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07.03.2025

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# ***The Fragile Mountain***

**facing the dynamics  
of a changing alpine climate**



fig.1 remnants of the Höllental-glacier. Photo taken on the hike 2023

## August 2023

It's 7am. Most of the people must have already left the mountain hut before sunrise. I step outside into the narrow valley, still filled with dark shadow. Far in the distance I can see the reflection of the sun guiding my view towards the golden summit cross of the Zugspitze. At 2962 meters above sea level, it is the highest mountain in Germany and easily reached from my hometown Munich. I've come here often by train to ski in winter, but today, I'm finally taking on the hike that's been on my list for years. Hiking up the highest mountain in Germany has been an obligation for me. And apparently not only for me. Ahead of me I can already see the long line of people slowly making their way up to the top.

I turn around to get my backpack out of the new Höllentalanger hut. Not the most beautiful, many say. It doesn't have the Charme of the old one, but safety required rebuilding - the old hut had shifted 20 centimetres from where it was originally built. Snow and

rock had moved it over time. This new structure, with its stepped pitched roof, seems protected, integrating into the slope to let avalanches and rockfall pass by without a problem.

As I hike, I notice the changing landscape. The trees have disappeared, and I enter an open scree field. Finally, I can see the white glacier shining in front of the masses of rock. One more time I fill up my bottle with the ice-cold water that it releases under the burning sun. What a gift in this heat, though a bittersweet one. After crossing the glacier, with its deep crevasses, I reach the edge and the beginning of the via ferrata that leads to the summit. But as I look up, I notice the ladder I need to climb is two meters above my head. Only after glancing left I realize that I'm at the wrong entry point; this ladder used to connect to the glacier when it was thick enough. Today, the via ferrata starts further up, where the gap between the warm rock and the melting ice is still small enough to step over.

Almost at the top, I look back into the long valley shaped by glaciers in a time when they still moved down over the rocky landscape. I lose my gaze in the unimaginable vastness of the landscape before climbing up the last meters to the top. But reaching the summit felt like a shock.

“Hundreds of tourists were waiting to reach the summit cross, many of them without proper footwear. There were people with Selfiesticks, families having a picnic, elderly people in wheelchairs and dogs on leashes. They all came by one of the three cable cars which they had paid at least 60€ for. The experience of the summit was dominated by a mix of buildings from weather-station to cable car station to restaurants and souvenir shops. The place I have been looking up to, was a theme park!”<sup>1</sup>

1 Maximilian Loeschke, 'From Shelter to ThemePark. Manifestations of Sublimity in the Architectural Evolution of the Zugspitze.' (Delft, Delft University of Technology, 2024), 7.

fig.2 the summit. Photo taken on the fieldtrip 2024



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Zurich

Lyon

Milan

Nice



Munich

Vienna



Ljubljana

Venice

fig.3 location of the study area.  
map produced by author. 2024

# introduction

## on uncertainty

The convergence of visible climate change effects and intense human interest on the Zugspitze has led me to question our relationship with it. Standing on the summit of the Zugspitze, it can feel as though we've conquered it. However, through my research for the history thesis *From Shelter to Theme Park*<sup>2</sup>, I repeatedly came across the "Schneeferner Haus," a former hotel now repurposed into a research station above the remnants of one of the two glaciers left on the Zugspitze. The station, with a long tunnel crossing from one side of the mountain to the other, is ideally located to study the mountain's interior, and what the researchers have found is concerning. Due to a warming climate, the permafrost stabilizing the rock since the last ice age is melting, and is likely to disappear entirely by the end of the century.<sup>3</sup> Alongside this, heavy rainfall and melting glaciers further destabilize mountain landscapes, increasing the likelihood of rockfalls, debris flows, and floods.<sup>4</sup> Recent years have thus seen a rise in reports of natural "disasters" across the Alps.<sup>5</sup>

However, reading these sudden natural events as disasters need to be contextualized. With a disaster we mainly imply to a negative effect on humans, imposing a human-centered view that frames nature as chaotic and threatening only when it impacts us. As we have introduced architecture and infrastructure into the mountain, the destruction of these human objects through natural forces needs to be seen as a consequence of our own actions. Disasters are therefore a social construct that preference humans over the more-than-human species and systems.<sup>6</sup> Blend out, for example the human elements of a large rockfall event (see fig. 4) and it would stop being disastrous or frightening; it would simply be a natural event.

***"The scale of forces, this time, is planetary; the scope is centuries; the stakes are what we call civilization; [...] Earth will be fine, no matter what; so will life. It is humans who are in trouble"***<sup>7</sup>

- Stewart Brand

As climate science increasingly reveals the effects of a warming climate on erosion of the mountain, the once confident narrative of conquering it through our inhabitation is challenged. The rising risks of rockfalls, landslides, and other mass movements cast doubt on our ability to inhabit and build on these landscapes as we have in the past.

2 Loeschke, 'From Shelter to Themepark. Manifestations of Sublimity in the Architectural Evolution of the Zugspitze.'

3 'Permafrost Und Böden Im Bereich Der Zugspitze' (Umwelt Forschungsstation Schneeferner Haus, 8 December 2021), <https://schneefernerhaus.de/news-article/permafrost-und-boeden-im-bereich-der-zugspitze-114/>.

4 Thomas Kissling, Vogt Landschaftsarchitekten, and Eidgenössische Technische Hochschule Zürich, eds., *Solid Fluid Biotic: Changing Alpine Landscapes* (Zürich: Lars Müller Publishers, 2021), 92–93.

5 Werner Bätzing, *Die Alpen: Geschichte und Zukunft einer europäischen Kulturlandschaft*, 4th ed (München: C.H. Beck, 2015), 249.

6 Dale Dominey-Howes, 'Hazards and Disasters in the Anthropocene: Some Critical Reflections for the Future', *Geoscience Letters* 5, no. 1 (2018).

7 Johannes M. Hedinger and Institute for Land and Environmental Art, eds., *Learning from the Earth*, ILEA Book 1 (St. Gallen Berlin: Vexer Verlag, 2023), 91.

## Massive Swiss rockfall stops short of evacuated village of Brienz

16 June 2023

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Imogen Foulkes  
BBC News, Bern



fig.4 images altered by author, 2024, from BBC-article: <https://www.bbc.com/news/world-europe-65926381>

In response, we have adopted a techno-managerial approach: insulated foundations, flood barriers or soil drainages are engineered solutions that seek to minimize uncertainty. These human in(ter)ventions reveal not only a reactive effort to stabilize a dynamic landscape but also the extent to which we are now managing the very uncertainty we have created.



fig.5 debris flow barrier  
Divjak, Paul. Alpine Interventionen. Wien: Folio, 2006.



fig.6 torrent control  
Divjak, Paul. Alpine Interventionen. Wien: Folio, 2006.

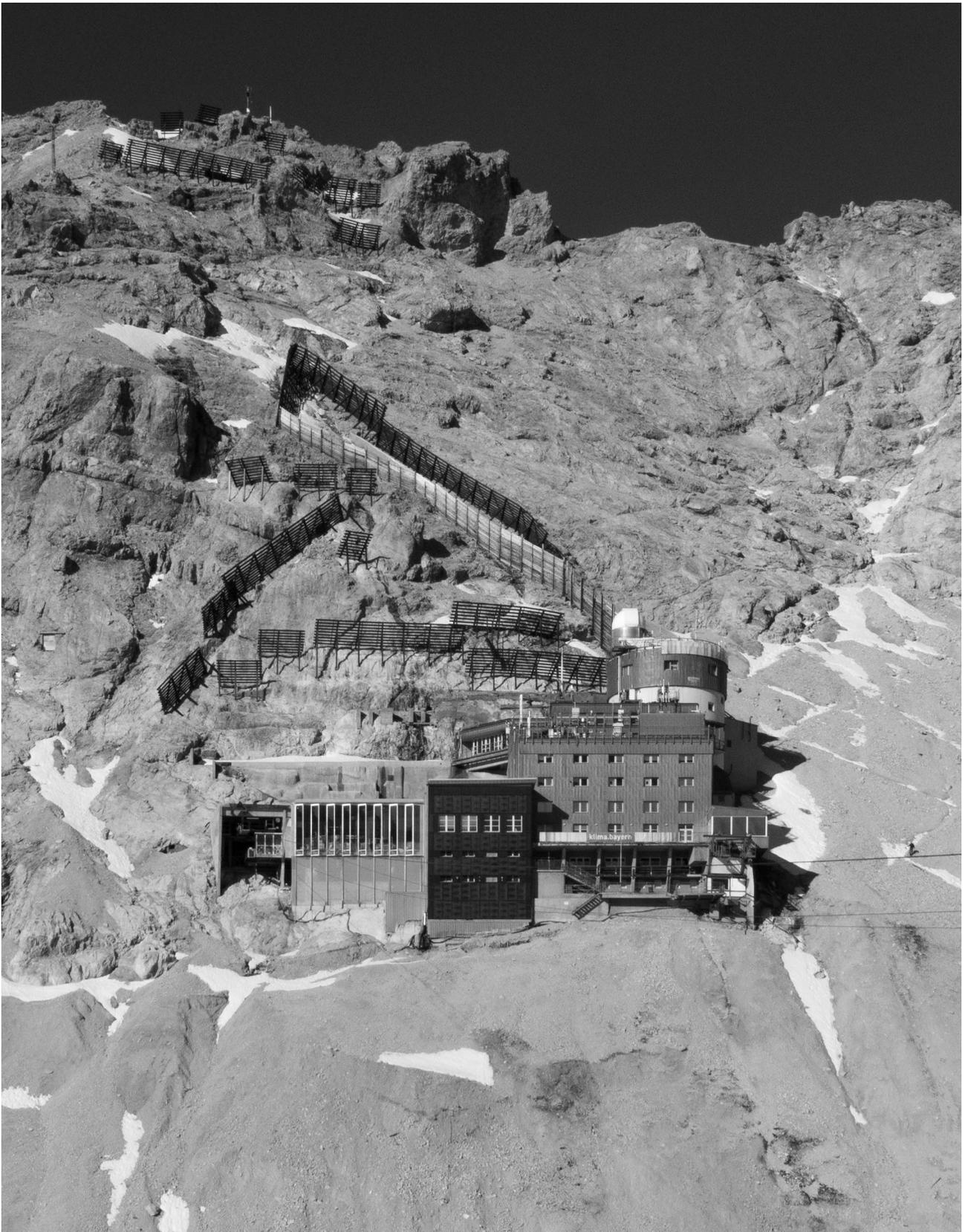


fig.7 Schneeferner Haus. Photo taken on the field trip, Zugspitze 2024

fig.8 debris cone (bright spots indicate recent movement). Photo taken on the field trip, Zugspitze 2024



### On fragility

The Alps have always been in motion. Formed by tectonic collisions, they rose from the plains while natural forces of wind and water continue to erode it. This constant change, coupled with the formation of a steep, layered geological relief, makes dynamics such as rockfall and debris flow an intrinsic part of a young, high alpine landscape.<sup>8</sup> Though difficult to perceive in the present, these forces become visible when viewed in *deep time*.

***“Deep time is measured in units that humble the human instant: millennia, epochs, and eons, instead of minutes, months, and years. Deep time is kept by rock, ice, stalactites, seabed sediments, and the drift of tectonic plates. Seen in deep time, things come alive that seemed inert. New responsibilities declare themselves. Ice breathes. Rock has tides. Mountains rise and fall. We live on a restless earth.”<sup>9</sup>***

**- Robert Macfarlane**

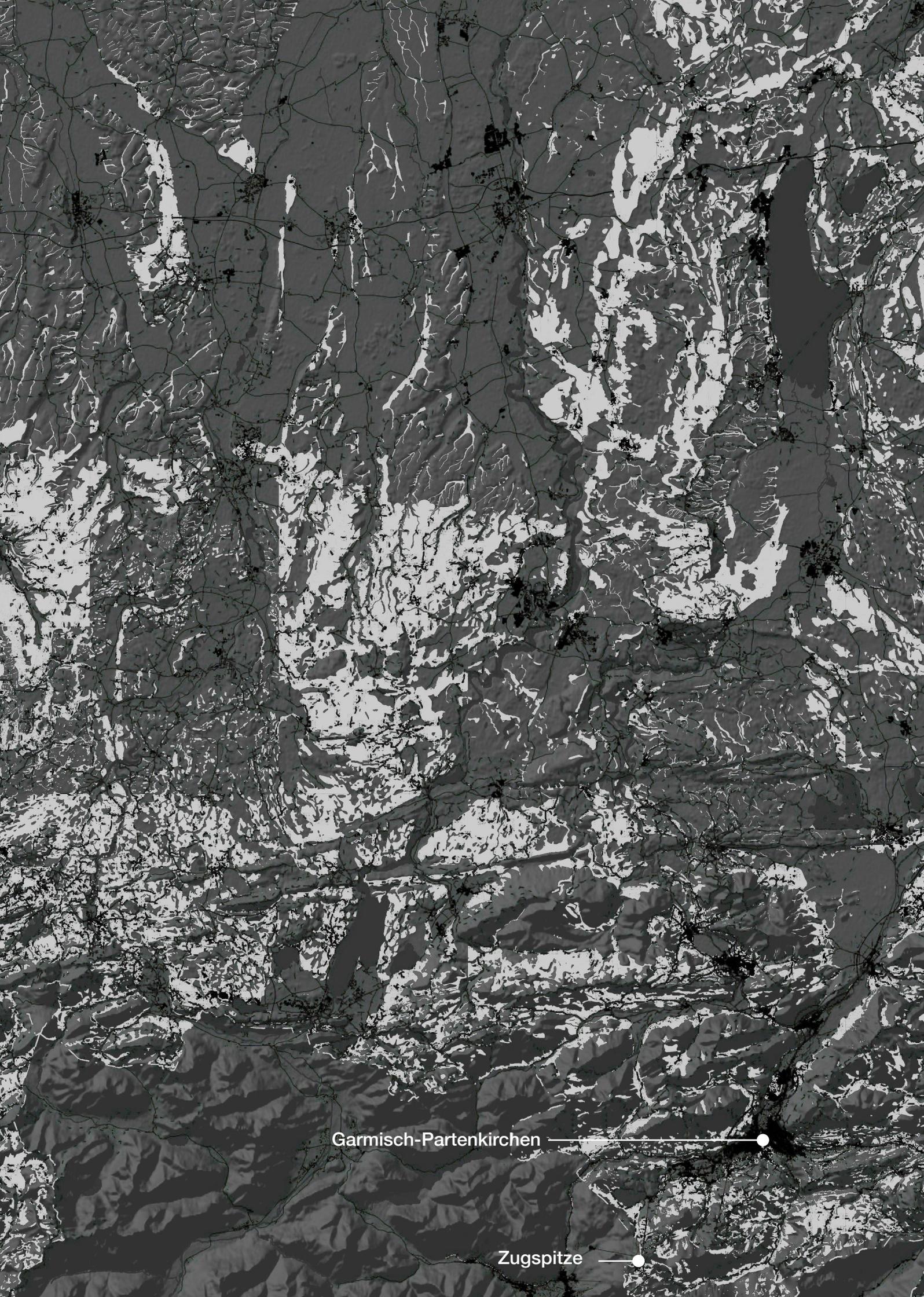
Yet today, climate change is accelerating this temporality to a scale we can perceive in real time. As in the Alps, warming is occurring faster than the global average,<sup>10</sup> we see glaciers shrinking, habitats shifting, and melting permafrost triggering large rockfalls. In this process, climate change reveals to us the inherent fragility of alpine landscapes.

What we must recognize is that the fragility of the mountains is certain, how we engage with it uncertain.

8 Werner Bätzing, *Die Alpen: das Verschwinden einer Kulturlandschaft* (Darmstadt: wbg Theiss, 2018), 67.

9 Hedinger and Institute for Land and Environmental Art, *Learning from the Earth*, 114.

10 Tobias Hipp et al., ‘Klimawandel Im Alpenraum. Auswirkungen Und Herausforderungen’ (Deutscher Alpenverein e.V., n.d.), 6, <https://www.alpenverein.de/files/broschue-re-klimawandel-im-alpenraum.pdf>.



Garmisch-Partenkirchen

Zugspitze

Munich —●

- sediments of moved rock\*  
\* moraines, debris flows and rockfall
- buildings
- transportation routes

fig.9 traces of the glacier. map  
produced by author, 2024

## Garmisch-Partenkirchen and its mountain rivers

The town of Garmisch-Partenkirchen lies at the foot of the Wetterstein Mountains and serves as the main gateway for tours and transport to Germany's highest peak and ski area, the Zugspitze. The mountain river Partnach, which originates from the Zugspitz plateau, flows into the town and joins the larger Loisach River.

In addition to its position on the historic alpine trade route between Augsburg and Venice, Garmisch-Partenkirchen also prospered due to its location along this river, which supported timber rafting for the wood trade.<sup>11</sup> Logs harvested from the surrounding forests were floated down the Partnach and bound into rafts to be transported to larger cities.

Timber rafting became obsolete in the 19th century with the expansion of railway infrastructure, and the river gradually lost its role as a transport route. However, the river's power to carry material downstream was dramatically demonstrated during the catastrophic floods of 1999, when driftwood and rocks from the mountains were washed into the town.<sup>12</sup> In response, the municipality has since invested approximately 46 million euros in flood protection measures to address the growing threat of heavy rainfall and flash floods.<sup>13</sup>

In recent years, the construction of flood barriers and the canalization of waterways within the urban area have irreversibly altered the river landscape and diminished its ecological function.<sup>14</sup> The encroachment of buildings up to the riverbanks further reduces the visibility and presence of rivers and streams in the townscape and its fringes.

Since the local water management authority identified two flood-prone areas on the outskirts of the town in 2021<sup>15</sup>, the location for the design project will focus on the flood zone created by the River Partnach on the southwestern edge of Garmisch-Partenkirchen, adjacent to the famous ski jump and a local sawmill.

11 Eggensberger, Astrid, Marion Weber, Alexander Over, Inge Ebert, Andreas Bergmann, Anna Nägele, Tobias Hölzl, et al. 'Integriertes Städtebauliches Entwicklungskonzept Markt Garmisch-Partenkirchen'. Munich: Markt Garmisch-Partenkirchen, December 2019, 35.

12 'Pfungsthochwasser 1999'. Wasserwirtschaftsamt Weilheim, 1999, 14.

13 Bayerisches Staatsministerium für Umwelt und Verbraucherschutz. 'Glauber: Jede Massnahme Zählt', 6 November 2024.

14 Eggensberger et al., 'Integriertes Städtebauliches Entwicklungskonzept Markt Garmisch-Partenkirchen', 53.

15 'Antrag Auf Festsetzung Des Überschwemmungsgebietes Im Bereich Des Marktes Garmisch-Partenkirchen'. Weilheim: Wasserwirtschaftsamt Weilheim, 22 September 2021, 23-24.

fig.10 flashflood in Garmisch-Partenkirchen, 'Pfingsthochwasser 1999'. Wasserwirtschaftsamt Weilheim, 1999.



fig.11 recent flood protection measures and canalization of the mountain rivers in Garmisch-Partenkirchen, google earth images, 2025

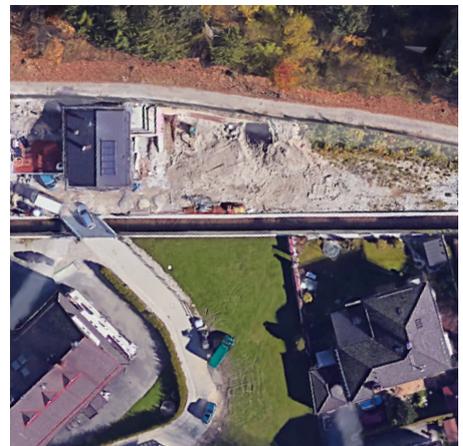
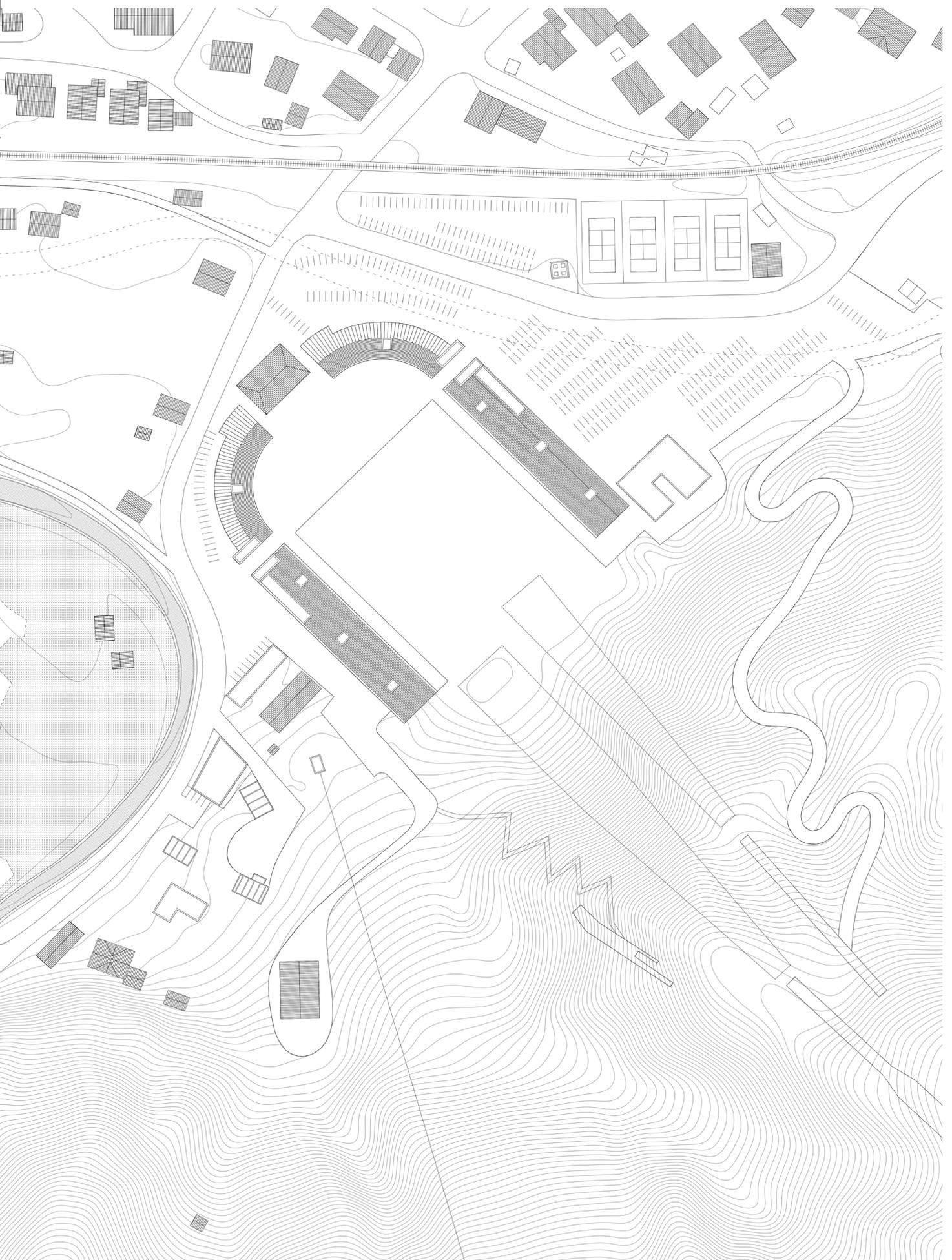




fig.12 siteplan of the floodrisk area, map produced by author



# *problem statement*



fig.13 slope after debris flow.  
Photo taken on the field trip,  
Reintal, 2024

Flooding, rockfall, debris slides, and avalanches are part of natural erosion processes in mountainous regions. In the Alps, where temperatures are rising twice as fast as the global average, climate change accelerates these processes through melting glaciers, thawing permafrost, and increasing heavy rainfall. The resulting sudden dynamics that we label as disasters are in fact a characteristic of the inherent fragility of mountains. For decades, it has been assumed that this fragility can be controlled through technical interventions, like dams or torrent and debris flow barriers. However, this techno-managerial approach, solely based on mitigation and restriction, can lead to a detached relationship with natural dynamics.

***How can design reveal the fragility of a mountain to support a deeper understanding of the relationship between human and natural dynamics?***

In order to answer this question, the research focusses on the area of Germany's highest mountain, Zugspitze, and its river Partnach, which flows down to the town of Garmisch-Partenkirchen. The three sub-questions progressively narrow the scale of investigation, while the design question will address a specific site identified through the research.

To understand the mountain's fragile state, a broader timescale will be considered:

**Which natural processes contribute to the fragile condition?**

In the present, the human role will be examined:

**How have human activities in the Anthropocene altered the natural cycle of erosion?**

This understanding will inform an analysis of the affected materials:

**What types of material are most prone to erosion and how do these materials move and transform over time?**

The knowledge about temporal and spatial trajectories of eroded material will inform a design that addresses the following question:

**How can the dynamic of eroded material be redesigned to communicate the mountain's fragility?**

***research question(s)***

# *methodology*

## **fragility in deep time**

An exploration of the mountains as a dynamic and fragile landscape, presented through three maps

**Desk Research:** Foundational research examines the geomorphic cycle of erosion and the Anthropocene's role in altering it.

**Mapping:** Using geological maps and sections to draw the cycle of erosion from the orogeny to the Anthropocene. The Maps contextualize erosion patterns with climate change data, focusing on material fragility and transformations over time.

## **erosion in the anthropocene**

Understanding material fragility and movement through direct engagement. Findings are synthesized in a section along the path and field journals tracing eroded material's trajectory in the form of a photographic essay.

**Hiking as Phenomenological Method:** Hiking upwards provides a dynamic interaction with the mountain's erosion moving downwards. The slow pace enables detailed observation of human interventions.

**Sample Collection:** Stones and vegetation samples provide material evidence of erosion and ecological variations.

**Photographic Documentation:** Photographs capture visual patterns of erosion, human interventions, and ecological shifts. Annotated images will serve as evidence and a basis for further analysis.

## **design**

In designing the natural and the human become one system that produces a space that demonstrate the temporality and materiality of the fragile mountain.

**Sketches, Models and Plans:** Using architectural tools are used to not to design a finished outcome but states of becoming. Sequences become important to communicate this process.

fig.14 landscape altered by snow management. Photo taken on the field trip, Zugspitzplatt, 2024



# *field trip route*



A topographic map of a mountainous region, likely in the Alps, showing a field trip route. The map features contour lines indicating elevation. A white line traces the route from a high peak to a lower valley. Two specific points are marked with white dots and labeled with their names and elevations. The background is a grayscale topographic map with contour lines.

Zugspitze  
2.962m

Reintal  
1.369m



Garmisch-Partenkirchen  
708m

inger-hut

human construction  
hiking route

fig.15 hiking route. map  
produced by author, 2024

# *field journals*

## **materials in transition**

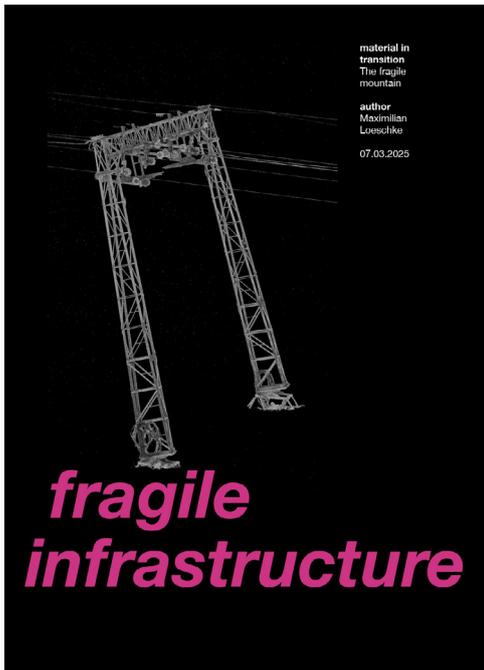
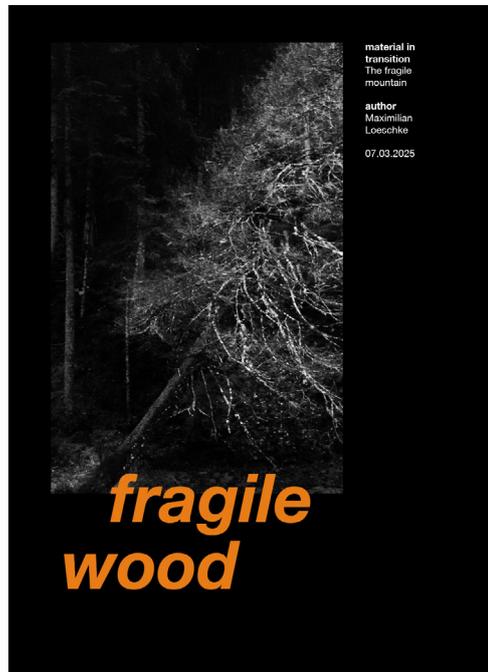
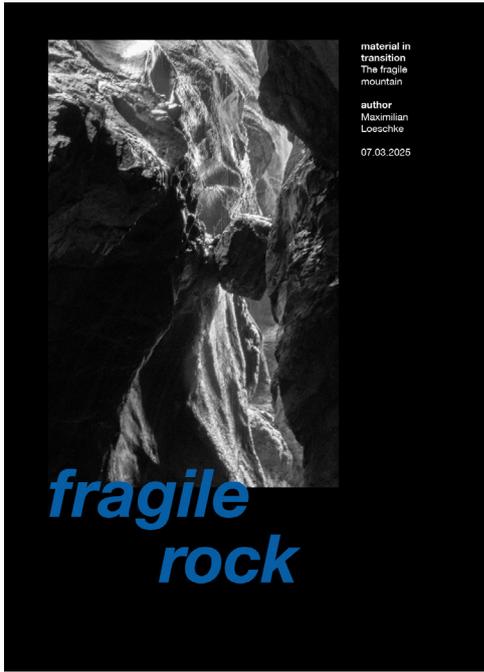
While hiking from Garmisch-Partenkirchen to the mountain top at the Zugspitze my attention was drawn to the landscape of materials in transition. Matter caught between coming from and going to somewhere. While I am hiking upwards I encounter material on its journey downwards, pulled by gravity. I focused on perceiving the dynamic within the seemingly static present.

This tension is captured in photographs, still images of a landscape in motion, each accompanied by a short caption reflecting on the temporal processes at play.

I identified three distinct material types: driftwood, bedload rock, and steel infrastructure. Each booklet is centered on one of these, inviting you to observe, reflect, and engage with the mountain landscape. They serve both as field journals and focused explorations of erosion in the Anthropocene.

The reflections in these booklets emerged from moving through the terrain, closely observing how materials shift, settle, and resist. As I followed visible traces of erosion on hikes, I began to see the landscape not as fixed, but as constantly in motion, shaped by both natural forces and human interventions.

Each booklet concludes with a site where natural erosion and human use visibly converge. These are places where different modes of material management occur and where design might be able to reveal the inseparability of human and natural systems in the Anthropocene.



# ***expected outcome***

This research aims to find a basis for an architectural approach that not only fosters environmental awareness but also emphasizes contextual sensitivity. By embracing the landscape as a living subject with which we must cohabit, rather than contest, the research aims to shape an architectural understanding that respects and aligns with natural rhythms, considering its past, present, and future. It should give an understanding of the ground not as a solid but a dynamic condition.

The analysis of the trajectory of eroded material will reveal the points of intersections with human interventions, revealing the techno-managerial relationship with nature. The outcome is therefore expected to redefine our place in the alpine environment in which fragility should not be understood as a potential for catastrophes, but as a potential for a closer relationship with nature.

# *design prospective*

The outcome of the research could lead to a reimagined architectural language, one that reflects on the mountain's inherent fragility and creates a sense of place.

Instead of adopting a purely defensive strategy against erosion, the design can repurpose the extracted waste material of the mountain as a building resource, giving it new meaning and fostering a closer relationship between humans and the mountain environment. The design project will involve not just designing the process of material extraction but also reimagining the sedimentation process as architecture itself.

Determination of the site will largely depend on the outcome of my research in which the field trip will be evaluated. As hiking from the valley to the top personally made me realise changes in the mountain's dynamic, I want to design interventions along this path that address its uncertain future.

During the hike I could already find interesting locations that emerged wherever changes in human ambition and environmental circumstances overlapped: Namely, a recently build retention area for possible floodings in the valley, a weir at which bedload rock accumulates, a drift wood rake under construction and the ski area on the glacier. As those sites are located along the river Partnach, through which wood and stone get carried down the mountain, this would give me the opportunity to directly relate the gravitational dynamic to an architectural project.

In a material distribution network along the river, hikers will be able to get in contact with the masses of material eroded from the mountain. Extraction sites would highlight the points of interference with natural dynamics and a collection and distribution site would exhibit the material in the form of storage. The proposed design will transform the mountain's dynamic processes into tangible, interactive spaces, where visitors will experience how architecture can not only respond to natural forces but also harness them, admitting the human influence in the system of erosion. The resulting architecture of locally sourced materials will serve as evidence of the Anthropocene, where the boundaries between natural forces and human intervention blur.

# relevance

Hiking the Zugspitze in 2023 and witnessing the glacier melt firsthand has taught me, both visually and emotionally, the profound impact that a warming climate has on our environment. However, this is just the first visible sign of broader effects that climate change exerts on the complexity of an ecological system. Realising this complexity in the fragile alpine environments, raises awareness about our own position within these ecosystems. It reminds us that we are not simply inhabitants of the world but co-habitants, existing within a system over which we cannot always have complete control.

This perspective encourages an approach to architecture that is more attuned to the environment and its uncertain future. The Alps provide an ideal location to test this thesis. Here, the annual mean temperature has increased more than twice the global average<sup>16</sup>, making the landscape's transformation and shifting boundaries strikingly visible. Acknowledging the ground as fragile and dynamic opens up a discourse for design that is not just applicable in the Alps, but globally. As sea levels rise and wildfires and floods become more frequent, the lessons learned from the Alps can help guide us toward a more balanced relationship with nature, one that allows for cohabitation in a changing environmental context.

16 Kissling, Vogt Landschaftsarchitekten, and Eidgenössische Technische Hochschule Zürich, *Solid Fluid Biotic*, 8.

fig.16 driftwood rake under construction. Photo taken on the field trip, Reintal, 2024









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