Connectivity Issues in Slope Mound-Contourite Systems*

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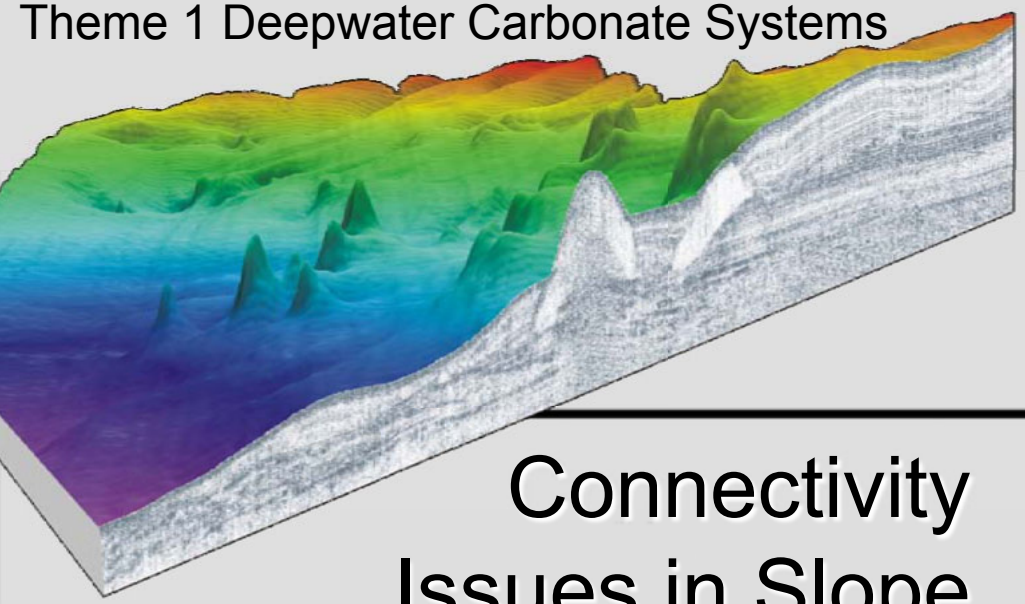
Abstract

Carbonate mound provinces are increasingly reported on continental margins, in water depths ranging between 500 and 1000m. Their potential should not be overlooked. In Porcupine Seabight, west of Ireland, four major provinces yield a total estimate of some 4000 mounds.

The analysis of both 3D seismic data sets and dense grids of very-high resolution 2D data, ground-truthed by coring and IODP drilling (Exp. 307), suggests that carbonate mounds should not systematically be regarded as isolated reservoirs once buried, but that their sole layer, when consisting of high-energy contouritic deposits, may play a significant role in the connectivity issue. In the midslope 'Belgica' and 'Viking' mound provinces, mounds indeed are frequently rooted on high-energy contouritic layers with clinoform deposits, which might provide the pathway for fluid migration.

In addition to these 'coupled mound-sole' reservoir systems of hybrid biogenic/terrigenic nature, one might pay attention to the spatially associated reservoirs of turbiditic nature. Canyon breaks control the accumulation of perched turbidite deposits, while downslope plunge pools collect turbiditic sediments from the inter-mound drainage systems.

AAPG International Conference Cape Town 2008
Theme 1 Deepwater Carbonate Systems and Reservoirs



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Connectivity Issues in Slope Mound-Contourite Systems

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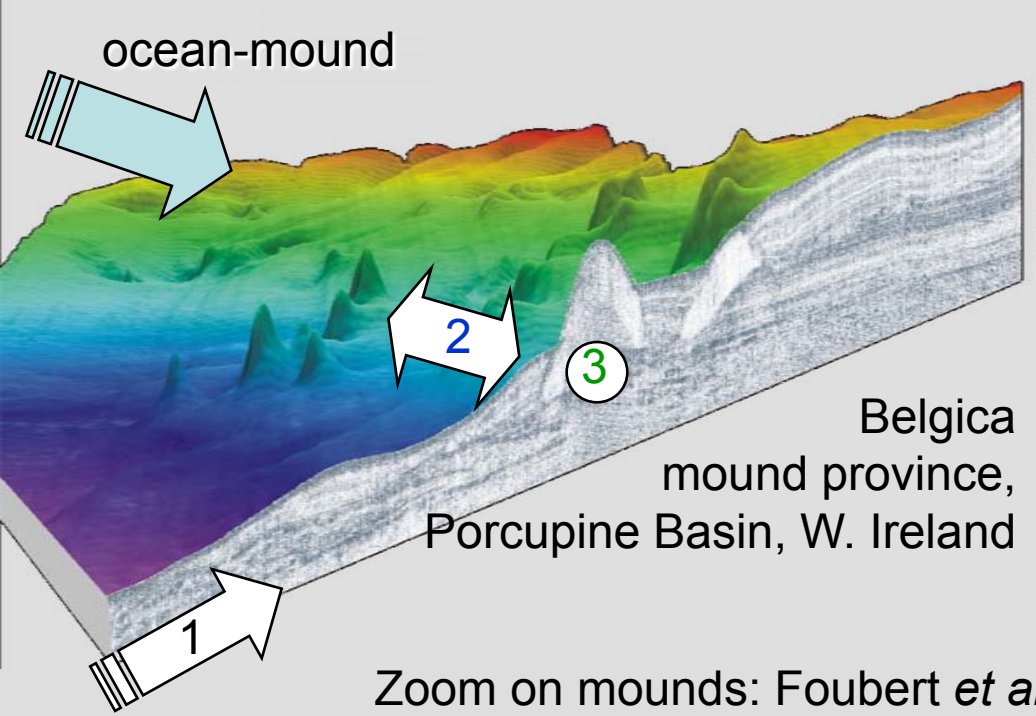
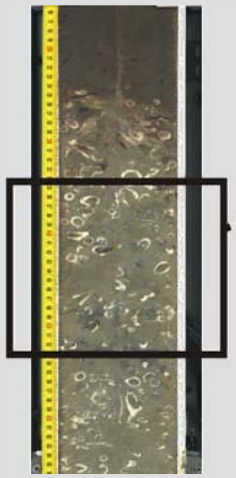
Renard Centre of Marine Geology, Ghent University, Belgium



Belgica
mound province,
Porcupine Basin, W. Ireland



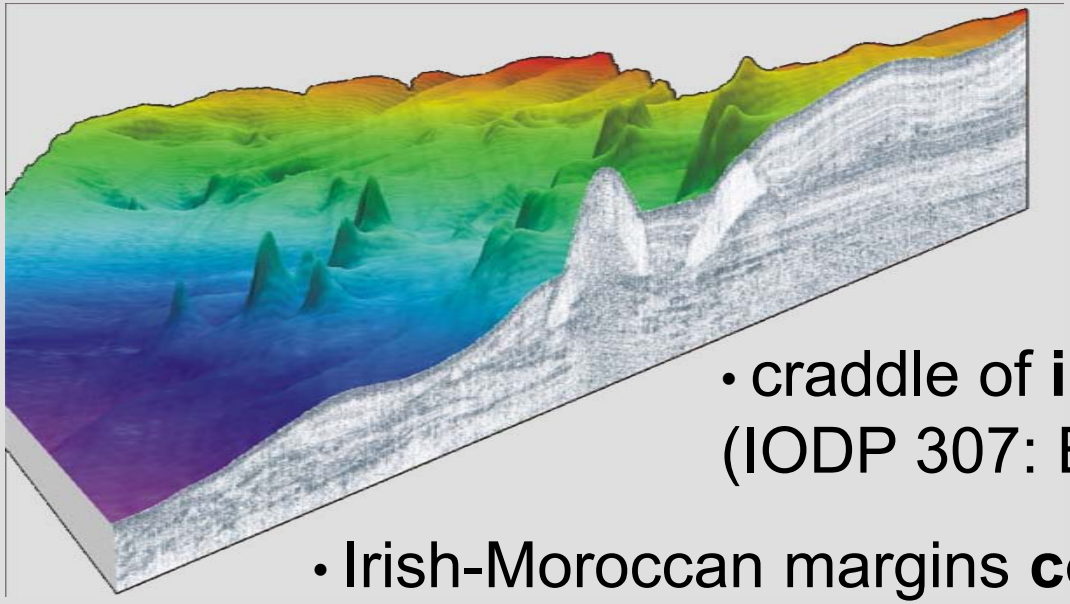
3

3

Zoom on mounds: Foubert *et al.*
Zoom on contourites: Van Rooij *et al.*
Zoom on microbial diagenesis: McKenzie *et al.*

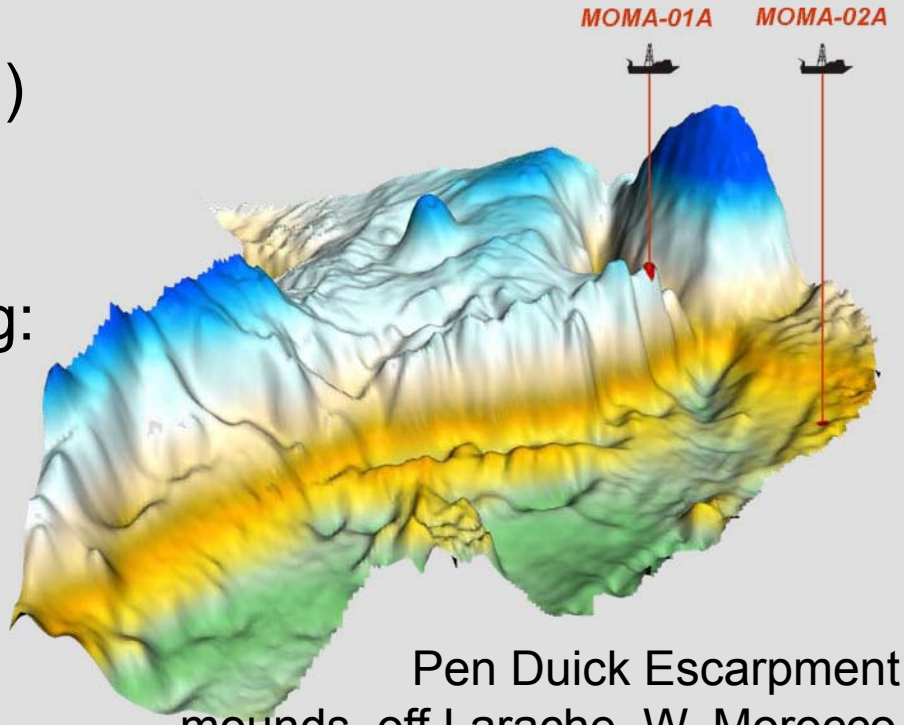
Connectivity Issues: 3 levels of "connection" within the "Subseafloor Ocean" (*sensu* Science Plan IODP)"

1. Basin scale: basin – mound province connection
2. Mound province scale: mound-mound connectivity
3. Mound scale: inter-compartment connectivity

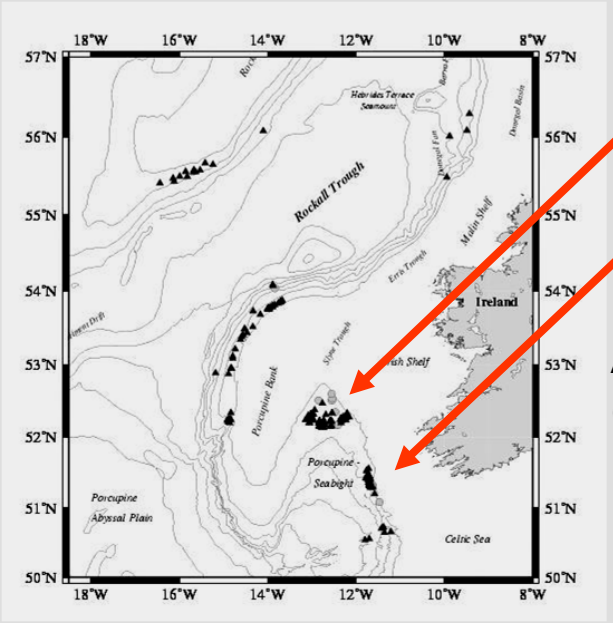


Strategy issues:

- Irish margin as **mound reference site**
- craddle of **international cooperation** (IODP 307: EU, US, Japan, China)
- Irish-Moroccan margins **comparative study**
- Morocco margin (IODP 673-Full) as **bridgehead** and **stepping stone** for pan-African and trans-Atlantic studies (Capacity building: IOC-UNESCO)
- Morocco margin study as **spearhead for Academia-Industry cooperation** (JIP COCARDE)



Pen Duick Escarpment mounds, off Larache, W. Morocco

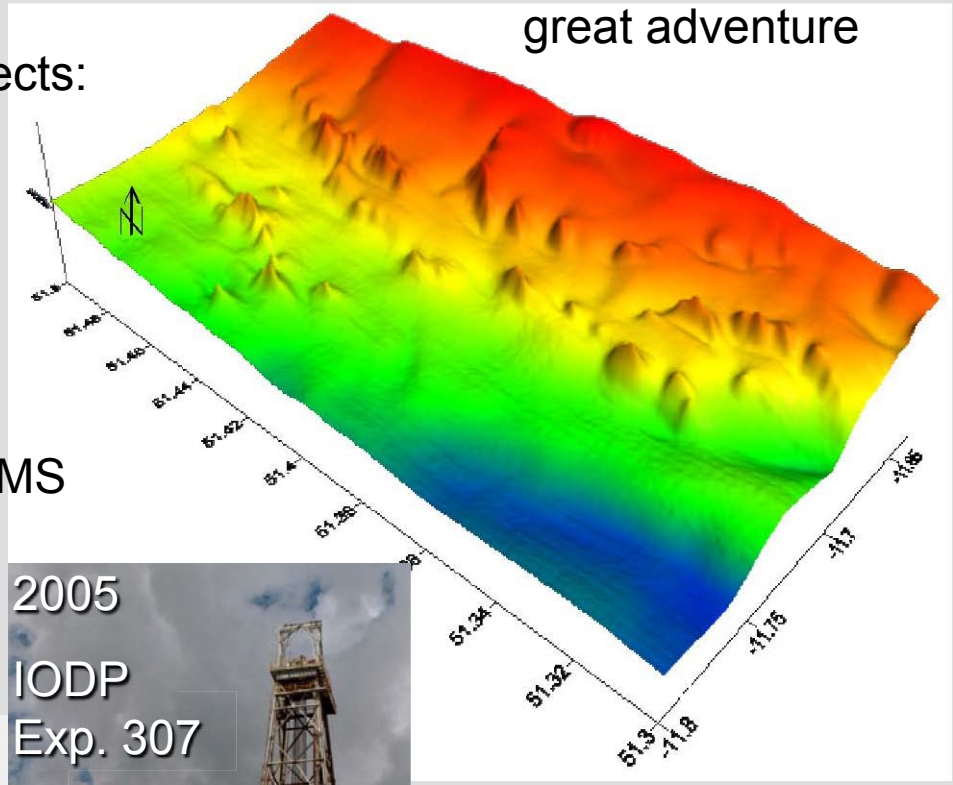


mound data base P. Croker, PAD

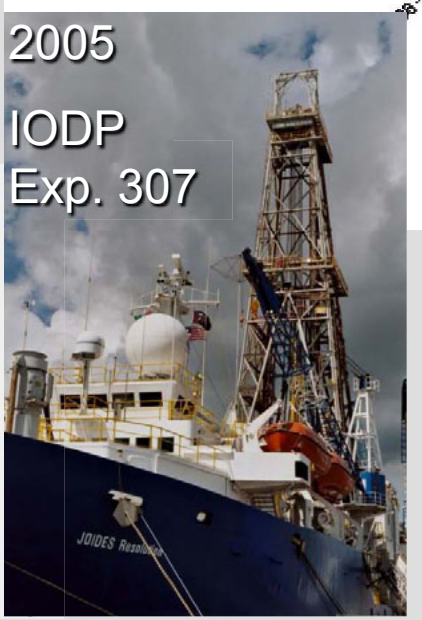
1994: M. Hovland *et al.* report large carbonate 'knolls' in Porcupine Basin – the 'Hovland mounds'

1997: discovery of the 'Belgica mounds', start of a great adventure

European Projects:
ACES
GEOMOUND
ECOMOUND
MoundForce
EURODOM
OMARC
MiCROSYSTEMS
HERMES
HERMIONE



Mound Challenger



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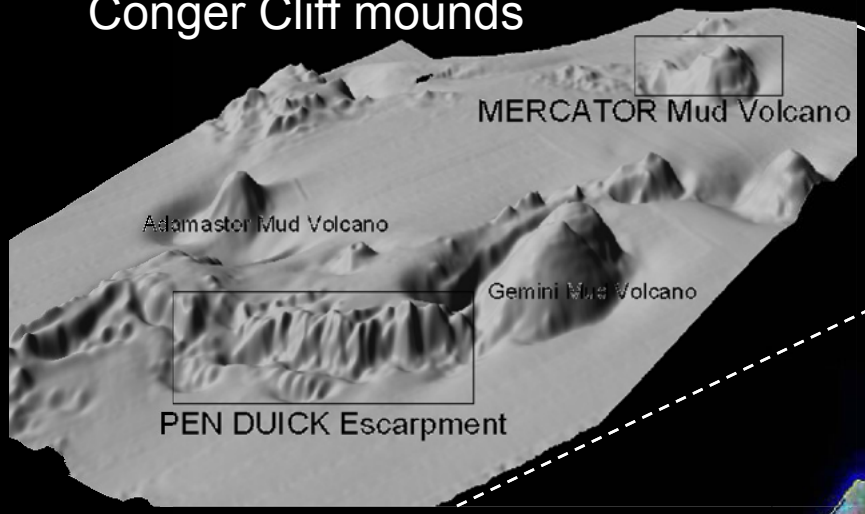
Conger Cliff mounds



Pen Duick mounds

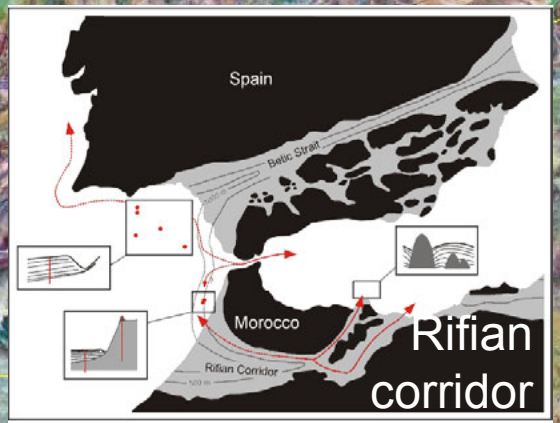
2002

2007

Mellila mounds

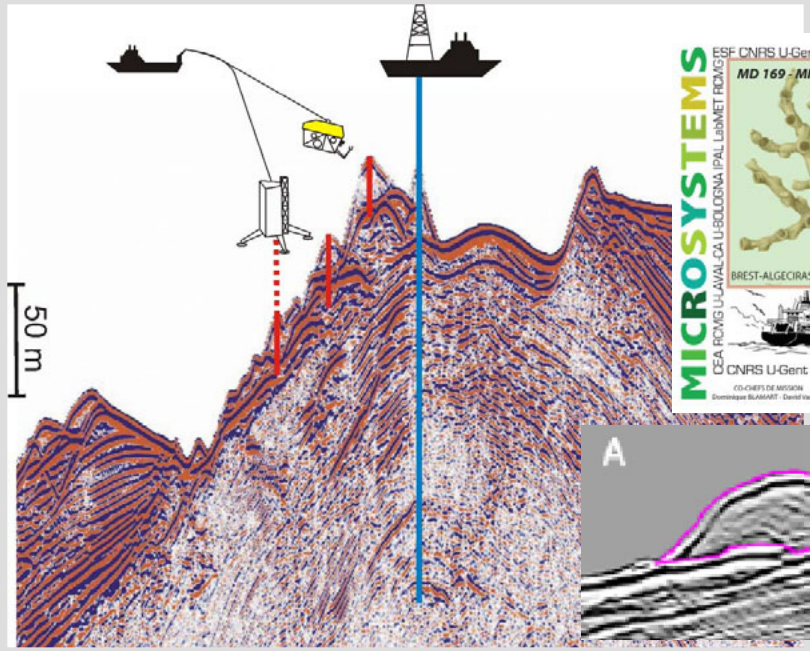
Liassic sponge mounds

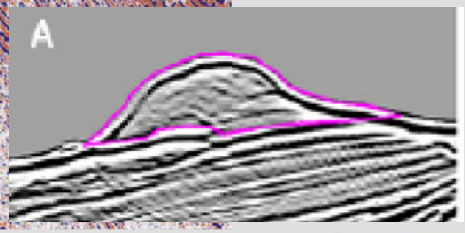
The Morocco "Mound Factory": a dream world for Recent-Past comparisons

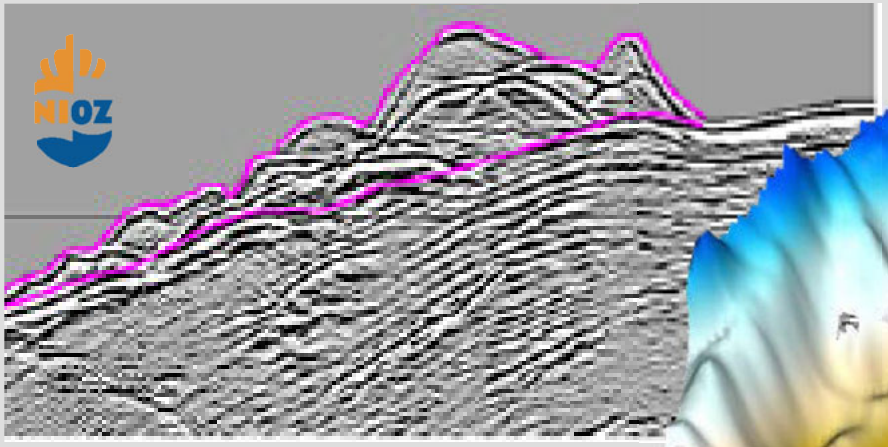


IODP Proposal 673-Full

Atlantic Mound Drilling II: Morocco Margin

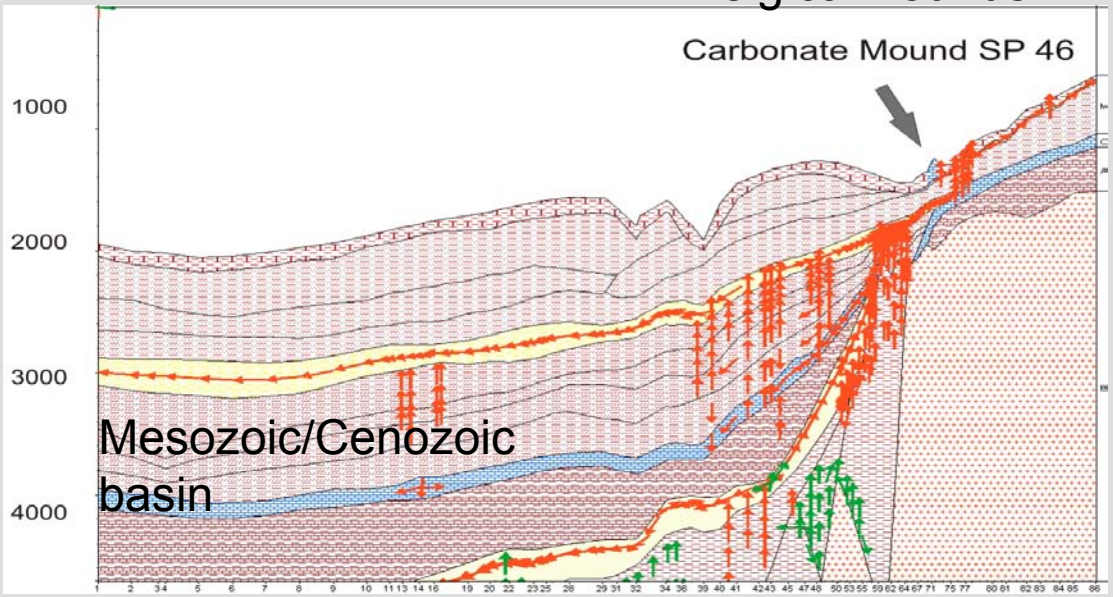






Horizon 2011 ?

Belgica mounds



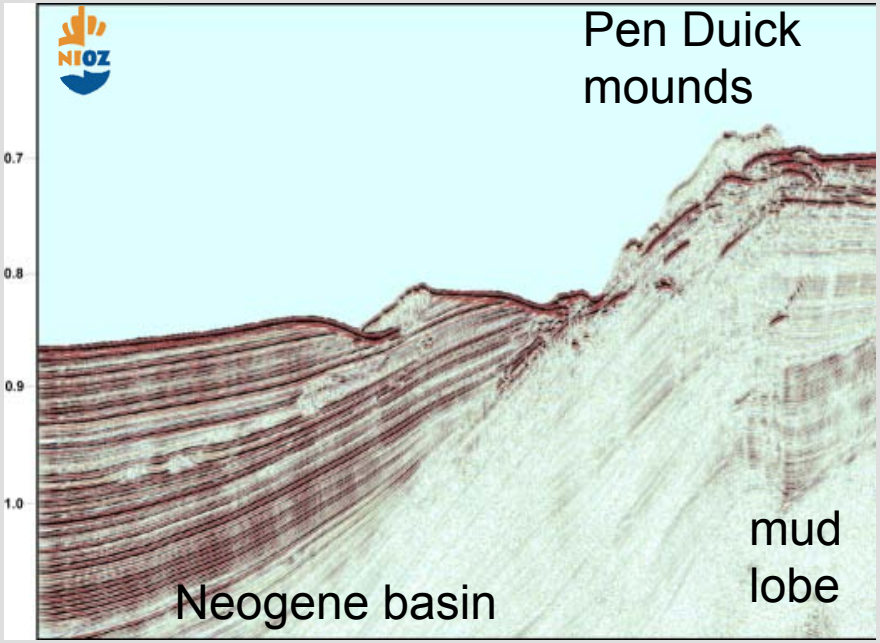
Basin modelling (Naeth, GFZ Potsdam)

red arrows: gas

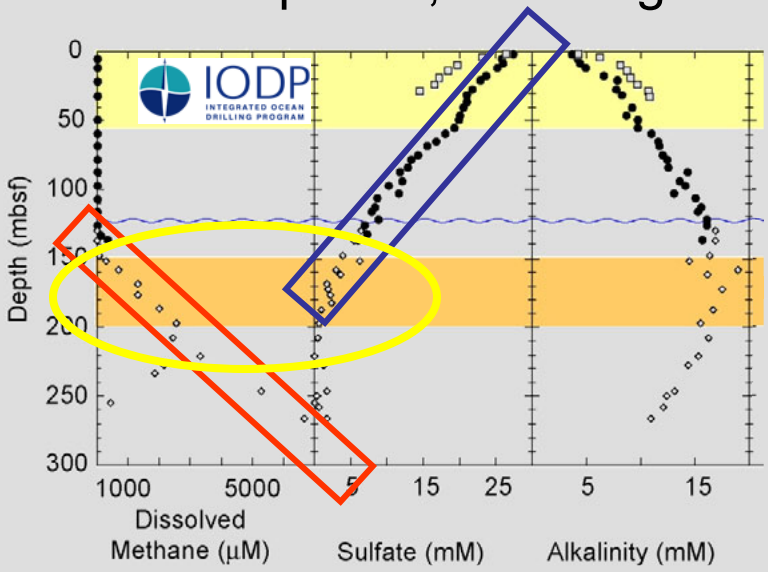
green arrows: oil

Both Belgica and Pen Duick mounds root on Miocene outcrops (IODP 307, LAR-1)

Basin scale: slope mound provinces off Ireland and Morocco are **located on plausible stratigraphic fluid migration pathways**



IODP Exp. 307, Challenger Mound



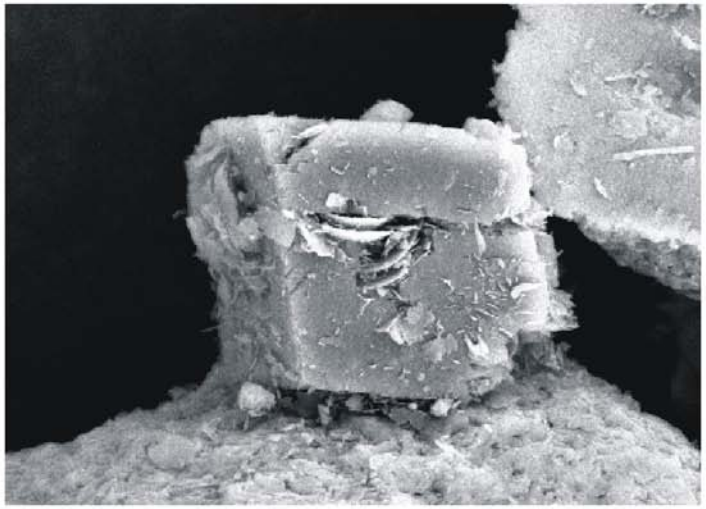
Mound base

AOM microbial activity

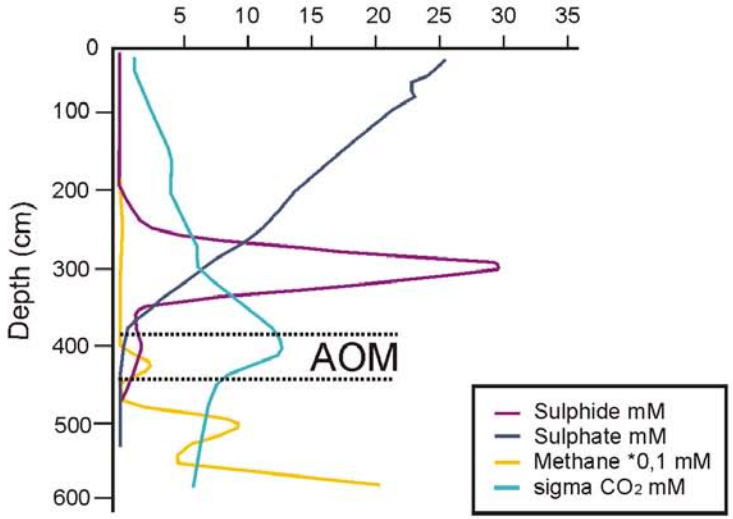
Both sites feature a methane front and anoxic oxidation zone of methane (AOM): below the mound base (Challenger) or at 4 m bsf (Pen Duick). Methane has a mixed thermogenic/biogenic signature

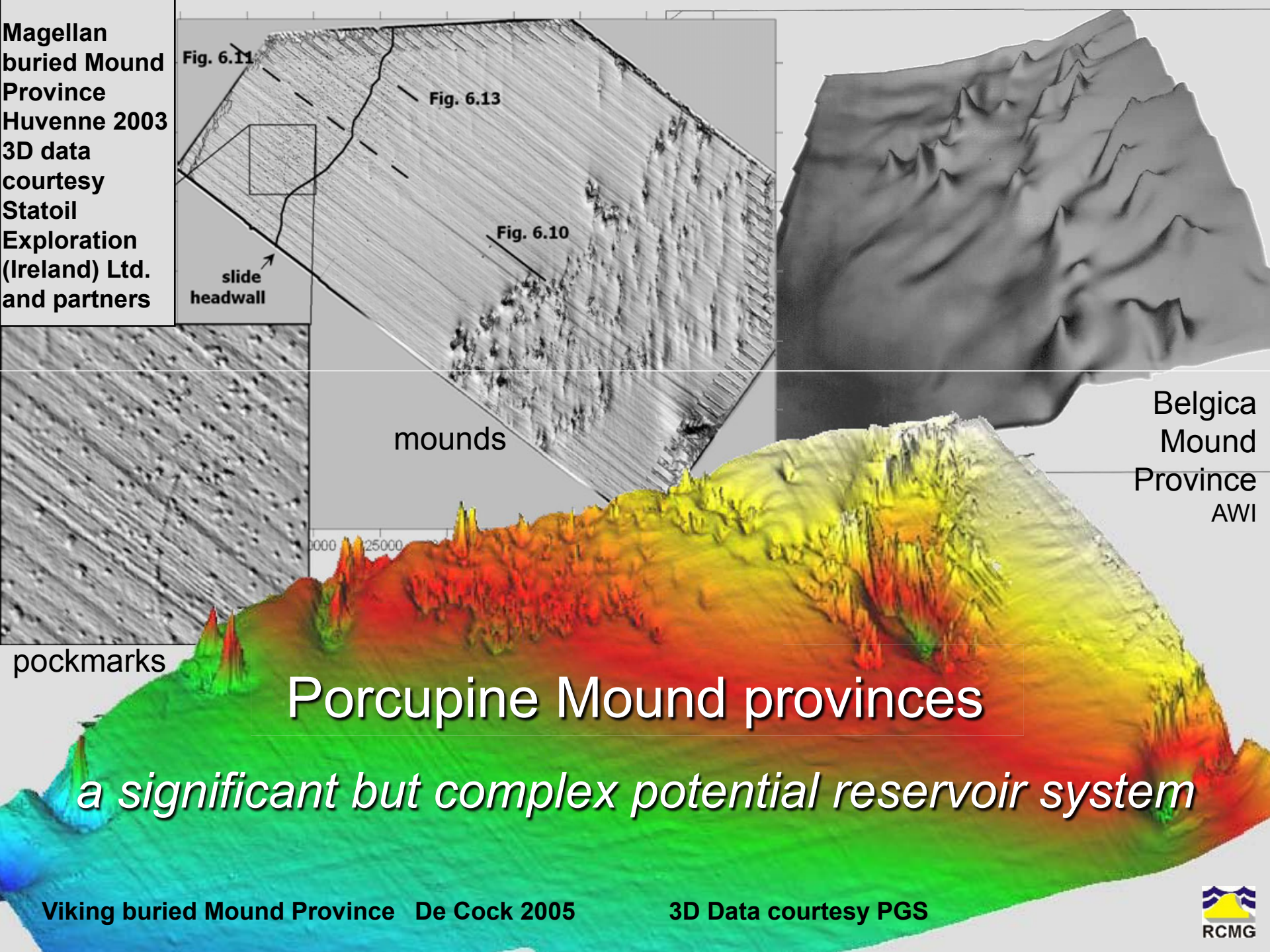
Pen Duick Escarpment, Alpha mound

Authigenic dolomite



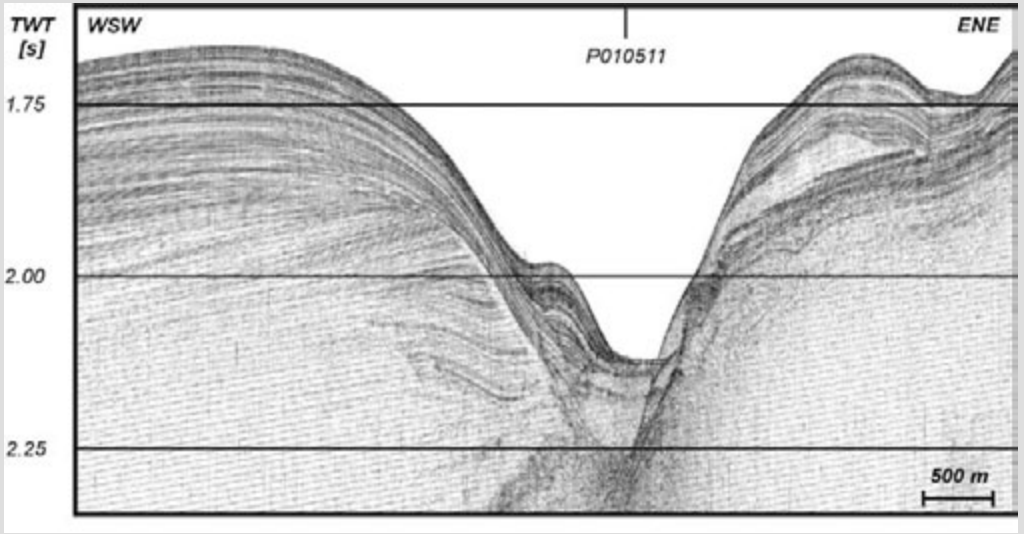
Photograph S. Templer, ETH Zürich




Magellan buried Mound Province Huvenne 2003 3D data courtesy Statoil Exploration (Ireland) Ltd. and partners
Fig. 6.11
Fig. 6.13
Fig. 6.10
slide headwall
mounds
Belgica Mound Province
AWI
pockmarks
Porcupine Mound provinces
a significant but complex potential reservoir system
Viking buried Mound Province De Cock 2005
3D Data courtesy PGS
RCMG

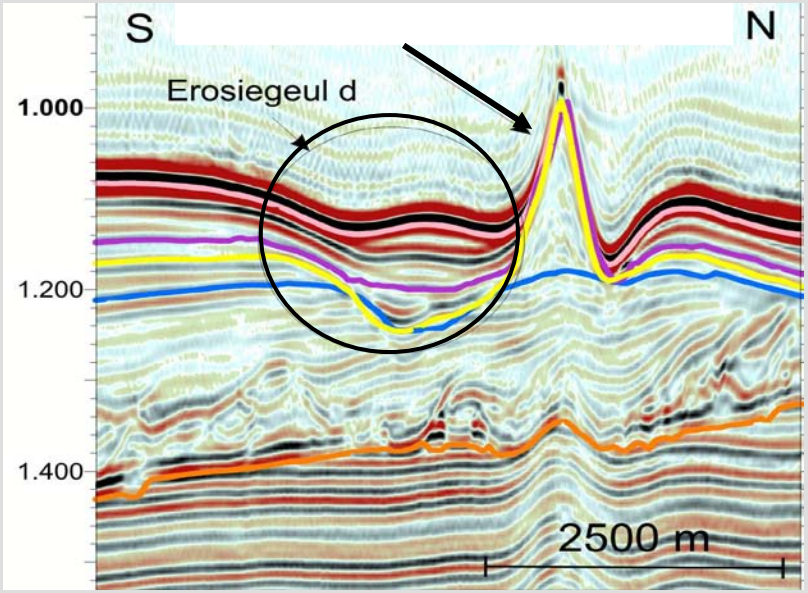
Mounds are not alone !

- perched turbidites
- turbiditic plunge pools



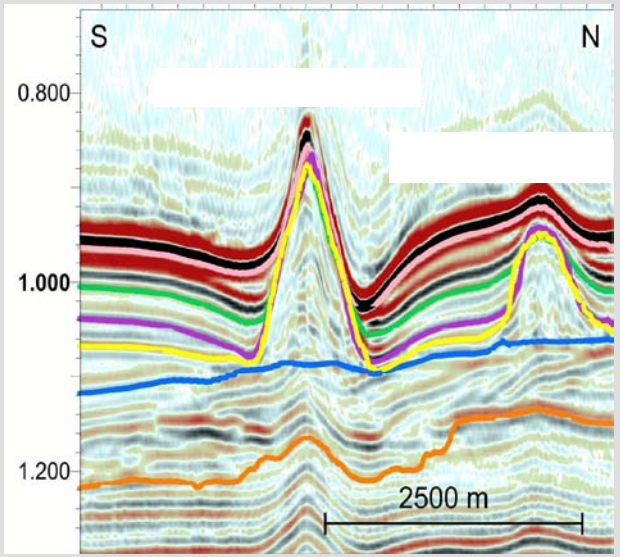
Hybrid HC reservoir systems: carbonate -turbiditic

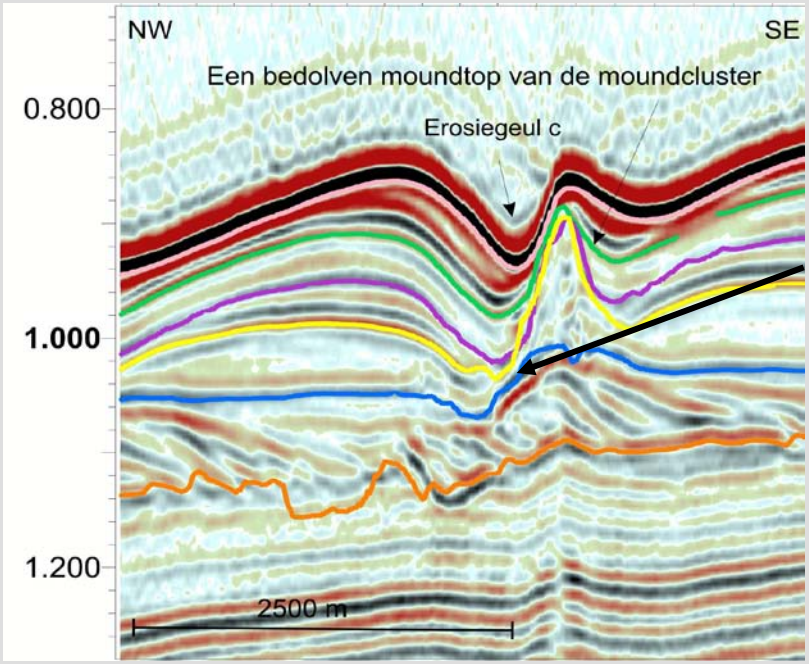
Mounds are not isolated: coupled mound-sole reservoir system !



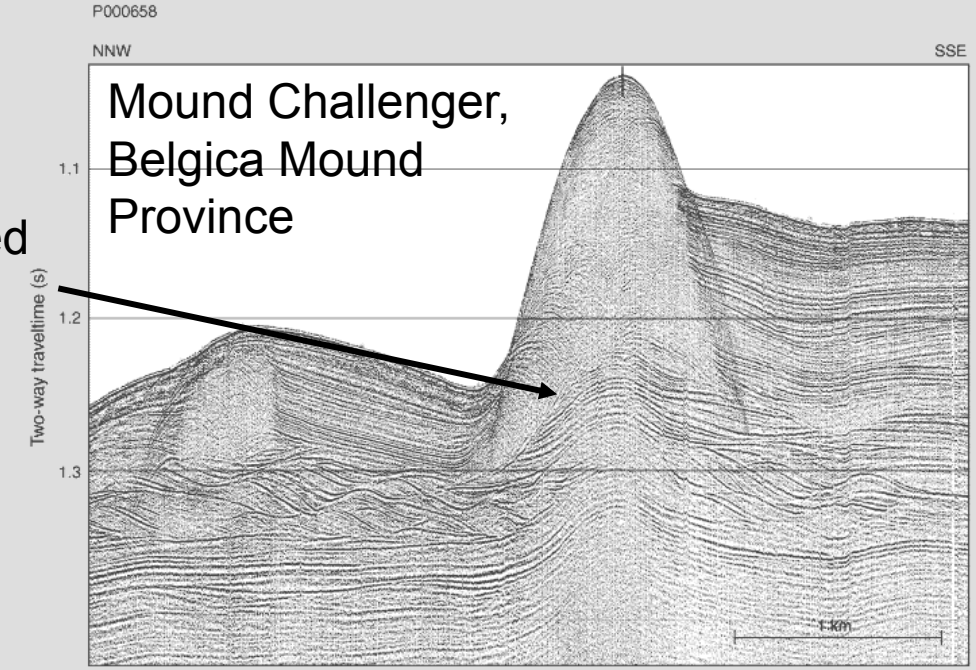
Viking mounds

mound sole: sigmoidal high-energy contourites, siltstones (IODP 307)





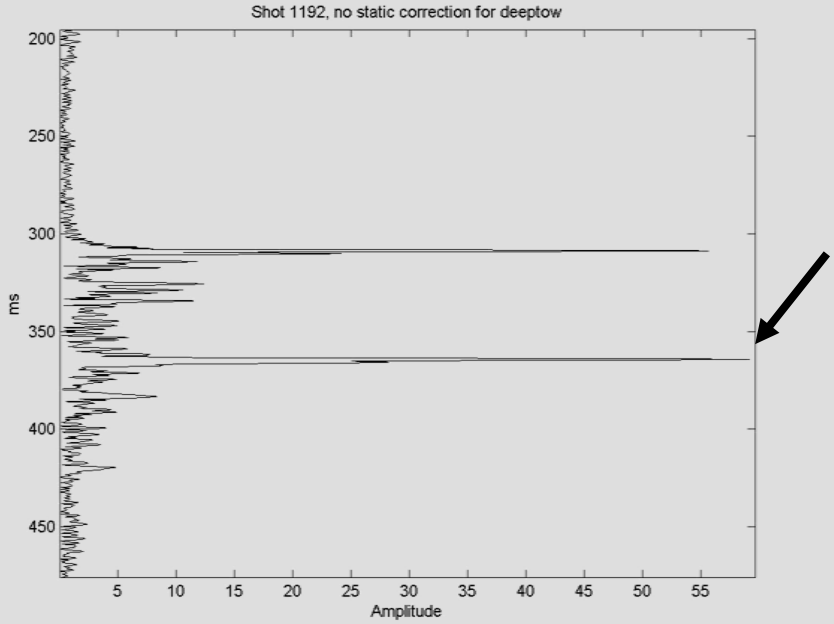
buried cliff

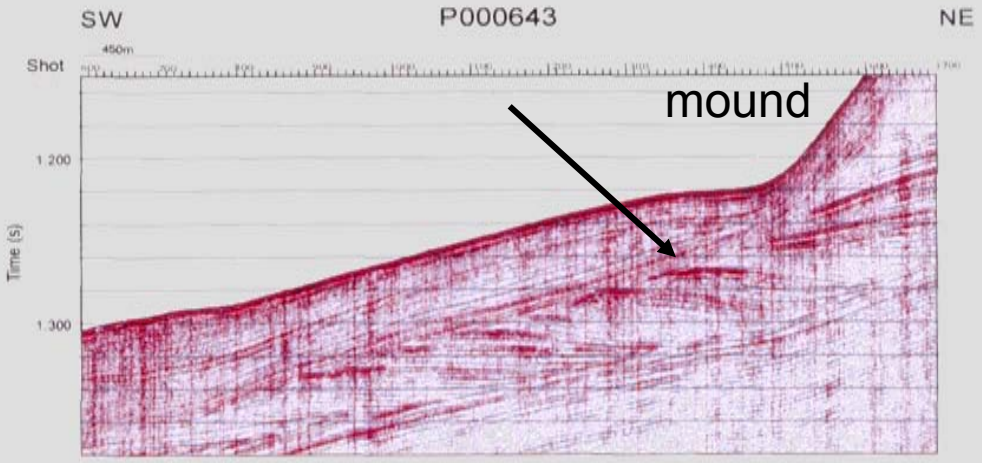


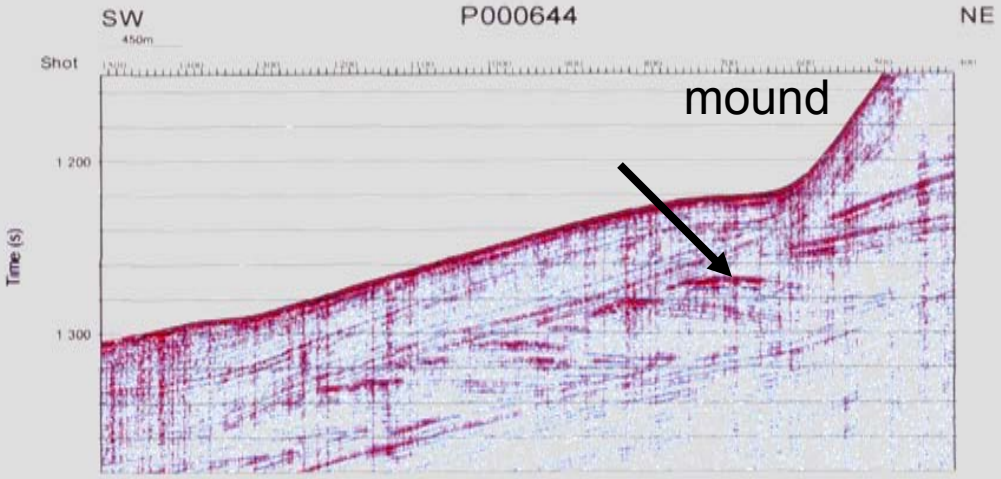
Geophysical clues of gas migration through the mound sole (⇨ connectivity !): bright spots

Irish margin

deeptow
chirp source

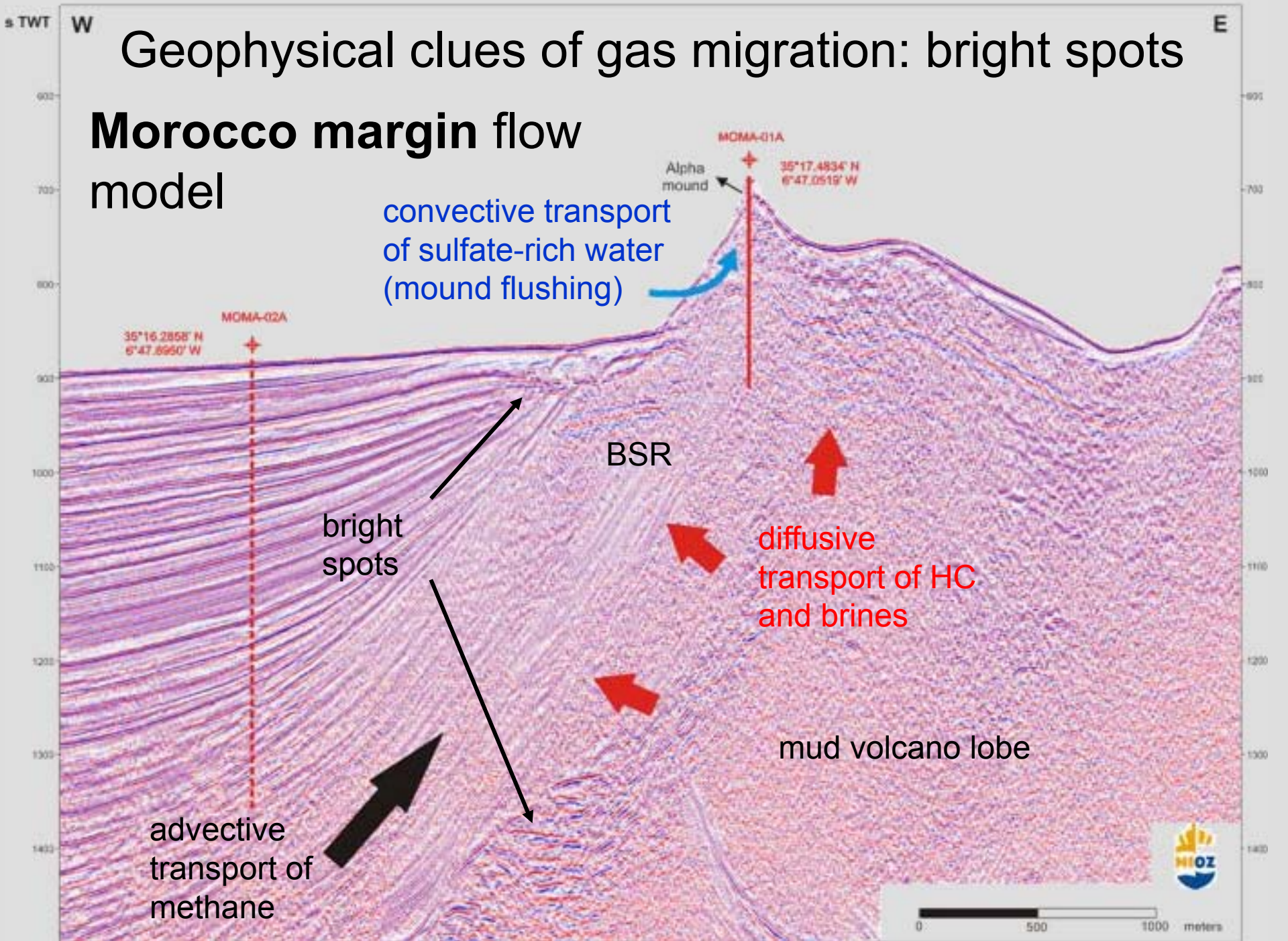


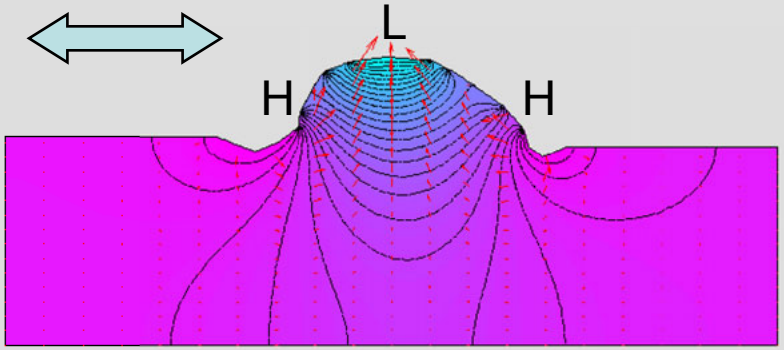


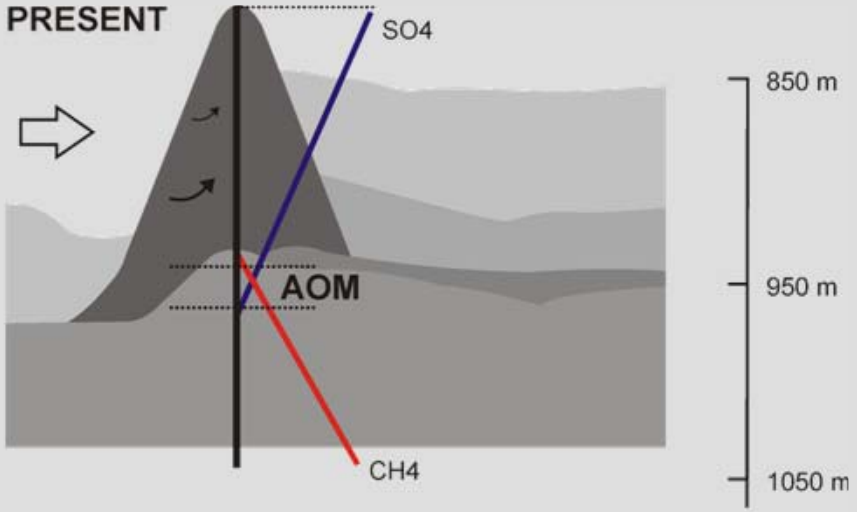


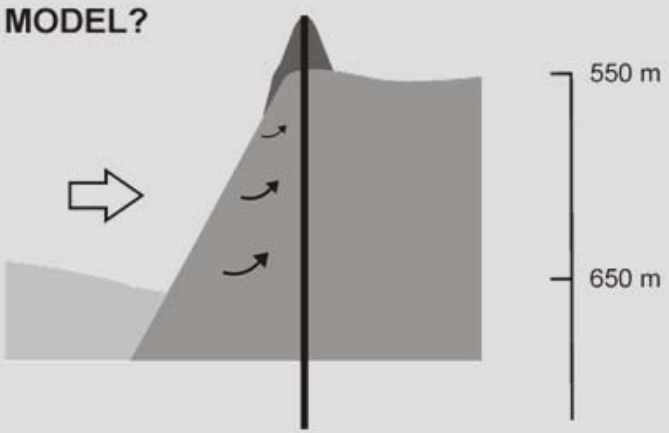
Geophysical clues of gas migration: bright spots

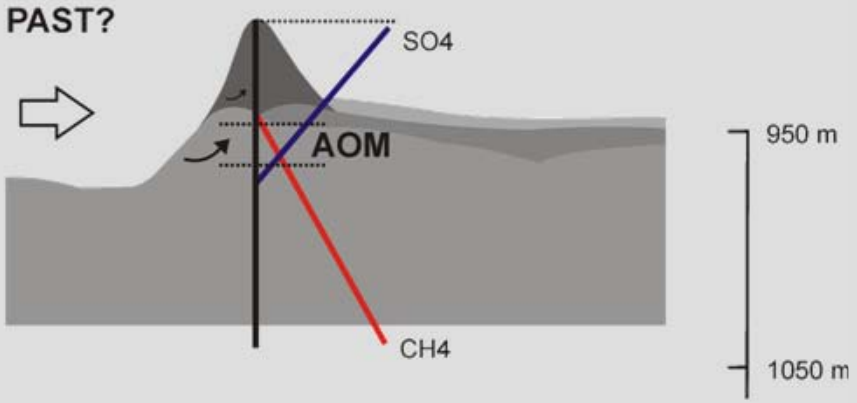
Morocco margin flow model



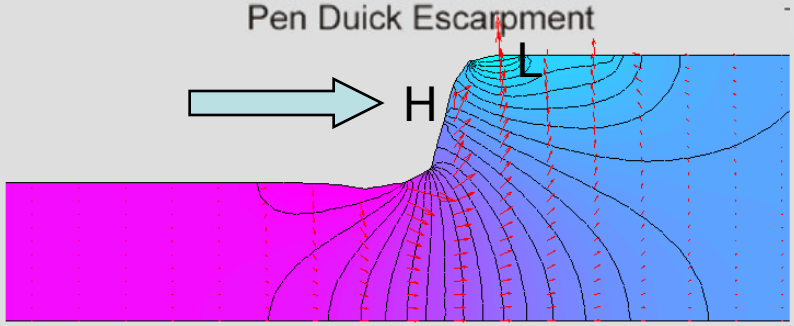






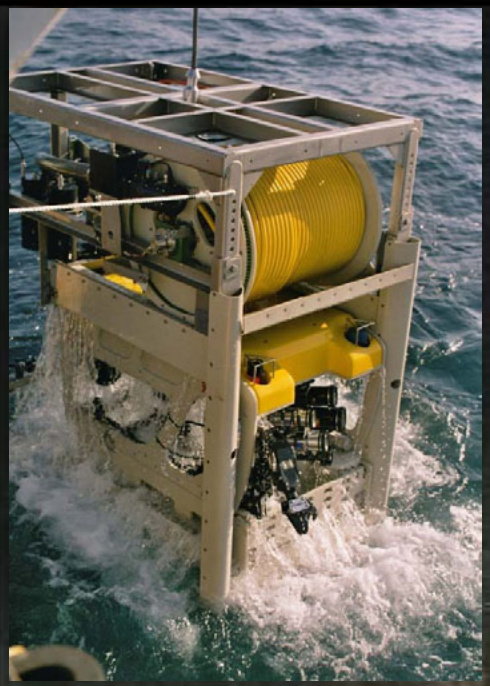


Pen Duick Escarpment



Challenger Mound

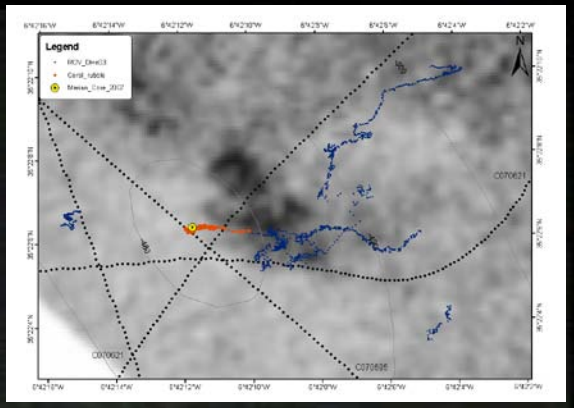
Convective transport of sulfate-rich water through cliff and mound (flushing) (model PhD Depreiter) may explain the deep AOM in Challenger Mound: a fossil position, locked at the level of the past seafloor ?



R/V Belgica ROV
Genesis 2007

Pen Duick mounds 2007: ROV dives reveal thick, open coral rubble plates, grand graveyards

…les grands cimetières sous la mer



Off-plate:
mud

Cryptic microcosms: sponges, slimy microbial worlds.

Privileged sites for bio-erosion, organo-mineralisation and sediment trapping ?

PhD Lies De Mol

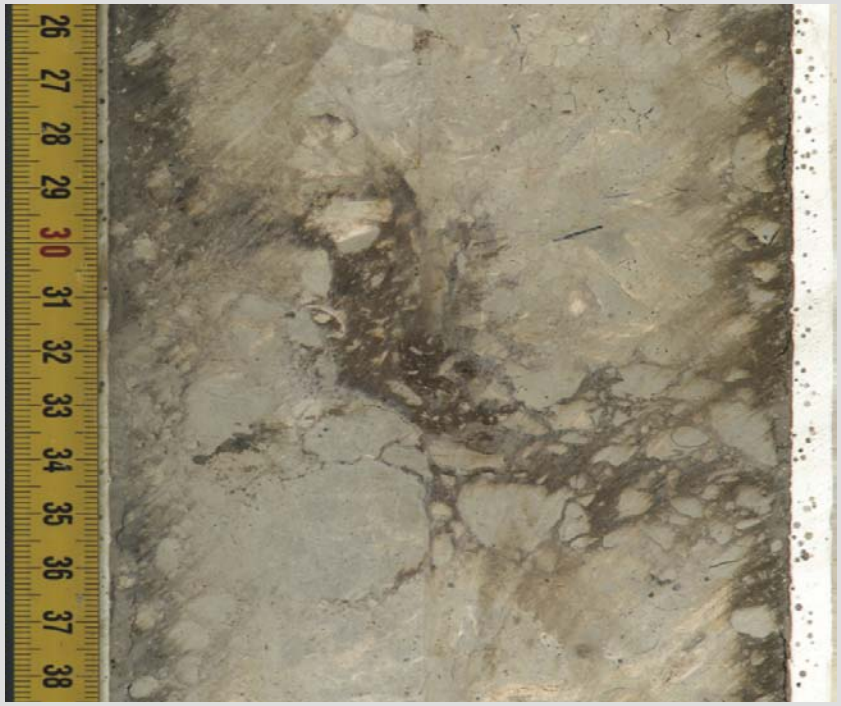
MiCROSYSTEMS
Associate partner
F. Neuweiler
Laval, Québec

Are these rubble plates the templates for mound compartmentization ?
Are they at the origin of the “strength” of giant mounds (frame elements)?

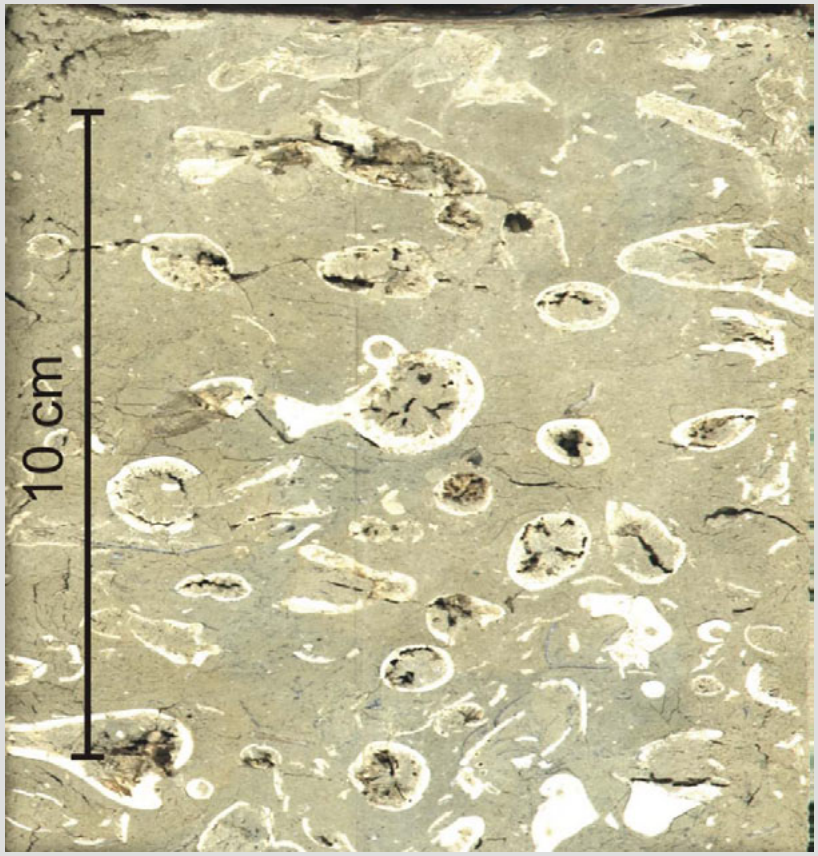
Early (open system) diagenesis: shallow horizons with a high degree of dissolution of corals in mounds

Mount Perseverance, Porcupine Basin

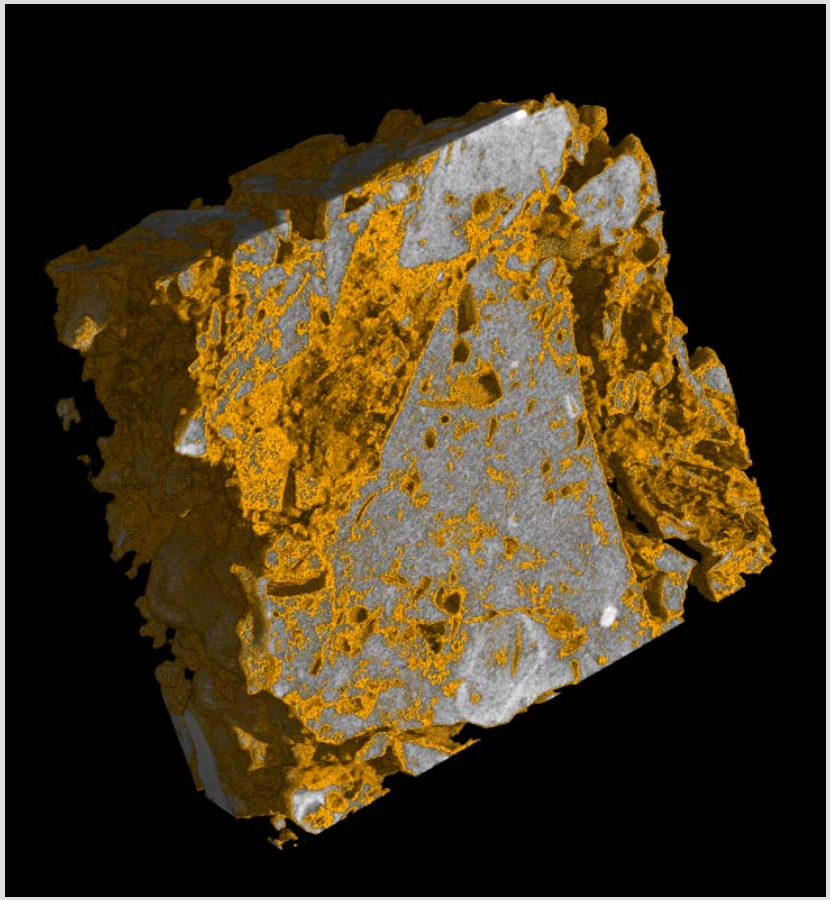
Below a carbonate hardground, 4 m below the seafloor…



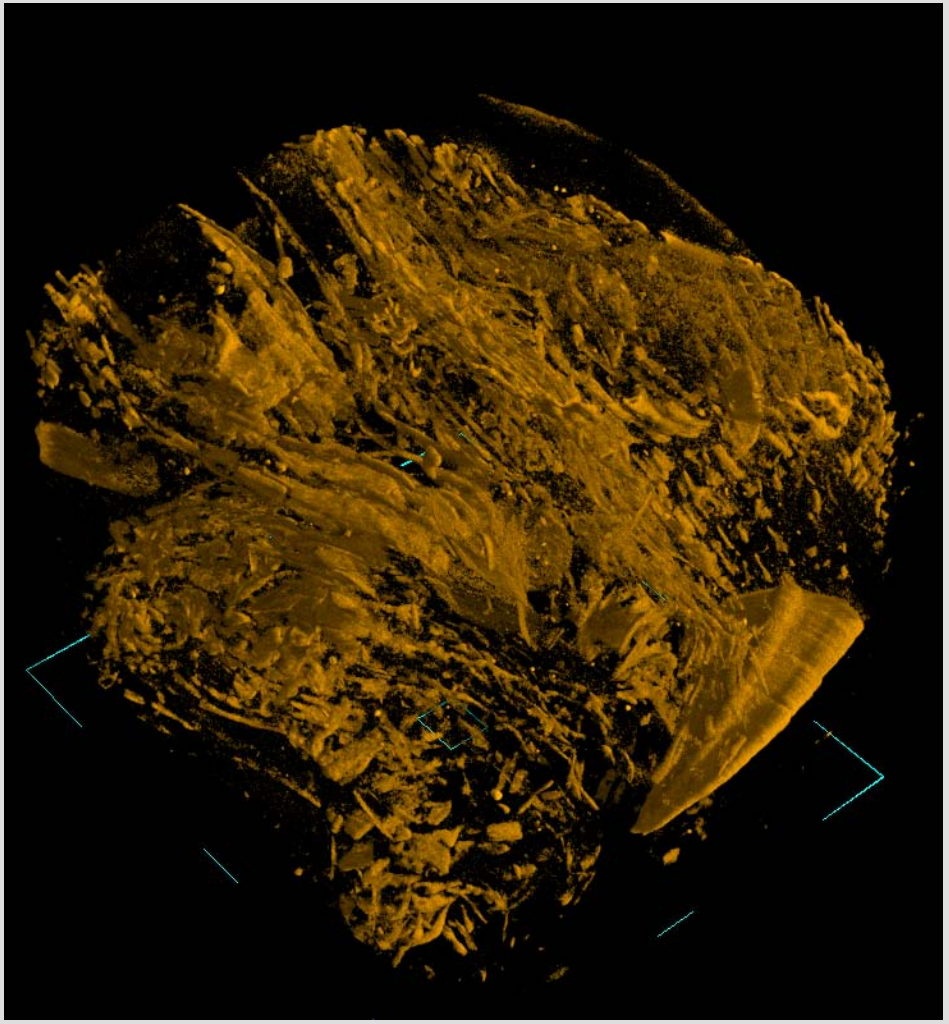
… development of mouldic porosity



Medical scans
Hans Pirlet,
RCMG 2008



… to vuggy porosity, with large dissolution cavities



… and close to total dissolution of the corals (colour: coral remains)

μCT scans Hans Pirlet, RCMG 2008

1. slope mound provinces off Ireland and Morocco are **located on stratigraphic HC migration pathways**; HC feature mixed thermogenic and biogenic signatures

2.1 the Irish slope mounds argue for a **coupled mound-sole reservoir system**; the basal, permeable high-energy contourites are potential (i) **feeder channels** and (ii) **mound connectors**

2.2 perched **turbidites** and turbiditic plunge-pools are co-occurring

3.1 **thick coral rubble plates** are potential (i) **sediment traps**, (ii) **prime** bio-erosion and organo-mineralisation **reactor sites**, (iii) **mound framework elements**, and (iv) **templates of reservoir compartments**

3.2 while exposed at the seabed, mounds are (i) **active hydrogeological systems** and (ii) **sites of early, open diagenesis**

3.3 **early moldic porosity** develops in the **immediate subsurface**, concurrent with carbonate precipitation; subsurface chemical exchanges may be activated by tidal forcing (pumping)

3.4 deeper chemical exchanges may be activated by the **competition** between (i) internally driven, episodic advection of HC and (ii) externally forced (currents), long-term convective fluxes of sulfate-rich waters