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# Dating the Cart-Ruts of Terceira Island, Azores, Portugal

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## Abstract

Unlike other cart ruts found elsewhere in the world, the Azorean cart-ruts, engraved on volcanic stone, at the middle of the Atlantic, raise many questions: How old are they? Who created them? Were they made during a short or long time? These mysteriously enigmatic parallel grooves are noticed on the hard volcanic rock of the nine Azorean Islands in several locations. Recent scientific evidences have provided some support to the hypothesis of human presence in the Azores Islands before Portuguese settlement during the 15$^{th}$ century. Are the Azorean cart-ruts pre-Portuguese? Here we try to establish a chronology for the cart-ruts of Terceira Island, Azores, Portugal, using a historical approach, a geological approach and also a $^{14}$C dating approach, the last one obtained by dating a placic horizon found in the grooves of the cart-ruts named "Passage of the Beasts", which indicates the presence of human activity in the island at least during the 11$^{th}$ century, or probably before. The date obtained is consistent with another date achieved through similar methods for a man-made basin in the same island and is also consistent with the historiographical records.

## Keywords

Azores, Cart-Ruts, Ox-Carts, Pre-Portuguese, Volcanic Activity

## 1. Introduction

There are cart-ruts all around the world considered to be ancient. But are the Azorean cart-ruts ancient? Addressing this question can be confusing, because all cart-ruts in the Azores have been considered to be man-made within the context of the Portuguese economy of the islands from the 15$^{th}$ to 17$^{th}$ centuries.

We need to look at the cart-ruts phenomenon more holistically, taking into account several features across time and places, and with multiple scientific perspectives (stemming from history, ethnography, physics, chemistry, geology, genetic, ecology, economy, culture, etc.), and if necessary, to change the existing paradigm. Indeed, recent scientific evidence suggests the human presence on the Azores Islands before the arrival of the Portuguese settlers in the 15th century. These evidences include a genetic study on the *Mus musculus* (Gabriel, Matias, & Searle, 2013), which connected the genetic attributes of the house mouse in some of the Azores islands with genetic characteristics of house mouse populations in Northern Europe, suggesting earlier navigational routes that predate the Portuguese arrival, as an explanation for this phenomenon. Another study links the genetic characteristics of the Azorean weasel (*Mustela nivalis*), usually introduced on the islands as a predator for the mouse, to the Mediterranean Region and not to the Iberian Peninsula, again suggesting earlier navigational routes than Portuguese settlement's (Rodrigues et al., 2017). However, despite their usefulness for tracing possible navigational routes, genetic studies provide no evidence as far as dating is concerned, and hence must be associated with other studies when making inferences on possible human presence in the islands, including scientific dating, historiographical elements, and archaeological context.

At the Portuguese Madeira Island, closer to Europe and Africa than the Azores, ancient bones of mice were obtained and dated (Rando, Pieper, & Alcover, 2014). They date from 1033 BP ± 28 BP and document the earliest evidence for the presence of mice on the island. The result suggests that those humans could have reached Madeira around four centuries before Portugal officially took possession of the island. A singular and unpublished result appeared in late 1999, during the process of installing a water catchment, at Porto Santo Island, Madeira Archipelago, where construction crews happened upon a 1300 ± 100-year-old skeleton, dated by radiocarbon at the Royal Institute for Cultural Heritage on Brussels (Centro de Estudos de Arqueologia Moderna, 2017).

Recent scientific evidence on dating has arisen in a novel analysis of lake sediments in São Miguel Island (Rull et al., 2017), which led to the conclusion that there was human activity in the island at least in the 13th century, well before Portuguese arrival at the Azores in the 15th century. The evidence of such human activity includes deforestation, the cultivation of various cereals, animal husbandry and the use of fire, although human impact on the island was more limited before the Portuguese arrival than after. Analysis of a man-made bowl in Terceira Island, which inside sediments was dated through Accelerator Mass Spectrometry at Beta Analytic, Miami, is highly suggestive of human presence in the island at least during the 11th century, if not before (Rodrigues et al., 2015).

The studies mentioned above were led by six entirely different groups of researchers, most of whom were not concerned with finding evidence of pre-Portuguese presence in the Azores Islands or Madeira Islands, and obtained such evidence as a by-product of the investigations they were conducting, be it genetic studies on rodents, the study of natural and anthropogenic dynamics in vegetation or dwelling activities. So it is quite natural that the studies above have not yet led to an integrated picture of human presence in the Azores Islands before Portuguese arrival. This is compounded by the fact that studies on this matter (Rodrigues, 2013; Pimenta et al., 2013; Rodrigues, 2015; Rodrigues et al., 2015; Ribeiro et al., 2017) are still in their infancy, so there is no clear archaeological context that enables solid inferences as to which specific human culture may have existed in the Azores Islands before Portuguese arrival.

Within the Azorean historiography, the topic is addressed by Francisco Ferreira Drummond (1859), who produced the most complete and authoritative history of Terceira Island, and argues that several cart-ruts in the island cannot be explained as a result of Portuguese activity.

Through an analysis of official documents of the Praia da Vitória city hall (which by then was called "Vila da Praia") from the 16th century, analysis of the economic activity in Terceira Island in the 17th and 18th century and on the interviews he did to the elders on the island who told him that their parents had already told them about these ruts, Drummond (1859) concludes that the cart-ruts found in Terceira Island were not made after the Portuguese arrival, and must have been produced by some other human population that lived on the island before the Portuguese. These cart-ruts also puzzled Charles Darwin when he arrived at Terceira Island in his return journey from his voyage in the Beagle, given their similarity with those existing at Pompeii—see Martins (2015) for a discussion of Darwin's remarks, as well as for a contextualization of Drummond's contribution within the Azorean historiography.

While Drummond's inference is indeed the most authoritative writing within Azorean historiography on this matter, which is certainly reinforced by Darwin's remarks (Martins, 2015), no scientific evidence has been produced so far regarding the cart-ruts builders or activities that produce them on Terceira Island. The present work attempts to address this gap in the emerging literature on this subject, by presenting the first scientific dating of the cart-ruts on the Azores.

## 2. Existing Explanations of the Cart-Ruts on Terceira Island

Cart-ruts around the world raise several intriguing questions, and are considered, in some places like Malta, something of a mystery. The existence of similar structures in Terceira Island, Azores, Portugal, being located in the middle of Atlantic Ocean, renders the subject even more perplexing. Like in Malta, the Azorean tracks or "cart-ruts" remain an enigma because they have not been satisfactorily explained by the ethnographic or archaeological works, at least so far. Only Mendes et al. (2011) made a study (ethnographic study) on the Azorean cart-ruts.

The most consensual ethnographic explanation for the Azorean tracks attributes their origin to the Portuguese settlement of the islands in the 15th century, whereas others claim that their formation must have taken place during the 17th and 18th centuries (Borges, 2011). The presence of parallel tracks in all the nine Azores Islands is explained, by the locals, in a similar fashion. As a consequence, the Azorean tracks have been largely marginalized in the archaeological and geographical literature: they have never been the subject of an island-wide scientific investigation. For example, to show that, the first cart-ruts of Corvo Island (the smallest island of the Azores) were discovered and reported only in November of 2017 on a local newspaper (Diário Insular, 2017).

As mentioned before, first historical mention of the Terceira Island cart-ruts was made by Francisco Ferreira Drummond in the 19th century, who provides the following observation on Terceira Island, which was initially called Jesus Island:

"We observe thus, that the first track for going into the woods was made only in the decade of 1500, and probably not to find timber or wood, for all this existed in the same inhabited places, besides the fact that the village was too small, and the difficulty associated with the pathways and the distance of three leagues [20 km] was too great an obstacle, those vestiges could not be found at first sight, nor could those cart tracks be done during the 17th and 18th centuries, during which there was no need of bringing those carts into the high woods, where the vestiges mentioned are. An obstacle may be raised against this observation, which is reasonable at first sight; this is: that only there we find them, and not elsewhere. To which we may answer that in some excavations signs of older buildings were found, as other things which cause perplexity. Thus the Jesus Island seems to have been inhabited by another people (back in very early ages)" (Drummond, 1859: pp. 20-21).

The archaeologist Borges (2011: pp. 4-5) argues that the ox-cart grooves found in the Azores are a proof of the continued use of technologies and traditions, in his words "brought from Europe by the first settlers". He argued that "these technologies evolved very little until the 1970's, when the roads used by oxcarts were abandoned or modernized to be used by automobiles with rubber tires". He also mention that "in fact the oxcart grooves are seen everywhere as marks left on the ground by the ox-carts over decades and centuries, and even millennia of use, as on some Roman roads". The intriguing nature of these marks, leads a divergence between opinions that characterises the literature discussing the use of cart-ruts.

In 1836, when Charles Darwin visited Terceira Island, he passed by the cart-ruts with the name of "Passagem das Bestas" (*The Passage of the Beasts*):

"I noticed in several places, from the long traffic of bullock waggons [sic], that the solid lava which formed in parts the road, was worn into ruts of the depth of twelve inches. This circumstance has been noticed with surprise in the ancient pavement of Pompeii, as not occurring in any of the present towns of Italy. At this place the wheels have a tire surmounted by singularly large knobs; perhaps the old Roman wheels were thus furnished." (in Armstrong, 1992).

It is important to note, however, that Darwin's writing suggests that he is thinking of an analogy between Roman cars and the 19th century Portuguese cars he observed in Terceira Island (Martins, 2015: p. 193).

For a long period "*The Passage of the Beasts*" was forgotten. In the 1988 these cart-ruts were rediscovered by José Maria Botelho, a member of the local speleological association. The cart-ruts were completely covered by local vegetation (Barcelos, 2011). When we looking to the "crossings" from one rut to another, the ethnographical explanation of "*The Passage of the Beasts*" present a navigational nightmare for waggon drivers that would attempt to use them. Is not easy to imagine how such manoeuvres have been repeated, if we assume that the ruts were made with repeated passes. Borges (2011) believes that the depth and the quantity of the ox-cart grooves in the place, which are adjacent and cross and link with each other, constitutes a proof of the strong industrial activity in Terceira Island, both in what concerns the number of carts and the volume of firewood transported each year. But such a conjecture is not supported by historical or biological facts (poor soil at the site for wood production and at the timberline transition) or with a clear connection between this place and the main town of Terceira Island.

Another speculation that enhances further confusion of the cart-ruts of Terceira Island and also on another Azorean Islands is the characteristics of the tracks. The depth and size of the cuts differ substantially, and some are shaped as a "U", others take the form of a "V" or "W" and others quasi-U or rectangular shapes. At Porto Martins village (Terceira Island) the ruts tend to suddenly disappear at the edge of the island and seem to continue under the sea water.

## 3. Comparing Cart-Ruts Hypothesis

Until now the cart-ruts have remained an unsolved puzzle to all scholars who tried to describe their functionalities. All proposed theories are based on previous assumptions and limited evidence. Until now no one has tried to see if the Azorean cart-ruts fit well with the hypotheses explored on other places. We believe that this is the first attempt.

Cart-ruts are not unique to Terceira Island or indeed the Azores Islands; they can also be found in Malta (Mottershead, Pearson, & Schaefer, 2008) or Switzerland, France and Italy (Schneider, 2001) among other countries. The most famous ancient cart-tracks area in the world is Malta's cart-ruts and there is no direct clear evidence that they are manmade, because when we observe the rut walls no evidence, or even hint, of human activity in excavating ruts, such as might be provided by pick marks (Mottershead et al., 2008). But other countries with cart-ruts do seem to have supporting evidence for manmade cart-ruts, such as Italy or Switzerland, at least in the Roman period (Hughes, 1999; Schneider, 2001). For Malta, only Dawkins (1918) considered the cart-ruts entirely natural features and of no archaeological significance. The cart-ruts of Pompeii are clearly manmade and the most obvious features are, according to Poehler (2008) and Schneider (2001), wheel ruts left in the paving stones. Here we can clearly assume that the "Passage of the Beasts" car-ruts were man-made because the archaeological context in which they were found includes man-made bowls.

Despite the renewed interdisciplinary academic interest in Maltese prehistory, the spatial and chronological dimensions of the ancient track network (the most studied cart-ruts in the world) were not addressed until 2000. A study that intended to address the significance of cart-ruts in ancient landscapes of Malta was funded by the European Culture 2000 programme (Department of Information-Malta, 2005). This led to the most comprehensive explanation of cart-ruts thus far published, and its inception resulted into a previous assumed mind-set hypothesis of wheeled-vehicle tracks, like for the Azorean cart-ruts. Even now, there is no comprehensive explanation of animal traction pulling carts or waggons through the Maltese cart-ruts (Sagona, 2015) and also this could be said for the Azorean cart-ruts.

Assuming for the Azorean cart-ruts the same complexity of the dating processes of the Maltese cart-ruts and their functionalities, this work will be not centred on the discussion of the nature of the Azorean cart-ruts. Rather, it merely tries to establish a chronological interval for their construction or appearance. But it was clear from the beginning that it would be impossible to avoid comparisons with the Maltese cart-ruts, not least when considering dating methods.

Bugeja (2001), made a revision of the different dating methods of Maltese cart-ruts, and points out the main limitations of these investigations. Almost of the works mentioned by this author point to the Maltese cart-ruts as a transport system of soil, stones or goods, but it is difficult to make a clear connection between the ruts and the transported or explored material. The entire hypothesis points out to the transport of heavy material trough the ruts. Similarly, no old quarries near the "*The Passage of the Beasts*" were found and the hypothesis of soil transport is inappropriate because the area has a poor and thin layer of soil from volcanic origin. If we assume the use of the ruts for transport of any kind of goods, the only coherent hypothesis will be wood. If wood were carried out off the Guilherme Moniz Caldera (the place where *The Passage of the Beasts* is installed), a huge amount must have been transported and that implies probably exportation.

A possible explanation could be the production of furniture, infrastructure and ships in Terceira Island after Portuguese arrival, much of which exported, given how appreciated the island's cedar (*Juniperus brevifolia*) was, even if, for this hypothesis to work, the quantity of wood transported would have to surpass whatever is conceivably given the existing historical economic analysis or historical records. Azorean cedar is not present at the place where the studied cart-ruts are. This could be also associated to ecological constrains that made the *Juniperus brevifolia* (Seub.) Antoine appear especially in mountainous areas above 500 m (Elias & Silva, 2008). The mean altitude of the Guilherme Moniz caldera is close to 500 m and is a flattened area. These two facts weaken the previous hypothesis, if the landscape has been preserved intact since Portuguese colonisation. It is possible that the original vegetation cover has been partially destroyed by human activity during historical times. In the past, the *Juniperus* *brevifolia* distribution on Terceira Island could be different from today. Today this species mostly occurs at higher elevations, but evidence from historical records (Frutuoso, 1873) suggests it grew at much lower elevations in the past. This is confirmed by pollen evidence from low-elevation lakes on São Miguel Island (Rull et al., 2017). This also means that we are not able to reject the hypothesis of the "Passage of the Beasts" cart-ruts being used for wood transport.

## 4. "*The Passage of the Beasts*" Cart-Ruts Main Characteristics

In recent years (2015-2016), the City Hall of Angra do Heroísmo, the main town of Terceira Island, have decided to remove the vegetation inside the ruts of *The Passage of the Beasts*. These cleaning activities became an opportunity to study the "Passage of the Beasts" cart-ruts system, because parts of them were covered, at least, by a tinny layer of soil. To understand the place it was important to know their geological context, because the geologic past offers a sobering perspective on the rates of human resource use and environmental degradation or space occupation. Figure 1 shows the location map of where the cart-ruts occur in relation to volcanoes of the island.

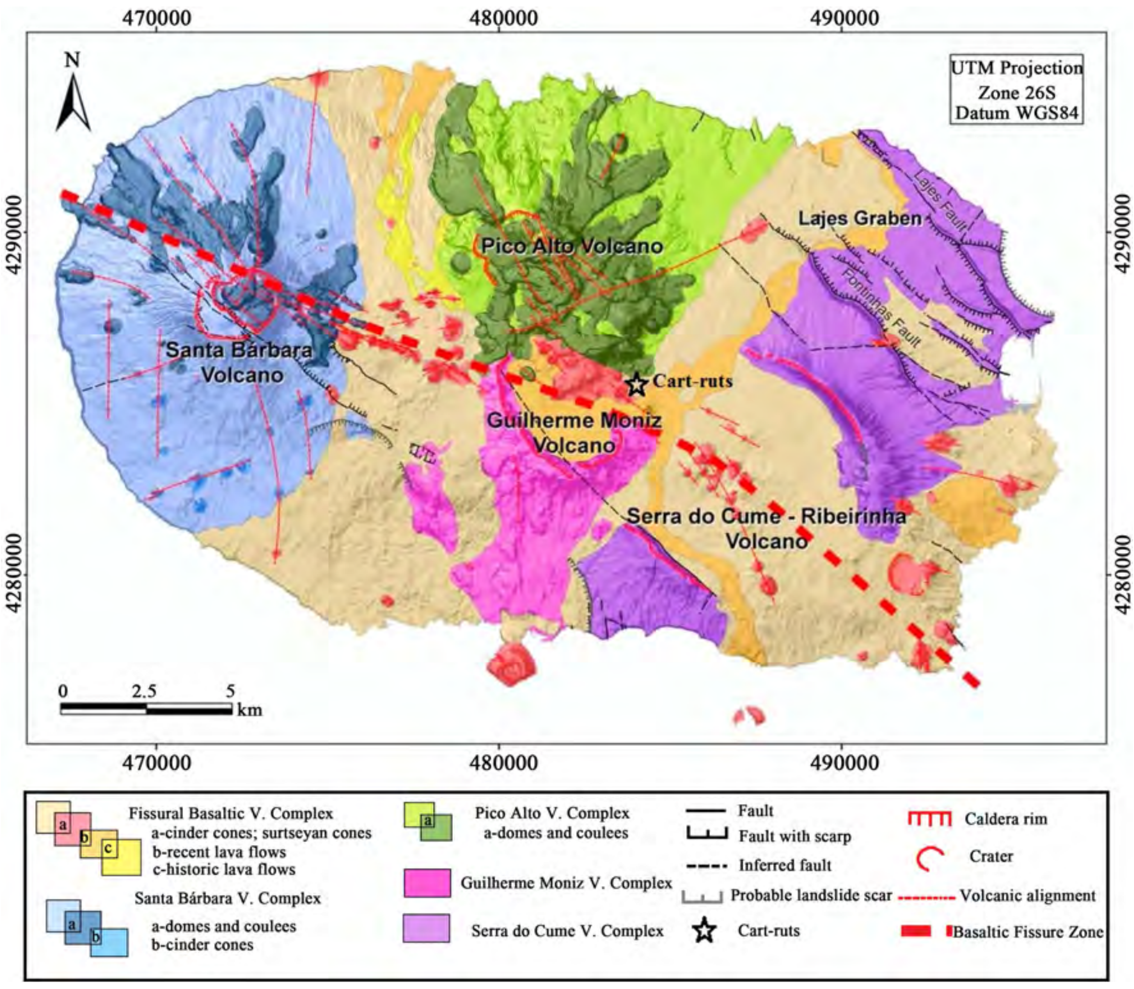


**Figure 1.** Simplified geologic map of Terceira Island (adapted from Quartau et al., 2014).

Terceira Island grows and evolves by the action of several geological processes. Their present-day morphology is the result of the activity of volcanic, erosional, depositional, tectonic, isostatic, eustatic, and mass-wasting processes (Ramalho et al., 2013).

"*The Passage of the Beasts*" is installed on the Guilherme Moniz strato-volcano with 270,000 years (Calvert et al., 2006) built on the western flank of the Serra do Cume-Ribeirinha shield volcano and is predominantly composed of trachyte domes and lava flows, with minor associated pyroclastic deposits (Quartau et al., 2014).

The extension of the parallel ruts thus found was 213 m. The deepest groove found measures up to 32 cm (Resendes & Moniz, 2015). Another cleaning of *The Passage of the Beasts* ruts was undertaken in 2017, and the extension of the ruts is much greater than thought. At this moment this extension of the ruts are greater than 300 m, and the deepest groove found measured 40 cm. The degree of rut incision varies considerably from traces (3 cm) to 40 cm. The ruts show a persistent rounded U-shaped profile, exhibiting a more flattish shape only where duplication or crossings has occurred (see **Figure 2** and **Figure 3**).

**Figure 2.** Rut shape as crossings (coordinates: 38˚42'32"N 27˚10'58"W).

**Figure 3.** Ruts deep and crossings (average 30 cm depth). The grooves at the end of the left side where filled with volcanic ashes.

The gauge characteristics of the tracks vary from 1.1 m to 1.4 m, averaging 1.14 m. When we compare these measures with those ones reported by Hughes (1999) for the Maltese cart-ruts, the distances between paired ruts are shorter but the depth of the tracks is similar. When we measure the distance between ruts along the main trail, it is possible identify at least five distinct distances (see Figure 4):

1) Ten measurements between parallel ruts with 1.1 m which constitute the statistical mode of the observed measurements,

2) Four measurements under the measure of 1.1 m (1.07 m) which constitute the minimum of the distance between parallel tracks measurements but with a standard deviation (a measure of the data variability) able to put them in the same group of the 1.1 m cluster,

3) Seven measurements with 1.15 m, statistically different from the ones above mentioned (even if we consider the standard deviation),

4) One measurement with 1.28 m,

5) One measurement with 1.38 m which constitutes the maximum distance between parallel ruts.

The maximum distance between ruts was observed near a crossing with an X shape with well-defined triangles. Looking from above, this resembles intersecting railway lines, with their turns and junctions in several route directions (see Figure 5).

The 1.28 m distance between parallel ruts was observed after a fracture of the bed rock, probably associated with non-historical seismic activity. At certain places of "*The Passage of the Beasts*" we find a strong gradient between the two rails. The only explanation for the fracture here is that the rock had been moved by seismic activity after the rails were used, but the seismic activity is not able to explain the enlargement of the distance between parallel ruts.

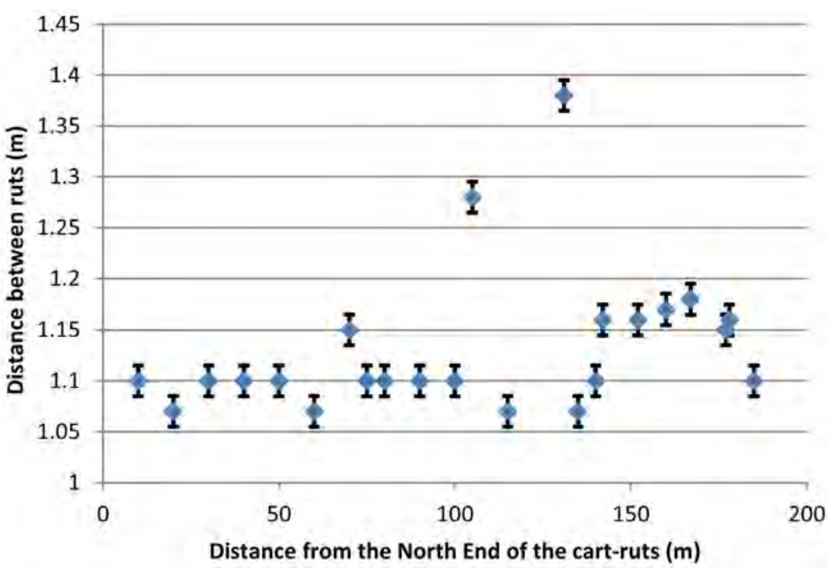


Figure 4. Pattern of the distance between parallel ruts at "*The Passage of the Beasts*" in the main cart-ruts. The black line represents the standard deviation.

Figure 5. Aerial view of *The Passage of the Beasts* with few unearthed branches. The image of a man standing up there serves as scale (Assigned to this work from Paulo Pereira, 2017).

The statistical distribution of the measurements is not Normal and tends to fit a Poisson distribution. When we remove the extreme high values (outliers) and test our data again we are then close to the Normal distribution. If we remove the outliers, is not possible to explain the distance between parallel ruts by the use of ox-carts over decades because the axis of the oxcarts were not extensible or were not made with the same and precise standards during decades or centuries. On other hand, if we attend to the adversity of the steep slopes of "*The Passage of the Beasts*" and to the surface irregularity of the bedrock we conclude that these cart-ruts were not possibly used by oxen, horses or donkeys (animals with hooves): only humans could have used them. A good correlation between the width of the left side groove and the width of the right side groove seems to appear in the central cart-ruts of "*The Passage of the Beasts*" (see **Figure 6**) with a similar average width (18.1 cm and 18.3 cm respectively). This correlation is not related to local variations in the hardness of the rock because the incisions are observed in the same lava flow.

Like in **Figure 4**, an outlier appears connected with the observed fracture. Both statistical distributions are Normal, even we include the outlier. If we exclude the outlier we are able to explain the widths of both grooves because, when one wheel of a car, or a fix device, slides to the left side, the other wheel or extreme of the device slides into the same direction. This result seems to contradict the conclusions about the distance between parallel grooves along the main trail, but it is clear that we have four distinct distance between grooves, with the same sliding effects (see **Figure 7**) when we remove the outliers.

To explain the observed trends we must admit that the axis of the device that produced the grooves varied or the bed rock has expanded or has compressed through time. We can argue that this suggests an unknown seismic activity on the site, but the fact that the grooves are carved in rigid volcanic rock make this explanation unlikely.

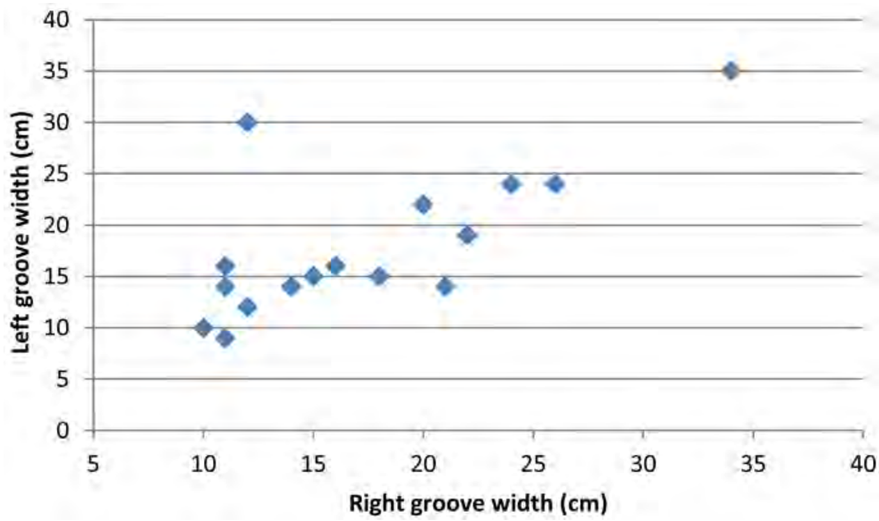


Figure 6. Correlation between the widths of the right and the left grooves.

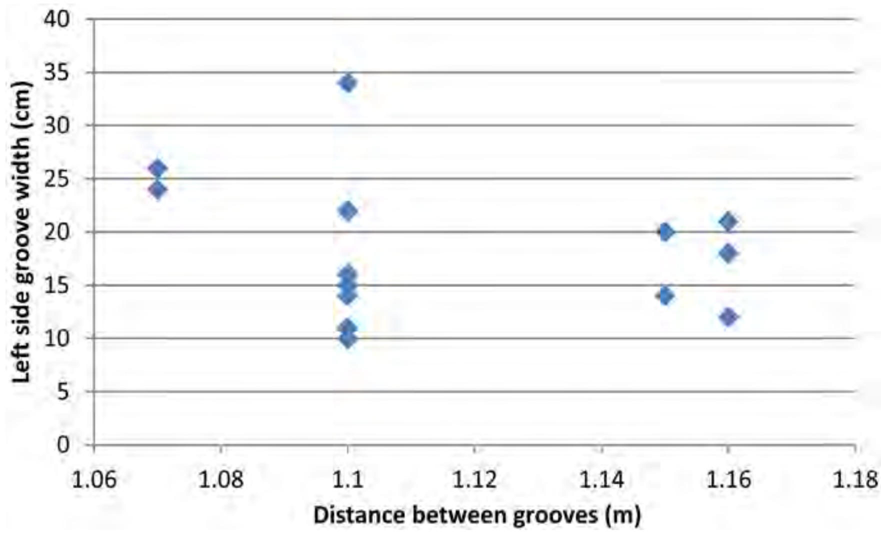


Figure 7. Distance between parallel grooves versus width of the left side groove.

Only a few places of the studied cart-ruts appear to have a direct correspondence between the depth of the right and the depth of the left grooves. Globally, no correlation was found between the depths of the grooves along the main trail. Both depth data distributions are Normal and are not related with a chemical heterogeneity of the stone or different slopes of the bed rock where the ruts are. Several branches on the main cart-ruts were found, which means, ruts adjacent to the main paired tracks, with crosses and links with each other. It is not easy to explain these derivations that in some cases turn up again.

## 5. Dating the Cart-Ruts of "*The Passage of the Beasts*"

The tracks of "*The Passage of the Beasts*" had a tendency to run downhill with a gradual slope, far away from the modern road, and parallel to a water line. The closest known historical road coincides with the modern road.

During the recent cleaning and unearthing of the tracks, new connections between ruts were perceived as it was inferred that volcanic deposits obscured earlier ruts. Until now, five lateral trails of the "*The Passage of the Beasts*" were fully covered by volcanic ash (see **Figure 8**).

Terceira Island presents active volcanism and a significant seismic activity which can explain the observed fracturing of the bed rock.

Since Terceira Island settlement in the 15th century, only one volcanic eruption took place on land in 1761. This volcanic eruption were not able to cover "*The Passage of the Beasts*" cart-ruts because was an aa-type lava flow, not present in this place, with an average thickness of about 3 meters, strongly controlled by the paleomorphology of the area (Nunes et al., 2014). Before that time we find several candidate eruptions, the most recent related with Pico Alto Volcanic Complex: a tightly spaced cluster of trachyte domes and short flows, which is a younger part of Guilherme Moniz Volcano. Stratigraphic studies and radiocarbon analysis suggest that the Pico Alto eruptions occurred at 1000 years BP (Self & Gun, 1976; Calvert et al., 2006; Nunes et al., 2014; Quartau et al., 2014). The Pico Alto strato-volcano was built on the northern flank of Guilherme Moniz Volcano. It has a radius of 6 km and culminates at an elevation of 808 m, with a 3.5 km wide summit caldera (Quartau et al., 2014).

The tracks of "*The Passage of the Beasts*" were incised on a lava flow on Guilherme Moniz Caldera. Guilherme Moniz Volcano has developed with the initial formation of an imposing shield volcano. Subsequently, it evolved into a more explosive character, culminating in the caldera collapse, which occurred less than about 270 thousand years ago (Gertisser et al., 2010). If the volcanic ashes that were found covering "*The Passage of the Beasts*" cart-ruts comes from an

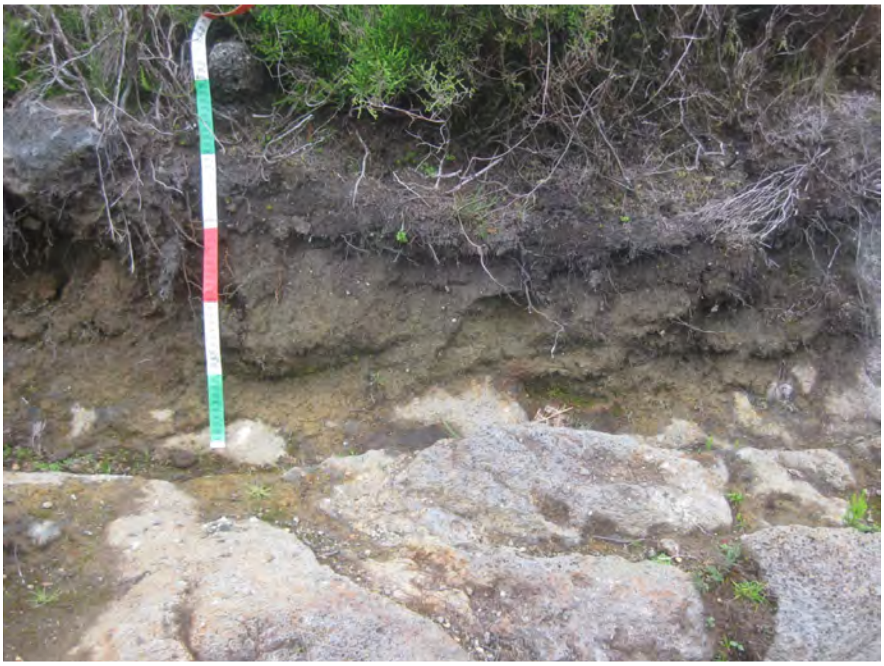

**Figure 8.** Unearthed groove filled above with volcanic ashes.

eruption of Pico Alto, we can date them as being, at least, 1000 years old. We can have also others volcanic eruptions as candidates, to cover the observed car-ruts, such as the lava flow come from Algar do Carvão eruptions, that according to Calvert et al. (2006) are dated between 1880 years BP and 10,090 years BP. Pico Alto eruption seems to be the youngest candidate if the observed ashes comes from a volcanic eruption rather than deposited by erosion of older pyroclastic deposits or an unknown human activity on the area.

According to Self and Gunn (1976) we have at Guilherme Moniz Caldera a chaotic assemblage of comendite and pantellerite domes and coulées largely infilling this caldera. The Caldera floor is covered by young basalts erupted from the adjacent fissure zone.

The pyroclastic flows erupted from Pico Alto, in the central part of the Terceira Island, generally followed topographic depressions towards the North and South coasts. The pyroclastic flows from Pico Alto travelled over flat interfluve surfaces where they left thin deposits (Self et al., 2005).

"*The Passage of the Beasts*" cart-ruts are clearly in an interfluve area at the middle of two actual deepest water-lines.

As can be perceived, on the **Figure 9**, part of "*The Passage of the Beasts*" cart-ruts was covered by a pyroclastic flow. We can clearly see that in other branches of the cart-ruts were we found pyroclastic accumulations with 50 cm to 2 m of thickness. The pyroclasts found inside the cart-ruts varies from agglomerate to very fine ashes and tuffs.

**Figure 9.** Branch of unearthed cart-ruts, with pyroclasts in front and lateral sides.

We made a terrain profile (**Figure 10**) in order to see the changes on the cart-ruts slopes and their possible relationship with general pattern of the soil horizons, because, despite no historical eruptions being known in this area, the volcano's eruptive activity of Pico Alto has been quite recent, occurring the last one in about 1000 years BP, according to estimates of Calvert et al. (2006) and Self and Gunn (1976). Given the uncertainty regarding to the time when the ashes covered the cart-ruts, it was important to study the configuration of the volcanic material laid on the top of them.

The obtained profiles 3 and 7, which are at the same altitude, were located on two distinct branches of "*The Passage of the Beasts*". All the observed cart-rut branches of this system are connected with the main central path of "The Passage of the Beasts", as can be seen in the **Figure 5**.

On **Figure 11** it is presented the found horizons in the different profiles, which varies from an organic soil (O Horizon) to basaltic rock/cart-ruts (R Horizon) for all the sampled sites.

The thickness of the "cart-ruts layer" corresponds to the groove deepness of the cart-ruts at each sampled sites. In all the sampled places, except in the first point, the grooves were filled with a Birm Horizon (a cemented Horizon or placic Horizon) above a small layer of fine pumice.

Above the Birm Horizon it was found, except in site 1 and 7, a layer of fine pumice. In the site 1 (the less extended and variable profile) it was found basaltic lapilli under a Bt Horizon (probably a transformation of the C Horizon with clay accumulation indicated by finer soil textures), and in site 7, the fine pumice layer was above a layer of trachytic lapilli.

Sites 2, 6 and 7 present a reddish brown Bir Horizon on the top of the pumice layer. The site 2 also has a Bir Horizon on the top of a Bt Horizon, and site 7 has a Bir Horizon in the middle of a volcanic tuff layer. These Bir Horizons reveal the stability of the above volcanic material layers.

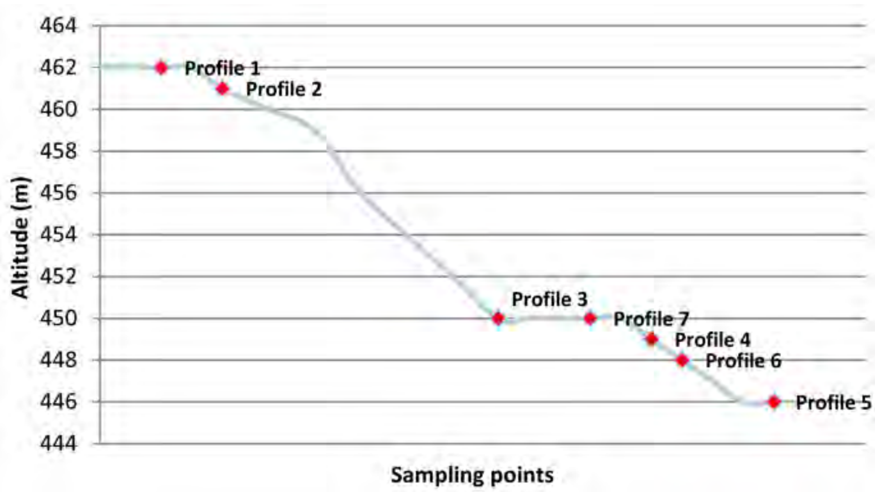


**Figure 10.** Altitude of the sampling points to determinate the general pattern of the horizons.

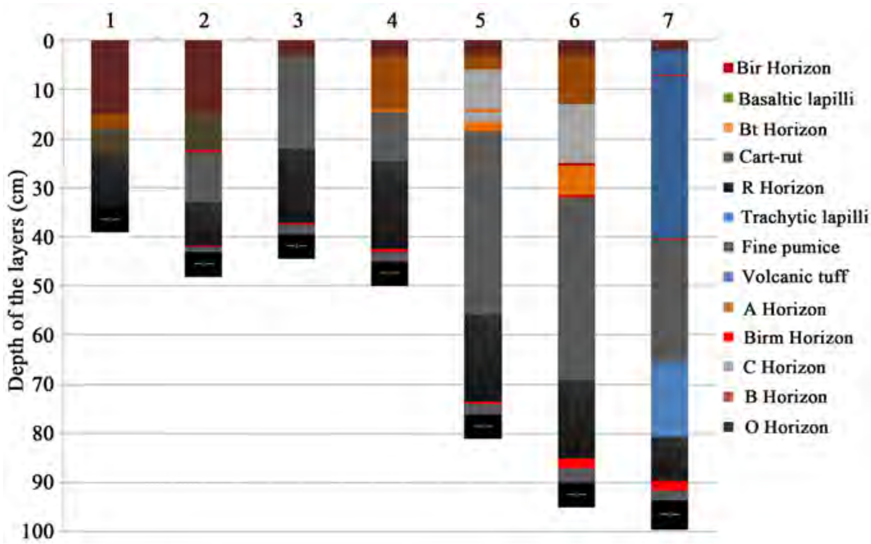


**Figure 11.** Distinct layers covering the grooves of "The Beast Passage" according the USDA soil taxonomy.

The same temporal stability seems to be present at sampled site 7, because the volcanic tuff layer, above the fine pumice layer, seems to result from the compaction of the ash onto a solid rock by consolidation. The consolidation involves a decrease in the water content of the saturated soil without replacement of water by air. In general this is the process in which reduction in the volume takes place by expulsion of water under long term static loads. This can explain, at site 7, the existence of a pumice layer (less consolidated) under a volcanic tuff layer.

Sites 2, 4, 5 and 6 present small Bt Horizons that only show clay skins on vertical ped surfaces.

An A Horizon was present on sites 1, 2, 4, 5 and 6. Taking into account all the results, the thickness of the A Horizons seems to correlate negatively with the thickness of the O Horizons.

Globally, the seven profiles seem to have different pedogenic processes related with the natural organization of particles that forms discrete units separated by pores or voids. The observed layers also seemed dependent of the vertical water infiltration and points to a long temporal stability, which means unchanging horizons in quantity, quality or physical conditions. For other hand, the studied area has soils containing very different horizons whenever compared to an "ideal" soil. When we look to site 7, located few meters away from site 3, the horizons seems to have different origins with volcanic ash consolidated on site 7 and not at site 3. This could be associated to the fact that the area is a chaotic assemblage of domes and coulées as mentioned by Self and Gunn (1976) or to a heterogenic ashes dispersion influenced by the wind during eruptions, given an enormous heterogeneity to the terrain.

The pumice deposits found at the studied sites are compatible with last largest sub-plinian pumice deposits erupted from Pico Alto, and also compatible, with the isopach map of pumice deposits for such 1000 years eruption, produced by

Self (1976).

No older soils were found on Guilherme Moniz Caldera, or around the sampled sites, able to remobilized carbon to these places from more developed surrounding soils. No paleosols interbedded within tephra layers were observed. All this seems to mean that either the pedogenesis was incipient because of the lack of time between volcanic episodes or because of the unfavourable morphological position of the deposits, or, being well developed, the upper horizon may have been eroded. If an erosion surface was not observed to truncate a placic horizon, the dating obtained through him, although it represents rigorously only a *terminus post quem*, must be close to the real age of the volcanic ashes above this horizon.

To have certainty about the age of the materials above the cart-ruts, a blackish-brownish layer (placic Horizon) formed inside the grooves were analysed. The studied layer was cemented mostly by iron, manganese and organic matter (see **Figure 12**).

The layer was analysed by a soil specialist (Professor João Madruga, co-author of this work) from the University of the Azores and it was classified as a placic horizon.

The placic horizon generally has a thickness between 2 mm and 10 mm (USDA, 1999). The placic found onto the cart-ruts has a thickness between 2 mm and 3 mm.

Most placic horizons occur in areas of moist climates with low evapotranspiration as in this case. The annual average precipitation at the cart-ruts place round the 2800 mm/year whereas the evapotranspiration is about 666 mm/year (Novo, 2009).

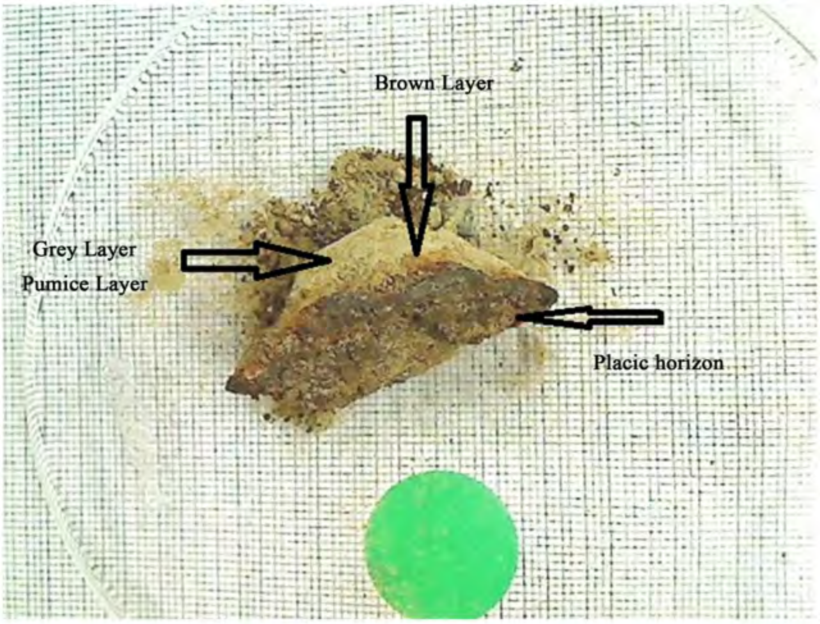


**Figure 12.** The pumice layer was inside a groove at site 6, and the placic horizon is above the brown iron rich layer.

Research on placic horizons genesis suggests that the iron is reduced and mobilized in the horizon surface, than oxidized and precipitated in the B horizon, where it can adsorb soluble organic matter (USDA, 1999). The placic horizons form in material with a variety of textures ranging from sands or volcanic ashes to clays. In the British Isles the placic Horizons occur under peat-forming ericaceous or grassy semi natural vegetation, which was a 3000 years look-a-like forest that was subjected to periodic burns (USDA, 1999). Similarly, the Guilherme Moniz Caldera vegetation is composed essentially by native vegetation of *Erica azorica* Hochst. ex Seub. (ericaceous) and sphagnum peat (S*phagnum* sp). No traces of fire near the area of cart-ruts were observed.

If the information extracted from geological data with pedological data (volcanic ashes origin and placic horizon genesis) is compared, we are able to point out a possible chronology for "*The Passage of the Beasts*" cart-ruts: They are older than 1000 years.

In order to cross this chronology with further dating methods, a sample of placic horizon (see **Figure 12**), collected inside a groove of one unearthed cart-rut was taken for Accelerator Mass Spectrometry (AMS) dating. The sample was sieved through a 180 micrometre sieve. After the treatment of that sediment with acid, it was analysed at Beta Analytic Lab (USA). The AMS radiocarbon dates were calibrated using IntCal13 and Marine13 radiocarbon age calibration curves 0 - 50,000 years cal BP (Reimer et al., 2013).

At a first glance, the material caught in the sieve did not appear to be organic due to the fact of having large amount of iron and manganese. The factors influencing the formation of these cemented horizons are poorly understood, and it was assumed that the sample had also organic matter. The sample was than treated with a stronger acid to break up and dissolve the iron and the emitted $CO_2$ recovered. The conventional radiocarbon age obtained was 920 ± 30 years BP (Beta Analytic code—460931). The calibrated result (95% probability) was Cal AD 1025 to 1190.

In wet or flood plains, a dated sample may be composed of carbon from several sources, which may have been younger or older than the level it was deposited in, but normally younger pyroclastic products (pumice falls associated with pyroclastic surges, pumice flows or volcanic breccias) cover the older deposits. It is also possible to have run water through the impermeable grooves, in the bed rock, which can bring in carbon of younger ages. Thus, as far as we could see at different profiles, and taking into account the cart-ruts slopes, the cavities on Guilherme Moniz Caldera and the isopachs of the pumice dispersions of the Pico Alto eruptions, any $^{14}C$ ages from such placic horizons could simply be seen as a minimum age (*terminus post quem*) for the grooves. We have no any kind of evidence of water re-deposition of ashes or erosion on the different horizons, except on the topsoil.

When we look to the dating processes approaches presented in this work (historical, volcanic, placic genesis and carbon dating), we have a minimum objective date for "*The Passage of the Beasts*" cart-ruts: 920 years $^{14}C$ BP

(1025-1190 cal AD). This result is compatible with the estimated of Calvert et al. (2006) for the youngest eruption of Pico Alto, that took place 1000 years BP (500 years before the Portuguese arrival) and with the time it takes for a placic horizon formation.

## 6. Conclusion

Comparing historical references with geological, pedologic data and physical analysis we can find evidence that suggests we could push back the chronology of "*The Passage of the Beasts*" cart-ruts, at least, for 1000 years B.P..

If we assume 1000 years old for "*The Passage of the Beasts*" construction, these cart-ruts do not seem to be Roman or Portuguese. We only can say that they are likely to be pre-Portuguese.

The topographic parameters of "*The Passage of the Beasts*" cart-ruts on Terceira Island, Azores, Portugal, clearly show that the grooves were not made as water ways or as an old system for water to flow to certain spots. Taking into account the humidity and rain patterns of the island and soil profile of the Guilherme Moniz Caldera (little top soil), no irrigations system was needed for agricultural production at that place (assuming that the climate has never changed, being the same described by Gaspar Frutuoso (1873) when the first settlers arrived to the Azores). These grooves are parallel to a natural water line and have a water catchment nearby. It seems unlikely that these grooves were used for irrigation, drainage or agriculture.

The irregularity of the surface of the bed rock, where the ruts are made, points towards an explanation other than the extensive use of ox-carts. It seems difficult for animals with hooves, like oxen, horses or donkeys to move across the irregular shape of the bed rock with the observed slopes. At the Azores, traditionally, the ox-carts were pulled by two oxen, but at this place part of the cart-ruts system is embedded in the ground and only permits the passage of a lonely animal.

The presented chronology for the Passage of the Beasts is consistent with previous chronologies that point towards human presence in Terceira Island in or before the 11$^{th}$ century and also contributes towards the emerging literature on pre-Portuguese presence in the Azores Islands.

Furthermore, our analysis seems to confirm an important observation made by Drummond (1859) the most complete and authoritative historian of Terceira Island, thus addressing an important hypothesis within the Azorean historiography that had not been subject to scientific testing so far. This enables integration between scientific and historiographical elements that provides a fruitful route for future investigation, even if much further work is still necessary in order to identify a clear archaeological context for further inferences on which specific culture may have existed in the Azores Islands before Portuguese arrival.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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# WWII German Military Structures in Angers (FR)

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## Abstract

In previous publications, some WWII German military structures around Angers (FR): at Mûrs-Érigné, the Domaine de Pignerolle and Bouchemaine, during the German Occupation period were described and analyzed. The discovery in 2014 in a private archive of a French Resistance map dated 1942 showing further German military structures on the right side of the Maine and a plan of a large bunker in La Reux at Saint-Barthelemy d'Anjou forced the resumption of the researches about German military structures in the Angers sector. The Angers sector retreated from other WWII German more sensitive military sectors in France and less exposed to allied air attacks, offered for a quite long time, during the Occupation, a quiet place for developing military activities. The visits on the sites permitted, at about seventy years from the end of the WWII, to better understand the purpose and estimate the preservation state of the surviving structures.

## Keywords

WWII, Occupation, Atlantic Wall, Pignerolle, Saint-Pierre, V149, UCO, R 608, La Reux, Bessonneau, Angers, France

## 1. Introduction

Angers, in North-West France, played during the WWII an important role as witnessed by German military structures erected at of Mûrs-Erigné (Suquet, 2010; Tomezzoli, 2016), the Domaine de Pignerolle (Tomezzoli et al., 2013) and Bouchemaine (Tomezzoli, 2018). It was the discovery on 2014 in a private archive of a French Resistance map dated November and December 1942, prepared for the Central Office of Information and Action (*BCRA—Bureau Central de Reinseignement et Action*) in London showing further German military structures on the right side of the Maine and the plan of a large bunker in La Reux at

Saint-Barthelemy d'Anjou that forced the resumption of the researches about the German military structures in Angers in the period of the Occupation with the integration of materials collected in the past.

## 2. Angers during the WWII

After the Polish army defeat in September 1939, the higher Polish authorities decided to exile. In crossing Romania, under German diplomatic pressure, the Polish president Mr. Moscicki, the ministers, the chiefs of the army and all the soldiers present were interned. The president Moscicki, in the impossibility of exercising his functions, according to the Polish constitution, appointed as new president the vice-president Mr. Raczkiewicz, who appointed the army general Mr. Sikorski as prime minister of the Polish government in exile.

Angers was selected by the French authorities as site of the new Polish president and government in exile and the foreign accredited ambassadors, including a French ambassador. The Pignerolle castle at Saint-Barthelemy d'Anjou was assigned as residence to president Raczkiewicz, who took possession on 2nd December 1939.

The rapid German invasion of France on June 1940 obliged, on 12th June, the Polish president and government to leave Angers for Great Britain through Spain. An English headquarters took then place at the castle for only two days (Lemesle, 1974).

Angers was invaded by refugees coming from Belgium, Luxembourg and North France escaping the German invasion. Civilian and religious establishments were requisitioned and the Red Cross, the Scouts and most part of the Angers population organized themselves for their aid. The town population grew up rapidly from 88,000 to 100,000 inhabitants, and in order to satisfy the needs of the increased population and because of the war restrictions on the supplies, the municipality provided to ration the provision by introducing the food cards.

The French army, faced to the German invasion retreated in disorder, sometime opposing a valid resistance, as the cadets of the Saumur cavalry school on 19th-21st June. Angers suffered various German Air Force (*Luftwaffe*) bombings. On 14th June the Avrillé airfield was hit and on 17th June the rail stations of Saint Serge and Saint Loud were hit. In this last about twenty Senegalese soldiers of the 27th Colonial Mixed Infantry Regiment were killed. Overall, thirty killed and thirty wounded were registered in the districts of the two rail stations. Because of the bombings about 20,000 inhabitants leaved the town to be relocated South to the Loire (Lemesle, 1981; Lemesle, 1996).

On 19th June at about 8:30 a.m. German troops arrived at La Flèche, 50 km from Angers. From a post office, a German commander menaced the municipality of intensive bombings in case of Angers defense. The mayor and the prefect of Angers informed about the German menace general Langlois, responsible of the Angers defense who intended to resist. But at 11:00 a.m. he received the authorization to declare Angers open city. Later, the mayor, the prefect and a military representative went to Seiches-sur-Loir, 20 km from Angers, giving guarantee to the Germans about the non-defense of Angers. At 15:00 p.m. the German troops entered in Angers without accidents. On 20th June Angers was taken over by general von Boeckmann commander of the Angers occupation corps and his headquarters, which went to the city hall and hoisted on the facade the German swastika flag (Lemesle, 1996).

After the Occupation, Angers was seat of the Military Administration—Zone B (*Militärverwaltung—Zone B*), for which a great portion of the buildings of the West Catholic University (*UCO—Université Catholique de l'Ouest*), 10 big school buildings and 280 other buildings were requisitioned. Part of the hospital and all the military establishments were equally requisitioned. The Angers castle hasted an ammunition depot and headquarters of the German Land Army (*Heer*) veterinary services.

The Avrillé airfield was requisitioned and adapted, by requisitioned civilians, for fighters and night bombers during the Battle of Britain. The War Navy (*Kriegsmarine*) on 8th July requisitioned the castle and the Domaine de Pignerolle at Saint Barthelemy d'Anjou to install the Commander (*Befehlshaber*) of *U-Bootes* and his headquarters, the castle and Domaine of Saint-Pierre at Mûrs-Érigné to install the *Kriegsmarine* Atlantic Coast (*Atlantikkuste*) headquarters (Lemesle, 1996; Coiffard, 2006; Suquet, 2010; Tomezzoli et al., 2013) and the castle and the Domaine de La Doubinière for install a logistic base popularly named "The Bank" (Tomezzoli, 2016).

The *Heer* withdrew from Angers between 1st-6th August 1944 leaving on place some combat groups. The 5th Infanterie Division US Red Diamond freed Angers on 10th August and the Angers district on 1st September.

## 3. The Map N° 200b

The map N° 200b, scale 1/20,000 (**Figure 1**) was prepared on November-December 1942 by the communist French Resistance in Angers and sent to the *BCRA* in London. It shows German military structures in Angers on the right side of the Maine. The accompanying explicatory sheet N° 510, mentioned in the map is, unfortunately, lost.

The map is a copy of an original preserved at the *Musée de la Resistance d'Ivry* and identifies the following military structures:

(1) Point E, important house and barrack camp under a wood

(2) Point G

(3) Transformer

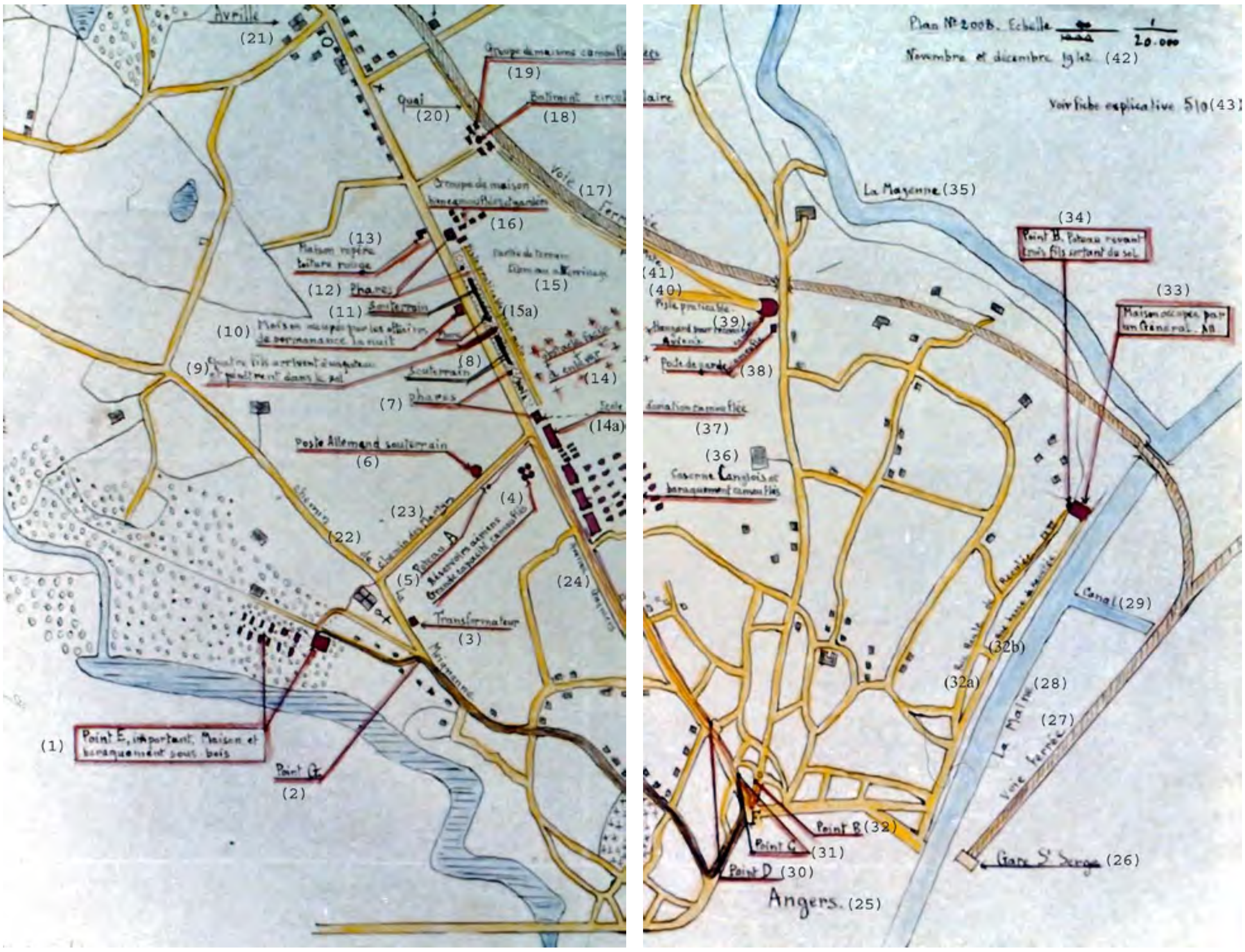
(4) Camouflaged air fuel reservoirs of large capacity

(5) Post A

(6) Underground German place

(7) Projectors

(8) Underground




(A) (B)

**Figure 1.** Map N° 200b: (A) west portion; (B) east portion (courtesy M. Letertre).

(9) Four cables arrive to a post and penetrate the soil
(10) House occupied by the night duty officers
(11) Underground
(12) Projectors
(13) Landmark house, red painted
(14) Obstacle easy to enter
(14a) School
(15) Portion of land free for landing
(15a) Practicable track for cars
(16) Group of well camouflaged and guarded houses
(17) Railway track
(18) Circular building
(19) Group of camouflaged houses
(20) Dock
(21) Avrillé
(22) Chemin de la Mayenne
(23) Chemin des Martyrs

(24) Avenue Gasniers
(25) Angers
(26) Rail station St. Serge
(27) Railway track
(28) Maine river
(29) Canal
(30) Point D
(31) Point C
(32) Point B
(32a) Rue Haute de Reculée
(32b) Rue basse de Reculée
(33) House occupied by a German general
(34) Point H Post raising three cables coming out of the ground
(35) Mayenne river
(36) Barrack camp Langlois and camouflaged barrack camp
(37) Camouflaged Aviation School
(38) Camouflaged guard post
(39) Camouflaged hangar for aircrafts
(40) Practicable runway
(41) Runaway
(42) Map N˚ 200b. Scale 1/20,000 November and December 1942
(43) See explanatory sheet 510

Figure 2 shows structures that survived undamaged the allied bombardments on Angers of 17 June 1944.

(A) (B)

Figure 2. Structures survived the bombardments: (A) structures (39)-(41)-C1522-0421_1944_US7GP2926_2016, n˚2016, 1/9974, Argentique, 14/08/1944; (B) structures (4) (36)-C1522-0421_1944_US/GP2926_2015, n˚2015, 1/9974, Argentique, 14/08/1944.

## 4. *V*149 and Saint-Pierre Castle

In winter 1942, the Kriegsmarine installed at Mûrs-Érigné the headquarters of the *Kriegsmarine Atlantikkuste* headed by Admiral E. Schirlitz. The headquarters comprised: Captain on Sea (*Kapitäin zur See*) O. Günther, Navy Artillery Captain (*Käpitain Marineartillerie*) Panzel, Frigate Captain (*Fregattenkapitän*) Braun Ditzen, Corvette Captains (*Korvettenkapitäne*) H. Müller, Nusche, Schaafhausen, Lieutenant.

Commander (*Kapitänleutnant*) H. Hansen, Doctor Saby and some other hundred officers and soldiers (Suquet, 2009). They were installed at the Saint-Pierre castle, residence of the Admiral, the "Bank", the castles of Besson-neau (47˚28'16.2"N, 0˚32'19.51"W), Jau (47˚24'3.1"N, 0˚31'58.0"W), Garenne (47˚24'13.0"N, 0˚31'52.4"W) and other requisitioned properties in Mûrs-Érigné as the mansion "Ma Normandie" (47˚24'13.3"N, 0˚31'40.2"W) at the entrance of the actual rue des Fusillés, which welcomed in its hotel-restaurant and luxury brothel also German officers serving in the Angers sector (Suquet, 2009).

A *V*149 (**Figures 3-6**) was built on 1943 at great urgency, day and night by the light of projectors, by the Brochard and Gaudichet firm of Angers under the


**Figure 3.** *Kriegsmarine Atlantikkuste* headquarters—(1) Saint-Pierre castle; (2) possible small bunker; (3) *V*149; (4) personnel lodgment barrack. C1522-0241_1948_CDP3038_0010, n˚10, 1/4944, Argentique, 17/09/1948.

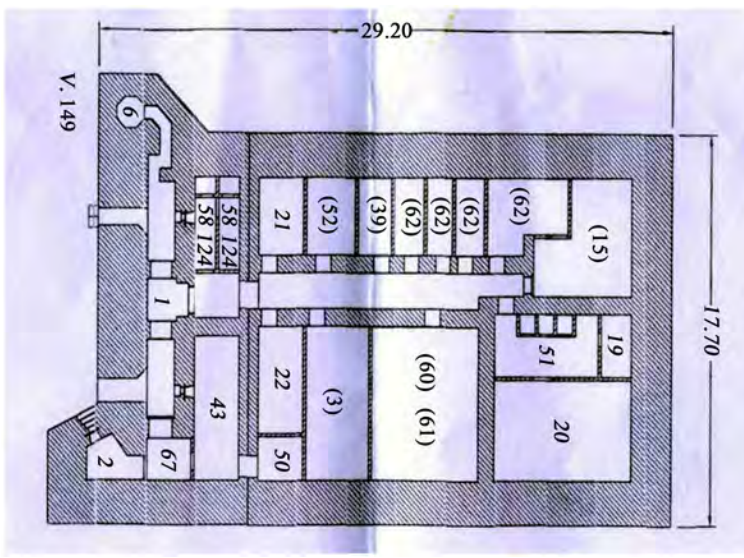
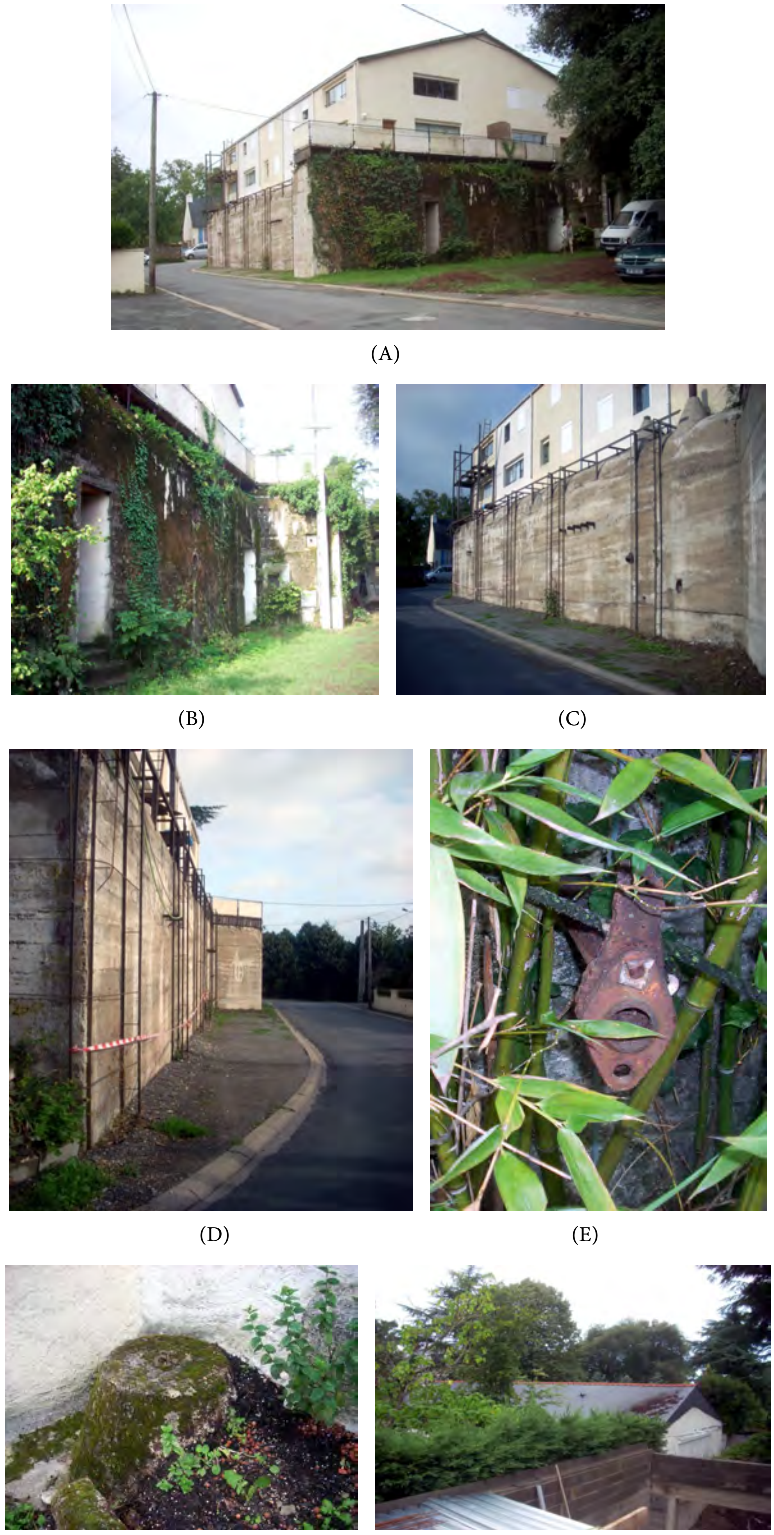



**Figure 4.** *V*149 plan-1 gas lock; 2 close combat room; 6 observation post; 19 wireless officer room; 20 wireless room; 21 heating room; 22 ventilation room; 43 engine room; 50 fuel room; 51 telephone exchange room; 58, 124 latrines/washrooms; 67 gear room (plan: P. Heijkoop); possible identification of the other rooms: (3) crew room; (15) charger room; (39) officers room; (52) telegraph room; (60) Naval Lieutenant room; (61) radio reconnaissance room; (62) work room (Rudi, 1988).



(A)

(B) (C)

(D) (E)

(F) (G)

**Figure 5.** *V*149—(A) general view of *V*149 and superposed house; (B) facade covered by creeper plants and entrances—on the upper right opening of the close combat room; (C) external concrete structure with exits for the communication cables; (D) external concrete structure with oval white painted window as camouflage; (E) communication cable; (F) vertical antenna basement; (G) renovated personnel lodgment barrack.

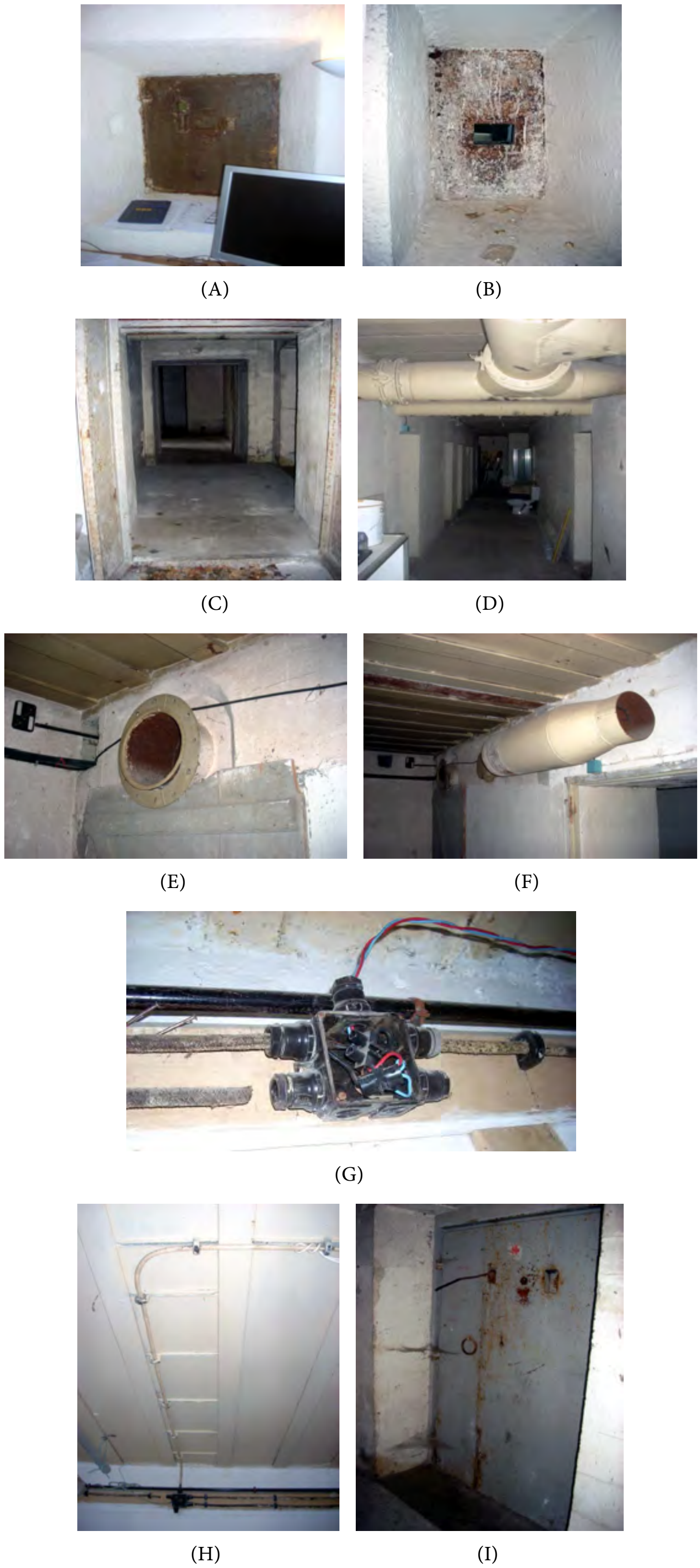



**Figure 6.** *V*149 interior—(A) close combat room, loophole plate; (B) internal loophole; (C) gas lock; (D) internal corridor; (E) and (F) ventilation conduits; (G) and (H) telephonic cables; (I) double sided door.

direction of the Organization Todt (*OT*) Major Aderbach. The bunker permitted through its overhead, underground and wireless lines communications of the headquarters with the headquarters of the Befehlshaber der *U-Boote* at Pignerolle castle in Saint Barthelemy d'Anjou (Tomezzoli, Pottier, Marquet, & Letertre, 2013) and by underground wired network with various other headquarters in Nantes, Rennes and Berlin via Paris. It assured also the radio links with the German surface ships based in the French Atlantic coast ports.

The visit of the *V*149 (47˚24'1.94"N, 0˚32'9.73"W, 41.85 m, 42.08) took place on 19th September 2011. A white house with balcony occupied the whole *V*149 coverage. The visible *V*149 external concrete structure was in a good preservation state showing the traces of the construction formwork elements typical of the German masonry and no damages due to bombardments or combats. The internal walls preserved the original white color with re-painted portions and no traces of a thermal insulation system. The metallic ceiling preserved rusted portions and beige re-painted portions. Original, white painted conduit portions of the ventilation system were still at their place. All the original room furniture and electronic devices disappeared. Portions of electrical and telephone connections remained in place on the walls and ceiling. A renovated original personnel lodgment barrack was near the *V*149 entrances.

The visit of the castle (47˚23'53.67"N, 0˚32'10.67"W, 52.22 m) (**Figure 7(A)**)

(A)

(B)

**Figure 7.** *Kriegsmarine Atlantikkuste* headquarters—(A) Saint-Pierre castle; (B) possible small underground bunker.

took place on 30 July 2013. It hosted the *Fraternité Chrétienne des Personnes Malades et Handicapées & Association Gestion St. Pierre* and *Service aux Personnes* organizations. The interior was renovated and nothing revealed its past function of *Kriegsmarine Atlantikkuste* headquarters. However, near the castle a mound (47˚23'53.45''N, 0˚32'11.57''W) (**Figure 7(B)**) betrayed the possible presence of a small, about 5 × 5 m, buried bunker. The other castles and domains mentioned above are private residences not accessible to the public.

## 5. The UCO R 608

The presence of bunkers in the *UCO* campus was first mentioned by Mr. Suquet in 2009. Ms. Boumard, *UCO* Library conservator, on 2012 declared that on 1940 the *Wehrmacht* requisitioned all the university rooms, letting free only the university Palace in which the courses continued. After the German retreat, on the campus were found ash heaps, rests of tons of burned archived documents and two bunkers, one of the two, the bigger (**Figures 8-10**), was not possible to demolish and subsisted under the grass glaze which brings to the great teaching building (Bazin Palace) of Rabelais road (**Figure 10**).

The ash heaps of burned archived documents suggested for the bigger bunker a commandment place of the *Heer*. This hypothesis has been recently confirmed by the *UCO* students of the *Association Mémoire Angevine*, which localized (47˚27'45.68''N, 0˚32'47.32''W), excavated and identified the bigger bunker as an *R* 608: battalion regimental headquarters bunker on one floor.


**Figure 8.** *UCO* campus—(1) university Palace; (2)-(3) university buildings; (4) excavation and R 608 C1522-0421_1944_US7GP2926_2021, n˚2012, 1/9980, Argentique, 14/08/1944.

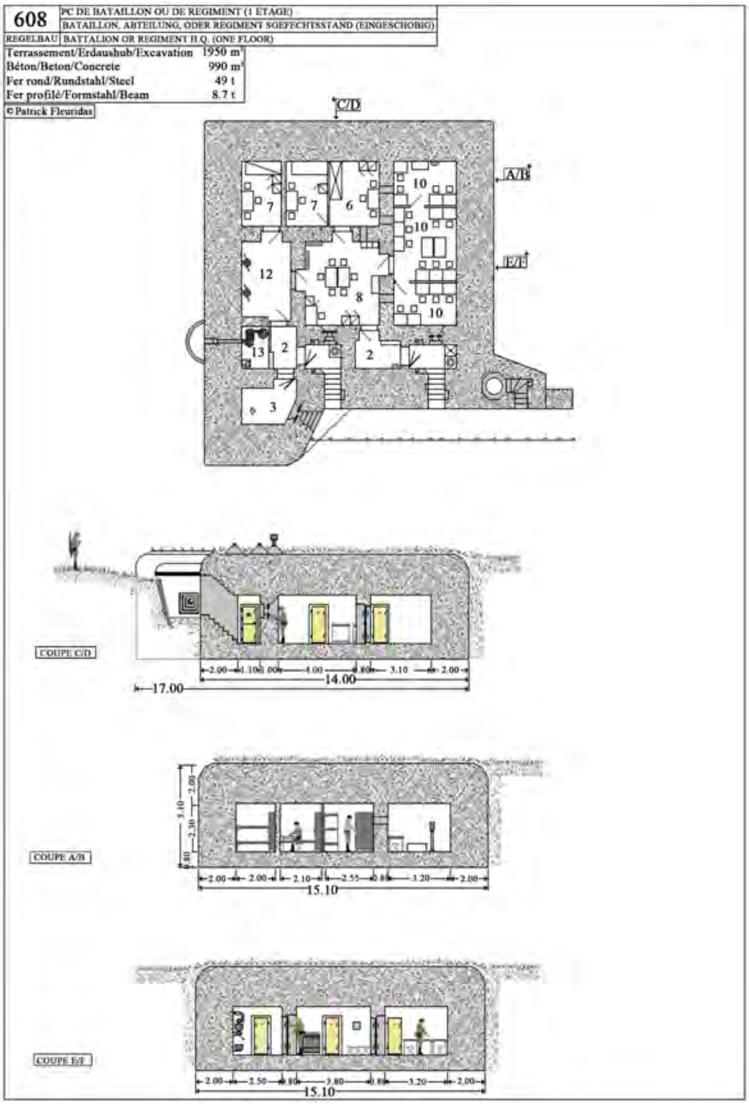
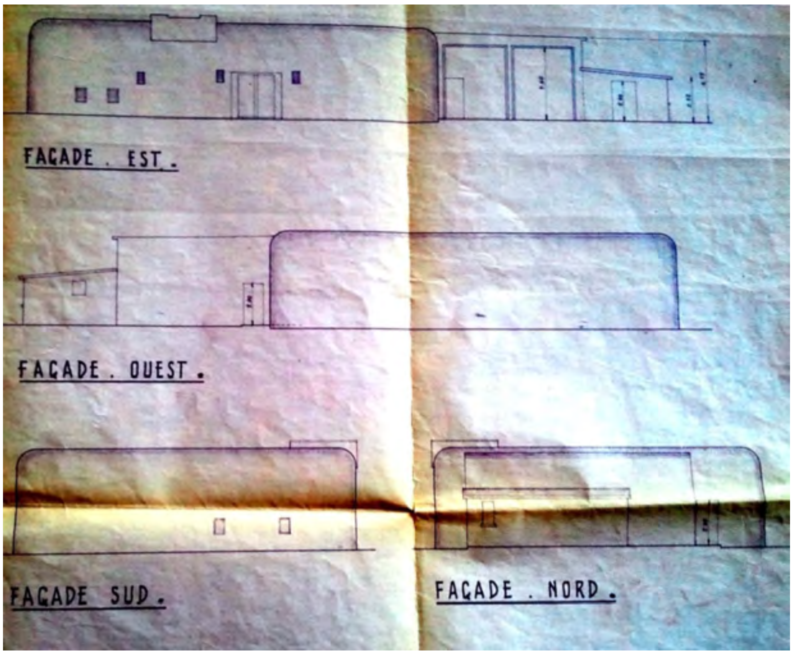



**Figure 9.** *R* 608—(2) gaslock; (3) close combat room; (6) commander room; (7) crew room; (8) work room; (10) wireless/chart/plotting room; (12) ventilation room; (13) kitchen room (courtesy P. Fleuridas).

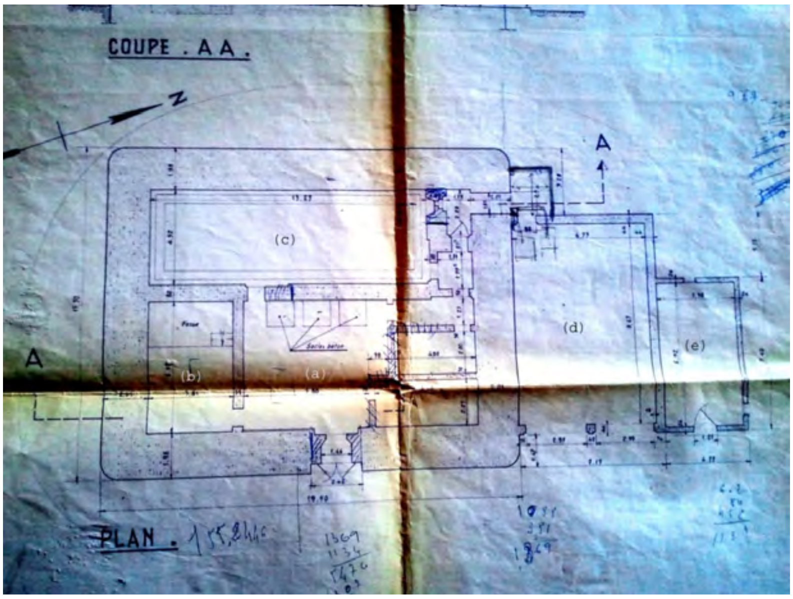

**Figure 10.** UCO campus—(1) University palace, (2)-(3) University buildings; (4) R 608; (5) Janneteau palace; (6) Bazin palace; (7) Rue Rabelais (Geoportail).

## 6. La Reux Bunker Complex

Located at Saint-Barthelemy d'Anjou, in the locality La Reux, on one side of the actual Route d'Angers, about 2.6 km fat from the Domaine de Pignerolle, a bunker complex (47˚28'10.63''N, 0˚30'31.76''O, 44.6 m) was composed by a 19.70 × 19.50 m main component, a 7.17 × 10.55 second component leaning against the main component and a 4.22 × 7.40 m third component leaning against the second component (**Figures 11-14**).




(A)




(B)

**Figure 11.** La Reux bunker complex—(A) external concrete structure; (B) plan: (a)-(c) rooms; (d) second component, (e) third component (courtesy M. Letertre).

Figure 12. La Reux bunker complex—on the right bunker main component with camouflaged coverage, second and third components, on the left five antenna emplacements IGNF_PVA_1-0__1948-03-02__C1522-0501_1948_CDP2928_0385.

(A)

(B)

(C)

Figure 13. La Reux bunker complex—(A) main component, main entrance two-sided metallic door; (B) third component coverage; (C) third component side view.

The visit took place on 04th May 2014. Pieces of furniture, materials and creepers plants anywhere prevented an accurate determination of the preservation state of the external concrete structure, which, in general, appeared, for each component, in a good preservation state, without relevant damages due to


**Figure 14.** La Reux bunker complex—main component interior—(A) personnel access; (B) and (C) internal rooms encumbered by materials; (D) ceiling without metallic coverage; (E) and (F) ventilation conduits; (G) main entrance metallic door (courtesy M. Letertre).

bombardments or combats. The main component preserved the main entrance with its original, rusted two-sided metallic door and a personnel entrance on the adjacent side. Possible cable exits or antenna basements where not remarked. The internal inspection was possible through the personnel entrance. An incredible quantity of any kind of materials encumbered every room, preventing to distinguish possible rests of original furniture. However, apparently, all the original furniture and electric/electronic devices disappeared. Surprisingly, the ceiling had no metallic coverage letting visible the traces of construction formwork elements. Valves and part of ventilation conduits remained in place on the walls. A private house occupied a portion of the bunker coverage. The third component preserved on the coverage an external, tar insulation (**Figure 13**). The interior, of the second and third components, completely crowded by materials, were not accessible. Emplacements for five antennae in the nearby field (**Figure 11**) were occupied by modern constructions.

## 7. Bessonneau Bunker

The Bessonneau industry was the most important industry in Angers. On 1920 it employed 10.000 workers on 35 ha area for the production of canvases and ropes. During the Occupation it worked for the Germans and a bunker (**Figure 15**) was built near the castle for protecting, in case of attacks, the *Kriegsmarine Atlantikkuste* officers installed there. The workshop Ecce Homo, which grouped the weaving chains, was destroyed during the air bombardments of May 1944. Only the bunker survived the destruction of the industry (Robert, 2014).

The visit took place on 30th July 2013. The bunker in Angers, on the actual rue Louis Gain (47˚28'11.24"N, 0˚32'26.28"N, 39.27) was completely masked by vegetation. Its external concrete structure (**Figure 16**) emerging from the terrain was in a good preservation state showing the traces of the construction formwork elements and no damages due to bombardments or combats. Two rusted metallic plates blocked the bunker entrance corridors, so that the internal inspection was not possible. However, looking through offset portions of the plates it was possible to ascertain that they preserved their original white paint. In one of them an original, rusty heavy metallic door 434*PO*1 was still in place and metallic conduits were visible on the floor.

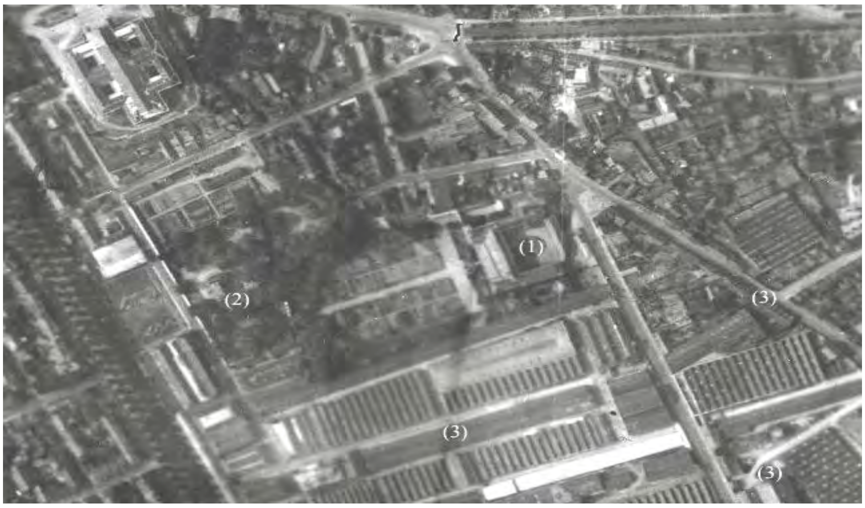



**Figure 15.** Bessonneau industry—(1) Bessonneau castle; (2) bunker; (3) industry sheds C1522-0421_1944_ US7GP2926_2021, n˚2021, 1/9980, Argentique, 14/08/1944.


**Figure 16.** Bessonneau bunker—(A) exterior appearance; (B) and (C) external concrete structure; (D) coverage; (E) metallic plates blocking the entrances; (F) entrance corridor, on the top, louver of the close combat room, on the right rusty heavy metallic door 434*PO*1, on the floor, metallic conduits.

## 8. Discussion

The attempt to access the original map N˚200b and the explicative sheet N˚510 at the *Musée de la Resistance d'Ivry* received, unfortunately no feedback. Point E (1) corresponds to the Parc de La Haye castle, bunkers, wood barracks and pool which hosted a radio jamming centre linked to the *Befehlshaber der U-Bootes* headquarters at Pignerolle. Officers were lodged in the castle and the personnel, comprising an important group of Wehrmacht female auxiliaries (*Helferinnen*) lodged in the wood barracks. Four nearby trenches about 10 × 6 m, 2 m deep hosted copper cables emerging each two meters from water, probably part of the radio jamming system. After the war, French families escaped the bombardment of 17 June 1944 on Angers lodged in the wood barracks (Vincent, 2013). (6), (8), (11) correspond to bunkers, (9), (34) to communication lines, (7), (12) to projector emplacements for driving the anti-aircraft artillery (Flak) fire. Except for Point E, the absence of the explicative sheet N˚510 let the meaning and the importance of the Points B - D, H to be evaluated. **Figure 2** shows two air recognition images taken immediately after the end of the Occupation and shows that the allied bombardments on Angers were not always effective because the structures (1), (4) (36), (39)-(41) corresponding respectively to the French camouflaged air fuel reservoirs, the barrack camp Langlois and the Avrillé airfield, dismantled in the years 70ts, remained intact.

The *V*149 was a bunker for the commander of MBTs (*Schnellboote*) considered suitable and adapted for the *Kriegsmarine Atlantikkuste* headquarters communications. Because of their military interest and sensitivity all the original *V*149 room furniture and electric/electronic devices were probably seized by the American and/or French military authorities. At the moment it is not possible to know which naval operations were coordinated through the *V*149.

The headquarters hosted by the *UCO R* 608 and the type and function of the smaller bunker, this last not visible in **Figure 8**, remain to be determined.

The main component of La Reux bunker complex (**Figure 11(B)**) was a special construction (*Sonderkonstruktion*) bunker having 1.98 m thick walls and coverage. The presence of a pit (*fosse*) in room (b) let suppose that there was hosted a fuel reservoir for one or more electrical (*diesel*) generators for electrical transformers located on the three square concrete basements (*socles beton*) in room (a). The purposes of room (c), 13.27 × 4.52 m, provided with combat louver toward the personnel entrance, and of the other bunker rooms remain to be determined. The extensions of rooms (a)-(c) and the thickness of walls and coverage let to think that the main component hosted sensitive, bulky and powerful generators, transformers and devices. A rectangular emplacement on the coverage near the main entrance (**Figure 11(A)** and **Figure 12**) hosted probably either a *Flak* gun or an antenna emplacement or the exhaust pipes of the generators. The generators and transformers were connected with the five antennae emplacement in the nearby field. **Figure 12** shows that a paint camouflage was present on the coverage of the main component for increasing its safety, and fuzzy areas on the terrain near it and the second component (d) suggest areas covered by terrain removed during the foundation works. The second component (d), because of the two large, 3 m × 3.60 m, entrances and the site access road which directly leads to it (**Figure 12**), was a garage for at least two long vehicles, i.e. cistern or fire trucks. The third component (e) because of its 1.21 m narrow entrance and two windows was a personnel lodgement or a workshop. Its demolished front wall and actual walled windows (**Figure 13(C)**), with respect to the original plan, witnesses its adaptation as store after the war. The particular disposition of the five antennas at the corners and in the middle of a square area (**Figure 12**) let think that they were part of a radio goniometric system. Two other possible white dots near the component (e) indicate the possible presence of two other antennae (**Figure 12**). The kind of antennae is unknown. They and their basements were eradicated after the end of the war and before the 2nd March 1948. The kind of operations performed and which German unit led the bunker complex remain to be determined. Because of their military interest and sensitivity all the original electric/electronic devices were probably seized by the American and/or French military authorities. The private houses which occupy the coverages of the *V*149 and the coverages of the main component and second component (d) of La Reux bunker complex are not surprising, because other examples were already encountered in the Finistère (Tomezzoli & Colliou, 2017).

Because of the absence of visible specific architectural elements, it was not possible to determine the Bessoneau bunker type. However according to the information received, the two entrance corridors communicate with a gas lock in which a single entrance introduces in a single room provided with two lowers protecting the two entrance corridors.

A further German bunker has been signaled in Angers at the locality La Chêne Ronde.

## 9. Conclusion

The precedent publications and the present article aid to better understand the organization of the German military presence in the Angers sector. However, they do only a portion of Angers city. Therefore, a further effort should be made for extending the search and identification of possible surviving German military structures in Angers areas not covered by said studies.


## Acknowledgements

I thank very much Mr. M. Letertre for sharing the copy of the Map N˚200b, the plan, the images of the interior of La Reux bunker and the information concerning the Bessoneau bunker, Ms. Boumard, UCO Library conservator, for her information concerning the UCO campus bunkers, Mr. Fleuridas for sharing the R 608 plan, Mr. Leclerc for the V149 plan and for his permission to visit this bunker and the proprietor of the La Reux bunker for his permission to Mr. Letertre to visit this bunker.


## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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# Hemiunu Used Numerically Tagged Surface Ratios to Mark Ceilings inside the Great Pyramid Hinting at Designed Spaces Still Hidden Within

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## Abstract

In 1883, W. M. Flinders Petrie noticed that the vertical thickness and height of certain stone courses of the Great Pyramid[2] of Khufu/Cheops at Giza, Egypt markedly increase compared to those immediately lower periodically and conspicuously interrupting a general trend of progressive course thinning towards the summit. Having calculated the surface area of each course, Petrie further noted that the courses immediately below such discrete stone thickness peaks tended to mark integer multiples of 1/25th of the surface area at ground level. Here I show that the probable architect of the Great Pyramid, Khufu's vizier Hemiunu, conceptualized its vertical construction design using surface areas based on the same numerical principles used to design his own mastaba in Giza's western cemetery and conspicuously used this numerical theme to mark the location of known spaces inside the Great Pyramid. The theme is not only consistent with some spaces proposed still awaiting proof but also suggests there are some still undiscovered.

## Keywords

Great Pyramid, Khufu, Cheops, Hemiunu, Egypt, Giza, Pyramid, Architecture, Hidden Chamber

[1]URL: https://www.bu.edu/cgs/citl/institute-for-the-study-of-the-origins-of-civilization/.

[2]During the era of Khufu in the language of the ancient Egyptians, this pyramid was named *khwfw akhet*, "Khufu's Horizon". The pyramid of Khafre was named *khaf-re wr*, "Great is Khaf-re". Even though the term Great Pyramid therefore more accurately refers to Khafre's pyramid, the popular convention has been to use that designation for Khufu's Horizon and for clarity I will adhere to that popular convention.

## 1. Introduction

Khufu's pyramid (a.k.a. Cheops Pyramid, the Great Pyramid, Khufu's Horizon) was constructed in the 26th century B.C.E. during the reign of Khufu according to the current historical model. Its likely architect was Khufu's (half-) nephew and his early vizier Hemiunu. In a prior article, I presented evidence that essential architectural features of Khufu's pyramid like its base length, height, angle, and concavity-creating indent were cleverly incorporated by Hemiunu into the original dimensions of his own mastaba Giza 4000 (G 4000) located in the western cemetery nearby, before a later remodel extended both its length and width (Seyfzadeh, 2018). In addition, the scale-up factors five (5) and eight (8) appear to have carried special significance to Hemiunu. The Meydum Pyramid's exterior dimensions compared to those of Khufu's Pyramid are proportionally smaller by 5/8. Hemiunu's mastaba's original long side appears to have embedded 1/5 (i.e. 88 royal Egyptian cubits; abbr.: rc; 1 rc = 0.5236 m, 20.614 in) of the base length of Khufu's pyramid at 440 rc. The later-extended long and short sides of G 4000 were likely designed to be five times as long as the length and width of the so-called King Chamber inside Khufu's pyramid (20 × 10 rc). The basic horizontal architectural unit used was 11 rc which is 1/8 of G 4000 and the pyramid's core masonry was likely designed with eight sides by indenting its faces by 0.92 m = 1.76 rc = 8 × 1/1000 × 220 rc ~ 1 rc 1 palm 1 finger (Seyfzadeh, 2018). It therefore appears as if Hemiunu used his own mastaba as an architectural blueprint of the Great Pyramid.

This numerical theme of "five and eight" may have astronomic and hence theological roots in ancient Egypt. The planet Venus appears low over the horizon at dusk and dawn with a near perfect periodicity of five inferior conjunctions per eight sidereal Earth years each observable as the period (~365¼ days) between two helical risings of the star Sirius. Evidently, both Venus and Sirius were alternate manifestations of the falcon god Horus (Krauss, 1997: pp. 216-222; Allen, 2005: p. 47, Recitation 172). The numbers five and eight were also deeply embedded in Egyptian religious thought. In the cosmogony of Hermopolis, eight primordial gods created the world with a Lotus flower (which often possesses an eight-petaled inner calyx) rising from the cosmic sea giving birth to the sun. The upper priesthood of Hermopolis consisted of the Five of the House of Thoth and Hemiunu was their greatest, presumably presiding member based on inscriptions found in his tomb. In short, the numbers five and eight were likely of special significance to the ancient Egyptians of Khufu's time originating from astronomic periods, converted to theological teaching, and possibly architecturally expressed in pyramids and mastabas.

When W.M. Flinders Petrie, a British surveyor who investigated the Giza Pyramids in the late 19th century, examined and measured Khufu's pyramid, the exterior façade of casing stones had long been stripped and only the core masonry remained as it still appears today. Among many measurements, Petrie determined the incremental and cumulative vertical thickness of the four, now denuded pyramid corners with each added course of limestone blocks and reported these data in 1883 (Petrie, 1883: Plate VIII). He noted that the general trend of lesser elevation with each added level was periodically interrupted by a significantly thicker course followed by a series of gradually thinning courses. One such thicker course, the 35th, can easily be seen nowadays from all four sides of Khufu's pyramid (**Figures 1-3**) and the periodic occurrence of this course height "Peaking and Decay" throughout its walls from bottom to summit creates the visual effect of a "feathered" texture (or "waves"; personal communication Jean-Pierre Houdin) when the pyramid is viewed from a distance. Petrie annotated

**Figure 1.** Southwest corner of the Great Pyramid showing the position of the 35th course which runs immediately above the Queen Chamber's roof inside. The corner edge is one of four where Petrie made his measurement of course thickness up the 203 currently surviving course levels. Photograph taken by the author in February 2017; modified.

**Figure 2.** The 35th course is marked in red on the east side of the Great Pyramid shown in the foreground. Its thickness visibly stands out relative to that of the courses immediately below. Khafre's and Menkaure's pyramids are in the background. Photograph taken by the author in February 2017; modified.

Figure 3. The 35th course is marked in red on the north and west sides of the Great Pyramid. Photograph by Adobe Photostock, license # 102571012; modified.

these thickness peaks at the top of his plot because he had realized that the pyramid levels immediately below had surface areas which were near round-number multiples of 1/25th the surface area of the pyramid at the base, i.e. (440 rc)$^2$. The significance of these peaks and ratios however remains a mystery to date and it is not known if they were necessary architectural features, esoterically encode a message of the architect, or a random feature of how stones were cut and delivered to the construction zone from the quarries.

However, since this series of thickness peaks on the way up the pyramid appears non-random and given that some amount of computation would have been required to generate a numerical sequence based on surface area ratios, I reexamined Petrie's data to see if they comport with what I earlier observed in the design of Hemiunu's mastaba and if they may reveal heretofore unappreciated features of Khufu's pyramid, for example as yet undiscovered passages, chambers or corridors. While hidden voids have been proposed to exist (e.g. Morishima et al., 2017), evidence is difficult to procure non-invasively and so numerical clues, especially when corroborated with architectural evidence, may guide researchers where to look with non-invasive means. Furthermore, the mere identification of voids does not prove they were intentionally made and data which suggest they exist may be still challenged as artifactual (e.g. Lightbody, 2018). In the absence of a blueprint by the architect unequivocally demonstrating intended design, a numerical theme associated with voids, on the other hand, especially when also found in the purported architect's own tomb, is powerful evidence of what the architect meant to conceive.

## 2. Methods

Petrie published vertical thickness (i.e. course height) data pertaining to the 203 nowadays remaining courses of Khufu's pyramid as a composite column plot of 4-corner measurements (i.e. each column represents four measurements taken at the N.E., S.E., S.W., and N.W. corners making the column tops look striped) relative to the overall height of the course in the pyramid (Petrie, 1883: Plate VIII). From this visual representation of successive pyramid layers' heights, one can observe at least 23 discontinuous, "sudden" increases in the height of some courses within an overall context of generally decreasing thickness as one ascends the pyramid to the summit. Such distinct peaks are, with few exceptions, followed by a series of gradually thinning courses resuming the overall trend towards the summit. Consequently, some of these consecutive peaks have as few as one thinner layer between and some as many as eighteen. At the top of Petrie's plot, some but not all peaks show fractions of twenty-fifths (1/25$^{th}$) explained in the legend:

"*The levels of twenty-fifths of the area of the pyramid section are marked along the top, and appear to coincide with the thicker courses.*"

Repeating Petrie's calculations it becomes clear that these notations refer to courses immediately below such peaks. For example, the thirty-fifth course (#35) is a much thicker course than the preceding courses #23-34 which show a gradual thinning trend interrupted by #35 (Petrie, 1883: Plate VIII). Petrie's "16/25" written above refers to the ratio of the surface area of course #34 relative to that at the base, i.e. the squared length of the pyramid sides at ground level when they were fully cased (=440 rc). Therefore, "*The levels of twenty-fifths*" noticed by Petrie are numerically "round" integer fractions (**16**/25, **14**/25, **10**/25, **9**/25, etc., as opposed to **15.65**/25, **14.32**/25 for example) denoting surface area ratios of those courses which immediately precede a "suddenly" thicker course going up the pyramid. I am going to refer to these courses as "pre-peak" (abbr. P.P.) in this paper.

To recapitulate Petrie's computations in deriving these fractions and to apply this process to all courses immediately below the 23 thickness peaks observed, I used his cumulative height measurements on the X-axis of his plot marked "N.E." and "S.W." and generated an average between the two measured heights corresponding to these courses. After converting inch to royal Egyptian cubits at 20.61[3] inch per rc, I calculated the surface area in square cubits of each of these pre-peak courses using the known angle of the pyramid (known as the *seqed* in ancient Egypt) of 5½ rc base recess (or "run") per 7 rc rise in overall height[4]:

P.P. Surface Area = [440 rc – (P.P. height in inch /20.614 in/rc) × (5½ rc/7 rc) × 2]$^2$

From these surface areas, the pre-peak surface area ratios (**SAR**s) relative to the pyramid's base at (440 rc)$^2$ = 193,600 rc$^2$ were computed and the resulting decimal ratios were converted to multiples of 1/25$^{th}$ as per Petrie's notation at the top of his plot and within the margin of error of 13 parts per 100 which thus includes course #34 at 16.11/25$^{th}$. Petrie's representation of the data as multiples of

[3]This conversion from inch to royal cubits is based on Lehner and Goodman's (Dash, 2012) average exterior casing length measurements in meters combined with the generally held assumption that the base length was intended to be 440 rc and the conversion of 1 imperial inch per 0.0254 meters.
[4]The *seqed* was the ancient Egyptians method to construct the angle of a pyramid using a step-wise process in which the base length of each successive course was let in, i.e. made shorter, by a certain amount per one-cubit rise depending on what angle was desired.

1/25th appears to be a good match of the data within this reasonable margin of error. Using 13 parts per 100 as a cut-off, I then defined all those peaks of the 23-total identified, which might belong to the sequence of round multiples of twenty-fifths. My inclusion criterion for the definition of "round" in this study of Petrie's data is therefore any number which is within 13 parts per 100 of an integer.

## 3. Results

**The choice of thicker courses was not random, but premediated**. Below twenty-three observable peaks in stone course thickness, Petrie marked the pre-peak course of ten (**Table 1**). No mention is made of Petrie's exclusion criterion and why he excluded the other pre-peak SARs. However, the data show that four additional courses could be included using the criterion (13 parts per 100) employed in this study: Courses # 21, 117, 129, and 195. Their inclusion expands Petrie's set of ten to a total of twelve significant data points which conform to a sequence of integer multiples of 1/25th. The last two fractions close to the pyramid summit, 1/50th and 1/100th are not integer fractions of 1/25th (i.e. **0.5**/25th and **0.25**/25th) but instead represent successive halvings of 1/25th; this also appears non-random and so these courses are included in this analysis. The ratio 0.19/25 (**Table 1**) could also be interpreted as 1/125th, but this does not affect the conclusions of this paper. The fact that these ratios conform to a numerical sequence based on round number fractions with the common denominator "25" and that all of them mark the imminent occurrence of thicker courses suggests a premeditated design theme and not a random coincidence. The remaining nine courses immediately below thickness peaks number 6, 17, 46, 56, 83, 85, 107, 137, and 149 do not significantly conform to this sequence.

**Pre-Peak courses in the lower 2/5 of the Great Pyramid align with known structures inside the Great Pyramid and tend to be associated with ceilings**. **Figure 4** shows an illustration by Petrie (1883) with the position of all pre-peak courses, conforming to round fractions of twenty-fifths or not, in the lower 2/5th of the Great Pyramid. Course #6, whose SAR at 22.65/25th is not an integer fraction of 1/25th, is nevertheless associated with the ceiling of that part of the descending passage which joins the ascending segment (**Figure 4**). A similar illustration by Maragioglio and Rinaldi (1965: Tav. 3) confirms this position of course #6.

Course 17's SAR at 19.79/25th (**Table 1**) does not fulfill the criterion of a whole number multiple of 1/25th and is not associated with the ceiling of a known pyramid structure.

Course #21 (19/25th) is associated with the notch created by the lower pair of chevrons above the main entrée in the north wall (**Figure 5**). This alignment is confirmed by Maragioglio and Rinaldi (1965: Tav. 2, Fig. 10; the top of #21 is marked with the number 19.12 (p)).

Course 34 (16/25th) is associated with the peak of the ceiling rafters of the Queen Chamber and this is confirmed by Maragioglio and Rinaldi, C.A (1965: Tav. 3).

**Table 1.** Great Pyramid Surface Ratios of Pre-Peak Courses expressed as Fractions of 25. Listed are the twenty-three courses immediately below noticeable peaks in Petrie's plot of course thickness as a function of course height. Surface ratios were calculated as described in the Methods section. The third column shows all those pyramid courses whose surface ratios closely conform to integer multiples of 1/25th. In the fourth column, four new courses were identified whose surface ratios relative to the pyramid's square base also closely matches an integer multiple of 1/25th, or halvings thereof, but were not marked by Petrie. Course #43 has a SAR of 13.94 which rounds to 14/25th and it is this course which is noted in Petrie's plot to have a SAR expressed as a round number of twenty-fifths. Based on this paper's definition of a pre-peak plot, i.e. the course immediately below a significant increase in thickness, it is listed as "not Pre-Peak" in this table. Its significance is discussed under Results. The cut-off criterion used was a deviation from a perfect integer ratio by equal or greater than 13 parts per 100 to include Petrie's 16/25 value for the pre-peak course #34 and course #129.

| Pre-Peak Course # | Surface Ratio in 1/25th | Petrie Sequence | Proposed Sequence |
|---|---|---|---|
| 6 | 22.65 | | |
| 17 | 19.79 | | |
| 21 | 18.91 | | 19/25 |
| 34 | 16.11 | 16/25 | 16/25 |
| 42 (Pre-Peak) | 14.16 | | |
| 43 (not Pre-Peak) | 13.94 | 14/25 | 14/25 |
| 46 | 13.26 | | |
| 56 | 11.53 | | |
| 66 | 10.05 | 10/25 | 10/25 |
| 73 | 8.95 | 9/25 | 9/25 |
| 83 | 7.71 | | |
| 85 | 7.47 | | |
| 89 | 7.03 | 7/25 | 7/25 |
| 97 | 5.99 | 6/25 | 6.25 |
| 107 | 4.76 | | |
| 115 | 4.06 | 4/25 | 4/25 |
| 117 | 3.89 | | 4/25 |
| 129 | 2.87 | | 3/25 |
| 137 | 2.35 | | |
| 143 | 2.00 | 2/25 | 2/25 |
| 149 | 1.66 | | |
| 161 | 1.12 | 1/25 | 1/25 |
| 179 | 0.53 | 1/50 | 1/50 |
| 195 | 0.19 | | 1/100 |

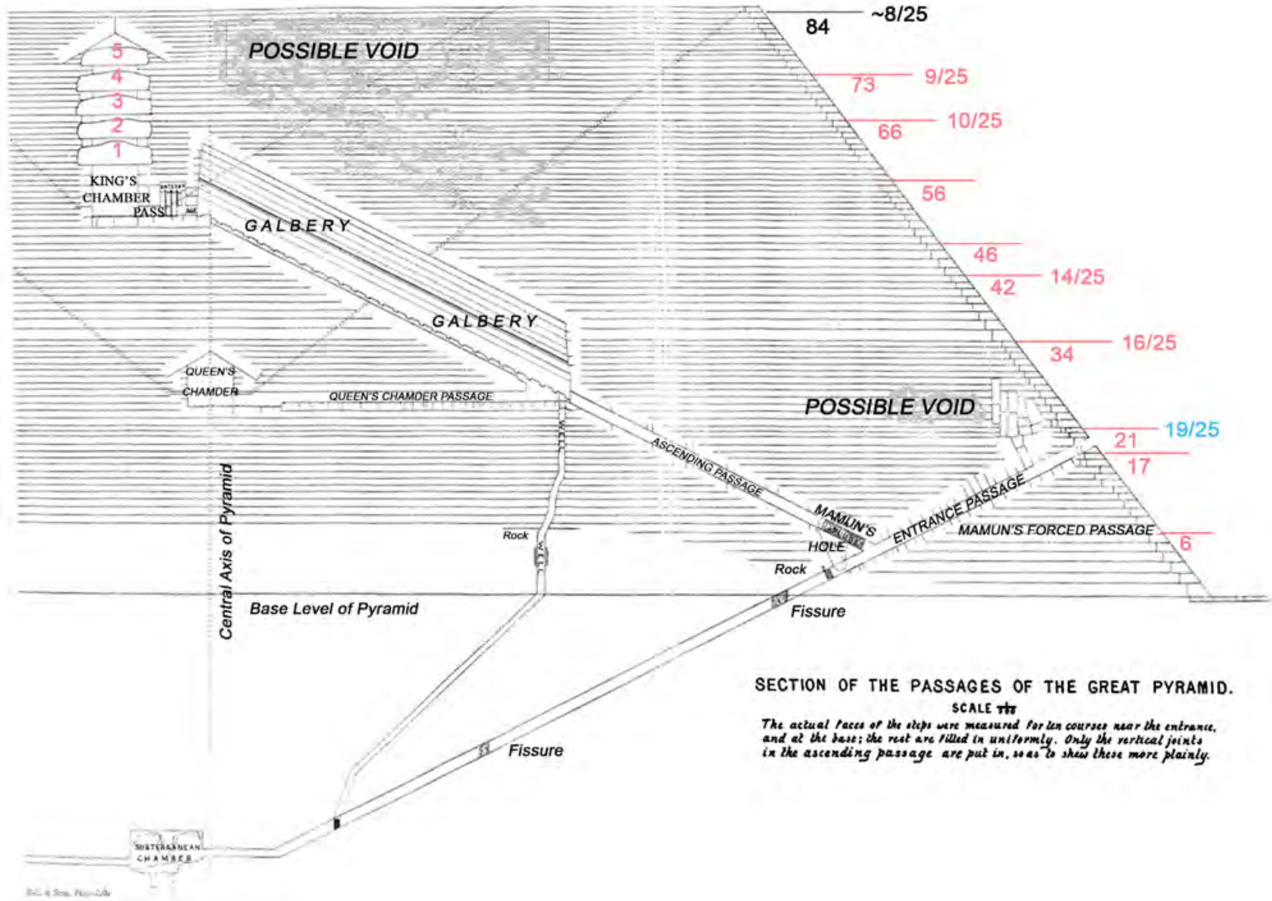


**Figure 4.** Illustration showing the location of pre-peak courses in the lower 2/5th (below the 85th course of 210 presumed total) of the Great Pyramid's north side. Pre-peak courses noted by Petrie on Plate VIII as inter fractions of 1/25th are marked with their respective ratios in red color and those proposed in this paper in addition to Petrie's are in blue. At the top in black is shown course #84, whose pre-peak course #83 is conspicuously absent (there is no course with a round SAR of 8/25th) in the numerical sequence of round twenty-fifths and coincides with the top of the granite tower structure above the King Chamber. The five ceiling-elevating chambers within the granite tower above the King Chamber are numbered in red. The proposed voids recently detected by muon scanning and their possible orientations are shown as grey zones within the body of the pyramid. Note that in this illustration the casing stones are represented even though they no longer existed when Petrie came to Giza. Illustration by Petrie, 1883; Plate IX, modified. For fine details of the original illustration see: http://www.ronaldbirdsall.com/gizeh/petrie/photo/plate9.html.

Course #42 (14/25th) intersects the approximate center, both vertically and lengthwise, of the Grand Gallery where it crosses the north shaft of the Queen Chamber in the horizontal plane (the north shaft runs west of the Grand Gallery and these two structures only appear to cross paths in this vertical, two-dimensional illustration). Here, there is a discrepancy between the drawing of Petrie and that of Maragioglio and Rinaldi, C.A (1965, Tav. 3) who show course #40 to align with this architectural point (marked 34.77 in their figure). It is not clear if this discrepancy is due to an inaccuracy of either author's drawing or the inappropriate inclusion of course #42 in the sequence based on the criterion chosen. The SAR of #42 is 14.16/25th and since this is the value furthest removed from an integer fraction in the entire sequence of twelve, this course may not mark a specific ceiling point of significance after all.

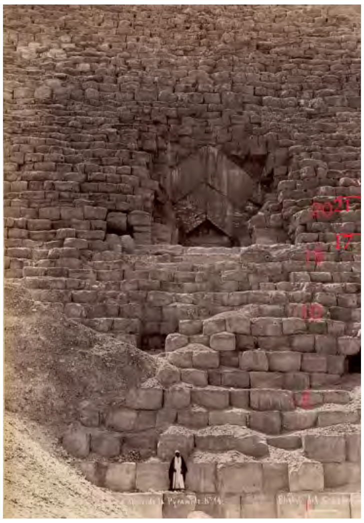

Figure 5. Main entrance to the Great Pyramid on its north wall. Shown in red are the course numbers and the tops of courses 17 and 21 are marked in red for orientation and to point to the thicker courses #18 and #22 immediately above. The thicker courses are immediately above in each case. Only #21 appears to mark a ceiling specifically the bottom notch of the lower pair of chevrons arching over the entrée. Note that this photo shows the Great Pyramid in its current state without the casing stones. Photo courtesy of Boston Public Library: "**The Entrance to Great Pyramid**" created by William Vaughn Tupper (https://www.flickr.com/photos/boston_public_library/2469130012); modified. Creative Commons License.

However, #43 though technically not a P.P. course, has a round-number SAR of 14/25$^{th}$. This course does not have an association with a known ceiling inside the lower 2/5$^{th}$ of the Great Pyramid. However, Jean-Pierre Houdin's model of the pyramid's interior includes two "Secret Rooms" (see Dassault Systèmes website at URL: https://blogs.3ds.com/perspectives/khufu%E2%80%99s-secret-rooms/). It is possible that #43 aligns with the base of the corbelled ceiling of these chambers proposed to rest a few courses above the Queen Chamber's roof (course #35) and below the ground level of the King Chamber (course #50), although Muon scanning did not detect them, if they exist. It is also possible that #43 marks the ceiling of a different space from those proposed by Houdin and too small to be detected by Muon scanning or a space not in the path of the Muon stream measured.

Courses #66 (10/25$^{th}$) and #73 (9/25$^{th}$) correspond to the approximate tops of the irregular ceiling rafters of ceiling-elevating chambers 2 and 4 in the granite tower over the King Chamber.

Course #84 corresponds to the level immediately above the peak of the ceiling rafters of the granite tower. Course 84 is not immediately below a thickness peak but is itself a thicker course. The SAR of the course immediately below, course #83, is not an integer multiple of 1/25$^{th}$. Therefore, the 8/25$^{th}$ SAR is conspicuously absent in the otherwise continuous sequence which begins at 10/25$^{th}$ and ends at 1/100$^{th}$ with the 195$^{th}$ course. The only other exception is the also conspicuously absent 5/25$^{th}$ SAR integer fraction.

**Pre-Peak and thicker courses in the upper 3/5th of the Great Pyramid are not associated with any known interior structures**. There are six courses with SARs conforming to the continuous sequence of 1/25th in addition to two at 1/50th and 1/100th for a total of eight which are hence numerically non-random (**Figure 6**). No interior structure has ever been found in this part of the pyramid. However, an internal spiral ramp has been proposed (Brier & Houdin, 2008: pp. 139-143).

**The architect of the Great Pyramid conceptualized the base as a square of 5 units of 88 royal Egyptian cubits and used one such unit to design his own mastabas**. In a prior publication (Seyfzadeh, 2018), I showed that the base dimensions of Hemiunu's mastabas G 4000 in the western cemetery were designed to represent essential architectural features of the Great Pyramid providing evidence that Hemiunu was in fact its architect and used his own mastabas to enshrine the blueprint of his pyramid design. The original length of G 4000 before its

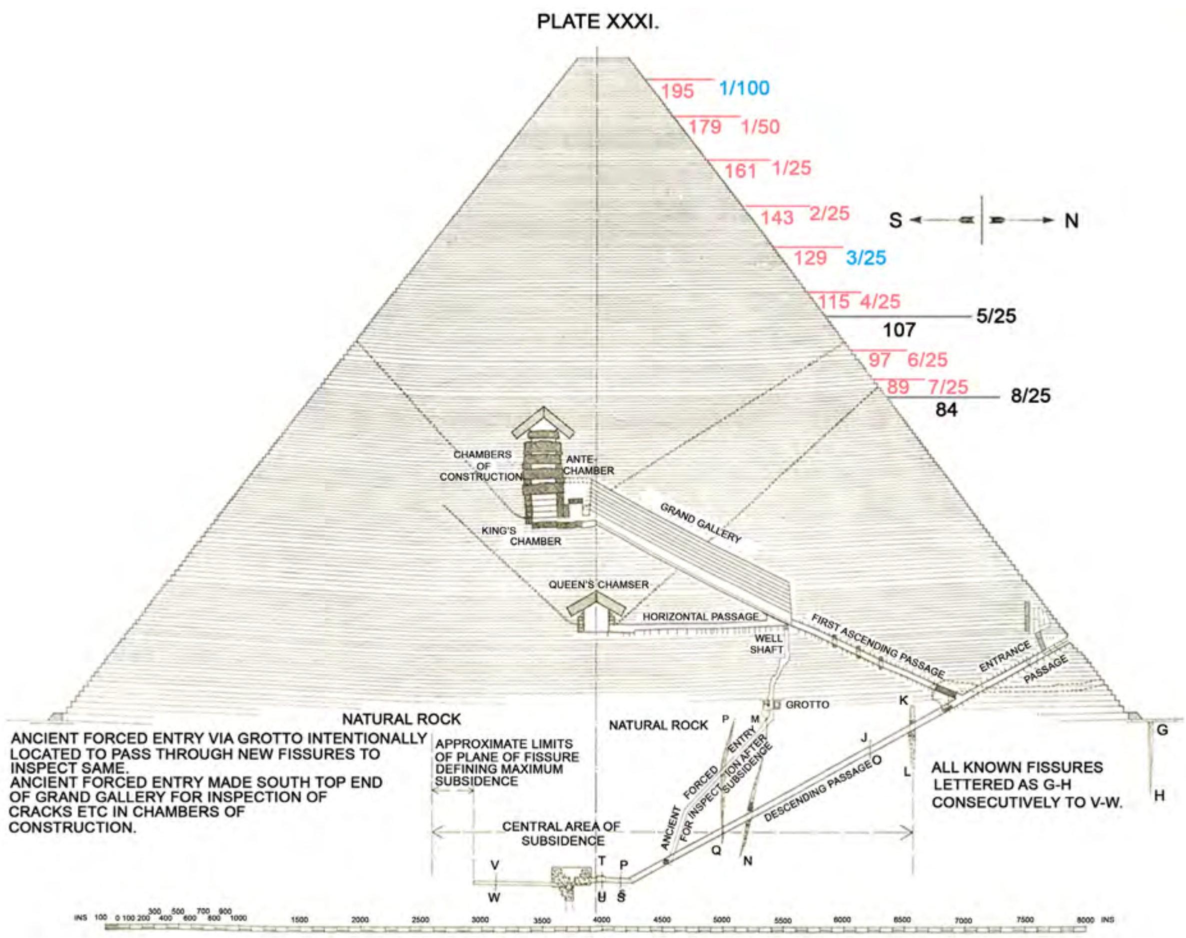


**Figure 6.** Illustration showing the approximate location of pre-peak courses in the upper 3/5th (above the 85th course of the presumed total of 210) of the Great Pyramid's north side. No known structures exist in the interior of the Great Pyramids corresponding to these courses. Illustration from The Great Pyramid: It's Divine Message by D. Davidson & H. Aldersmith, 1936. London: Williams and Norgate Ltd.; modified. Photo file courtesy of William Struse, http://www.countdowntothemessiah.com. For fine details of the illustration follow this link to page 97: https://archive.org/details/DavidDavidsonTHEGREATPYRAMIDLib.DavidsonTheGreatPyramidItsDivineMessage.pdf.

later expansion was 89 rc 5 palms and 2 fingers[5] long (47.00 meters; Junker, 1929: p. 132). The evidence suggests that Hemiunu purposefully added the fractional cubit amounts of 1 rc 5 palms 2 fingers to 88 rc and 6 palms 3 fingers to 40 rc to enshrine both 1/5th of the length of the Great Pyramid's base at 440 rc, the pyramid angle of 5½ palms per 1 cubit and the length of the indent of the four pyramidal faces (0.92 m, 1 rc 5 palms 1 finger). This indentation produces concavities of the core masonry on all four sides (the casing layer was not indented; Glen Dash, personal communication) and thus the appearance of an eight-sided pyramid in certain lighting once it was stripped of its casing stones (Seyfzadeh, 2018).

The apparently non-random sequence of courses with SARs conforming to whole number multiples of 1/25th suggest that Hemiunu conceptualized the base of the Great Pyramid as a square of five units (5 × 5 = 25), each 88 rc long to more easily plan the vertical growth of the structure. In this way, he was able to preconceive surface areas of higher-up courses of architectural significance as integer fractions of 1/25th, and perhaps also 1/50th, and 1/100th. Therefore, he used the same conceptual unit of 88 rc to design his own mastaba, the base of the Great Pyramid, and its vertical expansion.

**In the upper 3/5th of the Great Pyramid, the SARs 8/25 and 5/25 are conspicuously absent as integer multiples in the otherwise continuous sequence**. The numbers five and eight were of significant astronomical, theological, and architectural significance during the era in which Hemiunu lived, i.e. the Old Kingdom. The fact that the design employed an otherwise continuous, non-random numerical sequence based on surface ratios marking ceilings and thicker courses inside the Great Pyramid but omitted these two integer fractions suggests that they were of special significance to Hemiunu.

## 4. Discussion

Petrie observed that a comparison of successive heights of the 203 remaining courses of the Great Pyramid reveals a non-random pattern in whole-number multiples of twenty-fifths immediately below discrete reversals of a general course thinning trend. Adding to Petrie's insight that this pattern is based on surface ratios relative to the surface area of the base, four additional courses can be shown to expand the prior set of ten to fourteen.

In the lower 2/5th of the body of the pyramid, these thickness peak-associated courses tend to mark the ceilings of known structures within and the thicker courses immediately following run above those ceilings. In the upper 3/5th, no known structures have been found to co-locate with these courses.

In an otherwise continuous set of twenty-fifths from 10/25th to 1/25th, the courses whose surface area ratios could have closely conformed to 8/25th and 5/25th were not made large enough to generate these whole number ratios. Instead, two additional courses stand out at the top, 1/50th and 1/100th, which

[5]A royal Egyptian cubit was divided into seven palms. Each palm was further divided into four fingers. A cubit, therefore, was twenty-eight fingers long. It was ~0.524 meters or ~20.6 inch.

complete a set of ten marked courses in the upper 3/5$^{th}$ of the pyramid. This non-random sequence of twenty-fifths, fiftieths, and one-hundredths suggests that the base was conceptualized as a square of 5 units on its side and that each one unit represented a length conspicuously embedded in the length of the original long side of Hemiunu's mastaba G 4000 (Seyfzadeh, 2018).

The present investigation corroborates Gantenbrink's (1997: Figs. 2-4) observation that architectural reference points of structures within the Great Pyramid were located at the ceiling level and not the ground. Gantenbrink's argument is as follows: Only lengths measured from ceilings produces round numbers of cubits. These round numbers conformed to a theme which involve multiples of 1/40$^{th}$ of the base of the Great Pyramid (i.e. 11 rc) or its height (i.e. 7 rc). Some lengths are based on prime numbers (Gantenbrink, 1997: Fig. 6). However, it appears as if linear distances, either based on prime numbers or multiples of 7 and 11 royal cubits, were used mostly, with a couple of exceptions, to design the *horizontal* dimension of structures within the Great Pyramid. The exceptions relate to the design of the *Ka*[6] passages (alternatively called star shafts or air shafts) emanating from the King Chamber and the 11 rc height of the ceiling joint where the descending passage meets the ascending passage (see Fig. 6 and 7 in Gantenbrink, 1997). 2½ rc above this reference point is the top of course #6 whose SAR is 22.65/25$^{th}$ (**Table 1**). In other words, the cumulative height of the pyramid including the joint and the ceiling made up of course #6 is 13½ rc.

Therefore, at course #6, the two design principles appear to overlap. The height of the ceiling joint above ground between descending and ascending passages is both 1/40$^{th}$ of the pyramid base, 11 rc (Gantenbrink, 1997: Fig. 6 and 8), and the stone course which covers that joint to a cumulative height of 278 inch (see Petrie, 1883, Plate VIII; sixth course cumulative height in inch: N.E. = 278.1; S.W. = 278.4) to form the ceiling at that point is followed by the thicker course #7. Gantenbrink concluded that the architect worked on a 1/40 scale to design the Great Pyramid in units of either 7 or 11 rc and he observed that most lengths between architectural points could be derived as multiples of either unit (Gantenbrink, 1997). The question remains, why did Hemiunu employ two design principles in determining ceilings, one based on 1/40$^{th}$ of the pyramid's key dimensions and another based on surface area ratios in 1/25$^{th}$? The answer to this question ultimately has to do with how a system of lengths fits into the overall theme of how Hemiunu conceptualized the pyramid as a three-dimensional structure.

From Gantenbrink's analysis and knowing the pyramid angle, 5½ palms per each one cubit rise, one might expect that successive courses rise by multiples of one royal cubit such that a proportional multiple of 5½ palms could be let in from the two ends of each added course's base. Surprisingly, this is not observed reviewing Petrie's plotted data of course thicknesses. Most courses are less than two royal cubits thick, but there is a large variation in thickness both above and

[6]In ancient Egyptian belief, the *Ka* was the life force of a person which left the body after death.

below that average value. The marked variation in thickness diminishes only above the 154th course though still interrupted by three more thickness peaks. Most courses are not a round number of royal cubits thick and so the *seqed* of the pyramid was probably not Hemiunu's guide to the vertical growth of the pyramid with each added course even though this may seem counterintuitive at first. Why was the ease of conforming course thickness to round numbers consistent with the *seqed* sacrificed for an ostensibly haphazard theme of erratically varying course thickness?

To solve this riddle, we must remind ourselves that Hemiunu appears to have employed a theme not based on lengths, as was the case for his design of horizontal dimension but based on unique surface ratios which conform to round fractions of twenty-fifths. At first look, this theme seems to contrast with the 1/40 scale proposed by Gantenbrink to have guided the interior design in two dimensions. However, the two numerical themes need not be mutually exclusive since they pertain to different aspects of the overall design of the pyramid, one mostly horizontal and one vertical. This was demonstrated in the lower 2/5th of the pyramid. Also, 1/40 = 25/1000. Numerically therefore, the two themes are related: 1/40 × 1/25 = 1/1000 and 25 × 440 rc/1000 = 11 rc! 1/1000 (written with the hieroglyphs "Re/kh3") is also a factor which was evidently used to determine the aforementioned indent: 0.92 m = 1.76 rc = 220 rc × 8 × 1/1000 ~ 1 rc 5 palms 1 finger (Seyfzadeh, 2018). This factor numerically expresses the cosmogony of the Ogdoad taught at Hermopolis: The Sun over the Lotus. But an esoteric motive cannot fully explain the economic price paid by not conforming to the simple numerical rule expressed by the *seqed* in designing the rate of rise of each pyramid course.

Interestingly, the vertical design theme proposed here shares a feature with its horizontal counterpart proposed by Gantenbrink, namely the insistence on round-number multiples. The other feature, "suddenly" thicker courses, can now be explained as well: The likely reason for placing a series of tapering thicker stone courses above a course which formed the ceiling of an interior space was to buttress and reinforce the void's roof to prevent stone block failure under pressure from above. If this was indeed the reason, then the presence of other courses of exceptional thickness higher up in the pyramid *must* mark the ceilings of yet unknown voids immediately below. The pay-back, so to speak, for sacrificing the *seqed* as a straight-forward building principle was the perceived enhanced stability of the interior spaces inside the pyramid. The very presence, therefore, of varying course thickness, whenever this can be observed, proves that at least six if not up to ten designed spaces exist inside the pyramid at those levels, because of the cost, i.e. custom-made instead of stereo-typical thickness quarrying, incurred by not using round numbers derived from the *seqed*, i.e. 5 ½ rc per 7 rc. This is the main conclusion of this paper.

The second conclusion is that not all spaces in the Great Pyramid seem to have been created equally. Some spaces appear to have an added, esoteric, importance. One cannot *a priori* assume that architectural design must only employ practical considerations to the exclusion of ideological, in this case theological, principles.

In a prior publication (Seyfzadeh, 2018), I argued that Hemiunu was indeed the architect of the Great Pyramid because its essential design features can be found in the design of both Hemiunu's original mastabas G 4000 and the dimensions of the larger upgrade. Here, I find new evidence to further support the idea that Hemiunu was in fact the architect of the Great Pyramid. The vertical growth of the pyramid conceptualized in units of 88 royal cubits (i.e. 5 × 88 rc × 5 × 88 rc = 440 rc × 440 rc) is a length also conspicuously embedded in G 4000's original long side (as 88 rc + 1 rc 5 palms 2 fingers). Furthermore, the numbers five and eight, which stand out indirectly by their absence in the numerical theme presented here based on SARs, also stand out at G 4000. Here, they are conspicuously absent from the sequence of round number fractions of twenty-fifths in the upper 3/5$^{th}$ of the Great Pyramid even though the courses with which these ratios are associated, #83 and #107, are below distinctly thicker courses, i.e. #84 (also #86) and #108, respectively (**Table 1**; Petrie, 1883: Plate VIII).

Of interest is that the thicker course above #83, course #84, aligns with the peak of the rafters above the granite tower structure over the King Chamber (**Figure 4**), which, once the pyramid grew past this level, was hidden from the view of even the builders since it was sealed with no access. #83 aligns with the rafters themselves. #83 also coincides with the approximate upper extension of a proposed void observed with Muon scanning called the "Big Void" (Morishima, et al., 2017; see the possible orientations of this proposed void in **Figure 4**). Therefore, it is possible that course #107 also defines the ceiling of a, yet undiscovered, chamber. This chamber, if it exists, would have been of special significance to Hemiunu because the surface area of the course which could covers its ceiling, i.e. course #107, relative to the pyramid's base is not a round fraction of twenty-fifths. Like the integer fraction 8/25$^{th}$, a course with a SAR of 5/25$^{th}$ was "omitted" from the sequence of SARs.

Not representing the numbers five and eight as round numbers in the sequence of twenty-fifths could be coincidental or it might be intentional though this is difficult to prove without other examples. In ancient Egyptian belief, Heka magic was the annunciation of certain words to activate them with real consequences for those present including *Ka* spirits of the deceased who were instructed to use such spells by the Pyramid Texts as they proceeded through the chambers and passages of their pyramids (Seyfzadeh & Schoch, 2018: pp. 109-110). Certain words were avoided or phonetically embedded within others to avoid inappropriate activation. Similarly, by not expressing five and eight as round numbers designing appropriately sized surface areas at courses #83 and #107, Hemiunu might have wished to seal and hide chambers roofed by these courses to leave them "inactivated", but this remains speculation without further proof from other examples. My friend Nagui Guorgui, a native Egyptian, perhaps said it best in a recent conversation about this: "You don't divide a sacred number".

An alternative possibility to a "Secret Chamber" is that course #107 defines the ceiling of a corridor, for example part of an internal ramp as proposed by Brier and Houdin (2008: p. 139ff.). This theory predicts period notching at the pyramid's edges during construction, where contiguous, ascending ramp corridors make ninety degree turns (Brier & Houdin, 2008: pp. 130-132). Even though these notches were later hidden inside the fully cased pyramid, the authors identify one curious stone defect of the Great Pyramid's northeast edge easily visible today (**Figure 7**) which matches the position of the ninth notch in their internal ramp model and which, presumably due to internal failure and collapse at that spot, became exposed (Brier & Houdin, 2008: pp. 137 ff.). Significantly, the floor of this notch measures $5 \times 5 = 25$ rc$^2$, reminiscent of the concept of twenty-fifths apparently employed by Hemiunu to model the vertical design of the entire pyramid. Course #107, however, does not run through the ceiling of this notch, but closer to its floor, which is at the 104$^{th}$ course (Jean Pierre Houdin, personal communication). Also, Bob Brier was unable to detect airflow from a fissure inside the cavity causing the notch, in an area where a corridor might have been suspected based on the model. Therefore, it is not clear if this course does in fact define a corridor ceiling and if this notch indeed represents a remnant of a corner of the proposed internal ramp. Of course, it is possible that #107 is more closely associated with the ceiling of a lower notch,


**Figure 7.** Northwest edge of the Great Pyramid showing the notch proposed to be an exposed turn of the internal ramp (Brier & Housing, 2008: pp. 137-138). Indicated in red are the positions of courses #97, 107, and 117 with SARs shown in parenthesis. Course #107 traverses the notch approximately 3 courses above its floor. Photography (01/17/2011) by Peter Der Manuelian courtesy of Digital Giza, Harvard University; Creative Commons License. Direct link to photo:
http://gizamedia.rc.fas.harvard.edu/images/GPH/PDM%202011/07%20Monday%20Jan%2017%202011/PDM_2011.01.17_235.jpg.

for example the eighth corner in the ascending spiral presumably situated at the southeast corner.

This point deserves further emphasis. Even though Petrie's measurements from all four corners suggest that the thickness of all 203 courses was uniformly varied across all stones making up those individual courses, the motivation for any variation, as it is argued here, may have been the ceiling of a space which often represents a comparatively small part of that course. The alternative of course would have been to only vary the thickness of stones above such spaces, build the rest of the course with regular blocks, and fill in the deficit with the next layer of stones. The implicit assumption of this paper is therefore that the measurable variation in the thickness of the courses based on the current exterior, accessible layer of stones are a proxy for architectural features which may reside deep in the core of the pyramid, far removed from this exterior layer and otherwise inaccessible. In other words, what one sees on the outside is a reflection of the inside.

Altogether ten courses in the upper 3/5$^{th}$ of the Great Pyramid define levels below thickness peaks, whose SARs are round number multiples of either twenty-fifths, fifties, or hundredths. It is possible that these ten courses define the position of corridor ceilings, or the ceilings of corners were such corridors meet on the four pyramid edges, which are part of an internal spiral ramp and this ramp only commences at course #66 whose SAR is 10/25$^{th}$. Interestingly, Houdin's full, ground-to-summit internal ramp model predicts a total of 23 corner turns (Brier & Houdin, 2008: p. 131) and that is the total number of thickness peaks one observes from Petrie's data including all those peaks not preceded by courses with SARs which conform to the SAR sequence of round number multiples of twenty-fifths noticed by Petrie.

Even though recent muon scanning did not detect an internal void consistent with an internal ramp (Morishima et al., 2017), such narrow voids may have escaped detection. The positive control experiment involved the detection of the upper chamber of the Bent Pyramid, but its passages were not discernible in the actual data even though they were predicted to be observable in the simulation (HIP, 2016). Therefore, any chamber smaller than the upper chamber of the Bent Pyramid relative to the length of the Muon path through solid stone may escape detection with this method. The distance traveled by incoming muons through less obstructing segments formed by any such hypothetical voids relative to the length of the path through solid stone towards the detector plates inside the Queen Chamber and in front of the pyramid at ground level was likely too short. In other words, there would not be enough difference in arrival time at the detectors between muons whether or not they traveled through a short segment of air caused by the height or width of a ramp corridor crossing the path of these particles.

Alternatively, and if not marking the ceilings of an internal ramp, it is also possible that these ten courses mark ceilings over chambers and passages smaller than the "Big Void" found by Morishima et al. (2017) just as they do in the lower

2/5$^{th}$ of the Great Pyramid and were hence also missed in that study due to their relatively small size. One possible way to test these alternatives would be a new muon scan with detectors placed inside Campbell's chamber, the fifth relieving chamber above the King Chamber, or inside the cavity which produces the notch on the northeast edge of the pyramid. By reducing the measured muon paths' trajectories through solid stone, the signal-to-noise ratio will increase making such experiment a more sensitive probe of hidden voids in the upper part of the Great Pyramid than the previous one.

Finally, a few more words about the theme of twenty-fifths apparently employed by Hemiunu to conceptualize the Great Pyramid's vertical expansion. First, numerically simplifying a base of 193,600 square cubits (440 rc)$^2$ to 25 units each to represent 7744 square cubits (88 rc)$^2$ makes it easier to get a feel for the size of higher-up levels. This would have helped Hemiunu to estimate the number of stone blocks required at key levels of the growing pyramid. For example, if he was able to gauge the effort required to build a square of 88 rc, a length almost identical to the long side of his own mastaba, he could simply multiply this effort by an integer fraction of twenty-fifths to predict the time required to quarry and transport the necessary stone supply to build a given course.

Second, the sequence of twenty-fifths noted by W.M. Flinders Petrie reveals a mindset which had long been established since the time of king Djoser, alive a century before Hemiunu: That the original Egyptian pyramid was a series of mastabas each successive one somewhat smaller than the one below. If indeed round fractions of twenty-fifths designated the ceilings of conceptualized mastabas in such a stack, then the idea that each of these mastabas contained a chamber is no longer inconceivable (Nagui Guorgui, personal communication).

## 5. Conclusion

A renewed look at Petrie's data from his 1883 survey of the Great Pyramid has revealed new evidence that Hemiunu was its architect, that he computed surface area ratios and generated a sequence of round-number fractions of twenty-fifths to plan the placement of ceilings over voids in the lower parts of the pyramid, and possibly also in its upper parts. Besides this architectural application of the proposed numerical theme, he may have used numbers of theological significance in his time to mark certain areas inside the Great Pyramid where still-hidden chambers, corridors, and passages may one day be found at positions tagged with such numerical marks.

These findings permit a fascinating glimpse into the methods and thinking of an ancient architect who designed one of the most sophisticated stone structures ever conceived. Numerical tags, while alone, do not prove the existence of undiscovered internal voids inside the Great Pyramid, and may assist future researchers to non-invasively probe its interior at certain target sites with a higher chance of success.

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## Dedication

To the People of Egypt.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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# The Methods and Recent Invented Tools and Techniques Used in Archaeology for Delicately Preserving the Past for the Future

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## Abstract

The present paper attempted to detect the all possible methods used in archaeology and also tries to pick up modern tool which is to some extent less destructive to the archaeological sites in modern time. The methods can be put into three regions: selecting sites, collecting artifacts and ordering the past artifacts. The prehistoric time involves uses of organic and inorganic materials which may crumble to dust when exposed to atmosphere. So, it has also been explained in the present paper about the Ground Penetrating Radar (GPR) which is a Non-Destructive Techniques (NDT). Secondary sources served the purpose to track out all the possible methods. The methods help to discover archaeological sites and artifacts which are then dated by different dating methods and are arranged in an order. Later, the experts may trace about the prehistoric settlement pattern, trading system, religious belief, artworks and social organizations by interacting the artifacts.

## Keywords

Methods, Sites, Excavation, Artifacts, Technology, Classification, Ordering, Interactions

## 1. Introduction

The world is a place of suspense which can be uncovered by layers of layers beneath the soil. Anthropologists have always been interested to know the early cultural pattern of the prehistoric people. This is not an easy task. To do so the different methods, tools and advanced technology have brought a revolutionary change in the field of archaeology. The study of this paper has been oriented by the following objectives:

- To track out all the methods used in archaeology in a nutshell.
- To detect the techniques and tools for identifying archaeological site, to excavate and ultimately to put the artefacts in an orderly manner.

## 2. Selecting Sites and Survey

The best place for finding the past is not-other than an "Archaeological site". An archaeological site is a site where the past activity is preserved and it is traced by various things like food remains, structures, humanly manufactured objects and others. According to Jess Beck, "the areas with a large number of artifacts are good targets for future excavation, while areas with small number of artifacts are thought to reflect a lack of past human activity (Beck, 2015)". A site may be varied from large area to small area and might be classified according to the activities that occurred there (Beck, 2015). There are some effective strategies in order to detect a site.

### 2.1. Survey

Survey in its simplest form can be defined as a way of walking across a landscape for searching artifacts (Beck, 2015). Survey can be divided into two aspects on the basis of its intensity carried out. One is large scale survey and another one is small scale survey. An intensive survey involves collecting as much information about as many sites possible from the local people or landowners or from the people residing in that area. Survey serves the purpose to know about the previous settlement pattern of the prehistoric people to a great extent. Surveys require a great deal of time and budget. It is not easy to manage and make a balance between these two in order to carry out for a particular archaeological site.

If we want to site an example of survey, then we may put the example of Cache River Archaeological Project (CRAP) which was under the contract of US Army Corps of Engineer. And, Schiffer and John House were the masterminds of the projects to conduct. The project undertook multistage survey programs and testing. The Cache River Basin is approximately two thousand square miles in extent and it took probability sampling strategy in the field survey (Schiffer & House, 1975). The survey helped out to explore many cultural resources, artifacts and predicted uncovered things which were important for the project.

Moreover, in 1967, with a team of eight members, Paul Martin and Fred Plog surveyed 5.2 square miles of the Hay Hollow valley in east-central Arizona and walked over the area at thirty-foot intervals, which helped them to find two hundred and fifty sites (Fagan, 1978).

### 2.2. Aerial Photography

Aerial photography is the overhead view of the past. Sites can be observed from many directions and altitude at different times of a day and at various seasons (Beck, 2015). Numerous sites have been discovered by using aerial photography. Military photographers have captured much of the world which serves a great purpose to select a site. For example, in Viru Valley of Peru 315 sites have been plotted by the team led by Gordon Willey. There are many natural marks which can be used as a detector of a prehistoric site like shadow marks, crop marks, soil marks. These features may be meaningless from the ground but are highly visible from air. Roger Agache in Northern France, Antoine Poidebard in Syria, L. W. B. Rees in Jordan, O. G. S. Crawford in England and Sir Henry Welcome in the Sudan and Giacomo Boni in Italy can be called as the pathfinder of the aerial photography.

On the other hand, we can also analyse the private collection of the aerial of photography which was taken by Dr. Pouchin Mould. She is an author and has got interest in archaeology. As she is a flying instructor, she has been taking oblique aerial photography (**Figure 1**) for more than forty years (Lambrick, 2008). She has got collections of the parts Tipperary, Cork, Kerry and also other extend parts of Southern Ireland. The collections include thousands of images and are preserved for future inquiries and research work.

## 2.3. Remote Sensing

Remote sensing techniques in the field of archaeological research is an important and valuable tool (Rindfuss & Stern, 1998). Infrared films which three layers sensitized to green, red, and infrared detects reflected solar radiation at the end of the electromagnetic spectrum. The different reflection indicates the different cultural and natural features (Fagan, 1978). There are other tools like radar sensors, scanners which is used for this purpose.

**Figure 1.** This is a picture containing the outline of the enclosing bank of the early medieval ecclesiastical site at Tullylease, taken by Dr. Mould in December 1992. [Source: Lambrick, G. (2008). Air and Earth: Aerial Photography in Ireland.]

The sophisticated technology such as satellite is also being used here. The satellite archaeology is now an emerging field of archaeology. It uses high resolution satellites with thermal and infrared capabilities to point out the possible sites of interest in the earth (Bloch, 2013). Satellite can make a 3D image which helps to detect man-made structures beneath the soil. Moreover, according to National Oceanic and Atmospheric Administration (NOAA, 2013), LIDAR (Light Detecting and Ranging) measures distance to a target by illuminating that target place with a pulsed laser light and also measures the reflected pulses with a sensor. Differences in the returning of the laser times and wavelengths is used to make digital 3D representation.

On the other hand, a resistivity survey meter can be used to measure the resistance of the ground to the electric current. For example, stone walls retain less dampness than a deep pit filled with earth and these differences can be measured accurately by a resistivity meter.

Mine detector is a well-known device for many purposes like detecting natural resources, wealth or treasures. This device is also very helpful to the archaeologists to track the iron objects, fire clay materials, and pottery etc. There is a fact that, heated features retain a weak magnetism so there is a device called proton magnetometer which may be used for measuring the differences between undistributed soil magnetism and heated pottery materials which have been heated somewhere in the past.

#### Identification of Walls and Moats of Fort of Srirangapatna

Srirangapatna, the head-quarter of the taluk of the same name in Mandya District, Karnataka, is an island in river Cauvery with an area of 8.6 sq·kms (Rajani, 2016). It is a historical place and has a history back from 9$^{th}$ century AD where The Gangas, Hoysalas, Vijayanagar Kings, The Wodeyars of Mysore and Hyder Ali & Tipu have left their sign. It is also a place where ancient monument ranges from 894 AD's Sri Ranganathan temple to British period bungalows and memorials (Rajani, 2016). The fort of Srirangapatna contains concentric layers of walls and moats which made the fort unique from other historical places. But due to the ignorance, the fort has lost its importance. The thick vegetation has covered most of the parts which is difficult to uncover on the ground. A research team which includes the personalities Dr. M.B. Rajani, Ms. Ekta Gupta and Ms. Sonia Da has tried to cull out the history again through the addition of the value of remote sensing and GIS into the area. The research team has identified the presence of the vegetation on the walls via the high-resolution multispectral image as linear positive crop mark. The team used interpretation keys crop-mark, pattern, tone, texture etc. and anaglyph image to identify layers of walls and moats on the high resolution. They also formed a virtual 3-D visualization (**Figure 2**) in Erdas Imagine (Rajani, 2016). The 3-D visualization is as **Figure 2**.

### 2.4. GIS (Geographic Information System)

Since 1990, the GIS has been playing an important role in the field of archaeology

Figure 2. The 3-D visualization using Erdas Imagine. [Source:-Rajani, M.B. (2016). Cultural Heritage of Karnataka: A Remote Sensing and GIS Perspective. National Institute of Advanced Studies (NIAS) IISc Campus, Bangalore-560012].

(Conolly & Lake, 2006). Therefore, it is an important means for selecting or tracking an archaeological site. The mapping for the target area can be accurately identified by this system. GIS can answer not only mapping of the target area but also to the basic and main questions about the location, condition trend, routing, pattern and modelling.

The GIS can have four typical application in Archaeology (Conolly & Lake, 2006) which are as follows:

- Management of Archaeological Resources
- GIS and Excavation
- Landscape Archaeology
- Spatial and Simulation Modelling

### 2.4.1. Management of Archaeological Resources

This is most appropriately is run by the government bodies and the archaeologist who have been given the charges and tasks for recording and managing different archaeological resources. For instance, the UK archaeological databases termed "Sites and Monuments Records" (SMRs) for including information like historic buildings, fort, parks, gardens, etc. (Conolly & Lake, 2006).

### 2.4.2. GIS and Excavation

Archaeology has many things to do in pre-excavation, excavation and post-excavation period. There are many works after returning to an excavation like ordering the photographic records, detail analysis of the artefacts, environmental sample, etc. From a GIS perspective, the research nowadays involves massive digital recording methods for spatial data. Many tasks which were taken out in the post-excavation period are now being carried out during the excavation and GIS in this regard, plays an extra ordinary role as a data management tool and allows rapid visualization of spatial data at or soon the collection process during or after the excavation (Conolly & Lake, 2006).

**1) The West Heslerton Project**

In "Geographical Information Systems in Archaeology", Conolly and Lake had put a case study called "The West Heslerton Project" which may help us to have a better understanding regarding GIS in the archaeological field. The project was directed by Dominic Powlesland in West Heslerton, a village in Yorkshire, England, which is a great setting for the English Heritage rescue archaeological projects. The project is of a great importance for both the Late Roman/Early Anglo-Saxon and Early/Middle Anglo-Saxon transitions (Conolly & Lake, 2006). The data involved nearly 30,000 context records and plans, 90,000 objects records and around a million animal bone fragments alongside the photographic, stratigraphic, geophysical and other datasets (Conolly & Lake, 2006). The thing which made West Heslerton different from other projects are the use of digital recording techniques and GIS to manage, visualise, facilitating and analyse archaeological spatial data. GIS also helps to exceed in the publication process.

### 2.4.3. Landscape Archaeology

The projects which are being carried out regionally, are of great importance to the GIS as the tool of the GIS readily associates the work of the projects. The landscape archaeologist is facing one of the major challenges regarding ordering of data from various projects after the data collection via different methods and systems (Conolly & Lake, 2006). Here, GIS can provide great advantages to the solution of these challenges and a better spatial resolution of an area.

Moreover, digital acquisition of the background such as extant field system, walls, buildings, roads, pathways, etc are the starting point for any landscape scale project (Conolly & Lake, 2006) and these background needs a good resolution to carry the project smoothly and GIS is a potential useful tool in landscape archaeology.

### 2.4.4. Spatial and Simulation Modelling

The term spatial modelling refers the use of geospatial data to simulate a process, understand a complex relationship, predict an outcome or analyse a problem (Conolly & Lake, 2006). Spatial modelling helps the archaeologists in the use of elevation models to understand visibility, elevation and terrain data to understand movement across landscape. It also helps to understand ecological modelling of the objects (Conolly & Lake, 2006). Conolly and Lake has mentioned about some approaches:

- Data extraction from a spatial database
- Mathematical manipulation of one or more datasets
- Dynamic modelling

## 2.5. Unexpected Discoveries

Some prehistoric sites have been found by the dint of accidental discoveries. Where, any caches of buried weapons, coins, bones, and treasures which is buried in times of stress by the people from the past is yielded. For this, no methods or techniques were used, rather the discoveries were spontaneous. For example, when the Mexico city's metro was tunnelled down under the modern city the workers naturally uncovered that the city is built on the site of Aztec city, Tenochtitlan. Moreover, 40 tons of pottery, 380 burials, and even a small temple was recovered (Fagan, 1978). Bolors, a site in Portugal was discovered when a farmer noticed some concentrations of artifacts and bones along the border of his fields (Beck, 2015).

The mother nature has also opened up many sites which is then studied very carefully by the archaeologists. A great example in this regard can be the Olduvai Gorge's campsites of the past. Earthquake is one of the natural calamities which has discovered many great archaeological sites.

## 3. Methods Used in the Process of Collection of Artifacts or in Excavation

The human of all ages had the passion and curios mind to excavate and thus to reveal the early human's culture and settlement pattern which not only serves to the field of anthropology alone but also to the field of archaeology as a separate field of study. Sir Flinders Petrienoted that there were two objects of an excavation, one is to obtain plans and topographical information and another one is to obtain portable antiquities (Petrie, 1904). The aim of the early was at the recovery of information about the major structures and the artefacts (Harris, 1989). The history of excavation methods reflects the changing attitudes of generations about considering the valuable objects. We can know about this from the book named "Principles of Archaeological Stratigraphy" written by Edward C. Harris where it was clearly written as, "When the early nineteenth-century excavator, Richard Colt Hoare, 'merely dug holes in barrows to procure the chief relics at the greatest possible speed' (Gray, 1906: p. 3), his interest was not in the potsherd or in the stratigraphic detail, but in the whole pots, objects of precious metal and other complete artefacts" (Harris, 1989).

The first principle of excavation is that "digging is destruction" (Fagan, 1978). It is very hard work to uncover the artifacts beneath the soil without harming or injuring to a little part of the artifacts. So, an archaeologist has to be so careful and has to follow some methods in order to examine during a dig.

### 3.1. Research Design

A sound research design is a first and necessary step in order to excavate a site in a proper way. This is prepared in the first stage of investigation before a single trench is made on the ground. The different and possible excavating problem is analysed while the design is made. A research design involves procedures of excavation which is need to be made in the site, tools which might be needed and other safety issue regarding the excavation. It may also include a statistical validity of the excavation. For example, in the Koster research design, Stuart Struever and James Brown needed to control a mass of complex variables that affected their data. The Koster site is a fine example of having an elaborate research design which comprises of complex computer technology.

## 3.2. Types of Excavation

By observing a site and the research design, the type of the excavation is chosen. Moreover, in the present days where the cost of digging is comparatively high, the archaeologist tries to complete the investigation with the availability of the total budget and tools.

### 3.2.1. Vertical Excavation

Vertical excavation involves digging relatively small-scale horizontal areas of a site where the past culture is deposited. Most of the investigation has to be carried out by a minimum expenditure of time and money. So, a vertical excavation process might be suitable for a minimum expenditure (Fagan, 1978). Some of the world's most significant site was excavated through this method like; Coxacatlan Cave in Tehuacan Valley, Mexico. This method is used to obtain artifact samples and sequencing the ancient building construction or histories (Fagan, 1978). A hypothetical image of digging by using vertical excavation is given below as (**Figure 3**).

### 3.2.2. Area Excavation

In the paper named "Excavation techniques in Historical Anthropology" by Edward Higginbotham, it has been written that the substitute name of horizontal

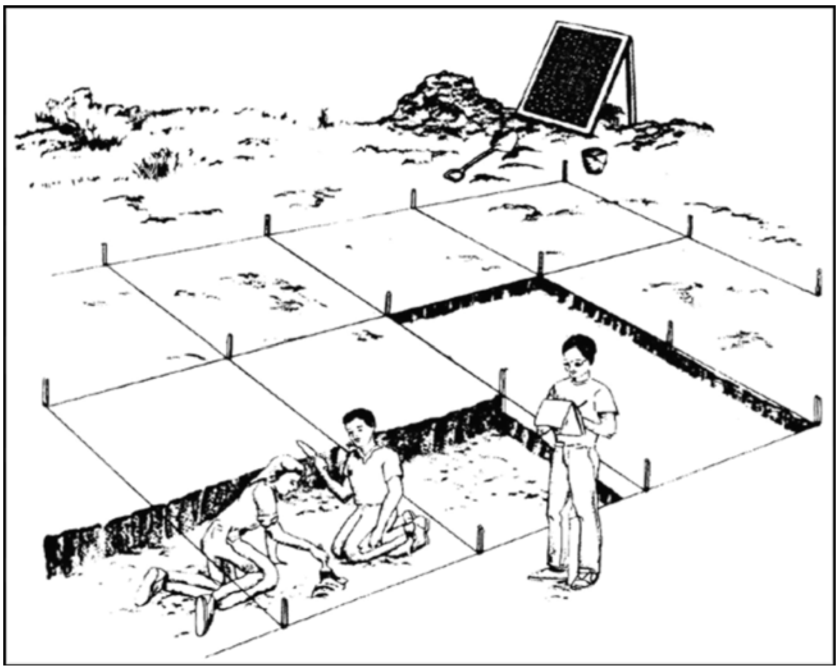

**Figure 3.** Vertical excavating an archaeological site. (Source: Ward, H. T. and R. P. Stephen Davis, Jr. (1999). Time Before History: The Archaeology of North Carolina. Chapel Hill University of North Carolina Press. [Figure 5.18.])

excavation is the area excavation. Wheeler termed the grid layout an area excavation. Mainly area excavation is a large-scale excavation carried out in a large and wider area of a site. This is mainly used to uncover house plans and settlement layouts. It is also expensive. The excavators use a grid of sequences with its own letter and number to participate in digging and recording of the past (Fagan, 1978). **Figure 4** is showing an area excavation Haft Tappeh archaeological site in south western Iran.

## 3.3. Non-Destructive Technique (NDT)

Excavation is risky because there always prevails a chance of damage to the site. So, non-destructive technique nowadays is an increasing technique to the field of archaeology which can also be applied even to the field of south Asian archaeological site. Non-destructive technique or NDT allows the future researcher to verify or re-verify a site by causing a minimal damage. According to, The American Society for Non-destructive Testing (2017), Current NDT methods are: Acoustic Emission Testing (AE), Electromagnetic Testing (ET), Guided Wave Testing (GW), Ground Penetrating Radar (GPR), Laser Testing Methods (LM), Leak Testing (LT), Magnetic Flux Leakage (MFL), Microwave Testing, Liquid Penetrant Testing (PT) etc. But the six most frequently used NDT methods are eddy-current, magnetic-particle, liquid penetrant, radiographic, ultrasonic, and visual testing.

### Ground Penetrating Radar

Ground penetrating radar is one of the tools of NDT. Within the methods used in archaeological excavation GPR is a unique both in its ability to detect small

**Figure 4.** Excavation area of the Haft Tappeh archaeological site in southwestern Iran. Photo Taken by Behzad Mofidi-Nasrabadi.

objects at great depths, and in distinguishing the depth of sources. Ground penetrating radar is used to detect and map subsurface archaeological artifacts, features, and patterning (Lowe et al., 2014). The radar uses radio waves of frequency of range of 10 - 3000 Mhz in order to map structures and burial objects in the ground. Radar transmitting antenna emits an electromagnetic impulse which is reflected by a dielectric discontinuity in the ground, and gathered by receiving antenna. Figure 5 is showing a designed GPR technique.

### 3.4. Digging and Tools

Excavation needs to be carried out with the help of some tools. Archaeologists use many digging tools in their field. Picks, shovels, pick axe, mattock, and long-handled spade are also used. Moreover, the most common tool is the diamond-shaped trowel. Trowel is used for tracing layers in walls, clearing pits and other small objects.

On the other hand, paint brushes are often handy and used in this purpose. Several note books and graph papers, tapes are also used (Fagan, 1978). Camera is also a common and important tool for clicking photographs for the field which is to be excavated.

### 3.5. Recording of the Data

Recording is an important aspect and method in the process of excavation of a site cause without records the excavation is not worthy. The excavation notebooks record each day's trench. Important finds about valuable artifacts are kept in the recordings.

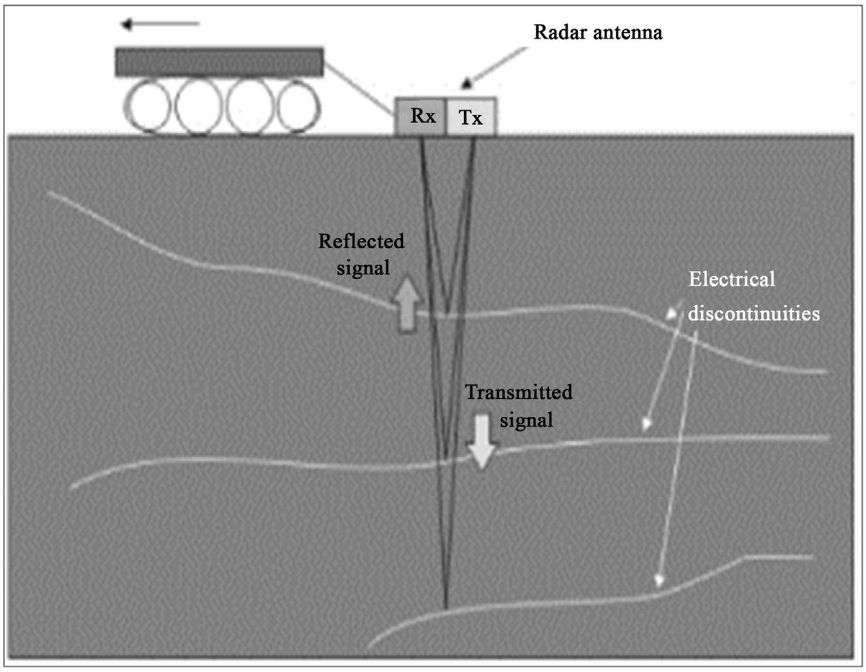


**Figure 5.** Designed GPR technique. (Source: Pettinelli, E. and Barone P. M. (2014) non-destructive techniques in archaeology: recent gpr investigations in crustumerium).

## 4. Identifying the Age of the Artifacts

After a well and sound excavation, a huge responsibility goes to date the age or time of valuable artifacts which has been found during an excavational work. People have tried to find out and date the past in a chronological sequence. And in this regard, dating method has played a significant role. There are mainly two types of dating methods. One is relative dating method and another one is absolute dating method.

### 4.1. Relative Dating Method

It is a method which compares artifacts in order to classify them according to their similarity or dissimilarity by linking them in a particular time. This technique is used when it is not possible to carry out absolute dating methods. Archaeologists identify the cultural objects by comparing one artifacts to other. This method or task may be treated as one of the most time consuming archaeological research.

#### 4.1.1. Stratigraphy

Stratigraphy is a relative dating method and also used in the modern field of archaeology. It can fix events represented by contexts and by time (Harris, 1989).

#### 4.1.2. Seriation

It is a relative dating method. The artifacts from various sites, in different culture, are placed in chronological order with the help of this method. Seriation is a standard method of dating in archaeology. It may be used to date stone tools, pottery, different fragments, and other artifacts. In Europe, it has been used frequently to reconstruct the chronological sequence of graves in a bone-yard (Jorgensen, 1992).

### 4.2. Absolute Dating Method

Absolute dating methods are generally available to the archaeologist and they are well tried techniques such as, tree-ring dating (dendrochronology), potassium argon dating and there is some experimental method like, obsidian hydration, amino acid racemization and thermoluminescence.

#### 4.2.1. Radiocarbon Dating

This is known as the best of all chronological methods. It was pioneered by physicist J. R. Arnold and W. F. Libby in 1949. When an organism dies the carbon 14 atom starts to decay and forms carbon 12 at a known rate, so that after 5568 years, only half the original amount will be left and to be continued. The radiocarbon samples might be charcoal, burnt bone, shell, hair, wood or other organic substances. The samples are then kept to laboratory where it is converted to gas and pumped into a proportional counter. The amount of C14 is then counted and compared to the modern sample (Fagan, 1978). Therefore the age of the artifacts are identified.

#### 4.2.2. Dendrochronology

It is a scientific study of dating tree-rings. This method is based on the variation in tree growth from one year to another which is influenced by sunshine, temperature, soil type and all other environmental conditions. It has a significant role in archaeology. Each year a tree grows a ring. The seasonal weather can be marked by studying this tree-ring. The tree rings are taken with a borer from living or felled trees. The sequences of the rings are compared with other and with a master chronology of rings which is then dated on the basis of an accurate master sequence. The tree-rings dating not only give the information about the time or the date but it also reveal about the existed seasons of a particular area.

#### 4.2.3. K-Ar Dating (Potassium-Argon Dating)

Archaeological sites can be dated by a radioactive counting technique known as potassium argon dating. This is used by geologist to date rocks as early as four to five billion years ago. Potassium is an element presents in most of the minerals. And its natural form contains small amount of radioactive $^{40}K$ atoms. The process of decay over time of $^{40}K$ continues so it is possible to measure the amount of concentration of Argon 40 that has accumulated since the rock formed using a spectrometer.

#### 4.2.4. Thermoluminescence

Firstly, it is needed to mention that this technique is applicable to the pottery materials which were burnt or baked in the earlier time. The things could be burnt stone, burnt clay pot, volcanic products, baked hand made things and others. Various pottery materials and other burnt things emits thermoluminescence when heated to 500˚C. This thermoluminescence is received by the photomultipliers. The emitted light comes from the mineral grains which resides in the pottery. The sources of radioactivity are 4˚K, 87Rb, thorium, and uranium. In order to calculate the rate of emission, a "thermoluminescence clock" is set to zero first. And when the heated samples started cooling down, the thermoluminescence begins to gather and therefore measured by photomultiplier (Atiken, 1997). "The natural TL measured in the laboratory now is directly related to the total radiation the ceramic has experienced since a 'time zero' was set up by the original firing" (Fleming, 1976). Therefore, the chronological age of the burnt pottery materials can be known.

#### 4.2.5. Obsidian Hydration Dating

Obsidian was a preferred material for many past cultures of human for making stone tools. It is high in potassium and silica and derives from volcanic eruptions. In the year 1960, geologists Irving Friedman and Robert Smith introduced obsidian hydration dating. This technique depends on the fact that obsidian contains only 0.2 percent water. When a piece of obsidian is broken, it catches water at a uniform rate until a saturation point of 3.5 percent water comes. The rate of hydration is affected by various climatic condition. Obsidian artifacts are hydrated when human being works on them by flaking techniques so that the date be determined by measuring the extent of hydration (Barnouw, 1971).

#### 4.2.6. Paleomagnetism or Archaeomagnetism

This method is associated with the shifts in the earth's magnetic poles. It works best with the fireplace or the pottery making places. This method has been applied for dating to the site of Paleolithic and Mesolithic sites of the Old world. "When baked clay cools down from firing it acquires a weak permanent magnetization in the same direction as the field and of a strength proportional to the intensity of the field. To be a useful record of direction the clay must be part of a kiln, hearth, or oven so that it has exactly the same orientation today as when it cooled down" (Barnouw, 1971).

#### 4.2.7. Racemization

This dating method has been used for artifacts dating between 40,000 - 100,000 years ago. It includes analysis of arrangements of amino acids in the organic materials. The 20-amino acid found in the living things have the same configuration and they undergo a change after their death. This process is the basis of "protein clock". This method was tested by Jeffry Bada (Barnouw, 1971).

## 5. Methods for Ordering the Past

After locating the archaeological site, collecting the artifacts and dating the samples by different dating methods, the main and most important part is to order the human manufactured and used object in a chronological way. It may take weeks after weeks or even months after months to classify and order a brief excavation event.

### 5.1. Classification and Taxonomy

Every scientific field needs classification. Classification helps to arrange the data or information in a particular by the dint of anything's particular attributes or characters or features.

Archaeology uses classification as a research tool for ordering the large quantities of artifacts. So, classification may serve the purpose to be the solution of possible problem which might be faced later.

There is no well recognized archaeological taxonomy throughout the world. But the British archaeologists refer to "cultures", North-Americans to "phases" and the French to "periods". All the archaeologists do agree that the purpose of taxonomy is to make both the chronological and cultural relationships between different sites and areas to understand (Fagan, 1978).

The different artifacts assemblages which are found in the excavation field may be classified by the attributes it possesses. Each sample has their attributes like they might have different colour combinations, shapes, sizes and decoration. Moreover, clay structures may vary within different types of pottery objects, so, by the attributes it is easier to identify and to put a particular form of object in a particular classification group. A comprehensive attribute list may be made based on the entire collection of the artifacts.

**Natural type of classification** may also be carried out by the dint of own's cultural experience. Basically, the prehistoric people obviously had the idea of "right" artifact design. But it is a matter to think that, the design that a particular artifact have, does it reflect the same cultural experience that we have or not. So, the **analytical type** may serve the purpose to a great extent to classify the artifacts in a more analytical way. The associations found with an artifact helps to understand and to make a comparatively authentic classification.

### 5.2. Units of Ordering

When the artifacts and its associations are analysed and classified, they are ordered in space and time. Site is the fundamental unit for all stratigraphic studies in archaeology. Phase or culture serves for the unit as well. Phase or culture is normally named after a key site.

**Large archaeological unit** is helpful to handle a situation when a particular form of cultural style is found throughout the different parts of the world. For instance, the technological stages of prehistory developed by Chriatian Jurgensen are: stone age, bronze age and iron age. These ages are labelled by the large archaeological unit of ordering.

Actually, the units and concepts used in the ordering are highly explanatory and descriptive. **Explanatory ordering** is very helpful to study the cultural change throughout the past to the present. This units puts artifacts and other culture traits into a correlation in time and space.

## 6. Interactions and Knowing about the Past

A cultural material which is recovered from a site, when arranged and analysed, the different associate matters and facts relating to that object can be known. The patterning of an artifact, remaining food remains, animal's bone, different pottery, hunting tools and weapons—all these gives an indication to the past settlement patterns, catchment areas, trade, subsistence patterns like prehistoric diet, domestication system, rock art (**Figure 6**), social organizations and religious beliefs.


**Figure 6.** Rock art-Cederberg-South Africa (Source: Ramsay, Scott (2011). Secret Rock Art in The Caderbarg. Accessed [January 22, 2018]. Year in The Wild Blog. Link—http://www.yearinthewild.com/secret-rock-art-in-the-cederberg/)

If we start from the past diet pattern, the remaining of food not only give us the scope to relate about how the people obtained their own food but also give us the scope to identify about their diet plan. The analysis of animal bone helps to know about the domesticated animal which was then in practise. Not only this, we can also trace about the then human occupation. For example, Richard MacNeish obtained a sequence of human occupation for the period 10,000 years ago to the Spanish Conquest from Tehuacan Valley in Mexico (Fagan, 1978). Moreover, the rock art gives an idea both of cultural art history and the way of obtaining their food. A hunter-gatherer or a fisherman might have left a painting on the wall of rock in the caves.

Apart from this, the archaeologists may have a vivid insight about the patterned structures of earlier houses, storage pits as they study the artifacts and other remaining tools of prehistoric people which gradually will reflect about the previous households and communities. And there is of course a relation between the then communities and towns. In 1993, the German geographer Walter Christaller developed statement about the relationships between South German towns and the rural communities which is later known as **central place theory.** So, it can be understood that in the previous time of human being, the communities of different areas have a connection to a central place which did meet some functions and might have provided some service to others local places. Therefore, it becomes helpful to find out the different forms of communication which is interlinked to one place to another.

## 7. Conclusion

The analysis of artifacts and its associates is a great way to study about the past social structures and settlements. From the very first step of finding site by different methods through collecting artifacts in the fields to ordering the past in the lab, all are interlinked to each other. From the very early time, different methods were used in the field of archaeology. And by the time, there developed many modern tools which served and helped the existing and new methods in a sophisticated way. The astonishing diversity of the living past can be best represented by the interactions of the artifacts and other remaining tools used by the prehistoric people. By studying the artifacts and its patterning style we can gain a deep insight about the society's changing religious and cultural beliefs and characteristics. And in this regard the significance of innovative research which formulates new idea in the vast field of archaeology has no boundary. From the hunter gatherer society to the complex societies of the modern time, archaeological research is the best way to study and to explore the human society with the artefacts and material remains of the past.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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