Re-creating Recreation: Climbing Replicas and their Effects on the Sport

Walsh, M (2023).

Acknowledgements

A special thank you to:

Alex Dimitrakopolous
Nina Sky Robertson
Steven Hall & Logan Mohr
The Material Matters Lab
Drummond and Kathryn Brodeur
Ed Parkinson
Madison Walsh

…and of course my dear supervisor Sophie Gaur.

Much of this work is tied to the land it takes place on. Indeed, one of the goals of this thesis is to strengthen the relationship between climbers and the land. As such I humbly, and wholeheartedly, acknowledge that the research for this thesis took place on, and was guided by, the traditional, ancestral, and unceded territory of the Coast Salish peoples - Skwxwú7mesh (Squamish), Tsleil-Waututh & Musqueam First Nations.

Abstract

Rock climbing is a sport with a contentious relationship to technology. Technical innovation has improved safety for participants creating new styles of climbing. This allows for a wider range of climbs to be set up on natural rock that are also less invasive to the environment itself. Since it is a sport born of the outdoor movement with philosophical roots in Romanticism, technology is often regarded suspiciously. It detracts from the experience. But technology breeds innovation, and 3D scanning, and CNC technology means that increasingly, outdoor climbs are replicated out of indoor holds. A practice-based study, coupled with research into existing replica use, was undertaken with the goal of understanding how replicas are made as well as how they affect the experience of rock climbing.

When climbing outdoors, participants interact with the rocks as the shape of the rock guides their movement. Through the act of climbing, they build a relationship to the rock, however brief that may be. As indoor climbing became more popular, indoor holds became abstract from natural stone. This means climbers interact much more with hold shapers and route setters.

Through 3D scanning, and CNC technologies, we can now near perfectly recreate popular outdoor routes out of indoor holds, bringing outdoor rock back into the gym. Replicas can invite participants to consider the rock more thoughtfully but fall short of emulating the entire experience of climbing outdoors. Ultimately, nature can't be faked, but the replica forces the climber to consider the real outdoor stone which can help guide them to a more authentic experience. However, replicas can still ease the transition from gym to crag**,** remove barriers to trying climbs that might be otherwise difficult to access, and preserve climbs that might be threatened by excessive erosion or rock fall.

Table of Contents

Glossary of Terms

Anchor: Equipment on or in the rock, at the top of a climb that a climber is able to rappel or lower off of.

Beta: the choreography required of a climber to reach the top of a climb.

CNC tech: Technology that uses Computer-Numerical Control to operate an effector on a robot. Examples of CNC tech include 3D printers and CNC mills.

Crag: A mass of rock with multiple rock climbs that forms a climbing area.

Flash: Climbing a route cleanly (i.e. without falling or weighting the rope) in one attempt, *with* some prior knowledge or training specifically for the route.

Indoor Hold: An often polyurethane piece that can be bolted to a wall and used for indoor climbing.

Onsight: Climbing a route cleanly in one attempt, *without* prior knowledge or specific training.

Projecting: Spending an extended period of time training on a route with the goal of climbing it cleanly.

Quickdraw: A piece of climbing protection made of a small nylon sling with a carabiner on either end.

Rappel: The act of lowering oneself down a fixed rope.

Replica: A set of indoor climbing holds that attempt to recreate the experience of climbing a specific outdoor route.

Send: Climbing a route clean.

Smearing: pressing the sole of your shoe directly into the rock using friction rather than a hold to gain vertical ground,

Introduction

On a crisp August morning, before the sun had crested the ridge, I was hanging from a cliff. I was nervous. Once the sun was up my cliffhanging would end and I would have to make my way to the ground. I was hanging there to collect 3D scans of a crack in the granite, and the bright sun would blow out the sensors on my scanner. I had woken up early to dangle in the half-light.

Figure 1: Sun up in Squamish
Walsh, M (2023)

The sinuous crack was called *Crime of the Century*, and it's considered one of the best finger cracks in Squamish, a climbing destination north of Vancouver and first nation. No wider than 4 inches at its widest, it limits the places toes and fingers can fit, making it near impossible to climb. Every climber that attempts it has to first learn the unique choreography its form demands. Climbers can spend countless hours of the limited Squamish climbing season trying to learn that choreography. I would know, I have. I was hoping to make a replica of the crack out of polyurethane resin, so that it could be mounted in a climbing gym.

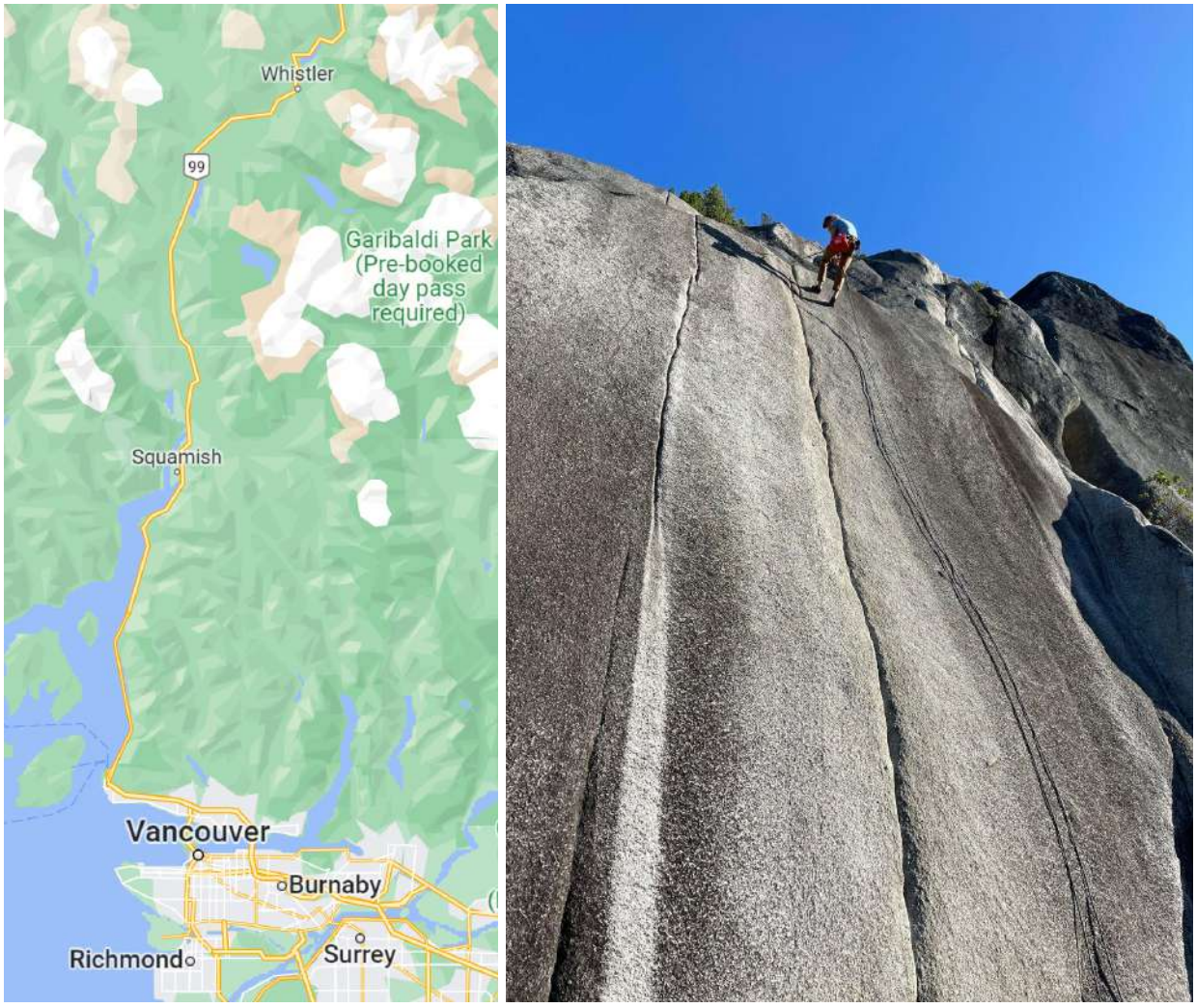


Figure 2: Left: Vancouver, Squamish, and Whistler. Right: Rappelling down *Crime of the Century*
(Google, n.d.)
Walsh, M (2023)

This would allow for more time spent with the crack outside of high season. Additionally, it decouples the crack from place, allowing it to be climbed remotely, a Zoom call of climbing of sorts. Although, as we all know, while Zoom is an important communication tool, it can't fully replicate the experience of a face to face conversation. Furthermore, it decouples the crack from time. *Crime* is an incredibly popular climb, and erosion from climber traffic, as well as the elements, slowly changes its shape. Softer rock like sandstone can change even quicker, and rockfall events risk destroying climbs completely.

Replica training (i.e. training on an indoor climbing route that's meant to recreate the experience climbing a specific outdoor route) has been steadily gaining popularity in climbing over the past decade. In this paper I'd like to discuss what's been done already in this space, my own experience attempting an ambitious replica, and how replicas, and the technologies that make them possible might play a role in the future of the sport.

Research Question

This research investigates the design and impact of climbing replicas. It also interrogates how these devices can strengthen/assist the relationship between climbers and specific climbing sites. It takes the form of a research-led study into the ways in which climbing replicas are currently being used and the discourse around them. Additionally, a practice-led study aims to develop a workflow for creating replica *crack* climbs, a style of climbing route yet to be replicated that offers its own unique set of challenges.

Let's Get out for a Climb

What is Climbing?

Prior to the early 60s, rock climbing was seen as a sometimes needed skill for mountaineering. Mountaineering could involve skiing, hiking, and glacier travel, all with the intention of ascending a mountain. However, as a new generation began learning the skills, climbing began to evolve into its own sport. Its popularity grew and now it is difficult to find a mid-sized city in North America without some form of indoor climbing available (Climbing Business Journal [CBJ], 2023). For the layperson, the sport can broadly be divided into 3 disciplines: bouldering, sport climbing, and trad climbing. These three categories depend on the system used to keep the climber safe. Which system is used depends on the size and shape of the rock, which affects the quality and style of the climb.

Bouldering is low to the ground, usually performed on large boulders. Climbers do not tie into a rope, and instead rely on foam mats to keep them safe should they fall. Since the routes are often short, bouldering usually focuses on specific, difficult movements that can be both highly technical and exhausting.

Sport climbs are taller than boulders, (although outliers can be found that buck the trend) and the climber ties into a rope to protect their falls. As they climb a belayer pays out rope, which the climber attaches via quickdraw to bolts drilled into the rock. The aim of sport climbing is to link all the required moves in sequence to reach the top of the pitch cleanly.

Finally, trad climbing (short for *traditional* climbing), is similar to sport climbing. Rather than clipping their rope to bolts drilled into the rock, the climber clips into specialized devices (most commonly cams and nuts) that they wedge into natural gaps and fissures in the cliff. The geomorphology of Squamish lends itself to trad climbing as the granite rock is full of deep cracks that accept trad climbing gear. Similar to sport climbing, the aim is to link all the moves in sequence to reach the top. However, there's the added challenge of finding good spots to place protective gear.

Figure 3: From left to right: examples of bouldering, trad climbing, and sport climbing.
Walsh, M (2023).
Outside Magazine. (2020).
REI (2019).

Climbing as a Suitsian Game

In Bernard Suits' *The Grasshopper: Games, Life, and Utopia* he defines playing a game as "the voluntary attempt to overcome unnecessary obstacles," (1978). The goal of climbing is simple: to reach the top. But if that were all there was to it, there wouldn't be any climbs on cliffs that already have a road or trail to the top. Thi Nguyen, builds on Suits definition of a game in terms of means and ends in their essay *The Aesthetics of Rock Climbing*: "in ordinary practical activity, we take the means for the sake of an independently valuable end. But in gaming activity, we can take up an artificial end for the sake of going through a particular means," (2017). In climbing the artificial end is reaching the top, and the particular means is via the cliff face.

Another suitsian game, *Rush Hour,* uses shuffled location cards to place cars on a board. This generates a unique board for participants to begin play. The artificial end is getting the red car off the board and the particular means is by moving the cars to make a path. In climbing the board is set by the shape of the rock, and the participant moves their body up the rock so they may reach the top. Though, unlike *Rush Hour*, where the challenges were created by a coordinated system of pieces, board, rules, and instruction, all of which are human centered; in climbing, the actual shape of the route and thus the challenge was carved by natural processes like erosion. Humanès don't design the challenge, so much as they discover it.

In climbing, through embodied movement, the participant gives over to the challenge set by the rock to achieve an elevated experience. In climbing gyms, as in *Rush Hour*, that challenge is set by other people (route setters and hold shapers) through the medium of plastic climbing holds. While this distinction might be minimal to the beginner, the differences between plastic and rock, and indeed between different types of rock, becomes more apparent with more time.

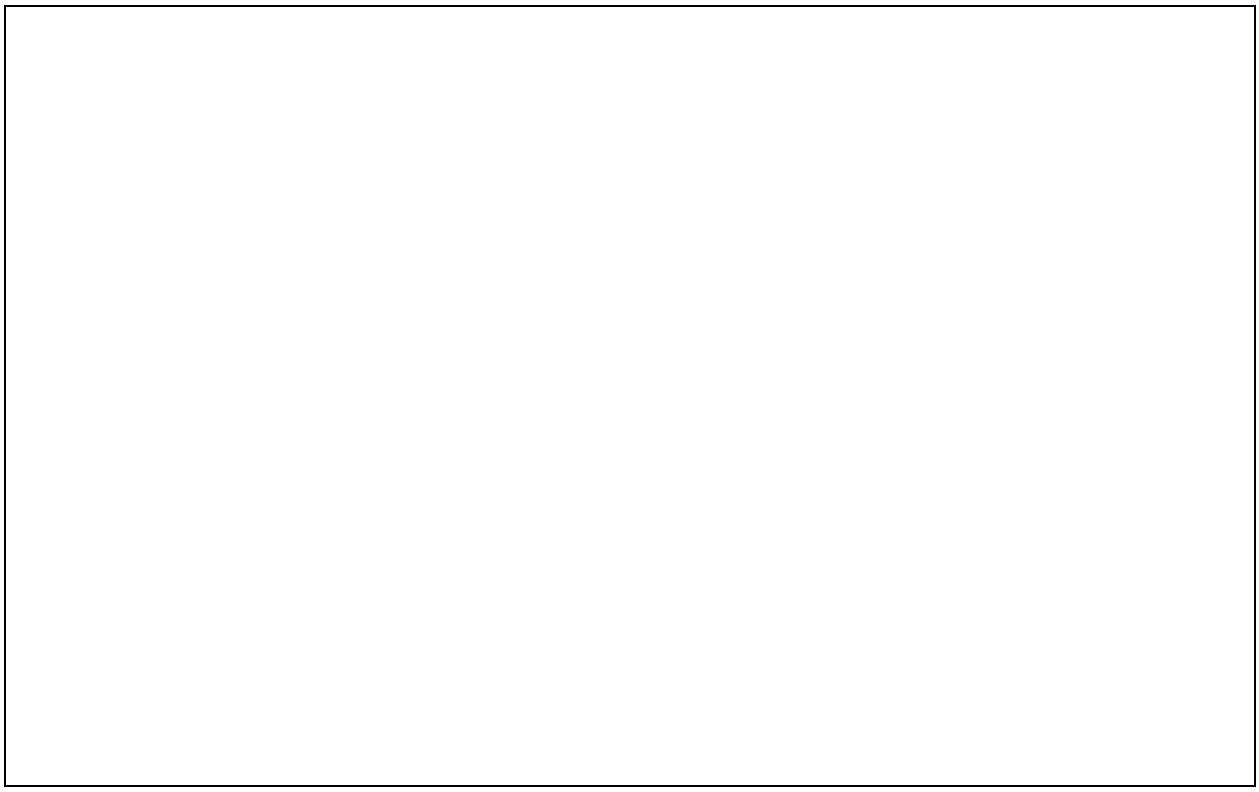


Figure 4: Rush hour board game and problem cards.
Welt-Der-Form (2013). *Rush Hour sliding block puzzle.* [photograph]. Wikipedia.
https://en.wikipedia.org/wiki/Rush_Hour_%28puzzle%29#/media/File:Rush_Hour_sliding_block_puzzle.jpg

Indoor Climbing as Simulation

Indoor climbing gyms began appearing in the 80s, the first manufacturer of indoor holds being a company called Entre Prises (Climbing Business Journal contributors, 2014). Making a hold generally involves three steps: a master is shaped (often out of foam), a mold is made from the master, and the final hold is cast from the mold (often out of polyurethane resin).

Indoor climbing originally aimed to be a simulation for the outdoor sport. When indoor climbing was in its infancy, the holds and routes were designed to mimic climbs one might see outdoors (Climbing Business Journal contributors, 2014). They were what Baudrillard calls first level simulacrum, attempting to reflect what's real (1981).

As the practice of hold making evolved, hold shapers played a larger role, as more emphasis was placed on ergonomics. The thinking was that indoor climbing should be comfortable and enjoyable. A philosophy that lowers the barrier to entry for the sport, reduces injury, and allows for longer sessions (Robinson, 2014). As expected this second level simulacrum attempts to mask reality in favour of comfort.

We find third level simulacrum as route setters combined these ergonomic holds in increasingly abstarct and exciting ways. Producing moves and challenges rarely, if ever seen outdoors.

The fourth level simulacrum in the novelty holds produced for children. Holds shaped like animals or ice-cream cones were meant to broaden the appeal of the sport. The intent is not to mimic, or make comfortable, but to find mass appeal.

Finally, competition climbing represents the fifth stage of simulation. A level of mass consumption. Crowds gather to watch athletes attempt routes not based on any outdoor rock, and perform moves rarely, if ever, seen in nature. Routes become their own pure simulacrum, and athletes are challenged strictly by the hold shapers and route setters. The outdoors is entirely out of the picture.

The story of indoor climbing, is the story of a relational, outdoor sport becoming increasingly industrialized and modified for mass consumption. The pendulum swung from mimicry to abstraction, and the sport becomes increasingly, if not entirely, divorced from the outdoors and nature. In doing so many participants no longer interact with the rock or outdoors on any level.

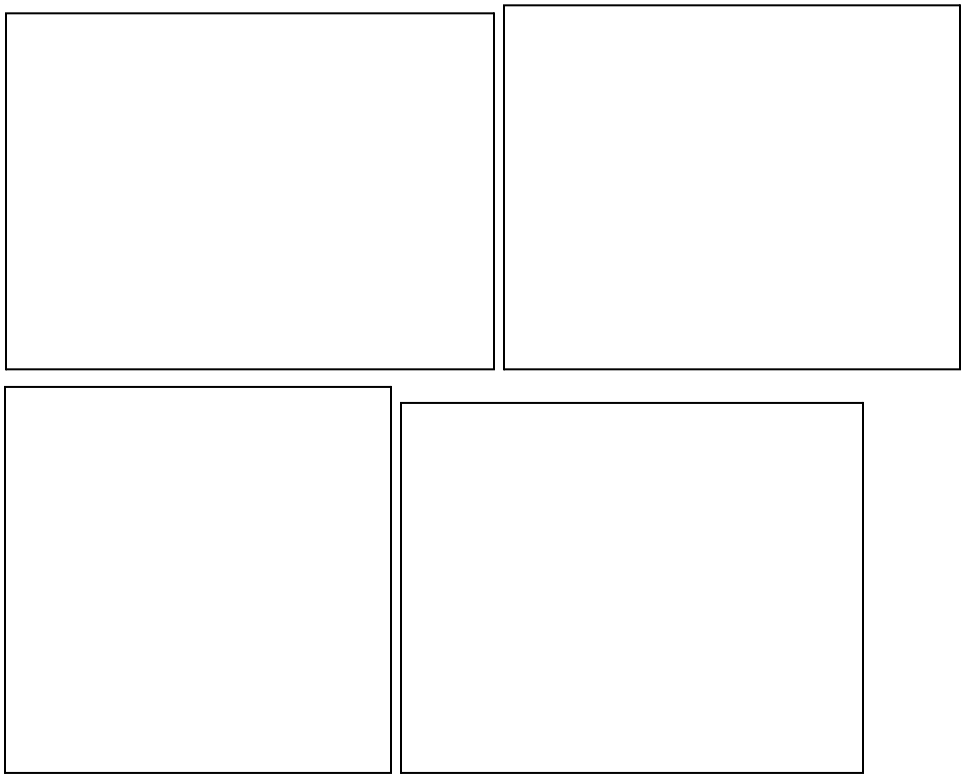


Figure 5: Clockwise from top left: A hold meant to mimic real rock, Ergonomic "bubble wrap" holds, Novelty animal holds, A comp climber performing moves rarely seen outside on holds abstracted from real rock.
Hughbanks. G, Routesetters Anonymous. (2014). *Original EP* [photograph]. Climbing Business Journal. https://www.climbingbusinessjournal.com/evolution-of-the-climbing-hold/
Jegrimpe.com. (2014). *Bubble Wrap* [photograph], Climbing Business Journal. https://www.climbingbusinessjournal.com/evolution-of-the-climbing-hold/
Atomik. *Animals* [photograph] Atomik Climbing Holds. https://www.atomikclimbingholds.com/kids-climbing-holds
Maja Hitij/Getty Images. (2021). *Climbing at the Olympics, When and How to watch it* [photograph]. Mercury News. https://www.mercurynews.com/2021/08/03/climbing-at-the-olympics-when-and-how-to-watch-it/

Rationale

According to *The New York Times,* and as every mountaineer knows, when asked why he was attempting to summit Everest, British mountaineer George Mallory replied: “Because it’s there!” (1923). But good anecdotes make for poor histories, and Mallory actually elaborated on his answer:

> ... Sometimes science is the excuse for exploration, I think it is rarely the reason. Everest is the highest mountain in the world, and no man has reached its summit. Its existence is a challenge. The answer is instinctive, a part, I suppose of man’s desire to conquer the universe. (Climbing Mount Everest is Work for Supermen, 1923)

In the eyes of Mallory, putting a man on Everest was inevitable.

Many of the great narratives in outdoor sports follow a similar pattern. An individual, at the top of their game overcoming great odds to achieve something thought impossible by the rest of the world. These narratives help drive the sport forward, whether its Alex Honnold climbing the 900 meter El Capitan without ropes (Chin, Vasarhelyi, 2018), or Margo Hayes becoming the first woman to climb 5.15a (Walker, 2023), these achievements change what’s considered possible. But there are also quieter, every day narratives that drive the sport as well. Standardizng the mounting system for indoor climbing holds allowed for the expansion of indoor climbing, and targeted classes like the Hive’s *Women in Bouldering* help bring in new and diverse people. While Honnold and Hayes’ stories push the depth the sport, narratives like these push the breadth. Climbers ask not “can I do this?” but instead “can I share this experience?”

Replication falls into the latter category. It’s an attempt to increase the breadth of the sport. An attempt to help more people gain access to climbs that might otherwise be blocked to them, whether those barriers are geographical, mental, or logistical.

Attempting to replicate the world around us is not new to the human experience. What Umberto Eco calls “the pleasure of imitation” (1985, pg 57) can be found in our earliest human archeological sites. Such as the Lascaux cave paintings depicting images of paleolithic life 20, 000 years ago.

Recreating form can begin disciplines. Sculptors have been practicing perfect recreation of form through casting for centuries. What the relatively new technologies of 3D scanners, computer storage, and CNC machines can offer is a far easier and far less invasive method of doing so. An object need only be visible for its form to be scanned and stored digitally. From there it can be endlessly shared and altered before being brought back into the physical world. In the case of replica climbing routes, the sharing of the form allows for the sharing of experience.

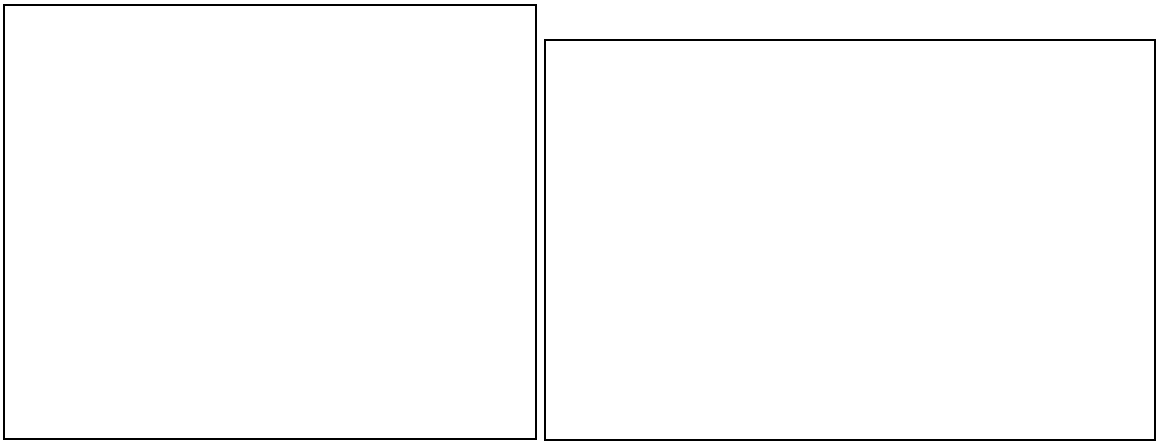


Figure 6: From left to right: George Mallory and Andrew Irving pictured with their oxygen tanks, cave paintings at Lascaux AP/John Noel Collection. (1924) *Mallory and Irving Preparing to Leave their camp.* [photograph]. Mallory Expedition https://malloryexpedition.com/index.php/team-mallory/
X (2006). *Aurochs, horses and deer painted on a cave.* [CEVA] Wikipedia. https://en.wikipedia.org/wiki/Lascaux#/media/File:Lascaux_painting.jpg

Theoretical Framework

Although climbing has found space indoors, climbing comes from outdoors sport, and as such carries the historical baggage that comes with that. The social and environmental impacts of the industrial revolution at the end of the 18th century pushed the philosophers and artists of the day outdoors as they developed the art and ideas of the Romantic Movement (Shultis, 2001, pg 57). This new movement into the outdoors did so in opposition to the growing technology of the day. Writers like Muir and Theroux, would further emphasize this Nature/Tech dichotomy in their writing, which helped disseminate the ideas more broadly. As such, outdoor recreationists, the philosophical offspring of the romanticists, have always regarded technology encroaching on nature with suspicion if not outright hostility. However, as Shultis points out, new technology has allowed more and more people to enjoy the outdoors. A pair of vintage skis might look nice on the wall, but are hard to compare to modern ones in terms of performance. Indeed it was the railroads and later the automobile connecting cities to the country, that allowed the National Park system to be created and to thrive.

In *Travels in Hyperreality,* a recollection of Umberto Eco's odyssey across America's odder museums (1985). He identifies what he calls a "constant of the American imagination [...] a philosophy of immortality as duplication," (1985, p. 5). While Eco identifies the phenomenon as distinctly American, the need to preserve and share experiences and information has been a driving force for technology since the invention of media.

Nature can't be faked. A study by Kahn et al. found that staring at a blank wall had the same effects as staring at a plasma screen window, whereas staring out an actual window reduced the stress of participants (2009). Climbing replicas attempting to fully simulate outdoor climbing will always fall short. But they do open climbers to a greater relationship with the rock. Even if the holds are bright orange, and the room air conditioned, the contributions of the rock face to the experience is felt. It invites the participant to make the comparison. How they process these differences, is entirely up to them. The replica may push them towards the

original or away from it, but they are forced to consider the sport more carefully through the simulation.

Artist Cosmo has Wenman long been advocating for 3D printers and scanners in the art world. He identified how the nature of printers and scanners as networked machines means 3D media can be propagated fluidly and endlessly allowing for limitless reproductions as well as modifications of works (2014). During an exhibition at the Carrousel du Louvre, Wenman remarked on how people responded to a 3D print of the *Venus de Milo*, that was placed within walking distance of the original: "I don't think they're responding to the novelty of a 3D print […] They're responding to the recognition of the design, and the importance, and the emotional appeal and history of the design. Ultimately they want to touch it, pick it up, and possess it as well," (2015). During a different exposition, Wenman observed a blind patron touch his recreation of a horse head that was part of the Parthenon. The patron was able to explore the design directly in a way that wouldn't otherwise have been permissible (2015).

What's made evident through Wenman's work is the potential of 3D scanning and 3D printing to reveal and transform ways of knowing by giving diverse people unique perspectives from which to learn from.

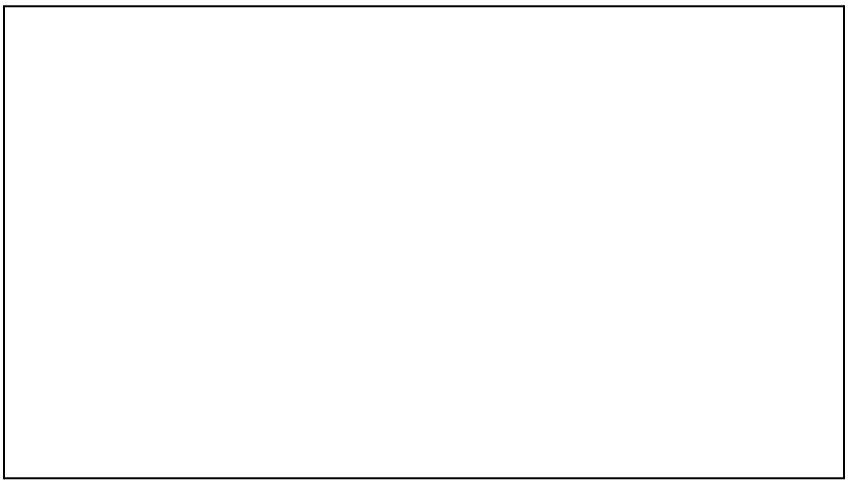


Figure 7: Cosmo Wenman's Venus de Milo (Venus de Milo de Wenman)
Wenman. C (2013) *Venus de Milo*. [screen capture] Cosmo Wenman.
https://cosmowenman.com/2013/12/28/venus-de-milo-published-update-12282013/

Methodology

Scanning

Figure 8: Scanning *Crime of the Century*
Walsh, M. (2023)

One reason for undertaking this project is due to the growing availability and decreasing cost of 3D scanners as non-invasive ways to capture form. Currently, scanners can be organized in 3 groups based on the technology they use: structured light scanners, laser-based scanners, and cloud based “scanners.” Each of these technologies have their own advantages and drawbacks.

Structured light scanners consist of a projector light and a camera. The projector will shine a series of striped lights on the object one wishes to scan. The scanner is able to infer the shape of the object by the way the pattern distorts on it. Unfortunately, these types of scanners only work in certain lighting conditions, and require the object and scanner to be stationary relative to one and other during a scan.

Laser based scanners work by bouncing a laser off an object, and recording the reflection with a sensor, repeating the process thousands or even millions of times is what produces a point cloud. These scanners do better in a wider variety of light conditions and many have built-in software that allow the scanner to track the object once it has a base idea of where it is. This means a wider variety of angles can be captured in order to minimize occlusion. LiDAR falls under this category.

Finally, cloud-based “scanners,” are able to recreate an object based solely on visual inputs. Photogrammetry is the most popular of these solutions although NERB technology is also becoming more sophisticated. These solutions have the lowest barrier to entry, the user is only required to have a camera that’s able to record sufficient images or video. The subject captures images of the object at varying angles. After uploading the photos to a server, an AI trained in photogrammetry will release its best estimation of the shape of the object in 3D. This technology is improving quickly, however the fidelity to which it’s able to recreate form is dependent on the quantity and quality of photos uploaded, and the experience of the AI.

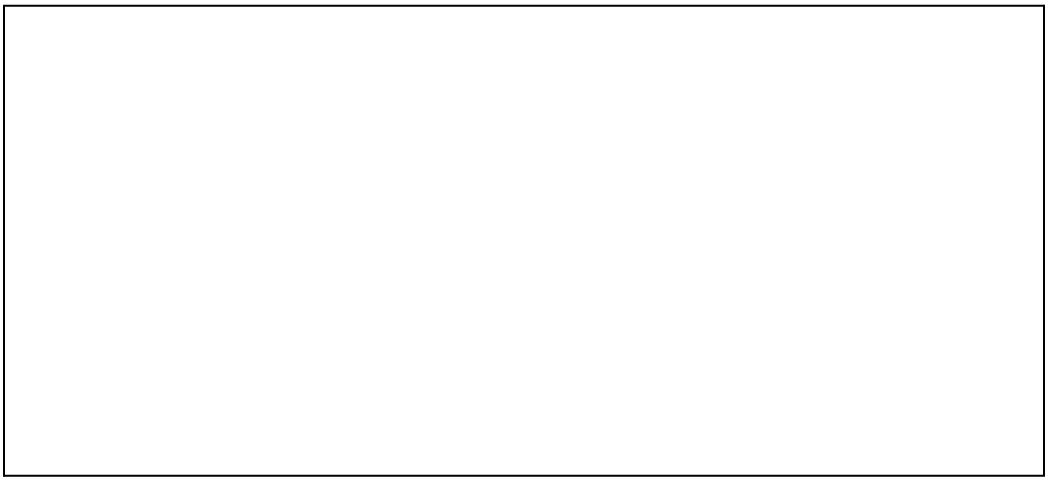


Figure 9: Working principle for a Structured Light Scanner
Bitfab (2023). *Structured Light Scanner* [diagram]. Bitfab. https://bitfab.io/blog/3d-structured-light-scanning/

Autodesk offers a limited version of their photogrammetry software for free that allows users to upload up to 100 pictures to their servers so that they may be transformed into 3D models. Two explorations were conducted with the software. First attempting to recreate a rocky bluff in an abandoned quarry, to gain an idea of how well it does with the amorphous shape. The

results weren't anywhere close to the level of detail required, the resulting 3D object nowhere near the shape of the blugg. A smaller more focussed object was "scanned" with the hopes that it'd yield better results. The 100 photo limit was likely restricting the quality of the digital object, regardless, the fidelity of the smaller 3D object was still lacking. Although photogrammetry was abandoned for this project, other groups have found success with the software in creating their boulder replicas (Twin Climbs, 2018).

The conditions for lighting, and the requirement of relative stillness made structured light scanners unfit for the task, so a laser based scanner would have to be used. Fortunately, an iSense ipad scanner was available to borrow from the Material Matters lab at Emily Carr University. Initial experiments were performed on a cracked rock with similar features to the climbs in Squamish. After a brief learning period to get acquainted with the tech, the results reached an acceptable level of accuracy.

The 3D scanned replicas that have appeared over the past few years have largely been boulder problems as there's less surface that needs to be scanned, and it can likely be scanned from standing. Squamish is famous for its crack climbing. A style of climbing where the participant works their way up a series of fissures in the rock. Unlike other types of climbs, the holds are more defined by their negative space as climbers squeeze digits and limbs into cracks to generate enough friction to push or pull on. This type of climbing has yet to be made into a climbing replica and its recreation offers a unique challenge, and a direction for the boundary to be pushed.

The selected climb would need an easily accessible anchor to rappel off of to access all parts of the climb. Since the scanner could only handle a small area, multiple scans would need to be stitched together posthumously, in a CAD software. So a climb would need to be selected, that was relatively obvious and continuous. *Crime of the Century* was selected since the beta for the climb stays mostly confined to the crack save some smearing with the feet, and follows a fairly straight and vertical trajectory.

Figure 10: Crime of the Century
Brodeur, R. (2022). *Crime of the Century* [photograph].

A good rule of thumb to remember when 3D scanning is that they work optimally in light that is comfortable to the human eye. Diffuse, not too dark and not too bright. *Crime* is south facing and faces the northern ridge of the Stawamus Chief. The rock in this part of Squamish is patterned with quartz and micas which, due to their crystal structure, reflect light and cause the rock to sparkle. Additionally, due to its popularity, climbers working 9 to 5 would likely want access to it in the evening. This left only a short window for scanning from dusk until the sun crested the ridge. After that, the reflective sprinkles in the granite would blow out the scanner's sensors. Over the course of several mornings, a repository of scans was built up that captured the entire surface of *Crime*.

Figure 11: Scanning *Crime of the Century*
Walsh, M. (2023)

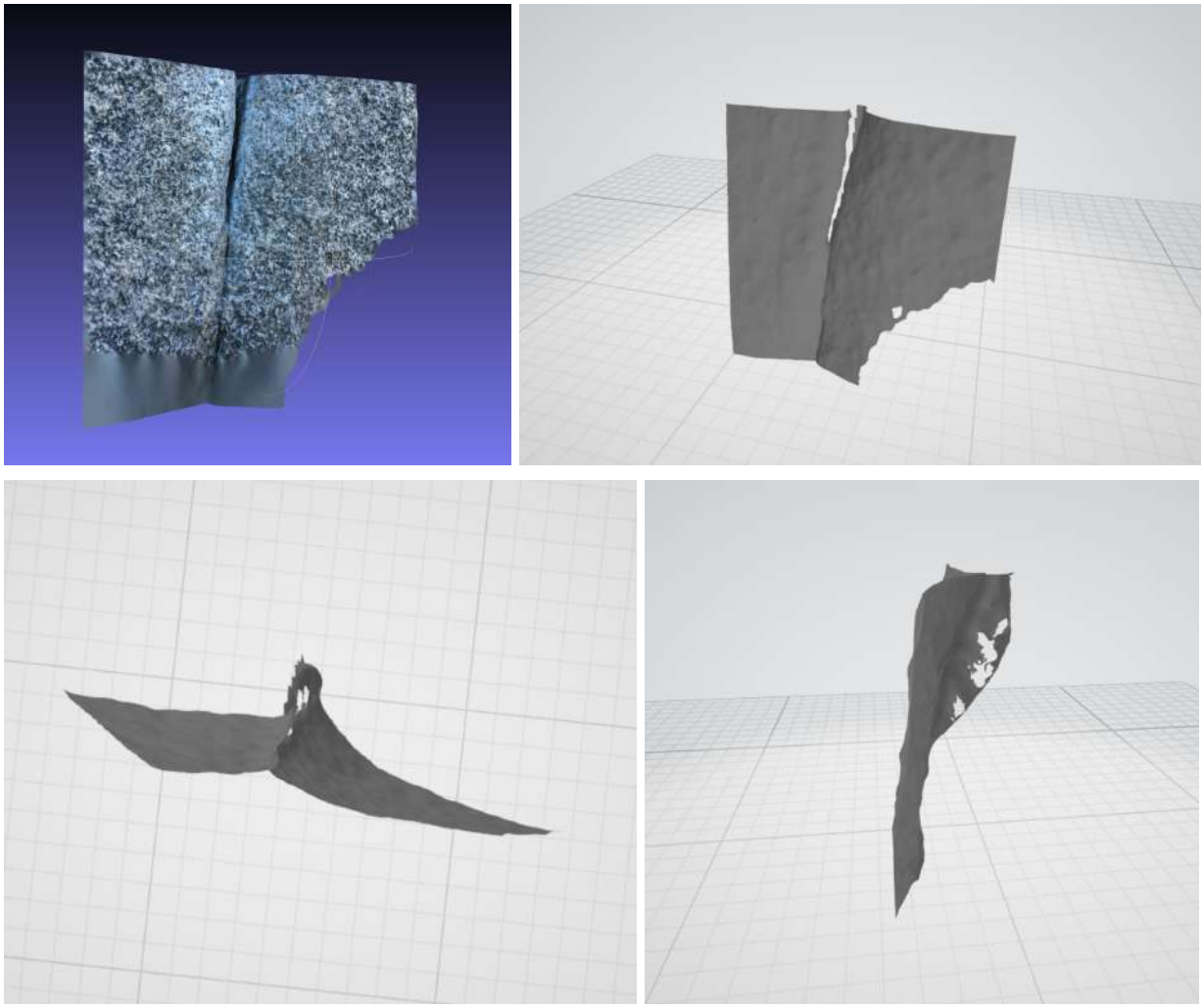


Figure 12: Raw Scan Data of the start hold of *Crime of the Century*
Brodeur, R (2022). *Crime Scans* [3D scans].

Digital Making

At this point, *Crime* was collected in a series of 39 .obj files, each scan overlapping slightly with the previous one to make up the entirety of its 15 meters. The 39 pieces first had to be aligned before stitching them together properly. *Crime* is near vertical, it actually tapers slightly, so when aligning the scans in Meshmixer their angle was adjusted to sit more vertically. While this made the climb more difficult, it was unlikely to alter the beta. Additionally, due to occlusion and shortcoming of the equipment, the scans were full of holes and artifacts that needed to be cleaned up. Rhino was used for this clean up due to its bridging, stitching, and hole filling features. It was important to get all the small details right, so based on photos, and experience climbing the route, a map was drawn of all the pockets one could feasibly use to climb the wall, as well as other landmarks and features to aid in an accurate recreation. In Rhino, the gaps were bridged and holes filled until the entirety of the climb was one complete surface.

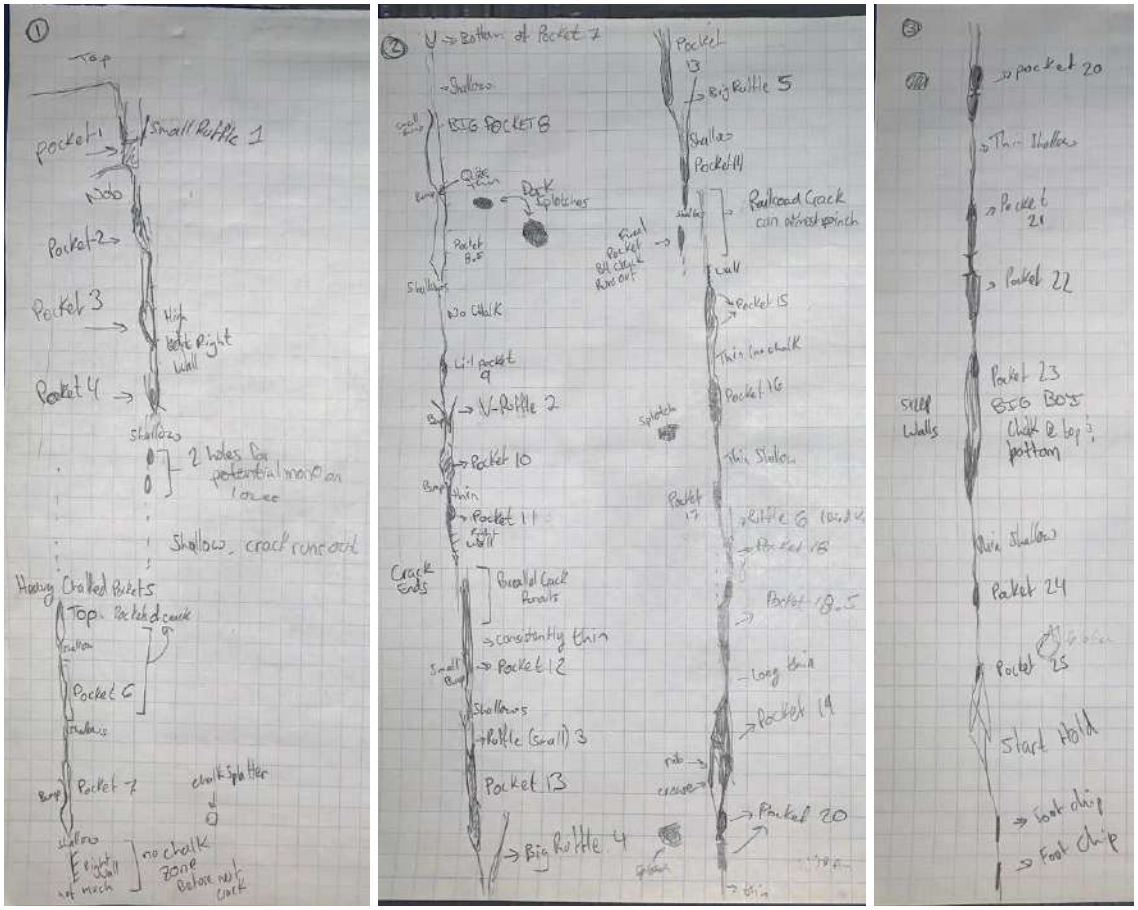


Figure 13: Map of *Crime of the Century*
Brodeur, R (2022).

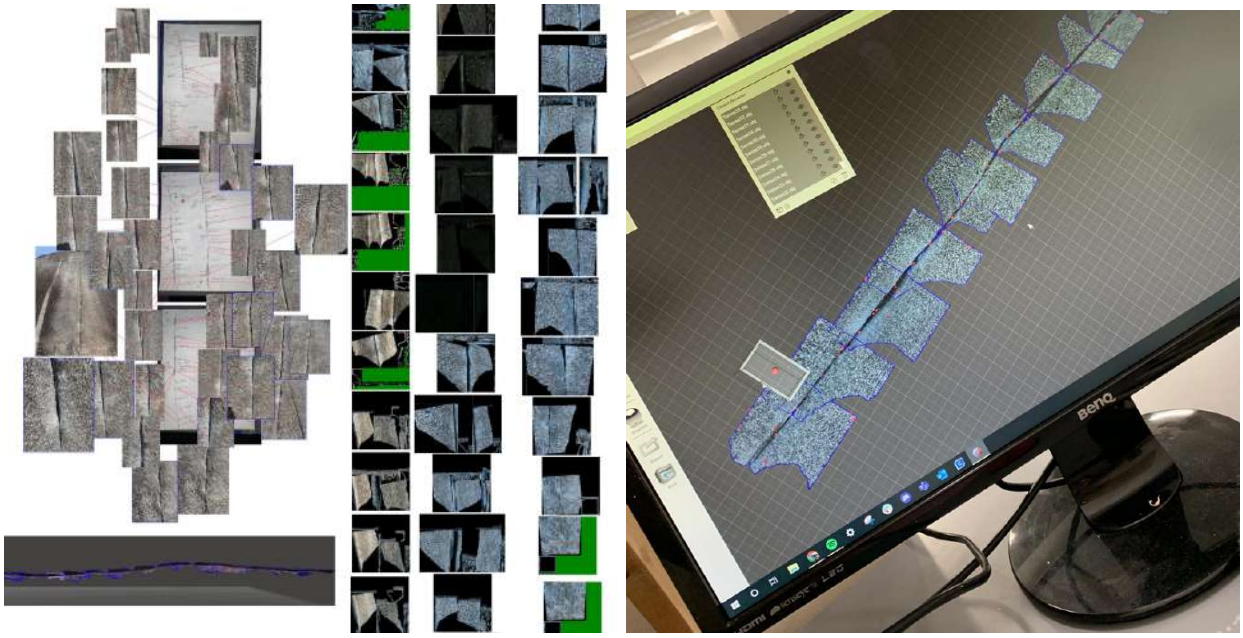


Figure 14: Left: Matching raw scan data to the landmark map
Right: Raw scan data properly aligned and adjusted vertically.
Brodeur, R. (2022)

One of the reasons *Crime* was chosen is that it was near vertical. Gym walls often have portions that angle in or out slightly, but where and how varies site to site. A vertical climb would be easiest to get into the most locations. Additionally, climbing walls have been standardized in North America to accept ⅜” diameter bolts in a grid formation, but the spacing and angle of this grid can vary. Any complete prototypes would be first mounted at the Aviary, a climbing gym at UBC, so its dimensions were used in the model. Recreating that grid in Rhino, bolt holes were added and the climb was cut up into different sections based on the map I’d made. This highlights one of the difficulties of climbing replicas, since the holds need to be placed perfectly relative to each other, the bolt holds would need to be designed for a specific grid. Since the holds would be quite large, in the intertest of reducing cost and weight, the area recreated was shrunk to an absolute minimum.

Importantly too, in the business of climbing gyms, replicas offer a poor value proposition. One of the benefits of climbing hold sets is the ability to mix and match them into different routes. A benefit that hyper specific replica holds take away from. While 3D scanners, and computers have managed to record and store climbs, the nature of hold manufacturing and the business of gyms make it difficult for broad adoption.

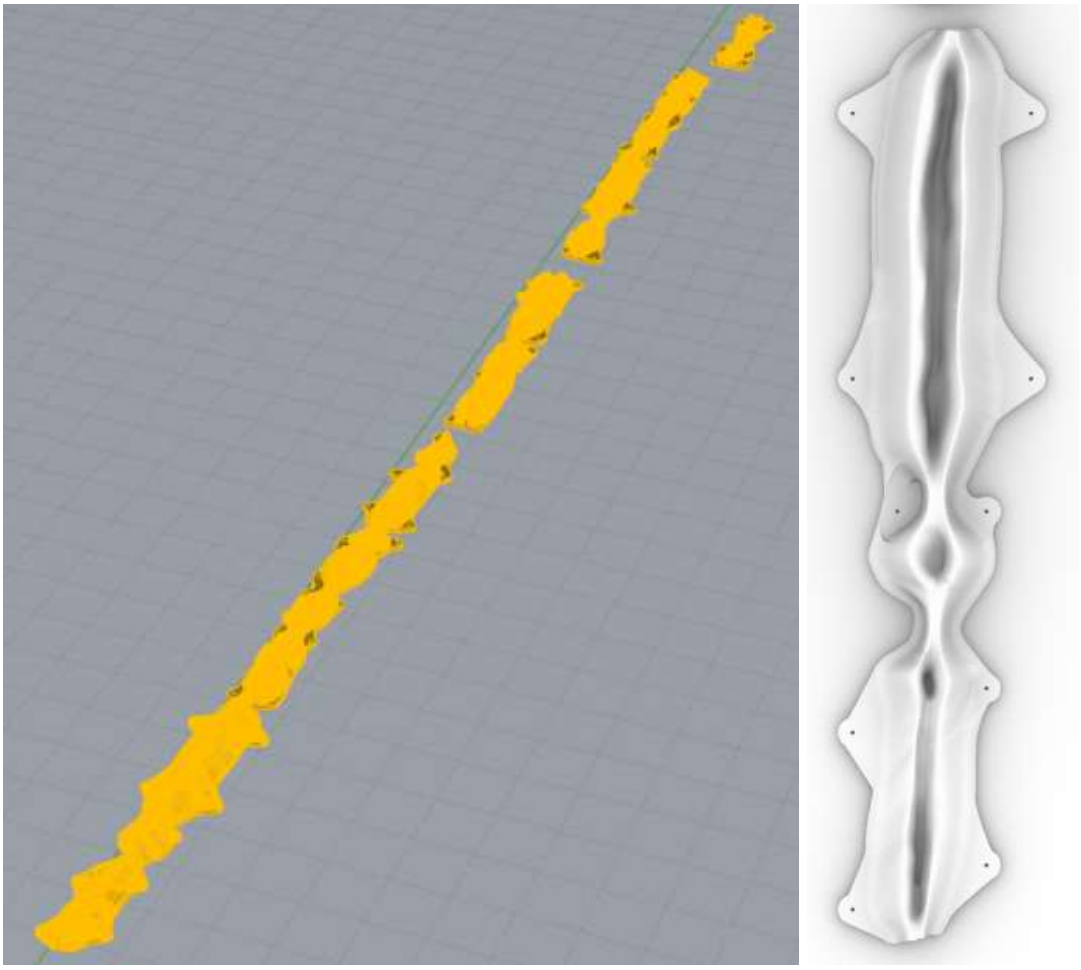


Figure 15: Left: Digital model of the complete hold set
Right: Front view of the start hold
Brodeur, R (2022)

Manufacturing

In the same way that the speaker outputs the specific sounds stored on the pressed record, tech was needed to output the specific shape stored on the harddrive to make the holds. 3D printers were the most obvious choice. A master could be 3D printed and then used to make a mold that could then be used to cast the final hold. Other replica makers have left the master in the computer entirely, directly printing a mold that they can cast a hold from. However, due to the shape of the crack, the hardened polyurethane hold would become locked to the mold. Flexible filament for 3D printers is available, it's expensive and finicky as the 3D printer needs to be recalibrated to the requirements of the new material, often with plenty of trial and error.

Initial small scale prototypes were made to gain familiarity with the casting techniques. The master was 3D printed and used to make 2 molds. The first mold was based on just the 3D printed part, while the second had its edges altered with plasticine additions. Plasticine could be used to add to the shape, and overcome some of the limitations of 3D printing. The first attempt casting polyurethane yielded bubbled results due to too high of a moisture content. The second attempt saw more successful results.

Figure 16: 3D printed part with plasticine added, mold, hold
Brodeur, R (2022)

A full sized prototype was limited by the size of the print bed on the 3D printers. If the width of the masters was kept to 3.5 “, two 7” lengths of the crack could be printed at a time on the school's Tinkerine 3D printers. The idea being to stack up printed bricks of crack to make a master that could be used to cast a mold. After printing the blocks of the first finger jam that starts the climb the mold was made out of Oomoo, a flexible rubbery material, which was then used to cast the final hold out of polyurethane resin.

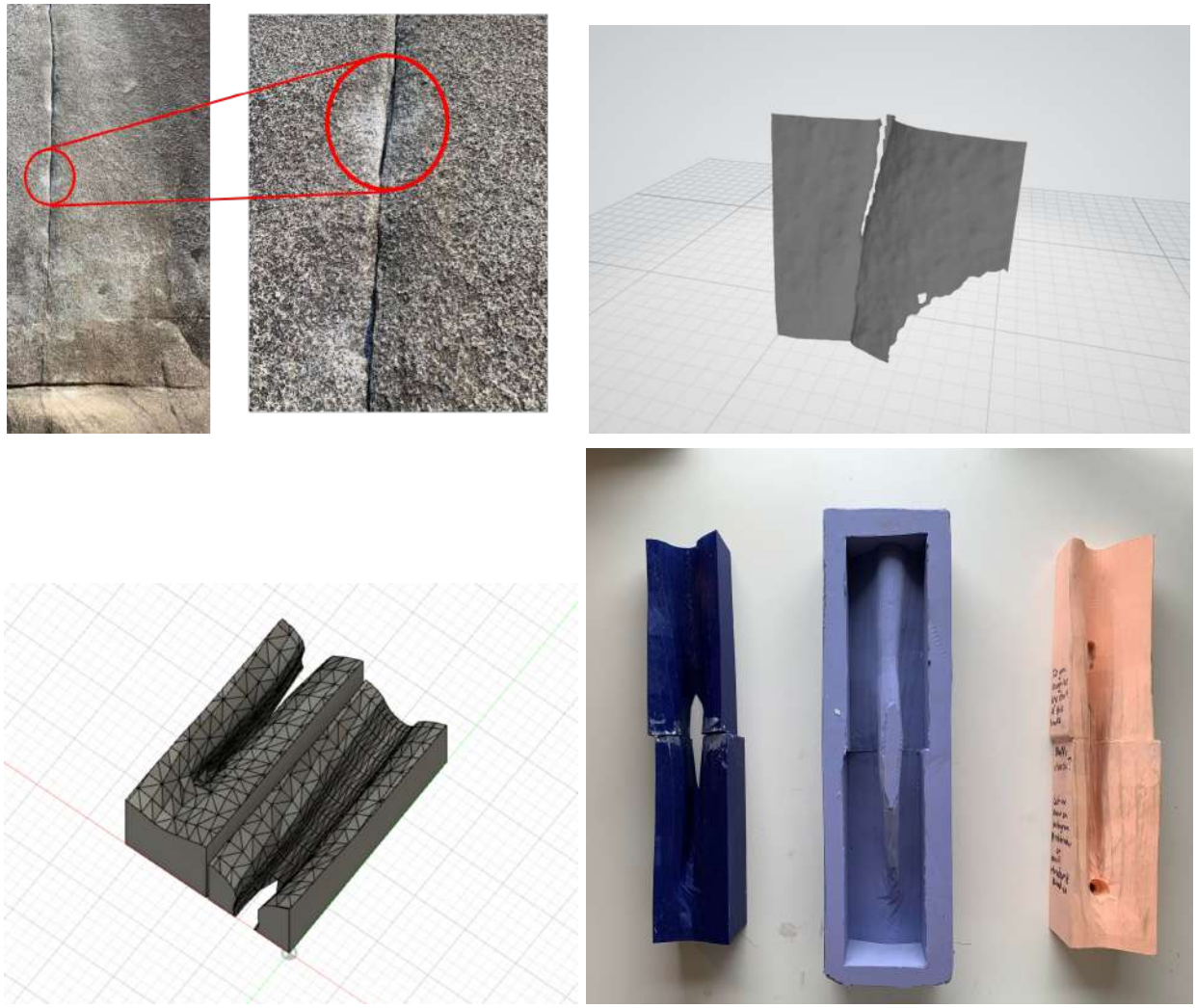


Figure 17: The Start Hold: From rock to scan to digital model to master to mold to hold
Brodeur, R. (2022)

Other options were explored to streamline the process. There are a number of 3D printers currently on the market that are able to print larger formats. Printing to a conveyor belt is a relatively new innovation that allows for “infinite z-axis” printing in theory. Attachments can also be bought to convert CNC mills (which often have a larger working area) to 3D printers. Both of these options could result in cleaner holds as aligning the bricks inevitably produces a seam. Additionally, while this was the most common making process for replica holds, the volume of material it required made it un-ideal for replicating a fifteen meter crack.

CNC milling was one option for making larger holds, but is limited by how deep the router bit can cut into the material. But, by slicing the holds in horizontal sections and adding details for alignment, the final hold could be CNC'd out in sections, stacked, glued, and painted.

Figure 18: The first few feet, from rock to plywood
Brodeur,R (2022-2023)

The final prototype was CNC'ed out of plywood to see whether moves could be linked together in a way that mimicked the real climb.

Data Collection and Analysis

Both the cast polyurethane and CNC'ed plywood holds were rough around the edges, but were clearly different from other climbing holds on the market. On the polyurethane hold, the triangles from the mesh were clearly visible and its surface texture showed the layers from the 3D printing. This was considerably smoother than the sandpaper texture most holds have, and made for slicker climbing. The CNC'ed plywood hold was a hazard before being sanded with many opportunities for splinters. In trying to smooth it out, not only was the friction worse, but the shape itself was altered enough that the original beta became much more difficult. Further iterations of this project would need to explore ways to add texture somewhere along the assembly line.

However, the prototypes still did an adequate job capturing the shape and feel of the crack for the purposes of climbing it. Locking into the finger jam felt familiar and uncomfortable (just like the real finger jam) on the polyurethane hold. The polyurethane prototype was mounted unlabeled in two local climbing gyms with a placard asking whether climbers recognized it as the start of a climb in the Smoke Bluffs. Most respondents were confident and correct, although a few confused it for a route called *Flying Circus*. This was predictable as *Flying Circus* is a much easier finger crack and likely is more familiar to less experienced climbers.

The CNC'd plywood hold was mounted in the Aviary. Though the holds were in the right spots, the altered details changed the nature of the climb. The different texture provided less friction, the shape of the crack itself was smoothed out and lost depth, and the angle of the wall was slightly steeper. A stronger climber, however, may still be able to climb it with the added challenge.

Figure 19: Testing out the prototype.
Top and bottom left: Brodeur, R (2023)
Bottom Right: Dimitrakopolous, A (2023)

Despite lacking the context for the rest of the climb, and the details lost throughout the making practice, climbers testing the holds fell into the same body position as the real climb leading them to remember the experience of climbing *Crime*. It lends credence to the fact that climbing is a highly embodied sport, and while the climb may act as architect/choreographer, it's the feelings and movements of the climber that let a crack become *Crime of the Century*. By replicating the shape of the climb, we give the participant the opportunity to replicate the experience, and thus the climb itself.

Outcomes

Throughout the making process and with input from other members of the climbing community, the potential of more widely available replicas was speculated upon. A replica can allow for an easier transition from gym to crag, especially in the case of crack climbs which are harder to recreate in the gym. Furthermore, climbing is a seasonal sport in most parts of the world, and the replicated routes allows climbers to train the beta in the off season so that they can attempt to send their project in fairer weather. By making the shape of outdoor climbs more widely available, climbers are able to strengthen or begin building their relationship with the rock. For more timid or beginner climbers, this can mean meeting the rock in a more familiar and secure place, while more experienced climbers are able to spend more time with it.

Nothing is set in stone, not even stone. Climbs slowly erode over time due to weather and traffic. More drastic fluctuations in weather patterns due to climate change affects the moisture content in cliff faces and can lead to more rock fall. A heatwave in the summer of 2021 is the likely cause for the increased rockfall seen on the Stawamus Chief (a mountain and climbing destination in Squamish) that year (Brend, 2023). The rising global temperature has also been melting alpine permafrost. Permafrost can act as a glue that holds many alpine rock formations together (Brend, 2023). This type of melting is likely what caused the rockfall on Snowpatch Spire in the Bugaboos in late December of 2022 (Tait). In the words of professional mountain athlete Will Gadd, “This is where I live and work and my office is falling apart,” (Brend, 2023). As Eco expressed, replicas find some immortality through duplication, but, in climbing, are still only able to simulate the embodied movement of a climb, not the entire experience.

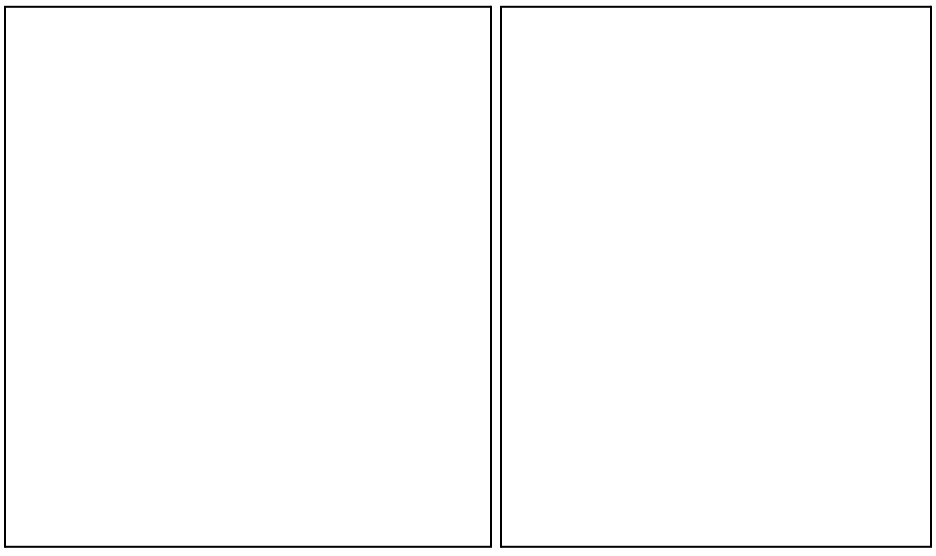


Figure 20: Rockfall Closures on the Chief (left) and Snowpatch Spire (right)
Bourdon, M (2021)
Friends of Bugaboo Park (2022)

Rock climbers have been able to elevate simple cracks in rocks into world famous destinations. People will travel around the globe for the opportunity to climb the classics in Indian Creek, or Chamonix. And while much of that enjoyment might come from the location

itself (the weather, the environment, the exposure etc.), at the core of these world famous climbs, is high quality climbing. Like the pressed record did for music, that high quality climbing can now be shared with a much broader audience. Indeed, despite not completing a full scale prototype of the climb, the 3D model means the project can easily be taken over by another group.

Recommendations on Form Recreation Technology

The technologies explored in this practice-led study are set to evolve. While 3D scanner hardware is still improving, it's not improving nearly as quickly as 3D scanner software. Since software is much easier to iterate upon, and the increasing sophistication of machine learning, software solutions for 3D scanning like photogrammetry and NERBs are vastly outpacing traditional scanners. This reduces the need to continually upgrade hardware as the only input required of the user is enough photographs or video footage. While these solutions aren't without their drawbacks, the speed with which they're improving will have them become the preferred digital twin technology for an increasing number of applications. This stands to drastically increase the sheer number of real world objects made digital. The increase in the volume of simulated objects will greatly expand AR opportunities as more objects are put into a language computers understand.

As for software to store and adjust your scans, mesh based ones are preferred to boolean ones since scans are usually saved as a mesh. Occlusion will likely be one of the more irritating problems a designer faces, leading to holes in their surface. In the different softwares explored, Rhino was the strongest for its hole filling, bridging, and knitting, functions which allow a great deal of control over the shape. Aligning multiple scans can be some of the trickiest work in creating a complete digital twin and, for the most part, will require some manual input. If the scans have considerable overlap, Geomagic Control X is among the most effective softwares to do this automatically. The scans that made up the *Crime of the Century* replica were fit together by hand since the area of overlap was often too small for the software to comprehend. Aligning algorithms try to overlap the greatest area possible which makes it difficult to simply align the two pieces close to the edge. Also, they require the object to be decently featured. Since the scans were first stitched together and then blocked out into holds, a more forward thinking approach would be to align the seams of the scans at the natural stopping points already, although this risks inaccurate spacing between pieces.

Finally, in terms of making the actual physical holds, additive and subtractive CNC technology can make effective replica hold sets given enough time and patience by the operator. However, these hold sets offer a difficult value proposition for gyms, due to their lack of versatility. One way for replicas to be adopted more broadly, is a shift away from discrete holds in indoor climbing. A wall whose shape can easily adapt to any form and return to flat without creating waste, a technology not yet available anywhere, but is approaching soon. MIT's shapeshifting table allows a surface to change shape and return to flat on its own, but the poor "resolution" and discrete nature of the actuators make it difficult to scale. Universal grippers are also a potential piece in the puzzle. A flexible membrane filled with granular matter can be sculpted at atmospheric pressure, but when the membrane becomes depressurized the gripper locks into shape. A surface operating under the same principles could potentially change shape

and return to flat without issue, and also be a continuous surface as opposed to a discrete one. It wouldn't, however, be able to do this under its own power.

Figure 21: Top: MIT's shape shifting table
Bottom: Principle behind a universal gripper..

Hobson, B. (2014). *MIT's interactive shape-shifting table* [photograph]. Dezeen. https://www.dezeen.com/2014/05/09/movie-hiroshi-ishii-transform-shape-shifting-table-top-mit-media-lab/
Brown, E., Rodenberg, N., Amend, J., et al. (2010) *Universal Robotic Gripper* [diagram]. Wevolver. https://www.wevolver.com/specs/universal.robotic.gripper

Ethics of 3D Scanning Rocks

Scanning and replicating a route called *Crime of The Century*, felt metaphorically relevant, since despite never taking anything physical away from the crag, I was still taking *something*. An old adage in outdoor recreation is to “take nothing but photos, and leave nothing but footprints.” An argument can be made that 3D scanning should fall under the same category of photos since they’re both representations of the landscape. However, as we’ve explored, 3D scanning can be used to recreate experience. While photographs may be freely given, the replication of experience may not be so transactable.

When a sport is so tied to land and place, the politics of both the determinants become important considerations. Access to crags is not indefinite, and as the ownership or zoning of land changes, so too can climber access. If access to a crag is changed, limited or curtailed, 3D scanning could be used to capture the routes so they can be replicated in the future. If the reason for the closure is to discouraged climbers from this *area*, be it no longer safe or appropriate to climb there, this can be an effective compromise. However, if the reason for closure is to remove climbers from the *rock itself*, scanning and replicating these climbs might still be an act of transgression. Additionally, since replicas can’t capture the full experience of a climb, it’s plausible to assume making a portion of that experience available may push people to seek out the entirety of the experience, creating unintended consequences.

The ethics of replicating land morphologies get muddied further when they’re used for profit. When profiting off replicas, the seller profits off the labour of the volunteers that clean and maintain that climb, and additionally off the land itself. I believe that since something’s being taken, something should be exchanged. Who or what it’s being taken from, will vary case by case. Certain crags exist on private land, and landowners have been able to work out deals with recreationists so they feel there’s been a fair exchange. This can be by charging for access, or taking a commission from the guidebooks that make reference to their property, to name a few. However, the notion of private property is a colonial one, and paying the “owner” doesn’t guarantee that that land will be respected. Importantly, when recreation sites are on indigenous land, its important to first open a dialogue with a representative about whats intended, and to seek permission from the nation itself. Fortunately, websites like Native-Land.ca can help situate which Nation presides over the territory, and the correct people can be contacted.

People leave a mark wherever they go, while that mark can seem minimal on the human timescale, it gets built upon with each passing participant. On the timescale of rock and mountains, the impact is much larger, and we need to ask what right the Land might have to self determination. To ethically replicate a climb or crag, requires an understanding of the culture and history of a place.

In attempts to replicate a climb *faithfully*, a designer has to zoom in on all the small details that make that climb *climbable*. To replicate a climb ethically, I argue, a designer has to zoom out, to understand how that climb came to be. It raises the question of singular and collective ownership, and interrogates whether the experience replicas offer, is freely given, and by whom.

Contributions to Design

What this project contributes to the larger field of design is the method devised and insights gleaned for replicating the form of objects that are fixed in space in a minimally intrusive manner. The process of scanning a form and adjusting it using designated software allows the form to be recreated with CNC manufacturing. This twin can then be used for mold making, or painted or changed in ways that would not have been possible on the original.

While I'm not the first to use this process (or at least one very similar), the unique nature of the making practice offered insights into the strengths and shortcomings of it as well as speculation about how it could evolve in the future.

Conclusion

I was surprised with how much the process connected me to the climb. The differences between the real climb and simulation highlighted the importance of the small details. I think specifically of a bump on the initial pocket. On the real climb, the slight bump constricts the crack such that it's able to bite into my pinky finger enough to pull on. On the wooden replica, I can still feel that bump, but it is less aggressive to the point that my hand slips out. In making a replica, I've acquainted myself with far more details of the climb than necessary for most climbers, each curve has become more familiar, and any deviation from its true form is noticeable.

The rock was kind enough to erode in such a way that allowed climbers to play on it. In allowing itself to be simulated, it becomes kinder still, changing its shape so it may better hold our hands.

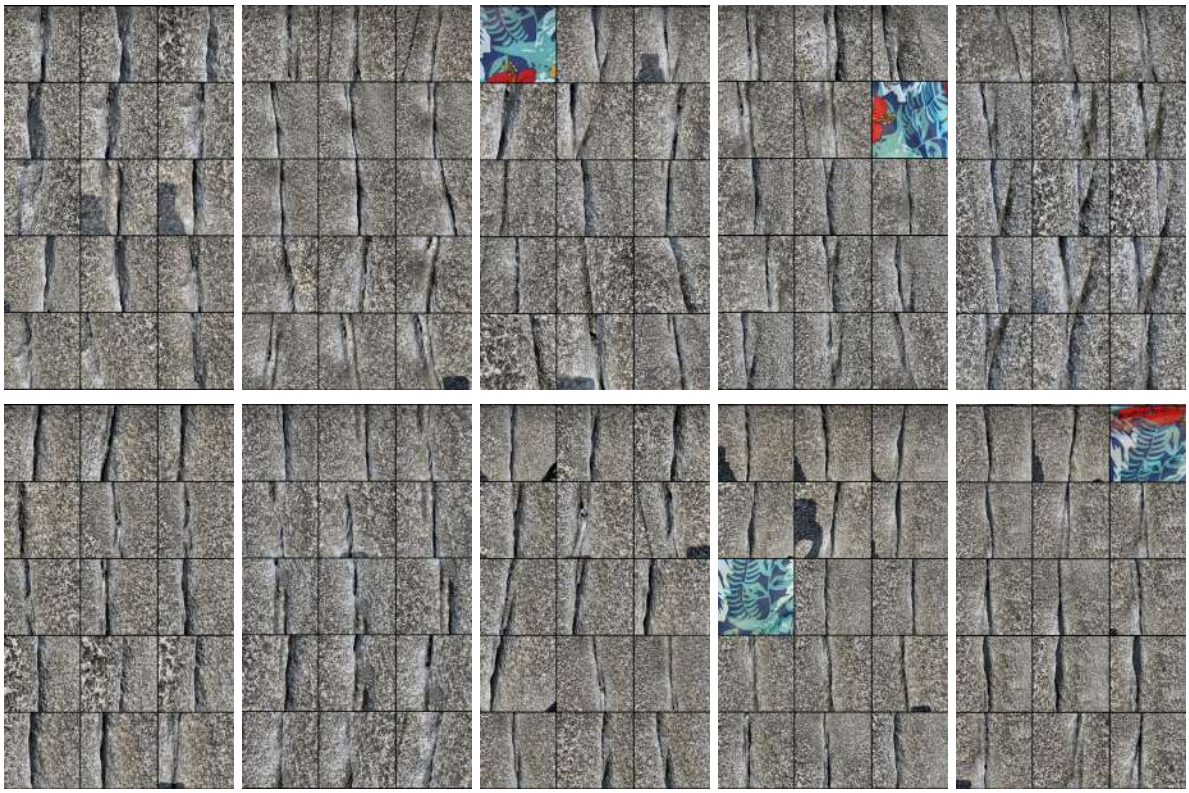
Appendices

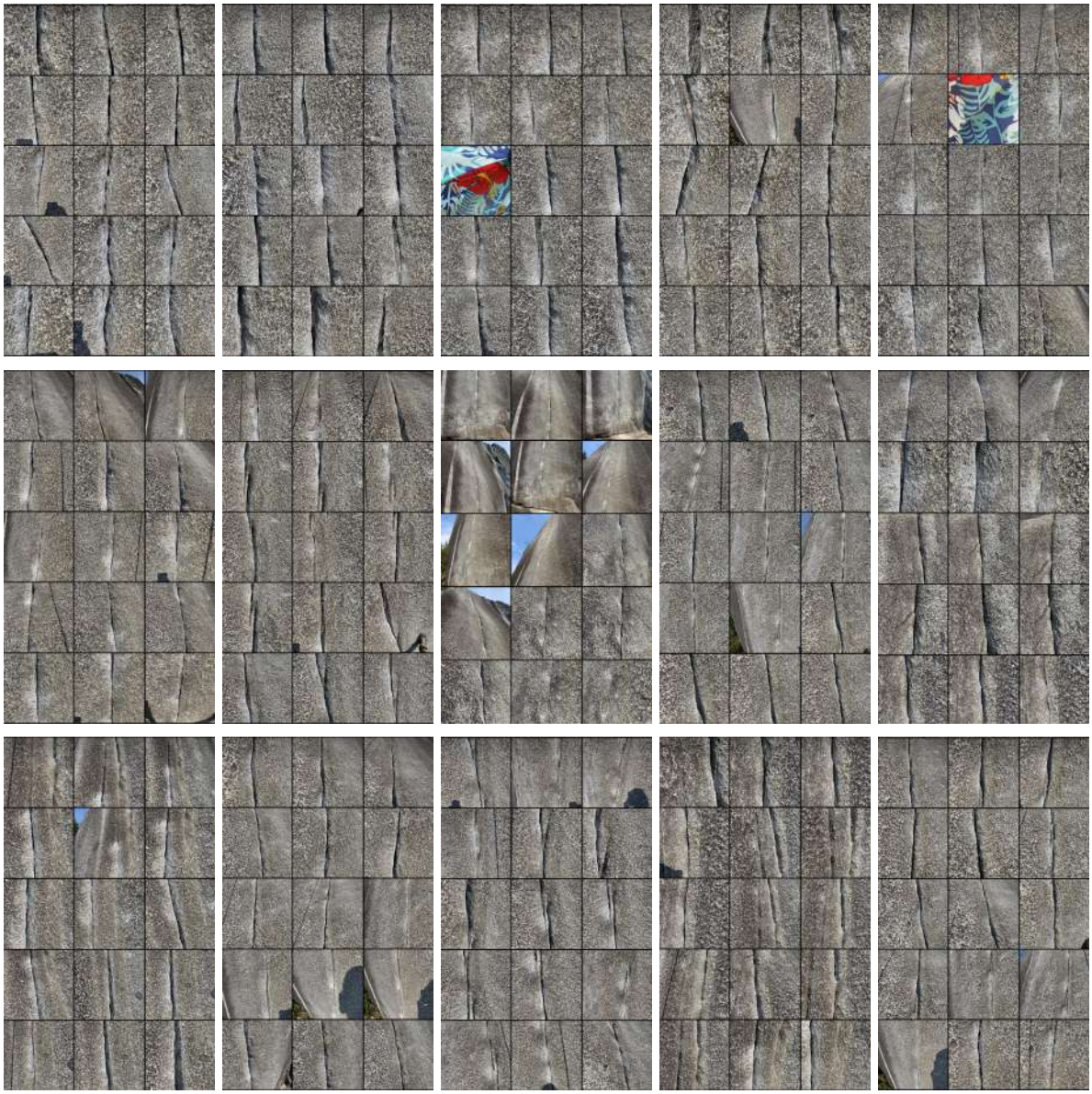
Appendix 1: An Additional Note on Flashing and Replicas

As replicas become more commonplace, a conversation has begun about what role replicas play when it comes to Flashing a climb. Or put more plainly: Does prior training on a replica count as a Flash? While the question may seem frivolous, it's a question of ethics within the sport. New technology forces participants to update the "rules" we should live by as a community.

The value of a flash is based on two factors: the athletic achievement i.e. the difficulty of the climb relative to the climber's ability, and how little prep went into the attempt (Bastian, 2023). How much replica training affects these two factors can tell us whether or not it should be considered a flash. Undoubtedly, replica training increases the amount of prep as more unknowns become known, and as beta becomes more familiar the athletic achievement of climbing the actual climb is diminished as well. So while a poor replica trained on very little might barely affect these factors, a near perfect replica can push those margins to near zero. Since a perfect replica is impossible, those margins can never reach zero exactly, meaning that while replica training can reduce the value of a flash, it still counts as a flash. Importantly though, past a certain amount of replica training, on a replica that's accurate to a certain level, the value gained from the athletic achievement and prep period can become close enough to zero that to most participants they become negligible. Where this limit is, however, is subjective, and will vary climber to climber and replica to replica.

Appendix 2: *Crime of the Century* Reference Photos

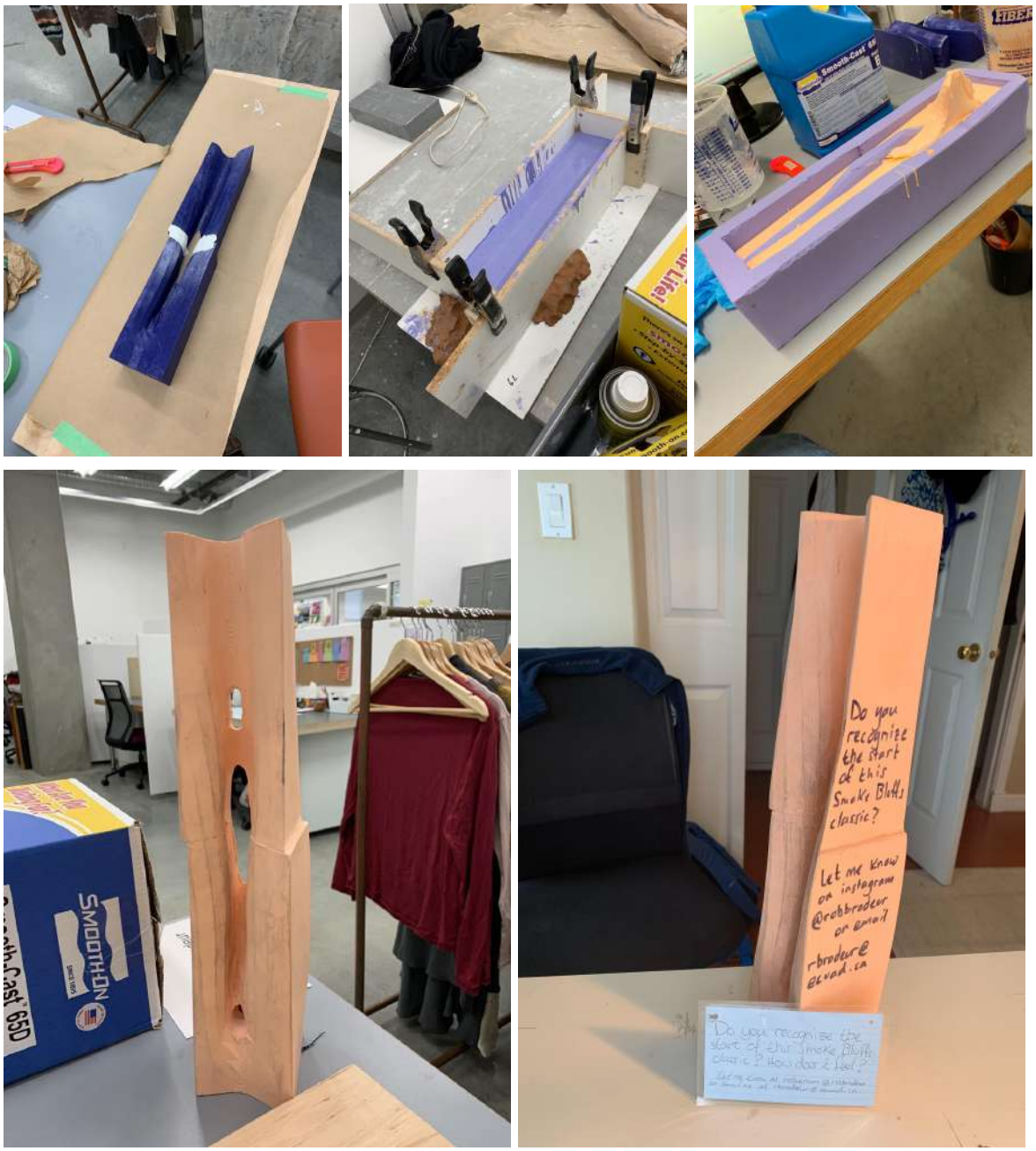




Reference photos of all the details on *Crime of the Century*. These were originally going to be used for photogrammetry before they became a valuable repository for rebuilding the climb in Rhino. Occasionally, photos were taken of the bold pattern on my shirt to break up different sections.

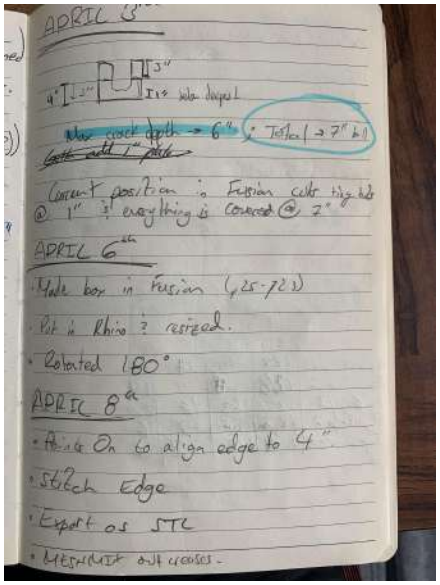
Appendix 3: Polyurethane Resin & 3D Printing Experimentation

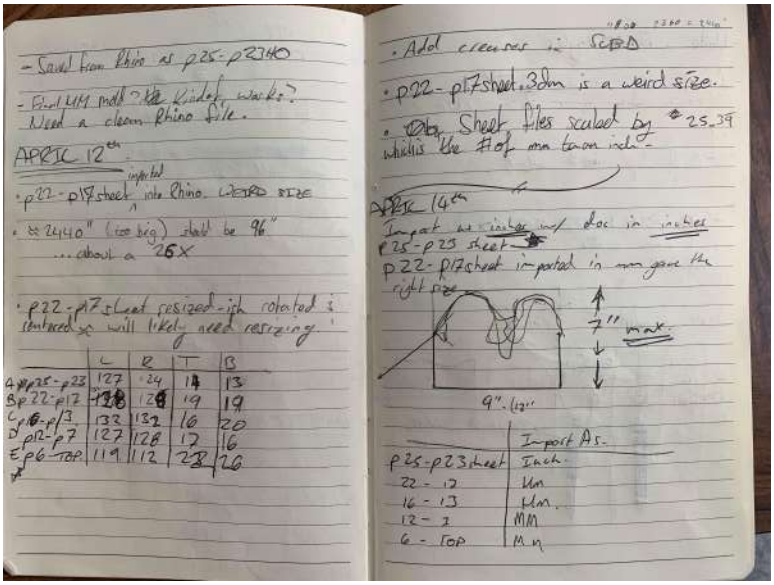
Early experimentation with 3D printing and resins at a small scale. Moisture in the mould created bubbling on my first attempt.

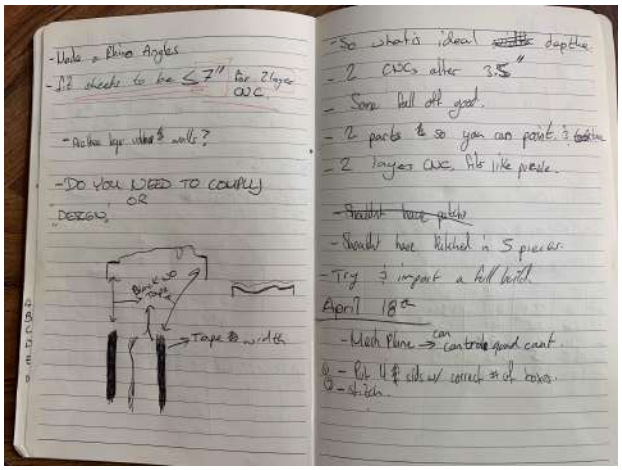


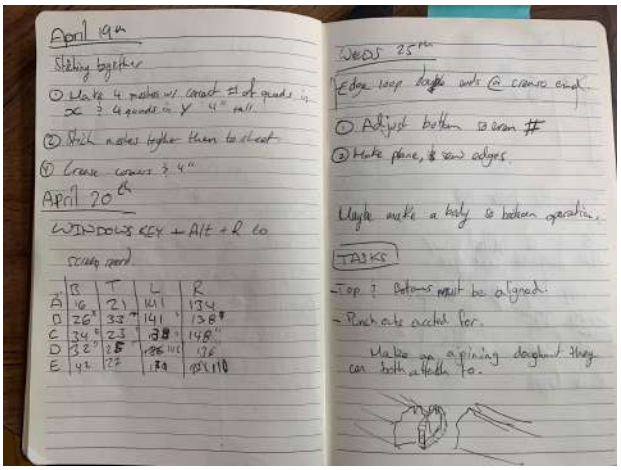
Casting full sized holds from polyurethane resin. The final two photos were taken after it was placed in gyms to be climbed on. The prototype shows its wear.

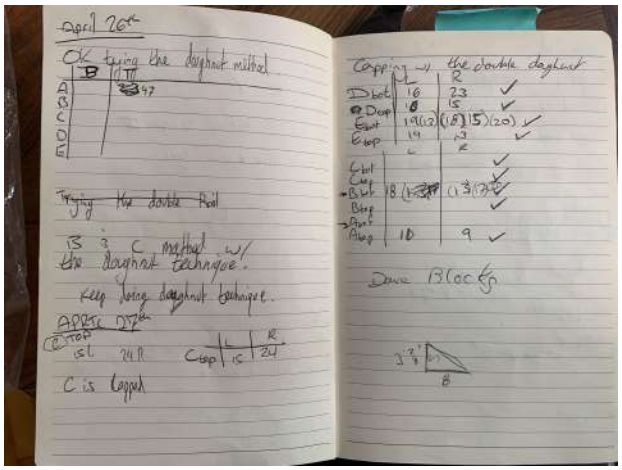
Appendix 4: Notes From Process Book

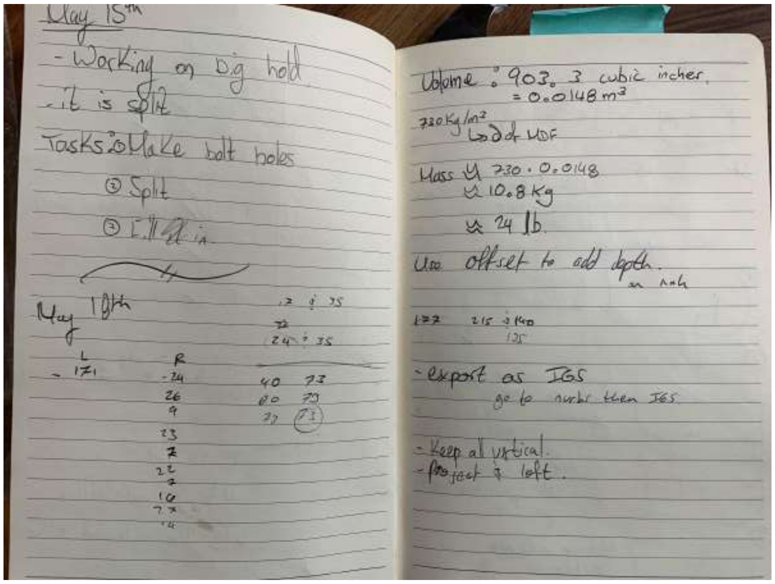












May 15th

- Working on big hold
- it is split

Tasks: ① Make bolt holes
② Split
③ Fill it in

May 18th

L R
- 171 - 24
26
9
23
2
22
2
16
22
24

17 ; 75
22
24 ; 35

40 73
80 73
37 (73)

Volume : 903.3 cubic inches
= 0.0148 m³

730 Kg/m³ Load of MDF

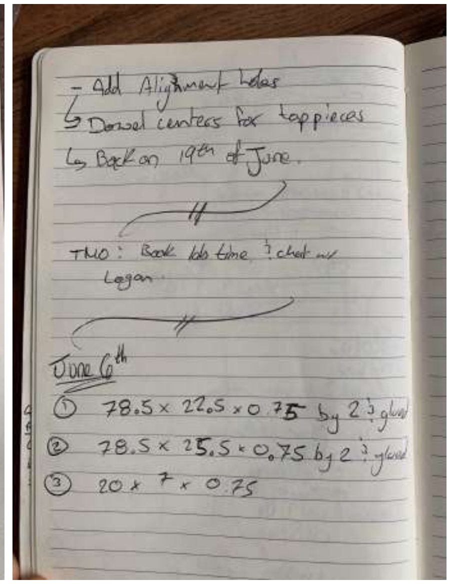
Mass ≅ 730 · 0.0148
≅ 10.8 Kg
≅ 24 lb.

Use offset to add depth on each

177 215 ; 140
135

- export as IGS
go to nurbs then IGS.

- Keep all vertical.
- project ; left.

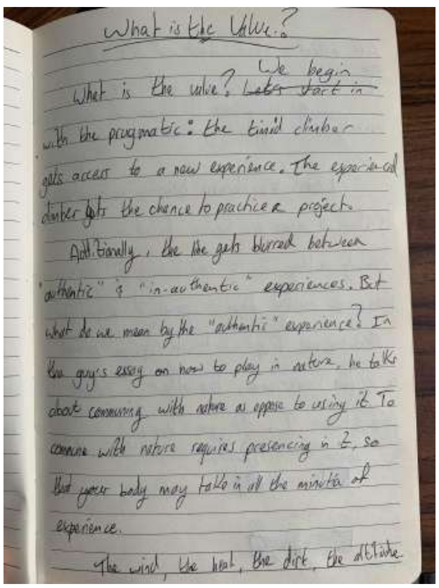


- Add Alignment holes
↳ Dowel centers for top pieces
↳ Back on 19th of June.

TODO: Book lab time ; chat w/ Logan.

June 6th

① 78.5 × 22.5 × 0.75 by 2 ; glued
② 78.5 × 25.5 × 0.75 by 2 ; glued
③ 20 × 7 × 0.75

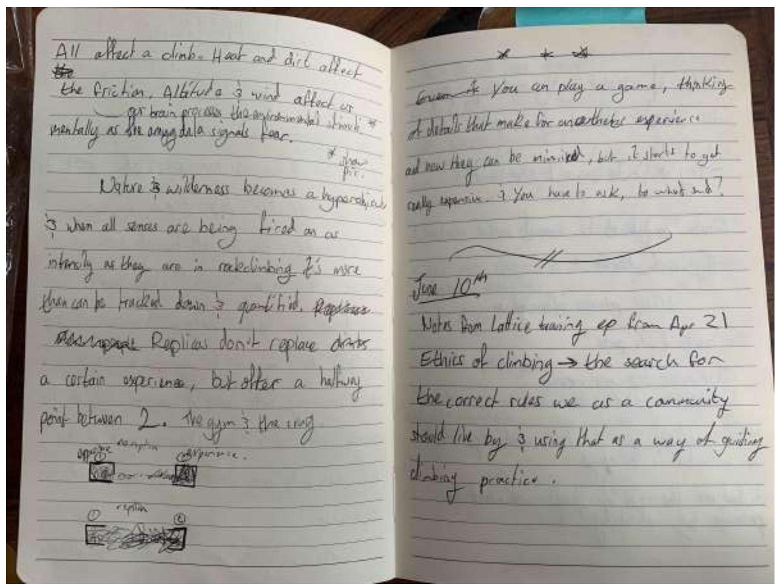


What is the Value?

What is the value? ~~Lets start in~~ We begin with the pragmatic: the timid climber gets access to a new experience. The experienced climber gets the chance to practice a project.

Additionally, the line gets blurred between "authentic" & "in-authentic" experiences. But what do we mean by the "authentic" experience? In the guy's essay on how to play in nature, he talks about communing with nature as oppose to using it. To commune with nature requires presencing in it, so that your body may take in all the minutia of experience.

The wind, the heat, the dirt, the altitude



All affect a climb. Heat and dirt affect the friction. Altitude & wind affect us mentally as our brain processes the environmental stimuli & the coming data signals fear.

Nature & wilderness becomes a hyperstimulus & when all senses are being fired on as intensely as they are in rockclimbing it's more than can be tracked down & quantified. Replicas don't replace ~~the~~ a certain experience, but offer a halfway point between 2. The gym & the crag

gym — replica — experience

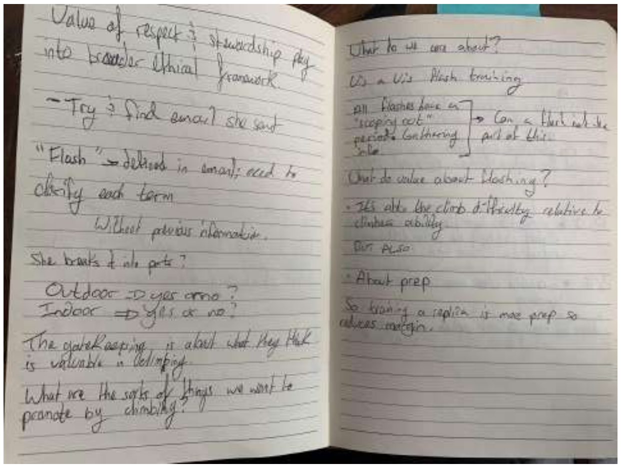
① replica ②

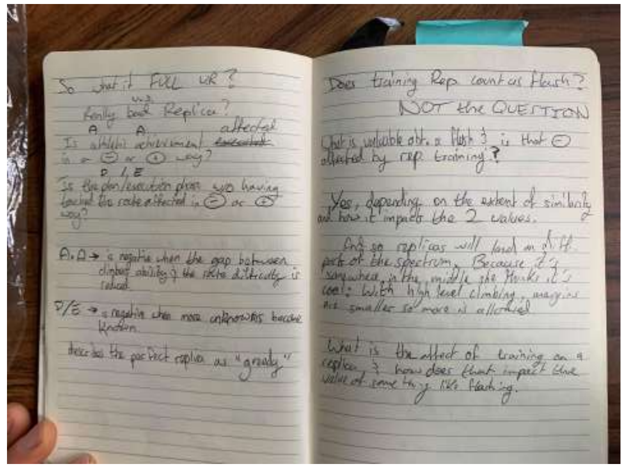
* * *

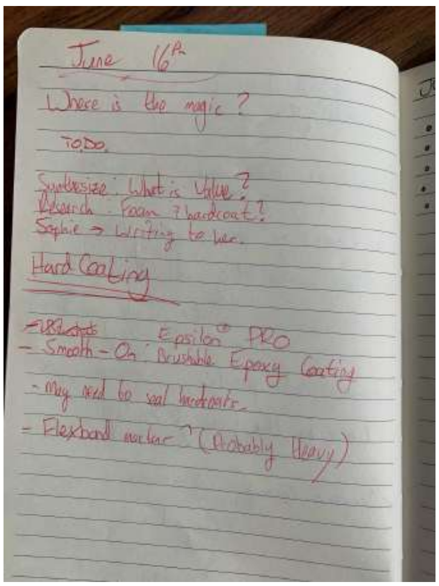
You can play a game, thinking of details that make for an aesthetic experience and how they can be mimicked, but it starts to get really expensive & you have to ask, to what end?

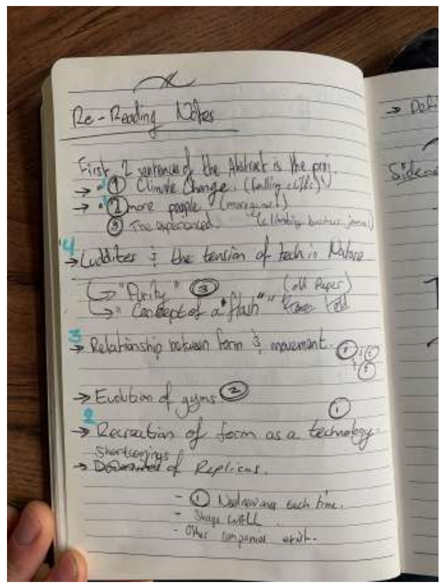
June 10th

Notes from Lattice training ep from Apr 21
Ethics of climbing → the search for the correct rules we as a community should live by & using that as a way of guiding climbing practice.

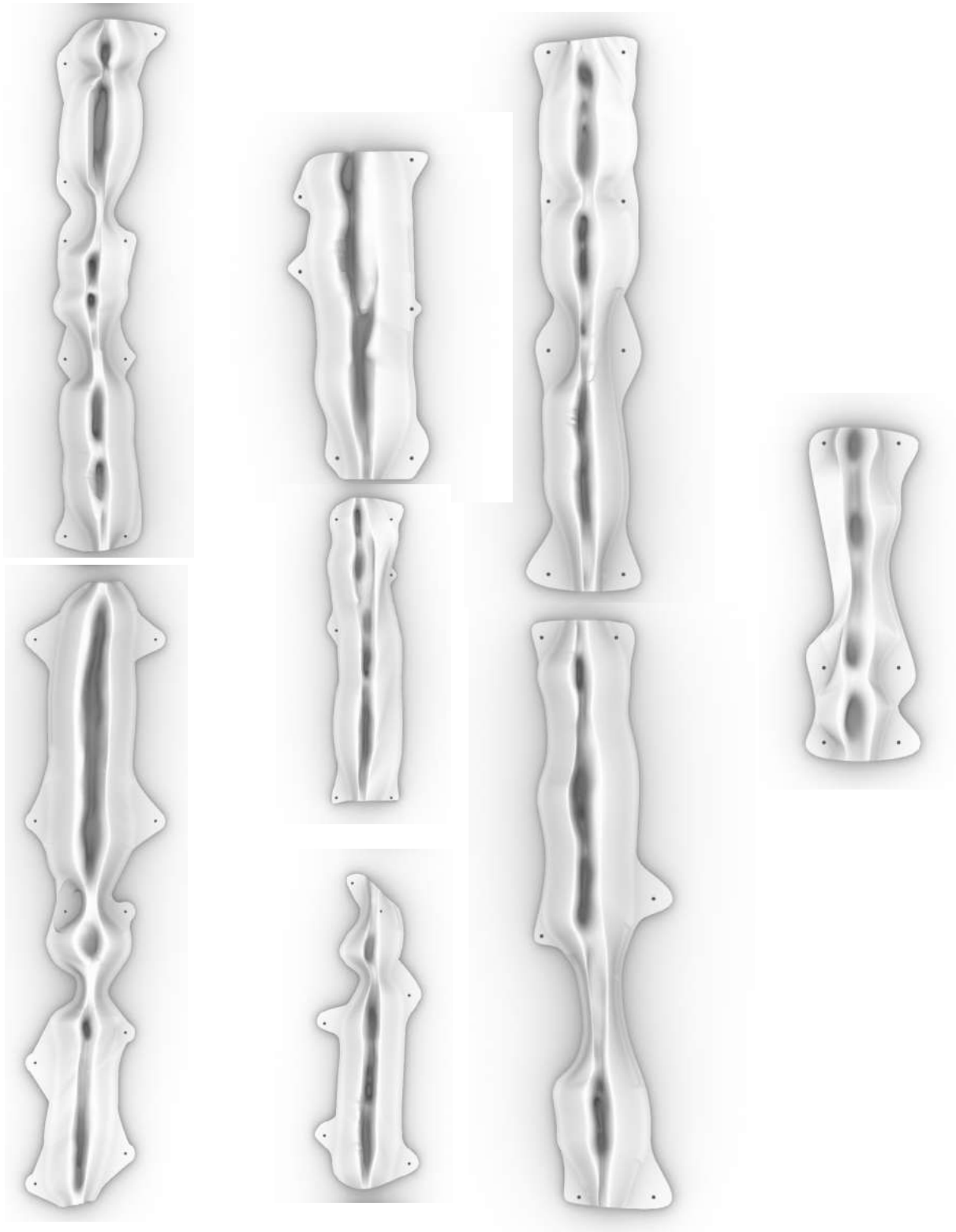

- Try & find email she sent
"Flash" → defined in email; need to clarify each term
Without previous information.
She breaks it into parts?
Outdoor ⇒ yes or no?
Indoor ⇒ yes or no?
The gatekeeping is about what they think is valuable in climbing
What are the sorts of things we want to promote by climbing?
What do we care about?
OS v.s. Flash training
What do value about flashing?
About prep
So training a replica is more prep so values remain.


So what if FULL UR?
Does training Rep count as Flash?
NOT the QUESTION
Yes, depending on the extent of similarity and how it impacts the 2 values.
What is the effect of training on a replica & how does that impact the value of something like flashing.


June 16th
Where is the magic?
TODO
Synthesize: What is Value?
Research: Foam? hardcoat?
Sophie → Writing to her.
Hard Coating
Epsilon PRO
- Smooth-On Brushable Epoxy Coating
- May need to seal hardcoats.
- Flexbond mortar? (Probably Heavy)


Re-Reading Notes
First 2 sentences of the Abstract is the proj.
① Climate Change. (falling cliffs)
② more people
③ The experienced
→ Luddites & the tension of tech in Nature
→ Relationship between form & movement.
→ Evolution of gyms
→ Recreation of form as a technology
→ Shortcomings of Replicas.

Appendix 5 - *Crime of the Century* hold set



References

Baudrillard, J. (1994). *Simulacra and Simulation* (S. Glaser, Trans.). University of Michigan Press.

Brend, Y. (2023). *Ice climbers and mountain adventurers fear climate change creates new unpredictable risks | CBC News*. (n.d.). Retrieved 27 January 2023, from https://www.cbc.ca/news/canada/climate-change-adventure-sports-1.6719595

Chin, J., & Vasarhelyi E. C. (Directors). (2018). Free Solo [Film]. National Geographic Documentary Films

Climbing Business Journal contributors (2014, February 27). Evolution of The Climbing Hold. *Climbing Business Journal*. https://www.climbingbusinessjournal.com/evolution-of-the-climbing-hold/

Climbing Business Journal contributors (2016, February 22). 3D Hold Printing Gets Real. *Climbing Business Journal*. https://www.climbingbusinessjournal.com/3d-hold-printing-gets-real/

Climbing Business Journal contributors (2023, February 10). 2022 CBJ Gym List Awards. *Climbing Business Journal*. https://www.climbingbusinessjournal.com/2022-cbj-gym-list-awards/

Eco, U. (1986). *Travels in hyper reality: Essays*. Harcourt Brace Jovanovich.

Escobar, A. (2017). Designs for Transitions. In *Designs for the Pluriverse* (pp. 137–164). Duke University Press.

Gripped contributors (2020, July 12). *For the Tick-List: Crime of the Century 5.11c in Squamish*. Gripped Magazine. https://gripped.com/profiles/for-the-tick-list-crime-of-the-century-5-11c-in-squamish/

Häkkilä, J., & Colley, A. (2020). *Designing for Interaction in Outdoor Winter Sports* (pp. 263–274). https://doi.org/10.1007/978-3-030-45289-6_14

Livingston, A. S. (2022). Technology that Inspires a Connection to Nature: Reframing the Role of Technology in Outdoor Engagement and Conservation. *Journal of Outdoor Recreation, Education & Leadership*, *14*(1), 87–94. https://doi.org/10.18666/JOREL-2022-V14-I1-11136

Mountain Project Contributors. *Rock Climb Crime of the Century, British Columbia*. (n.d.). Mountain Project. Retrieved 25 January 2023, from https://www.mountainproject.com/route/105842838/crime-of-the-century

Native-Land Contributors. Native Land. Retrieved 1 October 2023, from https://native-land.ca/

Scarles, C. et al. (2020). Bringing The Outdoors Indoors: Immersive Experiences of Recreation in Nature and Coastal Environments in Residential Care Homes. *E-Review of Tourism Research*, *17*(5), 706–721.

Schneberger, R. (Speaker). (2017, February 6). *Those who are 'nature-wise' have an edge in today's world | Ronna Schneberger | TEDxCanmore*. https://www.youtube.com/watch?v=kYNpQu0jIyE

Shultis, J. (2001). Consuming Nature: The Uneasy Relationship Between Technology, Outdoor Recreation and Protected Areas. *The George Wright Forum*, *18*(1), 56–66.

Sneed, J. C. et al. (2021). Nature Connection and 360-Degree Video: An Exploratory Study With Immersive Technology. *Journal of Experiential Education*, *44*(4), 378–394. https://doi.org/10.1177/10538259211001568

Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human–nature interactions. *Frontiers in Ecology and the Environment*, *14*(2), 94–101. https://doi.org/10.1002/fee.1225

Tait, C. (2023, January 10). Landslide reshapes popular climbing spire in B.C. *The Globe and Mail*.

https://www.theglobeandmail.com/canada/british-columbia/article-landslide-reshapes-popular-climbing-spire-in-bc/

Thi Nguyen, C. (2017) *The Aesthetics of Rock Climbing—The Philosophers' Magazine*. (n.d.). Retrieved 23 November 2022, from https://www.philosophersmag.com/essays/170-the-aesthetics-of-rock-climbing

Twin Climbs. (2018). *Bouldering problem in Queens Park, Sydney—YouTube*. (n.d.). Retrieved 11 August 2023, from https://www.youtube.com/watch?v=1zJhz2UgdRY

Vidon, E. S. et al. (2018). Wilderness state of mind: Expanding authenticity. *Annals of Tourism Research*, *73*, 62–70. https://doi.org/10.1016/j.annals.2018.09.006

Walker, N. (2023) A Brief History of 5.15 Rock Climbs. (2023, March 27) *Gripped Magazine* https://gripped.com/profiles/a-brief-history-of-5-15-rock-climbs/

Wenman, C. *3D Scanning and Museum Access. Adapted from a presentation by Cosmo… | by Cosmo Wenman | Medium*. (n.d.). Retrieved 31 July 2023, from https://medium.com/@CosmoWenman/3d-scanning-and-museum-access-9bfbad410d46

Wenman, C. (2020, January 23). 3D Printing, 3D Capture, and Opportunities for Design Custodians. *Medium*. https://medium.com/@CosmoWenman/3d-printing-3d-capture-and-opportunities-for-design-custodians-7985097d2ac4

Whitfield, T. (2023, April 21). *Does Flashing a Replica Count as the Send?* Lattice Training. https://latticetraining.com/2023/04/21/does-flashing-a-replica-count-as-the-send/

Williams, F. (2012) Take Two Hours of Pine Forest and Call Me in the Morning. (2012, November 28). *Outside Online*. https://www.outsideonline.com/health/wellness/take-two-hours-pine-forest-and-call-me-morning/