Geological and geophysical evidence for a mafic igneous origin for the Porcupine Arch, offshore Ireland

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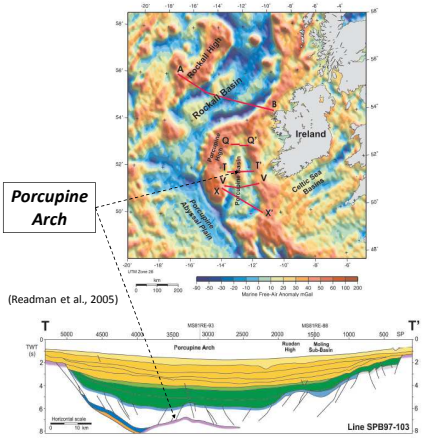
Introduction



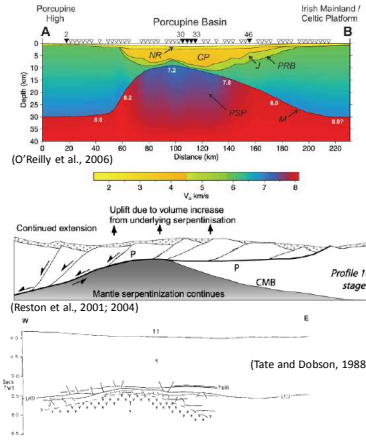
(Readman et al., 2005)

Porcupine Arch: defined by convex-up shaped high-amplitude reflector; corresponds to a pronounced gravity anomaly high. Broadly coincides with higher velocities (>7 km/s). **Not sedimentary in origin**.

- ***Locus of igneous activity and underplating ?*** (Tate & Dobson, 1992; Calves et al., 2012);
- ***Locus of mantle serpentinisation ?*** (Reston et al., 2001; 2004; Readman et al., 2005; O'Reilly et al., 2006);
- ***Mylonitic zone at top of basement ?*** (Johnson et al., 2001)

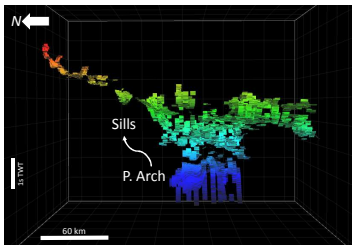
→ Relevance to thermal history!

Key: integration of all available data at both Porcupine Arch and Porcupine basin scales.

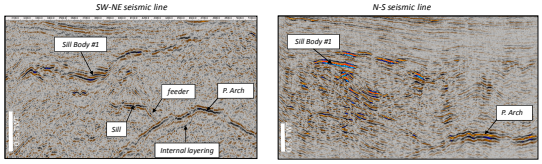


(O'Reilly et al., 2006)
(Reston et al., 2001; 2004)
(Tate and Dobson, 1988)

Geological Inferences

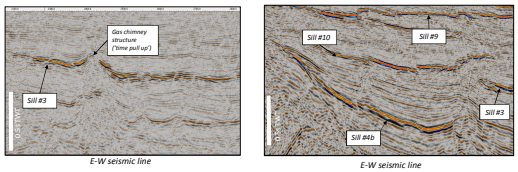


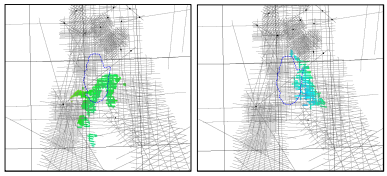
Sills cluster at the Arch location in Porcupine (this study; Fernandez, 2011), but extent further North and South at higher structural level.
K-Ar dating of sills: early Tertiary (Tate & Dobson, 1988)



Apparent linkage between sills and Arch, internal layering of the Arch structure ***→ seismic interpretation supports igneous origin as mafic layered igneous intrusion.***

More than 20 bodies have been identified and mapped in Porcupine Basin:

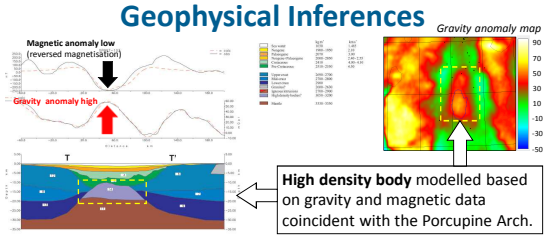



Sill Body #3 (in Cretaceous sediments)
Sill Body #2 (in Jurassic sediments)

Gas-escape chimney structure commonly found adjacent to Arch, or directly emanating from it.

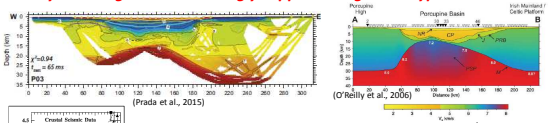
Interconnected sill complex extending from Arch up to higher structural/stratigraphic levels (up to upper Cretaceous chalk).

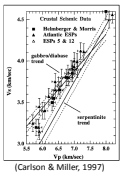
Geophysical Inferences



- **Similar gravity/magnetic anomalies common in mafic/ultramafic intrusive complexes**: Mull intrusive complex; Kaapvaal craton, Bushveld complex….
- **Gravity anomalies due to igneous activity also found along a number passive margins**: Rockall Trough, Porcupine basin (Brendan Igneous Centre), Vøring basin.

Gravity and magnetic data strongly support the igneous hypothesis!

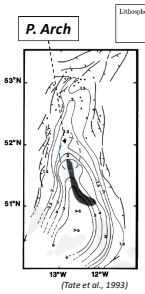

(Prada et al., 2015)
(O'Reilly et al., 2006)


(Carlson & Miller, 1997)

- **Modelled high P-wave velocity zone** (>7.0-7.5 km/s) using WAS data coincide with the Porcupine Arch.
- Might reflect **low degree of mantle serpentinisation** (O'Reilly et al., 2006; Prada et al., 2015).
- Feature also common in plume-related **mafic magma underplating** (Farnetani et al., 1996).

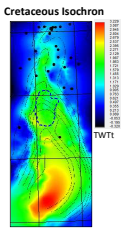
P-wave velocity modelling also supports the igneous hypothesis….
Vs/Vp ratios needed to effectively discriminate (Calson & Miller, 1997) ?

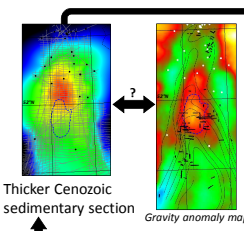
Regional Inferences



(Tate et al., 1993)

Beta-factor variations (from subsidence analysis): **Southward increase in amount of extension** (proportional to thickening of the Cretaceous section) → Enhanced crustal thinning in South Porcupine, **not at the Arch level !**



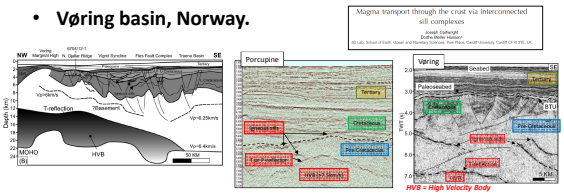

Thicker Cenozoic sedimentary section
Gravity anomaly map

Transient Paleocene uplift (300-600m) in Porcupine basin followed by **Eocene subsidence** (500-800m) related to mantle plume activity and anomalous hot mantle (Jones et al., 2001).

Uplift may have modified the **sediment pathways with enhanced clastic influx**

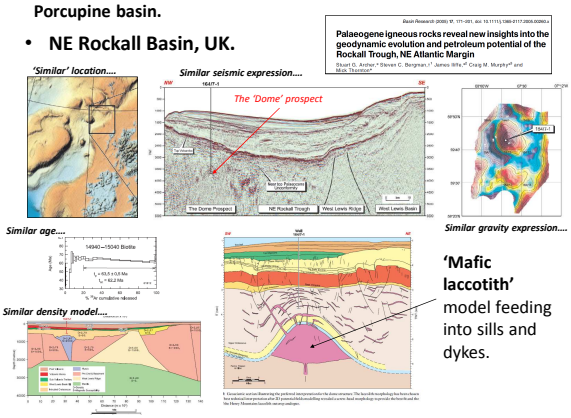
Analogues in NE Atlantic margin

- **Vøring basin, Norway.**



- Presence of seismic reflector ('T') marking top of lower crustal 'High Velocity Body' (>7 km/s) likely sourcing sill magmatism.
- Defining complex plumbing system with interconnected sill network.
- **Similar stratigraphic, igneous and tectonic framework to the Porcupine basin.**

- **NE Rockall Basin, UK.**



'Mafic laccotith' model feeding into sills and dykes.

Conclusions and Implications

- **The mafic intrusion hypothesis for the origin of the Porcupine Arch** is supported by a range of geological and geophysical evaluations – **data integration is key!** The relationships between Arch and sills is particularly important, which has not been considered before.
- **Model does not preclude serpentinisation** (possible given enhanced crustal thinning), but emphasises the importance of the early Tertiary igneous activity in understanding the geological evolution, heat-flow history and crustal structure in North Porcupine basin.
- **Implications**: Emplacement of a large mafic igneous body at base crustal level in the early Tertiary will impact significantly on heat-flow conditions in time and space (e.g. Clift and Turner, 1998; Clift, 1999) hence on source rock maturation and petroleum generation. This will be further evaluated in the next phase of the project through basin modelling.

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