THE GEOPHYSICAL STUDY OF BURIED ARCHAEOLOGICAL REMAINS AND THE PRESERVATION OF THE ARCHITECTURAL PATRIMONY OF MEXICO CITY

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ABSTRACT:
Five years ago, the Archaeological Research Laboratory established a pilot project to study the archaeological remains buried under the present surface of the Coyoacán and Churubusco neighborhoods in southern Mexico City. The structures that once were part of these important pre-Hispanic settlements were destroyed and their remains have been covered by sediments through the years. Nowadays, the differential sinking of the floor of the Basin of Mexico is producing a topographic relief just in the places where a previous compaction of the sediments has taken place. Our team has proved that the best approach to study archaeological remains under modern urban developments is the application of geophysical techniques. Top date, results from the study carried out at Coyoacán have demonstrated that magnetic gradient, electrostatic resistivity and earth penetrating radar are the best geophysical techniques to locate and study buried archaeological structures avoiding any damage to the surface. Some studies have reached the Churubusco neighborhood where some ceremonial and domestic structures were excavated. The same kinds of studies can be applied to the whole of Mexico City. The long-term goal is to produce an inventory of the location of buried archaeological remains underneath the city's pavement to prevent any damage caused by the construction of modern private buildings or public urban structures. Besides this evident function, we have observed that many problems affecting the stability of the structures included in the inventory of the city's heritage are closely related to the existence of archaeological remains underneath them. This is especially dangerous during the seismic events the city frequently experiences. The main contribution of this project is to provide information to locate, evaluate and preserve the buried archaeological remains and the patrimony that is part of the modern city.

1. INTRODUCTION

In some locations in Mexico City its surface appears rippled, irregularities that are not evident in photos and drawings from the turn of the century. This is associated to two origins: Location of pre-Columbian settlements and the recent sinking of the city. At the Anthropological Research Institute's Archaeological Prospection Laboratory a project is under way to systematically study archaeological sites so to make an inventory to work in a city where the predictive aspects are hard to consider. The difference between geotechnical properties in pre-compacted soils in relation to their environs has been remarked recently with the intensification in the city's rates of sinking. This differential affectation can be seen in the re-accommodation and fractures both on the surface as well as on the buildings. The speed with which water is being extracted from the city's subsoil ensures that this process is unstoppable and the sinking will continue thereby worsening the phenomenon. In this sense, studies will enable us to locate most damaged areas and to explain the causes that produce them.

In the present paper we resort to the geotechnical properties of pre-compacted soil in respect of their environs, which are causing differential sinking. The hypothesis under study is that if these differences represent changes produced by human settlements, then, archaeological sites covered by modern urban settlements can be recognized and studied from the surface, using geophysical techniques.

2. CARTOGRAPHIC BACKGROUND

To determine the approximate localization of sixteenth century human settlements, we studied ancient maps of what used to be the lake zone and its association with the present day city. Furthermore the toponyms were analyzed for they indicate the presence of ancient settlements. It's surprising how many nahuatl toponyms are still extant and can be seen in modern maps, in the names of alleys, streets, neighborhoods and the like.

Sixteenth century maps show a recently rebuilt Mexico City with some islets surrounding the center of the former Mexico-Tenochtitlan. In the Cortez Map, *chinampas* are vaguely depicted as concentric alignments surrounding the main settlement. The Uppsala Map doesn't pay much attention neither to the islet nor to the *chinampas*, since it only identifies Iztacalco. Recently, the map drawn by González Aparicio (1973) and published in a modified fashion by the *Arqueología Mexicana* magazine (1995), shows the location of several islets built on the western part of the Texcoco Lake. Sites of potential pre-Hispanic settlements appear to be concentrated in a space spanning the western lakeshore and the San Lázaro dyke, and between Tepeyac and Culhuacán as well.

These maps show that the western part of the lake was the least deep. This might have been the consequence of the buildup of sediments coming from the Sierra de las Cruces range. Therefore, this zone was the most likely to be settled, since its shallowness eased the building of a landfill which raised the level of the lake's surface artificially by resorting to man-made islets, *chinampas* and the like. In the Cortez Map, the Tenochtitlan islet can be seen at the center, completely surrounded by water. Nevertheless, 50 years later, in the Uppsala Map, the land ranging between Tacuba and Azcapotzalco is depicted as dry land. Churubusco, after being a lake settlement, it becomes a lakeshore village in the Uppsala Map. In the following half-century, the entire western region of the city gradually became dry land which during the rainy season turned into quagmires. From 1520 to 1620 the lake level could have diminished by some meters, thus reducing the body of water between the eastern parts of the dyke to the Texcoco lakeshore.

For the reasons so explained, the western zone of the basin favored the founding of most settlements depicted on the ancient maps. However, historic cartographic limitations produced inaccurate maps that make pinpointing areas on present day urban maps especially difficult. It's evident that for this and other reasons we cannot to assure the location of islets in a determined zone, by resorting to this information alone.

We can consider that the group of islets in the lake should have been formed by regularly spread *chinampas* and canals. Nonetheless, the ruling centers of each community should have contained larger islets whose better foundations supported heavier structures. This would cause different soil pre-compaction conditions, lighter on the farming *chinampas* and heavier on the ritual and administrative zones. The other extreme would be constituted by the ruins of the Main Temple, wherein the soil is mostly pre-compacted. Succeeding building phases gradually compacted the subsoil further, which, now freed from the load of colonial buildings and having lost most of its original volume and weight, is now recovering itself and rising over the street level that used to cover it (Mazari *et al* 1985).

3. THE SINKING OF THE CITY

The sinking of Mexico City is one of the great problems this major urban center is facing. The problem is originated in its inhabitants' huge water supply needs and the consequences are manifold. For the purposes of this research, the most relevant consequence is structural affectation caused by differential sinking. In many places within the city it is noticeable the crinkles and the caving in of architectural structures whose walls thus show tilted cracks. This causes huge maintenance costs, specially in structures classified as part of the nation's architectural heritage. A recent example is the great effort undertaken to save the Metropolitan Cathedral, deformed by differential sinking and by the existence of pre-Hispanic structures beneath it, for which a huge amount of economic resources are being spent every year (Matos 1992). The proposed solution has to do with the importance of the structure being preserved, yet as the features of the damaged structures are so varied and so many, it's however crucial to understand the phenomenon that affects them so to prevent aspects which are later hard to correct.

Studies complied by Marsal and Mazari (1969) and Kumate and Mazari (1990) on the city's problems, have helped to understand the phenomenon causing the difference in performance of pre-compacted soils. Ovando and Manzanilla (1997:65), describe that after applying a charge to the clays that form the city's subsoil, they expel water and diminish its volume, thus causing the material to harden and become less compressible. In this case, most of the studied pre-compaction cases appear to be a result of the accumulation of building materials throughout some centuries.

In the case of a larger structure that would have required a foundation with wooden beams, the performance of the land would be even more contrasting. This type of foundation would support remains of a pre-Hispanic structure with its floors and the toppling of its walls and roofs, which would sink at a different speed than in the less altered terrain that surrounds it. These differences can currently be seen as sinking and topographic relief at the streets of Mexico City. Yet more still, these differences in building techniques are in stark contrast with the soil that was once the bottom of the lake, which lack human labor and consequently pre-compaction. Together with the overall sinking of the city, differential sinking occurs daily in which the sinking of the less consolidated soil is faster than that of the pre-compacted land, then the presence of mounds over the surface is a phenomenon every day more evident.

Summing up, in ascending order we can tentatively sort out the precompaction process in the bottom of the unaltered basin, the less-altered farming plots, and the landfills used to built platforms and floors. At the highest level, we would have the ceremonial and administrative stone structures with wooden foundations which represent the utmost alteration level. Currently, the latter would be plots of land that would show outstanding differences on the topographic relief and these would be what we might record in this study.

As it's well known, there is an average rate of sinking for the city. However, every zone has its own particular rate. Registers collected in the past century (Kumate and Mazari 1990) enable us to know how some areas of the city have been sinking. Average sinking varies from 7 to 9 meters, yet there are specific zones in which the rate is just 6 or 7 meters, which are revealed as mounds measuring 1 or 2 meters.

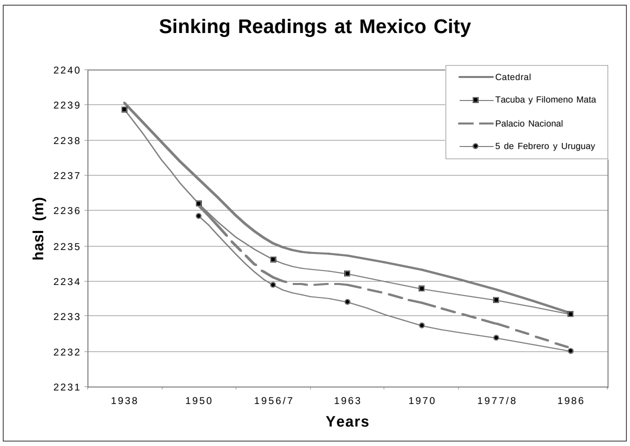

Figure 1. Table of readings of height above sea level through time in four points at downtown Mexico City

Due to the presence of big architectural structures now in danger of collapsing, one of the locations under study from a geotechnical standpoint is downtown Mexico City. However, throughout the lake basin there are other sites sharing the same features that, at a lesser scale, harbor similar problems. It's quite likely that the currently visible mounds do correspond to an artificial islet formed on the lake basin, due to the accumulation of layers of earth and building materials from pre-Hispanic times.

4. SURFACE INDICATORS

The participation of the Prospection Laboratory in archaeological projects undertaken in lake areas such as: Terremote-Tlaltenco (Serra 1986); the archaeological rescue of the Xochimilco zone (Lazcano 1995); Loma Alta and Guadalupe, Michoacán (Hesse et. al, 1996) and more recently in Santa Cruz Atizapán, Mexico State, have enabled the localization and study of these ancient islets. The results of these projects contributed in determining the presence of residential units, or larger structures of communitarian or ceremonial character.

Thus Avila's work (1991) in the Iztapalapa and Tlahuac zones recorded the existence of *chinampas* and islets built by their dwellers. These represent artificial mounds raised upon the average level of the lake's surface, wherein the buildings were put up, and where the inhabitants undertook all of their main activities (Rojas 1995). Data collected during the studies at Tlaltenco and Xochimilco show that these islets could only measure 50 cm or exceed 1.50 meters in height, while its shape might be round, oval, or elongated in the shape of a 20 to 50 m long at its central axis. These features are closely related to the form and the height of some of the mounds now seen on the city's streets. As Masari et al. (1989) has documented thoroughly, islets built based on the accretion of land use to constantly sink, thus making adding soil periodically necessary to keep the surface above the water level. This causes a progressive compaction of soil which has gone normally unnoticed. Namely, these differences in soil pre-compaction weren't discovered till 1940 when the water extraction rate increased thus causing the rapid sinking of the city and the appearance of those mounds in certain areas of the city.

4.1 Recording of Mounds

Based upon a documental study, cartographic observations were verified. knolls on the city streets were recorded so to produce maps that could emphasize them, for they might constitute ancient islets. As has been stated before, some previous measurements (Marsal & Masari 1969; and Kumate & Masari 1990) were used, since they show the progressive sinking of the city.

The investigation gave priority to nahuatl toponyms which directed the search towards neighborhoods with an irregular and narrow urban plan, a feature of ancient settlements. At these zones every street was analyzed thoroughly, recording every knoll on a map. At the same time a photographic record was undertaken. Thus zones such as Zacahuizco, Tetepilco, Tultengo, Iztapalapa, Culhuacan, Iztacalco, Churubusco, Coyoacán, Acoxpa, and Coapa were studied.

By the end of this stage, we had a clear idea of the areas wherein mounds were concentrated, representing the larger archaeological structures lying beneath the pavement of southern Mexico City, especially downtown area. At the present, we have a database pinpointing these sites, their structures and some of their features.

Figure 2. Areas of Mexico City where mounds are concentrated (dotted lines)

5. RESULTS

The map based on González Aparicio's study (1973) gathers the documentary and archaeological information available in the seventies. It determines the probable places of pre-Hispanic settlement in the lakeshores and in the lake itself. One of the main features of this map is that it refers both to Tenochtitlán's main islet and to the smaller settlements as well. For the first time it offered a clear idea on the distribution of the pre-Hispanic settlements, which by recent data, coincide in many cases with the mounds found in some of the city's traditional neighborhoods.

For instance, the Aztlacalco area, which shows a great concentration of topographic knolls, is spread across most of the Roma neighborhood. Zacahuizco and Tetepilco, in turn, show concentration zones with clearly drawn mounds and they preserve their former pre-Hispanic names. At the Tultengo and Mixhuca zones we haven't found any association with street mounds thus far. However, downtown Mexico City, including the erstwhile Tenochtitlan islet, corresponds to the distribution of a great

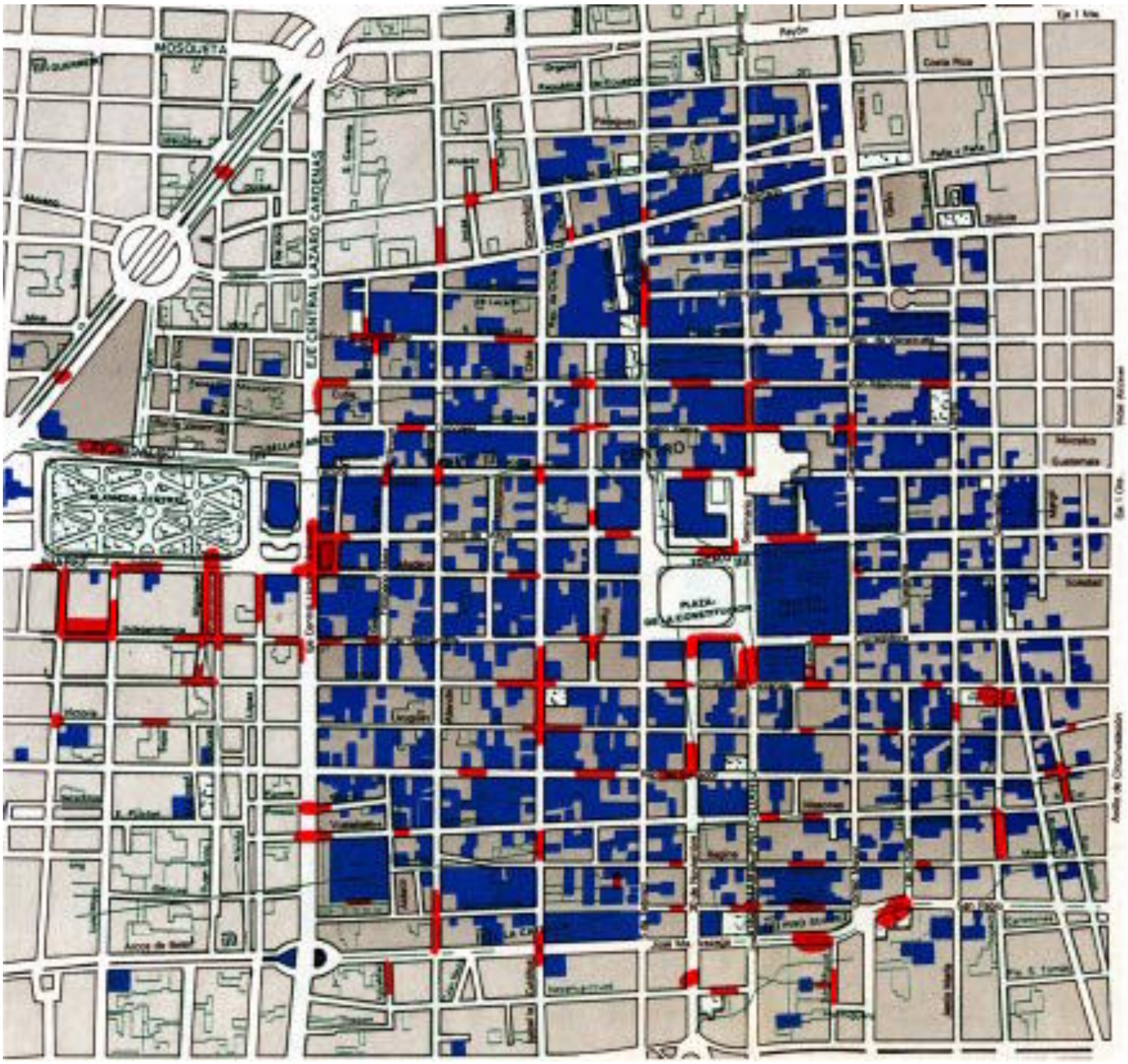

Figure 3. Patrimonial buildings and topographic prominences in downtown area Mexico City. There is a clear relationship among cataloged buildings and the marks of the mounds produced by archaeological remains.

concentration of recorded prominences. On most streets there are major topographic knolls indicating the presence of big structures. However, out of the old islet's boundaries, there are little topographic mounds on record, which suggests precisely that the knolls constitute structures built within the territory of the main islet.

The concentration of knolls proves the existence of pre-Hispanic settlements. Nonetheless, the classification of the mounds, alongside the geophysical results, allows for identifying a settlement's main structures. The second phase of the project is now under way to study, using geophysical techniques, the features of the located knolls. This part of the research project resorts to topographic, magnetic, electric and radar equipment determining the presence and the characteristics of the building remains. Excavations and sounding drills constitute other study techniques so to confirm hypothesis posited from the results of the earlier stages.

At the Coyoacán zone experiments were carried out to prove that geophysical high-resolution techniques are adequate to the task of studying archaeological sites in urban contexts. Topographic maps were made to carefully record the zone's relief. Over the surface of the Conchita square a magnetic gradient study was undertaken which was able to overcome the interference produced by the urban infrastructure. There is good concordance between magnetic data and topographic knolls. A technique that has given good results has been electrostatic resistance, which without galvanic contact with the earth enables to obtain readings on the pavement. This eased the study of most streets surrounding the square producing a close correspondence between topographic mounds and high electrostatic resistance values. Preliminary results state that most mounds recorded are produced by materials that modify the magnetic and electric properties of the soil, also generating clear reflections of radar electromagnetic waves. Georadar has discovered the approximate depth and shape of accumulated collapsed materials that generate clear reflections and affirm doubtless the existence of buried architectonic remains.

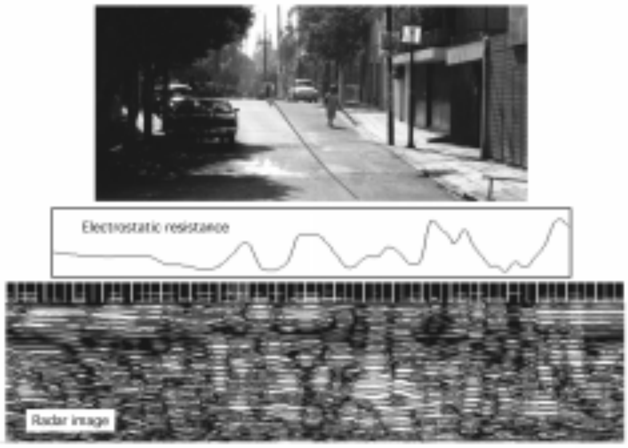

Figure 4. Topographic, electric and radar images from Higuera street at Coyoacan, Mexico City

6. CONCLUSIONS

Across our city, where pre-Hispanic settlements were built with the accumulation of building materials, so to keep them above water level, it can be seen topographic mounds produced by differential sinking. The present work produced a record of pre-compacted mounds that sink at a slower pace. It has been seen that these islets had kept their nahuatl names and even are still represented on the urban plan and the city toponyms.

Investigations' results thus far have located archaeological sites underneath the city's pavement. The record of mounds on the surface points to place where there are remains of structures which once belonged to ancient lake settlements. This has been proven at Coyoacán and Churubusco where geophysical studies have pointed to the presence of remains, later excavated.

To mitigate the formation of mounds it would be necessary to reduce drilling for water in the city's subsoil, regardless of the consequences to its water supply for its inhabitants. These mounds are likely to continue growing, thus risking many monuments belonging to Mexico's and Humanity's heritage. Likewise, many houses and their dwellers are in danger if they are on top of archaeological remains affecting the buildings' stability.

The slow sinking process has allows nevertheless the correction and preservation of some structures such as the Metropolitan Cathedral, yet these conditions become very risky during seismic events that use to hit our country. The relationship found between archeological remains and the collapse of buildings during the 1985 earthquake, at least suggests that this is a factor to be taken into consideration so to minimize its impact.

Therefore, restoring and consolidating architectural structures in Mexico City must begin with the study of buried structures. If we do not understand prior settlements and the effect of their remains upon the performance of the soil and surface structures as well, many interventions would be at best a temporary placebo but would not be offering a long-term solution, far from it.

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