STRUCTURAL MODELLING OF THE BRISTOL CHANNEL

Nicholas Reiss, Marios N. Miliorizos and Nikolaos S. Melis

TANGRAM ENERGY

European Geosciences Union

University of South Wales Prifysgol De Cymru

1 INTRODUCTION

Advances in seismic imaging technology can discourage the integration of outcrop data into modern interpretation workflows. Yet, instigation of hydrocarbon exploration still requires the use of legacy seismic data, especially within mature petroleum provinces of the UK. Typical exploration workflows include expensive pre-stack seismic reprocessing, to better resolve prospects. This is a resourceful but timely process that can be enhanced by integrating structural geological analogues.

The inner Bristol Channel has extensive outcrop: to the east the Severn Estuary, to the north the South Wales Coalfield and Vale of Glamorgan and to the south along the Somerset, Devon and Cornish coastlines. These areas of prolific geological data, when combined with legacy exploration refraction, reflection and recent earthquake seismology, make the inner Bristol Channel an ideal natural laboratory to integrate analogues with seismic data in order to produce accurate interpretations and explanations of complex heterogeneous structures. Most especially in places concealed by Mesozoic and Quaternary cover, marine waters and estuarine sediments typical of many parts of the inlet.
Successful structural analysis is always reliant on well-processed pre-stack seismic data. It is demonstrated however that numerous known structural inversion events also necessitate the best choice of analogues to resolve the geometry and kinematics of any major faults offshore accurately enough to reach a reliable understanding of the petroleum system.

Here, in response to the Department of Energy and Climate Change (DECC) 2016 data release and the 31st licensing round, we use case studies from the inner Bristol Channel to demonstrate the value of structural geological analogues by integrating them into 1985 2D legacy seismic data at an early stage in the seismic interpretation process. With suitably chosen analogues, structural dissection and reconstruction are carried out to generate geometric and kinematic models. The wider waters of the Bristol Channel are situated in quad 105; in which exploration was instigated in the 1970's by exploration companies. Currently, interest in reliable structural analogues is made relevant by further exploration.

2 REGIONAL GEOLOGY

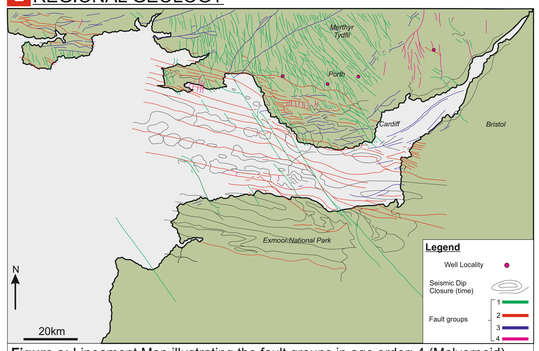


Figure a: Lineament Map illustrating the fault groups in age order: 4 (Malvernoid), 3 (Caledonoid-Variscan Hybrid), 2 (Variscan), 1 (Composite, Alpine, Recent)

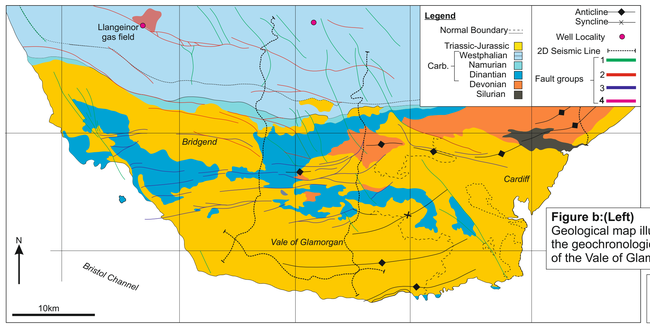


Figure b:(Left) Geological map illustrating the geochronological packages of the Vale of Glamorgan

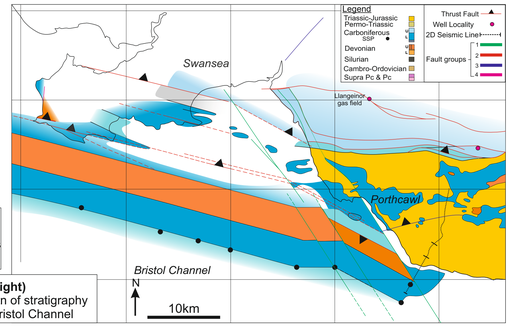
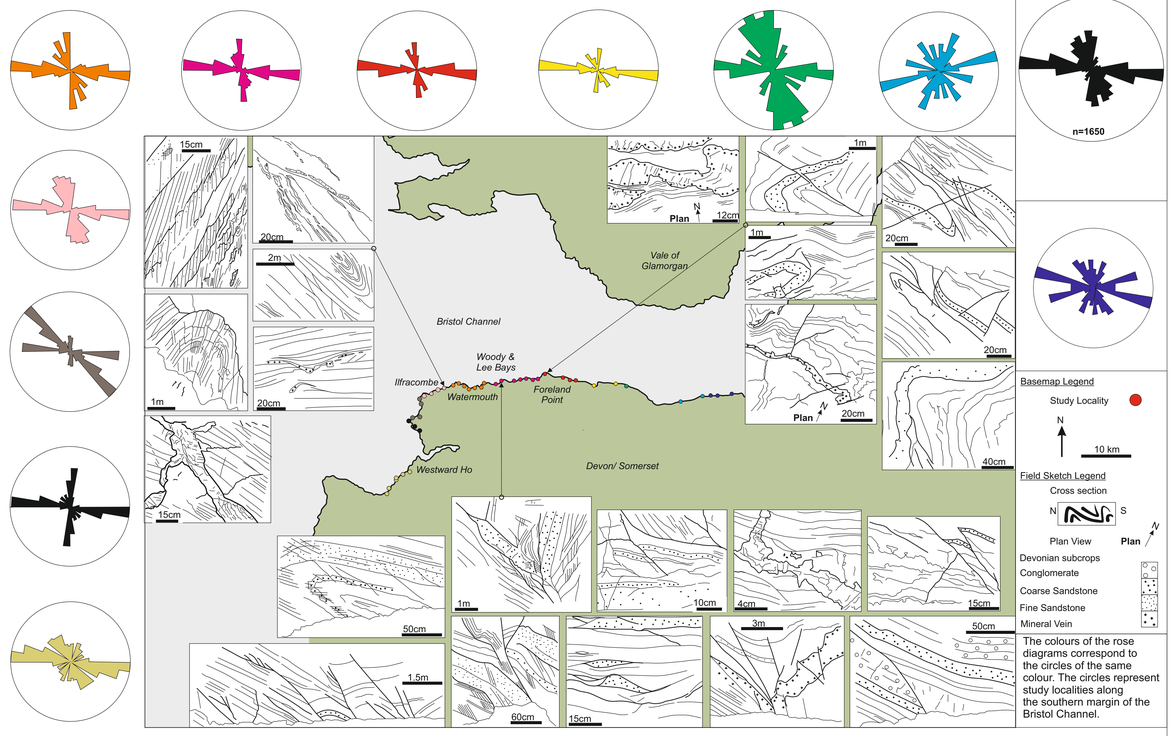


Figure c: (right) Extrapolation of stratigraphy within the Bristol Channel

3 FIELD OBSERVATIONS: STRUCTURAL TRENDS

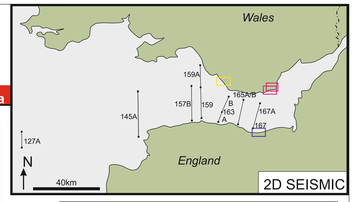


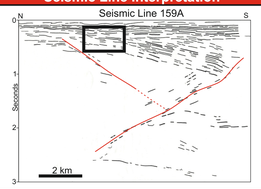
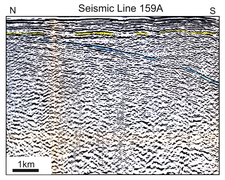
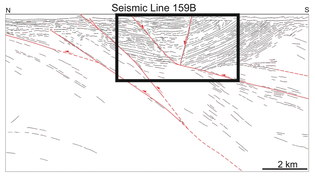
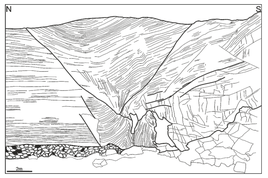
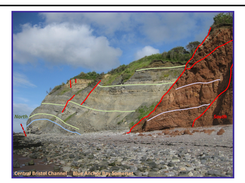
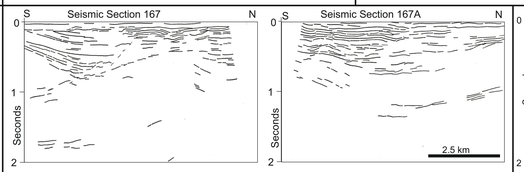
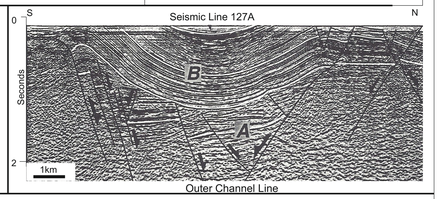
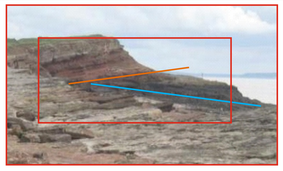
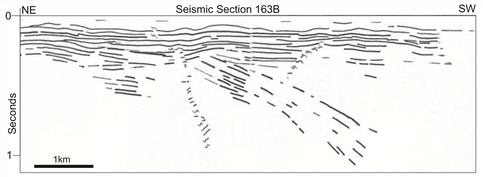
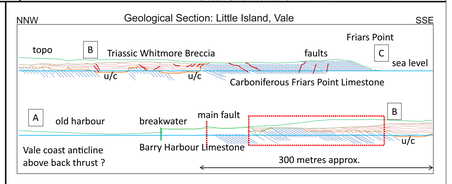
The colours of the rose diagrams correspond to the circles of the same colour. The circles represent study localities along the southern margin of the Bristol Channel.

A montage combining structural sketches with strike measurements taken in the field along the northern coasts of Devon and Somerset. There is a dominant WNW-ESE overprinting trend seen upon the combined rose diagram (top right) which is interpreted here to be of pure Variscan origin. This Variscan fabric points to a NNE-SSW maximum principal stress that controlled the styles of displacement on many of the major faults in the region. Furthermore, under the current NW-SE regional stress regime, seismology reveals that WNW-ESE lineaments linked to NW-SE lineaments are the cause of seismic activity in the Bristol Channel within recent decades. NNW-SSE and NE-SW lineaments are important in this context within the southern Wales area, north of the Bristol Channel.

4 FIELD ANALOGUE SEISMIC COMPARISON

Having compiled decades of field images, a handful of analogues were picked from the collection to illustrate the similarities to legacy seismic data within the Bristol Channel.



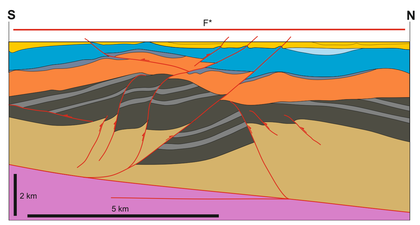
	Photograph	Seismic Line Interpretation	Field Sketch/ Raw Seismic Data
Vale of Glamorgan Coast			
Trwyn yr Wrach, Vale of Glamorgan			
Blue Anchor Bay, Somerset			
Sully and Little Island, Vale of Glamorgan			

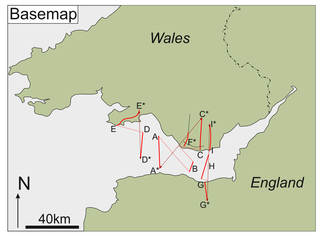
Description: the analogues are arranged in a matrix and show examples of structures that are direct analogues of the apparent seismically imaged geology. They are of smaller scale, but clearly mimic the seismic images within the Bristol Channel. All examples are comparable and cited by the authors. The Outer Channel Line is described previously in detail by McClay in the GS special publication on Basin Inversion. The analogues illustrate faults, folds and uncon- formities around the key localities within the Channel. The analogues clearly illustrate the benefits of integrating field data into siesmic interpretation and unravelling the hydrocarbon potential of overlooked basins with legacy datasets.

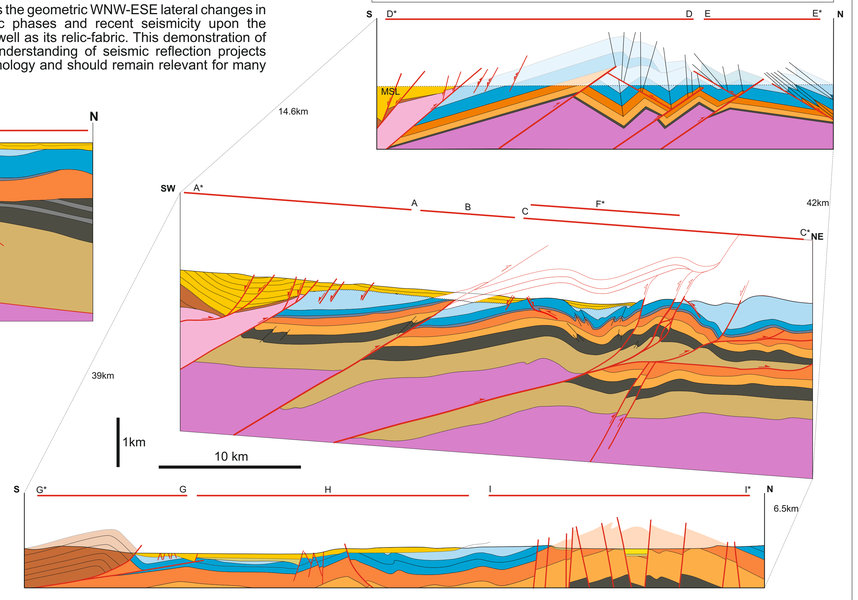
5 CONCLUSIONS

Our study augments the extensive field work carried out over at least three decades of academic research by generations of scholars. The targeted investigations conducted along the southern coast of Wales and the north coast of Somerset, Devon and Cornwall lead to revised syntheses, to better extrapolate, predict and model the structural architecture beneath the inner Bristol Channel. Exemplary Welsh field analogues are accounted in detail, measured, restored and integrated into an interpretation of the 2D 1985 Western-Geco dataset (WG85 2D 2001). The analogues include Trwyn yr Wrach, the Cold Knap, St Mary's Well and Sully Island, among many others.
In conclusion, the practical methodology exemplifies the geometric WNW-ESE lateral changes in structure and the effects of numerous kinematic phases and recent seismicity upon the architecture of the inner Bristol Channel basin as well as its relic-fabric. This demonstration of analogues improves immensely the geological understanding of seismic reflection projects whether legacy data, reflection, refraction or seismology and should remain relevant for many more crucial and modern geophysical acquisitions.

GEOLOGICAL SECTIONS DERIVED FROM SEISMIC AND ANALOGUE DATA







A Demonstration of the Tectonic Evolution of The Inner Bristol Channel UK: Application of Structural Geological Analogues to Interpretation of Legacy Seismic Data.

M.N. Miliorizos University of South Wales (1)
N. Reiss Tangram Energy Ltd (2)
N.S. Melis NOA Greece (3)

EGU European Geosciences Union

University of South Wales

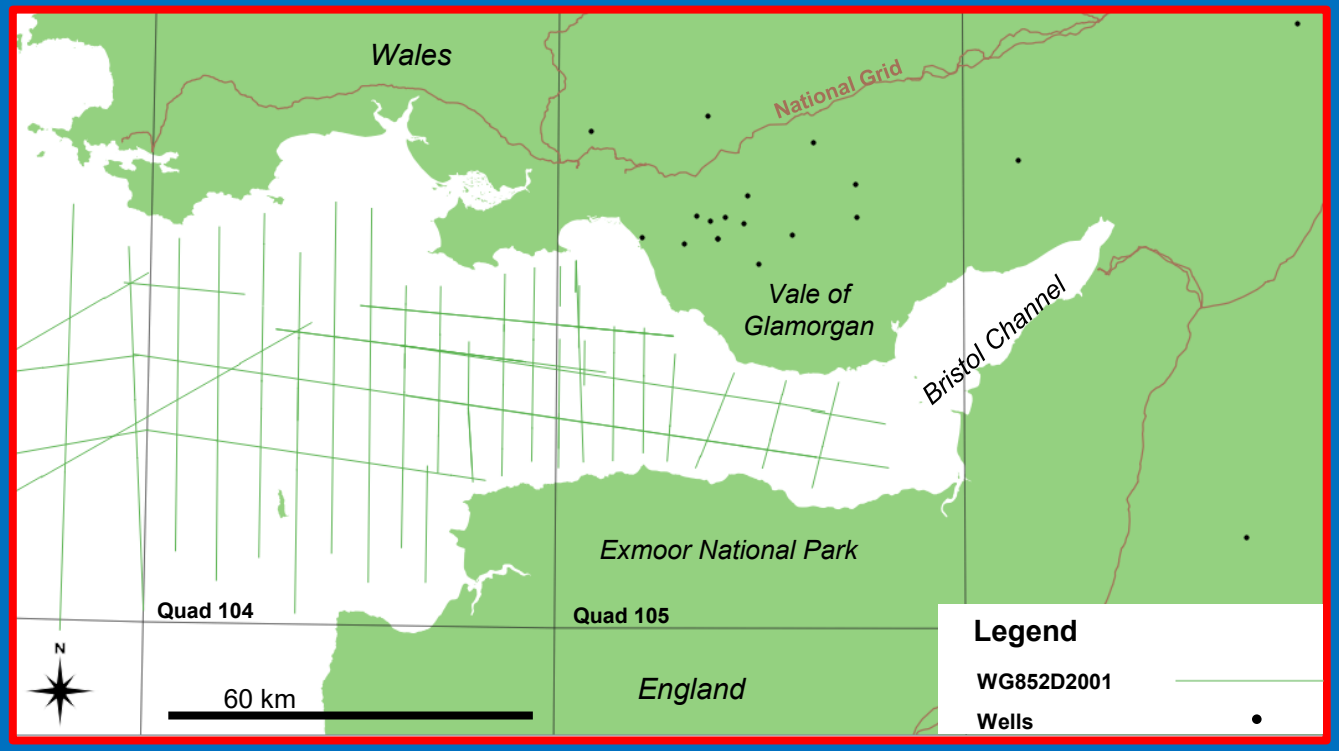
TANGRAM ENERGY

Introduction, Aims and Objectives

- **Challenges using legacy data**
- **Stratigraphy well understood**
- **Frontier hydrocarbon province**

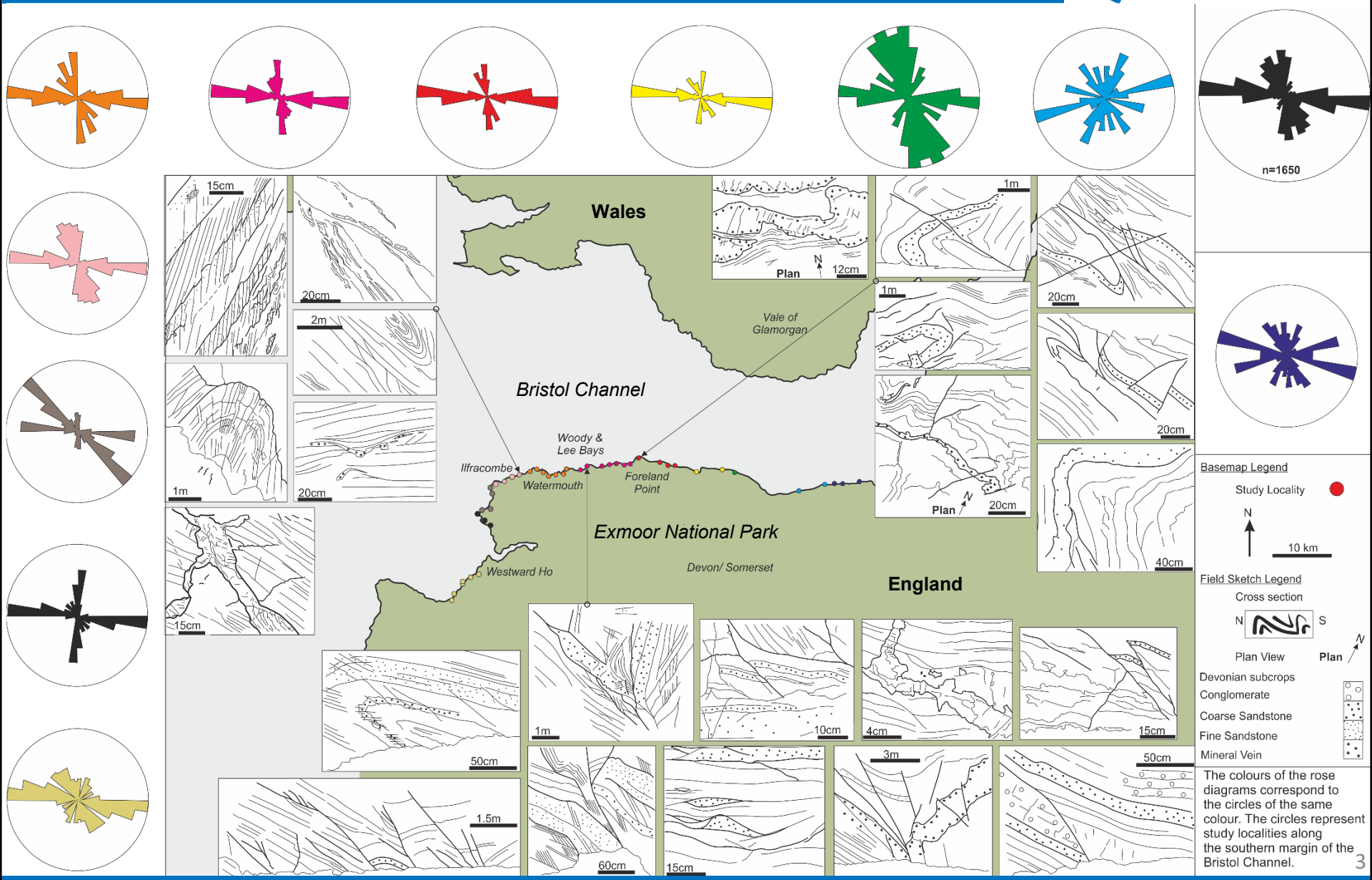
Aim: To better understand the tectonic evolution of the Inner Bristol Channel

- Integration of >30 years of outcrop and legacy seismic data
- Comparison of coastal outcrop structures to large scale structures
- Restoration of a complex inversion history



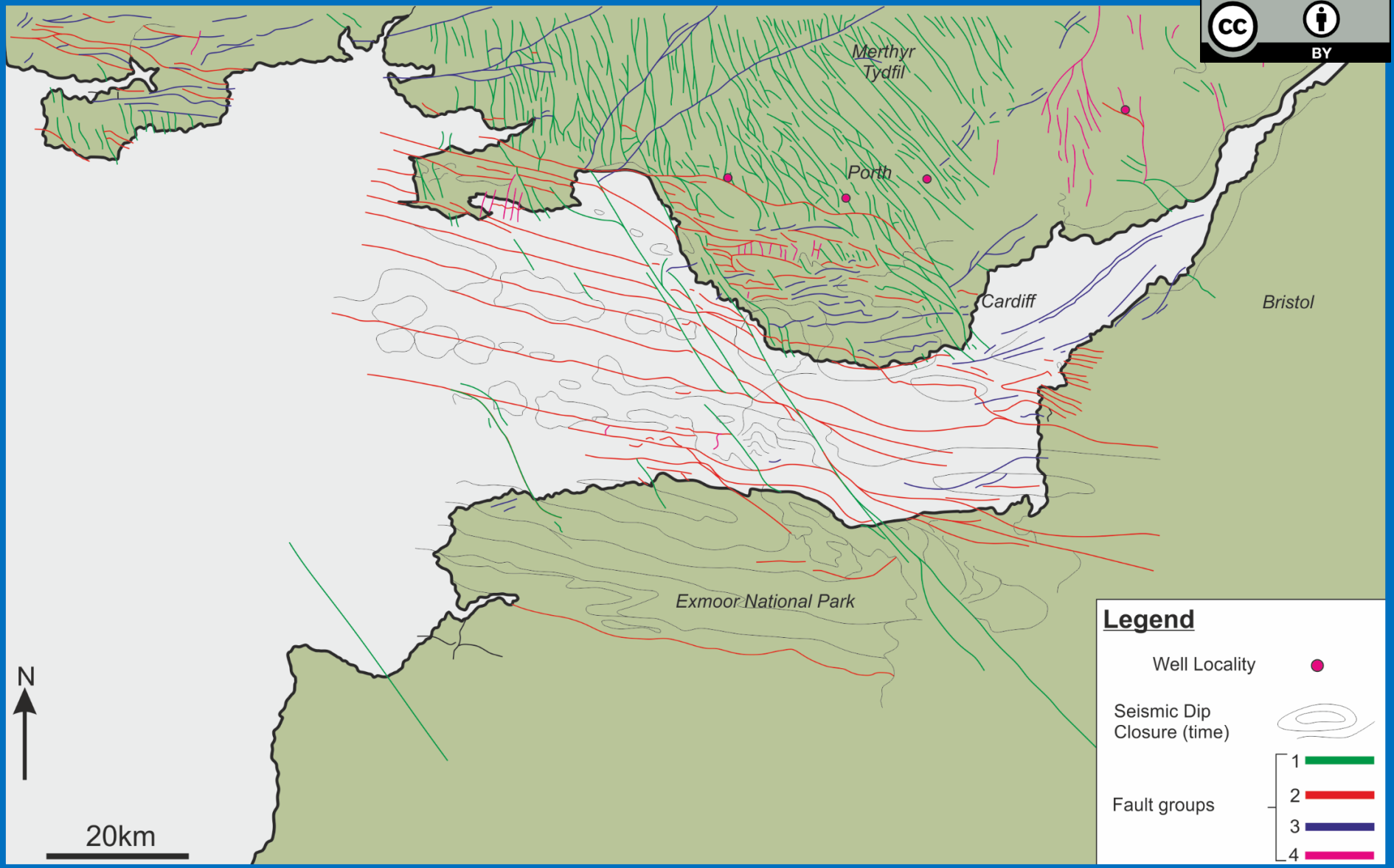
M.N. Miliorizos University of South Wales [1], N. Reiss Tangram Energy Ltd [2] & N.S. Melis NOA Greece [3]

Field Observations and Data Collection



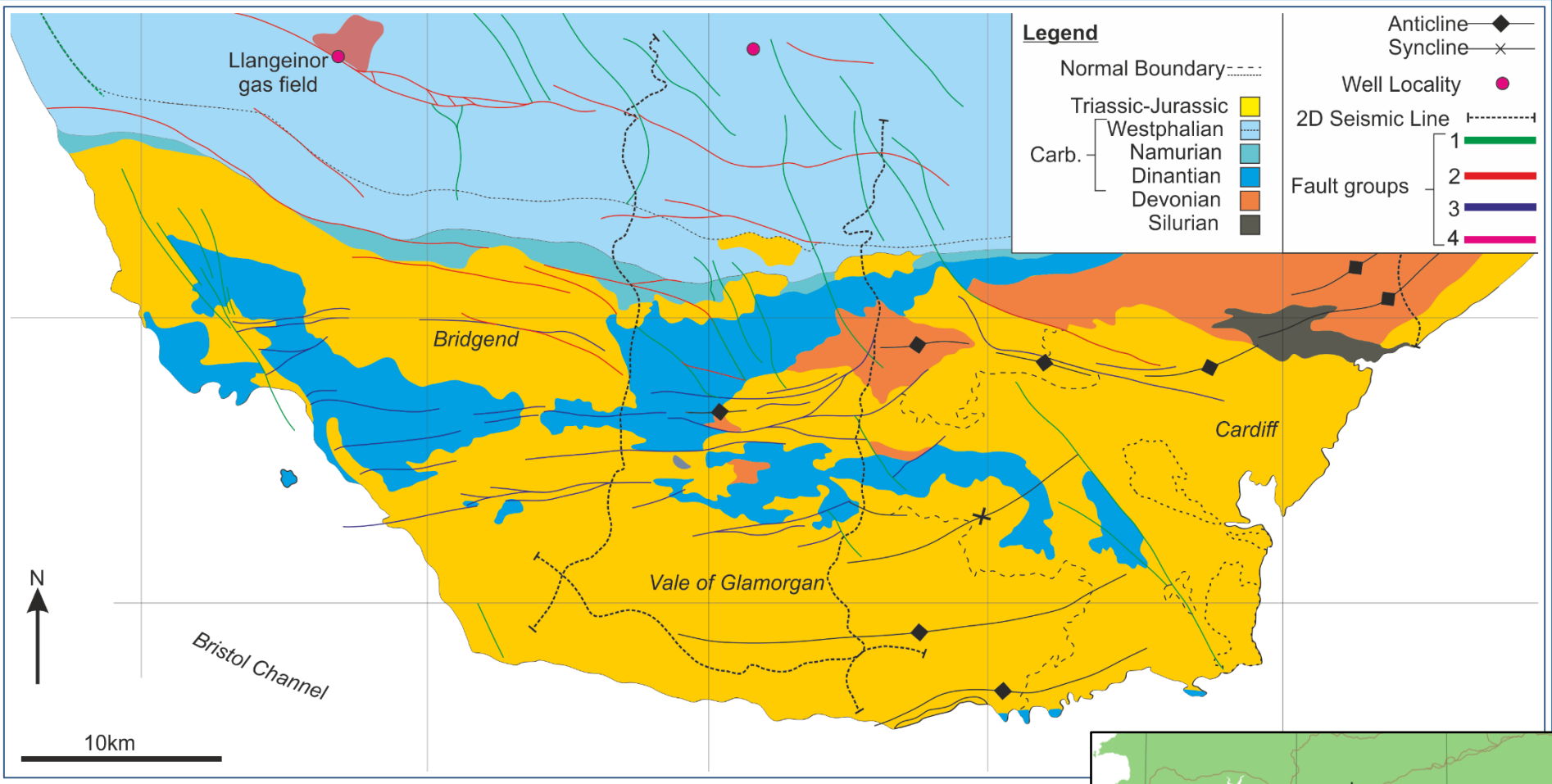
M.N. Miliorizos University of South Wales (1), N. Reiss Tangram Energy Ltd (2) & N.S. Melis NOA Greece (3)

Lineament Map: Inner Bristol Channel

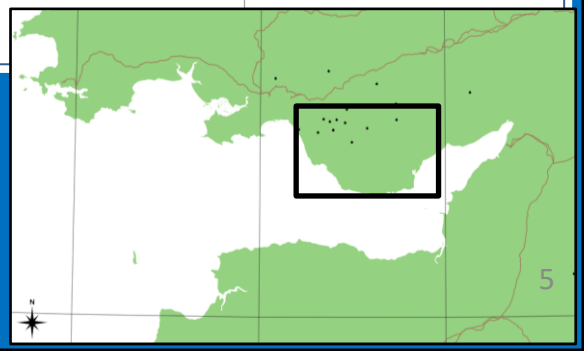


M.N. Miliorizos University of South Wales (1), N. Reiss Tangram Energy Ltd (2) & N.S. Melis NOA Greece (3)

Subaerial Geology: Vale of Glamorgan

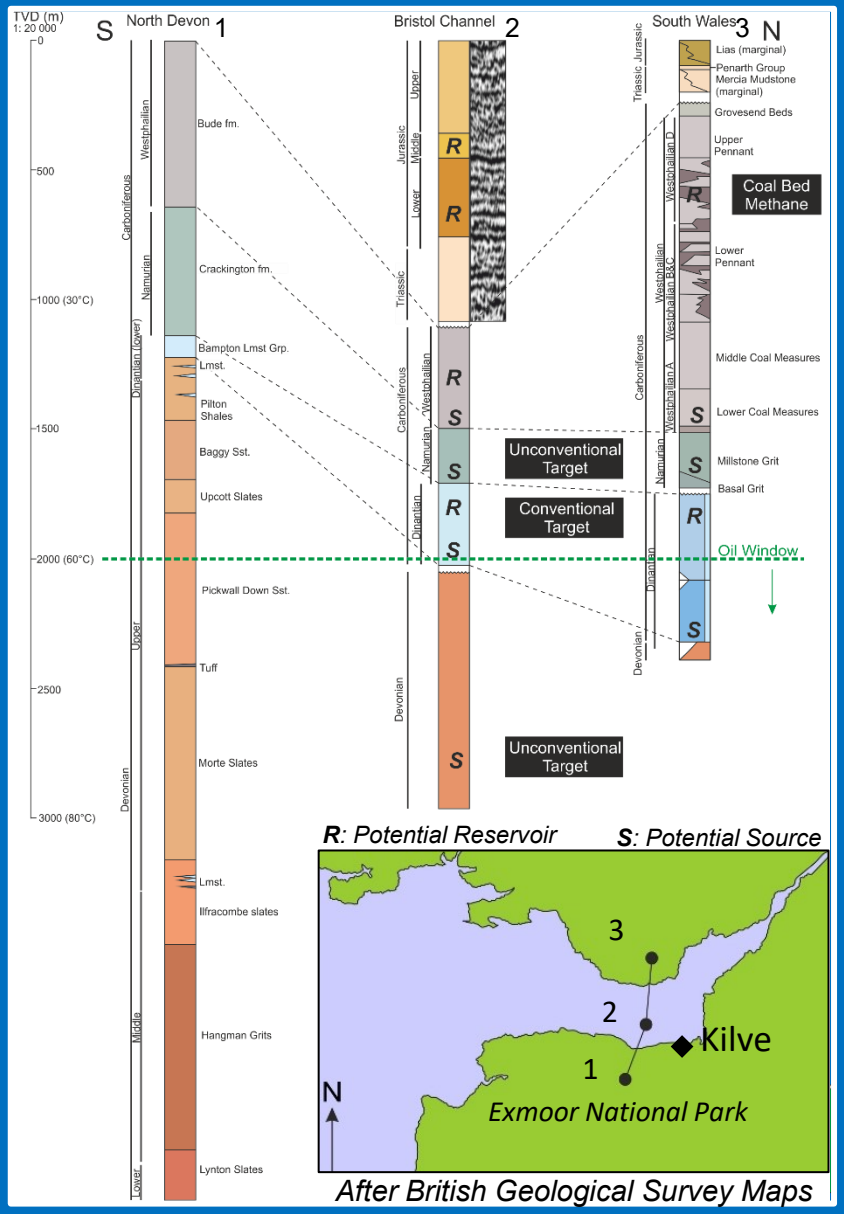


- Units identified in chronological order
- Data extracted from outcrop along coastline



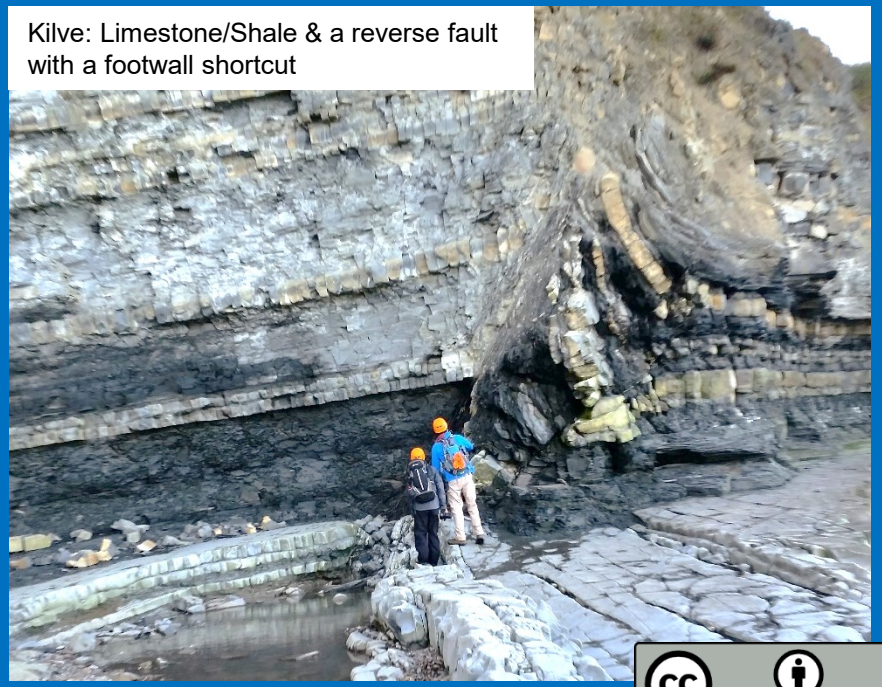
M.N. Miliorizos University of South Wales (1), N. Reiss Tangram Energy Ltd (2) & N.S. Melis NOA Greece (3)

Pseudo-well Correlation & Stratigraphy



- Pseudo-well stratigraphy identified by British Geological Survey
- Heterogeneity across localities a result of complex structural architecture
- Metamorphic grade increases to the South (Exmoor National Park)

Kilve: Limestone/Shale & a reverse fault with a footwall shortcut

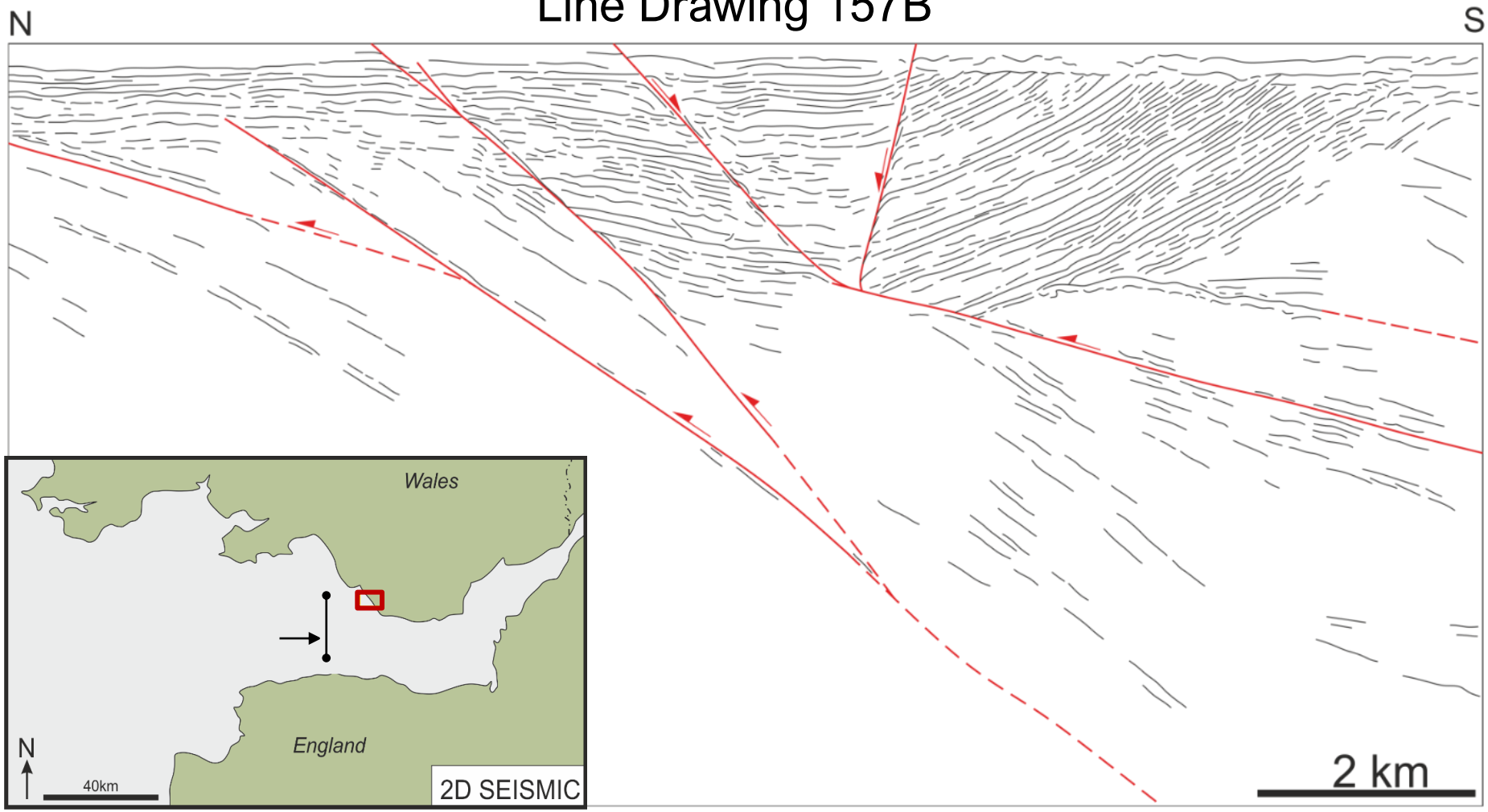


M.N. Miliorizos University of South Wales (1), N. Reiss Tangram Energy Ltd (2) & N.S. Melis NOA Greece (3)

Analogues: Regional to Outcrop Scale

Trwyn Yr Wrach, Vale of Glamorgan

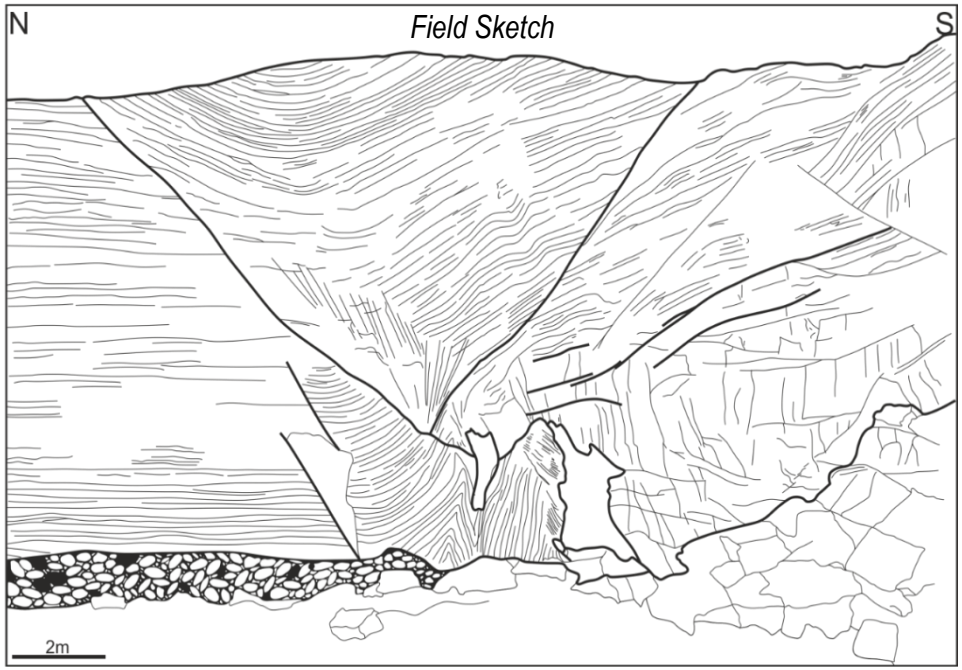
Line Drawing 157B



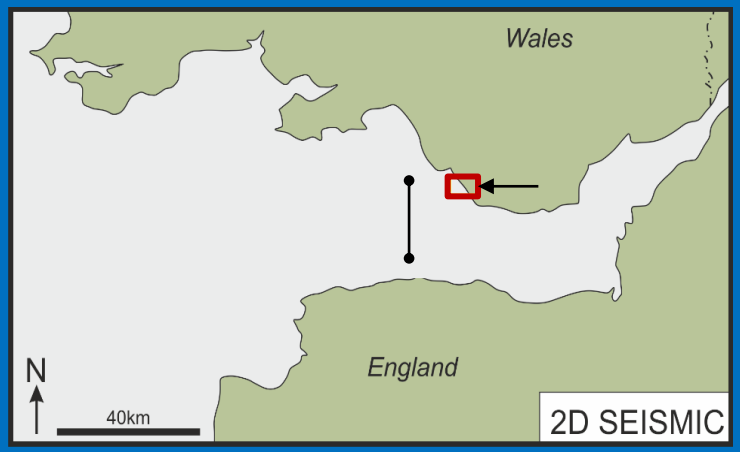
M.N. Miliorizos University of South Wales (1), N. Reiss Tangram Energy Ltd (2) & N.S. Melis NOA Greece (3)

Analogues: Regional to Outcrop Scale

Trwyn Yr Wrach, Vale of Glamorgan



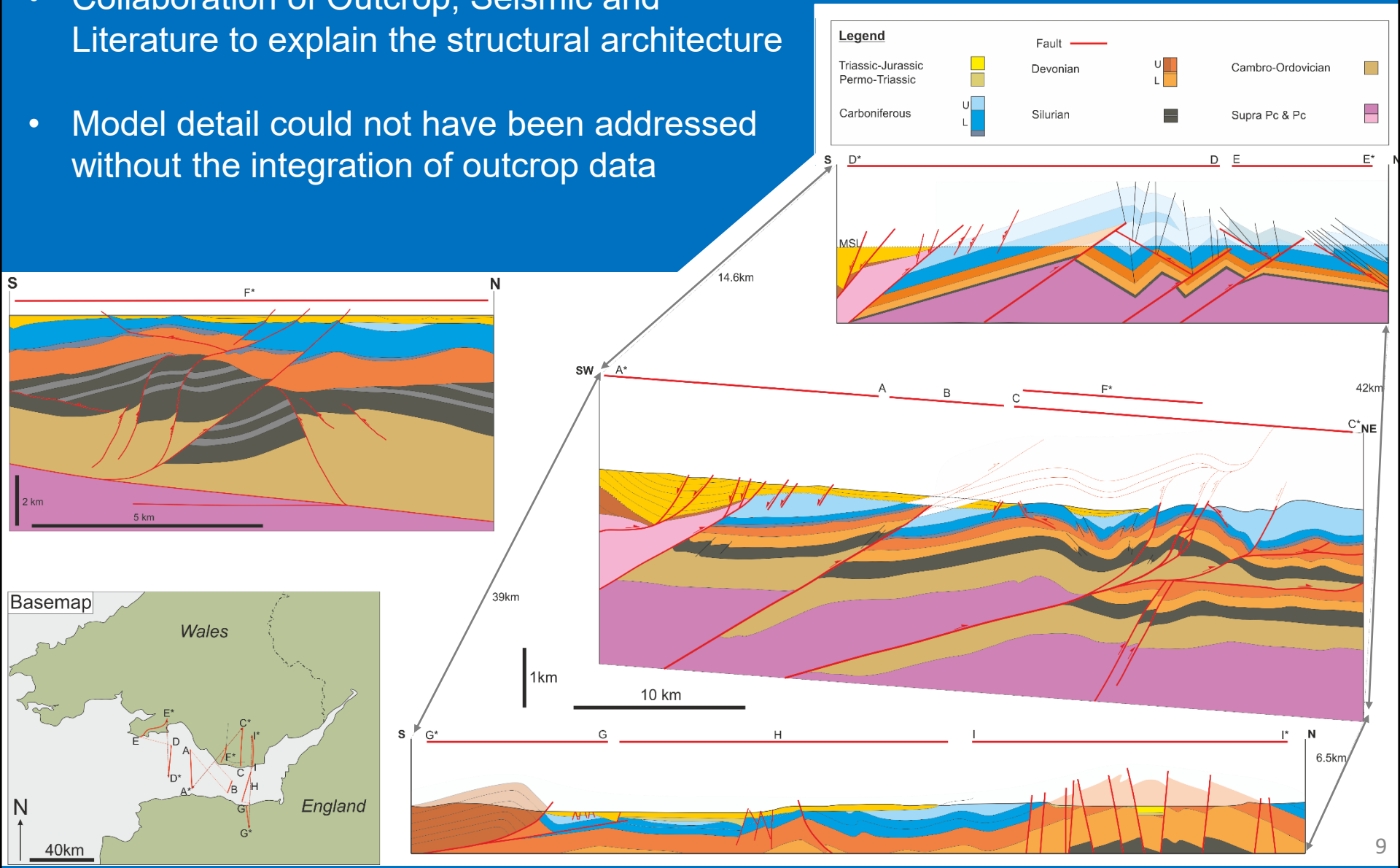
- Coastal outcrops display analogous features to structures identified in Seismic Data
- Structures are within proximity (~10km) to each other
- Field interpretations aid seismic interpretations



M.N. Miliorizos University of South Wales (1), N. Reiss Tangram Energy Ltd (2) & N.S. Melis NOA Greece (3)

Inner Bristol Channel: Structural Model

- Collaboration of Outcrop, Seismic and Literature to explain the structural architecture
- Model detail could not have been addressed without the integration of outcrop data



M.N. Miliorizos University of South Wales (1), N. Reiss Tangram Energy Ltd (2) & N.S. Melis NOA Greece (3)

Conclusions

- Thirty years of outcrop data has been integrated within this study to understand the tectonic evolution of the complex Inner Bristol Channel.
- Integration of outcrop data from Somerset, Devon, Cornwall and the Vale of Glamorgan help better model the structural subsurface architecture and helps illustrate the lateral heterogeneity across major lineaments
- This demonstration of analogues improves immensely the geological understanding of seismic interpretations and helps predict the presence of structures below seismic resolution
- The workflow illustrated within this study benefits hydrocarbon exploration by potentially avoiding costly reprocessing techniques while de-risking a potential drilling target.

M.N. Miliorizos University of South Wales [1], N. Reiss Tangram Energy Ltd [2] & N.S. Melis NOA Greece [3]

Thankyou for Listening

We Welcome Any Questions

M.N. Miliorizos University of South Wales (1)

N. Reiss Tangram Energy Ltd (2)

N.S. Melis NOA Greece (3)

University of South Wales

TANGRAM ENERGY

A demonstration of the tectonic evolution of the inner Bristol Channel UK: application of structural geological analogues to interpretation of legacy and new seismic data.

Marios N. Miliorizos[1], Nicholas Reiss[2] and Nikolaos S. Melis[3]

[1]University of South Wales, Energy & Environment Research Institute, Faculty of Computing Engineering & Science, Pontypridd Wales, United Kingdom of Great Britain and Northern Ireland (marios.miliorizos@southwales.ac.uk)
[2]Tangram Energy Ltd., London United Kingdom of Great Britain and Northern Ireland (nicholas.reiss@tangram-energy.com)
[3]National Observatory of Athens, Institute of Geodynamics, Athens, Greece (nmelis@noa.gr)

1

A demonstration of the tectonic evolution of the inner Bristol Channel UK: application of structural geological analogues to interpretation of legacy and new seismic data.

European Geosciences Union

EGU2020-3178 EGU General Assembly 2020 © Miliorizos, Reiss & Melis (2020). This work is distributed under the Creative Commons Attribution 4.0 License.

2

EGU 2020

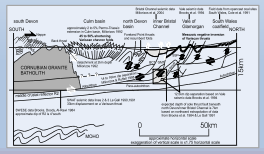
Welcome to the Geology & Geophysics *of the* Bristol Channel UK

from Marios Miliorizos

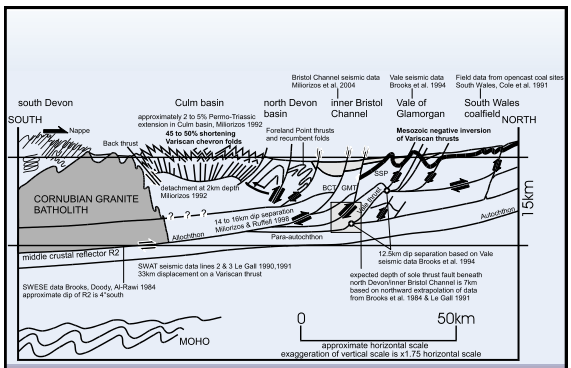
3

A 'Geo-phantasmogram' of the Structure

- *Structural Models*
- *References:*



4



5

A demonstration of the tectonic evolution of the inner Bristol Channel UK: application of structural geological analogues to interpretation of legacy and new seismic data.

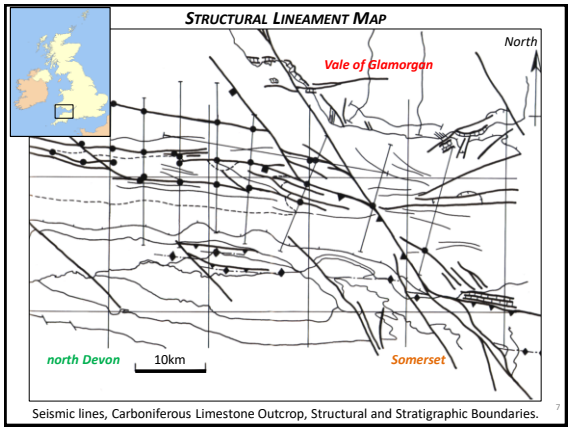
M.N. Miliorizos(1)
N. Reiss(2) & N.S. Melis(3)

(1) University of South Wales
(2) Tangram Energy
(3) NOA Greece

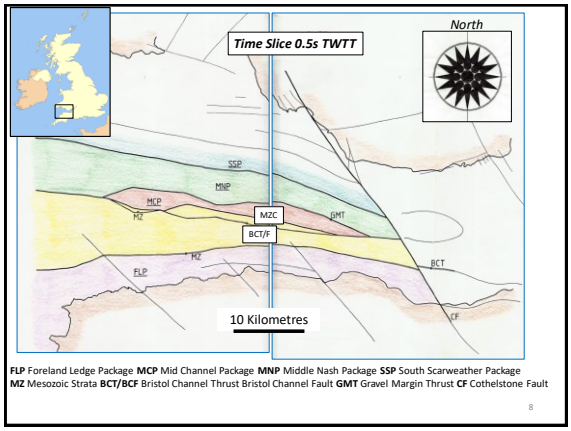
PART A: Time Slices and Structure beneath the Central Bristol Channel

EGU April – May 2020

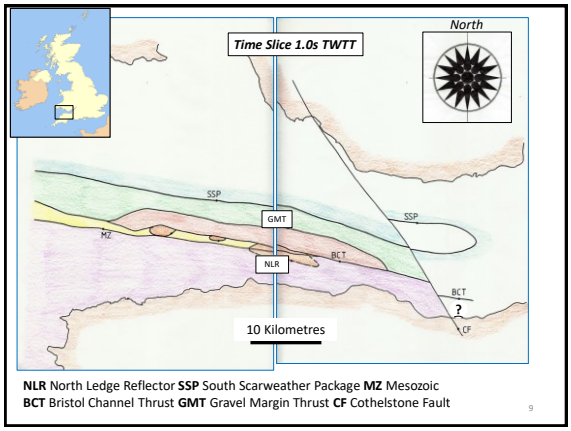
6


STRUCTURAL LINEAMENT MAP
North
Vale of Glamorgan
north Devon
10km
Somerset
Seismic lines, Carboniferous Limestone Outcrop, Structural and Stratigraphic Boundaries.
7

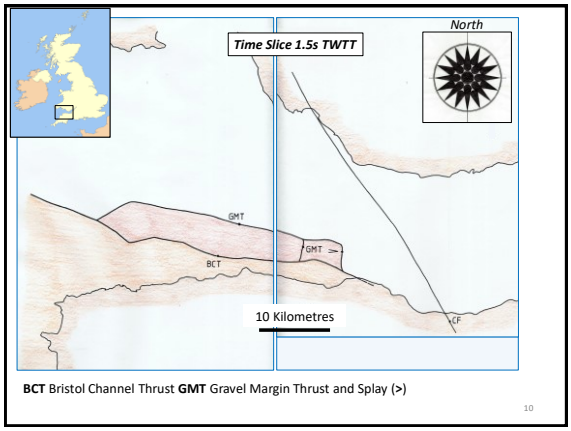
7


Time Slice 0.5s TWTT
North
SSP
MNP
MCP
MZ
MZC
BCT/F
GMT
FLP
BCT
CF
10 Kilometres
FLP Foreland Ledge Package MCP Mid Channel Package MNP Middle Nash Package SSP South Scarweather Package
MZ Mesozoic Strata BCT/BCF Bristol Channel Thrust Bristol Channel Fault GMT Gravel Margin Thrust CF Cothelstone Fault
8

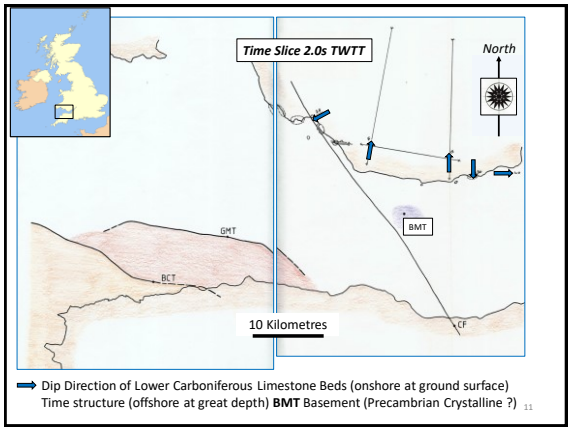
8


Time Slice 1.0s TWTT
North
SSP
GMT
SSP
MZ
NLR
BCT
BCT
?
CF
10 Kilometres
NLR North Ledge Reflector SSP South Scarweather Package MZ Mesozoic
BCT Bristol Channel Thrust GMT Gravel Margin Thrust CF Cothelstone Fault
9

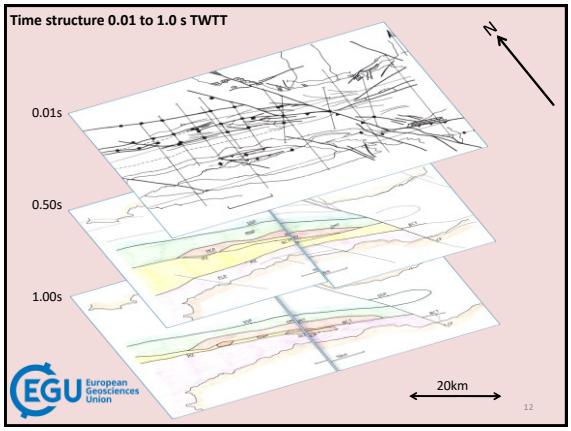
9


Time Slice 1.5s TWTT
North
GMT
GMT
BCT
10 Kilometres
CF
BCT Bristol Channel Thrust GMT Gravel Margin Thrust and Splay (>)
10

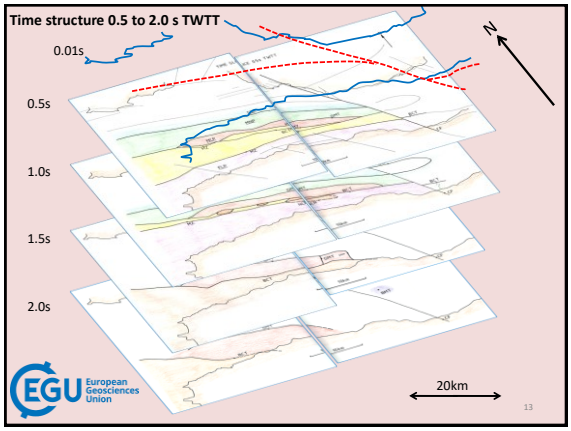
10


Time Slice 2.0s TWTT
North
BMT
GMT
BCT
10 Kilometres
CF
Dip Direction of Lower Carboniferous Limestone Beds (onshore at ground surface)
Time structure (offshore at great depth) BMT Basement (Precambrian Crystalline ?)
11

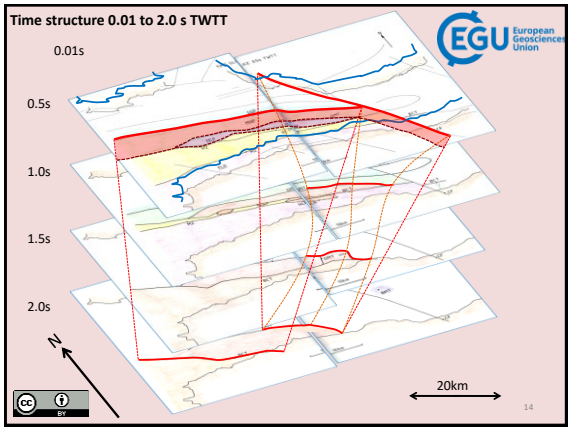
11


Time structure 0.01 to 1.0 s TWTT
N
0.01s
0.50s
1.00s
EGU European Geosciences Union
20km
12

12

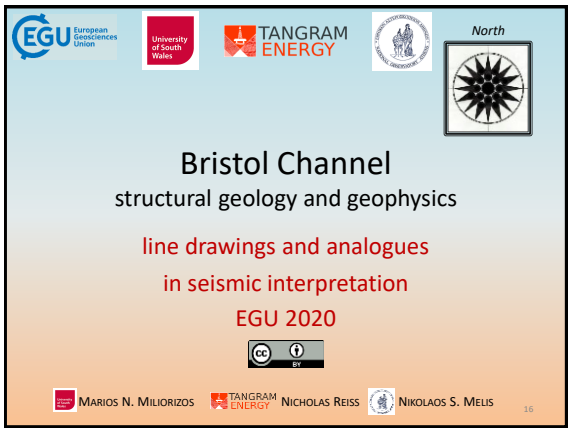


13

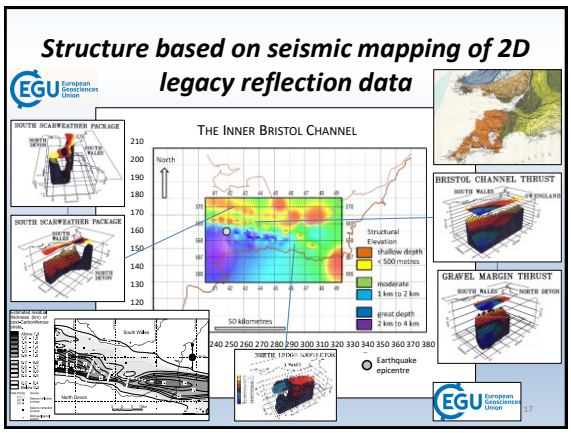


14

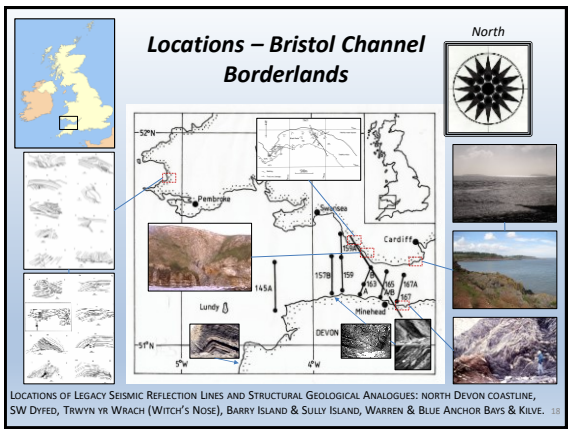
15



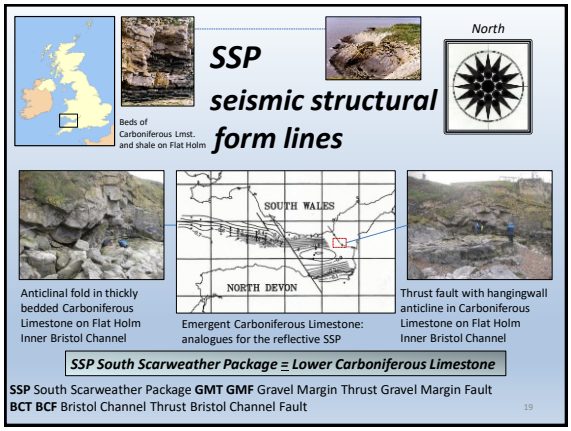
16



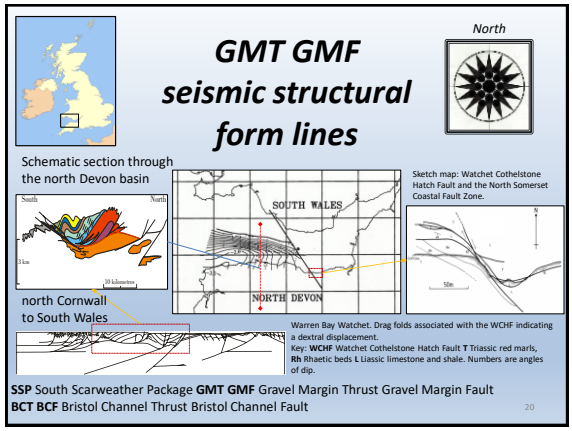
17



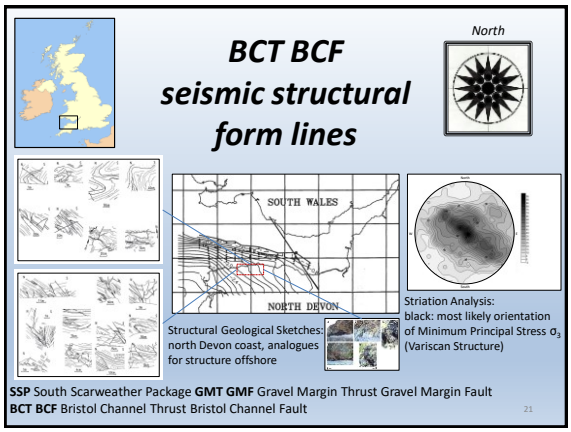
18



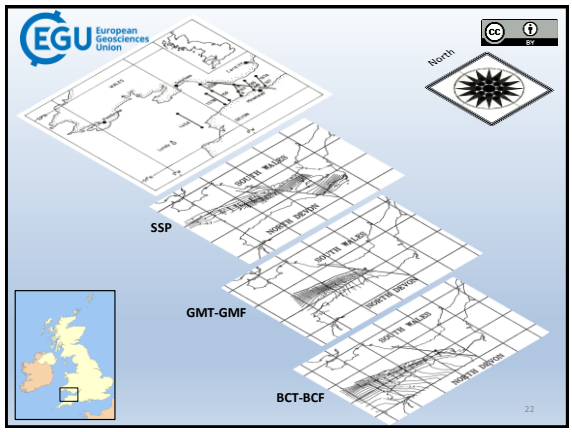
19



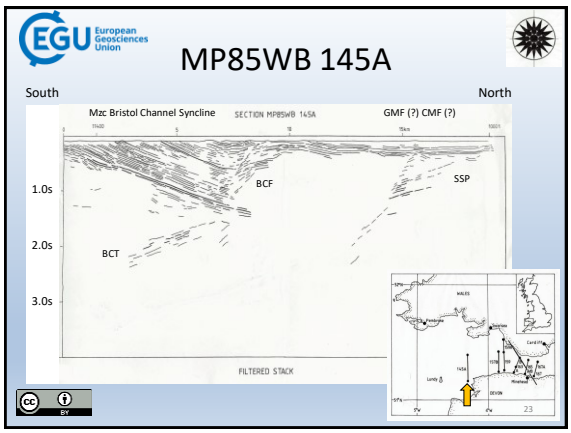
20



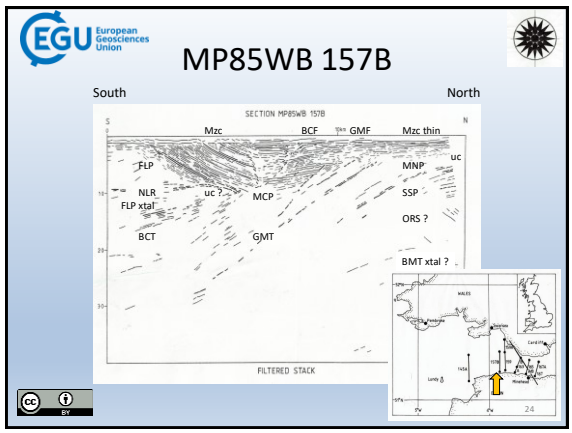
21



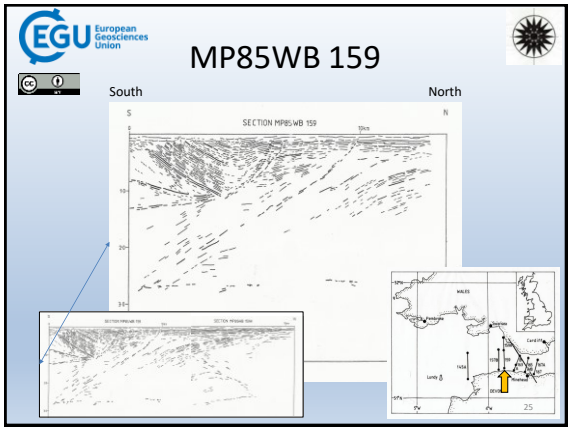
22



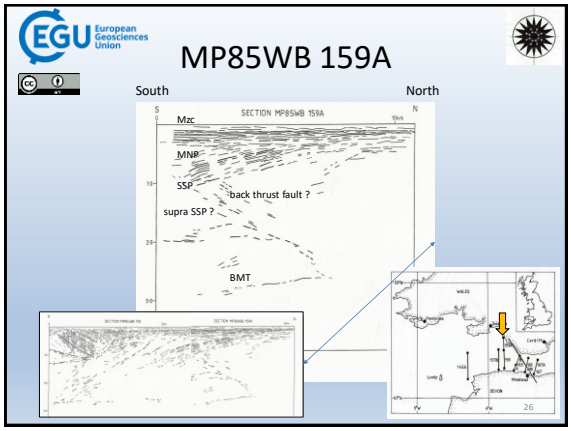
23



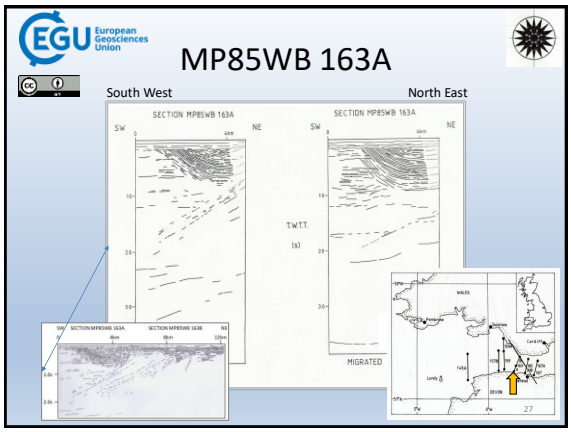
24



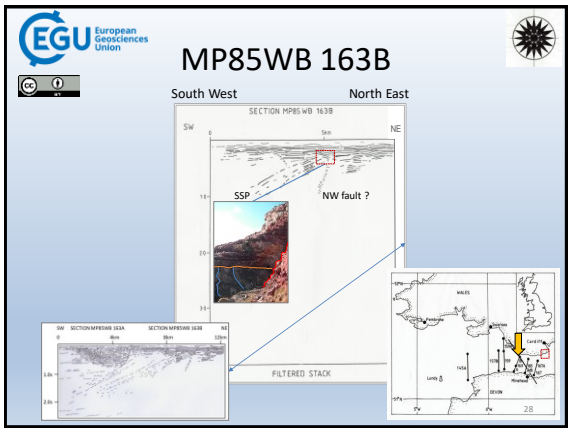
25



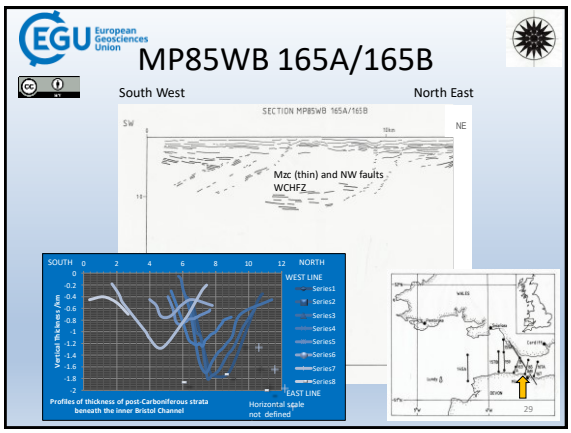
26



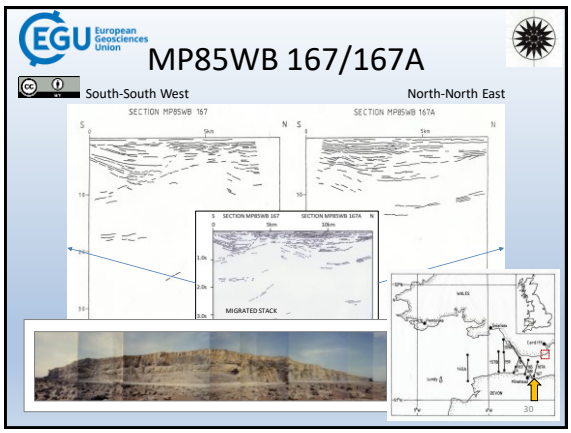
27



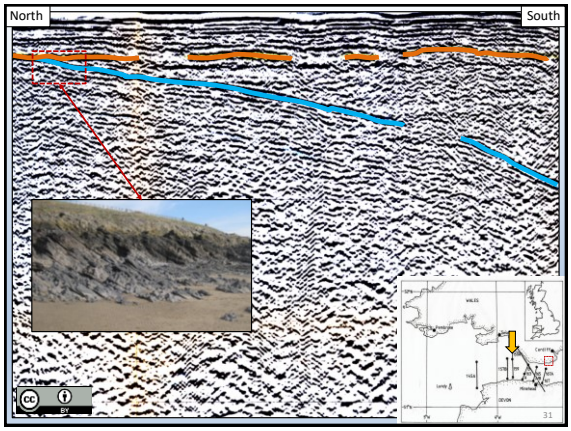
28



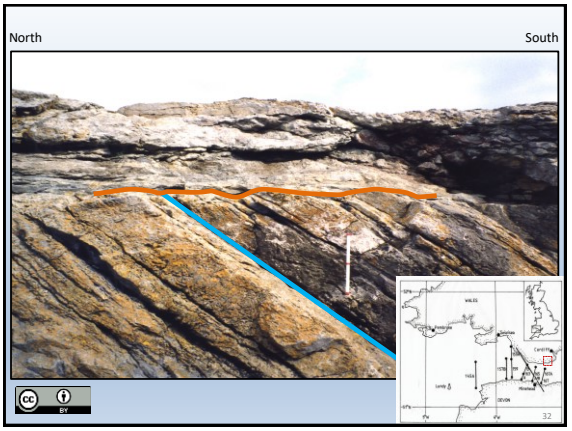
29



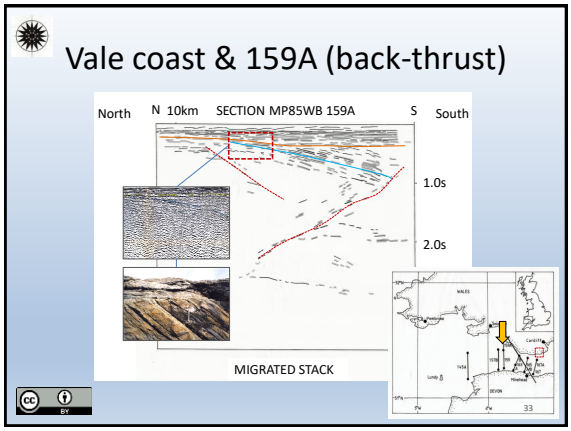
30



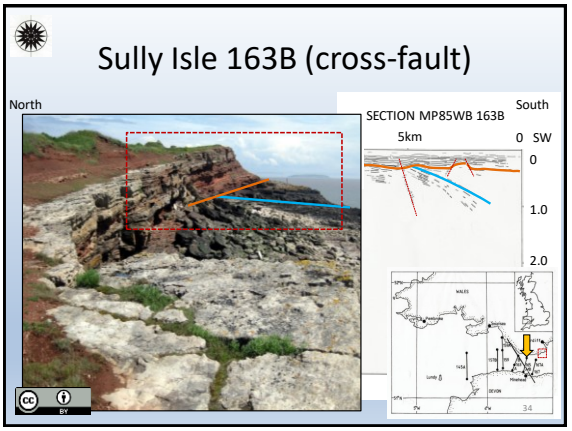
31



32

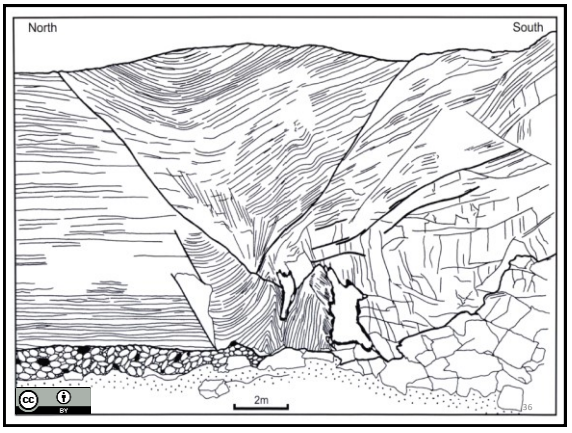


33

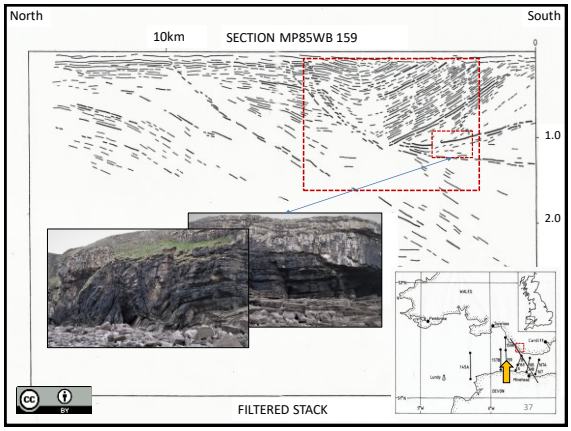


34

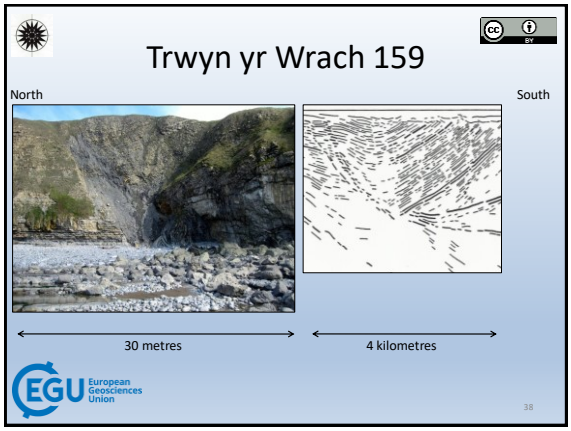
35



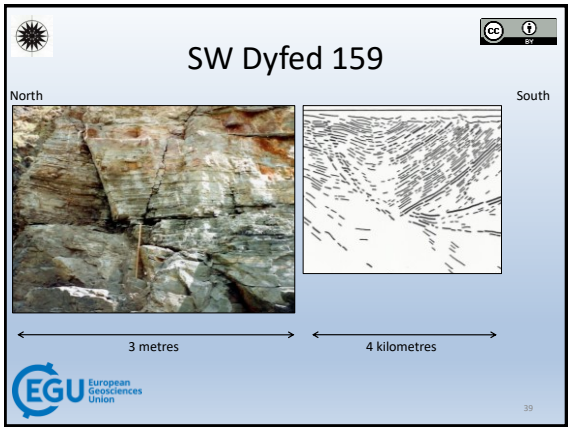
36



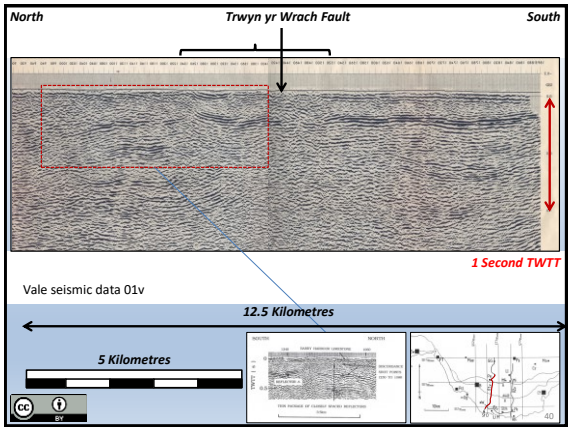
37



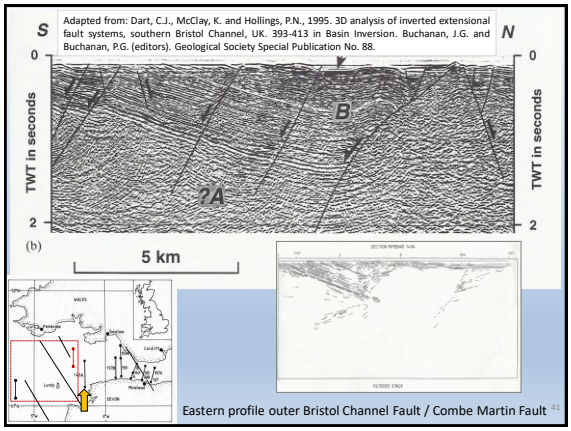
38



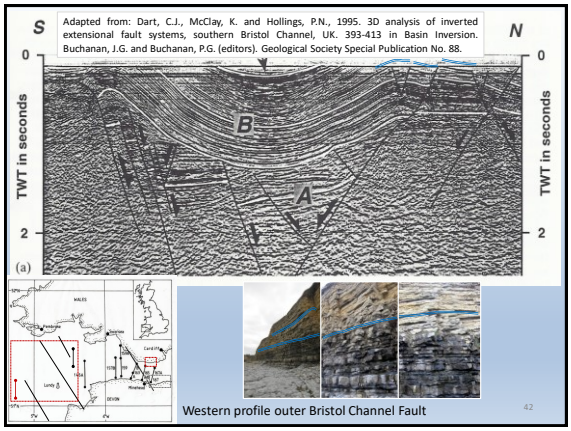
39



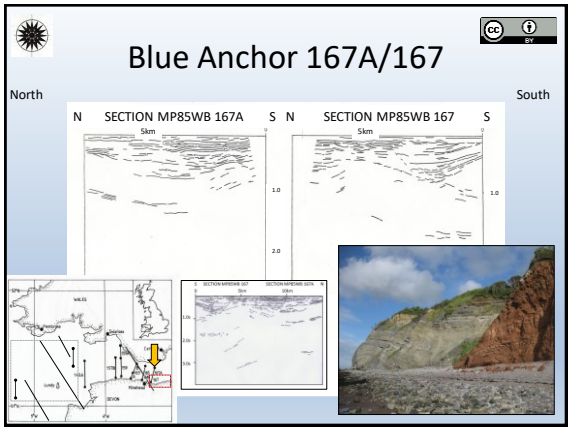
40



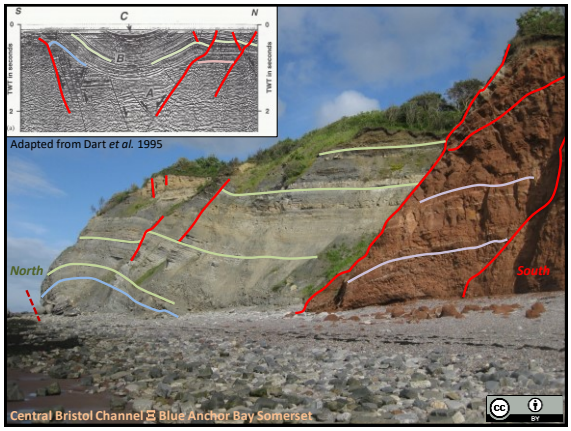
41



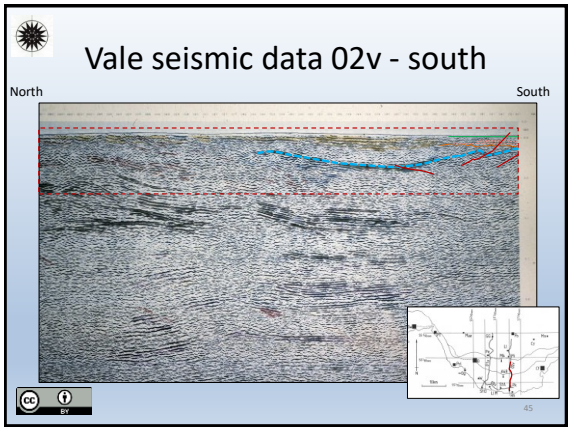
42



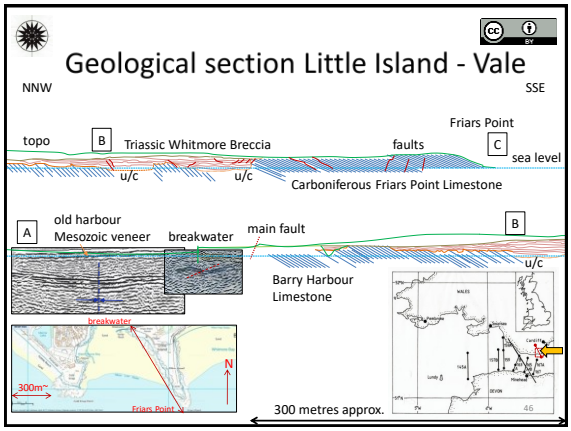
43



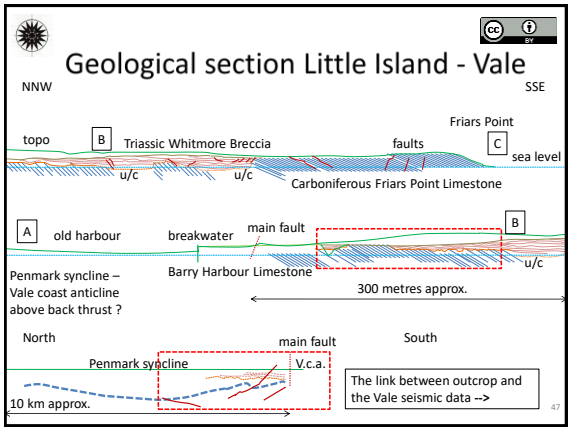
44



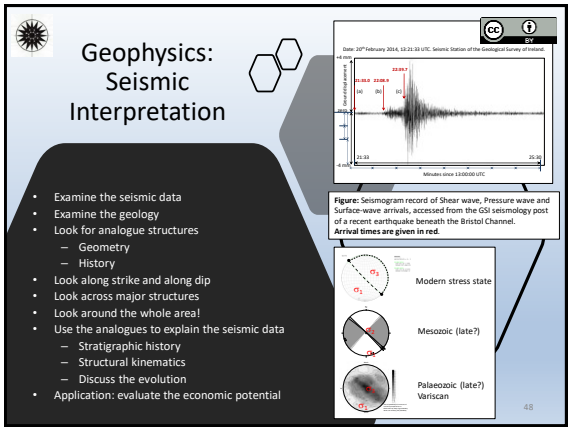
45



46



47



48

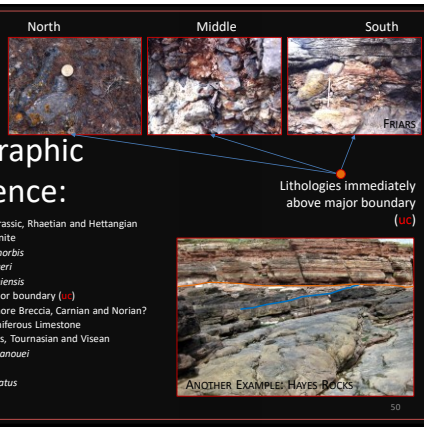
A demonstration of the tectonic evolution of the inner Bristol Channel UK: application of structural geological analogues to interpretation of legacy and new seismic data.

M.N. Miliorizos(1)
N. Reiss(2) & N.S. Melis(3)

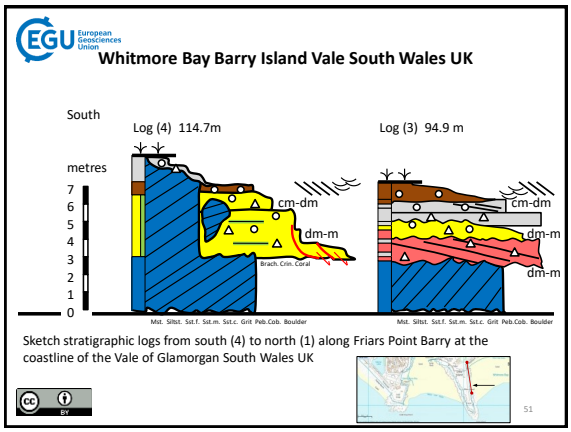
(1) University of South Wales
(2) Tangram Energy
(3) NOA Greece

PART C: Analogues:
Friars & Nell's Point Whitmore Bay
Barry Old Harbour & Cold Knap.
An Evolving Earth – Case Study
EGU April – May 2020

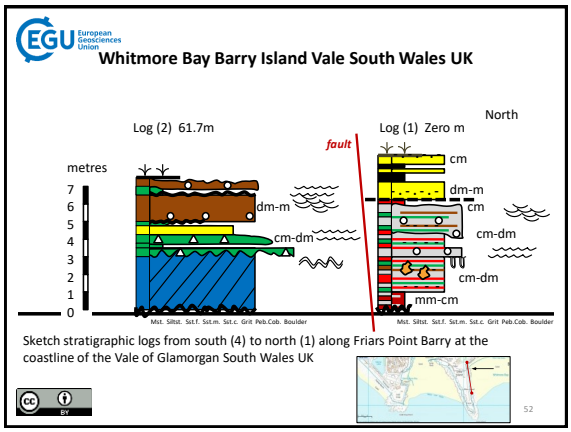
49



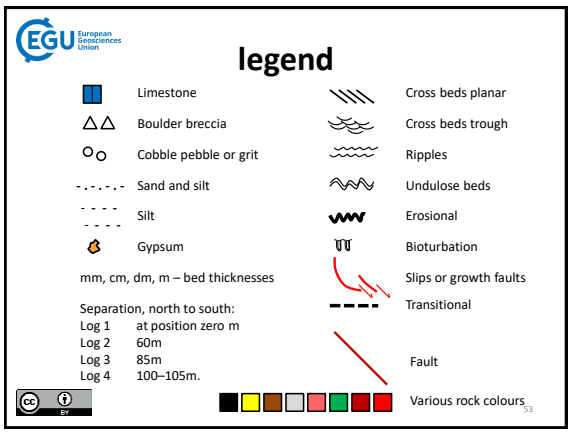
50



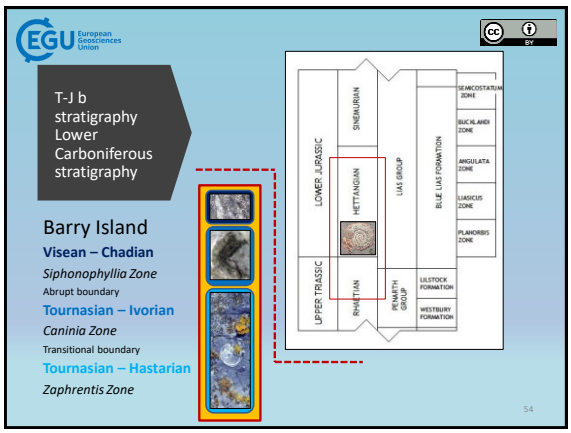
51



52



53

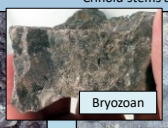


54

Palaeozoic: South of the major fault


Rugose corals – *Zaphrentis sp.*


Crinoid stems and branches


Bryozoan

Brachiopod – *Spirifer attenuatus*

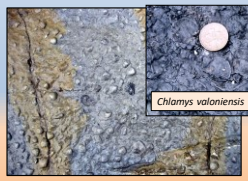
Crinoid stem

55

Mesozoic: North of the major fault


Ammonites – more robust shell


Ammonite with ribs in section



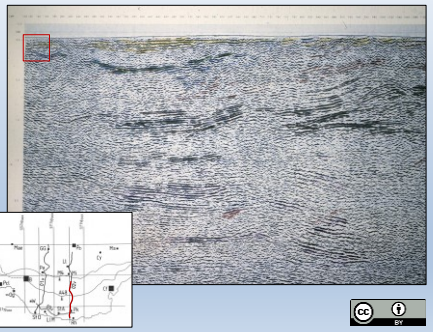
Chlamys valoniensis

Oyster bed – *Liostrea hisingeri*

Psiloceras planorbis – thin shell

56

Vale of Glamorgan seismic section, south (left) north (right)



57

Blue Lias in hangingwall

58

Blue Lias – hangingwall with faults

59

Late positive inversion (Tertiary?)


Somerset 1991


North

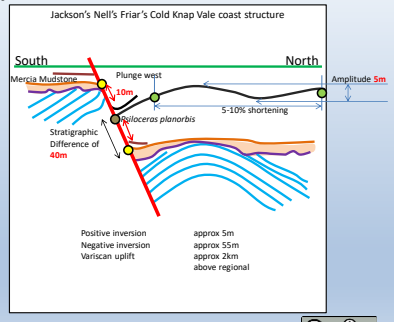

NE

St Mary's Well Bay July 2018

Old Barry Harbour 2017

60

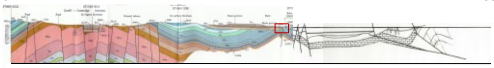
Barry Old Harbour sketch section



61

Cardiff-Inner Channel-Quantock Section

North South



Estimate of present shortening due to late (+ve) inversion 1% 0.31 units

measurement of present shortening 18.95% [(38.25-31.00)/38.25]100
measurement of present extension 5.62% [{31-1.65}-31)/29.35]100

restored measurement of extension 6.75% [{31-1.96}-31)/29.04]100
restored measurement of shortening 24.73% [(38.25-29.04)/38.25]100

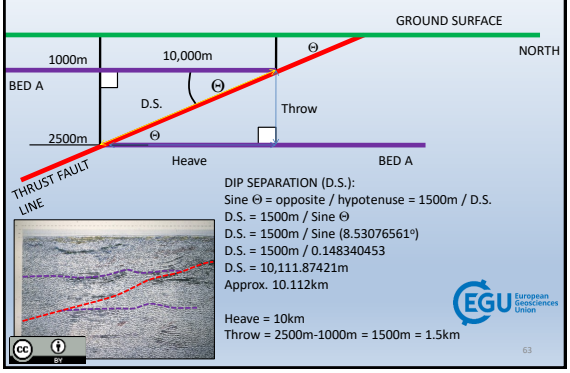
i.e. Estimate of shortening due to Variscan compression is 25%

Over 40km it represents a displacement (heave) of 10km

62

Measurement

CALCULATION OF DIP SEPARATION, HEAVE AND THROW
17/02/2004

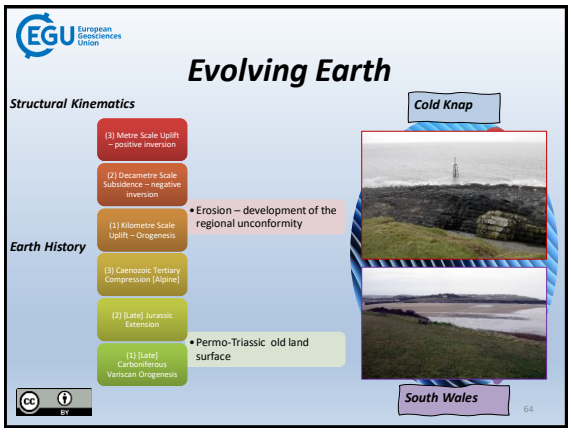


DIP SEPARATION (D.S.):
Sine Θ = opposite / hypotenuse = 1500m / D.S.
D.S. = 1500m / Sine Θ
D.S. = 1500m / Sine (8.53076561°)
D.S. = 1500m / 0.148340453
D.S. = 10,111.87421m
Approx. 10.112km

Heave = 10km
Throw = 2500m-1000m = 1500m = 1.5km

63

Evolving Earth



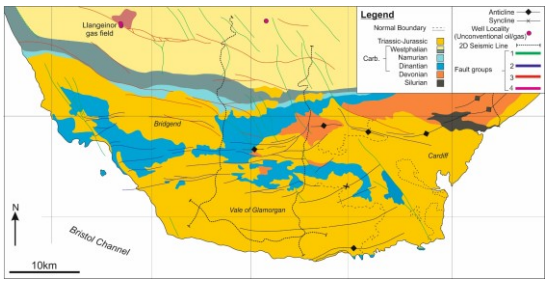
64

EGU 2020

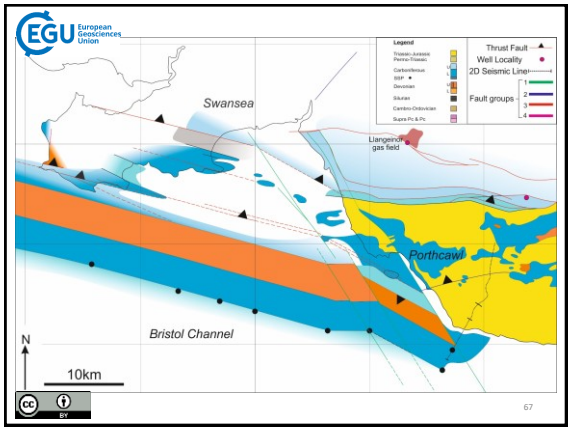
© Miliorizos, Reiss & Melis 2020
Figures mainly from poster presentation:

Appendix

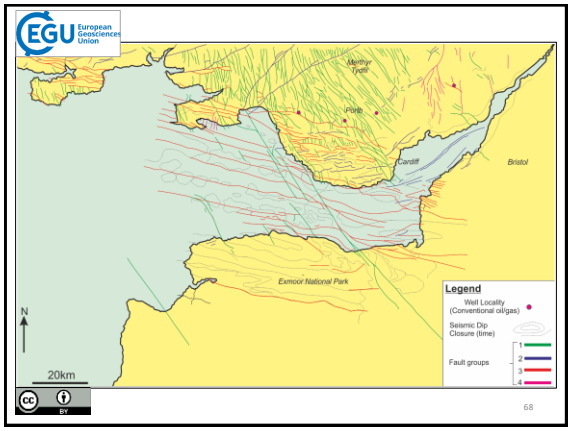
65



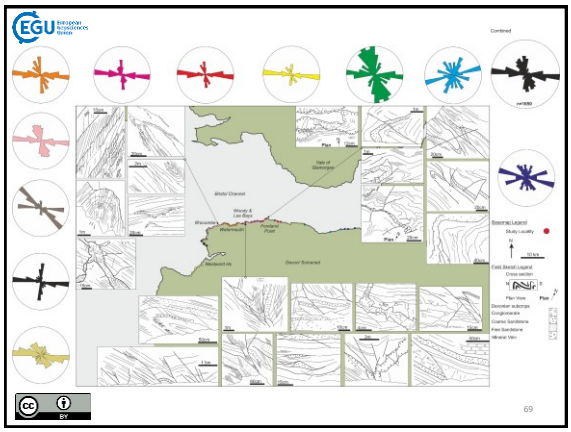
66



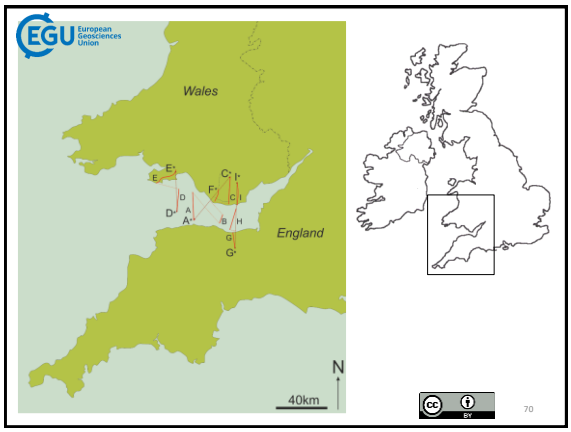
67



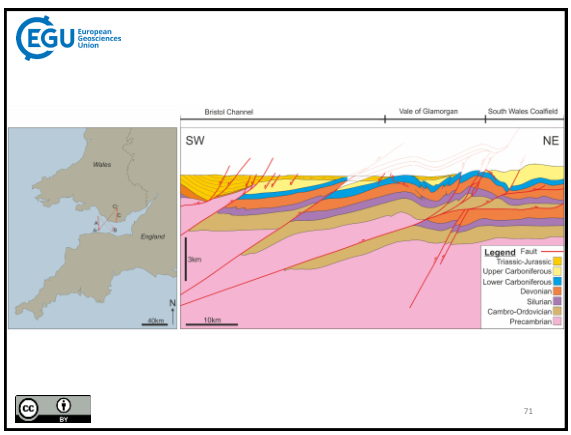
68



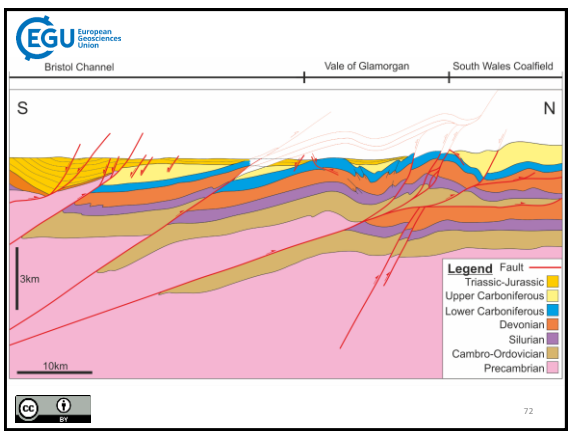
69



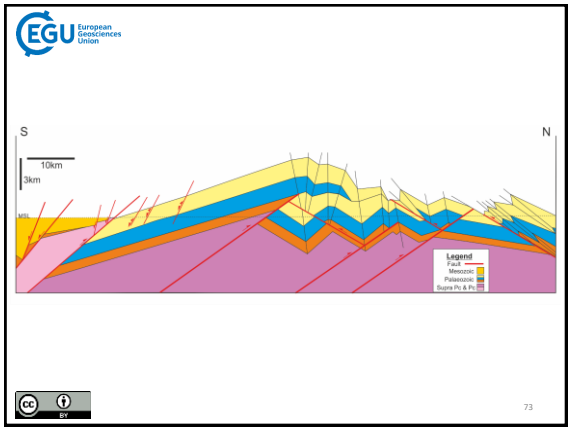
70



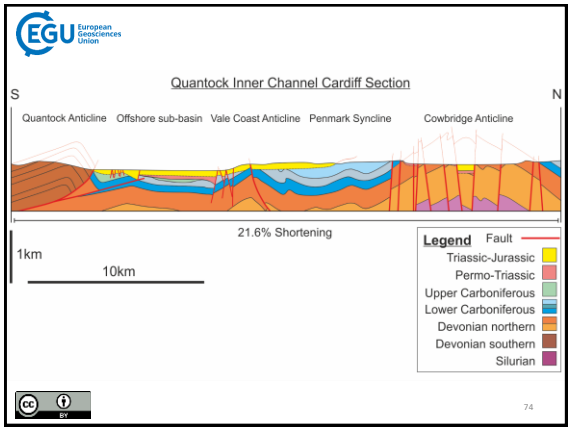
71



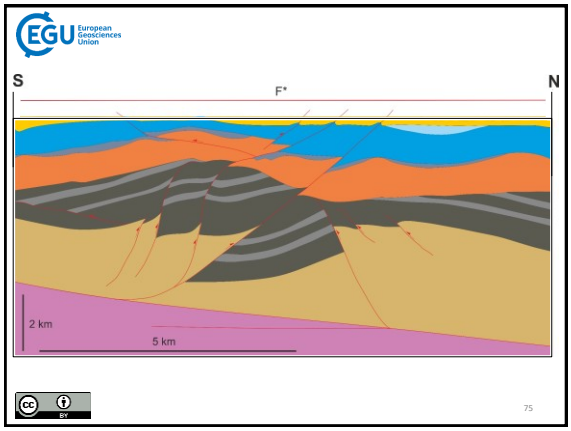
72



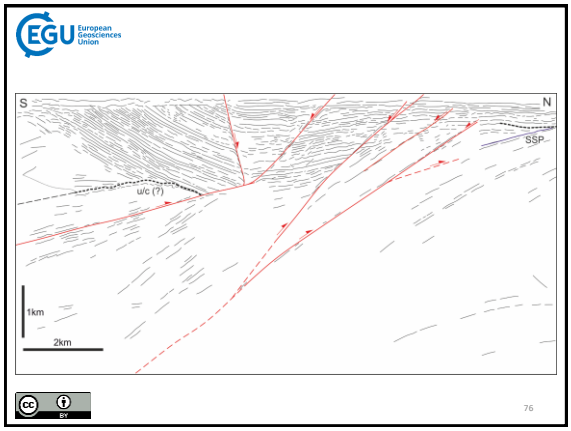
73



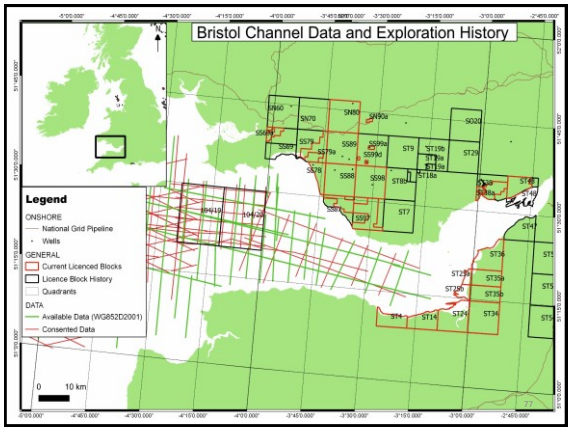
74



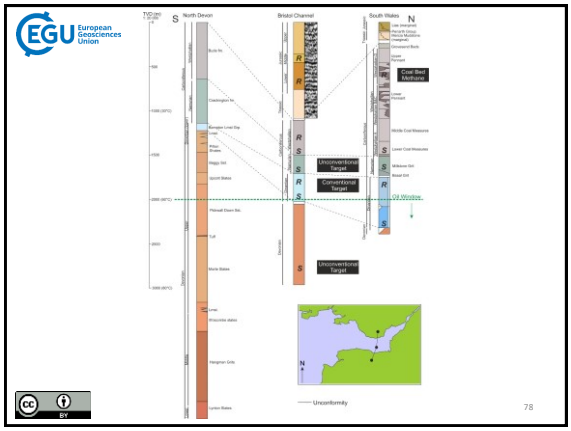
75



76



77



78