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Application of Tephrochronology to the Dating of a Multi-proxy Study of High Resolution Marine Shelf Records at the North Atlantic Oceanographic Polar Front

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The chronology of marine sediment cores from high resolution basins on the North Icelandic shelf is based on combined tephrochronology and AMS 14C datings. Reliably dated tephra markers provide age control for archives of Holocene palaeoceanographic changes in the vicinity of the oceanographic Polar Front. The present position of the Polar Front separates Arctic surface water of the East Greenland and the East Icelandic currents (Polar Water) from branches of the North Atlantic Current, the Irminger Current (Atlantic Water) to the west and north of Iceland. The area is also within the realm of the Arctic Front that delineates the maximum extent of the winter sea ice, which periodically extends from Greenland to Iceland. The Norwegian Sea Deep Water replaces the surface and intermediate water masses at a depth of 300-400 m off North Iceland. The modern salinity and temperature data from the area show that the deep water masses may be expected to encroach into topographic lows and basins on the shelf during periods of active deep water formation in the Nordic Seas. Another climatic boundary is represented by the North Atlantic Atmospheric low-depression track and the accompanying westerlies across Iceland. The strong gra-

dients both in the ocean and in the atmosphere make this region extremely sensitive to climatic changes. The study area on the North Icelandic shelf has the advantage of being close to numerous source volcanoes of Holocene tephras. Tephra markers that can be traced from volcanic source regions into the marine depositional environment can provide control on radiocarbon dates from that environment. The ages of Icelandic tephra markers used in this study are based on historical records from Iceland for the last 900 years, on correlation to the Greenland ice-core chronology and on radiocarbon dates of terrestrial material. High resolution tephra stratigraphy can be used to link chronologies in the terrestrial North Iceland and the high resolution marine sediment core MD992275 (66°33'N; 17°42'W; 440 m water depth). A detailed land-sea correlation of the regional terrestrial tephrochronology with the marine record has been demonstrated. This comparison of a tephrochronological age model and a radiocarbon one makes it possible to study local reservoir age problems. A marine reservoir correction of 400 years is generally applied for Holocene radiocarbon datings in the region. However, recent results from the North Icelandic shelf show that the reservoir age has not been constant in the area through Holocene time. Tephrochronology enables us to obtain independent control on radiocarbon datings from sedimentary records in an oceanographic boundary region between Atlantic and Arctic water masses. Numerous parameters from core MD992275 have been studied for reconstructing the Holocene palaeoceanography of the region, including benthic and planktonic foraminiferal data, stable isotopes, diatom transfer function based SST, alkenone palaeo-thermometry, magnetic properties, ice rafted debris content and grain size properties. A high resolution study of these parameters is presented for the last two millennia. Benthic and planktonic foraminiferal assemblage distributions and stable isotope records show changes in bottom and surface water temperature and salinity as a result of variations in the relative strength of the Irminger Current and the cold East Icelandic Current. Also, the ice rafted debris flux and the diatom-based reconstruction of sea-surface temperatures reflect the fluctuations in the influence of Arctic surface waters. The highest IRD fluxes are observed in the eastern part of the area, where the surface waters are generally coldest. The benthic productivity (number of benthic foraminifera/cm2/year) is generally relatively high during cold periods and low during warmer periods. This is presumably determined by the position of the marine Polar Front close to the coring site during cold spells. The time period between 1200 and around 7-800 cal. BP, including the Medieval Warm Period (MWP), was characterized by relatively high bottom and surface water temperatures due to a rather strong influence of the Irminger Current. A general drop temperature in the area after 7-800 cal. BP marks the transition to a period with increased influence of the cold, low-salinity Arctic waters of the East Icelandic Current. As a result, the time interval between 7-800 and 3-400 cal. BP, corresponding to the early part of the Little Ice Age

(LIA), experienced a pronounced temperature decrease, not only in surface waters but also at the sea floor. The time interval after about 3-400 cal. BP is characterized by a further increase in the inflow of Arctic waters to the area. The surface waters were particularily influenced by highly variable inflow of cold and low-salinity waters, while the sea floor appears to have been under some influence of dense, high-salinity Atlantic waters. As a result, there was a pronounced stratification of the water masses during this later part of the Little Ice Age and into modern times. Diatom proxies from the modern position of the oceanographic Polar Front north of Iceland record variability in sea-surface temperatures during the past 2 millennia. Comparison of changes in summer SST on the North Icelandic Shelf with variations in the atmospheric circulation above Greenland, North American Atlantic coastal SSTs, and mean temperature anomalies for the Northern Hemisphere suggests synchronous North Atlantic-wide fluctuations, which would seem to imply a common forcing factor. Both the summer (SSTs) and the winter (SSTw) sea-surface temperatures show multidecadal-to-centennial timescale fluctuations and the magnitude of fluctuations, from relatively warm to cold periods is about 1.0-1.5 degrees Celcius. There is a prominent drop in SSTs at AD 1300 and in both SSTs and SSTw at AD 1600. Changes in the sea-surface and bottom water environments, including temperature fluctuations, on the North Icelandic shelf are correlated with the MWP and the LIA. The timing of the relatively warm MWP (AD 850-1300) and the cold LIA (AD 1300-1900) north of Iceland corresponds to that reported in historical sources from Iceland. It is also in accordance with climatic changes recorded in Greenland ice cores and in Europe, as well as the Northern Hemisphere temperature anomaly fluctuations. Palaeoceanographic variations within the LIA on the North Icelandic shelf is also similar to the indication of the Iceland Sea Ice Index and other historical sources in Iceland. A high resolution record of the magnetic properties from the MD99-2275 core for the last 10000 cal. BP (before 1950) has allowed to identify some important features of Holocene climatic variability at northern latitudes. Increased oceanic instability, probably linked to climatic variability, is observed from around 6000 cal. BP, with enhanced short-term oscillations in the more recent period. The Medieval Warm Period is well expressed in our record (670-930 cal. BP; AD 1020 to 1330) by reduced concentration in magnetic minerals and coarser magnetic grain size, probably linked to renewed activity of the Irminger Current and increased North Atlantic Deep Water formation. Several similar periods of reduced concentration in magnetic minerals and coarse magnetic grain size in the record (2700-3010, 3410-3770 and 4900-5100 cal. BP, and maybe also 7500-7700 and 8000-8200 cal. BP) are presumably also related to ocanographic changes. A strong cyclicity, which is particularly enhanced in the last 6000 years, is observed with periods of 100, 170, 240 and 720 years. A high resolution proxy record of alkenone SST reconstructions was generated in core MD992275 retrieved from the north Ice-

landic shelf. Here we compare alkenone paleo-thermometry over the last 2000 years with other proxies, with the alkenone proxy mean resolution of 4 years. The overall record exhibits a decreasing trend from c. 9°C down to 7°C. The AD 980-1340 interval is characterized by warmer SSTs (averaging 9°C) coinciding with the MWP. The structure of the temperature record correlates well with the GISP2 oxygen record. A similar interval from c. AD 300 to 700 probably coincides with the Roman Warm Period. Our record also shows significant SST coolings coincident with major solar radiation minima. Covariations of the proxies from the North Icelandic Shelf with each other and with temperature anomalies from the North Atlantic region indicate that the variability at decadal to centennial time scales in these records reflects the regional climate rather than local temperature fluctuations. A positive and significant correlation between our diatom based SST record from the North Icelandic Shelf and inferred insolation, together with modeling experiments, supports the hypothesis that solar forcing is an important constituent of natural climate variability in the northern North Atlantic.