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Carbonate Ramp Controlled by Alternate Fault Activity, Geological versus Seismic Expressions

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Introduction

Carbonate units with equal thicknesses over very large areas were hard to comprehend until the birth of the carbonate ramp model. The concept was intriguing but the evidences were often missing for the existence of prograding patterns often referred as clinoforms. The present paper will address both the geological and geophysical expressions of clinoforms; the main emphasis being subsurface examples and seismic models based on synthetic seismograms. Some aspects of the control by faults will be investigated.

Methodology

The first stage of the study has been to identify well developed prograding carbonate ramps from well data and from seismic. The aim has been to understand when and why clinoforms are recognizable in wells and in seismic (Figs.1 and 2). Another aim has been to find which contrasting lithologies would most commonly be recognized in a well defined clinoform and why. An attempt has been made to address the difference in nature and expression of clinoforms on the basis of their apparent preservation angles (using a break down proposed by Grélaud, 2005).

The geological expression

Clinoform surfaces commonly represent a pseudo timeline event; thus, maximum transgressions, commonly well expressed by anoxic and radioactive shales, are easily recognizable in wireline logs. Catastrophic events can also be very well expressed because foreign material is transported downslope and can result in dramatic changes in facies; the two main types of such sediments are grain-supported carbonates (mainly crinoidal grainstones and packstones in the Lower Banff) and cherty units.

The lithological expression of the clinoforms was examined with the help of wireline log and cutting descriptions from Canstrat. The 3-D geometry and the map expression of various clinoforms were analyzed with respect to the structural setting of each area studied (Fig.1).

The seismic expression

Clinoforms are sometimes associated with a well defined seismic signature (Fig.3); however most clinoforms are not readily or barely recognizable on seismic. Three clinoforms from various parts of West-Central Alberta have been examined from a combined geological and geophysical view point. Synthetic seismograms have been generated using density and sonic logs and a series of cross-sections have been created for various seismic frequencies. Depth is a major controlling factor to the frequency of the signal; below 40Hz (about 2200m) clinoforms have not been recognized; above 60Hz (about 1700m) clinoforms are commonly recognizable on seismic in West Central Alberta. Repetition of parallel and long linear features is a common characteristic of many clinoforms.

Alternate fault control

Whereas the structural control of these clinoforms is not a new idea, our recent study shows that during the Lower Banff time one area exhibits two different faults that have been alternatively controlling the prograding pattern of the carbonate ramp (Figs. 1 and 4). In Oman, similar shifts of progradation directions have also been identified and described (Droste and van Steenwinckel, 2004; and Grélaud, 2005).

Conclusions

Log facies maps are very powerful at displaying progradation patterns. Major shaley transgressive events are outstanding markers, whereas cherty units and to a lesser extent grain-supported carbonate facies are locally very good progradation identifiers. Work is on-going to determine if any lithofacies were systematically better than others as seismic reflectors. So far our cutting based analysis indicates that cherty units and bases of gradual coarsening up sequences are seemingly, locally, well imaged on seismic.

Seismic expression of clinoforms is clearly controlled by the seismic frequency. Some clinoforms are expressed only in seismic, some only in wells (logs map and cross-sections), some are identifiable in both.

References

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Droste, H. and Van Steenwinkel, M., 2004. Stratal geometries and patterns of platform carbonates: The Cretaceous of Oman. In, G. Eberli, J.L. Masaferro, and J.F.R. Sarg (Eds.), Seismic Imaging of Carbonate Reservoirs and Systems. American Association of Petroleum Geologists, Memoir 81, p. 185-206.

Grélaud, C. 2005. Enregistrement Stratigraphique des Phases d'Emersion sur les Plate-formes Carbonatées: une étude intégrée à l'affleurement et en sismique de la plate-forme cénomanienne d'Oman (Formation Natih). PhD Thesis, Université Michel de Montaigne Bordeaux III, 262 p.

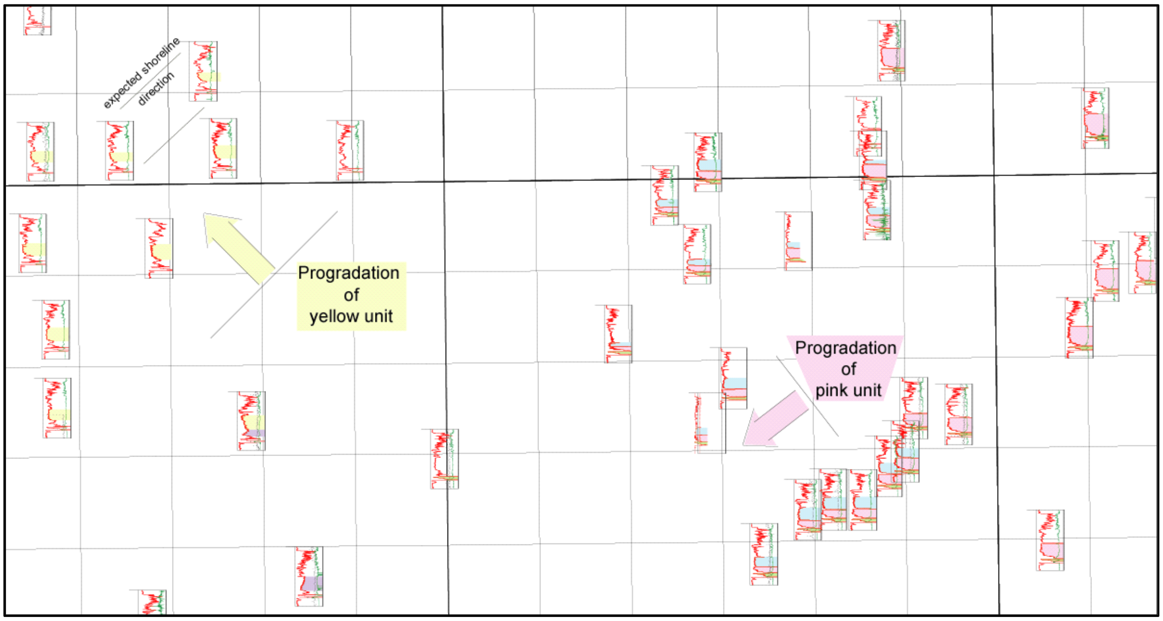


Fig 1 Dramatic change in progradation direction in the Lower Banff of West Central Alberta (Chatellier et al. 2008)

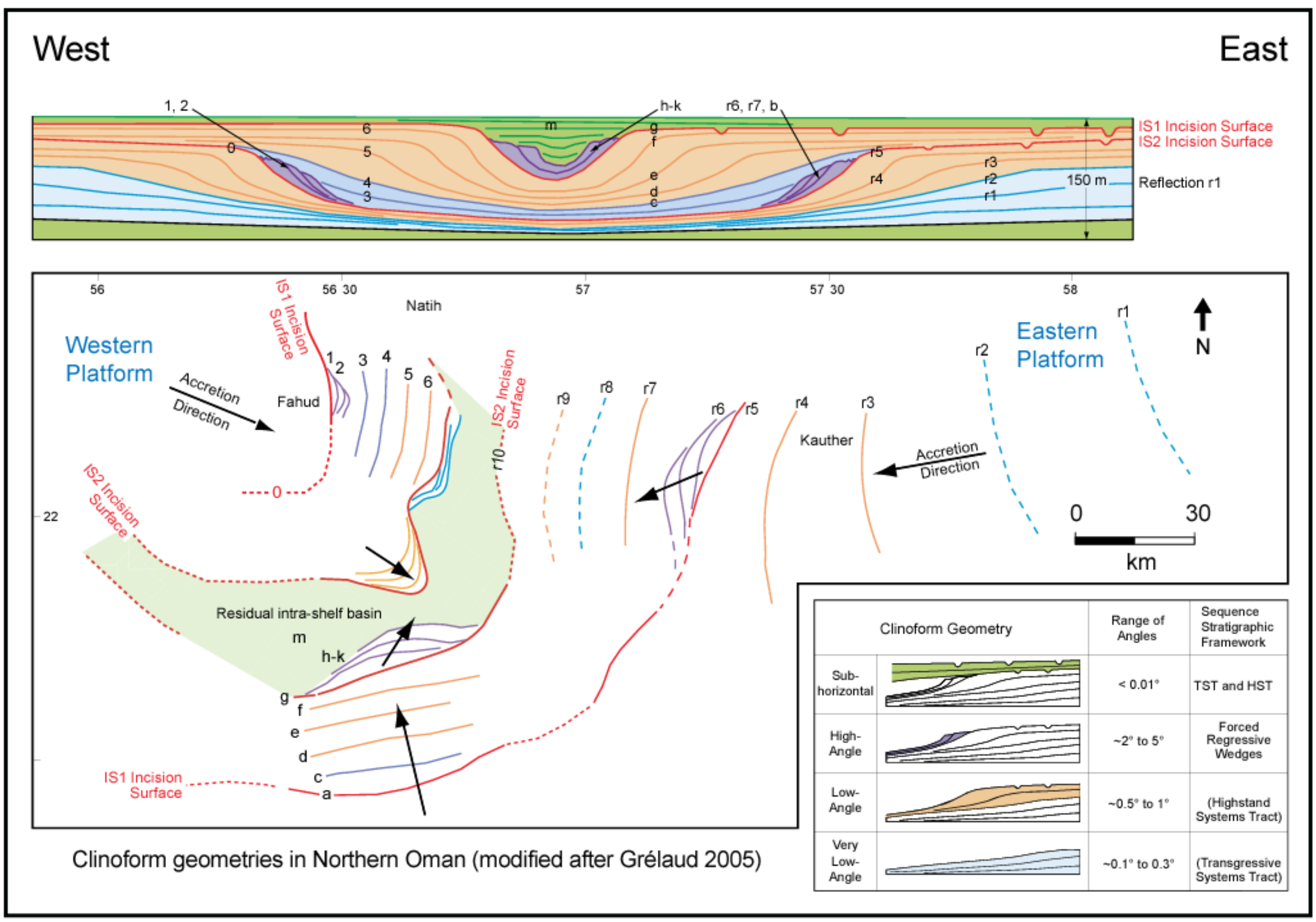


Fig.2 Dramatic change in progradation direction and variability of clinoform geometry in Northern Oman

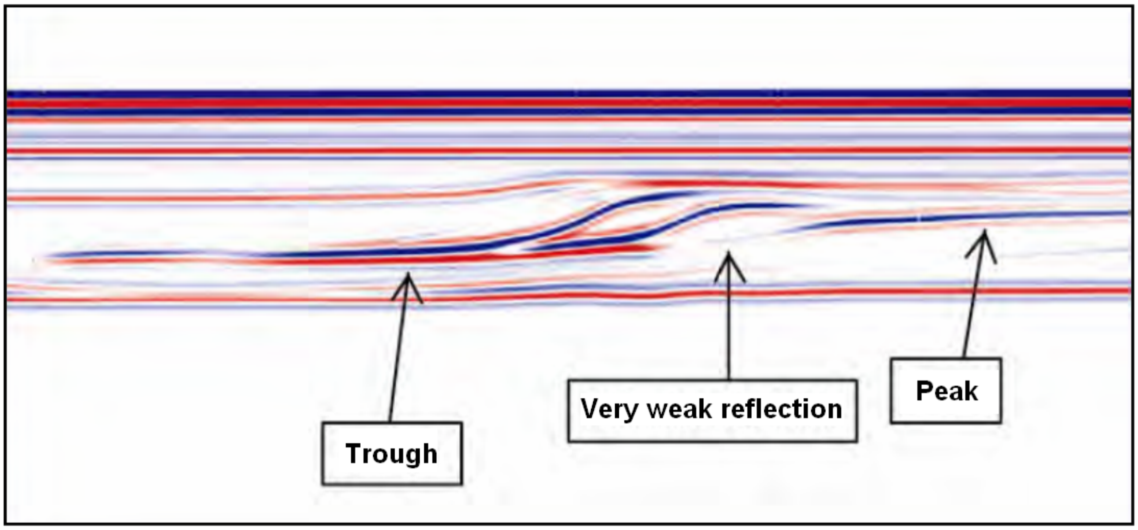


Fig.3 Variability of seismic expression along a clinoform (after Grélaud, 2005)

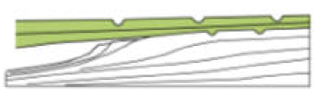
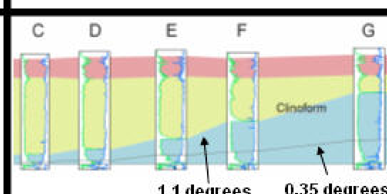
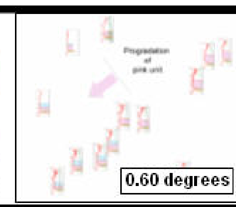
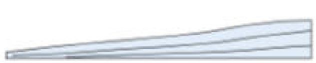
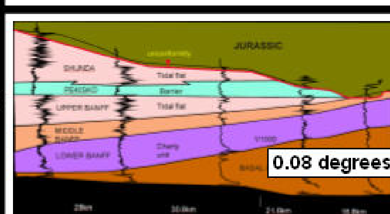
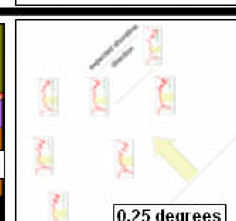
Reflection geometry		Dip	Banff Formation Examples	
Sub-Horizontal		<0.01°	Not studied	
Strong Oblique		~2 to 5 °	Not identified in study area	
Sigmoidal weak to strong angle		~0.4 to 1.5 °		
Sigmoidal very weak angle		~0.1 to 0.3 °		

Fig. 4 Clinoform geometries in the Banff Formation (West Central Alberta) – classification from Grélaud, 2005