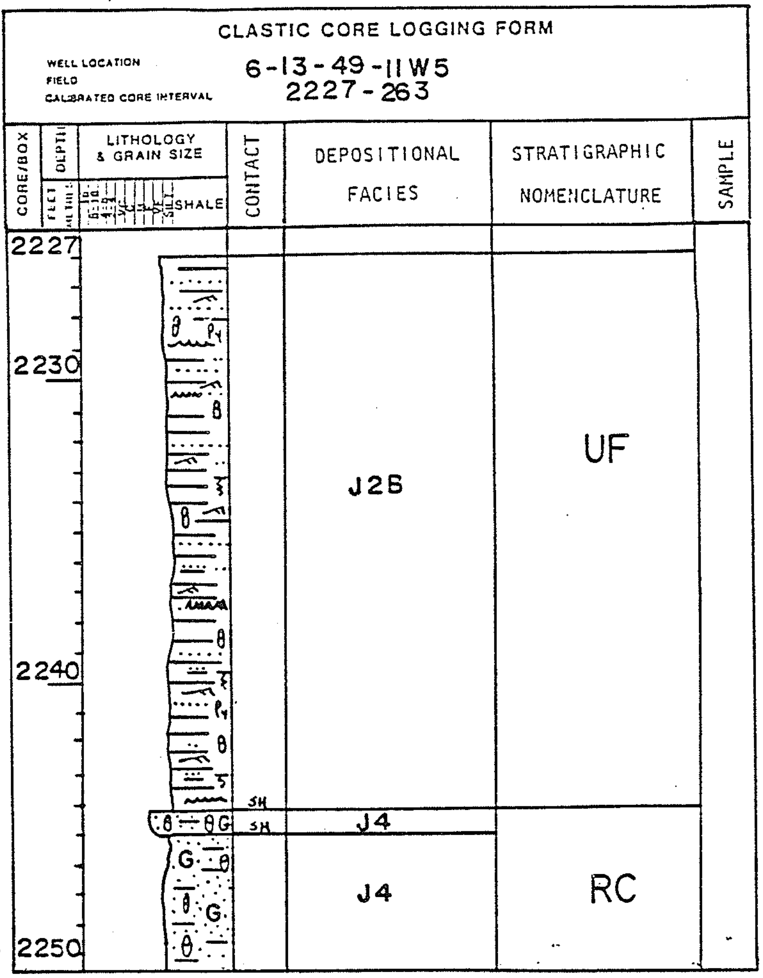


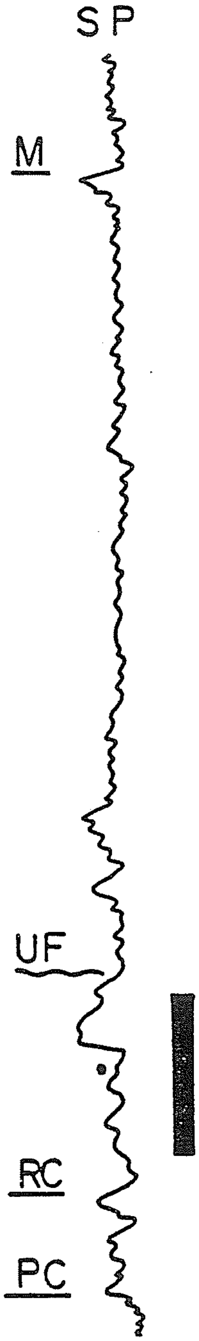
CLASTIC CORE LOGGING FORM

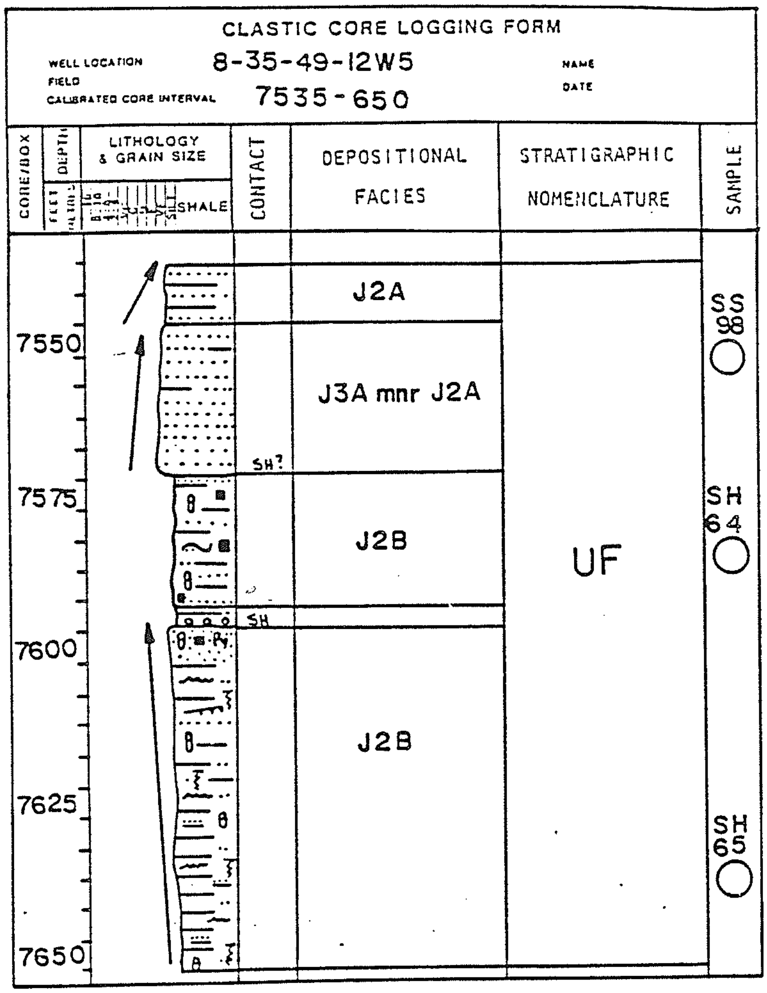
WELL LOCATION 7-11-49-10W5
FIELD
CALIBRATED CORE INTERVAL 2200-227

CORE/BOX	DEPTH FEET / METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2200		SH	J2B	UF	
		G θ	SH	J4		
		G θ G θ G θ	SH	J2C		
	2210	θ θ θ θ BASE NOT LOGGED		J4	RC	


GR
M
G
DV
UF
RC
PC
N


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-13-49-11W5
2227-263
CORE/BOX
DEPTH
FEET
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2227
2230
2240
2250
SH
SH
J2B
J4
J4
UF
RC

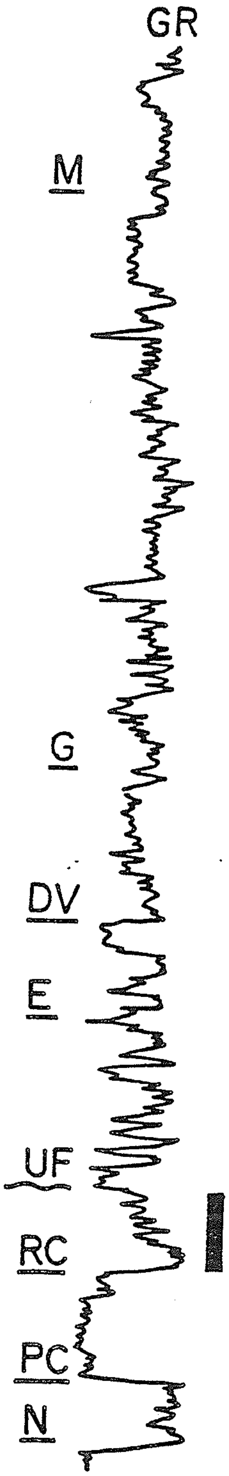


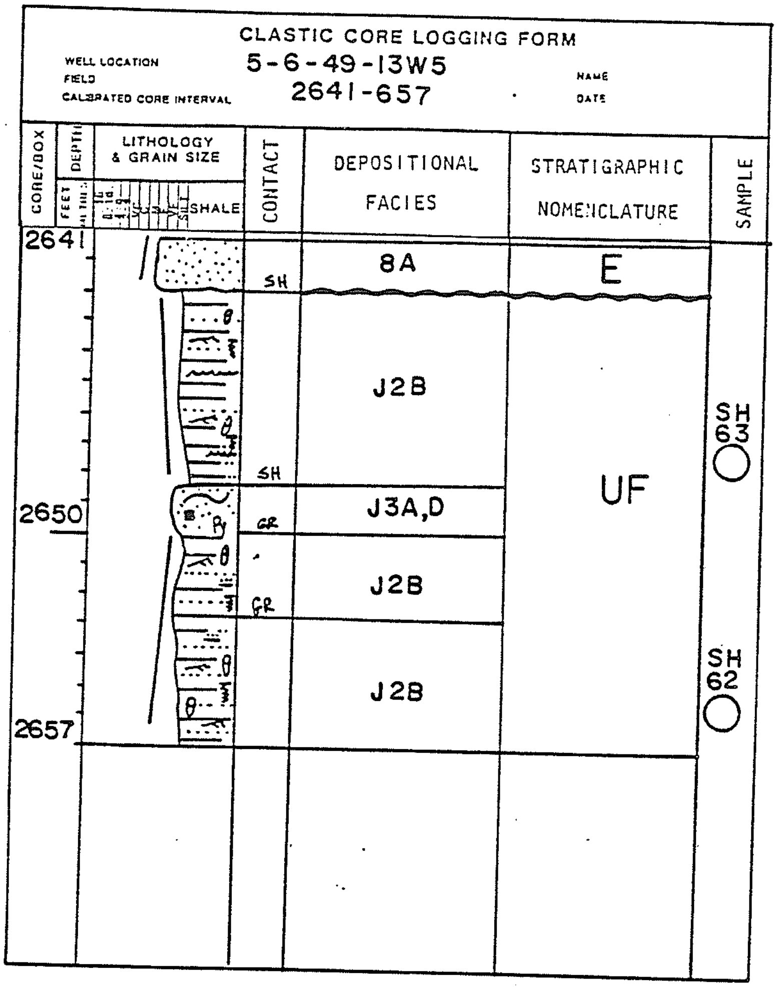


CLASTIC CORE LOGGING FORM

WELL LOCATION 8-35-49-12W5
FIELD
CALIBRATED CORE INTERVAL 7535-650
NAME
DATE

CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
				J2A	UF	SS 98
	7550		SH?	J3A mnr J2A		
	7575			J2B		SH 64
			SH			
	7600			J2B		
	7625					SH 65
	7650					

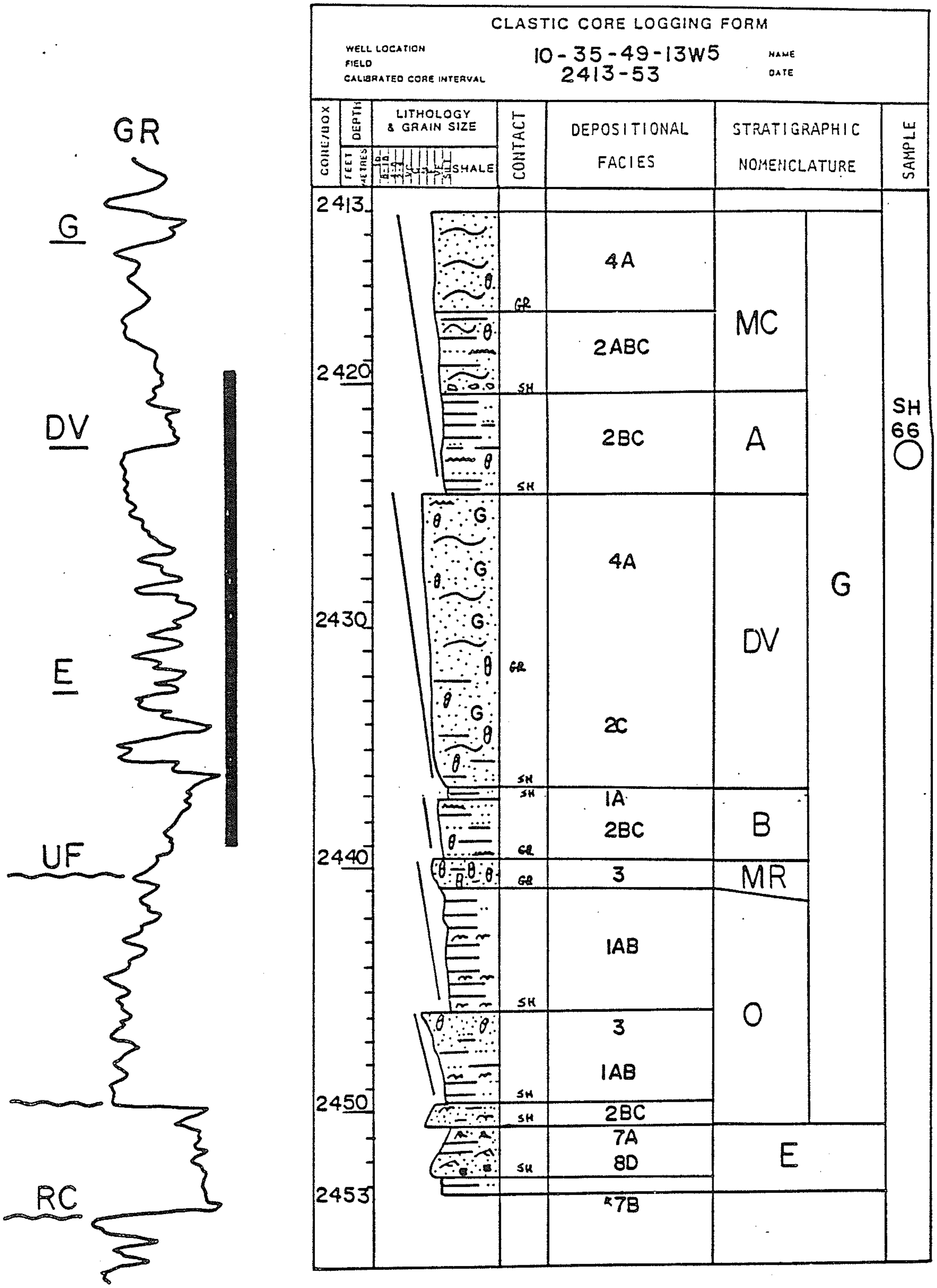




CLASTIC CORE LOGGING FORM

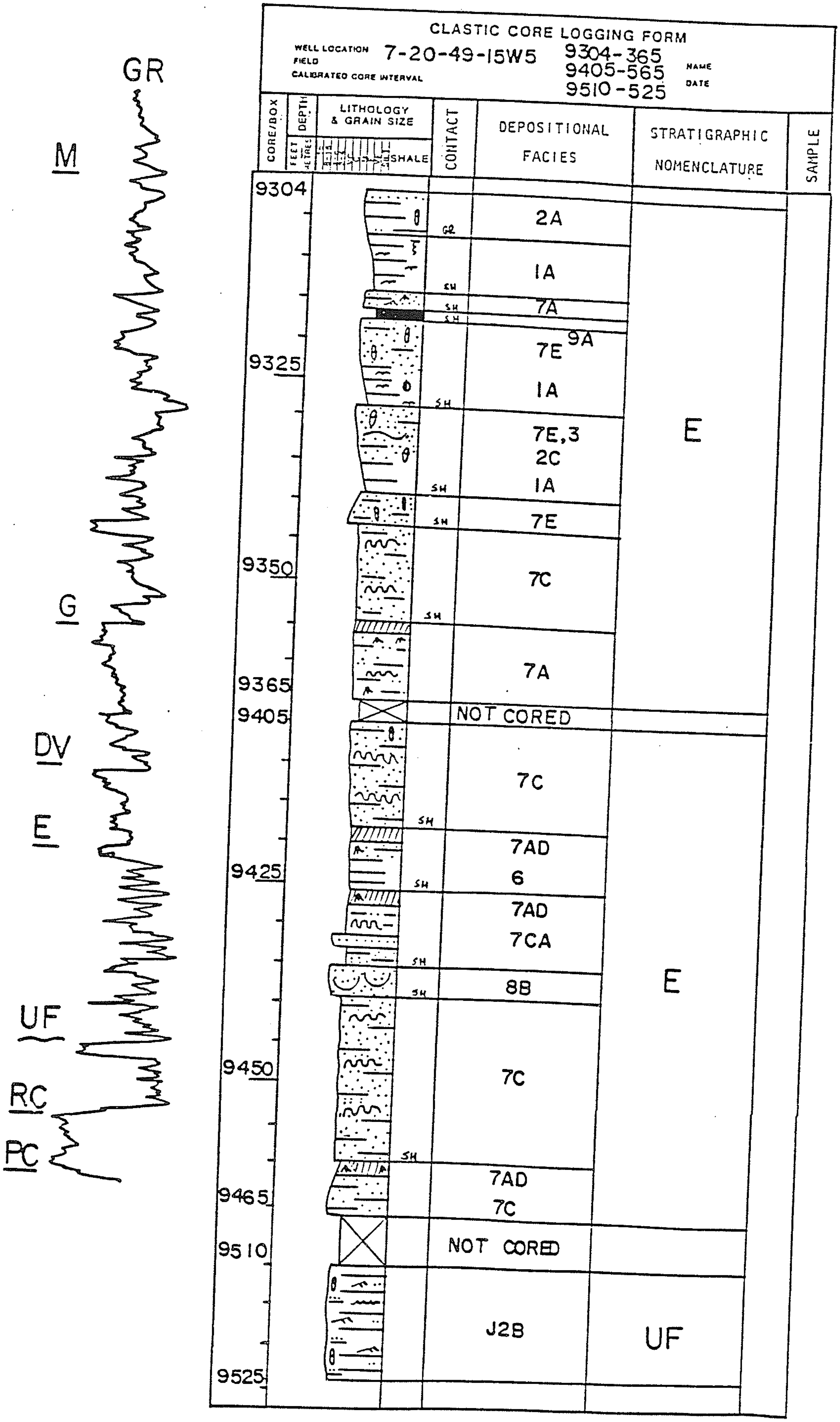
WELL LOCATION 5-6-49-13W5
FIELD
CALIBRATED CORE INTERVAL 2641-657
NAME
DATE

CORE/BOX	DEPTH FEET	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
2641			SH	8A	E	
			SH	J2B	UF	SH 63 ○
2650			GR	J3A,D		
			GR	J2B		
				J2B		SH 62 ○
2657						



CLASTIC CORE LOGGING FORM

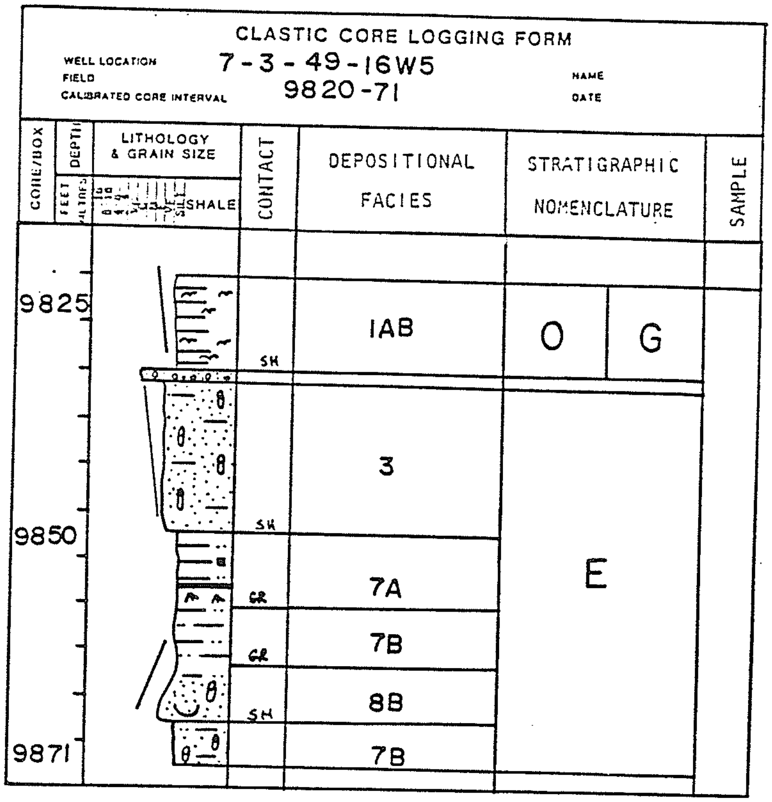
WELL LOCATION 10-35-49-13W5
FIELD
CALIBRATED CORE INTERVAL 2413-53
NAME
DATE



CLASTIC CORE LOGGING FORM

WELL LOCATION 7-20-49-15W5
FIELD
CALIBRATED CORE INTERVAL
9304-365
9405-565
9510-525
NAME
DATE

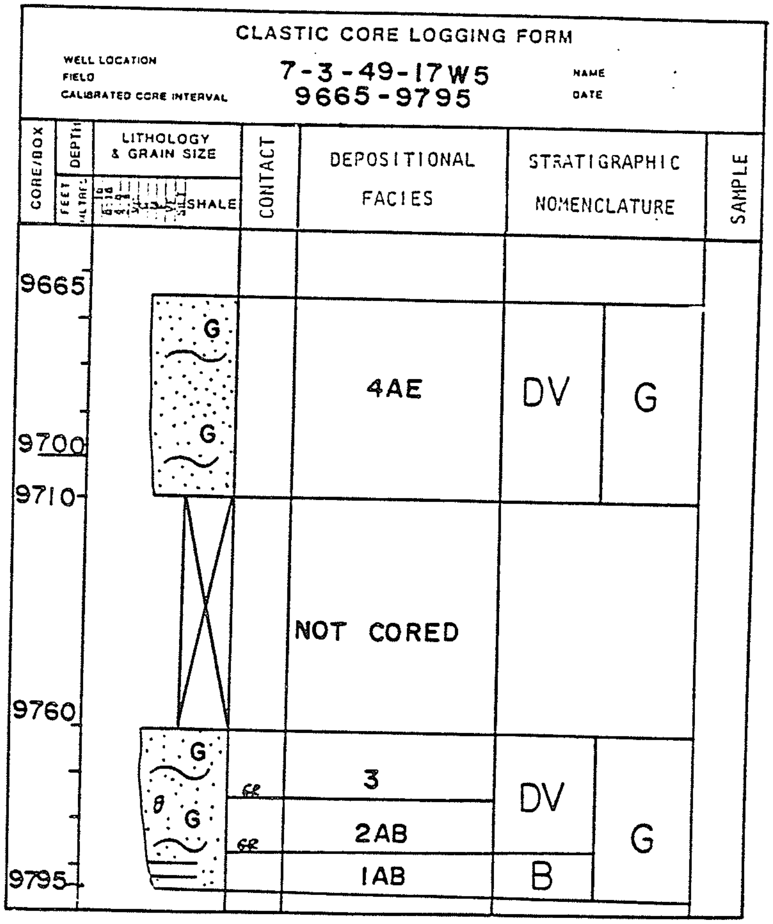
LOG NA



CLASTIC CORE LOGGING FORM

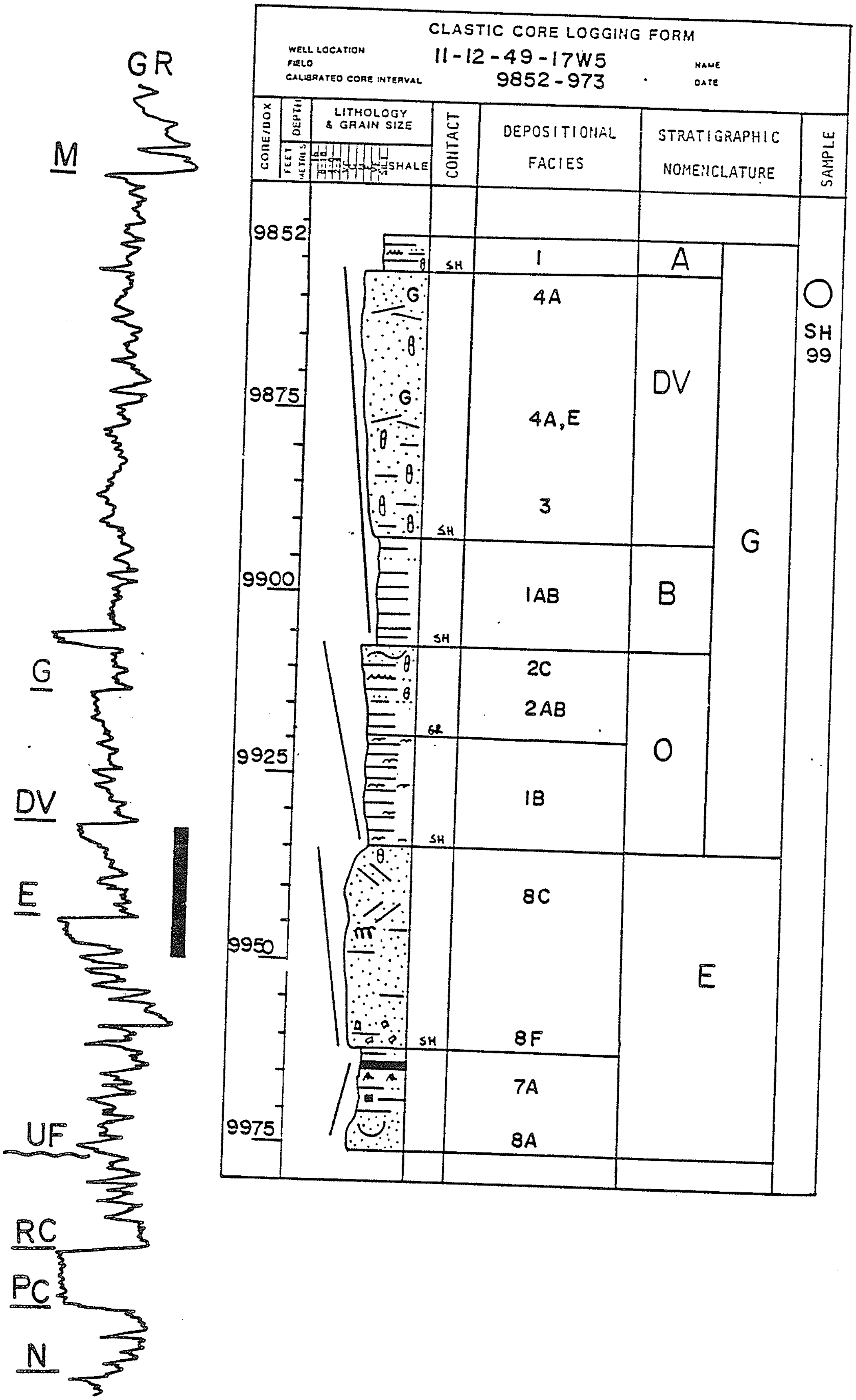
WELL LOCATION 7-3-49-16W5
FIELD
CALIBRATED CORE INTERVAL 9820-71
NAME
DATE

LOG NA



CLASTIC CORE LOGGING FORM

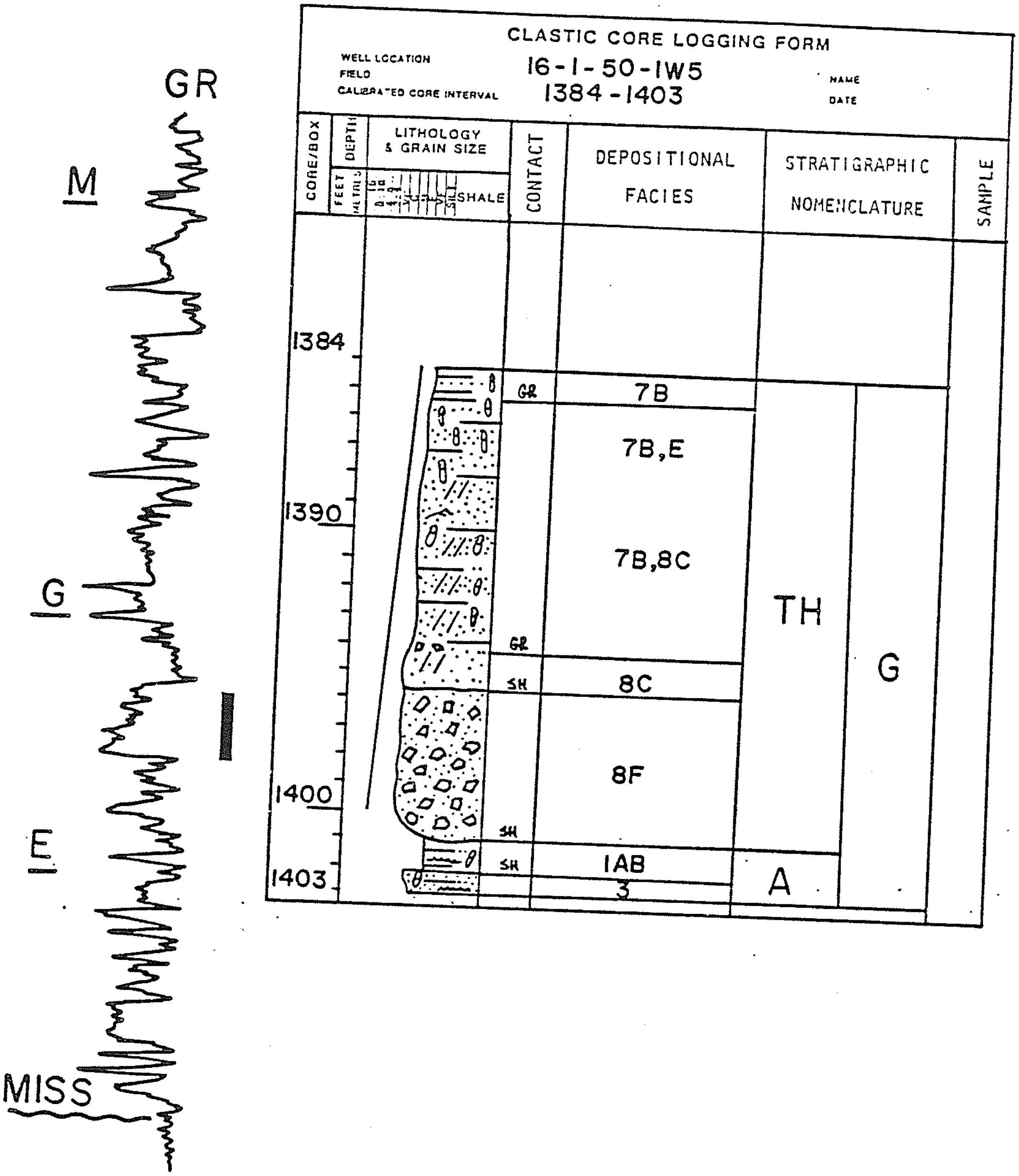
WELL LOCATION 7-3-49-17W5
FIELD
CALIBRATED CORE INTERVAL 9665-9795
NAME
DATE



CLASTIC CORE LOGGING FORM

WELL LOCATION 11-12-49-17W5
FIELD
CALIBRATED CORE INTERVAL 9852-973
NAME
DATE

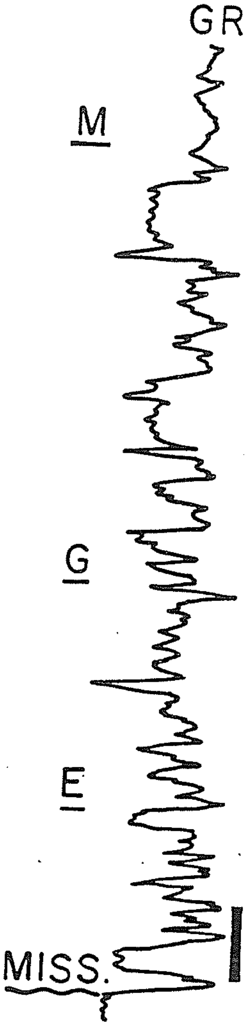
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	9852		SH	1	A	G	○ SH 99
				4A 4A,E 3	DV		
	9900		SH	1AB	B		
			SH	2C 2AB	O		
	9925		GR	1B			
	9950		SH	8C 8F	E		
	9975		SH	7A 8A			

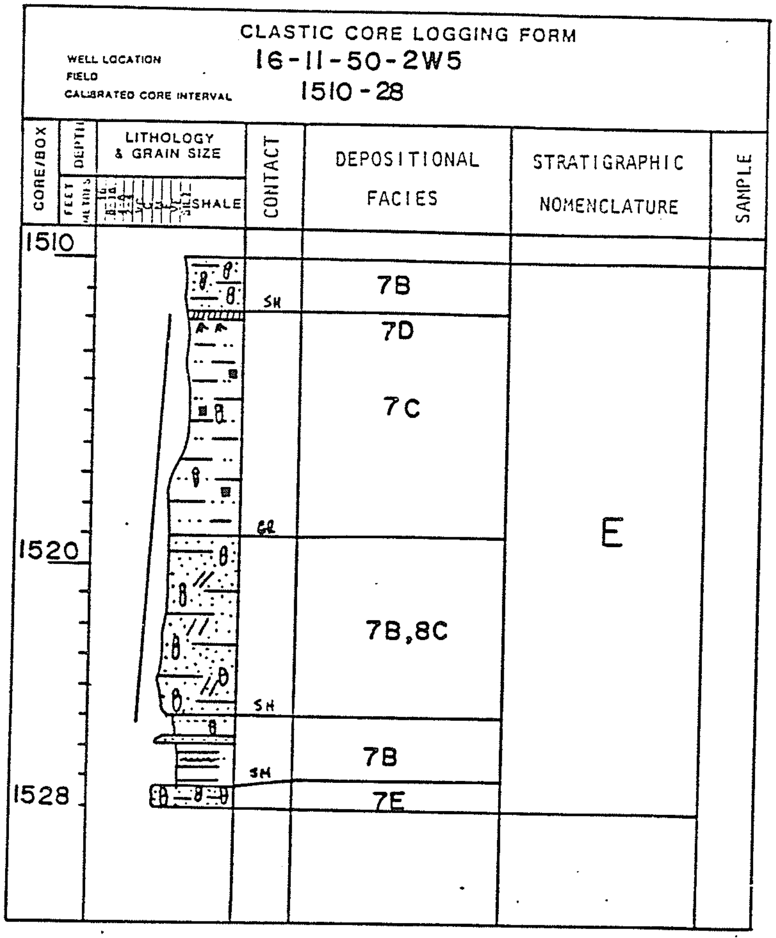


CLASTIC CORE LOGGING FORM

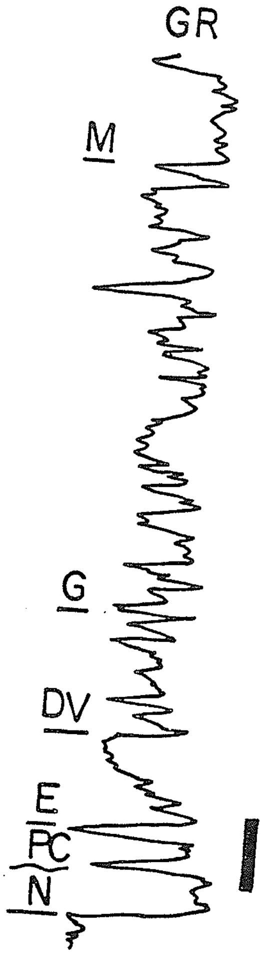
WELL LOCATION
FIELD 16-1-50-1W5
CALIBRATED CORE INTERVAL 1384-1403
NAME
DATE

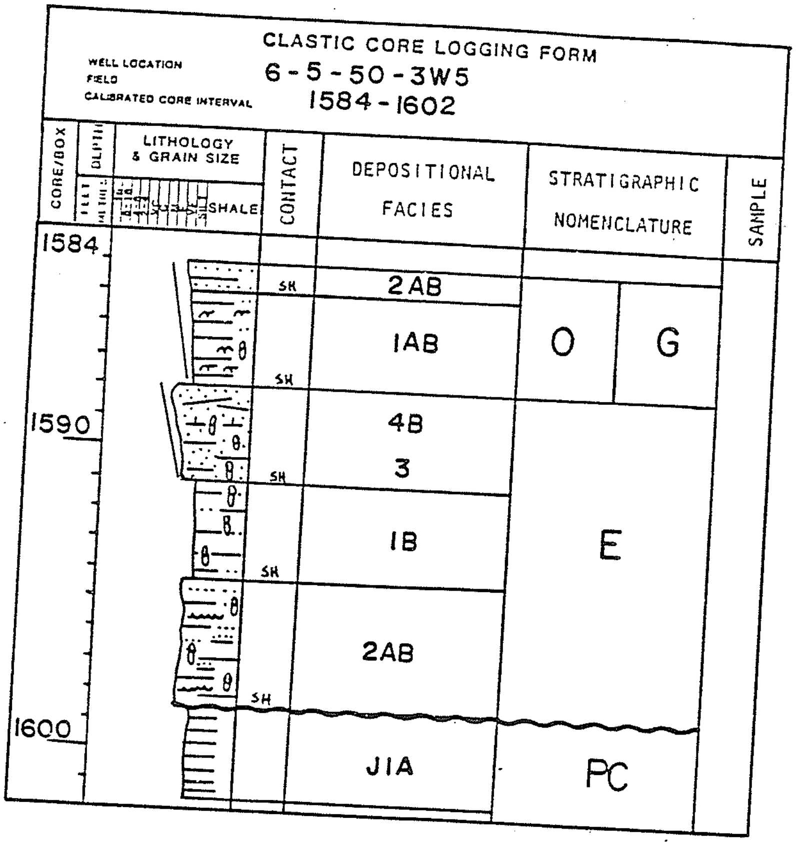
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1384		GR	7B	TH	G	
				7B,E			
	1390			7B,8C			
			GR				
			SH	8C			
	1400			8F			
			SH				
	1403		SH	1AB	A		
				3			




CLASTIC CORE LOGGING FORM

WELL LOCATION 16-11-50-2W5
FIELD
CALIBRATED CORE INTERVAL 1510-28

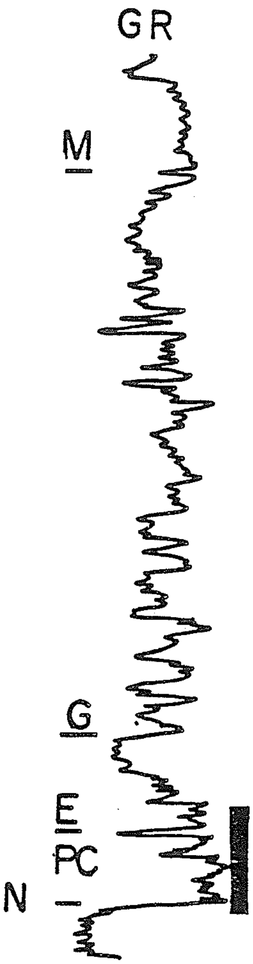


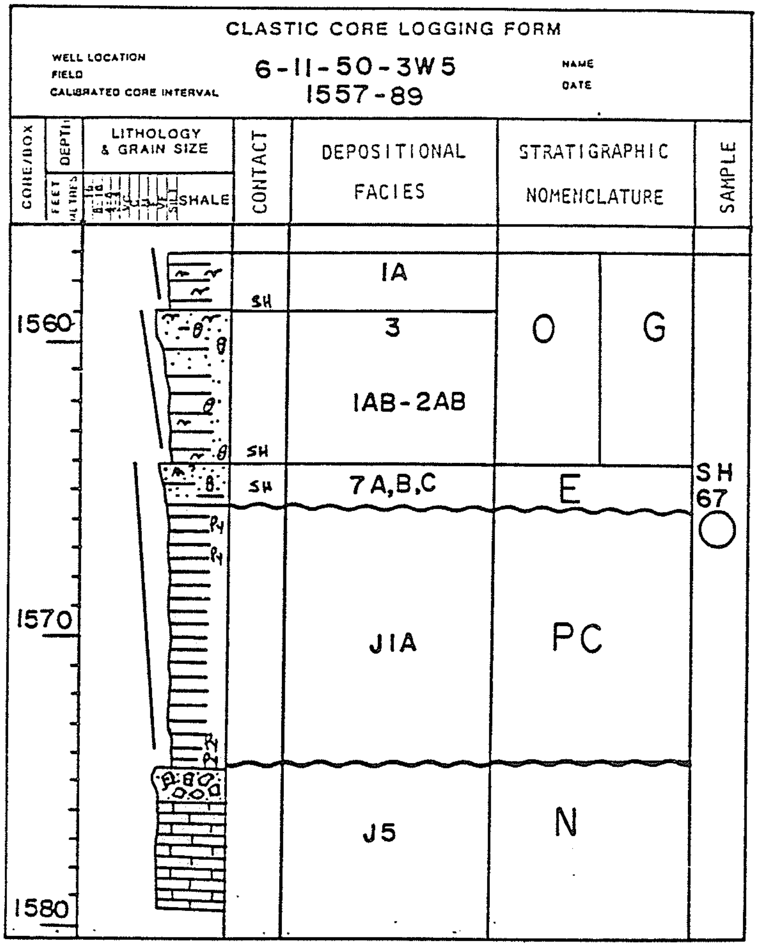


CLASTIC CORE LOGGING FORM

WELL LOCATION 6-5-50-3W5
FIELD
CALIBRATED CORE INTERVAL 1584-1602

DEPTH	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	
1584	SH	2AB		
	SH	1AB	O	G
1590	SH	4B 3	E	
	SH	1B		
	SH	2AB		
1600		J1A	PC	



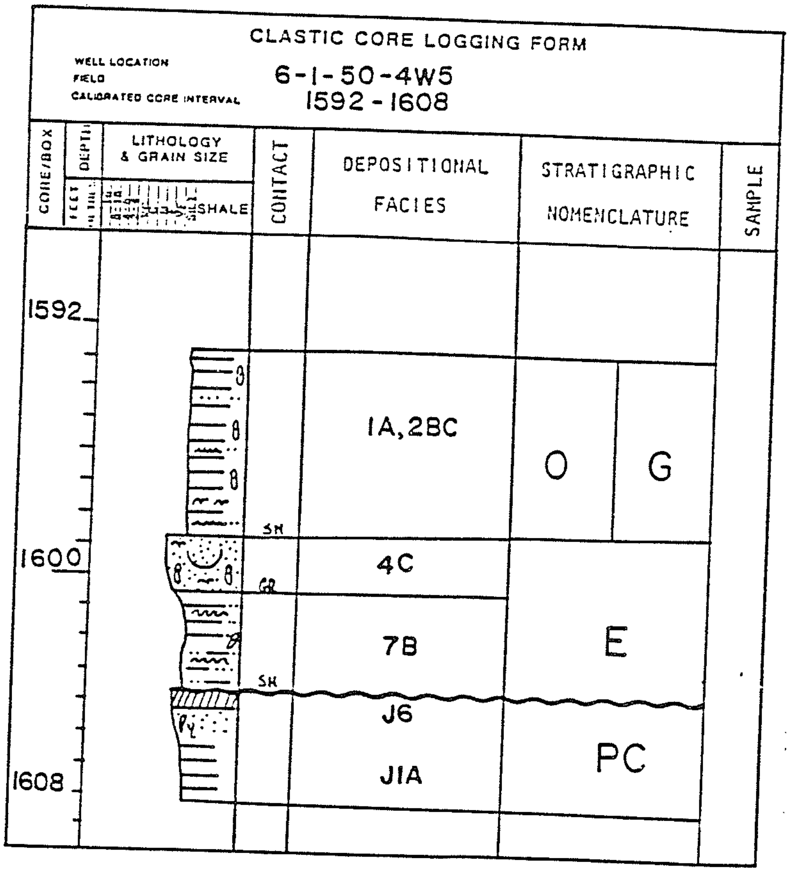


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 6-11-50-3W5
CALIBRATED CORE INTERVAL 1557-89

NAME
DATE

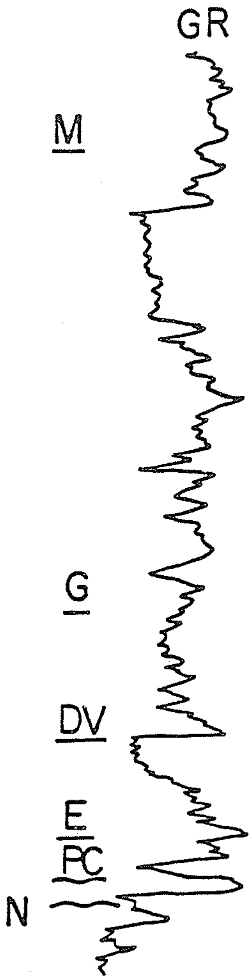
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
			SH	IA	O	G	
	1560		SH	3 IAB-2AB			
			SH	7A,B,C	E		SH 67 ○
	1570			JIA	PC		
	1580			J5	N		

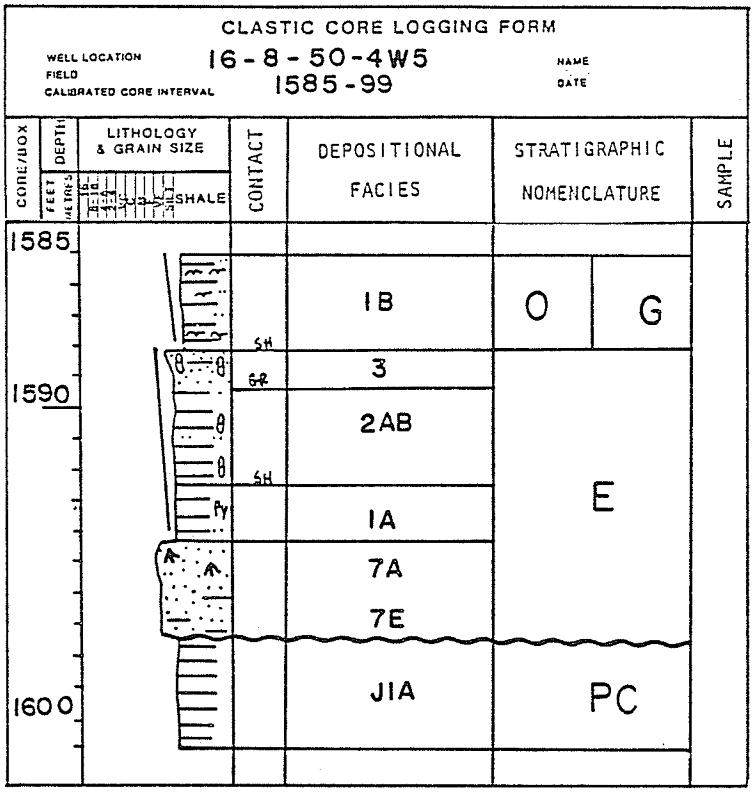


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 6-1-50-4W5
CALIBRATED CORE INTERVAL 1592 - 1608

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1592		SH	IA,2BC	O	G	
	1600		GR	4C	E		
			SH	7B			
				J6	PC		
	1608			JIA			





CLASTIC CORE LOGGING FORM

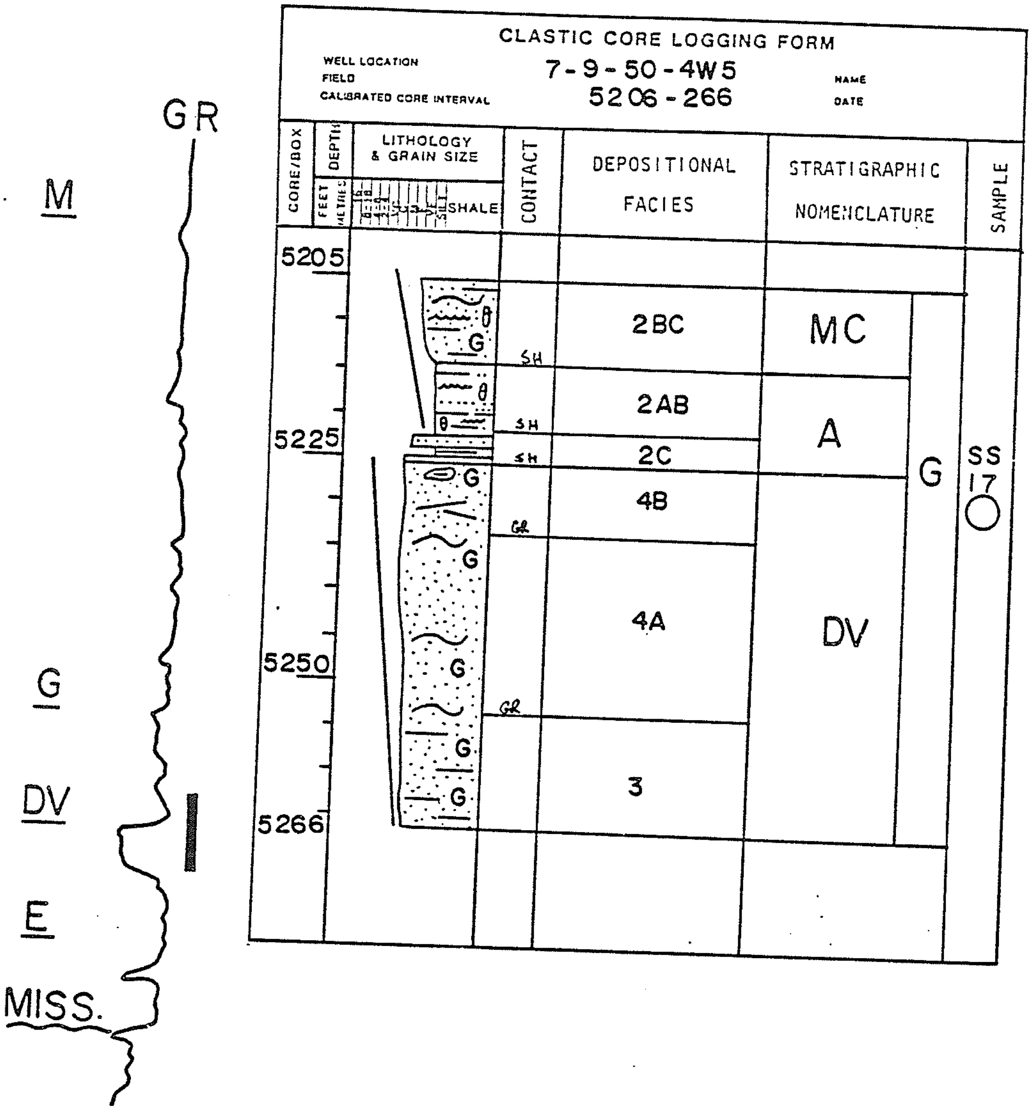
WELL LOCATION 16-8-50-4W5

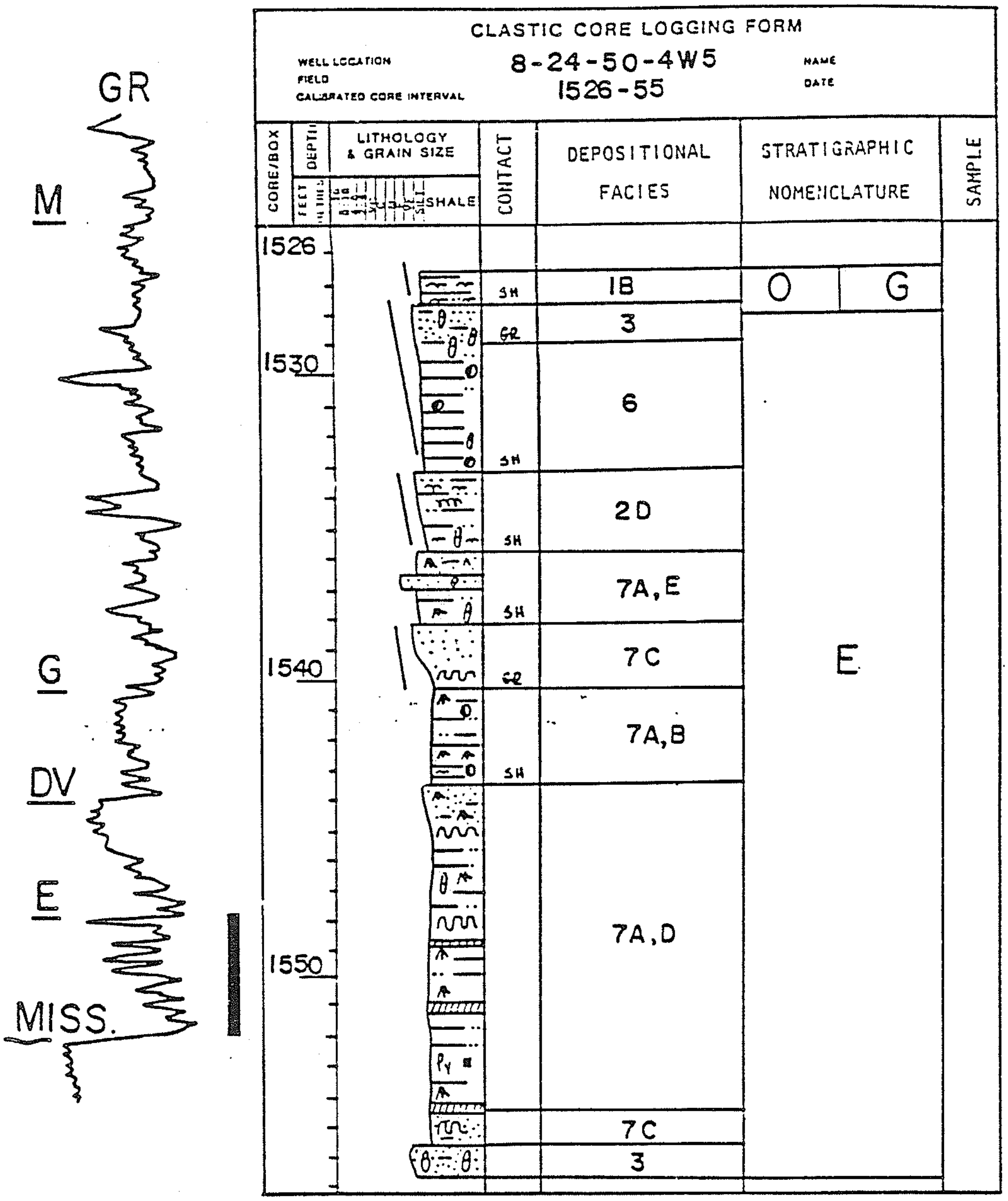
FIELD

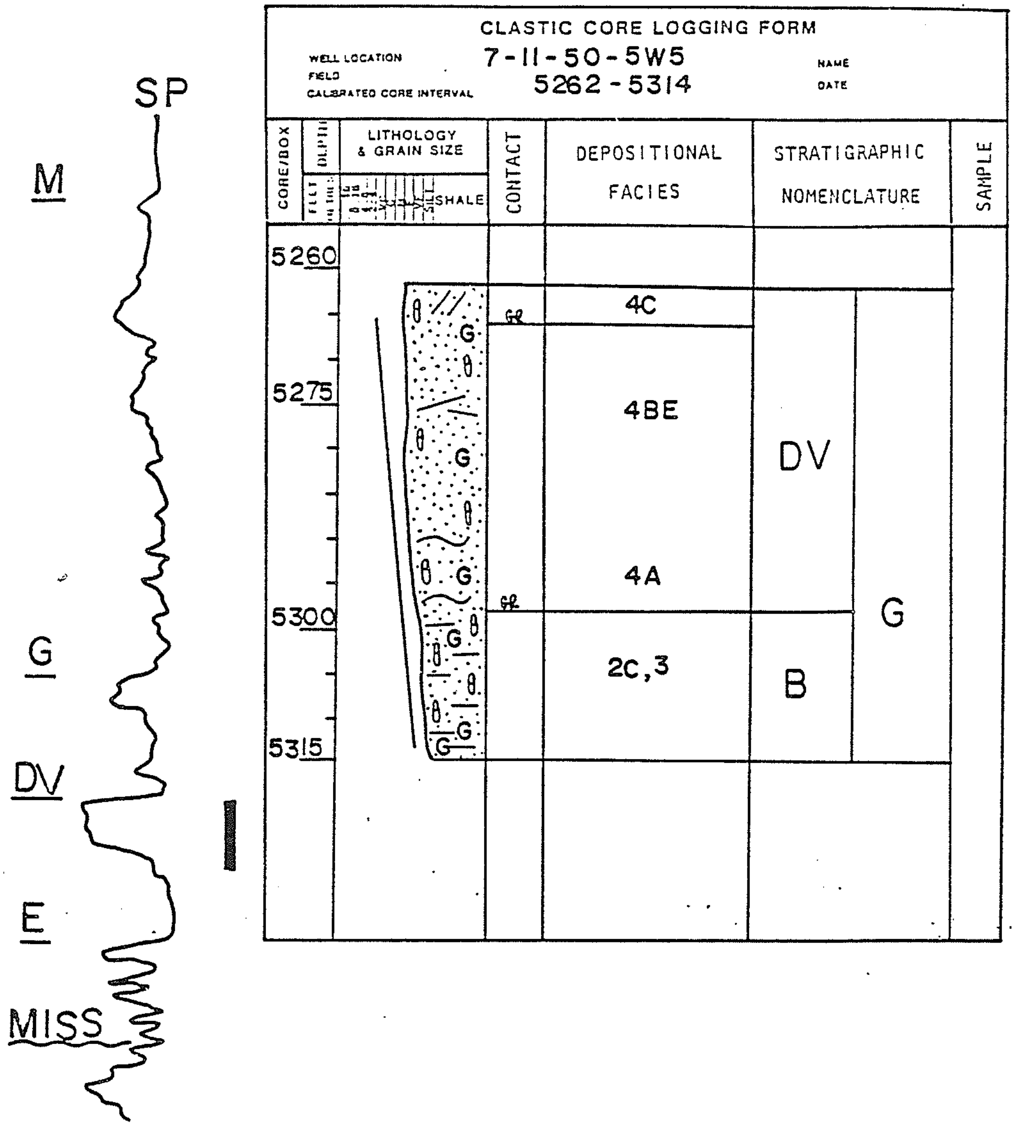
CALIBRATED CORE INTERVAL 1585-99

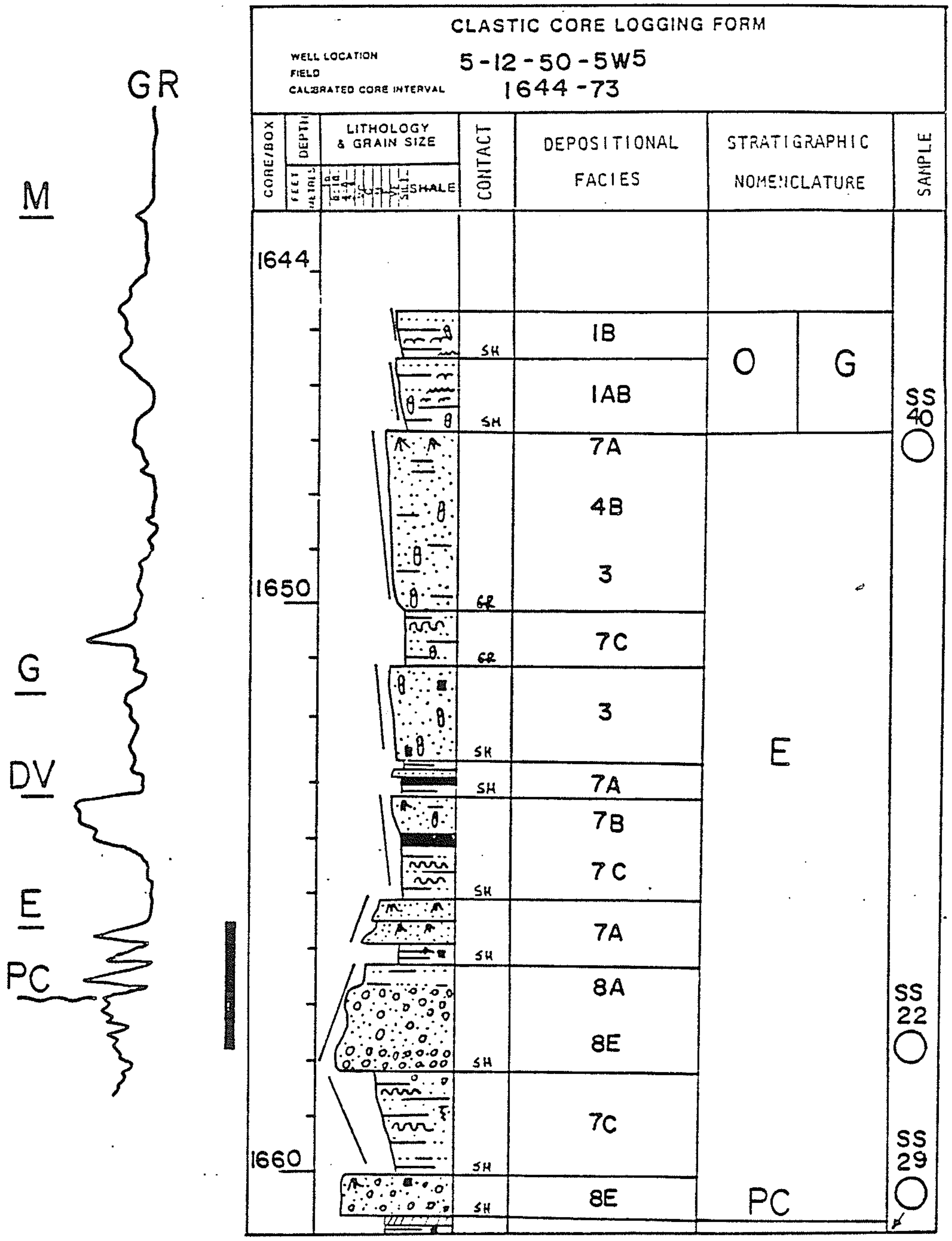
NAME

DATE


GR
M
G
DV
E
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
7-9-50-4W5
5206-266
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SILT
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
5205
5225
5250
5266
SH
SH
SH
GR
GR
2BC
2AB
2C
4B
4A
3
MC
A
DV
G
SS 17

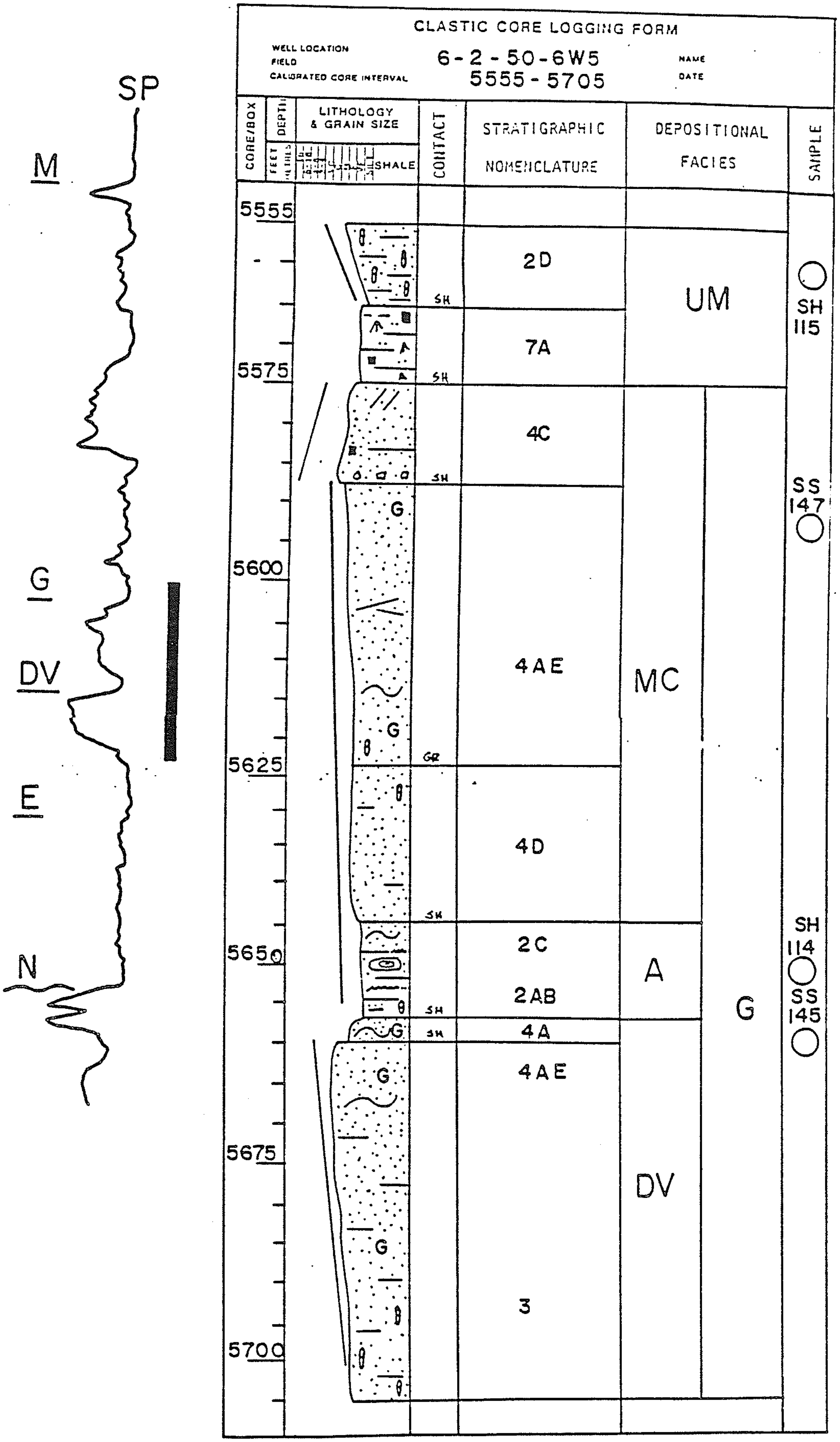

CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
8-24-50-4W5
1526-55
NAME
DATE
GR
M
G
DV
E
MISS.
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1526
1530
1540
1550
SH
GR
SH
SH
SH
GR
SH
1B
3
6
2D
7A, E
7C
7A, B
7A, D
7C
3
O
G
E

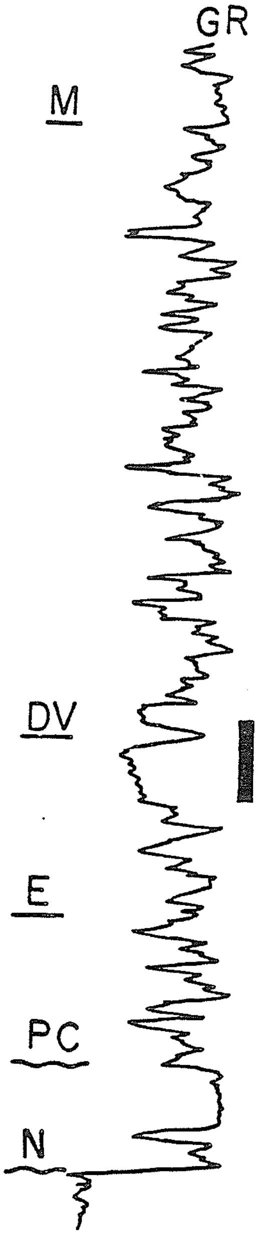

SP
M
G
DV
E
MISS
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
7-11-50-5W5
5262 - 5314
NAME
DATE
CORE/BOX
FEET
DEPTH
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
5260
5275
5300
5315
G
4C
4BE
4A
2C,3
DV
B
G

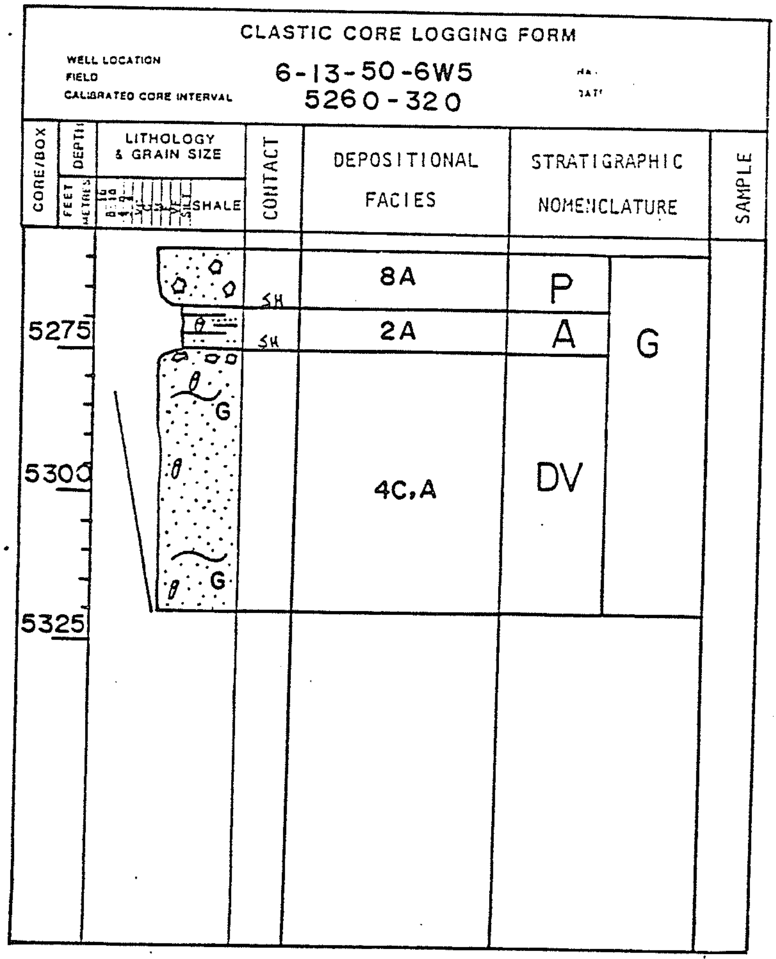


CLASTIC CORE LOGGING FORM

WELL LOCATION 5-12-50-5W5
FIELD
CALIBRATED CORE INTERVAL 1644-73


SP
M
G
DV
E
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-2-50-6W5
5555-5705
NAME
DATE
CORE/BOX
FEET
METRES
DEPTH
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
STRATIGRAPHIC NOMENCLATURE
DEPOSITIONAL FACIES
SAMPLE
5555
5575
5600
5625
5650
5675
5700
SH
SH
SH
GR
SH
SH
SH
2D
7A
4C
4AE
4D
2C
2AB
4A
4AE
3
UM
MC
A
DV
G
SH 115
SS 147
SH 114
SS 145

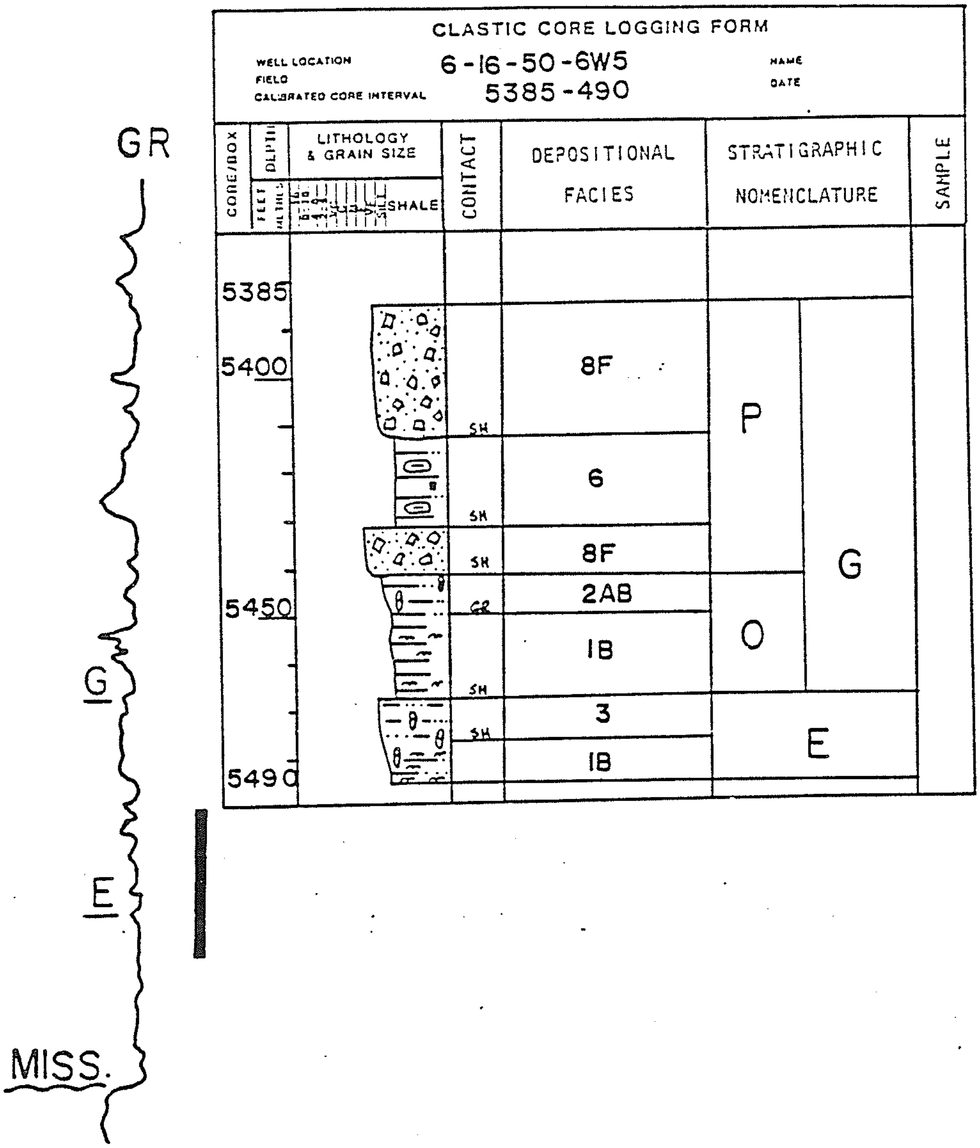


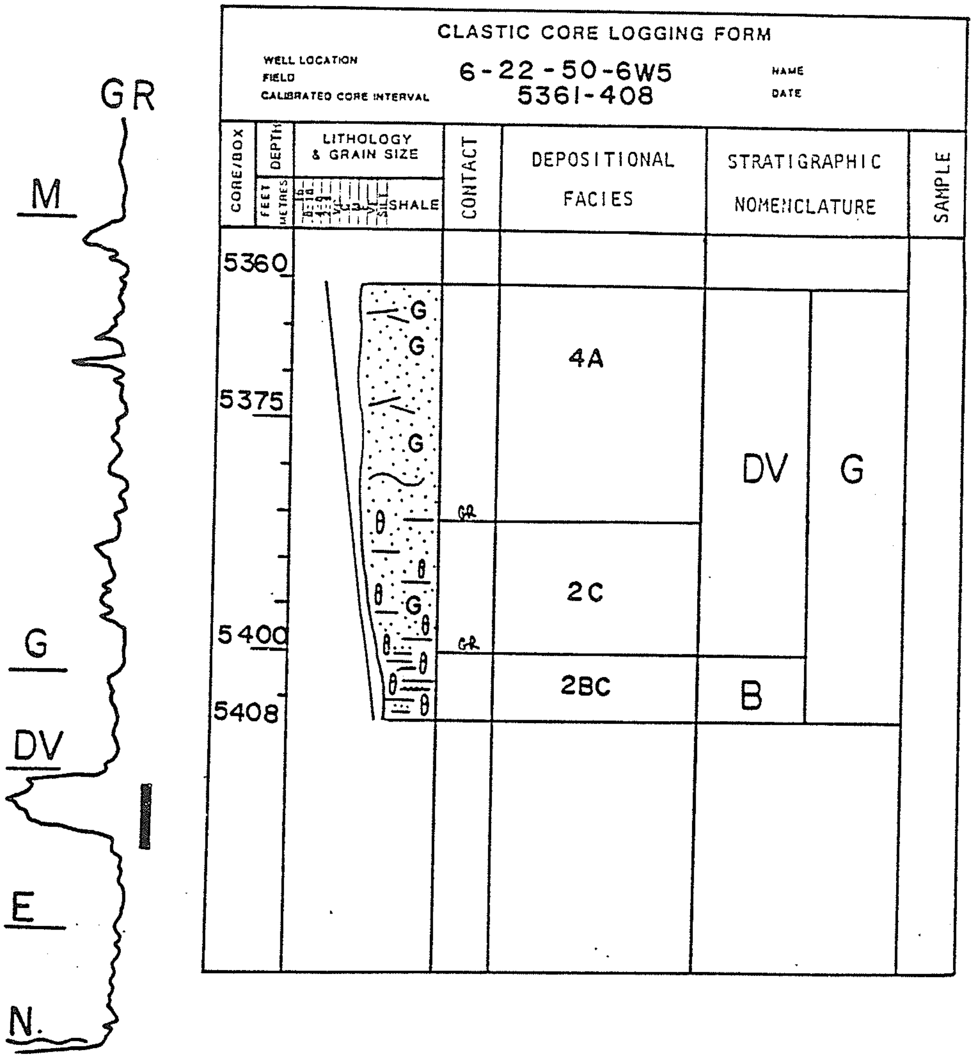


CLASTIC CORE LOGGING FORM

WELL LOCATION 6-13-50-6W5
FIELD
CALIBRATED CORE INTERVAL 5260-320

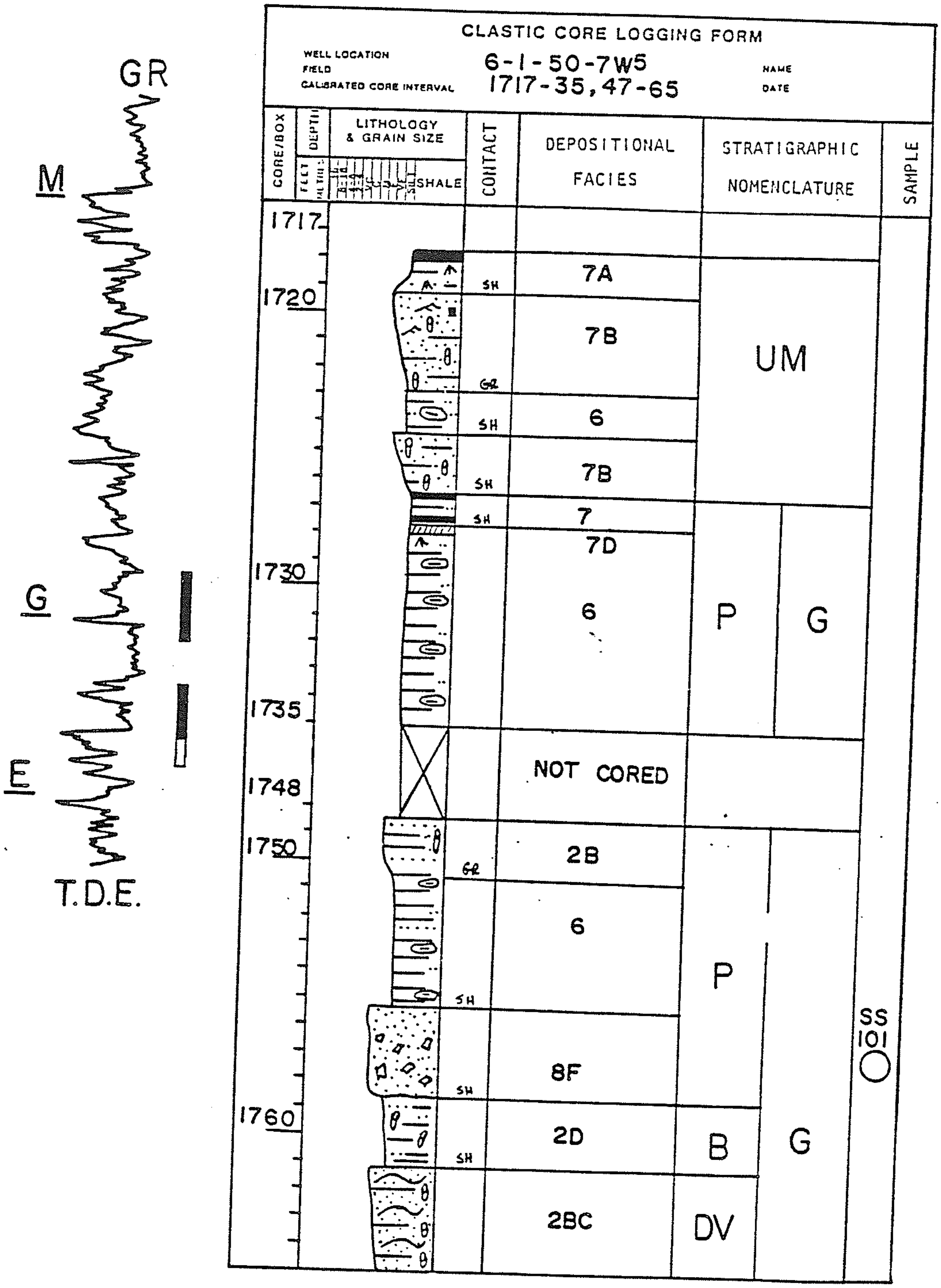
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
			SH	8A	P	G	
	5275		SH	2A	A		
	5300	G G		4C,A	DV		
	5325						


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-16-50-6W5
5385-490
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
5385
5400
5450
5490
SH
SH
SH
GR
SH
SH
8F
6
8F
2AB
1B
3
1B
P
O
G
E
GR
G
E
MISS.



CLASTIC CORE LOGGING FORM

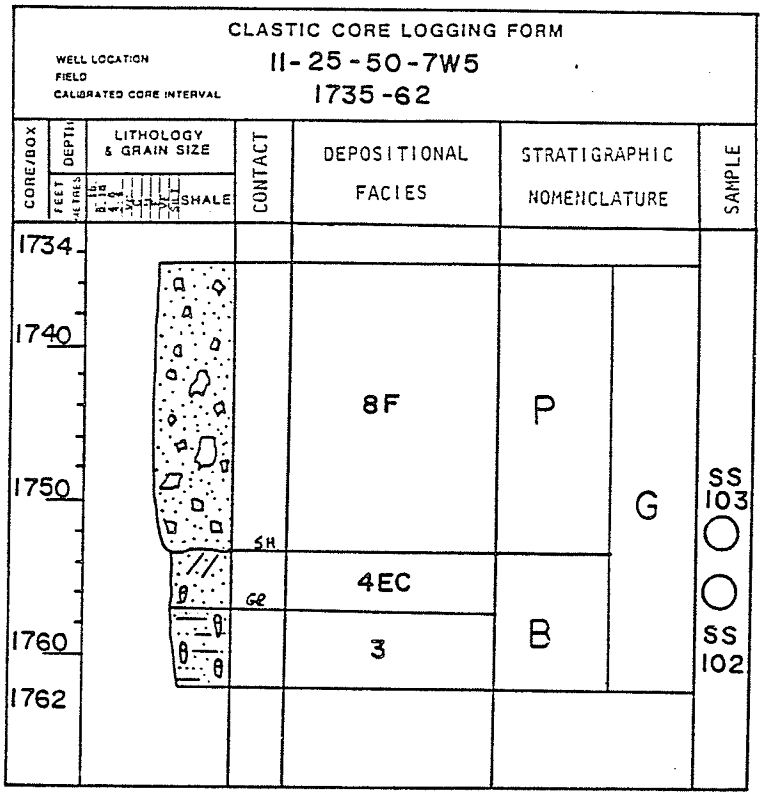
WELL LOCATION
FIELD 6-22-50-6W5
CALIBRATED CORE INTERVAL 5361-408
NAME
DATE



CLASTIC CORE LOGGING FORM

WELL LOCATION 6-1-50-7W5
FIELD
CALIBRATED CORE INTERVAL 1717-35,47-65
NAME
DATE

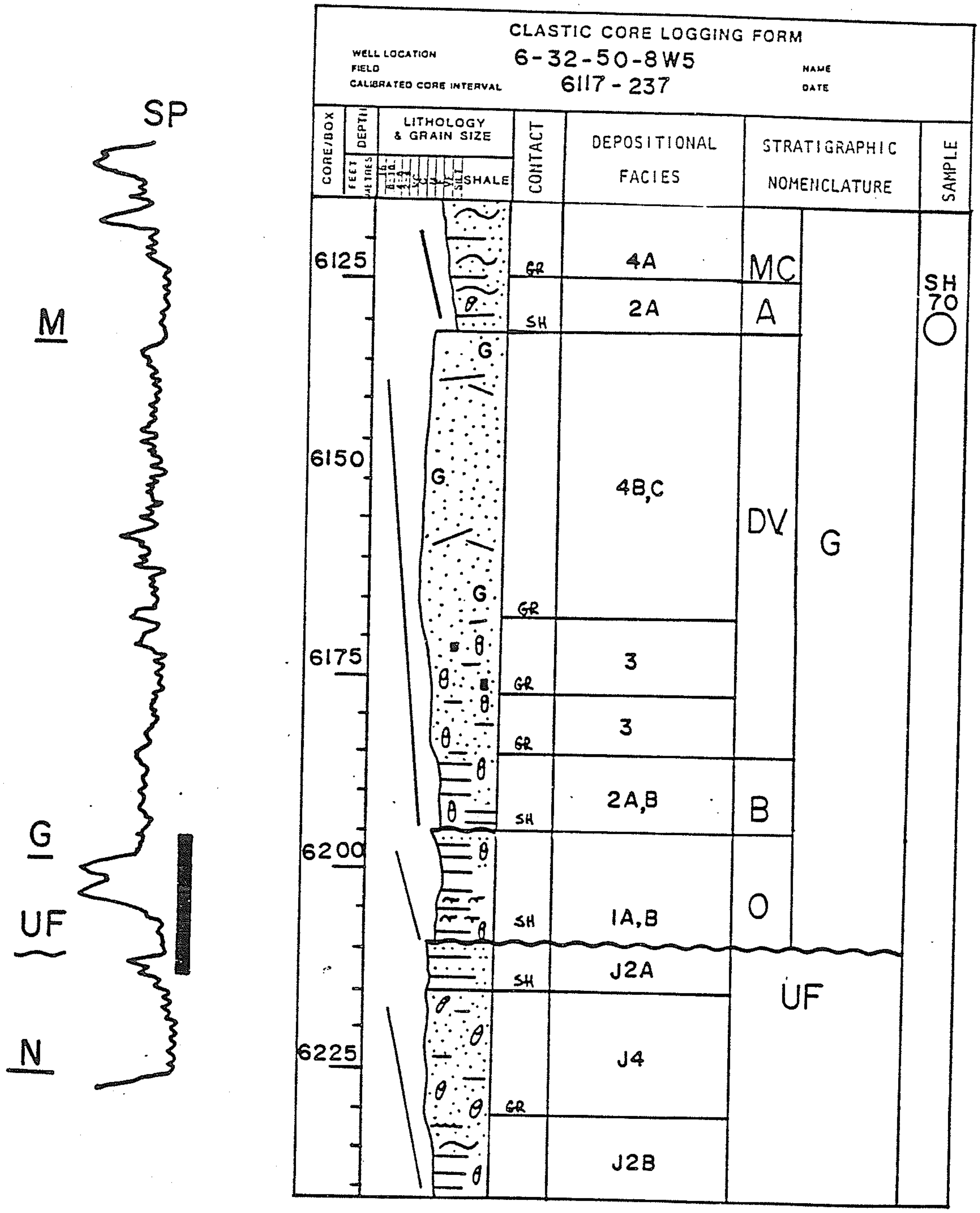
CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
SH	7A	UM		
GR	7B			
SH	6			
SH	7B			
SH	7	P	G	
	7D 6			
	NOT CORED			
GR	2B	P	G	
SH	6			
SH	8F			SS 101 ○
SH	2D	B		
	2BC	DV		



CLASTIC CORE LOGGING FORM

WELL LOCATION 11-25-50-7W5
FIELD
CALIBRATED CORE INTERVAL 1735-62

CORE/BOX	DEPTH FEET	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	1734						
	1740			8F	P	G	SS 103
	1750		SH				
			GR	4EC	B		
	1760			3			SS 102
	1762						



CLASTIC CORE LOGGING FORM

WELL LOCATION 6-32-50-8W5

FIELD

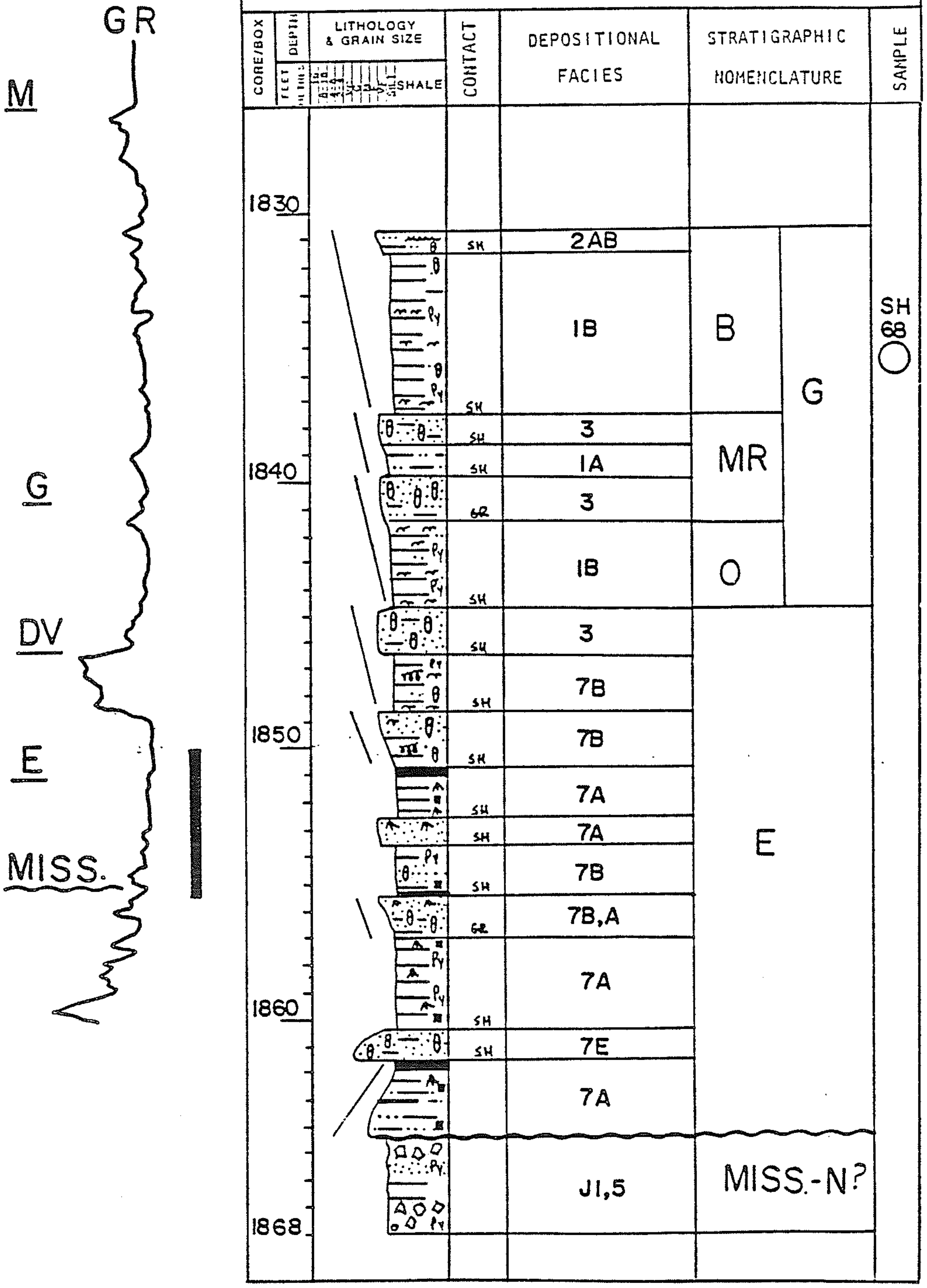
CALIBRATED CORE INTERVAL 6117 - 237

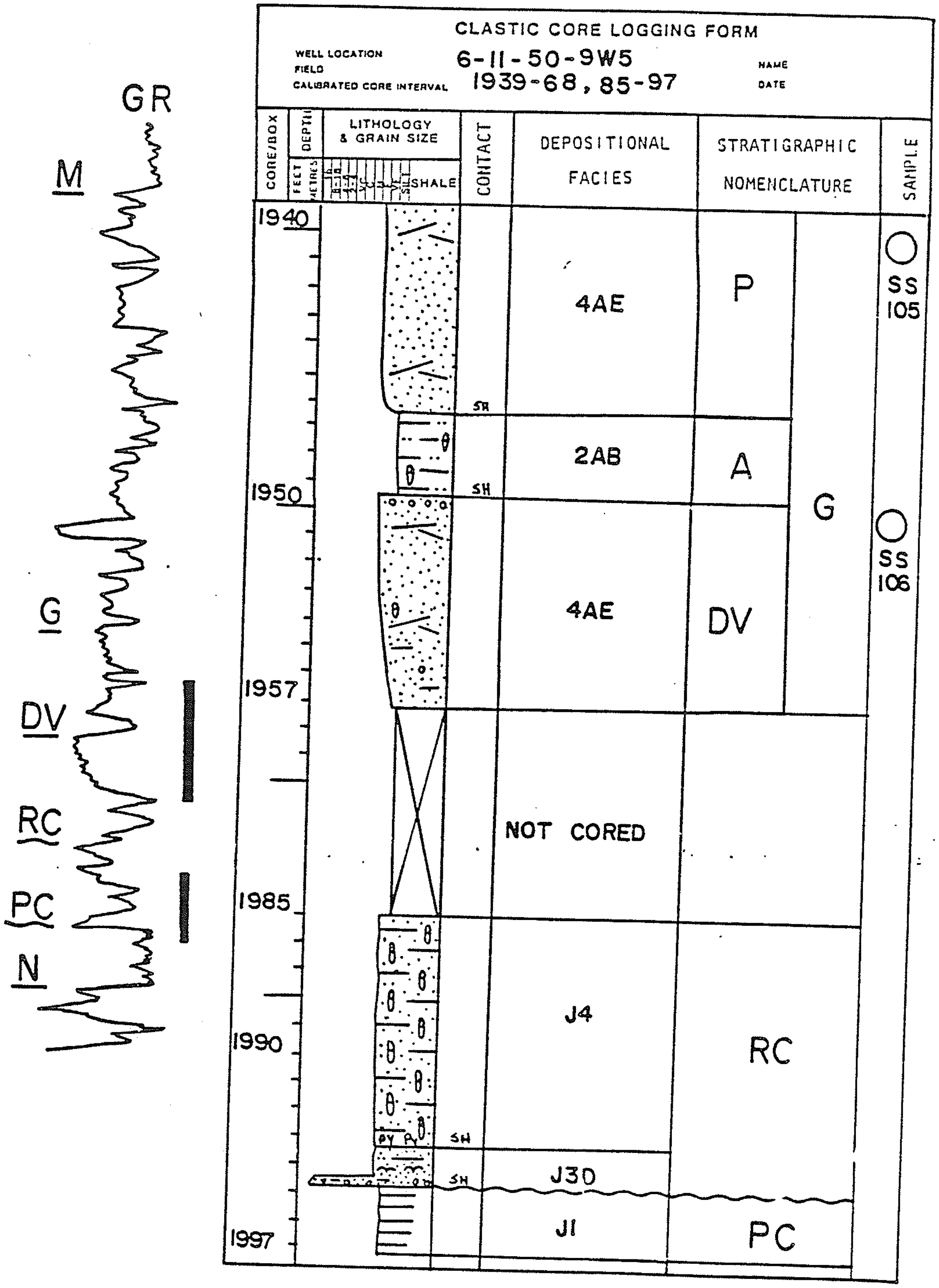
NAME

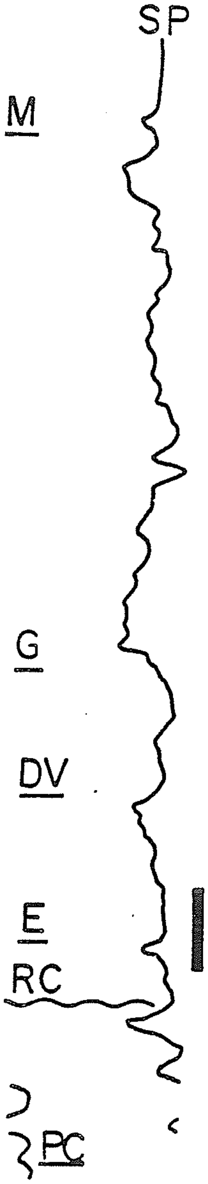
DATE

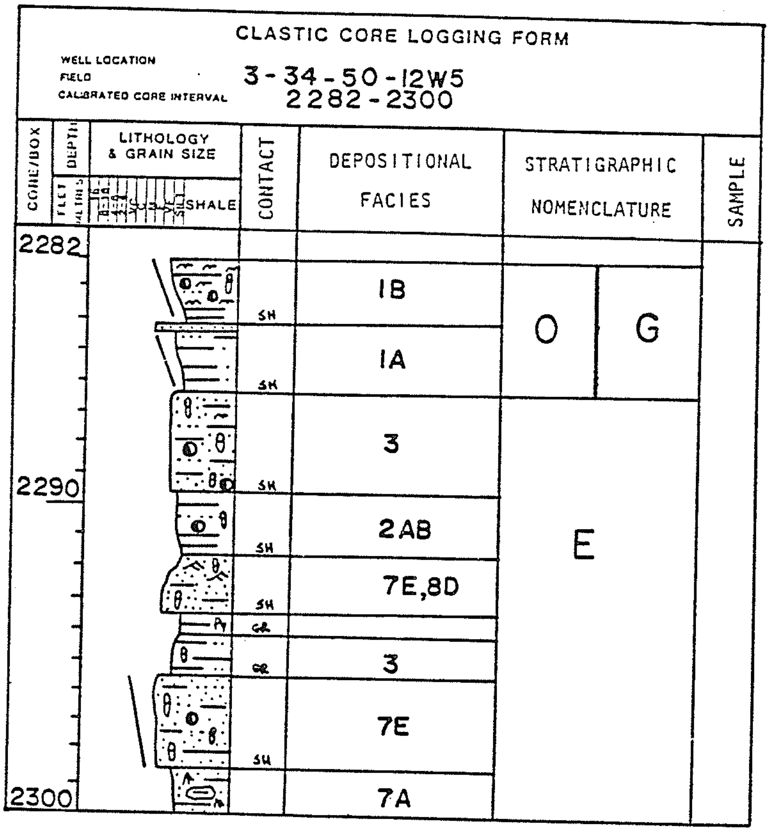
CLASTIC CORE LOGGING FORM

WELL LOCATION 10-15-50-7W5
FIELD
CALIBRATED CORE INTERVAL 1832-68
NAME
DATE




GR
M
G
DV
RC
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-11-50-9W5
1939-68, 85-97
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SILT
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1940
1950
1957
1985
1990
1997
SH
SH
SH
SH
PY
4AE
2AB
4AE
NOT CORED
J4
J3O
J1
P
A
G
DV
RC
PC
SS 105
SS 106

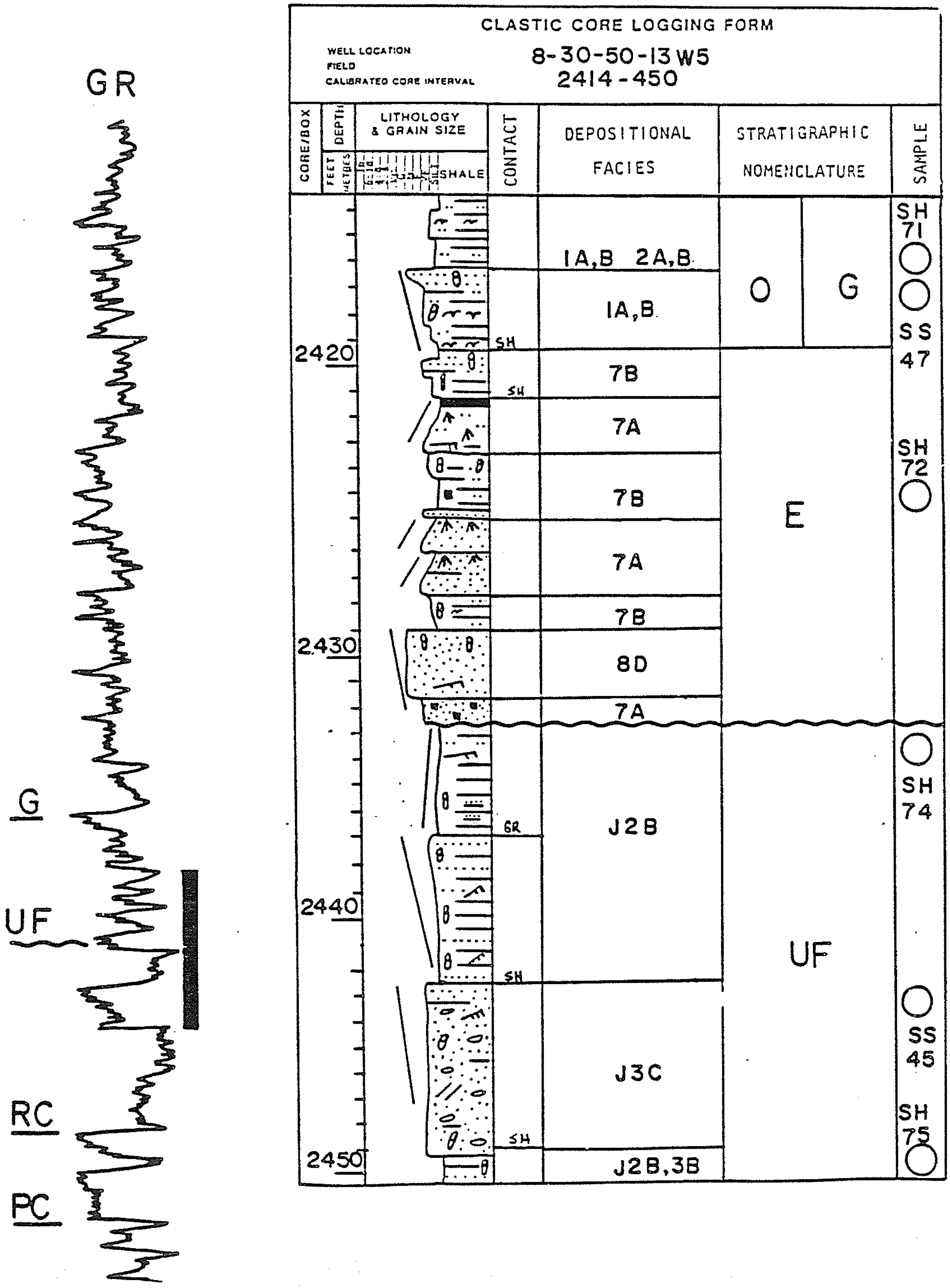


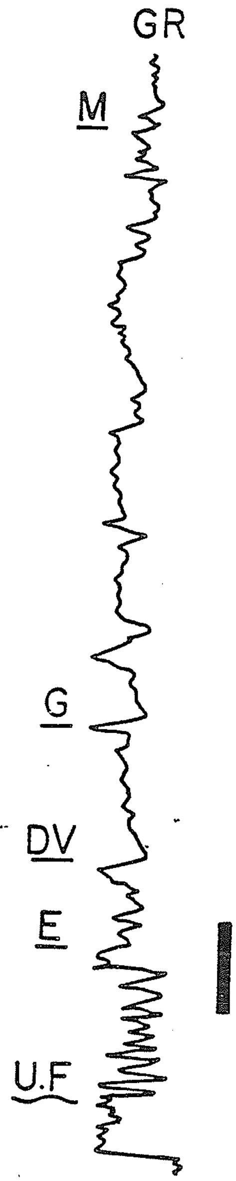


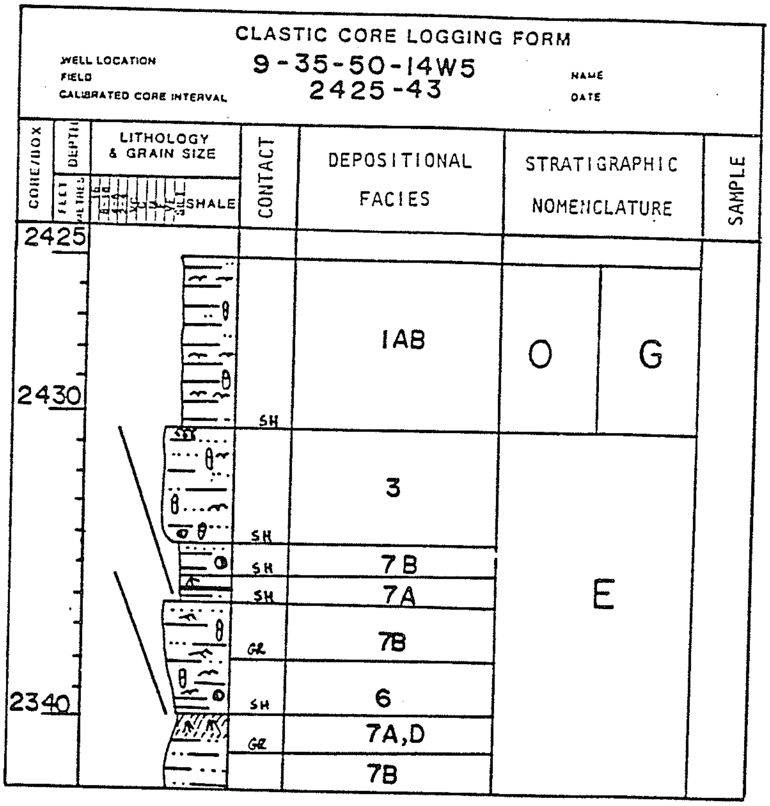
CLASTIC CORE LOGGING FORM

WELL LOCATION 3-34-50-12W5
FIELD
CALIBRATED CORE INTERVAL 2282-2300

CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2282						
			SH	1B	O	G	
			SH	1A			
			SH	3	E		
	2290		SH	2AB			
			SH	7E,8D			
		Py	GR				
			GR	3			
			SU	7E			
	2300			7A			


GR
G
UF
RC
PC
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
8-30-50-13 W5
2414-450
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2420
2430
2440
2450
SH
SH
GR
SH
SH
1A,B 2A,B
1A,B
7B
7A
7B
7A
7B
8D
7A
J2B
J3C
J2B,3B
O
G
E
UF
SH 71
SS 47
SH 72
SH 74
SS 45
SH 75

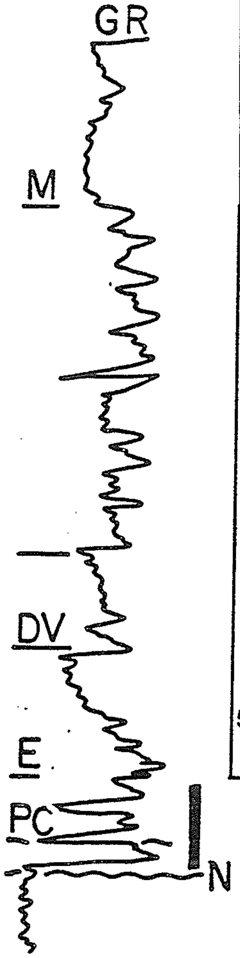


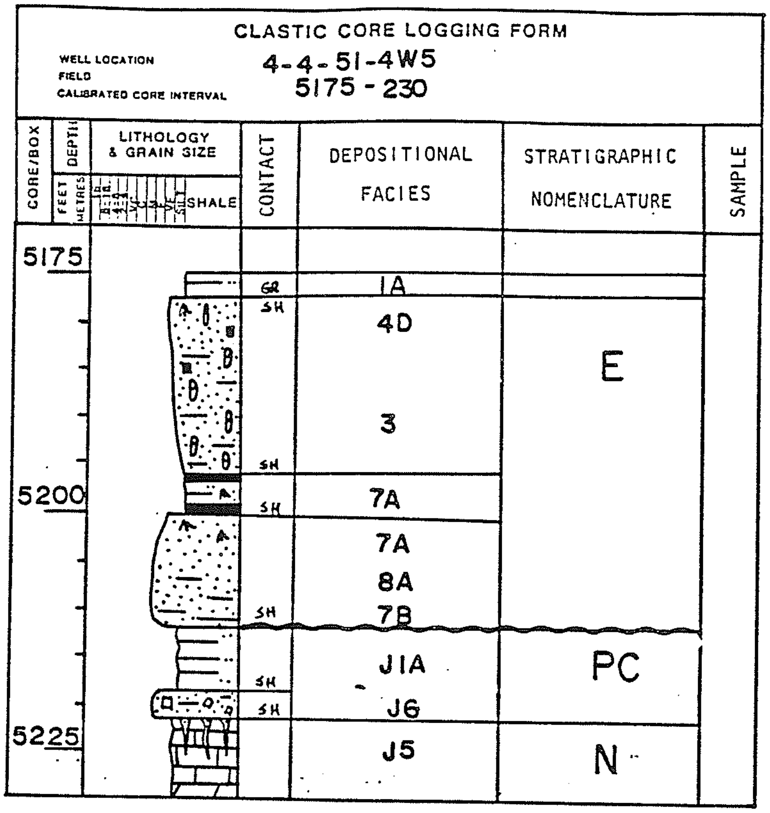


CLASTIC CORE LOGGING FORM

WELL LOCATION 9-35-50-14W5
FIELD
CALIBRATED CORE INTERVAL 2425-43
NAME
DATE

DEPTH	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	
2425				
2430	SH	1AB	O	G
	SH	3	E	
	SH	7B		
	SH	7A		
	GR	7B		
2340	SH	6		
	GR	7A,D		
		7B		

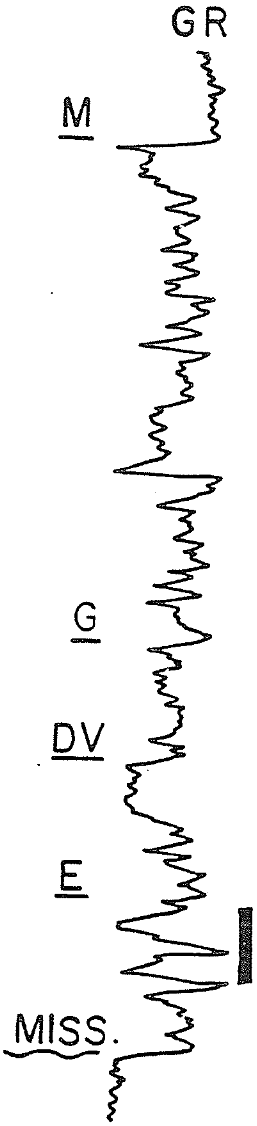


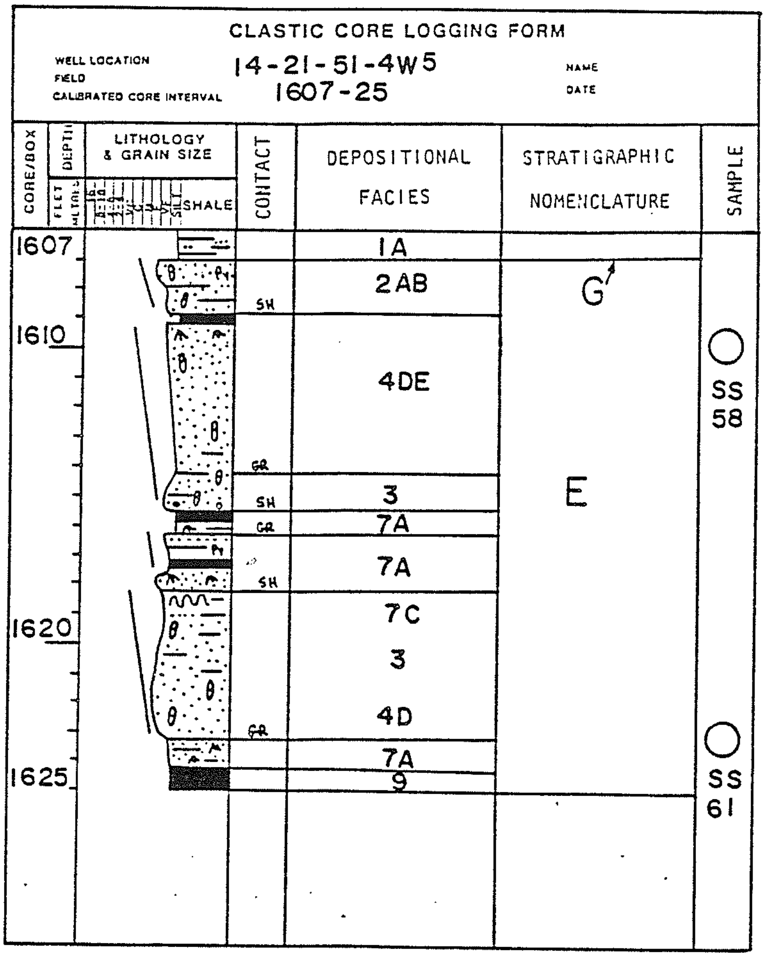


CLASTIC CORE LOGGING FORM

WELL LOCATION 4-4-51-4W5
FIELD
CALIBRATED CORE INTERVAL 5175 - 230

CORE/BOX	DEPTH FEET / METRES	LITHOLOGY & GRAIN SIZE / SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	5175					
			GR	1A		
			SH	4D 3	E	
	5200		SH	7A		
			SH	7A 8A 7B		
			SH	J1A	PC	
			SH	J6		
	5225			J5	N	

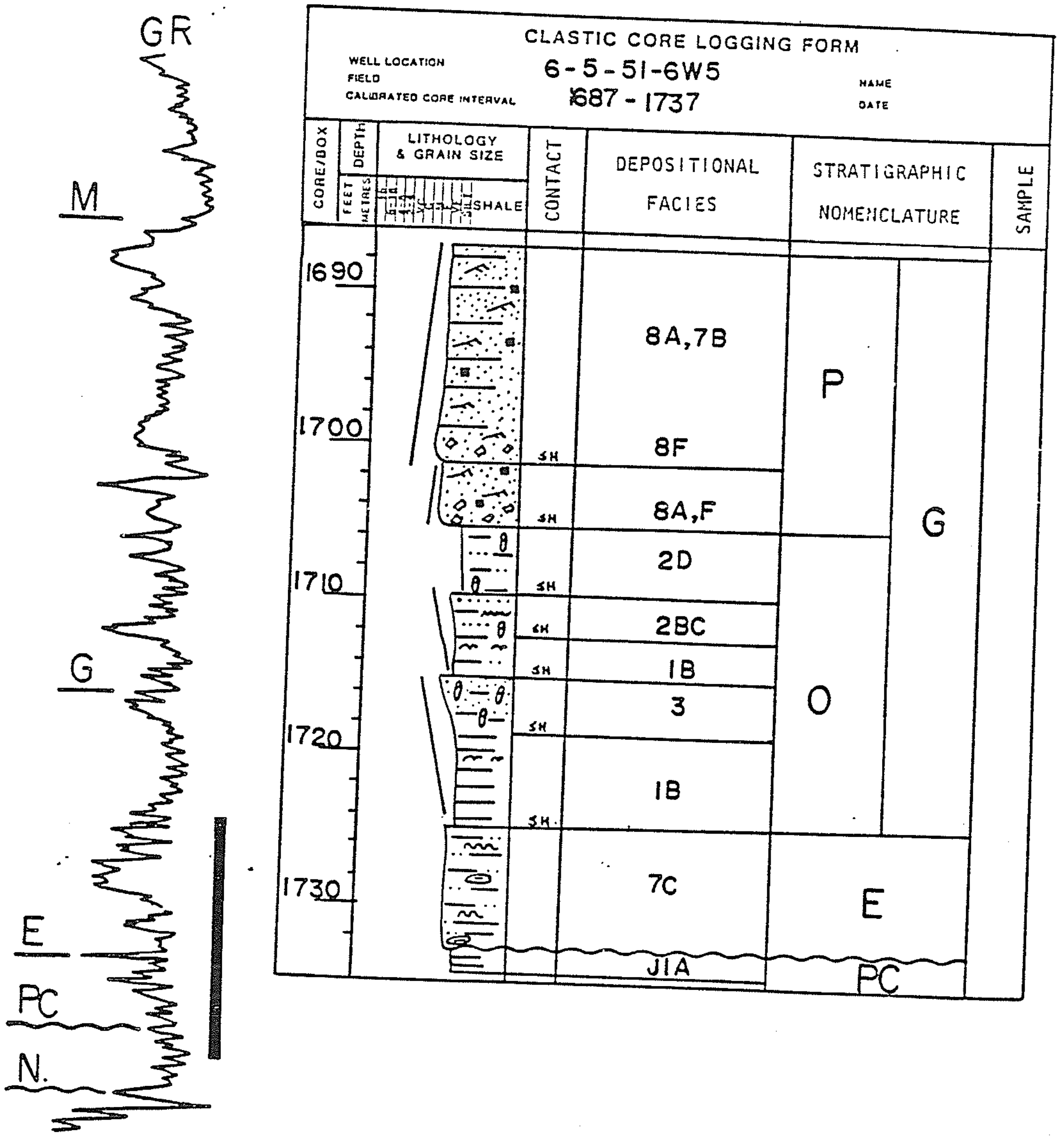




CLASTIC CORE LOGGING FORM

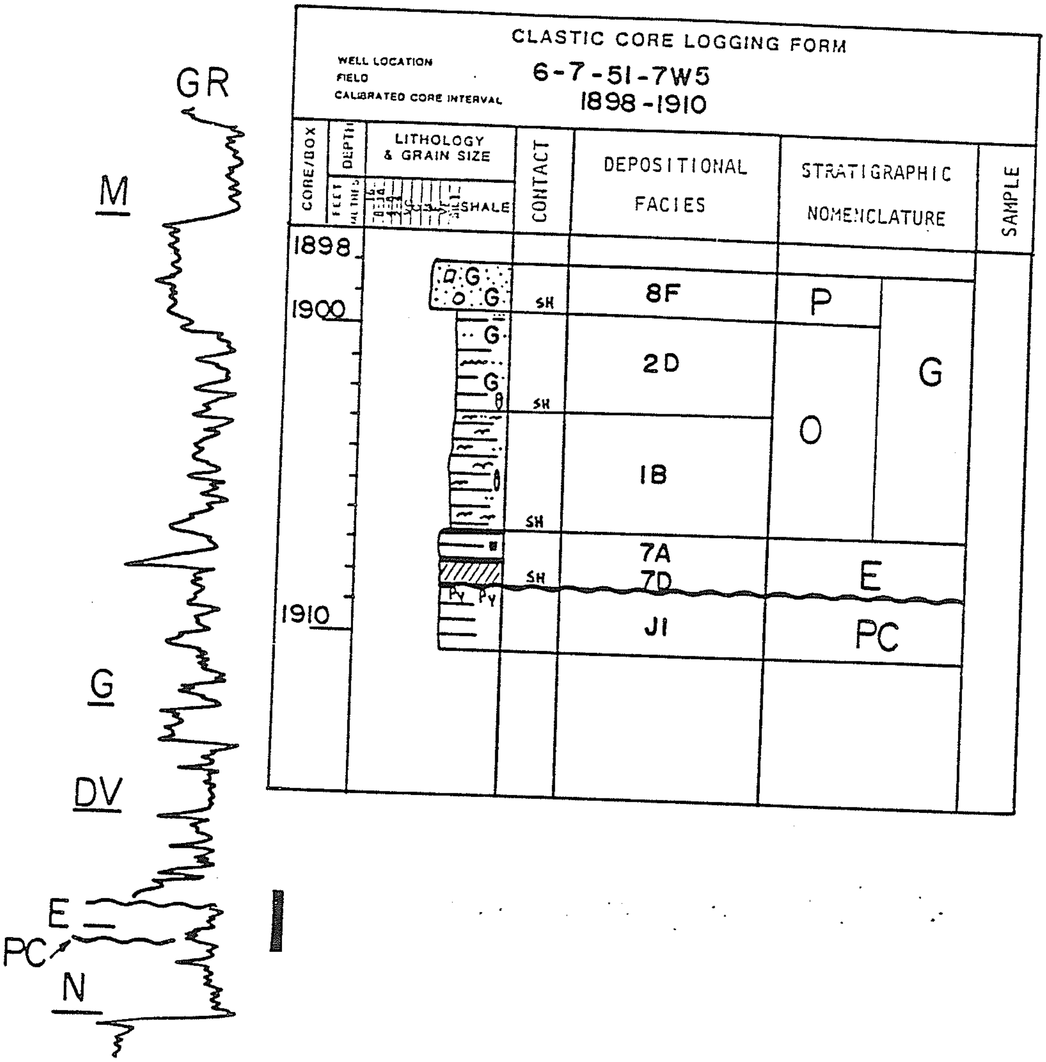
WELL LOCATION 14-21-51-4W5
FIELD
CALIBRATED CORE INTERVAL 1607-25
NAME
DATE

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SILT SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	1607			1A		
			SH	2AB	G	
	1610		GR	4DE		SS 58
			SH	3	E	
			GR	7A		
			SH	7A		
	1620		GR	7C 3 4D		
				7A		SS 61
	1625			9		



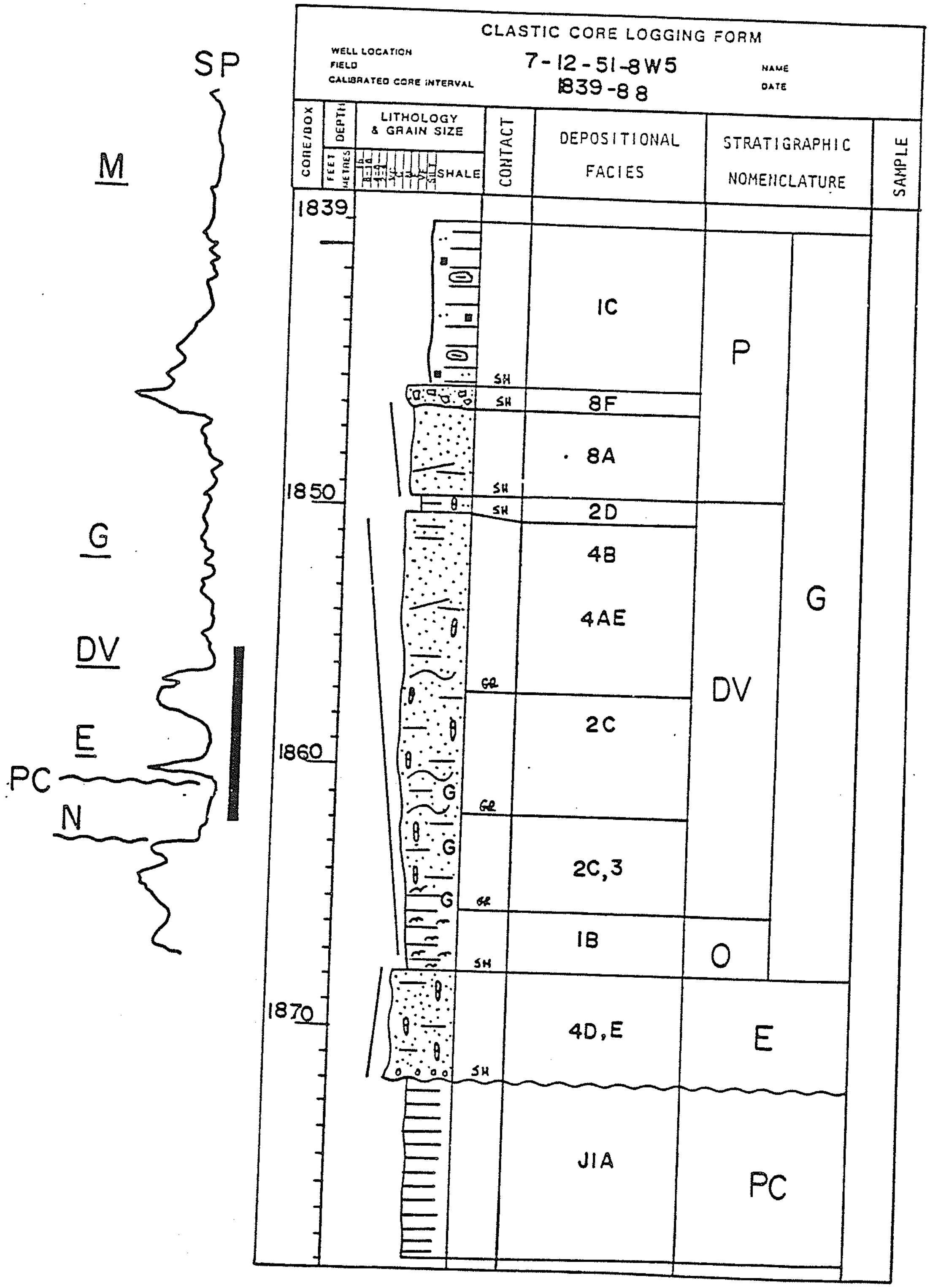
CLASTIC CORE LOGGING FORM

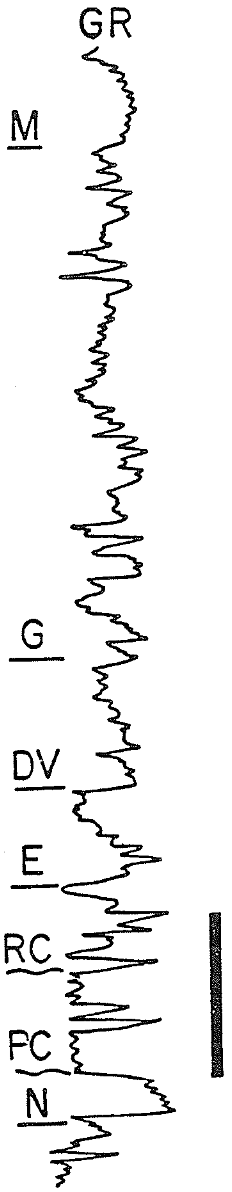
WELL LOCATION 6-5-51-6W5
FIELD
CALIBRATED CORE INTERVAL 1687 - 1737
NAME
DATE

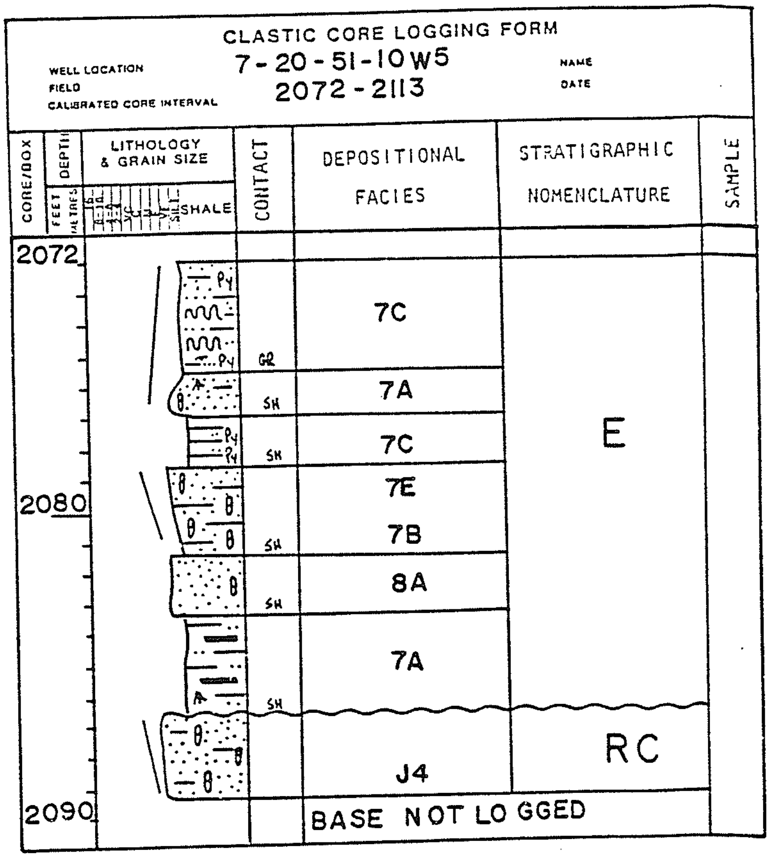


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD 6-7-51-7W5
CALIBRATED CORE INTERVAL 1898-1910


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
7-12-51-8W5
1839-88
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1839
1850
1860
1870
SH
GR
1C
8F
8A
2D
4B
4AE
2C
2C,3
1B
4D,E
J1A
P
G
DV
O
E
PC
SP
M
G
DV
E
PC
N





CLASTIC CORE LOGGING FORM

WELL LOCATION 7-20-51-10W5

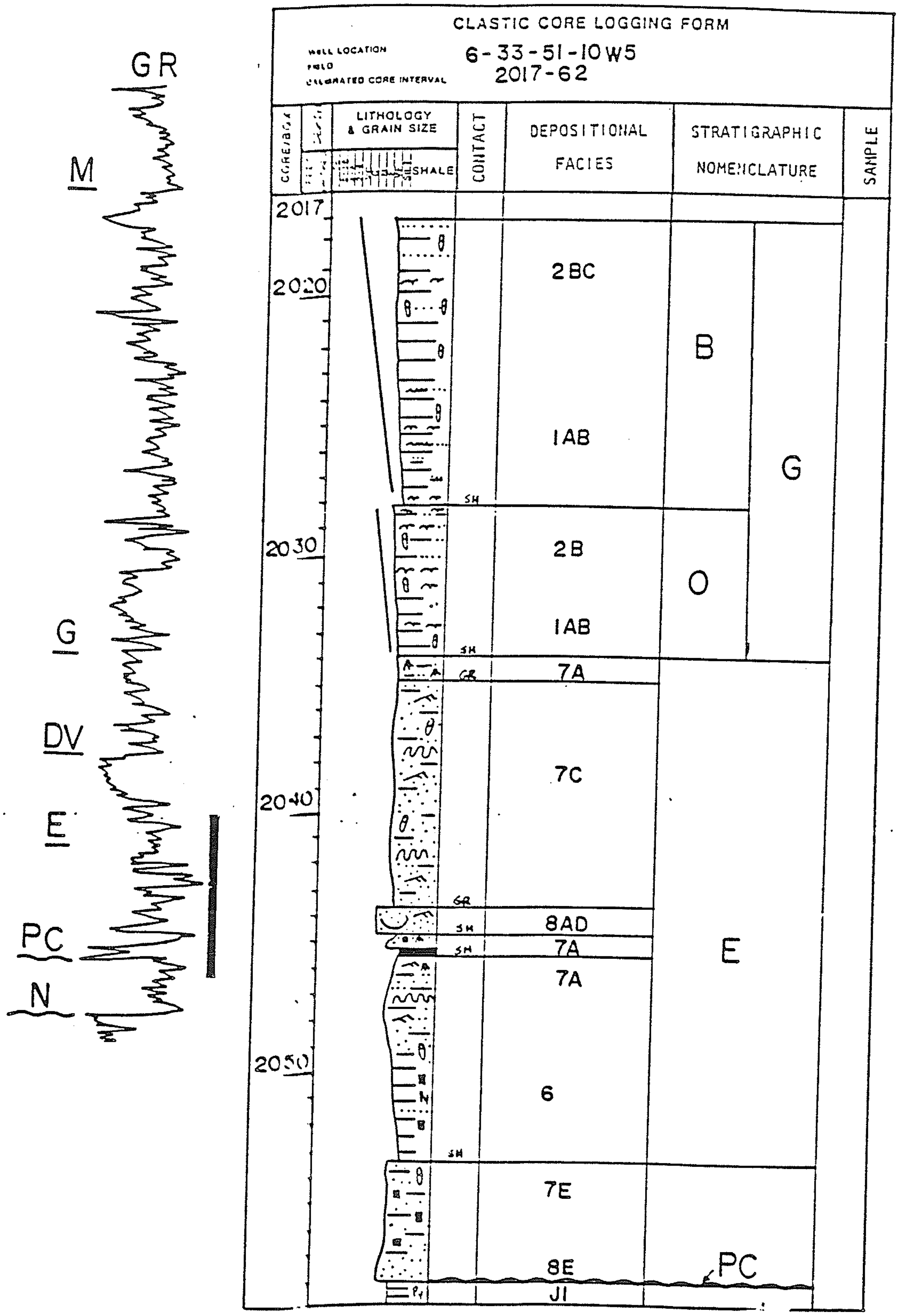
FIELD

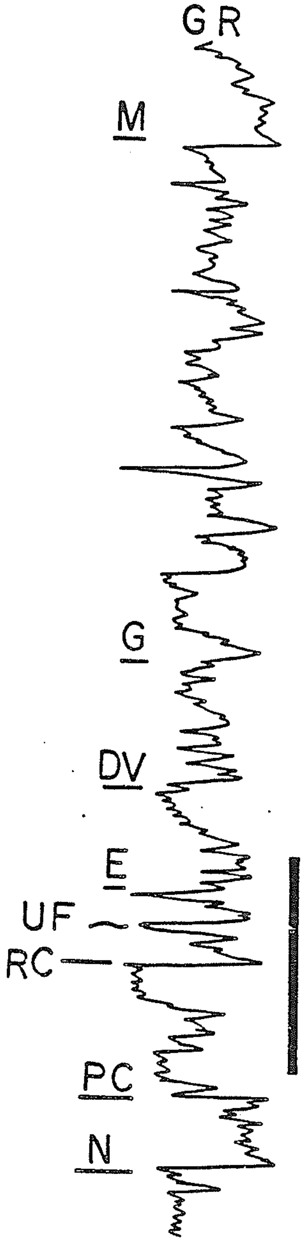
CALIBRATED CORE INTERVAL 2072-2113

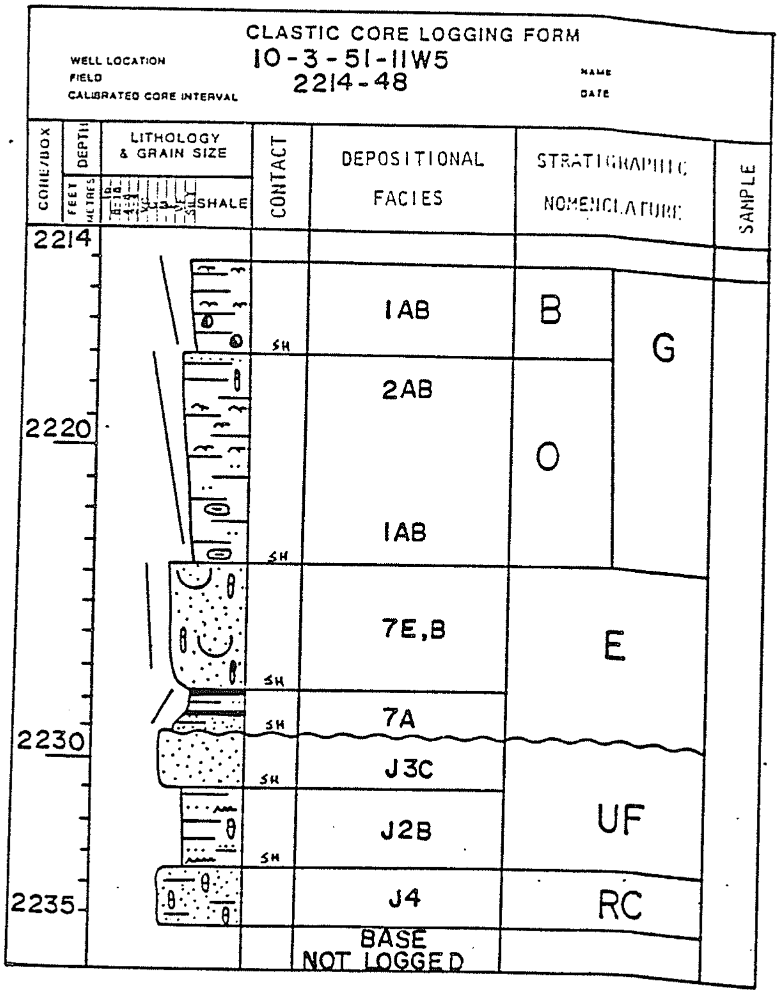
NAME

DATE

CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2072		GR	7C	E	
			SH	7A		
			SH	7C		
				7E		
	2080		SH	7B		
			SH	8A		
			SH	7A		
				J4	RC	
	2090			BASE NOT LOGGED		


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-33-51-10W5
2017-62
CORE/BOX
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
GR
M
G
DV
E
PC
N
2017
2020
2030
2040
2050
SH
GR
2BC
1AB
2B
1AB
7A
7C
8AD
7A
7A
6
7E
8E
J1
B
O
G
E
PC

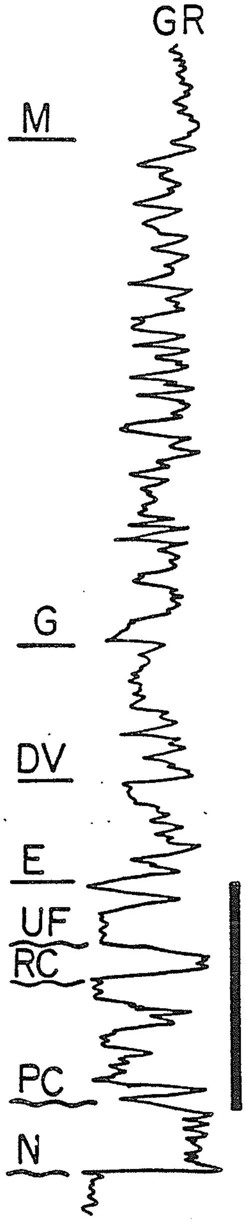


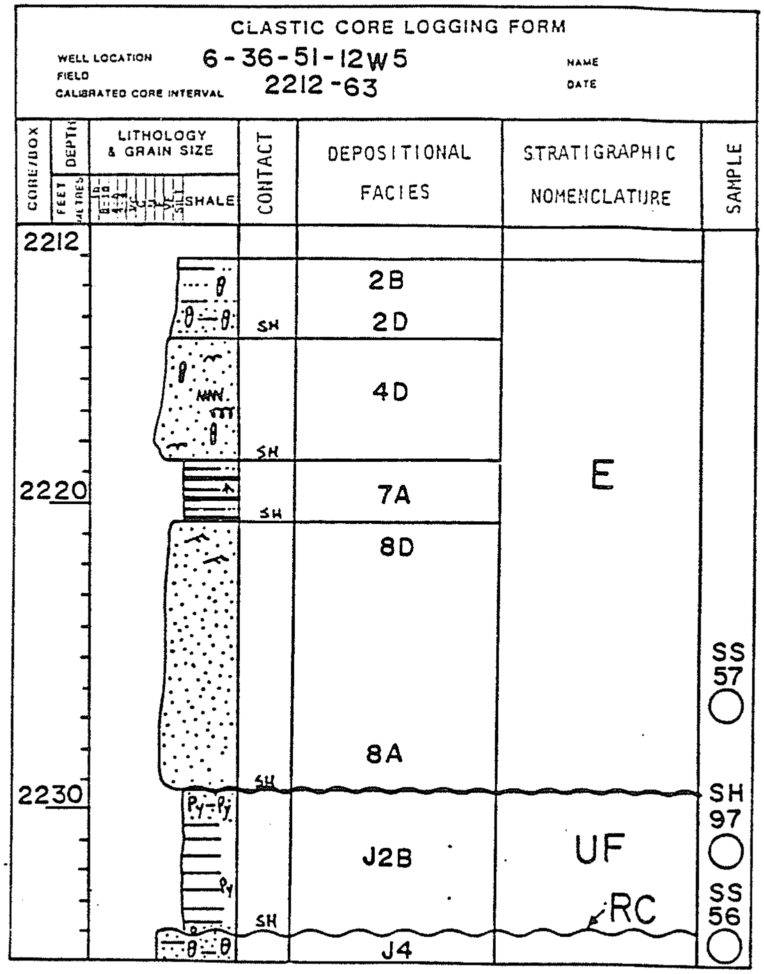


CLASTIC CORE LOGGING FORM

WELL LOCATION 10-3-51-11W5
FIELD
CALIBRATED CORE INTERVAL 2214-48
NAME
DATE

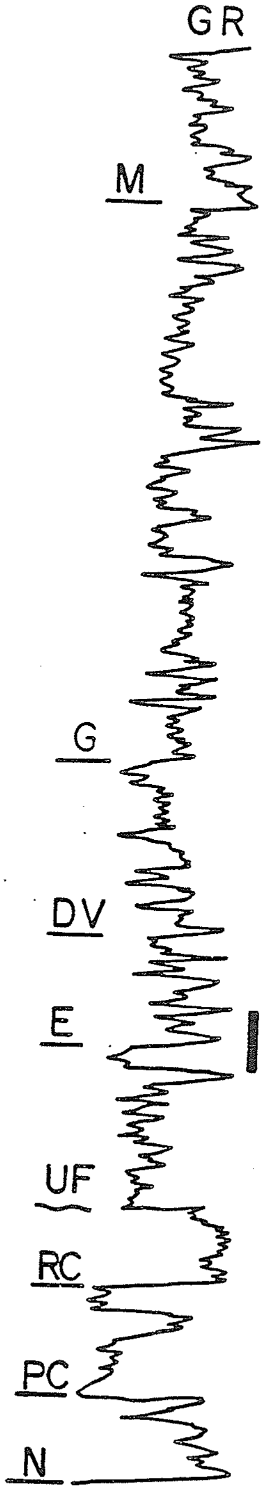
CORE/BOX	DEPTH FEET / METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2214		SH	1AB	B	G	
	2220		SH	2AB 1AB	O		
			SH	7E,B	E		
	2230		SH	7A			
			SH	J3C	UF		
			SH	J2B			
	2235			J4	RC		
				BASE NOT LOGGED			

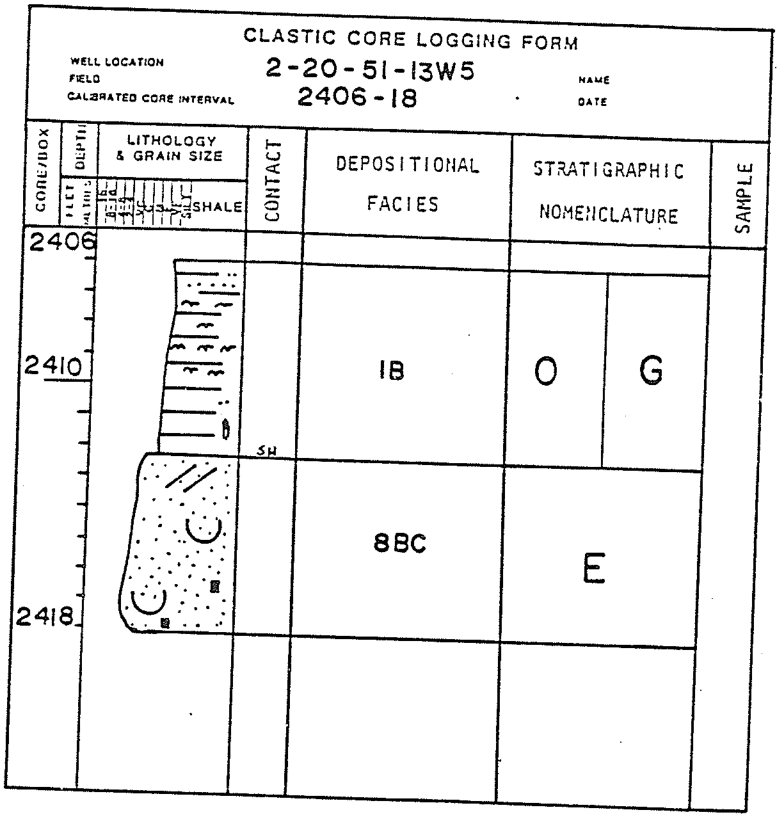




CLASTIC CORE LOGGING FORM

WELL LOCATION 6-36-51-12W5
FIELD
CALIBRATED CORE INTERVAL 2212-63
NAME
DATE





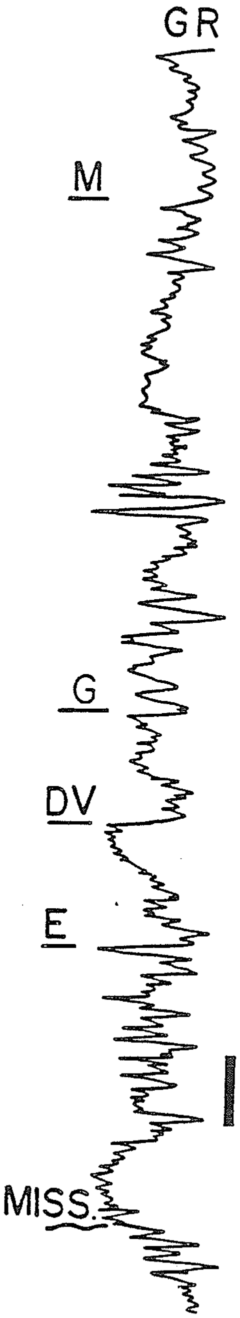
CLASTIC CORE LOGGING FORM

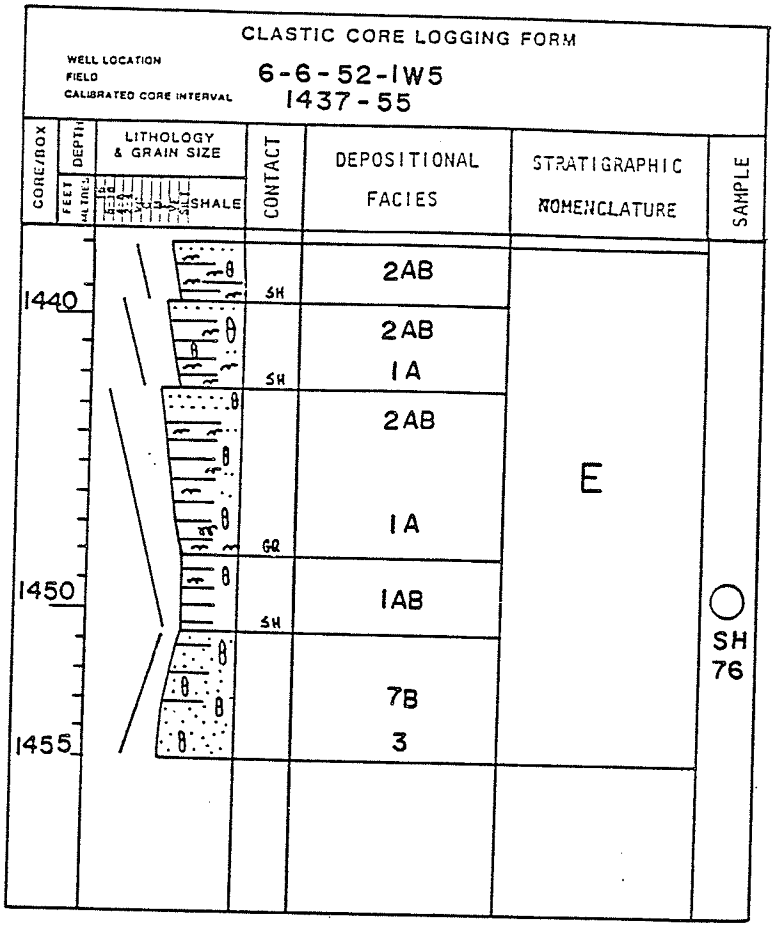
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

2-20-51-13W5
2406-18

NAME
DATE

CORE/BOX	DEPTH FEET	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
	2406						
	2410			1B	O	G	
			SH				
				8BC	E		
	2418						



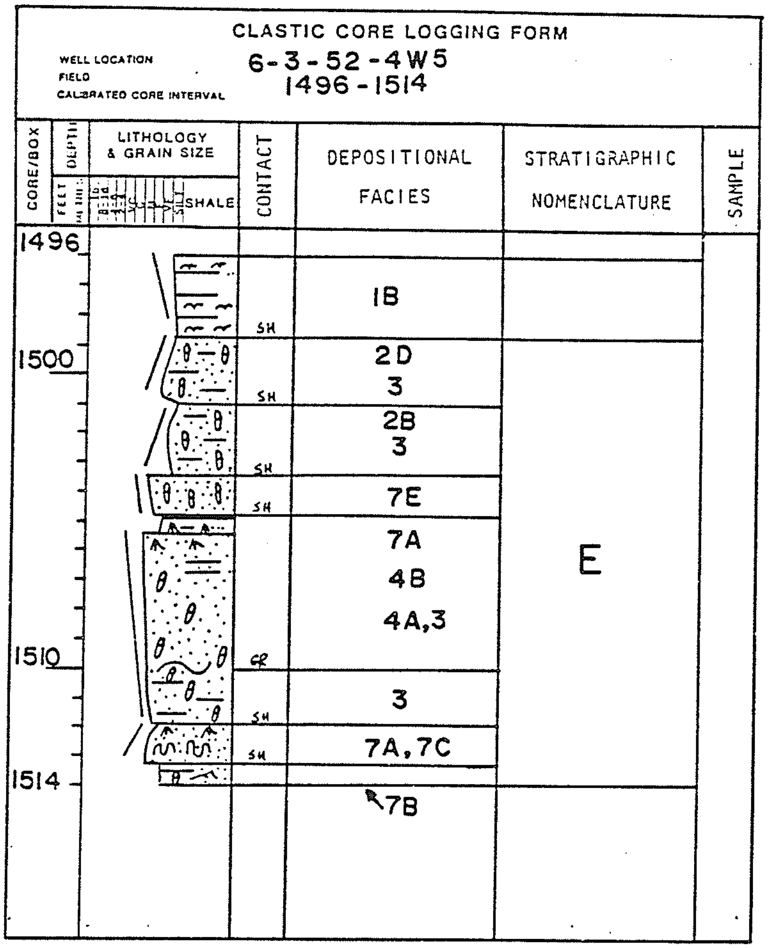


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

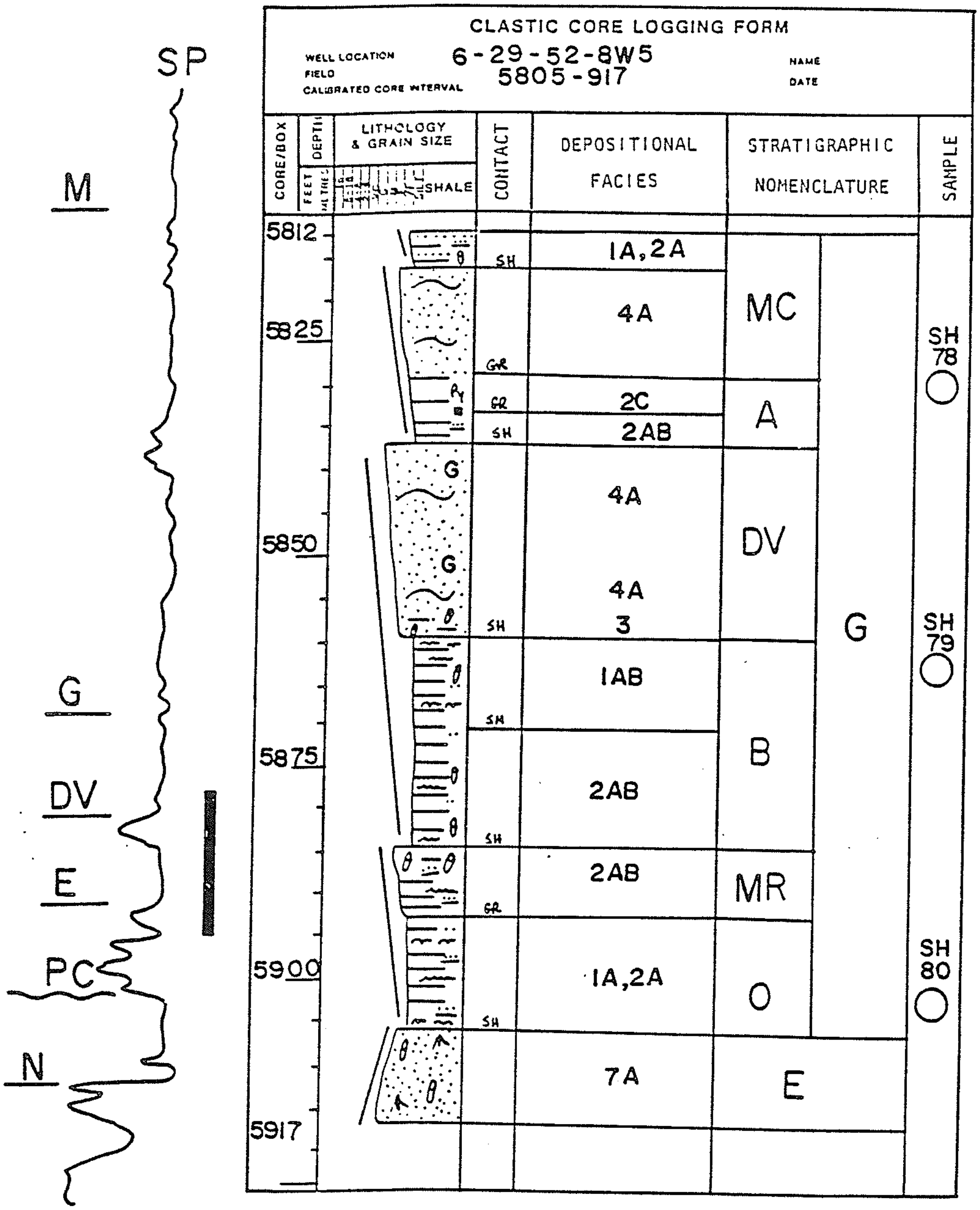
6-6-52-1W5
1437-55

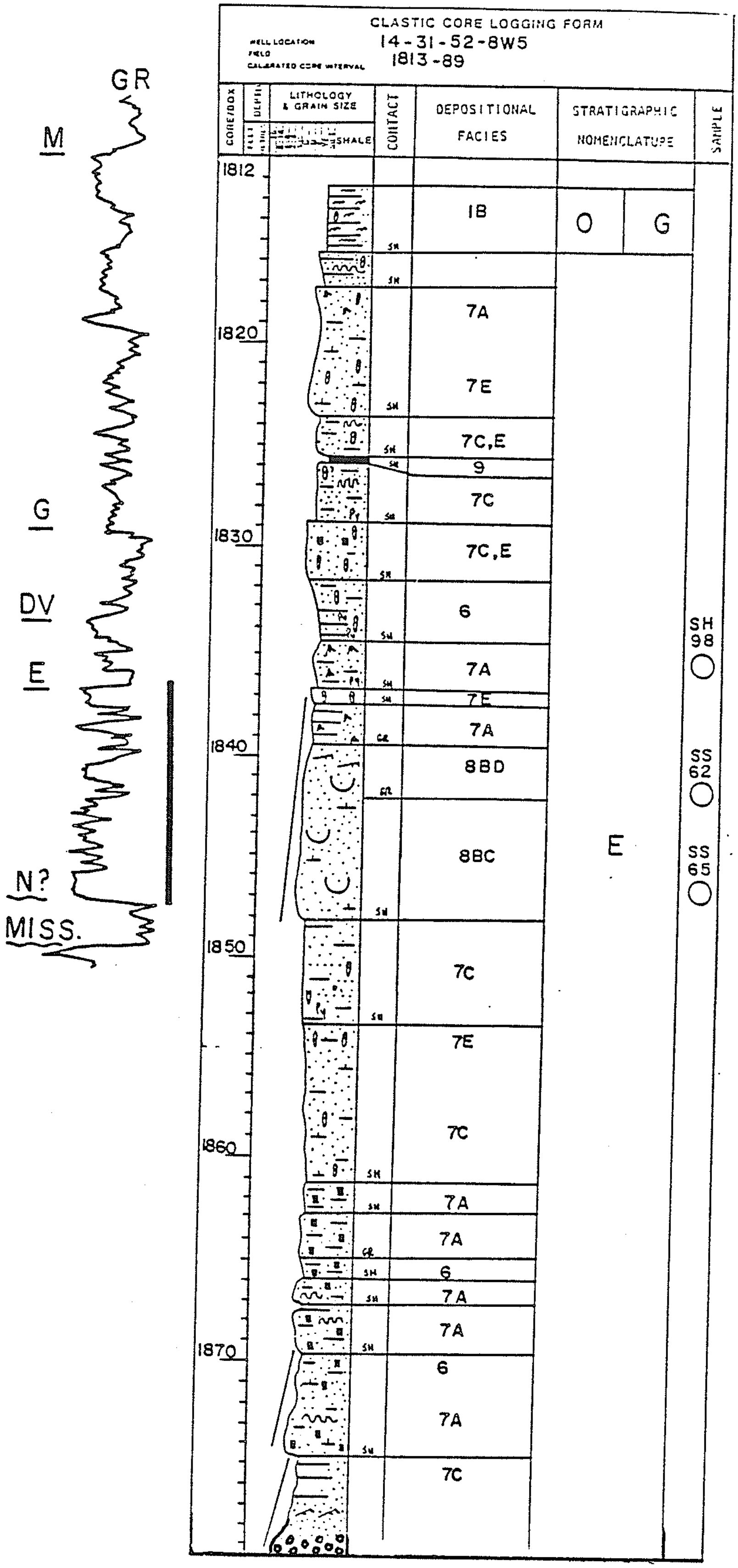
CORE/BOX	DEPTH (FEET / METRES)	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
			SH	2AB	E	
	1440		SH	2AB 1A		
			GR	2AB 1A		
	1450		SH	1AB		○ SH 76
	1455			7B 3		

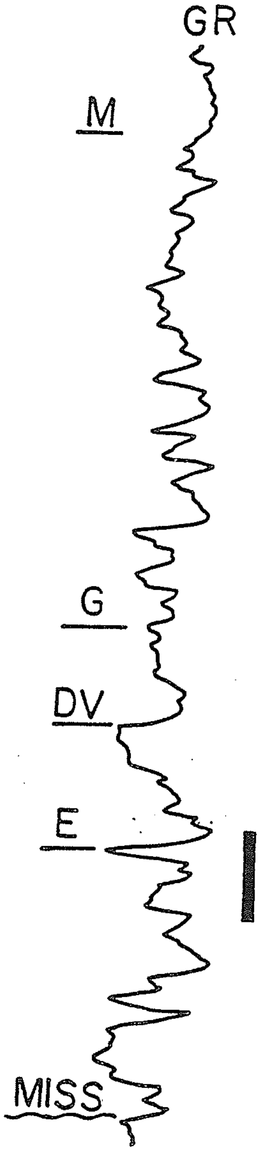


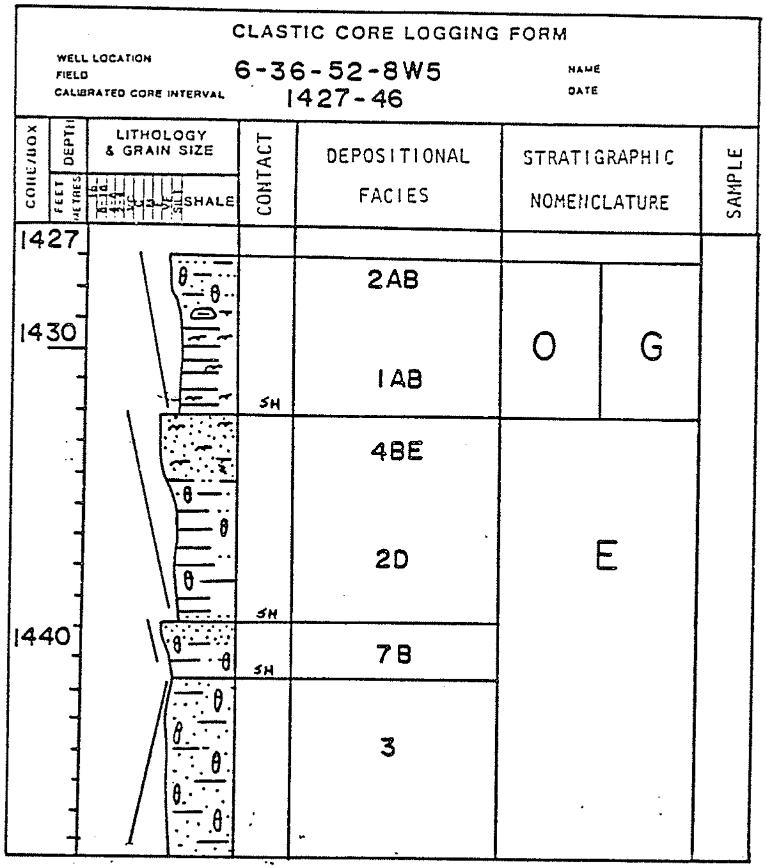
CLASTIC CORE LOGGING FORM

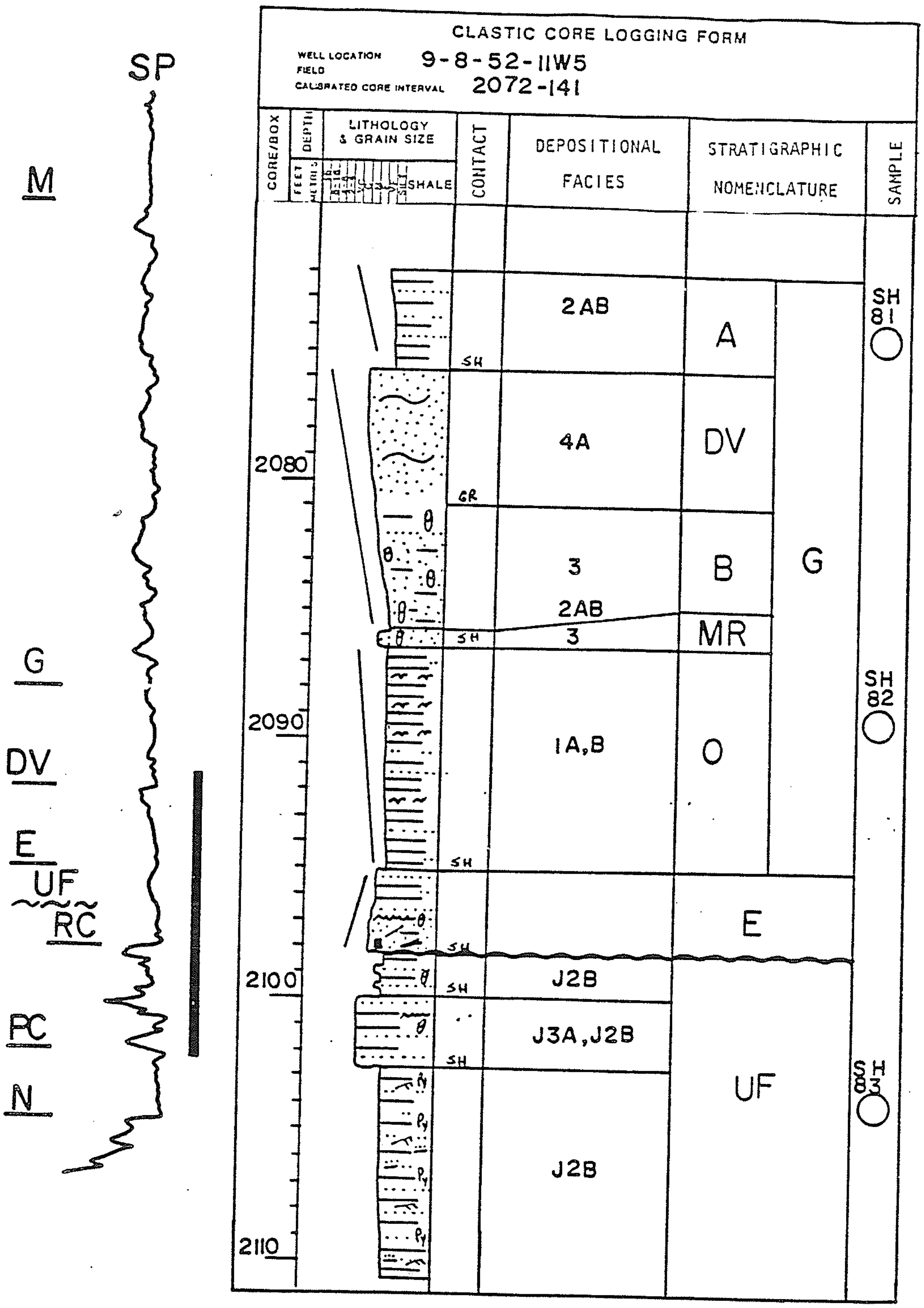
WELL LOCATION 6-3-52-4W5
FIELD
CALIBRATED CORE INTERVAL 1496-1514

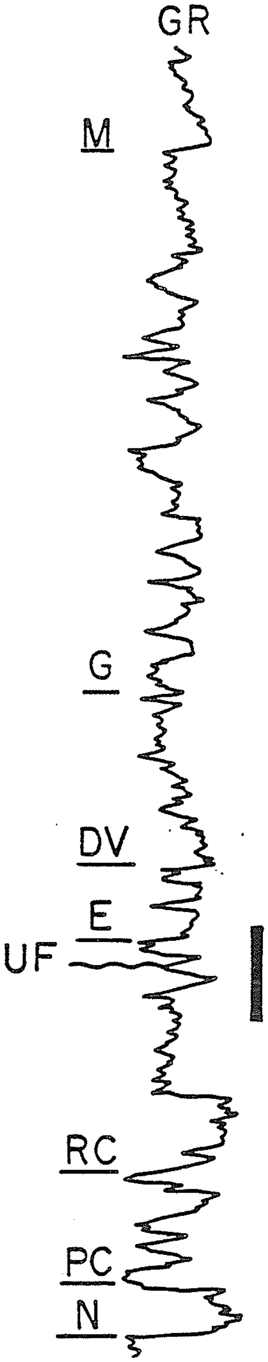

SP
M
G
DV
E
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-29-52-8W5
5805-917
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
5812
5825
5850
5875
5900
5917
SH
GR
GR
SH
SH
SH
SH
GR
SH
1A,2A
4A
2C
2AB
4A
4A
3
1AB
2AB
2AB
1A,2A
7A
MC
A
DV
B
MR
O
E
G
SH 78
SH 79
SH 80
G
G
Py

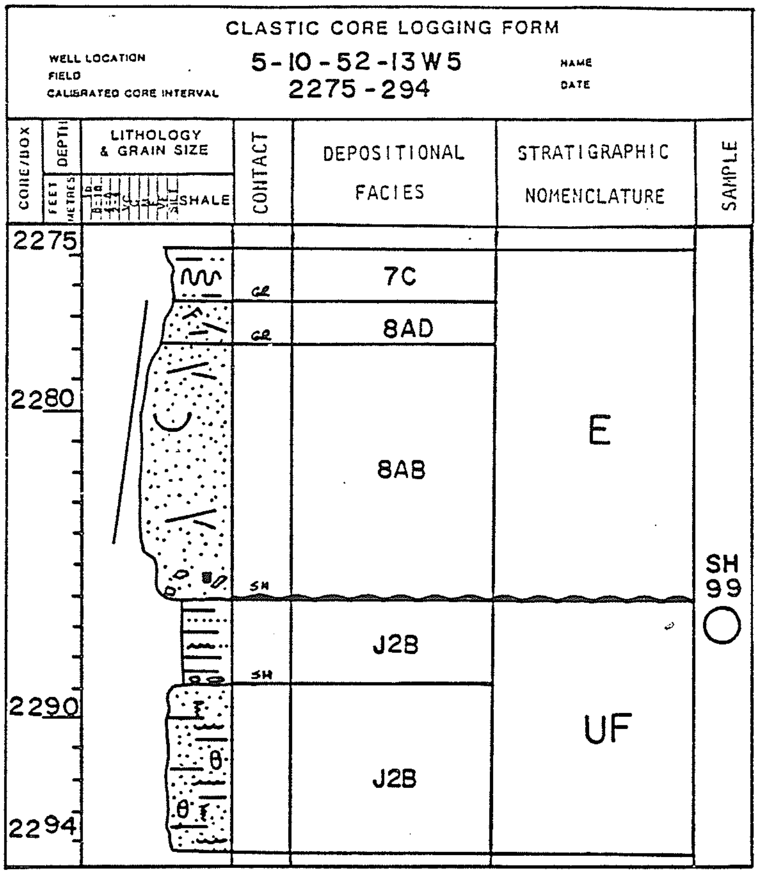

GR
M
G
DV
E
N?
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
14-31-52-8W5
1813-89
CORE/BOX
DEPTH
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1812
1820
1830
1840
1850
1860
1870
1B
O
G
7A
7E
7C,E
9
7C
7C,E
6
7A
7E
7A
8BD
8BC
E
7C
7E
7C
7A
7A
6
7A
7A
6
7A
7C
SH
GR
SH 98
SS 62
SS 65


GR
M
G
DV
E
MISS


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-36-52-8W5
1427-46
NAME
DATE
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SILT
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1427
1430
1440
SH
SH
SH
2AB
1AB
4BE
2D
7B
3
O
G
E


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
9-8-52-11W5
2072-141
SP
M
G
DV
E
UF
RC
RC
N
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SILT
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2080
2090
2100
2110
SH
GR
SH
SH
SH
SH
SH
2AB
4A
3
2AB
3
1A,B
J2B
J3A,J2B
J2B
A
DV
B
MR
O
G
E
UF
SH 81
SH 82
SH 83

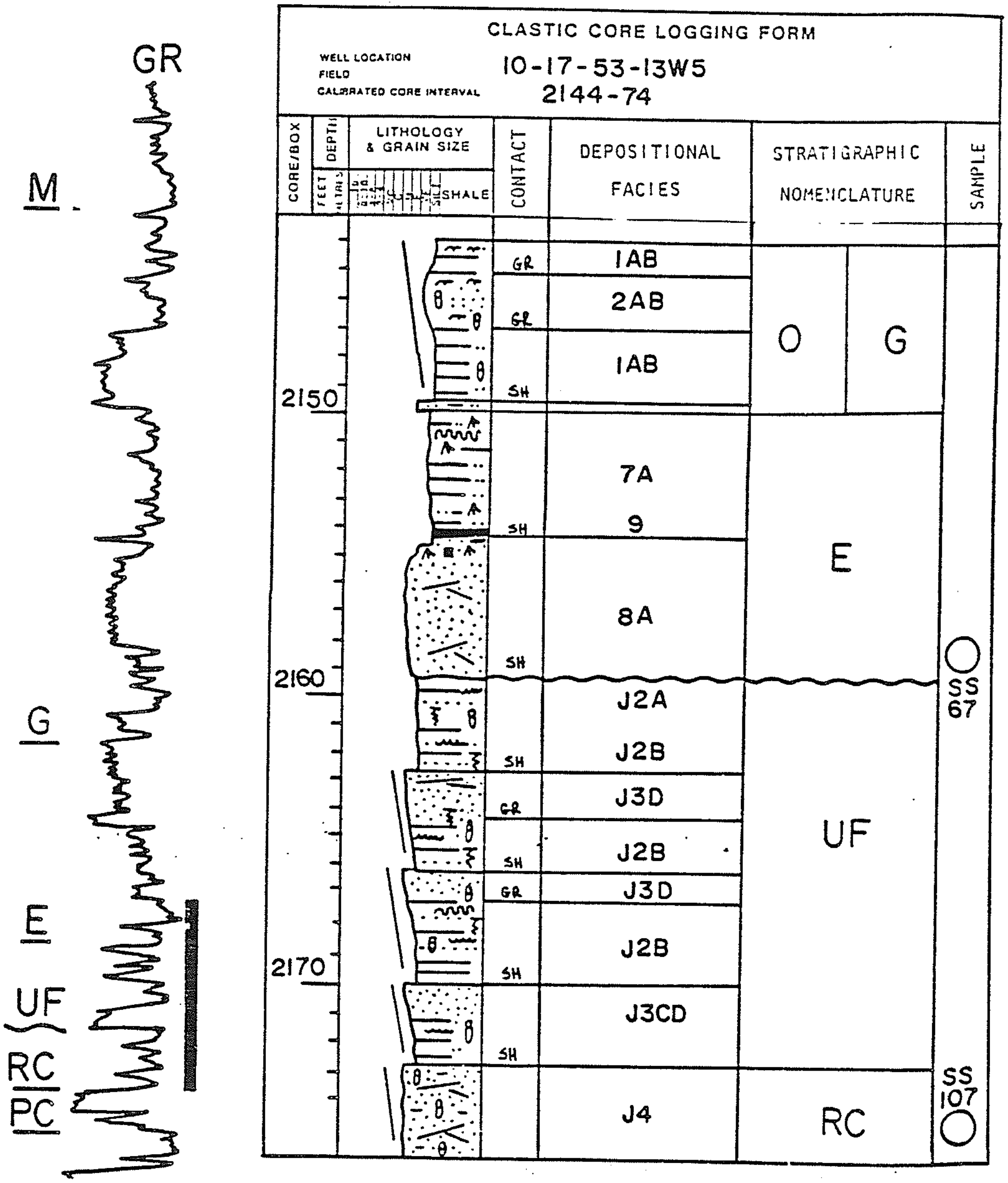




CLASTIC CORE LOGGING FORM

WELL LOCATION 5-10-52-13W5
FIELD
CALIBRATED CORE INTERVAL 2275-294
NAME
DATE

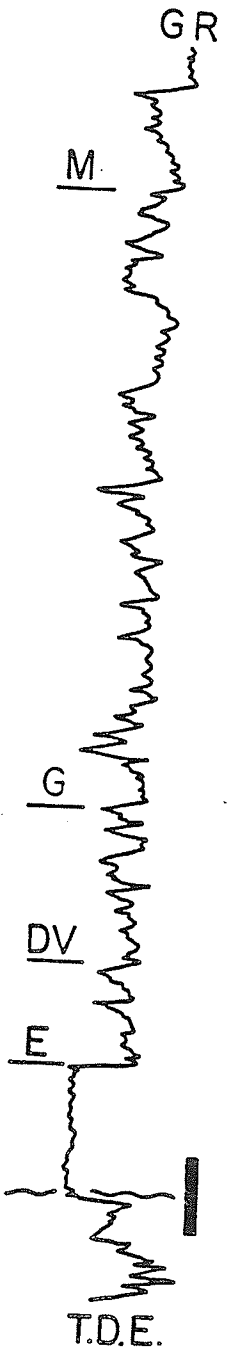
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	2275		GR	7C	E	
			GR	8AD		
	2280		SH	8AB		SH 99 ○
			SH	J2B	UF	
	2290			J2B		
	2294					

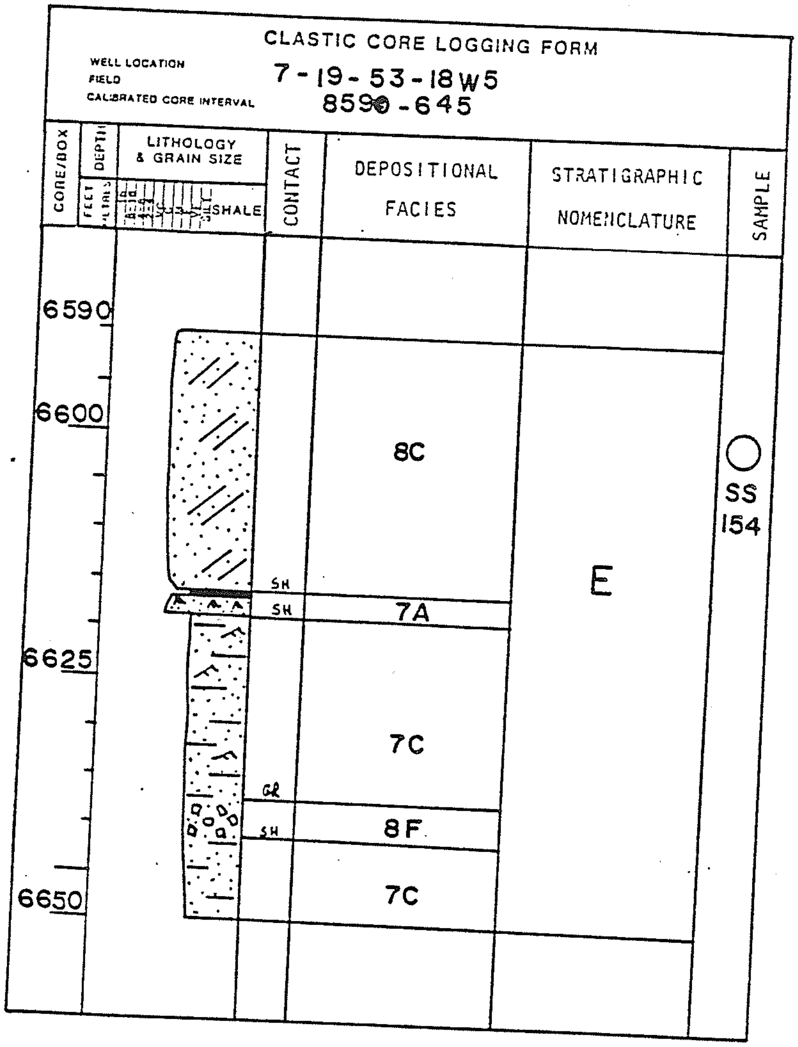


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

10-17-53-13W5
2144-74

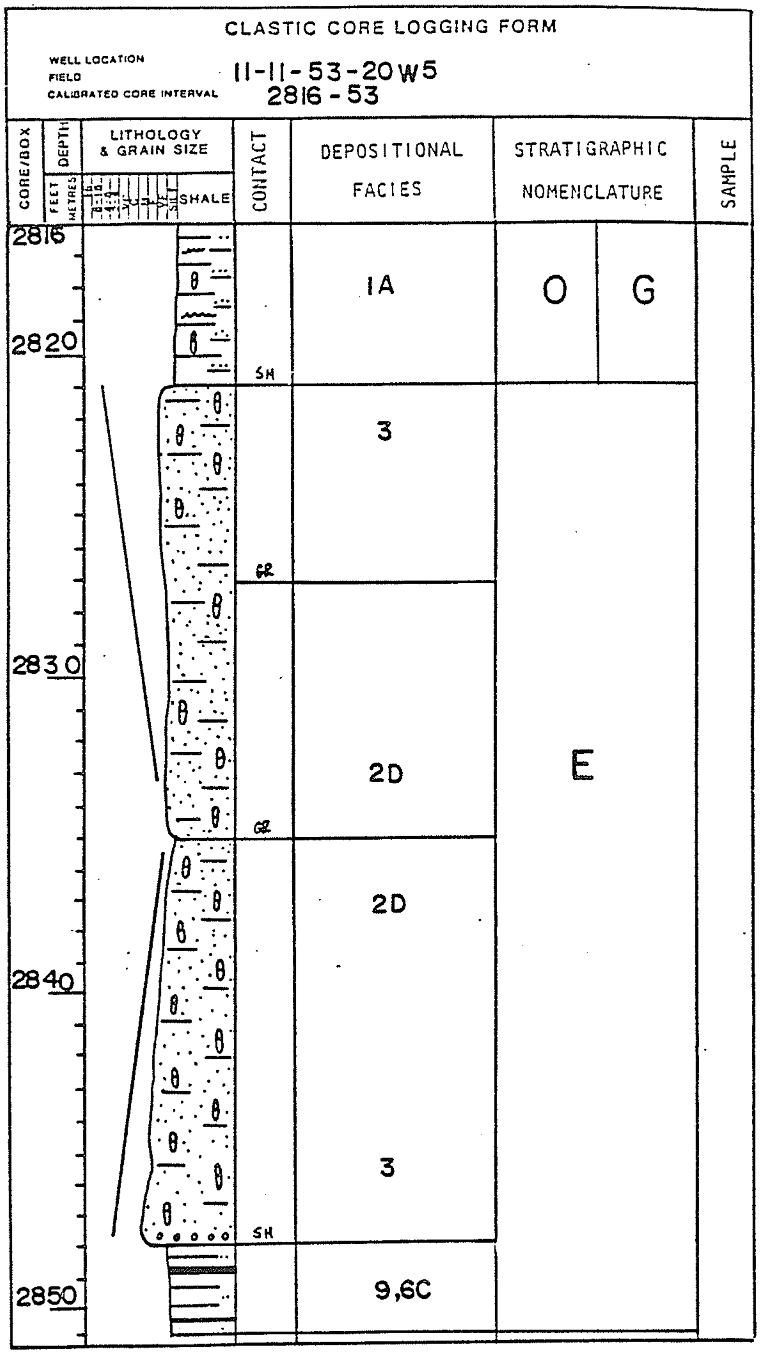




CLASTIC CORE LOGGING FORM

WELL LOCATION 7-19-53-18W5
FIELD
CALIBRATED CORE INTERVAL 8590-645

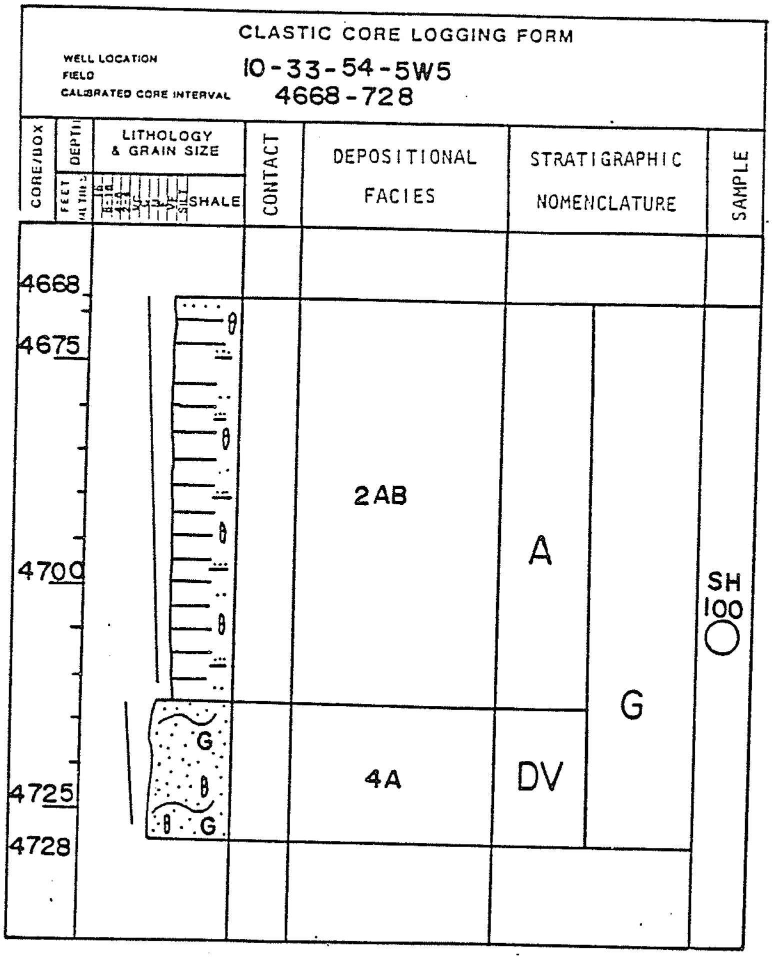
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	6590					
	6600			8C	E	○ SS 154
			SH			
			SH	7A		
	6625			7C		
			GR	8F		
			SH			
	6650			7C		



CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

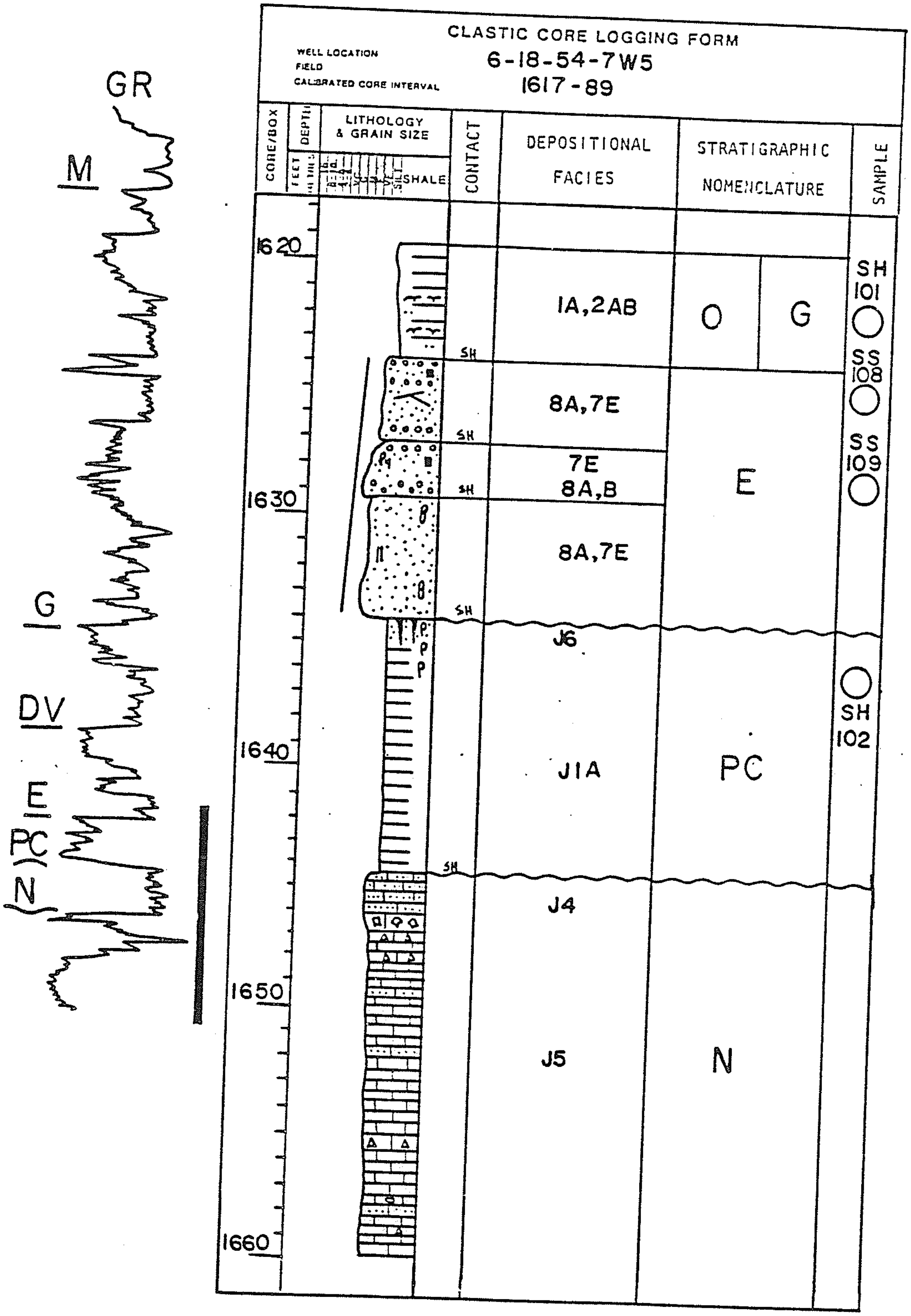
11-11-53-20W5
2816-53

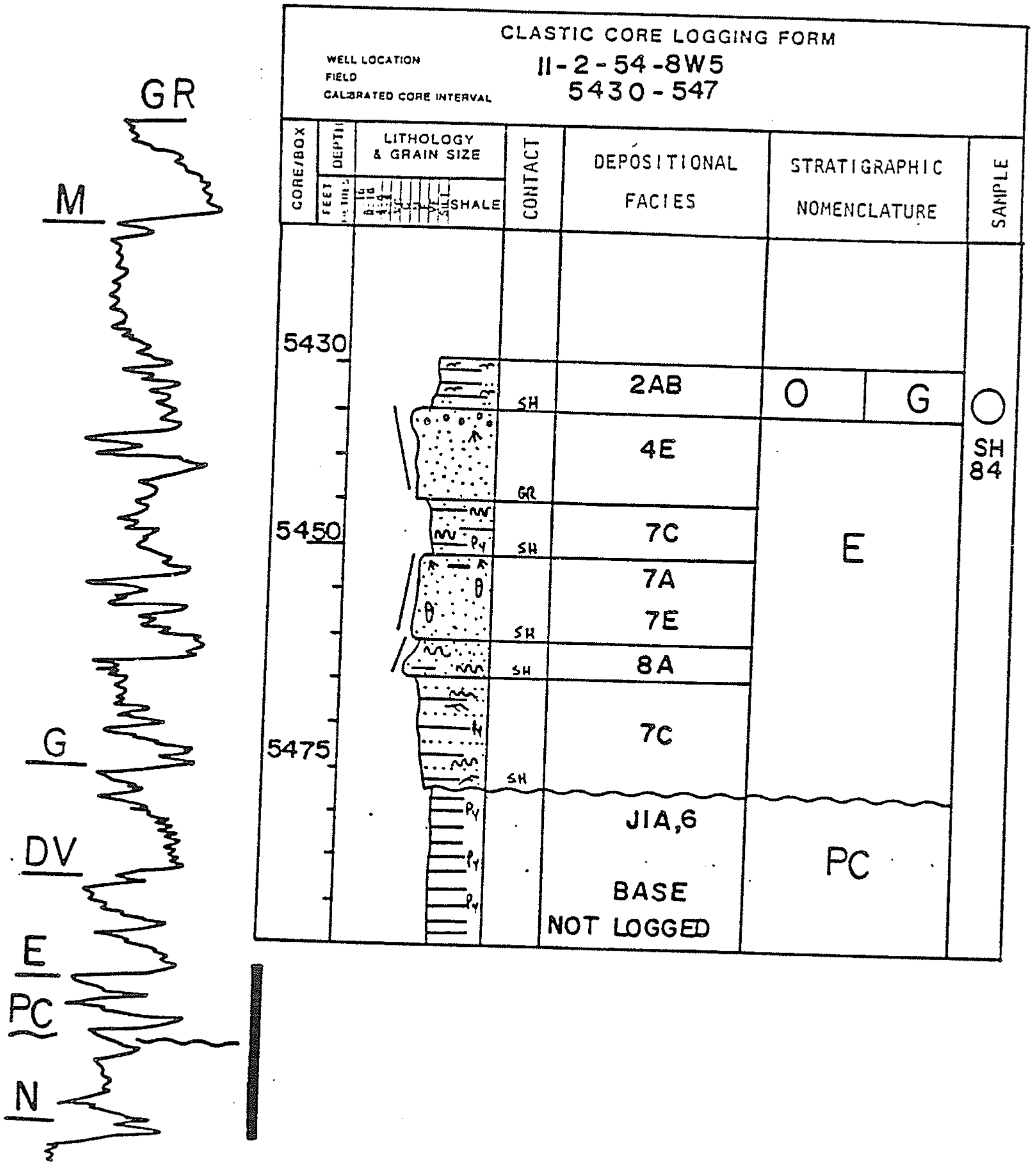


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

10-33-54-5W5
4668-728

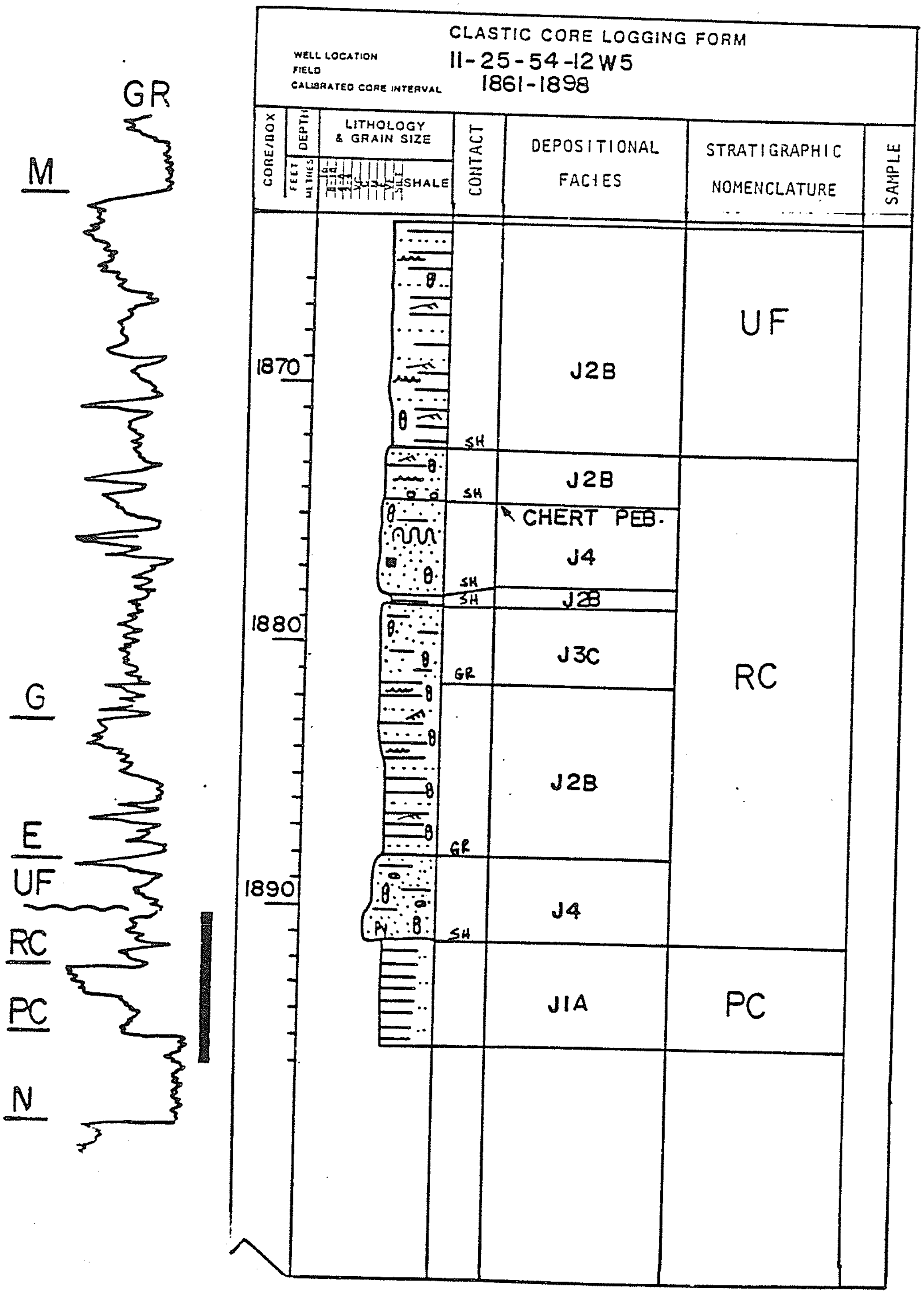

GR
M
G
DV
E
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-18-54-7W5
1617-89
CORE/BOX
DEPTH
FEET
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1620
1630
1640
1650
1660
SH
1A,2AB
O
G
SH 101
SS 108
8A,7E
SS 109
7E
8A,B
E
8A,7E
J6
SH 102
J1A
PC
J4
J5
N



CLASTIC CORE LOGGING FORM

WELL LOCATION 11-2-54-8W5
FIELD
CALBRATED CORE INTERVAL 5430-547

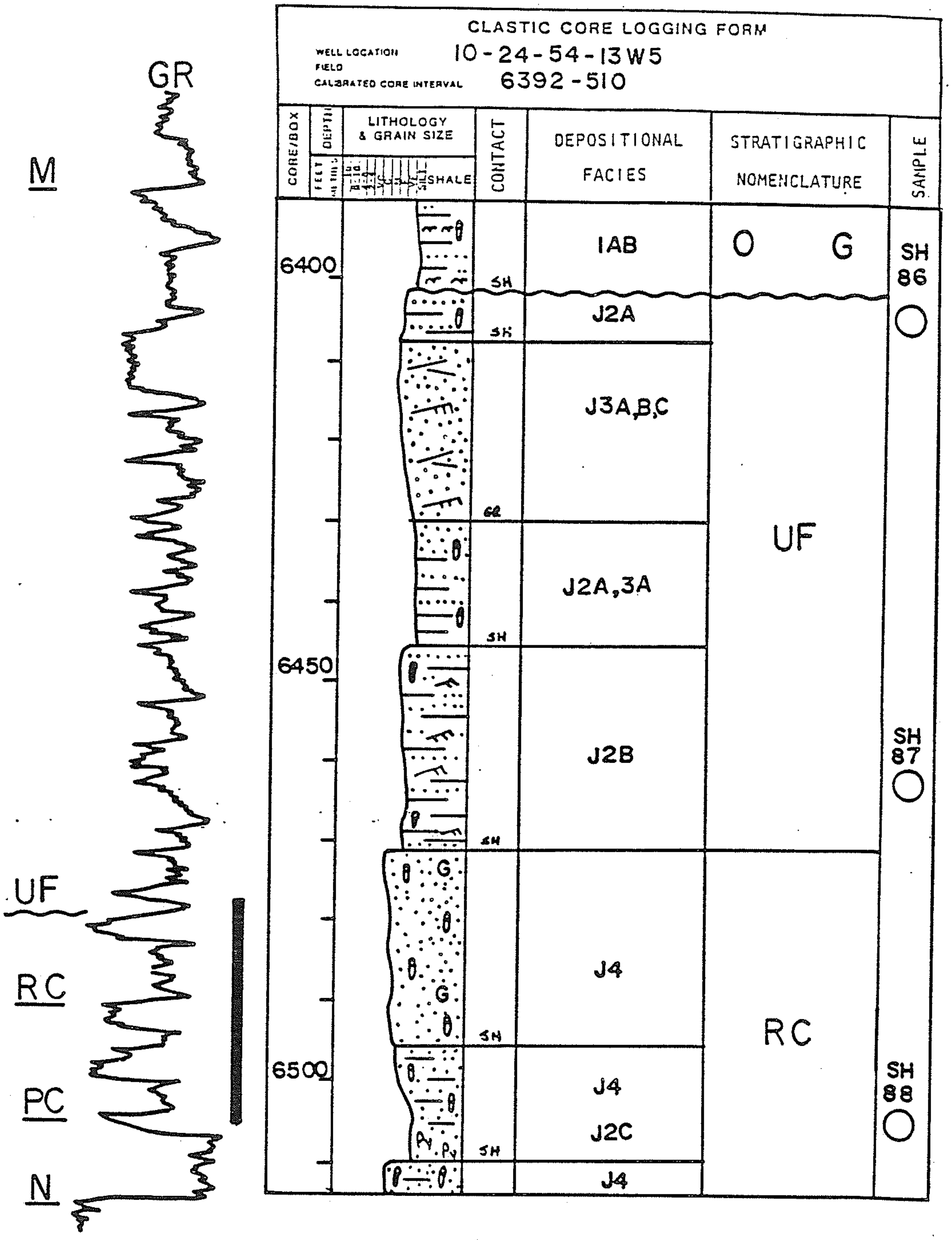
CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
SH	2AB	O	G	○ SH 84
GR	4E	E		
SH	7C			
SH	7A 7E			
SH	8A			
SH	7C			
	JIA,6 BASE NOT LOGGED	PC		

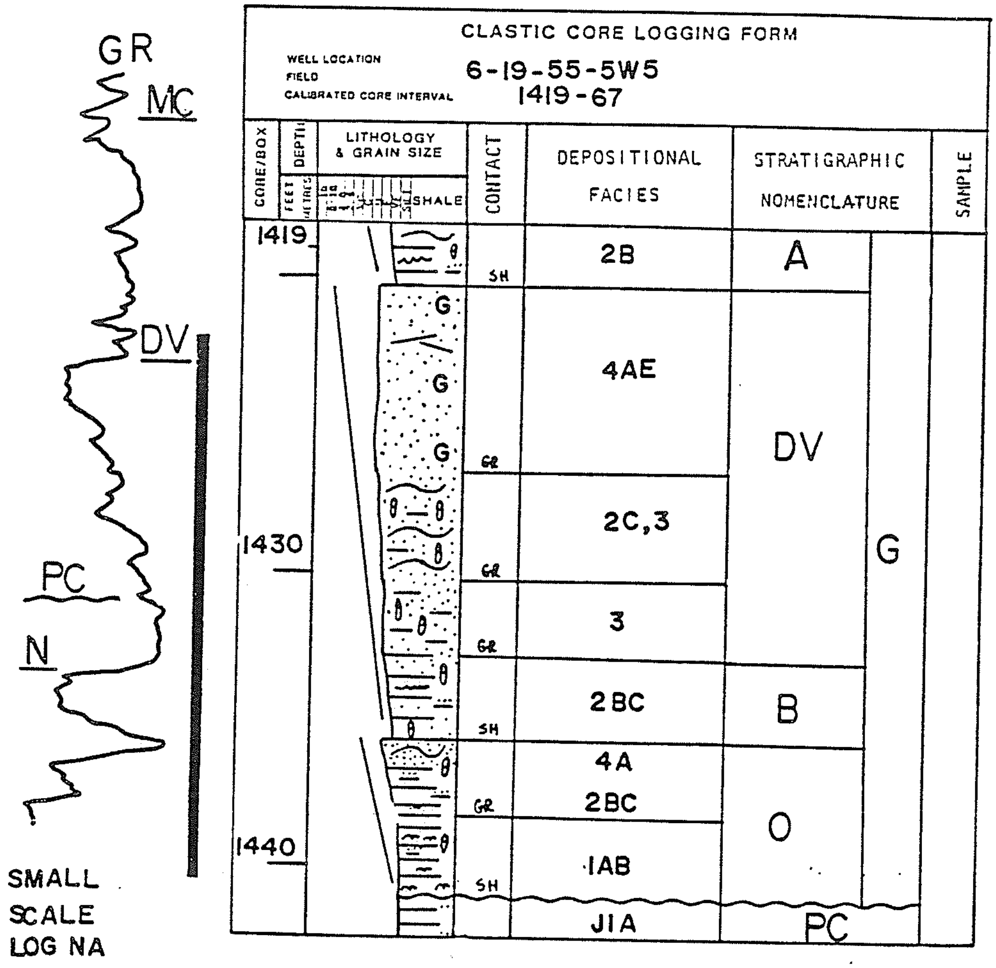


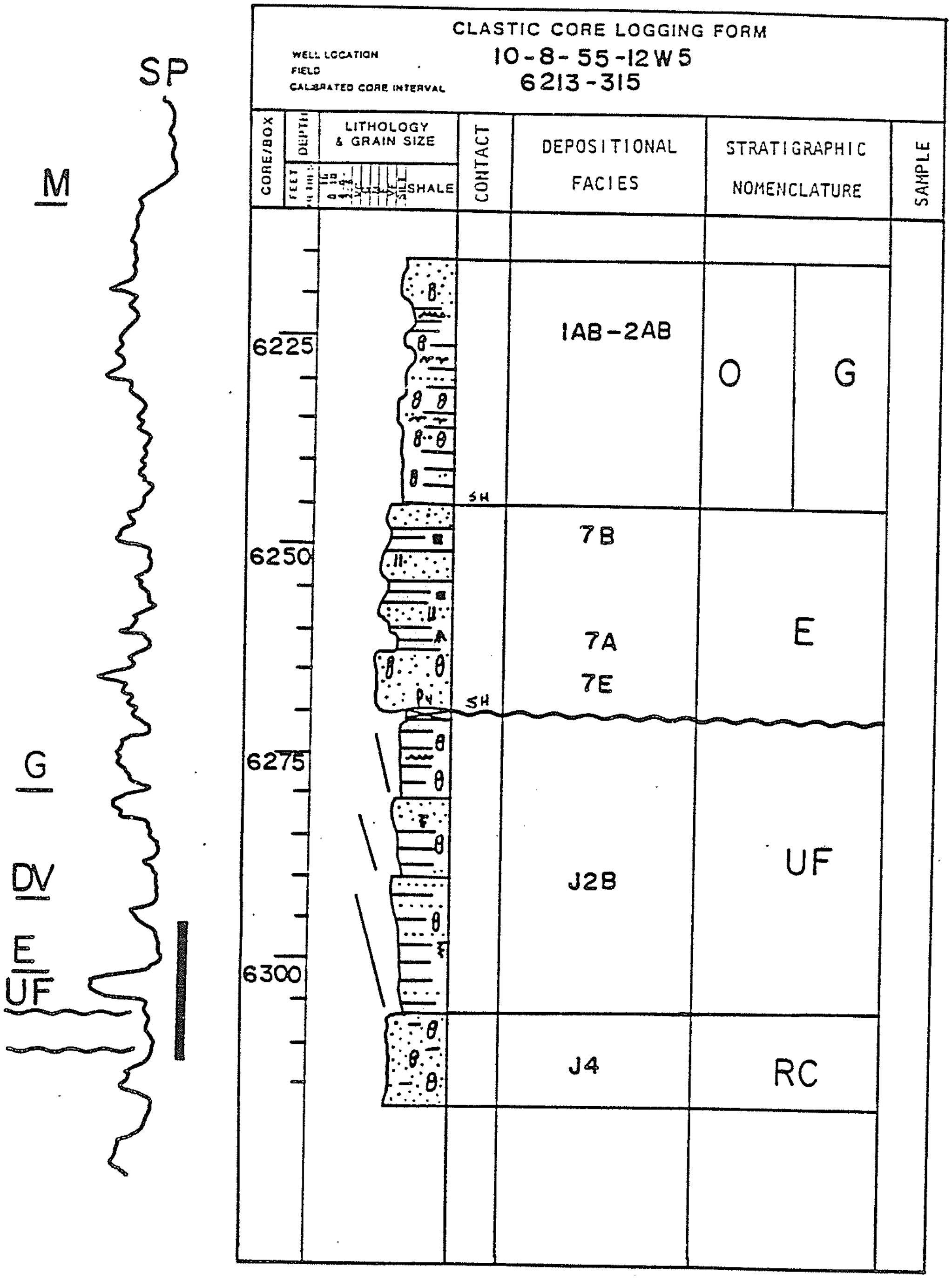
CLASTIC CORE LOGGING FORM

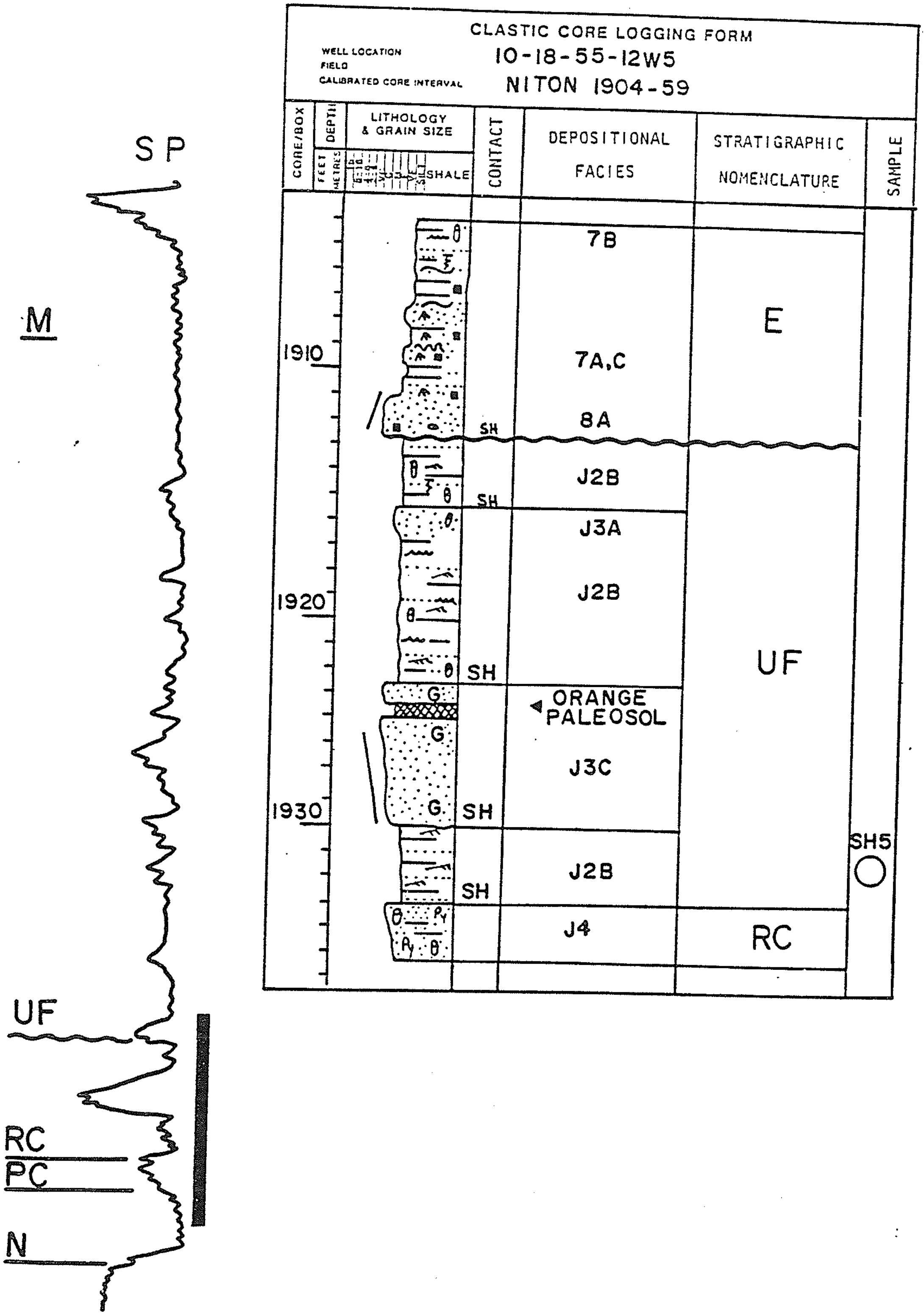
WELL LOCATION 11-25-54-12W5
FIELD
CALIBRATED CORE INTERVAL 1861-1898

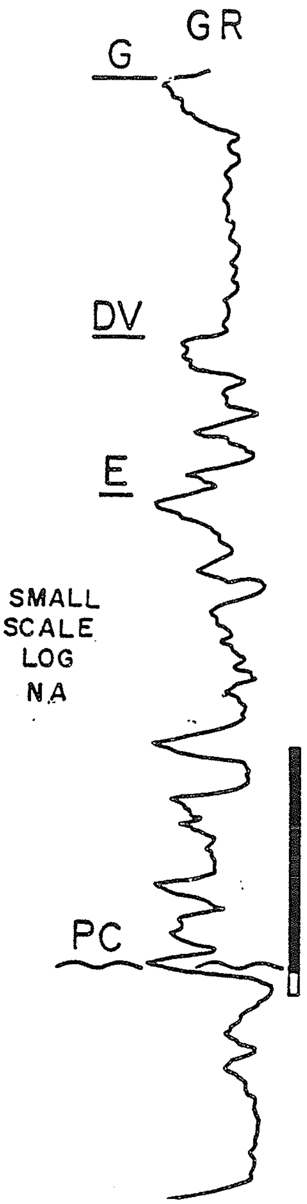
CORE/BOX	DEPTH	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
			SH	J2B	UF	
			SH	J2B	RC	
			SH	J4		
			SH	J2B		
	1880		GR	J3C		
			GR	J2B		
	1890		SH	J4		
				J1A	PC	

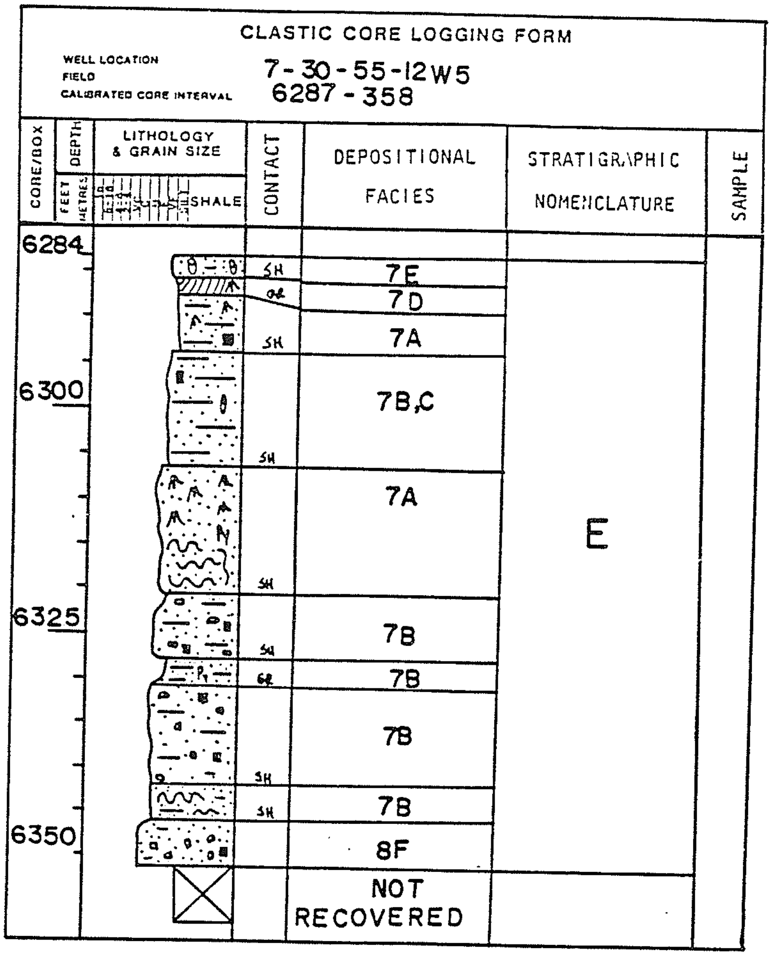

GR
M
UF
RC
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
10-24-54-13W5
6392-510
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
6400
6450
6500
SH
GR
IAB
J2A
J3A,B,C
J2A,3A
J2B
J4
J4
J2C
J4
O G
UF
RC
SH 86
SH 87
SH 88


GR
MC
DV
PC
N
SMALL SCALE LOG NA
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-19-55-5W5
1419-67
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1419
1430
1440
G
G
G
SH
GR
GR
GR
SH
GR
SH
2B
4AE
2C,3
3
2BC
4A
2BC
1AB
J1A
A
DV
B
O
G
PC


SP
M
G
DV
E
UF
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
10-8-55-12W5
6213-315
CORE/BOX
DEPTH
FEET
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
6225
6250
6275
6300
SH
SH
1AB-2AB
7B
7A
7E
J2B
J4
O
G
E
UF
RC


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
10-18-55-12W5
NITON 1904-59
CORE/BOX
FEET
METRES
DEPTH
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
1910
1920
1930
7B
7A,C
8A
J2B
J3A
J2B
ORANGE PALEOSOL
J3C
J2B
J4
E
UF
RC
SH
SH
SH
SH
SH
G
G
G
SH5
SP
M
UF
RC
PC
N

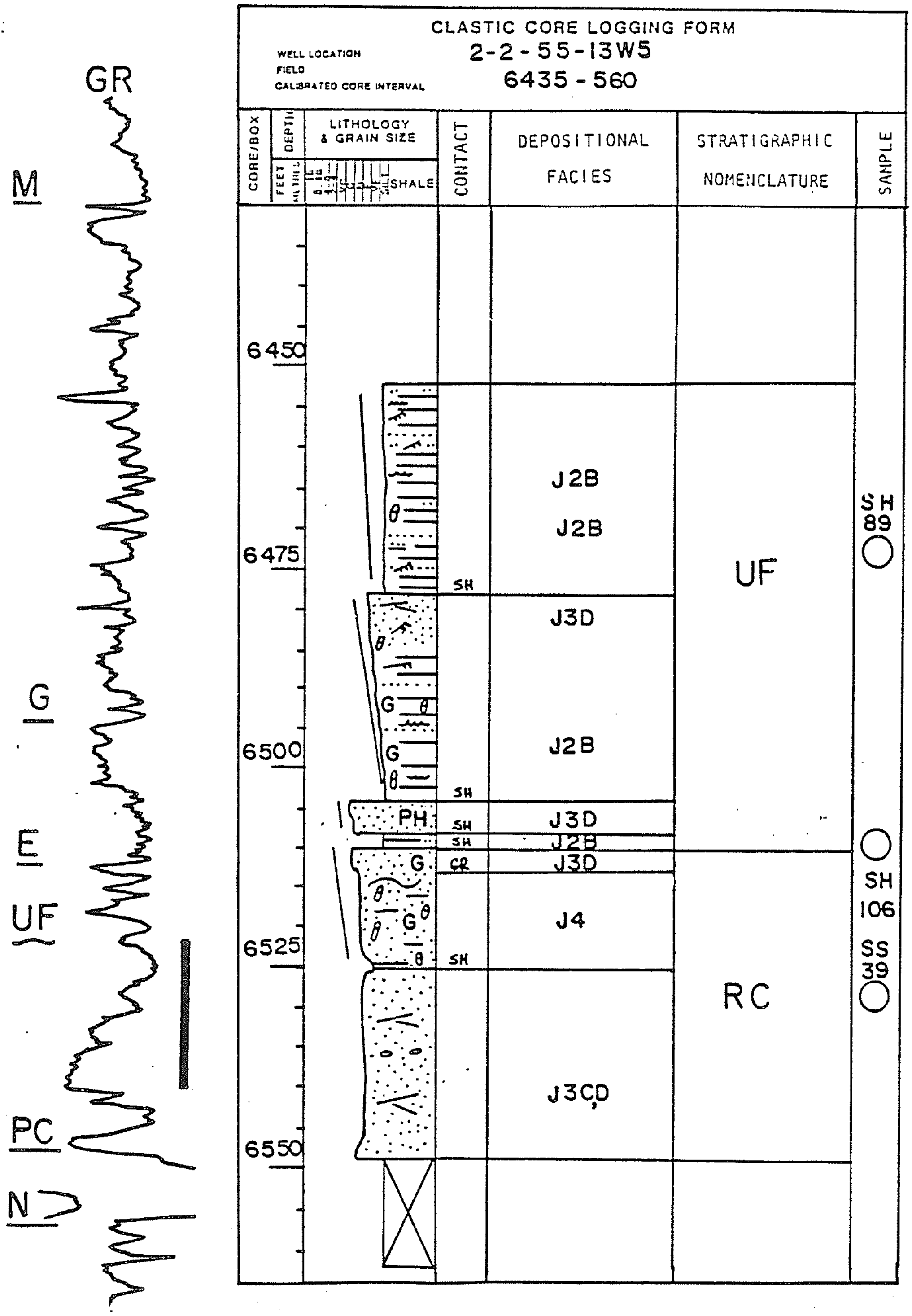


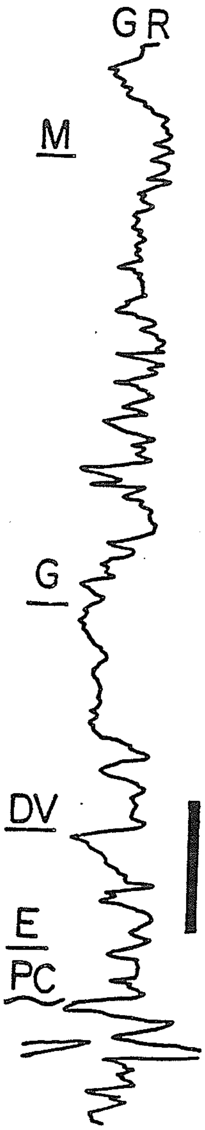


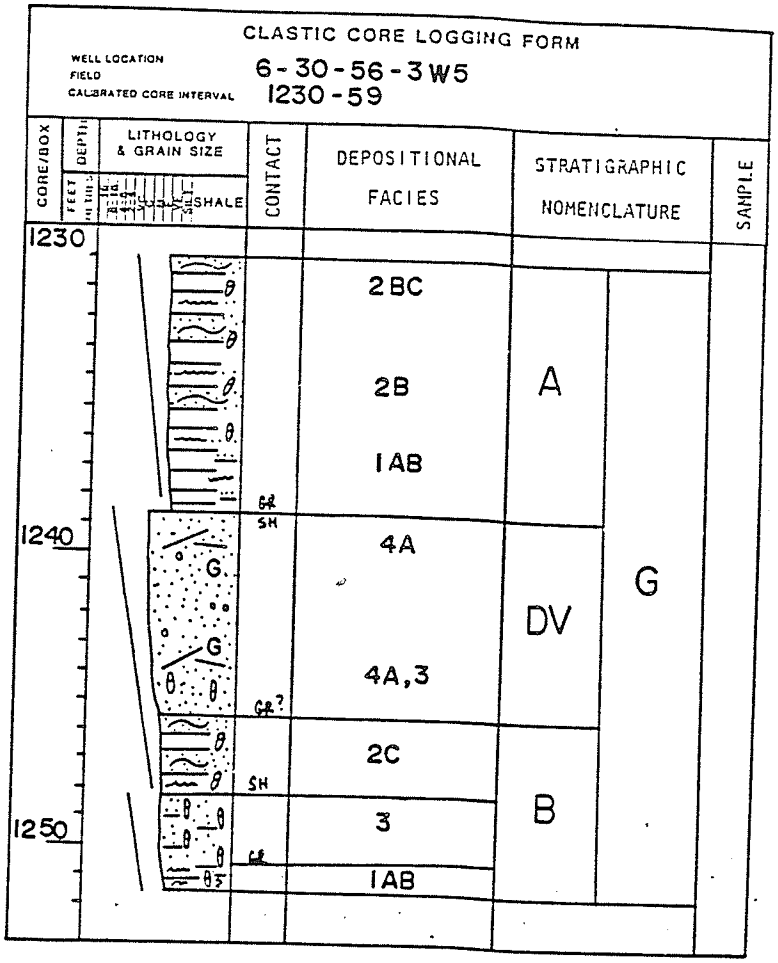
CLASTIC CORE LOGGING FORM

WELL LOCATION 7-30-55-12W5
FIELD
CALIBRATED CORE INTERVAL 6287 - 358

CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	6284		SH	7E		
			GR	7D	E	
			SH	7A		
	6300		SH	7B,C		
			SH	7A		
	6325		SH	7B		
			GR	7B		
			SH	7B		
			SH	7B		
	6350			8F		
				NOT RECOVERED		

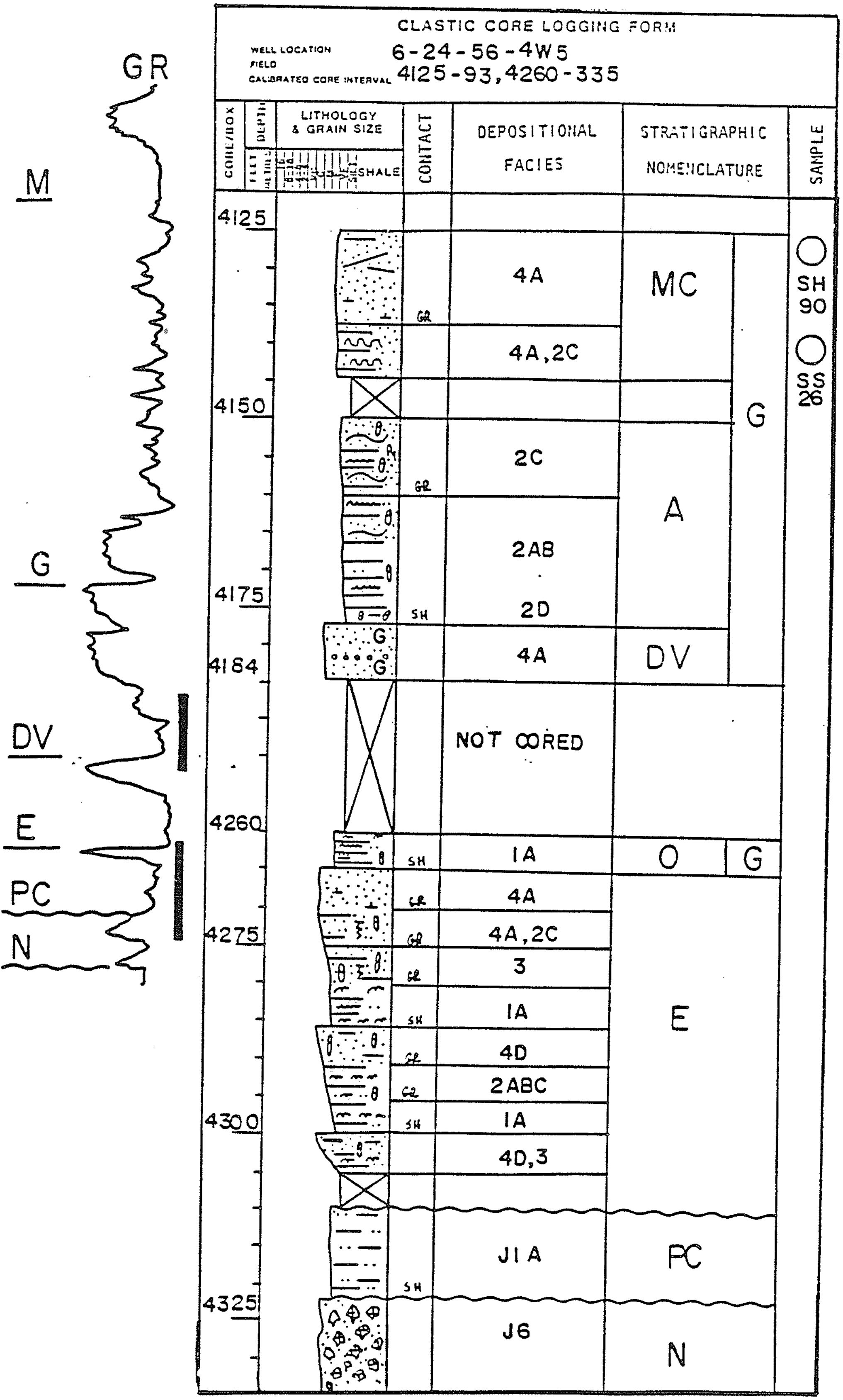

GR
M
G
E
UF
PC
N
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
2-2-55-13W5
6435 - 560
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
6450
6475
6500
6525
6550
J2B
J2B
J3D
J2B
J3D
J2B
J3D
J4
J3CD
SH
SH
SH
SH
CR
SH
G
G
G
PH
G
G
UF
RC
SH 89
SH 106
SS 39





CLASTIC CORE LOGGING FORM

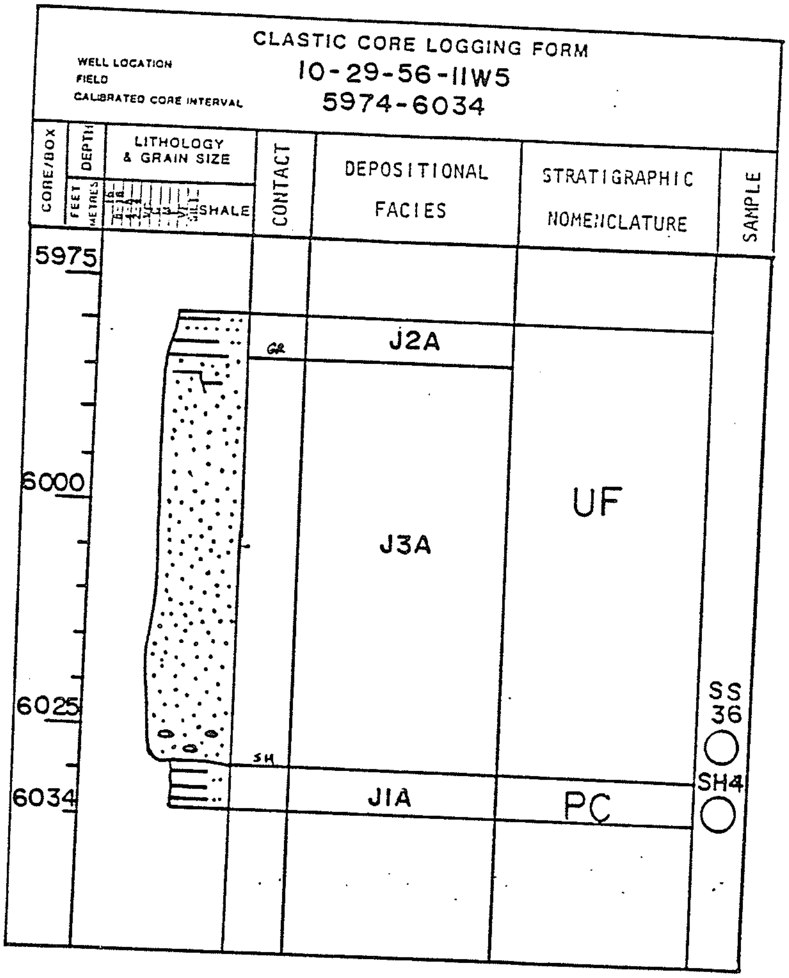
WELL LOCATION 6-30-56-3W5
FIELD
CALIBRATED CORE INTERVAL 1230-59



CLASTIC CORE LOGGING FORM

WELL LOCATION 6-24-56-4W5
FIELD
CALIBRATED CORE INTERVAL 4125-93,4260-335

CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE		SAMPLE
GR	4A	MC	G	SH 90
	4A,2C			SS 26
GR	2C	A		
SH	2AB 2D			
	4A	DV		
	NOT CORED			
SH	1A	O	G	
GR	4A	E		
GR	4A,2C			
GR	3			
SH	1A			
GR	4D			
GR	2ABC			
SH	1A			
	4D,3			
SH	J1A	PC		
	J6	N		

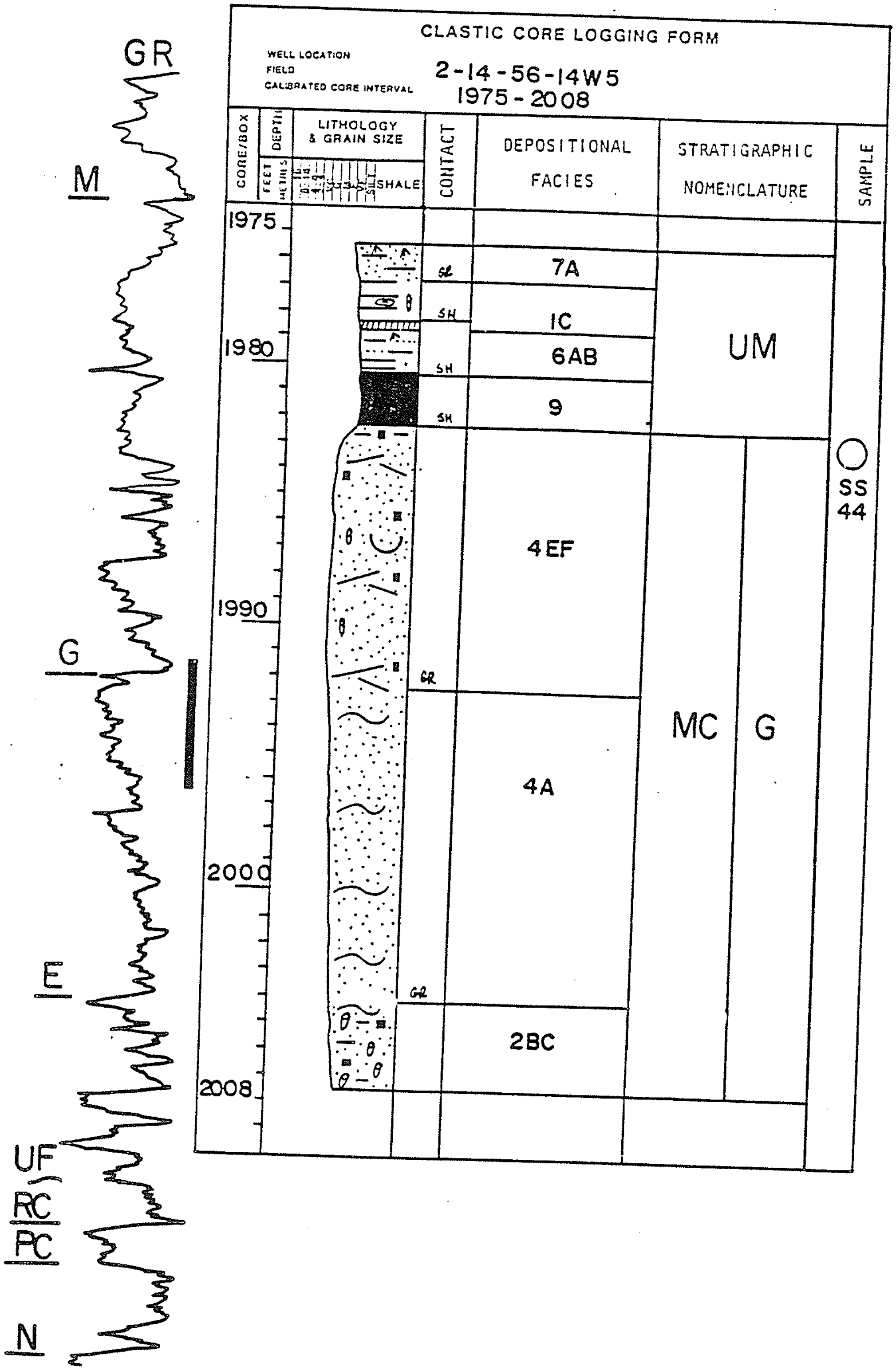


CLASTIC CORE LOGGING FORM

WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL

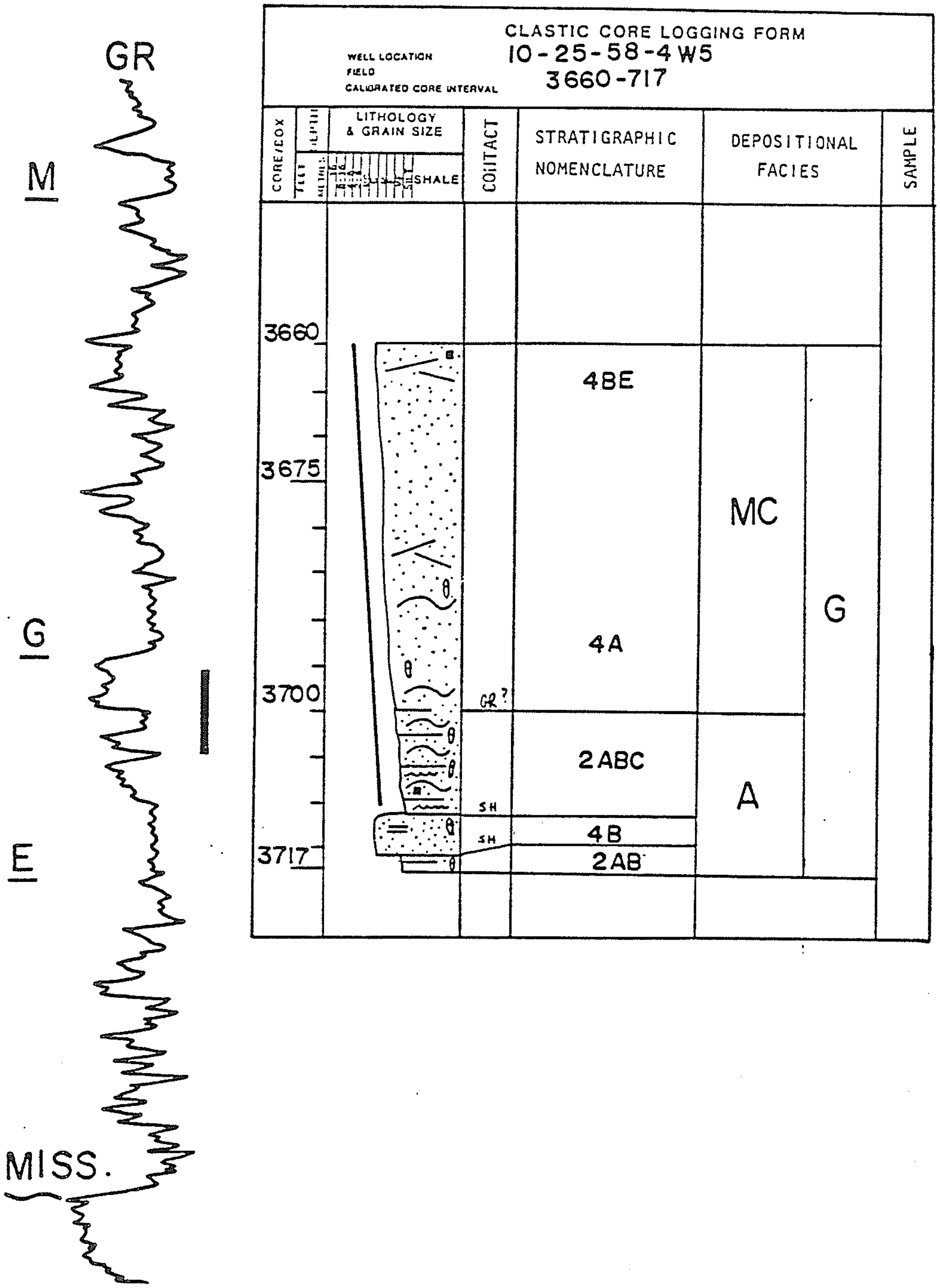
10-29-56-11W5
5974-6034

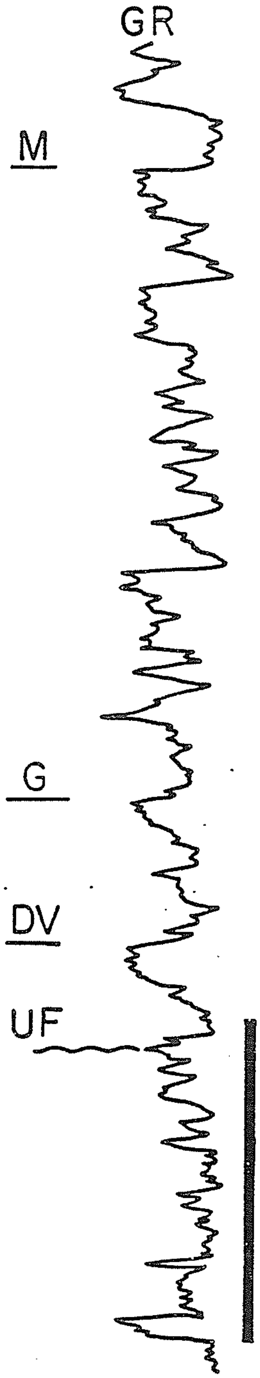
CORE/BOX	DEPTH FEET METRES	LITHOLOGY & GRAIN SIZE SHALE	CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
	5975					
			GR	J2A		
	6000			J3A	UF	
	6025					SS 36 ○
	6034		SH	J1A	PC	SH4 ○

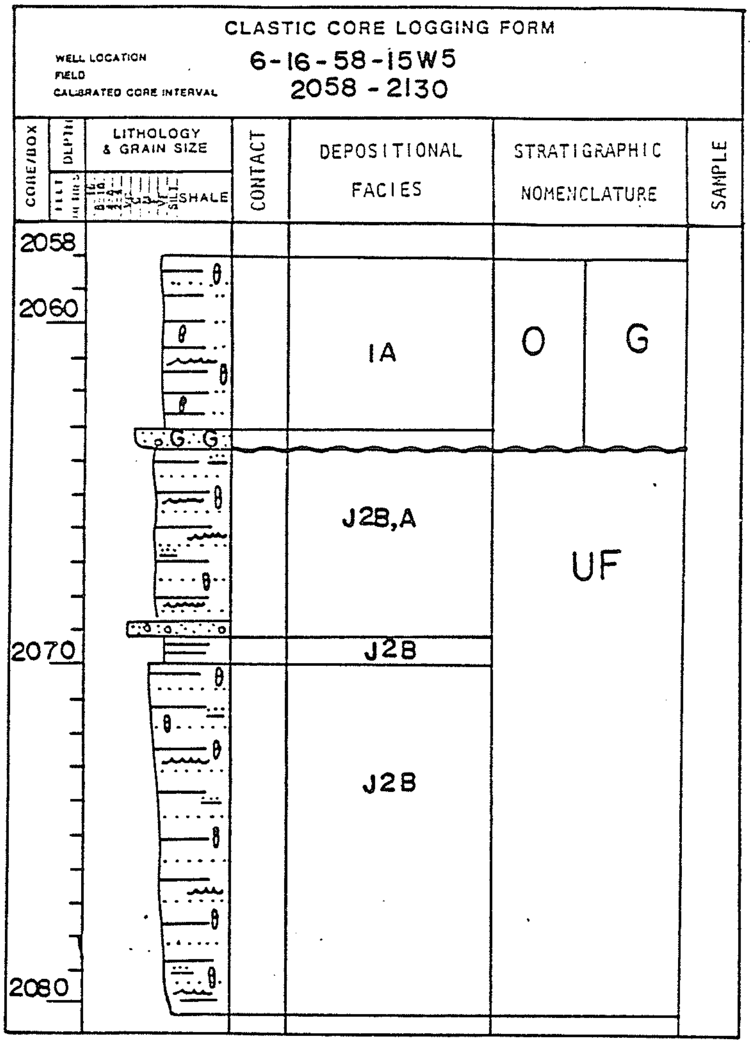


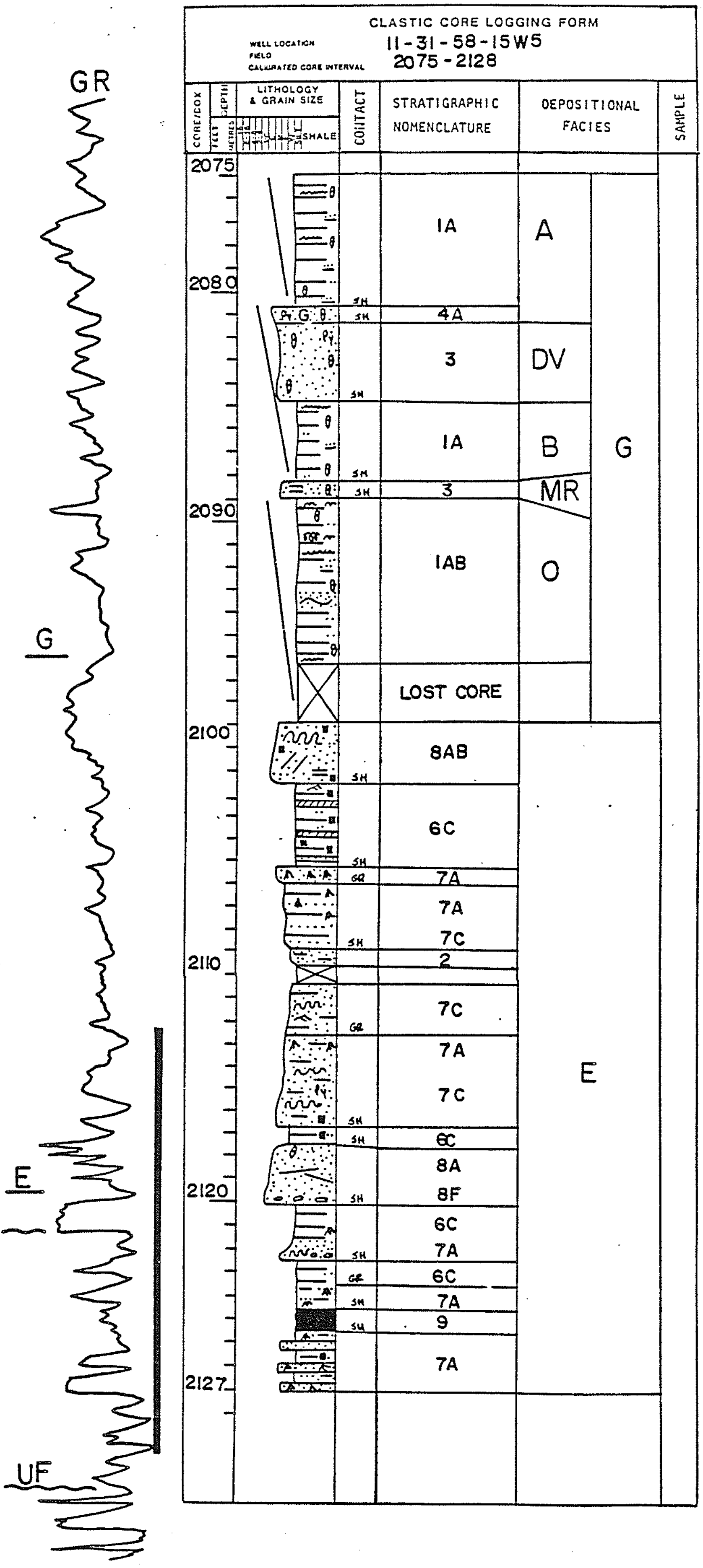
CLASTIC CORE LOGGING FORM

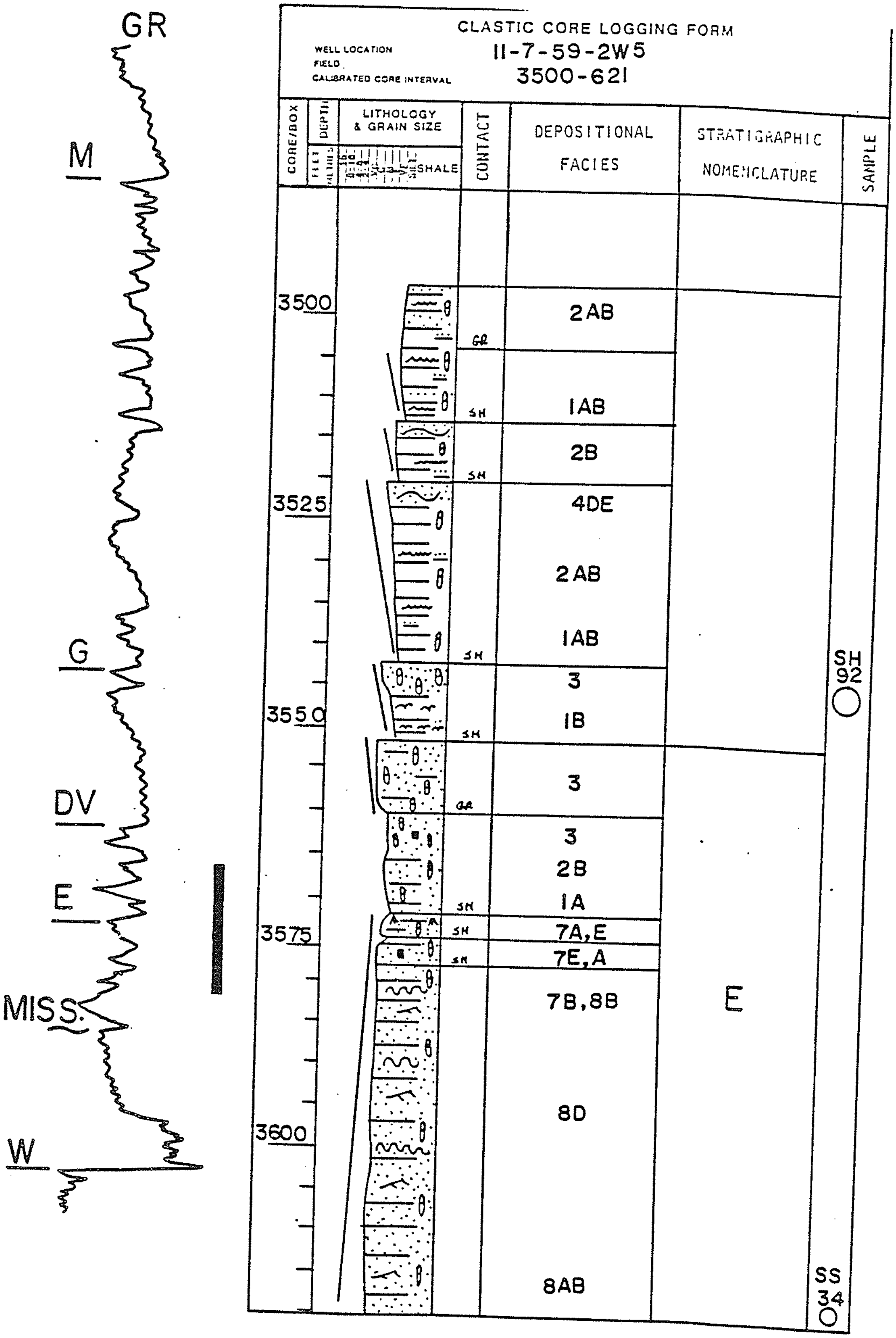
WELL LOCATION 2-14-56-14W5
FIELD
CALIBRATED CORE INTERVAL 1975 - 2008


GR
M
G
E
MISS.
CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
10-25-58-4W5
3660-717
CORE/BOX
DEPTH
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
STRATIGRAPHIC NOMENCLATURE
DEPOSITIONAL FACIES
SAMPLE
3660
3675
3700
3717
GR?
SH
SH
4BE
4A
2ABC
4B
2AB
MC
G
A

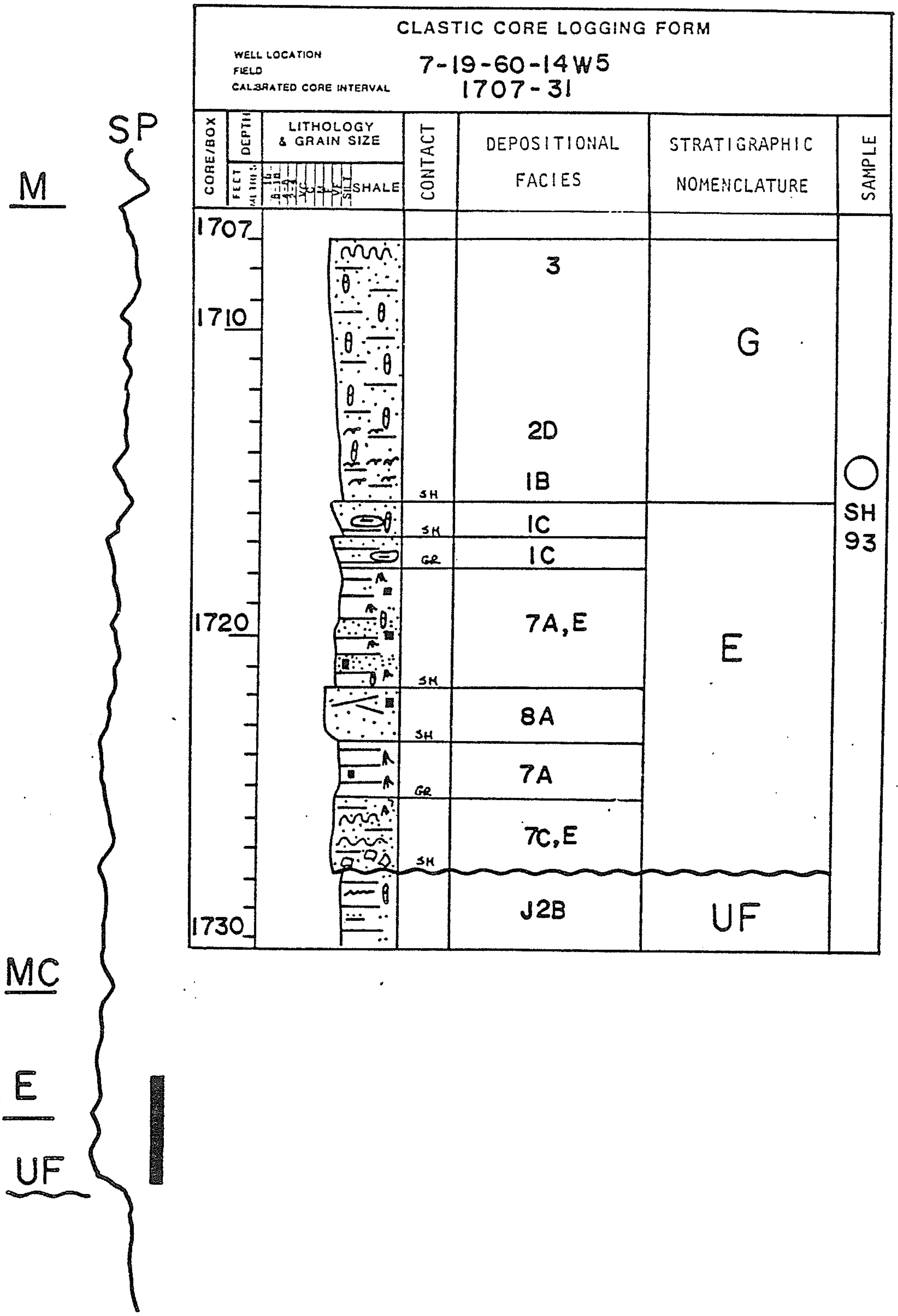

GR
M
G
DV
UF


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
6-16-58-15W5
2058 - 2130
CORE/BOX
DEPTH
LITHOLOGY & GRAIN SIZE
SILT
SHALE
CONTACT
DEPOSITIONAL FACIES
STRATIGRAPHIC NOMENCLATURE
SAMPLE
2058
2060
2070
2080
IA
J2B,A
J2B
J2B
O
G
UF


CLASTIC CORE LOGGING FORM
WELL LOCATION
FIELD
CALIBRATED CORE INTERVAL
11-31-58-15W5
2075-2128
CORE/BOX
DEPTH
FEET
METRES
LITHOLOGY & GRAIN SIZE
SHALE
CONTACT
STRATIGRAPHIC NOMENCLATURE
DEPOSITIONAL FACIES
SAMPLE
GR
G
E
UF
2075
2080
2090
2100
2110
2120
2127
SH
GR
1A
4A
3
1A
3
1AB
LOST CORE
8AB
6C
7A
7A
7C
2
7C
7A
7C
6C
8A
8F
6C
7A
6C
7A
9
7A
A
DV
B
MR
O
G
E



CLASTIC CORE LOGGING FORM
WELL LOCATION 11-7-59-2W5
FIELD
CALIBRATED CORE INTERVAL 3500-621



CLASTIC CORE LOGGING FORM

WELL LOCATION 7-19-60-14W5
FIELD
CALIBRATED CORE INTERVAL 1707-31

CONTACT	DEPOSITIONAL FACIES	STRATIGRAPHIC NOMENCLATURE	SAMPLE
SH	3 2D 1B	G	
SH	IC	E	○ SH 93
GR	IC		
SH	7A,E		
SH	8A		
GR	7A		
SH	7C,E		
	J2B	UF	

APPENDIX 4 SANDSTONE PETROGRAPHY DATA SHEETS

a FRAMEWORK COMPOSITION JURASSIC (FERNIE-KOOTENAY AND NIKANASSIN) SANDSTONES

FORMATION		QUARTZ		FELDS.			LITHICS			%	GLAUC	OPK	O ·	CEMENT			FOLK		
SAMPLE #	GRAIN SIZE	Qm	Qp	K	P	?	CHT	CARB	?	FRAME				QTZ	Cc	CLAY	O	F	L
ROCK CREEK																			
SS-16	VFG	65	7	-	-	-	-	-	-	72	-	9	4	*	-	*	100	-	-
SS-56	VFG	92	3	-	-	-	1	-	-	96	<1	<1	2	**	-	-	99	-	1
SS-68	VFG	96	2	-	-	-	-	-	-	98	1	-	1	***	-	*	100	-	-
SS-87	LFG	72	3	-	-	-	-	-	-	75	10	-	15	-	-	*	100	-	-
SS-107	FG	92	2	-	-	-	1	-	-	95	2	<1	2	***	*	**	99	-	1
SS-116	FG	68	8	-	-	-	1	-	-	77	3	-	10	**	-	*	99	-	1
UPPER FERNIE																			
SS-36	VFG	82	1	-	-	-	1	-	-	84	-	<1	15	**	-	-	99	-	1
SS-39	VFG	87	1	-	-	-	1	-	-	89	<1	-	10	*	-	-	99	-	1
SS-45	LFG	88	3	-	-	-	1	-	-	92	1	1	1	***	*	**	97	-	3
SS-60	FG	50	14	-	-	-	11	-	-	77	-	-	6	**	-	*	83	-	17
SS-63	VFG	70	8	-	-	-	-	-	-	78	-	<1	1	*	-	**	100	-	-
SS-64	UFG	63	8	-	-	-	9	-	3	83	-	-	6	-	-	**	86	-	14
SS-98	FG	52	11	-	-	-	16	-	-	79	-	-	4	*	-	**	80	-	20
SS-158	FG	79	1	-	-	-	7	-	-	87	-	-	13	**	-	-	92	-	8
MEAN		75.4	5.1	-	-	-	3.5	-	0.4	84.4	1.2	0.8	6.4				95		5
N=14																			
KOOTENAY-NIKANASSIN																			
SS-114	FG	25	6	-	-	-	14	4	4	53	6	-	0	**	-	-	58	-	42
SS-164	FG	31	4	-	-	-	28	2	3	68	-	<1	0	**	-	*	51	0	49
SS-165	MG	20	2	-	-	-	33	4	4	63	1	1	0	**	-	*	35	0	65
SS-166	MG	13	2	-	-	-	54	7	2	78	-	<1	0	**	-	*	19	-	81
SS-167	FG	70	2	-	-	-	23	-	1	96	-	-	0	***	-	-	75	-	25
SS-168	FG	67	-	-	-	-	23	2	-	92	2	1	0	***	-	-	73	-	27
SS-169	FG	46	2	-	-	-	30	2	3	83	-	-	0	**	-	*	58	-	42
MEAN		38.8	2.6	-	-	-	29.3	3	2.4	76.1	0.3	1.3	0				53	-	47

CEMENT ABUNDANCE

-	ABSENT
*	RARE
**	COMMON
***	ABUNDANT

b FRAMEWORK COMPOSITION MARINE SANDSTONES, GLAUCONITE FORMATION

FORMATION	QUARTZ		FELDS.			LITHICS			%	GLAUC	OPK	O	CEMENT			FOLK		
SAMPLE #	Qm	Qp	K	P	?	CHT	CARB	?	FRAME				QTZ	Cc	CLAY	Q	F	L
GRAIN SIZE																		
SS-25 FG	46	8	-	-	3	14	-	12	83	5	5	5	**	-	*	65	4	31
SS-42 FG	38	7	-	-	2	14	-	15	76	8	<1	5	*	-	***	59	3	38
SS-51 FG	37	2	1	-	5	17	7	4	73	3	<1	9	*	-	*	53	8	39
SS-53 FG	44	5	-	-	2	17	-	11	79	2	6	12	**	-	-	62	3	35
SS-54 FG	69	17	-	-	-	10	-	2	98	-	-	<1	***	-	-	88	-	12
SS-55 FG	59	5	-	-	2	11	-	3	80	5	2	13	***	-	-	80	3	17
SS-73 FG	60	9	-	-	-	9	-	3	81	5	-	14	**	-	-	85	-	15
SS-74 FG	40	9	-	-	-	20	-	24	93	2	-	5	**	-	-	53	-	47
SS-77 FG	24	2	-	-	-	38	-	10	74	4	5	3	*	-	**	35	-	65
SS-79 FG	75	5	-	-	-	4	-	-	84	-	-	14	***	-	-	95	-	5
SS 80 VFG	32	7	-	-	2	21	-	11	73	17	4	-	*	-	**	53	3	44
SS85 VFG	51	7	-	-	4	9	1	7	79	6	<1	14	**	-	**	73	5	22
MEAN	47.9	6.9	0.1	-	1.7	15.3	.7	8.5	81.1	4.8	1.9	7.9				67	2	31
N=12																		
DRAYTON VALLEY MEMBER																		
SS-17 FG	29	5	2	-	7	20	-	5	68	4	1	15	*	*	*	50	13	37
SS-23 MG	46	7	-	-	-	20	2	10	85	3	2	6	**	-	-	62	-	38
SS-99 FG	29	11	5	-	8	16	-	16	85	2	2	5	**	-	-	47	15	38
SS106 FG	51	2	-	-	7	16	-	5	81	2	1	12	**	-	*	65	9	26
SS145 VFG	38	11	-	-	5	18	-	11	83	3	<1	14	*	-	*	59	6	35
SS102 MG	10	7	-	-	-	39	-	27	83	6	-	11	*	-	*	20	-	80
MEAN	33.8	7.2	1.2	-	4.5	21.5	.3	12.3	80.8	3.3	1.1	10.5				51	7	42
N=6																		
MEDICINE RIVER MEMBER																		
SS152 VFG	80	2	-	-	-	5	-	1	88	-	1	10	**	-	*	93	-	7
SS153 VFG	89	1	-	-	-	2	-	-	92	-	1	7	**	-	*	98	-	2
MEAN	845	1.5	-	-	-	3.5	-	5	90.0	-	1.0	8.5	-	-	-	96	-	4
N=2																		
MODESTE CREEK MEMBER																		
SS-26 VFG	17	6	2	-	13	11	1	10	60	1	4	<1	-	**	-	38	25	37
SS-35 VFG	19	3	2	-	23	17	2	14	80	1	4	<1	-	**	-	28	31	41
SS-44 FG	24	8	2	-	12	8	2	27	83	<1	4	8	*	**		39	17	44
SS-88 VFG	14	2	1	-	15	10	7	10	59	<1	-	15	*	**	-	27	27	46
SS147 MG	12	7	1	-	15	21	-	6	62	3	-	23	-	*	*	31	26	43
MEAN	17.2	5.2	1.6	-	15.6	13.4	2	13.4	68.8	1.2	2.4	9.4				33	25	42
N=5																		

C FRAMEWORK COMPOSITION MOOSEBAR, GATES AND BEAVER MINES SANDSTONES

FORMATION	QUARTZ		FELDS.			LITHICS			%	GLAUC	OPK	O	CEMENT			FOLK		
SAMPLE # GRAIN SIZE	Qm	Qp	K	P	?	CHT	CARB	?	FRAME				QTZ	Cc	CLAY	Q	F	L
LOWER MOOSEBAR																		
SS163 VFG	98	1	-	-	-	1.0	-	-	100	<1	5	-	**	-	*	71	4	25
SS151 FG	41	5	1	-	5	23	-	11	86	-	<1	2	-	-	*	53	7	40
SS160 FG	36	7	2	-	3	20	-	12	80	14	2	2	**	-	*	54	6	40
CRESCENT FALLS -RUBY CREEK AREA																		
SS113 VFG	15	1	-	-	-	18	2	2	38	17	1	0	-	*	***	42	-	58
SS129 VFG	35	1	-	-	-	4	38	2	80	5	-	<1	-	-	**	45	-	55
SS119 FG	40	5	-	-	-	26	-	10	81	15	3	<1	-	**	**	59	1	40
MEAN	37.6	3.8	.5	-	2	18.2	6.7	6.8	75.6	9.3	1.2					54	3	43
N=7																		
TORRENS MBR (GATES FM)																		
SS-111 FG	17	12	9	-	22	24	-	9	93	<1	1	5	-	**	*	31	33	36
SS-115 FG	20	8	3	-	17	24	-	12	84	1	1	8	*	-	*	33	24	43
SS-118 FG	12	2	2	-	13	9	-	4	42	-	<1	-	-	**	-	33	36	31
SS-138 FG	15	6	5	-	24	18	-	14	82	3	-	<1	-	-	*	26	35	39
MEAN	16	7	4.8	-	19	18.8	-	9.8	75.3	1.1	0.6	3.4				31	32	37
N=4																		
BEAVER MINES FORMATION																		
SS-2 MG	14	9	1	-	8	26	-	25	83	-	5.0	2.0	-	*	**	28	11	61
SS121MG	19	6	20	-	30	16	1.0	3.0	95	-	-	-	-	**	***	26	53	21
MEAN	16.5	7.5	10.5	-	19	21	0.5	14	89	-	2.5	10				27	32	41
N=2																		

d FRAMEWORK COMPOSITION INCISED CHANNEL SANDSTONES, GLAUCONITE FORMATION

CAROLINE CHANNEL																			
SS155	FG	80	3	-	-	-	1	-	-	84	-	1	12	**	*	-	99	-	1
SS-49	FG	79	9	-	-	-	9	-	-	97	-	-	3	***	-	-	91	-	9
SS-50	FG	68	3	-	-	-	3	-	1	75	-	2	3	**	-	*	95	-	5
MEAN		75.6	5.0	-	-	-	4.3	-	.3	85.3	-	1.0	11.7				95	-	5
THORSBY CHANNEL																			
SS-92	FG	36	10	10	-	13	12	1	3	85	-	1	5	-	-	***	54	27	19
SS-93	FG	38	2	7	-	13	11	2	2	75	-	1	19	**	**	*	53	27	20
SS-94	FG	35	6	6	-	13	8	1	3	72	-	1	20	-	**	-	57	26	17
SS-95	MG	41	1	9	-	15	12	2	3	83	1	1	13	*	*	*	51	29	20
SS-96	FG	52	2	5	-	11	5	3	4	82	<1	2	8	*	**	-	66	20	14
SS100	FG	45	4	3	-	8	10	-	3	73	-	-	22	**	**	*	67	15	18
GILBY CHANNEL																			
SS-75	FG	18	4	2	-	15	23	1	14	77	-	1	10	*	**	*	29	22	49
SS-76	FG	15	5	3	1	15	24	1	6	70	-	1	11	*	**	-	29	27	44
PEMBINA CHANNELS																			
SS101	MG	12	4	2	-	9	25	-	9	61	-	-	6	-	**	-	26	18	56
SS103	MG	17	7	4	-	14	27	1	8	78	1	1	7	*	**	*	31	23	46
SS105	FG	23	13	1	-	2	22	-	7	68	-	2	<1	-	***	-	53	4	43
HOADLEY-STRACHAN CHANNELS																			
SS-81	FG	67	13	-	-	5	2	-	-	87	4	2	2	**	*	-	92	7	1
SS-82	FG	42	7	-	-	-	14	8	9	80	1	2	5	**	*	-	61	-	39
SS-84	FG	19	8	-	-	13	23	3	7	73	-	3	9	*	*	-	37	18	45
SS156	FG	9	7	5	-	9	34	2	8	74	<1	<1	3	-	*	*	22	19	59
SS157	FG	12	8	3	-	15	21	1	6	66	-	1	7	*	**	**	30	27	42
EDSON CHANNEL																			
SS154	MG	20	10	-	-	-	35	1	22	88	-	-	12	**	-	-	34	-	66

e FRAMEWORK COMPOSITION GLADSTONE AND ELLERSLIE SANDSTONES.

FORMATION	QUARTZ		FELDS.			LITHICS			%	GLAUC	OPK	O	CEMENT			FOLK		
SAMPLE #	Qm	Qp	K	P	?	CHT	CARB	?	FRAME			QTZ	Cc	CLAY		Q	F	L
GRAIN SIZE																		
GLADSTONE FM																		
SS-3 UMG	40	10	-	-	-	40	5	5	100	-	-	0	**	-	-	50	-	50
SS-4 LFG	19	5	-	-	-	44	-	5	73	-	1	6	**	*	-	33	-	67
SS-128 MG	20	9	-	-	-	42	1	22	94	-	1	2	**	**	-	31	-	69
SS-142 MG	19	13	-	-	-	15	6	6	59	-	2	0	-	**	**	54	-	46
SS-149 FG	25	6	-	-	-	18	17	8	74	-	-	6	*	**	-	42	-	58
SS-161 FG	23	4	-	-	-	12	7	23	69	-	2	-	*	**	*	39	-	61
MEAN	24.3	7.8	-	-	-	28.5	6	11.5	78.2	-	1.3	2.7				42		58
N=6																		
ELLERSLIE FORMATION																		
SS-22 MG	30	5	-	-	-	40	-	-	75	-	-	19	-	-	*	47	-	53
SS-34 VFG	71	-	-	-	-	2	2	-	73	-	1	20	-	-	*	97	-	3
SS-37 FG	54	13	-	-	-	22	-	-	89	-	-	8	***	-	*	75	-	25
SS-40 VFG	86	-	-	-	-	1	-	-	87	-	2	5	*	-	*	99	-	1
SS-47 MG	33	1	-	-	-	29	-	5	68	-	1	6	-	***	-	50	-	50
SS-57 FG	59	6	-	-	-	3	-	1	69	-	5	17	**	-	*	94	-	6
SS-58 FG	73	5	-	-	-	3	-	1	82	-	2	9	*	-	*	95	-	5
SS-59 FG	44	6	-	-	-	27	-	3	80	-	9	7	**	-	*	63	-	37
SS-61 VFG	81	-	-	-	-	2	-	-	83	-	-	14	*	-	-	98	-	2
SS-62 FG	26	2	-	-	1	9	3	7	48	-	-	6	*	**	8	58	1	41
SS-78 FG	64	2	-	-	1	11	-	2	80	-	1	14	**	-	*	83	1	16
SS-86 MG	66	2	-	-	-	7	-	-	75	-	-	20	**	-	*	91	-	9
SS-89 FG	65	8	-	-	-	7	-	2	82	-	1	7	**	*	*	89	-	11
SS-90 MG	25	3	-	-	-	55	-	1	84	-	-	3	*	**	-	33	-	67
SS-91 MG	30	9	-	-	-	32	2	11	84	-	1	6	*	*	*	46	-	54
SS-97 MG	54	2	-	-	-	13	-	3	72	-	-	1	-	***	-	78	-	22
SS-108 FG	63	3	1	-	-	5	2	9	83	-	2	7	*	*	*	80	1	19
SS109 FG	52	4	-	-	-	25	-	3	84	-	-	12	**	-	***	67	-	33
MEAN	54.2	3.9	<1	-	1	16.3	0.4	2.7	77.7	-	1.5	10.1				75	-	25
N=18																		

APPENDIX 5 ROCK EVAL DATA

5A JURASSIC SAMPLES

SAMPLE #	TOC	TMAX	S_1	S_2	S_3	H1	01	$S_1 + S_2$	$\frac{S_1}{S_1+S_2}$	S_2/S_3
2	0.29	361	.80	.84	.27	289	93	1.64	.487	3.11
4	1.04	445	.25	3.53	.17	339	16	3.78	.066	20.76
5	1.25	445	.30	2.66	.16	212	12	2.96	.101	16.62
6	3.27	450	1.6	9.32	.66	285	20	10.92	.147	14.12
24	0.49	440	.16	1.28	.43	261	87	1.44	.111	2.97
26	2.29	457	.85	4.68	.76	204	33	5.53	.154	6.15
31	1.58	479	.30	1.05	.18	66	11	1.35	.222	5.83
46	4.37	454	.83	5.9	.46	135	10	6.73	.123	12.82
52	2.04	468	.34	1.73	.42	84	20	2.07	.164	4.11
53	0.46	456	.06	.24	.40	52	86	.30	.20	0.60
60	12.83	441	2.53	77.36	1.02	602	7	79.89	.032	75.84
62	1.54	465	.35	1.77	.64	114	41	2.12	.165	2.76
63	1.58	463	.57	1.67	.68	105	43	2.24	.254	2.45
64	2.37	458	.69	4.33	.81	182	34	5.02	.137	5.34
65	2.97	458	.77	5.78	.67	177	22	6.05	.127	7.88
83	2.63	458	.75	3.75	.47	142	17	4.5	.167	7.97
86	0.09	411	0	.07	.46	77	511	.07	0	0.15
87	2.8	447	.65	6.22	.38	222	13	6.87	.095	16.36
88	0.65	438	.13	.75	.23	115	35	.88	.148	3.26
89	3.62	442	.84	8.24	.42	227	11	9.08	.093	19.61
97	2.25	455	.49	3.32	.37	147	16	3.81	.129	8.97
99	1.9	461	.53	3.97	.74	208	38	4.5	.118	5.36
102	0.91	428	.02	.27	.40	29	43	.29	.068	0.67
106	2.62	445	.40	2.36	2.04	90	77	2.76	.145	1.15
n = 24	mean 2.32					**182**				

5B ELLERSLIE SAMPLES

SAMPLE #	TOC	TMAX	S_1	S_2	S_3	H1	01	$S_1 + S_2$	$\frac{S_1}{S_1+S_2}$	S_2/S_3
3	2.94	442	1.08	11.42	.85	388	28	12.5	0.86	13.43
7	2.04	449	1.47	6.02	.78	295	38	7.49	.196	7.71
8	2.67	452	.91	4.13	.86	154	32	5.04	.181	4.80
9	2.59	448	1.55	6.54	.79	252	30	8.09	.192	8.27
16	1.08	454	.69	1.25	.45	115	41	1.94	.356	2.77
23	3.12	459	.86	7.08	.35	226	11	7.94	.108	20.22
28	3.50	472	1.14	3.31	.38	94	10	4.45	.256	8.71
40	1.81	453	.72	3.78	.19	208	10	4.5	.16	19.89
42	2.61	454	.74	3.52	.19	134	7	4.26	.174	18.52
44	1.29	463	.35	.92	.70	71	54	1.27	.276	1.31
45	1.49	462	.51	1.44	.24	96	16	1.95	.262	6.00
49	2.90	443	.95	6.15	.32	212	11	7.10	.133	19.21
56	2.02	446	.32	2.70	.27	133	13	3.02	.106	10.00
58	3.35	445	1.29	12.13	.91	362	27	13.42	.096	13.32
59	1.41	438	.41	2.37	.55	168	39	2.78	.147	4.30
61	1.02	444	.43	1.92	.80	188	78	2.35	.183	2.40
72	4.02	470	.79	3.27	1.11	81	27	4.06	.194	2.94
74	2.02	470	.53	1.94	.22	96	10	2.47	.215	8.81
75	2.27	467	.57	3.85	.46	169	20	4.42	.129	8.36
76	1.36	446	.28	2.8	1.42	205	104	3.08	.091	1.97
95	1.81	440	.62	5.61	1.05	309	58	6.23	.100	5.34
96	2.40	429	.25	3.76	.66	156	27	4.01	.062	5.69
98	7.24	442	4.56	35.52	1.21	490	16	40.08	.114	29.35
103*	3.65	420	.57	2.65	4.83	72	132	3.22	.177	0.54
107*	1.26	4.72	.47	.64	.55	50	43	1.11	.423	1.16
108*	1.67	499	.06	.60	.90	35	53	.66	.091	0.66
109*	5.59	502	.07	1.04	2.15	18	38	1.11	.063	0.48
110*	2.45	459	.66	4.05	.44	165	17	4.71	.140	9.20
111*	1.20	494	.08	.34	.58	28	48	.42	.190	0.58
113*	4.14	381	3.15	25.09	2.97	606	71	28.24	.112	8.44
n = 30	mean 2.56					183				

5C GLAUCONITE - MOOSEBAR SHALES

SAMPLE #	TOC	TMAX	S_1	S_2	S_3	H1	01	$S_1 + S_2$	$\frac{S_1}{S_1+S_2}$	S_2/S_3
1	2.61	452	.41	5.11	.19	195	7	5.55	.074	26.89
11	1.24	444	.22	1.12	1.73	90	139	1.34	.164	0.64
12	.91	443	.24	1.13	.58	124	63	1.37	.175	1.94
17	1.88	445	1.04	1.94	.28	103	14	2.98	.349	6.92
18	1.22	447	.75	3.81	.24	312	19	4.56	.164	15.87
19	3.30	448	2.09	9.75	.89	295	26	11.84	.177	10.95
20	2.88	449	.83	3.27	1.01	113	35	4.1	.202	3.23
21	2.64	449	2.47	7.27	.84	275	31	9.74	.253	8.65
22	2.43	461	.71	3.82	.35	157	14	4.53	.221	10.91
25	1.49	453	.48	2.98	.30	200	20	3.46	.139	9.93
27	1.05	481	.09	.43	.43	40	40	.52	.173	1.00
29	1.47	452	.15	1.01	.38	68	25	1.16	.129	2.65
30	1.20	448	.18	1.46	.21	121	17	1.64	.110	6.95
32	2.98	449	.70	2.57	1.41	86	47	3.27	.214	1.82
32A	2.83	448	.69	2.62	2.01	92	71	3.31	.208	1.30
33	1.14	451	.22	1.12	.38	98	33	1.34	.161	2.94
34	4.20	451	1.56	7.12	.46	169	10	8.68	.18	15.47
35	1.05	454	.21	1.00	.54	95	41	1.21	.174	1.85
36	1.97	456	.87	4.35	.81	220	41	5.22	.167	5.37
37	.71	443	.11	.47	.14	66	19	.58	.190	3.35
43	1.14	470	.24	.57	2.05	50	179	.81	.296	0.27
47	1.64	447	.41	2.25	.22	137	13	2.66	.154	10.22
48	1.15	448	.88	5.36	.39	466	33	6.24	.141	13.74
54	1.52	448	.30	2.55	.42	167	27	2.85	.105	6.07
55	.95	446	.32	.86	.43	90	45	1.18	.271	2.00
57	2.74	441	.69	12.12	.51	442	18	12.81	.054	23.76
66	.98	460	.14	.73	.43	74	43	.87	.161	1.69
68	2.49	444	.45	10.37	.81	416	32	10.82	.042	12.80
70	1.12	437	.23	1.34	.39	119	34	1.57	.146	3.43
71	1.31	464	.43	1.11	.44	84	33	1.54	.279	2.52
78	.79	438	.25	.92	.32	116	40	1.17	.213	2.87
79	2.89	446	.80	15.64	.89	541	30	16.44	.049	17.57
80	1.19	444	.86	3.47	.95	291	79	4.33	.199	3.65
81	.98	451	.17	.97	.47	98	47	1.14	.119	2.06
82	2.49	450	.70	5.85	.46	234	18	6.55	.107	12.71
84	2.24	448	.67	9.10	.76	406	33	9.77	.069	11.97
90	1.52	437	.18	1.07	2.83	70	186	1.25	.144	0.37
92	2.98	444	.77	5.58	1.17	187	39	6.35	.121	4.76
93	1.68	450	.44	3.37	.40	200	23	3.81	.115	8.42
100	1.95	440	.36	2.03	1.94	104	99	2.59	.151	1.04
101	1.69	445	.60	7.43	.57	439	33	8.03	.074	13.03
n = 41	mean					187				
	1.82									

APPENDIX 6 MICROPALEONTOLOGY DATA/INTERPRETATIONS

Micropaleontology report on 16 samples (eight subsurface core and eight outcrop) from the Jurassic (?) and Cretaceous of the central Alberta Plains and Foothills, collected and submitted by Mr. Lorne Rosenthal of Brandon University in August 1987 (NTS 82-O, 83-B, C,E,F and G).

The relevant parts of any manuscript prepared for publication that paraphrase or quote from this report should be referred to the Paleontology Subdivision, Calgary, for possible revision.

Introduction

These samples were collected by Mr. Rosenthal in conjunction with his doctoral research project at the University of Manitoba on a sedimentological study of the Lower Cretaceous Mannville Group in western Alberta. Mr. Rosenthal is associated with Dr. D.A. Leckie of the I.S.P.G. in preparing transects of Mesozoic strata from the Plains to the Foothills at various latitudes in Alberta for inclusion in field guides of the Canadian Society of Petroleum Geologists.

The samples have been assigned C-numbers but only the microslides are being retained at the I.S.P.G. In the report, the samples are listed in sequence following the collector's numbering system. In many cases informal names are used to designate the units from which the samples were obtained.

Sample No., Depth and Stratigraphy	Locality, Microfossils, Age, Environment and Residue	GSC Loc. No.
SH-18 7275 ft. "Medicine River" shale	HB Home Medicine River 2-19-39-4W5 NTS 83 B/7 Foraminifera (rare): **Saccammina**(?) sp. - one genus indeterminate - a two-chambered incomplete specimen Miscellanea - incertae sedis: siliceous, tube-like entity of indeterminate origin - may be an infilled primitive foraminifer, such as Bathysiphon, but this can't be confirmed - about 15 specimens Ostracoda ? (rare): two shell fragments possibly from this group Age: Indeterminate. Environment: Appears to be marine, possibly brackish, based on minimal data. Residue: Grey shale with some pyrite.	C-98343 /7275
SH-19 6725 ft. "Glauconitic Shale" (basal)	California Standard Gilby 10-19-40-2W5, NTS 83 B/8 No microfossils were obtained except for a cluster of aragonite possibly belonging to a molluscan shell, which by itself is inadequate for drawing any interpretation.	C-98344 /6725

Sample No., Depth and Stratigraphy	Locality, Microfossils, Age, Environment and Residue	GSC Loc. No.
	Residue: Grey shale, in part finely silty.	
SH-20 2288m "Glauconitic Shale" Channel fill mud	Bow Valley Willesden Green 14-4-40-5W5, NTS 83 B/7 No microfossils in slide. Residue: None received, although one was reported to have been mailed.	C-98345 /2288
SH-35 2019m "Glauconitic Shale"	Placid Minihik 16-21-44-4W5 NTS 83 B/15 No microfossils obtained by either collector or author. Residue: Brownish grey, homogeneous shale with some glauconite, pyrite, very finely disseminated carbonaceous material and very few quartz grains - pebbles.	C-98346 /2019
SH-54 1506m Channel fill mud	Pan Canadian Thorsby 8-5-49-1W5 NTS 83 G/1 Foraminifera (very rare): **Verneuilinoides** sp. cf. **V. cummingensis** (Nauss)? - one specimen Age and Environment: As only one questionably identified foraminifer was recovered, it is speculative to offer an interpretation. However, the foraminifer is known from the late Aptian(?) - early Albian marine strata of the central Foothills (McLean and Wall 1981). Residue: Dominantly light brownish grey shale with some siltstone, pyrite and finely disseminated carbonaceous material.	C-98347 /1506
SH-101 1623m "Glauconitic Shale" (basal)	Colgas Jigger 6-18-54-7W5 NTS 83 G/11 No microfossils obtained except for a few fragments of fish teeth and bone material from which it is not possible to draw any interpretation on age or environment. Residue: Brownish grey shale.	C-98348 /1623
SH-105 Blaimore Group, base of a channel sand cutting into mudstone ("Upper Moosebar")?	Bighorn River, Alberta, NTS 83 C/8 Sec. 28, Tp. 39, Rge. 17 W5 (one mile upstream from Crescent Falls) Ostracoda (very rare): genus unidentified, low, elongate, subrectangular, - one carapace - an identical or closely related specimen was recovered in SH-116 at Fall Creek from the "Upper Moosebar"	C-98349

Sample No., Depth and Stratigraphy	Locality, Microfossils, Age, Environment and Residue	GSC Loc. No.
	Age: Probably Early Cretaceous, early Albian, but this is not confirmable without additional microfaunal of microfloral evidence. Environment: Forms similar to that above have been observed by the author in what were considered to be dominantly freshwater or possibly slightly brackish-water assemblages. Residue: Not available.	
SH-107 Moosebar Fm., 5m above its base	Crescent Falls outcrop #3, Alberta Sec. 27, Tp. 39, Rge. 17 W5 NTS 83 C/8 Ostracoda: **Bisulcocypris albertensis** Pinto and Sanguinetti - fairly prominent **Limnocythere** (?) **calmontensis** (Loranger) - one carapace Age: Early Cretaceous, late Aptian(?) - early Albian. Environment: Dominantly freshwater to slightly brackish. Residue: Not available.	C-98350
SH-109 Moosebar Fm. (lower)	Burnt Timber Creek, Alberta Sec. 36, Tp. 30, Rge. 9 W5 NTS 82 O/11 Ostracoda: **Bisulcocypris albertensis** Pinto and Sanguinetti - mostly incomplete specimens genus or genera indeterminate - small forms, some of which are embedded in matrix. Age and Environment: Assumed same as for previous entry. Residue: Dark grey shale.	C-98351
SH-110 Moosebar Fm., 5m above its base	Cadomin, Alberta, NTS 83 F/3 Sec. 5, Tp. 47, Rge. 23 W5 Ostracoda: **Bisulcocypris albertensis** Pinto and Sanguinetti - common Gastropoda (opercula): **Scalez** sp. cf. **S.** sp. B of McLean and Wall 1981 (pl. 6, figs. 13,14) - a small, incomplete specimen Age and Environment: Same as for two previous entries. Residue: Dark grey shale with many ostracode specimens embedded in matrix on the 20-mesh screen implying that sample could have been further disaggregated.	C-98352

Sample No., Depth and Stratigraphy	Locality, Microfossils, Age, Environment and Residue	GSC Loc. No.
SH-111 Black shale at base of Torrens Mbr. of Gates Fm. (="Upper Moosebar")	McIntyre Railroad (Grande Cache area, Alberta), NTS 83 E/14 Sec. 28, Tp. 57, Rge. 8 W6 Foraminifera: **Saccammina** sp. **Ammodiscus crenulatus** Chamney **Haplophragmoides** sp. A of Stelck and Wall 1956 **Ammobaculites** sp. **Gaudryina tailleuri** (Tappan) **Uvigerinammina athabascensis** (Mellon and Wall)? - one poorly preserved specimen **Dentalina strangulata** Reuss - one **Discorbis norrisi** Mellon and Wall - poorly preserved specimens **Serovaina loetterlei** (Tappan)? - poorly preserved specimens **Conorbina** sp. B of Stelck and Wall 1956 - one poorly preserved specimen Age: Early Cretaceous, late early Albian, **Gaudryina nanushukensis** Zone, **Marginulinopsis collinsi - Verneuilinoides cummingensis** Subzone in the zonal scheme of Caldwell et al (1978, p. 505). This microfauna is characteristic of the Moosebar Formation in northeastern British Columbia and its equivalents in northern Alberta. Environment: Marine, normal salinity, moderate depth in shelf zone (This assemblage is the most diversified of any encountered in this group of samples). Residue: Medium grey shale - appears somewhat dirty with implication it was not washed sufficiently.	C-98353
SH-112 Moosebar Fm., 5m above its base	Crescent Falls outcrop #3, Alberta Sec. 27, Tp. 39, Rge. 17 W5 NTS 83 C/8 (same locality and level as SH-107 =C-98350, but some distance removed horizontally) Ostracoda: **Bisulcocypris albertensis** Pinto and Sanguinetti - most specimens crushed or fragmentary Age: Early Cretaceous, late Aptian(?) - early Albian. Environment: Dominantly freshwater to slightly brackish.	C-98354

Sample No., Depth and Stratigraphy	Locality, Microfossils, Age, Environment and Residue	GSC Loc. No.
	Note: Residue vial broken in shipment and mixed with that of next entry, SH-113 from Ruby Creek. Faunal content could not be further checked.	
SH-113 Moosebar Fm. at base	Ruby Creek, Alberta, NTS 83 C/15 Sec. 2, Tp. 45, Rge. 21 W5 Ostracoda: as in previous entry with same implication for age and environment Residue: Vial broken in shipment and contents mixed with that of previous entry rendering impossible any further faunal check.	C-98355
SH-114 5648 ft. "Glauconite Fm."	Pan Am Lobstick 6-2-50-6W5 NTS 83 G/7 No microfossils obtained by either collector or author. Residue: Greyish brown shale with some siltstone to fine grained sandstone, scattered pyrite and carbonaceous splinters.	C-98356 /5648
SH-115 5560 ft. "Glauconite Fm."	Same locality Foraminifera (sparse): **Miliammina sproulei** Nauss - two **Trochammina** sp., poorly preserved - one Ostracoda: genus indeterminate, appears marine - represented by fragmentary valves Age: Early Cretaceous, stage uncertain but probably Albian. Environment: Marine, shallow shelf. Residue: Grey siltstone to finely silty shale with carbonaceous splinters and trace glauconite.	C-98356 /5560
SH-116 "Upper Moosebar" shale at base "Hoadley equivalent" sandstone	Fall Creek, Alberta, NTS 83 B/4 Sec. 6, Tp. 38, Rge. 11 W5 ("mid-way between two sets of falls") Foraminifera (?): **Saccammina**(?) sp. - one Thecamoebians (?): Thecamoebian B of McLean and Wall 1981 or a saccamminid foraminifer - one Ostracoda: limnocytherid(?) genus X, sp. A of McLean and Wall 1981 **Dryelba** sp. aff. D.(?) **angularis** (Peck) **fide** Finger 1983	C-98357

Sample No., Depth and Stratigraphy	Locality, Microfossils, Age, Environment and Residue	GSC Loc. No.
	Bisulcocypris albertensis Pinto and Sanguinetti genus unidentified - represented by one low, elongate subrectangular specimen identical or closely related to one in SH-105 at Bighorn River from what the collector questionably considers as "Upper Moosebar" Gastropoda: opercula fragments Age: Early Cretaceous, late Aptian(?) - early Albian. Environment: Dominantly freshwater but perhaps with a brackish influence in view of the probable occurrence of one to two foraminifera. Residue: Medium grey shale.	

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Calgary, Alberta
April 11, 1988

Palynological slides prepared from 10 samples by the Institute of Sedimentary and Petroleum Geology were examined to determine their age, environment of deposition, kerogen composition and thermal alteration index. The Department of Supply & Services Contract Number was 23294-7-0657/01-SG and the Scientific Authority was Dr. T.P. Poulton of the Institute of Sedimentary and Petroleum Geology.

The results are summarised below and described in greater detail in Section 2.

12-32-42-9W5

Sample	Depth	Age	Environment	TAI
SH-31	2650m	M. Jurassic - E. Cretaceous	Shallow Marine	3-

6-14-46-10W5

Sample	Depth	Age	Environment	TAI
SH-42	2420m	L. Oxfordian - E. Kimmeridgian	Marine	2 to 2+

8-35-49-12W5

Sample	Depth	Age	Environment	TAI
SH-64	7587'	Oxfordian, ?Middle	Nearshore marine	2+
SH-65	7640'	L. Callovian - M. Oxfordian	Nearshore marine	2+

8-30-50-13W5

Sample	Depth	Age	Environment	TAI
SH-74	2433m	L. Jurassic - Cretaceous	Non-marine	2+
SH-75	2450m	?L. Oxfordian- ?E. Kimmeridgian	Non-marine	2+

6-14-46-10W5

Sample:	SH-42
Depth:	2420m
Age:	Late Oxfordian - Early Kimmeridgian
Environment:	Open marine.
TAI:	2 - 2+
Inertinite:	Trace
Vitrinite:	99 (mostly finely degraded collinite)
Sapropels:	1

Remarks

This sample yielded a rich assemblage of dinocysts, spores and pollen. The great abundance of *Leptodinium mirabile*, *Gonyaulacysta jurassica* and *Valensiella* spp. indicate a Late Oxfordian to early (probably earliest) Kimmeridgian age and an open marine environment.

Species Recorded

Cerebropollenites mesozoicus
Bisaccate pollen (A)
Lycopodiumsporites austroclavatidites (A)
Vallizonosporites cf. pseudoalveolatus
Ischyosporites variegatus

Leptodinium mirabile (A)
Gonyaulacysta jurassica (A)
G. cf. cladophora

Callialasporites turbatus
C. dampierii
Neoraistrickia truncata
Gleicheniidites senonicus
Concavissimisporites crassatus

Valensiella spp. (A)
Tubotuberella sp.
Meiourogonyaulax spp.

10-24-54-13W5

Sample	Depth	Age	Environment	TAI
SH-86	6406'	?Middle Jurassic - E. Cretaceous	Non-marine	2
SH-87	6460'	M. Callovian	Marine	2
SH-88	6505'	Bathonian - E. Callovian	Restricted marine	2

2-2-55-13W5

Sample	Depth	Age	Environment	TAI
SH-89	6475'	Probably M. Oxfordian	Nearshore marine	2

Methods

Wherever possible, slides of 3 different seived fractions were examined for palynomorphs. The +45u usually yielded the richest and most diverse assemblages but the +20u - 45u also contained some useful information. Kerogen abundances and TAI values were determined using the total unoxidized kerogen slide. The abundances quoted in this report are averages of 5 separate readings. In some cases, accurate assessments were difficult due to the overwhelming abundance of finely disseminated organic material.

Sample: SH-65
Depth: 7640'
Age: Late Callovian - Middle Oxfordian
Environment: Nearshore marine. Estuarine/lagoonal.
TAI: 2+
Inertinite: 4
Vitrinite: 95
Sapropels: 1

Remarks

The terrestrial fraction here is particularly rich and dinocysts are extremely rare. The age is based on the presence of *Acanthaulax senta*.

Species Recorded

Bisaccate pollen (A)
Concavissimisporites cf. apiverrucatus (A)
Deltoidospora sp. (A)
Leptolepidites pluritubersosus
Callialasporites dampierii

Acanthaulax senta

Cerebropollenites mesozoicus
Lycopodiumsporites spp.(A)
Neoraistrickia truncata
Ischyosporites sp.
C. turbatus

Ellipsoidictyum spp.

Sample: SH-65
Depth: 7640'
Age: Late Callovian - Middle Oxfordian
Environment: Nearshore marine. Estuarine/lagoonal.
TAI: 2+
Inertinite: 4
Vitrinite: 95
Sapropels: 1

Remarks

The terrestrial fraction here is particularly rich and dinocysts are extremely rare. The age is based on the presence of Acanthaulax senta.

Species Recorded

Bisaccate pollen (A)
Concavissimisporites cf. apiverrucatus (A)
Deltoidospora sp. (A)
Leptolepidites plurituberosus
Callialasporites dampierii

Acanthaulax senta

Cerebropollenites mesozoicus
Lycopodiumsporites spp.(A)
Neoraistrickia truncata
Ischyosporites sp.
C. turbatus

Ellipsoidictyum spp.

12-32-42-9W5

Sample:	SH-31
Depth:	2650m
Age:	Middle Jurassic - Early Cretaceous undifferentiated
Environment:	Shallow marine.
TAI:	3-
Inertinite:	10
Vitrinite:	90
Sapropels:	Trace

Remarks

Very few palynomorphs were recovered but the presence of Escharisphaeridia spp. indicate a Middle Jurassic to Early Cretaceous age for the sample. Recycled Carboniferous spores are present. The rarity of fossils and the presence of dinocysts suggests a shallow-marine environment.

Species Recorded

Cerebropollenites mesozoicus
Bisaccate pollen
Lycopodiumsporites reticulumsporites

Escharisphaeridia spp.

8-35-49-12W5

Sample:	SH-64
Depth:	7587'
Age:	Probably Middle Oxfordian
Environment:	Nearshore marine. Estuarine/lagoonal.
TAI:	2+
Inertinite:	7
Vitrinite:	92
Sapropels:	1

Remarks

This sample is very rich in bisaccate pollen but marine palynomorphs are very rare. The presence of *Acanthaulax* spp., including *A. senta*, along with *Gonyaulacysta jurassica* indicates a latest Callovian to Middle Oxfordian age. Because of the lack of Callovian - Early Oxfordian species, a Middle Oxfordian age is tentatively proposed although an age as old as Late Callovian cannot be ruled out.

Species Recorded

Bisaccate pollen (A)
Cerebropollenites mesozoicus
Concavissimisporites cf. apiverrucatus
Callialasporites dampierii

Leptolepidites pluritunerosus
Foveotriletes subtriangularis
Neoraistrickia truncata
C. trilobatus

Acanthaulax spp.
Gonyaulacysta jurassica

A. senta

8-30-50-13W5

Sample:	SH-74
Depth:	2433m
Age:	Late Jurassic - Cretaceous
Environment:	No evidence of marine influence.
TAI:	2+
Inertinite:	5
Vitrinite:	92
Sapropels:	3

Remarks

Spores and pollen are extremely rare and no marine palynomorphs were recovered. The lower age limit is based on the results from the underlying sample.

Species Recorded

Bisaccate pollen (A)
Klukisporites sp.
Lycopodiumsporites sp.
Stereisporites sp.

Sample:	SH-75
Depth:	2450m
Age:	? Late Oxfordian - ? Early Kimmeridgian
Environment:	No evidence of marine influence. Lacustrine/upper lagoonal.
TAI:	2+
Inertinite:	1
Vitrinite:	98
Sapropels:	1

Remarks

This sample proved to be rich in spores and pollen but barren of marine palynofloras. The age assigned is based on the presence of a specimen of Retitriletes cf. aklavikensis, a species which has so far only been recorded from the Late Oxfordian - Early Kimmeridgian. The remaining species have long ranges but no specifically Cretaceous markers are present. The assemblage resembles the non-marine fraction in SH-42, 6-14-46-10W5.

Species Recorded

Bisaccate pollen (A)
Lycopodiumsporites cf. reticulumsporites
Retitriletes cf. aklavikensis
Concavissimisporites spp.
C. apiverrucatus
Deltoidospora spp.
Callialasporites turbatus
C. dampierii
Leptolepidites plurituberosus
Vallizonosporites cf. pseudoalveolatus

10-24-54-13W5

Sample: SH-86
Depth: 6406'
Age: ? Middle Jurassic - Early Cretaceous
Environment: No evidence of marine influence; ? channel.
TAI: 2
Inertinite: 55
Vitrinite: 45
Sapropels: Trace

Remarks

Palynomorphs are extremely rare and consist of bisaccate pollen grains, indeterminate spore and recycled Carboniferous spores. The kerogen appears to have been winnowed and a low-energy channel environment is proposed. The lower age limit is based on the age of the underlying sample.

Sample: SH-87
Depth: 6460'
Age: Middle Callovian
Environment: Marine.
TAI: 2+
Inertinite: 8
Vitrinite: 83
Sapropels: 9

Remarks

This sample yielded a rich assemblage of spores, pollen and dinocysts. The presence of abundant *Escharisphaeridia rudis* and specimens of *Occicucysta* aff. *thula*, *Meiourogonyaulax callomonii* and *Polystephanephorus paracalathus* indicate a Middle Callovian (probably late Middle) age at this horizon.

Species Recorded

Bisaccate pollen (A)
Deltoidospora spp (A)

Callialasporites dampierii
C. turbatus

Escharisphaeridia rudis (A)
Occicucysta aff. thula
Polystephanephorus paracalathus

Cerebropollenites mesozoicus
Concavissimisporites cf.
apiverracutus (A)
Rotverrusporites cf. major

Egmontodinium sp. (A)
Meiourogonyaulux callomonii

Sample:	SH-88
Depth:	6505'
Age:	Bathonian - Early Callovian
Environment:	Restricted marine, ?lagoonal.
TAI:	2
Inertinite:	20
Vitrinite:	15
Sapropels:	65

Remarks

The age of this sample is based on the presence of Korystocysta norrisii and Escharisphaeridia pocockii. The great abundance of the latter species indicates some environmental stress such as reduced salinity.

Species Recorded

Bisaccate pollen (A)
Classopollis spp. (tetrads) (A)
Concavissimisporites spp.
Tigrisporites sp.

Escharisphaeridia pocockii (A)
Korystocysta norrisii

Cerebropollenites mesozoicus
Ischyosporites jurassicus
Callialasporites turbatus
C. dampierii

Glomodinium evittii
Veryhachium spp.

Report No. 11-JHW-1986

Micropaleontology report on 14 samples (12 subsurface core and two outcrop) from the Mesozoic of the Plains and Foothills of central and southern Alberta, collected and submitted by Mr. Lorne Rosenthal of Brandon University in July 1986 (NTS 82-G, 83-B, C, G and H).

The relevant parts of any manuscript prepared for publication that paraphrase or quote from this report should be referred to the Paleontology Subdivision, Calgary for possible revision.

Introduction

These samples were collected by Mr. Rosenthal in conjunction with his doctoral research project at the University of Manitoba on a sedimentological study of the Lower Cretaceous Mannville Group in western Alberta. Mr. Rosenthal is associated with Dr. D.A. Leckie of the I.S.P.G. in preparing transects of Mesozoic strata from the Plains to the Foothills at various latitudes in Alberta for inclusion in field guides of the Canadian Society of Petroleum Geologists.

Where no stratigraphic unit is indicated on the left side column below, it was either not designated or unknown by the collector at the time the samples were submitted.

Wells are arranged in sequence from south to north and from east to west within the same range. The two outcrop samples are listed at the end of the report. All of the material, except for the Bighorn River outcrop sample, was used in the processing.

Sample Designation & Well Depth	Locality, Microfossils, Age Environment and Residue	GSC Loc. No.
C-2306 m	Dekalb Willesden Green 4-33-39-5W5 NTS 83B/7 Foraminifera: **Saccammina** sp. - one specimen Ostracoda: genus indeterminate - fragmentary valves Age: Indeterminate. Environment: Uncertain, but probably brackish marine. Residue: Dark grey shale.	C-46036 /2306
D-2311 m	Same locality No microfossils obtained. Residue: Dark grey shale, grey brown siltstone, with pyrite and a few carbonaceous splinters.	C-46036 /2311

2-2-55-13W5

Sample: SH-89
Depth: 6475'
Age: Probably Middle Oxfordian
Environment: Nearshore marine. Estuarine/lagoonal.
TAI: 2
Inertinite: 10
Vitrinite: 46
Sapropels: 44

Remarks

This assemblage closely resembles that from SH-64, 8-35-49-12W5 at 7587'. It contains a small number of specimens of *Acanthaulax senta* and *Gonyaulacysta jurassica* along with *Ctenidodinium ornatum* and *Escharisphaeridia* spp. and a Middle Oxfordian age is assigned although (as in SH-64) an age as old as Late Callovian cannot be ruled out.

Species Recorded

Bisaccate pollen (A)
Cerebropollenites mesozoicus (A)
Ischyosporites jurassicus
Callialasporites turbatus
C. trilobatus

Deltoidospora spp. (A)
Concavissimisporites spp.
C. cf. apiverrucatus
Klukisporites spp.

Acanthaulax senta
Ctenidodinium ornatum

Gonyaulacysta jurassica
Escharisphaeridia spp.

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Sample Designation & Well Depth	Locality, Microfossils, Age, Environment and Residue	GSC Loc. No.
E-2315 m	Same locality Ostracoda: **Bisulcocypris albertensis** Pinto and Sanguinetti - common and only taxon recovered. This species has been identified in most papers prior to 1983 as **Metacypris persulcata** Peck or **M.** cf. **persulcata** (Loranger 1951, 1954; McLean and Wall 1981), but Finger (1983) has given its proper designation. Age: Early Cretaceous, Aptian(?) - Early Albian. Environment: Dominantly freshwater to slightly brackish. Finger (1983, p. 330-331) reviewed the interpretation of the paleoecology of this genus generally considered to be freshwater. However, its occasional association in Alberta with various other fossil groups suggests it may have been able to tolerate a wider salinity range. Residue: Dark grey shale with traces of pyrite.	C-46036 /2315
H-2337 m	Same locality No microfossils obtained. Residue: Dark grey, somewhat silty shale with some carbonaceous splinters.	C-46036 /2337
B-2128 m Jurassic or Cretaceous(?)	Gulf Gilby 8-33-40-3W5 NTS 83B/8 No microfossils obtained. Residue: Brown-grey sand, quartzose, kaolinitic, micaceous.	C-46037 /2128
A-1909 m Shale, 5 m above top Hoadley sandstone	Pan Canadian Westerose 13-17-44-2W5 NTS 83B/16 No microfossils obtained. Residue: Medium grey, soft, flaky shale with some carbonaceous splinters and pyrite(?).	C-46038 /1909
A-1588 m	Aberford Pembina 14-23-48-2W5 NTS 83G/1 No microfossils obtained. Residue: Grey argillaceous silt with some carbonaceous splinters.	C-46039 /1588

Sample Designation & Well Depth	Locality, Microfossils, Age Environment and Residue	GSC Loc. No.
B-1598 m	Same locality Foraminifera: **Hippocrepina barksdalei** (Tappan) **Ammodiscus** sp., very thin-walled, possibly referable to **A.** sp. of Stelck and Wall 1956, later included in the synonymy of **A. crenulatus** Chamney 1978 **Reophax** sp. - one specimen **Haplophragmoides** sp. A of Stelck and Wall 1956 **H.** sp.-spp. **Ammobaculites fragmentarius** Cushman **Uvigerinammina athabascensis** (Mellon and Wall) Age: Early Cretaceous, Early Albian. Similar siliceous assemblages were recorded in the Moosebar Member of the northern Foothills (McLean and Wall 1981), as for example at Little Berland T.H. 70-07. Environment: Marine, probably inner shelf. Residue: Grey shale with some carbonaceous splinters.	C-46039 /1598
Sample 2 2492 m	Chevron Brazeau River 5-34-48-12W5 NTS 83G/4 Foraminifera: **Ammodiscus** sp., thin-walled, siliceous, poorly preserved - about 20 specimens, only taxon recovered Age: Indeterminate, could be Jurassic or Cretaceous. Environment: Marine, probably shallow and somewhat restricted. Residue: Grey silt with much quartz in fine fraction; some carbonaceous splinters.	C-46040 /2492
B-1933 m	Sabine Niton 10-18-55-12W5 NTS 83G/13 No microfossils obtained. Residue: Grey siltstone and shale with much pyrite. some mica and carbonaceous splinters.	C-46041 /1933
A-3845 ft.	Midwest Alexander 6-15-56-27W4 NTS 83H/13 Ostracoda: genus indeterminate - valve fragments Age: Indeterminate. Environment: Uncertain, although the ostracode	C-46042 /3845

Sample Designation & Well Depth	Locality, Microfossils, Age, Environment and Residue	GSC Loc. No.
	fragments are suggestive of a fresh to brackish-water form. Residue: Dark grey shale with carbonaceous and brown cuticular material; quartz grains.	
B-6032 ft. shale at base of Paddle River sandstone, Jurassic or Cretaceous(?)	Atkinson Paddle River 10-29-56-11W5 NTS 83G/13 Foraminifera: **Haplophragmoides** or **Ammobaculites** sp., small, pyritized - one specimen **Trochammina**(?) sp. - one specimen Gastropoda: conch, very small, pyritized - one Age: Indeterminate. Environment: The foraminifera, although very sparse, indicate a marine influence. The two specimens were found upon a repick of the residue. Their preservation is so different that an observer might suspect they don't belong together, or in other words that one of them may not be **in situ**. Residue: Medium grey, soft, flaky shale with some pyrite.	C-46043 /6032

Outcrop Samples

Shale at base of Beaver Mines Fm.	Gladstone Creek, NTS 82G/8 Approximate location calculated by writer is Sec. 23 or 26, Tp. 5, R2W5 No recognizable microfossils obtained but there are two to three nondescript siliceous entities which may be organic in origin and represent some sort of protistid. Age: Indeterminate. Environment: Indeterminate. Residue: Medium grey, slightly silty shale with thin carbonaceous splinters.	C-46044
Luscar Group	Bighorn River, NTS 83C/8 Approximately 1 km upstream from Crescent Falls on west side of river, Tp. 39, R17W5. Shell fragments of unknown affinity. Age: Indeterminate. Environment: Indeterminate. Residue: Medium grey siltstone with some carbonaceous splinters.	C-46045

Comments

Most of this set of samples were either barren or contained insufficient microfossils for age and environmental interpretation. Only two samples, E-2315 m from the Willesden Green well with the ostracode **Bisulcocypris albertensis** and B-1598 m from the Aberford Pembina well with arenaceous foraminifera, yielded adequate fauna for meaningful interpretation. The impending palynological report being prepared by Dr. A.R. Sweet may be expected to provide additional information on this collection.

References

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Loranger, D.M.
1951: Useful Blairmore microfossil zone in central and southern Alberta, Canada; American Association of Petroleum Geologists Bulletin, v. 35, no. 11, p. 2348-2367.

1954: Useful Blairmore microfossil zone in central and southern Alberta, Canada; **in** Clark, L.M., **ed.**, Western Canada Sedimentary Basin - A symposium: Tulsa, Oklahoma, American Association of Petroleum Geologists, Ralph Leslie Rutherford Memorial Volume, p. 279-296 (A reprinting with revisions of 1951 paper).

McLean, J.R. and Wall, J.H.
1981: The Early Cretaceous Moosebar Sea in Alberta; Bulletin of Canadian Petroleum Geology, v. 29, no. 3, p. 334-377.

for B.S.N. John H. Wall

Paleontology Subdivision
Institute of Sedimentary and Petroleum Geology
Calgary, Alberta
December 23, 1986

Report AS-86-16

Applied research report on 14 samples (12 subsurface core and two outcrop) from Jurassic and Early Cretaceous strata of the plains and foothill regions of central and southern Alberta (NTS 82G, 83B, 83C, 83G and 83H) as requested by Lorne Rosenthal, Brandon University (copy to D. A. Leckie, J.H. Wall and T.P. Poulton).

The relevant parts of any manuscript prepared for publication that paraphrase or quote from this report should be referred to the Paleontology Subdivision, Calgary for possible revision.

For additional background information on the following samples see GSC Internal Report 11-JHW-86 by J.H. Wall.

A. Report on 4 samples from the Dekalb Willesden Green well; C-46036; 4-33-39-5-W5M; NTS83B/7.

Sample P2930-1, C-2306 m.

Selected Pollen and Spores:
- **Appendicisporites problematicus** (Burger) Singh 1971 (c-111.2x7.4)
- **Cicatricosisporites** sp. (c-118.8x7.3, common)
- **Gleicheniidites** sp. (common)
- **Microreticulatisporites uniformis** Singh 1964 (c-119.0x7.2)
- **Schizosporis reticulatus** Cookson & Dettmann 1959 (b-115.6x14.2)
- **Tigrisporites reticulatus** Singh 1971 (b-119.6x11.2)
- **Trilobosporites trireticulosus** Cookson & Dettmann 1958 (b-128.8x15.3)

Dinoflagellates: Abundant. A thin walled assemblage of mostly certatioid dinoflagellates of the **Muderongia-Vesperopsis** complex with rare specimens of **Canningia** (b-128.3x15.3) and **Oligosphaeridium** is present.

Comments: Recovery good, preservation poor. Organic residue dominated by exinite. Palynomorph assemblage dominated by bisaccate, gymnosperm pollen and dinoflagellates.

Age: Probably Middle Albian or younger based on the presence of **Tigrisporites reticulatus**.

Environment of deposition: Marine, marginal.

Sample P2930-2, D-2311 m.

Selected Pollen and Spores:
- **Appendicisporites problematicus** (Burger) Singh 1971 (c-

119.1x18.2)
Cicatricosisporites sp. (c-129.8x14.2, 126.5x18.3)
Gleicheniidites sp. (common)
Microreticulatisporites uniformis Singh 1964 (c-122.2x5.4)

Dinoflagellates: As above.

Comments: As above

Age: Probably as above.

Environment of deposition: As above.

Sample P2930-3, E-2315 m.

Selected Pollen and Spores:
Cicatricosisporites sp. (b-127.8x14.7)
Gleicheniidites sp. (scarce)
Microreticulatisporites uniformis Singh 1964 (c-124.6x15.8)
Trilobosporites trireticulosus Cookson & Dettmann 1958 (b-120.2x16.7)

Dinoflagellates: Common to abundant. A thin walled assemblage of mostly certatioid dinoflagellates of the **Muderongia-Vesperopsis** complex.

Comments: As above.

Age: Indeterminate but probably as above.

Environment of deposition: As above, but possibly with less marine influence as indicated bya reduction in dinoflagellate diversity.

Sample P2930-4. H-2337 m.

Selected Flora:
Cerebropollenites sp. (common)
Trilobosporites sp. (b-122.1x21.4)

Comments: Preservation and recovery good. Organic residue dominated by more or less equal amounts of woody debris, cuticle and exinite. Palynomorph assemblage dominated by gymnosperm pollen and miospores.

Age: Indeterminant.

Envirnoment of deposition: As no dinoflagellates observed and as the organic residue has a continental aspect, a non marine environment of deposition is concluded.

B. Report on 1 sample from the Gulf Gilby well; C-46037; 8-33-40-3-W5M; NTS83B/8.

Sample P2930-5. B-2128 m.

Comments: Sample effectively barren of palynomorphs. Organic residue of amorphous appearing debris.

C. Report on 1 sample from the PanCanadian Westerose well; C-46038; 13-17-44-2-W5M; NTS83B/16.

Sample P2930-6. A-1909 m: shale 5 m above top of Hoadley sandstone.

Selected Pollen and Spores:
- **Appendicisporites problematicus** (Burger) Singh 1971 (b-110.8x12.4, 117.5x13.3)
- **A. unicus** (Markova) Singh 1964 (b-116.2x21.2, common)
- **Cicatricosisporites augustus** Singh 1971 (abundant)
- **Clavatipollenites hughesii** Couper 1958 (c-129.3x13.8, 132.7x13.7)
- **Concavissimisporites variverrucatus** (Couper) Brenner 1963 (b-110.7x19.3, common)
- **Gleicheniidites** sp. (rare)
- **Liliacidite** sp. (c-133.3x17.3)
- **Microreticulatisporites uniformis** Singh 1964 (c-110.6x8.7, common)
- **Schizosporis reticulatus** Cookson & Dettmann 1959 (b-110.7x9.7)

Dinoflagellates: Rare. One specimen of the certatioid dinoflagellate, **Muderongia** (b-122.8x8.1) seen.

Comments: Recovery good, preservation excellent. Organic residue dominated by exinite. Palynomorph assemblage dominated by gymnosperm pollen and miospores.

Age: Early Cretaceous, Barremian or younger.

Environment of deposition: Continental to marginal marine.

D. Report on 2 samples from the Aberford Pembina well; C-46039; 14-23-48-2-W5M; NTS83G/1.

Sample P2930-7. A-1588 m.

Selected Pollen and Spores:
- **Appendicisporites problematicus** (Burger) Singh 1971 (a-118.6x15.2)
- **Cerebropollenites** sp. (a-115.4x7.2; scarce)
- **Clavatipollenites** sp. (a-123.4x21.3, 126.3x5.3)
- **Classopollis** sp. (a-115.7x10.7, common)
- **Concavissimisporites punctatus** (Delcourt & Sprumount) Brenner 1963 (118.2x9.7, 120.6x20.5)

C. variverrucatus (Couper) Brenner 1963 (a-137.2x15.3)
Costatoperforosporites sp. (a-125.2x20.1)
Dictyotriletes granulatus Pocock 1962 (a-113.4x9.3, common)
Foraminisporis wonthaggiensis (Cookson & Dettmann) Dettmann 1963 (a-113.6x17.8, 115.6x9.3)
Gleicheniidites sp. (scarce)
Pilosisporites sp. (a-122.0x13.5, 132.2x18.0)
Trilobosporites apiverrucatus Couper 1958 (a-122.0x15.4)
T. trireticulosus Cookson & Dettmann 1958 (a-119.2x9.0, 123.3x16.4)

Dinoflagellates: Not observed.

Comments: Recovery and preservation good. Organic residue dominated by exinite. Palynomorph assemblage dominated by bisaccate, gymnosperm pollen.

Age: Early Cretaceous, Barremian or younger.

Environment of deposition: Continental.

Sample P2930-8. B-1598 m.

Selected Pollen and Spores:
Cerebropollenites sp. (a-112.6x8.7, common)
Cicatricosisporites spp. (a-114.0x10.2, 115.0x9.8)
Dictyotriletes sp. (a-115.1x15.5)

Dinoflagellates: Scarce to common and diverse (a-112.7x14.8, 114.0x17.4, 116.8x6.2, 120.8x19.8, 126.3x5.6, 130.6x7.8)

Comments: Recovery sparse to good; preservation poor (degraded). Organic residue dominated by exinite. Palynomorph assemblage dominated by gymnosperm pollen.

Age: Early Cretaceous.

Environment of deposition: Marine, based on a sparse but diverse suite of dinoflagellates.

E. Report on 1 sample from the Chevron Brazeau River well; C-46040; 5-34-48-12-W5M; NTS83G/4.

Sample P2930-9. Spl.2-2492 m.

Selected Pollen and Spores:
Aquitriradiates sp. (b-120.2x12.30
Dictyotriletes sp. (b-110.6x18.3, 121.4x11.7)
Foraminisporis wonthaggiensis (Cookson & Dettmann) Dettmann 1963 (b-132.8x20.2)
Lycopodiumsporites sp. (b-112.3x11.4)
Neoraestrickia sp. (b-110.6x14.7; common)

Dinoflagellates: Scarce (b-110.6x10.2, 121.7x10.4, 124.2x14.3)

Comments: Recovery good, preservation poor (probably due to a relatively high degree of carbonization). Organic residue of about equal amounts of fusinite and exinite. Palynomorph assembalge dominated by gymnosperm pollen.

Age: Probably Early Cretaceous based on the combined presence of **Foraminisporis** and **Aquitriradiates.**:

Environment of deposition: Probably marine based on the presence of dinoflagellates.

F. Report on 1 sample from the Sabine Niton well; C-46041; 10-18-55-12-W5M; NTS83G/13.

Sample P2930-10. B-1933 m.

Selected Pollen and Spores:

- **Callialasporites dampieri** (Balme) Sukh Dev 1961 (b-111.6x19.9, common)
- **C. trilobatus** (Balme) Sukh Dev 1961 (b-110.2x10.4, 115.3x10.3, common)
- **Cerebropollenites** sp. (abundant)
- **Classopollis** sp. (abundant)

Dinoflagellates: Rare probable dinoflagellates (b-120.6x17.3) and scarce acritarchs (c-117.2x5.3)

Comments: Recovery and preservation excellent. Organic residue dominated by exinite and amorphous and cuticular debris. Palynomorph assemblage dominated by gymnosperm pollen.

Age: Late Jurassic

Environment of deposition: Probably marine.

G. Report on 1 sample from the Midwest Alexander well; C-46042; 6-15-56-27-W4M; NTS83H/13.

Sample P2930-11, A-3845ft.

Selected Pollen and Spores:

- **Appendicisporites tricornatus** Weyland & Greifield 1953 (b-115.1x14.8)
- **Botrycoccus** sp. (b-119.4x15.2)
- **Cerebropollenites** sp. (b-108.8x13.1, scarce)
- **Cicatricosisporites** sp. (b-108.8x17.2)
- **Costatoperforosporites** sp. (b-111.0x4.8)
- **Gleicheniidites** sp. (abundant)

Dinoflagellates: Abundant. A thin walled assemblage of mostly certatioid dinoflagellates of the **Muderongia-Vesperopsis** complex (b-112.8x13.0) is present.

Comments: Recovery and preservation good. Organic residue dominated by exinite. Palynomorph assemblage is dominated by gymnosperm pollen.

Age: Early Cretaceous.

Environment of deposition: Marginally marine as indicated by the presence of dinoflagellates of the Muderongia-Vesperopsis complex.

H. Report on 1 sample from a shale at the base of the Paddle River sandstone, Atkinson Paddle River well; C-46043; 10-29-56-11-W5M; NTS 83G/13.

Sample P2930-12, B-6032 m.

Selected Pollen and Spores:
- Callialasporites dampieri (Balme) Sukh Dev 1961 (b-118.3x16.7, 119.6x19.4, common)
- C. trilobatus (Balme) Sukh Dev 1961 (b-126.4x18.0, 128.3x4.7, common)
- Cicatricosisporites sp. (b-124.4x9.8, 123.3x13.1)
- Classopollis sp. (abundant)
- Dictyotriletes spp. (b-119.7x13.7, 120.8x12.3)
- Lycopodiumsporites sp. (b-126.4x10.3)

Dinoflagellates: Abundant, diverse including mumerous specimens of Nannoceratopsis pellucida Deflandre 1938 and Meiouroganyaulax sp.

Comments: Recovery and preservation excellent. Organic residue dominated by exinite and amorphous and cuticular debris. Palynomorph assemblage dominated by gymnosperm pollen and dinoflagellates.

Age: Late Jurassic

Environment of deposition: Open marine.

I. Report on 1 sample from a shale at the base of the Beaver Mines Formation on Gladstone Creek: C-46044; from Sec. 23 or 26, Tp. 5, R2 W5 (as calculated by J. H. Wall); NTS82G/8.

Sample P2930-13.

Selected Pollen and Spores:
- Appendicisporites problematicus (Burger) Singh 1971 (b-118.6x20.4)
- Cerebropollenites sp. (b-115.3x15.5: common)
- Cicatricosisporites sp. (b-121.2x13.3)
- Gleicheniidites sp. (common)

Dinoflagellates: Abundant. A thin walled assemblage of mostly certatioid dinoflagellates of the Muderongia-Vesperopsis complex is present.

Comments: Recovery good, preservation average. Organic residue dominated by fusinite and exinite. Palynomorph assemblage is dominated by gymnosperm pollen.

Age: Early Cretaceous.

Environment of deposition: Marginally marine as indicated by the presence of dinoflagellates of the Muderongia-Vesperopsis complex.

J. Report on 1 sample of Luscar Group from Bighorn River approximately 1 km upstream from Cresent Falls on west side of river; C-46045; NTS83C/8.

Sample P2930-14.

Comments: Recovery sparse, preservation poor. No age diagnostic palynomorphs obaserved. Organic residue dominated by fusinite (woody debris) and appears to be highly carbonized.

GENERAL COMMENTS

The productive samples can be grouped into three classes based on the palynomorph assemblage and type of organic residue present. Three samples, P2930-4, -6 and -7, have the characteristics of a continental environment of deposition and four samples, P2930-8, -9, -10, and -12, most probably represent a fully marine environment of deposition. The environmental interpretaion of the assemblage and residue present in samples P2930-1, -2, -3, -11, and -13 is more tenuous as ceratatioid dinoflagellates, which are dominant in these samples, occur in both marine and fresh water at present. Although the conventional wisdom dicates these assemblages to be marginal marine, this interpretation needs to be verified in a multidisciplinary study.

A. R. Sweet

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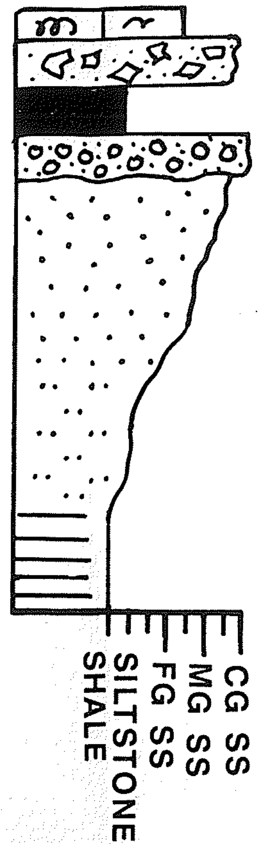
Institute of Sedimentary and Petroleum Geology
Calgary, Alberta.

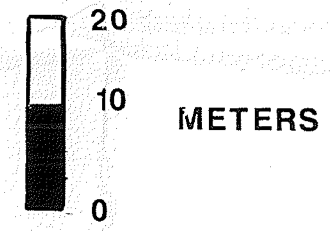
ARS/ars

LEGEND

LITHOLOGY

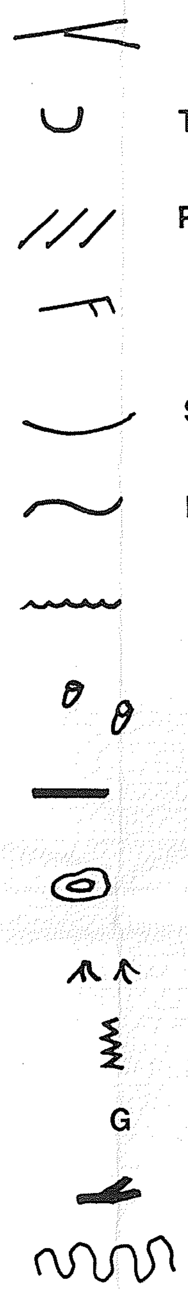


BIOCLASTIC LIME MUDSTONE
INTRACLAST BRECCIA
COAL
CONGLOMERATE



VERTICAL SCALE
NO HORIZONTAL SCALE IMPLIED

SEDIMENTARY STRUCTURES



PARALLEL TO LOW ANGLE CONVERGENT LAMINATION
TROUGH CROSS STRATIFICATION
PLANAR TABULAR CROSS STRATIFICATION
CURRENT RIPPLES
SWALEY CROSS STRATIFICATION
HUMMOCKY CROSS STRATIFICATION
WAVE RIPPLE LAMINATION
BIOTURBATION STRUCTURES
CARBONACEOUS LAMINAE
CONCRETIONS
ROOTS
SYNAERISIS CRACKS
GLAUCONITE
WOOD FRAGMENTS
SOFT SEDIMENT DEFORMATION STRUCTURES

SOUTHERN(LANDWARD LIMIT)
UPPER MOOSEBAR TRANSGRESSIO

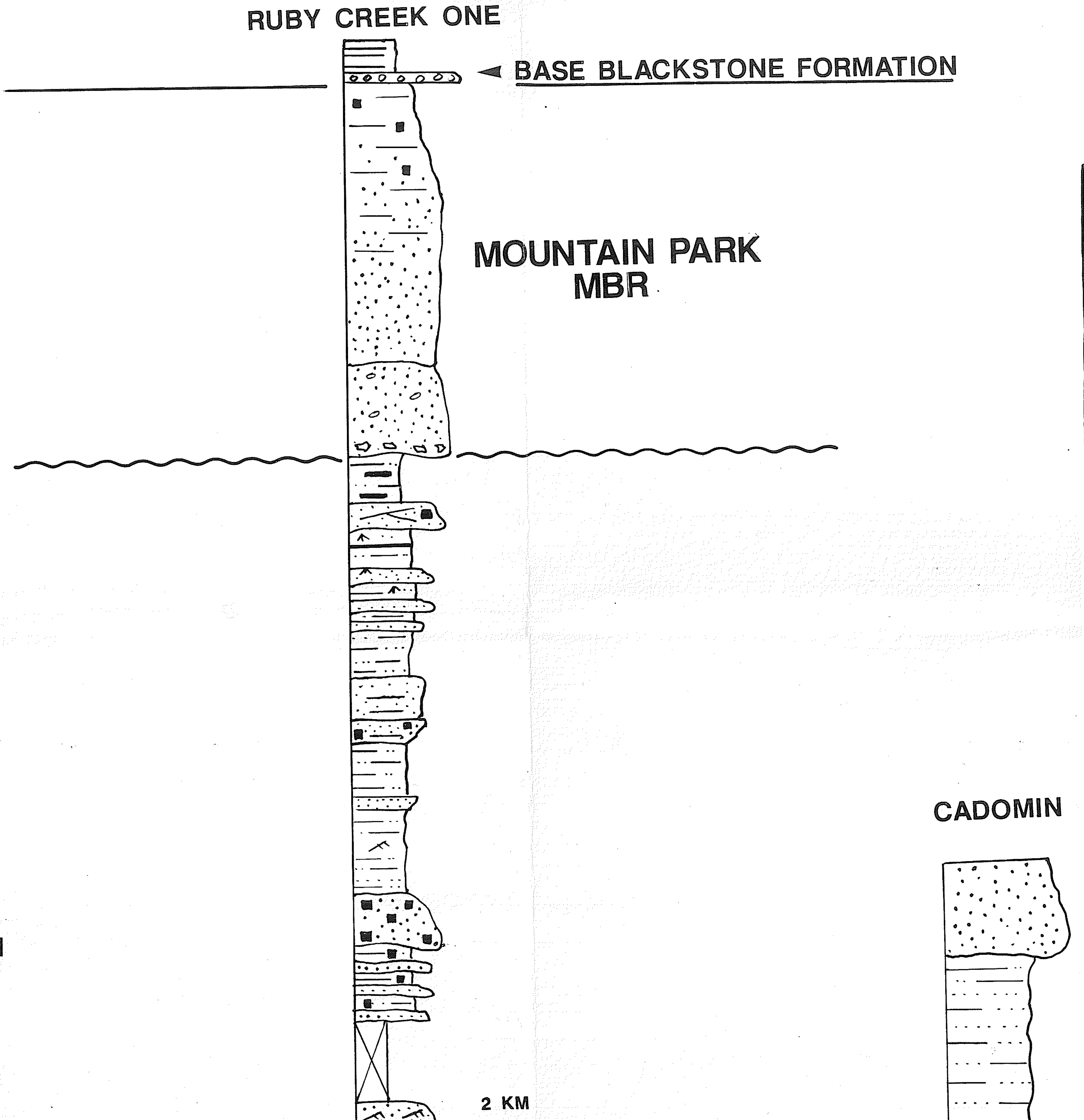
SOUTHERN FOOTHILLS

RAM RIVER

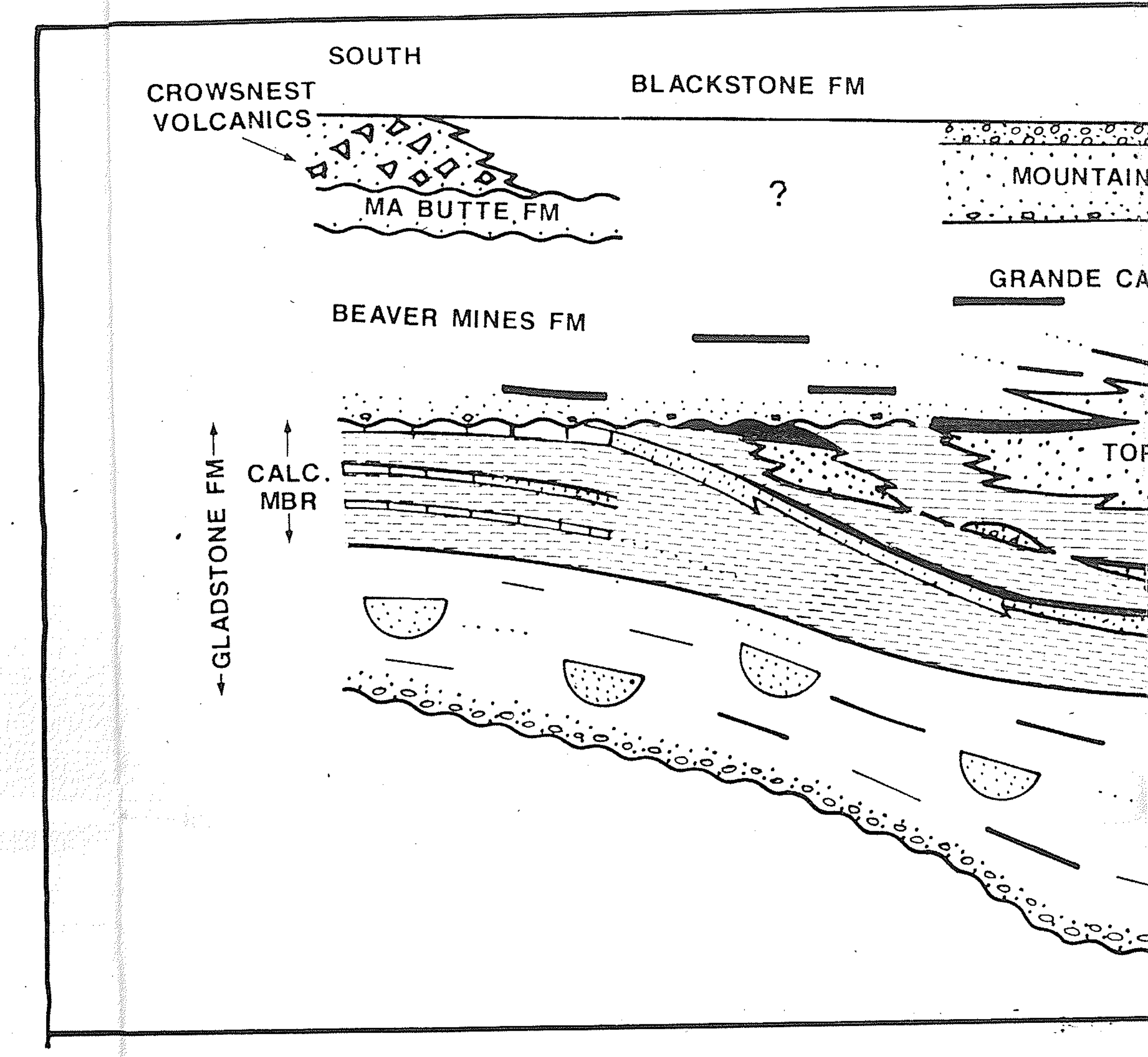
27.2 KM

N

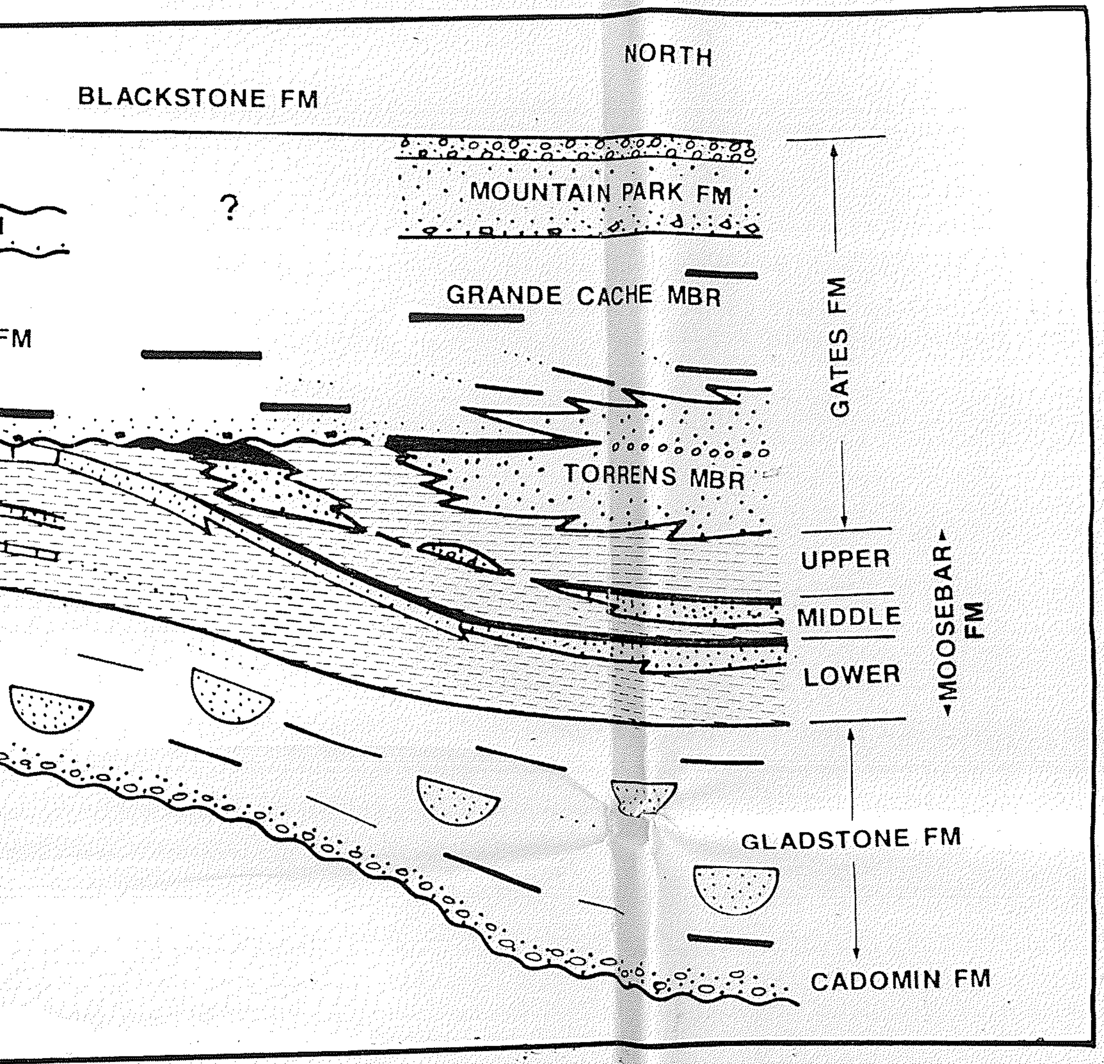
LIMIT)
RESSION



SCHEMATIC DIAGRAM SHOWING
SIMPLIFIED STRATIGRAPHIC RELATIONS



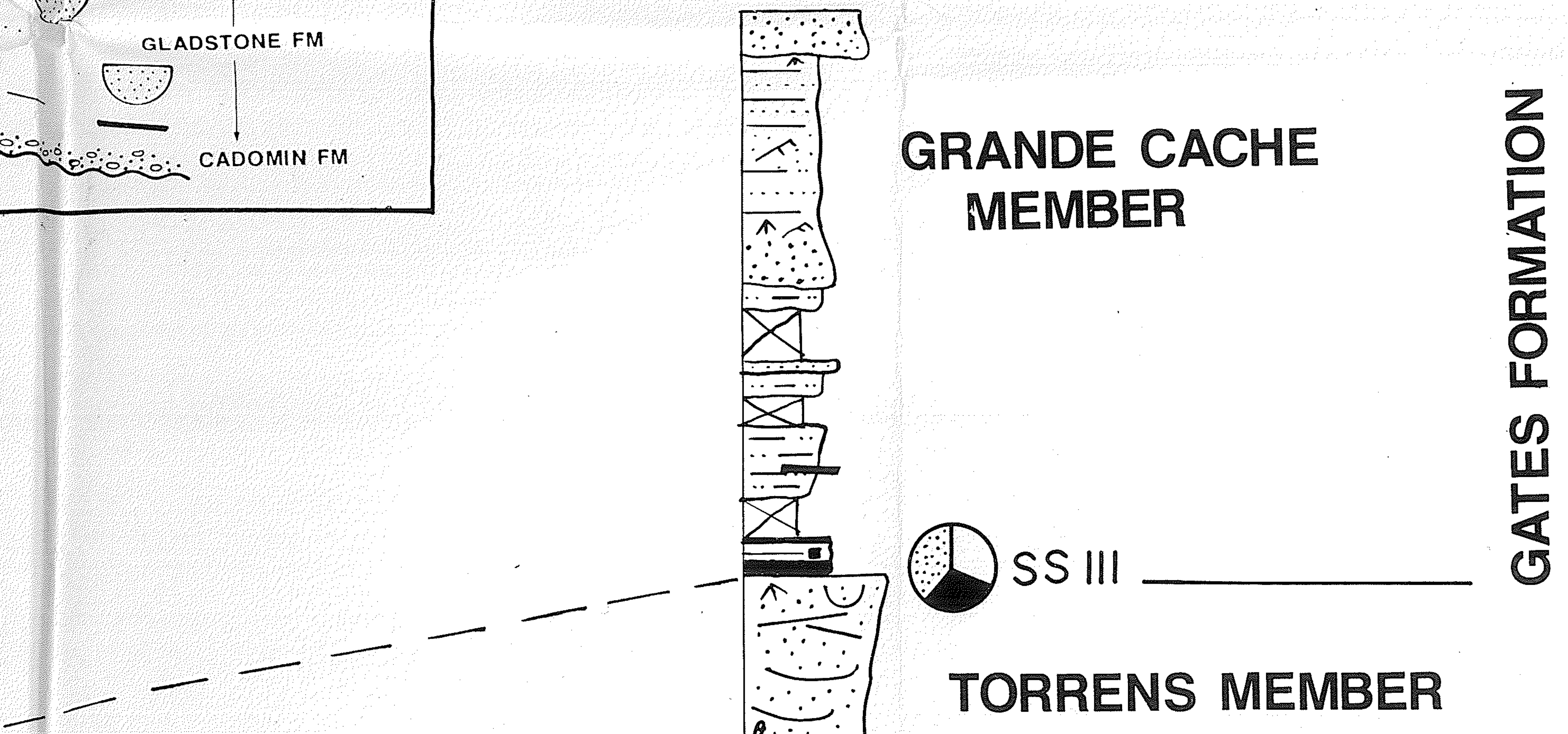
TIC DIAGRAM SHOWING
RATIGRAPHIC RELATIONSHIPS

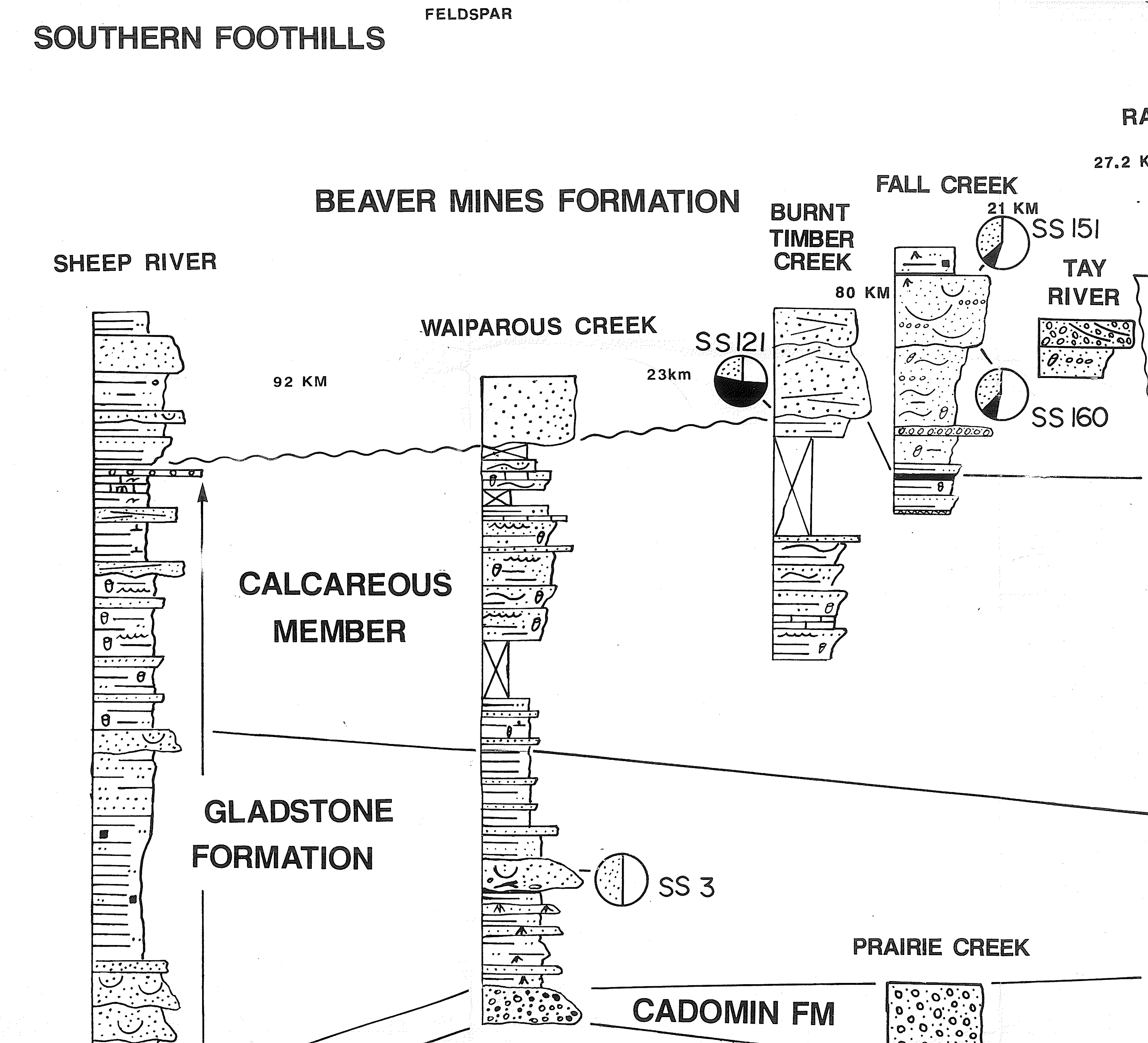


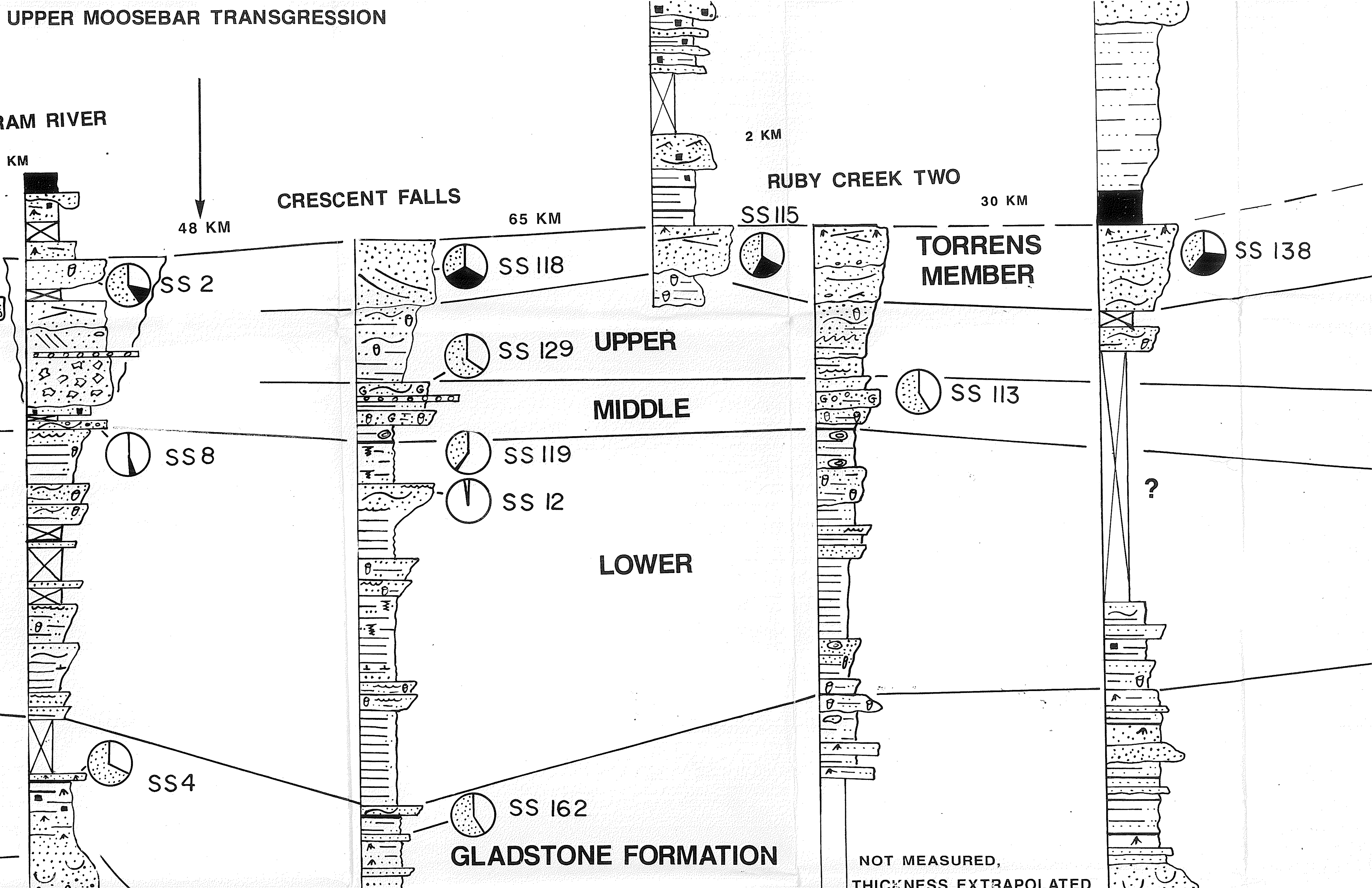
153 KM

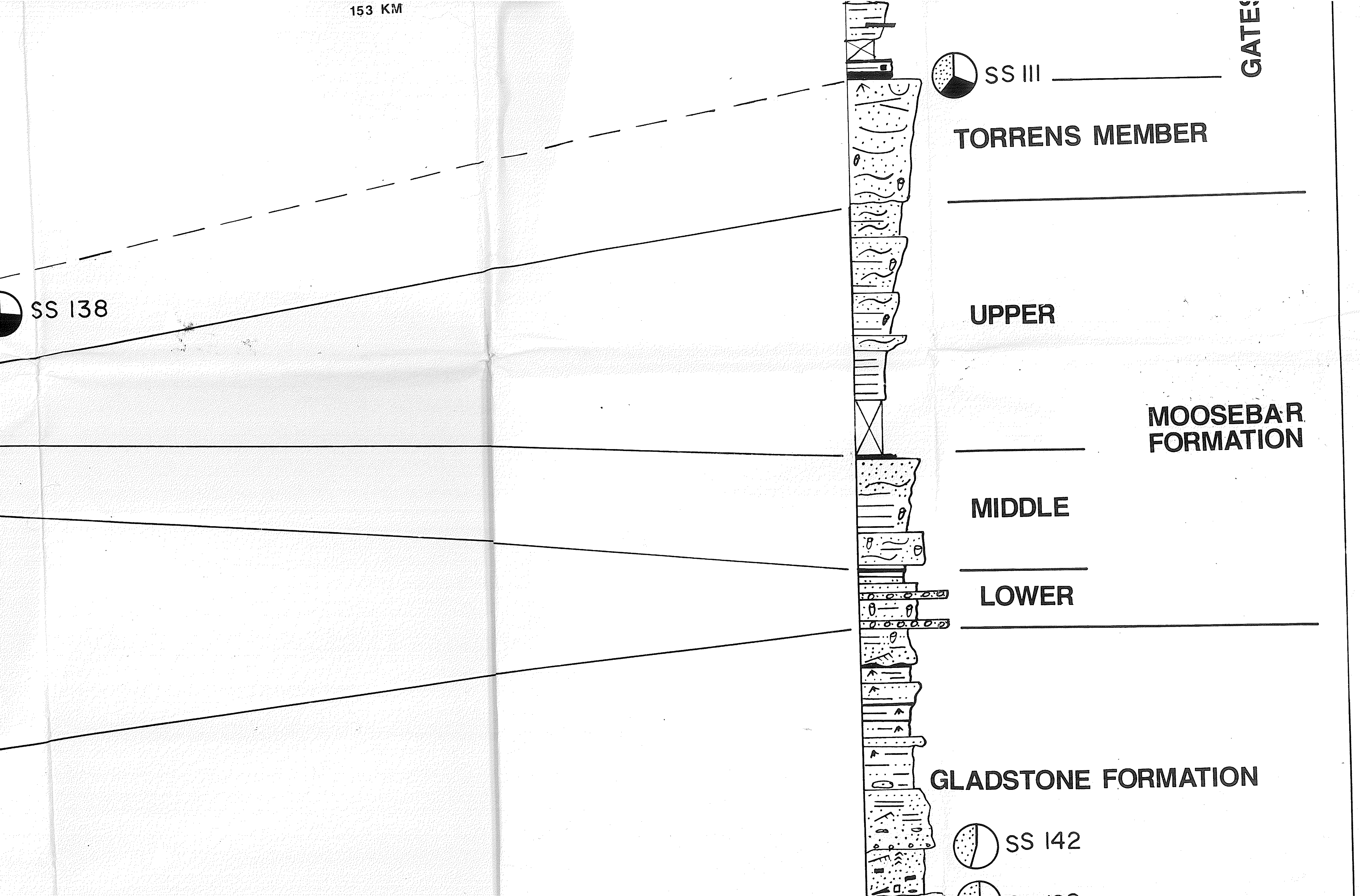
NORTHERN FOOTHILLS

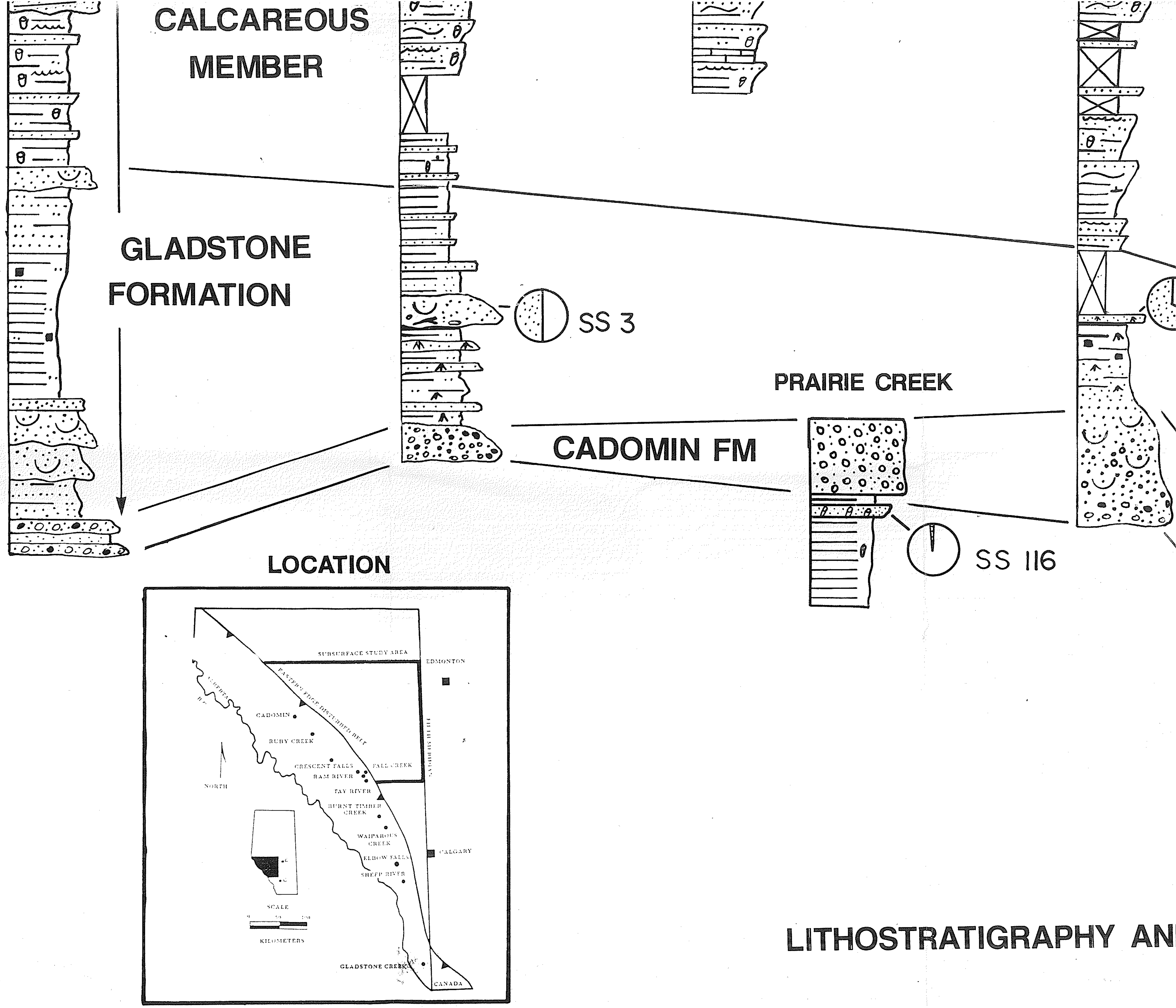
McINTYRE MINES SECTION
GRANDE CACHE AREA



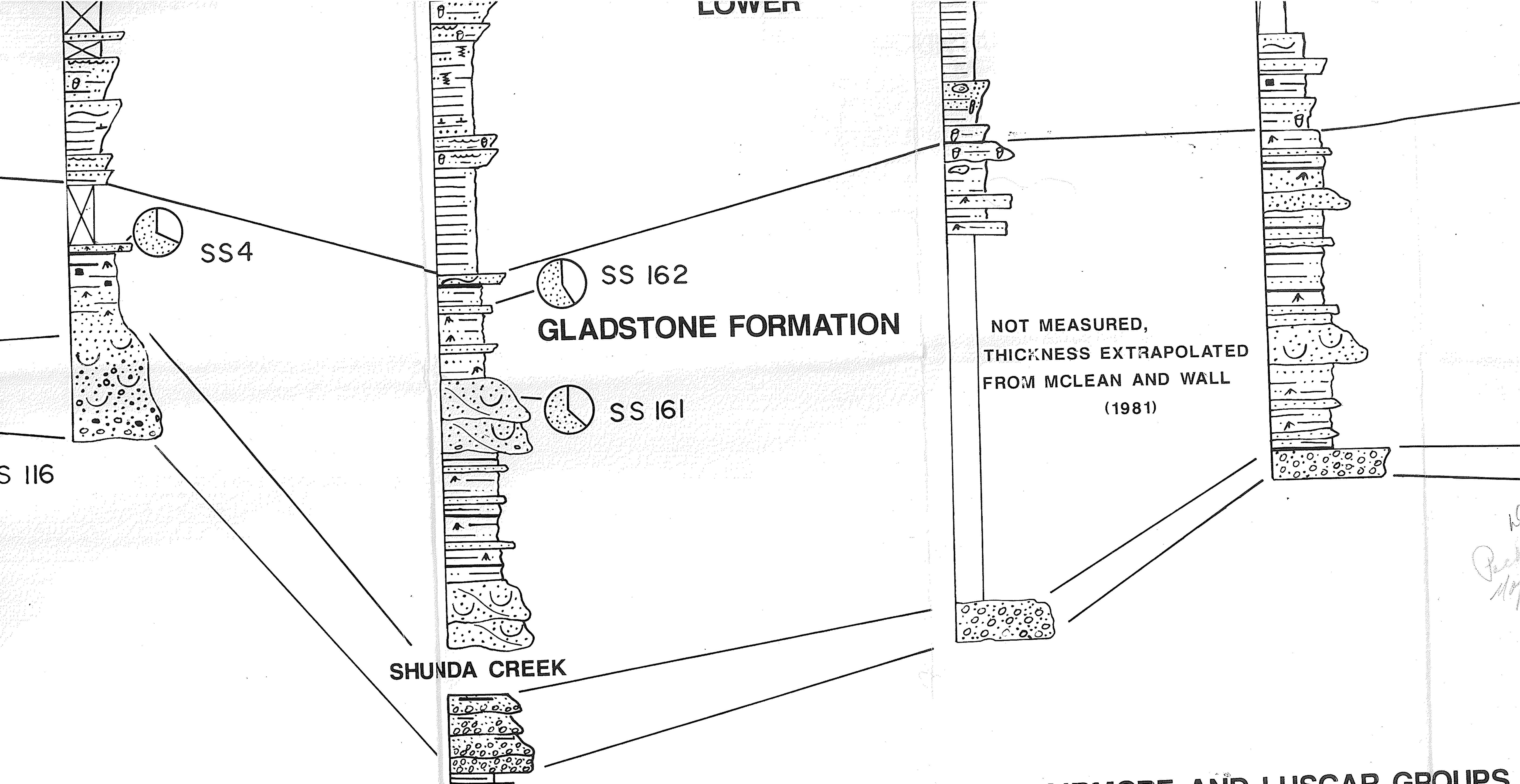

FELDSPAR
SOUTHERN FOOTHILLS
RA
27.2 K
BEAVER MINES FORMATION
FALL CREEK
21 KM
SS 151
BURNT TIMBER CREEK
80 KM
TAY RIVER
SHEEP RIVER
WAIPAROUS CREEK
SS 121
23km
SS 160
92 KM
CALCAREOUS MEMBER
GLADSTONE FORMATION
SS 3
PRAIRIE CREEK
CADOMIN FM


UPPER MOOSEBAR TRANSGRESSION
RAM RIVER
KM
48 KM
CRESCENT FALLS
65 KM
2 KM
RUBY CREEK TWO
30 KM
SS 2
SS 8
SS 4
SS 118
SS 129
SS 119
SS 12
SS 162
SS 115
SS 113
SS 138
TORRENS MEMBER
UPPER
MIDDLE
LOWER
GLADSTONE FORMATION
?
G
NOT MEASURED,
THICKNESS EXTRAPOLATED

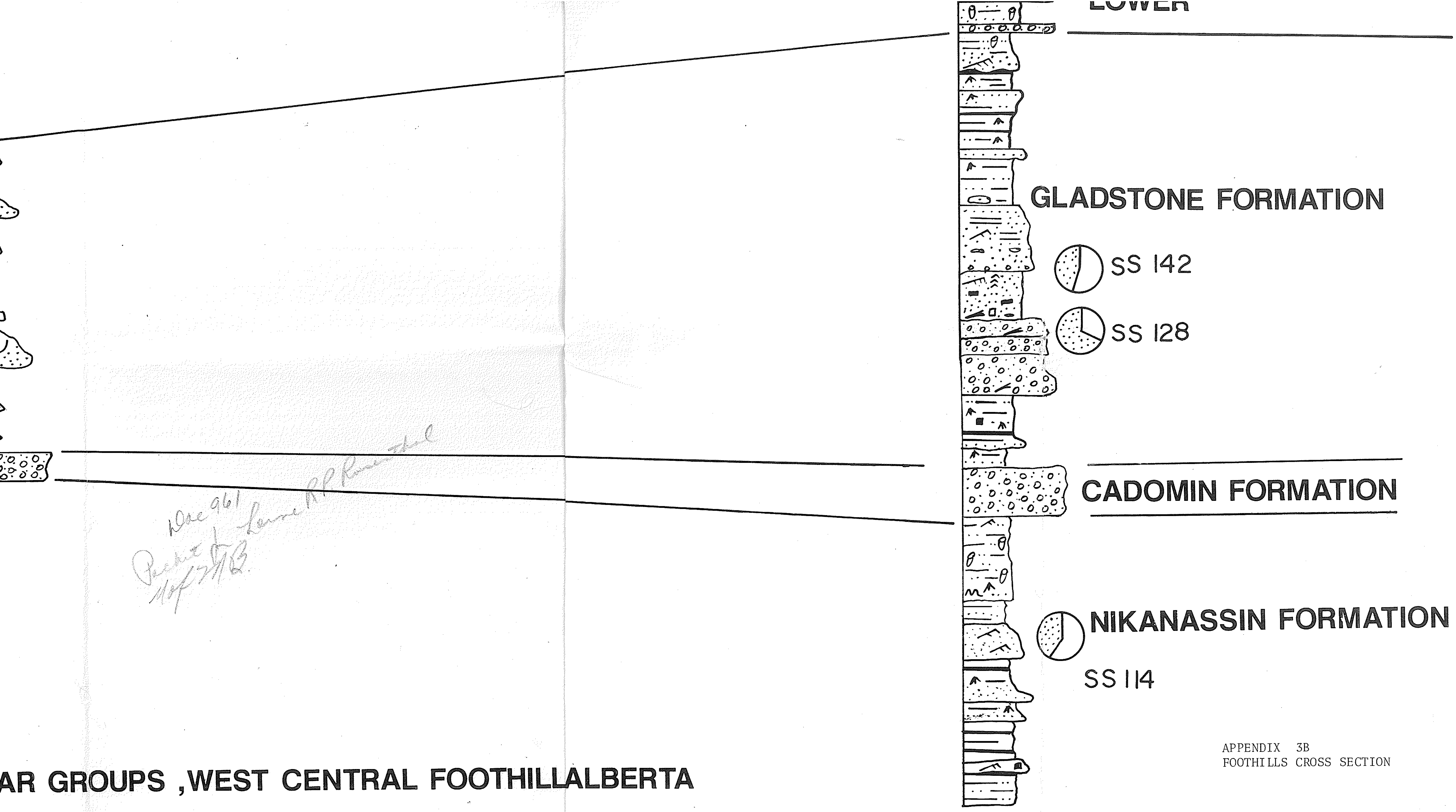

153 KM
SS 138
SS 111
GATE
TORRENS MEMBER
UPPER
MOOSEBAR FORMATION
MIDDLE
LOWER
GLADSTONE FORMATION
SS 142



LITHOSTRATIGRAPHY AN



GRAPHY AND FACIES CORRELATIONS IN THE LOWER CRETACEOUS BLAIRMORE AND LUSCAR GROUPS

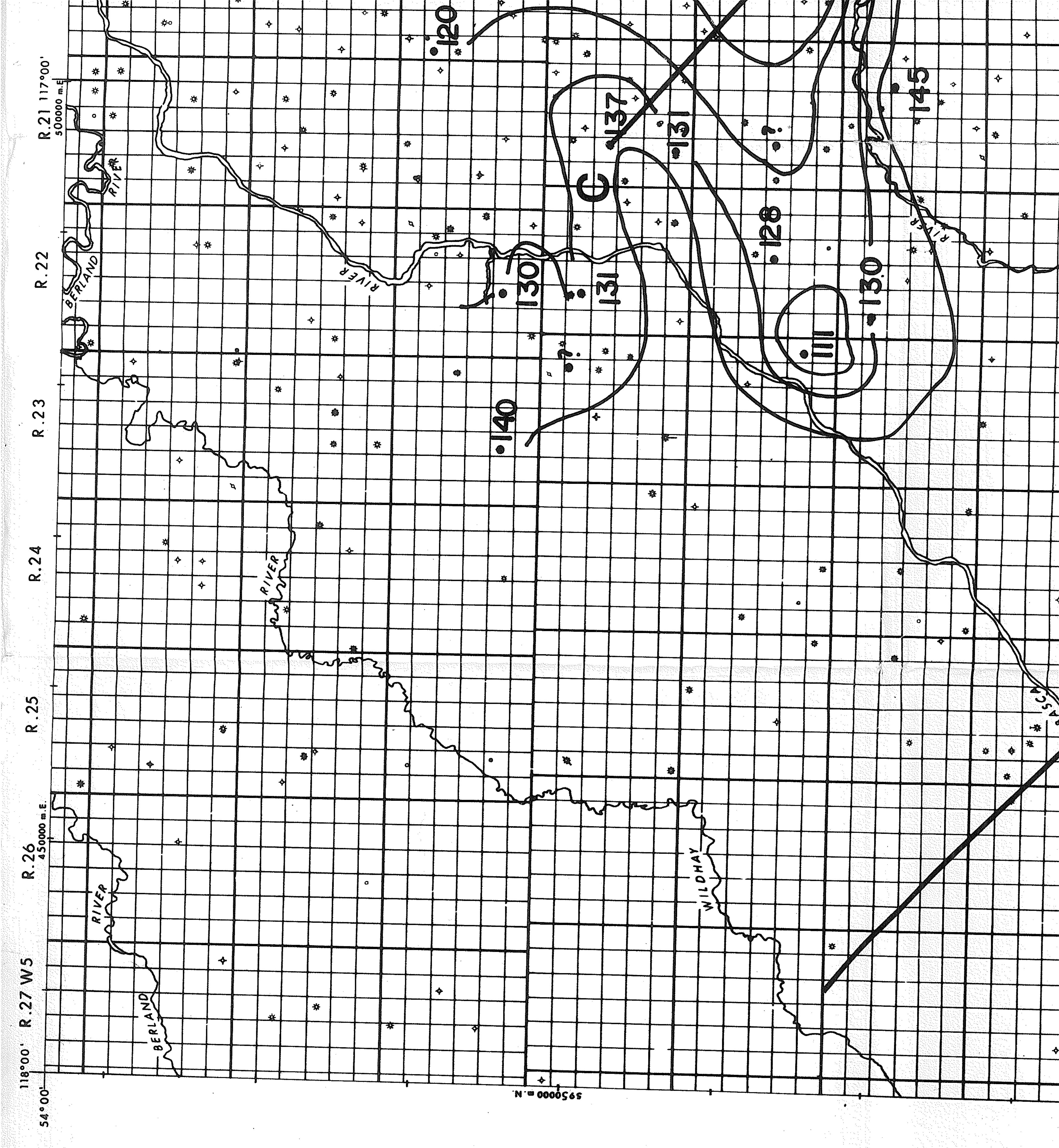


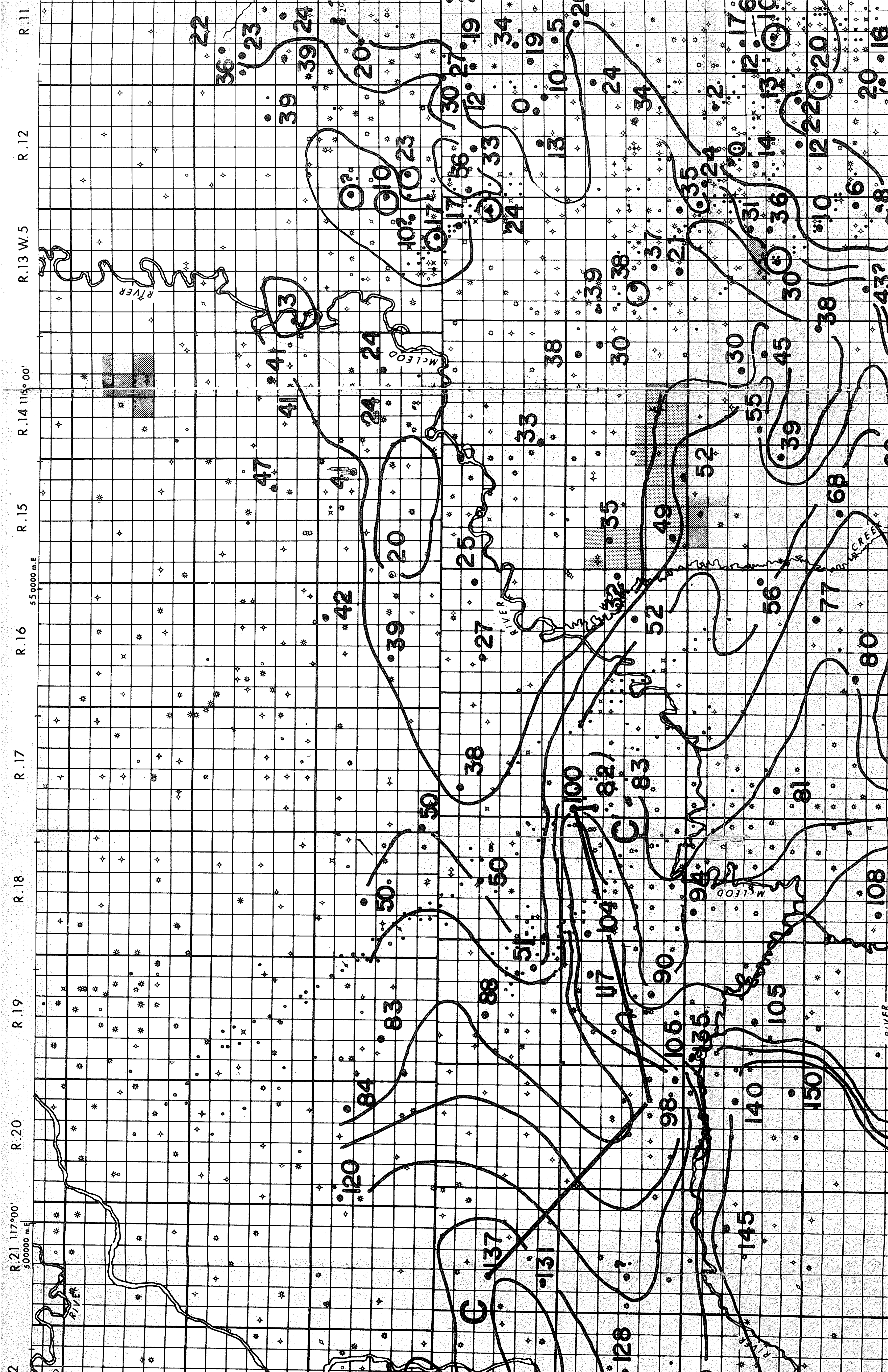
Wae 961 Lorne R.P. Rosenthal
Packet [illegible]
May 27/82

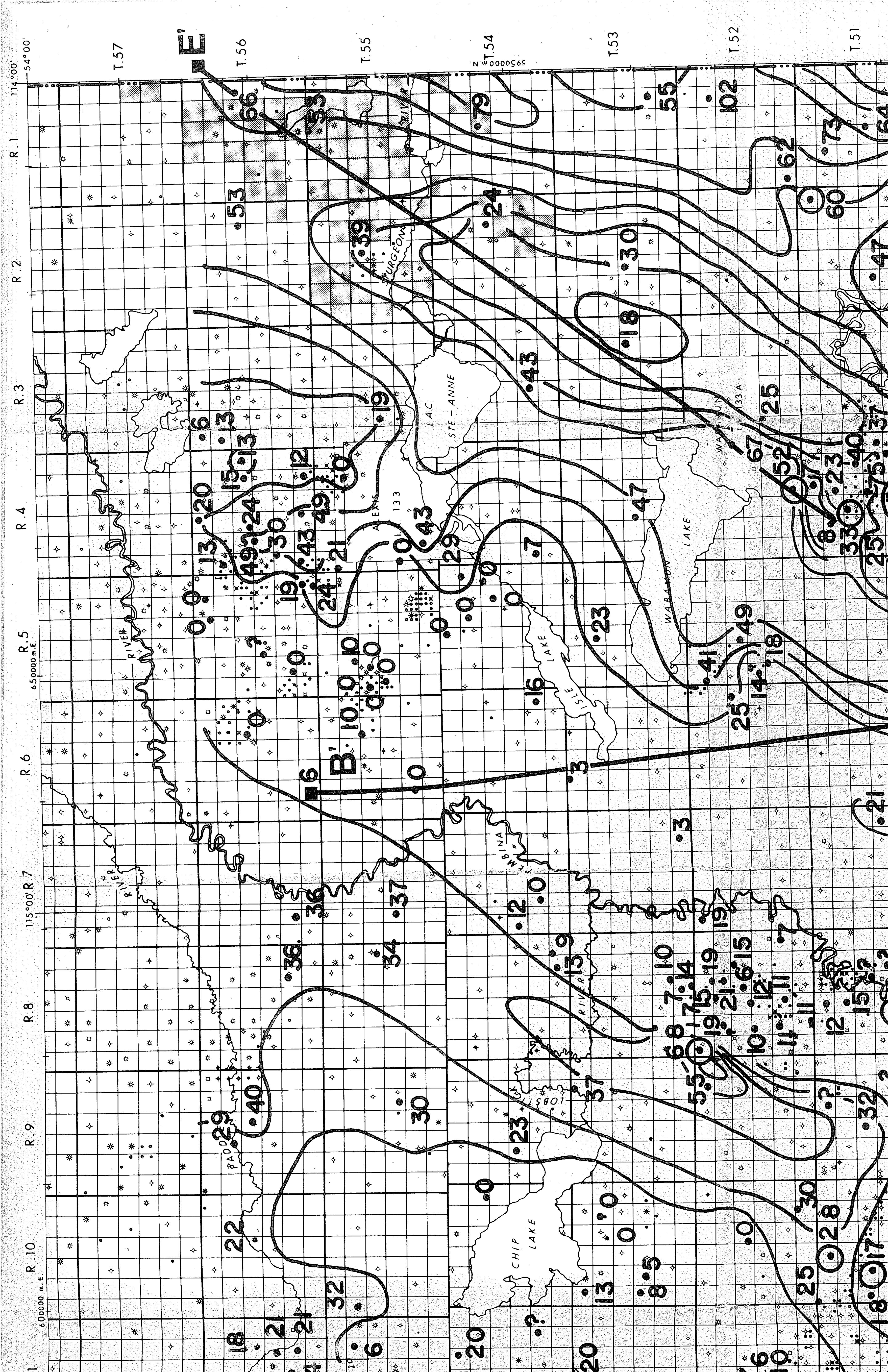
APPENDIX 3B
FOOTHILLS CROSS SECTION

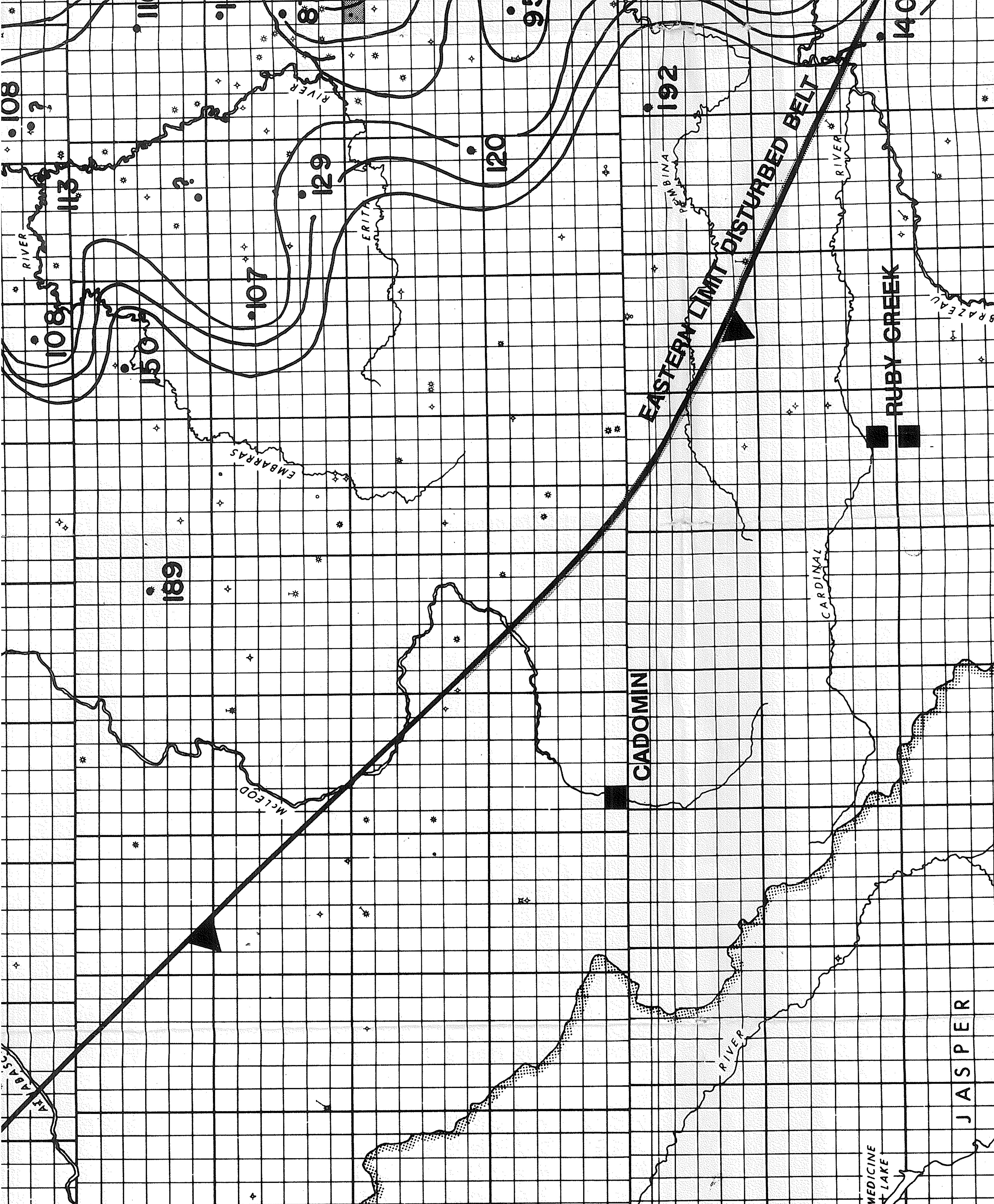
AR GROUPS ,WEST CENTRAL FOOTHILLALBERTA

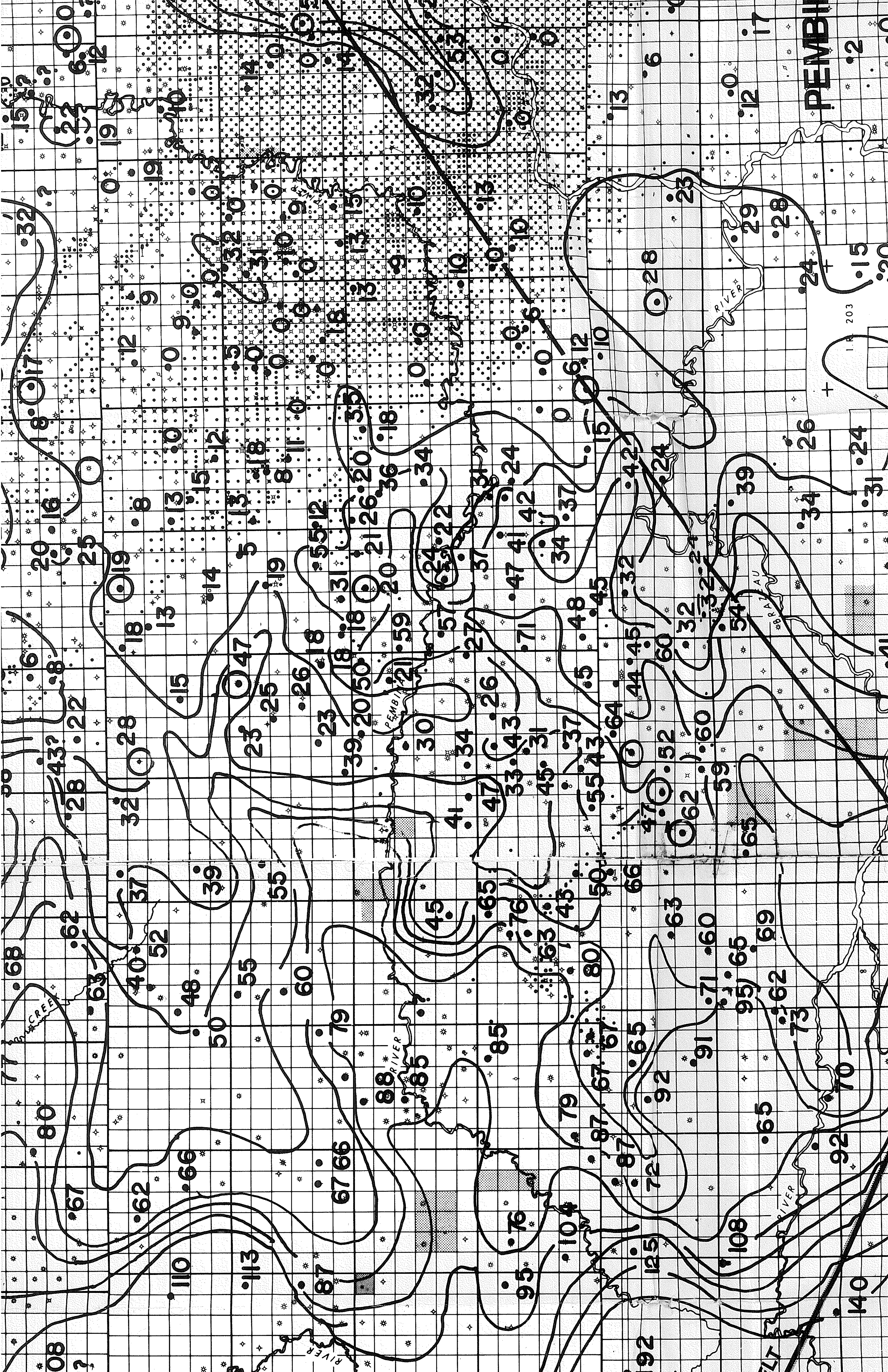
GEOLOGY AND DRAFTING BY LORNE ROSENTHAL,

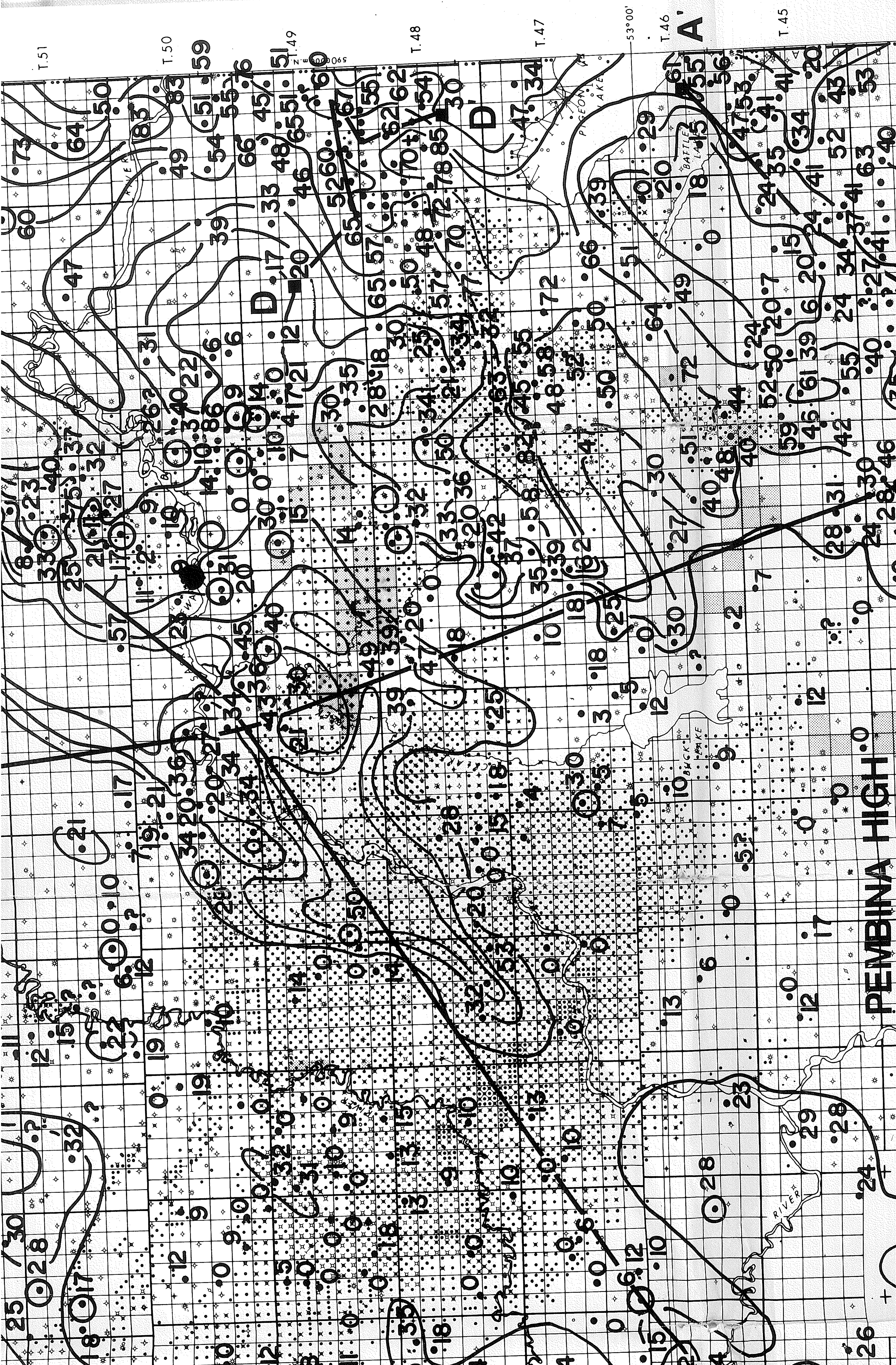

R.21 117°00'
500000 m.E.
R.22
R.23
R.24
R.25
R.26
450000 m.E.
R.27 W5
118°00'
54°00'
595000 m.N.
BERLAND
RIVER
RIVER
RIVER
RIVER
BERLAND
WILDHAY
RIVER
C
120
137
131
145
?
128
130
131
130
111
130
?
140

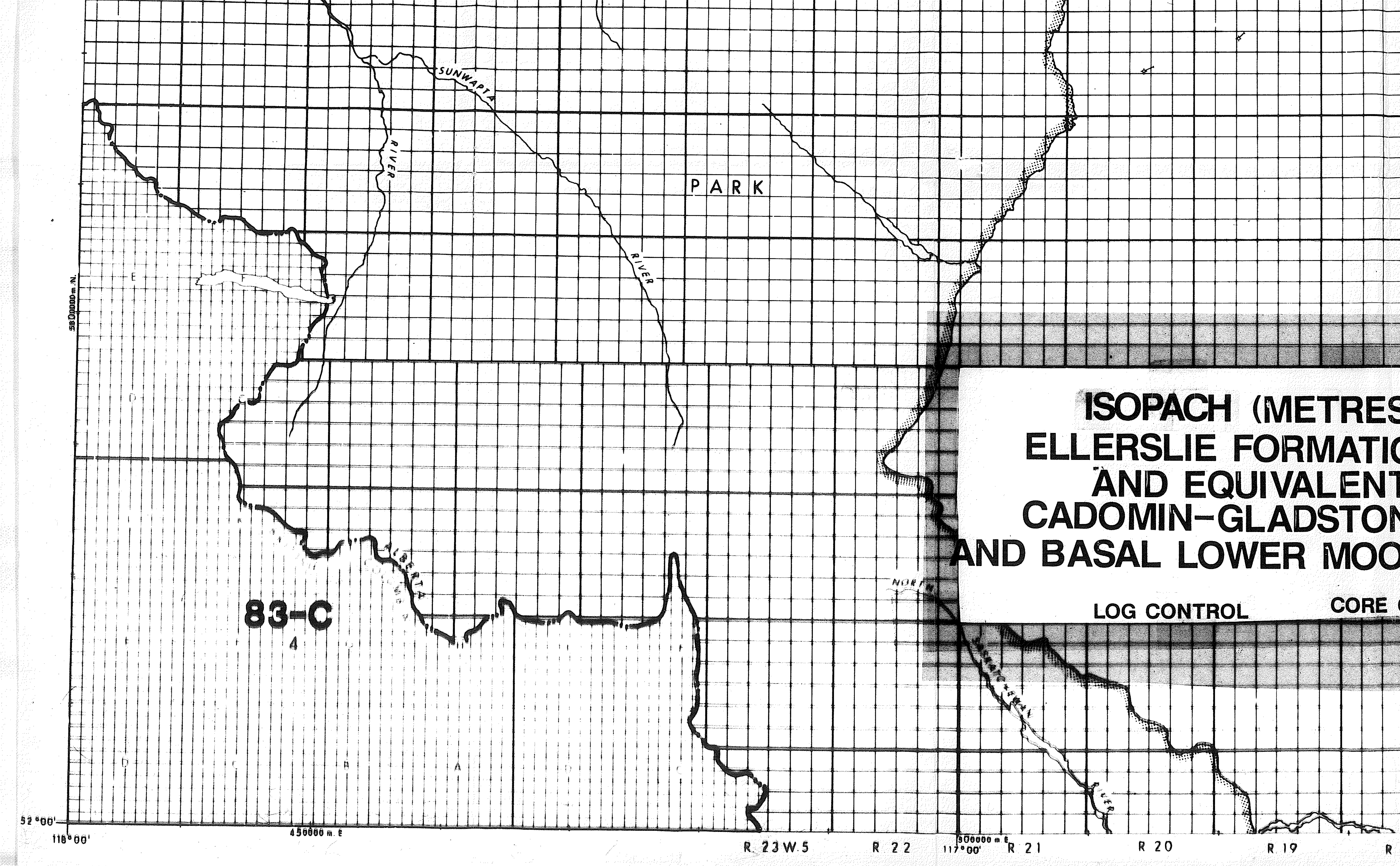

R.11
R.12
R.13 W.5
R.14 115°00'
R.15
550000 m.E
R.16
R.17
R.18
R.19
R.20
R.21 117°00'
500000 m.E
RIVER
McLEOD
RIVER
CREEK
McLEOD
RIVER
RIVER
RIVER
C
C
C


114°00'
54°00'
T.57
T.56
T.55
T.54
T.53
T.52
T.51
5950000 m.N.
R.1
R.2
R.3
R.4
R.5
R.6
R.7
R.8
R.9
R.10
650000 m.E.
600000 m.E.
115°00'
E'
B'
STURGEON RIVER
LAC STE-ANNE
I.R. 133
I.R. 133A
WABAMUN LAKE
LAKE ISLE
PEMBINA RIVER
RIVER
LOBSTICK RIVER
PADDLE
CHIP LAKE


108
113
108
107
150
129
120
192
189
EASTERN LIMIT DISTURBED BELT
PEMBINA
RIVER
RUBY CREEK
BRAZEAU
CARDINAL
CADOMIN
ERITH
EMBARRAS
McLEOD
RIVER
RIVER
JASPER
MEDICINE LAKE
RIVER
ROCKY
BRULE LAKE
590000m.N.
53°00'
5850000m.N.


PEMBI
RIVER
PEMBI
RIVER
CREEK
BRAZEAU
RIVER
RIVER
RIVER
I.R. 203

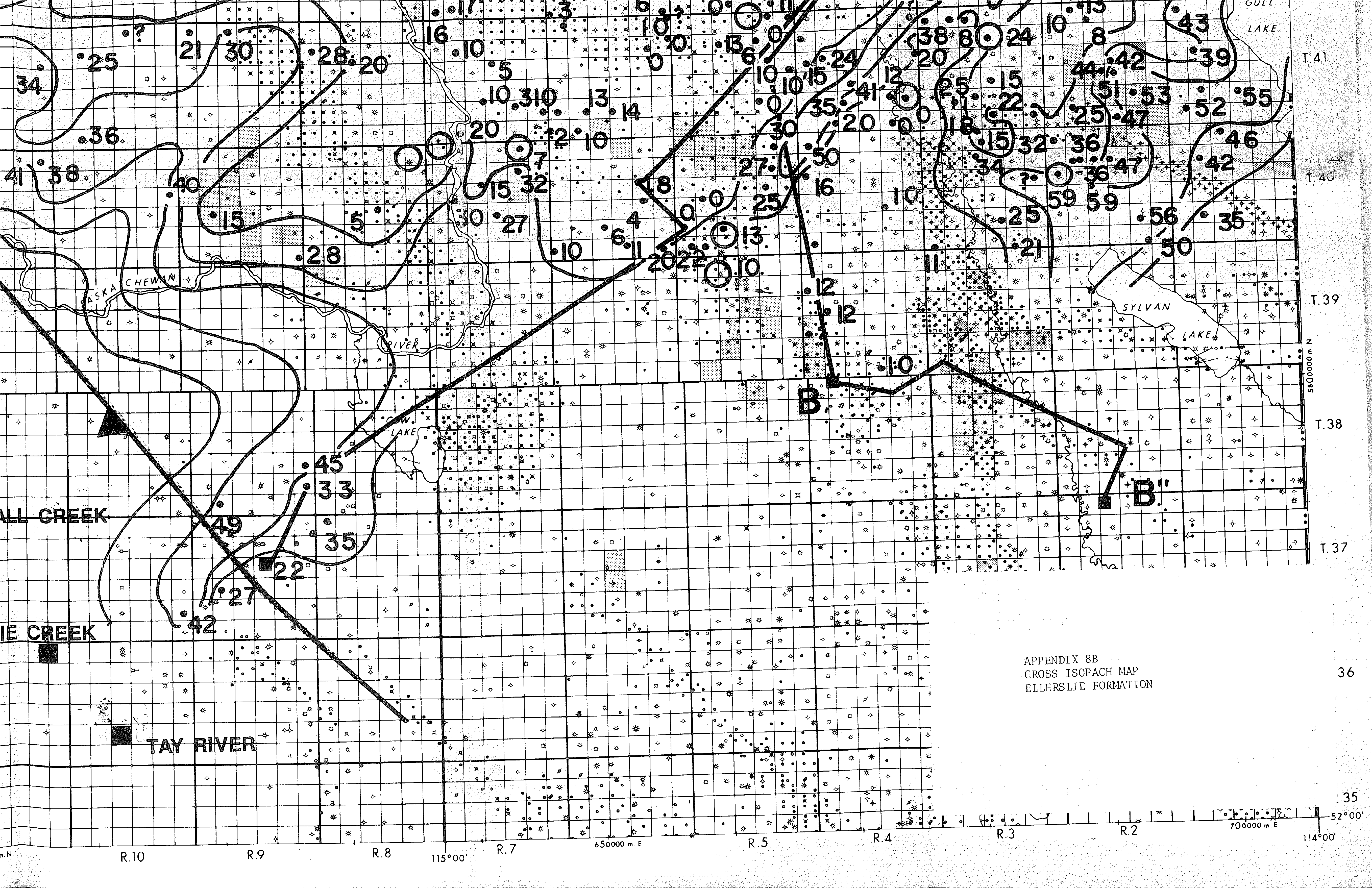

T.51
T.50
T.49
T.48
T.47
T.46
T.45
53°00'
A'
D
D'
PIGEON LAKE
BATTLE LAKE
BUCK LAKE
RIVER
PEMBINA HIGH

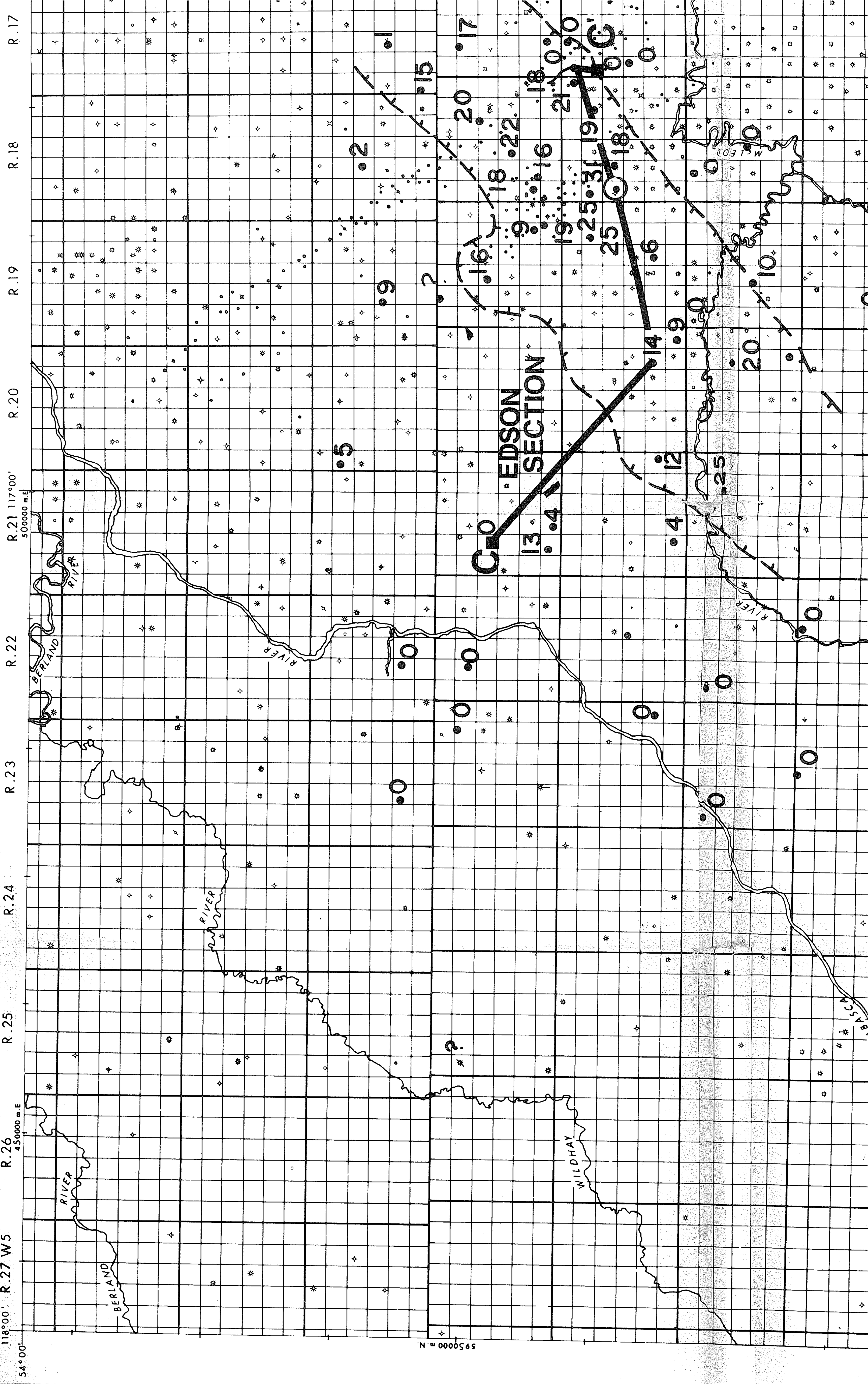

ISOPACH (METRES
ELLERSLIE FORMATIO
AND EQUIVALENT
CADOMIN-GLADSTON
AND BASAL LOWER MOO
LOG CONTROL
CORE
SUNWAPTA
RIVER
RIVER
PARK
ALBERTA
83-C
NORTH
SASKATCHEWAN
RIVER
580000 m. N.
450000 m. E
500000 m. E
52°00'
118°00'
117°00'
R 23 W.5
R 22
R 21
R 20
R 19
R

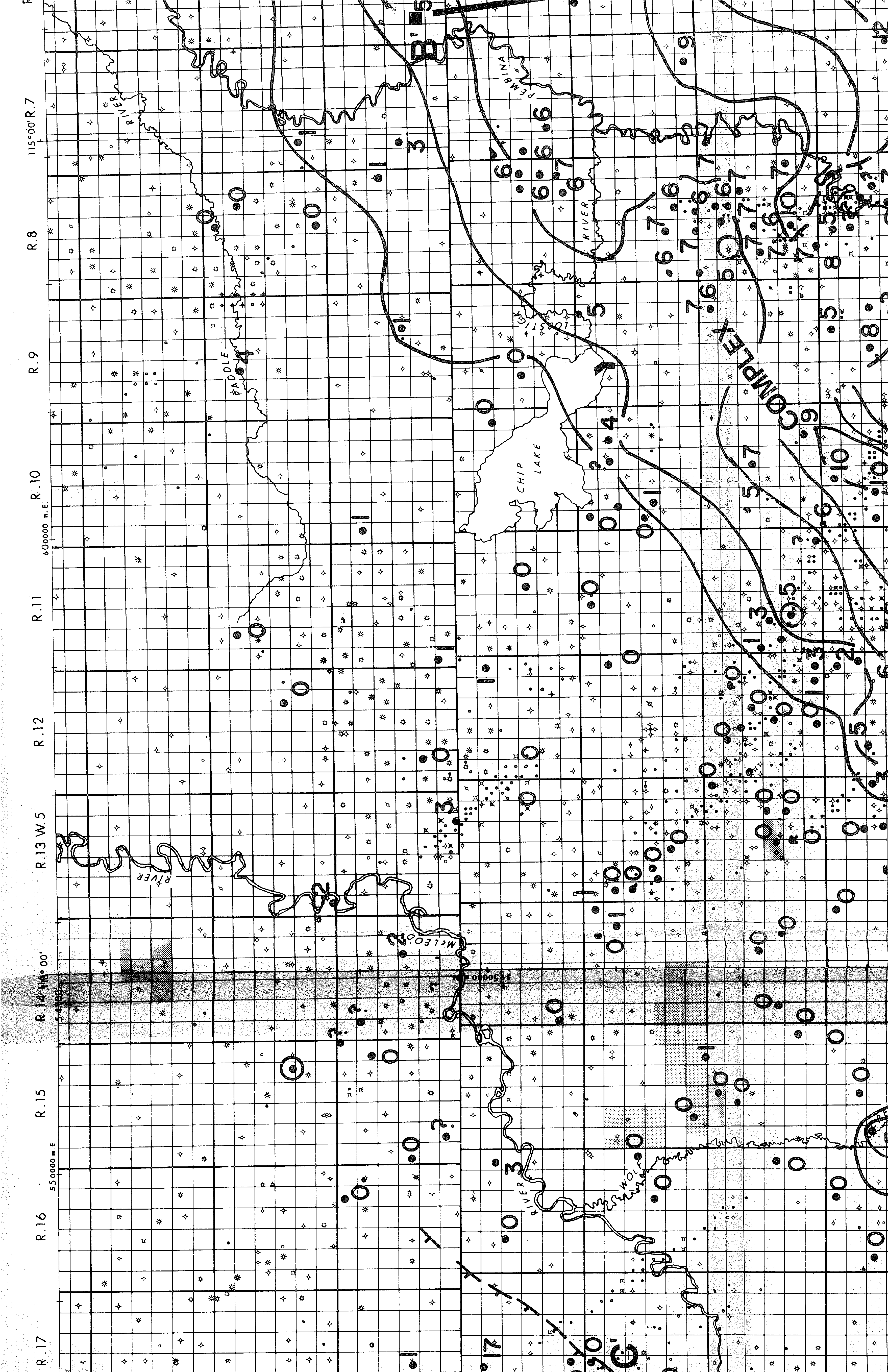
ISOPACH (METRES)
ELLERSLIE FORMATION
AND EQUIVALENT
CADOMIN-GLADSTONE
BASAL LOWER MOOSEBAR

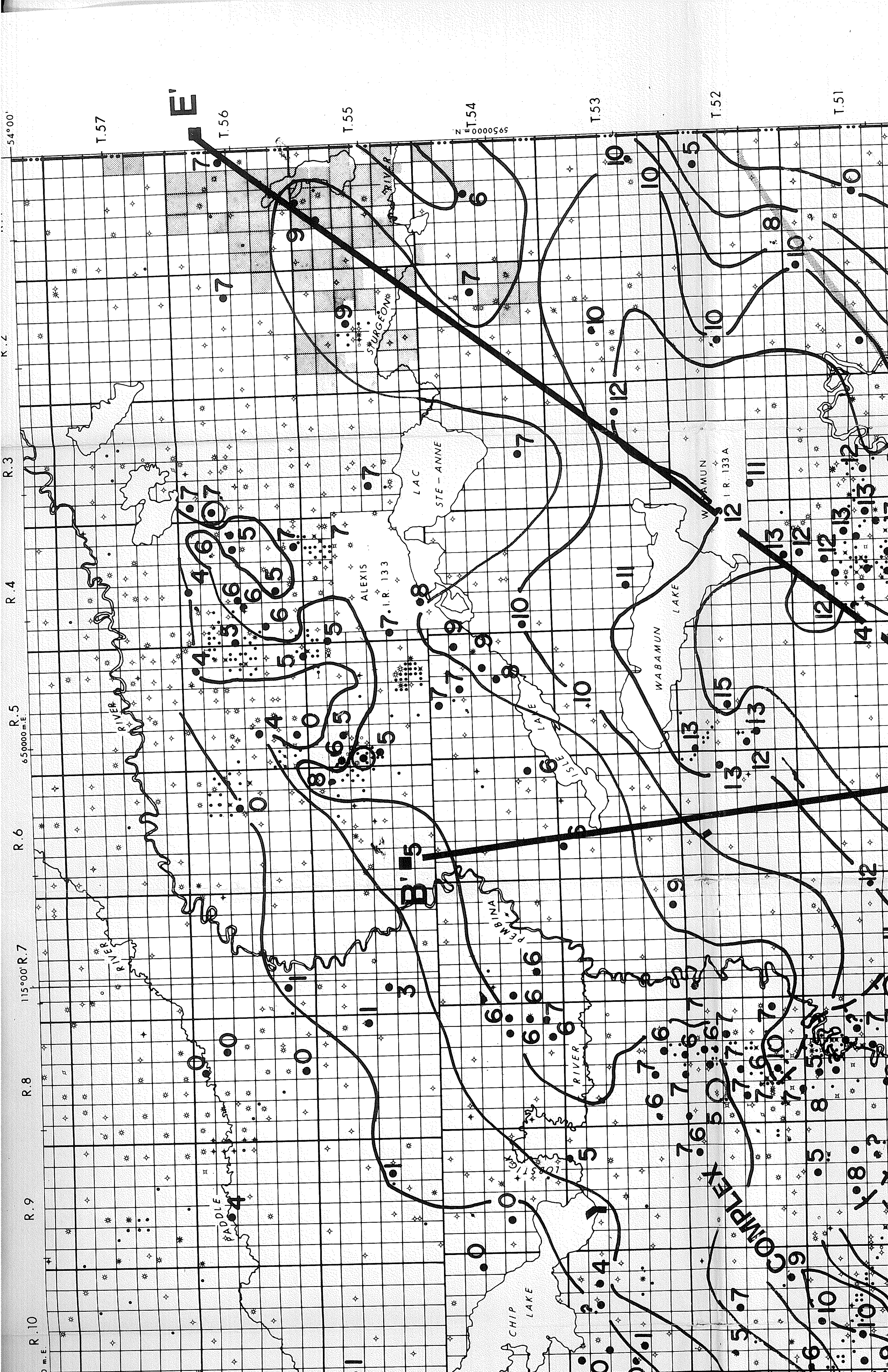
LOG CONTROL CORE CONTROL

APPENDIX 8B
GROSS ISOPACH MAP
ELLERSLIE FORMATION

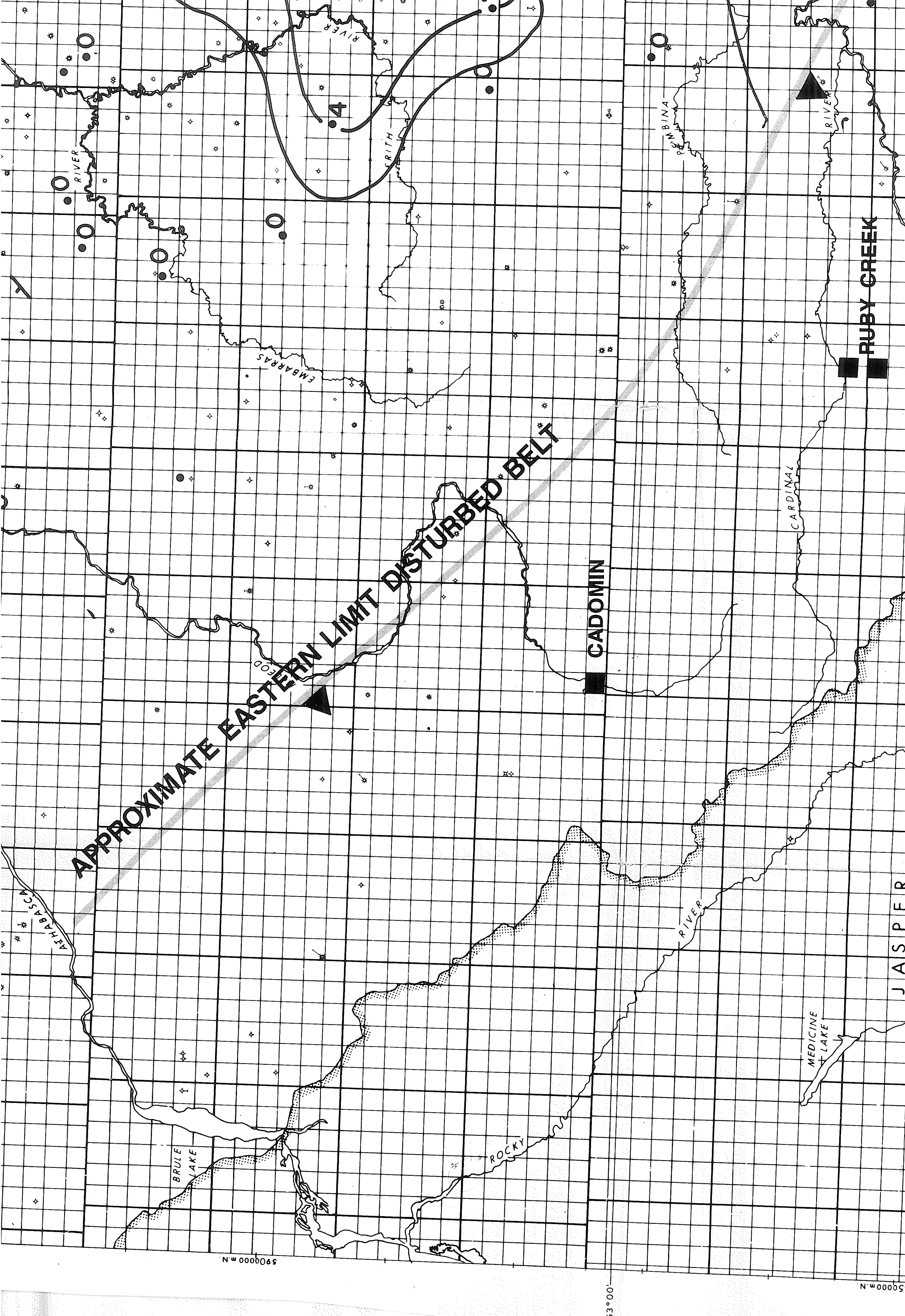


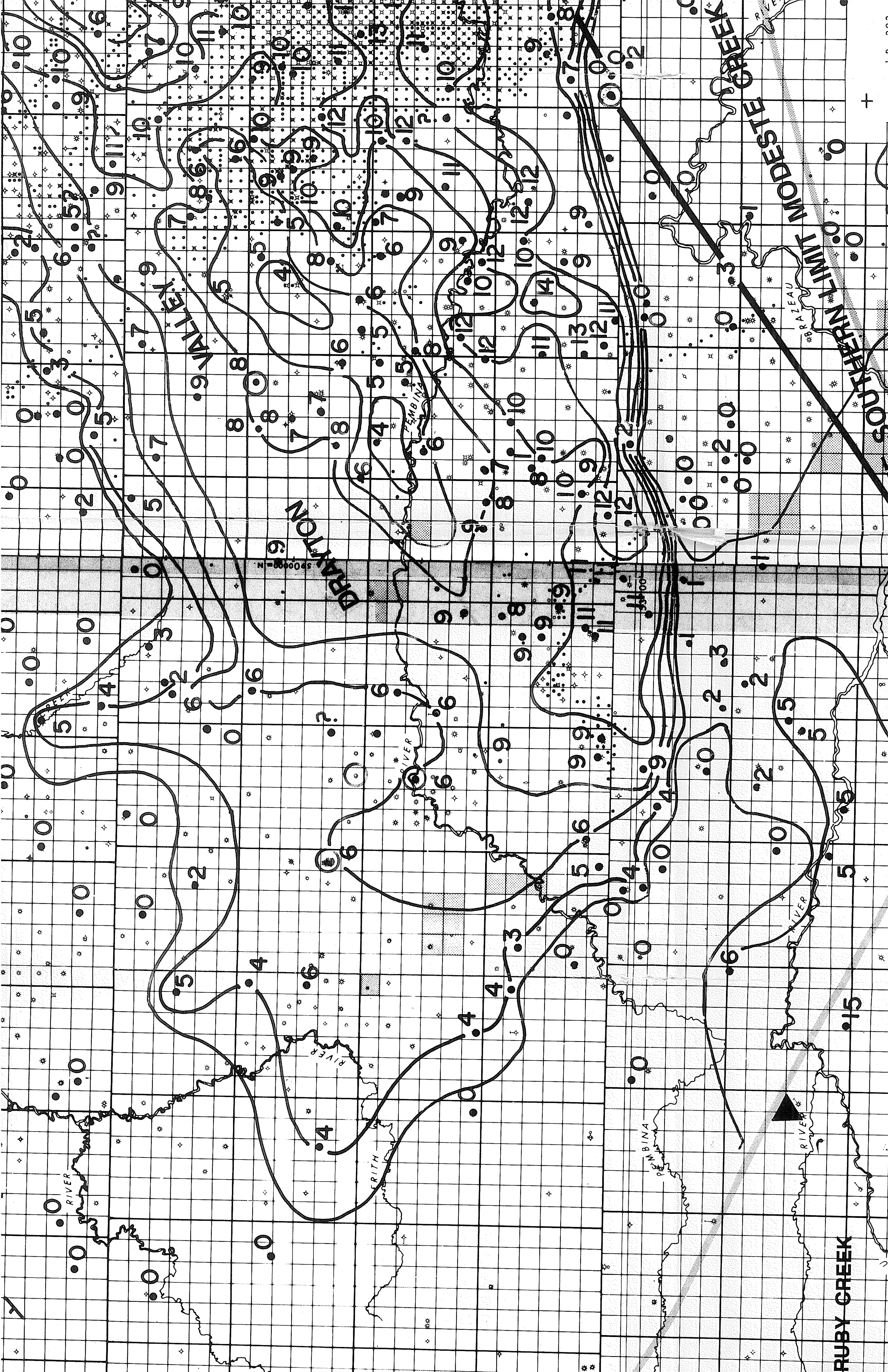

R.17
R.18
R.19
R.20
R.21 117°00'
500000 m.E.
R.22
R.23
R.24
R.25
R.26
450000 m.E.
R.27 W5
118°00'
54°00'
5950000 m.N.
EDSON SECTION
C
C'
BERLAND
RIVER
RIVER
RIVER
RIVER
BERLAND
RIVER
WILDHAY
McLEOD
RIVER
BASCA
17
15
20
18
0
0
21
22
19
18
16
31
18
2
25
19
25
9
16
6
9
10
0
9
14
20
5
12
25
4
13
4
0
0
0
0
0
0
9
0
0
?
?


115°00' R.7
R.8
R.9
R.10
600000 m.E.
R.11
R.12
R.13 W.5
R.14
116°00'
54°00'
R.15
550000 m.E
R.16
R.17
PEMBINA
RIVER
PADDLE
RIVER
LOBSTICK
RIVER
CHIP
LAKE
RIVER
McLEOD
5550000 m.N
WOLF
RIVER
COMPLEX
B'
C'

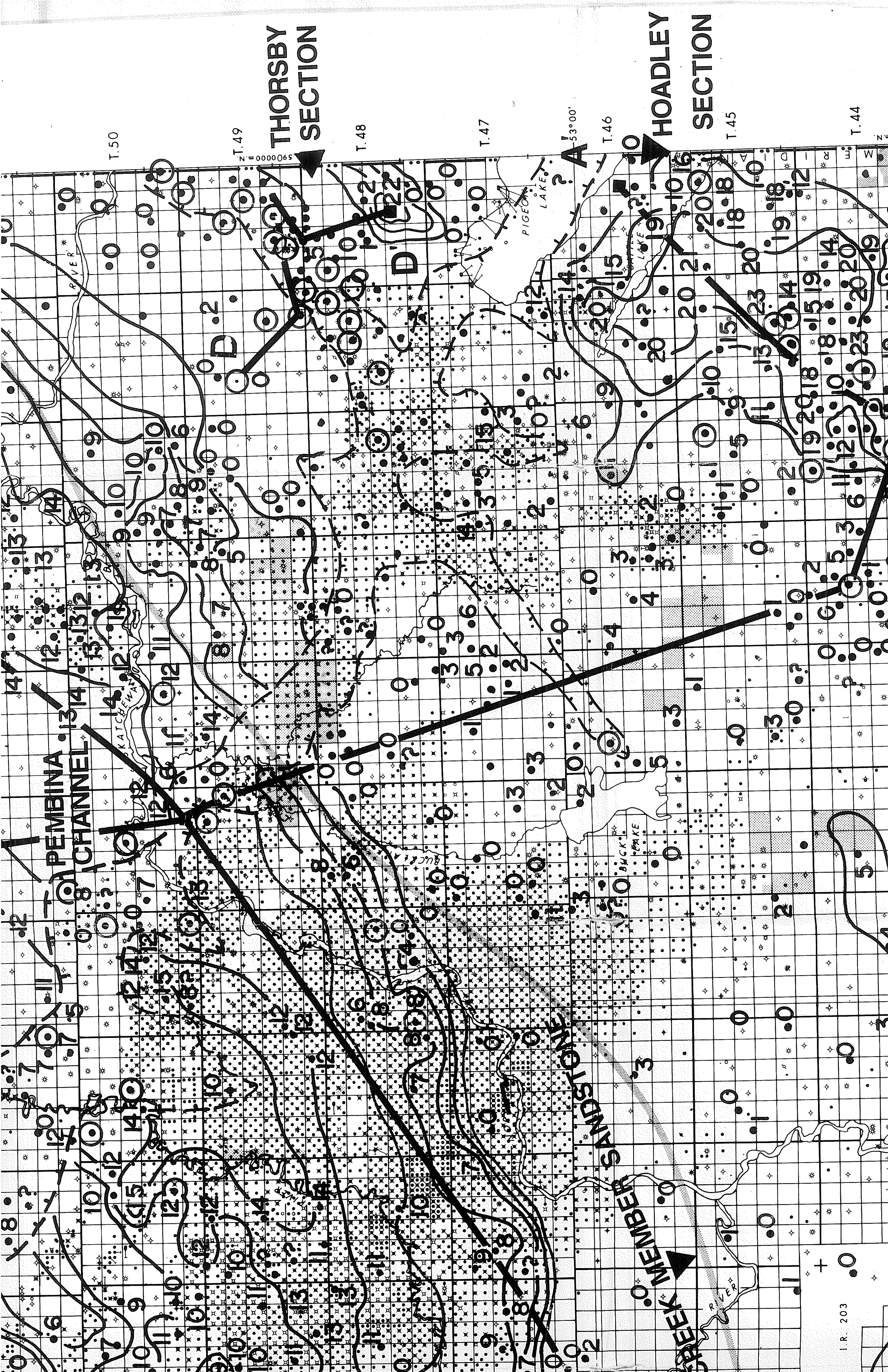


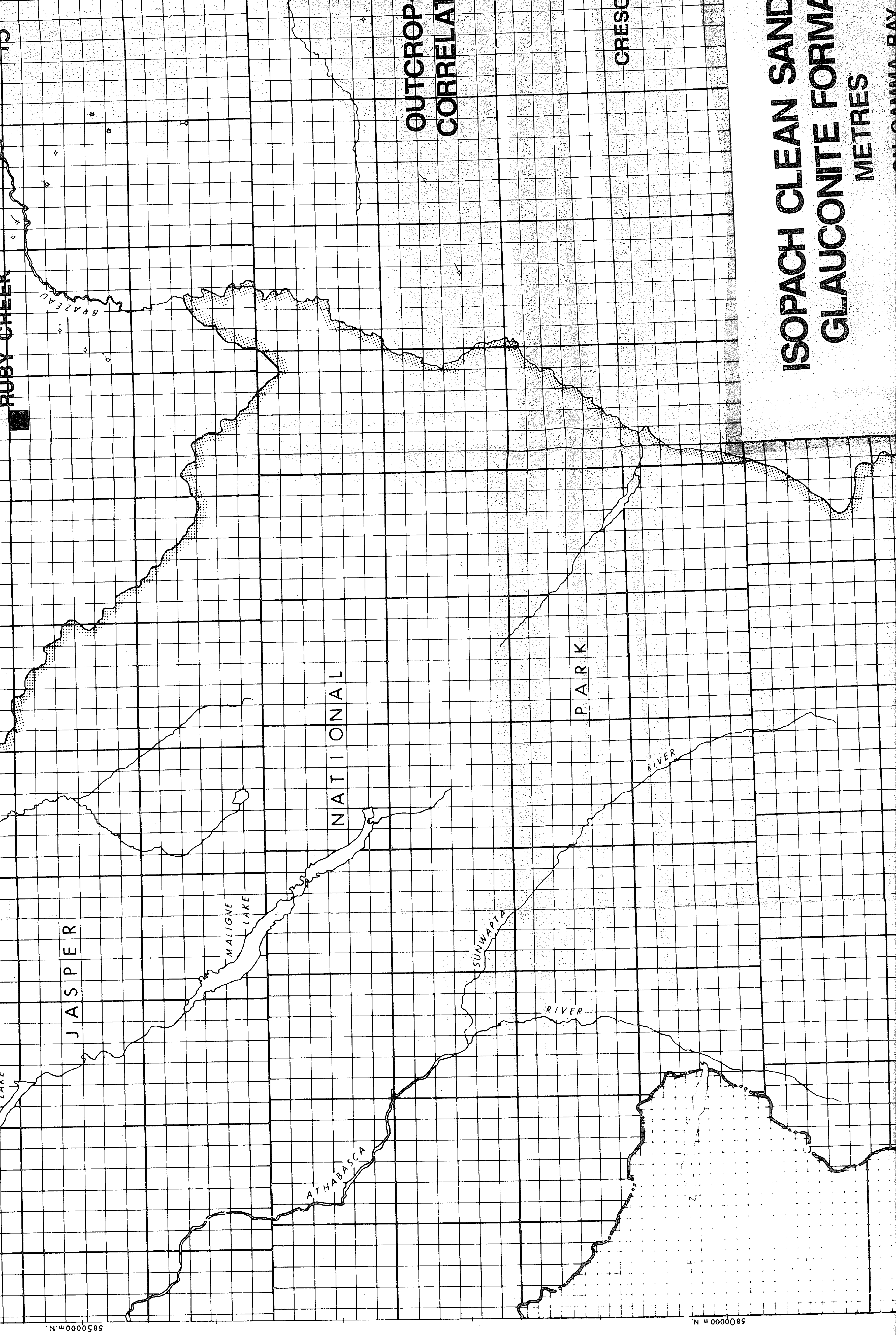
E'
B'
54°00'
115°00'
T.57
T.56
T.55
T.54
T.53
T.52
T.51
R.2
R.3
R.4
R.5
R.6
R.7
R.8
R.9
R.10
650000 m.E.
5950000 m.N.
STURGEON
RIVER
LAC STE-ANNE
ALEXIS I.R. 133
WABAMUN I.R. 133A
WABAMUN LAKE
ISLE LAKE
PEMBINA RIVER
RIVER
PADDLE
LOBSTICK
CHIP LAKE
COMPLEX

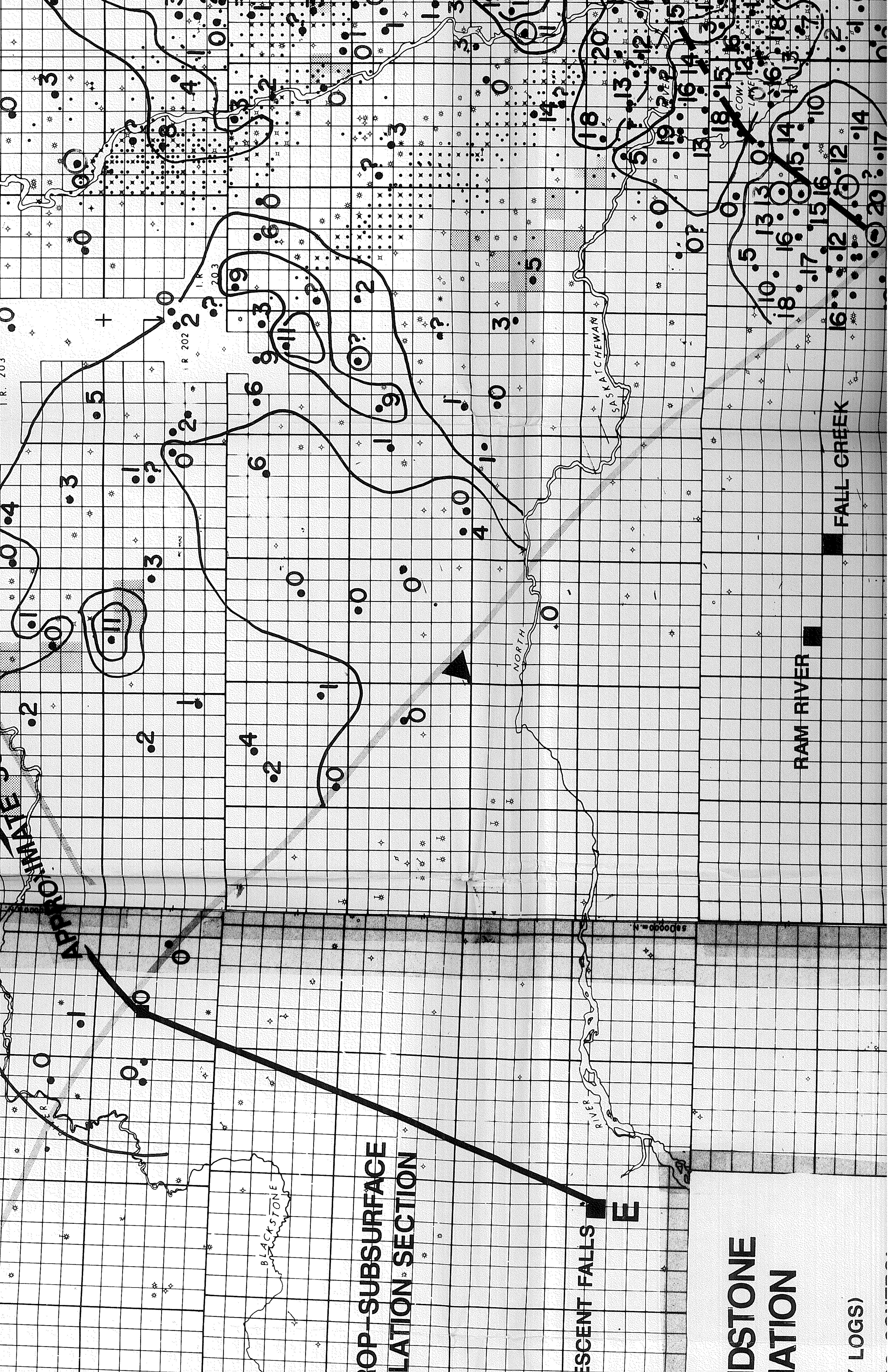

APPROXIMATE EASTERN LIMIT DISTURBED BELT
CADOMIN
RUBY CREEK
JASPER
RIVER
FRITH
4
EMBARRAS
PEMBINA
RIVER
CARDINAL
EOD
ATHABASCA
BRULE LAKE
ROCKY
RIVER
MEDICINE LAKE
5900000 m.N.
53°00'
5000 m.N.



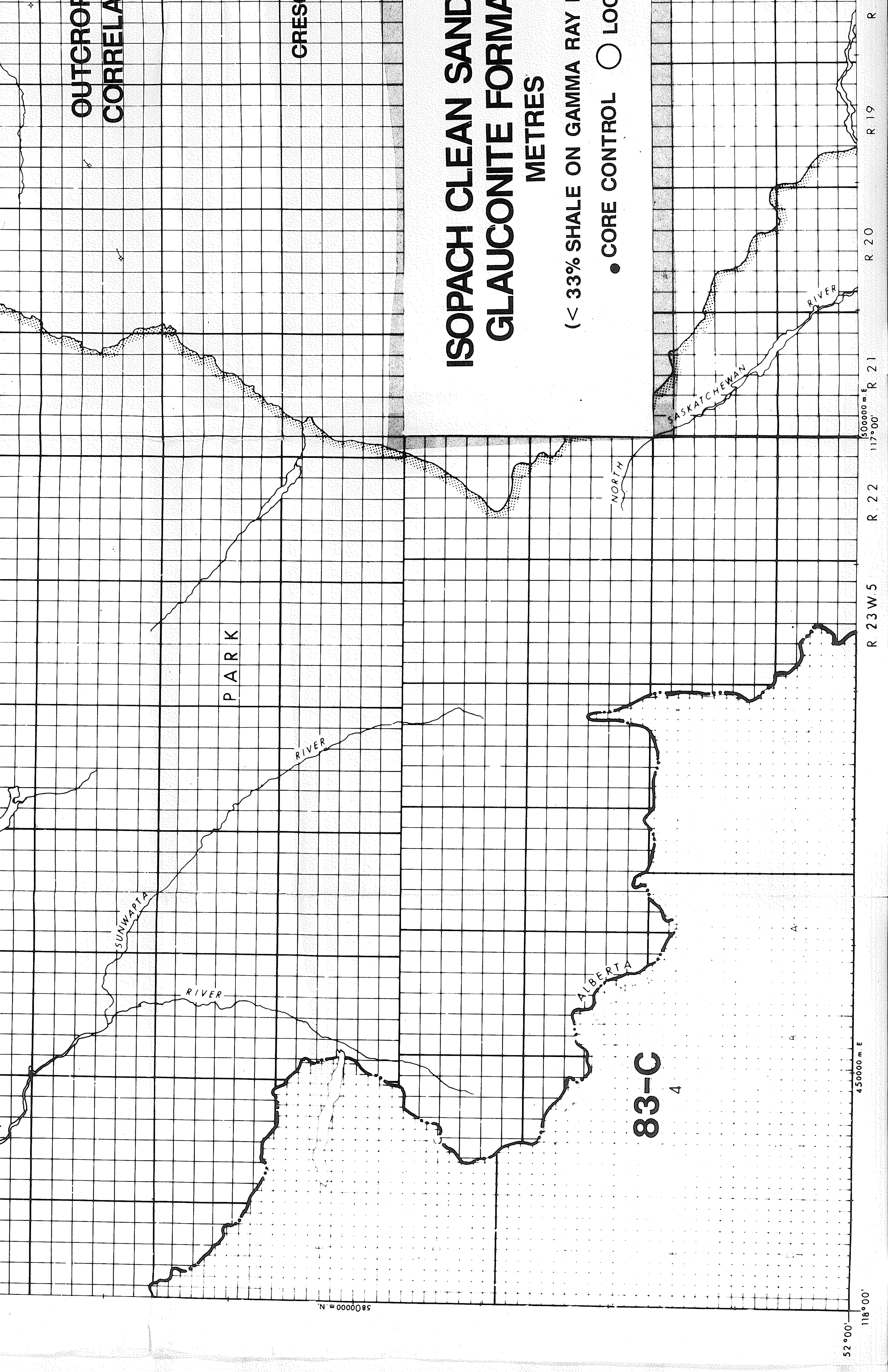
VALLEY
DRAYTON
SOUTHERN LIMIT MODESTE CREEK
RUBY CREEK
PEMBINA
RIVER
BRAZEAU
FRITH
5900000 N

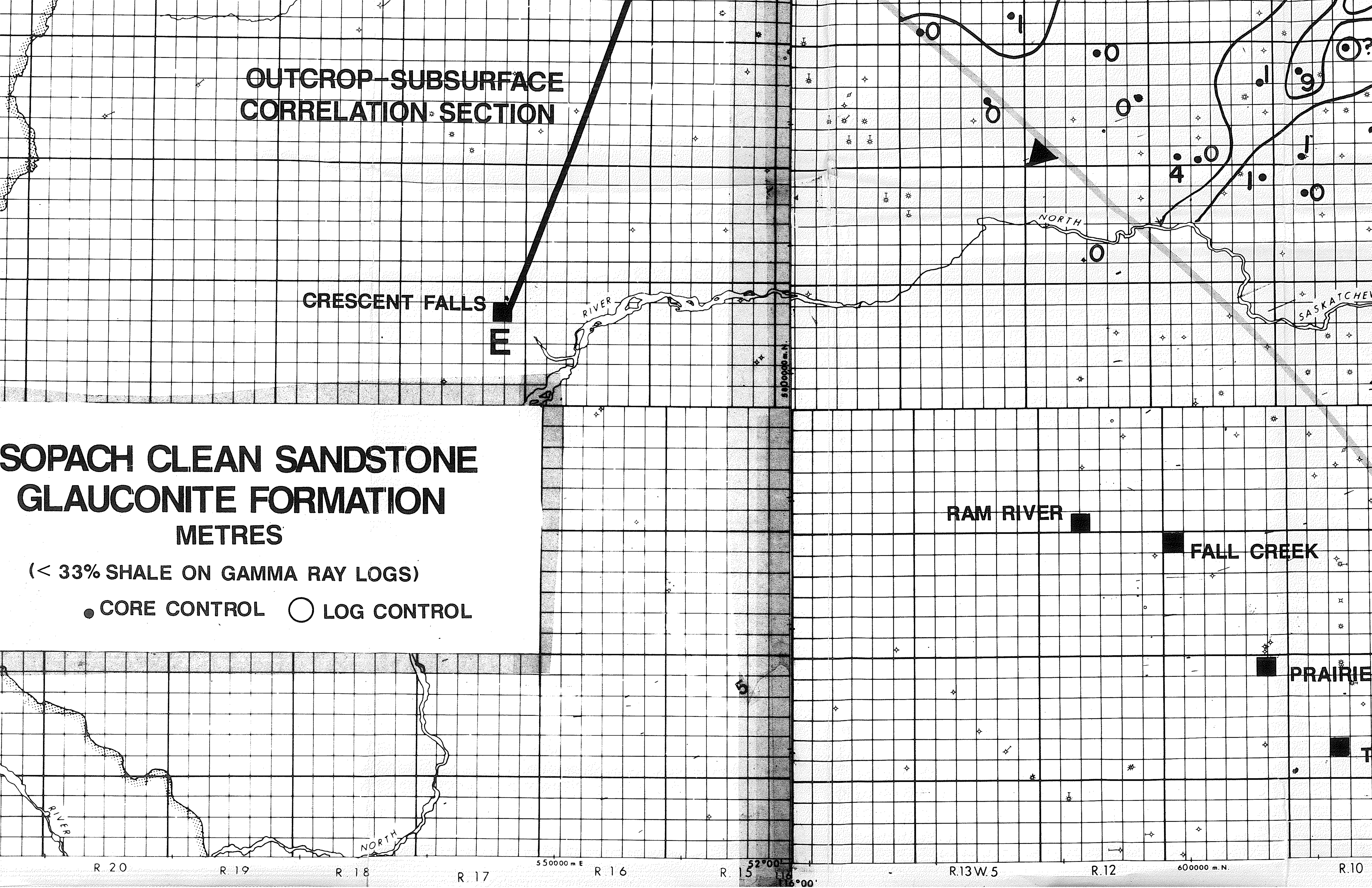

THORSBY SECTION
HOADLEY SECTION
PEMBINA CHANNEL
SANDSTONE
MEMBER
REEK
D
D'
A'
T.50
T.49
T.48
T.47
T.46
T.45
T.44
53°00'
590000m E
PIGEON LAKE
BUCK LAKE
RIVER
SASKATCHEWAN
I.R. 203

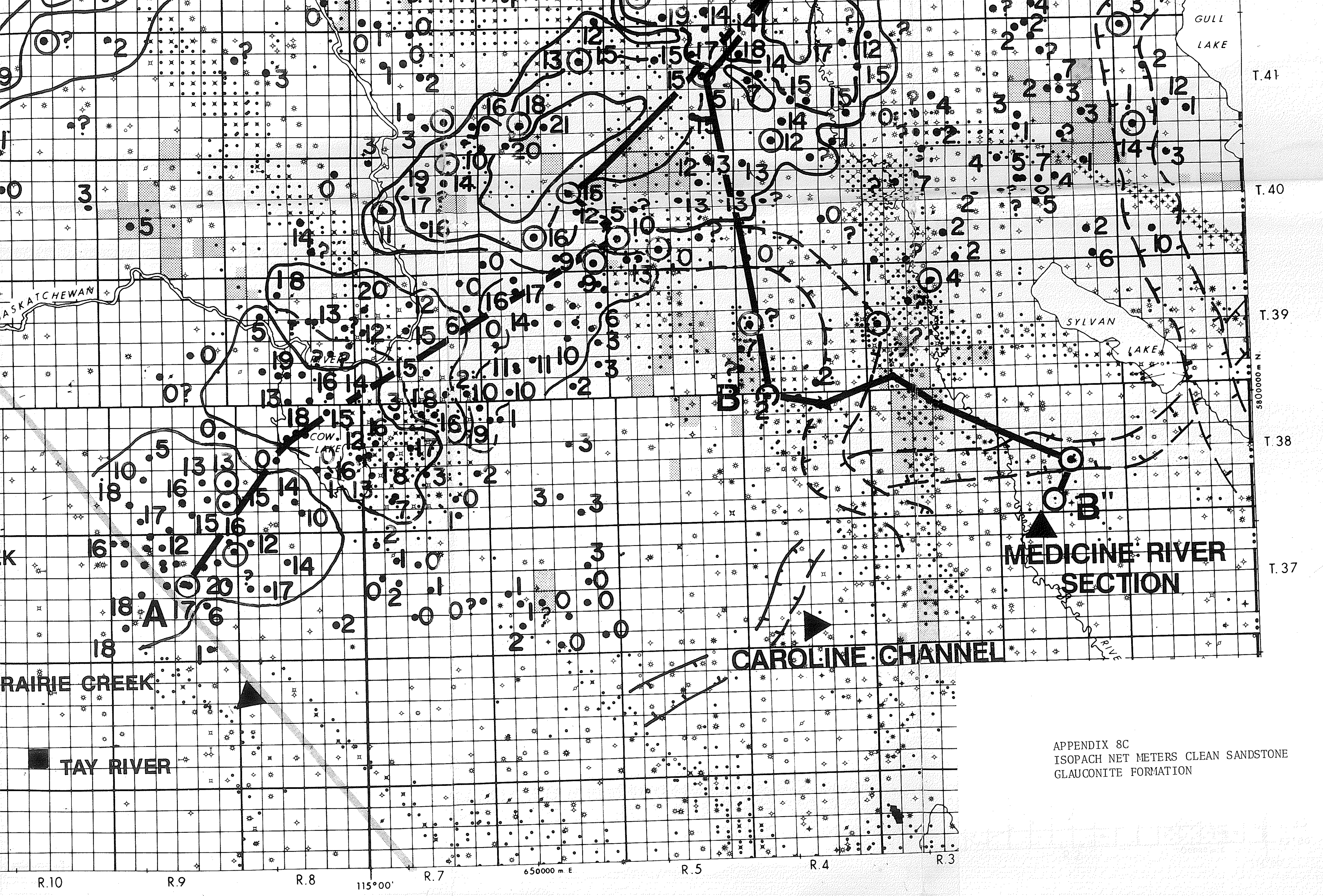

ISOPACH CLEAN SAND
GLAUCONITE FORMA
METRES
ON GAMMA RAY
OUTCROP
CORRELAT
CRESC
15
RUBY CREEK
BRAZEAU
JASPER
NATIONAL
PARK
MALIGNE LAKE
LAKE
SUNWAPTA
RIVER
RIVER
ATHABASCA
5850000 m. N.
5800000 m. N.


APPROXIMATE
NORTH
SASKATCHEWAN
RIVER
COW LAKE
I.R. 203
I.R. 202
FALL CREEK
RAM RIVER
BLACKSTONE
E
ESCENT FALLS
OP-SUBSURFACE
LATION SECTION
DSTONE
ATION
LOGS)

T.43
T.42
T.41
T.40
T.39
5850000 m.N.
MERIDIAN
GULL LAKE
SYLVAN LAKE
MEDICINE LAKE
MEDICINE
RIVER
SASKATCHEWAN
I.R. 203
I.R. 202


OUTCROP
CORRELA
CRES
ISOPACH CLEAN SAND
GLAUCONITE FORMA
METRES
(< 33% SHALE ON GAMMA RAY
● CORE CONTROL ○ LOC
R 19
R 20
R 21
R 22
R 23 W.5
500000 m.E
117°00'
NORTH
SASKATCHEWAN
RIVER
PARK
RIVER
SUNWAPTA
RIVER
ALBERTA
83-C
450000 m.E
580000 m.N.
52°00'
118°00'


SOPACH CLEAN SANDSTONE
GLAUCONITE FORMATION
METRES
(< 33% SHALE ON GAMMA RAY LOGS)
● CORE CONTROL ○ LOG CONTROL
OUTCROP–SUBSURFACE
CORRELATION SECTION
CRESCENT FALLS
E
RAM RIVER
FALL CREEK
PRAIRIE
NORTH
SASKATCHEW
RIVER
5
0
1
4
9
?
5800000 m.N.
550000 m E
600000 m.N.
52°00'
116°00'
R. 20
R. 19
R. 18
R. 17
R. 16
R. 15
R. 13 W. 5
R. 12
R. 10



APPENDIX 8C
ISOPACH NET METERS CLEAN SANDSTONE
GLAUCONITE FORMATION