Athabasca Oil Sands Database

McMurray/Wabiskaw Deposit

Alberta Geological Survey

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Disclaimer

Acquisition Options

The data described in this report can be obtained in electronic form. Custom retrievals and mapping of the results can be offered as a special service. Requests for more information should be sent to:

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Introduction

In 1986, the Alberta Geological Survey began a project to map systematically the McMurray Formation and the overlying Wabiskaw Member of the Clearwater Formation in the Athabasca Oil Sands Area. The McMurray/Wabiskaw Oil Sands Deposit contains approximately 142 x 10^9 m^3 of bitumen (ERCB, 1990), making it the largest oil sands deposit in Alberta and in the world (Meyer and Duford, 1989). From project inception, it was intended to acquire and store data electronically in order to facilitate data manipulation, generation of maps and cross sections, and the ultimate release to the public. The electronic data which accompany this report are one of the most significant products of the project and will hopefully facilitate future development of the oil sands.

The Athabasca Oil Sands Area was divided into four regions (Figure 1); North (T 91–104, R 5-21W4), Central (T 80-90, R 1-18W4), South (T 67-79, R 1-18W4) and West (T 70-90, R 19W4-5W5). The study was designed to provide a regional geological framework and publications have been released for each of the areas: North (Flach, 1984; Andersen et al., 1993), Central (Keith et al., 1990), South (MacGillivray et al., 1992) and West (Strobl et al., in press).

This report serves as a user guide for the electronic database. It provides a description, including representative well logs and two cross sections, of the stratigraphic picks contained in the database as well as descriptions of the database and the method of well log analysis. The database is implemented on a VAX station 4000 using INGRES, a commercially available database management system. It contains data on 2193 wells, including about 750 wells which have core analyses.

By using a relational database to manage both the picks and log analysis data for the resource characterization studies, data management is greatly simplified and data consistency is assured. Database entry forms provide an easy method for adding and updating data. Database reports are based on using Structured Query Language (SQL) statements, a standard of the American National Standards Institute (ANSI), and are used to extract data for all standard maps, while interactive SQL can be used for special queries. The database management system performs all necessary calculations as the data are extracted.

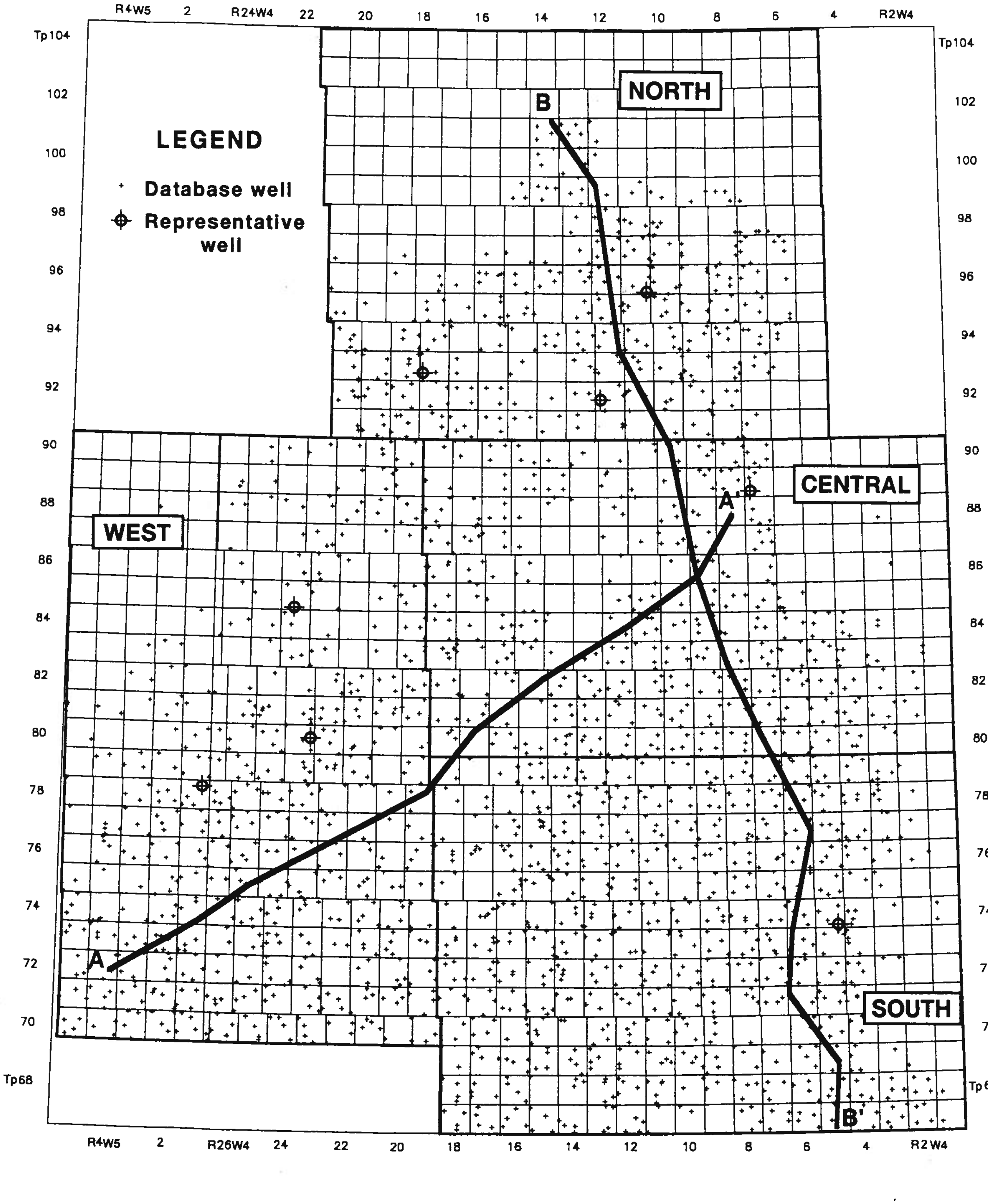

Figure 1. Study area with locations of wells, representative wells and cross sections.

Stratigraphic Data

Four wells per township were used to characterize the bitumen, gas and water resources within the Athabasca Oil Sands Area (Figure 1). Wells were selected on the basis of geographic distribution, quality of the geophysical logs (gamma ray, resistivity and porosity), and the presence of core analysis. Formation tops and markers picked from well logs were verified by selected cored wells and a network of interlocking stratigraphic cross sections.

Data quality varies within any study so a parameter was developed to record this variation. Each stratigraphic pick was assigned a quality code which indicates the presence or absence of a pick and the degree of confidence placed on the correlation. The quality codes are: (-1) no pick, pick is unknown, or no data available; (0) pick is missing or eroded, high degree of confidence based on a complete data set and log suite; (1) good pick, with a high degree of confidence based on geophysical log correlation and core control; (2) pick is highly interpretive, but confirmed by surrounding wells; (3) pick is uncertain, due to poor or missing data and/or low degree of confidence in correlation; and (4) pick is based primarily on drillers logs or other reliable drilling information.

The majority of picks in the database have a quality code of '0' or '1' indicating a high degree of confidence in the pick. Quality code 4 applies only to the Paleozoic (sub-Cretaceous unconformity) pick. Some wells penetrate a very short distance into the Paleozoic section and geophysical tools are unable to record the unconformity due to slumping or 'short hole' conditions.

Stratigraphic framework

The McMurray Formation forms the basal unit of the Lower Cretaceous Mannville Group and directly overlies the sub-Cretaceous unconformity developed on Paleozoic carbonates in the Athabasca area. It represents the initial sedimentation on a long standing unconformity in response to a relative rise in sea level to the north. The McMurray Formation is predominantly a channelized succession of fresh to brackish water deposits, with the degree of marine influence generally increasing to the north (Flach, 1984; Wightman and Pemberton, 1993).

At the end of McMurray time, the boreal sea transgressed southward creating a marine environment in which the Wabiskaw Member, the basal unit of the overlying Clearwater Formation, was deposited. The contact between the McMurray Formation and the Wabiskaw Member is erosional and usually marks a change from continental/brackish water deposits (McMurray Formation) to more fully marine sediments (Wabiskaw Member). As well, the McMurray Formation is more quartzose than the Wabiskaw Member due to a change in provenance (Badgley, 1952; Bayliss and Levinson, 1976; Flach, 1984; Wightman et al., 1991).

A new sequence stratigraphic framework, which is applicable to the entire Athabasca area, has been developed for the McMurray/Wabiskaw interval. The new stratigraphic scheme provides the basis for a consistent oil sands database, fundamental to regional resource assessment, and facilitates detailed reservoir continuity studies. It consists of two types of regionally correlatable surfaces: E surfaces, which are erosional surfaces with pronounced relief, and T surfaces, which are transgressive erosional surfaces with low relief. These surfaces include the E10, T10.5, T11, E14, T15, and T21 within the McMurray/Wabiskaw interval. Surfaces within the overlying Clearwater and Grand Rapids formations include T31, T51 and T61. The sub-Cretaceous unconformity, which underlies the McMurray Formation and is developed on rocks of Paleozoic age, and the top of the Mannville Group were also picked.

The Mannville Group outcrops in the Athabasca area, with post-Cretaceous erosion progressively downcutting to deeper stratigraphic horizons to the northeast due to an overall southwesterly dip. In parts of Athabasca North, Pleistocene and Holocene erosion have removed the Wabiskaw Member and part or all of the McMurray Formation. In the areas where the McMurray Formation has been partly eroded, the picks within and above the Wabiskaw Member have no depth values.

T and E Surfaces

T surfaces as used in this study are surfaces of erosion that mark the base of marine transgressions and therefore signal abrupt increases in water depth. Similar surfaces have been termed marine flooding surfaces (Van Wagoner et al., 1988), ravinement surfaces or transgressive surfaces of erosion (Walker, 1992). Parasequences are conformable successions that are bound by transgressive surfaces of erosion (Van Wagoner et al., 1988). T surfaces are usually picked at the base of mudstones that form the lower part of coarsening upward parasequences. However, the surfaces can be correlated in a shoreward direction where the mudstone disappears and the erosional contact separates two sands. In these instances, the erosional contact is usually marked by a high degree of bioturbation (with a chaotic trace fossil assemblage), the presence of glauconite and lag deposits in the overlying sand. T surfaces tend to display low relief and the amount of associated erosion may be relatively minor, consisting mainly of reworking the underlying sediment.

E surfaces as used in this study represent surfaces of subaerial erosion formed by a relative drop in sea level and a basinward shift in shoreline position. E surfaces commonly display high relief and include such features as incised valleys. In sequence stratigraphic terms, this type of surface is similar to a type 1 sequence boundary (unconformity; Van Wagoner et al., 1988). Outside of incised valleys, E and T surfaces tend to merge and are indistinguishable on well logs. However, within incised valleys the E and T surfaces separate and an isopach of the separation represents the valley fill. Incised valleys can have a variety of fills including continental sediments, marine sediments deposited during the subsequent transgression, or a combination of the two.

Pick descriptions

Two cross sections (Figures 2 and 3) illustrate regional correlations in the Athabasca area and representative wells (Figures 4 to 11) depict the marker and formation picks in detail. The characteristics of each of the picks is described in the following section.

Paleozoic (Sub-Cretaceous Unconformity)

The McMurray Formation overlies the sub-Cretaceous unconformity, which is usually picked using the density or sonic log. On density logs the unconformity is identified by a distinct increase in density passing from the Lower Cretaceous siliciclastics to the underlying Paleozoic carbonates (Figures 4 to 9). Similarly, the sonic log displays a distinct decrease in transit time in the Paleozoic section. These signatures are best defined with dense, clean carbonates which underlie the sub-Cretaceous unconformity surface over most of the region. Sonic and density responses may be less well defined where the Paleozoic succession is shaly (e.g. Ireton Formation). The shaly carbonates still have higher densities than Cretaceous mudstones and the resistivity log is useful as the oil sands in the McMurray Formation have high resistivities.

McMurray Formation

McMurray (Top of McMurray Formation)

Within the McMurray Formation, some stratigraphic units and surfaces are correlatable over short distances, but no surfaces were found that were correlatable at the regional scale of this study. As can be seen near Fort McMurray, outcrops along a single river valley are distinguished by variability, with channel and off-channel deposits at different levels within the formation (Wightman and Pemberton, 1993).

The top of the McMurray Formation is best picked in cores and then correlated to the surrounding wells. The McMurray Formation is distinguished by brackish water trace fossils, while the Wabiskaw Member contains larger trace fossils with more of a marine affinity (Wightman et al., 1991). Mudstones in the McMurray Formation tend to be light grey to tan; mudstones in the Wabiskaw Member tend to be dark blue-grey. The sands can be distinguished based on mineralogy, and an erosional surface, commonly with a lag deposit, marks the contact. On well logs, the neutron curve may show a shift to higher porosities in the Wabiskaw Member, which probably reflects the mineralogic change from the quartzose McMurray Formation to the litharenitic Wabiskaw Member (Figure 8).

In parts of Athabasca North, Pleistocene erosion has removed the Wabiskaw Member and cut down into the McMurray Formation, leaving it anomalously thin (Figure 9).

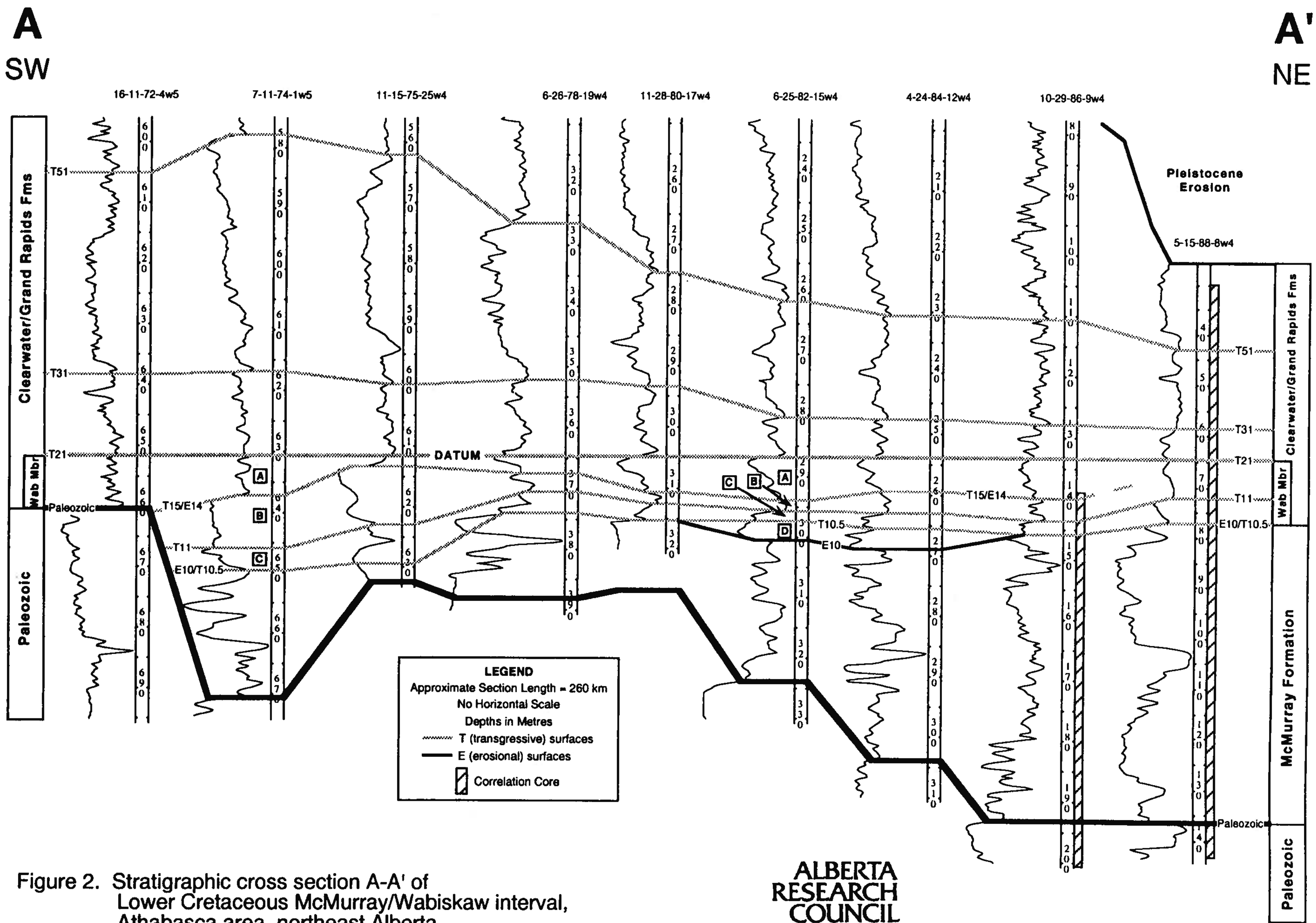

Figure 2. Stratigraphic cross section A-A′ of Lower Cretaceous McMurray/Wabiskaw interval, Athabasca area, northeast Alberta.

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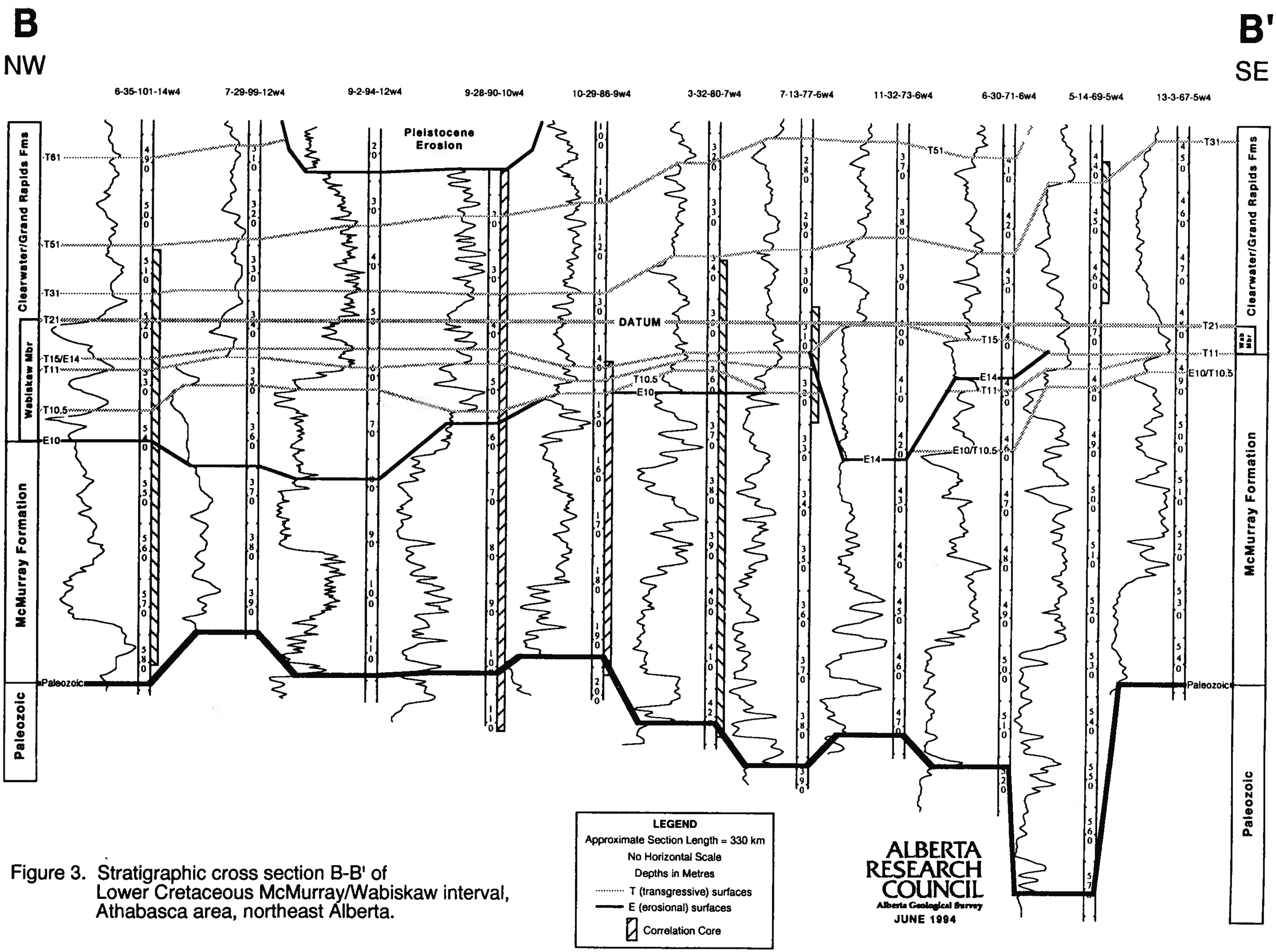


Figure 3. Stratigraphic cross section B-B' of Lower Cretaceous McMurray/Wabiskaw interval, Athabasca area, northeast Alberta.

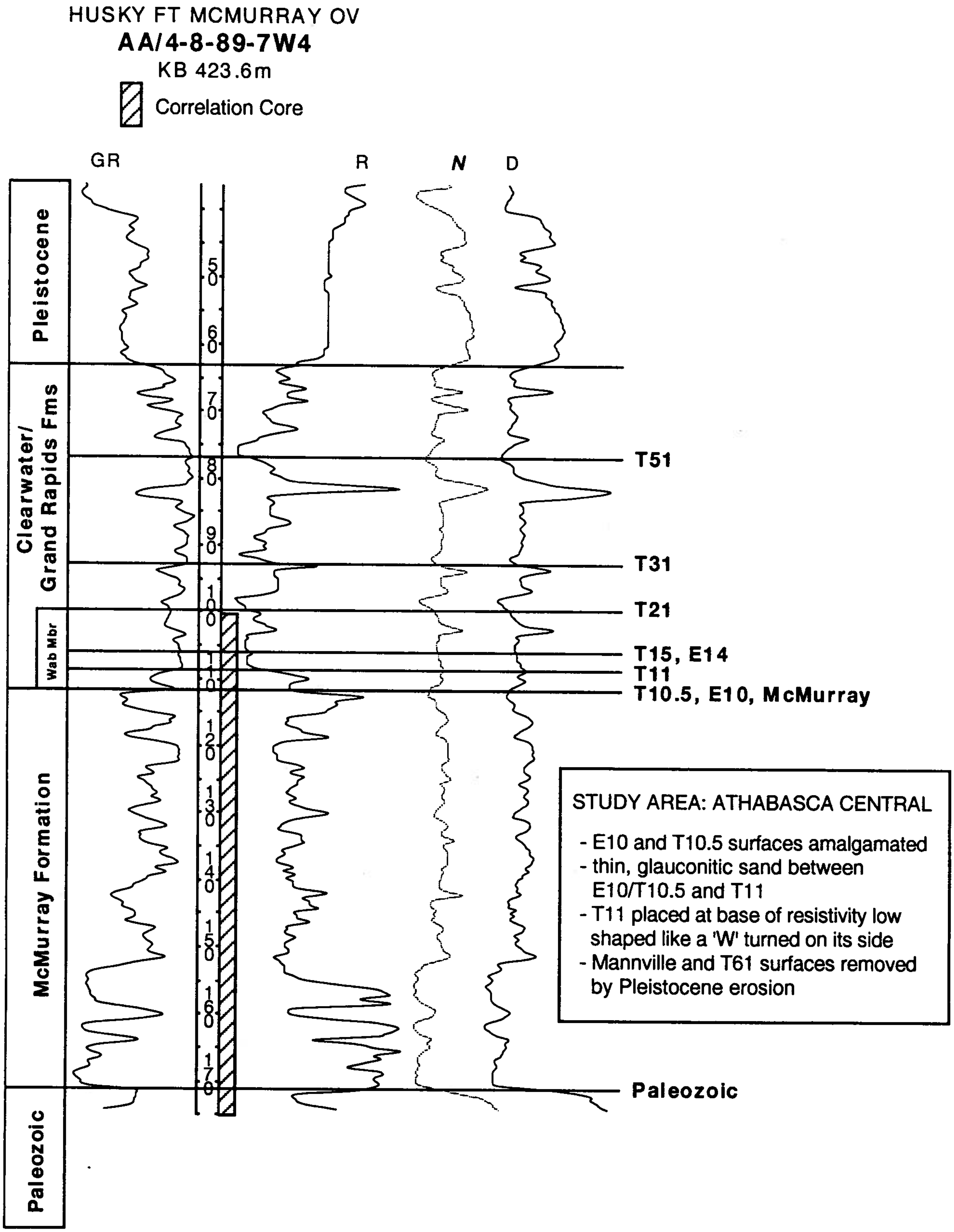


Figure 4. Representative well: 4-8-89-7w4.

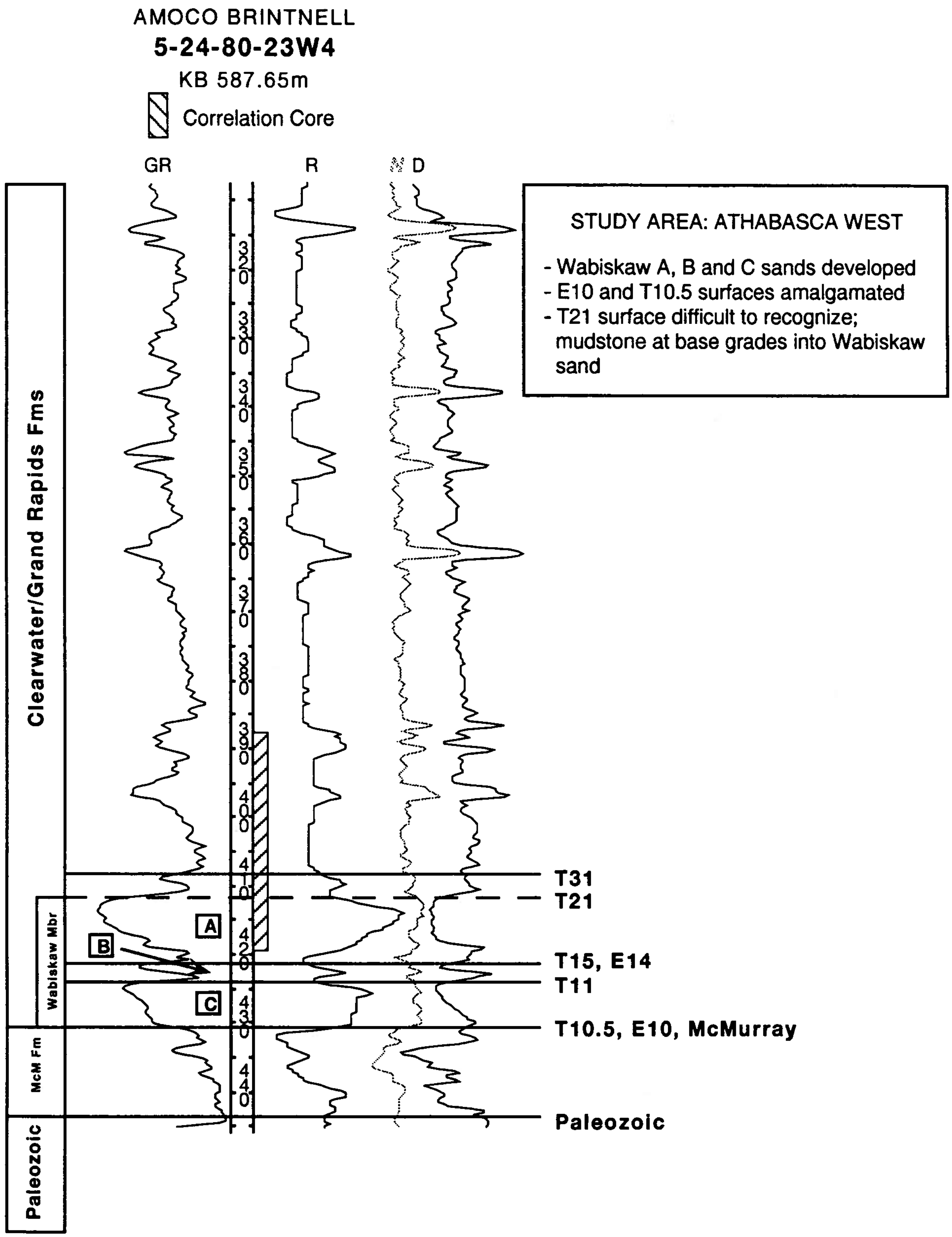


Figure 5. Representative well: 5-24-80-23w4.

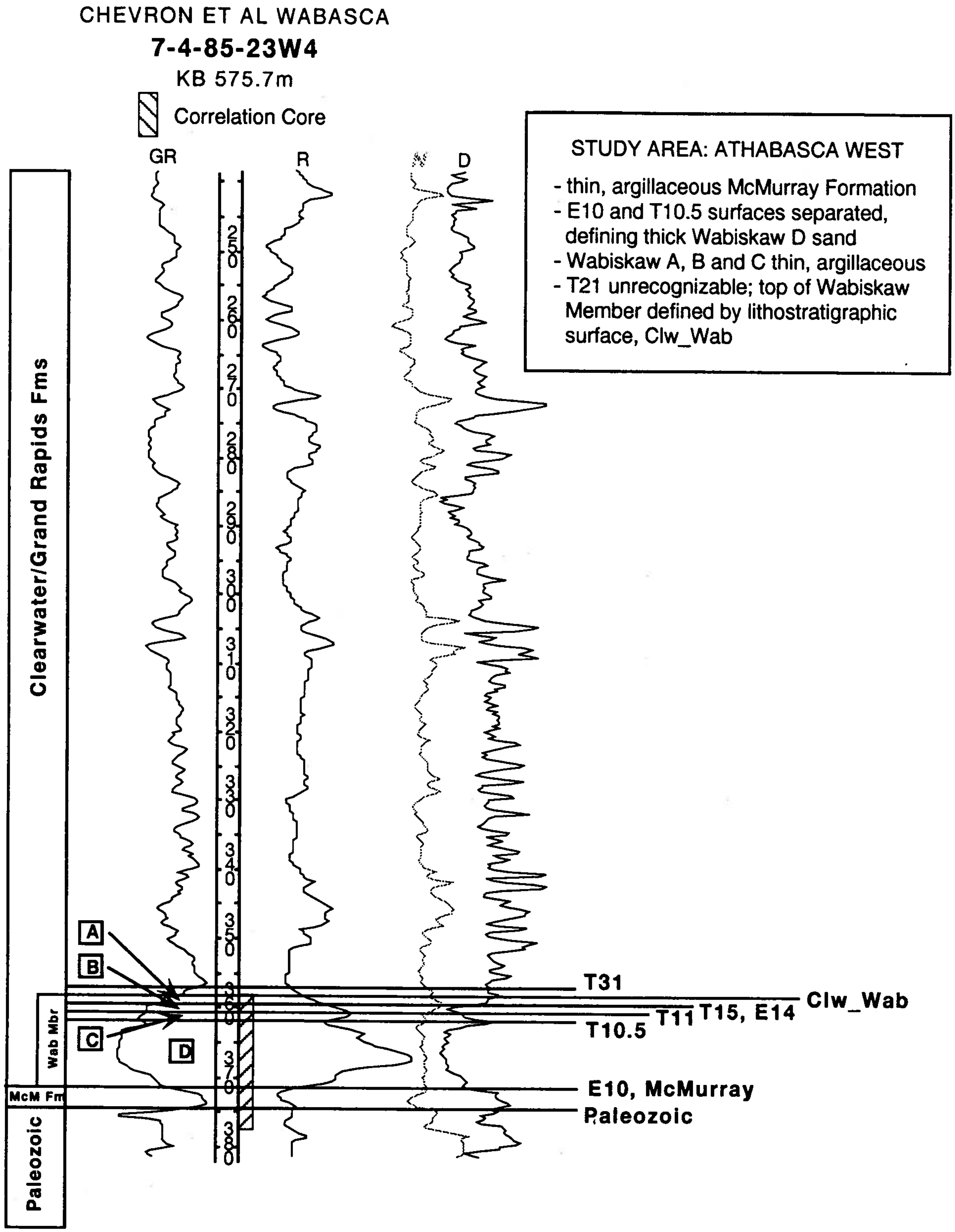
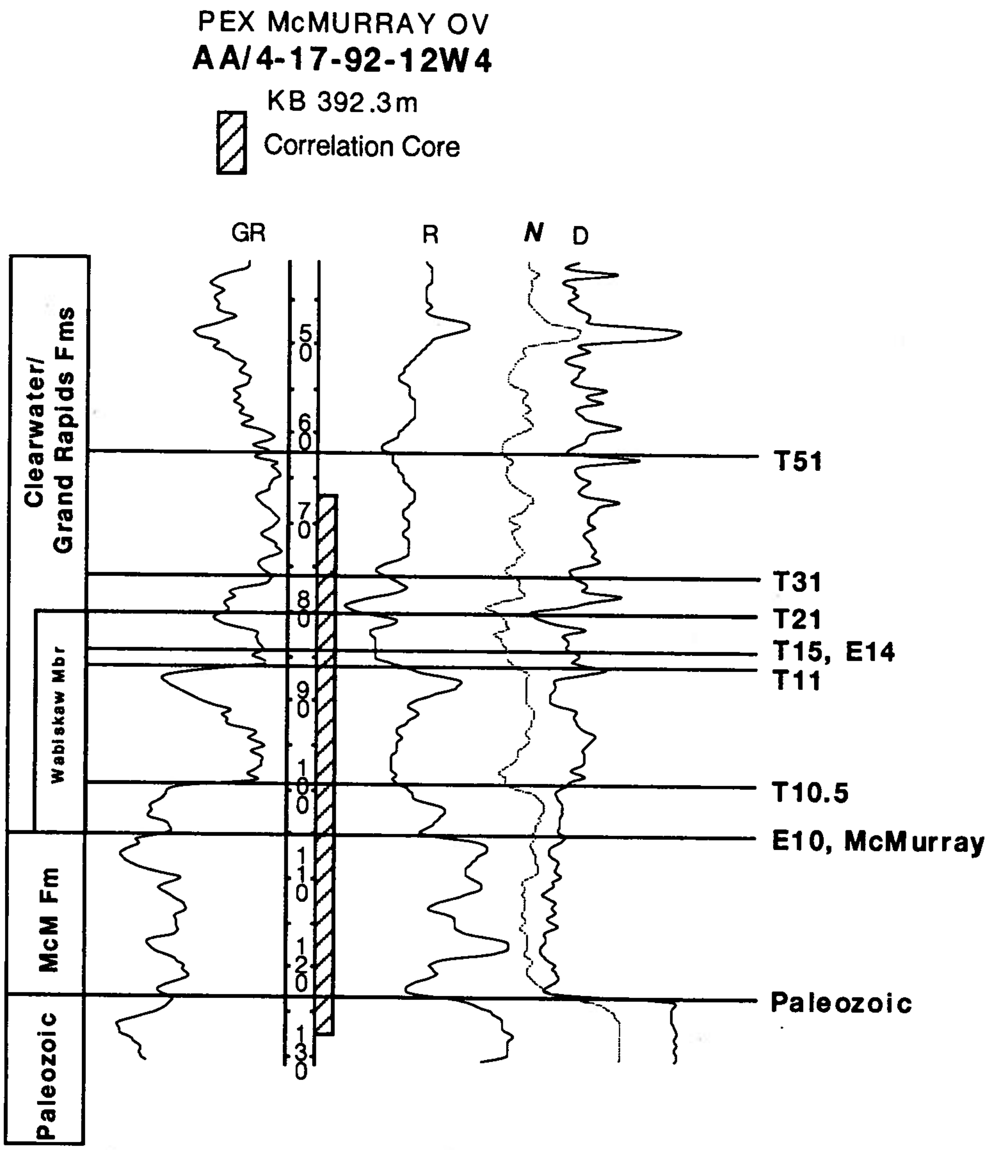


Figure 6. Representative well: 7-4-85-23w4.



STUDY AREA: ATHABASCA NORTH

- E10 and T10.5 surfaces separated
- T10.5 marked by sharp break in lithology
- thick interval between T10.5 and T11

Figure 7. Representative well: 4-17-92-12w4.

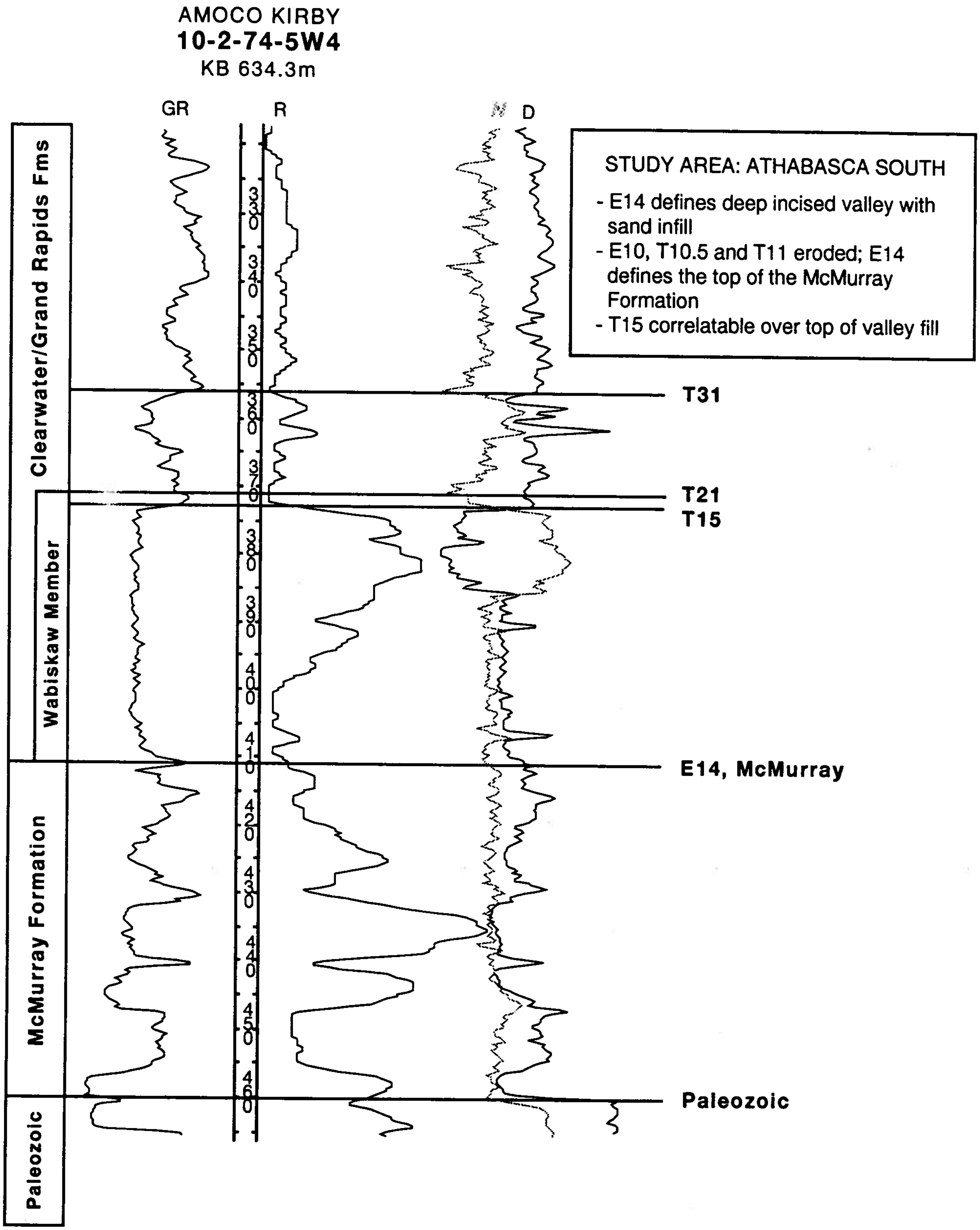
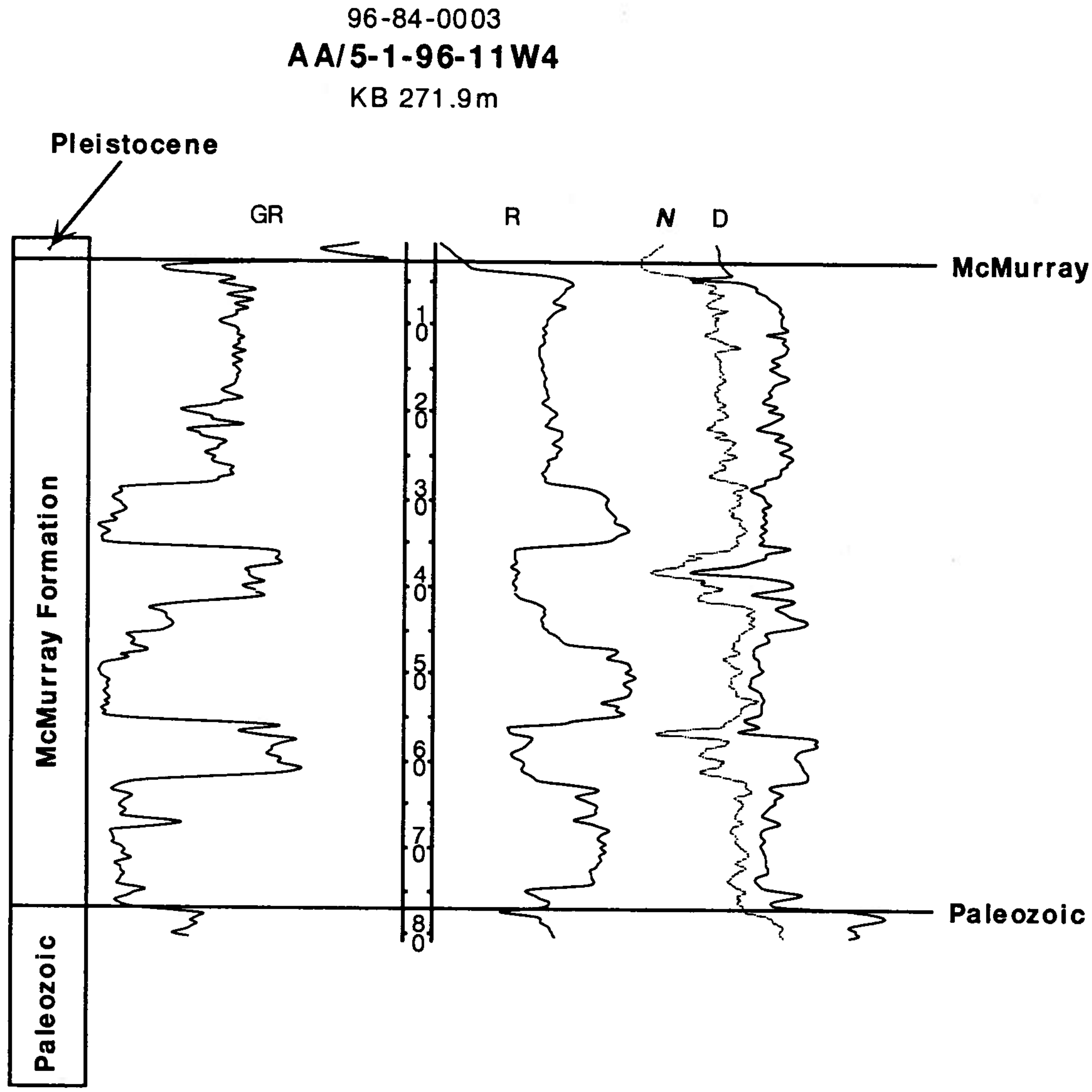


Figure 8. Representative well: 10-2-74-5w4.



STUDY AREA: ATHABASCA NORTH

- Pleistocene sediments directly overlie McMurray Formation
- E10, T10.5, T11, E14, T15, T21, T31, T51, T61 and Mannville surfaces removed by Pleistocene erosion

Figure 9. Representative well: 5-1-96-11w4.

E10

A relative drop in sea level at the end of McMurray time resulted in erosion and development of incised valleys at the top of the succession (Figures 2 and 3). These are particularly prominent in Athabasca West and North. In the interfluves, E10 merges with the overlying transgressive surface of erosion, T10.5 (expressed as E10/T10.5). Over most of the Athabasca area, E10 or E10/T10.5 corresponds to the top of the McMurray Formation/base of the Wabiskaw Member (Figures 4 to 7, 10 and 11).

Wabiskaw Member

T10.5

Transgression of the boreal sea in early Wabiskaw time resulted in infill of the incised valleys and a transgressive surface of erosion overlying the valley fills and the adjacent interfluves, where E10 and T10.5 merge. T10.5 is commonly marked by a coarse grained lag, glauconitic sands and large trace fossils that produce a chaotic bedding. Where the Wabiskaw Member is from 5 m to 10 m thick below T11 and there is no discernible or correlatable break within the succession, T10.5 is put at the same position as E10 (Figures 4, 5 and 10). Where the Wabiskaw Member is greater than 10 m thick below T11, there is generally a recognizable break between E10 and T10.5 (Figures 6, 7 and 11).

T11

T11 is picked at the base of the regional marine shale (RMS), the first regionally correlatable lithological unit in the McMurray/Wabiskaw interval. This laterally extensive mudstone is most often identified by a resistivity low in the shape of a 'W' turned on its side (Figure 4). In addition, the neutron curve generally displays a significant shift to a high neutron porosity within the RMS. In the interfluves in Athabasca Central and South, E10/T10.5 and T11 are commonly separated by a very thin glauconitic sand (less than 3 m) which is discernible on logs; however, this should be verified by core. In some areas, particularly in Athabasca West, T11 can be correlated landward where the mudstone pinches out and the surface lies within an amalgamated sand (Figure 2).

E14

A relative drop in sea level during deposition of the Wabiskaw Member resulted in erosion of the regional Wabiskaw succession and development of incised valleys. This surface is well developed in the Primrose area of Athabasca South where the valley fill is comprised of a thick sand (Figures 3 and 8). Valley incision was deep so that E14 marks the top of the McMurray Formation/base of the Wabiskaw Member in most of the Primrose wells. E14 merges with T15 outside of the incised low (Figures 3 to 7, 10 and 11).

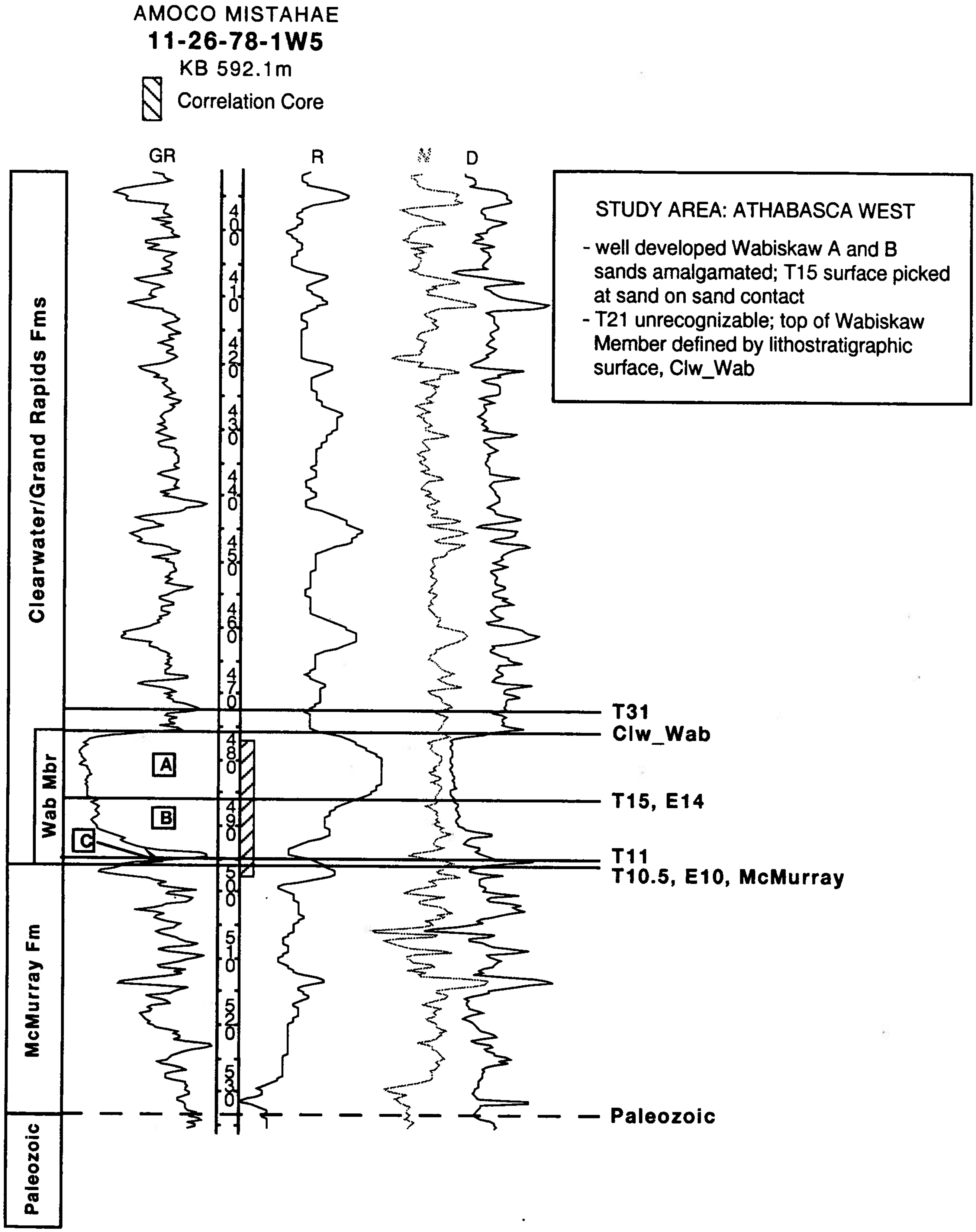


Figure 10. Representative well: 11-26-78-1w5.

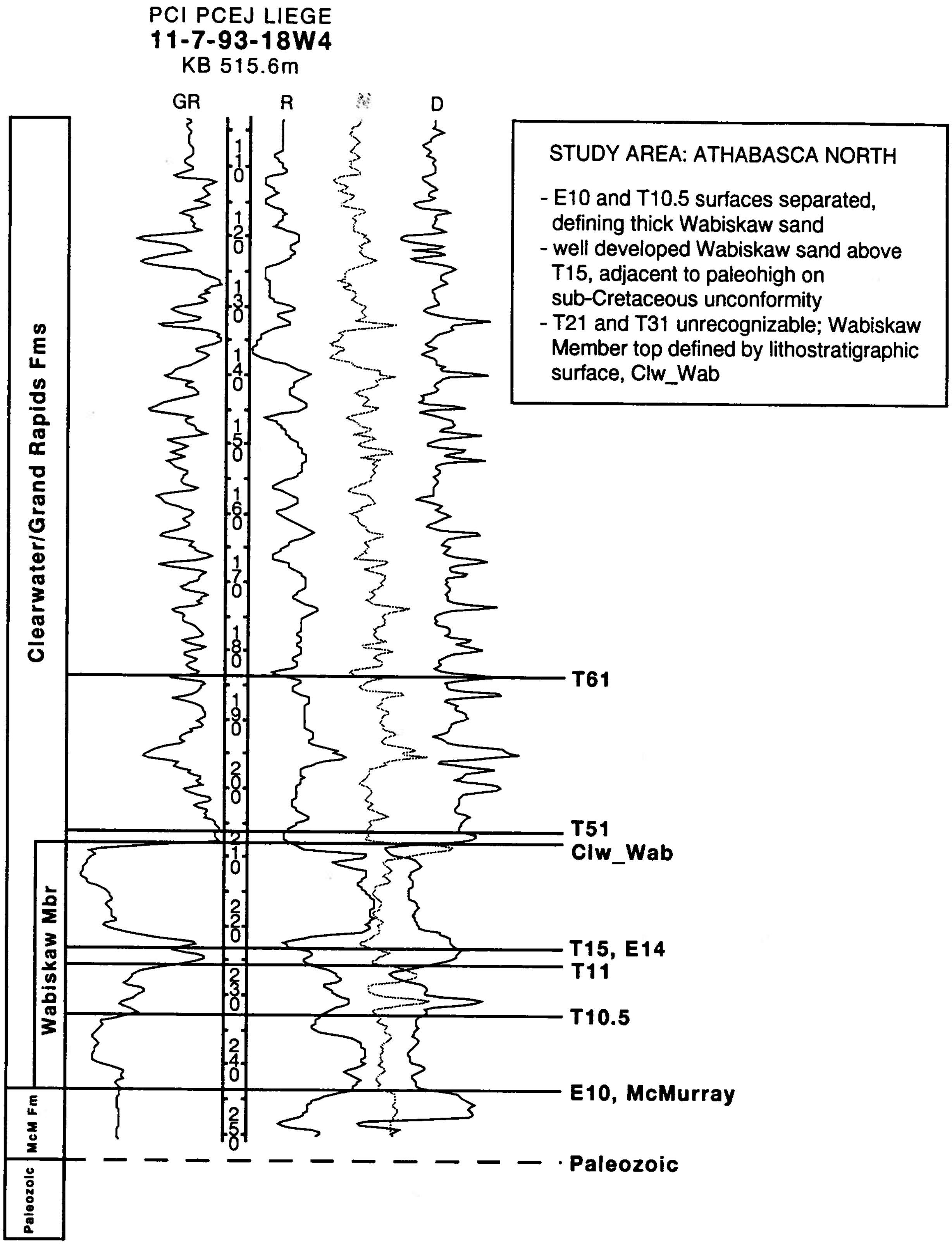


Figure 11. Representative well: 11-7-93-18w4.

T15

In Athabasca North, Central and South the RMS has a characteristic 'W' shape, turned on its side, on the resistivity curve. The middle spike of the 'W' represents a siltstone which is underlain and overlain by mudstones which comprise the RMS. T15 marks the base of the mudstone that overlies the siltstone and is thus a marker within the RMS (Figure 4). Where the siltstone thins and pinches out, mainly to the north, this surface is not identifiable. In Athabasca West, the thin siltstone coarsens and thickens into a sand so that T15 marks the base of the mudstone overlying the 'B' interval (Figures 2 and 5); in a landward direction, the mudstone pinches out and T15 occurs within an amalgamated A/B sand (Figure 10).

T21

T21 is placed at the base of a distinctive low resistivity mudstone, termed the Wabiskaw Marker, that also defines the top of the Wabiskaw Member (Figures 4, 7 and 8). This mudstone is usually less than 5 m thick, tends to have a high neutron porosity and, in core, is generally black. In the extreme southeast of the study area (Figure 3), the RMS and Wabiskaw Marker merge into one mudstone.

Clw_Wab

In several areas in Athabasca North, Central and West, the top of the uppermost sand in the Wabiskaw Member rises stratigraphically and the Wabiskaw Marker (T21) merges into this sand. In these instances, the top of this sand is designated as the Clearwater/Wabiskaw (Clw_Wab) and is used to define the top of the Wabiskaw Member, even though it is slightly younger than t21 (Figures 10 and 11). T21 also downlaps to the northwest where it becomes difficult to distinguish, due to loss of its characteristic log response; it is also designated as the Clearwater/Wabiskaw in this area, to define the top of the Wabiskaw Member (Figure 6).

Clearwater Formation

T31

T31 is placed at the base of a distinctive, low resistivity mudstone that has a high neutron porosity and is generally less than 5 m thick (Figures 4 to 8 and 10). The mudstone is the lowest unit in the Mannville Group that has a pronounced northward downlap (Figure 3). In Athabasca West, it was used as a datum for cross sections as there is less downlapping to the north in this area. In the south, T31 correlates with the base of the shale that defines the top of the Clearwater Formation in the Cold Lake area (Wightman and Berezniuk, 1991).

Grand Rapids Formation

T51 and T61

T51 and T61 mark the bases of two distinctive, low resistivity shales that are regionally correlatable (Figures 4, 7 and 11). T51 and T61 are prominent in Athabasca North, Central and South where they downlap to the north (Figure 3). Within the database, T51 and T61 are picked only in Athabasca North and adjacent areas of Central and West where these surfaces were used as datums for cross sections.

Mannville (Top of Mannville Group)

The top of the sand dominated Mannville Group is marked by an erosional contact which is overlain by marine shales of the Colorado Group; the contact is less certain in the extreme northwest where the Mannville Group becomes shaly. This pick is absent over much of the northeastern part of the study area due to post-Cretaceous erosion.

Well Log Analysis

Well log analysis was performed using INTELLOG, a product of D&S Knowledge Systems Inc., on a 486 based workstation running the SCO XENIX System V Operating System. The workstation contains an Ethernet card for high speed communications with a VAX Cluster.

INTELLOG is an integrated log analysis system containing modules to enter/edit data, including logs and parameters; perform computations; plot logs; generate reports containing raw data, parameters and results; and a communications module for moving data in and out of the system. It contains an internal relational database particularly suited to log analyses. All logs, constants, tops and markers, algorithms, routines, computations, plot formats, and other entities used for log analysis are stored in the database. The system comes with a variety of predefined algorithms, routines, computations, and plot formats. The user can add to and modify any of these entities.

Data Entry and Editing Module

Four types of records must be entered into the INTELLOG database before analysis can be performed.

1. Well records

   Well records contain information such as well name, well location, Kelly Bushing (KB) elevation, top and bottom depths, and sampling rate of digital log curves. An example of the well record used for well 00/03-12-095-16W4/0 is included in Appendix A.

2. Log header records

   Log header records contain information on mud weight and resistivity, bottom hole temperature, and other parameters needed to interpret the log curve. An example of a log header record is included in Appendix A.

3. Log curve records

   Well logs, printed from microfiche, were digitized with a sampling interval of 0.25 m. Where possible the following logs were digitized:

   CAL - calliper.

   GR - gamma ray.

   PHIN - neutron porosity.

   PHID - density porosity.

   RESD - deep resistivity.

4. Constants records

Constants records contain information such as tortuosity exponent (A), cementation exponent (M), saturation exponent (N), densities of matrix and fluids, cutoff values such as gamma ray readings for pure sand and shale, and resistivity of formation water (RW). A constants record can be defined for all of the wells in a study, each well in a study, multiple intervals in each well, or any combination of these. An example of a constants record is shown in Figure 12.

Constant Name	Value	Comments
A	0.62	tortuosity exponent
GASCOR	1	use gas correction (0 - no, 1 - yes)
GR0	35	gamma ray reading in 100% clean zone
GR100	130	gamma ray reading in 100% shale zone
M	2.15	cementation exponent
N	2	saturation exponent
PHIDSH	0.23	density log reading in 100% shale zone
PHIMAX	0.38	maximum expected porosity in clean zone
PHINMA	1	neutron matrix
PHINSH	0.4	neutron log reading in 100% shale zone
RHOHY	1004	hydrocarbon density
RHOMA	2650	density of matrix
RHOSH	2700	density of shale
RHOW	1000	density of water
RSH	30	resistivity of shale
RW	0.6	resistivity of water
RWT	15	temperature of formation water
TRACE	0	flag used for output
USEMINVSH	1	use maximum Vsh of all methods

Figure 12. Example of a constants record.

Computations Module

INTELLOG uses three levels of computation: algorithms, routines, and computations. Combining these with constants records provides great flexibility during log analysis.

Algorithms

Algorithms are the basic unit of computation. Algorithms perform a single function such as calculating the shale volume using a particular technique, assigning a lithology code based on particular criteria, or converting the bitumen content from a ratio to weight percent. For example, 'VSH = (GR - GR0) / (GR100 - GR0)' is an algorithm to calculate the shale volume from a gamma ray log. GR is the gamma ray curve; GR0 and GR100 are constants from a constants record; and VSH is a new curve representing the volume of shale. During analysis, the algorithm processor decodes the algorithms, carries out the processes defined, and places the results in the appropriate records.

INTELLOG comes with many predefined algorithms based on standard log analysis techniques. It also has its own programming language for writing or modifying algorithms. A listing of several algorithms is included in Appendix A.

Routines

A series of algorithms is called a routine. Routines calculate all of the results for a single unit or zone such as a sandy shale or a coal seam. Algorithms in a routine are executed sequentially. When routines are executed they are associated with a constants record. Individual algorithms within a routine can be switched on or off to handle conditions such as bad hole, gas corrections, or missing data. An example of a routines record is shown in Figure 13.

This routines record (Figure 13) lists a series of algorithms for calculating shale volume, density, porosity, fluid saturation, lithology, bitumen content, and gas content. The principal algorithms used in this routine are listed in Appendix A and are explained in detail by Crain (1986) and Schlumberger (1989). The Clavier correction was usually used in highly interbedded sand and shale intervals. Porosity was calculated mainly from neutron and density porosity logs, although sonic logs were used if these were unavailable. Archie's equation for water saturation was used in most intervals, while Simandoux's equation was used in clay rich intervals, especially in the Wabiskaw Member. In general, RW is first obtained from Struyk (1987) and then refined based on porosity and bitumen saturation measurements obtained from core analyses, where available.

Computations

A series of routines is called a computation. Computations calculate the results for all of the units or zones which make up a well. A computations record contains a list of the intervals, associated routines records, and associated constants records to be used for each zone, an example of which is given in Figure 14.

A computations record divides a well into one or more intervals for different processing. Figure 14 shows that three intervals were defined in the well. One routine, ARC General, was used for all three intervals; however, different constants records were associated with each interval. The intervals usually correspond to changes in lithology and, to a lesser extent, stratigraphy. Most of the wells in this study were divided into a McMurray and a Wabiskaw interval due to differences in lithology.

Algorithm Name	Switch	Comments
START	ON	Always ON does housekeeping
VSHgr	ON	GR Shale
VSHbal	ON	Materials balance equation
VSH c1	OFF	Clavier Correction
DENS	ON	Density from PHID
DENSc	OFF	Shale corrects density
DENStSc	ON	Structural shale correction
PHIDc	ON	Matrix corrected PHID
PHINI	ON	Converts PHIN to limestone
PHINc	ON	ON for complex LITH NO
PHINm	ON	Matrix corrected PHIN
PHIxcl	ON	Complex Lith XPLOT porosity
PHIbal	ON	Materials balance for PHI
RW@FT	ON	RW at formation temperature
SWa1	OFF	Archie water saturation
SWs	ON	SIMANDOUX water saturation
SWsmth	ON	SW balance and smoothing
PHIxSW	ON	For plotting
LITH FOR SMALL COLUMN	ON	Lith Codes
SW FOR COAL	ON	Sets SW to 0 in coal
TAR CONTENT	ON	Converts to weight percent
SILT	ON	Calculated silt
FIND GAS FROM PHIN AND PHID	ON	Finds gas and sets SW to -1

Figure 13. Example of a routines record.

From Depth	To Depth	Routine Name	Constants Record
132	160	ARC General	CLW01-01-096-07W4
160	186	ARC General	MIMCM01-01-096-07W4
186	205	ARC General	MCM01-01-096-07W4

Figure 14. Example of a computations record.

Plotting Module

INTELLOG provides a very flexible plotting module, as plots can contain any number of tracks with associated headers, labels, axes, log curves, and data points. The curves can be of raw logs or calculated logs. Colour fill and patterns can be used between curves to enhance features. Plots can be displayed on the screen or printed using an ink jet printer, as shown in Figure 15.

Report Module

INTELLOG contains a report generator which can be used to tailor the export of any data contained in INTELLOG's internal database to meet specific format criteria. The report generator language can specify format options such as the position of headers, footers, titles, pagination, text on the page, character size, and line spacing.

The report generator was used to specify the format for exporting log analysis results into a text file. This file contains a header, which includes the well ID, and a table of results sampled every 0.25 m. An example of part of an output file is shown in Figure 16, which contains the following data:

- Depth.
- Lithology code.
- Weight percent bitumen.
- Water saturation.
- Shale volume.
- Porosity.
- Water resistivity at the formation temperature.

Communications Module

The communications module is used to import and export all data to and from the INTELLOG system. Importing data into INTELLOG also uses inverse reports and conversion functions. These functions allow for data that are in LAS, LIS, BIT, or ASCII format to be decoded and read into the INTELLOG database. Custom routines were supplied by the vendor to import the core analysis data used for calibration purposes.

The log analysis workstation is connected to a VAX system running Ingres by using Ethernet for high speed communications. The network protocols are TCP/IP and FTP, a file transfer utility, moves files between the systems.

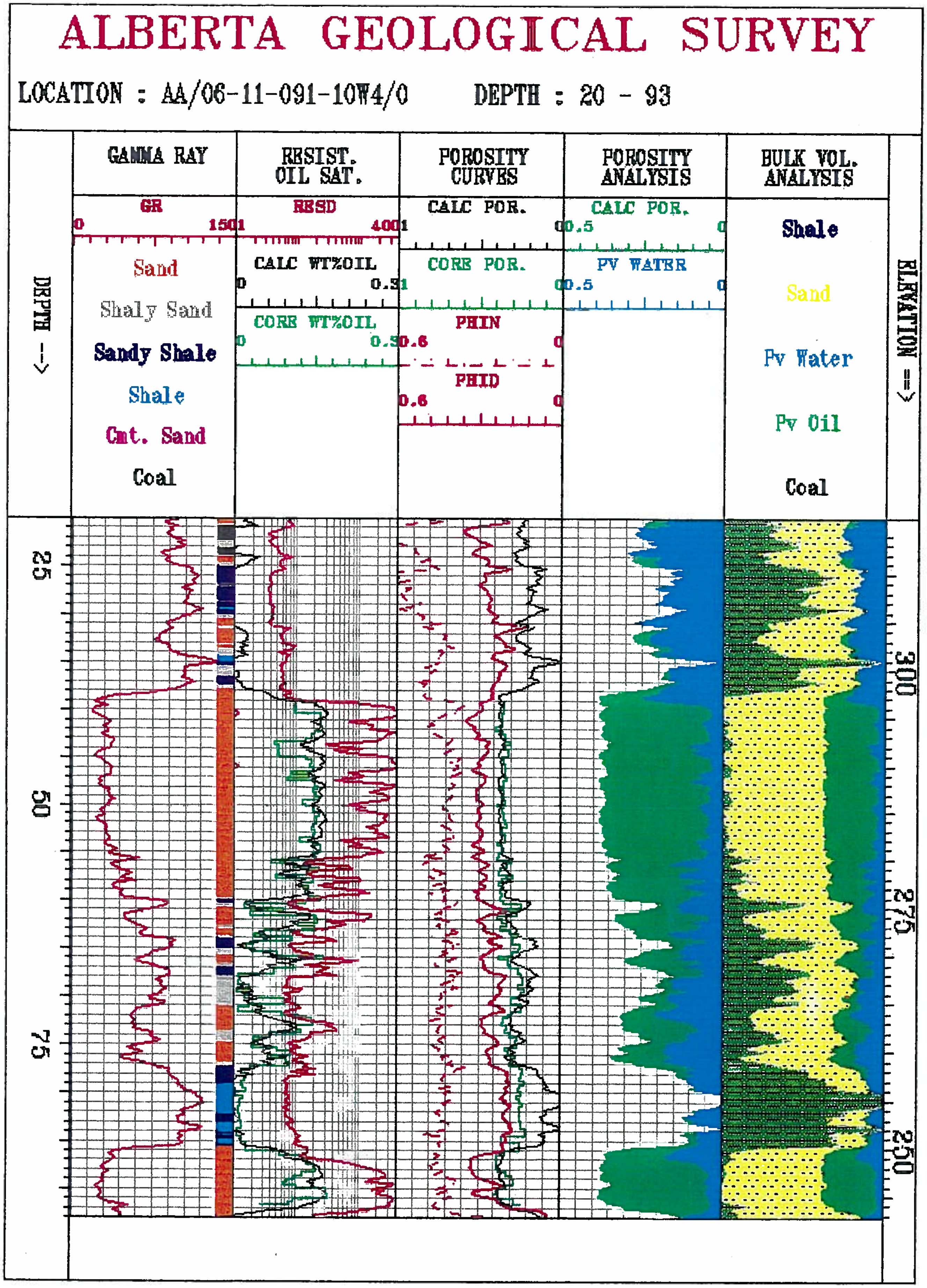


Figure 15. INTELLOG plot from well AA/06-11-091-10W4/0.

RESOURCE CHARACTERIZATION

LOCATION:AA/06-11-091-10W4/0

1 : SAND
2 : SHALY SAND
3 : CEMENTED SAND
4 : SANDY SHALE
5 : SHALE
6 : COAL

DEPTH METRES	LITH	WT % BIT	SW	VSH	PHI	RW@FT
37.00	4	0.006	0.913	0.635	0.139	0.560
37.25	4	0.014	0.831	0.537	0.174	0.560
37.50	2	0.014	0.854	0.460	0.205	0.560
37.75	2	0.022	0.813	0.365	0.241	0.560
38.00	1	0.049	0.656	0.227	0.294	0.560
38.25	1	0.064	0.615	0.116	0.336	0.560
38.50	1	0.075	0.657	0.000	0.380	0.559
38.75	1	0.073	0.615	0.000	0.380	0.559
39.00	1	0.101	0.451	0.000	0.370	0.559
39.25	1	0.152	0.192	0.000	0.377	0.559
39.50	1	0.148	0.127	0.039	0.346	0.559
39.75	1	0.161	0.101	0.000	0.363	0.559
40.00	1	0.166	0.099	0.000	0.371	0.559
40.25	1	0.173	0.088	0.000	0.380	0.559
40.50	1	0.173	0.088	0.000	0.380	0.559
40.75	1	0.168	0.097	0.017	0.373	0.559
41.00	1	0.152	0.155	0.045	0.363	0.559
41.25	1	0.143	0.193	0.058	0.358	0.559
41.50	1	0.158	0.130	0.038	0.366	0.559
41.75	1	0.161	0.133	0.020	0.372	0.558
42.00	1	0.156	0.137	0.043	0.364	0.558
42.25	1	0.165	0.092	0.038	0.366	0.558
42.50	1	0.167	0.105	0.014	0.375	0.558
42.75	1	0.163	0.109	0.034	0.367	0.558
43.00	1	0.157	0.106	0.067	0.355	0.558
43.25	1	0.148	0.123	0.068	0.343	0.558
43.50	1	0.124	0.303	0.055	0.358	0.558
43.75	1	0.125	0.282	0.056	0.352	0.558

Figure 16. Part of the output file for well AA/06-11-091-10W4/0.

Database

The Athabasca Oil Sands database is implemented at the Alberta Geological Survey using Ingres, a commercially available relational database management system. It is a part of the Alberta Geological Survey's Well DataBase (AGSWDB) which encompasses selected information for all oil or gas wells drilled in Alberta. Three customized components were designed specifically for stratigraphic and log analysis data in the McMurray/Wabiskaw interval of the Athabasca area.

Tables for storing data.

Entry forms for adding and updating data.

Reports for extracting data.

Tables

All data in AGSWDB are stored in tables. Figure 17 shows how the tables, including several which are not specific to oil sands data, are related. These tables are an essential part of the database and are used while updating or extracting data; detailed information on tables can be found in Appendix B.

General Data

All tables in AGSWDB are keyed to a unique site ID for each well. The table GEOLOCATION is used to relate the site ID to a location, in terms of latitude and longitude, and to the KB elevation. The custom tables used specifically for storing the oil sands data also use the same site ID to identify wells.

The location (latitude and longitude) of the bottom of each well is calculated from data in the General Well Data File obtained from the Energy Resources Conservation Board (ERCB). The location refers to the bottom of the hole and the calculation is based on the Alberta township system of land descriptions. In addition to the legal-subdivision, section, township, range and meridian, the General Well Data File also contains codes to indicate direction, from reference boundaries, and the distances from these boundaries to the location. The algorithm for calculating latitude and longitude is based on the theoretical position of township corners. It was obtained from the University of Alberta and later modified by the Alberta Geological Survey to address some deficiencies and to extend it to all regions in Alberta. The latitude and longitude calculated in this way are slightly different from the latitude and longitude found in the General Well Data File.

The table MASTER is used to relate the site ID to the well name used by the ERCB. The table CORES_CUT is used to obtain information on cores cut during drilling. The table CORE_ANAL contains core analyses. The core analyses data are downloaded to the log analysis workstation for calibration purposes.

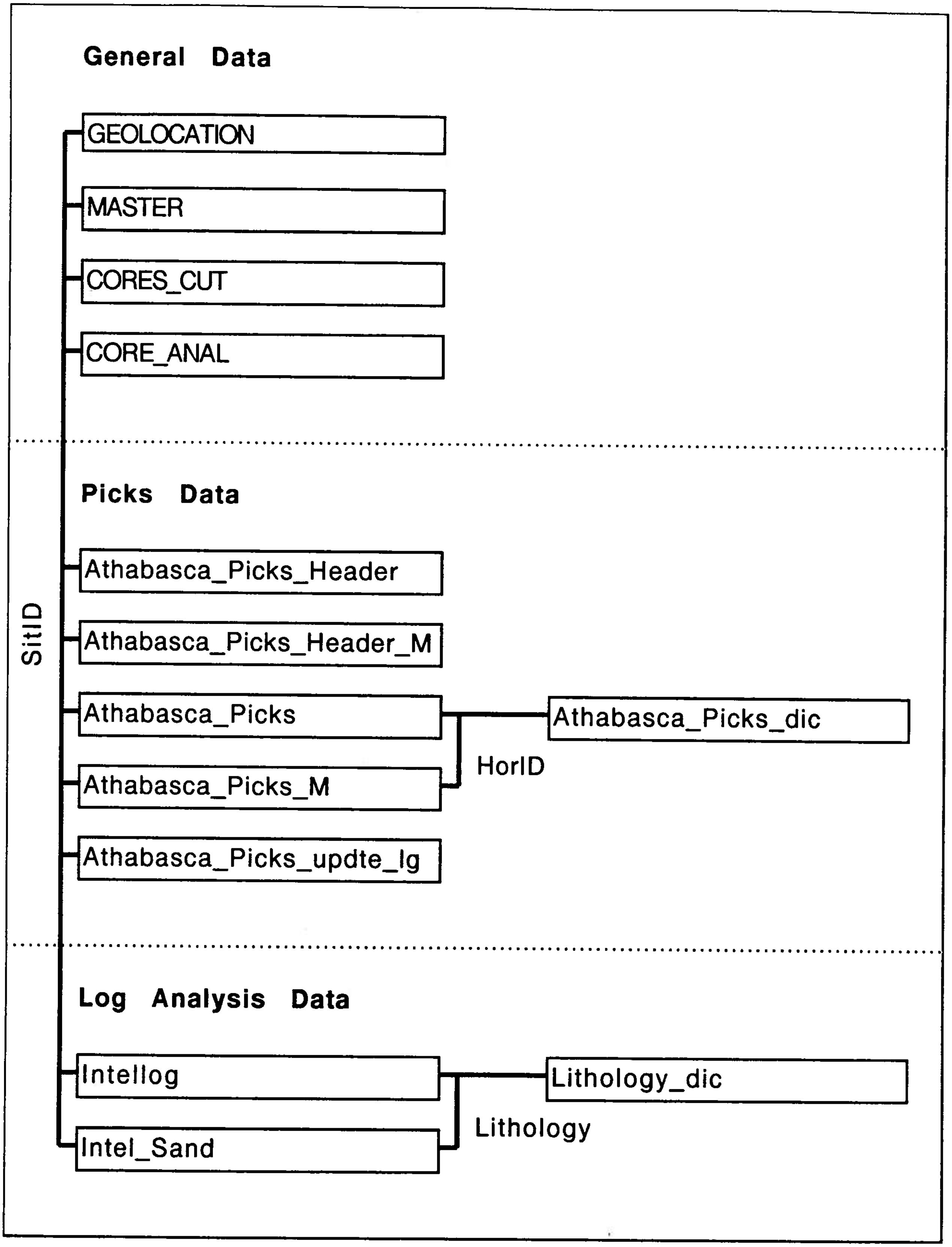


Figure 17. Database tables, including those not specific to oil sands data, and their relationships.

Picks Data

The picks data are contained in three primary tables. Basic information about each well is stored in a header table (Athabasca_Picks_Header). All pick depths and corresponding quality codes for the wells are contained in a picks table (Athabasca_Picks). A dictionary table (Athabasca_Picks_dic) is used to define codes used for stratigraphic horizons or markers.

The picks data are obtained from well logs. In the case of older logs, the depth and all related measurements are in feet. After about 1970, the metric system was adopted and all such measurements are in metres. To simplify data entry and checking of picks from well logs, depth can be recorded in either feet or metres. All picks for a well must use the same units of measurement, and a field in the picks header table is used to indicate which units of measurement were used for that well.

Initially, the picks header table and picks table were accessed through an Ingres view. This automatically converted all measurements to metric as data were extracted from the database. Due to the nature of some reports, Ingres did not always produce an efficient query when using this technique. As a result, secondary header and picks tables were created which use only metric units for measurement. Using the secondary tables, Ingres always generates an efficient query when extracting data from the database.

As secondary tables are used when extracting data from the database, it is important to update these tables after the primary tables have been updated in order to maintain data consistency. A procedure was written to perform this task.

All changes made to picks or quality codes in the picks table are tracked and a log of the changes is kept in a special table (Athab_Picks_Updte_lg). The information retained includes site ID, date changed, the name of the person requesting the change, the reason for the change, the column changed, as well as the old and new data values.

Log Analysis Data

Log analysis is performed on a 486 based workstation using INTELLOG. The results of the analysis for each well are saved as a text file and then copied back to the system running Ingres. The results are then loaded into the primary log analyses table (Intellog). Most of the reports used to extract data, based on log analyses, use only the data for sand or shaly sand units; therefore, a secondary log analyses table (Intel_Sand) was created which contains only the data for these units. By using the secondary log analyses table, the processing time needed to extract data for sand, bitumen, gas, water and slice maps can be reduced by about 40%. A dictionary table (Lithology_dic) is used to define codes used for lithological units.

Other Tables

When extracting data from the database it is often necessary to use 'complex horizons'. A 'complex horizon' enables a user to specify alternative horizons when the primary horizon is absent . It is built in stages from the picks table. A primary pick is first specified. If this pick is not defined in the picks table a second pick can be specified. If the second pick is not defined then a third pick can be specified; this process can be repeated as many times as necessary. It would be very complex to build a database query based on this concept but the process can be greatly simplified by building an intermediate table. This table is built in stages just as a 'complex horizon' is defined. These tables are created as needed and are normally deleted after they have been used.

A number of tables have been created which contain a list of site IDs. These tables provide a very convenient method for working with a subset of the oil sands wells. By including a reference to the site ID in one of these tables, as part of a database report, only data for wells referenced in this table will be extracted from the database. All of the standard database reports include a reference to one of these tables. To date, five such tables have been created, one for the whole area and one for each of the study areas, North, Central, South and West.

Adding and Updating Data

A custom application was designed, using Ingres Vision, for adding and updating information in the picks and picks header tables. This application is intended for use on VT2XX and VT3XX type terminals. The numeric keypad can be used for entering data and the function keys can be used for database operations such as: next record, save changes, and search for record. After invoking the system, the user is presented with four options (Figure 18).

View Picks	View picks from the Athabasca_Picks table
Change Picks	Update picks in Athabasca_Picks
Add Wells and Picks	Add a well and picks to Athabasca database
View Changed Picks	View the changes made to a well

Figure 18. Options for viewing and updating the oil sands data.

View Picks

This option enables the user to browse through the picks and picks header data using the form shown in Figure 19. The information in the upper part of this form is from the picks header table, while pick depths and quality codes for the well are displayed in the lower part of the form. Only information from one well can be displayed at a time.

SITID	Loc_Exc	LSD	SEC	TWP	RGE	MER	Event_Seq	KB	Scale
quality: source:	core top: core base:						viewing: sampling:	Old DB: Entered By:	

Pick/Marker	Depth	Qu

Figure 19. Blank data form for displaying information from the picks and picks header tables.

Initially the user is presented with a blank form and a list of commands:

Go(Do) Clear(F12) . . . End(PF3)

displayed at the bottom of the screen. The next step is to select the wells to be displayed. This is done by entering a numeric site ID or entering a unique well identifier using the Alberta township system of land descriptions. Note, the township is a three character field; the location exception, legal-subdivision, section, and range are two character fields; and the meridian and event sequence are one character fields. Leading zeros must be used to fill the fields (e.g. 10-2-74-5w4 is specified by 10;02;074;05;4). The 'Tab' key can be used to move forward through the fields, and '<Ctrl>p' can be used to move in the reverse direction. Press the 'Do' key to initiate the search. If any wells are found which match the search criteria, the data for the first well in the selection will be displayed on the form, and the commands:

Next(Do) Help(Help) End(PF3)

will be displayed at the bottom of the screen.

The search is based on matching all of the criteria specified. To view a particular well by site ID, enter only the sitid and press 'Do'. To view all the wells in a township, enter both the township and range and press 'Do'. If the selection contains more than one well, use the 'Do' key to view successive records or the 'PF3' key to initiate a new selection. After the last record in the selection has been viewed, the user will automatically be given a blank form to initiate a new selection.

Change Picks

This option enables the user to update the picks and picks header tables. After selecting this option, the user is prompted for a password. If the correct password is entered, the user is presented with a blank form to select wells for updating. Wells are selected in the same way as for viewing the picks.

After a well selection has been made, data for the first well in the selection is displayed on the form and the commands:

Next(Do) Save(F10) Delete(F13) . . . End(PF3)

are displayed at the bottom of the screen. The picks data can now be updated. As fields are modified, checks for validity and consistency are performed and the user is notified if any problems are encountered. When the changes are complete, the user should press 'F10' to save the changes. The user's name and the reason for each change will then be requested. This information is saved in Athab_picks_updte_lg.

Adding Wells and Picks

This option enables the user to add data for new wells to the picks and picks header tables. As for the previous two options, the user is presented with a blank form and the commands :

Save(F10) Clear(F12) . . . End(PF3)

are displayed at the bottom of the screen. A site ID or Alberta township land description should be entered to initiate a search. Initially, the Location Exception and Event Sequence are not required but can be entered if known. A search is then performed on the table MASTER within AGSWDB.

If no wells are found which match the search criteria, the user is notified and can start another search. If more than one record matches the search criteria, it means that more than one well has been drilled in a legal-subdivision. The user is also notified in this case and must enter the Location Exception and/or Event Sequence to uniquely specify the well.

If only one record matches the search criteria, the site ID and the complete Alberta township description are obtained from the table MASTER. The KB elevation is obtained from the table GEOLOCATION. The core top (top of the first core cut) and core base (base of the lowest core cut) are obtained from the table CORES_CUT. All picks are set to 'Null' and the quality codes to '-1'. The user can now enter picks and quality codes, pressing 'F10' to save the record.

View Changed Picks

This option enables the user to examine any changes made to the picks data. The user is presented with a blank tabular form containing all of the fields in the table Athab_Picks_update_lg. The commands:

Go(Do) Clear(F12) . . . End(PF3)

are displayed at the bottom of the screen. The user can now enter search criteria. By entering the character '>' followed by a date (eg. >1-Jun-1992), all changes made on or after that date will be selected. By entering a pick name, all changes to that pick will be selected. As with the other options, pressing the 'Do' key initiates the search.

Extracting Data

Data are normally extracted from the database and printed by using database reports. A database report contains instructions to the database regarding which tables to access, the fields to be extracted, the format to be used for printing, the order in which the records are to be printed, and any constraints on extracting the data. Other information such as titles, headers, footers, page numbers, and summary calculations can also be specified in a database report.

Database reports provide a convenient and flexible tool for extracting data from a database. The data extracted by all reports are based on a query statement. Ingres reports may include setup and cleanup sections, where any number of SQL statements can be executed, which simplifies the design of moderately complex reports. All tables referenced, fields to be extracted, and constraints can usually be specified when the report is run. This requires some knowledge of Ingres, SQL, and the structure of the database.

Reports have been designed to extract the following information from the oil sands data:

Overburden

KB Elevation

Structure

Isopach

Sand Isopach

Water Isopach

Bitumen Isopach

Gas Isopach

Slice Maps

In the case of very complex queries, embedded SQL, part of the ANSI standard, can be used to build special purpose applications, two of which have been written. The first is used to obtain the data for bottom water isopach maps. The second is used to calculate, at each well location, the total bitumen production, the rate of production, and the steam/oil ratio for a generic plant based on the Steam Assisted Gravity Drainage (SAGD) technology. These applications can handle additional constraints such as: minimum overburden, minimum thickness and bitumen cut off used to define a pay zone, shale or water sand breaks in a pay zone, and minimum net to gross pay ratio.

Summary

This text report is designed as a user guide to the electronic database and as such contains a description of the database, its contents and methods of data acquisition. Comments, queries and suggestions on the report and database are encouraged and should be sent to:

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Appendix A - Log Analysis

The following are examples of well and log header records:

Example of a well record

Field Name	Value	
FULL WELL NAME	NORTHSTAR ENERGY CORP.	
FULL WELL LOCATION	00/03-12-095-16W4/0	
UNIQUE WELL IDENTIFIER	00/03-12-095-16W4/0	
ENTERED BY (NAME)	JOETTE	
GROUND ELEVATION (OPT)	559.5	metres
KB ELEVATION (OPT)	562.9	metres
DATUM ELEVATION	562.9	metres
DRILLED DEPTH	320	metres
DEFAULT TOP	170	metres
DEFAULT BOTTOM	305	metres
SAMPLE RATE	0.25	metres/sample

Example of a log header record

Field Name	Value
BHT	21
BHTDEP	320
MDTP	15
MWT	1030
NEUTRON	1
RESIST	0
RM	0.33
RMC	0.58
RMF	0.32
SUFT	4

The following are examples of the algorithms used for log analysis:

Algorithm - SW FROM ARCHIE

```
LOCAL VECTOR RESULT1
IF PHI > .001                                ! STOPS THOSE NASTY DIVIDE BY ZEROS
    RESULT1 = (A * RW@FT / (PHI ^ M) / RESDc2) ^ (1 / N)
ELSE
    RESULT1 = 1
END IF
SW = RESULT1
```

Algorithm - SW BY SIMANDOUX

```
LOCAL CONSTANT CONST1
LOCAL VECTOR RESULT RESULT1 RESULT2 RESULT3 RESULT4
CONST1 = 2 * RSH
IF (PHI > 0.001)                                          ! DONT DIVIDE BY ZERO
    RESULT2 = (1 - VSH) * A * RW@FT / PHI ^ M
    RESULT1 = RESULT2 * VSH / CONST1
    RESULT3 = RESULT2 / RESDc2
    RESULT4 = RESULT1 ^ 2 + RESULT3
    RESULT4 = MAX(RESULT4, 0)                  ! IF NEGATIVE DONT TRY POWER
    RESULT = (RESULT4 ^ .5 - RESULT1) ^ (2 / N)
ELSE
    RESULT1 = 1                              ! IF NO PHI THEN SET SW TO 100%
END IF
SW = RESULT
```

Algorithm - VSHbal

```
! THIS ALGORITHM CLIPS VSH TO BE IN THE RANGE O TO 1

vshmore1    = SUM( VSH > 1)        ! count vsh more than one
vshless0    = SUM(VSH < 0)         ! count vsh less than zero

VSH  = MIN(VSH, 1)
VSH  = MAX(VSH, 0)
```

Algorithm - LITH FOR SMALL COLUMN

```
! This algorithm calculates the lithology classification curve

LOCAL VECTOR sand sh_sd sd_sh cmt_sd shale silt coal

sand     = (VSH <= 0.3)  AND  (PHID >= 0.15)
sh_sd    = (VSH <= 0.5)  AND  (VSH > 0.3)
cmt_sd   = (VSH<= 0.5)   AND  (PHID < 0.10)   AND  (PHIN < 0.25)
sd_sh    = (VSH <= 0.7)  AND  (VSH >0.5)
shale    = VSH > 0.7
coal     = (VSH <= 0.5)  AND  (PHID >= 0.55)

IF (cmt_sd = 1)
   sh_sd = 0
END IF

IF (coal = 1)
   sand  = 0
   sh_sd = 0
END IF

LITH = sand + 2*sh_sd + 3*cmt_sd + 4*sd_sh + 5*shale + 6*coal
```

Algorithm - TAR CONVERT

```
LOCAL VECTOR vmatrix so total_mass wshale
LOCAL CONSTANT shale_dens

vmatrix = 1 - VSH - PHI                                 ! volume of matrix
so =      1 - SW                                        ! saturation of oil
shale_dens  = PHIDSH * RHOW + (1 - PHIDSH) * RHOMA      ! density of shale

Wwater   = PHI * SW * RHOW                              ! MASS OF WATER
Wtar     = PHI * so * RHOHY                             ! MASS OF TAR
Wrock    = vmatrix * RHOMA                              ! MASS OF SAND
wshale   = VSH * shale_dens                             ! MASS OF SHALE

total_mass   = Wtar + Wwater + Wrock + wshale

Wtar     = Wtar / total+_mass
Wwater   = Wwater / total_mass
Wrock    = Wrock / total_mass
```

Appendix B - Database Tables

The following is a list of tables in AGSWDB used specifically for the oil sands data. The underscore character '_' is part of the table name.

Table Name	Description
Athabasca_Picks_Header	Stores basic information about each well (about 2,000 records).
Athabasca_Picks_Header_M	Metric version of previous table.
Athabasca_Picks	Contains oil sands stratigraphic pick depths and corresponding quality codes (about 32,000 records).
Athabasca_Picks_M	Metric version of previous table.
Intellog	Contains all log analysis results (about 500,000 records).
Intel_Sand	Contains a subset of the data in the table Intellog. Only records for sand and shaly sand are included (about 275,000 records).
Athabasca_Picks_dic	Dictionary table of stratigraphic pick names and their equivalent codes (15 records).
Lithology_dic	Dictionary table of lithology names and their equivalent codes (6 records).
Athab_Picks_update_lg	Contains a record of all changes to the picks or quality codes in the table Athabasca_Picks.

The following tables are also used for resource characterization studies. They are part of AGSWDB and may be referenced during data entry, while running database reports and for downloading data to the log analysis workstation. Most of the data contained in these tables has been obtained from ERCB files.

Table Name	Description
MASTER	Contents include the unique well identifier and well name used by ERCB.
GEOLOCATION	Contents include the well location in latitude and longitude and the KB elevation.
CORES_CUT	Contents include depth to top and base of all cores cut.
CORE_ANAL	Contents include the results of core analysis.

The following is a description of the field names within tables which are used for the oil sands data. The first column contains the actual field name used in Ingres. The second column contains the data type and length of the field. The third column contains a short description of the field.

Table - Athabasca_Picks_Header

Field name	Field type	Description
Sitid	Integer(4)	Unique well site ID.
Loc_Exc	Char(2)	Location Exception - code used as distinguishing factor when more than one well drilled in an LSD.
LSD	Char(2)	Legal Subdivision - Alberta geographic legal subdivision of a section.
SEC	Char(2)	Section - Alberta geographic section of a township.
TWP	Char(3)	Township - Alberta geographic township designation.
RGE	Char(2)	Range - Alberta geographic range designation.
MER	Char(1)	Meridian - universal geographic meridian.
Event_Seq	Char(1)	Event Sequence - code used to distinguish between various major events which can occur in the life of a well.
KB	Float(4)	KB Elevation - elevation of the Kelly Bushing above sea level as measured at drilling rig floor.
Quality	Integer(2)	Code used to indicate availability and quality of logs.
Source	Integer(2)	Code used to indicate source of the logs.
Scale	Integer(2)	Code used to indicate if measurements are in metric or Imperial units.
Core_Top	Float(4)	Depth to the top of highest core taken.
Core_Base	Float(4)	Depth to the base of lowest core taken.
Viewing	Integer(2)	Code used to indicate if core can be viewed.
Sampling	Integer(2)	Code used to indicate if core can be sampled.
Old_DB	Char(1)	Code used to indicate if well was used in a previous study.
Entered_By	Char(2)	Code used to indicate who entered original data.

Table - Athabasca_Picks

Field name	Field type	Description
Sitid	Integer (4)	Unique well site ID.
Horid	Integer(2)	Unique horizon ID code used for this study; these codes are listed in the table Athabasca_Picks_dic.
Pick	Float(4)	Depth from KB to the pick.
Pick_Q	Integer(1)	Quality code associated with each pick; the meaning of these codes is discussed earlier in this report.

Table - Intellog

Field name	Field type	Description
Sitid	Integer(4)	Unique well site ID.
Depth	Float(4)	Depth.
Lithology	Integer(1)	A code for lithology as determined during log analysis.
W_Tar	Float(4)	Weight percent bitumen.
Sw	Float(4)	Water saturation.
Vsh	Float(4)	Volume of shale.
Phi	Float(4)	Porosity.
RW	Float(4)	Water resistivity at formation temperature.

Table - Athabasca_Picks_dic

Field name	Field type	Description
Horid	Integer(4)	Unique horizon code.
Hordesc	Vchar(32)	Horizon name.

Table - Lithology_dic

Name	Type	Description
Lithology	Integer(1)	Unique lithology code.
Lith_Desc	Vchar(32)	Lithology name.

Table - Athab_Picks_updte_lg

Field name	Field type	Description
Sitid	Integer(4)	Unique well site ID.
ChngDt	Date	Date change occurred.
Rq_By	Vchar(35)	Who requested the change.
Chng_Col	Vchar(24)	Pick changed.
Old_Value	Float(4)	Old value.
New_Value	Float(4)	New value.
Old_Value_q	Integer(4)	Old value for quality code.
New_Value_q	Integer(4)	New value for quality code.
Reason	Vchar(80)	Reason for the change.

Table - GEOLOCATION

Field name	Field type	Description
Sitid	Integer(4)	Unique well site ID.
BhaLat	Float(4)	Bottom hole latitude.
BhaLon	Float(4)	Bottom hole longitude.
Edatm	Float(4)	KB elevation.
...	...	...

Table - MASTER

Field name	Field type	Description
Sitid	Integer(4)	Unique well site ID.
Srcid	Vchar(16)	Source ID. For the resource characterization studies, this is the same as the unique well identifier used by the ERCB.
Wname	Vchar(48)	The name of the well used by the ERCB.
...	...	...

Table - CORES_CUT

Field name	Field type	Description
Sitid	Integer(4)	Unique well site ID.
Core_No	Integer(4)	Core number.
Core_Int_Top	Float(4)	Depth to the top of the core.
Core_Int_Base	Float(4)	Depth to the base of the core.
. . .	. . .	. . .

Table - CORE_ANAL

Field name	Field type	Description
Sitid	Integer(4)	Unique well site ID.
CA_Number	Integer(4)	Core analysis number.
Interval_Top	Float(4)	Depth to the top of the interval.
Interval_Base	Float(4)	Depth to the base of the interval.
Kmax	Float(4)	Maximum permeability
K90	Float(4)	Permeability measure at 90° to maximum permeability.
Kvert	Float(4)	Vertical permeability.
Porosity	Integer(2)	10000 x porosity.
Grain_Den	Integer(2)	10000 x density.
B_Mass_Oil	Integer(2)	10000 x bulk mass oil.
B_Mass_Water	Integer(2)	10000 x bulk mass water.
P_Vol_Oil	Integer(2)	10000 x pore volume oil.
P_Vol_Water	Integer(2)	10000 x pore volume water.
G_Mass_Oil	Integer(2)	10000 x grain mass oil.
G_Mass_Water	Integer(2)	10000 x grain mass water.