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Reconstruction of the Middle-Late Pleistocene and Holocene Palaeoenvironments of the Piégu Palaeolithic Site (Brittany, France) based on Biostratigraphical Data

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Guzel DANUKALOVA^a, Bernard HALLÉGOUËT^b, Jean-Pierre LEFORT^c,
Jean-Laurent MONNIER^c and Eugenia OSIPOVA^a

Abstract: This paper is devoted to the reconstruction of the palaeoenvironment of the surroundings of the Piégu archaeological site located in Brittany (France). For the first time a full set of the onshore and offshore stratigraphical subdivisions is described following three sections. These fundamental data were remaining unpublished up to now. The Western, Eastern and Offshore sections are illustrated by many different figures. The malacological determinations developed for this study are compared with preexisting palaeontological and geochronological data. The results of the determination of the continental malacofauna have been used to restore the original palaeoenvironments prevailing in this area during the sediments deposition. The complete stratigraphic history of the site, as well as the fauna, demonstrates the existence of three glacial / interglacial cycles contemporaneous with a human occupation.

Résumé : Cet article est consacré à la reconstruction des paléoenvironnements pléistocènes et holocènes du site archéologique de Piégu en Bretagne (France). Pour la première fois des données lithostratigraphiques émanant de trois sections complémentaires sont décrites et font l'objet de corrélations. Les déterminations malacologiques récentes développées dans le cadre de la présente publication sont comparées avec les données paléontologiques et géochronologiques disponibles. Les résultats de la détermination de la malacofaune continentale ont été utilisés pour reconstruire les paléoenvironnements contemporains du dépôt des sédiments. L'histoire stratigraphique complète du site, aussi bien que la faune, démontre l'existence de trois cycles glaciaire-interglaciaire avec des présences humaines bien affirmées.

Keywords: stratigraphy, Palaeolithic, Quaternary, Piégu site, molluscs.

Mots clés: stratigraphie, Paléolithique, Quaternaire, site de Piégu, mollusques.

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1. INTRODUCTION

The site of Piégu is located in Brittany ($48^{\circ}35'49$ N and $2^{\circ}33'08$ W) at the westernmost end of Europe (figure 1 / A & B). Study of the Western section of the cliff started in 1987 in very difficult conditions (Monnier & Hallégouët, 1997) because the steepness of the cliff and the rescue terms (figure 2). The initial research concentrated on the cliff itself but more data were also obtained from a neighboring beach and in a reentrant of the cliff located more to the East. The site of Piégu is famous for its archaeological artifacts. It was first described by Monnier (1973; 1974; 1976 & 1980) and latter in preliminary reports (Hallégouët *et al.*, 1987; Van Vliet-Lanoë *et al.*, 1997) dealing with the flint industry, the findings associated with the offshore geological drillings and with the cuttings obtained in trenches opened for water supply (Hallégouët *et al.*, 1987) (figure 1 / C). Contrary to the flint industry which was mainly found in the actual beach and which is characteristic of the Levalloisian style (Monnier *et al.*, 1985) many remains of big mammal have been recovered in the cliff itself (Auguste *et al.*, 2005). The stratigraphy of the Pleistocene deposits which constitute the Western section was first based on archaeological artifacts. The various authors which were involved in this study and which have been working to strengthen the initial archaeological dating were Auguste, Lefebvre, Keen, Brebion & Lauriat-Rage (in Keen *et al.*, 1997). It is important to stress that it exists now a few buildings at the place of the Eastern excavations and that a large concrete wall was built against landslides, front of the Piégu cliff itself, which prevents any re-sampling of the site. Despite all the previous researches done in this area, a full stratigraphic description of the site has never been presented. The main purpose of this paper is to describe the stratigraphic subdivisions recorded in this site and to summarize briefly some of the preexisting palaeontological data in order to compare the previously published results with the malacological determinations developed for this study. At last we will present an overview of the environment which prevailed in this area during the sediments deposition.

2. GENERAL BACKGROUND

Local stratigraphy and correlation with the international stratigraphical subdivisions

All the stratigraphical divisions and ages attributed to the Quaternary layers studied in the Northern part of Brittany are based on the global framework established

Figure 1: A. General situation of the Piégu site in Westernmost Europe. B. Location of Piégu in the framework of the Saint-Brieuc Bay. C. Location of the drillings (1), composite profiles (2), Eastern onshore excavation (3), trenches (4) and Western onshore excavation (5). Legend: W – Western onshore excavation; E – Eastern onshore excavation; O – Offshore boreholes. (A & B by <http://maps.google.ru/maps?hl=ru&tab=wl>).

Figure 1 : A. Situation générale du site de Piégu à l'extrême ouest de l'Europe. B. Localisation de Piégu dans le cadre de la Baie de Saint-Brieuc. C. Localisation des sondages (1), profils reconstitués (2), fouille à terre à l'est (3), tranchées (4) et excavation à l'est sous l'estran (5). Légende : W – Excavation Ouest; E – Excavation Est à terre; O – Sondages sous l'estran. (A & B by <http://maps.google.ru/maps?hl=ru&tab=wl>).

by Monnier (1973, 1979, 1980; Bigot & Monnier, 1987; Monnier & Bigot, 1987; Loyer *et al.*, 1995; Monnier *et al.*, 2011). It relies on the sedimentological similarities existing between dated and undated sections known in the same area. Recently, a correlation of these formations with the marine isotope stages has been proposed (Monnier,

Figure 2: General view of the Piégu site. The paleo-dale filled with carbonated sands is visible above the frost shattered screes.

Figure 2 : Vue générale du site de Piégu en cours de fouille. On voit le paléo-vallon rempli par des sables carbonatés, au-dessus des éboulis de blocailles.

2006). The following estimations are now accepted by all Quaternary researchers working in Brittany: The Formation of Nantois corresponds with MIS 6 to 10 (330 – 127 ka). The Formation of La Haute-Ville can be correlated with MIS 5 (127 – 75 ka). The Formation of Port-Morvan spreads between MIS 4 and the beginning of MIS 3 (75 – 40 ka). The Formation of Sable-d'Or-les-Pins developed between the second half of MIS 3 and MIS 2 (40 – 15 ka). A correlation between the Middle and Upper Pleistocene subdivisions of Northern Brittany and other units of Western Europe is proposed in Table 1.

Archaeological background

A summary of the many studies developed on the Piégu artifacts has been made by Monnier *et al.* (1985), Monnier & Hallégouët (1997a) and Hallégouët *et al.* (1993). We will just remember here briefly the situation of this outcrop in the archaeological history of Brittany. This settlement corres-

Global Quaternary scheme Gibbard & Cohen (2008)			West European stratigraphic divisions* (The Netherlands) / Ma		Sibrava, Bowen & Richmond (1986)	Northern Brittany Monnier <i>et al.</i> (1997)	Marine Isotope Stages	
System	Series	Subseries, stages	Turner (1998), Zagwijn (1996), Busschers <i>et al.</i> (2008)					
QUATERNARY	HOLOCENE	UPPER	Upper		Holocene	Holocene	1	
		MIDDLE	Middle					
		LOWER	Lower 0.01					
	PLEISTOCENE	UPPER	Upper Weichselian		Weichselian	Sable d'Or les Pins Formation	2	
			Middle Weichselian			Port Morvan Formation	3	
			Lower Weichselian			La Haute-Ville Formation	4	
			Eemian 0.127			Eemian 0.132	La Haute-Ville Formation	5a-d 5e
		MIDDLE	Saalian	Drenthe glaciation Cold Interval with permafrost		Warthe 0.198	Nantois Formation	6
				Bantega interstadial		Drenthe-Warthe 0.252		7
				Cold Interval		Drenthe		8
				Hoogeveen Interstadial		Domnitz 0.338		9
				Cold interval with permafrost		Fuhne 0.352		10
			Holsteinian Interglacial 0.427		Holsteinian 0.428	11		
			Elsterian		Elsterian 0.480	12		

Table 1: Comparison between the Middle to Upper Pleistocene stratigraphic units previously recognized in the Northern part of Brittany with known successions of Westernmost Europe. *The West European stratigraphic divisions for the Upper Middle Pleistocene are given according to Busschers *et al.* 2008 and to Turner (1998), and the Late Pleistocene divisions according to Zagwijn (1996).

Tableau 1 : Comparaison entre les unités stratigraphiques du Pléistocène moyen et supérieur antérieurement reconnues dans le nord de la Bretagne avec les successions connues à l'extrême ouest de l'Europe. * Les divisions stratigraphiques pour le Pléistocène moyen sont données d'après Busschers *et al.* 2008 et Turner (1998), et les divisions du Pléistocène supérieur d'après Zagwijn (1996).

ponds to an old rocky shelter located in the lowest part of a cliff which was inhabited during a regressive marine episode. It was conveniently exposed to the South in a reentrant of the cliff. The industry is mainly made of flints which belong to the Levalloisian technique (Monnier *et al.*, 1985). Study of the archaeological excavation permitted to understand that there were three periods of Palaeolithic dwelling:

a/ A small handaxe found on the lower fossil beach (figure 3, Layer B, MIS 9) corresponds to a first occupation.

b/ An indurated soil resting on a fossil beach (figure 3 Layer F, MIS 7) testifies of a second occupation (this situa-

tion is usual in Brittany where re-entrants located at the base of cliffs often acted as shelters during marine regressions).

c/ A butchering site, first located on top of the cliff but which collapsed during a warmer episode involving bones and flaked flints mixed with fallen debris (figure 3, Layer G) represents the third occupation. The second level of occupation corresponds to a Lower Middle Palaeolithic episode characterized by a Levalloisian method and many Levalloisian points. The butchery site could be more or less of the same age (Monnier *et al.*, 2011; Bahain *et al.*, 2012).

We will see latter that a Saalian age can be attributed to these main settlements on the basis of stratigraphic evidences, which has been confirmed recently by radiometric datations. In total the industry found in this site belongs to the old Middle Palaeolithic.

Malacological background

Up to now, the available palaeontological data have only been presented in a field guide (Van Vliet-Lanoë *et al.*, 1997) where they were given in tables with few or no comments.

The first results dealing with the continental and marine molluscs have been listed in Keen *et al.* (1997). The description of the molluscs found in the Eastern excavation was based on sample 20 (figure 4). It shows the existence of 13 terrestrial species. The list of the molluscs found in the Western excavation (layer J) (figure 3) has been also given by Keen (Keen *et al.*, 1997) which described 8 terrestrial, 3 freshwater and 5 marine taxa. The marine mollusc assemblage found in the different excavations made in the actual beach (layer H) (figure 3) was formerly determined by Lauriat-Rage and Brebion (Keen *et al.*, 1997), they were considered to be of Eemian age. 19 different species of bivalves were also determined by Lauriat-Rage in the level H of the beach and in 3 drill holes. Brebion has shown that 10 species of gastropods determined in these samples are still living today.

In contrast with the previous studies which were mainly undertaken to strengthen the archaeological investigations, this work concentrate on the understanding of the detailed evolution of the complete sections during the Middle Pleistocene and Holocene times.

Former geochronological data

Until recently it was difficult to compare our stratigraphical reconstruction with the geochronological data since the few ages which were available were suggesting ages ranging between 162 and 234 ka for one tooth and 127 to 277 ka for a few mammal bones. It was clear that these ages were

Figure 3: Profile of the Western onshore section of Piégu (Van Vliet-Lanoë *et al.*, 1997) with author corrections. Same lithological captions as for Figure 4. The description of the lithology of the various layers is given in Table 2.

Figure 3 : Profil de la section Ouest (Van Vliet-Lanoë *et al.*, 1997) avec corrections des auteurs. Même légende lithologique que pour la figure 4. La description de la lithologie des différentes couches est donnée dans le tableau 2.

Figure 4: Profile along the Piégu Eastern onshore section. Legend: 1 – soil (horizon A); 2 – soil (horizon B); 3 – loam; 4 – red clayish sand; 5 – clay; 6 – sandy loam; 7 – loamy sand; 8 – sand; 9 – pebbles; 10 – consolidated pebbly layer (ancient beach); 11 – carbonate; 12 – location of the numbers referenced in the molluscs study; 13 – artifacts; 14 – gastropod shells; 15 – bivalve mollusc shells; 16 – mammal bones. The description of the lithology of the various layers is given in Table 3.

Figure 4 : Profil selon la section Est de Piégu à terre. Légende : 1 – sol (horizon A); 2 – sol (horizon B); 3 – limon; 4 – sable argileux rouge; 5 – argile; 6 – limon sableux; 7 – sable limoneux; 8 – sable; 9 – galets; 10 – couche consolidée à galets (plage ancienne); 11 – carbonate de calcium; 12 – localisation des numéros référencés dans l'étude malacologique; 13 – artefacts; 14 – coquilles de gastéropodes; 15 – coquilles de mollusques bivalves; 16 – os de mammifères. La description de la lithologie des différentes couches est donnée dans le Tableau 3.

not compatible with the sedimentary formations of Piégu when compared with dated sections known elsewhere in Brittany (Hallégouët *et al.*, 1997; Monnier *et al.*, 1997c). It is the reason why those ages, which were looking too young or too old, useless to control our reconstruction, will not be discussed here. The reason for the imprecision of these data will be presented in the discussion where the old data will be compared with the recent geochronological dates.

3. THE NEW STUDY

Methods and materials

Save for the Western cliff, the stratigraphical description of the deposits which constitute the Eastern and Offshore

sections was never made before; this description has been established thanks to field notes, photos and drawings made previously by two of us (J.L. Monnier and B. Hallégouët).

The colors of the natural sediment (before drying) have been describe with help of the Munsell Soil Color Charts.

111 samples of the Piégu site which were still available have been re-examined for this study. However, because they were initially sampled during the archaeological excavations, the volumes of the samples are very different. They were recalculated for each stratigraphic level and are now given in Table 5 in cubic decimeters. The samples were washed using sieves of 0.5 mm in laboratory conditions. 38 samples were containing mollusc shells. Shells were examined and extracted individually because the number of mollusc shells is important in the Pleistocene land deposits. The quantity of extracted shells was very different depending on the exa-

mined level (Table 5). The gastropods abundance is given according to the method of Ložek (1964) – we counted the number of complete shells plus the number of apices or apertures which were considered as equivalent to one shell when taken together. The molluscs of associations were classified according to their modern ecological preferences in air temperature, humidity, and vegetation cover following the criteria proposed by Ložek (1964), Likharev & Rammelmeier (1952), and Sümegi (in Wilis *et al.*, 2000).

The determination of the species was made according to Likharev & Rammelmeier (1952), Shileyko (1978, 1984), Shileyko & Likharev (1986), Kerney & Cameron (1999), the determination tables and the systematic is given according to Falkner *et al.* (2002).

Stratigraphical description

The Piégu site is composed of three separated sections which, taken together, give an idea of the sedimentation processes which developed during the Middle, Late Pleistocene and Holocene.

The description of the different layers of the Piégu site is based on the observations made before (Monnier, 1973) and during the archeological study of the cliff (Monnier *et al.*, 1985; Monnier & Hallégouët, 1997a) but also on the data collected during various drillings surveys made in the neighboring beach and in two trenches open for water supply. The main problem of this site is the large development of the coarse slope deposits (represented by fragments of Palaeozoic rocks) which incorporate only few palaeontological remnants. We also had sometimes to face the approximate location of some of the samples collected in the cliff as well as on the beach which arose some difficulties for their correlation. The excavated layers were numbered and described from the bottom to the top.

The Western onshore section

The Western section is the best known because of the archaeological artifacts found in it (Figure 1 / A / W). The layers discovered during the excavations and which constitute the Western onshore section are shown on table 2 and figure 3. In the stratigraphic description of this section we kept the original lettering given by van Vliet-Lanoë *et al.* (1997).

• Marine deposits

0. (A) Marine abrasion surface.

1. (B). Rounded pebbles with molluscs. The thickness is around 0.3 m. The presence of a small Palaeolithic flint-made hand axe of Acheulean style is worthy of note.

• Slope deposits

2. (C). Fragments of Palaeozoic rocks with traces of frost-shattered screes. The thickness is around 2 to 4 m.

• Accumulation of marine and aeolian (dune) deposits

3.(D). Brownish yellow (7.5 YR 5/8) rounded pebbles (old beach) with a thickness of 0.3 to 0.4 m.

4.(E). Dark brown and coarse non-calcareous very well sorted sand (7.5 YR 5/8) which can be linked with the pebbly beach. The thickness ranges between 0.2 and 0.4 m.

• Slope and eluvial deposits (soil)

5. (F). Dark brown soil (10 YR 3/3) of a Palaeolithic settlement located at the level of the beach (layer 9) and containing flint flakes and tools. Its thickness is of 0.5 m. This soil is mainly anthropogenic (it is made of a non calcareous blackish humic sediment containing angular pebbles) which probably incorporate some slope (colluviums) deposits. The lithic industry (no bones preserved) is characterized by the Levalloisian flaking style, many Levalloisian points, many side-scrapers (shaped on one side, two sides or with oblique convergent reworked sides) have been found. It is a Mousterian industry (Old Middle Palaeolithic).

• Slope deposits

6. (G). Angular fragments of Palaeozoic rocks with frost-shattered screes and numerous bones of large mammals. The presence of Palaeolithic artifacts must be underlined. The thickness of this layer is up to 3 m. It is interpreted as a remnant of a butchery station which was previously located at the top of the cliff and which collapsed down the slope.

• Aeolian deposits (dune) and reworked marine sands

7. (J). Light yellowish brown calcareous fine-grained sand (10 YR 5/6) with numerous shells of terrestrial and marine molluscs. The quantity of species and shells decreases towards the base of the layer. Its thickness ranges from 1.5 to 3 m.

• Eluvial deposits (soil)

8. (K). Yellowish brown (10 YR 5/5) sandy soil with indeterminate shell detritus. The thickness is up to 0.5 m.

During this interval, marine pebbles and sand (H) accumulated in the beach. The thickness is about 0.2-0.3 m. The pebbly layer containing marine Bivalve and Gastropod shells is embedded in a wave-cut notch at the base of the cliff. It is the reason why the Upper Pleistocene deposits are still preserved.

Traces of erosion.

Layer	Munsell colour (dry sediment)	Key characteristics	Thickness, m	Deposit genesis interpretation	Archaeological artifacts	Palaeontological data	Stratigraphical divisions	
A		Abrasion surface	–	Marine			Nantois Formation	Middle Pleistocene
1/B		Rounded pebbles	0.3	Marine	Flint-made hand axe of “Acheulean style” (Old Middle Palaeolithic ?)	Molluscs		
2/C		Fragments of Palaeozoic rocks with traces of frost-shattered screes	2.0 – 4.0	Slope				
3/D	7.5 YR 5/8 Dark brown	Rounded pebbles	0.3 – 0.4	Marine (old beach)				
4/E	7.5 YR 5/8 Dark brown	Coarse non-calcareous very well sorted sand linked with the pebbly beach	0.2 – 0.4	Aeolan (dune)				
5/F	10 YR 3/3 Dark brown	Loam located at the level of the beach	0.5	Anthropogenic (soil of a settlement)	Palaeolithic settlement with artifacts of a Mousterian industry (Old Middle Palaeolithic)			
6/G	10 YR 5/6 Light yellowish brown	Angular fragments of Palaeozoic rocks with frost-shattered screes and sandy matrix at the top	up to 3.0	Slope	Palaeolithic artifacts (Old Middle Palaeolithic)	Numerous bones of large mammals		
7/J	10 YR 5/6 Light yellowish brown	Calcareous fine-grained sand	1.5 – 3.0	Aeolian (dune) and reworked marine sands		Terrestrial and marine molluscs	La Haute-Ville Formation	Upper Pleistocene
8/K	10 YR 5/5 Yellowish brown	Sandy soil	up to 0.5	Eluvial (soil)		Shell detritus		
8/H		Pebbles and sand embedded in a wave-cut notch at the base of the cliff	0.2 – 0.3	Marine		Marine molluscs	Port-Morvan Formation	
9/I	10YR 7/6 Yellow	Sandy loam matrix between angular fragments of Palaeozoic rocks which size ranges from gravel to blocks	0.5 – 1.0	Slope				
10/L	10 YR 7/6 Light yellowish grey	Dust-like calcareous sandy loam forming a matrix between soliflucted blocks	0.5 – 1	Slope with reworked aeolian deposits			Sables-d’Or-les-Pins Formation	Holocene
11/N	10 YR 7/1 Light grey	Sandy loam matrix between angular fragments of Palaeozoic rocks of different size	0.4 – 1.5	Slope			Holocene	
11/M	10 YR 7/1 Light grey	Pebble and sand	0.5 – 2.0	Marine (modern beach)				

Table 2: Stratigraphical facies identified in the Western section.
 Tableau 2 : Faciès stratigraphiques identifiés dans la section Ouest.

- Slope deposits

9. (I). Angular fragments of Palaeozoic rocks which size ranges from gravel to blocks in a yellow sandy matrix (10YR 7/6). Its thickness ranges from 0.5 to 1 m.

- Aeolian deposits

10. (L). Light yellowish grey dust-like calcareous sandy loam (10 YR 7/6) forming a matrix between soliflucted blocks. This layer probably corresponds with the base of the Sables d'Or Les Pins Formation. Its thickness ranges between 0.5 and 1 m.

Some traces of weathering can be observed.

- Slope deposits

11. (N). Angular fragments of Palaeozoic rocks of different sizes incorporated in a light grey sandy and loamy matrix (10 YR 7/1). The thickness ranges from 0.4 m at the top of the slope to 1.5 m in its lower part.

Contemporaneous marine pebbles and sand accumulated in the modern beach (M).

The Eastern onshore section

The composite Eastern onshore section was built up using the local descriptions collected in two trenches and excavations made in two different areas (figure 1 / III / B). These data have been associated in order to present a more continuous stratigraphic section. They are shown on table 3 and figure 4.

- Slope-aeolian-marine deposits

1. Calcareous loam. The excavated thickness is about 0.2 m.

2. Thin ferruginated sand layer with mollusc shell fragments (sample 42). The thickness is up to 0.3 m.

3. Loamy ferruginated sand with rare molluscs and shell detritus (samples 39, 40 and 41). The thickness is up to 0.5 m.

4. Calcareous loam. The thickness is up to 0.1-0.2 m.

5. Loamy sand with rare mollusc shells (sample 38). The thickness is up to 0.2 m.

6. Loamy sand (=soil?) with rare mollusc shells (sample 37). The thickness changes from 0.2 to 0.3 m.

7. Thin sand with rare molluscs and shell detritus (sample 36). The thickness is up to 0.3 m.

8. Calcareous loam with rare shell detritus (sample 33). The thickness is up to 0.5 m.

9. Calcareous loam. The thickness is up to 0.3 m.

10. Loam. The thickness is up to 0.3 m.

Traces of weathering.

- Eluvial-slope deposits

11. Yellow grey sandy loam (10 YR 7/6) reworked by soil processes containing artifacts and shell detritus (samples 43 and 34). The thickness is up to 0.5 m.

12. Humiferous grey loam (soil) (10 YR 7/1) with shell detritus (samples 35 and 29). The thickness is up to 0.2 m. Erosional level.

- Aeolian-marine deposits (dune)

13. Dark brown sand (7.5 YR 5/8) containing numerous mollusc shells, with small pebble in the middle part of the layer and humiferous sand in its lower part (samples 20 and 28). The thickness reaches 0.8 m. Alternation of pebbles (samples 22, 24 and 9), sand (samples 8, 10 and 30) and consolidated pebbly layers (samples 23 and 31) with marine molluscs which replaces the sand at the base of the slope.

14. Pebble, gravel and sand containing artifacts. The thickness is of 0.2 m.

- Slope deposits

15. Greyish brown loam (10 YR 5/2) with rare mollusc shell detritus (samples 27 and 32). The thickness is around 0.2 m.

Traces of weathering.

- Eluvial-slope deposits

16. Light grey calcareous sandy loam (10 YR 7/1) reworked by soil processes with mollusc shell detritus (sample 26). The thickness ranges from 0.4 to 0.5 m.

Erosional level.

- Eluvial deposits (podzolic soil)

17. Dark grey sandy loam (10 YR 4/1) with rock fragments and numerous mollusc shells. The thickness ranges from 0.2 to 0.3 m.

- Aeolian deposits (dune)

18. Yellowish brown sand (2.5 Y 6/4) The total thickness ranges between 0.3 and 0.5 m.

The offshore stratigraphy

The boreholes and the trenches excavated in the western and eastern parts of the Piégu (figure 1 / C / O) modern beach provide enough data to build a section of the lower part of the local Quaternary deposits. Table 4 and figure 5 summarize the organization of the deposits located under the surface of the beach.

Layer	Munsell colour (dry sediment)	Key characteristics	Thickness, m	Deposit genesis interpretation	Archaeological artifacts	Palaeontological data	Stratigraphical divisions	
1	10 YR 5/6 Light yellowish brown	Calcareous loam	0.2	Slope-aeolian-marine			Nantois Formation	Middle Pleistocene
2	7.5 YR 5/8 Dark brown	Thin ferruginated sand	up to 0.3	Slope-aeolian-marine		Mollusc shell detritus		
3	7.5 YR 5/8 Dark brown	Loamy ferruginated sand	0.5	Slope-aeolian-marine		Rare molluscs and shell detritus		
4	10 YR 5/6 Light yellowish brown	Calcareous loam	0.1 – 0.2	Slope-aeolian-marine				
5	10YR6/6 Brownish yellow	Loamy sand	0.2	Slope-aeolian-marine		Rare mollusc shells		
6	10YR6/6 Brownish yellow	Loamy sand	0.2 – 0.3	marine deposits reworked by soil processes		Rare mollusc shells		
7	10YR6/4 Light yellowish brown	Thin sand	0.3	Slope-aeolian-marine		Rare molluscs and shell detritus		
8	10YR7/4 Very pale brown	Calcareous loam	0.5	Slope-aeolian-marine		Rare shell detritus		
9	10YR7/4 Beige-brown	Calcareous loam	0.3	Slope-aeolian-marine				
10	10YR6/3 Light brown	Loam	0.3	Slope-aeolian-marine				
11	10 YR 7/6 Yellow grey	Sandy loam	0.5	Slope deposits reworked by soil processes	Artifacts (Old Middle Palaeolithic ?)	Shell detritus	La Haute-Ville Formation	Upper Pleistocene
12	10 YR 7/1 Grey	Loam	0.2	Eluvial (soil)		Shell detritus		
13	7.5 YR 5/8 Dark brown	Sand with pebble in the middle part of the layer and humiferous sand in its lower part Alternation of pebble, sand and consolidated pebbly layer	0.8	Aeolian-marine (dune)		Numerous mollusc shells		
14	10YR6/2 Light brownish grey	Pebble, gravel and sand	0.2		Artifacts (Young Middle Palaeolithic ?)			
15	10 YR 5/2 Grayish brown	Loam	0.2	Slope		Rare mollusc shell detritus	Port-Morvan Formation	Upper Pleistocene
16	10 YR 7/1 Light grey	Calcareous sandy loam reworked by soil processes	0.4 – 0.5	Eluvial-slope		Mollusc shell detritus		
17	10 YR 4/1 Dark grey	Sandy loam with rock fragments	0.2 – 0.3	Eluvial (podzolic soil)		Numerous mollusc shells	Middle	Holocene
18	2.5 Y 6/4 Yellowish brown	Sand	0.3 – 0.5	Aeolian			Upper	

Table 3: Stratigraphical facies identified in the Eastern section.

Tableau 3 : Faciès stratigraphiques identifiés dans la section Est.

Marine deposits

1. Red-orange and dark brown sand (7.5 YR 5/8) with pebbles at the lower boundary with undetermined fragments

of mollusc shells. The excavated layer is about 1 m in thickness (Samples 1, 11, 14 and 15).

Erosional level.

Layer	Munsell colour (dry sediment)	Key characteristics	Thickness, m	Deposit genesis interpretation	Archaeological artifacts	Palaeontological data	Stratigraphical divisions	
1	7.5 YR 5/8 Red-orange & dark brown	Sand with pebbles at the lower boundary	1.0	Marine		Mollusc shell detritus	Nantois Formation	Middle Pleistocene
2	10 YR 7/1 Grey	Clay	0.2			Molluscs		
3	10 YR 7/6 Beige-yellow	Sand	0.4			Mollusc shells and detritus		
4	10 YR 6/1 Grey	Sandy clay	0.7			Mollusc shell detritus		
5	10 YR 6/1 Grey	Clay	0.2			Mollusc shell fragments		
6	5 YR 5/4 Brown-reddish	Sand	0.3			Mollusc shell detritus		
7	10 YR 6/1 Grey	Clay	0.8			Mollusc shells and detritus	La Haute-Ville Formation	Upper Pleistocene
8	10YR6/4 Light yellowish brown	Loamy gravel	0.8			Mollusc shell detritus		
9	7.5 YR 5/8 Dark brown	Sand	0.2					
10	10 YR 6/1 Grey	Clay	0.2		Artifacts (Middle Palaeolithic)			
11	5 YR 5/6 Yellowish red	Sand	0.3					
12	10 YR 6/1 Grey	Clay	0.3					
13	10 YR 5/6 Yellowish brown	Sand	0.3				Holocene	

Table 4: Stratigraphical facies identified in the offshore section.
 Tableau 4 : Faciès stratigraphiques identifiés dans la section sous l'estran.

Figure 5: Piégu Offshore section. The signification of the ornaments is the same as for Figure 4. The description of the lithology of the various layers is given in Table 4.

Figure 5 : Section de Piégu sous l'estran. La signification des symboles est la même que pour la Figure 4. La description de la lithologie des différentes couches est donnée dans le Tableau 4.

- Marine deposits (coastal deposits covered by water)

2. Grey clay (10 YR 7/1) with molluscs (sample 12). The thickness is up to 0.2 m.

3. Beige-yellow (10 YR 7/6) sand with molluscs and shell detritus (samples 13 and 3). The thickness is up to 0.4 m.

4. Grey sandy clay (10 YR 6/1) with mollusc shell detritus (sample 2). The thickness is up to 0.7 m.

5. Grey clay (10 YR 6/1) with small-undetermined mollusc shell fragments (sample 4). The thickness is up to 0.2 m.

6. Brown-reddish (5 YR 5/4) sand with mollusc shell detritus (sample 5). The thickness is up to 0.3 m.

7. Grey clay (10 YR 6/1) with molluscs and shell detritus (sample 6). The thickness is up to 0.8 m.

Erosional level.

- Marine deposits

8. Loamy pedogenized gravel with small-undetermined fragments of mollusc shells (sample 7). The thickness is of 0.8 m.

9. Sand. The thickness is up to 0.2 m.

10. Grey clay (10 YR 6/1) containing artifacts. The thickness is up to 0.2 m.

11. Yellowish-red sand (5 YR 5/6). The thickness is of 0.3 m.

12. Grey clay (10 YR 6/1). The thickness is of 0.3 m.

Erosional level.

- Marine deposits

13. Yellowish brown sand (10 YR 5/6). The thickness is of 0.3 m.

- The stratigraphical attributions

The possible stratigraphic subdivision and their correlation with the marine isotope stages given for the different layers recognized in the Piégu area are based on the previous observations made by Monnier (1973), Monnier *et al.* (1985) and Monnier & Hallégouët (1997a). This stratigraphy is supported by the existence of equivalent facies known in various neighbouring sites located in the same Pléneuf-Val-André area (Laforge, 2012) and in the Eastern part of the Normano-Breton gulf where Pleistocene deposits have been dated (Bahain *et al.*, 2012).

– In the Western section we identified the following layers:

Lower part of Nantois Formation (Layers A – C): Middle Pleistocene

Upper part of Nantois Formation (Layers D – J): Middle Pleistocene

Lower part of La Haute-Ville Formation (Layers K & H): Upper Pleistocene

Port-Morvan Formation (Layer I): Upper Pleistocene

Sables-d'Or-les-Pins Formation (Layer L): Upper Pleistocene

Layers N & M: Holocene

– In the Eastern section we identify the following layers:

Nantois Formation (Layers 1-10): Middle Pleistocene

Lower part of La Haute-Ville Formation (Layers 11 & 12): Upper Pleistocene

Upper part of La Haute-Ville Formation (Layers 13 & 14): Upper Pleistocene

Port-Morvan Formation (Layers 15 & 16): Upper Pleistocene

Layer 17: Middle Holocene?

Layer 18: Upper Holocene

– In the offshore section we identify the following layers:

middle part of Nantois Formation (Layer 1): Middle Pleistocene

Upper part of Nantois Formation (Layers 2-7): Middle Pleistocene

Lower part of La Haute-Ville Formation (Layers 8-12): Upper Pleistocene

Layer 13: Upper Holocene

The correlation between the investigated sections is given in figure 6. Their attribution to the General Quaternary subdivisions and to the Marine Isotope Stages is shown in Table 1.

- Recent malacological data

A total of 4298 mollusc shells belonging to 40 species were identified in the deposits previously attributed to the Middle and Upper Pleistocene and to the Holocene (Table 5). The mollusc shells were collected in the Nantois Formation considered to be Middle Pleistocene in age, in La Haute-Ville and Port-Morvan Formations of Upper Pleistocene age and in the Middle? Holocene deposits. The marine mollusc shells found in the continental deposits have been considered as the result of a redeposition of previous marine sediment or transported by winds blowing towards the coast. It is difficult to determine these shells because they are fragmented in small pieces or correspond to juvenile individuals badly preserved which could lead to numbering errors. In our calculations we did not take these species into account and focused only on terrestrial species because they permit a better understanding of the evolution of the palaeoenvironment for a given period.

Figure 6: Correlations between the investigated sections and possible attribution to the regional (A) and general (B) stratigraphical schemes used in this paper. Legend: W – Western onshore excavation; E – Eastern onshore excavation; O – Offshore boreholes and trenches. For the lithological and the geochronological data as well as for the description of the layers see Figs 3-5 and Table 6.

Figure 6 : Corrélations entre les sections étudiées et attribution stratigraphique possible aux schémas régional (A) et général (B) utilisés dans cette note. Légende: W – excavation Ouest à terre; E – excavation Est à terre; O – sondages et tranchées sous l'estran. En ce qui concerne les données lithologiques et géochronologiques et les descriptions des différentes couches se reporter aux figures 3 à 5 et au tableau 6.

Stratigraphical subdivisions	PLEISTOCENE										HOLOCENE	
	Middle										Upper	
	A	B	82W, 36E, 38E, 39E, 40E, 41E, 42E	87W	80W	81W, 81/80W	JW	13C, 2C, 4C, 5C	D	E	F	G
Taxon	BW	1C, 11C, 14C							KW, 16W, 29E, 43E, 34E, 35E, 7C	20E, 28E, 22E, 24E, 10E, 30E, 31E	27E, 32E	26E
SAMPLES												
Volume of the sample, dm ³												
1	1	3	13	12	1.7	10.5	21	25	12	17	2	1
<i>Peringia ulvae</i> (Pennant, 1774) + <i>Peringia</i> sp.	2	3	4	5	6	7	8	9	10	11	12	13
<i>Valvata pulchella</i> (Studer, 1820)		4	20	6	10	95	311	18		12	1	2
<i>Galba truncatula</i> (O. Müller, 1774)						14	19					
Lymnaeidae								2 j				
<i>Anisus leucostoma</i> (Müller, 1830) + <i>Anisus</i> sp.						3	14+2 j					
? <i>Gymnulus</i> sp.						1 j						
<i>Carychium minimum</i> O. Müller, 1774						4	3					
<i>Succinea oblonga</i> (Draparnaud, 1801)						105	251					
<i>Oxyloma elegans</i> (Risso, 1826)							1					
Succineidae	1	1			2 j	8	7 j					
<i>Cochlicopa</i> sp.						3	23					
<i>Lauria cylindracea</i> (Da Costa, 1778)												48
<i>Vallonia costata</i> (O. Müller, 1774)									1	4		137
<i>V. pulchella</i> (O. Müller, 1774)								1		3		37
<i>Vallonia</i> sp.		1						1				
<i>Papilla muscorum</i> (Linnaeus, 1758) + <i>Papilla</i> sp.	3	1			10	3	432	10		1		366
<i>Truncatella cylindrica</i> (A. Férussac, 1807)												3
<i>Verigo pygmaea</i> (Draparnaud, 1801) + <i>V. cf. pygmaea</i>					2	3	19					
<i>V. antivergo</i> (Draparnaud, 1801)						1	1					
<i>V. alpestris</i> Alder, 1838						1						
<i>Verigo</i> sp.				1		1						5
<i>Clausilia bidentata</i> (Ström, 1765)						1				1		
Clausiliidae												46
<i>Cecilioides acicula</i> (O. Müller, 1774)						3	25	1				
<i>Punctum pygmaeum</i> (Draparnaud, 1801)						3	5					
<i>Vinea crystallina</i> (O. Müller, 1774)					3		1 j					
<i>Oxychilus draparnaudi</i> (Beck, 1837) + <i>Oxychilus</i> sp.	2	3	4	5	6	7	8	9	10	11	12	13
1												2+3 j
<i>Vitrea pellucida</i> (O. Müller, 1774)												1
<i>Cochlicella acuta</i> (O. Müller, 1774)	1 r											89 j
<i>Trichia hispida</i> (Linnaeus, 1758) + <i>Trichia</i> sp.						58	776	16		4		
<i>Helicella tiula</i> (Linnaeus, 1758) + <i>Helicella</i> sp.						2	2	1		6		
<i>Ceruella virgata</i> (Da Costa, 1778) + <i>Ceruella</i> sp.						335 j	122+9 j	7		6		270+200 j
<i>Cepaea nemoralis</i> (Linnaeus, 1758)	7 r											
Limacidae			2									
<i>Gibbula</i> sp.						3 j	1 j	4 j		3	2.	
<i>Tricolia pulula</i> (Linnaeus, 1758)						2	3 j	2				3 j
<i>Bititum reticulatum</i> (Da Costa, 1778)						26	61	20		6 j		
Rissoaceae		2 f	3			9	36	19		5	1	
<i>Onoba semicostata</i> (Montagu, 1803)						2 f				1		
? <i>Buccinum</i> sp.						3	5	3		2		
<i>Retusa</i> sp.						n j	n j	5	f	1		
Gastropoda			1									
<i>Nucula</i> sp.										1		
Cardiidae	f									3		
<i>Acanthocardia</i> sp.	1 + f									3 j		
<i>Spisula</i> sp.						1 j	2+4 j					
<i>Pisidium</i> sp.						6			f	3		1
Bivalvia												
Total shell number per sample	8 r + 1	10	29	7	27	691	2140	110	1	65	4	f
shell detritus	f	f	f	f	f	f	f	f	f	f	f	f

Table 5: (Previous page) Summary of the distribution of the molluscs found in the Western, Eastern and Offshore excavations. Legend: f – shell detritus not calculated as a number of individuals; n – numerous; j – juvenile shell; r – redeposited; 82W, 36E, BW, 1C – numbers of samples, location shown on Figures 2-4, W – Western section, E – Eastern section, C – offshore trenches; J, B, G, K, H – layers of the Western section. Stratigraphical subdivisions: A – Hoogetveen Interstadial, MIS 9; B – Bantega interstadial, MIS 7; C – Drenthe glaciation, Cold Interval with permafrost, MIS 6; D – Eemian, MIS 5e; E – Lower Weichselian, MIS 5 a-d; F – Lower Weichselian, MIS 4; G – Middle Weichselian, MIS 3; H – Holocene, MIS 1.

Tableau 5 : (Page précédente) Résumé de la distribution des mollusques trouvés dans les excavations Ouest, Est et sous l'estran. Légende: f – fragments de coquilles non comptés comme des individus entiers; n – nombreuses; j – coquilles de juvéniles; r – redéposées; 82W, 36E, BW, 1C – nombres d'échantillons, localisation montrée sur les Figures 2-4, W – Section Ouest, E – Section Est, C – Tranchées sous l'estran; J, B, G, K, H – Couches de la section Ouest. Subdivisions stratigraphiques: A – Interstade d'Hoogetveen, MIS 9; B – Interstade de Bantega, MIS 7; C – Glaciation de Drenthe, Episode froid avec permafrost, MIS 6; D – Eémien, MIS 5e; E – Weichsélien inférieur, MIS 5 a-d; F – Weichsélien inférieur, MIS 4; G – Weichsélien moyen, MIS 3; H – Holocène, MIS 1.

4. MALACOLOGICAL STUDY RESULTS AND INTERPRETATION

The Nantois offshore and western aeolian formations

Mollusc shells were found in the marine deposits incorporated in the Nantois Formation of the Western section (attributed to the Hoogetveen Interstadial, MIS 9), in the marine deposits of the Offshore section (correlated with the Bantega Interstadial, MIS 7-10) and in the aeolian deposits of the Western section (formed during the Drenthe glaciation and Interval with permafrost, MIS 6).

– In the lower part of the Nantois Formation we only discovered fragments of marine bivalves in the coastal deposits of the Western section (correlated with the Hoogetveen Interstadial) (MIS 9). Two fragments of the terrestrial molluscs discovered in the same deposits were very likely redeposited from the cliff.

– The middle part of the Nantois Formation was also poor in mollusc fossils. Rare fragments of terrestrial Succineidae and *Pupilla* sp. as well as marine *Peringia* sp. and *Rissoa lilacina* C. Récluz, 1843 were determined in the deposits attributed to the Bantega interstadial (MIS 7-10).

The best mollusc remnants were discovered in the calcareous dune which accumulated during the first half of the Drenthe glaciation, Cold Interval with permafrost (MIS 6) (figure 7).

This formation is characterized by the existence of terrestrial and aquatic molluscs which complete the list previously given by Keen (Keen et al., 1997). *Succinella oblonga* (Draparnaud, 1801), *Pupilla muscorum* (Linnaeus, 1758) and *Trichia hispida* (Linnaeus, 1758) dominate in this association. *Carychium minimum* O. Müller, 1774, *Cochlicopa* sp. (cf. *Cochlicopa lubrica* (O. Müller, 1774)), *Vertigo pygmaea* (Draparnaud, 1801), *Punctum pygmaeum* (Draparnaud, 1801), *Vitrea crystallina* (O. Müller, 1774) and *Ceruella virgata* (da Costa, 1778) are less abundant. *Oxyloma elegans* (Risso, 1826), *Vallonia* sp., *Vertigo antivertigo* (Draparnaud, 1801), *Vertigo alpestris* Alder, 1838, *Clausilia bidentata* (Ström, 1765) and *Helicella* sp. are rare (Table 5). We had some doubts during determinations of the Hydromiidae species because these shells are represented by juvenile individuals and are badly preserved. Nevertheless we tried to separate (with some question mark) this mollusc family into three species – *T. hispida*, *C. virgata* and *Helicella* sp.; two of them are shown in Table 6. *T. hispida* has an open umbilicus at the entrance and become narrow and cylindrical in the deep. *C. virgata* has variable umbilicus shapes but is always open; shell has a light brown band at the periphery of the whorl (Animal base).

The molluscs of this association were classified according to their modern ecological preferences in air temperature, humidity, and vegetation cover. Most of the species correspond with mesophilous conditions. *S. oblonga* and *P. muscorum* are cold resistant and eurytherm species. The classification of the molluscs, according to present-day humidity rate indicates that most of the species were hygrophilous. Only four species (*P. muscorum*, *C. lubrica*, *V. pygmaea* and *Helicella* sp.) are mesophilous. *C. virgata*, *S. oblonga*, *O. elegans*, *P. pygmaeum* inhabited wet environments characterized by sparse vegetation. *C. bidentata*, *T. hispida*, *P. pygmaeum*, *V. alpestris*, *V. antivertigo* and *C. minimum* show a woodland preference. The Piégu area was, thus, characterized by a relatively cool forest – steppe – like environment composed of adjacent mosaics of drier and humid habitats. Numerous fragments of marine molluscs and juvenile shells evidence their transportation by winds blowing towards the coast. Freshwater molluscs suggest the existence of small stagnant ponds or of small creeks.

The La Haute-Ville Formation

In La Haute-Ville Formation, molluscs were mainly discovered in the marine deposits of the Western section, in the eluvial-slope deposits of the Eastern section (correlated with the Eemian, MIS 5e) and in the aeolian and slope deposits of the Eastern section (correlated with the Lower Weichselian) (MIS 5).

Figure 7: (See colour plate I) Middle Pleistocene (MIS 6) terrestrial gastropods of Piégu, Brittany, France: 1 – *Vitrea crystallina* (Müll.), IG n° 228/3454/4 (sample 80W); 2 – *Vallonia pulchella* (Müll.), IG n° 228/3422/1 (sample 13C); 3 – *Punctum pygmaeum* (Drap.), IG n° 228/3492/5 (sample JW); 4 – *Carychium minimum* Müll., IG n° 228/3390/5 (sample 81/80W); 5 – *Vertigo pygmaea* (Drap.), IG n° 228/3454/3 (sample 80W); 6 – *Vertigo antivertigo* (Drap.), IG n° 228/3493/8 (sample JW); 7 – *Cochlicopa* sp., IG n° 228/3390/7 (sample 81/80W); 8 – *Pupilla muscorum* (L.), IG n° 228/3454/2 (sample 80W); 9 – *Pupilla muscorum* (L.), IG n° 228/3493/6 (sample JW); 10 – Limacidae, IG n° 228/3436/2 (sample 38E); 11 – *Trichia hispida* (L.), IG n° 228/3493/10 (sample JW); 12 – *Cerņuella virgata* (Da Costa), IG n° 228/3493/11 (sample JW); 13 – *Succinella oblonga* (Drap.), IG n° 228/3390/6 (sample 80W); a – apertural view; b – lateral view (top right); c – abapertural view (view from the opposite side of the aperture); d – apical view; e – umbilical view or for Limacidae – basal view (view from the opposite apical side); W – samples of the Western section; C – sample of the offshore section. Drenthe glaciation, Cold Interval with permafrost – samples 80W, 38E; Drenthe glaciation – JW, 81/80W, 38E, 13C.

Figure 7 : (Voir planche couleur I) Gastéropodes du Pléistocène moyen de Piégu, Bretagne, France: 1 – *Vitrea crystallina* (Müll.), IG № 228/3454/4 (échantillon 80W); 2 – *Vallonia pulchella* (Müll.), IG n° 228/3422/1 (échantillon 13C); 3 – *Punctum pygmaeum* (Drap.), IG n° 228/3492/5 (échantillon JW); 4 – *Carychium minimum* Müll., IG n° 228/3390/5 (échantillon 81/80W); 5 – *Vertigo pygmaea* (Drap.), IG n° 228/3454/3 (sample 80W); 6 – *Vertigo antivertigo* (Drap.), IG n° 228/3493/8 (échantillon JW); 7 – *Cochlicopa* sp., IG n° 228/3390/7 (échantillon 81/80W); 8 – *Pupilla muscorum* (L.), IG n° 228/3454/2 (échantillon 80W); 9 – *Pupilla muscorum* (L.), IG n° 228/3493/6 (échantillon JW); 10 – Limacidae, IG n° 228/3436/2 (échantillon 38E); 11 – *Trichia hispida* (L.), IG n° 228/3493/10 (échantillon JW); 12 – *Cerņuella virgata* (Da Costa), IG n° 228/3493/11 (échantillon JW); 13 – *Succinella oblonga* (Drap.), IG n° 228/3390/6 (échantillon 80W); a – vue de l'ouverture; b – vue latérale (sommet droit); c – vue du côté opposé de l'ouverture; d – vue apicale; e – vue de l'ombilic – vue basale (vue du côté opposé de l'extrémité apicale); W – échantillons de la section Ouest; C – échantillon of the section sous l'estran. Glaciation de Drenthe, épisode froid avec permafrost – échantillons 80W, 38E; glaciation de Drenthe – JW, 81/80W, 38E, 13C

For this level we had only some remnants of the samples at our disposal. This level is characterized by small detritus of thick marine shells of Cardiidae (including *Acanthocardia* sp.). As indicated in the chapter dealing with the previous determinations made by Lauriat-Rage and Brebion (Keen et al., 1997) 19 different species of marine bivalves and 10 species of gastropods were determined in this level. These data confirm the existence of a warm climate during the Eemian.

The aeolian deposits of the Eastern section which correspond to the Lower Weichselian contain shells of terrestrial and marine molluscs. Our determinations complete the list of species initially proposed by Keen (Keen et al., 1997). *Helicella itala* (Linnaeus, 1758) is the dominant species. *T. hispida*, *P. muscorum*, *C. virgata* and *Vallonia costata* (Müller, 1774) are the other significant species. *Vallonia pulchella* (Müller, 1774) is poorly represented; the other species are rare (Table 5).

According to the modern mollusc climatic distribution, this complex indicates that the best represented species are usually found in mesophilous conditions. Few species were cold resistant.

According to the present-day humidity rate these species preferred a subhygrophilous and mesophilous environment. The dominating species preferred open semi-dry and warm habitats (calcareous grasslands, south-exposed slopes covered by grasses and shrubs but also dunes and sea cliffs). The less abundant species are typical of woodland and intermediate environments. At that time the area was characterized by a relatively warm forest – steppe (or grassland) – like environment composed of adjacent mosaics of drier and humid habitats.

These data confirm the conclusions of Keen and show that the climate was still warm at the beginning of the Early Weichselian. The presence of juvenile shells of marine molluscs as well as their fragmentation observed in the aeolian and slope deposits of the Eastern section can be explained by the influence of marine winds blowing towards the coast.

The Port-Morvan Formation

In the Port-Morvan Formation shell detritus were only discovered in the eluvial-slope deposits of the Eastern section (correlated with Middle Weichselian, MIS 3).

The Holocene formation

Molluscs were found in the Middle Holocene sediments, in the podzolic soil of the Eastern section. They are represented by numerous terrestrial species (figure 8). *C. virgata* and *P. muscorum* are the dominant species. *V. costata*

and *Cochlicella acuta* (O. Müller, 1774) are the next more significant species. *V. pulchella* and *Lauria cylindracea* (Da Costa, 1778) are present. *Vitrina pellucida* (Müller, 1774), *Oxychilus draparnaudi* (Beck, 1837), *Truncatellina cylindrica* (Férussac, 1807), and *C. bidentata* are rare (Table 5). *Ceciloides acicula* (Müller, 1774) is a modern burrowing subterranean species. According to the modern mollusc climatic distribution this malaco-complex is partly characterized by species usually found in mesophilous conditions. In general, the species of this complex show preference for mesophilous or subhygrophilous humidity. The highest percentage of species preferred an intermediate habitat. Fewer species are characteristics of open or woodlands environments. *C. bidentata* lives under tree barks or in cracks in shady places and may support the existence of isolated trees or of small forests. *V. costata*, *V. pulchella*, *T. cylindrica*, *V. pellucida* are found in various ecological environments and were able to live in forests as well as in open areas. These data suggest the existence of open landscapes covered by grasses with isolated bushes and small forests. Small marine shells of *Peringia ulvae* (Pennant, 1774), *Tricolia pullus* (Linnaeus, 1758) and other marine shell detritus were transported by winds during storms towards the adjacent cliff area.

5. GENERAL PALAEOENVIRONMENTAL INTERPRETATION

We will separate here, the results and the interpretations related with the Western onshore cliff studied for archaeology where a continuous observation was possible from those, more discontinuous and randomly distributed, which were used to build the Eastern and Offshore sections.

The cliff

The hardcore landslides which hide the initial basement cliff previously cut by the sea, are usually not cemented by any matrix save in some places where the aeolian sand deposited between the fragmented rocks. This sandy sediment was probably deposited after sliding along the slope or by infiltration in the “head”. Loams also inject by place small gelifRACTED beds which developed on top of the upper debris accumulation. They correspond with a period when the cliff was more or less stabilized. The big-size blocks reworking and overlapping this formation display a series of slabs resting at right angle respect with the surface. The underlying rocks are squeezed together and oriented in a parallel way respect to the surface (generally dipping between 40 to 50°) (figure 2). This layer is characterized by a poorly developed

Figure 8: (See colour plate II) Holocene (MIS 1) terrestrial gastropods of Piégu, Brittany, France (sample 17E): 1 – *Vallonia pulchella* (Müll.), IG n° 228/3397/4; 2 – *Vallonia costata* (Müll.), IG n° 228/3397/3; 3 – *Lauria cylindracea* (Da Costa), IG n° 228/3397/2; 4 – *Pupilla muscorum* (L.), IG n° 228/3397/5; 5 – *Truncatellina cylindrica* (Fer.), IG n° 228/3397/6; 6 – *Clausilia bidentata* (Ström), IG n° 228/3397/7; 7 – *Cochlicella acuta* (Müll.), IG n° 228/3397/11; 8 – ?*Oxychilus* sp., IG n° 228/3397/9; 9 – *Cecilioides acicula* (Müll.), IG n° 228/3397/8; 10 – *Vitrina pellucida* (Müll.), IG n° 228/3397/10; 11 – *Cernuella virgata* (Da Costa), IG n° 228/3397/12; a – apertural view; b – lateral view (top right); c – abapertural view (view from the opposite side of the aperture); d – apical view; e – umbilical view; 17E – sample 17 of the Eastern section.

Figure 8: (Voir planche couleur II) Gastéropodes terrestres de l'Holocène (MIS 1) de Piégu, Bretagne, France (échantillon 17E): 1 – *Vallonia pulchella* (Müll.), IG n° 228/3397/4; 2 – *Vallonia costata* (Müll.), IG n° 228/3397/3; 3 – *Lauria cylindracea* (Da Costa), IG n° 228/3397/2; 4 – *Pupilla muscorum* (L.), IG n° 228/3397/5; 5 – *Truncatellina cylindrica* (Fer.), IG n° 228/3397/6; 6 – *Clausilia bidentata* (Ström), IG n° 228/3397/7; 7 – *Cochlicella acuta* (Müll.), IG n° 228/3397/11; 8 – ?*Oxychilus* sp., IG n° 228/3397/9; 9 – *Cecilioides acicula* (Müll.), IG n° 228/3397/8; 10 – *Vitrina pellucida* (Müll.), IG n° 228/3397/10; 11 – *Cernuella virgata* (Da Costa), IG n° 228/3397/12; a – vue de l'ouverture; b – vue latérale (sommet droit); c – vue du côté opposé de l'ouverture; d – vue apicale; e – vue de l'ombilic; 17E – échantillon 17 de la section Est.

stratification of the material and the variation in size of the debris may reflect small climatic variations (Ozouf, 1987). Some larger blocks (up to 1.5 m in length) are sometimes inter-bedded in this layer. Gelifraction and gravity represent here the most important phenomena. The microdiorite outcrop which generated this rocky landslide is very altered and fragmented. The largest part of the 2000 cubic meters of debris which were produced here, resulted mainly from gelifraction. The orientation of the cliff, open towards the south, probably favored the successive freezing-defreezing processes. However, it is now known that a very cold climate is not necessary to generate such a big amount of fragmented rocks. In our case it is almost certain that the fragmentation was mainly ruled by a very important moisture (Ozouf, 1987).

Taken as a whole the evolution of the outcrop during the Middle – Late Pleistocene and Holocene can be described as follow:

Middle Pleistocene

During a first transgressive episode responsible for the deposition of the lower part of the Nantois Formation (Hoogeveen Interstadial, MIS 9) the sea completely cleaned out the foot of the cliff and removed the previous deposits. Abrasion processes were active and it is possible that the reentrant of the cliff favored the digging of a cave at that time. After the regression of the sea this shelf, covered by boulders (the B layer), was buried under a rocky landslide (the C layer) corresponding also to the lower part of the Nantois Formation (Cold interval, MIS 8). This organization evidences the existence of the first interglacial / glacial cycle.

Later, during the Bantega interstadial (Middle part of the Nantois Formation, MIS 7) the sea partly eroded the previous deposits although it did not clean all of them. The traces of this transgression are now represented by a boulder bar (the layer D) which delivered an Acheulean biface (first human occupation). At the beginning of the following regression the wind created a sand dune (the layer E). The deposits of layer E are contemporaneous with the second human occupation (during the Middle Palaeolithic) located at the foot of the cliff (the layer F).

This area was then, covered by the upper rocky landslide (the layer G), during the Cold Interval characterized by the permafrost and the Drenthe glaciation (MIS 6). It corresponds with the Upper part of the Nantois Formation. Layer G is interpreted as a remnant of a butchery station (showing numerous mammal bones) which was previously located at the top of the cliff and which collapsed down to the foot of the slope. We don't know if the remnants of the butchery

witness the existence of a third human occupation or if they are contemporaneous with the second occupation.

Mammal fauna was found only in the Western part of the site. In the Western excavation, mammal bones of *Cervus* sp., *Bos primigenius* Bojanus, *Equus* sp., *Canis lupus* L., *Dicerorhinus hemitoechus* (Falconer), *Capreolus* sp., *Sus scrofa* L., *Megaloceros* sp., *Panthera leo spelaea* Goldfuss (?) have been found in the colluvium of layer 6/G. Remnants of *Cervus* sp. are numerous and represent 85% of the total bones (August *et al.*, 2005). Large mammals indicate a forest environment (Auguste *et al.*, 2005). The small mammals (*Arvicola terrestris* Linnaeus, 1758) inhabited the banks of water reservoirs, swamps and wet meadows. These species suggest a Middle Pleistocene age for this layer.

This period was followed by the formation of a new sand dune (the layer J). This dune displays cross-bedding stratifications with coarser levels richer in continental gastropods. After the malacological study it appears that this period is characterized by species suggesting a relatively cool forest – steppe – like environment composed of adjacent mosaics of drier and humid habitats. The dune seems to correspond to a “pre-loessic” evolution, that is to say that it was probably deposited at the beginning of a “loessic cycle”. It is likely that the loess which probably existed above this formation disappeared later. A complete loessic cycle can be found for example in the adjacent site of Nantois (Monnier *et al.*, 1997b) where both types of deposits still exist.

So far as the marine mollusc shells are concerned, the existence of many broken shell pieces suggests that they were transported by strong winds.

The D to J ensemble represents, thus, a second interglacial / glacial cycle.

Upper Pleistocene

A third marine transgression corresponding to the Eemian Interglacial (lower part of La Haute-Ville Formation, MIS 5e) produced a new shelly sand bar (the layer H) at the foot of a cliff cut in the Pleistocene deposits. The retreat of the sea was contemporaneous with the formation of a soil on top of the cliff (the layer K).

During the Early Weichselian (upper part of La Haute-Ville Formation) the dune developed on the beach (the Eastern site). Then the slope was buried again during the deposition of the Weichselian formation (Port-Morvan and Sables-d'Or-les-Pins formations) (MIS 2 – 4) under a rocky landslide (the layer I) and sandy loams (the layer L). The layers H, K, I and L represent consequently a third interglacial / glacial cycle.

In the H beach (Eemian Interstadial, MIS 5e) a rich fauna of gastropods, bivalves and foraminifers was found.

The malacological study (see Lauriat-Rage and Brebion lists in Keen *et al.*, 1997) was twinned with the study of 4 drill holes made in the fossil beach.

Most of gastropods were living on rocky outcrops save *Buccinum undatum* (Linnaeus, 1758) and *Nassarius* (*Hinia*) *reticulatus* (Linnaeus, 1758) which are usually found on sandy-loamy surfaces. *Patella*, *Monodonta*, *Littorina*, *Nucella* and maybe *Myosotella* are typical of tidal zone associations. Nowadays, this association is well known along the French Atlantic shores. Only *Astraea*, which usually does not extend north of Biscay Bay, is characteristic of warmer zone. We observe, thus, a meridional influence in these species which is not easy to characterize because of the few samples and the particular sedimentary facies.

During the Upper Pleistocene, identical associations were found in other places of Western Europe. In Selsey, in Southern England seven Franco-Iberic shapes were found mixed with local fauna but without *Astraea rugosa* (Linnaeus, 1767) (West *et al.*, 1960; Bates *et al.*, 2006). In Maillezaie in Vendée an association limited to 2 species was displaying the Mediterranean-like shape *Cerithium vulgatum* Bruguière, 1792 (Lauriat-Rage *et al.*, 1993). At last in Portugal at Cap Espichel the almost tropical shape *Cymbula nigra* (da Costa, 1771) is known to live amongst species typical of this area (Lauriat-Rage *et al.*, 1993). These data confirm that a clear warming episode existed during the late Interglacial which fits with the definition of the Eemian. This warmer phase was better expressed in the Mediterranean realm than in the European Atlantic domain (Brebion, 1980; Lauriat-Rage *et al.*, 1993).

Amongst the bivalves (which are characterized by thick shells), the best-represented taxa are *Mytilus* sp., *Pecten maximus* (Linnaeus, 1758), Cardiidae, *Eastonia rugosa* (Helbling, 1779) and *Venus verrucosa* (Linnaeus, 1758). *P. maximus* and *V. verrucosa* are widespread. All these species are still living now and half of them were already known during Miocene time. The other species developed during the Pliocene save *Macoma balthica* (Linnaeus, 1758) which is of Pleistocene origin. *Glycymeris pilosa* (Linnaeus, 1758), *Mytilus galloprovincialis* Lamarck, 1819 and *E. rugosa* belong to a meridional bio-province (Lauriat-Rage *et al.*, 1993; Lindner, 2005; Huber, 2010; Doneddu & Albano, 2012). *G. pilosa* and *E. rugosa* are restricted to the Mediterranean Sea and adjacent Atlantic Ocean (Lauriat-Rage *et al.*, 1993; Lindner, 2005; Animal base). *M. galloprovincialis* was restricted to the Black Sea, Mediterranean Sea and later were spreading until England (Lindner, 2005; Audibert & Deleamarre, 2009; Animal base). For all these reasons the mollusc fauna of layer H is attributed to the Eemian which represents a warm interglacial period. Those infra-tidal bivalves were

living in slightly different biotopes. Most of them belong to the endofauna and a smaller part to the epifauna. They accumulated as thanatocenosis in a tempest bar.

The benthic foraminiferous associations previously determined by Lefebvre (Keen *et al.*, 1997) (Western site, layerH) show a mixture of warm and lukewarm species in the studied Eemian deposits.

After the recent malacological study the area was characterized by a relatively warm forest – steppe (or grassland) – like environment composed of adjacent mosaics of drier and humid habitats during Early Weichselian.

Holocene

After Last Glacial time, during the Early and Middle Holocene, the slope was covered again by a new landslide (the layer N of the Western section). Modern deposits are now forming the actual beach (the layer M). This Holocene deposit was described by Hallégouët *et al.* (1997).

Numerous land gastropods were found in the eluvial deposits mixed with rock fragments of the Eastern section (layer 17) (Table 5). The continental malacofauna extracted from these deposits is represented by species which lived in moderately warm and wet climate and usually preferred open landscapes covered by grasses with isolated bushes and small forests, warm rocky slopes or dunes. The climate was moderately wet and warm. It is possible that those deposits belong to the Middle Holocene.

The beach

The sand of the actual beach rests above an erosional limit which cuts across the remnants of two phases of deposition (figure 5).

The Upper phase is dipping towards the Southwest and extends up to the reentrant of the old cliff. This ensemble lies above a former erosional surface which affects the oldest known marine formations. The loams and the sands of the lowest ensemble are well developed in the Eastern part of the beach where they were preserved. This is why we can still sample the pre-Eemian layers. On the contrary in the Northwest, the pre-glacial deposits are rare. The rocky landslide seems to be limited in extension and does not extend laterally. The only possible correlation which can be suggested between the Western onshore cliff and the beach, concerns the sandy dune formation (J) which could be linked with the calcareous sandy layers located above the lower orange sands found under this beach. Some bones and artifacts have been sampled at the boundary between these two formations. In these conditions the loams and the sands of the lower phase found under the beach would be equivalent

to the periglacial formations which were previously covering the Piégu cliff. If this is correct the sand injected in the first debris flow of the cliff (the E layer) would be equivalent to the orange sand of the northern part of the beach (layer 1, figure 5).

The eroded fossil shelf found front of the “archaeological” cliff can be extended under the rocky landslide. There, boulders reworking sometimes prehistoric artifacts fill palaeo-topographic depressions. South of this palaeo-shelf a second marine eroded surface displays aeolian sands injecting an old rocky landslide. Here a second Palaeolithic industry but without “bifaces” has been found.

6. DISCUSSION

Piégu site is of a great stratigraphic interest because it is characterized by the local preservation of very rare Pleistocene deposits older than MIS 5 and mainly by a palaeo-cliff carved in the Saalian sediments by the Eemian Sea. This situation is similar to the organization of La Cotte Saint-Brelade site in Jersey (Callow & Cornford, 1986). The stratigraphic interpretation of the Piégu sections is supported by the known stratigraphic successions established for various neighbouring sites located in the same Pléneuf-Val-André area (Laforge, 2012) and in the Eastern part of the Normano-Breton gulf where Pleistocene deposits have been dated (Bahain *et al.*, 2012).

ESR and US-ESR data (table 6) have been recently obtained on quartz and biological samples from Piégu, they have been commented in detail in Bahain *et al.* (2012) where the methodology is discussed. It is important to underline the

good agreement observed between the various results obtained on the different materials. The second set of measurements confirms generally the former results except for those previously obtained by Laurent (1993) on quartz samples. This is due to the new bleaching protocol. This new protocol permitted to understand that the bleaching rate (and consequently the ESR age) estimated by Laurent (1993) for the level J of Piégu was strongly underestimated.

The geochronological data now available for Piégu and for some other neighbouring Palaeolithic localities of the Pléneuf-Val-André region show that the last regional chronostratigraphic framework proposed by Monnier *et al.* (2011) is fully supported by the new ESR and US-ESR dates.

– If we take account of these results and of the available geological and palaeontological data, it seems reasonable to correlate the layer G of Piégu with the late MIS 7 or the early MIS 6 (with a mean quadratic age of 193 ± 6 ka obtained on 9 samples) (Bahain *et al.*, 2012). The archaeological and palaeontological assemblage witnesses the existence of a human occupation at the top of the cliff during an interglacial stage (which is in accordance with the biochronological framework of Northern France; Auguste, 2009). Latter, this material was reworked in a head deposit when the top of the cliff collapsed during early stages of the next glacial period.

– The correlation between the level J of Piégu and the neighbouring archaeological layers of Les Vallées (layer 21) and Nantois (layer 35) proposed by Monnier *et al.* (2011) is confirmed by the new dating results. Other ages obtained on “Les Vallées” archaeological level (Bahain *et al.*, 2012), with its cold palaeontological assemblage, can be correlated with the middle part of MIS 6 (mean quadratic age of $164 \pm$

Site, layer	Uncalibrated age, ka	Reference	Material	Methodology
Piégu, level 6/G	207±18	PG0508	Tooth	US-ESR age
Piégu, level 6/G	200±16	PG0504	Tooth	US-ESR age
Piégu, level 6/G	199±19	PG0506	Tooth	US-ESR age
Piégu, level 6/G	186±15	PG0502	Tooth	US-ESR age
Piégu, level 6/G	182±16	PG0501	Tooth	US-ESR age
Piégu, level 6/G	178±36	PG9102	Tooth	US-ESR age
Piégu, level 6/G	165±33	PG9202	Tooth	US-ESR age
Piégu level G	197±12	LV9402	Bone	US-ESR age
Piégu level G	187±18	LV9401	Bone	US-ESR age
Piégu level 7/J	164±32	PG-J	Sand	ESR age
Piégu level 8/H	123±23	PG-H	Quartz	ESR age
Piégu level 8/H	122±14	PGCOQ	Shell	US-ESR age

Table 6: List of the various ages recently obtained on Piégu (after Bahain *et al.*, 2012).

Tableau 6 : Liste des datations récemment obtenues pour Piégu (d'après Bahain *et al.*, 2012).

13 ka obtained on 5 samples), that is to say before the glacial maximum attested in this area by the loess deposits observed in the sections above the archaeological layers (Monnier *et al.*, 2011). It also permits to observe a good agreement between quartz and bones data.

– At last, the marine level H of Piégu which shows a mean quadratic age of 122 ± 23 ka (based on 2 samples) can be clearly attributed to the Eemian stage (MIS 5e) after the ESR and US-ESR dates.

Considering that the lowest marine deposits observed in the Piégu stratigraphy (layers D and B) corresponds to two older interglacial stages, it becomes possible to attribute them in a first approximation to MIS 7 and 9 respectively.

In conclusion the ages obtained by ESR and ESR/U-series methods on the different analysed materials of Piégu confirm that bones can be used to date late Middle Pleistocene sites. These results permitted to assign palaeodosimetric ages to several stages of the regional geological evolution and allowed the dating of several archaeological evidences, during late MIS 7 – early MIS 6 for Piégu.

7. CONCLUSION

For the first time the stratigraphical subdivisions of the Western and Eastern onshore and Offshore sections are fully described and illustrated by different figures.

The archaeological excavation of Piégu carried out in 1987 confirmed that the Palaeolithic industry that was found earlier on the actual beach, was probably older than the last interglacial (i.e. MIS 5e or Eemian). This age was already supported by the sedimentological analysis and by the stratigraphy. It has been also shown that there were three human settlements. One, on an old beach located at the base of the Pleistocene deposits (probably MIS 9 in age). Another one located on the fossil beach (probably MIS 7 in age). And a third one, recognized at the top of the cliff. So far as this occupation is concerned, we know that the lithic industry and the associated mammal bones collapsed from the upper member of the section as frost-shattered screes.

The new radiometric ages now published confirm the chrono-stratigraphy previously suggested. The above contribution which incorporates many data previously unpublished, some information poorly known before and the many observations made in the trenches and boreholes undertaken East and South of the main excavation contribute to a better understanding of the whole area than the sole documents extracted from the “archaeological” site alone. The new data complete and confirm our previous stratigraphical knowledge of the site. The new malacological

data, incorporated together with the previous determinations, provide, for the first time, a detailed synthesis of the environmental evolution of Piégu area during the Middle to Late Pleistocene and Holocene times.

At the regional scale, the site of Piégu is of a major interest from a stratigraphic and archaeological point of view. It represents one of the very rare sites of westernmost Europe where calcareous deposits and bone remnants associated with a Palaeolithic lithic industry are still preserved. Elsewhere, in Brittany, the acidity of the soil destroyed almost always bones and mollusc shells. The results are also important if we take account of the large amount of data collected in the rescue conditions which prevailed during this survey. They are also highly valuable since neither the cliff nor the trenches can be now directly observed. Study of this site brings some light on the first populations of the far west of Europe since three different periods of occupation were found.

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Figure 7 : Guzel DANUKALOVA *et al.*, Reconstruction of the Middle-Late Pleistocene and Holocene Palaeoenvironments of the Piégu Palaeolithic Site (Brittany, France) based on Biostratigraphical Data (p. 21)

Figure 8 : Guzel DANUKALOVA *et al.*, Reconstruction of the Middle-Late Pleistocene and Holocene Palaeoenvironments of the Piéguy Palaeolithic Site (Brittany, France) based on Biostratigraphical Data (p. 23)