What Slides, Crumbles, Drifts…

Drawing Cartography into Movements and Flows

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Abstract

In the urgent context of climate adaptation, enhancing representational and design tools within the landscape discipline is crucial for building a comprehensive understanding of the natural processes driving phenomena in hazardous landscapes. Moreover, the context of the more-than-human paradigm poses new challenges. If we view water, soil, and rocks as lively processes and nonhuman actants—agents with their own agencies and rights—how can mapping practices help us better understand, interpret, and recognize their processes, movements, and behaviors?

Based on an interpretative cartographic technique using LiDAR imagery, this paper introduces a series of cartographic experiments that depict water and rock as dynamic, lively processes. The resulting maps aim to enrich our representations of the forces driving natural hazards and provide a new “language” that enhances our understanding of their multiple agencies.

Keywords

Landscape architecture, cartography, LiDAR, interpretation, large-scale landscapes, more-than-human, natural hazards, rock, water.

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Introduction: Lively Forces in a Risky Landscape

The frequency and severity of climate risks—such as flooding, drought, and landslides—are increasing in Norway, as in many other parts of the world. These escalating risks pose new challenges for rural cultural landscapes experiencing disruptions due to accelerating climate change and its unpredictable effects. The Undredal Valley in western Norway exemplifies these challenges[1]. Here, risks affect the community's ability to adapt to changing geomorphological conditions and the site's inherent dynamics. The situation necessitates that landscape architects and planners simultaneously consider adaptation and mitigation strategies to address natural phenomena at the scale of the valley or watershed.

This paper forms part of a PhD project within a larger interdisciplinary research initiative focused on implementing adaptation and mitigation strategies through a landscape approach. The NATURACT research project aims to promote nature-based solutions[2] that encourage a process-based approach to adaptation at the scale of the entire valley[3].

Representational and design methods are closely intertwined, with maps and cartography playing a critical role in landscape architecture due to the range of design scales and stakeholders involved (Palmboom et al., 2020). Our practice-based research highlighted the need for tools that better analyze and understand natural phenomena. Enriching representational methods seemed essential to capture both the living dimension of natural processes and the fluid nature of this complex cultural landscape. As James Corner (2011) notes, maps can help to reveal invisible natural phenomena, fostering greater awareness and appreciation of their agencies. This study explores how cartographic representation can enhance our understanding of water, rain, and rocks as active elements, emphasizing their dynamic and vivid qualities. The paper presents initial cartographic experiments representing water and rock as dynamic processes. It centers on the question: *Can new mapping methods for natural processes of rock and water better express their agency—and possibly their subjectivity?*

1 The Undredal Valley is in the Aurland municipality on the western coast of Norway. The location can be seen on Kilden, the Norwegian public cartographic portal, and accessed here: https://kilden.nibio.no/.

2 See International Union for Conservation of Nature ‹Nature-based Solutions›: https://www.iucn.org/our-work/nature-based-solutions.

3 The NATURACT research project is an interdisciplinary research project that seeks to develop large-scale nature-based solutions in response to natural hazards. The research project (2022–2026) is led by five Norwegian research institutions in a broad interdisciplinary team and is funded by the Research Council of Norway. The research project aims to demonstrate the value of a landscape approach to natural hazards and build guiding strategies for adaptation and mitigation in large-scale nature-based solutions. It relies on three case studies, one of which is the Undredal Valley. For more information, see: https://www.ngi.no/en/projects/naturact---landscape-based-climate-mitigation/

The Need for *Other* Maps

GIS mapping is integral to creating risk assessment and susceptibility maps at the Norwegian Water Resources and Energy Directorate (NVE)[4]. These constitute valuable tools for assessing and managing natural hazard risks in Norway. Risk assessment maps play a crucial role in planning by identifying areas vulnerable to natural hazards, thereby guiding land-use decisions, infrastructure development, and mitigation strategies. However, they have limitations when viewed from a holistic landscape perspective. Typically anthropocentric, they focus on human safety, interests, and infrastructure, assessing risk potentials primarily in relation to human structures (Fig. 1).

The research project's framework (around building landscape-based responses to natural hazards) calls for supplementing the technical and engineering approach to understanding natural phenomena with a more comprehensive cartographic method—one that provides new representations of natural hazards encompassing not only human safety but also landscape agencies and multispecies perspectives.

Geographic Information System (GIS) mapping has offered a method for considering a territory's geographical and cultural complexity. Its usefulness for landscape disciplines is not in question. However, its distanced view must be adapted to new practices in landscape architecture. Several scholars have noted that GIS mapping's presumed objectivity is problematic because it excludes living beings and ecosystem dynamics (Arènes, 2017; Bracke et al., 2022).

Landscape architecture historian Susan Herrington critiques Ian McHarg's map-overlay method, arguing that it conflicts with viewing nature as a dynamic phenomenon marked by gradual changes (2010). She observes that the method was grounded in the belief that science served as a "truth serum" for landscape architecture, providing both explanatory and prescriptive models for understanding nature (2010). By deconstructing this approach, Herrington demonstrates that—despite its scientific claims—it relied on inaccurate and inconsistent data, exposing flaws in McHarg's conception of the method as scientifically defensible.

GIS maps have been criticized for lacking critical engagement with the ground (Mattern, 2017), limiting their ability to capture the dynamism of earth, water, climatic events, and ecosystems—all crucial for developing effective climate adaptation strategies. By providing static snapshots and imposing boundaries that may not align with living processes, GIS mapping enforces a static view of natural entities and phenomena.

4 The Norwegian Water Resources and Energy Directorate (NVE) susceptibility maps identify areas prone to natural hazards based on geological and environmental conditions. They function according to layers concerning different types of hazards (landslides, snow avalanches, rockfalls, and floods). (See: https://kartkatalog.nve.no/#kart). NVE/NGI uses risk assessment maps as more operative tools that analyze and visualize the potential impacts of natural hazards on human infrastructure and safety. They assess the probability and consequences of natural events, helping to guide risk management and mitigation efforts.

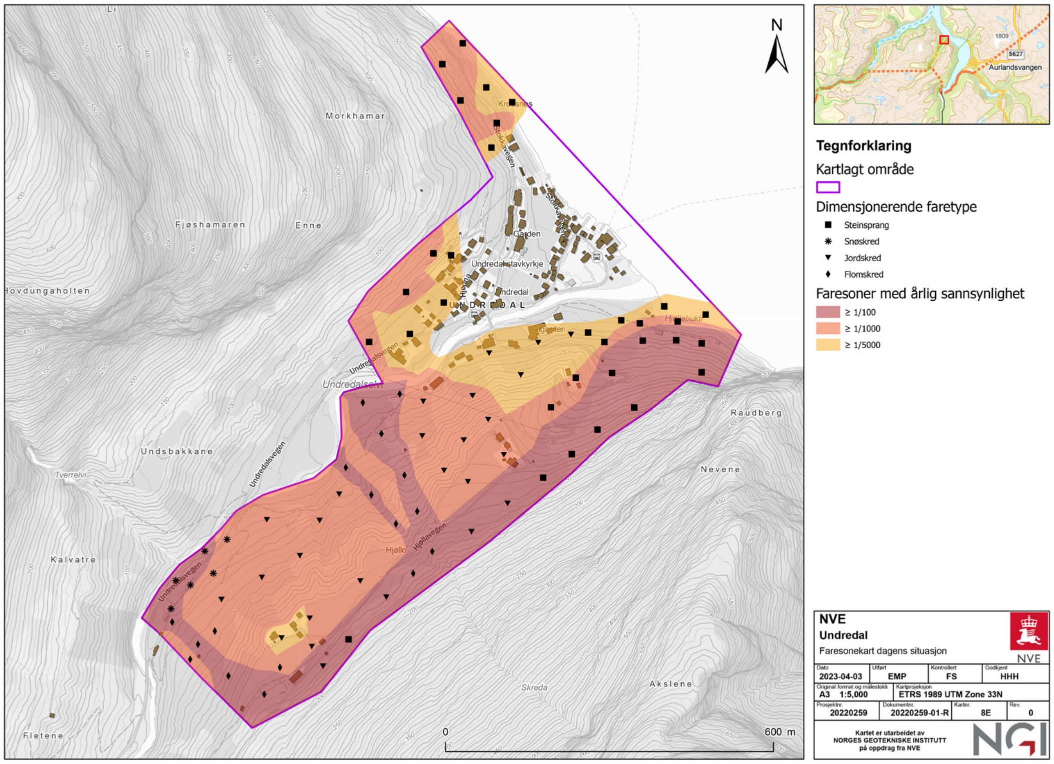

FIGURE 1 *Risk assessment map of the Undredal village (Norway).* The different colours refer to hazardous zones with annual probability and indicate varying levels of risk associated with natural hazards, represented by different dark symbols. Squares refer to the risk of rockfall; triangles refer to the risk of landslides, and rhombuses to mudslides. (Source: Norwegian Water Resources and Energy Directorate (NVE) and Norwegian Geotechnical Institute (NGI), 2023.)

Hence, the necessity for experimentation with mapping becomes particularly crucial within climate action, particularly in developing adaptation strategies. Within this context, a demand arises for innovative map types that nurture more prosperous approaches to natural phenomena, surpassing solely human-centric perspectives.

The more-than-human turn –a paradigm shift across fields that recognizes natural beings as living entities with rights and agencies (Descola, 2005; Morizot, 2020)– has influenced the landscape discipline (Elkin, 2017; Ezban, 2023; Prominski, 2014). It urges a view of landscapes not as passive backdrops but as dynamic sites and processes inhabited by a wide range of nonhuman agents (Tsing, 2015; Tsing et al., 2021). This shift calls for a deeper understanding of natural entities and processes, in line with Anna Tsing's call for critical description (Tsing, 2015). In addition, it prompts a reevaluation of our representational tools, sparking proposals for alternative cartographic methods.

As such, the need for alternative representations better suited to depicting natural entities and processes has grown in recent decades to align with the recognition of natural beings, emphasizing the need to integrate the interests and perspectives of these entities into design processes. Bruno Latour has urged us to overcome an external posture (from the outside) of a spectacular relationship to the landscape, challenging our tendency to see the landscape from above—where we are "outside of Nature." Instead, he advocates for an "approach from the inside," challenging us to recognize that "there is no outside anymore" (Latour, 2017, 3:33).

A landscape as a Meshwork of *Actants*

The Undredal Valley is a 20 kilometre long, narrow and rugged valley that reaches the deep and narrow Aurlandsfjord. The region is enveloped by rugged mountain landscapes, with peaks rising sharply from the fjord and steep rock faces on the upper slopes. In this landscape, scree, deposits, rocks, and boulders in the riverbed, among other elements, reveal the activity of a mountain in motion. People have skillfully established settlements in this narrow valley, cultivating grazing livestock on parts of the slopes. The pastoral landscape shaped by goat herding in the summer season is an intricate tapestry woven with rocky mountains and forests in a delicate interplay (Fig. 2), shaped by human adaptation to rugged terrain.

Through time, breeders have accommodated natural hazards and have adeptly adjusted their practices and routes to navigate these constraints, acknowledging the inherent instability of their landscape as an integral aspect of their relationship with the land (Fig. 3). However, unpredictable hazards have raised concerns of increasingly extreme weather patterns threatening cultural practices. In recent years, there has been an increase in extreme weather events, mainly heavy rainfalls, leading to more landslides, mudslides, and debris falls (Fig. 4)[5]. More frequent floods erode sections of the valley floor during torrential overflow.

From a landscape perspective, the Undredal Valley represents a rapidly evolving terrain, shaped by complex and intricate dynamics that must be unraveled to provide meaningful adaptation efforts. The fluid, vernacular evolution of its cultural landscape further underscores the need for such guidance, as the increasing frequency of natural hazards poses growing challenges to the community's resilience.

Expanding on the need for nuanced ways to navigate change, adopting a more-than-human approach to the landscape illuminates Undredal's hazardous cultural landscape as a polyvocal or multi-actor landscape. Here, water, rocks, soils, goats, breeders, and forests all interact in multifaceted ways, resonating with Jane Wolff's view of the landscape as a myriad of forces—an interplay of human and nonhuman processes (Wolff, 2017).

"Does life only make sense as one side of a life-matter binary, or is there such a thing as a mineral or metallic life, or a life of the it in 'it rains'? I think that there is, and that there are good ecological and biotechnical reasons for us to get better acquainted with it." (Bennett, 2010, p. 53)

Political theorist Jane Bennett, who wrote the quote above, is one of the many scholars who believe that the boundaries between the mineral and living worlds are more porous and interconnected than traditional Western epistemologies might suggest. She argues for an expanded understanding of agency and vitality, including human and nonhuman entities, for example, minerals and other material objects (2010). Bennett uses the concept of *actant* to refer to any entity within a network that can exert influence, act, and possess

5 The geotechnical report titled Faresoneutredning skred i bratt terreng – Aurland kommune (Hazard zone assessment of landslides in steep terrain – Aurland municipality) provides several descriptions of natural hazards (mainly landslides) that have occurred due to extreme weather events in the last two decades. The report includes descriptions of all previous natural hazards registered with NVE (the Norwegian Water Resources and Energy Directorate). As a stunning example, the description of the damages caused by landslides and debris flows after extreme weather in December 2011, following the Dagmar storm, vividly illustrates the rapid activation of the mountain's natural processes. See: https://publikasjoner.nve.no/eksternrapport/2023/eksternrapport2023_13.pdf.

vitality or liveliness[6]. Echoing Bennett, geologist Marcia Bjørnerud discusses the agencies of rocks and argues that rocks are not passive objects but active participants in Earth's ongoing processes. She highlights that they constantly record and communicate information about past events while influencing future developments. By viewing rocks as verbs, she emphasizes their agency and the interconnectedness of geological processes across different time scales. Her perspective encourages a deeper appreciation for the dynamic nature of landscapes and underscores the importance of understanding geological time (2018).

The concept of actant, as articulated by Bennett, helps us move beyond the dichotomy between nature and culture and recognize natural phenomena as active drivers in the making of the landscape. This perspective allows us to explore landscape processes from a multifaceted viewpoint that includes nonhuman influences, deepening our understanding of natural hazards as materials in motion and products of living processes, such as melting ice, the interaction of rock with water, and eroding rocky slopes.

From a landscape architectural perspective, the notion of actant enables us to engage with the vitality of natural entities like rocks, soils, water, and glaciers. It provides a framework for analyzing complex landscapes, helping us understand cultural and natural processes that intertwine in hazardous cultural landscapes such as the Undredal Valley.

Thus, with this understanding, natural hazards are no longer seen merely as disturbances (to a human-centric world) but rather as expressions of conflict or tension—arising when the actants' (natural entities') own interests—the overflow—become incompatible with the interests of the locals.

To acknowledge natural phenomena as actants, one can seek to understand the *personality* of the river, the water, and even the rock—their temperament, rhythms, movements, and amplitudes (de Toledo, 2021). These actants have their logic, characteristic behaviors, or ways of 'thinking' that, as landscape architects, we would benefit from understanding more deeply.

First, water is one of the significant actants in the crafting of the Undredal Valley landscape. It can both dig and erode and bring about more weighty events when entangled with other matters. Then, water can dislodge boulders and hasten the instability of stones. Heavy rains initiate various mountain processes and influence the stability of rocks and soil, resulting in multiple textures such as rockslides, mudslides, debris flows, and landslides.

The upper slopes of the valley are marked by steep rocky faces that have been shedding rocks since the last Ice Age, emphasizing rock as another significant actant alongside the water. This ongoing process has resulted in several meters of scree material accumulating on the lower slopes, further contributing to unstable soil layers.

During several fieldwork sessions, three additional landscape actants were identified: herds of goats, the forest, and the soil. Goat herds fulfill a dual role: as individual goats, they act as independent nonhuman agents, while as herds, they function as actants shaped by human interactions. Then, the forest, influenced by declining logging practices and rising temperatures, is advancing and asserting itself as a hybrid ecology, influenced by the grazing of goats in its undergrowth. Lastly, soil, an unstable and heterogeneous entity, is deeply interconnected with rock processes, water, and weathering.

This preliminary study and initial paper, therefore, focus specifically on two primary actants, water and rock, due to the methodological framework outlined below.

6 Bennett's concept of actant reflects her broader project of reimagining human/nonhuman relationships, described in the book *Vibrant Matter*.

FIGURE 2 *The mountain's rocky landforms witness centuries of rockfalls (scree materials).* The Undredal Valley is a landscape where pastoral practices are delicately interlaced with the forces of water and rock. Here, the Undrelaselvi River winds its way between the summer pastures of Melhus. The wood summer stables shelter farmers and herds of goats during summer grazing. One of these shelters (red in the background) is threatened by bank erosion. (Source: author, 2023)

FIGURE 3 *The Undredalselvi is the main torrent of the valley.* It behaves like an active mountain stream. The picture witnesses how it can sometimes accelerate and literally swallow up a piece of the bank. (Source: author, 2023)

FIGURE 4 *A partly damaged trail on the opposite bank.* This trail has a strong value for the community and is used by hikers and breeders. The Breskrida is one of the active side streams that run along the slopes before joining the main river on the valley floor. (Source: author, 2023)

Method

Building Site Knowledge

The cartographic work is grounded in a deep understanding of the site, developed over several months through extensive fieldwork. Conducting fieldwork across different seasons was crucial for capturing the varied behaviors of water (including the main river and numerous side streams) and the dynamics of rock slopes. This fieldwork combined various methods and included collaborative visits by co-walking with fellow researchers from the NATURACT research team, focusing on geological and hydrological insights. Additionally, site knowledge was supplemented through cartographic analysis of satellite imagery and document analysis, including archival materials and scientific and geotechnical studies. These resources were often shared and explained by research fellows. The scientific significance of the study relies on solid interdisciplinary collaboration and comprehensive geotechnical documentation. Such support was essential to ensure scientific knowledge could effectively validate and enhance the interpretative approach conducted through mapping.

Capturing Flows and Movements through the LiDAR Cartographic Interpretation Method

The experiments presented in the following section are grounded in traditional orthographic map-making. Although planimetric cartography may not be the most valuable tool to capture dynamic features of natural processes, it was chosen for two main reasons. First, it is an essential tool in planning and landscape design, especially for adaptation and mitigation strategies (that rely heavily on GIS and satellite data). Second, this media fosters interdisciplinary collaboration—particularly with geologists and geo-engineers—by serving as a shared medium for facilitating dialogue between scientific fields and landscape disciplines. Hence, with respect to designing strategies, this study situates itself within a framework that seeks to complement GIS-layer maps. Another key methodological choice is adopting a replicable, straightforward, and partly analogue method. The work heavily relies on LiDAR images as a primary resource[7]. LiDAR, known for its precision, provides detailed, three-dimensional representations of terrain and vegetation. Functioning as a ground surface scanner, it offers a vivid depiction of landscapes, revealing not only traces of activities but also a palimpsest of different temporalities (Fig. 5). In addition to satellite imagery, it provides a new and rich dataset about the ground surface that articulates a geomorphological expression, revealing intricate details and nuances, such as crevices and other ground textures[8]. This resource is widely utilized in landscape analysis, archaeology, and geography.

7 Light Detection and Ranging (LiDAR) is a technology used to create high-resolution models of ground elevation with a vertical accuracy of 10 centimeters. The Norwegian public mapping portal Kilden provides free access to very fine-resolution LiDAR imagery.

8 In Norway, LiDAR imagery is available through the NIBIO/Kilden public cartographic platform (which also provides GIS layer maps). See: https://kilden.nibio.no/.

FIGURE 5 *LiDAR map of a section of the Undredal Valley, at Melhus.* The map is howcasing intricate details on rocky slopes and the riverbed at a high resolution. It is extracted at a scale 1/1000 from the Kilden online public cartographic platform. (Source: NIBIO, https://kilden.nibio.no/, 2023.)

However, its potential for interpretation in landscape architecture remains underexplored. Given the extensive data captured by LiDAR, selecting specific information for map conversion becomes crucial, adhering to standard cartographic interpretation practices within the discipline. As James Corner emphasizes, this process requires deliberate interpretation and data selection, acknowledging the inherent subjectivity in cartographic translation (2011). This paper's cartographic experiment interprets complex LiDAR data through a three-step process:

Reading and Identifying

The first step in the drawing process involves analyzing the image's significant signs, lines, and features. The intricate textures revealed by the LiDAR data demand meticulous attention, requiring a careful, selective reading of crevices, reliefs, gullies, and micro-topographies. LiDAR allows us to identify details in a geomorphological field. By closely examining the topographical data, potential traces embedded in the image can be identified, revealing pathways, rock trajectories, waterways, and water flow patterns. The site knowledge gained through fieldwork is essential for interpreting these visual elements, creating a mental analogy between what is observed on the surface of the image and the landscape experienced in the field.

Selecting Relevant Patterns and Signs

Identifying distinctive ground patterns crucial to understanding water or rock agency entails a blend of intuitive interpretation and scientific expertise. This process is dynamic and iterative, relying on continuous interaction between insights from LiDAR, site knowledge, and various documentary sources related to hydrology, geology, and geotechnical engineering[9]. The process also integrates cross-disciplinary dialogue with a more extensive scientific team[10]. The triangulation between subjective interpretation of LiDAR, site knowledge, and scientific inputs from earth sciences is essential to ensure that interpretation decisions are informed.

FIGURE 6 *Preliminary overlay experiments on a printed LiDAR map.* Several overlay experiments were performed to generate tracings and experiments with a graphical interpretation of the data. Hand drawing with pencil on transparent paper at scale 1/2500. (Source: author, 2023.)

9 The surveys also entail old and recent geological studies, risk assessment reports (from NGI and NVE), various cartographic resources, old photographs, and GIS maps from the Kilden cartographic database.

10 These are research partners from the NATURACT research project and include geologists, geotechnicians, and hydrologists. The Norwegian Geotechnical Institute (NGI) is one of the five Norwegian institutions involved in the research project and is the lead institution.

Tracing Signs on a Map

The next step involves translating the identified patterns into graphical symbols or tracings via an overlay process. Drawing is done both by hand, using traditional tools like pencil and tracing paper, and digitally, with a graphics tablet in Photoshop. With both tools, the drawing hand responds subtly to the LiDAR image, enacting a drawing and translation process that is both interpretative and informed, allowing for a slow, deliberate engagement with the behavior of the actant—whether water or rock.

Here, drawing is to be understood as a *verb*, a process that gradually allows me to access a kind of subjectivity of the natural entity being drawn. Through each line, I attempt to capture the inherent logic of water or rock—the forces that drive its trajectories. The patterns created aim to uncover a more extensive behavior, an idea of displacement or movement. This tracing process involves various graphical choices common to all cartographic work, including decisions about simplification, emphasis, enhancement, or exaggeration of specific features. Through this process of cartographic interpretation, the drawing gradually gains intentionality.

In the following sections, I refer to this approach as the *LiDAR Interpretation Method*. It is an initial step, emerging as an intuitive engagement with the rich, layered material of the LiDAR. The maps presented are early results from an ongoing investigation, a first act of drawing and tracing that allowed me to sense its depths. Though the work is still in its early stages, some preliminary insights are offered to guide future research direction.

Findings: Exploratory Cartographies

Early-stage Experiments : The Watershed as a Living Organism / The Valley as a Rockscape - the Watershed as Rockshed

The first preliminary investigations represent water and rock distinctly through two hand-drawn thematic maps at the scale of the entire watershed—the scale that best aligns with natural phenomena. The first map brings the watershed and its hydrographic network to life, transforming the landscape into a water-filled scene [fig. 7], showing an intense and hairy network that evokes what looks like a vibrant organism.

The second map, which focuses on rock agency, emphasizes the role of the watershed in initiating rock processes. It introduces the idea of a 'rockshed'—an area where rock material is collected, channeled, or shed from higher elevations [fig. 8]. Thus, the rockscape/rockshed map helps provide a new understanding of the terrain, highlighting the active mountain faces in releasing stones. Both drawings offer insights into interpreting rock and water as distinct yet interconnected entities with distinct patterns. These initial sketches helped validate the effectiveness of LiDAR interpretation at a large scale (1/10,000), showing that this method not only enhances geomorphological expressiveness but also reveals potential to convey movement across the entire catchment area.

FIGURE 7 *Early-stage experiment: The watershed as a living organism.* Early-stage study cartographies to experiment with the potential of LiDAR interpretation at a large scale and about the understanding of the watershed. Hand-drawn with pencils on transparent paper at a scale of 1/10000 and reworked in Photoshop. Original drawing size: 110X160cm (Source: author, 2023).

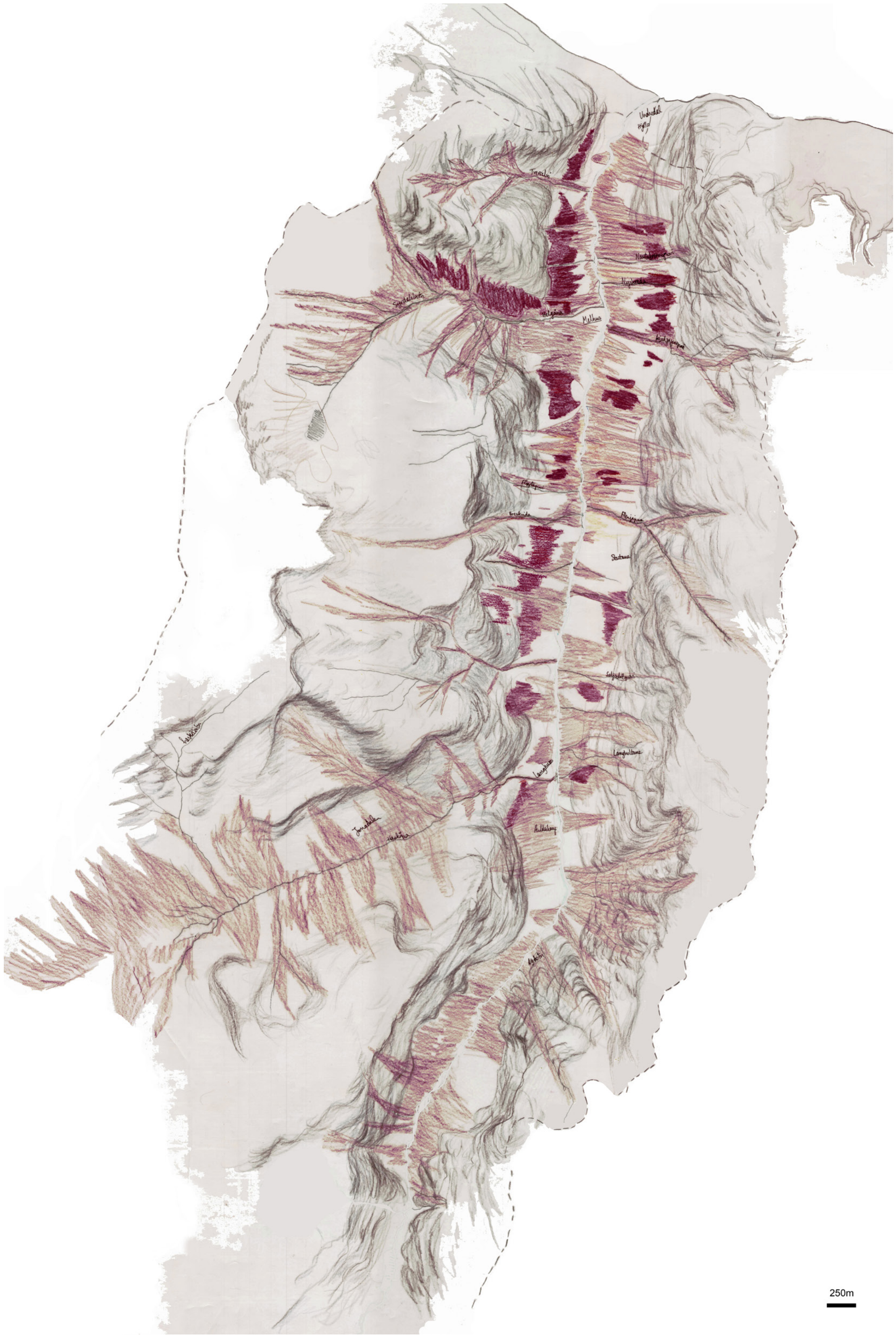

FIGURE 8 *Early-stage experiment: The valley as a rockscape - the watershed as rockshed.* Early-stage study cartographies to experiment with the potential of LiDAR interpretation at a large scale and about the understanding of the watershed. Hand-drawn with pencils on transparent paper at a scale of 1/10000 and reworked in Photoshop. Original drawing size: 80X116 (Source: author, 2023).

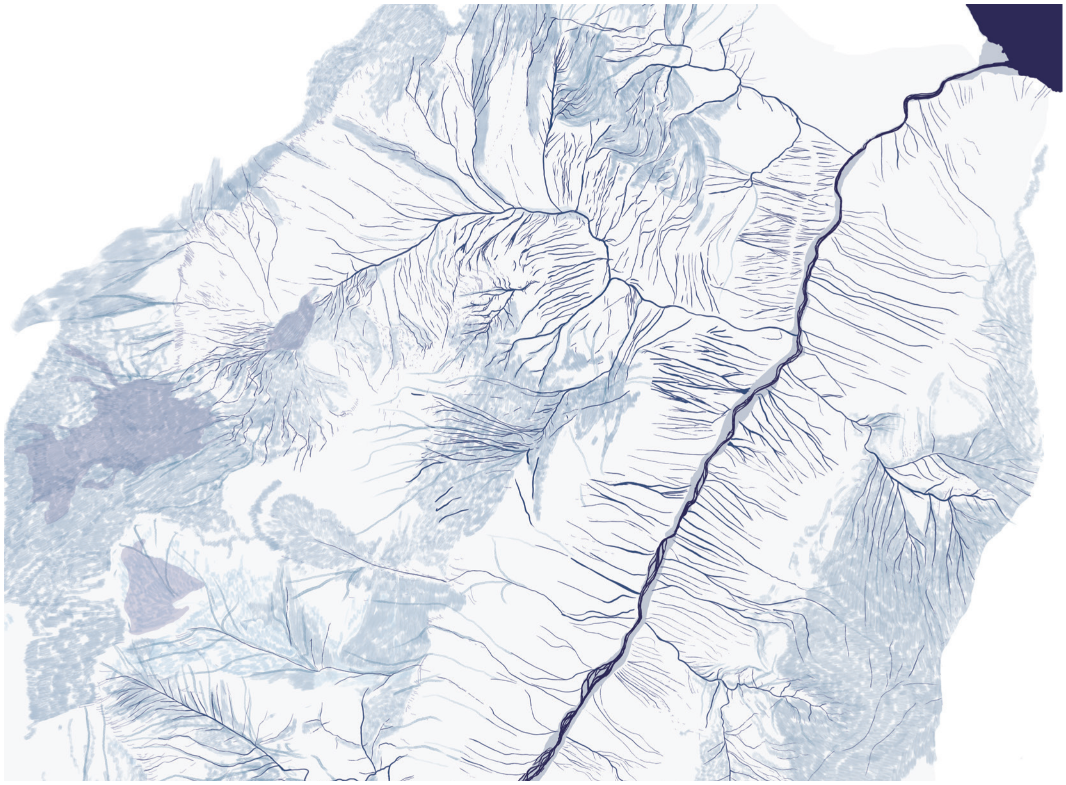

FIGURE 9 *Speculative map of heavy rainfall in the spring season.* Drawn at scale 1/5000 in Photoshop, using a drawing tablet. Original drawing size: 115 X 99 cm (Source: author, 2024).

Speculative Map of Heavy Rainfall in the Spring Season

Can the pathways that water traverses through the landscape be delineated and portrayed as etched into the soil? This map explores this possibility, drawing upon topographic data and a selective interpretation of slope lines, which can be construed as rainwater pathways and routes. With extreme rain events projected to increase in frequency and intensity in this region (Rønningsbakk, 2018), understanding the impact of rainwater has become increasingly crucial in Undredal, as it governs all geohazards. The map proposes illustrating flows and trajectories of water during intense rainfall events in the new heavy rainfall regime. It speculatively enhances the watershed's agency, illustrating both past and potential future events. It portrays water as more abundant and dynamic than typically represented in standard cartographic databases. By emphasizing the physical characteristics of waterways shaped during heavy rainfall, the map aims to convey water's powerful movement and forces. Further experimentation could help refine this aspect, deepening the spatiotemporal dimension and offering a more comprehensive representation of movement's depth and velocity. The map highlights various water behaviors across distinct territories:

- The riverbed on the valley floor shows its evolutionary trajectory, including its primary bed, expanding zones, and inactive meanders;
- Blue surfaces, marked by relief, indicate areas where water accumulates in late spring as snow and ice on plateaus and summits, remaining static for extended periods (release areas);
- Light blue lines suggest speculative water trajectories, revealing sub-watershed logic;
- Darker blue lines show water rapidly descending the valley, carving through rocks and steep slopes.

FIGURE 10 *Tracing a mountain in motion.* Drawn at scale 1/5000 in Photoshop, using a drawing tablet. Original drawing size: 80 X 95 cm (Source: author, 2024).

Tracing a Mountain in Motion

Leveraging LiDAR data unveils a rich tapestry of patterns etched onto mountain slopes, narrating the history of rock movements over time. This map seeks to capture rock's dynamic essence, integrating its natural processes into the landscape to evoke mountains' organic character. It graphically interprets these rock patterns, correlating them with watershed dynamics and geomorphological processes from peaks to valley floor. The darker surface represents release areas—higher-altitude sections prone to rock detachment, often characterized by fragile gneiss material. LiDAR interpretation subtly delineates these areas, offering critical insights into rockfall drivers. In contrast, the lighter surface with lines indicates discharge areas where rocks descend along slopes. These patterns evoke traces of past landslides, rockslide pathways, or gullies, illuminating connections between release areas and slope dynamics. The map conveys rock's vitality and fluidity, inviting deeper understanding of interconnected geological processes shaping the landscape.

FIGURE 11 *What crumbles, rolls, slides... Sketch drawing.* Drawn at scale 1/2500 in Photoshop, using a drawing tablet. Original drawing size: 42 X 53 cm (Source: author, 2024).

This preliminary sketch aims to capture a mountain slope's dynamics in simplest terms, using few swiftly executed strokes. It represents diverse past events inscribed on the ground surface and validates that various mountain processes can be read in LiDAR data. The graphical interpretation reveals traces of past scree, and ravines through which material accumulates and rolls down steep slopes.

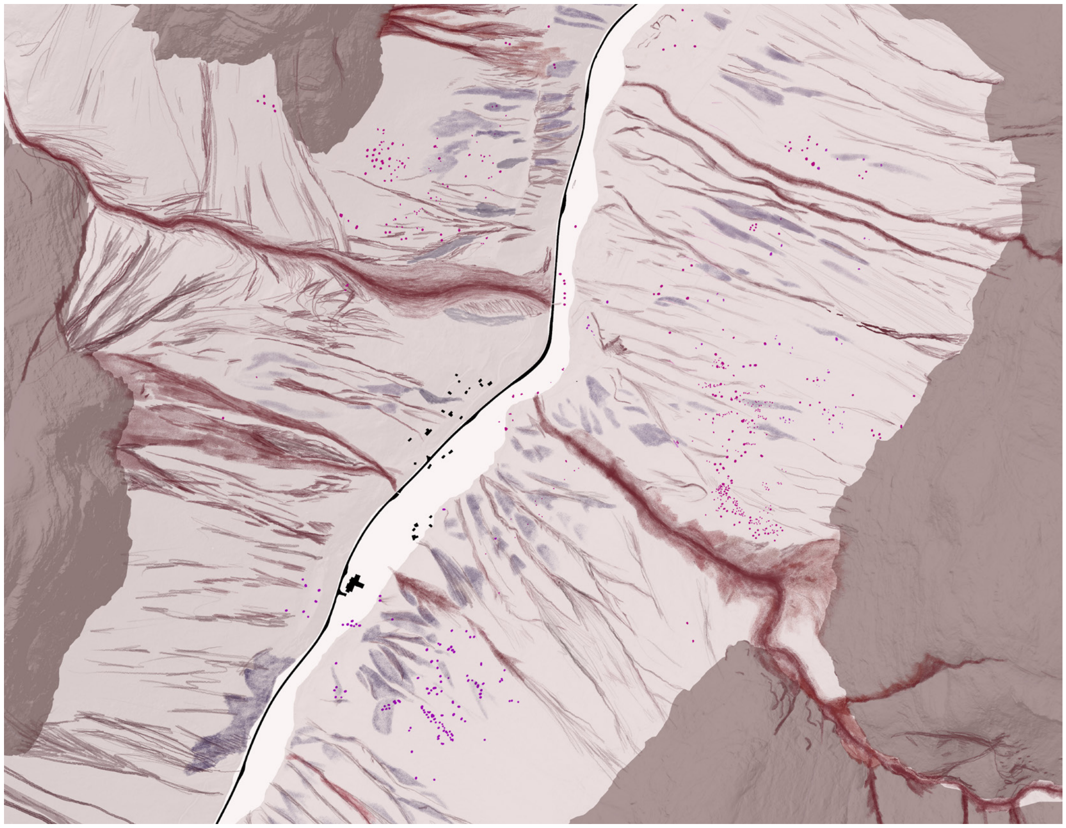

FIGURE 12 *What crumbles, rolls, slides: Interpretation of different mountain behaviors.* Drawn at scale 1/2500 in Photoshop, using a drawing tablet. Original drawing size: 77 X 72 cm (Source: author, 2024).

- Black tracings: human infrastructure (main road, mountain pastures)
- Pink dots: rock deposits (large blocks tumbling down slopes)
- Thick red corridors: debris flow-prone channels
- Purplish rown surfaces: past rockfalls and material accumulations
- Thin brown lines: smaller paths of less solid materials such as mud

What Crumbles, Rolls, Slides: Interpretation of Different Mountain Behaviours

Combining diverse datasets (geotechnical surveys and maps) with LiDAR interpretation, this map graphically represents movements and processes shaping rocks and mountains, illustrating a range of rock behaviors. It translates terrain contours into tracings of movements—rockslides, debris flow channels, and stone deposits—revealing past events and their landscape imprints. Each graphic pattern conveys a unique geological process, gesturing toward a "language of the mountain" reflecting contemporary and historical geological timescales.

While not a formal scientific document, this representation could serve as an interpretive complement to technical maps, offering an alternative perspective emphasizing landscape vitality and processes. Bridging scientific rigor and interpretive exploration encourages reflection on how such approaches deepen understanding of geological phenomena's dynamics and interconnections between past occurrences and potential future events. However, integrating multiple temporalities, movement traces, and event types remains a developing approach, inviting further research.

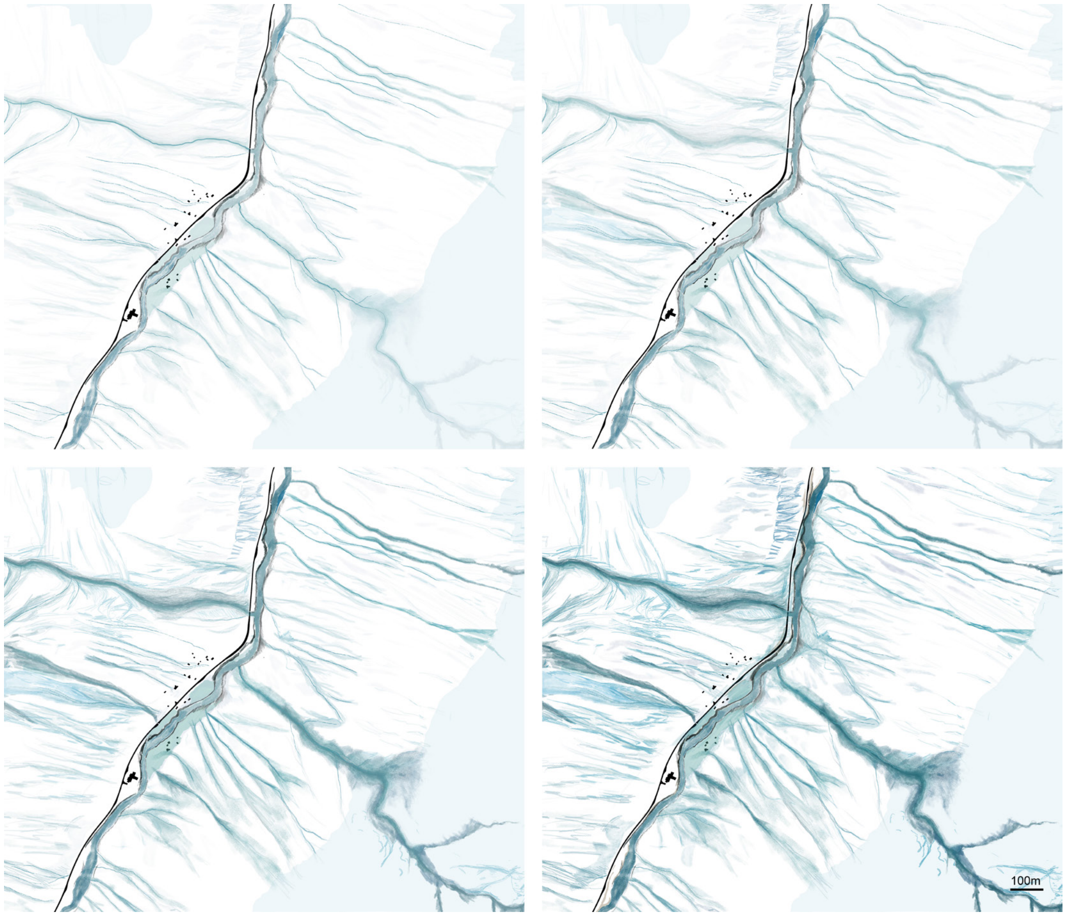

FIGURE 13 *Attempts to represent the impacts of intense rainfall.* Based on site observation from July 23, 2023. Drawn at scale 1/2500 in Photoshop, using a drawing tablet. (Source: author, 2024).

Attempts to Represent the Impacts of Intense Rainfall, based on Site Observation from July 23, 2023

This series suggests a temporal interpretation of a rainfall event and a process-oriented approach to how water floods the landscape during an intense rainstorm. (Read from left to right, bottom to top.) The four maps convey a narrative, illustrating a heavy rainfall, like one observed in August 2023 when streams quickly filled and water carved new channels outside regular streambeds.

LiDAR data enables interpreting varying runoff intensities on slopes and within channels, highlighting stream forces. Variable thickness and patterns in watercourse traces illustrate gradual landscape filling with water. Each map represents a time interval of approximately one to two hours. This representation makes rainwater more comprehensible, revealing water as an actant with distinct temperament and behaviors, while highlighting terrain friction.

Though speculative, these maps retain accuracy value for climate adaptation strategies. Further experimentation—particularly regarding temporal aspects—is essential for fully realizing their potential.

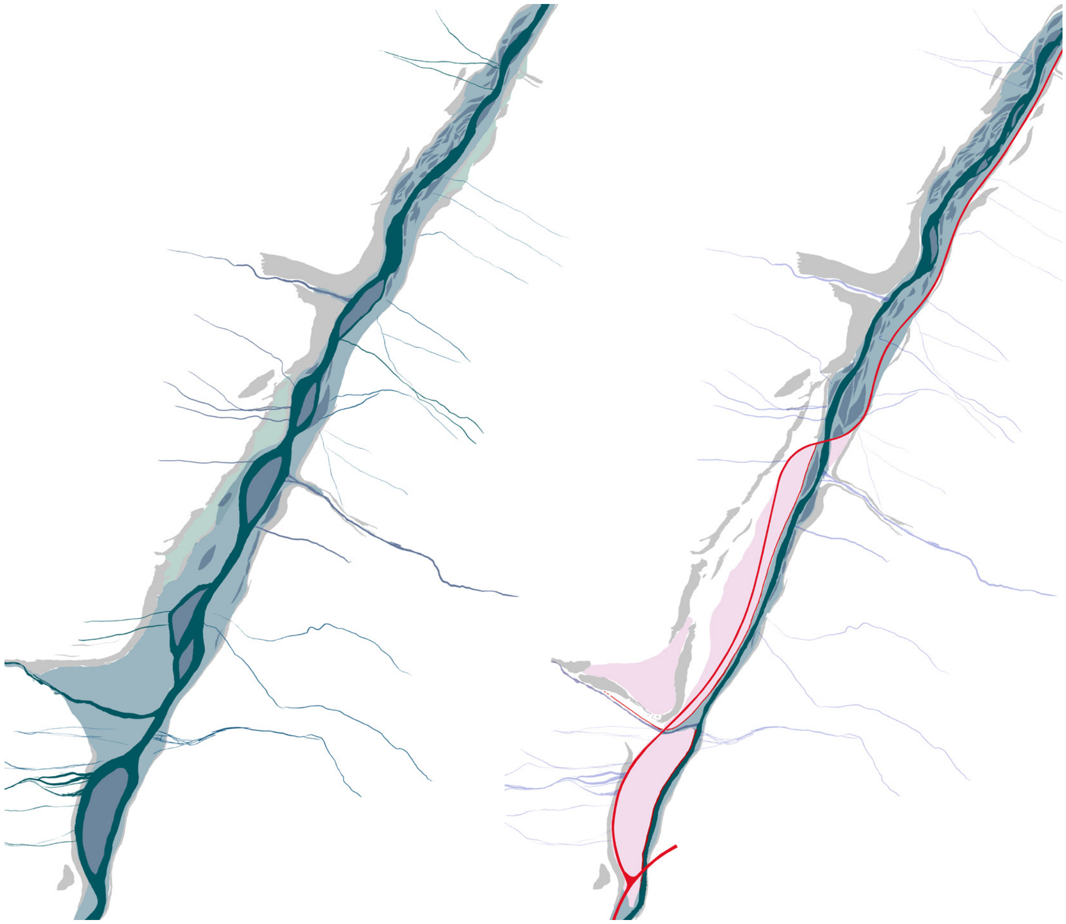

FIGURE 14 *What the river is enduring.* Red and pink features indicate road infrastructure and a large landfill area that now obstructs part of the riverbed, forcing it into a near-straight line and eliminating its previously dynamic, alternating channels. On both maps, grey areas represent embankments delineating the river's boundaries. Dark blue, curving shapes illustrate the river's natural meanders, which once shifted seasonally. Drawn at scale 1/2500 in Photoshop, using a drawing tablet. Original drawing size: 62 X 79 cm (Source: author, 2024).

What the River is Enduring

Two maps depict a river's course within an upstream valley section that has undergone notable recent changes. LiDAR interpretation reveals the riverbed's evolution, showing natural hydro-morphological patterns and anthropogenic structures that have constrained its flow.

The left map shows the river's original pre-1970s path (shaded blue) before the road was built. The right map shows current conditions.

These visualizations emphasize the river's intrinsic need to move within a changing landscape, highlighting human infrastructure impacts. By juxtaposing these maps, the effects of the massive landfill become clear—most notably the river's confinement, leading to agitated flow, increased velocity, and various accelerations downstream. The maps portray the riverbed as a conflict zone, with the river being forced to lose its natural path, along with part of its territory and flow rights. Visualizing this conflict between human and natural forces fosters a critical perspective and empathy for the river's struggle. This approach resonates with Dirk Sijmons' call for renewed sensitivity and compassion toward both human and non-human elements of a site in the Anthropocene (2020).

Discussion: Expressing Other-than-Human Subjectivities through Movement

The LiDAR interpretation method is preliminary and requires further testing across different cases, landscapes, natural phenomena, and scales. While relatively simple and low-tech—relying on an overlay drawing method and interpretation practices familiar to landscape architects—the technique is easily replicable. Despite being time-consuming when applied to large-scale landscapes or watersheds, it provides a valuable tool for engaging with detailed geomorphological understanding across scales, offering deeper insight into natural processes. This experimental cartographic technique effectively traces the genealogy of natural events, allowing us to map the underlying processes that generate them. Ultimately, it enables the creation of vivid, rich representations of natural processes, transforming invisible or silent dynamics into a compelling visual language that can inform planning and strategy development tools.

One particularly valuable aspect is the strong narrative potential of these cartographic representations. These maps can be interpreted as depictions of past processes and, more importantly, offer the possibility of creating speculative representations of future events. By providing a projected vision of potential behaviors of water and rock, they can generate speculative maps grounded in scientific data. This dimension remains in its early stages in these initial attempts and warrants further research. A more precise and attentive representation of temporal aspects would be necessary to deepen this hypothesis. While the maps here capture dynamic features, they primarily depict intermediary states rather than sustained movement. Further experimentation is needed to explore drawing techniques that could, for instance, incorporate different dates or situations within a single image or depict them as a continuum to visualize dynamics across time and space (Fig. 13). With development to better convey movement, adopting a spatiotemporal approach, these maps could become critical tools for climate adaptation strategies (van Dooren & Nielsen, 2018). Additionally, emphasizing movement could improve the maps' ability to represent a more-than-human perspective, allowing for a more nuanced portrayal of nonhuman actants and their distinct ways of being and behaving.

It is worth noting that other recent mapping practices increasingly focus on representing invisible movements to make nonhuman actants in landscapes more visible. Architect Alexandra Arènes, for example, captures the temporal and processual aspects of nonhuman beings in landscapes[11], emphasizing that living entities, primarily animals, need to be decoded, reinterpreted, and articulated through mapping (Arènes, 2017; Aït-Touati & Grégoire, 2021). Arènes argues that representing the *signature of movement* through cartographic drawing can shift our perception from a fixed view of the landscape to one that is dynamic and alive (2017). This idea is further explored in *Terra Forma: A Book of Speculative Maps* (Aït-Touati et al., 2022), which proposes innovative methods to depict earth processes, flows, and dynamics. Similarly, the *BeingAliveLanguage* project, led by Teresa Galí-Izard at ETH Zurich in collaboration with the Office of Living Things, compiles work visually representing the movements of living entities (such as roots and watersheds) through mapping[12]. In the realm of animal agency, related efforts have sought new approaches to understanding animal actions and behaviors by mapping the spatiotemporal patterns of nonhuman entities (Bracke et al., 2022). These diverse cartographic examples share a common focus on

11 For an overview of Alexandra Arènes› cartographic work and research, see: http://s-o-c.fr/.

12 For more information about the BeingAliveLanguage project and the researchers involved, see the project presentation here: https://gali-izard.arch.ethz.ch/language-description and here: https://gali-izard.arch.ethz.ch/beingalivelanguage-visualizing-soil-information-from-a-design-perspective-to-enhance-multidisciplinary-communication-zhao-ma-and, or works from the Office of Living Things: https://officeoflivingthings.com/sharing.

depicting the movement of nonhuman actants to access their perspectives or subjectivities, often relying on scientific collaborations and resources. They illustrate that representing movement can be central to a more-than-human approach, deepening our understanding of otherwise invisible or intangible natural processes and thereby contributing to their consideration as living processes. This alignment invites further exploration into post-anthropocentric cartographic drawing and supports the continuation of my research. Across current discourses, cartographic works, and research in the landscape discipline, the attention toward representing the movement of natural phenomena—and flowing and dynamic matter such as water, soil, rocks—emerges as a promising approach to more fully integrate their agencies and ways of behaving into our understanding of the landscape.

Toward Navigational Maps

Further research is needed to examine how such maps can mediate human and nonhuman concerns in the context of accelerating climate risks and serve as navigational tools, as proposed by November, Camacho-Hübner, and Latour (2010). They argue that maps are not mere representations of reality but dynamic instruments shaping how we perceive and interact with the world, influencing our actions and decisions. Navigational maps enable users to navigate and orient themselves within complex networks, encompassing physical spaces and associated risks, providing a more comprehensive understanding of potential hazards and uncertainties, and enabling them to decide, plan, and strategize.

Building on this concept, I propose exploring the navigational potential of LiDAR interpretative maps. In climate adaptation discussions with local communities, such maps have the potential to help people navigate hazardous, shifting landscapes by visualizing changes in natural phenomena and relating them to climate events and watershed dynamics. I hypothesize that this approach could foster dialogue and offer practical guidance, warranting further investigation into how these maps can be co-produced and used collaboratively, in rural mountain landscapes.

Conclusion

As the need for climate action intensifies, the LiDAR cartographic interpretation method meets the demand for landscape researchers and practitioners to engage with interdisciplinary approaches to deepen site reading practices and the way we understand natural phenomena and their multiple fluid processes. There is a need to strenghten strong collaborations with earth sciences and ecology to better understand complex hazardous landscapes.

The LiDAR cartographic interpretation method uncovers previously invisible past events inscribed on the ground, revealing signs that can help anticipate future landslides, rockslides, and mudslides in valley and mountain landscapes. It allows for a deeper understanding of the unstable nature of the landscape by exploring different temporalities simultaneously. By integrating rocks and water—entities often difficult to perceive as living—this method acknowledges their agency by making visible processes that are absent not only from our traditional maps but also from our common thought patterns. It offers the opportunity to understand the language of rock and water as actants whose behaviors, needs, and demands become legible through interpretive practices.

The method has the potential to complement GIS maps by highlighting the processes driving natural phenomena, thereby enhancing our understanding of natural hazards. While community knowledge and perspectives are essential to climate adaptation, this type of cartographic work can help build a richer understanding of place in hazardous or rapidly changing mountainous environments, complementing embedded, experiential, and participatory forms of knowing. They can serve as tools to negotiate more-than-human perspectives, challenging the purely anthropocentric view often held of hazardous landscapes and encouraging planning and strategy that *work with*, rather than *against*, the ‘forces at play’ (Clément, 2014).

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