# Exercise 1: Introduction to the Ross Basin

**Objective**

You will get a short introduction to the Ross Basin as we walk through this exercise together – a group discussion lead by the instructor. We will review the known geology based on outcrops and a few onshore wells.

**NOTE**: The geology and HC story are real, just NOT for the Ross Basin.

**Materials**

- Exercise instructions, which include six figures.

**Introduction**

We will simulate the state of knowledge before hydrocarbon exploration began in the Ross Basin (early 1960s). The geology of the Ross Basin was known primarily based on the third of the basin located onshore. There are many Cretaceous to Eocene outcrops in coastal cliffs and mountains. There were several onshore wells. A few seismic lines and cores were obtained in the offshore part of the basin by oceanographic institutions.

For the energy industry, the main question about the offshore were:

- Will we be able to find economic quantities of oil or gas?

Corollaries to this question were:

- Are there large traps that have reservoir-quality rocks capped by sealing lithologies?
- Are there rich source rocks that have generated large amounts of oil or gas?
- Have oil or gas molecules migrated into the large traps?
- Can we extract enough HCs to make a profit?

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# Exercise 1: Introduction to the Ross Basin continued

| Step | Action |
|---|---|
| 1 | Figure 1 shows the location of the Ross Basin in Antarctica.<br>Note the rectangles in the offshore. These are blocks that the Antarctican government plans to auction off. We will conduct a mock lease sale in Exercise 2b (in about an hour).<br>Also note that:<br>• A third of the Ross Basin extends onshore<br>• There are many outcrops of K through Eocene rocks<br>• There are a number of onshore wells<br>• There are **NO** offshore wells. |
| 2 | In Figure 2 the upper left gives a brief tectonic summary. The Ross basin is an extensional, pull-apart basin. Rifting started in the Cretaceous. Active extension ceased at the end of the Cretaceous. The basin continued to sag (thermal cooling) up to the present.<br>Also, note the onshore stratigraphic summary. From shallow to deep, the Neogene has thin, fluvial deposits. The Oligocene has fluvial to nearshore deposits. The Upper Eocene is shelfal and the Lower Eocene is slope deposits. The Paleocene has deep water shales. The Upper K is fluvial to nearshore-offshore |
| 3 | Figure 2 also has a summary of the geologic history. During the Upper K there was a major regression with the paleo-shoreline close to the present shoreline. A major unconformity occurred at the end of the Cretaceous. The area subsided rapidly, which resulted in a major marine transgression. As subsidence slowed, a new regression occurred. During the Eocene the basin slowly filled (slope to shelfal). The regression continued to the present moving the shoreline to its present position. |

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# Exercise 1: Introduction to the Ross Basin continued

| Step | Action |
|---|---|
| 4 | Figure 3 explains the origin of a major unconformity in the Ross Basin at the end of the Cretaceous. This basin started as a segment of an extensional triple junction. Active rifting caused the basin to form and subsidence during the Late Cretaceous. Around the end of the Cretaceous, extension ceased in the Ross Basin – it is an aulacogen (failed rift arm).<br><br>Once extension ceased, the area rapidly subsided and was flooded. Tectonic readjustments resulted in a major unconformity. High portions of tilted fault blocks were eroded. There was also an abrupt change from fluvial-deltaic to nearshore deposits to deep water sedimentary facies.<br><br>The Late Cretaceous Scott Formation has fluvial to nearshore (beach) deposits near the current shoreline – these are potential reservoir rocks. The Paleocene Shackleton Formation consists of deep water shales deposited as the basin rapidly subsided during a major marine transgression – there are potential sealing rocks.<br><br>This major unconformity is called the Top of Scott unconformity, for the name of the underlying formation. It is abbreviated TOS. |
| 5 | Figure 4 illustrates three (3) key play elements that may exist in the Ross Basin. We have the potential for large, extensional fault blocks. There can be HC traps on the high-side of these fault blocks.<br><br>The Scott Formation has potential fluvial and nearshore reservoir rocks. The overlying Shackleton Formation consists of deep water shales which can be a very effective seal. Thus, we might have the juxtaposition of a quality seal over a quality reservoir rock within structural anticlines or high-side fault closures.<br><br>If there are good source rocks that have generated oil and/or gas and adequate HC migration paths, we have all the play elements working together favorably. Thus the HC potential for the Ross Basin is high. |

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| Step | Action |
|---|---|
| 6 | Figure 5 discusses what we might expect in terms of seismic responses for the Shackleton and Scott Formations.<br><br>The lithology for the Shackleton should be primarily deeper water, low energy, distal shales and pelagic “snow” (pelagic material). There should not be much variation laterally or vertically in acoustic properties, velocity and density. Thus, the amplitude of seismic reflections should be very low.<br><br>The lithology for the Scott should be interfingered fluvial to shallow water sands, silts, shales and coals due to pulses of deposition (parasequences and parasequence sets). There should be more significant vertical variations in velocity and/or density. Thus, seismic reflections should have higher amplitudes. |
| 7 | Now we are ready for the heart of the exercise. Figure 6 shows a portion of a seismic line from the offshore portion of the Ross Basin. Take a few minutes to examine this line. Can you see some faults? Can you spot a major unconformity? Can you hypothesize where the Shackleton and Scott Formations are positioned?<br><br>After a few minutes, the instructor will discuss these geologic features. |

## Ross Basin, Offshore Antarctica

Exercise 1

- Offshore blocks will be offered up in a lease sale
- A third of the Ross Basin extends onshore
- There are many outcrops of Cretaceous and Early-Tertiary rocks
- There are a number of onshore wells
- There are **NO** offshore wells

● **Onshore well locations**

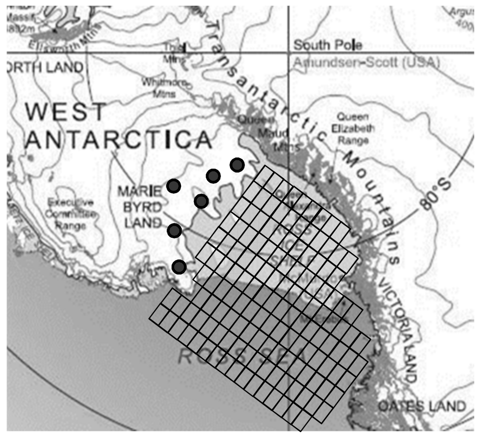


**Figure 1. Location map for the Ross Basin offshore blocks.**

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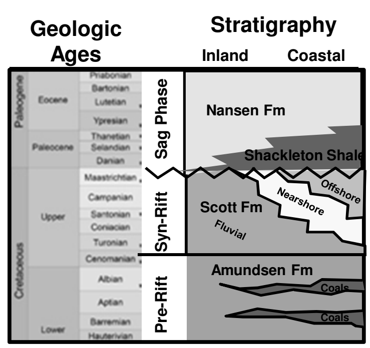
## Ross Basin, Offshore Antarctica

Exercise 1

### Tectonic Summary
- The basin is an extensional, pull-apart basin
- Rifting started in the Mid Cretaceous
- Extension ceased near the end of the Cretaceous

### Onshore Stratigraphic Summary
- The Neogene has thin, fluvial deposits
- The Oligocene has fluvial to nearshore
- The Eocene is mid slope to shelfal
- The Paleocene has deep water shales
- The Upper K is fluvial to nearshore-offshore




### Geologic History Summary
- During the Upper K there was a regression with the paleo-shoreline ending up close to the present shoreline
- A major unconformity occurred at the end of the Cretaceous
- The area subsided rapidly, which resulted in a major marine transgression
- As subsidence slowed, a new regression occurred
- During the Eocene the basin slowly filled (slope to shelfal)
- The regression continued to the present moving the shoreline to its present position

**Figure 2. Geologic summary for the Lower Cretaceous to Upper Eocene.**

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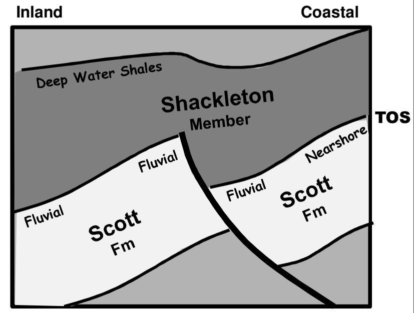
## A Major Unconformity

Exercise 1

**The TOS Unconformity**

- The Ross Basin started as a segment of an extensional triple junction
- Active rifting caused basin subsidence from during the Late Cretaceous
- Around K-T boundary, extension ceased in the Ross Basin (a failed rift segment)
- Once extension ceased, the area rapidly subsided and was flooded
- The tectonic readjustments resulted in a major unconformity with erosion of highs on tilted fault blocks and an abrupt change from shallow to deep water facies




- The Upper K Scott Formation has fluvial to nearshore (beach) deposits near the current shoreline – these are potential reservoir rocks
- The Paleocene Shackleton Member consists of deep water shales deposited as the basin rapidly subsided during a major marine transgression – these are potential sealing rocks

**Figure 3. Explanation of the Top of Scott (TOS) unconformity.**

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## Trap, Reservoir & Seal

Exercise 1

- Rotated, extensional fault blocks form large potential structural traps
- The Scott Formation has fluvial and nearshore sands that can have reservoir quality porosity & permeability
- The Shackleton Member can be a very effective seal

  - **Anticlinal Traps**
  - **Scott Reservoirs**
  - **Shackleton Seals**

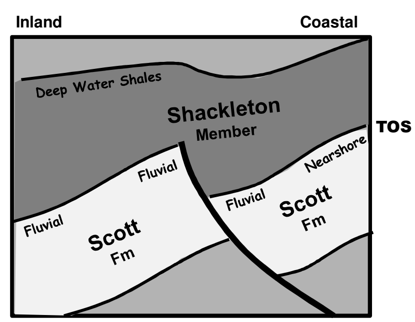


**Figure 4. Potential traps, reservoirs and seals in the offshore blocks.**

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## Likely Seismic Responses

Exercise 1

### Shackleton Seals

- Should be primarily deeper water, low energy distal shales and pelagic "snow"
- Not much variation laterally or vertically in velocity or density
- Thus very low amplitude seismic reflections

TOS Unconformity

### Scott Reservoirs

- Should have interfingered sands, silts and shales due to pulses of deposition (parasequence sets)
- More significant vertical variations in velocity and/or density
- Thus much higher amplitude seismic reflections

Figure 5. Expected seismic amplitude responses for the potential seal and reservoir units.

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# Offshore Seismic Line



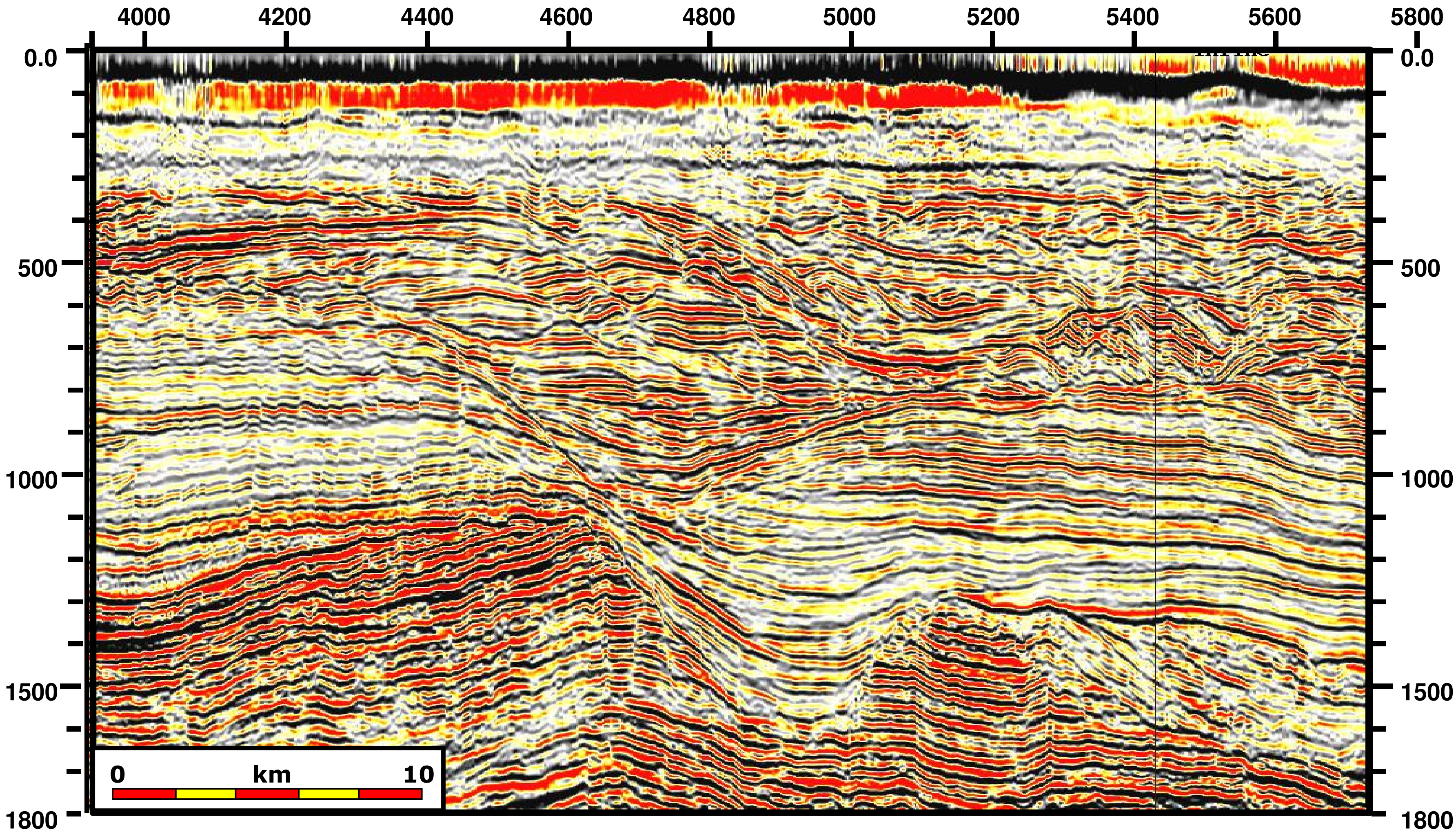


**Figure 6. A representative seismic line from the offshore portion of the Ross Basin.**

# Exercise 3a: Play Adequacy

**Objective**

In this exercise, you will briefly consider the play elements for fifteen (15) offshore blocks in the Ross Basin. The goal is for your team to be ready to place bids on some of these blocks in exercise 3b.

**Materials**

- Exercise instructions, which includes six (6) play element maps
- Color pencils
- Tracing paper

**Introduction**

The bulk of the work to prepare for a lease sale has been done for you. This work is synthesized for you in a series of play element maps. We will examine these maps together briefly. Then your team will consider which blocks offer the best chance for having significant oil or gas fields. Keep in mind that you will be placing bids on 3 or more blocks in exercise 3b.

You will use tracing paper to help determine which blocks have the proper combination of the five (5) play elements. You may want to come up with a system to score blocks to identify the best several ones to bid on.

| Step | Action |
|---|---|
| 1 | **TRAP**<br>Figure 1 is a map showing time structure (in milliseconds) for the Top of Scott (TOS) horizon. This is a proxy for depth in meters (or feet). You can use this map to identify structural highs, which we will assume can be traps. You are interested in large trap volumes, so the area and amount of closure (relief) are both important.<br>Which blocks are promising in terms of structural traps? |

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| Step | Action |
|---|---|
| 2 | **HC MIGRATION**<br>Figure 2 is based on the TOS surface relief that is shown in Figure 1. The HC ‘drainage divides’ are marked with solid lines.<br>Use a color pencil to transfer the drainage divides onto the tracing paper. This will help you evaluate the other play elements relative to your best traps. |
| 3 | **SOURCE FACIES**<br>Figure 3 shows the source facies for the Amundsen Formation, which is the primary source interval. Note that terrestrial organic matter (plants) is more likely to generate gas. Marine organic matter tends to yield oil. Oil is more valuable than gas as a target.<br>How does the source facies impact the type of HC you might expect in your traps? Use one (1) different color to add source facies information to the same piece of tracing paper. |
| 4 | **SOURCE MATURITY**<br>Figure 4 shows source rock maturity. The source is immature in the northwest. It transitions from the oil window to the gas window to overmature towards the southeast.<br>How does the source maturity impact the type of HC you might expect in your traps? Use a third color to add source maturity information to the same piece of tracing paper. |

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# Exercise 3a: Play Adequacy **continued**

| Step | Action |
|---|---|
| 5 | **RESERVOIR**<br>Within our study area the Upper Scott consists of fluvial to offshore depositional environments. It was deposited during a marine transgression, so the basin was gradually deepening. As indicated in Figure 5, the primary facies in the northwest is fluvial. Deposits such as point bar sands can be good reservoirs, but reservoir quality varies considerably vertically and laterally.<br>Nearshore environments (barrier islands, beaches, etc.) often are excellent reservoirs with good vertical and lateral connectivity.<br>Offshore environments tend to be silty and shaley and hence not good reservoirs.<br>How do the depositional environments for the Upper Scott impact the presence and quality of the reservoir in your traps? Use another color to add reservoir quality information. |
| 6 | **SEAL QUALITY**<br><br>Figure 6 shows the expected seal quality for the Shackleton member. It varies from excellent (SE) to fair (NW).<br>How does the seal quality impact your traps? Use a different color to add seal quality information to the same piece of tracing paper. |
| 7 | **SYNTHESIS**<br>If you have extra time, begin to synthesize your findings on a block-by-block basis. First, you might eliminate from consideration blocks that do not have large structural highs. For the blocks that remain, you might develop a score sheet. For example, your team could use a relative scale of 0 to 5. The biggest two structures would score a 5, the next two largest score a 4, etc. A large drainage area would score a 5, a moderate drainage area might score a 3, etc. An oil prone source facies gets a 5, mixed gets a 3 and gas prone gets a 2. Similarly score maturity, reservoir and seal. Now add the scores for the blocks with highs and develop a rank list of blocks.<br>You will have some more time for synthesis in Exercise 3b. |

# Top of Scott Time Structure

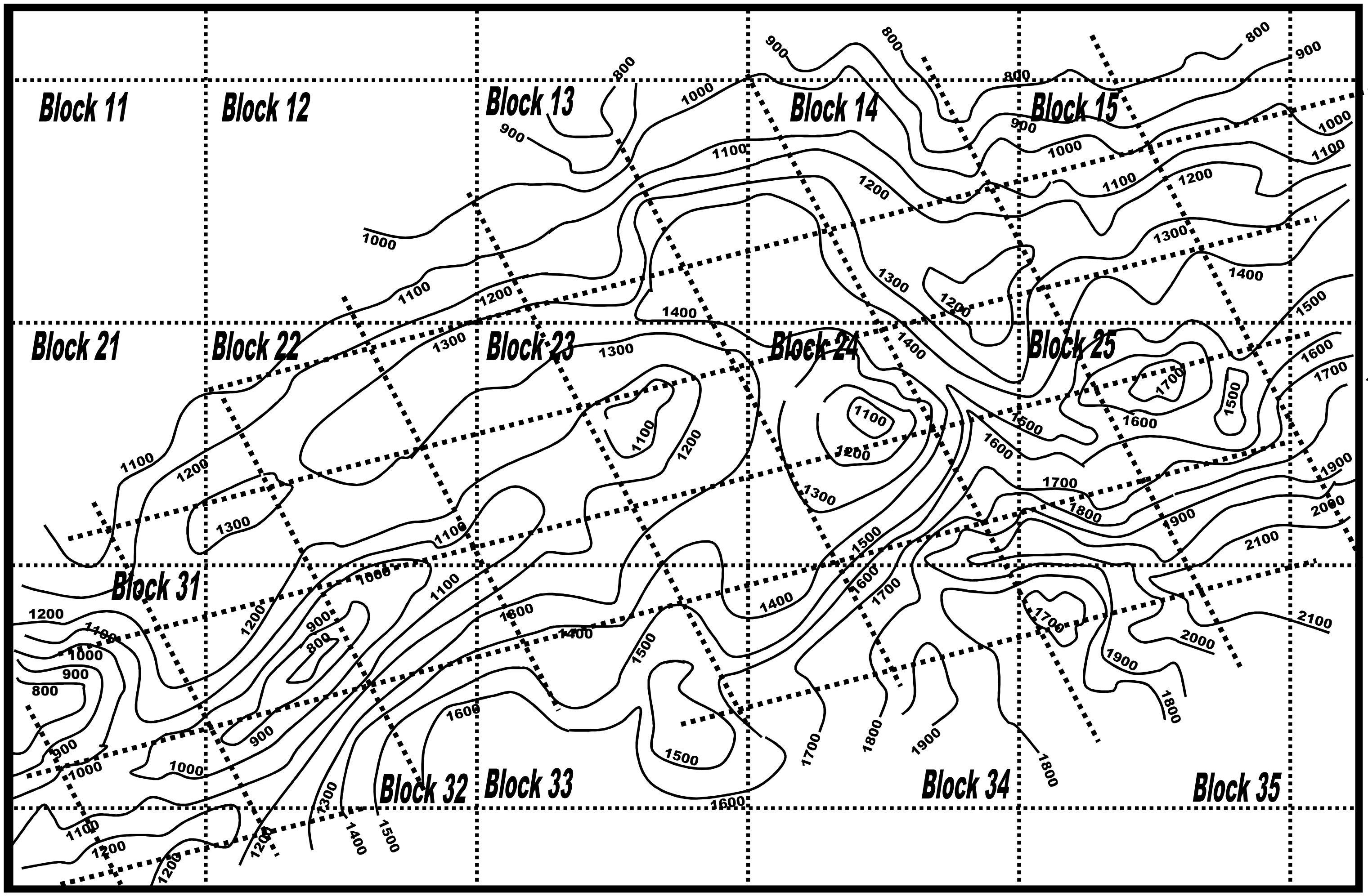


Figure 1. Map showing time structure (in milliseconds) for the top of Scott (TOS) horizon. This is a proxy for depth in meters.

0 Km 20

# Uppermost Scott Drainage Divides

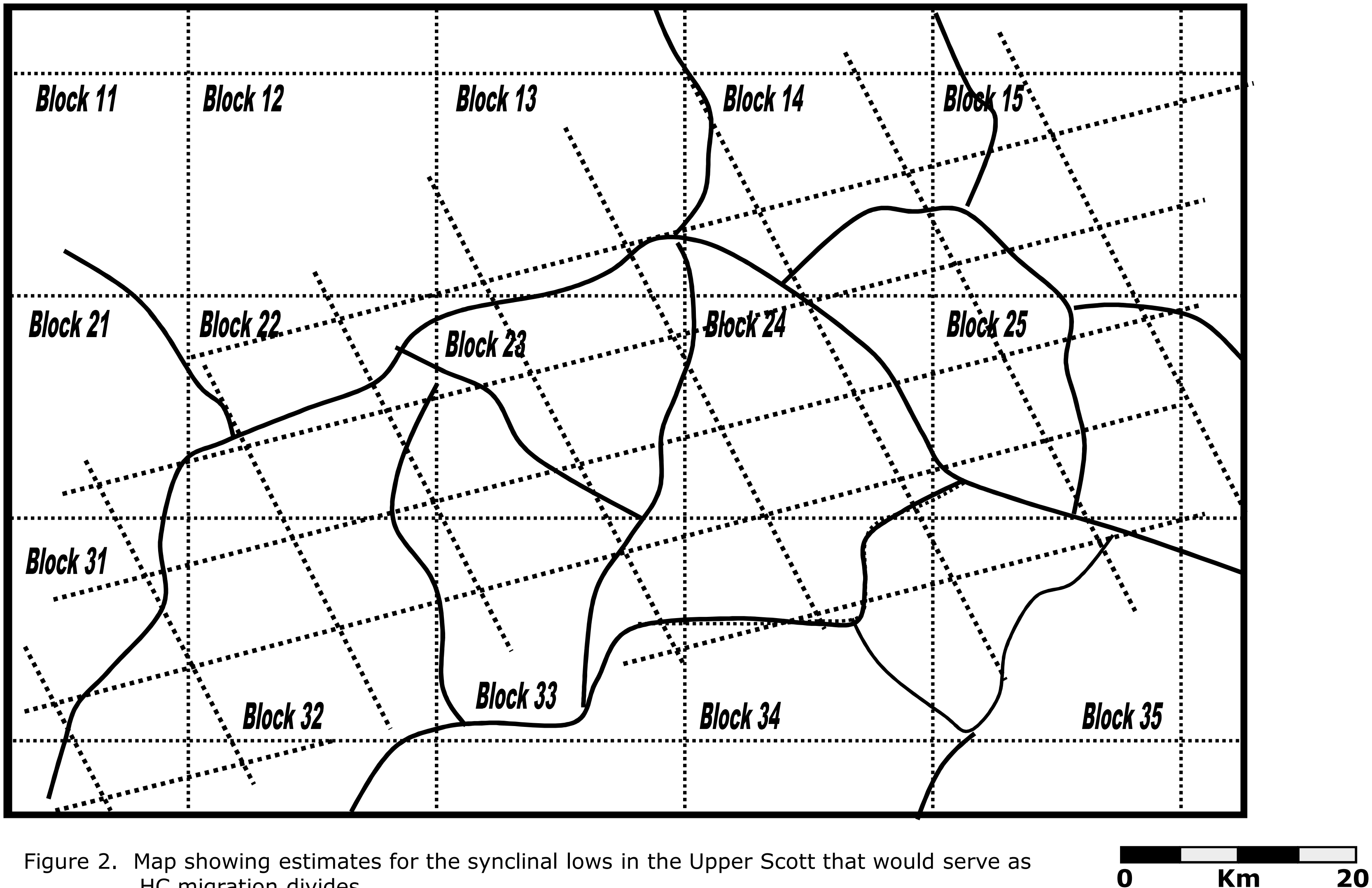


Figure 2. Map showing estimates for the synclinal lows in the Upper Scott that would serve as HC migration divides.

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# Golden Beach Source Facies

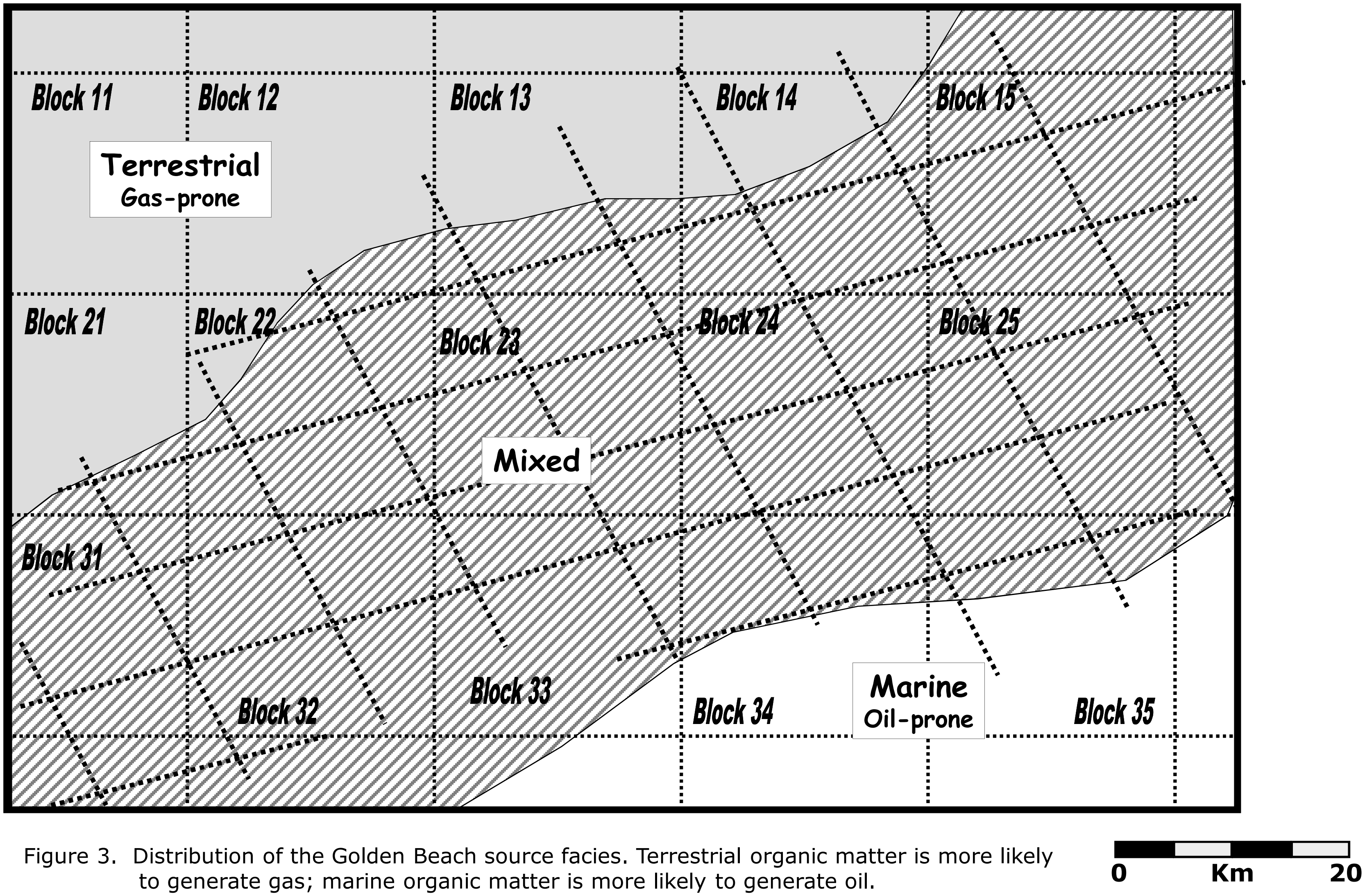


Figure 3. Distribution of the Golden Beach source facies. Terrestrial organic matter is more likely to generate gas; marine organic matter is more likely to generate oil.



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# Present-Day Source Maturity

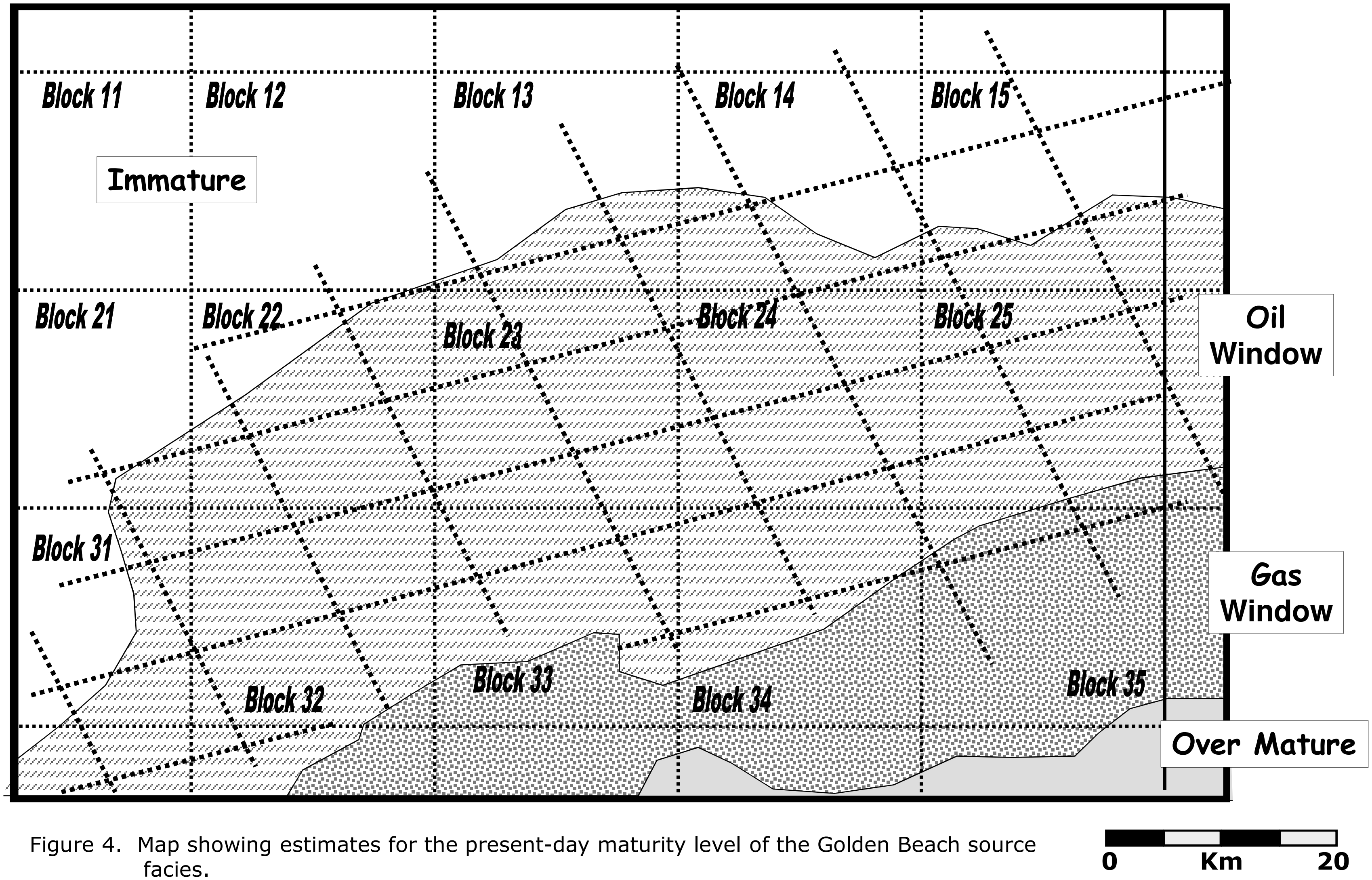


Figure 4. Map showing estimates for the present-day maturity level of the Golden Beach source facies.

Exercise 3

# Uppermost Scott Reservoir

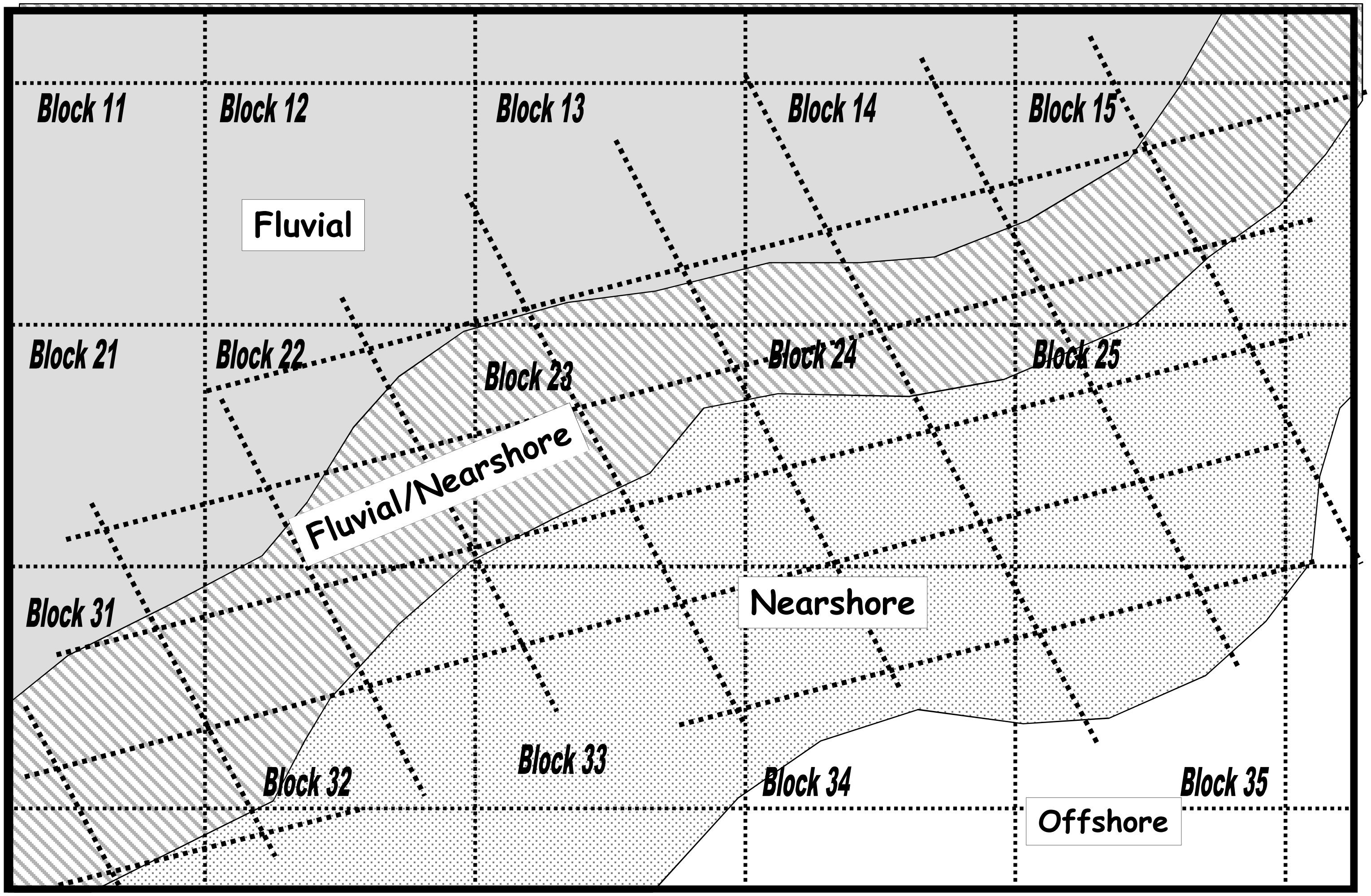


Figure 5. Map showing the environments of deposition for the uppermost portion of the Scott Formation. Nearshore sands should have better reservoir properties (porosity, permeability).



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# Shackleton Seal Quality

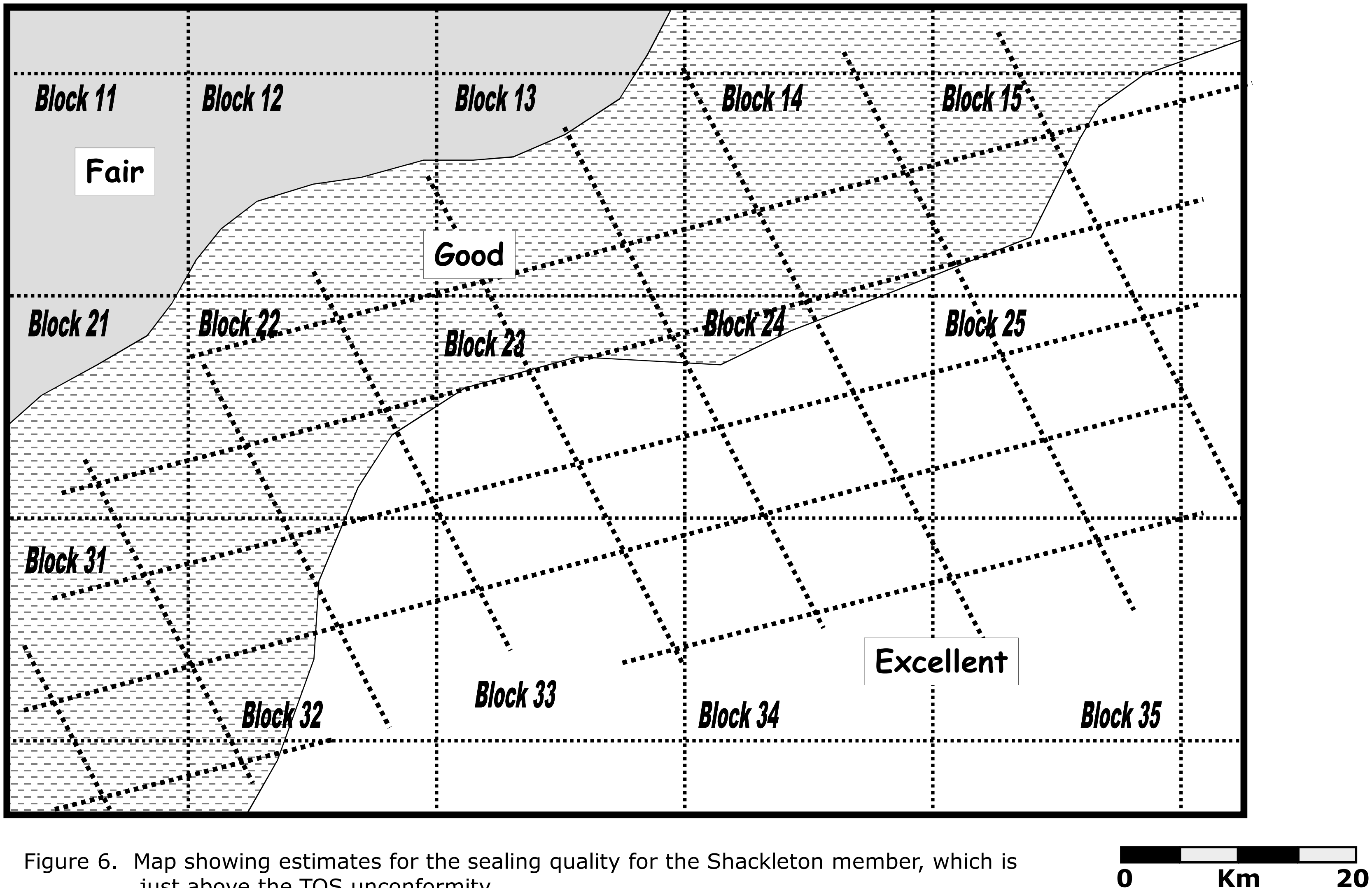


Figure 6. Map showing estimates for the sealing quality for the Shackleton member, which is just above the TOS unconformity.



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# Exercise 3b: Lease Sale

**Objective**

In this exercise, you will decide which blocks out of the 15 your team wants to bid for and how much money to bid for each. You have to bid on three (3) or more blocks. Each team has the same amount of money.

**Materials**

- Exercise instructions
- Previous set of maps and analyses
- Envelope

**Introduction**

Now is the time to put some action behind your work. Here is what you will do:

1. Finalize your evaluation of the most-promising blocks
2. Complete your team's bid sheet
3. Turn in your bid sheet ***BEFORE THE DEADLINE***

Here are the rules:

1. We have a budget of $50 million
2. You have to bid on at least three (3) blocks
3. The minimum bid for a block is $1 million
4. Bids must be in multiples of $1 million (e.g., no decimals, like $3.2M)
5. Bid sheets must be turned in before the posted time
6. Your team must work independently – no team partnerships.

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| Step | Action |
|---|---|
| 1 | **SYNTHESIS**<br>Complete the synthesis of your findings from exercise 2a. Develop a list of blocks ranked by your level of interest.<br>Remember that you must bid on three (**3)** or more blocks. You have about 10 minutes for the synthesis. |
| 2 | **STRATEGIZE**<br>Decide on which blocks you want to bid on. Consider your competition. You can gamble on the best block(s) or perhaps have a better chance to win one or two of the less stellar blocks.<br>You want to end up with at least ONE block.<br>You have about five (5) minutes for this step. |
| 3 | **Complete Your Bid Sheet**<br>The next page is the bid sheet. The 15 blocks are listed. Write your bid for the blocks you decide to go after, in units of $1 million. The total must not exceed 50 – there is no reason to hold back any money. Fill in the name of your team. |
| 4 | **Submit Your Bid Sheet**<br>Place your completed bid sheet in the envelope. Hand the envelope to the instructor BEFORE time is called. Late bids are not accepted in the real world. |

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## Exercise 3b: Lease Sale **continued**

TEAM NAME: ____________________________________________

| BLOCK | BID<br>in units of $1 Million |
|---|---|
| Block 11 | |
| Block 12 | |
| Block 13 | |
| Block 14 | |
| Block 15 | |
| Block 21 | |
| Block 22 | |
| Block 23 | |
| Block 24 | |
| Block 25 | |
| Block 31 | |
| Block 32 | |
| Block 33 | |
| Block 34 | |
| Block 35 | |
| **TOTAL** | **$50 Million** |

# Exercise 5: Mapping a Prospect

**Objective**

In this exercise, you will use a grid of 2D seismic lines to map the top of the Scott (TOS), which is the top of the primary reservoir and a major unconformity. Then you will generate a time-structure map to understand the 3D form of this surface and consider where you would locate a wildcat well.

**Materials**

- Exercise instructions
- A basemap showing the location of the lines (2 copies)
- 10 seismic lines (black & white and color, 11x17 inches)
- Color pencils
- Lead pencil
- Cardboard scale (to measure TWT value)
- Eraser

**Introduction**

Your company has 5 years to discover HCs within block the three blocks it won in the lease round. They have acquired and processed a grid of 2D seismic lines with a 4 x 5 km line spacing. They are acquiring a 3D seismic survey, but those data will not be available for about 6 months.

Your task is to use the 2D seismic lines to map the TOS unconformity and obtain a time structure map. Interpretation is provided on six of the ten lines (to make the exercise doable in our class timeframe). You should mark fault offsets, but do not worry about details. Detailed fault analysis is an important step, but we don't have time to include this today.

Mark the TOS surface with a color pencil in a "white" half cycle or loop. You can use any color (although the interpreted lines have the TOS horizon marked in red). You may want to erase your interpretation, if the horizon doesn't tie, so draw your initial TOS horizon faintly.

Once you have mapped the TOS horizon, you will post two-way time values down to this surface on basemap #2. Then you will contour the two-way time values to get a time-structure map for the TOS surface. From the regional mapping of the TOS (Exercise 2a – Figure 1), you should expect a large anticline elongate in a NE-SW direction.

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**Introduction** continued

**NOTE:** The seismic lines and base maps show the seismic lines AND locations that are 1/3 and 2/3 of the way between each line. This is to facilitate the step of measuring two-way time values. More on this later.

| Step | Action |
|---|---|
| 1 | Examine basemap #1 and note the layout of the lines. The lines interpreted for you are in solid lines (lines 10, 12, 14, 60, 62, 64). The lines you need to interpret are dotted. |
| 2 | Examine the seismic lines. The available 2D lines are shown as solid vertical lines on the seismic sections; the numbers of the intersecting lines are labeled. The dashed lines are equally spaced 1/3 of the distance between the available lines.<br><br>Examine basemap #2. The small circles mark the locations of the lines and where the dashed lines on the seismic would be located. |
| 3 | There are two (2) tasks for this exercise: (1) complete the TOS interpretation, and (2) read, post and contour two-way time values on basemap #2.<br><br>You can divide the work among your team members. Some can complete the TOS horizon interpretation. Even while they are doing this, others can start reading and posting time values from the interpreted lines on basemap #2. It works best to have one person read off values and a second person write the numbers on basemap #2. |
| 4 | For those completing the TOS interpretation, here is the basic process; we call this line-tying:<br>1. Take a line with the TOS interpretation (any even numbered line), e.g., Line 10. Fold it where a line without interpretation crosses it (the odd line numbers), e.g., line 61.<br>2. Place the folded line on the intersecting line at the point of intersection, e.g., place Line 10 at the fold onto Line 61 where the two lines intersect. |

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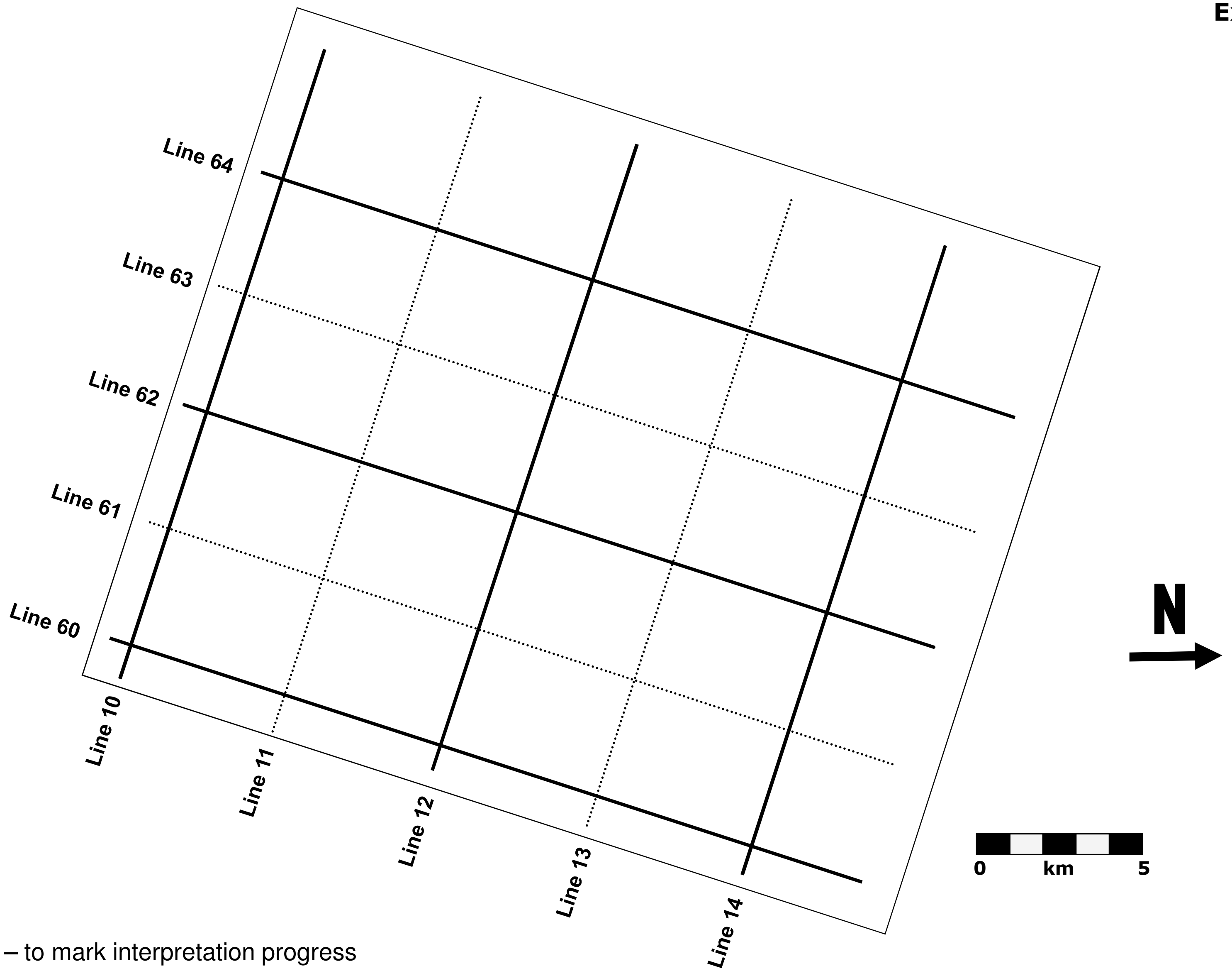
# Exercise 5: Mapping a Prospect continued

| Step | Action |
|---|---|
| 4 Cont. | 3. Transfer the TOS horizon (red line) from the interpreted line to the uninterpreted line, e.g., place a red dash on Line 61 at the tie point.<br>Given the amount of interpreted lines, it should not take too long to get a spatially consistent TOS surface on all ten (10) lines.<br>It is beneficial to use basemap #1 to keep track of your progress. Use any color pencil to mark the even lines, which have interpretation. As you interpret the odd numbered lines, update basemap #1 to show your progress on interpreting all the lines. |
| 5 | Almost immediately, two from your team can start reading time values and posting the numbers at the appropriate locations on basemap #2. Since the positions to read values are marked on the seismic sections (solid and dashed vertical lines) and on basemap #2 (small circles), you can 'process' a line quickly.<br>Continue to read/post values until you have done all ten lines. |
| 6 | The final step is to contour the time values so that you get a time-structure map. Use a contour interval of **100 ms**. The contour map gives you a way to visualize the topography of the TOS surface. Since oil and gas molecules migrate due to buoyancy, they will collect at the high points on the TOS surface (assuming there is a trapping geometry and an overlying seal – a reasonable assumption given our understanding of the regional geology).<br>Ideally, we would want to convert the time values (in milliseconds) to depth values (in meters or feet) by using velocity information. For our task and timeframe, we will assume that the time-structure map is close to what a depth-structure map would reveal. |
| 7 | If you have time, consider where you would recommend drilling a wildcat well to test our assumption that oil and/or gas would be trapped on a high point of the TOS surface (Scott reservoir capped by Shackleton sealing shale). |

Exercise 5




Basemap #1 – to mark interpretation progress



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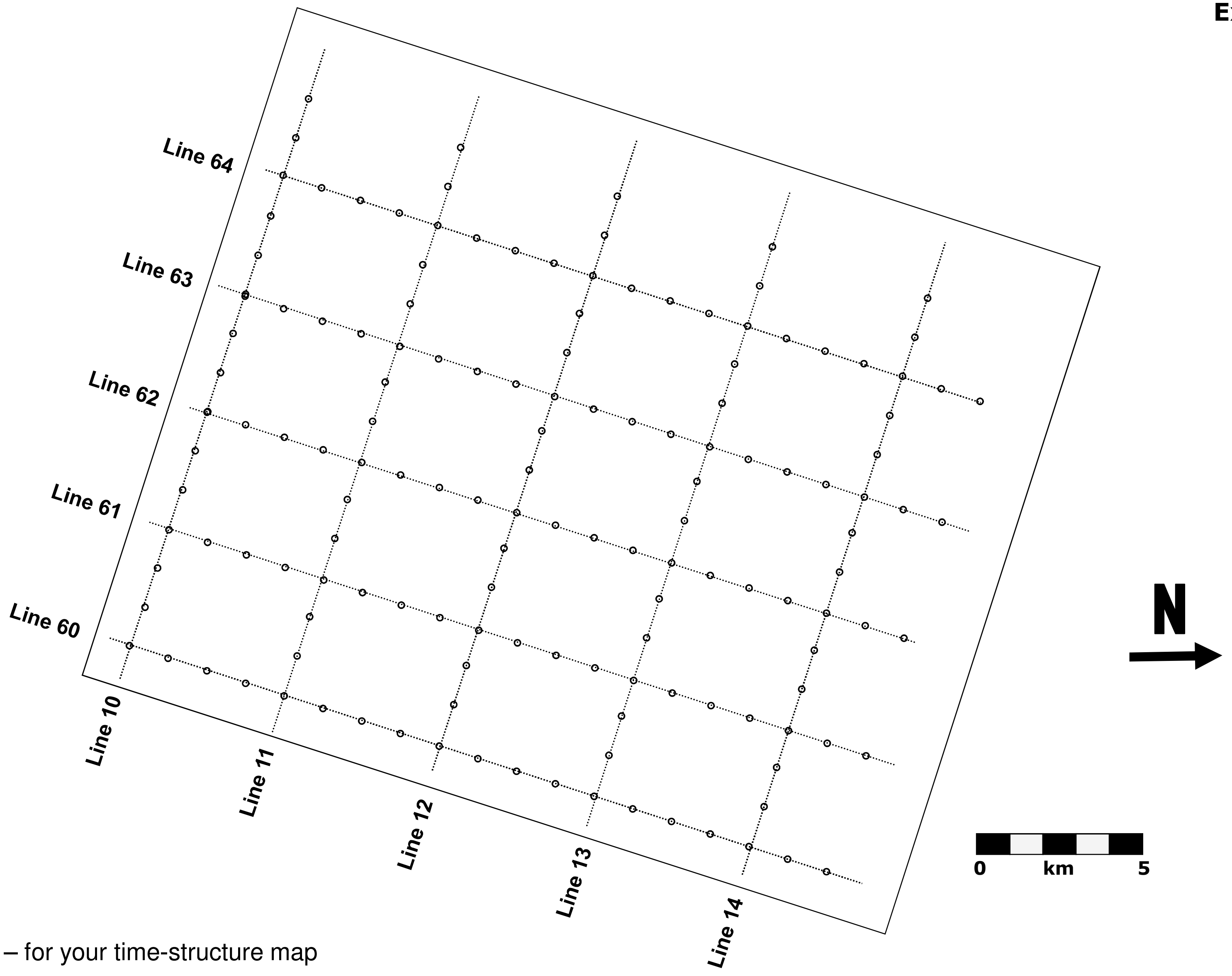
**Exercise 5**




Basemap #2 – for your time-structure map



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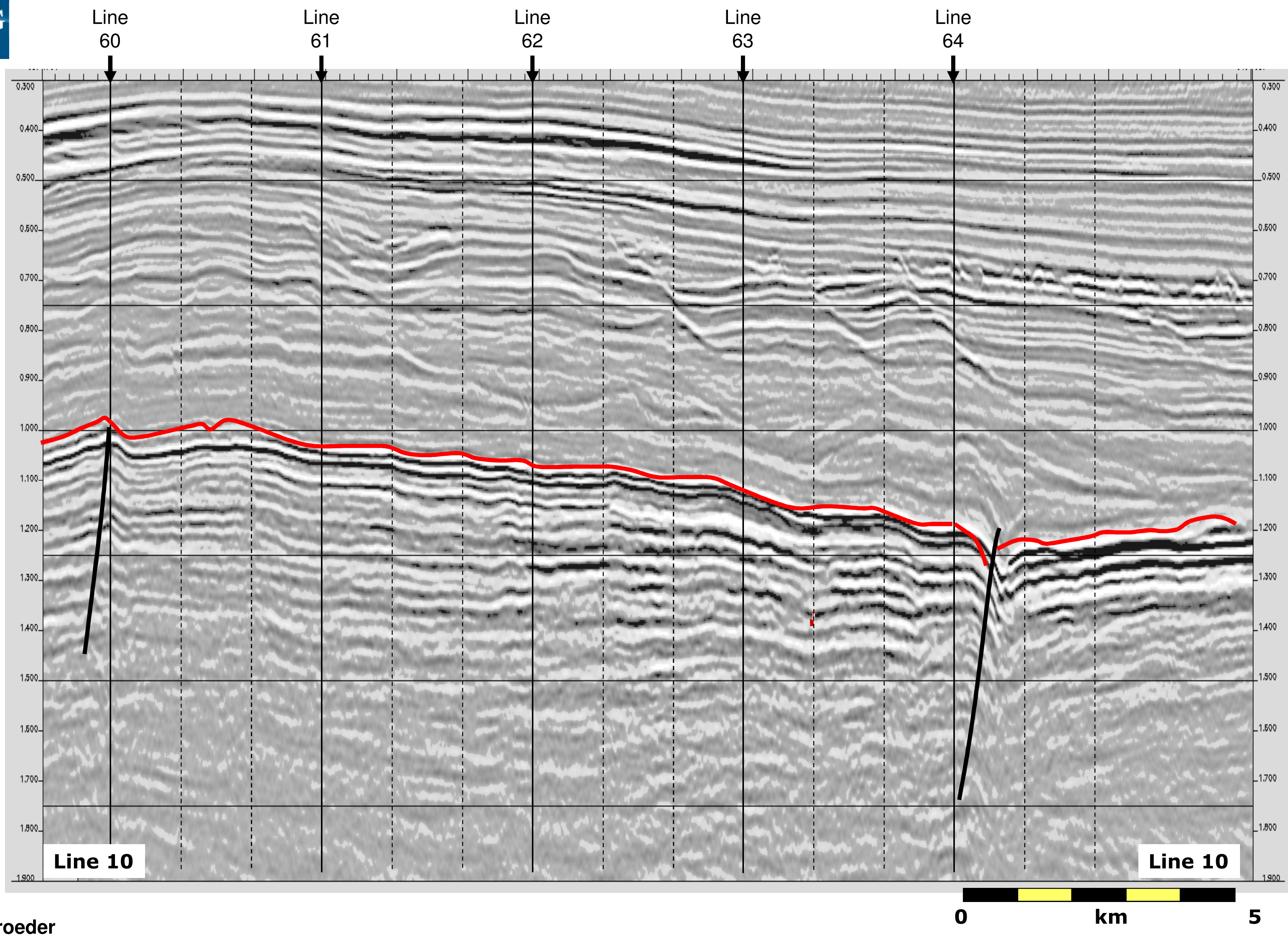
# Exercise 5

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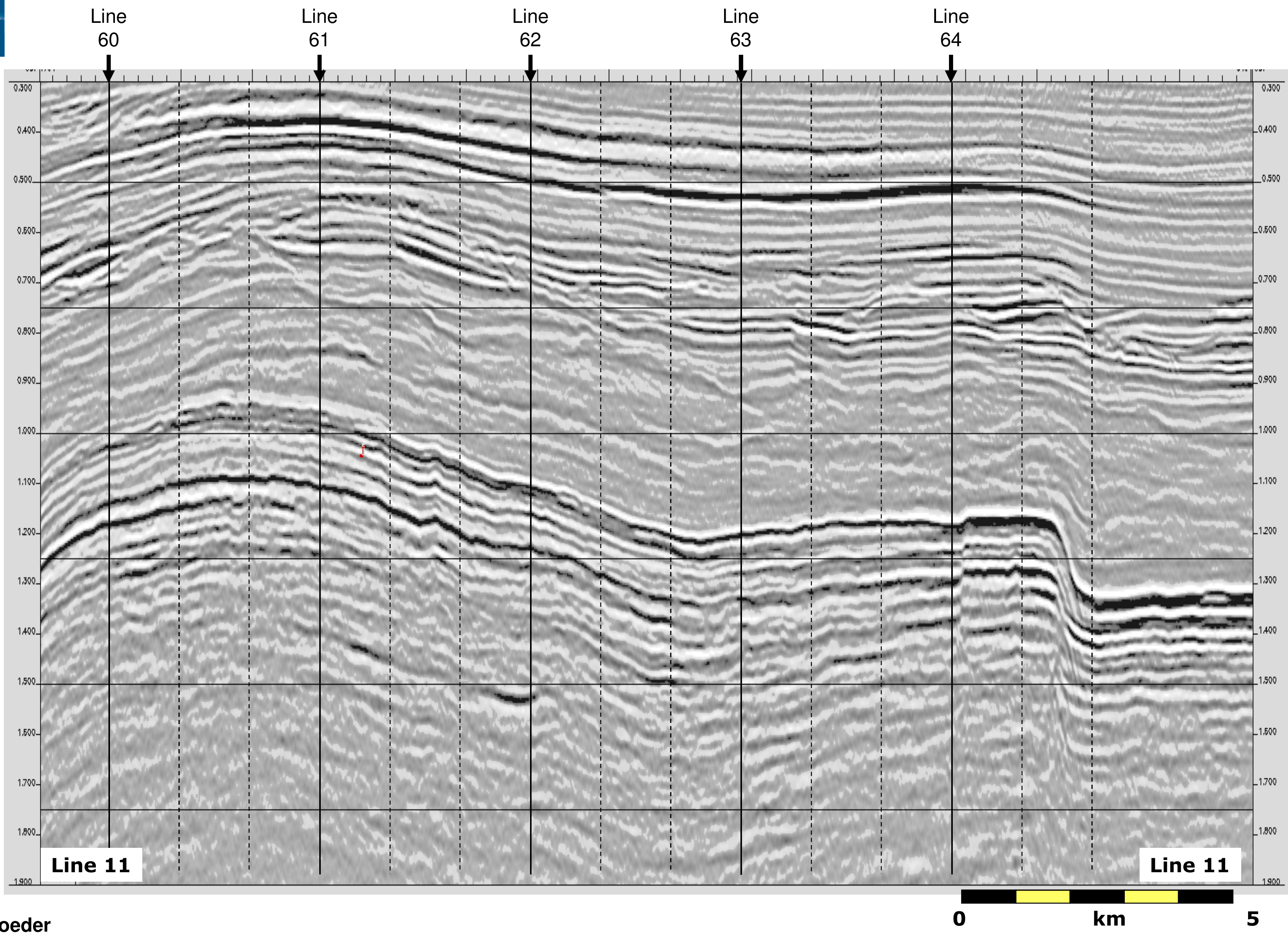
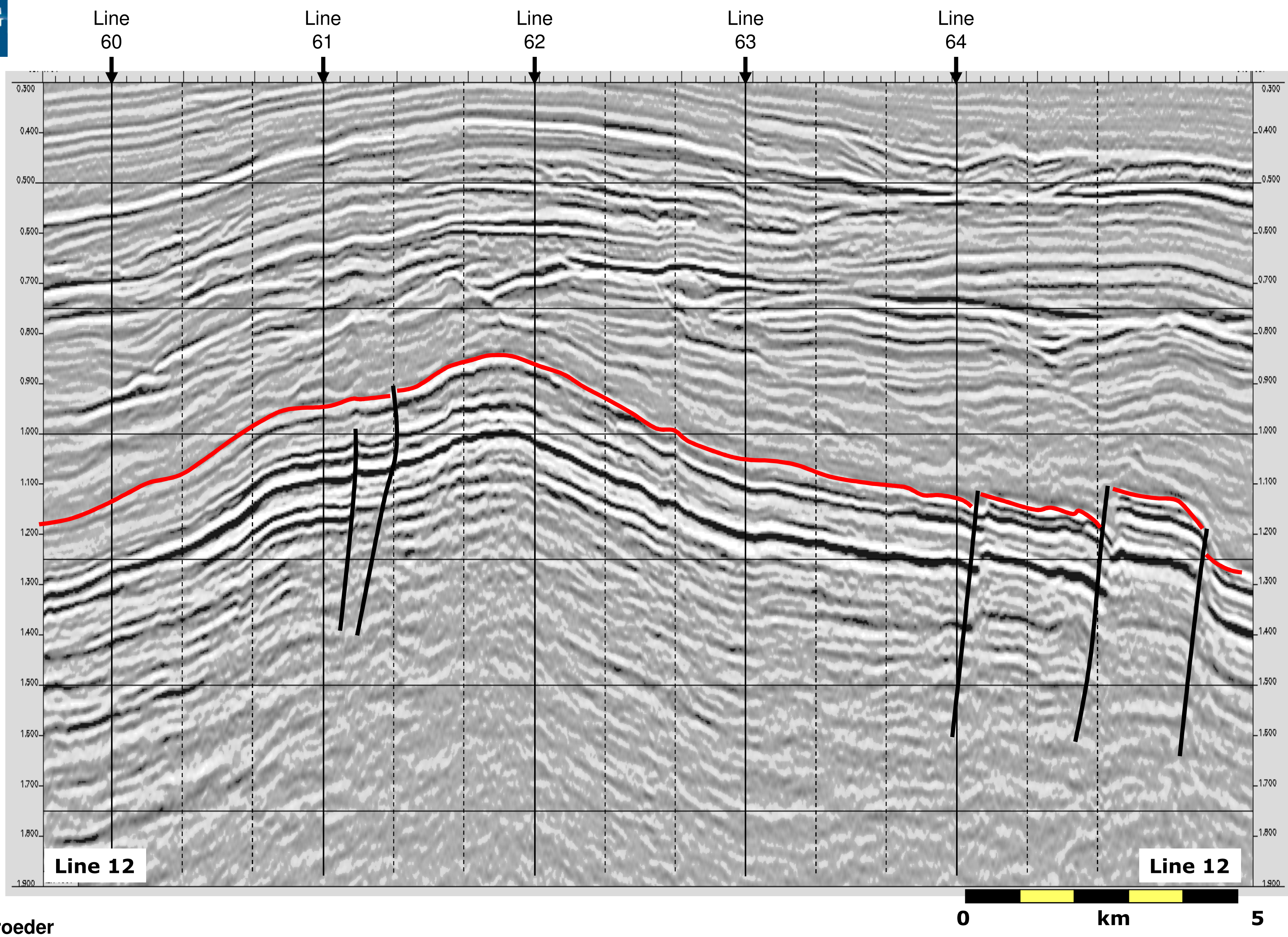
## Exercise 5



**Exercise 5**

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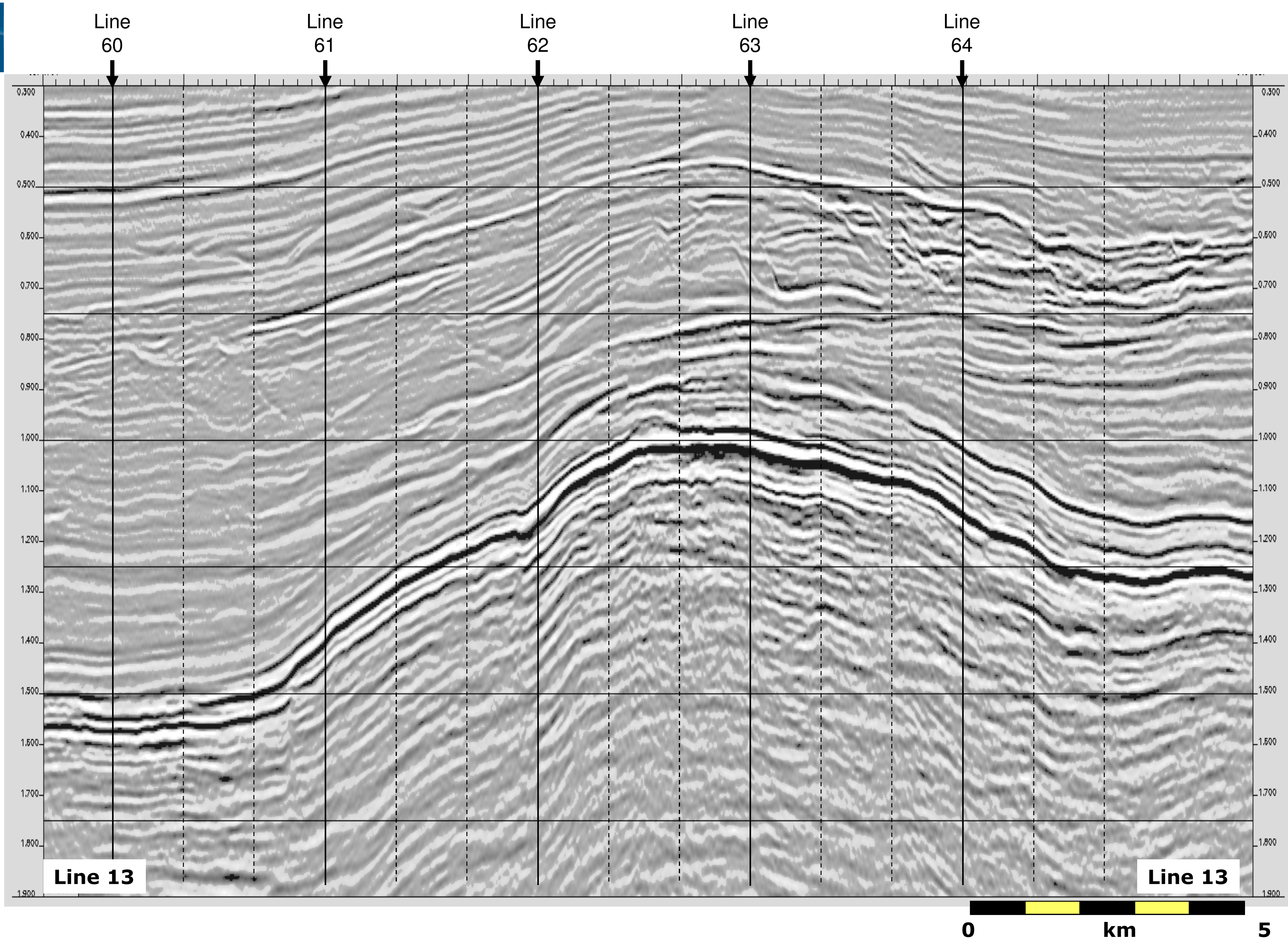
**Exercise 5**

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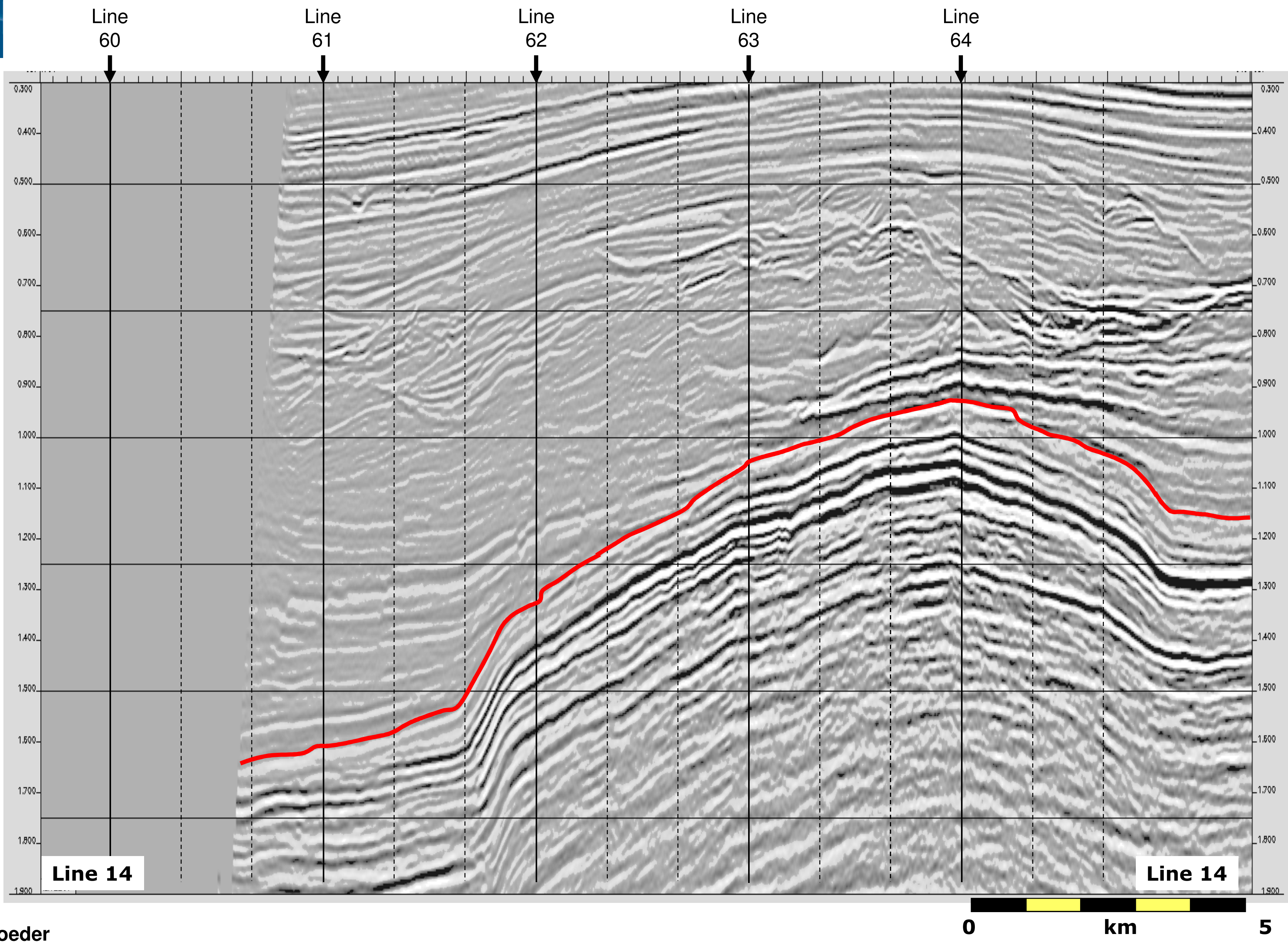
**Exercise 5**

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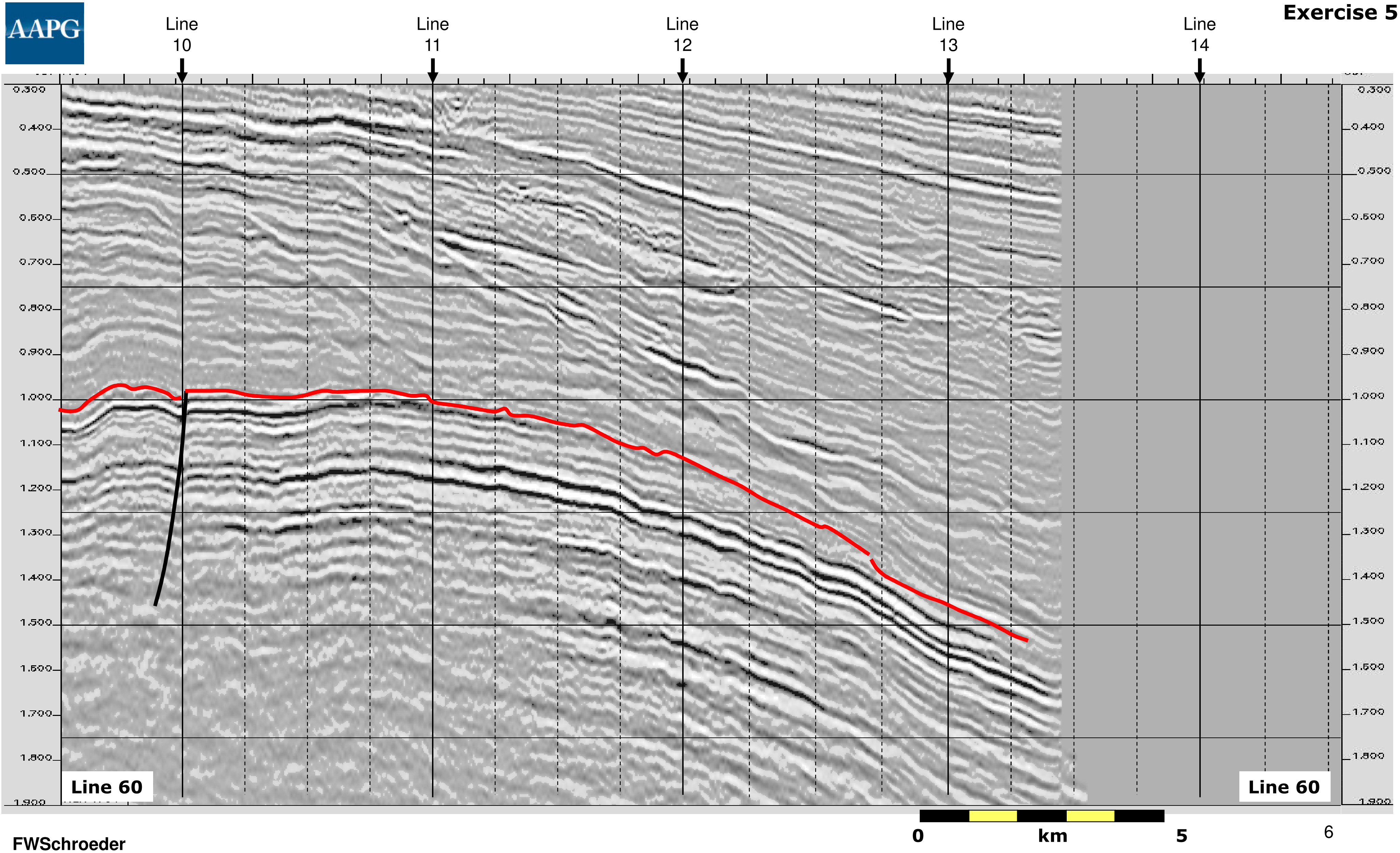
## Exercise 5

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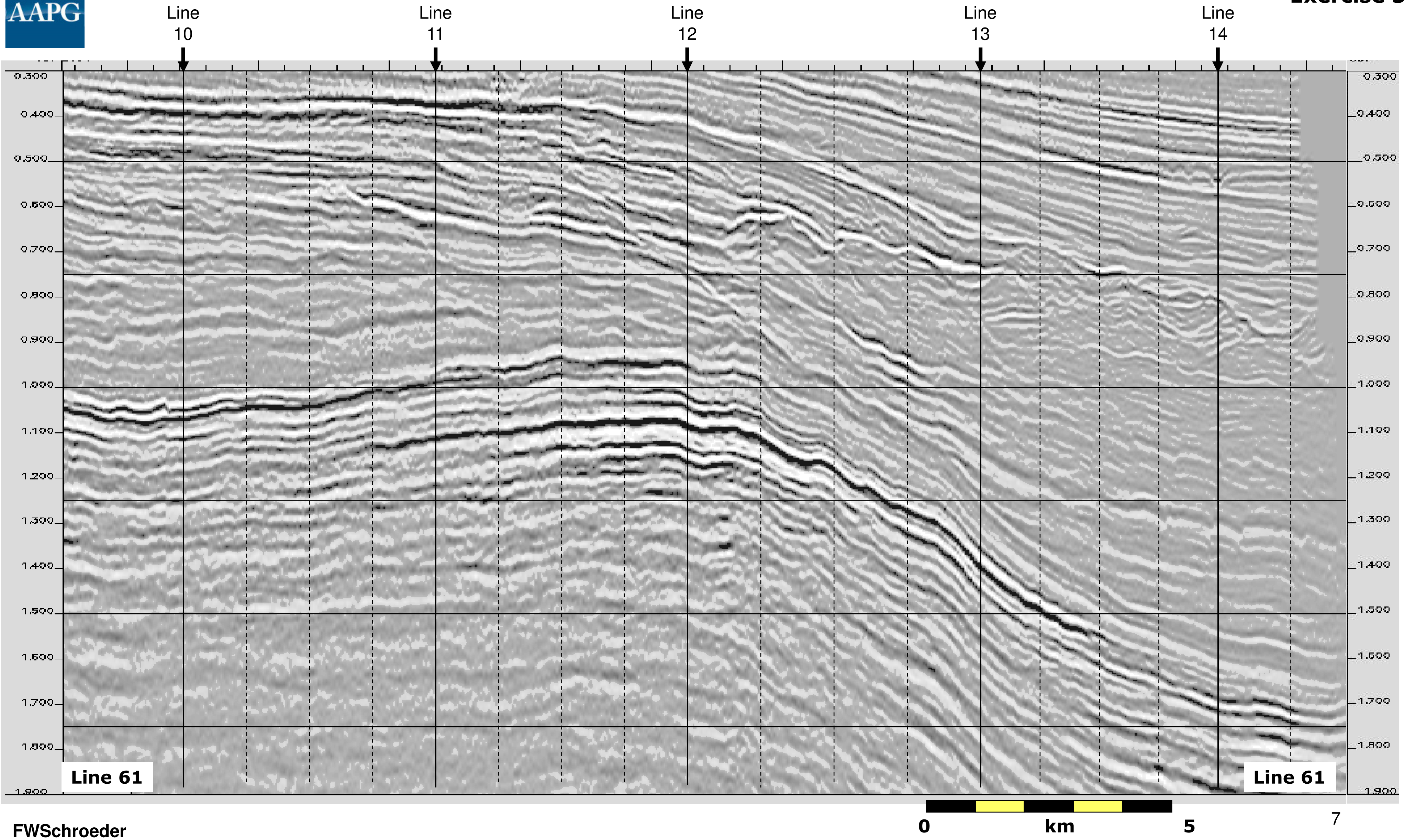
# Exercise 5

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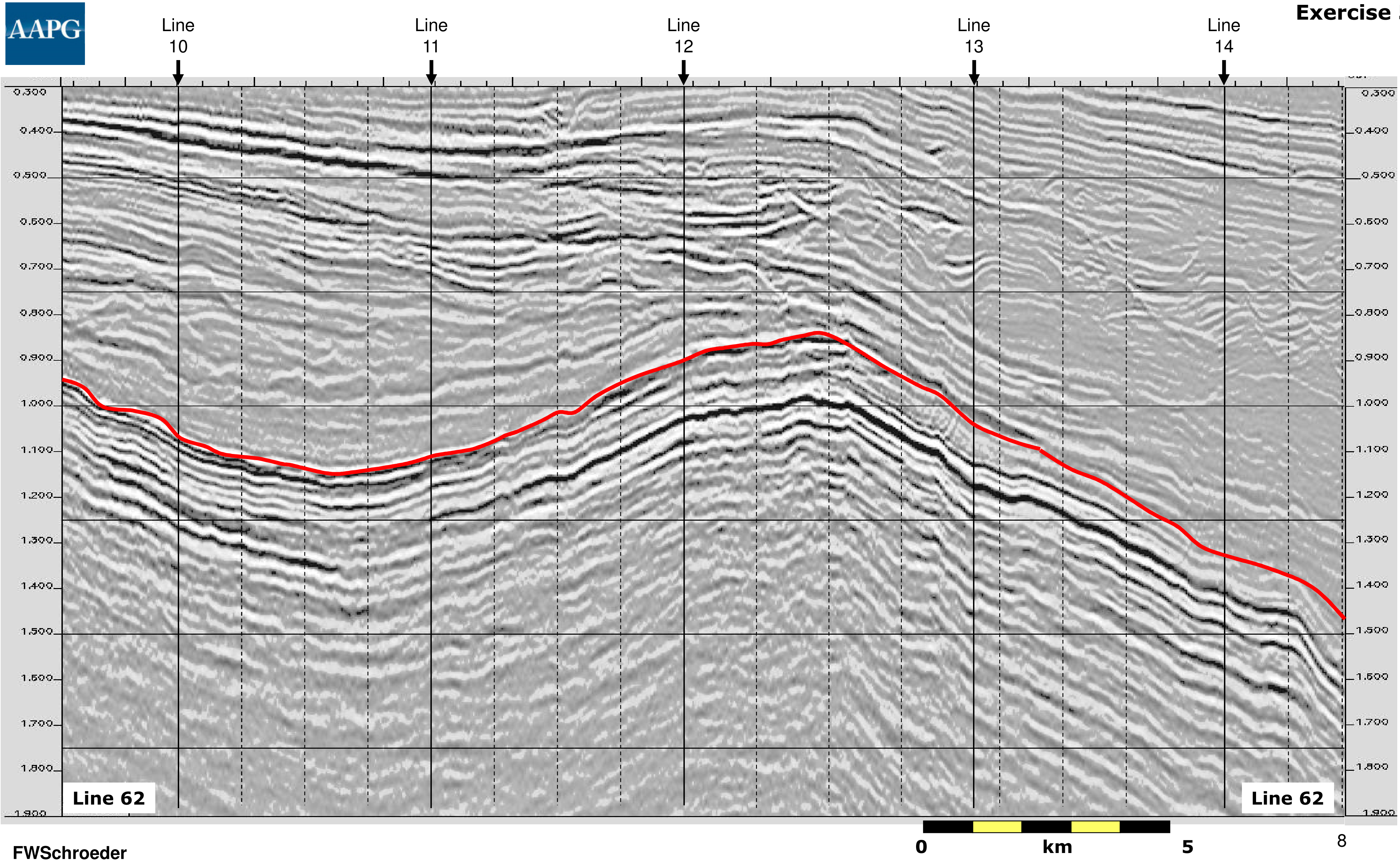
**Exercise 5**

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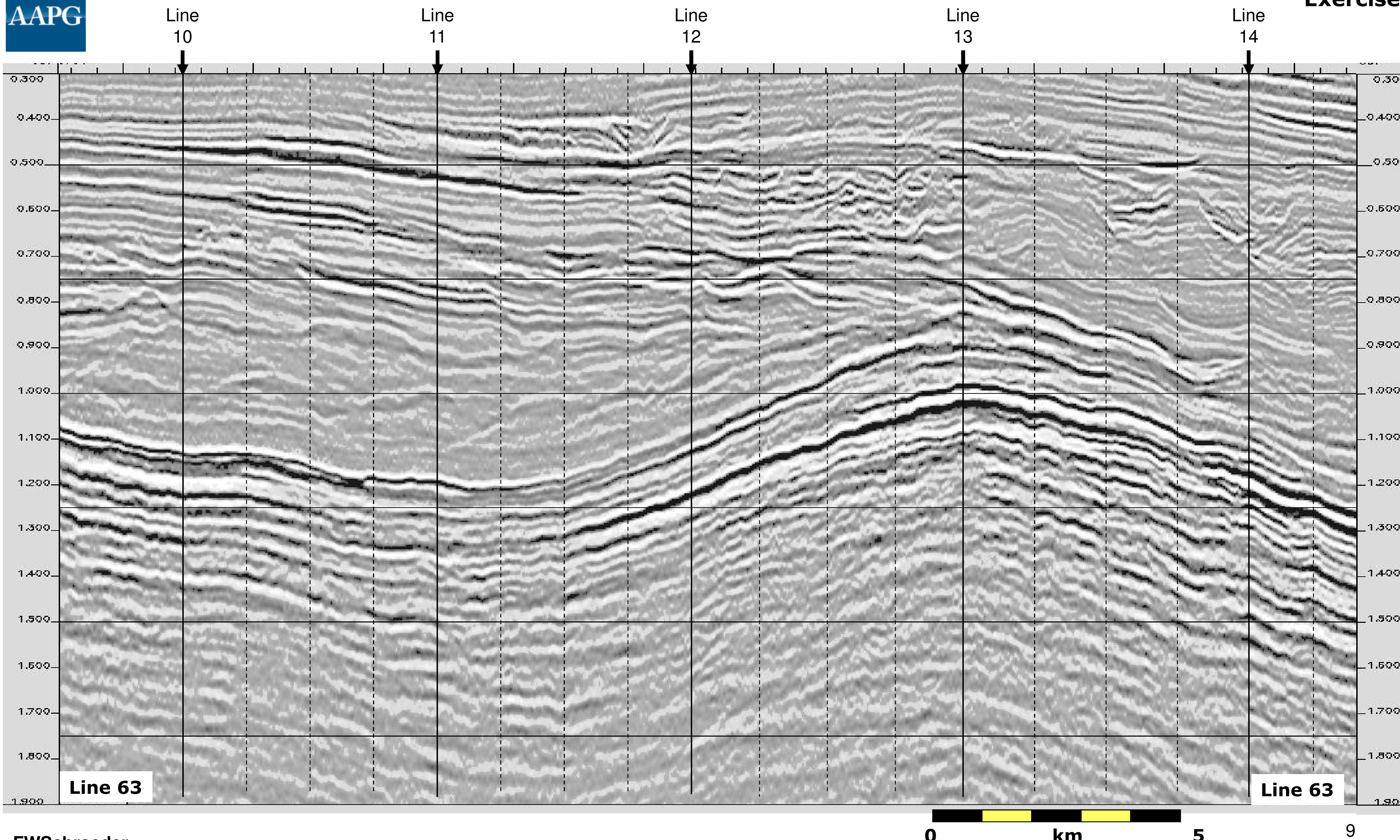
## Exercise 5

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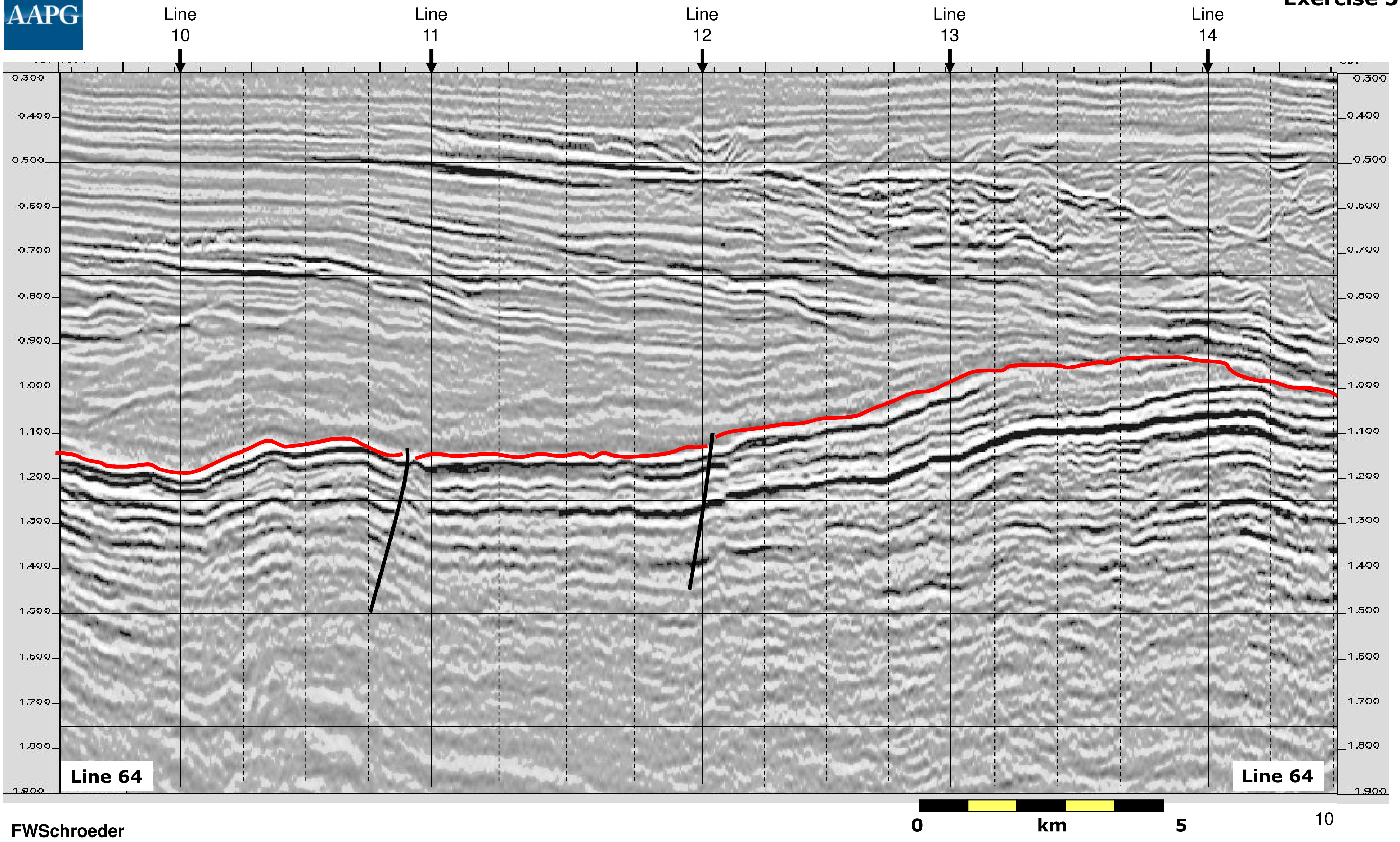
# Exercise 5

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