SHEAR-WAVE REFLECTION IMAGING OF GLACIAL-DEPOSIT AQUIFERS IN NORTHERN ILLINOIS

By

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SHEAR-WAVE REFLECTION IMAGING OF GLACIAL-DEPOSIT AQUIFERS IN NORTHERN ILLINOIS

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Abstract: Geologically-complex glacial sediment present challenges in mapping shallow aquifers with the conventionally-used electrical and electromagnetic geophysical methods. Horizontally-polarized seismic shear (SH)-wave reflection aided by water well information is presented in this study as an effective alternative for mapping aquifers within these sediment. SH-waves cannot be directly used to locate groundwater, however, when combined with borehole data from nearby wells, the sand and gravel potential aquifer units can be delineated. In this study, eight SH-wave seismic profiles with a total length of 17 kilometers were processed and interpreted in an attempt to delineate different glacial aquifers in the study area. The seismic data were correlated with adjacent well logs (gamma ray, conductivity, Vp, Vs) and lithologic descriptions from the available boreholes. Several logs were close enough to the seismic profile to be correlated and this proved to be very useful to register the seismic horizons to their corresponding lithological units in the borehole. The correlated data was interpreted and several individual units were mapped as potential groundwater aquifers along the seismic profiles including three main aquifers and several smaller potential aquifers. The extent and thickness of these unit aquifers were interpreted along the seismic profiles. Though, the SH-wave seismic proved to be effective in this study, the rapid variation in sediment types over short distances, necessitates drilling more wells and acquiring more closely-spaced seismic profiles in order to gain complete understanding of the geology and aquifers in the area.

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CHAPTER I

INTRODUCTION

In recent years, northern Illinois' groundwater sources have been increasingly stressed, and new sources of groundwater are needed but have proven difficult to find. The use of Lake Michigan as a source of water is geographically limited, strictly regulated, and limited by the economics of building pipeline infrastructure. This has forced many communities in northeast Illinois to investigate new water supplies, which include shallow, sand and gravel aquifers. The geology of northern Illinois is extremely complex due to the presence of extensive glacial deposits. Glacial deposits are exceptionally complex as a result of sediment heterogeneity arising from deposition during glaciation as well as the variation in the underlying geology. Thus, shallow sand and gravel aquifers in northern Illinois are difficult to characterize. Geophysical methods such as electrical and electromagnetic methods are typically used for mapping groundwater aquifers (Gowd, 2004, Jin et al., 2008, Chatterjee et al., 2018), but the complexity of the glacial aquifer systems and the high groundwater level in northern Illinois inhibits the effectiveness of these techniques.

This project aims to use shear (SH)-wave reflection to characterize the glacial sediment within the study area (Figure 1.1), and to image groundwater aquifers within these sediments to estimate the availability of groundwater resources. SH-wave reflection does not identify groundwater in the subsurface. However careful characterization of the seismic attributes of the glacial deposits and the integration of the seismic data with well-log information from nearby water wells can lead to locating groundwater aquifers within these sediment, proving to be an effective approach for this type of environment than traditional groundwater geophysical imaging methods.

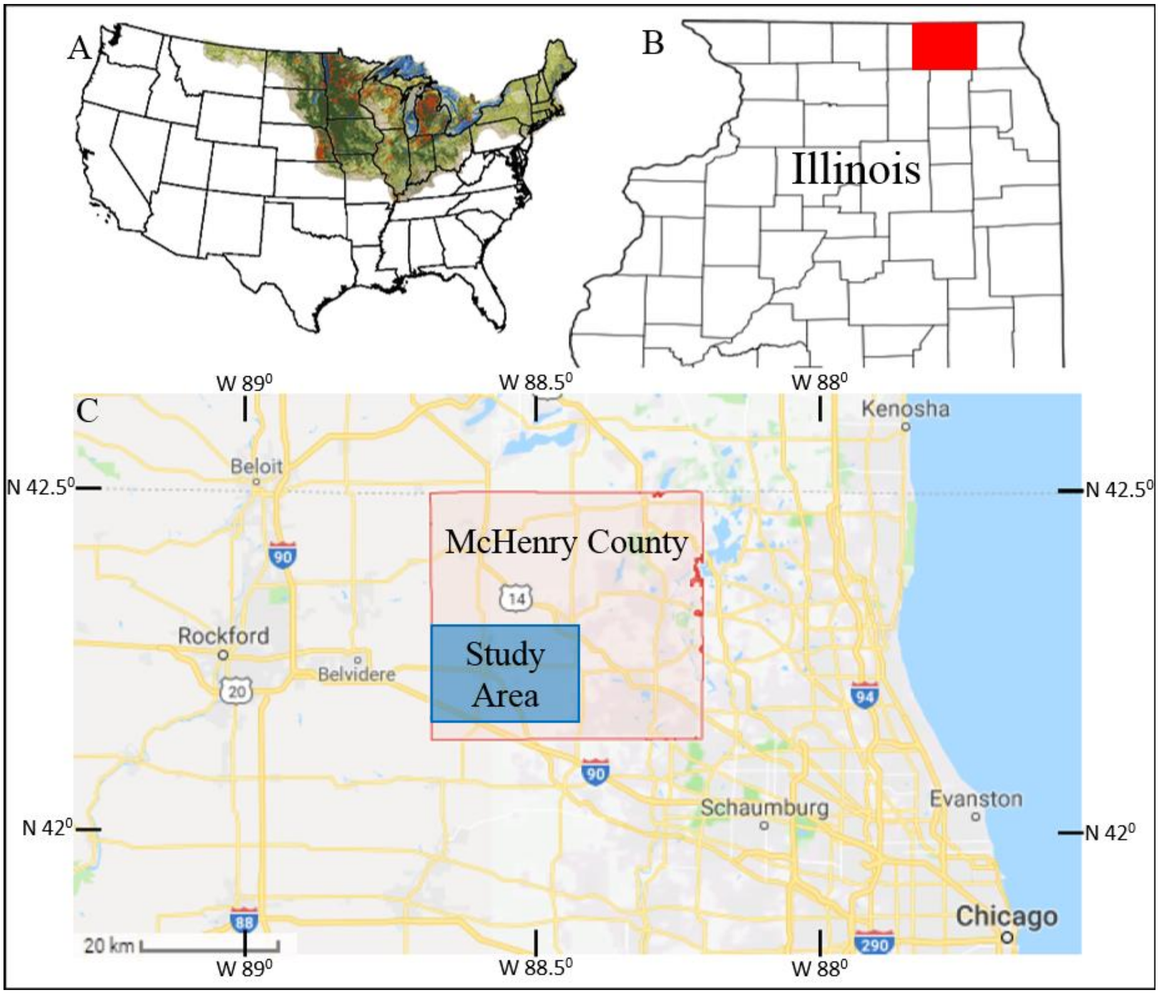


Figure 1.1: A map of glacial extent in the U.S. (A), Northern Illinois with McHenry County highlighted in red (B), and the location of the study area in McHenry County (C).

The complex nature of the glacial sediment inhibits the use of traditional geophysical techniques used for locating groundwater aquifers, such as electromagnetic and electrical methods. Alternatively, seismic techniques have been shown to be more effective (Jarvis, 2001, Pugin et al., 2009, and Juhlin, C. et al., 2000). Hence, developing new seismic techniques for imaging groundwater aquifers within complex glacial sediment is imperative because it will lead to more extensive research and a better understanding of complex glacial settings. Previous studies have shown that using seismic reflection is an accurate and cost-effective method for imaging glacial deposits and locating groundwater aquifers. For example, Oldenborger et al. (2016) have shown that the integration of seismic reflection, well log, and airborne electromagnetic surveys resulted in providing quality data for aquifer mapping in southern Manitoba in Canada that is geologically similar to northern Illinois.

Groundwater aquifers are likely to be found in glacial deposits due to the high porosity and permeability of sand and gravel sediment. This study focuses on characterizing the glacial sediment and on imaging potential groundwater aquifers within the sediment using high-resolution SH-wave reflection. For this, this work specified certain objectives to be achieved: 1) analyze and interpret the available SH-wave reflection data 2) integrate the SH-wave reflection with water well well-log information for better characterization of groundwater aquifers in the area, and 3) advance the knowledge of using seismic data for studying complex glacial environments. It is important to continue improving the use of SH-wave reflection method for better imaging and more accurate characterization of groundwater aquifers in glacial deposits that will allow for their use by the communities of northern Illinois.

SH-wave reflection does not image liquids, but can successfully characterize the glacial sediment and this can lead to the identification of groundwater aquifers. The glacial deposits in northern Illinois have been studied since the 1960’s for the purpose of better understanding groundwater resources (Walton, 1964, Walton, 1960, and Hackett, 1965) and glacial deposition cycles

(Kempton, 1963, Walton, 1962, Selkregg and Kempton, 1958). However, although many studies have been conducted in the region, there is still a need for additional studies to better understand the groundwater potential of the glacier deposits. This is becoming more apparent as the population increases, hence the demand for freshwater.

CHAPTER II

GEOLOGY

The study area is located in McHenry County in Illinois, approximately 80 kilometers northwest of Chicago (Figure 2.1) and encompasses an area of approximately 315 square kilometers. The area lies within McHenry County, which is one of the fastest growing counties in the United States. Between 1930 and 2015 the population grew from 35,000 to 308,760, which is almost an 800% increase, making it the fastest growing county in Illinois (U.S Census, 2010, McKinney, C, 2011, Seipel et al., 2016). The population is expected to increase by another 75% -115% by 2030, and by the year 2050, the population is expected to be just under 590,000, which is almost twice the current population (Dziegielewski and Chowdhury, 2008, Northeastern Illinois Planning Commission, 2007). The Chicago Metropolitan area has seen a similar trend. With the population increasing from around 5 million in 1950 to 8 million in 2000 this trend is expected to continue and have the population increase to around 10 million by 2030 (Seipel et al., 2016, Northeastern Illinois Planning Commission, 2007). This shows that the population of the entire region of northern Illinois is increasing at a very rapid rate, which, in turn, is resulting in an increased need for groundwater.

The landscape of northern Illinois was shaped by at least three separate glacial cycles starting at about 730 ka (Berg et al., 1997) and ending at about 14 ka (Thomason et al., 2013). Each glacial maximum was followed by a warming period causing meltwater that resulted in the deposition of more uniformly sized and well-sorted sediment than the glacial deposits. This allowed for the formation of sand and gravel aquifers between the deposits of each period of glacial advance (Roadcap et al., 2015). These glacial and inter-glacial cycles resulted in the formation of complex glacial sediment interbedded with proglacial outwash sand and gravel aquifers (Figure 2.1).

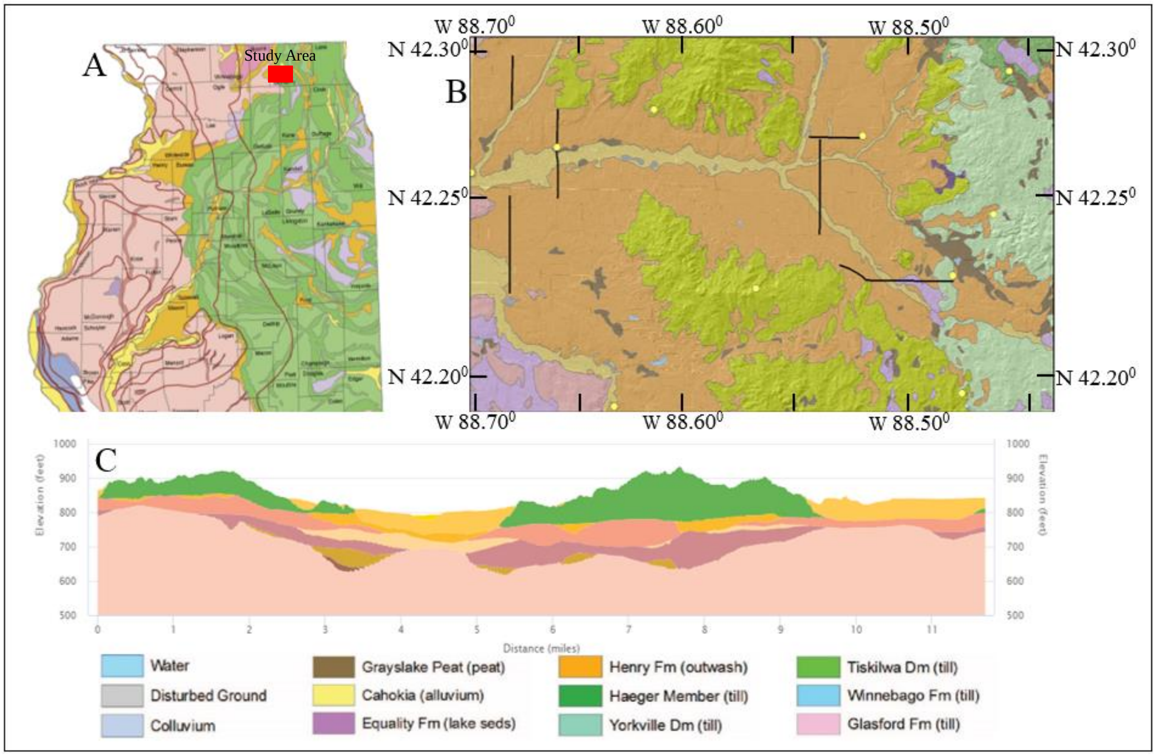


Figure 2.1: Geologic map of northern Illinois with the study area highlighted in red (A), the study area with seismic surveys (black lines) and well locations (yellow dots) shown (B), and a South-North cross-section through the study area (C).

The modern-day landscape was primarily formed during the late Wisconsinian deposition of the Harvard Sublobe of the Lake Michigan Lobe. The Harvard Sublobe advanced and retreated at least three times in the study area as a result of the warming and cooling cycles (Curry et al., 1997). The first advance of the Harvard Sublobe occurred during the Marengo Phase, approximately 25,000 to 23,500 years ago, which resulted in the deposition of the Tiskilwa Formation. The second advance occurred during the Livingston Phase, approximately 17,000 years ago. This event deposited the Yorkville Member of the Lemont Formation. The third, and final, advance occurred during the Woodstock Phase, approximately 16,500 years ago. This final advancement formed low-relief hummocky terminal moraines that run northwest-southeast and buried the previously deposited sediment while also depositing the Haeger Member Till and the Henry Formation.

The Kishwaukee River valley runs through the study area. It represents a bedrock paleo-valley that was formed from rivers prior to glaciation. Because of the glacial cyclicity, the valley was filled with an alternation of glacial sediment and glacial outwash sediment in the form of sand, gravel, and clay. The glacial outwash sediment formed the groundwater aquifers that are the focus of this study (Curry et al., 1997; Seipel et al., 2016; Ritzi Jr. et al., 1994; Berg et al., 1999; Carlock et al., 2016).

There are several aquifers that contain groundwater within these sediment as well as several carbonate bedrock aquifers. Approximately 25% of the groundwater comes from bedrock aquifers within shallow, fractured bedrock and deeper, confined sandstone aquifers. Additionally, about 75% of the groundwater in this area comes from the sand and gravel aquifers (Berg et al., 1997). The shallow bedrock and glacial aquifers are interconnected with each other, which makes the groundwater flow paths complicated and difficult to predict. These aquifers vary in depth, thickness, and hydrologic parameters such as hydraulic conductivity that makes imaging them difficult. The sand and gravel aquifers which are generally located within the glacial sediment are typically shallow. These shallow aquifers require more rigorous protection from environmental contamination and need closer monitoring. If a contaminant was released into the shallow aquifers, it could contaminate all of the aquifers in the area.

For this study, the primary formations of interest are the sand and gravel formations which include the Henry Formation and the Pearl Formation. Also of interest are the glacial till layers (diamictons) which include; the Haeger and the Yorkville Members of the Lemont Formation, the Tiskilwa Formation, and the Glasford Formation. The Equality Formation, which is a Lacustrine deposit, the Peddicord Formation , which is a silt and clay rich lacustrine deposit, and the Robein Silt, which is an Athens age (50,000 to 20,000 year old) silt loam, are also present in the study area. The Bedrock within the study area is varies between Silurian-Ordovician dolomite and shale units (Thomason and Keefer, 2013).

The Equality Formation is part of the Mason Group and it is Pleistocene in age. It is composed of silt and clay with local lenses of sand, gravel, diamicton, and some organic debris. It was deposited during the Hudson and Wisconsin Episodes between approximately 26,000 years ago and modern day. The Equality Formation is a lacustrine deposit that was deposited in glacial and post-glacial lakes. It has been found to be a good record of the transition from glacial to post-glacial deposition. It is regionally extensive although it is discontinuous in its distribution. For the most part, it ranges in thickness from less than 2 meters to greater than 20 meters. However, it is more than 50 meters thick beneath Lake Michigan (Hansel and Johnson, 1996). In the study area, the Peddicord Tongue of the Equality Formation is also present consisting of tongues of silt and clay that can be as thick as 10 meters. It was deposited in a low-energy lacustrine setting between 26,000 and 19,500 years ago as the Tiskilwa ice margin reached its maximum position. The Peddicord Tongue is typically found in lower-elevation areas such as valleys and basins associated with the Pre-Michigan Sub-episode. It underlies both the Ashmore Tongue of the Henry Formation and the Tiskilwa Formation (Hansel and Johnson, 1996).

The Henry Formation is part of the Mason group and was deposited during the Wisconsin Episode, mostly during the Michigan Sub-episode between 26,000 and 11,000 years ago. It was deposited in three different environments. These include a glacial outwash, a nearshore sand and gravel deposited in glacial lakes, and an eolian deposit forming sand dunes and sand sheets that originated from the erosion of the glacial, fluvial, and nearshore lake sediment (Hansel and

Johnson, 1996)). The Ashmore Tongue, which contains the Surficial Aquifer, was deposited as glacio-fluvial sand and gravel and consists of fingers of medium to coarse stratified sand and gravel. It is overlain by the Tiskilwa Formation. It is discontinuous and not regionally extensive and can be as much as 10 meters thick (Hansel and Johnson, 1996).

The Lemont Formation is part of the Wedron group and was deposited between 18,500 and 15,500 years ago. It was deposited in the form of a number of offlapping glacial sequences. The lithology consists primarily of diamicton units with lenses sand, gravel, silt, and clay lenses (Hansel and Johnson, 1996). The upper boundary of the Lemont Formation is the Haeger Member and the lower boundary is the Yorkville Member (which contains a small aquifer). The Lemont Formation follows outwash drainage pathways extensively and extends into neighboring states. It is regionally distributed but it is not continuous. It ranges in thickness from less than 1 meter to more than 65 meters within valleys (Hansel and Johnson, 1996, William and Frye, 1970). The Tiskilwa Formation is a diamicton that consists of clay, loam, sand, with gravel, silt, and regionally-distributed clay lenses. It was deposited during the early Michigan Sub-episode approximately 26,000 and 18,500 years ago. The Tiskilwa Formation was deposited during multiple glacial sequences creating a wedge-shaped deposit that pinches out beneath the overlying Lemont Formation to the north and east. It is approximately 90 meters thick within valleys (Hansel and Johnson, 1996, William and Frye, 1970).

The Glasford Formation is a Pleistocene age (2.5 million years ago to 11.5 thousand years ago) glacial deposit consisting of till and outwash deposits. It was deposited during the Illinois Stage, with the exception of the earliest deposits, and the entire Sangamonian Stage (125,000 to 75,000 years ago). The majority of the Glasford Formation was deposited from the glaciation of the Lake Michigan Lobe of the Wisconsinian Advance of the Laurentide Ice Sheet. However, small portions of it were deposited from the Lake Erie Lobe of the same ice sheet. In the study area, four subunits are present. these include the Oregon Member, the Sandy Facies, the Fairdale

Member, and the Kellerville Member. The Glasford Formation is the most regionally extensive glacial formation in Illinois. The furthest southern tip of the Glasford Formation is the southern limit of continental glaciers in the northern hemisphere (Willman and Frye, 1970).

The Pearl Formation is a Pleistocene age sand and gravel deposit. It was deposited in a glacial outwash environment during the Illinois Episode and occurs in valleys associated with the Illinois Episode glaciation where it is approximately 40 meters thick. The Pearl Formation contains one of the main aquifers in the study area, along with the Ashmore Tongue of the Henry Formation which hosts the Pearl-Ashmore Aquifer (Willman and Frye 1970). The Robein Member of the Roxana Silt (Robein Silt) is a massive silt loam that contains small amounts of organic debris (Willman and Frye, 1960). It was deposited during the Athens Sub-episode between 50,000 and 20,000 years ago, with the earliest deposition beginning during the Alton phase around 50,000 years ago. In the study area, it is found beneath the Tiskilwa Formation or the Henry Formation and is regionally extensive but discontinuous. It is an overall thin unit with a thickness ranging from 2 to 4 meters (Willman and Frye 1970, Hansel and Johnson 1996).

CHAPTER III

HYDROGEOLOGY

A study by Dziegielewski and Chowdhury (2008) found that between the early 1960's and the early 2000's, groundwater withdrawal rates tripled from a rate of around 50,000 cubic meters per day to a rate of 148,000 cubic meters per day. Withdrawal rates are projected to continue to increase significantly (McKinney, 2011). The majority of the water used in northern Illinois is for municipal and domestic purposes (Meyer et al., 2013). Meyer et al. (2013) found that high withdrawal rates could result in a reduction in the discharge from the aquifers into lakes and streams, which would result in a decrease in their flow levels. A study by Seipel et al. (2016) found that current withdrawal rates are sustainable for the aquifers because recharge rates are greater than withdrawal rates, but the increase in population and subsequent demand for water could result in an increase of withdrawal rates. If withdrawal rates surpass recharge rates, groundwater levels will decrease and eventually become insufficient sources of freshwater. If this were to happen, it would lead to a water shortage and a dire need for alternative freshwater sources.

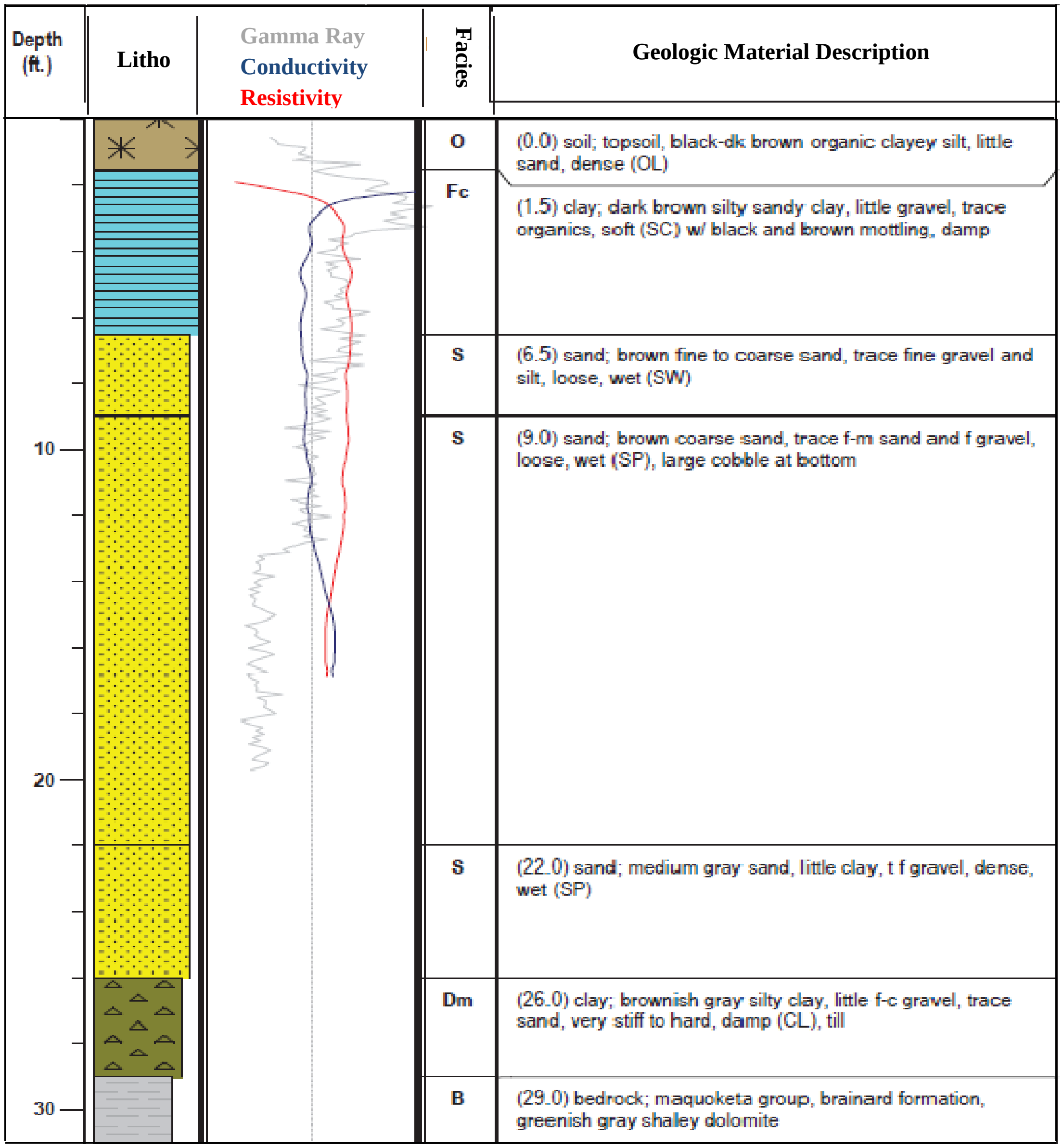
There are three primary aquifers of interest for this study besides several smaller aquifers as well. The aquifers of interest for this study are the Surficial Aquifer, the Pearl/Ashmore Aquifer, and the bedrock aquifer (Curry et al., 1997; Thomason and Keefer, 2013). There are a few smaller aquifers, but these are much less important in terms of being sources for groundwater. They are unimportant due to them being thin and isolated. For example, the Yorkville Aquifer, which lies below the Yorkville Member of the Lemont Formation and above the Tiskilwa Formation is at most only 6 meters thick and is not regionally extensive (Berg, 1999). The vast majority of the groundwater withdrawn in the study area comes from the three major aquifers mentioned.

Beneath the Kishwaukee River is where the thickest aquifers are located. It lies in a paleo-valley that was filled with sediment during the glaciation periods. During glaciation, the bedrock was continually eroded and altered as a result of the glacier movement, glacial outwash, and rivers formed from glacial melt during the warming periods. The glacial rivers running through the valley deposited glacial sediment, which filled the valley with more uniform sand and gravel sediment (Seipel et al., 2016).

The shallowest and most important aquifer in the study area is the Surficial Aquifer, which is a shallow unconfined aquifer that is exposed at the surface. The Surficial Aquifer was deposited during the Wisconsin Episode from meltwater streams (Seipel et al., 2015) It is part of the Henry Formation and the Beverly Tongue of the Henry Formation. It is found in glacial meltwater stream valleys, which are easily identified on the surface in alluvial valleys. It is primarily composed of sand and gravel deposits that are much more well-sorted and uniform than the surrounding glacial deposits (Thomason and Keefer, 2013). This creates a layer with high porosity and permeability, allowing for high groundwater withdrawal rates and recharge rates. The Surficial Aquifer ranges in thickness from less than 1 meter to greater than 36 meters within valleys (Seipel et al., 2015). The aquifer supplies groundwater for domestic, municipal, and agricultural needs. There is a large amount of groundwater withdrawn for agriculture, primarily for irrigation purposes. The Surficial Aquifer is exposed to the surface in many areas, and in others it is found at very shallow depths. Because of this, additional monitoring efforts needs to be implemented for this aquifer in order to protect it from contamination. The deeper aquifers in the area are interconnected with each other and with the Surficial aquifer (Thomason and Keefer, 2013). Therefore if the Surficial aquifer becomes contaminated, it could affect all of the aquifers in the area.

The Pearl/Ashmore Aquifer is a sand and gravel aquifer that was deposited from proglacial outwash during the retreat of the Illinois Episode and the advance of the Wisconsin Episode glaciation. It is part of the Pearl Formation and the Ashmore Tongue of the Henry Formation and is composed of coarse sands and gravels with pockets of fine to medium sands. Because it is part of two formations, it is thicker than the other aquifers in the area (Carlock et al., 2016). Also, due to it being formed as a result of channel deposits from proglacial outwash, the Pear/Ashmore Aquifer ranges in thickness from less than 10 meters to more than 40 meters (Carlock et al., 2016, Thomason et al., 2013).

The deepest aquifer in the study area is the bedrock aquifer. It can be found at a depth greater than 60 meters and is hydraulically connected to the overlying Basal Drift Aquifer. In this study, the Basal Drift Aquifer and the bedrock aquifers are considered to represent a single aquifer because both are found along the interface between the bedrock and the basal sedimentary layer (Thomason and Keefer, 2013). The Basal Drift Aquifer is part of the Glasford Formation. The Basal Drift Aquifer is used primarily for domestic and municipal wells (Thomason et al., 2013). These aquifers are primarily identified in borehole data from water wells including lithology, gamma ray, and conductivity readings (Figure 3.1). The borehole logs and descriptions indicate what sections of the well had water present, indicating the presence of an aquifer.



(0.0) soil; topsoil, black-dk brown organic clayey silt, little sand, dense (OL)

(1.5) clay; dark brown silty sandy clay, little gravel, trace organics, soft (SC) w/ black and brown mottling, damp

(6.5) sand; brown fine to coarse sand, trace fine gravel and silt, loose, wet (SW)

(9.0) sand; brown coarse sand, trace f-m sand and f gravel, loose, wet (SP), large cobble at bottom

(22.0) sand; medium gray sand, little clay, t f gravel, dense, wet (SP)

(26.0) clay; brownish gray silty clay, little f-c gravel, trace sand, very stiff to hard, damp (CL), till

(29.0) bedrock; maquoketa group, brainard formation, greenish gray shaley dolomite

Figure 3.1: The borehole data from the Coral well showing the gamma ray log, conductivity log, resistivity log, and lithologic descriptions.

CHAPTER IV

METHODS AND DATA ANALYSIS

Due to the ineffectiveness of traditional geophysical techniques such as electric and electromagnetic in aquifer detection in complex glacial deposits, high-resolution SH-wave reflection seismic data are preferred to be used. The steps performed for final interpretation of aquifers include processing of the seismic data and the integration of the processed seismic data with well logs and lithologic well descriptions. Well log data from water wells that are in close proximity to the seismic profiles are used to aid in the correlation between the seismic profiles.

The seismic data used in this study were horizontally polarized shear wave (SH) reflection data acquired by a team from the Illinois State Geological Survey (ISGS) using SH-wave land streamer technology. SH-wave data are obtained when the source orientation is perpendicular to the orientation of the receiver line. A 2-kg sledgehammer striking the horizontal axial of ruling metal cylinder was used as the energy source. Table 4.1 shows the parameters used in the SH-wave data acquisition. The land streamer method (Figure 4.1) is a seismic data collection technique where a set of geophones are pulled behind a vehicle and shots are taken at specific intervals, similar to how marine surveys are collected. For this data, 24 14-Hz horizontally polarized geophones were used at 0.75 meter spacing, with a shot spacing of 1.5 meters.

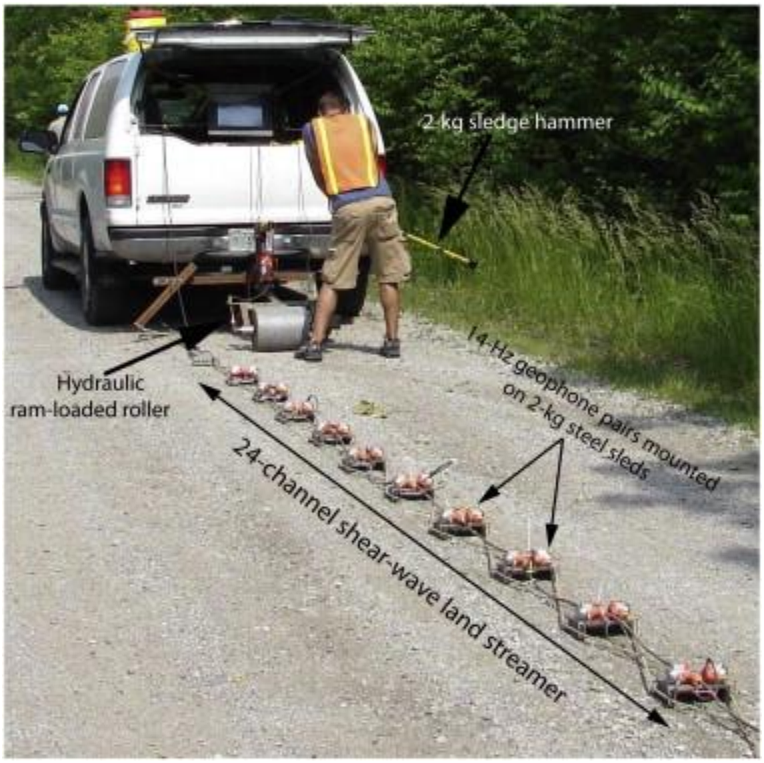
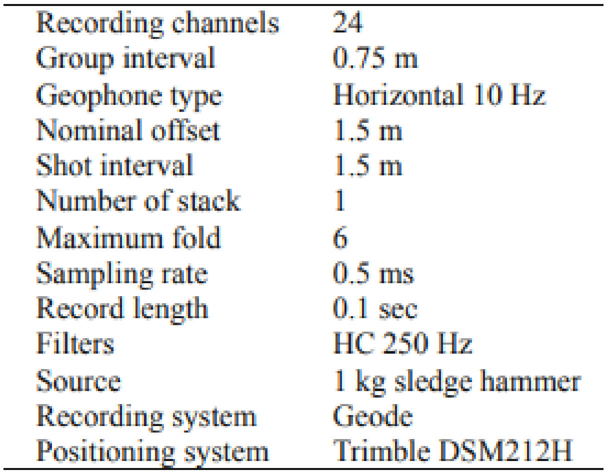


Figure 4.1: Field photograph illustrating the components and layout of the SH-wave land streamer seismic acquisition method (Ismail et al., 2014).

The SH-wave reflection data were acquired along 8 straight profiles ranging in length from 0.75 kilometers to 3.3 kilometers with a cumulative length of 17.0 kilometers. The coordinates of the changing locations of the source and receivers along the seismic profiles were measured using Trimble DSM212H Global Positioning System (GPS). The land streamer method is an efficient technique as it allows for the collection of seismic data over long profiles in a relatively short time compared with the traditional seismic acquisition methods, which require each geophone to be individually moved. The geophones do not have to be manually moved after each shot, rather, they are just pulled by the vehicle which saves time and man power. A long profile survey can be conducted with only a few geophones, as opposed to laying many geophones along the entire profile, which can take a large amount of time, depending on the number of people involved in the data acquisition. After receiving the SH-wave reflection data from ISGS, the data were processed using Landmark's Seisspace Promax software on Oklahoma State University's computer system through the High Performance Computing Center. This work adopted a processing workflow that includes several steps shown in Table 4.2. These steps will be described in the following section.

Table 4.1. A table showing the parameters used for acquiring the SH-wave data used in this study (Ismail et al., 2012).



Recording channels	24
Group interval	0.75 m
Geophone type	Horizontal 10 Hz
Nominal offset	1.5 m
Shot interval	1.5 m
Number of stack	1
Maximum fold	6
Sampling rate	0.5 ms
Record length	0.1 sec
Filters	HC 250 Hz
Source	1 kg sledge hammer
Recording system	Geode
Positioning system	Trimble DSM212H

Once the data in SEG-Y format are loaded into the Landmark's Seisspace Promax software, the geometry of each seismic profile was created and assigned to the profile. The geometry step applies a unique number to each trace by using shot and receiver locations. A stack flow was created to stack the data and compare the stacks before and after processing steps were applied. A bandpass filter with frequency values of 5-15-80-90 Hz, and a notch filter with a frequency of 60 Hz were applied to the raw shot gathers (Figure 4.2). The undesired seismic signals were removed through a bandpass filter at specified frequencies (Figure 4.2). Surface wave velocity and frequency ranges were estimated from the raw shot gathers to be around 150-190 m/s and 3-20 Hz, respectively. The surface waves were removed through a surface wave removal module that involves a two-step procedure where singular value decomposition (SVD) estimated the surface within a localized time-space window based on their estimated velocity and frequency then adaptively subtract them from the data in the second step (Figure 4.2). Deconvolution removes frequency-dependent responses of the source and receivers. Predictive deconvolution adopted in this study uses characteristics from earlier segments of a trace and then uses that information to predict and deconvolve later segments of the trace, which aids in removing noise and multiples (Figure 4.2). Residual statics was then applied to clean the data using the Maximum Power Autostatics function. The statics function removes discrepancies related to the placement of the source and receiver close to the surface. It also corrects for differences in velocities between different source and receiver stations. Residual statics was used to estimate and apply these corrections (Figure 4.2). A normal move out (NMO) correction was applied with velocity values that were calculated from the velocity analysis step. The velocity analysis allows the user to pick accurate velocity profiles for ensembles of gathers. The velocity fields derived from the velocity analysis of each SH-wave profile was later used to convert the profile from time to depth after relatively simple smoothing.

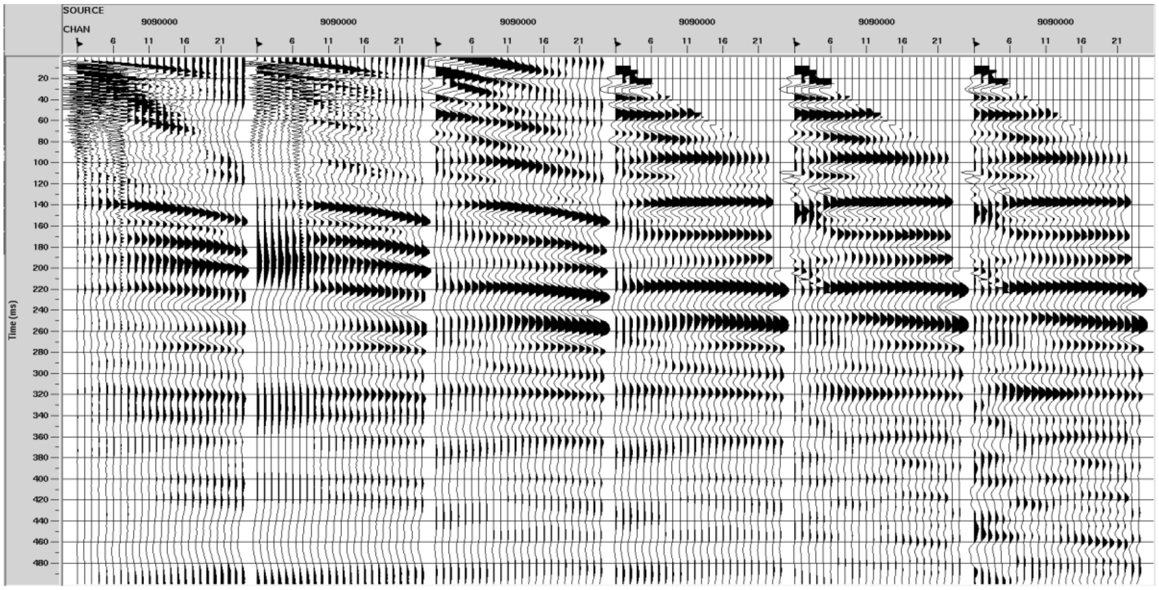
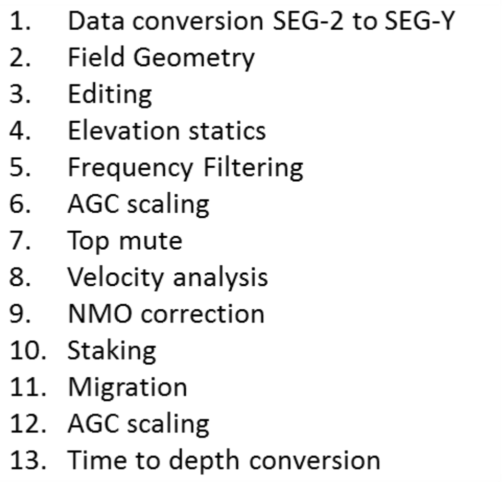


Figure 4.2: Seismic shot gather from profile 909 with some processing steps applied from left to right: raw shot gather, surface wave removal, bandpass filter, normal moveout correction, deconvolution, and automatic gain control.

Table 4.2. The main processing steps used in processing the data.



1. Data conversion SEG-2 to SEG-Y
2. Field Geometry
3. Editing
4. Elevation statics
5. Frequency Filtering
6. AGC scaling
7. Top mute
8. Velocity analysis
9. NMO correction
10. Staking
11. Migration
12. AGC scaling
13. Time to depth conversion

There are 10 water wells in the area that contained gamma ray, conductivity, and resistivity logs. The well data were interpreted and correlated with the seismic data to aid in the interpretation, mainly for aiding in locating the aquifers. Using the Kingdom software, several interpretation steps were completed. Two cross-sections were created between two sets of wells. The cross-sections provided constraints of how the lithological units change across the study area. Three wells were located near a seismic profile and were correlated. In order to correlate the seismic and well data, the lithologic, gamma ray, conductivity, Vp, and Vs logs were matched to depth. The logs were then put next to the zoomed in seismic profile. Horizons were then picked according to their coherency and how well they correlated to a formation in the well logs. Once the horizons were picked from the well log data, they were picked across the entire survey and then correlated to nearby profiles. Geologic cross-sections were then created from the seismic horizons across all profiles.

The conductivity provides information on lithology and it is sensitive to water content. Hence, it can aid in locating groundwater aquifers. Vp and Vs logs can provide information on lithology and rock density. They measure P-wave and S-wave velocities from within the borehole (Potter and Stewart, 1998). The gamma ray logs are indicative of grain size and clay content, which can indicate different lithologies. Porosity information can be inferred from gamma ray logs, for example a low gamma reading indicates low clay content, which indicates the presence of sand or gravel formation that has a higher porosity and permeability (there are no limestone formations within the studied depths).

CHAPTER V

INTERPRETATION

In this study, eight seismic profiles covering a total length of 17.0 kilometers were interpreted (Figure 5.1) with the aid of borehole logs from ten water wells. To begin the interpretation process, two sets of wells were correlated and then cross-sections were generated using the gamma ray and conductivity log curves and the lithologic descriptions.

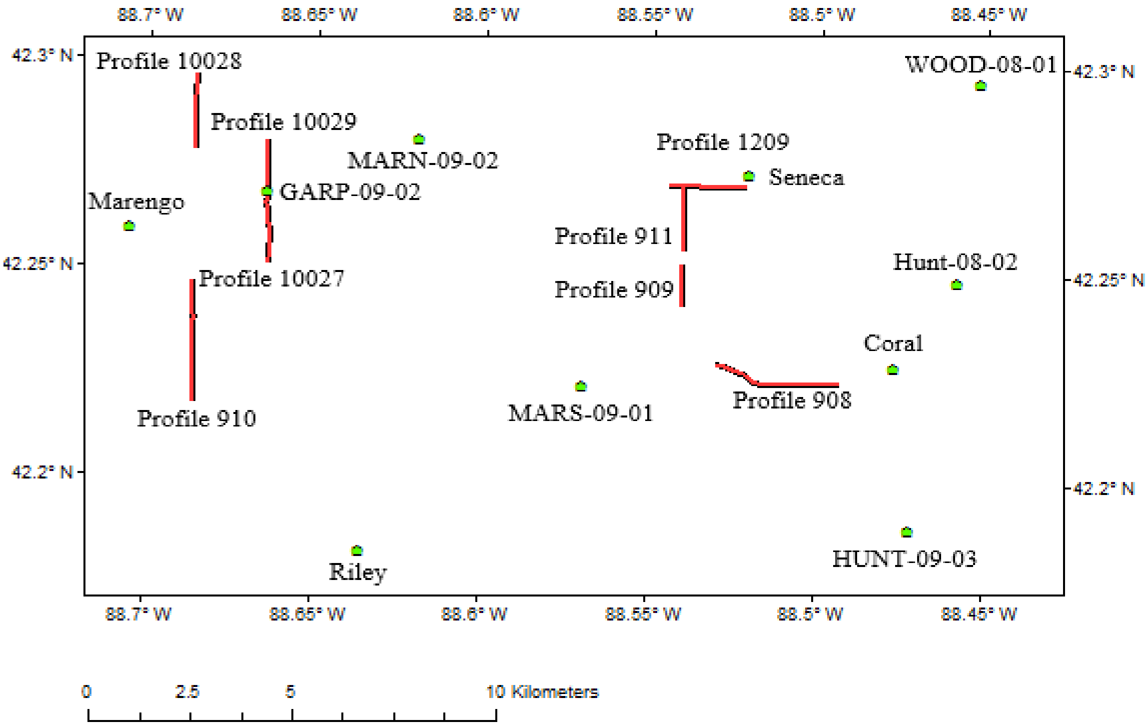


Figure 5.1: A map showing the location of the SH-wave survey lines and well locations.

5.1 Well Log Correlation

The first cross-section (figure 5.2) was created using gamma ray, conductivity, and lithologic logs from the Marengo, GARP-09-02, and MARN-09-02 wells (Figure 5.2). The cross-sections runs from southwest to northeast and cover a total length of approximately 7.7 kilometers. The cross-section intersects seismic profile 10029 where the GARP-09-02 well lies in close proximity. In the first cross-section (Figure 5.2) the uppermost unit is sand and gravel of the Henry Formation, except to the southwest, where the overlying unit is a 2 meter thick soil from the Equality Formation. It can be characterized using a decrease in both gamma ray and conductivity readings. The Henry Formation thickens in the middle of the cross-section, where the Kishwaukee River Valley lies, and thins to the northeast, where it is broken into the 2 meter thick diamiction unit of the Henry Formation and 4 meter thick gravel unit representing the Beverly Member of the Henry Formation. The Henry Formation ranges in thickness from 7 to 16 meters, the thickest portion lying within the Kishwaukee River Valley. To the northeast, the Tiskilwa Formation (diamicton and gravel), Peddicord Tongue of the Equality Formation (lacustrine silty clay), and the Robein Silt (silt loam) are found beneath the Henry Formation, but they are not present to the southwest. The Tiskilwa Formation is characterized by a slight increase in the gamma-ray signature from the overlying Henry Formation sand with a slight drop in the lower portion where it becomes more gravelly. The Peddicord Tongue is characterized by a significant spike in both gamma ray and conductivity readings due to increased clay content. The Robein Silt is characterized by a decrease in both gamma ray and conductivity due to decrease in clay content from the overlying Peddicord Tongue. Beneath the Henry Formation (and Robein Silt to the northeast) lies the diamicton layer with some silt and gravel assigned to the Oregon Member of the Glasford Formation. There is an increase in clay content which causes an increase in gamma ray and conductivity readings. The Oregon Member overlies the Bedrock to the southwest. It ranges in thickness from 5 to 9 meters, and thickens within the Kishwaukee River Valley, and thins to the northeast. Below the Oregon Member lies the Sandy Facies of the Glasford Formation which consists of sand and gravel and is characterized by a decrease in gamma ray and conductivity readings as a result of larger grain size and a decrease in clay content. It ranges in thickness from 0 to 10 meters and thickens to the northeast. The Sandy Facies indicates a potential aquifer layer.

The Fairdale Member of the Glasford Formation, which is a silty diamicton layer that becomes more gravelly to the northeast underlies the Sandy Facies. It is characterized by small, low value, conductivity and gamma ray signatures. In the center of the cross-section, the Fairdale member is too silty and clay-rich to be considered a viable aquifer. However, to the northeast it consists of dimaicton units interbedded with horizons of gravel. These gravel horizons could potentially act as useable aquifers. Below the Fairdale Member lies a unit with larger, boulder-sized clasts associated with the basal gravel aquifer. This layer pinches out and is replaced by the Kellerville Member of the Glasford Formation to the northeast, where it is a diamicton. In the GARP-09-02 well, below the basal gravel aquifer, lies the Bedrock Aquifer, which is a sand and gravel aquifer that overlies the bedrock unit. The combined thickness of the Bedrock Aquifer and the Talus Aquifer in the GARP-09-02 well is 20 meters. It can be characterized by relatively low gamma ray and conductivity readings with a small spike in the conductivity curve that could indicate the presence of water. The bedrock is Silurian dolomite and to the southwest underlies the Oregon Member of the Glasford Formation and is found at a depth of 13 meters. In the GARP-09-02 well the bedrock lies beneath the Bedrock Aquifer layer and is at a depth of 66 meters. The well log information was not deep enough to show the bedrock to the northeast.

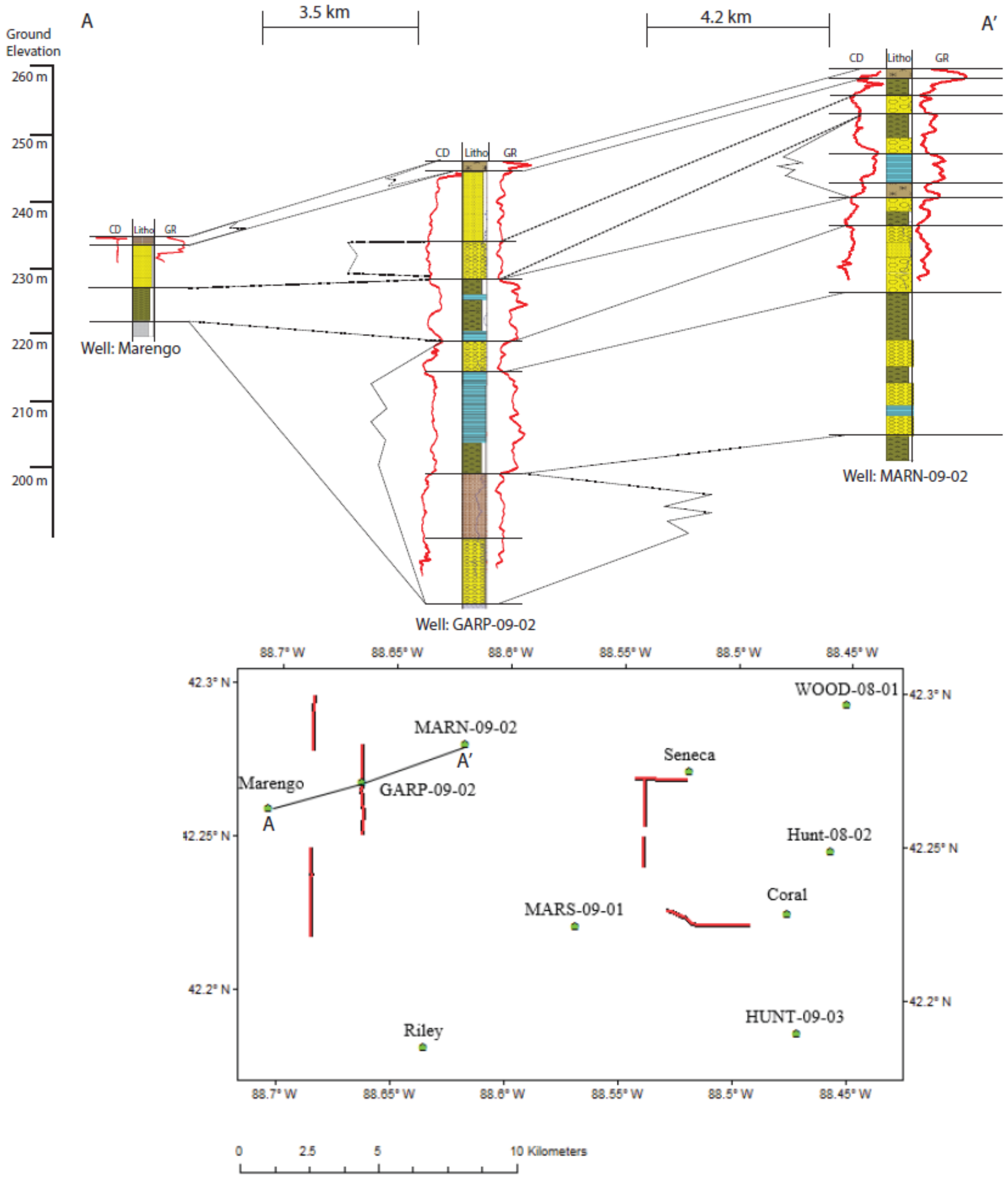


Figure 5.2. Upper panel - cross-section 1 showing the correlation between the Marengo, GARP-09-02, and the MARN-09-02 wells. The correlation uses gamma ray, resistivity, and lithologic logs. Lower panel – the location of the cross-section within the study area.

The second cross-section (figure 5.3) correlates the Coral, Seneca, and MARS-09-01 wells were used for the construction of this cross-section. It covers a total length of 13.3 km and runs from the MARS-09-01 well to the west, the Coral well to the north, and then southeast to the Coral well (Figure 5.2). The uppermost unit to the west is a 32 meter thick diamicton named the Tiskilwa Formation. The Tiskilwa Formation is characterized by high conductivity readings that decrease with depth until the readings become relatively low. The Tiskilwa Formation pinches out to the north and east, where it is replaced by the Henry Formation, which consists of sand and gravel with a thin layer of silt to the north. To the east, the Henry Formation is split by the Yorkville Member of the Lemont Formation, which is a 9.5 meter thick diamicton layer. Beneath the Yorkville Member lies two subunits of the Henry Formation, an unnamed gravel unit and the Ashmore Tongue, which is a thick sand layer. The Henry Formation ranges in thickness from 0 meters to the east and thickens to north and west to 27 meters. It can be characterized by relatively low gamma and conductivity readings, with the exception of the more gravelly and silty layers found in the Seneca well to the north. The Henry Formation is a good potential aquifer in this area. The Robein Silt lies below the Henry and Tiskilwa Formations. It is often associated with a thin paleosol with clay loam and is characterized by an increase in conductivity and gamma ray readings with a slight increase in Vp and a slight decrease in Vs readings. To the east, the Robein silt pinches out and it is replaced by the Pearl Formation, which is a sandy aquifer. To the east, below the Pearl Formation lies the Glasford Formation, which in the Coral well is a 1.5 meter thick diamicton unit. The Glasford Formation becomes much thicker to the north where it is divided into the Sandy Facies and the Fairdale Member. The Sandy Facies is a sand and gravel unit that is 3 meters thick and extends to the southwest where it becomes slightly thicker and more gravelly. The Fairdale Member underlies the Sandy Facies to the north and west. In the Seneca, it consists of silt, clay, sand, gravel, and a thin diamicton unit. The gamma ray readings decrease significantly between the silty clay and the sand, which could be a confined aquifer, as it has silty clay both above and below it. The upper portion of the Fairdale member to the southwest is a diamicton layer. The lowest portion of the Fairdale member in the Seneca and MARS-09-01 wells is a sand and gravel layer that is likely associated with the unit constituting bedrock aquifer.

The overall thickness of the Glasford Formation ranges from 1.5 meters in the southeast to 15 meters thick to the northwest. The bedrock lies at the bottom of each well and it is shallower in the southeast where it is found at a depth of 37 meters. It becomes as deep as 65 meters in the north, and is 47 meters deep to the southwest.

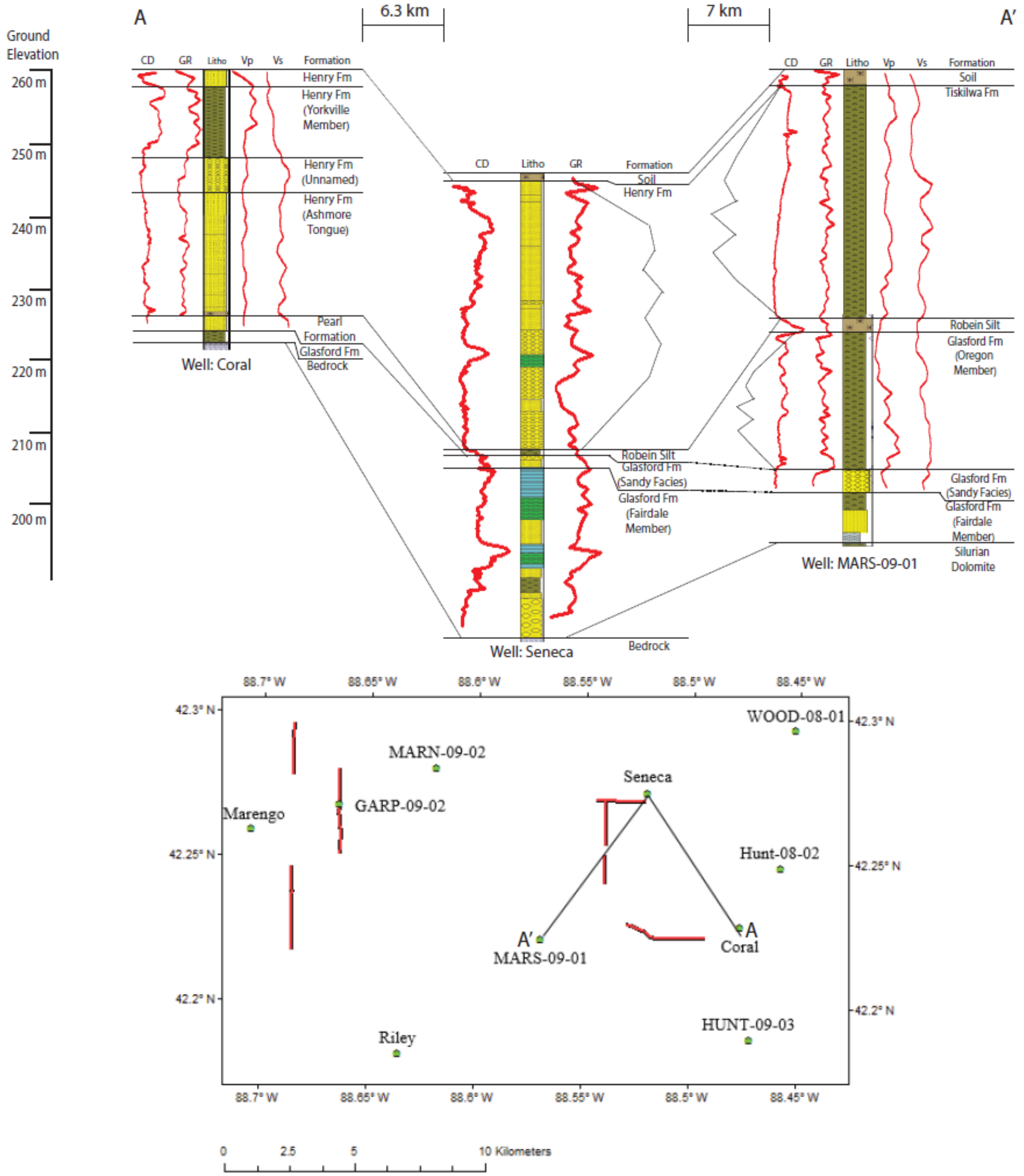


Figure 5.3: Upper panel - cross-section 2 showing the correlation between the Coral, Seneca, and the MARS-09-01 wells. The correlation uses gamma ray, resistivity, Vp, Vs, and lithologic logs. Lower panel – the location of the cross-section within the study area.

5.2 Seismic-Well Log Correlation

The borehole data used for correlating the well data with the seismic data only contained gamma ray and electrical logs. Only one well included VS and Vp logs, so synthetic logs were not used for correlation. The gamma ray log is typically an effective tool for distinguishing more sand-rich sediment with low clay content from higher-clay sediment. Gamma ray logs can also be used to identify grain-size changes within sandy layers, where a higher gamma reading usually indicates finer-grained sediment and a lower gamma reading indicates coarser-grained sediment. The conductivity log can also be used for identifying lithological trends in borehole data where high conductivity typically indicates higher clay content and low conductivity typically indicates more sandy low clay content sediment (Isyaku et al., 2016). Although gamma ray and conductivity logs do not provide information on seismic velocities, they can provide information on the lithologic makeup and changes in the subsurface. Gamma ray and conductivity logs, when paired together, can be a powerful tool for assigning lithological units. Typically, gamma ray and conductivity logs are used together as they both are good indicators of lithological changes (Isyaku, et al., 2016). For example, sand and gravel aquifers can usually be identified by low gamma ray and conductivity readings while aquitards can be identified by their high gamma ray and conductivity readings (Pullan et al., 2002). These logs are effective at delineating variations in lithology within the borehole, which can be paired with seismic reflection. Seismic energy is not affected by changes in density but rather by changes in the cohesiveness of the media. Reflections in seismic data are a result of lithological changes as well, so it can be correlated with the lithological changes seen in the conductivity and gamma ray logs.

Figure 5.4 shows the correlation between the GARP-09-02 well and seismic profile 10027. It shows 6 major reflectors that align with the well log interfaces. The deepest reflector is the bedrock, which is found at a depth of 56 meters and appears to become shallower to the north. The bedrock has a bright reflector because of the change from gravel to dolomite between the overlying sand and gravel bedrock aquifer unit. Overlying the bedrock is a gravel bedrock aquifer that is 10 meters thick and becomes shallower and thinner to the north. The reflector marking the top of this aquifer is not as bright as that marking the top of the bedrock because the overlying unit is the gravelly Talus Aquifer, so the lithology and density changes are not significant. The Talus Aquifer lies at depth of 46 meters. It shows a weak reflector, but strong enough to be followed laterally. The reflector is weak due to the presence of similar lithologies across it. Above the Talus Aquifer lies the Fairdale Member of the Glasford Formation, which is approximately 15 meters thick. Although the Fairdale Member consists of an upper silty loam, and a lower diamicton unit, they are imaged as one horizon by the seismic data due their similar clay content and densities.

Overlying the Fairdale Member is the Sandy Facies of the Glasford Formation at a depth of 27 meters and a thickness of 5 meters measured along the borehole. The change from clay to gravel unit produced a laterally-continuous strong seismic reflector that marks the top of the Fairdale Member. The overlying layer is silty clay and diamicton Oregon Member of the Glasford Formation. The significant contrast between the gravel and the diamicton produced a reflector that can be followed in the seismic profile. The Oregon Member is found at a depth of 18 meters and a thickness of 9 meters at the borehole. The Henry Formation sand and gravel is the uppermost formation, at a depth of 1.5 meters and a thickness of 16 meters at the borehole. Just above the Henry Formation is a thin soil layer. The shallower reflectors appear to be relatively flat, while the deeper reflectors appear to be steeper and less coherent. This could be due to the fact that the quality of the seismic data decreases with depth, but could also be due to the presence of a glacial deposit unit.

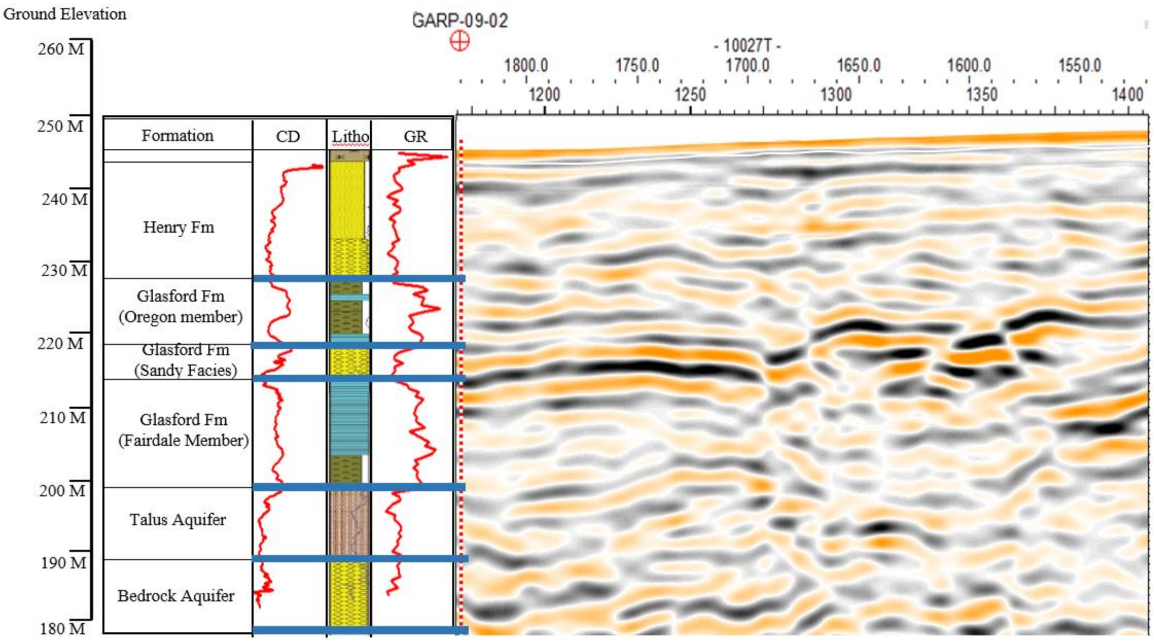


Figure 5.4: The correlation between seismic profile 10029 and the GARP-09-02 well with lithological description, conductivity log (CD) and gamma ray log (GR). Six distinct horizons are correlated between the borehole and the seismic profile.

Figure 5.5 shows the correlation between the Seneca well and seismic profile 1209. The lowest mapped unit in this interpretation is the bedrock layer. It is composed of Silurian Dolomite, which creates a sharp velocity and density contrast with the overlying silt and sand unit, hence creating a strong reflector between them. The bedrock is at a depth of 47 meters at the borehole. Overlying the bedrock is the silt and sand Fairdale Member of the Glasford Formation. The Fairdale Member is found at a depth of 30 meters and is 17 meters thick at the borehole and has a weak reflector between the overlying sand and diamicton layer. Above the Fairdale member is the wet sand and gravel Oregon Member of the Fairdale Member grouped with the Robein Silt and Paleosol. The Oregon Member is a thin layer (1 meter) of fine wet sand and gravel. The lower Henry silt and sand Formation overlies the Robein Silt and it is found at a depth of 18 meters and it is 9.5 meters thick. Overlying the lower Henry Formation is the gravelly middle Henry Formation. The change from silt to gravel produced a sharp reflector at the base of the middle Henry Formation. The middle Henry Formation is 5 meters thick and it is found at a depth of 13 meters at the borehole. This formation can be identified utilizing the gamma ray and conductivity logs by a drop in both log curve signatures. Above the middle Henry is the upper Henry sand and gravel unit. The upper Henry Formation is 12.5 meters thick and at a depth of 0.7 meters. Above the upper Henry is the unconsolidated and thin (0.7 meters) soil layer. The unconsolidated nature of the soil creates a significant difference between the more uniform and denser henry Formation. The boundary between the soil and the upper Henry Formation is seen in the conductivity and gamma ray logs by an increase in both logs.

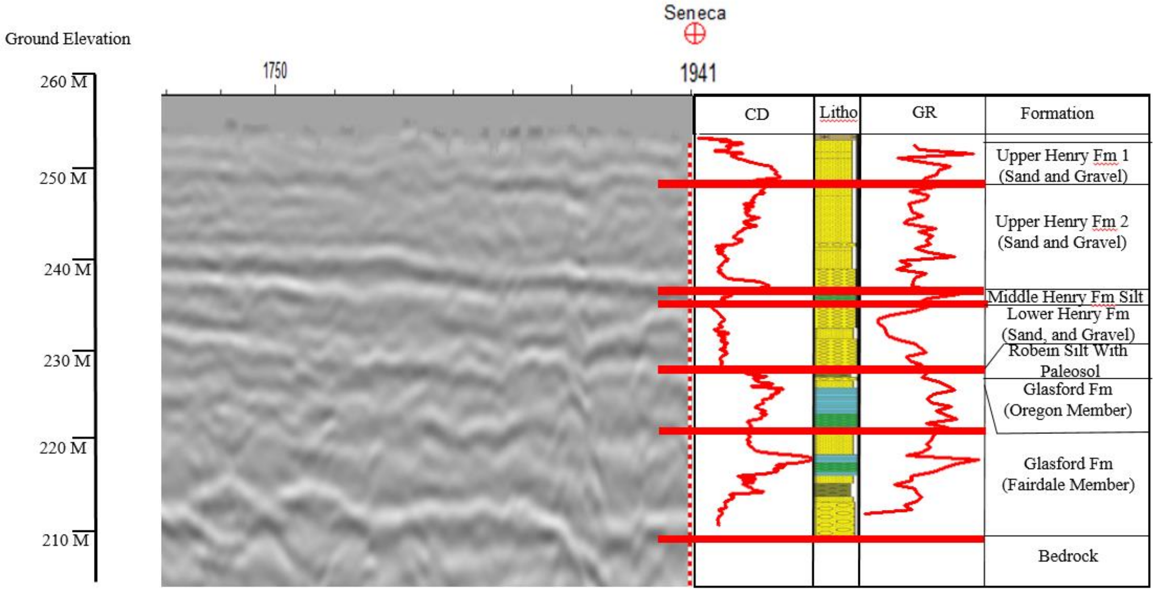


Figure 5.5: The correlation between seismic profile 1209 and the Seneca well with lithological description, conductivity log (CD), and gamma ray log (GR). Six distinct units are correlated between the borehole and seismic profile. The borehole is located on the eastern end of the profile.

Figure 5.6 shows the correlation between the Coral well and seismic profile 908. The Coral well lies 1.3 kilometers away from seismic profile 908. Because of the horizontal nature of the reflectors in the seismic profile, the lithologic units in the well data are assumed to correlated with the reflectors. The lowest reflector visible in the data is the Ashmore Tongue of the Henry Formation, which is divided into three subunits including the Upper, Middle, and Lower Ashmore

Tongue. The Ashmore Tongue is sub-divided due to a change in lithology within the unit. The Ashmore Tongue potentially holds the Pearl/Ashmore Aquifer. Overlying the Ashmore Tongue is an unnamed sand unit of the Henry Formation. Above the unnamed sand unit of the Henry Formation lies the Yorkville Member diamicton of the Lemont Formation. There is a bright reflector between the Yorkville Member and the unnamed gravel unit of the Henry Formation due to a drastic change in lithology between the diamicton and the gravel. This is seen in the borehole data by a decrease in conductivity and gamma ray and an increase is Vs readings. The Yorkville Member itself is characterized by high gamma ray, conductivity, and Vp readings and low Vs readings. The surface layer which overlies the Yorkville Member is the Henry Formation sand that is characterized by low gamma ray, conductivity, Vp and Vs readings. The units appear to be horizontal and continuous within the seismic.

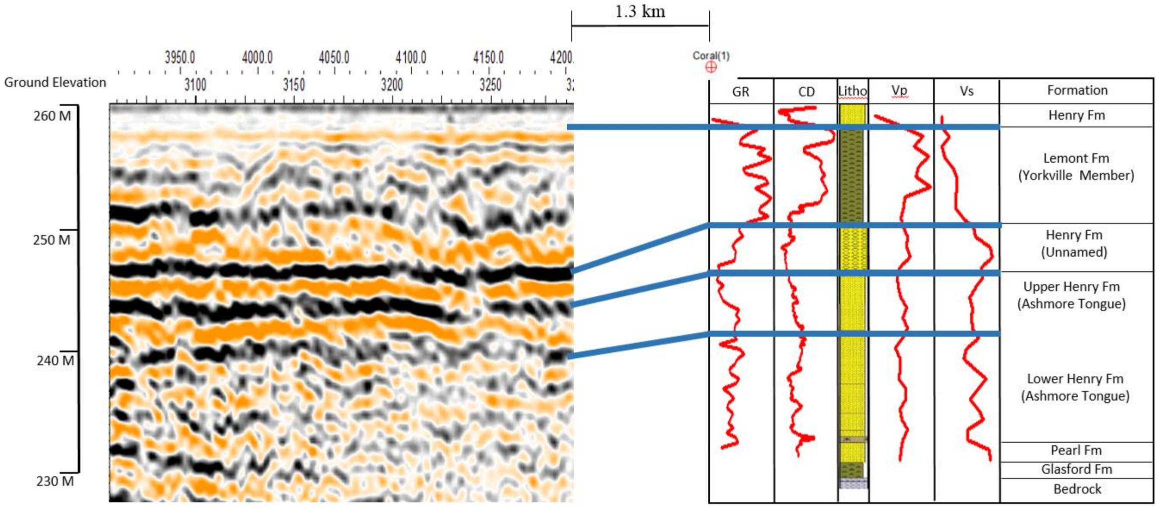


Figure 5.6: The correlation between seismic profile 908 and the Coral well with lithological description, conductivity log (CD), and gamma ray log (GR). The well is located 1.3 kilometers northeast of profile 908, which might explain the slight difference in the depth of the units between the well and the seismic profile.

5.3 Seismic Interpretation

The correlations between the seismic profiles and the well logs allowed for the identification of subsurface seismic horizons representing different lithologic units. Figure 5.7 identifies six units found in seismic profile 908. The units in the seismic profile are relatively horizontal with only minor changes in their continuity along the profile. From top to bottom the units identified in the seismic profile are the Henry Formation sand, which likely contains the Surficial Aquifer. The Henry Formation deepens in the middle of the seismic profile and it becomes shallower on both sides. The Upper Yorkville diamicton Member of the Lemont Formation underlies the Henry Formation and appears to thicken to the west. Below the Upper Yorkville Member lies the Lower Yorkville diamicton Member, which behaves similar to the Upper Yorkville in that it thickens to the west. There is likely some small lithologic change that results in a weak reflector that is laterally continuous and can be followed across the seismic profile. Below the Lower Yorkville Member lies an unnamed gravel unit of the Henry Formation. This gravel unit has a constant thickness of approximately 5 meters and may contain an aquifer that is bounded on top by the Yorkville diamicton. The sandy Upper Ashmore Tongue of the Henry Formation is the next lowest unit. It is only visible in the easternmost 1000 meters, where it tapers off and pinches out to the west. Below the Upper Ashmore Tongue in the east and the unnamed gravel unit of the Henry Formation lies the Lower Ashmore Tongue sand, which potentially contains the Pearl/Ashmore Aquifer in this area. No other seismic horizons are seen in this profile, including the bedrock. The deeper horizons are not visible; most likely due to the limited penetration depth of the imparted SH-wave energy from the seismic source.

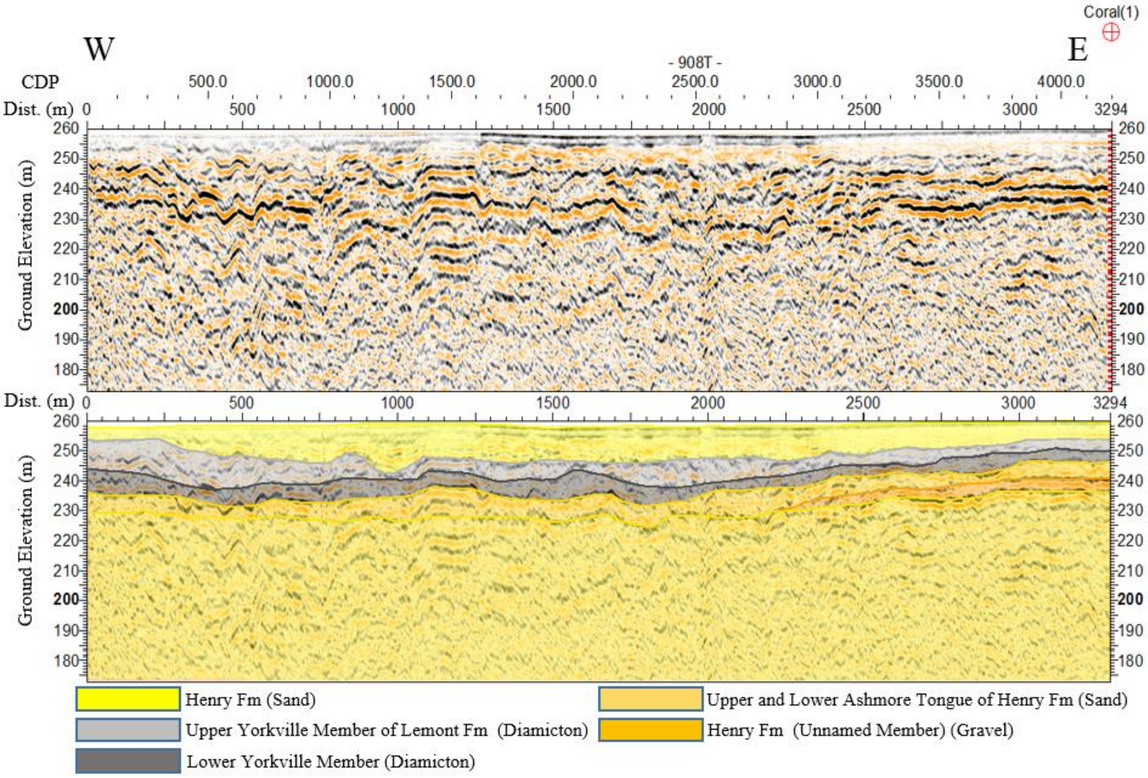


Figure 5.7: Seismic profile 908 without interpretation (top), and with interpretation (bottom).

Figure 5.8 shows seismic profile 1209 which runs from west to east and shows eight distinct units. The surface layer throughout this profile is the Upper Henry sand Formation, which is 10-12 meters thick. Below the Upper Henry lies the coarser sand and gravel of the Upper Middle Henry Formation. It is 3-6 meters thick, becoming thicker to the west. To the west, this formation overlies the Fairdale Member of the Glasford Formation, and to the east it overlies the Middle Henry, Lower Henry, and Robein Silt and Paleosol Formation. The Middle Henry is a small channel-like feature that is around 1 km in length and it is filled with gravel. This was a glacial stream that eroded through the overlying sand of the Upper Middle Henry and deposited gravel sediment. Below the Upper Middle Henry Formation lies the Lower Henry Formation gravel and silt, which is around 10 meters thick and terminates against the Robein Silt and Paleosol to the east in the center of the profile. The Robein Silt with Paeosol layer lies beneath the Lower Henry. The Roben Silt and Paleosol is included with the underlying sand and gravel unit. The Robein Silt unit is around 8 meters thick and terminates in the center of the profile, against the Fairdale Member below. The Fairdale Member diamicton of the Glasford Formation lies below all of the overlying sediment within the profile and acts as a seal between the overlying Surficial Aquifer and the underlying potential aquifer to the west. The Fairdale Member is around 8 meters thick and thickens to 13 meters on the western end of the seismic profile. Below the Fairdale Member in the western half of the seismic profile is an unknown sand unit that could be a potential aquifer. It is 18 meters thick and thins until it terminates to the east. This unit could be part of the Bedrock Aquifer as it maybe hydraulically connected with the bedrock below. The bedrock in this area is a vuggy dolomite. It is 53 meters deep on the western end, becomes shallower to around 35 meters in the center and deepens to 45 meters to the east. The overlying sand and gravel layers that comprise the entire Henry Formation are considered the Surficial Aquifer and are sealed below by the clay-rich diamicton of the Fairdale Member.

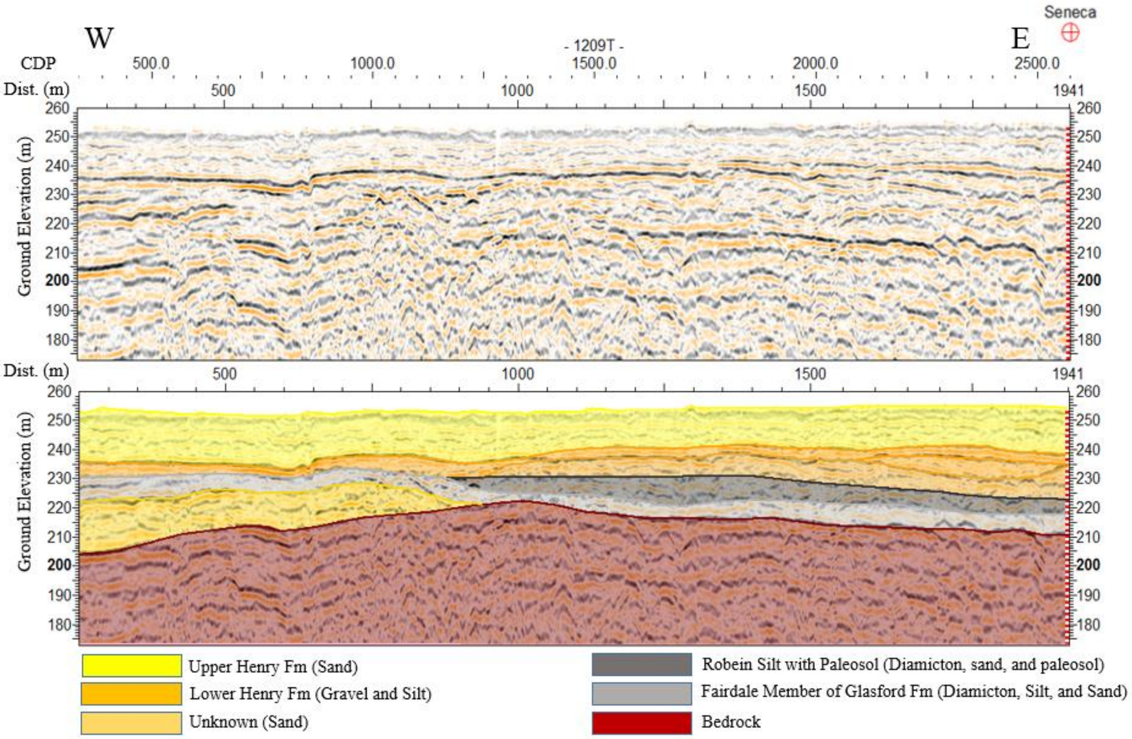


Figure 5.8: Seismic profile 1209 without interpretation (top), and with interpretation (bottom).

Figure 5.9 shows seismic profile 911 and 909, which runs from south to north and almost perpendicularly intersects profile 1209 just past the northern end. The units interpreted in these profiles were correlated with those from seismic profile 1209. Seven individual units were interpreted in profiles 909 and 911. The uppermost unit interpreted is the Upper Henry Formation sand, that potentially contains the Surficial Aquifer. It is relatively consistent 15-18 meters thick unit on both ends of the profiles except in the middle where it thins to about 10 meters where the other units appear to become shallower. Below the Upper Henry Formation is the gravel and silt Lower Henry Formation. The change from sand to gravel and silt produced the observed reflector horizon. The Lower Henry Formation ranges in thickness from 3 to 5 meters throughout the profile and it is potentially an aquifer bounded by the diamicton on top and the silty lacustrine deposits below. The Fairdale Member diamicton of the Glasford Formation lies below the Lower Henry Formation. In the seismic profiles, the unit is thin to the south, becomes thicker in the middle, and then thins slightly to the north. In the middle portion of the profile, it becomes thicker in what appears to be a channel-like formation. Above this channel-like formation in the Fairdale Member lies a thin lacustrine deposit that is about 4 meters thick and extends about 900 meters along-profile extent where it pinches out on each side. This lacustrine deposit could be the result of glacial erosion of the upper portion of the Fairdale Member and then deposition of the lacustrine deposits in a glacial lake. Below the Fairdale Member on northern and southern end lies two unnamed sand units. They could be part of the same unit, but they were interpreted to be different units in this study. Because of the complexity of the geology and the rapid changes that occur over short distances, it is difficult to determine if they are the same formation. Both sand units are approximately 10 meters thick on both sides of the seismic profiles and pinch out towards the middle. It is possible that they were once connected but were subsequently separated by the erosional processes that created the channel-like feature in the middle. These units could potentially hold the bedrock aquifer. Below these sand units (and the Fairdale Member in the middle of the profile) lies the Bedrock. The top of the bedrock is relatively flat in the south, becomes slightly shallower and has two topographic highs and then becomes deeper to the north, where it may be nearing the Kishwaukee River Valley.

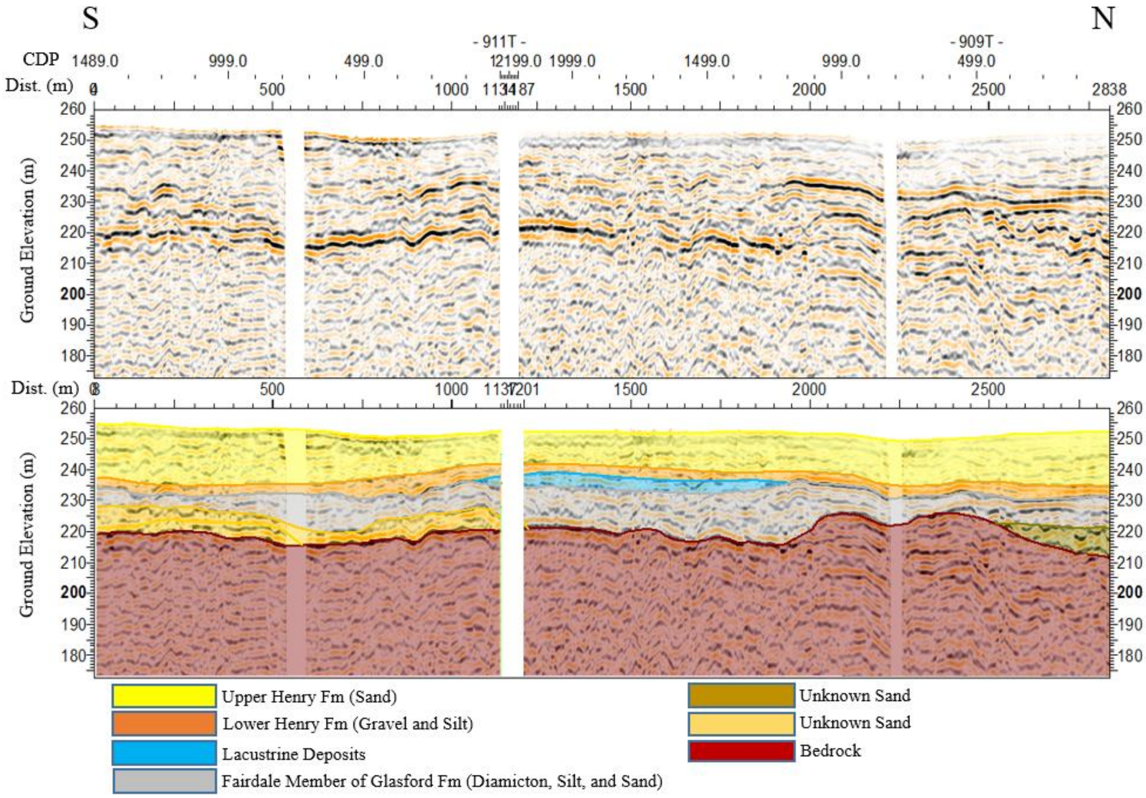


Figure 5.9: Seismic profiles 909 and 911 without interpretation (top), and with interpretation (bottom).

Figure 5.10 shows seismic profile 910, which runs from south to north. There are no wells adjacent to this profile, but the flat and shallow nature of the beds is similar to what is shown in the Marengo well located about 1.5 kilometers to the northwest, so the well data from that well was used to infer the seismic units. The uppermost unit was interpreted to be lacustrine clay of the Equality Formation. It is approximately 3 meters thick throughout the profile. Below the Equality Formation lies the Upper Henry Formation sand. It is fairly flat throughout the profile and thins to the south and its thickness ranges from 10 meters in the north to 5 meters to the south. The Lower Henry Formation sand lies below the Upper Henry Formation. The reflector between the two sandy units of the Henry Formation could be due to a change in grain size, which would cause a change in density resulting in reflected seismic energy. The Lower Henry is flat throughout the profile and it is about 8 meters in the north and thins to 4 meters to the south. The Glasford Formation diamicton is present in the southern two-thirds of the profile and pinches out between the overlying Lower Henry Formation and the underlying bedrock. The Glasford Formation is about 10 meters thick throughout the profile. The base of the diamicton is illustrated by a bright reflector because of the difference in lithology and density between the Lower Henry sand and the overlying more clay-rich diamicton unit. The top of the bedrock is marked by a bright reflector on the northern end of the profile, but this reflector becomes less distinct to the south when the Glasford diamicton unit appears. The reason that the bedrock becomes less visible is because the seismic energy is absorbed and scattered as it travels through the overlying diamicton unit.

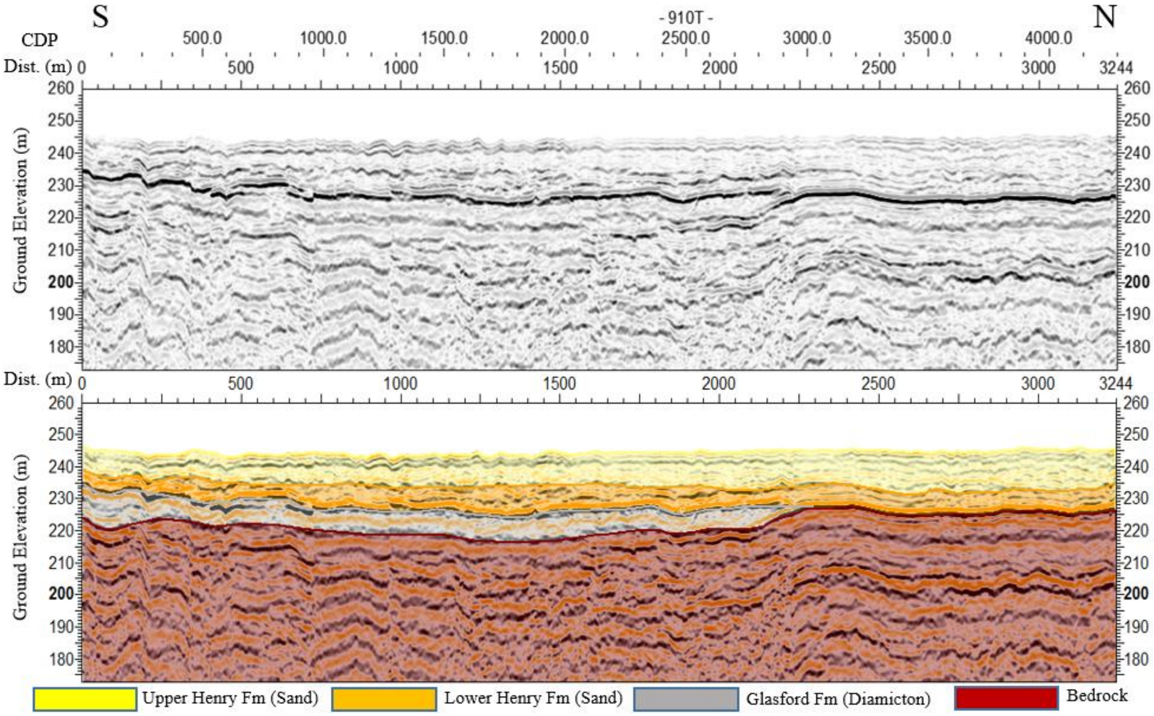


Figure 5.10: Seismic profile 910 without interpretation (top), and with interpretation (bottom).

Figure 5.11 shows profiles 10029 and 10027 which runs from south to north and shows 11 distinct reflectors and units. The uppermost unit is the Upper Henry Formation sand followed by the Lower Henry Formation gravel. These two units combined contain the Surficial Aquifer. The aquifer unit ranges in thickness from 1 meter in the north, thickens to 18 meters at the borehole, and then thins to 5 meters to the south. Below the Lower Henry gravel lies the Oregon Member diamicton of the Glasford Formation. It is present throughout the profile and its thickness fluctuates between 3 and 13 meters within the profile. The Sandy Facies of the Glasford Formation lies beneath the Oregon Member and is distinguishable due to the change from diamicton to gravel. The Sandy Facies is 3-4 meters thick unit throughout the profile, but thickens to about 10 meters to the north where it pinches out against the bedrock.

The Upper Fairdale Member diamicton of the Glasford Formation underlies the Sandy Facies in the southern two-thirds of the profile. The Upper Fairdale Member is a subglacial silty clay layer that is 5-10 meters thick throughout the profile, but it thins to the south. It pinches out to the north, when it becomes at the same stratigraphic level as the Lower Fairdale Member. The Middle Fairdale Member silty clay, the Lower Fairdale Member diamicton, and the Talus Aquifer underlie the Sandy Facies and the Upper Fairdale Member around the borehole. These three units are slope features. The Lower Fairdale Member and the Talus Aquifer are features due to the steep cut in the bedrock. The Upper Fairdale Member was likely deposited, eroded by glacial processes, and then filled with sand to the south. The unit that filled the eroded Upper Fairdale member is an unnamed sand unit that is 20 meters thick and thins until it pinches out further south. This is because the Middle Fairdale unit eroded away and then filled with a sand unit from glacial outwash. This unit could potentially be an aquifer. Overlying the bedrock throughout the profile, except on the northern end, is the gravelly Bedrock Aquifer layer. It can be considered to be hydraulically connected to the bedrock. The bedrock in this profile is a vuggy Ordovician-aged carbonate. The bedrock was glacially eroded to form a basin that was filled with the overlying sand, silt, and diamicton layers. It is almost 40 meters deep to the south, deepens to over 70 meters at the deepest point in the basin and then becomes as shallow as 10 meters on the northern end of the profile.

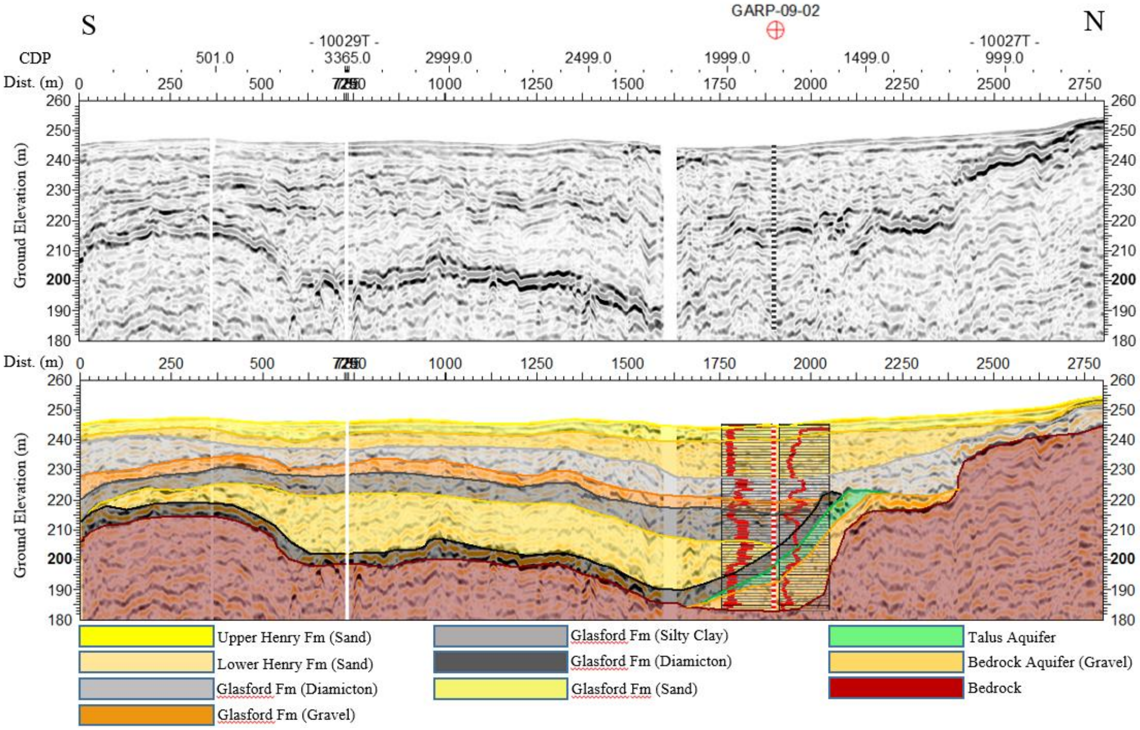


Figure 5.11: Seismic profiles 10027 and 10029 without interpretation (top), and with interpretation (bottom).

CHAPTER VI

DISCUSSION

This work is, in part, intended to highlight the potential of seismic SH-waves for mapping lithological units that present potential aquifers in a glacial – interglacial geologic setting dominated by high frequency alternation between sand and gravel units and diamicton, silt, and clay units. Several horizons were mapped between units of similar lithology, which indicates that SH-wave reflection is capable of imaging smaller changes in lithology. Correlating the seismic profiles with well data proved to be vital for improving the interpretation as it allowed for the correlation of identified lithologic units with the observed reflectors in the seismic data. This is useful for mapping groundwater aquifers. The capability of SH-waves to highlight major differences in lithology can be translated to the indirect identification of sand and gravel units characterized by higher porosity and permeability and contrasting them from the overlying and underlying layer of clay or diamicton that has very low porosity and permeability.

Nevertheless, it is important to highlight the challenges encountered with the interpretation of the seismic data in this study. First, there are a few reflectors that are not continuous and are more difficult to see in the seismic most likely as a result of the manifesting horizon being thin and below the resolution of the seismic data. Second, there was difficulty at times correlating the seismic data to the well log data. For example, in seismic profile 908, which was correlated with the well log of the Coral well, the deeper units of the Pearl Formation, the Glasford Formation, and the bedrock could not be identified in the seismic profile. This is also the case for seismic profile 910 where the bedrock reflector becomes less distinguishable when the diamicton is encountered overlying it. This is because the diamicton absorbs much of the seismic energy so the geological horizons below become less distinguishable in the seismic profile. Third, the fact that the geometry, depth, and thickness of the geological units as well as their frequent tapering out makes the interpretation of the seismic data more difficult and less accurate. Seismic profiles 10027 and 10029 show how this complexity presents challenges in interpreting the seismic data.

Despite the above challenges, for the large part, the lithological units were resolved and more importantly, potential aquifers were identified. In seismic profile 908 the possible locations for the Surficial Aquifer and the Pearl/Ashmore Aquifer were identified within the study area. Two additional potential aquifers were identified in seismic profile 1209 represented by the Surficial Aquifer and the Bedrock Aquifer. The Surficial Aquifer is present and very thick throughout this profile and the Bedrock Aquifer is present on the western portion of the profile where it is thickest. Perpendicular to profile 1209 is profiles 909 and 911. The aquifers identified in profile 1209 were laterally extrapolated into profiles 909 and 911. The Bedrock Aquifer shown in both profiles depicts a channel-like shape, indicating a sandy channel fill aquifer that is likely hydraulically connected to the bedrock below. The Surficial Aquifer is documented to be present along the entire length of profile 910 and this was associated with a shallower bedrock. In profiles 10027 and 10029, the Surficial Aquifer was interpreted to be defined by the topmost unit. There is an unknown thick sand in the deeper parts of the eroded bedrock basin that is potentially an aquifer as well as a Talus Aquifer on the edge of the steep drop-off in the bedrock that is confined on top by a diamicton. The fourth aquifer identified in these profiles was the Bedrock Aquifer, which is likely hydraulically connected with the unknown sand aquifer and the Talus Aquifer and with the bedrock.

CHAPTER VII

CONCLUSION

By focusing on northern Illinois, this study showed that seismic SH-wave reflection, along with borehole data, is effective in imaging thin, complex lithological units as well as identifying potential aquifer in a complex glacial – interglacial geological setting where traditional geophysical methods of groundwater detection and imaging are ineffective. In this study several aquifers were imaged and mapped using the seismic data. There are many areas around the world with similar geologic settings that could use a similar approach to that used in the study for imaging aquifers. This study is important because it gives an idea of the extent and thickness of the aquifers and could lead to a better understanding of the aquifer's overall architecture. This is useful, especially in areas similar to northern Illinois, which has a rapidly growing population and an increasing demand for freshwater. This study has aided in better understanding groundwater aquifers in northern Illinois. Understanding freshwater sources is becoming increasingly important as demand continues to increase and sources are depleting. With better knowledge of freshwater aquifers comes the ability to use those aquifers more sustainably and avoid a need for freshwater without viable alternative sources.

Further geologic, geophysical, and hydrogeologic research needs to be carried out in this area. The seismic profiles and the well log data are relatively far apart from each other and only two seismic profiles were close enough to a well that can allow unequivocal correlation between the two data sets. It is recommended that more seismic surveys are carried out both near the water wells and also between the seismic surveys that have already been acquired. Additional wells and seismic data will allow for high resolution interpretation with more accuracy. Isopach maps of different formations could be created which would greatly aid in visualizing the overall geologic trends in the area. Many of the logs used to correlate with the seismic data did not have Vp or Vs data, so synthetic logs were not generated. Acquiring Vp and Vs logs and generating synthetic logs would increase the resolution and accuracy of the interpretation in this area.

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