

# **Identification of Seismic Facies and Effect of Seismic Data Quality on Hydrocarbon Distribution in Pict Field, Central North Sea, United Kingdom\***

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## **Abstract**

A detailed 3D seismic interpretation study was carried out of the Pict Field located in Block 21/23b in the Central North Sea, United Kingdom to identify different types of seismic facies and to assess the hydrocarbon distribution within the Tay Sandstone, which is an Eocene reservoir unit. The effect of seismic data quality on the hydrocarbon distribution was also analyzed. The results were then confirmed from the detailed well log information.

Three types of seismic facies were marked on the maximum seismic amplitude maps. From seismic amplitudes, we were able to relate sandstone facies to maximum seismic amplitude, and mudstone facies to minimum seismic amplitude. The intermediate amplitudes were interpreted as mixed (sand and mud) facies. The presence of these facies in the specified areas was also confirmed by the well log data. The Pict Field has a distinct amplitude anomaly at the base of the anticlinal feature, initially thought to represent the possible oil water contact (OWC). However, detailed analysis suggested that the amplitudes extent is tilted and extends beyond the structural closure of the Field, as found in 2D Two-Way Travel time maps. Since the hydrocarbon presence was confirmed within the sand mound in the discovery well, and as this sand thins at the limbs of the mound, it may display higher amplitudes due to seismic interference. Hence, the higher amplitudes were interpreted not due to the response of hydrocarbons, but also the lithology effect enhanced by seismic tuning as the sand unit thins to the margins of the channel.

## **Introduction**

The study area is located in the Central North Sea, offshore UK. It is situated to the west of Scotland, at a distance of approximately 120 km, in Block 21/23b ([Figure 1](#) and [Figure 2](#)) near the western margin of the Central Graben in the western platform.

The project was initiated by Petro-Canada to evaluate the distribution of an Eocene reservoir called the Tay Sandstone Member of the Horda Formation ([Figure 3](#)) in the Pict Field area. There were only limited details available in the public domain from this area of the Central North Sea because the Field was not developed for a long time after it was discovered. The data was made available for scientific applications and research after the Field's development.

### **Exploration History of the Field**

The Pict Field, originally called Thrush, then Grebe, was discovered in January 1981 by Shell through discovery well 21/23-b-1. It is located approximately 18 km northwest of the Clapham Field in the Central North Sea ([Figure 5](#)). Nearly 85 feet (25.9 m) of good quality 33 degree API oil capped with 118 feet (35.9 m) of gas was encountered in the discovery well. Ten years later an appraisal well, 21/23b-6 ([Figure 5](#)), was drilled and only 11 feet (3.35 m) of oil column was found. In 1993, Shell a evaluation concluded that the Field is uneconomical to develop. Five years later the Field was re-evaluated using modern seismic techniques and found to be economical to develop. In 2001, another technical study was conducted to investigate further development options. However, in July 2003 the Field was sold to Petro-Canada as part of a package of assets. The Field started production on June 19, 2005 at a rate of 10,000 barrels of oil equivalent per day and is expected to produce over the next three years. Pict Field is estimated to have reserves of about 15 million barrels of oil.

### **Reservoir at Pict Field**

The Tay Sandstone, a Member of the Horda Formation, is the main reservoir unit at Pict Field ([Figure 3](#)). Knox and Holloway (1992) defined the Tay Sandstone as a deep water sandstone. They include Eocene sandstones of UK quadrant 21 and 22, as they are more distributed in these areas as compared to rest of Central North Sea. The reservoir quality is good with a high net-to-gross (N:G) of 95% as found in the discovery well 21/23b-1. These are clean and unconsolidated sands with low detrital clay contents. Due to the absence of detrital clay, the sandstone diagenesis was very low. The porosity over the field is >30% with more than one Darcy permeability.

### **Eocene Stratigraphy of Pict Field**

Deegan and Scull (1977) proposed the first formal lithostratigraphic scheme for the UK and Norwegian sector of the North Sea. They simply divided the Post Balder Formation (Early Eocene) sediments into the Hordaland and Nordland groups. They placed their boundary within the Miocene. Knox and Holloway (1992) replaced the Hordaland Group in the UK sector with the Stronsay and Westray groups ([Figure 3](#)). The Stronsay Group ranges in age from Early Eocene to earliest Oligocene.

The Stronsay Group consists of two formations ([Figure 3](#)), the sandstone-dominated Mousa Formation which is 200 to 300 m thick, and the Horda Formation to the east which largely consists of hemipelagic mudstones and mud-dominated turbidites with some deep water sandstones.

The Tay Sandstone is a Member of the Horda Formation and represents major sand-dominated deep marine complexes. They were deposited during Early to Middle Eocene in the Central North Sea. The Tay Sandstone is divided into four increasingly retrogradational sequences (Jennette et al., 2000) containing lower sediment volumes but with increasing sand contents. It is proposed that the tectonically driven shelf-edge failure is responsible for the sand-rich sediment flows into the basin. Aggradation of shelf-edge deltas occurred due to the large volume of sediment supply in the Paleogene in the Central North Sea which, during high frequency lowstands, failed to provide sand-rich flows into the deeper basin.

### **Aims of Study**

The main aims of this study were:

- To map the Tay Sand and key stratigraphic markers above and below, around the Pict Field.
- To assess the distribution of amplitudes within the Tay Sand reservoir interval and analyze the possible cause of amplitude anomalies.
- To analyze the seismic facies distribution in the study area.
- To assess the hydrocarbon distribution in the Pict Field.

### **Regional Structure and Tectonic Evolution of the Central North Sea**

[Figure 3](#) illustrates the regional structure of the Central North Sea. The western platform bounds the western boundary of Central Graben but the eastern limit is not precisely defined. The Central Graben consists of a series of asymmetric half Grabens which are bounded by NNW-SSE trending faults.

Two sub-basins lie in the north of the Central Graben which are separated by the Forties-Montrose high. Towards the west of Forties-Montrose high lies the West Forties Basin, which is also called the Western Trough. The East Forties Basin is located to the east of Forties-Montrose high.

Three major rifting stages were explained by Rattey and Hayward (1993), which are as follows:

## **Permian Rift Stage**

In the Early Permian, extension of the North Sea resulted in uplifting and creation of two large basins known as the North and South Permian basins. The North Permian Basin was overlain by the entire Central Graben. Conglomerates were deposited in the lows overlain by fluvial plain and alluvial fans. The subsidence related to faulting was found to be greater than the sediment deposition rate. This led to an under-filled basin which then underwent Middle Permian transgression and resulted in desert lakes up to 900 feet below sea level (Hodgson, 1992). After this transgression, cycles of periodic flooding and high evaporation generated thick halite deposits. These salt deposits formed shallow detachments separating the basement deformation from Post-Middle Permian sediment cover.

## **Triassic to Middle Jurassic Rift Stage**

This phase was dominated by east-west extension which started in the early Triassic. During this phase, the Central Graben was offset from the rift axis and a very minor extension affected it (Ziegler, 1981). Extension during the Late Permian was pervasive throughout Central Graben, generating small faults which induced salt mobility in the overlying strata. This extension was a result of reactivation of Permian faults while the Upper Permian salt accommodated the extension by shear and gravity flow (Hodgson, 1992). The sediments infilling this accommodation created by salt withdrawal comprise Lower Triassic fine clastics. Extensional deformation in salt was enhanced by sediment fill in the developing depressions due to sediment loading. This continued until the Triassic basins joined to the basement at some places due to complete salt withdrawal (Ziegler, 1981). This irregular nature of pod-like basins reflects the lateral shift in the depocentres which would be expected in a fluvial environment with a strongly meandering river system.

During the Middle Jurassic the Central Graben was initiated. In the Central North Sea, the Lower Jurassic section is not present (Hodgson, 1992). Ziegler (1982), Erratt et al. (1999) and Badley (1988) proposed that this is due to thermal updoming at the 'triple junction' ([Figure 4](#)) between the Viking, Witch ground and Central Grabens which started post-depositional erosion. This thermal collapse of the dome created accommodation space which was filled by up to 1500 ft of Middle Jurassic sediments, preserved in the center of the Graben. However, the section is largely absent to the west of the Central Graben, from the Forth Approaches Basin, Forties Montrose Ridge, Jaeren High and the Fulmar/Clyde Terrace areas (Hodgson, 1992) due to lack of accommodation.

## **Late Jurassic to Tertiary Rift Stage**

The precise timing of Late Jurassic rifting is uncertain which has resulted in a series of predominantly ENE dipping tilted blocks bounded by NNW-SSE oriented faults (Hodgson, 1992). The rift was a result of re-initiation of salt movement and the growth of salt ridges, domes and diapirs along the major faults bounding the Jurassic basin (Glennie, 1998). The salt provided a major detachment zone in a way that deformation major faults in the basement and was accommodated in the cover by a series of listric faults that die out into the salt.

## **Database**

Two types of data were used during the study of Pict Field, 3D seismic data and well logs.

## Seismic Data

The three-dimensional seismic survey (tex 93\_fm) was provided by Petro-Canada for the Pict Field study and it covers an area of about 751 km<sup>2</sup>. The data was presented in milliseconds two-way travel time (ms TWTT) with a maximum value of 4000 ms. Some well logs were also loaded and displayed with the seismic (particularly well 23/23b-1), with Gamma Ray, Sonic, Resistivity and Density curves, and were tied with the seismic for the study.

## Well Logs

Data from five different wells located in the Pict Field ([Figure 2](#)) was provided for the Pict Field study. They contain Gamma Ray, Sonic, Density and SP log curves. A well correlation section was made using four wells:

- 21/23C-5
- 21/23B-6
- 21/23B-3
- 21/23A-4

The data from the discovery well (22/23b-1) was displayed with the seismic and was principally used for the study because it was tied with the seismic data in order to identify key stratigraphic and formation tops.

## Methods

### Seismic Manipulation

Seismic mapping was carried out using Schlumberger's GeoFram/Charisma software to map major horizons identified on the seismic data. These horizons were picked on the basis of continuity, amplitude, changes in seismic character above and below the horizon, and reflective strength of the seismic trace. A total of four horizons were traced and surfaces were then generated for each of these horizons. Surface maps were then produced, including one unconformity surface, a Lower Tertiary unconformity and top and base of the reservoir unit, and Tay Sandstone. A seismic line from the data displaying horizons and other features is shown in [Figure 6](#).

Time thickness maps were also generated for the sediment packages to analyze the changes in thickness and to understand the processes responsible for these changes. In addition, 3D views of the surfaces were generated using GeoFram-Geoviz software. Some of the surfaces were exported to Petrel to generate contours and two-dimensional two-way travel time maps to clearly display trends, highs and lows.

Another important step was the production of seismic attribute maps (maximum seismic amplitude) of each surface. Surface-based maps, as well as volume based maps, were generated to visualize the amplitude anomalies. Random seismic lines were also produced to better understand sediment patterns within the mapped packages.

### **Well Data and Well Correlation**

A number of wells have been drilled in the Pict Field ([Figure 5](#)). Oil was found in some of the wells (21/23b-1 and 21/23b-6) while others were found to be dry (21/23c-5). The well data was utilized to produce a well correlation in order to understand the subsurface geology of the Pict Field. The composite logs were loaded into Petrel software, which is Schlumberger's Windows-based 3D seismic interpretation and modeling tool. It allows detailed well correlation with certain flexible changes and conversions. This tool is easy to use and has certain advantages as it increases structural accuracy, provides repeatable and highly detailed mapping of discontinuities and significantly reduces manual interpretation time. The correlation is done on the basis of available well reports showing formation tops as well as considering the log characters. The available logs (Gamma Ray, Sonic, Density, etc.) were studied and lithologies of the different intervals in the study area were noted and interpreted.

Two wells (21/23b-1 and 21/23c-5) were loaded with the seismic data and used for the well ties with the seismic. These also helped in picking the formation tops to generate horizon mapping. Peculiar morphological features, such as channels, were identified and interpreted during the study and compared with similar examples from other areas.

## **Results**

### **Two-Way Travel Time Mapping**

The seismic characters of the intervals were used to pick and define the key events. It is represented by the seismic amplitude which is a result of acoustic impedance contrast at the contact of two rock layers. The quality of the seismic horizons was poor in places, which made picking difficult at some localities during interpretation of some horizons.

Following four major horizons were picked during the interpretation of seismic data:

#### **Top Horda Formation (Eocene)**

The seismic character of top Horda Formation was highly variable throughout the section. Dominantly, it showed weak amplitude due to low acoustic impedance. But at some places it displayed high amplitude ([Figure 6](#)). It was difficult to pick in some places due to poor seismic quality and weak reflection strength. This horizon was picked as a soft event on the seismic (-ve maximum amplitude).

The TWT map of the Horda Formation ([Figure 7](#)) was generated after picking and tracking. The TWT values range from 0.87 to 2.32 seconds; a clear trend running NW-SE was noted. The Southwest part of the study area is shallowest and Northeast side is deepest. The dipping trend makes a shelf-slope profile from SW to NE. A few very small local highs are marked on the top of the Horda Formation.

### **Top Tay Sandstone (Lower to Middle Eocene)**

The top Tay horizon was picked as a soft event on the seismic section ([Figure 6](#)). The Tay Sandstone is the reservoir in the Pict Field. The seismic character of the top Tay was not uniform throughout the data. In certain areas it was more complicated to pick due to reflector discontinuity and weak reflection strength. The TWT values range from 0.97 to 2.50 seconds on the seismic section and TWT map ([Figure 8](#)). The top Tay Sandstone is present at shallow depth in the Southwest and becomes deeper towards the Northeast ([Figure 8](#)). The deepest part is in the extreme Northeast, as indicated by the maximum two way travel time (2.5 seconds). The overall dipping trend defines a gentle slope which is steeper in the Southwest direction ([Figure 8](#)). Several local highs and lows are marked on the TWT contour map ([Figure 9](#)) particularly in the northwest and central parts of the area (one of which is the Pict structure).

Several wells have been drilled in the Tay reservoir and some of them were provided for the study. They are concentrated in the Northwest part of the region. Locations of wells 21/23C-5 and 21/23B-1 are shown on the TWT contour map of top Tay Sandstone ([Figure 9](#)). Well 21/23B-1 was the discovery well, drilled on the top of a high, on an anticlinal structure.

### **Top Lista Formation (Upper Paleocene)**

The TWT values range from 1.1 to 2.5 seconds on the TWT contour map of the Lista Formation ([Figure 10](#)). It was picked as a positive peak (hard event) on the seismic data. This reflector shows moderate amplitude response due to low acoustic impedance contrast at the contact with overlying strata. Due to the homogeneous lithology the internal seismic character was almost uniform throughout this package (top to bottom). The Lista Formation is present at shallow depth in the southwest of the area and deepens towards northeast with a gentle slope ([Figure 10](#)). Some highs and lows are distributed in the northwest and central parts of the area, but most of the region displays a uniform surface configuration.

### **Top Chalk Group (Lower Paleocene)**

The seismic character of top Chalk Group remained strong throughout the study area. This strong response of the top Chalk Group ([Figure 11](#)) resulted due to the high acoustic impedance contrast at the contact between the shaly Lista Formation and the limestone of the Chalk Group. It was picked as a soft event on the seismic data. The two-way travel time (TWT) values ranged from 1.25 to 2.65 seconds on TWT map. This horizon was easily picked on the data set due to its good continuity and high seismic amplitude.

The high area is lying to the northwest, while deeper strata are present to the northeast. The top Chalk surface is marked by several highs and lows present mainly in the central part. These are in part controlled by deeper faulting.

The top Chalk is a regional marker throughout the North Sea Basin and considered to be an unconformity surface. It is characterized by erosion and the reflector termination across the entire seismic data set. The rocks under this surface are highly faulted. Most of the underlying faults do not cut the top chalk, indicating that it is a major event.

### Seismic Attribute Mapping

A number of seismic attribute maps were generated to analyze the different characteristics of the key intervals around the Pict Field. Best results were seen on the amplitude maps and vertical time thickness maps.

#### Amplitude Extraction

Maximum seismic amplitude was extracted within the Tay Sandstone (Figure 12), which is the reservoir unit to analyze amplitude anomalies. The following dominant features were identified on the basis of amplitude variation across the area.

**Linear Amplitude Anomaly:** A significant linear feature showing high amplitude was identified showing different widths at different places ([Figure 12](#)). It is aligned in an east-west direction on the map. This linear high amplitude feature was interpreted to be a channel running from the shallow part (west) towards the deep basin (east). The channel shows low sinuosity and the flow direction is roughly from northwest to southeast. These high amplitudes may be related to the presence of channel sands.

**Low Amplitude Events:** This channel is surrounded by relatively low amplitude strata ([Figure 12](#)). The lowest amplitude areas are lying in the extreme northwest of the study area, while maximum amplitude is displayed by the area lying in the east-southeast. The lowest amplitude events are interpreted to be related to mudstone presence. The areas of intermediate amplitudes may be caused by mixed lithology (sand and mud).

**High Amplitude Events:** High amplitudes were observed in the eastern part of the study area ([Figure 12](#)). The channel seemed to terminate into these high amplitude areas. These high amplitude areas were interpreted to be fan complexes. These complexes are present on the basin floor (deeper parts of the basin). The channel was assumed to be feeding these fan complexes. A similar, but less significant feature can be clearly seen on the map in the direction from southwest to east-northeast.

#### Vertical Time Thickness Mapping

A vertical-time thickness map was generated for the reservoir unit (Tay Sandstone) during the study of the Pict Field ([Figure 13](#)). The map shows the sediment thickness variation in different parts of the study area. It was observed that the reservoir unit is thicker in the northeast and southwest direction as compared to other regions. The unit is found thinnest in the central parts of the area, but shows roughly uniform thickness in the Pict Field.

The Horda Formation overlies the Tay sandstone and acts as the seal in the Pict Field area. A vertical-time thickness map was also produced for the top Horda Formation ([Figure 14](#)) to give better understanding of sediment cover at the top of Tay Sandstone.

Thin sediments are present in the northern part, while the southern part contains thick sediment cover. Sediment thickness is almost uniform around the Pict Field area from the southern edge that shows slightly thicker sediments ([Figure 14](#)). The thickness variation in the Horda Formation is observed to be opposite the Tay Sandstone unit showing infilling of low areas seen at top Tay Sandstone.

## **Discussion**

The following discussion is divided into various individual aspects considered during the study.

### **Mapping/Relationship of Trends**

The top Chalk surface (top Ekofisk Formation) represents a regional unconformity and a key marker distributed throughout the North Sea. It shows onlap of immediately overlying reflectors and erosional truncations to the immediately underlying reflectors ([Figure 6](#) and [Figure 15](#)). The two-way travel time map of top Chalk shows its presence at shallow depth in the southwest, with a deepening trend towards the northeast.

The comparison of top Chalk with top Lista Formation, and top Tay Sandstone ([Figure 8](#), [Figure 10](#) and [Figure 11](#)) shows almost the same trend. In fact, top Lista Formation and top Tay Sandstone follow the trend of top Chalk surface. This leads to the view that the sedimentation pattern is controlled by pre-existing topography produced by the salt structures. The similar depositional pattern was suggested by Armstrong (1987).

Furthermore, the idea was supported by the vertical time thickness maps of overlying strata ([Figure 16](#)). These include late Paleocene Lista formation and early to middle Eocene Tay sandstone. Their comparison shows that the thickness variations among these units are identical and thick and thin sediment accumulations follow similar trend ([Figure 16](#)).

The youngest, Horda Formation which overlies the Tay Sandstone, shows a different trend on the vertical time thickness map ([Figure 14](#)). It clearly fills in the pre-existing topographic depressions. Mudstones of Horda Formation provide a good seal for the Tay Sandstone reservoir unit.

### **Seismic Facies Distribution**

Three types of seismic facies were identified on the basis of amplitude variations within the Tay Sandstone unit.

- a) Facies associated with the high amplitudes.
- b) Facies associated with the medium amplitudes.

c) Facies associated with the low amplitudes.

As mentioned in the previous section, a major channel was identified on the basis of alignment of high amplitudes on the Tay Sandstone maximum amplitude map ([Figure 12](#)). The same channel is also observed on the seismic data as well. The highest amplitudes have been observed within the channel body which can be interpreted to be related to channel sand facies, since good quality clean sands can be expected in the channel environment ([Figure 17](#)). The presence of channel sand has also been confirmed by well 21/23b-1 during drilling.

Adjacent to the highest amplitudes, intermediate amplitudes have been observed ([Figure 17](#)) in the Pict Field area. These amplitudes can be interpreted to be related to mixed material, i.e. sand and mud. As we move away from the main channel body (away from areas of highest amplitudes), the seismic amplitude also decreases, which may indicate that the amount of sand starts decreasing and the amount of mud starts increasing. This shows mixed deposition and the intermediate seismic amplitudes may relate to these mixed facies associations.

Further away from this area, toward the north and south, the seismic amplitude becomes minimal ([Figure 17](#)). These minimum seismic amplitudes may be due to the mudstone/claystone lithology. In short, sandstone facies are distributed within the main channel body, but as we start moving away from the channel the amount of mud starts to increase.

### **Reservoir Presence Risk Mapping**

Reservoir rock is the key element in every petroleum system. The Pict Field reservoir belongs to the channel sand and is distributed along the channel body running from the shallow basin (northwest) toward the deeper parts (eastern side), identified on the seismic as well as on the maximum seismic amplitude map ([Figure 12](#) and [Figure 17](#)). On the basis of this character, a reservoir presence risk map ([Figure 18](#)) has been produced to indicate the areas where the reservoir may be present, as well as to identify areas where it could be absent or very thin. The green areas indicate the localities with a high chance of reservoir presence (low risk). Red areas show that there is no reservoir or thin reservoir present (high risk), while yellow areas indicate that the chances of finding reservoir are fifty percent (moderate risk).

The reservoir presence and absence in different areas has been confirmed by well data. The discovery well (21/23b-1) was drilled in the green area ([Figure 18](#)) and had penetrated good quality clean channel sand with an 85-foot oil column. The reservoir was absent in well 21/23a-4 which encountered thick mudstone strata. This well falls in the red area of our risk map which further supports the interpreted seismic mapping based on amplitudes.

### **Hydrocarbon Distribution**

The discovery well 21/23b-1 was drilled on a mounded anticlinal trap within the Tay Sandstone reservoir unit. The presence of a possible OWC is very clear on the seismic data represented by high amplitudes. The top structure and the high amplitudes (possibly relating to OWC) were marked on the seismic data to define the lateral extent of these high amplitudes with respect to the structural closure ([Figure 19](#)). This was done by producing 2D and 3D TWT maps for the OWC and the top structure and then overlying these two maps ([Figure 20](#) and [Figure 21](#)). It

was observed from the maps that the high amplitudes, originally thought to be associated with an OWC under the structure, extend beyond the structural closure ([Figure 21](#)). This could happen due to following reasons:

- 1) The OWC can go beyond the structure if the trap is partly stratigraphic.
- 2) The higher amplitudes may not originally be associated with the hydrocarbons, but related to sandstone distribution and/or tuning effect as the sandstone thins to the margins.

To find out the reason, seismic resolution has been calculated by the following procedure:

$$\begin{aligned}\text{Length of the wavelet} &= 24 \text{ ms} \\ \text{Frequency} &= 1000 \text{ ms} / 24 \text{ ms} \\ f &= 42 \text{ Hz} \\ \text{Seismic velocity within the interval} &= 3000 \text{ m/s} \\ \text{Wavelength (?) } &= V/f \\ &= 3000 / 42 = 71.4 \text{ m} \\ l/4 &= 71.4 / 4 = 17.8 \text{ m} \\ \text{Thickness of Separability} &= (l/2) = 36 \text{ m}\end{aligned}$$

It is evident that the seismic data resolution is not very high. It can, therefore, lead to the conclusion that the high amplitudes going beyond the limit of structure may be due to the tuning effect. Since the hydrocarbons are present within the sand mound and as this sand thins at the limbs of the mound, it may display higher amplitudes due to seismic interference. This can further be supported by the fact that the higher amplitudes are associated with channel sand rather than the fluid presence in the study area.

### **Conclusions**

- 1) The sediments feeding the main Tay fan complex were transported from the shelf into the deeper basin through a channel system. Sandstone facies are distributed within the main channel body, but as we start moving away from it the amount of mud starts to increase. The presence of good quality clean sand is confirmed by Gamma Ray logs and drill cuttings from various wells that have been drilled into the area of high seismic amplitudes. Hydrocarbons have been discovered from the wells drilled into the area of high seismic amplitudes related to channel sands, while dry wells have been encountered in the areas of low seismic amplitudes which are related to mudstones.
- 2) A distinct high amplitude anomaly has been observed at the base of the anticlinal feature. The amplitude extent is tilted and extends beyond the structural closure of the field. It was concluded that these amplitudes are not only due to the response of hydrocarbons, but could also be due to the lithology effect enhanced by the seismic tuning effect as the sands thin to the margins of the channel.

## **Recommendations**

- 1) Core data should be acquired to investigate more detailed facies distribution in the study area.
- 2) Seismic data with improved vertical resolution is needed to eliminate the seismic tuning effect and to develop a better understanding of hydrocarbon distribution in the Pict Field.
- 3) The eastern part of the study area, adjacent to Pict Field, may contain additional hydrocarbon reserves if a structural or stratigraphic trapping mechanism are developed, and reservoir is probably present as suggested by the higher seismic amplitudes.
- 4) Additional data from discovery well (which was not available to this study) is needed for the well correlation to better understand the geology of the Pict Field and for more detailed study

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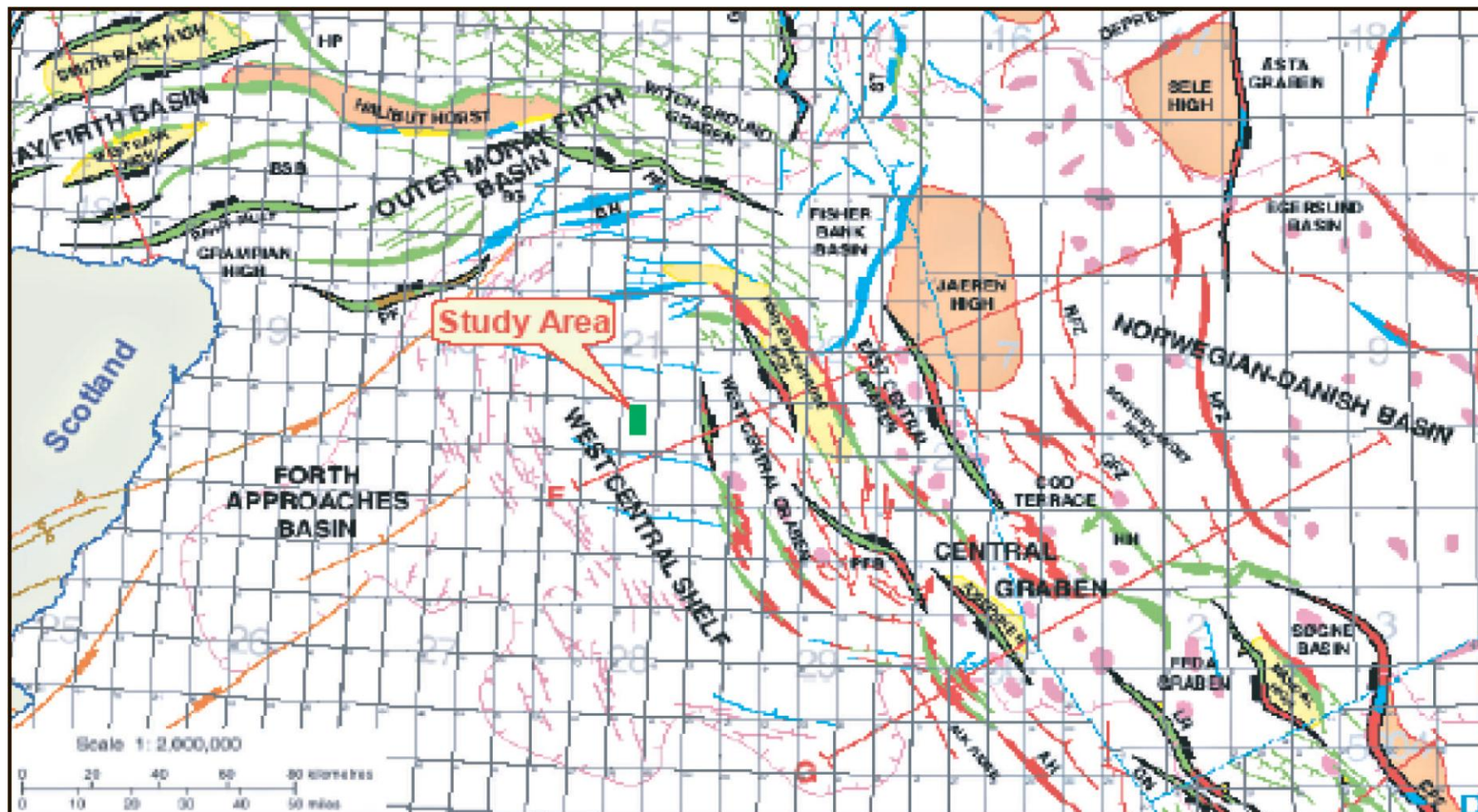


Figure 1. Regional map of the North Sea showing the location of the study area.

Ma	Epoch/Age		Group	Formation	Member	Main Lithology	
--31	<b>Oligocene</b>	Early	Westray Group				
--34	<b>Eocene</b>	Late	Stronsay Group	Mousa Formation (mainly shelf Sandstone) & Horda Formation (mainly basinal Mudstone)	Grid Sandstone Member		
--37		Mid					
--42					Tay Sandstone Member		
--55					Early		
--59		<b>Paleocene</b>			Late		Moray Group
--63			Sele Formation				
--70	Early		Montrose Group	Lista Formation			
				Maureen Formation			
	<b>Cretaceous</b>	Late	Chalk Group	Ekofisk Formation			
				Tor Formation			

Figure 2. Eocene stratigraphy of the central North Sea.

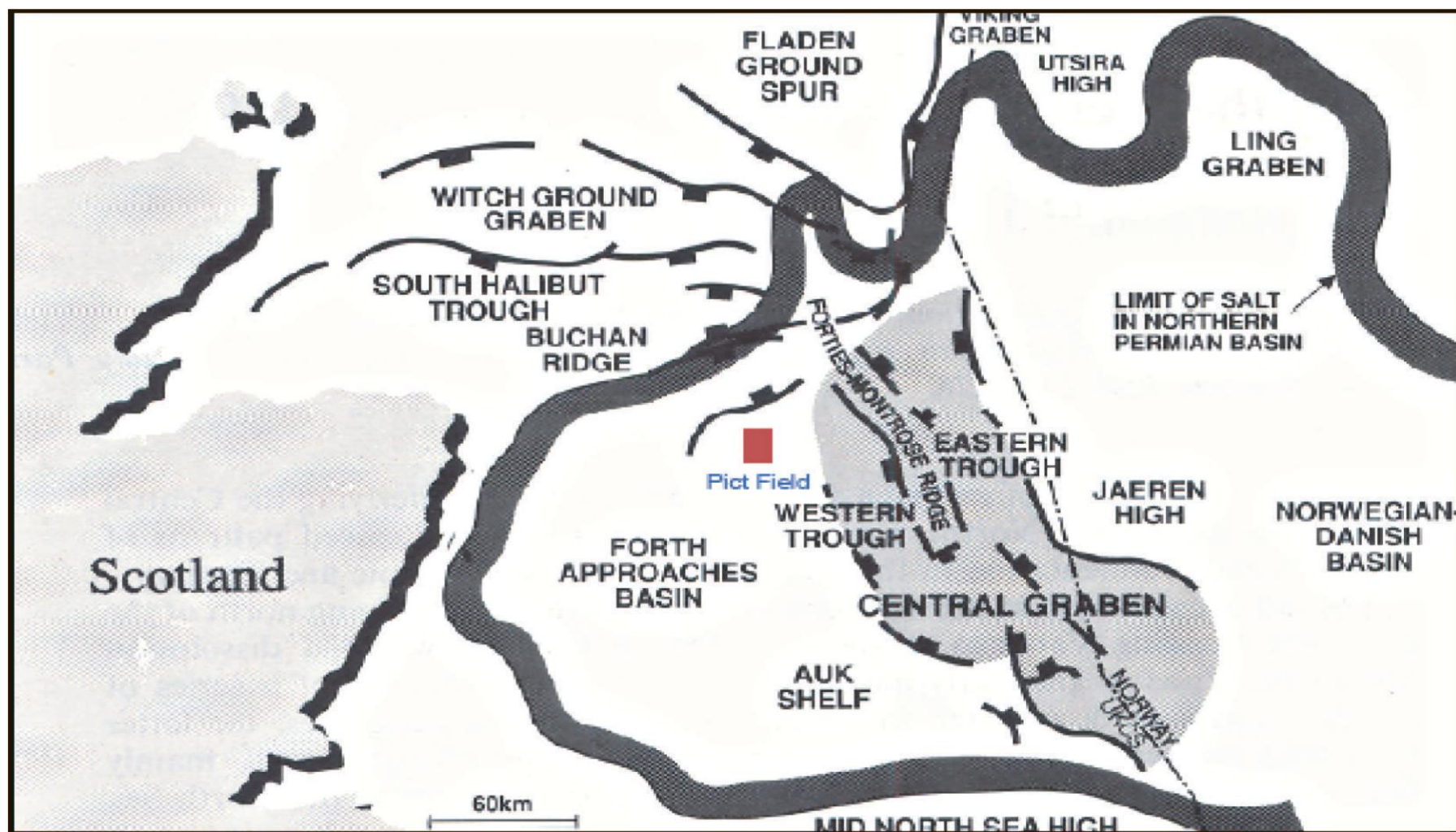


Figure 3. Major structural features of the North Sea (Hodgson, 1992).

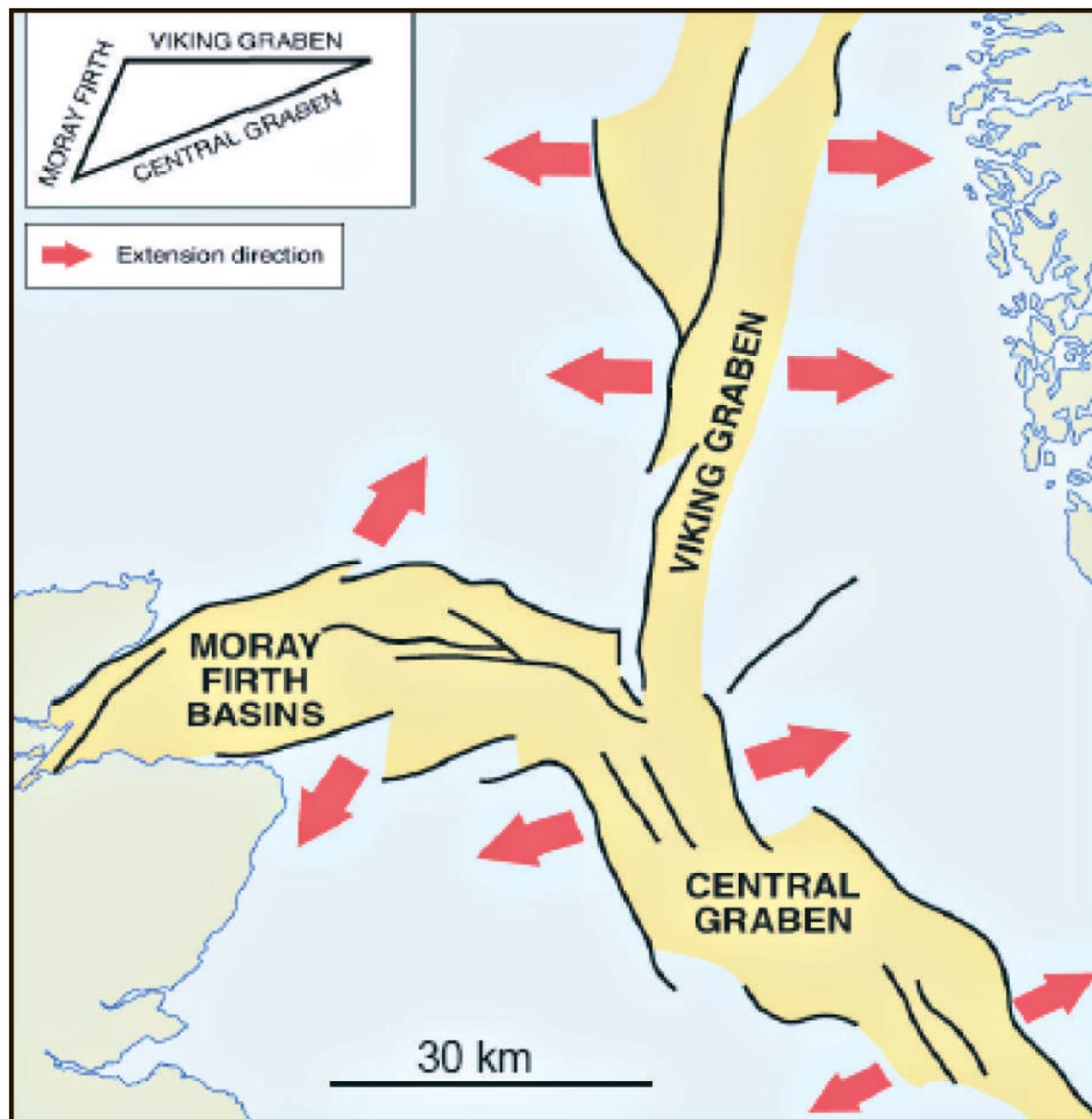


Figure 4. The North Sea Triple Junction (Posamentier et al., 1991).

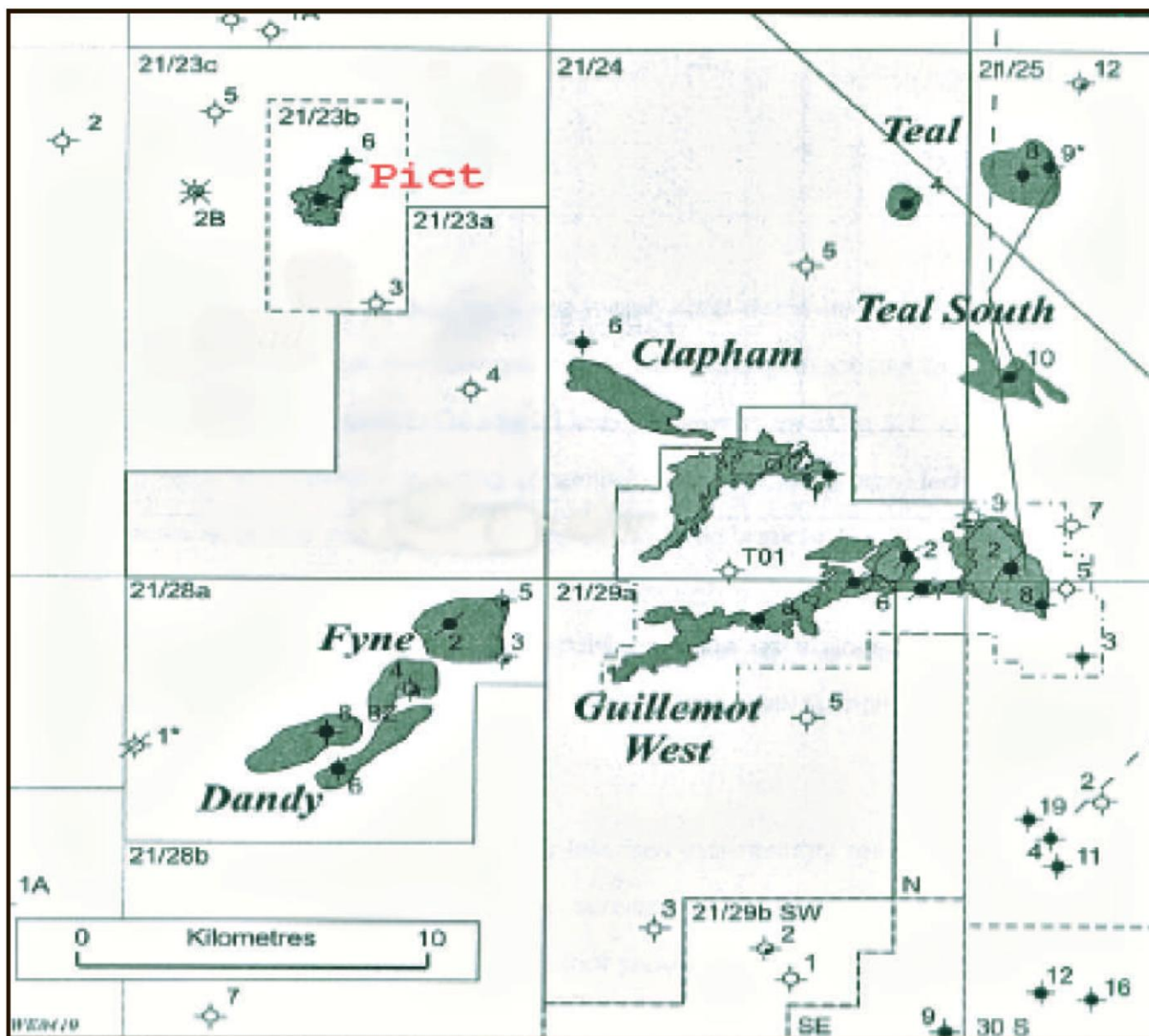


Figure 5. Location of Pict Field in Block 21/23b.

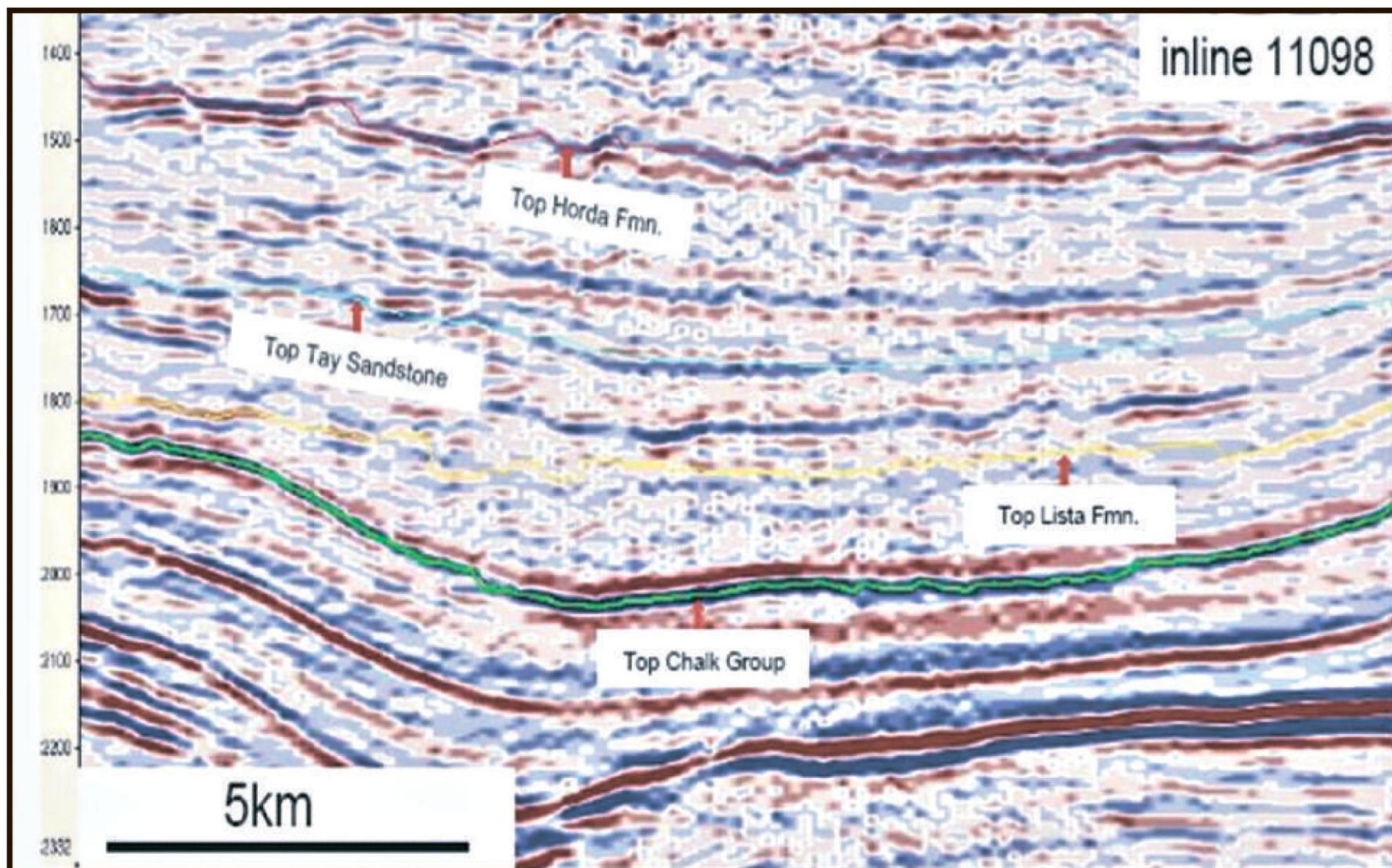


Figure 6. Seismic section showing four mapped horizons.

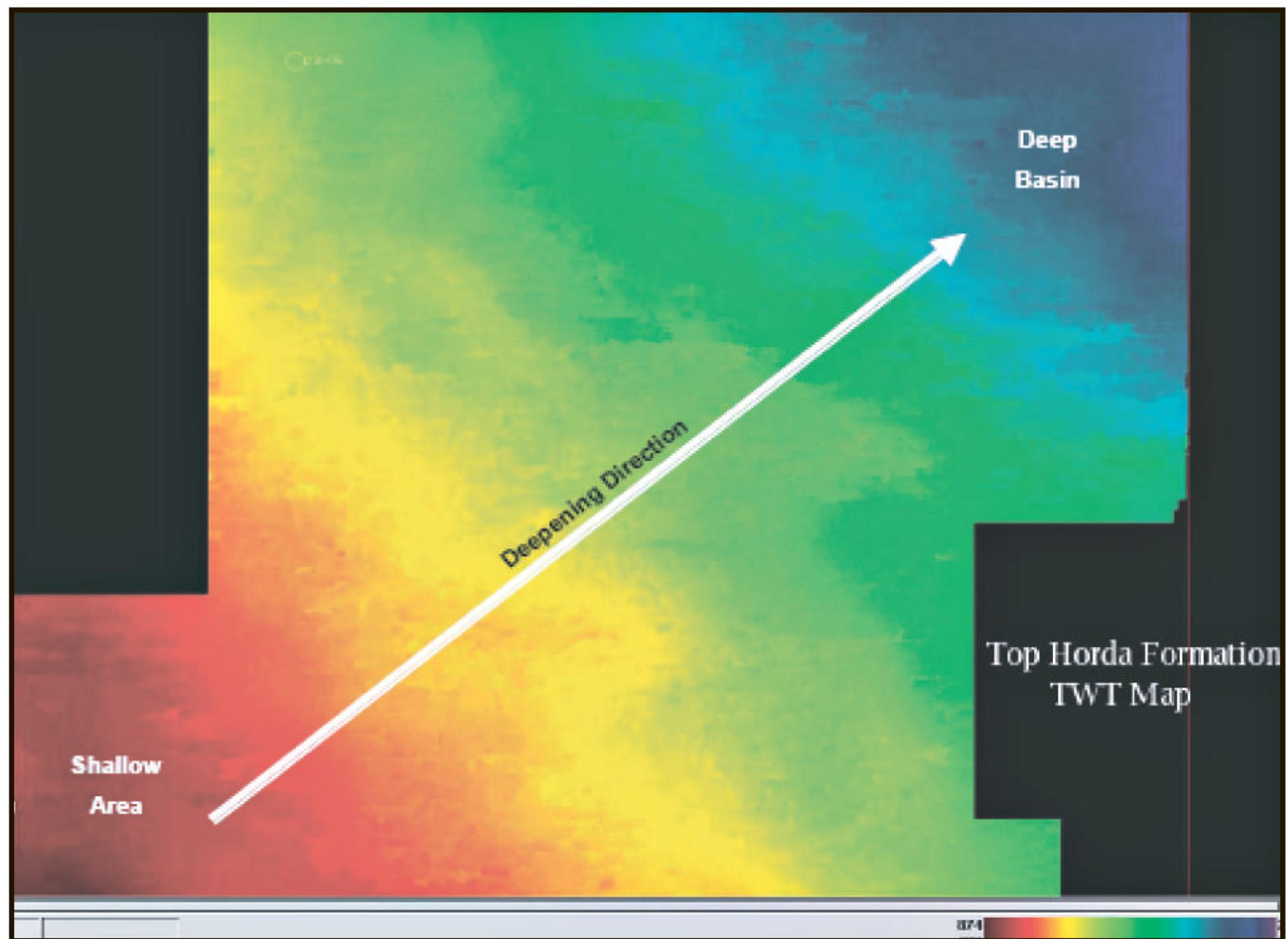


Figure 7. Top Horda Formation TWT map.

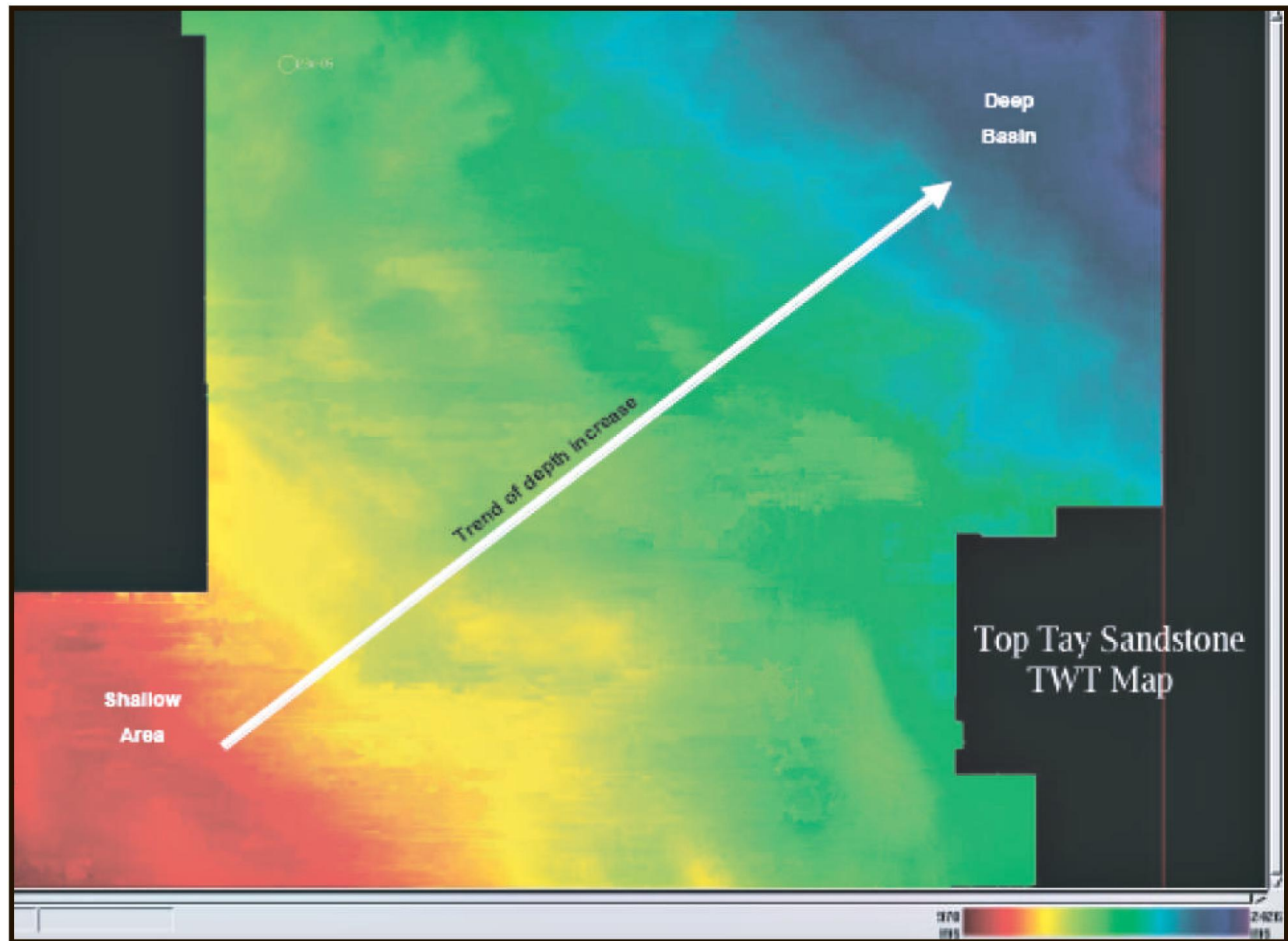


Figure 8. Top Tay Sandstone TWT structure color map.

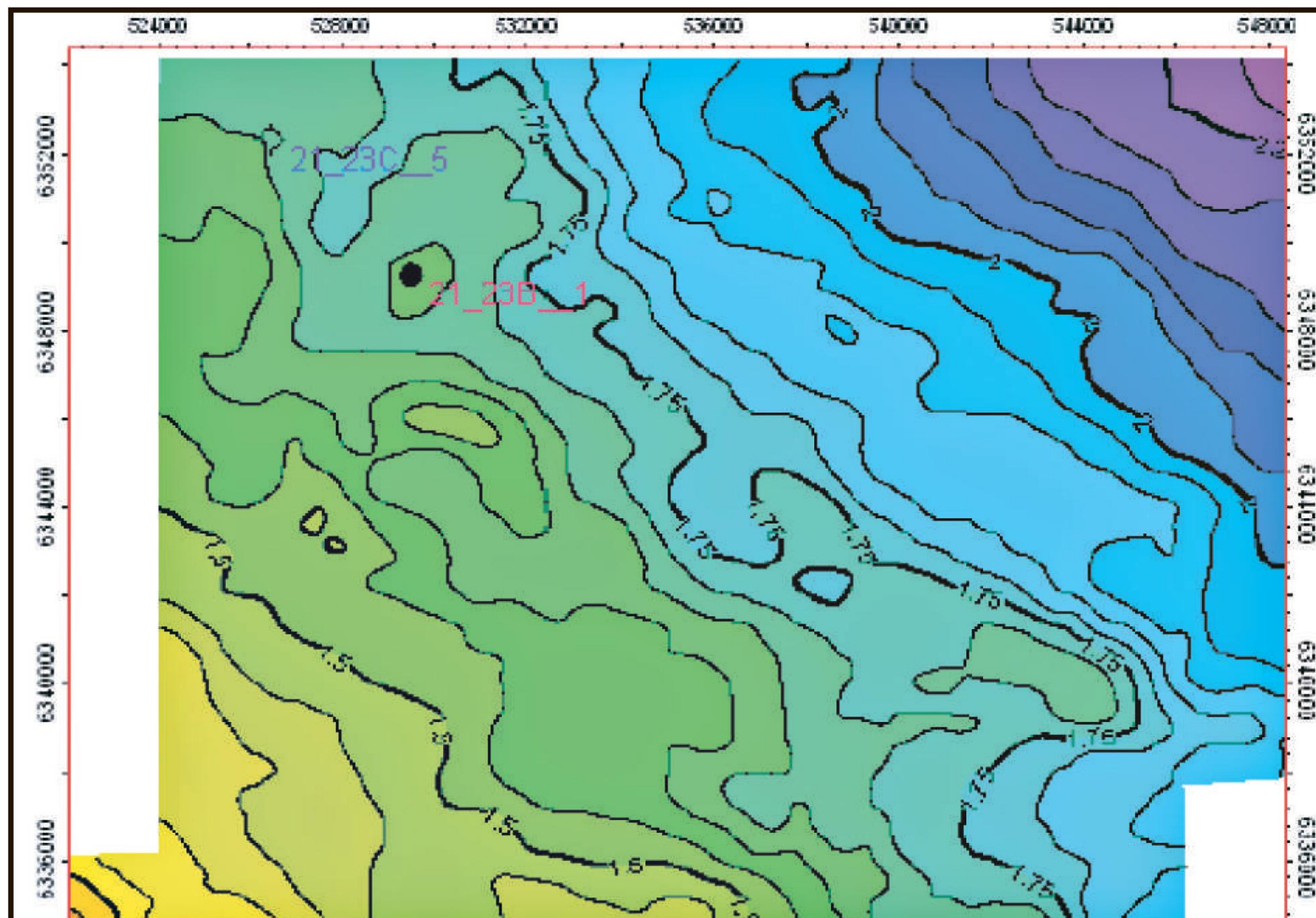


Figure 9. Top Tay Sandstone TWT structure contour map.

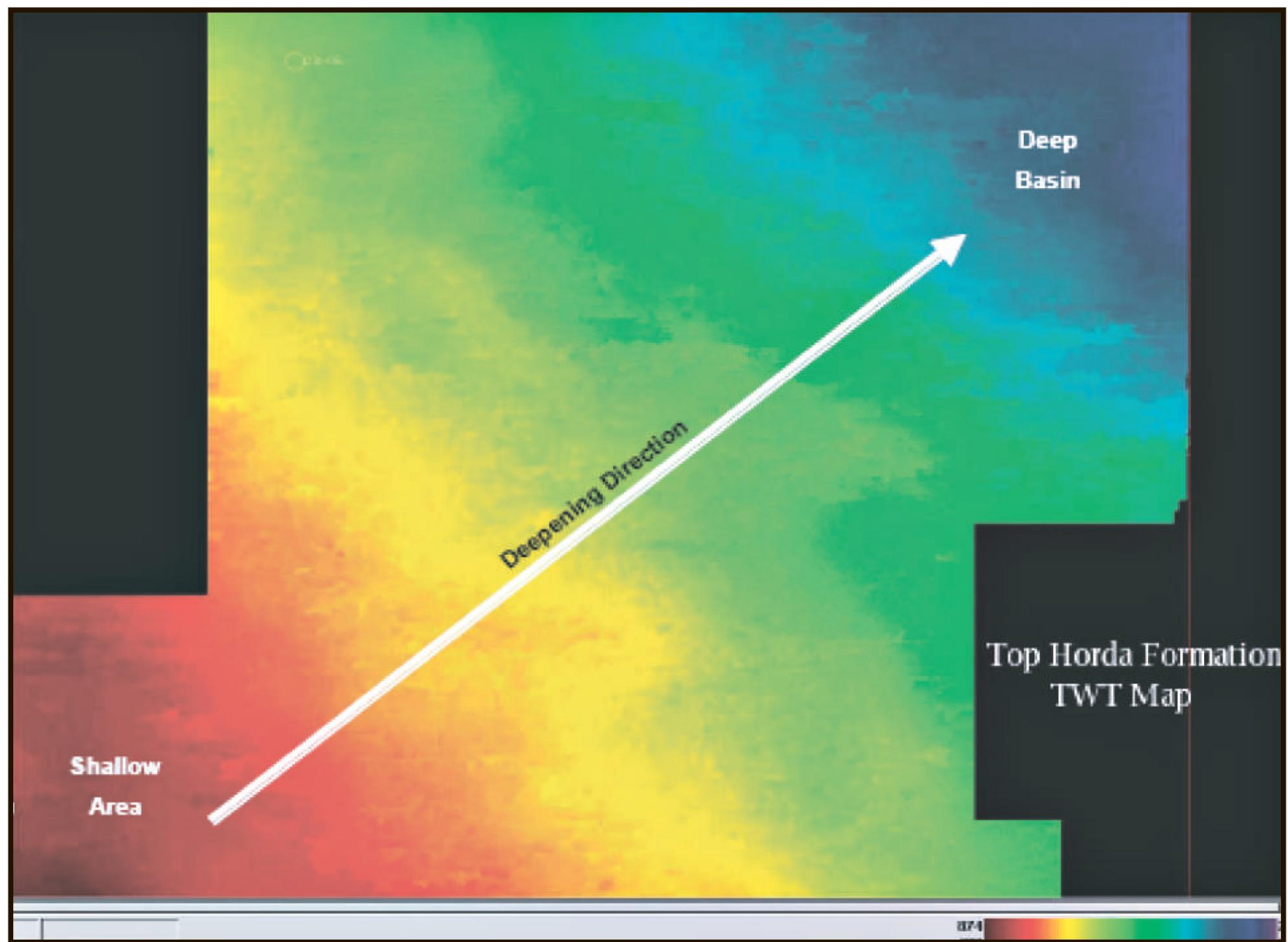


Figure 10. Top Lista Formation TWT structure color map.

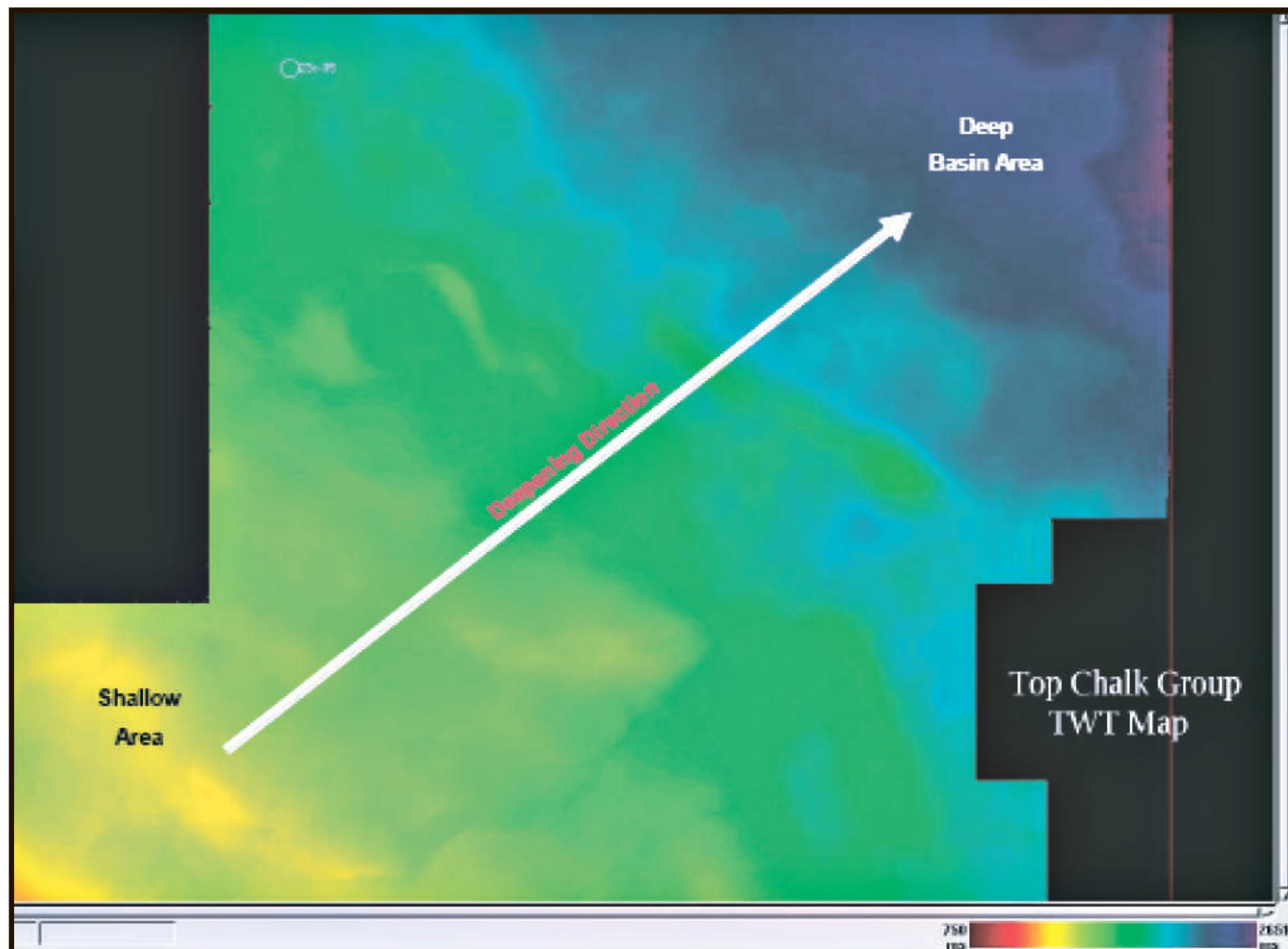


Figure 11. Top Chalk Group TWT structure color map.

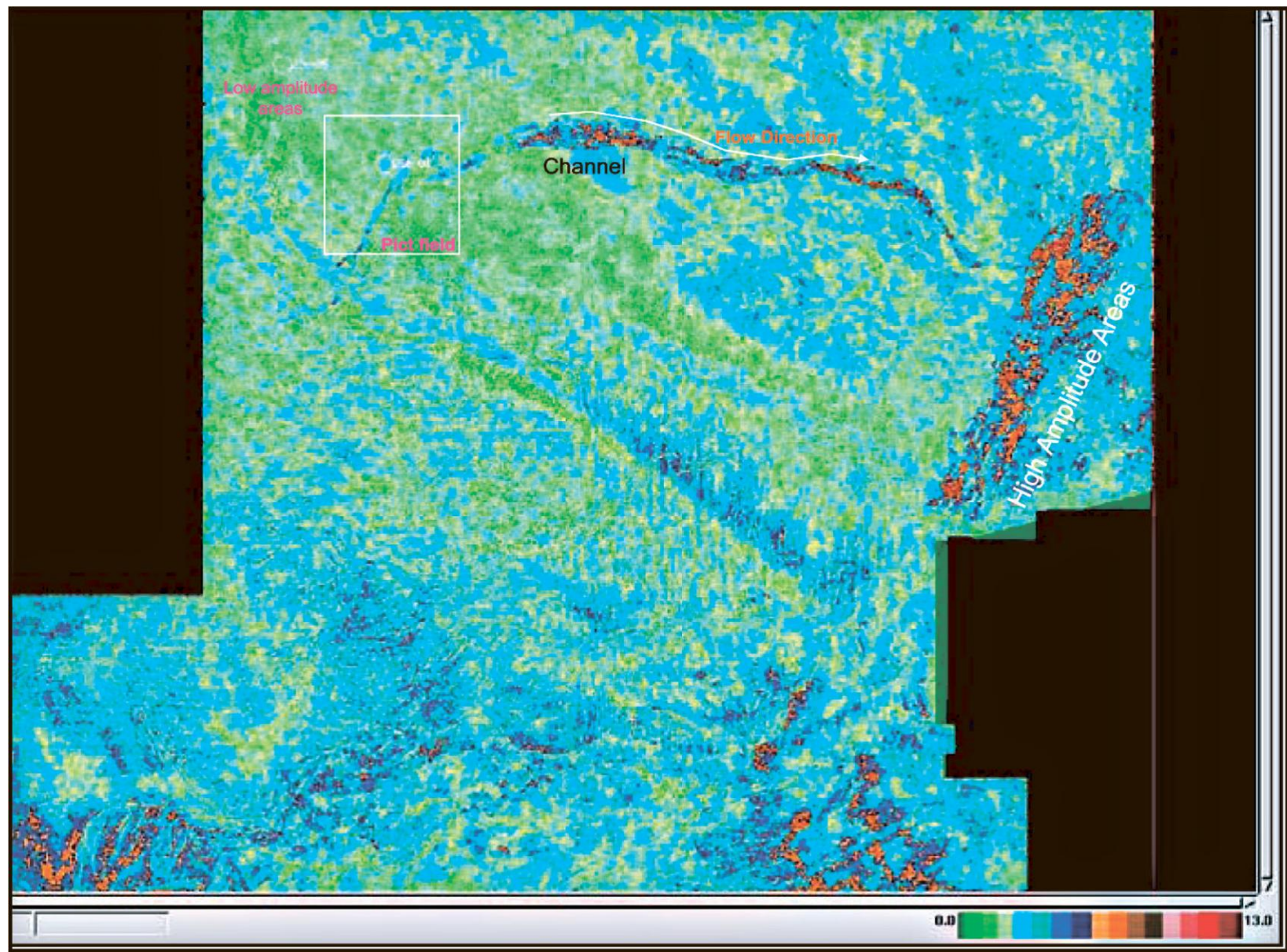


Figure 12. Maximum seismic amplitude map within the Tay Sandstone showing seismic amplitude anomalies.

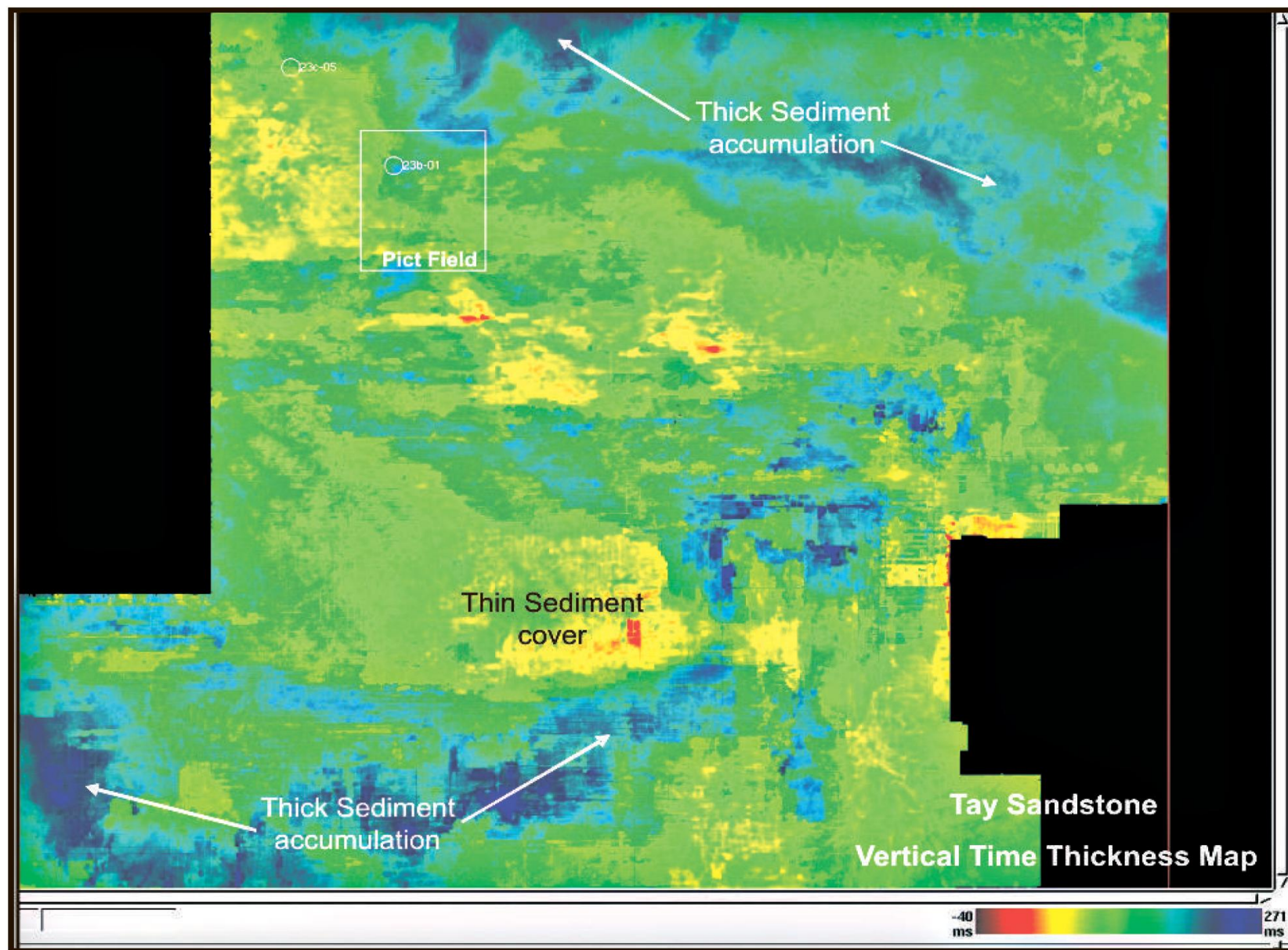


Figure 13. Tay Sandstone sediment thickness variations in a vertical time thickness map.

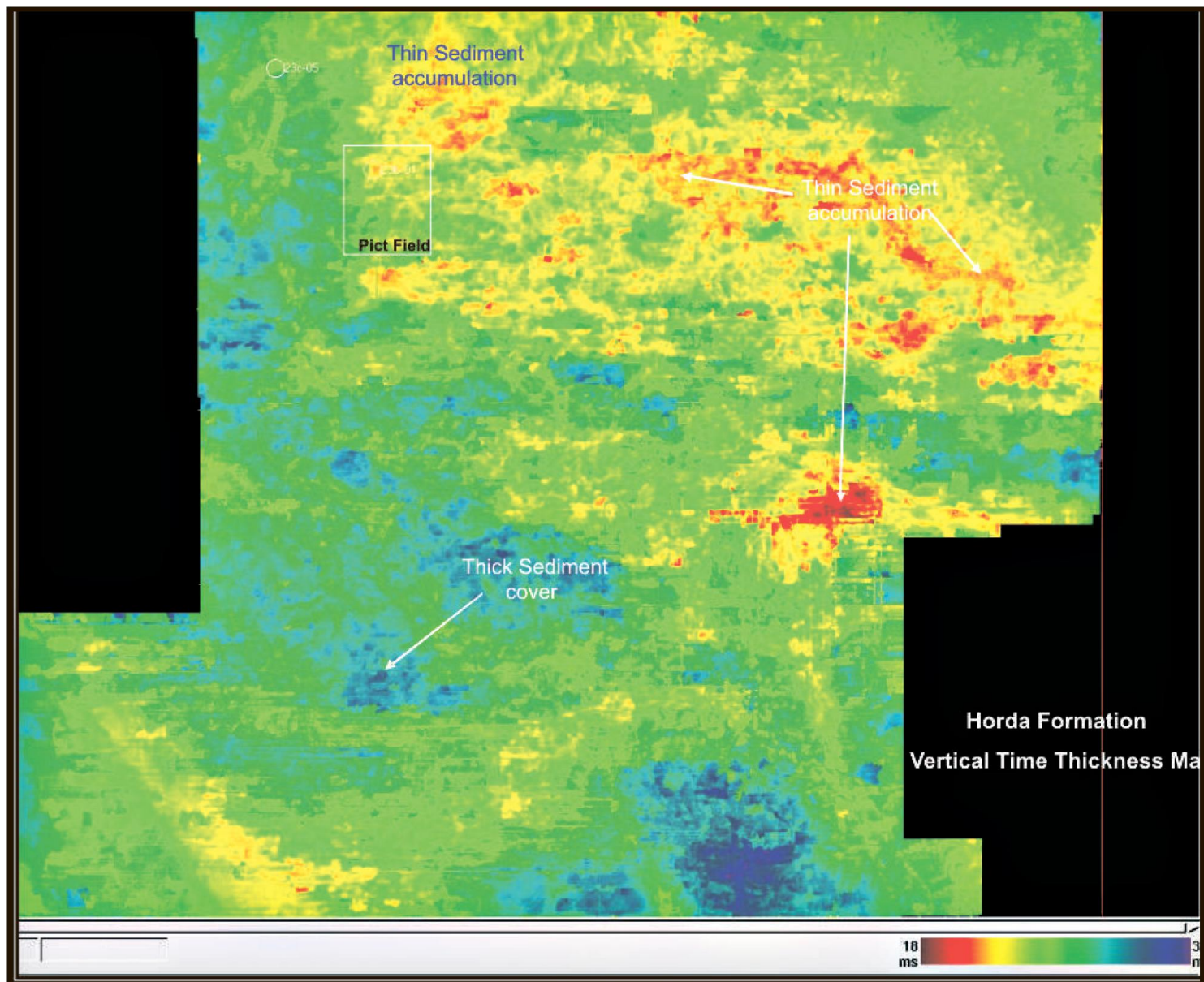


Figure 14. Horda Formation sediment thickness variations in a vertical time thickness map.

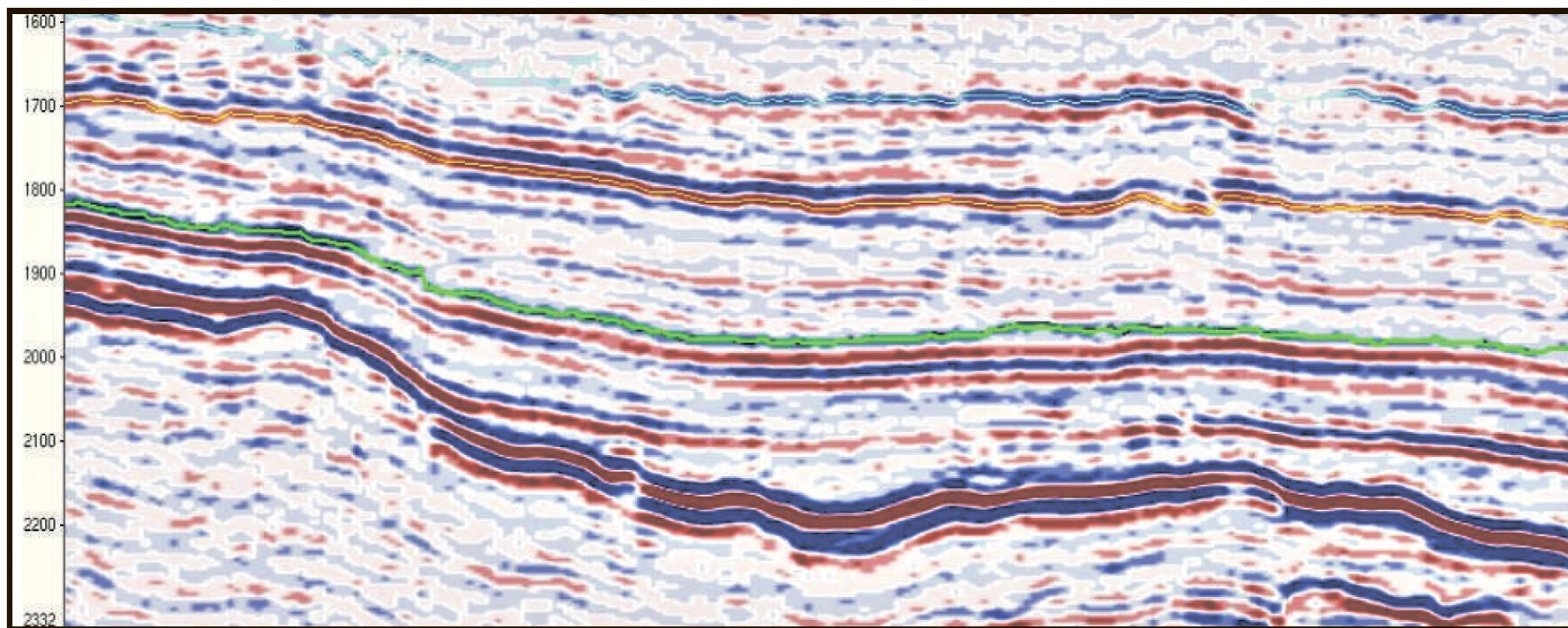


Figure 15. Seismic section showing strong reflection strength of top Chalk Group.

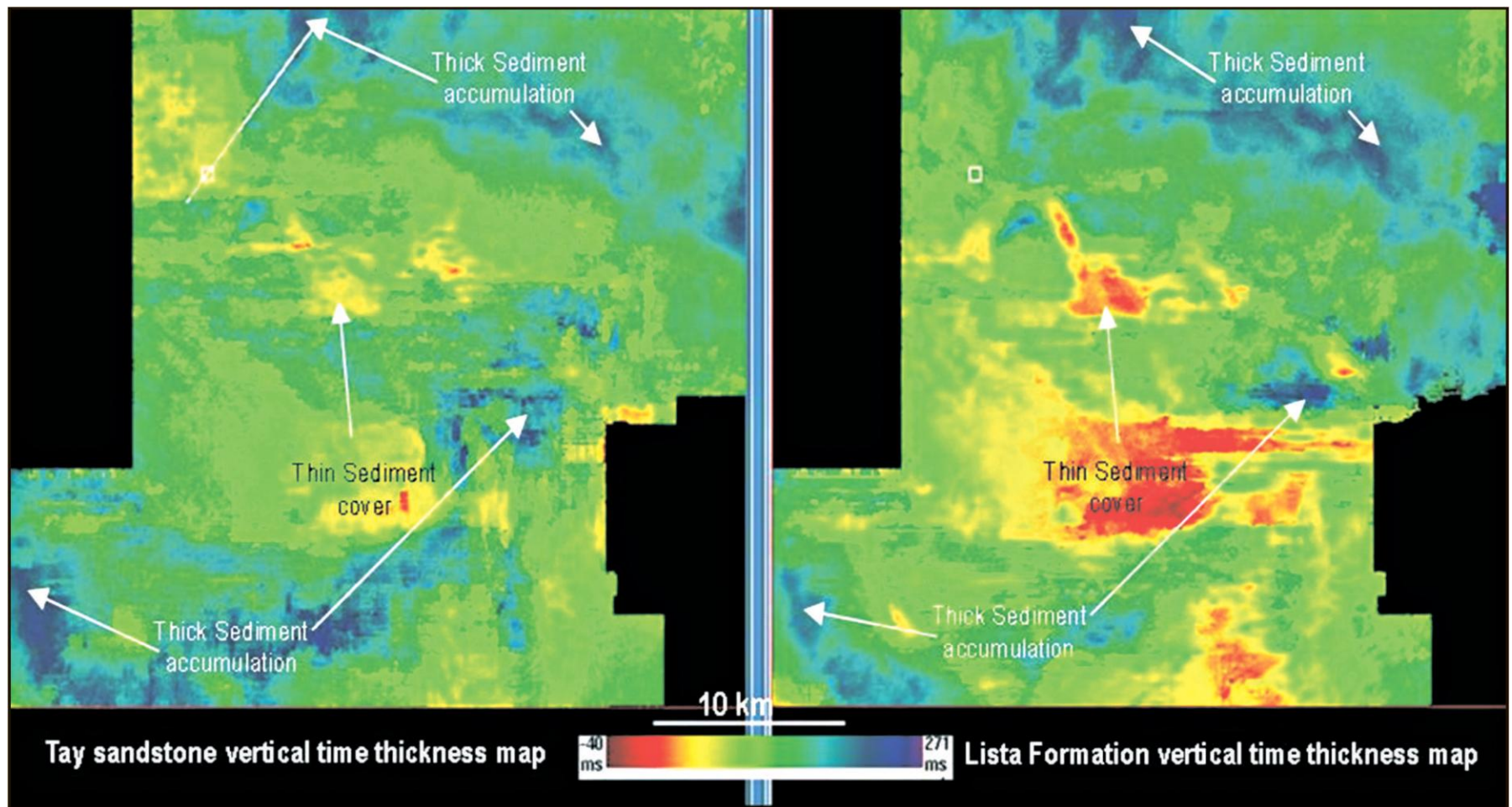


Figure 16. Comparison of vertical time thickness maps of strata overlying top Chalk Group.

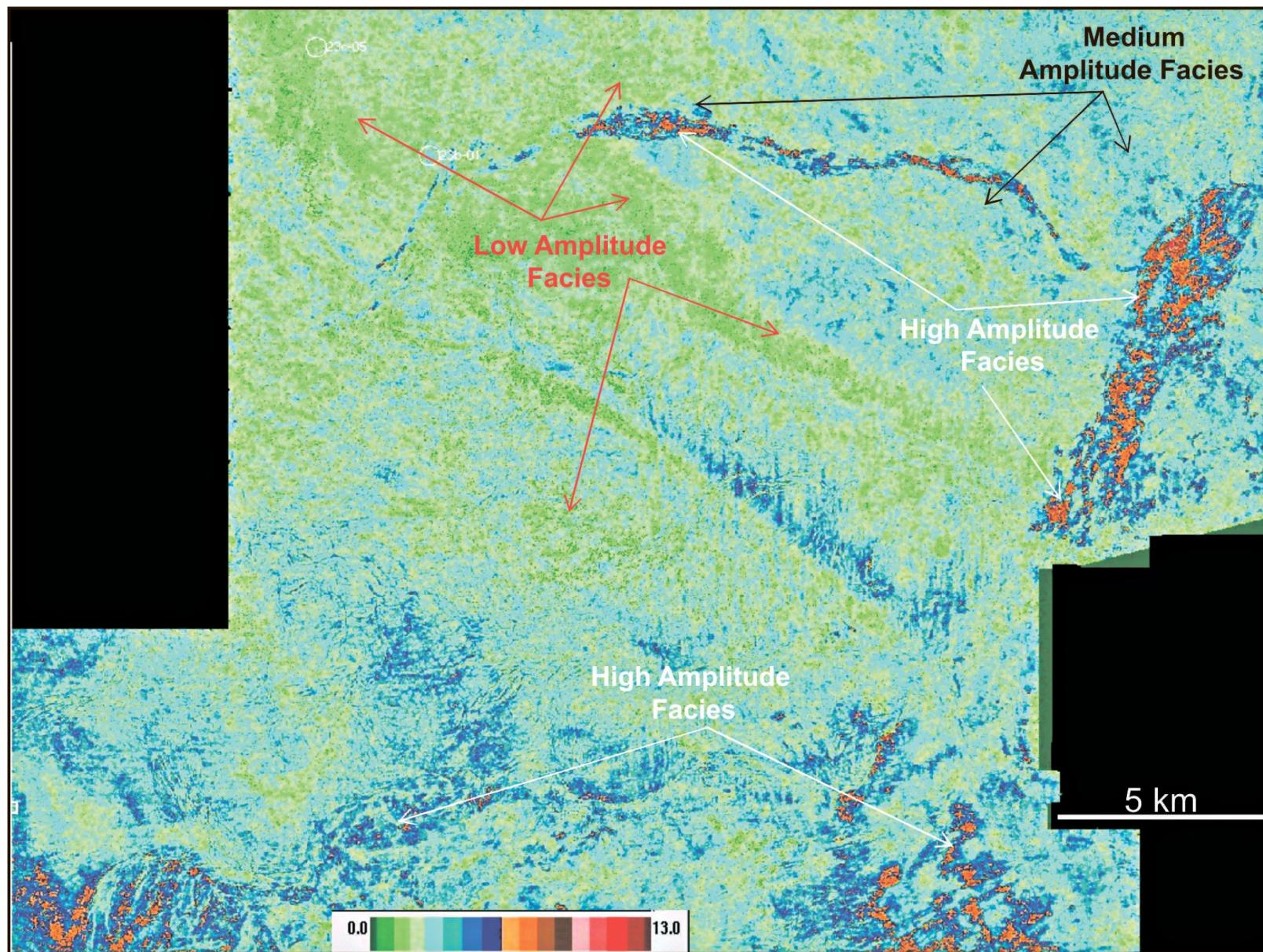


Figure 17. Seismic facies distribution map in the study area, marked on the basis of seismic amplitude analysis.

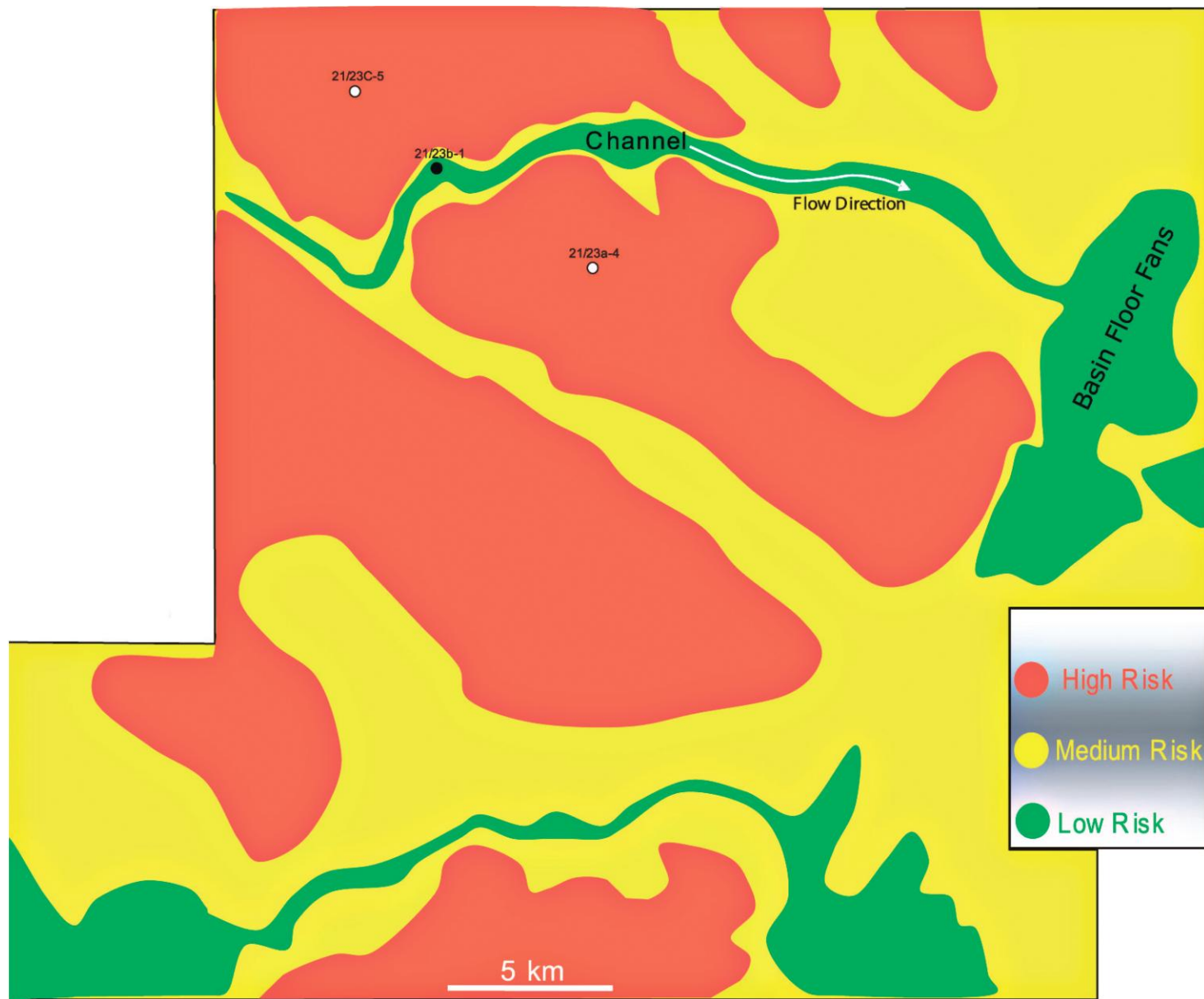


Figure 18. Reservoir Presence Risk Map.

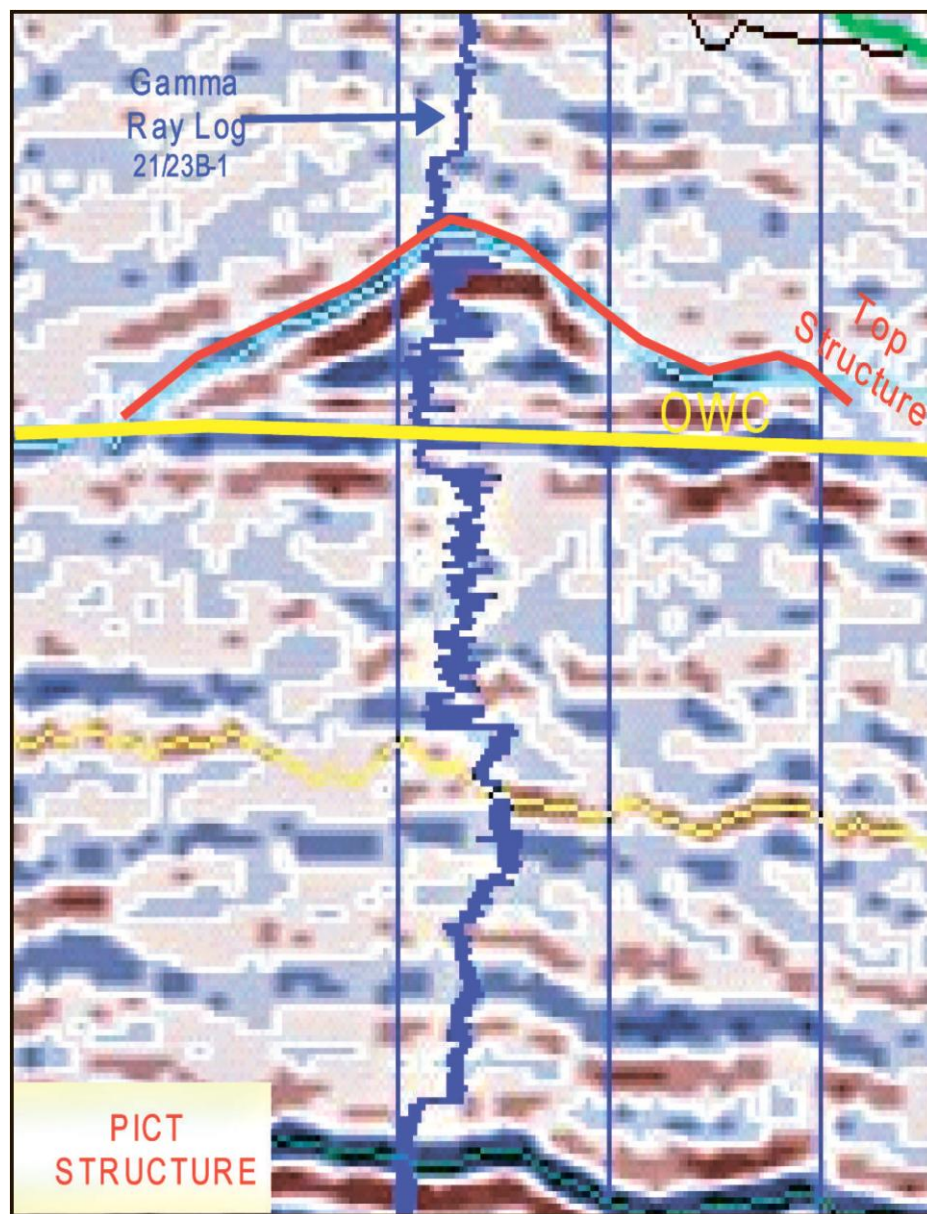


Figure 19. Image of interpreted seismic line showing Pict Field structure; and the position of the top of structure and Oil-Water Contact.

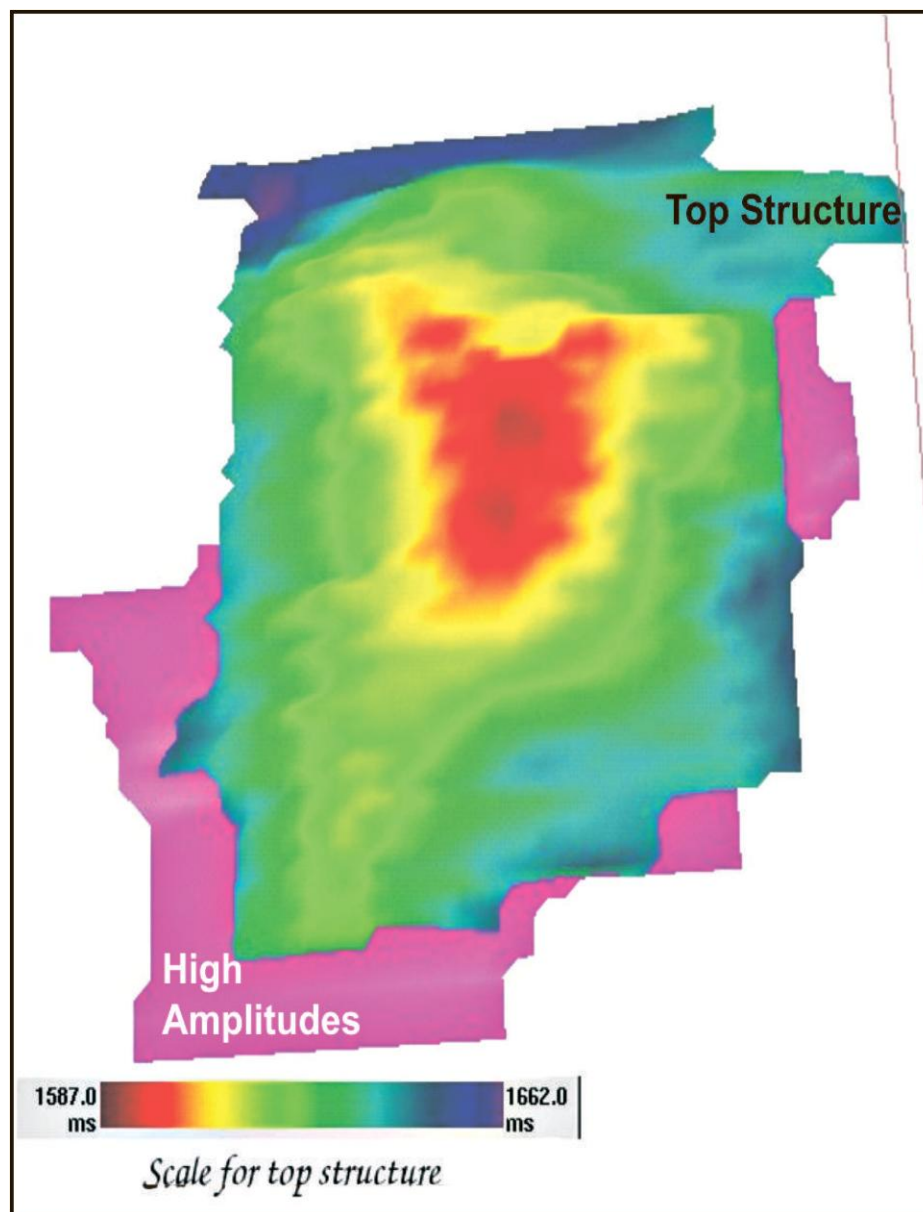


Figure 20. Three-Dimensional view of the Pict Field top structure and high amplitude anomaly.

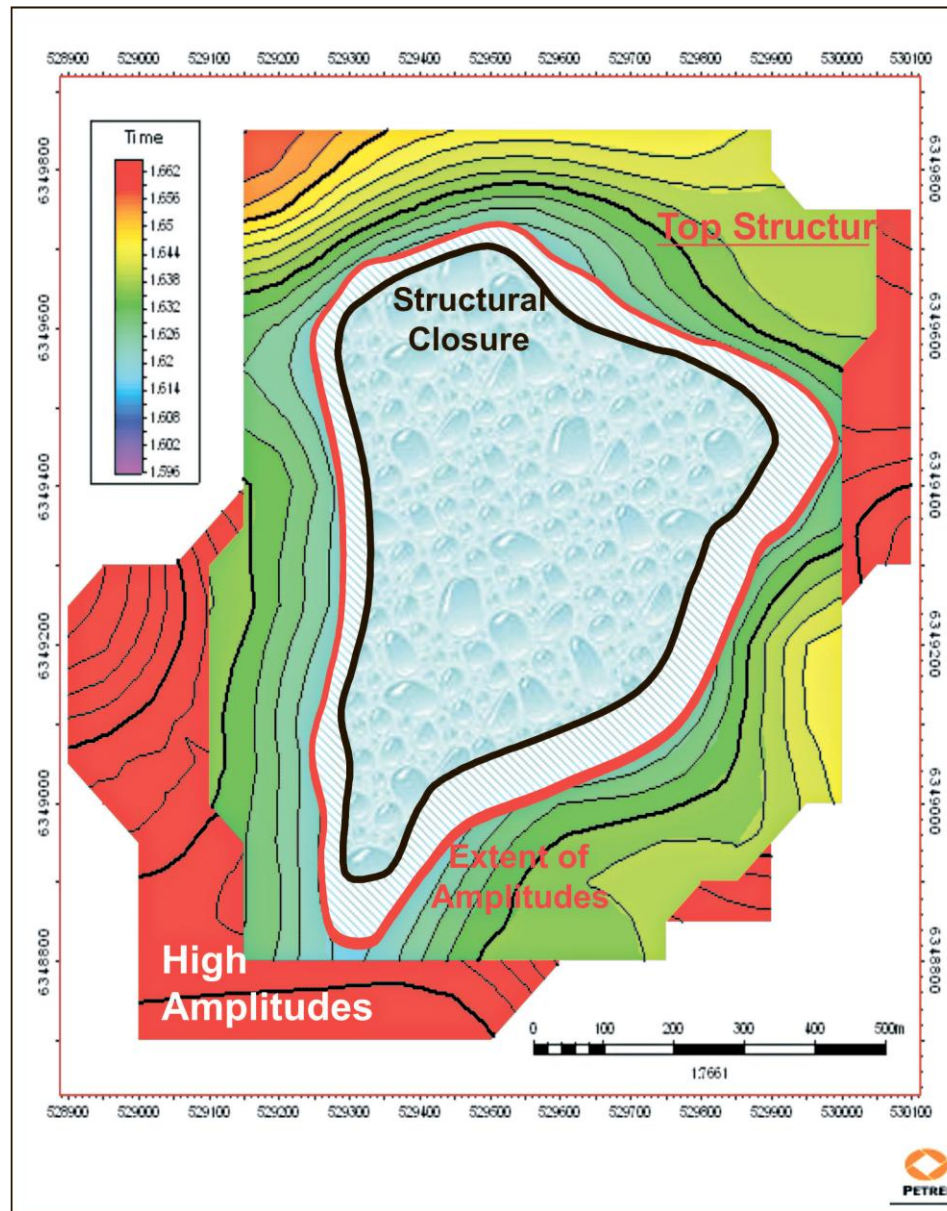


Figure 21. Contoured maps of high amplitude distribution under the mounded anticlinal trap marked on the seismic data (generated in Petrel).