HOW DOES MAGMA FLOW IN DIKES WHEN ASCENDING TOWARDS THE SURFACE: A CASE STUDY AT SUMMER COON VOLCANO, COLORADO

by

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Dikes are intrusions of magma that flow vertically towards the surface, cutting through existing country rock. The aim of this project is to compare the size and shape distributions of host rock and volcanic glass in seven images of the inside one dike of Summer Coon volcano, Colorado. Aspects of these thin sections that were analyzed were chosen because of their potential to provide information in terms of flow direction, particle size distribution, and orientation of particles within this dike, radiating from the Summer Coon volcano, in Colorado. Parameters chosen were circularity, number density, and orientation. There is a high degree of erosion of the country rock around the dikes, which are well-preserved in comparison to other dikes at other, similar volcanoes. This provides the grounds for the collection and analysis of samples spanning the whole length of the dike. After collecting samples, analysis was done tracing host rock and volcanic glass within thin sections of the rock at five locations along the dike. One image was split into 3 analyses due to the high degree of vertical flow in the center of the thin section. After tracing particles, plots and orientation diagrams were drawn between different thin sections. There were high degrees of randomness found with analysis proximally to distally in terms of orientation, summarizing there is no trend in terms of flow direction. Circularity decreases with increasing particle diameter. In terms of number density of particles,

volcanic glass particles located closer to the conduit of the volcano tend to have a higher percentage of smaller particles. There are trends within the thin sections themselves, and through the comparison of the most proximal and most distal samples. There are also trends on a smaller scale, but not on the dike scale itself. Further research will need to include the analysis of the most proximal samples in situ.

Acknowledgements

Thank you to all the wonderful people who have supported me throughout this journey: my advisors, friends, and family, in providing guidance, support, and mentorship for me along the way as I completed my thesis. Thank you to Thomas Giachetti and Kate Mondloch, my primary thesis advisor and CHC advisor. This research wouldn't have been able to be completed without you all. To Thomas and Gui: thank you for letting me work closely with you the last few years, through not knowing what my thesis topic was even going to be, to now having completed said thesis. This idea wouldn't have come to light without you! To all my friends and family, the continued love and support brought me through to the completion of this thesis. Thank you to the Earth Sciences Department and the Robert D. Clark Honors College at the University of Oregon for the opportunity and assistance in completing this work.

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Project Description/Introduction

To provide context, dikes are vertical intrusions of magma that tend to rip off and pick up country rock material (host) and incorporate that into the magmatic flow as they cut through country rock while flowing towards the surface. They form from the flow of viscous magma that propagates through weak rock that fractures easily, allowing the fluid to make its way through (Rivalta, 1). The dikes at the Summer Coon volcano in Colorado, active for 100,000-200,000 years between 32-34 Ma, have differing magma/host vs clast composition at various points through the proximal and distal ends of these intrusions, where proximal means being closest to the central conduit of the volcano. This thesis builds upon research I did during Winter and Spring term of 2023-2024, where I worked with PhD candidate Gui Aksit and Earth Sciences associate professor Thomas Giachetti, analyzing thin section images of rocks making up a specific dike, dike D, which radiates out from the now eroded Summer Coon volcano in Colorado. There has been research done on particle analysis on other dikes, which propagate northwest and southwest, but gathering information from another dike helps determine whether particle size and shape distribution vary or not across the dikes around the volcano (Poland, 156), and thus better understand the circulation of magma in these dikes. My job has been to highlight particles on images of thin sections taken from rock samples of the dike, differentiating between 1) volcanic glass, which is the now cooled magma, and 2) host rock (lithics) fragments incorporated from the sides of the dike into the magma as it forces its way through the country rocks. The magma composition of dike D is rhyolitic, which is one of the most viscous magmas that may fragment into smaller pieces to be able to force its way through and advance within the country rocks.

Notches are used on the thin sections to orient the section compared to the dike itself, with the notches indicating the direction up (e.g., see section 5-2in **Fig. 1)**. Another notch on the side means “out”, thus meaning the side leading distally away from the conduit. Long arrows used show outwards orientation as well, or facing distally, while short arrows indicate an upwards orientation. These symbols can be seen in **Fig. 4**, comparing the bare thin sections with the traced versions.

This thesis also contains a section dedicated to art. The interaction between science and art governs how I think about creating and learning, and I knew from the beginning of starting my thesis that art was going to be a part of it. Seemingly the opposite, I see art as being a striking medium to provide a different understanding of a scientific subject. By viewing science through an artistic lens, a deeper understanding of the topic at hand could result. It provides a unique way of viewing scientific information – for the viewer/reader, and myself as I interact with the data I collected in such a separate way. Art can explain science in a more digestible way, so I feel it will help with my goal of increasing public knowledge of science, as it is ever important these days.

Background

Diving into more detail, dikes are sub-vertical volcanic intrusions of magma. They propagate in country/host rock, cutting through the rock at a high angle (Emerman, 231). These sheet-like intrusions have compositions mainly aligning with low viscosity granitic magma and basaltic magma (Emerman, 231).

The Summer Coon volcano is part of the San Juan volcanic field in Southern Colorado, previously reaching an elevation of 4200 meters (Poland, 157). This volcano has a 17° surface slope, with a substantial amount of erosion as this feature of the landscape erupted in the

Oligocene, around 35 million years ago, although the dikes are still well preserved (Noblett, 349). Over the years, around 59 km^3 of material of the volcano has been removed due to erosion, leading the height to decrease by 1700 m (Poland, 157). The composition of this volcano is mainly basaltic andesite and rhyolite, being both intrusive and extrusive in nature (Poland, 157).

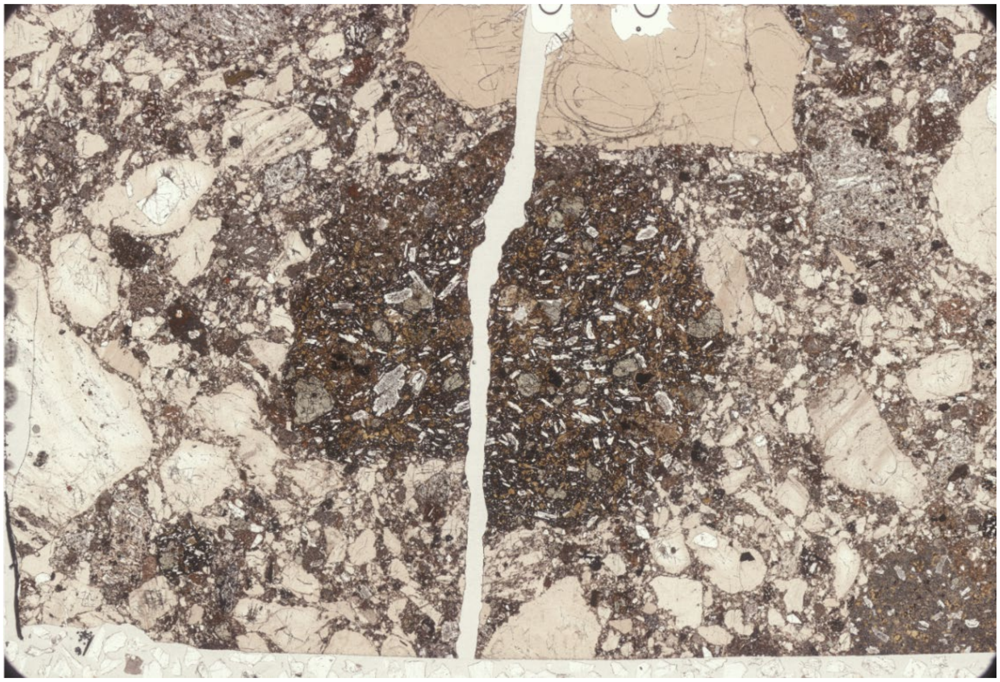

Figure 1: is an image of thin section 5-2, before the crystals, glass, and clasts have been traced to differentiate them.

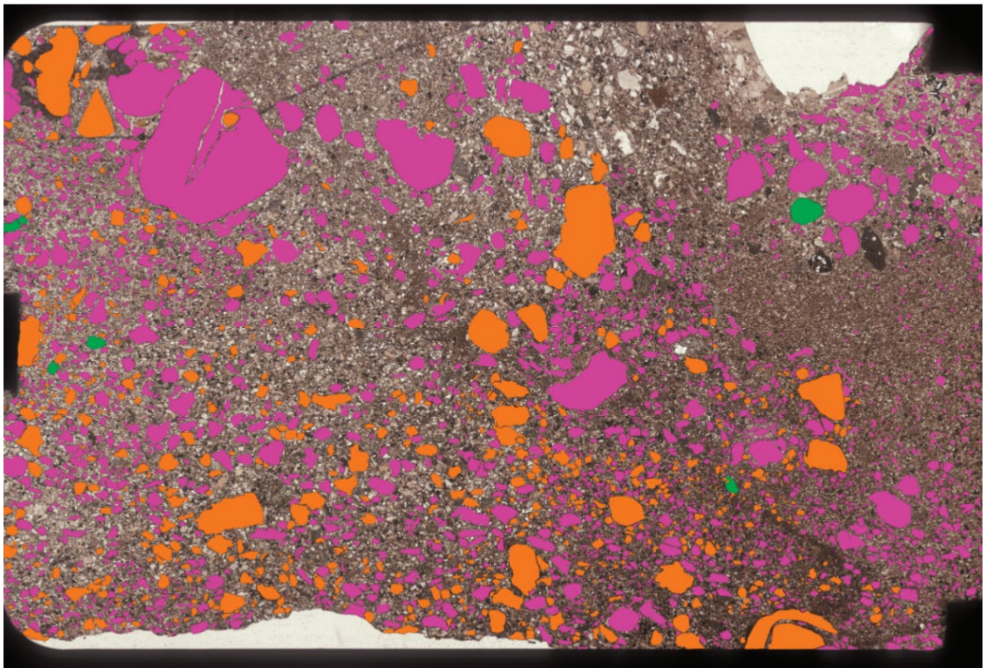

Figure 2: shows image analysis of thin section 4-1 as an example with completed tracing of the host vs clast composition. I traced over with orange to show clasts, and with pink to highlight glass fragments.

Research Questions

My project advances research of the Summer Coon volcano in the size and shape distributions of volcanic glass and host clasts that have not been extensively studied. The orientation of plagioclase crystals in another dike (A) of Summer Coon that radiates 6.5 km North of the center of the volcano, has been analyzed under a thin section to show the orientation of magma flow (Poland, 161). Viewing the axis parallel to the longest orientation of these crystals helps researchers detect flow direction. By using the shape and size of fragments in the rock making dike D, I researched the background regarding how the magma was broken into fragments, whether it be a one-time fragmentation event, a repeated process incorporating host material, etc.

I am exploring questions such as “what is the particle size and shape distribution of clasts in dike D in the Summer Coon volcano in Colorado?,” and “what do these analyses add to the previous research of flow direction, including why there are such different clast and host compositions throughout the proximal and distal ends and width of the dike?” A further question is “How does clast analysis help us understand about the bigger picture of the Summer Coon volcano dikes, using a micro scale under a microscope and combining that with a macro scale?”

Literature Review

Volcanic dikes tend to lack grooves that are created during intrusion of magma through more brittle rock material and products of their deterioration over time, due to the rock around them being able to fragment more easily, exposing the dike in a quicker amount of time. At the Summer Coon volcano in Colorado though, research done around 2003 shows that the erosion specifically at this volcano is an excellent site for viewing dikes. There is not an extensive amount of erosion and the areas of the dike that are exposed show the upper intrusion surfaces still containing grooves, making this dike a candidate for research (Poland, pg. 156).

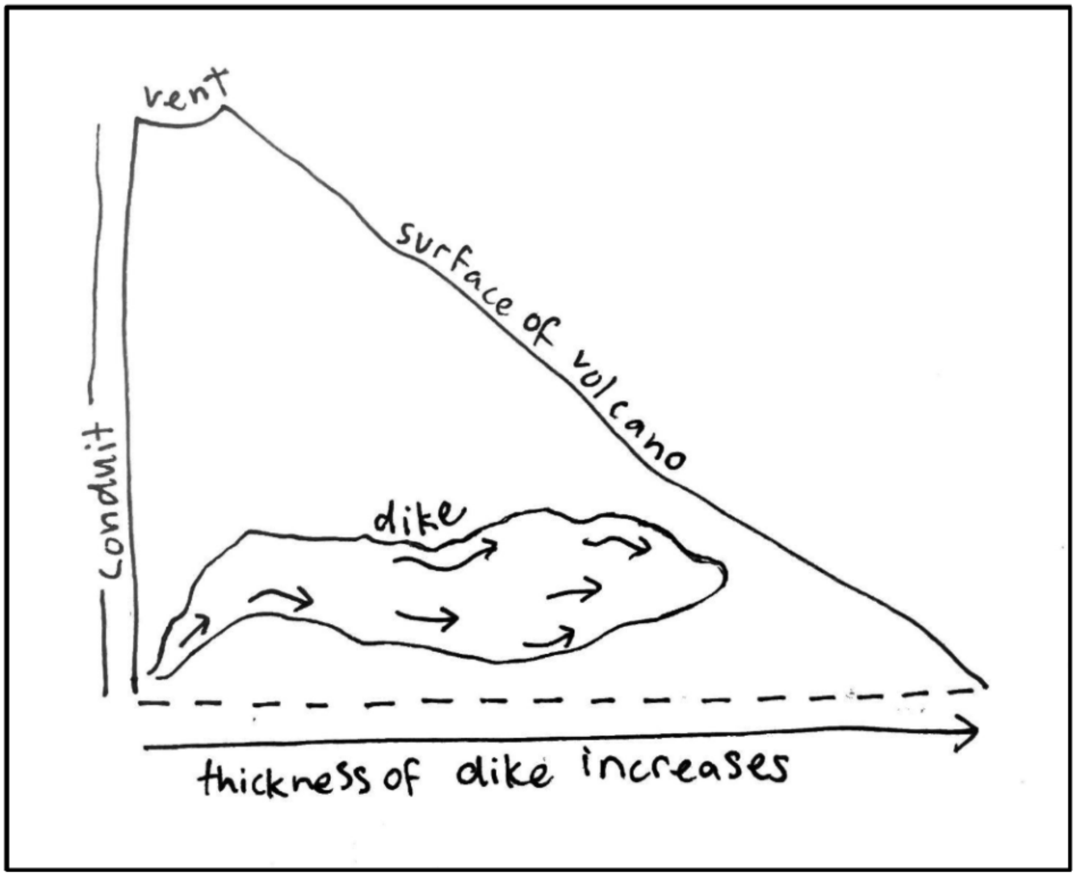

Figure 3: this diagram is a cross section that shows the thickness of dikes increasing with distance away from the conduit or the vertical part of the plumbing system that magma extrudes from.

The Summer coon volcano erupted in two phases, starting with “an early, voluminous, mafic phase dominated by basaltic andesite with minor amounts of rhyolite and dacite,” followed by “a less voluminous, late-stage phase of dacite magmatism” (Poland, pg. 157). As the dikes formed from the two major volcanic events taking place at this location, grooves and ridges formed as magma intruded through the brittle material of the volcano. Previous research has indicated that there is an increase in thickness of the dikes with radial distance from the conduit, indicating a “higher driving pressure” (Poland, 157), because as the magma continues propagating from the center of the volcano, there is an increase of the sheer amount and weight of the magma pushing on it as it flows.

Basaltic andesite dikes populate at the hundreds radially extending from the conduit of Summer Coon, accompanied by around 20 larger silicic, more viscous dikes. The dikes ended up in a perfect radial formation, which leads future research to ask the question if composition of the dikes varies not only in the dikes themselves, but across all the dikes in this volcano. I’m continuing to answer the question of confirming flow direction within a dike, specifically the rhyolitic dikes surrounding this volcano, as they are less studied and understood than the basaltic ones.

Vitrophyre is a term to describe the glassy margin near the contact of the dike with country rock (host rock), as fine-grained particles weld together “to form a dense glass” (Unwin, 18). At the Mule Creek Vent, around 50 cm from the contact of the dike to the vitrophyre, the clasts are more elongated than the clasts in the center of the intrusion, “indicative of shear deformation parallel to the vent margins, and clasts are also more strongly welded together” (Unwin, 7). This vent also shows in-situ fracturing, seen by the jigsaw fit of the clasts. In-situ refers to the material staying in the same location it formed in. Comparison of clasts in dike D of the Summer Coon volcano would help me determine how these clasts were transported (Unwin, 13). In this vent, the fracturing was caused by pressure as material kept pushing inside the vent to allow it to extrude from the volcano.

The patterns of how dikes usually propagate help explain some of the crystal orientation. Dikes flow in directions perpendicular to the field of least compressive stress (Rivalta, 3). Dikes intrude through rock that is brittle, with the least stress to go through, where the rock has a higher likelihood of fracturing.

In terms of their shape, dikes have a significant decrease in their thickness in comparison to the horizontal aspects of their measurement, which are length and width, with thickness being the vertical measurement (Rivalta, 3). They have a tabular shape because of this, but also because as previously mentioned, they are "driven by internal fluid pressure," and propagate into already brittle rock (Rivalta, 3).

Worldly Volcanic Connections

Research conducted from similar volcanic events in other areas of the world aids in providing context to how and why events might have occurred. Specifically, information gathered from the Mule Creek vent in New Mexico on a volcanic conduit and its structures during an eruption helps broaden the scope of our research by being able to connect this one volcanic event to others around the world. This conduit is also well-exposed, a rare phenomenon as mentioned earlier, with the effects of erosion allowing to study this feature "that records the processes controlling conduit formation and evolution" (Unwin, 27). The exposure at Mule Creek is part of a shallower plumbing system, while at Summer Coon, I am looking at a deeper and less commonly exposed part of the system.

Researchers working on this project in New Mexico prepared thin sections using hand samples, particle size distribution, and analyzed pixels to further look at size and shape of particles (Unwin, 3-4). These are the exact same processes I continued to use to determine particle size and shape distribution as I've progressed on my thesis.

Hypothesis

Based on previous literature and my own research analyzing thin sections from this dike, I hypothesize that the amount of particles and their size will decrease as you go further away from the margins of the dike. As the magma continues to flow, clasts that were contained closer to the conduit would be getting brecciated more as the flow continues and pushes those smaller particles into the center as new clasts weld and form the glassy outer layer. Clast analysis helps connect large scale to micro scale analysis. It connects large scale radiating dikes to flow direction, linking to small scale analysis of clast orientation and size that also shows flow direction from orientation of crystals and clasts.

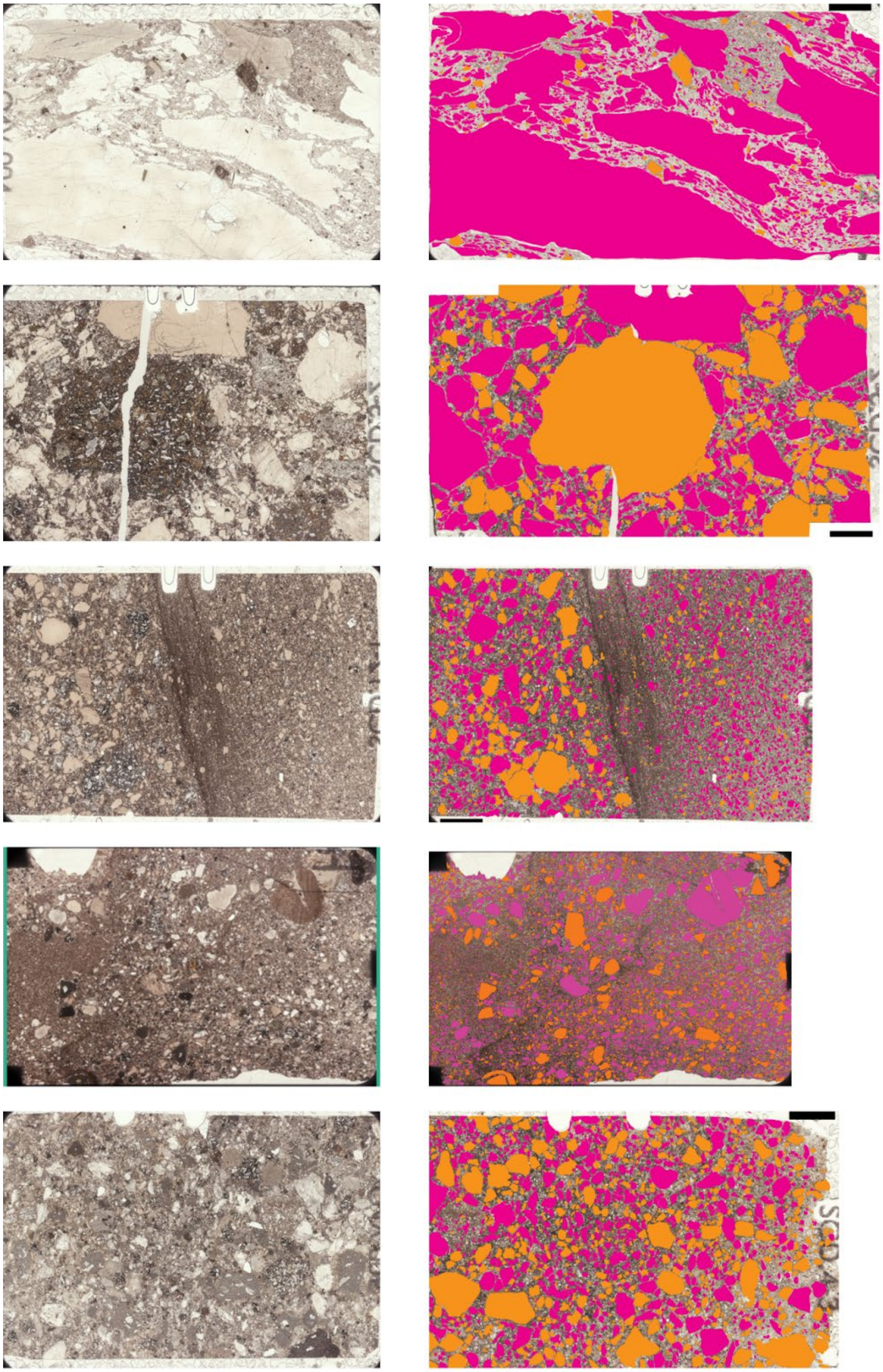

Figure 4: Thin section without (left) and with (right) manually highlighted particles. They are ordered from proximal (closer to the center of the volcano) to distal from top to bottom: 17-1-2, 5-2, 12-1, 4-1, and 4-3.

Methods

Initial Methods

For this project, using scanned images of thin sections from dike D, I worked on training my eye to differentiate between host rock and glass particles, using different colors to separate them. I used an image editing software called Adobe Photoshop to highlight the two types of particles on the images.

Before I started working on this project, work was done preparing thin sections to be further used. Gui Aksit collected rocks from the proximal to distal ends of the dike, as well as from the margins to the center of the dike. After collecting the rocks, she cut them into cubes, then into thin sections, which are 30 microns thin. She then scanned the thin sections into Adobe Photoshop, and that's where I have been working from. Standard thin sections are 30 µm (microns) thick, with a width and length of 26x46mm (Rock and Thin Section Preparation Lab).

I analyzed five thin sections for this project. My primary goal was to differentiate between host and glass particles. After tracing these thin sections, I was able to move into shape and size analysis. Through using different technologies, I can get a full picture of the dikes from a micro to a macro scale. I used various parameters to determine host vs. glass composition, including aspect, size, color, and angularity.

Another substantial aspect of my thesis is classifying the shape and size of the clasts found in this dike. Angularity is a parameter I will use, which is based on area and perimeter. Gathering evidence from multiple scales is integral to seeing the full picture of this dike.

My research has been looking at pictures of thin sections, so on the closer end to a micro scale. But next steps involving a Scanning Electron Microscope will zoom into the samples and examine them at the micro scale.

The size and shape of these particles matters greatly in the context of where in the dike these thin sections came from. Thin sections collected from the center of the dike vs the margins, and from proximal to distal ends will yield different results, in turn providing valuable information about fragmentation, crystal/flow orientation, and mainly in determining if size and shape distribution does in fact change from proximal to distal ends of dike D. Binarization is the process of converting color or grayscale images into two colors, usually black and white. With the images I analyzed, I used pink and orange to differentiate host rock from glass composition when I was tracing the particles.

Fragmentation explains the rip-up clasts from the margins of dike D as the magma flowed through, as heat, mechanical, and shear stress ripped off and ground material from the sides of the dike, incorporating it into the magma as it continued to flow. This could explain the highly brecciated and angular clasts found in this dike and is what analyzing thin sections from all distances and widths of the dike will answer.

Methods of Choosing Thin Sections

For my analysis, I chose thin sections to compare based on their location in the dike, number of host clasts and glass particles present, flow direction indications, and variation in size of clasts and glass. Number on image, number per surface area, number per volume, orientation, aspect ratio, cumulative number, circularity, and solidity are parameters that can be used in Matlab to graph particles accordingly, based on the results needed. Focusing on orientation, circularity, and number per mm^2 plotted against equivalent diameter (m) keep the scope of my project on questions regarding shape and size distribution of clasts and glass, and what that indicates about flow direction. Size relates to interpretations that can be made about orientation and dispersion, explaining why all parameters are plotted against diameter.

Results

In comparing diameter versus circularity, I thought about how distance from the volcano, moving either proximally or distally, would affect particles. Does the size of the particles decrease? Are they more crushed - (i.e., smaller), and more rounded further from the volcano? In that same vein, does circularity increase (i.e., particles are more rounded) with distance? Does flow direction change regularly with distance away from the vent?

I analyzed 5 thin sections from Dike D, with thin section 12-1 traced in three different sections to separately analyze the right, central, and left parts of the thin section. To provide context, I have used the labels 4-1, 4-3, 5-2, 12-1-center, 12-1-left, 12-1-right, and 17-1-2 to differentiate between the images and plots made. From closest to the conduit (proximal) to furthest away (distal), the thin sections are ordered as 17-1-2, 5-2, 12-1-left, 12-1-center, 12-1-right, 4-1, and 4-3. In further analysis, the nature of how sample 17-1-2 was collected needs to be considered. This sample is the most proximal sample (i.e., closest to the conduit) that was collected, and it was found in a random orientation on the ground, not in situ with the other rock of the dike. Therefore, the orientation of this sample is unknown. Educated guesses about its high glass content and flow seen are used as strong evidence in orientation analysis discussed later but cannot be confirmed due to the float nature of this sample.

Comparison of Thin Sections 4-3 vs 4-1

Comparing these images involves the most distal samples, with thin section 4-3 coming last or farthest away from the vent after 4-1. In a comparison of the diameter in mm vs the number of clasts per surface area, 4-3 has a much lower clasts density with 4-3 not even reaching 0.2 clast per mm^2 and the glass in 4-1 reaching a high of one clast per mm^2.

When looking at the diameter of glass from both thin sections 4-3 and 4-1, it steadily increases as circularity decreases, but with a greater number of points indicating particles concentrated towards the smaller end of diameter. Diameter of the clasts increases as well, but at less of a higher rate than the glass particles. Both glass and host clasts from image 4-3 are higher than 4-1, with 4-3 being the most distal thin section analyzed. In terms of orientation, as diameter increases from around 0.35 mm to 1.5 mm, orientation trends generally upwards for 4-3 glass. Most of the points are concentrated around the 0° orientation angle, from an equivalent diameter of 0.04 to 0.2 mm.

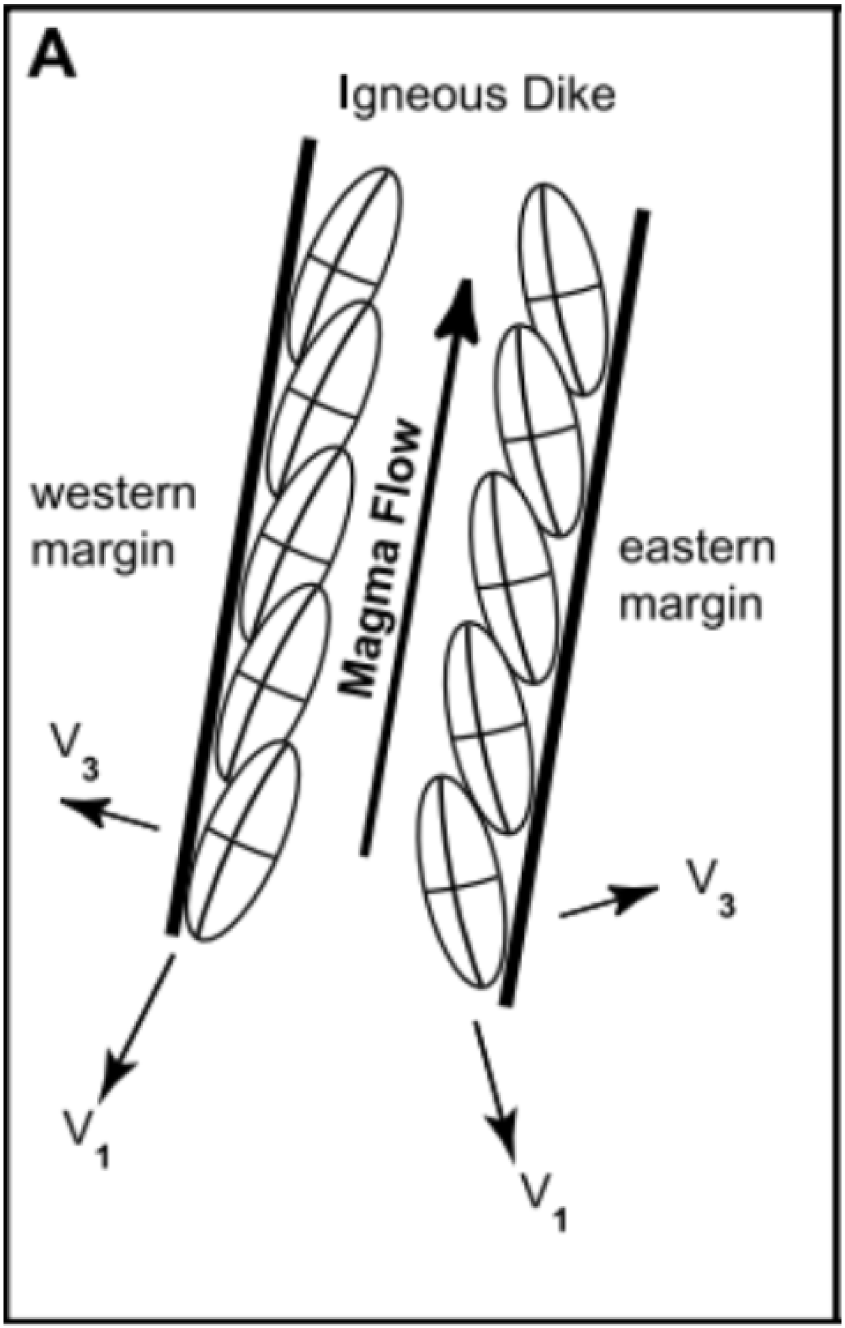

Figure 5: this diagram is a model showing orientation of elongated phenocrysts and magnetite grains in a dike. Elongated crystals typically face their longest orientation towards the direction of flow.

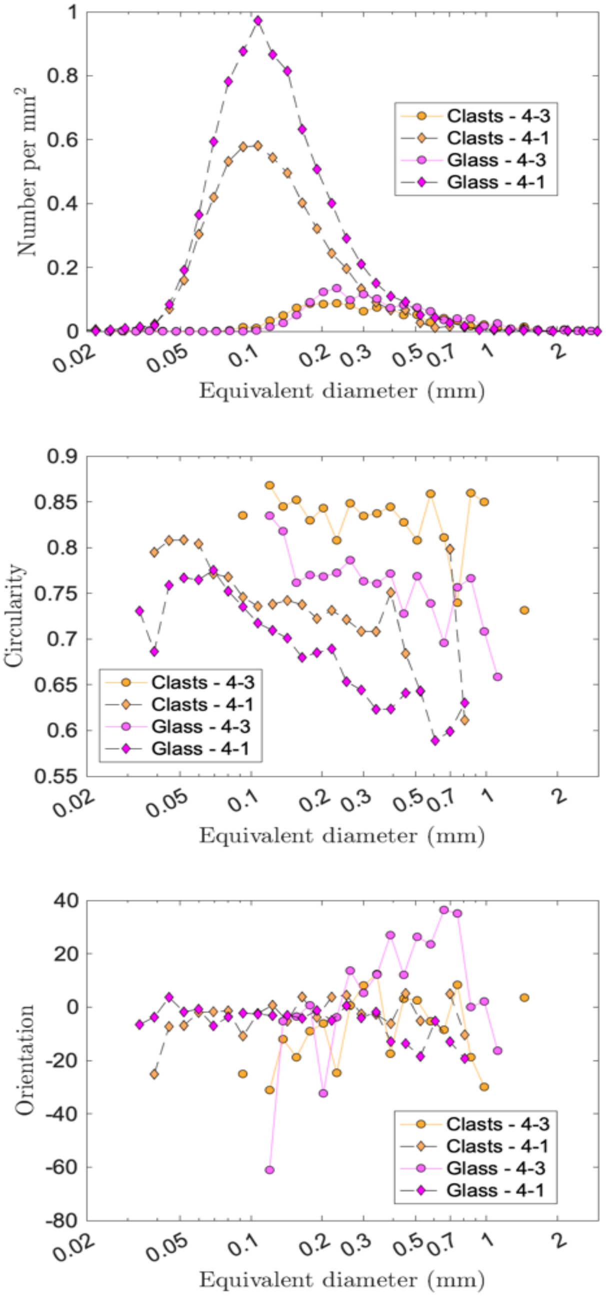

Figure 6: contains graphs showing equivalent diameter (mm) in comparison with number density per surface area, circularity, and orientation from thin sections 4-3 and 4-1.

Comparison of Thin Sections 4-3 vs 17-1-2

As with the comparison of 12-1-right and 12-1-left, glass fragments have the highest number per mm^2. Sample 17-1-2 is the most proximal and 4-3 is the most distal thin section analyzed. Around 0.05 mm is generally where all the thin sections analyzed start increasing at a rapid rate. There is no preferred orientation with randomness, and preferred orientation of particles with orientation. Comparing 17-1-2 and 4-3 are the two extremes of the samples collected from the most distal and proximal ends of the dike, which is why I chose to compare them. Closer to the conduit, there is less time for larger clasts to develop. There is more magma pushing as you move distally from the conduit of the volcano. Brecciation and the elongation of both clasts and glass decreases as you move away from the conduit. This can be seen in **Fig. 4**, which shows sections 17-1-2 and 4-3. The most explosive force of magma occurs nearest to the conduit, and could explain the higher amount of large fragmented glass pieces closest to where the magma comes from.

Clasts for both 17-1-2 and 4-3 have a higher circularity than glass. This sticks with the trend of my other analyses; as diameter increases, circularity decreases. The trend from glass particles in thin section 17-1-2, the most proximal thin section analyzed, is unique from the other clast and glass trends. It starts at a fairly circularity level and increases its diameter at a much more rapid rate than the other trends. There is a very low amount of clasts in comparison to glass in 17-1-2. There is an equal amount of clasts to glass in section 4-3, which is the furthest from the conduit. This area of the dike is distal and would have more time to cool and grow crystals than a sample taken from closer to the conduit, where more glass is present, taking a shorter time to cool.

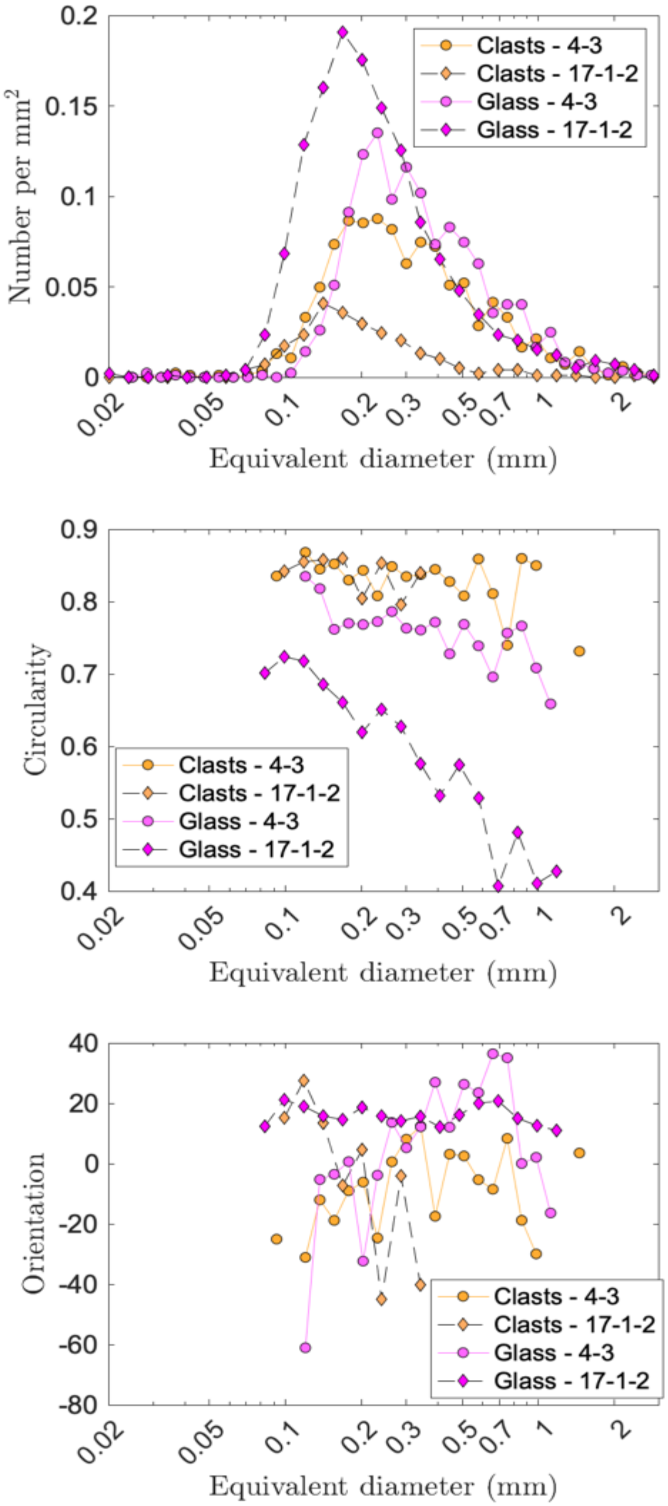

Figure 7: contains graphs showing equivalent diameter (mm) in comparison with number density per surface area, circularity, and orientation from thin sections 12-1-right and 12-1-left.

Orientation Distribution of Clasts

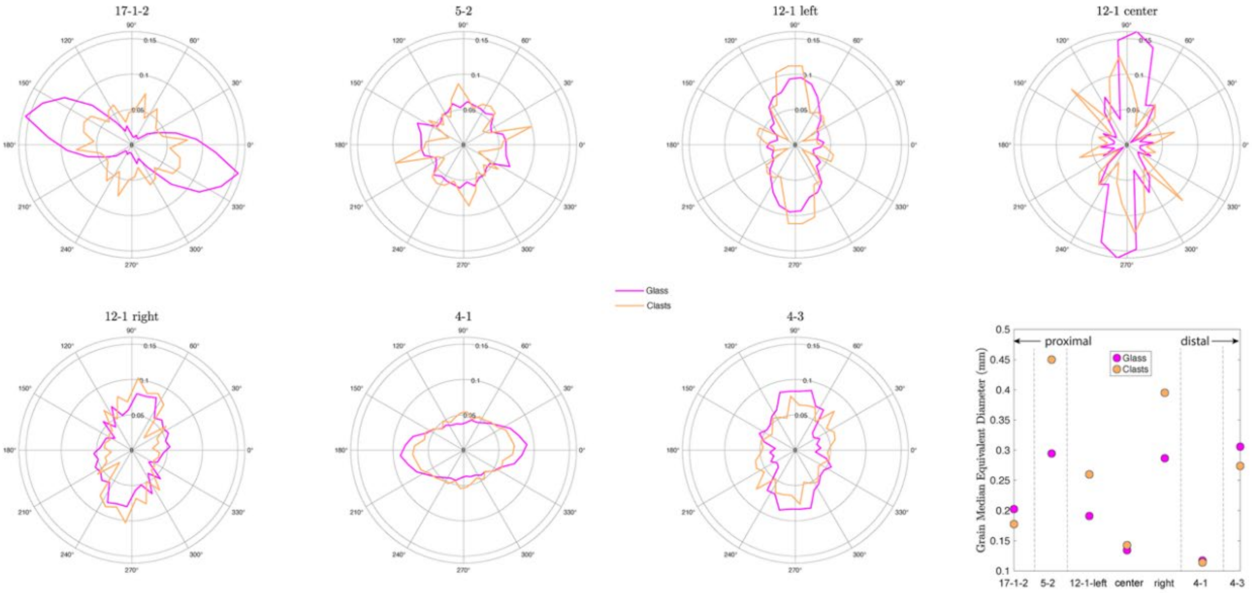

Figure 8: distribution of orientations of the clasts and glass. Top left is the most proximal and second from bottom right is the most distal sample. The bottom right plot shows each thin section plotted on the x-axis with the median equivalent diameter in mm for clasts and glass plotted on the y-axis, proximal to distal from left to right.

Fig. 8, shown above, is an image displaying the orientation of the glass and clasts for each thin section. The top left image of 17-1-2 is the most proximal and 4-3 on the bottom right shows the furthest or most distal thin section. The bottom right-most plot shows each thin section plotted on the x-axis, against grain median equivalent diameter (mm) on the y-axis, showing the evolution of clasts. On each circular plot, the percentage of clasts that reach a certain orientation is shown. The first ring is 5%, the second shows 10%, and the third ring is 15%. This means that if you cover up half of the graph horizontally, leaving just a half-circle for viewing, there is a trend that shows how many clasts fall at each angle. For example, look at 12-1-center, the top right image in **Fig. 9** above. 15% + of the glass particles have an orientation around 85°. Each peak on the lines showing clast and glass orientation corresponds to a number of particles. This makes sense, because the whole 12-1 image has a vertical orientation, as seen in **Fig. 4**, which displays all the thin sections.

Analysis

This analysis on Dike D at the Summer Coon volcano provides context and information regarding parameters measured throughout my research. Although there are not significant trends in terms of the orientation distribution of particles moving proximally to distally, there are important conclusions to draw in terms of future research to conduct and the relationship between diameter and circularity. As a refresh, the thin sections are ordered as so; 17-1-2, 5-2, 12-1-left, 12-1-center, 12-1-right, 4-1, and 4-3 moving away from the center of the volcano.

Diameter vs. number per mm^2

Comparing image 4-3 and 4-1 shows the exceptionally low numbers per mm^2 of 4-3 glass and 4-3 clasts, with a mean around 0.25 mm. Sample 4-1 glass and host clasts peak with a diameter of 0.1 mm with peaks of number per mm^2 ranging from 0.6 to 1. Within this dike, brecciation due to the explosive force of the magma extruding from the conduit and the elongation of both clasts and glass decreases as you move away from the conduit. The most explosive force occurs nearest to the conduit, which could explain the higher amount of fragmented glass pieces closest to where the magma comes from. In contrast to other thin sections, 12-1 is in the middle between proximal and distal ends of dike D.

Diameter vs. Circularity

As the size of the particles increases, it is harder for the particles to remain circular because it is harder to maintain the shape of a larger object, whether glass or host clast. Regarding magnification, all the thin section images were taken at the same magnification. This means that bigger objects are represented by more pixels. There is an effect due to the resolution of the images themselves; smaller clasts will contain less pixels and thus less details on their edges, leading to a higher circularity. On the other hand, a higher resolution artificially lowers circularity, which is important to keep in mind when considering the following analysis.

Regarding the comparison of 4-3 and 4-1, there is a higher circularity, and particles are more rounded in distal regions than proximal regions, such as 17-1-2. This is most likely due to more abrasion of these particles leading to more rounded shapes.

When looking at thin section 12-1, there are much larger clasts on the right side of the section. There is a very low amount of clasts in comparison to glass in 17-1-2. There is an equal amount of clasts to glass in section 4-3, which is the furthest from the conduit. This area of the dike is distal and would have more time to cool and grow crystals than a sample taken from closer to the conduit, where more glass is present and forms and cools quickly. With distance from the volcano, there are more opportunities for the magma to rip off clasts from the sides of the margin, because there is more surface area the magma has and can cover. This could also account for the higher percentage of clasts in the more distal samples.

Diameter vs. Orientation

With a comparison of diameter vs orientation, clasts from 12-1-right generally have an orientation angle trend around -20°. There is no significant correlation of orientation, unlike glass fragments from thin section 4-1, shown in the orientation vs diameter plots in both **Fig. 7** and **Fig. 8** above. From the plot of 4-3 vs. 4-1, glass from 4-1 has a constant orientation at 0° from the smallest diameter to 0.2 mm. Glass from 17-1-2 has a constant orientation of -20°. Clasts from 4-3 hover around -10°, while 4-3 glass and 17-1-2 clasts are randomly distributed.

Plotting diameter against orientation brings up the conclusion that with many of the thin sections compared, there is a preferred orientation of the particles. They are the two most extreme samples, with 17-1-2 being the most proximal and 4-3 the most distal sample collected.

As previously mentioned, there is a preferred orientation of the glass fragments in 17-1-2 around 20°, but further analysis on the orientation of particles in other silicic dikes around the volcano would need to be researched to draw a conclusion. As seen in the lower right plot of **Fig. 9**, the closer together the points representing the clasts and glass are the more similarity there is in their diameters. There is no trend in terms of corresponding diameters within glass and clasts or from proximal to distal, just a random distribution. I would have expected to see a higher amount of orientation with distance away from the conduit.

Orientation Distribution Analysis

Orientation is integral in helping determine the flow and path magma took when forming this dike. As seen in **Fig. 9** and the thin section image in **Fig.4,** the more rounded the particles, the less oriented they are, like in thin section 5-2. The orientation plots show a circular shape of distribution for both clasts and glass, with the clasts spiking at an orientation around 15°from the horizontal. There is not a clear orientation for clasts and glass within thin section 5-2. Thin section 5-2 is second in most proximal behind 17-1-2, and it has a higher clast content than 17-1-2. The glass particles are smaller in comparison to 17-1-2, meaning the clasts possibly have not had time to orient themselves because they are early in the flow of the magma.

With image 12-1, whether it be left, center, or right, the particles are orientated fairly vertically. This is a change from the most proximal 17-1-2 and 5-2 samples, with a high and large-particle glass content, and horizontal orientation for 17-1-2. 12-1-center has the highest percentage of vertical orientation of glass, peaking at around 86°. There is no significant trend in terms of orientation from proximal to distal ends of the dike.

Art and Science in Connection

Background

The intersection of art and science has always been a major connection in my brain. Art can utilize science to make an impact on a broader range of people, some who may not be well-versed in the topic being discussed, through a different visual interpretation. Art is another medium to be able to express hypotheses, results, images, and processes that take place during research. By creating art based on my research, I hoped to make this subject more digestible to a wider range of individuals and allow specialists in the field to see my work and science in general in a more creative light. Art has always been integral and guiding my life, so I am very excited to have the opportunity to incorporate it in my senior thesis to wrap up my research and college career.

Methods

I have translated images I traced of host vs. glass compositions, analyses I do under the microscope, and lidar images captured of the dikes of the Summer Coon volcano in my artwork. I always knew I wanted to incorporate art into my thesis. Printmaking is one of my primary mediums, and I have created prints and screen-printed clothing that can be worn in the field based on the topics mentioned above. I love wearing field clothing - items made for mobility, hiking across difficult terrain and allowing your body to get to places that hold answers in the rock for your research. It is based on practicality, and by incorporating printing into my thesis, it provides the avenue for the art to be the physical pieces themselves. An aspect of the art tis also wearing these pieces in the field. Printmaking is a unique form of art - you can choose to repeat your image hundreds of times into an edition - or clean your screen and further carve your block to stop that image from being further printed. This play with permanence and repeatability is one of my most treasured aspects of printmaking.

Jewelry is also a direct avenue to be able to incorporate rocks and geology into creative works. I love creating different forms and works based on the shapes and crystals I get to analyze throughout my time working on this thesis. Texturing metal is something I have been playing around with a lot, as well as with my jewelry. For this project, I wanted to use rocks from the field or found around campus to provide a unique texture to the metal. Using an obsidian stone to set in the center of the cuff, acting as an aerial view of the conduit, is a beautiful way to marry the science and art sides of my thesis.

The process of creating a cuff bracelet using the overview pattern of the dikes, radiating out from the conduit, seen in **Fig. 10**, has been a long one. The dikes are tabular and long in shape, which allows me to slightly alter their lengths to be able to translate the image to wrap comfortably around the wrist. I created multiple paper models to simulate how the cuff would wrap around the wrist and extended some of the north and south radiating dikes to be able to reach fully around to create the cuff shape. Texture, and the process of figuring out which tools create different patterns is an important aspect of my work. For this project, I knew I wanted to use rock to add meaning to the process used to create this piece. After cutting out, sanding, and filing the base of the cuff out of copper, I used nickel to create tiny lines that represent the paths of a few of the dikes as seen in **Fig. 10** below.

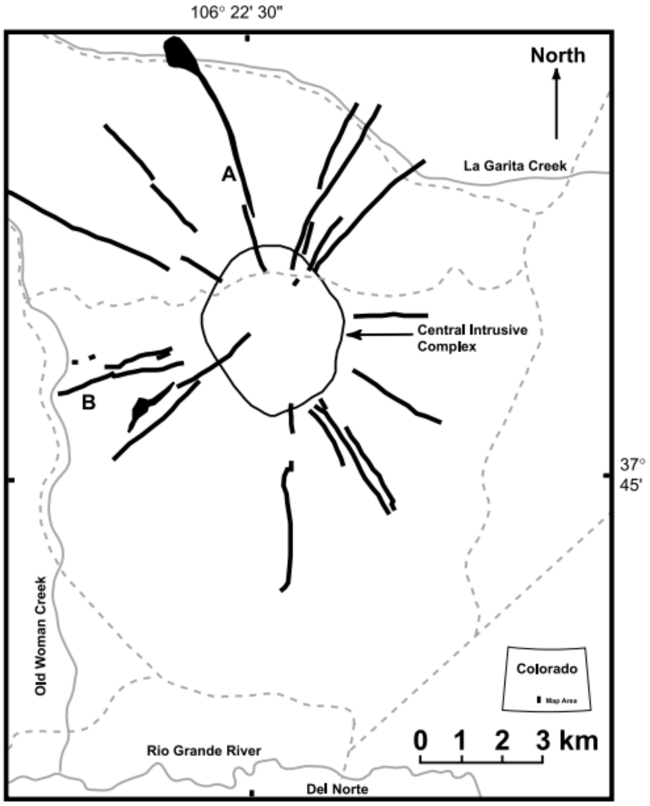

Figure 9: this is an image of the overview of all the silicic dikes radiating out from the central conduit of the Summer Coon volcano.

Process and Results

The process of translating images I've been looking at for around 2 years in a scientific context into my artistic world has been a challenging and rewarding journey. To print on, I gathered pants I have worn in the field - made for practicality, maneuverability, and functionality. I used thicker western paper to print on as well, taking thin section images, diagrams, clasts of varying scales, and dike overview images in a context they have never been in before.

For my first pair of pants, I burned thin section image 5-2 onto my screen and used black screen-printing ink to display it in varying sizes. I printed on the front and back of the pants, wanting the image to show up from any direction even when moving through the field. I also used the aerial image of the dikes to move the eye down the other leg, using a dusty orange color close to the shade I used to trace all the clasts on the thin sections. Scale and size are two aspects of the thin sections I looked at extensively while analyzing them. For my second pair of pants, I knew I wanted to distort the scale of the clasts and make them unrecognizable, almost like a camo print. I did this by choosing a variety of clasts and glass shapes and cutting out large scale versions of those shapes. I printed them in white onto my black field pants, letting those shapes shine. I kept these pants simpler than the first pair, letting the clasts shine as I got to know their shapes so well over time. I further played with scale by burning a new screen. I cut out smaller particles from the larger clasts and then printed those onto the other leg of the pants in a light purple color to contrast with the bright white against the black.

When printing on paper, I wanted to explore scale in regards to the aerial overview of the dikes. For multiples of my prints, I used different scales, colors, and orientations to provide intrigue and dimension. I traced a cross-section onto acetate paper to further be burnt into my screen, but I really liked how it looked on the acetate. I decided to keep that and instead sewed the acetate directly onto the paper. I also crumpled the paper of this print, to give the effect of the paper possibly being a map, rolled up in a geologist's backpack and getting dirty while trekking through the field.

Throughout the printing process, I got to know these images and my project through a different lens. By objectively looking at separate images used in my project and aspects in the images themselves I took them out of the context I knew them in. Not only for myself, but I translated them into the world of wearable and viewable art to marry art and science - the two focuses of my college career. Throughout my life and schooling, science and art have stayed connected as two ties in my brain, weaving around each other in a dance. Translating science into art makes the scientific side more digestible and easier to understand, by putting it in a different light.

Fig. 10: Image showing a print, printed rock, and pair of field pants I screen-printed.

Figure 11: this figure shows the three main prints I created for this thesis, as discussed later.

Figure 12: an overview of all the screen-prints created for this thesis.

Creating the final cuff bracelet representing the overview of the pattern of dikes was a long process. After cutting out the main shape and dikes from the copper, I textured the metal using rocks outside the jewelry studio. Texture in jewelry-making is typically done by a hammer, but I wanted to use rocks to further integrate aspects of my research into this project. I then soldered thin shapes of nickel I sawed out to create depth by adding these on top of the copper to contrast with the cut-out shapes of the dikes. This process proved to be challenging. I had never soldered something that small onto another piece of metal, so a lot of re-doing and trial and error took place. I then used a larger piece of metal, cut to abstractly convey the location of the conduit.

Volcanic glass is a major aspect of my thesis, so I knew I wanted to include a piece of obsidian into this bracelet. I set a bezel for it - the thin strip of metal that holds the stone in place - and soldered that together before soldering the bezel onto the cuff. I then set the stone, bending the metal gently over the obsidian to secure it. To give it the effect of being in the field, possibly near the Summer Coon Volcano itself, I added patina to the surface, which darkens the texture given to the metal and provides depth. After shaping and bending the malleable copper to fit my wrist, this project was completed. I am very happy with the results. The size of the bracelet itself, the obsidian contrasting with the luminosity of the metals, and the patina that adds even more texture are aspects of this project I am excited about.

Figure 13: various angles of the copper dike cuff bracelet.

Discussion

The analysis conducted in this thesis provides some conclusions to the questions I asked regarding the change of particle size within the dike, moving away from the volcano, and the degrees of fragmentation and shape of the particles. There are high degrees of randomness with all the conducted analyses, which does provide a conclusion and a push for research into other dikes from this volcano.

The high degree of randomness leads me to the conclusion that at least in Dike D, there are no significant trends in terms of orientation, size distribution, and circularity. There are minor trends within size distribution, as larger glass particles tend to stick to the most proximal areas. Circularity tends to increase with distance from the conduit and as size of particles decreases, but resolution of the images needs to be remembered when thinking about this analysis, as a higher resolution artificially lowers circularity. As distance from the volcano increases, there is more magma available and more surface area to rip off clasts. There is also a higher degree of fragmentation further from the conduit., leading to a higher percentage of clasts in the distal samples. Across all the plots, most points plotting particles stay on the lower and higher end of diameters, around 0.02 to 0.1 and 1-2 mm. Glass tends to have the highest number density out of any of the previous comparisons.

When looking at trends of diameter of the glass, there is no trend in the dike itself moving away from the conduit, but there are trends with comparing individual thin sections against each other. In regards to 4-1 and 4-3, diameter steadily increases and circularity decreases. There are generally smaller particles going further away from the conduit, and no trend in terms of diameter changing from proximal to distal images, showing randomness.

The most explosive forces of magma occur nearest to the conduit, which could explain the high degree of fragmentation in the large glass particles in the proximal thin sections analyzed. There is a high degree of smaller clasts and glass that have experienced fragmentation moving from proximal to distal. The force and amount of magma impacting the particles increases as you go further away from the chamber.

Given the lack of trends found in circularity, orientation, and size distribution, there are no conclusions that can be drawn in terms of the trend of the flow of magma moving proximally to distally. There are very likely internal flow trends within the magma that is undetectable in the thin sections used for this project. Sample 12-1 is the only thin section that shows significant sub-horizontal flow. Despite the lack of trends found within the analysis of 5 thin sections and 7 images for Dike D, this is still important research contributed to the field of volcanology in the research of dikes.

Conclusion

There are no detectable trends of flow direction in Dike D, found through the analysis of thin sections gathered proximally to distally along the length of the dike. These samples were collected with the goal of gaining more understanding about flow direction, circularity trends, orientation of particles, and the distribution of size of particles.

As seen in **Fig. 9** above, there are significant trends in orientation distribution within thin sections, such as the glass in 17-1-2 being oriented strongly vertically, and 12-1-center strongly sub-horizontal, almost vertical. This analysis shows randomness for the trend of orientation distribution moving proximally to vertically. In the analysis of circularity within each thin section, an increase in diameter leads to a decrease in circularity. There are no trends large-scale of circularity or orientation moving proximally to distally within the analysis conducted in Dike D. There are large concentrations of particles of both glass and clasts along the x-axis of plots shown in topmost graphs of **Fig. 6-8**, towards the smaller and larger end of diameter size. This concentration ranges from around 0.02 to 0.1 and 1-2 mm.

There are no significant trends noticed in this analysis, but that conclusion still provides information about the dike. The lack of a trend in flow direction explains how there is so much randomness and variation in the parameters graphed earlier. Within the comparison of thin sections individually and standing by themselves, there are trends that do not contribute to the bigger picture. These small-scale trends will contribute to flow direction overall and less-detectable internal flow with data from more samples in further research. Overall, this indicates that there is either no trend in the flow, which could alter the trends of the other parameters, or that more data along the dike needs to be collected to provide a more thorough investigation

Future Applications of This Research

Results gathered during this analysis process provide context for the randomness found in Dike D, in terms of previously mentioned parameters compared. More research involving variation in flow direction within dikes, specifically sub-horizontal flow, is needed to provide further context for this data and data collected on this dike and other dikes around the Summer Coon volcano in the future. Gui Aksit, PhD candidate, is completing her PhD investigating magma properties at this volcano. She is doing in-depth research into SEM images and individual crystals themselves, which will help connect and possibly draw new conclusions with the connection to my research.

Further investigation into the most proximal sample of Dike D needs to take place. The sample collected that made the thin section 17-1-2 was a float rock. This means it was loose and wasn't in situ with the surrounding rock, so it lost the important context of orientation direction. This would provide more information about flow direction proximally, which would add to the question of flow direction throughout the whole dike.

I would love to have the opportunity to continue researching this dike and other dikes at this site to investigate and draw conclusions about possible flow direction throughout numerous dikes radiating from this volcano, and to add to previous research conducted on dikes A and B. More samples being collected to fill in the gaps between these samples could lend useful information about flow trends. Further research should include the collection of more samples along Dike D and significant analysis of the occurrence of trends proximally to distally at the other radial dikes around this volcano.

Bibliography

"City." *Myperfectweather.com*, 2020, myperfectweather.com/api/cityinfo/41069Mit/degF/Average-Weather-in-Mitchell-Oregon-United-States-Year-Round. Accessed 9 Nov. 2024.

Emerman, Steven H., and Randall Marrett. "Why Dikes?" *Geology*, vol. 18, no. 3, 1990, p. 231, pubs.geoscienceworld.org/gsa/geology/article-abstract/18/3/231/205025/Why-dikes?redirectedFrom=fulltext, https://doi.org/10.1130/0091-7613(1990)018%3C0231:wd%3E2.3.co;2. Accessed 1 Apr. 2023.

Poland, Michael P, et al. "Patterns of Magma Flow in Segmented Silicic Dikes at Summer Coon Volcano, Colorado: AMS and Thin Section Analysis." *Earth and Planetary Science Letters*, vol. 219, no. 1, 28 Feb. 2004, pp. 155–169, www.sciencedirect.com/science/article/pii/S0012821X03007064?via%3Dihub, https://doi.org/10.1016/S0012-821X(03)00706-4. Accessed 14 Apr. 2023.

Rivalta, E., et al. "A Review of Mechanical Models of Dike Propagation: Schools of Thought, Results and Future Directions." *Tectonophysics*, vol. 638, Jan. 2015, pp. 1–42, https://doi.org/10.1016/j.tecto.2014.10.003. Accessed 7 Sept. 2022.

"Rock and Thin Section Preparation Lab." *Ku.edu*, 2024, geo.ku.edu/rock-and-thin-section-preparation-lab. Accessed 19 Nov. 2024.

Unwin, Holly E, et al. "The Exposed Mule Creek Vent Deposits Record the Structure of a Volcanic Conduit during a Hybrid Explosive–Effusive Eruption." *Bulletin of Volcanology*, vol. 85, no. 5, 4 Apr. 2023, https://doi.org/10.1007/s00445-023-01638-z. Accessed 7 Sept. 2023.

Walker, R J, et al. "Dike Propagation and Magma Flow in a Glassy Rhyolite Dike: A Structural and Kinematic Analysis." *Geological Society of America Bulletin*, vol. 129, no. 5-6, 17 Feb. 2017, pp. 594–606, https://doi.org/10.1130/b31378.1. Accessed 16 Jan. 2024.