ROMAN POMPEII, GEOGRAPHY OF DEATH AND ESCAPE: THE DEATHS OF VESUVIUS

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by

Brandon Thomas Luke

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Thesis written by
Brandon T. Luke
B.A., Kent State University, 2011
M.A., Kent State University, 2013

Approved by
___________________________________, Advisor
___________________________________, Chair, Department of Geography
___________________________________, Dean, College of Arts and Sciences
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CHAPTER 1: INTRODUCTION

Imagine a large, busy city that serves as a port of call for goods from not only the empire in its entirety, but foreign lands as well. This is how Pompeii operated on a daily basis. There were many busy shops, and many different services that were provided. August 24, 79 would be an eventful year for the town of Pompeii.

The eruption began, according to the letters of Pliny the Younger, around two or three in the afternoon (Paul, 1890). The eruption was observed from their home. A large, pine tree like cloud was in the sky over Vesuvius (Paul, 1890). The people of Pompeii tied pillows to their heads to avoid being hit by falling pumice. The citizens of Pompeii began fleeing the city if they were able to, and many of them ran to the coast to see if there was any way of fleeing by sea (Paul, 1890). The cloud and the eruption that caused it made the city as black as night, and so people were forced to move through darkness with torches.

Pliny the Elder would eventually die near the city of Stabiae. The evidence appears to indicate that he died of natural causes (Paul, 1890). The majority of deaths during this catastrophe would be caused by pyroclastic surges and falling pumice. There are some that survived, and many who died. Can hazards geography shed a light on to these issue
The dangers that people face when living near or in a geographic space that is prone to natural disasters has improved drastically with mitigation over what has been historically unavoidable circumstance. There is always value in looking at the strides that have been made in mitigation and emergency management in comparison to their pre-existing standards. In dealing with disasters it becomes clear that there has been progress. In this thesis, I illustrated how modern mapping and hazard planning would affect the geography of mortality surrounding the volcanic disaster of Mt. Vesuvius in Roman Pompeii.

Through the pyroclastic flow, ash, pumice deposits and the locations of the bodies as found throughout the many excavations, it is my intention to show how the modern understanding of hazards and hazard mitigation could have affected those that died. I used ArcGIS to show escape routes that could have been posted throughout the city or made known, if modern policies regarding mitigation were in use during the time of the disaster.

I used geostatistics such as hotspot analysis that will give me a Z score to show significance of clustering in the deaths, which may indicate an area with the least amount of escape access. The Z score will be rendered visually in the maps for clarity and I then compared this to potential escape routes that I identify. I also used kernel density analysis to show the highest amount of deaths along possible escape routes. Clusters and outliers show statistically significant oddities among the dead’s location, whether high or
low on a standard deviational curve. Another important statistical test was the mean and median centers of the deaths as well as a standard deviational ellipse. This shows death trends in a way that will form a spatial pattern for clarity. These and other tests show the statistical significance of how, where, and when deaths would occur in relation to possible routes of escape. I show geographic factors of death, and how this played out in regards to the deaths and bodies that have been found so far. Although there is a large percentage of the city that is still buried, I use accepted “assumptions” about how the city itself played out and show this in map form, so that I take into account the full city.

There is much to examine when looking at a site such as Pompeii. There is a purely physical side, with the work of Wilhelmina Jashemski, as well as Kirk Martini, representing a more straightforward quantitative look into the aftermath and destruction. Kirk Martini is a professor of architecture, but his work has many spatially orientated viewpoints that lend itself easily to geographic thoughts on space. His work focusing in on the specific damage that was seen to buildings was essential in helping me to map out the area for GIS examinations.

Showing the escape routes through the city gives a deeper understanding to how hazard mitigation and planning could have affected an old Roman city, something that is not touched upon in the literature of Geography. I would hope that this study would lead to the further geographic examinations of Ancient Rome, and lead to perhaps future research that the combination of geography, space, and hazards in the ancient world has yet to produce.
The literature of this thesis is at a crossroads of three distinct branches of knowledge, namely the classical world, hazards geography, and human geography. It is my hope that through the application of these literatures that the geography of mortality will be better served through the examination of what is and what is being done through this work. The examination of the past is always relevant to the future, and an examination of past events can often prevent history from repeating.
CHAPTER 2: POMPEII

The city of Pompeii is a town that is east and south of the city of Napoli, or Naples in English (Jashemski, 2002). The city is situated near the southeastern cone of Mount Vesuvius on the Mediterranean coast (Scar, 2009). The formation of the city is dated to the 8th century B.C. according to soil sampling (Jashemski, 2002). The population at the time of the disaster was estimated to be 20,000 (Sigurdsson, 1982).

The issue of population raises several points. The first is that this is estimation, not an exact census number. There appears to be a lack of an exact surviving census that would give an exact number of people directly before the eruption but after the earthquake. The issue of population also comes up when we talk about survivors. The amount of survivors from Pompeii is unknown.

The eruption itself lasted for hours, and there is a presumption that some people would have left during this time. While it is impossible to know what happened during the time the eruption was beginning to the time it ended, there would certainly have been time for people to safely evacuate, if they left immediately upon the initial wave of destruction.

There are several important issues I examined when choosing a research site for this thesis. The city of Pompeii is the perfect place to look into the hazards of life and death because of its recovered history. The availability of that data in some ways chose the site for me.
The geography of Italy has always affected its inhabitants. The natural hazards of the Campania region played an immense role in the destruction of the city of Pompeii, as well as the surrounding cities of Herculaneum, Stabiae, and Oplontis. The naturally fertile soil around the base of Mt. Vesuvius allowed the city to use that resource in its farms that exported its produce, wine, and oil across the world.

This was not without risk however, as Mt. Vesuvius is an active volcano. All the hazards that accompany volcanism such as earthquakes, landslides, and lava flow affect Pompeii. While it is true that Herculaneum is also a viable site in that regard, the city will not be the focus of this thesis.

Herculaneum was a coastal town that was closer to Mt. Vesuvius then Pompeii. Herculaneum is also a poor choice as, according to the work of Wallace-Hadrill, it was a wealthier city (Wallace-Hadrill, 1990). The town of Herculaneum was a coastal town, and had many beautiful coastal villas. Much of the Herculaneum is under a current Italian city Ercolano, so there have not been as extensive excavations for the city as with Pompeii, which is also a reason to avoid its inclusion.

This fact, along with the closer proximity to Mt. Vesuvius means that instead of the 5-6 meters of ash and other volcanic deposits covering Pompeii, Herculaneum was covered with up to 25 meters of tuff. The city is still mostly buried, and therefore not a good choice to get an accurate picture of what happened definitively. It would also be inaccurate to make assumptions off of a site that is mostly buried as well.
There are important aspects to look at when studying Pompeii. As far as mapping
go, there are several issues that needed to be addressed by me. There is a complete and
utter chaos when dealing with the city of Pompeii in terms of city layout. No one points
this out better then Ray Laurence, who discusses some key factors that must be,

The first of these factors is the haphazard way the city is laid out. Pompeii had
zoning issues that led it to having a layout that adheres to no standard set of rules in what
was built where. A second factor is zoning issues, which in this case led to blocks having
radically different buildings next to each other. It is possible to have a home next to a
livery for example (Laurence, 1996, p.17). This kind of building placement was not
altogether uncommon in Roman towns, but was taken to the extreme in Pompeii.

This stems from a theory by Laurence that unlike many Roman cities, Pompeii
was not planned. Planned in this case being the traditional way that a city was laid out in
a grid form with separate “zones” for living and working, much the way cities today are

There are questions that have been raised regarding the outcome of Pompeii after
the volcano. The famous earthquake that was responsible for many destroyed buildings
and left a previously prosperous city in shambles after 62 A.D. (Dobbins, 1994). Rome
sent a team to repair the Forum in Pompeii. This was not a simple renovation, but was in
fact a complete and updated remodeling (Dobbins, 1994). There was a comprehensive
repair plan, focusing on the forum’s east side, and the prominent northeast and
southeastern entrances (Dobbins, 1994). This was expanded to the unification and monumentilization of the urban center, through linking the facades of surrounding buildings with that of the forum, as well as upgrading the building materials to be more modern (Dobbins, 1994).

There are many excavations that show that repairs were made by private residents as well. New studies show that repairs were done to private homes in addition to government buildings. There are newly found repairs done to several homes in region I, in the southeast corner of the city (Fulford, 1998). This indicates the willingness by citizens to repair damage and begin their lives again in the city they know is vulnerable to natural disaster.

This warrants mention for several reasons. This indicates primarily that Rome cared whether Pompeii was depressed after the earthquake or not. The reason that this is important is that it indicates a willingness to help after a natural disaster. This was not the case after the eruption. The city was a fertile land for farming, and would have certainly “paid” off any repairs in goods for trade.
CHAPTER 3: HAZARDS AND GEOGRAPHY

There is an extensive history of hazards work in geography. The papers and books of Gilbert White set the stage for a geographic interpretation of hazards and their relation to space and place, in hopes of saving lives. There are issues still associated with hazard knowledge, including having a lot of academic knowledge that is not being instituted and still results in death and heavy property damage (White, Kates, Burton, 2001).

The work of Susan Cutter focuses on hazard vulnerability. In her paper she discusses the fact that more than 50 years of modern hazards research isn’t lessening the amount of vulnerability to populations that need it most (Cutter, 1996). This is a telling fact when dealing with what could be learned from more than 2000 years of hazards warnings and cultural issues regarding those hazards, as evidenced by the Pompeii disasters.

She discusses in her article that there are many hurdles to overcome when dealing with vulnerability and lose in the wake of a natural disaster. Cutter raises the issue of a lack of good definition’s when dealing with loss due to natural disaster. The lack of a firm definition, or a more clear definition of what loss is being prevented, whether individual or social, is something that she believes is necessary for proper mitigation (Cutter, 1996). Cutter addresses the issue of vulnerability in geography for more than a decade, without much consensus into what it truly means (Cutter, 1996).
Cutter discusses methodology for vulnerability, which she claims is highly varied. I used many of the variables that she discusses as being relevant to vulnerability, such as proximity to the source of the threat, incident frequency, the probability of encountering this vulnerability, magnitude, and spatial impact (Cutter, 1996). These vulnerability variables shape what is to come as far as factors for not only what happened, but how mitigation and escape plans and routes could have helped the situation.

Dr. Susan Cutter discusses how socio-economic factors figure into hazards vulnerability (Cutter, 2005). There is much that can be learned about failures in the past regarding natural disasters that would appear very apt to modern studies of similar proportions. Mathew Kahn (2005) brings up several interesting interactions for geography regarding natural disasters. His article is a remarkable piece that compares natural disasters and deaths among dozens of countries.

Kahn raises several good issues that require to be address and remedied. One of the questions posed is the differences in American fatalities due to natural disasters and that of India. The article is by an MIT professor, and not surprisingly is a very quantitative piece that presents a prodigious amount of data. The numbers provided by Kahn prove that India suffered 31,000 more fatalities than the United States during the period of 1980-2002, for about the same amount of earthquakes (Kahn, 2005). The primary reason of which is that India is more densely populated in urban areas then the United States as a whole.
This is relevant to Pompeii in many ways. Many of the buildings in Pompeii are still standing. There is no doubting the Roman’s ability to construct buildings and homes are “1st” world quality, relative to the time they were constructed. There were no building codes for hazard mitigation however, and the homes were vulnerable to pumice, tremors, and larger earthquakes that would be able to be mitigated against currently. There were also only the materials available to them at the time, and so there are roof vulnerabilities due to lack of roof strength, foundation issues, materials use like untreated wood and other vulnerable aspects to homes.

These same issues affect developing nations now and this will always lead to loss of life because of financial limitations. Something that Kahn brings up in the article that is unavoidably true regarding natural disasters is that some areas are “cursed” by their own geography (Kahn, 2005). If you live in an area prone to natural disasters, you will invariably be impacted by them.

The work of Graham Tobin is valuable when looking at volcanic hazards in geography. In a 2003 article Graham and co-authors Lucille Lane and Linda Whiteford look at the issues that can arise with public safety for false alarms (Lane et al., 2003). This is not a new phenomenon and is something that has threatened public safety numerous times in the ancient world as well. People living in an area that has an active volcano will invariably have tremors caused by said volcano. It can be a desensitizing phenomenon, as you get use to tremors with no volcanic eruption, which can reduce actionable time.
There are many works that examine public response to emergencies. There appears to be, according to Mileti and Peek, a consensus about how people react to emergencies, and that this is what drives researchers (Meliti et al., 2000). They discuss the unifying effect that any disaster warning has on an individual or group, regardless if it is a nuclear accident, tornado, or volcano (Meliti et al., 2000).

Mileti and Peek discuss the effects that hazard warnings have on people’s immediate actions. When a warning or hazard is perceived, people will take stock, quickly, of the actions they need to perform based on the amount of danger they believe themselves to be in (Meliti et al., 2000).

This is relevant in many ways to the life and deaths in Pompeii. There were people found dead who were in a position of shelter. Their bodies were curled up to protect themselves, and they were inside a building. Miletti and Peek describe this as people defining themselves as in immediate danger, with a perception that no other action other than this should take place (Meliti et al., 2000). This is important in hazards work because how people define their reality has to be taken into account when doing mitigation work.

In a volcanic geographic work by Mark, he discusses the statistical methods he employed to study a relatively new chain of volcanoes in Australia (Bishop, 2007). Bishop uses his work to show that the eruptions are not entirely spatially random. This would go a long way, eventually, in helping with volcanic understanding and mitigation.
CHAPTER 4: VOLCANIC MITIGATION

There is much being done in the academic and real world applications of volcanic hazard mitigation. Scott discusses the effects that volcanic hazards can have on communities in ways that are unexpected. Volcanic landslides do not require an active eruption to begin, and can travel for excess of 100 kilometers. Unanticipated debris flow is often not mitigated against, even though it can cause massive loss to life and property (Scott, 2001).

In an article by Paton et al. (2008), they discuss how risk perception influences the actions of mitigation that one believes necessary. While they discuss their findings on the basis of mitigation education programs and perceived risk of others, it is still applicable in Pompeii. It would not be farfetched to assume that while there is no evidence of volcanic mitigation being taught publicly in Pompeii, it is safe to assume that they were aware of the volcano nearby, and took stock of their risk factors.

The study that Paton et al. (2008) performed showed that even people who experienced a volcanic phenomenon were often not motivated to take future volcanic activity into account and showed no attempt to prevent their future exposure. Although this is one study, it is not without precedent. There are people who live below sea level, or on a beach, in the Florida Keys for example, who are denied home insurance because there is a greater chance that their homes will be destroyed by water. The people who live in, and then rebuild their homes continuously, appear to not be motivated to change their habits. It is also presumably apparent that even though there was, and still is, an
active Volcano near Pompeii, many people believed the fertile growing soil or access to a port overruled what might have been a fear of natural disasters. This can be assumed as according to the work of Roberto Scandone, Lisetta Giacomelli, and Paolo Gasparini, the Greeks and Romans were aware of the volcanic nature of Vesuvius (Scandone, Roberto; Lisetta Giacomelli; and Paolo Gasparini, 1993).

An important article by Mastrolorenzo looks at the mortality of pyroclastic surges effects on people and buildings, taking aim at Pompeii (Mastrolorenzo et al., 2010). The new information was very valuable in helping to piece together new information regarding the effects that pyroclastic surges would have on escape routes as well as structural damage.

The article yielded several important facts, to their belief conclusively, regarding the events of the pyroclastic flow on those attempting to find shelter or flee the city (Mastrolorenzo et al., 2010). A few of the key points are that they believe that surges of at least 250° C of a distance of 10 kilometers from the vent would be enough to cause instant death, even if there was a protective building between them and the vent itself (Mastrolorenzo et al., 2010). This is relevant because there was very fertile growing land near the base, certainly closer than 10 Kilometers.

Another point raised by the article was that when assessing risk, it is important not to underestimate possible deaths due to flow that had poor particle load or were mostly gaseous, as these could have the temperatures necessary to cause death as effectively as any heavy particle flow (Mastrolorenzo et al., 2010).
The article study analyzed the bodies and discovered that 76% of the people of the 93 that were used randomly in their study had what they called “life-like” postures when their bodies were found and excavated. This indicates that the people were caught in a “suspended action”, such as standing or walking, when their bodies were found and excavated (Mastrolorenzo et al., 2010). This was relevant because the fourth surge, of six, was the most fatal, but had the least amount of pyroclastic debris. The findings show the dangers of gaseous pyroclastic flows.

Volcanic mitigation, and taking into account ancient disaster’s while looking through a modern lens is not new to academics. Ancient accounts of disasters to gauge the threat level of natural disasters, and even talk about the account given by Pliny the Younger about the eruption of Mount Vesuvius are useful for identifying past disasters (Cronin et al., 2007).

The act of using history to assess damages and see what can be applied in the present is something that more people should be looking into. Many of the large, historically terrible events are so rare that only by looking into the past can a proper mitigation plan be put into effect. The mount St. Helen’s eruption is often hailed as the event in learning about eruption’s and was one of the first time’s that technology was able to be used to capture everything that volcanologist’s, and others studying the effects of the eruption, could want digitally.

Three important factors in risk mitigation are location, time, and guidance (Meliti et al., 2000). The location of the disaster is important because it is important for people
to go geographically away from the danger. The location of a natural disaster is generally an obvious one. If there is volcanic activity, as a resident you are aware of where a large volcano is. This is of course less so with some disaster’s, but would still require information so that people knew in which way to evacuate while taking into account the volcano’s position.

Time is important because it is a necessary variable that tells someone what can and cannot be done regarding their safety. If there is a volcanic eruption, and the lava flow is incredibly viscous, then there is more time to evacuate then if it is a very fast, porous flow that will do most of its damage through heated gases. Time is always a factor when regarding natural disasters, but it is more of a factor depending on these variables.

Guidance is incredibly important because it guides the people that you are attempting to help reach a point of safety. There is a term PAR, or protective action recommendation, that should come with any warning so that people have some idea of how to protect themselves and their family as best as possible (Meliti et al., 2000).

These and other factors are critical to public safety. Dispelling myths about public safety and emergency response are also a key area of interest. One belief that I had, that has been dismissed through research, is that properly posted disaster escape routes might not be a viable method, as people would not heed them in a time of crisis. This was proven wrong in several accounts, but in the article by Meliti et al., their statistics proved that people panicking in response to a natural or manmade disaster was false (Meliti et
al., 2000). It was show that overwhelmingly this was not the case, and that people will in fact head warnings and guidance that is provided (Meliti et al., 2000).

**ESCAPE ROUTES**

Hazard mitigation has long put escape routes into effect because of the common sense idea that guiding people towards an exit in a time of crisis will save lives. Geoffrey Berlin has written an article as a means of saving lives due to fire in a building (Berlin, 1978). While a building is a much smaller, and in many ways different then a city, there are similarities to all hazard escape processes. Berlin defined an escape route as a path that has a straight sequence of attached paths that ends at a place of safety (Berlin, 1978). I believe that is the perfect definition and that has defined how I handled escape routes in the mapping section.

Some important concepts from Berlin’s article that apply in the context of a city is backtracking and circling (Berlin, 1978). Backtracking is exactly as it sounds, a person or person’s is going one way, believing that it will lead to safety, only to realize that it is either blocked off or otherwise impassable, and that the individual or individuals must return to the location that they started at.

Circling, is simply defined, as a person or person’s winding up in the same impassible or impractical room on more than one occasion from different or convergent paths. This is similar to backtracking, as pointed out by Berlin, but different because it
becomes increasingly more difficult to tell which way has been explored before (Berlin, 1978).

A new article by De Vivo and Rolandi deals with the current hazard situation that Vesuvius plays to one of Italy’s largest cities, Naples. They discuss several hazard mitigation recommendations as well as many puzzling aspects with the current situation surrounding Mt. Vesuvius.

The authors broke the region around Vesuvius into three zones. These zones are the Red Zone, which has the most risk, the Yellow Zone, which is at risk for fall-out deposits, and the Blue Zone which is prone to mud flows and lahar deposits (De Vivo et al., 2013). The authors performed this analysis so that they could be submitted to the Italian Civil Defense Authority, or DPC. The DPC decided against heading this warning for what the authors believed to be administrative rather than logical reasons (De Vivo et al., 2013).

The risk zone that Pompeii falls under is the Yellow Zone. This is not to say that it would always be in this “zone” as it can shift depending on the type of eruption that takes place (De Vivo et al., 2013). I will operate however under the idea that it suffers from more of the effects that the authors have deemed to be more prevalent in the Yellow Zone.
CHAPTER 5: DATA

The data that I have access to was in many different forms. There can be no doubt that a great majority of what I relied on are historical documents of many different varieties, as well as previous academic work. The most important source of data will be archaeological discoveries and past work on the city itself. There are many articles and archeological digs that can be used in addition to my own research, to find as much information as possible about the disaster and who were found where and how.

Another important source are the data sets that I have created. I used ArcGIS to map out the entire city. By effectively having the entire city at my disposal, I have created different maps to illustrate where deaths occurred in relation to several variables (Brewer, 2006). One of these variables is the position of homes to Mt. Vesuvius. This is an obvious variable as it involves lava flow, which would limit escape routes and claim lives.

The pumice that fell would be a large barrier to escaping as well. There was a clustering in homes by fleeing or hiding Romans to avoid the pumice that was falling in large quantities, as discovered when casts of bodies were found by excavators. These kinds of hazard variables, as well as water hazards and other road blocks to escape will be discussed and mapped by region.

There are different accepted divisional regions of Pompeii, and maps will be used in those regions to show where bodies were found. This is important for several reasons.
The primary reason is that I had no intention of changing the accepted divisions, as I feel it is important to keep the map familiar to those that research Pompeii if they wish to use or adapt them in some way. Another reason is there is no justifiable reason in my mind to alter the layout that came before.

The maps that are created will visually illustrate where bodies were found when excavations took place. This is important because forensic scientists can determine cause of death by several factors that are still present in the remains that were preserved from this tragedy (Henneberg, 1999). The work of archaeologists is a source of data that played another important role in my research. There have been dozens of excavations and digs from the renaissance to the current excavations today. I used only the newest, most reputable articles regarding body position and cause of death.

The most important aspect of data regarding the deaths is work done that took the time to carefully pinpoint where bodies were found and how. The placement of the bodies themselves, whether inside or out, are important in determining deaths by region and deaths during a transition from region to region.

Many of the articles that I made use of and that are referenced throughout had exact placement of bodies. When this wasn’t possible, in many instances due to the recovered body being documented before people were as careful to mark location as they are now, the body was placed in the center of the building, visually. This was done for the main reason that it would not be fair to stick it in a spot that could alter the statistics.
because it was in a location that was more advantages for clustering, based on nothing but my placing it arbitrarily there.

The work of Luongo, particularly from the journal of volcanology and geothermic research, rely on these facts to portray accurate numbers regarding deaths and placement. This kind of work is crucial to my own and my analysis would not be possible without their efforts.

I am working with a group that is attempting to raise funds and awareness for Pompeii called the Pompeii project. I have been discussing the site with Dr. Eric Poehler who has been most gracious to offer his expertise in all things Pompeii, including helping with data collection. His group hopes to raise educational and scholarly knowledge of the Pompeii area, while also having funds for researchers and preservation.

Along with my own research into this I used the expert writings of Dr. Martini. Dr. Martini is an architect who publishes papers on ancient architectural topics, especially the amazing work done by the Romans (Martini, 1998). His insight into Pompeii will be valuable to what I am doing going forward.
CHAPTER 6: METHODOLOGY

PROGRAMS AND METHODS

Methodology has been discussed in the above sections, although it will be reiterated here for clarity and discussed. I followed methodological archival approaches similar to the work of Dr. Todd Jick, whose work on mixing qualitative and quantitative analyses will be very valuable (Jick, 1979).

The mixing of qualitative and quantitative data is something of a challenge for many as they are seen as a diametrically opposed set of factors. While I believe this is not the case, it will be imperative to illustrate this as being not only possible but understandable. Not every issue is a clear-cut, black and white fact or issue, and these grey areas serve to illustrate issues or hypotheses in all academic discussions.

Another tool I used is ArcGIS, which allowed me to utilize mathematical methodologies in comparison. ArcGIS is a computer tool that allows for complex mapping and statistical analysis in a way that would be difficult if only remarkably time consuming without it as a tool to be used by map makers and statistician’s. The program is created and maintained by ESRI, who are among the leaders in the field in geographic programming.

ArcGIS allowed me to make dynamic maps of anything that can be expressed visually. It will also allowed for database creation and the input of numbers and figures.
that allowed for computer run statistical output. This has proved valuable in multiple ways, and the varied tests I performed, as well as the results that will be discussed in the future of this chapter.

I also compiled my own data to create databases and maps of the city of Pompeii. I used the databases I created to get an accurate visual picture of where people died. I also utilized Pearson’s R correlation statistical methods to show correlations in deaths and status in relation to space. The statistical methods mentioned in the beginning such as hotspot analysis, kernel density, mean and median centers, and standard deviational ellipses were crucial as well.

ArcGIS will be the tool that most accurately conveys the escape routes, and the maps will be used to show a variety of routes out of the city. A large percentage, up to 40% in fact, of the city remains unexcavated. However, there are several available hypotheses on how the unexcavated portion of the city is in fact laid out.

The Pompeii project was generous enough to offer me a shape file that was nearly complete regarding these archaeological discoveries in regions that are currently covered by ash and debris. These shapefiles, along with other articles allow for a complete picture of the unexcavated land, which in turn will allow for planning escape routes.

There are many studies that use ground-penetrating radar in the various unexcavated areas to see what is underneath the ash and debris. One of the newer such studies was undertaken by Barone et al. Their article has information about the buildings, roads, and types of buildings that are found underneath the earth there. Their studies
show a type of “suburb” that has rich citizens housing, as well as the types of structures that surround the region (Barone et al., 2011).

The bodies that are catalogued throughout the thesis are representative of bodies found when excavators began to carefully extract bodies and to take care to note where they were found. This was not always the case, as there were countless bodies lost to looting.

There are a few geographers doing prominent work with regards to Pompeii. These are almost exclusively urban geographers who are looking at past cities to see patterns, or to better understand city evolution. There are several spatial orientated articles about Pompeii edited by Laurence and Newsome. These articles pull from the space syntax method developed by Bill Hillier and looks at what would be the likeliest busiest streets and side streets in Pompeii (van Nes, 2011).

The work put forward by Bill Hillier and van Ness is a fantastic tool, and they discuss it in a way that it is applicable in cities from the past. There are issues of population and migration during a natural disaster that people believe render any statistics from this method skewed, and therefore the mapping that takes place will attempt to remain an examination of past activities that is self-contained and will focus on possibilities from a historical perspective.

This work cannot proceed without the following caveats regarding mapping and any statistical outputs regarding comparisons or correlations. Romans were heavy users of census information for tax purposes and to take stock of the empire. However many of
these are lost, and there is nothing saying that one right before the events ever even existed, let alone survived. Therefore the exact population of Pompeii directly before the volcanic eruption is unavailable. The exact population that survived and moved elsewhere is also unavailable. This does not discount the results, and it still provides useful information that moves ideas forward.
CHAPTER 7: RESULTS

The first map, figure 1 is a view of Italy highlighting the cities that are discussed throughout this work. It serves as a starting point and reference to the position of Pompeii to that of Mount Vesuvius. The city of Herculaneum is placed as it shares a common history with Pompeii, and the cities of Rome and Naples are placed for modern reference.

Figure 1. Italy with Western Europe Inset.
Figure number 2 is showing the regions of Pompeii. The regions are divided by color as shown in the legend. I used the accepted region divisions and have them highlighted with a width of 3 to show the divisions easily for the next map showing death totals.
Figure 3. Death total by region choropleth map.

Showing the regions highlighted by the amount of bodies found inside of it gives a clear indication of the path of destruction. The map, figure 3, illustrates this by color-coded region (Luongo et. al, 2003).

The map data also deals with the amount of people in the streets. In an article by Luongo et. al the causes of death of the inhabitants inferred by stratigraphic analysis and areal distribution of the human casualties, the researchers find that 49% of the bodies found are in the streets, with 51% in buildings (Luongo et. al, 2003).
Figure 4. Outside deaths by region showing death ranges choropleth map.

Figure 4, above is a detailed map of outside deaths by region. The bodies that are in the street closest to a region are therefore assigned to that region. The map shows what I would logically expect to be seen from the pyroclastic flow coming from a northwestern direction. There are some facts that need to be pointed out however.

Regions three, four, and nine are very much unexcavated. This does skew the numbers in those regions, and could paint a different picture to the above map. There is also the fact that there were many bodies and body placements destroyed from centuries
of looting, and so even the numbers that are in fully excavated regions could also be off. I do believe it is a telling piece of information though, and illustrate that people were caught outside in the bottom three regions while fleeing away from the flow. Region six had a large number of outside deaths only when you consider the people at the docks, away from the region itself while they waited for help. If the dock deaths were taken away, the region would have a yellow classification.

Figure 5. Total Inside Deaths by volume choropleth map.
Figure 5 shows the total deaths in buildings in the city itself. The map shows some very interesting patterns. The first region that appears radically different is region two. This was the highest rated region for outside deaths, but is now the one of the lowest for inside deaths. Once again, region’s three, four, five, and nine are still very much unexcavated. Region nine was the region that I expected to have the highest death total, because of lack of exits and gates that would be needed for someone to go to safety.

The first aspect that should be addressed about the total of inside deaths is the higher numbers then outside. The bodies that are found in Pompeii are often found grouped together, and as can be seen by the numbers, inside. This was something that I logically expected, as it is reasonable to assume that people would think that hiding inside would be safer than attempting to run outside.

The grouping is evident by most modern excavations, and is represented in multiple articles, including those by Luongo et. al as referenced above. The grouping of bodies is typical of scared people, huddling together for comfort and safety. This can be seen in many examples throughout campaign, and is highlighted by many maps in this thesis.
The pyroclastic directional flow is illustrated in figure 6. The pyroclastic flows super-heated gas was recently discovered to have been more responsible for the deaths at Pompeii then ash suffocation (Mastrolorenzo, et. al, 2010). The map illustrates the direction of the flow, and the work by Mastrolorenzo et. al, show that people, even hiding in buildings, were still subject to death from the hot gas. People at a distance of 10km from the vent would still be subject to the effects.
The exits that exist in the city are highlighted by figure 7. This is important to show because it indicates the availability of major exits during a crisis. While the number of exits would indicate an ability to flee from a region, there are several caveats that must be addressed.

There is no evidence of how many, or if any, people left their region to travel to another. This factor can skew the deaths in a region. As mentioned above in the work of Luongo, there was a large percentage, 49%, of bodies found in the street (Luongo et. al,
There is a logical assumption that people would be fleeing away from the pyroclastic flow, and so would be traveling in a South Eastern pattern through the city.

Figure eight is a map that shows total deaths by region while highlighting in black the major gates out of the city. The most available gates in the city for evacuating are in the south and south east of the city itself. Regions one and two have 5 gates between themselves alone. Regions two and three have 4 gates. Section one and seven share 4 gates as well.
There was a wall around the city that served as protection. Many ancient cities shared this feature, and Pompeii was no exception. The gates serve as exits from a city by being large and relatively easy to access. This is important in a scenario that involves leaving rapidly due to natural disaster. There were of course people who chose to remain behind, for whatever reason, and those who remained at the dock even though they could have, at least theoretically, fled to safety. These people presumably stayed behind waiting to be rescued from sea, as often happened with Roman towns being evacuated.

There were many hours that people who feared what might be coming could have left, and because of this, the exits are still relevant. The map of these exits show that many regions had exits that would have been utilized, but that those in region IX would have to choose an adjacent region to seek an exit. Logic would dictate that people would flee to region I. This is an assumption based on fleeing the pyroclastic flow coming from the north but down through a southeast pattern.
The exact placement of bodies that have a reliable location from excavators who took care to note position is located in figure 9. This is a very detailed map that contains the placement of bodies that were recorded. As with everything historical, the work cannot begin without discussing some possible issues. As with many maps above, the green area is unexcavated, and therefore shows regions as having very little body placement. Deaths outside the city are very much prevalent, especially in what was the dock area near region six, and above region five.
This data allows for many maps and statistical analysis that can show significance. In figure 10 the kernel density shows the clustering of deaths encompassing the whole city. The settings of the test were default with the following exceptions. The output cell was moved from 2 to 4, and the test was run in meters, to remain consistent with the data. The search radius of 30 was used to create a clearer map. The map itself shows that the clustering of deaths in the center region is overshadowed geographically by the density of deaths outside the walls of region five. The kernel density map is showing significance through a calculation that places value on clustering density. The closer the number is to 1, with zero being insignificant,
the more significant the clusters are, based on the finite data that I have provided, namely the body positions. This shows the significant sources of individual clustering, with the variable being the body positions themselves (Gibin et al., 2007).

Hotspot Analysis, or Gettis-Ord Gi is a statistical calculations that illustrates, visually, statistically significant or insignificant clustering. This is done through the application of standard deviation to show statistically significant clustering using z-score outputs. This shows whether a collection of clustering is important or not, or in other words, what you would expect to see if there was a randomization of the samples.
themselves. The map in figure 11 illustrates these clusters. The most significant clustering is in region seven, eight and nine. As with other maps in this thesis, some of the numbers are affected by areas in regions that are unexcavated, particularly regions, one, three, five, and nine. Regions five and nine, even with the unexcavated portions show the most significant clustering. Presumably this would continue even if both regions were fully excavated, assuming regions three and four did not skew the analysis.

Although region one and two had significant fatalities, the clustering wasn’t significant in there grouping. Region three and four are practically nonexistent as well, although this is almost certainly due to the fact that the areas are almost completely unexcavated.
The map in figure 12 represents three different spatial statistical outputs. The first one is the mean center. This is a test that shows the mean center of a group of values of an environment of the output coordinate system. The mean is made from a spatial reference from the output coordinate system. This is not unsurprisingly in region five which is also the region that is highlighted in the hotspot analysis as having one of the greatest clustering regions.

The map also shows the median center. This is a statistical output that shows, in Euclidian geometry, the overall distance of the features in a particular dataset, which in
this case are the body locations in Pompeii. The median and mean centers are measures of central tendency, but the median center is less influenced by outliers. These tests are both relevant as they show different versions of the center that are both statistically relevant.

The standard deviational ellipse is another tool that is illustrative of spatial patterns in directional trends. This test illustrates the directional relationship of the phenomenon, which in this case is bodies found in Pompeii, to the mean center. The pattern is an East to West directional significance. This test however appears to be biased by the fact that there are many regions in the northeast that are unexcavated, particularly regions three and four.
Figure 13. Spatial statistics of Pompeii showing standard deviational ellipse and mean for each region.

The map in figure 13 is showing multiple spatial statistics and outputs for each region of Pompeii. Every region provided interesting spatial outcomes except for one, region four. Region four had far too few results to provide any relevant individual spatial statistics. This is in itself something of note of course; however it is almost certainly a result of the region being almost 100% unexcavated.

Region one, in green, is also partly unexcavated, and because of this the standard deviational ellipse is skewed in an almost east to west direction. The mean center of the region is in the northern center of the region, above the unexcavated line. Region one shares its deviational ellipse direction with only one other region, region seven. A fully
unexcavated region one would conceivably change the directional pull of the region, as well as the mean center.

Region two shows a north-south directional ellipse. The standard deviational ellipse is influenced heavily by the people found clustering in the southwest of the region inside, where presumably they believed themselves safer. Region two also has the only vertical standard deviational ellipse out of any region. The mean center of region two is in the region of the clustering in the southwest corner as well.

Region three is a mostly unexcavated region that had enough bodies to run the tests, unlike region four. The locations of the excavations are almost certainly skewing the results. The shape of the ellipse is mirrored in the top three regions that have results, so it is possible that the data that is being presented would in fact hold no matter how much was excavated in the region. The mean center is located between the excavated bodies and rests in the center of the region in an area that is unexcavated.

Region five is represented with the most common shape of the standard deviational ellipse, following a northwest to southeast directional path. Although much of the region remains unexcavated there are massive findings in what was excavated, and there are many deaths nearby, that while technically are people who fled the city, are included in this region in this study.

Region six is a completely excavated which allows for a complete picture in the standard deviational ellipse. The size of the ellipse is of course altered by the inclusion of the deaths of those on what was once a dock. These deaths brought the ellipse to a
much more extreme east west direction then would be present without it. The people that were found on the docks were waiting, presumably, for an evacuation that was expected from Rome proper but was not coming, or if lost in time, just simply late. The mean center of deaths is also in a unique place compared to other regions because of the dock fatalities, and is in the top most western corner of the region.

Region seven has a standard deviational ellipse that I would have expected from the region considering the shape of the region, and the fact that it is completely unexcavated. The region has a southwest to northeast slant, and that is the pattern of the ellipse itself. The mean center is in the center of the region, in a way that you would expect to see with a fully archived region.

Region eight shows a clustering in the ellipse that I did not expect, as I logically expected the region to have a west to east ellipse similar to the ellipses in one and seven. This was not the case when the tests were run however, and we have a clustering of the ellipse in the eastern portion of the region. The mean center is therefore in the eastern portion of the region as well.

The last region, nine, has an almost circular standard deviational ellipse. This is almost certainly due to the large amount of unexcavated land in the region. There are many bodies that have been found in the region however and if you extrapolate out, it becomes possible to see that an almost circular ellipse would be the norm even if the
The entire region were explored, because the region itself is almost square. The mean center is almost in the center of the region, even with a large portion remaining unexcavated.

Figure 14 is a cumulative map that incorporates the regional spatial statistical outputs but also overlays the entire cities outputs as well. It makes sense that the mean center would be located in region nine, as it is essentially the city center; however I was surprised by the standard deviational ellipse. I expected a much wider, thinner version then what was revealed, as it seems to ignore the clustering in regions six and two.
Figure 15. Clusters and outliers of Pompeii showing significance in grouping.

The mean center and median center are where you would expect, region nine. Their positioning could certainly change based on the bodies that are awaiting discovery in regions three, four, five, and nine. The standard deviational ellipse is similar in directional shape to four other regions, and in geometric shape with 6 of the 8 possible ellipses. An excavated region nine and four could make it a similar directional ellipse with 8 of nine regions.

Figure 15 shows a statistical method of clusters and outliers, as available in ArcGIS which uses an Anselin Local Moran statistic. The clusters range from high value
statistically significance, represented by HH, and low value statistically significant features represented by LL. Outliers are mathematical anomalies that can throw off an entire dataset. The anomalies do this by having values at the extreme ends of a spectrum, both high and low. This test takes those anomalies into account and then filters them.

The map shows significant high value clusters in seven, eight, and nine. Region one and two has significant values of low value clustering. The values could be changed with further excavating, but in the present sense show what I would imagine to be a logical output. The significant clustering, specifically region nine, was a region that had no exits, and so the people would have to either leave it and be outside or attempt to wait it out in their home and hope they were spared.

The significant values, whether high or low, are in the regions that one would expect to see from people fleeing in a southern direction. The only real anomaly is the people of region six waiting at the dock. This was confirmed with the outputs in figures three, four, five, and eight, but it is a more significant output when dealing with specific body positions and not overall totals.

The mapping of each region, and the city itself, using standard deviational ellipse, mean center, and median center serves to show patterns of body clusters. The regions themselves definitely share a similar pattern with the city itself. The few regions that are essentially or completely unexcavated have the possibility of increasing these similarities.
Figure 16 shows the positions of bodies using a geographically weighted regression, or GWR. The GWR test uses, in this case, the position of bodies to geographically weight varying spatial relationships in relation to neighbors and to geographic space. This test differs from the above clusters and outliers test by making all variables geographically dependent rather than dependent on only the variables themselves.

The GWR shows spatial significance in clusters that highlight key aspects of recovered body positions. The shift from clusters and outliers to GWR is a more eastern
emphasis, while also showing the significant clusters in regions five and six that are not there in the standard deviational ellipse outputs. There are significant deaths outside regions five and six. These deaths are reflected as significant in clustering in the GWR map.

In region five the significant clustering is shown just outside the city walls. The distribution might be different with further excavation, but the clustering that is there is significant. There is no record of why people are clustered in the top, just outside of region five, but presumably people were intending to flee out of a nearby gate, and were caught by the pyroclastic flow.

The deaths in region six are similarly shown to have significance outside of the region, in what was once the dock area. It was not uncommon for Rome proper to send assistance in times of crisis; therefore it is not unusual to assume many people were waiting for an evacuation that was not coming.

Significant GWR results in region one are expected as it is the region with the most total fatalities. This is place that people would be fleeing to from region nine at the minimum, but also those in south of region five who are fleeing south away from the pyroclastic flow. The abundance of gates in the south would lead to people attempting to flee in those directions.

Many of the clusters of dead bodies are along the main road in region one that leads to the most gates in the region, in the southeastern portion of the region. I expected something similar, as those people would almost certainly attempt to flee the city through
the large gates that exist at the end of large main and intersecting roads in all regions except nine.

The significant clustering of region five is also directly outside of the large gate in the northwestern area of region five. The gates in all the cities acted as a fast track to safety. I would assume that more excavating outside of the regions gate areas and beyond would yield bodies, and would show those unfortunate few who did not get far enough away quickly enough.
CHAPTER 8: CONCLUSION

There are many different factors when looking at information like this applied geographically. The issue of people fleeing to safety was one that encompassed geography in its very core. There is geography of space that is championed by people like Tuan when he discusses place as security, it certainly becomes that way for people and homes in times of danger or disaster (Tuan, 2001). This is never more evident in Pompeii then the bodies that were found dead, huddled in what was believed to be a safe place, the home.

Geography defined many people’s actions whether they thought of it as geography or not. Many people fleeing will naturally run away from whatever it is they are attempting to escape, and therefore the geography of the land becomes important in escape. Those fleeing in a southeastern pattern in an attempt to outrun the pyroclastic flow could have been better served with maps and plans for escaping the city in just such an event.

The deaths in the city have a clear geographic placement. The regions that would be expected to have the highest fatalities based on pyroclastic flow do in fact have the highest number. Region 9 was one region in particular that I expected the highest death counts to occur. While the region had a high count, it was not as much as I thought when my research was finished. I would have expected the numbers of fatalities outside to be higher than those inside, but that is not the case as evident in the outcome of figure 5.
The standard deviational ellipse shows the correlation of deaths, and it follows a southeastern and northwestern path as expected by the amount of death in those regions. The pull of the ellipse however is skewed in part by the large percentage of unexcavated land. The available data that is here however shows a directional standard deviational ellipse that mirrors what I imagined coming into the work itself, one that is a northwest to south east direction, similar to the pyroclastic flow direction itself.

Every test revealed important information about the city’s deaths. When simply dealing with the deaths by region, it becomes clear that the expected results, of high deaths at an indoor and outdoor level being in the south most three regions, represented by regions eight, one, and two, are therefore obvious.

The regions with the most outside deaths are the southern most regions. This is to be expected logically, because people would be fleeing to those regions to escape from the direction of Mt. Vesuvius. Region six has a large percentage of outside deaths as well; however it is mostly a result of the deaths of people waiting at the docks.

When dealing with inside deaths, it becomes clear that region one was the largest source of these deaths. An interesting fact revealed from the map of outside deaths is that region two, which was a very large source of outside deaths, has fallen off dramatically from that position. Inside deaths were most often associated with the regions one, six, seven, and nine.

Regions one and nine were the regions where I expected the most inside deaths by far. I expected region nine because it doesn’t have any immediate gates to evacuate from
and region one because it is a southern region away from Vesuvius that also is directly below region nine.

Figure 8 highlighting gates was also a very interesting output. Most regions had two main roads that led to gates, with the exception of region seven and nine. I have operated on the assumption that these gates would be opened and available during a time of crisis to let the people evacuate. I also assumed that there would be heavy deaths around these gates as people were attempting to leave but couldn’t make it in time. This is really only true outside of the gates in region five.

The deaths outside the gates in region six were entirely from people waiting at the docks for an evacuation. I don’t count this as the same kind of death as the ones of other outside regions, because the people purposely waited outside the gates there at the docks believing it to be safe, it wasn’t an act of evacuation and attempting to flee for one’s life in a panicked manor that one associates with “fleeing”.

Figure 9 showing the map of the body positions show a very large variety of body disbursement throughout the city, but far more clustering then I would have expected. Figure 15 shows different clustering analysis all proved to be interesting, and confirmed that the areas highlighted by total deaths are reflected in the deaths from regions that had accurately reported bodies.

Kernel density shows the clustering across all regions in the clearest way possible with the intensity of clustering. Figure 10 shows that there was clustering in every region that had more than 10% excavations. The hotspot analysis and clusters and outliers
showed that there was a definite coalition in the clusters and deaths found in the regions of one, seven, eight, and nine.

The geographically weighted regression is the clearest clustering tool as far as significance in geographically weighted clustering. It clearly shows that the significant clustering of deaths is in the regions that people were evacuating to or could not leave, such as region nine. This along with other tests that show it to be the “hotspot” of death proves that the idea that people who had access to gates would be able to leave and that those without it, or those who attempted to ride it out in their home were doomed if they did not get out when sigs of the eruption were first visible.

A proper escape plan or maps of exits and how to know when evacuation makes the most sense would have prevented most if not all of the fatalities that occurred. While it is impossible to judge based on modern standards or ideas, it does show that the way that disaster is approached and handled is something that has grown over time, and is in fact a way to save lives.
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