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Molecular fossils inferring Quaternary sea-level changes

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HIGHLIGHTS

- **Molecular fossils** preserved in sediment can track changes in the **origin of organic matter** (OM), including shifts from terrestrial to marine environments.
- Molecular fossils provided **extra information** in the study of **sea-level changes from Quaternary sediments** even when microfossils were not well preserved.
- Molecular fossils can be used as an **extra approach** as well as a **standalone technique** to study past sea levels.
- **THE STUDY HAS MAJOR IMPLICATIONS FOR GLOBAL SEA-LEVEL STUDIES, UNLOCKING A FAR WIDER SET OF SEDIMENTS THAT CAN BE USED.**

INTRODUCTION

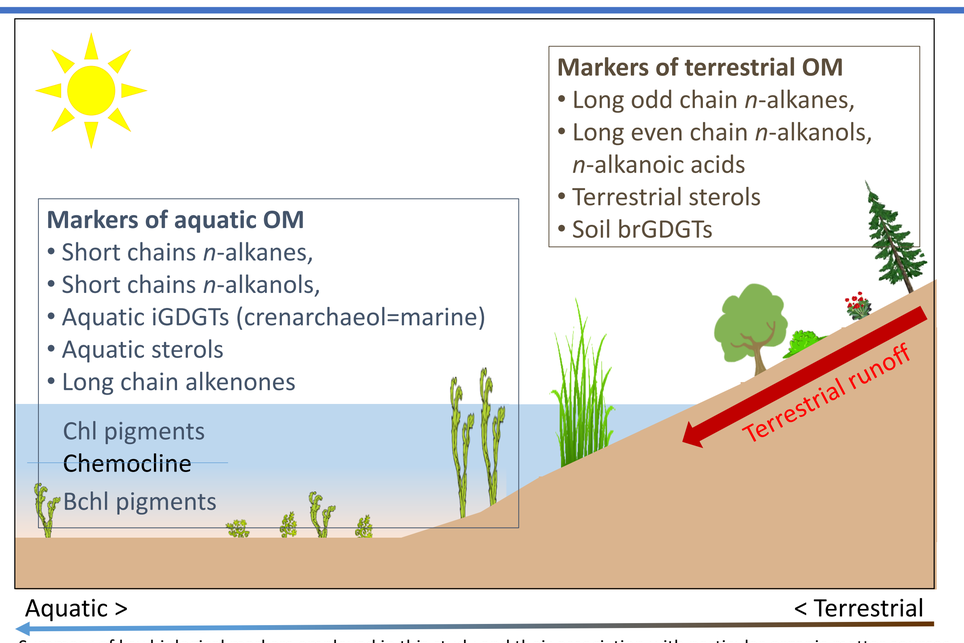
Sea-level changes have occurred many times, especially during the Quaternary (last 2.6 Ma), due to glaciation/deglaciation and/or crustal rebound.

Determining the modes of sea-level changes is traditionally carried out by macro- and micro-fossil, lithological and geophysical analyses.

Problem: low numbers / lack of macro and microfossils due to degradation, lack of preservation

Solution: distribution of organic geochemical markers reflect changes in past climate conditions

- Chlorophyll pigments reflect aquatic photoautotrophs [1]
  - Chlorophylls = oxygenic photosynthesis → O_2 in water column
  - Bacteriochlorophylls = anoxygenic photosynthesis → absence of O_2 in water column
- *n*-alkanes, *n*-alkanols, *n*-alkanoic acids :
  - long chains *n*-C_{25-33} = land plants
  - prevalence of short chains *n*-C_{15-21} = algae [2]
- Glycerol dialkyl glycerol tetraethers (GDGTs)
  - Branched (brGDGT) = bacteria ⇒ soil organic matter (OM)
  - Isoprenoid (iGDGT) = Archaea ⇒ aquatic OM [3]
- Long chain alkenones represent marine haptophyte algae [4]
- Specific sterol structures for plants and aquatic producers [5]



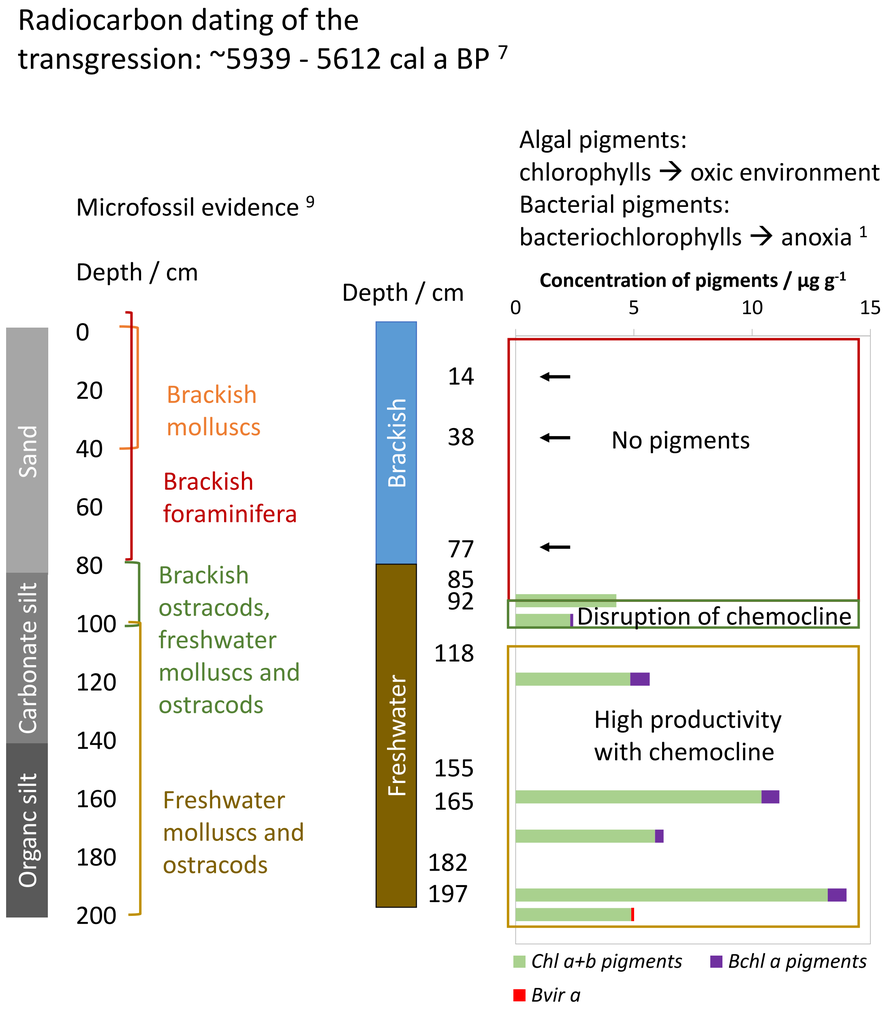
Summary of key biological markers employed in this study and their association with particular organic matter sources.

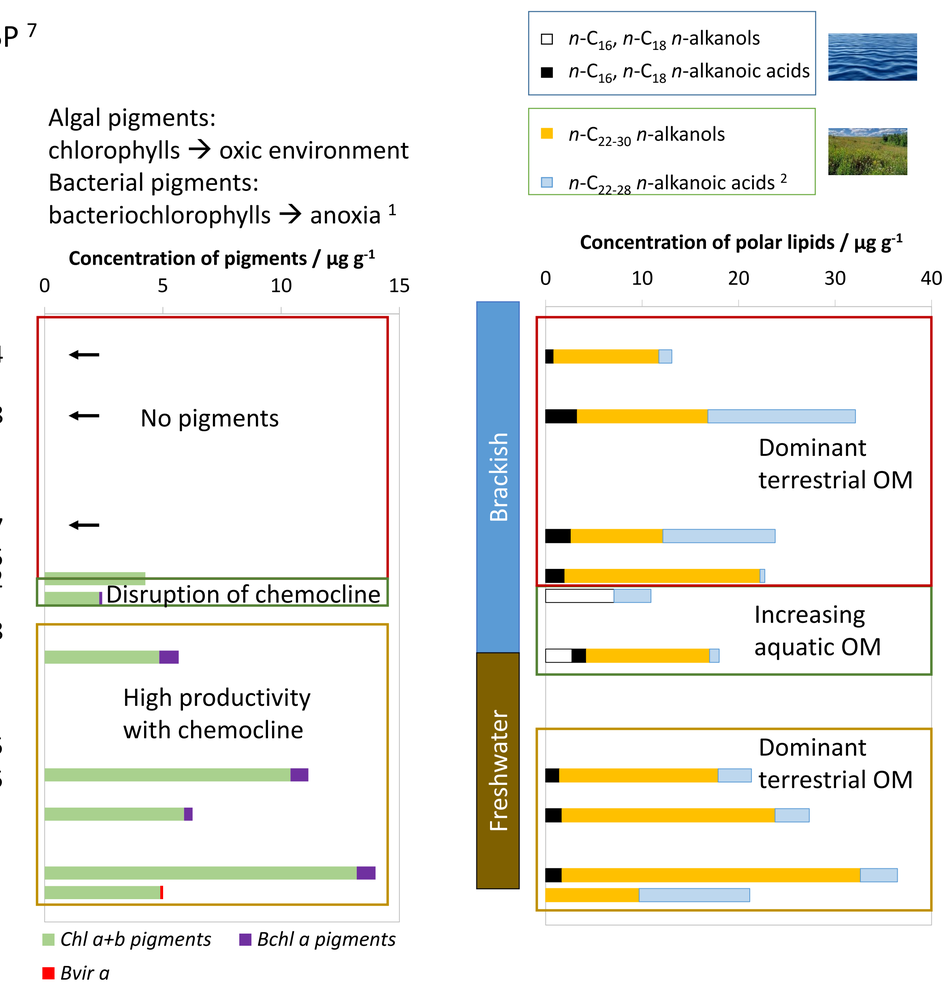
RESULTS AND DISCUSSION

Experimental: Molecular fossils are extracted from the sediment matrix by solvent extraction. Chromatographic separation, detection and quantification are carried out [6,7,8].

Loch of Stenness, Orkney (UK) – Test approach on sea-level increase at the end of the last glacial (Conti *et al.*, under review)

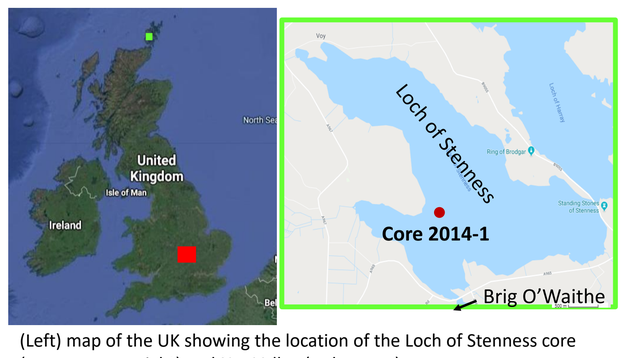
Radiocarbon dating of the transgression: ~5939 - 5612 cal a BP [7]





BIT (br and i tetraether) index: ratio between membrane lipids of archaea and bacteria.
BIT ~1 = terrestrial;
BIT ~0 = marine [3]

Depth / cm	BIT
14	0.67
38	0.62
77	0.71
85	0.94
92	1
118	1
155	1
165	1
182	1
197	1



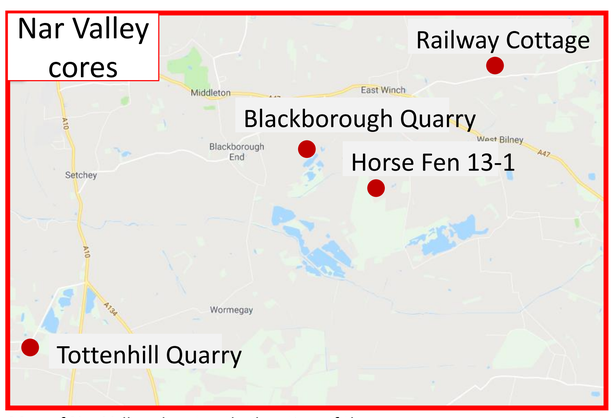
(Left) map of the UK showing the location of the Loch of Stenness core (green square, right) and Nar Valley (red square).

77-14 cm: brackish lake with terrestrial and marine OM (BIT). Absence of pigments can be related to the brackish conditions where few photosynthetic organisms can survive.

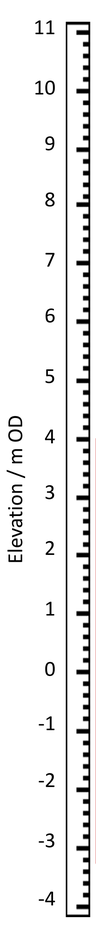
118-85 cm: productive lake with increasing algal production. 118-92 cm: increase in algal lipids may point towards an earlier start to the transgression. 85 cm: disruption of the chemocline and lower BIT → brackish conditions established.

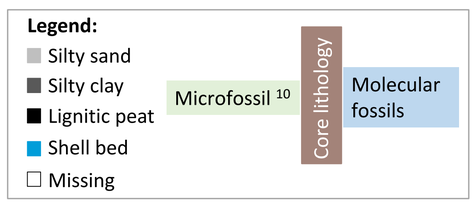
197-155 cm: freshwater lake with terrestrial and aquatic organic matter. 197 cm: oxidised chemocline (bvir *a*) indicates shallow waters. 182-92 cm: fully developed chemocline (chl and bchl pigments), deeper water column.

Nar Valley, Norfolk (UK) – Extension to much earlier sea-level rise MIS 11 and/or 9



Map of Nar Valley showing the location of the cores.





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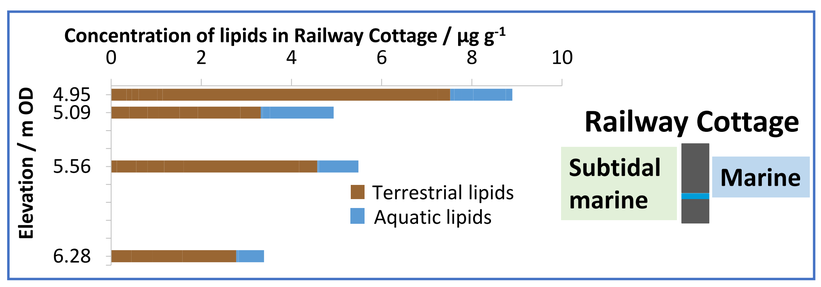

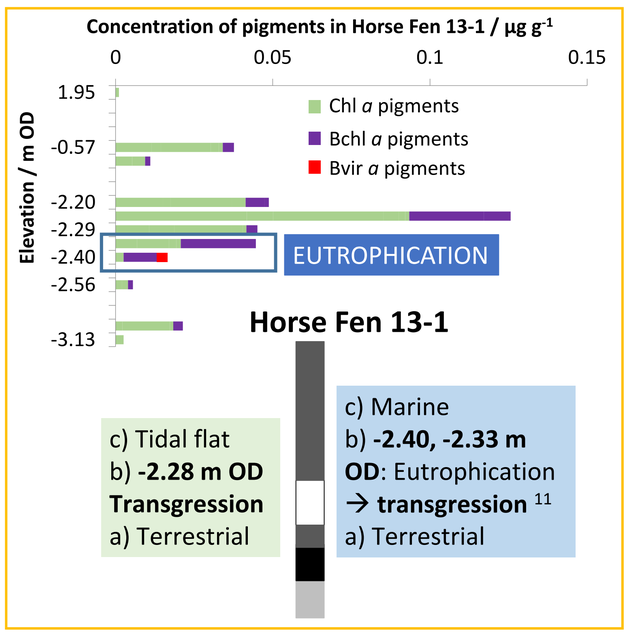

Tottenhill Quarry

Terrestrial (no forams)

c) **Transgression ?**
b) Terrestrial
a) **Regression ?**

Elevation/m OD	BIT [3]
2.63	0.81
2.44	0.93
2.33	0.98
2.08	0.88
1.95	0.80

Blackborough Quarry

c) Intertidal / subtidal (poor microfossil preservation
b) **-1.10 m OD: Transgression**
a) Terrestrial

c) Marine
b) **-1.05 m OD: Transgression**
a) Terrestrial

Elevation/m OD	BIT [3]
-0.54	0.43
-1.05	0.92
-1.08	0.98

Conclusions:

- The molecular fossil evidence complements the microfossil analyses of Barlow *et al.* (2017) [10].
- Highlights palaeoenvironmental features that were not previously evident.
- The high degree of similarity in molecular fossil distribution between the four Nar Valley cores could indicate that the sequences relate to similar palaeoenvironmental conditions, though without conclusive dating, correlation of the cores to the same MIS remains uncertain.

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