

Exercise 6: Source Mapping & Generation

Objective You will use the results of a 1-D source generation model to determine where the oil and gas windows are within the fetch area of the Tiger prospect. Then, you will calculate a first-order estimate of the volume of oil and gas available to this prospect.

Materials

- Exercise instructions, with figures
- Computation sheet
- Pencils and erasers

Introduction We will do a little work on source rocks and the amounts of hydrocarbon generated for the Tiger prospect. We will use a number of assumptions:

A 1-D model of HC generation is appropriate for the region.

The source is always 500 m below the TOS horizon.

The volume of HC generated from a given volume of source rock material is close to our assumed constant.

HC migration efficiency is 90%.

Step	Action
1	The geochemist on our team worked on the source rock maturation history. She modeled several sites around the Tiger anticline using the interpreted horizons with their predicted ages. She used an extensional model to develop a heating history. Then, she derived one source maturation model for the Tiger region (Figure 1).

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Exercise 6: Source Mapping continued

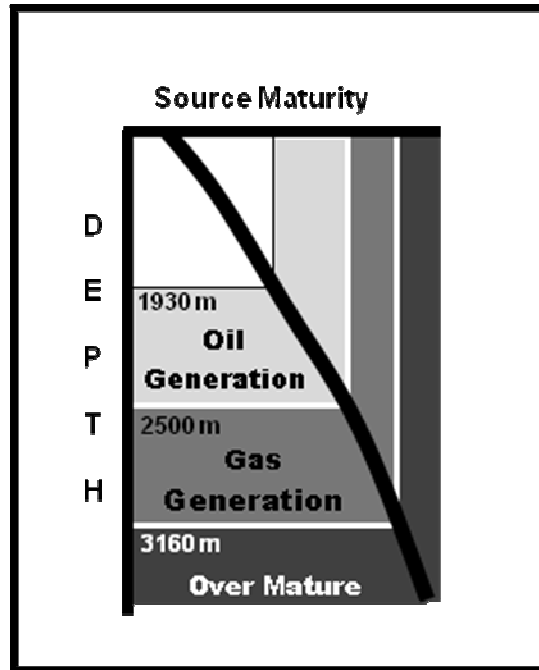


Figure 1. A composite source maturity model for the Tiger region.

Step	Action
2	<p>Information on the local source rocks comes from outcrop data and a few wells. Our assumed source rock is Lower Cretaceous (Amundsen Fm) coals and coastal plain coaly shales. These are dominantly terrestrial plants with high total organic carbon (TOC) values.</p> <p>Wherever we have data, the source is about 500 m below the TOS unconformity. The top of the source is not easy to map on the offshore seismic data. So we will assume that the source is 500 m below the TOS in the Tiger region.</p>

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Exercise 6: Source Mapping continued

Step	Action
2 Cont.	<p>From Figure 1, we note that the top of the oil window is at 1930 m. This is equivalent to where the TOS is at 1430m (500 m shallower). Similarly, the top of the gas window is at 2500 m, which is equivalent to where the TOS is at 2000 m. The top of the over mature zone is at 3160 m, or where the TOS is at 2660 m.</p>
3	<p>Next, we have to convert the TOS depths given in Step 2 to two-way time values. We can get average velocities from our seismic data processors.</p> <p>The top of the oil window is equivalent to a TOS depth of 1430 m. The average velocity to this depth is 2200 m/s. With the math for two-way travel time, $(\{1430/2200\} * 2)$, this equates to 1300 ms.</p> <p>The top of the gas window is equivalent to a TOS depth of 2000 m. The average velocity to this depth is 2500 m/s. With the math for two-way travel time, $(\{2000/2500\} * 2)$, this equates to 1600 ms.</p> <p>The top of the over mature window is equivalent to a TOS depth of 2660 m. The average velocity to this depth is 2800 m/s. Thus, a two-way travel time of 1900 ms.</p>

Exercise 6: Source Mapping continued

Step	Action
4	<p>Figure 2 is a time structure map for the TOS surface in ms. The fetch (drainage area) for the anticline is shown by the dotted line.</p> <p>For the fetch area ONLY, use a color to lightly shade in the oil window (between 1300 and 1600 ms). Use a different color to lightly shade in the gas window (between 1600 and 1900 ms).</p> <p>Figure 2 also has a gray rectangular grid. Each grid box is 5 x 5 km (area of 25 km²). We want the area within that fetch of the oil window and the gas window. To do this:</p> <ol style="list-style-type: none"> 1. For each box, estimate if the oil (gas) window extends over $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ or all of the box. 2. Total the number of quarter-boxes in the oil (gas) window. 3. Divide your total by 4, the number of full boxes. 4. Multiply the quotient by 25 to get the area in km². <p>You can use the calculation sheet to record your numbers as you go through the remaining steps.</p> <p>OIL:</p> <p>Sum of $\frac{1}{4}$-boxed = _____</p> <p>Sum / 4 = full boxes = _____</p> <p>Area (# full boxes * 25) = _____</p> <p>GAS:</p> <p>Sum of $\frac{1}{4}$-boxed = _____</p> <p>Sum / 4 = full boxes = _____</p> <p>Area (# full boxes * 25) = _____</p>

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Exercise 6: Source Mapping continued

Step	Action
5	<p>Based on available data, the source interval averages 400 meters in thickness. Multiply the oil (gas) areas by 0.4 km (i.e., 400 m). This gives you an estimate of the volume of source material in the oil and gas generation windows.</p> <p>OIL:</p> <p>Volume (area * 0.4) = _____</p> <p>GAS:</p> <p>Volume (area * 0.4) = _____</p>
6	<p>Time for some more assumptions. Given the terrestrial nature of the source material, it will generate more gas than oil.</p> <p>For source material in the oil window, our geochemical modeling suggests that 1 km³ within the oil window will generate 0.08 km³ of oil and 0.06 km³ of gas.</p> <p>For source material in the gas window, no additional oil will be generated, but 1 km³ of source material will generate 0.36 km³ of additional gas will be generated.</p> <p>Use the calculation sheet (rows 4 and 5) to estimate the amount of oil and gas that we think would be generated within the Tiger fetch area.</p>

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Exercise 6: Source Mapping continued

Step	Action
7	<p>Not every molecule of generated HC will migrate to the trap. Some will remain in the migration route. If 90% of the generated oil makes it to the trap, use the calculation sheet to estimate the amount of oil potentially reaching the Tiger anticline. If 95% of the generated gas makes it to the trap, use the calculation sheet (row 7) to estimate the amount of gas potentially reaching the Tiger anticline.</p>
8	<p>Perhaps your boss is more accustomed to using English units for HC volumes; barrels for oil and cubic feet for gas. So we can convert km^3 to these values using established conversion factors.</p> <p>For oil, 1 km^3 equals 8.4 billion barrels (Bbbls). For gas, 1 km^3 equals 35.3 billion cubic feet (BCF). Perform the unit conversion and enter your results into row 8 of the calculation sheet.</p>

Top of Scott Time Structure

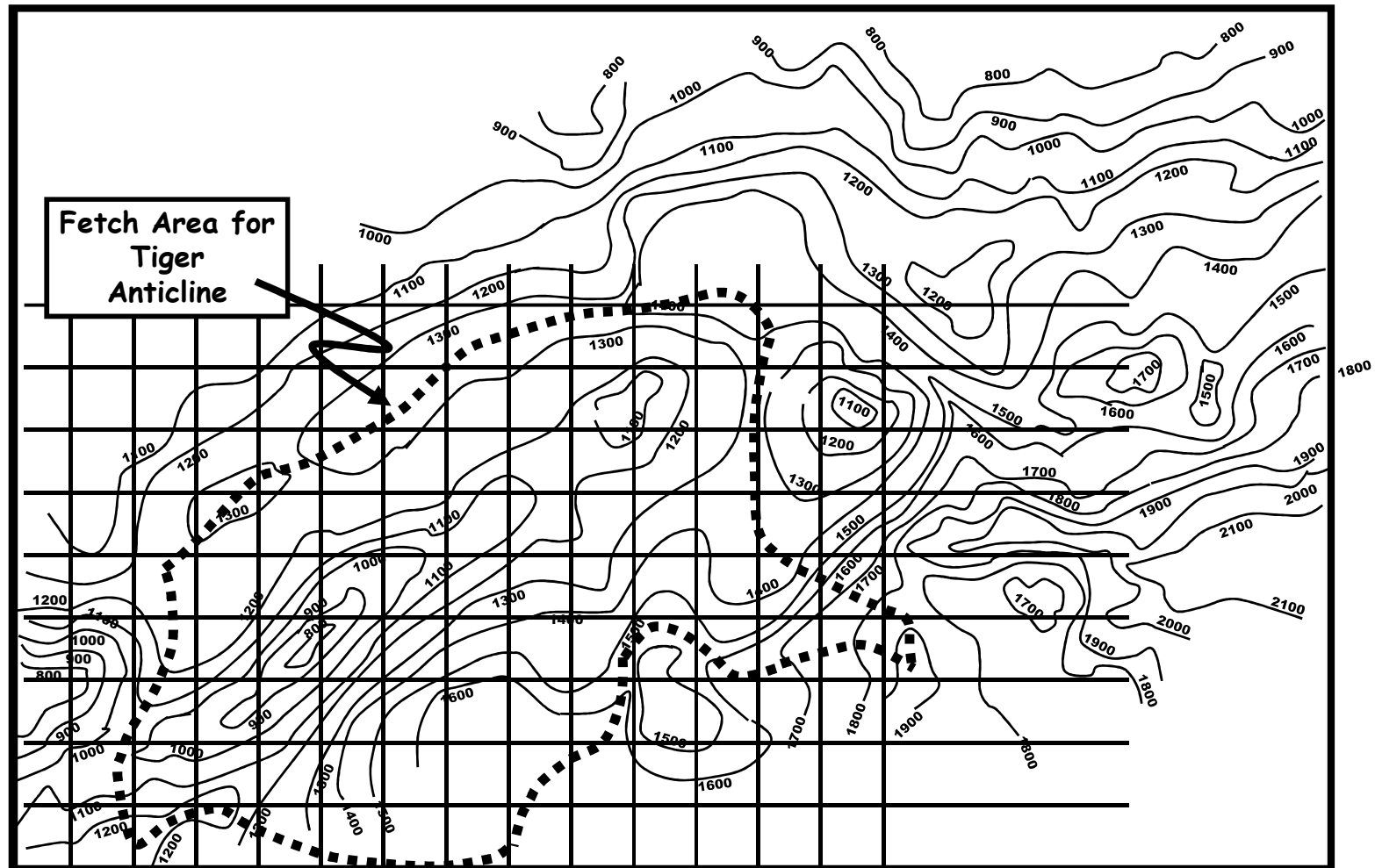


Figure 2. Map showing time structure (in milliseconds) for the top of Scott (TOS) horizon. This is a proxy for depth in meters. The fetch area is indicated by the dotted line.

0 Km 20



Exercise 6

ROW	PARAMETER	Oil Window	Gas Window
1	Total ¼ grid blocks		
2	Total Area (# Blocks/4) * 25 Units = km ²		
3	Source Rock Volume Units = km ³		
4	Volume of Generated Oil Units = km ³		
5	Volume of Generated Gas Units = km ³		
ROW	PARAMETER	Oil	Gas
6	Total Volume Generated Units = km ³		
7	Total Volume to Anticline Units = km ³		
8	Unit Conversion		

Exercise 7: Reservoir Evaluation

Objective Our goal is to evaluate the environments of deposition (EODs) of the targeted reservoir unit (Upper Scott). From regional analysis, we expect fluvial to delta plain sands, possibly getting to delta front sands from west to east. Reservoir quality is controlled to a large extent by EODs, with porosity and permeability expected to transition from fair to good to excellent as the sands go from fluvial to delta plain to delta front EODs.

To make EOD predictions, the targeted reservoir unit was “sliced” into six proportional (equal thickness) slices. Then, for each slice, the absolute values of amplitude were averaged at each seismic trace. These attribute maps have been interpreted for you. You will be asked about vertical stacking within the Upper Scott and how the lateral extent of the EODs vary laterally for the uppermost unit.

Materials

- Exercise instructions, with figures
- Color pencils and erasers
- Tracing paper

Introduction In the exercise introduction, the instructor will explain what a proportional slice is and the attribute that was extracted from each slice. Just take note that slice 1 is the oldest and slice 6 is the youngest.

Land data (outcrops and onshore wells) suggests that the Upper Scott in our block should consist of fluvial and delta plain sands (west is proximal; east is distal). Reservoir properties differ as a function of the environments of deposition (EODs). We would like to know how EODs and hence reservoir properties vary vertically and laterally at the Tiger Anticline.

Figure 1 shows an inline across the crest of Tiger. The same line is shown in Figure 2 after it was flattened on our interpreted based of reservoir horizon. The reservoir interval varies slightly in thickness and the seismic reflections are fairly parallel. Figure 2 also shows how the reservoir interval was sliced into 6 equal-thickness intervals. Slice 1 is the oldest.

We can extract many seismic attributes for each slice. The attribute we chose is the sum of the absolute values of amplitude for each seismic trace and divide the total by the number of samples. This gives the average magnitude of the amplitude without regard to the sign (+ or -).

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Exercise 7: Reservoir Evaluation continued

Introduction

Cont.

Why did we do this? We expect a delta plain environment, where storms rework the sediments winning out fine grain sizes, to be lithologically homogeneous. Thus the average magnitude should be fairly constant. For a fluvial environment, we would expect considerable lateral changes in lithology (on the scale of seismic data) as we have channel complexes alternating with interfluves. Average magnitude should be quite variable. For the delta plain environment, we expect minor variations in average magnitude.

This logic was used to interpret EODs for the 6 proportional slices (figures 3 – 8). This step was highly subjective, but at least gives us some interesting patterns.

Step	Action
1	<p>Examine the six attribute extraction maps. Note how the logic stated in the introduction was used to pick the EOD boundaries. You may differ on where you think the boundaries are located. Other information was available to the person who made the shown interpretation. It is certainly OK to disagree, but let's accept the shown interpretation.</p> <p>The amplitudes respond to two main factors: (1) the rock properties, which are affected by the EODs, and (2) the fluid type. We believe there is geophysical evidence for the presence of HCs at the crest of Tiger.</p>
2	<p>Your first task is to consider the vertical stacking of EODs in the Upper Scott. To do this, you will consider how the Fluvial--Delta Plain boundary has shifted with geologic time.</p> <p>Overlay the tracing paper on slice 1 (Figure 3). Put some registration marks on the tracing paper so that you can align it properly on other slices (e.g., the map edges and the location of the proposed well).</p> <p>Select a color pencil and trace the Fluvial—Delta Plain EOD boundary (dashed yellow line). Write a small “1” on your line on the tracing paper so that you have a way to recall its relative geologic age (oldest of 6 intervals).</p>

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Exercise 7: Reservoir Evaluation continued

Step	Action
3	Register the tracing paper on slice 2. Use a different color pencil to trace the Fluvial—Delta Plain boundary on this slice. Write a small “2” on this new line so that you can recall that it corresponds to the second of six intervals.
4	Repeat Step 3 for slice 3, slice 4, slice 5, and slice 6. Your tracing paper should have 6 lines of different colors and the lines should be labeled 1 through 6.
5	Compare the relative positions of the facies boundaries as you consider the slices from oldest (slice 1) to the youngest (slice 6). From oldest to youngest are the facies boundaries moving <div style="margin-left: 40px;"> <input type="checkbox"/> seaward (to the right) This would be an overall regressive package OR <input type="checkbox"/> landward (to the left) This would be an overall transgressive package of rocks </div> What does this say about the vertical stacking of parasequences within the Upper Scott?
6	Figure 9 shows the interpreted extent of the seismic DHI (direct hydrocarbon indicator). Add to your tracing paper the Delta Plain – Delta Front boundary. Next place the tracing paper on Figure 9. About what percentage of the area within the dashed black line is: <div style="margin-left: 40px;"> The Fluvial EOD _____. The Delta Plain EOD _____. The Delta Front EOD _____. </div>

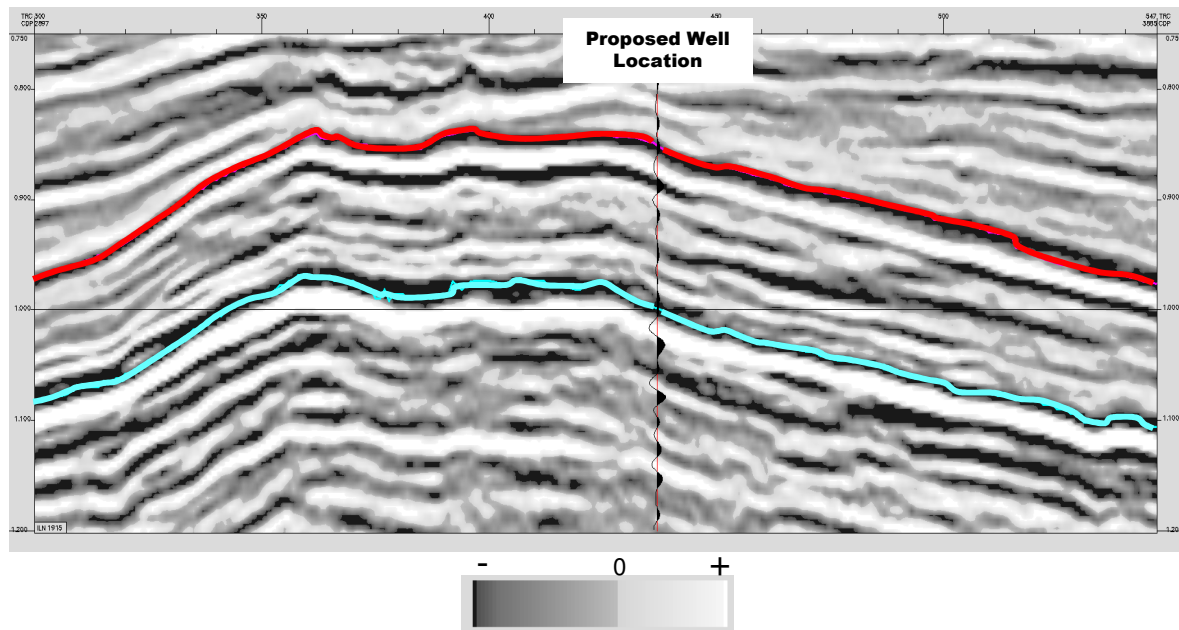


Figure 1. Inline 1915 across the Tiger Anticline. Red is the top of the target reservoir. Cyan is the interpreted reservoir base.

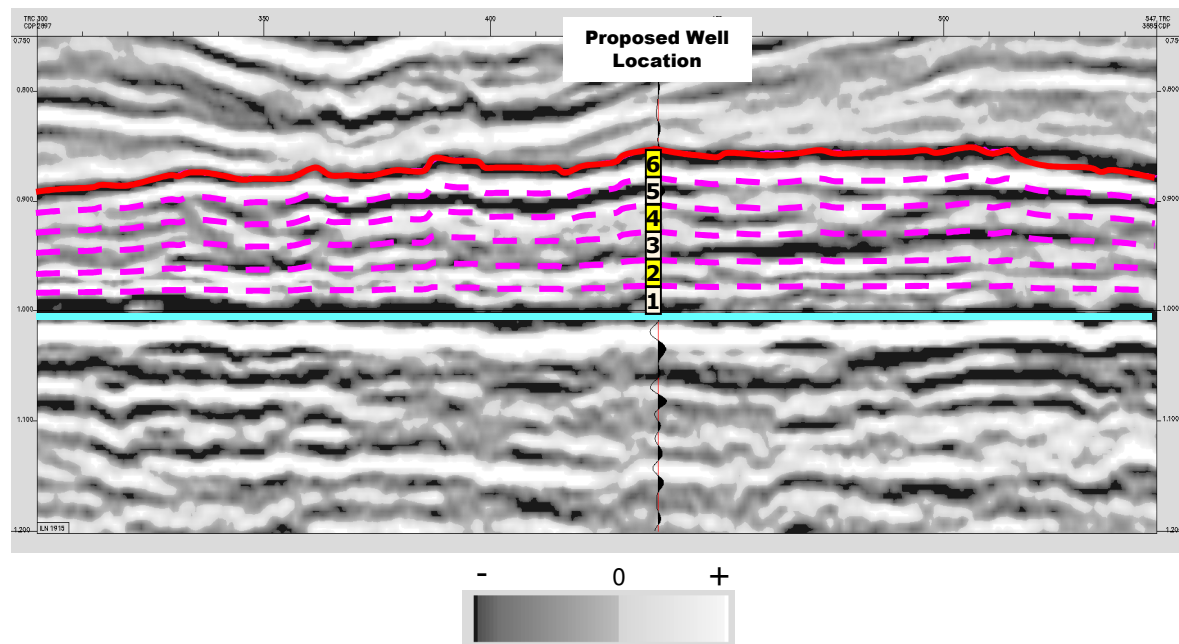


Figure 2. Inline 1915 across the Tiger Anticline flattened on the cyan horizon. The Upper Scott has been sliced into 6 equal-thickness intervals. The oldest slice is numbered 1.

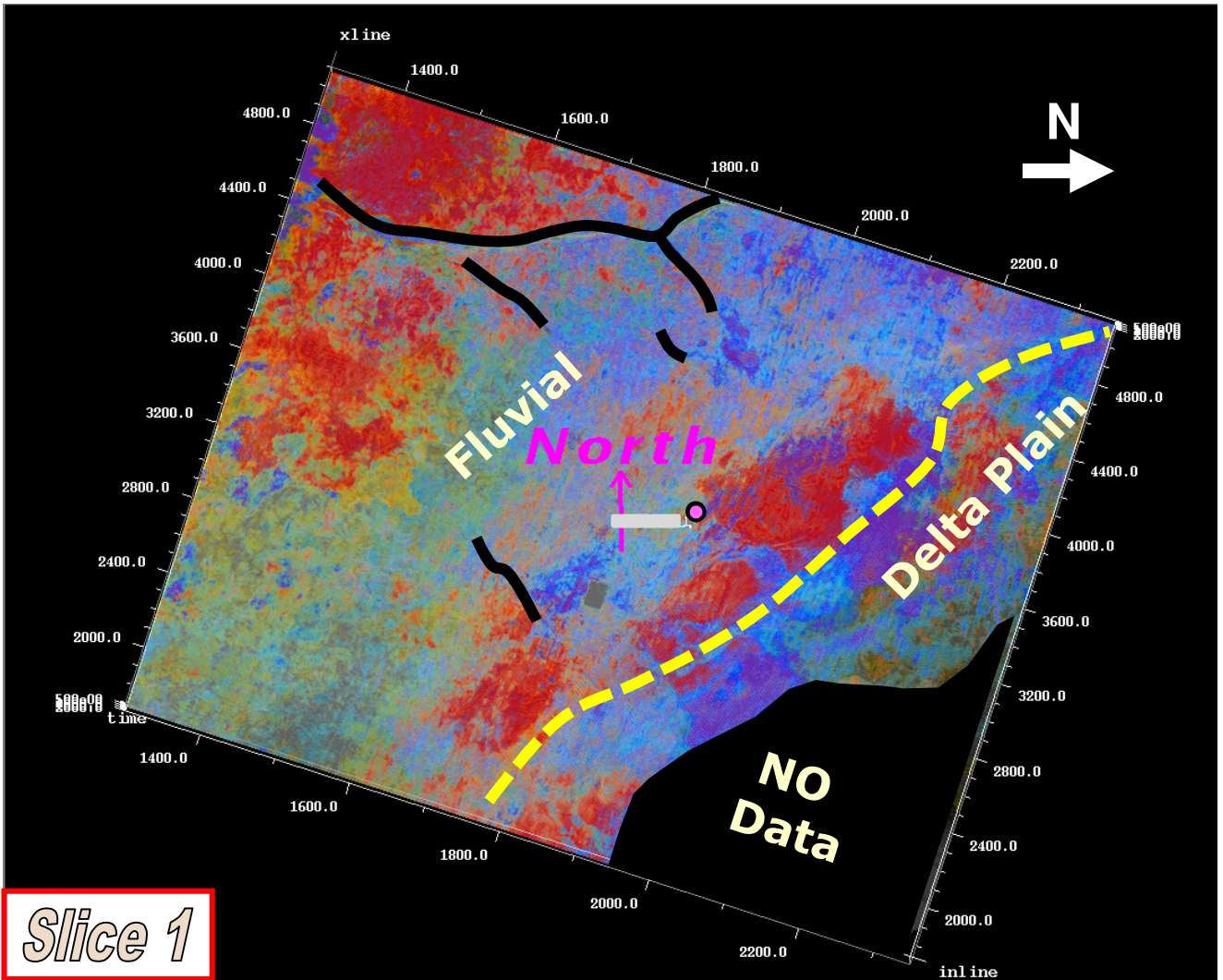
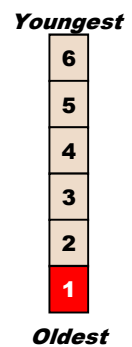


Figure 3. Average magnitude (absolute values of amplitudes) for Slice 1, which is the youngest. An interpretation of the boundaries between the fluvial, delta plain and delta front is shown.



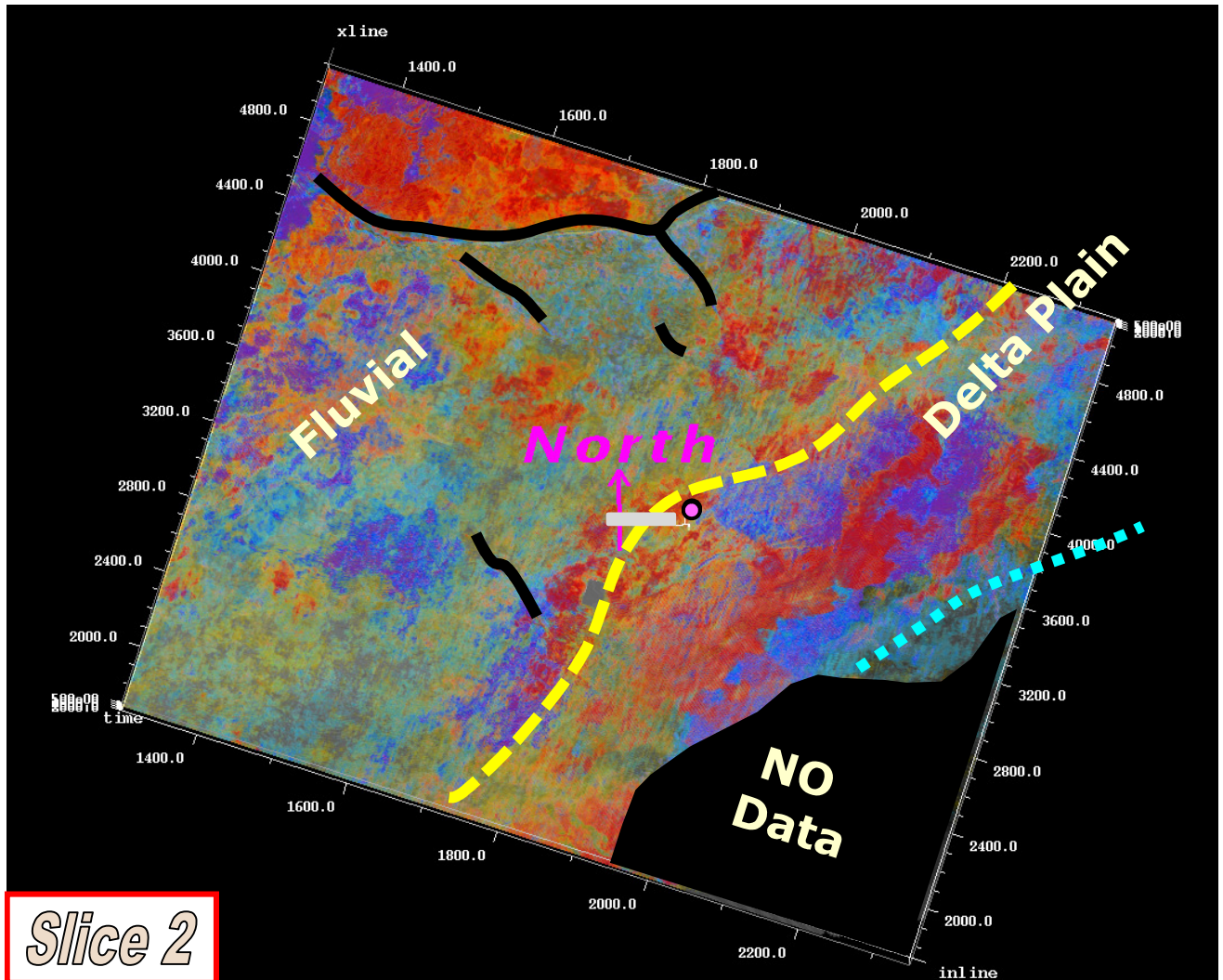
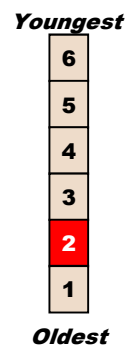


Figure 4. Average magnitude (absolute values of amplitudes) for Slice 2, which is the youngest. An interpretation of the boundaries between the fluvial, delta plain and delta front is shown.



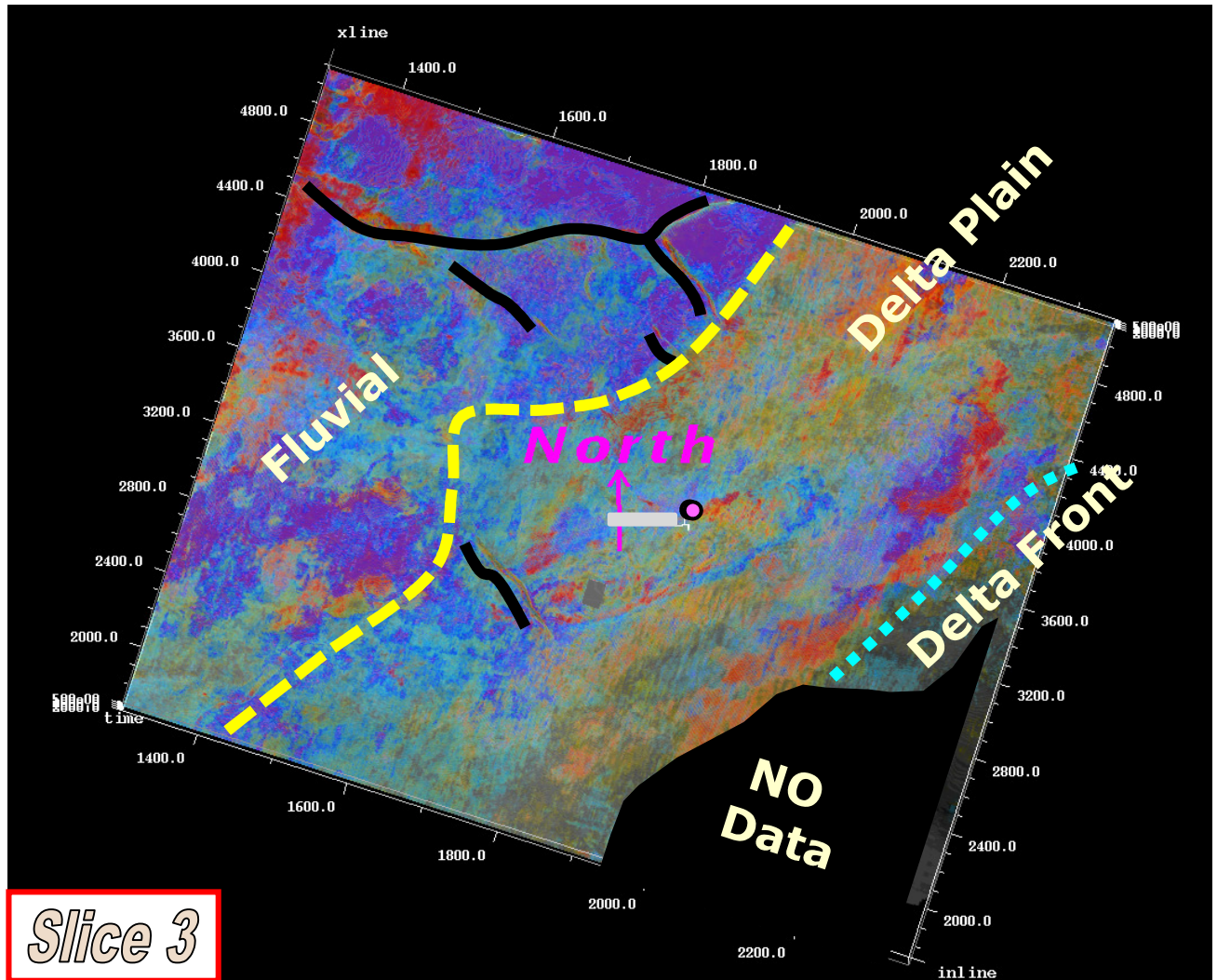
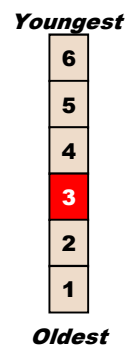


Figure 5. Average magnitude (absolute values of amplitudes) for Slice 3, which is the youngest. An interpretation of the boundaries between the fluvial, delta plain and delta front is shown.



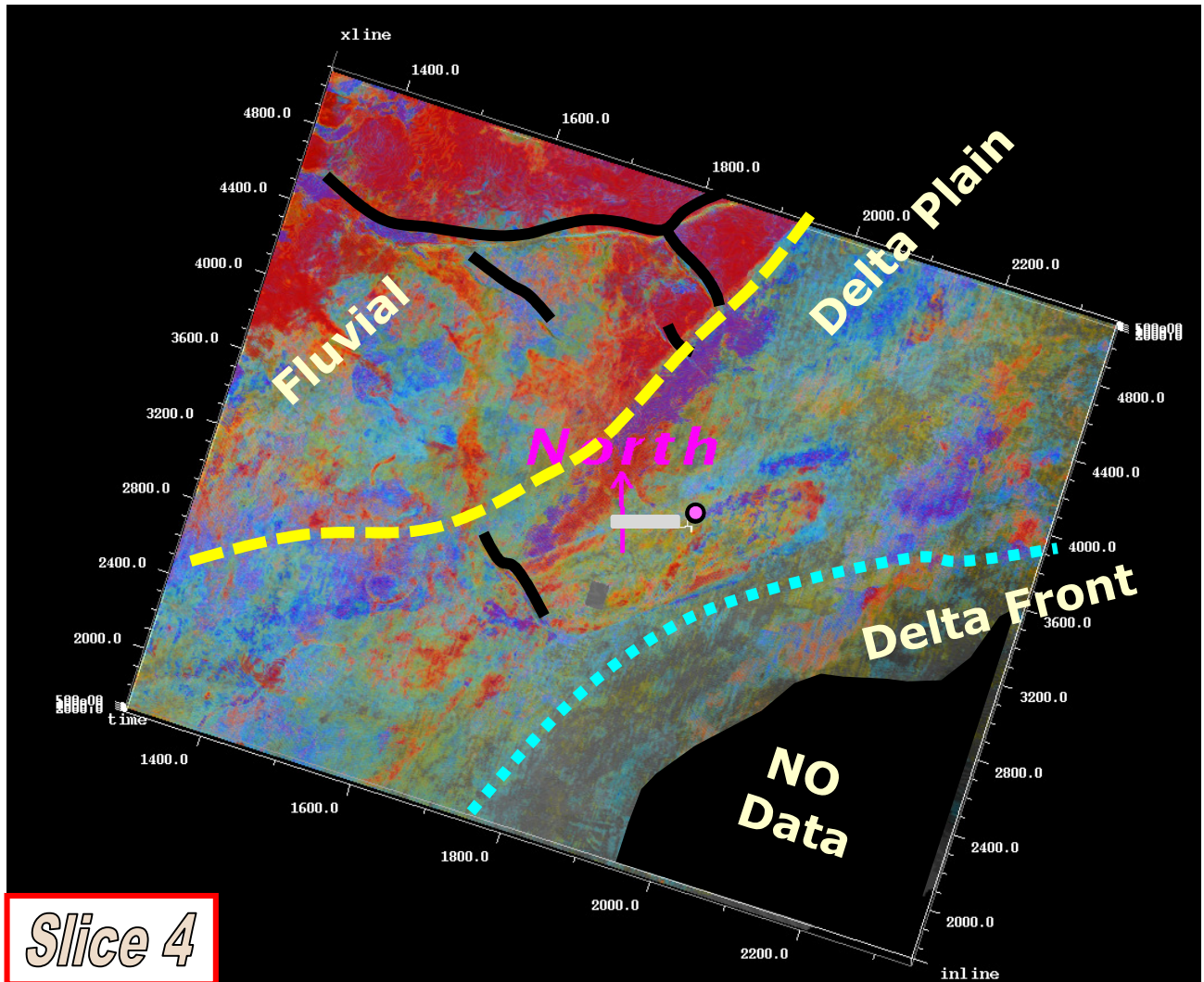
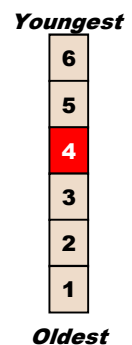


Figure 6. Average magnitude (absolute values of amplitudes) for Slice 4, which is the youngest. An interpretation of the boundaries between the fluvial, delta plain and delta front is shown.



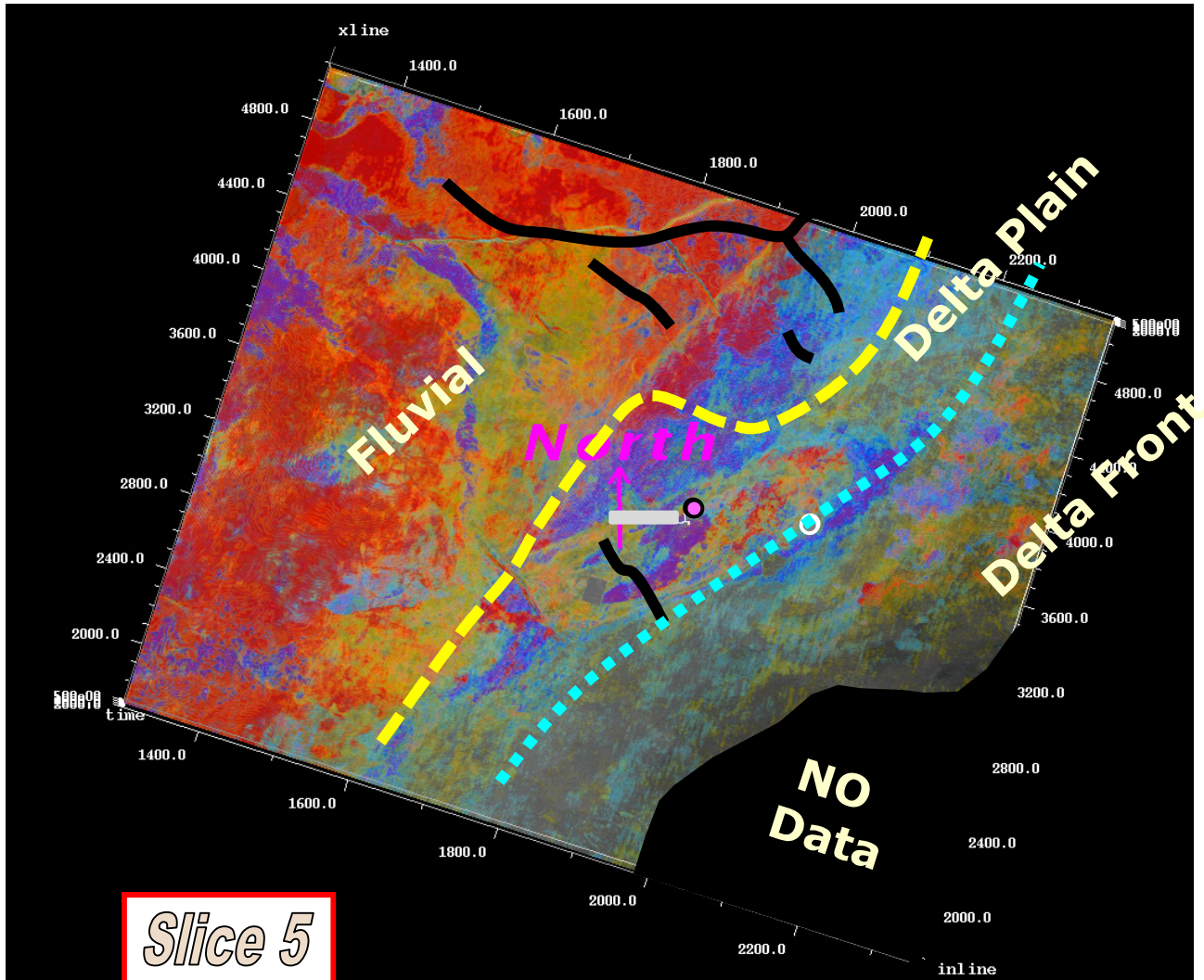
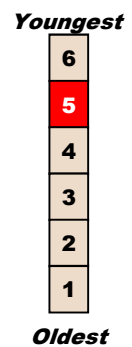


Figure 7. Average magnitude (absolute values of amplitudes) for Slice 5, which is the youngest. An interpretation of the boundaries between the fluvial, delta plain and delta front is shown.



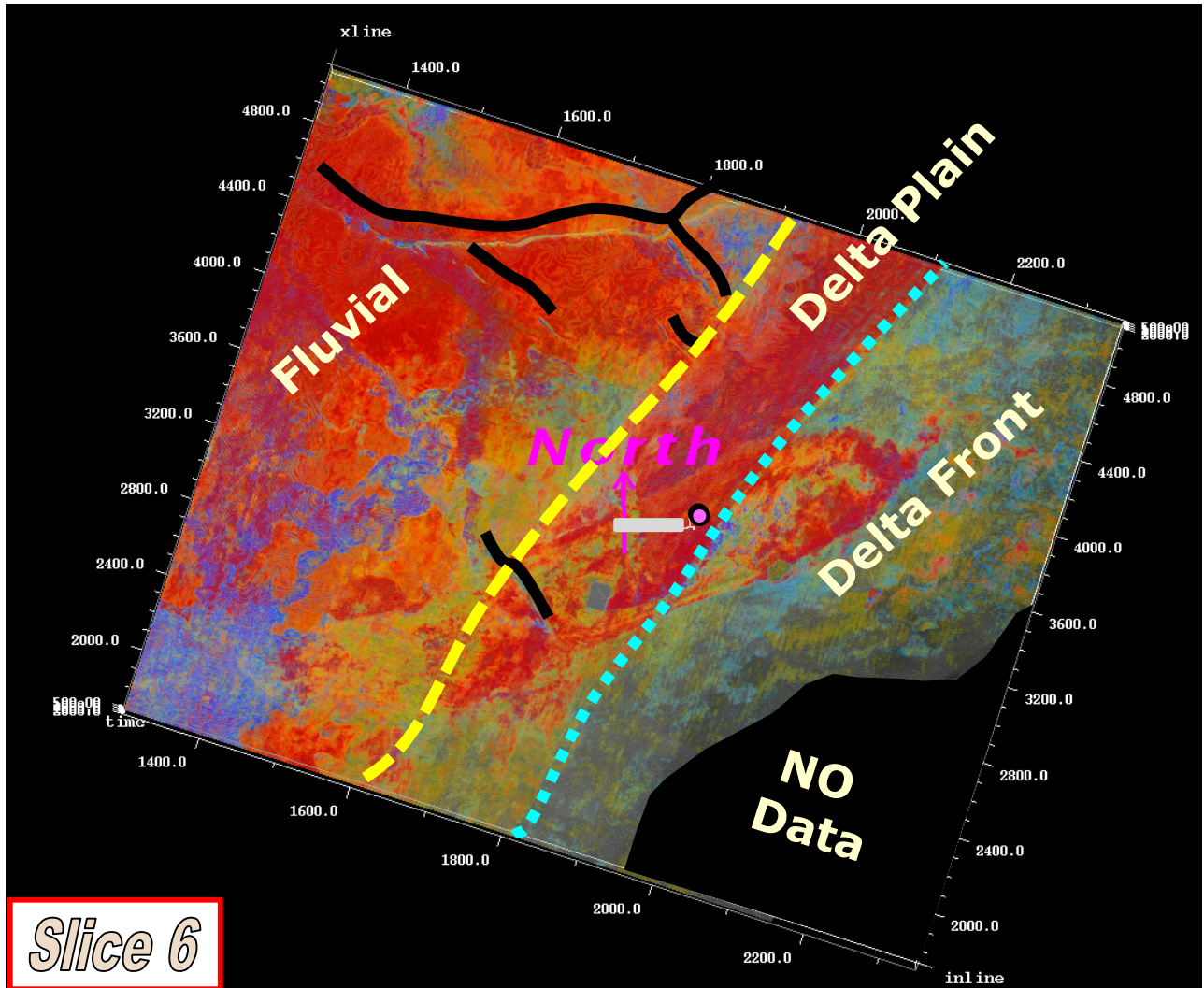
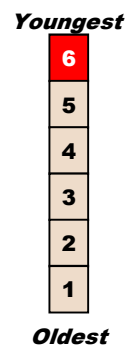


Figure 8. Average magnitude (absolute values of amplitudes) for Slice 6, which is the youngest. An interpretation of the boundaries between the fluvial, delta plain and delta front is shown.



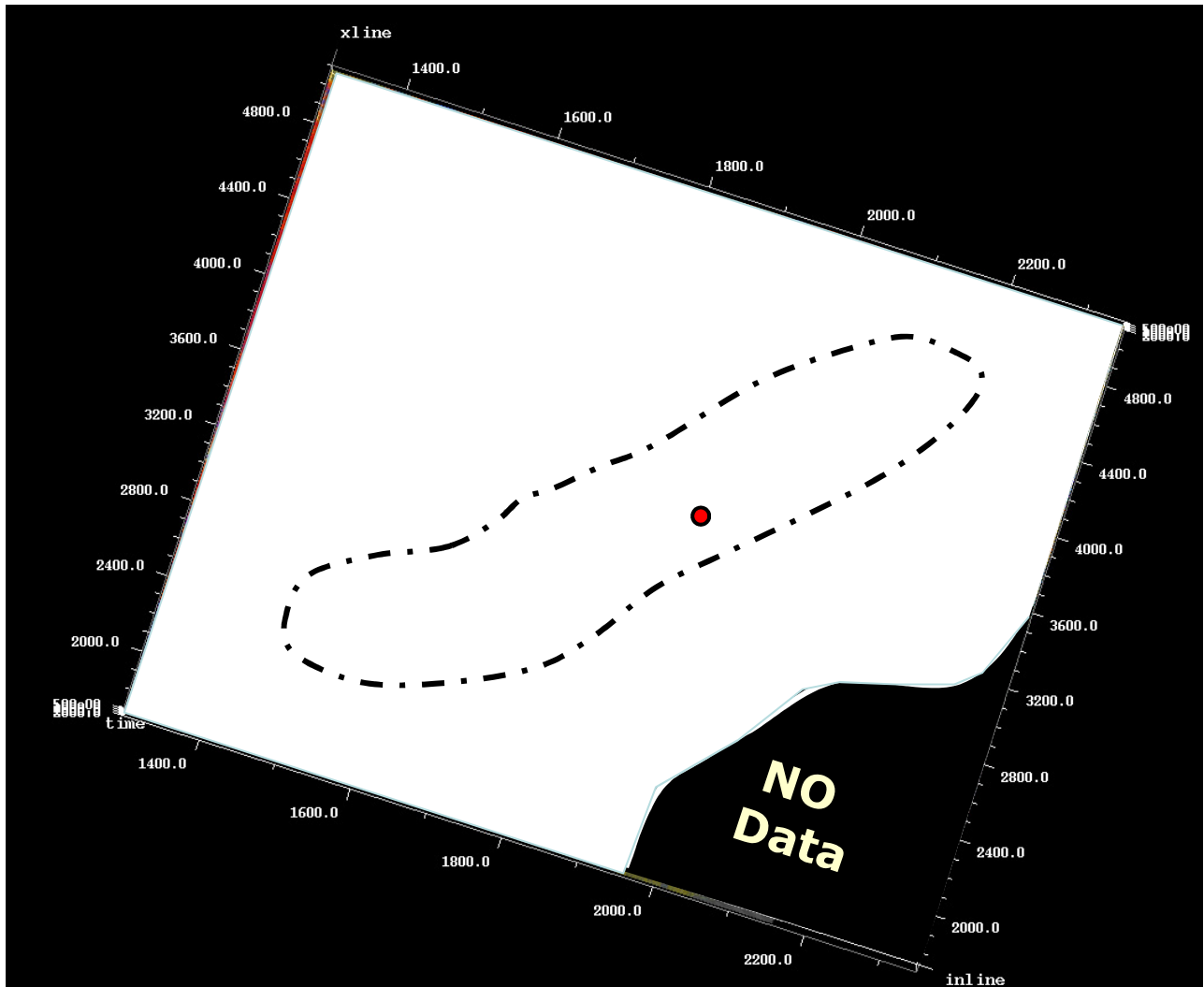


Figure 9. Base map of the 3D seismic survey showing the proposed well location and the seismic evidence for a change of fluid type, presumably brine outside the dashed black line and HC (oil or gas) inside.