The quaternary of Britanny

Brigitte Van Vliet-Lanoe, Bernard Hallégouet, Jean-Laurent Monnier

THE QUATERNARY OF BRITTANY

Guide book

of the excursion in Brittany, 12-15 September 1997

Quaternary Research Association

Organisators:
Brigitte VAN VLIET-LANOE, Bernard HALLEGOUET, Jean Laurent MONNIER

Travaux du Laboratoire d'Anthropologie ,
Universite de Rennes 1
Special volume

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with the contributions of

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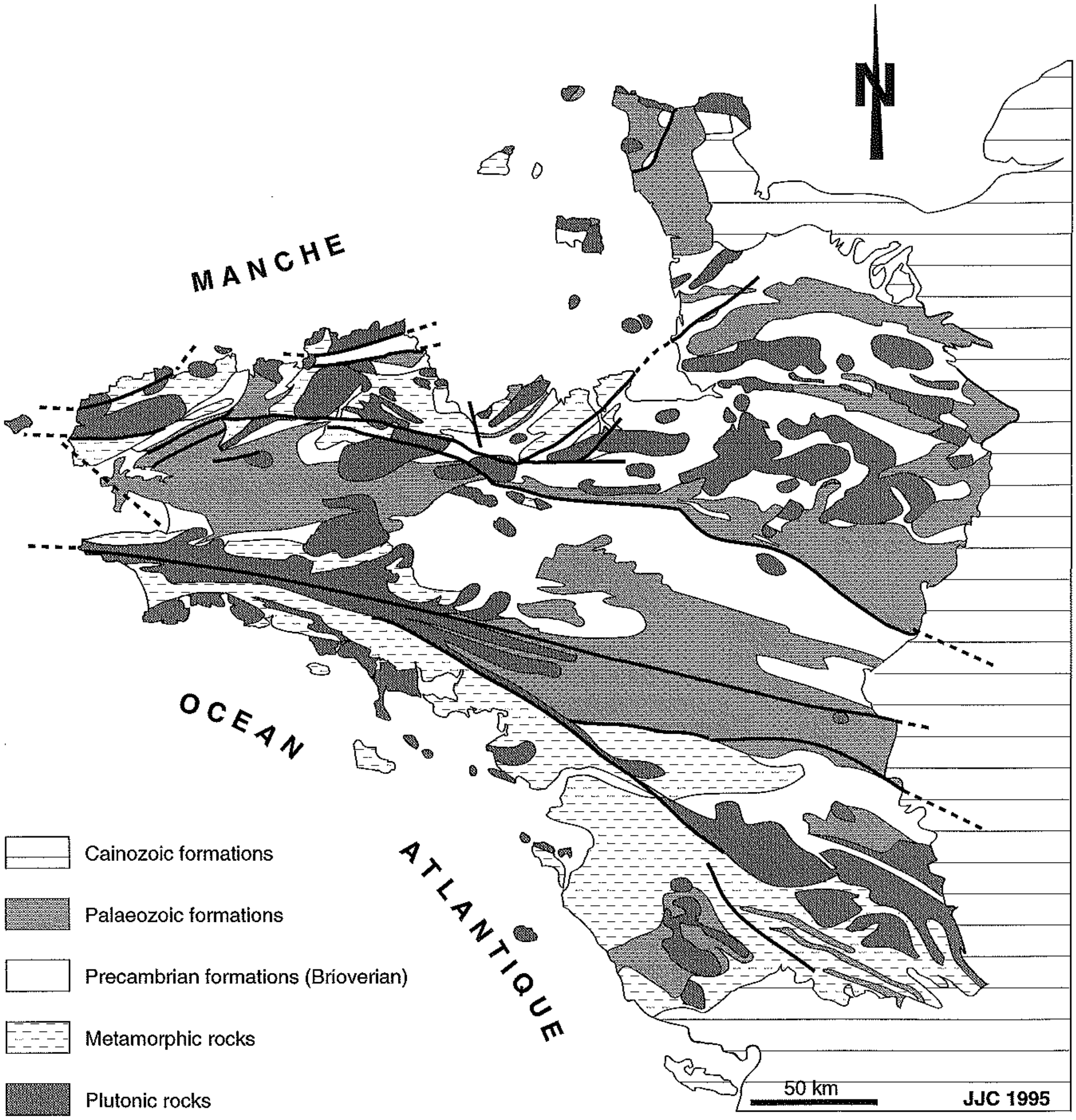
CONTENT:

FOREWORDS

This guide-book represents the synthesis of new works performed in Brittany since 1986 (INQUA Normandy-Jersey-Brittany field trip). Stratigraphical concepts, datings, especially by ESR on quartz, new typological approaches of archeological sites and a better knowledge of the neotectonic have allow a strong re-evalution of the former stratigraphical interpretations. Franco-British collaborations inside CNRS Scientific Programs (DBT II, Fleuves et erosion ; Paleoenvironnements et Hominidés) have allowed and consolidate completitive researches on both sides of the Channels. Most of the papers presented in this guide-book will be published in the Revue Archéologique de l'Ouest, n°12, 1997.

Brigitte Van Vliet-Lanoë, (Géosciences , UPR 4166 CNRS, Univ. Rennes1)



Geologic map of the Armorican Massif

(without the Tertiary basins)

THE GEOLOGY

J.J.CHAUVEL

The Pre-Mesozoic geological framework of the Armorican Massif is the result of three successive orogenic cycles:

- the *Icartian Cycle* is the oldest (around 2 Ga)
- the *Cadomian Cycle* which ended about 540 Ma
- the *Hercynian* (Variscan) Cycle of which the last events characterize the Late Carboniferous.

The ICARTIAN CYCLE

The outcrops of the Icartian basement are rare and are all located in the North of the Armorican Massif between the lannion Bay in the SW and Cherbourg in the NE. The Icartian rocks are mainly gneiss of which the ages are between 2203 $^{+49}/_{-44}$ Ma (Omonville-Gréville, near Cherbourg) and 1790 $^{+19}/_{-17}$ Ma (Port-Béni, near Lannion).

The CADOMIAN CYCLE

The Cadomian Cycle appears to have been very short because the radiochronological data are comprised between 670 and 540 Ma. The more recent model for the Cadomian orogenesis, build up in the recent years comprise from N to the S:

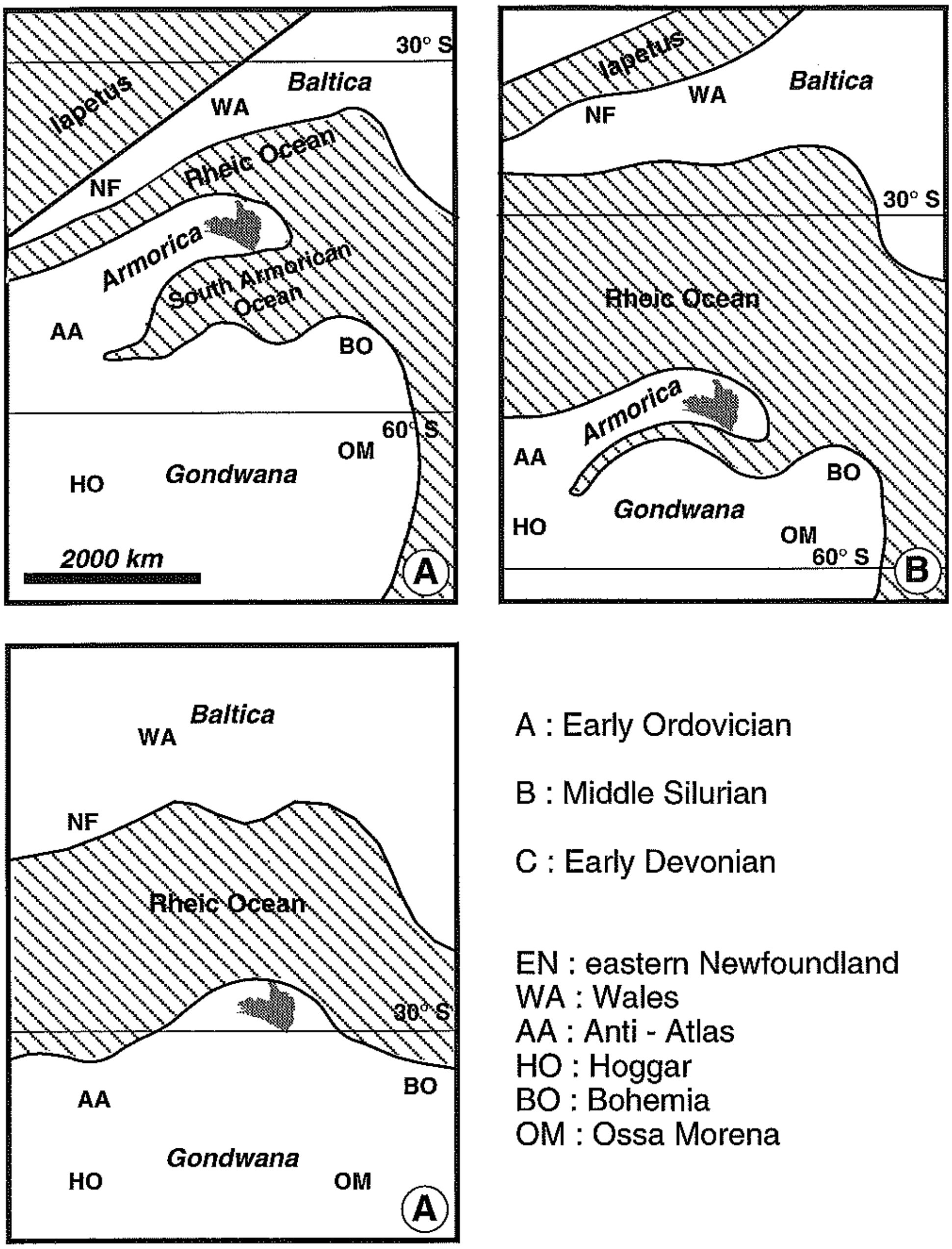
- an oceanic domain (celtic Ocean)
- the Icartian block
- a volcanic arc basin
- a continental plateform

The development of the Cadomian orogenesis resulted from subduction of the Celtic Ocean crust beneath the old Icartian continental edge during the Late Proterozoïc. Closure of the back arc basin led to the rise of the Cadomian Cordillera and to its overthursting over the continental margin. This tectonic shortening is dated at between 600-585 Ma by the associated plutonism. Later (540 Ma) the overthickening of the crust led to anatexis with the development of Guimgamp and St-Malo migmatites and the intrusion of granitic plutons.

In the Armorican Massif , all the formations situated under the oldest Palaeozoic sediments are known as **Brioverian**. The Brioverian is generally divided in two parts:

- the Lower Brioverian (or phtanitic Brioverian)
Deposited before the closure of the back arc basin, the Lower Brioverian is characterized by the development of volcanic rocks associated to the terrrigenous sediments and by the presence of black cherts (phtanites). These cherts have provided an abundant microbios constituted by blue-green algae (*Palaeocrytidium, Bavlinella*).

- the Upper Brioverian (post-phtanitic Brioverian)
The Upper Brioverian is mainly constituted by terrigenous sediments with locally some associated limestone. It is characterized by the presence of reworked phtanitic grains. In Normandy and in the Mancelian domain, the Upper Brioverian must be attributed to the Upper Proterozoic because it is deformed by the Cadomian Orogeneis, intruded by plutons dated at 540 ± 10 Ma and unconformably overlain by fossiliferous Cambrian



A : Early Ordovician

B : Middle Silurian

C : Early Devonian

EN : eastern Newfoundland
WA : Wales
AA : Anti - Atlas
HO : Hoggar
BO : Bohemia
OM : Ossa Morena

Paleozoic evolution of the Armorican Massif sediments. In contrast, the age of the Upper Brioverian raises some problems in Central Brittany. In this area the oldest Palaeozoic formations are constituted by volcanics dated between 465 ± 1Ma and 486 ± 28 Ma, Proterozoic plutons are lacking and the only deformation of the Brioverian series must be attributed to the Hercynian orogenesis. So the Upper part of the Upper Brioverian could have been deposited during the Early Cambrian times. Recently this hypothesis has been supported by:

- the analysis of reworked zircon grains provided by Upper brioverian sandstones and dated at 540 and 541 Ma,
- the study of volcanic tuffs associated to the Upper Brioverian series (Crozon peninsula) and dated at 543 ± 18 Ma.

The HERCYNIAN CYCLE

With other regions of southern Europe and North Africa, the Armorican Massif was a part of the North Gondwana margin during the palaeozoic times.

The first marine transgression on the Cadomian peneplain started as early as the Tommotian in Normandy and reached the Vendean domain during the Middle Cambrian. The first period is followed by a general regression and by the development of an important continental volcanism. The "true" Palaeozoic transgression started during Arenig and flooded most of the Armorican Massif.

The evolution of the Palaeozoic sedimentation is directly linked to the evolution of the North Gondwanian margin. During the Devonian the Armorican plate migrated towards tropical latitudes and sediments became mainly carbonated.

The history of the hercynian ororgensis started with Arenigian extensional events leading to creation of contiental rifts with an important associated volcanism. These basins were infilled first by red continental sediments, then were progressively flooded by the Arenigian transgression. During this period, some granitic plutons emplaced, specially in the South of the Armorican Massif.

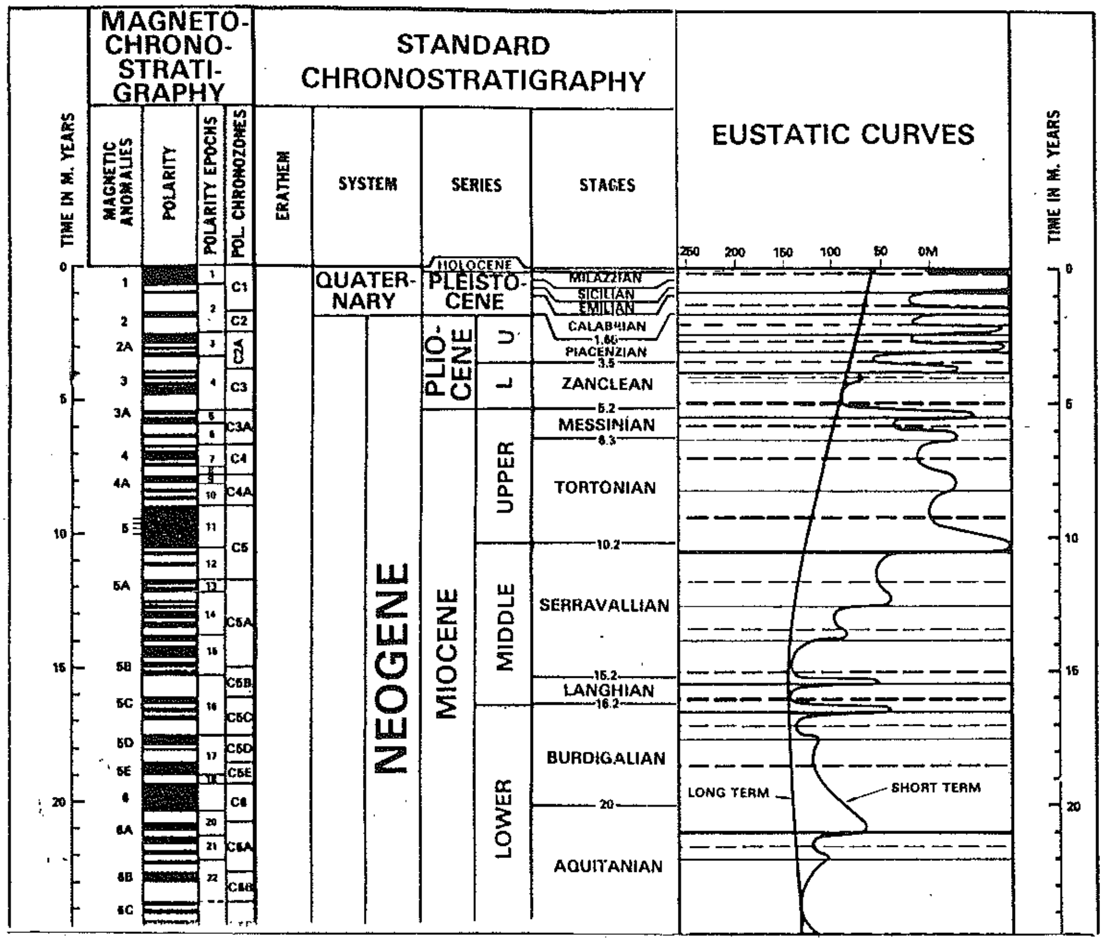
Eo-Hercynian tectonic events are known in the Leon Area and in the South Armorican domain. This domain seems to be the result of the stacking of continental masses during a continuous period of collision. The HP metamorphism linked to this collision (eclogite, blue schists....) is dated between 360 Ma and 440 Ma.

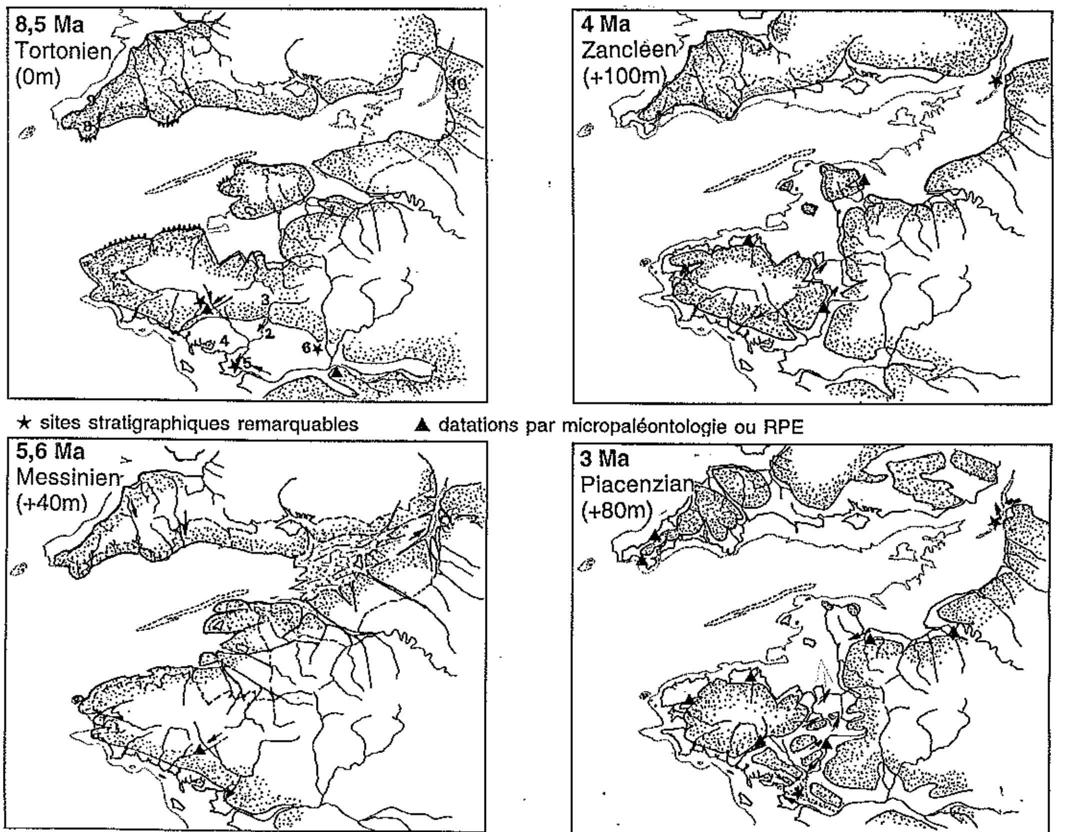
The main deformation period started during the Devonian (Breton phase). All the oceanic spaces were closed and the main collision process has started. These tectonic events resulted in the deformation of sediments leading to the development of E-W folded structures. The formation of the Hercynian cordillera is accompanied by plutonic intrusions (dated at between 340 and 285 Ma) and by the development of important shear zones.

The end of the Hercynian history is characterized by the development of coal basins.

The MESOZOIC AND CAINOZOIC HISTORY

The Mesozoic is a continental period and the sediments are today only preserved on the margins of the Armorican Massif (shelf and East). These continental conditions prevailed untill the Eocene and were characterized by a hot climate with the development of a very deep weathering. Between the Oligocene and the Pliocene, the Armorican Massif was locally flooded by short and shallow marine transgressions.





1) Réguiny, 2) St Malo de Phily , 3) Rennes, 4) Lauzach, 5) Missillac, 6) Segré, 7) Esquay, 8) St Erth , 9) St Agnès, 10) Slack

Mio-Pliocene evolution of the Armorican Massif and the Channel area (Van Vliet-Lanoë et al.1997c)

THE CAINOZOIC EVOLUTION

B.VAN VLIET-LANOË , B.HALLÉGOUËT , M.LAURENT

A) PALEOGENE

The geodynamical understanding of the evolution of the Armorican Massif during the Cainozoic goes trough the continental sequences and mostly trough the sedimentary bodies preserved outshore on the shelf. During Cretaceous, Brittany was mostly submerged especially during the high stands of the Cenomanian (200m). It his difficult to know if Brittany was covered by chalk with flints as on the shelf, on the southern part of Cornwall and the Flamanville Cape in Normandy or by other facies like the ochre's Cenomanian sands visible in the eastern part of the Massif, even at Laval. Locally, in south-east Brittany, cretaceous glauconite was observed below the Eocene. On the shelf, chalky sedimentation is nearly continuous up to the upper Eocene and turn into shore vicinity bioclastic facies from the Ypresian to the Oligocene. Neogene is mostly characterised by clayish calcareous mud.

During the Eocene, Brittany is uplifted in response to the Pyrennean and Alpine orogenesis, with some tectonical inversion, during the opening of the west European rift (boundary between the Ypresian and the Lutetian; Ziegler, 1990). Large detrital, prograding deposits including brown coal occur like at la Trinité Porhoët (Ollivier Pierre, 1964), in basin controlled by hercynian faults. These deposits consist in coarse sands with rounded quartz gravels and white clays. During the Oligocene, most of the deposits in Brittany are continental (Ollivier Pierre, 1980) and sedimentation in tectonical basin more clayish (smectites) and organic. At that time, a fluviatile valley, flowing down from central Brittany was filling the St Renan-Aber Ildut basin . This sedimentation stopped abruptly with a strong inversion also sensitive on the shelf and related at the boundary Oligo-Miocene boundary and the St Renan valley becomes isolated from central Brittany. An erosional surface took place, the Paleogene surface defined by Wyns (1991).

Nevertheless, continental Brittany was a very flat abrasion surface rising during the Paleocene, and suffered deep weathering (Estéoule-Choux, 1967) from that time and the Eocene. Saprolite are true ferralithic soils, deep, at least more than 30m, rich in kaolin. Occasionally, bauxite occur. During dryer episodes of the late Eocene, some silicifications occurred at shore face or in form of true silcretes.

B) NEOGENE EVOLUTION

1) Lower and Middle Miocene.

At the end of the Oligocene, the strong tectonic episode related to the Alpine and Pyrennean orogenesis occurred, stopping sedimentation in basins (Ziegler, 1987). At that time, Brittany is uplifted and new valley incisions occurred related to the Chattian regression. During the Middle Miocene, Western Brittany emerged already and the Langhien-Serravalian transgressions invaded the new valley system despite a relatively high sea level (150m). The preserved deposits are mostly faluns (or "crags")

2) The Mio-Pliocene

In the Armorican Massive, the widespread Red Sands facies has been formerly attributed to an Upper Pliocene marine environment. They consist in prograding bodies coarse azoïc quartz sands with some glauconite, usually preserved in a paleovalley system. A detailed study of several excavations in Brittany, Anjou, Cornwall and Normandy allow a better definition of these facies in the global tectonical context of Europe (Van Vliet-Lanoë et al. 1997c).

In the upper valley of the Blavet river (Reguiny, central Brittany), a ENE-SWS shallow basin has made possible the study of fluviatile and esturarine bodies, never described in this region. Complementary data were obtained in south Brittany (Rieux, Lauzach, Missilac), in Central Brittany (Rennes, Ploermel), in Normandy (Esquay). ESR dating, sedimentology, sequence stratigraphy, palaeopedology and microtectonical studies were performed on these sediments in which fauna and pollens are usually lacking. Sands originate in mostly local and presumed cretaceous (to the East) sources with local aeolian reworking. Several formations were defined at Reguiny (central Brittany) and observed in most of the sites.

After the "Helvetian" period, the climate cooled down and a large regression occurred at the base of the Tortonian, around 10.5Ma. A new valley system is excavated as also recorded in form of a large sedimentary body on the Western Approaches, the Cockburn Formation (Evans, 1990). At that time Brittany is no more uplifted: the Tortonian transgressions (0 and 15m) invade most of the southern Brittany: the Bolan Formation, a Tortonian fluviatile to estuarine clayish sand body, dated by ESR at 8.5 and 7 MA.

This formation is truncated by a well developed paleosol and incised by a coarse fluviatile sands and gravels, the Reguiny Formation, attributed to the Messinian crisis and associated with strong syngenetic neotectonic and paleoseismicity, the Post-Helvetian crisis of Durand (1960) . Regional stress field is shearing compressive (N150°). Again Brittany is uplifted of about 100m related to the eustatic curve.

Because of this uplift, the Zanclean transgression, the first one of the Pliocene, was only locally known in Brittany: in the Rennes Basin at Apigné. Recent field work has allow us to connect some of the sandy facies to the classical falun"Redonian" from Apigné (Durand, 1960; Margerel, 1968,89; Pomerol, 1973). ESR datings gives and age of 5,3 Ma and fits with the Zanclean attribution. New observations in western Brittany (Hallégouët et al., 1997) shows also the presence of zanclean infra-tidal clays resting in the Elorn valley. Zanclean sandy facies are now recognized also in southern Brittany at Lauzach and Missilac on the main platform, south of the CSA (southern shearing zone).

These two formations are truncated by the Radenac Formation, the "classical Red Sands": it corresponds to a Piacenzian fluviatile complex with 3 main estuarine transgressions, whose setting is partially controlled by neotectonic and low level seismicity dated by ESR between 3.5 and 3 M y. True shore face formations are only recognised at Missilac (30m) in southern Brittany and at Roz/Couesnon (85m) on the northern coast. At the Elorn valley and in Tregor, the platform is still invaded by deep water. The Leon, which was emerged during the Zanclean (100m) becomes submerged despite a lower high stand (80m). Brittany is sinking.

3) The Plio-Quaternary transition

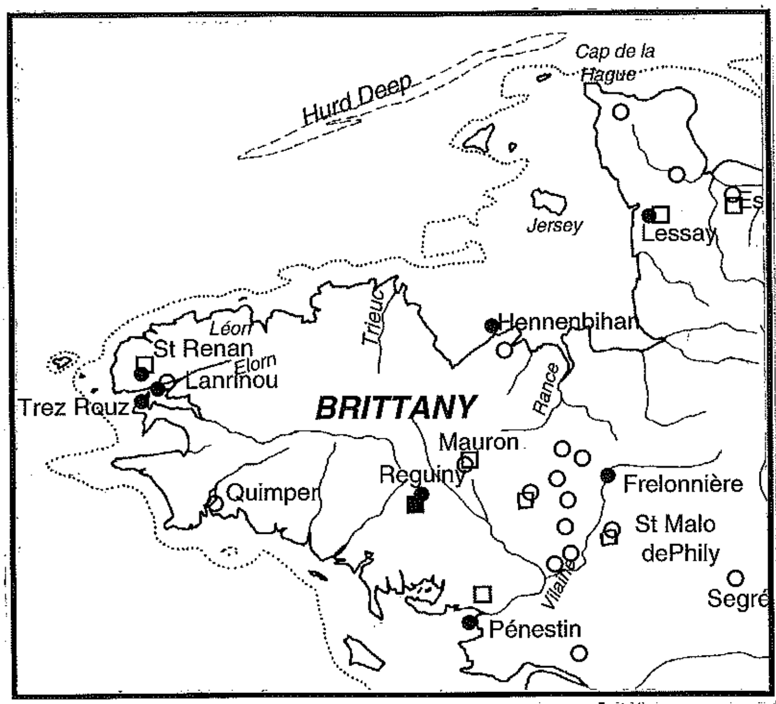
Around 2.6-2.4 Ma, the sedimentation changes abruptly, related to the main cooling of the Pre-Tiglian, but also with a new tectonical crisis, related with deformations at various wave length. Stratified clays as at St Jean la Poterie (Morbihan), Guindy (Tregor), at Landerneau (Elorn valley) and other sites of the western coast of France are observed as a rather homogenous assemblage, foraminifers excepted (Margerel, 1968, 89). ESR dating of this unit gives and age 2.4 Ma at Reguiny. A cooling of sea water, observed by foraminifers since the base of the Zanclean seems to come from the North, not from the Atlantic, and is probably related with an initial opening of the Dover Strait related with the Messinian crisis (Van Vliet-Lanoë et al., 1997a & b).

	BRITTANY CORNWALL	**NORMANDY**	**N. BELGIUM**
LOWER QUATERNARY = Eburonian + Tiglian C5 (mild)	cold	cold	cold
GELASIAN (1,8- 2,6 Ma) = Tiglian A-C4 + Pre-Tiglian + Reuverian B-C End Piacenzian	FBN9 *Elphidium ottomani* *Aubingnya marei marei* **mild**	Pliocene 3 ***Elphidiella hannai*** **cold**	
opening Behring (3 Ma) **PIACENZIAN** (3- 3,6Ma) closing Panama (3,5 Ma)	FBN7 *Pseudoeponides pseudotepidus pseudot.*	Pliocene 2 + ***Bucella frigida*** ***Faujasina*** **cooler in Normandy**	BFN6 ***Elphidiella hannai*** *Cribronronion excavatum* **cold**
ZANCLEAN (5,3- 3,6 Ma) warm **CHANNEL MICROFAUNA: NORDIC AFFINITIES**	*Polymorpha frondiformis* *Elphidium paraskevaidisi*	Pliocene 1	BFN4 *Florilus boueanus* *Mospeliensina pseudotepida* *(Palm tree)*

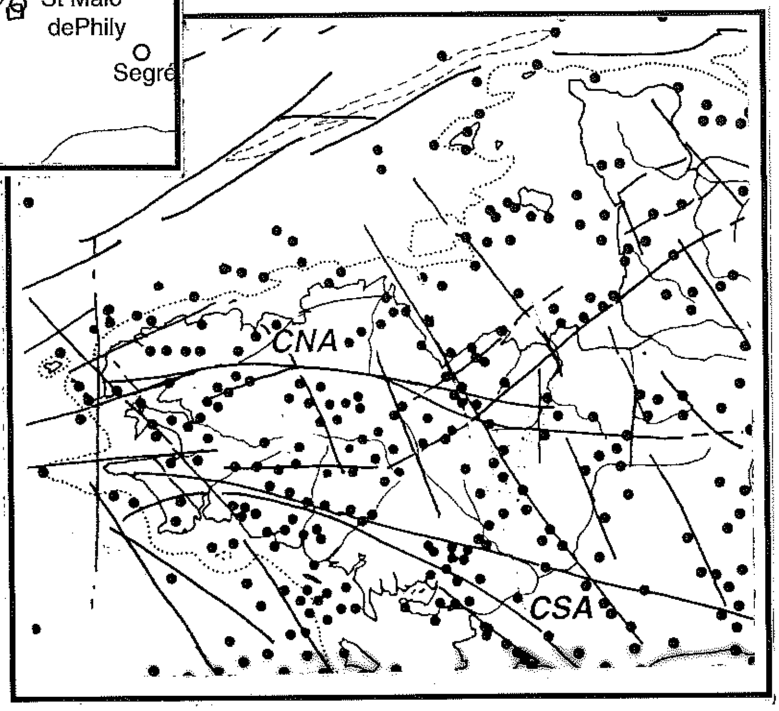
CHANNEL MIOCENE MICRO FAUNA: LUSITHANIAN AFFINITIES
modified from Margerel, 1968, 89; Pomerol, 1973; Zagwijn, 1990

4) Conclusion

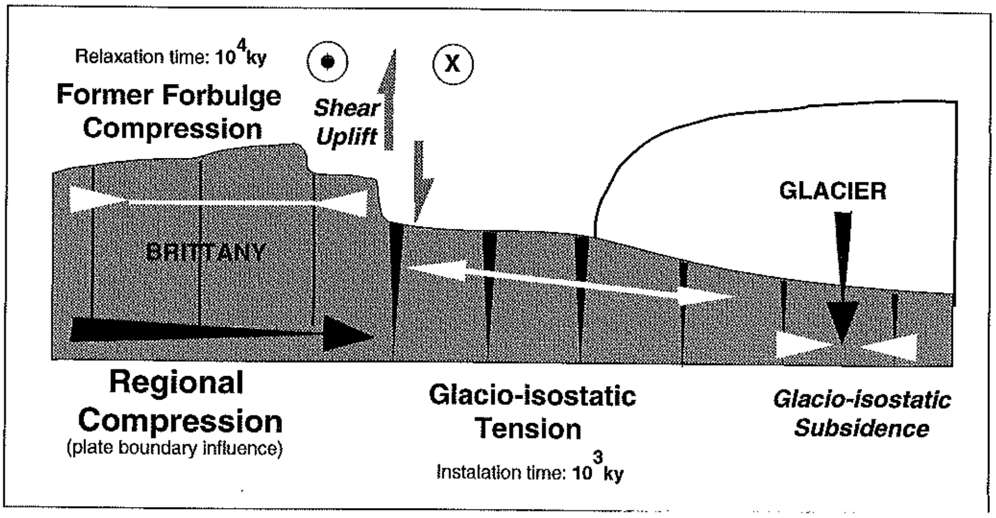
After this clayish formation, regional sedimentation rate is low and even since Middle Quaternary, erosion prevails: early and middle quaternary neotectonics are important modifying drastically the valley system. First meandering valley alluvium are dated from the Pre-Tiglian, but the first periglacial braided rivers date from the Waalian (ESR 1.4Ma). Brittany evolution through out the Cainozoic can be resumed as follow: a long period of stability with mostly sedimentary aggradation on the shelf and deep weathering on the emerged surfaces up to end of the lower Eocene (50Ma), a shift to prograding sedimentation on the shelf related to the successive uplifts (long waves deformations) of Brittany up to now after that time, with an acceleration from the base of the Tortonian (11 Ma). With the global lowering of the sea level since the Pliocene,



Paleoseismicity :
- ❍ Quaternary age unknown
- ● Quaternary age known
- ❑ Neogene, age unknown
- ■ Neogene, age known



Map of present-day and historical seismicity, adapted from Grellet etal., 1993 and Wittaker et al.,1989.



Sketch of the geodynamical implications of glacio-isostatic forbulge overlap in a regional compression stress field.

inland sedimentation is essentially restricted to fluviatile transit and aeolian sedimentation.

C) QUATERNARY NEOTECTONIC AND SEISMIC ACTIVITY IN THE ARMORICAN : REGIONAL STRESS FIELD WITH GLACIO-ISOSTATIC INFLUENCE? (J.Geodynamic, 24, 1-4)219-239)

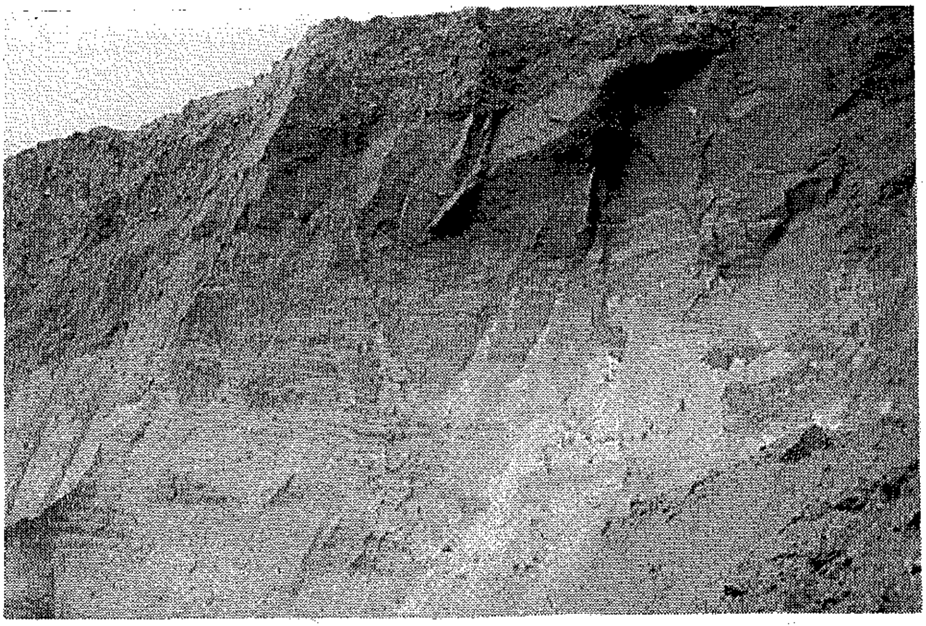
In Brittany , evidence for low magnitude Quaternary seismicity may be found in sand pit exposures and beach sections. Present-day (interglacial) maximal recorded earthquake magnitude is 5.2 . Focal depths are shallow and shift from about 5km to the West (Kerforne F.S.) to about 15 to the East (CSA, close to Nantes) (Levret *et al.*, 1994).

Beside these quaternary neotectonic and co-seismic crisis, major events are recorded in Brittany during the Eocene, at the end of the Oligocene, during the Messinian age and close to the end of the Pliocene, in relation with the different phases of the Alpine and Pyrenean orogenesis. These events have also strongly influenced the neogene sedimentation and its preservation.

Quaternary deformations are especially well seen in alluvial and estuarine complexes resting on Late Pliocene sands or thick saprolite. A systematic study of Late Tertiary and Quaternary outcrops in the regions under study has shown an association of epigenetic sedimentary "structures" which in a few sites were interpreted before as resulting of periglacial activities. New data show the widespread character of these features in the whole region considered, with the highest frequency in the area described here above . Three main types of figures were described: folding and diapirism-like-features, faulting and loading. Several sites visited during this excursion present these types of deformations. Pénestin section (southern Brittany) St Renan (Bodonou, Aber Ildut), Trez Rouz section (western Brittany) Réguiny (in central Brittany), La Frelonnière sand pit (west of the city of Rennes), St Malo-de-Phily (30 km south of Rennes).

The deformations are usually shallow, dominantly hydroplastic (high water table) and lead to overconsolidated sands, silts or clays. They reveal normal loading at micro (millimetric) and macro (decametric) scale as controlled by the local rheological properties of the sediments, by strike-slip faults associated with positive flower structures, folding or with intraformational water expulsion , or by hill slope sliding with reverse microfaulting . All the sites where these features occur, are in the vicinity of presumed active faults or of steep slope in a highly fractured Proterozoïc basement indicating a possible shearing zone. In most of the case, these features are not associated with synsedimentary deformations, as strong superficial red pedogenesis is generally reworked by these. All these features are reworked by microfaulting after overconsolidation.

No direct evidence of rupture have been observed in this area. All the vertical displacements observed along abundant microfactures are small and can replace larger evidences. Furthermore periglacial slope activity during the glacial periods can have mask these features under slope deposits. In conclusion, most of the observations can be attributed to co-seismic deformations associated to compressive shear folding and outstanding horizontal displacements under low intensity earthquakes (Serva, 1994),

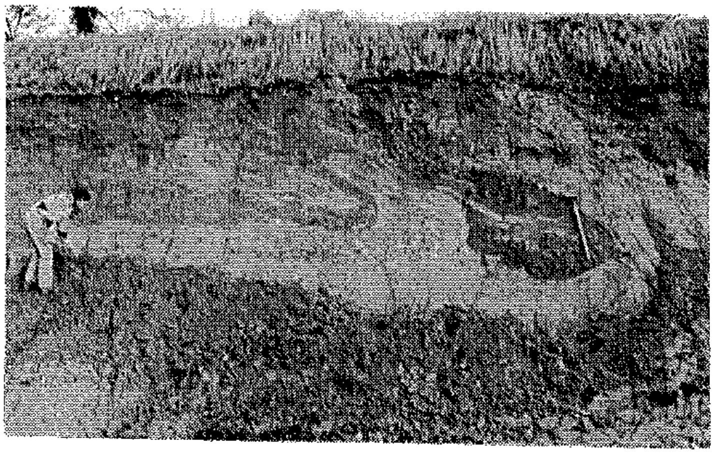


Fracturation in Piacenzian sands and early Quaternary terrace, La Frelonnière (Rennes bassin)

Fracturation in Piacenzian sands and loading in early Quaternary terrace, La Frelonnière (Rennes bassin)

Loading in saprolithe bending in the slope direction , Bédé ,central Brittany →

Reverse microfaulting associated with a co-seismic slump, Reguigny, Central Brittany.

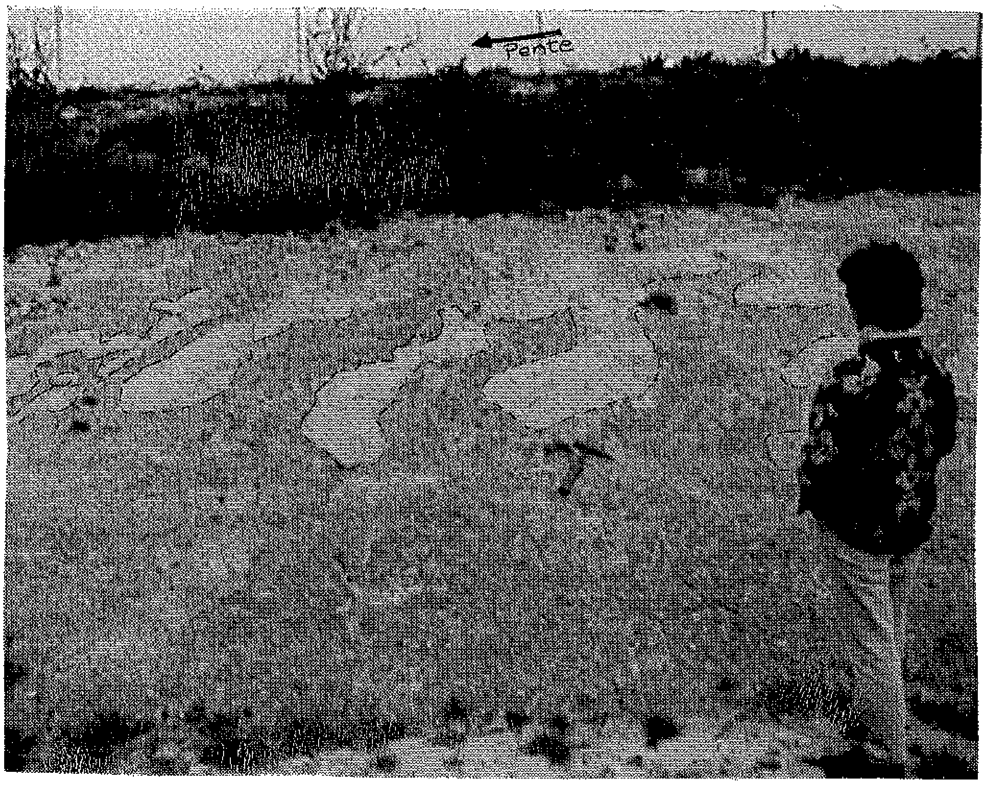


Pseudo cryoturbation induced by a co-seismic slump associated with loading .Early Quaternary. Reguigny, Central Brittany.

not much stronger than the present one. The deformation described above, seem related to a seismic crisis or a cluster of earthquakes of rather weak magnitude.

Further periglacial features are superimposed on these and often confused with them. These deformations occurred after the development of Holsteinian peat's (isotopic stage 11, 400 ka BP) at Trez Rouz, after 317 ka BP (beginning of isotopic stage 9) in the Vilaine estuary (Penestin), and in most of the other sites before the last rubified pedogenesis in middle Pleistocene (presumed isotopic stage 9). These dates correspond to the same episode that have rise to the last main reactivation of the fossil cliff around 300 ka B and to local uplift. One or several seismic clusters have taken place, probably due to delayed crustal rebound after a major glacial event (stage 10) and to rapid loading resulting from younger ice sheet growth (stage 8). Similar events occurred in late stage 7 and late stage 5. These events can have locally amplified the crustal deformation of the old Brittany Hercynian massif resulting from the regional stress field especially from 400 ka to 200 ka BP.

These co-seismic involution's have often been confused with cryoturbation or simple diapirism (from natural or periglacial origin). Microfractures followed by pedogenetic tonguing is a discrete but clear index of palaeoseismicity. Local conditions, e.g. sedimentary basin and deep saprolites in the vicinity of an active fault have amplified their record. The strongest crisis, related with hydroplastic deformations and weakly incised valleys (with a high water table) is relatively recent, close to 300 ka BP, probably occurred in relation to a residual forbulge, with isostatic loading induced by the Saalian I Glaciation and with a possible stronger compressive stress field at the southern limit of the European plate. A similar crisis of lower intensity occurred after stage 7 but prior to 160 ka BP and is related with microfracturation in already drained terraces. It means that latest main terrace incision occurred pro parte in relation with these two uplift crisis. The mechanism of uplift/tilting of Hercynian blocks induced by a temporary reduction of the strain (seisms cluster) in the regional stress field during the initiation of the forbulge could be one of the elements responsible for the late uplift steps of Hercynian massifs in Europe or only an weak .



III SEA LEVEL CHANGES

B.HALLEGOUËT, B.VAN VLIET-LANOË, M.LAURENT

A) THE PLIO-QUATERNARY SYSTEM

Evolution of the shore system is different following the considered region.

1) the South.

The shore platform is very ancient, certainly pre-Eocene and probably late Cretaceous. The sedimentation recorded in small tectonical basin along the Morbihan shows the successive reoccupation of the same platform during Tertiary and Quaternary. This platform has been faulded during the Eocene and Late Oligocene tectonical phase. Fore -shore channels are cut certainly after the Tortonian regression.
In this region, the first shore face unit, outcropping south of Penestin section (Vilaine estuary) was dated at Mesquer by ESR at 2.2 Ma (+5m). The first beach at the base of Menez Dregan (Audierne bay) is dated at 1.4 Ma (+10m). At the West of Audierne, the Plogoff beach was dated at 750 kA. The estuarine complex of the Vilaine records younger events. The base , related with shore ice rafting events is probably 600 to 650 ka (isotopic stage 16?) old. The top of the sequence is 320 ka. The region is globally subsident since the early Tertiary (Pomerol, 1973), but a strong acceleration is sensitive from the base of the Tortonian and mostly the Messinian crisis. This platform is tilted of 2‰ . Eemian beach is not visible at the outlet of Morbihan.

2) the West.

Crozon peninsula records many events. But most of them seem related with the 400ka crisis. Some on them are probably related with the 800 and 650 ka beaches of the south coast but not datings are available. Some Pliocene gravel's outcrop on the 80m surface and close to the sea level, back of the Trez Rouz. Sands and gravels outcrop on a 110-80m surface and also in fossil talweg crossing the peninsula at the east of Trez Rouz , from 35 to 10m in altitude.

3) **the North.**

Most of the outcrops along this coast shows about the same record, related with the 400ka crisis. despite, some small altitudinal changes due to neotectonic and possibly glacio-isostatic deformations. The northern part of the Trégor and the Léon seems stable , probably since the end of the Pliocene. Cap Sizun is in uplift as also the Penestin peninsula in the South. Southern area of the St Brieuc bay seems subsident, probably related with the eastern compartment of the Quessoy-Nort/Erdre fault. .

B) THE MID-PLEISTOCENE-UPPER PLEISTOCENE SHORE COMPLEX

B. HALLÉGOUËT, B.VAN VLIET-LANOË, M.LAURENT, D. KEEN & J. SCOURSE

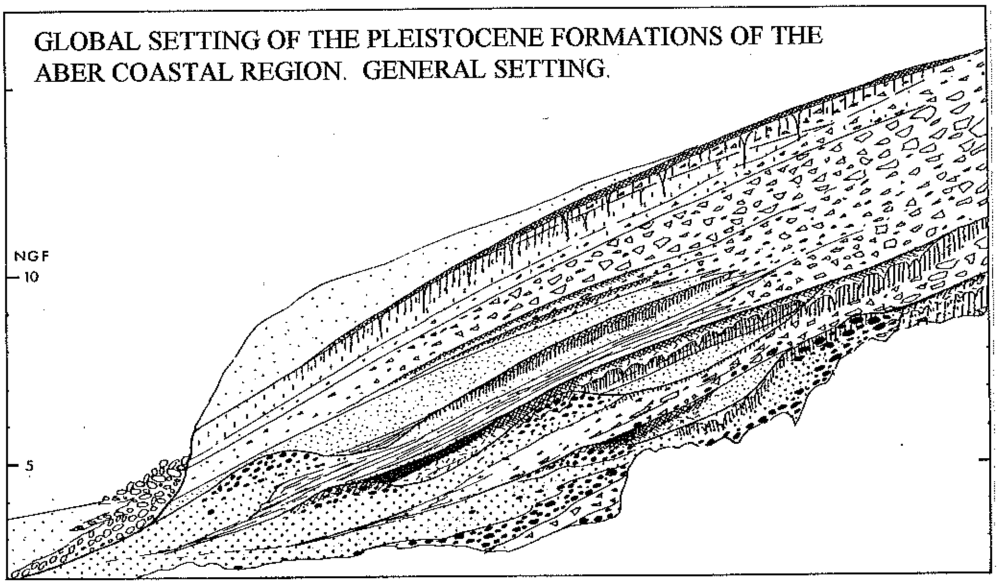
1) Introduction

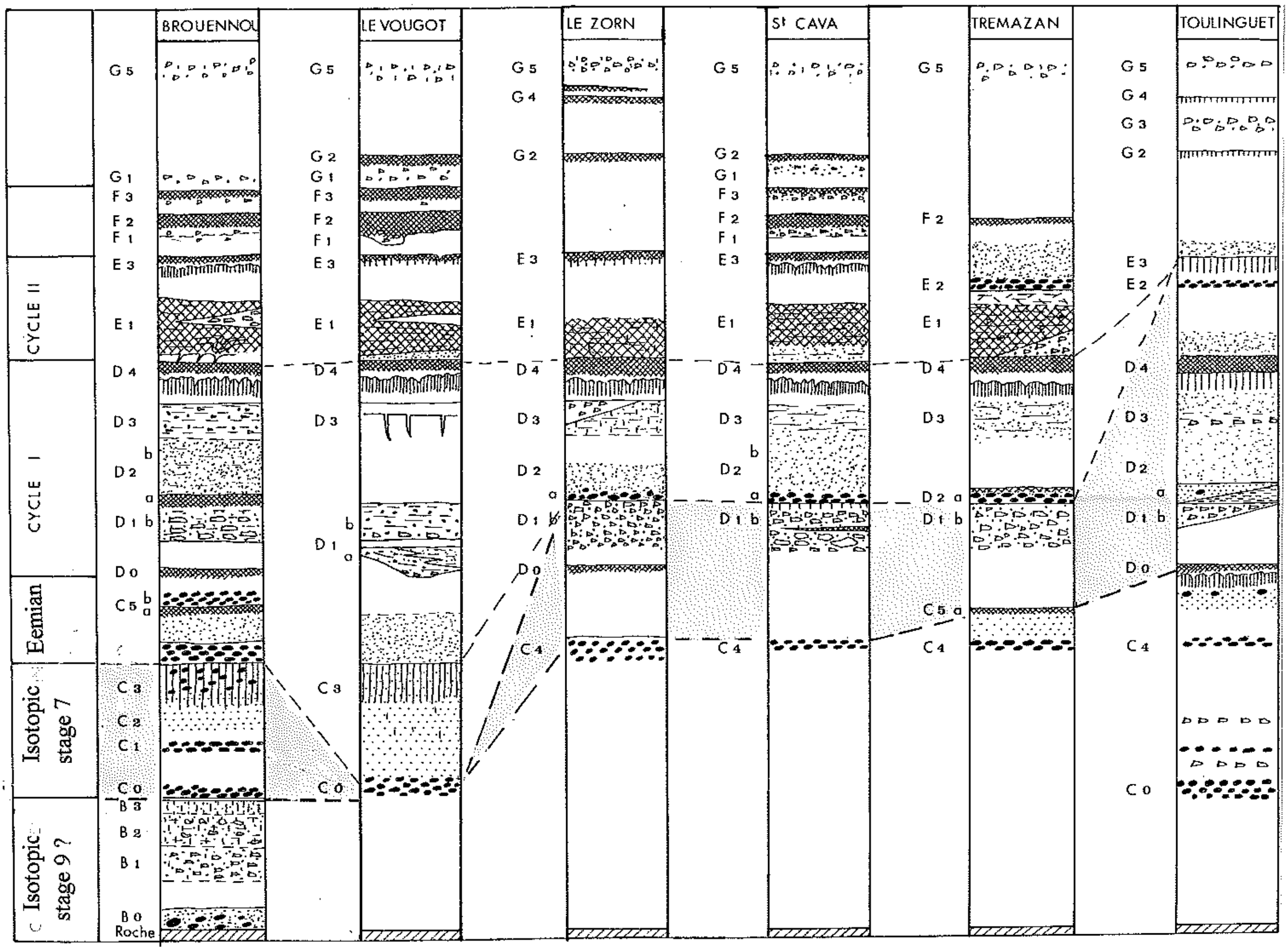
Evidence for repeated reoccupation of the present-day shore platform during Pleistocene high sea-level stands is preserved on both sides of the western English Channel, on the coasts of Normandy, Brittany, Devon and Cornwall (Hallégouët 1973; Morzadec 1974; Lautridou *et al.* 1986; Van Vliet-Lanoë 1988; Jones & Keen 1993; Scourse 1996). Previously, beach heights along the Channel have been considered only as evidence of eustatic events, related to the global fall in sea-level since the beginning of the Neogene. More recently, Preece *et al.* (1990) have suggest the influence of basin-marginal sedimentary-isostatic uplift compensating for sedimentary loading in the North Sea at the Island of Wight to be as important as eustatic controls for the height of former shorelines. Most raised beaches on the Channel coasts were assumed to have been deposited in temperate conditions as indicated by their palynological, micropalaeontological and mollusc records. Most of these shore formations are devoid of biological indicators and are formed of decalcified coarse clastic or sandy bodies at various altitudes on the same low platform, classically ranging from 3-10m . Some of these beach units are strongly weathered, other extremely fresh and this distinction has a clear chronological significance. The age of these shore face formations have been generally attributed to oceanic oxygen isotope stages 5 and 7 (Keen, 1995). Older events attributed to the Holsteinian or Cromerian on the base of biostratigraphy have been observed at Herzeele, north of the Strait of Dover (Sommé et al., 1978), at Luc sur Mer, in Normandy (Pellerin *et al.,* 1987) at Boxgrove, Sussex (Roberts, 1986), at Bembridge Isle of Wight (+40m OD, Preece *et al.*, 1990) and at Earnley (below OD; West *et al.*, 1984).

2) Stratigraphical context

Stratigraphic correlation's between interglacials defined by the palynology and isostopic stages are difficult. The following proposal is an attempt to clarify the stratigraphy. The major glacial phase in the European Middle Pleistocene is attributed to the Elsterian/Anglian glaciation and may correspond to Oxygen Isotope Stage 12 (Bowen et al., 1986), to Stages 12 and 10 (Sumbler, 1995) or to Stage 10 (Kellaway et al., 1975; Laurent, 1993). From a palynological point of view, Holsteinian is clearly Stage 11 and has a high internal climatic instability including cold phases (de Beaulieu & Reille, 1995), an interglacial complex separated from the Eemian by 2 interglacial complexes. From the 21°N site 658 Atlantic core, Stage 10 seems colder than Stage 12, and Stage 11 is climatically unstable (Dupont et al., 1989). These major glaciations are followed by an interglacial (Stage 9) which appears to equate with most of the classical Hoxnian, slightly warmer than stage 11 (de Beaulieu J.L. pers.com.), and another severe glaciation, the Saalian I/"Wolstonian" (Wijmer, 1995) in Stage 8.

Permafrost extension is a good indicator of the intensity of cold climate. All the ice wedge casts, and sand and gravel wedges observed in Brittany formed during Stages 8 & 10. During Stage 6, permafrost extension was limited in Brittany (Loyer et al., 1995). Dupont et al. (1989), consider that intense glacial stages were only found after 480 ka (Stage 12). This evidence may suggest that the major glacial phase in the Middle





Stratigraphical logs of Aber coastal sections

Pleistocene was in Oxygen Isotope Stage 10 rather than 12. The British Hoxnian is post-dates the coldest glaciation

3) New synthesis

The marine platform is widespread on both coasts of the Channel and provides a base for subsequent sedimentary events. Systematic microstratigraphic work carried out during 1994-1996 on each side of the Channel and at Barnstaple Bay, has been supported by a palaeopedological survey and ESR dating. This new work or reworking allows us to modify the traditional view of the number and age of high sea-level events (cf.Lautridou 1989). Special attention as been paid to the beach/cliff geomorphic system and related slope deposits, and also to rafting by shore, fluvial or glacier ice.

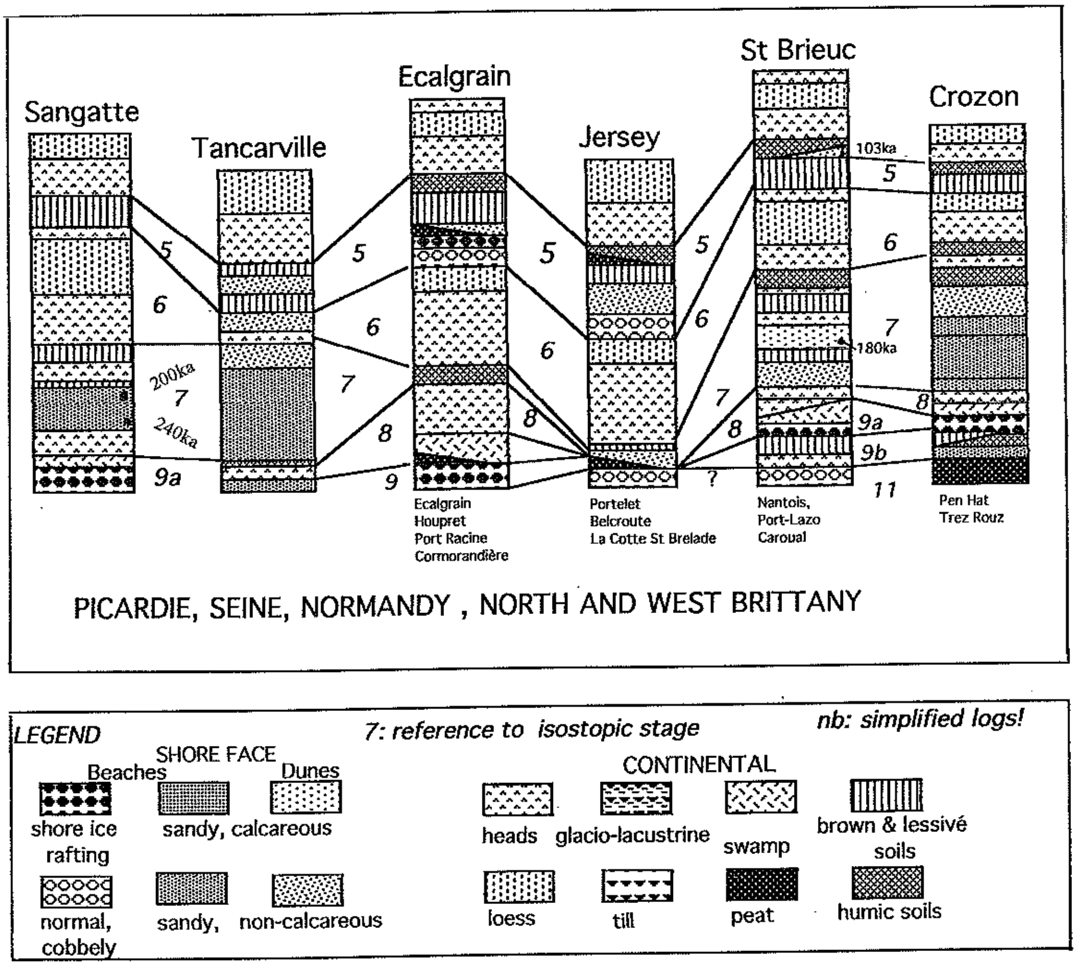
The stratigraphy has been divided in members with specific sequences of events (dynamic , geomorphic and climatic events). Each shore face member is characterised by a distinctive sequence of shore face and slope deposits, including soils, allowing the individual stages to be identified even when in stratigraphic isolation. The deposits on the platform can be divided into three members, equating to complexes of sediments of broadly similar age: Lower Member, Middle Member , Upper Member

The ESR dates are consistent with amino zones defined for the Devon and Cornwall sites by Bowen et al. (1985) and Davies & Keen and seems to fit well with the U/Th dates obtained by Proctor & Smart (1991) from Berry Head on the south side of Torbay. ESR dating also seems to conform with dates obtained for high sea-levels for Stage 9 and 7 in other regions of the world such as Japan, Chile, and the Canaries (Radtke, 1989; Meco et al., 1993; Radtke et al., 1996).

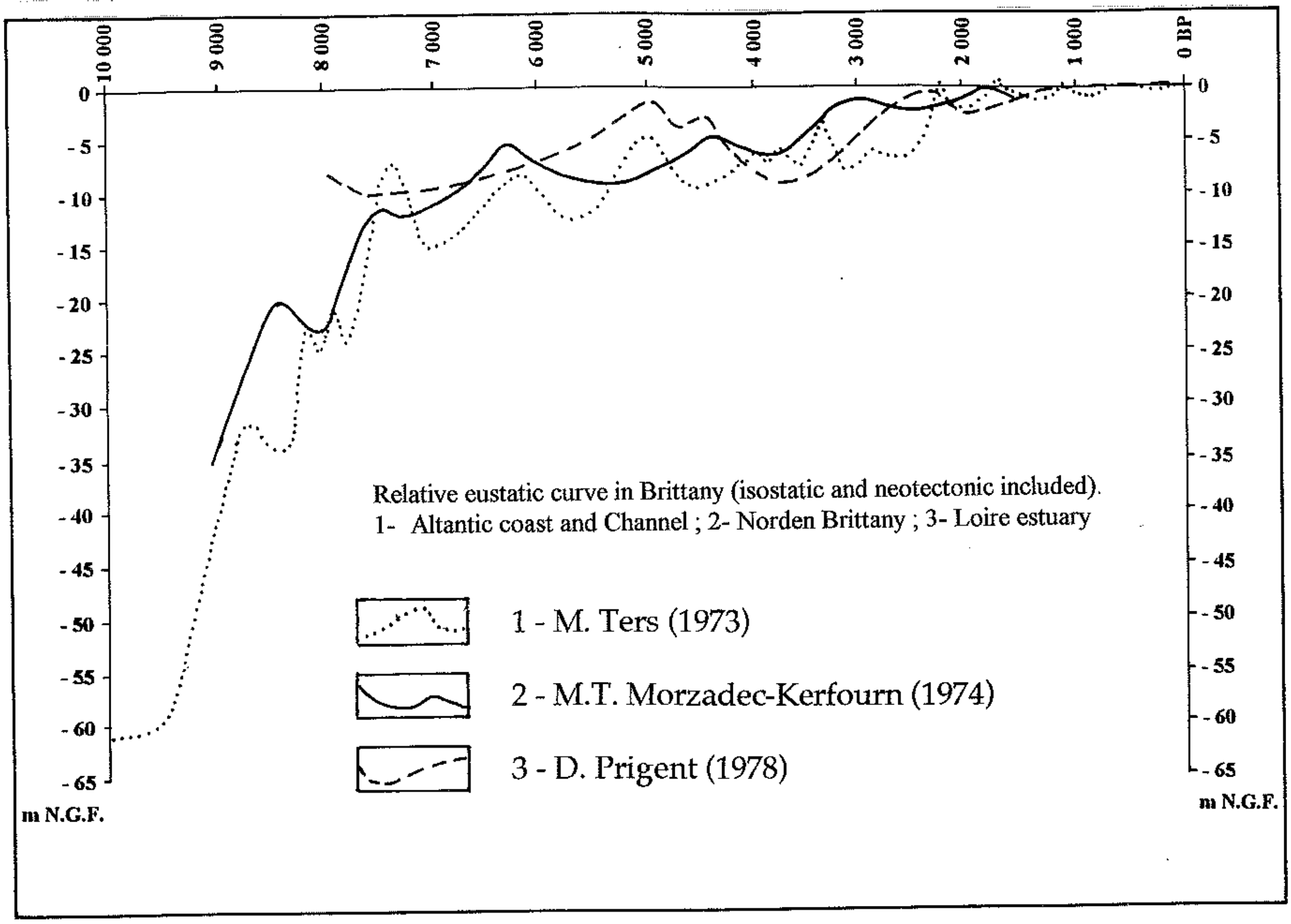
The ages of the sediments on the platforms including these three shore face members cover indicating six phases of high sea-level re-occupation of the original marine platform. Ice-rafting at two or three stages suggests minimum dates for glacial events in the western Channel.

Upper Member : stage 5e, 2 high stands + **shore ice rafting**
Middle Member : the transition between 8/7a (MMA base: 260-240 ka),
7b (MMA: 220-200 ka),
7c (MMB: 190 ka)
Lower Member : isotope stages 9b (LMB 300 ka), **shore ice rafting**
9a (340-320 ka LMA), **iceberg rafting**

At least two events indicating shore-ice rafting by sea ice are preserved within the whole sequence indicating arctic to cold temperate shore conditions (cf. winter 1962-63 in Western Europe) . The first event was immediately following a phase of marked cliff re-activation during the Middle Pleistocene around 300 ka BP (Oxygen Isotope Stage 9), and one apparently within Oxygen Isotope Stage 5e. The event in Oxygen Isotope Stage 9b is clearly the result of a rapid sea-level transgression-regression cycle, but at a level expected to reach only -10m from the _$^{18}0$ record (Martison *et al.* 1987), in rather cold boreal to subarctic conditions. A rapid transgression within the Northern Atlantic during early Stage 9, could also explain calving and the occurrence of Icelandic basalt and other exotic shore-ice rafted blocks



Comparative stratigraphic logs along the southern shore of the Channel (Van Vliet-Lanoë et al., 1997d)



observed by Hallégouët & Van Vliet-Lanoë (1989) on the low level raised shore platforms in western Brittany.

The last phase of the Stage 9 cliff reactivation appears to be associated with evidence for neotectonic or isostatic-induced crustal movement, and sites on both sides of the Channel provide evidence for a major neotectonic and seismic crisis at this time synchronous with volcanic events (Van Vliet-Lanoë et al., 1995). This hypothesis of isostatic deformation could also permit the formation of the high, unweathered raised beaches immediately prior to the last cliff reactivation, recorded from 15 m NGF in S and SW Brittany (Hallégouët, 1990), 20m NGF in NW Brittany (Hallégouët, 1973), 18 m OD in the Channel Islands (Keen, 1978) up to 25m OD in the Scillies, and to 29 m OD in Penzance (weathering unknown; Scourse, 1996), and to 35 m OD for the fluviatile terrace at Welcombe, Devon. This abnormal situation is confirmed by the preservation of reddish Glossudalf or peaty soils, of Hoxnian age (Stage 9a), truncated by this beach but also very locally preserved on the present-day shore platform below the Stage 9b beach (Port Lazo, Beauport at theWest of St Brieuc; above Trez Rouz Hosteinian peat complex).

To conclude, the evidence of at least 6 different transgressions from Stage 9a to the end of Stage 5 show the complexity of the sea-level record in a region unstable for isostatic and neotectonic reasons. Altitudes of shore-face deposits have no meaning by themselves in terms of stratigraphic position. Trangressions are possible in cold end-glacial or early-glacial environments and are not necessarily of interglacial status (cf. Eyles & MacCabe, 1991). The peculiar character of the stage 7 will be discussed further , in the context of the St Brieuc Bay. The coastal platform, as discussed previously was initially cut far back into the Pleistocene and is an ancient feature which seems to have been re-trimmed several times especially by highly efficient shore-ice rafting at least since Stage 9 and also probably 11. The sea apparently rose to about the same level of stand at Stages 11, 9 and 7, despite the differences recorded in the $\delta^{18}O$ curve .

4) **Shore Ice dynamic** (Hallégouët& van Vliet-lanoë, 1989)

Some raised beach in the Armorican Massif include sporadically erratic rocks, unknown in Western Europe. There are also characterised by giant blocs, drifted ont several km from there outcrops. Some of the raised beach bars , in area exposed to fetch, present an heterogenous petrographic composition intermixed with angular to weakly rounded clasts of local origin. Olivine basalts found on the shores of the Channel (Cotentin, Cornwall) and of western Brittany are of quaternary radiometric ages (Belon et al.,1988) and originated probably from the southern coast of Iceland. Those rocks were rafted by icebergs, driven to Europe thanks to the north Atlantic current or during cooling events at the end of interglacials with a sea level not yet lowered and an active winter shore ice dynamic, able to move giants blocks (up to 10 tons) on several kms. Beach bars in footh of fossilised cliff smoothed by active geliflucion were fed in angular clasts buried before being rounded. These beaches are characterised by an openwork upper cobble ridge, an active beach with a clast-supported loamy matrix and a flat muddy fore-shore with flat lying large blocks (block line) truncating as well sediments as rocks. These beaches are ofren interstratified into heads and somewhat deformed by frostcreep.

3)THE HOLOCENE TRANSGRESSION

B.HALLÉGOUËT

After the Weichselian regression, (about -130m between 17 and 20 ka BP), the glacio-eustatic rise is irregular, controlled by climatic induced events recorded in form of glacial pulses in N.America and Fennoscandia (Ters, 1973). We have also to take in count the instability of Brittany for neotectonic and glacio-isostatic reasons. The glacio-isostatic reequilibration can induce significative modification of the apparent sea level, possibly about 20m in Western Brittany (Lambeck, 1997).

All these data are necessary to interpret regional sea-level curves builded on the base of sedimentological , faunal, palynological data and radiocarbon datings (Morzadec-Kerfourn, 1974 ; Ters, 1973 ; Prigent, 1978 ; Visset, 1979). Visible differences between sites of the same age can also result from differential consolidation of sediments , differential tide intensity and also contamination of radiocarbon by younger labile matter. Prevailing sedimentation conditions (rocky coast, marshes or estuary) are also of prime importance (local exaggeration of the fetch by foreshore or wind conditions).

The speed of the sea rise was not constant along the coast during the Holocene and the acceleration or braking episodes observed along the Channel are not always recorded along the southern coast. In Dol marshes, several trangressive events have been quoted by Morzadec (1995) :

8200-6750 y BP
6500-5600 y.BP
5400-3800 y.BP(with a maximum between 4800-4400 y.BP)
3400-3000 y.BP
2400-1400 y.BP

Braking phases or even regressions have been observed . They have been approximately compared with the low stands of St Marc, of Tréompan, of Artgenton and Belle-Ile defined by Ters (1973).

On the southern coast of Brittany and in Vendée, the high stands identified by Ters (1973) are higher in altitude compared with the Channel coasts. D Prigent (1978) has also shown for the Low Loire river, significative differences comparative with the data of northern Brittany. In La Grande Brière, the transgression brakes from 5700y.BP, sea is absent from the depression between 5000 and 4500 BP, in association with a regression. A new transgression occurred after 4500 BP with a renewed braking between 3000 and 2600 BP. A second regression occurred at the end of the Bronze Age and during the early Iron Age, allowing salt exploitation on the risen tidal flats. Around 2000 BP , the southern Brière is for the third time invaded by fluvio-marine waters relative to the Roman transgression (Visset, 1990).

The comparison between the curves reconstructed in Brittany and the classical data concerning the Flandrian transgression shows some common points but also many shifts from North to South, probably related with the glacio-isostatic readjustement , and, from West to East relative hydro-isostatic (eustatic) loading of the crust.

IV CONTINENTAL FORMATIONS

1) TERRACES AND FLUVIAL SEDIMENTATION

B.HALLEGOUËT, B.VAN VLIET-LANOË, M.LAURENT

The river net in Brittany is polygenetic. A first valley system with time to time estuarine influence occupied the southern Brittany during the Eocene on both sides of the CSA. A part of the sedimentary supply reworking mostly paleogene saprolites was coming from the East, probably from the Lore basin. This is well outcropping at St Malo de Phily and NE of Missilac.

A second clear valley system existed during the Oligocene , as in the Aber Ildut valley , in the Concarneau bay and in the paleo-Oust valley at la Trinité-Porhoët. These valley systems predate the late Oligocene tectonical phase responsible for basin inversion in the Channel (Wessex, Weald) and the Messinian crisis, both resulting in a « bulging » of Brittany, steeper valley slopes, incision related with eustatic lowstands and important reworking of saprolite, mostly from the base of the Tortonian.

The initiation of the present-day valley system started at that time, re-using some part of the former nets as in the rade de Brest or the Vilaine basin. From the base of the Tortonian up to 2.6 Ma, little modification occurred. Most of the deposits consist in trangressive sedimentation and aggradation. Around 2.5 Ma , a new tectonical phase, related with a first step in sea level lowering (Gelasian) is responsible first for meandering channels and muddy aggradation in the low valleys, mostly dated at 2.4 Ma by ESR (pre-Tiglian cooling).

The first true periglacial braided river system, already associated with ice rafted debris begin with the Eburonian : ESR datings of these units give an age of 1.4 Ma. This corresponds roughly to the highest terraces, resting often in conformity on the former unit as at Reguigny or in the Rennes basin, despite large difference in altitude. Gravels are generally weathered and partly desilicified. A new tectonical phase occurred between 1 Ma and 0.8 Ma , related with som uplift in central Brittany and a first important incision of the valley or even a lateral shift with the incision of a new talweg , more adapted to the substratum fracturation. From this time, erosion prevailed on transit or sedimentation. This phase is mostly responsible for the Middle Terrace, covered by several sedimentary sheets of braided river deposit, rather unweathered. Most of this sheets are related with lateral cones , responsible for lateral migration of the main stream (Péllerin and Van Vliet-Lanoë, 1997). From about 0.4 Ma , the Middle Pleistocene crisis , a new tectonical phase proceeds, related with very abrupt incision lacking terraces in North and central Brittany (Rance, Gouessant, Blavet, Oust, Aulne a .s.on). At the base of this incision we find generally in a lower terrace position two alluvial sheet and in the valley channel, the gravels of the last glacial. Holocene transgression in relation with recent subsidence (<400 ka and more recently) can bury the terrace as for the Vilaine/Oust system close to Redon or the Aulne valley.

This means that the valley shaping in Brittany is discrete in the time, mostly controlled by tectonic readjustments related with the regional stress flied, glacio-isostatic deformations and in a second hand only , eustatic levels. The instability of quaternary eustatic levels is to great to reach the equilibrium profiles of the rivers. Each river has its own story, related with the position of tectonical basins and the vicinity of shearing zones. There shaping is controlled to the whole story of Cainozoic uplift of Brittany, related to the subsidence of the Western Channel and of the southern Brittany platform.

2) LOESSES

J.L. MONNIER, B.VAN VLIET-LANOË, B.HALLÉGOUËT, M.FRECHEN

In Brittany, J.L. Monnier has taken up his earlier loess studies (Monnier, 1973, 1980) and is looking at them afresh with B. Van Vliet-Lanoë, B. Bigot and B.Hallegouët. Present results are summarised in the following text.

The periglacial loesses do not reach any significant development inland compared with the infill of the hard rock, coastal cliff, sediment traps. Humidity is the main factor of loess accumulation. Inland loessic outcrops are generally associated with the occurrence of saprolites developed on proterozoïc shales, large valleys with alluvial accumulation (Aulne valley), subsident basins like the Qiou in N.E.Brittany or the Rennes Basin, or large estuarine like the Loire, in S.Brittany. Large tidal flats as the St Brieuc Bay or the Mt St Michel bay have provided during the Weichselian and Saalian II regression large amount of calcareous silts. Before the anthropogenic erosion, sedimentation rate was of about 2m on the NE coast to about 50cm in southern Brittany, with some local variation controlled by the sedimentary supply, the topography (snow banks) and the nature of the bedrock. Massive accumulation occurred along shore cliffs, especially those exposed to the East in wind shadow. Prevailing winds were mostly NW in St Brieuc and Qiou area's, W-NW in the Aulne valley though in SE Brittany , it seams to be locally SE.

The stratigraphy of the Pleistocene of northern Brittany is essentially based on the study of these coastal cliff sections. Inland, stratigraphy is unclear because of pedogenesis and biological mulching, excepted in the Fougères Forest.

<u>Three stratigraphical units have been identified:</u>

Older loesses including the Valais and Nantois Units with intercalated fossil beaches (Langueux Unit) and palaeosols '"lessivés" These soils are earlier than the last interglacial

littoral deposits, solifluction and colluvial deposits, palaeosol '"lessivé complexes (Haute-Ville Unit) corresponding to the last interglacial (Eemian) and the early Weichselian

loams and younger loesses which include weakly developed palaeosols":

- Port-Morvan Unit corresponding to the Weichselian, Lower and possibly Middle Pleniglacial
- Sable-d'Or-les-Pins Unit corresponding to the Weichselian Upper Pleniglacial

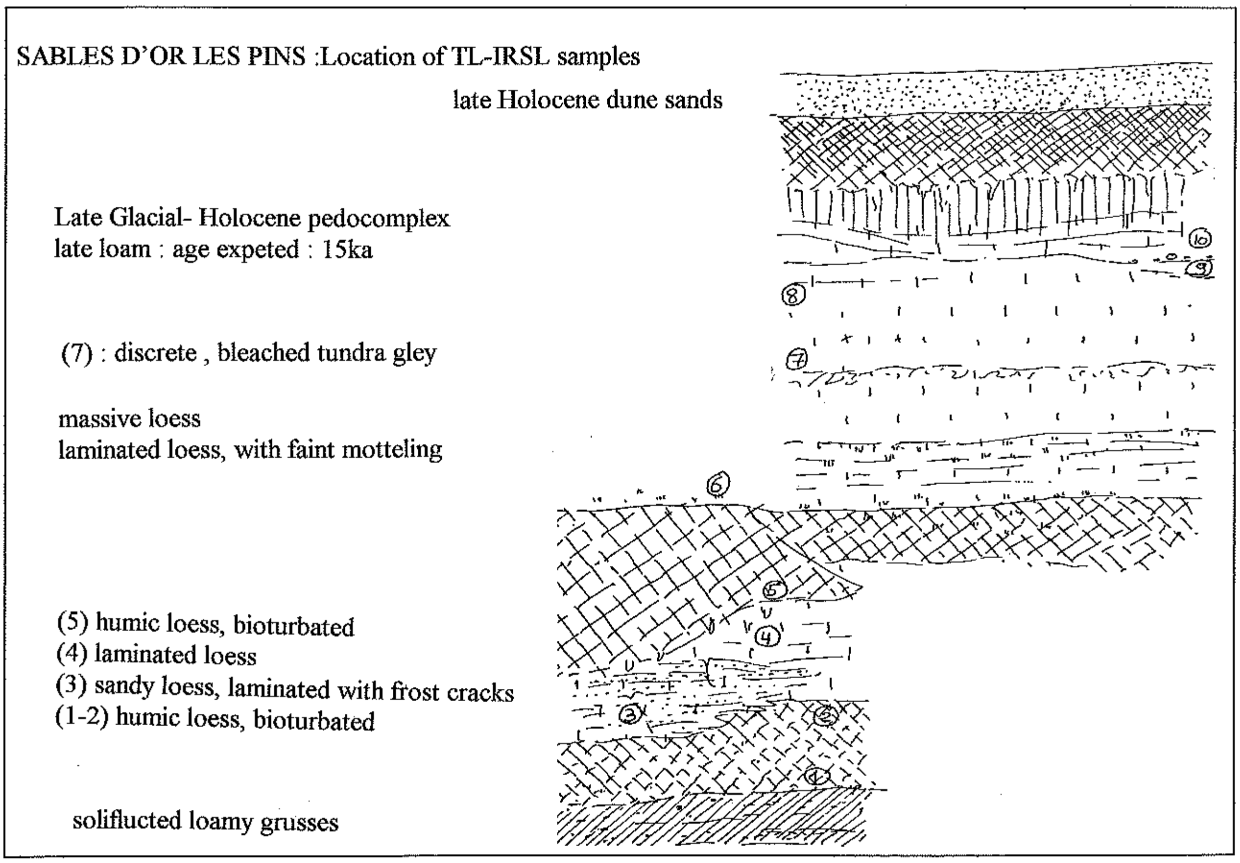
The fossil coastal deposits in these sections belong to two groupings:
- fossil beaches and/or dunes located at about the highest water mark of present tides and earlier than the Saalian formations.
- fossil beaches and/or dunes, likewise situated at about the highest water mark of present tides but dating from the last interglacial and the beginning of the Weichselian.
The true loesses belong in part to a Saalian II Pleniglacial phase (isotopic stage 6) and in part to the Weichselian Upper Pleniglacial. They form four successive loesses (Upper Loesses: Sables d'Or unit).

The calcareous sandy loams accumulated at the beginning of the Weichselian as the marine regression gathered place. Analogous deposits formed during an older phase of Saalian II age .

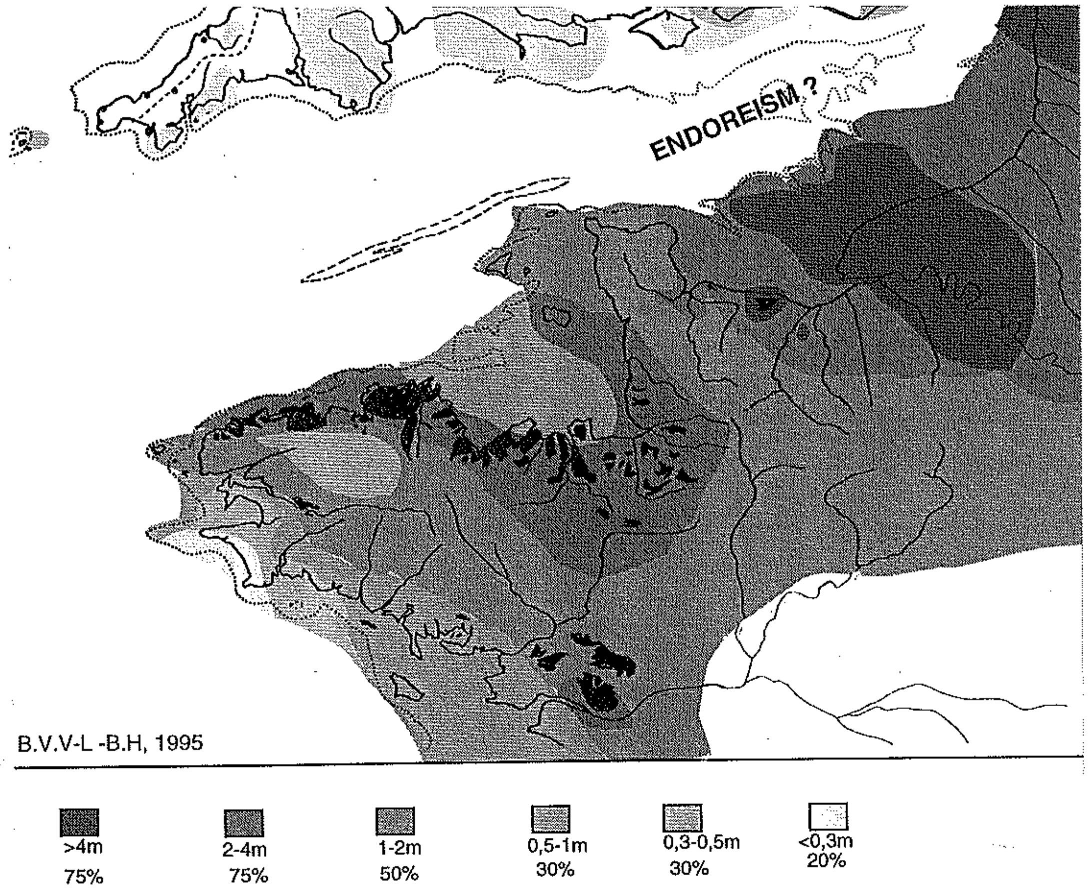
The two main sedimentary successions, belonging to the last interglacial/ glacial cycle and described from the Bay of St-Brieuc, reflect two very different dynamics. The lower succession (Haute-Ville Unit) is characterised by an unbalanced sedimentary record with many coastal deposits and important pedogenesis (a sequence of "sols bruns lessivés"). It corresponds overall to the dynamics of an interglacial period but laced with short cold periods and belong in the Eemain s.s. and early Weichselian. The upper sequence is marked by a well developed loessic (even pre-loessic on the basis of its sandy calcareous nature) sedimentation which has led to the fossilisation of only slightly evolved soils (soils of the Arctic meadow and calcareous brown soils which are indicative of interstadial oscillations). The sequences corresponds overall to the dynamics of a glacial period and involves the Port-Morvan and Sable-d'Or-les-Pins units, evidence of the presence of Middle and Upper Weichselian deposits.

Some TL datings were performed by S.Loyer in 1993 and a more systematic series has been undertaken by Manfred Frechen (Univ.Köln- Univ.Cheltenham), confirming the proposed chronostratigraphy.

Stratigraphy	Expected Age	TL-IRSL (Frechen), TL Loyer
Upper Loesses		
upper sandy loesses	top 15ka	15.9 ka ± 1.5 (F)
	base 27 ka	24.6 ka ± 3.1 (F)
lower sandy loesses	ca 70ka	67 ka ± 4 (L)
Lower Loesses	top 140 ka	saturation (F)
	base 160 ka	saturation (F)

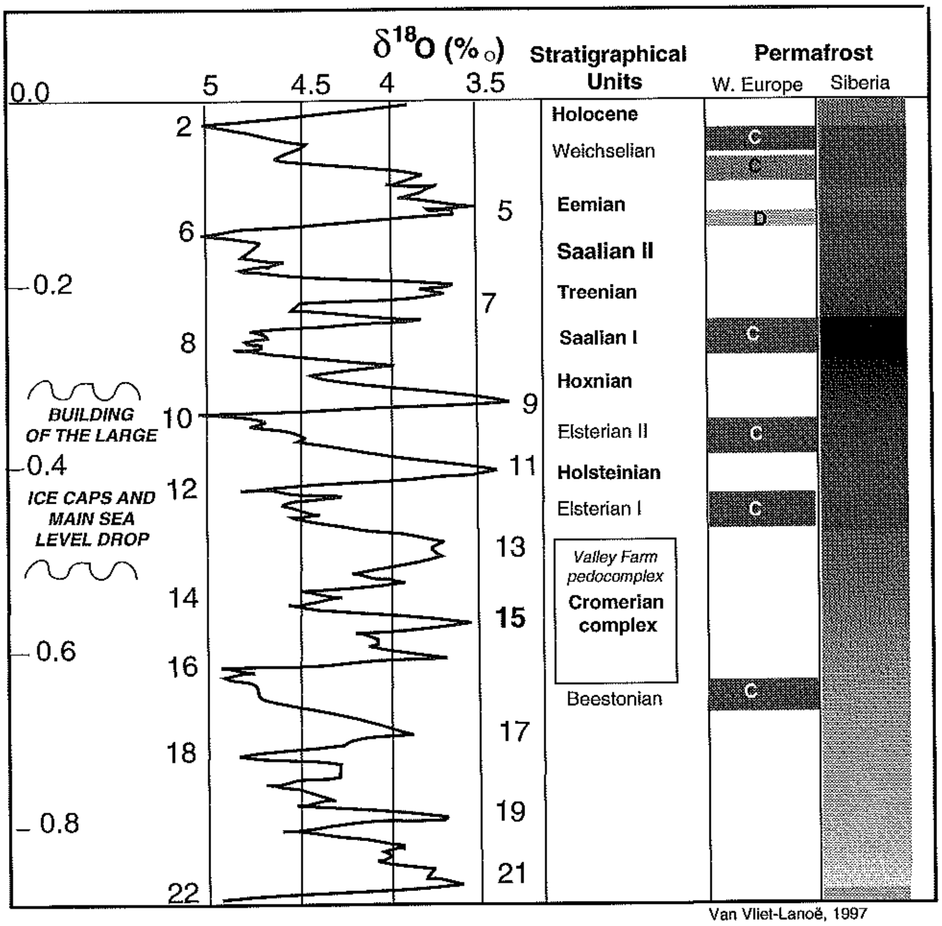


Map of the maximal extension of the aeolian cover at the end of the Pleniglacial (15ka BP)
In black : residual outcrops of loess <1m thick in Brittany (DBT II, CNRS programm 1994-95)

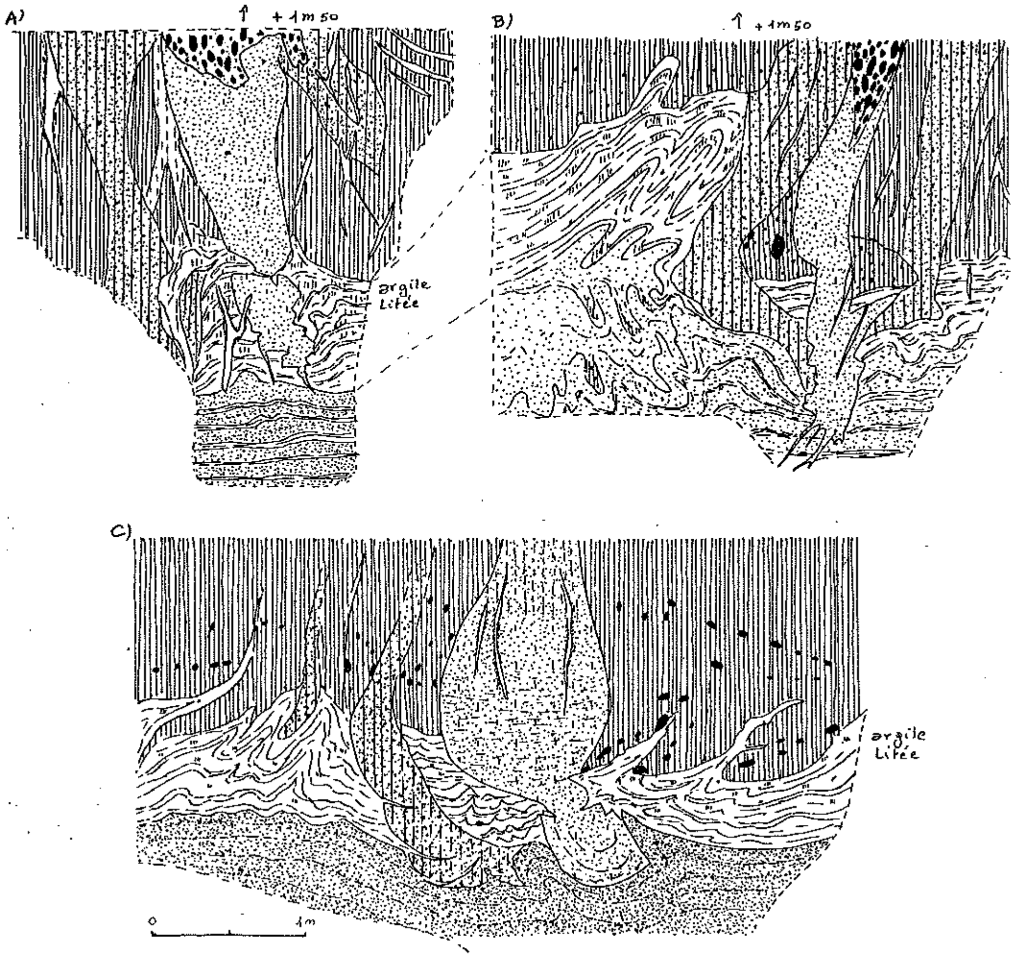


TL-IRSL datings of Sables d'Or les Pins, by M.Frechen (Cheltenham Univ.), July 1997
ADD : additive dose method ; REGEN : regeneration method.

Sample	TL ED/REGEN [Gy]	TL age REGEN [10^3 yr]	TL ED/ADD [Gy]	TL age ADD [10^3 yr]	IRSL ED/REGEN [Gy]	IRSL age REGEN [10^3 yr]	IRSL ED/ADD [Gy]	IRSL age ADD [10^3 yr]
SDP96-1	57.4±2.5	22.9±2.0	52.9±0.7	21.1±1.7	47.3±3.3	19.8±2.0	63.2±5.6	26.4±3.1
SDP96-2	43.1±2.9	19.1±1.9	39.4±1.1	17.5±1.4	38.2±3.4	17.4±2.0	53.9±5.4	24.6±3.1
SDP96-3	34.2±1.0	16.0±1.3	36.8±3.3	17.2±2.0	31.1±2.0	14.8±1.5	50.9±14.7	24.2±7.2
SDP96-4	41.0±2.8	17.3±1.8	37.7±0.6	15.9±1.2	27.2±9.0	11.9±4.0	35.8±1.7	15.6±1.4
SDP96-5	40.5±1.7	17.0±1.5	39.1±2.9	16.4±1.8	35.8±2.0	15.2±1.4	48.0±4.1	20.4±2.3
SDP96-6	35.1±1.2	14.9±1.2	34.9±1.0	15.8±1.2	30.5±1.7	13.3±1.2	51.8±4.5	22.6±2.6
SDP96-7	36.5±1.0	14.4±1.2	34.4±0.6	13.6±1.1	33.0±2.1	13.3±1.3	48.8±3.3	19.7±2.0
SDP96-8	40.6±1.0	16.4±1.3	38.0±0.9	15.3±1.2	32.4±1.7	13.5±1.2	52.2±4.7	21.7±2.6
SDP96-9	38.7±1.1	14.0±1.2	38.6±0.9	14.0±1.1	33.5±1.5	12.3±1.1	48.4±4.5	17.8±2.2
SDP96-10	41.3±0.9	15.3±1.2	39.3±1.5	14.6±1.2	32.5±1.6	12.2±1.1	42.2±2.5	15.9±1.5



Stratigraphical location of permafrost events in Western Europe .C= continuous, D= discontinuous



Old complex ice wedges-sand and gravel wedges affecting late Pliocene and early Quaternary alluvial formations. Rieux (Le Grenit). Relative to Pénestin stratigraphy, the sandy loam infilling date from istopic stage 8. Notice the squeezing of the wedge by differential frost heave of the laminated clay. Cauldron forms are related to wetter environment.
(BVV-B.H, 85)

3) PALEOPEDOLOGY AND PERMAFROST

B. VAN VLIET-LANOË

3-1 Soils

Neogene

After the deep weathering during late Cretaceous and Paleogene, weathering intensity diminished and oxisols (Miocene and end of the Zanclean) or temperate soils develop (Upper Pliocene) giving ochre's brown soils, often associated with pseudogley or goethitic iron pans. Deep saprolites are eroded during the uplift phases leading to the progressive of Monts d'Arrées. During Pre-Tiglian soils are mostly podsolic.

Early to Middle Quaternary *(from 1.4 Ma to 320ka)*

During this period, very little thing is clearly recorded . On alluvial formation cumulative pedogenesis, rubified with some occurrence of Al-goethite and mostly hematite developed, associated with a desilicification of the rocks fragments. Clay illuviation is deep red, intense, probably in form of acid argillo-humic complexes. It correspond to the british "Valley Farm" pedocomplex . From Penestin section , it is clear that the last rubification occurred during isotopic stage 9b (320 ka); it post-dates also the last cliff reactivation. In Pliocene sands, this late pedogenesis is recorded in the form of a banded Bt horizon, with very large leached tongues. It is difficult to give a precise classification tò this type of soil, but it looks like a Rhodustult in the American Soil Taxonomy.

Middle to Upper Pleistocene *(from 300ka)*

Paleosoils recorded in Brittany during that time depend strongly on the nature of the substratum. In loessic material, they are not too different from the sequences recorded in classical sections, especially in Eastern St Brieuc Bay, with grey wooded soils in long interstadial position. Like in N.Cotentin and at Jersey, soils developed on shore vicinity are over-illuviated because of the sodium dispersive effect. To the West and to the South, paleosoils are mostly humic, on granite or shale material. Cryptopodsolic ranker , shifting laterally to acid humic gley are common, even in early glacial position (also in stage 9a). They are often associated with coniferous charcoals. During stage 4, arctic to subarctic meadow soils develop on loesses to the West (cf. Le Vougot). They are replaced by ranker on acidic material, rizing difficulties in the lecture of the stratigraphy (cf. Pen Hat, Port Lazo, Gwen Drez). Another point is the contrasted moisture between the northern and the southern coast, as well reflected in the paleosoils and the dynamic of slope deposits. Solifluction is extremely active in the West (Le Vougot, Crozon), even during the Younger Dryas, less in north-facings slope of St Brieuc bay (Nantois). Other sites like Gwen Drez (Audierne) or Piegu are truly dry.

Late Glacial to Holocene

A pedostratigraphical record and an attempt of morphogenic and pedogenetic budget have been performed on a series of loess profiles on the Fougères granite massive, whose morphology is inherited from Tertiary and middle Quaternary. Traces and microrelief formed by the periglacial environment are clear from the middle Pleniglacial, but the sedimentation budget remains poor, despite the loess importation. Holocene is a true biostasic period, beginning with the Bølling, and persisting at least until the end of the Roman time. From the XIth century, man-made management's destabilise slightly the soil cover and result in thin organic and mineral accumulations in secondary valleys. The illuviation of the surface soils is attributed to the Bølling-Allerød interstadial (begin of the biostasy). At St Brieuc bay, in shore cliff, clay illuviation continued probably later, during the Holocene because of the slope and the carbonates content in the loess. During the Holocene, pedogenesis on loess is restricted to darkening and aluminisation in the former eluvial horizon and in anthropogenic colluvial deposits. In the other regions, on shales or on granite the soil shifted from a cryptopodsolic ranker to an acid brown or a mesic humic brown soil related to anthropogenic manuring. Darkening is extremelly strong. Land desertion leads to heath re-extension and ranker aggradation. In oceanic Europe, mechanical erosion effectiveness is low under periglacial condition, non-existent under non-anthropogenic interglacial condition .

3-2 Permafrost

Early Quaternary permafrost

There is evidences of valley glaciers in Scandinavia from 2.6 Ma and of an ice cap since 2.3 Ma (Höleman and Heinrich, 1993) and 2.2 Ma in the Alps (Schluchter et al., 1997). The biostratigraphy of the large European faunas presents two quite different sequences: a system of oscillations, between 2,4 and 1Ma and a system of alternating faunas beginning about 1 Ma ago (Bonifay, 1995). From isotopic curves, notable cold phases started only around 600 ka (Martison *et al*, 1987). From the site 658 Atlantic core, located at 21°N, intense glacial stages were only found after 480 ka (stage 12) (Dupont *et al.*, 1989).

Some authors such as Vandenberghe (1993) claimed that permafrost developed early in the Quaternary, as old as the Tiglian (1.8 Ma) at Beerse, a tectonic graben (Kaase, 1993). Old "cryoturbations" described by Lautridou (1985) at La Londe (Normandy) correspond to karstic slumps. In many cases "old" features are not from periglacial origin. As in Britain (Rose *et al.*, 1985; Worsley,1987) , in Brittany, evidences of true ice wedge casts are not older than the Beestonian (stage 16). Most of them probably correlate with stages 12 (420-480 ka BP) and 10 (340-360 ka BP) at the end of the Valley Farm Pedocomplexe because they are younger or occurring just before to the last period of soil rubification (redder than 5YR; isotopic stage 9). They are often in superposition with faulting or other co-seismic features. A widespread ventifact level is clearly visible on the southern part of Brittany. It seems to correlate with isotopic stage 8, stage 6 beeing globally too wet.

Middle and Upper Pleistocene

Permafrost installation was delayed in Brittany because of the relative vicinity of the sea, especially in the West. During the isotopic stage 6 , it was only discontinuous on the northern coast, even in cold sites as at Nantois, very late in the stage, just before the Linexert interstadial . During stage 3, it was mostly discontinuous or absent. It developed before 15 ka at Nantois (East St Brieuc), at Fougères (200m altitude) around 23 ka, but was absent in southern and western Brittany . It was probably existent in altitude, in Monts d'Arrées and central Brittany, responsible for the occurrence of periglacial type of fragipan.

V ARCHEOLOGY

J.L.MONNIER, P.GIOT, N.MOLINES

1) PALEOLITHIC AND MESOLITHIC

The Armorican **Lower Palaeolithic**, of which the first evidences seem to appear towards 500.000 years ago, chiefly spreads out during the second half of Middle Pleistocene. Its geographical distribution is linked with the deposits of that period. Two groups are clearly distinguishable: - tool assemblages with hand-axes (*"Acheulean"*bifaces, of which the typical site could be La Ville-Men at Planguenoual (Côtes-d'Armor), - and industries with pebble tools (the *"Colombanian"*), specially present at Menez-Drégan, Plouhinec (Finistère). The Colombanian presents itself as an Armorican and Atlantic regional facies.

The **Middle Palaeolithic** is rather densely present along the periphery of the Armorican Massive, with a particular abundance along the northern coast of Brittany, in the Loire district and the North of the Cotentin. This localization comes from geological causes (distribution of the deposits of the end of Middle Pleistocene and of the Upper Pleistocene), from ecological ones (presence of natural shelters, of zones favourable for game...) and also the presence of good quality raw materials (flint, "glossy" quartzite or "Grès lustrés"). The Armorican Middle Palaeolithic is strongly particularized by tool-kits with bifacial implements. On one side the group of Bois-du-Rocher, of rather central-european affinities; and on the other the group of La Trinité - *"Charentian"* features can be more or less discerned in both these groups. Tool-kits without hand-axes have a more marginal distribution. The Ferrassie-type Mousterian, in particular, had an occidental apparent limit on an arc staked out by the sites of Jersey, Mont-Dol, Saulges and Roc-en-Pail. The Quina type Mousterian is confined to the meridional fringe of the old massif. In the Cotentin appear tool-kits of blade-facies. In general, the populations of the Armorican Middle Palaeolithic show a relatively small mobility, with subsistance journeys in a radius of 10-20 km around more or less permanent camp-sites; this does not exclude hunting resting-places and small butchery sites.

Though modest, the Armorican **Upper Palaeolithic** is nowadays clearly known, though its bone objects are almost unknown. It is often disclosed by lithic kits very specialized or non-typical. Classical forms only appear on the margins or in the Loire district. The rarity of sites, which can at least be partly explained by the erosion with the rising Postglacial sea-level, can also come from the scarceness of flint (a greater quality requirement during Upper Palaeolithic as to the choice of raw materials) and the lack of natural shelters during a period of very rigorous climate. It is worthy of note that the ancient and later stages of the Upper Palaeolithic are better present (the blank corresponding to the cold climax), that the small karst of the Erve valley (Mayenne) has given a rather complete sequence in caves, and that most stations could have been seasonal camps (Plasenn-al-Lomm at Bréhat, Beg-ar-C'hastel at Kerlouan). Contrary to the Middle Palaeolithic, a high mobility appears to have been existant.

The extreme **end of the Upper Palaeolithic** (Epipalaeolithic) is exemplified by the tool-kits of Roc'h-Toul (Guiclan, Finistère) and of the small island of Guennoc (Landéda, Finistère). Roc'h Toul, the hole in the rock (faults in a quartzite), is a 40 m long cave, 2 to 4 m in breadth of which only the eastern third is lit by day-light.

Old excavations gave an industry with 43 % blades and bladlets of flint (from the coast 20 km away), some quartzite and quartz also, rough and non-typical - a few good scrapers and a series of Azilian-like curved back points. A few other sites have given isolated pieces or small series more or less of this group, sometimes with engraved pebbles or plates. On the Armorican border, the caves of the Erve valley and other nearby sites have given also azilian or early Epipalaeolithic elements.

The Guennoc flint industry appears the next stage towards the **Ancient Mesolithic**. Residual flint artefacts show an outside site on the top of what was still a rocky spur. Bladlets, points, microburins announce the microliths of the Mesolithic. The very incertain chronological position may correspond to the Preboreal phase, between 8000 to 7000 B.C.

The **Middle Mesolithic** of the Boreal period, between 7000 and 5500 B.C., shows more diversified flint productions, near the coasts and also in the interior of Brittany. Several groups have been distinguished by the typologists: The industries of Bertheaume type†; the northern Breton group (or normano-breton); the southern Breton group (or that of the Morbihan).

The **Late Mesolithic** developped during the Atlantic phase, between 5500-4800 B.C. It encompasses the Retzien group, more eastern and near the Loire estuary, but present along the Vilaine valley; and the coastal Armorican Mesolithic, chiefly along the southern coast, some times associated with shell-middens. The tool-kits develop trapeze forms. The name "Teviecian", still in use, comes from the Téviec isle site (St Pierre Quiberon) excavated in the late twenties by M. and S.J. Péquart, and well-known because of the cemetery and the well preserved skeletons (also they excavated later another cemetery in the island of Hoëdic).

2) THE NEOLITHIC

Late Mesolithic groups of inventive hunter-gatherers were still thriving in Western Brittany around 5000 CAL. B.C. The Armorican Massif is further West than the convergence zone of the Southern or Mediterranean ("Cardial" current of neolithization (which arrived at least along the Loire towards 5500 CAL. B.C.), and of the so-called "Danubian" or continental current, present in the Paris Basin already towards 5500 CAL. B.C. The later forms (Early Middle Neolithic) of this last cultural current are known in Normandy, the Channel Islands, extreme North-East Brittany, in the Loire valley and from thence to the southern coast of the Morbihan.

Which of the derivative cultures of these two currents arrived first, and blended with the Late Mesolithic people to produce the Middle Neolithic cultures so characteristic of Western Armorica, with its regional megalithic specificities, is still a contentious problem. Groups of people of different cultural affinities may have lived side by side.
Some huge barrows of the Morbihan, covering closed chambers, have produced numbers of polished stone axeheads and other ceremonial grave-goods, some of local fibrolite, but plenty of others (jadeite, etc) coming from the internal zones of the

Piemontese Alps, a rather Southern connection, possibly as old as 4500 CAL. B.C., if not before.

Thus the origin of the oldest types of megalithic tombs, the passage-graves (dolmens chambre et couloir) is a difficult problem, especially as, with plenty of local variants, they are known from Southern Iberia to Scotland, Ireland and Northern continental Europe. Since 1860 at least, all sorts of diffusionist theories have been proposed!

In Brittany, the oldest well dated monuments cluster more or less just after 4500 CAL. B.C. The first standing stones (menhirs; decorated stelae in some cases) may be as old as the early passage-graves, as fragments of some have been reutilized to build other passage-graves (Locmariaquer, Gavrinis, etc). The development of the diverse megalithic techniques in Brittany went on for 2500 years, even 3000 in we include the Early and Middle Bronze Age barrow chambers following the same traditions; forty years ago, before the impact of radiocarbon dating, one imagined this development over about 500 years only! The later Middle Neolithic tombs still belong to multiple variants of the passage-graves; after 3000 CAL. B.C. Late Neolithic ones belong to the gallery-grave (allées couvertes) general style. Most alignments, and other compound structures of standing stones probably are of these Late Neolithic times, though an earlier inception is not impossible.

We know about a small fraction of the monuments that were built. Apart from natural erosion (the rising sea-level), hiding under sand dunes (more than 50 monuments discovered), a majority have been destroyed by human inteference (quarrying, clearing the fields, etc). The Neolithic men seem to have built for eternity; in fact they also altered or destroyed quite a number of monuments in order to build other ones of different fashion. Possibly some time there existed a hundredfold of those we know about, including the possible megaxylic monuments, in the districts far away from good stones.

3) SETTLEMENT AND ANTHROPIZATION

In our Western parts, we have very little information about the settlements of these populations, chiefly because of loam and soil erosion, and also the destruction by later peoples. The stray finds of stone Neolithic artefacts generally show a denser distribution in the better coastal districts. In the center of Western Brittany the important axe factory at Plussulien (metadolerite) only produced after about 3800 CAL. B.C. onwards. Of course the coastal low-lying districts have been more or less eradicated by the rising sea-level: some residues of settlements (post-holes, hearths, artifacts) have been observed on erosion sections of loamy soils around the present mean sea-level (the zero of IGN maps), especially when they had been preserved, up to then, by an overlying layer of marshy peat, or sometimes, at a slightly higher altitude (present high tides) under a sand dune.

Of course, all around Brittany, submerged or at least partly submerged megaliths at high tides are well known. On the north-western coast, the lowest sited menhir (Plouguerneau) has its foot just above the low tides; there are several Late Neolithic gallery-graves sited between the present mean sea-level and the high tides.

In Brittany, the action of Man (anthropisation) shows up distinctly at the end of the Atlantic period (Neolithic) with the breaking up of the primitive forests (mixed oak), chiefly in the littoral zones. The clearings and the practice of agriculture led to the formation of regressive heathlands. Beginning with the Early Neolithic period in the South of the Armorican Massif. Cereal culture extended largely during the Middle Neolithic. Although very progressive, the shifting of the shore which went along with the postglacial transgression had important effects on coastal settlement. Now submerged, many megalithic monuments, farming structures, prehistoric or protohistoric settlements witness this processus. The myths of the town of Is and of the Forest of Scissy took their roots in it. Still rapid between 10000 and 7000 years ago, the oceanic rise slackened down towards the beginning of the Neolithic. At that moment, the coast line was near the present situation, but the high tides were towards the level of present low tides. In front of the scarp of the cliffs, the Pleistocene loamy cover was still not very eroded and offered spaces favourable for settlement and agriculture. This explains the large number of archaeological remains, from the Neolithic to the Bronze Ages found on the strand zones. At the end of the Bronze Age and at the beginning of the Iron Age, the sea arrived at the foot of the present cliffs. Then, at the end of the Iron Age and during the beginning of the Gallo-Roman period, one observes another slackening of the transgression and perhaps a very slight regression. This general schema must be smoothed down: regional variations exist, coming from local geomorphology, isostasy, compaction of sediments or neotectonics. Thus the data from Jersey seem to show that the sea might have reached 2 or 3 m above the present sea-level already during the end of the Neolithic, and this for about 2000 years. In another district, the Brière, the Holocene transgression is at a standstill at the beginning of the Atlantic period, before picking up again and transforming this depression in a large estuary; during the Subboreal, the sea subsides and the oak forest is settling; but at the end of this period and chiefly during the Subatlantic one, marshy conditions are developped, leading to the asphyxia of the forest and to important peat deposits.

4) ORIGIN OF THE FLINTS

In connection with the palaeoenvironmental problems, we must evoke that of the origin of flint, and in general, of the materials worked by prehistoric Man (Men?). The Armorican Massif, a Palaeozoïc old platform, does not conceal any flint outcrops. The flint utilized comes from Mesozoïc formations (essentially Upper Cretaceous) exposed on submarine floors around Brittany, especially under the Channel (also a small district SW of the Finistère); there are also Middle Jurassic formations with it on the Eastern border of the Massif, from Normandy to the Maine. Of course the accessability of the present sea floor sites depended on the local palaeogeography and in particular the position of the successive sea shores. On paper, flint could be obtained in two ways: directly on the exposures, in the form of nodules, or either from the offshore bars in the form of pebbles, at a variable distance of the present coastline.This distance is of course a function of the sea-level at each moment, and thus in direct relation to the climate. Observation shows that the first hypothesis was rarely effective, only during the Upper Palaeolithic, and not systematically: it supposed of course an important regression (between - 55 and - 90 m) with at the same time a very rigorous and unhospitable climate. Most Armorican flint implements come from pebbles. A very interesting model was successfully compared with the facts from the Cotte-de-Saint-Brelade (Jersey) site: during low sea-levels, but transgressive, there is a drift of flint pebbles and thus a large availability of material; when the shore arrived to the foot of the break of slope which corresponds to the contact of the ancient massif with the Mesozoïc formations, the availability is maximum in best conditions (of distance especially); when the sea level is at its maximum (present level), the pebbles of local stones are dominant and flint is rare ; during a regression period the abandoned bars are covered up by solifluction deposits and access to flint is difficult; at the lowest level, flint is present but the distance to cover is unfavourable for an easy supplying (if the men continue to inhabit the same site). According to conditions one witnesses the use of local materials, substitutes of flint, in variable proportions. These are varying types of rocks, some times taken, like flint, under the form of pebbles, but often directly from the exposures near the habitats. From this point of view, the men of the Palaeolithic periods showed a Knowledge, of course empirical, but surprising, of their geological environment: thus they were capable of finding the materials the most apt to be chipped, for instance on the side of dykes where the rock is more isotropic. The rocks thus utilized during the Palaeolithic are either sedimentary (sandstone, quartzite, siliceous shale - phtanite), either of magmatic origin (dolerite, microgranite, tuff, rhyolite, granite...). One mineral, quartz coming from the numerous veins and metasomatic silifications which intersect and impregnate the Armorican block, has been often worked. Amidst the sandstones, the "grès lustré" (in silicifed flagstones from cenozoïc sands) has procured large deposits. One should note that good flint has been generally prefered because of its technical qualities, at least when one could be satisfied by the small size of the pebbles (and if these had not been knocked about in the offshore bars). Thus the manufacture of "heavy" instruments (choppers, chopping-tools, handaxes, cleavers), needing important blocks of stone, induced nearly always the choice of local rocks, more often sandstones, quartzites or quartz. At the beginning of the Postglacial period, during the Mesolithic and Neolithic phases, the rapid rising of the sea-level near to the present coastline largely reduced the possibilities of acquiring flint; then it came essentially from very small pebbles.

ESR DATING OF QUARTZ EXTRACTED FROM QUATERNARY AND NEOGENE SEDIMENTS : METHOD, POTENTIAL AND ACTUAL LIMITS

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ESR dating of sediment may improve our knowledge on the chronostratigraphy of the Tertiary and Quaternary periods and especially in case of azoic deposits.Quartz extracted from volcanic effluents (Shimokawa et al., 1984), sediments baked by lava-flow (Yokoyama et al., 1986) or burned in fireplaces (Monnier et al., 1994) have been dated by ESR method. Bleaching of quartz was studied in quaternary sediments (Yokoyama et al., 1985; Buhay et al., 1988; Li et al., 1993; Laurent et al., 1994; Brumby et Yoshida, 1994).

We present here the technical basis of the method. The study is realised on actual and fossil sediment in order to establish a good determination of the palaeodose. The reliability of the method was checked on two sedimentary systems: the Somme Basin (Quaternary sediments) and Brittany basins and beaches (Tertiary and Quaternary sediments).

ESR dating on bleached quartz is based on the behaviour of aluminium centre (Al): it is constituted by an aluminium atom substituted to a silicium centre (Wei, 1984). The diamagnetic centre [(AlO_4/M^+)] becomes paramagnetic under ionising radiation [(AlO_4/h)] (see details and other references in Ikeya, 1993). Light acts photoelectric effect releasing trapped electrons. They will be collected by aluminium hole centre. This process will induce the bleaching phenomena. However, the energy light scale allows only a part of trapped electrons which means that the bleaching is incomplete. In order to date quartz, it is important to determine the residual intensity after the light bleaching. Actual coast or blank sands have a constant ESR intensity after a very long exposition under black-light . Fossil sands and irradiated actual sands have a decreasing intensity under black-light. The latter tend to reach their natural intensity . Al centre in quartz reach residual level which corresponds to the maximum of bleaching. Dating of quartz extracted from sediment implies a sedimentological state in which an exposition to a solar light is long.

For fossil quartz the maximal bleaching intensity is calculated by a least square method fitted by an exponential decay added to a constant value (Walther and Zilles, 1994).

$$F(x)=a.\exp(-bx)+c$$

The total accumated dose (AD) is determined using an exponential fit. The palaeodose P is deducted from the subtraction of the residual dose RD to the total accumulated dose AD Each sample consists in about 400 g sediment closed in a hermetic and opaque bag. Water content is determined by drying sediment at 40_C. After granulometric analysis, the most representative fraction is taken. Quartz are exposed under black light (UV lamp with a wavelength in range of 365-400 nm). U, Ra, Rn, Th and K activities of sediments were determined by gamma-ray spectrometry. A k-value of 0.15+-0.10 was assumed. Alpha and beta attenuations in quartz are estimated from

the calculations of Bell (1980) and Mejdahl (1979). Cosmic doses are calculated using the formula given by Yokoyama et al., 1981.
Measurements errors are due to gamma dosimetry, intensity height determination of Al centre, radioelements contents counting and water sediment percentage. The amount of errors is estimated about 5 to 15%.

ESR dating of fluvial, fluvio-marine and beach sediment is tested on Al centre . These dates are performed in conjunction with sedimentological, stratigraphical and neotectonical studies. The technical basis of the method is presented in the light of the study made on actual and fossil sediment in order to establish a good determination of the palaeodose. The application on a Neogene Basin samples allows to push back the dating ESR limits at least to the late Oligocene.Recently, ESR results obtained on bleached quartz extracted from Tertiary formations were presented (Van Vliet-Lanoë et al., 1995). Results show that ESR dating of sediment can give a good chronozone necessary to the understanding of the history of a basin where classical chronological markers do not exist. ESR method applied on bleached quartz give ages in agreement with stratigraphical data if the samples have been exposed to solar light for a long time (at least 6 months), and if diagenesis processes do not induce uranium, thorium and daughters and potassium migrations in the sediments.

This study shows the great potential of ESR method which can date the whole Quaternary period and also Tertiary formations.

THERMOLUMINESCENCE AND INFRA RED SIMULATED LUMINESCENCE

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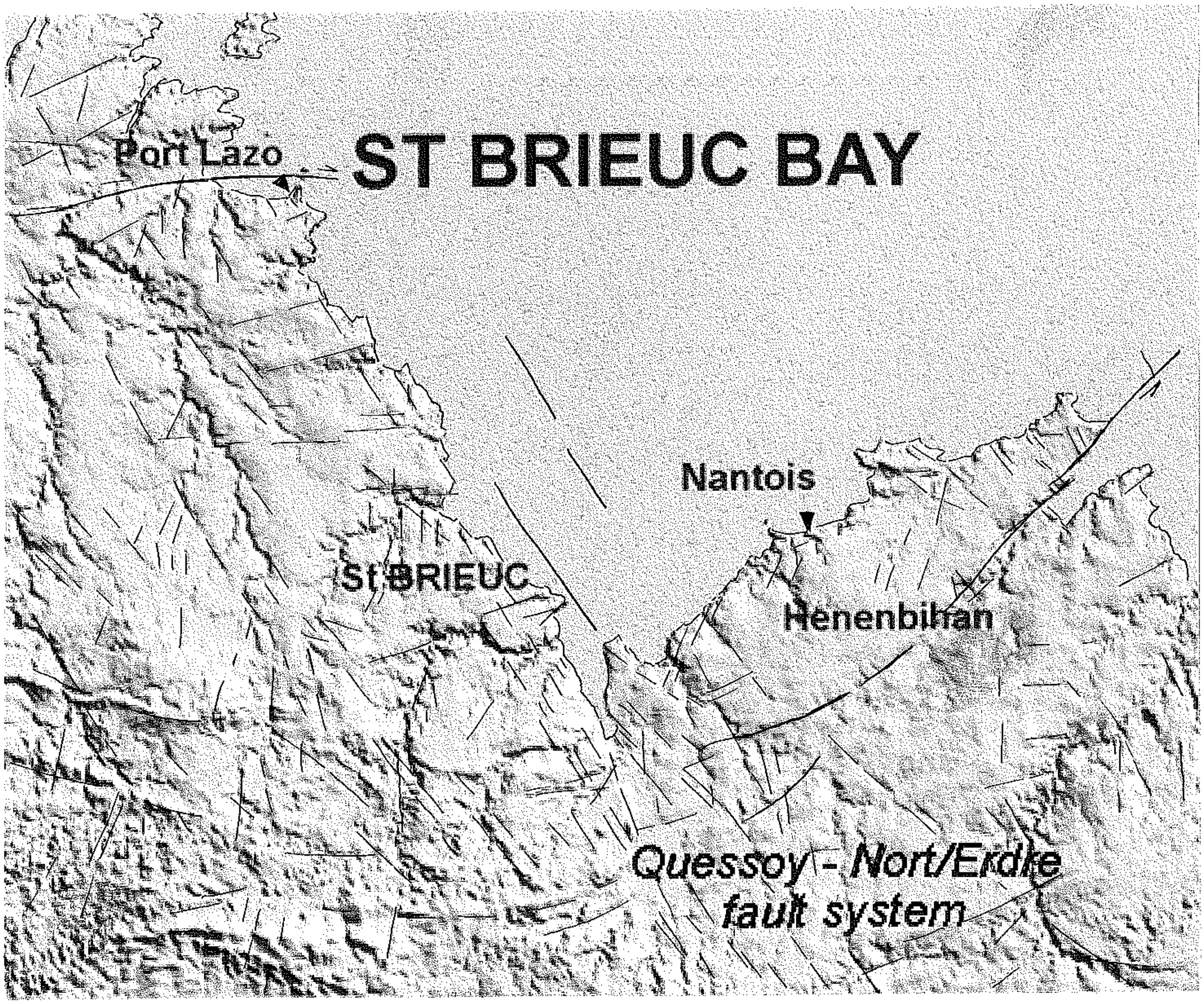
The samples were prepared with the fine grain technique (4-11μm) with 100 aliquots per sample as described in Frechen et al ., 1966. Routine bleaching for regeneration method was carried out with an Osram-Ultra-Vitalux 300 Watt lamp. After irradiation with a ^{60} Co gamma source and an ^{241} Am alpha soucre the aliquots were stored for at least four weeks at room temperature . Before the measurments all aliquots were preheated at 150° C° for 16 hours on a hot plate. The measurments were carried out in a Risφ TL/OSL -Reader (TL-DA-12 , photomultiplier type 9235QA) with a fliter combination of a Schott BG-39 (5mm) and a Chance Pilkington HA-3 for IRSL and TL. Rthe shine down was applied 25 seconds by infrared lght diodes (880±80nm) immediately was determined by exponential regression analyses for both the regeneration and the additive dose methods. The annual dose (AD) was evaluated by gamma spectometry in the laboratory. Cross checks with alpha and beta counting were undertaken.

PART II

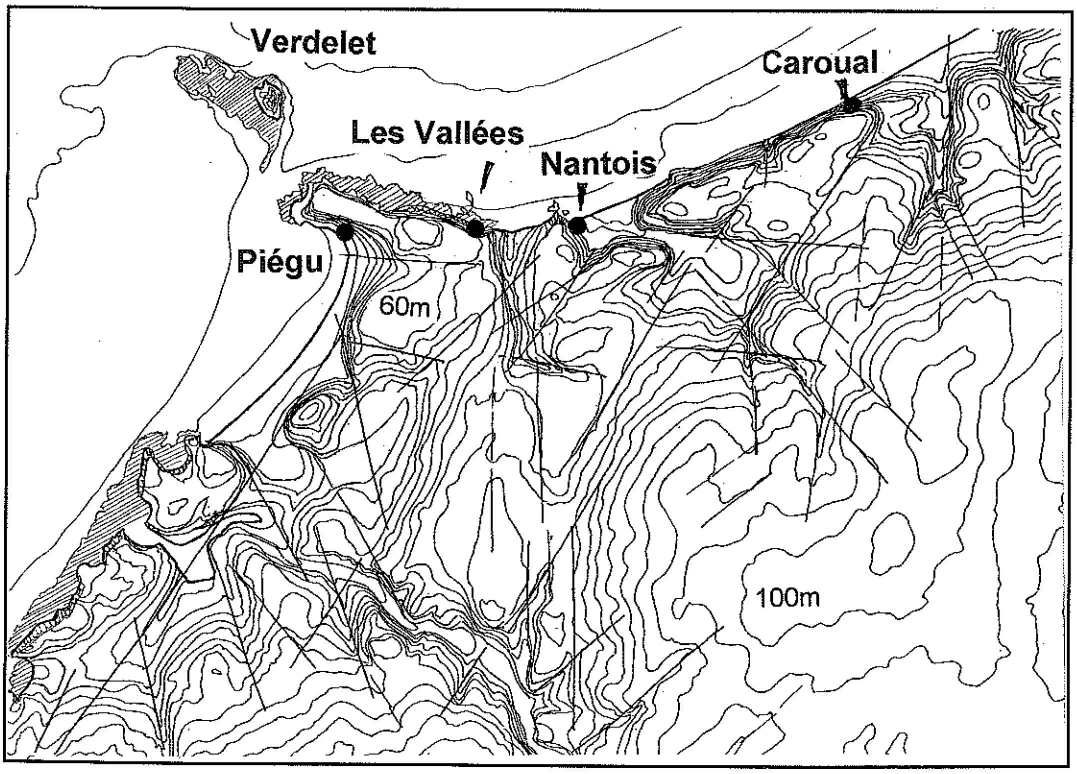
THE SECTIONS



St Brieuc Bay is a wide bay, with a very flat and shallow bottom, controlled to the West by a very old and important fault system, the Quessoy-Nort-sur Erdre fault system (N130°), mostly active during the Hercynian Orogeny, reactivated during the Oligocene and more recently. To the West, the land is still uplifting. The Eastern coast is controlled by a branch of the Northern Armorican Shearing Zone (CNA; N070°), still very active from a tectonical and seismical point of view. A Mio-Pliocene basin is preserved at St Samson-Henenbihan, not very far from the bay of La Fresnaie. The morphology of the valleys are controlled both by the hercynian and more recent fault directions (fig.1); Lower Loess at Les Vallées show sometimes meridian faulting. Holocene peat is faulted at Caroual (N70°) , 2km further North. From Hillion to Erquy, this sector of the bay seems subsident at least since 400ka BP. Nantois and Piégu sections are located close to Pléneuf-Val André, on the East shore of the St Brieuc Bay. Port Lazo is located at the N-W edge of the bay.

Topography close to Pléneuf-Val André shows a 100m paleosurface truncated by a lower level (60m). To the East this surface is coverd by Eocene to Pliocene deposits. This platform is incised by deep valleys in equilibrium with the present tidal flat . The sea has cut an important section across periglacial deposits following the steepest part of the east to Northeast facing coastal slope at this locality which is located on the eastern side of the Baie de St-Brieuc. The associated valley opens to the north.

Figure 1: Pléneuf-Val André inland morphology (from the 1/25000 topographical map).



NANTOIS,

SAALIAN LOESSES, EEMIAN PEDOCOMPLEX, WEICHSELIAN SUCCESSION

J.L. MONNIER, B.VAN VLIET-LANOE, B.HALLEGOUET

The Nantois cliff exposes a succession of well developed older and younger "limons" which dip quite steeply to the east.

Lithostratigraphy (see fig. 2)

From the bottom up, that is to say moving from right to left along the base of the cliff, two major units of heads and loams are seen to be separated by an important soil complex.

The lower of the two sequences can itself be split into two which from the base up:

- Lowermost Heads with screes near the base and an interstratified fossil beach (bed 38).

- Partly calcareous loamy sands occur towards the top of this complex (bed 35).These loamy sands and the Lower Heads immediately above them include a soil complex (beds 33-34), the Lower Pedocomplex.

- very well developed calcareous loesses (beds 28-29), or Lower Loesses are truncated by a loamy bedded head and by a soil complex (sols lessivés) (beds 21-27) which includes a reworked dune.

The upper of the two sequences comprises:

- a sandy colluvial deposits (bed 20)

- loamy calcareous sands with a terrestrial molluscan fauna and containing interstratified pedogenetic horizons (beds 13-19)

- a serie of bedded loams and heads, Upper Heads (beds 6-12)

- the Upper Loesses belonging to the Sable-d'Or-les-Pins Units but incomplete (bed 5),

- fine sands, and reworked loam with faint pedogenesis (filling gullies incised into the underlying loess, corresponding to thermal fissures) and with soil development (banded Bt of a sol brun lessivé) (bed 4), interconnected in the Nantois depression with a fragipan soil developed in bed 12.

- post-glacial humic soils and dune (beds 1-3)

Upper Loesses (lithostratigraphy and sedimentology)

Only the loesses with sandy laminae and the upper homogeneous loesses are found at Nantois (cf. Sable-díOr-les-Pins Unit) .The upper loesses are calcareous (16%) and are typical. They are well sorted with a median of 33,5 µm. Here sedimentation begin immediately on solifluction lobes, with an hummocky paleosol preserved at the base , and laterally interstratified with a thick braided channel gravely infilling (Nantois river). This sedimentation condition is very close to what is observed today in the Advent valley in Svalbard. These loesses are buried locally by fine grained thin aeolian sands. The ensemble is cut into by gullies over the length of the main slope (fig. 5) probably associated with thermal fissures.

The uppermost fine grained sands are decalcified and have a typical aeolian granulometry with the median value varying between 50 and 60 µm. Their mineral assemblage puts them into a loessic context (hornblende - epidote - garnet association). This aeolian sandy influx at the end of the deposition of typical loess reflects a significant rise in sea level.

The gullies relate to a general glacis at the end of Pomeranian stadial (15ka BP). They are filled with loess and fine sandy colluvial deposits. As in the majority of the littoral Brittany sites, a recent soil profile is developed. Its deep illuviation horizon is banded and should not be confused with "Limon à Doublets".

Stratigraphical interpretation

The Upper Loesses and Upper Heads are clearly of Weichselian Age. From nearby Sables d'Or section, IRSL datings (Additive dose method) of the Upper Loesses range from about 27 ka (base) to about 16 ka for the last unit. This means that loessic sedimentation started with the cooling after Heinrich layer H3, confirming the interpretation by the paleopedological data. The Middle Pedocomplex belong to the whole isotopic stage 5, though the basic horizon with "Limon à Doublets facies belong to the Linexert Interstadial, a short warming well recorded at 140 ka BP in N.Hemispher (Seidenkrantz et al., 1995). Lower Loesses and Lower Heads belong to Saalian II as shown by the ESR date of the bone and the saturation of TL/IRSL dating performed by M.Frechen. Climate conditions were milder and wetter than during the Weichselian Pleniglacial as shown by the importance of the valley infilling at Les Vallées and the installation of permafrost was very late, probably just before the "Limon à Doublets"

Lower Pedocomplex and calcareous dune seem to be correlative of isotopic stage 7.

The scree and the cliff knoch are older probably of stage 8 and 9, comparative with other Channel shore sites, but no elements existing in this section permit this interpretation.

developed aversely angular polyhedric structure and coatings and downslope into a pseudogley..
In the same type of sediment, a second Lessivé complex is developed (fig. 3, bed 2). This is marked at the base by thick bleached clayey coatings. Towards the top it is rapidly changed by frost creep . Former hydromorphism is marked by the presence of smectite a second Bt horizon developed strongly. It constitutes a compacted glossic Bt horizon with a very fine angular polyhedric structure (fig. 3, bed 3). A strong hydromorphism then occurred which was probably contemporaneous with the establishment of a marsh behind a coastal bar (fig. 3, bed 4) and apparent sea level a little lower than at present (local neotectonism) . This complicated palaeosol passes laterally along the base of the main slope to gleyed soil with a peaty level (gyttja).
The Middle Pedocomplex at Nantois is bended by frost creep. It is overlain by a bed of thin loamy head . It also reworks about 1% marine sand in a dune cover (fig. 3, bed 5).
A moderately rubified thick marine sand with some clay was deposited on top, probably by solifluction as the basal contact is deformed. This dune or littoral sand (fig. 3, bed 6) received no input of loamy pebbles from the slopes and at its base, part of the underlying head is eroded probably by wash or swach (compaction). The rubified soil is very illuviated as a result of its topographical position and its mineralogy (smectite). Rubification is linked to the presence of goethite and could result from contrasted climate. Laterally this pedogenesis affects the glossic soil as a clay-humic illuviation with a tendency towards forming a grey wooded soil (from thin sections), a feature that would confirm the notion of the dryness of the "dune" soil.

Port-Morvan Unit (fig. 3, beds 7 to 9)
The Port-Morvan stratotype site will not be visited on this excursion. However, the Unit , though incomplete at Nantois, is represented above the middle soil complex where, from the bottom up, there are:

- a sandy colluvium ("Colluvium de Nantois") resulting from muddy flows reworked secondarily by cryoturbation and frost creep (fig. 3, bed 7). At the base there is some hydromorphism as well as frost cracks which extend down into the clayey sand below.

- a loamy calcareous bioturbated sands with molluscan *shells (Trichia hispida, Vallonia costata, V. pulchella, Pupilla muscorum...)* and a small humic horizon at the top (an arctic meadow soil with a calcareous mull which has been deformed by frost creep (fig. 3, bed 8).

- a calcareous sandy loam with Bt horizon at the top, a solifluction calcic brown soil characterised by both an important decalcification and a slight development of clayey coatings (fig. 3, bed 9).

- foliated sandy loams and bedded gravels which are exceptionally well developed at Nantois as result of their position at the bottom of the slope (fig. 1, c. 7-12).

The Lower Pedocomplex (Lithostratigraphy, sedimentology, pedology) (see fig. 3)

The fossil beach (bed 38) is formed of a moderately fine, well sorted sand (mean = 22 µm) with somewhat roughened grains though the bed as a whole was still water deposited.
The lowest soil complex (fig. 3) is developed on a head along with some water-lain loamy sands. Il rises above a bedded loamy calcareous dune sand which is partly decalcified. This sand is fine grained (mean = 88 µm) and well sorted; it is a marine origin though with a percentage of roughened, but still glossy grains indicative of some wind action. Shell fragments and forams show root weathering. The dune formation was stabilised and lightly altered before it was involved in slump movements. The true soil complex developed on the dune after it had moved and becomes more and more impure, with input of loam, towards the top where it is also decalcified. It is a sol brun lessivé characterised by a fine yellowish brown clay illuviation . Only the lower horizons are preserved (B3t to C2).

The soil is cut across by a loamy pebbly head which has itself undergone some soil forming processes to produce a brown soil with some weak leaching . It has an average sub-angular polyhedric structure with fine clayey humic coatings. This second soil passes upward into a coarser head with a loamy and lightly humic matrix showing evidence of frost creep that caused reworking of lower horizons. It seems to have produced a slightly developed grey forest soil. This soil complex appears to represent two slightly temperate or cold temperate climatic phases separated by relatively short lived cold spells with reworking of littoral deposits. This complex possesses the characteristics of an interglacial. Two humic loamy heads en the sequence. A bone of *Bos primigenius* was found at the top of the second one.

At Les Vallées (parking) and at Caroual (2km to the East), the calcareous loamy sand is replaced by a soliflucted dune (Nantois Pt) resting sometimes on a calcareous beach, both including malacofauna. This will be developed further.

The Lower Loess (lithostratigraphy and sedimentology)

These typical loesses are calcareous (12,5%) and contain large loess dolls. There are flow bedding lines (the granulometry indicates the presence of a slight sandy component). The sorting is very good with the mean lying at 35 µm. From a sedimentological viewpoint these older loesses are identical with the Weichselian Upper Pleniglacial Nantois loesses. Tectonical meridian faulting is visible in the Lower Loesses and Lower Heads west of the Nantois Pt. Valley incision affecting the loesses and mostly the heads and consisting in a braided river gravely infilling is connected with Les Vallées river.

The Middle Soil Complex (lithostratigraphy, sedimentology and pedology) (see fig. 3, beds 1 to 6)

The oldest pedogenesis is formed on a loamy head related to the reworking of the older loess. On the slope, it presents a "Limon à doublet" facies, rather thick but transforms midslope in B3t yellowish brown horizon with a very well

THE CALCAREOUS SHORE FACE COMPLEX OF EASTERN ST BRIEUC BAY

D.KEEN, A.LAURIAT-RAGE,PH. BREBION ,D.LEFEBVRE,
B.VAN VLIET-LANOË, B.HALLÉGOUET

Corresponding to the Middle Pedocomplex at Nantois, this unit is very frequent in the East of St Brieuc Bay, much more than the Eemian beach. It is better developped in other sites such as Les Vallées, Nantois Pt, Caroual, Le Verdelet Island, and Piegu archaeological site than in the main section of Nantois. A Piégu, the calcareous dune is affected by a strong pedogenesis and is disconnected from a beach level (sample 20 - Keen), calcareous including forams and shells.

At the base, at Caroual, we can observe

- the cliff knoch with greenish brown non-calcareous sand, interstratified with screes.
- screes and heads (lowermost)
- a dune sand body, somewhat soliflucted with stones
- a banded Bt paleosol
- a calcareous sand body with a malacofauna
- Lower Heads

At Les Vallées, the sequence recorded is somewhat similar, at the base:

- a greenish non-calcareous sand with some blocks at the top
- a calcareous beach sand including some cobbles
- a calcareous dune body, in situ
- a calcareous soliflucted or colluviated dune with stone incorporation
- Lower heads with at the base a « Lessivé « soil.

From this, at least 3 shoreface sequences are observed in a short time span. From Piegu the dates cover 160 to 200 ka BP (ESR and U/Th performed by M.Laurent and J.J.Bahain) for the calcareous material. In other words, the upper 2 high stands of the sea belong stage 7. The greenish non-calcareous sand can belong to the lower most.

Interesting data are given by the malacofauna and marine fauna.

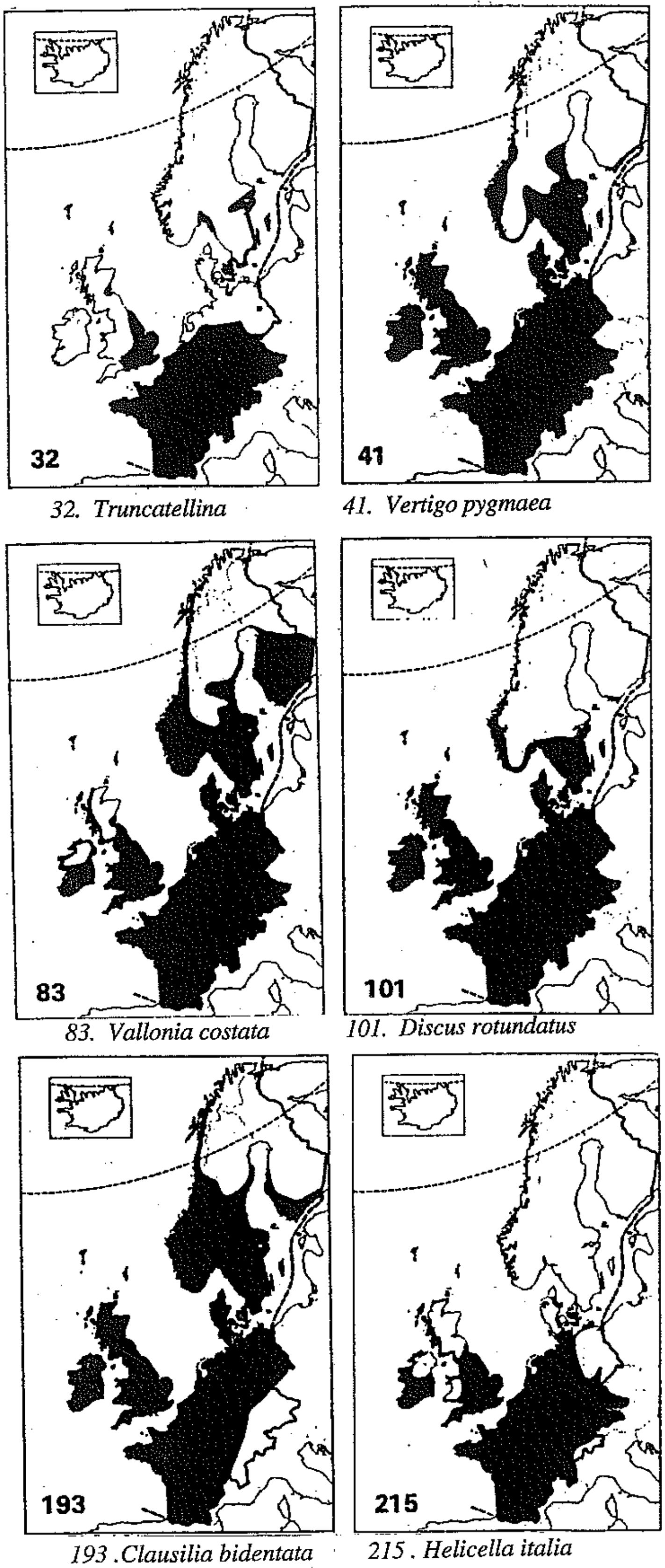
CONTINENTAL MALACOFAUNA (David KEEN, Coventry)

Methodology:

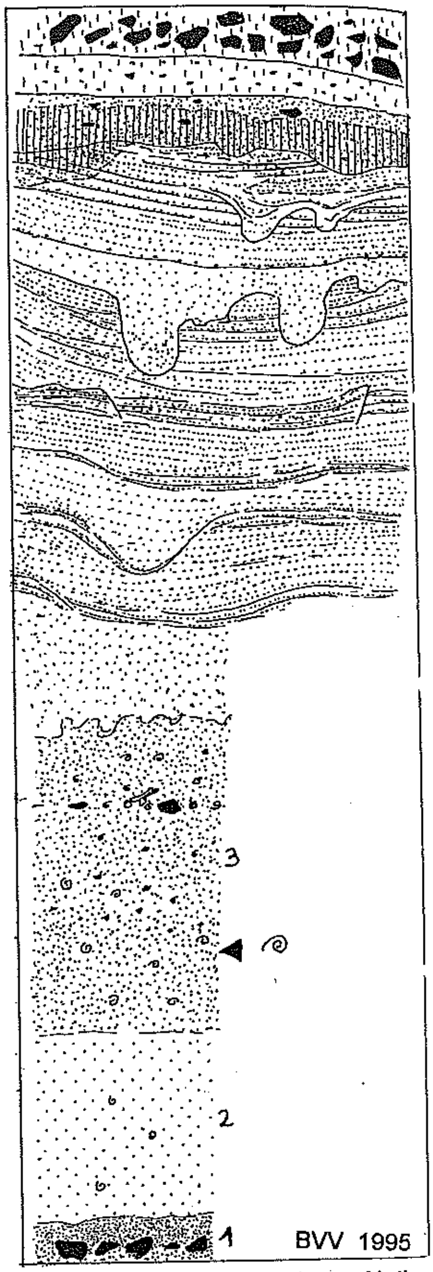
The samples were sieved to 500 µm. Because of abundance of shell the residue was divided into two using a splitter and one half sorted for Mollusca. The other half was scanned for rare taxa, but otherwise left unsorted. As the assemblage was entirely a land one, the nomenclature follows that of Kerney & Cameron (1979).(table I)

Samples from Caroual, Nantois Pt, Les Vallées soliflucted dune and Les Vallées upper beach were investigated.

Mollusca can be used as climatic indicators in two ways. Because the number of species declines rapidly in northern areas of Europe (see Kerney & Cameron, 1979), the number of species present is often a good guide to the climate of deposition, with large numbers of species indicating warmer climates. Secondly, the current distribution of



Geographical spreading of the different land snails found in calcareous dunes of East St Brieuc Bay



Les Vallés paleodune section . Notice the paleosoil at the top of the reworked dune. (1) Kaki beach, (2) calcareous beach, (3) calcareous dune.

Mollusca: Piégu

sample	10	11	18	18W	18sup	20	J	B
Land taxa								
Succinea oblonga Draparnaud	0	0	22	32	25	0	3	0
Oxyloma pfeifferi (Rossmässler)	0	0	4	1	1	0	1	0
Succineidae undet	0	0	1	17	6	1	0	0
Cochlicopa lubrica (Müller)	0	0	1	2	0	0	0	0
Cochlicopa lubricella (Porro)	0	0	0	0	6	0	0	0
Cochlicopa sp	0	0	0	0	0	0	1	0
Vertigo pygmaea (Draparnaud)	0	0	0	9	1	0	0	0
Pupilla muscorum (Linné)	1	13	6	58	72	26	2	0
Lauria cylindracea (da Costa)	0	5	0	0	[1]	0	0	4
Vallonia costata (Müller)	2	0	0	0	0	19	0	0
Vallonia pulchella (Müller)	0	1	0	0	0	16	0	0
Vallonia excentrica Sterki	1	0	0	0	0	19	0	0
Acanthinula aculeata (Müller)	0	0	0	0	0	1	0	0
Ena sp	0	0	0	0	0	2	0	0
Punctum pygmaeum (Draparnaud)	1	1	0	1	1	0	0	0
Discus rotundatus (Müller)	0	0	0	0	0	1	0	0
Vitrina pellucida (Müller)	0	1	0	0	0	0	0	0
Vitrea crystallina (Müller)	0	4	0	5	0	0	0	0
Nesovitrea hammonis (Ström)	0	0	0	0	4	0	2	0
Aegopinella nitidula (Draparnaud)	0	0	5	9	0	0	0	0
Aegopinella sp	0	0	0	0	0	1	0	0
Oxychilus cellarius (Müller)	0	0	0	0	0	1	0	0
Cecilioides acicula (Müller)	0	8	0	0	0	0	0	0
Clausilia bidentata (Ström)	1	0	0	1	0	2	0	0
Cernuella virgata (da Costa)	4	37	8	27	[1]	0	1	16
Helicella itala (Linné)	3	4	109	72	176	89	10	0
Cochlicella acuta (Müller)	0	36	1	0	[1]	0	0	0
?Perforatella rubiginosa (Schmidt)	0	0	8	0	7	0	0	0
Trichia hispida (Linné)	5	2	43	96	128	41	14	0
Arianta/Cepaea spp	0	0	0	0	0	1	0	1
Helix aspersa Müller	0	1	0	0	0	0	0	0
Freshwater taxa								
Lymnaea truncatula (Müller)	0	0	1	5	9	0	2	0
Lymnaea peregra (Müller)	0	0	0	2	0	0	0	0
Anisus leucostoma Millet	0	0	2	7	1	0	1	0
Pisidium casertanum (Poli)	0	0	1	1	0	0	1	0
total	18	113	204	345	438	214	38	21

Marine taxa

sample	10	11	18	18w	18sup	20	J	B
Patina pellucida (Linné)	0	0	1	0	0	0	0	0
Gibbula umbilicalis (da Costa)	3	0	0	0	1	0	0	0
Tricolia pullus (Linné)	0	0	0	0	1	0	0	0
Lacuna sp	0	0	0	0	0	0	1	0
Littorina littorea (Linné)	1	0	0	0	1	0	0	0
Littorina saxatilis (Olivi)	0	0	0	0	1	0	0	0
Littorina obtusata (Linné)	0	0	0	1	5	0	0	0
Pseudamnicola confusa Frauenfeld	0	0	0	2	0	0	0	0
Onoba semicostata (Montagu)	0	0	0	2	0	0	2	0
Cingula trifasciata (J. Adams)	0	1	0	53	21	0	7	0
Rissoacea undet	2	0	1	6	2	0	2	0
Bittium reticulatum (da Costa)	0	1	0	0	1	0	0	0
Triphora adversa (Montagu)	0	0	0	0	1	0	0	0
Turbonilla sp	2	0	0	0	0	0	0	0
Nucula sp	1	1	0	0	0	0	0	0
Pectinacea undet	0	0	1	0	0	0	0	0
Arctica islandica (Linné)	1	0	0	0	0	0	0	0
Cardiacea undet	1	0	0	0	1	0	0	0
Spisula sp	1	0	0	0	0	0	0	0
Balanus sp	+	+	+	+	+	0	+	0
total	12	3	3	63	35	0	12	0

(Totals in parentheses are Holocene species which are intrusive into a Pleistocene sample).

D.H. Keen 29th November 1996

Land Mollusca from Les Vallées

Cochlicopa lubrica (Müller)	1
Cochlicopa lubricella (Porro)	24
Vertigo *pygmaea* (Draparnaud)	1
Pupilla muscorum (Linné)	170
Vallonia costata (Müller)	11
Vallonia pulchella	20
Vallonia sp.	1
Vitrina pellucida (Müller)	1
Nesovitrea hammonis (Ström)	18
Oxychilus cellarius (Müller)	3
Limax sp.	4
Helicella itala (Linné)	231
Trichia hispida (Linné)	72
Total (12 species)	658

Caroual

Pupilla muscorum (Linné)	4
Helicella itala (Linné)	10
Trichia hispida (Linné)	5
Capaeal Arienta sp.	1
Anisus leucostoma (Millet)	1
total (5 species)	21

Land snails and marine taxa determined in dune material from Caroual, Les Vallées and Piégu sections. Analyse : D.KEEN, 1996

Quatenary faunal association in raised beaches, Piégu, West and East

Shells (Lauriat-Rage)

Glycymeris (G) pilosa (L.)	*Acanthocardia (A.) echinatum (L.)*
Mytilus (M.) edulis L.	*Acanthocardia (A.) erinaceum (Lmk)*
Mytilus (M.) galloprovincialis Lmk	*Acanthocardia tuberculatum (L.)*
Chlamys (A)opercularis (L.)	*Cerastoderma edule (L.)*
Pecten (P.) maximus (L .)	*Lutraria (L.) lutraria (L.)*
Anomia (A). ephippium (L.)	*Eastonia rugosa (Helb).*
Loripes lacteus (L.)	*Solen (S.marginatus (Penn)*
Tellina A. crass Penn.	*Venus (V.)verrucosa L.*
Tapes (R.) decussatus (L.)	*Ostrea (O.) edulisL.*
Macoma (M.) balitica L.	

Gasteropodes (Brebion)

Patella vulgata (L.)	*Astrea (B.) rugosa (L.)*
Monodonta (O.) lineata (Da Costa)	*Bittium reticulatum (Da Costa)*
Littorina (L.) littorea (L.)	*Nucella lapillus (L.)*
Ovatella myosotis (Drap.)	*Buccinium undatum L.*
Hinia reticulata (L.)	*Tritonalia erinacea L.*

Foraminifers (Lefèvre) (West beach only)

Dominants species:

Cibicides lobatus (Walker & Jacob)	(dominant).
Agulogerina angulosa (Wiliamson)	(abundant)

Other species:

Spiruloculina sp.	*Fissurina lucida* (Williamson)
Quinqueloculina seminulum (Linné)	*Fissurina orbignyana* (Seguenza)
Quinqueloculina viennensis (Le Calvez)	*Bolivina pseudo-plicata* (Heron, Allen & Earland)
Quinqueloculina longirostra (d'Orbigny)	*Bolivina variabilis* (Williamson)
Quinqueloculina aspera (d'Orbigny)	*Bulimina elongata* (d'Orbigny)
Quinqueloculina chiarensis (Heron, Allen & Earland)	*Bucella frigida* (Cushman)
Quinqueloculina trigonula (Terquem)	*Gavelinopsis praegeri* (Heron, Allen & Earland)
Quinqueloculina elegans (d'Orbigny)	*Rosalina bradyi*(Cushman)
Quinqueloculina undulata (d'Orbigny)	*Rosalina globularis* (d'Orbigny)
Quinqueloculina angulata (Williamson)	*Rosalina granulosa* (Margerel)
Miliolinella subrotunda (Montagu)	*Ammonia beccarii* (Linné)
Lagena clavata (d'Orbigny)	*Elphidium crispum* (Linné)
Lagena williamsoni (Alcock)	*Elphidium pulvereum* (Todd)
Lenticulina rotulata (Lamarck)	*Elphidium articulatum* (d'Orbigny)
Globulina gibba (d'Orbigny)	*Elphidium excavatum* (Terquem)
Oolina globosa (Montagu)	*Elphidium cf. incertum* (Williamson)
Oolina hexagona (Williamson)	*Elphidium gerthi* (Van Voorthuysen)
Oolina melo (d'Orbigny)	*Elphidium cf.cuvilliery* (Levy)
Oolina sp.	*Protoelphidium paralium* (Tintant)
	Globigerina sp.
Cassidulina reniforme (Norvang)	*Cibicides fletcheri* (Gallaway & Wissler)
Cassidulina sp.	*Planorbulina mediterranensis* (d'Orbigny)
Nonion depressulum (Walker & Jacob)	*Heterolepa pseudo-ungeriana* (Cushman)

and pond elements. Keen (1985) suggested that this assemblage dated from a phase at the transition from temperate interglacial conditions to a colder climate. A similar habitat could be proposed for the Les Vallées fauna.

B) Piégu, .

Sample 20 is different to those described above. Although grassland indicators such as *P. muscorum* and *H. itala*, and disturbed ground species (*Trichia hispida*) are still the most numerous present, the wetland and aquatic species are absent. In their place are numerous specimens of *Vallonia pulchella* indicative of wet grassland, *Vallonia excentrica* and *Vallonia costata*, found in dry grassland, but less often in dunes, and shade and woodland elements such as *Acanthinula aculeata, Ena sp, Discus rotundatus* and *Clausilia bidentata.* Although these last taxa are restricted in number their occurrence with a dune grassland assemblage suggests that the dune environment was at least partly wooded or under scrub. It is possible that such species *as Clausilia bidentata* could obtain shade in rocky rather than wooded areas as they do in Scotland today where the population are survivors from former forest environments now destroyed, but the occurrence of leaf-litter species such as *Acanthinula aculeata* suggests that woods or at least scrub rather rocks were present in the area. The absence of identifiable marine shells in sample 20 perhaps indicates a position near the inland edge of a dune field where transport over some distance has destroyed much marine material. However, coastal environments were not too distant as sample 20 contained two lightly abraded specimens of the benthic foraminifers *Elphidium crispum* (Linné (identified by Ms Stella Kortekaas, Coventry University the fragile tests of which would not stand much transport without damage.

This site is more firmly indicative of a warm climate. The presence of *Vallonia costata, A. aculeata, Ena sp* and *C. bidentata*, all with northern limits in southern Scandinavia, strongly indicates a temperate climate, with summers as warm as Brittany at present and winters perhaps only a little colder. The occurrence of *E. crispum* in sample 20 also suggests a climate similar to that of today as Murray (1991) records this species as living off Brest now and suggests that it indicates sea temperatures of between 8 and 18°C.

Both Piégu assemblages are of interglacial character, but there are no biostratigraphic indicators in the faunas to determine age and few sites elsewhere in western France with a molluscan fauna comparable to that of Piégu to indicate to which interglacial the assemblage may belong.

MARINE FAUNAL ASSEMBLAGE (A. Lauriat-Rage & P.Brebion , Museum, Paris and D.Lefèbvre , Geol. Univ.Rouen)

These data concerns only Piégu East and West beach.

All thse species of shells and gasteropods are common in present -day shores. All of them are represented along the french Atlantic coast, *Astrea rugosa* excepeted, remaining today south of the Biscaye Gulf. All the shells are present- are present-day forms and a half existed already during the Miocene, the other half appeared from the Pliocene. *Macoma balthica* represents a specific Pleistocene importation. Four other species as *Glycymeris pilosa, Mytilus galloprovinciallis, Acanthocardia erinaceum* and *Estonia rugosa* are unkwon today in the Channel and belong to southern provinces. *G.pilosa* and *A. erinaceum* are only mediterranean today. This faunal association is species in Europe is partly climatically controlled and can also give a general indication of the environment of deposition.

A) Upper beach at Les Vallées, the most in situ sample.
The assemblage from this sample shows the evidence of shore face conditions with a lot of abraded marine shells, ostracodes and forams. The malacofaunal assemblage consisted of twelve species of which three were overwhelmingly the most numerous. Such restricted numbers of land species might be thought to come from a periglacial environment (see Keen, 1987). However, the true local environment is one of dry conditions prone to extreme changes of temperature. Such an environment occurs in unvegetated areas such as braid plains and tundra in the periglacial realm, but also occur in dunes or open grassy areas in temperate regions. Such open, dry conditions are suggested by the occurrence of *Pupilla muscorum, Helicella itala* and *Trichia hispida.* That conditions were not periglacial is however suggested by the geographical ranges occupied by some of the species today. *Trichia hispida, Vallonia costata* and *Cochlicopa lubricella* can be found as far north as Arctic Circle at present (Kerney & Cameron, 1979), but they only attain such latitudes in the favoured environment of the Norwegian coast, and their general distribution is in southern Scandinavia. *Vertigo pygmaea* is more of a southerner, being found only in south Sweden, *Oxychilus cellarius* occurs in three localities on the SW Swedish coast, and *Helicella itala* is restricted to Scotland and Jutland and is absent from Norway and Sweden. Thus, although the fauna is from an open habitat, there is no particular suggestion of a cold climate. The majority species are tolerant of extreme dryness as would occur on dunes, but *Cochlicopa lubricella, V. pulchella, Nesovitrea hammonis* and *O. cellarius* are species of wetter habitats such as would occur in dense grassland. The land snail assemblage was accompanied by restricted numbers of remains of marine molluscs (Rissoid gastropods and bivalve debris) and of *Balanus sp.* plates, probably blown into the area as clasts in a dune system.

Correlation with other sites: The assemblage was remarkably similar to that from a late phase of dune reworking (Nantois Pt) , in terms of major species present, although in detail Les Vallées has three more species than Nantois and two further species found at Nantois were not found at Les Vallées/beach . Samples from Piegu corresponding to the calcareous dune give similar assemblages (ESR dating) .At Piégu, the assemblages are dominated by species of dune grassland (*Pupilla muscorum, Helicella itala*), species of disturbed ground (*Trichia hispida*) and of wetland (*Succinea oblonga, Oxyloma pfeifferi, Lymnaea truncatula, Lymnaea peregra, Anisus leucostoma* and *Pisidium casertanum*). Caroual assemblage is very similar. The occurrence of the two latter species suggests that small pools may have existed alongside the swamps occupied by the succineids as *Lymnaea truncatula.* The occurrence of two specimens of *Pseudamnicola confusa* in sample 18W suggests that the ponds may have been slightly brackish as this species lives in water of salinities of 2/$^{\circ\circ}$ a degree of salinity which could be tolerated by other aquatics species present.

There was little difference in the climate suggested by the assemblages, with clear indication of an environment similar to that on dunes in Brittany today. As well as Nantois , Caroual and Piégu, elements of the Les Vallées fauna were found at Portland West (Keen, 1985) in the Portland loam overlying the West Beach, although the Portland environment was wetter and the dry ground species were subordinate to marsh inferred to the Eemian s.s. : it is warm and quite different from these of the Holstenian of Luc sur Mer in Normandy, dominated by a majority of cold species as *Macoma balthica.* This species occur at Piegu only in the eastern part of the site.

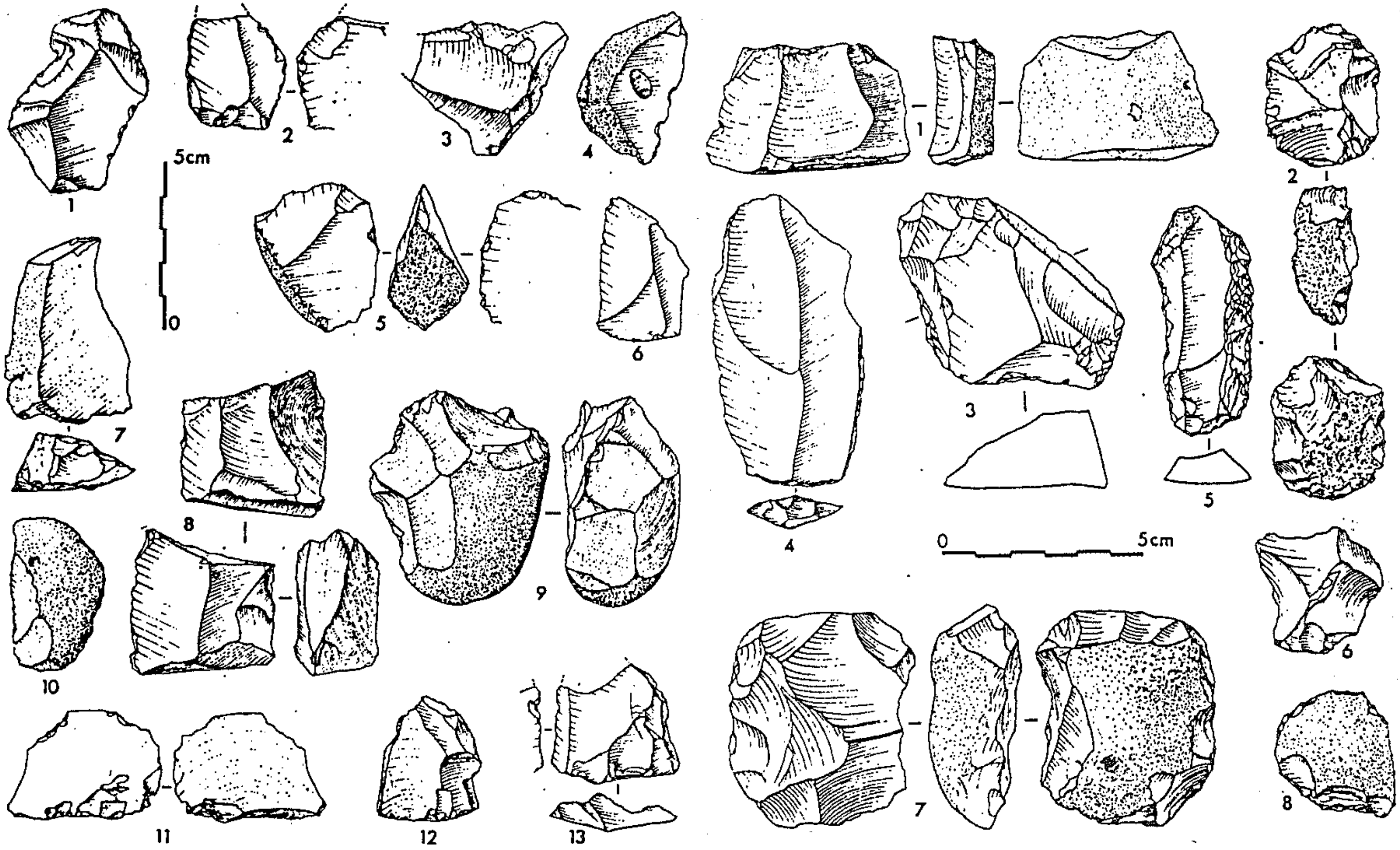
The formaminifers association of the western beach at Piegu are similar to the present-day association of the Channel and can be inferred to a temperate interglacial. Presence of *Rosalina granulosa* (Marg.) infers an Eemian signature as it is also found in Pliocene and Eemian deposits of western France and Britain. It is absent today in the Channel.

CONCLUSION

Local faunal and morphological conditions during stage 7 indicate a cliff foot with local marshy to lagoonal environment at the back of dune bodies or beach bars. This deposit belongs mainly to stage 7b, the end of the second high stand of this interglacial. Because of the rapid burial of the beach and sand dunes by head during end of stage 7, calcareous sediments with a malacofauna are well preserved, mostly because of continental climate conditions, as also recorded from the faunal remains found in association with archaeological material (see next page). This is a main difference with stage 5e as observed in Eemian beaches of La Hauteville and Port Morvan (Monnier & Van Vliet-Lanoë, 1986). At Piégu beach, marine fauna associated with land malacofaune assemblage are clearly indicative of Lusitanian sea conditions and associations, in this stratigraphical context, leading to a stage 5e shore face interpretation.

In late stage 5e, a pedogenesis occurred in western France, after the cooling event at 117 ka, decalcifying most of the outcrops. It also explains why all around the Channel and in Cornwall, stage 7 beach complex is calcareous (Van Vliet-Lanoë et al., 1997d) and the Eemian not.

PALAEOLITHIC INDUSTRY OF NANTOIS LIVING FLOOR (Shore face)



ARCHEOLOGY

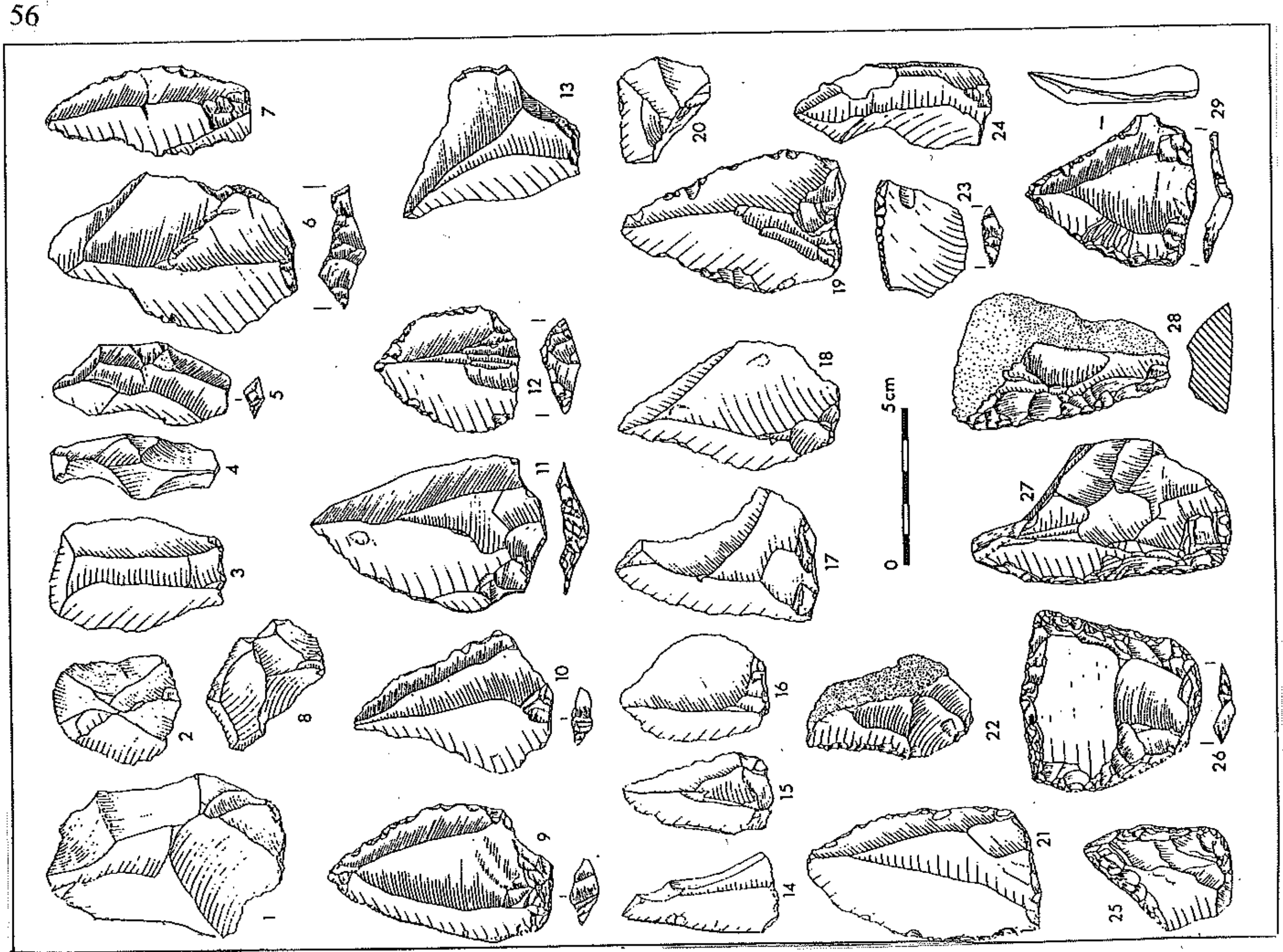
J.L.MONNIER & B.HALLÉGOUËT

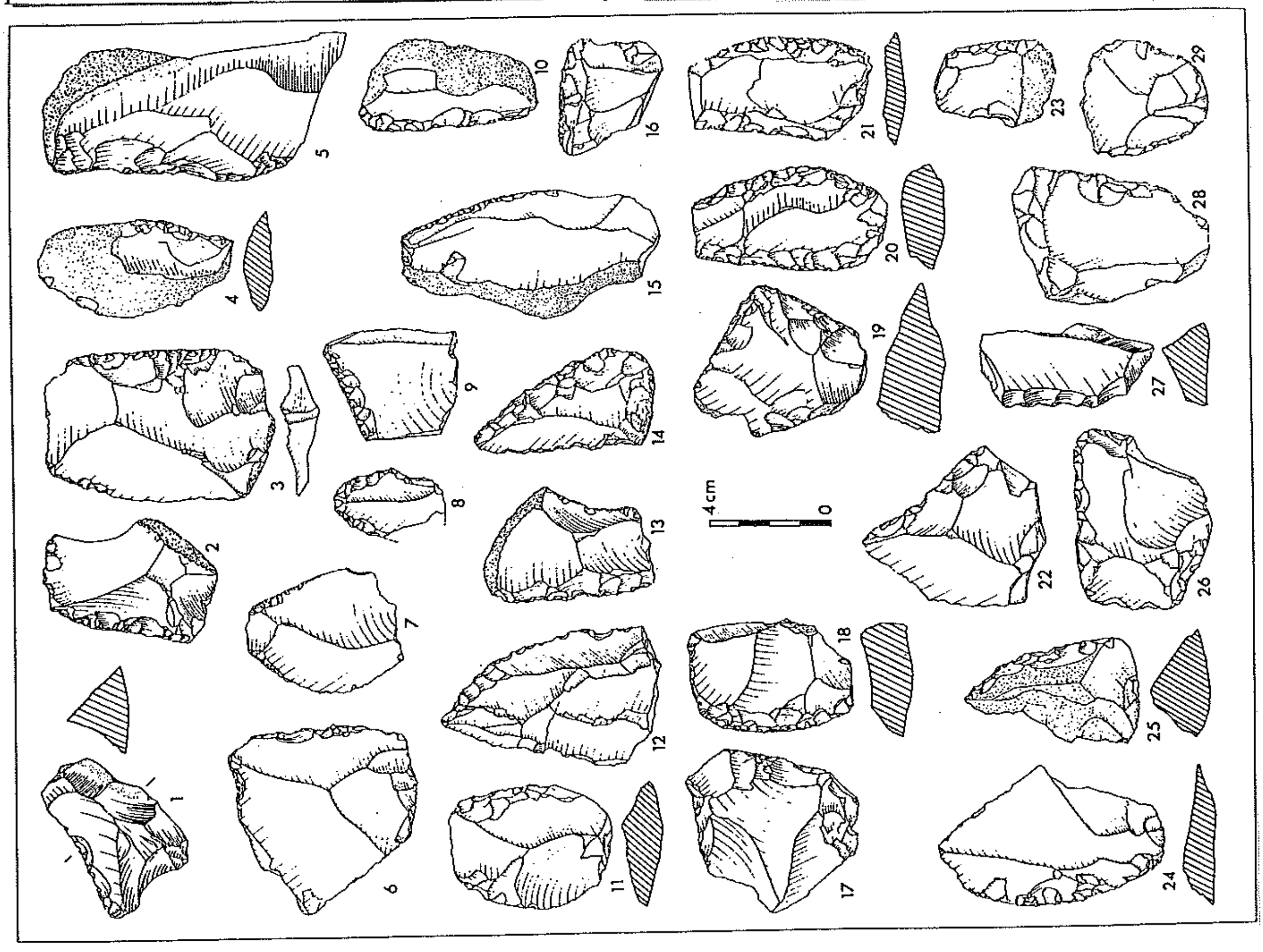
The site of the beach of Les Vallées, is known to have produced faunal remains (*Elephas primigenius, Equus caballus, Vulpes vulpes*, a Bovidae...) associated to worked flints (denticulate and notched tools). The archaeological level corresponds to a partly carbonated sand (ancient dune) ascribed to the B3 unit. Human presence, probably a butchery station (the site is exposed to the North, unusual position for the Palaeolithic Armorican habitats), would thus chronologically fit towards the late stage 7 or early 6 and not 5d as ascribed before.

A few hundred metres from Les Vallées, the Nantois site has given, under the strand zone, relicts of a Bovidae (aurochs), associated with thirty or so worked pieces (nucleus, brut flakes and notched tools). The sedimentological study has shown that the archaeological layer is connected with the B3 or B4 units. An attachment (?) of a scapula of an auroch has been found in situ in the level B4b. Here again we have a hunting and cutting-up site, nevertheless older than the Les Vallées one (beginning of stade 6).

The Piégu site, first known by collecting implements on the beach, has been the subject of an important excavation in 1987. The work revealed a complex stratigraphic succession, an original one, and also the presence of two or three phases of Palaeolithic occupation. First, at the basis, an old marine abrasion platform strown with some pebbles, witness of a first transgresion (isotopic stage 11); over it, screes of rubble stones; then a second ancient beach (stade 9?), formed of pebbles, continued by a dune deposit probably taking place at the beginning of a regression; over it, again, a second coat of coarse slip (or slide) material. The whole of these layers are cut (notched) in the form of a cliff during a third marine transgressive episode which left a beach of pebble mixed with Mollusca shells (stade 7); the recession of the coastline, once again, went with a dune formation filling in the upper part of the vale. At the top, the superficial part of the dune, still calcareous, is displaced (solifluction) and capped by a pronounced palaeosoil (stade 5?), itself covered by a flow of rubble stones and of reworked loess. There are thus no less than four temperate phases and as many long glacial periods that are recorded in the Piégu deposits.

The oldest human presence brought in evidence on the Piégu site is probably before the stade 9, thus it goes back to more than 325 ka ago. It is a small handaxe of acheulean type worn by rolling amongst the pebbles of the second fossil beach. The most numerous remains belong to the Middle Palaeolithic; they have been found on one hand in a soil over the second ancient beach, on the other in the fallen rubble stones caught on the side and which are clearly later. The habitat at the foot of the cliff has only given flint tools which one can easely match with the series picked up before on the present sea beach. The scree, on the contrary, have only given few stone tools,moreover they are raw or feebly retouched. These are the elements, slipped down the slope, of a butchery site primitively placed on the top of the cliff; quantity of bones of animals, of which a lot show decarnisation scratches, testify this. The fauna is typical of a rather temperate environment, near the forest but also of steppic biotopes; there are chiefly red deers, horses, Bovidae and rare rhinoceroces, also some wolves. The human occupations (Middle Palaeolithic) are thus between the isotopic stages 9 and 7, thus between about - 300 and - 200 ka BP. The industry of the habitat at the foot of the cliff is in flint.It is

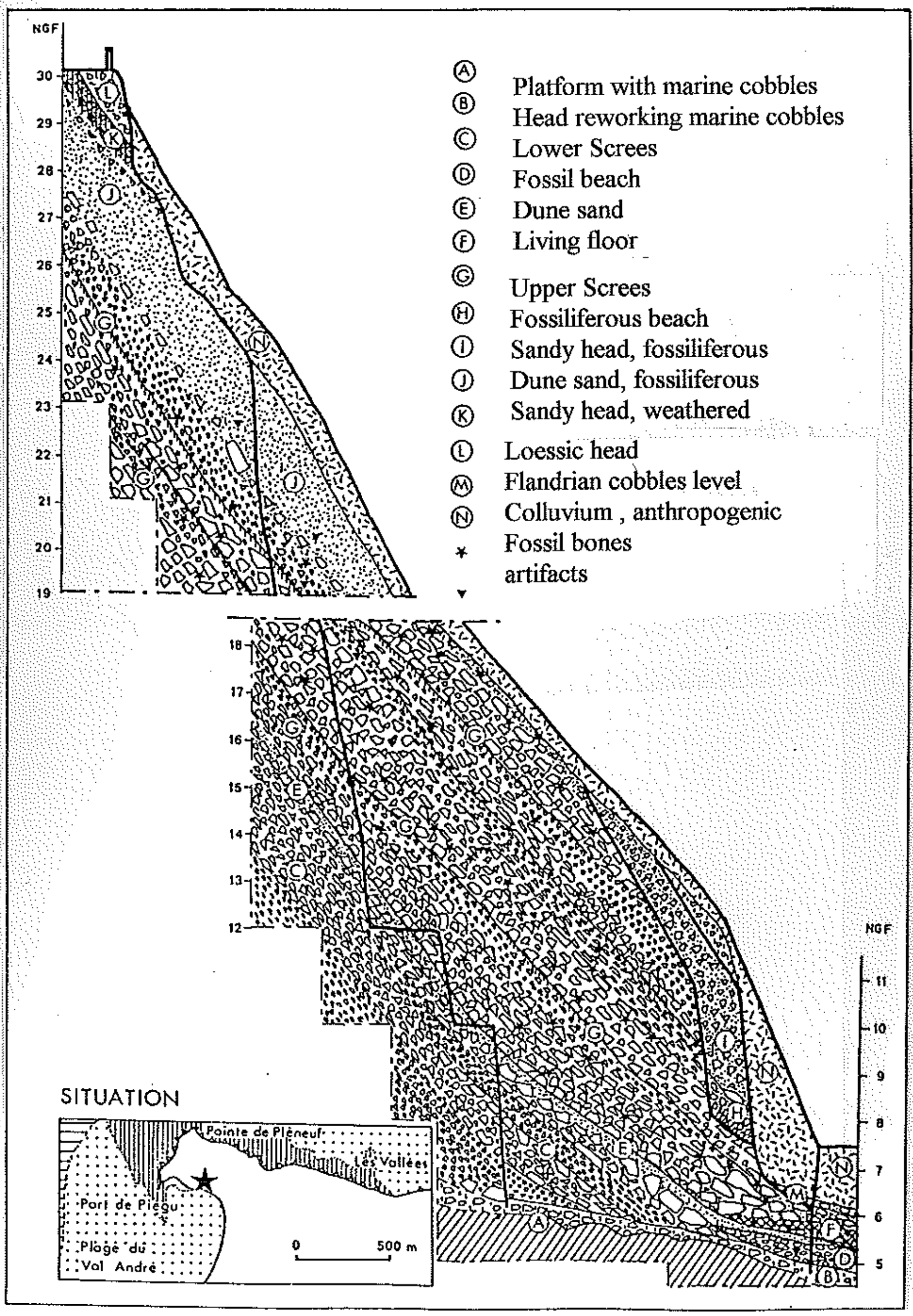


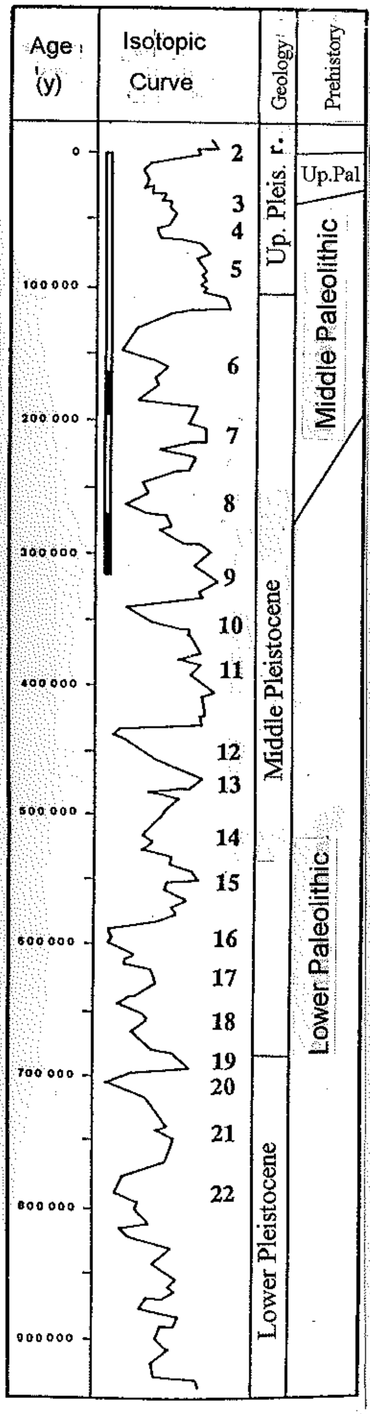


INDUSTRY OF PIEGU SECTION

marked by a Levallois flaking technique (24 %), with especially an important production of points and many brute objects preserved. Amongst the retouched implements, side scrapers are dominant (40 to 50 %), of good workmanship and of varying types. The tools with convergent retouched sides are well represented, but there are no true mousterian points. Hand-axes are absent.

Piegu section, main units and there stratigraphic position





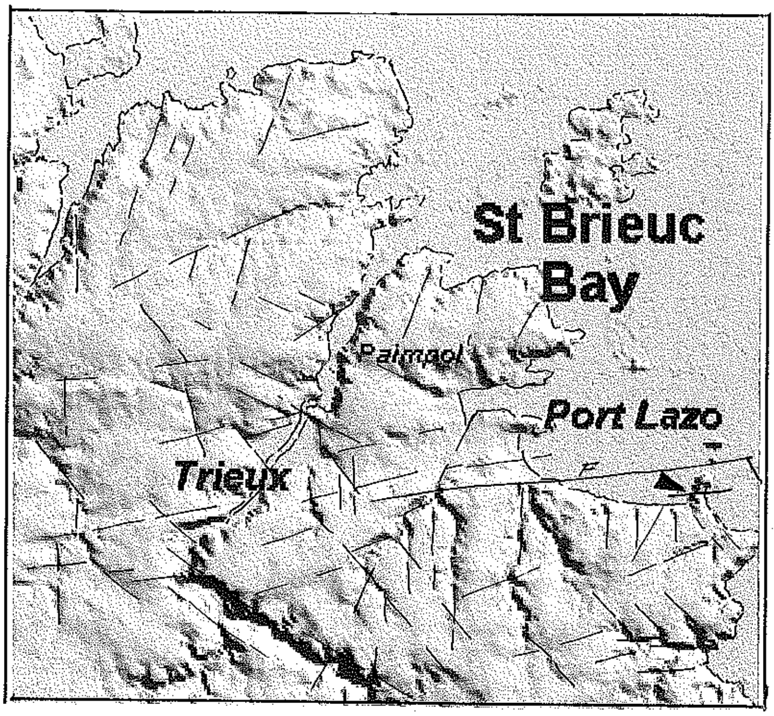


Figure 1a : Tectonical location of **Port Lazo** sections

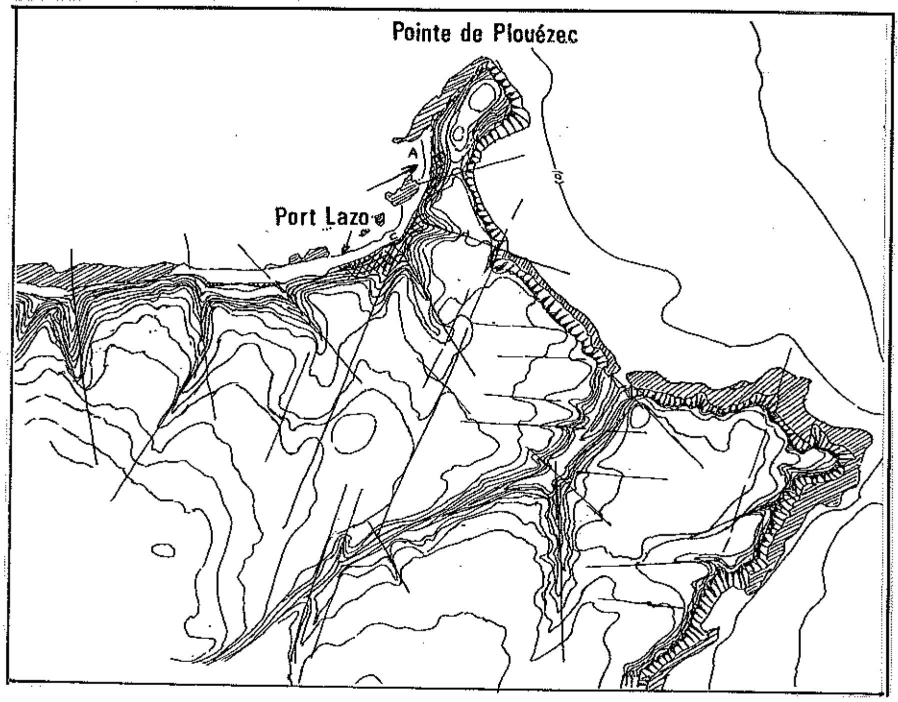
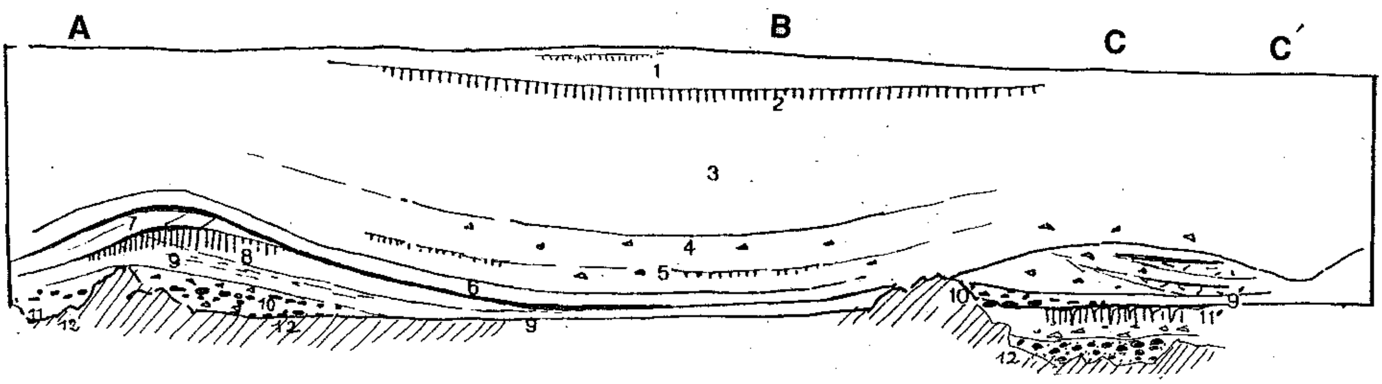


Figure 1b : general setting of the different units.



PORT - LAZO:

The longest stratigraphical sequence of the Northern Brittany coast.

Isotopic stage 11 to the Holocene.

B.VAN VLIET-LANOË, B.HALLEGOUËT, J.L.MONNIER

The Port-Lazo section is located on the western slopes of the Pointe de Plouézec, a narrow headland with its crest some 60 m above the sea. The deposits are preserved as thick loamy ledges shaped by the sea. There is a very large outcrop, discontinuous in 1986, which has been strongly eroded since clarifying the stratigraphy, now a day visible almost continuously. A tectonic lineament, roughly N90°, cuts the section at the North of the harbour road; a paleovalley is associated to it. Southern part of the section is more sheltered and present more recent units. To the West, about 200m form the harbour, the classical Eemian pedocomplex (cf. Nantois) is visible half altitude along a path climbing the sedimentary paleocliff. Humic gley as in the main section is visible at the level of the rock platform. At the Pointe de Plouézec, locally Upper Heads resting on a complex sandy beach with rounded small gravel is visible, very similar to classical outcrops of the Eemian beach.

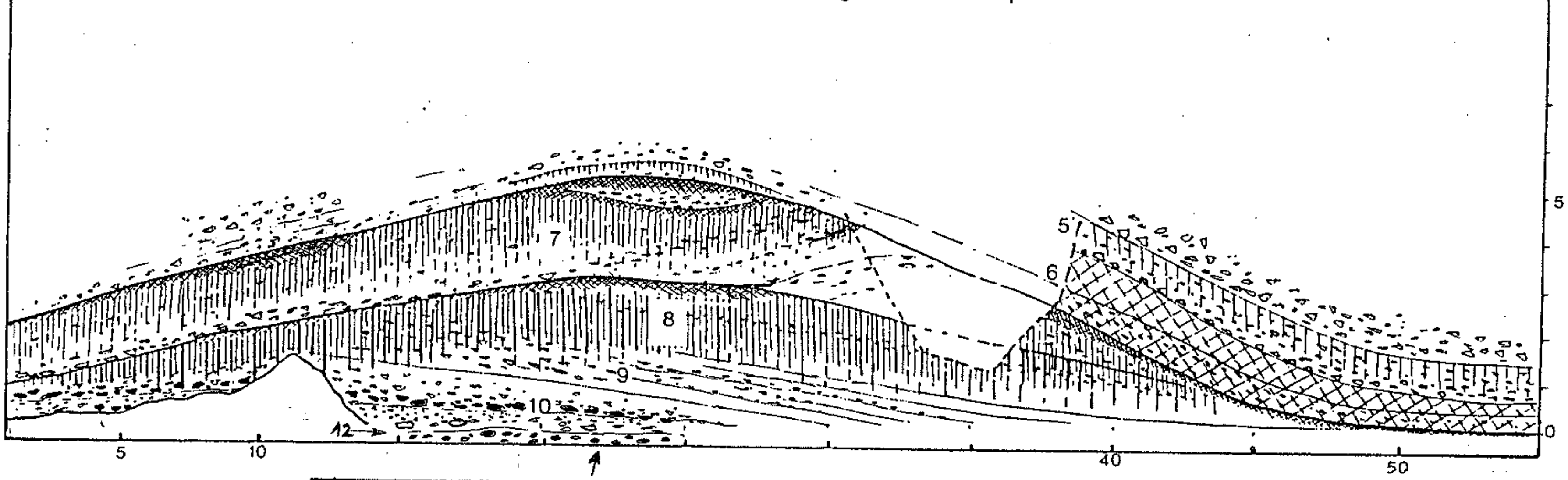
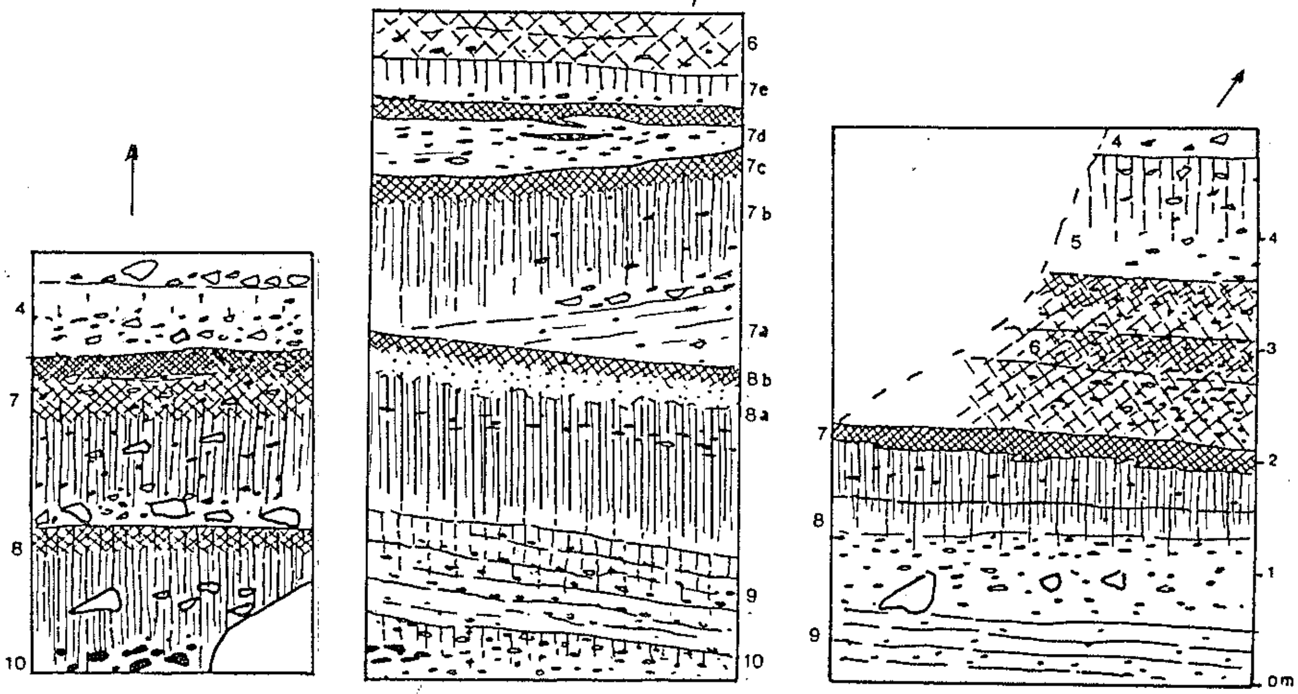
Stratigraphy

The section is described after a more general listing of the whole Port Lazo outcrop (Fig. 1).

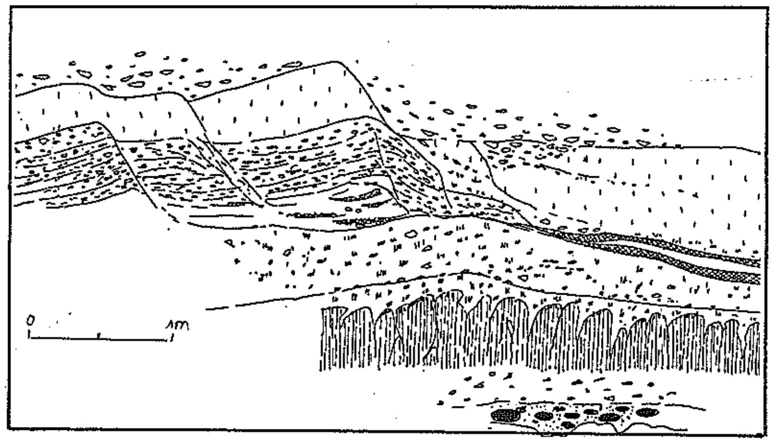
1a - recent colluvial deposits
1b - post-glacial slightly banded 'Sol brun lessivé"
1c thin loamy head
2- thick banded "Sol brun lessivé" resting on
3- Lower Loesses
4- Lower Loessic Heads, on the southern end of the section cut in paleocliff the units 8 to 12
5- small "brun lessivé" boreal palaeosol developed within the heads of bed 6
6- heads with a humic matrix derived from soils of arctic meadow type.

7- head complex dipping north and cut by an erosion surface; soil developments at a number of levels
8 - very compact head complex dipping south and cut off upward by the heads of level 7; the deposit is coloured strongly brown red by an important palaeosol
9 - bedded heads passing laterally into a rose coloured mud or to humic gley
10- open structure-head complex including a fossil beach with little roughened pebbles
11- stony head, compact , with a loamy matrix : remains of Lower Head II including the Lower Pedocomplex
12 - visible in the fore cliff only, remains of a beach: rounded cobbles in a sandy matrix.
13- rock platform in proterozoïc metamorphic rocks and red conglomerates

Figure 2 : Northern sections of **Port Lazo** (A) : stage 7 and stage 9b Pedocomplexes

Section C : slumping in head and deformation of paleosol (11') (stage 9b)



The **main pedocomplex** at the northern part of the section (1986 description)

7e- slight and thin head with a fairly strongly coloured B horizon; this bed caps the hog's back form of the rest of the beds comprising 7 and itself buried under the humic heads of layer 6.

7c-d - fairly humic ranker rich in charcoal (coniferous) and fragments of burnt rock divided into two parts by small depression filled with head.

7b- fairly strongly coloured Bt horizon of a "sol brun lessivé" with a brown-orange clayey humic illuviation seen in thin section; the bed is disturbed by frostcreep; the deposit formed after a strong erosion.

7a - block of head with opposite dip to beds both above and bellow; in thin section it is characterised by an intense brown-orange clayey illuviation and this is particularly marked at the contact with bed 8.

8b - slight humic soil developed at the top of paleosol 8 after the beginning of erosion that affected the deposits

8a - red "sol lessivé" with a moderate fragipan and of which the eluvial and clayey B horizons are both preserved; in thin section, the cryoturbation is brown-orange then clayey-humic, churned by cryoturbation and frost creep.

The **lower pedocomplex** at site B (1996 description)

9 - well , regularly stratified loamy gravely head, vertically truncated by a paleocliff

10 - rose loamy head complex shifting laterally to the South to the thick gley/humic gley complex (valley infilling) , with 2 main levels, studied by M.T.Morzadec (1973), laterally connected to the North at the base, to a coarse boulder beach, rather open work.

11a- shale head (5YR 5/4), including humic lenses rich in charcoal fragments, and loess-like lenses (7,5YR 4/6), apparently somewhat disturbed by slumping.

11b- loamy head weathered by a reddish glossic "lessivé" soil (5YR 5/3-6) , strongly mottled, with thick orange illuviation in thin section and an upper B1g perched hydromorphic horizon, abruptly truncated by 10.

12- cobble beach, including granite , with a greyish to yellowish coarse sandy matrix

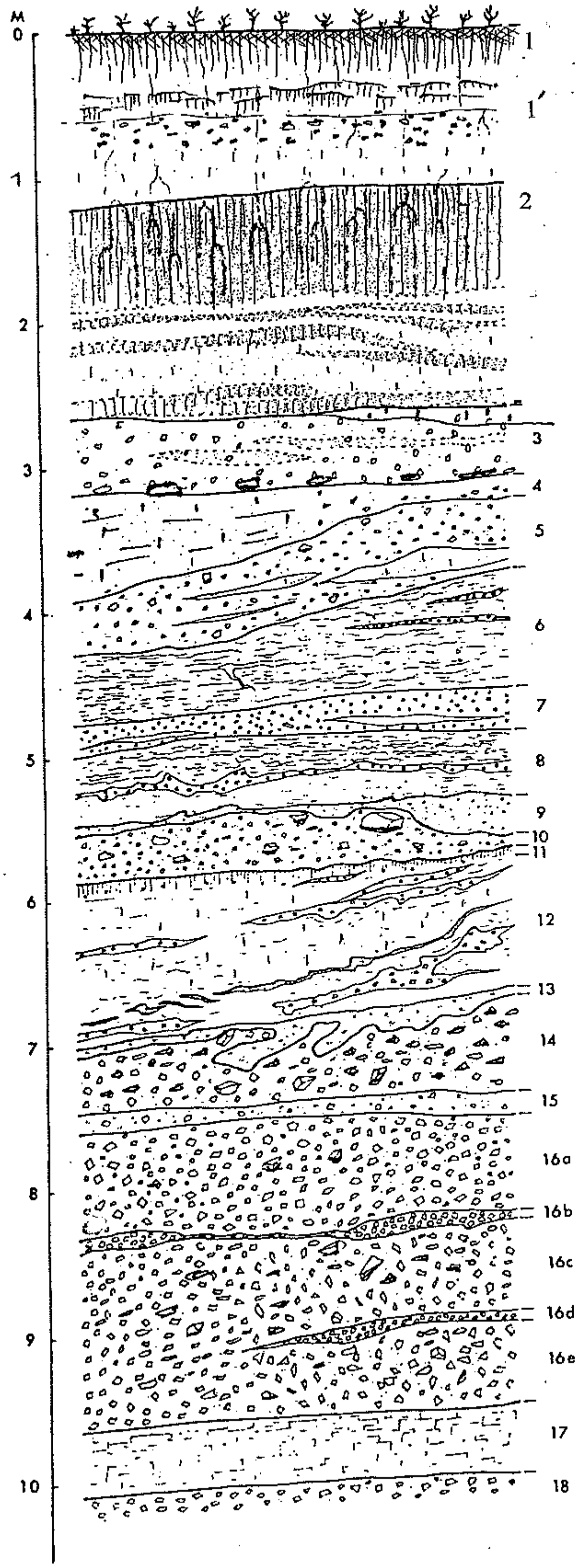


Figure 4 : Middle (B) section of **Port Lazo Old and Young Loesses**

Palynology of unit 10 (Morzadec, 1974) (Fig.3)
Tree vegetation is poorly represented. Trees and shrubs represent about 25-30% in the lower humic layer and further decrease to less than 5%in the upper part. Trees are boreal: birch, pine dominate. Thermophilous trees are present at the base of the deposit but become rare after. Herbs-like vegetation dominate with some halophytes (*Armeria, Chenopodiacea,*) wet lands (*Filipendula, Valeriana, Epilobium, Thalictrum*), open environment herbs dominate. This sequence is clearly representative of an ending interstadial, in wet conditions, as visible from the paleotopography. Occurrence of halophytes is significative of the vicinity of a shore face as represented by the boulder beach(base of unit 10).

PORT_LAZO , PLOUEZEC (Côtes du Nord)

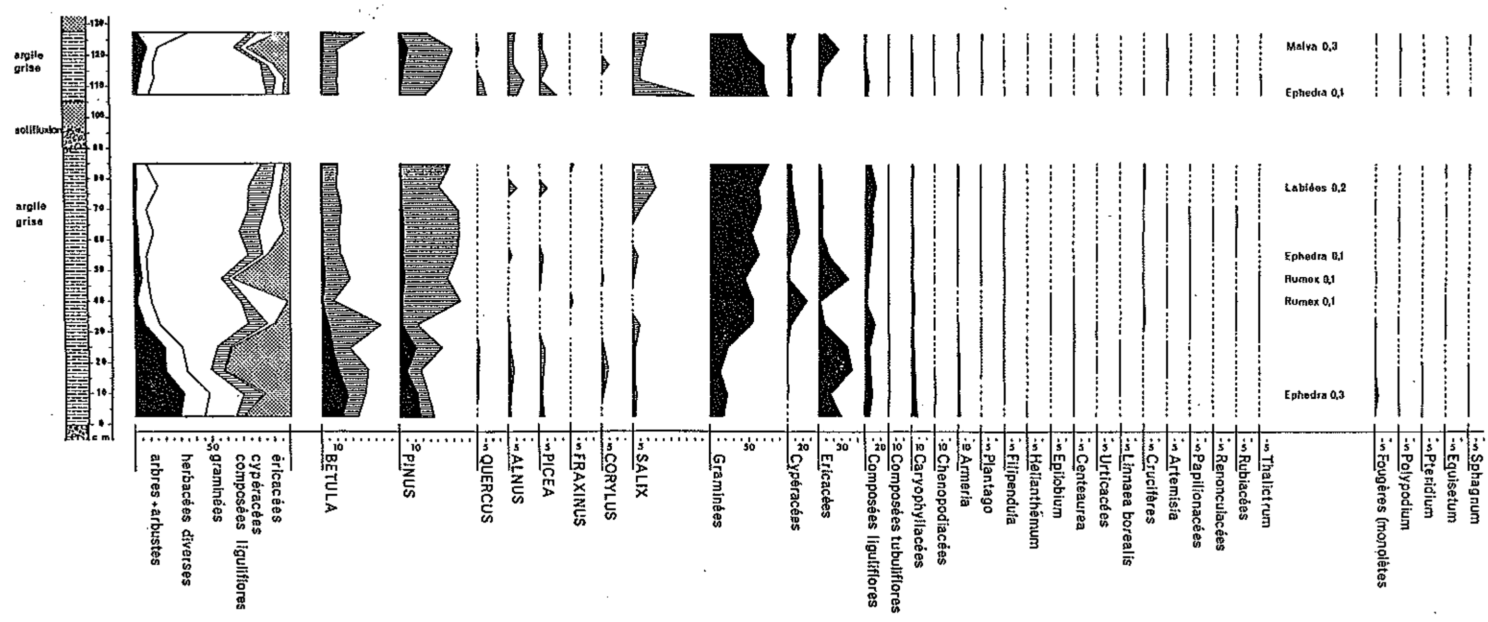


Fig.3. Pollinic diagram (Morzadec, 1974)

Loessic section (1986 description, Fig. 4; specific units)

16 a-e- succession of very rocky beds of head that are more or less clayey
15 - head more loamy than bed 4 and with hydromorphic mottling
14 - gravely head with rocky fragments and blocks in a loamy-clayey matrix
13 - grey gleyed clayey "limon" with its lowest part very convoluted
12 - units of bedded "limons" with lens of gravels, and orange sands, cryoturbated
11 - thinly bedded "limon" capped by a thin brown horizon
10 - head with sorted gravels and only a small amount of matrix which is of grey hydromorphic clay
9 - hardly bedded "limon" which is clay enriched and very distinctly gleyed
8 - bedded "limon" that is strongly cryoturbated with lenses of head material; there are hydromorphic traces
7 - fairly thick head with lenses of limon
6 - unit of "limon" and fine grained sand with cryoturbation (small involutions and frost cracks)

5 - gravely head with rock fragments and blocks of deposit with lenses of bedded loess
4 - residual loess with some rocky fragments
3 - gravely "limon" with illuviation layers
2 - truncated Bt horizon of a "sol brun lessivé" with thick illuviation banding the soil is developed on loessic colluvial deposits
1 - colluvial material

Clay mineralogy (with M.N.Le Coustumer, CNRS Caen)

Illite, kaolinite and vermiculite contents vary widely as a function of the nature of the heads. They are derived from the substrate and diminish markedly in the Lower Loesses. The beach present close to the base of the section (bed 10) is characterised by a different mineralogy that is always made distinct by its locally derived constituents, vermiculite excepted. There are fairly high smectite and chlorite contents, related to frost shattering and hydromorphism. The soil complex of layer 7 coming on top of the main palaeosol is characterised by the appearance of swelling interstrats that are only found in the head that underlies the fossil beach and in the loesses as at Nantois. Their appearance is thus linked to a reworking of the loesses.

Chronostratigraphy

Former interpretation given in 1986 is no more valid, as cliff erosion has clarified the connections and the stratigraphy.

1°- the loess sequence, first attributed to the Weischselian (Monnier & Bigot, 1987) belongs in fact to the Lower loess unit at Nantois . This is also very similar to the sequence recorded at Jersey (Keen et al., 1993; -1996). Only the uppermost part of the section corresponds to the Weichselian.

2°- On the southern side , the existence of a paleocliff in the most protected part of the bay shows clearly that most of the section is pre-eemian, a main difference from 1986 interpretation .

3°- The identified main palaeosol sequence is very close to these at Pen Hat (Crozon).

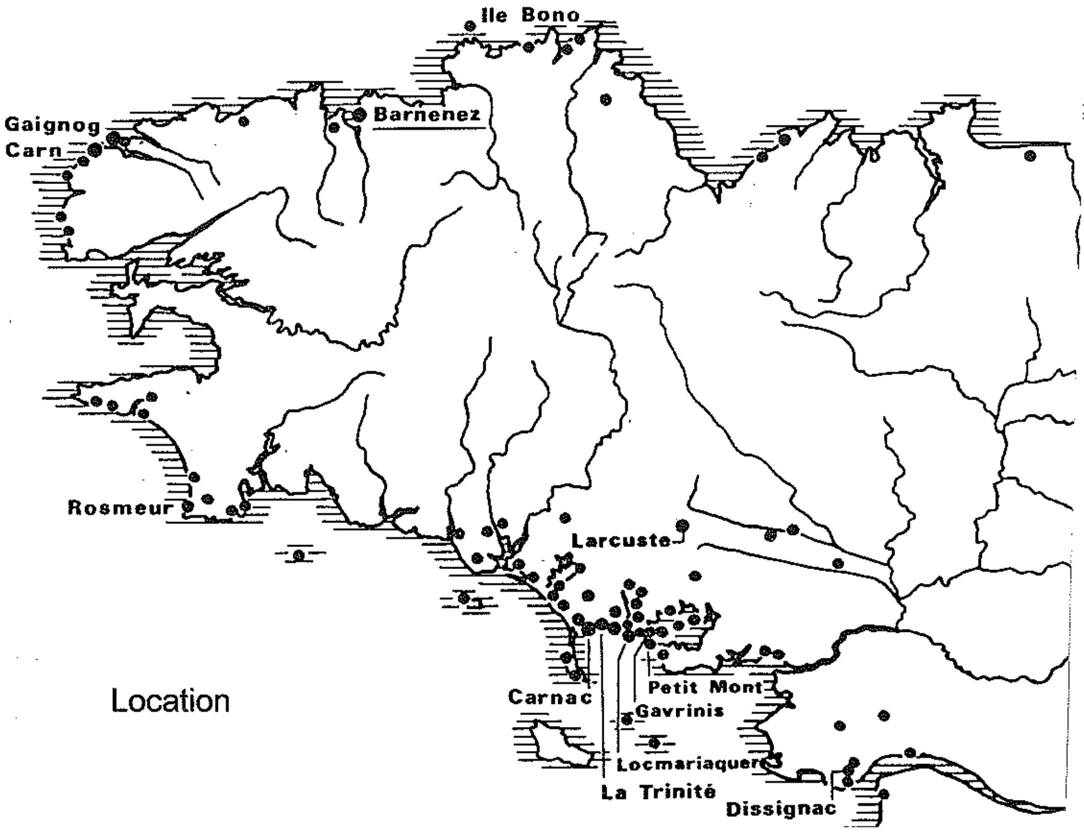
The deposits are distinctly more acid and ferriferous at Port-Lazo than in the other sites of the bay (Nantois) , as a factor that brings about a strong rubification of the soils and makes them comparable with those of the Cotentin and Finistère facies.

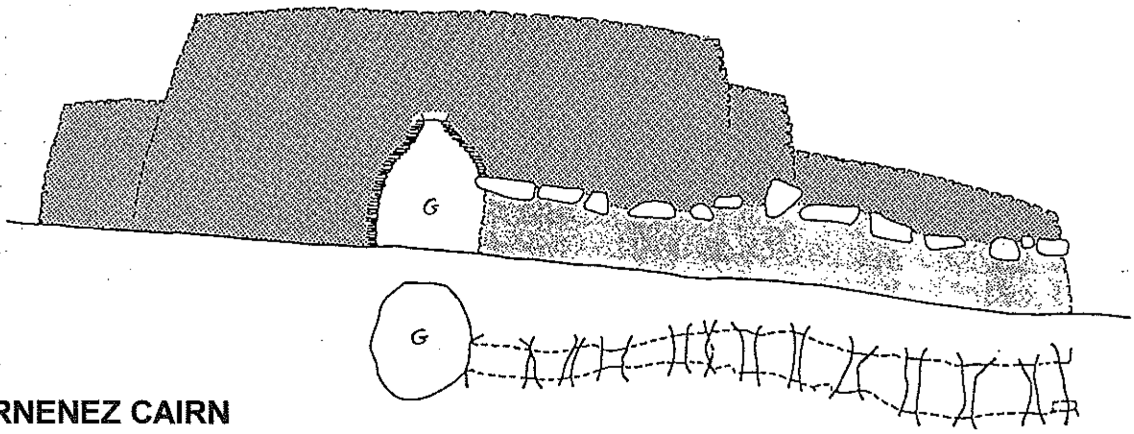
The Port-Lazo head complex above the main palaeosol of layer 8 is very thick compared to Weichselian. It appears to involve major muddy flows or founderings of rounded loamy masses. The upper pedocomplex is clearly pre-eemian, but the presence of thick Lower Loesses above it , without any major unconformity allow us to correlate it with the middle pedocomplex of Nantois, corresponding to the stage 7 .

4° - This interpretation allow us to attribute the boulder beach (level 10) pre-dating the main pedocomplex roughly to stage 9. Its association with the gleyed heads described by Morzadec-Kerfourn from the southern section and initially interpreted as Brørup in 1974 or as early Pleniglacial (Weichselian) in 1982. This section is now more easy to interpret than in 1986 . The facies is very similar to that found at the base of the Ecalgrain section and which was equated with stage 7 of the standard oceanic core (Lautridou et al., 1986). New data and ESR datings obtained along the Channel coast and in Cornwall (Van Vliet-Lanoë et al, 1997) allow us know to attribute the boulder beach to isotopic stage 9a, the second high stand of this interglacial, dated around 300ka, fitting with the boreal conditions with the persistence of halophytes, found by palynology. This means that the lower pedocomplex can belong to stage 9b and the lowermost beach level is presumed stage 11, the Holsteinian. This interpretation is coherent with the global quaternary shore face evolution as oustanding now from several sites along the Channel and the North Sea.

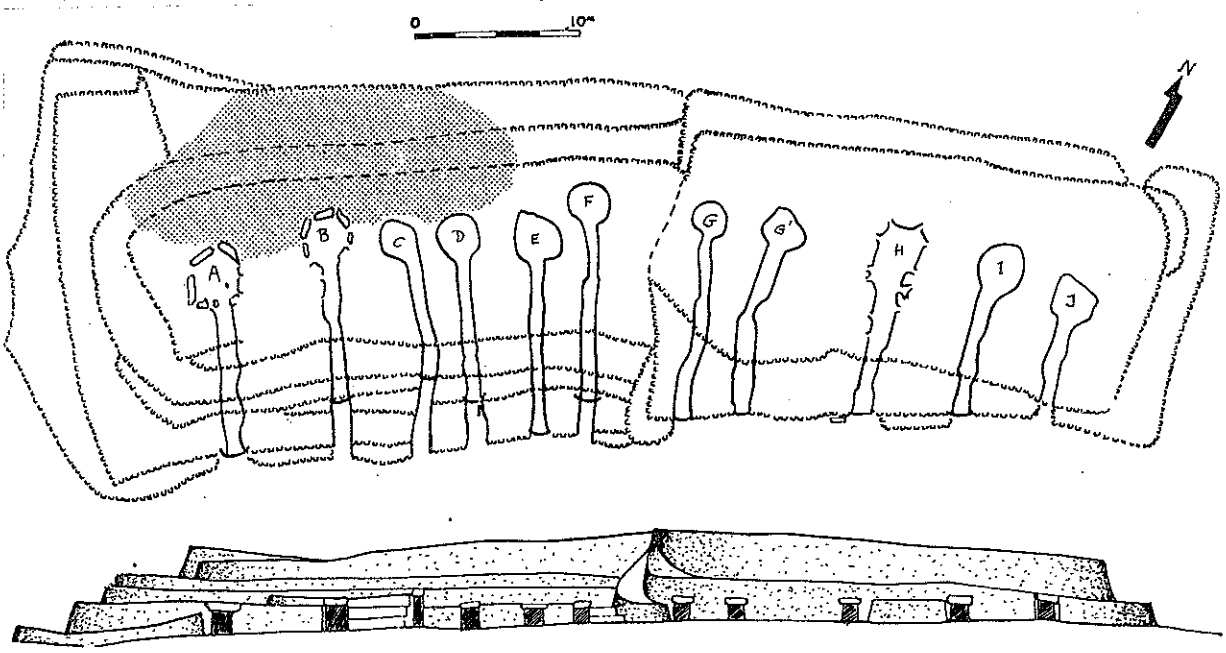
Prehistory

A number of worked flints have been found in place in the northern section at Port-Lazo and particularly in bed 8a (fig.2), a stratigraphical position very similar to the Piegu industry.





BARNENEZ CAIRN



THE BARNENEZ CAIRN

P.GIOT

On the Eastern shore of the outer marine estuary of the river of Morlaix, the small Kernelehen peninsula is crowned by a summit near the village of Barnenez, at 45 m NGF. In the Neolithic period, the sea penetrated barely a few km into the South of the estuary (instead of ten), so quite a lot of low-lying ground, now largely covered by oyster-beds, was available at the foot of the cliffs, of which the slope was attenuated by more Pleistocene deposits than at present.

Two mounds had been planned on the remarkable Ordnance Survey coastal map at 1/14 400 of 1780, one subcircular near the highest point, the larger and elongated one slightly lower down on a shelf. The napoleonian cadastral survey of 1830 showed them shared by many owners; the names of the plots (Querdi) are said to derive from a deformation of the word carn. In october 1850, at a meeting of a learned society in Morlaix, the mayor of Plouézoc'h, Mr de Kersauson, pointed out the presence of two large barrows of dry-stones near the place named "Barnenez-ar-Sant". They were not scheduled nor listed later, but simply mentionned in most guide-books; there were some legends about them, possibly confusing them with other antiquarian curiosities.

The northern cairn (probably the oldest), with approximatively residual dimensions 35 x 20 m, still at least 3 m high, was nearly completely destroyed in 1954 by quarrying for the road to Plouézoc'h. It covered at least one passage-grave. In 1955 the larger cairn was attacked at its N.W. side, and a preservation order stopped this vandalism when it got known†; the chambers of 4 passage-graves having been damadged. The apparent dimensions of the cairn, covered by gorse and a thicket, were 85-90 m long for 25 to 40 in breadth, downfall included. I began a rescue dig in June 1955, which became a complete excavation and restoration scheme, going on intermittently until the end of 1968, the State having meanwhile acquired the site. During the same period, I was excavating other large cairn sites of N.W. Brittany (on the islands of Carn and Guennoc), this helped in understanding the internal and external structures of such sites associating several passage-graves side by side.

The general principle of these monuments, built on rocky substrata where the digging of foundation holes for functional orthostats would have been difficult, is in general dry-stone walling, corbelled chambers, with only cap-stones on the passages. There can be a few non sustaining orthostats in some places, possibly for "decoration", casing the stone-walling which supports all the weight of the heavy high cairn superstructures.

This huge cairn is itself constituted of two successive parts. The eastern one was the first (the cairn primaire), the chambers of its five passage graves (G - Gí - H - I and J) are settled on the top of the geomorphological shelf at about 40 m NGF. The very long passages of the two western graves G and Gí are on a slope: their outer capstones are nearly on the level of the floors of their chambers. Clearly these two passages were built in two sequences, having been lenghtened with the widenning of the western end of the cairn towards a trapezoïdal form, before the building of the second cairn. Without being

The total volume of stone (taking in account the voids of course) was in the rough guess of 6500 to 7 000 cubic metres. A total weight around 12 000 to 14 000 tons can be reckoned, as a minimum.

To calculate the amount of work invested in such a monument, from the quarrying, the transport and the preparation of the stones and blocks, then the building itself, different scenarios are possible. Done in several episodes, along some duration of at least a century or two, it was quite realizable by a community of some hundred people.

The important elements are the eleven passage-graves, the architecture and the use of these "tombs". The initial passages of the primary cairn were relatively short, as in most of the cairns of this type. The transformation to long passages doubled the lengh in G G' H, with in G G'a broadening and an increase in height; in H and I there is a clear different disposition of the orthostats lining the dry-stone walls. The passage of J shows a short distance uncovered; its first capstone is a reutilized orthostat from another monument or another lay-out, as underneath its shows a carved motif which has only sense when it is on end. These monuments were built for eternity, but this did not exclude transformations, nor sometimes destruction a relatively short time after their building.

The chambers of these tombs of the primary cairn show differences. The two western ones G and G' are of quite small diameter, well built, intact, the top of the corbelled structure culminating at 2,5 and 3 m, with a few nice slate tablets completing the granite slabs. The central monument, H, is exceptional, having functional orthostats around its back chamber, preceded by an antechamber with a dry-stone corbelled roof†; the capstone of the end chamber being thick and large. Also in this end chamber there are figured motives, pecked on some stones, carved on another one separating back-and antechambers. The two eastern chambers I and J are broader than the western ones†; their corbelling collapsed owing to Iron Age interference above them†; this was also an effect of the eastern end of the cairn having been used as a source of stones for the field walls around (a degradation which had seriously attacked the northern side of the older barrow nearer to the houses of Barnenez).

The passage-graves of the primary cairn of Barnenez have given very few traces of the modes of utilization as tombs or for other cultural visits, apart from their architecture. After their last normal frequentation the passages had been very carefully condemned by well organized fillings of stone rubble; amongst the stones in the inner passage of G, one fragment of human leg was the only indication that there had been some kind of burials; in the chamber of H, only one sherd of pottery was left. Of course diverse modes of geochemical weathering may have dissolved some types of objects†: the preserved fragment of bone was sheltered by stones forming an umbrella against condensation drops of water, a lucky fact; because it had been heated, as often with bones from passage-graves, it had lost all traces of carbon.

The floor and the end of the inner passage of G had two adjacent scatterings of small grains of charcoal under the stones of the fillings. Those from the chamber gave a radiocarbon date in the 2 sigma range 4940 - 4330 CAL. B.C., those from the passage closing on with 4330 - 4000 CAL . B.C. The older date having a rather large sigma compares well, in spite of this, with the brackets from the dates of the secondary cairn, which come just after.

The tombs of the secondary cairn were much more informative about their use during the Neolithic, apart from E, which was parasited during the Middle ages, possibly for witchcraft, and had already been visited during the Iron Age. Iron Age people had also visited the tombs C and D, but had left there plenty of their Neolithic and Beaker Age grave-goods.

The chamber F is on the general line of those of the primary cairn, so it is further north than the other of the second cairn, also its passage is exceptionnally long and narrow. Pottery and flints were not very abundant, but there was a nice stratigraphy in the filling of the passage, giving two phases, the bottom one in the bracket 4710 - 4040 CAL. B.C., the upper one 4240 - 3630 CAL. B.C. The outer part of the passage has a short and narrow uncoved part, to come in alignment with the whole monument. E was at that end the only tomb of which the first capstone came directly to that alignment.

Because of their accessibility owing to long uncovered outer passages (hence the Iron Age visitors), C and D not only had plenty of Middle Neolithic grave goods, but also Late Neolithic and Bell-Beaker sherds; also this entrance facility occasioned, in front of the facade between C and D, an evident ceremonial place, with sherds from offerings.

All these tombs F-E-D and C had corbelled chambers of dry-stone walling. The next one, B, is quite different. The chamber is a classical little ' dolmen ', with six orthostats supporting a small cap-stone. The passage is also different : the cap-stones lie on dry-stone walling on both sides, but all along this is lined with a complete series of orthostats with no supporting role at all; indeed, they are so little set in the foundations that they are all inclined towards the axis, realising a condemnation of the monument without the necessity of bringing in many stones. In the short open-air entry to the passage, the orthostats have been brought back to the vertical for the restoration. It is in this outer part that most grave-goods were found.

The most western passage-grave, A, is a remarkable one. The polygonal chamber has functional orthostats, well founded by an artificial accumulation of stones wedging them in properly because of the slope, but these orthostats supported a dry-stone corbelled dome. Between chamber and passage, there is a half-door slab with an artificial little loophole. The grave goods were plenty of sherds of middle Neolithic pottery (one pot having its pieces distributed along 9 m between chamber and passage). Charcoal from an in-filling of loam gave a good radiocarbon date calibrating in the bracket 4580 to 3970 CAL. B.C. The passage was also lined by non supporting orthostats. The entrance is rather ceremonial, protected by the outer expansion of the cairn towards its corner. The two largest orthostats of the chamber are pieces from a same stone broken in two, possibly a menhir, and they are from a type of granite from the other side of the valley to the East of the monument. The first eastern slab at the entrance of the passage is of the same rock, and some figurations are pecked on it.

The site, and especially the large cairn of Barnenez are a good example of the complexity of megalithic structures. This gives a few slight glimpses or hints about the so dramatic, the refurbishing of the entrances of the three other passages was more effective from east to west. These transformations went with the building of an outer lower triangular massif of stones in front of the then inner revetment wall',; also afterwards of some additional buttresses all around the inner structures, especially around the angles, accounting to the local problems of slope and push. The result was a broader western end of the primary cairn. It is quite possible that this important structural alteration was performed in view of what was planned out for the second cairn (the cairn secondaire).

This greater extension westwards comprises six passage graves (A - B - C - D - E and F), and was built on a slope getting quite important at its extremity. This become a major difficulty, and clearly the Neolithic "engineers" did not step back, in spite of many other easier possibilities: there must have been an impelling cultural obligation for this. Hence the multiplication of the retaining walls, especially on the side of the entrances, and the widening of the lower western end, at the bottom of the slope, to retain the still more important push, giving a good ground-still (a semelle). There are also evidences of filling in irregularities of the ground before building on it, such as under the D passage, and especially under the chamber A, built over a very sloping area.

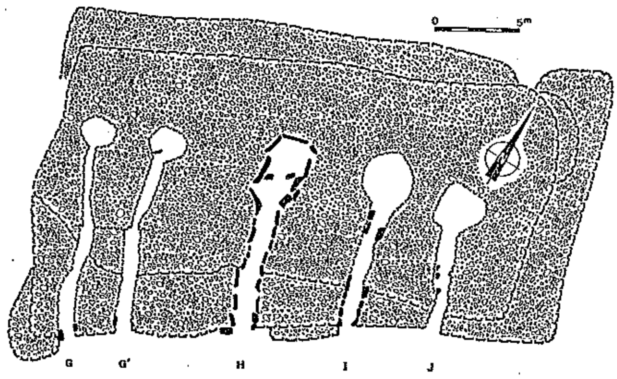
A few Iron Age sherds have been found at the foot of the most exterior facing-walls or kerb-stones prooving that still at that period all these walls were still visible, that thus they had been built to be visible, and that the degradation and crumbling down of some of these structures really began later. The real dimensions of the two additional cairns were smaller than those including the downfall. The total lengh was 72 m, which is what is now visible, the largest breadth of the first cairn 21 m, 27 m for the second one. The difference of level at the basement from one end to the other is 4,30 m. There are original parts of walling preserved from 5 m to 5,80 m above the basement. Of course the initial height was much more impressive. Taking in account the volume of the fall of stone all around and still there, one can estimate an initial height of about 9 m. It was a monument very visible at a great distance, and even now still is.

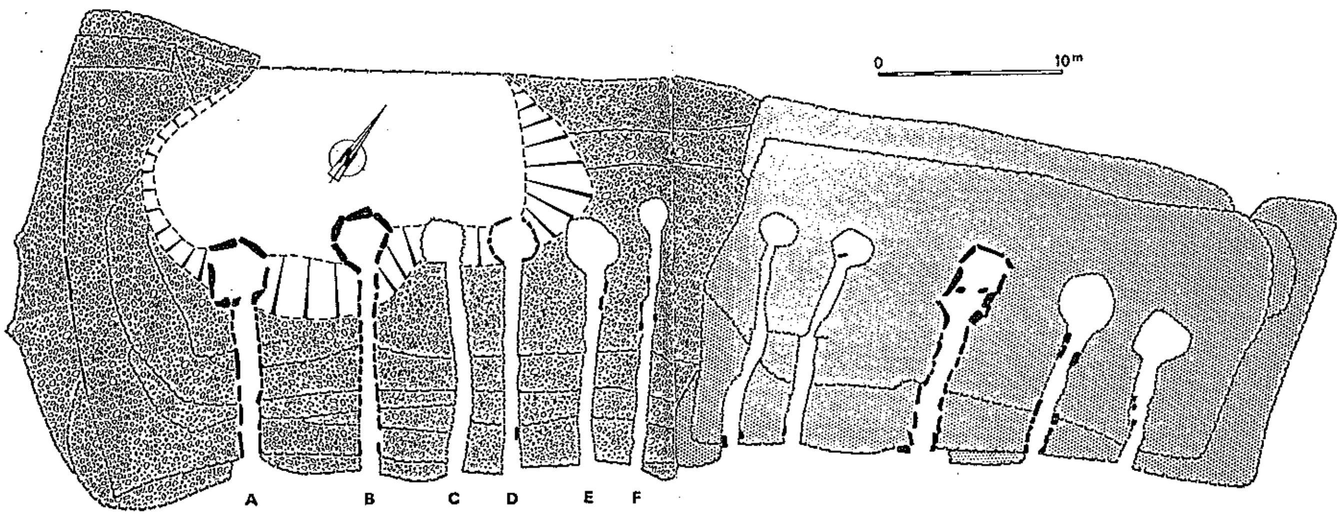
The stones utilized for building the monument of Barnenez are of two principle types. First the local metadolerite, available from some outcrops around and chiefly from the cliffs lower down; gathering the blocks will have been an important work because of the huge volume of this dark rock implemented. It was used for all the revetment walls and the mass of the primary cairn, something about 3000 tons. In the second cairn, it was used for the inner core, their two and partly three revetment walls.

The other category of stone was from four different varieties of leucogranites. In the first cairn two types of granites associated from the rock (present tidal island) of St Erec, 2 km to the North, were utilized for the orthostats, capstones and dry-stone walling of the passage-graves. In the second cairn two other granites, from the North-East and the South-East, at about the same distance, gave some slabs for the passage-graves, conjoined with those from St Erec; but here all these granites contributed also to the outer revetment walls. This is the reason why the primary cairn has a darker general hue than the secondary one, a quite noticeable point, especially from a distance.

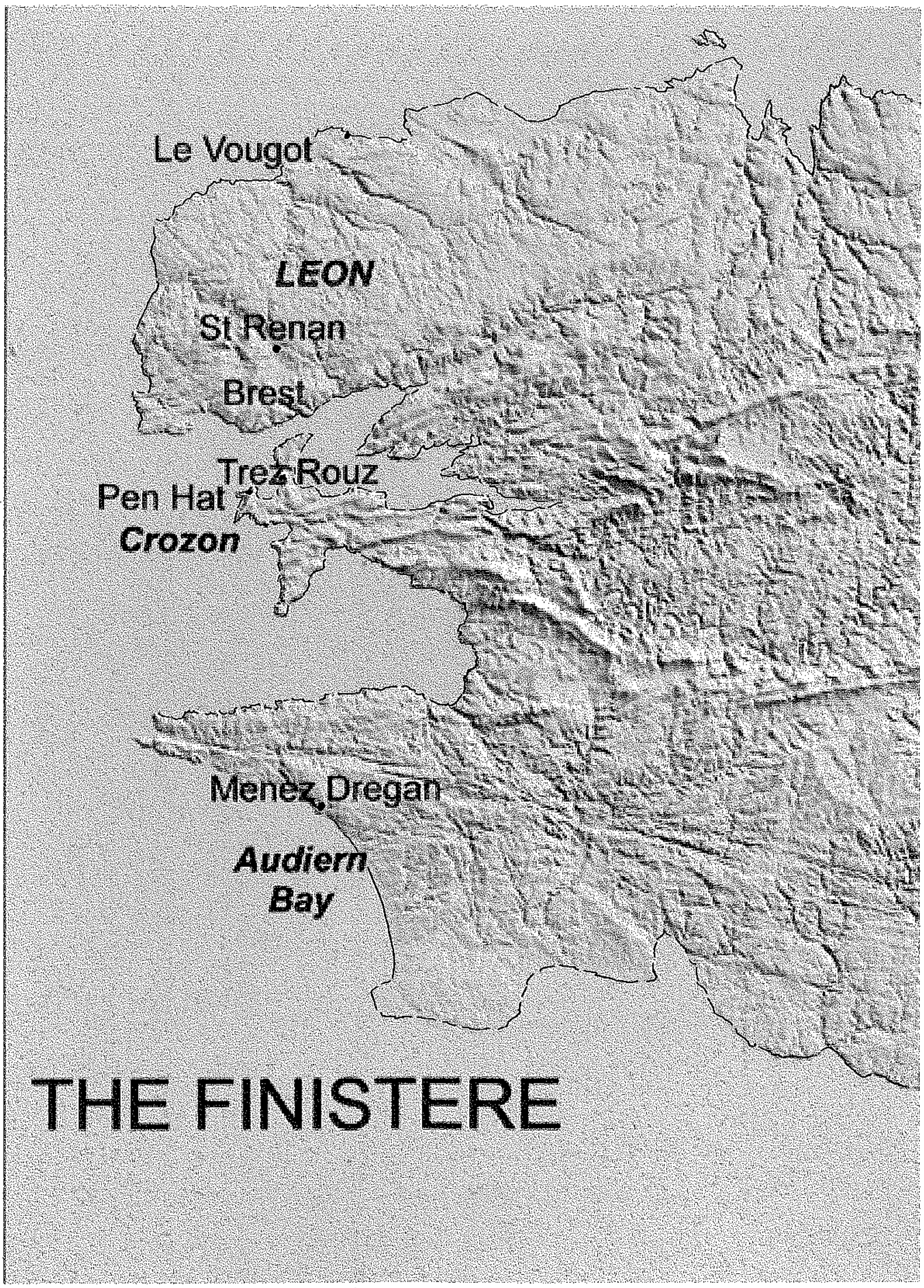
societies who engaged such efforts in building them. And some reasons to admire the technical capacities of their engineers.

CONSTRUCTION PHASE 1





CONSTRUCTION PHASE 2


Le Vougot
LEON
St Renan
Brest
Trez Rouz
Pen Hat
Crozon
Menez Dregan
Audiern Bay
THE FINISTERE

The north-western coast of Finistere, is strongly incised by small esturarine, called "Abers" or "rivière" and by a wide shore platform, partially flooded or buried by marine, dune or periglacial formations. Residual outcrops of granite forms rocks and are usually surrounded by the maximum thickness of deposits. A fossil cliff is locally preserved. Weichselian aeolian deposits are important in the East, near Roscoff, but their thickness decrease to the West and the South. The Upper Heads follow the same rules, allowing a fair preservation of older deposits in S-W Brittany. In the isles and at the edge of the shore platform, N of the Leon, marine sequences are poorly preserved, but in the matrix of all gravel bars, the elements of several successive transgressions are preserved, separated by interglacial pedogenesis. They are in direct superposition as in Molène, but sometimes with interstratified shore ice rafted blocks (Beniguet).When the general level of the platform lowers or is excavated by abers, the deposit at the foot of the fossil cliff are eroded by the sea. Between Le Vougot and le Zorn , the Holocene sea reaches the fossil cliff, leading to thick , complex shore face sequences interstratified with soils and periglacial formations, often preserved in shallow depressions of the platform. The main platform lies at 100m. Like at St Breech, this platform is rather old: pre-Oligocene valley elements incise it . It is the St Rennin /Abed Ildut depression.

Crozon Peninsula is another anomaly of the Finistere. It is formed by the southern flank of Rade de Brest synclinal is criss-crossed by several main fault systems such as the Kerforne (N145°) and the Elorn valley system (N070°-N045°). A high, relictual relief is preserved at le Menez Hom, with marine gravel remains up to 200m in altitude. Related with the fault systems, the block morphology of the peninsula allows the preservation of very old units. The Trez Rouz section is one of these exceptional sites. Penhat section, in front of the Atlantic waves, is with Port Lazo , one of the most complete sections for the middle and upper Quaternary of Brittany.

Audierne bay lays south of the CSA. It corresponds roughly to a shore platform tilted southward and reaching the sea level close to Pont l'Abbé. Most of the sector is controlled by faults parallel with the Kerforne Fault system. The cliff at Gwendrez is directly controlled by these as also at Menez Dregan.

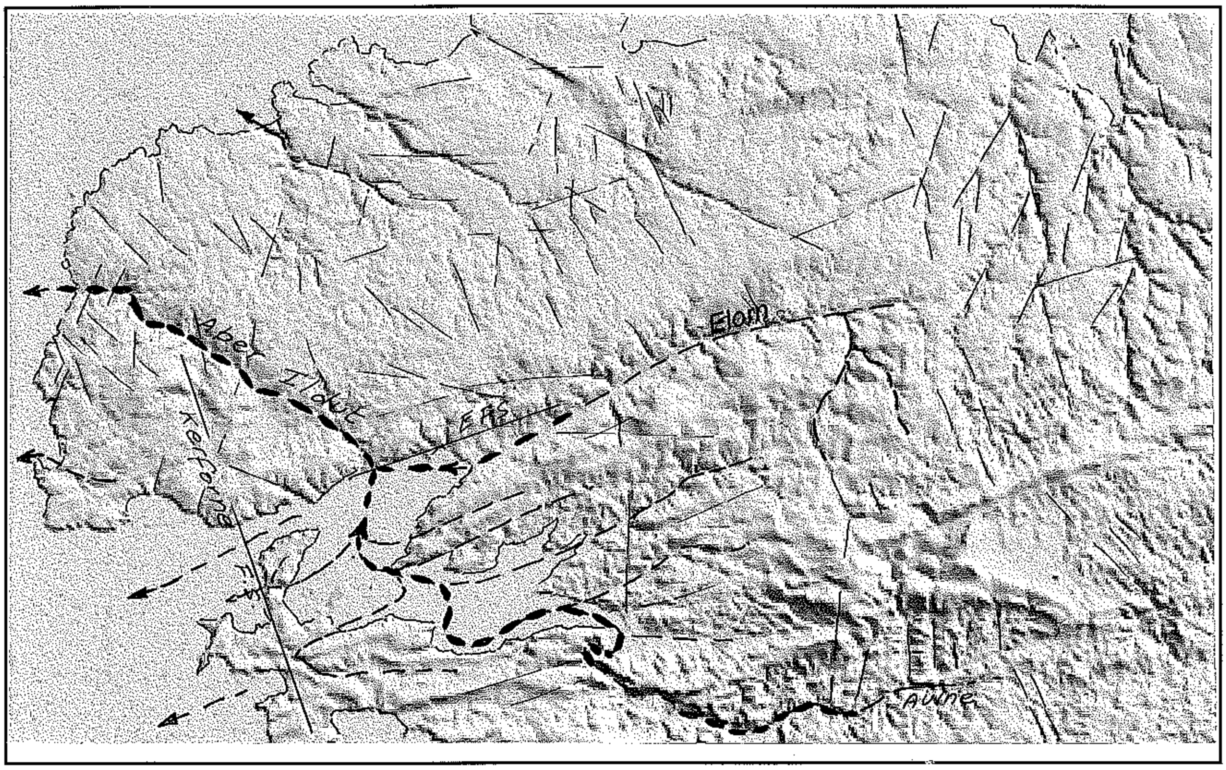


Fig. 1: Paleo-network of North Western Brittany
(Hallégouët,1971 & 1976)

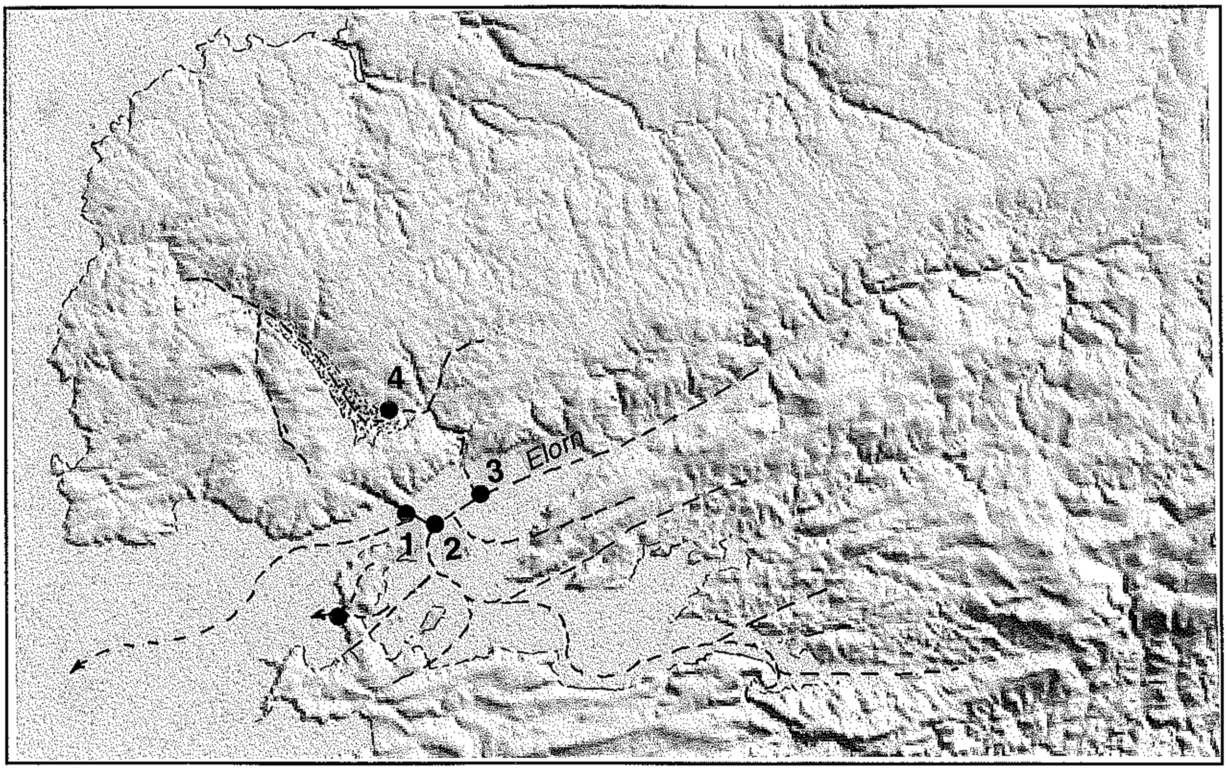


Fig. 2 : Successive steps of transformation
of the hydrographic network of the Aber Ildut

ST RENAN SECTION AND THE ABER ILDUT VALLEY

B.HALLEGOUET & B.VAN VLIET-LANOE

The Aber Ildut valley is a dead valley, formerly draining a basin equivalent to the whole drainage system of the Rade de Brest (Elorn, Aulne). This valley is incised in weathered granites and micaschists. After the exploitation of cassiterite rich pleistocene sediments, new prospectings were done in the sixties to find other placers. Deep showed the existence of older alluvial, marine and aeolian units, reworking armorican sandstones, and eocene quartzites, outcropping in Central Brittany only. Stratigraphy consist in gravels, sands, greyish clays, peats and heads. Palynological investigations of some organic layers, performed by M.F.Ollivier-Pierre (in Hallégouët *et al.*, 1976), showed that the lower units were belonging to the Lower Oligocene. At that time the river flowing trough a marshy valley surrounded by forest. Locally lignite and silicified or pyritized branches were found (*Castanea sp., Pinus sp., Cupressus sp.*). Evidence of a marine transgression at 35m was found and at that time the valley was active as an inlet just like a present day ria, with a very unstable apparent sea level. The architecture of the sedimentation is quite complex showing evidence of successive meandering systems including rocky islets. The organic beds of Pont Corf belong to the lower Stampian.

The fact that these formations do not outcrop in terrace but fill a former river bed show that this valley was already incised before the early Oligocene and remained active until the capture of the river head by these of the Goulet de Brest. The « Goulet » river captured first the Aulne, the Elorn and in last the Penfled-Aber Ildut. During the Neogene, the "Goulet" river has cleared the Rade de Brest. The Neogene high stands (Piacenzian and Zanclean) have again invaded the paleovalley. Peaty deposits in very acid enviroment occurred at the end of the Tertiary.

During the cold events of the Quaternary, periglacial activity and frost shattering, very active in this deeply weathered environment, have provided debris reworked by the braided periglacial rivers. Most of the deposits belong to the last Glaciation but some paleosols are older.

At St Renan (Bodonou), the valley morphology is controlled by a serie of small pull apart basins, controlled by a satellite of the Kerforne F.S. (N145°) and large paleogene meanders incising the slopes . The depression is filled by fluviatile formations apparently since the Oligocene. Two main phases of deformations are visible: a regular pattern of upward injections of clays, delimiting folds of 5-8m in diameter and 2-3m high, affects the lower fluviatile beds and ends with gyttja of presumed Praetiglian or Tiglian age (Gelasian) ; shearing microfaults (N160°), kinking fabric, sedimentary dykes and water escape pipes are common. The upper part of the sequence is a middle to upper Quaternary fluviatile sequence including humic silts , loesses and a pedocomplex ranging from isotopic stage 9 (?) to stage 5 (*sensu lato*). The deformations with upward silty injections, positive compressional flowers are oriented following a shearing component into the valley (anticline, N160°) and polyphased. The last phase occurred after stage 5 but before the main Young Loess deposition (stages 3-2) . St Renan (shear fold) seem also to correspond to a short-live compressional shear

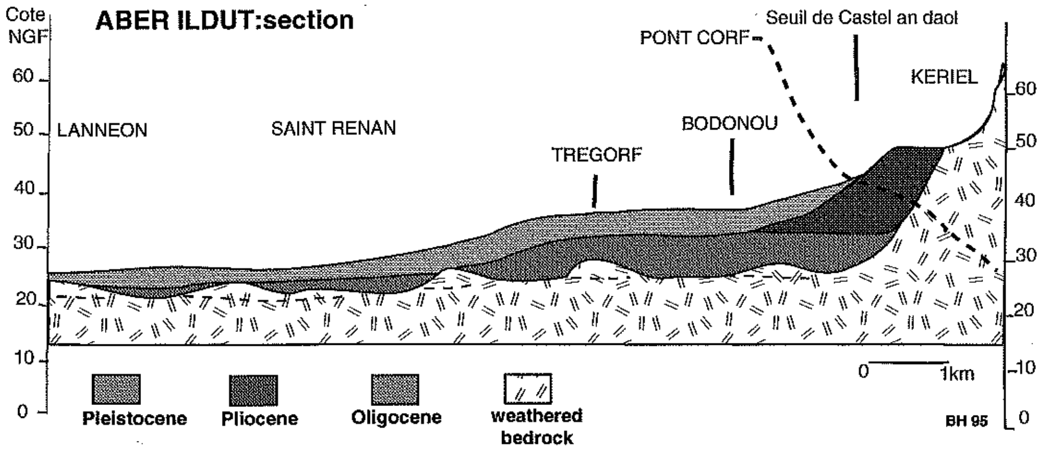
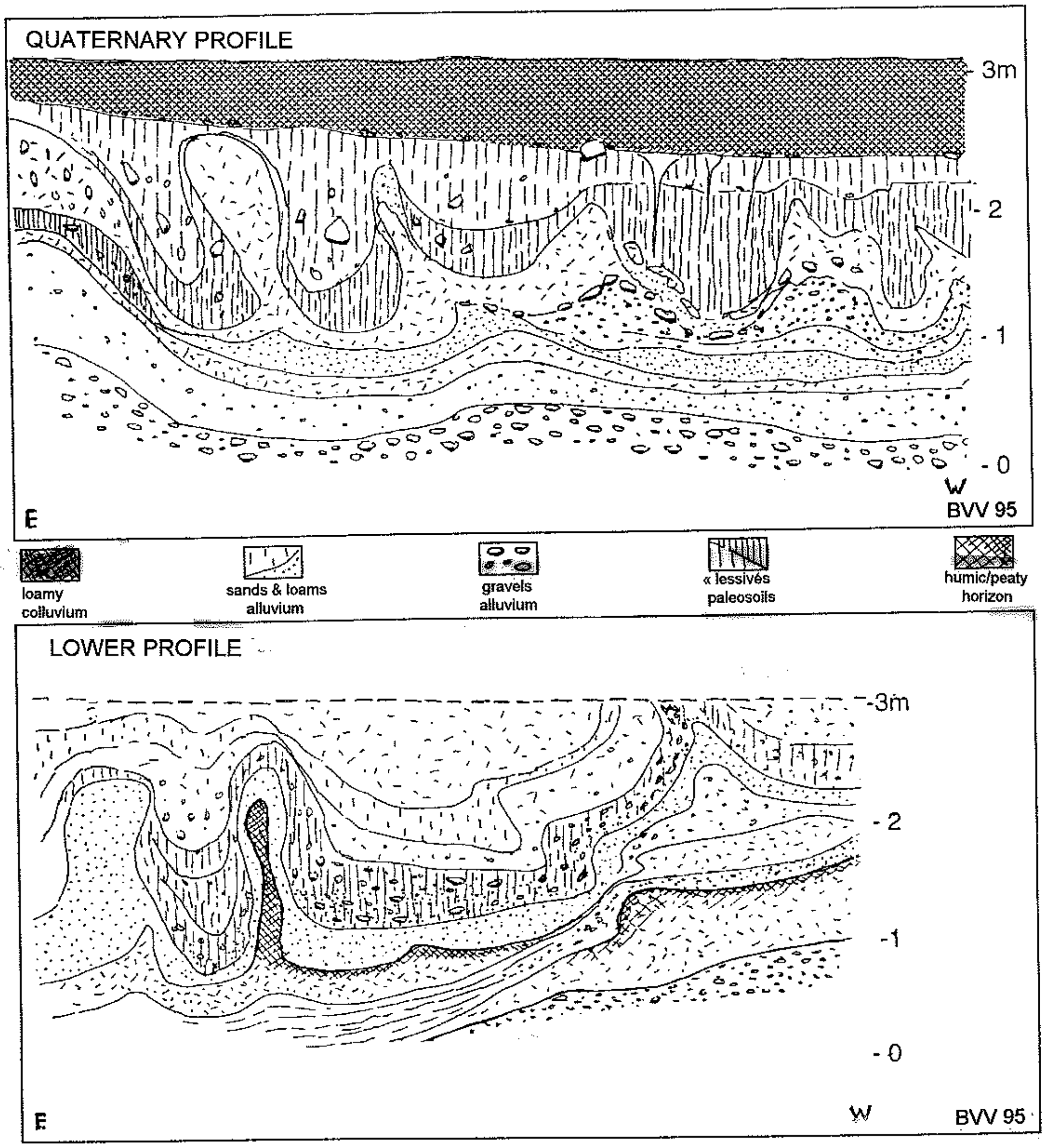


Figure 3 : crossection and profiles in the Aber Ildut valley . Profiles are located at Bodonou. Notice the deformations of the weathered substratum and the co-seismic involutions in Quaternary and late Tertiary (Pliocene ?) profiles.



deformation occurring roughly with a right strike-slip vector (Sylvester, 1988) on the Kerforne F.S..

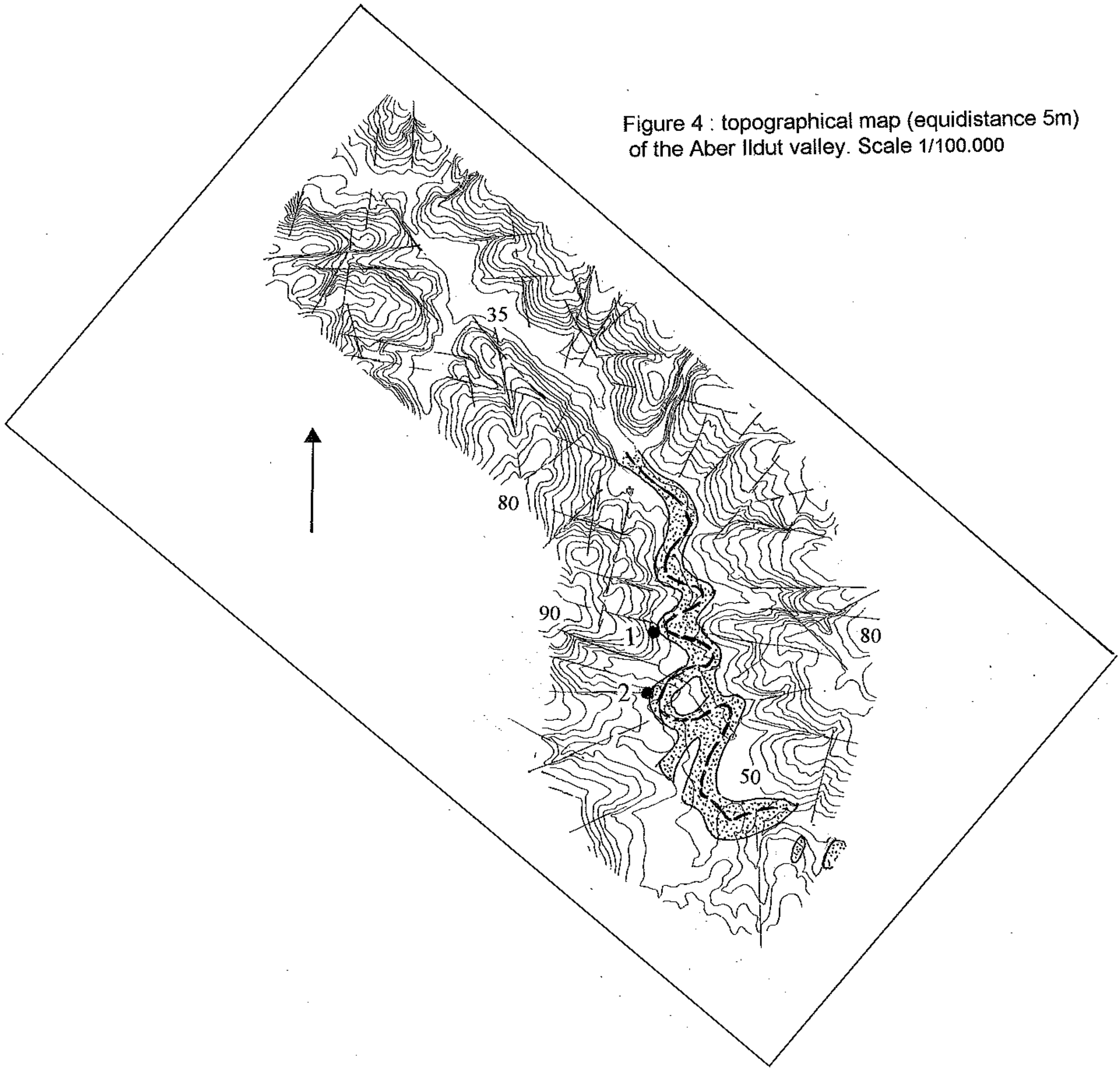


Figure 4 : topographical map (equidistance 5m) of the Aber Ildut valley. Scale 1/100.000

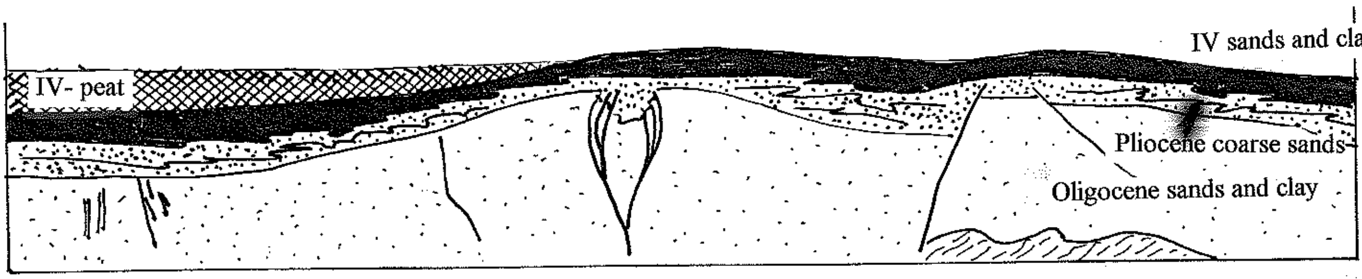
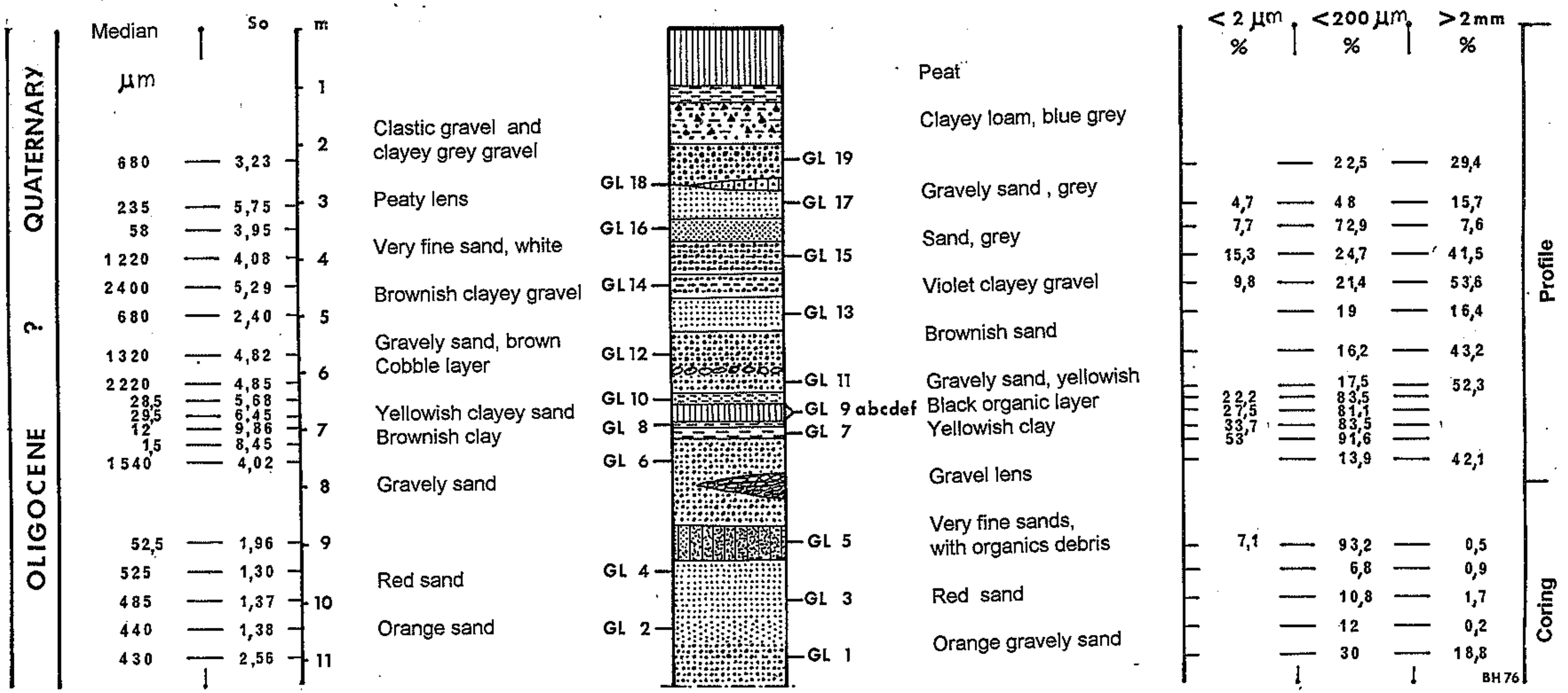


Figure 5 : compressive-shear figures (« negative flowers ») at St Renan (after a drawing of C.Hibsch)

GUILERS : PONT_CORF T1 : North-East Profile



LE VOUGOT
A last Interglacial -Glacial record

B.HALLEGOUET, B.VAN VLIET-LANOE

Location

The tidal platform of NW Brittany, between Kerlouan and Plougerneau peninsula is sligtly subsiding and the sea reaches directly the Pagan paleocliff (fig.1a, b, c). Opposite, there Leon platform seems raised. Close to the anchoring of the dune ridge of Vougot, marine erosion incise the slope deposits accumulated at the foot of the paleocliff. This profile is located 1 km north of the CNA, which correspond to the southern boundary of the metamorphic zone in the migmatites of Plougerneau. In front of the paleocliff, the Pagan tidal plateform is deeply incised by a submarine valley connecting at -80m with the Channel platform and is limited seaward by a step-like paleocliff from -15m to -80m. This drowned paleocliff dates probably from the Tortonian highstand.

Stratigraphy

The profile is partly buried under aeolian sands. There aggadation has allowed since 5 years the restoration of the dune ridge destroyed by anthropogenic perturbations. The main profile (fig.2) is still visible along 50m from the rocky cliff, where fossil beach gravels outcrop up to 15m above the highest sea level.

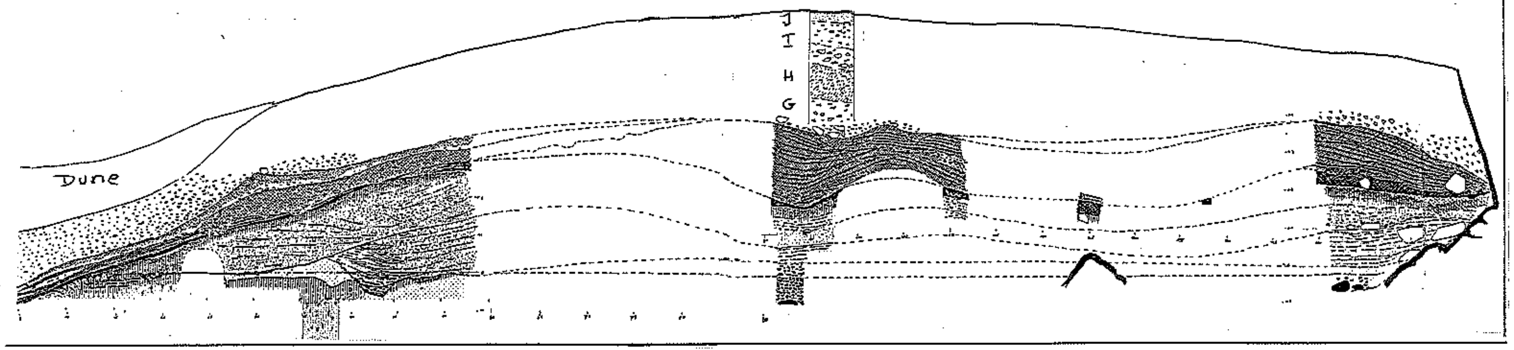
From the base to the top:

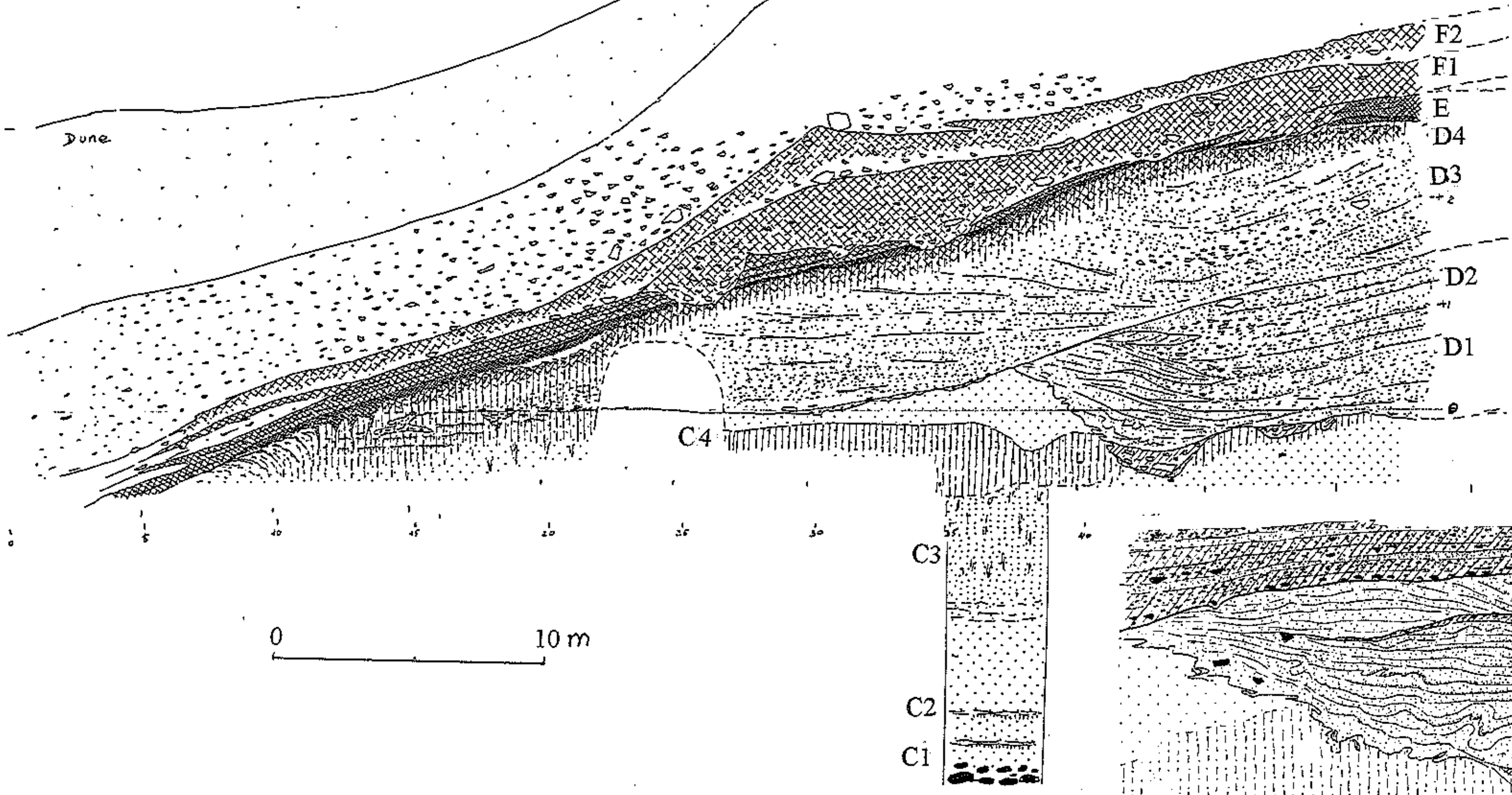
C1: gravel and cobbles in a sandy matrix, resting on an irregular tidal platform
C2: marine sands , including few, isolated cobbles
C3: old dune sands, finer in the upper part
C4: second dune sand, supporting an ochreous colour B horizon.
This basal complex is incised by a gully and further by heads

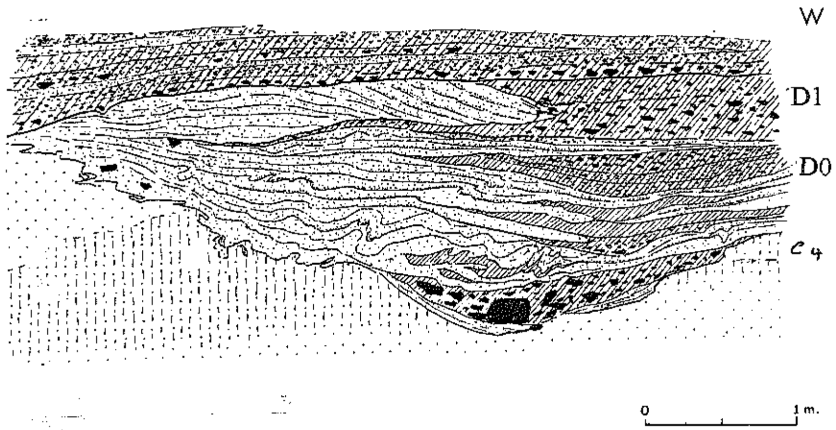
D0 : sand, including gravels and clasts in layers, regularily stratified with some involutions.
D1-D2: stratified sands and grusses, with coarser layers including clasts
D3 : stony sands and grusses , with loamy admixture in the upper part
This formations are strongly weathered by a podsolic soil and are associated with few frost wedges penetrating C units.
D4 : hydromorphic podsol, streched by frostcreep to the East

E1 : sandy humic heads including large granitic blocks, well preserved close to the cliff
E2 : cryptopodsolic ranker soil, only locally preserved from erosion and streching by frostcreep.

F: sandy loam, humic heads including 2 subarctic meadow soils, F2 and F3, reworked by gelifluction (granular microfabric).





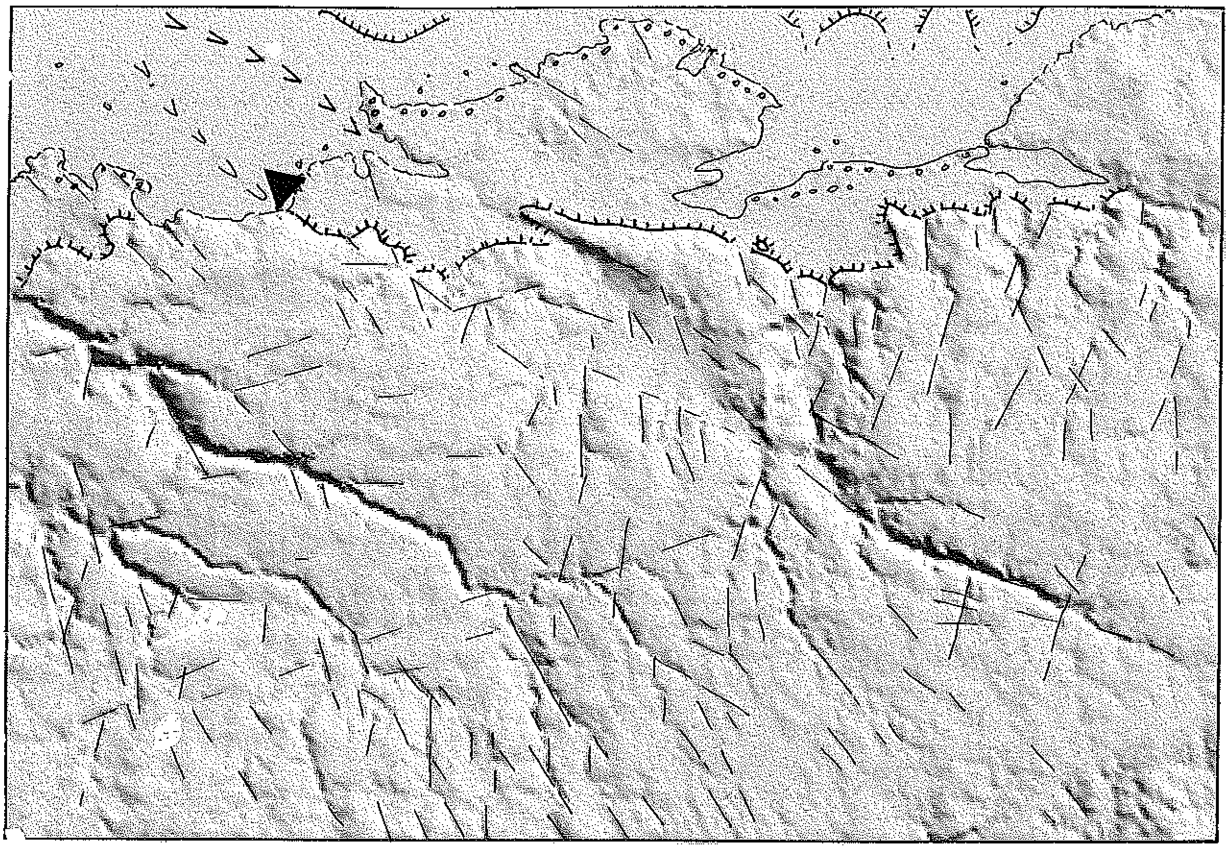


LE VOUGOT (BVV & BH 85)

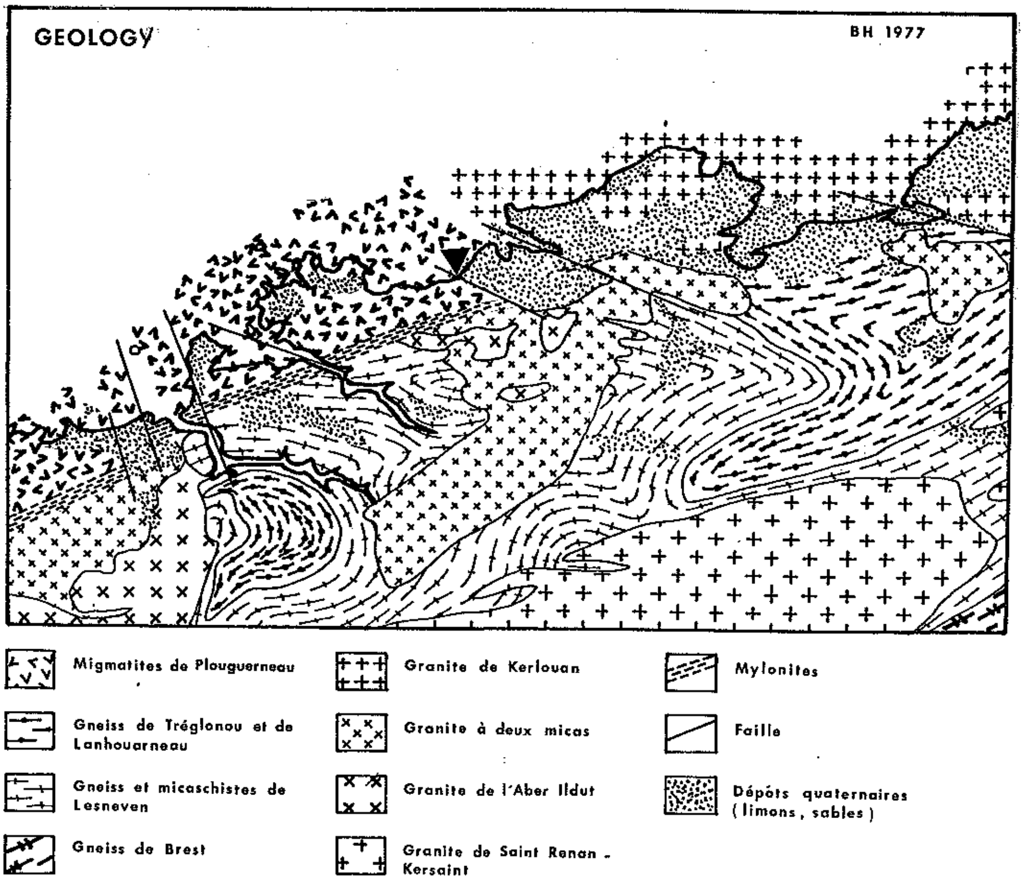
A) Main section (L : equidistance 5m, h : 1m)

B) Cliff section

C) Channel detail. It incises a late Eemian paleosoils



Le Vougot : Tectonical and Geological setting of the Northern Coast of Leon

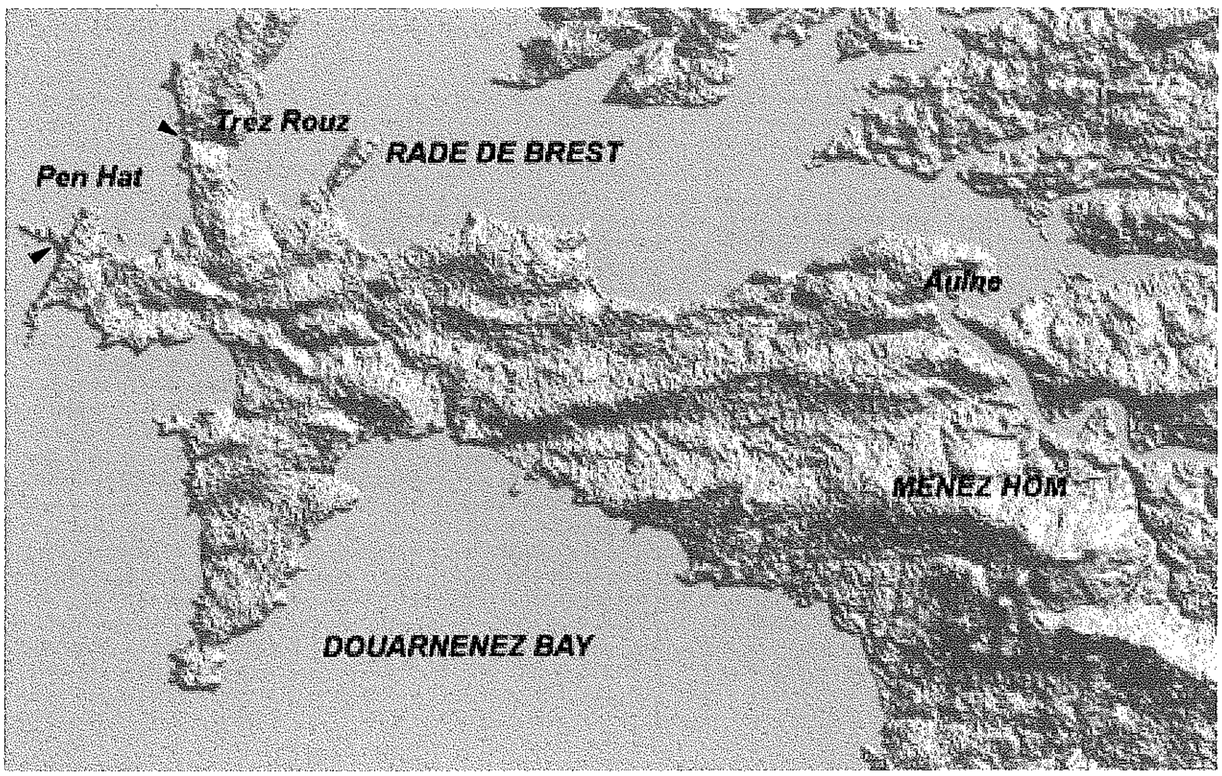


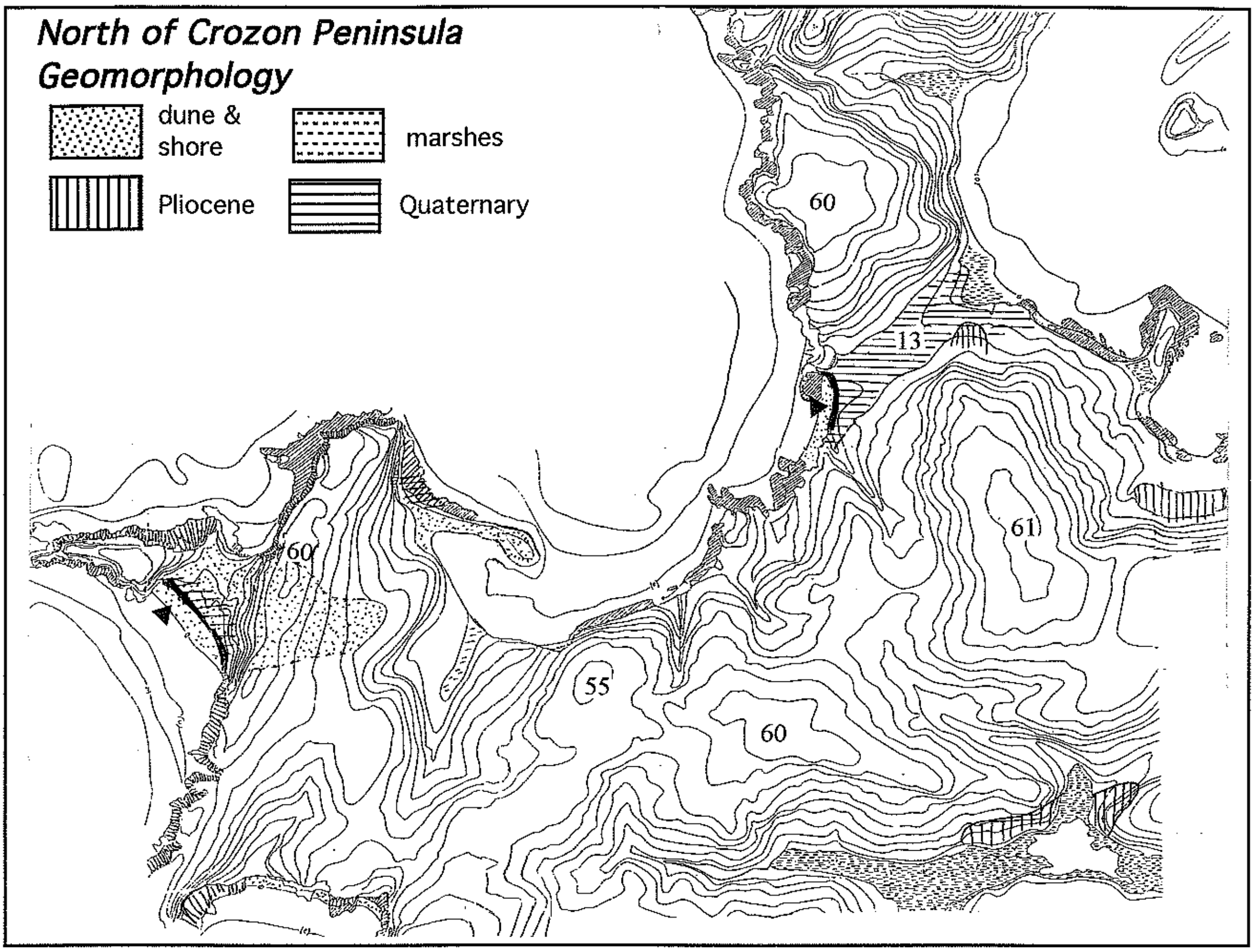
The upper part of the section is essentially heads and loams, streched eastward.
G: coarse grussy heads, with blocks and clasts, including a short stabilisation with a brown soil development
H: loamy heads
I : loessoid loams, thickening towards the East; including a Fraglosudalf
J: coarse loams eroding and reworking locally I.

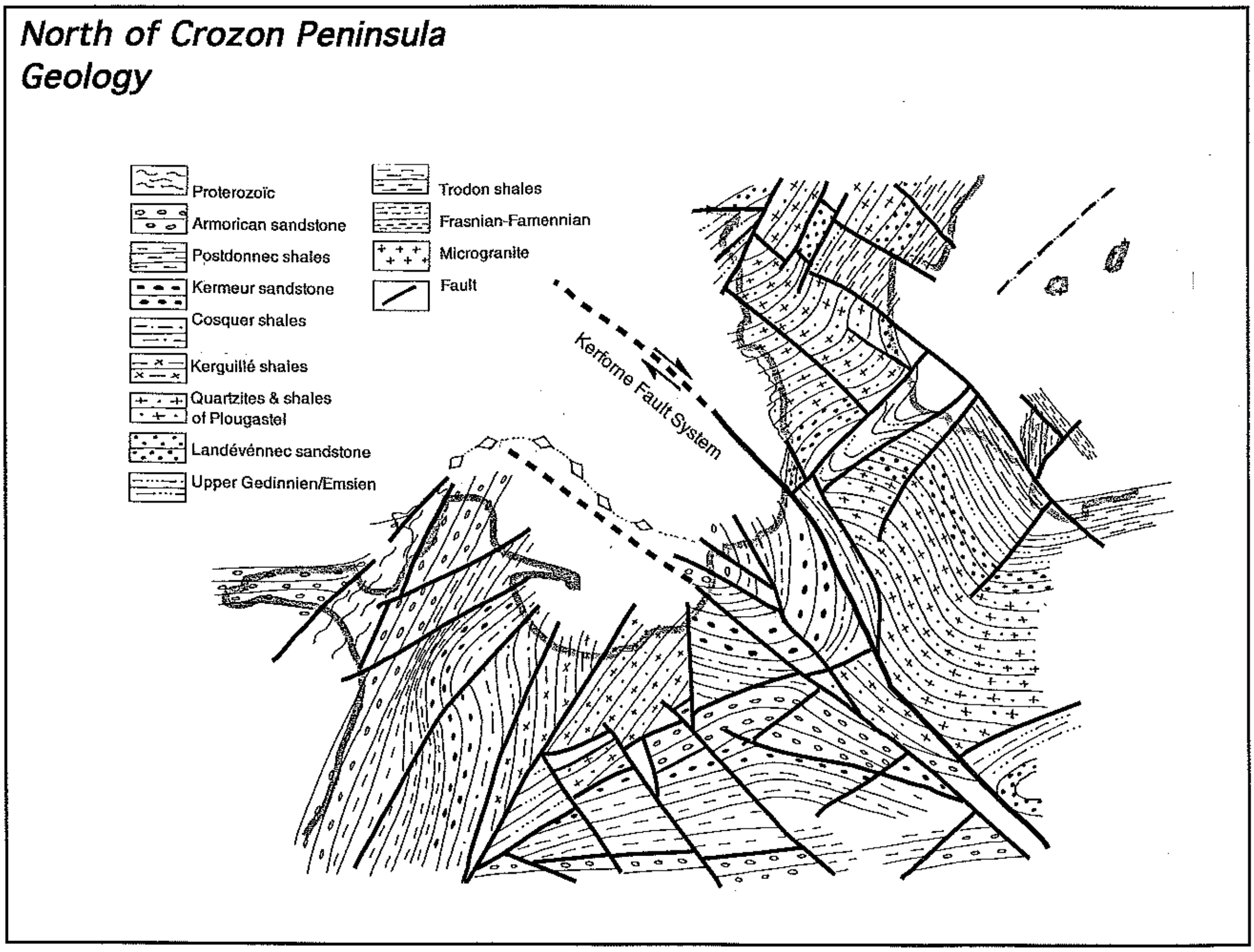
Interpretation
The lowermost unit , is presumed to belong to one of the phase of the Eemian. This interglacial complex has reached in the region (Plougerneau region) up to 2-3m above the HWM. The gully and its infilling belong to isotopic stage 5d . The main hydromorphic podsol correpond as in Normandy and Jersey to isotopic stage 5c, the hydromorphy developping in a late phase, after the Brouennou Event a short cooling event associated with frostcreep. Humic heads E1 cover stage 5b and the soil E2 isotopic stage 5a. The humic loamy heads F correspond to stage 4 as in most of the continental Western Europe and heads G , correspond rougly to stage 3. The Upper "Loesses" are correlated with stage 2 as in St Brieuc Bay, but here a late phase of frostcreep and erosion was active during the Younger Dryas, as in Cornwall, related to more humid paleoclimatic conditions already at that time.

Archeology
The heads and streched subarctic meadow soils (unit F) have provided some artifacts.

CROZON PENINSULA




North of Crozon Peninsula
Geomorphology
dune & shore
marshes
Pliocene
Quaternary
60
13
60
61
55
60


North of Crozon Peninsula
Geology
Proterozoïc
Armorican sandstone
Postdonnec shales
Kermeur sandstone
Cosquer shales
Kerguillé shales
Quartzites & shales of Plougastel
Landévénnec sandstone
Upper Gedinnien/Emsien
Trodon shales
Frasnian-Famennian
Microgranite
Fault
Kerforne Fault System

TREZ ROUZ

An Holsteinian shore complex

B.HALLEGOUET , B.VAN VLIET-LANOE, M.FIELD, M.LAURENT

Location

Trez Rouz section (western Brittany) is located on the northern branch of the Crozon peninsula, in a site under the influence of several branches of the Kerforne F.S. (N150-N160°) and at 300m to the north of a satellite fault from the Elorn F.S. (N020°) . The outcrop is at the western end of a graben crossing the northern branch of Crozon Peninsula, just in the prolongation of the Elorn fault system. This graben is surrounded by Pliocene deposits.

Above the high water mark (6m NGF), an alluvial folded / faulted Quaternary peat (TZ2, in the further description) is interstratified into periglacial slope deposits (Collin, 1913 ; Melou,1968). A sandy layer is intercalated within the peat complex attributed by palynology to the Holsteinian by Morzadec (1974),unit TRZ3. This complex rests on a weathered shore platform.

Stratigraphy

Main profile, limited to the north by a fault in contact with thick saprolite:

TZ 1: clayey loam including angular clasts; light yellowish brown (10YR 5/2); <u>lower head</u> *(TRS 1)*. This unit does not contain garnet (Mélou, 1968).

TZ2 : <u>the peat complex</u> . This unit reworks garnet.

- TZ2a: clayey loam, greyish with mottling (5Y 4/1), faintly stratified, laterally linked to organic accumulation of gyttja type, truncated by a stone line *(TRS2)*.
- TZ2b: loamy clay, organic , dark grey (5Y2/1) *(TRS3)*
- TZ 2c1: peat, homogenous, dark brown (10YR2/1) *(TRS3)*
- TZ2c2: water led accumulation of wood and bark fragments (coniferous, alder, birch, shrubs, ferns) , often in a vertical position (slumping) *(TRS3)*
- TZ2d: humic sand, sandy schorre soil *(TRS4)*
- TZ2e: peaty loam , rich in wood fragments, seeds (*Potamogeton*), richer in clasts to the top *(TRS5, TRM1)*

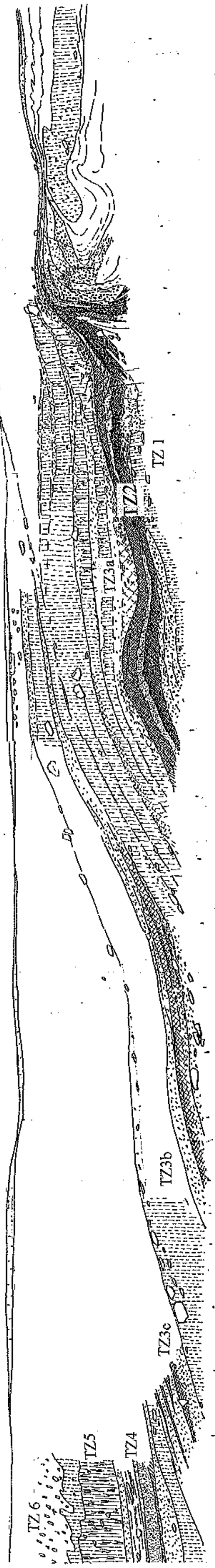
This complexe is buried by a serie of heads, sloping to the north :

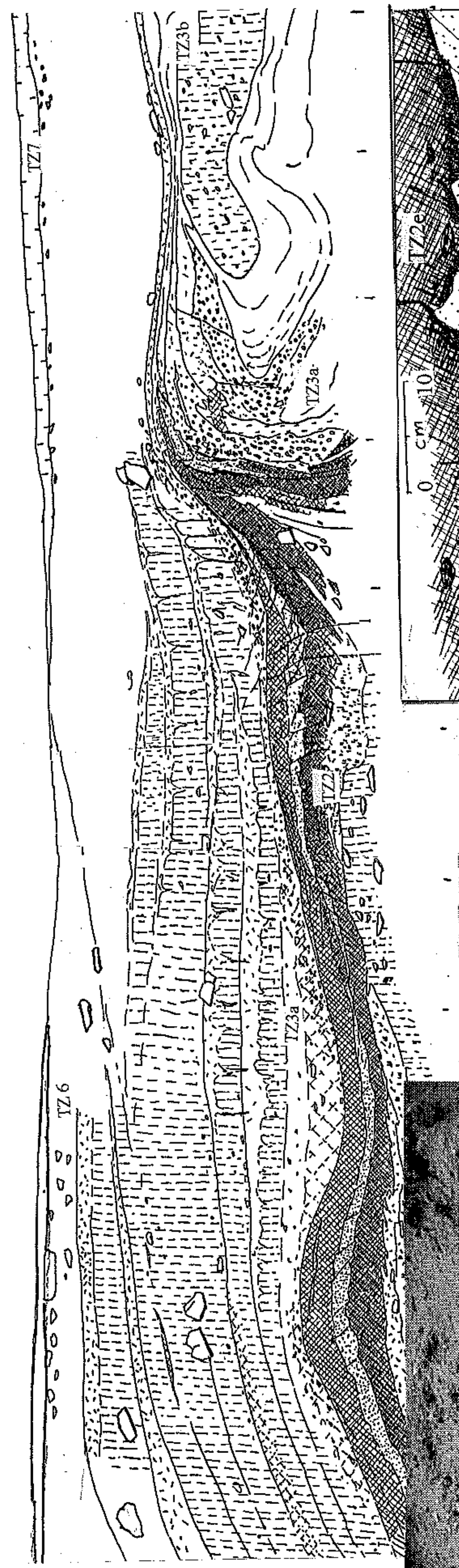
TZ3a :<u>a humic gley reworking quartz sand and gravel</u> *(TRS6)*.

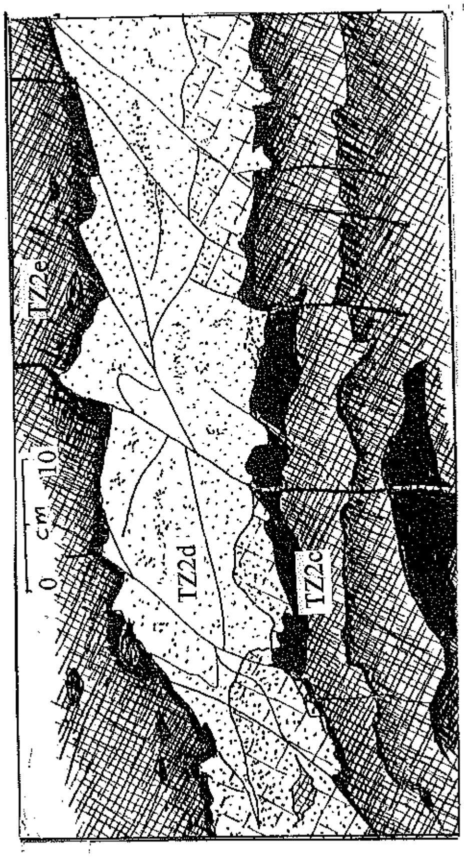
- TZ3b: consist in a serie of heads including several weakly developped paleosoils (pseudogleys to slightly humic heads), and ends with very coarse clasts *(TRM2)*.
- TZ3c: consists in a humic, very locally peaty material interstratified in heads *(TRN2)*,, with some coase clean sand at the base, A thick gley buried this serie *(TRS7, TRM3)*.

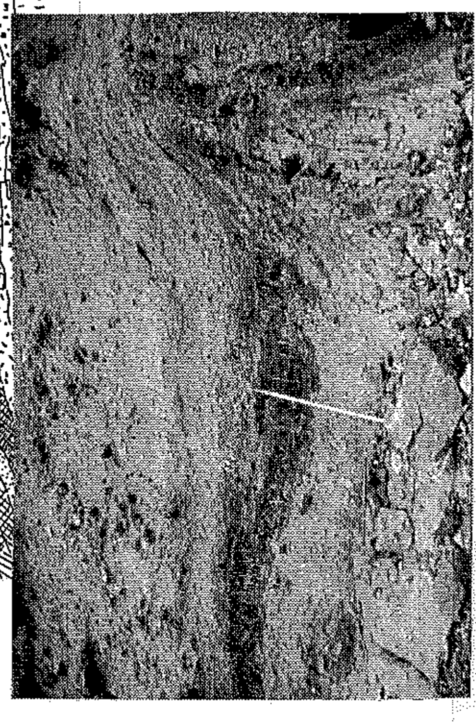
TZ4: <u>second serie of heads</u> (*TRN4, TRM6-7)*, partly reworking dune sand (TZ4c: *TRN5, TRM6)* and humic material (*TRM3-5)*, buried under bleached heads, including large clasts.

TZ5: clayey loamy <u>head, rubified</u> with some mottling (*TRN6, TRM8*), rubified pseudogley soil on reworked saprolite


TZ 1
TZ2
TZ3a
TZ3b
TZ3c
TZ4
TZ5
TZ 6


TZ7
TZ3b
TZ3a
TZ1
TZ3a
TZ 6


TZ2e
0 cm 10
TZ2d
TZ2c



TZ 6: yellowish heads *(TRN7, TRM9)*, mostly loamy, including stony pattern ground. Truncating the whole sequence with a slope toward the south. Including a « lessivé » paleosoil.

TZ7: thin loessic cover (to the south only)

On the southern side, between the most important injections, this layer is overthickened and consists in a deformed , metric aggradation of sandy to gravely serie including more loamy layers, somewhat organic. It ends apparently with a sandy loamy head, covered by a humic gyttja TZ3c. It looks like a tidal channel.

Two other bulgings of TZ2 complex occur to the south, only separated by 20m. After the rivulet, the bedrock is outcropping .

Palynology

Palynological analyse was performed in 1974 by M.T.Morzadec-Kerfourn. The interpretation given by this author is discussed further. The diagram has be reinterpreted in the light of the present-day geometry of the section.

PLANT MACROFOSSIL INVESTIGATION

M. FIELD (Coventry)

Sample locations are on fig. 3 .They correspond to TZ2a to TZ2e of the description.

Method

For each sample taken in the field a subsample of 200 cm3 was analysed for plant macrofossils in the laboratory. Subsamples were disaggregated in cold water and washed trough a nest of sieves down to a mesh of 150 µm mesh size. Macroscopic plant remains were then picked from the residues and identified with the aid of modern reference material.

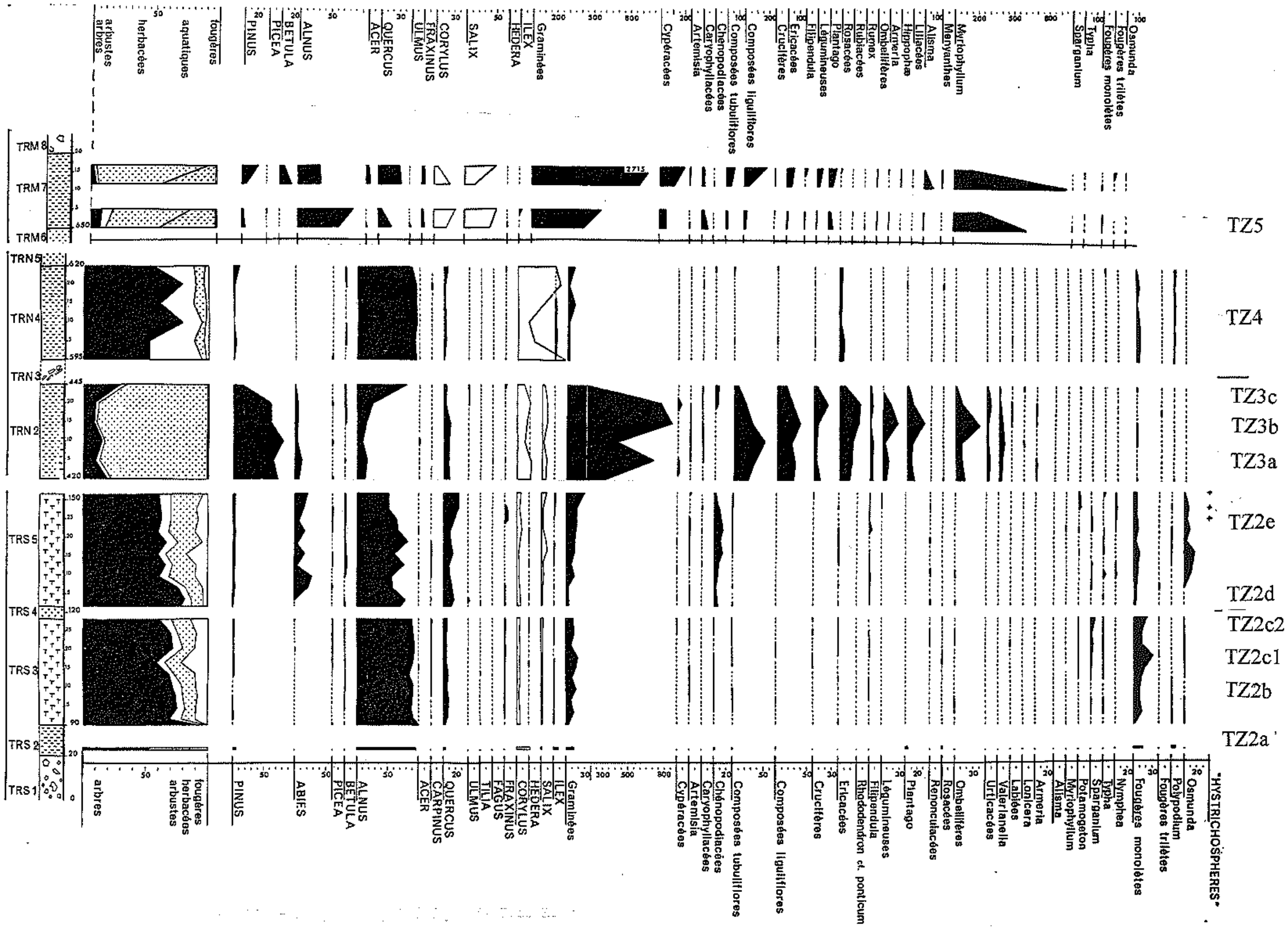
Results

The data obtained is summarised in fig. . This summary only includes well represented taxa and those important in the interpretation. The concentration of plant macrofossils varied through profile 1. In total, 52 taxa were recorded with 32 of these being identified to species level. It is possible to recognise four plant macrofossil zones: TZ2 /1 to TZ2/4

At the base of the profile, zone 1 is characterised by lack of aquatic plant remains. Both woodland, waterside and damp ground habitats are well represented. Various remains of *Alnus glutinosa* were recovered. This tree tolerates damp conditions and was probably growing as today , next to the marshy area. The sediment sample also yields a seed of *Taxus baccata.* Today *Taxus baccata* is not listed as a natural component of fenwoodland, but in the British Pleistocene record it did have this status (Godwin, 1975). The reedswamp contained at least 16 taxa including *Lycopus europeaus, Mentha* cf.*aquatica, Sparganium erectum* and *Typha.*

In the zone 2 which has a similar woodland, waterside and damp ground component, but differ from zone 1 because of the occurrence of a number of aquatic plants. The aquatic taxa suggest a shallow waterbody now existed. The water was probably still or

Palynological data of TREZ ROUZ sections. (from M.T.Morzadec, 1974) relocated in there logical stratigraphic position



slow-moving, medium to high alkalinity and mesotrophic to eutrophic. The presence of *Najas marina* may indicate that conditions were slightly brackish. other aquatic taxa represented that can tolerate slightly brackish conditions include *Ceratophylum demersum, Potamogeton pectinatus* and *Potamogeton pusillus.*

The next zone up the profile (1-3) has low concentrations of plant macrofossils. Remains of both aquatic , waterside and damp ground taxa were recovered. This zone corresponds to a sand horizon.

At the top of the profile it is possible to distinguish a further zone (1-4). Here the woodland, waterside and damp ground taxa are very poorly represented. The assemblage is dominated by three aquatic taxa: *Najas flexilis, Potamogeton pectinatus* and *Ruppia maritima.* The occurrence of the latter suggest that the waterbody was still shallow, but now possibly more brackish. *Potamogeton pectinatus* fruits are also common in this zone. this species survives a range of habitats and can tolerate up to 5,000 ppm Na+ (Haslem et al., 1975). *Najas flexilis* may also tolerate brackish conditions because Preston & Croft (1997) record it growing in machair lochs adjoining calcareous dune sand in Scotland. The reduction of freshwater obligates in this zone may also be a reflection of more brackish conditions and suggest that deposition of the plant macro-fossil more brackish than the water-body represented in zone 1-2. The poor representation of other habitats suggests the disappearance of a reed-swamp and damp woodland in the vicinity of the site.

Interpretation

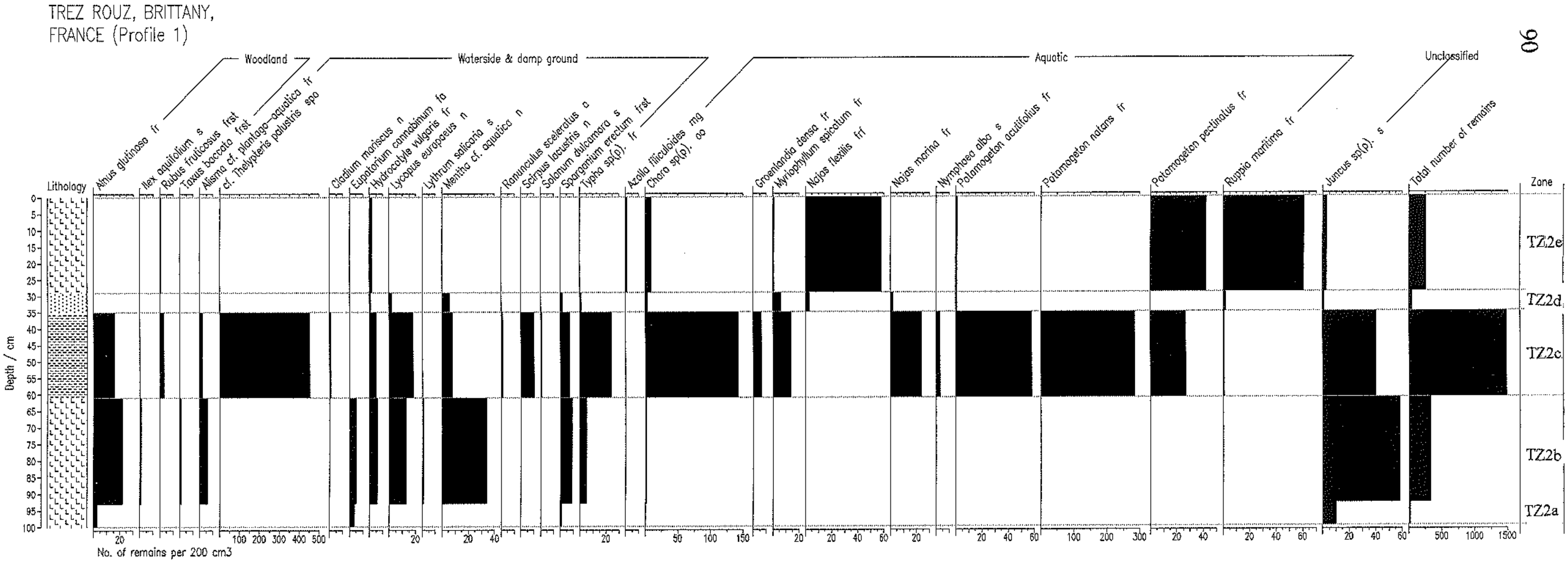
To summarise, at first , there may have been a marshy area which was then partly submerged under a slightly brackish , shallow water-body. After this, a period of sand deposition took place. This may relate to the movement of dune sand and its deposition into the waterbody. Finally, the water body may have become a shallow , but perhaps more brackish lagoon with the disappearance of both reed-swamp and damp woodland at the site. These events may have been triggered by salt spray during storms in combination with a rising sea level. An alternative explanation is the breach of a local dune barrier by the sea. .

The climate at the time of deposition may have been similar to that of north-west France today. All the taxa represented presently occur in the Massif Armoricain (Abbayes et al., 1971); Fitter, 1978), apart from *Najas flexilis* (Corillion, 1994). This species is absent from France today (Fournier, 1977) and has a modern amphi-Atlantic distribution with the bulk of its occurrences in North America (Godwin, 1975). Pennington (1969) describes *Najas flexilis* and *Najas marina* as thermophilous aquatic plants. The presence of *Ilex aquifolium* also attests to the relative mild conditions, as this species is intolerant of strong winter frost (Iversen, 1944).

It is difficult to determine the age of the sediments from the plant macrofossil assemblage alone. The presence of *Azolla filiculoides* may indicate a pre-Eemian age as it became extinct during the late Middle Pleistocene in Europe (Godwin, 1975). *Azolla filiculoides* was, however , reintroduced to Europe towards

Datings and stratigraphical attribution:

ESR Datings : Samples were taken for ESR at the level of TZ2d, TZ3a, TZ4b.



Plants macro-remains from TREZ ROUZ section . Analyse M.Field 1997.

The stratigraphical attribution is not problematic for the base compared with the attribution by Morzadec, 1974.

TRS5,TRM2,TRM3 = HO III = upper TZ 3
TRS2, TRS 3 = HO II = TZ 2

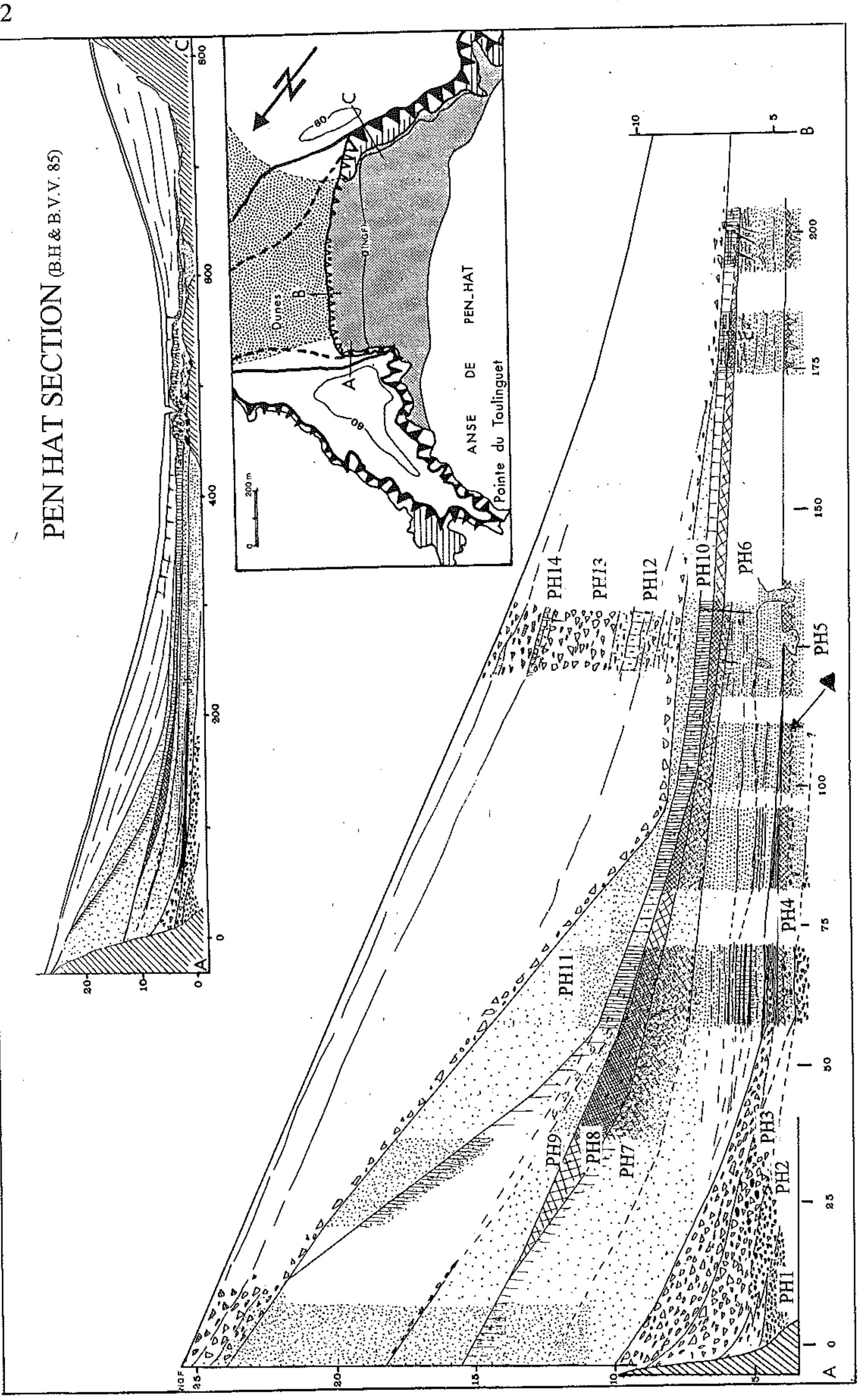
The last organic layers, the TZ4 complex is considered as an upper interglacial by Morzadec (1974) as Eemian (*TRN4, TRM7,TRN5, TRM6)*. The ecological attribution , an acid lacustrine deposit in a shore vicinity seems correct. The palynological data correspond to a eo-temperate vegetation *(Corylus,* despite presence of *Ilex)* for the lower part and the upper part to a late temperate period. The presence of a thin loess cover at the top TZ6 heads with pattern ground suggest that the whole sequence, below the rubified pseudo-gley soil in older than Eemian. In other dated sites, this rubification, partly inherited from the Landevennec sandstone , is related with some hydromorphism (thin sections) and seems correlative of isotopic stage 9a or older, never younger. The intensity of the pattern ground development is similar to these observed at the top of Pénestin section , developing during isotopic stage 8 (see Pénestin section p.).
The lower gravely part of TZ3 can be the trace of an tidal channel at the western end of the graben. This means that we have at least 3 tidal incursions (TZ2d, TZ3a, TZ4b) in cool temperate context, rich in sulfur (pyrite) and organics (low degradation of the OM). The altitude does not means anything as we are in a subsident area with neotectonic influence. As the profile does not present any trace of open channel from the Rade de Brest to the Atlantic, it implies that these apparently low shore levels

- or were settled at low altitude, as on Noirmoutier Island and in East Anglia ;
- or this peninsula was strongly subsident since that time. In Normandy, stage 11 outcrops at 30 m (Luc sur Mer).

This can means that the whole humic and peat complex (TZ2-4) can represent the whole Holsteinian as defined as defined by de Beaulieu et al. 1995, in other words the isotopic stage 11 of Martison et al., (1987) or stage 11 and 9b (TZ3).

Neotectonism

Deformation was attributed to periglacial activity. Recent observations have shown a succession of 3 to 4 upward dissymetric hydroplastic injections, oriented N020°, thin (less than 1m wide in section orthogonal to their extension) and mostly tilted to the S-E, in conformity with the present day slope. The deformations in the main injection include the sand, are later affected by antithetic micro-fracturation, dipping at 90° in the peat, underlined by jarosite, a sulphate complex inherited from the occurrence of pyrite, slipping in the TZ2c2 organic layer and in form of 20° microshear planes in the sand. Deformation and late faulting is sealed by heads TZ3c. These deformations can be attributed to co-seismic or neotectonic slump, occurring probably after the setting of TZ3. As the Kerforn F.S. is still very active today, occurrence of such deformations is not astonishing. .The age of the main deformation event can be deduced from the stratigraphy and ESR dates (Laurent, 1993). At Trez Rouz, the deformation is dated by the age of the peat Thus the deformation occurred within ocean oxygen isotope stage 11 or 9.



PEN HAT SECTION (B.H & B.V.V. 85)
ANSE DE PEN_HAT
Pointe du Toulinguet
Dunes
200 m
A
B
C
PH1
PH2
PH3
PH4
PH5
PH6
PH7
PH8
PH9
PH10
PH11
PH12
PH13
PH14

PEN HAT

B.HALLEGOUET , B.VAN VLIET-LANOË

Location

The Pen hat profile corresponds to a bay , at the westernmost end of the Crozon Peninsula, belonging to the Camaret township. It is located between the Toulinguet Point and these of Pen Hir, which continues westward with the « Tas de pois » rocks. Thoses points are armored by Armorican sandstones, rised by an anticline leading to the outcropping of Brioverian quartzophyllades. Thses rocks were abraded by marine erosion and are partly buried by pleistocene deposits, an holocene dune and a beach cobbles ridge occupying the northern part of the bay. Despite the presence of the beach ridge, the tide has excavated a cliff in the pleistocene formations inside the bay. This profile does not correspond to any paleotalweg. It is completely independant of the Rade de Brest fluviatile system.

Stratigraphy :

The most complete section is visible on the northern face of the bay, under the Toulinguet Point. The thickness of the Pleistocene outcrop reaches about 20m. The upper levels lower to the central portion of the bay, close to the pedestrian path to the beach and then climb again to the southern slope of the Pen Hir Point.

PH1 : marine cobbles and gravels in a loamy (coarse kaolinte) sandy matrix, resting on a platform cut into quartzophyllades.
PH2 : mixed pebbles and clasts in loamy matrix
PH3 : marine sands with some marine gravels
PH4 : hydromorphic podsol , buried by grey clayey sands with some sandstone and shales flakes ; locally incised by tidal hollows infilled by marine sands with local concentration of heavy minerals.
PH5 : marine sand bodies infilling hollows in PH4
PH6 : sand body interlayered with silty clay
PH7 : aeolian sand including gravels and clasts in its upper horizon and some frost wedges in southern part of the section.
PH8 : grey wooded podsolic soil developed in sand
PH9 : dune sand including some clasts
PH10 : reddish brown Bt horizon in sand
PH11 : loamy sands
PH12 : loam evolving to sandy loam to the top
PH13 : sandy-loamy head including many clasts of sandstone
PH14 : rubified and illuviated dune sand
PH15 : clast supported head, mixing sandstone and quartzophyllades
PH16 : discrete loamy lenses
PH17 : loamy head including many blocks of sandstone
PH18 :late to post-glacial soil
PH20 : Holocene dune sand including Pomatia elegans at its base, locally lithified (watertable -PH19) close to the access path.

STUDY OF THE INDUSTRY OF PEN HAT

N. MOLINES

The industry recovered by B. Hallégouët during the borings achieved in several points of the Penn-Hat cliff comes in the form of an homogeneous assemblage. 539 lithic pieces have been found.

This assemblage includes 53% of debris, that is to say some lithic remains whose mode of breakage can't be determined, and this without presuming their anthropic origin or not. Then, it comprises, by decreasing order, 33% of non-retouched flakes, 6% of cores, 4% of broken pebbles and more than 1% of lighter tools. The broken pebbles mostly show a cleavage parallel to their main axis.

The petrographic nature of the pieces is little varied: flint, glossy sandstone and quartzite. Except for the lighter tools, the flint is predominant with 85% of the debris, 91% of the cores and 89% of the non-retouched flakes.

The lighter tools only include denticulates on flakes, except for a tool on core. The most used raw material is the glossy sandstone (5 pieces out of 7). All these denticulates are well-made, with a convex cutting edge, an elaborated retouch, mainly stepped.

The "débitage" is non Levallois. There are 37 cores (34 of which are flint cores). The bifacial "débitage" is the most represented, mainly with the bipolar/unipolar combined mode and the centripetal/unipolar combined mode. The centripetal/bipolar combined mode also includes 5 pieces. The unifacial "débitage" mainly includes the bipolar mode with perpendicular striking platforms and the centripetal mode. On the whole, the "débitage" is quite simple despite the presence of the centripetal mode in the two types of "débitage". The average number of removals is 5. The cores are on average 44 mm long and 34 mm wide.

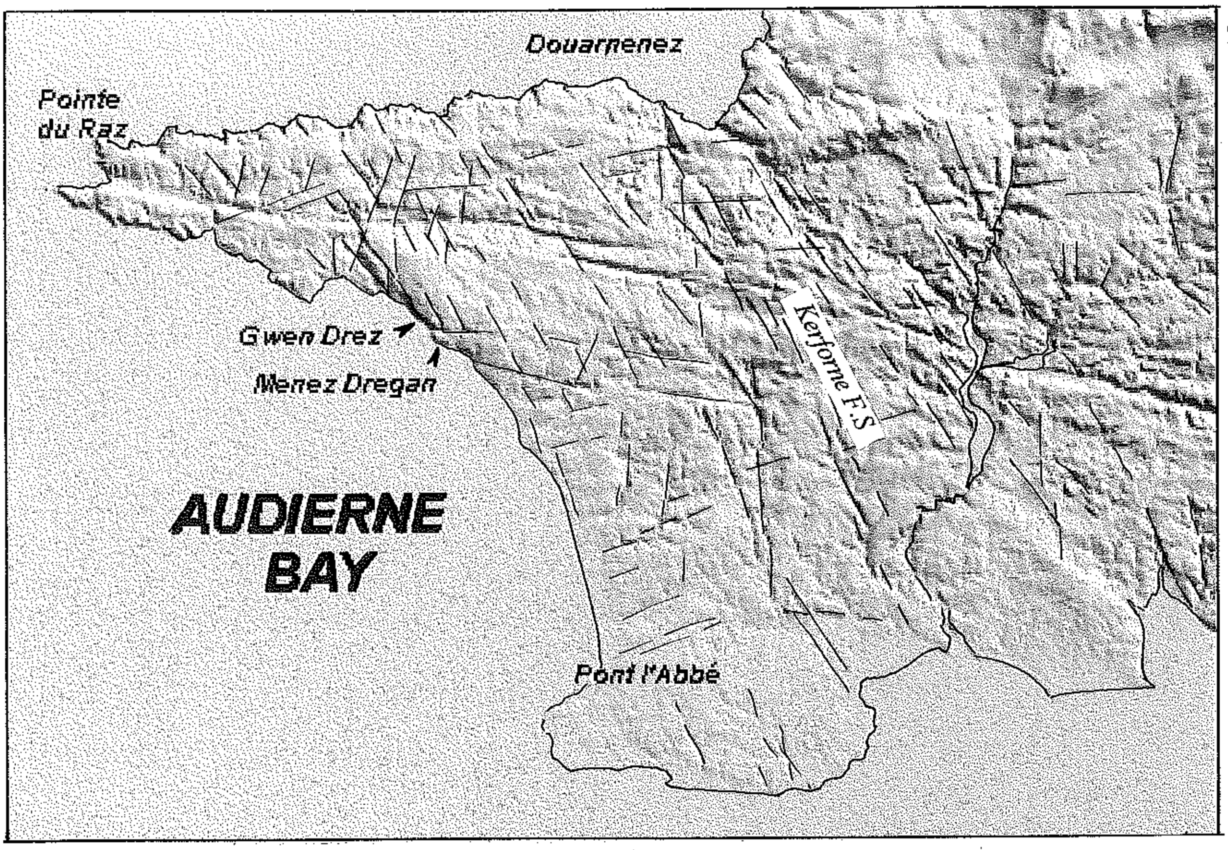
The non-retouched flakes are 182 in number. On the whole, whatever the raw material used is, the design features are the same. The first flakes and the flakes which present more than 50% of residual cortical surface are in great number, followed by the flakes without cortex, the pieces with a cortical back and the flakes which present less than 50% of residual cortical surface. The percussion cones are simple and the butts are, almost equally, either flat or cortical. There are no facetted or punctiform butts. The broken pieces are numerous (17%) as well as those which show traces of reflecting accidents (plunging or hinged flakes), which corresponds to 22% of the assemblage. The non-retouched flakes are quite small, they are on average 36 mm long whereas the majority of them is between 25 and 36 mm long. The average flaking angle is 95°.

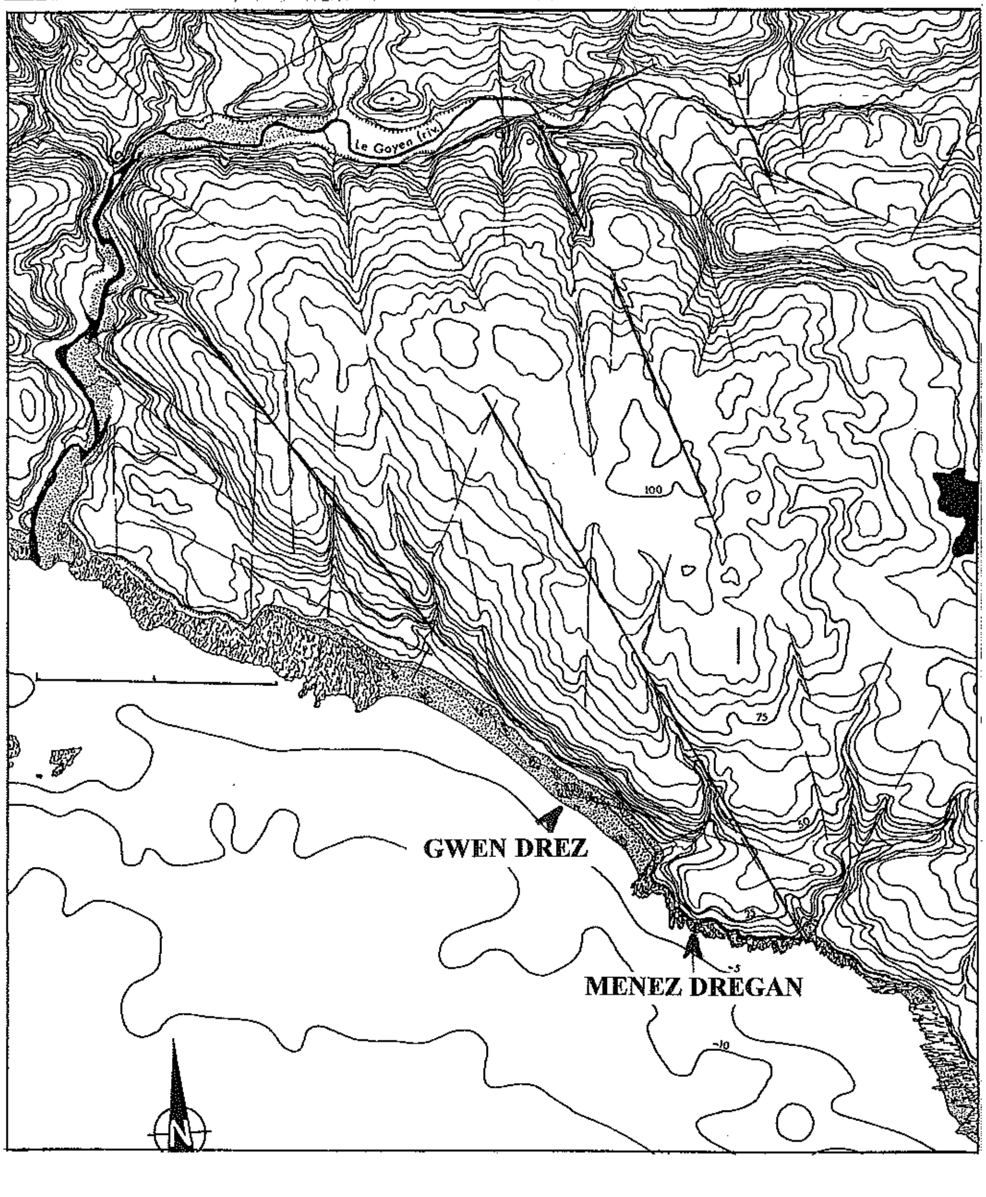
This industry attributable to the Lower Palaeolithic has numerous common characteristics with other sites situated along the South-Armorican coast (Menez-Dregan I, for instance, in particular for the industry of the layers 9 and 8). Even if some borings are achieved in Penn-Hat instead of an exhaustive excavation, the composition is similar : numerous debris and non-retouched flakes and the presence of broken pebbles in relative abundance. However, it is difficult to prove that the breakages of the pebbles have an anthropic origin since they may as well result from a percussion work or from some phenomenons such as the frost or anything else.

The design features are also simple: lack of Levallois technique, simple "débitage" which takes into account the centripetal mode. Because of their small size, the cores can't be exploited that's why the flaked blanks have accordingly been sized. This might explain why the blanks used for the lighter tools are made of glossy sandstone and are of a larger size.

In Penn-Hat, the lighter tools are mostly made of glossy sandstone whereas the site was the place of a very important flint "débitage" activity. In other sites, like Penn-Hat, the flint, even if it is only available in small nodule form, is the raw material preferred since the other materials don't have any clastic properties, unlike the flint.

In short, the site of Penn-Hat constitutes a supplementary landmark in order to explain the settlement of the Préhistoriques along the South-Armorican coast. Since the flint is only available in the Massif Armoricain in nodule form coming from the cretaceous chalks beds in the open sea, its presence in the offshore pebble bar might explain those settlements.





Geological & tectonical setting of Menez Dregan and Gwendrez

THE AUDIERNE BAY

MENEZ DREGAN AND GWENDREZ

J.L.MONNIER, B.HALLEGOUËT, B.VAN VLIET-LANOE, N.MOLINES, M.LAURENT, E.M. GEIGL, S.HINGUANT

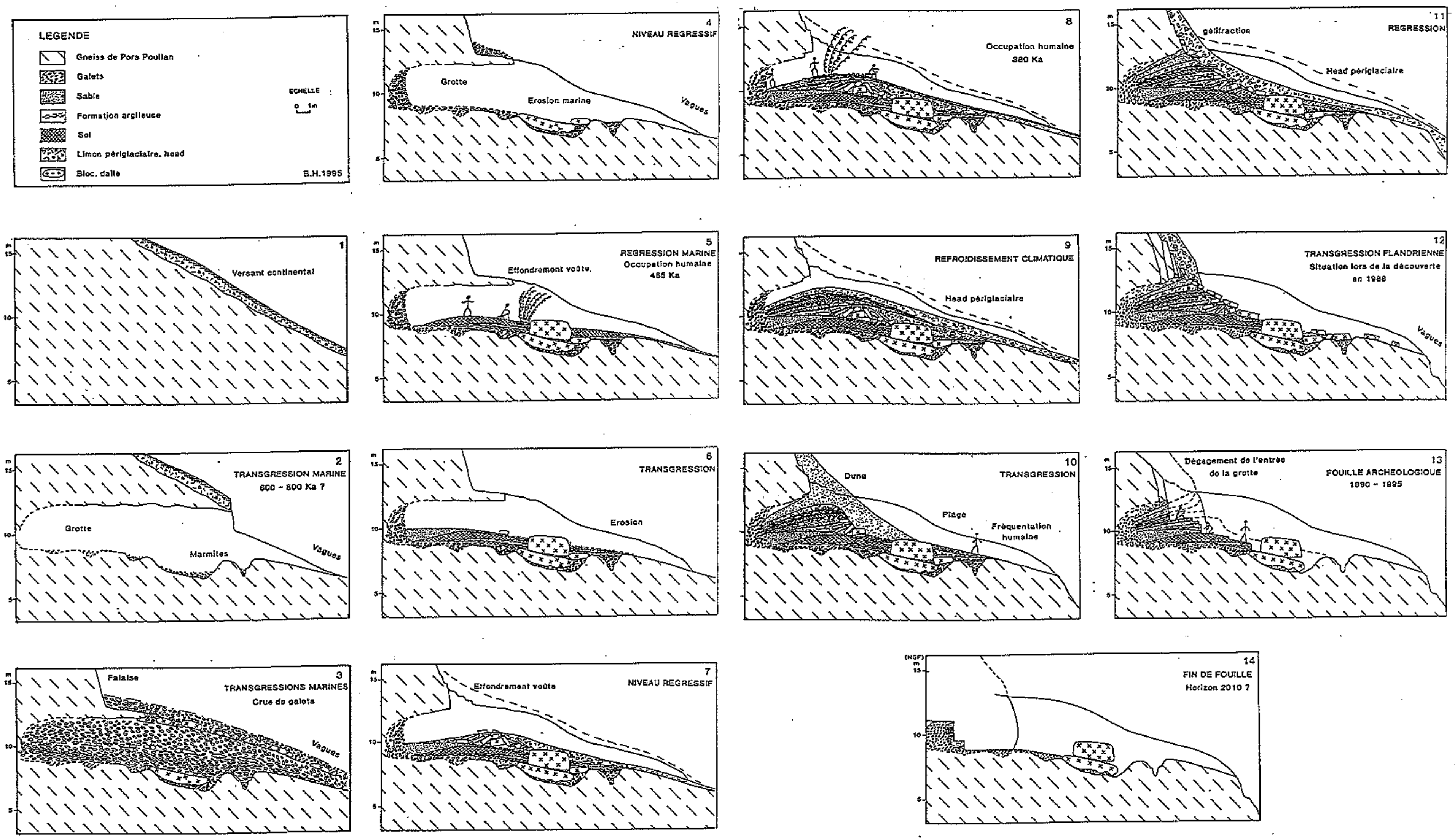
1) MENEZ DREGAN

The site of Menez-Dregan forms the subject of a thorough and fully multi-field study, associating geology, botany, biology, physics and chemistry. Menez Dregan I is an ancient sea-cave of which the roof progressively collapsed and of which the ultimate hollow, filled by pleistocene sediments, closes an abrasion corridor perched above the highest present tides. The cave originally included two lateral diverticula or branchings. The filling gives evidence upon a sedimentation balance rather feeble, dominated by the ancient littoral deposits and with numerous stratigraphic gaps (erosions).

- On the bottom, a fossil beach perhaps testifies of the first marine standing at that level, answerable for the shaping of the platform, more than 1 million years ago above appears an archaeological bed (layer 9) which corresponds to the first human occupation of the site, towards 465 000 years ago, according to ESR.
- A coming back of the sea deposited, on this level, sand and pebbles; then, taking advantage of a new removal of the shoreline (a marine regression linked to the beginning of a cold period) men settled down and left stone implements (layer 7). This layer is overlain by a deposit of pebbles, an old beach or an anthropic bringing in, any way strongly reworked by man with, above, a series of beds extremely rich in archaeological remains (layer 5), showing a human occupation probably between 350 000 and 400 000 years ago. The whole is covered up by side deposits (solifluction), with intercalation of a layer of dune sand.

Our knowledge of the human groups who followed one another at Menez Dregan is essentially based on the lithic implements they abandoned there. Those of the most ancient layers (9 and 7) are still badley known, in the present stage of the excavation. The industry of the upper levels (layer 5) corresponds to the definition of the Colombanian. Beside numerous flakes and nuclei, there are worked pebbles (essentially choppers), broken pebbles and pebbles with isolated removal of a flake†; also light tools dominated by notched tools and denticulated ones.

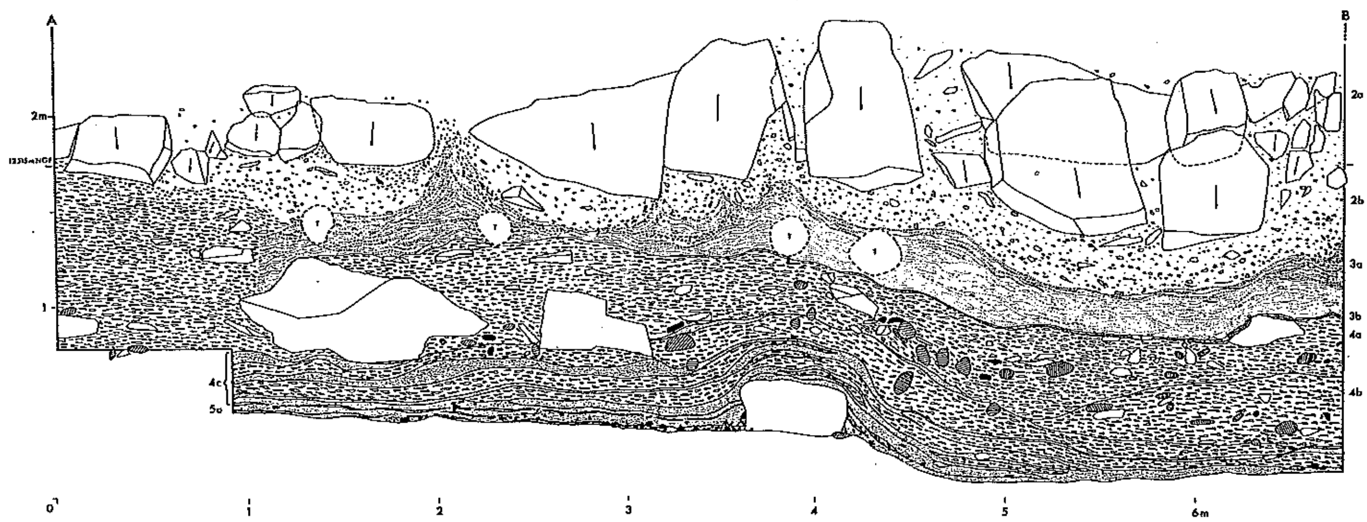
The interest of the site of Menez Dregan I results also from the presence of structures proving fires maintained by man, amongst the oldest ones known. Burning structures, associated with abundant debris of charcoal and bones, also with heated flints and stones, have been found in the layers 9, 7 and 5. In the layers 9 and 7, we have rubefied zones. At the foot of layer 5, it is a better "built" hearth (or better preserved), joining heated pebbles and an important concentration of carbonized material; the dating by ESR places it towards 380.000 years ago. At the top of layer 5, a curious structure made of small slabs disposed on a circle, with in the center a piece of an elephantís tooth, seams to be an ancient emptied fire-place.



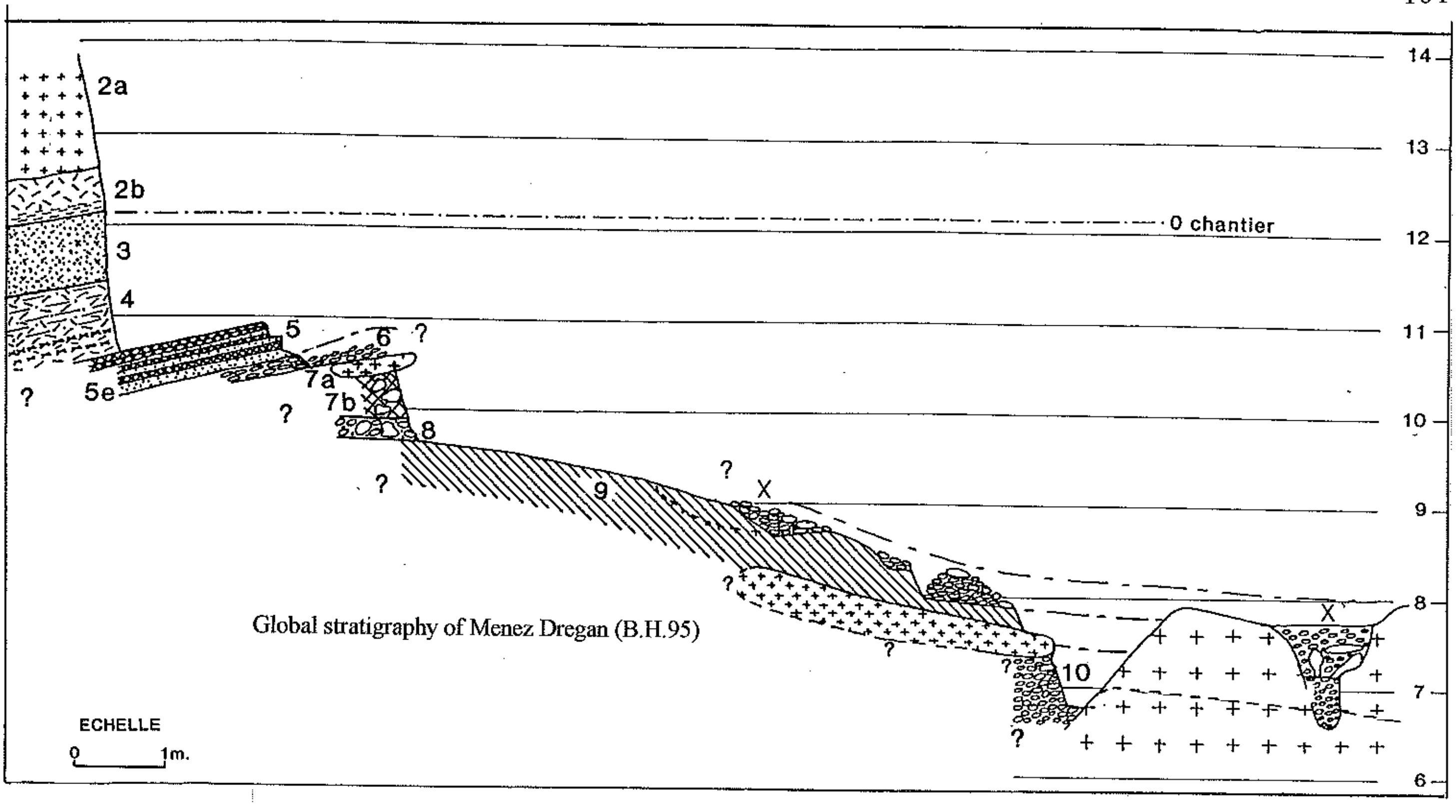
Different phases of setting of Menez Dregan shelter (B.H., 95)

Apart from the presence of this tooth, bones of large mammals have been disclosed in the layer 9, associated to stone tools. Their bad state of preservation has led to the development of a palaeogenetical program (characterization of ancient DNA): thus the presence of a Perissodactyl has been detected. We have thus the proof that the prehistoric man of Menez Dregan eat large herbivores (either hunting or carrioning), in an environment rather temperate and oceanic, at a few kilometres from the sea shore.

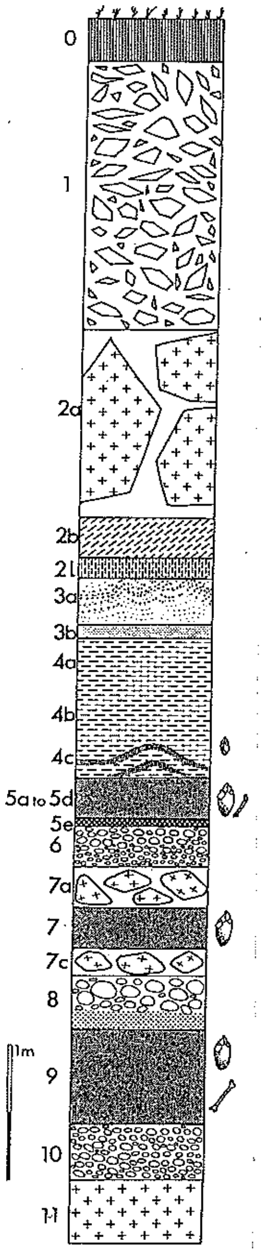
During the first phases of the site occupation, climate is mild to boreal oceanic. Weathering intensity is moderate despite the acidic context , resulting from the orientation of the fracturation, the regular sea incursion into the shelter rising the pH and sealing of the porosity by swach action. Moreover a gentle cementation by amorphous silica and neosynthesis of imogolite contributed to the preservation microfauna and larger bones. Abundant charcoals and plant remains are dominated by deciduous. From layer 8, climate progressively cooled down ; frost features occurred in association with some coniferous charcoal and rare remains of *Dryas* leaves (layer 5).
From this data and the range of ESR datings, it seems that the first occupation of site occurred before the important cooling of Middle Pleistocene, probably during isotopic stage 13, which seems rather long and temperate. The destruction of the ceiling of the shelter resulted probably from the combined action of more intense frost and perhaps also seism clusters ; this is strongly possible seeing the vicinity with the fault system satellite from the Kerforne F.S. as also occurring at Trez Ruz and Penestin.



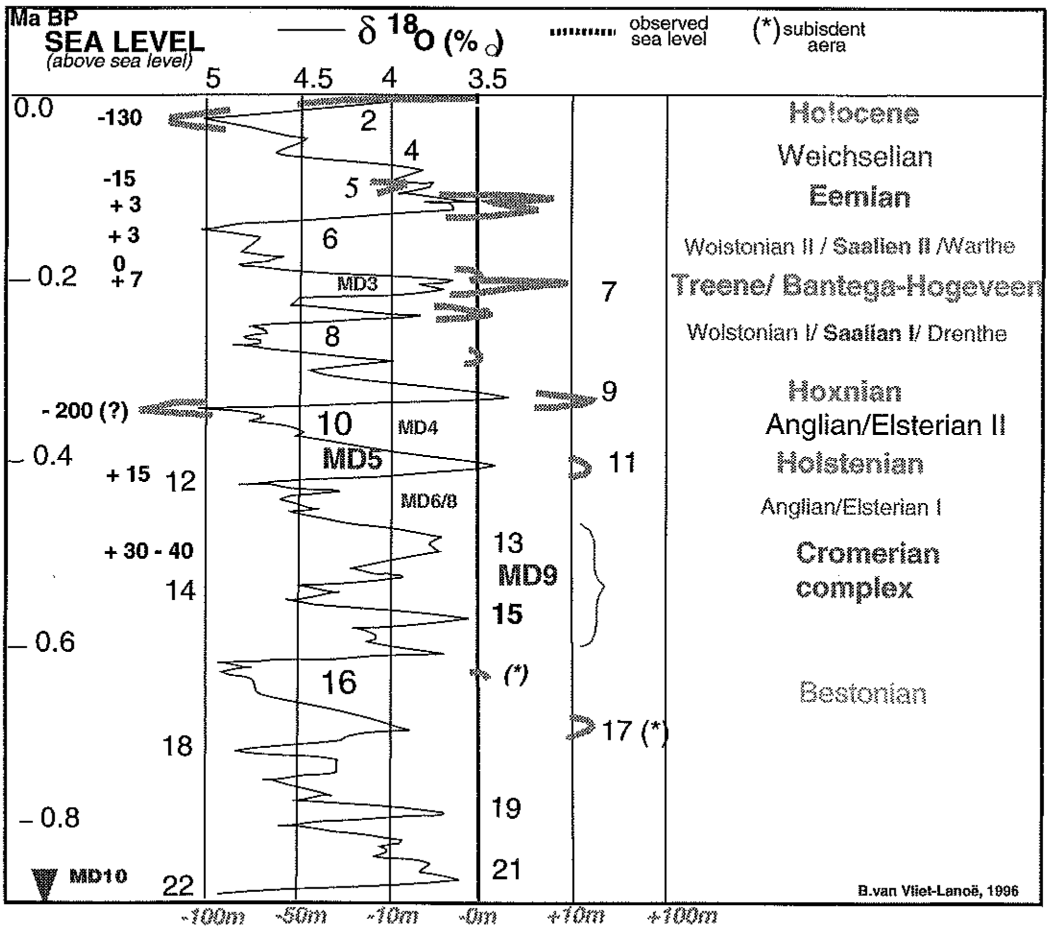
Detail of levels 5 to 2 setting and deformation , Menez Dregan (S.Hinguant,95)



Global stratigraphy of Menez Dregan (B.H.95)



Chronostratigraphical position of the different stratigraphical units related to the isotopic curve of Shackleton (1986). Based upon datings and pedostratigraphy. Grey lines correspond to ESR dated shorelines in Western Channel region.



STUDY OF THE INDUSTRY OF MENEZ-DREGAN I

N. MOLINES

The industry of Menez-Dregan I is a total of 21579 lithic pieces spread over several levels. These pieces have been studied according to a technological and technical approach.

Table 1: General composition of the industry per level. A: lighter tools, B: non-retouched flakes, C: cores, D: broken pebbles, E: pebble tools, F: isolated removal pebbles, G: debris.

	A	B	C	D	E	F	G	Nb.
4a	8	23	7	29	24	24	146	261
%	*3,06*	*8,81*	*2,68*	*11,11*	*9,19*	*9,19*	*55,93*	1,20
4b	73	554	134	63	36	60	1800	2720
%	*2,68*	*20,36*	*4,92*	*2,31*	*1,32*	*2,20*	*66,17*	12,60
4c	103	1043	244	18	12	12	2161	3593
%	*2,86*	*29,02*	*6,79*	*0,50*	*0,33*	*0,33*	*60,14*	*16,65*
5a	73	333	69	8	15	5	802	1305
%	*5,59*	*25,51*	*5,28*	*0,61*	*1,14*	*0,38*	*61,45*	*6,04*
5a'	50	474	61	5	-	4	1349	1943
%	*2,57*	*24,39*	*3,13*	*0,25*	-	*0,20*	*69,42*	9
5b	30	334	47	1	-	2	1172	1586
%	*1,89*	*21,05*	*2,96*	*0,06*	-	*0,12*	*73,89*	7,34
5b'	70	978	187	2	15	5	2075	3332
%	*2,10*	*29,35*	*5,61*	*0,06*	*0,45*	*0,15*	*62,27*	15,44
5c	40	220	60	3	9	2	1088	1422
%	*2,81*	*15,47*	*4,21*	*0,21*	*0,63*	*0,14*	*76,51*	6,58
5c'	8	131	24	-	2	1	363	529
%	*1,51*	*24,76*	*4,53*	-	*0,36*	*0,18*	*68,62*	2,45
5d	18	95	36	-	15	1	280	445
%	*4,04*	*21,34*	*8,08*	-	*3,37*	*0,22*	*62,92*	2,06
5d'	10	251	62	-	2	2	640	967
%	*1,03*	*25,95*	*6,41*	-	*0,20*	*0,20*	*66,18*	4,48
5e	12	175	60	5	9	6	161	428
%	*2,80*	*40,88*	*14,01*	*1,16*	*2,10*	*1,40*	*37,61*	1,98
6	45	427	197	31	44	29	691	1464
%	*3,07*	*29,16*	*13,45*	*2,11*	*3*	*1,98*	*47,19*	6,78
7	51	284	65	26	39	19	696	1180
%	*4,32*	*24,06*	*5,5*	*2,20*	*3,30*	*1,61*	*58,98*	5,46
8	12	35	6	4	3	2	61	123
%	*9,75*	*28,45*	*4,87*	*3,25*	*2,43*	*1,62*	*49,59*	0,56
9	5	45	4	2	2	1	222	281
%	*1,77*	*16,01*	*1,42*	*0,71*	*0,71*	*0,35*	*79*	1,30
Total	***608***	***5402***	***1265***	***205***	***227***	***175***	***13697***	***21579***
%	*2,81*	*25,03*	*5,86*	*0,94*	*1,05*	*0,81*	*63,47*	*100*

At the level of the general composition of the industry (table 1), some divergences appear in the proportions of the lithic remains in each layer, in particular for the flakes and the cores (table 1). It is worth noting that no pebble tool has been found in the levels 5a' and 5b and that they are quite scarce in the other levels which constitute the layer 5. Moreover, when the pebble tools are numerous (layers 4, 6 and 7), a great number of broken pebbles and of isolated removal pebbles is found with them. The debris, that is to say the pieces whose "débitage" mode can't be determined (lack of butts, concentric strias and hackles) form a very important group (63,47% of the assemblage) which is evenly distributed between the different levels (lower proportions in the levels 5e to 8).

1 - The non-retouched flakes

They represent 25,03% of the assemblage of pieces found in the site, that is to say 5402 pieces (table 1).

At the petrographic level, the flint is predominant in all the layers in proportions varying from 60% (layer 8) to 92,82% (level 5d'). The quartz is present in all the layers in relatively variable proportions, which also applies to the glossy sandstone. The other raw materials, sandstone, quartzite and microgranite are absent from some levels and always appear marginally, in particular the microgranite (table 2).

Table 2 : Petrographic nature of the non-retouched flakes found in the different levels.

	Flint	Quartz	Grès	G. lustré	Quartzite	Microgran.	Nb.
4a	78,26	13,04	-	8,69	-	-	23
4b	86,1	9,38	0,36	3,06	1,08	-	554
4c	84,94	9,68	0,36	3,73	-	0,95	1043
5a	91,89	5,70	0,90	1,20	0,33	-	333
5a'	85,65	11,60	-	1,47	1,26	-	474
5b	82,03	11,37	0,89	3,59	2,09	-	334
5b'	80,98	9,40	2,35	3,47	3,68	0,10	978
5c	77,27	5,9	-	7,72	3,63	-	220
5c'	85,49	9,92	-	4,58	-	-	131
5d	87,36	6,31	-	4,20	2,10	-	95
5d'	92,82	5,57	-	0,39	1,19	-	251
5e	84	9,14	-	6,85	-	-	175
6	86,18	7,96	-	5,85	-	-	427
7	85,56	10,21	-	1,05	3,16	-	284
8	60	17,14	2,85	17,14	2,85	-	35
9	77,77	13,33	-	6,66	2,22	-	45

From a technological point of view, the non-retouched flakes comprise 25,15% of pieces with a cortical back, 24,86% of flakes which present less than 50% of residual cortical surface, 23,08% of first flakes, 15,08% of flakes without cortex and 11,81% of flakes which present more than 50% of residual cortical surface (table 3). There's no trace of Levallois "débitage".

The proportions of these different types of flakes differ from one level to another, which is particularly noticeable for the first flakes. Despite that, the assemblage forms an homogeneous group. It is worth noting the presence of numerous pieces with a cortical back from the layers 8 and 9.

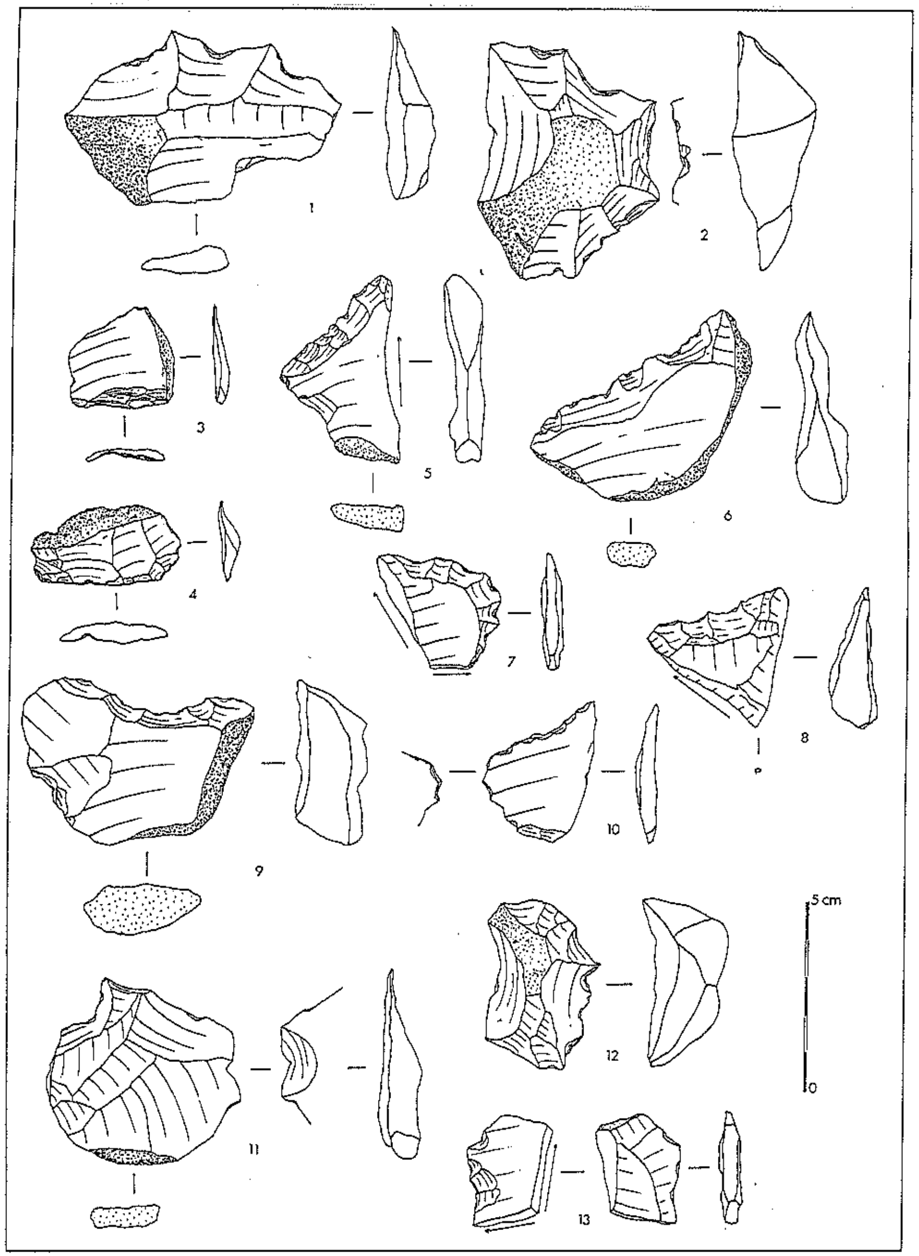


Figure 1 : Lighter tools: 1-2, 5-8, 12-13 : denticulates, 11 : notches; 3-4, 9-10 : scrapers.

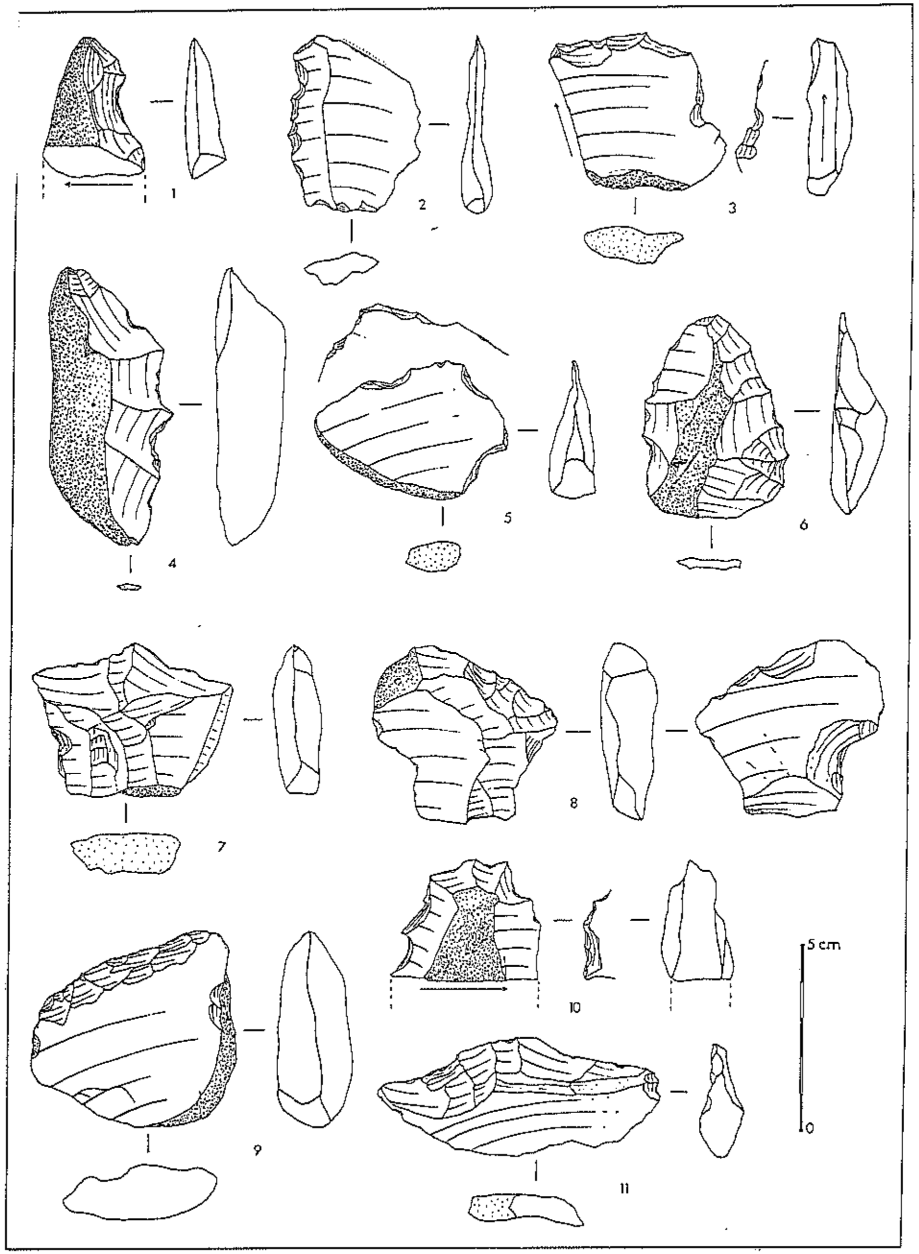


Figure 2 : Lighter tools : 1-8, 10-11 : denticulates, 9 : scraper.

Table 3: Technical analysis of the non-retouched flakes found in the different levels. A: first flakes, B: residual cortical surface superior to 50% of the total surface, C: residual cortical surface inferior to 50% of the total surface, D: without cortex, E: pieces with a cortical back.

	A	B	C	D	E	Nb.
4a	34,78	8,69	17,39	26,08	13,04	23
4b	26,45	9,56	23,10	14,25	26,71	554
4c	16,68	13,03	27,22	15,14	27,90	1043
5a	28,82	9	21,32	12,91	27,92	333
5a'	29,11	7,80	24,89	16,24	21,94	474
5b	20,35	9,88	25,44	18,26	26,04	334
5b'	23,82	11,55	27,91	15,13	21,57	978
5c	17,27	18,18	27,27	15,90	21,36	220
5c'	12,97	8,39	33,58	12,97	32,06	131
5d	31,57	15,78	10,52	12,63	29,47	95
5d'	31,07	12,74	20,71	13,14	22,31	251
5e	21,71	19,42	21,14	9,71	28	175
6	17,09	16,15	22,24	13,58	30,91	427
7	31,69	7,04	22,53	21,12	17,60	284
8	25,71	17,14	22,85	11,42	22,85	35
9	24,44	15,55	24,44	15,55	24,44	45
Total	*23,08*	*11,81*	*24,86*	*15,08*	*25,15*	*5402*

2 - The lighter tools

If we take all the levels into account, 608 tools have been recovered, the majority of which is fitted on flakes, which corresponds to 87,66% of the assemblage (table 4).

Table 4: Technical analysis of the lighter tools recovered in the different levels. Lighter tools on flakes. A: first flakes, B: residual cortical surface superior to 50% of the total surface, C: residual cortical surface inferior to 50% of the total surface, D: without cortex, E: pieces with a cortical back. F : Tools on cores, G : tools on debris (For these last two categories, the number of pieces is only given).

	A	B	C	D	E	F	G	Nb.
4a	33,33	16,66	16,66	16,66	16,66	2	-	8
4b	18,18	15,15	25,75	19,69	21,21	4	3	73
4c	12,12	15,15	30,30	15,15	27,27	1	3	103
5a	22,41	20,68	20,68	17,24	18,96	9	6	73
5a'	18,91	48,64	8,10	13,51	10,81	7	6	50
5b	22,22	18,51	22,22	14,81	22,22	2	1	30
5b'	10,76	10,76	43,07	26,15	9,23	3	2	70
5c	16,66	22,22	16,66	13,88	30,55	3	1	40
5c'	12,5	25	12,5	37,5	12,5	-	-	8
5d	18,75	12,5	25	18,75	25	1	1	18
5d'	22,22	22,22	22,22	33,33	-	-	1	10
5e	25	12,5	25	12,5	25	2	2	12
6	10,25	12,82	20,51	28,20	28,20	3	3	45
7	7,14	7,14	28,57	21,42	35,71	5	4	51
8	16,66	16,66	33,33	16,66	16,66	-	-	12
9	20	40	20	-	20	-	-	5
Total	*15,57*	*17,82*	*25,70*	*19,13*	*21,76*	*42*	*28*	*608*

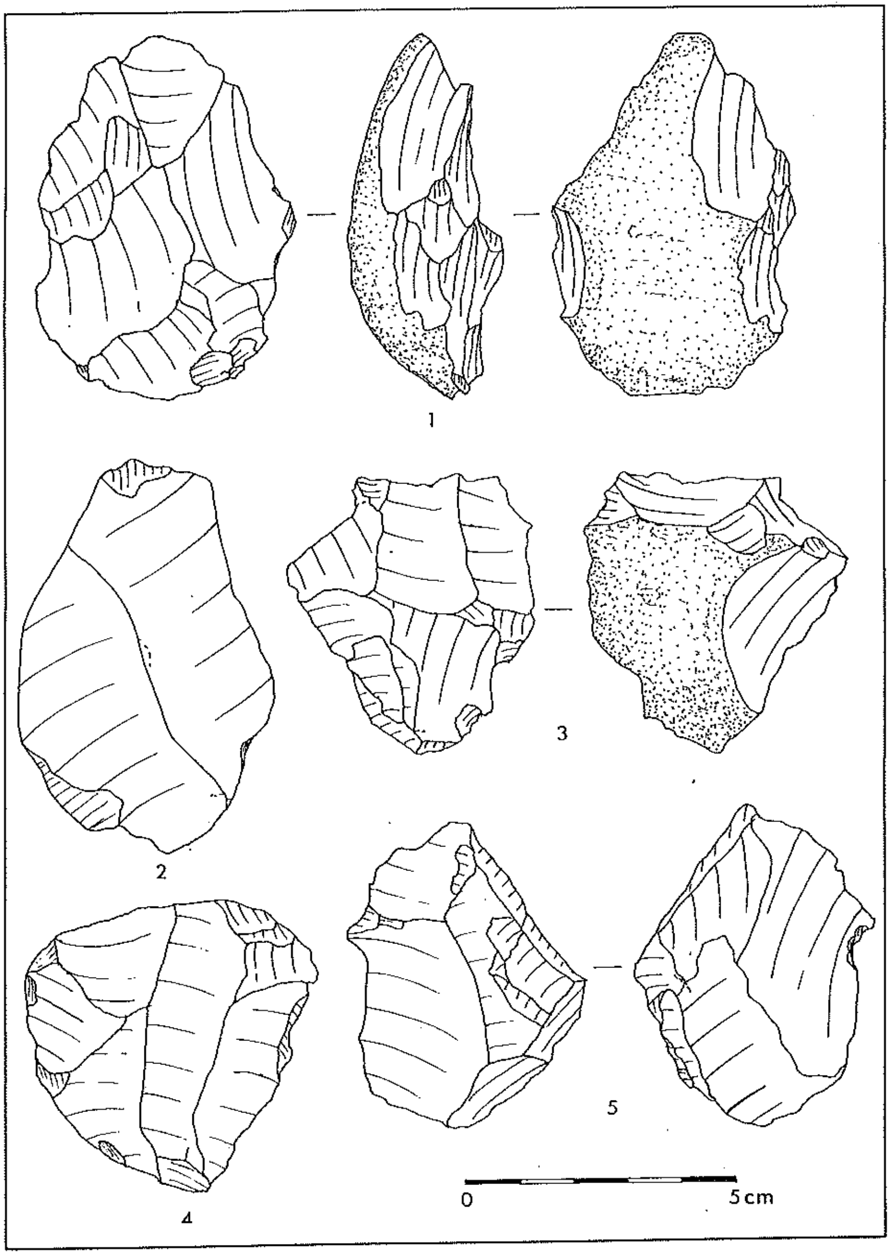


Figure 3 : cores.

The morphology of the butts differs from that of the non-retouched flakes. At the technological level, the tools on flakes comprise 25,70% of the blanks which present less than 50% of residual cortical surface, 21,76% of pieces with a cortical back, 19,13% of blanks without cortex, 17,82% of blanks which present more than 50% of residual cortical surface and 15,57% of first flakes (table 4).

In comparison with the non-retouched flakes, the tools on flakes regroup a little fewer pieces with a cortical back and mostly first flakes but much more blanks without cortex and flakes presenting less than 50% of residual cortical surface. The different technological categories to which the tools on flakes belong vary from one level to another in particular the upper levels for the blanks with a back.

Table 5: Count of the different types of tools recovered in each level. A: denticulates, B: notches, C: scrapers, D: composite tools, E:beaks, F: drillers.

	A	**B**	**C**	**D**	**E**	**F**	**Nb.**
4a	62,5	37,5	-	-	-	-	8
4b	42,46	21,91	21,91	8,21	4,10	1,36	73
4c	40,77	17,47	34,95	3,88	0,97	1,94	103
5a	45,2	27,39	16,43	8,21	2,73	-	73
5a'	38	28	14	2	14	4	50
5b	60	20	16,66	3,33	-	-	30
5b'	45,71	18,57	27,14	5,71	2,85	-	70
5c	42,5	10	30	7,5	7,5	2,5	40
5c'	50	25	25	-	-	-	8
5d	27,77	50	5,55	16,66	-	-	18
5d'	60	30	10	-	-	-	10
5e	66,66	33,33	-	-	-	-	12
6	53,33	22,22	13,33	6,66	-	4,44	45
7	31,37	21,56	37,25	5,88	1,96	1,96	51
8	41,66	33,33	25	-	-	-	12
9	40	20	20	-	20	-	5

The lighter tools are relatively varied in particular in the upper levels, the main types are the denticulates, the notches and the scrapers. The denticulates/notches group is predominant in all the layers. On the contrary, in the levels 4c, 5b', 5c and 7, there are more scrapers than notches (table 5). The main three types are present from the layer 9 as well as the beaks. The six types appear from the layer 7 as well as the composite tools.

On the whole, the lighter tools form an homogeneous group, with little varied types and pieces which are relatively crude except for som well-made glossy sandstone scrapers.

3 - The cores

1265 cores have been recovered, that is to say 5,86% of the assemblage. There's no trace of Levallois "débitage". There are on average 5 removals. If we refer to this number, we can theorically affirm that the major part of the "débitage" was on-site, which doesn't exclude the supply of flaked materials in another place.

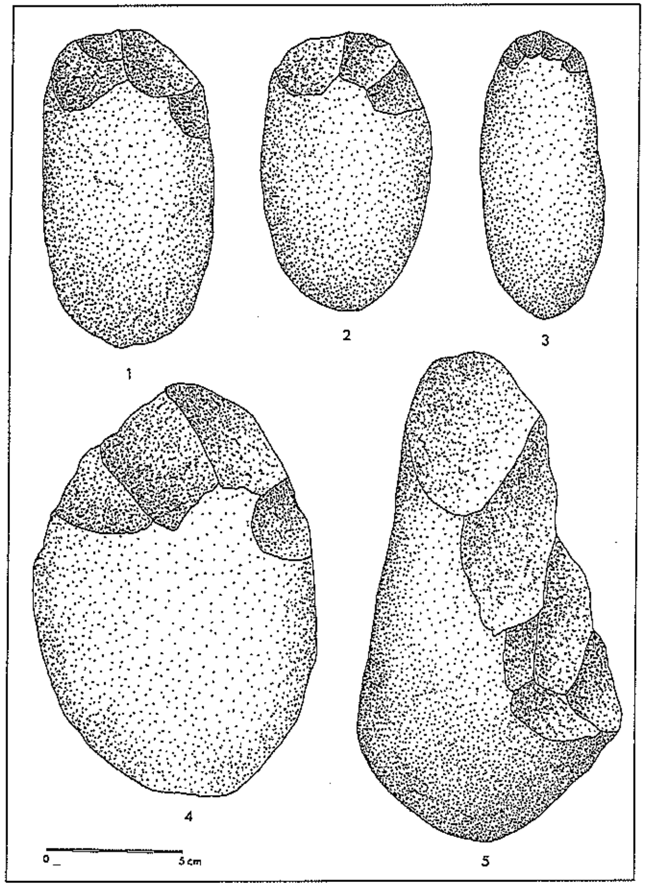


Figure 4 : pebble tools.

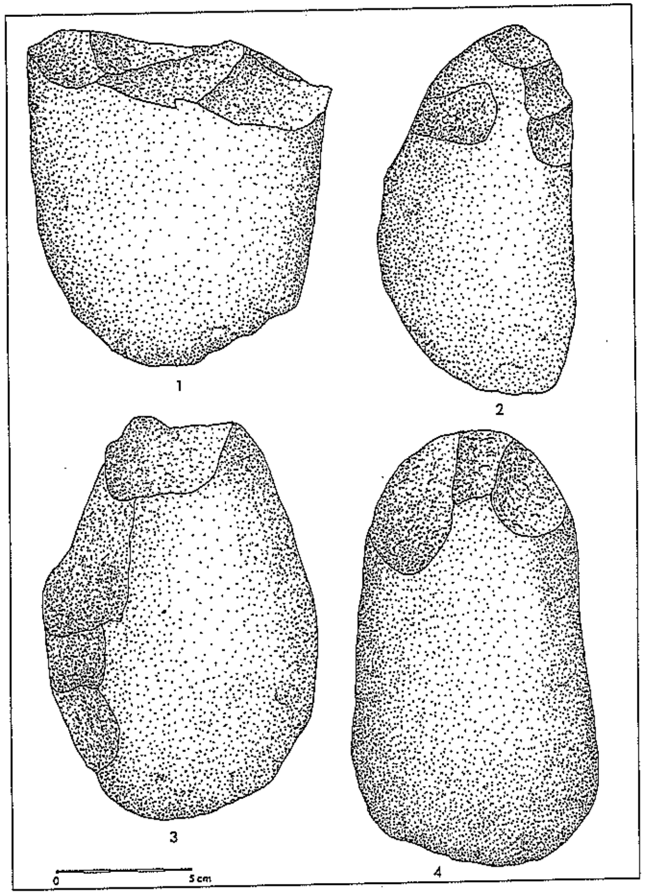


Figure 5 : pebble tools.

Except for some cases, most levels contain all the types of cores with a bifacial or unifacial "débitage". They are all present from the layer 7. The bifacial "débitage" is generally dominant (except for the levels 5c' and 5d) with a little more than 50% of the assemblage.

The bipolar and unipolar modes are predominant in all the levels. It is worth noting that the centripetal mode is sometimes well-represented in particular in the upper levels and that it is present from the layer 9.

Table 6: Types of cores found in the different levels. Unifacial "débitage" - A: unipolar mode, B: bipolar mode with opposed striking platforms, C: bipolar mode with perpendicular striking platforms, D: centripetal mode. Bifacial "débitage" - E: unipolar/bipolar combined mode, F: bipolar/unipolar combined mode, G: centripetal/unipolar combined mode, H: bipolar/bipolar combined mode, I : bipolar/centripetal mode, J: centripetal/centripetal combined mode

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**Nb.**
4a	-	28,57	-	14,28	14,28	14,28	14,28	14,28	-	-	7
4b	8,95	7,46	10,44	14,92	11,94	21,64	7,46	5,97	6,71	4,47	134
4c	5,32	6,96	9,01	8,60	11,47	24,18	9,83	12,7	6,55	5,32	244
5a	7,24	8,69	13,04	14,49	2,89	13,04	11,59	13,04	11,59	4,34	69
5a'	6,55	3,27	16,39	21,31	9,83	14,75	4,91	13,11	9,83	-	61
5b	2,12	10,63	2,12	17,02	14,89	17,02	14,89	10,63	6,38	4,25	47
5b'	3,20	8,55	6,95	13,90	10,69	22,99	8,55	11,22	5,88	8,02	187
5c	3,33	3,33	6,66	20	10	16,66	10	6,66	15	8,33	60
5c'	-	25	4,16	25	8,32	4,16	4,16	12,5	12,5	4,16	24
5d	11,11	19,44	13,88	19,44	-	2,77	8,33	19,44	5,55	-	36
5d'	4,83	3,22	11,29	11,29	14,51	19,35	8,06	16,12	6,45	4,83	62
5^e	5	10	8,33	23,33	1,66	18,33	6,66	10	13,33	3,33	60
6	5,58	10,15	15,22	18,27	7,10	19,28	7,61	7,10	6,59	3,04	197
7	20	6,15	12,30	4,61	7,69	16,92	4,61	16,92	6,15	6,15	65
8	16,66	33,33	-	16,66	-	16,66	-	16,66	-	-	6
9	-	25	25	-	-	25	-	-	-	25	4

4 - The heavy pebble tools

The heavy pebble tools include 227 pieces, 206 of which are choppers of relatively varied types. Besides, 11 partial handaxes (among which some unifacial types), 2 polyhedrons, 1 disk-shaped tool and 7 chopping-tools have also been counted (table 7).

The choppers are varied but the majority of them are modal pieces with a cutting edge which is mostly in cross position and fitted by some removals. In general, these cutting edges are not much worked. These tools are fitted on pebbles whose petrographic nature is varied.

The number of pebble tools can vary a lot from one layer to another. It is high in the layers 4, 6 and 7, low, indeed equal to zero in the levels which constitute the layer 5. As we have seen it before, in some layers, the number of broken pebbles and of isolated removal pebbles increases like that of pebble tools.

Table 7: Types of pebble tools recovered in the different levels. Choppers - A: modal, B: retouched, C: peripherical, D: horizontal removals, E: abrupt front, F: preliminary flaked, G: non-retouched preliminary flaked, H :Partial handaxes, I: chopping-tools, J: polyhedrons, K: disk-shaped tool.

	A	B	C	D	E	F	G	H	I	J	K	Nb.
4a	18	4	-	1	-	-	-	1	-	-		24
4b	12	7	2	2	3	2	1	4	1	2		36
4c	5	2	-	1	-	-	-	2	2	-		12
5a	6	4	-	-	2	-	1	-	1	-	1	15
5a'	-	-	-	-	-	-	-	-	-	-		-
5b	-	-	-	-	-	-	-	-	-	-		-
5b'	9	3	-	1	1	-	-	-	1	-		15
5c	7	2	-	-	-	-	-	-	-	-		9
5c'	1	1	-	-	-	-	-	-	-	-		2
5d	10	2	1	1	1	-	-	-	-	-		15
5d'	2	-	-	-	-	-	-	-	-	-		2
5e	5	1	-	1	-	-	1	1	-	-		9
6	22	15	-	3	1	1	-	1	1	-		44
7	20	12	1	2	-	1	-	2	1	-		39
8	2	1	-	-	-	-	-	-	-	-		3
9	2	-	-	-	-	-	-	-	-	-		2

Conclusion

In brief, apart from the proportions of pieces which may vary a lot from one layer to another, it appears practically no noticeable difference between the different levels, typologically and technologically speaking. The assemblage forms, at this stage of the excavation, a very homogeneous one. The continuation of the excavation, in particular of the lower levels (layers 8 and 9) will perhaps allow to put forward some differences between these levels and the layers 4 and 5.

SYNTHESIS

The site and the industry of Menez-Dregan I are part of a regional group which comprises pebble tools industries. This group, as well as its characteristics, has been defined thanks to recent studies.

Until the 80's, the pebble tools industries were not well-known in the Massif Armoricain, except for 2 indications of sites in the region of Carnac. After the excavation of the ore of Saint-Colomban in Carnac (Morbihan) (Monnier, Le Cloirec, 1979; Monnier, 1983; Monnier, Le Cloirec, 1985), the number of sites increased. Thus, around 20 sites or indications of sites were discovered until today. They are mostly situated on the South-Armorican coast. The stratigraphic context, when it has been preserved, is relatively constant on this part of the Atlantic coast.

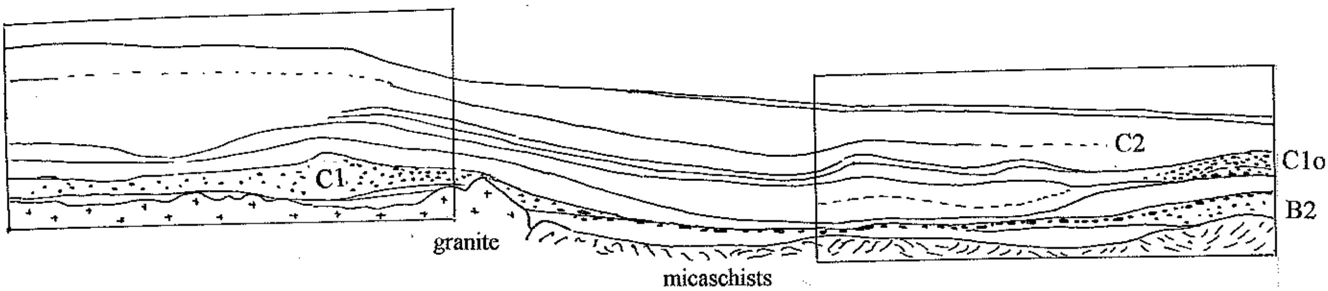
The techno-typological characteristics of the South-Armorican industry had led J.L. Monnier to define a "Colombanian" regional group. This group includes industries with a great number of pebble tools and is dominated by the choppers group whereas the handaxes are very scarce or absent. The lighter tools are mainly formed by the denticulates/notches group and the scrapers group.

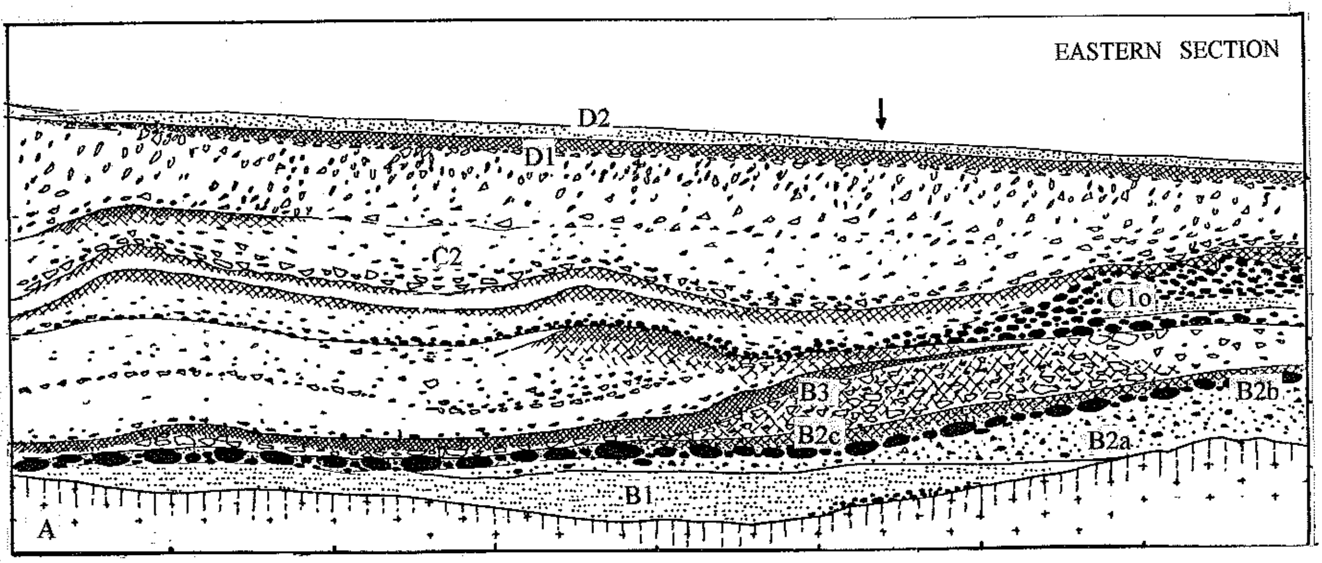
Out of its exceptional state of conservation, the site of Menez-Dregan I plays a particularly important role in the knowledge of the pebble tools industries of the Armorican coast.

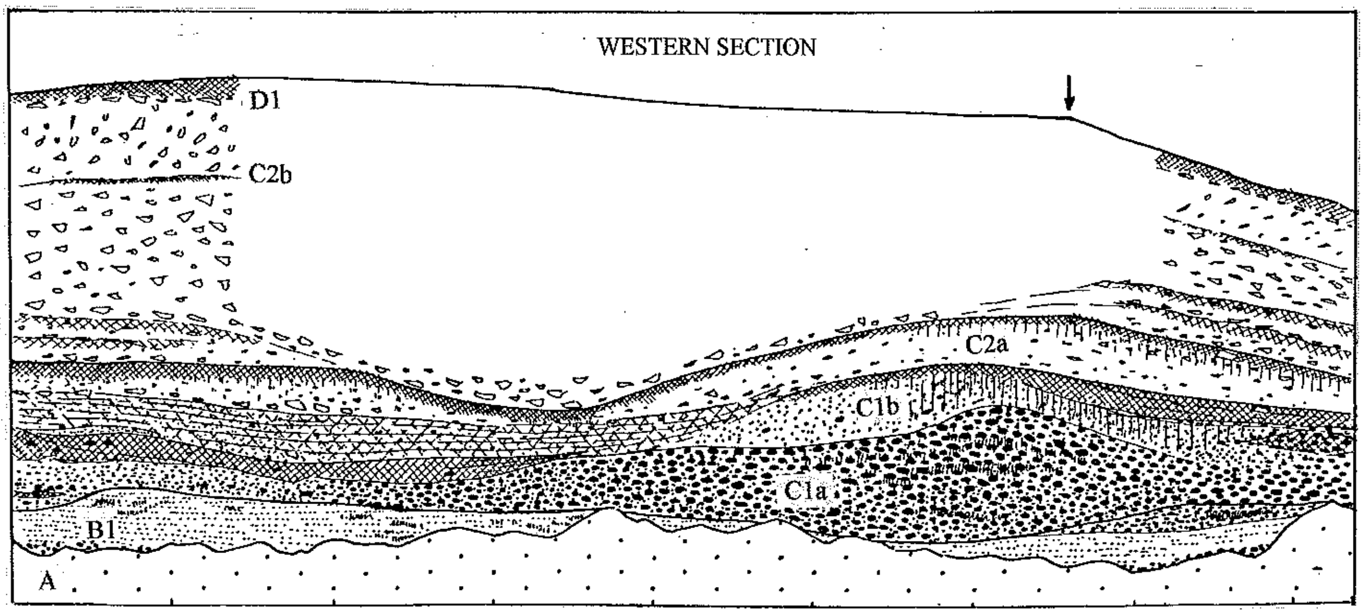
Some comparisons at the European levels showed that these pebble tools industries were largely spread at the Lower Palaeolithic and that the "Colombanian" group, out of its numerous characteristics, really constitutes an original regional group. However, the relations which unite these industries with the Acheulian must be defined yet, at least, if we agree to consider the Acheulian as a synonym of handaxes industry. This discussion doesn't relate anymore to the Massif Armoricain but reaches the European level.

In brief, the site of Menez-Dregan I and more generally the "Colombanian" group are fondamentally important for the knowledge of the Lower Palaeolithic in the West of France and of the first human settlements in western Europe. Therefore, the pebble tools industries of the Armorican coast contribute to the comprehension of the variability of the Eurasian Lower Palaeolithic.

GWENDREZ : global section







GWENDREZ

HALLÉGOUËT B. AND VAN VLIET-LANOË B.

This section is located to the West of Menez Dregan, but this time at the foot of the paleocliff. At the base of the section we can observe

Eastern section

A- granite and metamorphic rocks truncated by an abrasion platform, rising about 3m NGF.

B1 - amicaceous fine sand somewhat stratified, lower shoreface

B2a - a sand, incorporating rounded gravels and angular clasts

B2b - a large cobble beach, truncating the former units,

B2c - a sand with a ranker soil development at the top.

B3 - a serie of heads, including stabilisation with some important ranker soil development (at least 2 main phases)

C1o - beach complex (upper beach), rising apparently up to 6m NGF and truncating the former units

C2 - complex of heads with a loamy matrix including at least 3 stabilisation phases, with ranker soil development. The upper part is cryoturbated.

D1 - loamy ranker

D2 - dune sand

Western section

Resting on A and B1

C1a - a thick cobble bar with some sand at the base, inter-bedded with lagoonal sand to the West and stratified cobble beach to the East.

C1b - sandy humic sand covering C1a with a stratified lagoonal facies to the East and drained status to the West, with podsolic development : short stabilisation with dune construction and backshore lagoon infilling, including artefacts.

C2a - head complex , with a sandy loam matrix , including a humic podsol and 2 small ranker paleosoils

C2b - upper head complex including two units separated by a weak ranker soil development. The upper one is cryoturbated

D1 - loamy ranker.

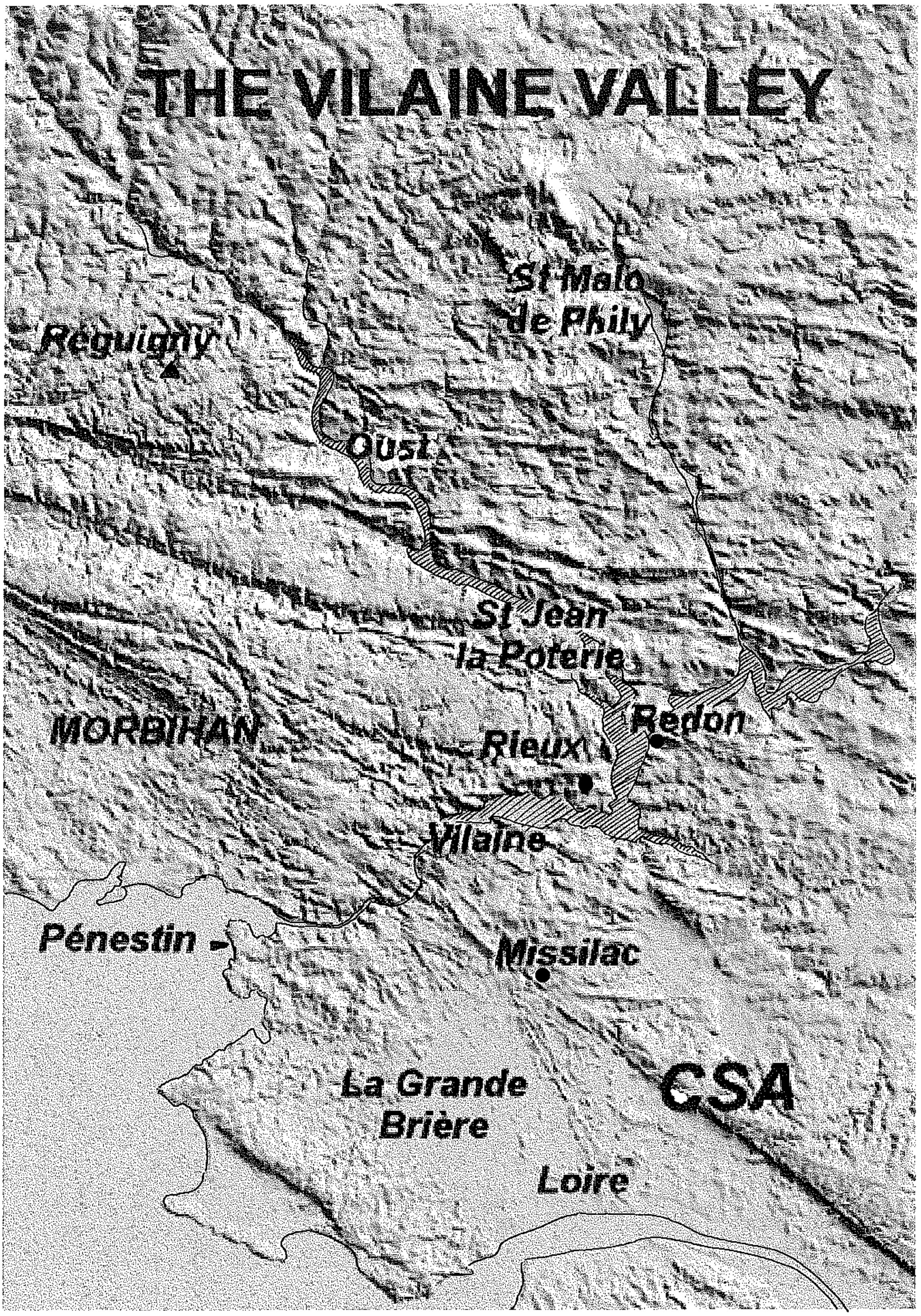
This units are more recent than those of Menez Dregan. The cliff knoch and the lower abrasion surface could be contemporaneous with the dune sand at Menez Dregan. Unit B2-3 East can be inferred to stage 8 and/or 7.

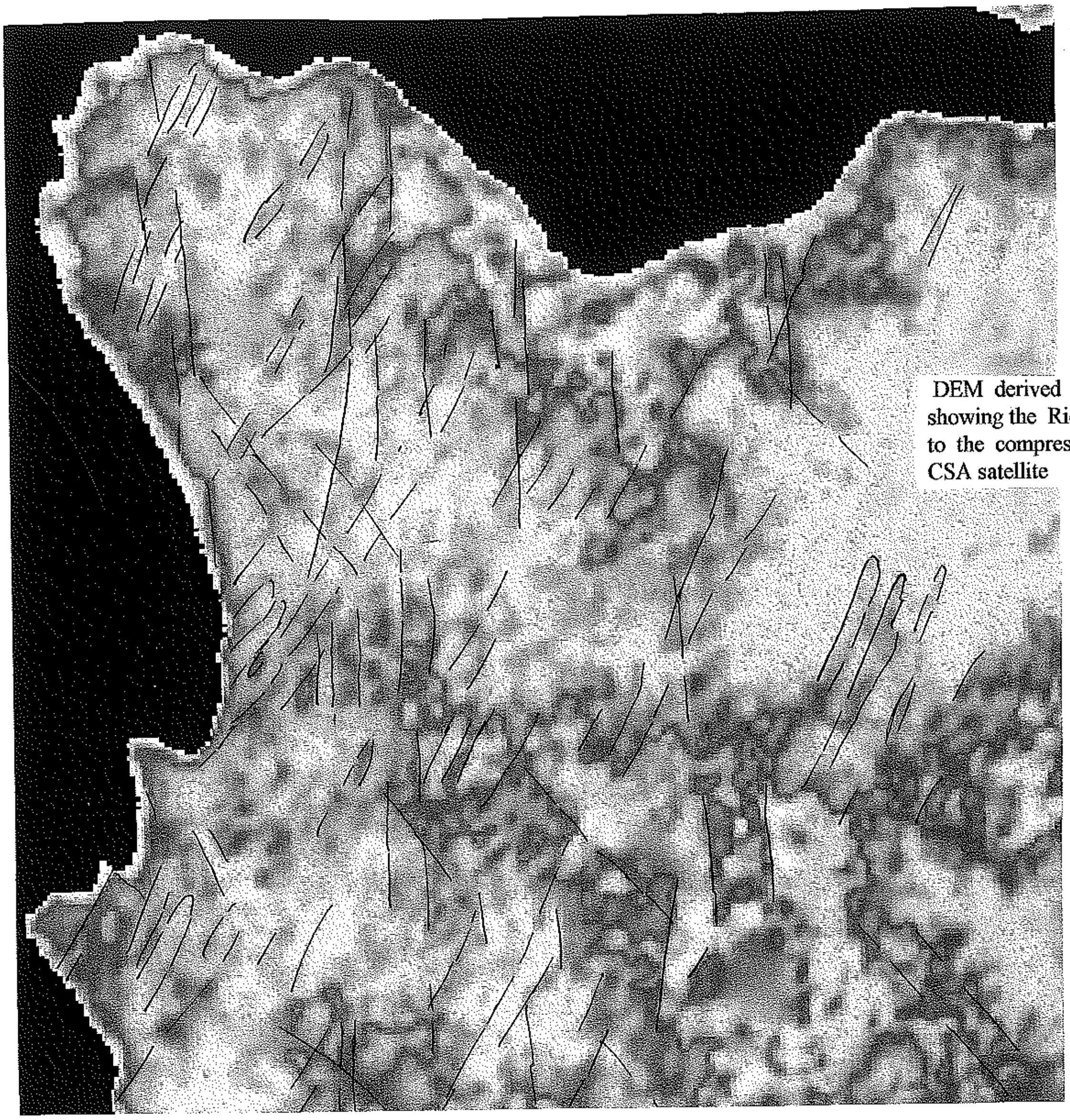
The position of C1o is not clear ; it can be inferred or to the Last Interglacial or to stage 7. The position of B2-B1 East looks like very much to stage 9a and 9b records observed in other sections of the Channel (cf. Pra Sands, Pen Hat, Ecalgrain) (Van Vliet-Lanoë et al, 1997d).

CONCLUSION

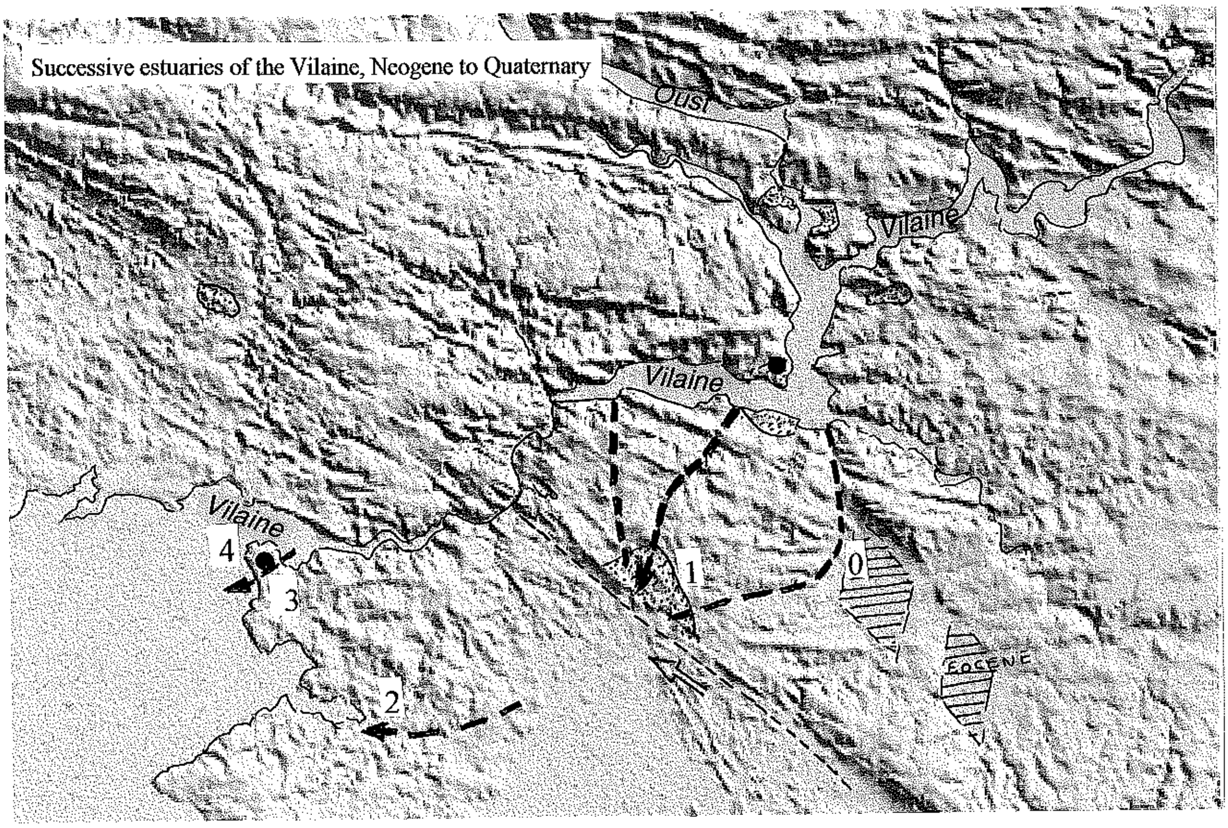
Menez Dregan and Gwendrez sections record in Western Brittany, one of the longest serie of shore evidences in the region : from 1.2 Ma up to the Holocene. This is completed by the recorded beaches with intermediary age at Plogoff (to the West of Audierne Bay) where one unit, infilling a cove has been dated by ESR at 750 ka. This explain s the building of large gravel aggradation as at the Ruvein (up to 15m NGF) which recorded probably the story of Neogene shore and certainly the whole Quaternary under a compacted form.

This discussion will be continued to the East with the Vilaine valley estuary.


THE VILAINE VALLEY
St Malo
de Phily
Reguigny
Oust
St Jean
la Poterie
MORBIHAN
Redon
Rieux
Vilaine
Pénestin
Missilac
La Grande
Brière
CSA
Loire



DEM derived from Spot Image showing the Riedel zones related to the compressive shearing along CSA satellite



Successive estuaries of the Vilaine, Neogene to Quaternary

PENESTIN

VAN VLIET-LANOE.B , HALLÉGOUËT B., LAURENT M.

The Pénestin section (southern Brittany is located (fig.1) on the left banks of the Vilaine esturary. It is outcropping nearby the Missillac Mio-Pliocene estuary of the Vilaine and about 30km eastward from the Morbihan Gulf. On the eastern coast of Morbihan Gulf, small Eocene basins have been recognized in boring , below the present-day sea-level and « Pliocene Red Sands » outcropping at the surface of the platform. This is remated to the position of a satellite shearing zone parallel with the main CSA accident, also visible close to Pénestin-Mine d'Or. At the Rhuys peninsula, south of the Morbihan Gulf, lower to mid Quaternary shore face outcrops are visible but the youngest events (stages 7 or 5) are lacking, evidencing a rather recent subsidence of this sector. Pénestin sector seems uplifting today from historical leveling. This profile is located East of the channel of the Vilaine, a river terrace complex from Middle Pleistocene age (from about 600 ka BP to 300ka BP)., associated to local estuarine invasions, interstratified with at least 3 regressive alluvial units , including ice rafted blocks. A rubified paleosol (Rhodustalf) developed after the latest alluvium . It outcrops as a shore cliff culminating at 15 m above the present high water mark. This sequence is 3km long, limited at the North by a gneissic paleoshelf and at its southern end by the Kerfaller fault system, a normal fault, related to the CSA , in horizontally laminated micashists. From a tectonical point of view, presnt-day stresses are compressive-shearing.

STRATIGRAPHY

From the base to the top , we can observe :

1- an abrasion surface cutting into the saprolithe. Shore ice rafted blocks of silicified sandstone, probably derived from a nearby Eocene basin (tidal or fluviatile, outcropping perhaps back of the main section as some evidence exists at the southern end of the main section) and cryoturbated gravel cover this surface. This unit is under ESR dating but is presumed 650 ka BP. It is locally consolidated by thick goetithic precipitation.

2- a thick fluviatile gravel reworking frost shattered debris. It corresponds partly to a braided river system. Higher up, it shifts progressively to prograding gravels and sand hydraulic dunes of the main stream (mostly at the North of the section) and reach a first estuarine sequence (« green sands » dated at 445±71 ka Bpby ESR).

3- this estuarine sequence is truncated first by meandering channel (south of the central access) evidencing a new fluviatile system.

4- a last fluviatile unit corresponds to braided periglacial gravels and sands shifting to the top to loamy decantation facies and locally to tidalite. The base of the unit has been dated at 317±71 ka BP by ESR.

5- a rubified pedocomplex, including residual, wind abraded gravel is covered by thin loess and dune sands, ending the record.

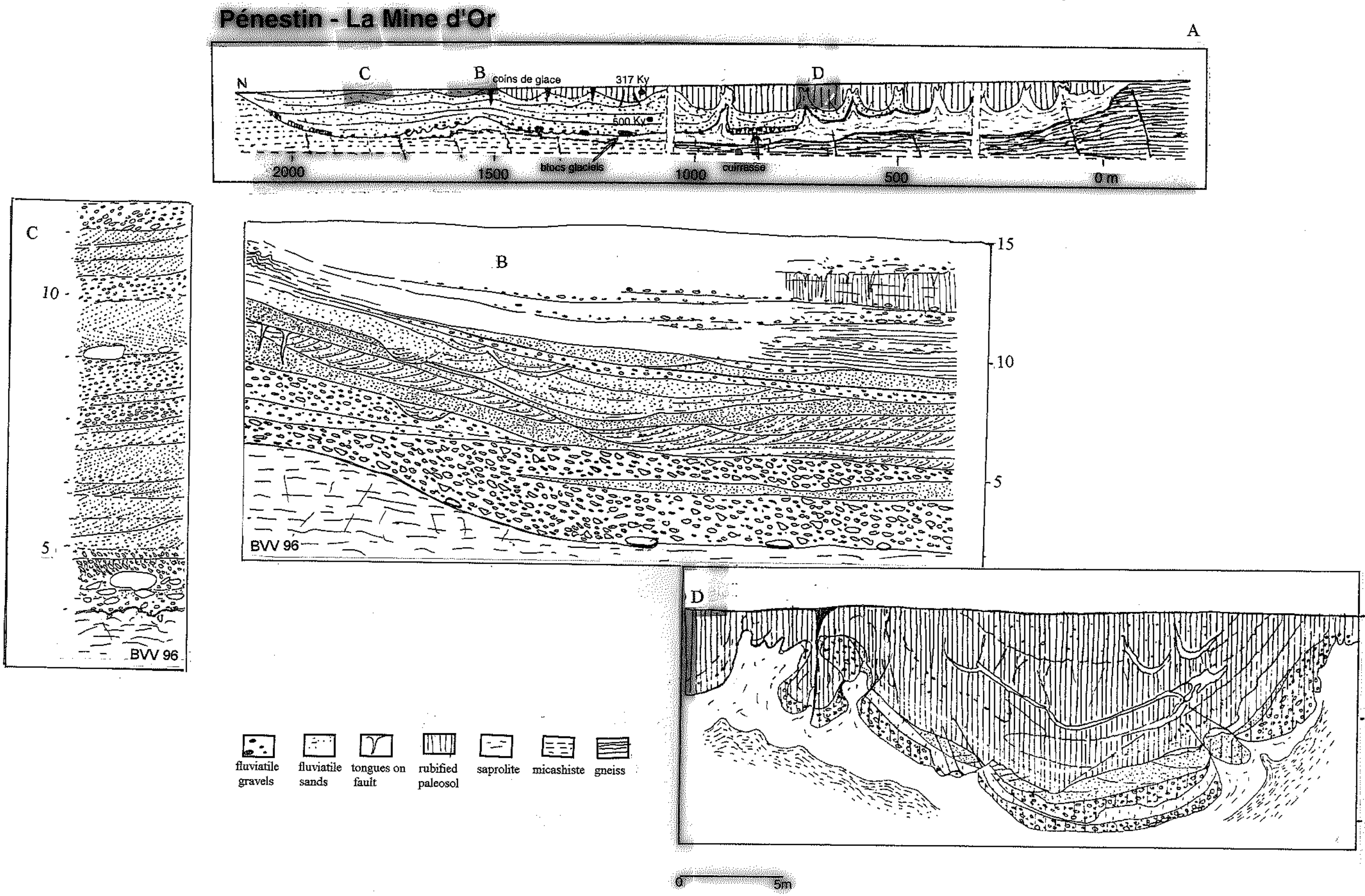
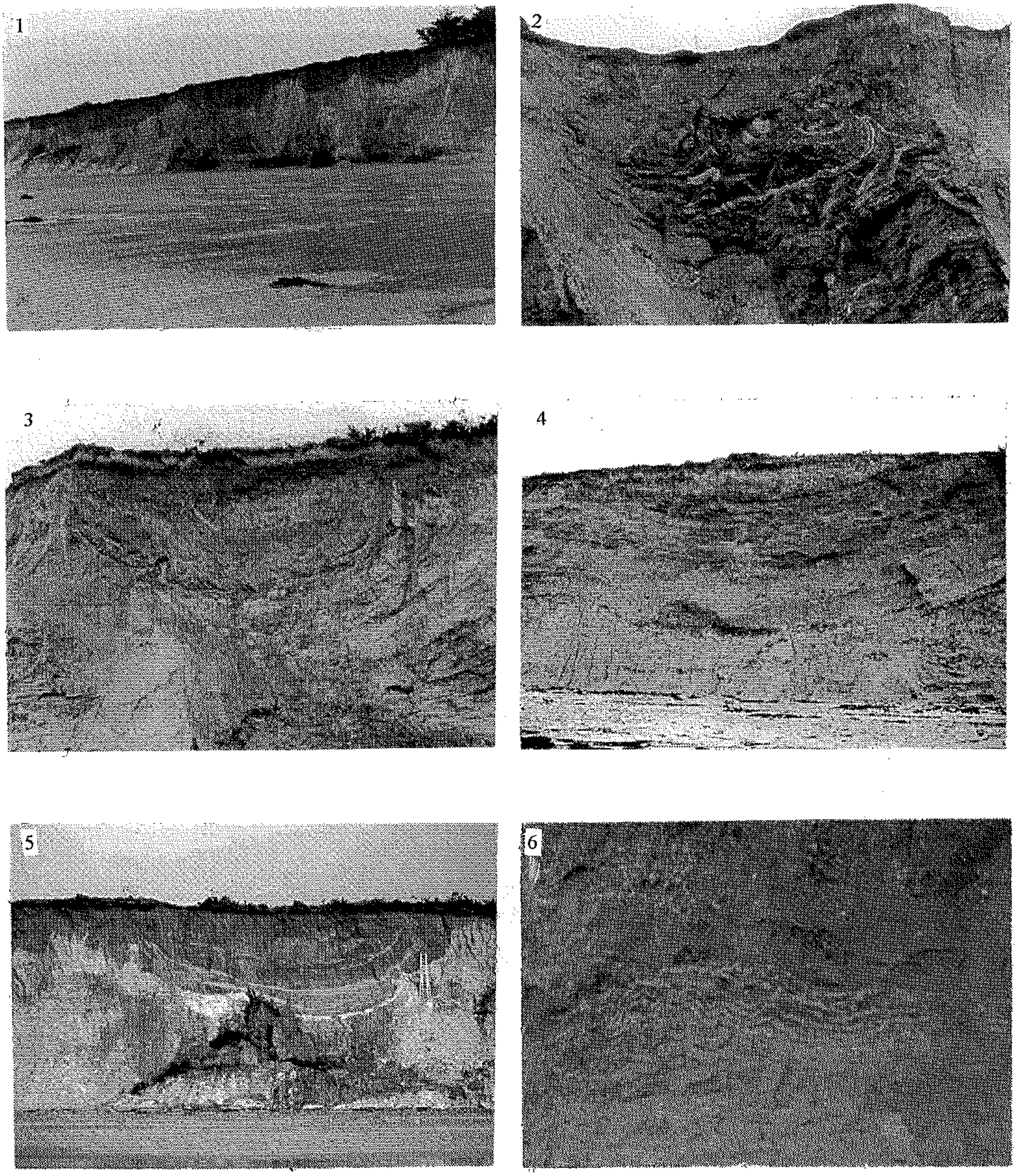


Figure 2 A) global sketch ; B) fluviatile-estuarine aggradation (* :datings) ; C) northern section ; D) deformation.

NEOTECTONIC.
The first 2km of the terrace, from the fault, is resting on deeply weathered micashists; it consists of kaolinitic silt, 2 to 8m thick (saprolite). This material is highly sensitive to liquefaction in winter. Gneissic material is also weathered but still coherent. When the thick layer of kaolinitic silt is present, the alluvial formation, a silty clayey gravel is regularly plastically deformed in elongated folds of which at least 12 can be seen, which are about 35m wide and 8 to 10m in depth (fig.2a). Between the folds, the kaolinitic silt is squeezed and injected along fractures, simulating cryoturbations (fig.2a-b); deformation intensity decreases with depth of the saprolite . Some of the folds are fractured orthogonal to their borders and sandy layers within the base of the alluvium are obliquely microfractured by stretching. Little evidence of synsedimentary deformation exist. When a consolidated iron conglomerate exists at the base of the alluvium, the process of fold formation is inhibited in the alluvium. Faults with horizontal left strike-slip displacement are observed in the saprolite at the base of most of the injections. Earlier plastic events are locally preserved, truncated by the base of the alluvial material (north of the southern access to the beach).
To the north, deformation change with the status of the weathered basement. Wavelength of the folds is longer 40 to 50m, less distinct because of the more sandy composition of the alluvium (lower silt and clays content leading to an increased rigidity) and shallower saprolite. The interfold zone is only marked - by microplications of the thinly laminated upper tidalite, - by later ice wedge casts (in tension position) and finally, - by gravel wedges associated with a wind abrasion surface (post-rubification). Dry bulk density of the alluvium and the kaolinitic silt is very high (1.8 to 2), shearing resistance too; kinking fabric (Van Loon *et al.*, 1984) is common in the close vicinity of the injections. A fragile metric fracturation with normal microfaults (N110° to N160°) occurred later, usually in conformity with the bed rock fracturation; it is followed by soil bleaching (tonguing); vertical displacement exceed rarely 20cm.

Interpretation
These deformations, have been interpreted as periglacial hydrolacolites or pingoes (Rivière et Vernhet, 1962; Guillaume-Bruno,1972). It is unlikely that they can be interpreted thus, because pingo occur in isolation ; moreover, after thaw consolidation, the infilling of the residual depression is cone shaped, with a final lacustrine sedimentation , the bottom of the depression being floored by material sufficiently permeable to allow water migration (De Gans, 1988) . The only forms in the group susceptible to be interpreted in that way are palsas (segregated ice mounds, with reticulate ice) which are usually of similar size, but Pissart (1983) has shown a completely different inner organisation after thaw collapse. Macro-differential frost heave of residual shale outcrops has been also proposed because of the occurrence of traces of lenticular ice lensing (Van Vliet-Lanoë, 1987).

The first detailed description (above) at Pénestin allowed to reinterpret these deformations, and also those of the other sections as a folding related with compressional strike-slip shearing (Cobbold *et al.*,1971; Van Loon *et al.*, 1984; Richard, 1990) and hydroplastic normal loading, probably induced by a shock (fracture opening) (Sylvester, 1988), resulting in a assisted pseudo-diapirism/positive flower at various scales. They can not be considered as simple load, as the high consolidated present status of the upper part of the saprolite of Pénestin should limit this feature. Moreover the dating of the alluvium in this section show the long time laps of the alluvial activity (at least 300 ky: Laurent, 1993). Continuous deformation during the sedimentation seems improbable, at



Pénestin :

1) general view of the southern part of the section ; 2) involutions in the weathered saprolite ; 3) small size (15m) deformation resting on saprolite, southern part of the section ; 4) long wave but little amplitude deformation in the fluviatile/ estuarine complex, northern part of the section ; 5) deformation studied in fig.2, the ladder gives the scale ; 6) microplicated tidalites (fig 2) .

least for the lower and middle fluviatile unit , even evidence of folding in the spaorlite are truncated by it. Accelerated deformation occurred in a kind of shear corridor oriented rougly meridiean to N160°, after the latset unit deposition, and continued with some faulting after the rubified pedogenesis. These « positive flowers structures » correspond apparently to a kind of « Riedel » figures as well visibles on the DEM (1 pixel = 20m) performed on the base of SPOT image (fig.1). At the time of the alluvial activity in the site , the water table was high , possibly enabling a temporary liquefaction of silt under shock or overburden pressure. Hydroplastic deformations, macroscopic and microscopic fluidized injections are commonly developing during present-day earthquakes in waterlogged conditions.

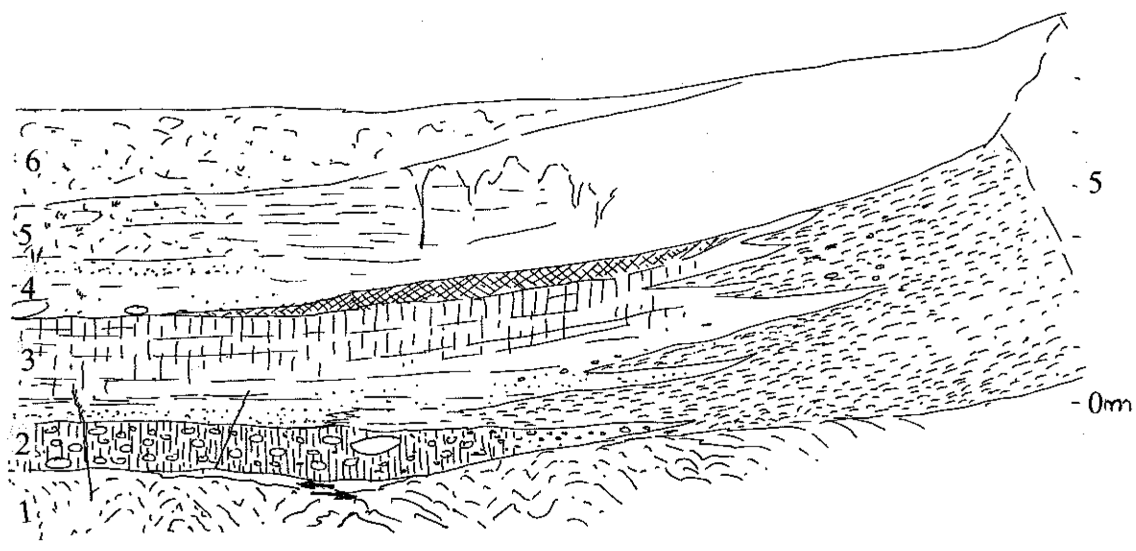
OTHER POINTS

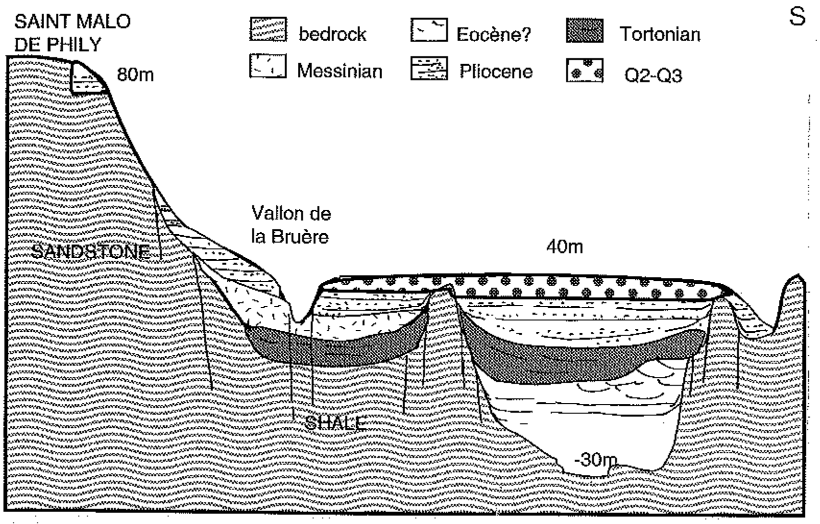
To the East, after the Kerfaller Point (fig.3), a thick greyish marshy unit covers the consolidated unit 2, disconnected from the weathered substratum by tectonic shearing. The greyish unit is interstratified with very early shaly heads corresponding probably to the end of stage 9a as in other sites of the Channel coast. In the next bay to the South, Mio-Pliocene sands occur on the same platform.

CONCLUSION

The Pénestin record evidences polycyclic reoccupation of the shore platform by successive trangressions from at least the Eocene up to Middle Pleistocene. Pénestin estuary is the third estuary of the Vilaine river since Neogene. First one (fig.1) occurred close to Missillac and was active from at least Tortonian up to Gelasian (Upper Pliocene). The second one is early Quaternary and was active from 1.2 Ma BP to probably up to 1 Ma BP (Mesquer Point). With the main tectonic phase prior to Cromerian, the estuary shifted to Pénestin, probably arround 800 ka BP. Pénestin section constitutes the unique record of the Middle Pleistocene alluvial aggradation thanks to a subsident location. At the end of stage 9, the estuary shifted to is present situation, related to the uplift of Pénestin block, still continuing today. It explains the anomalous altitude of the estuary compared to Damgan, Rhuys (North) and Quiniac (South). Most of the estuaries of the southern coast of Brittany shifted to the West since Neogene. Ice wedges and stone wedges developped during stage 8 and 6 respectivelly, in association with the ventifact pavement (stage 8). They represent the southernmost evidence of continuous permafrost in Western Europe.

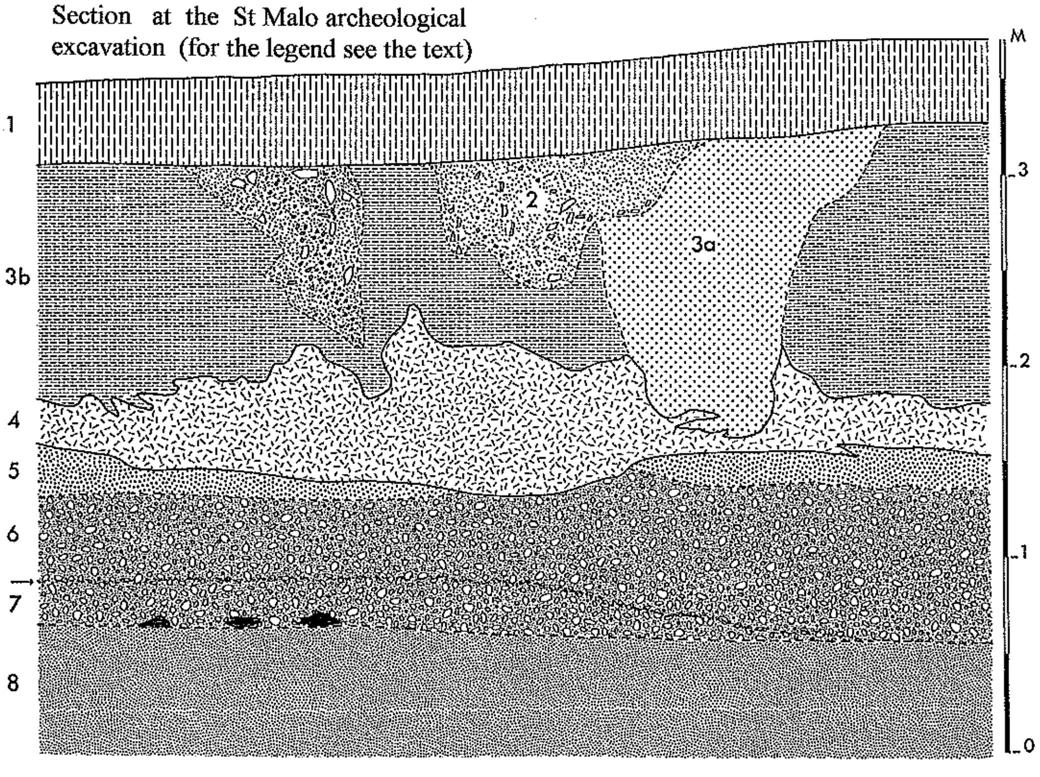
Figure 3 : Kerfaller , southern harbour section.





Geomorphology, tectonic and geological setting of St Malo de Phily section. Archeological excavation

Section at the St Malo archeological excavation (for the legend see the text)



SAINT MALO DE PHILY

B.VAN VLIET-LANOE, J.J.CHAUVEL, Y.MICHEL, J.L.MONNIER

The site of Saint Malo de Phily is located south of the Median Synclinorium. Basement is incised in proterozoïc shales, often weathered and the hill of St Malo is developed in the Armorican Sandstones. The site corresponds to a tectonic basin, first attributed to Pliocene only , but from which stratigraphy seems to be more complicated.

1. At the base, outcropping from -45m up to +30m is observed a thick kaolinitic sand estuarine formation, in large overlapping channels, prograding to the West, associated with bioturbations (scolithos) and burrowing shells holes at the surface of the outcropping horsts. This sand is very similar to the Eocene deposits described few km away, at Bain/Oust. This formation is located exclusively in the depression. Its age is probably Late Eocene or Oligocene.

2. This formation is truncated and incised by grey brownish sands, a fluviatile to estuarine aggradation, prograding to the South, with evidence of tidal currents. It corresponds to the "Bolan Formation" which can be ascribed to the Tortonian. This formation is also restricted to the depression and is strongly folded and faulted by some horst. A tropical podsol developed with the end of the sedimentation. Its orstein is faulted.

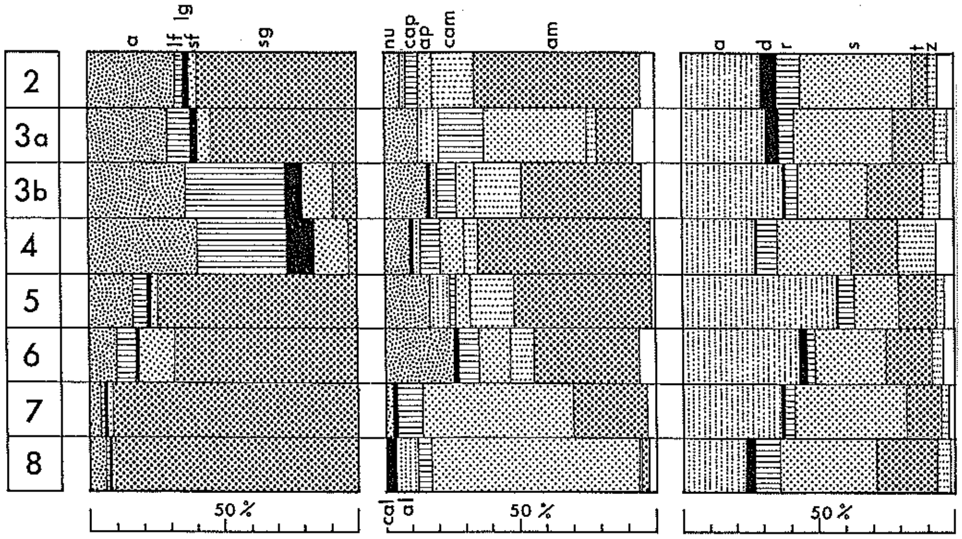
3. A third formation is incised in the former one: it is a detritic fan, reworking clasts, coming from the Armorican sandstone hill. It is tilted towards the south, at the foot of the hill. This formation or "Reguiny Formation" is ascribed to the Messinian.

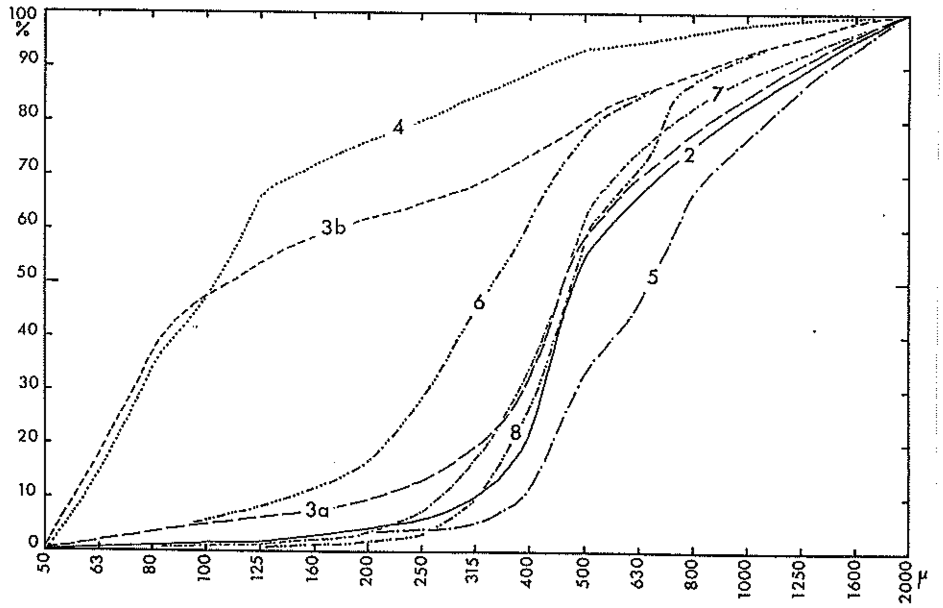
4. Mostly in stratigraphical conformity, a last fluviatile sand body, including several esturarine incursions outcrops mostly at the foot of the hill and in the upper part of the sandstone quarry of Montserrat, at 80m. This unit is syngenetic and epigenetic faulted. This formation covers probably the whole Pliocene and correspond to the Apigné and Radénac Formations.

5. In the depression, these sand bodies are truncated by several deposits of a braided Vilaine river, with some ice rafted blocks. A clay loam level is locally preserved as in other sites of the Vilaine, corresponding to an overflow event (1.4 Ma ?) often churned by co-seismic load casts. These deposits correspond to the 40m "middle" terrace and covering probably the Lower to the Middle Quaternary (Q1 and Q2). This formation (Cosquer Lojean Formation) is deformed by neotectonic activity (strike-slip), with local outcropping of the weathered palaeozoic substratum. Rubified polycyclic paleosol affects this deposits. Some syngenetic and epigenetic frost wedges casts are visible, they are probably not older than isotopic stage 12.

6. The 40m terrace is incised by the "vallon de la Bruère". This incision is related with a late rubifying banded Bt with very large tongues. This paleosol seems rather common for isotopic stage 9b.

couches / minéraux	2	3a	3b	4	5	6	7	8
opaques	75,00	69,23	78,07	79,62	66,20	64,75	54,26	39,63
amphibole	1,14	1,02	0,51	0,85	1,38	0,36	0	0
andalousite	28,98	30,62	37,44	27,36	57,24	43,12	36,17	23,79
chloritoïde	2,84	1,02	0	0,85	0	0,36	1,06	0,88
disthène	6,25	5,10	1,03	0,85	0,69	2,90	1,06	2,64
épidote	1,70	1,53	0	0,85	0	0	0	0,44
grenat	0,57	0	0	0	0	0,72	0	0
rutile	7,95	5,61	5,13	7,69	5,52	2,90	3,72	8,81
sillimanite	0	0	3,08	1,71	2,07	1,45	0,53	0,44
sphène	0,57	0	0,51	1,71	0	0,72	1,06	0,44
staurotide	41,48	36,22	25,64	27,36	15,86	26,09	40,97	36,12
tourmaline	5,68	14,29	20,51	17,09	13,79	17,39	12,77	22,03
zircon	2,84	4,59	6,15	13,68	3,45	3,99	2,66	4,41





Mineralogy and granulometry
of the archeological excavation

7. In the present-day valley, braided river accumulation form a low terrace (25m) correspond at least to 2 main cold periods (Q3, former quarries).

To conclude, the St Malo de Phily depression is an Eocene graben, re-incised during the early Tortonian regression, infilled during the late Miocene and Pliocene, with very little new tectonical vertical movements (Messinian crisis excepted), and eroded during the Quaternary, in relation with the global lowering of the sea level.

Archeology

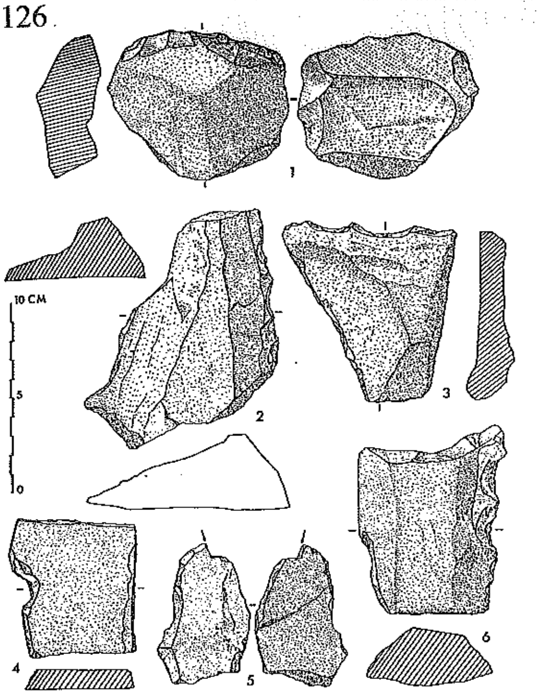
J.L.MONNIER, G.JUMEL

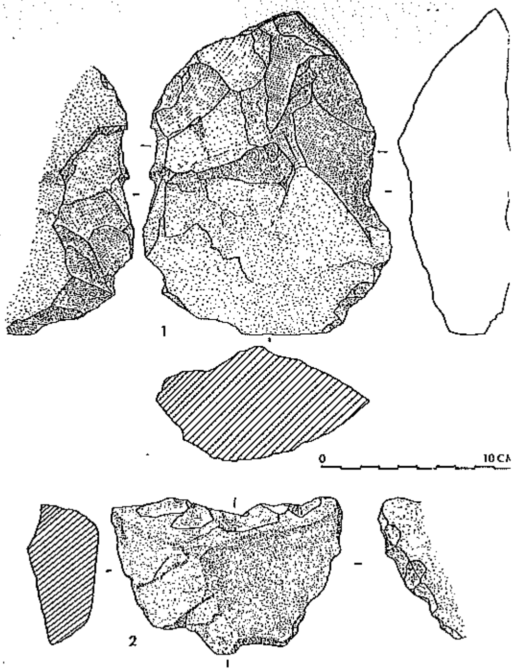
The artefacts of Saint-Malo-de-Phily are in a secondary position, in the Middle Terrace, close to the western edge of the basin. The habitat was probably established on the bank, above the flooding limit. The working face of a quarry shows, from bottom to top, the Mio-Pliocene sands, layers of gravely alluvium with sandy episodes; a grey clayey-loamy layer probably corresponding to overflow loams; a strongly rubifyed layer, penetrated by cut-and-fill ravines and crosscut by frost cracks or frost wedges. All this bears the stamp of important and complex pedogenesis. The sedimentological characteristics show up three important discontinuities. A phase of erosion and intense aeolian activities have preceded the deposition of the layers of gravels, of which the upper part, while preserving the trace of the aeolian agents, show a drift of fresh materials expressing an accentuation of upstream erosion. The clayey-loamy layer marks a diminution of the competency of the water course and thus a strong climatic change.

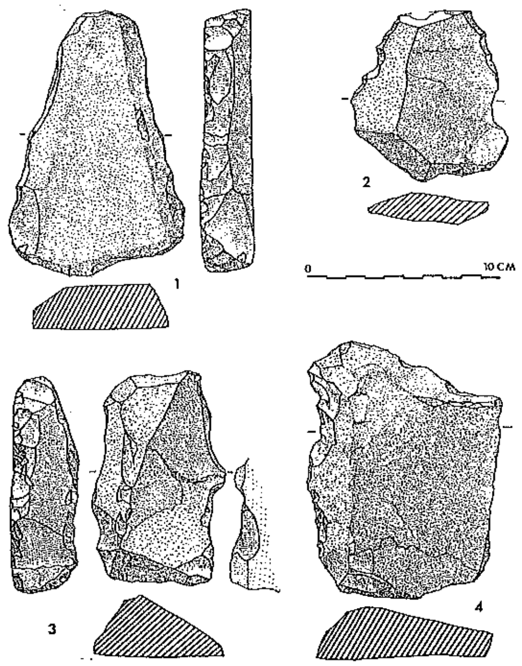
The stratigraphical position of the industry has been located in the foot of the coarse alluvium (unit 7). It is essentially made of quartzitic sandstone (the Armorican Sandstone), putting aside a few implements chipped in brown or greenish sandstones, probably also of paleozoïc age.

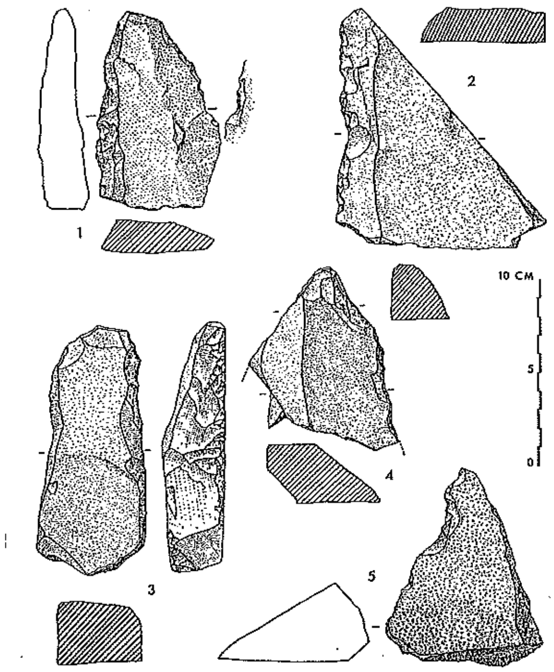
Typologically the implements are hard to classify. They are often kinds of large scraping-tools, thick or enormous notched implements. It is thus very rough and has sometimes opened doubts as to its truly anthropic characteristics. But the recent discovery of a specially evident pebble-tool, has happily confirmed the interest of the site. It is a typical chopping-tool, made out of a pebble of fine quartzite. This remarkable piece is, technologically and typologically, very different from the "Colombanian" pebble-tools .

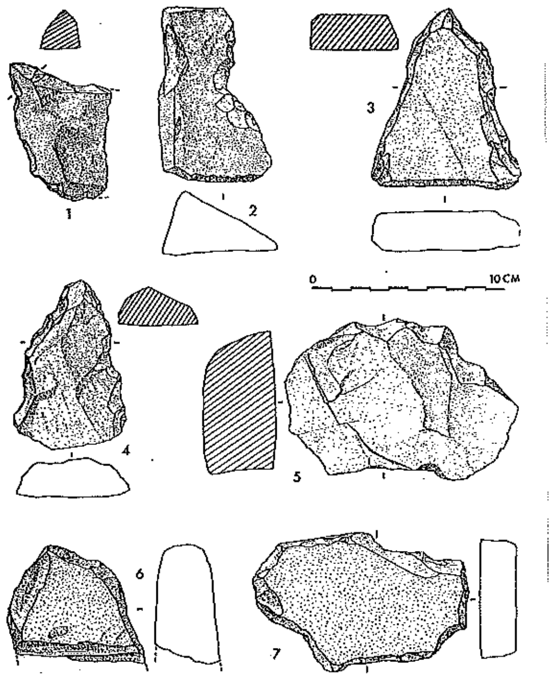
The age of the Saint-Malo-de-Phily site is not yet situated with certainty. It takes place among the highest terraces of the Vilaine river and is without doubt very ancient. The chronostratigraphic hypothesis is based on the interpretation of the paleosoils and of the nature of the deposits. The industry of Saint-Malo-de-Phily would take place at the beginning of Middle Pleistocene (isotopic stage 15 or 13).

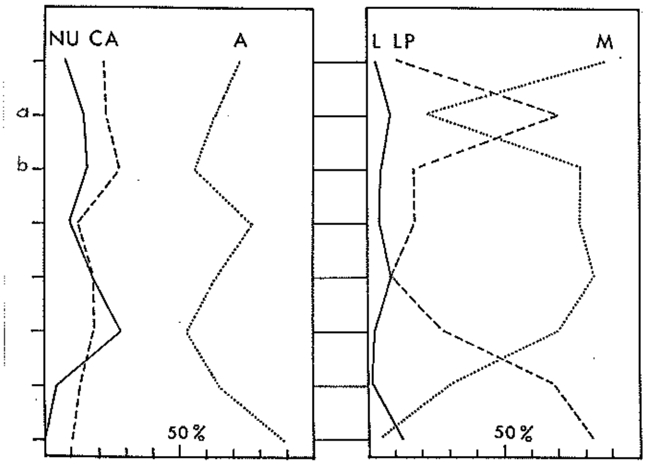












Industry of St Malo de Phily

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