Holocene climate as reflected by a malacological sequence at Verrières, France

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Though numerous analyses have been made of Holocene pollen sequences, they come from similar environmental contexts, mainly peat deposits. Land snails can provide good palaeoecological and palaeoclimatical data in different drier environmental settings. The Verrières deposits, located in the Seine Valley, southeast of Paris, provide rich and abundant malacofaunas. We compare the well-defined local biostratigraphy with other mollusc stratigraphies from Burgundy, the closest site to the studied region. Multivariate analysis of the malacofaunas indicates that temperature and moisture did not always vary in parallel during the Holocene. On the other hand, Verrières malacofaunas reflect the main Holocene changes, as observed in the classical pollen series, confirming the reliability of the local biostratigraphy. The Younger Dryas in Verrières was cold and dry. This was followed by the Preboreal phase, which is not well preserved at Verrières, but shows cool and humid conditions. The Boreal and Subboreal both show a cold and moist event bounded by two temperature phases. The Atlantic is also divided into two temperate phases by a cool and moist event. The Subatlantic shows temperature oscillations with cool peaks, but moisture shows a continuous trend to dryness.

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During recent years, much attention has been focused on Late Glacial and Holocene sequences, prompted by the progress in dating methods, particularly AMS methodology (Bard *et al.* 1987), and also by recent concern about climatic change. Detailed marine and ice records encourage comparisons with continental data. In the European area, pollen series yielded numerous references allowing precise comparisons and correlations (Mangerud *et al.* 1974). Also, insect studies, mainly with coleoptera, provide valuable information (Coope 1987; Ponel 1989). Nevertheless, these two kinds of biological remains always come from the same environmental context, i.e. peat deposits. For this reason other fossil data are needed to extend the climatic record. Among the palaeoecological indicators, terrestrial molluscs can play such a complementary role.

While they have been investigated for a long time, the Holocene mollusc series are not as numerous as pollen ones. Also, precision of the results is unequal, mainly due to the opportunities of fine sampling. For example, in a synthetic paper concerning the time series of the Holocene molluscs, Lozek (1972) clearly indicates the difficulty of good sampling. In his example, one stratigraphical level, and consequently one molluscan assemblage, corresponds to one Holocene chronozone. Another reason for the low precision of the possible comparison comes from the analytical method used. The classical method of species and individuals spectra, initially developed by Lozek (1964), allows a level by level comparison, yielding good environmental data but a poor record of climatic evolution (Alexandrowicz 1983; Fuhrmann 1973; Keen 1981; Lozek 1982; Meijer 1984; Piechocki 1977). Eleven ecological groups are defined, gathering species according to their ecological characteristics. The method used by Kerney (1963) does not propose any grouping and is similar to the classical pollen diagram representation. It clearly indicates how the succession of mollusc communities occurs, but, as noted previously, it does not yield a precise reconstruction of the evolution of climate.

We report here the results concerning a malacological Holocene sequence, located in the Seine Valley, northern France, and studied using both Lozek's and multivariate methods.

Location and stratigraphy

The Verrières site is located on the right bank of the Seine Valley (Long. 4°09'E, Lat. 48°13'N,

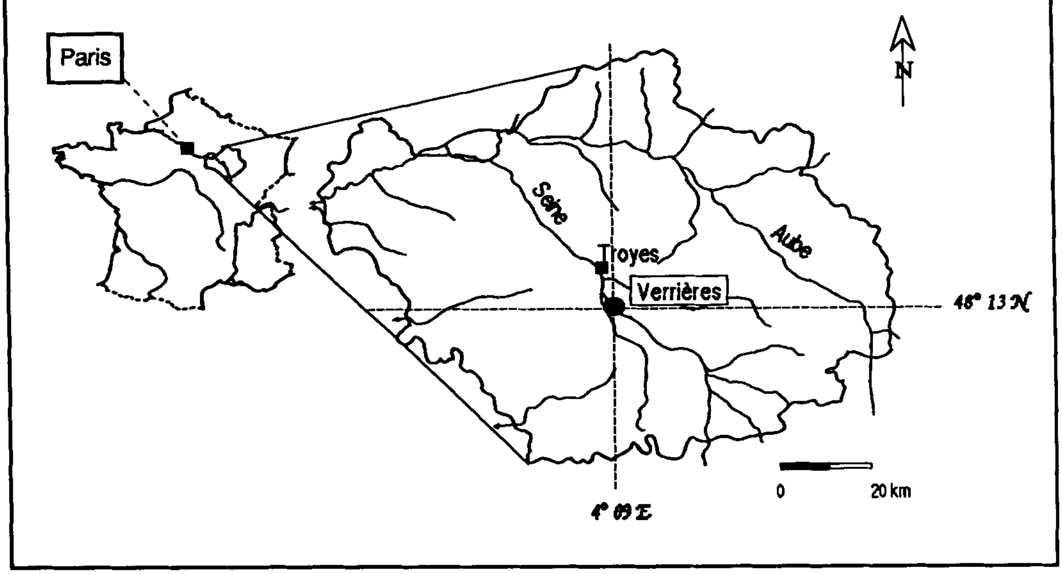


Fig. 1. Map of France with the location of the Verrières site in the Seine Valley.

and Alt. 120 m) about 10 km southeast of Troyes (Fig. 1). 'Marnes de Brienne', Cretaceous shales, are the bedrock and are located on the right bank at 115 m above sea level. An alluvial plain of Weichselian age (Krier 1990a) covers the whole width of the present valley and is 3.5 m deep (Fig. 2). Before the A5 and A26 motorways were dug, archaeological investigations of two settlements, Les Coeurs (Bronze age) and Grand-Champ (Middle Ages), yielded two well-preserved Holocene loamy sequences which were sampled for malacological investigations (Fig. 3).

The main stratigraphical section, 150 m in length and 3 m deep, was studied at Les Coeurs, and correlated, according to lithostratigraphy, with the Grand-Champ sequence, more than 200 m away (Fig. 4). The pedostratigraphy is composed of five main units from bottom to top:

unit a at the bottom, the alluvial plain consisting of gravels and sand;
unit b loamy-sandy levels, 1 m, with two dark organic interbedded layers. This set occurs in both outcrops but in the Les Coeurs section in the northern part;
unit c several channels in the central part of the valley, filled by loam and sand, cut into the preceding unit and containing reworked gravels from the alluvial plain;
unit d again loams completely filling channels;
unit e horizontal colluviums covering up all the previous units.

The Bronze age settlement occurs above unit c. Deposits in the northern part of the Les Coeurs section consisting of sand and gravels were not studied for malacological analysis because of poor preservation of the gastropod shells (Fig. 3; Cp008, 010, 011).

Malacological assemblages

About 10–15 kg of sediment was collected for each malacological sample. Of 60 total samples, 53 were fossiliferous (Tables 1–4). For precise stratigraphy, molluscan data were analysed and interpreted using the percentage frequencies of each ecological group (forest to aquatic) according to Lozek (1964) and Puisségur (1976). For each assemblage, molluscs were gathered into a maximum of 11 groups corresponding to their own ecological characteristics. The resulting stratigraphical series of the samples allowed us to determine environmental variations. Malacological successions are presented according to the stratigraphical units.

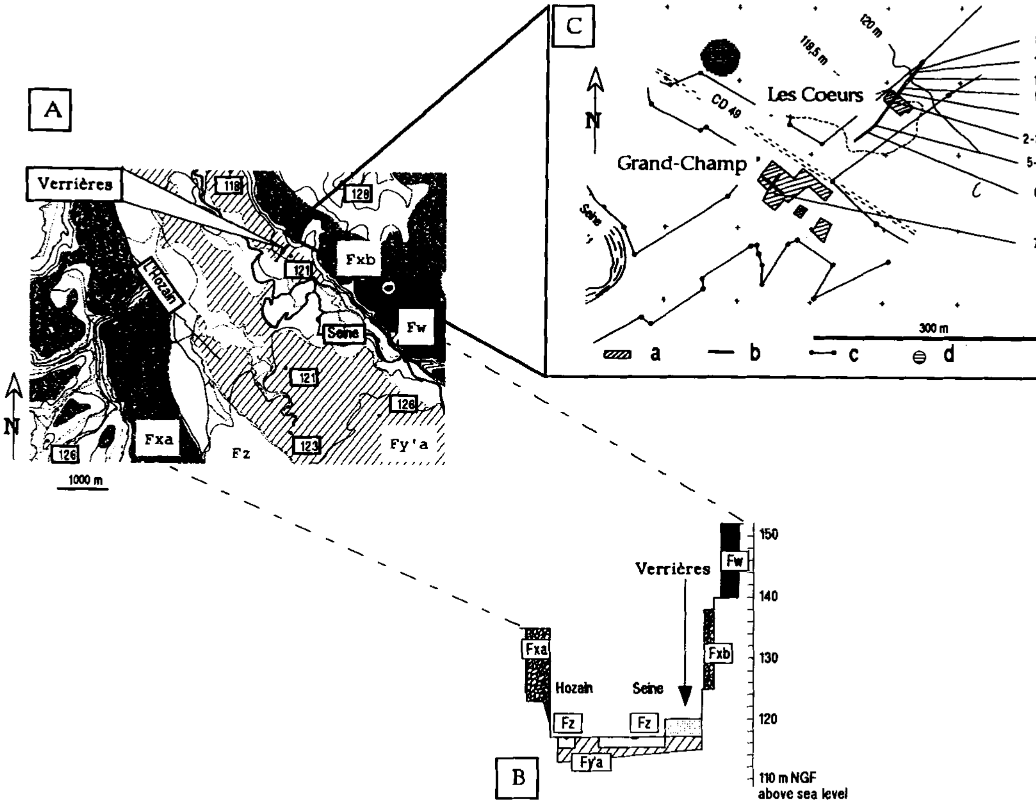


Fig. 2. Geological context of the Verrières sequence. □ A. Location of the different alluvial plains in the Seine Valley (after Krier, 1990a modified). □ B. Stratigraphic diagram of the alluvial plains: Fw – upper terrace, chalky gravels, between 140 and 152 m a.s.l.; Fx – middle terrace; Fxa – chalky gravels, between 120 and 135 m a.s.l. on the left bank; Fxb – chalky gravels and sands, between 125 and 138 m a.s.l. on the right bank; Fyla – chalky gravels and clay deposits. The elevation is 115 m on the right bank, 113.5 m in the middle and 112.9 m on the left bank; Fz – recent bed of the river, 2 m thick clay and sand deposits (after Krier, 1990a modified). □ C. Map of the site of Verrières (after Vacher, 1990 modified).

Unit a (stratigraphic columns Cp001, 007). – Three samples taken in the alluvial plain are barren because of the nature of the deposit. The preservation of the shells is impossible because of their fragility.

Unit b (stratigraphic columns Cp001, 007 and 009). – Malacological assemblages indicate a significant division of the base of the unit: first a dry phase (b1) and then a heavily flooded phase (b2) (Fig. 5). Molluscs of b1 subzone (Ma2/3/51/52) indicate an open ground landscape and a cold climate. Aquatic species are rarely present. In contrast, terrestrial ones, such as *Punctum pygmaeum* and *Abida secale*, which are often associated with stony ground, show high values. Forest taxa are practically non-existent. The corresponding environment of these assemblages is a dry valley, without any trees or bushes, scarce herbs and a few pools allowing certain aquatic species to survive (Fig. 5; Ma3/51). In Ma38/4/53 (unit b2), the sudden rise in aquatic species (up to 73.91, 89.26 and 96.45%) corresponds to a significant inundation throughout the valley.

The stabilization of this environment, i.e. the channelization, is indicated in the following assemblages Ma39/5/54 and 6/55 by reduced values of aquatic species. Here a lateral variation in the percentages of forest taxa also occurs. It is markedly present to the north in Ma39, less developed in Ma5/6, and absent in the southern part in Ma54/55 (Grand-Champ) (Fig. 5). Again

Table 1. List of the species recognized in sampling columns Cp001 and Cp009.

Ecological groups	Species	Cp001 MA2	MA3	MA4	MA5	MA6	MA7	MA8	MA9	MA10	Cp009 MA38	MA39	MA40	MA41	MA42	MA43	MA44	MA45
1.F1	*Clausilia bidentata* Ström				2	21				1		14	5			8	9	6
	Vertigo pusilla Müll																	
F2	*Acanthinula aculeata* Müll	1	1		1	23						2		1		3	3	2
	Aegopinella nitidula Drap				25	149		1		4		42	14	9	8	43	26	39
	Cochlodina laminata Mont															2	3	2
	Cochlodina sp.																	
	Ena obscura Müll				1	3												
	Ena sp.											3					1	3
	Macrogastra sp.																1	
	Sphyradium doliolum Brug																1	1
	Helicodonta obvoluta Müll														1	1		
2.fm	*Cepaea* sp./Gdes espèces				1	6		4		1		2	1	1		1	2	1
	Cepaea hortensis Müll																	
	Cepaea nemoralis L.																	
	Discus rotundatus Müll				6	20		1	7	3	1	6		8	10	10	13	13
	Bradybaena fruticum Müll															1		1
	Pomatias elegans Müll														1	1	1	
4.S	*Chondrula tridens* Müll																	
	Chondrula sp.																	
	Helicella itala L.																	
	Cecilioides acicula Müll					12	2	9	12	21		1		10	17	6	76	306
	Candidula unifasciata Poiret													2		1	2	7
5.	*Pupilla muscorum* L.	3														1	3	10
	Vallonia costata Müll	105	15	22	102	512				3	9	61	10	300	115	17	35	78
	Vallonia pulchella Müll	34	30		6		70			4	5	2		15	34	4	27	48
	Vertigo pygmaea Drap	10	5			5	4	8						1	3		3	3
	Truncatellina cylindrica Fér																	
6.	*Cochlicopa lubricella* Porro																	
7.M	*Euconulus fulvus* Mull					1												
	Euconulus sp.																	
	Oxychilus cellarius Müll																	1
	Oxychilus sp.																	
	Trichia hispida L.	50	26	6	35	59	1	1	11	10	3	19	4	12	28	21	51	60
	Vitrea contracta West	2		11	28	127	4	69	14	10	3	19	1	57	63	23	25	7
	Punctum pygmaeum Drap	3	3			16						1		11				1
h	*Cochlicopa lubrica* Müll	4	1	5	16	71	8	77	115	4		4	1	56	53	9	45	9
	Nesovitrea hammonis Ström	5	5	13	24	50	20	43	3	3		6	1	9	15	4	8	4
	Trichia plebeia Drap																	

fr	*Clausilia parvula* Fér	12	1											10	3	1		
	Clausilia sp.							3		2	1,							
	Helicigona lapicida L.					1						1		1		1		
	Abida secale Drap	43	5															
	Abida sp.																	
7'.	*Limaces*	1	2	5	4	31		103	57		3		11	10	1	4	3	15
8.	*Succinea oblonga* Drap	3	3	22	5	22				1		2		3	2		3	
	Carychium tridentatum Risso		3	2	7	177	8	7		1	2	14	8	2	6	9	6	8
	Vertigo angustior Jeffreys						1	71	2		1						1	
	Euconulus alderi Grey				1		2	10	62	3				39	26	2	8	2
	Vertigo substriata Jeffreys																	
	Columella edentula Drap																	
9.	*Oxyloma elegans* Risso	1	1	5	4	14		65	180	11	6	2	1	62	26	3	21	5
	Vertigo antivertigo Drap			5	5	23	43	72	18	2	8	6	4	17	5	3	6	
	Zonitoides nitidus Müll							13	81	12	8			40	40	2	89	9
	Carychium minimum Müll	1			1	16		900	1200	13	2		4	500	15	7	67	17
	Vallonia enniensis Gredler							647	588									
	Succinea putris L.																	
	Vertigo genesii Gredler						2		2									
10.A1	*Valvata cristata* Müll	3	10	122	158	41	20	340	265	59	272		10	174	129	85	146	44
	Galba palustris Müll		1	4	3		1	4	1		5		1			2	8	
A2	*Anisus leucostomus* Millet					2	3	133	43	11			1	36	31	35	6	1
	Aplexa hypnorum L.																	
A3	*Acroloxus lacustris* L.																	
	Armiger crista L.			3		4		1	5	2	2			41	2	6	4	2
	Valvata piscinalis Müll							7	20	427	2		1	116	123	107	194	74
	Planorbis carinatus Müll					5	6	5	3	5				2	2	2	6	
	Limnaea stagnalis L.							1	3	8								
	Planorbis contortus L.					19	70	49	13	5	5		3	22	15	18	6	4
	Radix ovata Drap					4	13	3		201	6	3		127	118	15	66	4
	Galba truncatula Müll				16	24	21	112	230	6		1	3	34	12	6	23	5
	Planorbis corneus L.									42								
	Gyraulus albus Müll									6				14	25	18	13	4
	Planorbis complanatus L.									2				2	2		3	
	Limnaea fusca Pfeiffer								9									
A4	*Ancylus fluviatilis* Müll									1				9	1		7	1
	Theodoxus fluviatilis L.																	
	Bythinia tentaculata L.	1	15	142	94	96	63	221	56	519	138	11	11	63	22	85	90	30
	Pisidium sp.			1			1	1	11	92	2		1	72	24	3	65	3
	Sphaerium sp.									2						4		
	Bythinella sp.					3	1	3	6	1				1				
	Sum	282	127	368	545	1557	364	2984	3018	1498	484	222	96	1889	978	574	1176	830

Table 2. List of the species recognized in sampling columns Cp007 and Cp003.

Ecological groups	Species	Cp007 MA51	MA52	MA53	MA54	MA55	MA56	MA57	MA58	MA59	Cp003 MA18	MA19	MA20	MA21	MA22
1.F1	*Clausilia bidentata* Ström										2				5
	Vertigo pusilla Müll														1
F2	*Acanthinula aculeata* Müll										1	9	1	3	18
	Aegopinella nitidula Drap							5	9	1	18	38	3	42	113
	Cochlodina laminata Mont								2					12	21
	Cochlodina sp.										1				
	Ena obscura Müll												1	5	9
	Ena sp.														
	Macrogastra sp.										1	1	1		
	Sphyradium doliolum Brug											9	1	3	13
	Helicodonta obvoluta Müll														
2.fm	*Cepaea* sp./Gdes espèces					1	1		7	1	1	5	2		24
	Cepaea hortensis Müll													12	
	Cepaea nemoralis L.							4							
	Discus rotundatus Müll					6	3	9	8	1	1	52	9	19	130
	Bradybaena fruticum Müll					1		1	1	1		1		5	
	Pomatias elegans Müll									1		1			8
4.S	*Chondrula tridens* Müll					1									8
	Chondrula sp.						1								
	Helicella itala L.		2		2	1		1	6	3					58
	Celilioides acicula Müll				5	39	93	256	168	64				3	4
	Candidula unifasciata Poiret								1	1				11	
5.	*Pupilla muscorum* L.	1	1			1	3	5	17	3		31	10	77	383
	Vallonia costata Müll	7	45		17	340	19	62	144	35	120	121	14	93	482
	Vallonia pulchella Müll	8	104	2		11	2		18	10	16	33	173	170	335
	Vertigo pygmaea Drap		11			2		2	5		1	11	2	56	192
	Truncatellina cylindrica Fér							1					2	7	28
6.	*Cochlicopa lubricella* Porro					6			1	1			1	4	43
7.M	*Euconulus fulvus* Müll														
	Euconulus sp.														
	Oxychilus cellarius Müll							3						9	
	Oxychilus sp.														
	Trichia hispida L.	21	113	1	3	85	14	26	83	28	24	53	30	61	451
	Vitrea contracta West				3	30	5	13	12		30	64	6	109	235
	Punctum pygmaeum Drap		29					1			3	11	3	29	53
h	*Cochlicopa lubrica* Müll		12		1	48	4	4	17	2	29	42	11	73	188
	Nesovitrea hammonis Ström		20		1	60	7	2	16	1	5	5	2	14	71
	Trichia plebeia Drap														4

fr	*Clausilia parvula* Fér					3					1			24	79
	Clausilia sp.	3	4				1	2	2	1		7	1		
	Helicigona lapicida L.										1				1
	Abida secale Drap		14			8									
	Abida sp.													2	4
7'.	*Limaces*		5		1	22	1	11	12	2	7	9	1	2	2
8.	*Succinea oblonga* Drap	1	18		1	15	3	2		2	4	9		12	11
	Carychium tridentatum Risso					2	3	8			14	95	14	185	335
	Vertigo angustior Jeffreys											2		1	9
	Euconulus alderi Grey		4	1		1	1	3			2	10	1	18	89
	Vertigo substriata Jeffreys											2			
	Columella edentula Drap										1	1			2
9.	*Oxyloma elegans* Risso		10	1		9	5	11	2	3	17	25	21	29	12
	Vertigo antivertigo Drap		1		2	1	7				7	9	3	41	239
	Zonitoides nitidus Müll		16	2	1	4	7	14	1		7	34	8	27	111
	Carychium minimum Müll		5				6	108	6		42	190	32	240	700
	Vallonia enniensis Gredler														
	Succinea putris L.							2	3						
	Vertigo genesii Gredler														
10.A1	*Valvata cristata* Müll	1				41	220	350	18	14	91	321	97	500	535
	Galba palustris Müll			35	1	2	2	3			2	5	1	19	40
A2	*Anisus leucostomus* Millet	2				4	5	7	9	2	7	26	15	35	188
	Aplexa hypnorum L.														
A3	*Acroloxus lacustris* L.														
	Armiger crista L.					21	114	25		1	5	26	3	14	
	Valvata piscinalis Müll	1			1	3	6	317	8	22	27	159	42	118	208
	Planorbis carinatus Müll					30	48	11	1	1	1	5	6	11	63
	Limnaea stagnalis L.				1			5	1	1				1	
	Planorbis contortus L.					11	22	122	3	2	4	36	8	48	105
	Radix ovata Drap	1	1	52	3	3	21	4	29	90	21	127	40	55	82
	Galba truncatula Müll	2	2	10	3	4	8	16	2		13	52	112	97	104
	Planorbis corneus L.										1				
	Gyraulus albus Müll	1						7	1	9	3	257	14	24	19
	Planorbis complanatus L.							3			1		2	1	2
	Limnaea fusca Pfeiffer										2	1			
A4	*Ancylus fluviatilis* Müll					1	10			1		2	2		
	Theodoxus fluviatilis L.														
	Bythinia tentaculata L.	1		93	34	116	230	62	94	98	127	200	73	188	413
	Pisidium sp.					9	30	130	9	3	15	91	12	1	3
	Sphaerium sp.														
	Bythinella sp.					1								9	8
	Sum	50	417	197	80	943	902	1616	718	405	676	2188	780	2519	6241

Table 3. List of the species recognized in sampling columns Cp005 and Cp006.

Ecological groups	Species	Cp005										Cp006				
		MA23	MA24	MA25	MA26	MA27	MA28	MA29	MA30	MA31	MA32	MA33	MA34	MA35	MA36	MA37
1.Fl	*Clausilia bidentata* Ström						2		1		1		5			
	Vertigo pusilla Müll															
F2	*Acanthinula aculeata* Müll								1		2					
	Aegopinella nitidula Drap						10	1	7		3	1	1			1
	Cochlodina laminata Mont						12	1			1					1
	Cochlodina sp.					1										
	Ena obscura Müll															
	Ena sp.			1			1		2						1	
	Macrogastra sp.						1	1								
	Sphyradium doliolum Brug															
	Helicodonta obvoluta Müll															
2.fm	*Cepaea* sp./Gdes espèces					4	8	1	1	1	3		1		1	2
	Cepaea hortensis Müll															
	Cepaea nemoralis L.															
	Discus rotundatus Müll		1	1			1				3	2	1		1	
	Bradybaena fruticum Müll					9	1	1	1	1						1
	Pomatias elegans Müll														1	
4.S	*Chondrula tridens* Müll								7	3	4					
	Chondrula sp.															1
	Helicella itala L.							22	47	10	10	1	4		6	9
	Cecilioides acicula Müll	1			1	3	49	47	200	11				12	14	300
	Candidula unifasciata Poiret					2	12			1						
5.	*Pupilla muscorum* L.						1	2	4	1	6	3	7	1	1	
	Vallonia costata Müll			1	8	68	33	14	232	9	17	17	31	3	15	66
	Vallonia pulchella Müll	7	5	8	9	183	212	61	29	33	17	14	41			74
	Vertigo pygmaea Drap	1				2	1		2		1		8			1
	Truncatellina cylindrica Fér					1						1	1			
6.	*Cochlicopa lubricella* Porro						7		2		2					
7.M	*Euconulus fulvus* Müll															
	Euconulus sp.															
	Oxychilus cellarius Müll															
	Oxychilus sp.									1	1					
	Trichia hispida L.	1	1	6	2	59	175	69	206	24	38	17	23	3	17	54
	Vitrea contracta West	1		2	3	8	36				5	5	57			2
	Punctum pygmaeum Drap					4	9					4	1			1
h	*Cochlicopa lubrica* Müll			4	1	12	40	1	4		12	5	39		1	3
	Nesovitrea hammonis Ström			2	1		3		1		1		4		2	1
	Trichia plebeia Drap															

fr	*Clausilia parvula* Fér										2		4		3	
	Clausilia sp.			1		1						1				1
	Helicigona lapicida L.															
	Abida secale Drap														3	
	Abida sp.															1
7'.	*Limaces*	1			1	13	26	13	28	16	1		12		3	14
8.	*Succinea oblonga* Drap						1				3		1			1
	Carychium tridentatum Risso					1	7					26				
	Vertigo angustior Jeffreys															
	Euconulus alderi Grey		1			1	4				1	4	10	2		1
	Vertigo substriata Jeffreys															
	Columella edentula Drap															
9.	*Oxyloma elegans* Risso	2	4	12		2	14				2	27	45	2		4
	Vertigo antivertigo Drap	1		3		1	1				1	3	1			
	Zonitoides nitidus Müll		3	1		2	5				4	49	189	1	1	1
	Carychium minimum Müll	7	1	11	3	17	116						260			
	Vallonia enniensis Gredler	4														
	Succinea putris L.											1				
	Vertigo genesii Gredler															
10.A1	*Valvata cristata* Müll	225	56	31	24	53	4	3		1	72	40	163	50	17	74
	Galba palustris Müll			3							1		8	2		
A2	*Anisus leucostomus* Millet	5	2				4				2		67		1	
	Aplexa hypnorum L.												25			
A3	*Acroloxus lacustris* L.			5	1											
	Armiger crista L.	64	1	6		11	2			1		1				3
	Valvata piscinalis Müll	149	163	201	111	45					9	6	2	21	9	25
	Planorbis carinatus Müll	7	3	11	25	35					26		32	5	6	1
	Limnaea stagnalis L.		9	30	19	2					2					
	Planorbis contortus L.	3	2	11	2	3	1				8	2	15	21	6	5
	Radix ovata Drap	3	13	58	29	4			1		2	63	10		18	6
	Galba truncatula Müll	4	3	13	1	4	14	1			3	142	125	1		
	Planorbis corneus L.															
	Gyraulus albus Müll	145	84	180	90	27					16	5	3			4
	Planorbis complanatus L.	4		2	5	2					41		1			
	Limnaea fusca Pfeiffer															
A4	*Ancylus fluviatilis* Müll															
	Theodoxus fluviatilis L.			1												1
	Bythinia tentaculata L.	123	148	350	160	340	120	21	10	2	237	29	56	100	40	10
	Pisidium sp.	92	85	150	92	5					14	20	65	4	2	2
	Sphaerium sp.										1					
	Bythinella sp.					2						11				1
	Sum	850	587	1105	588	927	936	260	786	115	575	500	1318	228	169	672

Table 4. List of the species recognized in Les Coeurs sampling columns.

Ecological groups	Species	(Cp003) MA15	(Cp003) MA16	(A177) MA11	(Cp002) MA12	(Cp002) MA13	(A317) MA14	(B262) MA17
1.F1	*Clausilia bidentata* Ström	5	5	8	6	1	8	13
	Vertigo pusilla Müll							
F2	*Acanthinula aculeata* Müll	5	9	7	5	4	1	14
	Aegopinella nitidula Drap	20	32	17	10	17	29	77
	Cochlodina laminata Mont	1	4	3	1	4	4	13
	Cochlodina sp.							
	Ena obscura Müll	1	13	6		4	4	11
	Ena sp.							
	Macrogastra sp.		2			1		1
	Sphyradium doliolum Brug	1	1	2	1	2	1	
	Helicodonta obvoluta Müll							
2.fm	*Cepaea* sp./Gdes espèces	5	9	1		2	2	7
	Cepaea hortensis Müll				2			
	Cepaea nemoralis L.							
	Discus rotundatus Müll	6	33	8	4	13	8	31
	Bradybaena fruticum Müll	1	1	1	1	1	1	1
	Pomatias elegans Müll		1	1			1	
4.S	*Chondrula tridens* Müll						2	
	Chondrula sp.							
	Helicella itala L.							
	Cecilioides acicula Müll	33	48	288	66	105	17	74
	Candidula unifasciata Poiret	1	2	7	2	5	7	4
5.	*Pupilla muscorum* L.	23	32	16	11	19	26	43
	Vallonia costata Müll	132	288	118	49	12	134	236
	Vallonia pulchella Müll	27	13	23	15	121	21	12
	Vertigo pygmaea Drap	2	2	3	1		1	7
	Truncatellina cylindrica Fér	2		1				1
6.	*Cochlicopa lubricella* Porro	1	4			1	2	3
7.M	*Euconulus fulvus* Müll					1	2	1
	Euconulus sp.			2	1			
	Oxychilus cellarius Müll							
	Oxychilus sp.							
	Trichia hispida L.	47	135	77	20	72	97	199
	Vitrea contracta West	9	28	12	8	5	20	50
	Punctum pygmaeum Drap	1		2	1	1	1	2
h	*Cochlicopa lubrica* Müll	15	41	22	10	89	29	36
	Nesovitrea hammonis Ström	1		1				
	Trichia plebeia Drap							
fr	*Clausilia parvula* Fér		1			1	1	3
	Clausilia sp.							
	Helicigona lapicida L.				1			
	Abida secale Drap							
	Abida sp.							
7'.	*Limaces*	6	10	7		1	7	10
8.	*Succinea oblonga* Drap	1	2	2			1	
	Carychium tridentatum Risso	10	7	8	6	1	11	55
	Vertigo angustior Jeffreys					1		
	Euconulus alderi Grey							
	Vertigo substriata Jeffreys						1	
	Columella edentula Drap							
9.	*Oxyloma elegans* Risso	1	2	2	1	1	4	4
	Vertigo antivertigo Drap	3		3		1	6	2
	Zonitoides nitidus Müll	3					7	4
	Carychium minimum Müll	2	1	4	2		3	3
	Vallonia enniensis Gredler							
	Succinea putris L.							
	Vertigo genesii Gredler							
10.A1	*Valvata cristata* Müll	35	13	52	8	6	65	44
	Galba palustris Müll							1

Table 4 (continued).

Ecological groups	Species	(Cp003) MA15	(Cp003) MA16	(A177) MA11	(Cp002) MA12	(Cp002) MA13	(A317) MA14	(B262) MA17
A2	*Anisus leucostomus* Millet	3	2	2	1	3	8	12
	Aplexa hypnorum L.							
A3	*Acroloxus lacustris* L.							
	Armiger crista L.		1	5			1	1
	Valvata piscinalis Müll	10	10	15	4	3	13	12
	Planorbis carinatus Müll			3	2		5	2
	Limnaea stagnalis L.			1				
	Planorbis contortus L.	4	3	4			8	3
	Radix ovata Drap	5	1				8	1
	Galba truncatula Müll	2		2			2	8
	Planorbis corneus L.		2	1				
	Gyraulus albus Müll	2	2	2			2	2
	Planorbis complanatus L.							
	Limnaea fusca Pfeiffer							
A4	*Ancylus fluviatilis* Müll			2	1			
	Theodoxus fluviatilis L.							
	Bythinia tentaculata L.	10	15	32	6	4	23	24
	Pisidium sp.		1	1		1	1	11
	Sphaerium sp.			1				
	Bythinella sp.			3	5		1	
	Sum	433	772	778	251	503	596	1039

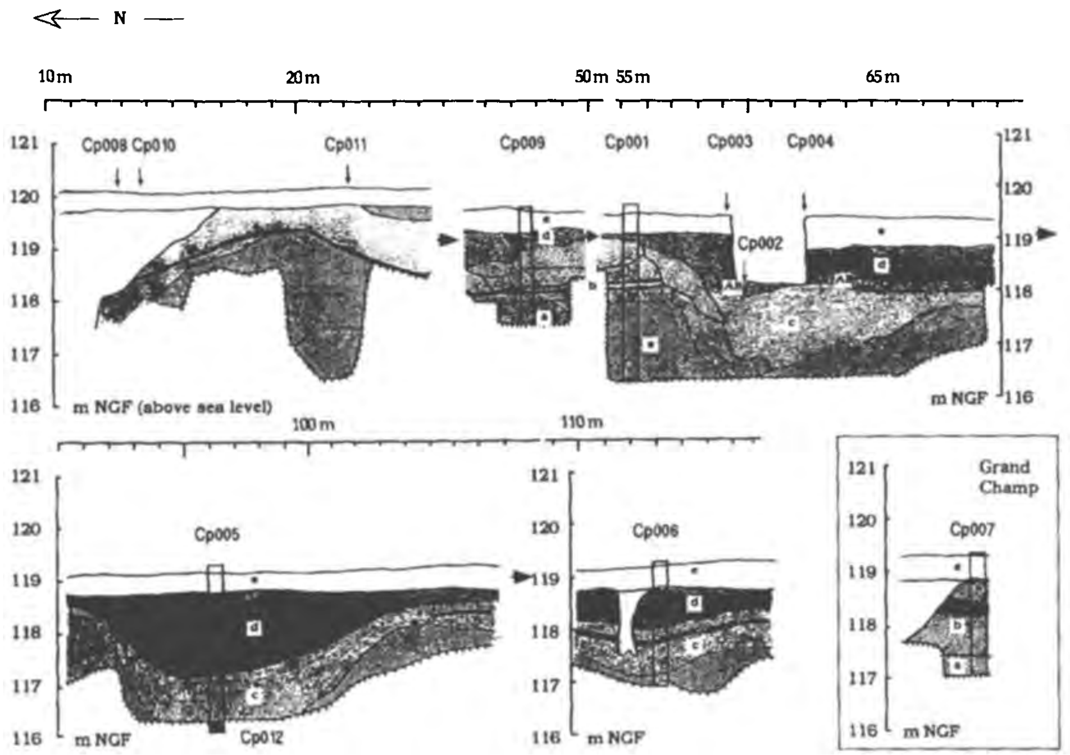


Fig. 3. Stratigraphical sections of 'Les Coeurs' and 'Grandchamp' in the Verrières site (after Krier, 1990a modified). Location of the sampling columns (Cp001–011). Column Cp002 refers only to the archaeological level (Bronze Age) and is located on the other side of the trench. a: gravels and sand (alluvial plain), b: silt and sand levels with two dark organic layers, c: channel digging and fill deposits of silt and sand (AB = Bronze Age layer), d: second phase of fill deposits, e: recent colluvials.

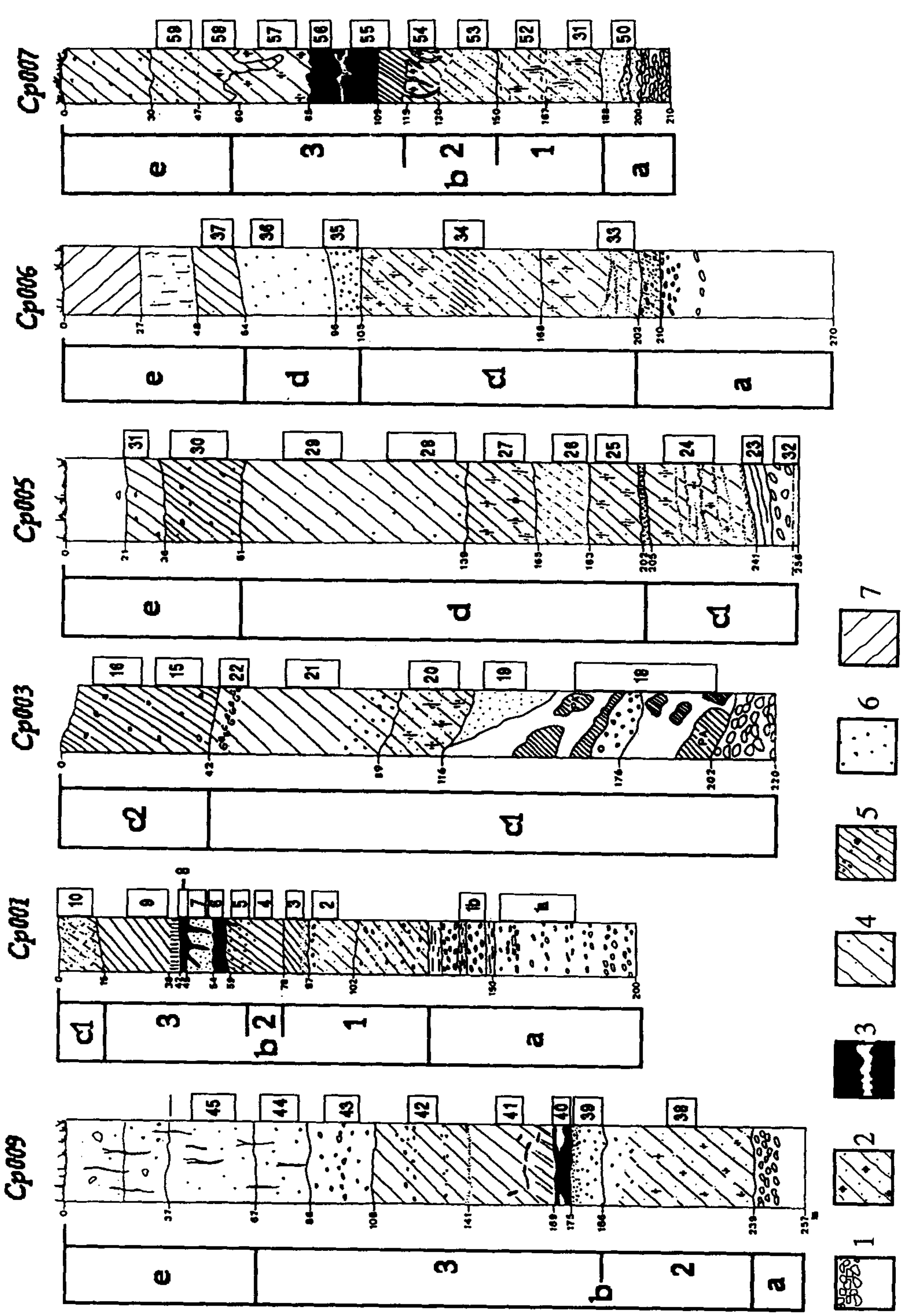


Fig. 4. Location of the different malacological sampling in columns Cp009, Cp001, Cp003, Cp005, Cp006 and Cp007. The letters correspond to the stratigraphical units described in the text. Sedimentological characteristics of the deposits: 1, gravels; 2, loamy-sandy; 3, organic; 4, grey loam; 5, brown loam with small calcareous gravels; 6, silty; 7, vegetable soil.

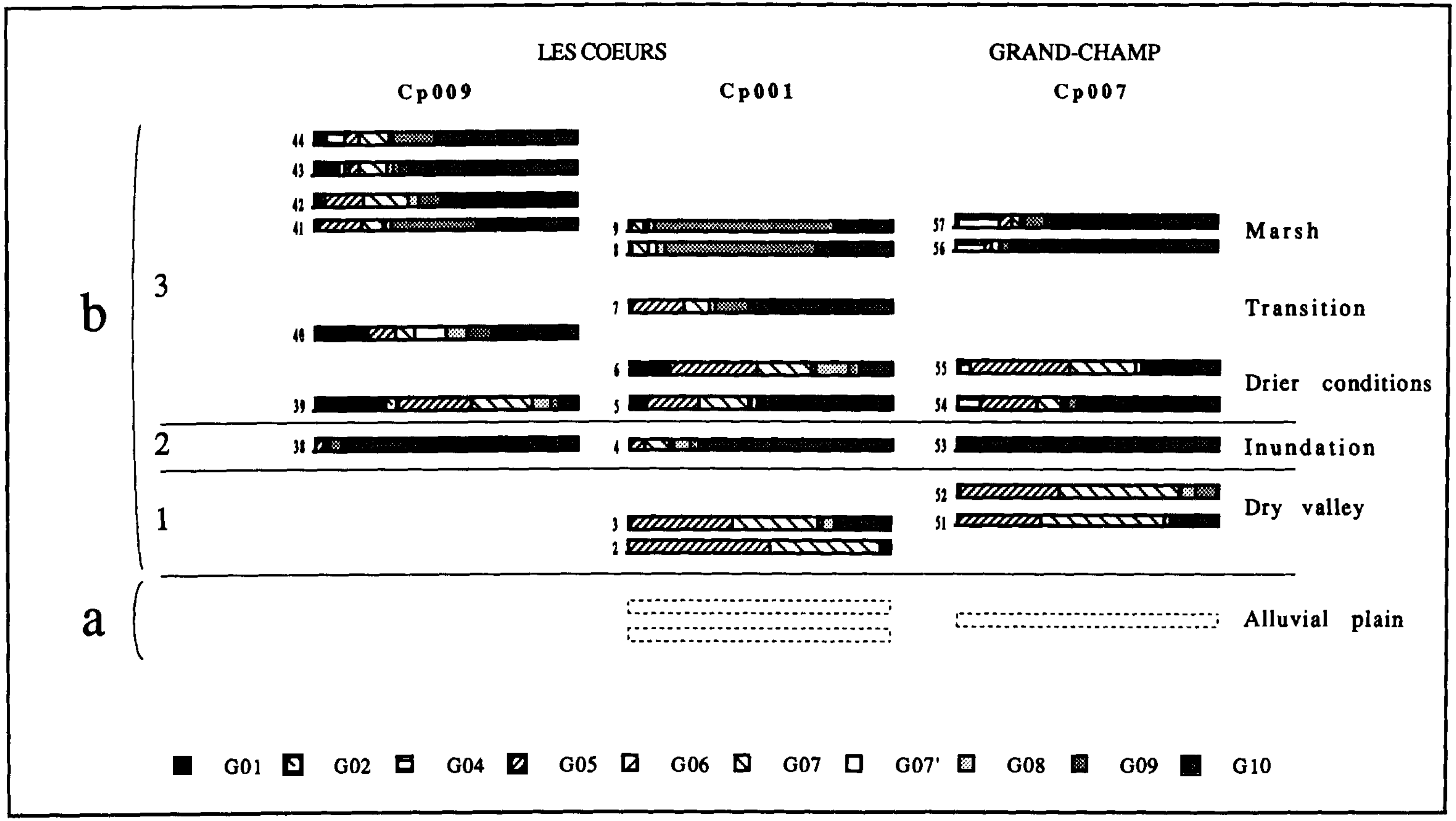


Fig. 5. Correlations between the malacological assemblages of units a and b. The malacofauna of each sample is represented by a rectangle of 100% value, divided in sectors according to the number of individuals in each ecological group (1: forest, 2: semi-forest, 4: dry open ground, 5: open ground, 6: xeric, 7: catholic, 7′: slugs, 8: damp places, 9: marshes, 10: aquatic). The first division is stratigraphic, separating gravels and sand deposits (unit a) from silts and sand sequence (unit b). The other two separations isolate very contrasted malacofaunas: assemblages of dry valley and inundation.

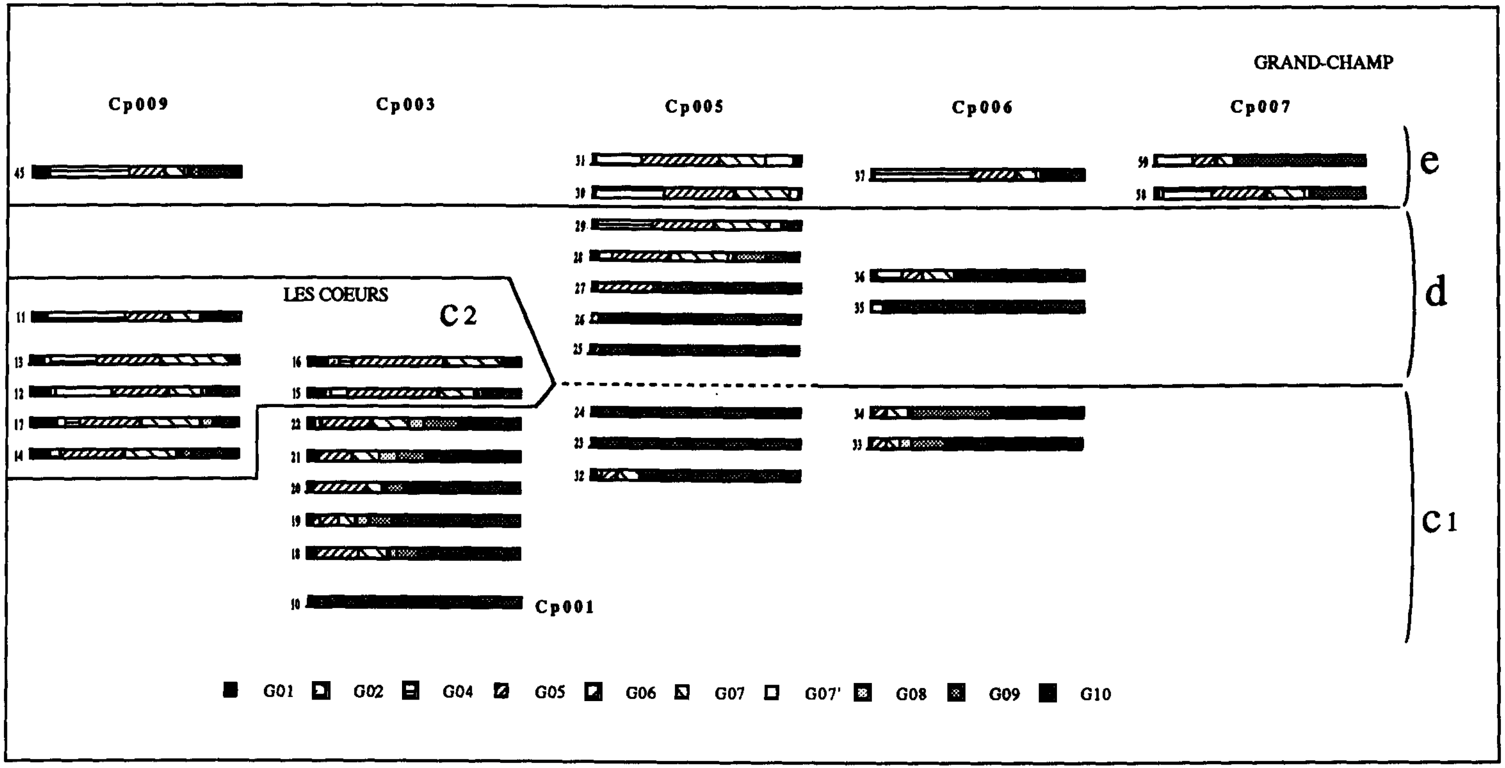


Fig. 6. Correlations between malacological assemblages of units c, d and e. Divisions according to sediment units: c1 – channels digging and first fill deposits; c2 – archaeological layer of Les Coeurs; d – second phase of fill deposits; e – recent colluviums corresponding to medieval occupation of Grand-Champ. Legend as in Fig. 5.

both Ma40 and Ma7 are rich in freshwater molluscs and already contain paludal species (Fig. 5). Malacological associations of the upper part of unit b indicate marshy conditions, as mainly shown in Cp001 (Fig. 5). A marshy environment still occurs in Cp009, while Cp007, 200 m distant, contains clearly aquatic assemblages (Fig. 5). Most of the associations representative of a marshy environment (Ma8/9) contain *Vertigo genesii*; its current Boreal and Alpine distribution reinforces the cold climatic interpretation of the assemblages. Up at the top of the unit, areas of free-moving water progressively replaced the marsh (Fig. 5).

Unit c (stratigraphic columns Cp003, 001, 005, 012, 006 and Bronze Age levels). – According to stratigraphic analysis (Krier 1990b), unit c relates to an active period in the development of channel systems (subzone c1). After a significant erosion of part of unit b (Fig. 4), channels became partially filled in. Cp003, 005 and 006 indicate similar dynamics of deposition. Accordingly, malacofaunas indicate the full activity of the channel (Ma32/23/24), the occurrence of neighbouring banks (Ma18 to 22) or marsh (Ma33/34) (Fig. 6). Malacofaunas show the evolution of each channel microenvironment but they cannot indicate whether or not particular microenvironments coexisted.

At the top of the deposits, samples taken from the prehistoric level (subzone c2) show a stabilization of the environment (Fig. 6). Seven samples (Ma11 to 17) indicate similar environmental conditions: a moist open ground, similar to a grassland, with few bushes or trees. The occurrence of certain forest species indicates a mild climate. The malacofaunas are abundant and well preserved. Furthermore, the homogeneous records of the environment indicate that human activity did not disturb the site.

Unit d (stratigraphic columns Cp005 and 006). – After the departure of the Bronze Age people, the filling in of the channels came to an end (Fig. 4). Malacological remains in the upper part of Cp005 and Cp006 indicate a progressive drying out of the channel and a general change to a drier environment (Fig. 6).

Unit e (stratigraphic columns Cp009, 005, 006 and 007). – This unit corresponds to colluvials covering all preceding deposits (Fig. 4). Malacological remains (Ma45, Ma30/31, Ma37 and Ma58/59) indicate a drying-out of the environment, open ground species being highly dominant (Fig. 6).

Consequently, the malacofaunas of Verrières recorded several climatic phases as indicated by their changes through time. Because the Verrières site is not too distant from Burgundy and because the deposition of the sequences was made under the same conditions (valley bottom), a comparison can be proposed between the Verrières sequences and well-dated Holocene Burgundian ones (Fig. 7) already studied by Puisségur (1976).

Proposal for a biochronostratigraphy: comparison of Verrières with four Holocene sequences in Burgundy (northeast France)

Malacofaunas associated with the sequences at Molesmes, Clénay, Beaume-lès-Créancey and Marcilly-sur-Tille highlight different deposition phases recorded in the stratigraphy. These phases correspond to the following sequence of environments: a cold dry valley, inundation, temperate open ground, cold marsh, moist cool open forest, inundation under colder climate, temperate grassland, generalized inundation of all the valleys, drying out of the valleys (Puisségur 1976) (Fig. 7). This succession bears a striking correspondence to the previously determined Verrières record. The similarity of the response of both the Burgundian and Verrières malacofaunas to changing climate allows us to use the biostratigraphical scale defined by Puisségur based on radiocarbon dates.

Malacological assemblages from dry valleys characterize the Late Glacial in Burgundy with a high content of *P. pygmaeum* and *A. secale.* All assemblages come from silt-clay layers immediately overlying the gravels and sand of the alluvial plain. The ^{14}C age of Molesmes sample 3 is 9,900 ± 290 BP and could support a Preboreal age allocation (Mangerud *et al.* 1974). However, because the malacofaunas are consistent with a cold and dry environment, a characteristic of the Younger Dryas chronozone, we retain an intermediate allocation at the Younger Dryas–Preboreal boundary (Fig. 7).

Samples of Verrières unit b1 (Ma2/3 and Ma51/52, Fig. 5) come from silt-clay layers overlying the alluvial plain, too. The malacofaunas, with significant frequencies of *P. pygmaeum* and *A. secale*, indicate a fair development of the open ground species and the quasi-absence of paludal and aquatic taxa. The climatic trends recorded by the malacofaunas indicate drought and cold temperatures. Consequently, they characterize the same dry and cold valley. The stratigraphic and malacological convergences between Burgundy and Verrières are clear and imply a Younger Dryas age for assemblages of the deposits of unit b1.

Molesmes sequence (Fig. 7), sample 4, again indicates an inundation (more than 85% of aquatic individuals in the assemblages) dated 9,280 ± 170 BP and allocated by Puisségur to the Preboreal.

Samples of unit b2 (Ma38/4/53, Fig. 5) also indicate an inundation which may have the same age.

Burgundian malacofaunas characterizing a temperate and dry phase are allocated to the beginning of the Boreal chronozone (Molesmes sample 6 is 8,720 ± 150 BP. Clénay samples 15–16a and b are 7,900 ± 170, 8,010 ± 130 and 8,540 ± 170 BP) (Fig. 7). The assemblages contain some forest taxa, and the open ground species develop well. In contrast, the following phase is

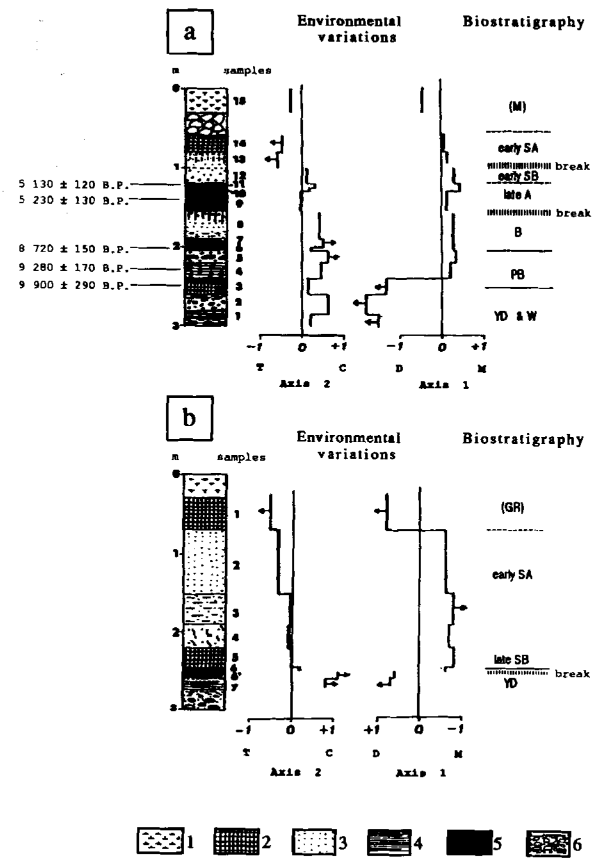
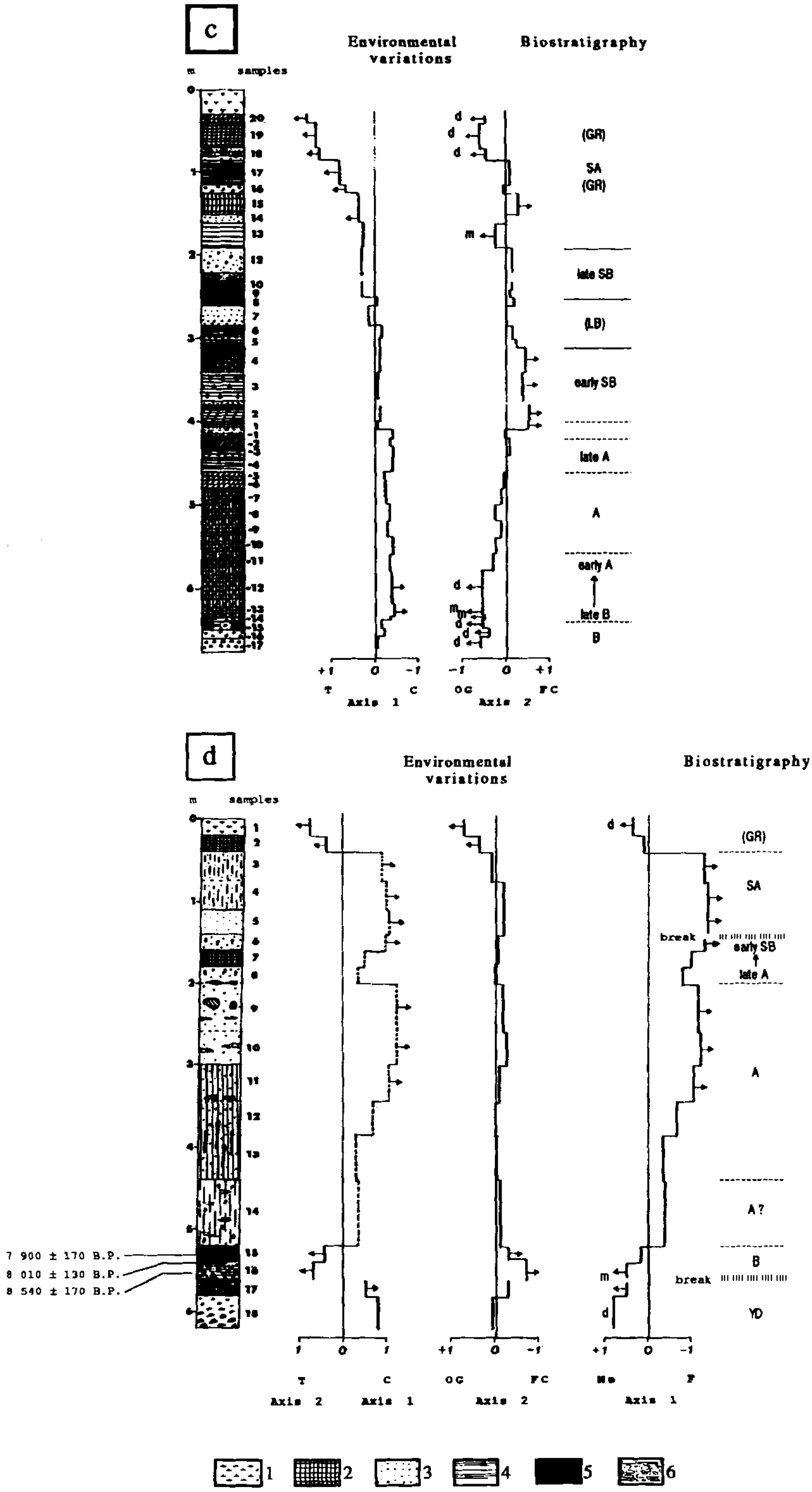


Fig. 7. Burgundian Holocene sequences used for the biostratigraphy. (a) Molesmes, (b) Marcilly-sur-Tille, (c) Beaume-lès-Créancey, and (d) Clénay. Correspondence analyses of the mollusc assemblages. Environmental variations are determined by plotting loadings of assemblages, taken in their stratigraphic position, on the corresponding axis. T, temperate; C, cold; D or d, dry; M or m, moist; OG, open ground; FC, forest cover; Me, mesophilous; F, floodings; M, Middle Age; GR, Gallo-roman; LB, Late Bronze; W, Weichselian; YD, Younger Dryas; PB, Preboreal; B, Boreal; A, Atlantic; SB, Subboreal; SA, Subatlantic. Sedimentological characteristics of the deposits: 1, vegetable soil; 2, humic soil; 3, pulverulent tufa; 4, silt; 5, peat layer; 6, gravels (after Rousseau *et al.* 1991 modified).


c
Environmental variations
Biostratigraphy
m samples
(GR)
SA
(GR)
late SB
(LB)
early SB
late A
A
early A
late B
B
T C
Axis 1
OC FC
Axis 2
d
Environmental variations
Biostratigraphy
m samples
(GR)
SA
break
early SB
late A
A
A ?
B
break
YD
7 900 ± 170 B.P.
8 010 ± 130 B.P.
8 540 ± 170 B.P.
T C
Axis 2 Axis 1
OC FC
Axis 2
Me F
Axis 1
1 2 3 4 5 6

cold and damp with paludal species dominant in the assemblages. Permanent marshes develop at the bottom of the valleys. Boreal and Alpine species, *V. genesii* and *V. substriata*, which are indicative of a cold climate, occur in the malacofaunas.

The assemblages of Verrières unit b3 show the same ecological succession. After the Preboreal inundation, the environment drains and open ground taxa dominate; simultaneously, the arrival of forest species indicates milder temperatures. A transitional phase marks the return of aquatic taxa and the occurrence of paludal ones. The overlying levels contain marshy associations. The valley is moist and subject to frequent inundation. *V. genesii*, a cold species, occurs in Ma7 and 9 assemblages. The amount of cold taxa, less apparent in the Seine Valley than in Burgundy, could indicate a difference in the intensity of the cold phases between the two regions (Limondin 1989, 1990).

After this phase, the Verrières site reveals significant erosion characterized by the consequent hollowing out of channels. Samples that follow the stage considered Boreal relate to the first filling in of the channels. The molluscs reflect the evolution of the microenvironments towards a drying out; however, the general climatic components are difficult to establish using these assemblages because they contain significant aquatic taxa. Allocating this phase to the Atlantic chronozone is an hypothesis that takes into account the chronological data provided by the occurrence of Bronze Age artefacts in the levels of unit c2. However, malacological information is rarely conclusive; in Burgundy, the deposits corresponding to this time-span are badly preserved. Only the Beaume section provides terrestrial malacofaunas and these are difficult to compare with the assemblages from the channels of the Seine Valley (Fig. 7). Further analyses will be necessary to clarify this stratigraphical allocation (Limondin 1990). The assemblages of the prehistoric layer at Les Coeurs (unit c2) indicate a temperate climate, the environment corresponding to an open ground, damp but above water level. Archaeological remains date the site to the end of the Bronze Age at around 3,000 BP (Vachen 1990), i.e. the end of the Subboreal interstage (Richard 1988). In Burgundy, the Subboreal deposits are also badly preserved. After a cold dry phase in the valleys (recorded at two sites), the stratigraphic sequences reach a break. At Beaume-lès-Créancey, however, one level shows an association that also corresponds to the final part of the Bronze Age. The molluscs indicate a temperate climate, similar to that at Verrières; however, the assemblages are more disrupted by human activity.

The Subatlantic chronozone is richer in malacological data. The four Burgundian sequences show malacological successions typical of a phase of flooding during the Subboreal–Subatlantic transition (Fig. 7). Following this, the malacofaunas show a drying out of the valleys; terrestrial species dominate.

The inundation that characterizes the Subboreal–Subatlantic transition cannot be clearly seen at Verrières. The malacofaunas that could correspond to the episode contain abundant aquatic taxa (Ma25/26 and Ma35/36; Fig. 6), but they relate to particular events (filling in of the channels, unit d). A generalized inundation thus appears difficult to propose from the Verrières results.

The malacofauna in the final unit e, colluvials containing the remains of the mediaeval site, indicates an open-ground environment, fairly damp according to the topography but not subject to regular inundation.

Statistical analysis of the molluscan assemblages

The environmental and climatic trends determined by spectral methods are not precise enough to explain mollusc variations within the Holocene fluctuations, therefore we use correspondence analysis (Benzecri & Benzecri 1980). This method is thoroughly described by Rousseau (1987) and Rousseau & Puisségur (1990). Briefly, data (counts) are put within a single set or table where columns are the species, rows the assemblages. The data list, however, must be homogeneous concerning the values, so it is necessary to code carefully the original data. In certain associations it is possible that some species show large differences in representation, thereby introducing important numerical gaps which can disturb the analysis. The coding procedure consists in transforming the data values as abundance classes on a logarithm scale (Rousseau 1987). Also, because they do not yield such precise climatic information as terrestrial individuals, aquatic species were grouped into only one taxa. In all, we analysed 53 assemblages, each of them corresponding to a stratigraphical level, described by 58 taxa.

The first three axes (or factors) explain 36.6% of the total variance (15.1, 12.0 and 9.5%, respectively). If all the assemblages and the taxa explain the total information in the same way, their contribution (or part) to this explanation would be 1/53 (1.8%) and 1/58 (1.7%) respectively. In fact this is never the case. So all the assemblages or taxa which indicate a higher value than the respective thresholds are taken into account to explain the distribution of the different elements on the axes (Tables 5 and 6).

Table 5. Correspondence analysis of the malacological samples. Significant contributions (higher than the theoretical threshold = 1/58) of species to the explanation of the variability of the data set according to the first three factors. Positive or negative signs indicate the location on the axes.

Species	Axis 1%	Axis 2%	Axis 3%
Vallonia enniensis	+33.2		+4.1
Carychium minimum	+6.7		
Vertigo angustior	+6.2		
Euconulus alderi	+4.4		
Oxyloma elegans	+4.0		
Vertigo antivertigo	+3.9		
Zonitoides nitidus	+3.1		
Vertigo genesii	+2.9		
Aquatic taxa	+2.0	−4.5	
Helicella itala	−4.5	−14.4	+6.0
Vallonia costata	−3.4		
Pupilla muscorum	−2.6		
Chondrula tridens	−2.3		+2.6
Abida secale		−11.4	
Trichia hispida		−5.7	
Vallonia pulchella		−3.6	
Limax sp.		−2.1	
Cecilioides acicula			+10.5
Carychium tridentatum		+5.3	
Ena obscura		+5.1	
Aegopinella nitidula		+5.0	
Clausilia bidentata		+5.0	
Acanthinula aculeata		+4.9	
Cochlodina laminata		+3.3	
Discus rotundatus		+3.1	
Sphyradium doliolum		+2.7	
Candidula unifasciata		+2.2	
Cepaea hortensis		+1.8	
Abida secale			−32.4
Punctum pygmaeum			−7.3
Succinea oblonga			−6.9
Clausilia parvula			−6.8
Nesovitrea hammonis			−5.2
Vertigo pygmaea			−5.1

Table 6. Correspondence analysis of the malacological samples. Significant contributions (higher than the theoretical threshold = 1/53) of assemblages or levels to the explanation of the variability of the data set according to the first three factors. Positive or negative signs indicate the location on the axes.

Samples	Axis 1%	Axis 2%	Axis 3%
Ma09	+29.0		+2.6
Ma08	+28.6		
Ma23	+4.6		
Ma30	−4.3	−6.2	+6.1
Ma31	−3.2	−7.8	+6.5
Ma16	−2.6		
Ma17	−2.2		
Ma13	−1.9		
Ma29	−1.9	−5.2	+4.3
Ma36		−7.3	
Ma02		−5.5	−25.5
Ma52		−5.2	−12.6
Ma37		−4.2	+2.2
Ma03		−3.3	−12.3
Ma55		−2.8	−2.9
Ma59		−2.1	
Ma51		−1.9	
Ma21		+6.5	−2.8
Ma22		+4.2	−2.0
Ma11		+4.1	
Ma17		+3.5	
Ma12		+3.3	
Ma16		+2.6	
Ma06		+2.7	
Ma39		+2.0	
Ma13		+1.9	
Ma14		+1.7	
Ma58			+1.7

The first axis discriminates paludal (*Carychium minimum*, *Oxyloma elegans*, *Vertigo angustior*, *Vallonia enniensis* or *Zonitoides nitidus*) or moist species on the positive pole, and xeric taxa characteristic of dry and sun-exposed environments (*Helicella itala*, *Chondrula tridens*) on the negative pole (Fig. 8, Table 5).

The assemblages indicating a high positive contribution to the variance come from black and grey loams which correspond to a permanent marshy environment (Cp001–Ma8, 9; Cp005–Ma23). Those with negative values, samples of the top of the stratigraphy (Cp005–Ma30, 31, 29) and of the protohistorical level (Ma16, 17, 13), characterize the open environment (Fig. 8, Table 6).

The negative portion of the second axis corresponds to species among which *Helicella itala* and *Abida secale* have highest values. They indi-

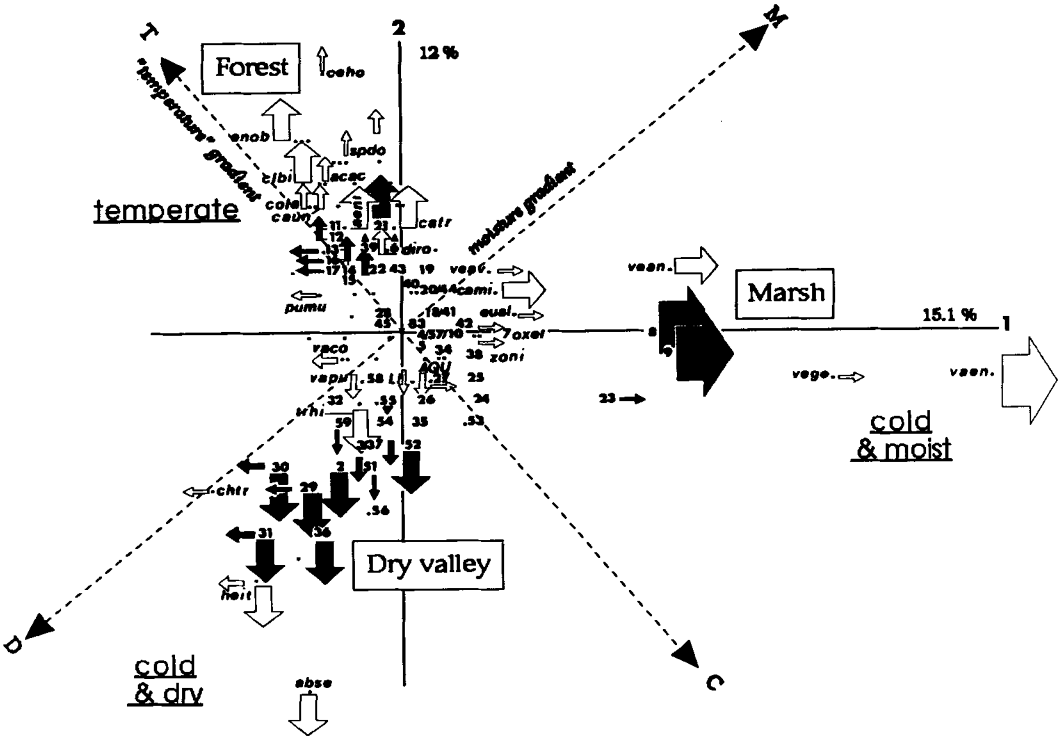


Fig. 8. Correspondence analysis of the malacofaunas of Verrières. Plot of the species (dark points) and of the malacological associations (numeric codes) on the first factor plane (Axes 1–2). The arrows indicate how the species (white arrows) and the associations (black arrows) explain the variability of the general data set. abse; *Abida secale*, acac: *Acanthinula aculeata*, AQU: aquatic species group together, brfr: *Bradybaena fruticum*, cami: *Carychium minimum*, catr: *C. tridentatum*, caun: *Candidula unifasciata*, ceac: *Cecilioides acicula*, ceho: *Cepaea hortensis*, Chtr: *Chondrula tridens*, clbi: *Clausilia bidentata*, clsy: forest *Clausilia*, cola: *Cochlodina laminata*, coll: *Cochlicopa lubricella*, coed: *Columella edentula*, diro: *Discus rutundatus*, diru: *D. ruderatus*, enob: *Ena obscura*, eual: *Euconulus alderi*, eufu: *E. fulvus*, heit: *Helicella itala*, hesp.: *Helicella sp.*, hepo: *Helix pomatia*, LI: slugs, neha: *Nesovitrea hammonis*, oxel: *Oxyloma elegans*, pumu: *Pupilla muscorum*, pupy: *Punctum pygmaecum*, spdo: *Sphyradium doliolum*, suob: *Succinea oblonga*, supu: *Succinea putris*, trhi: *Trichia hispida*, vaco: *Vallonia costata*, vaen: *V. enniensis*, vapu: *V. pulchella*, veal: *Vertigo alpestris*, vean: *Vertigo angustior*, veav: *V. antivertigo*, vege: *V. genesii*, vemo: *V. moulinsiana*, vepy: *V. pygmaea*, vesu: *V. substriata* and zoni: *Zonitoides nitidus*.

cate an open environment, but while the former may indicate temperate conditions, because of its southern origin, the latter is always present in the assemblages of the dry Younger Dryas valleys in Burgundy (Puisségur 1976). In fact the main characteristic of this negative pole is dryness. The positive portion of the second axis groups together numerous forest or semi-forest species (*Ena obscura*, *Aegopinella nitidula*, *Clausilia bidentata*, *Acanthinula aculeata*, *Cochlodina laminata*, *Sphyradium doliolum* – *Discus rotundatus*, *Cepaea hortensis*) which characterize a temperature climate; but because open-ground taxa also occur (for example *Candidula unifasciata*) the environment is a forest or open-forest with grassy areas that allow such taxa to develop (Fig. 8, Table 5).

On its negative pole, the second axis discriminates assemblages sampled in actual colluvials (Ma31, 36, 30, 29, 37, 59) and in loams overlying the alluvial plain (Ma2, 52, 51) which indicate an open-ground environment. On the positive pole, the most significant assemblages record an open-ground environment where trees and bushes are sufficiently numerous to allow forest or semi-forest taxa to develop (Fig. 8, Table 6).

The third axis discriminates species characteristic of an open-ground environment. Nevertheless, in spite of their one ecological demand, the set of taxa corresponds to two malacological assemblages described by Puisségur (1977) for a climatic intermediate phase. In this way, the positive pole groups together the *Chondrula tridens* association (with *Vallonia enniensis*, *Helicella itala*), while the negative pole represents the *Abida secale* association (with *Punctum pygmaeum*, *Clausilia parvula*, etc.). The former occurs at the transition between warm and cold periods in a steppe environment. The latter mainly occurs in France during the Late Glacial periods, when the climate was still cold and dry (Table 5).

So taking into account the preceding interpretations, the variations of species and assem-

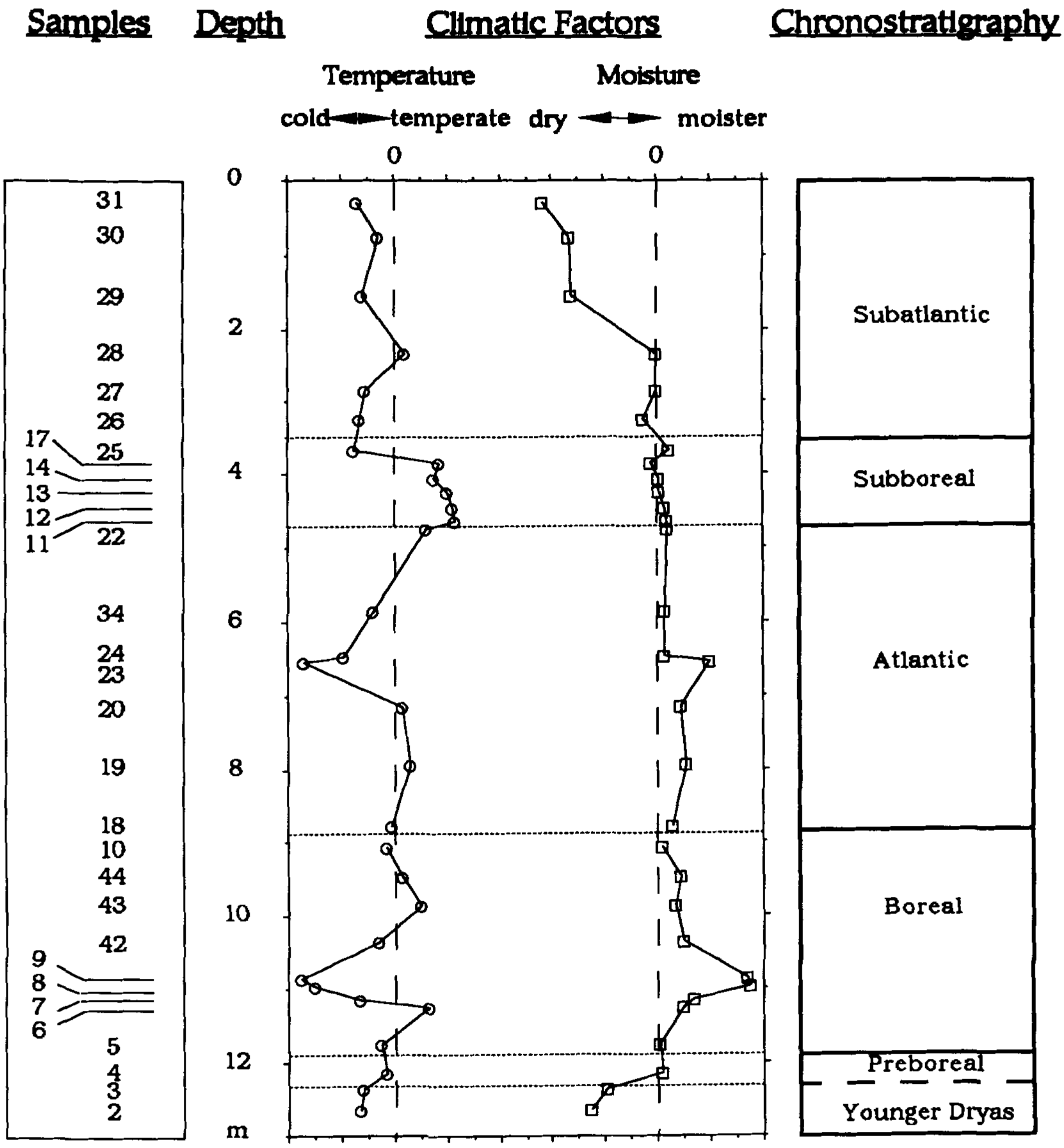


Fig. 9. Time series of molluscs from the Verrières sequence during the Holocene. Plot of the variations of the malacological associations on the temperature and on the moisture factors (first two axes of the multivariate analysis) against the stratigraphy of the site. The values correspond to the variability of the general data set along the axes. The white parts in the curves correspond to a major break recognized in the stratigraphy.

blages are mainly explained by the first two axes. The third axis allows us to infer some climatic information from intermediate assemblages. As already observed in the analysis of Quaternary assemblages, the distribution of malacofaunas on the first factorial plane is generally made in between four poles (dry, damp, cold and temperate) which permit an interpretation of mollusc time series in terms of 'temperature' and moisture (Rousseau & Puisségur 1990). These four poles are still present on the first plane in the analysis of the Verrières malacofaunas. But, because of the absence of typical pleniglacial assemblages, they are not located on each side of the axes. The fan shape of the distribution, however, clearly indicates that the forest associations, which correspond to temperate climatic conditions, are opposed to the other open-ground ones. So a climatic gradient can be drawn linking forest-temperate assemblages (negative side of axis one and positive coordinates of axis two), cool intermediate and cold open (positive side of axis one and negative coordinates of axis two). Then, plotting the loadings of each assemblage (in their stratigraphical position) on these two gradients suggests a palaeoecological interpretation for the different assemblages and permits us to draw the Holocene climatic history as reflected by the malacofaunas. The fluctuations in 'temperature' and in moisture are relative because no estimates of these two parameters were calculated using transfer functions. So the upper and lower boundaries of each parameter are only indicative ones: cold, temperate or dry, damp.

Holocene environmental history at Verrières

Taking into account the previous biostratigraphical interpretation, the Holocene climatic history recorded by the Verrières malacofaunas can be inferred from loadings associated with each assemblage (Rousseau & Puisségur 1990) on the temperature and moisture gradients (Fig. 9).

First of all, as already presented for the last three climatic cycles in the loess sequence of Achenheim (Rousseau & Puisségur 1990), the temperature and moisture curves do not have similar trends. Some phases (the Younger Dryas, end of the Boreal, beginning of the Atlantic, end of the Subatlantic) show 'opposite' evolutions, while in other ones there is a kind of 'parallelism' (Fig. 9).

As indicated in the diagram, the assemblages of the Younger Dryas, while they recorded drier climate, did not record very cold conditions. This leads us to conclude that those assemblages correspond to the end of this short event (Fig. 9). Two peaks corresponding to high moisture are determined, first during the Boreal and then during the Atlantic chronozones. They both correspond to cold events among which the former is more extreme (Fig. 9).

Concerning the general climatic trend, how consistent is the Verrières record with already published references? The main events recognized in pollen series or in the fluctuation of the tree line are recognized in malacofaunas, also. The Boreal and Atlantic stages are divided by a cold and moist event (Fig. 9). The Subboreal has two different phases: first, a warm one with a diminishing moisture and, second, a cold and moister one at the end of the stage. The Subatlantic begins with a cold and less moist phase and then fluctuations of temperature accompanied by a general trend to dryness occur (Fig. 9).

Conclusions

The molluscan assemblages of Verrières correspond quite well with Burgundian ones, which allows us to define a rather precise biostratigraphical framework. The multivariate analysis of the malacofaunas allows this framework to be tested by taking into account the evolution of the relative climatic parameters. The Verrières results indicate a similar evolution as that recognized in pollen series, or by the tree line. But the temperature and moisture parameters rarely indicate a parallel evolution (Fig. 9), which indicates that the complexity of climate is reflected by the mollusc faunas in short as well as long-time sequences. This in its turn indicates that molluscs do provide a record of climate, which compares well with pollen series.

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