Investigations multidisciplinaires au sein d’aquifères de socle faiblement productifs en Irlande : typologie, propriétés et importance pour le cycle de l’eau irlandais

Multidisciplinary investigations of poorly productive hard rock aquifers in Ireland: typologies, properties and significance in the Irish water cycle


Overview of Research Activities completed as part of Griffith Geoscience Project:

• Geophysics – borehole geophysics, ground based surveys (ERT, seismic, EM, GPR), airborne geophysics (AEM);
• Hydraulic Testing – Integral Borehole Pump Testing and Packer Testing;
• Tracer Testing – Borehole Injection and Dilution Tests;
• Structural Geology Mapping – outcrop mapping and borehole imaging;
• Hydrodynamic Monitoring – long-term groundwater & surface water level monitoring;
• Hydrochemical Analysis – major and trace element analysis;
• Geochemical Analysis – Rock-water interaction studies;
• Isotope Analysis ($^2$H, $^3$H, $^{18}$O, $^{13}$C, $^{14}$C) in precipitation, groundwater & surface water;
• Geochemical Modelling (NetPath).
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<tbody>
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</tr>
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<td>Upper weathered bedrock</td>
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</tr>
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<td>Middle fractured/fissured bedrock</td>
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<td>Weathering front</td>
<td>Fresh/unweathered bedrock</td>
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<td>Deep bedrock</td>
<td>Fresh bedrock</td>
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\(^{(2)}\) After Krasny (1996), Durand et al. (2006), Krasny and Sharp (2007)  
\(^{(3)}\) After Moe et al. (2010)  

Comte et al. 2012  

### Terminology

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- Duricrust/paleosol
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- Laterite
- Clayey saprolite

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- Overburden/subsoil
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**Irish terminology**
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- (absent)
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Comte et al. 2012

**International Conference Hard-Rock Aquifers: Up-to-date Concepts and Practical Applications, La Roche sur Yon 2015**
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\(^{(1)}\) Comte et al. (2012); Delage et al. (2006); Bodénès and Hulin (2000)

\(^{(2)}\) After Moe et al. (2010)

\(^{(3)}\) Lachassagne et al. (2011)
Study Sites

a) Mount Stewart (MS)
b) Gortinlieve (GO)
c) Glencastle (GC)
Structural Geology

At BH/outcrop scale:

- 2 dominant fracture sets:
  - WNW-ESE with dip angles 35°NNE and 60-70° SSW
  - NE-SW/NNE-SSW with dip angle 60-70 deg ESE

- at this meso-scale influenced by Alpine tectonics with Caledonian as secondary control

- at macro-scale (catchment/regional scale); lineaments typically associated with pre-alpine NE-SW trend

- cumulative distribution plots of fracture occurrence with depth bgf (actual & normalised) indicate steeper slope / larger fracture spacing in deeper bedrock boreholes (except GO3)

- GO3 affected by deeper weathering
Orientated rock samples:

- Foliation planes with WNW-ESE strike dip angle 26° NNE
- In thin sections 2 sets of interconnected micro-fractures:
  - both WNW-ESE strike
  - Set 1 dipping 25-32° NNE;  Set 2 dipping 65-72° SSW
  - commonly lined by Fe-oxides
- Lining reduces secondary porosity
- ‘Pinch-out’ terminations indicate discontinuous nature
- These structures span micro to meso-scale (also visible in BH/outcrop)
- Seen to act as micro/meso-scale pathways for weathering solutions and subsequent transport of dissolved species away from sites of mineral breakdown

Weathering:

- Qtz most resistant mineral present in bedrock; samples from highly fractured/fissured zones contain higher % of strained grains/weathered rinds
  - weakened crystal structure and proximity to micro-fractures makes them vulnerable to weathering
- Alteration of Na-feldspars main source of Na release
- Ubiquitous sieve-textured feldspar grains reflect preferential dissolution of more Ca-rich grain cores and replacement with sericite
- Secondary weathering products dominated by illite & montmorillonite
- Samples show variation in clay content across transition zone; clay-poor upper layer and clay-enriched lower horizon (see ERT)
  - reflects eluviation of secondary clay weathering products from upper weathering profile and accumulation in basal part as fracture density decreases with depth
  - driven by meteoric recharge transporting clays as a suspension
Hydrodynamic Parameters

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<th>Geometric mean</th>
<th>Range</th>
<th>No. data</th>
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<td>Hydraulic conductivity $K$ (m d$^{-1}$)</td>
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<td></td>
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<tr>
<td>Transition (broken/decomposed) zone</td>
<td>$2.3 \times 10^{-2}$</td>
<td>$8.4 \times 10^{-2}$ to $2.3 \times 10^{-1}$</td>
<td>4</td>
</tr>
<tr>
<td>Shallow (tissured) bedrock</td>
<td>$4.2 \times 10^{-1}$</td>
<td>$1.5 \times 10^{-1}$ to $4.2 \times 10^{-1}$</td>
<td>12</td>
</tr>
<tr>
<td>Deep (massive) bedrock</td>
<td>$2.1 \times 10^{-2}$</td>
<td>$8.4 \times 10^{-3}$ to $2.1 \times 10^{-2}$</td>
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Comte et al. 2014
• Subtle differences in the median values of pH and EC across the individual aquifer typologies at the 3 sites.

• Variation within individual bedrock units noteworthy; associated with the varying residence times as a result of aquifer properties.
  - Gortinlieve with wider variations.

• Degree of weathering major influence on absolute values of pH and EC; presence of deep weathered zones and considerably faster flows result in decrease of both pH and EC (e.g. at GO3).
Summary

- ERT highlights weathering profile – governed by lithology and faults
- ERT highlights varying clay content in transition zone – also seen in geochemistry
- Across scales dominant fracture sets; sets spanning micro- to meso-scale provide pathways for weathering process
- Depth-dependancy of hydrodynamic parameters (generalised for aquifer typologies)
- Hydrochemistry reflect dynamics of flow systems (broadly consistent with Toth’s model)
Acknowledgments

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- Irish Environmental Protection Agency (EPA)
- Northern Ireland Environment Agency (NIEA)
- Geological Survey of Ireland (GSI)
- Geological Survey of Northern Ireland (GSNI)

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