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Determining Depositional History Through Use of Cognitive Interpretation Workflows*

Ryan Williams[1] and Rachael Moore[1]

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[1]GeoTeric, London, UK. (Ryan.Williams@GeoTeric.com)

Abstract

Cognitive Interpretation is a method of understanding geology before interpreting seismic that harnesses our natural cognitive capabilities. Cognitive Interpretation combines the power of algorithmic computation within software with the benefits of an interpreter's knowledge and experience. About 40% of the brain is devoted to visual cognition and there are strong links between visual system and memory. Because of this, the brain effectively links current visual data with past experience and learnings in order to make sense of incomplete or ambiguous data. This linking of visual data and past learnings is what seismic interpreters do with data, by pattern matching what is seen with what geological features are known to look like. In this study, reflectivity data was directly translated into geological information, before any traditional line-by-line interpretation.

During a regional reconnaissance project, a seismic anomaly (Figure 1) was discovered in the Northern Graben of the Taranaki Basin, New Zealand (Hansen & Kamp, 2006, 2008), the origin of which caused much discussion. The depositional history of this anomaly was deciphered quickly through the use of software and workflows that are designed to support Cognitive Interpretation.

A top surface interpretation was tracked using an adaptive interpretation method. To get a better understanding of the depositional history, iso-proportional slices conformant to the interpretation was created. From these slices, the geology of the anomaly is interpreted to be a crevasse-splay from a larger channel event. Using Cognitive Interpretation workflows, a rapid understanding of the depositional history of this bright anomaly was determined. The ability to interactively slice through the RGB blend volumetrically enabled the team to visualize and hence understand the depositional evolution of the channel and fan systems. Being able to confidently interpret the relationship between the fan and the channels that feed into it would not have been possible by simply creating a surface on the high amplitude anomaly.

Method

Cognitive Interpretation is an interpreters' natural version of the Geological law of Uniformitarianism which can be simplified to "the present is the key to the past", whereby the interpreter is utilizing past experiences, processes, judgement and reasoning to make a formal decision on more recent interpretations. Essentially, using past experience to explain the present. To harness these natural cognitive capabilities it is possible to show large amounts of geological information at specific horizons in the subsurface. These reconnaissance volumes can be generated through High Definition Frequency Decomposition (HDFD), Blending Near, Mid and Far (NMF) angle stack envelope volumes and Iso-Proportional Slicing (IPS). HDFD Blends use a matching pursuit algorithm to maximise the vertical resolution of frequency whilst still having a high frequency resolution. By reducing the vertical smearing often associated to standard frequency decomposition methods it is possible to increase the accuracy of interpretation in the X, Y and Z orientations. This process can be used to identify individual geological events.

Once the events have been identified, IPS can be used to analyse laterally extensive areas with targeted vertical constraints. By targeting specific events it is possible to increase accuracy by not being influenced by events or anomalies that are not associated to specific events.

The identification and delineation of geological events is just one stage of the Cognitive Interpretation process. The next step is trying to understand the event. This can be achieved by creating interpreter guided geobodies of the event, using the earlier generated NMF Blend. The geobodies can then be analysed by a data driven Interactive Facies Classification (IFC) method to identify areas of similarity and difference within the event. The IFC analysis can be extended into the seismic volume to identify further areas of interest that match your defined target, and the process starts again with a new study area.

Results

HDFD colour blending of the full angle stack using discrete frequency bands and blending of the near, mid and far envelope volumes highlights an anomaly located at the base of a large relay-ramp structure (Figure 2). The HDFD blend illustrates some internal structure to the anomalies which supports the interpretation of a crevasse-splay feature from the larger erosive east-west amalgamated channel system. The NMF blend on the other hand can tell you more about the potential composition of the event. As the individual stacks are blended together and the anomaly is dominantly blue/cyan, this would suggest a strong input from the far envelope volume.

This strong far stack response can relate to a number of geological changes. This could be associated to a change in lithology from fine-grain over-bank deposits to coarser Bouma-like sequences associated to the crevasse-splay. With this change in lithology it would be expected that there will be a change in porosity, which can influence the frequency response. A third reason for a strong far stack response could relate to a change in fluid fill. AVO studies suggest a far off stack response can indicate gas fill sand bodies.

To enhance the interpretation of the anomaly IPS was undertaken using the earlier interpreted horizon using a window ±100ms (Figure 3). This separation process makes it possible to identify further details in the NMF Blend. This process identifies some of the smaller scale channel like systems that drain to the south of the feature into the adjacent hanging wall low area. The internal structure of the channel and further events to the south can be delineated due to the high vertical resolution of the HDFD Blend.

The additional information in Figure 3 shows smaller scale channel/flows to the south which are not the only geological response that was drawn from the IPS. The main anomaly itself can be sub-divided into a number of events. The main body of the channel shows a strong purple colour, which could suggest thicker sediments and some internal lineations which relate to clinoforms can be identified (Figure 3.3). An additional thin channel/flow can be seen parallel to the event on its northern edge (Figure 3.4). Along the south-eastern edge of the event some light pink responses are observed and have a fan like response to them (Figure 3.5). They appear to drain to the south where the newly generated depo-centre from the relay-ramp structure is situated. These may be late stage drainage features to the crevasse-splay event. Potential drainage events are identified on the north-eastern edge of the anomaly into the south-eastern channel (Figure 3.6 & 3.7). Two large scale channel systems can be defined to the northwest and southeast, both of which contain much smaller channel like events including abandoned channels and large meanders (Figure 3.8).

With the anomaly identified with the reconnaissance volumes and a theory about the geological environment gauged, it is further possible to delineate the event by creating a geobody (Figure 4). A single geobody was created of the event so that its component parts such as channel axis, channel fill and fan deposits can be defined in the IFC analysis. The geobody was created using the NMF Blend as it gave a strong constant response throughout the entire event. A number of sample areas were generated on multiple time slices, inline and crosslines to define the internal and external nature of response.

IFC was undertaken to identify differing areas within the geobody based on the frequency response of the event (Figure 5). The HDFD Blend was used in this instance, as we can start to make some basic assumptions about the response and how this will determine how the sample areas were defined. Commonly thicker events will have a red tinge to them as they tend to be more low frequency dominant. This can be observed in the anomaly and can be interpreted as the channel axis, where deposition is at its thickest. Alternatively, the thinner events which are predominately high frequency will have more blue responses. This is highlighted in the HDFD Blend with the fan-like drainage features towards the west.

With the Cognitive workflows complete it is possible to define the geological anomaly with a higher level of confidence as a crevasse-splay deposit, based on the intuitive manner in which the event is analysed. If the event was viewed at in purely a conventional 2D way, it is possible that the event may have been missed as the full stack volume shows no significant seismic brightening (Figure 1). Analysis of the event with the HDFD and NMF Blends made it possible to identify and delineate the event and guide the interpretation of the anomaly. This analysis was supported by the generation of a geobody and IFC which was able to identify differing areas based on interpreter guided decision making and interpretation.

A modern day example of the crevasse-splay deposit is shown in Figure 6 and is taken from the Columbia River, British Columbia. In this instance a crevasse-splay formed at peak flow and caused the river to burst its banks and deposits large amounts of sediments on the surrounding flood plain.

When comparing the example of the Columbia River against the New Zealand anomaly, similarities can be drawn on the style of deposition. Both events have a "core" sediment system (orange) which has been infilled by earlier sedimentation (yellow) with more fan like deposits in the distal region (brown/grey). The drainage pattern of both events flows towards the structurally lowest location. The Columbia River example is parallel to the direction of the primary channel, whereas, the New Zealand anomaly is towards the southern faults hanging wall depocentre. This cognitive method of analysing the data and interpreting using past experiences and modern day examples can enhance the quality and speed of seismic interpretation.

Conclusions

Undertaking interpretation of a geological event with cognitive-based methods has generated a quick, yet reliable result that can be explained based on the interpreter's past experience, judgement and reasoning. Analysing the frequency content of the event reveals the geology in greater detail than that of just the amplitude response. By identifying subtle changes in the frequency content, it is possible to identify the internal structure of the crevasse-splay flow event. Iso-Proportional Slicing through the event further delineates the event and helps place the debris flow in a semi-regional context.

The crevasse-splay deposit was able to be extracted as a geobody and examined in 3D. By creating this 3D representation of the event it may be easier for an interpreter to get a better understanding on flow orientation and event development, as opposed to a 2D visualisation. The delineation of the debris flow in 3D allowed for a detailed Interactive Facies Classification where it is possible to identify the channel axis, channel fill and potential fan features. This process assists with the detailed understanding of the crevasse-splay deposit and can be guided directly from the interpreter, based on previous experiences.

By combining the information together from all of these stages and using modern day examples it is possible to predict depositional history and the location of potential reservoir sands and assist in prospect generation and/or future well positioning.

Acknowledgments

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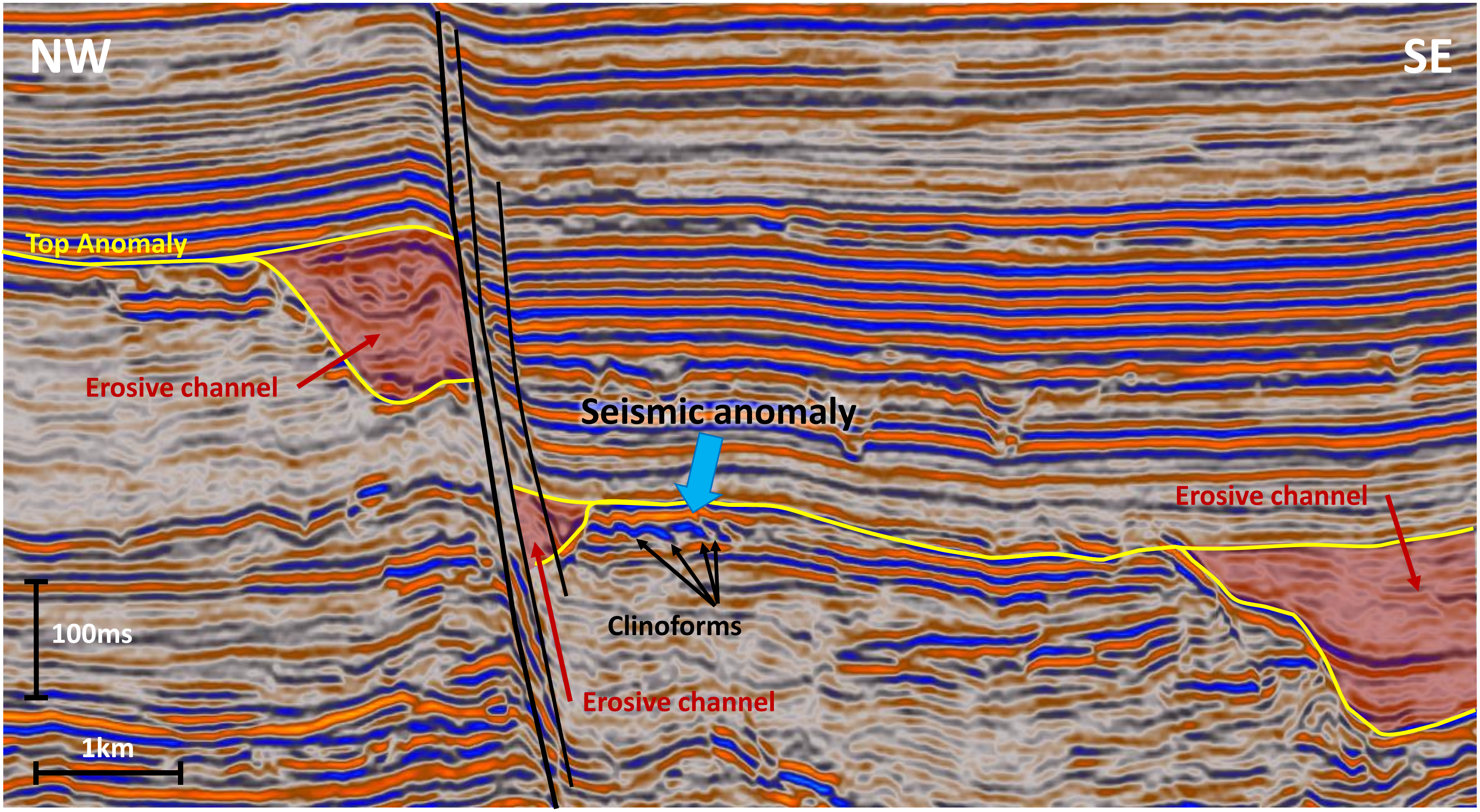

Figure 1. Seismic section highlights the seismic anomaly with its internal clinoform texture. The event is bound on both sides by large scale erosive channels which have subsequently infilled.

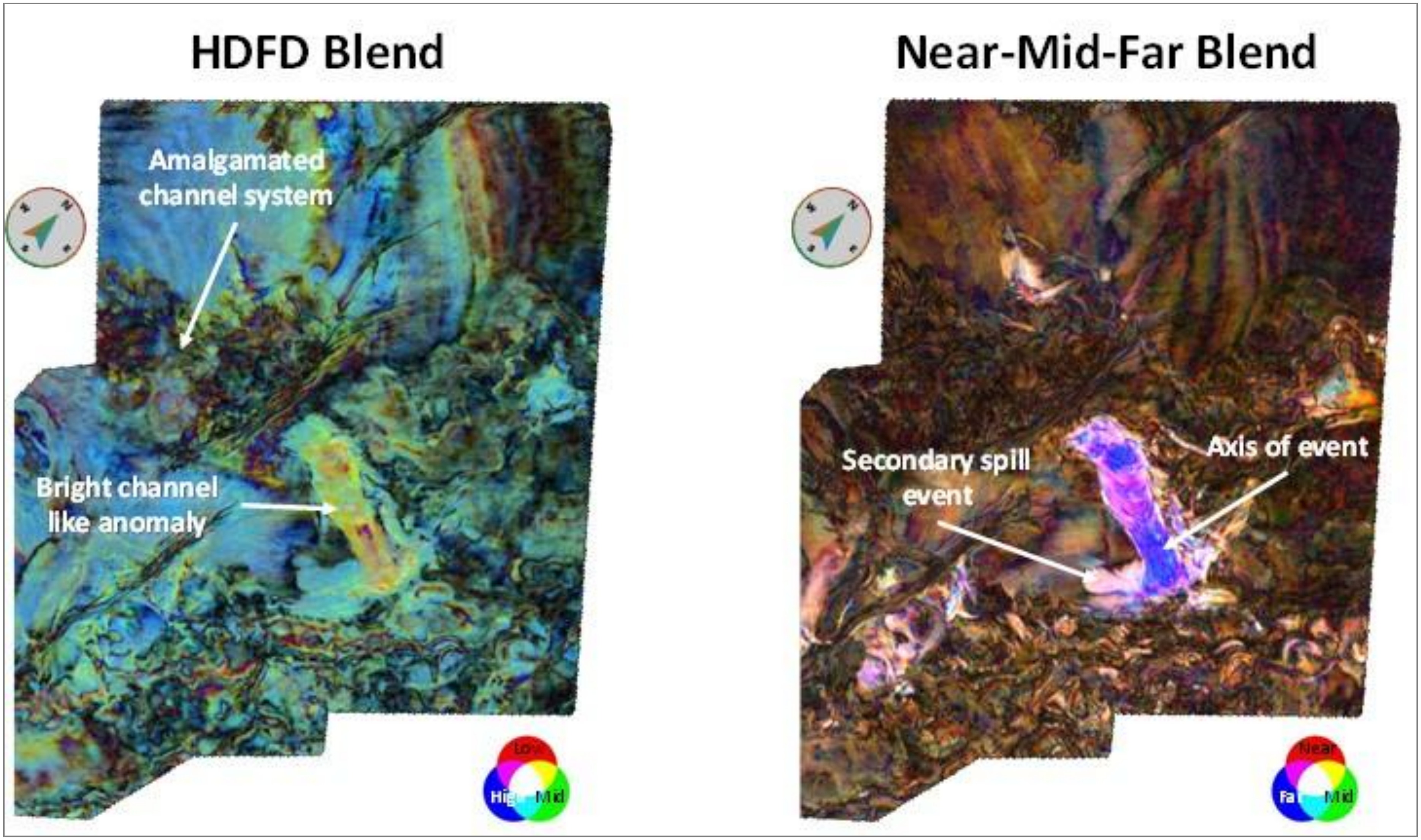

Figure 2. HDFD (left) and NMF (right) blends help identify the anomaly and its geological deposition of environment.

Figure 3. Iso-Proportional Slices from the NMF RGB blend through the anomaly, with 1 being the youngest and 8 the oldest. A number of events ranging from internal clinoforms, feeder channels and abandoned channels can be identified surrounding the anomaly.

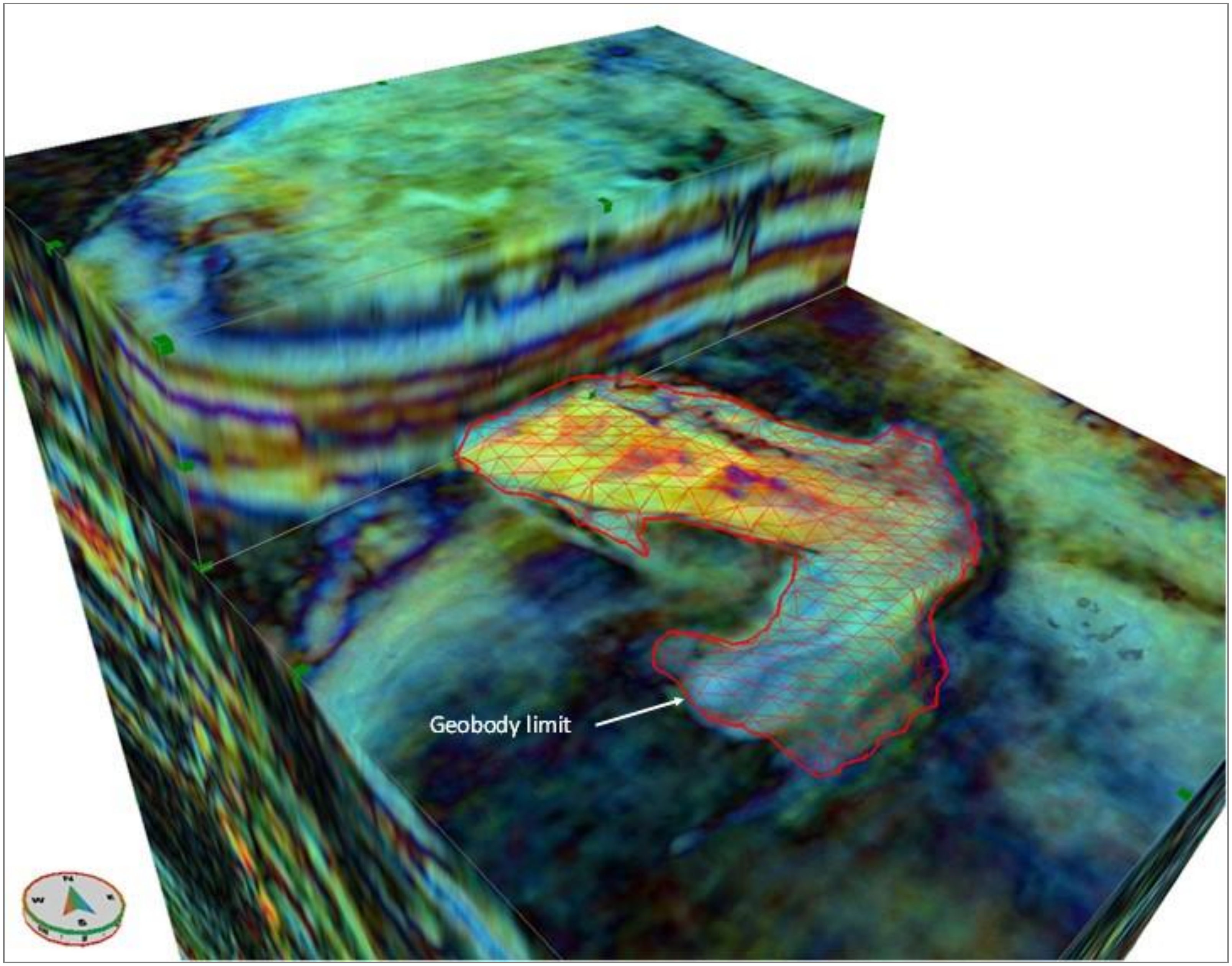

Figure 4. Geobody overlay and mesh view illustrate the extent of the geological anomaly against the HDFD Blend. The Geobody consists of the main channel body and the westerly spill/fan systems.

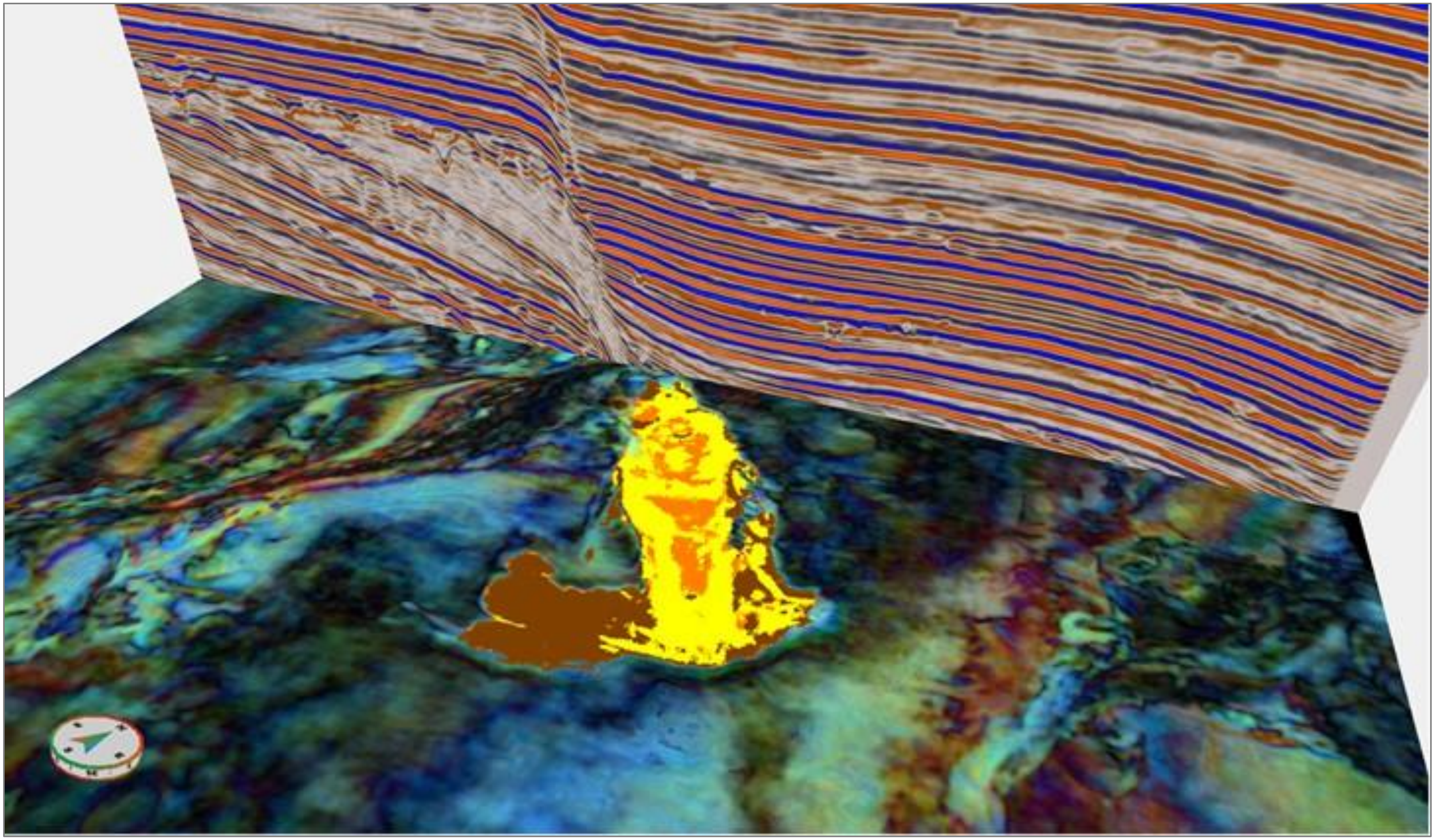

Figure 5. IFC results show the channel axis (orange), channel fill (yellow) and distal fan like deposits (brown) throughout the anomaly. Analysing on the HDFD Blend made it possible to separate these defined areas out based on frequency response.

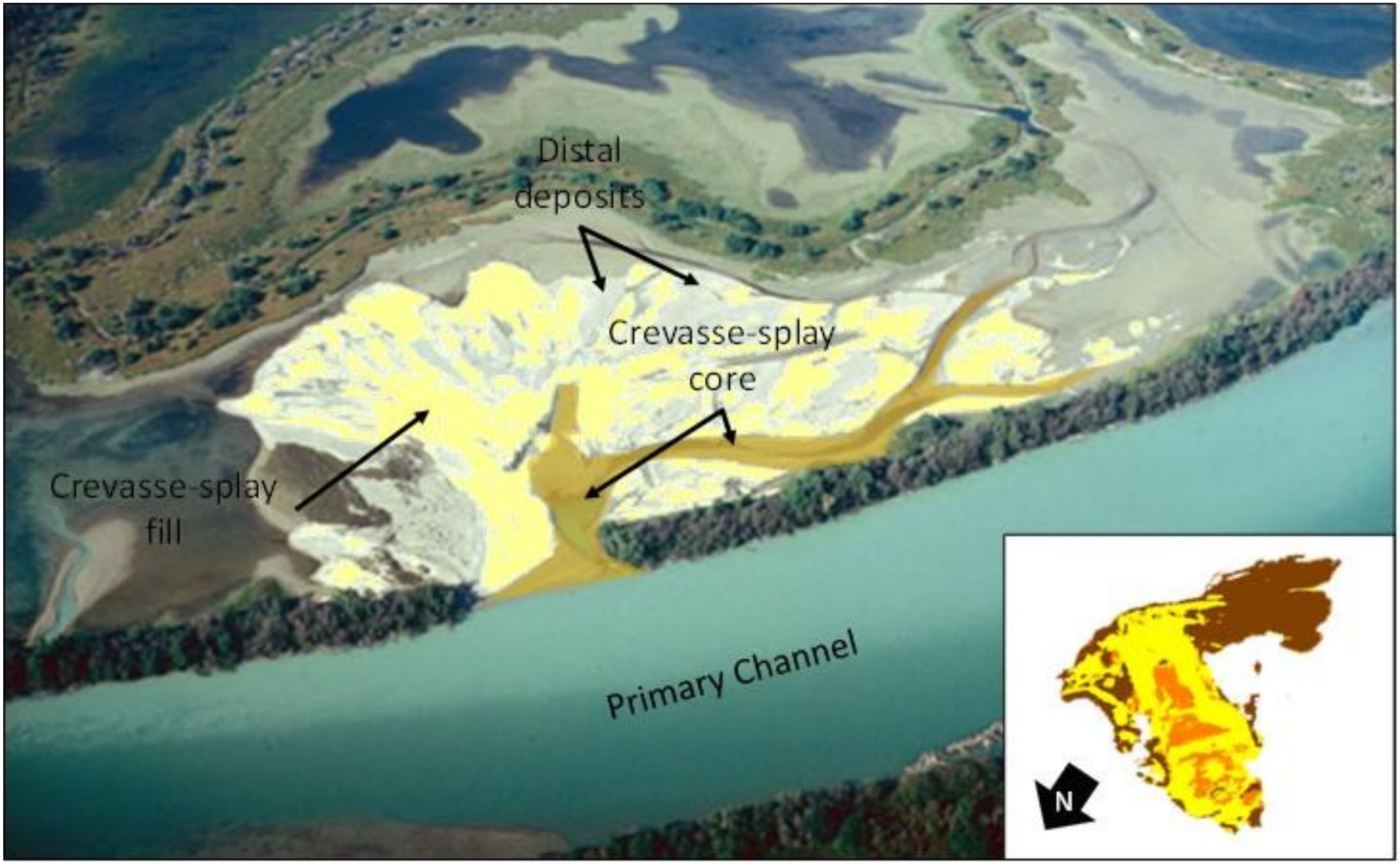

Figure 6. Crevasse-splay deposit from the Columbia River, British Columbia. Able to see the same complex system that is observed in the Parihaka anomaly. The channel core (orange), channel fill (yellow) and distal fan like deposits (grey) can all be identified (picture by H.J.A. Berendsen).