The Effects of Volcanic Deposits on Human Preservation

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The Effects of Volcanic Deposits on Human Preservation

Charles M. Nuncio

INTRODUCTION

Natural disasters capable of immense destruction occur frequently. When faced with extraneous circumstances, societies often fall into specific response patterns, regardless of time and location. As disasters are consistent, it is important to understand how populations respond. Specifically, environmental disasters have been characterized well by Earth scientists, however, require further assessment by behavioral researchers. One such example is regarding volcanic eruptions.

There are currently over 1,500 active volcanoes on Earth—many with high destructive capacity (Cotrell, 2015). In the case of volcanoes, there is little time available between precursor earthquakes and the eruption itself. Aside from sensing these earthquakes shortly before the beginning of an eruption, we lack reliable early detection methods. This unpredictability, combined with the high destructive capacity makes it clear that proper contingency response plans must be developed.

To predict behavioral response, it is necessary to evaluate the way previous civilizations have reacted to volcanism. In the modern era, no eruption is more infamous than the August 24th, 79 CE eruption of Mount Vesuvius. This specific disaster is of particular interest, as the residents of the city of Pompeii were aware of the implications of the earthquakes leading up to the eruption. When tremors began, the elite socioeconomic class vacated the city, leaving behind the sick and poor. The degree of destruction and resulting high level of archaeological preservation sets the city as an exemplary case study in understanding disaster response.

Through analyzing the destruction of Pompeii, this study evaluates where excavated victims were found in the Pompeii Archaeological Park, and possible reasons for their locations. This study further strives to understand the complex relationship between psychological and environmental factors in disaster decision making. It was found that Pompeii’s gate regions had the highest number of victims, implying that many attempted to evacuate at the beginning of the eruption, instead of taking heed of the precursor earthquake warnings. In combining social and physical scientific approaches, I explore potential reasons as to why.

BEHAVIORAL RESPONSE TO CATASTROPHE

Regardless of period and location, populations tend to gravitate to specific disaster responses. Such behavior may be influenced by one’s attachment to a location. This reasoning is known as Place Attachment Theory (PAT) and is defined by the relationship an individual has to an at-risk physical location (Giuliani, 2003). In this framework, an individual weighs their attachment to a location, against the risk of danger. PAT states that the likelihood of remaining in place increases with the number of experiences at the location that are considered central to one’s identity.

Financial risk is also considered within disaster response (Tigges et al., 2000). This line of reasoning can be evaluated in two ways: by analyzing the severity of the disaster using Risk Management Theory.
(Kasdan, 2016) or by assessing personal factors with Cost-Benefit Analysis Theory (Baum, 2012). In Risk Management Theory (RMT), a large component is the evaluation of how the disaster would impact the lifestyle and health of oneself (Slovic, 2010). If the threat is deemed consequential, the residents would vacate.

While using RMT details factors outside of one’s control, Cost-Benefit Analysis (CBA) assesses those within. Factors considered include predicting the physical damage, and both one’s financial and physical ability to vacate (Schwartz, 2010). Like RMT, if the holistic cost to evacuate outweighs the benefits, one may choose to remain in place. It is important to acknowledge that oftentimes, factors that contribute to the extent of an eruption are variable. Thus, it is difficult to fully rationalize the physical reach of an eruption within the framework of RMT.

Place Attachment, Risk Management, and Cost-Benefit Analysis Theory have been applied to volcanic eruptions in the past. One study details Kalta Volcano of Southern Iceland, where it was proposed that the location of a subject’s upbringing is the dominant factor in deciding whether to evacuate (Bird et al., 2011). It was found that statistically, rural individuals remained, while those from urban environments vacated. Notions of PAT are observed, as residents who remained cited strong relationships with their homes. This is a common experience, independent of one’s culture, and thus can be applied on a broader scale to better understand disaster response.

The intersection of these theories within Bird’s study is not isolated, as they further appear in many other eruption response case studies. These concepts were further expanded using models that predicted the likelihood of an evacuation alert to be declared (Bebbington and Zitikis, 2016). Although the algorithms were based on modern-day parameters, certain aspects remain broadly applicable—namely the minimum evacuation time necessary, determined by physical location and population distribution in an area. Such considerations are valuable in providing quantitative grounding for disaster response.

**PHYSICAL CHARACTERISTICS OF THE 79 CE ERUPTION**

To accurately assess response patterns, it is necessary to evaluate volcano structure and geographic relationships. Located eight miles inland of the Gulf of Naples and fourteen miles southwest of Pompeii, Mount Vesuvius stood at 4,200 ft prior to its infamous eruption. The volcano is understood to have formed approximately 4.6 million years ago from subduction of the African tectonic plate beneath the Eurasian Plate (Kozák, 2010). As the African plate melted, its magma breached the surface as lava, solidified, and built height over the course of many eruptions.

Many factors must be considered to understand the physical conditions of the eruption, such as the geographic location and weather. These further include wind direction, victim location in relation to Vesuvius, and proximity to the ocean. All mentioned variables influence how severely an individual may have been injured. Because of a strong southeastern wind direction (Barsotti et al., 2015), the majority of the volcanic outfall struck the city of Pompeii.

**CAUSES OF DEATH**

There is a correlation between proximity to Mount Vesuvius and severity of injury, with discourse surrounding the specific causes of death. The leading theory is that those in close proximity to the eruption experienced quick heat-flash that quickly dispatched them, with surges reaching as high as 572° F (Mastrolorenzo, 2010). The contorted positions of the excavated victims partially support this hypothesis, as soft
tissue tends to contract in the presence of high temperatures (Mastrolorenzo et al., 2001). Additionally, archaeological assessment of skeletal remains from Pompeii reveals fracture patterns reflective of quick, intense heating (Henneberg et al., 2006).

In contrast, there is evidence that victims instead experienced slow-but-constant heating, with temperatures low enough to incapacitate an individual, but not high enough to instantly dispatch them. Remains from Herculaneum, a city eight miles from the coastline, underwent collagen extraction and analysis (Martyn, 2020). Results suggest an extended, lower temperature heating period, opposed to the widely accepted heat-flash argument of Mastrolorenzo.

THE POMPEII SURVIVORS

The number of survivors of the Mount Vesuvius eruption is widely misunderstood. There is a popularized notion that there were no survivors from the city of Pompeii, however, this is misinterpretation. While casualties were upwards of 2,000, with no one remaining in the city and surviving, the majority of the estimated 12,000-20,000 residents managed to vacate (Flohr and Wilson, 2016). While there were many survivors from the Italian Peninsula, there are few surviving written records detailing the eruption. The larger understanding of the events following the eruption is based on a pair of letters written by Roman senator, Gaius Plinius Caecilius in response to the historian, Cornelius Tacitus. In his letters, Caecilius (better known by the name Pliny the Younger) recalls a hellfire landscape, describing it as “broken with rapid, zigzag flashes, reveal(ing) behind it variously shaped masses of flame” (Melmoth, 2001).

The majority of the two letters, however, details the heroic efforts of the author’s uncle, military elite, Pliny the Elder. When Mount Vesuvius erupted, the Roman commander was stationed at the Frazionian establishment, Misenum, located on the central-western cape of the Italian Peninsula. This area was out of reach of the volcanic fallout; however, the letters state that the Elder was preparing to set sail on the Gulf of Naples to observe the eruption from a safe distance (Haywood, 1952). It was then that he received a distress letter from two close allies, Pomponius and Rectina. The pair requested aid from the Elder, who quickly commandeered a “fast-sailing cutter,” and took for the city of Stabiae alongside the ship’s captain. As the two approached the coastline, the captain advised they turn around due to dangerous conditions, where the Elder then uttered the famous Latin proverb, “Audentes Fortuna Iuvat,” which roughly translates to, “fortune favors the bold.” To the Elder’s disservice, this was not the case. Upon breaking land, the Elder made contact with Pomponius, unsuccessfully attempted to locate a separated Rectina, then proceeded to take shelter. The following morning, Pomponius and the captain boarded the ship and escaped, leaving behind Pliny the Elder. He did not survive.

Returning to safety, Pomponius and the captain relayed the events to Pliny the Younger, which he then detailed in the pair of letters (Melmoth, 2001):

“He was now so close to the mountain that the cinders, which grew thicker and hotter the nearer he approached, fell into the ships, together with pumice-stones, and black pieces of burning rock: they were in danger too not only of being aground by the sudden retreat of the sea, but also from the vast fragments which rolled down from the mountain, and obstructed all the shore.”

Mastrolorenzo argues that the residents of Pompeii had little time to respond to the flash-heating of the eruption and thus experienced soft tissue contraction, however, Pliny the Younger’s letters argue otherwise. It is understood that Pliny the Elder received
the letter from Rectina on August 24th, 79 CE, the day that the eruption reached Pompeii (Fulford, 2003; Haywood, 1952). This implies sufficient time for a messenger to travel a far distance to deliver the letter to the Elder – suggesting lighter conditions representative of slow-heating or asphyxiation instead of intense flash-heating. It is, however, possible that there were different factors within just the city of Pompeii that could reduce the effects of the intense heating, which could result in many causes of death.

**METHODS**

Assessment of the nine Regios (regions) of the Pompeii Archaeological Park was conducted by cross-examining data from previous studies. Over five hundred remains have been excavated within the park, which this study focuses on the first sixteen recovered by the first archaeologist to excavate Pompeii, Giuseppe Fiorelli, due to the availability of thorough bioarchaeological descriptions. During early excavations of the area, Fiorelli noticed human-shaped cavities in the volcanic deposits that contained skeletal remains. It was determined that this was a result of victims becoming encased in the volcanic deposits (Lazer et al., 2021). When their soft tissue decayed over time, human-shaped cavities were left behind. Cast-mold was then injected, outlining the shape and position of the victim at the time of death. These Fiorelli-casts have been qualitatively categorized within this study, based on the degree of injury discerned from the mold.

Injury evaluations were then compared to open-source ArcGIS datasets of the park that included whether victims were excavated from predominantly lapilli or ash deposits. The conjoined Fiorelli-cast and ArcGIS datasets were further evaluated on geographic location, excavation elevation, and whether the victims were recovered inside (intramural) or outside (extramural) of a building. Data from all recorded victims were evaluated, returning the dominant volcanic deposit type for each Regio.

**FINDINGS**

Since the first excavations of the Pompeii Archaeological Park in the mid-1800s, few archaeological assessments have been made directly publicly available. The following qualitative descriptions of the Fiorelli-casts are based on the original excavation records (Fiorelli, 1850), and brief notes recorded by later scholars and members of the Pompeii archaeological team (De Caro, 1979; Dwyer 2005; Dwyer 2010, Lazer 2009).

| Victim 1 |
|-----------------|------------------|
| **Excavation Lead:** | Giuseppe Fiorelli |
| **Date of Excavation:** | February 5th, 1863 |
| **Archaeological Region:** | Regio VII – Vicolo Degli Scheletri (Alley of Skeletons) |
| **Site Significance:** | Passageway – Located Between Urban Dwellings |
| **Relation to Infrastructure:** | Extramural |
| **Relative Elevation:** | Street-Level |
| **Cast Status:** | Medium Preservation - High Injury: Missing Appendage(s) |

Victim #1 is notable for their enlarged stomach, caused by an excavation casting error. The left portion of the subject’s body is theorized by Fiorelli to have been injured by a mixture of lapilli projectile and ash flow. Due to the 1943 Allied bombing of Pompeii, the original Fiorelli-cast, containing the victim’s skeletal remains, was destroyed.
Victims #2 and #3 were discovered in contact with one another, with their bodies conjoined due to the casting process. As the victims were found in neutral positions, with low evident soft tissue damage, Fiorelli theorized that the cause of death was asphyxiation due to volcanic gases. There is debate on the biological sex of the victims as in Fiorelli’s original records, both were deemed as adult females, however, photographer Giacomo Brogi argued that the pair were adolescent and adult males. The former is widely accepted, while Brogi’s claim is regarded as a purposeful misclassification to garner public attention. The original casts of the two victims were also destroyed during the 1943 Allied bombing of Pompeii.

Victims 2&3

<table>
<thead>
<tr>
<th>Excavation Lead</th>
<th>Giuseppe Fiorelli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Excavation</td>
<td>February 5th, 1863</td>
</tr>
<tr>
<td>Archaeological Region</td>
<td>Regio VII – Vicolo Degli Scheletri (Alley of Skeletons)</td>
</tr>
<tr>
<td>Site Significance</td>
<td>Passageway – Located Between Urban Dwellings</td>
</tr>
<tr>
<td>Relation to Infrastructure</td>
<td>Extramural</td>
</tr>
<tr>
<td>Relative Elevation</td>
<td>Street-Level</td>
</tr>
<tr>
<td>Cast Status</td>
<td>Low Preservation – Low Injury</td>
</tr>
</tbody>
</table>

Figure 1: The Fiorelli-cast of Victim #1, placed in their original excavation site in Vicolo Delgi Scheletri (Dwyer, 2010).

Figure 2: Overhead view of Victim #1 (Brogi, 1863).
Figure 3: Overhead view of the original Fiorelli-casts of Victims #2 and #3 (Brogi, 1863).

Figure 4: The Fiorelli-cast of “The Pregnant Woman,” placed in their excavation site in Vicolo Delgi Scheletri (Amodio, 1868).

Figure 5: The Fiorelli-cast of Victim #5, photographed by Giorgio Sommer (Dwyer, 2010).
Victim 4: “The Pregnant Woman”

Excavation Lead: Giuseppe Fiorelli
Date of Excavation: February 5th, 1863
Archaeological Region: Regio VII – Vicolo Degli Scheletri (Alley of Skeletons)
Site Significance: Passageway – Located Between Urban Dwellings
Relation to Infrastructure: Extramural
Relative Elevation: Street-Level
Cast Status: Medium Preservation – Low Injury

Although coined as “The Pregnant Woman” by Fiorelli, the validity of the name is inconclusive, as the original cast was destroyed in the 1943 Allied bombing of Pompeii before the claim could be evaluated. It is likely that the victim’s title was given in reference to their enlarged abdomen, simply for public appeal. The victim was excavated in contact with an amber statuette and a bag containing multiple mirrors, silver, and houseware. On the victim’s cast, there are impressions of a ring and a boot on their left leg.

Victim 5

Excavation Lead: Giuseppe Fiorelli
Date of Excavation: March, 1868
Archaeological Region: Regio IX – Vicolo de Tesmo
Site Significance: Passageway – Located Between Urban Dwellings
Relation to Infrastructure: Extramural
Relative Elevation: Street-Level
Cast Status: High Preservation – Low Injury

The remains of Victim #5 show evidence of both long-term and flash-heating. While most casts outlined a head’s facial features, molding of Victim #5 revealed an exposed skull. Disintegration of soft tissue is attributed to long-term heating; however, contortion observed in the victim’s hands suggests muscle contraction representative of flash-heating. Due to the early-stage development of the Fiorelli method, recovery of the victim’s left leg was unsuccessful.

Victim 6

Excavation Lead: Giuseppe Fiorelli
Date of Excavation: March 45th, 1868
Archaeological Region: Regio IX – Vicolo de Tesmo
Site Significance: Passageway – Located Between Urban Dwellings
Relation to Infrastructure: Extramural
Relative Elevation: Street-Level
Cast Status: High Preservation – Low Injury

The cast-mold of Victim #6 is notable for the strong recovery of the outline of the victim’s face – showing almost mummy-like facial features. Unlike all prior casts created by Fiorelli, the outline of the victim’s toes is well defined. The victim was excavated from compact ash, and their position does not display any evidence of muscle contraction, implying asphyxiation from toxic fumes. The high level of preservation furthermore implies they were encased in ash before any soft tissue disintegration could occur. From Victim #6’s cast-mold onward, the molds transitioned from being limestone-based to gesso gypsum/chalk-based plaster.
Figure 6: The Fiorelli Cast of Victim #6, placed in their original excavation site in Insula III of Regio IX (Dwyer, 2010).

Figure 7: Overhead view of the Fiorelli-cast of Victim #6 (Brogi, 1863).

Figure 8: The Fiorelli Cast of “The Sick Man,” placed in their original excavation site in Vicolo de Tesmo of Regio I (Dwyer, 2010).
Despite the implications of the name, there is no evidence that the victim was ill prior to death. Fiorelli noted the “serene grace” of the victim, proposing they accepted the futility of the scenario and instead simply laid down outside of their dwelling instead of vacating. The high level of preservation can be attributed to conditions similar to Victim #6, where they were quickly compacted by ash before soft tissue could disintegrate.

This victim is unique to the Fiorelli-casts, as they are the only animal preserved. From casting, the mold revealed a collar around the neck of what Fiorelli hypothesized to be a dwelling watchdog. They were chained to the inner entrance of the house of Vesonius Primus, and is believed to have been abandoned by their family when the eruption began. Fiorelli proposed that the contorted position of the dog’s body was due to being chained to a doorway. As ash began to encase the interior of the dwelling, the dog likely climbed atop the depositing ash, in an attempt to escape. The higher the watchdog climbed, the less give the chain gave – until they were ultimately forced into the contorted position they were found in. The cause of death is attributed to suffocation by ash.

Victims #9 and #10 were found near one another. Based on the close proximity between their excavation site and the route leading away from the city of Stabiae, Fiorelli hypothesized that the two were fugitives attempting to evade the outfall – perhaps believing Pompeii to be in better condition than their own city. Based on their low-quality garbs preserved in the molds, Fiorelli claims that they were of lower social class. The two were discovered four meters above ground level, aligning with Fiorelli’s original hypotheses stating that ash was already compacting while Vesuvius continued to erupt.
Figure 9: Overhead view of the original Fiorelli-cast of “The Sick Man” (Brogi, 1863).

Figure 10: The Fiorelli-cast of “The Watchdog,” originally photographed by Giorgio Sommer (Dwyer, 2010).

Figure 11: Overhead view of the original Fiorelli-cast of Victim #9 (Dwyer, 2010).
Victim 11: “The Emaciated Child”

Excavation Lead: Michele Ruggiero
Date of Excavation: January 24th, 1882
Archaeological Region: Regio VIII – Casa di Acceptus e Euphodia (House of Acceptus and the Euphodia)
Site Significance: Urban Dwelling
Relation to Infrastructure: Extramural
Relative Elevation: Above Ground-Level (≈ 4 Meters)
Cast Status: Medium Preservation – Low Injury

The Emaciated Child gains its name from the feeble posture preserved in the cast-mold. In comparing limb length to overall height, lead archaeologist, Michele Ruggiero argued that the child was malnourished. Alongside the child, the skeletal remains of an adult’s forearm and hand were excavated. As the victim was discovered four meters above ground level, close to an outside wall of a damaged dwelling, and in close proximity to adult remains – Ruggiero proposed that an adult was attempting to carry down the child from the dwelling’s upper level, as the lower level and stairs may have already been filled by ash.

Victim 12

Excavation Lead: Michele Ruggiero
Date of Excavation: December 28th, 1882
Archaeological Region: Regio VIII – Insula 6.6
Site Significance: Functional Site – Market-place & Garden
Relation to Infrastructure: Extramural
Relative Elevation: Above Ground-Level (≈ 4 Meters)
Cast Status: Medium Preservation – Low Injury

Like other remains excavated by Ruggiero, Victim #2 was found about four meters above ground level. Ruggiero theorized that the victim attempted to escape over the compacting ash, however, succumbed to toxic fumes while in the Garden of Insula. His argument was based on the victim’s neutral position – often associated with asphyxiation. Victim #12’s remains are unusual, as those excavated at higher ground levels often have greater soft tissue decay, unlike the full preservation of the body outline that was observed.

Victim 13

Excavation Lead: Michele Ruggiero
Date of Excavation: August 12th, 1889
Archaeological Region: Regio VIII – Porta Stabia
Site Significance: Gateway
Relation to Infrastructure: Extramural
Relative Elevation: Ground-Level
Cast Status: Full Preservation – High Injury: Cranial Exposure

Little information is available regarding Victim #13, whose remains were excavated at the southern gate of Regio VIII, towards the city of Stabiae. While their cranium was exposed, the rest of their body was extremely well preserved in the cast-mold. This is unusual as the victim was found in a horizontal position, where heat should have theoretically damaged their full body equally.

Victims 14 & 15

Excavation Lead: Michele Ruggiero
Date of Excavation: October 11th, 1889
Archaeological Region: Regio VIII – Porta Stabia: Gladiator Barracks
Site Significance: Barracks, Turned Dwelling
Relation to Infrastructure: Extramural
Relative Elevation: Ground-Level
Cast Status: High Preservation – Low Injury

Victims #14 and #15 were excavated near one another and have few archaeological records. Ruggiero described Victim #14 as a mature biological male with a ring surrounding his calf – denoting him as having enslaved. Victim #15 was similarly ascribed as a mature biological female,
discovered faced down, lifting themselves by their forearms. Unlike other victims in Regio VIII who were excavated at four meters above the surface, Victims #14 and #15 were excavated at ground level. Ruggiero attributes their high level of preservation to being compacted by ash early into the eruption.

![Figure 12: Overhead view of the original Fiorelli Cast of Victim #10 (Dwyer, 2010).](image1)

![Figure 13: The Fiorelli-cast of “The Emancipated Child,” placed in their original excavation site in Casa di Acceptus e Euphodia of Regio VII (Dwyer, 2010).](image2)

![Figure 14: The Fiorelli-cast of Victim #12, placed in their original excavation site in Insula 6.6 of Regio VIII (Brogi, 1863).](image3)
Victim 16: “The Heavily Clothed Man”

<table>
<thead>
<tr>
<th>Excavation Lead:</th>
<th>Salvatore Cozzi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Excavation:</td>
<td>March 12th, 1890</td>
</tr>
<tr>
<td>Archaeological Region:</td>
<td>Regio VIII – Porta Stabia</td>
</tr>
<tr>
<td>Site Significance:</td>
<td>Hinterland</td>
</tr>
<tr>
<td>Relation to Infrastructure:</td>
<td>Extramural</td>
</tr>
<tr>
<td>Relative Elevation:</td>
<td>Street-Level</td>
</tr>
<tr>
<td>Cast Status:</td>
<td>High Preservation – Low Injury</td>
</tr>
</tbody>
</table>

The Heavily Clothed Man was excavated by lead archaeologist, Salvatore Cozzi, and received their name due to their clothing being well-preserved in the cast-mold. Of all sixteen evaluated in this study, they were the sole victim excavated in a region known as the “hinterland,” located 72 meters away from the city of Stabiae. While the clothing was well preserved, both of the victim’s feet and left hand were damaged during the molding process.

VICTIM DISTRIBUTION DATA

While descriptions of the Fiorelli-casts were primarily qualitative, ArcGIS victim distribution datasets allow for quantitative assessment of the archaeological park (Johnson et al., 2020). It is important to reiterate that the information of the sixteen victims were those whose qualitative descriptions were publicly accessible, and many more victims have been evaluated privately. All victims marked within Johnsons’ public datasets have been categorized as either being excavated from lapilli or ash dominant stratigraphy. Furthermore, many regions in the park remain largely unexcavated, thus statistical analysis of the available data is implicitly indefinite. A polygon-feature layer map, defining the boundaries of each Regio, was then overlain by the victim distribution layer. In doing so, volcanic deposit type percentages per region were correlated for statistical analysis.

Johnson categorized stratigraphy based on two volcanic deposit types: ash-pyroclastic density currents (PDC) and lapilli-tephra. Ash denotes smaller particle size of approximately 1 mm, while lapilli-tephra ranges between 2-64 mm in diameter. Particle size is important, as ash deposits generally lead to faster compaction, resulting in greater levels of soft-tissue preservation. Lapilli-tephra, on the other hand, poses a greater projectile threat when ejected from a volcano that can prove lethal on impact.

In layering excavation and volcanic deposit data over the Regio map, large differences in percentages of ash and lapilli were observed between regions. As seen below in Table 1, most regions had differences in deposit type of about 30% or larger. The exception to this was Regio I, which returned a <1% difference. Additionally, the northern six Regios (3-7 and 9) were found to have larger lapilli percentages, while the southern three (1, 2 and 8) were found to have higher ash percentages. In the ash-dominant regions, there was significantly smaller variability, while the lapilli-dominant regions returned variability of >40%. In considering all victims from every region, the majority were excavated from lapilli at 61.1%, while 38.9% of victims were excavated from ash deposits.
Figure 21: Victim distribution within the nine Pompeii Archaeological Park Regio’s, displaying which volcanic deposit type victims were excavated from.

<table>
<thead>
<tr>
<th>Regio</th>
<th>Ash-Pyroclastic Deposit</th>
<th>Lapilli-Tephra Deposit</th>
<th>Total Number Victims</th>
<th>Ash-Pyroclast Percentage</th>
<th>Lapilli Percentage</th>
<th>Dominant Stratigraphic/Volcanic Deposit Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>72</td>
<td>71</td>
<td>143</td>
<td>50.3 %</td>
<td>49.7 %</td>
<td>Ash</td>
</tr>
<tr>
<td>II</td>
<td>51</td>
<td>18</td>
<td>69</td>
<td>74.0 %</td>
<td>26.0 %</td>
<td>Ash</td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>6</td>
<td>7</td>
<td>14.3 %</td>
<td>85.7 %</td>
<td>Lapilli</td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>0.0 %</td>
<td>100.0 %</td>
<td>Lapilli</td>
</tr>
<tr>
<td>V</td>
<td>14</td>
<td>44</td>
<td>58</td>
<td>24.0 %</td>
<td>76.0 %</td>
<td>Lapilli</td>
</tr>
<tr>
<td>VI</td>
<td>24</td>
<td>80</td>
<td>104</td>
<td>23.0 %</td>
<td>77.0 %</td>
<td>Lapilli</td>
</tr>
<tr>
<td>VII</td>
<td>9</td>
<td>21</td>
<td>30</td>
<td>30.0 %</td>
<td>70.0 %</td>
<td>Lapilli</td>
</tr>
<tr>
<td>VIII</td>
<td>25</td>
<td>14</td>
<td>39</td>
<td>64.0 %</td>
<td>36.0 %</td>
<td>Ash</td>
</tr>
<tr>
<td>IX</td>
<td>21</td>
<td>84</td>
<td>65</td>
<td>20.0 %</td>
<td>80.0 %</td>
<td>Lapilli</td>
</tr>
<tr>
<td>Total</td>
<td>217</td>
<td>341</td>
<td>558</td>
<td>38.9 %</td>
<td>61.1 %</td>
<td>Lapilli</td>
</tr>
</tbody>
</table>

Table 1: Comparison of dominant stratigraphic/volcanic type percentages per Regio, and for the overall Pompeii Archaeological Park.

DISCUSSION
In assessing the first sixteen Fiorelli-casts excavated from the archaeological park, trends in the levels of bioarcheological preservation are not evident at first glance. Within the relationship between preservation, proximity to a dwelling, and excavation elevation – the connection seems sporadic. In a traditional sense, the findings of the first sixteen victims were quantitatively unsubstantial. While statistical analysis of the casts was inconclusive, the qualitative information surrounding the casts returned valuable

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information that was further substantiated by the ArcGIS datasets. Before Fiorelli-cast characteristics can be cross-referenced with stratigraphic information, it is important to recognize the limitations of the datasets. To assess the relationship between location and degree of preservation of a victim, this study first evaluated the proximity of a victim to surrounding buildings and the elevation from street-level at which they were excavated. Proximity to architecture was considered important in the study, as the majority of buildings in Pompeii were built from granite. Classified as a felsic intrusive igneous rock, granite is heat-resistant in nature (Wang et al, 2019), leading to a hypothesis that victims found within a granite building would have an added layer of protection against heat, and thus have higher degrees of preservation.

The heat-protection hypothesis was unsupported by the results of this study. Of the sixteen victims excavated, fourteen were found outside of buildings. The casts of the fourteen victims showed broad degrees of preservation, ranging from cranial exposure up to full cast-mold preservation of soft tissue. While the original hypothesis argued that victims found within granite buildings would have higher levels of preservation, the small data pool leads to statistically insignificant results. Between the two victims excavated from inside buildings, there was a large difference in the degree of preservation. The first, victim #5, was found to have the lowest degree of preservation out of all sixteen excavated victims, entirely missing their lower-left leg, and having a fully exposed skull—described as if it was artificially placed on the rest of their body. Victim #8, the Watch Dog, was also found within a building—notable for its extremely high preservation and for being the only animal cast in the original sixteen.

Of those excavated in Regio VII, Victim #1 uniquely experienced heavy damage to the right portion of their body. Fiorelli stated that the victim had portions of their body disintegrated by lava flow, however, there is no evidence in this study to support this—lapilli was the dominant deposit type. However, the question is now posed if lapilli flow itself is substantially damaging enough to disintegrate large portions of one’s body. If yes, then it remains consistent with the low preservation of other victims in Regio VII.

When further evaluating geographic trends in preservation, we observe decreasing lapilli percentages moving southwards. The northern Regio VI returned a lapilli percentage of 77%, while Regio VII was 70%, and the southern Regio VIII had significantly less at 30%. These trends were found to be consistent throughout the park with higher lapilli percentages in northern regions, and higher ash percentages to the south. This is logical, as when two materials with different masses are propelled with the same force, the lighter mass travels farther. Furthermore, materials with smaller particle sizes, such as volcanic ash, spread out in a uniform nature over an area. The observed and expected volcanic deposit type distribution were found to be consistent.

In evaluating victim distribution within the park, it is important to understand the function of each region. Regio I housed Pompeii’s primary southern gate, and was thus used as the main dispersal point of both goods and traveling populations (Poehler, 2016). This contextualizes the large number of victims excavated in the region, in contrast to the low number of Regio’s II and VIII, suggesting residents of adjacent regions clamored towards Regio I’s gate to escape the city.

While statistical analysis of the victim distribution is clear cut, what does the distribution itself suggest about the behavioral response? Following Occam’s Razor, the simplest answer is that most likely. In understanding the function of each region, the distribution suggests that most residents attempted to escape through either of the gate
regions: Regio’s I and VI. Holding the highest number of remains in the park, Regio I was a market district with few dwellings (Poehler, 2016), affirming citizens from residential districts likely travelled through the gate regions to escape. This, however, contrasts surviving text by Plini the Younger; which notes the majority of residents accepted their fate and instead chose to not evacuate (Melmoth, 2001).

Regio VI housed the northern gate of the city, and held the second highest number of victims. The difference between the two gate regions is that Regio VI was instead primarily a residential area. This is reflected in the region’s victim distribution where roughly half were excavated from within dwellings. It is notable that the main route between Herculaneum and Pompeii led directly to Regio VI, where many victims were discovered in the passageway directly outside of the northern gate, *Via Delle Tombe*. Assessment of these victims is inconclusive, as there is weak evidence on whether they were escaping from Herculaneum to Pompeii or vice versa. Future studies of these victims are made difficult, as most of the passageway has been built over by modern infrastructure.

Victim distribution given by the ArcGIS datasets suggests that most victims vacated, however, many victims were discovered within residential sites. Reasoning can be interpreted in many ways, but in applying Place Attachment Theory (Giuliani, 2003), it is possible that victims prioritized their relationships to their homes over their own safety. Bioarcheological assessment revealed that most victims excavated within dwellings were likely youthful and in good health – with no strong physical limitation to prevent evacuation. Thus, reasoning to not evacuate was likely psychological opposed to physical.

**CONCLUSION**

From interdisciplinary evaluation of archival, bioarcheological, and ArcGIS victim distribution data of the Mount Vesuvius eruption, we can piece together response pattern hypotheses. Victim distribution suggests that most travelled through the central three regions of the city, and then attempted to escape using the southern gate of Regio I. Residents of the northern three regions also possibly attempted to leave the city through Regio VI’s northern gate. These claims are evidenced through the disproportionately large number of victims found in these gate regions. In this assessment, we must recognize that a large majority of Regio’s III, IV, and V have yet to be excavated, and thus future research may contradict current findings.

Correlation was found between the bioarcheological degree of victim injury, and the dominant type of volcanic deposits they were excavated from. Lapilli has a heavier mass than ash, resulting in shorter travel distance. This was found to be consistent in Pompeii, as the northern six regions closest to Mount Vesuvius received the brunt of the lapilli projectiles, while the southern three were ash dominant. Due to the low number of victims with bioarcheological descriptions, it is inconclusive whether architectural composition played a role in the preservation of soft tissue. In the ArcGIS datasets, many excavation points were not placed with enough accuracy to determine if they were found inside or outside of buildings. Inferences, however, are made by the lapilli/ash classifications as many data points near buildings were classified as ash, while those irrefutably in open areas had higher lapilli ratios. Due to this discrepancy, the heat-protection benefits of granitic material are inconclusive.

Analysis of possible evacuation factors in decision making is simply assumption and should duly only be considered as such. The challenge in attempting to reconstruct reasoning based on loose documentation is that
unless explicitly written out, it is difficult to develop consistent hypotheses, and even more difficult to validate them. You go farther down this rabbit hole in considering that the letters of Pliny the Younger are the main source discussing the eruption, supplemented only by few economic records.

It is imperative to assess factors that rely less on written records, and instead seek information quantified through ArcGIS datasets. Victim distribution allows for the interdisciplinary consideration of volcanic deposit type, with other factors such as architecture and excavation elevation. Ultimately, this interdisciplinary inclusion presented hypotheses of potential routes that Pompeii’s residents likely took to escape the city. While this information is a step in the right direction, there is currently not enough publicly available information to stimulate most researchers on the topic. This groundwork must be laid before a reliable interdisciplinary evaluation of the archaeological park can be made. Additionally, all Regio’s must be fully excavated before holistic conclusions can be drawn. As such, further research in the park is necessary.

Due to the current excavation status of the Pompeii Archaeological Park, the findings of this study are limited. Available data revealed supporting evidence of a diverse number of reactions, ranging from panicked escape through the crowded market districts, to the morbidity of patiently waiting in place for one’s own death. In part to the overall lack of surviving historical records, we can only best attempt to recognize the depth of the final moments of the Pompeii residents. No matter how concise the archaeological evaluation, it is not enough to truly recover that elicited by the inescapable realization of one’s own mortality.

REFERENCES
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