Neuquen Basin Database Implementation: Benefits of Working with an Integrated Interpretation Platform

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Keywords: Integrated database, GIS, regional interpretation, standardization

Abstract:

Como parte del plan de desarrollo establecido por Pioneer, se ha implementado una base de datos de Cuenca Neuquina para llevar a cabo una evaluación de carácter regional. Los beneficios resultantes de la construcción de dicha base de datos como así tambien el uso del GIS y de las aplicaciones respectivas en el proceso de interpretación, han contribuido a utilizar eficientemente los datos existentes tanto desde el punto de vista económico como organizativo.

Los mapas y secciones que inicialmente se han construido a partir de la implementación de dicha base de datos han resultado ser inmejorables como guía para la planificación de futuros proyectos. Por otro lado, la interconectividad existente entre la base de datos, las aplicaciones y el GIS convierten a este sistema integrado en una herramienta sumamente poderosa y eficiente, lo cual ha permitido a los geólogos involucrados en el estudio, generar productos de gran calidad en forma rápida y eficiente.

Esta forma de encarar el trabajo de análisis de nuevos prospectos, resalta la importancia de organizar convenientemente los flujos de trabajo como así tambien definir una estandarización de datos, proceso en el que aún existen algunas dificultades inevitables. De todas formas, la estandarización ha sido sumamente beneficiosa tanto desde el punto de vista del gerenciamiento de los datos como el de la interpretación.

Si bien la implementación de una base de datos puede ser un proceso tedioso, los beneficios resultantes se amortizan ampliamente desde el punto de vista de la calidad de la interpretación como así tambien del tiempo empleado para esta tarea.

Introduction

Over the past year Pioneer has created and begun to utilize an OpenWorks[1] (OW) regional database for the Neuquen basin. During the preceding four years a sizeable number of intensively quality controlled development-scale projects had been created and interpreted on either a PC or Unix[2] based system. These projects were well suited to Pioneer's ongoing exploitation efforts. Unfortunately, from a regional prospective they provided limited assistance.

Pioneer is no exception to the industry rule, with a mixture of paper and digital data of all types in the files. It was apparent much of this data, especially the paper data, was being underutilized, in part because it was difficult to incorporate into the existing digital projects. Fortunately, most of the non-digital information had been compiled into Access[3] databases. The usefulness of these databases, which encompassed well logs, well files, seismic and maps, was somewhat limited from a regional perspective as they were not spatial and there had been no attempt to "standardize" the entries (all information entered strictly honored the original). This did not allow the data to be depicted in a map sense and restricted the ability to filter and query for desired data. In addition, significant amounts of data had yet to be properly catalogued.

All the above factors, together with the need to work at all scales (basin, block, field, well, etc.) led the team to design and build the regional database utilizing the spatial aspects of the GIS (Geographic Information System) application Arcview[4] in an integrated interpretation platform (OpenExplorer[5]-LandMark[6]). The basic premises for this decision were:

- The wide variety and significant volumes of desired input data types dictated the project be designed for and utilized on an integrated interpretation platform.
- It must be backed by a spatial database to allow for easier data visualization and querying.
- The project should be as cost and labor efficient as possible.
- Standardization greatly enhances efficiency and utility.
- Stacking of different data types at a single point significantly increases the value of each type of data (Figure 1).

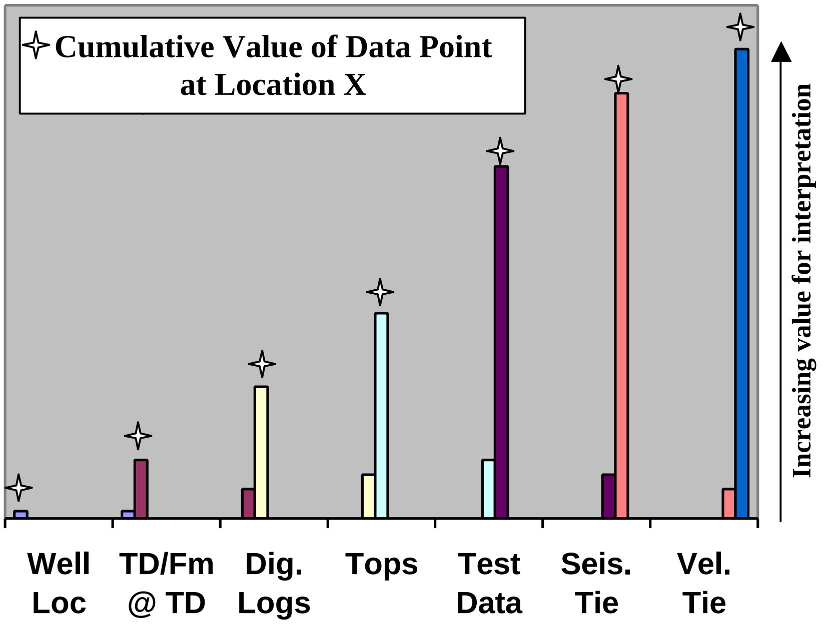

Figure 1. *Stacking different types of data at a single point significantly increases the value of each piece of data. In this example the number of different types of data for a single point (normally a well) is increasing to the right. Bars on the left are schematic, and are not intended to depict the relative value of any particular type of data. Bars on the right portray the concept that any combination of data types increases the value of each of those pieces of data. This concept of the impact of stacking data points is a significant driver in the efforts to populate the database.*

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Database Development

The variety and volume of data that Pioneer wanted to incorporate into the project was substantial (Figure 2). In order to organize the data loading and realize the maximum benefit in the least amount of time the data types were prioritized at the start of the project. The first tasks the geologists needed to accomplish in the regional evaluation were:

- Generate structure and isopach maps.
- Construct a regional grid of well and seismic cross sections.

Considering this, data loading was scheduled according to need, data availability, cost/benefit relationship and resources. To begin generating meaningful maps and cross sections as quickly and economically as possible it was necessary to utilize the extensive amount of digital and paper in-house data in the files, before investing in additional data.

Prioritization was defined as follows to be as effective as possible:

WELL HEADER DATA (UWI, coordinates, projection information, elevation information, total depth, status):

UWI: One of the most important considerations in database administration is to allow all data to be linked with existing databases. The best way to accomplish this is by identifying the well, field, etc. with a numeric code that allows data transfer in a smooth, easy way. In most countries this code, referred to as a UWI or API, is defined by the government agency that regulates the activity. Although Argentina has a version of this type of system, it is not widely utilized, so Pioneer created an in-house UWI generator based on country, province, well type, field and well number. This UWI is a 14 digit numeric code which proved to be extremely useful when transferring information among different databases.

Coordinates: projections are an issue since different geodesic datums have been utilized in the Neuquen basin, such as Inchauspe[7] and Chos Malal[8]. Unfortunately, most of the time data sources do not include information on the projection in which the coordinates are expressed. Normally it was assumed that pre 1990 coordinates were in Chos Malal, while data from the last three years are in Inchauspe (even though Campo Inchauspe has been for many years, many companies did not use it). This uncertainty applies to well coordinates and seismic planimetry. It can be especially damaging when well coordinates are expressed in one coordinate system and the seismic data in another. For a regional evaluation these differences wouldn't be an extremely important consideration, but at the scale of development activities they can be critical. Georeferenced satellite images with known Inchauspe locations were utilized to check well locations when projection information was unknown.

Elevation reference, TD and status: Even though having this information loaded in the database can be extremely helpful, it is not mandatory. The elevation reference is necessary when you have the log for this well. Usually log headers state the reference from which the log was measured. TDs can be very helpful in identifying the most significant wells in an area. Initial and current status are important in defining fluids recovered but it is possible to incorporate wells for which only a location is available.

EXISTING 2D DATA, CHECKSHOTS (from digital and paper sources):

The old seismic base maps were scanned and georeferenced. This file was loaded into the GIS, allowing existing digital data to be overlain to check coordinates, line names and shotpoints. In addition, all in-house paper seismic sections for which coordinates were available were loaded in the GIS. This allows Pioneer to determine whether gaps in the digital seismic coverage can be filled with in-house paper data. Scanning paper lines is expensive, so it is essential to have a complete, accurate, spatial inventory of all in-house seismic.

7 Campo Inchauspe: IGM-National Geodesic datum for Argentina.
8 Chos Malal: YPF – Local geodesic datum for Neuquen Province

Differences in the seismic datums are a pervasive problem throughout the 2D data set. Pioneer loaded all available digital data, taking note of the seismic datum where this information was available. Checkshot information was used to define the initial seismic datum, and all data is being shifted line by line to this datum. Though this process is slow and tedious, the “normalized” regional seismic grid which results is a very powerful data set, justifying the effort.

PICKS: (from digital and paper sources):

To produce regional displays it was necessary to have a meaningful set of picks covering a wide geographic area. The initial isopachs would cover rather large intervals. Accordingly, the strategy was to simplify and combine picks when possible and appropriate, keeping the number of basic picks to a minimum. Displaying and correlating logs at an extremely compressed scale was helpful in determining which picks were the most consistent regional markers.

Obviously there are differences in which horizons other people would have chosen and in how the myriad of names would be combined. There would also be endless discussions of whether certain horizons represent meaningful time lines or facies changes, but the names and intervals selected seem to be widely recognized in the literature. Initial results suggest those selected generally worked reasonably well at the regional scale.

CURVES:

Digital and paper logs are one of the most important data types loaded in the database. Although most of this information is now received digitally, the industry is struggling to convert over 60 years worth of paper data to a digital format. Problems encountered while dealing with logs included differences in the curve names and scales.

Aliases have been generated as a workaround for naming differences. These retain the original curve name but enable the user to incorporate data from wells spanning a significant period of time. Differences with respect to scales were not as common. Many of the old resistivity curves were expressed on a linear scale, while modern resistivity logs are on a logarithmic scale.

The spatial aspects of the GIS proved to be extremely helpful in identifying logs to be sent for digitizing. The first step in this process involved adding coordinates to all wells for which Pioneer possessed paper logs. Two layers or themes were then created in the GIS, one imported spreadsheet with wells for which paper logs were available, the other after making a relational SQL query in OW for wells with digital logs and sent to the GIS using the interconnectivity between OW and Arcview. The features of the GIS allow one to identify wells common to both layers. This eliminates any possibility of digitizing wells for which digital data is already available.

COMPLETION/ENGINEERING DATA: (perforations, well test results*):*

Engineering data in the regional project consists mainly of highly detailed information transferred from existing development projects. For non Pioneer operated areas the available completion/engineering data was often poorly organized and difficult to load. Consequently, most “new” data loaded in the regional project was limited to only perforation data and well test results. These data sets have none the less proven to be very useful, and efforts continue to load this data for key wells and select areas.

An example of a wellbore schematic can be found in Figure 3. The data for this schematic was transferred from one of our development projects where perforations, tests, tubing equipment, casings, cements, plugs, packers, etc. have been loaded.

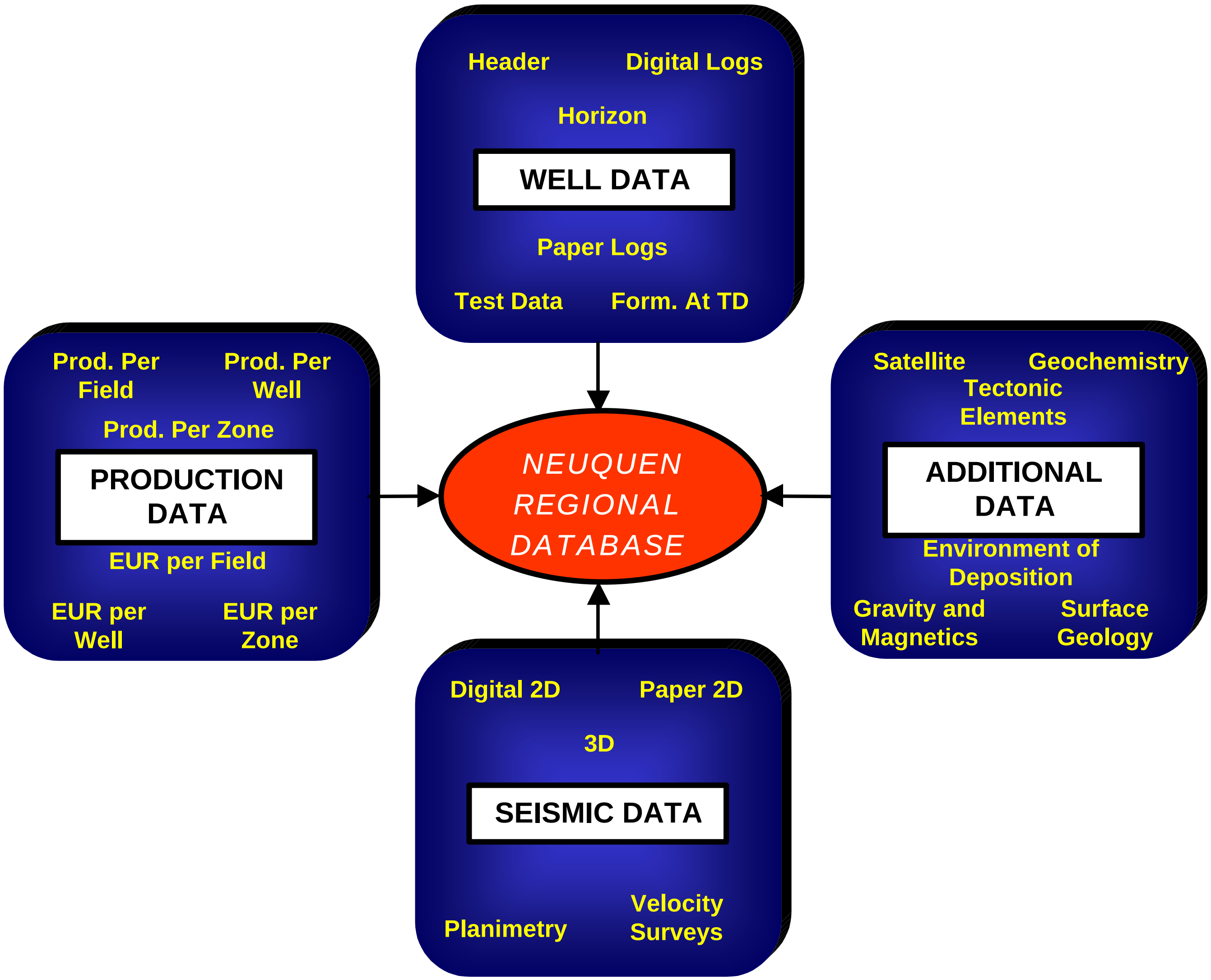

Figure 2. The data to be loaded into the regional database was divided into four categories.

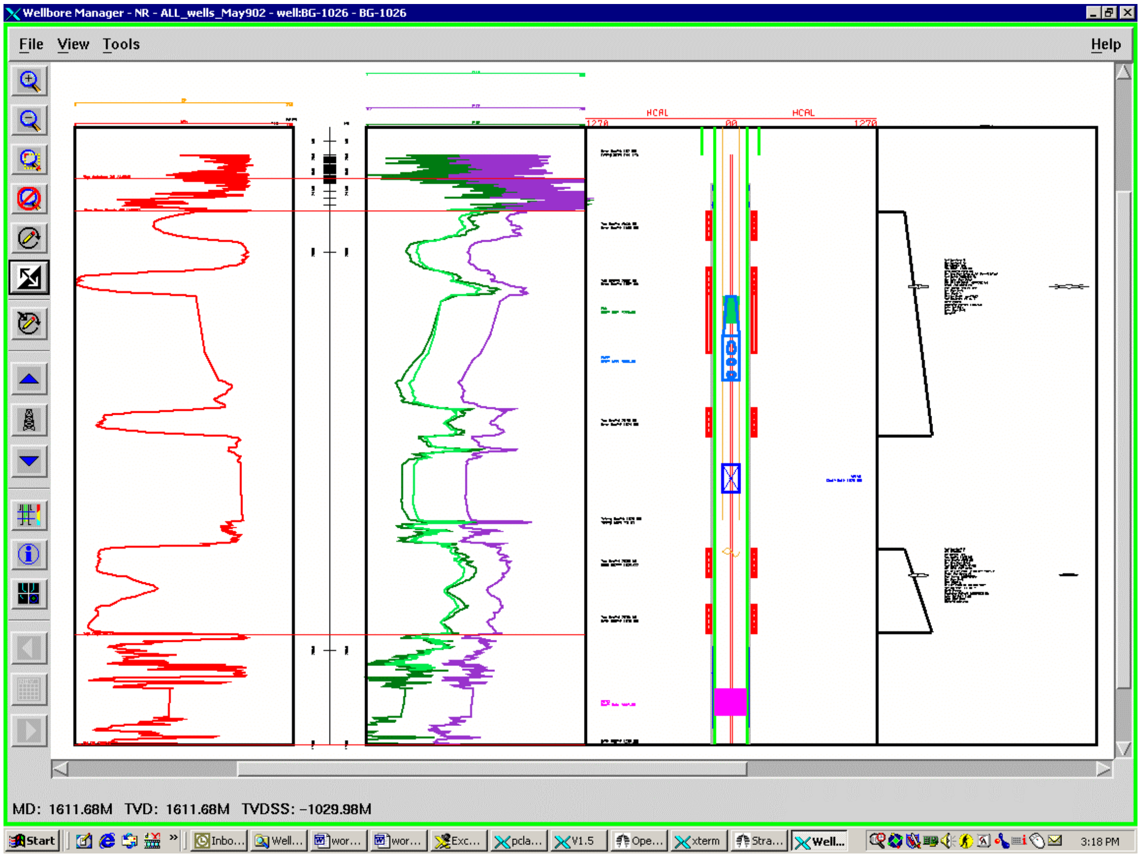

Figure 3. *Wellbore Schematic*

Special Features

Many of the GIS features of LandMark's integrated Arcview environment were very helpful in creating the database. While many of these features were utilized, only a few will be highlighted here. Among the most useful have been:

- Creation of different layers (themes) depicting the same type of information from different sources. For example, suppose wells have already been loaded to the database and subsequently, a new source of well data becomes available. By creating a new layer with the new data, prior to loading this new information into the database, it is possible to quickly and easily identify missing wells that can be added to the database or eliminate duplicates.
- To identify where different types of data are stacked at a single point. By turning on the different themes, it is possible to notice which wells are populated with multiple types of information. In Figure 4 themes displaying wells loaded to the project, wells with picks, wells with digital logs, wells with paper logs and wells with engineering data have been activated.
- Visualize information available for a well by activating the desired theme and selecting the well (Figure 5).
- Make relational queries and identify spatially the wells that meet these criteria. The example in Figure 6 shows all the wells with paper logs at a 1:500 scale. Those in cyan are the ones that meet the criteria. This information can also be displayed as a table, and results of relational queries can be exported as reports or to other software packages.
- Perform Boolean spatial queries. As shown in Figure 7 the operation selected all wells with digital log curves located within a distance of 160 meters (Chos Malal-Inchauspe shift) of wells for which Pioneer has paper logs. Those wells in cyan are the ones that meet these criteria. These paper logs will not be included in the digitization process, as digital curves are already loaded for these wells.

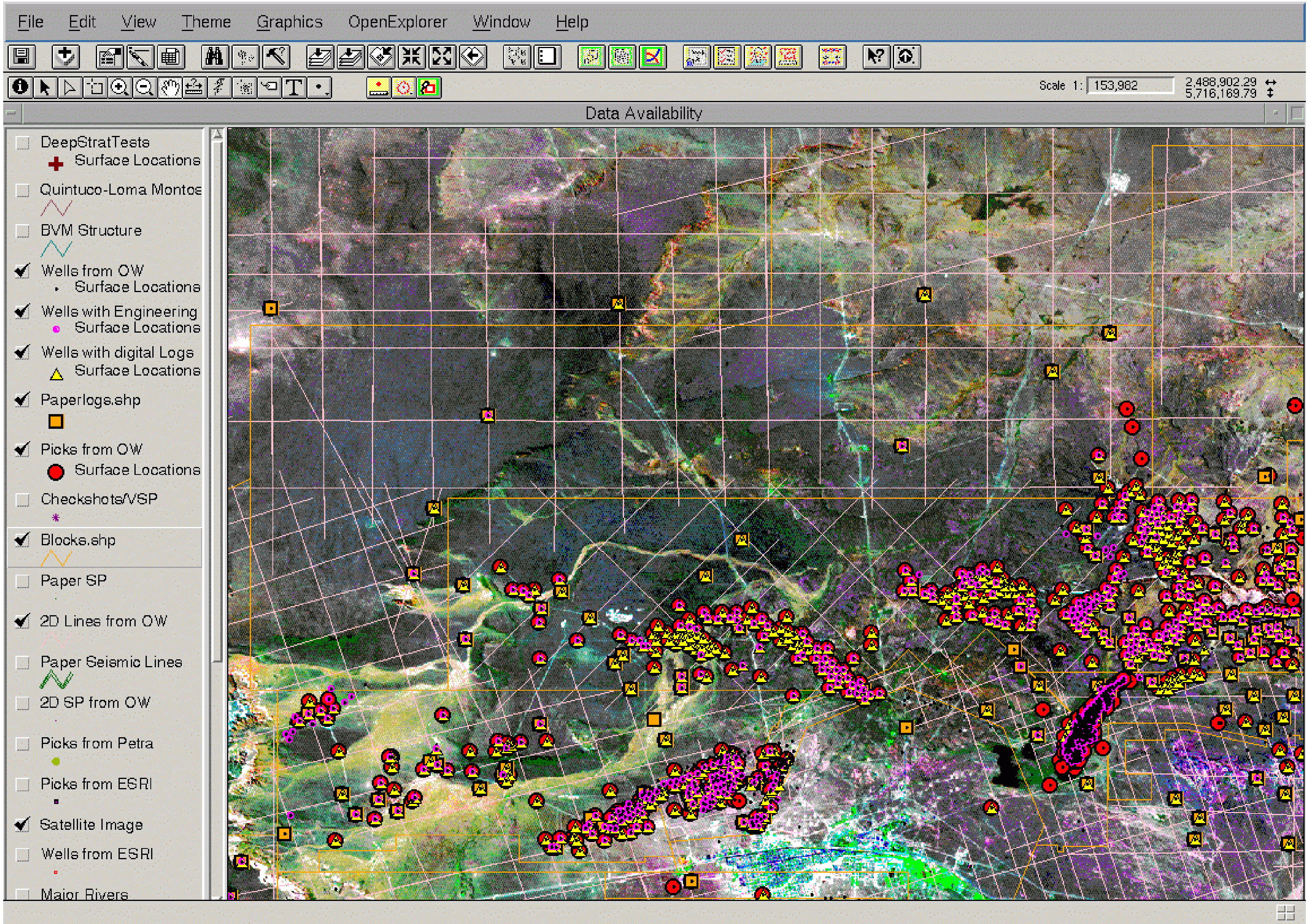

Figure 4 . GIS screen capture with different Themes of information turned on in the left part of the screen

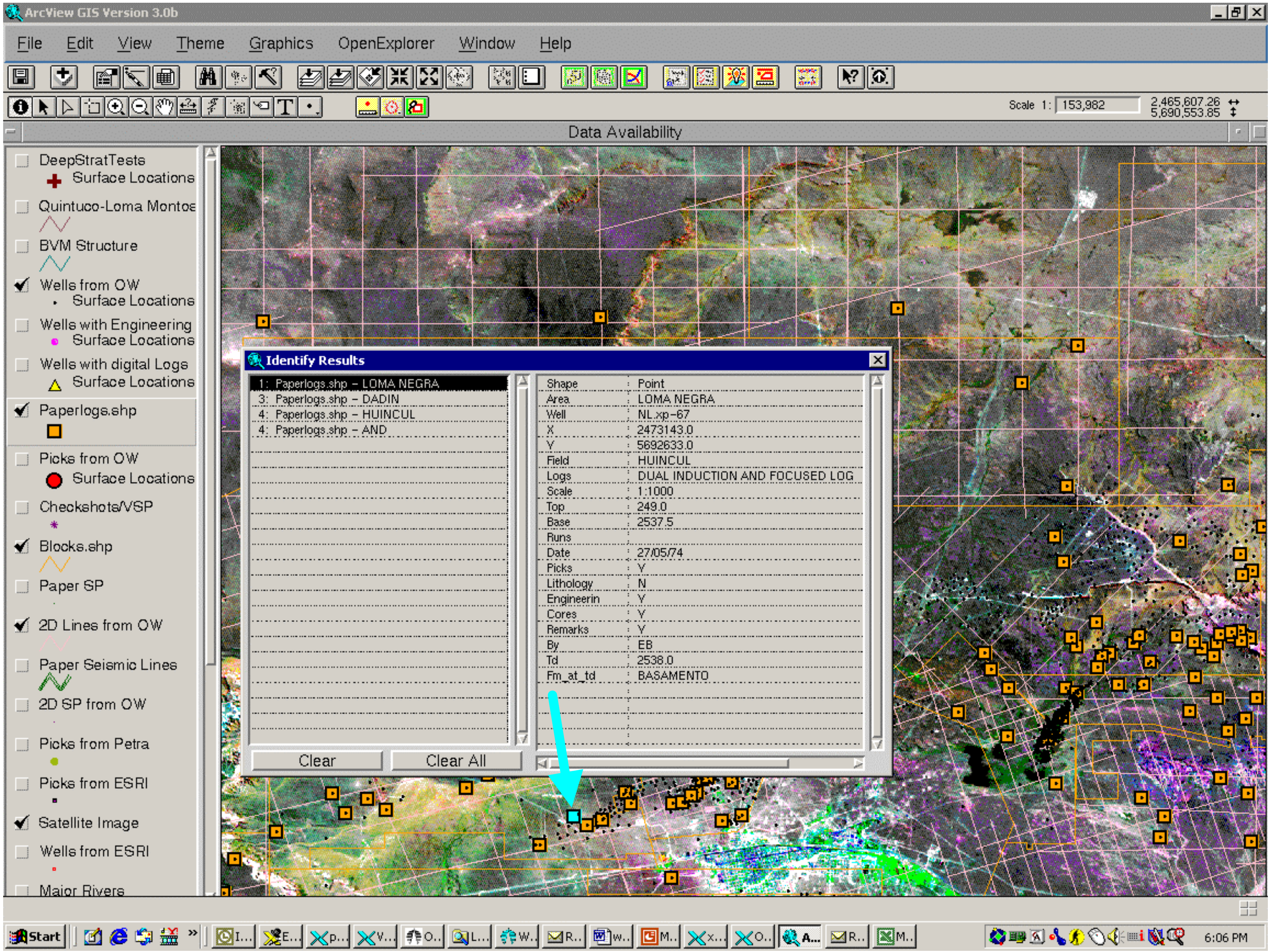

Figure 5. GIS screen capture indicating Paper Log info for a selected well (cyan symbol)

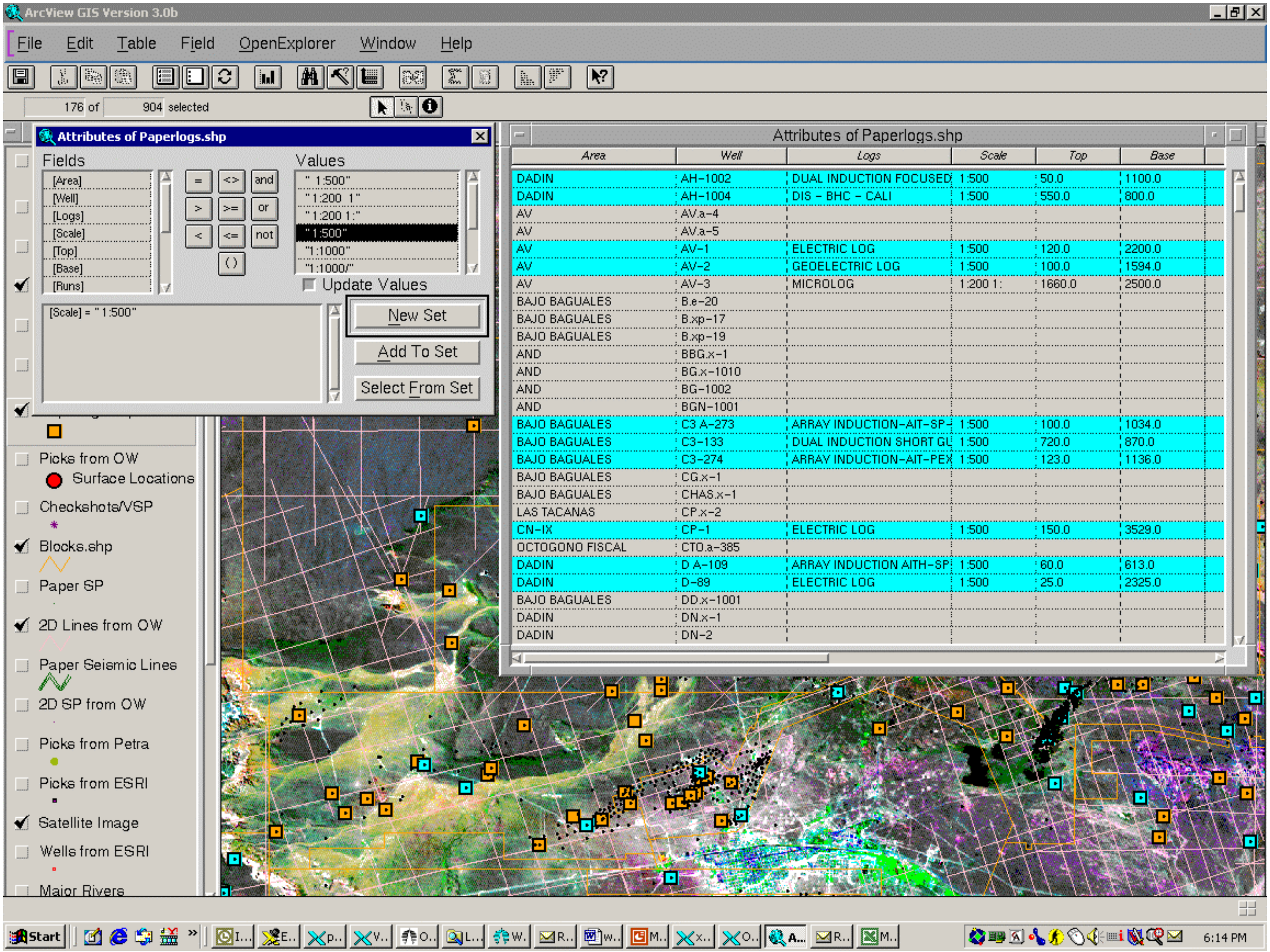

Figure 6. GIS screen capture with relational query for all paper logs with 1:500 scale

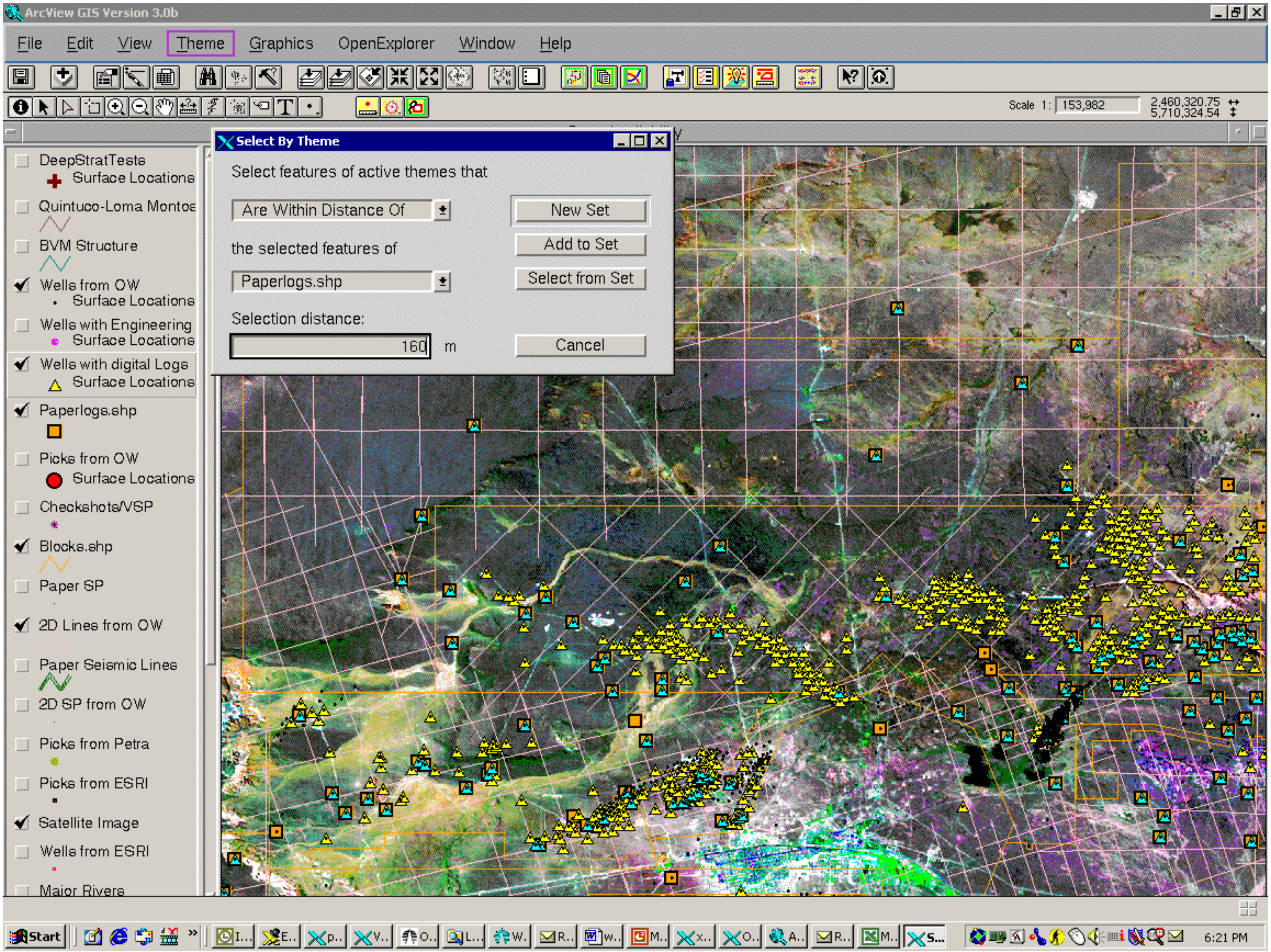

Figure 7. GIS screen capture performing spatial selection of wells with digital and paper logs available (cyan symbols)

INITIAL RESULTS

Value of the GIS

The experience with the spatial GIS database has been almost wholly positive. It has proven very useful with respect to visualizing, querying, overlaying and utilizing the various elements of the database. It is very useful in visualizing where certain types of data are "stacked" at a common point. It helps guide the almost daily decisions necessary in the ongoing efforts to populate the database, especially now that the initial, obvious, relatively inexpensive steps have been taken. Since it is "embedded" in the OpenExplorer it works smoothly with the interpretational side of the project. It is also an excellent way to access information which cannot be loaded easily into a standard E&P database, such as geochemical data from wells and outcrops. And it is an excellent way of incorporating information on data available from external sources, provided there is some common denominator (location, well name, UWI).

The GIS database has increased the level of utilization of data in Pioneer's paper and digital files. Adding spatial information to the paper files actually "discovered" some very valuable data. Initial efforts to populate the GIS database from the paper files concentrated on the composite logs. These efforts have proven so valuable they may be expanded to include additional paper data such as well file details, maps and cross sections by linking the scanned documents to a graphic object.

Structure and Isopach Maps

The initial output products have proven useful, thought provoking, insightful and, on occasion, a bit disappointing. Well control based structure and isopach maps have been generated for some of the more significant horizons and intervals in the basin (Figures 8 & 9). Seismically based structure and isochron maps have been generated for select levels and intervals for large areas of the basin (Figure 10). The efforts to fully integrate the seismic data are lagging because of the time necessary to shift the seismic to a common datum, interpret the seismic and depth convert/flex the horizons. While this process has been time consuming and occasionally frustrating, it has yielded great benefit and is worth the time invested.

Between the more stable picks the well based isopachs required surprisingly little editing (suggesting consistent picks). Regional seismic lines support this, showing greater continuity of the horizons within the stratigraphic interval where the picks are more stable (see following section). Recognizing this, every effort was made to populate the database with picks from this stratigraphic interval.

The shallower and deeper horizons, away from the more stable picks in the middle of the stratigraphic column, graphically illustrate the problems introduced by inconsistent picks and naming conventions or by stratigraphic facies complications. These intervals have been one of the chief sources of disappointments to date.

The tops input from paper, when combined with picks from the digital logs, generally provided sufficient density to give good regional maps. Efforts have begun to add relevant bubbles, pies and log signatures to the maps. It was recognized, somewhat belatedly, that formation at TD for key wells was extremely useful, especially for showing penetration density. This data is currently being added, concentrating on the exploratory and deep wells. With several sources for this data, efforts to integrate these into a single data set have been slowed by minor variations in the name of a well, the lack of a UWI and by naming preferences between various sources.

Well and Seismic Cross Sections

An initial set of regional seismic and well cross sections (Figures 11 & 12) has been constructed and the grid is currently being expanded. It is enormously helpful to design these with the GIS database and the initial output maps as guides. The cross sections highlight the usefulness, in fact the need, for the completion/test information and for standardization with respect to the picks.

A query was designed to select the deepest stratigraphic wells (all xp wells, all Precuyano penetrations, all wells with TD greater than 3500m). This list was augmented with additional key remote or deep wells. This list of deep tests (Figure 13) is very useful when deciding on data loading and acquisition efforts, as well as in cross section layout.

Problem Areas

Probably the single greatest source of disappointment to date has been in efforts to load well specific and zone specific production data. This data is very useful but difficult to obtain and what data is in the files often suffers from time synchronization problems. EUR per well and zone is the ultimate goal but is likely not something that can be achieved. Initial potentials may be a viable compromise. Or perhaps field cumulative production per zone, divided by the number of producers in the zone, provides the best substitute.

Likewise, efforts to incorporate other types of data into the database (gravity, magnetics, tectonic elements, fault patterns, paleogeographic environments, surface geology, etc.) have been slow due to three major factors:

- Determining what will be the most useful (there is a lot of this data).
- Deciding if the data needs to be digital, or if a georeferenced overlay would be sufficient.
- Where does it fit on the priority list?

CURRENT EMPHASIS

It will be necessary to augment and maintain the existing database. Specifically, to populate additional key wells with the completion/test data, including scout data. It is now possible to make more informed decisions on just which wells are most valuable and are readily available. This is crucial, as the completion/test data is extremely useful but tedious and time consuming to load. As outlined earlier, to maximize the value of this data it needs to be loaded in a standard way with an eye toward how it will be used, and completeness/standardization is crucial.

Additional digital log data will be added to fill key gaps in the coverage. In addition, scanning some additional seismic would significantly improve the level of control. The visualization and query features of the GIS database, combined with the initial output maps, provide very valuable assistance in making these costly decisions.

CONCLUSIONS

The year long process of compiling the OW database and integrating it with the GIS has allowed a better, spatial, understanding and fuller utilization of the data in the files. In order for this process to be effective, it was necessary to prioritize, organize and standardize data and workflows.

The nearly seamless interaction among the GIS, the OW database and the interpretational applications allows for wiser decisions on project work flow and investment of money and manpower. There are benefits from both the database administration and interpretation standpoint. From a data base administration perspective, it allows to properly organize data loading, detect data duplication and gaps and track data loading processes in a graphic spatial environment. GIS features have proven to be extremely useful in accomplishing the data administration tasks.

For this type of complex project the synergies realized with this approach justified the effort and increased the efficiency of the interpretational process. The initial maps and cross sections generated have proven to be useful and should help in identifying opportunities for growth.

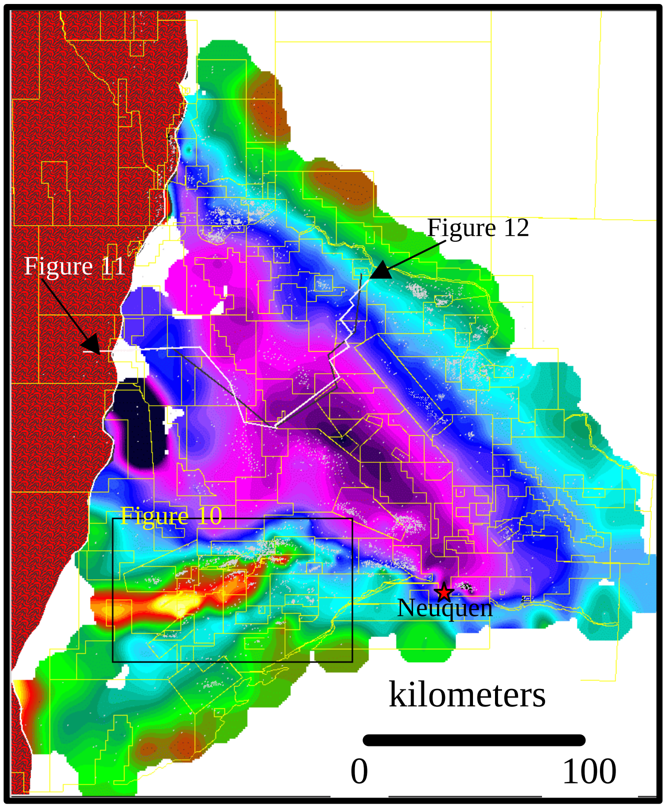

Figure 8. Structure map of Base Vaca Muerta from 2414 well control points. The extent of the highly disturbed fold belt shown in red on the west. City of Neuquen shown for reference. Contour interval was 50 meters. Grid size was 1 x 1 km.

The Base Vaca Muerta horizon is the most consistent pick in the basin. It is also a good seismic event. This seismic horizon will be converted to depth, then flexed to the wells, thereby incorporating both the detail of the seismic and the accuracy of the wells.

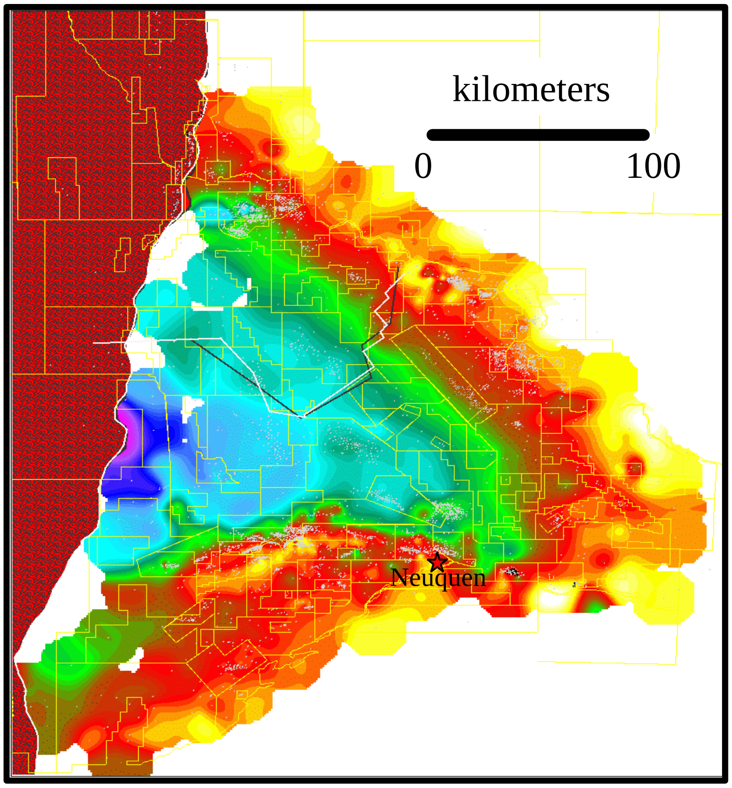

Figure 9. Isopach of the Quintuco – Base Vaca Muerta interval from the well control. The extent of the highly disturbed fold belt shown in red on the west. City of Neuquen shown for reference. Contour interval was 35 m. Grid size was 1 x 1 km.

The 2074 data points used to generate this map required surprisingly little editing. The patterns on the Northeast Platform are primarily the result of uncertainties in differentiating the Quintuco versus Loma Montosa and reflect differences between sources. Next stage in the project will involve standardizing tops at sequence levels.

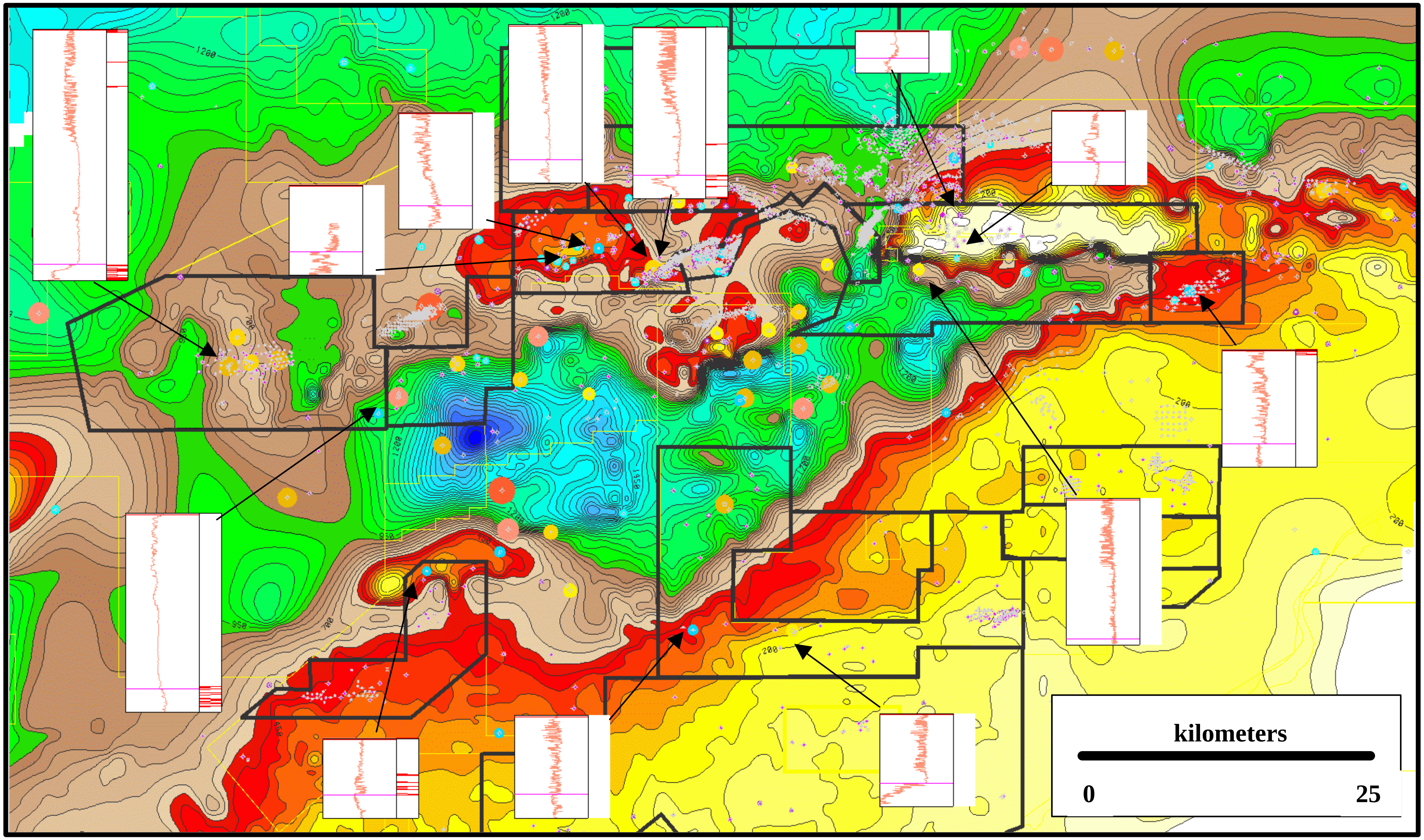

Figure 10. *Seismic isochron of the interval from Base Vaca Muerta – Base Cuyo in the southern portion of the Neuquen basin. The bubbles are scaled to the amount of section penetrated from Base Vaca Muerta to td (some Base Vaca Muerta picks were back interpolated from the structure map). Log signatures show the interval from Base Vaca Muerta – (up to) 200 m below the Base Cuyo for select Pioneer wells. SP on the left; perforated interval (when available and loaded) on the right. Contour interval is 50 msec. Pioneer operated blocks shown in black. Note the distribution of the shaly facies at the base of this interval (often called the Los Molles) is clearly related to the thickness of the interval. (See figure 8 for location.)*

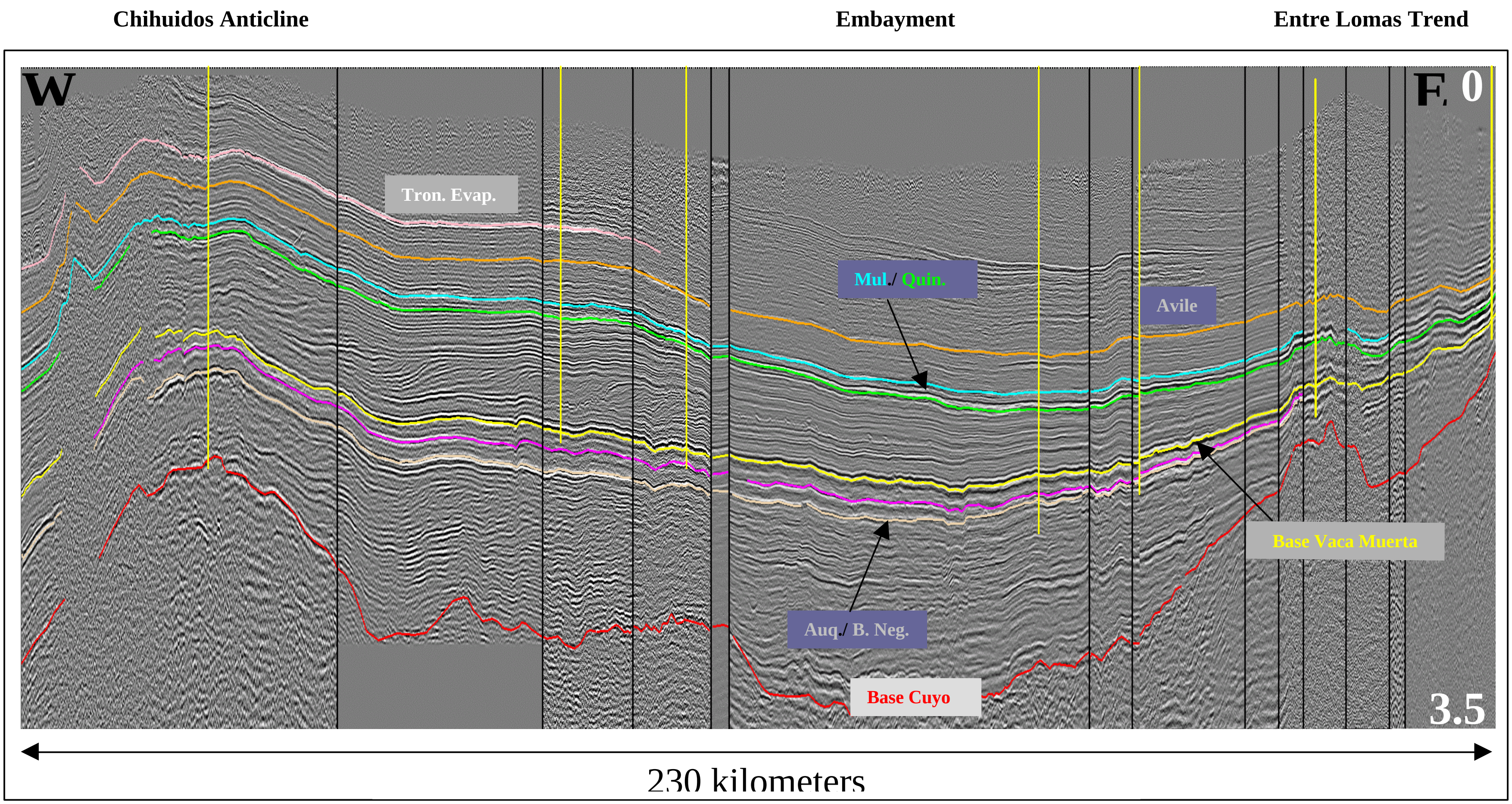

Figure 11. *Regional time seismic line, shifted to a common seismic datum, with regional seismic horizons. Note the relatively greater continuity of the horizons in the Mulichinco - Barda Negra interval. Well correlations (see figure 12) within this interval are more apparent and stable, and initial structure maps and isopachs for horizons and intervals from this portion of the stratigraphic column required relatively little editing. Key deep wells on or near this line are shown in yellow. (See figure 8 for location.)*

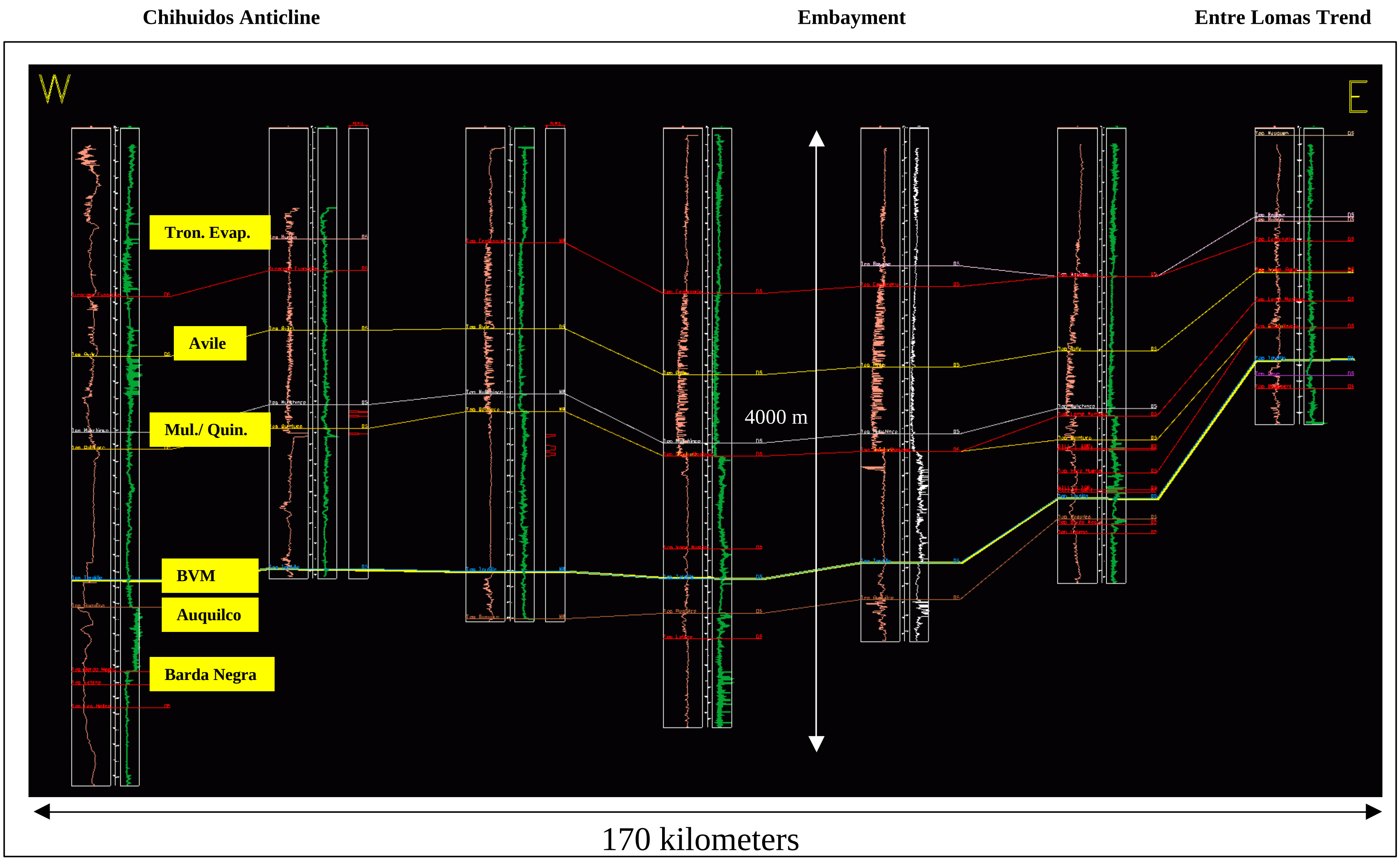

Figure 12. *Regional section showing correlations of the regional horizons. No horizontal scale. Section is datumed with respect to drill depth, not structurally or stratigraphically. SP curve on the left; resistivity curve on the right. Perforated interval (when available and loaded) on the far right. The highly compressed display assists in determining which horizons and intervals are more regional in scope. Note the relative stability of the picks between the Mulichinco and the Barda Negra. This display also point out the importance of having a consistent set of picks, fully populated whenever possible. (See figure 8 for location.)*

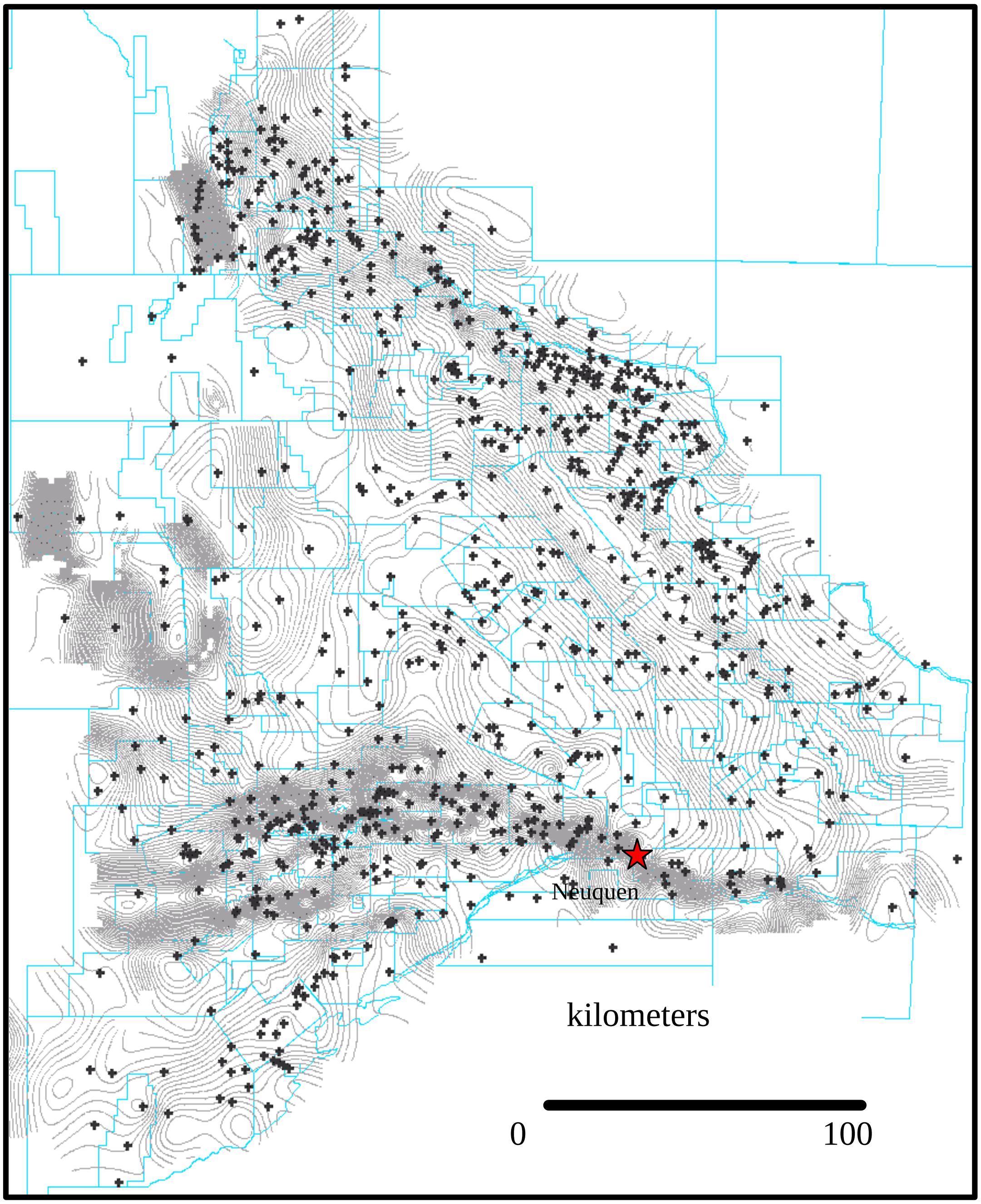

Figure 13. *Display from GIS depicting the key deep wells and deep stratigraphic wells overlain on the BVM structure. This is an example of the type of spatial database display that is very useful in deciding how to populate the database and in laying out cross sections.*

Acknowledgments

We would like to acknowledge the contributions of Néstor Straus, Guillermo Azpiroz and Erika Budic who helped in the arduous task of organizing, standardizing and loading the data.
We would also like to thank Inés Arocena for her contributions.