A Computer-aided Geo-archaeological Survey of the Classical Landscape of Central Anatolia

Frank Vermeulen
Department of Archaeology, Universiteit Gent
Blandijnberg 2, B-9000 Gent, Belgium.
E-mail: frank.vermeulen@rug.ac.be

Introduction

Between 1990 and 1996, a field survey, conducted by a Belgian team, around the Graeco-Roman town of Pessinus in Central-Anatolia, has yielded new data, for the study of classical landscapes and their evolution. Although the scale of this work was limited, the specific geo-archaeological approach and the use of computer-aided technology, contributed to a better understanding of a rural and suburban territory, and, in particular of the town-country nexus, in Antiquity.

During the first phase of the programme, geographers and archaeologists deployed separate sets of techniques, in order to be well prepared for the ultimate conjunct action. Due to the lack of adequate maps of the area under investigation, it was necessary for the geographic team to produce their own map information. Therefore, initially, fieldwork focused on mapping three main areas: lithology, land use and vegetation and geomorphology. To do this, satellite imagery (e.g., T.M., Soyuz images) were processed and photomorpic units were extracted and interpreted, where possible, based on point-observations, made during several field –campaigns, using GPS-technology. These maps, together with the existing ones, formed the basis of the geographical information system (G.I.S.), elaborated for the Pessinus area. In the meantime, an archaeological team evaluated the potential of a survey in the field. Intensive field surveys, in the suburban area of Pessinus, were not only aimed at locating the precise extension of the inhabited area, but were also concerned with tackling problems, such as bad visibility, dating, and interpreting structures and artefacts. The presence and visibility of sites, and especially non-sites (roads, field systems, etc.), were analysed, and several post-depositional processes were studied.

The second phase, of this research programme, had a full-scale, interdisciplinary character. Most of the fieldwork was then accomplished, conjunctively, between archaeologists and geographers. This intensive gathering and interpretation of data, was fully linked to the potential of the GIS.

In Pessinus, the use of GIS within the geo-archaeological approach basically is a two-fold one.

First, it was a means to visualise, analyse and interpret the landscape and its human components.

Within this, already classical use, much attention was paid to the spatial analysis of settlements. For the whole settlement system, as well as for each single site, environmental analyses could be produced. These took into account, among other things: the distances to springs or river water, the locations on slopes, the distances to outcrops of natural building materials, the relation to large areas of fertile land, the relation to other settlements (e.g., the town), or to lines of transport and cross-roads.

Second, GIS was utilised, to elaborate predictive models that could actively sustain and direct further survey work. Specific archaeological questions, such as inquir into the water supply-system of the town-centre, and the nearby fields, in the Roman period, which had already been dealt with, by these combined geo-archaeological methods. By combining satellite data with a digital elevation model, and the derived information, via flow models, possible source areas could be marked and potential aqueduct-areas, mapped. This work was followed by field survey, resulting in the discovery and mapping, from source to mouth, of the ancient town's aqueducts.

An archaeological project in Central-Anatolia

It is well known that survey archaeology can be very rewarding, on the Anatolian high plateau of central Turkey. Here, away from the coast and large urban centres, where the modernisation of rural life and agriculture is a slow process, relics of the (classical) past are still abundant on the surface level. As a result of this, much archaeological survey work is now being performed in this part of the world, by foreign, as well as by Turkish teams. These activities have been greatly stimulated over the past 5 years, as the central government has drawn up a national plan of obligatory registration and mapping, for the archaeological sites in Turkey. The purpose of most of these surveys, however, is for protection and management, also a much-needed task. Many surveys, therefore, are not based on a clear scientific questionnaire and lack the necessary multi-disciplinary approach to historical landscapes. Projects, which investigate the relationship between man and landscape, or between town and country, in Antiquity, on a diachronical basis, and with the help of intensive field survey, are rare. Essential questions, concerning the influence of Hellenisation and later Romanisation of the countryside, for instance, have not yet been fully formulated here. Well-aimed and systematic surveys have, however, much potential in this field. They can add a lot of information, not available from the still dominant, city-excavations in this country. Such central sites, where earlier, large-scale stratigrafic excavations have produced a framework for chronology and artefact identification, are especially ideal bases for the screening of the surrounding, rural landscape. If disciplines, such as historical and physical geography, archaeobiology, cultural anthropology, and the analysis of written sources, accompany the whole battery of archaeological field techniques, in order to study the historical landscape as a whole, then there is a real chance, to come to some understanding of crucial themes, such as the town-country nexus, land use, and the rural economy of the past.

A recent project, combining archaeological and geographical methods, was the survey conducted, since 1990, in the territory of the ancient city of Pessinus, in central Anatolia. These prospections were part of a long-term project, by the University of Gent, under the general direction of Prof. John Devreker. The central site of Pessinus was probably inhabited from early Phrygian times (8th century BC) onwards. It owes its importance, throughout the whole of Antiquity, to its much-visited sanctuary for the goddess, Cybele. The fame of this place and its excellent location explain the urban development, from late Hellenistic times (1st century, BC) onwards, when close contacts existed with the political centre of Pergamon. The town reached its full potential in Roman and early Byzantine times (25, BC – 8th century, AD), when it became the administrative capital of a part of Galatia. Its decline was rapid and thorough, from the 8th century, AD, onwards (Devreker & Vermeulen, 1994).

The excavations, by the Belgian team, which started in 1967, have made available some substantial, diachronic data, concerning parts of the monumental city centre (temple, forum, canalisation, theatre, etc.), living quarters, and two cemeteries. Such information provides a sound base for a geographically, more extensive research in the ancient territory, surrounding the former urban core of Pessinus. This investigation can mark the changes that occurred in the city's periphery and the countryside, during the period of some, 16 centuries, concerned, and relate them to changes in the nuclear settlement. Special attention must be directed towards adaptations of the landscape and the development of land organisation, from a purely economical point of view, as well as a cultural one.

Landscape context

The area under investigation was almost centrally placed, on the Anatolian plateau, and lay some, 130 km Southwest of Ankara. This high plateau is a summer dry and -warm region, very cold in the wintertime, and is almost treeless. It lies essentially between 800 and 1000 m, above sea level. Basically, 3 types of landscape can be distinguished here.

A few kilometres north and east of the ancient city centre, a massive mountainous region rises, culminating in the peak of the 1820 m high, *Dindymos* (now Günüyüzu Dagi). This area contains some fresh water sources, but vegetation is poor here. The tectonised mountains are especially rich in granites, gneiss, marbles and crystalline limestone. These rock types fulfilled a major role in the attraction and development of human occupation, in the region in Antiquity. The outcrops of granitic rock were ideally suited for the members of the Phrygian rock culture, of the Iron Age (8th-6th century, BC), as they could use them for the construction of open air sanctuaries and rock graves (Devreker/Vermeulen, 1991). Marble and limestone were frequently used, as local building materials, during the Hellenistic, Roman and Byzantine times.

Some 60 % of the available surface in the area is, however, taken in by the plateau landscape itself. This consists, mainly, of different kinds of marl, alternated with (in Antiquity) intensely exploited banks of limestone. Their situation above most source levels, poor vegetation and strong degradation, is the result of intensive grazing, which pushed large tracts of this area into marginal agricultural land. Today, this landscape functions partly, as an extensive grassland, for the many sheep herds, and partly, as grain fields.

Finally, the third landscape is composed of river valleys. These include the wide valley of the river Sakarya (ancient *Sangarios*), as well as a number of more deeply cut vales, some of which are irrigated by small, seasonal streams. The colluvial and alluvial marls and clays transformed them into fertile axes, with a well-used potential for mixed farming. The nuclear settlement of Pessinus developed, precisely, in such favourable surroundings, in the narrow valley, of the seasonal river of *Gallos*, already attested to in Antiquity. The presence of springs and, no doubt, also of re-usable stones explain why the site, after centuries of abandonment, during the early Ottoman Empire, attracted new settlers, in modern times. Above and between the antique ruins there has grown a large village, called Ballihisar. The expansion of the latter, partly as a result of the large scale re-use of *spolia*, explains why, today, almost no ancient ruins remain visible, *in situ*, above the surface.

Early prospections

From the accounts of some 19th century French, German and British travellers, we can clearly deduce that the stripping of stone relics - in view of re-use, as building materials in the local village - has caused considerable damage, during the last century. This is especially the case in and around the urban core, but also, elsewhere within the ancient territory, where several Turkish villages sprang up, to be close to water surces. The first regular prospections, which were undertaken during the oldest phase of research directed by Prof. Pieter Lambrechts (1967-1973), were, therefore, more of an epigraphic and monument-oriented kind. Ballihisar and the other villages, within the territory of Pessinus, were then systematically surveyed, in view of the registration of ancient *spolia*, visible in the walls of the houses, village monuments, and recently constructed water basins. Because most ancient stones, especially the white marble, clearly contrasted with the smaller, unworked limestone blocks of the Turkish houses, detection and recognition were rather easy. This was especially the case, in several places, where the houses, or even the whole village, were abandoned, and the walls, themselves, or the plastering, were seriously deteriorated.

This traditional survey method not only owes its relevance to the discovery of many ancient inscriptions, which considerably added to the study of the city's *testimonia*, but also contributed to a more refined delimitation of the ancient territory of Pessinus. Indicatives, in this respect, were, i.e., the many marble *stelae*, especially the so-called, "door *stelae*". These Roman funerary monuments were not only found in large numbers, in the trenches of actually excavated cemeteries, but, due to their fine workmanship and decoration, they were also greatly appreciated by the Turkish villagers, who re-utilised them in their houses. It is precisely

this decoration, their text and possibly the materials used, which can be helpful in the demarcation of the limits of the administrative territory and the spheres of influence, of Roman Pessinus.
In accordance with some historical information (e.g., that related to the neighbouring ancient cities) and geographical data, which suggest, for instance, that the mountain range of the *Dindymos* and the course of the river *Sangarios* are acceptable borders, we can now propose, that the ancient territory was at least 600 km² large. This proposition, thus, sets the limits, for further more systematic research.

Systematic fieldwalking

A second survey phase began, together with a re-formulation of the Pessinus excavations, in the second half of the eighties and especially, in the early nineties, when the Turkish administration became more flexible, with respect to fieldwork, outside of the nuclear settlement. A more intensive fieldwalking programme was developed, within the urban and circum-urban area. Starting from the actual village site, itself, an area of ca 3 km², was completely covered, with registration of all surface artefacts. This area included the southern, western and eastern peripheries of the city, as well as sampling zones, on the northern outskirts of town, and keaching a max. of 1.6 km from the monumental centre. Following this, a series of representative areas, chosen on account of differences in landscape structure, were surveyed, all lying at a greater distance from town. They included the *Dindymos* top, the foothills of the mountain range, large tracts of plateau landscape, and several vales.

It is important to note that accessibility was excellent, almost everywhere, and that the low population density in this region today guaranteed that, except for the core of the central settlement, only a small number of sites were built over. Visibility on the surveyed, pastoral and non-arable land was good. Since all prospections had hitherto been organised, during mid-summer (mostly August), visibility of pottery and other artefacts on arable land was reduced, due to the dryness of the soil. One should also realise that the historical erosion of this landscape, locally, has been considerable. The slopes connecting the plateaux and the valleys have especially been strongly subjected to this erosion, resulting in important depositioning of colluvial material, in the lower parts of the vales. Still, the general dispersion of surface finds and the preservation degree of some superficial relics (e.g., walls, funerary monuments), point to the fact that the recent and sub-recent impact of man, on the plateaux and the mountainous areas has been very limited. Colluviation and also alluviation, however, has been responsible for covering parts of the valley landscape.

The study of these partly, natural phenomena received much attention from the geomorphologists, in this project (under the direction of Prof. M. De Dapper). The analysis of soil formation processes, erosion and sedimentation were essential, because the much eroded soils on the plateau, actually represent the arable land in Antiquity. This study of soils and erosion is a key element in the investigation of the relation, between agriculture and the environment, in the region. It helps to answer questions, such as (Jameson/Runnels/van Andel, 1994):

- what kinds of soils existed in the past ?
- where were the surface sites located in a certain period, and where are they eroded, or completely covered by deposits ?
- when did the landscape become stable, and when were sedimentation and colluviation important ?
- which part of the responsibility for these phenomena should be attributed to nature, and which part, to farmers ?

The practice, of this geomorphologic fieldwork in Pessinus, showed that different phases of colluviaton and alluviation could be dated, when confronted with information from archaeological sites and artefacts. Certain sites, found on top of an alluvial or colluvial depot, procured an *ante quem* date, for the erosion. Often, it was observed that such erosion layers covered sites and artefacts, so that a post quem date for the erosion became available. A wider view was sometimes possible, when different systems of erosion had clear stratigraphic ties. Radiometric dates are not yet at hand, but these could refine chronometry, in the near future.

The general information, obtained so far, from the study of the phenomena of erosion, demonstrates in Pessinus, that long periods of stability were interrupted at regular intervals, by relatively short periods (a few centuries) of soil erosion and alluviation. It seems that the principal causes were rapid deforestation on the plateau, agriculture without specific precautions taken, and the general abandonment of laboured fields. It is also clear that the coming of the Seldjouks and Ottomans, from the 11th century onwards, was not the sole explanation for this geologically recent erosion of the environment. Already, in Antiquity, man had directly, or indirectly, caused soil degradation in this part of the Anatolian plateau.

From these remarks, about geological investigations and archaeological visibility, we can, however, conclude that the notion, "site", may indeed be used within the context of the Pessinus survey. The two most important conditions, formulated by Foley (1981), are fulfilled here :
1. we were mostly confronted with architectural remains (e.g., foundations of towers or enclosures, grave monuments, etc.) or other anomalies (e.g., stone quarries, rock cuttings, a small tell, etc.) which are still, clearly visible on the surface, and often, still, *in situ* ;

2. the surface concentrations of archaeological material were dense (> 10 sherds/m²), so that, at least, a first hypothetical consideration, about the presence and extent of the site, can be attempted.

For the interpretation and dating of sites, as well as for more isolated phenomena, only diagnostic artefacts (e.g., TS, glass, etc.) were collected, together with a sample of the variety of small finds. All these objects were stored in the local depot, where they could be studied, in association with the many finds from the stratigrafic excavations. All relevant data, concerning the site (location, landscape features, architectural features, extent, visibility, etc.) and its finds (pottery types, other small finds, chronometry, etc.) were inventoried and processed on a PC, with ACCESS and EXCELL software.

Although, up till now, only a limited number of man days (circa 50) were spent on this, strictly archaeological, circum-urban survey, the first results were remarkable. Among a hundred sites and finds, which merit a dot on the map and fall within the specific period, focused on within this project (ca. 800, BC – 800, AD) we distinguished almost all the important phenomena, which formed the hinterland of a classical town. For the best represented Roman period (1st-5th century) alone, we distinguished some, 60 sites and non-sites, within a distance of 1.6 km from the town centre, such as:

- suburban living quarters, especially on the intermediate slopes, near the edge of the city
- large cemeteries, especially on the plateaux, surrounding the valley, where the town centre lies, and along some access roads
- some remains of ancient roads, *in situ*
- limestone quarries, often with a secondary use, as a waste disposal dump
- watch towers, with an excellent view of the city centre and the major access routes
- remnants of aqueducts, for urban water supply and distribution
- traces of rural irrigation systems
- the first farms, some distance away from the urban core.

Together, these structures present a diachronic image of intense human exploitation, on the passage from the city to the countryside, which asks for comparison with other areas, in the ancient territory, that lay further away from the urban core. As the territory of Pessinus extended way beyond this small, circum-urban area, and geographical factors greatly influenced past human activity in this large region, it is obvious that part of the survey work had to rely on a sound, geographical basis.

Constructing a GIS

From the start of this survey project in 1990, a general geographical framework was constructed. It was clear that a Geographical Information System (GIS) would be the ideal tool, to link the geographical knowledge, concerning the area, with its archaeological data. Building a GIS, for archaeological purposes, required the collection of a huge amount of data, which had to be linked and juxtaposed. The GIS had to partly contain a list of data that could be stored in a database, such as a list of observation points, with information about the artefacts found there, plus the typical characteristics, such as altitude, lithology, slope, aspect, chronology, etc. On the other hand, it needied to consist of spatial data, stored as digital maps, such as lithological maps, maps of the topography, land-use maps, maps of the archaeological sites, etc. A GIS is a tool, based on computer technology, which makes it possible to link the database with spatial data, and which can also combine database queries and spatial (vertical and horizontal) queries. 'Queries' should be understood in a broad sense, including, for instance, the modelling of the data, to provide required answers.

To feed the GIS with information, three main sources were used: (1) the collection of data, via field observations, (2) the collection and digitization of existing cartographic data and its derived products, and (3) the derivation of information, from remote-sensed imagery. At a second stage, a combination of these data could produce more advanced maps, and could be used to build and run models. Finally, this could lead to the interpretation and the elaboration of hypotheses, based on firm data.

The field observations, concerning archaeology, vegetation, lithology, geomorphology, etc., needed to be located, in order to link the information in a spatial way. Parts of these observations were located with a portable GPS (Global Positioning System)-device. The GPS technology is based on the time-distance calculation, between a set of satellites and an observation point (the NAVSTAR satellite system is such a set of satellites, broadcasting signals for this purpose). The GPS calculated the time between the broadcasting of the signal and the receiving of the signal. Knowing the exact position of the satellite, and given the calculated distance from at least three satellites, the GPS could give the location on the Earth's surface.

The availability of detailed maps (topographic, geologic, cadastral, etc.), aerial photographs, and other cartographic information of the region, was very limited, due to military circumstances.
Only part of the necessary information, such as the basic topography of the area, could be processed and digitised, using AutoCAD.

We, therefore, had to look for alternatives to build a workable GIS and confront the archaeological data with environmental aspects.

Another efficient way of collecting up-to-date, spatial data was via the use of remote-sensing techniques. Currently, the range of remote sensed data becomes larger and larger. Although it took a long time, before satellite imagery allowed detailed study on a large scale, due to its limited spatial resolution, the observation of the Earth from space, for civil purposes, has now achived such detail, that is almost comparable to aerial photography. Towards the end of this century, several satellites will provide data with less than 3m spatial resolution. This will fill up a data niche (price-coverage-detail-frequency wise) which is not yet covered by existing remote-sensing systems, nor by current aerial photography. This trend was started with the Soyuz-data, providing satellite data of about 5m spatial resolution. Currently, there are already analogous pictures of 2m spatial resolution (SPIN-2) and digital pictures with 5-6m digital resolution (IRS-1C) available. In the near future, we can expect 3 and 1m digital resolution (e.g., Earthwatch, Eyeglass, etc.). Nevertheless, the less detailed satellite imagery will still be useful for its multi-spectral data, providing more information about vegetation, lithology, temperatures, etc.

Two kinds of remotely sensed products were available for this study:

- an analogous KFA-1000 image (Soyouz) with high spatial resolution
- a digital, multispectral Thematic Mapper image (Landsat).

The KFA-1000 image was available as an analogous product (negative), from which pictures were made at different scales (up to 1:25,000 scale). The images hade a spatial resolution of about 5m, and gave a detailed picture of the area. They were ideal documents for field-work annotations and mapping, especially when aerial photographs and topographical maps were not available.

Due to this high spatial resolution, roads, villages and the drainage network could be mapped, from this document. It was even possible to map the tract of the Roman road, to the north of Pessinus, although this road was hardly recognisable in the field (see further).

Although the spatial resolution of a KFA-1000 image is 6 times as detailed as the spatial resolution of the TM image, the major advantage of the TM imagery is its multispectrality.
The different lithological units have a specific spectral reflectance, which can be used to detect and mark the units on the images. This information should be combined with other spatial data, to achieve better results.

Digital elevation model (DEM)

A DEM is a digitally-coded form of the topographical surface (Antrop,1989), or a digital (discontinuous) representation of the continuous changes of the relief in space (Burrough,1986). There are a few possible digital structures for storing the digital surface. The digital structure that was used here was the raster structure. This is a two-dimensional matrix, in which every cell contains an altitude value. The height information, to build the DEM, was obtained from digitising contour lines from available topographical maps and using an interpolation routine, to create a raster DEM. Basically, IDRISI-software was used to fulfill these essential tasks.

The advantage of using DEMs is that derived information can be extracted in an automatic and standardised way, such as slope maps, aspect maps, drainage basin maps, etc. Also, 3D views, from the study area, can be produced. As an example of data extraction from a DEM, a flow model technique was applied to extract information of interest.

Flow models are frequently applied to hydrological applications (Mallants & Feyen, 1989; Romanowicz, et al., 1993; Kirkby, 1990; Desmet,1993). They are based on the simulation of a drop, which 'moves' over the digital topographical surface. The model reads the surrounding heights, the steepest way down is calculated, and the 'drop' moves to the new location, following the steepest way down. During the 'flow', several variables can be calculated and recorded to new maps.

The principle of the flow model can be used to derive a variety of geographical information, which is related to the combination of gravity and topography (e.g., mapping of colluvial material, mapping of drainage networks, modelling the flow of debris on archaeological sites, etc.). A program, COLWHAT, was written to be able to find out what kind of lithological debris can be found at certain places, by simulating colluvial processes, when a lithological map and a raster DEM, are available. The principle of the program is the following:

The program starts to read the lithological unit, at a certain place (raster cell). The height values are read from the surrounding raster cells, and the steepest way down is followed. Every time a new raster cell is passed, it is marked that the colluvium, from the lithological unit at the start, *can be* received at this position. If no direction down is found, a next starting cell is selected, and the program continues, until all the raster cells have been selected as the starting cell. It is obvious, that the possible location of the colluvium (or alluvium) is based on the current topographical situation. The method does not work for colluvial pockets, that are based on palaeo-topographic situations. If a map is used, of archaeological sites locations, instead of a lithological map, the end result will show places, where artefacts from those archaeological sites can be found, if they were removed by colluvial or alluvial processes. In this way, some of the post-depositional processes can be studied more closely.

The geo-archaeological approach

Since the beginning of this century, archaeologists have borrowed, and/or developed, a whole range of techniques to visualise, analyse and interpret spatial patterns, in the archaeological record. GIS has not only added a new technique, but has modified thoroughly, the underlying philosophy regarding the use of spatial data (Lock & Harris, 1990). The availability of such a system allows one to do real, geo-archaeological work, which is more than employing a series of geological or geographical methods, in an archaeological context. Geographical techniques should, indeed, be focused on the archaeological questionnaire, from the start of any regional project, especially with regard to site definition, settlement analysis, palaeodemography, ancient land use, soil erosion and processes of soil covering. The main purpose should be a flexible integration of geographical and archaeological aims, not the least of which should be at the field survey level, itself.

In Pessinus, the use of GIS, within the geo-archaeological approach was basically twofold. First, it was a means to visualise, analyse and interpret the landscape and its human components. Second, GIS was utilised to elaborate predictive models, that could actively sustain and direct further survey work.

1. Within its first and more classical use, much attention was paid to the spatial analysis of the settlement system. To do this, all digital information (be it of archaeological or geographical nature) was transferred (in 1997) to a suitable GIS-software environment, namely a combination of ARC INFO and ARC VIEW GIS.

The base for this analysis was the elaboration of dispersion maps, per period and/or per function for the sites. This permited, amongst other things, studying the forms of continuity between periods and sub-periods. In Pessinus, for instance, this lead to the visualisation of remarkable contrasts, between the pre-Roman, Roman and Byzantine occupations of the landscape. But also, clear differences between the very flourishing first century of Roman dominance, and the later Empire, could be observed.
These kinds of analyses acquired more importance, when the relationships between the archaeological phenomena and the environmental variables were investigated. For the whole

settlement system, as well as for each single site, environmental analyses could be produced. These took into account, among other things: the distance to springs or river water, the location on slopes, the distance to outcrops of natural building materials, and the relation with large areas of fertile land, or with lines of transport and cross-roads. The preference for a certain altitude, or a particular orientation was also measured.

Another series of maps was concerned with the relation among settlements, and with the relation between the farms and the urban core. Essential here was the hierarchisation of the sites, based on their superficies and/or their particular status. The former could be deduced from a critical appraisal of the survey information, taking into account problems of erosion and other post-depositional processes. The latter was more or less measurable, through the presence or absence of certain materials at the sites, such as for the Pessinus area: stucco, window glass, marble, terracotta pipes and pithoi. Again, it was important to study the evolution of these relations, and to weigh them against a geological and geographical background.

Although not all of the interpretative work has been completed (as some additional surveys, and especially the borings, remain to be done in Pessinus), at least, some interesting diachronic features of the occupation history have begun to be revealed. As this paper, above all, has a methodological objective, we will restrict our comments to two major observations.

A first, observable pattern was the general shift of settlement sites, from the foothills and mountainous areas, in Phrygian and pre-Hellenistic times, towards the valleys, at least from the Roman period, onwards. It seems that matters such as security and the presence of rock outcrops were dominant, for site location in pre-classical times. Agricultural motives and the connection with transport routes prevailed, in the more secure, Roman era. A more efficient use of different landscape components was part of the explanation here, so were the development of techniques for irrigation and land organisation.

Another, more remarkable, observation concerned the very low density of Hellenistic agrarian sites, within the city's territory. This was in great contrast to the Roman and early Byzantine, dispersed settlement, characterised by a more systematic land use, such as artificial irrigation in the valleys, the spread and ideal location of isolated farms, versus the different landscapes, and the probable presence of small specialised nuclear sites, for central processing and storage of agricultural products. Therefore, the question can be raised whether this central-Anatolian countryside had been more, or less, dramatically re-organised in early Roman times. Here, we can think of a shift from an agricultural system modelled on the Greek *polis*, with an urban centre, housing the peasant population, to a typical Roman system, that integrated the dispersed rural settlement, within a more firmly organised countryside. This interesting hypothesis is in keeping with the results from some other surveys in Turkey (Alcock,1994). Work in Troas, for example, demonstrated that the population of the region lived essentially in the urban areas. From the Early Roman period (Augustean era), onwards, when the monumental centre of Pessinus was in full expansion and the population grew rapidly, we can see a real "colonisation" of the rural *hinterland,* of the *polis*. This dispersion of small rural settlements in the landscape is probably proof of an intensive agriculture, implicating a large number of people and high profits (Alcock, Cherry & Davies, 1994).

2. A second, geo-archaeological field of application concerns modelling and survey support. Here, especially good and sometimes new opportunities, for the successful integration of both disciplines, are to be found. This could be demonstrated at Pessinus in a number of ways. Thus, for instance, joint field surveys by archaeologists and geomorphologists were organised, during the most recent campaigns (ca. 50 man days). They took place in areas, mainly large valleys, specially chosen on the basis of a predicted model for site location. This resulted in a high discovery percentage of settlements and cemeteries. Concerning the latter, for instance, the hypothesis, that especially, Hellenistic and Roman tombs would have been located in very visible zones (as they normally consisted of monumental structures, situated above ground (e.g., door stelae), was very helpful in detection work.

As a result of GIS manipulation of satellite data, also ancient, non-site (or off-site) phenomena were tracked and later confirmed in the field. Amongst others, we mention here the precise tracking of the main Roman road from Amorion to Germa, which crossed the Pessinus territory, and also the mapping of ancient quarries and potential quarries, for the extraction of marble and limestone building materials.

The best example of the elaboration of a hypothetical model, confirmed in the field, is related to Roman water supply. The 1991 urban excavations demonstrated, for the first time, that an intricate network of water pipes was constructed in Pessinus, during the first century, AD. This implies that the high comfort needs of the Romans, and especially the availability of running water for fountains, public baths, etc., necessitated, at least from the Flavian reign onwards, that the local water supply be supplemented by water, brought into the city. Thanks to the geomorphologic location of source areas, in the foothills of the tectonised mass, the GIS was called upon, to help locate plausible lines of water supply, within the Roman landscape.

From satellite imagery, areas that still have a green vegetation cover, during the summer, can be easily observed. This might be related to a certain aquifer. Combining the satellite data with the DEM, and the derived information via flow models, possible source areas could be marked. It was assumed that these source areas could have been the source areas that the Romans used, to get water to Pessinus, via an aqueduct. Knowing the location of the possible source areas, there are only a few possible areas, where the aqueducts could have been built. It was assumed that no big and complicated engineering works were carried out, to construct the aqueduct(s), if this was not necessary: an application of the "no-nonsense and least effort principle". As the aqueduct had to follow the topography, this general rule had to be observed: the aqueduct, at a certain place, could go to any surrounding place that was located at a lower elevation. A combination of the data, stored in the GIS, and this rule (translated in the AQUADUC-program, built by the Gent team) leads to the automatic mapping of the possible and potential aqueduct-areas.

This work was followed by an efficiently steered, joint field survey, resulting in the complete mapping, from source to mouth, of one aqueduct (length : circa 7 km) and the location, in part, of a second. Both were essentially terracotta pipelines, laid in a simple underground trench (*specus*), which generally followed the topography well. Fragments of such terracotta pipes were discovered at several locations, during fieldwalking. But, at least in one instance, more elaborate, marble and limestone constructions were needed, to cross a narrow valley. The northern aqueduct, which has been mapped from source to user, was locally built as a canal, made up of U-shaped blocks of marble. Negative remains of this, more expensive, local system (at least 200 m long) were discovered, in the shape of the calcified packs of slip layers, still attached to a thin coating of Roman concrete (*opus caementicium*). This petrified filling of the original aqueduct, was broken into large blocks, by the Ottoman population of a nearby village, and was reused by them, as tombstones in their graveyard, where they were found by the archaeologists.

Both aqueducts end in built reservoirs, lying on the high edges of the urban area, where distribution into the whole city centre was made possible. In one location, the remains, of such a distribution structure, were found, *in situ*.

It seems that part of the transported water was used for the irrigation of nearby fields, and possibly, also, for the provision of nearby Roman farms.

Conclusion

The study of the geomorphology, of the area around Pessinus, showed that certain landforms and elements of landforms changed enormously, during historical times. A further study and modelling, of this dynamic aspect of the landscape, seems important, in relation to archaeological prospections. Constructions or artefacts of pre-, proto- or historical times can be covered, removed and deposited somewhere else, depending on their topographical location. Archaeological research also contributes considerably, to the geomorphologic study of the area. The abundance, of archaeological artefacts in the area, helps to model the dynamic behaviour of the landforms, since these artefacts function as time-markers and tracers, in the thick, colluvial packets. Although the archaeological-geomorphologic dataset is still too limited, to quantify the landscape changes and model them in a mathematical, rather than descriptive way, it seems that this can become possible in the future, when more geomorphologic and archaeological, quantified data of the area are gathered.

Digital data about the topography, in the form of DEMs, make it possible to map the morphology in an automatic way. When automatic mapping from satellite imagery and a DEM are combined with geographical knowledge, concerning geomorphology, lithology, land-use and vegetation, they can produce information, that cannot be obtained from separate approaches. By using the geographical data in a GIS environment, important 'probable' answers to archaeological questions can be given, as was shown by the example of the Roman aqueduct. The answers to this type of problem will seldom be given by standardised procedures. Therefore, it seems that a combination of flexible procedures, and data in a GIS, are an efficient tool for the diachronic reconstruction of the historical landscape, for a given region. The specific, geo-archaeological approach, applied here, is certainly one method, to pursue further, in the near future.

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Fig. 3 Surface ruins of the urban core of Pessinus (cf., the Roman canal and colonnade) are only temporarily visible in the riverbed, in the village of Ballihisar.
Fig. 4 Colluvial deposits can be well studied in the Pessinus area. Sometimes they are related to dated archaeological sites.
Fig. 5 Archaeological visibility of surface features is excellent, especially in the non-arable land, on top of the plateau.
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