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Correlative chart of the European Oligocene and Miocene: Application to the Swiss Molasse Basin

By JEAN-PIERRE BERGER ¹⁾

ABSTRACT

Different correlative charts recently published are compared and discussed. Their graphical representation allows a rapid identification of the discrepancies between authors. Furthermore, the different Molasse units (UMM, USM, OMM, OSM) are correlated using this chart, as a synthesis of the biostratigraphic and chronostratigraphic data actually known.

Lastly, a critical analysis of the principal biozonations used in the Oligocene and Miocene is proposed.

RÉSUMÉ

Différentes chartes de corrélations récemment publiées sont comparées et analysées. Elles sont présentées sous forme d'un grand tableau permettant de visualiser graphiquement les divergences essentielles d'un auteur à l'autre. De plus, ce tableau permet, parmi ses applications possibles, le calage des différentes unités de la Molasse (UMM, USM, OMM, OSM) en corrélant les données biostratigraphiques et chronostratigraphiques connues.

Enfin, une analyse critique des principales biozonations généralement utilisées dans l'Oligocène et le Miocène, est proposée.

ZUSAMMENFASSUNG

Verschiedene kürzlich publizierte Korrelationstabellen werden verglichen und analysiert. Sie sind in Form einer grossen Tafel dargestellt, welche die Unterschiede von einem Autor zum anderen sichtbar macht. Des weiteren erlaubt diese Tafel, die verschiedenen Einheiten der Molasse (UMM, USM, OMM, OSM) festzulegen, indem die bekannten biostratigraphischen und chronostratigraphischen Daten korreliert werden.

Zuletzt wird eine kritische Analyse der wichtigsten Biozonierungen vorgeschlagen, die im Oligozän und Miozän gebraucht werden.

1. Introduction

A good appreciation of the time problem is absolutely necessary to present any synthesis about a basin, before interpreting geological data in terms of paleogeography or geodynamics.

Unfortunately, most geologists are discouraged by the extreme specialization of biostratigraphical studies (problems of paleontological nomenclature, definition of zones, unclear correlations, lack of consensus). As a result, they don't integrate the advances in biostratigraphy into their reconstructions or models.

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The aim of this paper is to describe advantages and disadvantages of the principal biostratigraphic zonations commonly used in the Molasse Basin (nannofossils, planktonic foraminifera, pectinids, charophytes, mammals, palynomorphs) and to describe their calibration with magnetostratigraphical and geochronological data. Sequence Stratigraphy is not discussed here because no studies have yet been published in the Swiss Molasse Basin.

Moreover, I present a correlation table for the European Oligocene and Miocene, providing the necessary informations to compare the Swiss Molasse Basin with other Tertiary basins in terms of biostratigraphy and geochronology. A first version of this chart has been shown as poster at the IXth Congress Regional Committee on Mediterranean Neogene Stratigraphy (R.C.M.N.S.) in Barcelona (see Berger et al. 1990).

2. The Correlative Chart: Method of Construction

During the last decades, different stratigraphic charts have been elaborated on by several authors from different schools and countries. The latest and most important ones are, for example, those of Berggren et al. 1985, Barron et al. 1985, Magne et al. 1987, Haq et al. 1987, Harland et al. 1989 and Steininger et al. 1990. The purpose here is not to discuss or criticize these papers, but to compare them and point out some differences. This comparison shows some very important discrepancies between the interpretations of biozone- or stage-boundaries, and their consequences for correlations and paleogeographic studies.

The principal differences may be due to the following reasons:

1. The boundaries between biozones may not be synchronous (see for example Dowsett 1989).
2. The stratigraphical position of the geological stage boundaries varies according to the different authors.
3. The "absolute" ages are theoretically based on radiochronology but are, in actual fact, often a simple extrapolation dependant on paleomagnetism (see Odin 1989).
4. The precision of radiochronologic measures may be wanting.
5. Taxonomic problems (difficulty or divergence in the determination of fossil markers) could explain some differences in the definition of zonal boundaries.
6. Endemism, provincialism, migration and reworking problems could be responsible for differences in the interpretation of boundaries.
7. Difficulty of correlation could be due to the rarity of direct correlation between marine and continental biozonations.

As shown in Fig. 1, units and limits plotted on this chart are taken from the publications listed at top of each column.

3. Discussion about the different columns of the Chart

I present here a detailed discussion of the data presented in the correlative chart. Each chapter corresponds to a column. The authors and publications listed in Table 1 are also mentioned at the top of each column of the chart. (Plate 2)

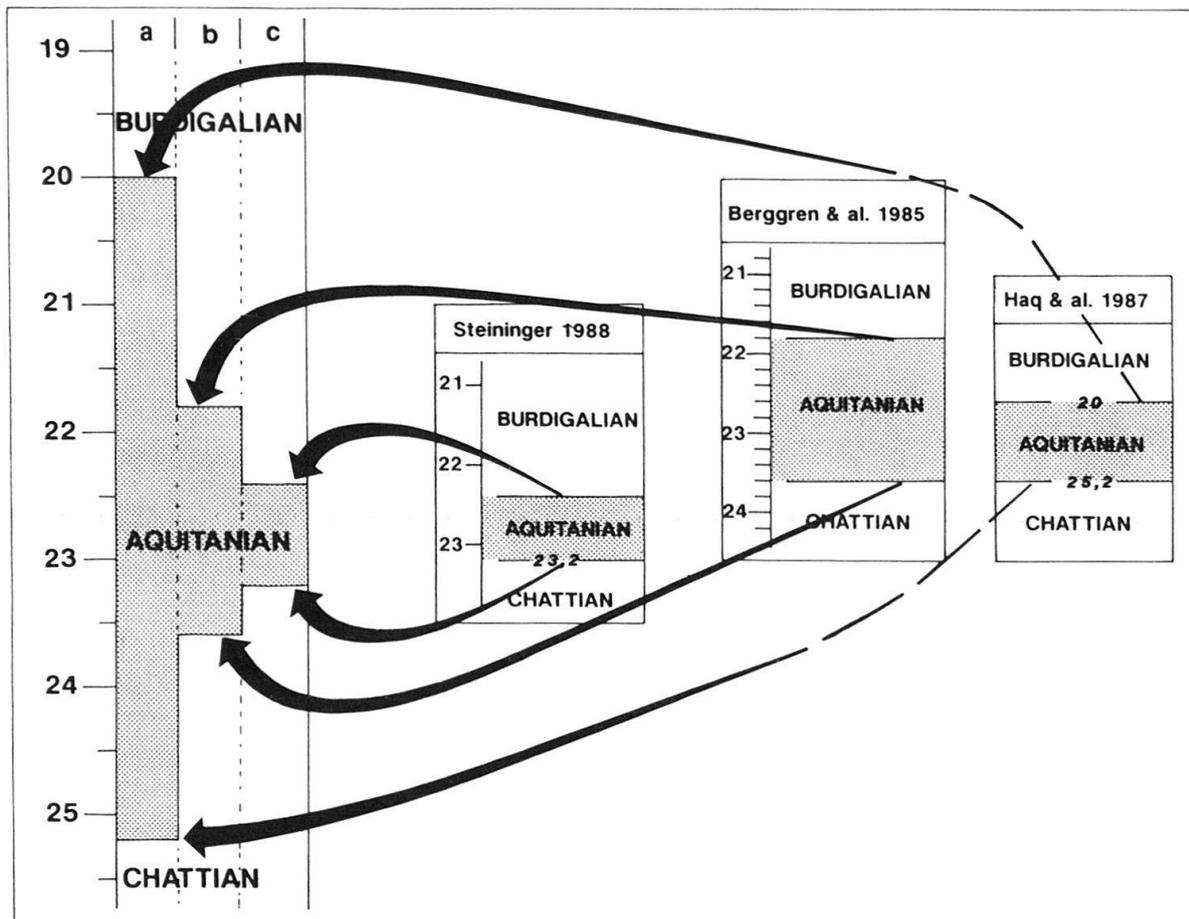


Fig. 1. Construction method of the correlative chart. We reported the data published by the different authors, even directly from numerical data (example: Haq et al. 1987), or indirectly recalculated after the published charts (example Berggren et al. 1985).

3.1. Magnetostratigraphy (Table 2)

Cavelier & Pomerol 1986 are not considered here because of the graphical difficulty of correlating their limits with numerical data.

The data from Harland et al. 1989 (Fig. 7.3) are not reported here. Concerning the Miocene, they are practically identical with those of Berggren et al. 1985. For the Paleogene, they are 0,5 to 1 million year younger than those proposed by Berggren et al. 1985.

3.2. Epoch

– Eocene-Oligocene Boundary

- a) Age of 36,0 Ma given by the authors.
- b) No ages.
- c) Age of 36,6 Ma given by Snelling 1985 p. 264
- e) No ages.
- f) $33,71 \pm 0,5$ Ma = 33,2 à 34,2 Ma. Given by the authors.
- g) Two limits are proposed by the authors (37,2 Ma and 37,6 Ma) but only one with the Lattorfian: 37,6 Ma.
- h) Two datas proposed by the authors: 33 and 36,5 Ma.

H = Harland et al. 1989 Fig. 1.7: 35,4 Ma given by the authors.

a)	HAQ & al. 1987 . According to their table graduated into 200.000 year subdivisions.
b)	STEININGER 1988. Table graduated into 1 million year subdivisions + numerical datas (* in Table 8) given by the author.
c)	BERGGREN , KENT & FLYNN 85 BERGGREN , KENT & VAN COUVERING 1985 BERGGREN , KENT , FLYNN & VAN COUVERING 1985 SNELLING 1985 Table graduated into 200.000 year subdivisions.
d)	BERGGREN & MILLER 1988. Table graduated into 1 million year subdivisions.
e)	STEININGER, BERNOR & FAHLBUSCH 1990 . Table graduated into 200.000 year subdivisions
f)	ODIN 1989, ODIN & MONTANARI 1989. Table graduated into 1 million year subdivisions.
g)	MARTINI & al. 1986 . Table graduated into 200.000 year subdivisions.
h)	CAVELIER & POMEROL 1986
i)	VASS & al. 1987 & 1988. Table graduated into 500.000 year subdivisions
j)	BOHN-HAVAS & al 1987 According to their fig.2 graduated into 1 million year subdivisions.
k)	DEMARCO 1990
l)	SPORES & POLLENS in VINKEN 1988
m)	DINOFLAGELLATES in VINKEN 1988
n)	ROEGL , HOCHULI & MUELLER 1979 . Table graduated into 5.000.000 year subdivisions.
o)	POWELL 1986 . Table graduated into 200.000 year subdivisions.
p)	WILLIAMS 1977 presented by WILLIAMS & BUJAK 1985 . Table graduated into 5.000.000 year subdivisions.
q)	RIVELINE 1985 and CAVELIER & POMEROL 1986
r)	BERGER 1986 and 1992 (GEC)
s)	SCHWARTZ 1985 , 1988 , 1989 and pers. comm.
t)	FEJFAR 1988. Table graduated into 1 million year subdivisions
u)	ALBERDI & AGUIRRE 1977. Table graduated into 1 million year subdivision and numerical data given by the authors. These numerical measures are noted by * in Table 6 and 7.
v)	TOBIEN 1987 + IN VINKEN 1988
w)	AGUILAR 1981. Table graduated into 500.000 year subdivisions
x)	IGCP 124 , VINKEN 1988
y)	STEININGER , WESSELY & ROEGL 1987
z)	BALDI 1984 :

H= HARLAND & al. 1989 Fig. 7.3.

Table 1: Papers discussed on the chart.

– Oligo-Miocene Boundary

- a) Age of 25,2 Ma given by the authors.
- c) Age of 23,7 Ma given by Snelling 1985 p. 264
- b) Age of 23,2 Ma given by the authors.
- e) Age of 23,3 Ma, according to their table graduated into 200.000 year subdivisions
- f), g) No ages.
- h) Age of 23 to 23,5 Ma given by the authors.

H : Harland et al. 1989 Fig. 1.7: 23,3 Ma given by the authors.

– Mio-Pliocene Boundary.

- a) Age of 5,2 Ma given by the authors.
- c) Age of 5,2 Ma according to their table graduated into 200.000 year subdivisions.
- b) Age of 5,4 Ma given by the authors.
- e) Age from 5,3 Ma according to their table graduated into 200.000 year subdivisions.
- f), g), h) No ages.

H : Harland et al. 1989 Fig. 1.7: 5,2 Ma given by the authors.

3.3. Planktic Foraminifera Zones (Table 3 & 4, Fig. 3)

a), b), c), d), e), g), i) See Table 1.

- f) Odin 1989: P15/P16 boundary is situated between $36,0 \pm 0,4$ and $36,4 \pm 0,3$ Ma.
P16/P17 boundary is dated from $34,6 \pm 0,3$ Ma.

Magnetostratigraphy									
Epochs	a	b	c	e	Chronozones	c	a	e	f
4					C3				
5	5,4	5,4	5,3	5,4	C3A	5,3	5,3	5,4	
6	6,0	6,0	5,9	6,0					
7	6,8	6,8	6,7	6,7	C4		6,7	6,7	
8	7,6	8,0	7,4	8,3					
9	7,8	9,0	7,9	8,9	C4A		7,9	7,9	
10	8,2	10,5	8,5	10,5					
11	9,0	11,8	8,9	11,5	C5	8,9	8,9	8,9	
12	10,5	12,3	10,5	12,2	C5A	11,5	11,8	11,5	
13	11,8	13,2		12,9	C5AA	12,9			
14	12,2	13,5		13,1	C5AB	13,2			
15	13,7	14,1		13,7	C5AC	13,7			
				15,1	C5AD	14,2			
16	15,4	15,8			C5B	14,9	15,0	14,9	
					C5C	16,2	16,2	16,2	
17	17,8	18,2		17,6	C5D	17,6	17,6	17,6	
					C5E	18,5	18,5	18,5	
18	19,0	20,0		19,1	C6	19,3	19,3	19,4	
19	19,4	20,4		19,4	C6A	20,9	20,9	20,9	
20	20,5	21,5		20,5					
21	21,3	22,5		20,9	C6AA	22,0			
22	22,2	23,6		22,4	C6B	22,6	22,6	22,6	
	23,9	24,7		23,3	C6C	23,3	23,9	23,3	
					C7	25,5	25,5	25,5	
					C7A	26,4	26,4		
					C8	26,9	26,9		
					C9	28,1	28,3		
					C10	29,6	29,8		
					C11	31,2	31,2		
					C12	32,3	32,3		
					C13	35,3	35,3		
					C15	37,2	37,1		34,7
					C13				35,2

Table 2: Magnetostratigraphy. Numerical data (million years) reported on the chart. The letters (a, b, ...) correspond to the authors listed in the chart (see Table 1) and discussed in chapter 3.1.

Planktic Foraminifera Zones									
N	a	c	b	g	i	d	e	f	f
N19	5,0	5,0	5,0						
N18	5,3	5,3	5,4				5,2		
N17	7,1	7,1	7,1				8,9		
N16	9,7	10,2	10,8				11,0		
N15	10,2	10,5	12,0				11,9		
N14	11,0	11,3	13,0				12,1		
N13	12,0	11,6	13,6				12,8		
N12	13,2	12,9	14,5				13,7		
N11	13,9	13,9	15,0				14,0		
N10	14,9	14,9	15,8		15,5		14,7		
N9	15,2	15,2	16,0		16,2		15,2		
N8	16,6	16,6	17,0		17,5		16,6		
N7	17,8	17,6	18,7				17,7		
N6	18,9	19,0	19,8				18,1		
N5	22,8	21,8	22,0				22,0		
N4	25,2	24,5	24,5	24,2		N4b 23,3 N4a 23,9			
N3/P22	28,0	28,2				28,3			
P21						P21b 30,0 P21a 31,7			
P19/20	31,7	31,6		31,6 P20 32,8 P19 33,9		32,9			
P18	34,2	34,0		33,9		34,0			
P17	36,0	36,3		37,2		37,2			33,7±0,5
P16	37,2	37,2		39,5				34,6 ±0,3	34,3±0,5
P15								36,0 ± 0,4	35,6±0,5

Table 3: Planktic foraminifera zones. Numerical data (million years) reported on the chart. The letters (a, b, ...) correspond to the authors listed in the chart (see Table 1) and discussed in chapter 3.3.

Odin & Montanari 1989: P18/P17 boundary is dated from $33,7 \pm 0,5$ Ma.
Other data are according to their table graduated into 1 million year subdivisions.

Cavelier & Pomerol 1986 were not considered for the same reasons as in chapter 3.1.

The data from Harland et al. 1989 are not reported here because of the impossibility of correlating their zonation (cf. their Fig. 3.13) with the numerical ages. Only a few boundaries could be included in the present chart:

N17/N18 boundary: 5,2 Ma
N 9/N10 boundary: 14,2 Ma
N 7/N 8 boundary: 16,3 Ma
P19/P20 boundary: 29,3 Ma

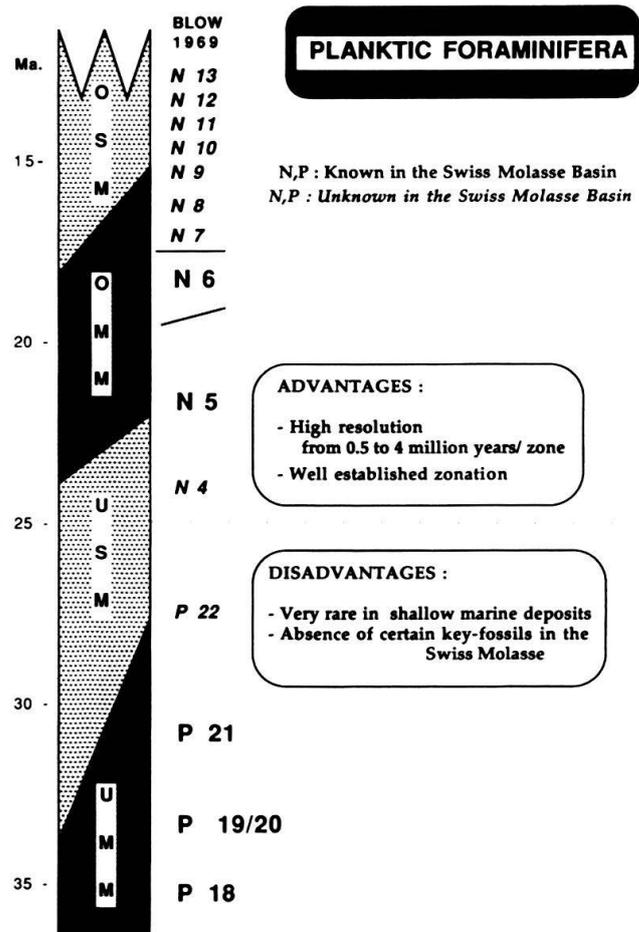


Fig. 2. Planktic Foraminifera in the Swiss Molasse

Comments on the biostratigraphic interest of planktic foraminifera in the Molasse (Fig. 2):

Blow's zonation of 1969, with P- (for Paleogene) and N- (for Neogene) zones, is frequently used in the European Tertiary. These zones follow a first attempt published by Banner & Blow 1965. Also in 1969 Berggren published a zonation with N and P zones attributed to "Berggren & Blow unpublished" (cf. Berggren 1969 table 1). A synthesis was later published by Berggren in 1972, and was subsequently adopted in publications. Recently, Berggren & Miller 1988 resynthesized the situation for the Paleogene.

Another zonation was elaborated on by Bolli and colleagues, using a taxon-denomination for the zones. This led to the paper published by Bolli & Saunders 1985.

Two other important zonations were published in 1985 by Iaccarino, (concerning the mediterranean Miocene and Pliocene) and in 1988 by Spiegler et al. 1988 (North european Tertiary).

A comparison of these different zonations is presented in Table 4.

BLOW 1969	BERGGREN & MILLER 1988	BOLLI & SAUNDERS 1985	IACCARINO 1985	SPIEGLER, GRAMANN & VON DANIELS 1988	
N 8		<i>P.glomerosa</i>	<i>P.glomerosa</i>	NPF 13	
N 7		<i>G.insueta</i>	<i>Gs.trilobus</i>		
N 6		<i>C.stainforthi</i>	<i>Gq.dehiscens dehiscens</i> <i>C.dissimilis</i>	<i>Gs.altiaperturus</i> / <i>C.dissimilis</i>	NPF 12
N 5		<i>C.dissimilis</i>			NPF 11
N 4		N 4 $\frac{b}{a}$	<i>Gs.primordius</i>	<i>Gq.dehiscens dehiscens</i>	
		P 22	<i>G.kugleri</i>		NPF 10
P 22 (= N 3)		<i>G.ciperoensis ciperoensis</i>			
P 21 (= N 2)	P 21 $\frac{b}{a}$	<i>G.opima opima</i>		NPF 9	
P 20 (= N 1)	P 20	<i>G.ampliapertura</i>		NPF 8	
	P 19				
P 18	P 18	<i>Cassigerinella chipolensis</i> / <i>Pseudohastigerina micra</i>			

Table 4: Comparison of planktic foraminifera zonations.

Discussion about the application of Blow's zonation in the European Oligo-Miocene:

a) P18, P19 and P20 (= N1)

Important divergences concerning the taxonomy and the stratigraphical repartition of markers (*Globigerina tapuriensis*, *G. sellii*, *Cassigerinella chipolensis*, *Chilogümbelina cubensis*, *Pseudohastigerina spp.*) yielded problems in the distinction, and consequently the calibration of the zone. The new P18-zone proposed by Berggren & Miller 1988 corresponds to P18 + P19 of Blow 1969. Consequently, P19 of Berggren & Miller 1988 = lower part of P20 of Blow 1969; and P20 of Berggren & Miller = upper part of P20 of Blow.

b) P22 (= N3)

General remarks: the principal discrepancies concerning this interval are essentially due to the different appreciations of the stratigraphic repartition of *Globigerinoides primordius*.

c) N4 to N6

Bizon (in Bizon & Mueller 1979) notes that Blow's zonation could be the base of the tertiary mediterranean biozonation but that some adaptations (due to the poor faunas) are necessary, especially in the Early Miocene (problems with *Globigerinoides primordius-altiaperturus-trilobus*, absence of *Gt. kugleri*). This is confirmed by Iaccarino 1985 whose "Gq. dehiscens/C. sissimilis"-zone corresponds to N4, N5 and N6 (see Table 4).

d) N7

The principal problems concerning this zone are due to taxonomic and stratigraphic discussions about the succession “*bisphaericus-sicanus-glomerosa*” (cf. explanation and details in Bolli & Saunders 1985, Iaccarino 1985, Jenkins et al. 1981).

3.4. Calcareous Nannofossil Zones (Table 5, Fig. 3)

a), c), e), g),

f) Odin 1989, Odin & Montanari 1989.

NP18/NN19 from $36,0 \pm 0,4$ to $36,4 \pm 0,4$ Ma, and NP20/NN21 from $34,6 \pm 0,3$ to $34,3 \pm 0,3$ Ma.

i) Vass et al. 1987, according to their table graduated into 500.000 year subdivisions, the age of 15,5 Ma (NN5/NN6 boundary) given by Vass et al. 1988.

Calcareous Nannofossil Zones						
NN/NP	a	c	e	g	i	f
NN12						
NN11	5,2	5,6	5,2		5,2	
NN10	8,2	8,3	8,2		8,8	
NN9	9,0	8,9	11,2			
NN8	10,0	10,0	11,9			
NN7	10,5	10,9	12,3		13,2	
NN6	11,7	13,1	12,8			
NN5	13,2	14,4	14,0		15,5	
NN4	16,0	16,2	16,5		16,5	
NN3	17,7	17,4	17,6		18,5	
NN2	18,8	18,9	18,1		19,2	
NN1	20,8	23,2	23,0		22,0	
NN1	25,0	23,7	23,9		23,0	
NP25	28,5	28,1				
NP24	30,5	30,4		31,6		
NP23	34,8	34,6		34,0		
NP22	35,5	35,1		35,2		
NP21	36,5	36,9		37,6		34,0-34,9
NP20 NP19	38,0	37,8		42,0		35,6-36,7

Table 5: Calcareous nannofossil zones. Numerical data (million years) reported on the chart. The letters (a, b, ...) correspond to the authors listed in the chart (see Table 1) and discussed in chapter 3.4.

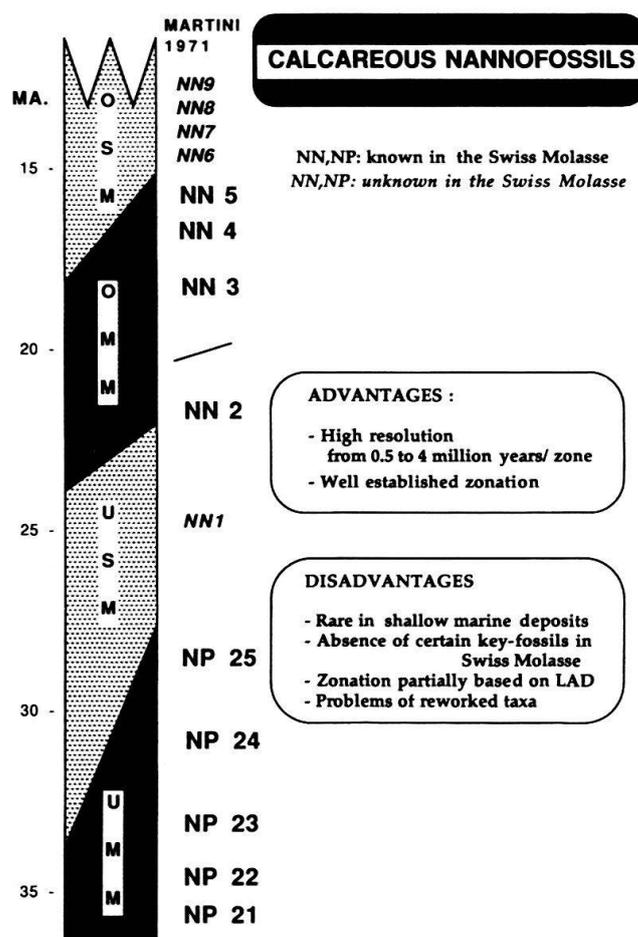


Fig. 3. Calcareous Nannofossils in the Swiss Molasse

Cavelier & Pomerol 1986 were not considered for the same reason as in chapter 3.1.

The data from Harland et al. 1989 were not reported here because of the impossibility of correlating their zonation (cf. their Fig. 3.13) with the numerical ages. Only one boundary could be included in this chart: the boundary between NP (Nannoplankton Paleogene) 25 and NN (Nannoplankton Neogene) 1 is dated as 23,3 Ma.

Comments on the biostratigraphic interest of calcareous nannofossils in the Molasse:

The biozonation of Martini 1971 (NP- and NN-zones based on FAD (First appearance datum), on LAD (Last appearance datum) and on acme-zones) is generally used in the European Tertiary, even if the zonation of Bukry 1973 (revised in Bukry 1975 and codified by Okada & Bukry 1980 with CP Coccoliths Paleogene and CN Coccoliths Neogene zones) could be more precise in open marine sediments. Elsewhere, Mueller (1979) pointed out the absence, in the mediterranean area, of many markers.

The calcareous nannofossils could be very useful for biostratigraphic purposes, but, unfortunately, they could be easily reworked. The reworked material is one of the principal disadvantages for the correlation of the biostratigraphic units based on calcareous nannoplankton.

Discussion about the application of Martini's zonation in the European Oligo-Miocene:

a) NP19/20

Several publications (Martini 1976, Perch-Nielsen 1985) demonstrate the necessity to combine NP19 and NP20 into a NP19/20 Zone.

b) NP21, NP22 and NP23

Perch-Nielsen 1985 pointed out the impossibility of distinguishing NP21 if the sample contains reworked material from the Eocene. Cavalier (1972, 1975, 1979) demonstrated the diachroneity of this zone compared with the Planktic Foraminifera zones.

Moreover, it is very important to recall that the definitions of NP21, 22 and 23 are essentially based on LAD. Consequently it is dangerous to distinguish these zones in clastic sediments such as the Molasse.

e) NN1

Mueller (1979) notes that NN1 is based, in the mediterranean area, on the absence of the small forms of *Helicosphaera ampliapertura* because the marker *D. druggii* does not exist in this region. This makes the boundaries between NP25, NN1 and NN2 impossible to define.

3.5. Pectinids (Fig. 4)

j) Bohn-Havas et al. 1987. According to their fig. 2 graduated into 1 million year subdivisions.

Chlamys rotundata/Chlamys gigas	NN1/NN2 boundary, 22,0 Ma
C. gigas/Chlamys palmata	in NN2, 21,0 Ma
C. palmata/Chlamys albina	N6/N7 boundary 18,7 Ma
Chl. submalviae/Pecten expansior	in NN4, Ottn./Karp. boundary 18,0 Ma
Chl. albina/Flabellipecten besseri	in NN5, Karp./Baden. boundary, 16,3 Ma
Chl. elegans/Pecten aduncus	NN5/NN6 boundary, 15 Ma
Top F. besseri	top NN7, 13,8 Ma

k) Demarcq 1990

PN0/PN1 =	base N4, 24 Ma
PN1/PN2 =	in N4, 22 Ma
PN2/PN3 =	base N5, 20,6 Ma
PN3 a/PN3 b =	N7/N8, 17,5 Ma
PN3 b/PN4 =	in N8, 16,5 Ma
PN4/PN5 a =	N9/N10, 15 Ma
PN5 a/PN5 b =	in the Serravallian, top of Badenian.
PN5 b/PN6 =	N14/N15 boundary, 10,5 Ma
PN6/PN7 =	base N17, 6,4 Ma
PN7/PN8 = 1	Mio-Pliocene boundary, 5,2 Ma

The numerical data are given by Demarcq.

We do not consider here the zonation of Hinsch et al. in Vinken 1988 (BM1 to BM22) because the majority of their taxa are unknown in Central and Southern-Europe. This zonation is not applicable to the Molasse basin.

Comments on the biostratigraphic interest of pectinids in the Molasse

As shown in Fig. 4, the main problems concerning the application of Pectinids to Molasse stratigraphy is their dependance on facies. In the Swiss Molasse, they could only be used in the upper part of the OMM ("Helvetian").

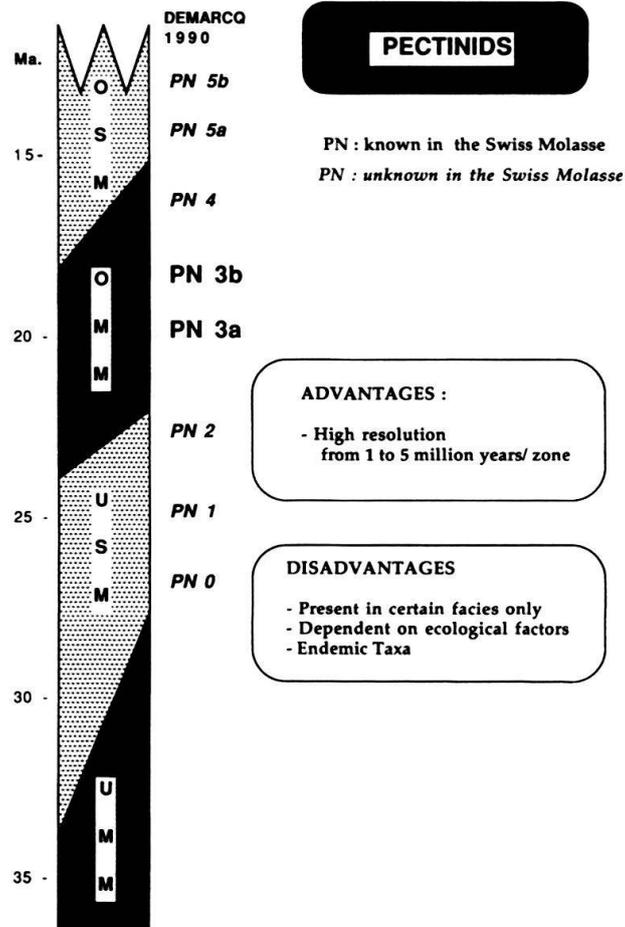


Fig. 4. Pectinids in the Swiss Molasse

3.6. Palynozones (Fig. 5)

l) Spores & Pollen

Paleogene subgroup IGCP 124, in Vinken 1988, Fig. 144 and 267

SP5/SP6: 33 to 36 Ma

SP6/SP7: in the Latdorfian

SP7/SP8: 26 to 29 Ma

Numerical data given by Vinken Fig. 267.

Neogene: Brellie, Meyer, Schuler & Zagwijn in Vinken 1988, Fig. 160

SP8a/SP8b: top NP25

SP8b/SP9a: just below NN4

SP9a/SP9b: end of NN4

SP9b/SP9c: in the Late Miocene

SP9c/SP10a: in the Late Miocene or Pliocene

Indirect correlations adapted from Fig. 160 of Brellie et al.

m) Dinoflagellates

Subgroup IGCP 124 in Vinken 1988 p. 165. Numerical data given in Fig. 267.

D12/D13: 33 to 36 Ma

D13/D14: In the Latdorfian

D14/D15: top Rupelian, 26 to 29 Ma

D15/D16: 22,5 to 24 Ma

D16/D17: 16,3 Ma

D17/D18: in the Serravallian.
 D18/D19: slightly older than 10,5 Ma
 D19/D20: top Tortonian
 Top D20: 5,3 Ma

n) Spores & Pollen

Roegl, Hochuli & Mueller 1979

According to their table graduated into 5.000.000 year subdivisions.

Pg18/Pg19 = NP20/NP21, 37,5 Ma
 Pg19/Pg20 a = in NP22, 35,5 Ma
 Pg20 a/Pg20 b = NP23/NP24, 32 Ma
 Pg20 b/Ng.I = In NP24, 28,5 Ma
 NgI/NgII = NP25/NN1, 24 Ma
 NgII/Otttang Flora = NN2/NN3, 19,5 Ma
 Top Otttang flora: 15 Ma

o) Dinoflagellates

Powell 1986, According to his table graduated into 200.000 year subdivisions.

LAN1A/LAN1B = 24,8 Ma
 LAN1B/LAN2A = 23,8 Ma
 LAN2A/LAN2B = 23,6 Ma
 LAN2B/LAN3A = 23,3 Ma
 LAN3A/LAN3B = 22,4 Ma
 LAN3B/LAN3C = 22,0 Ma
 LAN3C/LAN4A = 18,0 Ma
 LAN4A/LAN4B = between 16 and 17,7 Ma
 LAN4B/LAN5A = 15,5 Ma
 LAN5A/LAN5B = 15,1 Ma
 LAN5B/LAN6A = 14,3 Ma
 LAN6A/LAN6B = 13,5 Ma
 LAN6B/LAN7A = 13,0 Ma
 LAN7A/LAN7B = 12,7 Ma
 LAN7B/LAN8A = 12,3 Ma
 LAN8A/LAN8B = 11,9 Ma

h) Dinoflagellates (angulosa to partispinatum zones). Cavelier & Pomerol 1986

The boundaries proposed by the authors result from compilation of palynozone positions according to the NP zones and to radiometric data. Thus, the graphic representation (in my chart) shows very diachronous boundaries.

p) Dinoflagellates

Williams 1977 presented by Williams & Bujak 1985

According to their table graduated each 5.000.000 years

Areosph. diktyopus/Defl. heterophlycta 37 Ma
 D. heter./Cordosph. Funiculatum 33 Ma
 C. funic./ Cordosph. cantharellum 24 Ma
 C. cant./Lejeunec. fallax 17 Ma
 L. fall./Hystrichosphaeropsis obscura 12,5 Ma
 H. obsc./Achomosphaera ramulifera 5 Ma

The zonation of Manum et al. 1989 and the "Dinoflagellate horizon" from Stover (in Haq et al. 1987) are not considered here because they are too incomplete and not precisely correlated.

Comments on the biostratigraphic interest of palynomorphs in the Molasse

The principal disadvantage in applying palynomorphs to Molasse stratigraphy is the preservation problem (oxydation!). Concerning the pollens, a general remark could be

made: they reflect climatic changes more than evolutionary levels. Thus, they could be essentially used from an ecostratigraphic point of view (see Fig. 5).

3.7. Charophytes (Fig. 6)

- q) Riveline 1985 and Cavalier & Pomerol 1986
 Modified and correlated with the mammal zones proposed by Schmidt-Kittler 1987
- | | |
|----------------------------------|---------------|
| Vasiformis-Tuberculata/Vectensis | MP18/MP19 |
| Vectensis/Pinguis | MP20/MP21 |
| Pinguis/Major | MP21/22 |
| Major/Microcera | MP23/MP24 |
| Microcera/Ungeri: between | MP26 and MP24 |
| Ungeri/Notata | MP29/MP30 |
| Notata/Nitida | MP30/MN1 |
| Nitida/Berdotensis | MN1/MN2 |
- r) Berger 1986 and 1992 (European Group of Charophytologists)
 Correlated with the Swiss Mammal Levels.
- | | |
|-----------------------|------------------------|
| Berdotensis/Ginsburgi | Vully 1/Brüttelen 2 |
| Nitida/Berdotensis | Boudry 2/Fornant 11 |
| Notata/Nitida | Küttigen/Brochene Fluh |
| Ungeri/Notata | Rickenbach |

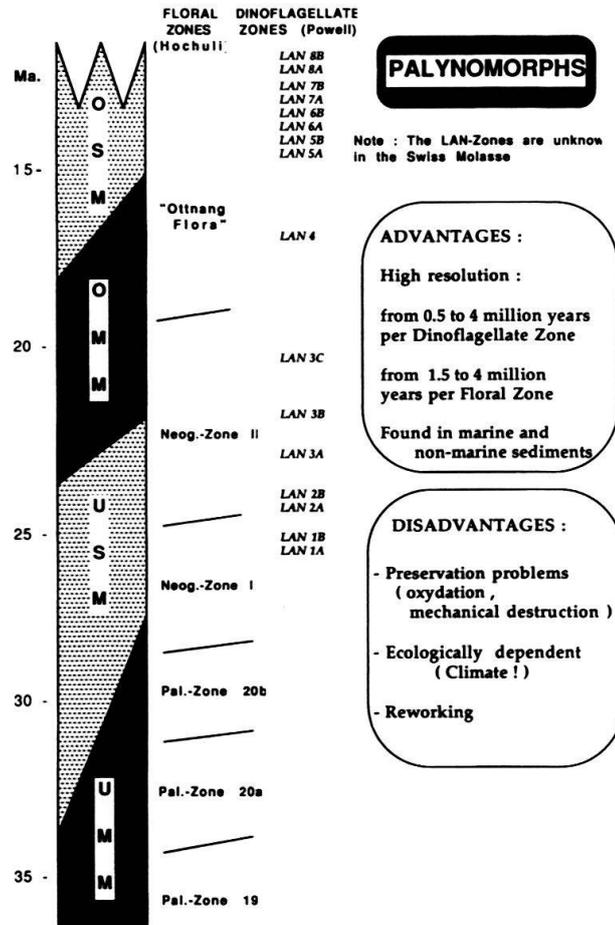


Fig. 5. Palynomorphs in the Swiss Molasse

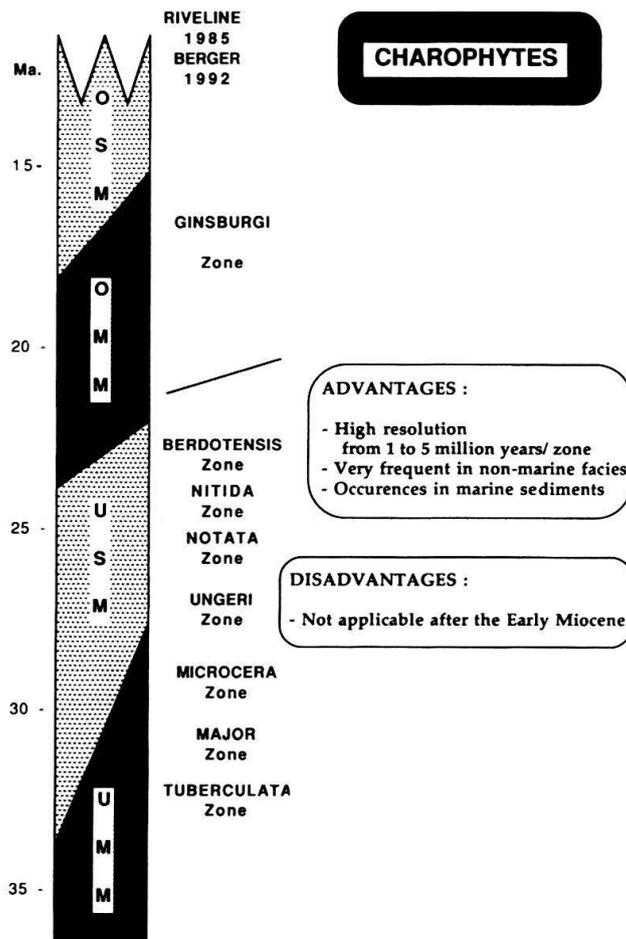


Fig. 6. Charophytes in the Swiss Molasse

Microcera/Ungerer
Major/Microcera
Tuberculata/Major

Wynau 1
Bumbach
before La Combe-Lovagny

s) Schwartz 1985, 1988, 1989 and pers. comm.

Modified by adaptation to the Riveline-zones and correlated with calcareous nannofossil zones.

Paulhiac	= Nitida + Berdotensis
Marseille/St. André	= NP25 = Notata + Ungerer
Fontainebleau/St. Vincent	= NP23 + NP24 = Microcera + ??Major pars
Bembridge sup.	= Major + ?Pinguis

Comments on the biostratigraphic interest of charophytes in the Molasse

The biostratigraphic usefulness of the tertiary charophytes was demonstrated firstly by Grambast (1962, 1964, 1972) then by Feist-Castel (Castel 1968, Feist 1977) and finally by Riveline (1985) who published a general biozonation for the Paleogene and Early Miocene. The application of charophytes to the Molasse basin has been principally studied and published by Kissling 1974 and Berger (1983, 1986, 1992). The great advantage of these fossils is their abundance in the non-marine sediments. The principal disadvantage results from the difficulty to distinguish charophyte-zones later than the "Ginsburgi-zone" (Middle Miocene).

Discussion about the application of the charophyte zonation in the European Oligo-Miocene:

- a) The first problem is a taxonomic one: the intraspecific variability could be very important and could produce several “artificial” taxa. Unfortunately, the inverse phenomenon occurs also: form convergences are frequent in charophytes. Consequently, a lot of species (recent and fossil) are impossible to distinguish as regards their gyrogonites.
- b) Some markers are difficult to determine: for example the distinction between *Chara microcera* and *Chara notata*, both zonal -markers, is not always clear.
- c) Endemism and migration are also to be noted: the genus *Gyrogonia*, for example, very useful for the Paleogene zones, seems to be confined to Western Europe. However, this remark is perhaps due only to the density of sampling.
- d) Some markers are very rare, as *Rantzieniella nitida*.
- e) The zonation is very useful in the Paleogene but not so in the Neogene: only 2 zones, corresponding to the Early Miocene have been established by Riveline 1985. A third zone was recently proposed by Berger (1992), which corresponds probably to the mammal zones NM3 to NM9. For the Late Miocene to the Recent, it is, at this stage, impossible to distinguish marker-taxa to continue the biozonation.

3.8–3.9 European mammal zones and “Swiss Mammal Levels”. (Table 6 and Fig. 7)

European mammal Zones:

- c) Berggren 1985 (MN1–MN14). Table graduated into 1 million year subdivisions
- f) Cavelier & Pomerol 1986 column 13, modified using the zones of Schmidt-Kittler 1987 (MP21–MN1)
- b), i), u), e) : see Table 1
- v) Tobien 1987 and in Vinken 1988 (MP zones, correlated with nannofossil zones)

MP30, 29, 28, 27, 26, 25	= NP25
MP24, 23	= NP24
MP22	= NP23
MP21	= NP22
MP20	= base NP21
MP19, 18	= NP20
- w) Aguilar 1981, according to his table graduated into 500.00 year subdivisions

A1/A2:	24,2 Ma
A2/A3:	23,7 Ma
A3/A4:	23,4 Ma
A4/A5:	22,8 Ma
A5/B:	22,4 Ma
B/C1:	17,5 Ma
C1/C2:	16,2 Ma
C2/C3:	15,6 Ma
C3/C4:	15,2 Ma
C4/C5:	13,5 Ma
C5/D1:	12,4 Ma
D1/D2:	10,2 Ma
D2/D3:	8,4 Ma
D3/D4:	7,5 Ma
D4/E1:	6,5 Ma
E1/E2:	6,2 Ma
E2/E3:	5,9 Ma
Top E3:	5,4 Ma

European Mammal Zones						
Zone	c	h	b	t	u	e
MN14	5,2		5,4	5,2		4,8
MN13	7,0		7,0	5,9	6,9*	6,0
MN12	8,5			7,2	9,2*	7,4
MN1	9,5		9,0	9,0	9,75*	9,0
MN10	11,0		10,6	10,0		10,6
MN9	12,5		11,8	11,0	11,5* or 12,5*	11,5
MN8	13,5			12,5		13,0
MN7	14			14	14,6*	14,0
MN6	15,5		15,5	15,8		15-16,0
MN5	17		17	17		17,0
MN4b					16,8	
MN4a	19		18,5	19		17,9
MN3	21		22,5	22		22,0
MN2b						23,0
MN2a	23			24	22	24,8
MN1		23,5		25		
MP30		~25		25,5		
MP29				26,5		
MP28		~28		27		
MP27		~29		27,6		
MP26				28,5		
MP25		~30		29,2		
MP24		~31		31,5		
MP23		~32		33		
MP22		~34		34,5		
MP21		~36,5		36		
MP20				37,5		
MP19						

Table 6: European mammal zones. Numerical data (million years) reported on the chart (only c, h, b, t, u and e). The letters (a, b, ...) correspond to the authors listed in the chart (see Table 1) and discussed in chapter 3.8.

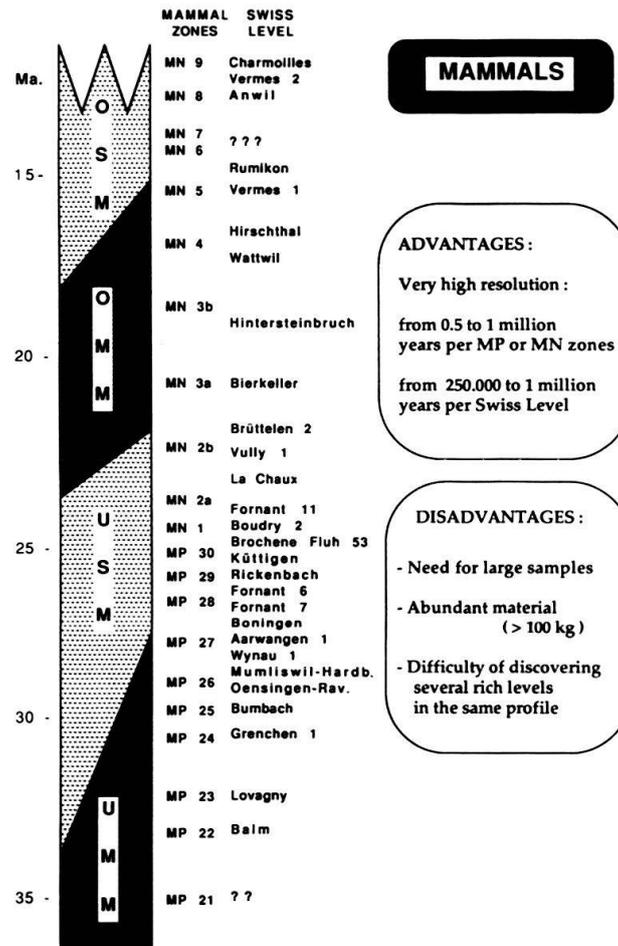


Fig. 7. Mammals in the Swiss Molasse

Swiss mammal Levels:

Compilation after Engesser & Mayo 1987, Engesser et al. 1981, Engesser 1987a, and 1990 a & b. These levels are correlated with the MN and MP zones.

Comments on the biostratigraphic interest of mammals in the Molasse

Following the pioneering studies of Stehlin (1909, 1934) and Hürzeler (1945), the first European mammal biozonation was published by Thaler (1965, 1972). A few years later, a consensus for a Neogene Mammal zonation was presented by Mein (1975, 1979) who proposed the MN-zones. Recently, the Paleogene zonation with MP-zones (Mammal Paleogene zones) was published by Schmidt-Kittler 1987. The very high resolution (the finest one in the tertiary biostratigraphy) is its great advantage. The principal disadvantage is the difficulty of discovering several mammal-rich levels in the same profile (see discussion below).

Discussion about the application of the mammal zonation in the European Oligo-Miocene:

Firstly, I must emphasize that the European mammal zonation is principally based on the synchronicity of the evolution-level of the different taxa. Because of the difficulty of

finding several mammal localities in the same profile, the zonation is based on taxa occurring at different sites (sometimes separated by distances of more than 100 km). This situation presents the problems:

1. The “reference levels” are not always representative of all paleogeographic provinces: several reference levels chosen in Spain, for example, do not share one common taxon with faunas of the same age found in Central Europe.
2. Several very rich faunas are found in karstic deposits, with a high probability of faunal mixing (reworking).

A possibility of avoiding these problems is to create local biozonations, correlated then lithostratigraphically and later to MN or MP zones. The “Swiss mammal levels” represent one of these local biozonations. They are based on localities correlated with a fine lithostratigraphy and sometimes with several rich horizons in the same profile (Findreuse, Fornant, Talent).

3.10 Mammalian Stages (Table 7)

u), c), b), t): see Table 1.

3.11. Mediterranean Stages (Table 8)

a), c), b), e) See Table 1.

g) Martini et al. 1986. Table graduated into 200.000 year subdivisions.

Rupelian/Latdorfian 34 Ma

Latdorfian/Priabonian 37,6 Ma

x) IGCP 124: Neogene after Berggren, Kent & Van Couvering 1985.

Paleogene dated after Odin:

Chattian/Aquitanian: $23 + 1 - 0,5 = 22,5$ to 24 Ma

Rupelian/Chattian: $27 + 2 - 1 = 26$ to 29 Ma

Mammalian Stages				
Stages	u	c	e	t
Headonian/Suevian				36
Suevian/Agenian				25
Agenian/Orleanian	21,5	21	22,0	22
Orleanian/Astaracian	15,3	15,5	15-16	15,8
Astaracian/Vallesian	11,5* or 12,5*	12,5	11,5	11,0
Vallesian/ Early Turolian	9,75*	9,5	9,0	9,0
Early Turolian/Late Turolian	6,8			
Late Turolian/ Ruscinian (Montpellierian in FEJFAR)	5,2	5,2	4,8	5,2

Table 7: Mammalian stages. Numerical data (million years) reported on the chart. The letters (a, b, ...) correspond to the authors listed in the chart (see Table 1) and discussed in chapter 3.10.

Mediterranean Stages					
STAGES	a	c	b	e	H
ZANCLEAN	5,2	5,2	5,4*	4,8	5,2
MESSINIAN	6,3	6,5	6,8	6,4	6,7
TORTONIAN	10,2	10,5	11,8*	11,5	10,4
SERRAVALIAN	15,2	13,0-15,2	16,0	14,7<	14,2
LANGHIAN	16,2	16,2	16,8*	16,5	16,3
BURDIGALIAN	20,0	21,8	22,4	22,0	21,5
AQUITANIAN	25,2	23,6	23,2*	23,3	23,3
CHATTIAN	30,0	30,0			29,3
RUPELIAN	36,0	36,6			35,4
PRIABONIAN					

Table 8: Mediterranean stages. Numerical data (million years) reported on the chart (only a, c, b, e and H). The letters (a, b, ...) correspond to the authors listed in the chart (see Table 1) and discussed in chapter 3.11.

h) Cavelier & Pomerol 1986:

Latdorfian = end of Priabonian

Priabonian/Stampian boundary: from 33 to 36,5 Ma

Stampien/Chattian boundary: 30 Ma

Top of Chattian: 23 to 23,5 Ma

H: Harland et al. 1989 Fig. 1.7: Numerical data given by the authors.

3.12 Position of Stratotypes

a), h) See Table 1

c) Berggren, Kent & Flynn fig. 5 p. 162, Fig. 6 p. 171

Berggren, Kent & Van Couvering 1985 Fig. 2 p. 217

g) Martini et al. 1986, Table 1 p. 39

3.13. Paratethys Stages (Table 9)

b), i), t), e),

y) Steininger, Wessely & Roegl 1987, numerical data given by the authors:

16,3 Ma for the Badenian/Karpathian boundary

30,0 Ma for the Egerian/Rupelian boundary

36,6 Ma for the base of the Latdorfian

z) Baldi 1984: Kiscellian/Priabonian boundary: 36–36,5 Ma

Kiscellian/Egerian boundary: ~29 Ma

Paratethys Stages				
STAGES	b	i	t	e
DACIAN	5,8	5,6	5,8	5,3
PONTIAN	8,8	8,7 à 7,0	8,6	6,5 - 7,9
PANNONIAN	11,6	11,5	11,5	11,6
SARMATIAN	13,8	13,6	14,0	12,8
BADENIAN	16,8	16,5	16,5	16,5
KARPATIAN	17,5	17,5	17,5	17,2
OTTNANGIAN	19,0	19,0	19,0	18,1
EGGENBURGIAN	22,4	22,0	22,0	22,0
EGERIAN			29	
KISCELLIAN			37,5	

Table 9: Paratethys stages. Numerical data (million years) reported on the chart (only b, i, t and e). The letters (a, b, ...) correspond to the authors listed in the chart (see Table 1) and discussed in chapter 3.13.

3.14. Groups omitted from the Chart (Table 10)

Benthic forams, Ostracods, Otolithes

I don't consider benthic foraminifera, ostracod and otolithe zonations in this chart for the following reasons:

- benthic foraminifera: no true zonation has been proposed in the Tethys or Paratethys (see Magné 1978, Wenger 1987).
- ostracods: in the Tethys-Paratethys area, the zonations elaborated by Carbonnel 1970 and Carbonnel & Jiricek 1977 are too imprecise for my purpose.
- zonations have been published by Graham & von Daniels in Vinken 1988 (benthic forams), Keen (1977 & 1978) and Uffenorde (1981, 1986) compiled by Gramann in Vinken 1988 (ostracods, with K- and U-zones) and Gaemers in Vinken 1988 (otolithes), but they are not applicable outside of the North European region.

A tentative application has been proposed by von Daniels et al. 1985 concerning the correlation of the *Uvigerina*-zones from North Germany and the Paratethys. Table 10 presents a correlation of the different ostracod zonations.

Radiolarians and Diatoms

Because of their absence in the perialpine basins, radiolarians and diatoms are not included in this chart.

	KEEN 1977,1978	UFFENORDE 1981,1986	CARBONNEL 1970	CARBONNEL & JIRICEK 1977
MIOCENE		ZONE U 3	BIOZONE D <i>Elofsonella amberii</i>	Datum à <i>Cyprideis</i>
			BIOZONE C <i>Rhodanicites tripartita</i>	Datum à <i>Carinocythereis</i>
		ZONE U 2	BIOZONE B <i>Neomonoceratina helvetica</i>	SUPERZONE <i>Neomonoceratina helvetica</i>
			BIOZONE A <i>Loxococoncha linearis linearis</i>	SUPERZONE <i>Hemicyprideis dacica grekoffi</i>
ZONE U 1				
OLIGOCENE	ZONE K 13			SUPERZONE <i>Hemicyprideis helvetica</i>
	ZONE K 12			

Table 10: Ostracod zonations of the European Oligocene and Miocene.

Phytostratigraphy

Phytozones have been created for example by Mai 1967 (“Florenzonen”) or Gregor 1982. Although they could be useful, especially in non-marine sediments, their correlation with other biozonations or radiometric ages are not clear enough to integrate them in this chart. Furthermore, these zonations are clearly dependant on climatic conditions which reduce the possibility of long distance correlation.

4. Biostratigraphy of the Swiss Molasse

Biostratigraphic results concerning the Swiss Molasse are presented in Plate 1. This Figure shows an application of the correlative chart to the Molasse Basin. Biostratigraphic indicators are plotted on the right hand side of the figure. Their respective positions are correlated across the chart. Thus, we have a biostratigraphic base to correlate the different lithostratigraphic units (UMM, USM, OMM, OSM). Complete informations concerning the stratigraphy in the Molasse Basin have been published by Habicht 1987.

The results presented in the Plate 1 necessitate the following comments:

4.1. UMM = Untere Meeresmolasse = Lower Marine Molasse

The base of the UMM is very diachronous between the Jura mountains and the subalpine area. The biostratigraphic correlations (see localities 19–21, 45–46 and 57–63) clearly show the interfingering and the respective position of the base of UMM and USM.

The top of the UMM is also very diachronous. The UMM-regression is:

- younger in the Jura than in the subalpine area.
- in the subalpine area it is younger in the Eastern part (locality 61) than in the Western part (loc. 55–56).

The Rupelian age classically attributed to the UMM is incorrect. A part of this unit (especially in the Jura mountains) can be attributed to the Chattian.

4.2. *USM = Untere Süßwassermolasse = Lower Freshwater Molasse*

USM is generally subdivided into a lower part (“Chattian”) and an upper part (“Aquitanian”). These chronostratigraphic terms are practical, but imprecise: as shown in Plate 1, a part of the USM is surely of Rupelian age, and another part could probably be attributed to the Burdigalian.

Consequently, the terms “Chattian” or “Aquitanian” should be used, in the Molasse, only as “local units”, and should be written with quotation marks, to avoid confusion with the chronostratigraphy. Otherwise, the top of the Subalpine Molasse (in Switzerland) seems to be not younger than Aquitanian.

4.3. *OMM = Obere Meeresmolasse = Upper Marine Molasse*

The transgression of the OMM is relatively well dated by mammals on the “Molasse du Plateau”. In the Jura Mountains, the diachroneity of the OMM-base is only deduced from indirect correlations and from geological patterns.

The subdivision of the OMM into a lower “Burdigalian” and an upper “Helvetian” part was generally proposed. As demonstrated by several recent studies (Schoepfer 1989, Schoepfer & Berger 1989, Keller 1989), the major part of the Upper Marine Molasse should be attributed to the Burdigalian. The “Helvetian” corresponds to a Middle to Late Burdigalian (ante- N7). Only the top of the OMM in the distal area (Jura mountains) belongs perhaps to the Langhian.

4.4. *OSM = Obere Süßwassermolasse = Upper Freshwater Molasse*

The regression of the OMM was surely not synchronous because of the occurrence of depocenter migration and variable relief created by alluvial fans. In the different regions, the OMM-OSM boundary could be dated between nannofossil zones NN3 to NN5 and mammal zones MN3 to MN5.

The OSM should be attributed to a Badenian-Sarmatian or Langhian-Serravallian age. Thus, the term “Tortonian” to indicate the Upper Freshwater Molasse should be definitively eliminated. Biostratigraphically, only the mammals could be useful to subdivide the OSM, which could be dated from the MN5 to MN6-?7 in the “Molasse du Plateau” and from MN5 to MN8 in the Jura mountains.

Along with biostratigraphic data, volcanic sediments (bentonites) of the OSM yielded radiometric ages (Plate 1 No 22, according to Fischer 1988, Fischer, Oberli & Meyer 1989):

- 14,4 Ma: bentonite of Mollen
- 15,2 Ma: bentonite of Erlenbach
- 15,4 Ma: bentonite of Wüsttobel

4.5. *The End of the OSM-Sedimentation and the "Pliocene"*

The top of the OSM is marked by:

- an erosion boundary, covered in parts by quaternary to recent sediments.
- a discordance covered by tertiary conglomerates, sands and gravels ("Graviers du Bois de Raube", "Hipparionsande", "Vogesenschotter"). These layers are dated from NM9 in one locality (Charmoilles). Recent studies (Engesser, Kälin under research) confirm the Middle to Late Miocene age of these sediments.

Thus, no Pliocene sediments are known in the north of the Swiss Alps.

5. Conclusions

The correlation chart presented here reflects the "state of the art" in 1990. Progress in biostratigraphy is very rapid and at the time of publication of this paper, new charts are probably being created. It is hoped that the future results will lead to a uniformity of the boundaries.

ACKNOWLEDGEMENTS

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Plate 1. Biostratigraphic synthesis of the Swiss Molasse

A: Mesozoic & Siderolithic

Localities	Ages, Biozones & References
1. Charmoilles	Mammal level Charmoilles (Hummel 1914, Engesser 1990)
2. Vermes 2	Mammal level Vermes 2 (Engesser, Matter & Weidmann 1981)
3. Anwil and Mt. Chaibeux	Mammal level Anwil (Engesser 1972, 1990)
4. Le Locle	Mammal level Anwil (Engesser 1990, Weidmann, Engesser, Berger unpubl.)
5. Vermes 1	Mammal level Vermes 1 (Engesser, Matter & Weidmann 1981)
6. Eplatures	Charophyte-zone Ginsburgi (Weidmann, Berger unpubl.)
7. Ponts de Martel	Nannozone NN5 (Weidmann, Berger, unpubl.)
8. La Pesse, Les Verrieres, etc.	Nannozone NN4 (Rangheard et al. 1991)
9. Tavannes	Mammal level Bierkeller (De Beaumont de Chambrier & Weidmann 1984, Engesser 1990)
10. Motier	Charophyte zone Nitida or Berdotensis (Weidmann & Berger unpubl.)
11. La Chaux	Mammal level La Chaux (Schaub 1925, Stehlin & Schaub 1950, Engesser 1990)
12. Brochene Fluh	Mammal levels Brochene Fluh 53 and Küttigen (Engesser 1990) Charophyte zone Notata (Berger 1986 + unpubl.)
13. Rochefort	Mammal level Rickenbach or Küttigen (Weidmann 1986) Charophyte zone Notata (Berger 1986, Weidmann 1986)
14. Savagnier	Charophyte zone Ungeri or Notata (Weidmann & Berger unpubl.)
15. Saicourt	Charophyte zone Ungeri or Notata (Weidmann & Berger unpubl.)
16. Reconvilliers	Charophyte zone Ungeri or Notata (Weidmann & Berger unpubl.)
17. Mümliswil	Mammal level Mümliswil (Mayo 1980, Engesser & Mayo 1987) Charophyte zone Major or Microcera (Berger 1986)
18. Courgenay, top	Nannozone NP25 (Weidmann & Berger unpubl.)
19. Courgenay (Middle) and Birse	Nannozone NP23 and NP24 (Weidmann & Berger unpubl., de Kaenel unpubl.)
20. Dornachbrugg	Mammal level Balm (Engesser & Mayo 1987)
21. La Scheulte and Delémont 1	Charophyte zone Tuberculata (Weidmann & Berger unpubl.)
22a, b, c. Bentonites of the OSM	14,4 m.a., 15,2 and 15,4 m.a. (Fischer 1988)
23. Top OSM East Switzerland	MN6-?? (Bolliger, Gatti & Hantke 1988, Bolliger & Eberhardt 1989, Berli 1985)
24. Rümikon and Oeschgraben	Mammal level Rümikon (Engesser 1990)
25. Pulverhüsli, Hüllistein, etc.	Mammal level Vermes 1 (Bürgisser, Furrer & Hünemann 1983, Engesser 1990)
26. Hirschthal	Mammal level Hirschthal (Engesser 1990)
27. Pectinids of St.-Gall. Formation	Pecten zone PN3, Eggenburg.-Ottngian Fauna (This study, after Demarcq 1990 and Keller 1989)
28.–29. Strontium analyses St. Gall. Formation	18 m.a. and 19 m.a. (Fischer 1988, Keller 1989)
30. Hintersteinbruch	Mammal level Hintersteinbruch (Keller 1989, Engesser 1990)
31. Bierkeller	Mammal level Bierkeller (Engesser 1990)
32. "Helvetian" Belpberg and Gubloux	Pecten zone PN3 (This study, after Demarcq 1990 and Schoepfer 1989) Nannozone NN3 (Schoepfer 1989) Planktonic Zone N6 (Schoepfer & Berger 1989)
33. Brüttelen	Mammal level Brüttelen 2 (Berger 1985, Engesser 1990)
34. Vully	Mammal level Vully 1 (Huerzeler 1945, Ramseyer 1952, Engesser & Mayo 1987) Charophyte zone? Berdotensis (Berger 1983, 1986)
35. Mèbre 698, Mauguettaz, Cheyres	Mammal level La Chaux (Berger 1985, Engesser 1990) Charophyte zone Berdotensis (Berger 1983 + unpubl.)

36. Ruchwil Planktonic Foram. zone N5 (Berger 1985)
37. Augine Planktonic Foram. zone N5 (Berger 1985)
Mammal level La Chaux or Vully 1 (Berger 1985)
Charophyte zone Berdotensis (Berger 1983, 1985 + unpubl.)
38. Bois Genoud Mammal level Fornant 11 (Mummenthaler, Peters & Weidmann 1981)
Charophyte zone? Berdotensis (Mumm. et al. 1981, Berger 1983)
39. Broye 555 Mammal level La Chaux (Berger 1985)
40. Findreuse and Fornant Position according to the ages of Mammal levels (Burbanks et al. 1992)
41. Findreuse and Fornant Position according to paleomagnetic datas. (Burbanks et al. 1992)
42. Wynau Mammal level Wynau 1 (Engesser 1990)
43. Oensingen Mammal level Oensingen (Mayo 1980, Engesser & Mayo 1987)
44. Talent Profil Mammal levels from Grenchen 1 to Brüttelen 1 (Engesser, Hurzeler & Mayo 1987, Weidmann unpubl.)
45. Balm Mammal level Balm (Engesser & Mayo 1987)
46. Orbe Charophyte zone Tuberculata (Weidmann 1984, Berger 1986)
47. Seligraben Mammal level Fornant 11 (Blau 1966, Engesser 1990)
48. Präserenbach and Waldenburg Mammal level Boudry 2 (Engesser 1990)
49. Gérignoz Mammal level Brochene Fluh 53 (De Beaumont & Weidmann 1981, Engesser 1990)
Charophyte zone Notata (De Beaumont & Weidmann 1981, Berger 1986)
50. Top "Molasse à Charbon" Mammal level Küttigen (Engesser, Mayo & Weidmann 1984)
Charophyte zone Notata (Fasel 1986, Berger 1986)
51. Schwendibach Mammal level Oensingen (Engesser & Mayo 1987)
52. Bumbach Mammal level Bumbach (Engesser & Mayo 1987)
Charophyte zone Major or Microcera (Berger 1986)
53. Foron Mammal zones MP23-24 (Charollais, Ginet, Huguency & Muller 1981, Engesser & Mayo 1987)
54. Lovagny and La Combe Mammal level Lovagny (Engesser & Mayo 1987, Engesser 1990)
Charophyte zone Major or Microcera (Berger 1986)
55. Ruisseau de Ruz Charophyte zone Major or Microcera (Berger 1986)
56. Vaulruz Mammal zone MP22 ("Villebramar") (Weidmann, Homewood & Fasel 1982)
57. "Val d'Illiez Formation" Planktonic zone P18 to P20 (Weidmann, Homewood & Fasel 1982)
NP21–23 (Berger unpubl.)
Dinoflagellate Gochti-zone (Powell & Berger unpubl.)
58. Top "Marnes à Forams.", Aravis Planktonic zone P18 to P19 (Lateltin & Mueller 1987)
59. Mar. Forams/Taveyannaz bound. Nannozone NP21 (Lateltin & Mueller 1987)
60. Hellschwandbach, "subalp. Flysch" Dinoflagellate zone Defl. heterophlycta (Hochuli 1982)
61. "Marnes à Forams. & Schistes à Melleta", Bornes Massiv Palynozone P19 to P20a, and Defl. heterophlycta-zone.
Planctonic forams zones P17–P19
Charollais, Hochuli, Oertli et al. 1980
62. Grisigermergel from Grisigen Dinofl. W. gochti zone (Hochuli 1982)
63. Grisigermergel from Rietbad Nannozone NP24 (Frei 1979).

