The Identification and Implication of Injectites in the Shwe Gas Field, Offshore Northwestern Myanmar*

Stephen Cossey[1], Dongil (David) Kim[2], Su-Yeong Yang[2], and Ho Young Jung[2]

Search and Discovery Article #20225 (2013)**
Posted November 25, 2013

*Adapted from oral presentation given at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013

[1]Cossey and Associates Inc. (cosseygeo@aol.com)
[2]Daewoo International Corp. (kimdi@daewoo.com)

Abstract

A large complex of sedimentary injection features (injectites) has been identified in the Pliocene offshore Shwe (biogenic) Gas Field in Myanmar. The injectites provide vertical and lateral continuity from a basal proximal lobe sequence (G5) to an overlying distal lobe sequence (G3). The G5 has a unique petrographic signature (low rock fragments, high mica) and the G3 shows low mica and high rock fragments. The injectites were discovered in one of the cored wells because there were anomalous structureless sands in the G3 which showed the petrographic characteristics of the underlying G5. The sills range in thickness from 5 cm to 2 meters thick in cored wells, have sharp bases and tops and show symmetrical grain size trends either side of the middle of the bed. In uncored wells, they are interpreted to be up to 6 meters thick with uniform (characterless) gamma ray response.

Once they were identified in core, several seismic scale features, such as wings, steeply dipping reflectors and an irregular G5 reservoir top were identified on the 3-D seismic. The injectites were probably triggered at least twice by several overlying slumps which rapidly buried and overpressured the sand-rich lobes of the G5. The gas-filled injectites seem to be mainly restricted to the northern part of the field where the underlying G5 reservoir is anomalously thin. The discovery of the injectites drastically changed the reservoir model and explained many of the unusual features of the field such as a common gas gradient, perched water and isolated pressure cells.

Selected References

De Boer, W., A. Hurst, and P.B. Rawlinson, 2007, Successful Exploration of a Sand Injectite Complex: Hamsun Prospect, Norway Block 24/9, *in* A. Hurst and J. Cartwright eds., Sand Injectites: Implications for Hydrocarbon Exploration and Production, AAPG Memoir 87, p. 65-68.

Hiscott, R. N., 1979, Clastic sills and dikes associated with deep-water sandstones, Tourelle Formation, Ordovician, Quebec, Jour. Sed. Pet., v. 49/1, p. 1-10.

Jackson, C.A.-L., M. Huuse, and G.P. Barber, 2011, Geometry of Winglike Clastic Intrusions Adjacent to a Deep-water Channel Complex: Implications for Hydrocarbon Exploration and Production, AAPG Bulletin, v. 95/4, p. 559-584.

Jolly, R.J.H., and L. Lonergan, 2002, Mechanisms and controls on the formation of sand intrusions: Journal of the Geological Society, v. 159, p. 605-617.

Lonergan, L., N. Lee, H.D. Johnson, J.A. Cartwright, and R.J.H. Jolly, 2000, Remobilization and Injection in Deepwater Depositional Systems: Implications for Reservoir Architecture and Prediction, GCSSEPM Foundation 20th Annual Research Conference, Deep Water Reservoirs of the World, December 3-6, 2000, p. 515-532.

Obermeier, S.F., 1996, Use of liquefaction-induced features for paleoseismic analysis; an overview of how seismic liquefaction features can be distinguished from other features and how their regional distribution and properties of source sediment can be used to infer the location and strength of Holocene paleo-earthquakes: Engineering Geology, v. 44/1-4, p. 1-76.

Truswell, J.F., 1972, Sandstone sheets and related intrusions from Coffee Bay, Transkei, South Africa: Journal of Sedimentary Petrology, v. 42, p. 578-583.

Winslow, M.A., 1983, Clastic dike swarms and the structural evolution of the foreland fold and thrust belt of the southern Andes: GSA Bulletin, v. 94, p. 1073-1080.

AAPG ANNUAL 2013
CONVENTION & EXHIBITION
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
WITH SEPM (SOCIETY FOR SEDIMENTARY GEOLOGY)
19-22 MAY 2013 • DAVID L. LAWRENCE CONVENTION CENTER • PITTSBURGH

The Identification and Implication of Injectites in the Shwe Gas Field, Offshore Northwestern Myanmar

Stephen P.J. Cossey[1], Dongil (David) Kim[2], Su-Yeong Yang[2], and Ho Young Jung[2]

[1]Cossey and Associates Inc., [2]Daewoo International Corporation

May 2013

Cossey & Associates Inc. geoconsulting

DAEWOO INTERNATIONAL

Contents

Introduction

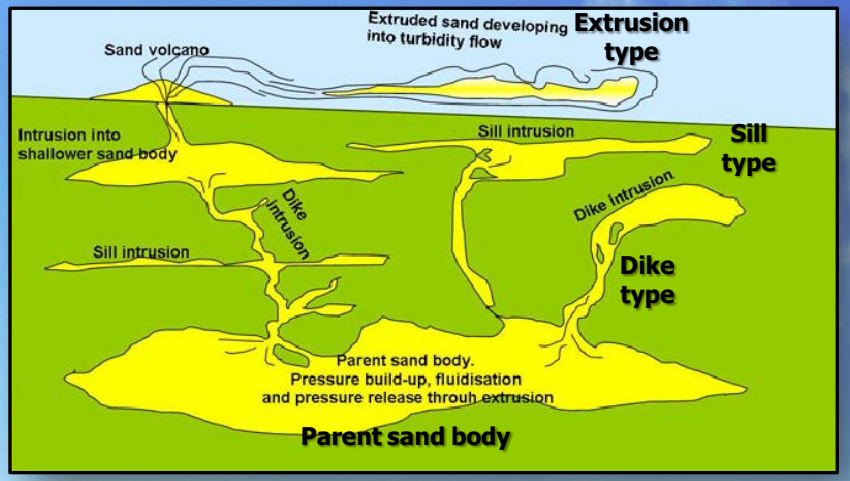
Injectite

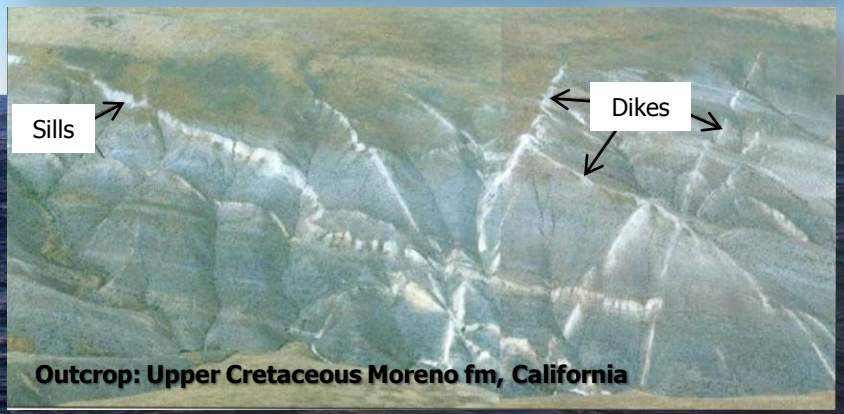
Definition:

. Unconsolidated sand remobilized and forced upward through overlying layers due to overpressure

Causes for Injectite

. Seismicity[1)]
. Regional tectonic stress[2)]
. Development of localized excessive pore-fluid pressures[3)]
. Lateral pressure-transfer[4)]
. Over pressuring created by petroleum migration from deep layers[5)]





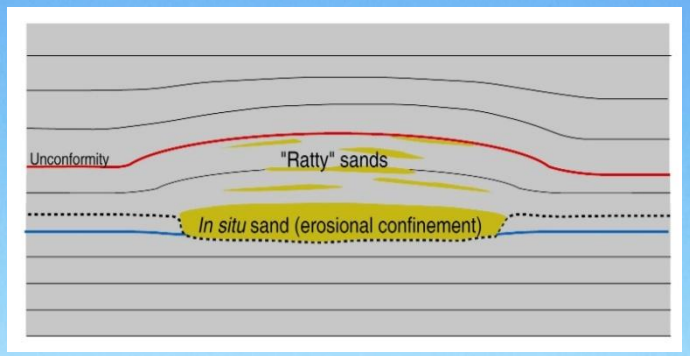
1) Obermeier, 1996
2) Winslow, 1983
3) Truswell, 1972
4) Thomson et al. 1989
5) Lonergan et al, 2000, Jolley and Lonergan, 2002

Introduction

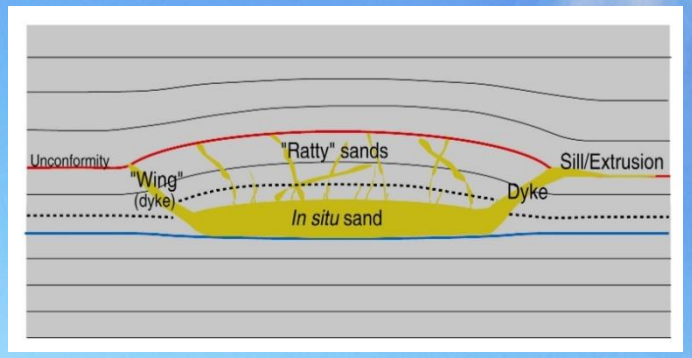
Injectite

Significance:

- Normally high porosity and permeability in case of no cementation
- Considerably enhance vertical connectivity
- Important role in planning and optimizing field development plan



Before Injectite Interpretation



After Injectite Interpretation

How can we interpret ratty sands as injectites?

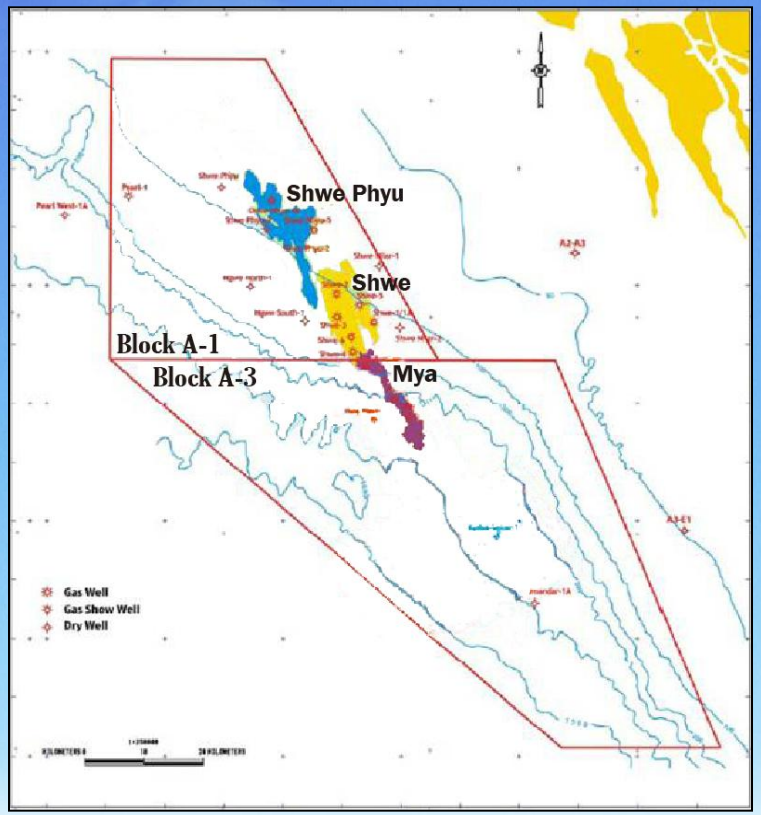
Study Area

Block Locations A-1/A-3/AD-7, Myanmar

Blocks	A-1	A-3	AD-7
Participation	2000	2004	2007
Equity (%)	51	51	100
Acreage(km^2)	2,119	3,441	1,684
Partners	ONGC Videsh, GAIL, KOGAS, MOGE		

Study Area

Gas Fields and Reserves



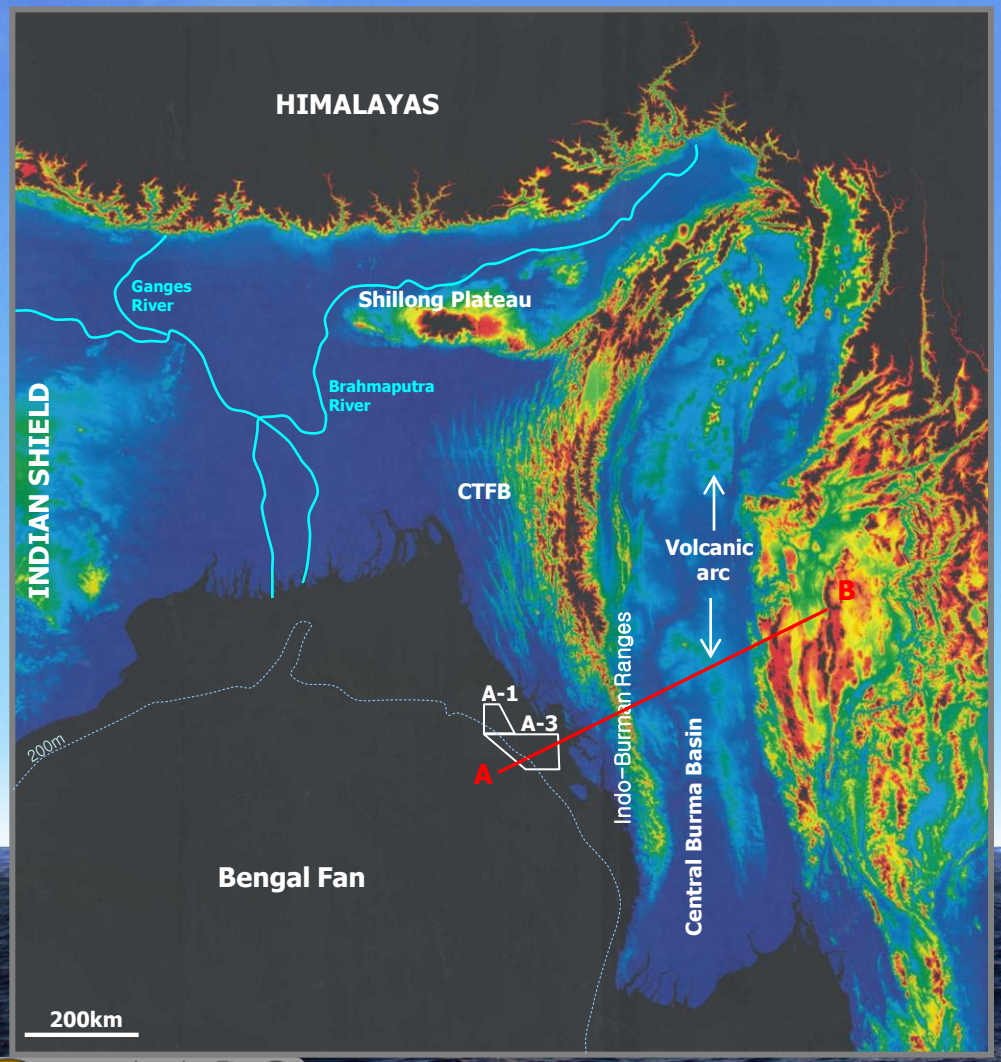
Resource Certification

Block	Gas Fields	Recoverable Reserves (TCF)
A-1	Shwe	2.87 ~ 4.67
	Shwe Phyu	0.38 ~ 0.91
A-3	Mya	1.28 ~ 2.16
Total		*4.53 ~ 7.74*

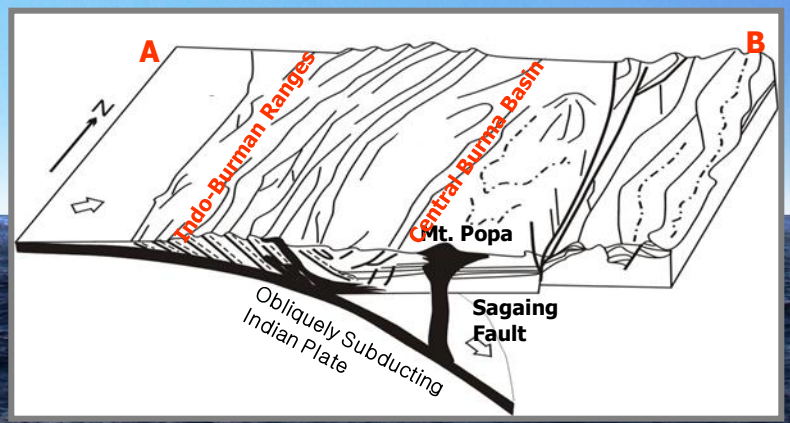
- Auditor : Gaffney, Cline & Associates (GCA)

Study Area

Regional Geology



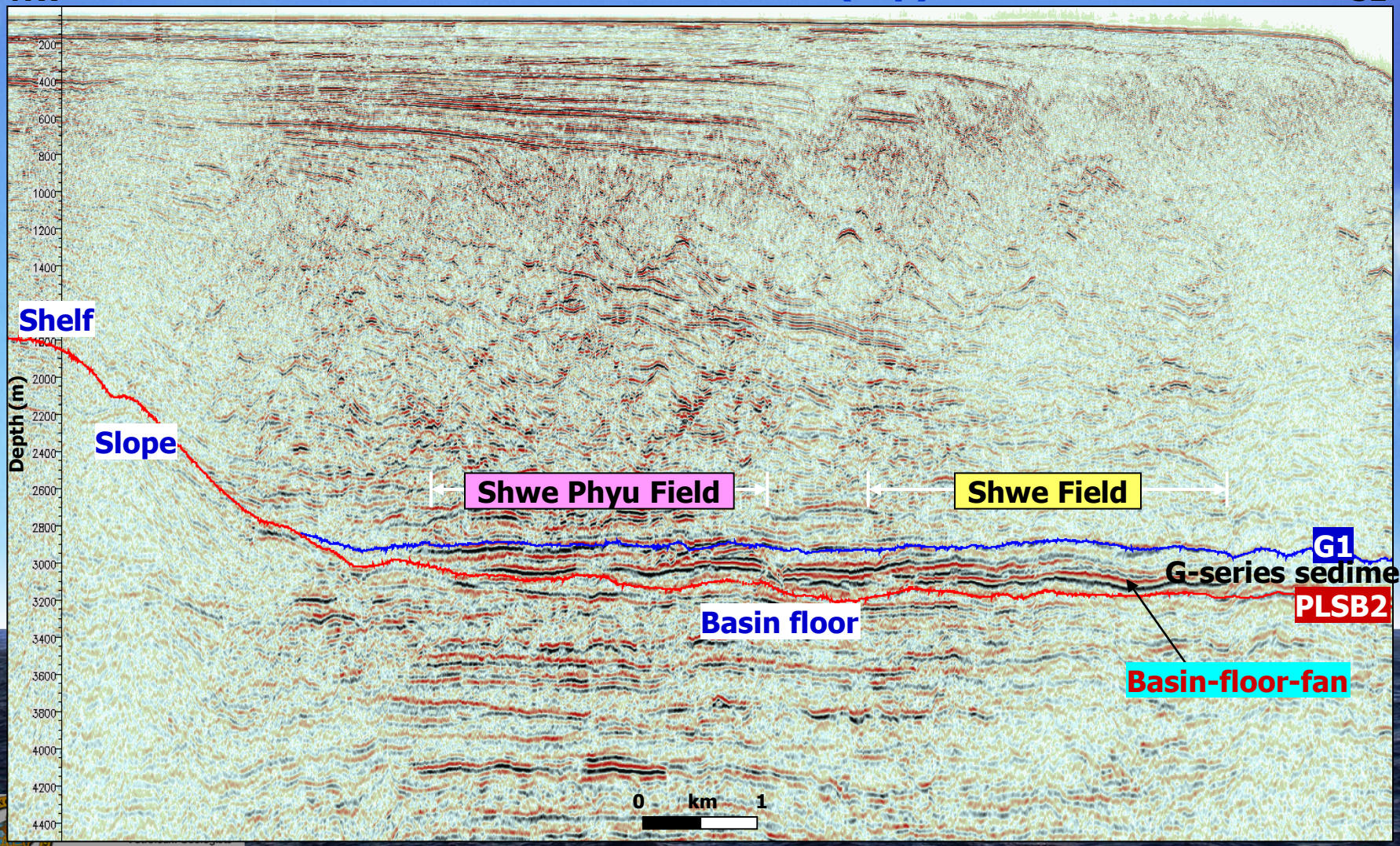
- **CTFB :**
  Chittagong-Tripura Fold Belt
- **Indo-Burman Ranges:**
  Accretionary prism by Bengal subduction
- **Central Burma Basin:**
  Fore-arc and back-arc basin of Bengal subduction



Study Area

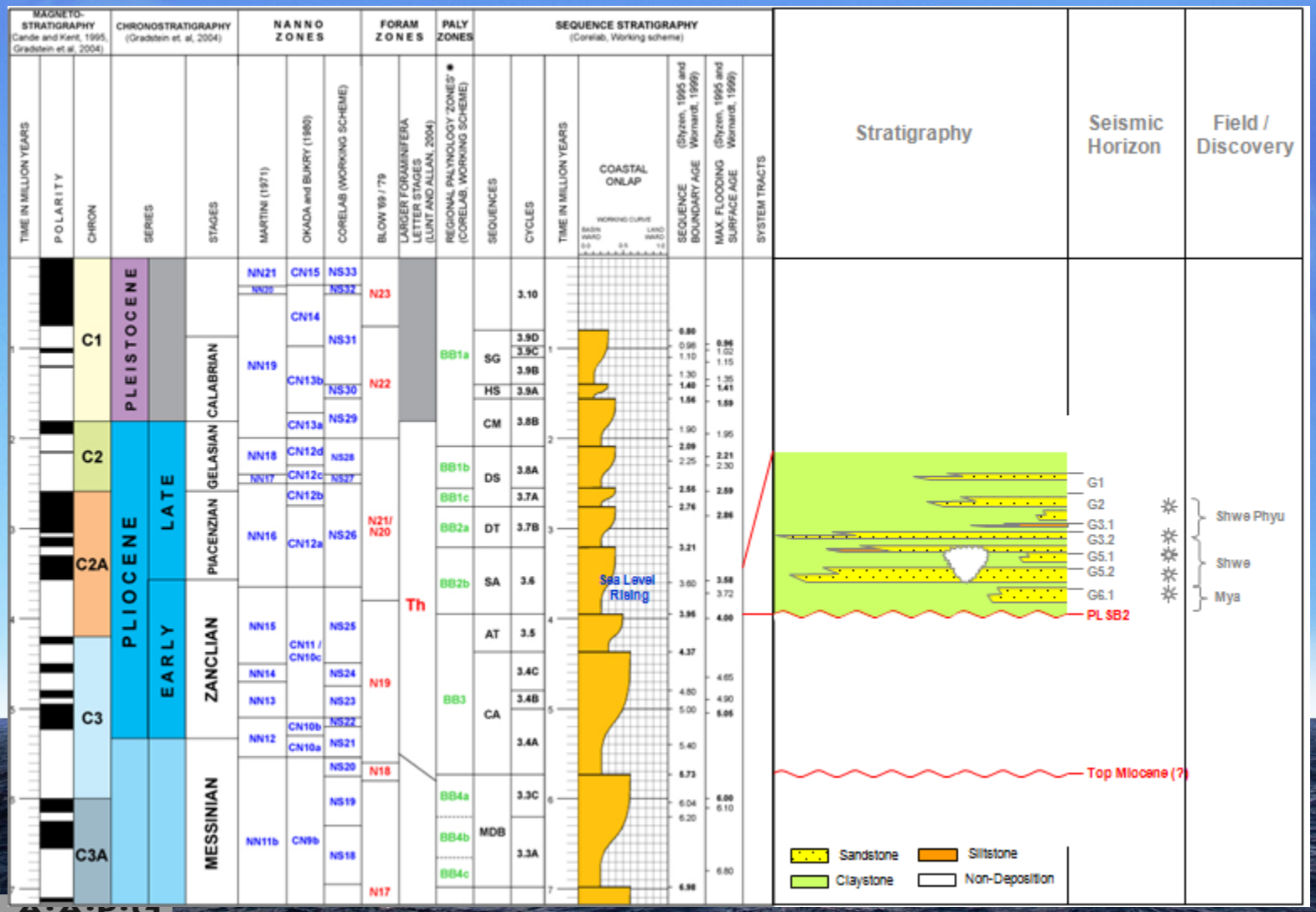
Seismic Stratigraphic Analysis

2D PSTM section (Dip)



Study Area

Stratigraphic Column

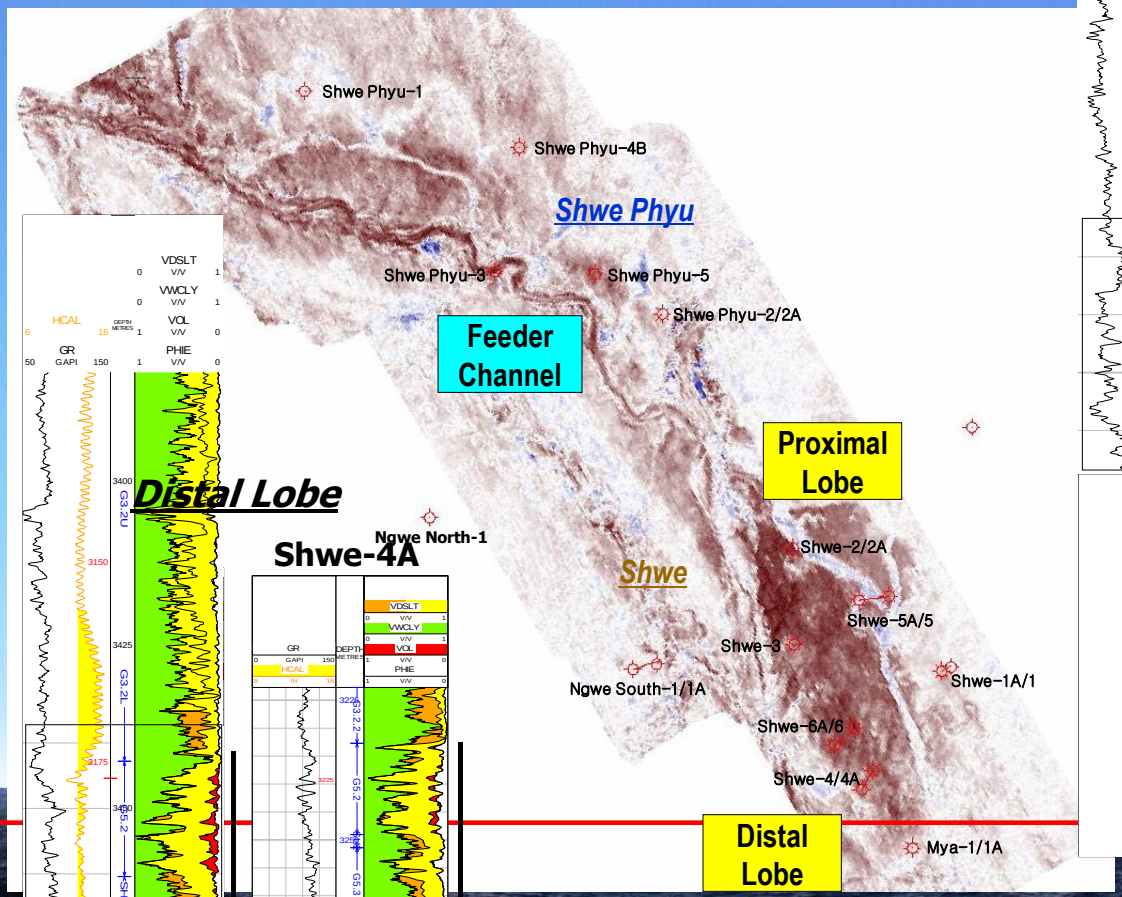


(Pleistocene - Miocene Biochronostratigraphy of the Bay of Bengal, Corelab)

Previous Model

Thick-bedded Reservoirs in G5.2

Lobe deposits

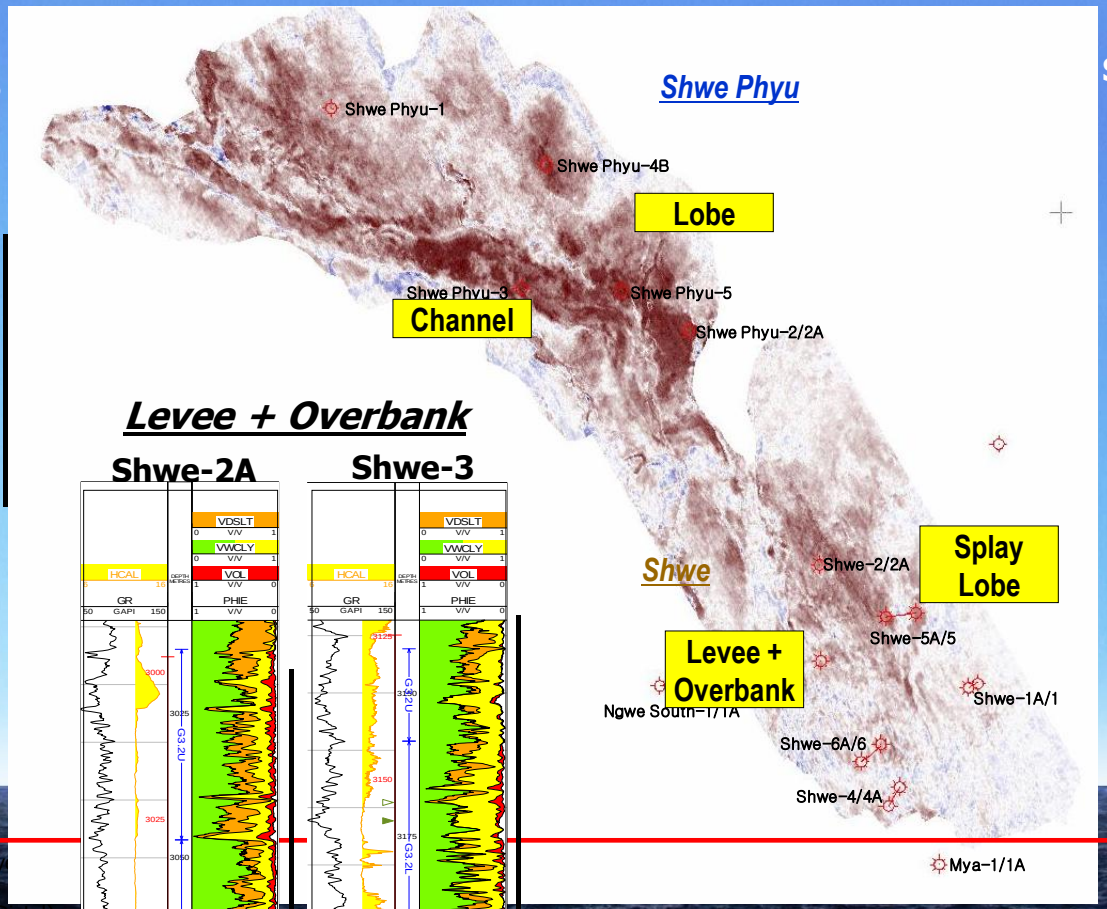


ap of Top G5.2 sand reservoir

Previous Model

Thin-bedded Reservoirs in G3.2

Channel related deposits such as channels, levee-overbanks and spla



Channel

Shwe Phyu-3

Lob

Shwe Phyu-4B

Splay

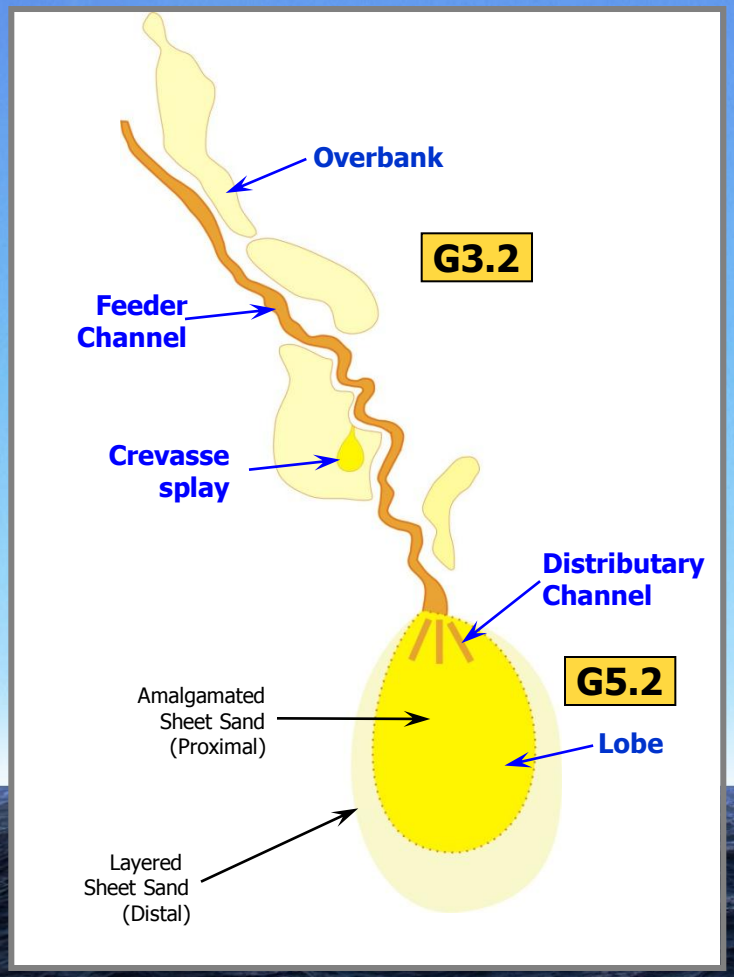
Shwe

Lay
Sheet
(Distal)

Am of nd reservoir

Previous Model

Conceptual Fan Depositional Model

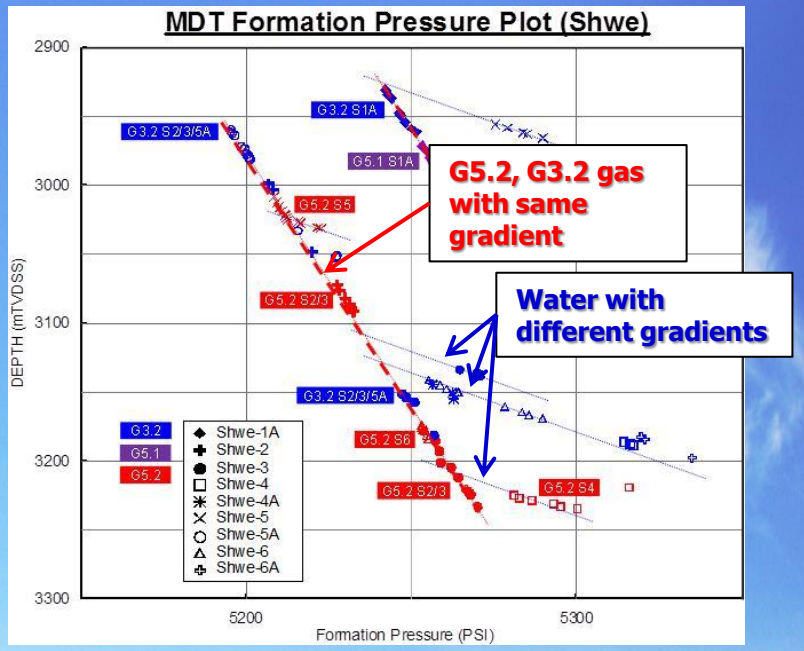


- **Lobe deposit (G5.2)**
  - Mostly thick sand
  - Proximal part : Amalgamated sand
  - Distal part : Layered sand
- **Channel – Overbank deposit (G3.2)**
  - Mostly thin ratty sand
  - Feeder & Distributary channels
  - Proximal & Distal levee/overbank
  - Crevasse splays

Previous Model

Key Questions Difficult to Be Answered

- **MDT formation pressure**
  - Why are G5.2 and G3.2 gas in the same gradient and different water gradients?
- **Core observation**
  - How can we explain thin Ta facies with minor Tb, Tc facies in G3.2 thin sand?
  - What controls the petrographic differences between G3.2 and G5.2?
- **G5.2 thickness trend**
  - Why is proximal part thinner than distal part in G5.2 lobe?

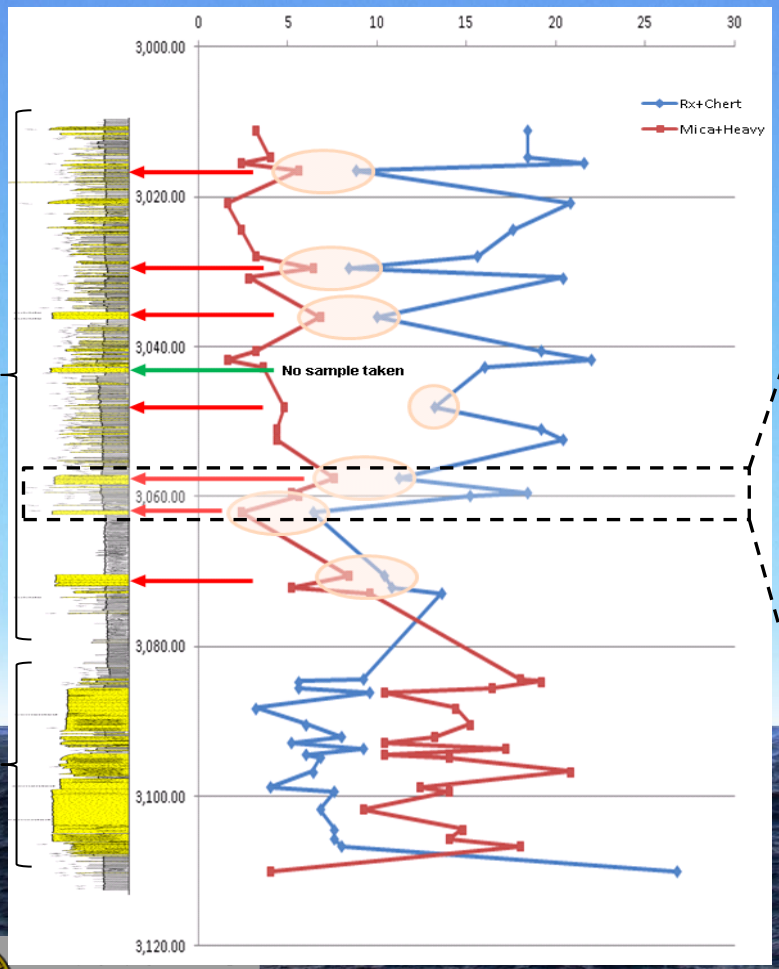


Injectite Model

Shwe-2A Core

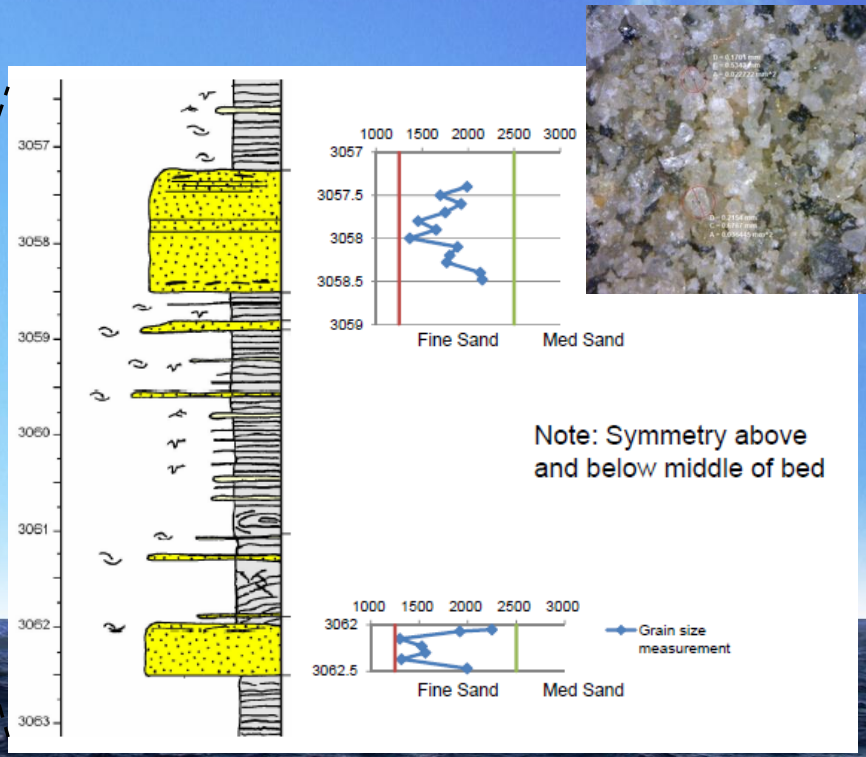
G3.2, G5.2 petrographic composition

- Similar trend in G3.2 injectite with G5.2 lobe



Core facies, Grain size distribution

- Dominant Ta facies, lack of Tb/Tc facies
- Symmetric distribution within injectite
- Normally turbidite shows fining upward trend



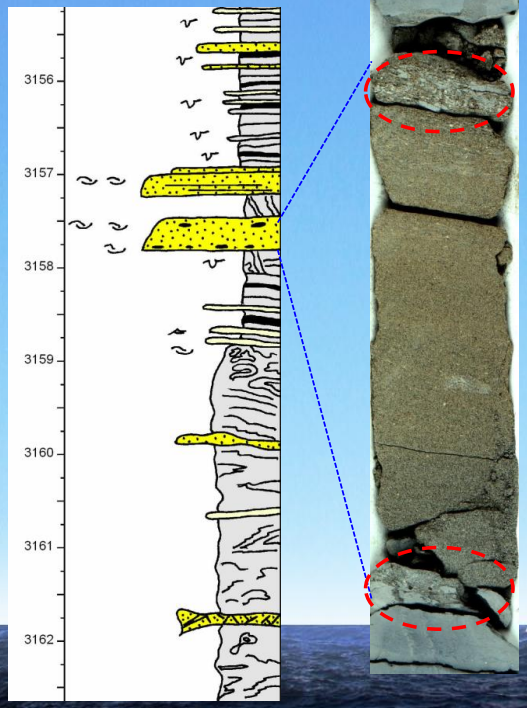
American Association of Petroleum Geologists
An International Geological Organization

Injectite Model

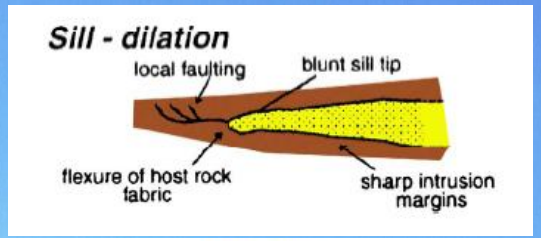
Shwe-3 Core

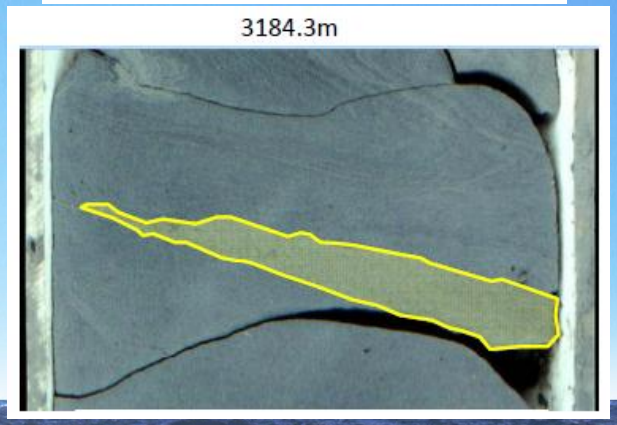
Injection with slumping

- This can explain why there are wet sand (upper), GWC sand (middle) and gas sand (lower) in G3.2 in Shwe-3 well



Rip up clasts in the bottom and the top of sand





Sharp margin termination of sand injection

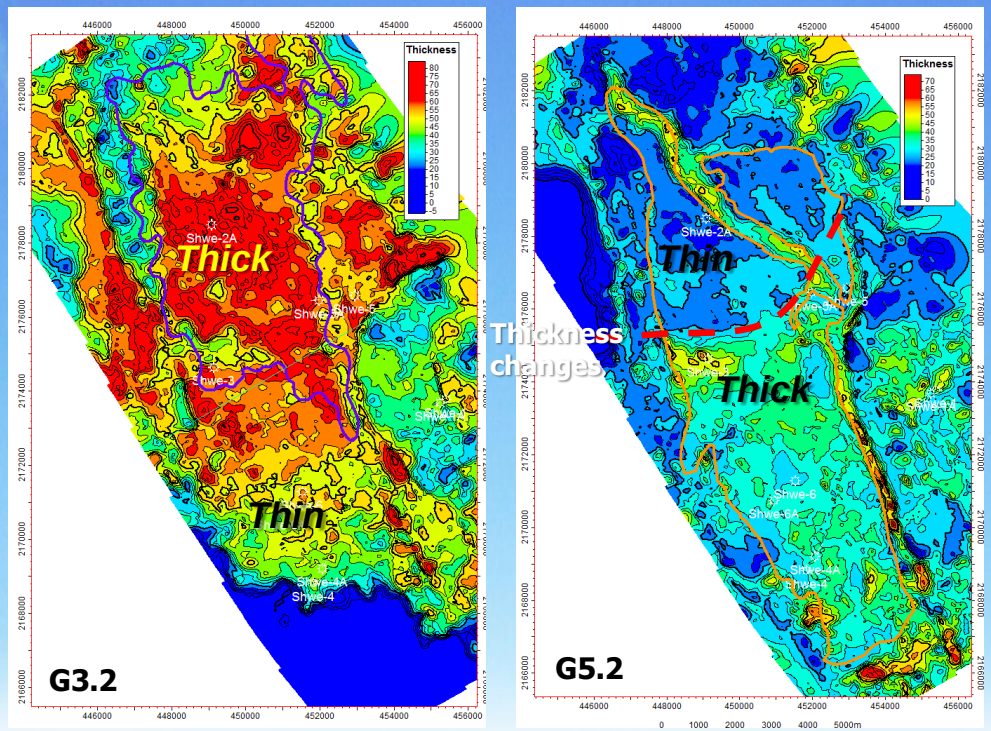
Upright angle to normal bedding

Injectite Model

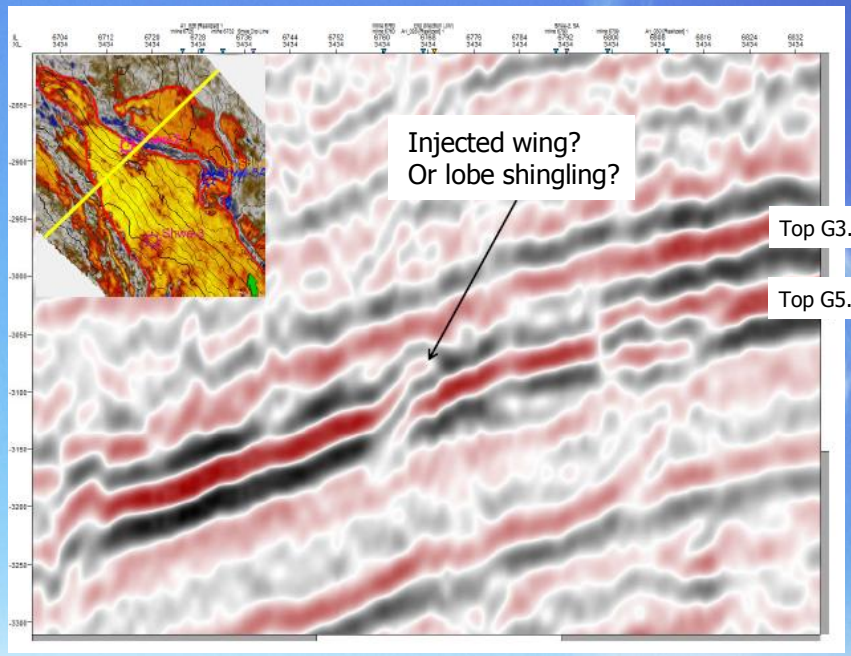
Isopach Map, Seismic Section

DAEWOO INTERNATIONAL

Isopach map of G3.2 & G5.2



Seismic section



- *Where G5.2 is thin, G3.2 is generally thick due to **vertical injection**.*
- *Proximal part (S2) is thinner than distal part (S3) in G5.2 due to **lateral injection**.*
- *No well penetration*

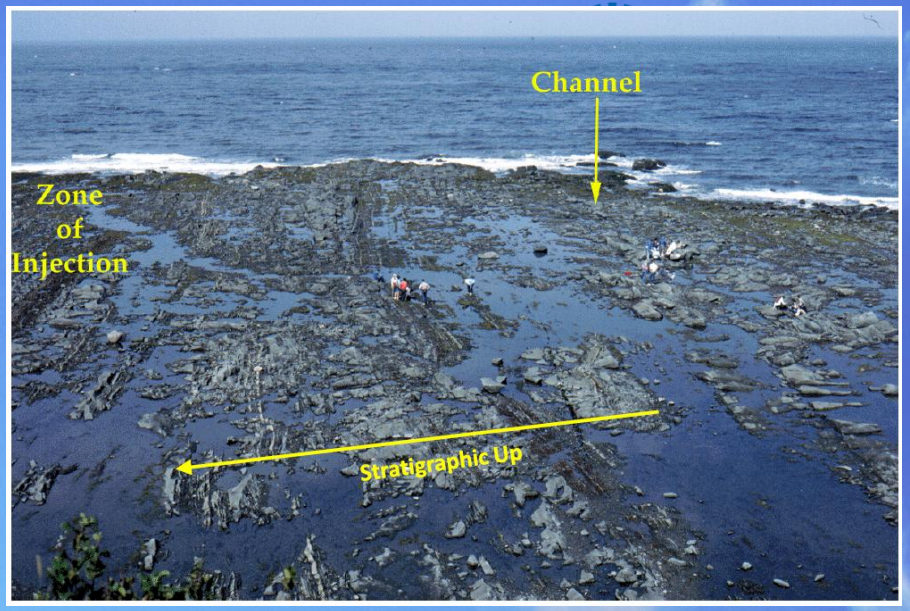
A·A·P·G
American Association of Petroleum Geologists
An International Geological Organization

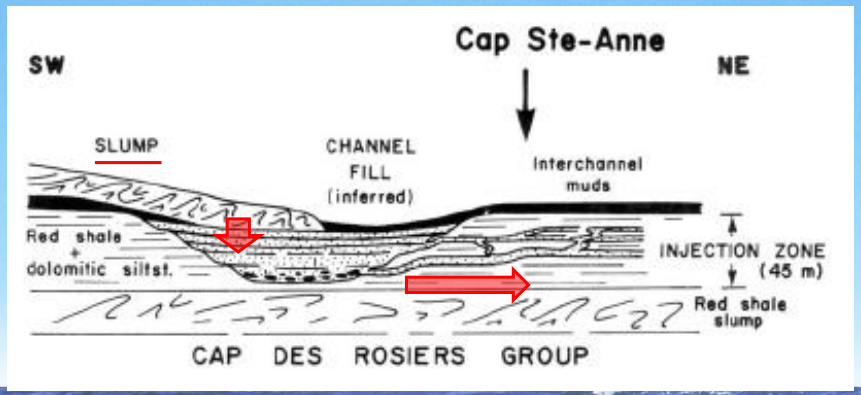
Injectite Model

Outcrop Analogue

Tourelle formation, Cap Ste-Anne, Quebec

- Dominantly lateral injection (Sill type)
- Up to 3m thick, sharp bases and tops
- Step up and down stratigraphically
- Poorly sorted
- Injected zone is 45m thick (Shwe: 72m)

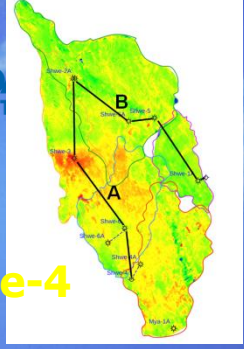


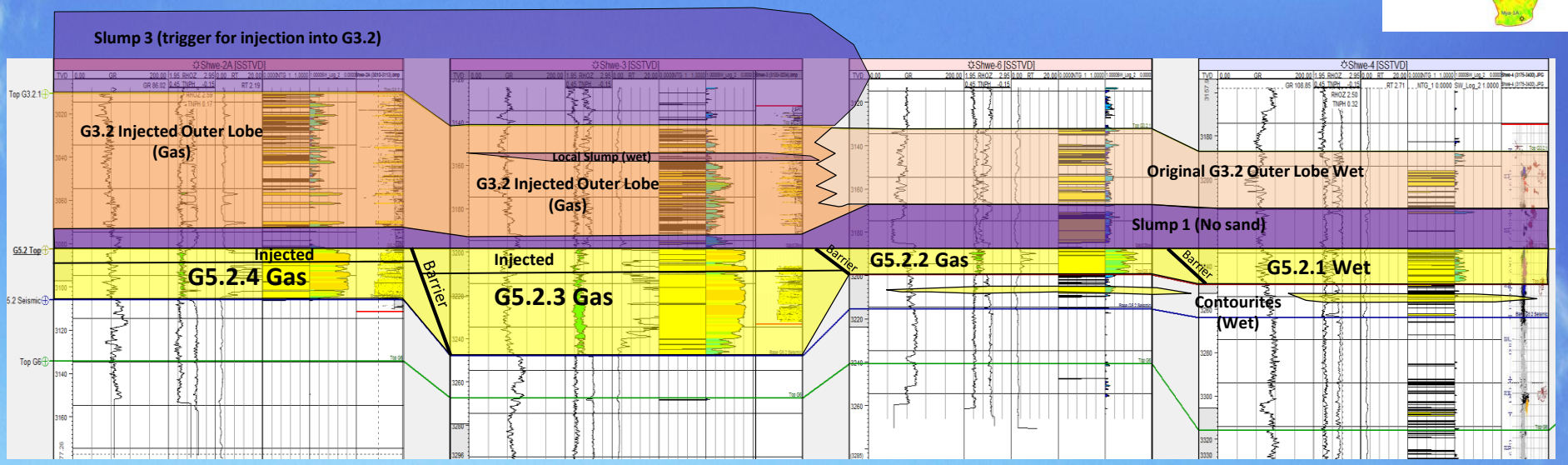


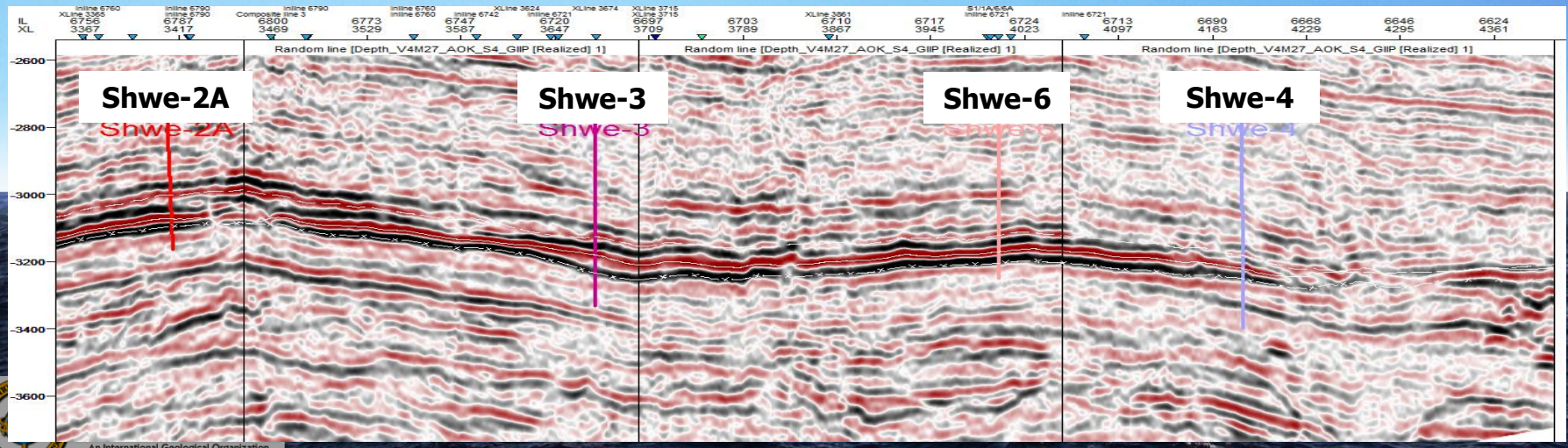
A·A·P·G
American Association of Petroleum Geologists
An International Geological Organization

Injectite Model

Well Correlation (Cross-section A)

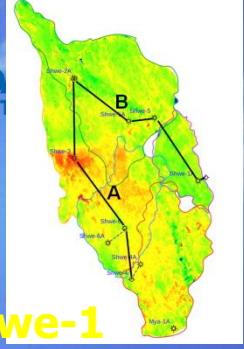


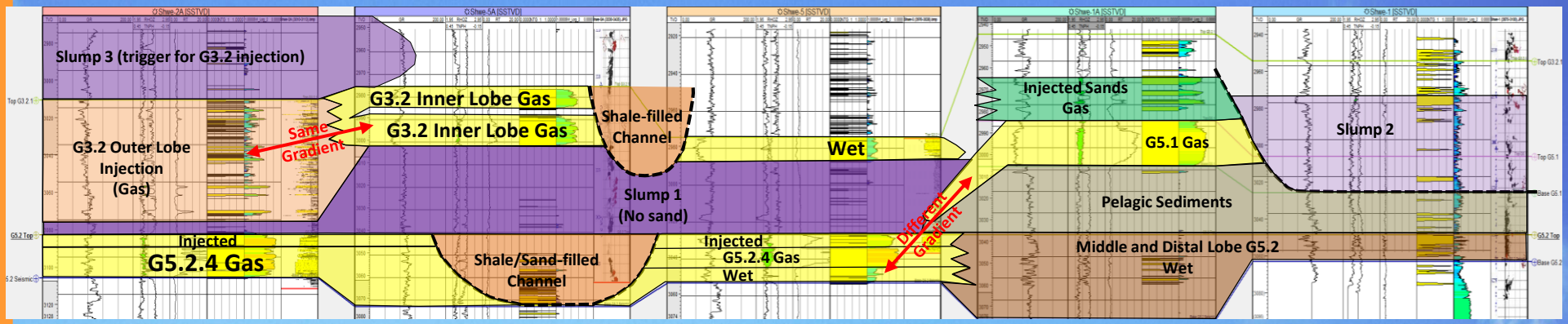


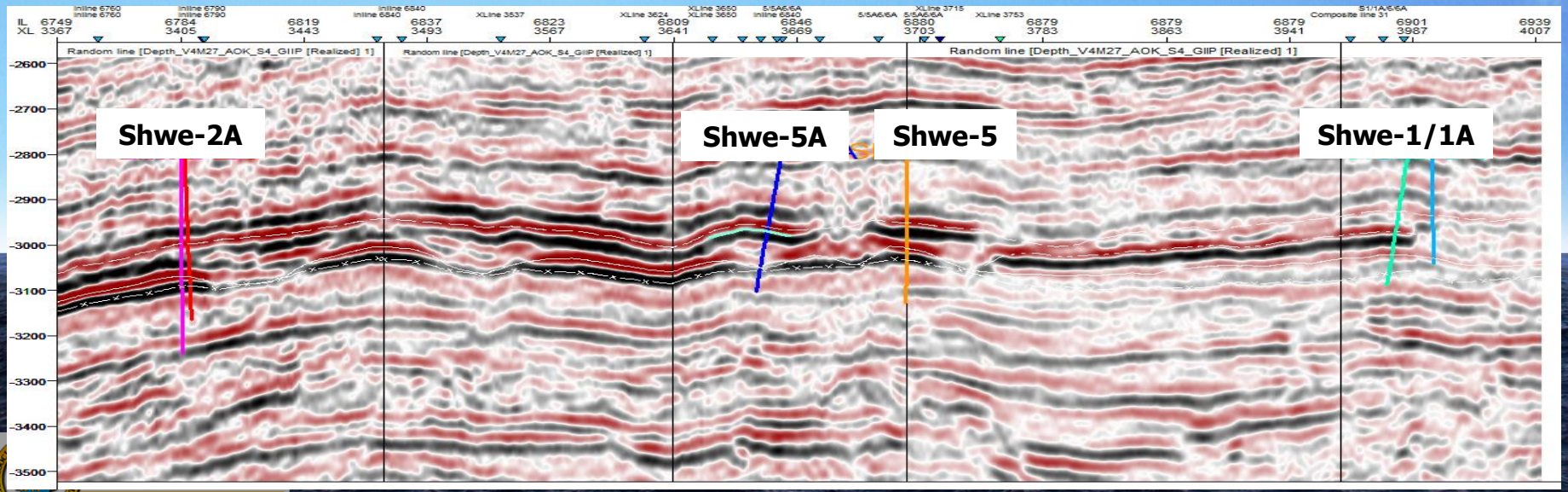


Injectite Model

Well Correlation (Cross-section B)

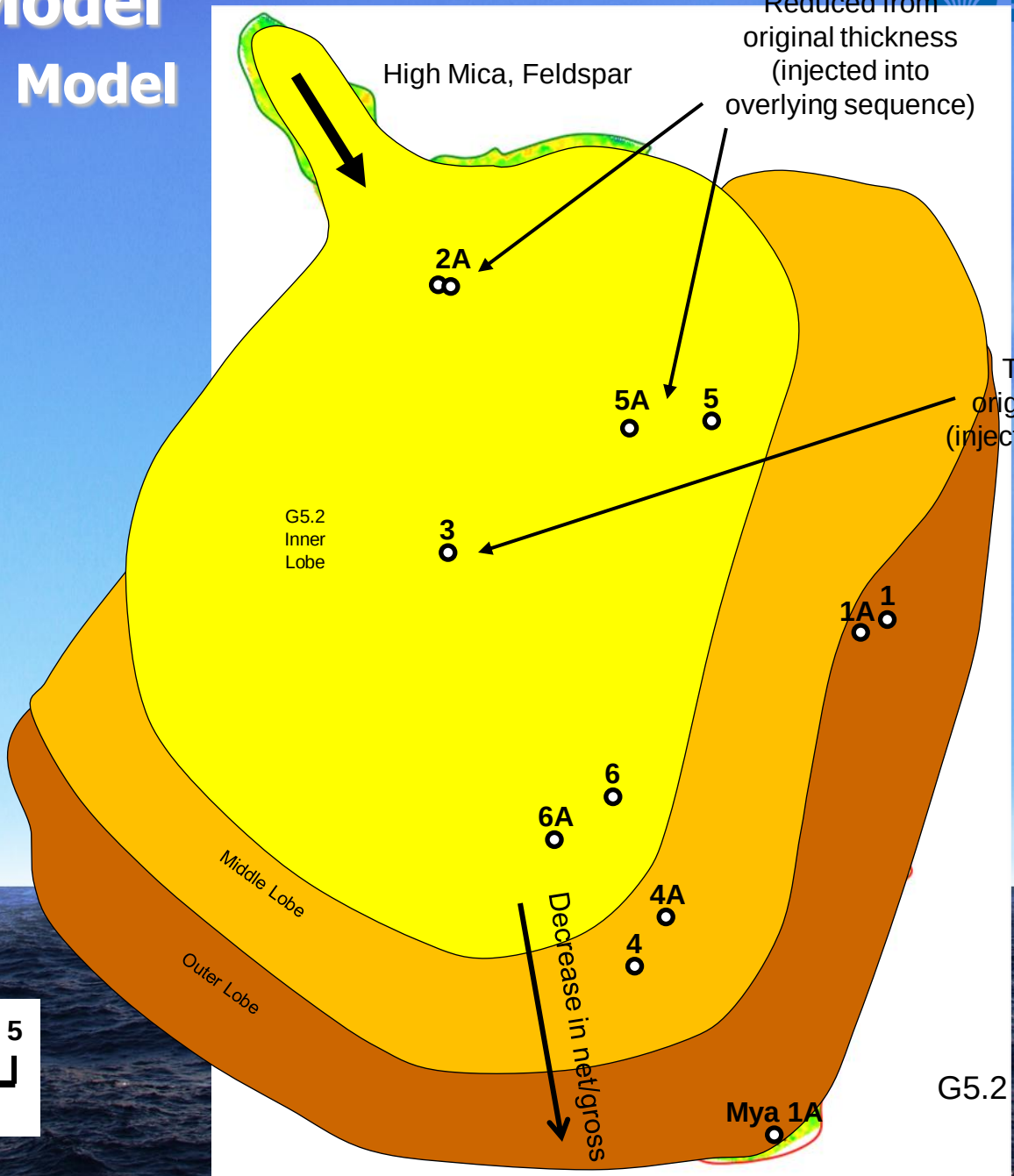






Injectite Model
Depositional Model

Shwe G5.2



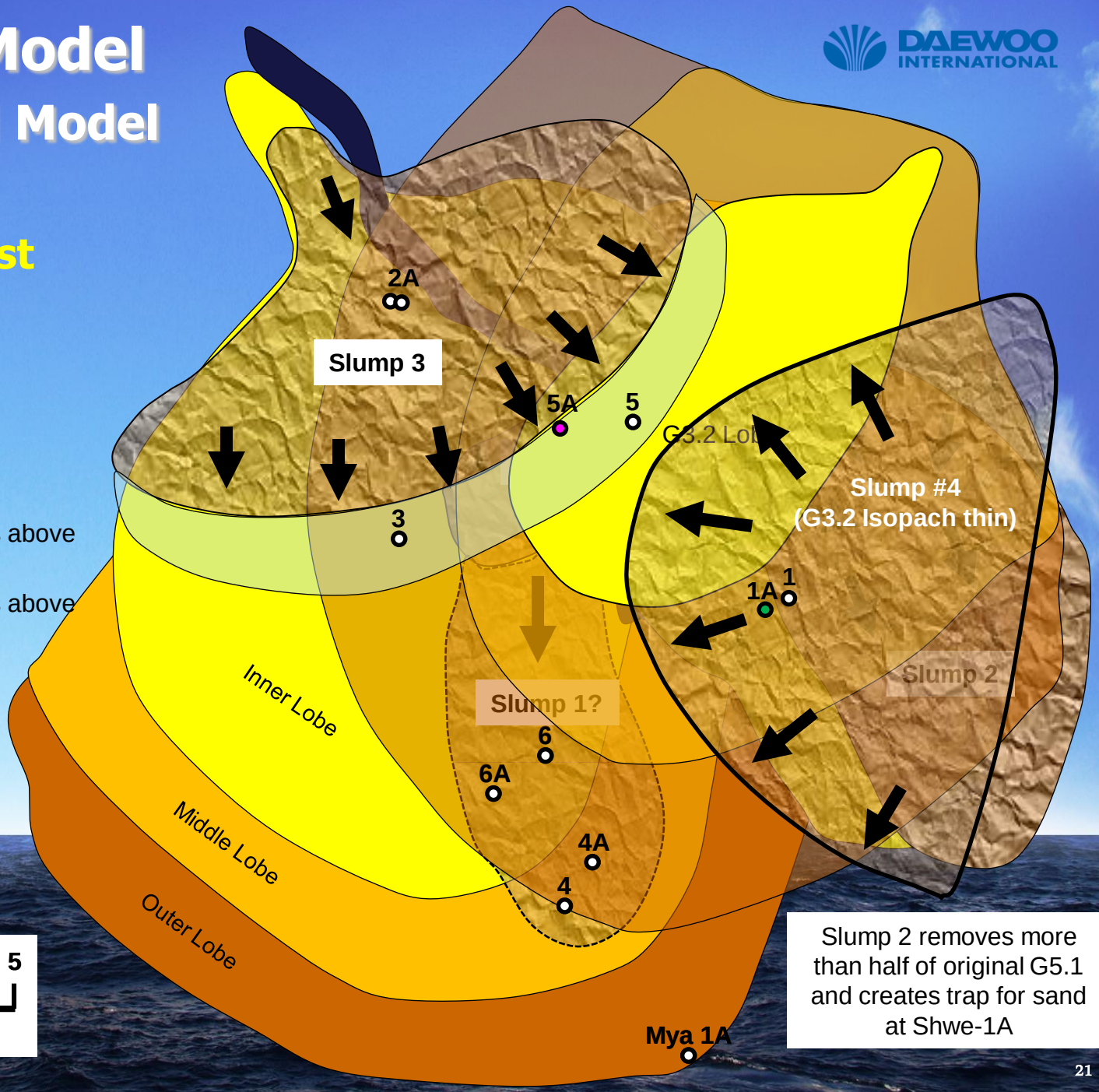
G5.2 Isopach Map

Injectite Model
Depositional Model

Shwe G5.2 Post Depositional Deformation

- Only gas-filled original G3.2 sands
- Gas-filled injected sands above G5.2 and within G5.2
- Gas-filled injected sands above G5.1 and within G5.1
- Only gas-filled original G5.2 sands

Lateral Injection (sills)



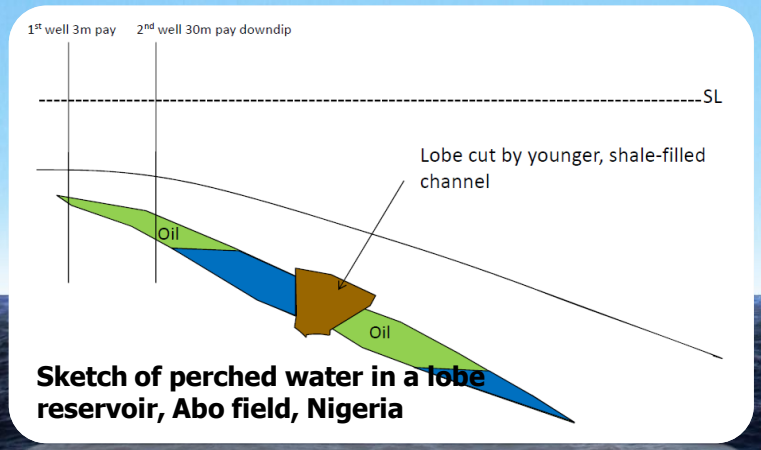
0 1 2 3 4 5
Km

Slump 2 removes more than half of original G5.1 and creates trap for sand at Shwe-1A

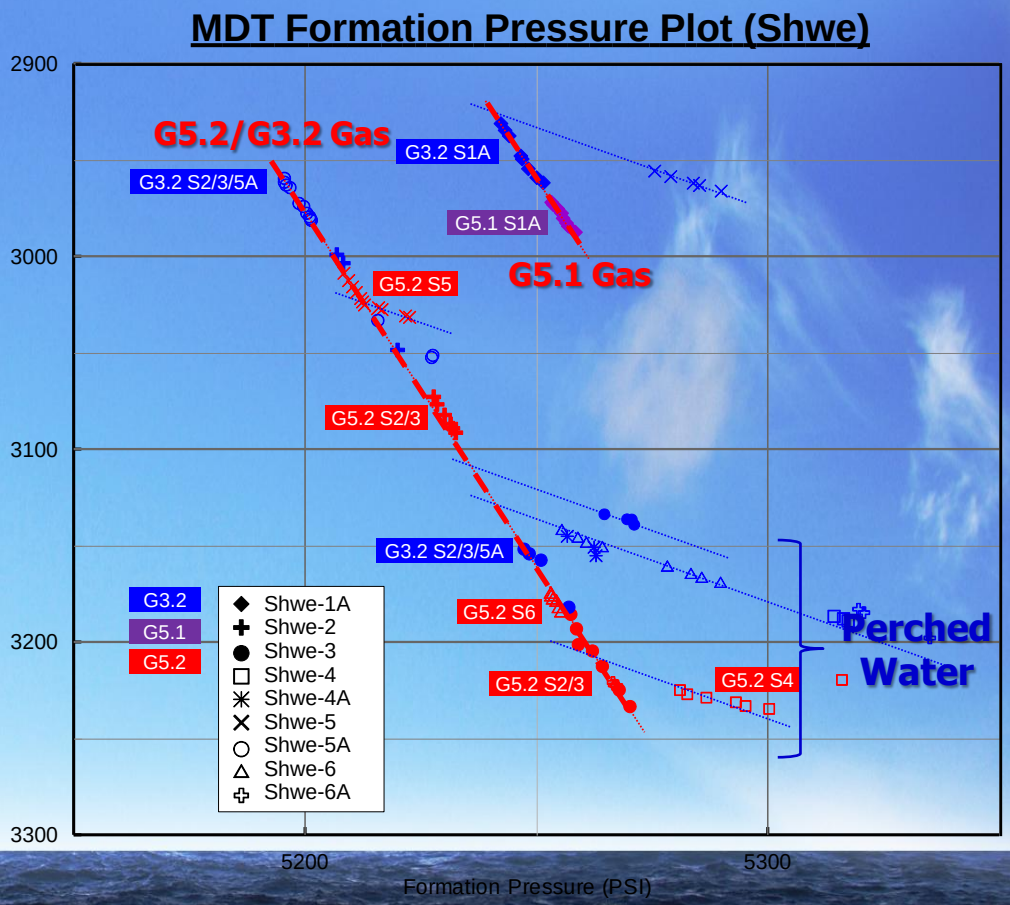
Discussion

MDT Formation Pressure

- G3.2, G5.2 gas are connected by injection
  - Same gas gradient
  - G5.1 gas in a separate pressure compartment
- Water is disconnected
  - Mostly perched water
  - Limited extent



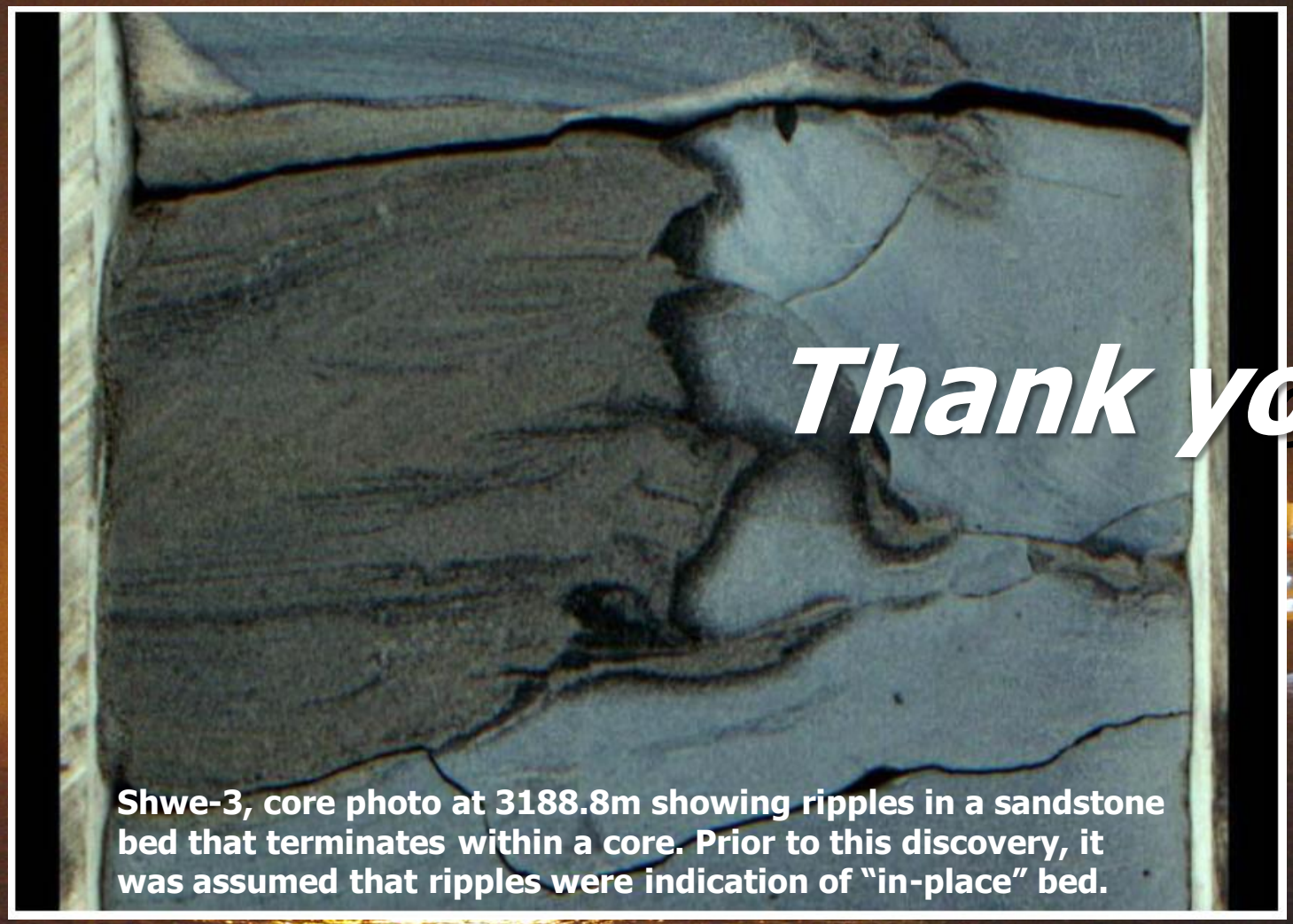
Sketch of perched water in a lobe reservoir, Abo field, Nigeria



Conclusion

- The depositional environment of G3.2 was channel related ratty sand in the previous model.
- However, this model could not explain key issues like MDT pressure, core facies, petrography and thickness trend.
- Based on detailed interpretation of core, log, seismic and analogue observation, G3.2 sands are injectites from G5.2.
- With the injectite model, we can explain all key issues with a reasonable depositional model.
- This injectite model will be validated and fine-tuned after drilling Shwe development wells.

(The 1st Gas Discovery Well in Block A-1, Offshore Myanmar)



Shwe-3, core photo at 3188.8m showing ripples in a sandstone bed that terminates within a core. Prior to this discovery, it was assumed that ripples were indication of "in-place" bed.

Thank you !

DAEWOO INTERNATIONAL