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ESEX exchange

Comments to Westaway and Bridgland – 'Causes, consequences and chronology of large-magnitude palaeoflows in Middle and Late Pleistocene river systems of northwest Europe'

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ESPL
Earth Surface Processes and Landforms

Westaway and Bridgland (*Earth Surface Processes and Landforms* 35: 1071–1094, 2010) discuss the causes, the consequences and the chronology of large-magnitude palaeoflows in Pleistocene river systems of northwest Europe. Based on their calculations, these authors suggest that the combined effects of meltwater from Alpine glaciers, rainfall, snowmelt and melting of permafrost during Heinrich Events (HEs) explain the large-magnitude discharges of the Fleuve Manche palaeoriver which punctuated the last glacial period.

This comment identifies some approximations and inconsistencies regarding (i) the timing of the last massive Fleuve Manche palaeoriver discharge and its relation to the de-glacial pattern of the British-Irish Ice Sheet (Point 1); (ii) the palaeoclimatic conditions prevailing on land and the antagonistic forcing mechanism proposed by the authors to explain the large-magnitude palaeoflows (Point 2); (iii) Westaway and Bridgland's (2010) revised interpretation of the deep-sea records from the Bay of Biscay (Point 3); and (iv) the relationship between the offshore sedimentation since the Middle Pleistocene and the formation of the Dover Strait (Point 4). Each point is discussed.

Point 1: Chronology and Land-sea Correlation

The chronology discussed, then adopted by Westaway and Bridgland (2010), for Marine Isotope Stage (MIS) 2 is controversial, particularly since their revised chronology relies on these authors' misinterpretations of the continental- and marine-based records recently published by Busschers *et al.* (2007) and Zaragosi *et al.* (2001, 2006), Auffret *et al.* (2002), Ménot *et al.* (2006), Eynaud *et al.* (2007), Toucanne *et al.* (2008, 2009a) and Penaud *et al.* (2009). Studies on the origin and the implications of the English Channel-floor palaeovalleys (e.g. Auffret *et al.*, 1980; Larsonneur *et al.*, 1982; Gibbard, 1988; Lericolais *et al.*, 1996, 2003; Bourillet *et al.*, 2003) prompted the investigations of deep-sea records from the northern Bay of Biscay. The latter records revealed that the last large-magnitude palaeoflow event of the Fleuve Manche, from *c.* 20 ka, with a maximum intensity between *c.* 18·3 and 17·5 ka, occurred in phase with the orbitally-induced rapid retreat of the mid-latitudinal European ice sheets and glaciers. Based on the regional chronology proposed by McCabe *et al.* (2007), the last large-magnitude palaeoflow of the Fleuve Manche and the subsequent steep decline in Fleuve Manche activity thus equates with the rapid retreat (i.e. the 'Cooley Point Interstadial'), then the moderate re-advance (i.e. the 'Clogher Head' and 'Killard Point' stadials), centred on 17–16 ka (from <18 to >15 ka according to McCabe *et al.*, 2007), of the Irish Sea glacier (Toucanne *et al.*, 2008).

Based on this chronology, Westaway and Bridgland's (2010, p. 1090) correlation of the most recent high-palaeoflow phase of the Fleuve Manche with the 'Linns Interstadial', a brief, moderate retreat of the Irish Sea glacier, which falls between the 'Clogher Head' and 'Killard Point' stadials at around 17.1–16.6 ka (McCabe *et al.*, 2007), must be questioned. This correlation is untenable because Westaway and Bridgland (2010) bring forward the onset of the highest last Fleuve Manche discharge (18·3 ka) by *c.* 1·2–1·7 kyr, yet fail to present a thorough, reasoned discussion of the land-sea correlation proposed by Toucanne *et al.* (2008). Furthermore, Westaway and Bridgland's (2010) correlation is also untenable since it does not take into account the substantial radiocarbon dataset upon which the Fleuve Manche activity is founded (Zaragosi *et al.*, 2001, 2006; Auffret *et al.*, 2002; Eynaud *et al.*, 2007; Toucanne *et al.*, 2008, 2009a). A precise chronostratigraphical framework for the land–sea correlation for northwest Europe is crucial for the understanding of past cryosphere–ocean interactions, particularly since the European ice-sheets and attendant glaciofluvial/fluvial discharge are known to have significantly influenced the Atlantic meridional overturning circulation (AMOC) (Peck *et al.*, 2006; Denton *et al.*, 2010; Toucanne *et al.*, 2010).

Point 2: Climate versus Forcing Mechanism

The revised chronology adopted by Westaway and Bridgland (2010) is surprising because it places the last significant increase of Fleuve Manche activity at a time when polar conditions occurred throughout the wider North Atlantic region. As previously mentioned, Westaway and Bridgland (2010) suggest that this discharge resulted from the combined effects of glacial meltwater discharge from the Alpine glaciers, rainfall, snowmelt and the melting of permafrost. However, it is widely established that the 17–16 ka interval was characterized by severe cold, windy and arid conditions throughout Europe (e.g. Bard *et al.*, 2000; Antoine *et al.*, 2009). These conditions initiated a significant increase in permafrost development (e.g. Huijzer and Vandenberghe, 1998; Renssen and Vandenberghe, 2003; Kasse *et al.*, 2007), associated with southwards migration of the sea-ice cover over the North Atlantic (e.g. Eynaud *et al.*, 2009) in response to the AMOC shutdown (McManus *et al.*, 2004). This observation challenges the authors' invocation of warm and relatively moist conditions to explain the large-magnitude discharge. It is possible that the authors deduced these conditions from the brief retreat of the Irish Sea glacier during the 'Linns Interstadial'. However, McCabe *et al.* (2007) conclude that this ice-marginal fluctuation only reflected either a negative mass-balance episode of the British-Irish Ice Sheet related to shutdown of the AMOC, or a calving-induced retreat of its marine margin. Therefore, the climatic conditions that prevailed over Europe between *c.* 17 and 16 ka, and also during the HE 2 interval, *c.* 24 ka ago (e.g. Bard *et al.*, 2000; Antoine *et al.*, 2009), were therefore incompatible with the causal mechanism of the Fleuve Manche activity proposed by Westaway and Bridgland (2010). This conclusion is supported by the detailed analysis of Weichselian-age soils in France, Belgium, the Netherlands and Germany which reveal a slow degradation of ice-poor permafrost at the end of the last glacial period (e.g. van Vliet-Lanoë, 2001), and especially between *c.* 15–13 ka (Kasse *et al.*, 2007; Blaser *et al.*, 2010).

Point 3: The Deep-sea Records Revised

Westaway and Bridgland (2010, p. 1087) revise the Fleuve Manche activity over the last glacial period (i.e. MIS 4–2) through a 'more detailed examination of [marine] data' published by Auffret *et al.* (2002) and Ménot *et al.* (2006), 'that can now be regarded (after Toucanne *et al.*, 2008; Toucanne *et al.*, 2009a) as proxies for the Channel river paleoflow'. Based on their re-examination of the data, the authors conclude that large-magnitude discharges of the Fleuve Manche palaeoriver punctuated each of the HEs. Since the Ménot *et al.* (2006) study focuses exclusively on the last 30 ka, Westaway and Bridgland (2010) probably based their assumption on Auffret *et al.*'s (2002) dataset. Nevertheless, since the reconstructed terrigenous fluxes (which we consider to be the only relevant proxy to discuss the Fleuve Manche-derived supplies in their dataset) fail to show significant increases during HEs (except during HE 2, *c.* 24 ka), we assume that the 'subsidiary peaks' (p. 1087) recognized in Auffret *et al.* (2002) probably correspond to ice-rafted detritus depositional maxima, i.e. detrital inputs by icebergs from circum-North Atlantic ice sheets, rather than high-magnitude palaeoflows of the Fleuve Manche, as Westaway and Bridgland (2010) conclude. Moreover, although Toucanne *et al.* (2008) describe some moderate increases in sediment supply off the Fleuve Manche palaeoriver at the time of the HE 3 (*c.* 31 ka) and HE 2 (*c.* 24 ka), sediment-flux reconstructions (Auffret *et al.*, 2002; Zaragosi *et al.*, 2006; Toucanne *et al.*, 2008, 2009a), palynological studies (Zaragosi *et al.*, 2001; Eynaud *et al.*, 2007; Penaud *et al.*, 2009) and BIT-index analysis (Ménot *et al.*, 2006) clearly demonstrate that the contemporaneous Fleuve Manche discharge was not of high-magnitude, contrary to that suggested by Westaway and Bridgland (2010), and was in no way comparable in scale to that occurring later. Recent quantitative analysis supports this assumption, showing a Fleuve Manche sediment load of *c.* 30×10^6 and 130×10^6 t yr^{-1} at around 24 and 18 ka, respectively (Toucanne *et al.*, 2010).

From a methodological point of view, the time-to-time comparison of 'peaks of Channel River palaeoflow' proposed by Westaway and Bridgland (2010, p. 1089) for the last glacial intervals is also debatable. Based on 'the data reported by Toucanne *et al.* (2009a)', the authors argue that the 'peak Channel River palaeoflow during MIS 8 [10] was ~70% [~40%] of its peak in MIS 2'. Firstly, these *quantitative* comparisons are made without any supporting analysis or evidence. Secondly, if these comparisons are based on the terrigenous flux reconstruction proposed by Toucanne *et al.* (2009a), they are debatable: only a comparison of terrigenous flux reconstructed for a similar time period from a uniform chronostratigraphical framework, i.e. 'peaks' reconstructed using identical chronological tie-points, can be considered as *quantitative* [e.g. figure 6, based on figure 3, in Toucanne *et al.* (2009a)]. This constraint, difficult to apply to a set of long marine records, leads therefore the (non-quantitative) time-to-time comparison of Fleuve Manche discharges throughout geological time to be based on a multi-proxy approach, itself to be compared to palaeoenvironmental reconstructions from regional to global scales (e.g. Eynaud *et al.*, 2007; Penaud *et al.*, 2009; Toucanne *et al.*, 2009a, 2009b). Regarding this latter point, it is curious, in the light of the accumulating continental-based reconstructions indicating a glaciated North Sea around the Last Glacial Maximum (Bradwell *et al.*, 2008; Sejrup *et al.*, 2009; Clark *et al.*, in press, among others), that Westaway and Bridgland (2010) omit potential ice-forcing from their calculations.

Point 4: The Megaflood Hypothesis and the Deep-sea Sedimentation in the Bay of Biscay

Finally, we dispute the apparent contradiction, highlighted by Westaway and Bridgland (2010), between the Fleuve Manche reconstructions proposed by Toucanne *et al.* (2009a) and the 'megaflood hypothesis' presented by Gupta *et al.* (2007), implicit in which is the instantaneous formation of the present-day English Channel palaeovalleys at an indefinite time. Toucanne *et al.* (2009a) demonstrate many episodic, potentially seasonal, massive discharges during each of the last four glacial intervals, from MIS 10 (which occurs at the bottom of the core, but implicitly not the base of the sequence) to MIS 2. The sedimentological analysis of the deep-sea records off the Fleuve Manche reveals, considering that the Hurd Deep (e.g. Lericolais *et al.*, 1996) did not act as a significant sediment trap between the European lowlands and the Bay of Biscay after the Middle Pleistocene, that the highest magnitude palaeoflows recorded since MIS 10, dating from *c.* 155 ka (MIS 6) and *c.* 20–18 ka (MIS 2), were not catastrophic in character. This demonstrates: (i) that the expected megaflood must predate MIS 10 (as partially confirmed by Toucanne *et al.*, 2009b), and (ii) that the high-magnitude palaeoflows noted earlier exploited the inherited Channel (Manche)-floor morphology. Contrary to the claim by Westaway and Bridgland (2010, p. 1089), Gupta *et al.* (2007) propose a MIS 12–6 age for the expected catastrophic flood, and neither Toucanne *et al.* (2008) nor Toucanne *et al.* (2009a) suggest that this flood 'caused the offshore sedimentation during ~18–17 ka'.

Conclusions

Westaway and Bridgland's (2010) study, and particularly its focus on the causes of the high-magnitude Fleuve Manche palaeoflows, is based on a continental approach which is complementary to those developed from the offshore evidence. This approach is crucial and would contribute to a higher level of understanding. Nevertheless, although Westaway and Bridgland (2010) raise some relevant questions regarding the contributions of snowmelt or melting permafrost to the sediment transfers from the land to the deep-sea, their approximations and inconsistencies, identified here, strongly undermine their conclusions. By attempting to reinterpret the marine records from the Bay of Biscay and the attendant chronology without assessing all the available evidence, Westaway and Bridgland (2010) place the large-magnitude palaeoflows of the Fleuve Manche during intervals when the prevailing climatic conditions could not have supported the causal mechanism invoked by these authors. Numerical modelling, on which Westaway and Bridgland (2010) based a significant proportion of their study, has its place in hypothesis testing. However, it must retain a supporting role, rather than leading the reconstruction of geological history and landscape evolution based on direct observation in the field or the laboratory.

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