Provenance of the Tullig Cyclothem sandstones from the Clare Basin: A multi-proxy approach

iCRAG IRISH CENTRE FOR RESEARCH IN APPLIED GEOSCIENCES
Contact : martin.nauton@icrag-centre.org

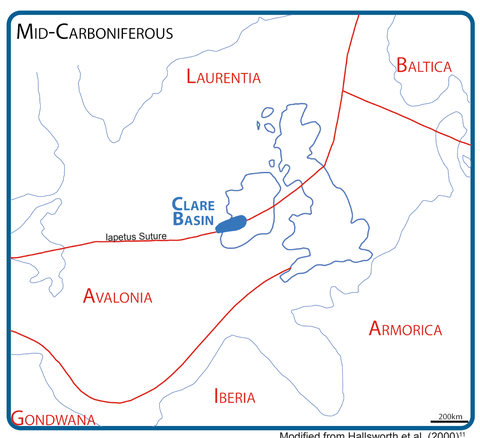
Nauton-Fourteu, M.[1], Tyrrell, S.[1], Morton, A. C.[2], Mark, C.[3], O'Sullivan, G. J.[3] and Chew, D. M.[3]

[1]Earth and Ocean Sciences, SORT, and Irish Centre for Research in Applied Geosciences (iCRAG), National University of Ireland Galway, Ireland

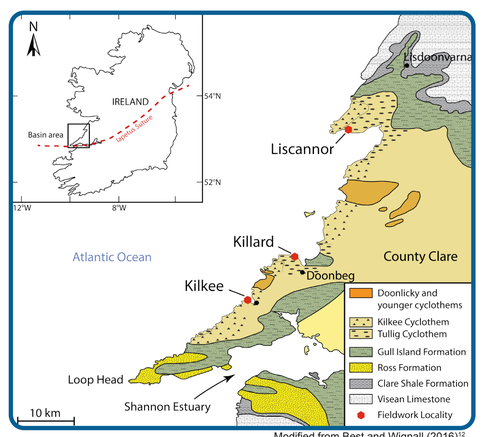
[2]HM Research Associates and CASP, University of Cambridge, UK [3]Department of Geology and iCRAG, Trinity College Dublin, Ireland

Background and Rationale

The Clare Basin consists of a deep-water to shallow marine mid-Carboniferous (315-330Ma) siliciclastic infill. The Tullig Cyclothem is the first of five deltaic cyclothems forming the shallow marine part of the basin. The basin depocentre lies along the Shannon Estuary, above the Iapetus Suture (***top left***). Potential sources for the basin infill are: 1) Laurentian terranes to the north of the basin (900-2500Ma); 2) peri-Gondwanan terranes to the south (550-650Ma) and 3) local granites associated with the Caledonian Orogeny (395-475Ma). Previous studies based on the basin's geometry and on palaeocurrent indicators interpret contradictory basin infill histories for the Tullig Cyclothem, suggesting sourcing either from the northwest or from the southwest (***bottom left***)[1,2,3,4,5,6,7]. Previous zircon U-Pb geochronology was performed on one sample from the Tullig Cyclothem[8], identifying sources both from Laurentian and peri-Gondwanan terranes (***bottom right***). The use of a multi-proxy provenance approach, investigating minerals with variable stabilities, should help better constrain the sources of sandstones of the Clare Basin.



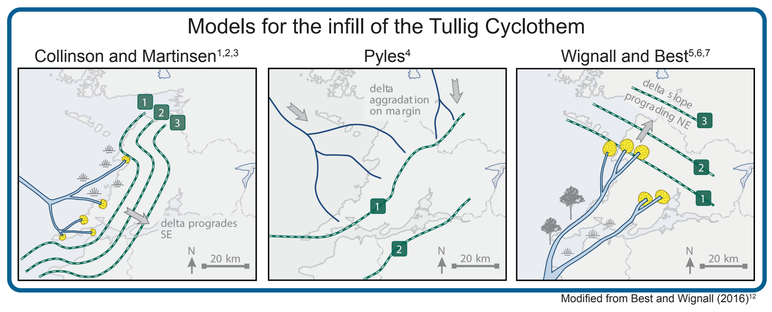
Modified from Hallsworth et al. (2000)[11]



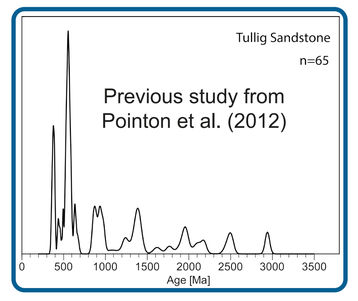
Modified from Best and Wignall (2016)[12]

Methodology

Field work was conducted at three localities: Liscannor, Killard and Kilkee (***top right***).
Coastal outcrops were logged in detail and sandstone samples were collected.
Petrographic analysis was performed on 35 samples using the setup and software PetrogLite™.
Heavy mineral assemblages of 17 samples were determined through optical microscopy.
Zircon and apatite picking was performed for six selected samples.
Zircon and apatite U-Pb geochronology was carried out using a LA-ICP-MS in TCD.

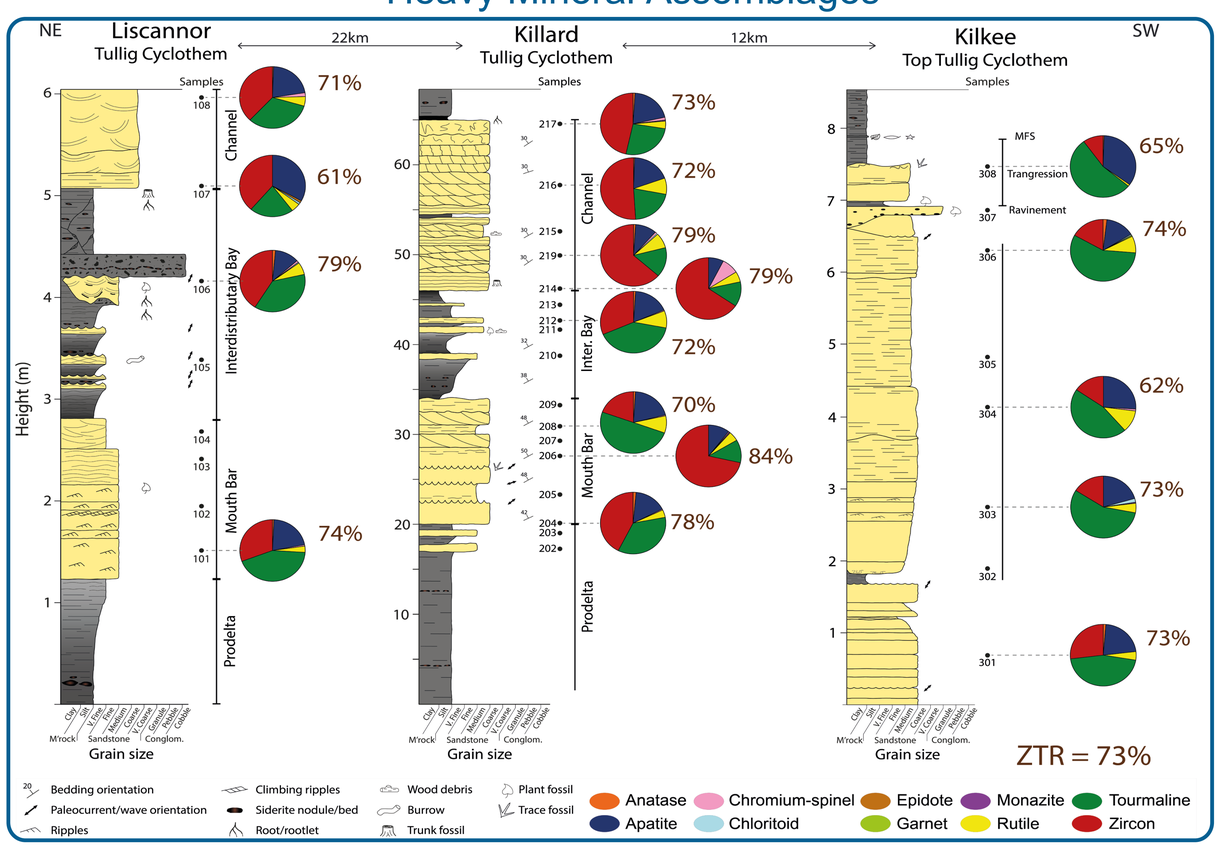


Modified from Best and Wignall (2016)[12]

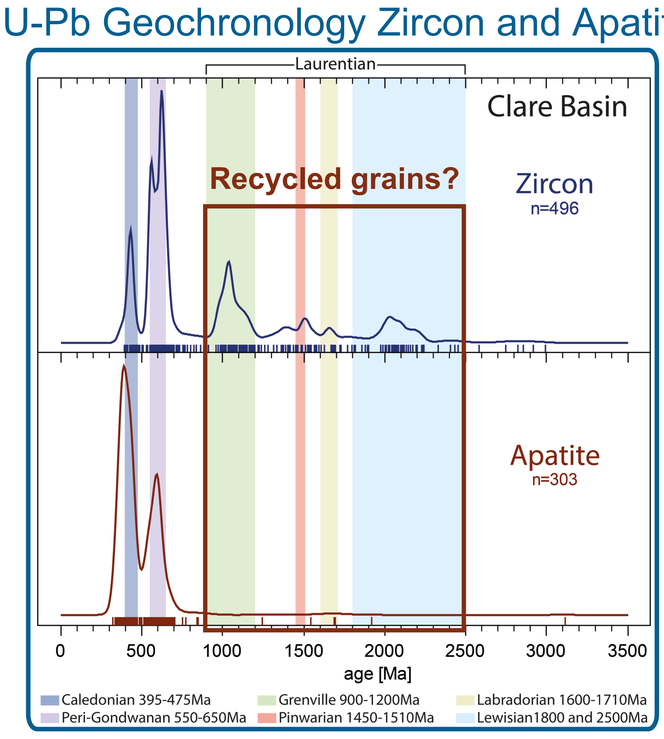


Results

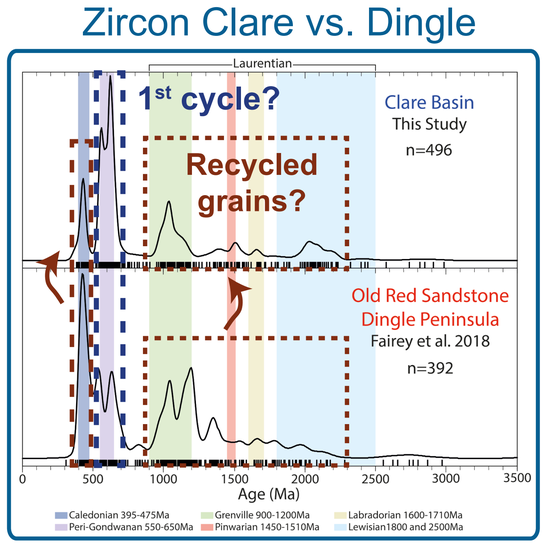
Heavy Mineral Assemblages



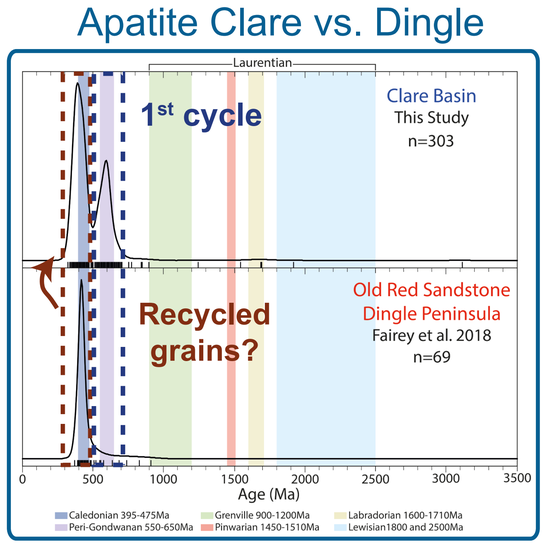
U-Pb Geochronology Zircon and Apatite



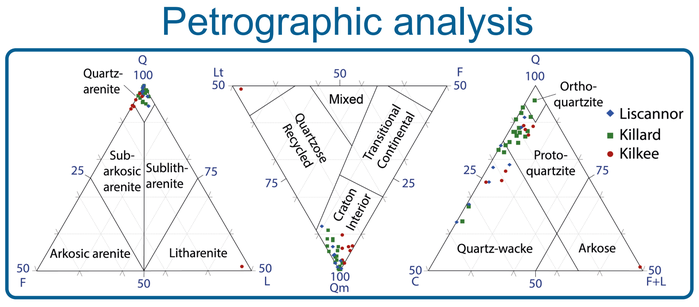
Zircon Clare vs. Dingle



Apatite Clare vs. Dingle



Petrographic analysis



Sedimentary logs display similar facies sequences at Liscannor and Killard. Prodelta muds are overlain by wave-influenced sandy mouth bars, interbedded mud/silt/sand from interdistributary bay deposits, and channelised sandstones. These facies successions are interpreted as being part of a delta progradation. At Kilkee, the top of the Tullig Cyclothem is characterised by a 7-meter thick succession of wave-influenced shelf sand bodies overlain by a transgressive facies and a goniatite-bearing marine band corresponding to a MFS (***top left***).
Petrographic studies highlight both mineralogically and texturally mature quartz-arenites (***right***).
Heavy mineral assemblages show some variation between the samples (***top left***), potentially linked with facies. The zircon-tourmaline-rutile index (ZTR) is relatively high (avg. 73%), probably indicative of recycling from pre-existing sedimentary rocks[9].
Zircon U-Pb geochronology results are similar over the six samples, indicating no change of provenance over the various facies and the outcrops. Results from all six samples have been regrouped on the same diagram (***top right***). The dominant zircon population corresponds to peri-Gondwanan terranes (c.550-750Ma). A second population seems to be derived from the Caledonian granites (c.400-470Ma). Older grains are believed to correspond to orogenic events which took place on the Laurentian continent (Grenville, Pinwarian, Labradorian) or to the Lewisian Complex of northwest Scotland.
Apatite U-Pb geochronology results show a main population of Caledonian age (c.400Ma) and a second population of peri-Gondwanan origin (c.525-700Ma) (**top right**).

Tullig Cyclothem Provenance Interpretation

Zircon U-Pb geochronology results concur with previous zircon geochronology data[8]. Comparing zircon and apatite data suggest that Laurentian associated grains, ultimately derived from the north, have been recycled from a sedimentary source. Comparing our geochronology results to provenance data from the Devonian Old Red Sandstone (ORS) on the Dingle Peninsula[10] allows for further provenance interpretation (**top right**). Zircon U-Pb geochronology indicates that a portion of the sediment in the Clare Basin was ultimately derived from Laurentia, but has been recycled through Devonian ORS basins to the south. The higher amount of peri-Gondwanan zircon in the Clare Basin implies a fresh input of first-cycle peri-Gondwanan material. The U-Pb apatite data seem to confirm a fresh input of peri-Gondwanan material and a potential recycling of Caledonian-aged grains.

Our provenance interpretation, based on the petrographic characteristics of the sandstones, the high ZTR indices and U-Pb geochronology results involves a sourcing from the south/southwest with input from recycled older sedimentary rocks and a fresh input of peri-Gondwanan material.

Modified from Kendall (2017)[13], Hallsworth et al. (2000)[11], Higgs (2004)[14]

Highlights and Future Work

- Tullig Cyclothem sandstones sourced from the south/southwest.
- Multi-proxy approach unravels a partial polycyclic origin for sandstones deposited in the shallow marine part of the Clare Basin.
- The next step of this project is to investigate the heavy mineral composition and the provenance of sandstones from the deep-water part of the basin.

Acknowledgments: Stephen Daly is acknowledged for the use of UCD crushing facilities.
This publication has emanated from research supported in part by a research grant from Science Foundaton Ireland (SFI) under Grant Number 13/RC/2092 and is co-funded under the European Regional Development Fund and by PIPCO RSG and its member companies.
Ireland's European Structural and Investment Funds Programmes 2014-2020 — Co-funded by the Irish Government and the European Union
European Union — European Regional Development Fund
Science Foundation Ireland — For what's next

References:
[1]Collinson et al., 1991, Early fill of the Western Irish Namurian Basin: a complex relationship between turbidites and deltas.
[2]Martinsen and Collinson, 2002, The Western Irish Namurian Basin reassessed - a discussion.
[3]Martinsen et al., 2003, Facies and sequential organisation of a mudstone-dominated slope and basin floor succession: the Gull Island Formation, Shannon Basin, Western Ireland.
[4]Pyles, 2008, Multiscale stratigraphic analysis of a structurally confined submarine fan: Carboniferous Ross Sandstone, Ireland.
[5]Wignall and Best, 2000, The Western Irish Namurian Basin reassessed: Basin Research.
[6]–, 2002, Reply to: The Western Irish Namurian Basin reassessed - a discussion.
[7]–, 2004, Sedimentology and kinematics of a large, retrogressive growth-fault system in Upper Carboniferous deltaic sediments, western Ireland.
[8]Pointon et al., 2012, The provenance of Western Irish Namurian Basin sedimentary strata inferred using detrital zircon U-Pb LA-ICP-MS geochronology.
[9]Hubert, 1962, A zircon-tourmaline-rutile maturity index and the interdependence of the composition of heavy mineral assemblages with the gross composition and texture of sandstones.
[10]Fairey et al., 2018, The provenance of the Devonian Old Red Sandstone of the Dingle Peninsula, SW Ireland; the earliest record of Laurentian and peri-Gondwanan sediment mixing in Ireland.
[11]Hallsworth et al., 2000, Carboniferous sand provenance in the Pennine Basin, UK: constraints from heavy mineral and detrital zircon age data.
[12]Best and Wignall, 2016, A Field Guide to the Carboniferous Sediments of the Shannon Basin, Western Ireland.
[13]Kendall, 2017, The Old Red Sandstone of Britain and Ireland — a review.
[14]Higgs, 2004, Ross and Bude Formations (Carboniferous, Ireland and England): reinterpreted as lake-shelf turbidites.

PIP Petroleum Infrastructure Programme