



The Deep Structure of Anglesey:

**Insights from Gravity, Magnetic
and Seismic data**



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Geo Môn
Global Geopark

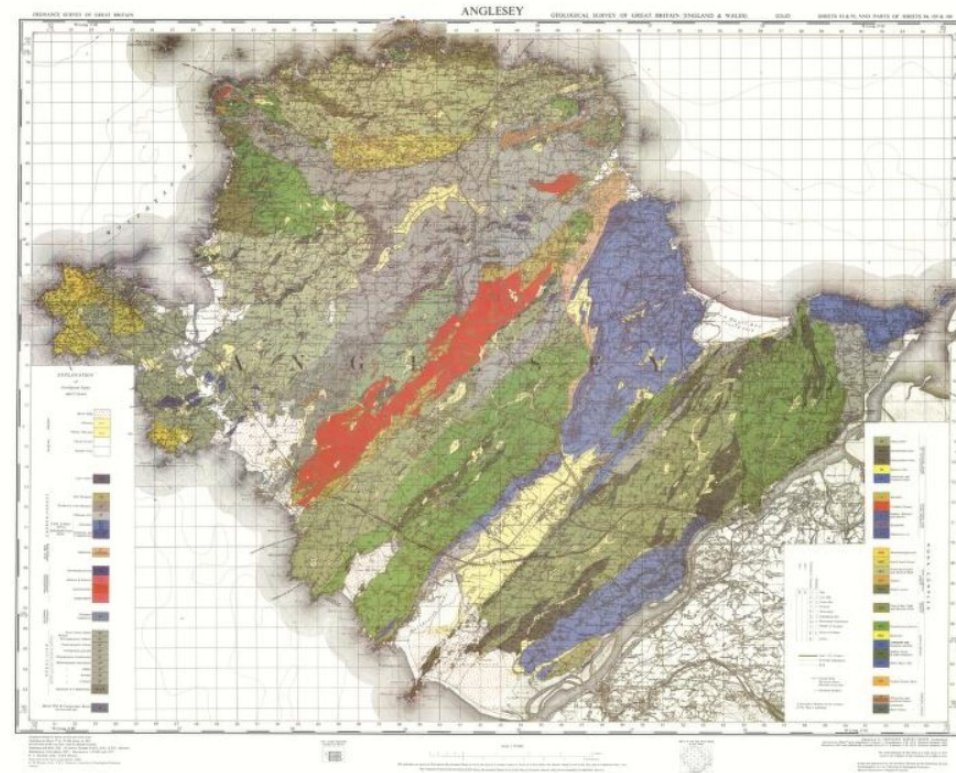


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Geo Môn
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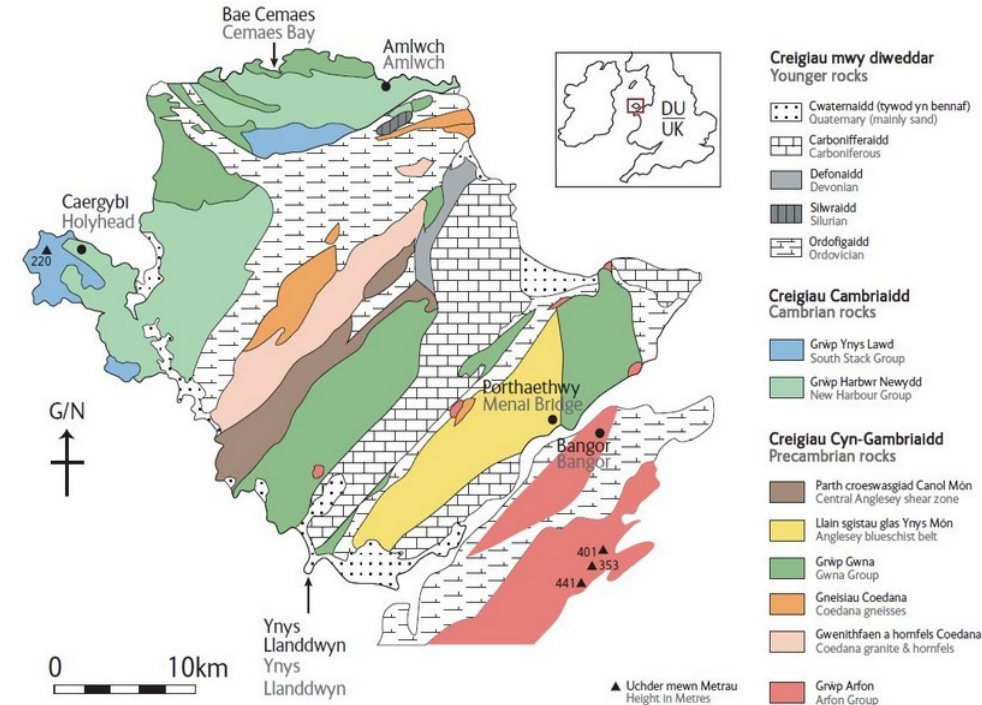
History of Research

- The geology of Anglesey was first described in 1822 by Robert Henslow who was Charles Darwin's tutor at Cambridge
- The island was mapped by Edward Greenly in his retirement after a career in the BGS
- Greenly's work was published by the BGS in 1919 as a two volume memoir plus a geological map
- The memoir has not been updated since 1919. Map last reprinted in 1980
- A cross section across the island has not been created since Greenly's version in 1919



Key points

- the island is extremely flat with poor inland exposures
- the main subject of this talk, the Precambrian and Cambrian rocks, are locally overlain by an unconformable cover of Ordovician and Carboniferous sediment. The boundaries of the major fault blocks are largely obscured
- the only continuous exposures are on the north coast
- structural work to date has concentrated on the north coast



GeoMôn Geology of Anglesey map 2020

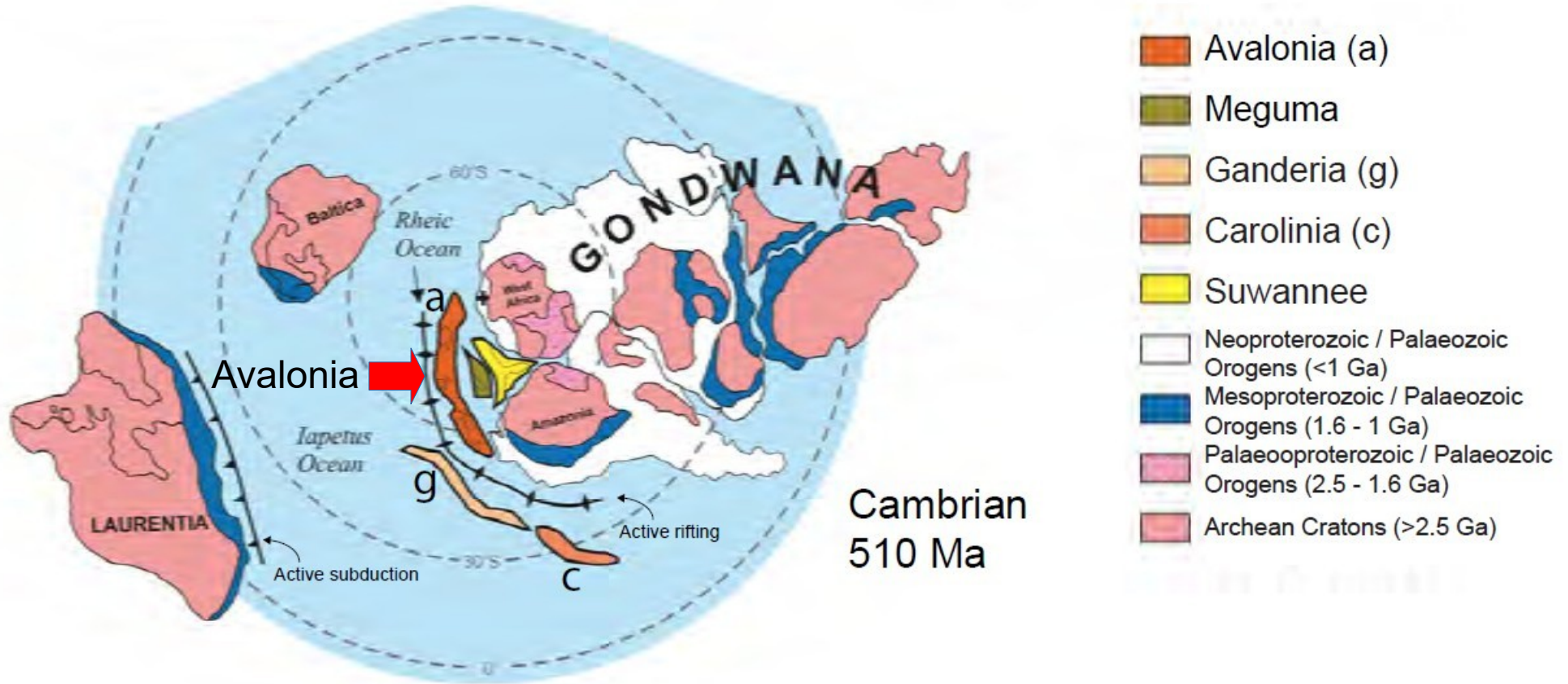


Part 1

- Plate tectonic overview
- stratigraphy and virtual field trip
- existing structural models

Brittania Bridge and the Swellies

Avalonia: Late Precambrian microcontinent accreted onto the margin of Gondwana



End Carboniferous:

Iapetus and Rheic Oceans closed and the formation of the Pangaeian supercontinent

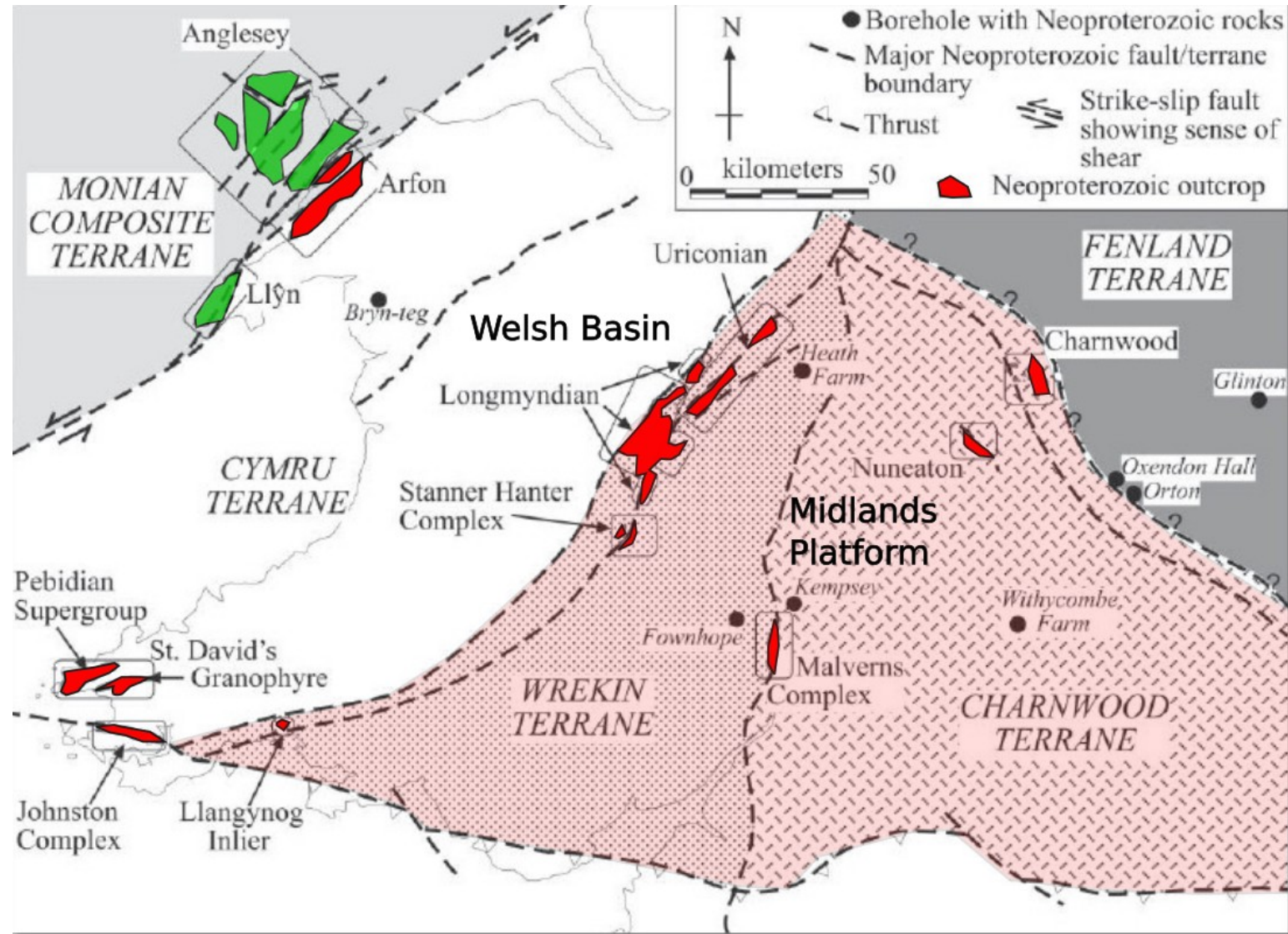


Avalon:

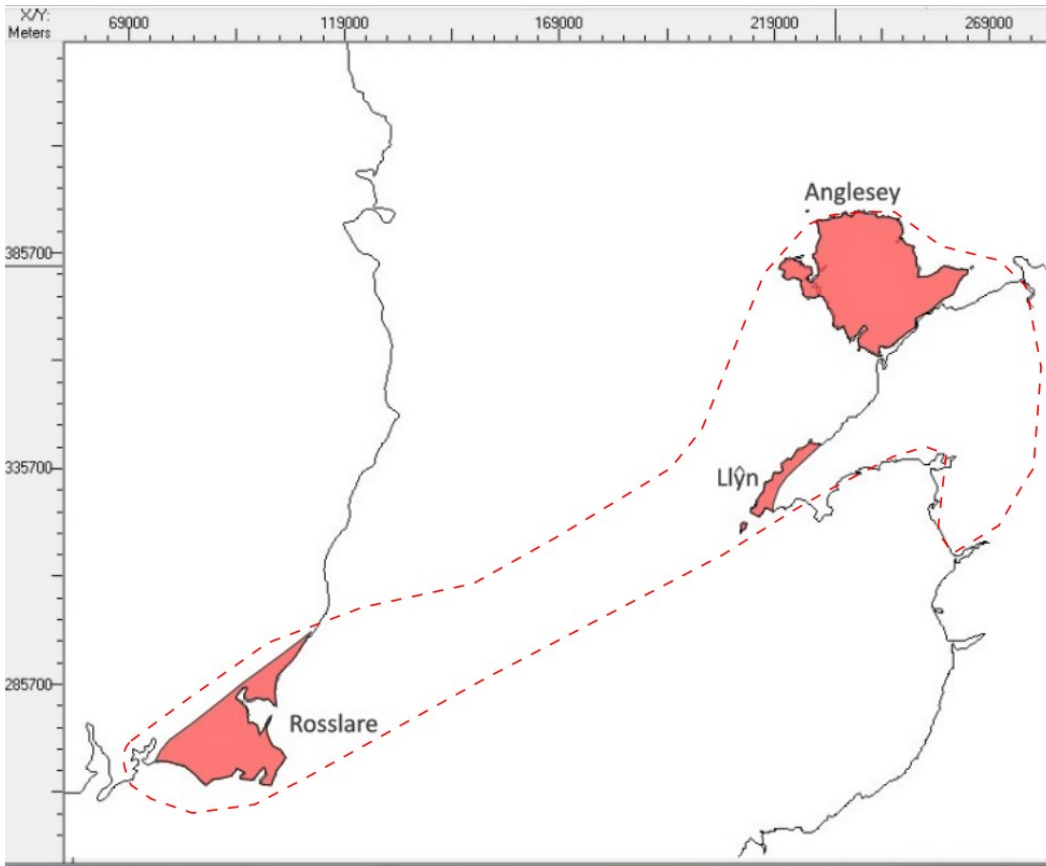
An island of Arthurian legend and possibly located in Glastonbury, Somerset



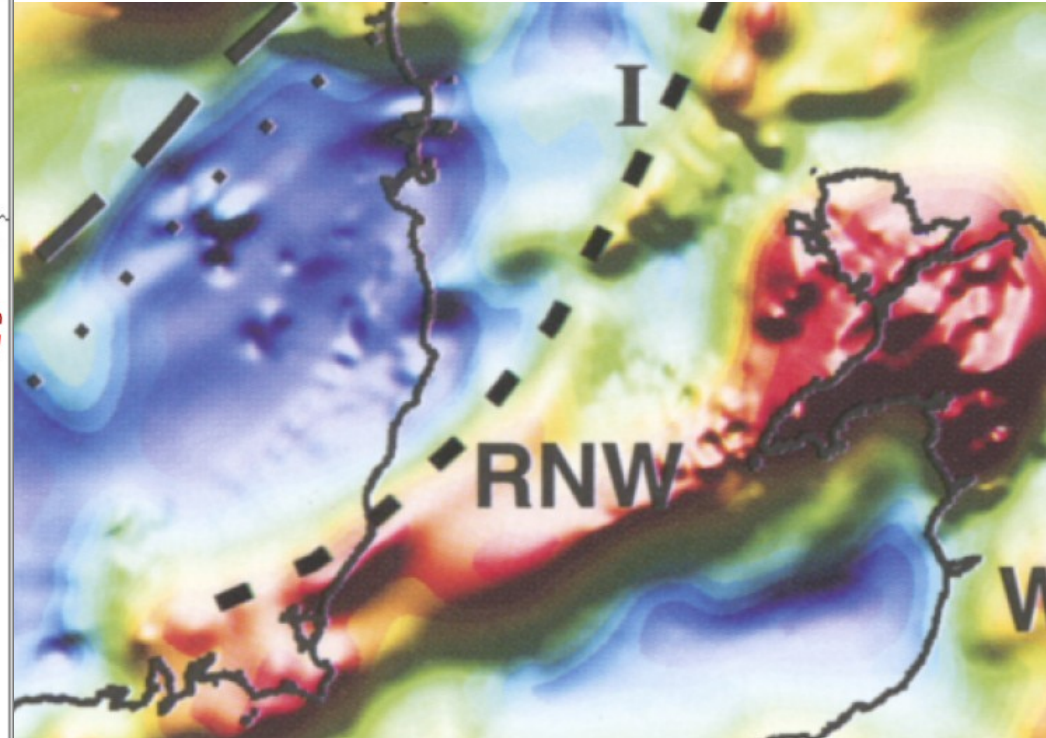
Avalonian basement of Southern Britain



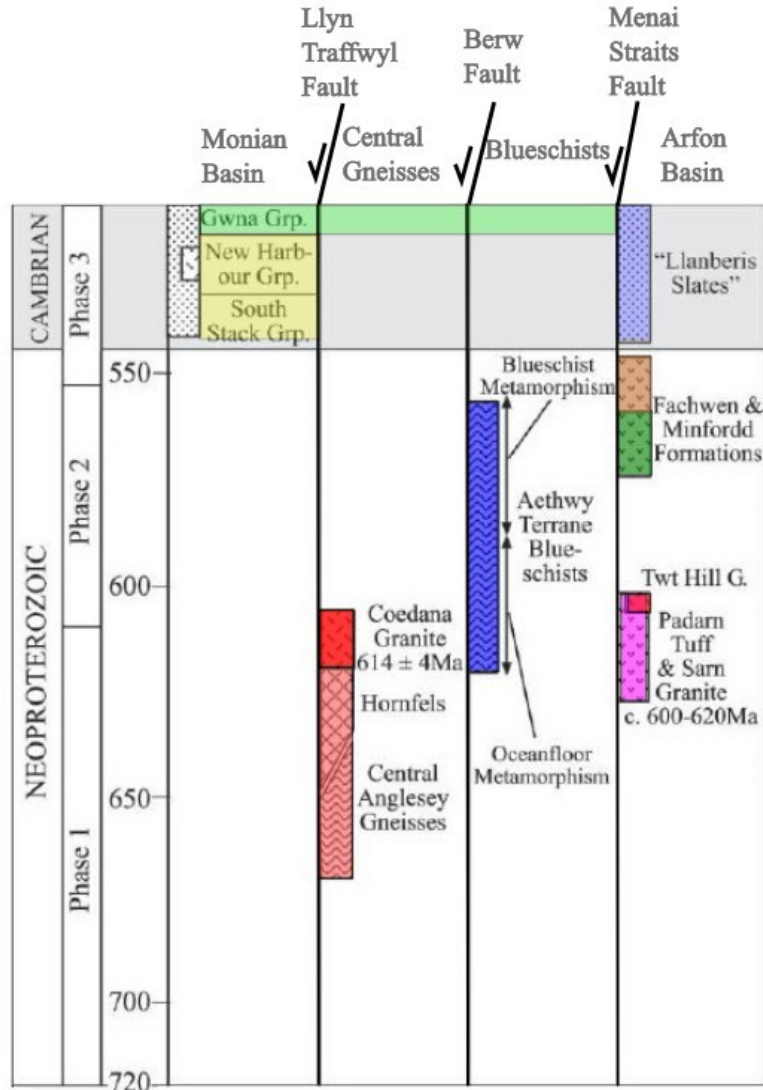
Monian outcrops



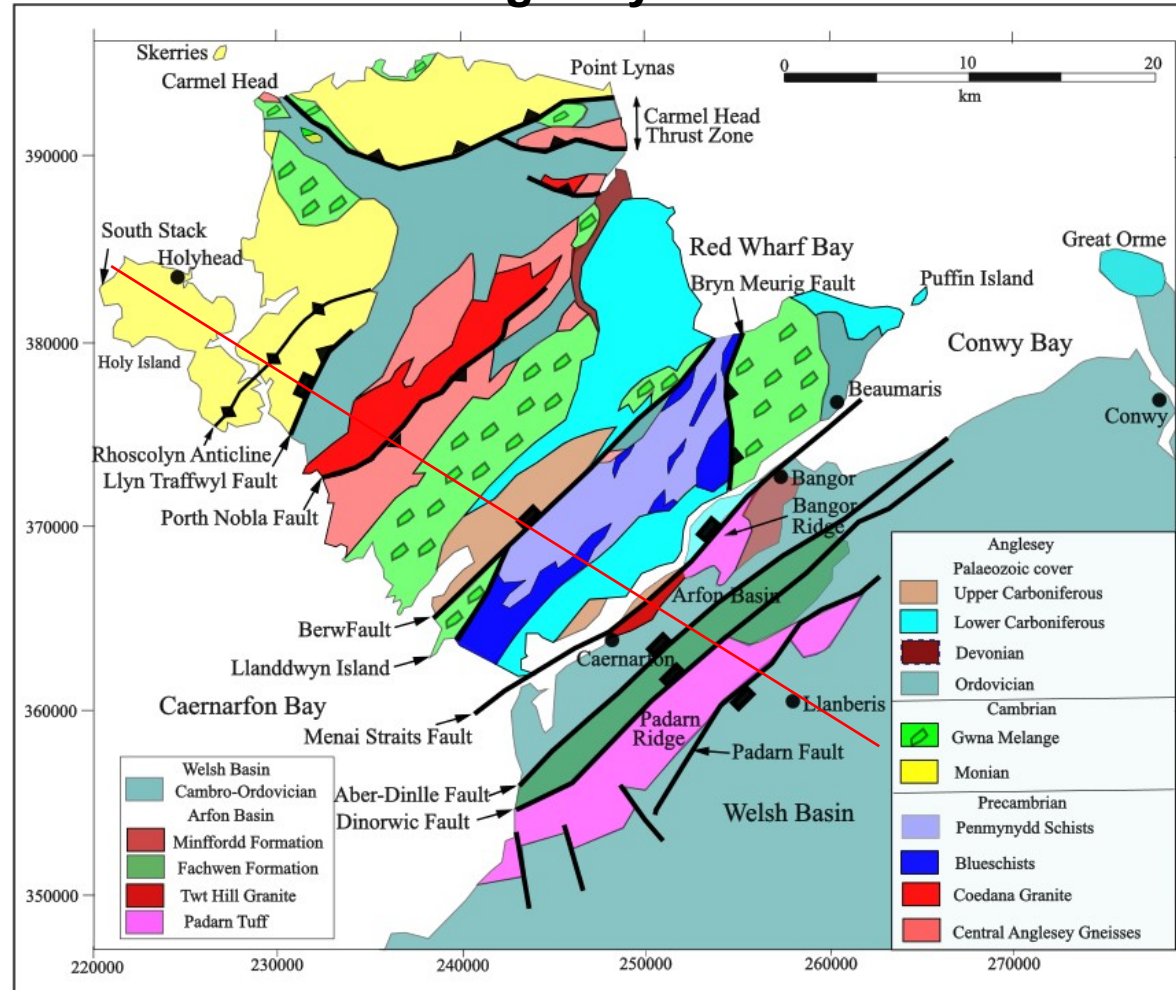
Magnetic anomalies



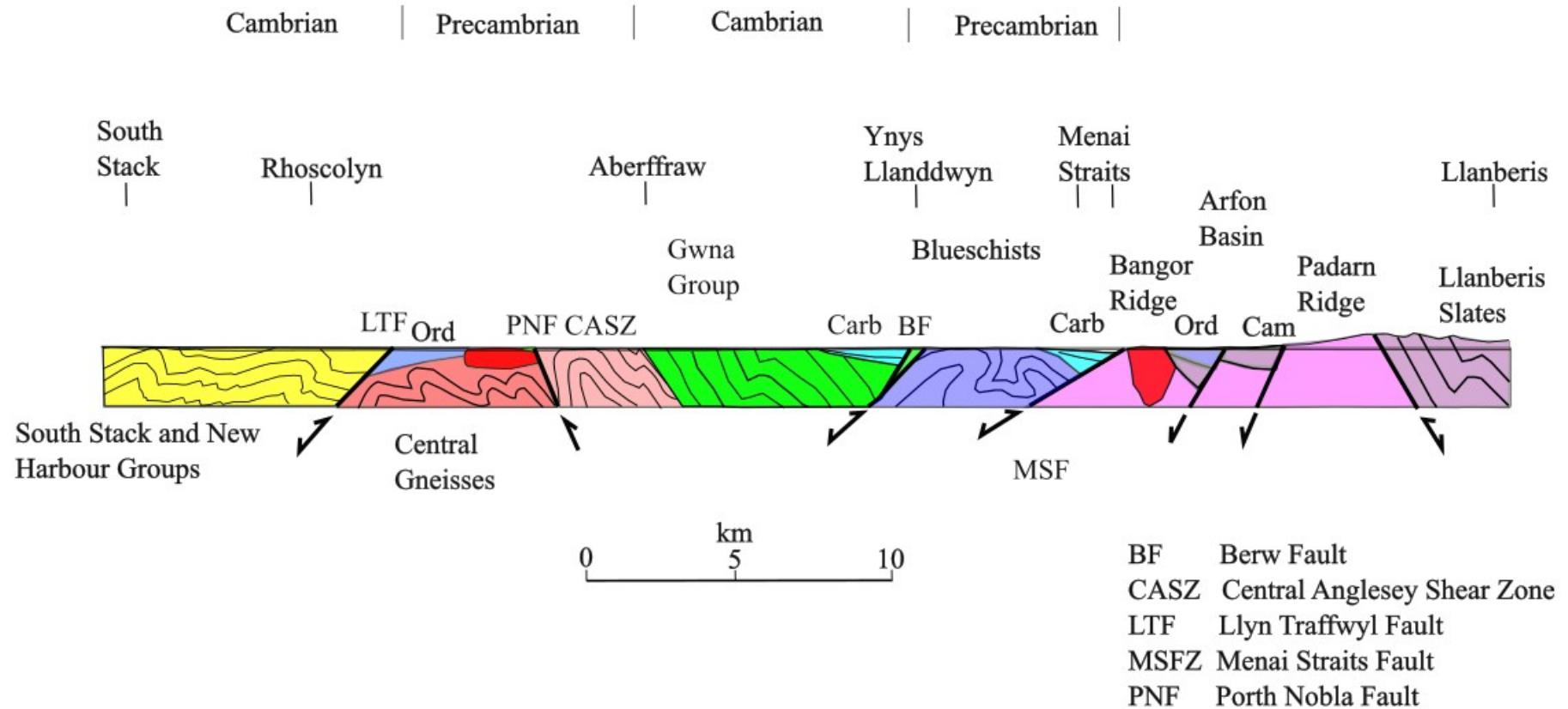
Precambrian and Cambrian stratigraphy of the Arfon Basin and Anglesey



Central Gneisses and Coedana Granite are now considered to be Avalonian

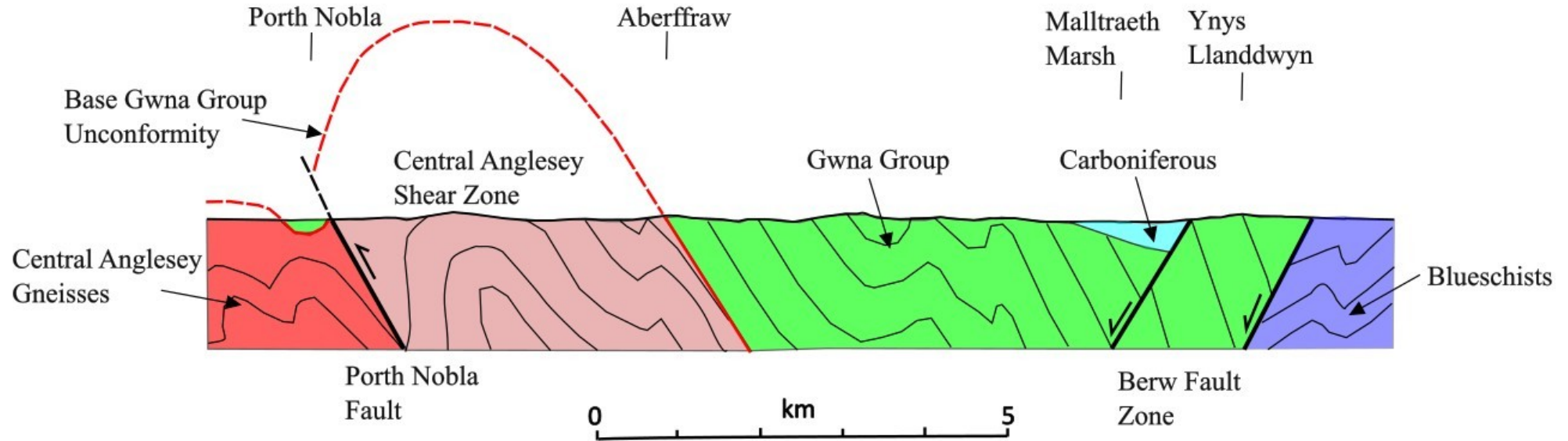


South Stack to Llanberis section



Compiled from various sources and map data

Key section in SW Anglesey: recently described anticline



Compiled from a map in a 2019 PhD thesis and written description in BGS 2021 paper

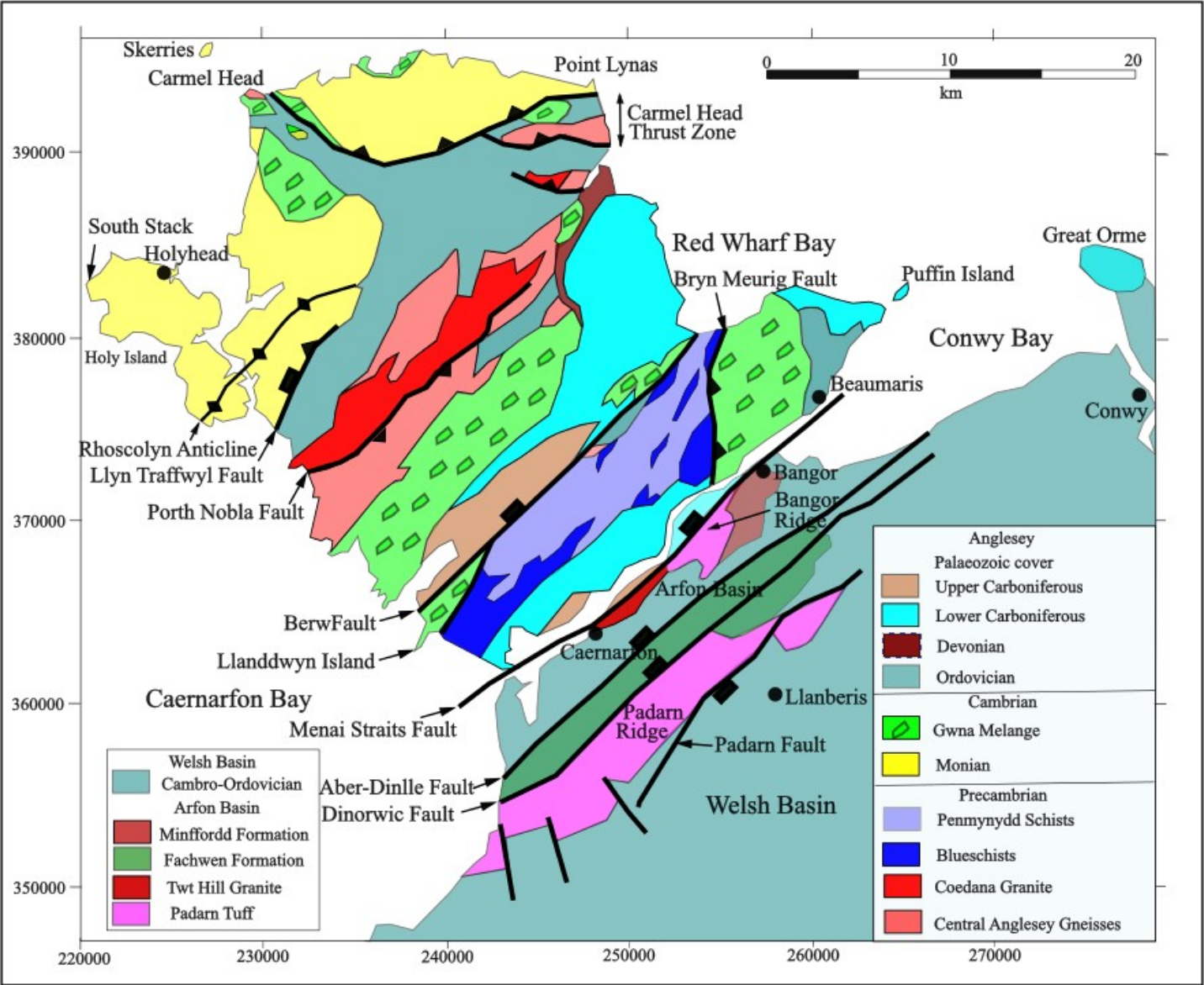
-No cross sections

Virtual Field trip

Disclaimer:

Not intended to be a comprehensive field guide

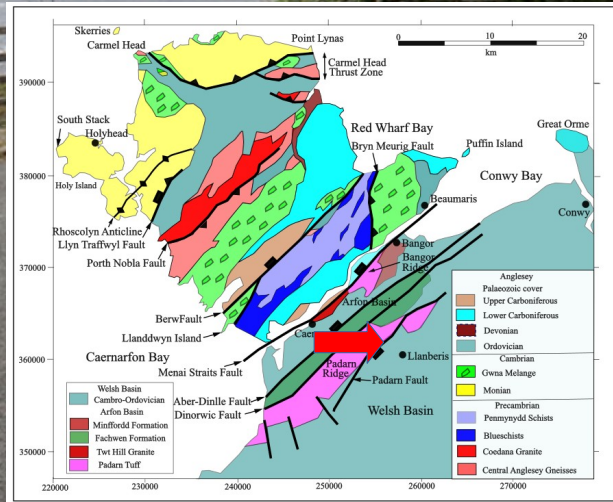
Emphasis is on key lithologies and structure



Avalonian Basement: Precambrian 614 Ma

Padarn Tuff at Craig yr Undeb.
Llyn Padarn

Ignimbrites. Rhyolitic ash flow tuffs



From: North Wales Bouldering website

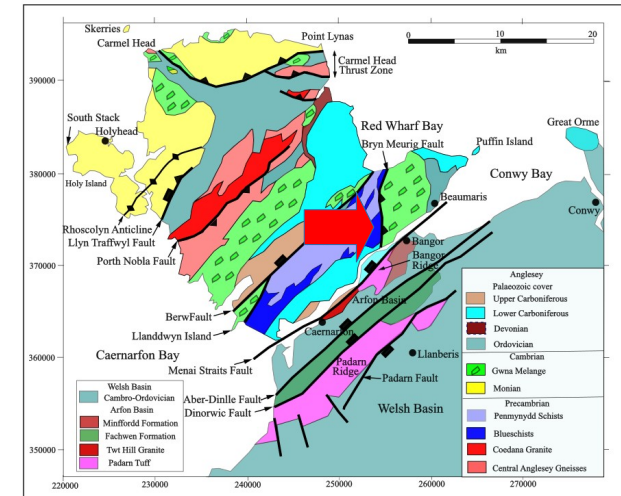


Blueschists at the base of the Marquis of Anglesey's column, Plas Newydd

Late Precambrian 590-580 Ma

Blueschist metamorphism indicates low temperature (ca. 500°C) and high pressure (ca 30km depth) in a subduction zone setting

Schistose metasediments and mafic igneous rocks. The diagnostic Blueschist minerals, Glaucofan and Lawsonite, are restricted to lenticular pods of basic rock.





Blueschists at the base of the Marquis of Anglesey's column, Plas Newydd

Late Precambrian 590-580 Ma

Sheared pillow lava in schistose metasediments

Note: It is not an Ophiolite

Image from
GeoMon



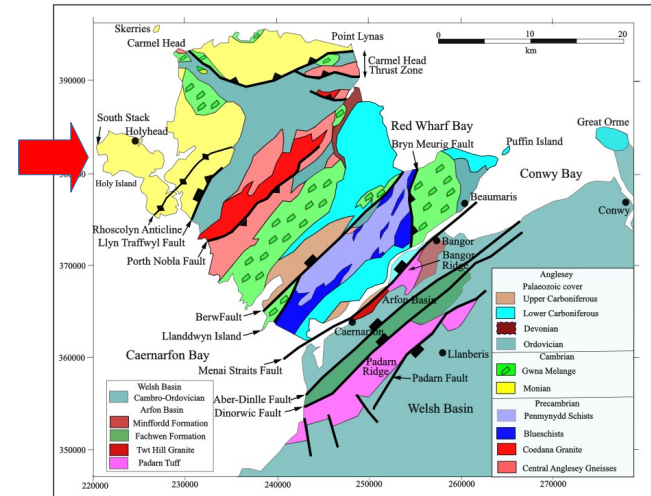
South Stack Group, South Stack Holy Island

Cambrian

Minimum age of 501 Ma from detrital zircons. Skolithos in overlying Holyhead Quartzite

Turbiditic sands and muds.
Lower Greenschist facies

SW verging major folds



Rope
Not a second lighthouse





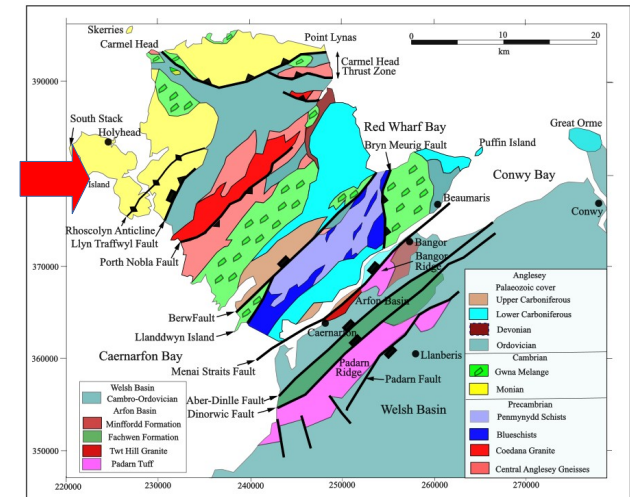
New Harbour Group, Porth y Pwll, Holy Island

Cambrian

Thinly bedded and fine grained

SE verging minor folds

Treagus, 2008



➡ Vertical and younging
to the SE



Pillow Lavas

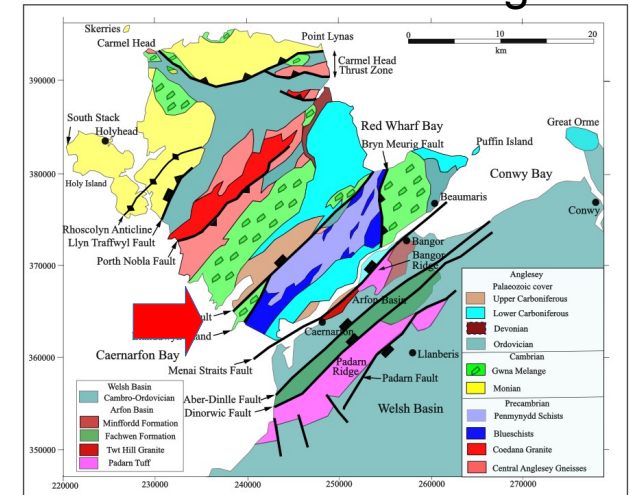
Image from Geomon

Gwna Group, Ynys Llanddwyn Cambrian

Olistostrome, Melange
or Mega conglomerate

Clasts range in size from
centimetres to hundreds of metres
and are a range of igneous and
sedimentary rocks in a sand or
mud matrix

Lower Greenschist to burial diagenesis



Gwna Group from Space

Medium size clasts
in the Gwna Group



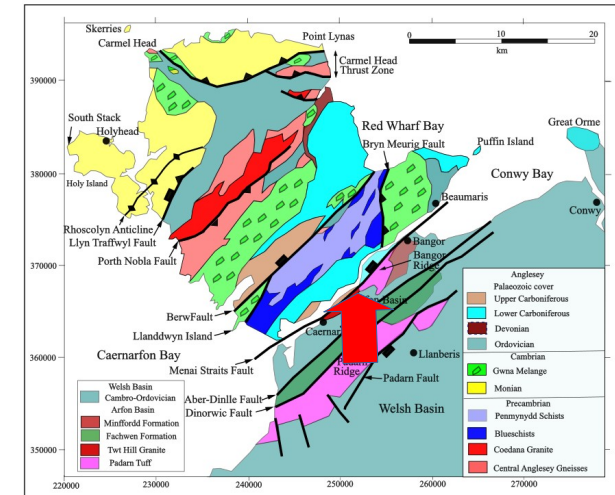


Lower Carboniferous

Dinantian Shelf Carbonates
Port Dinorwic/Y Felinheli

Menai Straits Fault is 200m
to the right.

Dip is towards the fault





Blueschists

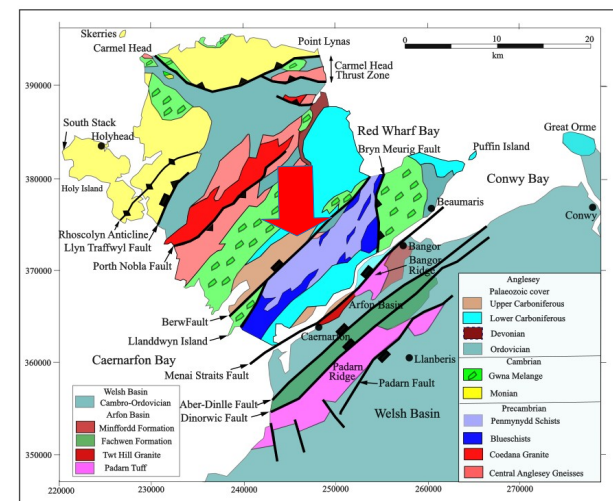
Berw Fault

Coal Measures

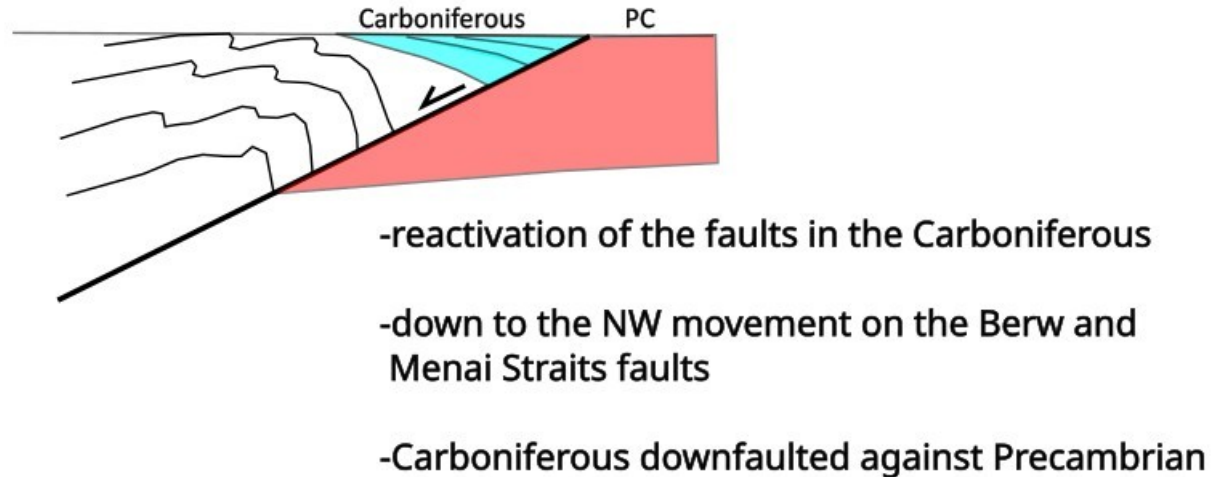
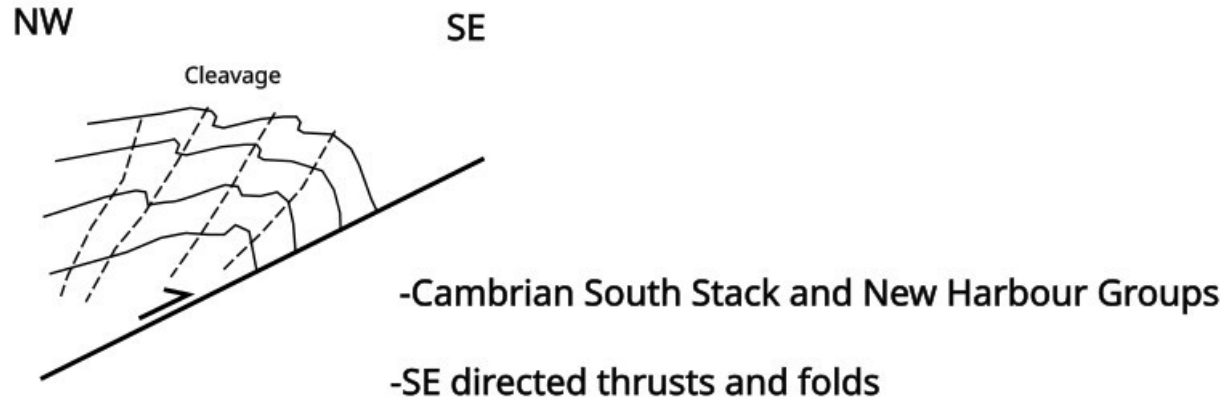
Upper Carboniferous Westphalian Coal Measures Berw Colliery

The Coalfield is beneath
Malltraeth Marsh. Mines required
constant pumping.

Record of coal exported from
Beaumaris to France in 1595.
Last colliery closed in 1878

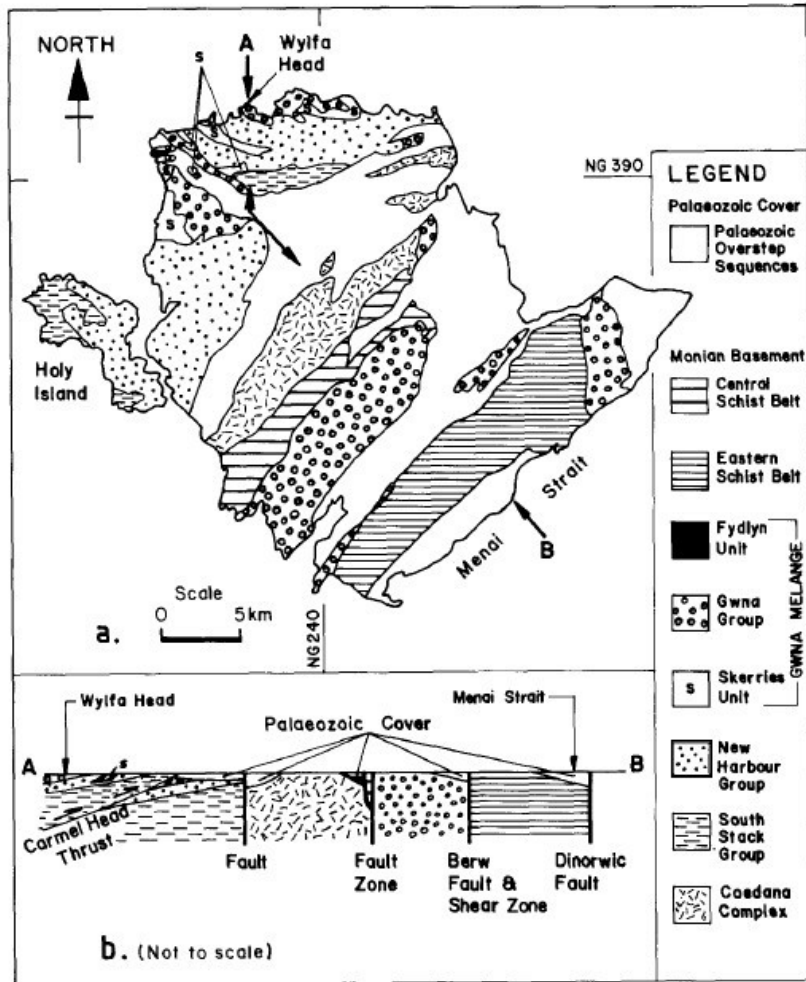


Structural observations from outcrop



Consistent with fault planes dipping to the NW

Gibbons and Ball, 1991



Tectonics: The California model

- fault blocks bounded by steep to vertical faults
- each fault block is considered to be an unrelated exotic or a suspect terrane
- considerable horizontal strike slip movement envisaged to emplace the fault blocks in their present positions
- all of the lithologies are Precambrian
- now the standard model for Anglesey

Fig. 1. Geological sketch map and section of Anglesey. The Coedana Complex may have formed a basement to the Monian Supergroup cover, although all contacts are now brittle faults or shear zones such as the 'Central Schist Belt'. The Eastern Schist Belt includes exotic blueschists lying between the Berw and Dinorwic Faults. Fydlun unit lithologies are considered part of the Gwna Group melange. Skerries unit lithologies occur both within the New Harbour Group and in the Gwna melange.

(a)

c. 485-475 Ma

Late Cambrian-Early Ordovician

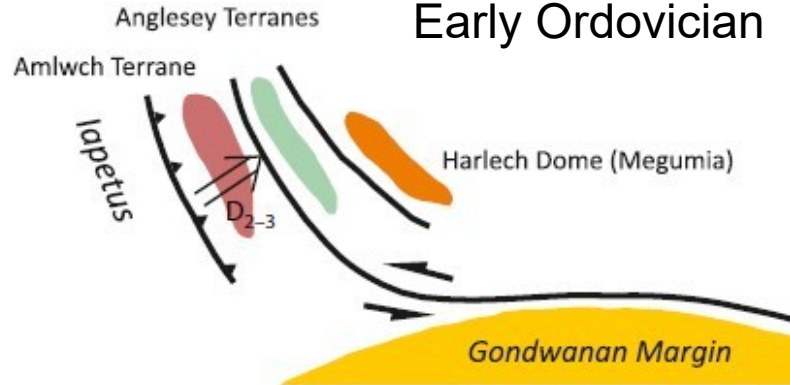
Penobscot Arc/Back-Arc and Amlwch Terrane



(b)

c. 475-470 Ma

Early Ordovician



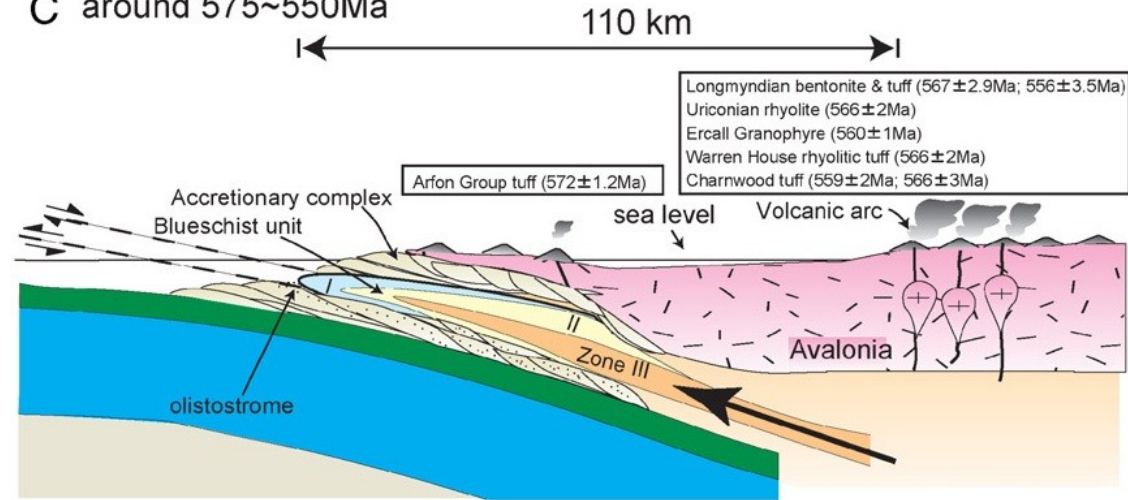
Tectonics: The Caribbean model

- fault blocks bounded by steep to vertical faults
- each fault block has a distinct lithology
- considered to be unrelated exotic or Suspect Terranes
- considerable horizontal strike slip movement envisaged to emplace the fault blocks in their present positions
- the Harlech Dome is included in the Suspect Terrane concept

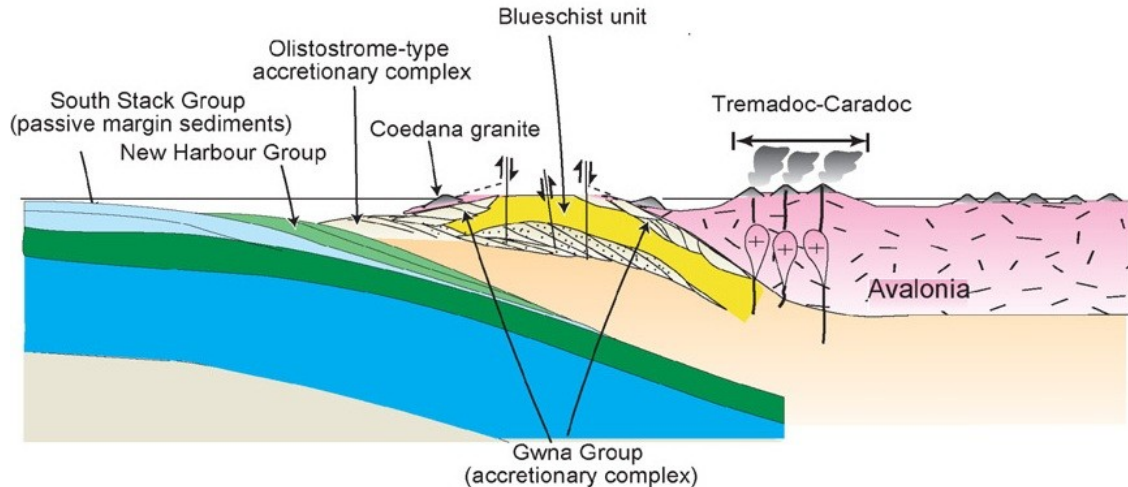
Schofield et al, 2021

BGS

Late Precambrian
C around 575~550Ma



D Tremadoc-Caradoc, c. 488-448 Ma



Kawai et al 2007

Tectonics: The Pacific model

- Team of Japanese researchers on sabbatical at the University of Leicester with Brian Windley
- the Blueschists fit the model
- No evidence of the South Stack, New Harbour and Gwna Groups being the products of an accretionary prism
- the structural fabric dips beneath the leading edge of Avalonia
- this is opposite to the evidence in this presentation

Part 2: Interpretation



- Feature mapping
- Gravity and Magnetic data
- Seismic data
- Gravity Model
- Cross section

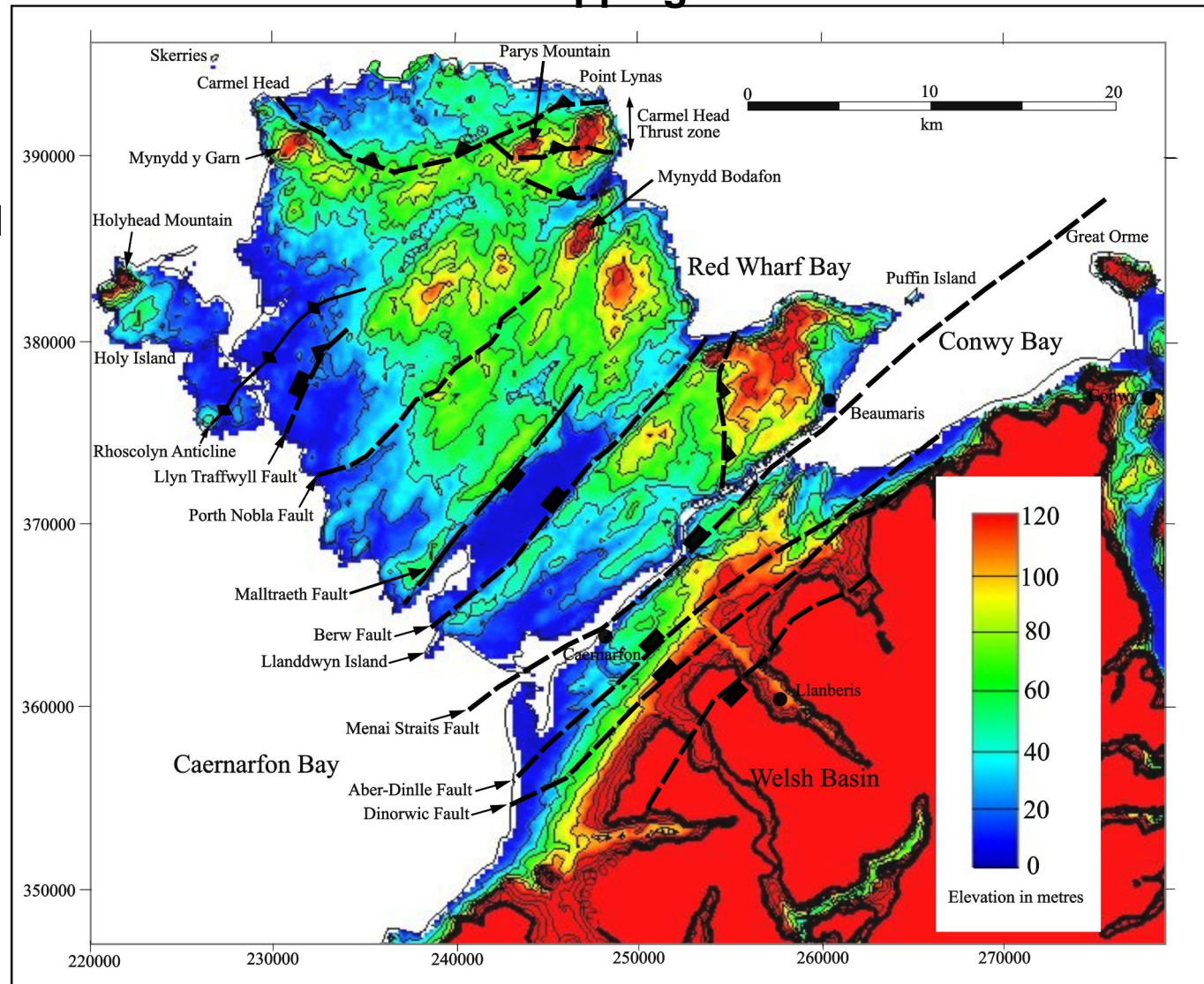
Looking west from the Conwy Estuary

Feature mapping

Ordnance Survey
Digital elevation model

Downloaded from the
Ordnance Survey
website as simple
XYZ grid

Anglesey was
peneplaned by the
Irish Sea Ice Sheet



Geophysical Data

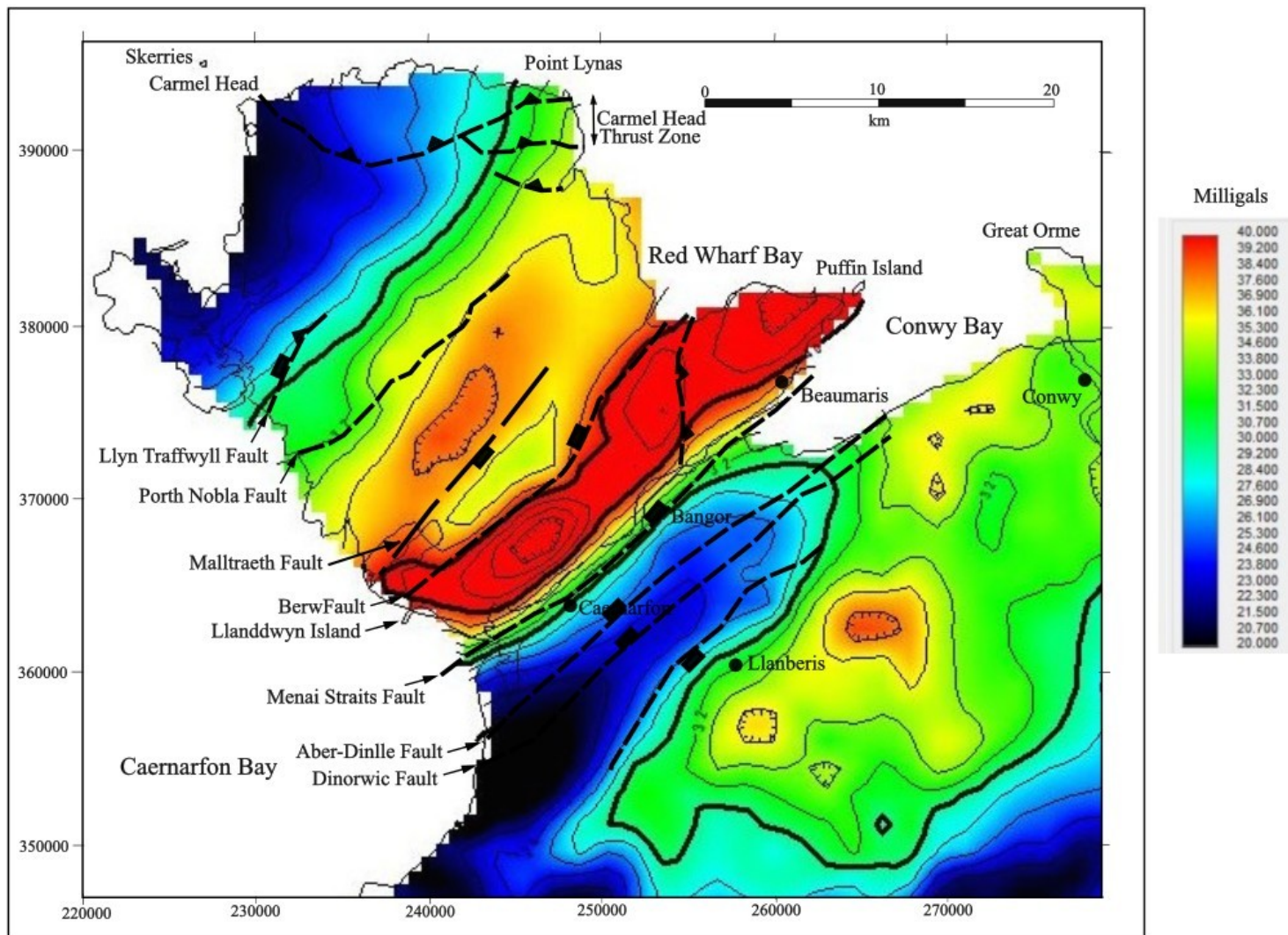
Potential Fields

- onshore gravity and magnetic data from the BGS (public domain)
- offshore satellite gravity data from the OGA/NSTA (public domain)

Seismic:

- associated with the UK Onshore Geophysical Library (UKOGL)
- access to all of the onshore seismic and borehole records
- offshore data has recently been added, including Cardigan Bay and Central Irish Sea

Bouguer Gravity

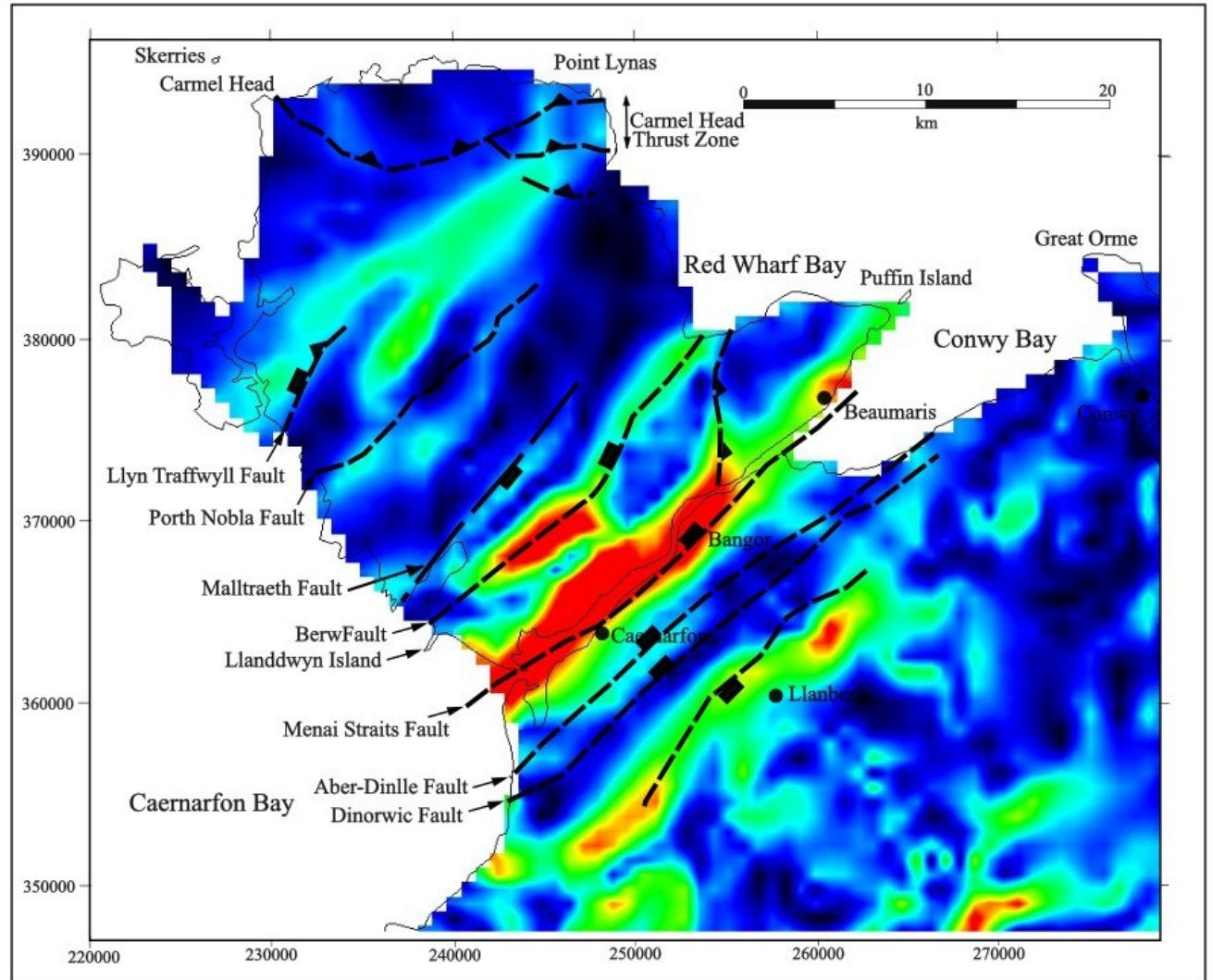


Bouguer Gravity

amplitude of gradient attribute

-Edge detection.

-lineaments are highlighted
with positive (red) values



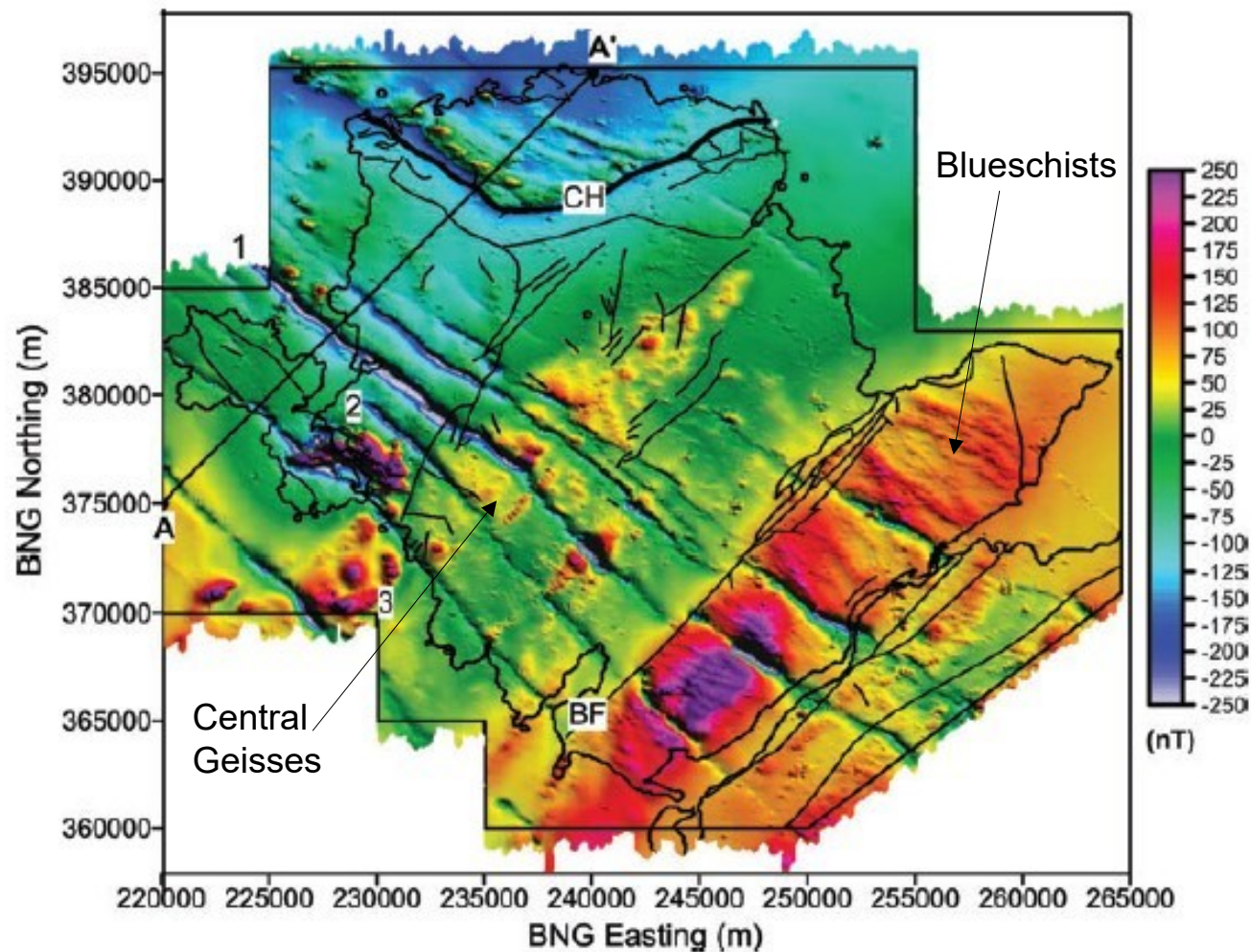
BGS High Resolution Aeromagnetic Survey

Acquired in 1998

Flight line spacing 240m

Flight height 90m

Not public domain

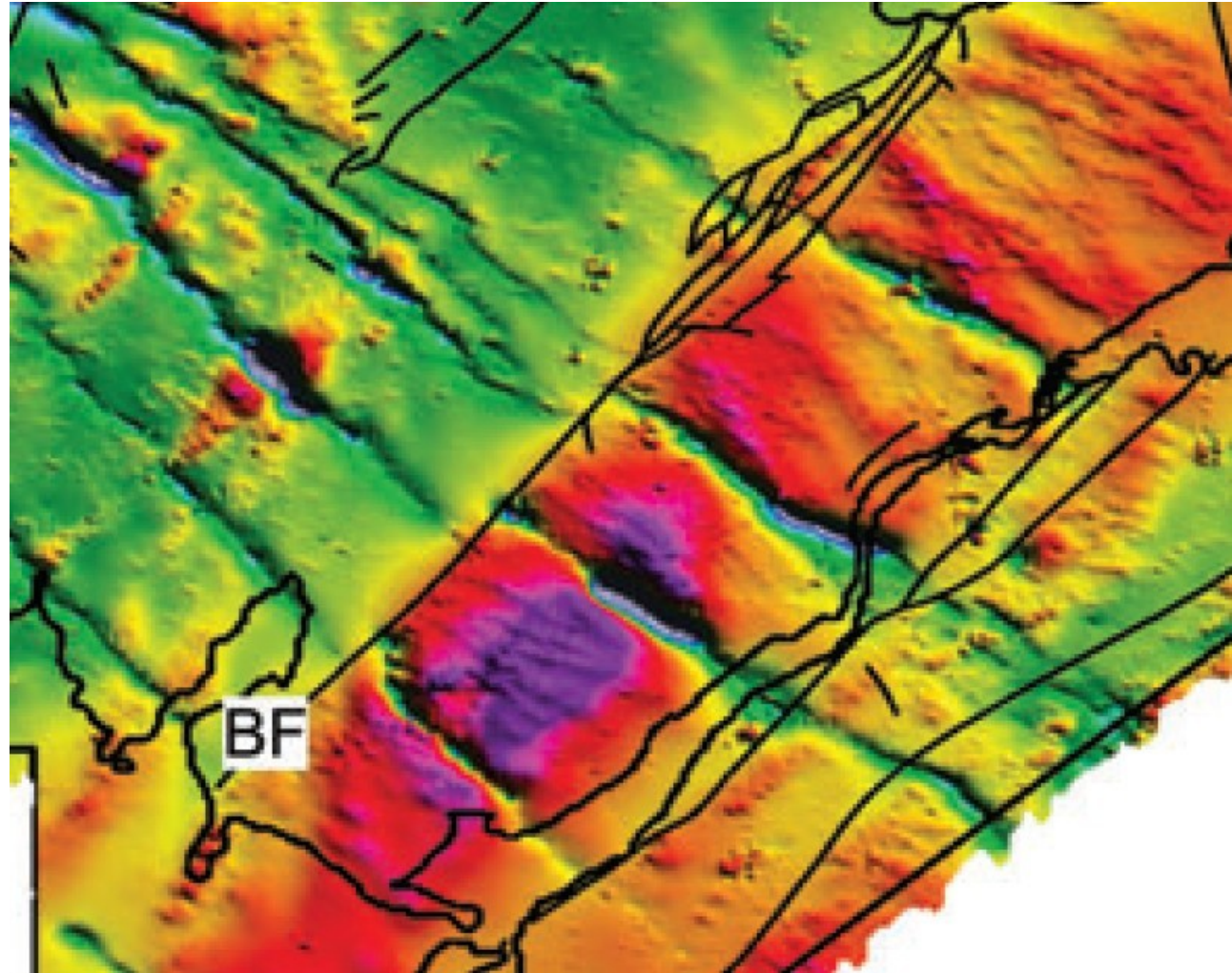


Tertiary Dykes

Part of a late Palaeocene dyke swarm extending from Northern Ireland to Shropshire and Staffordshire

The dykes display consistent left-lateral displacement across the Berw Fault

Post Palaeocene movement

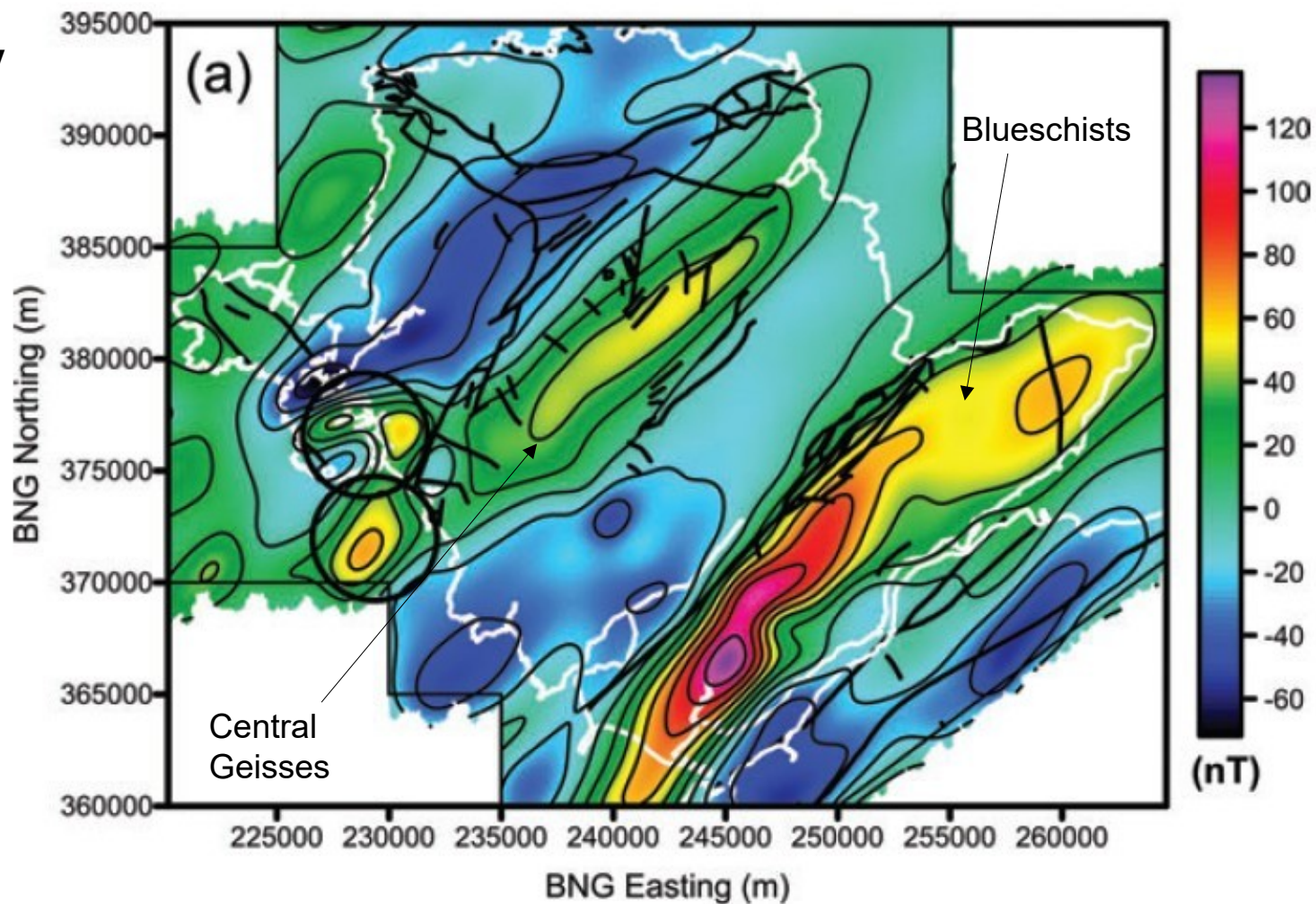


Menai Straits
Fault Zone

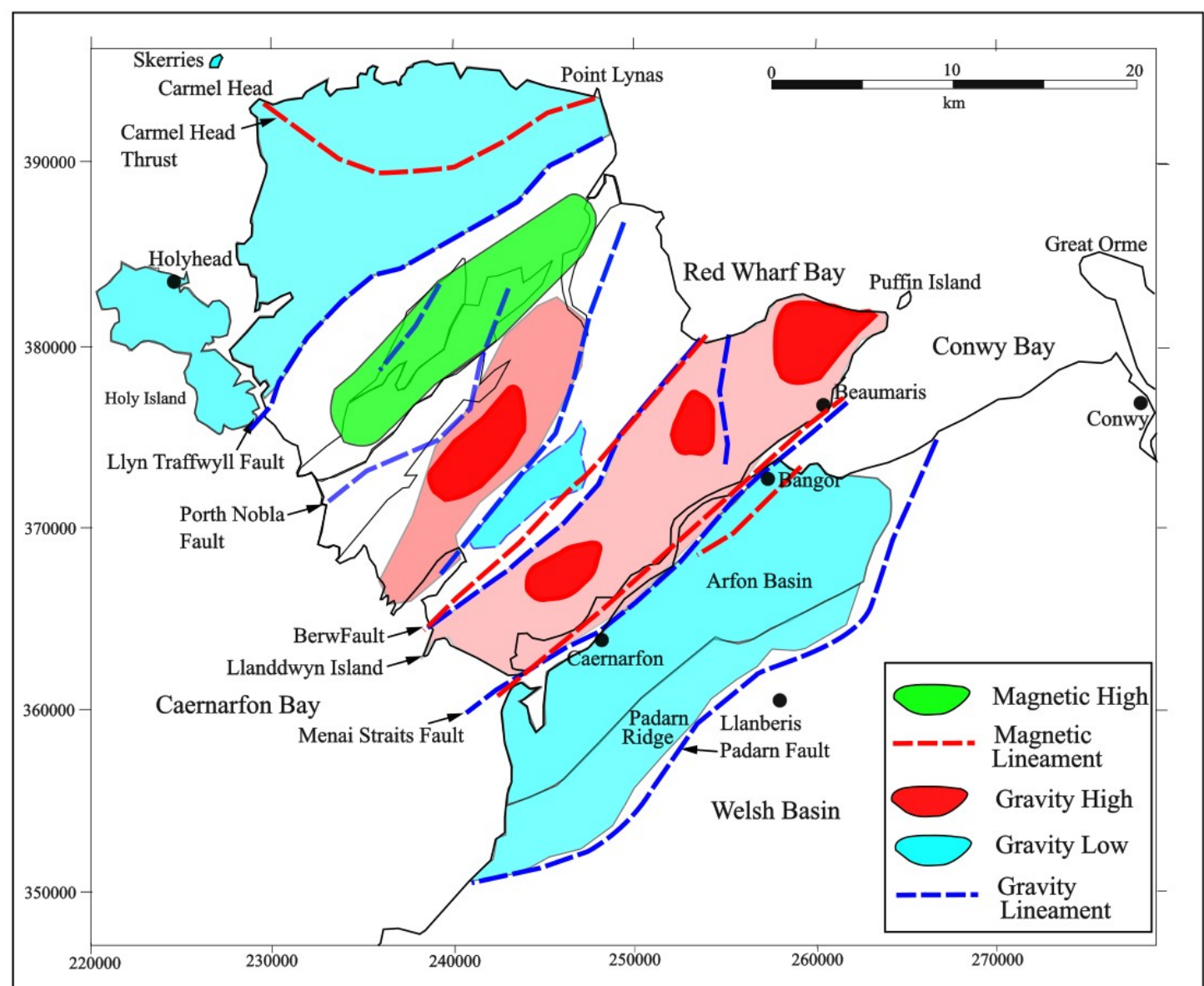
BGS High Resolution Aeromagnetic Survey

Depth to magnetic
basement

Precambrian structural
highs and Cambrian
Basins



Summary of gravity and magnetic anomalies



Greenly (1919)

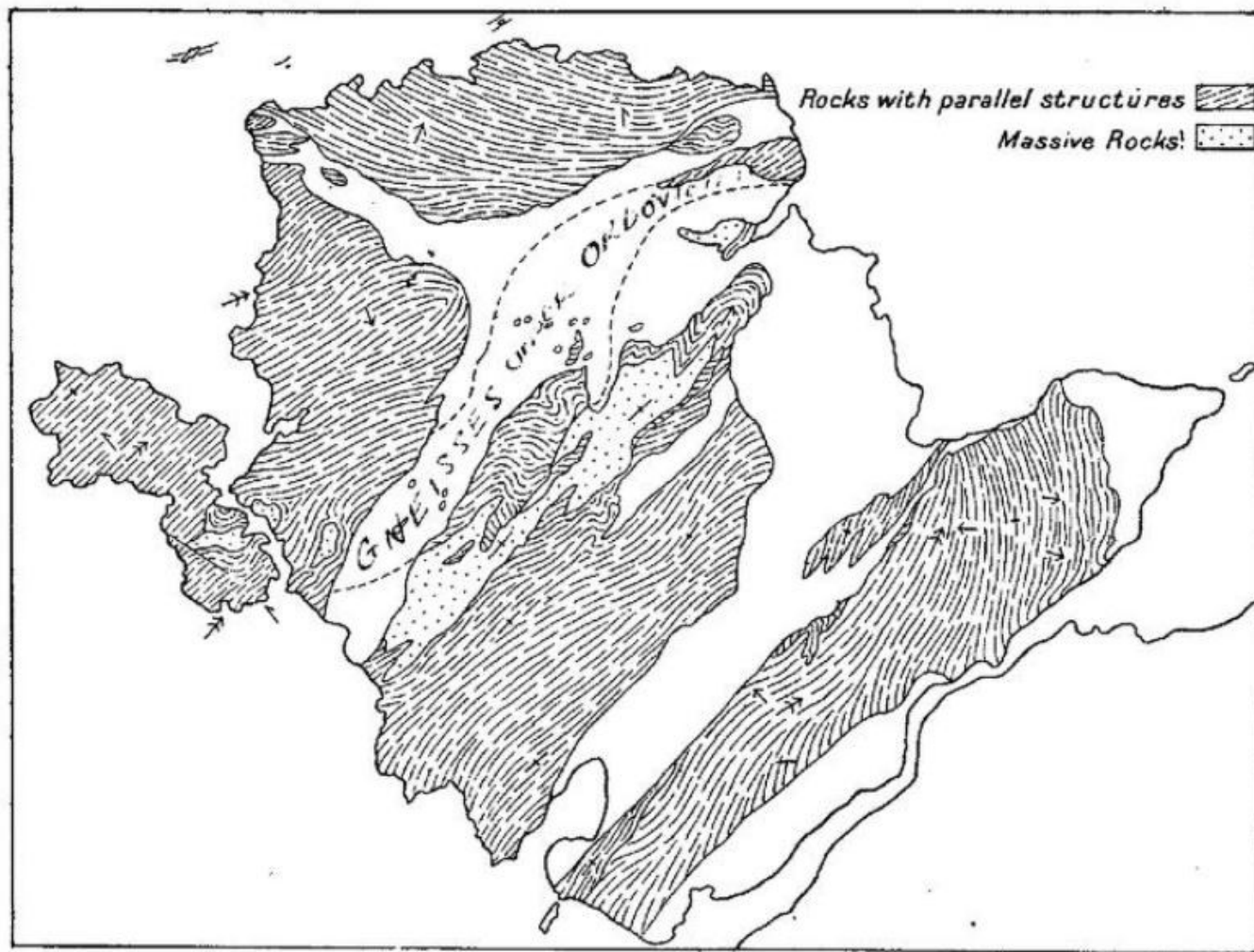
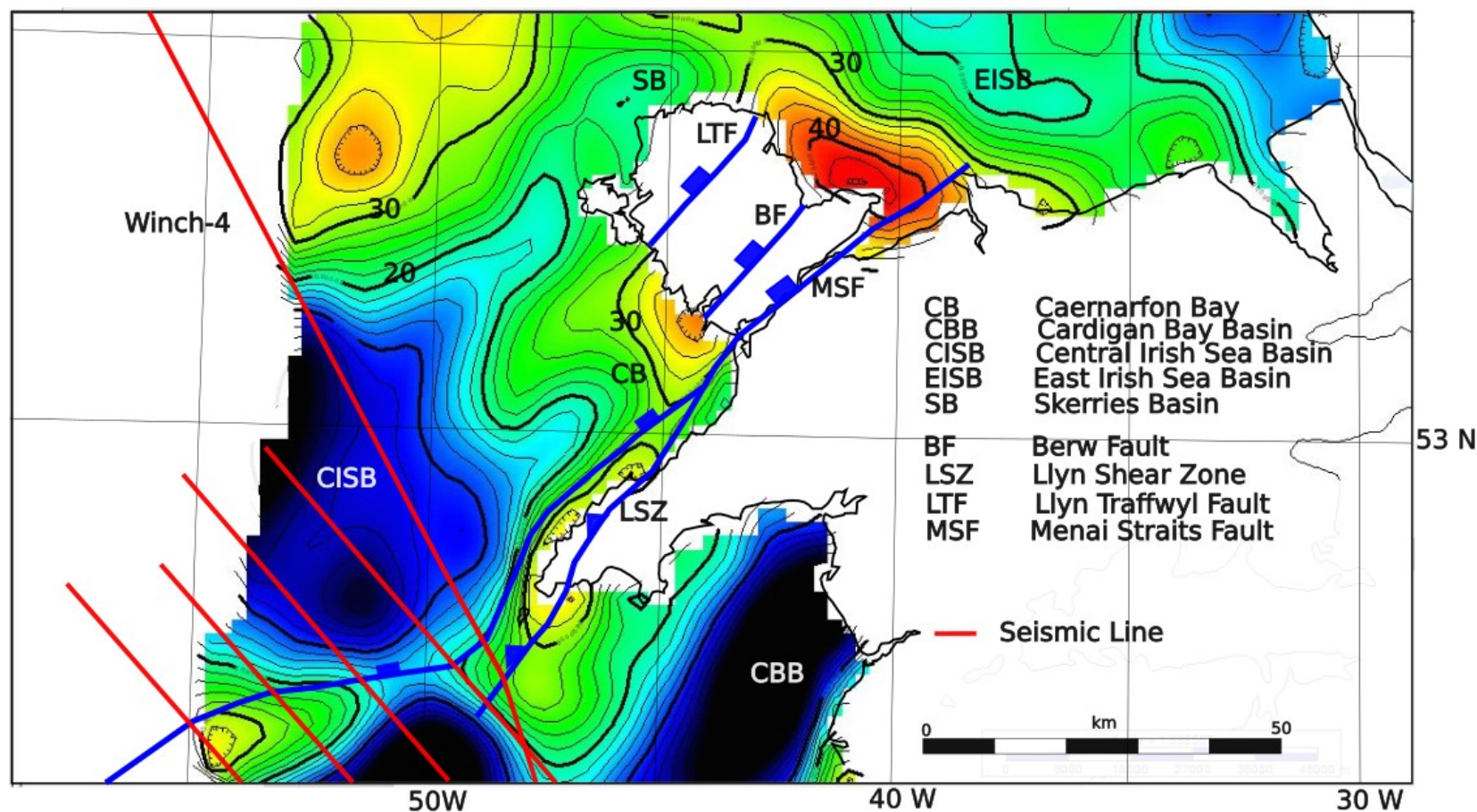
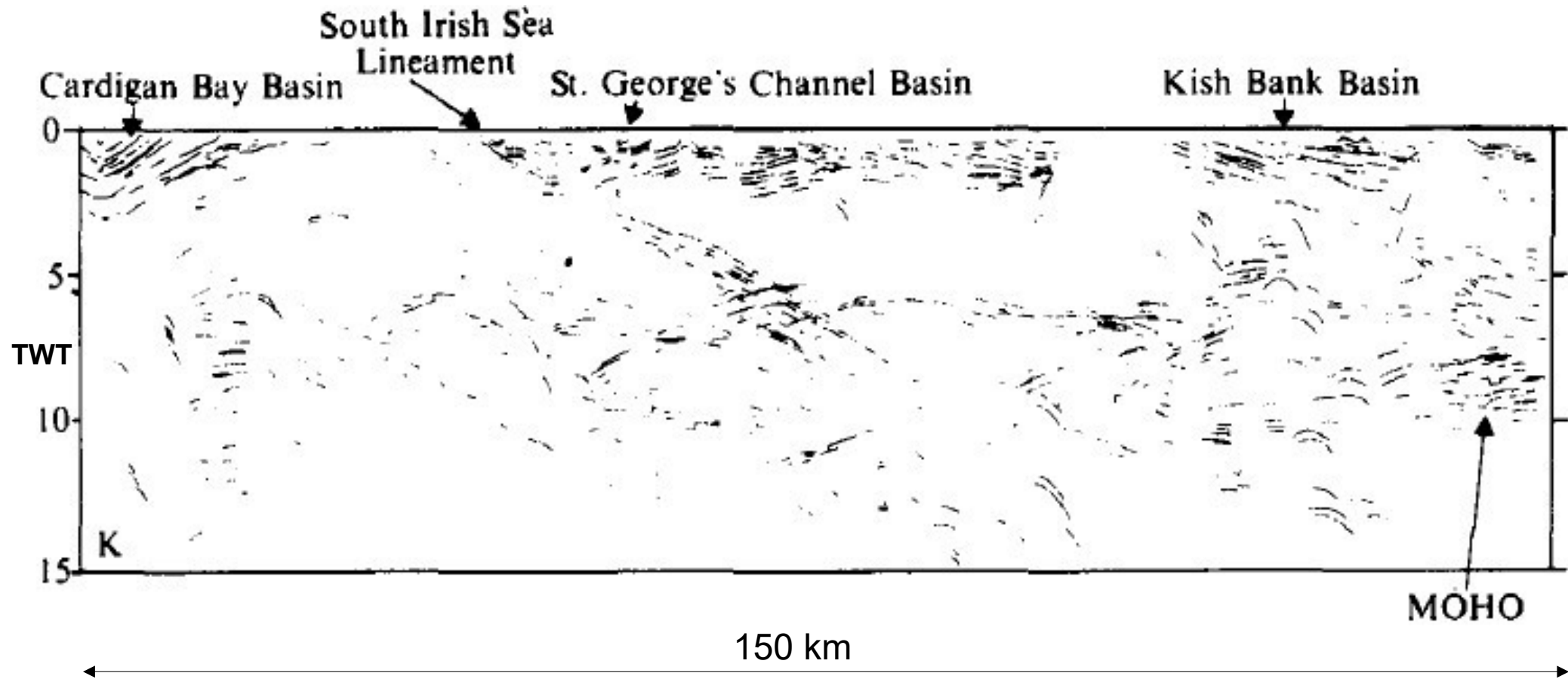


FIG. 101.—CHART SHOWING THE GENERAL DIRECTIONS OF STRIKE AND OTHER STRUCTURES IN THE MONA COMPLEX.

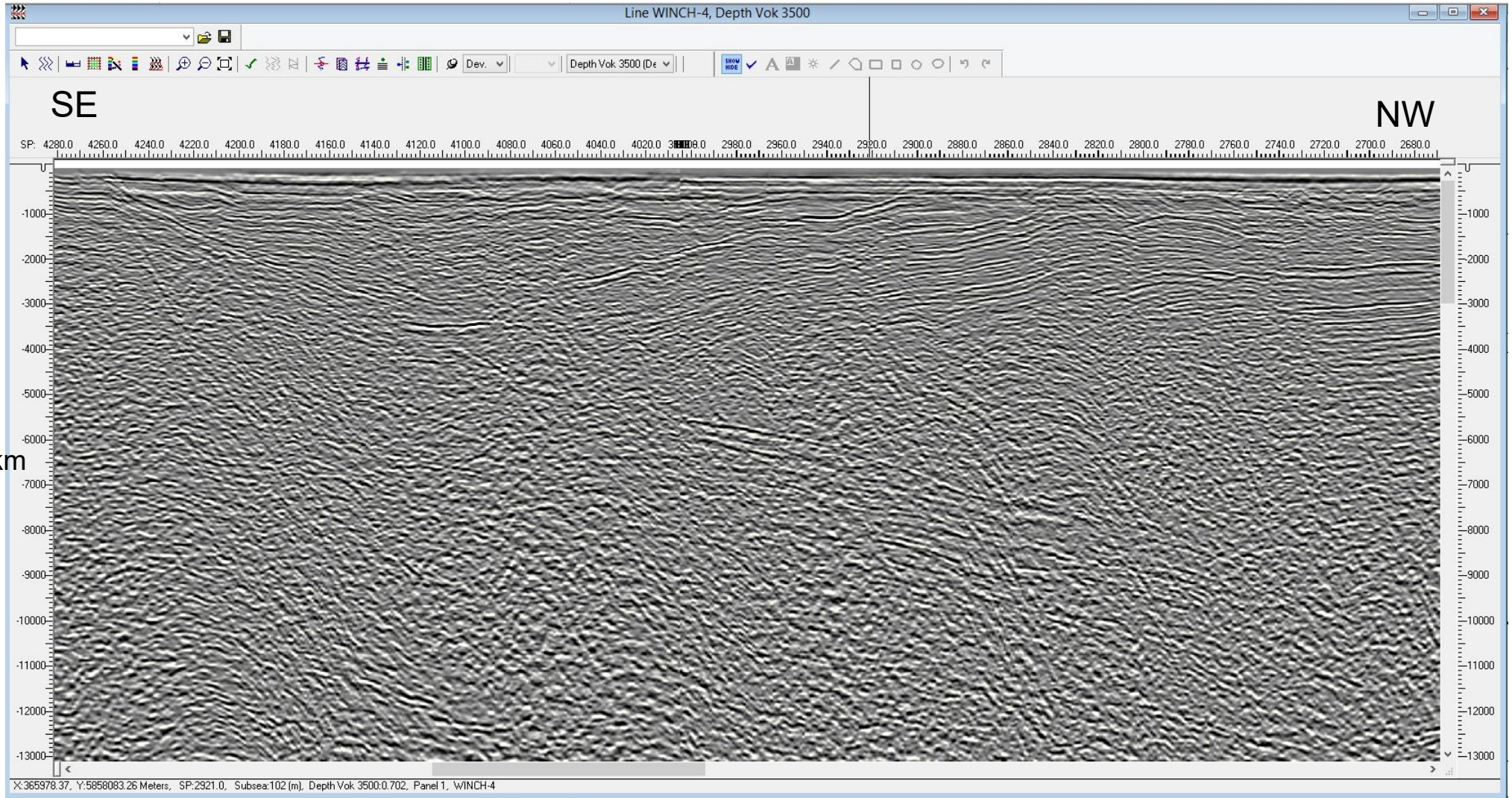
Evidence for the dip of the Menai Straits Fault:

Offshore Satellite Gravity data with seismic lines





Winch-4 line

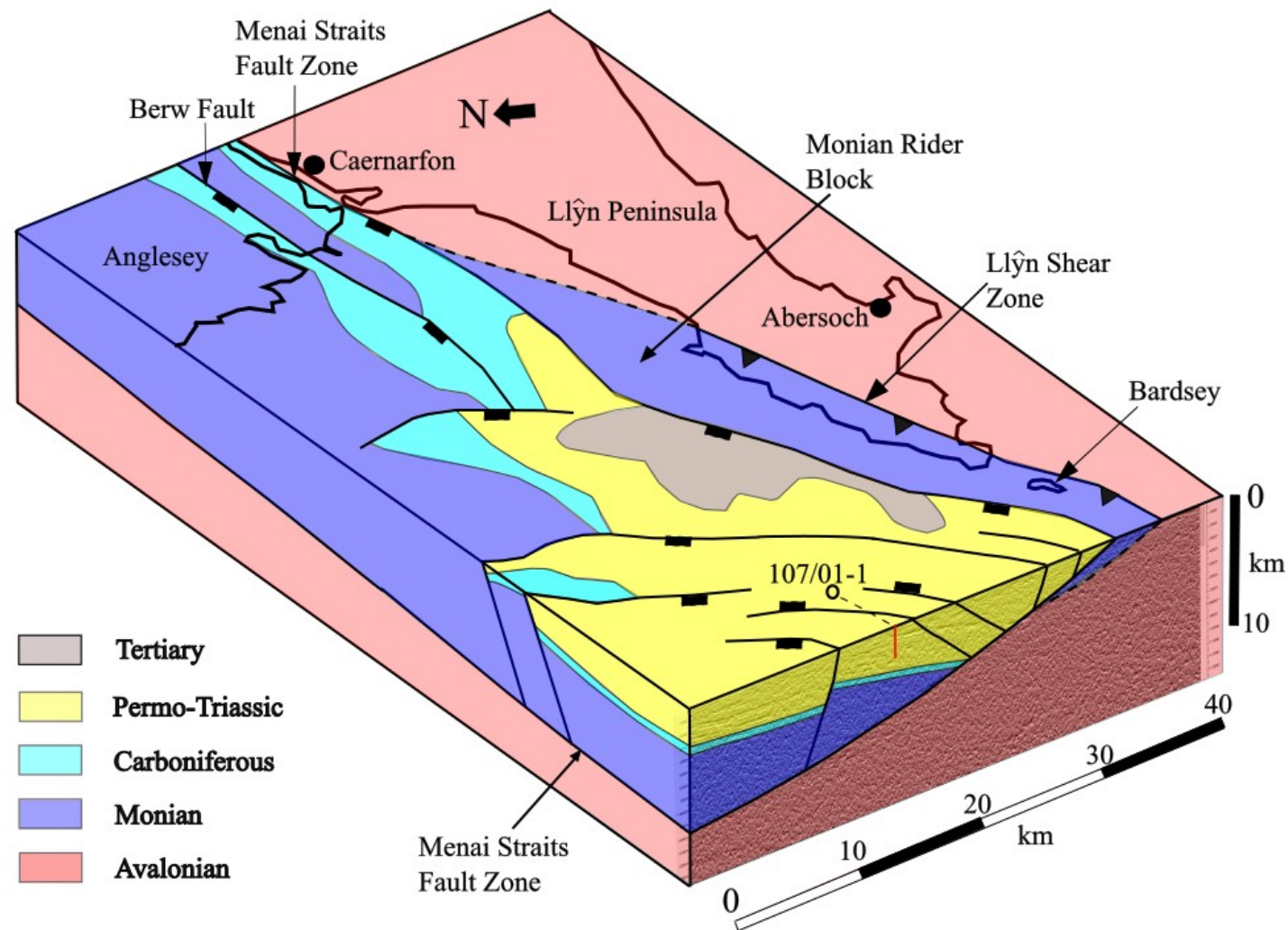


Depth converted True scale

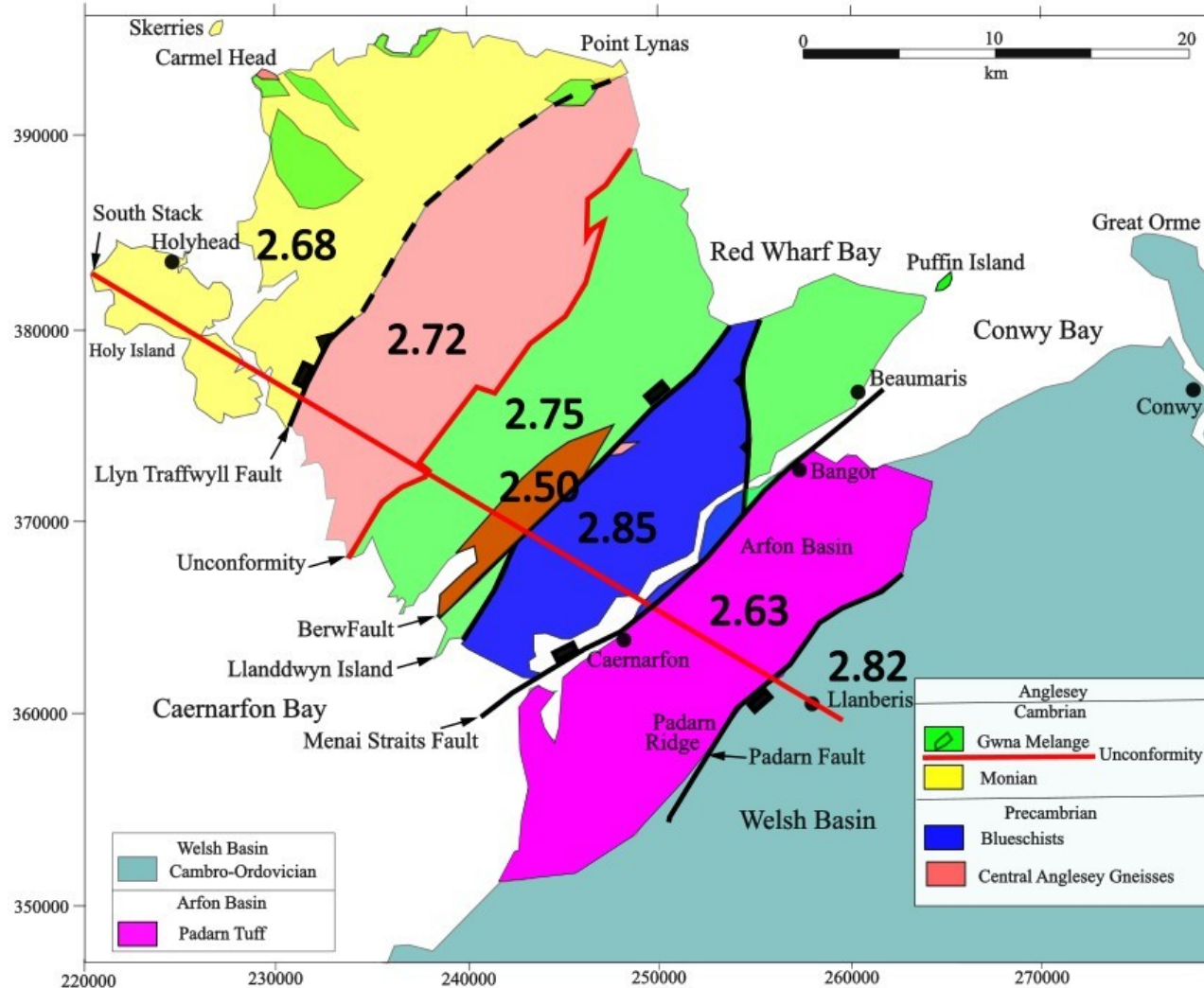
Fault dips at 30 degrees to the NW-reactivated thrust

Block diagram

- BGS seabed map
- Winch-4 seismic line



Simplified polygons used in the Gravity Model

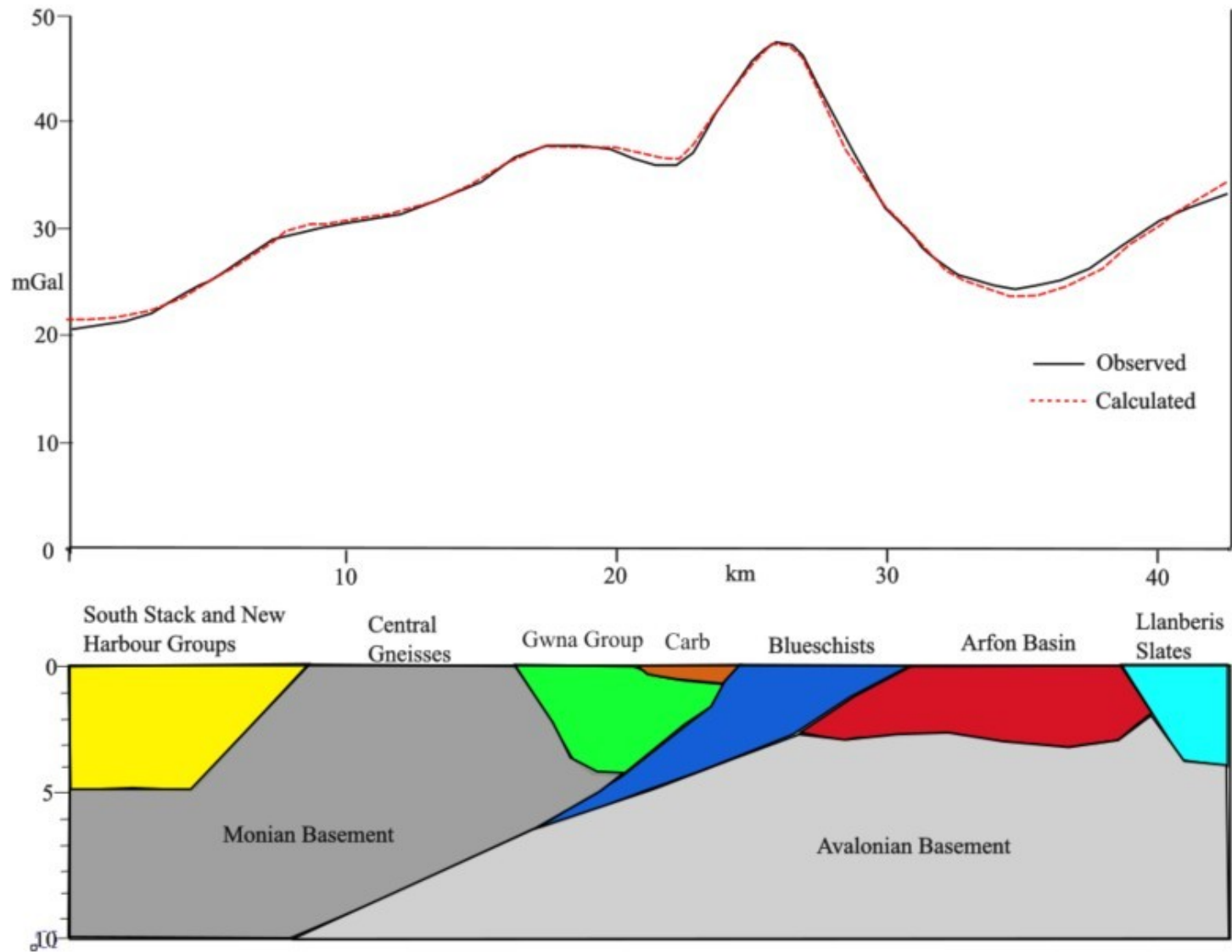


Input to the Gravity Model

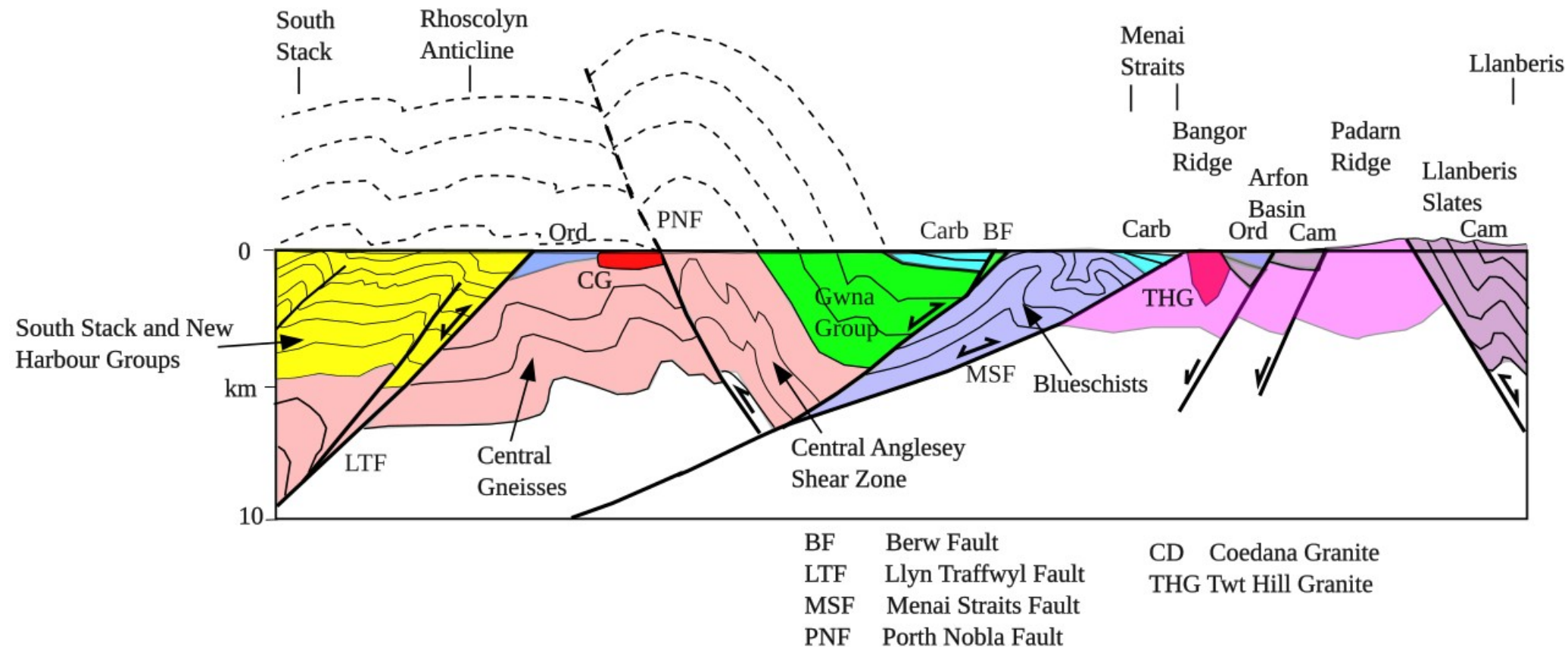
- cross section from South Stack to Llanberis
- fault trends from the gravity and magnetic data
- fault dips from the seismic data
- published average rock densities
- values in g/cm^3

Gravity model

South Stack to
Llanberis



Final cross section

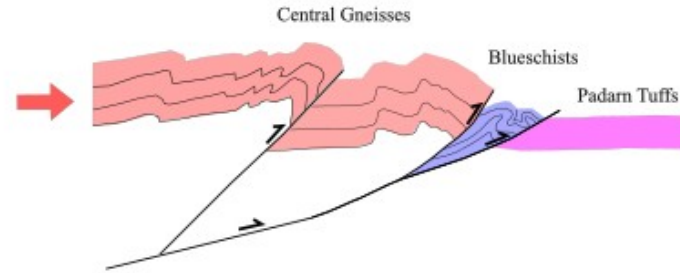


Cross Section Restoration

Late Precambrian

Closure of an oceanic basin and obduction of the leading edge of Avalonia

Gneisses and Blueschists thrust on to the Padarn Tuffs

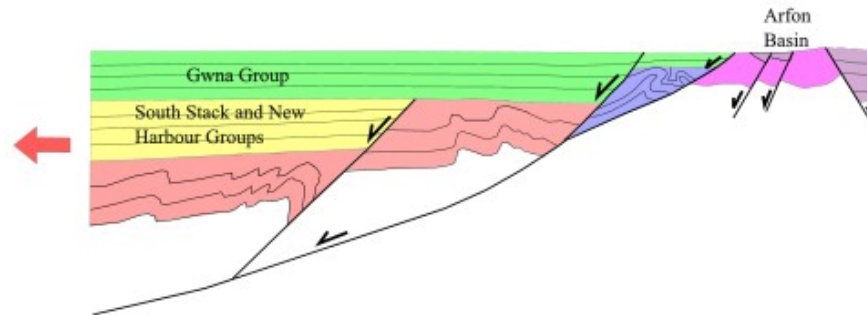


Cambrian

Reactivation of the thrust in extension.

10km of basin fill.

Sediment source from the north

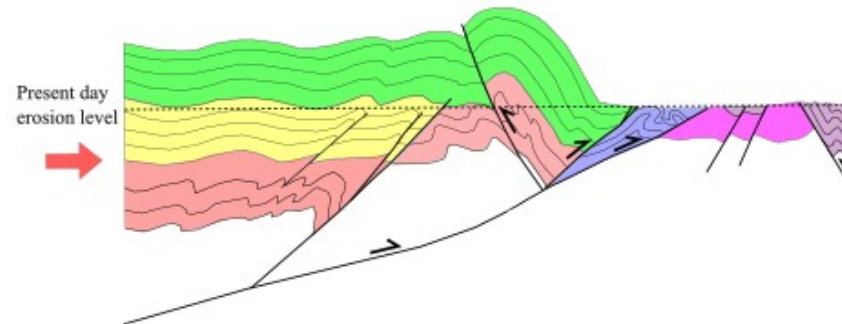


Early Ordovician (Late Tremadoc)

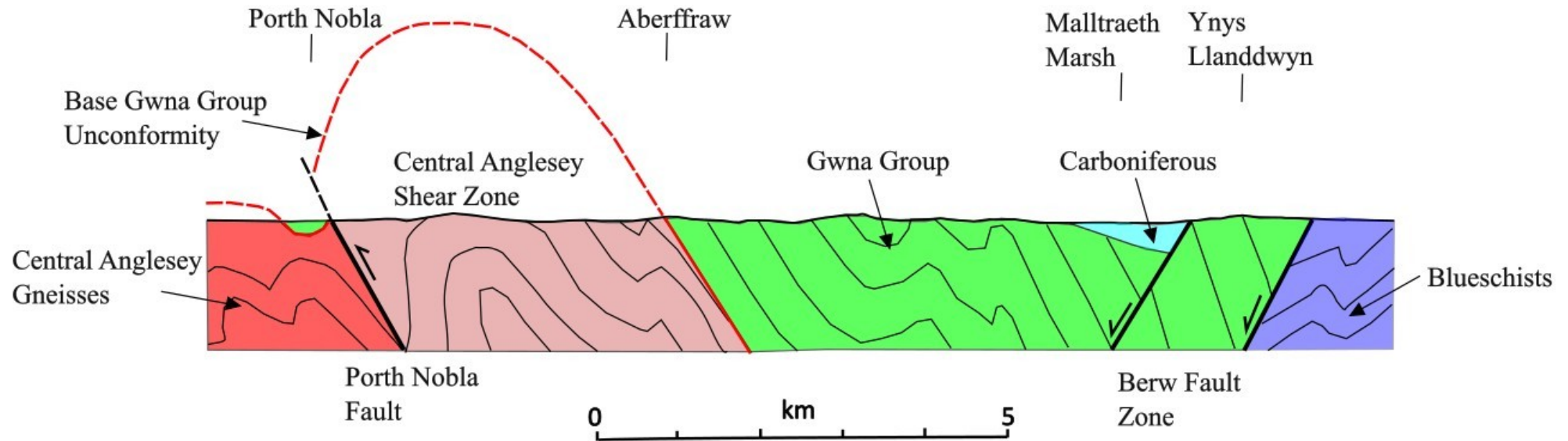
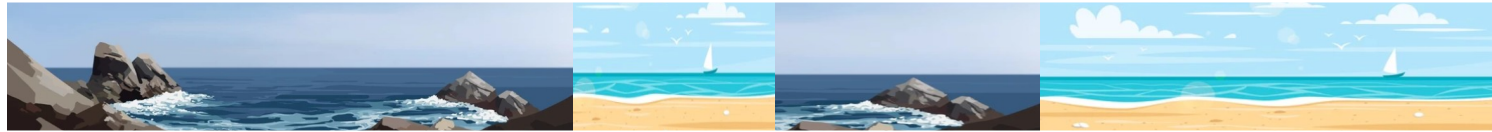
Penobscottian/Monian orogeny

Formation of the major monocline in Anglesey

Erosion of most of the Gwna Group prior to the Arenig transgression



Work to be completed: checking the cross-section in SW Anglesey



Thrust reactivation: It's not unusual

Examples

- Outer Isles Thrust and the Mesozoic Sea of Hebrides Basin
- Moine Thrust and offshore Devonian Basins
- Mesozoic basins in the SW Approaches
- Reactivated Variscan Thrusts
- Mesozoic Weald and Wessex Basins.
- Reactivated Variscan Thrusts

