

PS Medium-Scale Tidally Influenced Meandering Fluvial Deposits of the Middle McMurray Formation, Hangingstone SAGD Project, Alberta, Canada*

Satoko Watanabe¹ and Takashi Tsuji¹

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¹JAPEX, Tokyo, Japan (satoko.watanabe@japex.co.jp)

Abstract

The Middle McMurray Formation is the most important reservoir of the Athabasca oil sands. In recent years many studies using 3D seismic data have revealed that the middle McMurray Formation consists of large point bar deposits formed by tidally influenced meandering fluvial systems. Most of these studies were carried out on deposits near the axis of the McMurray valley system where the McMurray Formation is thickly deposited. In this study, a geological model was constructed in Hangingstone SAGD project area located in tributaries about 30 km upriver from the main valley system. Scroll patterns which are characteristic of meandering channels are clearly observed in seismic slices in part of this area, but not clear in some part of this area where regional sequences (correspond to A1 to B2 sequences reported by EUB) spread in the Upper McMurray Formation. The purpose of this study is to identify sediment bodies which consist of the McMurray Formation in this area without scroll patterns and to describe the geometry and sedimentological features of the main reservoir deposits using lithological data, gamma ray log, dip log, and borehole image logs of each well and 3D seismic volume.

The McMurray Formation in this study area was divided into 10 sedimentary units including point bar deposits and abandoned channel of tidal-fluvial channel system, lower unit which had not suffered channel incision, regional sequences and muddy channels incised lower sediment from each sequence base. In the south part of the point bar deposits, small erosional surfaces dipping gently to the southwest and large cross bedding dipping steeply to the northwest, indicating its flow direction, are observed in borehole images. In the northwest part of the point bar deposits low angle unidirectional dips to the southwest were predominant. The direction of the low angle dips is accord with the inclination direction of point bar surfaces observed in seismic sections. Based on these results, it is concluded that (1) The main reservoir in this study area consist of point bar deposits migrated to the southwest, with thickness of 20-30m surrounded by abandoned channel and muddy channels, and (2) Energy of the channel flow at bends was relatively strong in the south part, whereas flow energy was weak in the northwest part of the area. This is consistent with low gamma ray values of sand, around 30, in the south part, whereas high gamma ray values, 30-60, in the northwest part.

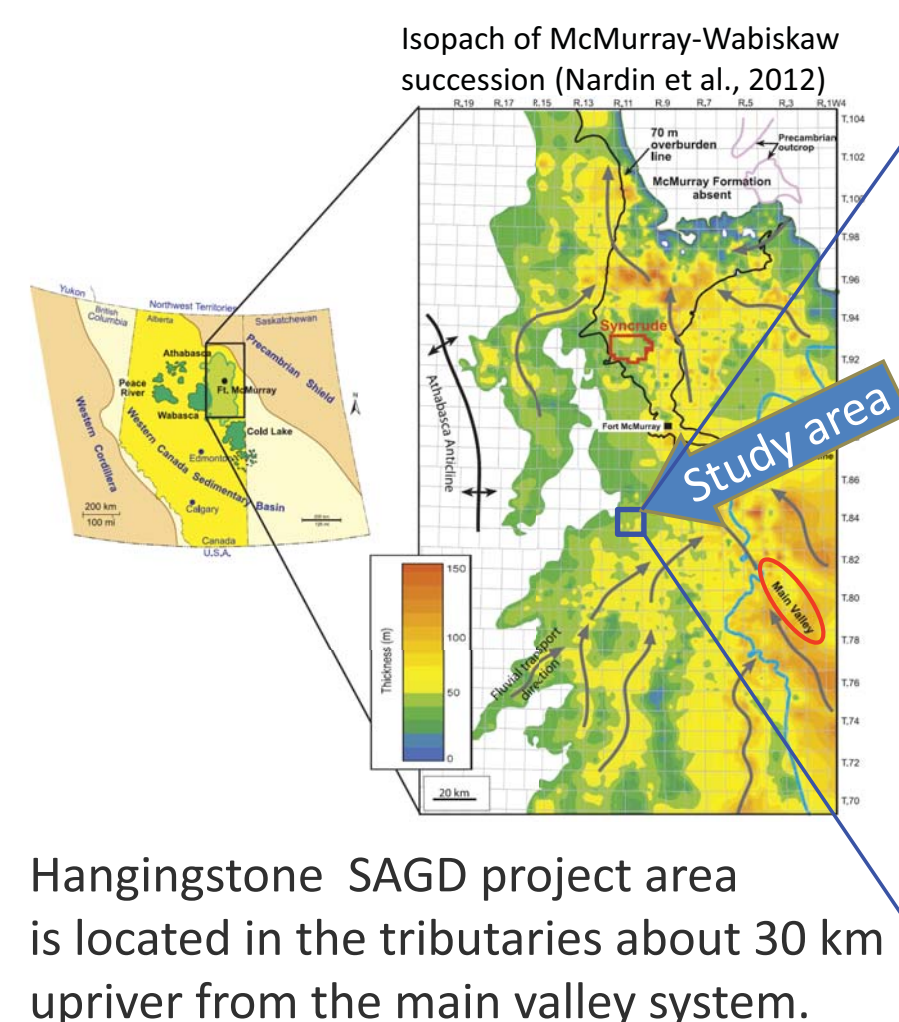
Medium-scale tidally influenced meandering fluvial deposits of the middle McMurray Formation, Hangingstone SAGD project, Alberta, Canada

Satoko Watanabe, Takashi Tsuji (Japan Petroleum Exploration Ltd.(JAPEx), Tokyo, Japan)

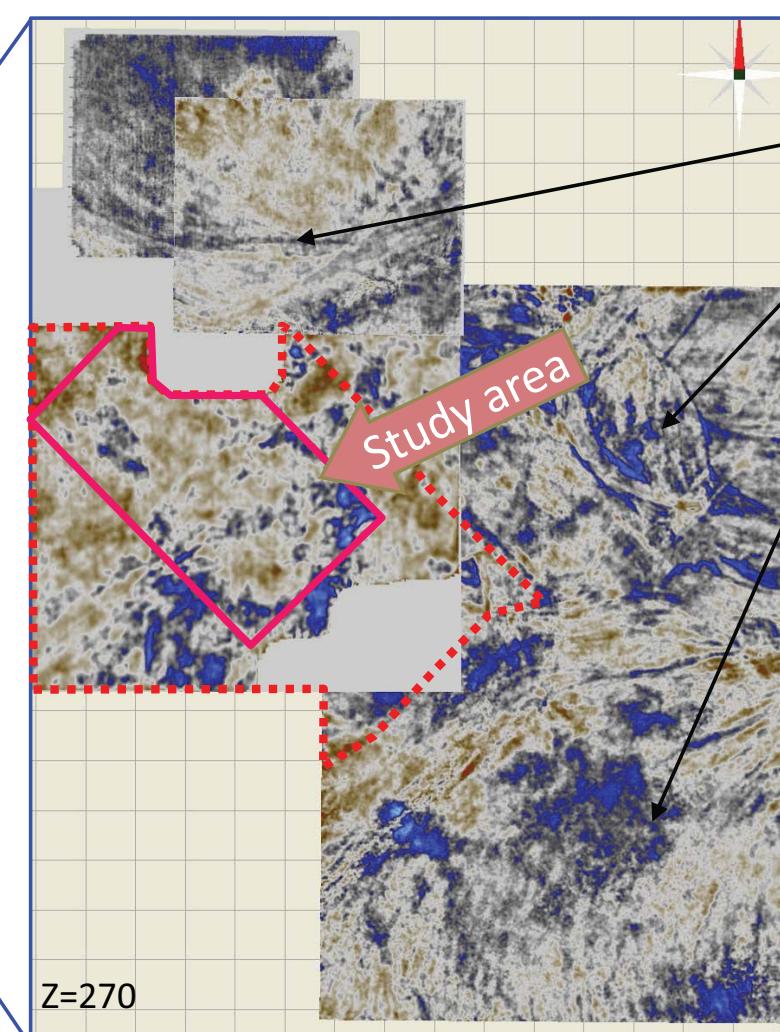
Abstract : Hangingstone SAGD project area is located in the tributaries of the main valley system during the McMurray Formation deposition. In this study area, regional sequences (which were correlated regionally in the Athabasca oil sands area by AEUB) preserved with gentle incision, and a medium-sized point bar deposits under the regional sequences are recognized as a significant reservoir. Although there are not scroll patterns which are known as characteristics of meandering fluvial channels in 3D seismic data, point bar deposits and other sedimentary units were identified in 3D seismic, gamma ray log curves and dip patterns of the wells. Additionally, paleo-flow directions and flow regimes during the point bar deposition were interpreted using borehole images and dip patterns.

Keyword: McMurray Formation, regional sequences, 3D seismic, Borehole Images, Dip pattern

Location



Characteristics in Seismic Slice of the Study Area

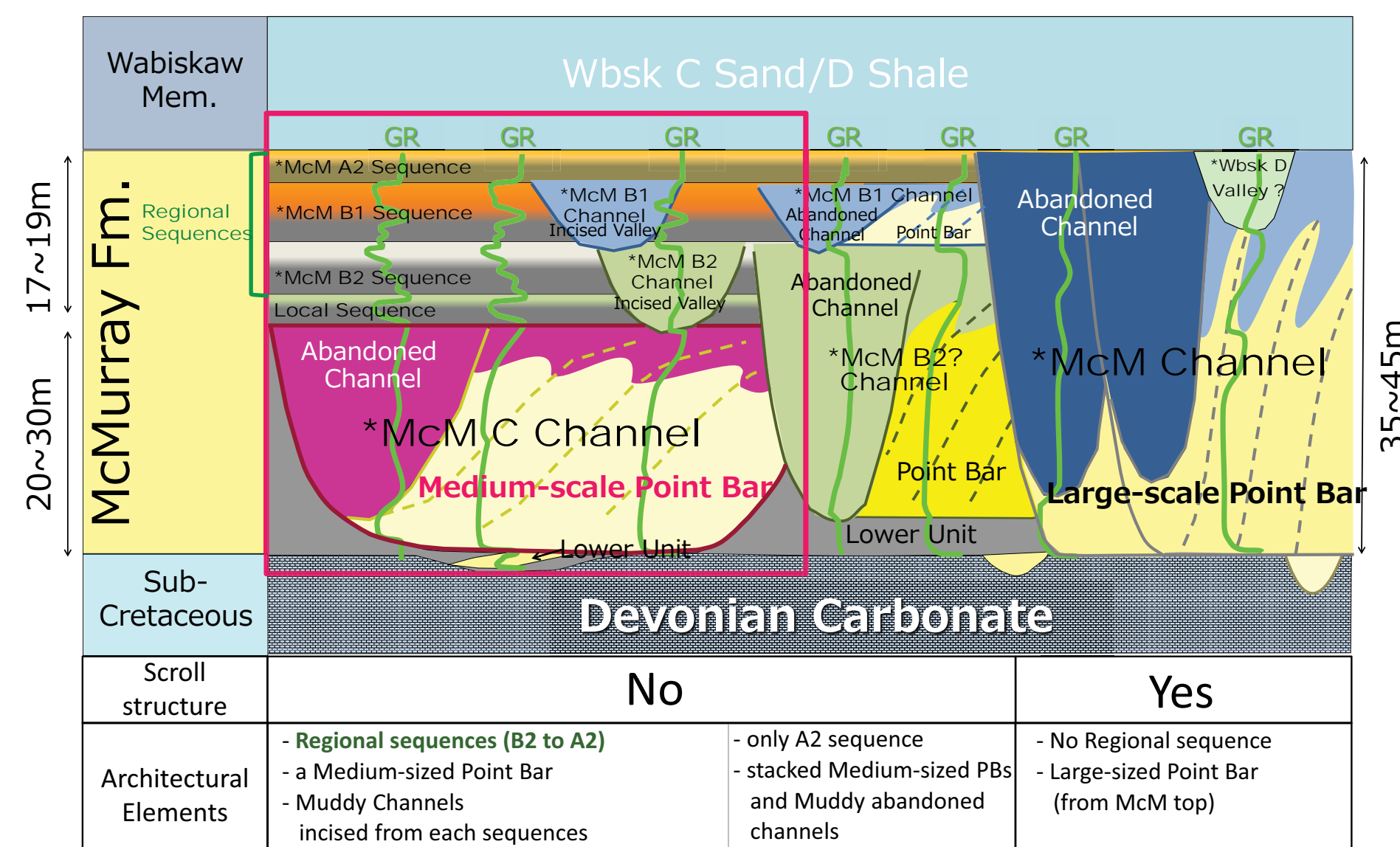


SCROLL PATTERNS which are characteristics of meandering channels are clearly observed in depth slices of the 3D seismic data in the Hangingstone SAGD project area except the area within red dashed line.

The reasons are considered as follows.

- gentle inclination of the point bar surfaces (3-4 degrees)
- resolution of the seismic data: poorer than that of the other area.

Stratigraphic Model in the Study Area



THE MCMURRAY FORMATION OF THE STUDY AREA is consist of

- some upward coarsening cycles (correspond to *McM B2 to A2 sequences defined by AEUB),
- additional upward coarsening cycle below the McM B2 sequence locally preserved in the study area,
- muddy valleys (*McM B1 channel, *McM B2 channel) incised lower sequences(*McM B1,B2 and the local sequence),
- some muddy channels (probably abandoned channels) incised the preceding point bar deposits and abandoned channel,
- a medium-scale point bar and related abandoned channel (*McM C channel), and
- lower unit which deposited before the point bar deposition.

* Stratigraphic nomenclatures of Alberta Energy and Utilities Board (2003) were followed.

Distribution of the Point Bar Deposits, Abandoned Channel and Other Channels

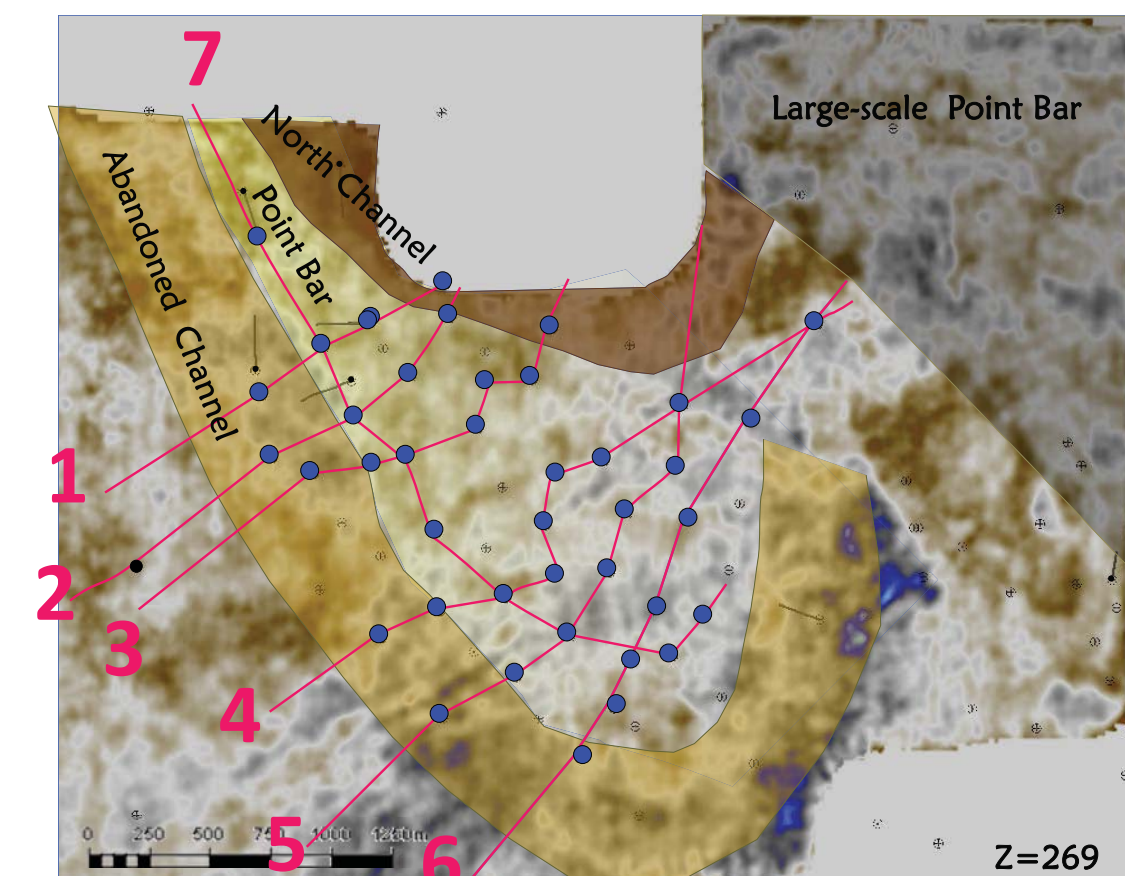
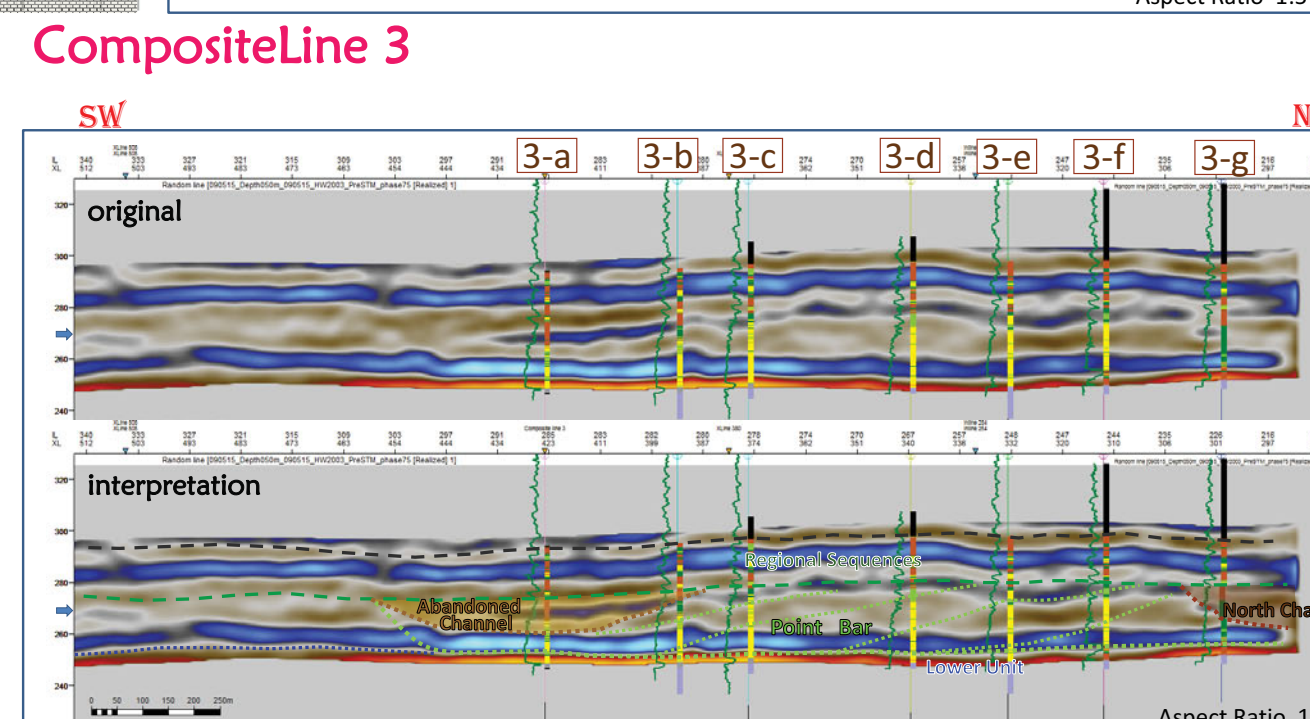
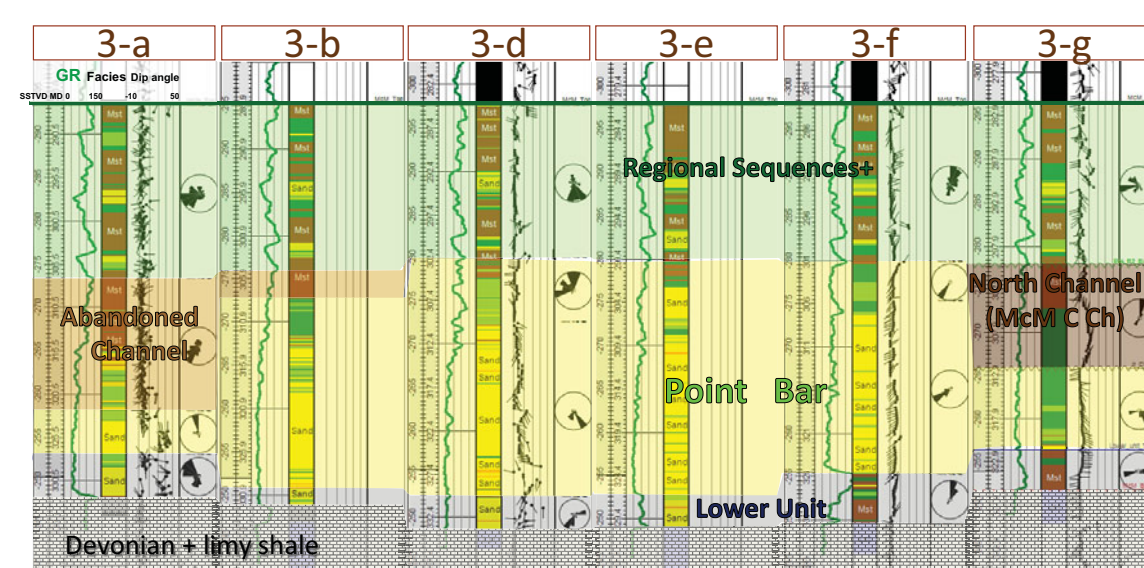
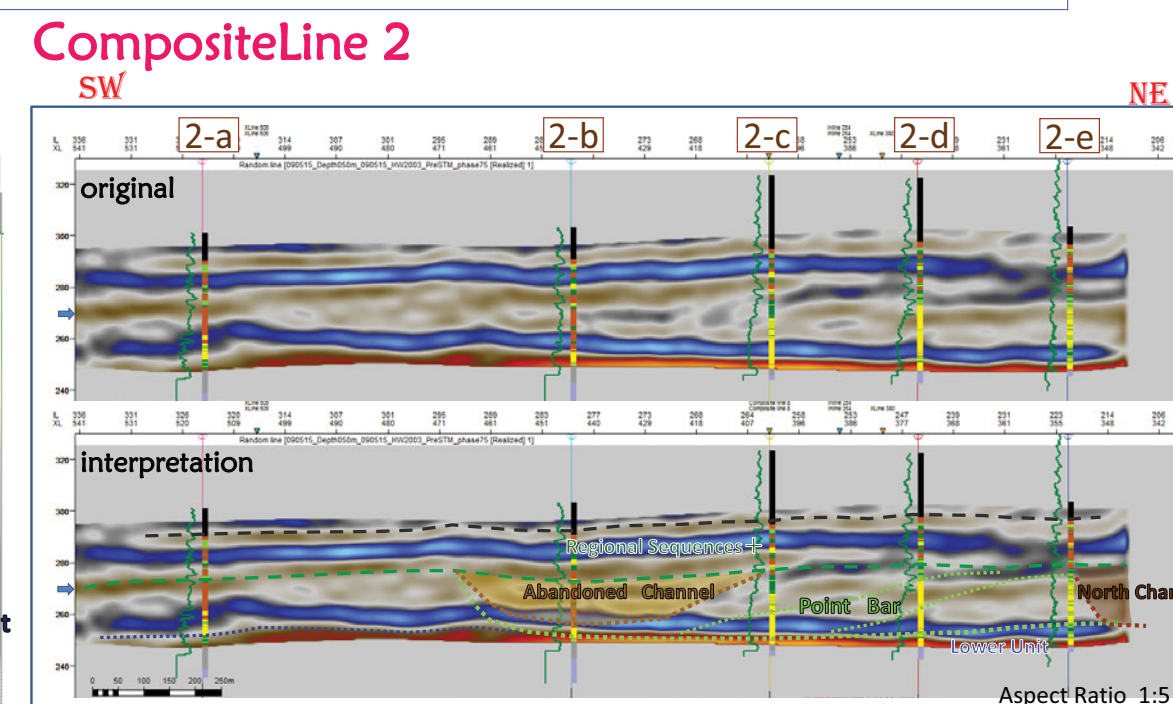
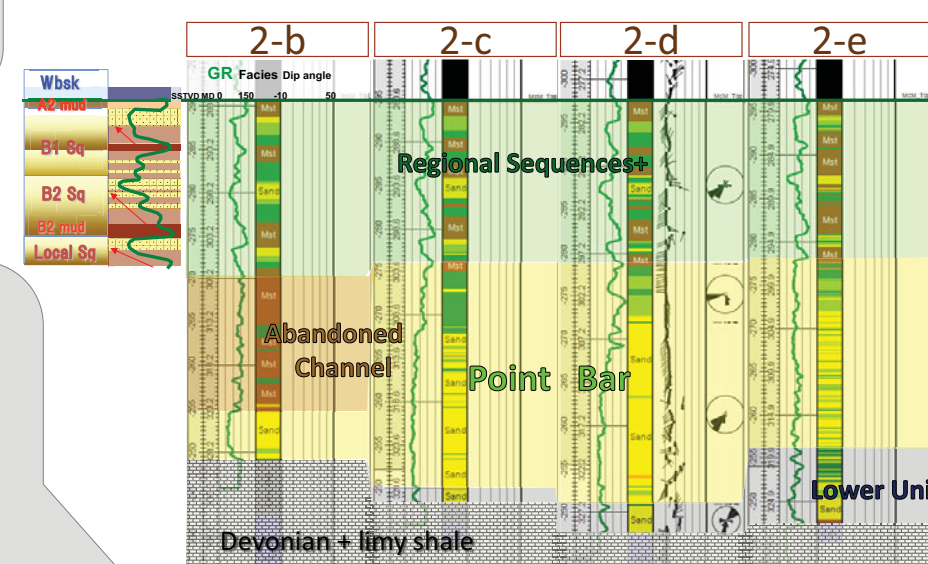
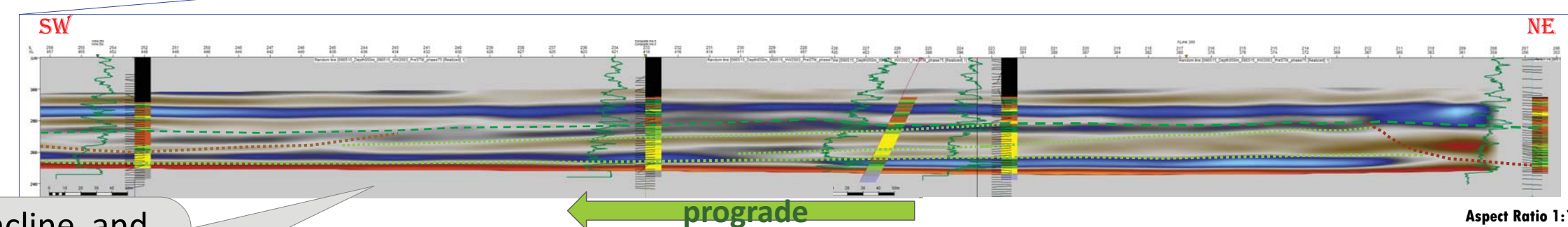
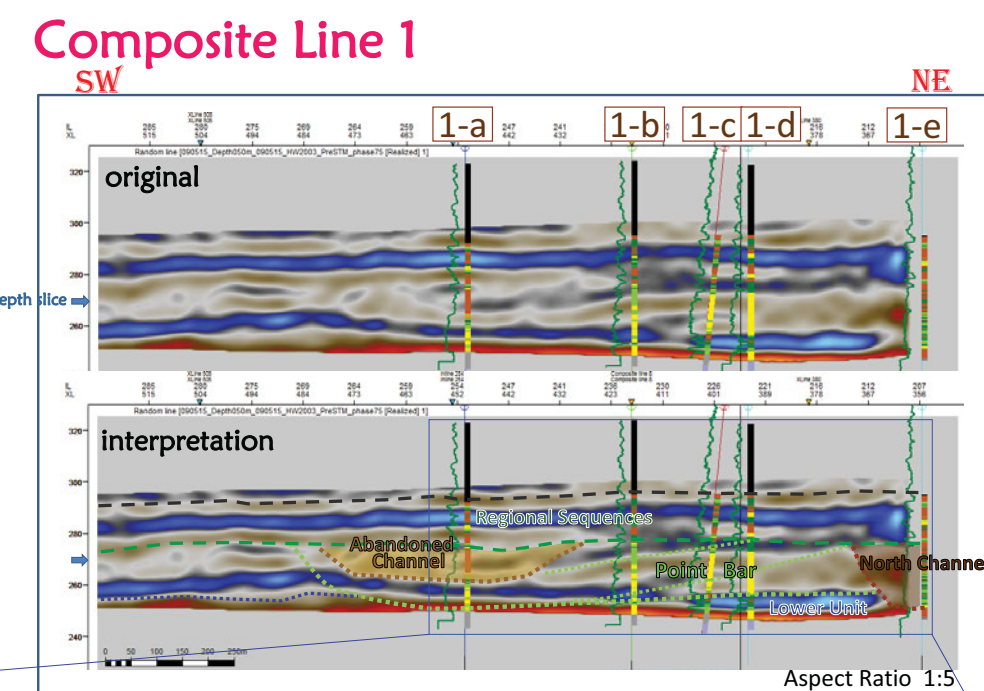
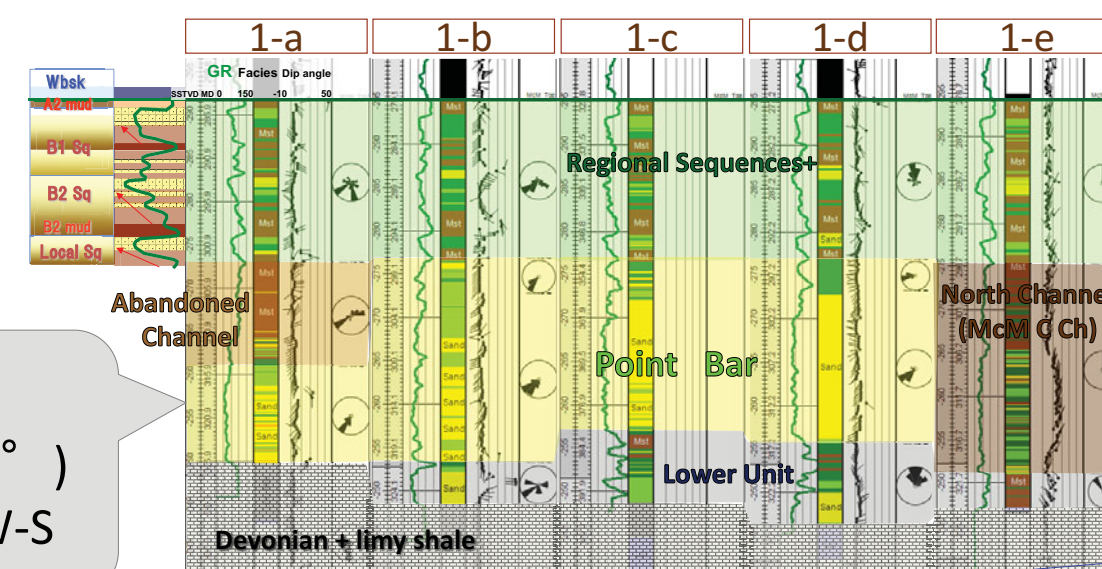
Northwestern Part

- Dips in the PB deposits
- low angle (generally $<5^\circ$)
 - unidirectional to the SW-S

Seismic reflectors incline and prograde to the southwest. Inclinations are consistent with dips of wells.

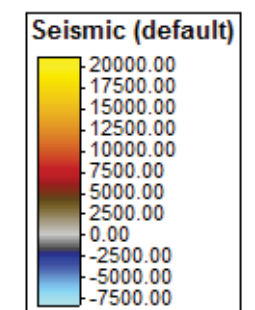
Abandoned channel is in the west end of the point bar.

North channel (McM C channel) incised the point bar deposits.



Well Facies

- Mudstone
- Mud-dominated Alt
- Sand-dominated Alt
- Sand
- Sand with Mudst. Clast



10 SEDIMENTARY UNITS were identified based on integrated interpretations of seismic sections and well log data. (smaller valleys incised regional sequences can be recognized in well log data.) IN THE NORTHWEST PART (composite lines 1 to 3), seismic reflectors characteristically inclined to the southwest.

Sandy facies are developed at the wells located within the clinoform. This succession indicates a series of point bar deposits.

Abandoned channel is observed in the west end of the point bar deposits. Muddy facies are dominantly distributed in the wells located in the channel.

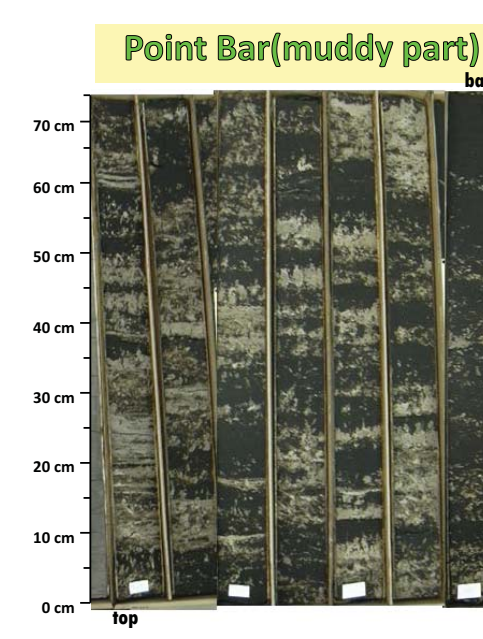
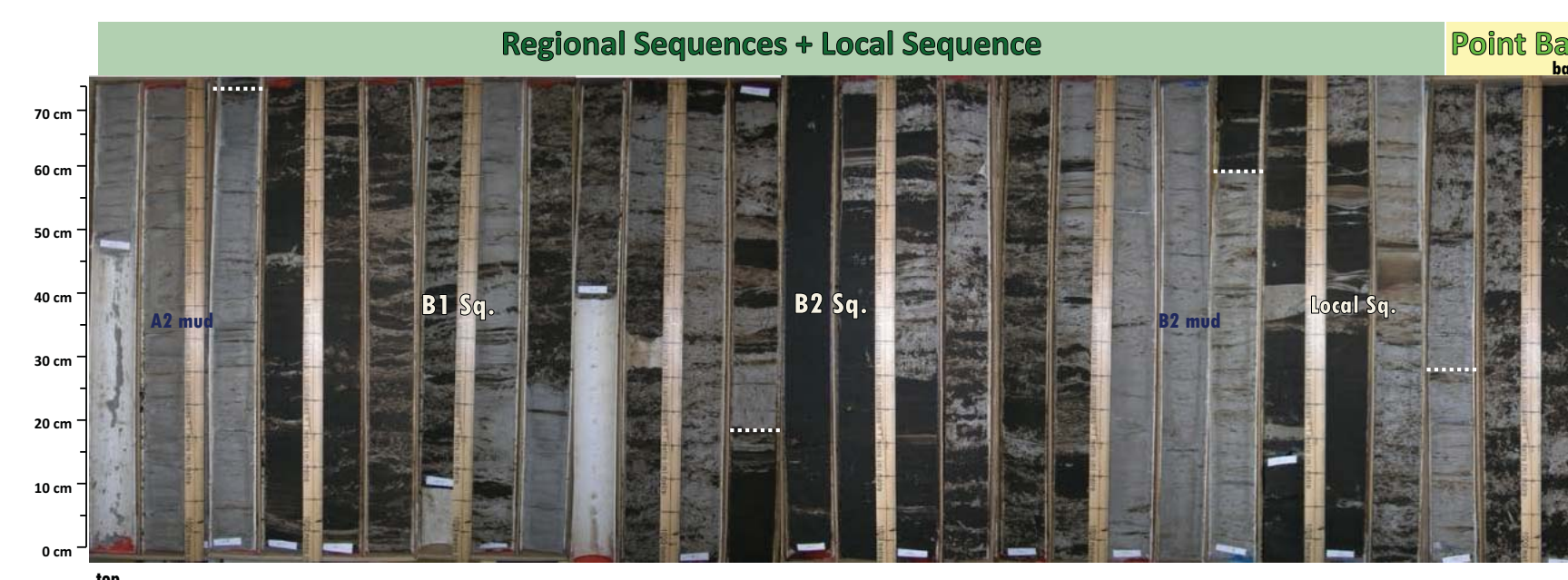
Dips of the point bar intervals are characteristically low angle (generally $<5^\circ$) and unidirectional to the southwest.

IN THE SOUTH PART (composite lines 4 to 6), some valleys and channels are recognized in the seismic sections. They also can be identified based on changes in dipmeter patterns and sedimentary facies in the wells.

Sandy facies mostly developed in the point bar deposits and muddy facies are distributed in the abandoned channels and the other valleys.

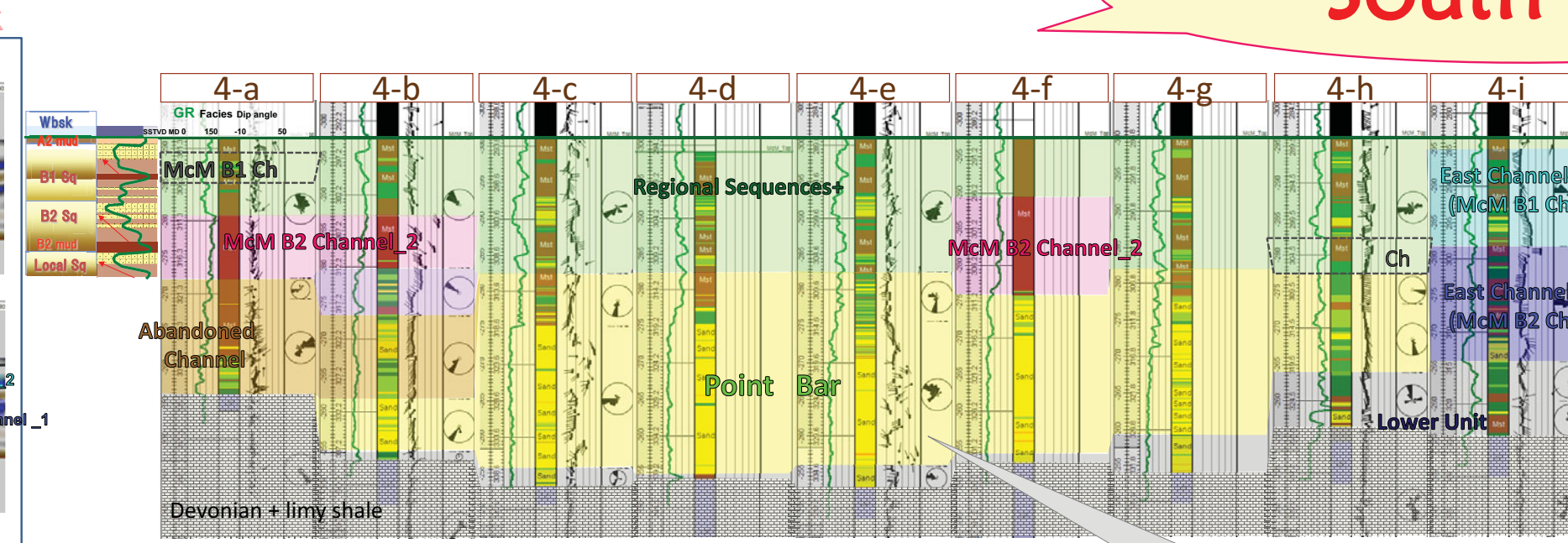
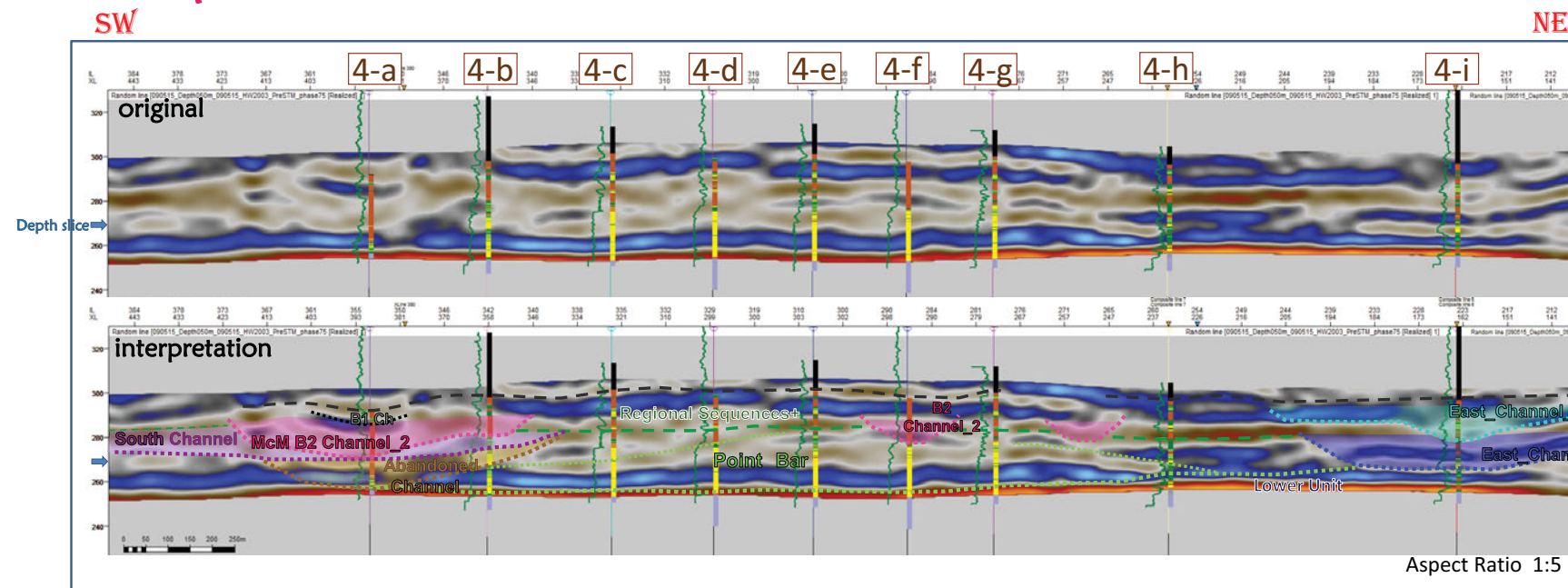
Dips of the point bar intervals are scattered and high angle ($30-40^\circ$) in part.

Typical core photos of point bar deposits

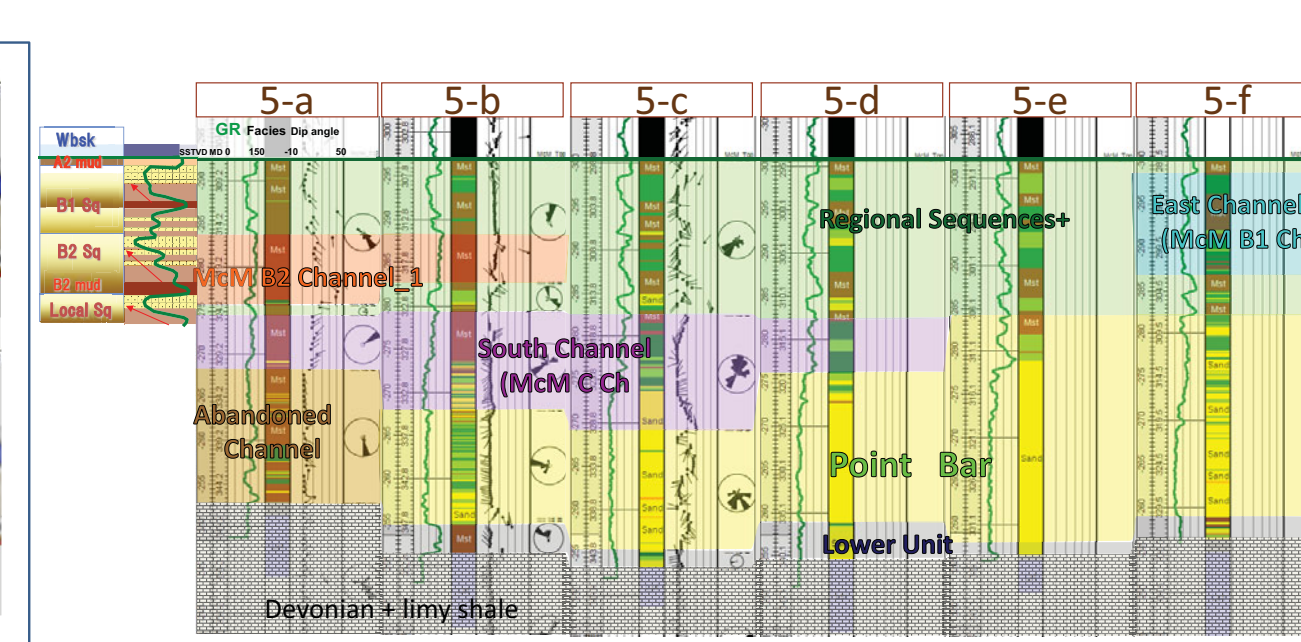
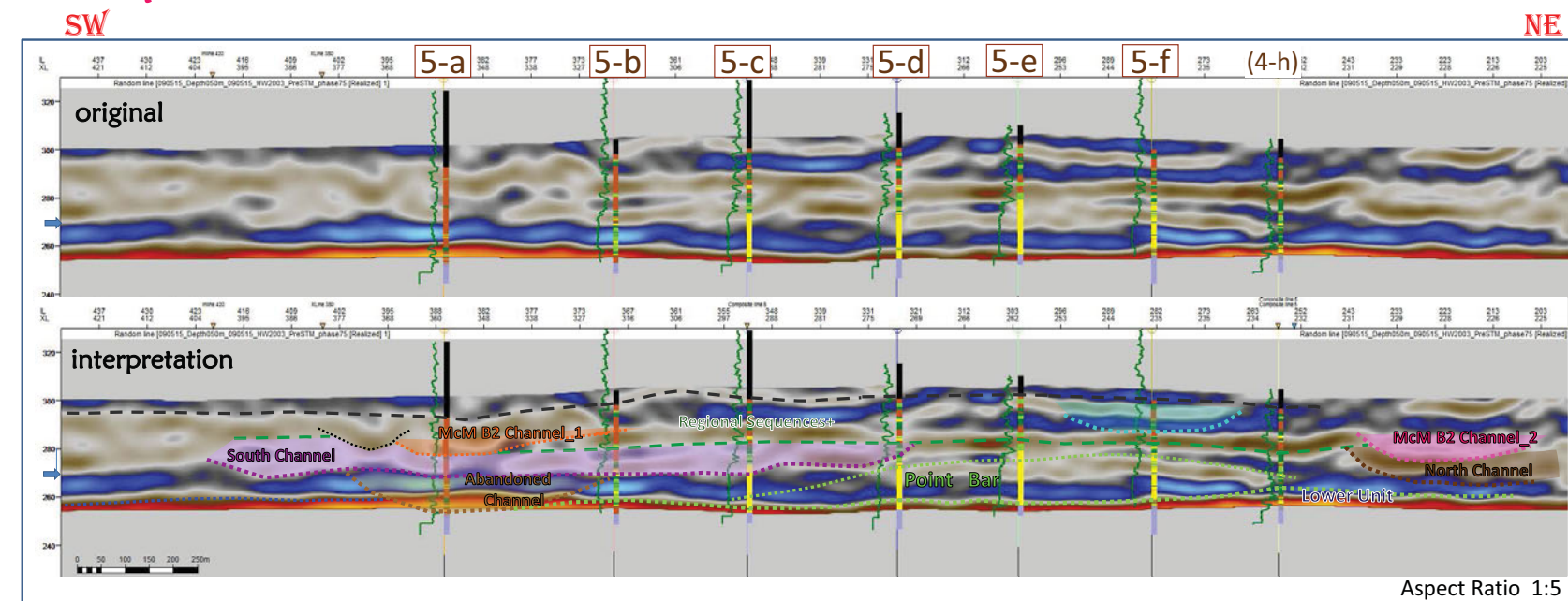


South Part

Composite Line 4



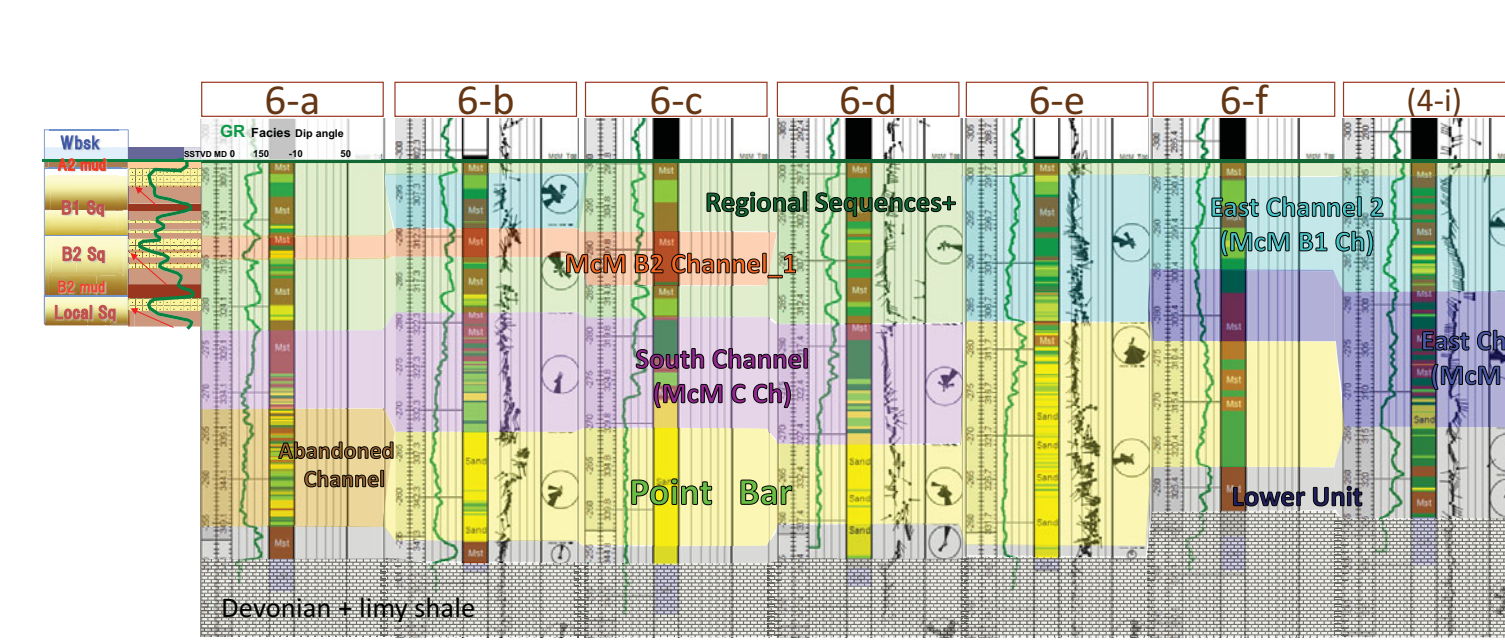
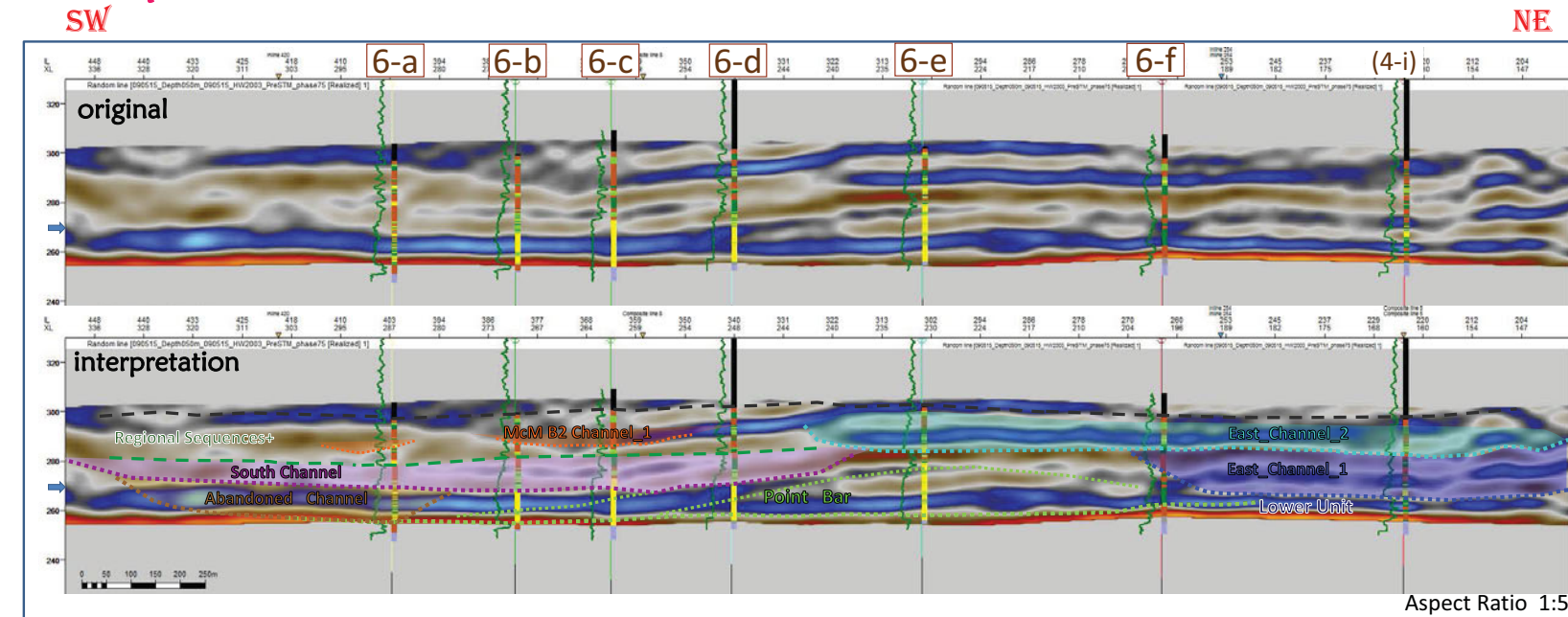
Composite Line 5



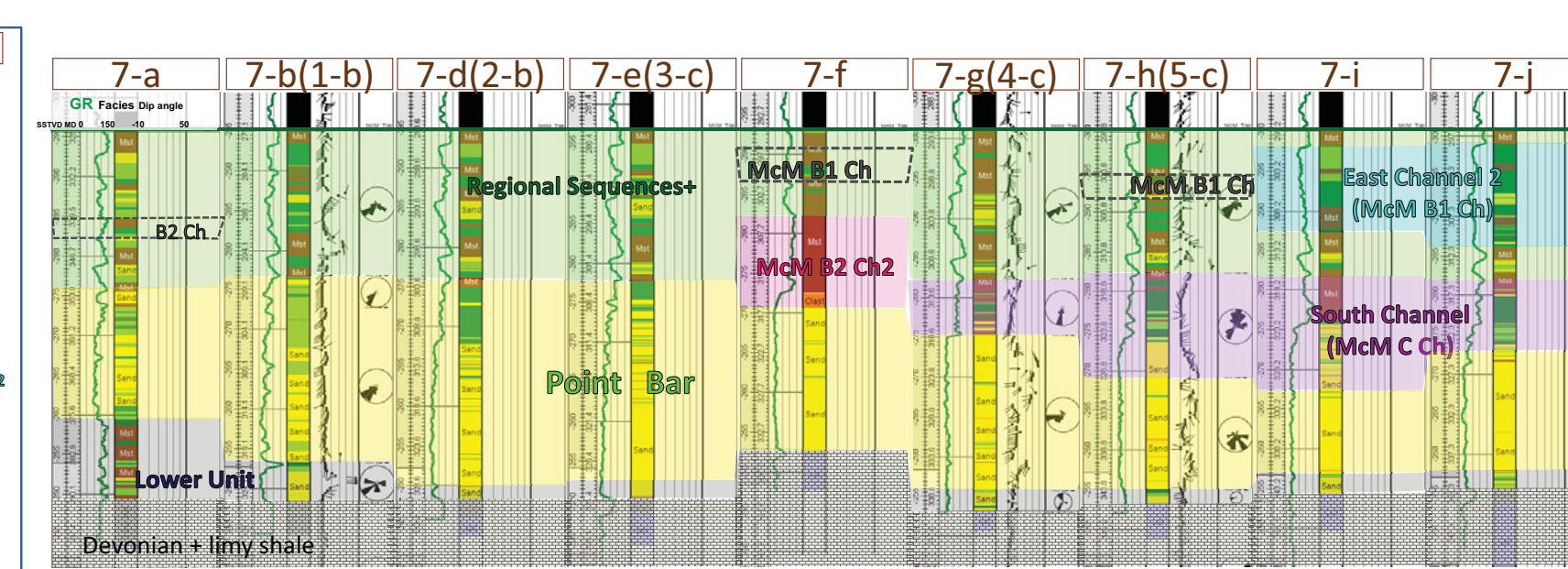
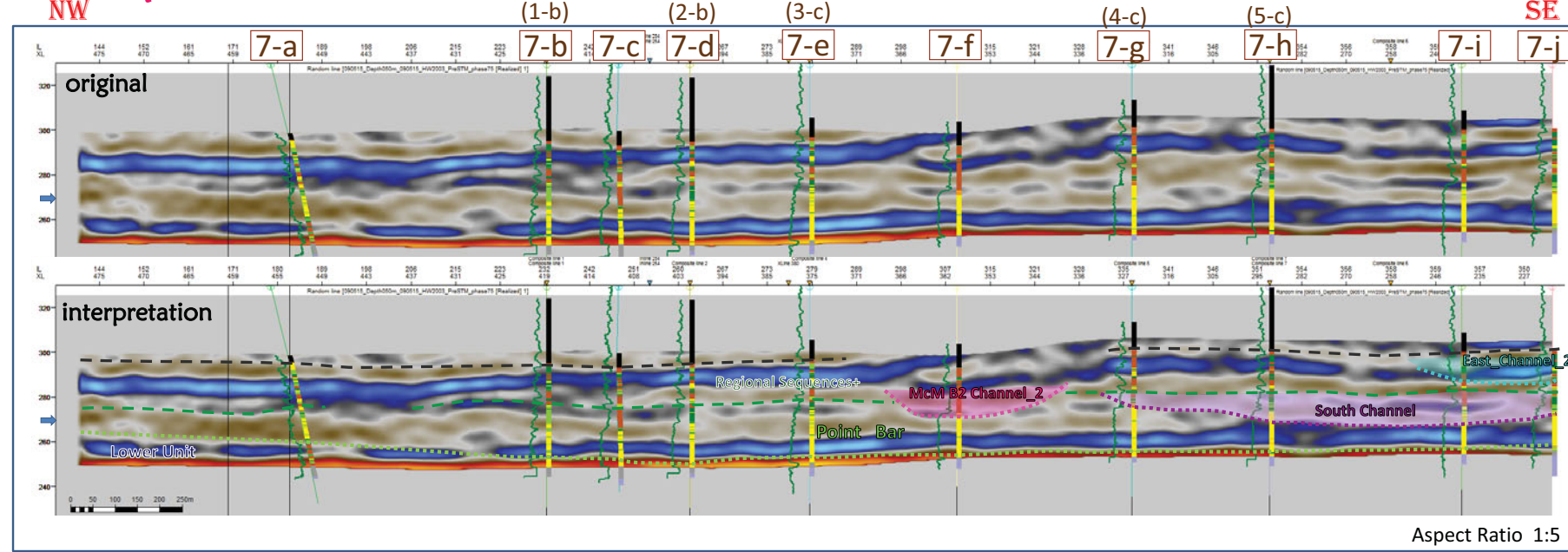
Dips in the Point bar intervals
- partly high angle(30-40°)
- dip to south, west and north

Some valleys (McM B2 Channel_1 and 2) and abandoned channels (East Channel_1 and 2, and probably South Channel) incised the regional sequences and the upper part of the point bar deposits.

Composite Line 6

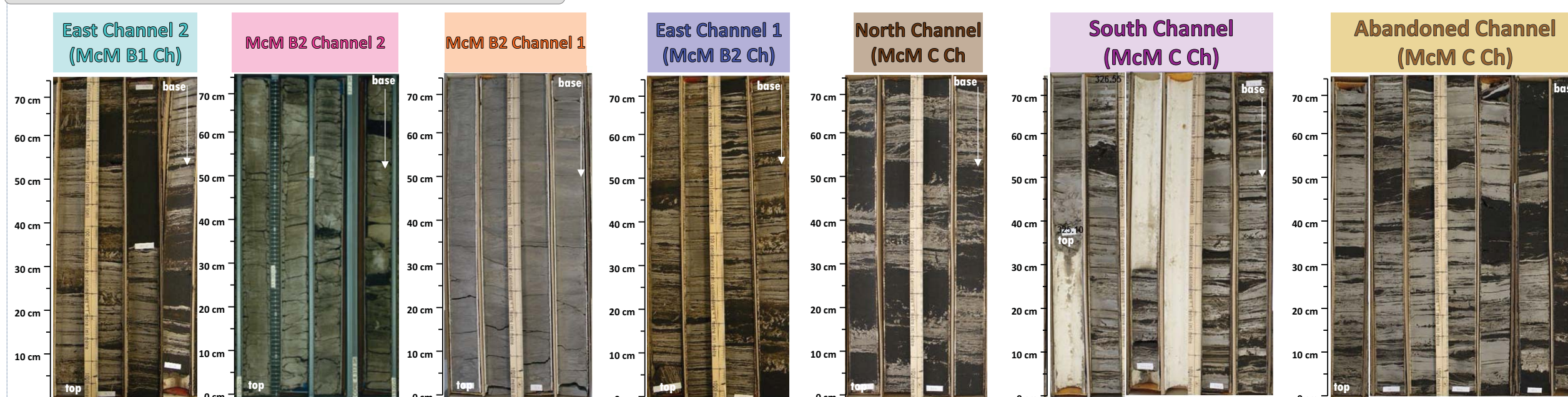


Composite Line 7



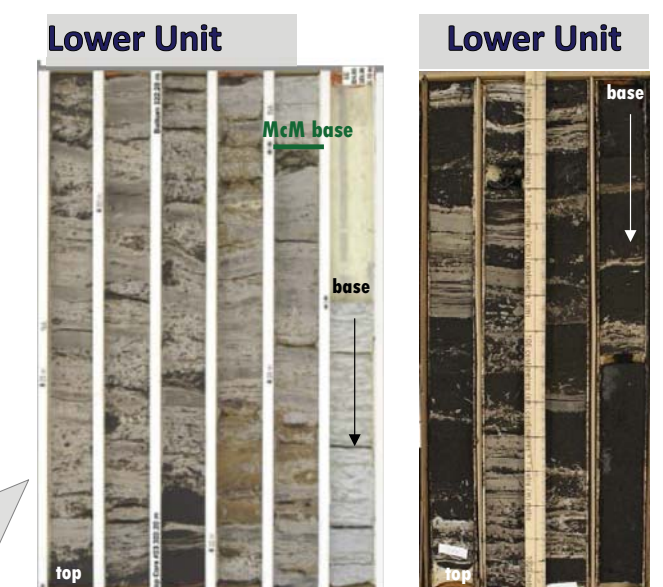
SEDIMENTARY UNITS	
Regional Sequences+	regional sequences and local sequence
McM B2 Channel_2	muddy Valleys
McM B2 Channel_1	
East Channel 2 (McM B1 Ch)	muddy (Abandoned) Channel
East Channel 1 (McM B2 Ch)	
South Channel (McM C Ch)	
North Channel (McM C Ch)	
Abandoned Channel (McM C Ch)	
Point Bar (McM C Ch)	
Lower Unit	

Typical core photos of each sedimentary unit



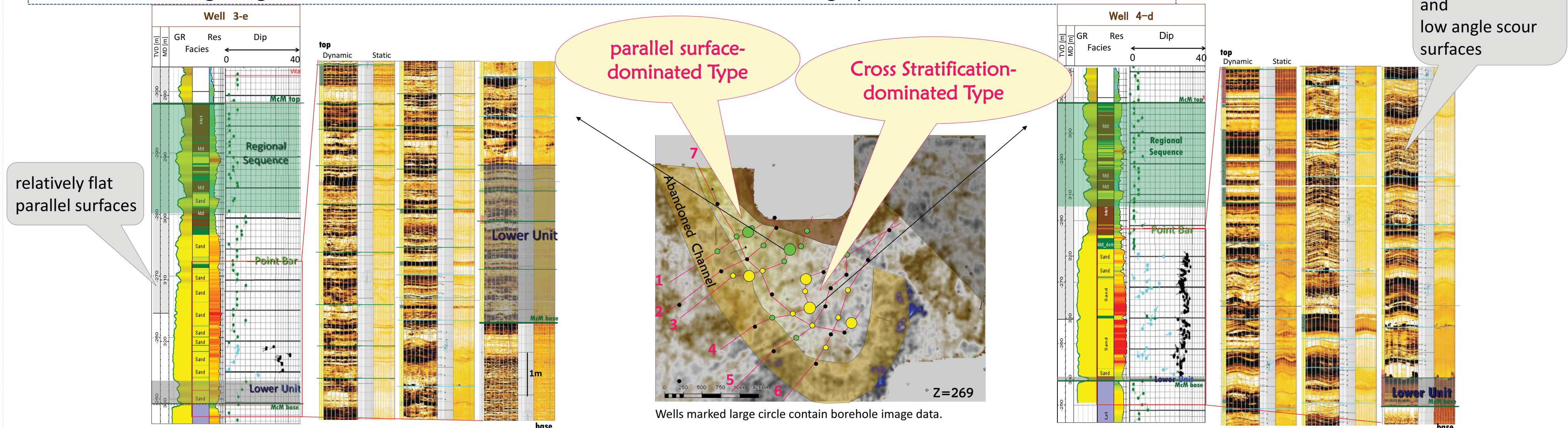
Each channel unit are different in mud proportion, sedimentary structures and bioturbation intensity.

Lower Unit is consist of various facies like tidal cyclic sediments, point bar deposits, and muddy channel deposits.

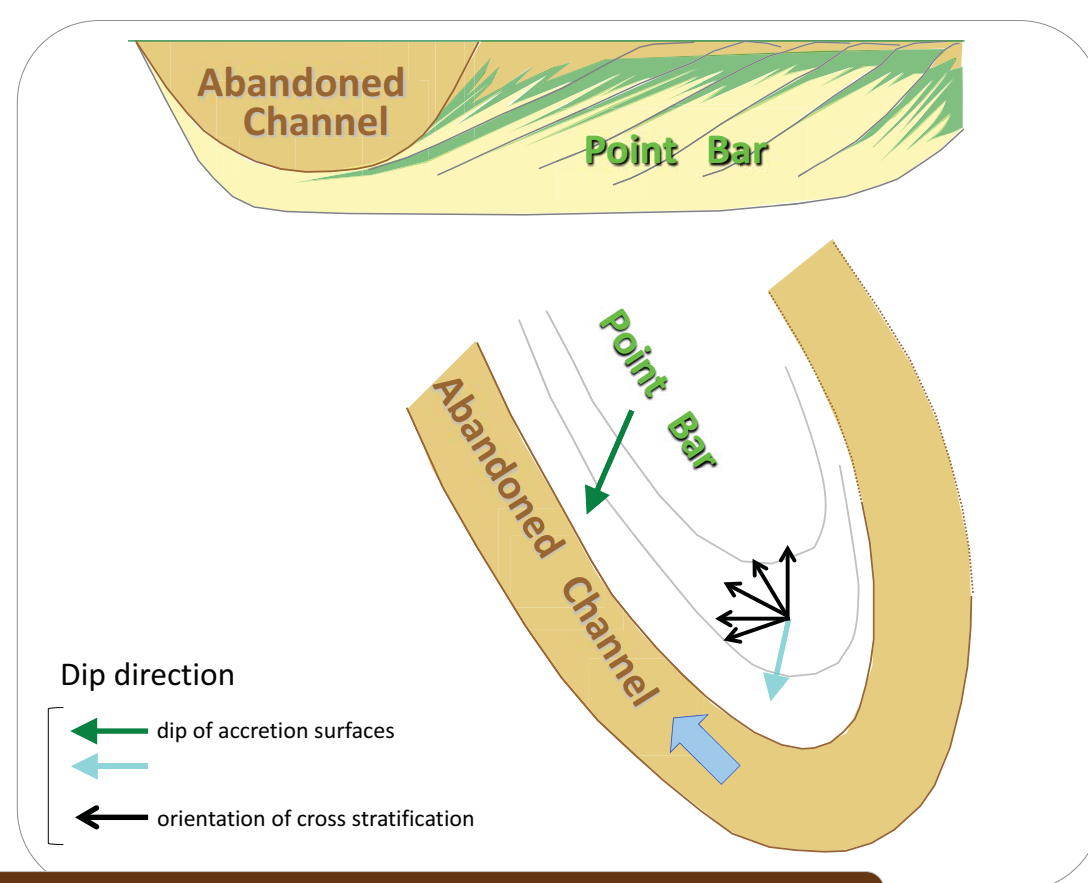


Sedimentary Structures and Dip pattern in Borehole Images

BOREHOLE IMAGES and **DIPMETER DATA** of the wells were used to examine characteristics of the point bar deposits. **Borehole images of the well 3-e (left)** show yellow to dark-brown color change cycles of tens of cm to 1m thickness and relatively flat surfaces in each cycle base (green line). These surfaces are represented as low angle and unidirectional dips inclined to the southwest (green tadpoles) those generally observed in dipmeter data of the wells in the northwest part of the point bar deposits (light green circles in the map). On the other hand, in **borehole images of the well 4-d (right)** and lower part of the point bar interval of the well 3-e, high angle fine laminations and relatively low angle scour surfaces (light blue line) are dominant. Dips of these laminations are high angle and direction displays scatter west to north (black tadpoles). Dips of scour surfaces are relatively low angle and scattered direction (light blue tadpoles). Those dip patterns can be found in wells located mostly in the south part of the point bar deposits (yellow circles in the map). The surfaces observed in the well 3-e are parallel to accretion surfaces of the point bar shown in 3D seismic sections. And combination of high angle laminations and scour surfaces are considered to be trough-planar cross stratifications.



Depositional Model of the Point Bar



Resulting from analysis of the borehole images and dip patterns, It is interpreted that

- **In the south part** of the point bar deposits, cross stratifications observed in the borehole images suggest relatively strong flow energy and indicate flow direction to north - west.
- **In the northwestern part**, sedimentary structures with a few cross stratifications suggest relatively week flow energy during deposition of point bar.
- The point bar deposits formed by the channel which flowed clockwise to the northwest and migrated to the southwest during deposition.

Conclusion

- 10 sedimentary units (containing point bar deposits, abandoned channels, regional sequences, muddy valleys) were recognized based on integrated interpretation using 3D seismic, gamma ray log curves and dip patterns of wells in the study area.
- The point bar deposits, which are main reservoir of the study area, were interpreted using borehole images and dip patterns.
- The point bar deposits were deposited under high flow energy environment in the south part, and under relatively week flow energy environment in the northwestern part.