Chapter 2
Identification and Interpretation of Historical Cemeteries Linked to Epidemics

Dominique Castex

Abstract Several types of event (wars, massacres, natural disasters, famines or epidemics) can lead to mortality crises resulting in the formation of funerary deposits unlike those found during more "ordinary" periods. This chapter specifically reviews the exploitation of demographic data from dental and bone remains to resolve the cause of a mortality crisis. Different age groups in a population are not affected in the same manner by all crises and it is therefore possible that the detection of possible anomalies in the demographic parameters among the archaeological series studied can be a useful indicator as to the origin of the deaths. This fact is illustrated by the analysis of three series in France in which palaeobiochemistry confirmed the presence of the Yersinia pestis plague bacillus. These results have allowed us to refine the methodological and analytical thematic study of both funerary archaeology and anthropology. Historical demographic analyses must be intensified in order to define more precisely the impact of different types of crisis on a population, thus deriving different typical profiles allowing interpretation of age and sex distributions and their possible anomalies. Analysis of osteological samples from periods of epidemic should cover as large a choice of sites as possible, both chronologically and geographically, in order to establish not only one "model" but several models illustrating crisis mortality.

2.1 Introduction

Certain events in the past (wars, massacres, natural disasters, famines or epidemics) have generated a great number of deaths and have led to veritable mortality crises. Although often studied historically, this theme, despite its rich potential, is relatively recent in the domains of archaeology and anthropology.

Dominique Castex
CNRS, UMR 5199 PACEA, Laboratory of Anthropology of Past Populations, Bordeaux 1 University, Avenue des Facultés, 33405 Talence cedex, France
E-mail: d.castex@anthropologie.u-bordeaux1.fr

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In response to multiple deaths, the treatment of the bodies undertaken often results in the formation of funerary deposits unlike those found during more "ordinary" periods, e.g. several bodies in a single container, sometimes several structures juxtaposed. Once archaeological methods prove the simultaneity of the deposits (Duday 2005, 2006) and a phenomenon of abnormal mortality linked to a particular event is suspected, an interpretation can be attempted. The grave and, on a larger scale, the cemetery can become choice objects of analysis in understanding mortality crises of the past. On the one hand, tombs – valuable witnesses of cultural investment – can provide information about the reactions and specific treatments sometimes undertaken during periods of crisis while, on the other hand, skeletons represent a biological reality that can help clarify the nature of death.

The development of "preventive archaeology" during the 1980s, together with revised methods of approaching the excavation of burial deposits, have contributed to the discovery of several funerary deposits that followed epidemic crises from different periods. Some of these deposits have already undergone various analyses, which now allow interpretative hypotheses (Castex and Cartron 2007). Although important information linked to funerary archaeology contributes to the understanding of these particular burial deposits, the scope of this article is voluntarily limited to a specifically anthropological angle of analysis, specifically to the exploitation of demographic data from dental and bone remains. By using precise methodology and tools, the analysis of the composition of an archaeological population by parameters of age and sex is revealed as very pertinent in the interpretation of abrupt mortality crises due to epidemics.

2.2 Plague Cemeteries: From First Interpretations to the Identification of the Great Historic Plagues

2.2.1 Analysis of Composition by Age and Sex: Some Methodological Reminders

The first stage is the acquisition of the individual biological data, sex and age at death, of all the exhumed subjects[1]. These parameters are then used to define the composition of the population by age and sex as well as possible; a second stage must include the establishment of a mortality profile and the calculation of the rate of masculinity[2]. It is then possible to verify whether the distributions as a function

[1] These estimates must be as reliable as possible and on this subject the reader is referred particularly to an article by Bruzek et al. (2005). The methods applied to different deposits varied as they depended inevitably on methodological progress. Nevertheless, the series studied earliest have since undergone readjustments, which now allow reliable comparison. In addition, the representativeness of the subjects has been voluntarily limited to those of less than 30 years as the imperfection of age estimation methods for adults does not allow discussion beyond this threshold; however, more recent methods may be worth attempting later (Schmitt 2002).

[2] The rate of masculinity is the ratio of the number of men to the number of men and women; the theoretical rate is 50%.

of age and sex, obtained from the available archaeological samples, are close to those expected in the case of a natural demography[3] or, on the contrary, if they reveal anomalies connected to a specialisation that needs to be interpreted (Masset 1987; Sellier 1996; Blaizot and Castex 2005; Castex 2007).

In order to compare the data obtained to those expected in a situation of ordinary mortality[4] the different ages at death are distributed into 5-year groups (with the exception of the first two groups, of 1 and 4 years, respectively) of attained age in accordance with Ledermann's life tables (1969). To establish the subjects' mortality profile, a mortality quotient[5] is established for each age group and the quotients obtained are then compared to those of Ledermann (1969)[6].

The constitution by age and sex of several sites found in epidemic contexts will be analysed on the basis of methodological acquisitions fully developed elsewhere (Sellier 1996) and recently applied in a particular case (Castex 2005). The benefits of the analysis of age and sex parameters in palaeobiological studies needs no further demonstration and such analysis is of particular interest in the case of abrupt mortality crises. In fact, the different age groups of a population are not affected in the same manner by all crises, the nature of which will inevitably operate a selection in terms of age and sex, and it is therefore possible that the detection of possible anomalies in the demographic parameters among the archaeological series studied can be a useful indicator as to the origin of the deaths.

2.2.2 Initial Analyses and Arguments in Favour of a Mortality Crisis Due to an Epidemic

2.2.2.1 Saint-Pierre, Dreux, Eure-et-Loir (Fourteenth Century)

The excavation of Place Métezeau at Dreux within the framework of an urgent salvage operation by a team of archaeologists from the Centre Region (P. Dupont, in charge, and

[3] By this we mean a classical distribution of age and sex, i.e. as close as possible to that expected in traditional populations found in a schema of archaic or pre-Jennerian mortality before the Industrial Revolution (Masset 1975; Sellier 1996).

[4] As a reference of ordinary mortality, Ledermann's (1969) life tables were chosen.

[5] The mortality quotient is represented by aQx, where x is the age of entry into an age group and a is the time spent in years in that group. The mortality quotient concerns the number of deaths within an age group as a proportion of the numbers of a population likely to die within that age group initially, and thus represents the probability of death within a precise age group. It differs greatly from the rate of death, which shows the proportion of deaths within an average population, and is hence much more pertinent to the comparison of a theoretical natural mortality and a mortality obtained from an archaeological sample.

[6] Ledermann's tables (1969) allow the calculation of a confidence interval (at 95%) of the mortality quotients, as shown by a range of values on all the diagrams presented. I have chosen to present only those references related to a life expectancy at birth of 30 years, as this parameter lies between 20 and 40 years for known pre-Jennerian populations (Masset 1975; Sellier 1996). Ledermann's data are the essential element of discussion in any comparison of theoretical natural mortality and the demographic characteristics of our archaeological populations.

Fig. 2.1 A simultaneous burial at Dreux (Saint-Pierre) during the excavation. *Photograph* P. Dupont and U. Cabezuelo (Center Region Archaeological Service)

U. Cabezuelo) benefitted from the sporadic intervention of an anthropologist (P. Courtaud, UMR 5199). The first surprise was to discover graves completely atypical to those expected (Fig. 2.1). The continuing excavation revealed a very particular utilisation of the funerary space, with the presence of numerous multiple burials containing between 2 and 22 subjects, adults and immature individuals combined. The first date proposed for the utilisation of this part of the cemetery, based on stratigraphic data and on fragments of ceramics contained in the grave filling, was the twelfth century, but further dating by ^{14}C more precisely indicated the fourteenth century. The interest of this site lay in its unusual problems and in the possibility of exploiting this type of context from both an archaeological and an anthropological viewpoint for the first time. The presence of several simultaneous and contemporary burials suggested a mortality crisis, but which observations could be applied to justify this conclusion? Which anthropological tools would allow interpretation of this crisis?

In total, 22 graves yielding 72 individuals, of which 35 were adults and 37 immature subjects, were studied (Castex 1992, 1994, 1995; Cabezuelo and Castex 1994). The structure by age of those inhumed was studied so as to highlight possible differences from a natural demography (Fig. 2.2). The proportion of immature subjects within the total population is compatible with that of a theoretical mortality (51.4%). However, a detailed study of the non-adult age groups clearly indicates a "non-natural" population, i.e. a total absence of newborn infants and few individuals from the 1–4 year age group, contrasting with the growing mortality of the older

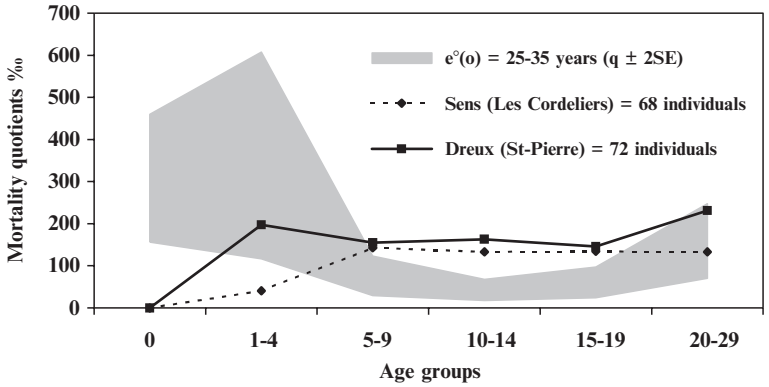

Fig. 2.2 Mortality profiles of immature individuals and young adults for Dreux (Saint-Pierre) and Sens (Le Clos des Cordeliers). Comparison with Ledermann's data (1969)

age groups from 5 to 19 years. The high mortality of the young adult age group (20–29 years) also differs sharply from that of a theoretical distribution obtained from typical tables (the proportion of young adults to that of the total adult population is 22.9%)[7]. In addition, the rate of masculinity of 72%[8] revealed a clear concentration of masculine subjects in this part of the cemetery. The particular nature of the graves encountered in the studied sector of the cemetery is thus associated with a specialised composition in terms of age and sex. The absence of precise stigmata on the skeletons allowed us to exclude violent death and, consequently, acts of war or massacre and oriented us towards the hypothesis of an epidemic[9]. The only noticeable pathological facts were, on the one hand, the abundance of dental tartar, which could be related to a particular type of alimentation implying a social connection between the individuals and, on the other hand, particularly frequent signs of anaemia, which seem to indicate that this human group suffered from numerous restrictions due to their surroundings (deficiencies, malnutrition, etc.) that could have presented an environment favourable to an epidemic.

2.2.2.2 Le Clos des Cordeliers, Sens, Yonne (Fifth–Sixth Century)

An archaeological salvage intervention carried out in 1989 by D. Maranski (the Sens municipal archaeologist) revealed structures for habitation as well as a funerary zone containing four multiple graves[10]. Unfortunately, the poor conditions of salvage did

[7] In a schema of archaic mortality this proportion evolves from 18 to 10% for life expectancies at birth when including individuals aged between 20 and 40 years, respectively.

[8] The difference from the theoretical distribution of 50% is significant at $P<0.05$.

[9] The diagnosis of an epidemic by analysis of bone remains is impossible as the rapid action of the infectious agents does not allow time for the development of osseous lesions, except in the case of those epidemic diseases that are non-lethal in the short-term, such as leprosy, tuberculosis and syphilis.

[10] This intervention completed those already undertaken in 1979 by J. Nicolle (archaeologist from Sens) and in 1985 by G. Depierre (TR Ministre de la Culture, UMR 5594).

not allow the recognition of the exact limits of these burials, which are also partly covered by elements of modern buildings. The graves are simple ditches hollowed in the earth without specific architectural elements apart from partial coverings of slabs from hypocausts in one case and large calcareous blocks in another. A first dating using stratigraphic arguments and with reference to the typology of an individual burial found in the same sector suggested the ninth–eleventh century. These burials have formed the basis of two research studies (Guignier 1996, 1997).

A taphonomic study revealed the simultaneity or near-simultaneity of the inhumations. Decomposition occurred in an infilled space, all the subjects appear in quite good anatomical condition, the so-called labile connections being generally well-preserved,[11] and entanglement of the bodies is seen at several levels (Fig. 2.3). These burials have now been radiocarbon dated to between the fourth and the sixth centuries.

The lowest number of individuals taken from these graves is 73, of which 45 were adults and 28 immature subjects. Although the proportion of immature subjects within the total population (38.4%) appears much lower than that of the site at Dreux; the distribution of age at death is, in many ways, relatively close (Fig. 2.2). Apart from the mortality quotient of the 1–4 year age group, which is clearly lower in the case of Sens, and that of the 20–29 year age group, compatible with a theoretical mortality[12], the similarity between the two death curves concerns the

Fig. 2.3 One of the four simultaneous burials at Sens (Le Clos des Cordeliers). *Photograph* D. Maransky (Sens Municipal Archaeological Service)

[11] The only movements observed are those directly linked to the synchronous decomposition of superimposed bodies (Duday 2005, p 198).

[12] The representativeness of adults under 30 years to that of the total adult population is 13.3%.

anomalies detected in the 5–9 year, the 10–14 year and the 15–19 year age groups. These groups are all over-represented and form an almost flat curve. The most noticeable difference concerns the rate of masculinity, which at Sens is 45.2%, very close to that of a natural demography. Supported by the total absence of pathological lesions, the hypothesis of a mortality crisis linked to an epidemic of an unknown nature, as in the case of Dreux, seems quite plausible.

2.2.2.3 Additional Arguments for Mortality Crises by Epidemic

The archaeo-anthropological funerary data and stratigraphical data, at both Dreux and Sens, allow us to interpret the adaptation of a community to a phenomenon of abrupt mortality. It is interesting to note that, in both cases, the laying down of the bodies reveals a relatively well-ordered administration and consequently gives a different picture to that of the disordered burial ditch one might associate with the context of a mortality crisis[13].

In addition to archaeological data, biological data, rarely exploited until now in such contexts, has provided arguments in favour of the hypothesis of multiple burials probably due to mortality crises linked to epidemics of an unknown nature. In spite of the absence of any precise historical records, the tools of biological anthropology have proved their utility in the interpretative process, in particular by detecting demographic anomalies, a non-negligible argument in any discussion on the origins of death.

For such little- or non-documented periods, it is important to insist on the fundamental necessity of accurate dating. The site at Sens is exemplary because the definite dating acquired during the analysis was of fundamental importance in that it allowed a reorientation of historical research and, consequently, raised the possibility that there was a relationship between the multiple burials of Le Clos des Cordeliers and the epidemic of plague that affected the town in 571 A.D. (Guignier 1997).

2.2.3 New Aspects from Archaeological and Historical Sources

2.2.3.1 A Case of Affirmed Plague: Les Fédons, Lambesc, Bouches-du-Rhône (Sixteenth Century)

An archaeological operation on the site of Les Fédons at Lambesc (north-west of Marseille) revealed 101 inhumed tombs. The excavation of this site, undertaken by a team of archaeologists from AFAN[14] under the direction of P. Reynaud, covered the entire cemetery. Burials were of two types: individual, of which there were 75,

[13] Cf. the recent study by Ph. Blanchard (2006).

[14] Association pour les Fouilles Archéologiques Nationales, now INRAP (Institut National de la Recherche Archéologique Préventive), since February 2002.

Fig. 2.4 A triple burial at Les Fédons (Lambesc, Bouches-du-Rhône). *Photograph* P. Reynaud (INRAP)

and multiple, of which 21 were double, 4 triple (Fig. 2.4) and 1 quadruple. As in the initial analysis of the site at Sens (Guignier 1996), the deposits at Les Fédons formed the basis of an evaluation and an archaeological report (Bouttevin et al. 1996; Reynaud et al. 1996) and has recently benefitted from an exhaustive publication (Bizot et al. 2005). Osteological observations realised in the field revealed that the deposits inside those graves containing several individuals were simultaneous, and archaeological data indicates an orderly and intelligent management of the cadavers (Moreau et al. 2005; Reynaud and Bizot 2005).

The great originality of this site compared to other known funerary contexts in times of epidemic, is that of the presence of individual graves alternating with double, triple, and one quadruple graves. This shows that a mortality crisis may generate individual graves – a point that must be taken into account in the global study of a site.

From the beginning, in order to optimise the biological data in the field, an effort was made to systematically consolidate bone remains, particularly those of the coxae for sex estimation. Of the 133 individuals inhumed, 72 immature subjects and 61 adults, 32 women and 29 men were counted. The profile of distribution of age at death, obtained from calculation of the mortality quotients, revealed numerous apparent anomalies compared to a theoretical mortality (Castex 2005) (Fig. 2.5). The infantile mortality quotients, which concern the 0–1 year and the 1–4 year age groups are very low compared to those found in the framework of a natural mortality,

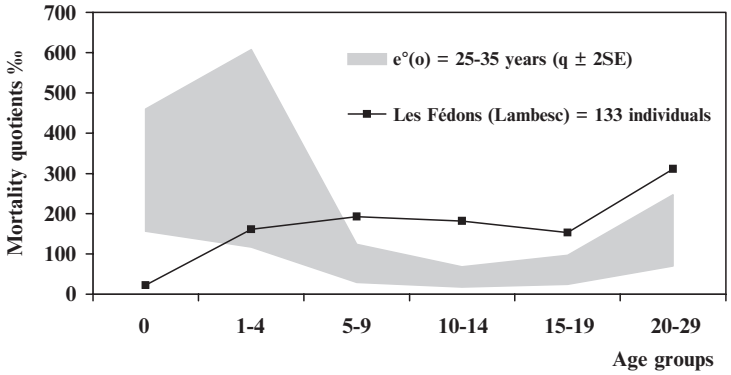

Fig. 2.5 Mortality profiles of immature individuals and young adults for Les Fédons (Lambesc, Bouches-du-Rhône). Comparison with Ledermann's data (1969)

showing an imbalance for children under 5 years – a deficit particularly noticeable for those under 1 year. On the contrary, calculations of the mortality quotients for the age groups 5–9 years, 10–14 years and 15–19 years show a clear over-representation of these groups, without the expected relationships, e.g. a minimum for the 10–14 year age group[15]. Another anomaly is the over-representation of young adults (20–29 years) within the total adult population (i.e. 31.3%); analysis of death distribution as a function of sex shows that this over-representation is specifically linked to a high female mortality within this age group. However, the sex distribution of adults as a whole remains equivalent to that of a natural demography, with the number of male subjects being equal to that of female subjects; the raw figures give a rate of masculinity of 47.5%, which conforms to the statistically theoretical rate of 50%. Thus, apart from the proportion of immature individuals within the total population (54.1%) and the sex distribution, both of which being compatible with that of a theoretical distribution, the age at death distribution of those under 30 years shows a clear distortion compared to that of a natural demography. In order to investigate whether the peculiarities observed at the site of Les Fédons could be considered characteristic of an epidemic of plague, we consulted several historical demographic studies of times of plague.

2.2.3.2 Exploitation of Archival Sources and Other Archaeological Data

The principal documents that can by utilised in relation to the estimation of mortality rates by age are those provided by the work of Hollingsworth and Hollingsworth (1971), concerning the London plague of 1603, and that of Mallet (1835), concerning plague in Geneva throughout the seventeenth century; these studies have also been

[15] In the case of a normal mortality, the age group for which the number of deaths is the lowest.

used by Biraben (1975). Using the raw numbers of deaths provided by the authors, mortality quotients for each age group[16] were calculated (Fig. 2.6). In both London and Geneva, the distribution of mortality quotients by age group during periods of plague is completely disturbed compared to that of a normal mortality: the infantile mortality quotient is very low and, in contrast, there is a clear super-mortality of young children, adolescents and adults during periods of plague. A comparison with the cholera epidemic that struck Paris in 1832 (Mallet 1835) shows important differences in the demographic impact of the two diseases: unlike plague, additional deaths due to cholera are little noticed during childhood and adolescence and become progressively more and more important during adulthood, especially in the oldest groups. These results are confirmed elsewhere by other analyses (Faron 1997). These studies provide similar profiles, always with the same variations between a classical mortality and mortality during periods of plague, a profile comparable to that obtained for the osteological series of Les Fédons. In fact, the profile of mortality by plague appears very close to the profile of a living population, thus demonstrating the non-selection in terms of age of the victims of *Yersinia pestis* (Castex 1996, 2005). Other historical demographic studies covering plague in Provence in the eighteenth century (Signoli et al. 2002; Signoli 2005) also show a clear difference between the demographic profile of ordinary mortality and that of plague.

We also considered other archaeological series from known epidemic contexts and, more precisely, two burial ditches discovered in 1994 of victims of the great

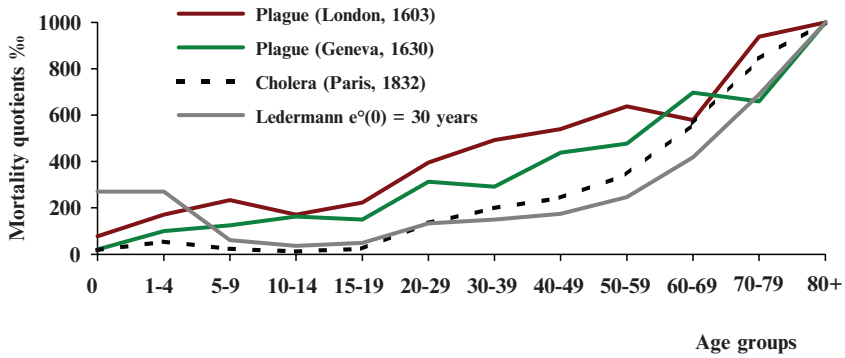

Fig. 2.6 Comparison of probabilities of death for different epidemics (data from Biraben 1975; Hollingsworth 1971; Mallet 1835) and comparison with Ledermann's data (1969). *Graphical representation* P. Sellier (UMR 5199) and D. Castex

[16] The data from the registers allowed an examination of the distribution of adults. These were sorted into decennial groups, which is difficult to achieve for adults over 30 years in the case of studies of archaeological series.

epidemic of plague of 1720–1722: the ditches L'Observance at Marseille and Le Délos at Martigues (Signoli 1998). Although the methodology and tools differed from ours, the data obtained from these two sites, particularly Martigues, revealed many points in common with observations made at Les Fédons. At L'Observance, the imbalances observed were distinctly less important and, apart from the deficit in the youngest age group, there was not the large proportion of children and older adolescents seen at Les Fédons. In an attempt to explain the differences between the mortality profile of Marseille and that of Martigues, an epidemiological hypothesis (Signoli 1998, 2005) has been proposed: the site of L'Observance may have been established during the recurrence of the epidemic in 1722[17], while that of LeDélos was established at the peak of the epidemic. Other interesting comparisons, based on archaeological series, between ordinary deaths and deaths linked to plague show demographic peculiarities, certainly linked to the epidemic impact, but also inherent to the constitution of the archaeological samples (Margerison and Knüsel 2002).

The few available historical and archaeological documents reveal comparable mortality profiles by plague as a function of age; however, as a function of sex, the results seem much more contradictory. These differences, which are difficult to understand from a medical point of view, could be linked to exposure to the disease (Biraben 1975). The high female mortality among young adults seen at Les Fédons could thus be due to the large number of young women employed at the infirmary of Les Fédons, as revealed in the archives (Rigaud 2005). Some historical studies corroborate this excess of females (Signoli 2005), whereas others tend to show an excess of males within the adult population, as in the parishes of Paris during the fourteenth century plague (Lucenet 1985), and in London during the plagues of 1603 and 1625 (Biraben 1975).

Following these archaeological discoveries, investigations within the scope of molecular palaeobiochemistry were rapidly undertaken. Residues of dental pulp from the L'Observance (Marseille) and Les Fédons (Lambesc) sites were able to provide ancient DNA sequences of the bacillus *Yersinia pestis*, the plague vector (Drancourt et al. 1998, 2005).

Within the fields of archaeology and biological anthropology, the site at Les Fédons thus appears a quite original funerary example; this site benefitted from an exhaustive excavation[18] and the inhumed population is perfectly dated, with a representative number of inhumations where the cause of death is known (archival sources and molecular palaeobiochemistry). The analysis of this site, in conjunction with available references to historical data, as well as comparison of the results with those obtained in other studies of cemeteries linked to plague, have allowed a very precise clarification of this mortality crisis.

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[17] Hypothesis founded upon a comparison of the demographic characteristics of the exhumed osteological sample and data from the records of the convent at L'Observance for 1722.

[18] This is particularly important as, in many cases, a non-exhaustive excavation can be held responsible, at least in part, for a sketchy interpretation of certain demographic anomalies.

2.2.4 Identification of the Black Death and Justinian Plague

The results obtained on the demographic impact of plague inevitably led to questions about previously studied funerary sites, e.g. Saint-Pierre at Dreux and Le Clos des Cordeliers at Sens (see above), which present an abnormal mortality and for which historical sources are lacking. The mortality quotients obtained at Dreux and Sens, when compared with those of Les Fédons, reveal striking similarities between the three sites (Figs. 2.2, 2.5): the anomalies registered between a mortality by plague and a natural mortality were very close to those observed between the two ancient series and Ledermann's theoretical data (Castex and Friess 1998; Sellier and Castex 2001). Although initially unable to affirm the impact of plague on the basis of this analysis alone, we nevertheless considered it a non-negligible argument, but requiring corroboration by other analyses for a final diagnosis.

Further molecular palaeobiochemistry research was undertaken (Drancourt et al. 2004) and the presence of the *Yersinia pestis* bacillus was confirmed in the two archaeological series: the Black Death at Dreux – thus corroborating the results obtained at Montpellier (Raoult et al. 2000) – and the "Justinian" plague at Sens, revealing for the first time the presence of the plague bacillus in the sixth century (Castex and Drancourt 2005). These results allowed the clarification of a major historical problem as the third pandemic of plague, which began in South-East Asia at the end of the nineteenth century, was the only one to have had a sure microbial origin clearly identified by Yersin in 1894. In particular, the identification of *Yersinia pestis* as being responsible for the Black Death ends the controversy as to its etiology, ruling out other pathogens that had previously been incriminated (Scott and Duncan 2001).

The following illustrates the importance of the results obtained: sites where the historical records attest an episode of plague allow an epidemic model or models to be confirmed, in turn allowing hypotheses of a particular epidemic crisis to be proposed at other sites where historical data is unavailable. Archaeological studies are thus orientated towards further indications and towards the search for further data (e.g. re-evaluation of the date of a site considered as known, molecular palaeobiochemistry research, etc.). These results and the distance necessary for their objective interpretation have allowed us to develop more precise methodological and analytical thematic studies in both funerary archaeology and anthropology, leading to a more systematic approach to future discoveries and studies and the co-ordination of interdisciplinary collaboration that is fundamental to the understanding of such contexts[19].

[19] This problem was developed within the framework of the quadrennial project 2003–2006 of La Maison des Sciences de l'Homme d'Aquitaine, specifically that on mortality crises. Several new sites linked to epidemics have been studied. Others are undergoing analysis.

2.3 "Possible" Plague Cemeteries: Epidemic Impact and/or Initial Selection

2.3.1 Saint-Benedict of Prague (Late Sixteenth Century): a Previously Selected Population?

The vast cemetery of Saint-Benedict of Prague, excavated in 1971, contains more than 800 graves, of which many are multiple inhumations[20]. Most of the skeletons from these burials were the subject of an anthropological study in 1988 (Hanakova and Stloukal 1988)[21]. The archaeological level on which we concentrated concerns the latest phase of the cemetery. This phase corresponds to a large number of inhumations (about 450, i.e. more than one-half of the total number of inhumations) which, according to initial examination of the records, could be linked to the plague of 1680, at which time the cemetery and structural elements discovered on the site belonged to the Premonstratensian order. By its very nature, the cemetery of Saint-Benedict of Prague was likely to introduce further elements warranting reflection into the particular context of acute mortality crises linked to plague (Castex et al. 2003, 2005). As the number of individuals was very large we concentrated initially on an exclusive study of the multiple graves[22].

To date, 20 multiple graves, containing 120 subjects, have been studied (Fig. 2.7)[23]. Compared with data from Ledermann's typical tables (1969), the mortality quotient curve shows various flagrant anomalies (Fig. 2.8). Firstly, there is a very clear under-representation of children under 5 years (and even under 10 years), with a total absence of the former age group. In fact, the number of immature subjects, as a proportion of the total population, is low at only 27.4%. The age groups 5–9, 10–14 and 15–19 years show a clear disproportion between each other, with a slow inflation of the mortality quotients. Finally, we see a peak of mortality in the 15–19 year and, above all, in the 20–29 year age groups, the representation of young adults within the total adult population being 47.8%. The rate of masculinity is particularly high at 83.6%.

It would therefore seem that the criteria of age and sex show a very selective composition: the mortality quotient curve, very different to that observed in the

[20] A large amount of archaeological data was made available. This data resulted from the report produced by B. Martinec, a Czech archaeologist in charge of the excavation (Martinec 1971).

[21] The aim of this study was to obtain general biological information on the population of Prague from the Middle Ages until a recent period and no distinction was made between those inhumed in individual graves and those in multiple graves.

[22] The long-term objective is to study all the graves in order to compare, for the same chronological period, mortality as a function of age and sex between two types of 'recruitment': one more or less 'natural' and the other linked to a mortality crisis.

[23] We have chosen to present a triple grave, which, with double graves, occurs most frequently, although at least three graves contain the remains of 9 subjects and another contains up to 20 (the deposits were organised in successive layers in very deep and narrow ditches.)

Fig. 2.7 A simultaneous burial at Saint-Benedict (Prague, Czech Republic). *Photograph* V. Martinec (Prague Archaeological Service)

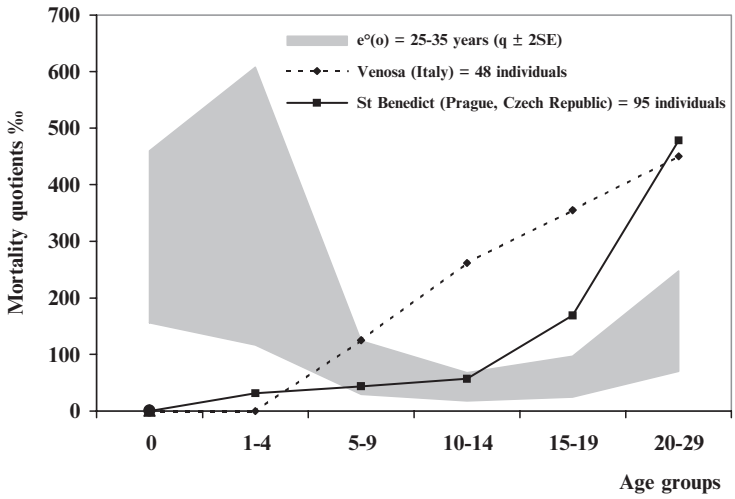

Fig. 2.8 Mortality profiles of immature individuals and young adults for Saint-Benedict (Prague, Czech Republic) and Venosa (Lucania, Italy). Comparison with Ledermann's data (1969)

case of a natural mortality, also differs from that expected in the case of plague, especially in the relationship between the quotients of the 5–9, 10–14 and 15–19 year age groups and in the excessive numbers of individuals aged 20–29 years. This divergence in the profiles invites various comments. The hypothesis of an epidemic

must be retained as it is supported by the archaeological facts, the suddenness of the deaths having caused the establishment of multiple graves, and the absence of specific lesions on the skeletons. Even if we are dealing with an epidemic of plague, this fact alone would seem unable to explain such large anomalies in the distribution of age and sex at death. In addition to the epidemic factor and its virulence, other mechanisms that may have contributed to this abnormal distribution of deaths must be invoked. An explanation must be found in the constitution of the original group. This requires the use of historical records, which alone are able to specify the status of the site and allow recognition of the existence of a possible relationship between the sector of multiple graves and the Premonstratensian monastery (a group of individuals selected according to sex with a large majority of young men?). Perhaps a different type of epidemic occurred, imposing once again the need to access textual sources in which a precise incident – maybe less noteworthy than plague, but nevertheless recorded in written form – may be identified.

2.3.2 Venosa, Lucania, Southern Italy (Eighth–Tenth Centuries): the Nature of the Crisis Reconsidered

At the site of Venosa, excavated in 1986 and 1987, five adjacent graves, dated to between the eighth and tenth centuries, each containing between 7 and 12 individuals (a total of 48 subjects) placed side-by-side or one above the other were discovered. The presence of several simultaneous inhumations led to the hypothesis of a mortality crisis (Fig. 2.9). Although no documentary source mentions it, the possibility of an

Fig. 2.9 A simultaneous burial at Venosa (Lucania, Italy). *Photograph* R. Macchiarelli, L. Bondioli (Pigorini Museum, Rome)

epidemic of plague was discussed because of the absence of specific lesions on the skeletons and because of the structure by age and sex of the osteological sample compared with those of models elaborated in historic demography. The deaths of the subjects had previously been distributed into 10-year age groups (except for the first group, 0–4 years, of which there were none). The over-representation of the groups 5–14 and 15–24 years registered for the burials at Venosa showed a mortality profile very different to that of a natural demography but comparable, in general terms, to that observed in periods of plague (Macchiarelli and Salvadei 1989). The latter point is the only argument supporting the interpretation of a possible occurrence of plague in this case, as the other two arguments would equally apply to any epidemic that causes a large number of deaths and that acts so rapidly that osseous lesions do not occur. Because of the small size of the sample, it is important to have as precise an age estimation as possible for immature individuals and their distribution into age groups, so as to reveal true demographic anomalies – the only element that can inform us about the nature of the crisis that affected these individuals. The mortality profile obtained from the authors' raw data revealed several anomalies, which finally appear quite different to those observed in known cases of plague (Fig. 2.8). The proportion of immature subjects within the total population is 58.3%; although large, this value remains compatible with that of a theoretical mortality for a life expectancy at birth of 30 years. The 0–1 and 1–4 year age groups are totally imbalanced with a complete absence of subjects. The older age groups show a very regularly growing curve, with abnormally high numbers for those of 10–14, 15–19 and 20–29 years. A very clear over-representation of young adults as a proportion of the total adult population (45%) was noted. Thus, when studied more precisely, the ratios between the different immature age groups is very different from that generally observed in confirmed cases of plague: should this mortality profile be considered representative of plague? In this case should the anomalies observed be attributed to the existence of a population already selected by age (perhaps a selection in part of the site only)? Or should, as for Saint-Benedict of Prague, the validity of the first diagnosis be questioned and an epidemic crisis of a different nature be envisaged?

2.3.3 Further Lines of Research

The analysis of age and sex distributions in the sites of Saint-Benedict and Venosa has thus revealed both quantitative and qualitative details that differ from those generally identified in the context of plague. This new data invites us not only to re-examine historical hypotheses, perhaps accepted too quickly, but also to take into account the existence of human behaviour, too often simply ignored yet capable of introducing numerous imbalances into the consideration of archaeological populations.

It is therefore necessary to undertake additional studies of the two sites. A re-examination of the dates already proposed is required as well as a greater use of

historical sources, especially at St. Benedict, where much more information ought to be available. In both cases, the interest of molecular palaeobiochemistry analyses becomes evident, e.g. the possibility of finding a pathogen different from that of plague[24] and thus proving, perhaps, that plague in the past was not necessarily linked to the action of *Yersinia pestis*. Within the framework of research on the validity of plague diagnosis, two more funerary sites, already considered promising in the long-term, may enrich the corpus available: the multiple burial at Gerasa, Jordan, may be linked to a seventh century plague (Seigne 2007), and the cemetery of the Santa Clara convent at Palma de Majorque, Balearic Islands, implicated by historical sources in the Black Death of the fourteenth century.

2.4 Other Cases of Cemeteries Linked to Mortality Crises Due to Epidemic

2.4.1 Issoudun, Indre (Seventeenth–Eighteenth Centuries): Epidemic Coupled with Famine?

In the context of a "preventive" excavation undertaken by INRAP from May to September 2002, 14 multiple graves were discovered in part of the ancient cemetery of Issoudun (Indre). These graves, dating from the late seventeenth to early eighteenth centuries, are grouped in a zone particularly dense with skeletons, resulting from the intensive use of a funerary space that functioned over a long period (thirteenth–eighteenth centuries). The funerary topography shows that the graves are aligned in relatively clear rows, all except two in the same orientation. The peculiarity of the context and the possibility of direct intervention in the field from the start of the excavation[25] (as at the site of Les Fédons, Lambesc, see above) allowed the use of recording methods adapted to a salvage excavation while favouring the maximum yield of information available to a post-excavation study, particularly of this type of site (Blanchard et al. 2003a, 2003b).

Apart from one double burial, the graves contained between 13 and 22 individuals, deposed simultaneously, and were composed of adults of both sexes and immature subjects showing a remarkable proportion of children over 1 year (Fig. 2.10). All the graves revealed a very rational organisation of the deposits according to age criteria (Fig. 2.11). On the basis of the arguments described above, the hypothesis of an epidemic was quickly formed, although its nature could not immediately be proposed. The minimum number of individuals was estimated at 203. The number

[24] Work has been engaged in this direction with Michel Drancourt, Unité des Rickettsies, CNRS UMR 6020, Faculté de Médecine, Marseille.

[25] Thanks to I. Souquet-Leroy, anthropologist in the field in charge of the excavation and study of the graves.

Fig. 2.10 One of the 14 simultaneous burials (S. 119) at Issoudun (Indre) containing 22 individuals. *Photograph* F. Porcell (INRAP)

of the archaeological sample, i.e. victims of this epidemic, was established from the total number of individuals from the multiple graves, both complete and incomplete, but also by taking into account some single graves suspected of being contemporaneous with the multiple graves[26]. The mortality curve revealed very noticeable anomalies compared with that of a natural population (Fig. 2.12). The numbers of 0- to 1-year-olds are very low whereas the numbers of 1- to 4-year-olds are high, although compatible with Ledermann's highest theoretical values (1969). The most surprising imbalance is the high number in the 5–9 year age group, followed by that of the 10–14 year age group. The corresponding quotients also show an over-representation. The proportion of immature subjects within the total population appears extremely high (76.4%).

[26] Their alignment with the multiple graves and the unusual deposit of the bodies inside the graves, e.g. several individuals lying on their stomachs, tended to prove their creation at a time of crisis.

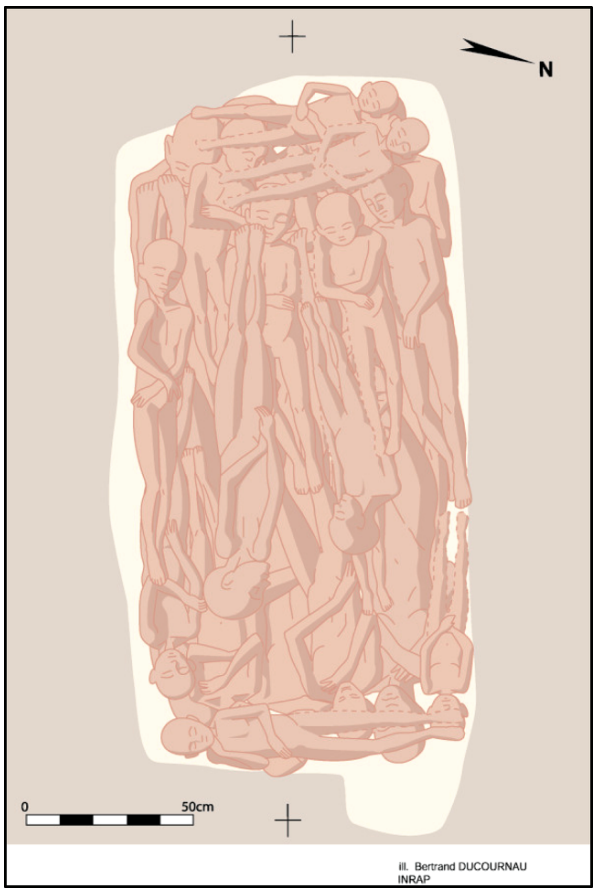

Fig. 2.11 Reconstitution of the organisation of the deposits in a simultaneous burial (S. 119) at Issoudun (Indre). *Illustration* B. Ducourneau (INRAP)

In spite of various gaps in the records, certain archival documents have allowed us to formulate some hypotheses as to the nature of the crisis that may have affected these individuals (Poulle 2007). Several examinations for the years following 1650, when excess mortality was particularly severe (war, famine and numerous diseases), were undertaken. For each of these years we were able to calculate different demographic parameters (proportion of immatures within the total population, rate of masculinity, etc.). Several comparisons were then made between crisis and non-crisis years and the findings were set against the results obtained from Issoudun's archaeological sample. Initially, two periods of crisis were targeted[27]: the years

[27] They had been skilfully analysed by regrouping the deaths into age groups comparable to those of our archaeological sample.

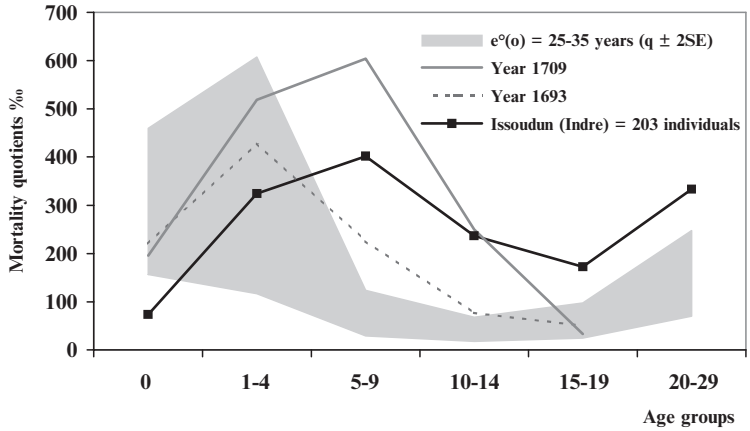

Fig. 2.12 Mortality profiles of immature individuals and young adults for Issoudun (Indre). Comparison with Ledermann's data (1969) and historical records for 1693 and 1709. *Documentation* P. Poulle (INRAP)

1693–1694 (various crises linked to the end of the reign of Louis XIV) and 1709 (well-known to historians as a year of poor harvests followed by famine and numerous diseases). Our attention was finally held by the crisis of 1709 as the ratios between the different age groups were the closest to those obtained for the archaeological sample from the multiple graves discovered (Fig. 2.12)[28]. Another argument for the choice of this crisis concerns the daily rate of death found in the archives, which was sufficient to account for the size of the multiple graves discovered[29]. If this is the case, it remains difficult to be precise as to the nature of the crisis that affected Issoudun's population. Molecular palaeobiochemistry analyses are, for the moment, negative[30] for the first pathogens researched (smallpox, plague, measles). In spite of this we maintain the highly probable hypothesis that the crisis which caused the multiple deaths at Issoudun was linked to an as yet unidentified human pathogen, perhaps associated with a famine, as indicated by a number of signs of growth stress identified on the teeth and bones (high frequency of linear hypoplasia of the dental enamel and numerous cases of cranial hyperostosis and rickets).

[28] When using the registers, no distinction could be made between young and older adults, which of course excluded a comparison of the 20–29 year age group.

[29] For example, in September 1709 there were up to 22 deaths on the same day.

[30] Report on palaeomicrobiologic analyses by L.V. Dang and M. Drancourt (UMR 6020, Faculté de Médecine, Marseille) within the framework of the Final Document of Synthesis on the site of Issoudun, at present being finalised. The absence of the pathogens researched does not, however, exclude the possibility of their having existed.

2.4.2 Boulogne-sur-Mer, Pas-de-Calais (Eighteenth Century): Hypothesis of a Smallpox Epidemic?

Seven multiple graves were found at a "preventive" excavation at L'Ilot Saint-Louis, Boulogne-sur-Mer, in all a total of 39 individuals. These graves were dated early eighteenth century (Belot and Canut 1995) (Fig. 2.13). The simultaneity of the osseous deposits associated with the contemporaneity of the different structures as well as the recurrence of the phenomenon led us to interpret this site as the result of an abrupt mortality crisis (Réveillas 2005; Castex and Réveillas 2007). It was possible to eliminate the hypotheses of war and famine in favour of that of an epidemic on the basis of historical, archaeological and anthropological arguments. The study of the ratios of the different immature age groups is worthy of attention. Except for a few details, the mortality profile overall appears close to that of a "natural" demography (Fig. 2.14). The number of adults is almost identical to that of immature subjects but the mortality quotient of children under 1 year is very low, whereas the age groups 15–19 years and 20–29 years show high numbers compared with those observed in a theoretical population. According to Ledermann's data (1969), the relation expected between the age groups 5–9, 10–14 and 15–19 is

Fig. 2.13 General view of two simultaneous burials at Boulogne (Pas-de-Calais). *Photograph* E. Belot (Boulogne-sur-Mer Municipal Archaeological Service)

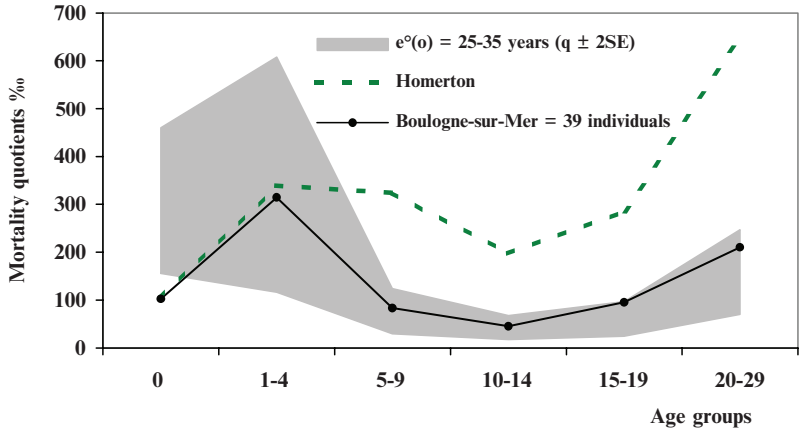

Fig. 2.14 Mortality profile of Homerton's hospital population and the archaeological population of Boulogne-sur-Mer. Comparison with Ledermann's data (1969)

respected, a minimum being found in the 10–14 year age group. The proportion of young adults is high, representing 21.05% of the total adult population. At 52.6%, the rate of masculinity conforms to that of a natural mortality.

These specific features, considered in regard to various historical, medical and demographic sources (Darmon 1986; Leca 1982), allow the elimination of certain epidemics, in particular plague. The data have been compared to that of a hospital at Homerton in the United Kingdom specialising in the treatment of smallpox (Razell 1977) (Fig. 2.14). Although the mortality quotients from Homerton are noticeably higher than those at Boulogne, the similitudes registered (low mortality quotient for children under 1 year and contrastingly high for the 1–4 year age group; relationships between the next three older age groups) perhaps indicate that smallpox is an interesting research path to follow, although other diseases, poorly documented but recurrent at that time (influenza, prickly heat, malaria), cannot be totally eliminated. Further research must be undertaken before proposing a definitive interpretation, in particular a more complete study of Boulogne's archives and additional inquiries into the demographic impact of smallpox and other types of epidemic, but also by molecular palaeobiochemistry analyses allowing the identification of specific micro-organisms.

2.5 Conclusions

In the domain of palaeobiology the parameters of age and sex of osteological series, far from being considered tools for the demographic reconstruction of past populations, appear more to furnish details, analysis of which is essential to the interpretation

of the functioning of these sites. In the particular case of mortality crises, it is possible to demonstrate global models that can be appropriately applied to certain crises. Thus, even in the absence of historical data, a hypothesis of a particular demographic crisis can be proposed.

Using the example of plague, we have followed the thematic strategy of palaeobiology, the ultimate aim of which is a better comprehension of past mortality crises, from its debut with the intrinsic characteristics of a site. This field of study has obviously been encouraged by the efforts made on more recent sites, which benefit from the availability of historical sources. However, apart from exceptional cases, such as the epidemic of plague at Marseille in the early eighteenth century where both an osteological collection, outcome of an affirmed plague, and historical demographic data relative to this epidemic (see above) are available, to try to make archaeological facts and historical events coincide systematically is somewhat questionable and the results obtained can in no way represent a "model" that could be applied unconditionally to more ancient osteological series whose initial constitution is unknown. For such series, the only possibility of identifying anomalies in comparison with as large a natural distribution as possible is to refer to the theoretical models proposed by standard tables, in this case those of Ledermann (1969), although other tables exist.

Although by now we have accumulated a great deal of experience with plague epidemics, we have seen that mechanisms other than that of the epidemic and its virulence can lead to an abnormal distribution of deaths and sex. As well as the indispensable analysis of archaeological facts, this latter factor requires that the constitution of the original population be discussed, even if this means, in some cases, calling into question the nature of the crisis proposed by historical sources. Types of crisis other than plague epidemics can be considered, as we have seen with some of the examples discussed above that must remain at the hypothesis stage.

In order to progress, this subject needs the continuing and indispensable to-and-fro between the recently available methodological expertise and the ancient (osteological) series, and the two complementary approaches must be conducted in parallel. Firstly, historical demographic analyses must be intensified so as to approach more exactly the impact of different types of crisis and thus allow different typical profiles to be proposed with which to interpret age and sex distributions and their possible anomalies. Secondly, the analysis of osteological samples from periods of epidemic must depend upon as large a choice of sites as possible, both chronologically and geographically, in order to establish not just one "model" but several models illustrating crisis mortality.

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