

BIOCHRONOLOGY OF SELECTED MAMMALS, MOLLUSCS AND OSTRACODS FROM THE MIDDLE PLIOCENE TO THE LATE PLEISTOCENE IN ITALY. THE STATE OF THE ART

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Riassunto. Gli Autori hanno elaborato quattro tavole di distribuzione cronologica delle faune a mammiferi (macro e micro), a molluschi e ad ostracodi di acqua dolce e salmastra, prendendo in considerazione i più significativi giacimenti del Plio-Pleistocene della penisola italiana. In questo lavoro viene istituita una nuova Età a Mammiferi (Aureliano) correlabile con la parte superiore del Pleistocene Medio e con il Pleistocene Superiore: di questa età sono state definite due Unità Faunistiche (Torre in Pietra e Vitinia) per l'Aureliano inferiore e medio, mentre nessun giacimento è stato considerato rappresentativo per l'Aureliano superiore. Le unità biochronologiche sono state calibrate con la magnetostratigrafia, con le scale isotopiche dell'ossigeno e attraverso datazioni radiometriche.

Abstract. The Authors have elaborated four range charts of mammalian (large and small), molluscs and fresh-water and brackish ostracodes faunas, for the selected Plio-Pleistocene fossiliferous localities of the Italy. A new Mammal Age (Aurelian) correlatable to late Middle and Late Pleistocene has been defined. Inside this age two Faunal Units (Torre in Pietra and Vitinia) have been defined as characteristic for early and middle Aurelian, while no gisements have been chosen for the late Aurelian. Biochronological units are calibrated on magnetostratigraphic and isotopic scales and by radiometric datings.

Introduction.

Present day knowledge about the terrestrial mammal faunas, non marine molluscs and freshwater brackish ostracods of the Italian Plio-Pleistocene enables us to attempt to construct an integrated biochronology. This has been achieved by means of constructing four distribution charts of selected taxa from the most significant Italian localities. It is worthwhile underlining that

the mammal ages used for the biochronological scale of the large mammals are also used (mainly for historical reasons) for the biochronology of the molluscs and ostracods.

The species distribution charts refer to the Faunal Units (F.U.) succession (Azzaroli, 1977; Azzaroli et al., 1982, 1988). This succession constitutes the biochronological scale for the continental succession in the Italian peninsula, and is calibrated with the geochronological scale by means of radiometric and palaeomagnetic dating. Successive faunal units are not separated by a boundary, because of the impossibility of defining them with precision. The unreliability of the boundaries derives from two causes of a different order:

a) continental successions are largely discontinuous and mammal remains are usually concentrated in horizons with a punctual distribution in stratigraphic successions. Therefore only exceptionally can the transition to the next association be recognised in stratigraphic succession.

b) the definition of F.U., which is based on all the species from local faunas selected as typical associations.

This latter point merits a brief discussion. Faunal Units in biochronology correspond to what in biostratigraphy are coenozones and, in the same way, their limits are not definable with precision. The distinction between successive coenozones is not based on single taxa appearance/disappearance bioevents, but on different associations of characteristic taxa. In fact bioevents characterising successive F.U. occur during the transition between the two F.U., and their calibration is conse-

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quently affected by some inaccuracy (for a wider discussion on this subject we refer the reader to De Giuli et al., 1986; Lindsay, 1990). Clearly this factor generates a certain "background noise" in the contents of the distribution charts. In addition an even more important bias is caused by the fact that different Faunal Units are not homogeneous from the point of view of the diversity of occurring species.

An example of this is given by the faunal renewal that occurred at the beginning of the Middle Pleistocene, between the Colle Curti and the Slivia Faunal Units. In fact the few species occurring at Colle Curti - which in any case are indicative of a renewal - does not make it possible to establish whether this faunal change was already under way previous to this faunal unit.

Despite these limitations, the picture which results from this work gives reasonably acceptable information about the timing of the faunal renewals during the Plio-Pleistocene.

The distribution charts.

The unreliability of biochronologies based on mammal assemblages mentioned above forced us to use some graphic conventions and symbols in the distribution charts which need some explanation.

On the left in Fig. 1 and 2 are the composite curve of oxygen isotopes modified from Shackleton (1995), the chronologically calibrated magnetostratigraphic scale (Baksi, 1993) and the geochronological scale. The boundary between the middle and the late Pliocene is placed at isotopic stage 103, just before the beginning of the marked cooling event which took place at about 2.5 Ma (Rio et al., 1994). The boundary between the early and the Middle Pleistocene is placed close to isotopic stage 25, following the proposal made by Cita & Castradori (1994). The boundary between the Middle and the Late Pleistocene is placed at isotopic stage 5e (Aguirre & Pasini, 1985).

Faunal units calibrated by radiometric and/or palaeomagnetic analyses are reported in the column "Calibrated local faunas". The graphic convention indicating the transition between Mammal Ages is a vertical bar which covers the space between the last and the first faunal unit of two successive mammal ages. The same graphic convention is used to indicate the base of selected events, which is placed in an intermediate position between two successive faunal units.

The distribution of the taxa is represented by a continuous vertical line when the presence of taxa is documented. When the presence of a taxon is inferred or is documented by scarce or fragmentary material, it is represented by a dotted line. The precise succession of the appearance/disappearance of each taxon characterising successive faunal units is not known. Only in a

few cases is it possible to reconstruct the relative chronological position of each local fauna within a faunal unit. For this reason local faunas in a faunal unit are conventionally reported in alphabetical order and first/last occurrences of taxa are conventionally placed at the base of each faunal unit, represented by a dotted line. The synchrony of events observable on the distribution chart is attributable to this graphic conventions.

For the reasons discussed above, the temporal gap between appearances is sometimes emphasised by the scarcity of local faunas, especially in the older part. Furthermore, the scale of the faunal renewal (measured by the number of new appearances) is biased by the greater or lesser richness of the local faunas which make up each faunal unit.

Large mammals.

Villafranchian Mammal Age.

The oldest fauna we are dealing with is the Triversa F.U., which dates back to the Middle Pliocene. Early Pliocene mammals in Italy are extremely poorly represented. A few fossils were collected in the Val di Pugna (Siena), assigned to *Stephanorhinus megarhinus*, *Sus minor*, *Alephis liryx* and *Felsinotherium gervaisi* (Azzaroli et al., 1988). A further find of this age is a fragmentary metapodial of *Alephis liryx* from the fluvio-lacustrine basin of Montecarlo near Lucca (Dallan Nardi, 1988). Early Pliocene mammals are not sufficiently well represented in Italy to be included in the distribution chart.

The fauna of the Triversa F.U. (the first faunal unit of the early Villafranchian) show a marked renewal with respect to previous associations which are well characterised in localities of Spain and southern France (see Azzaroli et al., 1988, with references) and which are composed of taxa which are typical of humid and dense forested environments.

The Triversa F.U. is characterised by the assemblage of fossils from various sites in the Villafranca d'Asti area (S. Paolo, Solbrito, Dusino, Fornace R.D.B., Casa Crotino, Casa Cassinotta, Arboschio, Arondelli) and takes its name from a small river in the area. The vertebrate bearing fluvio-lacustrine succession lies on Early Pliocene (MPL 4) marine clays. The age of this F.U. should be around 3.2 Ma, as suggested by palaeomagnetic analyses at Fornace R.D.B. (Lindsay et al., 1980), although new analyses by Lindsay et al. (1995, and oral communication) suggest that the Fornace R.D.B. section should be attributed to the upper part of the Gilbert magnetozone. The first date has however been confirmed by the palaeomagnetic survey recently carried out at Santa Barbara near Castelnuovo dei Sabbioni in the upper Valdarno (the first fluvio-lacustrine cycle

of the upper Valdarno), where a faunal assemblage of the Triversa Unit was found (Torre et al., 1996; Albiacelli et al., 1997). In addition to the above mentioned localities, local faunas referable to this F.U. are present in different areas of Italy: S. Giusto (Torre, 1987), Ponte a Elsa (Azzaroli, 1992), Case Nuove (Dominici et al. 1995; Benvenuti et al., 1995) in the lower Valdarno; Spoleto in Umbria (Tuccimei, 1898; Sardella et al., 1995) and Arcille near Grosseto in southern Tuscany (Hürzeler & Engesser, 1976; Masini & Torre, 1987).

In this unit there is the first recorded appearance of the genus *Pseudodama*, *Leptobos stenometopon* and *Stephanorhinus jeanvireti*, and several large carnivores such as *Acinonyx*, *Homotherium* and *Ursus minimus*. There are also forms of Viverridae (*Viverra* and *Megaviverra*) and an extinct form of panda (*Parailurus*). *Tapirus arvernensis* and *Sus minor* are still well represented while *Mesopithecus monspessulanus* occurs for the last time.

The beginning of the early Villafranchian (Triversa F.U.) thus represents a marked faunal turnover. The occurrence of new taxa enriches the fauna which, as a whole, has a more advanced character compared with the Ruscinian ones.

A marked faunal renewal marks the transition between this F.U. and the following Montopoli F.U.; taxa typical of wooded habitats disappear [*Zygodolopodon borsoni*, *Tapirus arvernensis*, *Sus minor* (= *Sus arvernensis*); *Ursus minimus*] and in Italy one sees the spread of a primitive elephant (*Mammuthus gromovi*), and the horse (*Equus livenzovensis*). Both taxa are indicative of more open landscapes. At that time *Stephanorhinus etruscus* also probably appears (Rustioni et al., 1995). The local Montopoli fauna, in the Lower Valdarno, was collected at the top of a marine succession with *Globorotalia crassaformis* and is calibrated with the Gauss/Matuyama transition in the magnetostratigraphic scale (Benvenuti et al., 1995; Lindsay et al., 1980; Torre, 1987).

The small local fauna at Colleparado, located in the Anagni basin in Latium, is composed of *Meganteleon cultridens*, *Nyctereutes megamastoides*, *Stephanorhinus* cf. *S. jeanvireti*, *Sus* sp. (of a small size), *Pseudodama lyra* and "*Hemitragus* cf. *H. stehlini*" (Cassoli & Segre Naldini, 1994). With some reservations due to the scarcity of material, this small fauna could be referred to the end of the early Villafranchian.

Middle Villafranchian faunas are poorly represented in Italy, and they are represented by small assemblages which have not yet been fully studied. One of these comes from the locality of Costa S. Giacomo, again in the Anagni basin. The Costa S. Giacomo local fauna is characterised by the first occurrence of the genus *Canis* s.s., *Sus* cf. *S. strozzi*, *Leptobos furtivus*, *Hystrix* cf. *H. refossa* and *Gazellospira torticornis*, and the last occurrence of *Anancus arvernensis* (Cassoli & Segre Naldini, 1994; Masini, 1989; Rook & Torre, 1996). The faunal

association also includes *Stephanorhinus* cf. *S. etruscus* while *Nyctereutes megamastoides*, *Stephanorhinus* cf. *S. jeanvireti* and the small sized suid are no longer present.

The beginning of the late Villafranchian (Olivola F.U.) is marked by the appearance of *Pachycrocuta brevirostris*, *Panthera gombaszoegensis* (= *P. toscana*), *Procampoceras brivatense* and new species of *Eucladoceros* and *Pseudodama* (*E. dicranios*, *P. nestii*). Furthermore modern dogs (*Canis etruscus*) become widespread. The majority of the Pliocene species which had survived the first crisis linked with the first arctic glaciation (isotopic stage 100 and afterwards) are no longer present or are extremely rare. The most important local fauna is that of Olivola (val di Magra) which is probably located in the Olduvai chronozone. In fact, research which is still in progress at Poggio Rosso (upper Valdarno; Torre, unpublished) suggests that the adjacent site at Matassino, which in the past had been attributed to this F.U. and palaeomagnetically calibrated with the β event in the upper part of the Olduvai chronozone (Torre et al., 1993, 1996), has a faunal assemblage with characteristics which are transitional between the Olivola F.U. and the following Tasso F.U.

The Tasso F.U. is characterised by the arrival of *Hippopotamus antiquus*, *Praeovibos*, a bison-like *Leptobos* (*L. vallisarni*), *Equus stehlini*, *Canis arvensis* and *Canis* (*Xenocyon*) *falconeri*, together with the disappearance of *Galogoral meneghini* and *Gazellospira torticornis* (De Giuli & Masini, 1987; Azzaroli et al., 1988; Ambrosetti et al., 1995a). These events determine a marked change in the faunal association, and it acquires a typically Quaternary character.

After the turnover responsible for the formation of the Tasso F.U., most of the typically Villafranchian taxa disappear or become extremely rare, and species which are phylogenetically closer to the Middle Pleistocene species appear. This new situation characterises the Farneta F.U. (Azzaroli, 1977). *Leptobos* and *Eucladoceros* are still present and, for the first time, a deer of the *Megaceroides* clade (*M. obscurus*) and the vole *Microtus* (*Allophaiomys*) appear (Masini & Santini, 1991; Azzaroli & Mazza, 1993; Abbazzi, 1995). The richest locality for this F.U. is Pietrafitta in Umbria (Ambrosetti et al., 1987; Ambrosetti et al., 1992 a, b) where there are characteristic small sized rhinoceroses (Mazza et al., 1993).

Pirro Nord-Cava dell'Erba, karst fissure fills in the Gargano, (De Giuli et al., 1987; Abbazzi et al., 1996 b), and Capena near Rome (Petronio, 1979) are two localities where the first occurrence has been recorded of a primitive bison, *Bison* (*Eobison*), and of a *Megaceroides* species, probably attributable to the *M. solihacus* phyletic lineage (Abbazzi & Masini, 1997). The presence of ovibovine remains at Pirro Nord is also very significant. These novelties characterise the Pirro Nord F.U.

Galerian Age.

Taxa which are considered to be classically Galerian (such as *Equus altidens*, *Equus* gr. *bressanus-suessensbornensis* and the genus *Megaceroides*) already occur in the F.U. of the Late Villafranchian and the faunal renewal that produced typically Galerian assemblages was a gradual phenomenon. The Colle Curti local fauna is conventionally used to mark the beginning of this Mammal Age. This faunal assemblage (Ficcarelli & Silvestrini, 1991), which unfortunately is not very rich, was found in sediments with a normal polarity and which are correlated with the base of the Jaramillo subchronozone (Torre et al., 1996; Albanelli et al., 1997). The fauna is characterised by the presence of the first forms of *Megaceroides verticornis*. The small number of species recorded in the assemblage does not make it possible to verify how many typical Galerian taxa were present at the time; fossils of a medium-sized bovine could be attributed either to a small *Bison* or, alternatively, to *Leptobos*. The presence of *Pliomys lenki* together with a *Microtus* (*Allophaiomys*), which was probably ancestral to *Microtus ex* gr. *oconomus*, confirms the innovative character of this faunal assemblage and strengthens its attribution to the Galerian.

Subsequently there were successive dispersal events of Asiatic and central European taxa into the Italian peninsula, probably in relation to phases of climatic cooling. At the same time new taxa appear as a result of local evolution. Within the Galerian complex it is therefore possible to recognise three successive associations characterising the early, middle and late Galerian respectively.

The early Galerian assemblage is characterised by the presence of *Megaceroides verticornis* and by the persistence of forms with Villafranchian affinities such as *Pachyrocota brevirostris*, *Homotherium* ex gr. *crenatidens-latidens*, *Mammuthus* (*Archidiskodon*) *meridionalis*, a small sized *Stephanorhinus* and an advanced form of *Pseudodama*. The Colle Curti F.U. is attributed to the early Galerian; it was established on the basis of the faunas of the Colle Curti site and those from Monte Peglia (van der Meulen, 1973; Piperno & Segre, 1984). At the latter site the large mammal assemblage, which has yet to be studied analytically, suggests the persistence of a large amount of Villafranchian taxa, while the small mammals indicate a more evolved assemblage than the one from Pirro Nord. It appears therefore that the early Galerian assemblage in Italy, even though it is poor in species and scarcely represented in terms of number of sites, constitutes a complex which is indicative of the transition between typical late Villafranchian and typical Galerian faunas.

The middle Galerian assemblage, which is characterised by the presence of *Cervus elaphus acoronatus*,

shows a more marked faunal renewal which can already be seen in the Slivia F.U. and which is much more noticeable in the Isernia F.U.. Lion, paleoloxodont elephants and the subgenus *Mammuthus*, a typical form of *Stephanorhinus hundsheimensis*, new megalocercines and new bovids such as *Bos* and bison belonging to subgenus *Bison* (*Bison*) and, among the equids, *Equus caballus*, all appear. Some Villafranchian large carnivores and equids as well as an advanced form of *Pseudodama* are still present. The oldest sites with middle Galerian faunas belonging to the Slivia F.U. are Slivia (Ambrosetti et al., 1979; Bon et al., 1992) and Monte Tenda (Pasa, 1947). Due to the persistence of some Villafranchian elements, the Selva Vecchia local fauna (Bon et al., 1991) seems to be slightly more archaic than that at Slivia. The assemblages from Isernia (Sala, 1983a, 1996a), Cesi (Masini et al., 1991; Ficcarelli et al., in press) Valdemino (Sala, 1992) and various sites in the surroundings of Ponte Galeria (Capasso Barbato & Petronio, 1984; Caloi & Palombo, 1994a) are attributed to the following Isernia F.U.

The fauna from Visogliano (Cattani et al., 1991) and Venosa-Notarchirico (Belli et al., 1991) are probably transitional with those of the late Galerian.

The late Galerian assemblage, to which the Fontana Ranuccio F.U. is referred, is characterised by the total disappearance of typical Villafranchian taxa with the exception of *Homotherium*, which is represented by an evolved form (Sardella, 1994). The red deer subspecies *Cervus elaphus eastephanoceros* is present (Di Stefano & Petronio, 1993) and *Dama clactoniana*, *E. altidens* and *E. suessensbornensis* continue to occur. The most representative sites are Fontana Ranuccio (Segre, 1984) and Cava Nera Molinario (Di Stefano & Petronio, 1993).

Aurelian Mammal Age.

A marked renewal occurs at the transition to the following faunal assemblage, with the extinction of some Galerian forms such as the megacercine cervids of the *Megaceroides verticornis* group, *Megaloceros savini* and the more archaic elaphine deer, while taxa which constitute the core of the modern mammal fauna appear for the first time. Very rich deposits are mainly located in the Tyrrhenian coastal area of Latium, along the S.S. 1 Aurelia. For this reason we propose to use the term Aurelian age for this faunal assemblage. Aurelian faunas come from deposits which date to the late Middle Pleistocene and the Late Pleistocene.

Bioevents such as the first occurrence of the modern large wolf *Canis lupus* and of *Ursus spelaeus* have been chosen to define this faunal assemblage. In the Aurelian faunal complex there are three different and subsequent associations (early, middle and late Aurelian) which are related to the progressive occurrences of diffe-

rent taxa of Asian origin or of other forms which evolved in the Mediterranean area.

The early Aurelian assemblage, which is represented by the Torre in Pietra F.U., is characterised by the first occurrence of the modern wolf and of the cave bear as well as by the first occurrence of *Megaloceros giganteus* and the diffusion of the most archaic forms of modern red deer *Cervus elaphus rianensis*. Correlations between the type locality of Torre in Pietra (Torre di Pagliacetto) and the Middle Pleistocene Tyrrhenian shorelines refer this faunal unit to isotopic stage 9 (Conato et al., 1980). The most representative deposits of this Faunal Unit, besides Torre in Pietra (lower levels) (Caloi & Palombo, 1978; Cassoli, 1978), are Castel di Guido (Sala & Barbi, 1996), Malagrotta and Riano (Caloi & Palombo, 1994a) and la Polledrara di Cecanibbio (Anzidei et al., 1989; Arnoldus-Huyzendveld & Anzidei, 1993), all located in Latium.

The next faunal assemblages, referable to the middle Aurelian (isotopic stage 7), are characterised by the occurrence and diffusion of the most primitive subspecies of the modern fallow deer *Dama dama tiberina* (Di Stefano & Petronio, 1997) and *Equus hydruntinus*, during a period of climatic amelioration which is also recognisable in the marine environment. The Vitinia F.U. has been attributed to the middle Aurelian; it is represented by the fauna from Vitinia, Bucine, Cerveteri, Sedia del Diavolo and Torre in Pietra (upper levels) (Caloi & Palombo, 1994a).

The late Aurelian assemblage, which begins with the Eemian and terminates with the end of the last glaciation, is difficult to define because it is mainly characterised by the disappearance of large and medium sized mammals. In the time span corresponding to this faunal assemblage there was a series of important climatic events and the different microclimatic and environmental conditions have strongly influenced the faunal composition along both the Tyrrhenian and the Adriatic coasts of the Italian peninsula (Sala 1983b; Masseti et al., 1995; Torre et al., in press). During this period the faunal assemblages become poorer and, in correspondence with the beginning of the last Interglacial, are more and more conditioned by anthropic influence. Even though the deposits related to this assemblage are both numerous and well studied, for the reasons mentioned above none of them can be considered to be fully representative of the late Aurelian faunal population, and as a result it is not possible to choose a local reference fauna to define faunal units within this assemblage.

The oldest local faunas (isotopic stage 5) referable to the late Aurelian assemblage are characterised by the first occurrence of the modern form *Dama dama dama*. The most important deposits are mainly located in central and southern Italy, such as S. Sidero (De Giuli,

1983) and Melpignano (Bologna et al., 1994), Grotta Moscerini (lower levels), Guattari and Fossellone (Circeo) (Caloi & Palombo, 1994b).

Subsequently, not only in Europe but also within the Italian peninsula, there was an enlargement of the distribution area of *Capra ibex* and the spread of large cold environment stenothermic mammals such as *Coelodonta antiquitatis* and *Mammuthus primigenius*. Several taxa of large herbivores and carnivores progressively disappeared in correspondence with the following phases of climatic deterioration.

The most recent late Aurelian assemblages come from a large number of localities all over Italy and have mainly been found in cave deposits. Among these the sites with the most complete palaeontological, palaeoecological and palaeoclimatic data are Grotta del Broion and Riparo Tagliente, (Bon et al., 1991) in Northern Italy, Grotta Breuil, Grotta Barbara and the upper levels of Grotta dei Moscerini, Grotta Fossellone, Grotta Guattari and Grotta S. Agostino in Central Italy (Caloi & Palombo, 1994b), and Grotta del Cavallo (Bartolomei, 1980), Grotta Paglicci (Sala, 1983 b; Abbazzi et al., in press b) and Grotta della Serratura (Bertolini et al., in press) in southern Italy.

Small mammals.

In contrast with the large mammals, studies of Italian fossil small mammals started only much more recently. In fact, with the exception of the research carried out by Bosco and Forsyth Major almost a century ago, it was only after the end of the Second World War that research was renewed by Pasa and Bartolomei and only since the seventies that a greater number of palaeontologists began to work on this topic.

The Middle and Late Pliocene and the Early Pleistocene small mammal record is relatively scarce and the number of sites is small, while the Middle and Late Pleistocene deposits are as numerous as those for the large mammals, although the number of sites with both kinds of faunal assemblages is relatively low.

The biochronological attribution of the assemblages follows the scheme proposed by Fejfar & Heinrich (1989). However, since the large mammal data for the Pliocene and Early Pleistocene in the Italian peninsula are considerably more detailed than that of the small mammals, where possible the fauna have been referred to the biochronological scale of the large mammals.

Villafranchian Mammal Age.

A rich fauna with insectivores, rodents and lagomorphs comes from Cascina Arondelli (Villafranca d'Asti, Piedmont) and is typical of the Triversa F.U. The assemblage is characterised by shrews such as *Episo-*

riculus gibberodon (= *Asoriculus* after Hutterer, 1994), *Blarinoides mariae*, *Petenya hungarica* and *Beremendia fissidens*, by the voles *Mimomys hajnackensis* and *Mimomys stehlini* and by other rodents and lagomorphs (*Muscardinus* cf. *M. pliocaenicus*, *Glirulus pusillus*, *Prolagus savagei* etc.) (Berzi et al., 1967; Michaux, 1970; Masini & Torre, 1987). The fauna from Arcille (Grosseto, Tuscany) with *Mimomys hajnackensis* and from San Giusto (Pisa, lower Valdarno, Tuscany), type locality of *Mimomys stehlini*, are also attributed to the Triversa F.U. These three faunas are referable to the early Villanyian (Masini & Torre, 1987). Many European deposits bearing the remains of *Mimomys hajnackensis* have been calibrated with the lower part of the Gauss normal magnetochronozone.

The following faunal assemblage was found in the karst deposit at Rivoli Veronese (Verona, Veneto). In this fauna there are several voles which occur for the first time: *Mimomys pliocaenicus*, *Mimomys pitymyoides*, *Mimomys tornensis*, *Villanya* cf. *V. exilis*, cf. *Ellobius* sp., a primitive form of the genus *Dinaromys*, *D. allegranzi* and a shrew of the subgenus *Sorex* (*Drepanosorex*). The specimens of the genus *Mimomys* found in the deposit allow this fauna to be attributed to the early Villanyian and the middle Villafranchian (Sala et al., 1994; Sala, 1996 b; Fanfani & Masini, unpublished data). Some remains of *Apodemus* cf. *A. dominans* found in Cava Toppetti (Todi, Umbria) (Abbazzi et al., 1996a) are roughly coeval with those found at Rivoli Veronese.

The isolated remains of *Mimomys pliocaenicus* found at Castelfranco di Sopra (Upper Valdarno, Tuscany) and Bocchignano (Sabina, Latium) (Masini & Torre, 1987; Kotsakis, 1988) are referred to the late Villanyian and to the late Villafranchian (Olivola F.U.) (on the basis of the geological context of the deposits and the large mammals assemblages).

Still in the Upper Valdarno (locality Case Inferno, Tuscany), in deposits containing large mammals of the Tasso F.U. (late Villafranchian), there was an isolated find of *Mimomys savini* (= *Cromeromys* after Neraudeau et al., 1995), a species that marks the beginning of the Biharian (Torre, 1985; Masini & Torre, 1987).

At Pietrafitta (Perugia, Umbria) the remains of voles were found associated with large mammals of the Farneta F.U. (late Villafranchian): *Mimomys pusillus* and the first forms known in Italy of the subgenus *Microtus* (*Allophaiomys*), *M. (A.) ex gr. M. (A.) ruffoi* and *M. (A.) chalinei*. The assemblage includes typical species of the early Biharian (Gentili et al., 1996).

At Pirro Nord (Foggia, Apulia), the type locality of the Pirro F.U. which is the last F.U. of the late Villafranchian, an abundant small mammal fauna was found associated with large mammals which included *M. (A.)* cf. *ruffoi* and the first occurrence in Italy of the shrew

Crocidura and of a modern type of mouse of the subgenus *Apodemus* (*Sylvaemus*) (De Giuli et al., 1987; Masini & Santini, 1991; Abbazzi et al., 1996b). The faunas from Palena (L'Aquila, Abruzzo) (Kotsakis, unpubl. data) and Soave Cava Sud (Verona, Veneto) (Pasa, 1947; Bartolomei, 1980) can also be referred to the Pirro F.U. All these micromammals assemblages indicate the early Biharian.

Galerian Mammal Age.

In the type locality of the first Galerian F.U., Colle Curti (Marche), together with large mammals there were the remains of *Microtus* (*Allophaiomys*) sp., which is probably a primitive form of the *Microtus oeconomus* group, and *Pliomys lenki* (Torre et al., in press; Abbazzi & Masini, unpublished data). The fauna from the karst deposit of Monte Peglia (Orvieto, Umbria) can be attributed to the same F.U., although it may be slightly older. At this site there are two fossiliferous levels, but the faunal composition of each is very similar. The rich assemblage of small mammals includes the last forms known in Italy of the genus *Beremendia*, *Glirulus*, *Ungaromys*. The subgenus *M. (Allophaiomys)* occurs with the more evolved forms, *M. (A.) nutiensis* (*Microtus* sp. A, in van der Meulen, 1973) and *M. (A.) burgondiae* (*Microtus* sp. B in van der Meulen, 1973). *Mimomys savini*, *Mimomys blanci* and *Pliomys episcopalis* are also present (van der Meulen, 1973). The Colle Curti and Monte Peglia faunas indicate the final phase of the early Biharian.

An assemblage composed of only two rodents, *Prolagus pannonicus* and (?) *Predicrostonyx* sp., associated with a molluscan fauna indicative of cold climatic conditions, was found at Fontignano (Ponte Galeria, Rome, Latium). This fauna comes from the clays beneath the conglomerates where the Ponte Galeria large mammals were found and corresponds with the final phase of isotope stage 22 (Kotsakis et al., 1992).

In the type locality of the second F.U. of the Galerian, the Slivia F.U. (Aurisina, Trieste, Venezia Giulia), some species of micromammals were found as well as numerous large mammal remains. In the breccia at this site there were *Mimomys savini* and *Dinaromys* sp., and the first appearance of *Allocricetus bursae* and *Microtus* (*Neodon*) *gregaloides* (Ambrosetti et al., 1979). This assemblage can be referred to the late Biharian. The fauna from the karst fill at Monte Tenda (Soave, Verona, Veneto) belongs to the same Mammal Age (Late Biharian). It is characterised by the occurrence of *Mimomys savini* and *Pliomys episcopalis* and by the first appearance of the subgenera *Microtus* (*Microtus*) and *Microtus* (*Terricola*) (Pasa, 1947; Bartolomei, 1969).

At the type locality of the following Galerian F.U., Isernia (Molise), both large and small mammal remains were found. In the fluvio-lacustrine deposits

Pliomys episcopalis, *Pliomys lenki*, *Microtus (Microtus)* aff. *M. (M.) arvalis* and *Microtus (Terricola)* gr. *multiplex-subterraneus* occur together with a *Clethrionomys* gr. *glareolus*, *Microtus (Iberomys) brecciensis* and a small vole, not very hypsodont, with mimomian enamel and at least one radicated M¹, which has been classified as cf. *Arvicola cantiana* (Coltorti et al., 1982; Sala, 1983a; Sala, 1996a). The fauna of Valdemino cave (Borgio Verezzi, Savona, Liguria), where *M. (I.) brecciensis* is very common and where a new species of lagomorph was found, *Oryctolagus burgi* (Sala, 1992; Nocchi & Sala, in press a), belongs to the same F.U. but to a different climatic phase. Both the Isernia and Valdemino faunas may be referred to the beginning of the Toringian.

The fauna of Riparo A di Visogliano (Trieste, Venezia Giulia), with its typical glacial features, is probably more recent than the faunas described above, with *Pliomys episcopalis*, *Dinaromys bogdanovi*, *Arvicola cantiana* and *Allocrietus bursae* and the first appearance of *Microtus (Stenocranius) gregalis*, *Sicista* sp. and *Ochotona* cf. *O. pusilla*. The fauna can be referred to the early Toringian and it is probably located between isotopic stages 14 and 10 (Bartolomei & Tozzi, 1978; Cattani et al., 1991; Tozzi, 1995). The fauna from the fluvio-lacustrine deposit at Notarchirico (Venosa, Potenza, Basilicata) can be attributed to the same period; together with *Microtus* aff. *M. arvalis* which is dominant, there are also the remains of *Pliomys episcopalis*, *Arvicola cantiana* and *Chionomys nivalis* (Sala, 1991).

Finally, two faunas can be referred by indirect correlation to the Fontana Ranuccio F.U., the last F.U. of the Galerian: that found in the ossiferous breccia at Boschiesanuova (Verona, Veneto) with voles such as *Pliomys episcopalis*, *Pliomys lenki*, *Dinaromys bogdanovi* and shrews (*Sorex runtonensis*, *Crocidura zorzii*) (Bartolomei & Pasa, 1970), and that found in the karst deposit at San Giovanni di Duino (Trieste, Venezia Giulia), where *Pliomys episcopalis*, *Dinaromys bogdanovi*, *Microtus (Terricola) savii*, *Allocrietus bursae* and other species occur (Bartolomei, 1976). In both deposits there is a large soricine, probably *Episoriculus* sp.. The faunas from these deposits are referred to the final phase of the late Toringian.

Aurelian Mammal Age.

The fauna from the outer levels at Grotta di San Bernardino Maggiore (Colli Berici, Vicenza, Veneto) is characterised by the presence of *Marmota marmota*, *Cricetus cricetus*, *Dinaromys bogdanovi* and *Microtus* gr. *arvalis-agrestis* (Bartolomei, 1960). These levels have been referred to the penultimate glaciation by the radiometric method U/Th (Falgùeres et al., 1996) and probably correspond with the Vitinia F.U. of the Aurelian Mammal Age.

The fauna from the karst fill deposits at San Sidero 3 (Maglie, Lecce, Apulia), where *Microtus (Terricola) savii* is the dominant species associated with *Microtus arvalis*, *Lepus europaeus* and *Oryctolagus cuniculus* (De Giuli, 1983; Nocchi & Sala, in press b), can be referred to the last Interglacial.

There is a large number of small mammal faunas which date to the last Glacial and the sites are distributed all over the Italian peninsula. During this period Italy represented a refuge area for many species of mammals, and for this reason in some localities temperate forms survived during the phases of maximum climatic deterioration. The geographical and morphological features of the Italian peninsula resulted in a subdivision into areas characterised by very different climates and landscapes. Therefore the small mammal assemblages vary not only as a result of the climatic changes in a given area but also vary significantly as a result of the geographical location and altitude. Notable differences existed between the Adriatic side of the peninsula, which was characterised by a colder and more arid Mediterranean climate, and the Tyrrhenian side which was more temperate, and between the faunal associations from coastal and foothill areas and those for the mountains.

The Last Glacial small mammal faunas are generally characterised by a greater abundance of *Microtus (Microtus) arvalis* and *Microtus (Microtus) agrestis* compared with the other voles and the mice of the genus *Apodemus* (e.g. Ingarano, Foggia; Capasso Barbato et al., 1992; Petronio et al., 1996). Dormice are represented by *Myoxus glis*, *Muscardinus avellanarius*, *Eliomys quercinus* and *Dryomys nitedula* (which were also found at Grotta Breuil - Monte Circeo, Latium; Kotsakis, 1991; Alhaique et al., 1995 - a locality situated between the two areas of Italy where it is currently found) and are usually very rare. Among the voles, *Microtus (Terricola)* always occurs in the Southern Italian regions which represented a refuge area, and it became more abundant during the more temperate phases (e.g. at Grotta di Castelcivita, Salerno, Campania, Cioni et al., 1979; Masini & Abbazzi, 1997). Among the insectivorous, besides the nearly constant presence of *Talpa* and *Erinaceus*, the shrews of the genus *Sorex* are relatively widespread, while *Crocidura* seems to be absent from Northern Italy. In the North Italian sites and those of the Adriatic coast there are sporadic occurrences of species with "steppic" affinities during colder and more arid periods which came from Northern or Eastern Europe. The main species is *Microtus oeconomus*, numerous populations of which are sometimes found in sites in the Po valley (Zanaldi, 1994). The occurrence of others "steppic" species (*Sicista* cf. *S. betulina* and *Ochotona pusilla*) is very rare and so far has been discovered only in the regions of Veneto and Marche (Bartolomei, 1980; Sala, 1990).

Among the most important stratigraphic sequences from the point of view of the abundance of the fossil record and the stratigraphical continuity is that at Grotta del Broion (Colli Berici, Vicenza; Zanalda, 1994). The first part of the Last Glaciation is well documented at Grotta di Veja, Riparo Mezzena, Riparo della Ghiacciaia (Monti Lessini, Verona) and the lower levels of Riparo Tagliente (Grezzana, Verona) (Bon et al., 1991).

The recent part of the inter-Pleniglacial is clearly documented in the deposits at Grotta della Cala (Marina di Camerota, Salerno; Bartolomei et al., 1975) and Grotta di Castelcivita (Monti Alburni, Salerno; Cioni et al., 1979; Masini & Abbazzi, 1997) in Southern Italy, while the Late Pleniglacial and the Late Glacial are well documented in many sites: these include the upper levels of the deposit at Riparo Tagliente (Grezzana, Verona), Grotta Paglicci (Rignano Garganico, Foggia; Bartolomei, 1975), Grotta della Serratura (Marina di Camerota, Salerno; Bertolini et al., in press), the upper levels at Grotta della Cala (Marina di Camerota, Salerno) and Grotta di Praia a Mare (Cosenza, Calabria; Capasso Barbatto & Gliozzi, 1995).

Molluscs.

Key for the distribution chart of the non-marine molluscs.

The Plio-Pleistocene assemblages of land and freshwater molluscs of the Italian peninsula are chronologically related to the mammal ages shown in the mammal distribution chart in this paper. Only extinct species and those living species which have some biochronological significance in connection with their appearance and extinction in Italy have been taken into consideration.

In the distribution chart the species of molluscs are plotted against their site(s) of provenance which, in turn, are ordered according to the mammal ages, since most of the sites are the same for both the molluscs and the vertebrates. In the case of sites which are important from a malacological point of view but lack vertebrates, the chronostratigraphic position was obtained by means of correlations with marine successions, palaeomagnetic data, isotopic stages or with other continental molluscan faunas.

The first part of the chart, which contains the list of coeval sites arranged in order, gives the impression for some species of a more extensive stratigraphic range than is actually the case, while for others their appearance is scaled over time. The second part of the chart, which is related to the mammal ages and not to the sites, gives a more realistic picture of the stratigraphic distribution of the species: column 1 contains the species

of deposits referred to the early Villafranchian Mammal Age; column 2 shows the late Pliocene species which can be correlated with the middle Villafranchian Mammal Age; species from sites referred to the faunal units of Olivola, Tasso, Farneta (late Villafranchian Mammal Age) are listed in columns 3, 4 and 5 respectively; species related to the Galerian Mammal Age are shown in column 6 and, finally, column 7 groups the species of the Aurelian Mammal Age.

Villafranchian Mammal Age.

Early Villafranchian Mammal Age. The non-marine molluscs of this mammal age are referred to the Middle Pliocene and to the Triversa F.U. These assemblages are characterised by an abundant stock of species, 35 in number, belonging mainly to land pulmonates, two thirds of which do not seem to reach the Middle Villafranchian. Whilst some species are limited to the Piedmont basin (*Viviparus pollonerai*, *Emmericia pliocenica*, *Discus pantanellii*, *Janulus angustiumbolicatus*, *Retinella (Lyrodiscus) cf. R.(L.) jourdani*, *Triptychia mastodontophila*, etc.), others are also widespread in central Italy (*Laminifera (Laminiplicata) villafranchiana*, *Carychium (Saraphia) pseudotetrodon*, *Negulus villafranchianus*, *Gastrocopta (Albinula) acuminata fossanensis*, *Gastrocopta (Vertigopsis) dehmi*, *Leiostyla gottschicki*, *Eostrobilops aloisii*, *Palaeoglandina lunensis*, etc.) (Esu & Girotti, 1991; Ciangherotti et al., 1996). Sacco (1887, 1897) cites numerous other taxa from Pliocene sediments at various sites in the Piedmont basin (Tassarolo, Ceresole d'Alba, etc.). Unfortunately the exact stratigraphic position of these sites is unknown and therefore these species are not listed in the chart. Nevertheless the age may be consistent with the Triversa F.U. (see also Esu et al., 1993). It is impossible to compare these assemblages with older ones (Ruscinian, Early Pliocene) because of the almost complete absence of data on molluscs from this period resulting from the scarcity of continental sediments in Italy which date to the Lower Pliocene (Esu, 1982). From a paleobiogeographic point of view some species of the Piedmont basin are also present in the basins of La Bresse (Rhône, France) and in the Rhine (Germany) (Esu et al., 1993).

Middle Villafranchian Mammal Age. Two Umbrian sites, Cava Toppetti ("upper beds") and Dunarobba, have been referred to the Late Pliocene (middle Villafranchian Mammal Age) for various reasons. At Cava Toppetti the lower levels, which are part of the Fosso Bianco Formation (Basilici, in Ambrosetti et al., 1995 b) and contain *Prososthenia* sp. n. and *Zilcheuchilus* sp. n., have been referred to the Middle and Late Pliocene on the basis of palaeomagnetic data (from Gauss to Reunion, see Albanelli & Napoleone, in press); the two

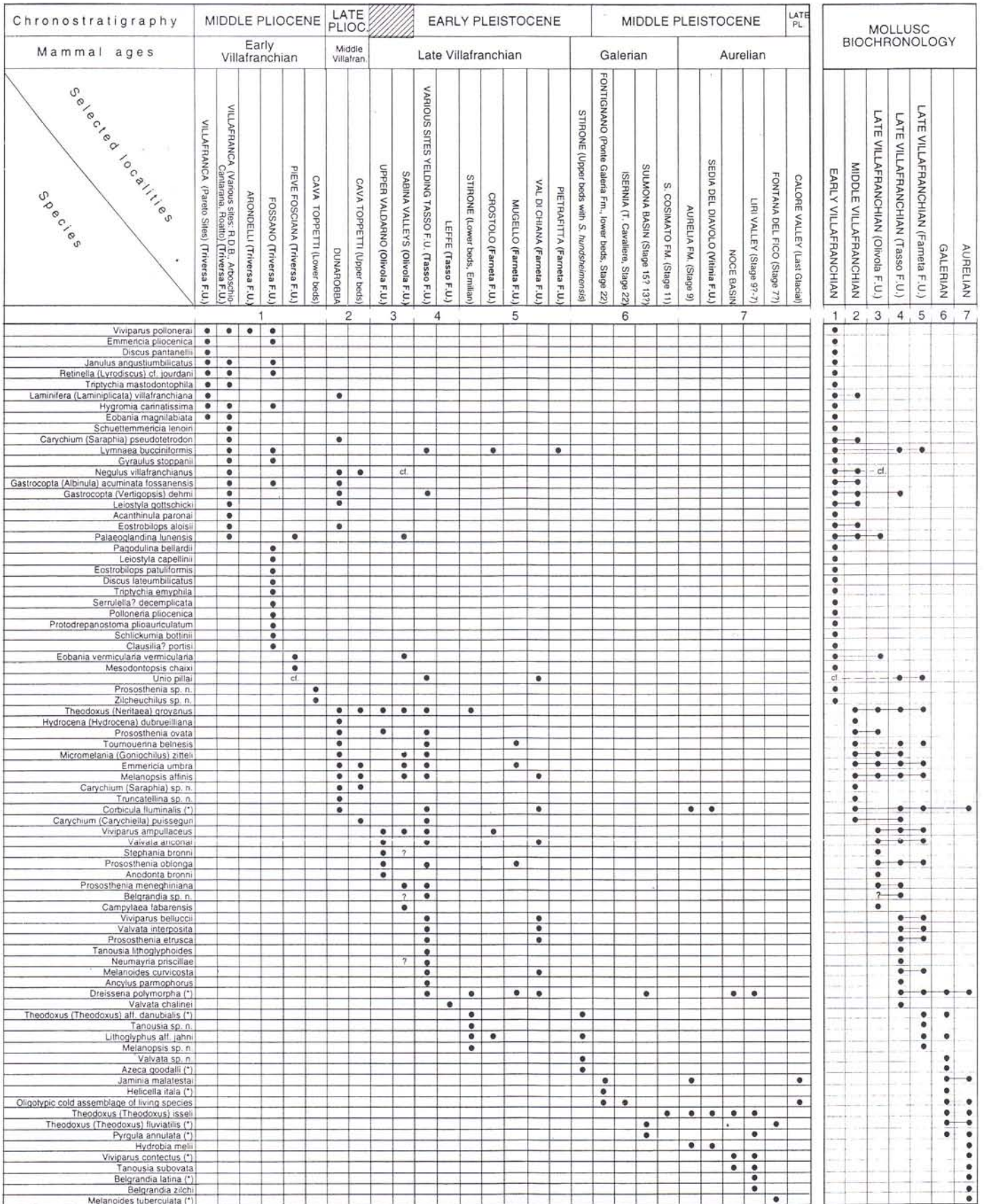


Fig. 3 - Biochronology of the extinct non-marine molluscs of Italian Peninsula from Middle Pliocene to Late Pleistocene. The asterisk indicates selected living species.

Prosobranchia mentioned above come from the levels with Gauss normal magnetic polarity. The "upper beds" (= Ponte Naja Formation, Basilici, 1995) are referred to the Late Pliocene (middle Villafranchian Mammal Age) by Abbazzi et al. (1996a) on the basis of their mammal content. The malacological assemblage in this formation is quite different from that of the "lower beds" and the species are mostly common to those of the Dunarobba site where the sediments belong to the top of the Fosso Bianco Formation (Ambrosetti et al., 1995b). The Prosobranchia of the two assemblages form a limited stock of freshwater species which reach the early Pleistocene in the Tiberino basin, whereas the land pulmonates disappear at the end of the Pliocene apart from *G.(V.) dehmi* which has recently been recorded in Upper "Villafranchian" sediments near Fighille (Anghiari, Arezzo) (unpubl. data).

Late Villafranchian Mammal Age. Non-marine assemblages from several sites, most of which are in central Italy, are referred to the late Villafranchian Mammal Age, divided between the various F.U. of the mammals. The rich malacofaunal complex is constituted by numerous species of prosobranchs and pulmonates (Esu & Girotti, 1975; Conti & Esu, 1981; Esu & Girotti, 1991; Ambrosetti et al., 1995a; Ciangherotti et al., in press b). Among the pulmonates some Pliocene species survive: *N. villafranchianus*, *P. lunensis*, *Eobania vermicularia* survive up to the Olivola F.U. while *Carychium (Carychella) puisseguri* and *G.(V.) dehmi* survive up to the Tasso F.U. The latter species was also found in a quarry near Fighille associated with remains of a bovid, *Leptobos merlai-furtivus* (pers. com. F. Masini). The prosobranchs are the most characteristic group of the late Villafranchian Mammal Age: genera (such as *Stephania*, *Prososthenia*, *Tournouerina*, *Neumayria*) and endemic species of central Italy (Tyrrhenian side) which disappear at the end of the Early Pleistocene. A small group of species is of Pliocene origin (*Theodoxus (Neritaea) groyanus*, *Prososthenia ovata*, *Tournouerina belnensis*, *Micromelania (Goniochilus) zitteli*, *Emmericia umbra*, *Melanopsis affinis*). Some species of prosobranchs and pulmonates occurring in the Tasso F.U. do not seem to be present in the Farneta F.U.: *T. (N.) groyanus*, *Stephania bronni*, *Prososthenia meneghiniana*, *Tanousia lithoglyphoides*, *Neumayria priscillae*, *M. (G.) zitteli*, *C.(C.) puisseguri*, *G.(V.) dehmi*, *Ancylus parmophorus*.

Two species, *Lithoglyphus* aff. *L. jahni* and *Theodoxus* aff. *T. danubialis*, occur for the first time in sediments of the Stirone and Crostolo Rivers (northern Italy) of Emilian age; these species survive in the same area up to the Galerian Mammal Age. The Stirone and Crostolo Rivers have an Adriatic drainage, but the Emilian sediments they cut also contain some elements

characterising the late Villafranchian basins of the Tyrrhenian side, such as *T. (N.) groyanus* and *Viviparus ampullaceus* (Crispino & Esu, 1995; Ciangherotti et al., in press, a).

The Lefte basin in Northern Italy (Bergamo) has a completely different fauna, with still living species and only one extinct species, *Valvata chalinei*, which has been found outside of Italy in the Late Pliocene and Early Pleistocene of the La Bresse basin (France) (Esu et al., 1993).

Galerian Mammal Age.

The malacofaunal complex referable to the Galerian Mammal Age is characterised by mainly modern prosobranchs and pulmonates; the Villafranchian species are completely extinct and only a few of the Galerian species. Of these, as far as we know, *L. aff. L. jahni* and *T. aff. T. danubialis* are only present in the upper beds of the Stirone sequence (early Galerian Mammal Age); *Theodoxus isseli* and *Jaminia malatestai* extinguish during the Aurelian Mammal Age (Esu & Girotti, 1991). The extinction of several Villafranchian endemic taxa of central Italy is due to the climatic and geological history of these basins at the end of the Early Pleistocene. At the beginning of the Galerian Mammal Age oligotypic assemblages similar to those recorded in the loess deposits of central Europe (Lozek, 1964) appear in central Italy (Kotsakis et al., 1992). They are composed of species which now live in northern countries (as *Helicella itala*) or of species still living in Italy but which are less common or widespread in northern Italy (as *Trichia hispida*). It is clear that the non-marine mollusc assemblages of the Middle (and Late) Pleistocene are influenced by climatic oscillations. Generally the polytypic assemblages are related to temperate and temperate-warm climatic phases, whilst during cold periods strictly oligotypic assemblages are recorded (Esu et al., 1989).

Aurelian Mammal Age.

The transition from the Galerian malacofaunas to the Aurelian ones is not detectable. Assemblages of cold-temperate and warm-temperate character similar to those of the Galerian Mammal Age continue to alternate. They are mainly composed of living species. In some Aurelian deposits of central-southern Italy various extinct species are recorded: *Hydrobia melii*, *Tanousia subovata*, *Belgrandia zilchi* (Esu & Girotti, 1991; Esu & Kotsakis, 1996). Two species, *T. isseli* and *J. malatestai*, which were present in the Galerian assemblages, become extinct during this interval. At the beginning of the Aurelian Mammal Age, during a warm climatic oscillation, a tropical living species, *Melanoides tuberculata* (see Esu & Girotti, 1991), was present in the southern part of the Italian peninsula, probably transported there by

birds. In general the Aurelian malacological assemblages are more useful for ecostratigraphic studies than for biostratigraphic or biochronological purposes.

Ostracods.

Distribution chart.

Studies on the Italian Plio-Pleistocene continental (fresh water and brackish) ostracod faunas are scarce. Only in the last few years particular attention has been paid to their analysis, since they proved to be very useful for detailed palaeoecological reconstructions. However, at the moment it is still not clear whether ostracod faunas are also a valid tool for Plio-Pleistocene biochronology, mainly for two reasons: 1) in several cases the life of the species is much longer than the time period under consideration (for example, and only to cite some species which are very frequent in Plio-Quaternary fresh water deposits, *Cyclocypris laevis* is known from the Danian to the present day, *Darwinula stevensoni* from the Oligocene to the present day, and *Candona neglecta*, *Potamocypris fulva* and *Pseudocandona marchica* from the Late Miocene to the present day); 2) ostracods are benthic organisms which are particularly sensitive to the environmental characteristics, and consequently their presence/absence in one particular deposit does not represent only a biochronological data but must be filtered through an environmental interpretation. In fact it is known that ostracods are used for both the definition of classical zones inside a conventional biostratigraphy (or biochronology), taking into account the same environmental conditions (e.g. littoral marine environment biozones), and for the creation of ecological community units (or ecozones) inside an ecostratigraphy (Martinsson, 1973). In both cases, in order to avoid the vertical distribution of the taxa being altered by ecological background noise, it is necessary to work with a large number of sites pertaining to different environments for each time period.

Despite the scarcity of sites where ostracods have been analysed so far in Italy, Fig. 4 shows a tentative chronological ordering of Italian ostracod faunas known from freshwater and brackish (oligo-mesohaline) environments. Here, the presence of several selected taxa from different Italian deposits is reported. Only those species not recorded prior the Middle Pliocene have been taken into consideration; almost all these species are still living in the Italian Peninsula, so Fig. 4 is only indicative of their first occurrence. The sites are referred to the Mammal Ages and, when possible, also to the Faunal Units which represent the datum-point for the Plio-Pleistocene biochronology.

It is important to point out that this table represents only a starting point and that other studies on dif-

ferent ostracod faunas are necessary in order to make out a distribution chart which could be of use for biochronological purposes.

Villafranchian Mammal Age.

There are few sedimentary series bearing ostracods referable to the early and middle Villafranchian Mammal Ages: the R.D.B. quarry (Villafranca d'Asti, Piedmont), Arondelli and Roatto (Piedmont) (Gliozzi, 1996) referable to the Triversa F.U., Cava Toppetti-Fosso Bianco Unit (Todi, Umbria) (probably referable to the Montopoli F.U.), Cava Toppetti-Ponte Naja Unit (Costa S. Giacomo F.U.) (Gliozzi, unpubl. data) and, finally, Dunarobba (Umbria) which is referable, on the basis of the mollusc assemblage (Ambrosetti et al., 1995a), to a generic middle Villafranchian (Gliozzi, unpubl. data). All these sequences pertain to a limnetic domain, except for Cava Toppetti-Ponte Naja Unit which records a brackish environment.

In this wide time interval, corresponding to the Middle and Late Pliocene, *Candona candida*, *Stenocypris* sp. *Candona fabaeformis*, *Paralimnocythere compressa*, *Pseudocandona parallela*, *Cyprideis* sp. 1 and *Cypridopsis parva* seem to appear. All these species characterise the modern Italian ostracod fauna, except for: 1) *Stenocypris* sp., a genus at present widely distributed at tropical latitudes, which was found as a fossil at the R.D.B. quarry; at present it is recorded as being present in Italy by Ghetti & McKenzie (1981) represented by the species *S. fontinalis* e *S. major* and is only found in lakes with a hot water input. According to McKenzie & Moroni (1986), these forms can be considered "foreign guests", that is forms which have been accidentally introduced by man with foreign good transports; 2) *Cyprideis* sp. 1, an extinct form found only at Cava Toppetti-Ponte Naja Unit, which seems to be limited to the Late Pliocene. This form pertains to the *Cyprideis torosa* group, but differs from *C. torosa* in several morphometric characters such as its dimensions and general shape (Gliozzi, unpublished data).

Three more species, *Limnocythere* aff. *L. inopinata*, *Metacypris cordata* and *Pseudocandona compressa*, were recorded by Di Napoli (1962) in the lignite deposits at Morgnano, Torgiano, Spina, Ilci, and Collazzone (Tiberino Basin), which he referred to the Late Pliocene. At present these deposits are no longer visible, and consequently a stratigraphic control using the recent Plio-Pleistocene chronological sequence is impossible; these species have therefore not been put into the stock of species which appeared during the Middle-Late Pliocene.

The deposits referable to the late Villafranchian Mammal Age (Early Pleistocene) are more numerous, but they are mainly located in central Italy: several localities in the Tiberino Basin (Umbria) [Bastardo I and II,

Deruta and Collazzone, generically referred to the first part of the Early Pleistocene; Bastardo III, IV, V and VI, referable to a post-Sanernian (Di Napoli, 1962), and Villa S. Faustino (Ambrosetti et al., 1995b) which can be correlated with the Tasso F.U., Pietrafitta (Umbria) (Gliozzi, unpublished data), several localities of the Rieti Basin (Latium) [Case Strinati, Fosso Filundici, Apoleggia, Vicchiagnone, correlated with the Tasso F.U. and Belmonte Sabino, probably referable to a younger Early

Pleistocene (post-Sanernian) (Barberi et al., 1995)] and Montallegro (Sicily) (Decima, 1963) correlated with the Emilian. The majority of these series record brackish, oligo-mesohaline environments. During the late Villafranchian Mammal Age the present living species of *Cyprideis torosa*, *Cytherissa lacustris*, *Herpetocypris chevreuxi*, *Candona levanderi*, *Limnocythere sanctipatricii* and *Potamocypris zschokkei* all seem to appear. Moreover *Limnocythere inopinata*, *Metacypris cordata* and *Pseudo-*

Chronostratigraphy	PLIOCENE		EARLY PLEISTOCENE	MIDDLE PLEISTOCENE	LATE PLEISTOCENE																
	MIDDLE	LATE																			
Mammal ages	Early Villafran.	Middle Villafran.	Late Villafranchian	Aurelian																	
Selected localities	TRIVERSA (Various sites) (Triversa F.U.)	CAVA TOPPETTI (Fosso Bianco Unit)	DUNAROBBA	CAVA TOPPETTI (Ponte Naja Unit) (Costa S. Giacomo F.U.)	TIBERINO BASIN (Various sites)	TIBERINO BASIN (Villa S. Faustino) (Tasso F.U.)	RIETI BASIN (various sites) (Tasso F.U.)	PIETRAFITTA (Farneta F.U.)	MONTALLEGRO	RIETI BASIN (various sites)	TIBERINO BASIN (various sites)	TORRE DEL PAGLIACCETTO (Torre in Pietra F.U.)	PIANA PONTINA (Migliara 47 drillhole) (Stage 9)	LIRI VALLEY (Stages 9-8-7?)	PIANA PONTINA (Migliara 47 drillhole) (Stage 7)	VALLE DI CASTIGLIONE drillhole (Stage 7)	PIANA PONTINA (Migliara 47 drillhole) (Stage 6)	LAGO LUNGO (Drillhole) (Stage 5)	PIANA PONTINA (Migliara 47 drillhole) (Stage 5)	VALLE DI CASTIGLIONE drillhole (Stage 5)	VALLE DI CASTIGLIONE drillhole (Stage 3)
Species																					
<i>Candona candida</i>	●			cf.	●									●						●	●
* <i>Stenocypris</i> sp.	●																				
<i>Candona fabaeformis</i>		●	●							●				●							
<i>Paralimnocythere compressa</i>			●																		
<i>Pseudocandona parallela</i>			cf.		cf.					cf.											
† <i>Cyprideis</i> sp. 1				●																	
<i>Cypridopsis parva</i>				●																	
<i>Cyprideis torosa</i>				●	●	●	●	●	●				●		●		●		●	●	●
<i>Limnocythere inopinata</i>				●	●	●	●	●	●		cf.										
* <i>Metacypris cordata</i>				●	●	●	●	●	●		●										
<i>Pseudocandona compressa</i>				●	●	●	●	●	●		●				●	●	●		●	●	●
<i>Cytherissa lacustris</i>				●	●	●	●	●	●		●				●	●	●		●	●	●
<i>Herpetocypris chevreuxi</i>					●					cf.	cf.									●	●
<i>Candona levanderi</i>						●								●							
<i>Limnocythere sanctipatricii</i>									●												
<i>Potamocypris zschokkei</i>										●	cf.				●				●		
<i>Candona pubescens</i>																					
<i>Herpetocypris reptans</i>																	●				
<i>Cypridopsis vidua</i>																					
† <i>Leptocythere</i> (<i>Amnicythere</i>) <i>fallax</i>																					●
°° <i>Candona caudata</i>																					
°° <i>Candona lobipes</i>																					
° <i>Scottia browniana</i>																					
°° <i>Eucypris pigra</i>																					
° <i>Herpetocypris intermedia</i>																					
° <i>Psychrodromus olivaceus</i>																					
<i>Cypricercus reticulatus</i>																					
<i>Prionocypris zenkeri</i>																					
<i>Cypris pubera</i>																					●
<i>Paralimnocythere messanai</i>																					
<i>Pseudocandona sarsi</i>																					●
<i>Eucypris clavata</i>																					●
<i>Eucypris serrata</i>																					cf.

Fig. 4 - Biochronology of selected living and extinct brackish and freshwater ostracods of Italian Peninsula from Middle Pliocene to Late Pleistocene. Legend: * species at present distributed at circumtropical latitudes; ° species at present living out of Italy at higher latitudes; °° species at present widely distributed at higher latitudes; + extinct species.

candona compressa are now recorded with certainty. Within this group, the presence of *Cyprideis torosa* needs to be explained better: *Cyprideis torosa* is recorded in the literature as being frequent in the European Pliocene, and sometimes it is reported as a species while at other times it is reported as *C. gr. torosa*. It is not possible to exclude the fact that this species may really have appeared during the Pliocene, although all the Italian deposits in which its presence has been controlled are of Pleistocene age.

Aurelian Mammal Age.

At present no studies on ostracod faunas referable to the Galerian Mammal Age have been carried out, while there are numerous studies on Aurelian deposits, unfortunately all of which are located in Latium (central Italy): Torre in Pietra (Molinari Paganelli, 1978) (correlated with Oxygen Isotope Stage 9), Pianura Pontina (Migliara 47 borehole) (Barbieri et al., in press) referable to Stages 9, 7, 6 and 5, several localities along the Liri Valley (Devoto, 1965) referable to Stages 9-8 and, tentatively, 7, Valle di Castiglione borehole, referable to Stages 7, 5 and 3 (Gliozzi & Mazzini, in press), and Lago Lungo borehole, referable to Stage 5 (Calderoni et al., 1994). The species that seem to appear at the beginning of the Aurelian Mammal Age are numerous, and this is partly due to the important taxonomic studies which have been carried out on Aurelian ostracod faunas by Molinari Paganelli (1978) and Devoto (1965): *Candona pubescens*, *Herpetocypris reptans*, *Cypridopsis vidua*, *Leptocythere fallax*, *Candona caudata*, *Pseudocandona lobipes*, *Scottia browniana*, *Eucypris pigra*, *Prionocypris zenkeri*, *Cypri-*

cercus reticulatus, *Herpetocypris intermedia*, *Psychrodromus olivaceus*, *Cypris pubera* and *Paralimnocythere messanai*. Actually, this noticeable abundance of forms is mainly due to the fact that some deposits of the Liri Valley correspond to cold periods (Isotope Stage 6) and many of the forms which occur during this stage are northern forms, presently found in central and northern Europe (*Scottia browniana*, *Herpetocypris intermedia* e *Psychrodromus olivaceus*) (which can be considered as "cold guests") or forms which, although they are still found in Italy (only in scattered localities of Piedmont and Lombardia), show their main distribution area located in more northern areas (*Candona caudata*, *Candona lobipes*, *Eucypris pigra*). Taking into account the fact that the Liri Valley ostracod faunas are the only cold ostracod assemblages known in Italy, it is not possible to ascertain whether these cold species entered Italy only from Stage 6 onwards, or whether they migrated southwards during other earlier cold periods. It is interesting to underline the presence during the Aurelian Mammal Age of an extinct form, *Leptocythere fallax*, and the first occurrence of *Paralimnocythere messanai*.

The beginning of the late Aurelian Mammal Age (Isotopic Substage 5e) records the appearance of the present-day living species *Pseudocandona sarsi*, *Eucypris clavata* and, perhaps, *Eucypris serrata*, characterised by having only one summer reproductive season (Bronshstein, 1947).

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