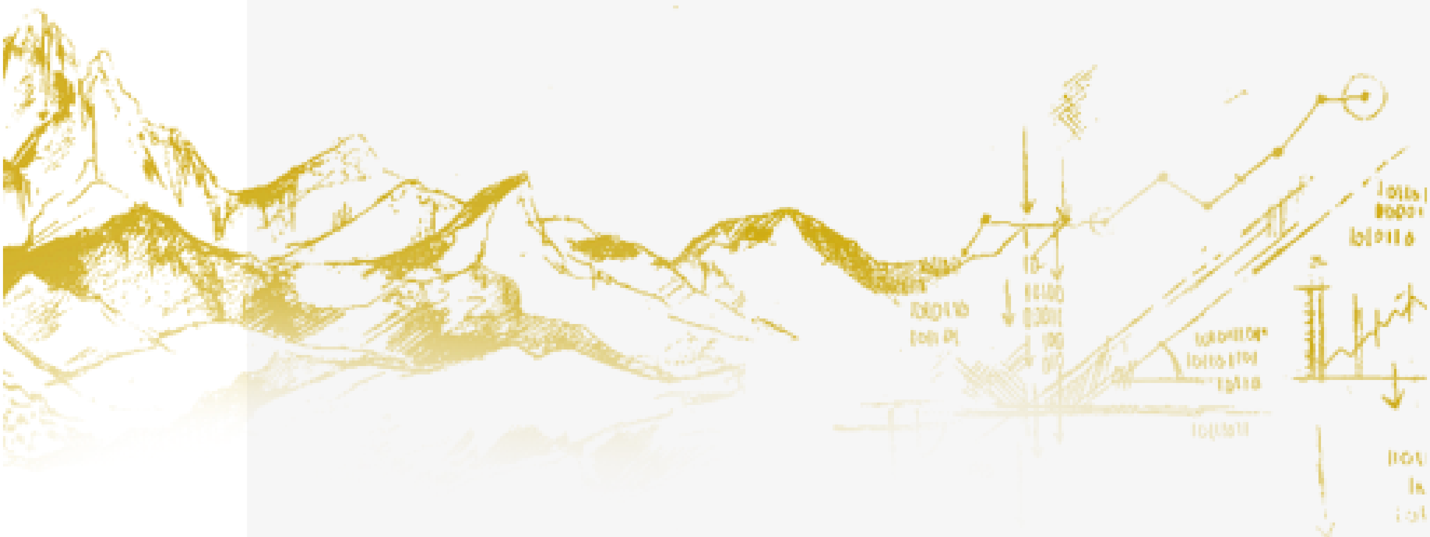
BIAS IN ANALOGUES



PREPARED AND PRESENTED BY

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SUMMARY

Geological modelling of reservoir fields is common practice in the process of assessing the predictability of hydrocarbon recoverability. Accurately representing subsurface geology is challenging when only limited data are available to start with, bed-scale heterogeneities are often overlooked or seen as unimportant, but it is these features that may act as baffles later in field life. We present here the results of a study where geologists were given a two-dimensional panel to construct, interpreting from well and sedimentary log data alone.

Results varied dramatically from person to person; where no fine-scale data was given at the start, in-facies heterogeneities were not interpreted. Where these smaller-scale details were provided in logs, they were included in the interpretations, however, architectures and geometries were still not accurately reproduced. Without having an appropriate analogue, the full range of facies and architectures cannot be captured, and correct geometries not predicted.

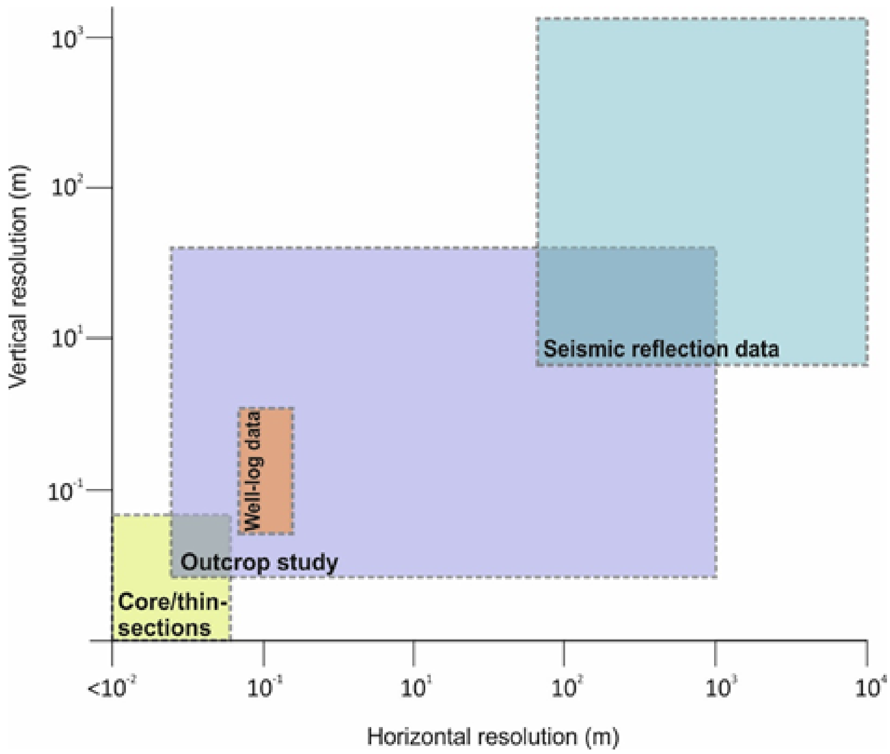
INTRODUCTION

Geological reservoir models aim to predict the volume of recoverable hydrocarbons by identifying the type and architecture of the reservoir rocks. In doing this, it is necessary to recognise and quantify features within the reservoir that will ultimately effect hydrocarbon production (Alexander, 1993). Geocellular models have become the standard way to simulate and understand subsurface reservoirs (Budding and Inglin, 1981; Keogh et al., 2007; Howell et al., 2014). These types of models serve several purposes; to aid field development, to support reservoir management business decisions, to integrate subsurface data that are orders of magnitude different from one another, and to help visualise the 3D nature of geological systems (Howell et al., 2014). Therefore, building accurate models is essential for any decisions regarding field performance.

The main challenge for reservoir modellers is producing heterogeneous distributions of reservoir properties between wells at a scale that will accurately represent the geology. Wells and seismic reflection data provide the foundation for initial reservoir models to be built; wells provide a high resolution, 1D ‘image’, though typically will provide a sample representing less than one millionth of a percent (Bentley, 2015) of the reservoir.

Seismic data will provide much more extensive coverage of the reservoir, but resolution will be low (Fig. 1). In early field life, a broad model of the subsurface may be sufficient, later on in field life, however, it is more important to reduce uncertainty, for example, the subtleties of a heterogeneous but broadly connected sand-rich reservoir may not be a major issue during the early lifecycle, but will be highly significant as the final infill wells are placed later in field life.

Figure 1: Data resolution across core, outcrop and seismic.



ANALOGUES

An analogue refers to something comparable to something else, both having similar functions or features. In geology, analogues are often used to make interpretations where data are limited. The power of using analogues can be shown in a simple example; recently imaged sinuous ridges and meandering features on the surface Mars (Fig. 2A) are interpreted to be the product of fluvial processes through comparison to similar features on the Earth's surface (Fig. 2B). This interpretation, therefore, implies large quantities of water were once present on Mars.

A reservoir analogue is an example of geologic similarity regarding reservoir character and depositional environment; and can be used for comparison to guide reservoir predictions and to bridge the gap between well and seismic scale (Fig. 1). Though, even with analogues, it is difficult to predict the sedimentary facies, diagenetic features and fracture distribution in unsampled areas (Alexander, 1993).

Here, we show that, without sufficient data it is difficult to accurately select appropriate analogue(s), and that interpretations from person to person, who are given the same starting data, can vary significantly. In building reservoir models, the most appropriate analogues may be unknown to the modeller, or, as is more often the case, in-built personal bias of the most suitable analogue(s) to use that are influenced by adjacent fields or prior knowledge of using particular examples that have been successful in the past. This can result in models lacking key information and inaccurately portraying the subsurface geology.

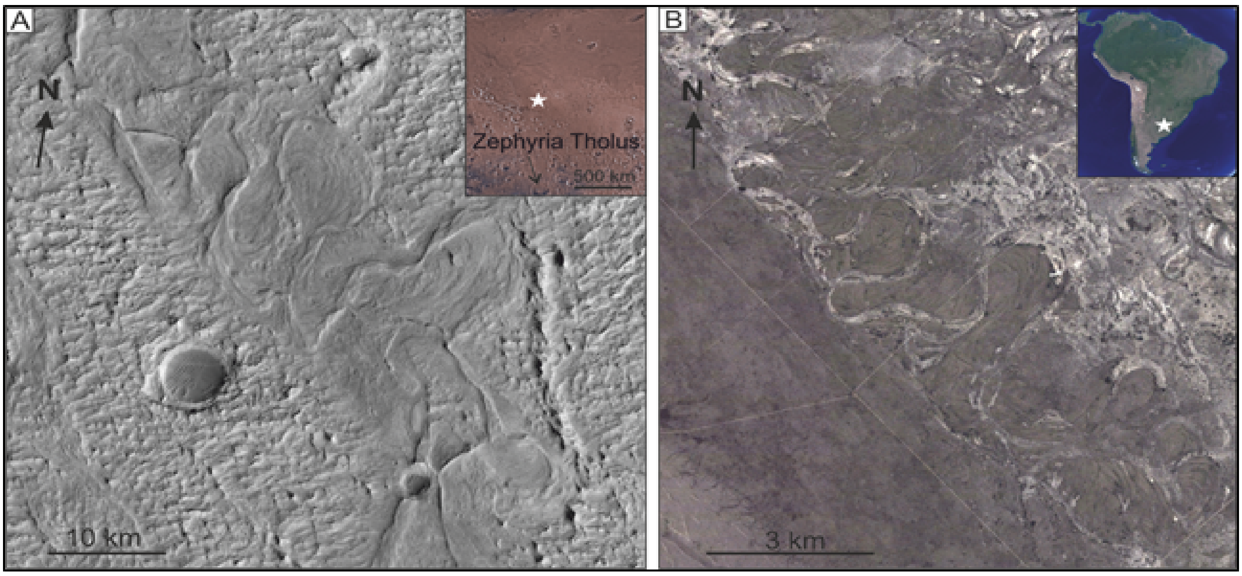


Figure 2: Using analogues to interpret features on the Martian surface. A) An example of a feature on Mars' surface that can be interpreted using analogues. Image from NASA/JPL/University of Arizona. B) River deposits from Rio Negro, Argentina. Sinuous channels and point bar deposits show remarkable similarities to features imaged on Mars.

CASE STUDY

Without using analogues, the prediction of smaller-scale heterogeneities (such as facies changes between beds) within a system is near impossible. To demonstrate this point we have taken a published correlation panel (Figure 7 from Hornung and Aigner, 1999), removed the ‘answer’ and asked several geologists to interpret between gamma ray, and sedimentary logs (Fig. 3B). The panel contains two logs over a 150 m section. In the first exercise, people were given only log responses with which to interpret and build a model. In a second run, the fully interpreted sedimentary logs were given alongside log responses (Fig. 3B); this is more detail than would be afforded from subsurface data.

The study is based in Upper Triassic Stubensandstein of Southern Germany. The Stubensandstein formation forms a sand wedge along the margin of the Keuper Basin of mainly fine to coarse grained clastic sediments. The system is interpreted to represent a terminal alluvial plain (Aigner et al., 1995) that was deposited in arid to semi-arid conditions (Hornung and Aigner, 1999). The panel used here is from the Katzenbühl quarry near Stuttgart, which is palaeogeographically situated in the medial part of the alluvial plain. Figure 3A is the original panel from Hornung et al., 1999; the western part of the outcrop has a moderate sand-to-mud ratio, whereas is the eastern part, muddy intervals are dominant. This is due to the sheet like sands being eroded out by channels later infilled with mud (Hornung and Aigner, 1999).

It is the smaller-scale details such as metre-thick muds separating sandy channel accretion deposits, which may be minor, or not identified in log responses, yet have the potential to act as baffles when modelling fluid flow, particularly for later in life field simulations. It is these, subtler features that arise as being fairly substantial uncertainties as the lifecycle of a development progresses.

RESULTS AND ANALYSIS

The first part of this study only gave wireline log responses and a broad geological setting (Fig. 3B); Figure 4 shows three individual interpretations given this information. With little information, Person A (Fig. 4A) has made a fairly accurate interpretation regarding facies. However, the main issue is whether the sand units are connected. Person B (Fig. 4B) did connect the units and modelled them as single reservoirs but remained uncertain as to the upper sands. Person C remained uncertain as to the connectivity or facies changes between logs; when modelling, this would not only create questionable reservoir connectivity and fluid flow pathways, but also put a large range on volume estimates.

Given more information in the form of detailed sedimentary logs in a second round of interpretation, Person A has added more detail regarding facies types, however, this has led to a possibly less accurate interpretation (Fig. 5). For example, the large section of lateral accretion in the upper half of the section has been modified to a suspended load channel fill. The question of connectivity between sand units remains. Person B, given cross-bedded sand interpretations has now over-estimated sand volumes and connectivity across the upper half of the section. Person C now has reduced uncertainty in overall connectivity.

Individuals' prior knowledge enable the main facies types and architectural element dimensions for this section to be estimated with a certain degree of accuracy, but in all cases connectivity between units was unpredictable (Figs 4 and 5). Even when more information is given (Fig. 5), the issue of selecting the most appropriate analogue(s) arises; the difficulty is in the large number of degrees of freedom in the processes of formation of reservoir rocks, and the limit of accessible, well-documented analogues (Alexander, 1993).

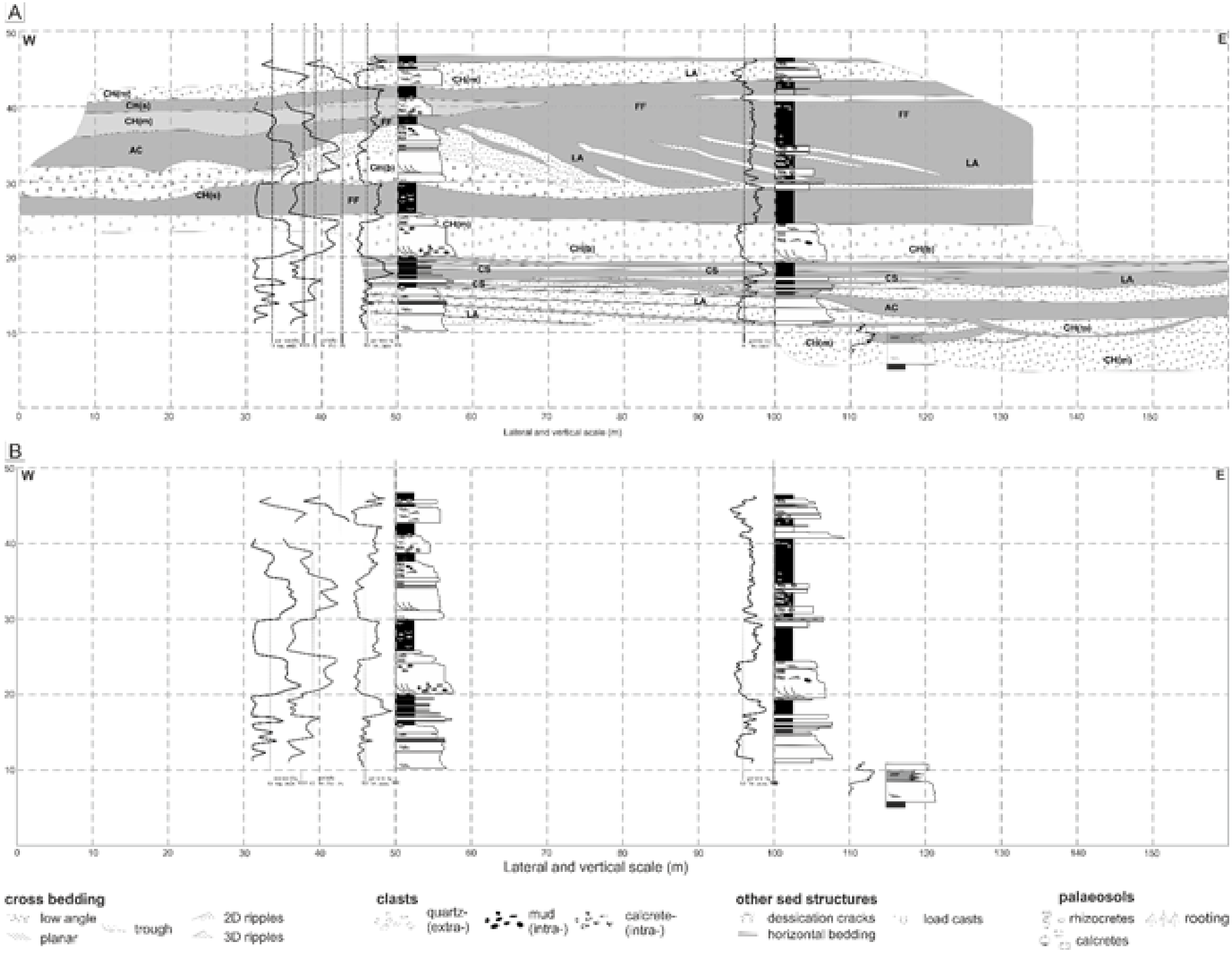


Figure 3: A) Outcrop panel of Katzenbühl with the mapped sedimentary structures and architectural elements, and calibrated by measured sections. Note the two different types of lateral accretion deposits depending on their stratigraphical position and stacking pattern (taken from Hornung and Aigner, 1999). B) Same panel with interpretation removed, this is the panel (both with and without the sedimentary logs that were given to geologists to interpret.

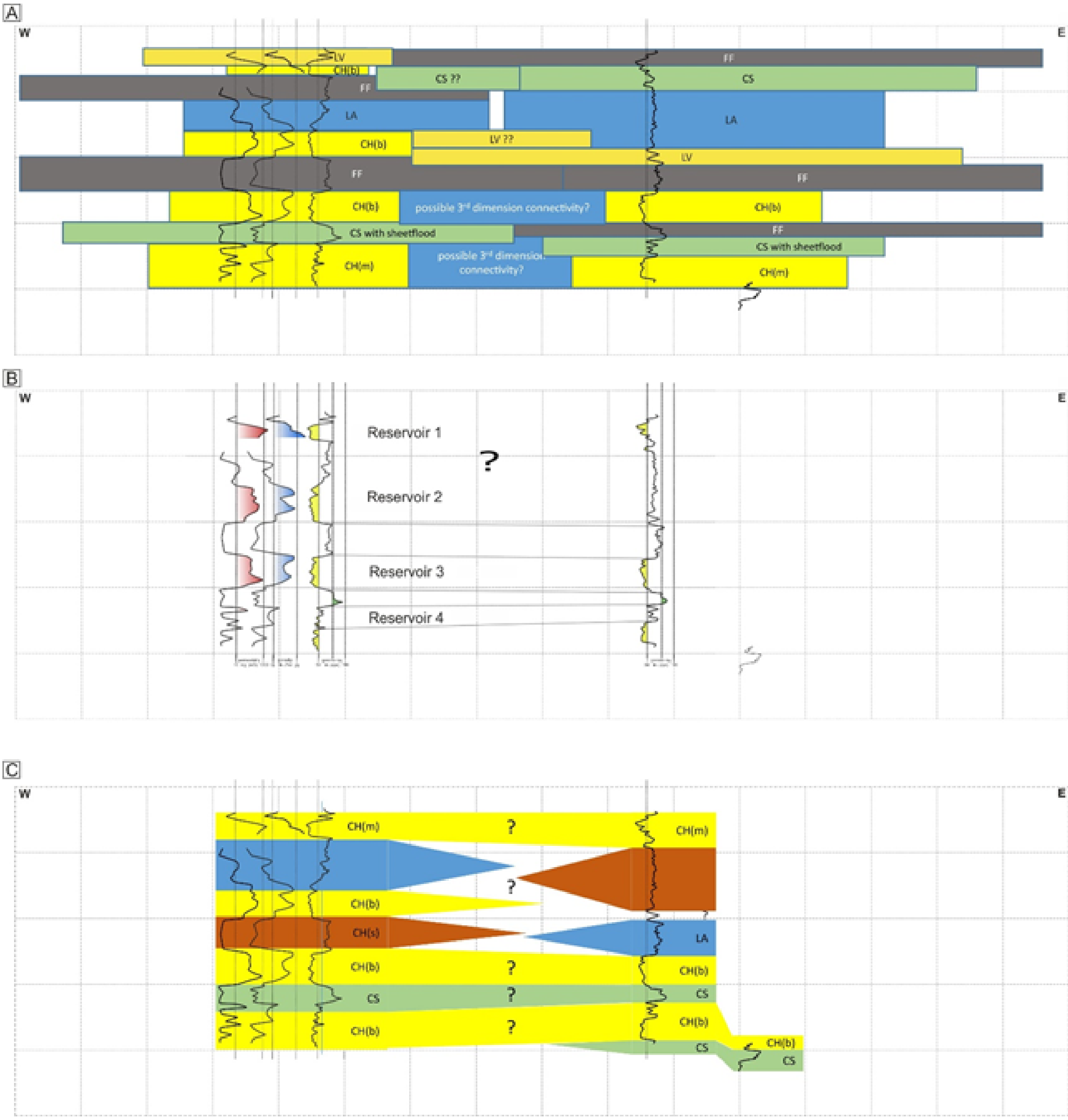


Figure 4: Interpretations using only the well log data. A) Person A has done a full facies interpretation but connectivity was left uncertain between sand bodies. CH(b) Channel (bed load); CH(m) Channel (mixed load); CH(s) Channel (suspended load); LA Lateral accretion; AC Abandoned channel; LV Levee; CS Crevasse splays; FF Floodplain; LC Lacustrine. B) Person B has connected two lower sand units but remains unclear as to the upper half of the section. C) Person C is uncertain as to facies types and connectivity between logs.

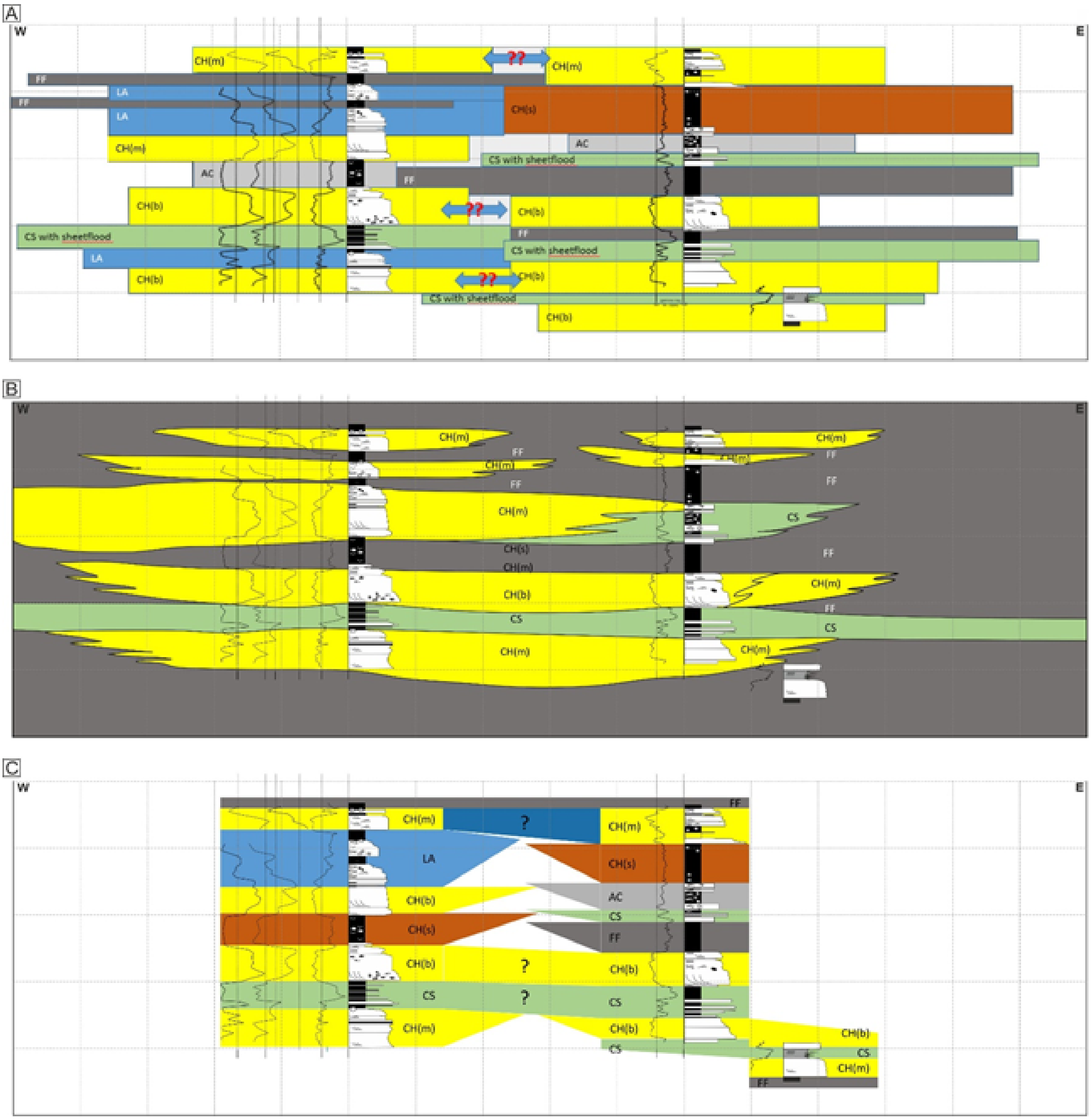


Figure 5: Interpretation of same panel with sedimentary log, and therefore facies, data now given. A) Higher resolution interpretation, with more facies types included. However, it should be noted that uncertainty between sand bodies remains. B) Sand body shapes now estimated, and connectivity between logs predicted. C) Uncertainty between logs also remains in this interpretation, though connectivity has been reduced in the lower sands.

CONCLUDING REMARKS

Reservoir models are built to simulate and understand subsurface reservoirs, without using the appropriate analogue(s) it may be near impossible to accurately simulate heterogeneous distributions of reservoir properties. We have presented here an example where geologists were given the same starting data to create a correlation. With no analogue to use, results relied on experience and prior knowledge, and varied dramatically; small-scale heterogeneities such as thin mud layers that may act as baffles were not captured. In the second example where more detail was given to correlate from, these smaller details and heterogeneities were incorporated into the model, but architectures and geometries were still not accurately captured.

This work demonstrates the importance, not only of using analogues to interpret subsurface geology, but using appropriate analogues without bias. This is somewhat more of a challenge, as people are limited by the extent of their own knowledge base, and often have a preference to use an analogue that has worked well in the past, even if for a different field.

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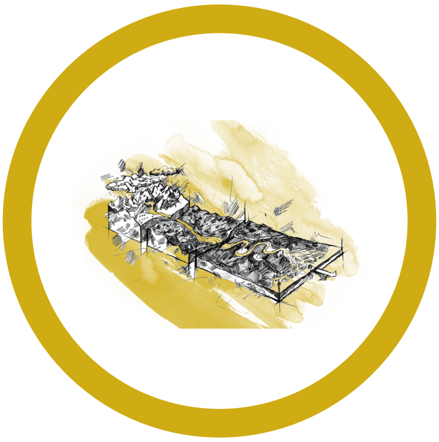
Petrotechnical Data Systems (PDS Group) is a leading provider of petrotechnical software solutions to the petroleum industry. For more than twenty-five years, PDS has delivered innovative software technologies, R&D and consulting services to the petroleum industry from technology centres in The Hague, Houston and London.



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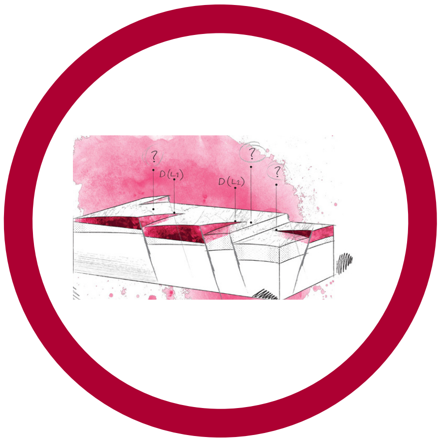

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