The Acquisition and Use of Outcrop Analogue Data in Reservoir Characterisation*

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Abstract

Petroleum companies need to overcome uncertainties in reservoir and seal continuity prediction at all stages of field appraisal and development. Because of the common scarcity of data to reveal the lateral continuity of geobodies, analogue data is used as a mean to estimate continuity. A common challenge in the industry is the prediction of reservoir continuity which leads to great uncertainly in a geological model. Therefore, good quality analogue data is imperative to building good reservoir models.

Outcrop analogues can be used to reduce a variety of uncertainties. The most frequent usage is that of supplementing depositional architecture. Width:thickness:length ratios, and lateral facies relationships can rarely be investigated in any other way. But fracture patterns, post-depositional deformation, faulting, and diagenesis are also aspects that can be assessed using outcrop analogues.

The way in which outcrop analogue data is acquired is extremely important for the industry. Because data acquisition is very time intensive, it is ideally suited for the academe. It provides superb training for students and early career researchers and often enables adventurous travels to remote locations. However, for the outcrop data to be useful in subsurface predictions, close collaboration and dialogue between industry and academe is needed. In addition, outcrop data acquisition and interpretation takes time, and long lead times and foresight, for the results have to be taken into account by all parties.

The acquisition and use of outcrop analogue data in reservoir characterisation

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Outline

- Rationale

- Analogues in reservoir characterisation workflow

- Research Training opportunities

- Aspect ratio (W:T) data

- Plan form geometric data

- Facies models

- Conclusions & Recommendations

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Rationale

- Common scarcity of data to reveal the lateral continuity of geobodies causes uncertainties in reservoir and seal continuity at all stages of field appraisal and development.

- Analogue data (outcrop and subsurface) is often used as a mean to estimate continuity.

  ▶ **Therefore, good quality analogue data is imperative to building good reservoir models.**
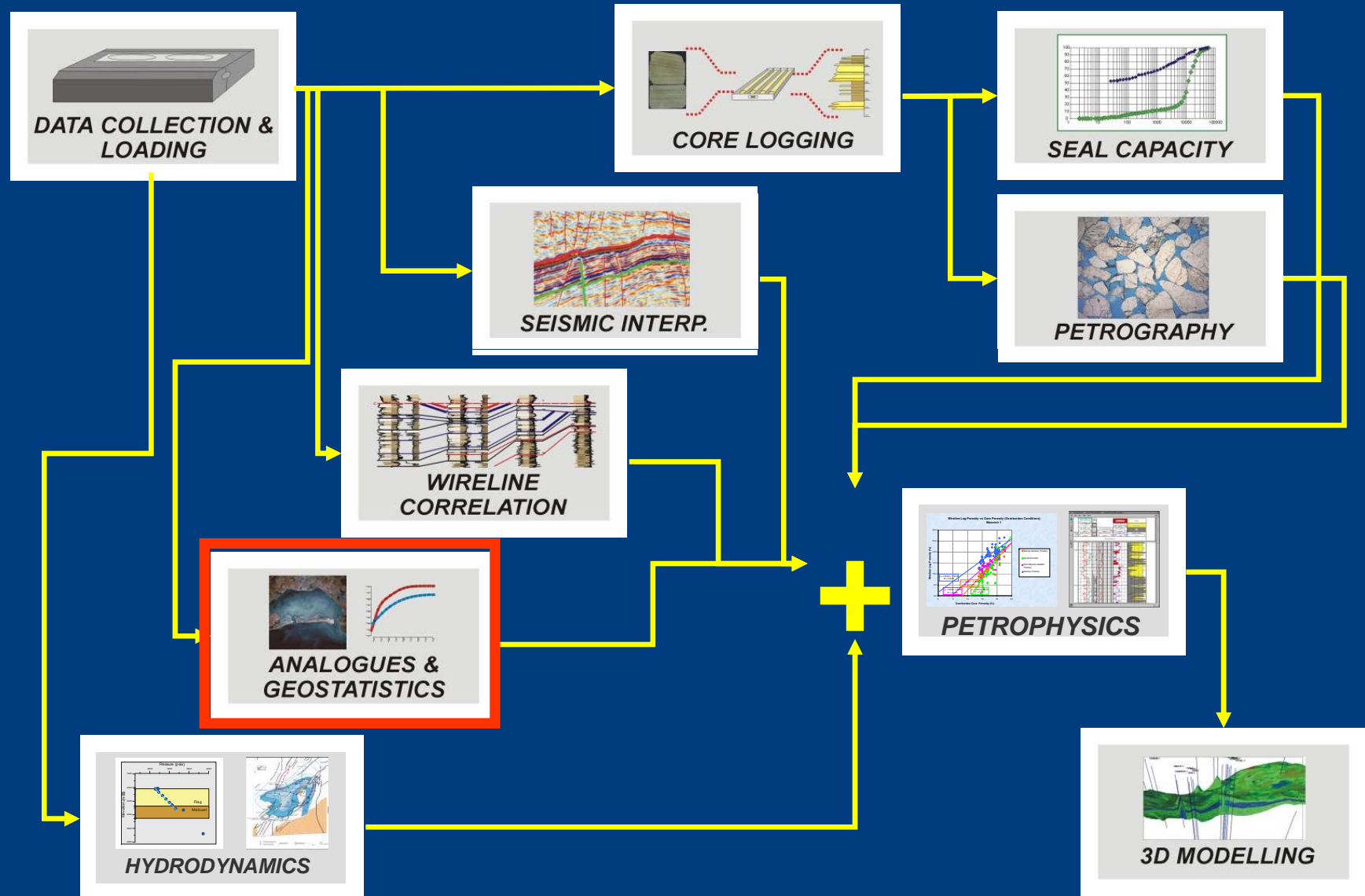
Rationale

- Most frequent use of outcrop analogues is in supplementing depositional architecture.

- Width:thickness:length ratios, and lateral facies relationships can rarely be investigated in any other way.

- No one analogue is perfect – strong need for multiple analogues to assess full range of uncertainties.

  - ▶ **Opportunity: Outcrop analogue projects ideally suited for the academic research providing superb training for students and early career researchers, and often enables adventurous travels to remote locations.**

  - ▶ **Challenges: 1) Data consistency within and across projects. 2) Plan form quantitative data in addition to cross-sectional data. 3) Consistent facies models**

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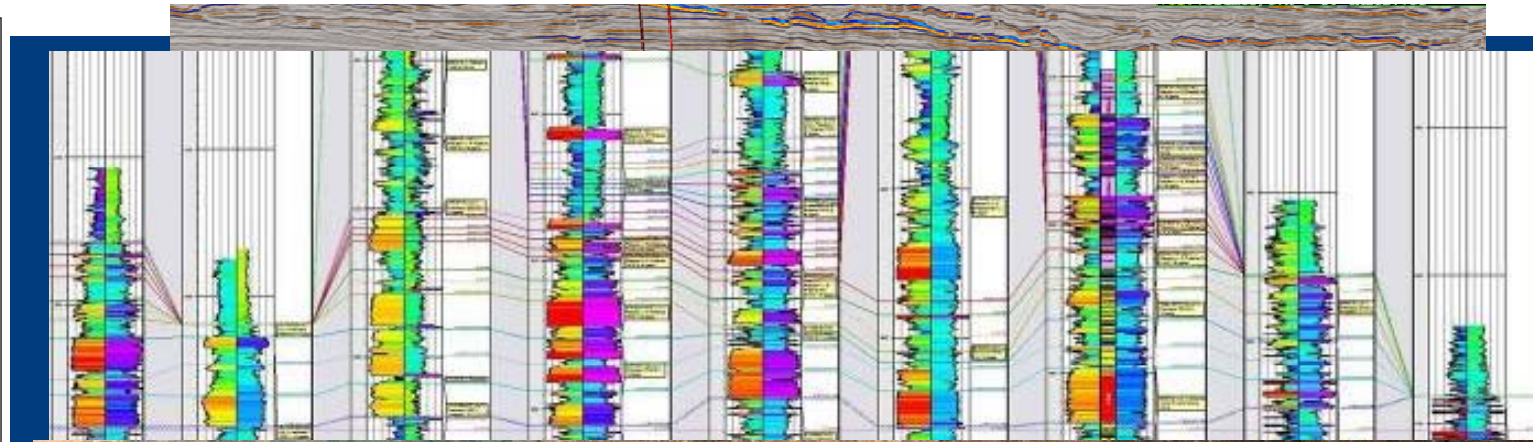
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Where do analogues contribute to reservoir characterisation?

DATA COLLECTION & LOADING

CORE LOGGING

SEAL CAPACITY

SEISMIC INTERP.

PETROGRAPHY

WIRELINE CORRELATION

ANALOGUES & GEOSTATISTICS

PETROPHYSICS

HYDRODYNAMICS

3D MODELLING

Outcrop analogues in reservoir description

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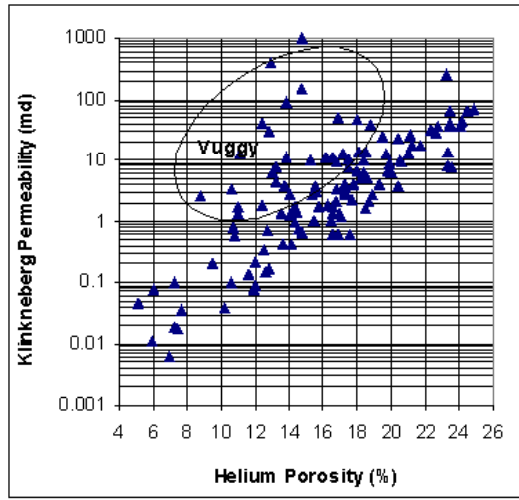
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Research training opportunities: remote places

Flinders Ranges, South Australia

Lake Eyre

Research training opportunities: critical skills

Photo courtesy of LEBARG

Research training opportunities: fun
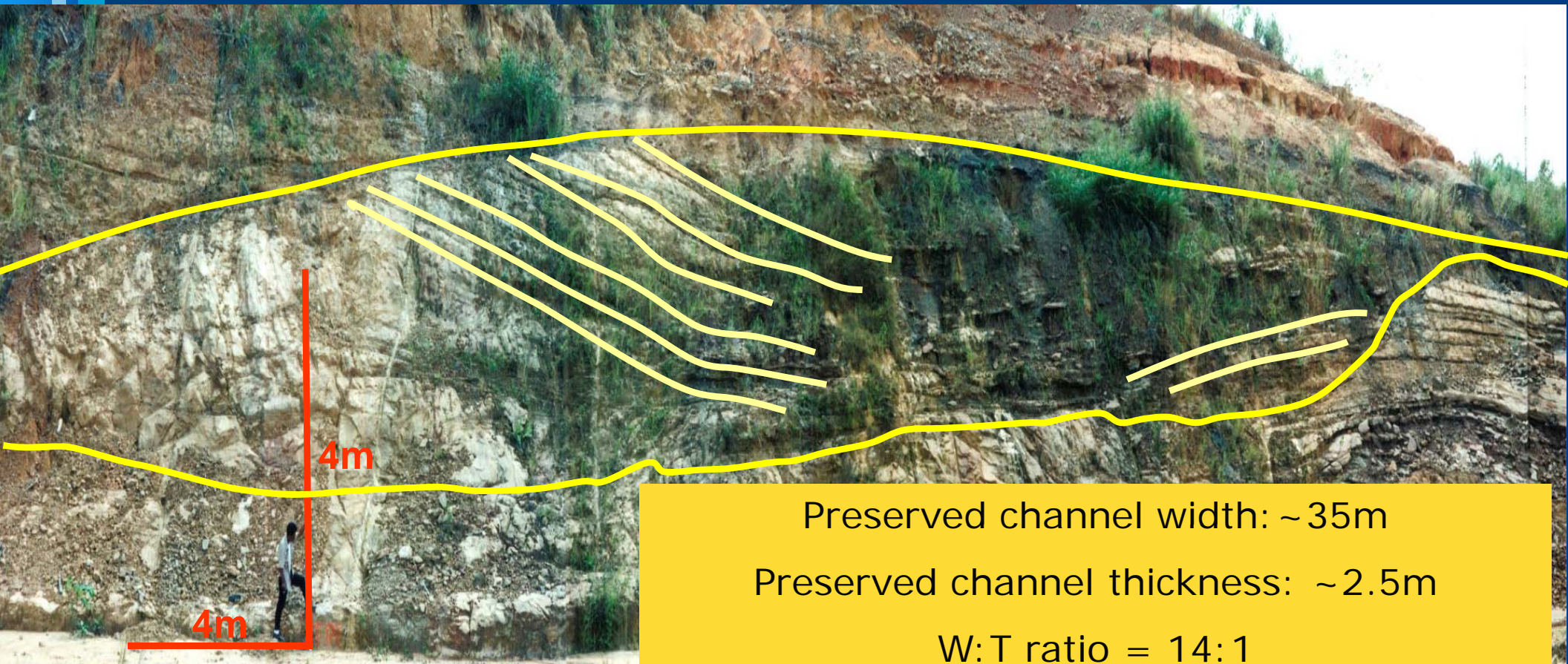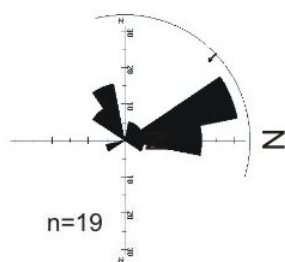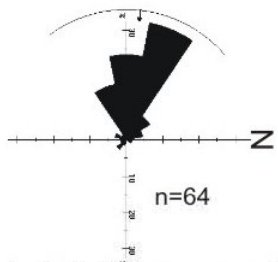
Photos courtesy of LEBARG[13]

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Distributary channel outcrop Miocene Mahakam Delta

4m

4m

Preserved channel width: ~35m

Preserved channel thickness: ~2.5m

W:T ratio = 14:1

Preserved sandstone width: ~20m

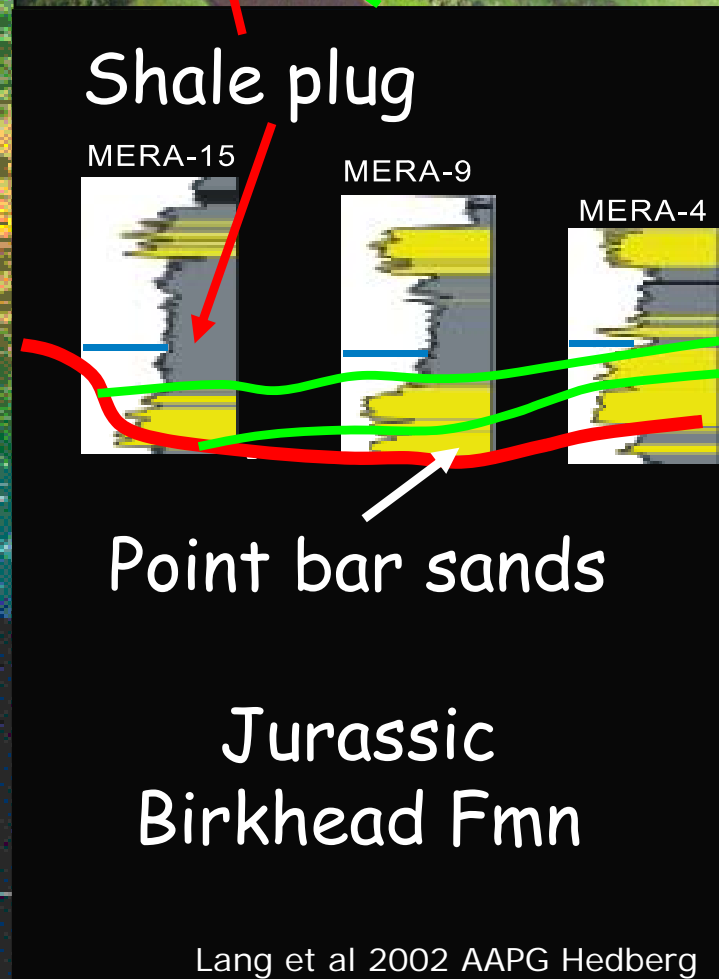Preserved sandstone thickness: ~2.5m

W:T ratio = 8:1

n=64

Trough & Tabular cross-beds

n=19

Lateral accretion surfaces

Outcrop location relative to a channel

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Payenberg & Lang 2003

FACIES
- Fluvial channel
- Crevasse splay channel
- Floodplain-crevasse splay complex
- Floodplain
- Cemented Adori Formation

dominant facies in upper Birkhead

dominant facies in middle Birkhead

Adori base
Upper Birkhead
FS2
Middle Birkhead
FS1

COO-1
PEL-1
PEL-2
PEL-3
FIC-1
NAR-2
NAR-1
PEL-5
BIN-1
MERA-15
MERA-9
MERA-4
MERA-1
MERA-7
MERA-S-1
MERA-2
MERA-13
PEL-S-1
PEL-4
MAS-1
MERR-4

1km

25m

N

Shale plug

Point bar sands

Jurassic Birkhead Fmn

Lang et al 2002 AAPG Hedberg

John Henry Member, Straight Cliffs Formation (Upper Cretaceous), Utah

Laterally continuous and vertically stacked sandstone bodies

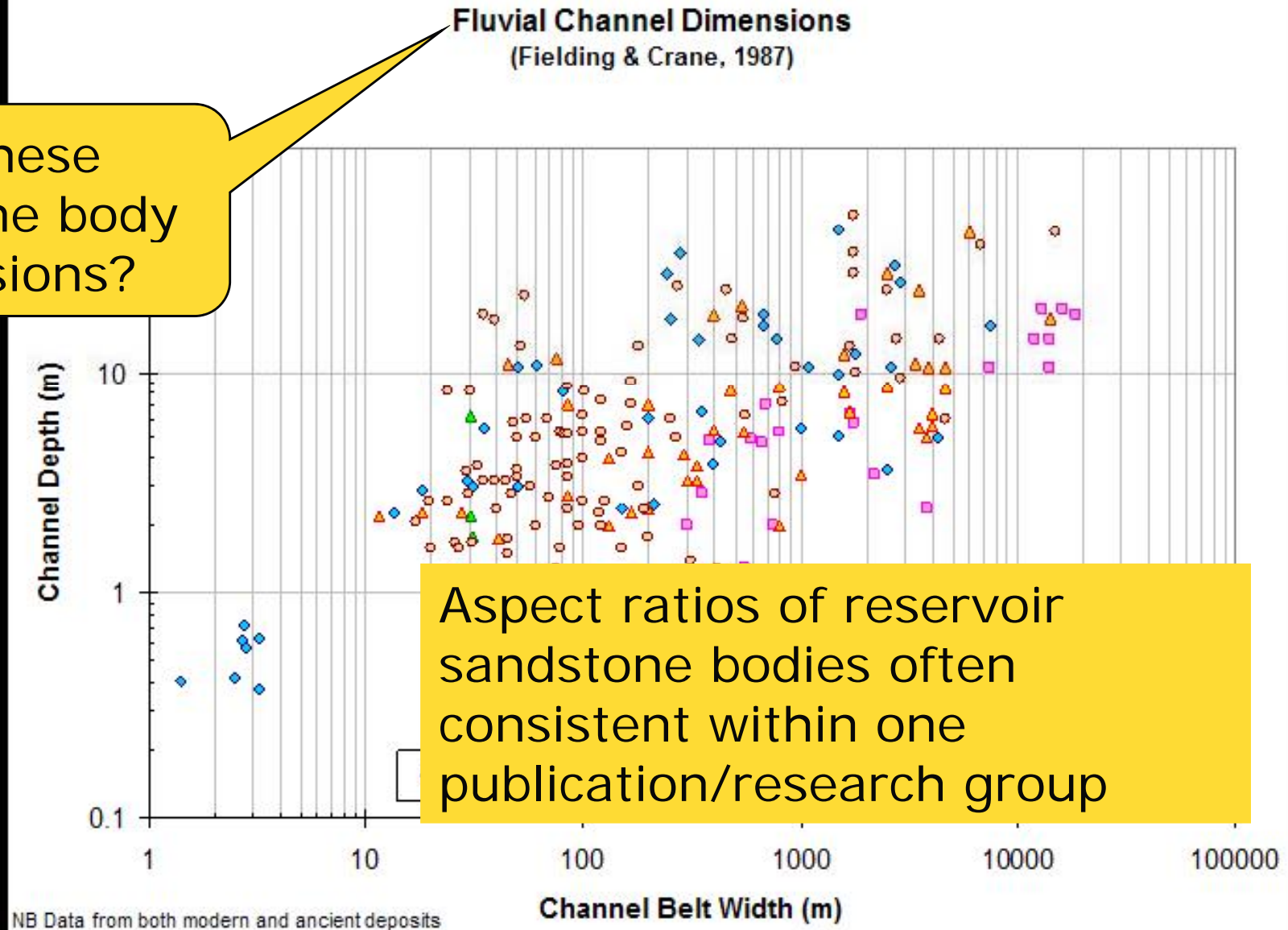classification?

Laterally continuous sandstone bodies

Laterally discontinuous sandstone bodies

Photo montage courtesy of Bryan Bracken

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Reservoir aspect ratio database

Data compiled by Jon Allen 18

Compilation of aspect ratios from various published sources

Sandbody Dimensions by Channel Type
(compiled from literature)

Aspect ratios of reservoir sandstone bodies inconsistent across research groups/publications

- ◆ Braided
- ◻ Low Sinuosity
- △ Meandering
- ⬠ Anastamosed
- ◆ Unknown

Data compiled by Jon Allen [19]
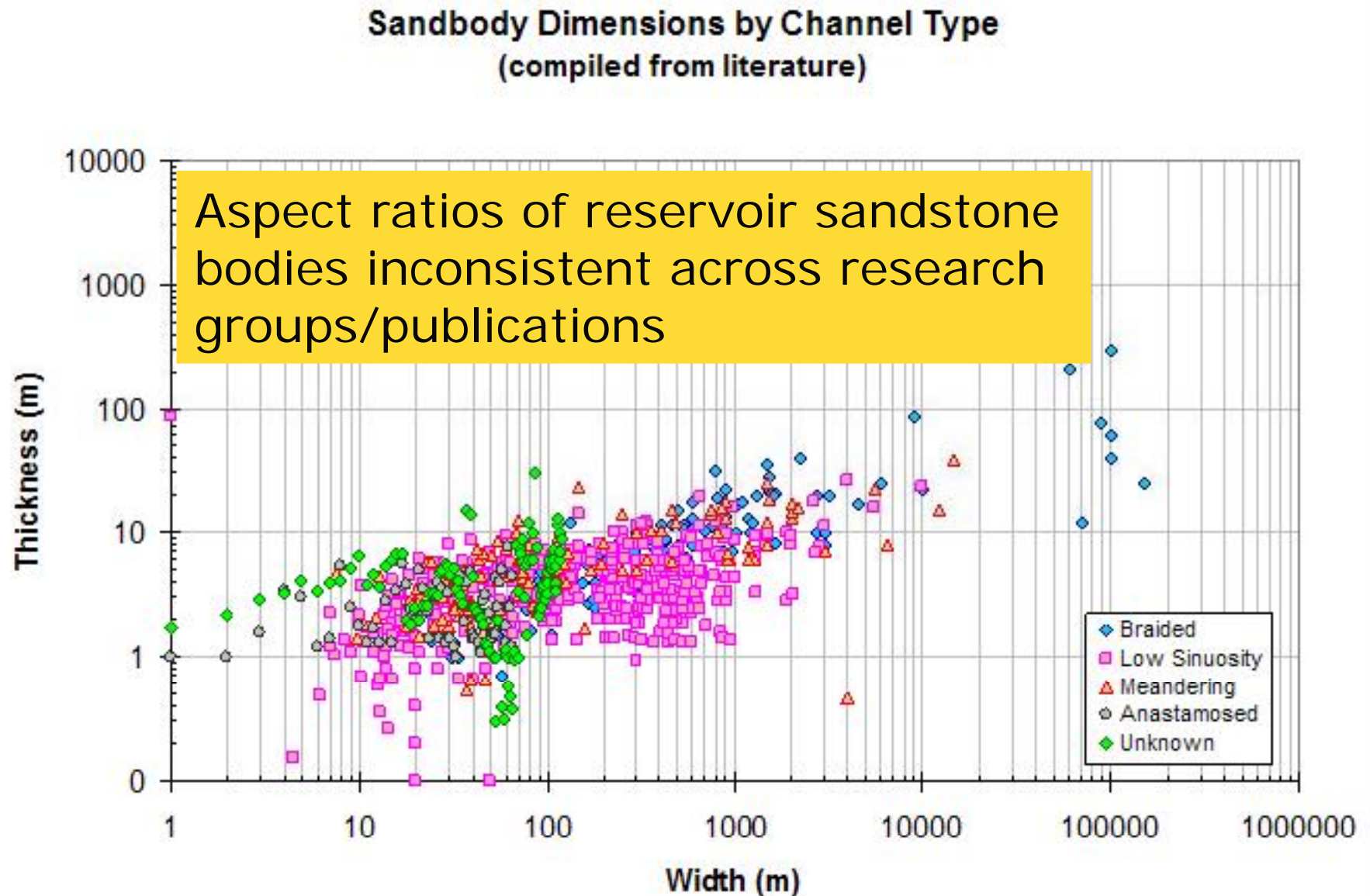
Aspect ratios for seal depositional environments

Little seal geometric data exists.
Does suggest usability

Legend :

- ◆ Back-Barrier Lagoon
- ■ Interdistributary Bay
- ▲ Lacustrine
- ✕ Lower Deltaic Plain
- ✻ Fluvial Overbank
- ○ Abandoned Channel
- ● Prodelta
- ● Shelf
- ● Marsh/Swamp, Coastal Plain
- ■ Tidal Flats
- ✕ Upper Deltaic Plain

Width (m)

Length (m)
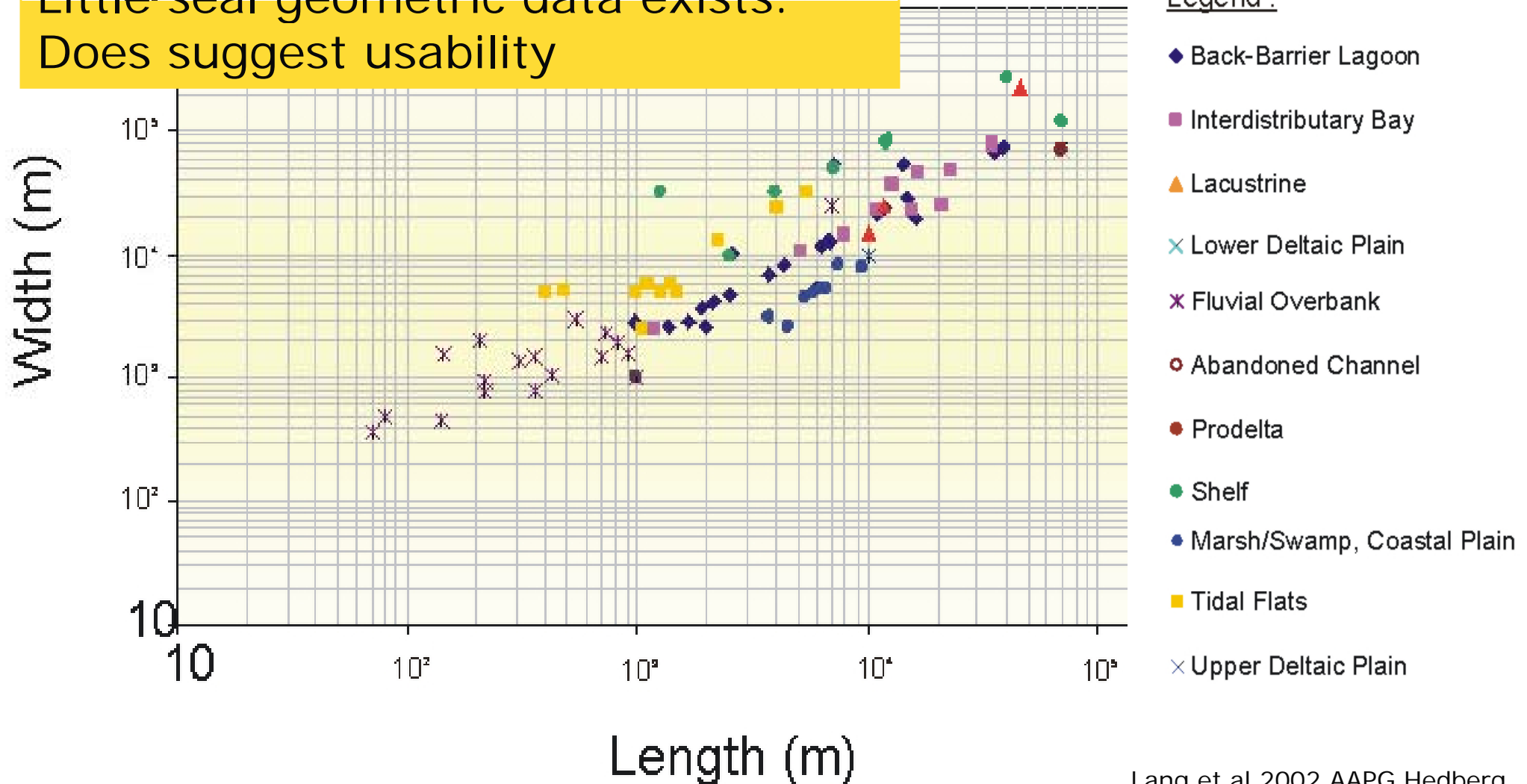
Lang et al 2002 AAPG Hedberg

Cross-sectional aspect ratios

- Inconsistent recording and interpretation of stratigraphic architecture between projects/researchers leads to incomparable results!

- Has led many to caution the use of aspect ratios!

- Clearly only a consistent acquisition or classification of reservoir (and seal) elements can lead to a complete comparative database

Plan form quantitative data

Morrison channel plan view – photo courtesy of Bryan Bracken

Seismic geomorphology – shallow Gulf of Thailand

High-sinuosity river: narrow channel, wide channel belt

Consistent interpretation and classification are key to a good database!

High-sinuosity river: narrow channel, narrow channel belt

From Hathaiporn Samorn (2006) 24

Plan form geometric relationships

Down stream variability in:

- Channel width

- Channel belt width

- Channel bar forms

- Splay belt width and frequency

Channel

Channel belt

10 km
10 mi

Image courtesy of googlemaps.com

Plan-view geometric data

- Little quantitative geometric plan form data available

- Seismic, satellite, aerial photographs readily available

- Most data is single-sourced and not well tied to facies models

- Challenge is relating plan form geometry to well/core/outcrop cross-sectional data

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Facies models

- Facies associations define geobodies – reservoir elements

- Geometric data of reservoir elements therefore need to be tied to facies models

- Next generation of facies models are currently being developed (incorporating processes more)

  - ▶ Creates necessity to redefine and interpret geometric data

  - ▶ Good facies models and good geometric data go hand-in-hand

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Conclusions & Recommendations

- Outcrop analogue data is imperative for the petroleum industry

- Ideally suited to academia: good research training, strong industry support and fun!

- Cross-sectional analogue data needs to be collected and interpreted consistently between research groups to allow comparison by data users

- Plan-form data is sparse and equally needed within the industry for model building purposes

- Quality geometric data requires up to date facies models and vice versa

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Thank You!

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