NORTH HILL CREEK 3-D SEISMIC EXPLORATION PROJECT

UTE INDIAN TRIBE
UINTAH & OURAY RESERVATION, UINTAH COUNTY, UTAH
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ABSTRACT

Wind River Resources Corporation (WRRC) received a DOE grant in support of its proposal to acquire, process and interpret fifteen square miles of high-quality 3-D seismic data on non-allotted trust lands of the Uintah and Ouray (Ute) Indian Reservation, northeastern Utah, in 2000. Subsequent to receiving notice that its proposal would be funded, WRRC was able to add ten square miles of adjacent state and federal mineral acreage underlying tribal surface lands by arrangement with the operator of the Flat Rock Field.

The twenty-five square mile 3-D seismic survey was conducted during the fall of 2000. The data were processed through the winter of 2000-2001, and initial interpretation took place during the spring of 2001. The initial interpretation identified multiple attractive drilling prospects, two of which were staked and permitted during the summer of 2001. The two initial wells were drilled in September and October of 2001. A deeper test was drilled in June of 2002. Subsequently a ten-well deep drilling evaluation program was conducted from October of 2002 through March 2004.

The present report discusses the background of the project; design and execution of the 3-D seismic survey; processing and interpretation of the data; and drilling, completion and production results of a sample of the wells drilled on the basis of the interpreted survey.

Fifteen wells have been drilled to test targets identified on the North Hill Creek 3-D Seismic Survey. None of these wildcat exploratory wells has been a dry hole, and several are among the best gas producers in Utah.

The quality of the data produced by this first significant exploratory 3-D survey in the Uinta Basin has encouraged other operators to employ this technology. At least two additional 3-D seismic surveys have been completed in the vicinity of the North Hill Creek Survey, and five additional surveys are being planned for the 2004 field season.

This project was successful in finding commercial oil, natural gas and natural gas liquids production on a remote part of the Uintah & Ouray Reservation. Much of the natural gas and natural gas liquids are being produced from the Wingate Formation, which to our knowledge has never produced commercially anywhere. Another large percentage of the natural gas is being produced from the Entrada Formation which has not previously produced in this part of the Uinta Basin. In all, at least nine geologic formations are contributing hydrocarbons to these wells. This survey has clearly established the fact that high-quality data can be obtained in this area, despite the known obstacles.

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APPROACH AND METHOD (EXPERIMENTAL SECTION)

Historical Background

The Uinta Basin of northeastern Utah has been an important producer of oil and gas for more than fifty years. Included within the Uinta Basin is the approximately 1.2 million acre Uintah and Ouray Reservation of the Ute Indian Tribe, with its headquarters in Ft. Duchesne, Utah. Oil and gas have been produced from Ute Tribe lands since the earliest days of Uinta Basin production.

The vast majority of oil and gas production from the Uinta Basin, including from tribal lands, has been from the Tertiary Green River and Wasatch Formations in the deeper portions of the basin, particularly in the Greater Altamont-Bluebell Area, the Greater Natural Buttes Area and Red Wash Field. Exploration activity in these areas dates back to the late 1940s and early 1950s, when several major oil companies engaged in wildcat drilling throughout the basin. Both this early activity and several episodes of later exploration activity resulted in the discovery of large reserves of oil and gas. As there was no pipeline to transport gas out of the Uinta Basin until late 1962, most of the wells drilled prior to that time were drilled and abandoned if they failed to find commercial oil production. Many wells that would now be commercial gas wells were victims of this lack of infrastructure and market.

Although considerable 2-D seismic data was acquired in the Uinta Basin from the 1960s through the 1980s, the most recent stage of seismic exploration technology passed this basin by. Prior to the 3-D seismic survey discussed in this report there were only two small 3-D surveys shot in the basin: an approximately ten square mile survey on Leland Bench and a smaller survey narrowly designed to solve a particular technical production problem at Natural Buttes. The reasons for this lack of 3-D seismic exploration effort include high costs associated with challenging topography, low expectations with respect to data quality due to near-surface reflectors, and a general orientation toward step-wise expansion of the existing large fields. Generally weak gas markets until quite recently also contributed to a lack of interest in exploring areas thought to be primarily gas-bearing.

The Ute Indian Tribe owns large tracts of mostly unleased mineral acreage in the southern and southeastern areas of its reservation where a thick multi-formation sedimentary section is structurally elevated relative to the major oil and gas-producing areas of the Basin. This structural advantage can be attributed to the basin margin location of the acreage as well as the further elevation of much of the area by the northwest plunging Uncompahgre Uplift. The result is that at least nine prospective oil- and/or gas-producing formations are accessible by drilling to a depth of approximately 12,000 feet, whereas only two or three of these Formations can be reached at this depth in the areas of existing development on the reservation. This area of the reservation is known as the Hill Creek Extension.

Wind River Resources Corporation (WRRC) made its proposal to the Department of Energy under National Petroleum Technology Office Program Solicitation DE-PS26-

99BC15184 for partial funding of a 3-D seismic survey in October of 1999. The proposal described a fifteen square mile survey to be conducted in a highly prospective area of the Hill Creek Extension.

In May of 2000, Wind River received notice from the DOE that its proposal had been tentatively accepted. By this time WRRC had identified a survey area and had begun negotiating with the Ute Indian Tribe and the Uintah & Ouray Agency of the Bureau of Indian Affairs for an Exploration and Development Agreement covering the identified acreage in Township 15 South – Range 20 East, Uintah County, Utah.

As soon as it became clear that the 3-D survey was likely to receive funding during calendar year 2000, WRRC undertook the biological and archaeological field studies that would be required as part of the permitting process for the survey. Concurrently, the owner/operator of the Flat Rock oil and gas field, located in Sections 28, 29, 30 and 32 – Township 14 South – Range 20 east, was approached to determine if his company would have an interest in expanding the survey to cover his acreage and producing wells. This was an important step, because the DOE funds could only be used on "non-allotted Native American…lands" and could not be spent on split estate lands, such as Flat Rock field, where the surface was tribal trust land but the mineral estate belonged to the federal or state governments. The wells at Flat Rock would provide vital well control for the survey, and blocking up the survey to include these lands would prove critical to the acquisition of full fold seismic data

When Flat Rock Field operator, Del-Rio/Orion Energy Resources, accepted the invitation to participate in the survey, the area was expanded to twenty-five square miles. The survey area now included an analog field with approximately twenty wells ranging in depth from 3,500' to 12,897'. Among them was a newly drilled, but not yet completed, 11,600'-deep wellbore suitable as the host for a vertical seismic profile which would be used to tie the seismic survey data to the known Formation tops as determined from the well logs.

There is a perimeter approximately one-half mile wide around a survey of this type where full fold will not be achieved. Since the width of this reduced fold area is fixed for specific data acquisition parameters, expanding the area of the survey significantly increased the ratio of full fold coverage area to reduced fold coverage and resulted in a more efficient survey.

The survey results presented in this report cover the fifteen square miles of Ute Indian surface and mineral acreage with the proprietary data from the remaining ten square miles of split estate lands removed. The data were separated in such a way that maximum available fold is maintained to the edges of this data set, i.e. more data is included than would have been available from the originally proposed fifteen square mile survey. The discussion of design and acquisition of the survey includes information for the entire twenty-five square mile area.

Regional and Local Geology

The North Hill Creek 3-D Seismic Survey was conducted in Township 14 South – Range 20 East and Township 15 South – Range 20 East, Uintah County, Utah. This location is shown on Figure 1, which is an index map used to locate the Uinta Basin within Utah, and to locate the survey area within the Uinta Basin. (It should be noted that the name of the geologic basin does not include an "h" as its last letter.) The map also shows the boundary of the Uintah & Ouray Indian Reservation in blue, the WRRC acreage in yellow (mostly in T15S-R20E), and existing oil and gas fields in green and red, respectively. The eastern boundary of the survey area coincides with the eastern boundary of the reservation.

Figure 2 (modified after Don Stone, 1977) is an isopach map that shows the relationship between the Uinta Basin and the Uncompahgre uplift. The Uncompahgre uplift is an extremely important feature of the geology of the survey area. Bounded on the south by the Uncompahgre fault zone and on the north by the Garmesa fault zone, both of which include a significant strike-slip component, the plunging nose of the Uncompahgre uplift dominates the structural geology of the southern Uinta Basin. Most, if not all, of the significant gas accumulations in this area are directly related to the uplift and the structures that are related to this deeply buried feature.

In the survey area, the Minton State #1 (ne/4se/4 Sec. 32-T14S-R20E), drilled in 1955 by Carter Oil Company, found the Chinle Formation in contact with the crystalline basement rocks at 12,600'. In a deep well approximately eleven miles to the north, on the opposite side of the Garmesa fault zone, the base of the Chinle is at 13,980', but the well reached a total depth of 15,400' in the Mississippian Leadville Limestone (see Figure 3 – Uinta Basin Stratigraphic Column).

While the more than 1,600 Wasatch and Mesaverde gas wells in the basin-centered Natural Buttes Field top the Wasatch Formation in the 5,500' range, the depth to the Wasatch top in the uplifted survey area is on the order of 2,200'. This makes nine or ten formations, from the Eocene Wasatch to the Triassic Chinle, prospective at depths of 3,400' to 12,500'. A 12,500' well at Natural Buttes would still be in the upper Cretaceous. In addition to being accessible 3,000' shallower than at Natural Buttes, the Wasatch Formation in the survey area exhibits a wholly different reservoir quality, having been deposited in a higher energy environment. As a result it is not as tight as it is to the north and good natural completions, unheard of at Natural Buttes, are possible in the survey area.

When the North Hill Creek 3-D Seismic Survey was conceived there was established oil and gas production from the Wasatch Formation at Flat Rock Field within the survey area. There were also several Dakota/Cedar Mountain gas wells six or more miles to the south. The San Arroyo field, 25 miles to the south east, encompasses 105 wells with cumulative production of 140 Bcfg, mostly from the Dakota, Cedar Mountain and Morrison Formations. The Entrada at San Arroyo produced 600 Btu gas with nitrogen and carbon dioxide being the major contaminants. There was no record of truly commercial production anywhere in the Uinta Basin from the Mancos Shale, Dakota

Silt, Curtis, Kayenta or Wingate Formations. The Wingate is believed not to have been a commercial producer anywhere previously.

The WRRC grant proposal to the Department of Energy established exploration for Uncompahgre uplift-related structures and well-developed stream channels as the objective of the 3-D survey. It was expected that these would be found in the Wasatch, Mesaverde, Dakota and Cedar Mountain Formations. In an effort to image the shallow Wasatch Formation, the survey was designed with unusually close-spaced source and receiver points. Figure 4 is a site-specific stratigraphic column showing the lower Cretaceous to Precambrian basement as it is actually found in the survey area. Although the potential for production from the Jurassic rocks was considered by WRRC, the importance of the gas contributions made by these formations, particularly from the previously unrecognized and well-developed dune sands of the Entrada and Wingate Formations, has greatly exceeded anyone's expectations.

The expected value of the Wasatch and Dakota/Cedar Mountain stream channels has been confirmed. It is a simple fact that to date this value has been overshadowed by the gas produced from the deeper sand dunes found in the Entrada and Wingate Formations.

3-D Survey Design

The objectives of the North Hill Creek 3-D seismic survey were as follows:

- Run a safe operation
- Obtain high-quality data throughout the 2,000' to 12,000' depth range of the prospective geologic Formations in order to image both gross structures and more subtle structural and stratigraphic elements
- Cover as large an area as possible with the available budget
- Overcome the challenges posed by a hard, reflective sandstone exposed at, or buried just a few feet below, the surface under most of the survey area.

The field acquisition work for the survey was bid out to CGG Americas, Grant Geophysical, Veritas and Western Geophysical. Western Geophysical was selected to do the work on the bases of design, cost, and crew availability.

The survey area was focused on an irregular-shaped mesa at an average elevation of slightly more than 7,400' above sea level. The central portion of Flat Rock Mesa, named for its widespread outcrop of patio-like sandstone, is a nearly flat area covered by sagebrush. The mesa is bounded on the east and west by the 1000-foot deep canyons of Willow Creek and Hill Creek, respectively. These canyons, and the incised drainages associated with them, create extremely rugged topography all around the mesa. Most of the drainage areas, and some of the flats, are covered by pinion pine, Utah juniper, and in a few places by aspen and spruce trees.

Acquisition cost considerations precluded the use of the heli-portable shot hole drilling that would have been necessary if the survey area were to include the most rugged

topography. The most efficient survey shape was determined to be a slightly askew “T” covering all of the flat, sage-covered acreage and as much of the rougher acreage as was necessary to maintain the integrity of the survey. The flat, treeless area, about 81 percent of the total, was surveyed using articulated Vibroseis buggies as the energy source. Articulated buggy-mounted shot hole rigs were used to fill in as much of the rough terrain as practical with shot holes using dynamite as the energy source. Areas too rough for source point installation were strung with receiver lines in an effort to record data for as large an area as possible.

With objectives including a dozen different geologic formations from 2,000’ to more than 12,000’ in depth, considerable effort went into the layout and design of the energy source and receiver patterns. The receivers were set out in east-west lines across the field area, spaced 660 feet apart. Groups of six geophones each were spaced 220 feet apart along these lines. The source lines were oriented diagonally, northeast to southwest, with 1,320-foot source pattern spacing and 220-foot source intervals (see Figure 5). This design was intended to produce a common depth point coverage of 45 nominal fold. It was a cooperative effort among Western Geophysical, Black Coral LLC, and WRRC.

The actual survey consisted of 2,313 source points and 5,672 receiver points. Nineteen percent, or 459, of the receiver points were shot holes drilled to a depth of 45 or 60 feet and loaded with ten or fifteen pounds of dynamite, respectively. The remaining 81 percent of the source points were Vibroseis stations occupied by four 59,000-pound articulated buggy vibrators. Receiver points located in areas too rough to accommodate source points numbered 1,046.

Field Acquisition of 3-D Seismic Data

This survey was performed under the terms of a Categorical Exclusion from the requirements of the National Environmental Policy Act, issued by the Uintah & Ouray Agency of the Bureau of Indian Affairs on September 9, 2000. The initial phase of fieldwork consisted of raptor surveys and endangered plant surveys conducted in June of 2000. A Categorical Exclusion was also granted by the Bureau of Land Management ,Vernal Field Office, for the sliver of federal acreage on the east edge of the survey area. The use of this acreage was necessary to achieve full fold on the adjacent tribal lands.

Upon receipt by WRRC of notice that funding was in place for the survey, a team of archeologists and a team of biologists initiated block clearance surveys to identify any points or areas that would have to be avoided during the seismic survey. The archeology report listed several sites for avoidance, but the biological survey found no endangered plants or animals in the survey area. This work was performed by AIA Archaeologists of Laramie, Wyoming, and Buys & Associates of Denver, Colorado. It was supervised by Alvin Ignacio of the Ute Indian Tribe’s Energy and Minerals Department.

On September 26, 2000, Western Geophysical land surveyors entered the field with Trimble 4000 SSE GPS equipment, found their control points, established a radio repeater station, and commenced surveying the individual source and receiver points. Six teams of surveyors were employed in this work.

In early October two articulated buggy shot hole drilling rigs arrived in the field and began drilling and loading shot holes identified by the surveyors as source points unsuitable for the vibroseis buggies. On October 25, 2000, Western Geophysical Survey Crew 780 arrived in the field and began laying out cables in the extreme northwestern portion of the survey area.

On October 28, 2000, Baker Atlas personnel and equipment arrived in the field from Houston and Casper equipped to run a zero-offset vertical seismic profile (VSP) in the recently drilled, but yet to be completed, Del-Rio/Orion 32-11A. This 11,600-foot deep well was drilled inside the survey area, and a complete suite of open-hole logs had been obtained from it. Prior to the commencement of the Vibroseis work on the survey, two of the AHV-3 vibrator buggies were located 234 feet from the wellhead and operated by the logging engineer to provide an energy source for the VSP. The VSP was run over an 18-hour period with the downhole receiver recording data at fifty-foot intervals from 11,600 feet to 500 feet from the surface through ten-second sweeps from 8 to 120 Hz.

Upon completion of the VSP, the vibrators were deployed in the field for a day of sweep testing to determine the optimal acquisition parameters for the survey. It immediately became obvious that the hard sandstone layer at or near the surface, to which Flat Rock Mesa owed its name, would be an obstacle to good data acquisition. Both the VSP and the sweep testing were supervised by Bret Gunneson and Jim Labo, consultants to WRRC.

Actual field data acquisition began on October 30, 2000, in the northwestern portion of the survey area, and was concluded on December 7, 2000, in the south-central portion of the survey area. Although it was cold and snowy during most of the time that Crew 780 was in the field, only one day was lost to weather. The “ringy” character of the shallow Horse Bench sandstone member of the Green River Formation made it impossible to see the data in the field, so the entire survey was shot trusting that WesternGeco’s processors would be able to process the data into usable form. The project manager for field acquisition was Louise Sandberg, and the crew chiefs for Western Geophysical Crew 780 were Randy Shannon and Mike Waugh. Jim Labo represented WRRC in the field on a daily basis. Alvin Ignacio was the field monitor for the Ute Indian Tribe.

Figure 5 is a post-plot map for the entire twenty-five square mile survey, including both split estate and non-split estate lands. Figure 6 is a post-plot map showing the source and receiver locations on the lands where both surface and minerals are held in trust by the United States for the Ute Indian Tribe. The orange line separates tribal from split estate minerals. Figure 34 – “Index Map of Wells Drilled Using North Hill Creek 3-D

Seismic Survey" shows the outline of the survey relative to the locations of pre-survey wells in the Flat Rock Field and the wells that were drilled subsequent to the survey.

It should be noted that during field acquisition of the North Hill Creek 3-D Seismic Survey the contractor was involved in a merger that transferred control of Western Geophysical from Baker Hughes to Schlumberger and renamed the surviving entity WesternGeco. The field acquisition work was performed by Western Geophysical, but the subsequent processing work was performed by the new company.

3-D Seismic Data Processing

Processing of the 3-D data volume commenced at WesternGeco in Denver as soon as the field data acquisition phase was complete in early December 2000. Western's processing team consisted of Irina Nicholson, analyst; John Markert, group leader; and John Young, supervisor.

The original estimate for completion of the data processing phase was six weeks, or approximately January 21, 2001. Black Coral's Dave Suek, Bret Gunneson and Paul Harrison, Marc Eckels of WRRC, and Mike Pentilla, geophysical consultant to Del-Rio/Orion, met regularly with the processing team at WesternGeco to provide input and direction and assess progress. They were not particularly surprised when the WesternGeco processors asked for additional time, largely due to the difficulty of processing out the noise created by the shallow reflector.

On February 14, 2001, the Western processing team made a presentation of the final processed data to Marc Eckels, Paul Harrison, Dave Suek, Bret Gunneson, David Allin and Mike Pentilla. The results were markedly improved from the previous progress meeting. In fact, data quality was actually quite good.

Upon receipt of the final processed data volume, it was decided that subsequent specialized coherency and edge processing might be helpful in the interpretation phase. This work was performed by Applied Research Concepts in Denver, Colorado, and it did help to define stream channels and other features.

3-D Seismic Data Interpretation

The processed seismic data were loaded onto workstations at Black Coral, LLC in Denver, Colorado; at the Fall-Line Exploration office (Paul and Denise Harrison) in Silverthorne, Colorado; and at the office of Mike Pentilla in Denver. After an initial analysis of gross features and correlations to determine Formation tops and general structure it was decided that the Harrisons would initially concentrate on the shallow Wasatch Formation while Mike Pentilla focused on the deeper intervals.

The following discussion of data interpretation for this project will refer to the thirty-four accompanying figures, several of which have been cited earlier in this report. The maps and cross sections provided with this report were exported from interpretation software

and imported into Microsoft Power Point. They are approximately 1”=3000’ scale. Figure 7 is a graph plotting acoustic travel time versus depth based on the vertical seismic profile obtained in the Del-Rio/Orion 32-11A well.

Phase One – Structural Analysis and “Deep” Mapping

The seismic events picked in the construction of the figures are all generally good continuous reflectors. The main structural element on all of these maps is an anticlinal axis trending west-northwest to east-southeast, commonly cited in the literature as the Hill Creek anticline. The anticline is bounded on the south by a deep-seated high-angle reverse fault that appears to have been reactivated in Dakota and Mancos time and is probably the locus of transform (transtensional) faulting that created structures in the younger section. Figure 8 – “Regional Arbitrary Line – Major Fault Systems”, and Figure 9 – “Cross Line 5230 – Second View of Major Fault Systems”, show the evidence for the tectonic history described above, including details of the faulting in the Wasatch and Mesaverde Formations and the reverse fault that cuts the Dakota and deeper formations.

Figure 9 shows the deep, high-angle reverse fault in detail. It also shows a near-vertical fault (transpressional fault?) cutting up from the Dakota and into the Mancos section. Finally, it shows the transtensional faulting in the Wasatch section. Note that faulting in the Mancos may be attached to the deeper reverse fault, but the Wasatch faulting is detached from the Mancos-level faulting.

The transtensional faulting in the Wasatch is generally oblique to the deeper fault trend and the trace of these faults trend in a more westerly direction. Prior to shooting the 3-D seismic survey, the Flat Rock Field was thought to be located on the crest of the Hill Creek anticline. The seismic data show the field to be located on the north flank of the anticline. However, there may be a structural element to the trapping of gas in the Wasatch provided by down-to-the-south transtensional faulting.

The most prominent anomaly on the Precambrian, Wingate, Cedar Mountain, and Dakota maps (figures 10, 11, 13 and 14) is a four-way closure in the ne/4 of Section 9-T15S-R20E. This closure is atop the Hill Creek anticline and is bounded on both the southeast and the northwest by saddles. Note how the isochron map between the Dakota and the Wingate (Figure 15) exhibits no thinning over this high. In fact this isochron map shows a thick along the axis of the anticline, which infers that most of the structural growth occurred during Dakota deposition or later.

There are two other highs on the Hill Creek anticline, one located at the southeast edge of the survey in the e/2 of Section 13-T15S-R20E, and the other at the west edge of the survey in Section 31-T14S-R19-E. There is probably closure on these highs that could be confirmed by acquisition of additional seismic data.

Figure 12 – “Triassic Wingate Amplitudes with Time Structure Contours” was one of the most revealing maps made during this interpretation effort. An examination of amplitude patterns displayed on this map resulted in the first realization that there were large

eolian sand dunes present in the section. The Carter Minton State #1 had previously penetrated this section, but was located down-dip and tested wet.

Figure 16 – “Dakota Marker to Base Cedar Mountain Isochron” shows some interesting anomalies, mostly in the eastern portion of the survey, that may be related to sand thickness. These trends were noted by Mike Pentilla, who performed a detailed evaluation of the Dakota interval.

Figure 17 – “Cretaceous Mancos Time Structure” shows relatively little relief along the axis of the Hill Creek anticline.

Phase Two – Shallow Mapping

A detailed interpretation was completed in the Tertiary Wasatch Formation. Mapping was restricted to those events below the BHR (base of high resistivity marker, see Figure 33) and above the top of the Mesaverde (Figure 18). The objectives of this work were to map structural closures, channel sands and potential stratigraphic traps.

Wasatch Formation

The Wasatch Formation consists of lake margin fluvial and alluvial plain sediments. Eocene Lake Uintah was a significant body of water with a history of fluctuating water levels influenced by the periodic, and sometimes major, tectonic movement of the San Rafael, Uncompahgre and Uinta uplifts and intermontane basin subsidence. The North Hill Creek 3D Seismic Survey is located near the southwestern shore of the ancient lake. Braided streams and fresh water deltas brought sediment from southern highlands towards the north and northeast. Within several of the mapped intervals, meandering high-amplitude events representing marginal lacustrine channels or nonlacustrine alluvial plain channels confirm this orientation.

The Flat Rock Field is productive of both oil and gas from the Wasatch Formation, as well as deeper formations, and is located on the northern flank of the Hill Creek anticline. As noted in an earlier section of this report, transtensional faults displace the Mesaverde and Wasatch Formations (see Figure 8). This faulting may provide a structural element to trapping hydrocarbons in the Wasatch.

Method

A sequence stratigraphic model conforming to the nonmarine environment described above was used to identify major sedimentary features within the section. For mapping purposes, zones were named AA through H, older to younger respectively. As mapping progressed, additional zones were encountered and were given descriptive names, such as “A channel” and “D unconformity”, to fit them into the sequence (see Figure 19 – “Arbitrary Line Showing Drilled Wells [Wasatch Detail])”. This interpretation was then integrated with detailed well information including production data, drillstem tests, mud log shows, and lithology from the Flat Rock wells.

A good correlation was observed between a relatively high-amplitude trough and the uppermost pay sand in the Del Rio/Orion 32-1A well. Because of this correlation and an assumption that amplitude anomalies in troughs could be related to pay, each trough within the Wasatch was mapped. Each trough was labeled as a “zone” which is defined as the interval between the zero-crossings above and below the trough. Each zone represents a sediment package of approximately 65 feet in thickness.

Several unconformities were mapped that confirm the geologic model, i.e., erosional remnants, etc. They were generally, but not always, picked at a positive to negative zero-crossing.

During the effort to integrate the seismic interpretation with the well data, it was determined that for the most part where there was a trough anomaly, there was a potential pay package. However, pay zones were also seen where there is less coherent and continuous seismic character. It is assumed that these pay zones are too thin to be expressed within the seismic resolution.

It appears from comparisons to the existing well data that thicker pay sections can be represented by relatively high-amplitude trough anomalies and should be the focus for selecting drill sites. It is recognized, however, that gas sands do exist in areas where the seismic character is nondescript.

An average pay or potential pay interval within Flat Rock Field is about 12 feet, or about 2 milliseconds. Often, several pays or potential pays lie within one zone. One can envision stacked channel sands formed by a channel remaining in one position over time and being represented by a single trough.

Wasatch Zone Maps

Following is a list of Wasatch zones identified during interpretation, along with corresponding figures and notable points about each of the zones:

Cretaceous Mesaverde (Figure 18):

- The top of the Cretaceous Wasatch base) is an unconformable surface
- The peak above the Mesaverde corresponds well to shaley intervals defined by Dave Allin

Tw-AA (Figures 20 and 21):

- First sediment package preserved after Mesaverde unconformity
- Limited to eastern portion of 3-D
- Prospective in section 12

Tw-A (Figures 22 and 23):

- Present over most of the survey (a transgressive event? widespread delta?)
- Location in section 12 is much higher structurally than probable pay zones in Flat Rock Field

Tw-A Mesa (Figures 24 and 25):

- Erosional remnant appears productive in three easternmost wells at Flat Rock
- Prospective at proposed locations in sections 11 and 12
- Del Rio radioactive log marker laid down on top of the Tw-A Mesa package

Tw-C: (Figures 26 and 27):

- Lithology inconsistent with seismic character in field area
- Meandering channel trending northeast present in section 11 (proposed location within anomalous amplitude and nearly closed high contour)

Tw Post -D Unconformity (Figure 28):

- Mid-Wasatch structure on unconformable surface
- Structurally closed on extreme western side of survey

Tw-EE (Figure 29):

- First sediment package deposited after the Tw Post-D Unconformity
- Isolated body prospective in section 12.

Tw-E and Tw-E Northeast (Figures 30, 31 and 32):

- Limited extent
- Remnants not cut by later channels, stratigraphically trapped (?)
- Structurally high position in section 12.

BHR (Base of High Resistivity Seismic Marker: (Figure 33):

- Structural configuration near top of Wasatch.
- Note areas of structural closure

Additional zones were mapped and studied in the Wasatch Formation. Those presented here were selected because they are located in the non-spit estate portion of the survey and exhibit features of interest.

RESULTS AND DISCUSSION

Deep Formations – Triassic Wingate Through Cretaceous Mesaverde

The closed structure cresting in Section 9 and 10-T15S-R20E is a high-quality seismic anomaly that should be drilled. Structurally, it is the highest point in the survey area with demonstrable four-way closure. It is recommended that a well be drilled on this structure to test the Wingate Formation. The cost of such a test justifies the reprocessing of the 3-D data volume by another processing company to confirm that the closure can be duplicated.

Shallow Formation – Tertiary Wasatch

Wasatch drill site locations were selected by searching for apparent stream channel sands and/or areas where “stacked” amplitude anomalies appear in the Wasatch

Formation. Two locations were initially proposed: one an obvious stream channel prospect and the other a location where several amplitude anomalies appeared to be stacked very high on the overall structure. The following proposed locations are shown on the cross section in Figure 19, as well as on the applicable maps.

The location proposed for the se/4nw/4 of section 11 had as its primary objective an apparent channel sand in the C-2 zone. The A Mesa zone and the A zone also appeared prospective at this location, which is structurally high and a safe distance from the fault to the south.

In the ne/4sw/4 of section 12 a location was proposed to test a series of apparently closed anomalies in the E, EE, A Mesa, and A zones. The section 12 location is on a small closure on the Cretaceous Mesaverde Time Structure (Figure 18). The structure appears to continue up-dip toward the southeast, off of the current 3-D survey.

Additional observations include the following:

- Existing Wasatch production in the Flat Rock Field may be partially controlled by down-to-the-south faulting on the north flank of the Hill Creek anticline. An examination of the Cretaceous Mesaverde (base of Wasatch) and the Base High of Resistivity (near top of Wasatch) structure maps indicate a structurally high trend in Sections 11 and 12-T15S-R20E.

- Existing production in the Flat Rock Field is primarily from rocks below the seismically mapped 'D Unconformity'.

- The presence of anomalous amplitudes in the D Zone package correlate relatively well with indicators of producible hydrocarbons within Flat Rock Field. The high reflection coefficient above this zone may indicate the presence of a regional sealing facies.

- Where the B Zone and C Zone packages are mapped above 0.685 seconds, there is an increased probability that a producible hydrocarbon reservoir exists.

- The A Mesa (erosional remnant) lies beneath the Base B Unconformity and has indicated pay in three wells on the east side of Flat Rock Field. This zone is present and structurally high at both proposed locations in Sections 11 and 12-T15S-R20E.

On April 30, 2001, a technical meeting was held at the Black Coral, LLC office in Denver, Colorado. Present for this meeting were Dave Suek, David Brewster and Jake Henderson of Black Coral; David Allin and Mike Pentilla, consultants to Del-Rio/Orion Resources; Randy Nickerson and Brian Coffin of Dominion Exploration and Production (interested in seeing the data as an aid to their seismic survey design effort for the

Naval Oil Shale Reserve No. 2); Walt Johnson, a consultant to a WRRC partner; and Marc Eckels of WRRC. A detailed analysis of both deep and shallow formations was presented. This presentation included the drilling recommendations presented above.

CONCLUSION

The Public Abstract for WRRC's DOE grant application stated that,

"There is every reason to believe that the channel sandstones and subtle structures that characterize the Basin's most productive oil and gas fields underlie the unexplored and undeveloped portion of the Ute Indian Tribe's 115,000 Hill Creek Extension mineral acres. Both of these reservoir types are readily identified in the subsurface using 3-dimensional seismic technology, although they might be missed on a 2-D survey."

The North Hill Creek 3-D Seismic Survey was the first survey of its size in the Uinta Basin. Although there were two previous surveys, the largest of which was ten square miles, both were shot in highly developed areas and neither was aimed at the sort of wildcat exploration that was purpose of the WRRC survey. This survey was successful in discovering oil and gas in precisely the situations described in the quote above. Beyond that, it provided the first detailed picture of the significant fault zone associated with the Hill Creek anticline, and it provided the first 3-D images of the thick eolian dune deposits of the Entrada and Wingate Formations that appear to underlie a very large area in the southern Uinta Basin.

In addition to the drilling results that will be discussed below, another measure of success is the number of similar 3-D surveys that this work has spawned. Since the initial interpretation of the North Hill Creek survey was completed, two additional 3-D surveys have been conducted on state and federal lands immediately to the southeast and a few miles to the east. One large survey has been permitted to the west. Three more surveys are in the permitting process immediately to the east adjoining the North Hill Creek Survey, six miles to the east, and more than ten miles to the east. Five additional surveys in the immediate area are in the design and planning phase. WRRC is involved in three of these surveys.

The impetus for these surveys has been the drilling success established on the basis of the North Hill Creek data. To date fifteen wells have been drilled to targets identified in the North Hill Creek data volume. There have been no dry holes in an area where the wildcat success rate without good 3-D seismic data might reasonably be ten to fifteen percent. Several of the wells have been among the best gas producers in the state of Utah.

WRRC has had constant competition for acreage around the perimeter of the North Hill Creek survey. Despite this fact, WRRC has shared information from the survey with a number of other operators in an effort to promote the additional surveys. Information has also been shared with the industry through a presentation made with Landmark

Graphics at the March 2002 AAPG convention in Houston, where Landmark's spectral decomposition capability was demonstrated by Bill Keach and Marc Eckels using the Wasatch Formation data volume. A presentation by Paul Harrison and Mike Pentilla at the February 2003 Rocky Mountain Association of Geologists 3-D Symposium dealt with the deeper formations.

Drilling Results – Shallow Wells

Wasatch Formation

The first well drilled on the basis of the North Hill Creek survey data was the North Hill Creek (NHC) 6-11-15-20 (WRRC's numbering system indicates 1/41/4, section, township and range, in that order, so the 6-11-15-20 is located in the se/4nw/4 of Section 11-T15S-R20E). Figure 34 shows the location of each well. The NHC 6-11, as discussed above, was intended to test several anomalies, the most promising of which was an apparent stream channel in the C2 zone of the Wasatch Formation. The well was drilled in late September and early October of 2001, to a total depth of 4,493' in the Mesaverde Formation. A complete suite of open hole logs was supplemented with an open hole magnetic resonance imaging (MRIL) log and a cased hole thermal multigate decay (TMD) log. Four sidewall cores were obtained from the Mesaverde and eighteen from the Wasatch intervals. These were the subject of routine core analysis and detailed description. Multiple shows of oil and gas were encountered while drilling. Four intervals between 4,104' and 4,315' gave good oil and gas shows but appeared wet on logs. These were perforated, and all tested wet. They were isolated below a bridge plug and the four additional intervals were perforated in the Wasatch Formation between 3,720' and 3,938'. Upon perforation of the interval at 3,752' to 3,762', the well pressured up and started flowing at the rate of 1,600 Mcfgpd. This well was put on production as a natural completion, which is extremely unusual for a Wasatch gas well. Through the end of 2003, this well had produced 0.44 Bcfg and was producing 350 Mcfgpd and less than 1 bwpd.

The second Wasatch well drilled was the NHC 11-12-15-20. This well was drilled in October 2001, to a total depth of 4,202' in the Mesaverde Formation. Severe lost circulation was encountered at 1,565', and the well was drilled to TD with aerated KCl water. Hole conditions precluded open hole logs or sidewall cores. The well was logged through the casing with a TMD log, which was also run in the NHC 6-11 for comparison purposes. The well was initially completed in the Wasatch A Mesa and B zones as a flowing oil and gas well producing at the rate of 50 bopd, 450 Mcfgpd and 25 bwpd. Water production increased in a matter of a few weeks, reducing oil and gas production. The well was put on a rod pump and had declined to about 10 bopd, 11 bwpd, and 20 Mcfgpd in January 2003, when it was recompleted in the Wasatch EE gas zone. After perforating and HCl acid breakdown, the isolated EE zone would build up 880 psi overnight, but would bleed the pressure off in minutes. A cross-linked gel sand frac was designed and executed. The well responded with an initial gas flow rate of 700 Mcfgpd. After recovery of the load water, however, water production continued at a high rate (200-300 bwpd), making it uneconomic due to the ninety-mile one-way water haul to an approved disposal facility. All indications were that the EE zone was dry. A production log showed water movement into the EE zone from a wet sand located uphole that must

have been reached by the frac. An attempt to shut off the water with an experimental "relative permeability modifier" treatment failed. The well has since been shut-in awaiting a solution or recompletion. Cumulative production is 4,398 bo, 45,118 Mcfg, and 18,000 bw. This well was an exploration success, but has so far been an economic failure due to technical problems.

Mesaverde Formation

The third well drilled by WRRC was designed to be a deep test of the closed structural high in sections 9 and 10. Located in the nw/4nw/4 of section 10, the NHC 4-10-15-20 was scheduled to drill into the Jurassic formations to a depth of 11,700'. Drilling began in late May 2002, with air and aerated fluid as the circulating media. At a depth of 4,518' in the Mesaverde the well encountered a 7,000-Unit gas show and started to flow at 3,500 Mcfpd. Drilling continued through the Mesaverde Formation to the Mancos Shale, where intermediate casing was to be set. While conditioning the hole to run casing, the well caved badly and stuck the drill pipe. The drill pipe was backed off one joint above the bottom hole assembly, and a decision was made to leave the fish in the hole and complete the excellent Mesaverde gas show. The completion of several deeper and less interesting Mesaverde gas shows was attempted, but all proved wet. The main show was then isolated above bridge plug and completed between 4,521' and 4,544' with a small HCl acid job. Initially the well flowed 2,700 Mcfgpd and 100 bwpd at 800 psi. Water production increased every day, and after several weeks the well was barely lifting 200 bwpd and dying periodically. A plunger lift system was tried unsuccessfully. After a rod pump was installed, production gradually increased to 700 Mcfgpd as the productive interval was dewatered. The rod pump worked for six months, at which point the 240 bwpd exceeded the pump capacity and production declined to less than 100 Mcfgpd. Cumulative production through 2003 was 88,000 Mcfg and 60,000 bw. This well is a candidate for downhole water separation and disposal, which should restore it to economic operation without the need for a larger pumping unit.

Drilling Results – Deep Wells

Flat Rock Field Entrada Formation (Dune) Wells

During the winter of 2001-2002, Del-Rio/Orion, then operator of the Flat Rock Field, drilled two wells to test the Entrada dune sands in Section 29-T14S-R20E. Both wells were completed without fracs at rates in the range of 2,500 Mcfgpd. At the end of 2003 each well had cumulative production of 1.4 Bcfg. One well was flowing 1,600 Mcfgpd, and the other was flowing 1,800 Mcfgpd.

North Hill Creek Deep Drilling Program

Following the completion of the NHC 4-10 well, WRRC entered into an agreement with a partner to conduct a ten-well drilling program to evaluate the deep potential of the North Hill Creek property. This drilling program commenced in October of 2002 and concluded in March of 2004. All of the wells were drilled to the Wingate at depths in the range of 11,800' to 12,300'. Three of the wells were directional holes drilled from relatively flat locations near cliffs to intercept target located under terrain too rugged for vertical drilling.

Wingate and Entrada Formations

All of the wells have been completed in multiple formations, and all have found gas in commercial quantities after hydraulic fracture stimulation. The most significant producing formation to date has been the Entrada, which has produced in every well. The Wingate has been almost as important, producing either large quantities of gas (>7,000 Mcfgpd) or lesser quantities of gas along with condensate and water. The Wingate has been productive in seven wells. The discovery of significant commercial production in these sand dune Formations in these ten wells and the two Entrada wells at Flat Rock Field is clearly the most important result to emerge from the interpretation of the 3-D data. Prior to this work neither of these formations was an exploration objective in this area. The Wingate had no previous history in the Uinta Basin, and most of the previous Entrada production had been inflammable gas. The multiplicity of 3-D surveys in the permitting or design phase in the area is largely a testament to the interest that these formations have generated.

Kayenta Formation

One well is producing gas from the Kayenta Formation. It is not thought that the Kayenta has been a commercial gas producer in the Uinta Basin, or perhaps elsewhere. A production log indicated that the Kayenta was producing 378 Mcfgpd. This is nothing like the 1,000-8,000 Mcfgpd produced from the Wingate and Entrada in the other wells, but it is certainly of interest.

Morrison Formation

To date four wells have been completed in the Morrison. None has yielded an isolated test or a production log, but the volumes are thought not to be large.

Dakota and Cedar Mountain Formations

Seven wells have produced from the Cedar Mountain, which was a primary objective of the program as it was originally conceived. All of the deep wells had the Entrada or Wingate as primary objectives, so finding a thick channel sand in the Cedar Mountain was a secondary objective. The final well, which is not yet on production, penetrated a 75-foot thick channel in the upper Cedar Mountain. This channel appears to be gas-charged and looks very much like the channel that has produced 5.3 Bcfg from the Fence Canyon Unit #1, approximately eighteen miles to the east. Hopes for this zone are very high. Perhaps as important is the fact that it is large enough to see on the 3-D data, and having drilled through and logged it will aid in the search for other such channels.

The Dakota Sandstone has been completed in seven wells. Like the Cedar Mountain, it should have some productive channel sands. It does not appear that any of the Dakota intervals completed in these wells is especially strong. However, the recognition of the Cedar Mountain channel discussed above should also be useful in the search for Dakota production. There are many >1 Bcf Dakota wells in the area to the south and east of the survey area. Most were drilled in the 1960s or 1980s. Typically, these wells

produce from commingled Dakota and Cedar Mountain sands or just Cedar Mountain sands, despite the fact that they are called Dakota wells.

Dakota Silt

The Dakota Silt is a very fine-grained tight sand. Its consistently distinctive coarsening upward log signature makes it an excellent log marker, although it is a surprisingly poor seismic reflector. This interval gives a consistent strong gas show, but is not believed to have been completed successfully elsewhere. After bypassing the opportunity in the first two deep wells, it has been completed in each of the remaining eight. The best production is approximately 500 Mcfgpd. Although it is not a spectacular performer, it is expected to be a long-lived one.

Mancos Shale

The entire survey area is underlain by approximately 3,800' of Mancos Shale. The Mancos is a well-known source rock and is commercially productive outside the Uinta Basin. Although there have recently been a number of apparently successful Mancos completions in the Natural Buttes area, at the time this survey was conceived it was not generally accepted that the Mancos was commercially viable in the Uinta Basin. The reason for this was the extreme tightness of the formation. It was hoped that the faulting and folding associated with the Hill Creek anticline might have induced the permeability that the Mancos typically lacks. This turns out to be the case, especially in the lower 1,000', which is highly fractured and gave excellent (up to 10,000-Unit) gas shows in every well. The Mancos has been completed in six of the deep wells using a modified "slick water" frac similar to the stimulations being applied to wells in the Barnett Shale of the Fort Worth basin. The best result to date has been 570 Mcfgpd. Again, it is expected that this zone will be a moderate producer for a very long time.

Final Comments

To date fifteen wells have been drilled based on data from the North Hill Creek 3-D Seismic Survey. Although two of these wells are presently shut-in awaiting solutions to water problems, there have been no dry holes. Production has been established from ten geologic formations ranging from the Eocene Wasatch at 3,500 feet to the Triassic Wingate at a depth of 12,250 feet. One well is producing from seven formations.

There is some question whether it is wise to commingle so many formations in a development drilling program. However, the ten well deep drilling program described here was not a development drilling program. Rather, it was an effort to learn as much as possible about the entire prospective sedimentary section as quickly as possible.

Some unanswered questions remain to be dealt with in the coming months. Although the area along the crest of the Hill Creek anticline has now been reasonably well explored, no wells have been drilled on the south side of the fault. There are several interesting structures and anomalies south of the fault and in the northeast corner of the 3-D data set. These areas are inherently more risky because they are near the edge of the data volume and are not structurally high. They appear to be quite promising,

especially in the Entrada, Wingate and Mancos, where it is not at all clear that structure is especially important.

WRRC is a participant in an extension of this 3-D survey to the area immediately northeast and east. This survey should reduce the risk for some of the off-structure features, so drilling in these areas will be delayed until the new data are available.

The total cost of the North Hill Creek 3-D Seismic Survey has grown to approximately $1.5-million for the entire twenty-five square mile area. Considering that the dry hole cost for a deep well is in the same range, it seems obvious that the application of this technology to exploration and development drilling programs in this area makes sense. There is a large area of unexplored and underexplored opportunities on Ute Indian lands, Utah state lands, and federal lands in the Book Cliffs of the southern Uinta Basin. This is an extremely wild and rugged area, poorly served by transportation infrastructure, and highly valued by hunters, outdoorsmen and environmentalists.

Environmental groups have opposed most seismic surveying activity because they understand that drilling programs run without seismic data are more risky and less likely to take place. A reasonable environmental ethic, one that is held by a consumer of oil and gas, recognizes that 3-D seismic surveys are environmentally friendly technology. The North Hill Creek survey is a perfect example. Four extremely dry years after the data were acquired it is not at all obvious on the ground that the survey ever took place. Fifteen wells have been drilled without a single dry hole. Typically, fifteen wildcat wells drilled at the risk level that these wells represent without 3-D seismic data would result in two or three producers. Aside from the economic waste associated with twelve or thirteen dry holes, the environment has been spared twelve or thirteen access roads and drilling locations. This is an important point. The nation requires fuels and cannot meet its projected future needs without the exploration and development of a lot of places similar to the Book Cliffs of Utah. Wherever a footprint has been left by this program there has been a significant contribution to meeting those needs.

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Young, Robert G., 1975, Lower Cretaceous Rocks of Northwestern Colorado and Northeastern Utah, *in* Bolyard, D.W., editor, Deep Drilling Frontiers in the Central Rocky Mountains: Rocky Mountain Association of Geologists, 1975 Symposium, p. 141-147.

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34	Index Map of Wells Drilled Using North Hill Creek 3D Seismic Survey (showing pre-survey wells in Flat Rock Field)

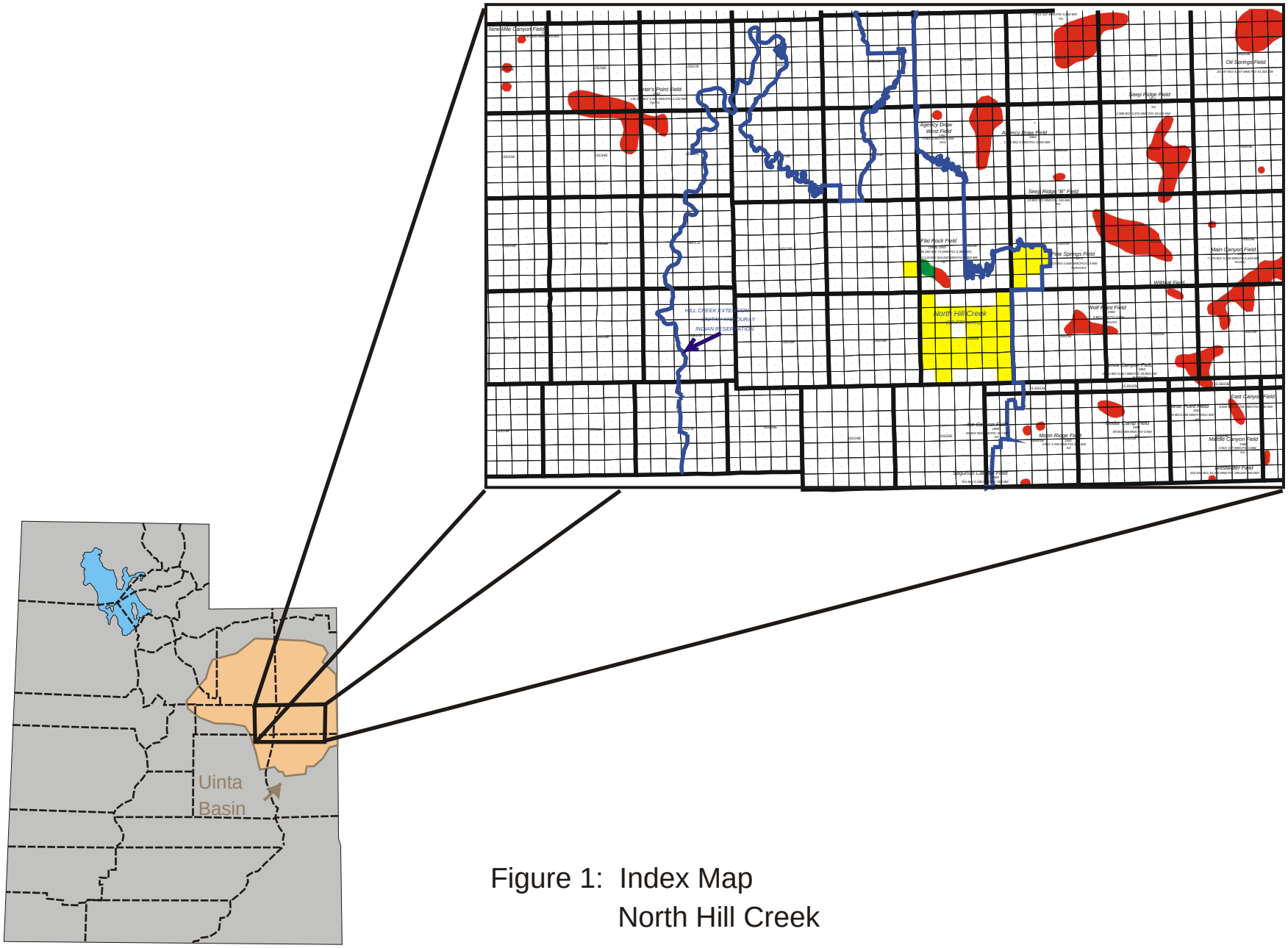


Figure 1: Index Map
North Hill Creek

Wind River Resources Corporation

Figure 1

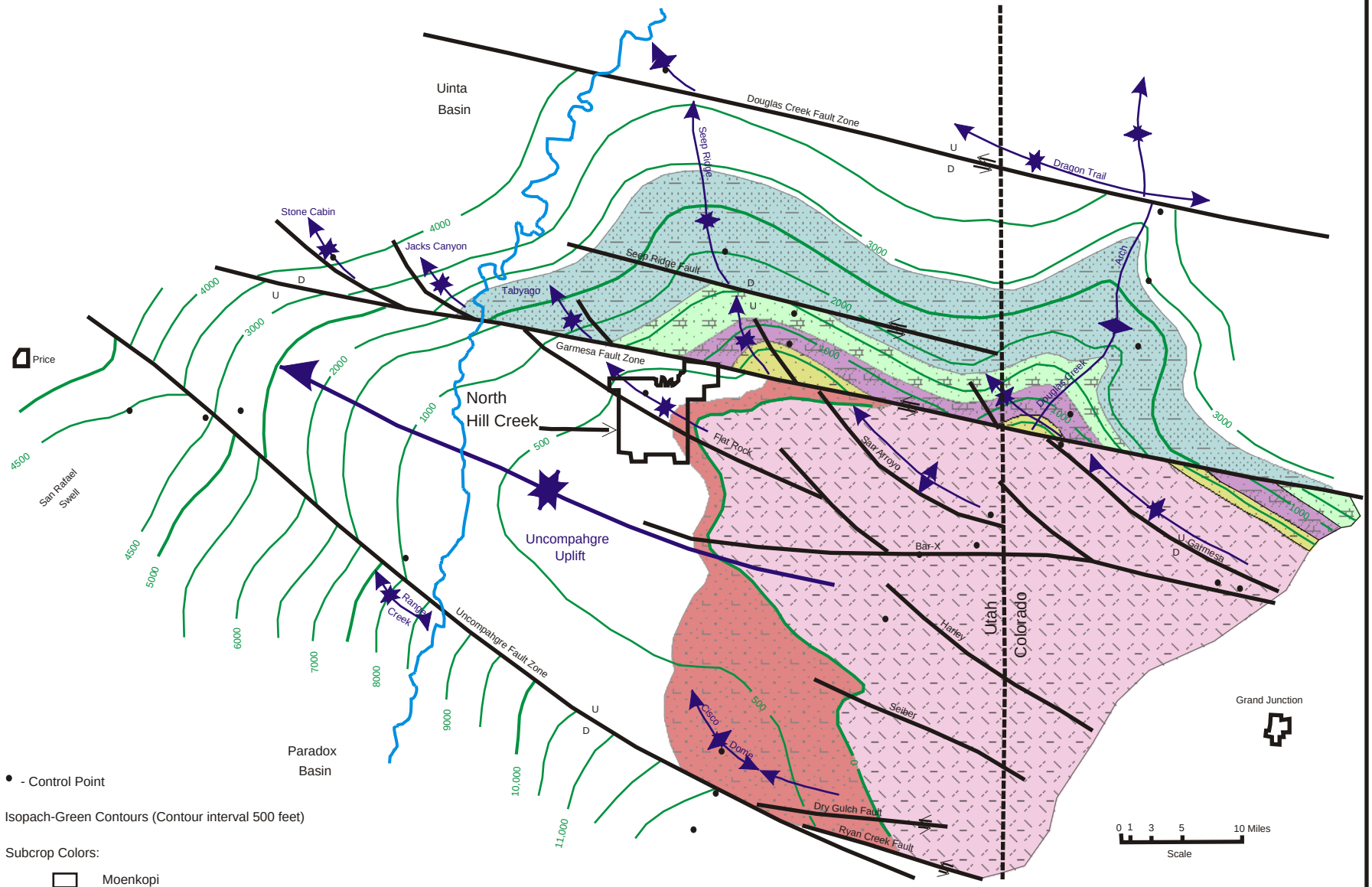
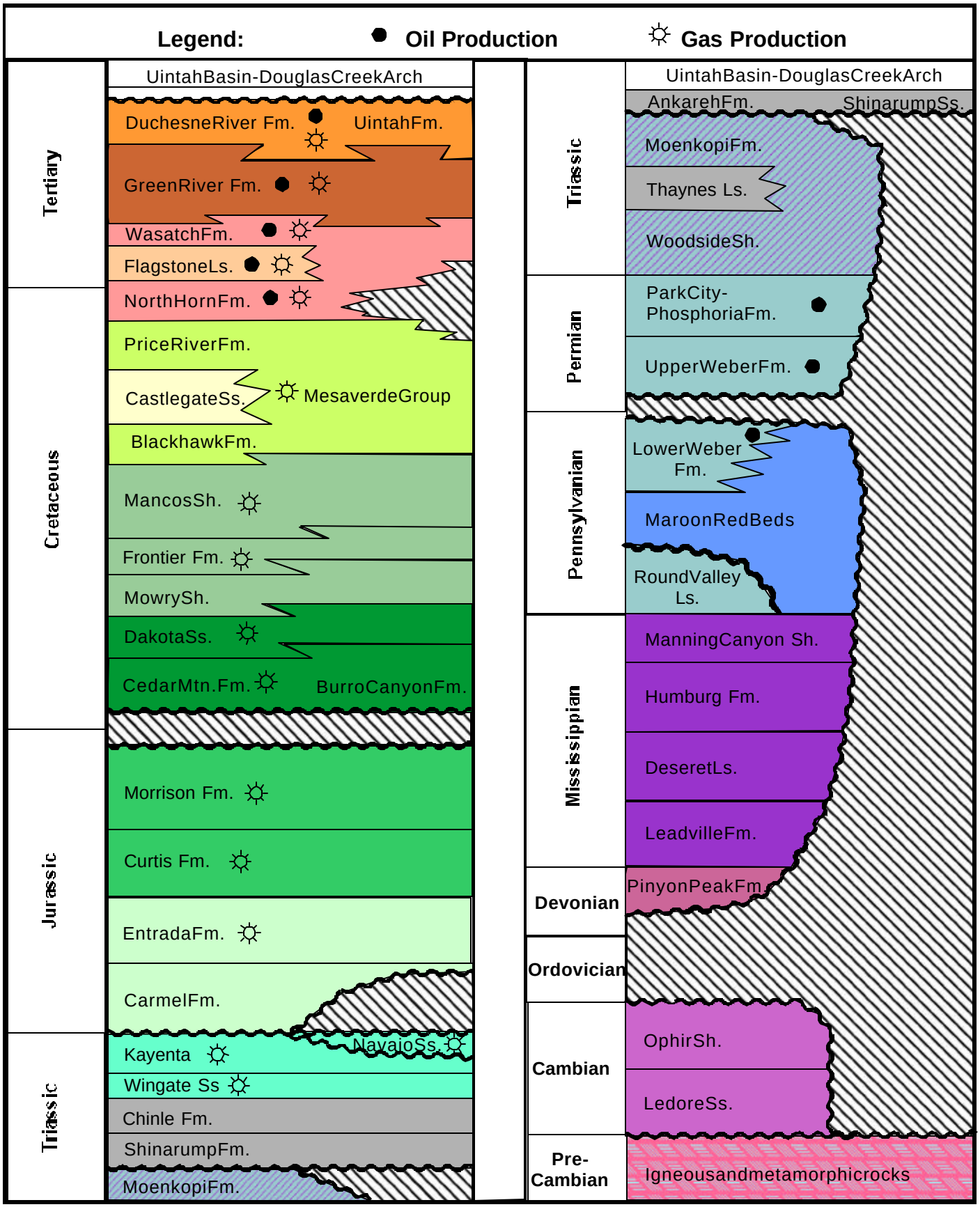


Figure 2- Isopach Map from the Base of the Upper Triassic Shinarump to the top of the Precambrian, with Subcrop Map of the rocks below the Shinarump Unconformity (Modified after Don Stone, 1977)

Wind River Resources Corporation

Figure 2

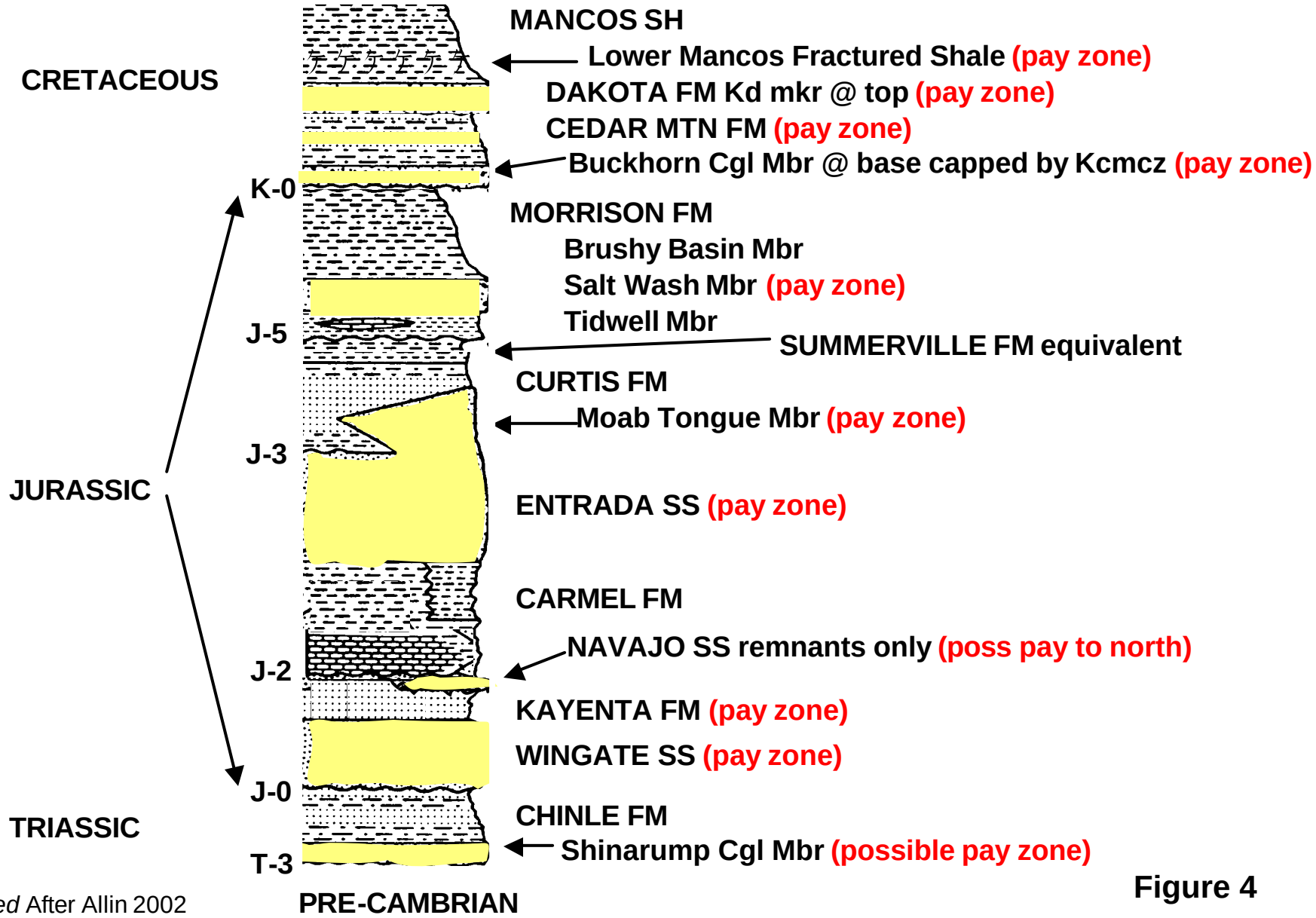


Uinta Basin Stratigraphic Column

After Clem, 1985

Figure 3

Schematic Stratigraphic Column: North Hill Creek Basement through Lower Cretaceous

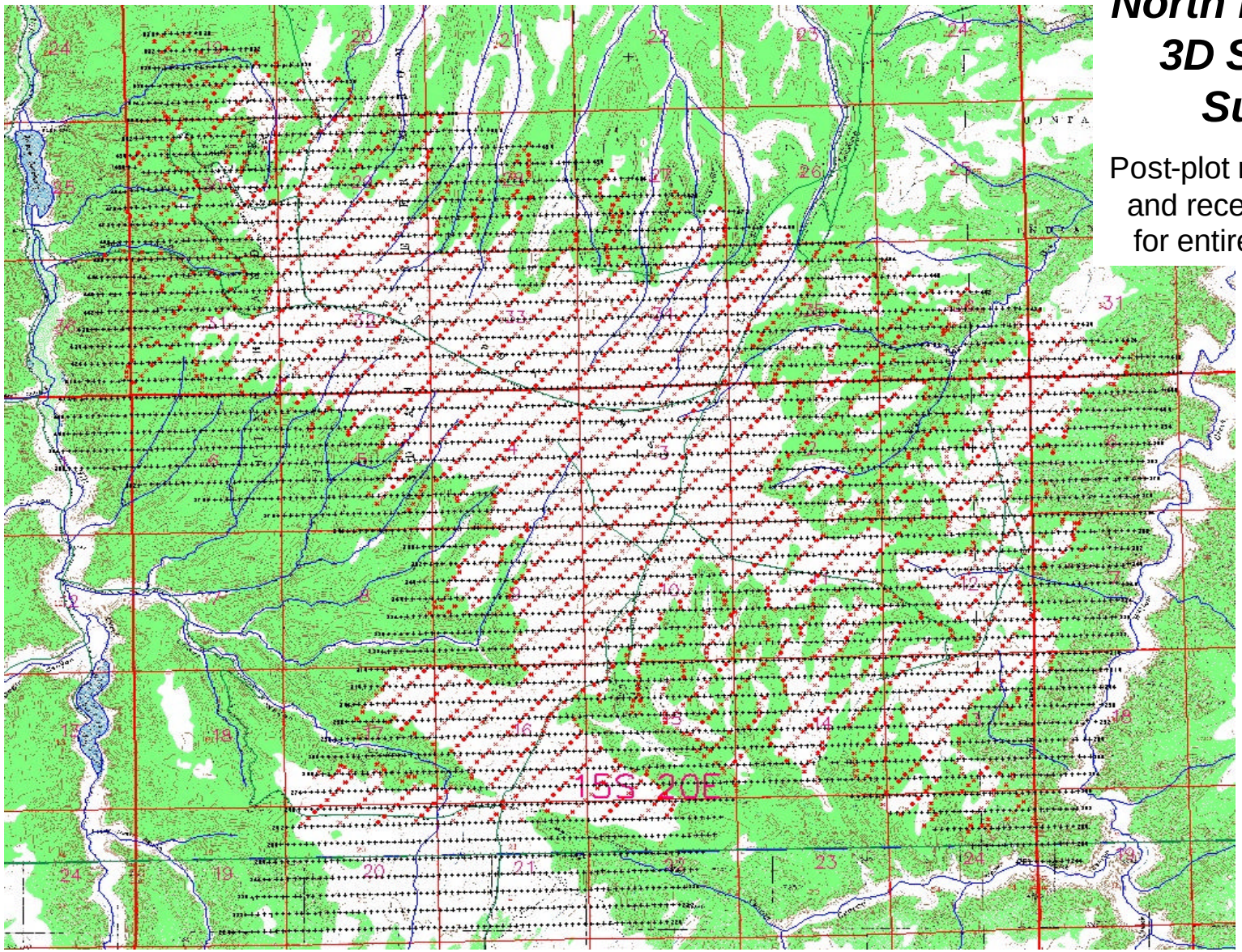


Modified After Allin 2002

Figure 4

North Hill Creek 3D Seismic Survey

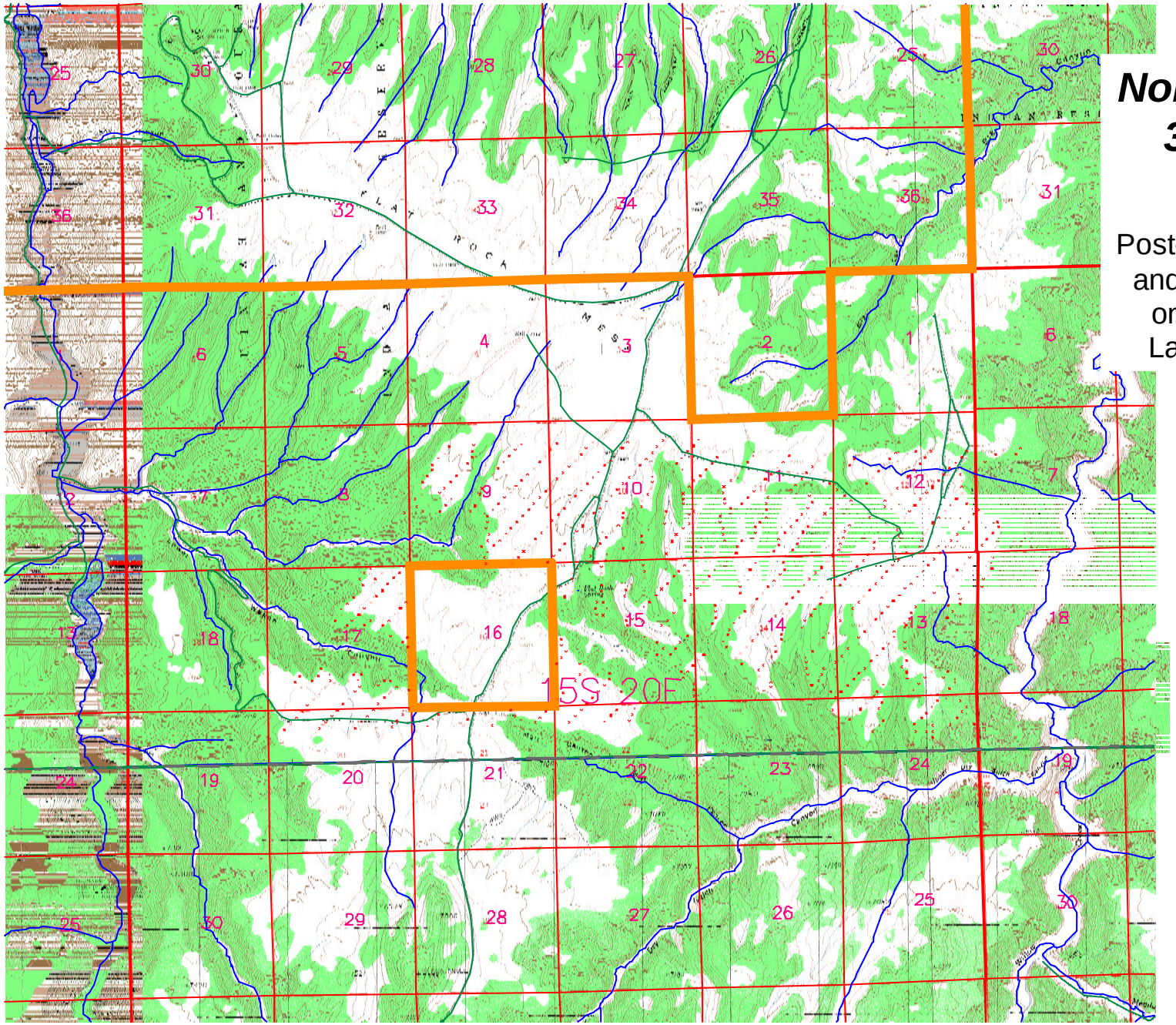
Post-plot map for source and receiver locations for entire 25 mi² area



X = source

+ = receiver

Figure 5



North Hill Creek 3D Seismic Survey

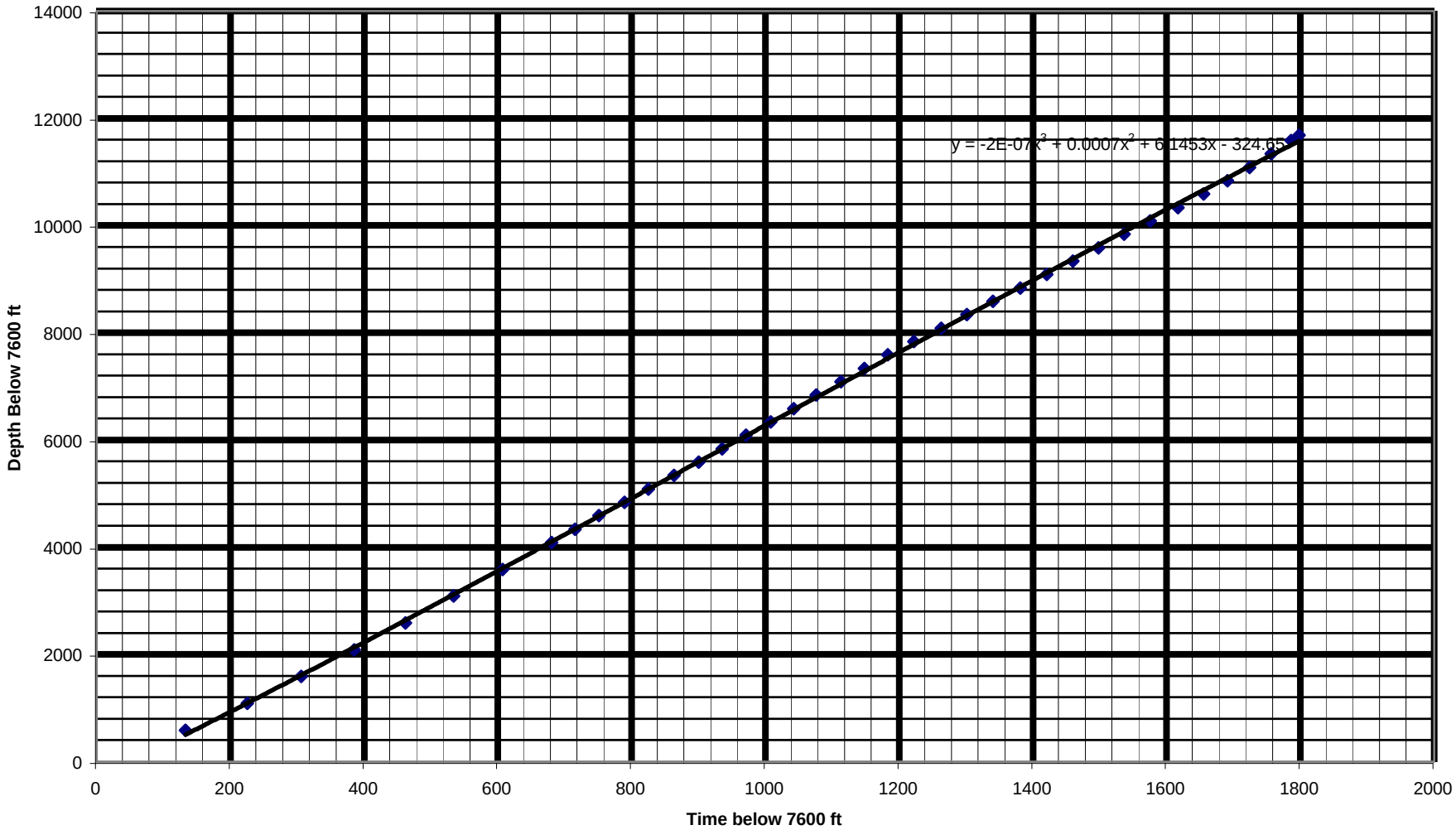
Post-plot map for source and receiver locations on Ute Indian Tribe Lands (15 mi² area)

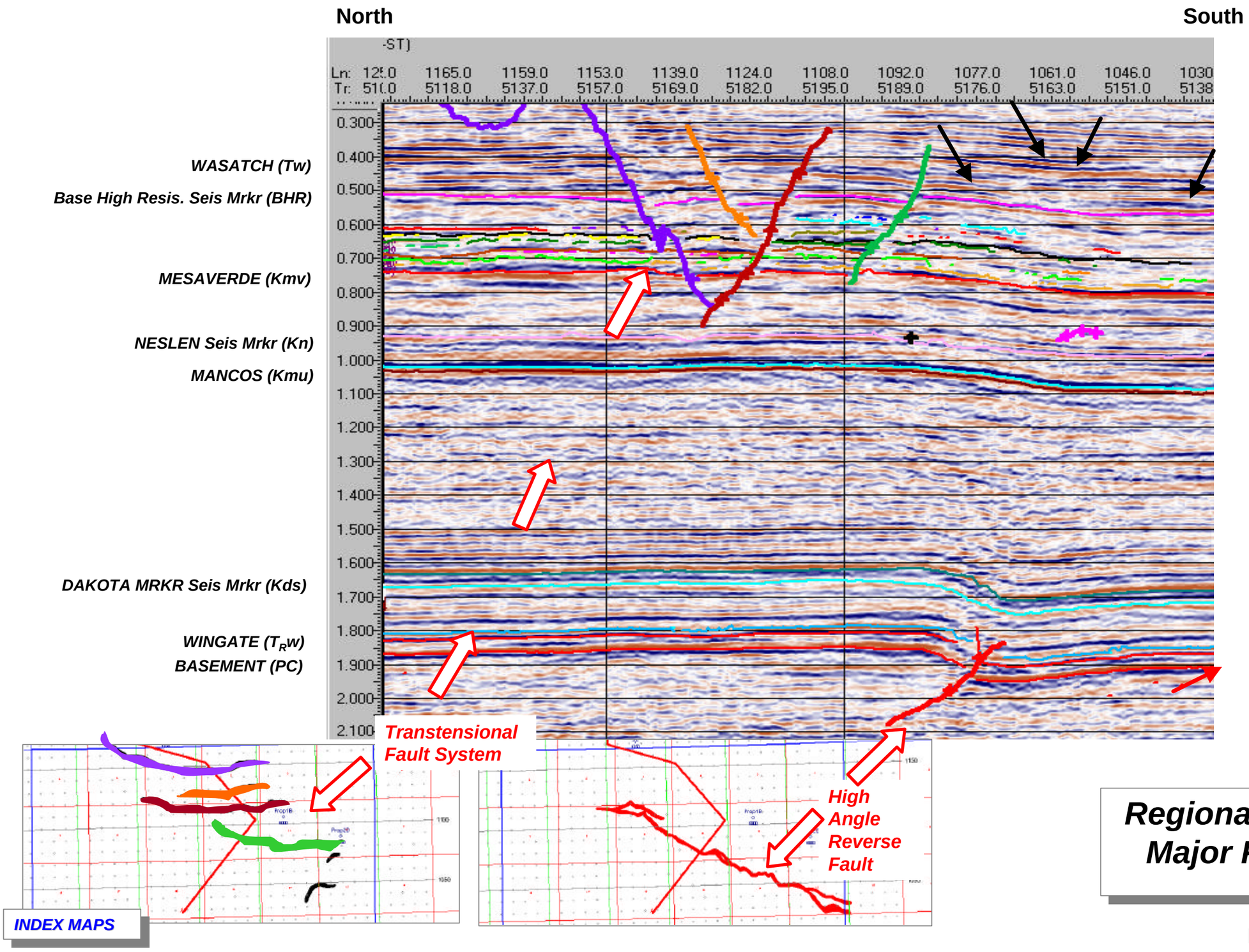
X = source

+ = receiver

Figure 6

Time vs Depth from Del Rio 32-11AVSP
(Time and Depths Related to 7600 foot Seismic Reference Datum)
Figure 7



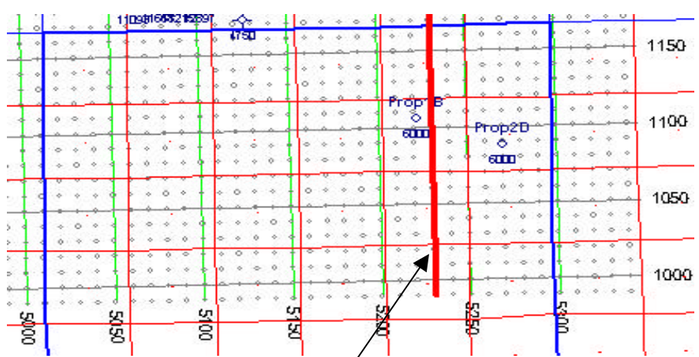


Regional Arbitrary Line
Major Fault Systems
5-4-04

Figure 8

Cross Line 5230
2nd View of Major Fault Systems

5-4-04



Cross Line 5230

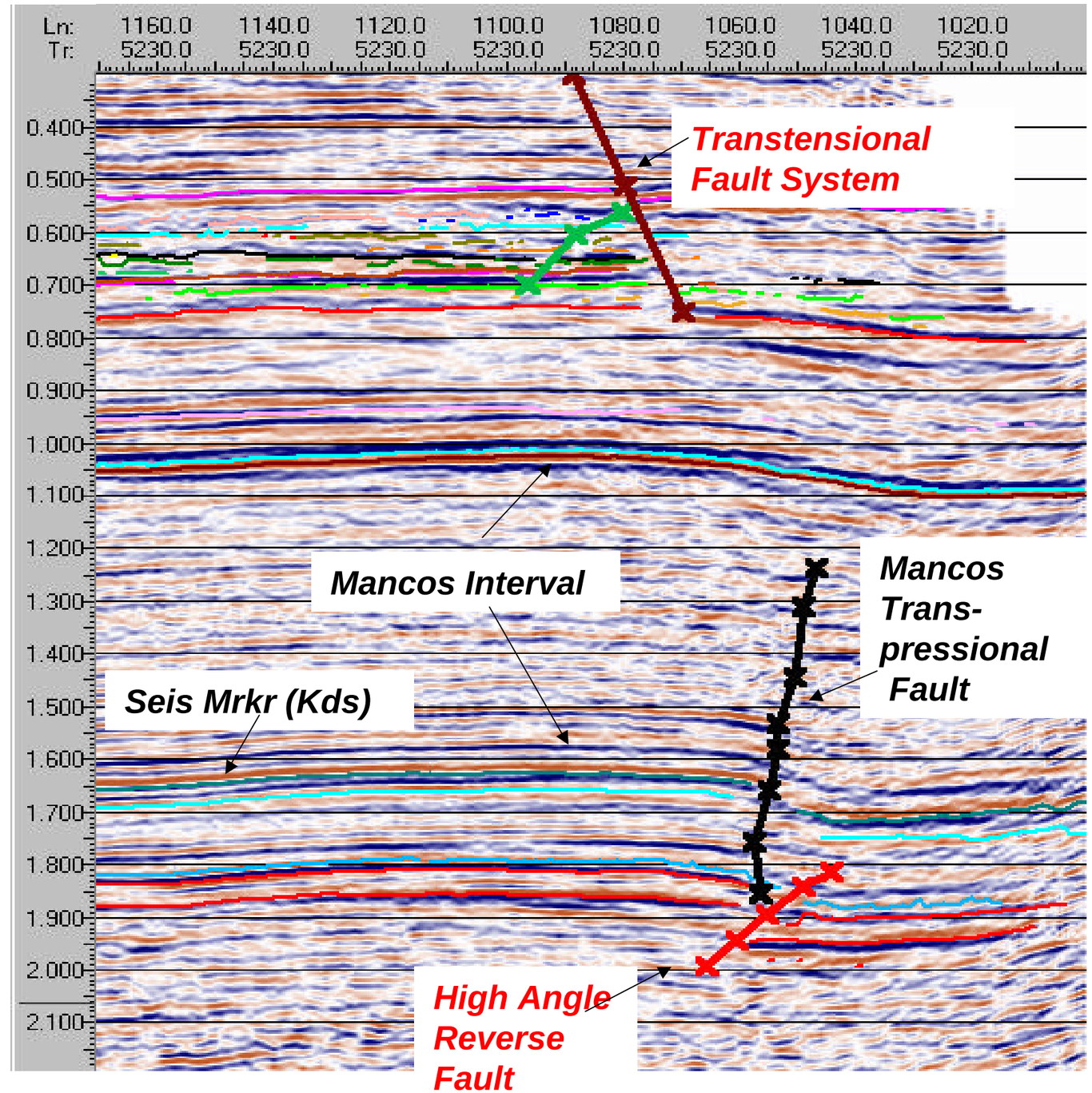


Figure 9

PreCambrian Basement Time Structure

CI = 10 ms (60') *5-4-04*

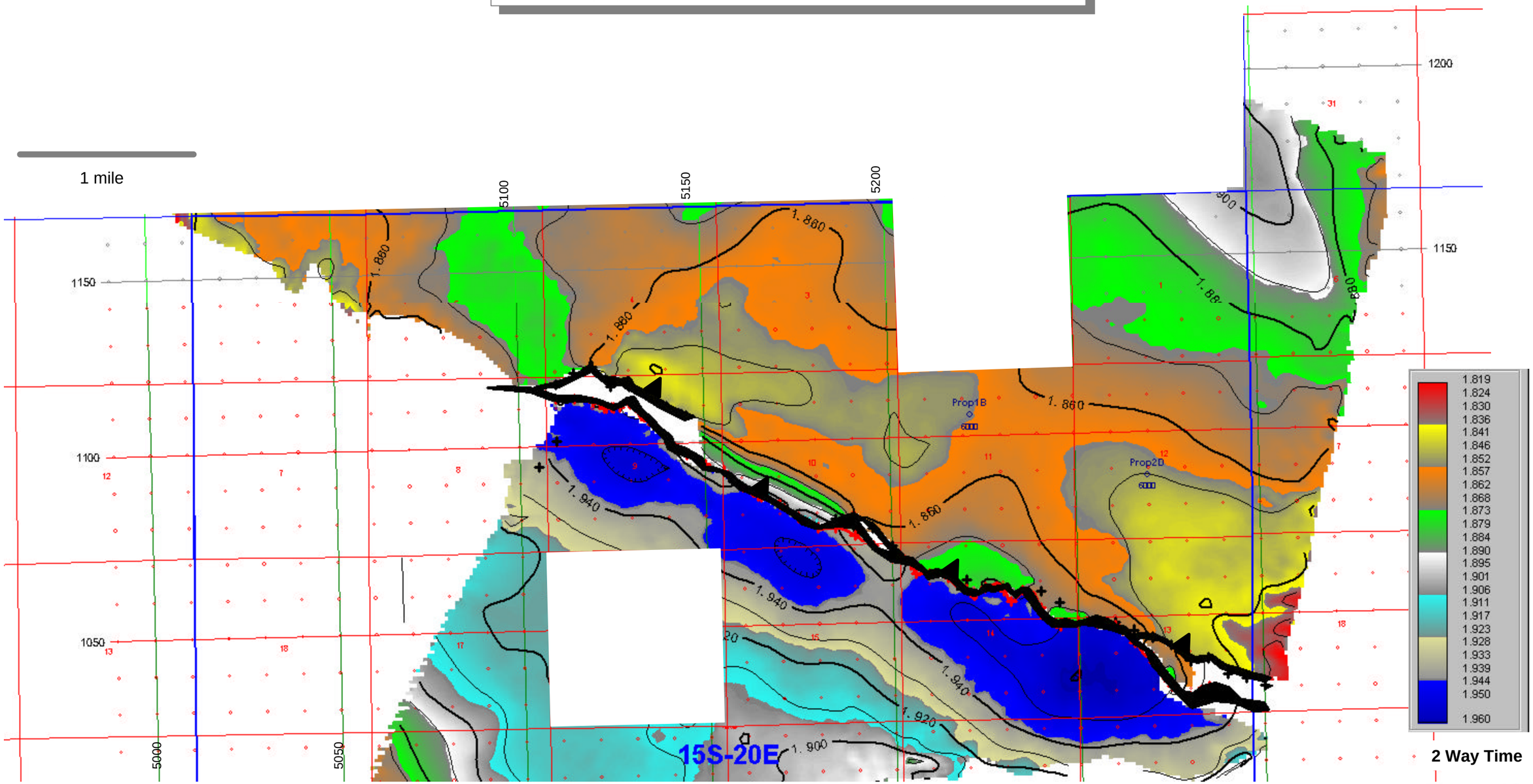


Figure 10

Triassic Wingate Time Structure

CI = 10 ms (60') *5-4-04*

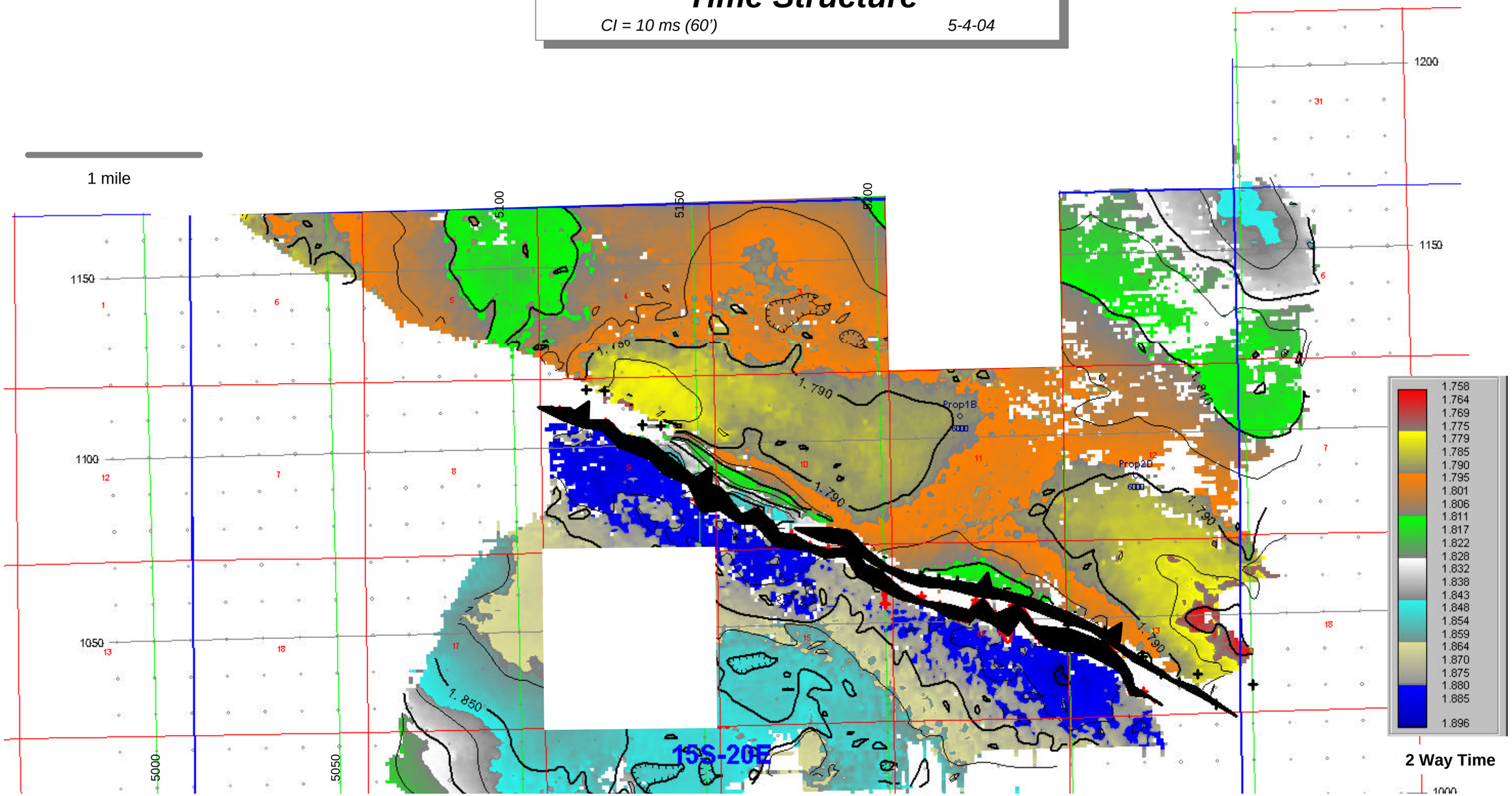


Figure 11

Triassic Wingate Amplitudes with Time Structure Contours

CI = 10 ms (60') *5-4-04*

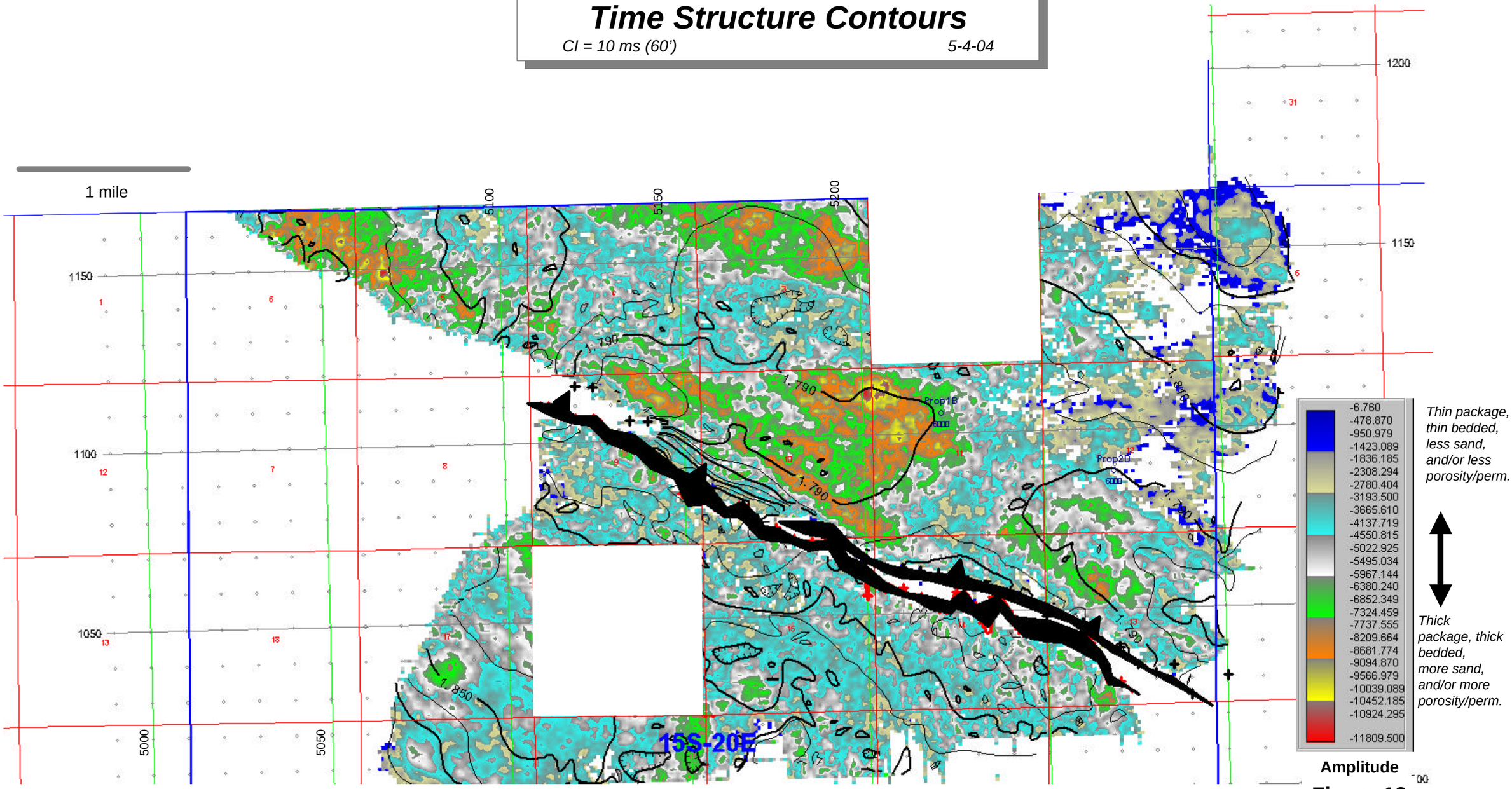


Figure 12

Cretaceous Cedar Mtn Seismic Marker Time Structure

CI = 10 ms *5-4-04*

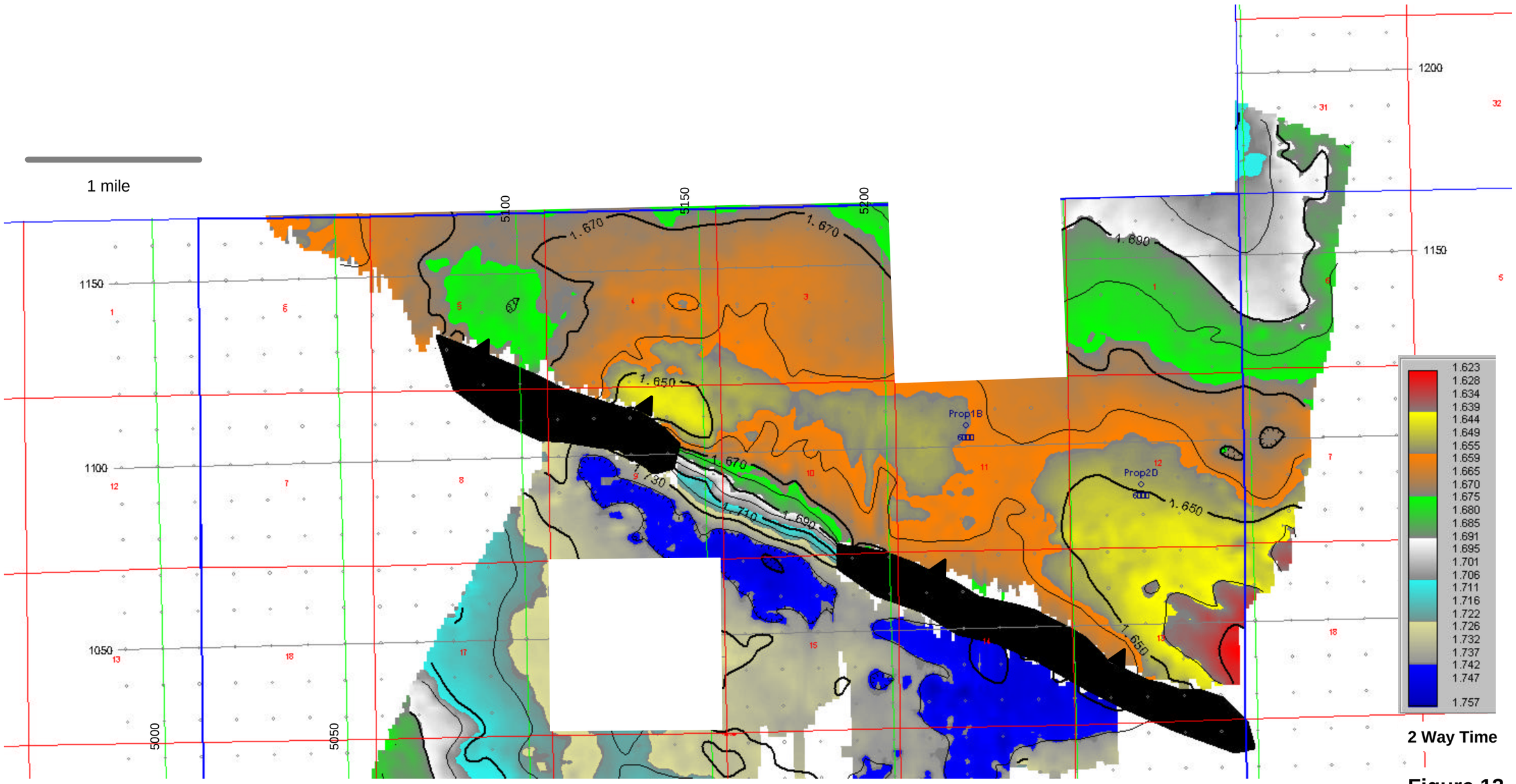


Figure 13

Cretaceous Dakota Seismic Marker Time Structure

CI = 10 ms *5-4-04*

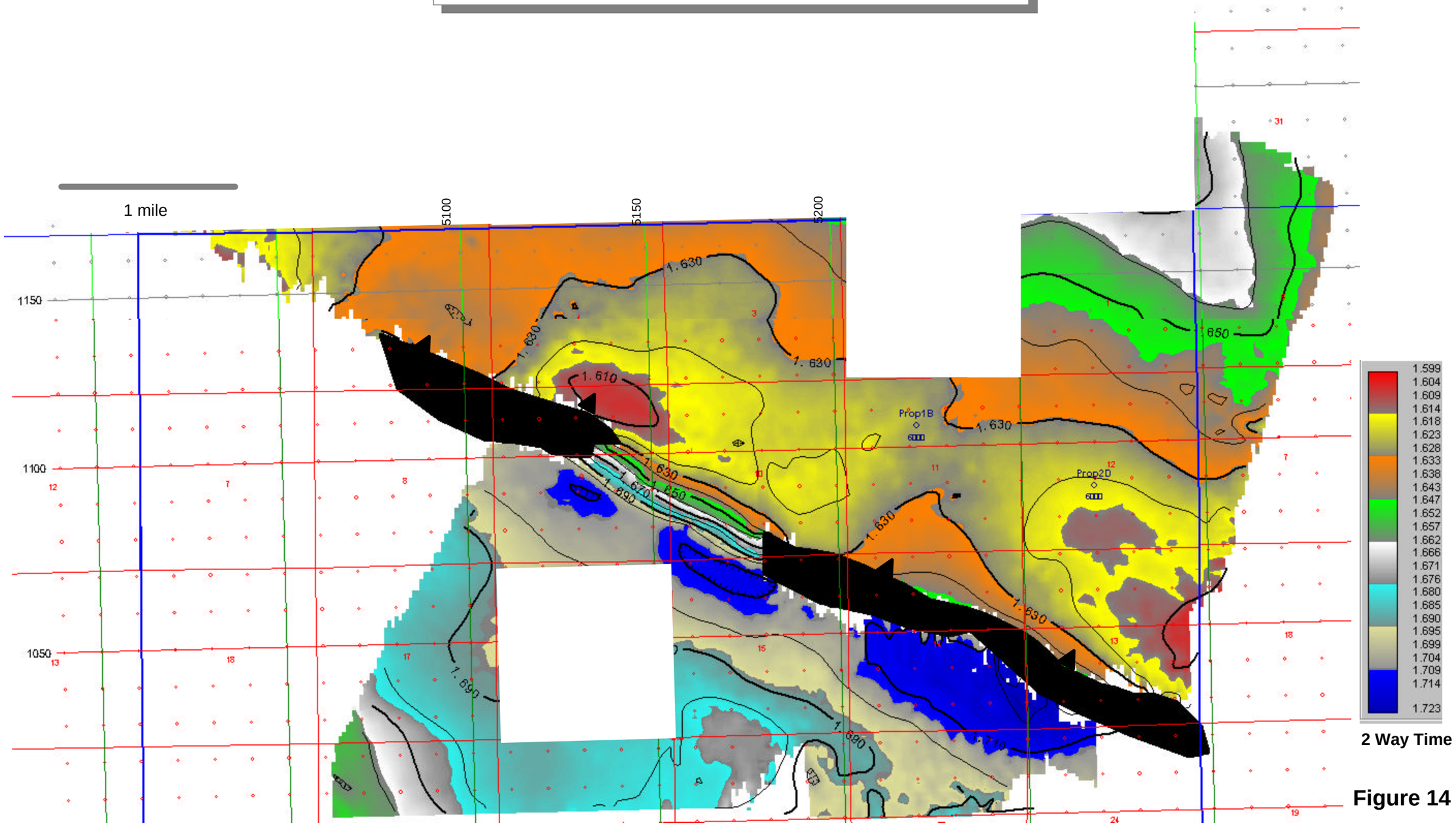


Figure 14

Dakota Mrkr to Wingate Isochron

5-4-04

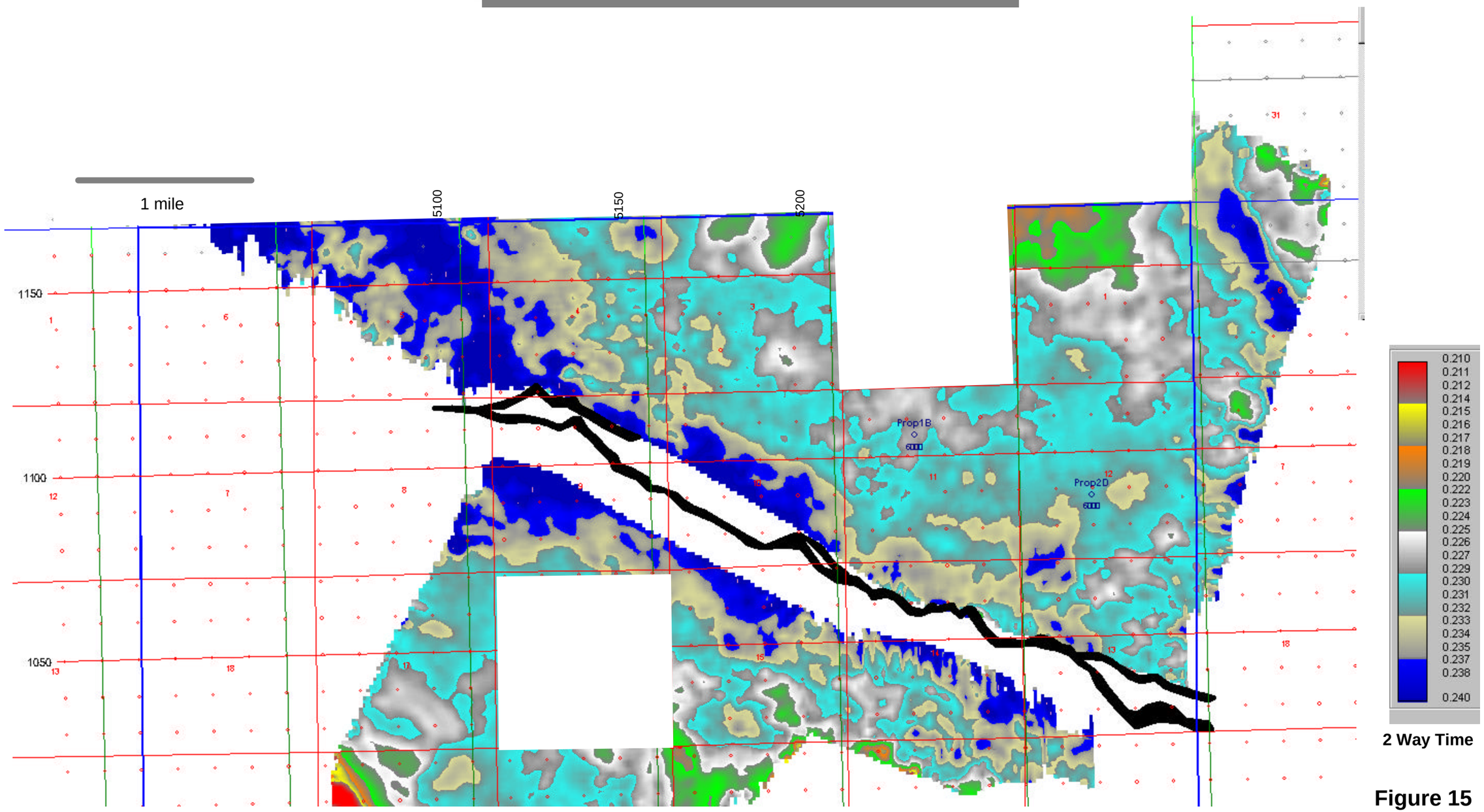


Figure 15

Dakota Mrkr to Base Cedar Mountain Isochron

5-4-04

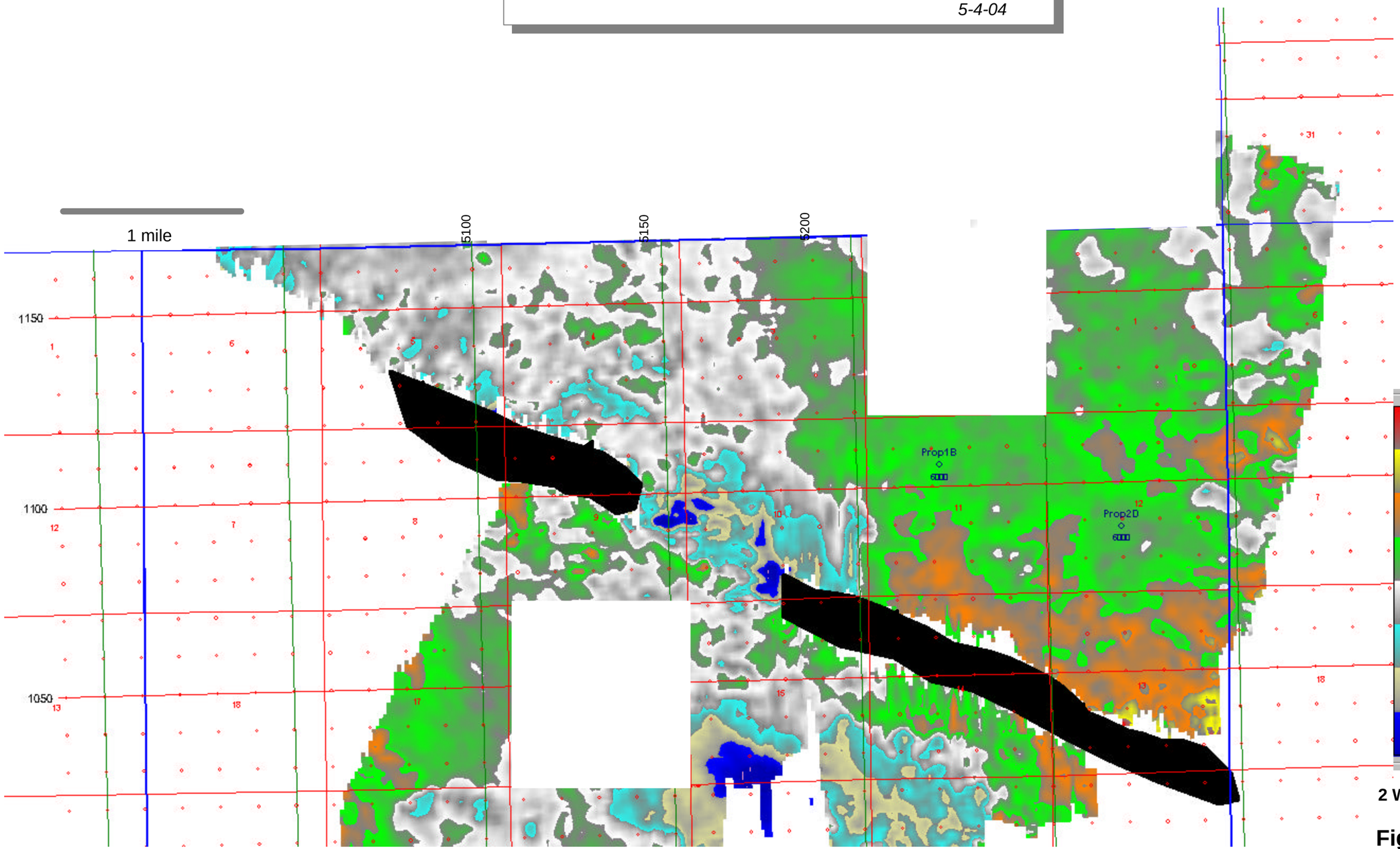


Figure 16

Cretaceous Mancos Time Structure

CI = 10 ms *5-4-04*

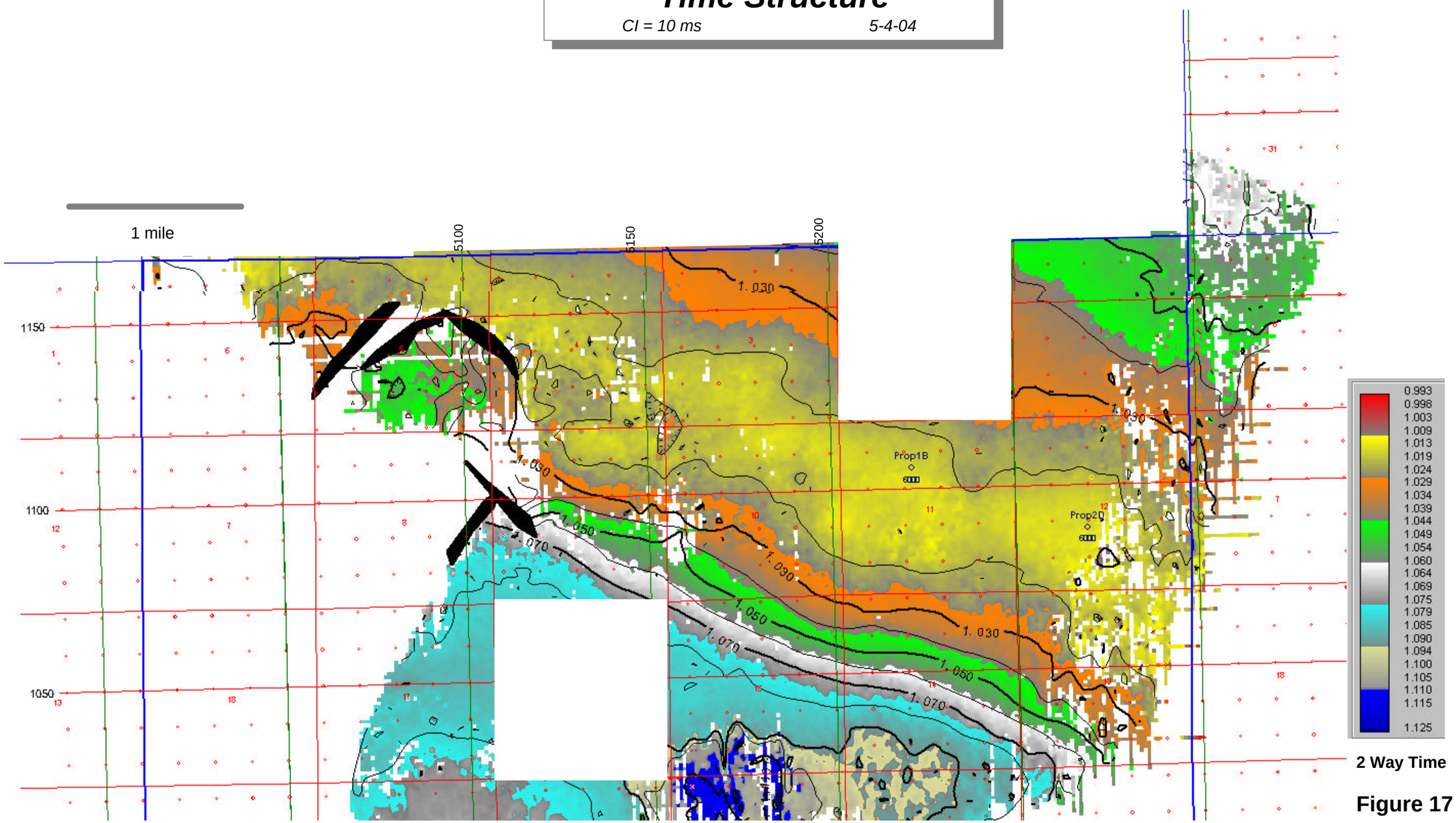


Figure 17

Cretaceous Mesaverde (Kmv) Time Structure

CI = 5 ms (30') *5-4-04*

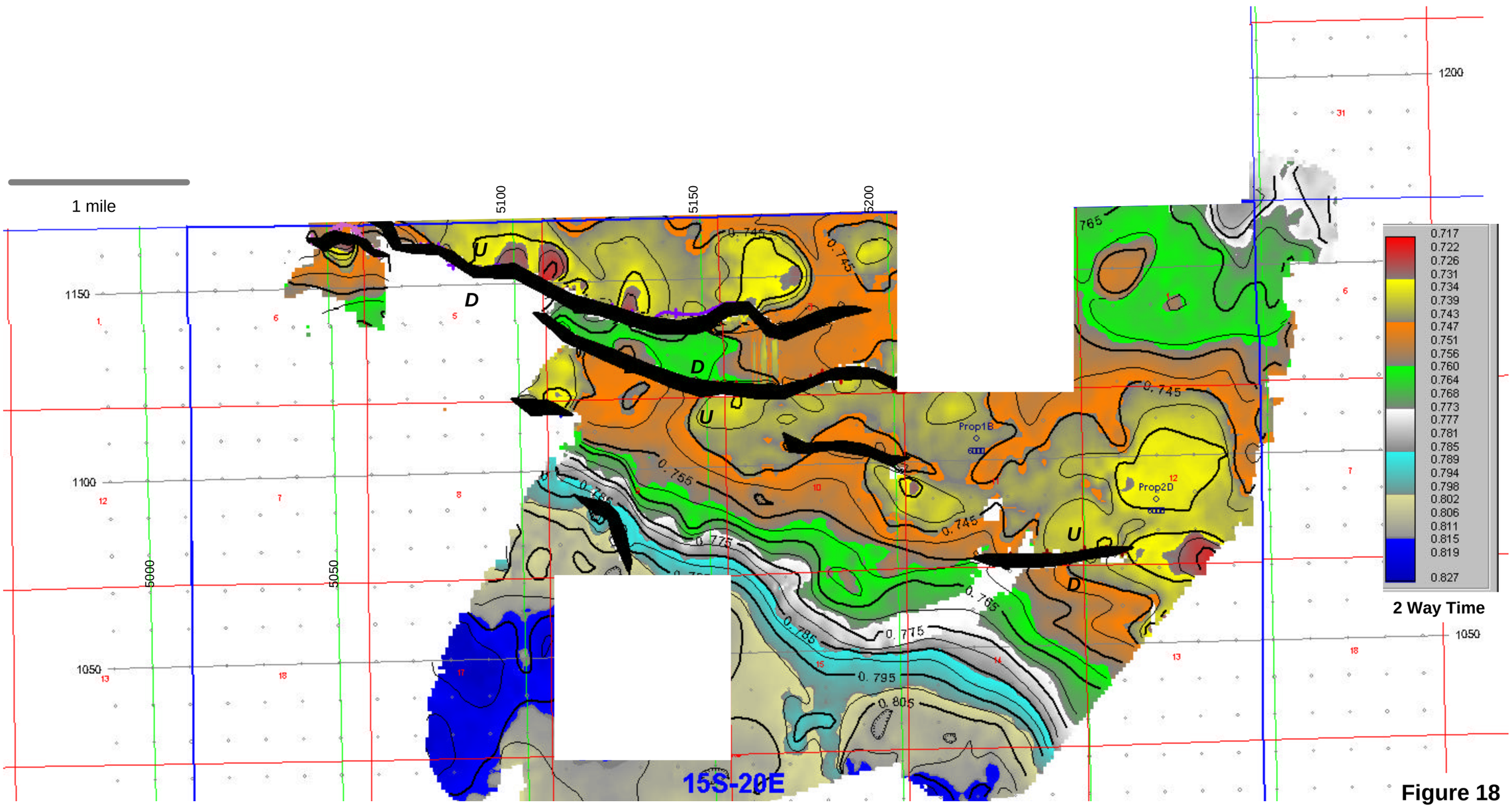
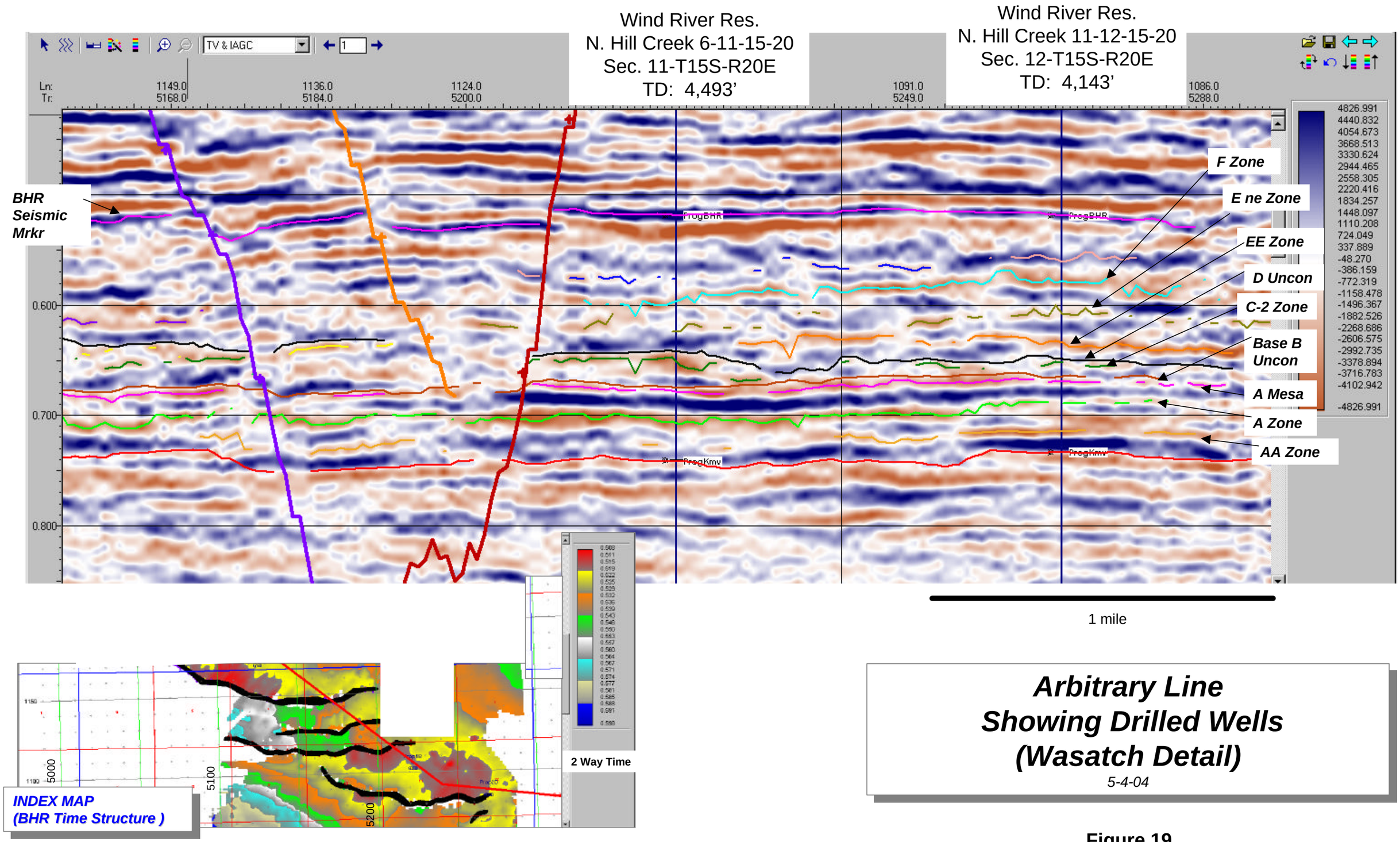


Figure 18



Arbitrary Line
Showing Drilled Wells
(Wasatch Detail)
5-4-04

Figure 19

Tw-AA Package Time Structure

CI = 5 ms (30') *5-4-04*

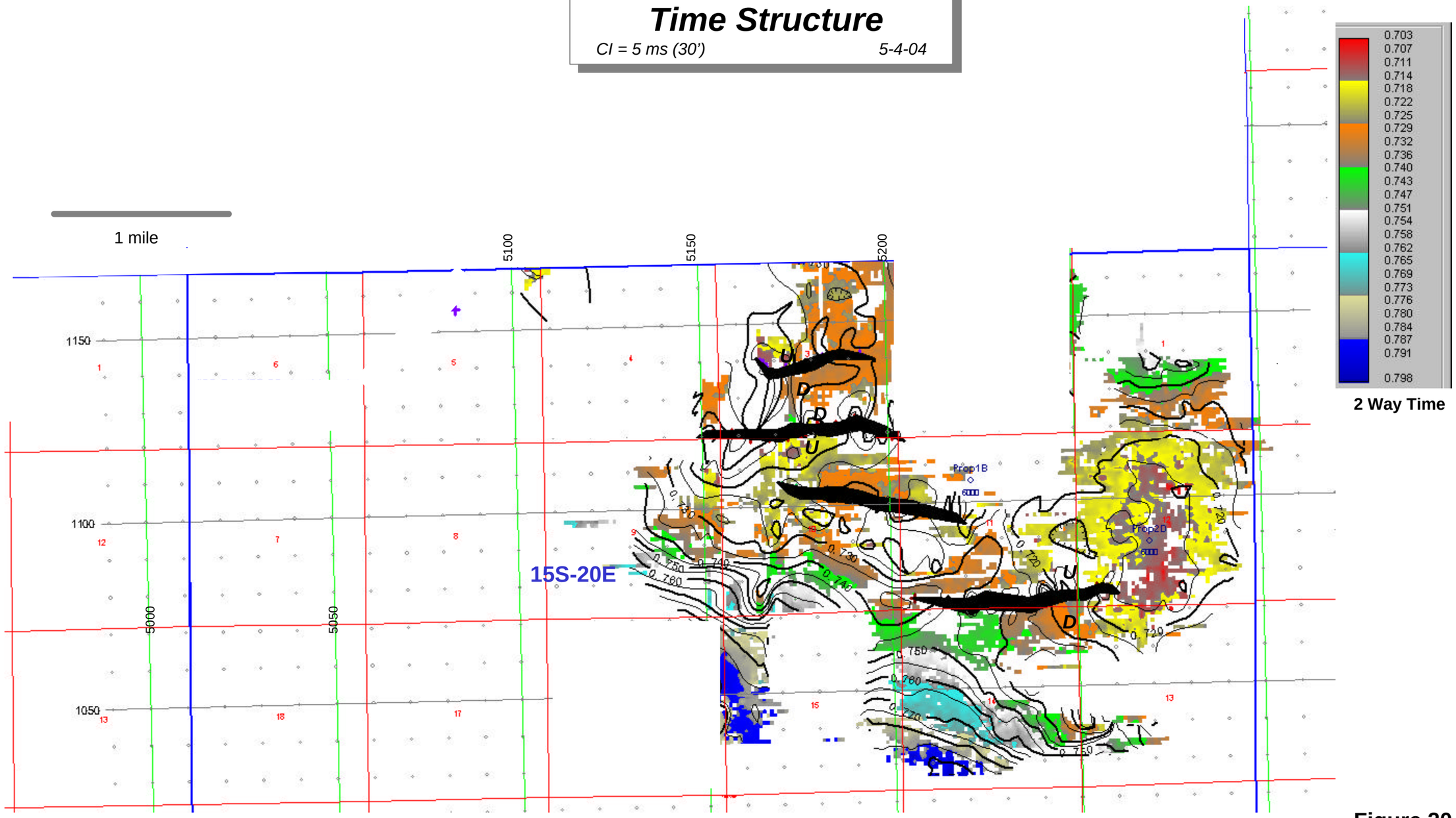


Figure 20

Tw-AA Package Amplitude with Time Structure Contours

CI = 5 ms (30') *5-4-04*

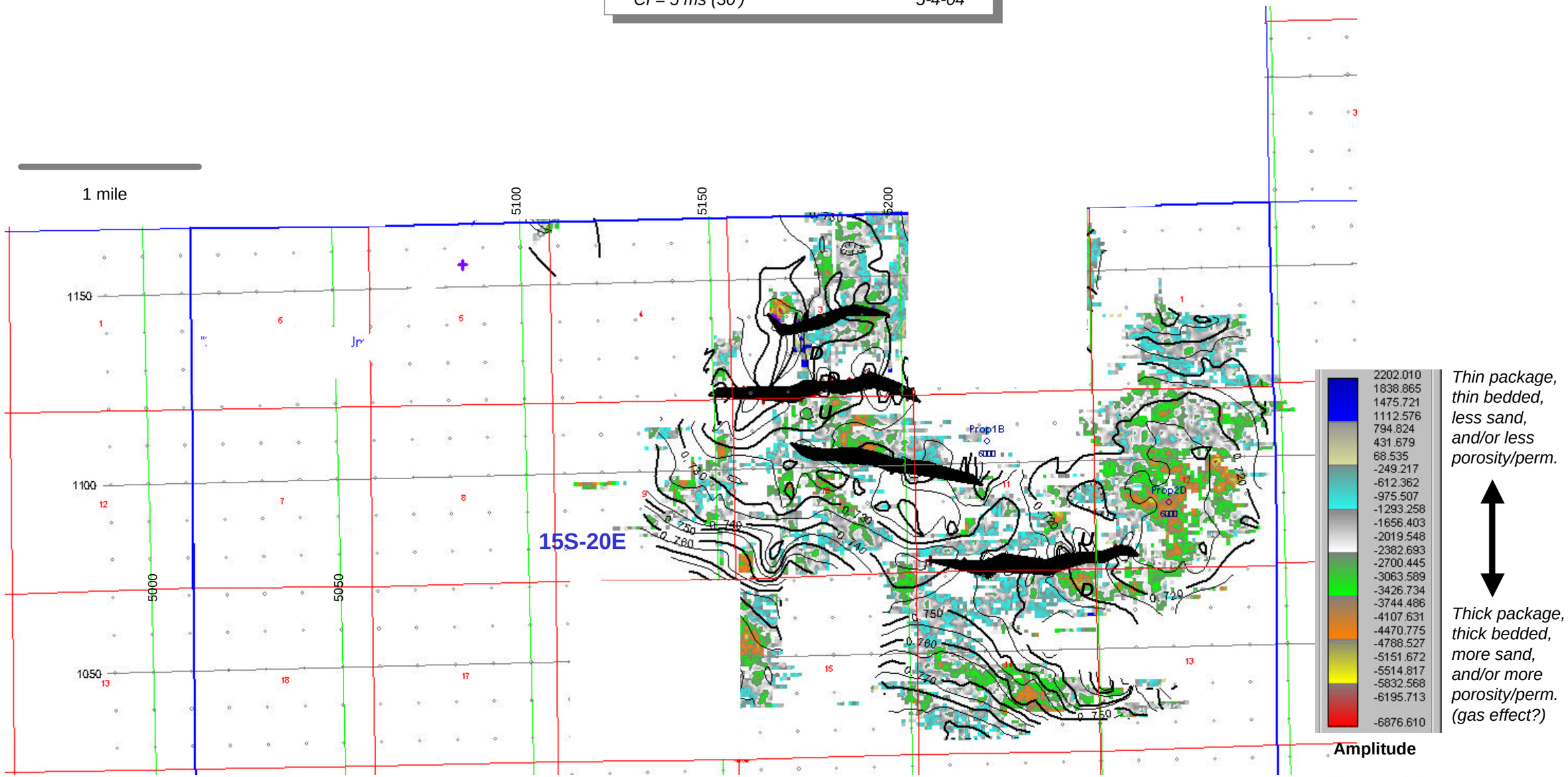


Figure 21

Tw-A Package Time Structure

CI = 5 ms (30') *5-4-04*

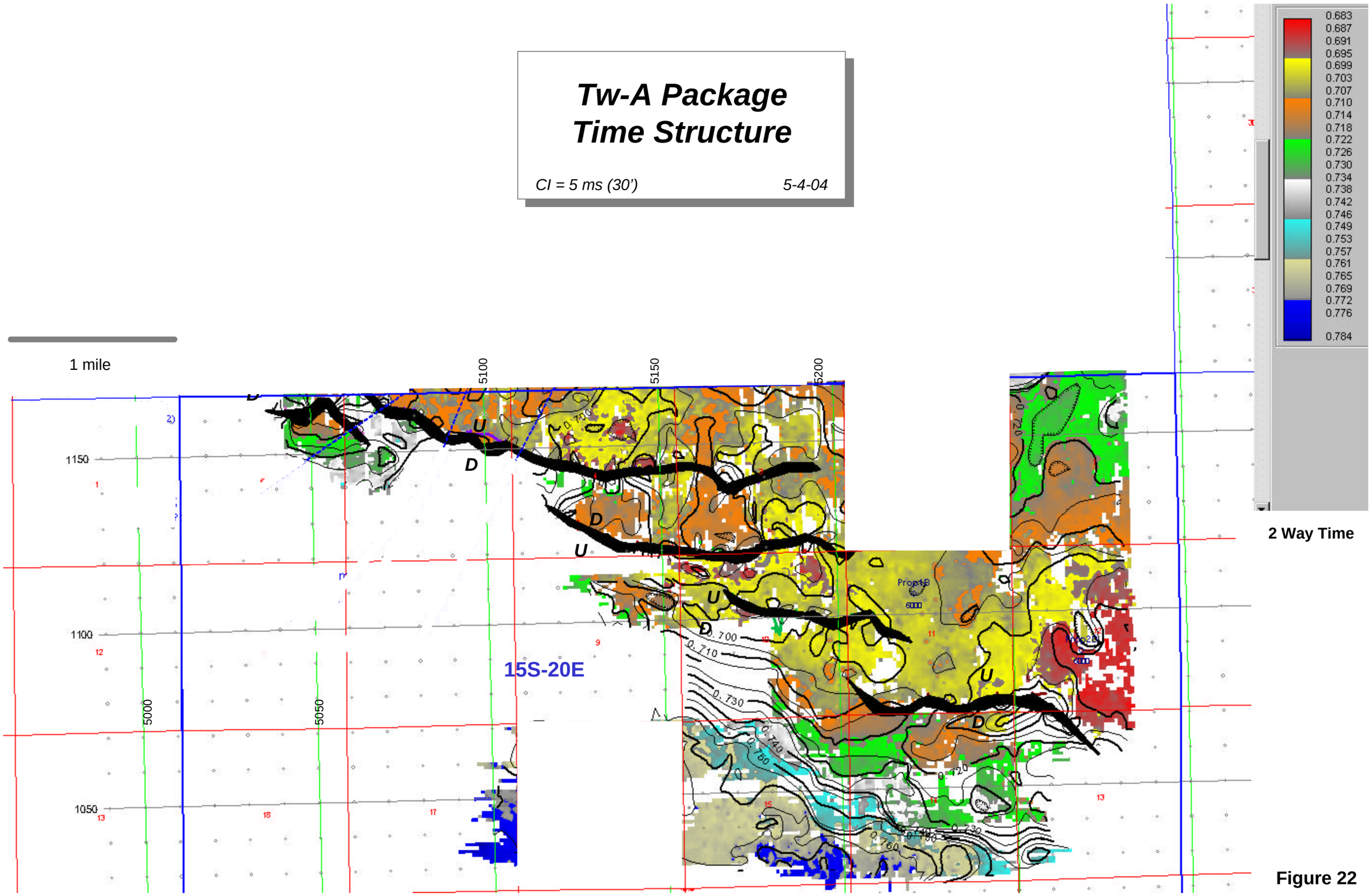
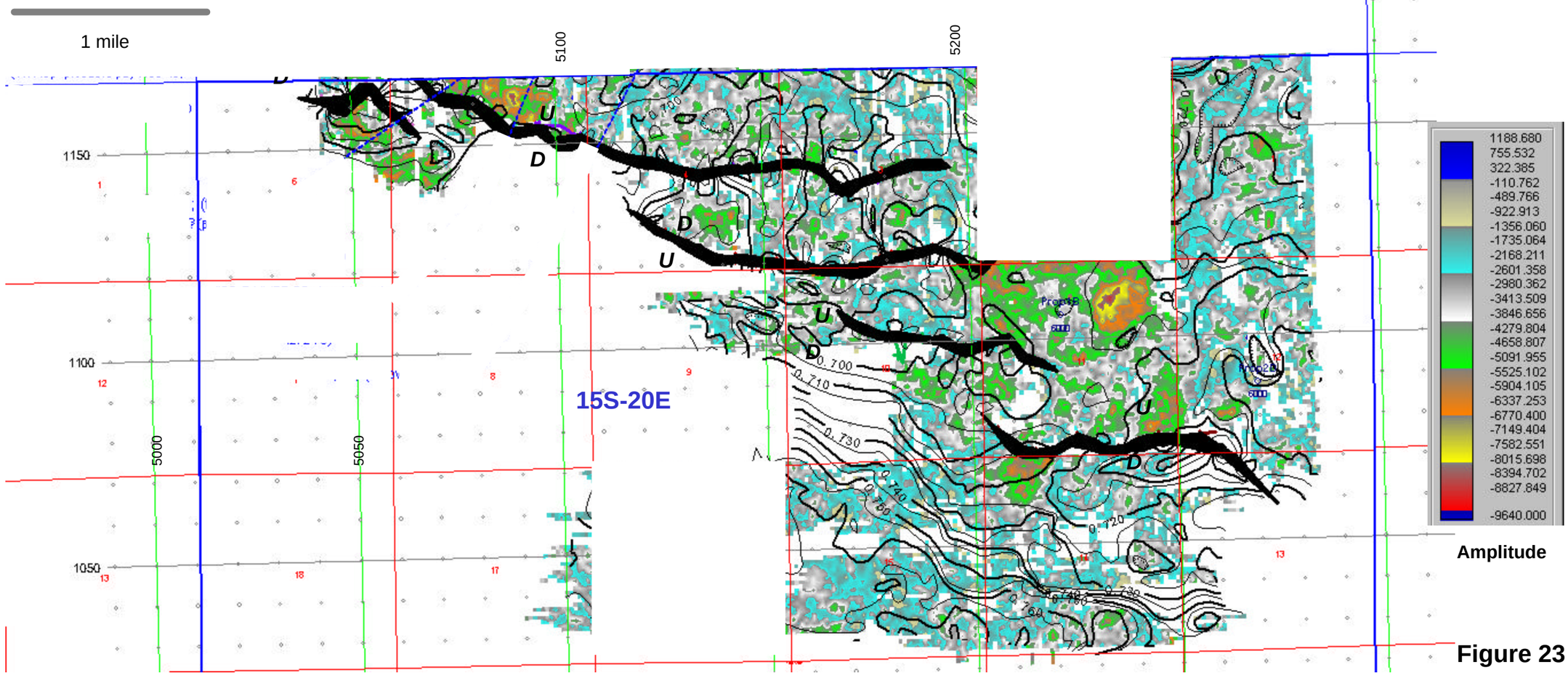


Figure 22

Tw-A Package Amplitude with Time Structure Contours

CI = 5 ms (30') *5-4-04*



Thin package, thin bedded, less sand, and/or less porosity/perm.

Thick package, thick bedded, more sand, and/or more porosity/perm. (gas effect?)

Figure 23

Tw-A Mesa Package Time Structure

CI = 5 ms (30') *5-4-04*

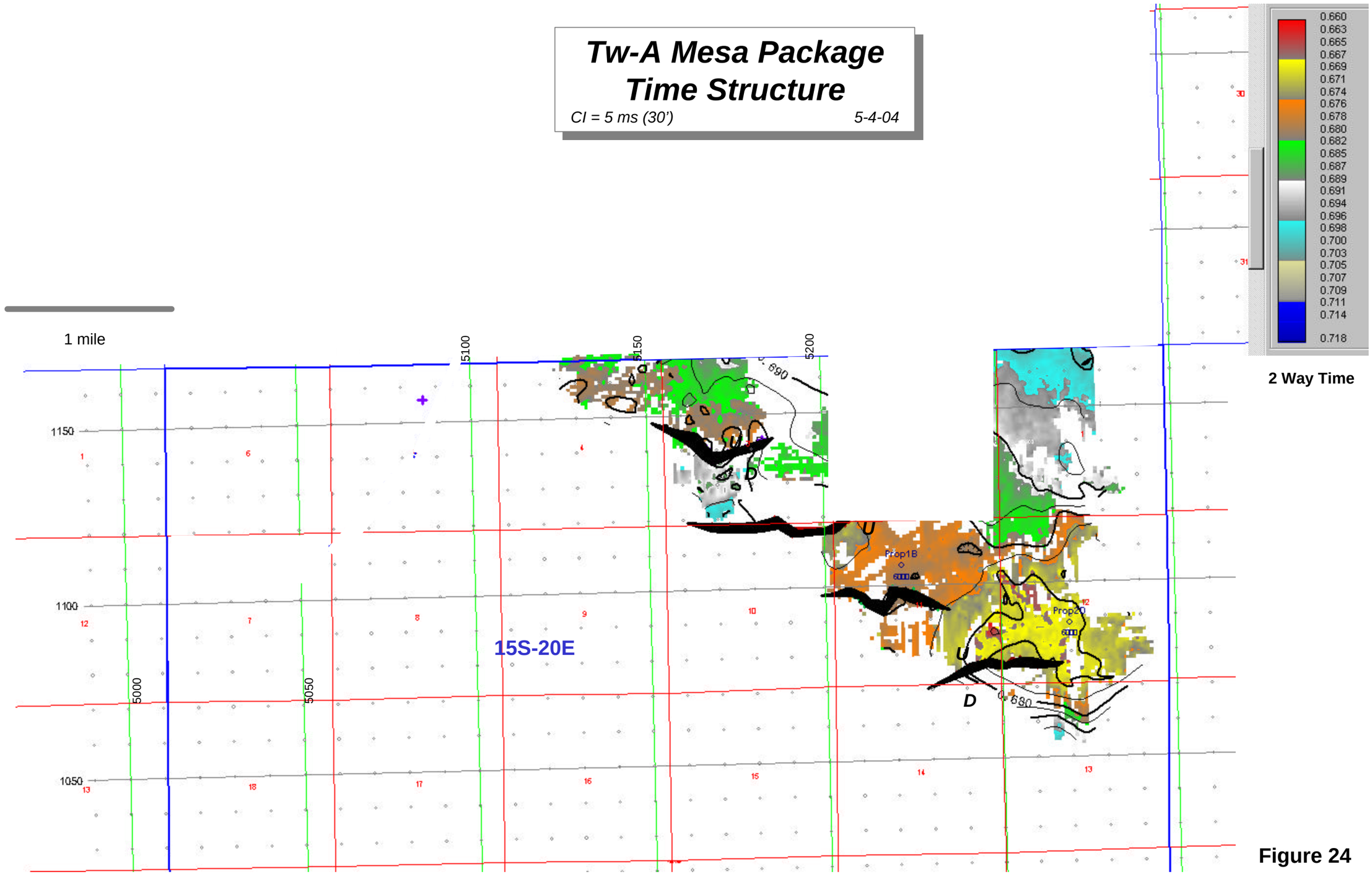


Figure 24

Tw-A Mesa Package Amplitude with Time Structure Contours

CI = 5 ms (30') *5-4-04*

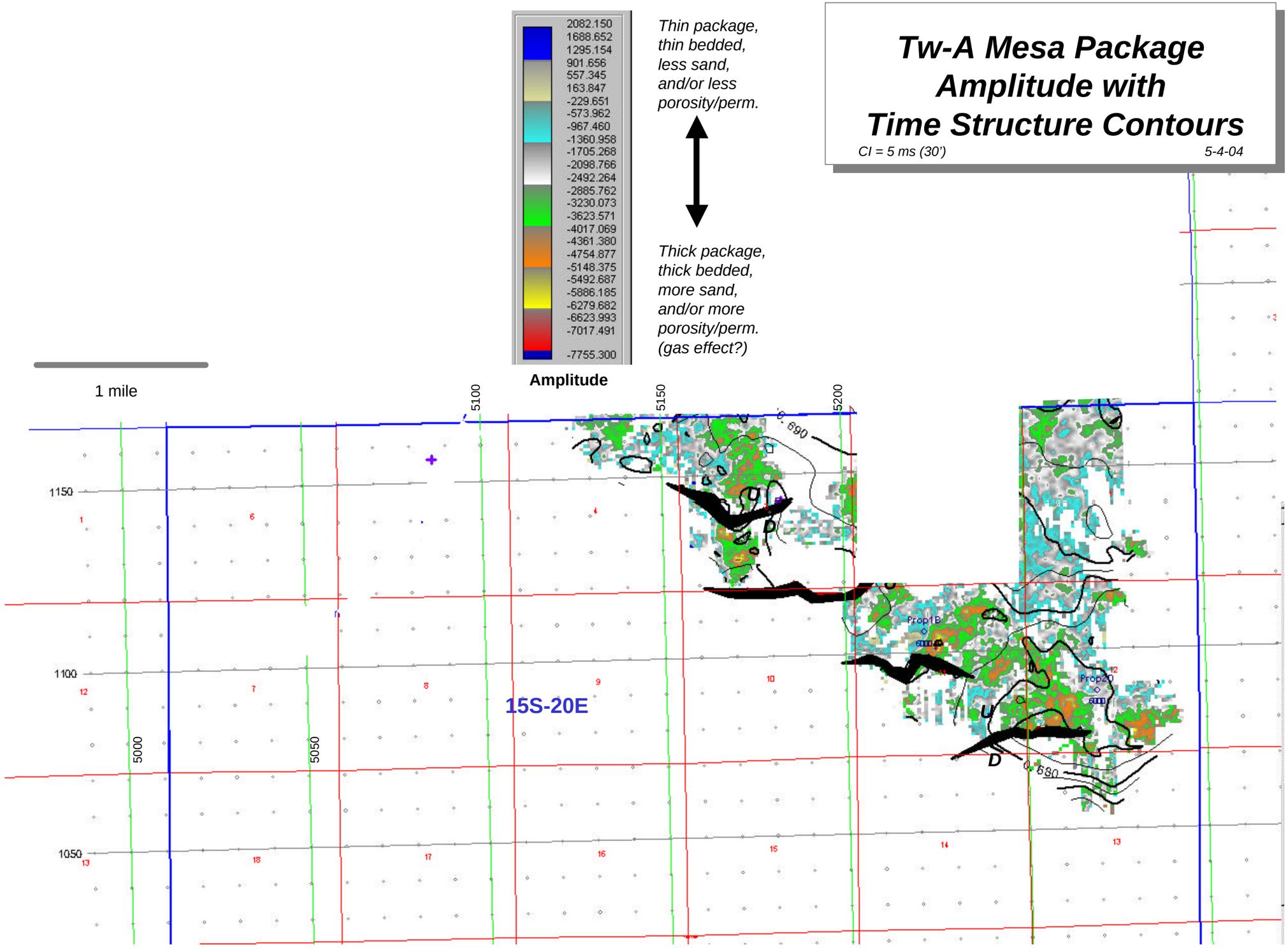


Figure 25

Tw-C2 Package Time Structure

CI = 5 ms (30') *5-4-04*

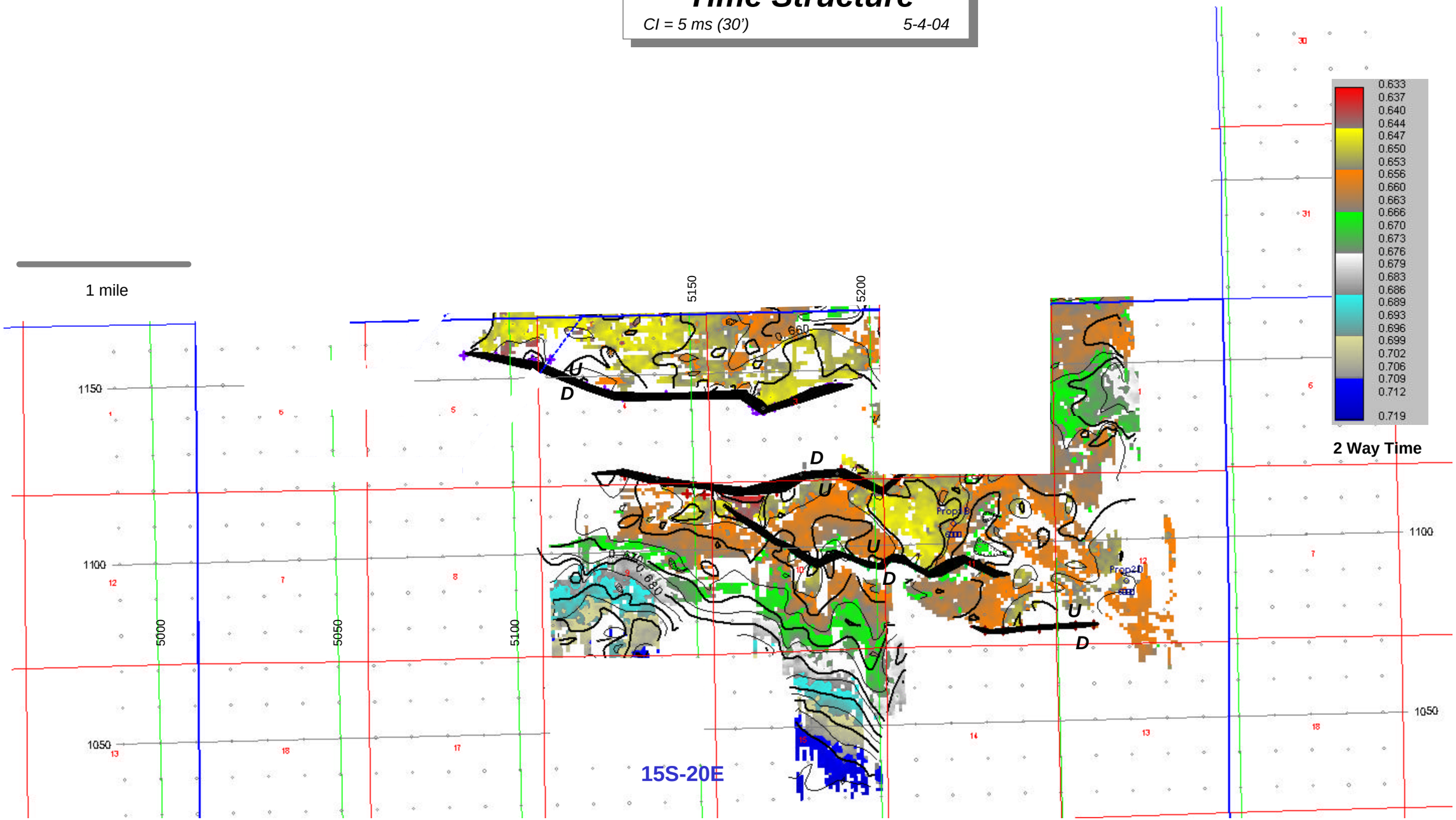
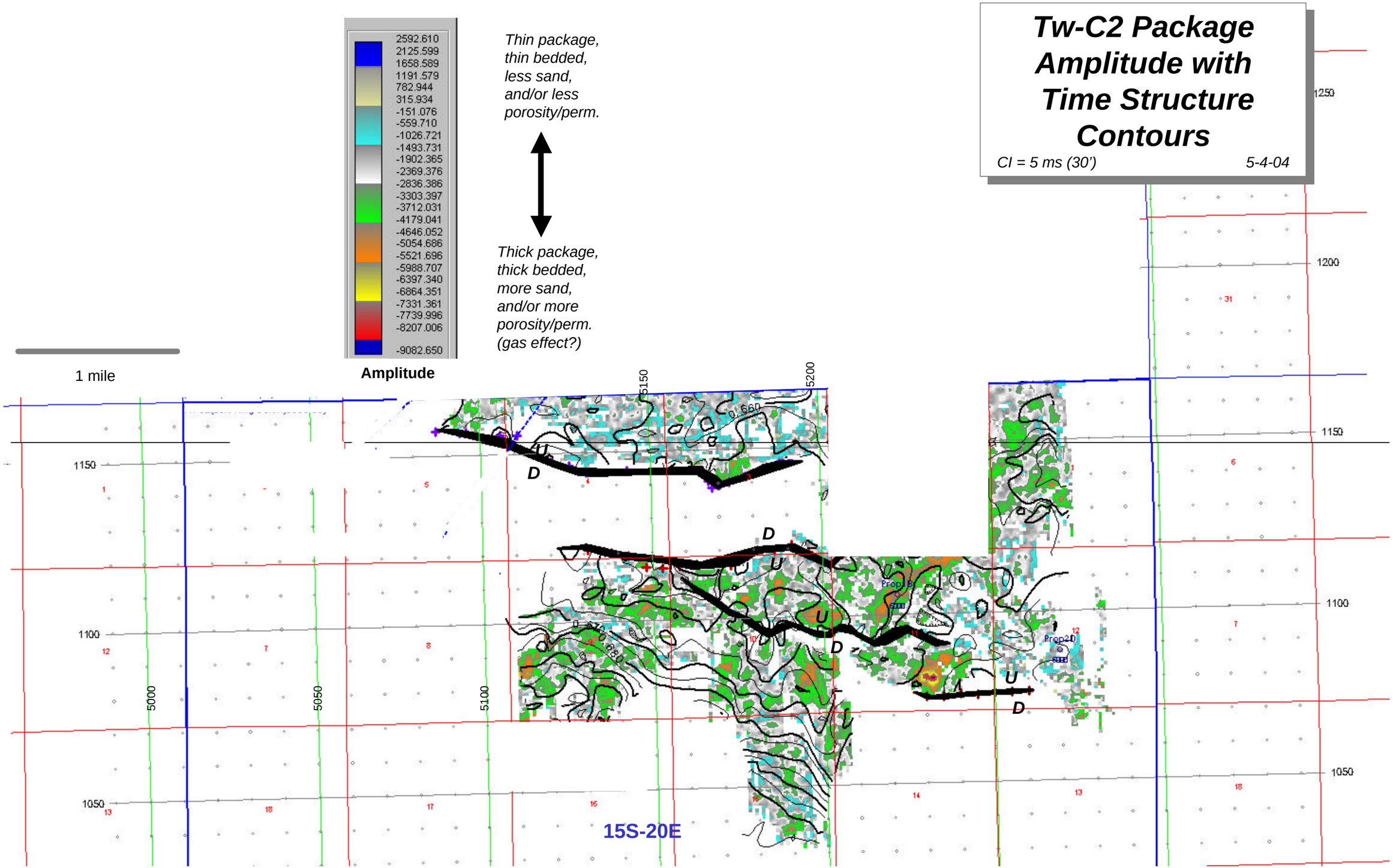


Figure 26



Tw-C2 Package Amplitude with Time Structure Contours
CI = 5 ms (30')
5-4-04
2592.610
2125.599
1658.589
1191.579
782.944
315.934
-151.076
-559.710
-1026.721
-1493.731
-1902.365
-2369.376
-2836.386
-3303.397
-3712.031
-4179.041
-4646.052
-5054.686
-5521.696
-5988.707
-6397.340
-6864.351
-7331.361
-7739.996
-8207.006
-9082.650
Amplitude
Thin package, thin bedded, less sand, and/or less porosity/perm.
Thick package, thick bedded, more sand, and/or more porosity/perm. (gas effect?)
1 mile
1250
1200
1150
1100
1050
5000
5050
5100
5150
5200
D
U
15S-20E

Figure 27

Tw-Post D Unconformity Time Structure

CI = 5 ms (30') *5-4-04*

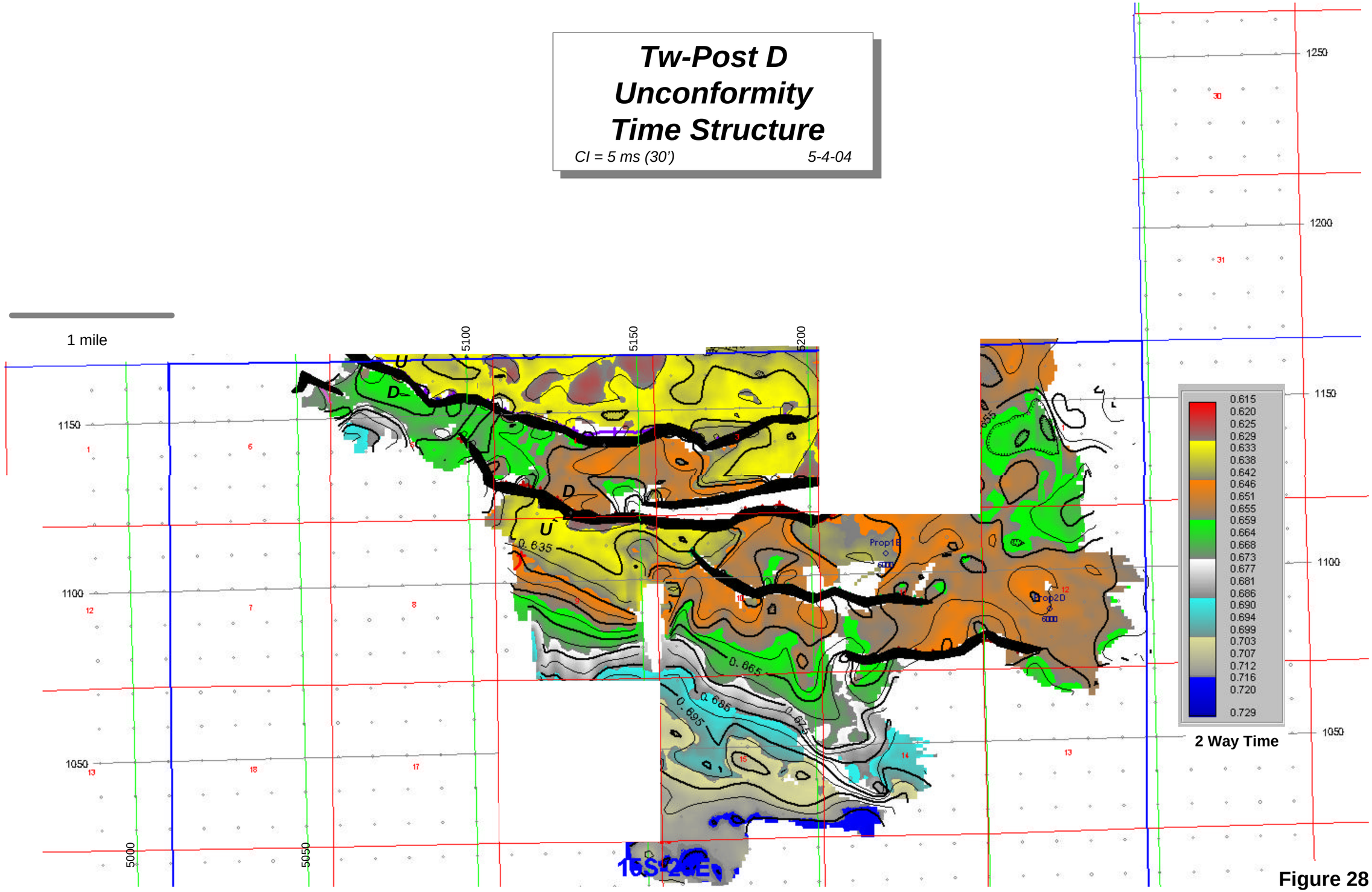
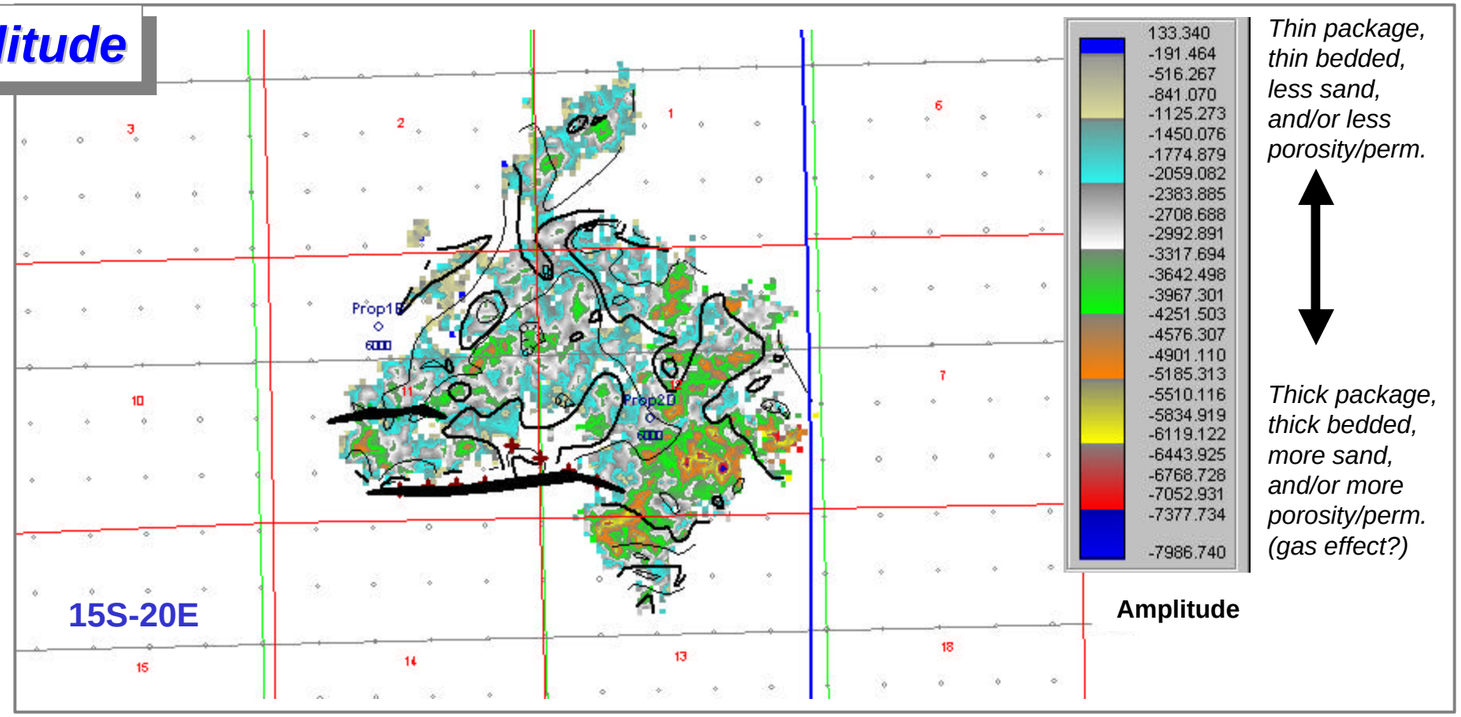


Figure 28

Tw-EE Package Amplitude and Time Structure

5-4-04

Amplitude



Thin package, thin bedded, less sand, and/or less porosity/perm.

Thick package, thick bedded, more sand, and/or more porosity/perm. (gas effect?)

Time Structure

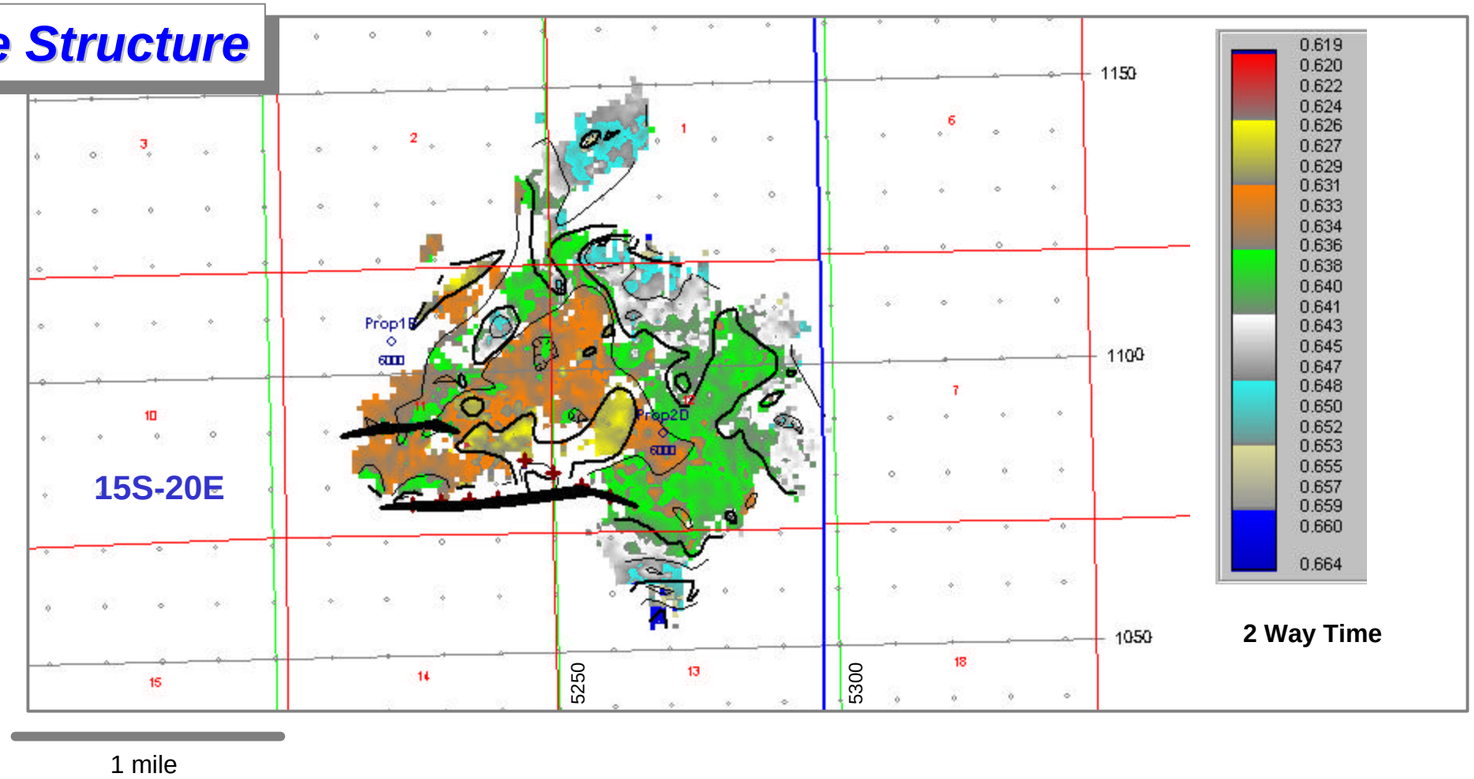


Figure 29

Tw-E Package
Time Structure

CI = 5 ms (30') *5-4--4*

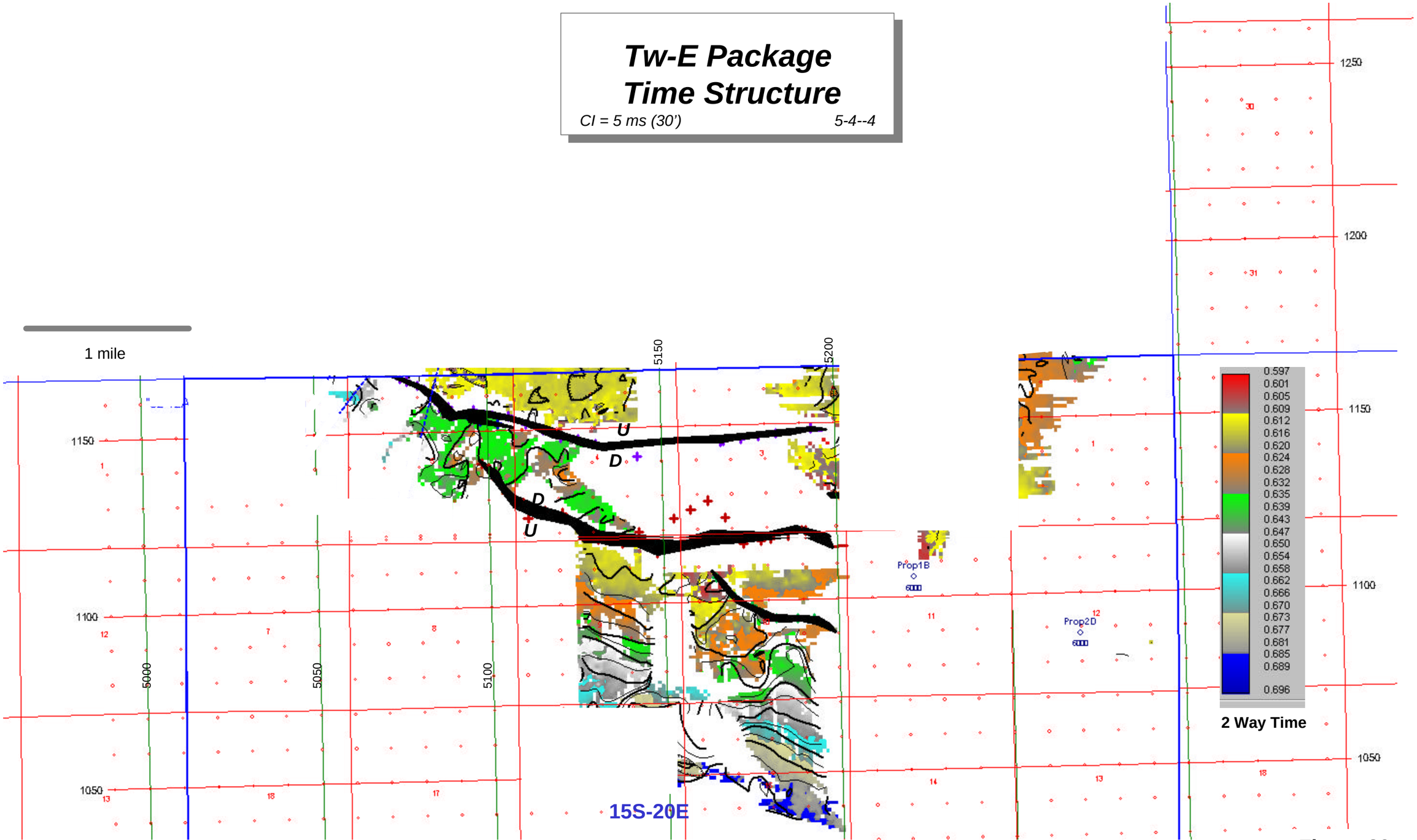


Figure 30

Tw-E Package Amplitude with Time Structure Contours

CI = 5 ms (30')

5-4-04

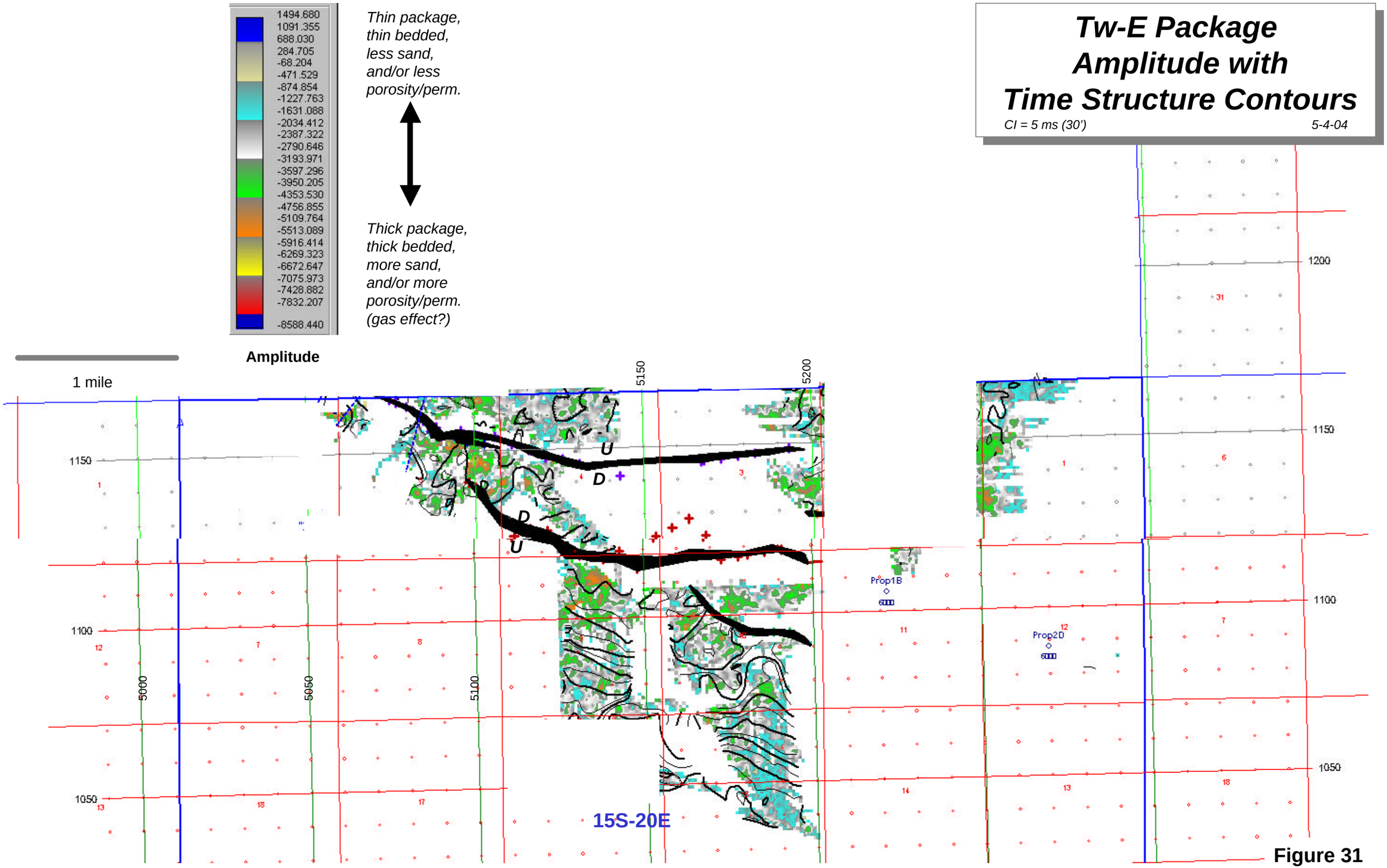
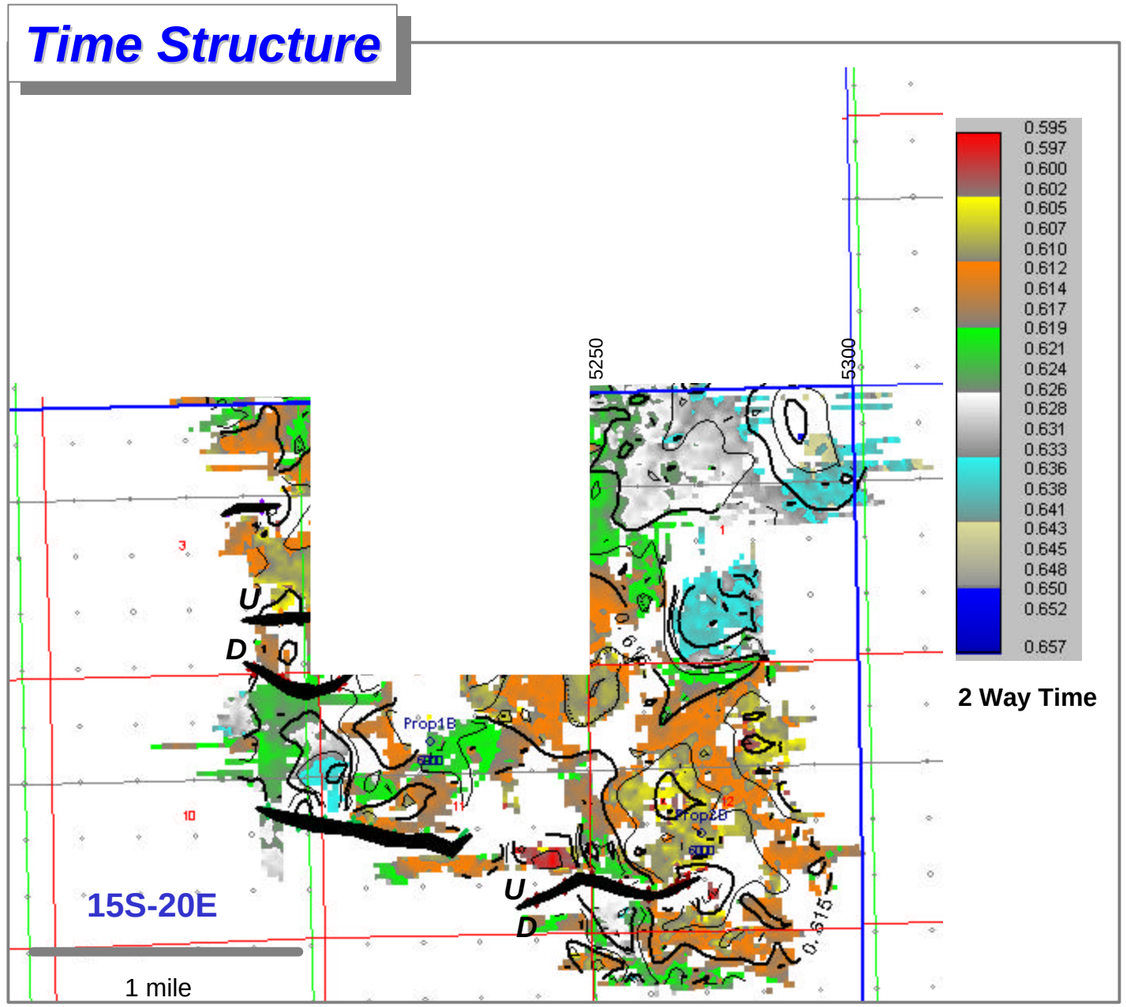
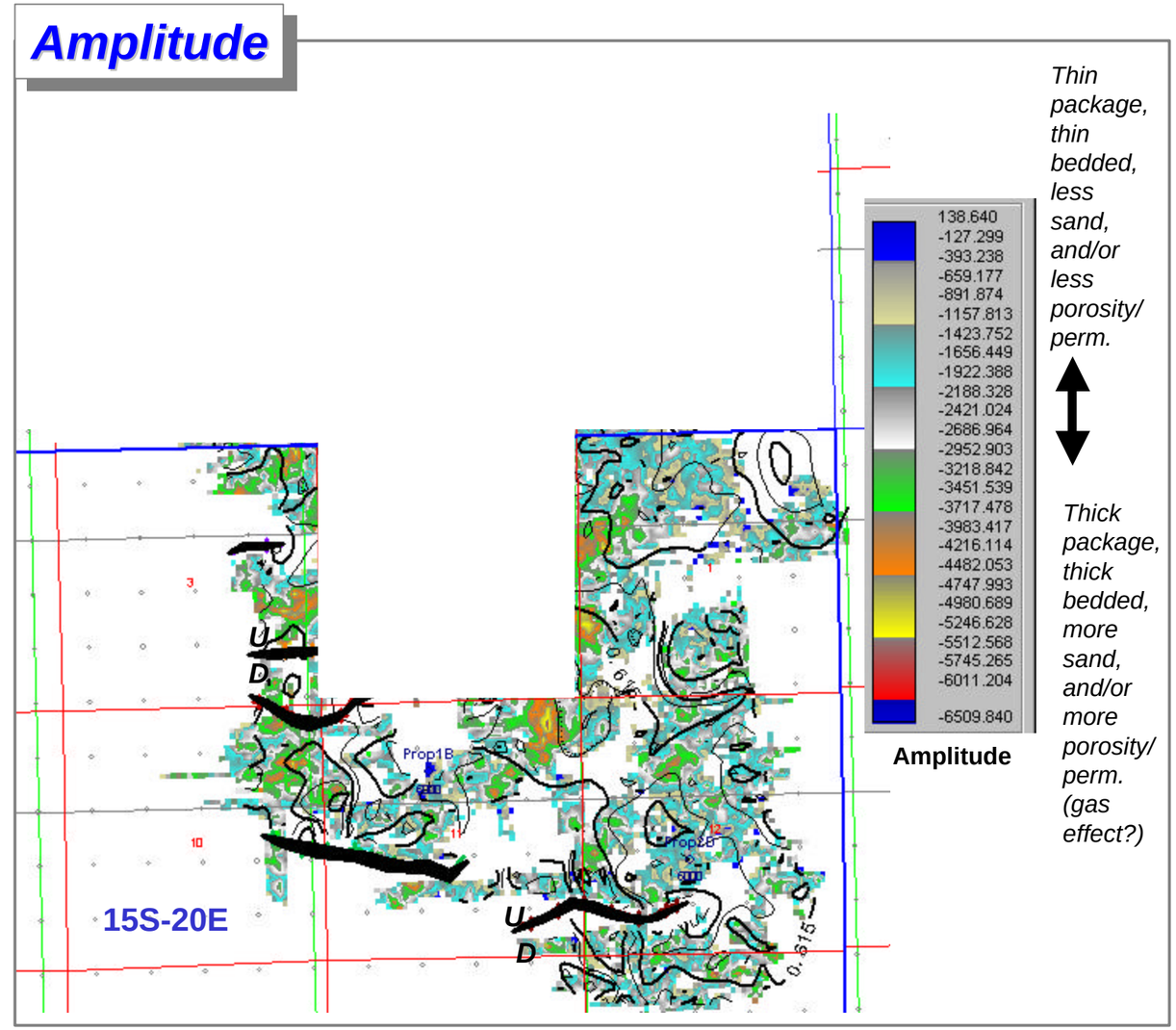


Figure 31





Tw-E Northeast Package Amplitude and Time Structure*

Equivalent to Tw-E in Field Area

5-4-04

Figure 32

BHR (Base High Resistivity) Seismic Marker Time Structure

CI = 10 ms (60') *5-4-04*

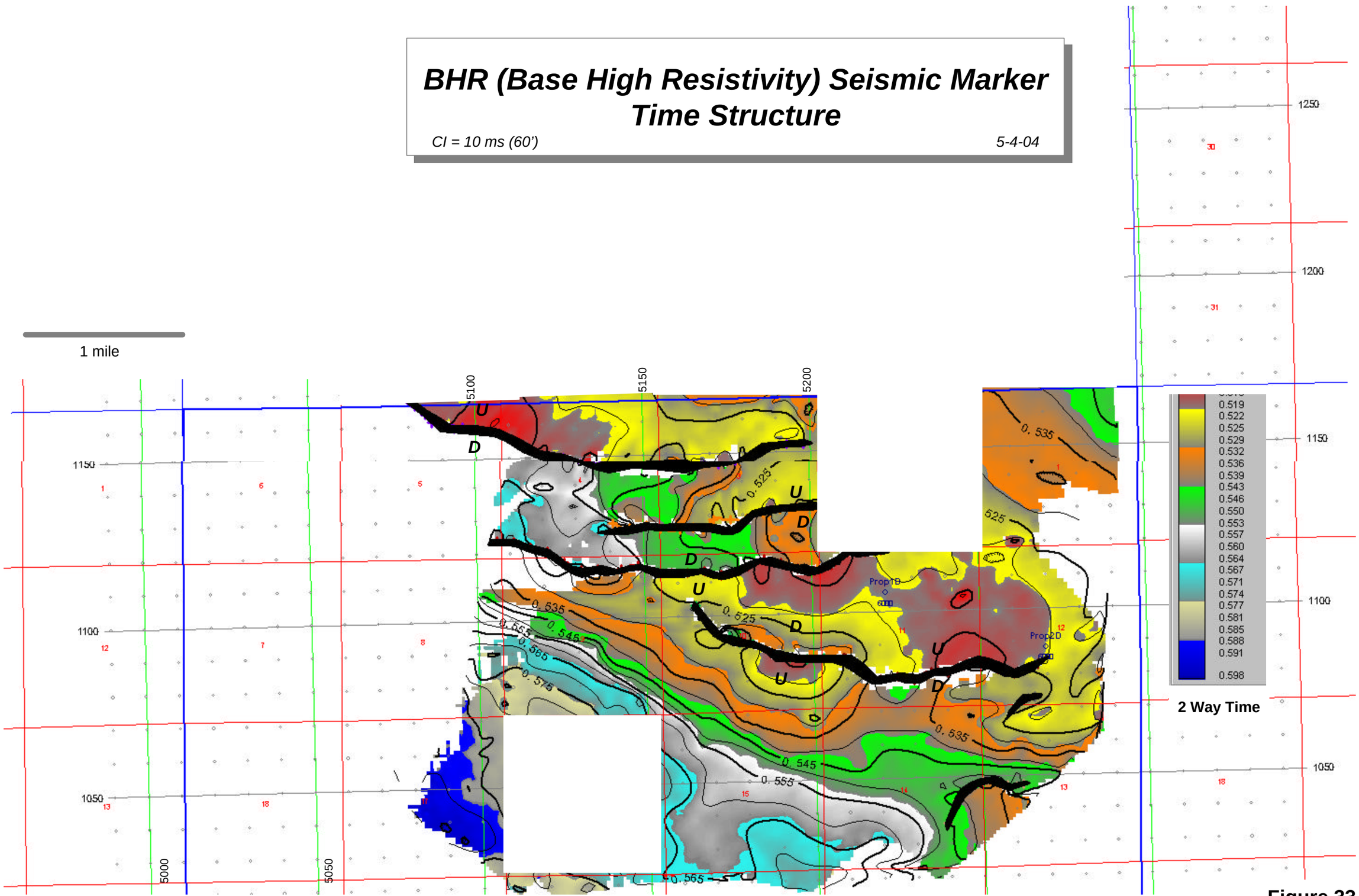


Figure 33

Index Map of Wells Drilled Using North Hill Creek 3D Seismic Survey

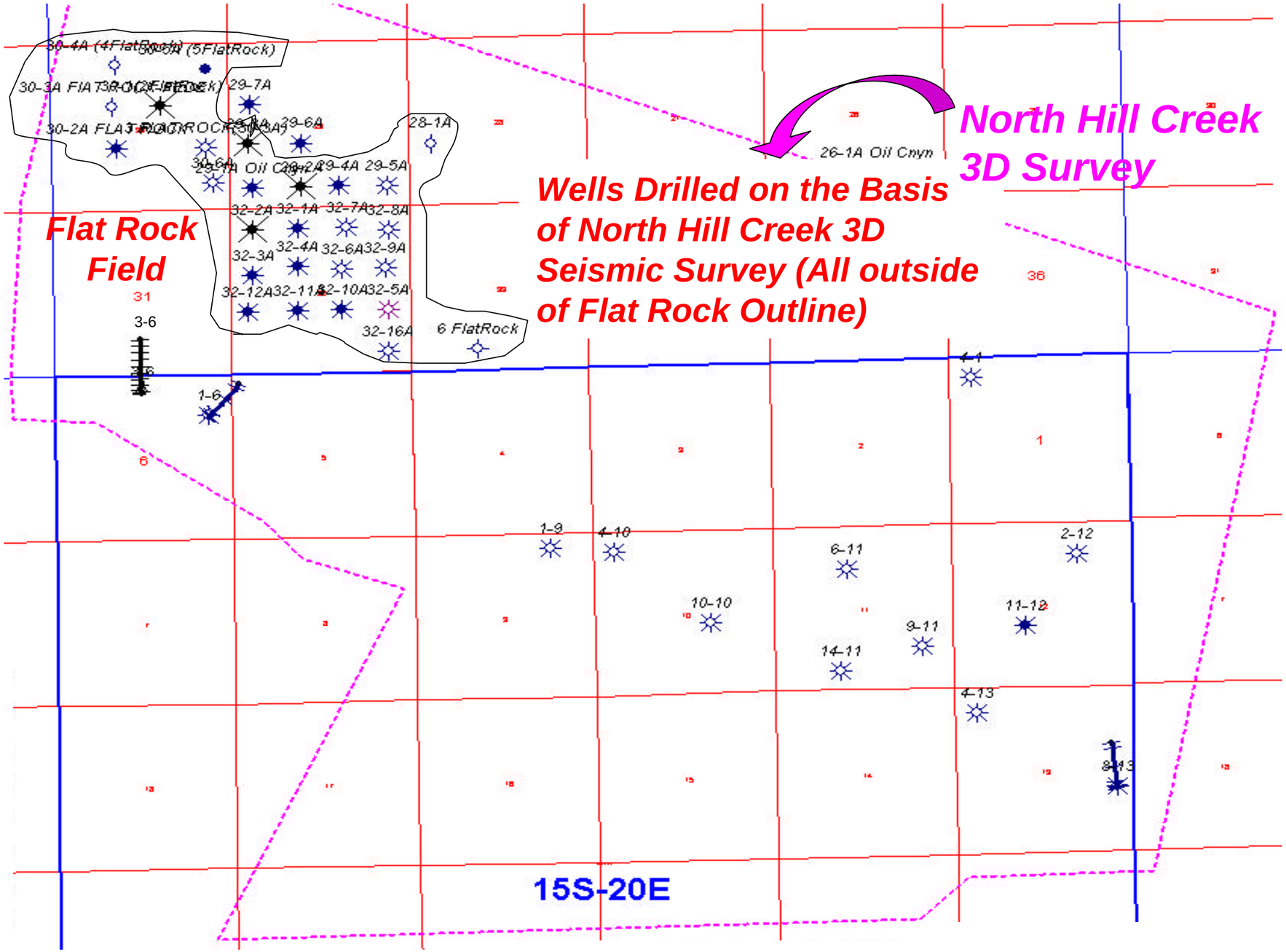


Figure 34