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SVALGEOBASE II: Tectono-thermal evolution of Svalbard, geological workshop, Svalbard 2024

# Digital Geology at UNIS: Tools for Supporting Arctic Research, Education, and Expedition Planning

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## 1. INTRODUCTION

The Arctic is one of Earth's most frontier areas, with numerous unanswered geoscientific questions. In addition, the Arctic is one of the most dynamic areas of the planet, with recent climate change occurring at much higher rates than in the lower latitudes. This phenomenon, the polar amplification effect, is most evident in Svalbard.

Svalbard is a Norwegian high Arctic archipelago comprising all islands between 74–81°N and 15–35°E, including the largest island Spitsbergen. Geologically Svalbard represents an important (and relatively well-accessible) window to understand the tectono-thermal evolution of the circum-Arctic (Senger et al. 2024). There are no indigenous people in Svalbard, but several remote permanent settlements including the "capital" of Longyearbyen. For its high Arctic location, it is easily accessible by regular and affordable flight connections to the Norwegian mainland. It also hosts the University Centre in Svalbard (UNIS), the world's northernmost educational institution.

UNIS is Norway's field university and offers field-based courses at bachelor, master, and PhD level in Arctic geology, geophysics, biology, and technology, with research and teaching conducted throughout the year. The large seasonal variation (Fig. 1) defines the institution's activity throughout the year. Largely as a consequence of this, UNIS is a leading user of digital geological tools that complement traditional fieldwork and extend the short field season to the entire year.

In this contribution we present two interlinked UNIS-led initiatives that openly provide geoscientific data to a broader audience. Specifically we focus on the photosphere-Atlas, VR Svalbard, and an integrated digital outcrop model database, Svalbox. Specifically we outline how data are acquired, shared, and how they are used in the context of Arctic research, education, and expedition planning. Finally, we showcase a virtual field trip developed specifically for the SvalGeoBase II expedition.

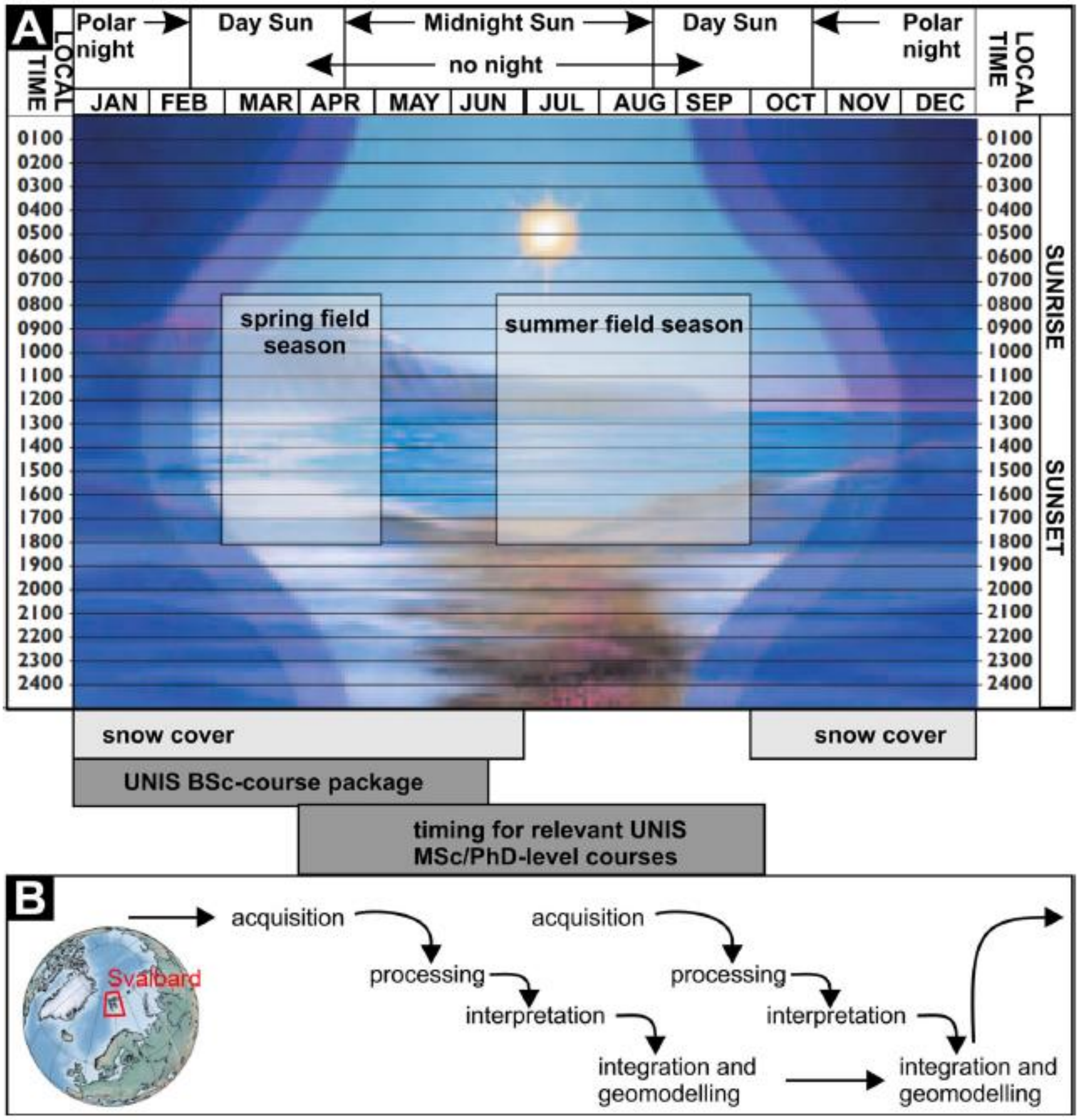


Fig. 1. Seasonal control on course activities in Svalbard: A) Sun diagram for Longyearbyen, overlain with the main field seasons and timing of courses at the University Centre in Svalbard. Sun diagram provided by Longyearbyen Community Council; B) Annual cycle of acquiring photographs for virtual outcrop model processing, interpretation and integration. The inset map shows the position of Svalbard between continental Norway and the North Pole. Figure and caption from Senger et al. (2021).

## 2. DIGITAL TOOLS

Geoscientists at UNIS have in recent years developed two complementary platforms to share geological data from Svalbard with the global community, VR Svalbard and Svalbox (Fig. 2). Both rely heavily on the use of unmannde aerial vehicles (i.e. UAVs, also known as drones) to acquire standard photographs. Photographs are subsequently processed into digital outcrop models or single photospheres (also known as 360° images). Over the years we have tried many different UAVs, but currently rely on the DJI Mavic 2 Pro and DJI Mavic 3 for the vast majority of data acquisition.

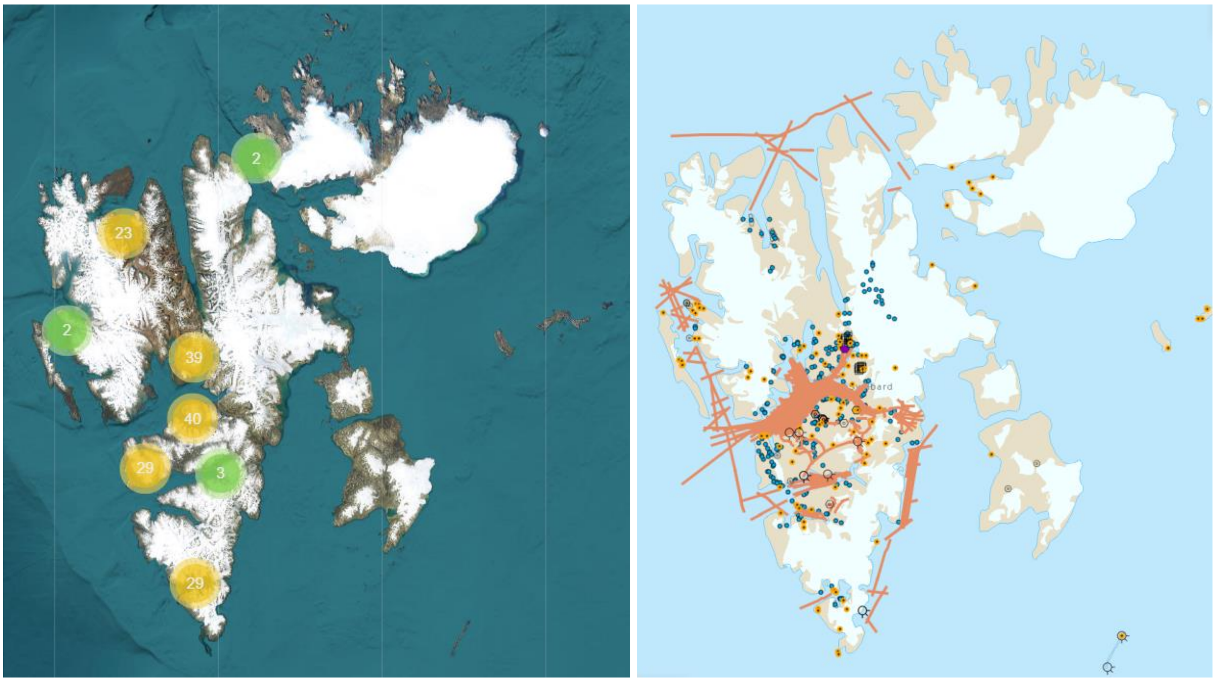


Fig. 2. Openly available digital geological portals led by UNIS: VRSvalbard (left; Horota et al. 2024; www.vrsvalbard.com/map) and Svalbox (right; Betlem et al. 2023; www.svalbox.no/map).

## VR Svalbard

VR Svalbard (www.vrsvalbard.com; Horota et al. 2024) is a photosphere-based Atlas of landscapes in Svalbard. Similar to Google Street View, photospheres allow the user to gain an overview of geological elements. As photospheres can be acquired very quickly, they can be taken in parallel with field activities and thus provide a digital representation of the specific conditions (snow cover, weather, etc.) of the field day.

In the platform, virtual field tours are a sequence of panoramic images that are spatially merged to create a virtual experience. Once created, the viewer can virtually experience local and remote field sites. Virtual field tours can be experienced through desktop computers, laptops, tablets, mobile devices, and even in an immersive view mode with head-mounted displays (Horota et al. 2024).

Virtual field guides, on the other hand, are interactive, digital experiences that provide users with a thematic storytelling exploration of a field area. In essence, they capture the real-world environment of a specific location or region through a variety of multimedia content, including images, videos, maps, gifs, and 3D models to teach. Virtual field guide experiences are only visualised via desktop or mobile devices (Horota et al. 2024).

## Svalbox

Since 2016 UNIS has been systematically acquiring digital outcrop models (DOMs) and openly sharing them through the Svalbox database (Senger et al. 2022; Betlem et al. 2023). Digital outcrop models (DOMs) have revolutionized the way twenty-first century geoscientists work. DOMs are georeferenced three-dimensional (3-D) digital representations of outcrops that facilitate quantitative work on outcrops at various scales. Outcrop digitalization has been traditionally conducted using laser scanners, but in the past decade, it has seen exponential growth because of efficient and consumer-friendly Structure-from-Motion (SfM) algorithms concurrent with the rapid development of cost-effective aerial drones with high-resolution onboard cameras (Betlem et al. 2023).

The Svalbox DMDb described by Betlem et al. (2023) is a regional DOM database geographically constrained to Svalbard. Svalbard offers exceptional-quality, vegetation-free outcrops with a wide range of lithologies and tectono-magmatic styles, including extension, compression, and magmatism. Data and metadata of the systematically digitalized outcrops across Svalbard are shared according to FAIR (i.e. findable, accessible, inter-operatable, and re-usable) principles through the Svalbox DMDb (Betlem et al. 2023).

These DOMs are georeferenced high-resolution 3D representations of the outcrops and facilitate quantitative sedimentological and structural work. Through Svalbox the DOMs are also put in a regional context through spatial integration of maps (geological, topographical, paleogeographic, geophysical, etc.), surface (digital terrain models, satellite imagery, etc.), and subsurface (boreholes, geophysical profiles, published cross-sections, etc.) data, as illustrated for the Festningen geotope by Senger et al. (2022).

## 3. APPLICATIONS AND CASE STUDIES

### Research

Digital data are of paramount importance for numerous research projects. Svalbox models have been actively used in numerous publications across a range of disciplines, including tectono-stratigraphy (Dahlin et al. 2024; Smyrak-Sikora et al. 2021), magmatism (Senger et al. 2013), and structural geology (Ogata et al. 2023).

One of the key benefits for using DOMs is that they are available year-round, not just during the short geological field season in Svalbard. The other major benefit is that DOMs allow more quantitative analyses including measuring thicknesses, orientations, and integrating various data sets (e.g., sedimentary logs, sample locations, shallow geophysical profiles).

### Education

DOMs and photospheres viewed with state-of-the-art visualization in the classroom facilitate efficient fieldwork through pre-fieldwork preparation and post-field work quantitative analyses. Both data types are heavily used by UNIS, with documented case studied provided for both bachelor (Senger et al. 2022) and MSc/PhD level courses (Senger et al. 2024).

Horota et al. (2023) integrates photospheres and DOMs together with other geoscientific data (exploration wells, seismic, digital terrain models, publications, etc.) in the context of a thematic data package (Fig. 3). The theme is Svalbard's most prominent structural feature, the West Spitsbergen Fold and Thrust Belt, and the publication with its rich digital data packages in both Petrel and QGIS serves as a foundation for both research-based teaching and research itself.

### Expedition planning, execution, and post-expedition data integration

Digital tools like VR Svalbard and Svalbox greatly facilitate expedition planning, providing a solid overview of the outcrop conditions that is not feasible using regional satellite data. Where available, the data facilitate virtual pre-expedition exploration of the regional study area to identify zones where targeted field work is desired. Access routes and, where relevant, sites for establishing base camp can be planned and discussed with local experts. Detailed field planning will reduce the environmental impact through, ideally, less time needed to be spent in the field.

During an expedition, digital databases can be set up in the base camp to merge the field observations of numerous field parties. Senger et al. (2024), for instance, demonstrates how such data integration worked during a geoscientific expedition to Woodfjorden. DOMs, sample locations and observations including field photos were seamlessly shared across the eleven team members through an application not requiring internet connection.

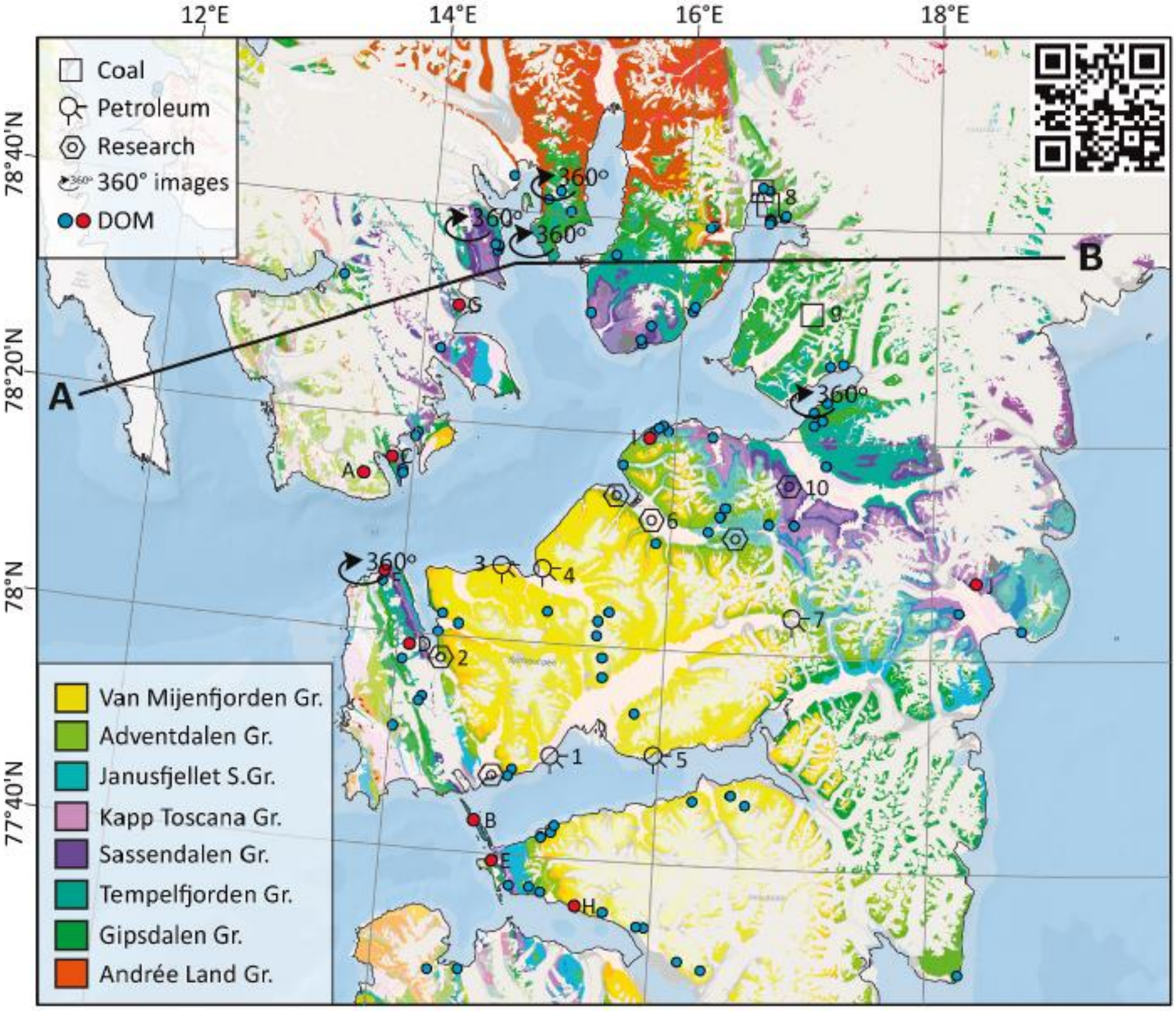


Fig. 3. Geospatial database of all georeferenced data containers provided in the interactive educational data package with this article. The interactive data are also available on the Svalbox online portal, which includes a lot more data sets than extracted for this thematic compilation. Geological map data are courtesy of Norwegian Polar Institute (2014): https://data.npolar.no/dataset/616f7504-d68d-4018-a1ac-34e329d8ad45. Bathymetry data are courtesy of IBCAO (Jakobsson et al. 2012). Figure and caption from Horota et al. (2023).

Following an expedition, digital models serve as a foundation to integrate detailed observations such as sedimentary logs, sample locations and field sketches. Furthermore, the data can be integrated in virtual field trips as a lasting memory for the expedition's participants.

## 4. SVALGEOBASE II VIRTUAL FIELD GUIDE

The SvalGeoBase II expedition visited many remote sites in Svalbard. Each landing was documented with photospheres. Short descriptions of the landing sites from this report are integrated with photospheres and available DOMs in an online virtual field guide accessible at URL (Fig. 4).

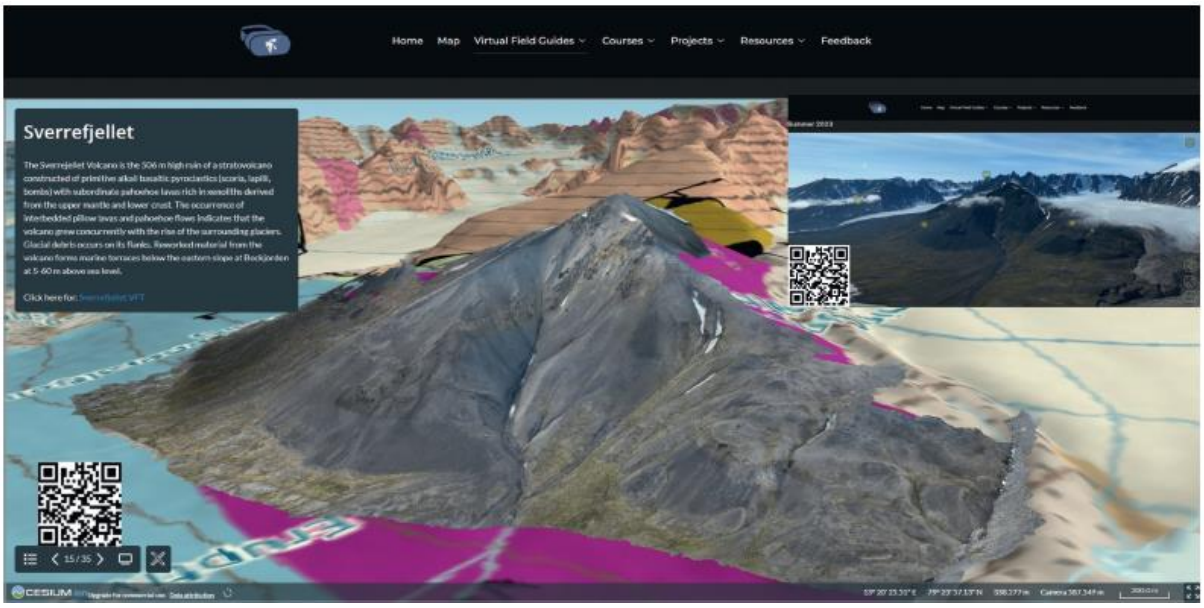


Fig. 4. Data integration and storytelling as a virtual field guide QRcode to URL https://vrsval.bard.com/neogene-quaternary-volcanism-and-thermal-springs/). Integration of ArcticDEM, Bing Satellite, Sverrefjellet DOM, geological map layer of Svalbard, text box and clickable link to the virtual field tour of Sverrefjellet displayed in the upper-right corner, accessible through the QRcode to URL https://vrsvalbard.com/Sverrefjellet/.

## 5. CONCLUSIONS AND FUTURE PERSPECTIVES

We have presented two central elements of digital geology used at UNIS in Longyearbyen. The VR Svalbard photosphere Atlas provides unprecedented bird's eye views of Svalbard's landscapes, focussing on geological elements. The Svalbox platform provides a growing database of digital outcrop models.

Geoscientists at UNIS will continue to acquire digital geological data for the foreseeable future and openly share it with the community. However, we rely on the Arctic and global geoscientific community to assist with utilizing these models in addressing various research questions. Big data and artificial intelligence may in relatively short time frames allow for semi-quantitative interpretation workflows – but let us not forget that geologists need not to only use digital tools but also spend considerable time out in the field discussing scientific problems with their peers.

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