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The Biomarker Inventory, Trace, and Source of Heinrich Events and Heinrich-type layers (MIS 8-16) in the North Atlantic

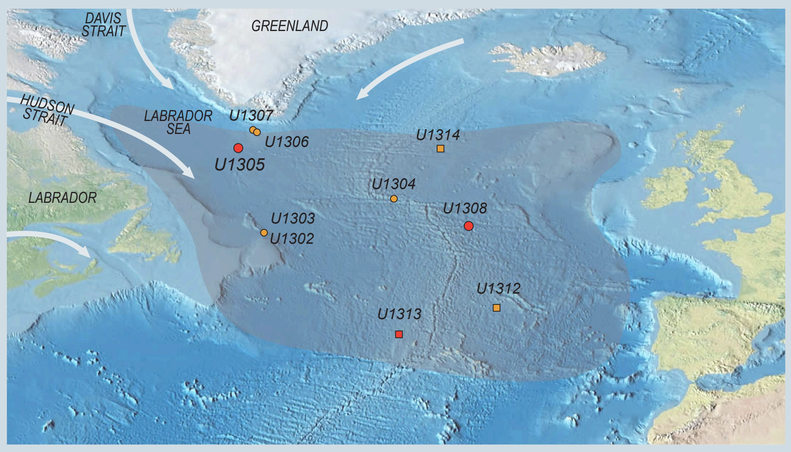


Figure 1: *Locations of drilling sites from IODP-Expeditions 303 (circles) and 306 (squares). Sites investigated for this study are marked red. Arrows indicate major ice(berg) sources. The grey-shaded area schematically outlines the extent of the North Atlantic influenced by Heinrich events.*

II: THE BIOMARKER TRACE OF HEINRICH EVENTS - Proximal Site U1305

Bulk & physical characteristics

Biomarker abundance & selectivity

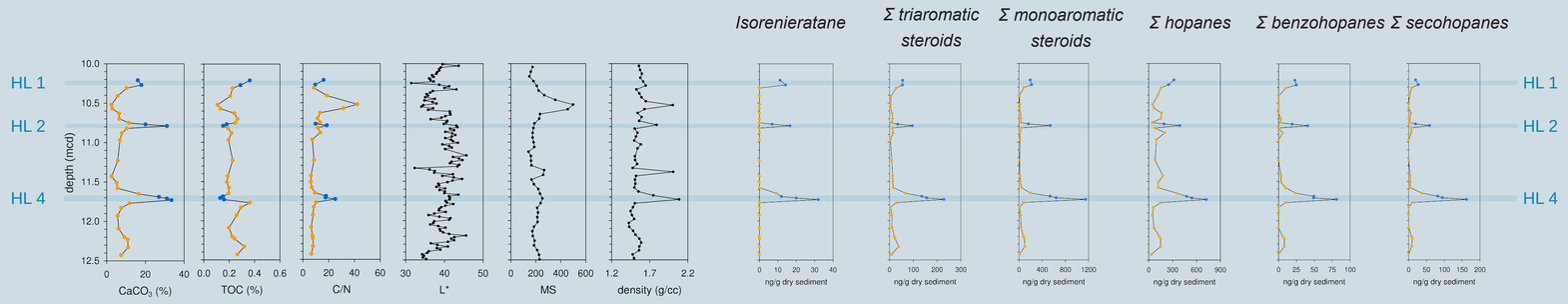


Figure 3:. *Left: Bulk geochemical and physical properties of the analyzed U1305 section. Colored datapoints are from this study, black datapoints obtained from http://iodp.tamu.edu/database/. L*: lightness, TOC: total organic carbon, C/N: TOC/total nitrogen, MS: magnetic susceptibility. The peak at ~11.35 mcd in the L*, MS and density record is due to the presence of a large gravel.*
Right: Selectivity of investigated compounds and compound classes to trace the occurrence of Heinrich events.

I: THE BIOMARKER INVENTORY
Example: HL4 (Site U1305)

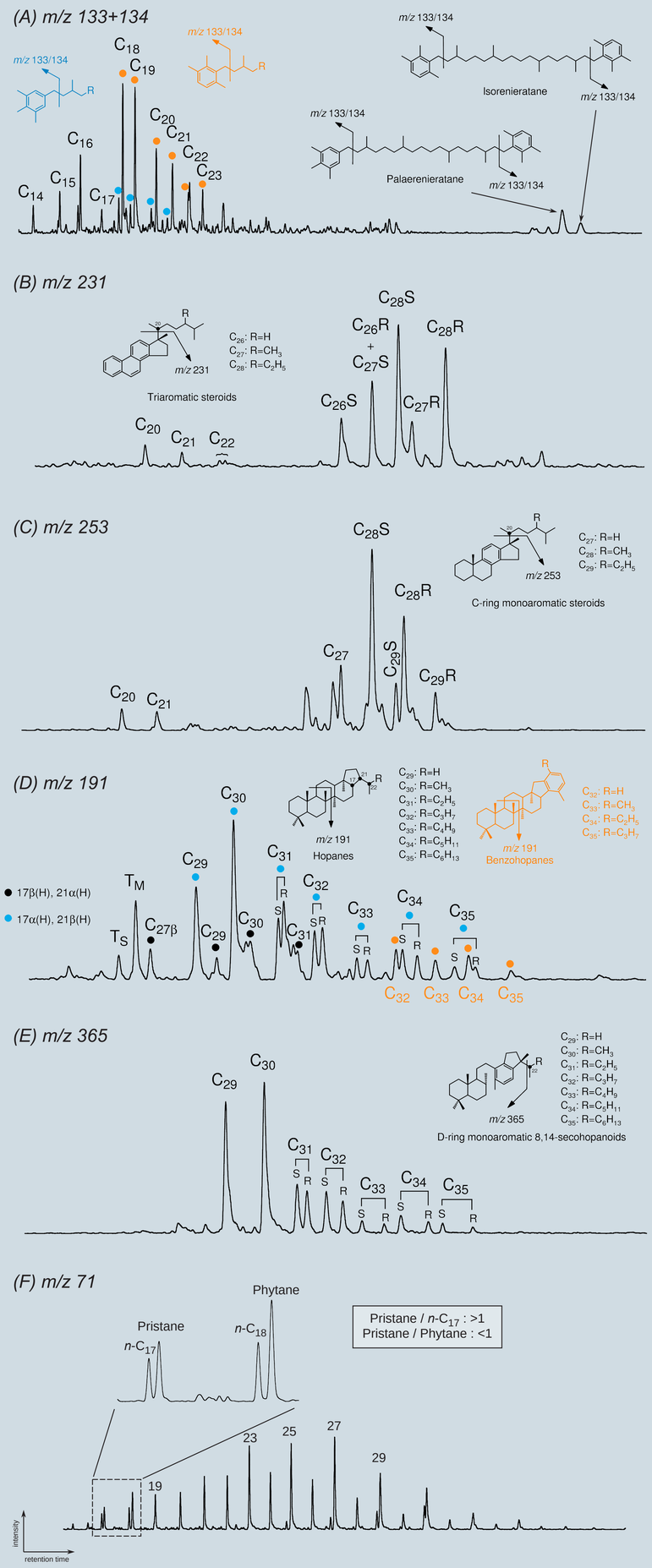
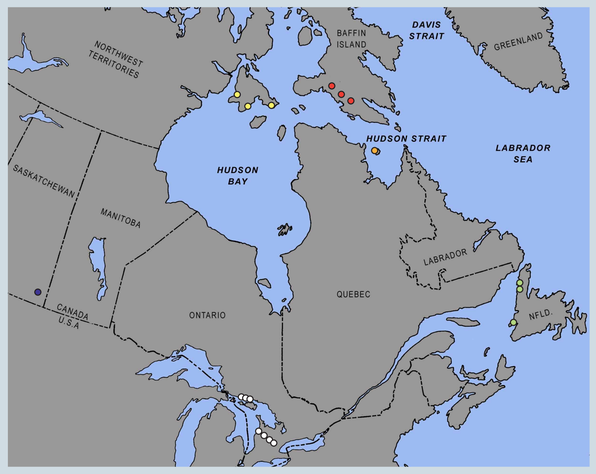


Figure 2: *GC/TOF-MS distribution of typical organic compounds from Heinrich layer 4 (**1305C-2H-4, 60-62 cm, 11.73 mcd**). (A) - (F) = ion chromatograms for indicated masses (m/z), characteristic for the compounds shown. Molecular structures and fragmentation pathways leading to distinctiv ions are also given.*
(A) *Trimethyl-arylisoprenoids. C_{14} to C_{23} = carbon atom numbers.*
(B) *Triaromatic and **(C)** ring-C monoaromatic steroid distribution. S/R on peak annotations refers to stereo-chemical configuration at carbon atom number 20.*
(D) *Distribution of hopanes/benzohopanes. C_{27}-C_{35} = carbon atom numbers, stereochemistry at carbon atom numbers 17 and 21 indicated by black and blue dots. S and R = epimerization at carbon atom 22. TS = C_{27} 17α(H)-trisnorhopane, TM = C_{27} 18α(H)-trisnorneohopane.*
(E) *D-ring monoaromatic 8,14-secohopane distribution.*
(F) *n-Alkanes and aliphatic isoprenoids. Numbers = carbon atom numbers.*

III: THE BIOMARKER SOURCE
Implications from Heinrich Events

POTENTIAL SOURCE ROCKS: ORDOVICIAN OIL SHALES



- Collingwood Member - S. Ontario
- Boas oil shale - Southhampton Island
- Unnamed carbonate - Akpatok Island
- Unnamed organic beds - Baffin Island
- Table Head/Green Point/Humber Arm groups - western Newfoundland
- Yeoman Formation/Winnipeg shale southeastern Saskatchewan

Figure 4: *Principal Ordovician oil shale - source rock localities of the central and eastern Canadian mainland.*

CORRELATION OF SOURCE ROCKS AND HEINRICH SAMPLES

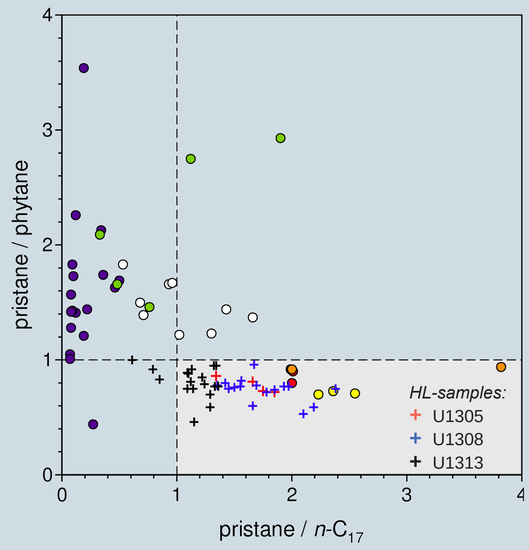


Figure 5: *Pristane/n-C_{17} vs. pristane/phytane ratios of Ordovician source rocks (symbol color as in Fig. 4) compared to samples from Heinrich and Heinrich-type layers (all investigated sites).*
Ordovician oil shale data from Macauley et al., 1990, Geological Survey of Canada, Paper 90-14.

BIOMARKER DISTRIBUTION OF THE BOAS OIL SHALE (PROPOSED SOURCE ROCK)

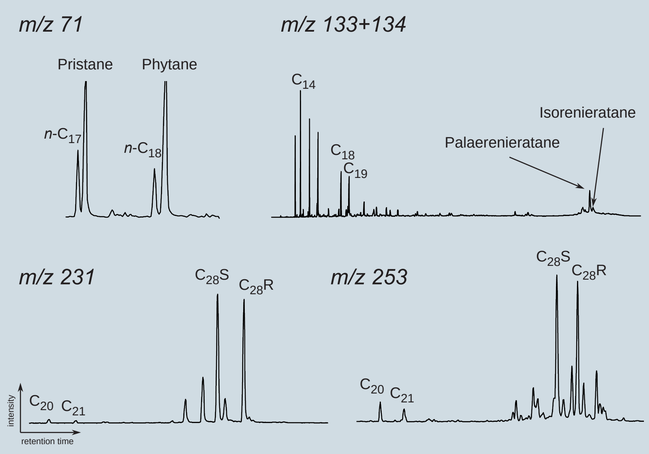


Figure 6: *Selected ion chromatograms for indicated masses showing the distribution of selected compound groups from a rock sample of the Boas oil shale. Notice the strong correlation to compounds observed within Heinrich Layers (Fig. 2).*

IV: DISTAL AND LONG TERM (MIS 8-16) RECORDS OF HEINRICH-TYPE EVENTS

Site U1308

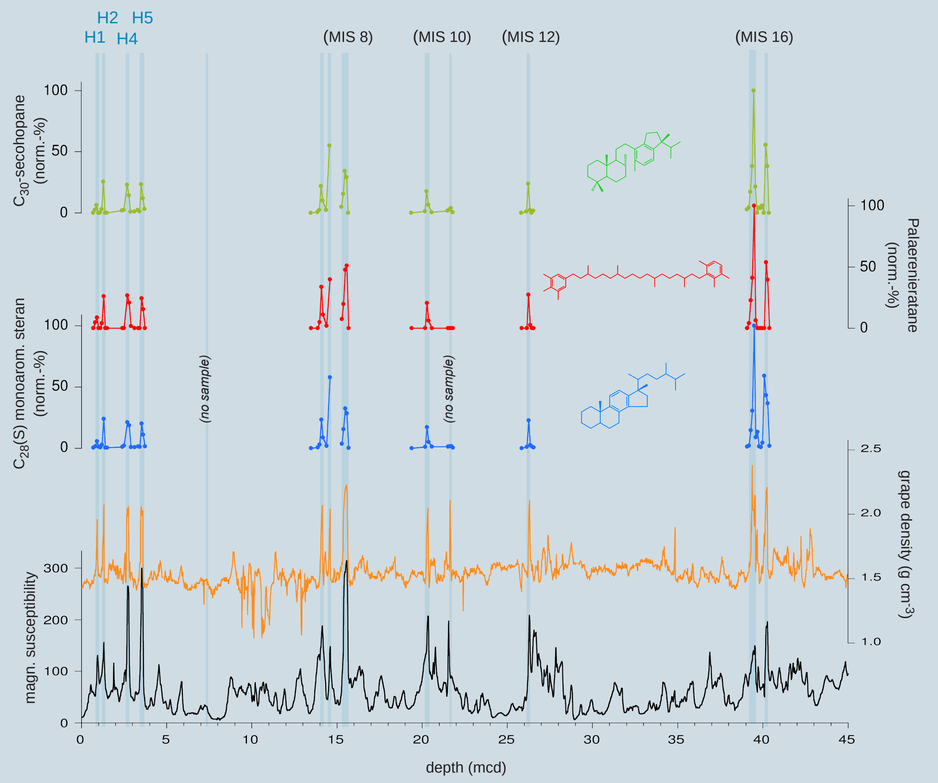


Figure 7: *Biomarker record of Heinrich Events 1, 2, 4, 5 and occurrence of Heinrich-type layers during glacial stages MIS 8 - 16 at Site U1308. Blue lines indicate detrital carbonate layers based on peaks in XRF Ca/Sr-ratios (D. Hodell, pers.comm).*

Site U1313

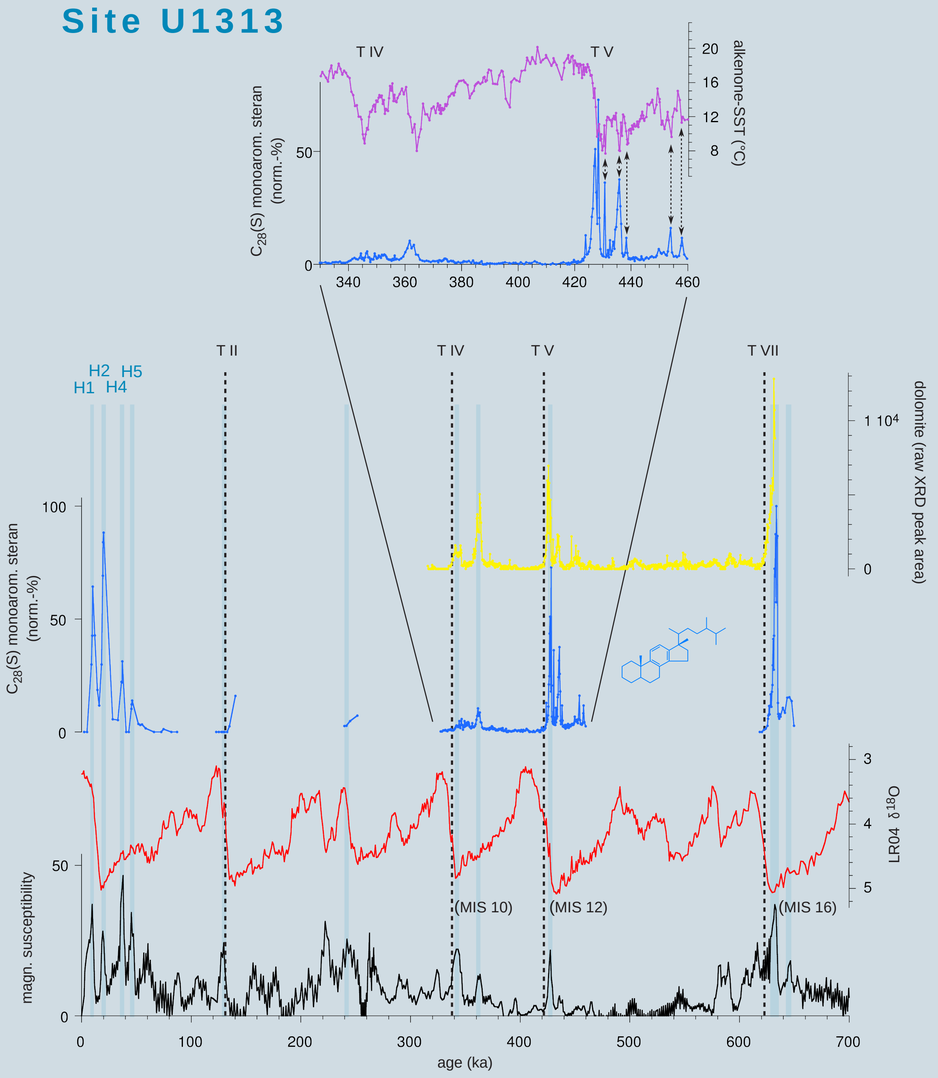


Figure 8: *Biomarker record of Heinrich Events 1, 2, 4, 5 and occurrence of Heinrich-type layers during glacial stages MIS 10 - 16 at Site U1313. Blue lines indicate peaks in magnetic susceptibility.*