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"Heinrich events" (& sediments): A history of terminology and recommendations for future usage

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ABSTRACT

We document the history of terms used to describe Heinrich (H-) layers and events and which mark major glaciological iceberg discharge events in the North Atlantic. We argue that the usage "Heinrich layer," "Heinrich zone", or "Heinrich event" should be restricted to only those sediments that can be ascribed to an origin from the Hudson Strait Ice Stream and the Laurentide Ice Sheet. We also argue that the commonplace understanding of these events—as dominated by massive iceberg discharges —fails to include the earlier well-documented evidence that these events were also massive meltwater events linked to deposition along the North Atlantic Mid-Ocean Channel (NAMOC) in the Labrador Sea. We make five recommendations for future usage of "Heinrich events," which include: restricting the usage to those events that can be mineralogically/geochemically linked to Hudson Strait; abandoning the term "Heinrich stadial"; and promote local terminology for "ice rafted events" that may be correlated, or not, with Hudson Strait Heinrich events based on calibrated radiocarbon dates or other appropriate chronological markers.

1. Introduction

In a recent paper (Andrews et al., 2017) comparing sediment records from north (PS2644) and south of the Denmark Strait (MD99-2260) (Fig. 1A and B) we stated, in terms of discrete ice rafted debris (IRD) events " …. *we suggest that this term (H-events) be restricted to sediments that have a diagnostic mineral and geochemical signature linked to that source (i.e. Hudson Strait/Hudson Bay)* (Andrews and Tedesco, 1992; Farmer et al., 2003; Hemming, 2004). *Despite our own prior usage we now argue that the IRD events recorded in MD99-2260 and PS2644 should be given their own designation (e.g. Kangerlussuaq IRD event 1 or PS2644 IRD event 2) and that temporal correlation with H-events may or may not be required."* This paper outlines the rationale behind this quotation.

The Hudson Strait Heinrich (H)-events originated from the major ice stream draining the Laurentide Ice Sheet (Alley and MacAyeal, 1994; Andrews and MacLean, 2003; Stokes et al., 2016), but it is important to note that this ice stream differs from virtually all others, at least in the Northern Hemisphere. It is not, for example, associated with the deposition of massive trough mouth fans (TMF) at the foot of the slope (O'Cofaigh et al., 2003; Vorren and Labert, 1997), but rather with a highly gullied slope that leads to the North Atlantic Mid-Ocean Channel (NAMOC) (Chough et al., 1987; Hesse et al., 1996; Praeg et al., 1986) (Fig. 1C). This implies that the Hudson Strait Detrital Carbonate events may not have equivalent counter-parts seaward of other Northern Hemisphere ice streams, and that proximal sediment processes might be very different. We would also affirm the statement made by Marshall and Koutnik (2006, p. 10 of 13) "*The difference between Heinrich events and D-O cycles has been broadly misunderstood by the paleoclimate community*". Our "Opinion Paper" is in no-way intended as an in depth review of all facets of H-events (Hemming, 2004), and thus, the purpose of this note is to:

1) discuss the history of the usage of the term H- layer/events,
2) emphasize the complexity of these ice stream collapse sediments,
3) compare and contrast with the terminology and usage of discrete volcanic tephra plumes, and
4) suggest the use of the term "Heinrich" be more rigorously restricted.

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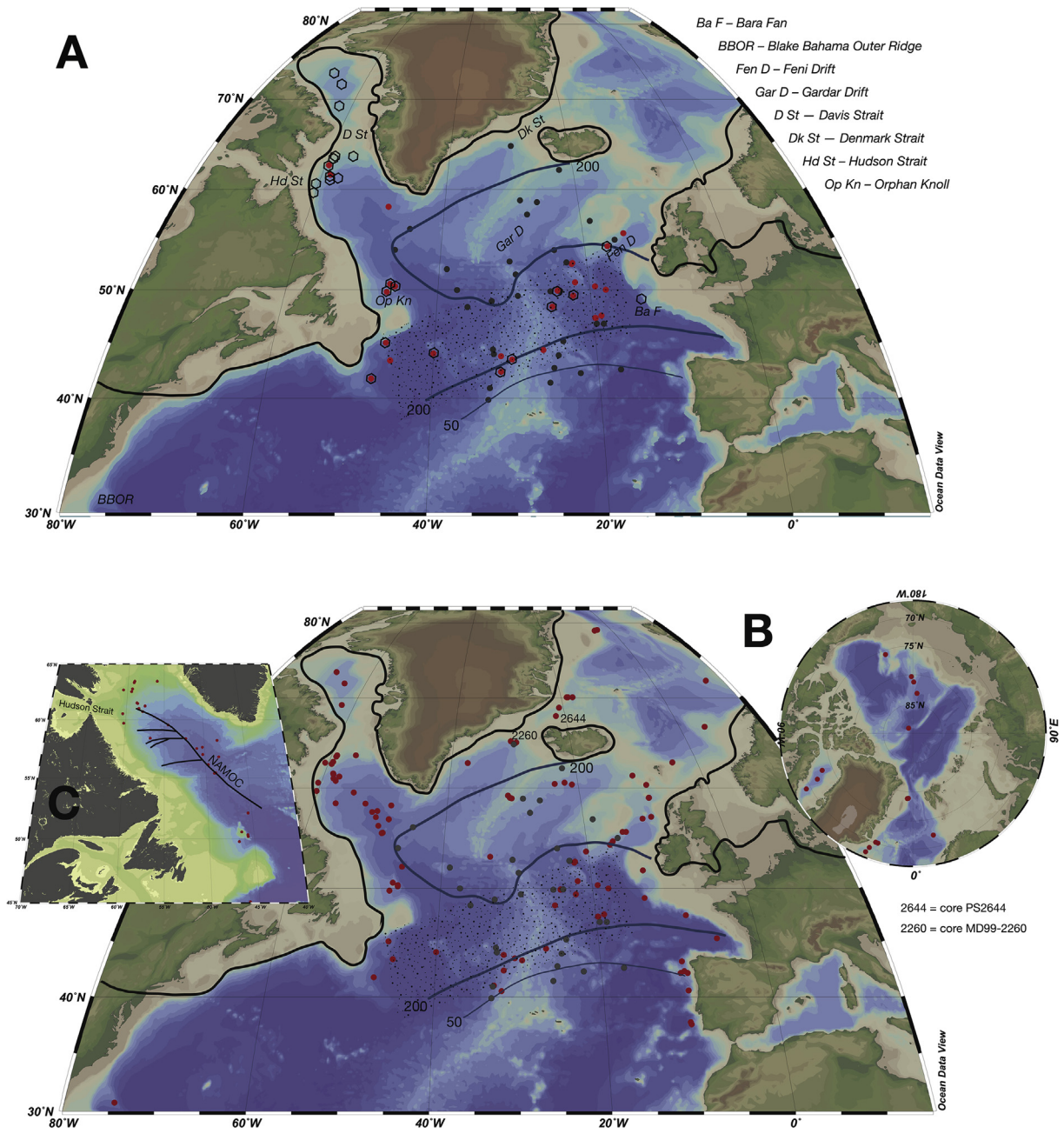

Fig. 1. A: Core sites of the initial Heinrich layer/event studies (red dots; published between 1988 and 1999; see Supplementary Table 1 for details) and sites with a detrital carbonate signal during Heinrich events (polygons). B: Core sites with IRD signals during Heinrich events (published between 1978 and 2017; see Supplementary Table 1 for details). Inset on the right shows cores in the Arctic Ocean with reference to H events. In A and B, the dark gray dots mark the core sites studied by Ruddiman (1977). Petrol-blue colored lines indicate IRD concentrations reconstructed by Ruddiman (1977) for the period from 25 to 40 ka, i.e. late Marine Isotope Stage 3 and encompassing H 3 and H 4, with numbers 200 and 50 (thinner line) denoting the respective concentrations [milligrams per square centimetre per 1000 y]. The stippled area marks the region referred to as "Ruddiman IRD belt". Black lines show the Last Glacial Maximum ice sheet extent according to Stokes et al. (2016) for North America, Greenland and Iceland and to Hughes et al. (2016) for Scandinavia, Ireland, England and northern Europe. C (inset on left in B): Close-up of the Labrador Sea with the North Atlantic Mid-Ocean Channel (NAMOC) and some feeder channels on the Canadian margin indicated by black lines. All maps were generated with Ocean Data View (Schlitzer, 2016). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

2. Definition and usage of Heinrich layers/events: history

On Fig. 1A, B, and C we illustrate the location of cores that have been associated with or correlated with H-events, whereas on Fig. 2 we show the large range in the number of citations linked to the key papers. In Supplemental Table 1 we document the papers that preceded and followed Heinrich's classic paper (Heinrich, 1988), the terminology and proxy/proxies employed, and the areas affected (Fig. 1A, B, C).

The role of icebergs and sea ice in contributing sediments to the ocean floor has a long history (e.g. Tarr, 1897; Trask, 1932) but the recognition of IRD in North Atlantic sediments may have been first documented by Bramlette and Bradley (1940), followed by Conolly and Ewing (1965) (see Andrews and Matsch (1983) for literature review and bibliography). Iceberg rafting gained paleoclimate prominence when Ruddiman (1977) described a series of sand-rich