ABSTRACT

Reservoir Characterization and Prediction of the Lower Cretaceous Glauconite Member
at Jenner-Suffield Field, Alberta, Canada

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Thesis Chairperson: Stacy C. Atchley, Ph.D.

Significant hydrocarbon reserves at Jenner and Suffield fields of southern Alberta, Canada, occur within the Lower Cretaceous Glauconitic Member of the Upper Mannville Formation. The Glauconitic Member accumulated within fluvial-estuarine environments during transgressive sea level rise following an episode of lowstand paleovalley incisement. Borehole data were used to identify petrofacies within the Glauconitic Member and characterize their controls on reservoir quality, production characteristics, and petrophysical attributes for facies prediction.

Analysis of facies-specific core data indicates that the greatest reservoir potential is associated with incised valley filling fluvial Fine and Coarse Channel Sand facies. Gamma ray and density porosity well logs and diagnostic well log patterns were used to generate a semi-quantitative algorithm for Glauconitic facies prediction. A blind test of the predictive algorithm produced 33.1% reproducibility to core observed facies distributions.

Reservoir Characterization and Prediction of the Lower Cretaceous Glauconite Member at Jenner-Suffield Field, Alberta, Canada

by

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A Thesis

Approved by the Department of Geosciences

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Submitted to the Graduate Faculty of
Baylor University in Partial Fulfillment of the
Requirements for the Degree
of

Master of Science

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August, 2017

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ACKNOWLEDGMENTS

This study was possible through the sponsorship of Imaginea Energy of Calgary, Alberta, in collaboration with the Baylor University Applied Petroleum Studies (APS) program, and a software donation from IHS Energy Accumap®. A special thanks is extended to Nolan Skains of the Arts and Sciences Technology Center at Baylor University for his maintenance of the computer resources within the APS workroom. A special thanks is also extended to Josh Brownlow for assistance in core description during 2016, and to Jayd McGrath and Donna Bird of Imaginea Energy for providing various subsurface maps of the study area.

The success of this study would not have been possible without the expertise of my advisor, Dr. Stacy Atchley. Thank you for being an exemplary advisor by not only providing technical support throughout the study, but most importantly by providing your endless encouragement and thoughtful motivation. Thank you, Alyssa Johnson, for being my project partner to lean on. You motivated me to work harder and wake up earlier. I couldn't have asked for a better team to work with. A special thank you to my family for all their support and love throughout this process.

CHAPTER ONE

Introduction

Prospect and Objectives

For over 70 years, incised-valley systems have been explored for their associated hydrocarbon accumulations within the Western Canadian Sedimentary Basin (Broger et. al., 1997; Brown, 1993; Dolson et. al., 1991, 1994; Van Wagoner et. al., 1990; Zaitlin et. al., 1994a, 1995; Zaitlin and Shultz, 1990). Brown (1993) estimates that 25% of the world's stratigraphically entrapped hydrocarbon accumulations occur within lowstand to early transgressive incised-valley filling siliciclastic deposits. In southern Alberta, Canada, the Lower Cretaceous Glauconitic Sandstone contains significant hydrocarbon reserves (Broger, et. al., 1997). The Alberta Energy Resource Conservation Board estimates that the upper Mannville contains 1139 x $10^6 m^3$ OOIP (7.165 billion bbls) and 1458.45 x $10^9 m^3$ OGIP (51.8 TCF) with an average primary recovery factor of 15% (ERCB 1988, 1991, 1992; Broger et. al., 1997). Due to the lack of water drive from the underlying Mississippian deposits, effective hydrocarbon recovery requires water injection to maintain reservoir pressure (Broger et. al., 1997). Effective schemes of secondary recovery provide a recovery factor of 55% (Broger et. al., 1997; ERCB, 1991).

Previous studies of the Glauconitic Sandstone include detailed rock-based description and analysis, seismic analysis, an assessment of regional paleogeography and associated channel morphology, structural geologic modification, and reservoir compartmentalization as defined sequence stratigraphically (Broger, et. al., 1997, Cederwall, 1991; Farshori, 1983; Hopkins, et. al., 1982; Koladich, 2004; Lynch, 2003; Lynch and Hopkins, 2001; Reinson, 1989; Sherwin, 1996; Strobl, 1988; Wood, 1994; Wood and Hopkins, 1989, 1992). No study, however, has evaluated the utility of well logs in characterizing and predicting Glauconitic reservoir facies distributions in wells lacking core control. Such a predictive tool would more accurately characterize the distribution of Glauconitic facies and thereby reduce the risk (and associated cost) of development drilling and production optimization. With this in mind, the objectives of this study are to: 1) create a core-calibrated depositional facies model for the Glauconite reservoir, 2) quantify the relationship between depositional facies, reservoir quality, and well log response, and 3) determine whether petrophysical algorithms may be used to accurately predict the occurrence of depositional (reservoir) facies in wells lacking core control.

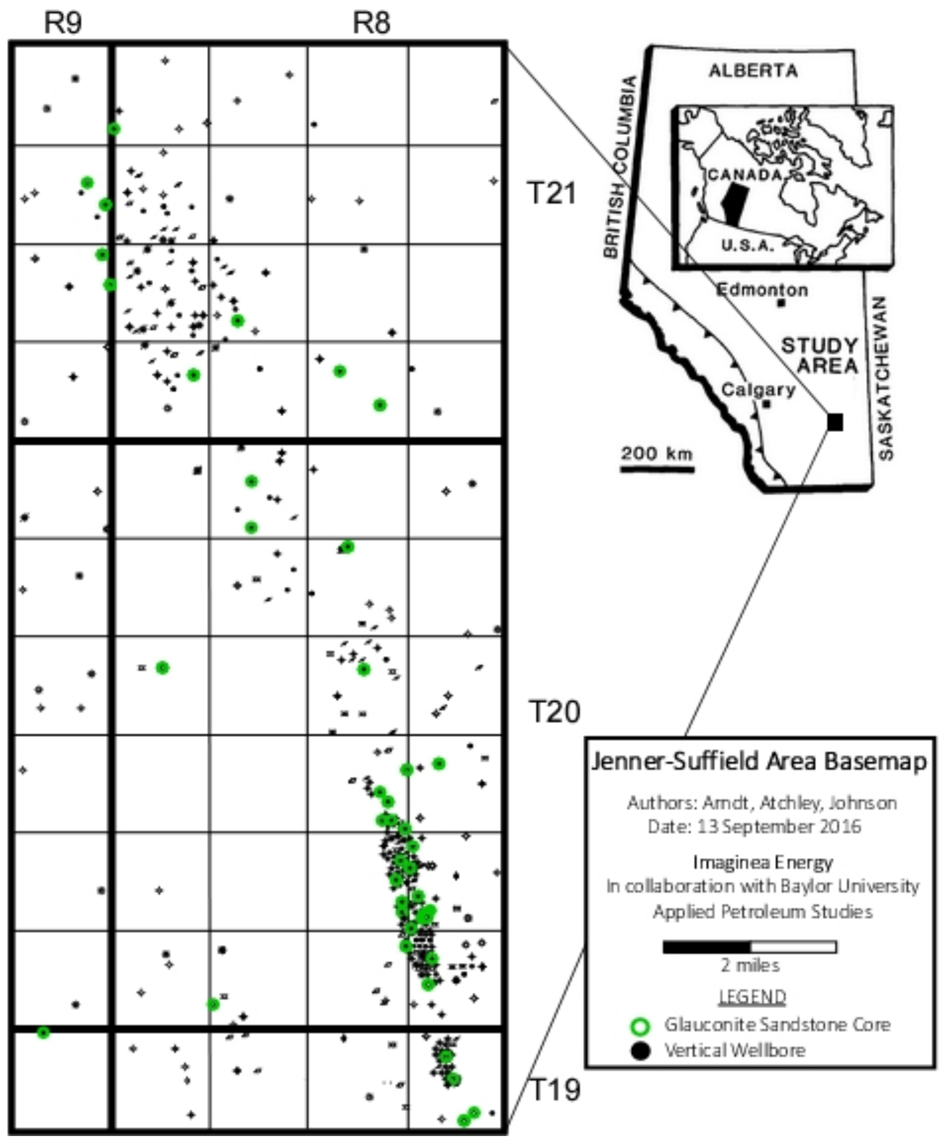


Figure 1: Basemap for the Jenner-Suffield field area. Data utilized in the study includes vertical wells with wireline logs (various black well symbols) and Glauconite core (green circles). Alberta reference map modified from Wood (1994).

Geologic Setting

The study area is located in southern Alberta, Canada within Townships 19-21N and Ranges 8-9W5 and includes the Jenner and Suffield fields (Figure 1). This portion of the Western Canada Sedimentary Basin (WCSB) experienced lithosphere loading and crustal thickening from the Late Jurassic Columbian Orogeny until the Late Cretaceous/Early Tertiary (Koladich, 2004; Smith, 1994) and caused the migration of the foreland basin depositional axis east of the present Canadian Rocky Mountains (Lynch, 2003). Tectonic uplift during this time resulted in deep erosion of the antecedent stratigraphic succession prior to Mannville Formation deposition (Jackson, 1984).

The Glauconitic Member of the Upper Mannville Formation is bounded below and above by unconformity surfaces induced by sea level fluctuations across the Lower Cretaceous (Aptian to Albian) paleo coastal plain (Figure 2) (Karvonen and Pemberton, 1997). The base of the Glauconitic Member across the study area consists of a NNW-trending incised valley complex along the western margin of the Cretaceous Western Interior Seaway that was back-filled by fluvial and estuarine deposits during an ensuing episode of sea level rise (Figure 3) (Hayes et. al., 2008; Karvonen and Pemberton, 1997; Koladich, 2004; Sherwin, 1996; Wood, 1994). During deposition, coastal plain environments occupied the southeastern portion of central Alberta, whereas wave-dominated sililiclastic shorelines occupied the northwestern portion (Chiang, 1984; Jackson, 1984; Strobl, 1988). This resulted in a complex association of fluvial, deltaic, and marine enivronments across central and southern Alberta during the Lower

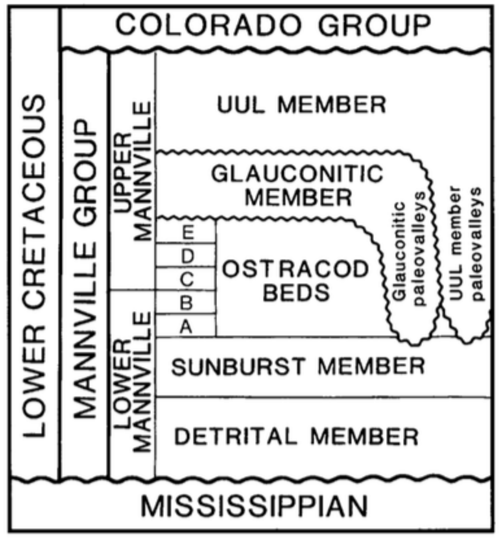


Figure 2: Stratigraphic summary chart for the Lower Cretaceous Mannville Group in southern Alberta. The Glauconitic Member occurs unconformably above the Ostracod Member and unconformably below the Upper Mannville Formation (UUL Member). Modified from Glaister (1959), Farshori (1983), and Wood and Hopkins (1989).

Cretaceous (Farshori, 1983; Hopkins et al., 1982; Hradsky and Griffin, 1984; James, 1985; Koladich, 2004). Within the study area, the Glauconite Member sandstone accumulated within fluvial channel fill environments, and across the region within a broader complex of fluvial, estuarine, deltaic, and shelfal marine environments (Farshori, 1983; Hopkins et al., 1982; James, 1985; Karnoven and Pemberton, 1994; Wood, 1994; Wood and Hopkins, 1989). Stratigraphic correlations across the study area indicate an association of stacked (multi-story) fluvial channels (Johnson, 2017). The fluvial channels are gradationally overlain by overbank mudrocks and coal deposits of the Upper Mannville. At Jenner and Suffield, most wells are hydrocarbon productive within the uppermost fluvial channel complex of the Glauconite Member.

LOWER CRETACEOUS PALEOGEOGRAPHY OF NORTH AMERICA

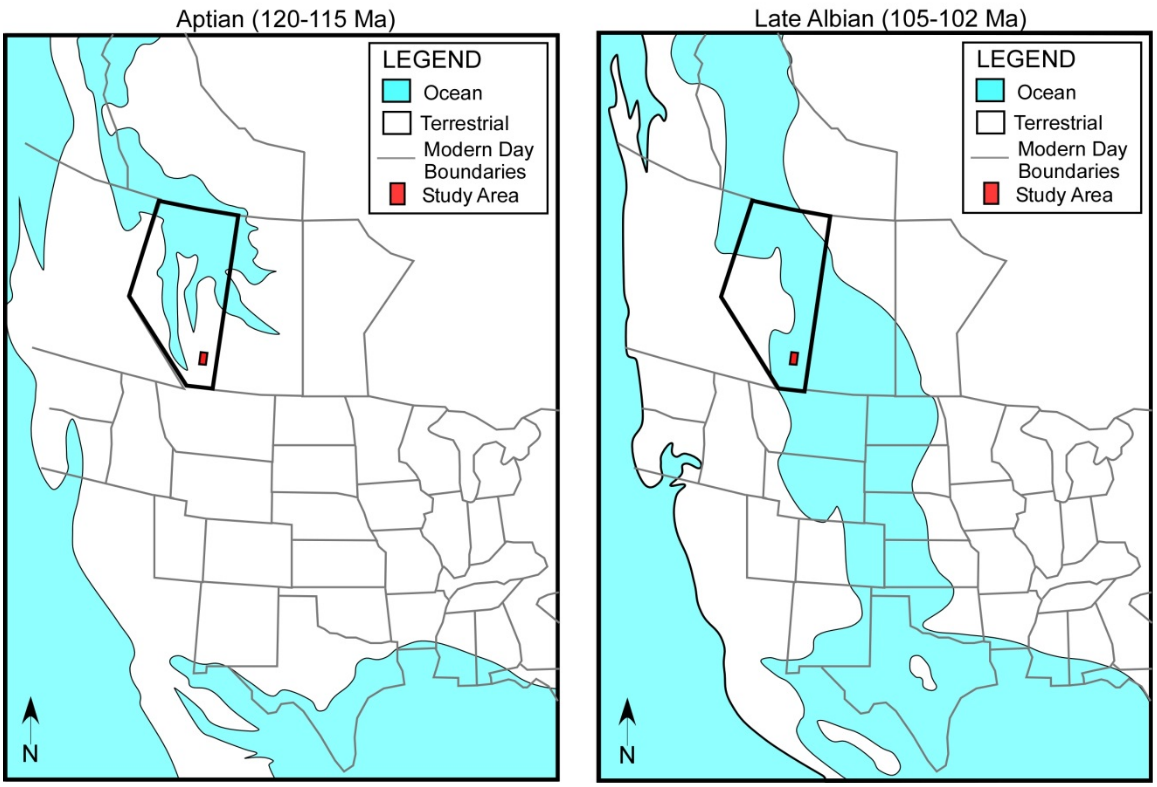


Figure 3. Relative lowstand (left) and highstand (right) paleogeographic reconstructions of North America during the Lower Cretaceous (Aptian to Albian). Alberta is outlined in black, and the study area is indicated by the small red box. Modified from Blakey (2016a and 2016b).

Data and Methodology

Digital wireline log and production history data from 333 vertical wells were retrieved through IHS AccuMap and included in the study (Figure 1). Well log data (gamma ray, neutron-density, and resistivity) and detailed core descriptions and accompanying core analysis data (porosity, permeability, fluid saturation) from 40 wells were used for reservoir characterization. Approximately 660 meters of core were described at the Energy Resources Conservation Board (ERCB) Core Research Centre in Calgary, Alberta. Core descriptions document the vertical distribution of dominant grain size, percentage of mud, type of mechanical sedimentary structures (if present), ichnofabric index (*sensu* Drosser and Bottjer, 1986) and associated ichnofacies, presence and type of cement, fracture density, and depositional environment (Appendix A). Diagnostic features and select intervals were photographed and the photo locations are annotated on the core descriptions for each well. Core descriptions were digitized within Microsoft Excel and merged with digital core analysis and wireline log data to generate univariate and bivariate statistical plots. A type well log for the study interval is provided in Figure 4.

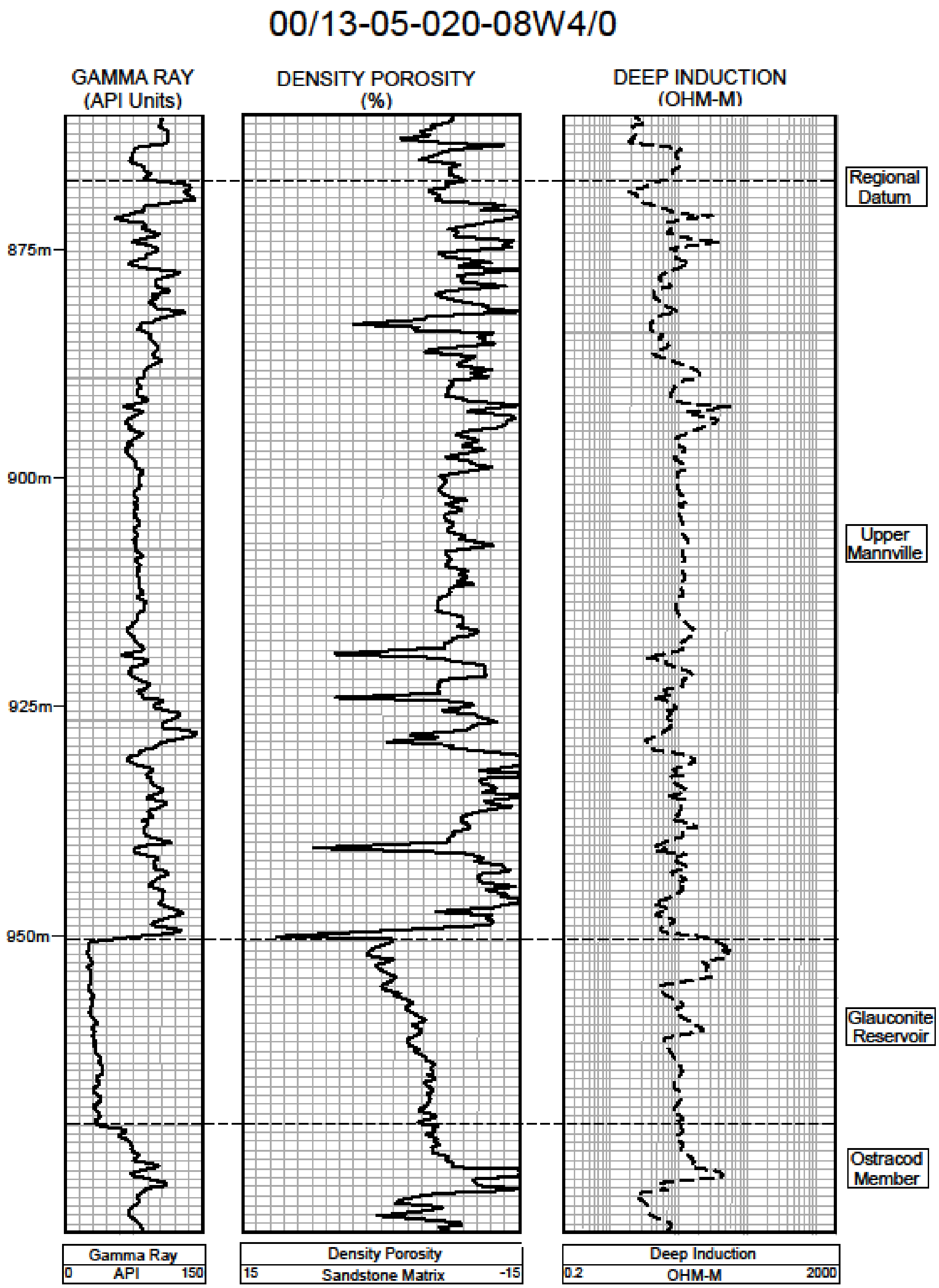


Figure 4. Type log for the Glauconitic Sandstone reservoir interval at Jenner-Suffield from well UWI 00/13-05-020-08W4/0. This figure highlights the position of the Glauconitic reservoir in relation to the Ostracod Member and Upper Mannville Formation.

CHAPTER TWO

Depositional Facies

Previous research has variably attributed Glauconitic Member deposition across central and southern Alberta to a shallow marine prograding shoreface (Jackson 1984; Koladich, 2004), highstand barrier islands and associated bar forms (Holmes and Rivard, 1976; Tilley and Longstaffe, 1984), coastal lowstand to early transgressive incised valley fill deposits that were either fluvial (Hopkins et. al., 1982; Hradsky and Griffin, 1984; Fashori, 1983; Karvonen and Pemberton, 1997), lacustrine (Farshori, 1983; Hopkins et. al. 1982; Hopkins, 1987), estuarine (Banerjee, 1989; Reinson, 1989, Wood and Hopkins, 1989), or tidally-influenced (Barclay and Smith, 1992; Cederwall, 1991; Leckie and Smith, 1992; Koladich, 2004). Observations within core suggest that the Glauconitic within the study area was deposited as incised valley fluvial fill, of which, four depositional facies are differentiated on the basis of textural composition, grain size, mud content, mechanical sedimentary structures, and ichnofabric index (*sensu* Droser and Bottjer, 1986). A summary of the diagnostic attributes by which each facies is recognized is provided in Table 1, and representative photographs of each facies are provided in Figure 5.

Table 1. Facies summary table for the Glauconite Member at Jenner-Suffield field.

Name	*Fine Channel Sand*	*Coarse Channel Sand*	*Organic Rich Coal*	*Very Fine (Argillaceous) Sand*
Environment	Fluvial Channel (Facies 1)	Fluvial Channel (Facies 2)	Swamp (Facies 3)	Fluvial Overbank (Facies 4)
Typical Mud Content	0-10%	0-5%	>50%	80-100%
Grain Size	Very fine to medium	Coarse to granule	Silt and carbonaceous mudstone	Very fine sand and mud
Ichnofabric Index	1-4	1-2	1-5	1-4
Ichnofacies	*Scoyenia* undifferentiated	Not observed	*Scoyenia* undifferentiated	*Scoyenia* undifferentiated
Mechanical Sedimentary Structures	mm and cm-laminations, planar-horizontal laminations, scours, trough cross bedding, planar tabular cross bedding, current ripples, root traces, soft sediment deformation	Trough cross bedding, scours, massive unstratified	mm-laminations, root traces, slickensides	Burrows, flaser bedding, root traces, mm-laminations
Average Porosity (fraction)	0.27	0.25	0.10	0.10
Median Kmax (md)	757	2145	201	1.5

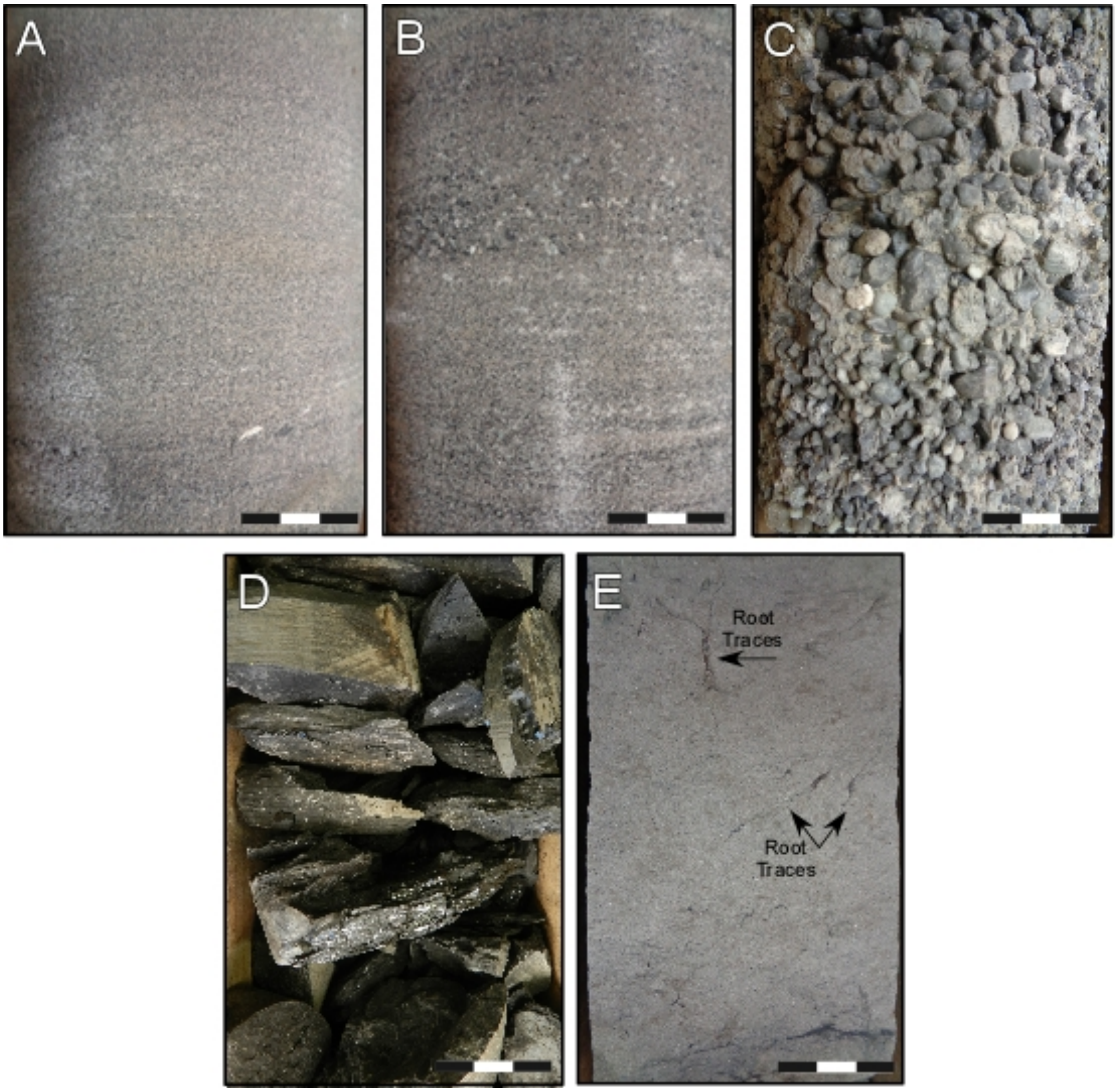


Figure 5. Representative core photographs of Glauconitic Member depositional facies observed within the study area. Scale bar is 3cm. (A) Fine Channel Sand in well 02/10-13-021-09W4/0 at a depth of -948m. (B) Fine Channel Sand in well 02-10-13-021-09W4/0 at a depth of -946m. (C) Coarse Channel Sand in well 00/04-19-021-08W4/0 at a depth of -951.6m. (D) Organic Rich Coal in well 02/09-16-020-08W4/0 at a depth of -911m. (E) Very Fine (Argillaceous) Sand in well 03/05-05-020-08W4/0 at a depth of -962m. Both A and B provide examples of the textural ranges within the Fine Channel Sand. Note the carbonaceous root traces in image E (labeled)

Facies FCH -Fine Channel Sand

Description - Fine Channel Sand (Figure 5A and 5B) is a quartz-rich, very fine to medium sandstone. Mud content is low (0-10%) and undifferentiated *Scoyenia* trace fossils range from 1-4 on the ichnofabric Index, and have an average value of 1. Mechanical sedimentary structures include mm- and cm-scale laminations, planar-horizontal laminations, scours, trough cross bedding, planar tabular cross bedding, current ripples, root traces, and soft sediment deformation. The average porosity is 27% and the median permeability is 757 md.

Interpretation - The *Scoyenia* trace fossils, current ripples, scours, and root traces suggest fresh water, uni-directional flow associated with a fluvial (channel) environment (*sensu* Frey, et. al., 1984; Todd, 1996).

Facies CCH – Coarse Channel Sand

Description - Coarse Channel Sand (Figure 5C) contains coarse to granule sized sand grains and low mud content (0-5%), and is interstratified with Fine Channel Sand. Trace fossils are rare and unidentifiable, and the ichnofabric index ranges from 1-2. Mechanical sedimentary structures include massive/unstratified, trough cross beds, and scours. The average porosity is 25% and the median permeability is 2145 md.

Interpretation - The coarse grain size, lower flow regime unidirectional bedforms, erosional scours, and intercalation with Fine Channel Sand suggest transport within a fluvial channel.

Facies ORC – Organic Rich Coal

Description - Organic Rich Coal (Figure 5D) is a silty, carbonaceous mudstone where mud content exceeds 50%. Undifferentiated *Scoyenia* ichnofacies trace fossils occur across the ichnofabric range of 1-4 and have an average value of 2. Mechanical sedimentary structures include mm-scale laminations, root traces, and slickensides. The average porosity is 10% and the median permeability is 201 md.

Interpretation - The presence of plant organic material and root traces suggest a terrestrial swamp (*sensu* Frey, et. al., 1984).

Facies VFS – Very Fine (Argillaceous) Sand

Description - Very Fine (Argillaceous) Sand (Figure 5E) includes very fine sand disseminated within mud (80-100% of sediment volume). *Scoyenia* trace fossils vary in abundance from 1-5 on the ichnofabric index and have an average value of 3. Mechanical sedimentary structures consist of mm-scale laminations, flaser bedding, and root traces. The average porosity is 10% and the median permeability is 1.5 md.

Interpretation - The abundance of burrows, root traces, and mud content suggest a fluvial overbank environment (*sensu* Frey, et. al., 1984). Areas that contain mostly laminated sand suggest high rates of sedimentation, possibly within a channel margin levee.

CHAPTER THREE

Depositional Controls on Reservoir Quality

Scatter plots of maximum daily production and cumulative production data (from cored wells) versus grain size, porosity, and depositional environment were evaluated to determine the controls on production. Within the Glauconitic reservoir, porosity ranges from 4-41% and the 25-75th percentiles are 21.5-28.7%. Permeability (Kmax) ranges from 0.01-10,240 md and the 25-75th percentiles are 311-3702.5 md. These values are consistent with studies by Lynch and Hopkins (2001) for the Upper Mannville at the C Pool for Cessford Field, and Koladich (2004) for the E Pool at Jenner Field.

Although the reservoir interval across the study area consists of 4 stacked channel "cycles" (aka, sequences), baffles to fluid flow are not observed (Johnson, 2017). A plot of cumulative production versus channel "cycle" indicates that channel "cycles" have progressively higher cumulative production in ascending stratigraphic order (Figure 6). This is in spite of each channel "cycle" having similar facies and associated reservoir quality attributes, and suggests bottom to top cross-flow between channel "cycles".

To further analyze the relationship between reservoir quality and depositional characteristics, the core analysis data were digitized, merged and depth corrected to effectively compare with digital wireline log data. Box plots of each attribute versus core neutron-corrected porosity and permeability (Kmax) were generated to illustrate the total range, mean, median, and 25$^{th\,-}$, 50$^{th\,-}$ and 75th –percentiles.

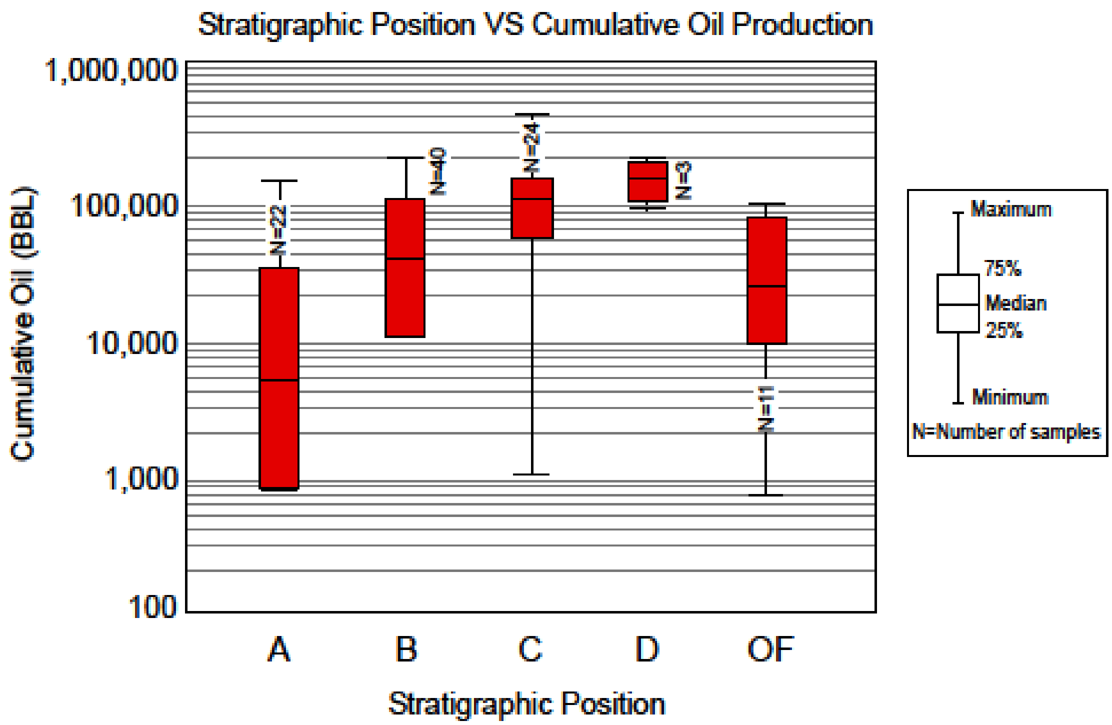


Figure 6. Stratigraphic position of channels A-D (A at the base, D at the top of the reservoir; OF-overbank fine portion) versus cumulative oil production within each channel.

Grain Size versus Porosity and Permeability

Figure 7 documents the relationship between grain size and porosity and permeability. Increasing permeability values correspond with increasing grain size, whereas porosity increases from the mud to fine sand fraction, and reaches a maximum in the fine and coarser size fractions.

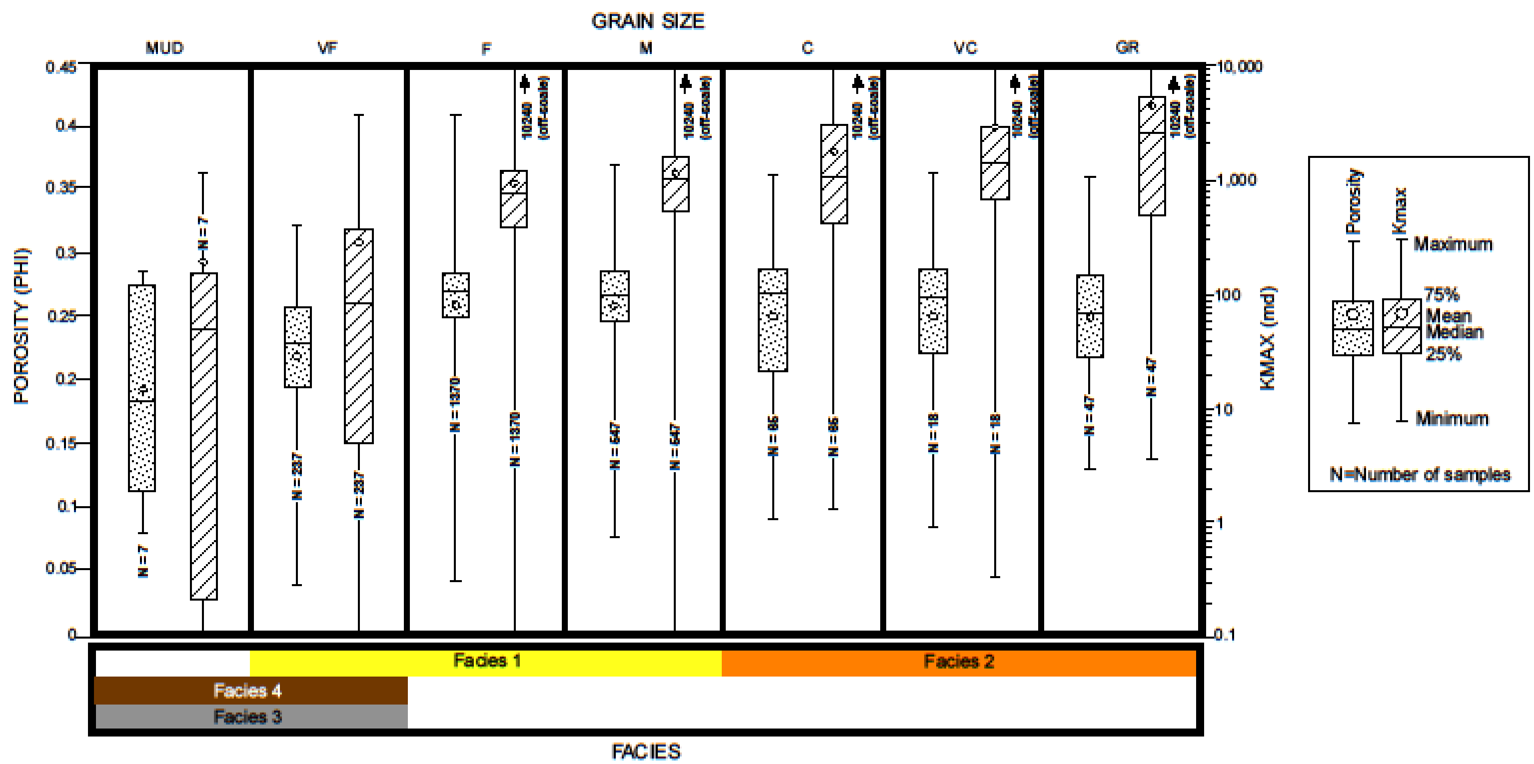


Figure 7. Combined box and whisker plots of grain size versus porosity and Kmax permeability. The colored boxes beneath the box plots highlight the range of grain size associated with each facies. Overall, permeability increases with increasing grain size, and porosity increases above very fine grain size and remains fairly constant in coarser grain size categories. Facies 1 = Fine Channel Sand, Facies 2 = Coarse Channel Sand, Facies 3 = Organic Rich Coal, Facies 4 = Very Fine (Argillaceous) Sand.

Depositional Environment versus Porosity and Permeability

Depositional facies (environments) were also compared with porosity and permeability (Figure 8). Coarse Channel Sand and Fine Channel Sand have the highest permeability, with mean values of 2,813 md and 1,001 md, respectively. The lower porosity and higher permeability of Coarse Channel Sand in comparison with Fine Channel Sand is owing to Coarse Channel being more poorly sorted (reducing porosity) but having comparatively larger grain size and therefore larger pore throat diameters that increase permeability. The Organic Rich Coal (swamp) has a mean permeability of 270 md, and the Very Fine Sand (overbank) has the lowest mean permeability at 178 md.

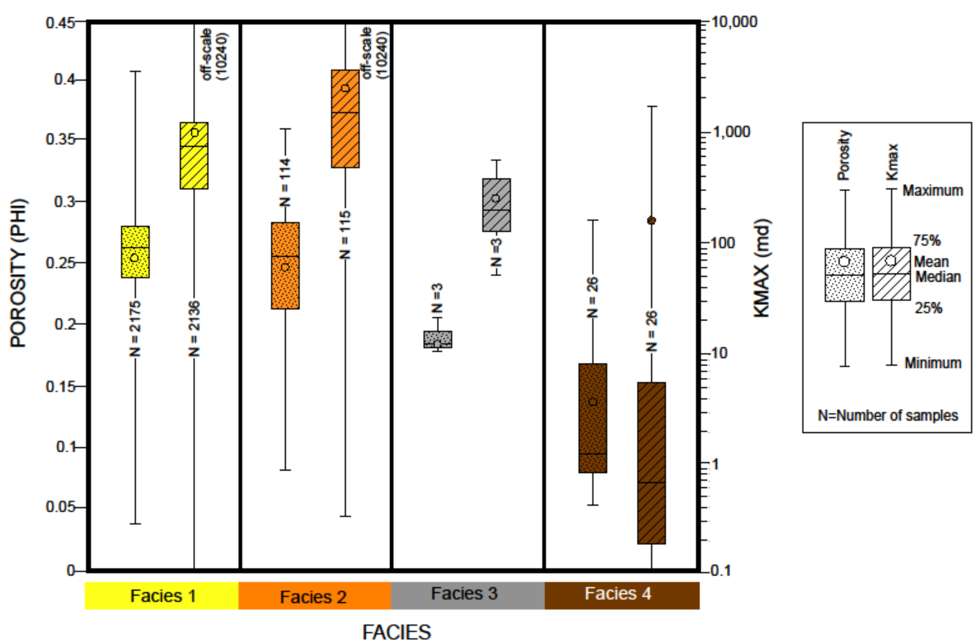


Figure 8. Box and whisker plots of facies versus porosity and Kmax permeability. The highest porosity and permeability is associated with facies 1 and 2. Facies 1 = Fine Channel Sand, Facies 2 = Coarse Channel Sand, Facies 3 = Organic Rich Coal, facies 4 = Very Fine (Argillaceous) Sand

CHAPTER FOUR

Petrophysical Model for Facies Prediction

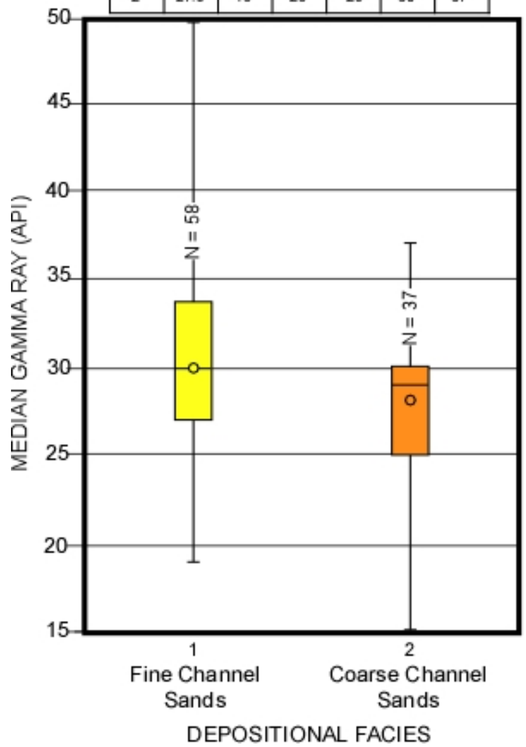
Digitized core descriptions were compared to gamma ray and sandstone-calibrated density porosity well log response to create a petrophysical algorithm for facies prediction in non-cored wells. These log types were used because they are present in all wells across the study area, and are sensitive to variations in mud content and associated textural variations that are often depositionally controlled. To evaluate depositional controls, box plots of channel facies versus well log values were created to identify the mean, median, 25^{th} -, 50^{th} -, and 75^{th} –percentile for each log type (Figure 9).

Depositional Facies versus Gamma Ray

Fine Channel Sand is characterized by overall higher gamma ray values than Coarse Channel Sand (Figure 9A). The lower gamma ray response associated with Coarse Channel Sand is due to the comparatively lower mud (and clay) content. Noteworthy is that both Fine Channel Sand and Coarse Channel Sand have considerable overlap in the gamma ray range (Figure 9A). This limits the effectiveness of gamma ray response or facies prediction. Both Fine Channel and Coarse Channel deposits are quartz-rich, and therefore have similar gamma ray response.

(A)

Facies	Mean	Min.	25%	50%	75%	Max.
1	30.5	19	27	30	34	50
2	27.9	15	25	29	30	37



(B)

Facies	Mean	Min.	25%	50%	75%	Max.
1	0.277	0.180	0.231	0.258	0.330	0.420
2	0.260	0.200	0.225	0.240	0.270	0.390

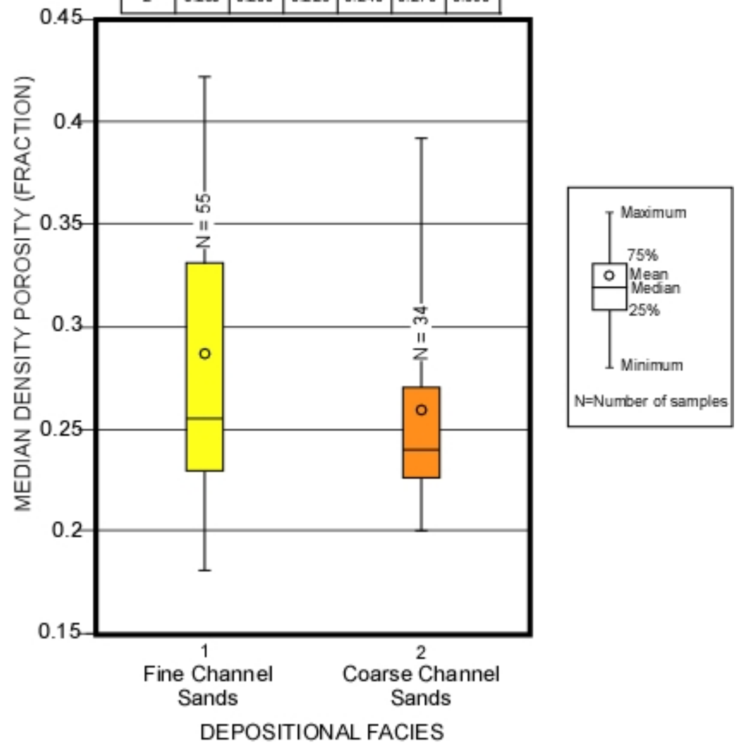


Figure 9. Box and whisker plots of channel facies versus (A) well log gamma ray, and (b) density porosity.

Depositional Facies versus Density Porosity

Channel facies were also compared to density porosity values calibrated to a quartz sandstone matrix value of 2.644 g/cc (Figure 9B). Fine Channel Sand has a notably higher range of porosity in comparison with Coarse Channel Sand. The higher porosity within Fine Channel Sand is attributed to better overall sorting. It is important to note, however, the significant overlap of porosity values between the range of 25-30% for both Fine and Coarse Channel Sand (Figure 9B).

Petrofacies Log Parameters

The guidelines used for discrimination of channel facies are based on the comparison with the gamma ray and density porosity log response as summarized in the box plots provided in Figure 9. In addition to the facies-specific summary statistics, overall log signature was also qualitatively used in the petrofacies prediction algorithm (Table 2). In regards to gamma ray, the Fine Channel Sand facies has a larger range of API normalized gamma radiation counts than the Coarse Channel Sand. The Coarse Channel Sand has comparatively lover overall gamma radiation. The Fine Channel Sand facies is characterized by consistently high density porosity values, whereas the Coarse Channel Sand facies has significant variability in density porosity and a characteristic "spikey" (extreme localized variability) log signature (Figure 10). Figure 10 summarizes the guidelines used in facies prediction.

Table 2. Guidelines for channel facies prediction using gamma ray and neutron porosity well logs.

Facies	Gamma Ray (API)	Density Porosity (fraction)	Characteristic Log Signature
Fine Channel Sand	Range: 19-50 25th Percentile: 27 Median: 30 75th Percentile: 33.75	Range: 11-45 25th Percentile: 22 Median: 27 75th Percentile: 30	Variable gamma ray and consistent density porosity. i.e., lacking sharp increases or decreases.
Coarse Channel Sand	Range: 15-37 25th Percentile: 25 Median: 29 75th Percentile: 30	Range: 11-36 25th Percentile: 22 Median: 27 75th Percentile: 29	Relatively “clean” (low) gamma ray activity with variable, “spikey” decreases in density porosity.

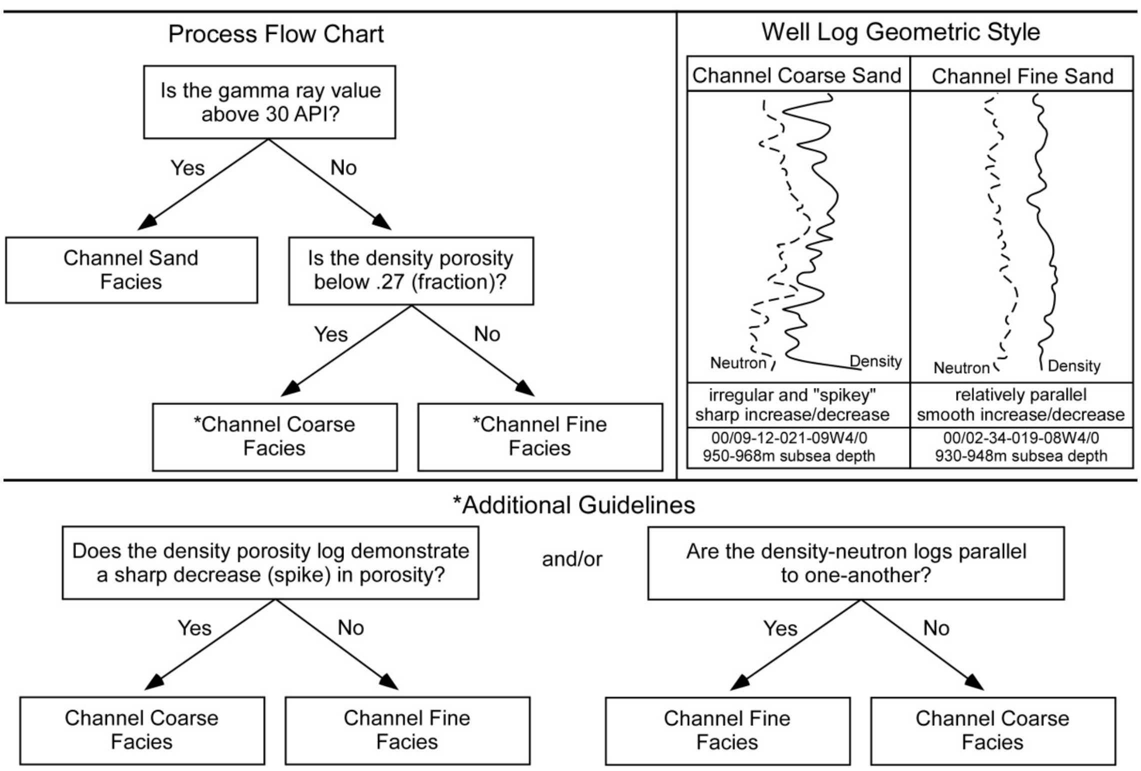


Figure 10. Flow chart for channel facies prediction utilizing the gamma ray and density porosity logs.

Blind Test Results

To evaluate the accuracy of the aforementioned semi-quantitative algorithm for channel facies prediction, a blind test was applied to all 40 cored wells. The results from two of these wells are provided in Figure 11, (i.e., 9-6-21-8W4 and 3-8-21-8W4). From the blind test, the overall accuracy of facies prediction is 33.1%; however, the algorithm is 45% accurate for beds ranging from 1-3m and 3-5m thick, and 64% for beds greater than 5m thick (Table 3). The overall low reproducibility is owing to both the typical occurrence of Coarse Channel Sand as thin beds, which are below log resolution, and the overlapping range of gamma ray and density porosity values between Coarse and Fine Channel facies. Additionally, Coarse Channel Sand only occurs in 40% (18 of 40 cored wells) within the study area, and the total thickness of Coarse Channel Sand accounts for only 4.5% of the cumulative reservoir thickness observed in core. As such, Coarse Channel Sand is less represented within the log-based summary statistics than Fine Channel Sand.

Table 3. Accuracy statistics of the algorithm for facies prediction from well logs.

Thickness Interval	All Wells	Beds>1m thick	Beds>3m thick	Beds>5m thick
*Prediction Accuracy	33.1%	45.0%	44.5%	63.6%

*The percentage of algorithm-interpreted facies coinciding with core observed facies. Predictions are based on gamma ray and density porosity log response.

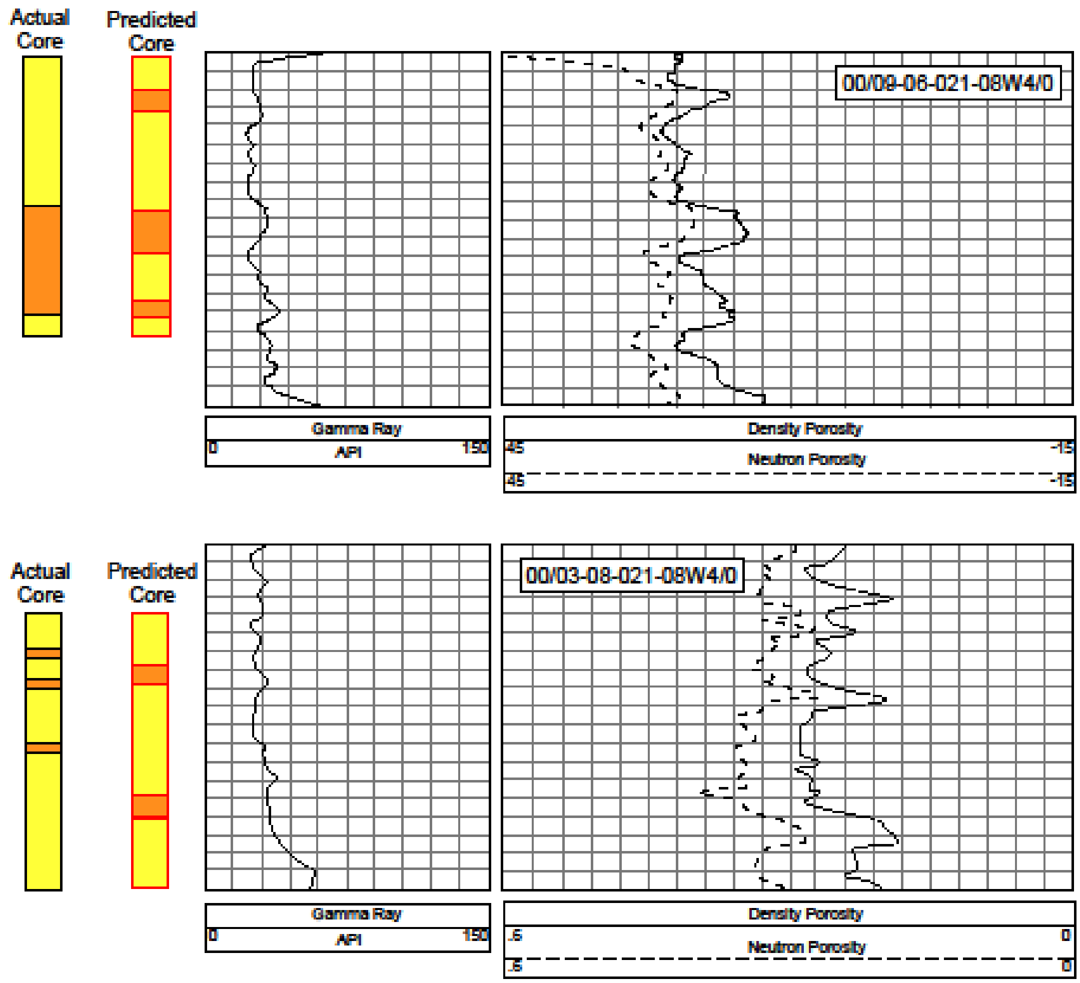


Figure 11. Representative well logs providing a comparison of “actual” versus well log “predicted” channel facies (indicated on the left-hand portion of the log). “Actual” facies is the observed distribution in core.

CHAPTER FIVE

Conclusions

1. The Glauconitic Member at the Jenner-Suffield field area consists of 4 facies deposited within an association of fluvial environments: Fine and Coarse Channel Sand within the fluvial channel, Very Fine (Argillaceous) Sands within the fluvial overbank, and Organic Rich Coal within a swamp. Overbank and swamp deposits occur above the channel deposits at the top of the Glauconitic Member.
2. Reservoir facies include the Fine Channel and Coarse Channel facies. The Fine Channel Sand has higher overall porosity, whereas the Coarse Channel facies has higher overall permeability. The differences in reservoir quality are owing to facies-specific variations in grain size and sorting. The Coarse Channel deposits have lower porosity due to comparatively poor sorting, but higher permeability due to larger pore throat diameter.
3. Channel fill is dominated by the Fine Channel Sand. Fine Channel facies constitutes 89.9% and Coarse Channel facies 4.49% of the reservoir interval.
4. The petrophysical facies prediction model is based upon the range of gamma ray and density porosity values, along with the characteristic log signatures of the Fine Channel Sand and Coarse Channel Sand facies. Fine Channel Sand is characterized by higher overall gamma ray activity and density porosity, whereas Coarse Channel Sand by lower overall gamma ray activity and more variable

density porosity. A blind test of the predictive model suggests that accuracy is greatest (64%) when Coarse Sand occurs as beds greater than 5m thick.

5. A more comprehensive suite of data (i.e., well logs, core descriptions, seismic data) would be needed to increase the likelihood of differentiating and predicting the occurrence of Fine Channel and Coarse Channel facies, or similar facies within analogous areas of exploration or production.

APPENDICES

APPENDIX A

Core Descriptions and Legend

Core Description Table of Contents

Core Description Legend

Grain Size

0 - Silt/Clay
1 - Lower Very Fine
2 - Upper Very Fine
3 - Lower Fine
4 - Upper Fine
5 - Lower Medium
6 - Upper Medium
7 - Lower Coarse
8 - Upper Coarse
9 - Lower Very Coarse
10 - Upper Very Coarse

Sedimentary Structures

- Planar Horizontal
- Planar Laminations
- Trough Cross Bedding
- Soft Sediment Deformation
- Planar Tabular
- mm laminations
- Climbing Ripple
- Firmground
- Organic Material
- Hummocks
- Current Ripple
- Wave Ripple
- Flaser Bedding
- Lithoclast
- Intraclast
- Bivalve undiff.
- Burrow
- Scour
- Rooting

Photos

7-1-16-nnn(initials of author)

Ichnofabric Index

1 - No bioturbation recorded; all original sedimentary structures preserved
2 - Discrete, isolated trace fossils; up to 10 percent of original bedding disturbed
3 - Approximately 10 to 40 percent of original bedding disturbed
4 - Last vestiges of bedding discernable; approximately 40-60 percent disturbed. Burrows overlap and are not always well defined.
5 - Bedding is completely disturbed, but burrows are still discrete in places and the fabric is not mixed. May also represent totally homogenized sediment in the absence of trace fossils.

Ichnofauna

Pl - *Planolites*
Th - *Thalassinoides*
Teich - *Teichichnus*
Pal - *Palaeophycus*
Zoo - *Zoophycos*
Cyl - *Cylindrichnus*
Sub - *Subphyllocorda*
O - *Ophiomorpha*
Ber - *Bergaueria*
Rh - *Rhizocorallium*
Sk - *Skolithos*
Ast - *Asterosoma*
Aren - Arenicolites
Ros - *Rosselia*
Diplo - *Diplocraterion*
Con - *Conichnus*
Chon - *Chondrites*
Phy - *Phycosiphon*
Ter - *Terebellina*

Ichnodiversity

n - number of taxa observed

Ichnofacies

1 - Nereites
2 - Zoophycos
3 - Cruziana (Restricted)
4 - Cruziana (Open)
5 - Skolithos

Depositional Environment

CH- Fluvial Channel
OF- Overbank Fines
SW- Swamp
SH- Shoreface

Cement

0 - No Cement Present
1 - Cement Present

Cement Type

0 - Quartz
1 - Calcite

Project/Location: Jenner / 02/06-32-019-08W4 **Logged By:** Johnson

Date: 7/21/16 **Page** 1 **of** 1

Depth	Dominant Grain Size (Mud: Cl, St; Sand: Vf, F, M, C, Vc; Gravel: Gr, P, Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
3165											
	TOP CORE										
3170							CH				7-21-16-071
	SORTING IMPROVES										7-21-16-070
3175											7-21-16-069
3180	POORLY SORTED -cm scale coarser layers										7-21-16-068
				NA	NA	NA		NA	NA	NA	7-21-16-067
3185											
3188.2											7-21-16-066
3190											
	SOME COARSE cm scale intervals										7-21-16-065
3195											7-21-16-064
3198											
3199	BASE CORE										

BITUMEN

Core diameter = 8.5cm

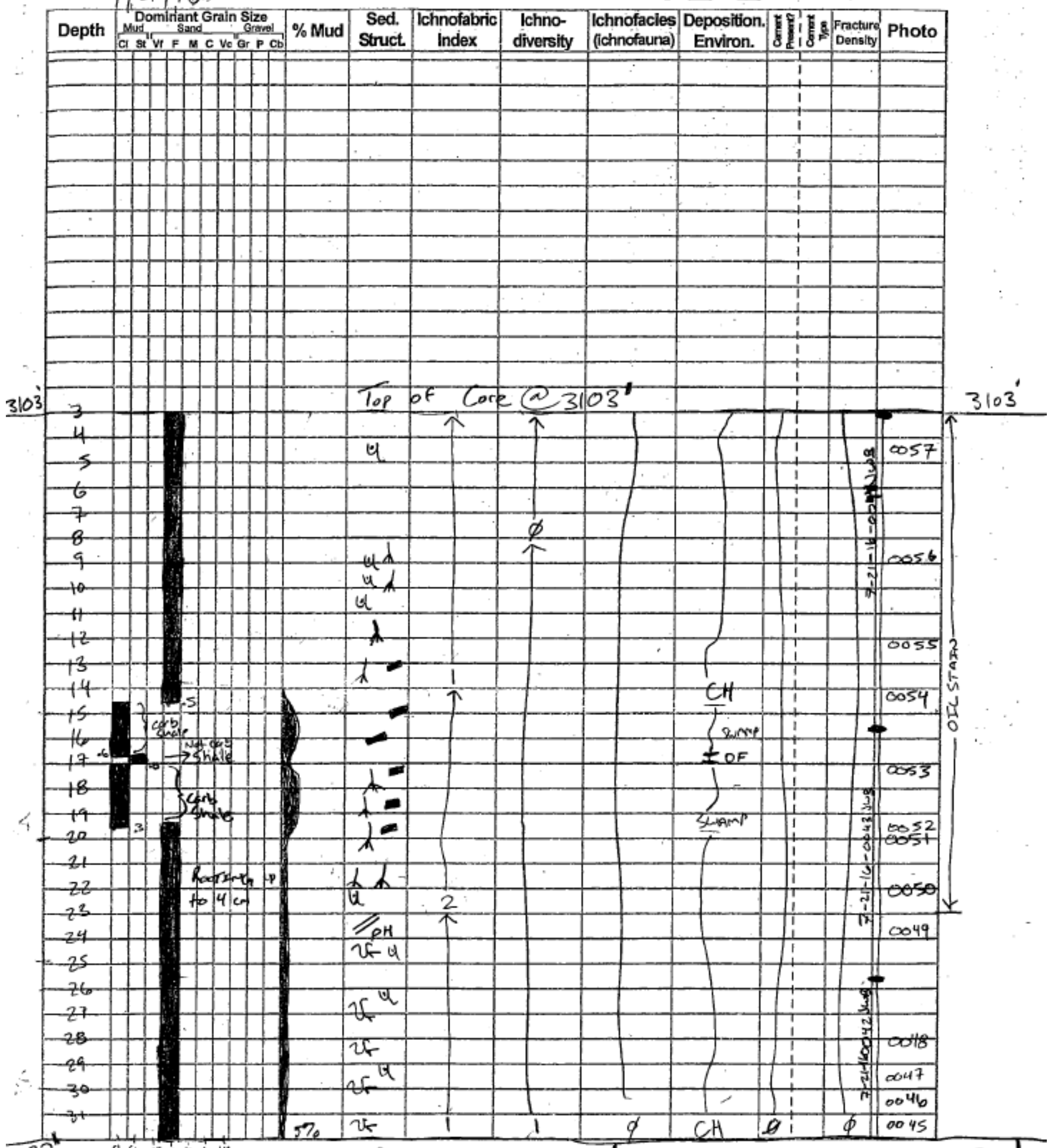
~~Metric Units (1" = 10')~~

DEPTH SHIFT = 0?

Each Box = 1 ft

Jenner
Project/Location: 00/08-33-019-08W4/0 **Logged By:** Brownwood

Date: 7/21/16 **Page** 1 **of** 1



Core diameter = 3.5" BASE OF CORE @ 3132' ~~Metric Units (1" = 10')~~

1 box = 1' = 5mm = 1'

Depth-Shift Adjustment to E-Log : Core (-) 5' = Log

Project/Location: Jenner. 00/16-33-019-08W4/0 **Logged By:** kristin

Date: 7/21/16 **Page** 1 **of** 1

TOP CORE

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present? / Cement Type	Fracture Density	Photo
3066	X								7-21-	16KA47
	X									
	X									
	X								7-21-	16KA46
3070	X									
	X								7-21-	16KA45
	X									
3075	X								7-21-	16KA44
	X								7-21-	16KA43
	X								7-21-	16KA42
	X			ND	ND	ND	CH		7-21-	16KA41
3080	X								7-21-	16KA40
	X									
	X								7-21-	16KA39
3085	X									
	X								7-21-	16KA38
	X									
3090	X								7-21-	16KA37
	X									
	X	2ft missing								
3094										

Bitumen

← O/W contact

Core diameter = 9cm

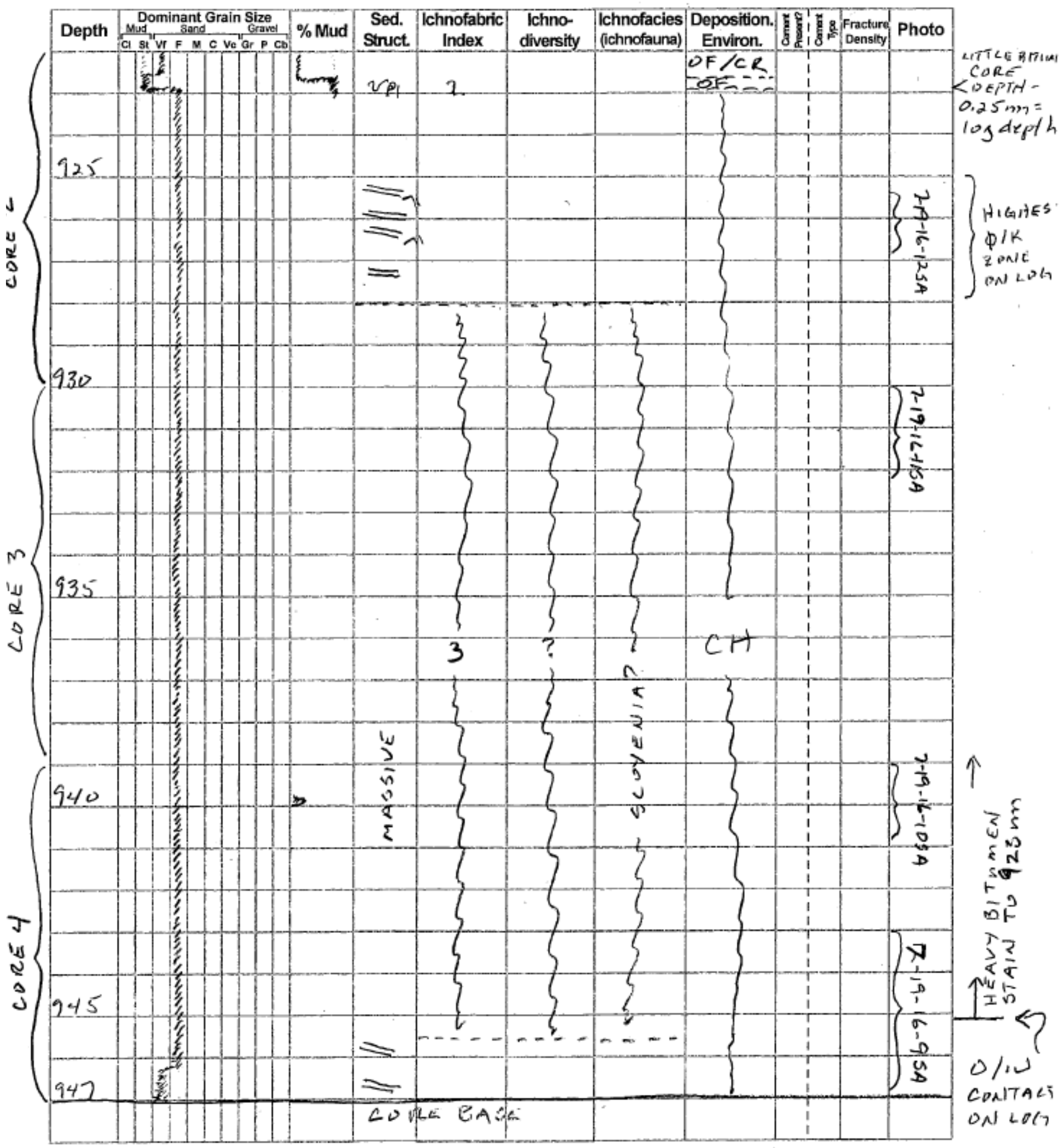
Core Base

Metric Units (1" = 10')

core depth = log depth

Project/Location: JENNER/2F34-19-8W4 **Logged By:** ATCHLEY

Date: 7/19/16 **Page** 1 **of** 2



Core diameter = 7cm

Metric Units (2.5cm = 3m)

CORE DEPTH ≠ LOG DEPTH

Project/Location: JENNER/2F34-19-8W4 **Logged By:** ATCHLEY

Date: 7/19/16 **Page** 2 **of** 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
910											
				CORE TOP							
				Vpl 1			SW				7-19-16-16SA
											7-19-16-15SA
915											7-19-16-14SA 7-19-16-13SA
							OF/CR				
920											
			Vpl	2			OF				
			Vpl	2							
				2			OF/CR				

CORE 1

LITTLE BITUMEN STAIN

Core diameter =

Metric Units (2.5cm = 3m)

Project/Location: JENNER 12-34-19-8w4 **Logged By:** ATCHLEY

Date: 7/21/16 **Page** 1 **of** 1

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
3080											
				CORE TOP							
				4	ʎ V?	SCOYENIA				5/ft	7-21-16-345A
				4	ʎ V?					5/ft	
3090			=								
			=								7-21-16-335A
			=								7-21-16-325A
			=								
			=				CHANNEL				7-21-16-315A
3100			=								
	ALTERNATING		=								7-21-16-305A
	CM-LAMINA		=								
	OF FINE &		=								
	COARSE		=								
3110			=								7-21-16-275A
			=								7-21-16-265A
3116				CORE BASE							

Core diameter = 9cm

Metric Units (1" = 10')

CORE + 1' = LOG DEPTH

Project/Location: Jenner 00/14-34-19-8W4/0 **Logged By:** Kristin

Date: 7/21/16 **Page** 1 **of** 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present? / Cement Type	Fracture Density	Photo	
			w						7-22	16KA19	Bitume
3035			w						7-22	16KA17	Poorly sorted ↓ Kmax
			w ≡mm						7-22	16KA16	
			Missing core								
3040											
			w						7-22 7-22	16KA15 16KA14	* ↓ Kmax poorly sorted up to coarse grains
			w								
3045									7-22	16KA13	
			w						7-22	16KA12	
			w						7-22	16KA11	
		Missing core									
3050											
			w						7-22	16KA10	
				ND	ND	ND	CH				
									7-22	16KA9	
3055			≡mm								
									7-22	16KA8	
			w						7-22	16KA7	
3060			≡mm								
			w						7-22	16KA6	inc. sort
									7-22	16KA5	O/W cont. start Bitumen stain
3065											
			w								
									7-22	16KA4	increase sorting
3070			w						7-22	16KA3	
			w					✓ cal	7-22	16KA2	
3074									7-22	16KA1	

Cl St Vf F M C VC Gr P Cb

CORE BASE

Core diameter = 8½ cm ~~Metric Units (1" = 10')~~

Depth shift: none

Project/Location: Jenner 00/14-34-19-8W4/0 **Logged By:** Kristin

Date: 7/21/16 **Page** 2 **of** 2

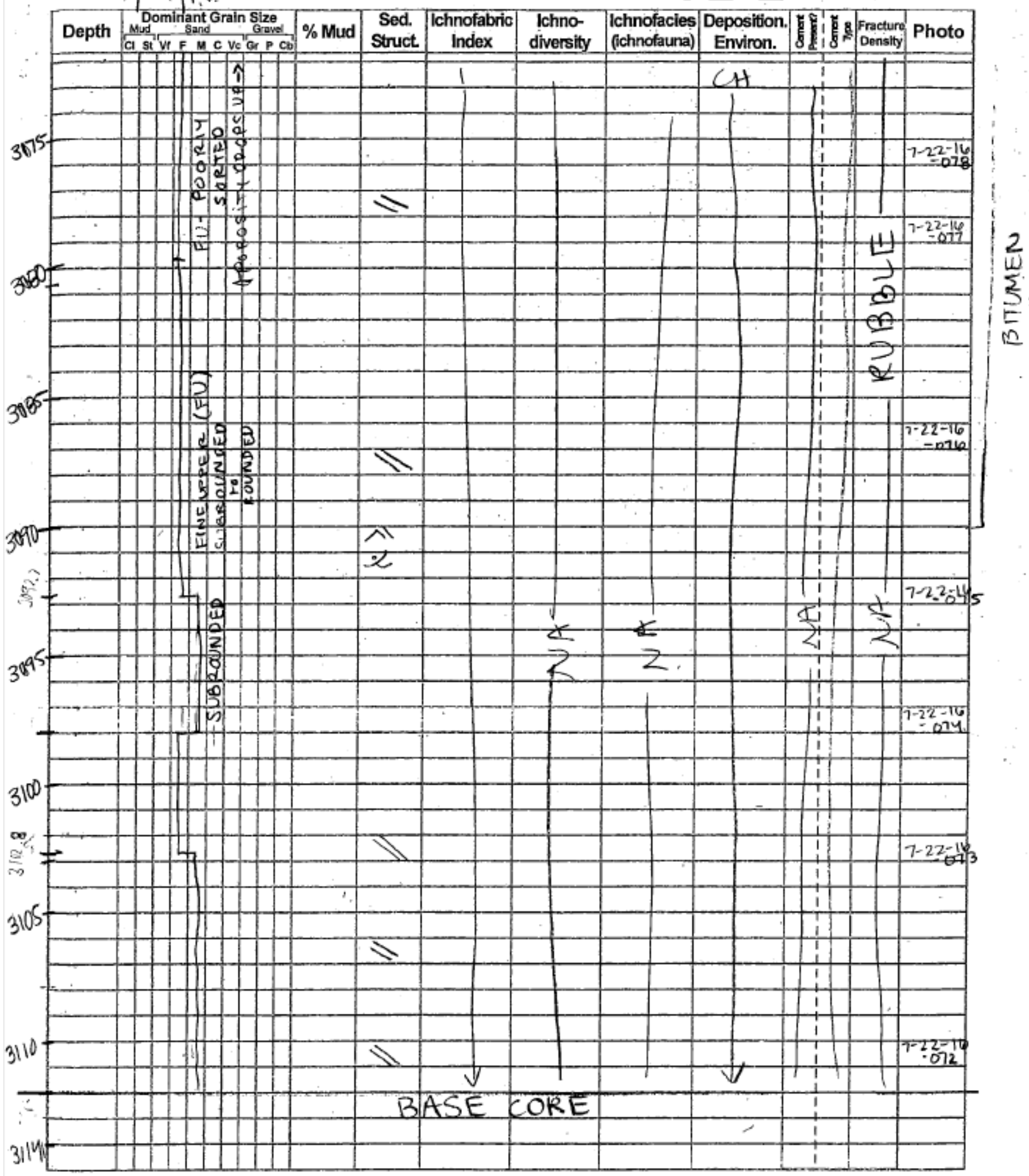
Depth	Dominant Grain Size (Mud: Cl, St; Sand: Vf, F, M, C, Vc; Gravel: Gr, P, Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo	
3015												
				TOP	CORE							
	Vf X										7-22 16KA24	rubble
	Vf X											
	Vf X										7-22-16KA23	Bitumen
3020	Vf X											stained
	Vf X										7-22-16KA22	Partially
	Vf X											throughout
	Vf X											
	Vf X			ND	ND	ND	CH					rubble
3025	Vf X										7-22-16KA21	
	Vf X										7-22-16KA20	
	Vf X											
	Vf X											
	Vf X											
3030	Vf X											
	F X										7-22-16KA19	1.5m thick poorly sorted

Core diameter =

~~Metric~~ Units (1" = ~~10'~~)

Project/Location: Jenner / 02/06-31-019-08W4/0 **Logged By:** Johnson

Date: 7/21/16 **Page** 1 **of** 3



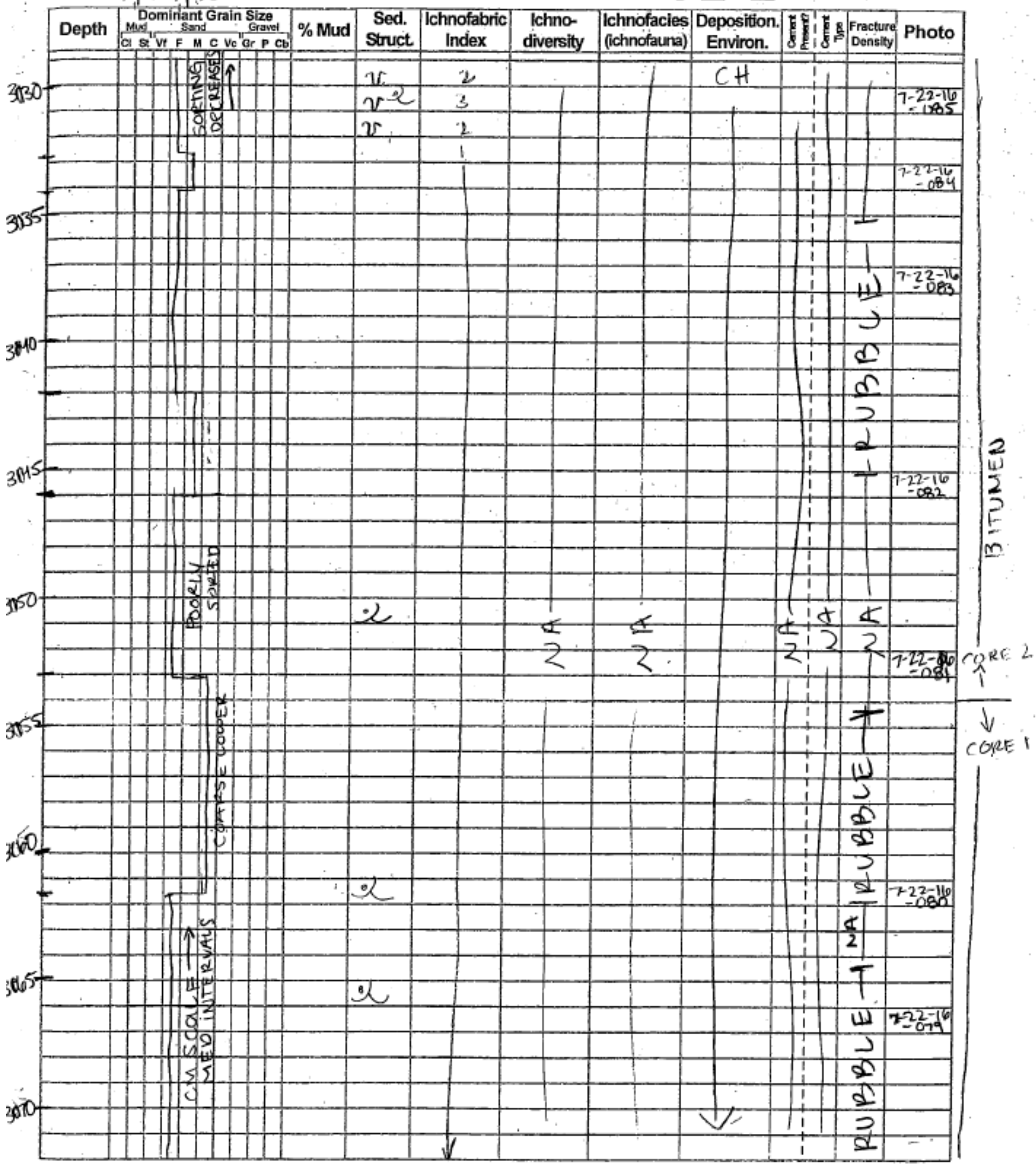
Core diameter = 8.5 cm

~~Metric Units (1" = 10')~~

DEPTH CORRECTION = 0 1 BOX = 1 FOOT

Project/Location: Jenner/02/06-34-019-08W4/0 **Logged By:** Johnson

Date: 7/21/16 **Page** 2 **of** 3



Core diameter = 8.5cm

~~Metric Units (1" = 10')~~

1 BOX = 1 FOOT

DEPTH CORRECTION = 0

Project/Location: Jenner / 02/06-34-019-08W4/0 **Logged By:** Johnson

Date: 7/21/16 **Page** 3 **of** 3

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
3120											
TOP CORE											
3125			v	2	NA	NA	CH	NA			7-22-16-087
											7-22-16-086

BITUMEN

Core diameter = 8.5 cm

~~Metric Units (1" = 10')~~

1 BOX = 1 FOOT

DEPTH CORRECTION = 0

Project/Location: JENNER /14-3-20-8W4

Logged By: ATCHLEY

Date: 7/21/16

Page 1 of 1

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
3000'						CORE DEPTH = LOG DEPTH					
			CORE TOP								
				4	?	SCOYENIA				5/ft	7-21-16-25SA
			=							1/ft	7-21-16-24SA
3010			=	"POKER CHIP" RECOVERY							
			=							1/ft	
3020			=								
			=								7-21-16-23SA
3030			=								
			=	"POKER-CHIP" RECOVERY ALONG PARTING LINEATIONS			CHANNEL				7-21-16-22 SA
3040			=								
			=								7-21-16-21 SA
3050			=								
			=								7-21-16-20SA
3060			=								
			CORE BASE								

CORE 2

CORE 1

BITUMEN

O/W CONTACT

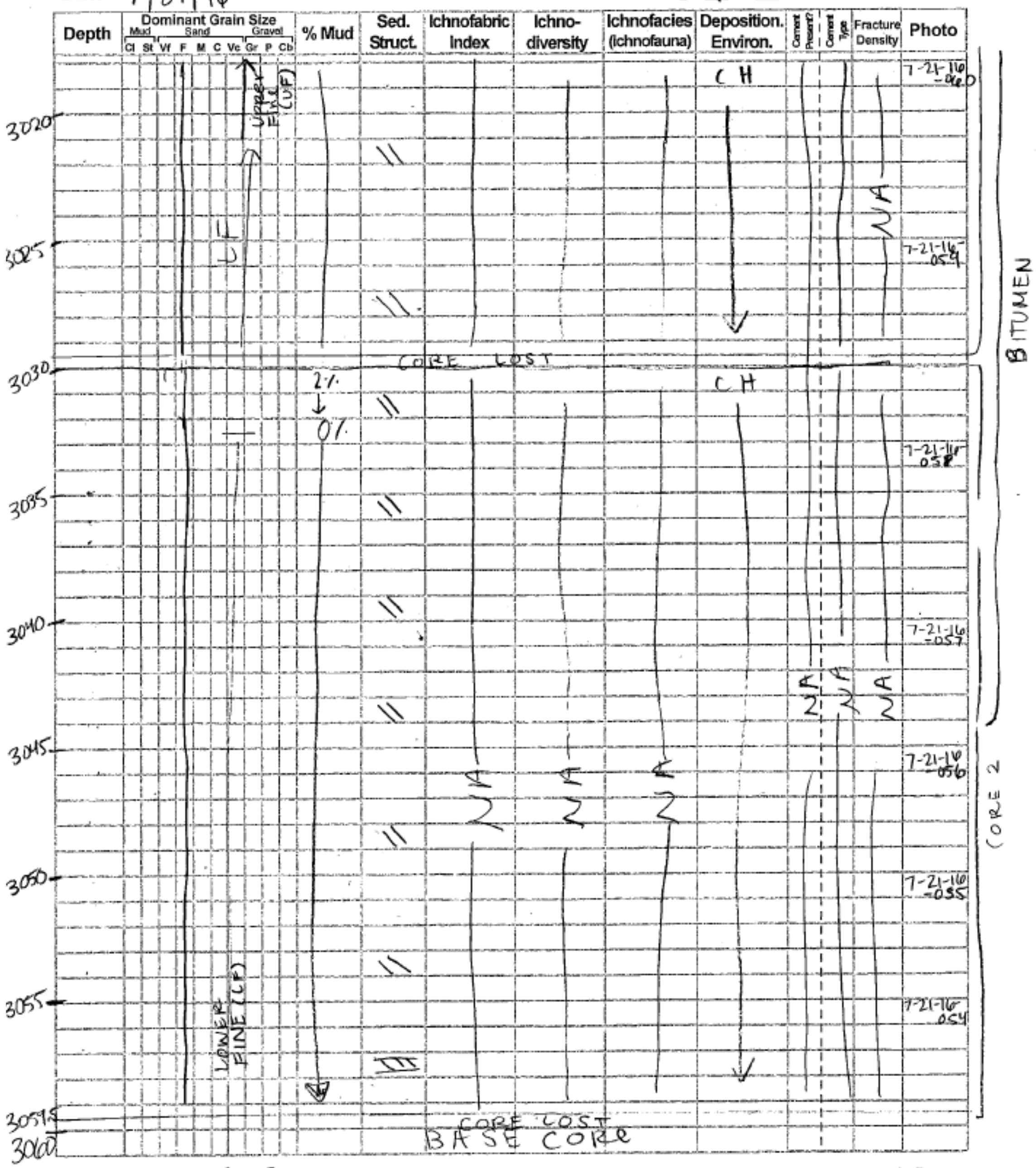
Core diameter = 9cm

~~Metric Units~~ (1" = 10')

CORE-4' = LOG

Project/Location: Jenner/02/06-03-020-08W4/0 **Logged By:** Johnson

Date: 7/21/16 **Page** 1 **of** 2



Core diameter = 8.5cm

~~Metric Units (1" = 10')~~ Each Box = 1 foot

DEPTH CORRECTION: ?

Project/Location: Jenner / 02/06-03-020-08w4/0 **Logged By:** Johnson

Date: 7/21/16 **Page** 2 **of** 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
3000				TOP CORE							
							CH				7-21-16-063
		3%	III								
		0%									7-21-16-062
3005											
			III								
											7-21-16-061
				NA	NA	NA		NA	NA	NA	
3010											
			III								
3015											
			III								

CORE 1

BITUMEN

Core diameter = 8.5m

~~Metric Units (1" = 10')~~

DEPTH CORRECTION = 0? Each Box = 1 foot.

Project/Location: Jenner / 00/08-04-020-08 W4/0 **Logged By:** Johnson

Date: 7/21/16 **Page** 1 **of** 1

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
				TOP CORE							
3040		0					CH			2	7-21-16-053
										2	
			ʋ =	3/4		ʋ?				2	7-21-16-052
			ʋ =	3/4		ʋ?				2	
			ʋ	2		ʋ?				2	
3045										2	
	Med L		ʋ	2		ʋ?				2	7-21-16-051
										2	
	Poorly sorted									0	7-21-16-050
3050											
								N/A	N/A		7-21-16-049
	Fine U										
3055			ʋ	2	N/A	ʋ?					
			∧ǁ								7-21-16-048
3060											
			ʋ	2		ʋ?					
			∧ǁ								7-21-16-047
3065											7-21-16-046
	Fine L										7-21-16-045
			∧ǀ								7-21-16-044
3069.5				BASE CORE							
3070											

BITUMEN

Core diameter = ~9cm

~~Metric Units (1" = 10')~~ Each box = 1 ft

DEPTH CORRECTION = 0

Project/Location: Jenner 03/16-04-020-08W4/0 **Logged By:** Kristin

Date: 7-22-16 **Page** 1 **of** 1

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
905											
											Alyssa's cam 7-22-16KA42/43
				TOP CORE							
	X X (Vf)	30%					OF				7-22-16KA64 7-22-16 KA63 7-22-16KA62
910	X X (Vf)	20%									7-22-16KA61 7-22-16KA60
	X X X (Vf)										7-22-16KA59 7-22-16KA58
	X (Vf)			4				Qtz Cement	10/ft frac		7-22-16KA57
	X X (F)										7-22-16KA56
	X X (F)										7-22-16KA55 7-22-16KA54
915	X (M)										7-22-16KA53 7-22-16KA52
	X X (M)										7-22-16KA51
	X X X (M)				ND	ND					7-22-16KA50
	X (F)		mm				CH				
	X X (F)										
	X (F)										7-22-16KA49
920	Y (F)							Controlled			
	X X (F)										7-22-16KA48
	Y (F)										7-22-16KA47
	Y Y (F)							Kmax			
	Y (F)										7-22-16KA46
	X X (F)										7-22-16KA45
	Y X (F)		mm								
926	X	Missing .13m									

CORE BASE

Qtz Cement 10/ft frac Controlled by Kmax

differential compaction of Qtz cement

top ~ 8cm dark carb mud

dark clasts

← Kmax ↑

mod. sorted

Poorly sorted

~113.5

more poorly sorted

Med-fine alteration

Bitumen stain

better sorted

wetter ← Kmax ↓ darker

could be v. fine

Core 3 — Core 2 (.17) — .15 — Core 1 (.87)

Core diameter = radius = 2cm

Slabbed

Metric Units (2.5cm = 3m)

Depth Shift none

Project/Location: Jenner 03/05-05-020-08W4/0 **Logged By:** Kristin

Date: 7-20-16 & 7-21-16 **Page** 1 **of** 1

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Photo	
955									
	TOP CORE								
.9							SW	7-21-16KA21	
.54		100%	mm				OF	7-21-16KA20	thin interbed. coal in carb. shale
.69							SW	7-21-16KA19	
.34								7-21-16KA18	
960		57.					CH		< 4cm carb shale
.83		100%					OF	7-21-16KA17	black carb. shale ½cm coal @ .??
.06		79%?		4			OF	7-21-16KA16	
.13			massive					7-21-16KA15	
965								7-21-16KA14	few dark streaks No coarse alt. bands
			mm					7-21-16KA13	
.05								7-21-16KA12	4cm coarse band
			mm, cw					7-21-16KA11	Med-coarse alternati bands
		0		ND	ND		CH	7-21-16KA10	2cm band
.41									
970								7-21-16KA9	increase sorting better
			mm						up to cm bands, 4H, ... dark
								7-21-16KA8	
			mm					7-21-16KA7	
								7-21-16KA6	coarse sand
.28		3%	mm & cm					7-21-16KA5, 7-21-16KA4	rare Gr size; Alternating bands & c size mm to cm
.42								7-21-KA3, 7-21-16KA2	Poorly sorted-... conglomerate; mm-cm alternati cm layers
.74		1%	mm & cm					7-21-16KA1	Rubble up to Gr. size
975.15				CORE	BASE				*coarse dom.
976									

Cl St Vf F M C Vc Gr P Cb

Core diameter = 8cm

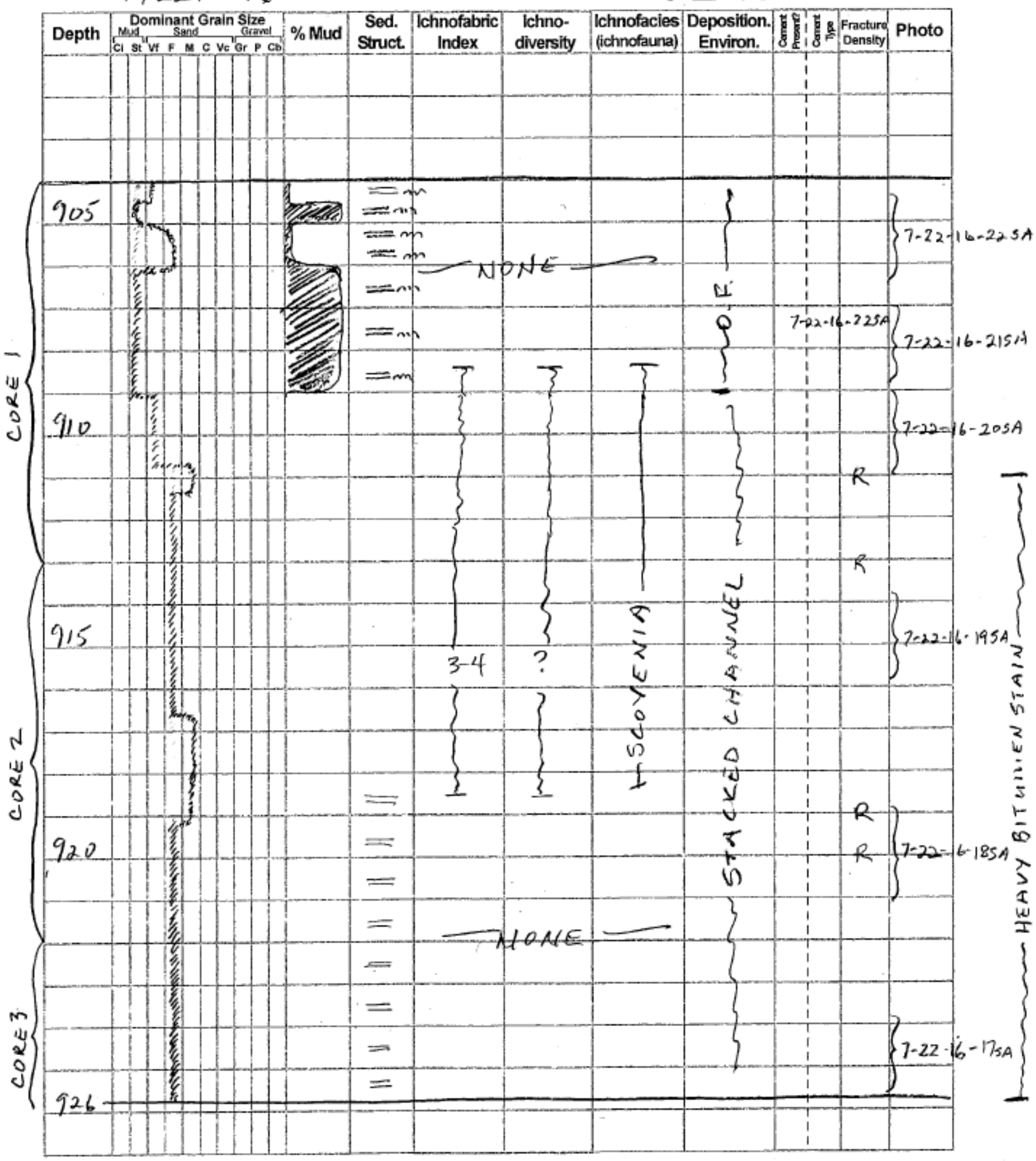
Metric Units (2.5cm = 3m)

.82

Depth shift: core + .66 = log (coal @ 960)

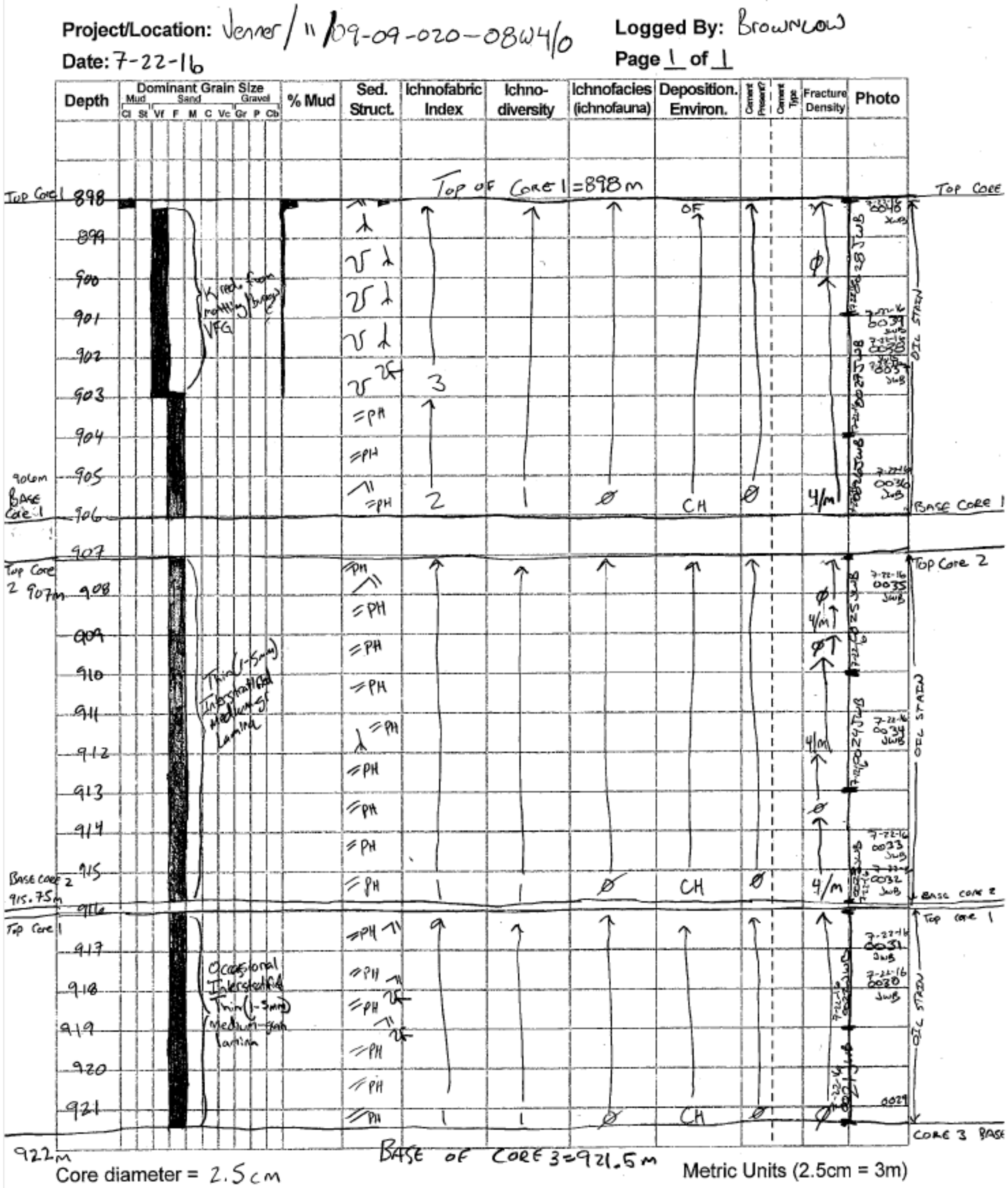
Project/Location: JENNER / 8-9-20-8W4 **Logged By:** ATCHLEY

Date: 7/22/2016 **Page** 1 **of** 1



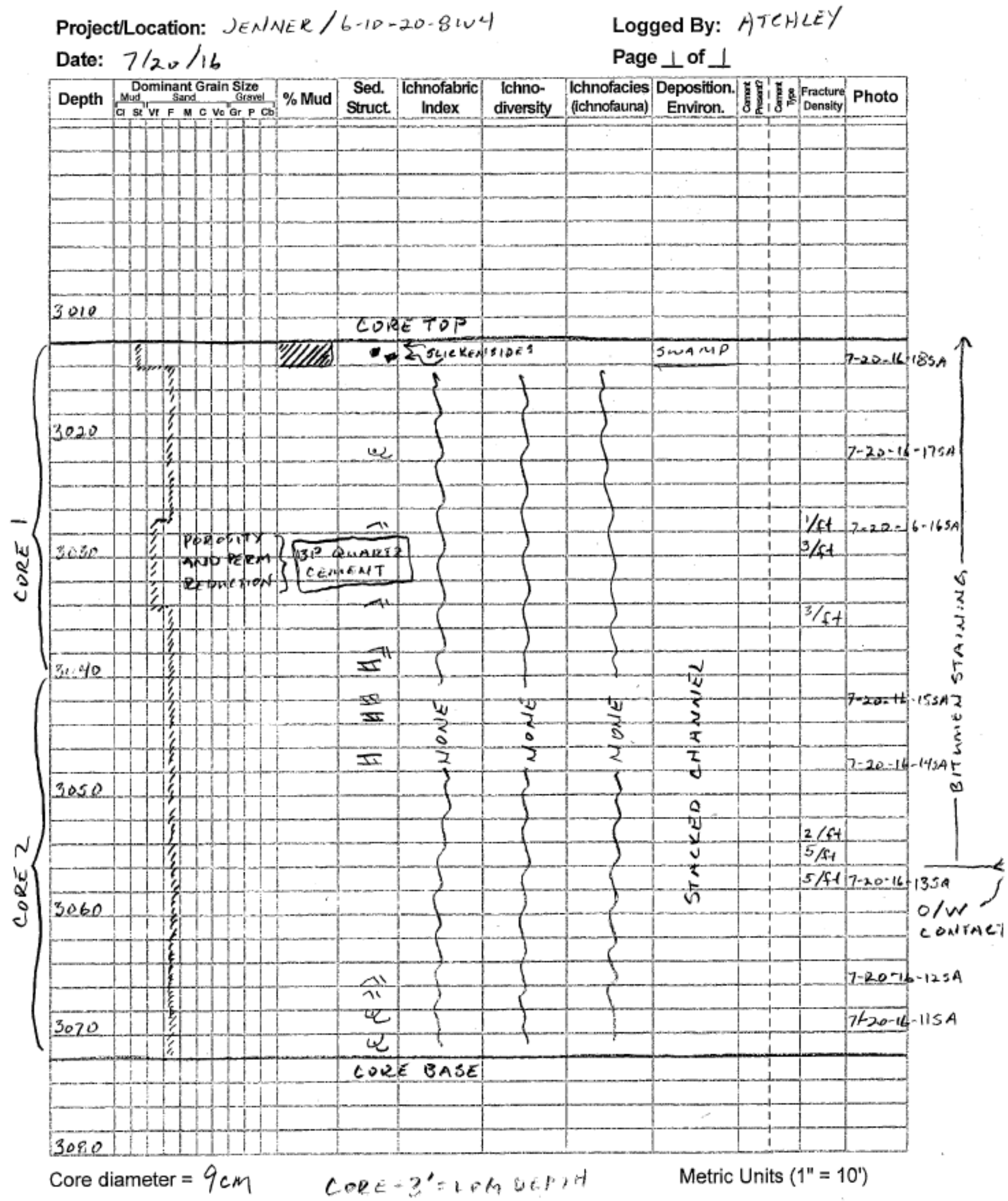
Core diameter = 7cm Metric Units (2.5cm = 3m)

CORE - 1.5m = LOG DEPTH



Depth Correction: Core ~ Log

Note: Lower interval not perfed; possible recompletion? Not Imaged though...



Project/Location: JENNER / 6-10-20-8W4
Logged By: ATCHLEY
Date: 7/20/16
Page 1 of 1
Depth
Dominant Grain Size
Mud Sand Gravel
Cl St Vf F M C Vc Gr P Cb
% Mud
Sed. Struct.
Ichnofabric Index
Ichno- diversity
Ichnofacies (ichnofauna)
Deposition. Environ.
Cement Present?
Cement Type
Fracture Density
Photo
3010
CORE TOP
SLICKENSIDES
SWAMP
7-20-16-18SA
3020
7-20-16-17SA
1/ft
7-20-16-16SA
3/ft
3030
POROSITY AND PERM REDUCTION
13% QUARTZ CEMENT
3/ft
CORE 1
3040
NONE
NONE
NONE
STACKED CHANNEL
7-20-16-15SA
7-20-16-14SA
BITUMEN STAINING
3050
2/ft
5/ft
5/ft
7-20-16-13SA
O/W CONTACT
CORE 2
3060
7-20-16-12SA
3070
7-20-16-11SA
CORE BASE
3080
Core diameter = 9cm
CORE - 3' = 1 m DEPTH
Metric Units (1" = 10')

Project/Location: JENNER / 13-10-20-8W4 **Logged By:** ATCHLEY

Date: 7/22/16 **Page** 1 **of** 1

Depth	Dominant Grain Size (Mud: Cl, St; Sand: Vf, F, M, C, Vc; Gravel: Gr, P, Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
905											
			CORE TOP								
910										0	7-22-16-7SA
										5/ft	7-22-16-6SA
										R	
										10/ft	
										10/ft	7-22-16-5A
										10/ft	7-22-16-4SA
										3/ft	
			=?	3	?	SCOYENIA	CHANNEL			2/ft	
										2/ft	7-22-16-3SA
915										5/ft	
										5/ft	7-22-16-2SA
										5/ft	
										3/ft	
										0	7-22-16-1SA
918			CORE BASE								

FRACTURE [illegible] (CHANNEL); POROSITY

HIGH FRACTURE ABUNDANCE = HIGH Φ/K

Core diameter = 9 CM

Metric Units (2.5cm = 3m)

Project/Location: Jenner 102/12-10-020-10W4 **Logged By:** Kristin

Date: 7-22-16 **Page** 1 **of** 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo	
	Vf		√									
	F			Varies 3-4							7-22-16KA42	Bitumen stained
	F										7-22-16KA41	
900	F										7-22-16KA40	
	F		^	3							7-22-16KA39	
	F			2								
	F			3								
	F		v									
905	F			2								
	F			4								
	F		√								7-22-16KA38	
	F											
910	F		≡mm									
	F	0		ND	ND	ND	CH				7-22-16KA37	More conspicuous bedforms
	F		≡mm									
	F		≡mm								7-22-16KA36	
.81 / .33	F		≡mm							10 Fract/ft	7-22-16KA35	↓ w/ cont. Med bands on top
915	F		^								7-22-16KA34	Alt. bands more/carbon; Better sorting ↑
	F		ɯ ^									
.71 / .75	F/M		^ ≡mm / ≡mm								7-22-16KA33 / 7-22-16KA32	Alternating gr. F-M-C
.91	F/M		ɯ ≡mm								7-22-16KA31 / 7-22-16KA30	Bands of coarser grained
.89 / 920	F/M		≡mm / ≡mm								7-22-16KA29 / 7-22-16KA28	Bands of Med grain
.42	M		≡mm / ^								7-22-16KA27 / 7-22-16KA26	
922	F		≡mm								7-22-16KA25	

Core 1 / Core 2 / Core 3

VF F M C

Core ~~diameter~~ = radius = 2.5cm CORE BASE

Slabbed

Metric Units (2.5cm = 3m)

Depth Shift: Core + 1.5 m (1-2m) = 109

Project/Location: Jenner 02/12-10-020-03W4/0 Logged By: Kristin

Date: 7-22-10 Page 2 of 2

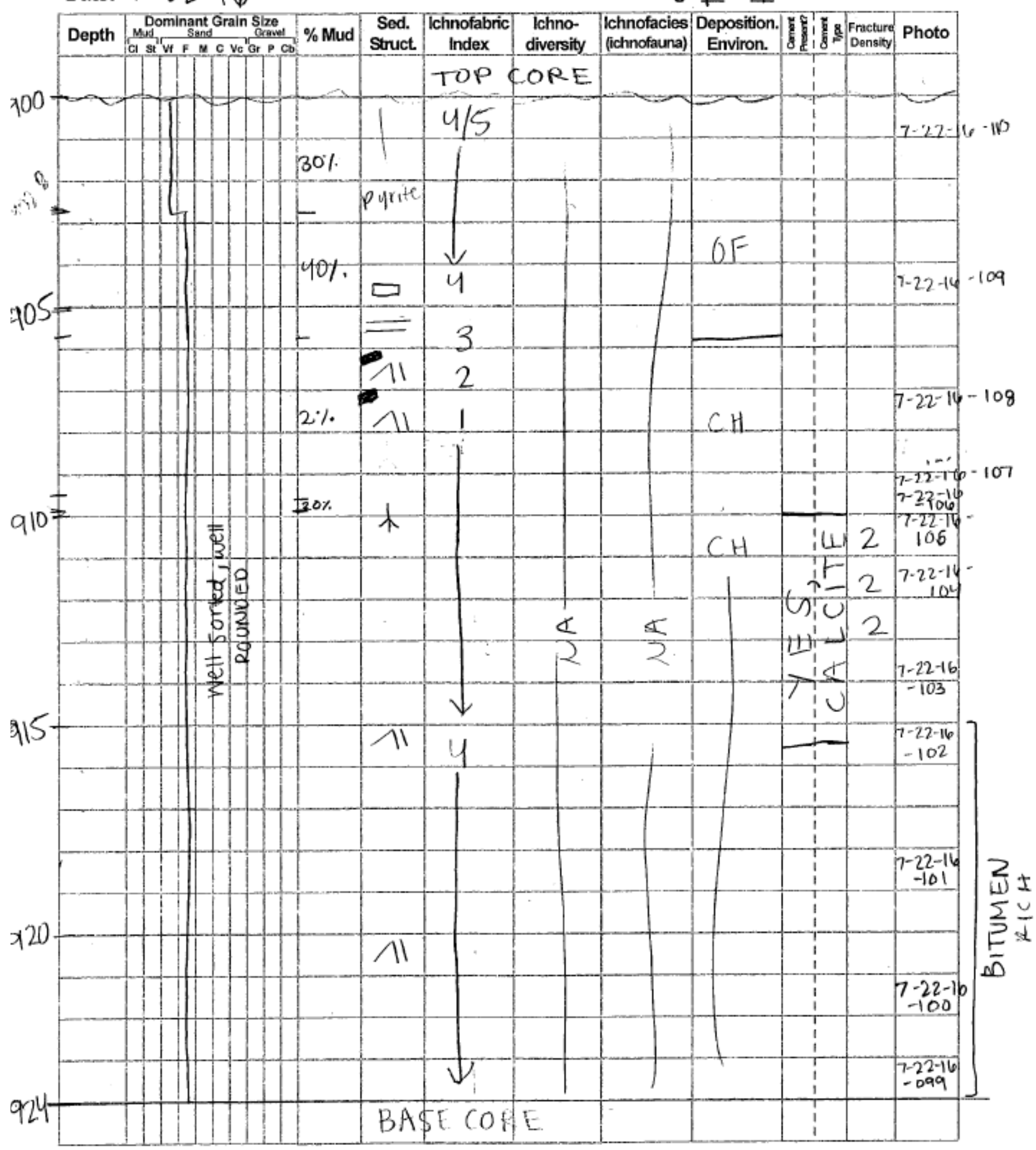
Depth	Dominant Grain Size: Mud Cl	Mud St	Sand Vf	Sand F	Sand M	Sand C	Sand Vc	Gravel Gr	Gravel P	Gravel Cb	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
895													TOP CORE							
			X X									v	2	1	1	CH			7-22- 7-22-	10KA44 10KA43

fine grained band

Core diameter =

Metric Units (2.5cm = 3m)

Project/Location: Jenner / 08/05-10-020-08W4/0 **Logged By:** Johnson
Date: 7-22-16 **Page** 1 **of** 1



Core diameter = 8.5 cm

Metric Units (2.5cm = 3m)

DEPTH CORRECTION = 0

Project/Location: JENNER / AD14-10-20-BW4 **Logged By:** ATCHLEY

Date: 7/20/16 **Page** 1 **of** 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
910											
			CORE TOP								
											7-21-16-8SA
							OF				
				4 / 4	? / ?		SWAMP				7-21-16-7SA HIGHLY FISSILE
915	SAND W/ ADMIXED MUD			4	?	SCOYENIA				10/ft	7-21-17-6SA
				4	?					5/ft	
				4	?					5/ft	
CORE 1				CORE FORMS PLATY "PUCKS" ALONG BEDDING SURFACES							
920											
							STACKED CHANNEL				
CORE 2											7-21-16-5SA
925					NONE	NONE					
											7-21-16-4SA
930											BITUMEN STAIN

Core diameter = 9cm

Metric Units (2.5cm = 3m)

CORE = LOG DEPTH @ 914.25m

Project/Location: JENNER / AD14-10-20-8W4

Logged By: ATCHLEY

Date: 7/20/16

Page 2 **of** 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (Ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
CORE 3											7-21-16-35A
935											7-21-16-25A
											7-21-16-15A
											7-21-16-195A
940											7-21-16-185A
CORE 4				NONE	NONE	NONE	STACKED CHANNELS				7-21-16-175A
											7-21-16-165A
945											7-21-16-155A
			RUBBLE								
950											7-21-16-145A
CORE 5											7-21-16-135A
											7-21-16-125A
955			?								7-21-16-115A
											7-21-16-105A
											7-21-16-95A
957											

BITUMEN

O/W CONTACT

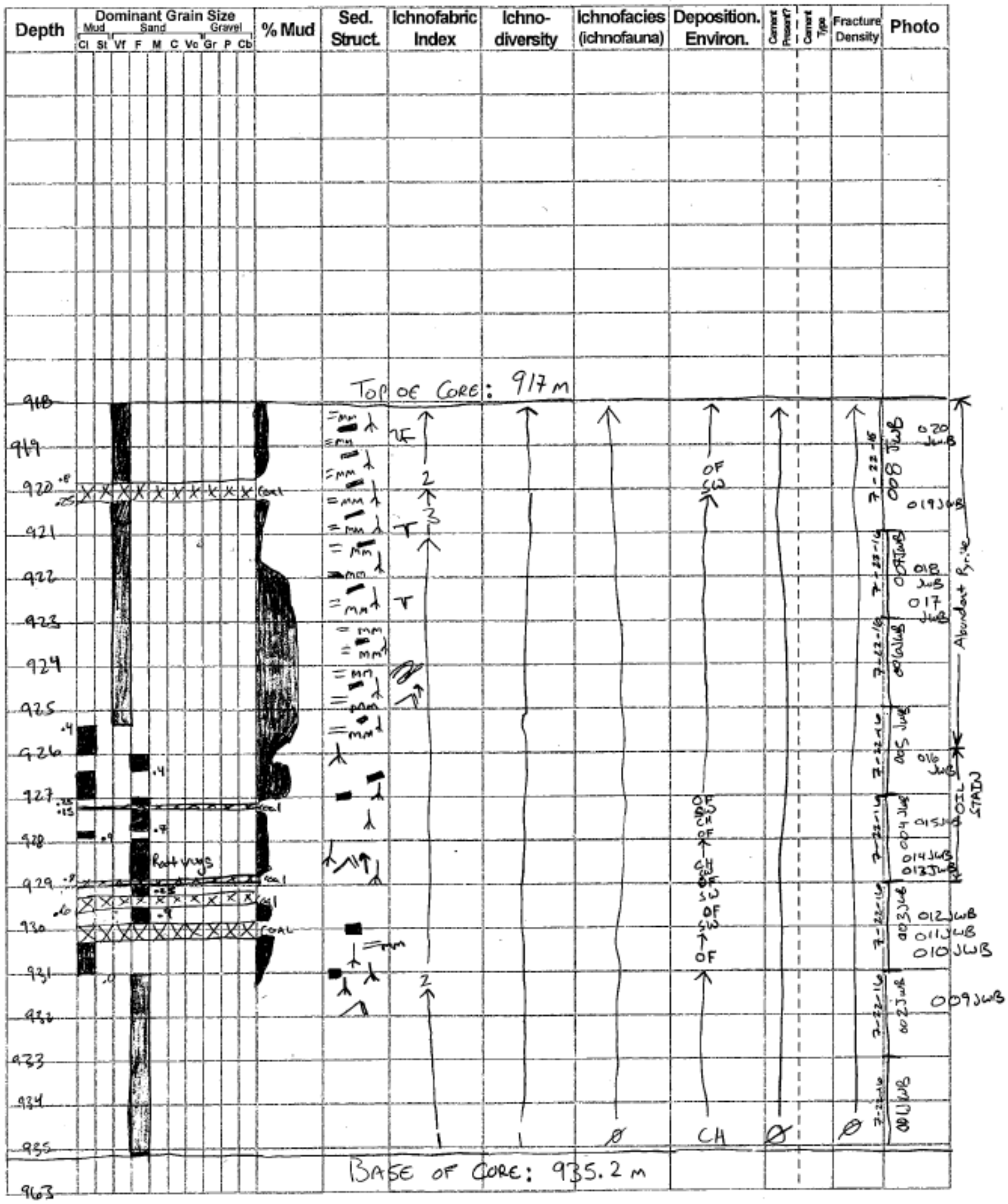
INCISEMENT SURFACE ?

Core diameter = 9cm

Metric Units (2.5cm = 3m)

Project/Location: Jones/F1/11-15-020-08W4/0 **Logged By:** J Browncoo

Date: 07-22-16 **Page** 1 **of** 1



Core diameter = 4cm

Metric Units (2.5cm = 3m)

Depth correction: Core = log

Project/Location: Jenner 00/02-16-020-03W4/0 **Logged By:** Kristin

Date: 7-21-16 **Page** 1 **of** 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (Ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo	Remarks
3010											7-21-16KA28	Core 1; up to coarse size; Bitumen partially throughout
3015												
3017											7-21-16KA27	Better sorted
3020			=mm									
3021			massive									
3024											7-21-16KA26	
3025												← O/W contact
3027							CH				7-21-16KA25	Core 2
3029											7-21-16KA24	Gradual change M→F
3030												
3032											7-21-16KA23	
3035												
3037											7-21-16KA22	
3040			≡								7-21-16KA30	
3041			CORE BASE									
3045												
3050												

Core diameter = 9cm

Metric Units (1" = 10')

Project/Location: Jenner 00/02-16-020-08W4/0 **Logged By:** Kristin

Date: 7-21-16 **Page** 2 of 2

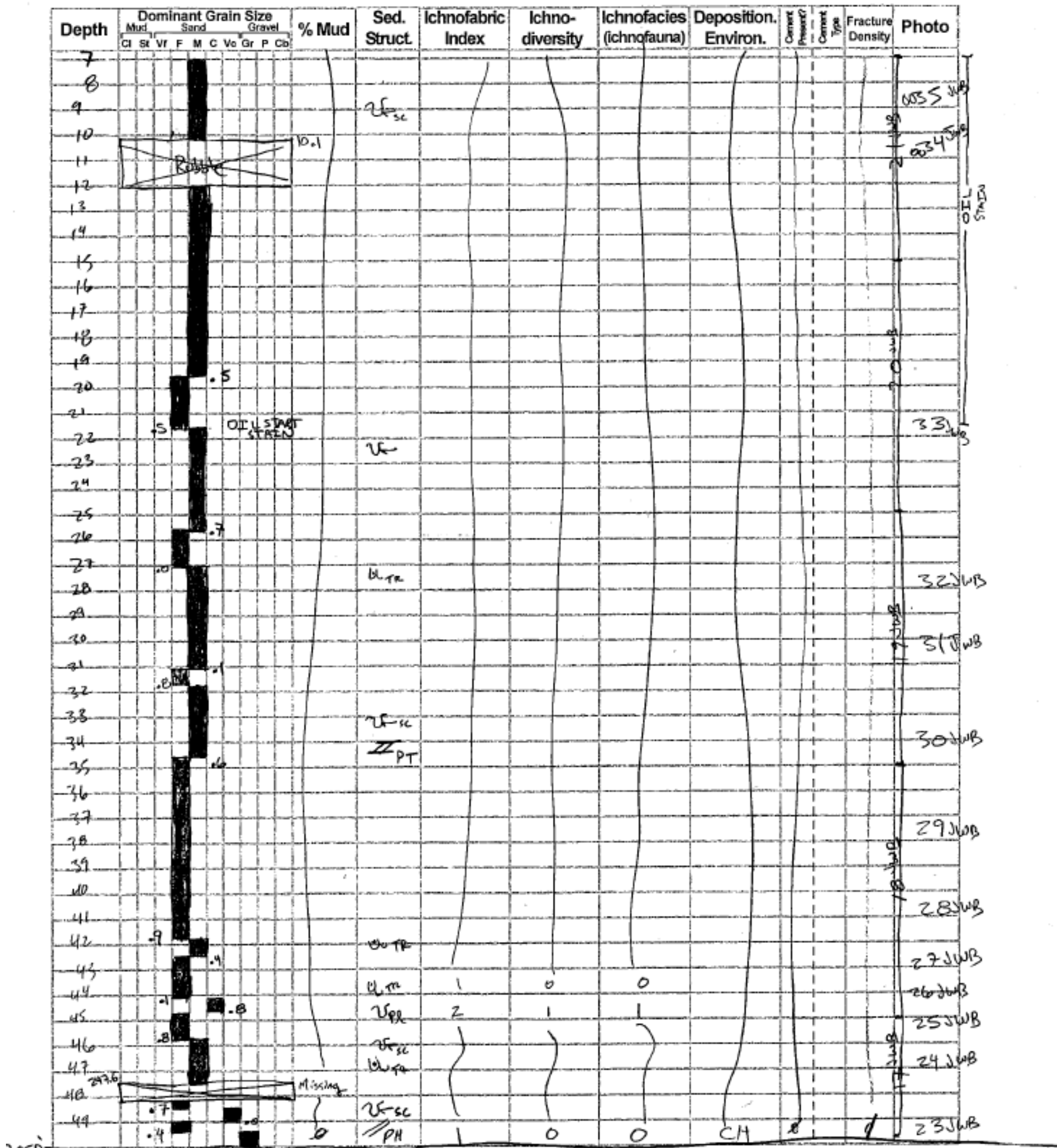
Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present? / Cement Type	Fracture Density	Photo	
2975											
2980	TOP CORE										
	Vf		λ							7-21-16KA35	
	St		≡mm							7-21-16KA34	Mud layer
2985	Vf		λ								
	Vf									7-21-16KA33	*argillaceous increase (see on log also)
	Vf		ν								
2990	Vf		λ							7-21-16KA32	rare coarse grains
	Vf	<6%									
	Vf		ν				CH				
2995	Vf			3						7-21-16KA31	
	Vf		λ								
3000	Vf										
	Vf		ν							7-21-16KA30	
	Vf		λ								
3005	M									7-21-16KA29	Top oil
	M										Bitumen Poorly sorted

core

Core diameter = Metric Units (1" = 10')

Project/Location: Jenner 00/10-16-020-08W4/0 **Logged By:** Brownlow

Date: 7-21-16 **Page** 1 **of** 2



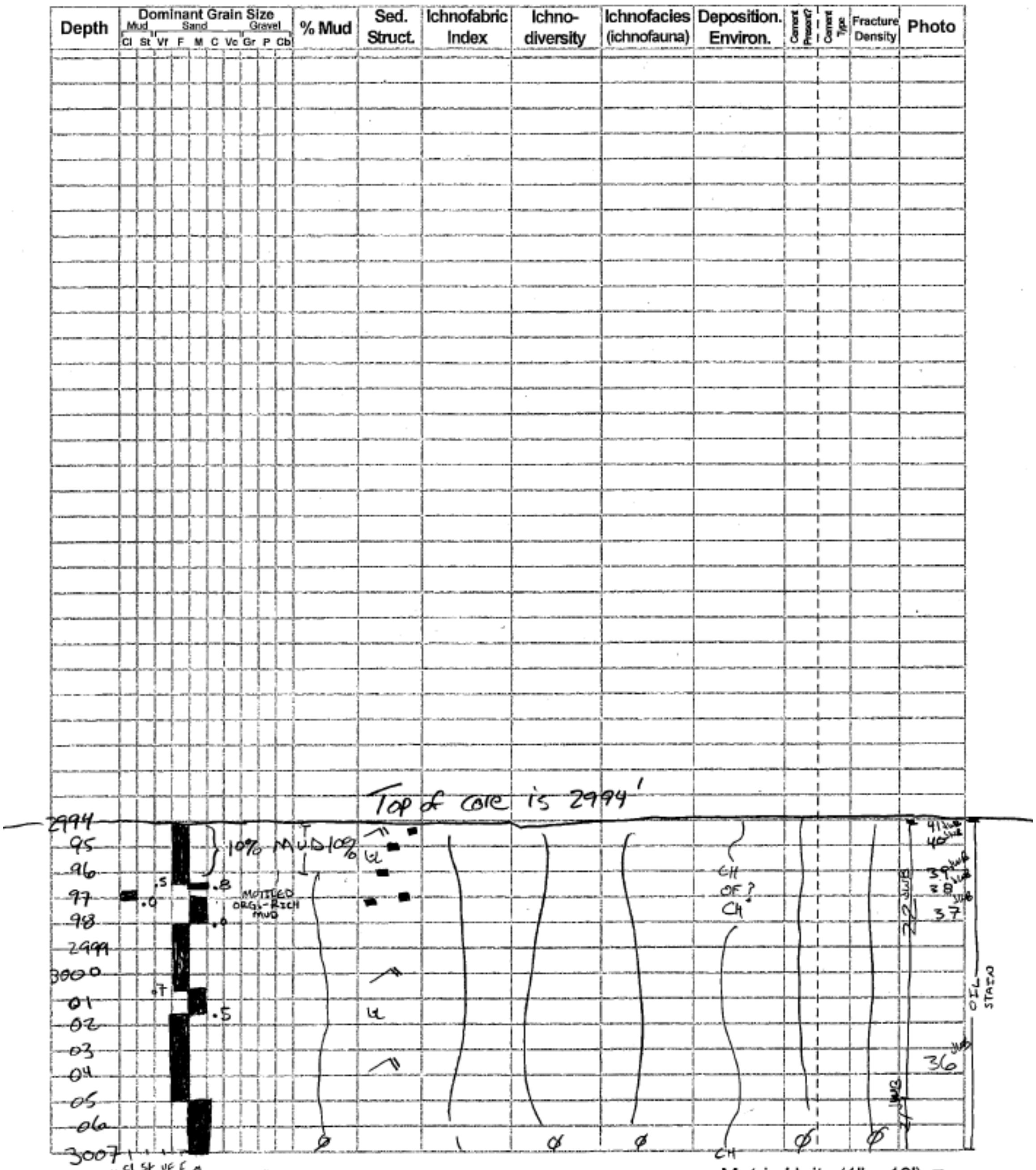
Core diameter = 3.5" BASE OF CORE = 3050' Metric Units (~~1" = 10'~~)

1 box = 1' or 5 mm = 1'

Log - Core adjust ?

Project/Location: Jenner 09/10-16-020-08W4/0 **Logged By:** Brownlow

Date: 7-21-16 **Page** 2 **of** 2



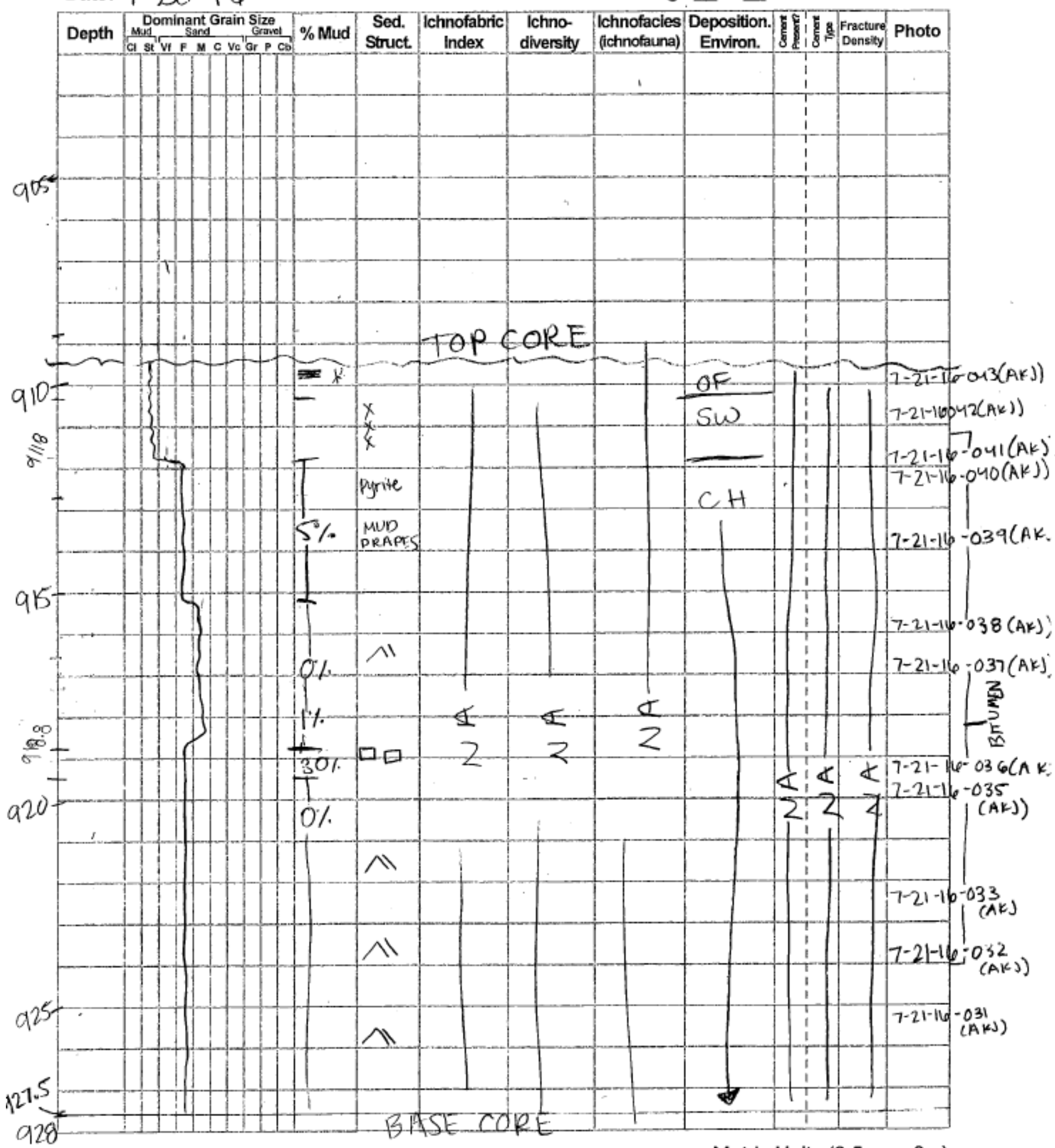
Core diameter = 3.5"

Metric Units (~~1" = 10'~~)

1box = 5mm = 1'

Project/Location: Jenner /02/09-16-020-08W4/0 **Logged By:** Johnson

Date: 7-20-16 **Page** 1 **of** 1



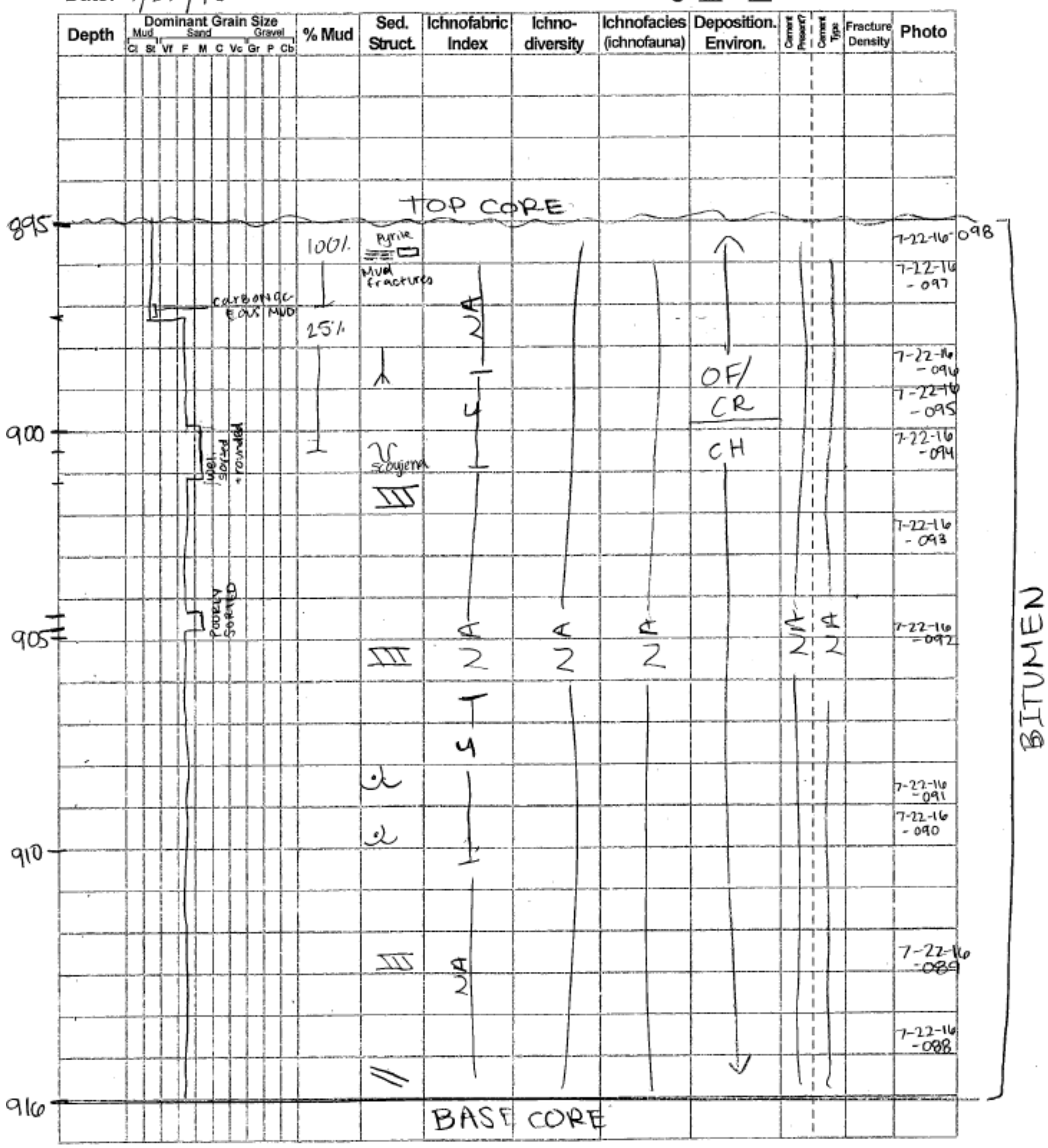
Core diameter =

Metric Units (2.5cm = 3m)
(1 box = 1m)

DEPTH CORRECTION = 0 m

Project/Location: Jenner/ 05/01-16-020-08W4/0 **Logged By:** Johnson

Date: 7/22/16 **Page** 1 **of** 1



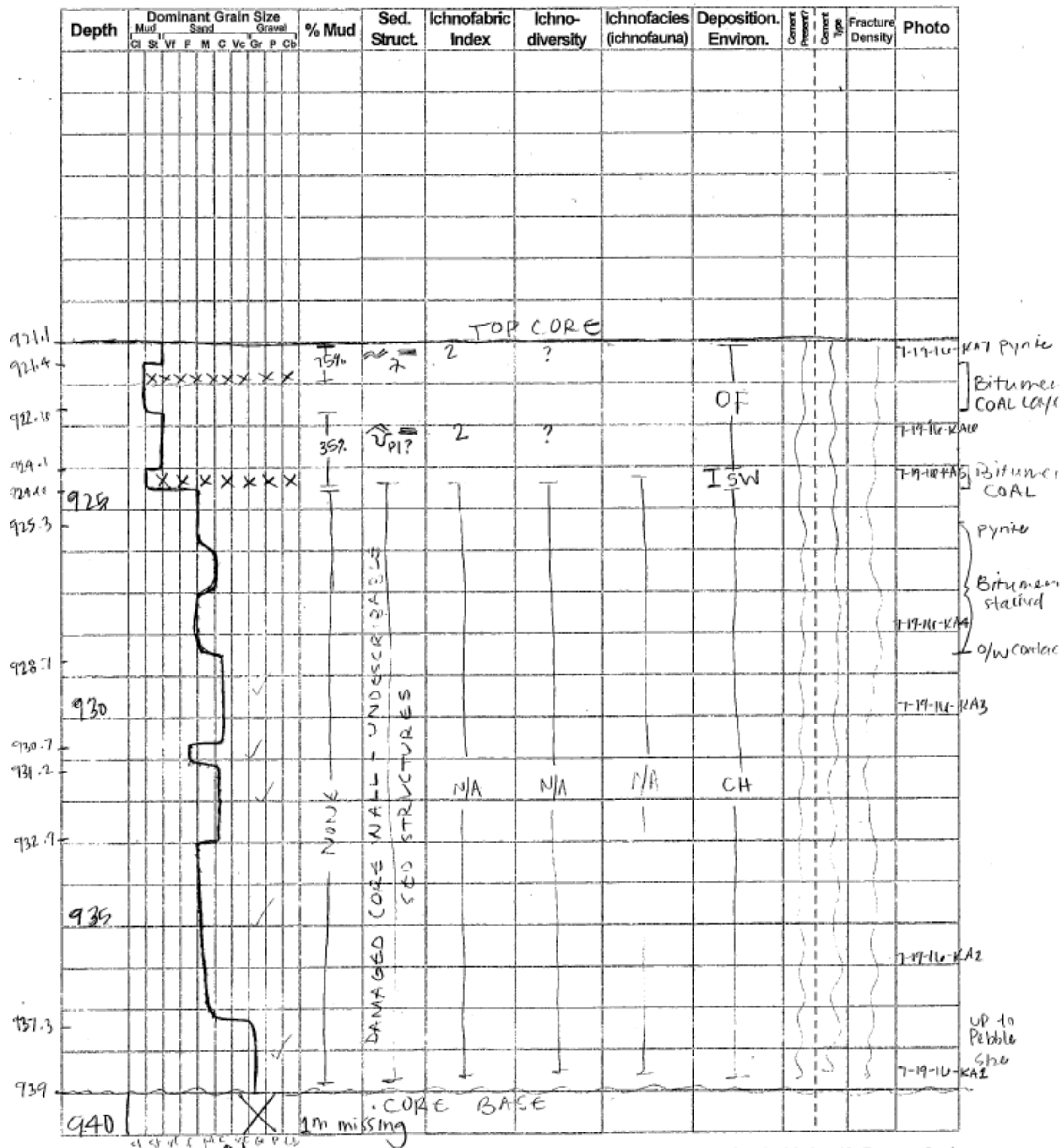
Core diameter = 2 cm (slabbed core)

DEPTH CORRECTION = 0

Metric Units (2.5cm = 3m)

Project/Location: Jehner/ 02/10-19-020-08W4/0 **Logged By:** Kristin

Date: 7-19-16 **Page** 1 **of** 1

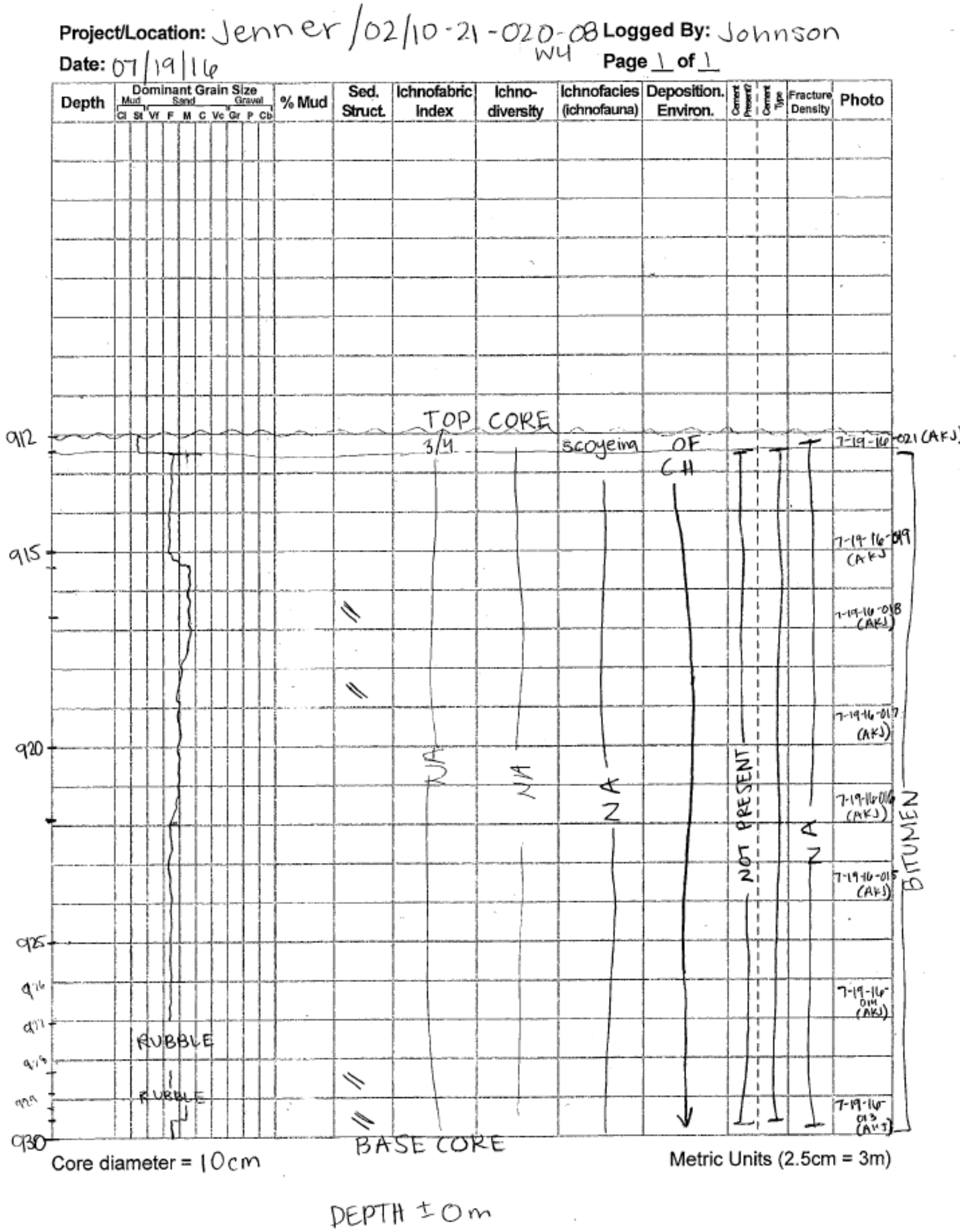


Core diameter = 8½ cm

Metric Units (2.5cm = 3m)

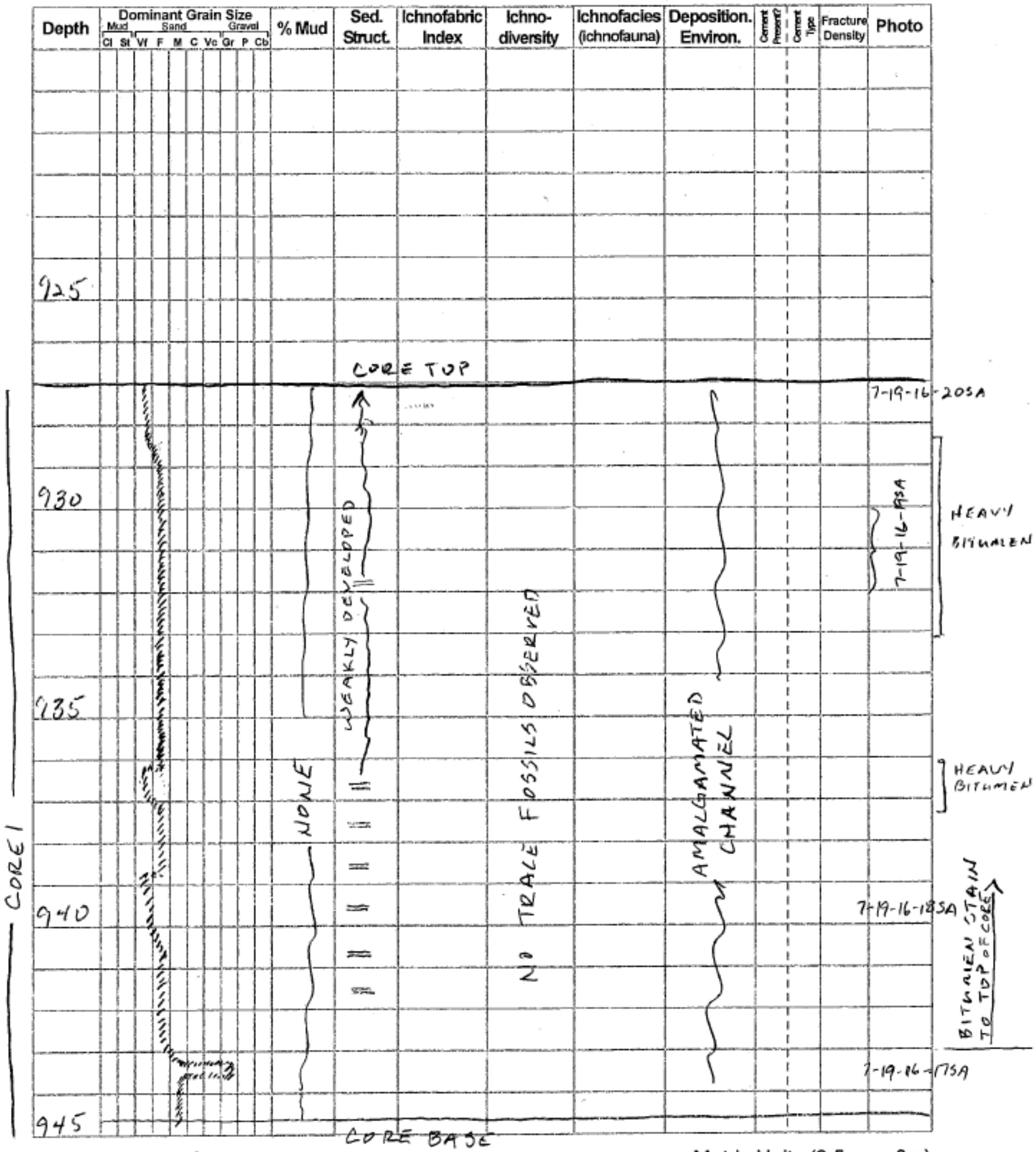
Depth shift core + ½ m = log

CH - channel
SW - swamp
OF - overbank fines


Project/Location: Jenner /02/10-21-020-08 W4
Logged By: Johnson
Date: 07/19/16
Page 1 of 1
Depth
Dominant Grain Size
Mud Sand Gravel
Cl St Vf F M C Vc Gr P Cb
% Mud
Sed. Struct.
Ichnofabric Index
Ichno-diversity
Ichnofacies (ichnofauna)
Deposition. Environ.
Cement Present?
Cement Type
Fracture Density
Photo
TOP CORE
912
3/4
scoyeing
OF CH
7-19-16-021 (AKJ)
915
7-19-16-019 (AKJ)
7-19-16-018 (AKJ)
7-19-16-017 (AKJ)
920
NA
NA
NA
NOT PRESENT
NA
7-19-16-016 (AKJ)
7-19-16-015 (AKJ)
BITUMEN
925
926
927
7-19-16-014 (AKJ)
RUBBLE
928
929
RUBBLE
7-19-16-013 (AKJ)
930
BASE CORE
Core diameter = 10cm
Metric Units (2.5cm = 3m)
DEPTH ± 0m

Project/Location: JENNER/11-32-20-8W4 **Logged By:** ATCHLEY

Date: 7/19/16 **Page** 1 **of** 1



Core diameter = 9cm

Metric Units (2.5cm = 3m)

Project/Location: JENNER/11-04-21-8W4 **Logged By:** ATCHLEY

Date: 7/20/16 **Page** 1 **of** 1

CORE TOP

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo	
935							OF				7-20-16-10SA	
							CHANNEL				7-20-16-9SA	
				4 4 4	? ? ?	SCOYENIA	SWAMP				7-20-16-8SA	
							SWAMP					
			SLICKENSIDES				SWAMP				7-20-16-7SA	PALEOVERT
940				4 4 4	? ? ?	SCOYENIA	CHANNEL				7-20-16-6SA	
							SWAMP				7-20-16-5SA	3-5% PLANT MATTER
											7-20-16-4SA	
945											7-20-16-3SA	INVERTEBRATE TRACKS
				NONE	NONE		CHANNEL				7-20-16-2SA	
											7-20-16-1SA	DISSEMINATED GRANULES?
950												

CORE BASE

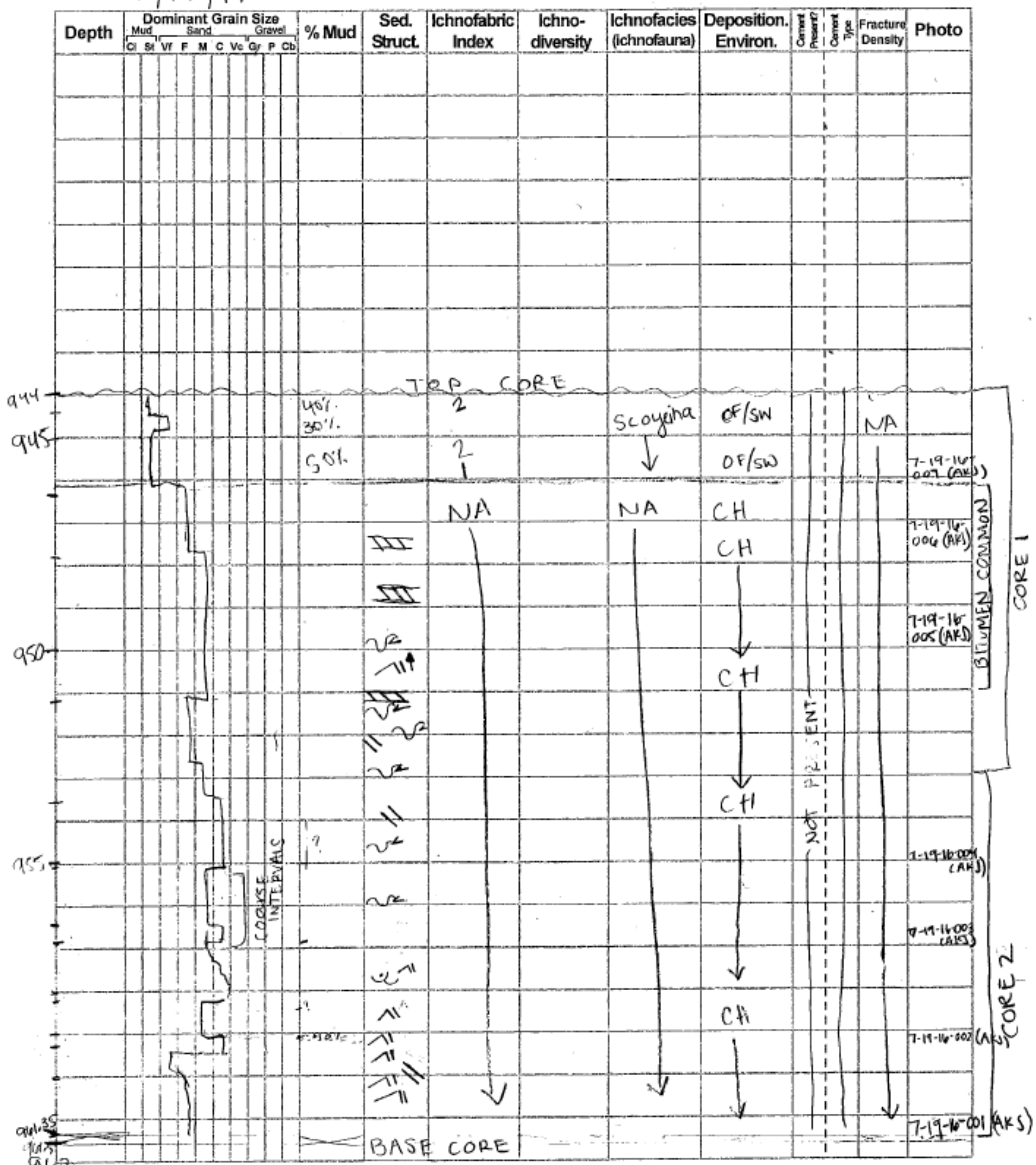
Core diameter = 9.8cm

Metric Units (2.5cm = 3m)

CORE + 1m = LOG

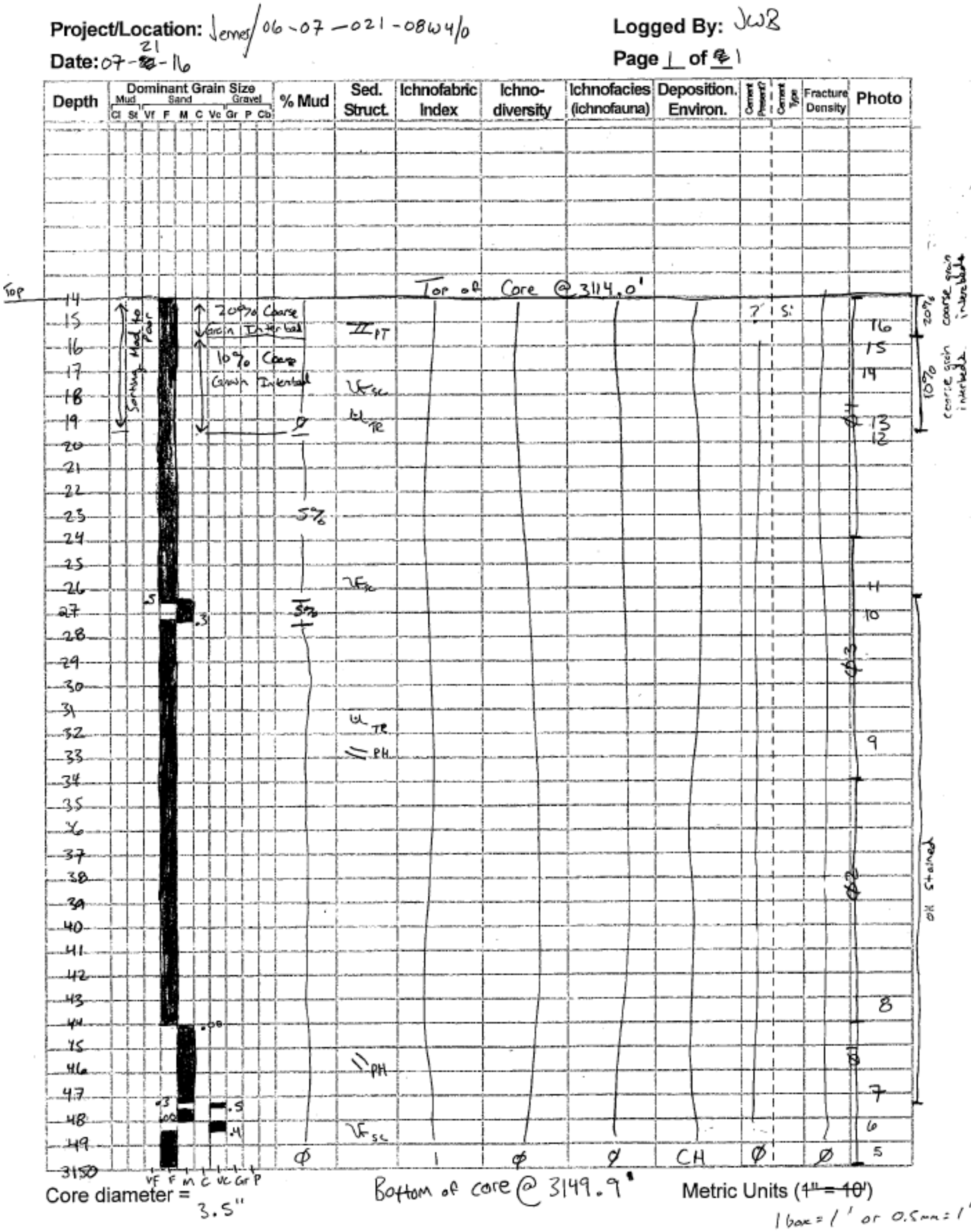
Project/Location: Jenner | 09.06.021-08W4|0 **Logged By:** Johnson

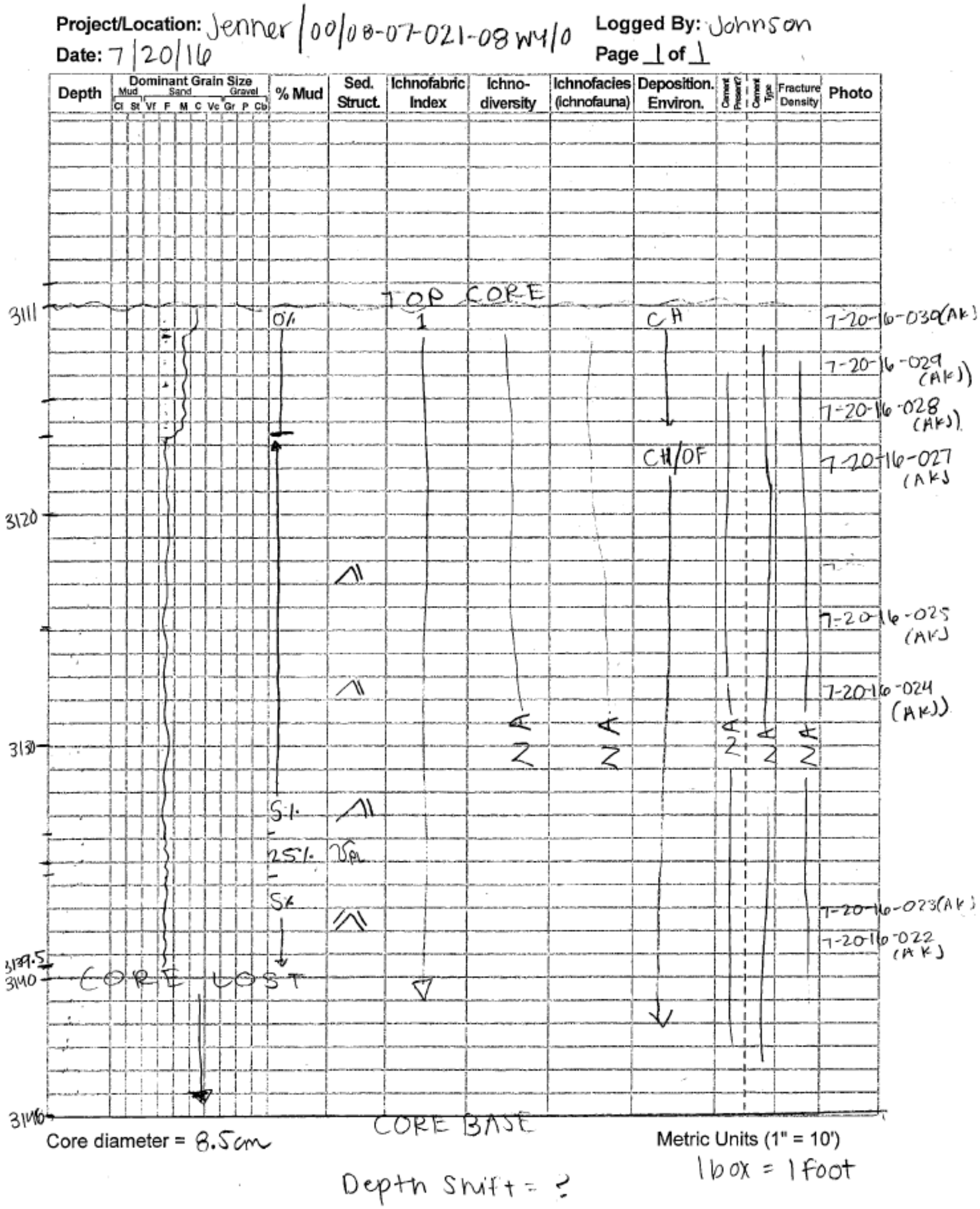
Date: 7/19/16 **Page** 1 **of** 1



Core diameter = 8cm Metric Units (2.5cm = 3m)

Depth shift: 0m


Project/Location: Jemes/06-07-021-08W4/0
Date: 07-21-16
Logged By: JWB
Page 1 of 1
Depth
Dominant Grain Size
Mud Sand Gravel
Cl St Vf F M C Vc Gr P Cb
% Mud
Sed. Struct.
Ichnofabric Index
Ichno-diversity
Ichnofacies (ichnofauna)
Deposition. Environ.
Cement Present?
Cement Type
Fracture Density
Photo
Top
Top of Core @ 3114.0'
Sorting Mod to Poor
20% Coarse Grain Interbed
10% Coarse Grain Interbed
5%
3%
CH
20% coarse grain interbeds
10% coarse grain interbeds
Oil stained
3150
Core diameter = 3.5"
Bottom of core @ 3149.9'
Metric Units (1" = 10')
1 box = 1' or 0.5mm = 1'



Project/Location: Jenner | 00/08-07-021-08 W4/0
Date: 7/20/16
Logged By: Johnson
Page 1 of 1
Depth
Dominant Grain Size
Mud Sand Gravel
Cl St Vf F M C Vc Gr P Cb
% Mud
Sed. Struct.
Ichnofabric Index
Ichno-diversity
Ichnofacies (ichnofauna)
Deposition. Environ.
Cement Present?
Cement Type
Fracture Density
Photo
TOP CORE
3111
0%
1
CH
7-20-16-030(AKJ)
7-20-16-029 (AKJ)
7-20-16-028 (AKJ)
CH/OF
7-20-16-027 (AKJ)
3120
7-20-16-025 (AKJ)
7-20-16-024 (AKJ)
NA
NA
NA
NA
NA
3130
5%
25%
5%
7-20-16-023(AKJ)
7-20-16-022 (AKJ)
3139.5
3140
CORE LOST
3146
CORE BASE
Core diameter = 8.5cm
Metric Units (1" = 10')
1 box = 1 foot
Depth Shift = ?

Project/Location: Jenner 00/14-07-021-08W4/0 **Logged By:** Kristin

Date: 7-20-16 **Page** 1 **of** 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo	
3115												
			√R									
			= mm								7-20-16KA29	
3120											7-20-16KA28	
			≡ mm									
3125												
											7-20-16KA27	Bitumen stained
3130												
											7-20-16KA26	up to Gr. sized Fra
3135												Poorly sorted
			= mm									
		0		ND	ND	ND	CH				7-20-16KA25	
3140												
												up to Gr. Sized ban kanglomem
											7-20-16-KA24	
			√R								7-20-16KA23	≤ 3 cm Thick
3145												
			= mm									
											7-20-16KA22	← O/W contact
3150												
											7-20-16KA21	
			= mm = mm									
											7-20-16KA20	Alternating cm Thick bed w/ v.c. grains
3155			= = cm								7-20-16KA19	
			Massive								7-20-16KA18	

Cl S VfFMCVcGPCb

Core diameter = 9cm

BASE CORE

Metric Units (1" = 10')

Depth shift: core + 1ft = 109

Project/Location: Jenner 00/14-07-021-08W4/0 Logged By: Kristin

Date: 7-2010 Page 2 of 2

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
				TOP CORE							
3105											
											7-2010 KA32
			≡ mm								
		<5%					CH	√	Qtz		
				NO	NO	NO					
3110											7-20-10 KA31 - stylolite
			≡ mm								7-20-10 KA30

rare coarse fragments

Core diameter =

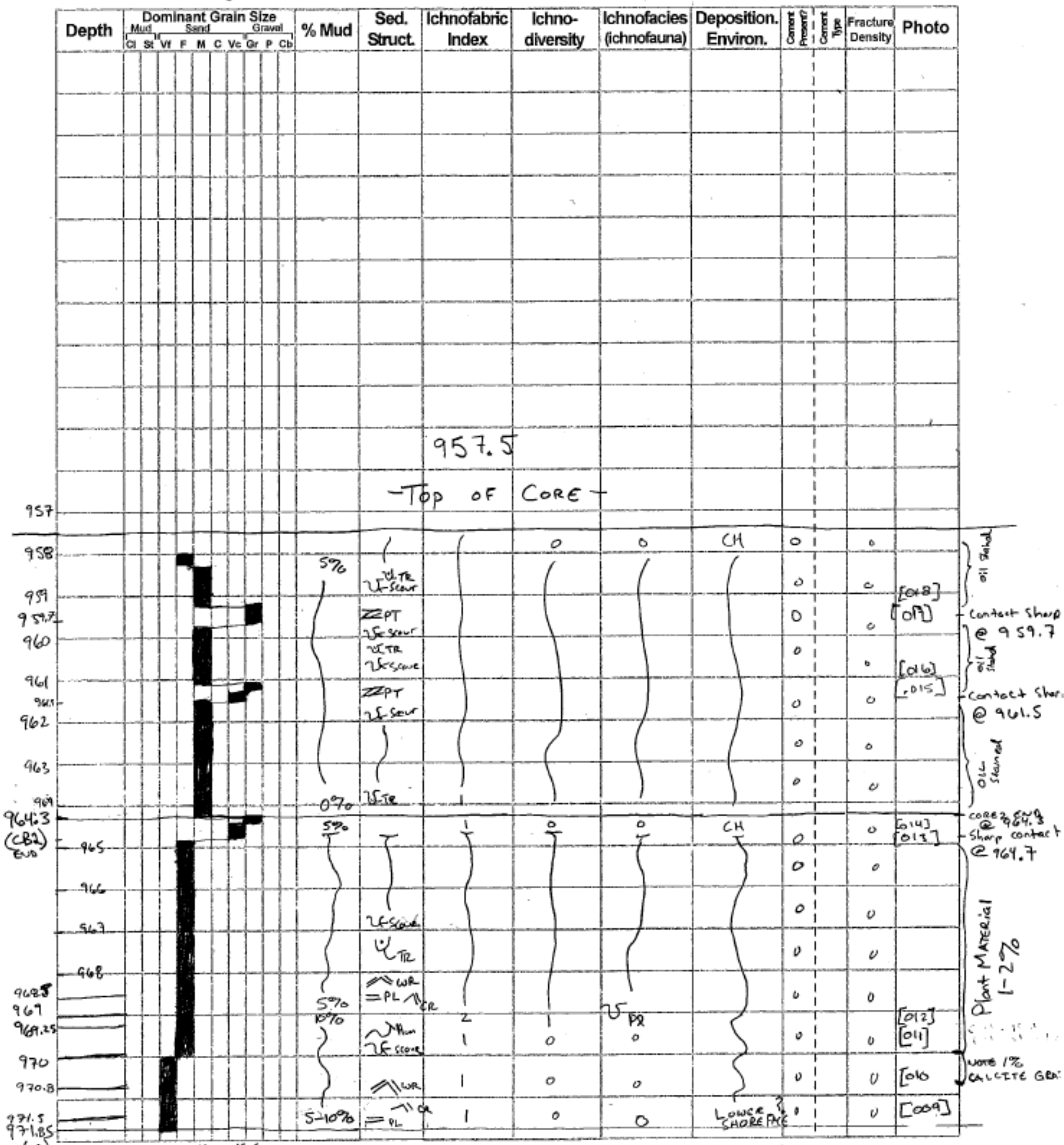
Metric Units (1" = 10')

Project/Location: Jenner / 3-8-21-BW4M

Logged By: Brownlow

Date: 07-19-2016

Page 1 **of** 1



Core diameter = 8cm

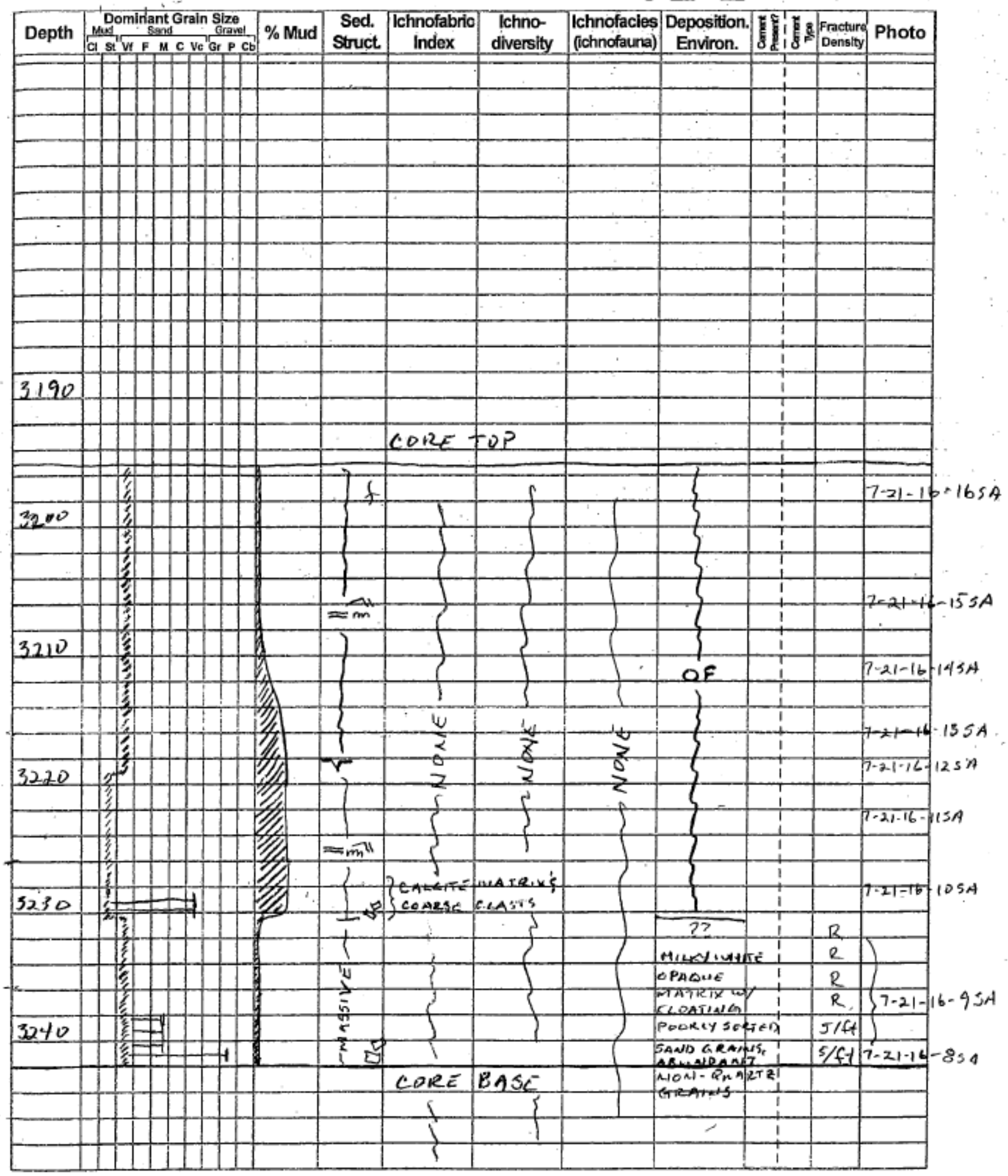
—Bottom of Core—
971.85 m

Metric Units (2.5cm = 3m)

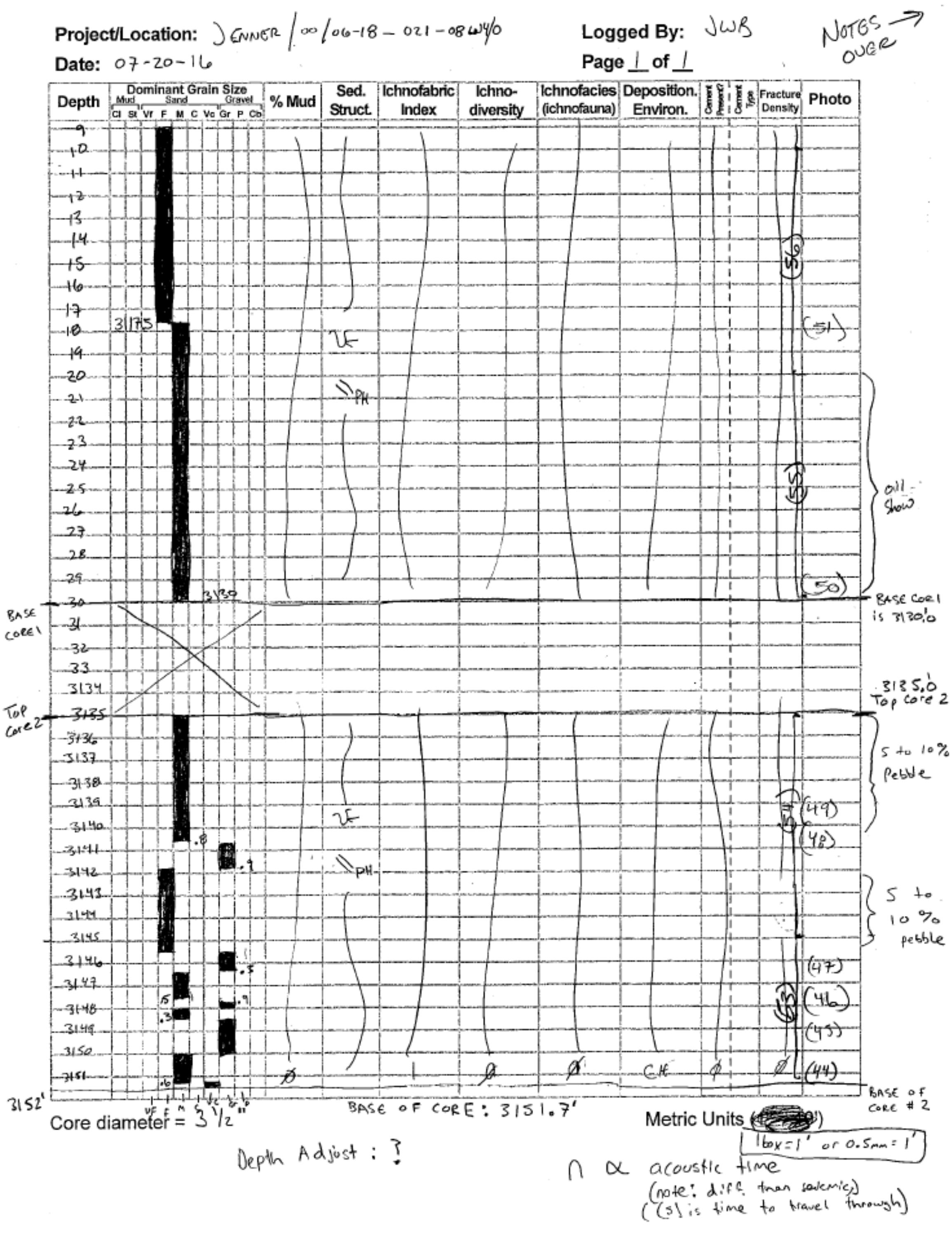
Core-Log Depth Correction: ?

Project/Location: JENNER/10-10-21-8W4 Logged By: ATCHLEY

Date: 7/22/16 Page 1 of 1



Core diameter = 9 cm Metric Units (1" = 10')


Project/Location: JENNER / 00/06-18-021-08W4/0
Logged By: JWB
NOTES OVER
Date: 07-20-16
Page 1 of 1
Depth
Dominant Grain Size
Mud Sand Gravel
Cl St Vf F M C Vc Gr P Cb
% Mud
Sed. Struct.
Ichnofabric Index
Ichno-diversity
Ichnofacies (ichnofauna)
Deposition. Environ.
Cement Present?
Cement Type
Fracture Density
Photo
3117.5
3130
BASE CORE1
BASE CORE 1 is 3130.0
3135.0 Top core 2
Top Core2
oil show
5 to 10% pebble
BASE OF CORE # 2
BASE OF CORE: 3151.7'
3152'
Core diameter = 3 1/2"
Metric Units
1 box = 1' or 0.5mm = 1'
Depth Adjust: ?
∩ ∝ acoustic time
(note: diff. than seismic)
((s) is time to travel through)

Project/Location: Jenner /00/06-18-021-08W4/0

Date: 7-20-16

Logged By: JWB

Page 2 **of** 2

Top of core: 3,100'

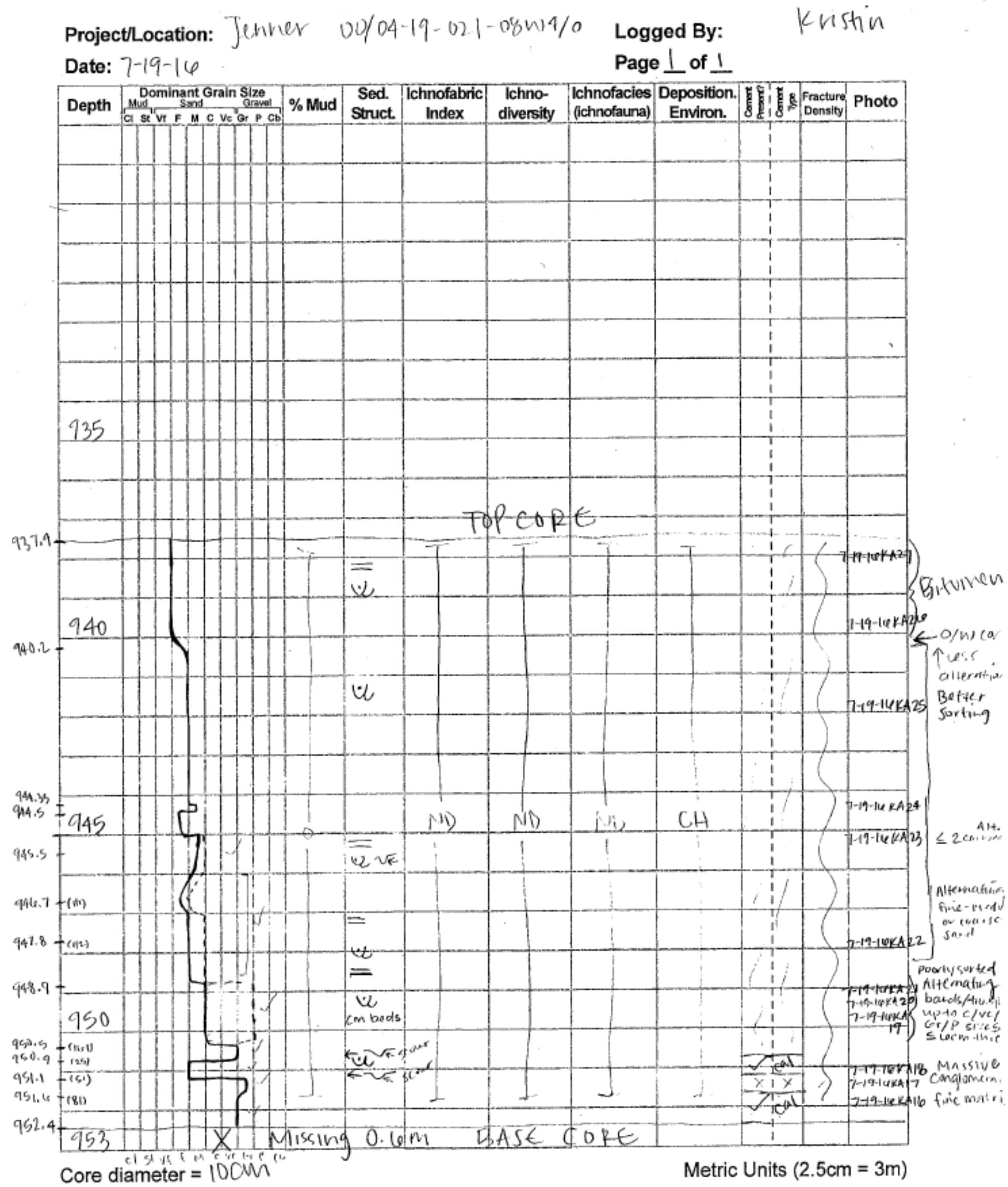
Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
3100 — 0											
1			=PH								(52)
2											
3			PT								
4											
5			=PH								(5[illegible])
6											
7											
8	Cl St VF F M	∅		1	∅	∅	CH	∅		∅	

END CORE #1

Core diameter = 3.5"

Metric Units (~~1"=~~10')

1 box = 1' or 0.5 mm = 1'



Depth shift : CORE - 1.2 = log
(940.2) (939)

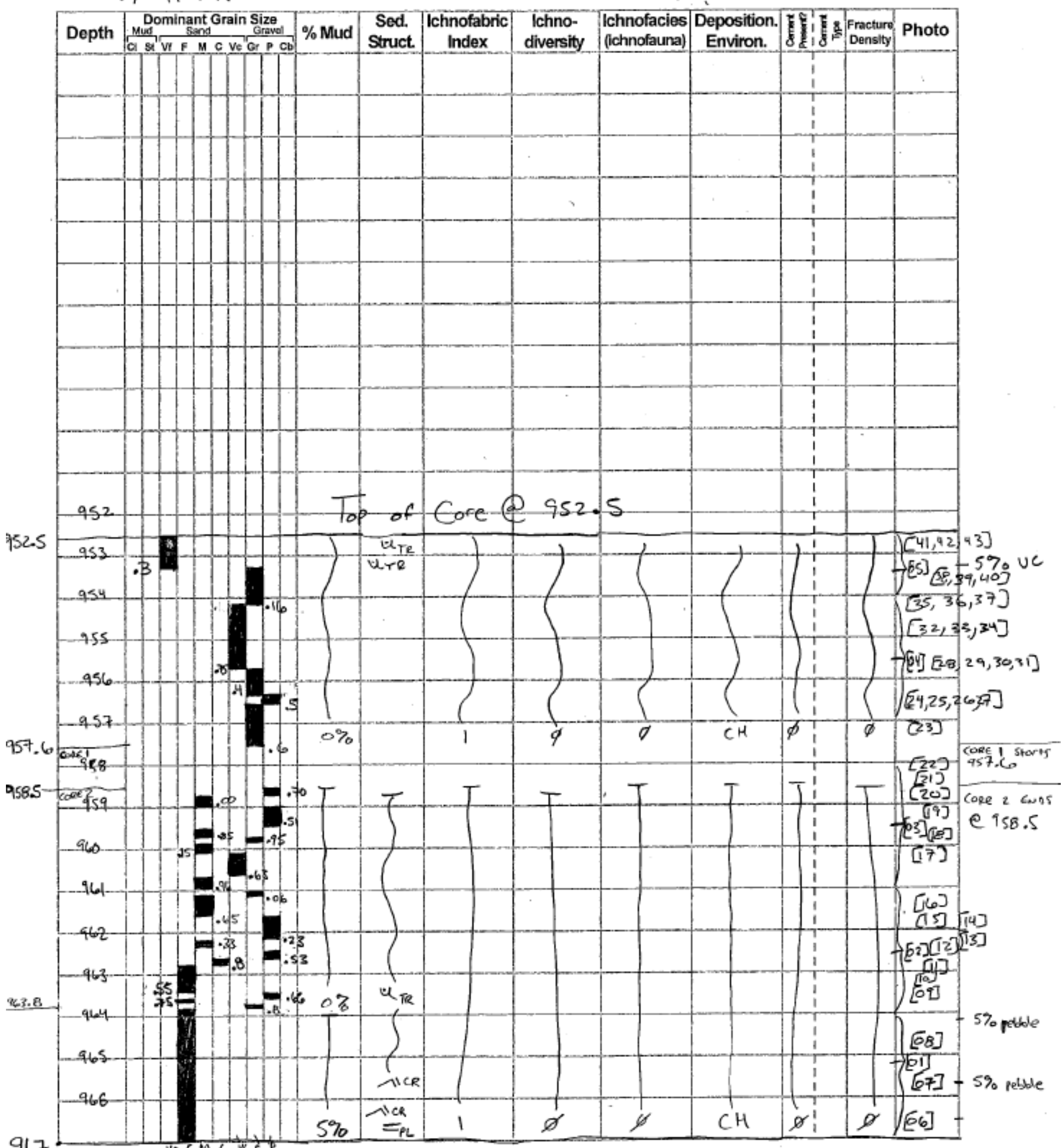
RECOMPLETE ? Well

Project/Location: JENNER / 09-12-021-09W4/0

Logged By: Brownlow

Date: 07 - 19 - 2016

Page 1 **of** 1



Core diameter = 8cm

BASE OF CORE @ 967.0 m

Metric Units (2.5cm = 3m)

See Back

ELOG - Core Adjust : ?

Project/Location: Jenner/ 00/14-12-21-9W4/0 **Logged By:** Kristin

Date: 7-19-16 **Page** 1 **of** 1

Depth	Dominant Grain Size (Mud: Cl St; Sand: Vf F M C Vc; Gravel: Gr P Cb)	% Mud	Sed. Struct.	Ichnofabric Index	Ichno-diversity	Ichnofacies (ichnofauna)	Deposition. Environ.	Cement Present?	Cement Type	Fracture Density	Photo
942				Core	Top						
942.25											
943											7-19-16 KA14
943.1											7-19-16 KA13
943.3											
943.7											
943.8 / 944		0%					CH				7-19-16 KA12
944.4											7-19-16 KA11
944.8 / 945											7-19-16 KA9
945.2											7-19-16 KA8 & KA10
945.4											
946	X	0.6m	Missing		CORE	BASE					

Conglomerate well round

Pebble-Granule

Prime Example Max-K

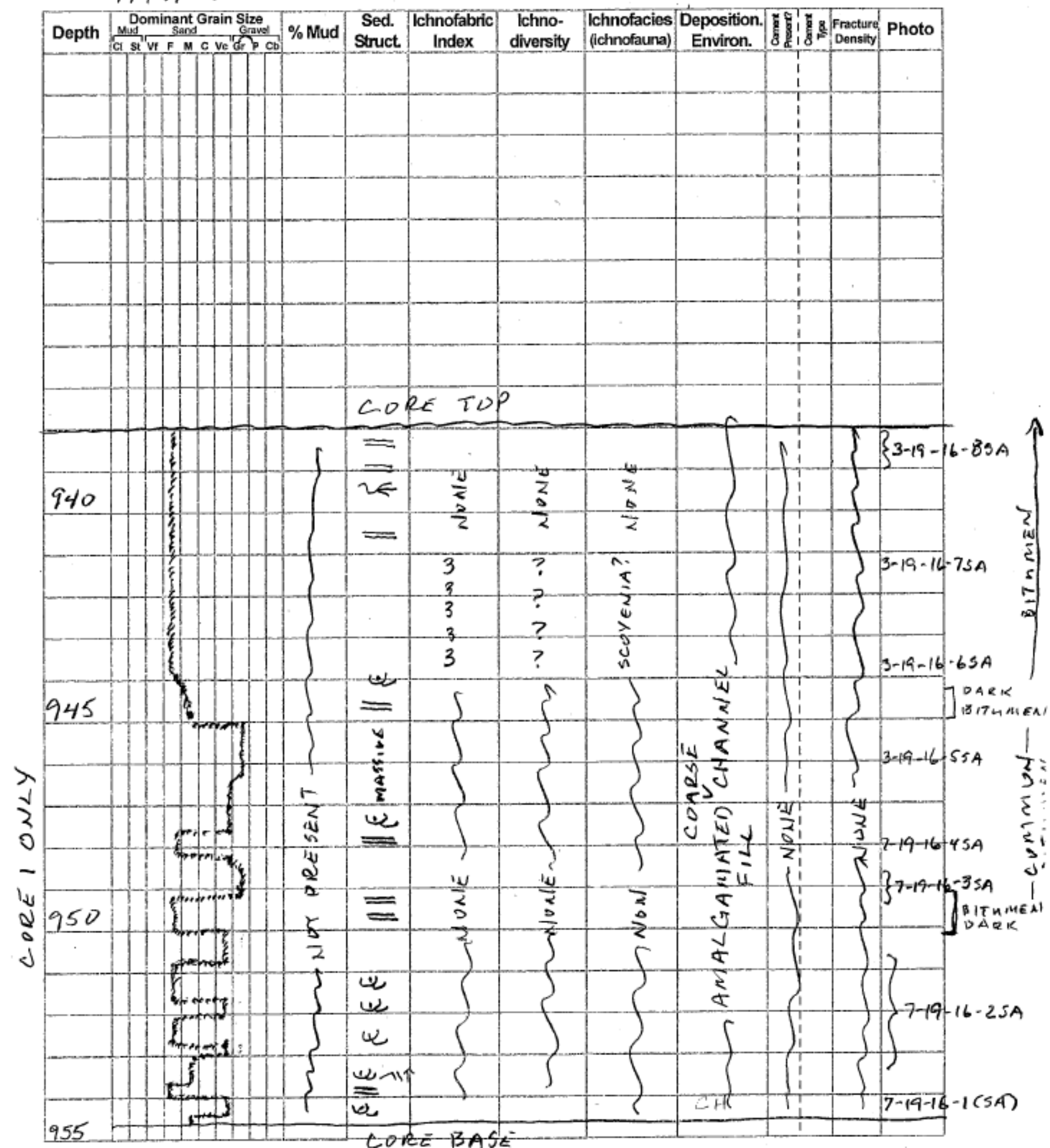
Core diameter = 9cm (vc/or)

? depth/log shift

Metric Units (2.5cm = 3m)

Project/Location: JENNER / 8-13-21-9W4 **Logged By:** ASHLEY

Date: 7/19/16 **Page** 1 **of** 1



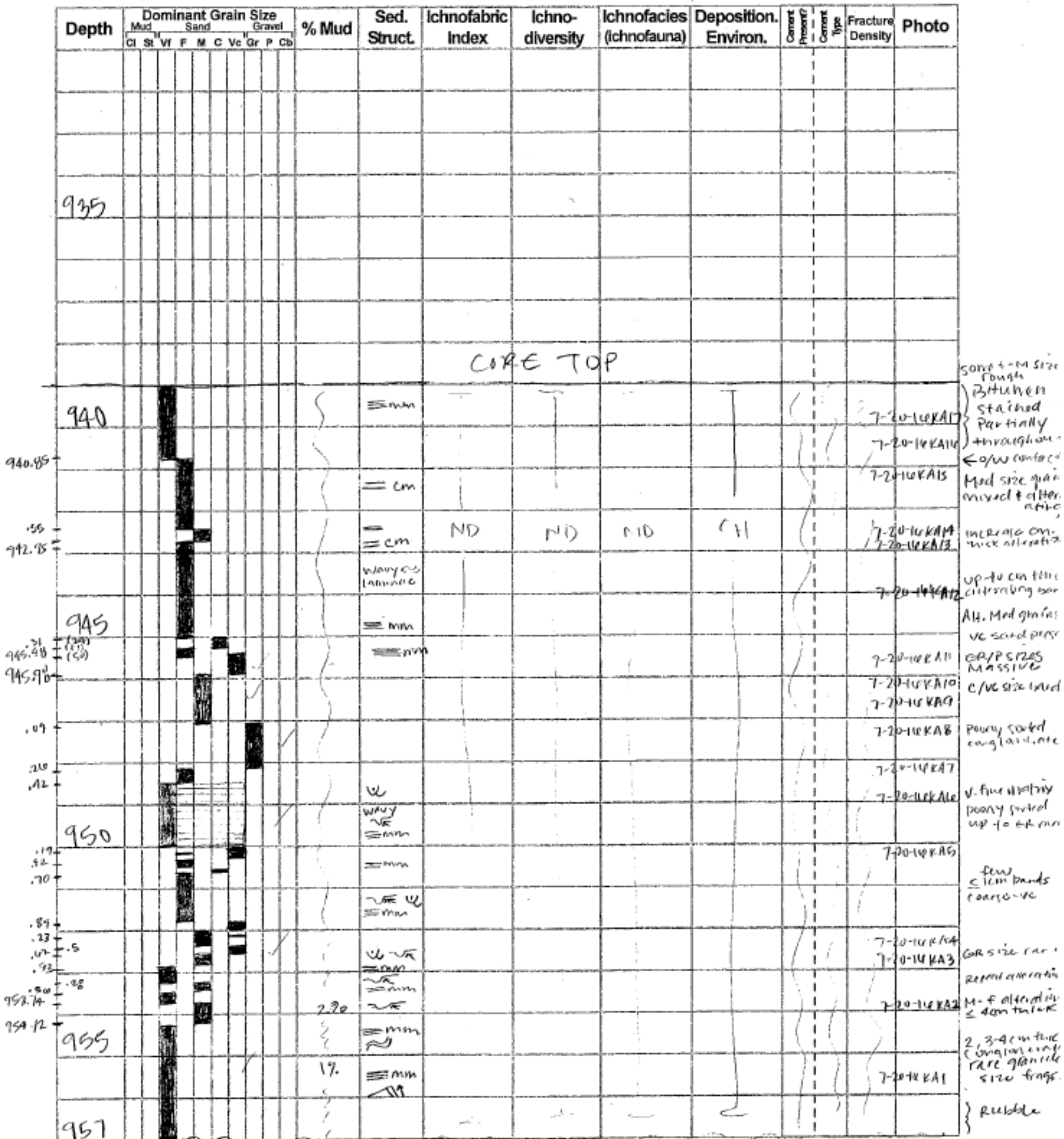
Core diameter = 9 cm Metric Units (2.5cm = 3m)

DEPTH SHIFT = ?

Recompletion/Redrill possible

Project/Location: Jenner 02/10-13-021-09W4/0 **Logged By:** Kristin

Date: 7-20-16 **Page** 1 **of** 1



Core diameter = 10cm Metric Units (2.5cm = 3m)

Depth shift: None
(If any slightly ↓)

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