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Plenary session: **Micro-data database and new developments in GIS-applications**

**Towards a GIS for the Study of Past Epidemics : the Example of the City of Martigues
(France, in the First Quarter of the XVIIIth Century".**

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Abstract

At the beginning of the XVIIIth century, the city of Martigues (in the South of France) was a community of medium importance, consisting *intra muros* of three parishes and of extent lands.

Research for some years has enabled us to constitute an important onomastic database, on the basis of the Census of 1702 and parish registers.

Concurrently, we have worked towards the creation of a Geographic Information System for the city, using fiscal data (XVIIIth century land registers and the "Napoleonic Cadastre" of 1817).

We put forward an urban reconstruction of Martigues in order to follow, as closely as possible, family after family, home after home, street after street, the spread of diseases which struck the city in the first half of the XVIIIth century.

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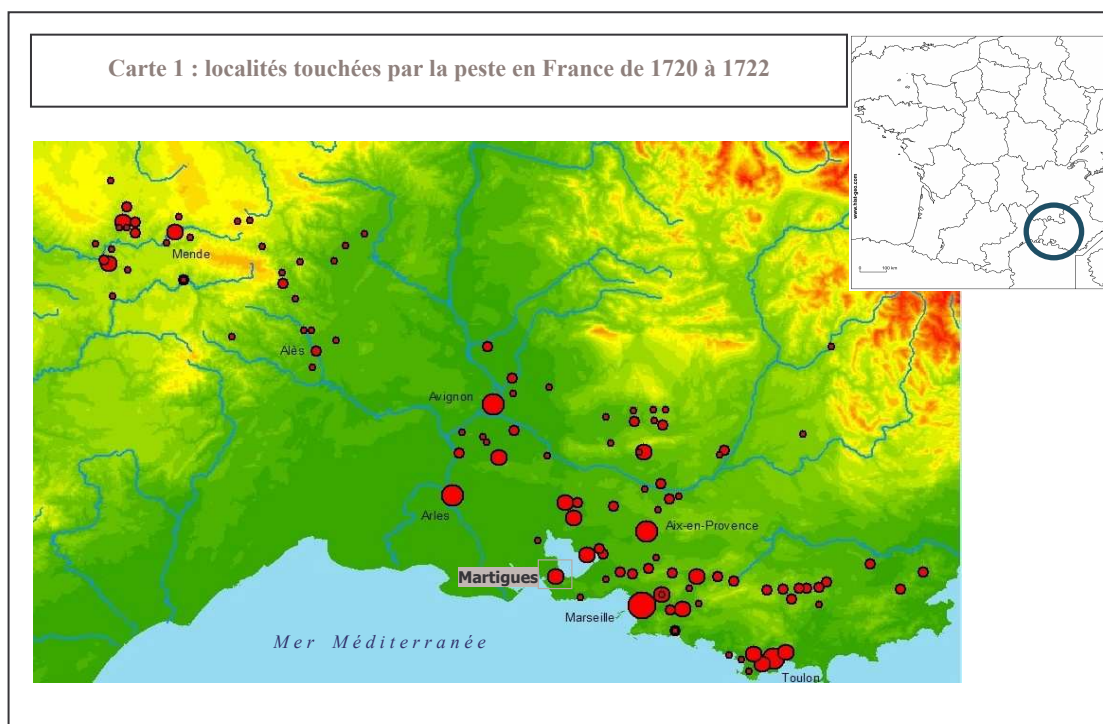
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Aims of our study

Initiated by Research Unit 6875 (National Centre For Scientific Research / Faculty of Medicine of Marseilles), this project aims at understanding the epidemics of the past, in order to anticipate those of the present. A pluridisciplinary team (archaeologists, anthropologists, historians, demographers, geomaticians, geneticists, epidemiologists and microbiologists) studies infectious crises, particularly plague, following new approaches. The last plague epidemic in France hit Provence between 1720 and 1722.

The study of past diseases is of demographic and historical interest, but it also allows us to understand the spread of infectious diseases at a time when there was no efficient medical treatment. The observation of conditions of the spread of pathogenic agents is of great interest to epidemiologists who are confronted nowadays with the re-emergence of these diseases.



Map 1 : Cities affected by plague in France from 1720 to 1722.

Our approach develops on two levels : firstly, on a macro level focusing on the entire area affected by the plague of 1720 (map 1) ; secondly, at a local scale with greater precision. We intend to study the modes of diffusion of some pathogenic agents, both in Provence and Lower Languedoc, an open but controlled area, and in the closed urban space of the city of Martigues.

Historical data concerning the XVIIIth century are abundant and their quality good. Besides, some communities kept lists of names from censuses conducted at the very beginning of the century. After corrections and data processing, these lists have allowed us to build a population database, so as to be able to assess the epidemic impact on the population.

This presentation concerns the methodological aspects of the reconstruction of the urban network of Martigues (South of France) at the beginning of the XVIIIth century and describes how we have tried to locate as precisely as possible each inhabitant in his own house. This first step is necessary before analysing our epidemiological, demographic, sociological and genetic data, in spatial contexts.

The use of Geographical Information System (GIS) allows us to go further than with computerized mapping, and to bring to light interrelations between geographical data (urban forms, environment, climate, seasons), and administrative, demographic, epidemiological and socio-economic specifics.

Supplemented by information on kinship (biological or religious), professional networks or relationships, relations of spatial proximity, this GIS will lead to analyses in terms of interhuman contamination (or animal/human contamination). It will allow also for analyses according to biological determinants which may encourage, within certain families, resistance to pathogenic agents (past pathogenic agents of which the revival is always feared).

Historical and geographical framework

Martigues, an Enclosed City Open towards the Mediterranean sea

In modern times, Martigues was an important city of Western Provence, that controlled the entrance from the Mediterranean sea to the marshy Etang de Berre by the Caronte channel. The city covered a large area of more than 7000 hectares (maps 2 and 3).

Martigues was a maritime city, owing to its situation and its activities of trade and fishing. Fish traps, or *bourdigues*, were fixed in the Caronte channel. These were pits consisting of posts and reeds to capture fish migrating between the sea and the Etang de Berre. The city of Martigues' land included olive plantations and grapevines. Struck by its hybrid aspect, "half-water, half-land", some writers have described Martigues as "Provençal Venice" (Degut et Vigne, 1964).



Map 2 : Cassini Map : Martigues and the Etang de Berre



Map 3 : Detail of the heart of Martigues

Martigues or The Martigues

The city of Martigues consisted of three districts, each corresponding to an ancient community: Jonquières in the South, l’Ile (the “Island”) on the channel, and Ferrières in the North. These communities, originally independent which were united in 1581 under the appellation of Martigues or “The Martigues”, to emphasize the fact that originally there were three districts.

The plan of the city shows the mark of the different powers which controlled the city before the act of Union. Ferrières was a “ville nouvelle” (new town), a creation of the archbishop of Arles; the Jonquières district was established by the Benedictine abbey of Montmajour ; the Ile district was founded by the counts of Provence. These three districts were created, more or less at the same time, in the XIIIth century.

Sea people, Land people

Urban society was marked by composite. The nobility did not live in Martigues, but in Aix. Professionals (doctors, surgeons, apothecaries), merchants, men of law and officers, export-merchants, ship captains and, at a lesser degree, fishermen constituted the middle class. The sea people formed the most important social category in the city, powerful both politically and economically. Country society fell into two distinct groups: the agrarian world (peasants, day-labourers, muleteers, blacksmiths) and quarrymen.

The population of Martigues also included an important group of poor, whose situation was followed the ups and downs of the economy.

The Demographic Decline (First quarter of the XVIIIth century)

The city of Martigues peaked economically and demographically in the XVIIth century. At the beginning of the XVIIIth century, its population was still large (Paoli, 1971, estimates that the city and its lands held about 10 000 inhabitants, of whom 7 200 lived inside the city). However, demographic crises and the maritime wars of Louis XIV caused a strong depopulation in the first quarter of the XVIIIth century. In 1716, the city counted no more than 8 000 inhabitants (Paoli, 1791, p. 14 ; and 5 888 according to l’*Etat du nombre des familles et des personnes de chaque lieu de Provence*⁴). During the plague of 1720 more than 2 000 persons died.

At the end of the first quarter of the XVIIIth century, Martigues’ population fell to less than 6 000 inhabitants, and remained at this level till the second half of the XVIIIth century. This depopulation was due to human loss of life, but also to a massive exodus after the “great winter” of 1709-1710 (*cf. infra*). Part of Martigues’ inhabitants (in most cases fishermen, but also peasants and artisans) left the city, at first for Marseille.

Onomastic data

Our ongoing research has allowed us to build an important database on the inhabitants of Martigues for the period 1701 – 1725, in which various onomastic sources confirmed each other.

⁴ Archives of Intendant Lebret, Bibliothèque nationale, ms fr 8908.
Numbers published by Jean-Noël Biraben (1975, p. 339 aud.)

A City Census in 1702

Following the re-establishment of poll tax or “*capitation*⁵” in 1701, families were counted in one (Jonquières) of the three districts of Martigues.

A *General Census of Martigues’ population* was undertaken in January 1702, covering the whole city. Each inhabitant was recorded, street after street, home after home, family after family. This census also recorded the name of the home’s owner ; his identity and age, the occupation of the head of the family ; the identity and age of his spouse ; the number of children, their individual surnames and age, as well as their possible occupation

Members of the larger family of the parents and domestic staff living with the family were also noted. This fiscal document contained some omissions : some houses outside the city walls seem to have been omitted and three pages of the Ile district are missing. The *Census* mentioned 5 602 inhabitants subjected to poll tax, but this population number seems to have been underestimated.

Parish Registers

We have also used parish registers in order to build a population database, which would provide the following information for each inhabitant : name, surname, sex, age at death, biological or marital ties, occupation, origin, address, victim or not of one of the diseases under study.

The parish registers⁶ of the three urban parishes from 1701 till 1725, were analysed in order to reconstruct the urban population’s moves between the 1702 Census and the beginning of the plague (Signoli, 1998), and so as to follow the individual destinies of Martigues’ inhabitants during those difficult years.

It should be noted that the registers of burials for the years 1720-1721 indicate a normal recording of deaths till the beginning of plague, after which they took the form of a list of the victims established at the end of the plague, whose violence had disrupted all civil and ecclesiastical administration. The burials registers provide patronymic name, surname, sex, age at death, date and place of burial, parents’ or spouse’s identity, occupation, and various other precisions (on ties of consanguinity).

Land Registers

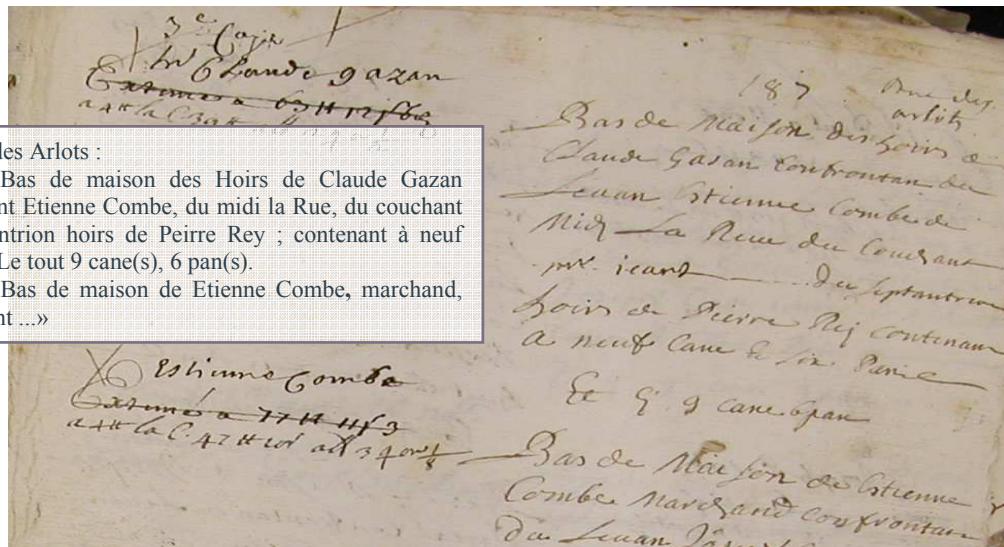
The city of Martigues was recorded in cadastral registers several times since the XVth century. Two land registers of the XVIIIth century are available, before and after the epidemic of plague. The land register of 1716⁷ follows that of 1580; any intermediate registers have been lost.

Similarly to a modern cadastre, these fiscal documents establish the nature, surface and value of land (built and not built) belonging to the community. Lists of ownership were established street by street. They point out the name, surname and status of the owners and describe the houses in relation with their neighbours, this allowing us to locate them on the city map (ill. 1).

⁵ This new tax, created in 1695 to cover the war-induced expenses, had to be paid by members of the nobility, as well as by commoners. Cancelled in 1698, the *capitation* was re-established in 1701.

⁶ Municipal Archives of Martigues, GG 14 to 16, 30 to 32 and 46 to 47.

⁷ Municipal Archives of Martigues, CC 361.



« 3^{ème} cahier. Rue des Arlots :

Claude Gazan. Bas de maison des Hoirs de Claude Gazan confrontant du levant Etienne Combe, du midi la Rue, du couchant Mr Icard, du septentrion hoirs de Peirre Rey ; contenant à neuf cane(s) et six pans. Le tout 9 cane(s), 6 pan(s).

Etienne Combe. Bas de maison de Etienne Combe, marchand, confrontant du levant...»

III. 1 : Land registers of Martigues : the Ile district, 1716.

The « Napoleonic » Cadastre

This land register was prescribed by Napoleon, in 1807 for each village of France. Its elaboration took several decades and the last "Napoleonic" land registers date from the end of the 1850s.

The "Napoleonic" cadastre of Martigues dates from 1817⁸. It appears under two forms : cartographic (map 4) and textual. The written document (*Etat des sections*) supplements and specifies the cadastral maps : for every numbered plot on the map, it indicates the nature, area, value and name of the owner.



Map 4 : Napoleonic cadastre of Martigues : map E, Ile and Ferrieres districts, 1817.

⁸ Departmental Archives of Bouches-du-Rhône, 3P 1275-1276 (*intra muros* districts).

The Epidemics at Martigues at the Beginning of the XVIIIth century

In the first quarter of the XVIIIth century, Martigues suffered great demographic crises, as in Provence and in France. These are detectable in the annual calculation of baptisms, marriages and burials. In time of crisis, burials increased, as the number of baptisms and marriages decreased. Such a situation is characteristic of 1705, 1709-1710 and 1720-1722

These three crises probably had an infectious origin, but due to different pathogenic agents.

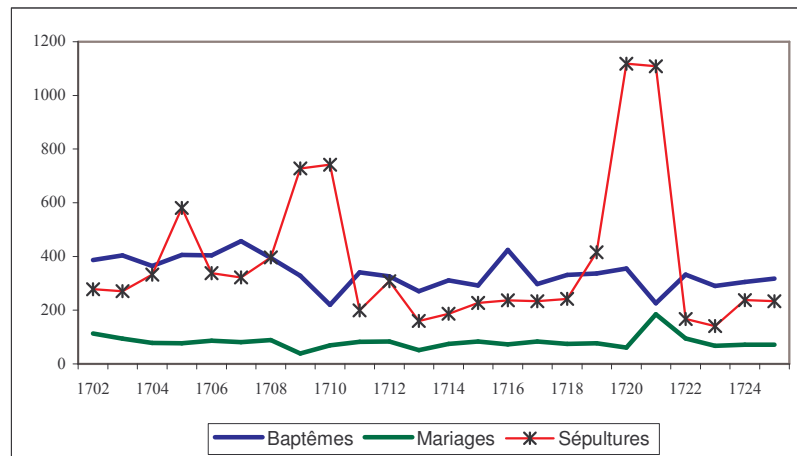


Fig. 1 : Annual number of baptisms, marriages and burials in Martigues (1701-1725)

1705 : A Silent Epidemic

The first demographic crisis of the century took place in 1705: mortality level was particularly high from August till December 1705 and affected the youngest children. This crisis is not well known by historians and historical documents are scarce. Its nature remains uncertain, but it appears linked to an eruptive fever such as measles or smallpox. It seems to us that the second diagnosis could be right.

At the beginning of the XVIIIth century, *Pox virus* infection was a quasi-endemic disease. Moreover, a side-effect of smallpox is the definitive immunity with which the surviving sick are endowed. When the proportion of the non-immunized population becomes important, the pathogenic agent finds a favourable ground for mutation from being endemic to becoming epidemic. Therefore, at regular intervals (5-10 years), smallpox killed the youngest, and those who had not been immunized during a previous epidemic.

This infectious disease, which was less spectacular than plague, however, was a serial killer, quietly decimating the youngest population.

1709-1710 : The Great Winter

The Great Winter crisis (1709-1710) is well-known by historians-demographers (Lachiver, 1991). A severe winter hit all France in 1709, including Provence where olive trees froze, herds of sheep were decimated, the Etang de Berre froze, all fishing activities stopped. Already, in the autumn of 1708, Martigues suffered of food scarcity ; the next following winter completed the task of exhausting the population.

Nevertheless, the maximum deaths did not take place at the end of winter, but in the autumn (fig. 2) ; so we believe that, rather than famine, it was putrid fevers at the end of the summer (dysentery, typhoid fever) which decimated and weakened the population.

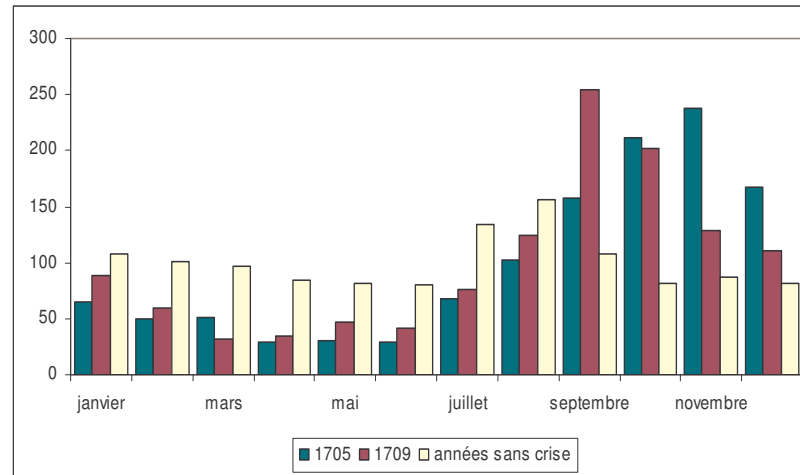


Fig. 2 : Burials seasonality during the demographic crises of 1705 and 1709, compared with "normal" years

1720-1721 : The « Marseilles » Plague Epidemic

In 1720-1721, the city of Martigues was struck by plague, as were another 241 communities. This infectious fire had an anachronistic character in XVIIIth century France, which had not been hit by plague since 1671. In Provence, the last plagues had been in the middle of the XVIIth century. The violence of the 1720 epidemic was certainly related to a long period of remission. This "forgotten" infection affected particularly badly organisms which were not "used" any longer to resisting to plague.

This particularly infectious disease progressed owing to the absence of any efficient medical treatment. The city of Martigues was reached by the plague on 6th October 1720 ; the epidemic ended on 17th June 1721. 2 150 persons died, according to the assessments ordered by the councilmen at the end of the plague.

The great mortality caused by *Yersinia Pestis* is different from other epidemics : all ages are equally touched and there are no seasonal preferences. Although the plague eruption seemed to coincide with Summer or the beginning of Autumn, the epidemic did not stop at the turn of the season : the contamination followed within the population, with a very quick development during the first months (fig. 3). While in "normal" times, children under 5 years were the first to die first, in the case of plague, all ages were hit, more or less in the same proportions (fig. 4). By taking its toll on the adults, the plague not only affected the demographic balance, but also disrupted all administrative and economic life.

Our long-term research focuses on these three major crises, using a multidisciplinary approach : demographic, epidemiological and genetic. The innovative side of this research lies in the use of new tools of space analysis and modelling.

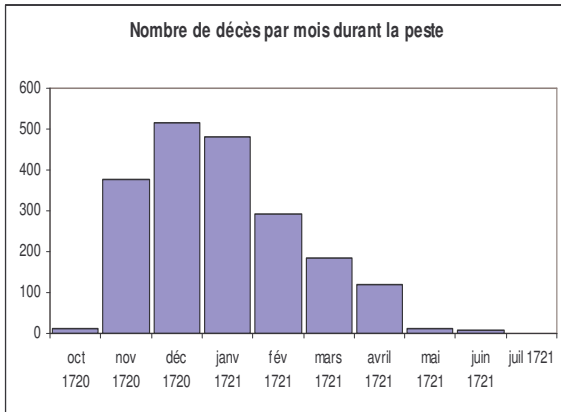


Fig. 3 : Monthly proportion of deaths during the plague at Martigues.

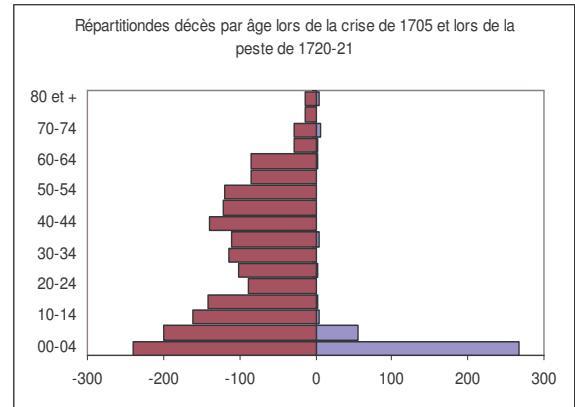


Fig. 4 : Proportion of deaths according to age during the 1705 disease and the 1720-21 plague

Geographical Information System and Epidemiology

The Contribution of a Geographical Information System (GIS)

A Geographical Information System (GIS) is a computer tool enabling representations and analyses of any event to be linked to space (environment, town planning, demography, public health). Unlike traditional mapping, in GIS geographical information is stocked in thematic layers, linked to each other (fig. 6).

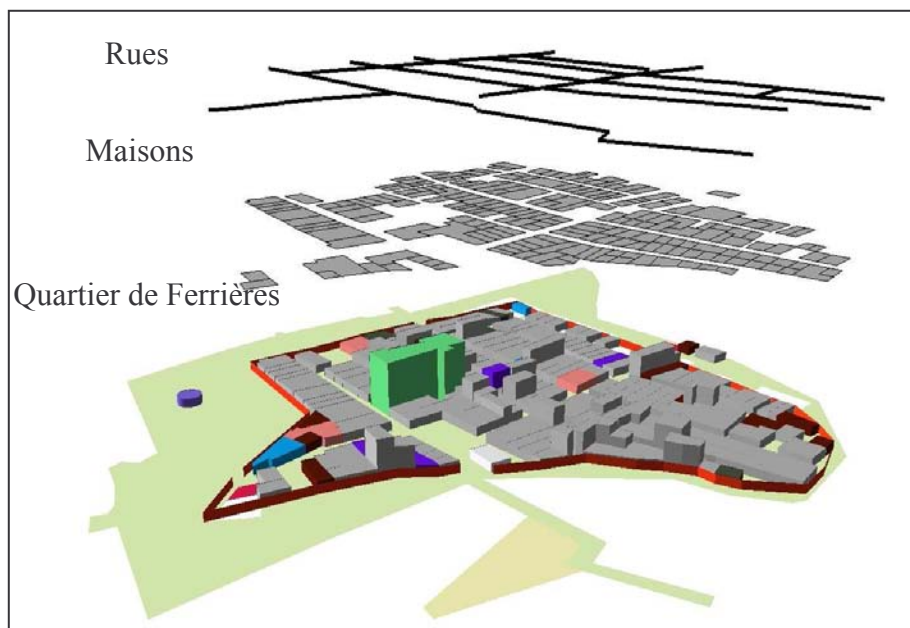


Fig. 5 : Thematic information layers

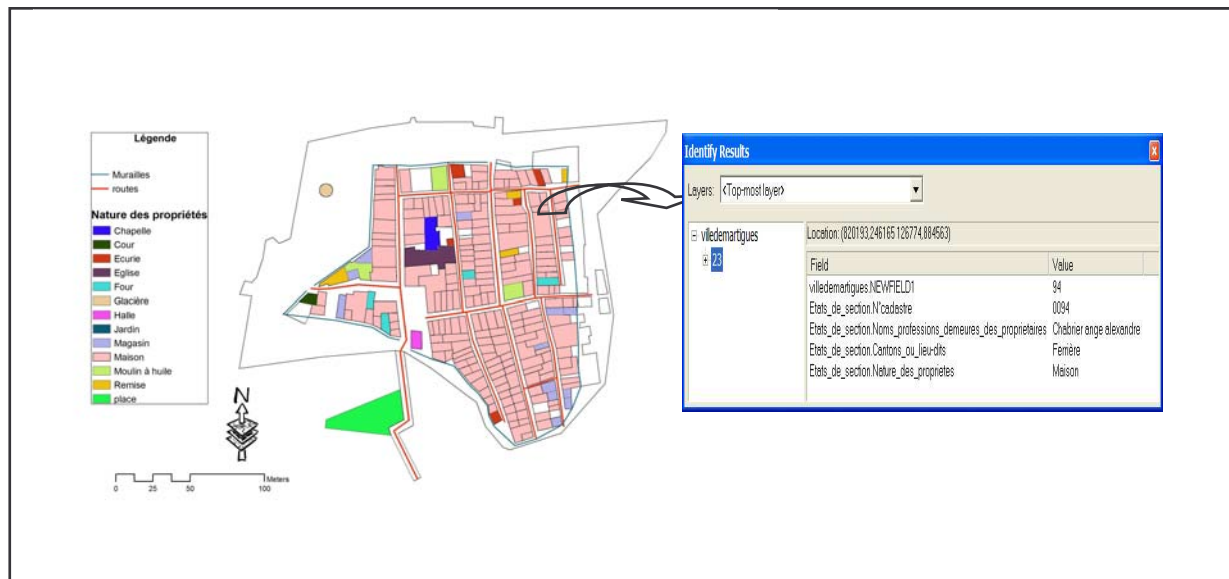


Fig. 6 : Geo-referenced map and database linked

GIS links a cartographic interface with a historical database (fig. 7). Cartographic information is digitalized (converted into a computer format) and historical data entered into or transferred onto Databases Management System where it is processed and analyzed.

Compared with traditional mapping, GIS offers a double advantage. On the one hand, it allows to create interactive maps quickly and easily : questions and analyses are answered by results presented on maps. On the other hand, and beyond this first characteristic, GIS allows for space and statistical analyses. Thus it is a perfect tool for epidemiological analyses.

Epidemiology and GIS

Mapping an epidemic diffusion is not new. One-and-a-half century ago in London, Dr John Snow located the polluted well which was at the origin of the 1854 cholera epidemic. Nowadays, health institutes use GIS to identify potential reservoirs (contaminated animals) and follow the spread of infectious diseases such as malaria, cholera, Lyme disease, and plague which is still endemic in some parts of the world. The use of these new technologies applied to epidemiological surveillance is rather new, most applications going back less than fifteen years (WHO, 1999).

But, as far we know, this project is the first to use GIS in order to follow an epidemic in the past⁹. It is particularly interesting because in recent years epidemiologists have turned towards the plague or smallpox, in the context of re-emerging epidemic diseases and bio-terrorist threats. To understand and to model the modes of epidemic diffusion, in past and violent episodes, is most useful, not only for historians but also for epidemiologists.

⁹ We should point out the use of historical applications in connection with the causes of death according to the geographical distribution of the various social classes in London (end of the XIXth century and end of the XXth century : Orford, *et al.*, 2002).

A GIS for the City of Martigues at the Beginning of the XVIIIth century

For lack of previous and reliable cartographic documents, we chose the "Napoleonic" cadastre as the cartographic support for the elaboration of our GIS. The Martigues cadastre shows on two maps the three parishes of Jonquières, Isle and Ferrières which constituted the three urban districts. These documents (maps and associated descriptive text) were produced with good topographical precision, this enabling their insertion into a geomatic application.

From the Present Cadastre Back to the « Napoleonic » Cadastre

SIG was elaborated with software Esri ArcGis-9. Both cadastral sheets were first digitized, then geo-referenced, and each numerized picture was given Lambert II coordinates. The present cadastre of Martigues is geo-referenced according to Autocad DXF.

From the land register of 1817, corrected and given Lambert II coordinates, we created a polygonal vector-layer, by following the drawings of houses. Each house drawn in vector mode is linked to its own information in the database.

The vectorial layers can be converted into three dimensions, the height of each house being calculated on the basis of the number of floors indicated in the list of owners.

It is thus possible to create an interactive map of the city of Martigues, which allows one to follow and analyse the spatial progression of epidemics.

A Regressive Approach towards the Urban Topography of the XVIIIth century

Taking into consideration important modifications in the city of Martigues, it has been necessary to adapt the topography of 1817, in order to be as close as possible to the 1716 topography, as known from land registers. At present, only the 1716 registers have been studied and their reconstruction in the form of plans is underway. There are some difficulties, and reconstruction requires a certain amount of interpretation (identification of streets and urban spaces which changed names and functions ; reconstruction of the number of storeys of houses).

Preliminary results and medium-term perspectives

Reconstruction of the Urban Topography of the City of Martigues in the early XVIIIth century

An ancient map (map 5) drawn in 1633 by Jacques Marez, depicted the city and its walls at the beginning of the XVIIth century.

A century later, the urban space such as we are able to restore it, had undergone no major transformations. All the religious buildings (churches, nunneries, chapels, hospitals) were in place since the beginning of the XVIIth century. Each district had its own parish church, chapels, ovens and mills. Hospitals, nunneries, schools and fountains were less evenly distributed.

The line of walls, which is very clear, still determined the topography of the city, although numerous houses had already been built beyond the walls, near the city gates.



Map 5 : Martigues drawn by Marez, 1633.

Thus, in Ferrières, the quarter of the “Bourgade” was located outside the walls, while “the countryside” (whose inhabitants had been partially counted in 1702), was characterized by the dispersed settlement of a rural zone. The line of the city walls in this quarter has been traced, as follows: towards the Etang de Berre, it was probably consisted of the walls of houses. The same situation seems to have prevailed on Southern side, at least up to the harbour of Ferrières, and the Saint-Jaume quay, where there was a real city wall. On the Northern and Western sides, however, the city wall was fortified by gates and defensive moats. At the beginning of the XVIIIth century, the city walls were badly maintained, the city gates were falling into ruin, and the moats, which were also used for the evacuation of stagnant waters, were silted up.

The Mediaeval *enceinte*, which had been enlarged at the end of the XVIth century so as to include the quarter of “Le Plan” and the “Rue Neuve” (New Street, which fell under the jurisdiction of the Ile district), had lost its ancient splendour. The city walls, however, restricted the city to a very narrow space; the regularity of the streets and the alignment of houses are reminiscent of the Mediaeval « new city ». Only subsequent modifications in the distribution of plots of land succeeded in breaking up the original regularity.

Reconstruction of Houses and Households

The land registers allow us to locate buildings in relation to each other and to differentiate between houses and shops, and between those built or in ruin in 1716. By crosschecking the onomastic data, we are able to spot the inhabitants who had already been named in the 1702 census, as owners or tenants. Consequently, we could allocate houses identified in 1716 to specific 1702 households. This implies that the house owners of 1716 had always lived in the same houses, that they had not let out their homes, and that their tenants of 1702 had not moved elsewhere ...

As regard houses whose owners had changed between 1702 and 1716, we decided to recreate the 1702 household by following the census recorder, from one house to next and from one street to the next. For the most difficult cases, we will use statistical tools of GIS in order to allocate homes within a range of possibilities.

The Ferrières district, which serves here as an example, is endowed with an unfortunate peculiarity : the number of households per house was not specified in 1702 ! If we allocate one house to each household, we end up with too many houses in the district. So, by a random process, we put several households into some houses, according to the surface of the house and the number of supposed storeys.

The 1705 Epidemic

We have not had enough time to present the diffusion of this epidemic throughout the city. As regards the sole quarter of Ferrières, it appears that this epidemic lasted seven weeks (from the end of September¹⁰ to mid-November 1705) and killed 72 persons (85 % of under five years olds and 95 % of under tens).

From a spatial point of view, the epidemic appears to have spread across the entire quarter, without a definite nucleus. From a chronological point of view, the epidemic started suddenly and affected exclusively children under 10 years old. The number of victims decreased until a resurgence of the disease four weeks later. It was only then that the epidemic hit older victims : two 10-year old children and a 80-year old individual, all three with family ties with one of the young victims.

The young age of the victims, as well as a period of incubation and of contagion between three or four weeks, seem to confirm the diagnosis of smallpox.

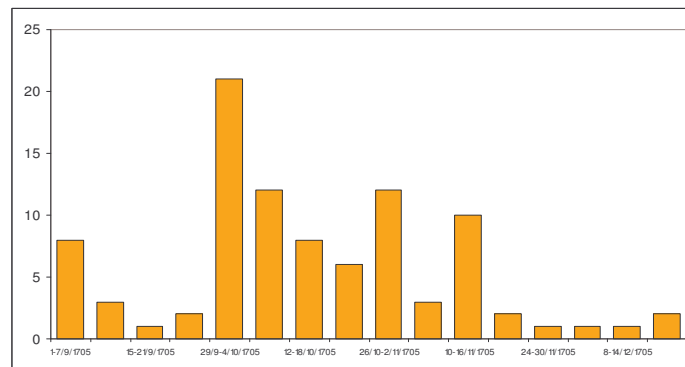


Fig. 7 : Number of weekly deaths at Ferrières, from September to December 1705

The Epidemics of 1709 and 1720-21

We started to work on the list of the dead from the plague and to detect them in the list of inhabitants by names and surnames. For the moment, the yield is small (about 20 % of the victims of 1720 correspond to families listed in the 1702 census). This seems to be due, not only to patronymic variants, but also largely to migrations which affected Martigues in this quarter of century.

Consequently, it will be necessary to obtain a continuous chain of information from 1702 to 1720, by means of the registers of baptisms, marriages and burials, in order to identify incoming families and those who left the city (work in progress). The idea is to allot, per street, to the newly arrived families, houses previously rented by outgoing families. If families owned their homes, their identification and localisation will be facilitated thanks to land registers.

¹⁰ The deaths of the first week of September represent the tail-end of the seasonal excessive mortality of August, resulting from fevers connected with the passage of herds of sheep (transhumance).

Medium-term Perspectives

Since the application of a GIS on a local scale (the city of Martigues) and on a regional one (Provence and Lower Languedoc) represents a major investment (Séguy, Bernigaud, *et al.*, to be published), we would like to use these tools within a broader context, both chronologically and thematically.

Subsequently, we intend to observe local and regional epidemics in the long term (XVIIth – XIXth century). The good preservation of registers enables us to widen our study, both in time and space.

The Martigues GIS also offers interesting perspectives in historical demography : the analysis of demographic phenomena could be based on an analysis of networks and on spatial-temporal dynamics.

Conclusion

The research described here highlights the necessary conditions for spatial analysis in historical demography. The reconstruction of the geographical space of modern populations presupposes that one has at one's disposal both precise and reliable cartographic documents as well as descriptive sources, both numerous and varied. Historical documents, even those bearing geographical descriptions, cannot be directly integrated into a Geographical Information System, which demands a high degree of topographical precision. The passage from one to the other, from a descriptive text to geo-referenced data rests on a number of hypotheses and sometimes partly on interpretation.

Taking into consideration chronological gaps between various documents, on the one hand, we were led to take into account topographical changes between the XIXth and the XVIIIth century, and on the other one, to assume a certain stability between 1702 and 1716.

As the information varies from one document to another, it is impossible to treat them in a homogenous fashion in covering the entire city, and many adaptations are necessary. We are better informed about those amongst the inhabitants who were landowners and generally stable, keeping to one residence. We know less about tenants (who were numerous), and localizing their residence entailed a certain amount of uncertainty.

The most important aspect of this epidemiological study, however, is not the accuracy of information down to each house, but spatial coherence and a certain knowledge of the relationships which linked together the inhabitants of Martigues.

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