Chapter 1

The "*Turritella* Layer": A Potential Proxy of a Drastic Holocene Environmental Change on the North–East Atlantic Coast

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Abstract A collection of data including sub-bottom VHR seismic (Seistec boomer), bathymetry and cores, was conducted in three sea lochs of the north west coast of Scotland, as part of an investigation of the sedimentological and climatic change records since the Last Glacial Maximum. Five acoustic facies have been correlated to the sediment of the core MD04-3204 and interpreted in terms of glacial activity, ice retreat and subsequent Holocene sedimentation. Grain size, pollen, foraminifera, geochemical analyses together with ^{14}C dating, indicate a

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complex series of palaeoclimate changes in the loch since the Last Glacial Maximum including “Rapid Climate Changes” described in literature.

A characteristic acoustic reflector, identified into the holocene sedimentary deposit, occurring into the different studied lochs, corresponds to a unique *Turritella* layer. A similar reflector has been identified on the continental shelf of South Brittany and is correlated to a *Turritella* layer. This *Turritella* layer seems to be related, in both case, to a drastic environmental change beginning around the 8,200 year BP cold event and finishing abruptly at 7,500 year BP in the North Atlantic.

1.1 Introduction

As the western Scottish sea lochs (Fig. 1.1) are located at an important junction between the North Atlantic Ocean and the European waters of the North Sea, these sites are adapted for observations on climatic variations at high latitudes, and in particular variations in sedimentation that have resulted from climatic changes since the Last Glacial Maximum (LGM) at high latitudes 56°N. Previous studies

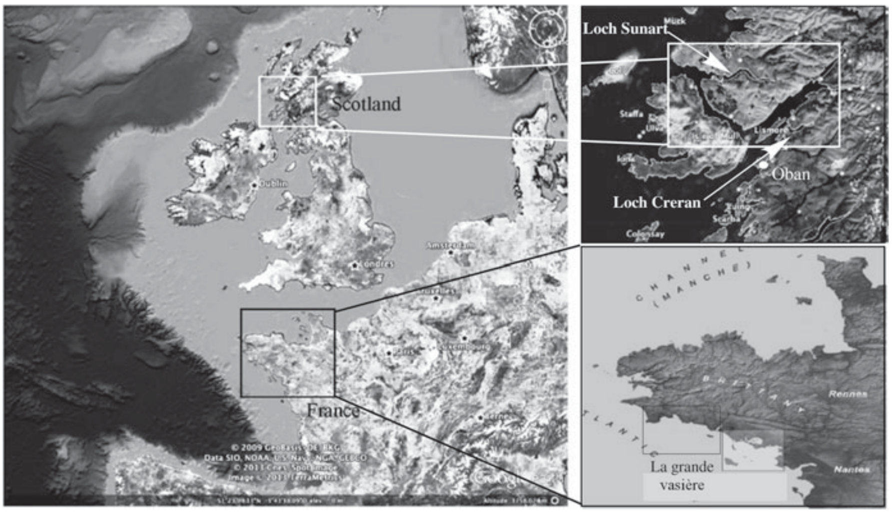

Fig. 1.1 Location of the two studies areas in the north west coast of Scotland and in south Brittany. The *white square* in Scotland, north of Oban, shows the location of two sea-lochs: Loch Sunart and Loch Creran. A first géophysic survey (SUCRE, 2002), allowed to acquire seismic profiles in both lochs and short cores in Creran. An oceanographic cruise with the Marion Dufresne (ORSANE 2004) permit to acquire 2 long cores. The *black square* on the south coast of Brittany shows the location of the “Grande vasière”, a huge muddy sand patch occurring on the shelf, up to 100 m of water depth

(Mokeddem et al. 2010; Baltzer et al. 2010) established the chronostratigraphy of sedimentary deposits in the Loch Sunart, based on the correlation between a long core (12 m) and seismic acoustic facies constrained by ^{14}C ages together with sediment analysis. An unusual reflector frequently occurs in the Holocene thick transparent sedimentary unit of Loch Sunart and Loch Creran which corresponds to a 15 cm thick layer of *Turritella communis* (Graham 1938, 1988) dated from base to top at 8,260–7,460 cal year BP.

On the southern part of Brittany, the core VK03-58bis retrieved in the Bay of Biscay gives an integrated image of the climate evolution at mid latitudes (45°N) through pollen and Dinocysts analyses (Naughton et al. 2007) from 8,850 year BP to present days. This core was acquired in “la Grande vasière” (Fig. 1.1) in a homogeneous silt sequence marked by a specific level rich in *T. communis* (Folliot 2004) dated at 8,482–7,520 year BP. In both cases the sudden disparition of *T. communis* seems to correspond to a drastic change of environmental conditions.

This paper presents hypothesis for the establishment and extinction of this *Turritella* layer, and its potential signification.

1.2 General Settings: Scottish Sea Lochs and South Brittany Shelf

1.2.1 Scottish Sea Lochs

The two Lochs presented in this paper, are localised on the West coast of Scotland. Loch Creran is located in the north of Argyll and Bute council whereas Loch Sunart is located near the Ardnamurchan peninsula (Fig. 1.1). These lochs are bordered by mountains whose altitude does not exceed 1,000 m. Vegetation cover is variable, including spaces of forests and grassland.

These lochs present a characteristic morphology of “fjord style lochs” with a steep sided narrow cross section and flat loch floor (Syvitski et al. 1987). This typical morphology provides protection from swell and wave action and could preserve long sedimentation records (Howe et al. 2002). Loch Sunart (Fig. 1.2) is the second longest Scottish loch with 31 km length (Bates et al. 2004), an average of 1.5 km width and has a maximum depth of 124 m. The length and the narrowness of this loch make it possible to meet a spectrum of hydrodynamic conditions, from well exposed conditions at the mouth, to extremely calm conditions at the head of the loch.

The Loch Creran (Fig. 1.3) is smaller than Loch Sunart, with 12.8 km length and a maximum depth of 49 m. Located at 8 km north of Loch Etive, its ocean connection is restricted by the Island of Eriska which protects the inner basin from the energy of the swell. The Loch Creran includes four basins and Glen Creran constitutes the principal supply of fresh water. The water of the Loch Creran is extremely well mixed (Edwards and Sharples 1986; Austin and Inall 2002).

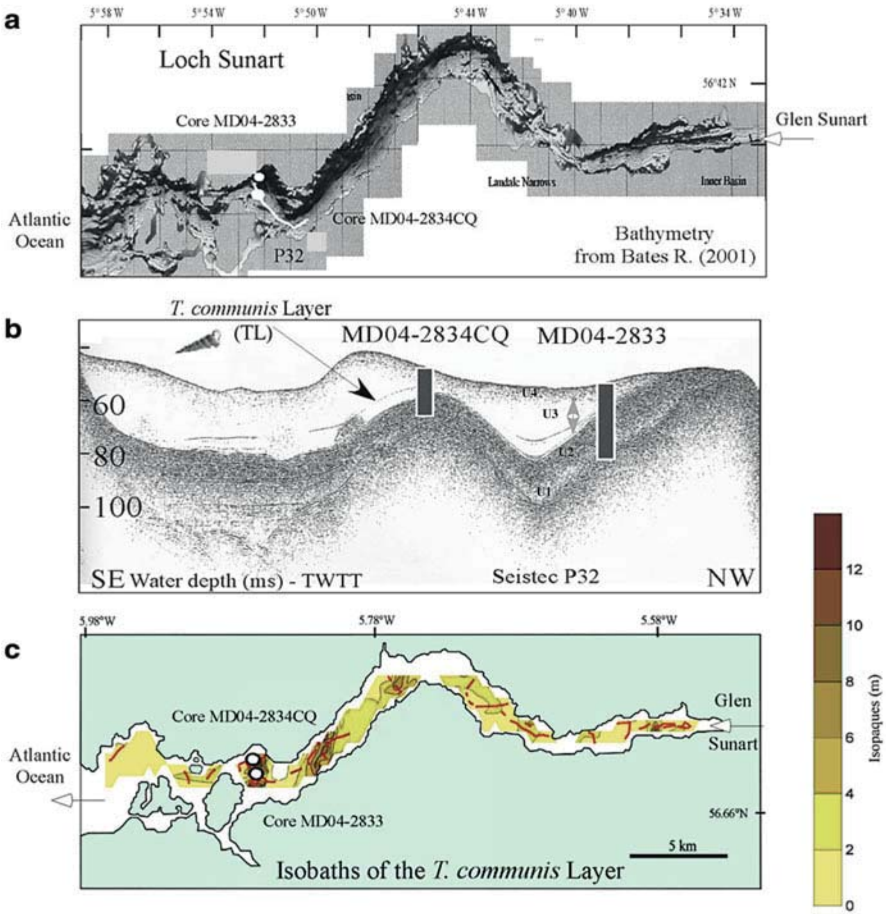

Fig. 1.2 Loch Sunart. (**a**) Bathymetric map of Loch sunart realized by Bates (Bates and Byham 2001). Location of the 2 long cores MD04-2833 and core MD04-234CQ acquired with the Marion Dufresne and the situation of the boomer seismic profile P32. (**b**) Seistec profile P32: characteristic profile with the different seismic units. The Turitella communis Layer is indicated by an *arrow* in the transparent unit (U3). The position of the long CALYPSO core MD04-2833 and the CASQ core MD04-2834CQ are indicated, showing the variation of Turritella Layer (noticed T.L. further on) depth. (**c**) Map of the T.L. isobaths. The seismic reflector related to the TL has been mapped. The resulting isobaths are shown on the figure and reveal the paleo-bathymetry at 7,500 cal year BP (age of the top of the TL.)

1.2.2 South Brittany Shelf

The Bay of Biscay presents a 300 km wide continental shelf in it's north-westernmost area and becomes narrow with a steep slope further south (30 km wide) (Fig. 1.1). This shelf is composed of two small and one large open-shelf mud patches: the West and South Gironde shelf mud fields and the "Grande Vasière"

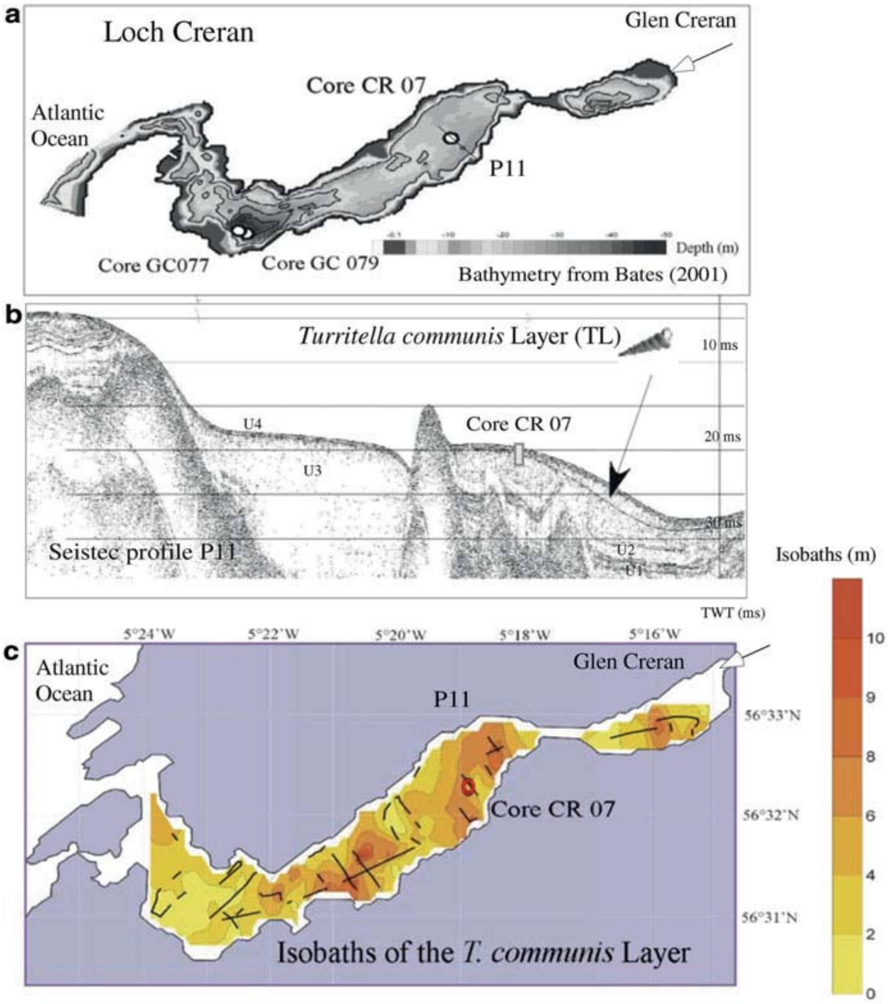

Fig. 1.3 Loch Creran. (**a**) Bathymetric map of Loch Creran realized by Bates (Bates and Byham 2001). Location of the short core CR07 acquired by divers during the SUCRE mission, and the situation of the boomer seismic profile P11. (**b**) Seistec profile P11: characteristic profile with the different seismic units. The Turitella communis Layer is indicated by an *arrow* in the transparent unit (U3). The position of the short core CR 07 is indicated, showing the variation of TL depth. (**c**) Map of the TL isobaths. The seismic reflector related to the TL has been mapped. The resulting isobaths are shown on the figure and reveal the paleo-bathymetry at 7,500 cal year BP (age of the top of the T.L.)

(Fig. 1.4) (Allen and Castaing 1977). According to McCave’s classification the “Grande Vasière” is a mid-shelf mud belt (McCave 1972). The “Grande Vasière” is large (more than 225 km length and 40 km wide), located between 80 and 110 m water depth and presents an annual mean sedimentary rate of 0.1–0.2 cm year^{-1} (Lesueur et al. 2001) (Fig. 1.1). Shelf upkeep depends essentially on: (a) continental supply by nepheloid layers (Jouanneau et al. 1999; Lesueur et al. 2001); (b) wave

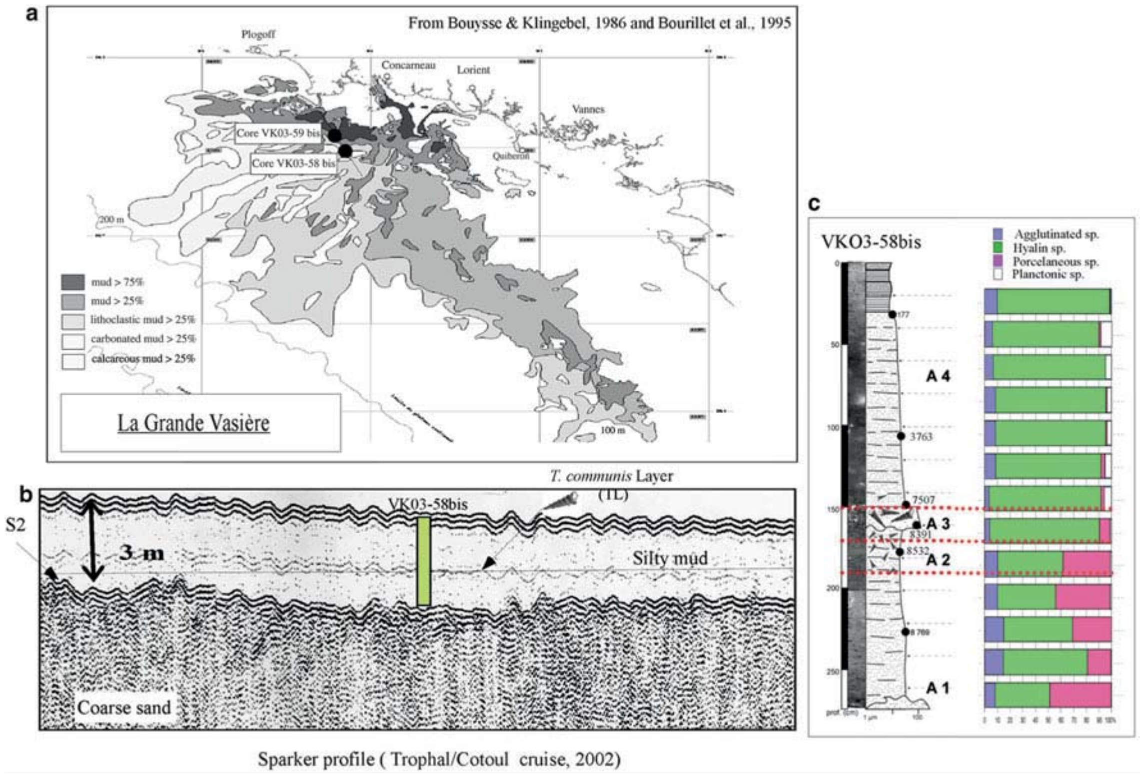

Fig. 1.4 The Grande Vasière. (**a**) Bathymetric map of the south Brittany shelf showing the surface of 8,000 km^2 covered by the "Grande Vasière", a mid-shelf mud belt, centered around 100 m of water depths. The repartition of the different mud facies is linked to the source of the sediments. Sands and gravels come from remobilization of the shelf sediments and the clays are supplied by the different rivers, especially the Gironde. (**b**) The Sparker profile shows the acoustic facies units: basal facies is constituted by coarse sands eroded by an erosional surface S2, which has a regional extension. The above unit is essentially composed of silty mud of varying thickness (from 3à cm to a maximum of 3 m). Within this unit, a dark continuous reflector reveals the presence of the Turritella Layer, sampled by the core VK03-58bis. (**c**) The log of the core VK03-58bis is presented here with the percentages of different foramonifera assemblages: Agglutinated species, Hyalin species, Porcelaneous species and Planctonic species

action (Pinot 1974) and hydrology, and (c) sea level changes (Lesueur and Klingebiel 1976). The "Grande Vasière" rests over two sandy units and consists of a thin (few decimetres) Holocene feature of muddy autochthon sand (Bourillet et al. 2002, 2005).

1.3 Material and Methods

In this paragraph, we only present materiel and methods deployed for our studies in Scottish lochs. The comparison with the work done by Naughton et al. (2007) on the cores acquired on the Brittany shelf will be tackled in the discussion part.

1.3.1 Geophysical Surveys

A complete set of data was acquired in the Loch Sunart: two geophysical surveys (bathymetric sidescan and a Seistec Boomer) where completed by the acquisition of a Calypso long core of 12 m. A Seistec Boomer System (IKB Ltd) was used to record sub-bottom profiles. It has a frequency range from 1 to 10 kHz, a pulse duration ranging from 75 to 250 ms at a power of 150 J, allowing a spatial resolution of 25 cm, with a penetration up to 100 m in soft sediments and 200 m in deep water soft sediments (Simpkin and Davis 1993). Thirty four profiles, recovering 60 km, were acquired in the loch with an average penetration of 50 m except in some areas where gas occurrence prevented any signal penetration. The Seistec sub-bottom profile 32 (Fig. 1.2b) shows a representative section of all five seismic facies that are present in the inner basin.

1.3.2 Sediment Cores

The long core MD04-2833 (Fig. 1.2b) was acquired by the giant Calypso core system on board the RV Marion Dufresne. This piston corer is similar to a gravity corer but a piston is used to reduce internal friction in the barrel, enabling the corer to recover complete and less disturbed sediment sequences than an open barrel gravity corer. The MD04-2833 core was 12 m long and was acquired in the middle loch to the west of Isle of Carna at a water depth of 38 m (Fig. 1.2). MD04-2834CQ is a casq long core (11.80 m) acquired close to the MD04-2833. The combined pollen, foraminifera and sedimentological analysis help us to interpret many of the features observed in seismic sections. The correlation of the seismic facies with the sediments units (Mokeddem et al. 2007, 2010; Baltzer et al. 2010) allowed to follow the evolution of the sediment fluxes linked to environmental changes. In these both cores, a specific layer of 15 cm thick, composed at 98 % of *Turritella communis* shells, occurs within the upper seismic section. Another short core CRE07, acquired in the Loch Creran, reveals a similar *Turritella* layer. Geochemical analyses have been realised on this *Turritella* layer (noticed TL) to complete this study.

1.3.3 ^{14}C Ages

Core MD04-2833 was analysed for sedimentation and microfauna with seven ^{14}C ages acquired on different shell samples, all in life positions (see Table 1.1) and one ^{14}C ages for the core MD08-2334CQ. A standard reservoir correction R(t) of 400 years was used as the regional average value for western Britain (Harkness 1983) and calibrated calendar ages were obtained from the calibration tables in Stuiver and Reimer (1993), Stuiver et al. (1998) by means of the CALIB 5.1.0b software.

1.3.4 Foraminifera Analysis

A preliminary analysis of foraminiferal assemblages, based on dominant species of 87 samples taken from the core has been conducted. Approximately 20 g of sediment samples were washed through 2 mm and 500 μm, 125 μm and 45 μm sieves. Residues were oven dried (40 °C) and dry sample weights recorded. The 125 μm and 45 μm fractions were observed under a binocular at 80× magnification

Table 1.1 ^{14}C ages acquired from core MD04-2833 *(italic)* and MD04-2834CQ (normal)

Material	Depth (cm)	Laboratory code	Radiocarbone age (year BP)	Corrected[b] (calibrated) age (cal year BP)	± 2[c] (cal year BP)
Turritella communis	81	[a]Poz-23471	1,405 ± 30	994	777–1,211
Wood fragment	198	[a]Poz-23648	4,885 ± 35	5,623	5,584–5,663
Turritella communis	265	[a]Poz-1054	6,910 ± 40	7,414	7,325–7,503
Turritella communis	270	[a]Poz-23648	6,920 ± 35	7,459	7,411–7,507
Turritella communis	271	[a]Poz-23472	6,950 ± 40	7,468	7,389–7,548
Pecten species	385	[a]Poz-13368	8,710 ± 50	9,374	9,262–9,447
Pecten maximus	776	[a]UL-2853	14,020 ± 210	16,760	16,067–17,454
Turritella communis	178	[a]Poz-23473	6,750 ± 40	7,320	7,212–7,407

[a]Poznan Radiocarbon Laboratory, °Laval University Laboratory

[b]Marine reservoir correction: 405 ± 40 year (Harkness 1983)

[c]Standard deviation (Stuiver et al. 1998)

to determine the dominant species. A total of 300 specimens were counted. The generic and specific identifications were based on taxonomic sources (Murray 1971; Loeblich and Tappan 1988; Murray 2000, 2003; Fontanier et al. 2002). The paleoenvironmental reconstitution is based on ecological and morphological groups of benthic foraminifers (Goubert et al. 2001; Mokeddem et al. 2010). The ecological significances of the species come from Murray (2006), Scourse (2002) and Mokeddem et al. (2010).

1.3.5 Geochemical Analyses (Oxygen and Carbon Isotope Composition) on Core MD2833

Mollusk gastropods are considered to precipitate their shells in isotopic equilibrium with seawater (Grossman and Ku 1986; Latal et al. 2004). Particularly, turritelid shells are considered to be a reliable archive of paleoenvironmental and paleoclimatic conditions (Andreasson and Schmitz 1996; Huyghe et al. 2012).

Two aragonitic *Turritella communis* shells were used for oxygen and carbon isotope composition. The first one was taken at 265 cm depth in the core MD04-2833 (shell ID: 265), corresponding to the center of the Loch Sunart and the other one was taken at 178 cm in the core MD04-2834CQ (shell ID: 178), corresponding to the edge of the same *Turritella* layer. The two samples were dated at 7,414 cal year. BP.

Sampling for $\delta^{18}O$ and $\delta\ ^{13}C$ analyses was achieved each millimeter along the transect of growth from the uppermost layer, by using a 0.5 mm drill bit. The powdered $CaCO_3$ samples were analysed according to standard techniques (Jones and Quitmyer 1996) which involved an initial reaction in vacuo with 100 % orthophosphoric acid at 90 °C for 15 min. An on-line automated carbonate-preparation system facilitated the production and purification of evolved CO_2 gas. The isotopic differences between the derived CO_2 gas and the VPDB standard were determined with a VG Instruments Isoprime mass spectrometer. Isotopic data were reported in conventional delta (δ) notation relative to the Vienna Pee Dee Belemnite (VPDB). The standard used for the analyses was an internal standard calibrated on the NBS-19. Standard deviation for $\delta\ ^{18}O$ and $\delta^{13}C$ is ±0.05‰.

1.4 Results

1.4.1 Seismic Data: Mapping of the "Turritella's *Reflector*"

Sedimentary processes in this loch have been grouped into four units (Mokeddem et al. 2007, 2010; Baltzer et al. 2010) from the Last Glacial Maximum (Fig. 1.5).

Unit 1 corresponds to a basal till sequence (numerous dropstones and gravels in a clayey silty mud matrix). Effective deglaciation processes appear only after

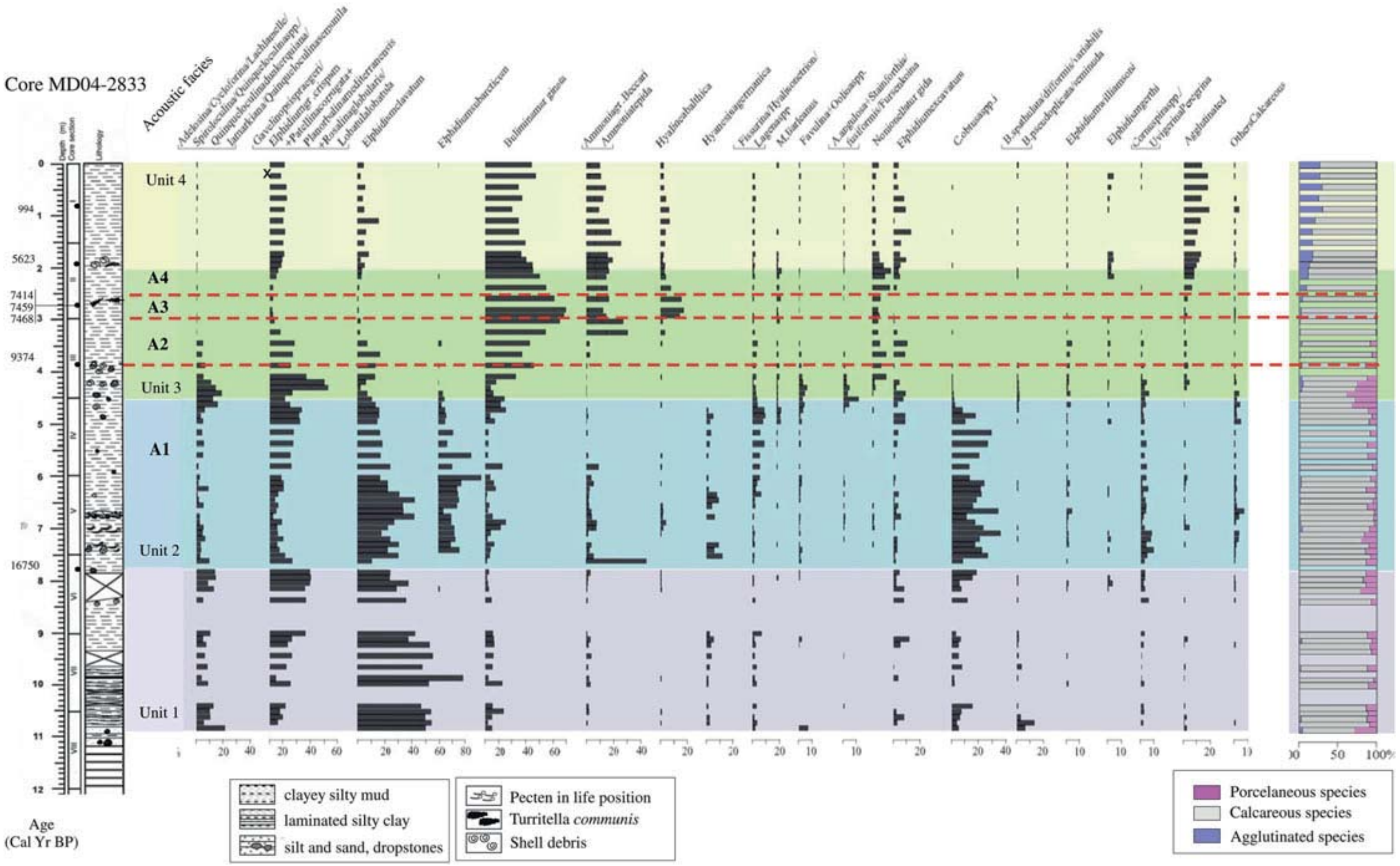

Fig. 1.5 Stratigraphic distribution of benthic foraminifera assemblages (percentages of total benthic faunas) in core MD04-2833. Four domains are delimited by global species changes and correspond to the four seismic unit facies (Unit 1, Unit 2, Unit 3, Unit 4). Three main species of foraminifera have been grouped: the Porcelaneous species, the Calcareous species and the Agglutinated species

16,750 cal year BP. The more temperate Bölling period (15,730 cal year BP), occurs at the end of this unit. Unit 2 presents fine acoustic layering of glaciomarine origin which corresponds to a period including the Younger Dryas sedimentation, when the ice cap re-advanced, stopped and retreat. A major unconformity surface cuts across the top of this unit with up to 40 cm of vertical erosion, probably related to the lowest position of the relative sea level (around 4 m) at these times. Unit 3 is interpreted as a time of rapid and large volume sediment supply where significant reworking was taking place, even under weak currents. The transparent facies of this unit suggests an unconsolidated state of the sediments associated with rapid sedimentation. A continuous and high amplitude reflector frequently occurs into this transparent facies (Figs. 1.2b and 1.3b) which corresponds to a 15 cm thick layer of *Turritella* shells dated from 7,468 to 7,414 cal year BP in the core MD04-2833. This TL was sampled in the "sister core" MD04-2834CQ acquired on the edge of the basin. The Unit 4, characterised by thin laminated beds of silty clay reveals a low sediment supply in a quiet environment and corresponds to recent sedimentation patterns with decreasing sediment supply.

The high amplitude of the "Turritella reflector" related to the TL, reveals a very high impedance which is in accordance with a shelly layer included in a soft deposit. The spatial extension of this reflector (Figs. 1.2 and 1.3) appears to follow paleo-bathymetry in loch Sunart and Creran. *Turritella communis* (Risso 1826) occurs locally and abundantly in gravelly muddy, more or less buried, in shallow water sediments up to 200 m (Graham 1988). *T. communis*, who have a highly specialized mud-burrowing habit, maintains contact with the water, from which the gill filters suspended particles (Yonge 1946) but without disturbing the surrounding mud. The actual distribution ranges from northern Norway (Lofoten Isles) to North Africa, including the Mediterranean Sea (Graham 1938).

These observations mean that the TL exactly underlines the paleo-bottom floor of the lochs.

1.4.2 Foraminifera Analyses

The Fig. 1.5 shows that the TL corresponds to abrupt variations of the different foraminifera curves.

The cold species abundance, *Hyalinea balthica* and the extinction of *Hyanesina germanica*, show a cooling event which began at 380 cm (8,200 cal year BP) and finished at 240 cm (7,400 cal year BP). This event is short in time and underlines an abrupt change of temperature. A net increase of *Bulimina marginata* and *Becarii* abundance traduces a complete environmental change with occurrence of confinement conditions. Simultaneous extinction of *Clavatum* species confirms a very low oxygen content. At 4,000 cal year BP climatic conditions improve with a net increase of the temperature, illustrated by the development of the porcelaneous species around the "climatic optimum".

The benthic foraminiferal assemblages show that the trophic equilibrium of the environments is disrupted according to the large dominance of opportunistic and infaunal species like *Bulimina marginata* and *Ammonia* spp.

1.4.3 *Oxygen and Carbon Isotopic Composition of* **T. communis** *Shells*

The two shells exhibit equivalent mean oxygen isotope composition ($\delta^{18}O_{265} = 2.28 \pm 0.25‰$ and mean $\delta^{18}O_{178} = 2.27 \pm 0.25‰$). The maximum range is closely similar: 1.10‰ for the shell 265 and 1.03‰ for the shell 178. Oxygen isotope values were converted into seawater temperatures using the paleotemperature equation of Grossman and Ku (1986), for the temperature-dependent fractionation of aragonite in mollusks relative to seawater: T (°C) = 21.8 − 4.69 [shell $\delta^{18}O_{VPDB}$ − (seawater $\delta^{18}O_{SMOW}$ − 0.2‰)]. The measured oxygen isotope composition of North-West Scottish coastal waters and sea lochs is 0.18‰ SMOW (Austin and Inall 2002). The mean estimated temperature is 11 ± 1.2 °C for shell 265 and 11.1 ± 1.2 °C for shell 178. The two profiles show clear seasonal cycles, with a winter average of 8.8 ± 0.7 °C (shell 265) and 9.5 ± 0.7 °C (shell 178), and a summer average of 12.4 ± 0.7 °C and 12.8 ± 0.4 °C (for shell 265 and 178 respectively) (Fig. 1.6).

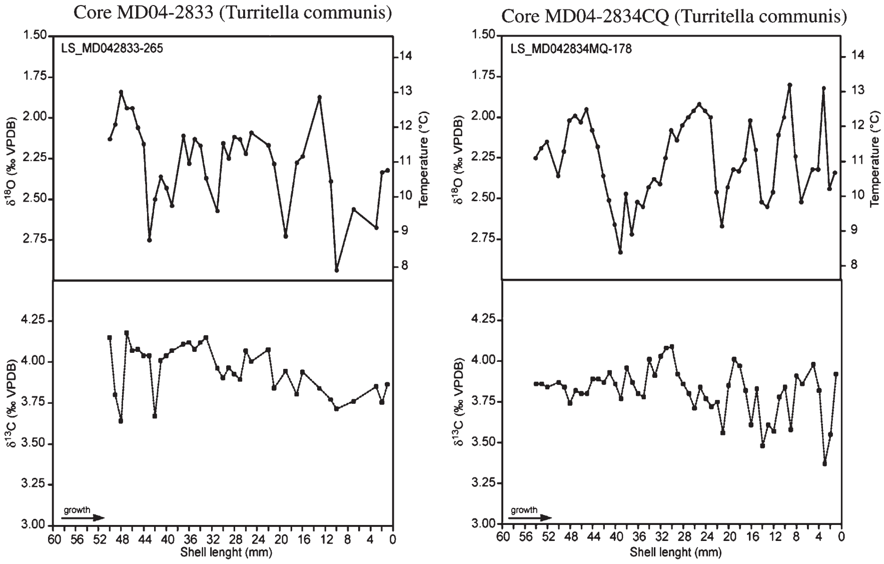

Fig. 1.6 High-resolution oxygen and carbon stable isotope profiles from *Turritella communis* shells, and $\delta^{18}O$-converted temperatures. On the left diagram, the shell was issued from the long core MD04-2833, sampled in the T.L. and aged of 7,414 cal year BP. The diagram on the right shows a shell sampled in the casq core MD04-2834CQ and aged of 7,320 cal year BP

The mean carbon isotope values of the two shells are close similar ($\delta^{13}C_{265} = 3.95 \pm 0.15‰$ and $\delta^{13}C_{178} = 3.82 \pm 0.13‰$). The shell $\delta^{13}C$ profiles are less variable than $\delta^{18}O$, with a range of 0.54‰ for shell 265 and 0.72‰ for shell 178. These $\delta^{13}C$ positive values are consistent with stable normal marine conditions for the two shell locations, without significant freshwater or organic inputs (Gillikin et al. 2006; Lartaud et al. 2010).

Calculated seawater paleotemperatures by the 7,414 cal year BP turritellid shells show data close to present day North-West Scottish seas (Austin et al. 2006). The estimated seasonal gradient is very low (3.5 °C). This may be related to seasonal thermal stratification of the water column, which conducts to significantly less intra-annual bottom water temperature variation than mixed regions (Austin et al. 2006). Scourse (2002) evaluated the timing of the onset of seasonal stratification in the Central Celtic Sea at 8,720 cal year BP.

1.5 Comparison and Discussion

1.5.1 Comparison with the Turritella *Layer of the "Grande Vasières" in South Brittany*

The chirp profile (Fig. 1.4) acquired during the Cotoul cruise (2001) shows an acoustic reflector similar to the *Turritella* reflector within a thick transparent acoustic facies. Three cores have been collected in the South-west of the Glénan sector of the "La Grande Vasière", retrieved at 96.8 m of water depth (Bourrillet et al. 2005), in south Brittany. This mud patch (47°36′ N and 4°08′ W) has been sampled using a vibrocorer during the "Vibarmor" oceanographic cruise (integrated in the "Défi Golfe de Gascogne", an Ifremer program). The Glénan sector is one of the end members of the "Grande Vasière" and is composed of 3 m of sediments with high percentages of fine material (greater than 80 %). Core description and sedimentological analyses including micro-granulometry, calcimetry, x-ray (SCOPIX image-processing; Migeon et al. 1999) and benthic gastropod *Turritella communis* counts were performed by Folliot (2004). Pollen and dynocists analyses have been realised and complete this approach (Naughton et al. 2007).

Five accelerator mass spectrometer (AMS) ^{14}C dates on *T. communis* were obtained on the core VK03-58Bis, indicating that this core sedimentary sequence covers the last 8850 years (Table 1.2). All AMS ^{14}C dated levels were calibrated using CALIB Rev 5.0 program and the global marine calibration dataset (marine 04.14c) (Stuiver and Reimer 1993; Hughen et al. 2004; Stuiver et al. 2005). This dataset uses the global marine age reservoir correction (R) of 400 years. *T. communis* dated levels from twin cores, "VK03-58" (47°36′ N, 4°08′ W; 97.3 m water depth) and "VK03-59Bis" (47°38′ N, 4°09′ W; 94.6 m water depth), were correlated with core "VK03-58Bis" for the age model construction

Table 1.2 ^{14}C ages acquired from core VK03-58bis

Lab code	Core-depth (cm)	Material	Conventional AMS ^{14}C age BP	Conv. AMS ^{14}C age BP (−400 year)	error	Weighted Mean Δr Arcachon France	95.4 % (2σ) Cal BP age ranges	Cal BP age median probability
POZ-10166	VK03 58Bis 106	*T. communis*	3,820	3,420	30	3	3,667 BP:3,865 BP	3,763
POZ-10167	VK03 58Bis 149	*T. communis*	7,020	6,620	30	3	7,427 BP:7,576 BP	7,507
POZ-10168	VK03 58Bis 160	*T. communis*	8,030	7,630	30	3	8,391 BP:8,576 BP	8,479
POZ-10170	VK03 58Bis 177	*T. communis*	8,170	7,770	30	3	8,532 BP:8,808 BP	8,652
POZ-10171	VK03 58Bis 226	*T. communis*	8,240	7,840	30	3	8,613 BP:8,938 BP	8,764

(Fig. 1.4c). As the ages have been obtained in the same laboratory (Poznan laboratory), it should be relevant to compare the ages from these different cores.

The core "VK03-58Bis" is characterised by an homogenous silt sequence marked between 210 and 150 cm by a level containing *T. communis* (Fig. 1.4). Between 210 and 160 cm this *T. communis* community presents all the characteristics of a biocenose: the shells are deposited in life position; both young and adult specimens are present within the same level; they do not present any evidence of shelf destruction by transport. Between 160 and 150 cm, there is an increase in *T. communis* abundance, and in contrast with the underlying level they are not in life position. This indicates a drastic change in the environmental conditions which probably resulted in their mortality. This single drastic episode has also been observed in the twin cores. Considering the shortness of this drastic *T. communis* mortality episode Naughton et al. (2007) can assume that this event has been synchronous in the three cores. *T. communis* death and the decrease of the *Lingulodinium machaerophorum* dinocyst, between 8,480 and 8,390 cal year BP, was most probably triggered by the opening of the English Channel.

1.5.2 Discussion

The stationary life is typical of ciliary feeders and *T. communis* is known to remain stationary for very long periods and possibly indefinitely under natural conditions (Riso 1826; Graham 1988), unless disturbed by external stresses. But they are able to survive in environments with fluctuations of salinity and temperatures. Thus, the establishment of *T. communis* populations indicates a very low sediment supply because of their life mode.

The decrease of temperature combined to the lower salinity are parameters characterizing the 8,200 cold event. The variations of these parameters could explain the absence of other fauna species and they will permit the *T. communis* development. Thus the occurrence of the T.L. corresponds to a change in environmental conditions (T° and S%) together with a stop or at least a slowing down of sediment fluxes which will avoid the burial of shells.

On a second phase, the brutal disparition of the *T. communis* could be explained by the lack of oxygen, as variations of the temperature and salinity are supported by this species.

To explain a decrease of the oxygen, we could propose three scenarii:

- The arrival of a cold water mass coming from the Agassiz and Ojibway lakes (supposed to initiate the 8,200 cold event) which implies stratification of the waters and thus diminution of oxygen conditions.
- The opening of the Channel Pas de Calais, which would drastically change the hydrodynamic and sedimentation conditions of the north west coast of France
- The increase of the sediment supply related to the rapid amelioration of the climatic conditions

The cold water temperatures could not only explain the disappearing of the *T. communis* as they are not especially sensitive to temperature either salinity variations. Another point is that chemical analyses do not show any variations of the salinity or temperature within the months before they died as demonstrated by the carbon and oxygen isotopic composition (Fig. 1.6).

The potential opening of the Channel proposed by Naughton et al. (2007), whereas the actual scientific papers are not confident with an opening of the Pas de Calais strait after 12,500 year BP (Cohen 2007), would probably change the environmental conditions and the sediment fluxes in the south of Brittany but would not reach the north western part of Scotland.

The rapid amelioration of the climate conditions after 7,800 cal year BP correspond to the beginning of the temperate humid Atlantic period. Thus, the erosion power of the fluvial systems is increased and allowed important sedimentation ratios. The seismic profiles show in both cases a transparent facies usually related to unconsolidated sediments linked to rapid sediment deposits. At this point, it is difficult to distinguish the part of the sediment supply increase and the part of the rapid rising sea level on the reduction of the oxygen content which cold explain the abrupt mortality of the *T. communis*. Further studies will be needed to better understand the role of the sediment fluxes on the TL existence.

The “Turritellids event” marks a great variation in biological, hydrological and sedimentological conditions of proximal environments such as Lochs or continental shelf of the Glenan islands.

1.6 Conclusions

This study establishes for the first time the relative importance of a *Turritella* layer signification. This work shows that a specific *T. communis* Layer, dated from 8,300–7,400 cal year BP in sea lochs on the northwestern coast of Scotland and on the south Brittany coast, marks an important change in environmental conditions, confirmed by the foraminifera species assemblages. On a first step, the establishment of this layer, exclusively composed of *Turritella* shells, illustrates rapid deteriorations of T° and S% probably due to the 8,200 cold event. On a second step, the brutal death of these *T. communis* populations at 7,500 cal year BP could be related to a drastic lack of oxygen. These anoxic or semi-anoxic conditions would be linked either to the stratification of water masses due to the rapid increase of sea level rise or/and to the abrupt increase of sediment supply which would burry the shells. Nevertheless, this layer materializes a global and rapid change in environmental parameters like sediment fluxes and/or sea level variations, depending on climate fluctuations. The global mapping of this *Turritella* Layer in other north Atlantic coastal areas would help us to understand the complete signification of this layer.

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