# EXAMENSARBETE I GEOLOGI VID LUNDS UNIVERSITET

## Historisk geologi och Paleontologi

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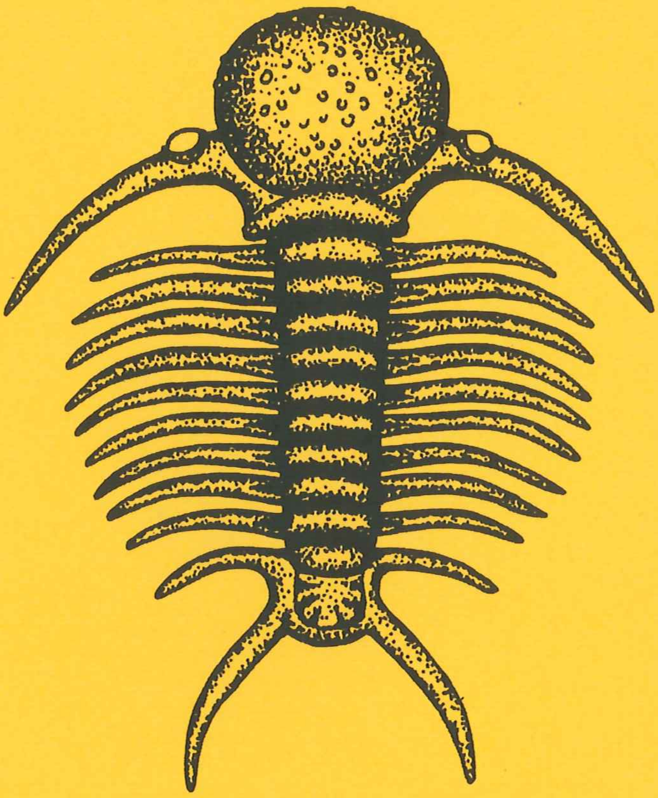

# Exploration of submarine fans along the Coffee Soil Fault in the Danish Central Graben

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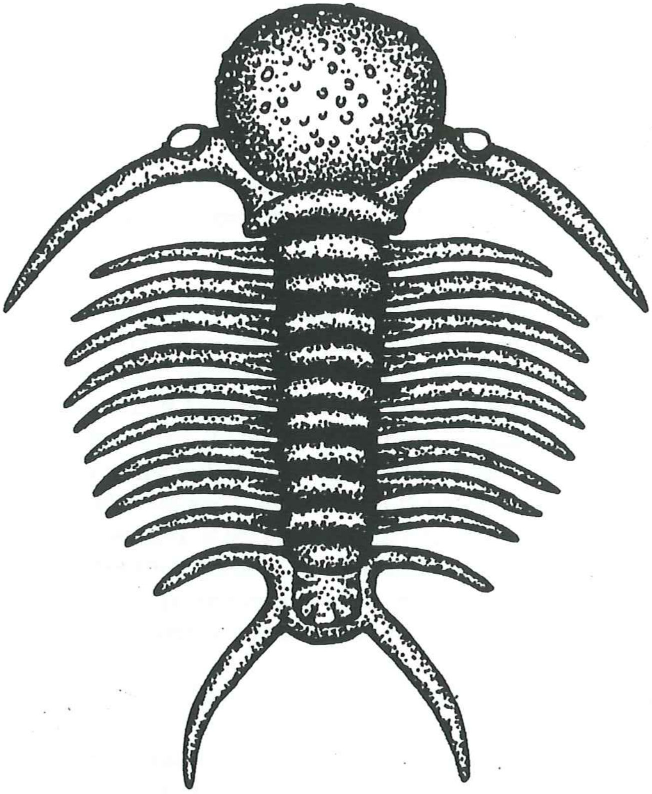

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JAKOB MAGNUSSON

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**Abstract**: On the footwall side of the Coffee Soil Fault in the Danish Central Graben, five potential petroleum reservoir structures were distinguished on seismic images. The deposits were formed during the Late Jurassic-Early Cretaceous transition. South of these structures coarse clastic sediments of Late Jurassic to Early Cretaceous age, interpreted as submarine fans, have been drilled in a few wells. To the north of them, contemporaneous, coarse clastic sediments have been drilled in one well. The location of the structures and the occurrence of possible submarine fans in adjacent areas, indicate that the investigated structures could be composed of submarine fan deposits. If so, they are likely to consist of turbidites with a fairly high sandstone content. The reservoir qualities of such sandstones would be uncertain. The communication with high quality oil prone source rocks is probably good, and the structures may well be sealed by internal shale layers or by superimposed shales.

**Keywords**: Late Jurassic, Early Cretaceous, Seismic, Danish Central Graben, Submarine fans.

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Submarine fans are the targets for this project, since their deposits can make up good reservoir rocks for hydrocarbons. The purpose of this project is, with the help of seismic data and well information, to define where and how to continue the search of submarine fans along the Coffee Soil Fault. Therefore the Upper Jurassic and Lower Cretaceous intervals were studied in well logs as well as on seismic images, since coarse clastic sediments from these intervals were drilled in some wells along the fault. Special interest was aimed towards the poorly known area along the fault where no wells have been drilled, e.g., between the wells Adda-1 and Gulnare-1 (Fig. 1).

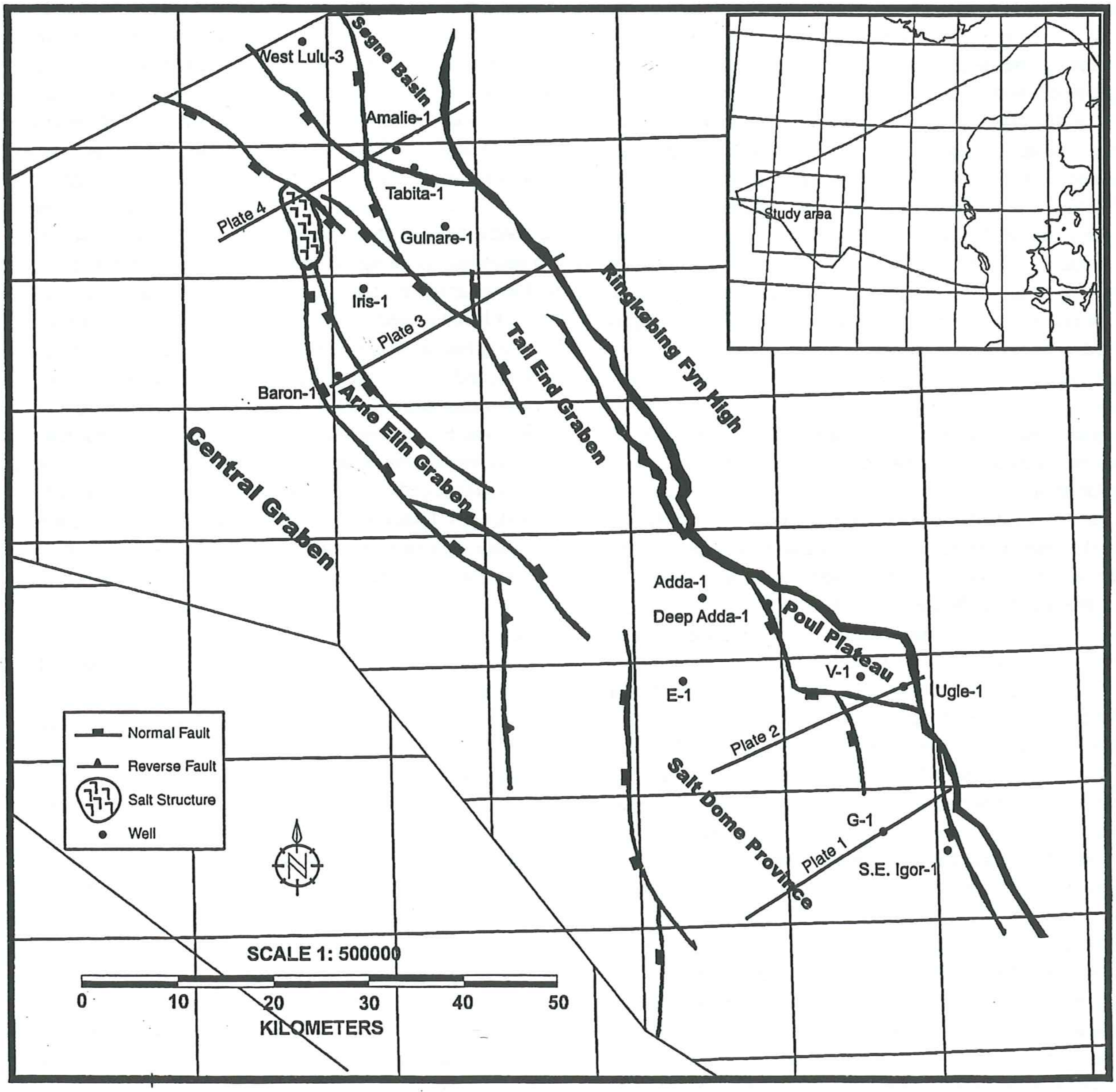

Fig. 1: Jurassic structural outline of the eastern part of the Danish Central Graben. Location of studied wells and the seismic sections shown in Plates 1-4 are given.

## *Structural geology*

The Central- and Viking Grabens transects the North Sea in a north-south direction. Together they have a length of about 1000 km. These two grabens are connected in a triple junction to the Moray Firth Basin, which is elongate in an east-west direction. Together with the Horda Egersund Halfgraben they form the Mesozoic North Sea rift system (Ziegler 1990). This system is connected to the Arctic-North Atlantic mega-rift system. The activity in the Arctic-North Atlantic mega-rift system had its culmination in early Eocene with the crustal separation between Greenland and northern Europe (Ziegler 1990). According to Ziegler (1990), the Central Graben was formed in the Early Triassic as the Norwegian-Greenland rift propagated southwards into the North Sea area. Conversely, Glennie (1986) claims that the development of the Central Graben started as early as the beginning of the Permian or even earlier. The Central Graben splits the east-west striking Mid- North Sea -Ringkøbing- Fyn Møn trend of highs (Ziegler 1990). After the separation the Mid-North Sea High and the Ringkøbing Fyn High became the western and the eastern border, respectively, of parts of the Central Graben.

The Central Graben transects the westernmost part of the Danish North Sea sector. It continues southwards into the German and Dutch sectors. To the north it extends into the United Kingdom and Norwegian sectors. To the east the Ringkøbing Fyn High forms the boundary of the Danish Central Graben, which is made up by basement-attached normal faults (Michelsen *et al.* 1987). The western boundary is less well defined, it is a gradual transition between the graben and the Mid North Sea High. The Danish Central Graben is a complex system of grabens, highs and intermediate plateaus. Since this study covers the area close to the Ringkøbing Fyn High, deals exclusively with the easternmost part of the Central Graben.

To the west of the Ringkøbing Fyn High four units with different Upper Jurassic and Lower Cretaceous subsidence histories occur (Møller 1986). From south to north they are the Salt Dome Province, the Poul Plateau, the Tail End Graben and the Søgne Basin (Figure 1). The Salt Dome Province (Plate 1) makes up most of the southern Danish Central Graben. It is bounded to the east by a normal fault zone along the border of the Ringkøbing Fyn High. Opposite to other areas, the Upper Jurassic sediments in the Salt Dome Province, have a uniform thickness in the western and eastern part. An increase in thickness of the Upper Jurassic sediments can be seen from south to north towards the Tail End Graben (Møller 1986). The Salt Dome Province is characterised by several salt structures. The Poul Plateau (Plate 2) is situated at the transition between the Salt Dome Province and the Tail End Graben, as an intermediate zone between the Ringkøbing Fyn High and the deeply subsided areas to the west.The Tail End Graben (Plate 3) is a pronounced halfgraben with its depocentre situated to the east of the Ringkøbing Fyn High. This is the area with the highest Late Jurassic subsidence rate within the studied area. A four km thick pile of sediments was deposited during the Middle and Upper Jurassic. In the Late Jurassic, the Arne Elin Graben was developed at the western margin of the Tail End Graben. This graben was later inverted, and can now be seen as a positive structure on seismic images (Michelsen *et al.* 1987). The northernmost part of the Danish Central Graben is occupied by the Søgne Basin (Plate 4) which is a half graben with a lower Late Jurassic subsidence rate compered to the Tail End Graben. The Søgne Basin extends into the Norwegian sector, and is bounded by the Mandal High to the west.

The main fault in the area, along the Ringkøbing Fyn High, i.e. the Coffee Soil Fault, strikes in a NNW-SSE direction. Transversely to this, a series of WNW-ESE trending faults occur (Møller 1986; Michelsen *et al.* 1987). These faults, striking obliquely to the main rift trend, have been called transverse zones by Cartwright (1987), who mapped three transverse zones in the Danish sector. The first one is called the Dan Transverse Zone and transects the middle part of the Salt Dome Province, though Cartwright (1987) incorporated the Salt Dome Province and the Søgne Basin as segments within the Tail End Graben. The second zone, the Adda Transverse Zone, makes up the boundary between the Salt Dome Province and the Tail End Graben. The third zone, the Lulu Transverse Zone, extends from the Mandal High to the main fault, and makes up the boundary between the Tail End Graben and the Søgne Basin. Right lateral strike slip movements along the transverse faults are responsible for the more pronounced Late Jurassic subsidence in the Tail End Graben compared to the surrounding areas. The right lateral strike slip ceased during the Early Cretaceous, and the subsidence continued, with a much slower and more uniform rate in the whole area along the Coffee Soil Fault (Michelsen *et al.* 1987). Inversion tectonics elevated several regions during the Cretaceous and Tertiary. Most of this took place while the chalk was deposited, i.e., during the Late Cretaceous. However, the first pulse of inversion movements probably occurred as early as the Hautervian (Vejbæk & Andersen 1987).

## *Deposition and stratigraphy*

A transgression reached its maximum towards the end of the Oxfordian. In the begining of the Middle Volgian a regressive phase commenced, which reached its peak in late Volgian times. In the latest Volgian a new transgression started, which continued until middle Hautervian times, though the relative sea level rise was slow (Rawson & Riley 1982). At the transition from Oxfordian to Kimmeridgian, and in response to the continuing transgression, the muddy Farsund Formation was formed. The amount of organic matter in the formation is high, 3-5%, and mostly of liptinitic origin (Lindgreen *et al.* 1982). The Farsund Formation is present throughout the Danish Central Graben with the exception of some intrabasinal highs (Feldthusen *et al.* 1986). However, the thickness varies greatly from place to place. In the Tail End Graben seismic data indicate a thickness of more than 3000 m (Møller 1986), and in the Salt Dome Province the thickness is between 200 m and 500 m. This suggests a higher rate of subsidence in the Tail End Graben than in the Salt Dome Province during the deposition of the Farsund Formation (Michelsen *et al.* 1987).

At places, a unit with anomalously higher organic carbon content than is present at the top of the Farsund Formation. This unit, called the Hot Unit because of the high level of gamma ray radioactivity, has an organic carbon content of up to 5-7 %, mostly of liptinic origin (Feldthusen *et al.* 1986). The deposition of the Hot Unit could be a response to the Volgian regression, which may have caused the enclosure of basins leading to restricted bottom water circulation, which in turn caused anoxic conditions (Michelsen *et al.* 1987). The Farsund Formation, particularly the upper part including the Hot Unit, is the major source rock in the Danish Central Graben (Damtoft *et al.* 1992). The maturity of the top part of the Farsund Formation is within the oil window in the northern part of the Tail End Graben, whereas the base is mature to postmature in almost the entire Danish Central Graben (Damtoft *et al.* 1992).

The Farsund Formation is succeeded by the shale-dominated Valhall Formation, which has a lower organic content than the Farsund Formation (Michelsen *et al.* 1986). The lowest part of the Valhall Formation is called the Leek Member. This member is distinguished by a notable carbonate content.

In some wells located close to the Ringkøbing Fyn High, coarse clastic sediments of Volgian to Valangian age have been found, which are included in the Poul and Vyl Formations. The Poul Formation is superimposed on, or interbedded within the Farsund Formation, while the Vyl Formation overlies the Farsund Formation at all places. The location of the sediments, on the footwall of an active fault, suggests that they were deposited by density currents in a submarine fan delta system (Damtoft *et al.* 1992). The Poul and Vyl formations were observed in the wells Ugle-1 and V-1 on the Poul Plateau (Damtoft *et al.* 1992). The Vyl Formation has later been found in the well Deep Adda-1. Coarse clastic sediments of the same age, informally referred to as the Kira sand, have also been drilled at the transition between the Tail End Graben and the Søgne Basin in the Amalie-1 well.

# Material and methods

## *Working strategy*

During this study, stratigraphic and geophysical well logs and processed seismic data were provided by Amerada Hess. My task was to get an overveiw of all the seismic lines and selected well logs, and to define and trace the main seismic reflectors and faults in the study area. When this was done areas with potential submarine fans in petroleum reservoir positions were identified.

## *Wells*

Twelve well logs were used in this study, from south to north: South East Igor-1, G-1, Ugle-1, V-1, E-1, Deep Adda-1, Adda-1, Iris-1, Gulnare-1, Tabita-1, Amalie-1 and West Lulu-3 (Fig. 1). The studied material is partly classified, and references can therefore not always be given. That is for instance the case for dating details of the wells.

The four wells Ugle-1, V-1, Deep Adda-1 and Amalie-1 are of particular interest, as these wells penetrate the Poul Formation, the Vyl Formation and the Kira sand. The depth intervals comprising these units have been studied in detail (Figs. 2-3).

The Ugle-1 well contains more than 200 m of sediments of the Poul and Vyl Formations. In Ugle-1 these two formations are separated by ten meters of limestone referred to the Mine Formation. Datings show that the Poul Formation is of late Volgian to middle Ryazanian age, whereas the Vyl Formation is of late Ryazanian to early Valangian age. The lower part of the Poul Formation consists of thinly interbedded shales and sandstones, whereas the upper part of the Poul Formation and the whole Vyl Formation consist of interbedded sandstones and limestones. There are no oil shows in the Ugle-1 well, and the porosity is very low.

The V-1 is located near Ugle-1, but at slightly greater distance from the Ringkøbing Fyn High. Both the Poul and the Vyl formations are present in this well, though they are thinner than in Ugle-1. The Poul Formation is here of middle Volgian age. The 50 m thick Vyl Formation has been dated to the early Valangian. The sandstones of both formations are fine grained, sometimes grading to siltstones. In contrast to Ugle-1, there are oil stains in these sandstones, but the porosity is very low.

In the Deep Adda-1 only the Vyl Formation is present, which is dated to the late Ryazanian. This 100 m thick succession consists of interbedded shales and fine grained, sometimes silty sandstone with very low porosity.

The Amalie-1 is the only well where the Kira sand has been observed. The Kira sand is a 9 m thick fine grained sandstone with high porosity and notable oil shows. Below the Kira sand, however, several thinner sandstone beds, of the same reservoir quality, has been found of wich the deepest beds occur some 300 m below the Kira sand. The age of these sandstones is from the middle Volgian to the late Ryazanian.

## *Seismic data*

This study includes data from six different seismic surveys. They are named, CGDI-85-R, CGD-85-R, DK, bp84c, DK1, DN90CT (Plate 5). Seismic lines that are of interest to this study, e.g. the ones close to the Ringkrbing Fyn High, have been studied on a Unix based Sun workstation using the software Landmark Seis Works / 2D . The maps in Plates 6-7 where constructed with the software Geoquest CPS-3.

Three reflectors were interpreted on all the studied seismic lines. These are, the Top Chalk reflector, which corresponds to the top of the chalk units, the Base Chalk reflector, which corresponds to the base of the same units, and the Base Cretaceous reflector, which corresponds to the transition between the Farsund Formation and the Valhall Formation. A fourth reflector was interpreted on

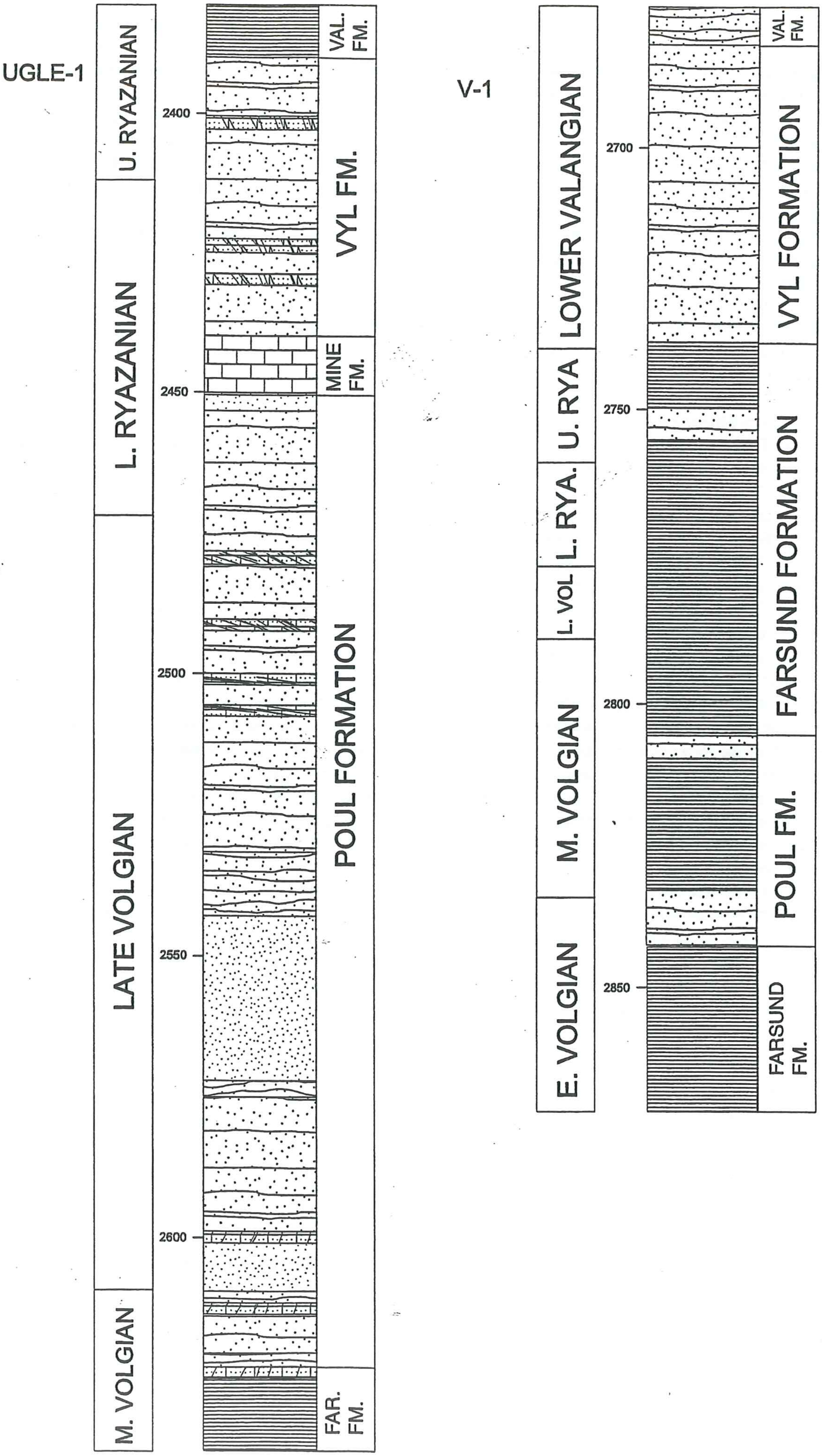

Fig. 2: Well logs for the Ugle-1 and V-1 wells.

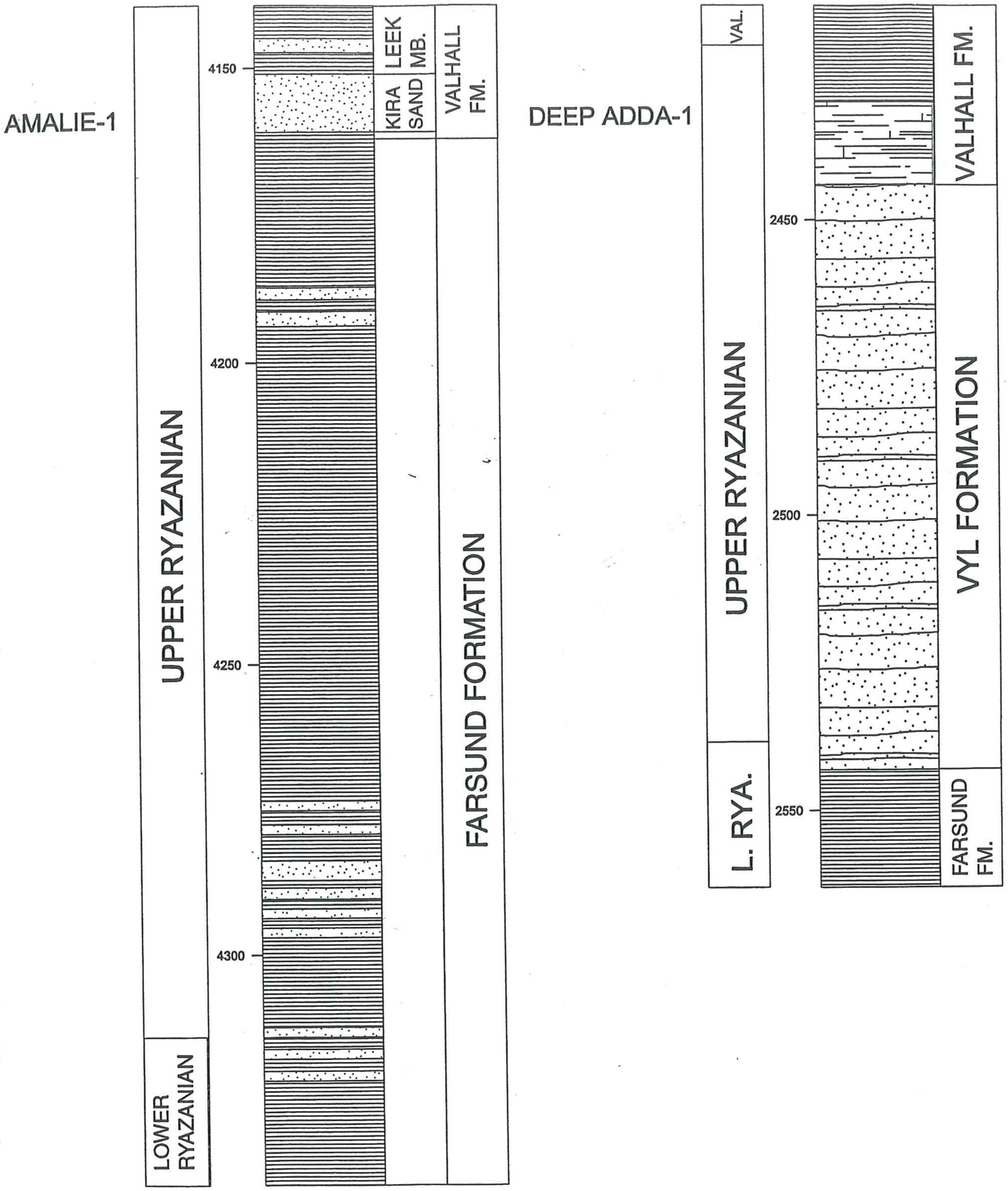

Fig. 3: Well logs for the Deep Adda-1 and Amalie-1 wells.

Tab. 1: Seismic velocities, used for the depth end thickness calculations, for different intervals in the wells (Nielsen & Japsen 1991). Above the Chalk is the interval from the surface down to the Top Chalk reflector. Chalk is the interval between the Top Chalk reflector and the Base Chalk reflector. L. Cretaceous is the interval between the Base Chalk reflector and the Base Cretaceous reflector.

| Well | Above Chalk | Chalk | L. Cretaceous |
|---|---|---|---|
| Adda-1 | 2008 | 3559 | 2384 |
| Deep Adda-1 | 2027 | 3688 | 3019 |
| E-1 | 2040 | 3655 | 2663 |
| G-1 | 2009 | 3773 | 2372 |
| Gulnare-1 | 2064 | 4732 | 3113 |
| I-1 | 2033 | 3048 | 2999 |
| Iris-1 | 2029 | 4377 | 2943 |
| S.E. Igor-1 | 2039 | 3548 | 2390 |
| Tabita-1 | 2066 | 4797 | 3180 |
| Ugle-1 | 2041 | 3935 | 3615 |
| V-1 | 2038 | 4222 | 3805 |
| West Lulu-3 | 2027 | 4395 | 3658 |

the lines shown in Plates 1-4. The interpretation of this reflector, the Base Upper Jurassic reflector, is uncertain. This reflector was tentatively added to give an idea of the potential thickness of the Upper Jurassic sediments in the Danish Central Graben.

The depth scale on all the seismic lines are given in two way travel time TWT. This is the travel time for the seismic signal from the surface down to a reflector and back to the surface. The seismic data was used to construct a map, showing the depth down to the Base Cretaceous reflector (Plate 6), as well as a map showing the thickness between the Base Cretaceous reflector and the Base Chalk reflector (Plate 7). First an interpolation of the TWT is done in areas not covered by seismic lines. In this way calculated TWT values for the reflector are obtained over the entire study area. Subsequently these TWT values are divided by two, to obtain the traveltime for the seismic signal from the surface down to the reflector. The next step is to find the seismic velocities for the different sediments between the sea surface and the reflector. The seismic velocities for sediments on different locations can be obtained from well logs. The velocities used in this project are presented in Table 1. In the same way as the TWT values are approximated between the seismic lines, the velocities are approximated between the wells (Plates 8-9). Finally the travel time values are multiplied by the corresponding seismic velocities, to obtain the depth values, which make up the base for the map. To produce thickness maps, the depth value for one reflector is subtracted from a deeper one.

Tab. 2: Parameters used to calculate the volume of recoverable oil in the A-E structures.

| Parameters | |
|---|---|
| Net-gross ratio | 0.35 |
| Porosity | 0.20 |
| Oil saturation | 0.75 |
| Shrinkage factor | 0.75 |
| Oil recovery factor | 0.25 |

### *Calculations of recoverable oil*

It is possible to calculate the recoverable oil volume of a structure. To do this the total volume of the structure, the gross volume, is multiplied with the net gross ratio, which in this case coincides with the expected sandstone to shale ratio. Thus, the net gross ratio is the factor showing the percentage of the structure with promising reservoir qualities. The remaining volume is then multiplied with the expected porosity of the sediments with promising reservoir qualities, with the expected oil saturation, and the shrinkage factor (as dissolved gas is lost upon pressure decrease). The volume now obtained is termed "oil in place". All oil in the structure, however, can not be recovered, and the oil in place has to be multiplied with the oil recovery factor.

During typical volumetric calculations, three different cases are being presented, i.e., the "best" case, the "worst" case and the "most likely" case. Here, only one case will be presented, to give a crude idea of potentially recoverable oil volumes. Plausible values (pers com; H. Ladegaad, Copenhagen, 1999) were used in the calculation (Tab. 2), and the results are presented in Tab. 3.

## Observations

On five locations reflectors of interest that could represent submarine fans were found, from north to south the locations A-E (Plate 6). They all start and end in contact with the Lower Cretaceous reflector, and are thus simultaneous with the coarse clastic sediments from the wells described earlier. The spaces between these reflectors and the Lower Cretaceous reflector make up isolated bodies with horizontal extensions of a few kilometres (Plates 10-11) that each can be seen on a few seismic lines (Plates 12-14). The extensions were determined by studying all the lines where the reflectors are present. The points where the sediments pinch out, i.e., where the reflectors terminate, is the limit for the sediment bodies on this line. By computer extrapolating those points together, the extensions of the bodies are given. The thickness of the body was calculated in the same way as the thickness between any two reflectors, as described earlier.However, in this case seismic velocity is not known from well data, which means that a velocity has to be assumed. In this case 3000 m/s was selected, as it is a plausible velocity for these sediments (personal communication; H. Ladegaad, Copenhagen, 1999). Thus the calculated thicknesses of the sediment bodies are very tentative. The volumes of the bodies were calculated by using the thickness and the area of the bodies.

Tab. 3: Gross volume and volume of recoverable oil for the A-E structures.

| Structure | Gross volume | Recoverable oil |
|---|---|---|
| A | 400 mil. $m^3$ | 3.9 mil. $m^3$ |
| B | 140 mil. $m^3$ | 1.4 mil. $m^3$ |
| C | 300 mil. $m^3$ | 3.6 mil. $m^3$ |
| D | 370 mil. $m^3$ | 3.0 mil. $m^3$ |
| E | 700 mil. $m^3$ | 6.9 mil. $m^3$ |

# Discussion

## *Location and development of submarine fans*

The five structures described were all found in the area along the Coffee Soil Fault where the Base Cretaceous reflector is situated at the greatest depth (Plate 6), with the exception of structure A. It is also in this area that the Lower Cretaceous sediments are thickest (Plate 7). This thick succession indicates higher rates of Early Cretaceous subsidence in the area of the studied structures A-E compared to other parts of the Danish Central Graben close to the Coffee Soil Fault. On seismic images, it can be seen that this area also had the greatest subsidence during the Upper Jurassic. The high rates of subsidence, combined with a low relative sea level would favour the development and preservation of submarine fans. During this time the Ringkøbing Fyn High was probably exposed to erosion, and simultaneously a lot of accommodation space was created and partly filled due to continuous rapid subsidence of the subsiding basins (Fig. 4). Given the location of the studied area, close to an active fault, the low relative sea level and the fact that contemporaneous submarine fans are present not far south of the study area, as well as coarse clastic sediments north of it, it seems likely that submarine fans would have developed along the Coffee Soil Fault, between the wells Amalie-1 and Deep Adda-1, during the uppermost part of Upper Jurassic and lowermost part of Lower Cretaceous. It is possible that the sediments were distributed parallel to the fault, resulting in a cover of fan sediments in almost the entire deepest part of the Tail End graben (cf. Shanmugam & Moiola 1988).

On the seismic images, indications of submarine fans were found at five locations. One of the five, the A structure, is highly tentative since the top reflector of the structure may be a seismic multiple. Two of the locations, the C and D structures, could be treated as one location, showing stacked fan deposits (Plate 14). As stated earlier, it is uncertain if deep sea fans can be discriminated in seismic images. For example in the Ugle-1 well, twohundred metres of coarse clastic sediments remains undetected in the seismic images. Therefore, it is possible that several other submarine fans, not seen on seismic images, exist.

## *Submarine fan reservoirs*

Submarine fans, found in grabens, are usually made up of coarse conglomerates and channel sediments in the proximal parts, and finer grained turbidites in the more distal parts (Shanmugam & Moiola 1988). The potential fans described in this paper would probably be fairly distal since they are found in the deeper parts of the basin. Thus, they are likely to consist of turbidites. The question whether the turbidites are proximal, with a high sandstone content, or distal, containing mostly shale is of great economical importance. The most favourable case would be proximal, cannibalistic turbidites with incomplete Bouma sequences, where the shale partings has been eroded, leaving a body consisting almost entirely of sandstone. On the other hand, if the bodies consists mainly of distal turbidites, they may contain very little sandstone. The first case would mean a body acting as one excellent reservoir, while the second case would give several smaller reservoirs, separated by shale partings. The most likely situation is that both proximal and distal turbidites can be found within the bodies. However, the sandstone to shale ratio is probably fairly high, considering the relatively short distance to the Ringkøbing Fyn High.

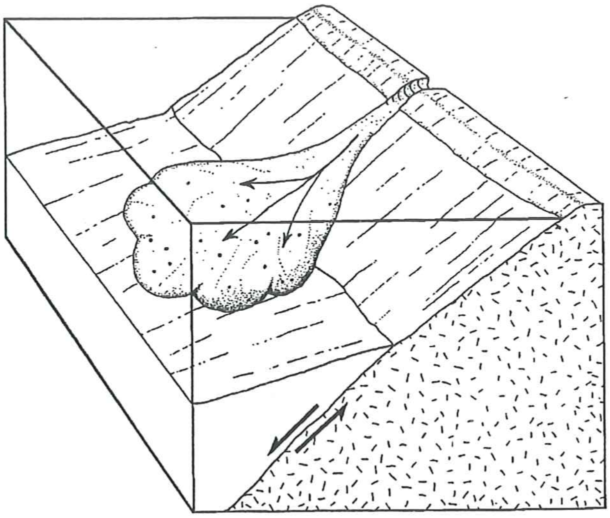

Fig. 4: A model of submarine fan on the footwall of an active fault.

## *Porosity and permeability*

The porosity and permeability of turbidite sandstones are of great importance. In this case it is also very uncertain. South from the investigated structures, the wells Deep Adda-1, V-1 and Ugle-1 are located. The porosities and permeabilities of the sandstones corresponding to the structures dealt with in this paper are very low. In contrast, the coarse clastic sediments of the Kira sand, found in the well Amalie-1, to the north of the structures B-E, is of good reservoir quality. It seems that these sediments have a different, more favourable source.

## *Source rock conditions of the study area*

In the wells Deep Adda-1, V-1 and Ugle-1 there were only small or no traces of oil. This is probably the result of poor communication with mature oil prone source rock (Damtoft *et al.* 1992). The chances of a better communication with a good, mature source rock is much better in the area of most of the studied structures (B-E), whereas the A structure is situated in a less favourable area. This can be seen if the locations of the structures are compared with maps, showing total organic carbon, kerogen type and maturity of the Farsund Formation (cf. Damtoft *et al.* 1992). In fact the structures B-E are located in a area where the oil source rock conditions are very promising. The A structure is situated to the north of the most promising source rock area. On the other hand the A structure is situated close to Amelia-1, which has yielded oil from the Kira sand.

### *Sealing conditions*

The potential oil-bearing structures could be sealed in different ways. For instance shale layers in the turbidite sequence, within the structures, could act as internal seals. The structures situated below the base of the Cretaceous could be entirely enclosed by the shales of the Farsund Formation, which thus could act as a good seal. Likewise, the shales of the Valhall Formation could act as a seal for the structures located above the base of the Cretaceous, as well as for some of the structures below.

## Conclusions

- From a petroleum reservoir perspective, four promising and one less promising structures have been identified.
- The sediments within these structures are probably turbidites, with a fairly high sandstone to shale ratio, and unknown porosity and permeability.
- The structures could have several seal types.
- If the structures consist of sandstones with fair porosity, it is likely that they are oil filled, considering the promising location of adjacent high quality source rocks.
- The most interesting structure in the studied material is the E structure, which has a much bigger volume than the others and is obvious on seismic images.
- Due to a possible seismic multiple the interpreted A structure is highly tentative.
- The remaining structures that are smaller than the E structure, are of intermediary interest.
- It could be a good idea to continue drilling beneath the identified structures, since stacked older fan sediments may be present below them.
- Due to the restricted size of the structures and the variable reservoir quality of contemporaneous corresponding deposits in surrounding areas, drilling in the studied area has to be considered a high risk enterprise.

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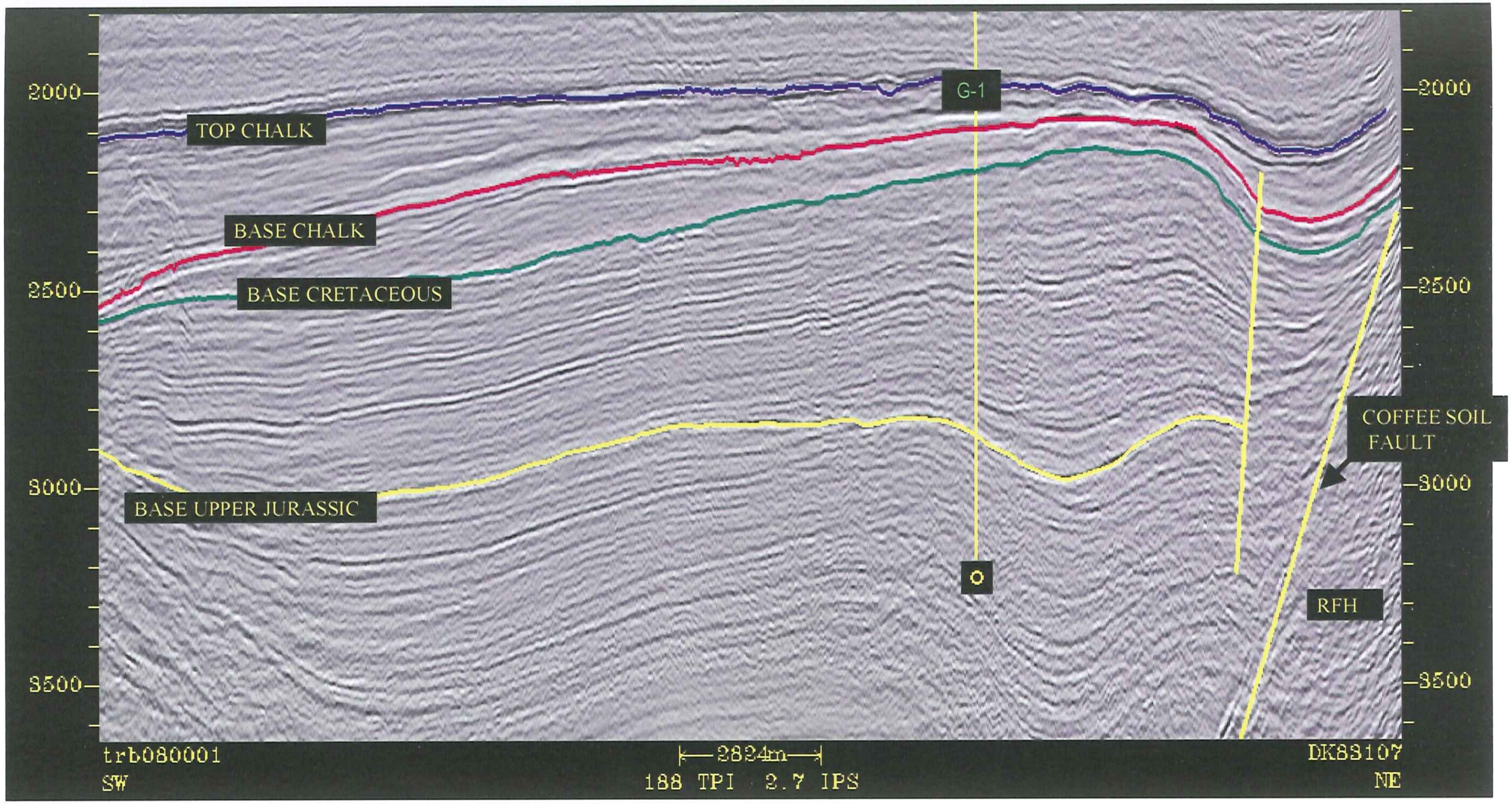

Plate 1: Seismic section DK 83107 from the Salt Dome Province. For location, see Figure 1. Depth scale is given in two way time. Depth scale and horizontal scale varies between the Plates 1-4.

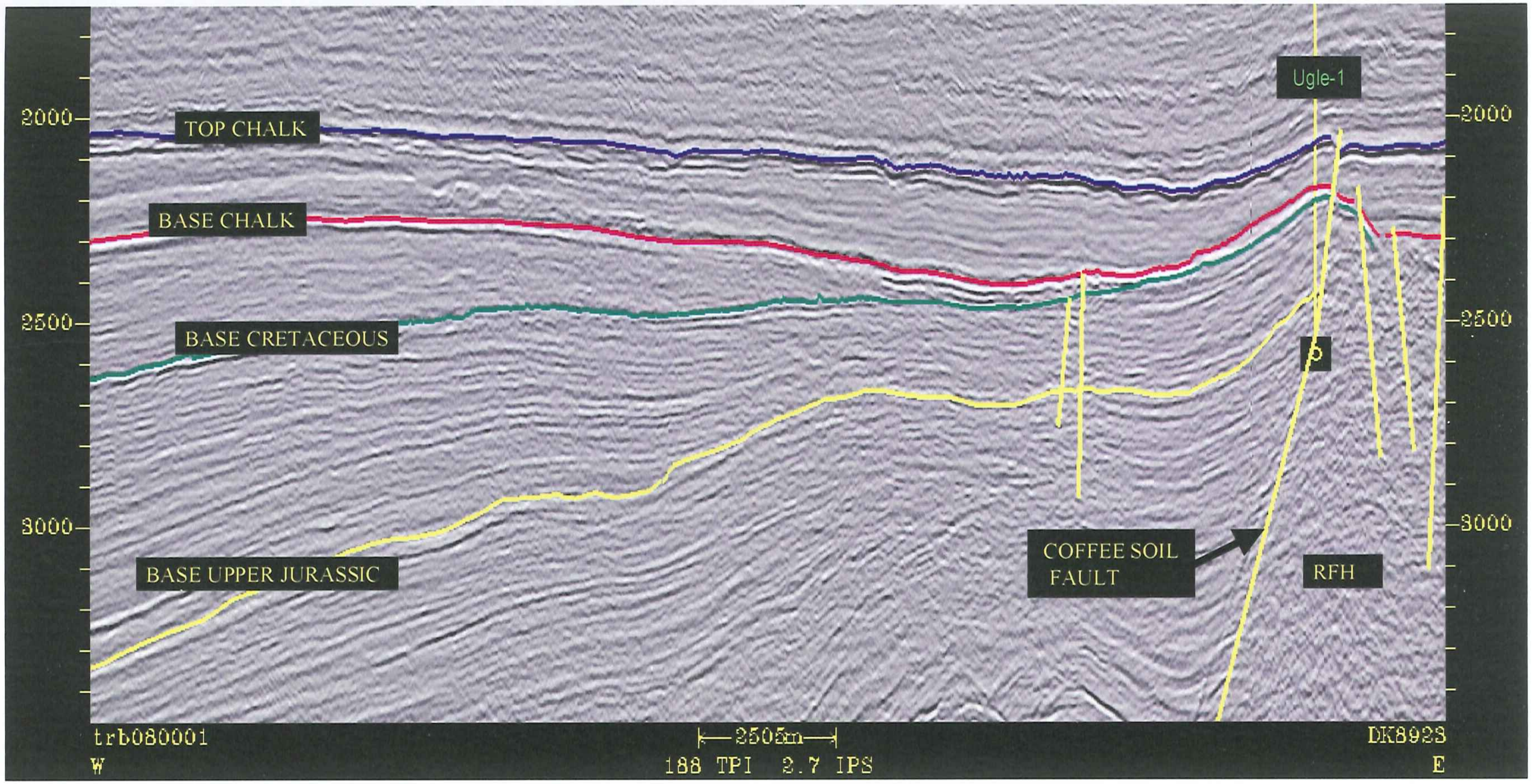

Plate 2: Seismic section DK 8923 through the Poul Plateau. For location, see Figure 1. Depth scale is given in two way time. Depth scale and horizontal scale varies between the Plates 1-4.

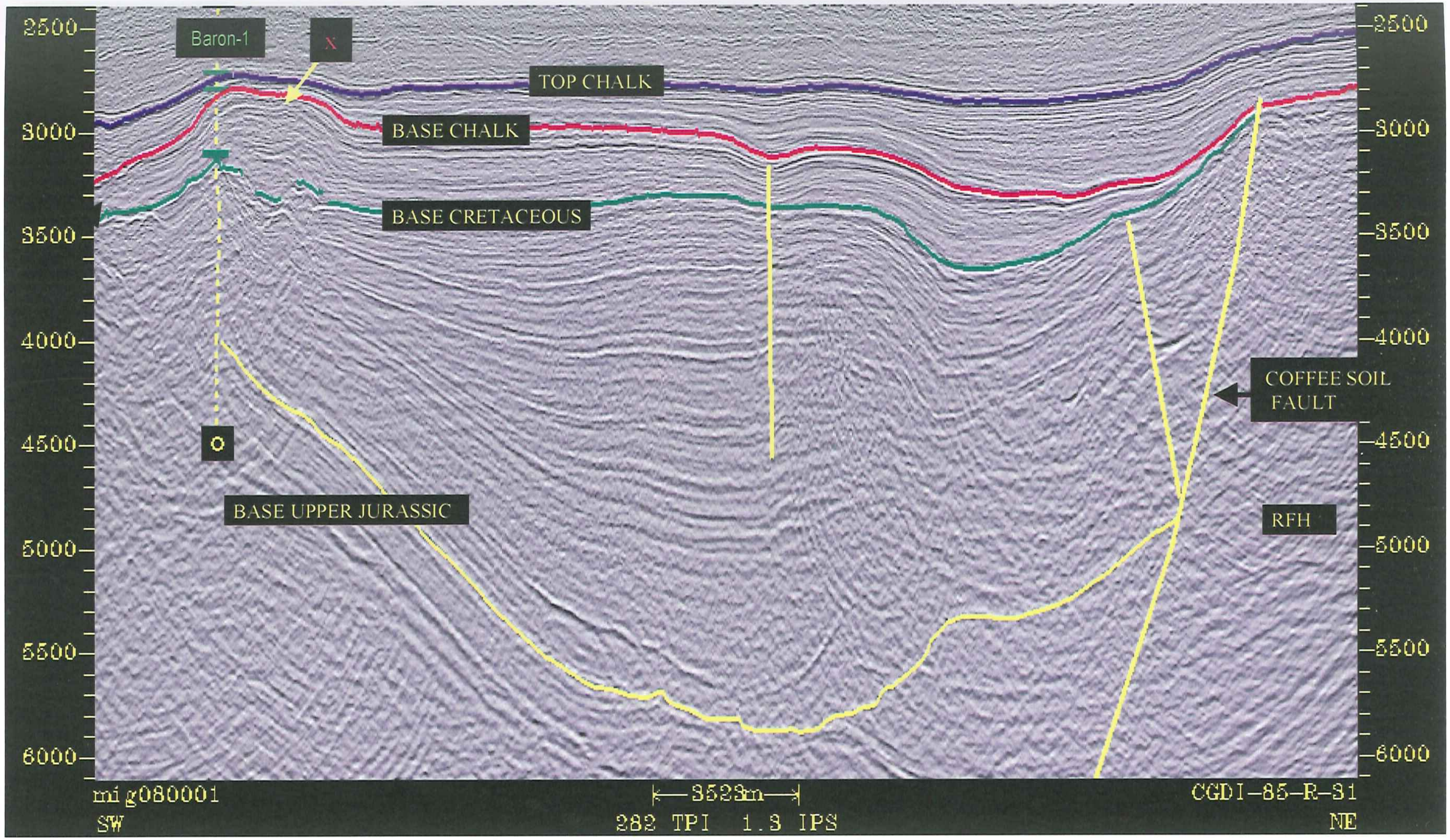

Plate 3: Seismic section from the deepest part of the Tail End Graben. The structure at the x marker is the Arne Elin Graben. For location, see Figure 1. Depth scale is given in two way time. Depth scale and horizontal scale varies between the Plates 1-4.

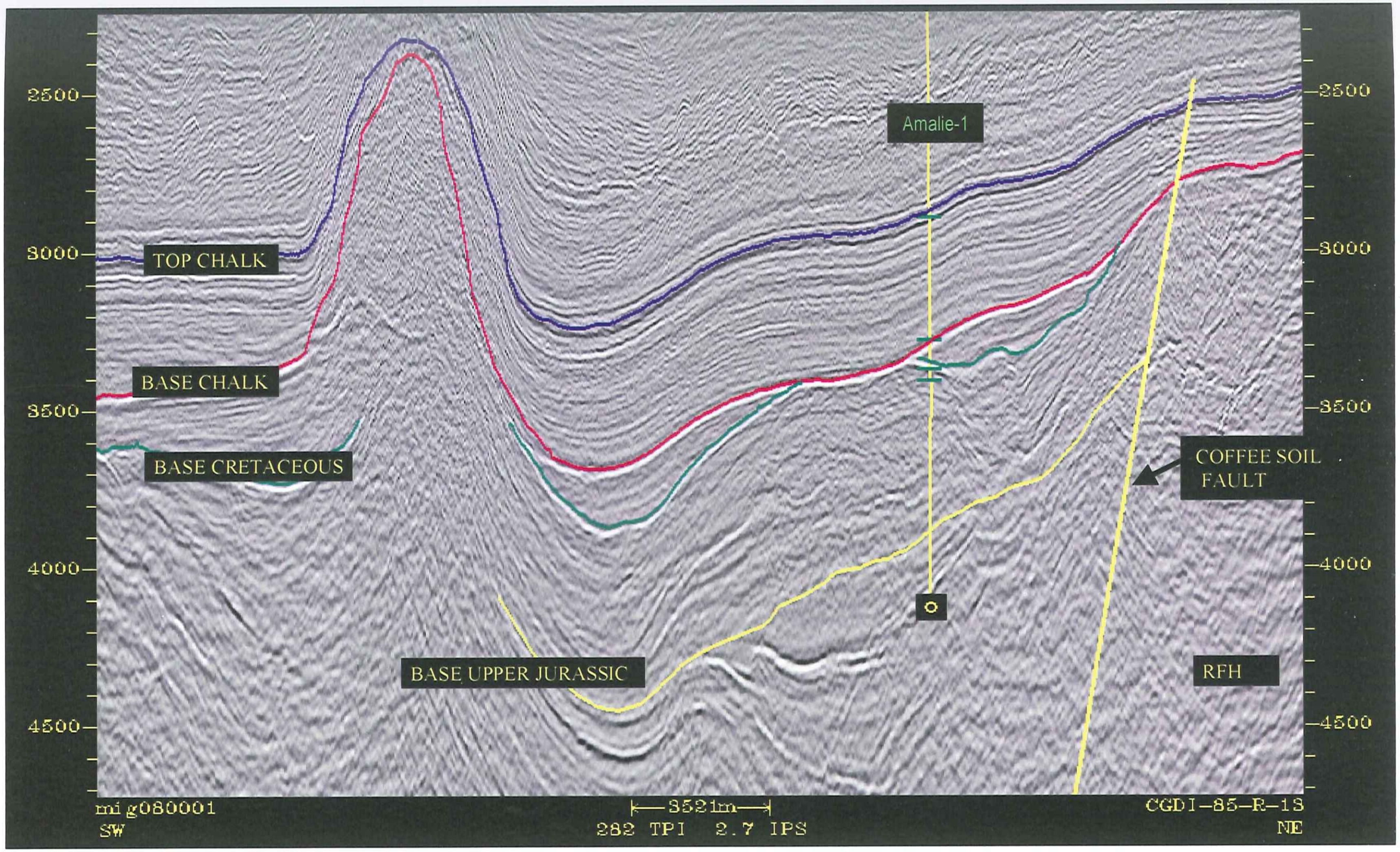

Plate 4: Seismic section from the southern part of the Srgne Basin. The pronounced high to the southwest in the section is a salt structure. The area where the Base Cretaceous reflector has been cut off, is the Mandal High. Depth scale is given in two way time. Depth scale and horizontal scale varies between the Plates 1-4.

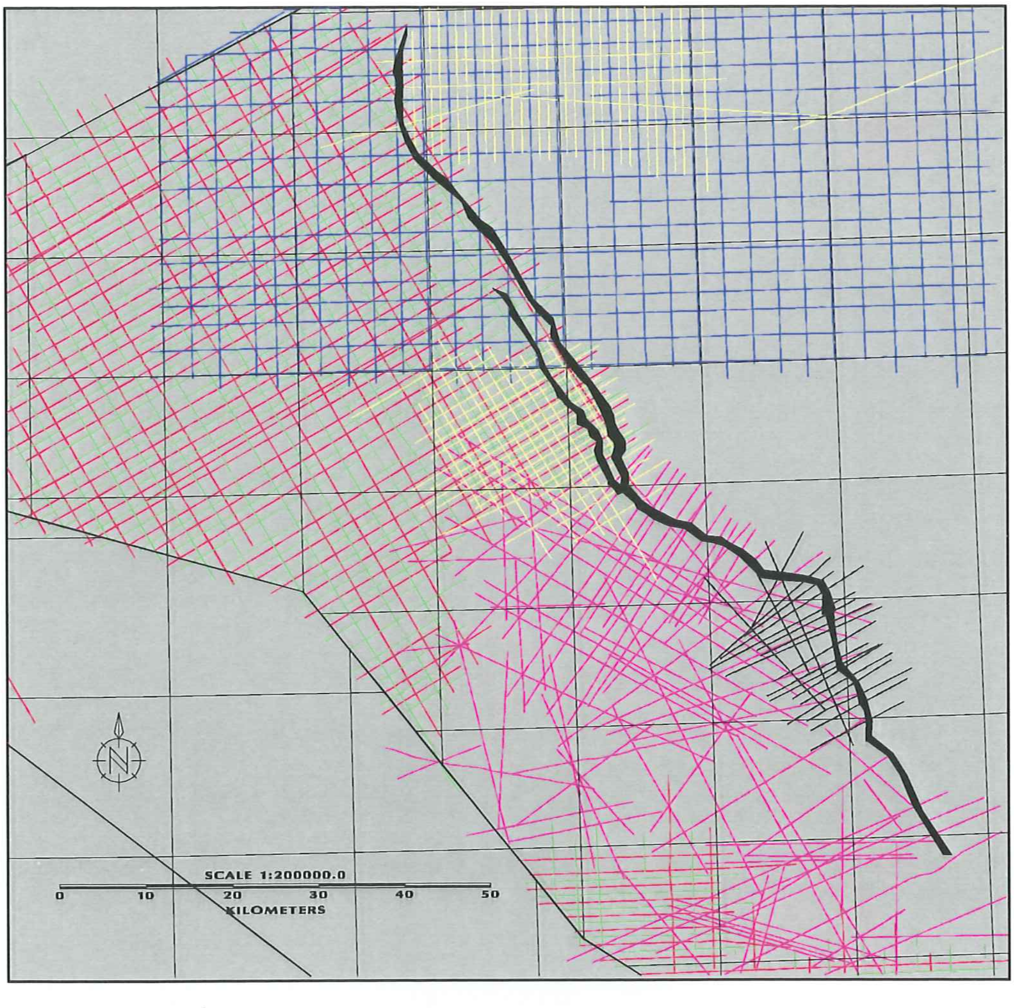

Plate 5: Seismic surveys used in this study. DK1: blue, CGDI-85-R: green, CGD-85-R: red, DN90CT: yellow, DK: purple, bp84c: black.

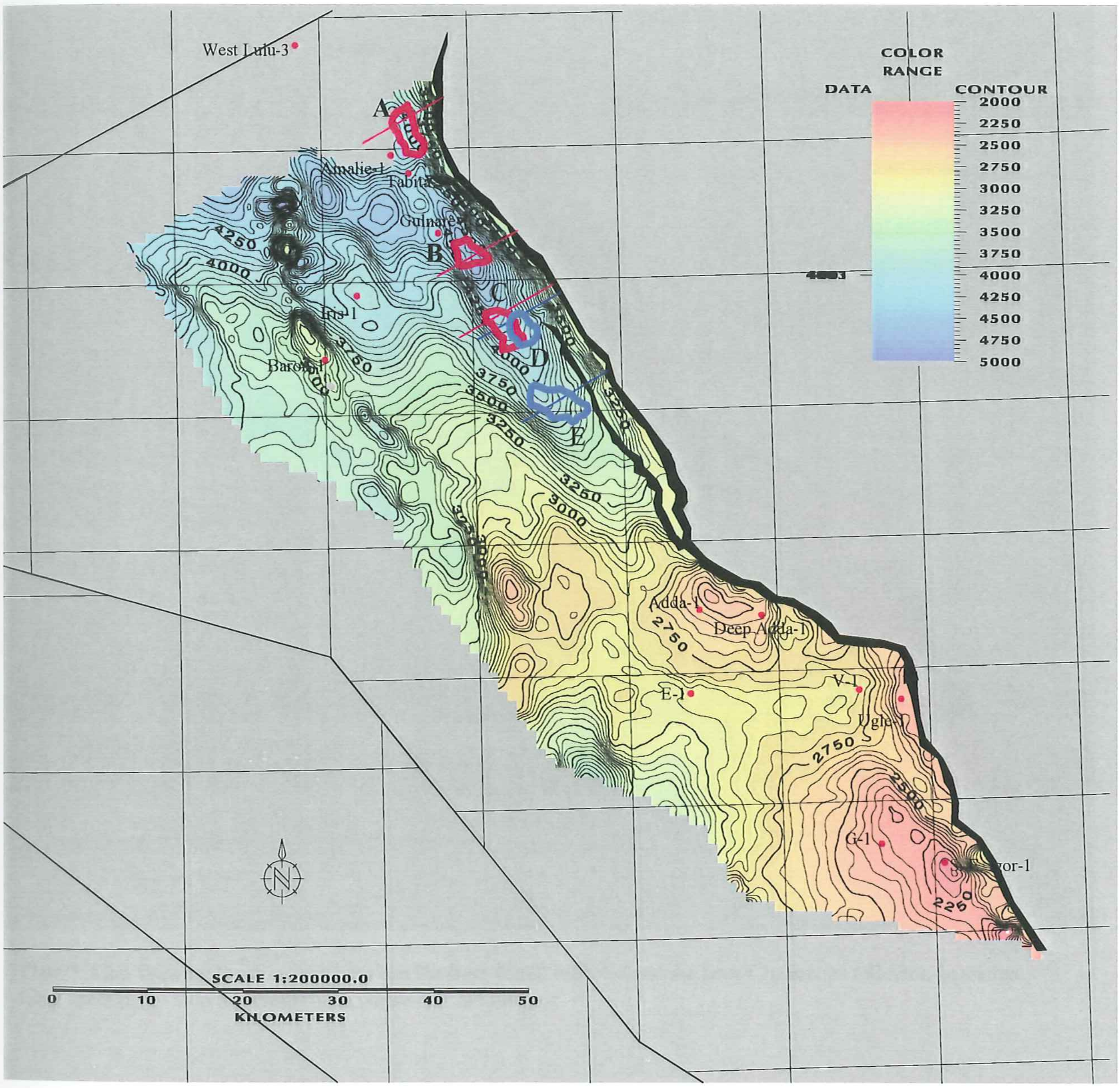

Plate 6: The depth to the Base Cretaceous reflector in the studied area in metres. The red and blue polygons represent the structures A-E and are shown in Plates 10-11. The lines that cut the polygons shows the locations of the seismic sections in Plates 12-14..

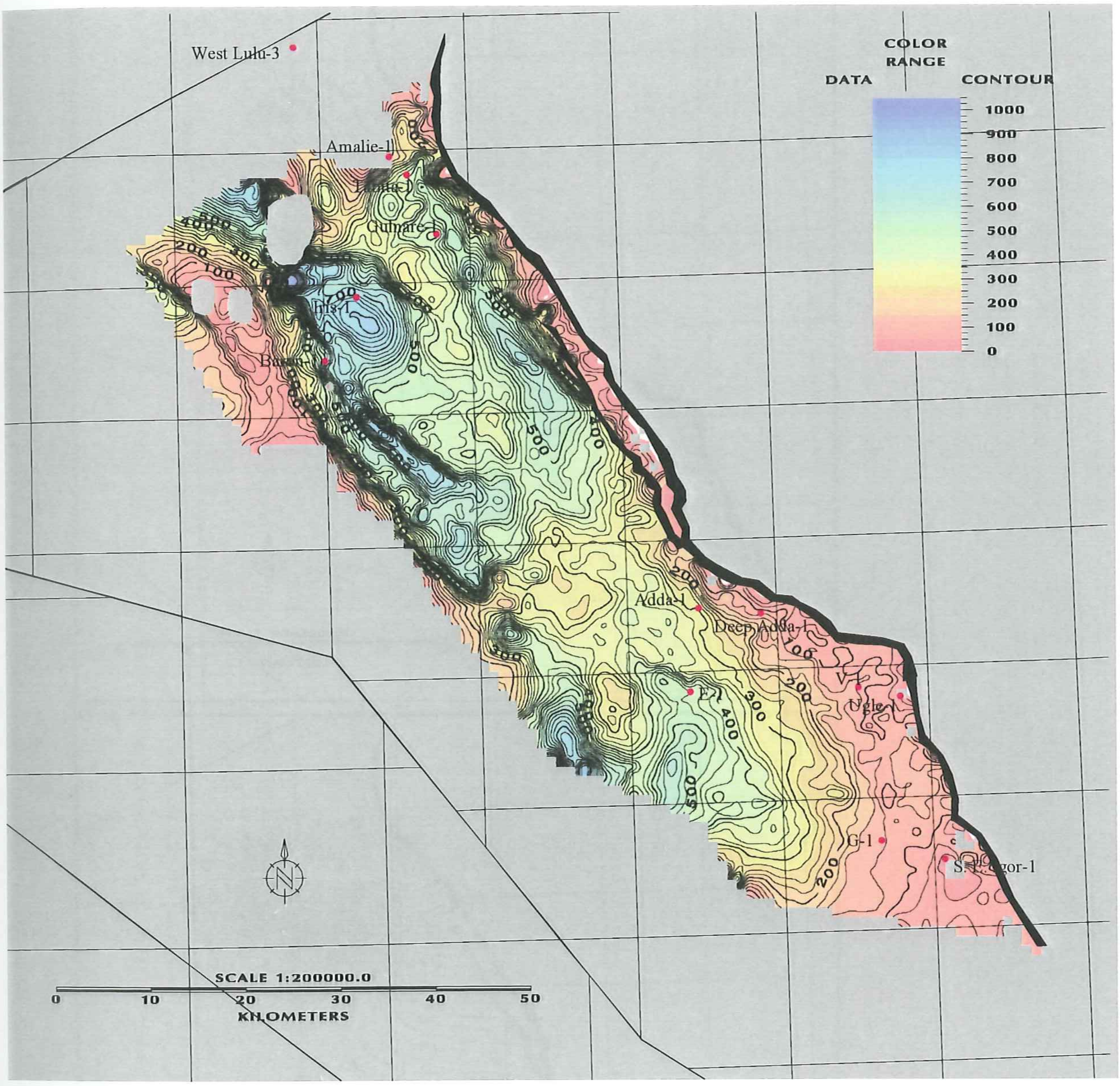

Plate 7: Map showing the thickness between the Base Chalk reflector and the Base Cretaceous reflector, in metres. Grey spots in the map represent fields where data are missing.

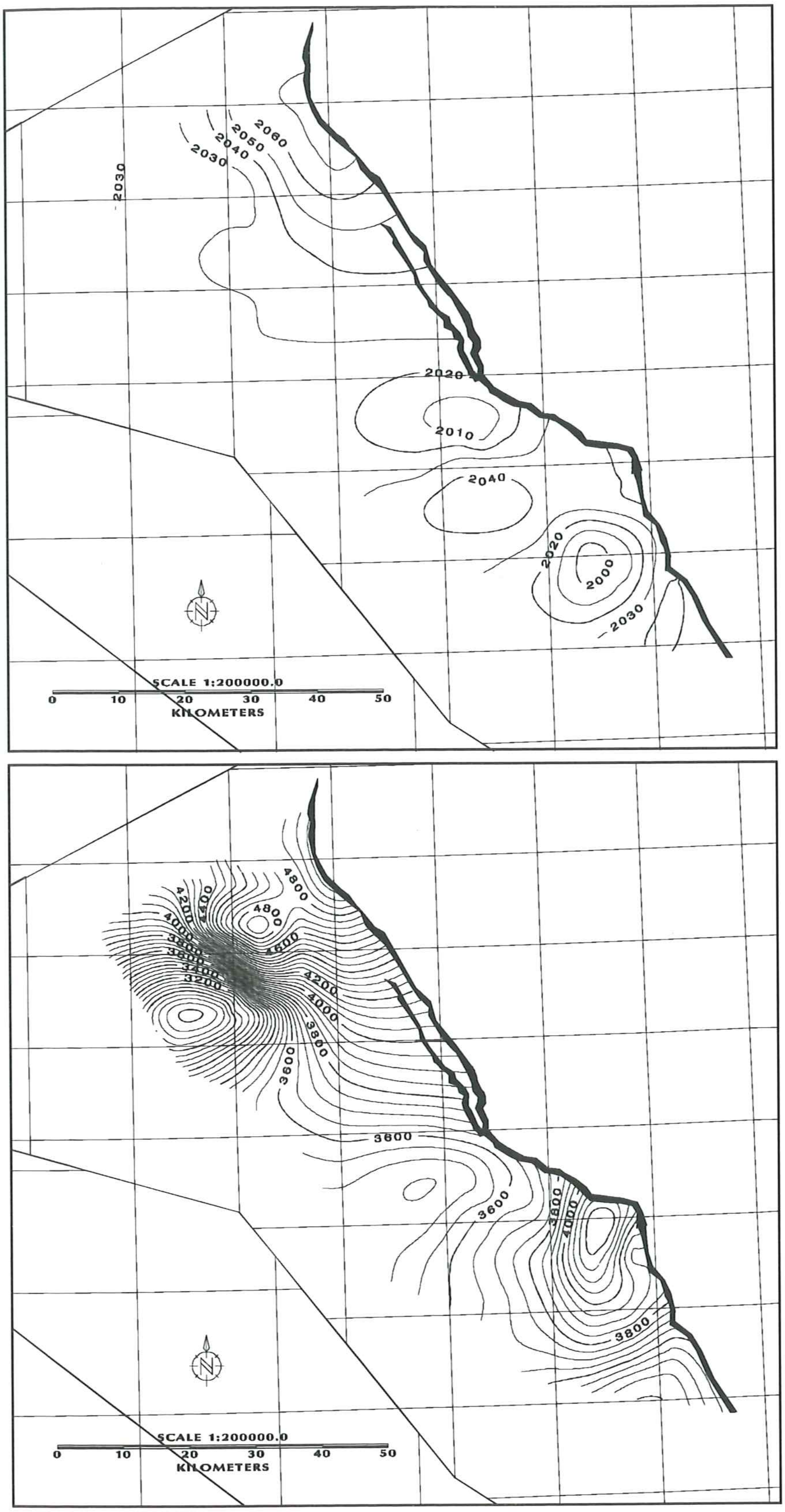

Plate 8: The calculated seismic velocities for the interval from the surface down to the Top Chalk reflector (above), and the interval between the Top Chalk reflector and the Base Chalk reflector.

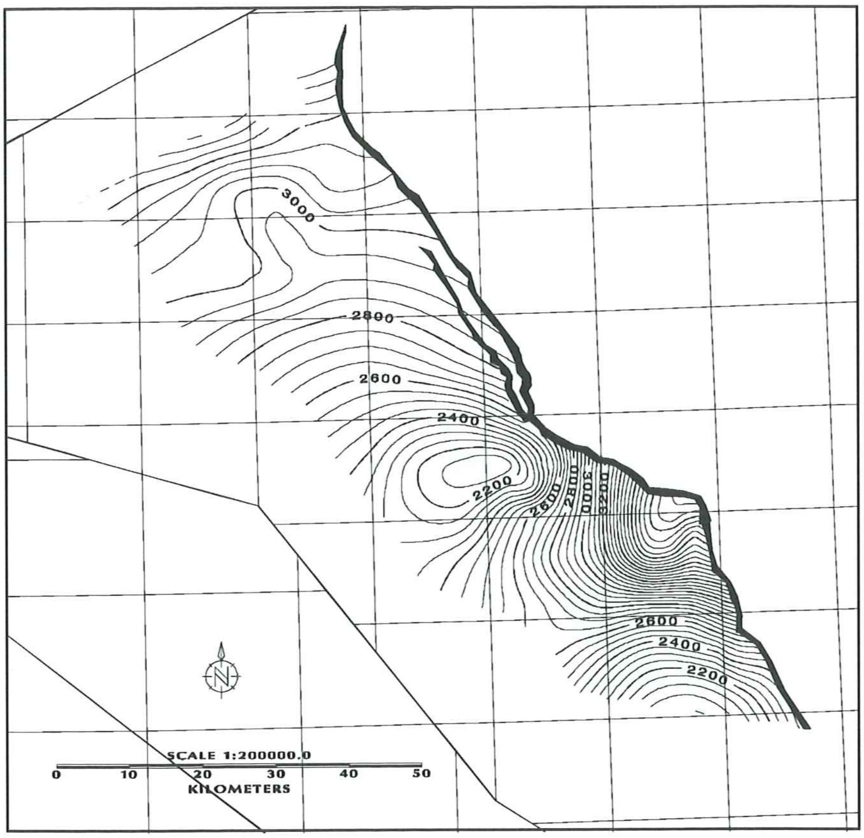

Plate 9: The calculated seismic velocities for the interval between the Base Chalk reflector and the Base Cretaceous reflector.

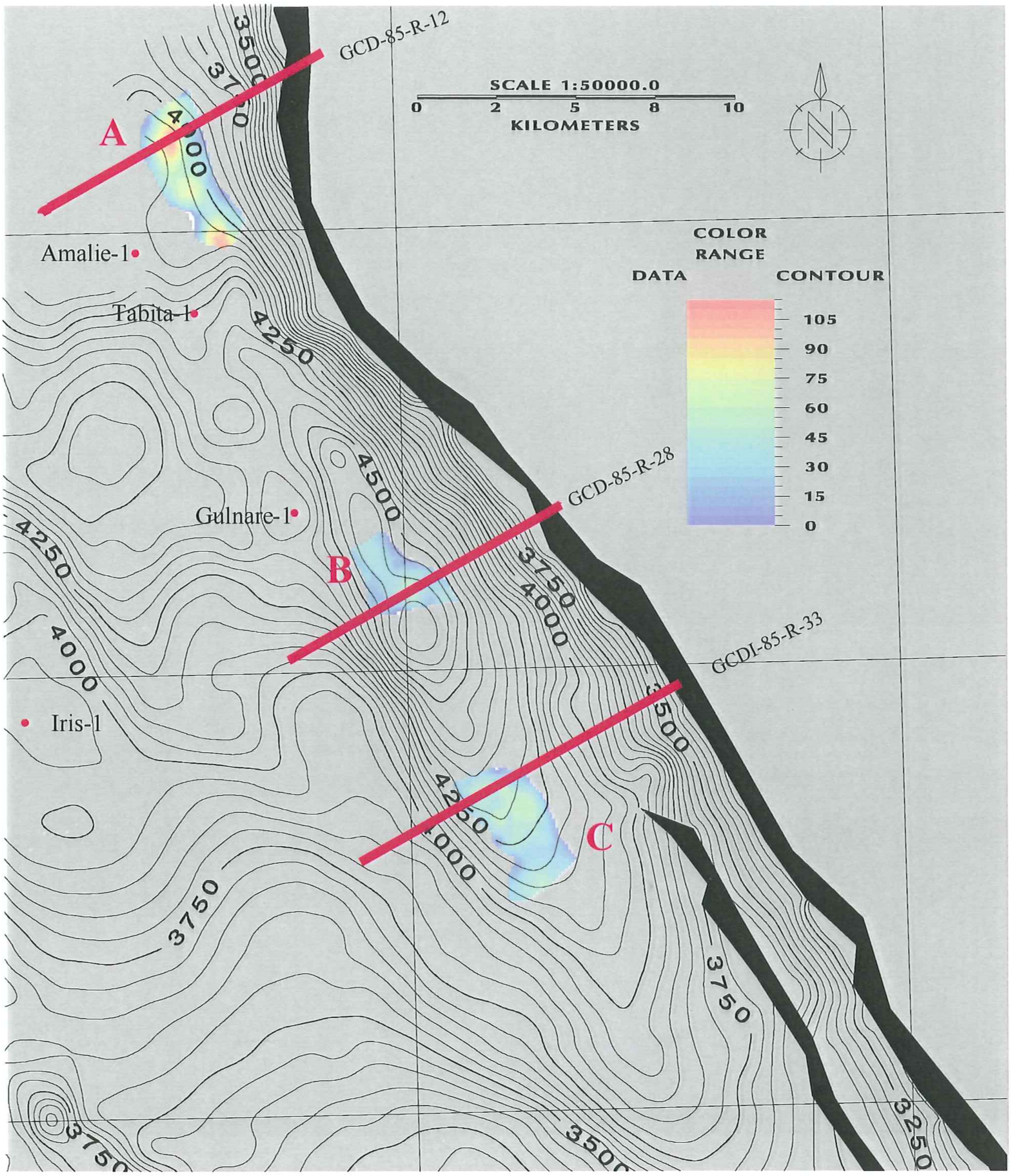

Plate 10: Map showing the extension and thickness (shown in colours) of the A-C structures. The isolines represent the depth of the Base Cretaceous Reflector. The thickness and the depth are given in metres. The red lines shows the location of the seismic sections shown in Plates 12-14.

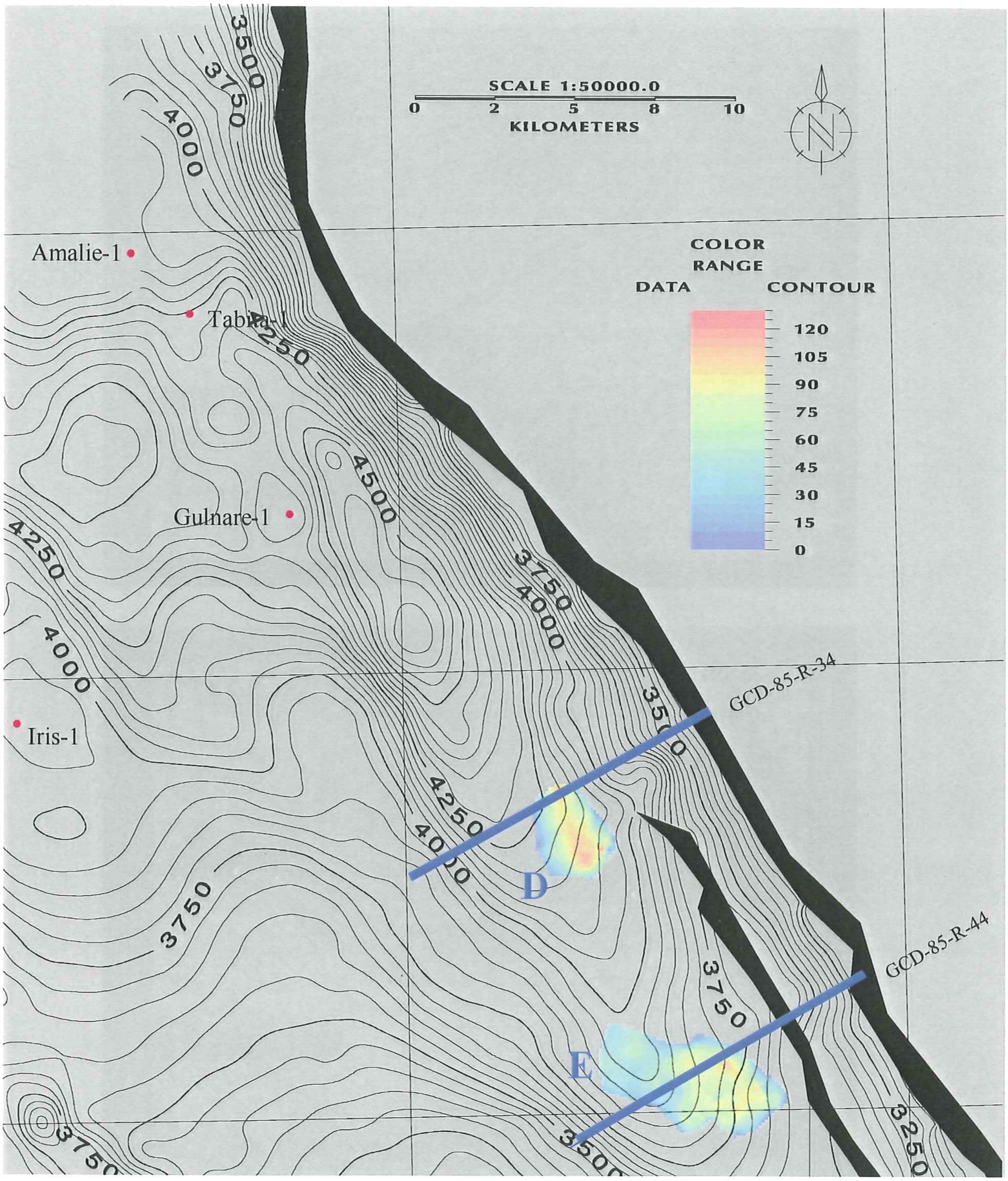

Plate 11: Map showing the extension and thickness (shown in colours) of the D and E structures. The isolines represent t the depth of the Base Cretaceous Reflector. The thickness and the depth is given in metres. The blue lines shows the location of the seismic sections shown in Plate 14.

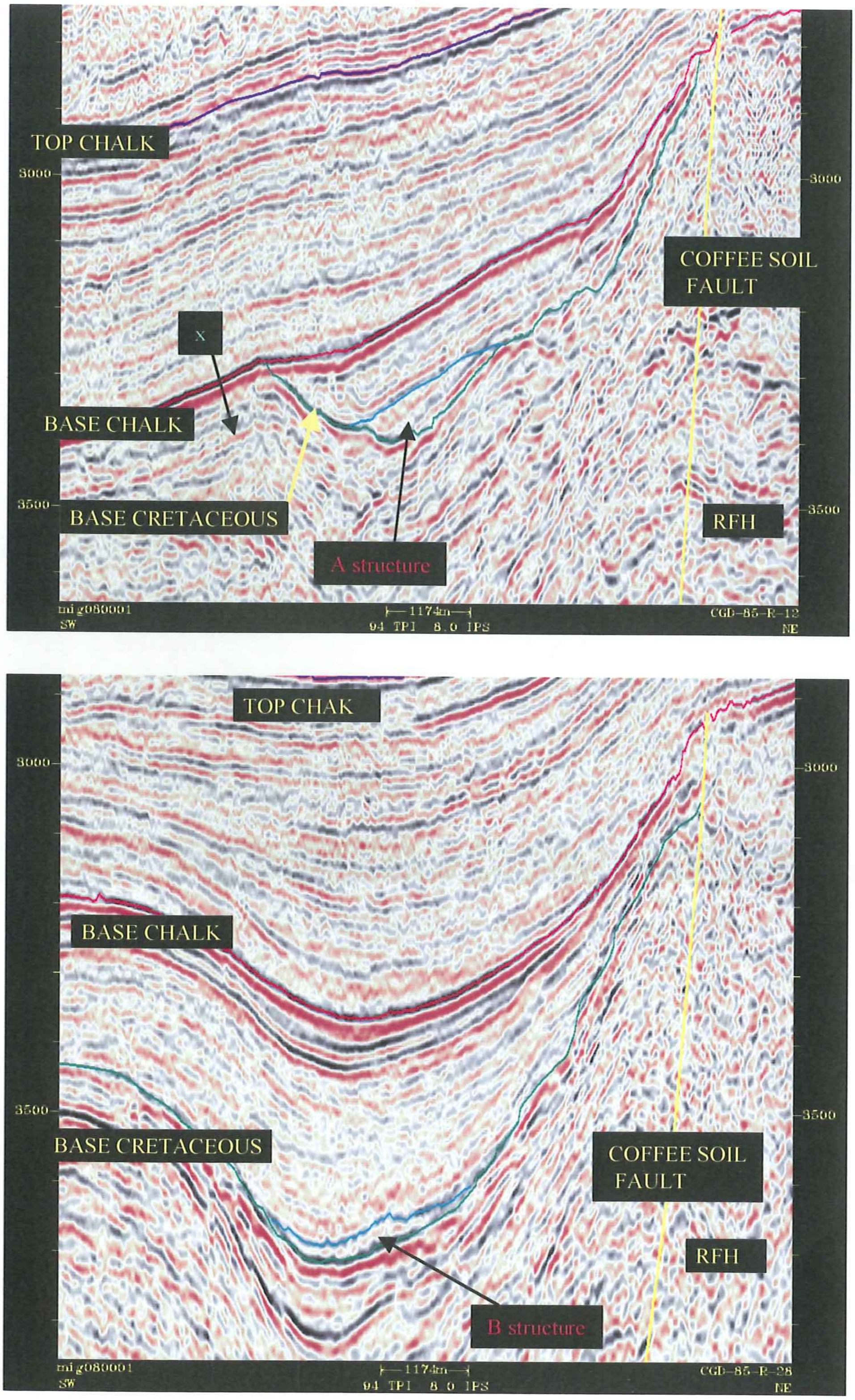

Plate 12: Seismic sections CGD-85-R-12 and CGD-85-R-28 showing the A and B structures. The A structure is very tentative, since the upper reflector possibly is a multiple (It can be traced both to the right and left from the structure, see the x marker.). For location, see Plate 6.

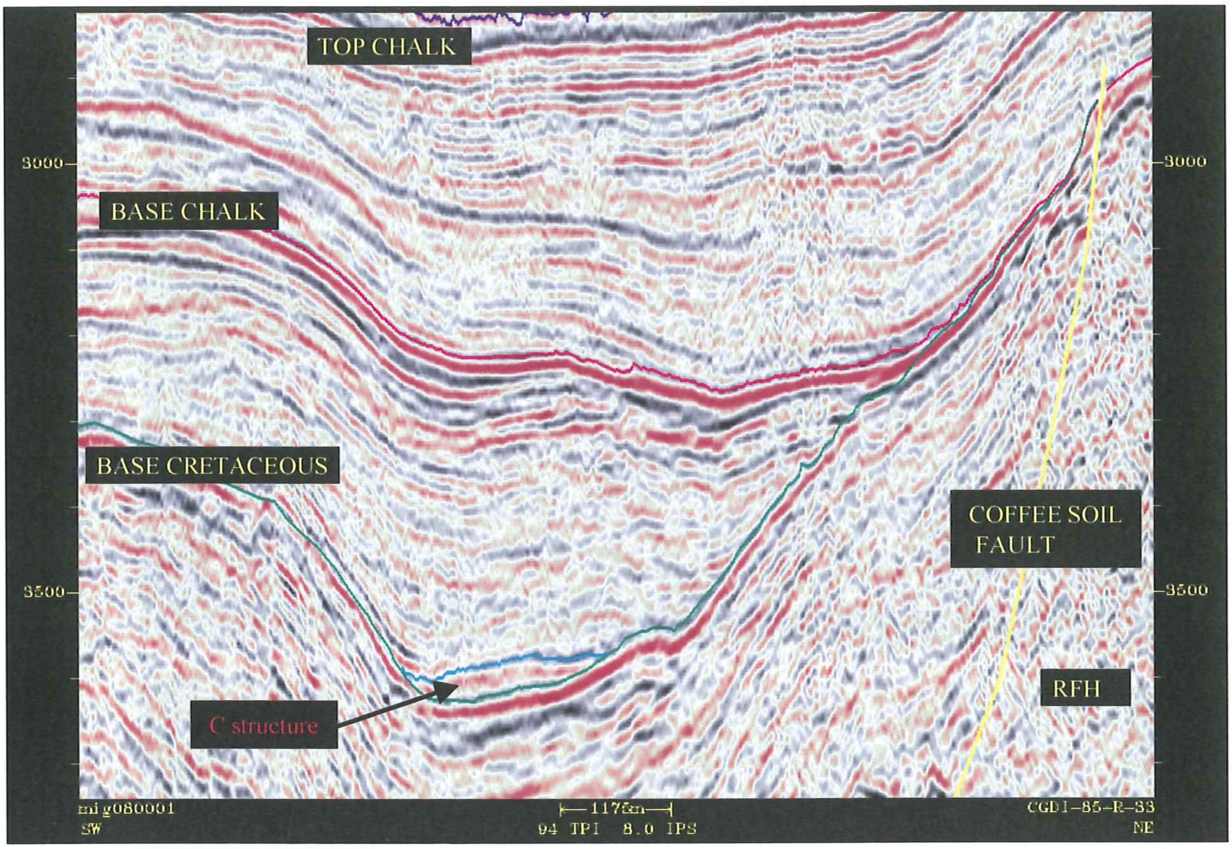

Plate 13: Seismic section CGDI-85-R-33 showing the C structure. For location, see Plate 6.

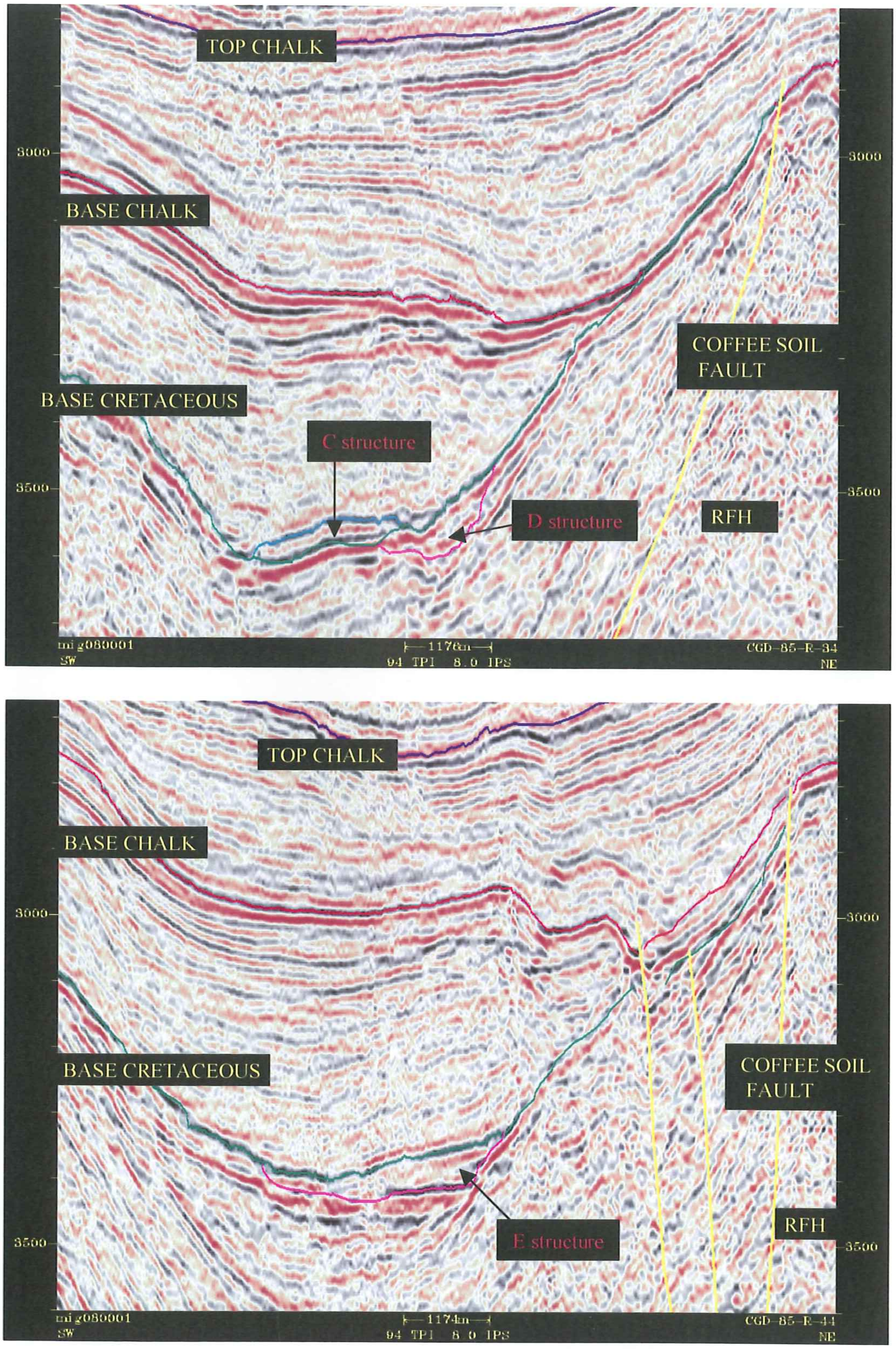

Plate 14: Seismic section CGD-85-R-34 and CGD-85-R-44 showing the D and E structure. The C structure is also seen. For location, see Plate 6.

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