Festningen – a digital field guide (DigFest)

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ABSTRACT: The renowned Festningen section in the outer part of Isfjorden, western Spitsbergen, offers a c. 7 km long nearly continuous stratigraphic section of Lower Carboniferous to Cenozoic strata. Tectonic deformation tilted the strata to near-vertical, allowing easy access to the section along the shoreline. The Festningen section is a regionally important stratigraphic reference profile, and thus a key locality for any geologist visiting Svalbard. The lithology variations, dinosaur footprints, as well as the many fossil groups, record more than 300 million years of continental drift, climate change, and sea level variations. UNIS staff digitized the entire Festningen section in September 2020 using photogrammetry, and the resulting high-resolution digital outcrop model allows free non-discriminatory digital access to this exceptional field site irrespective of season, weather and field budgets. The iEarth-funded DigFest project provides a complementary virtual field trip to Festningen, focussing on the evolution of fauna and flora during 300 million years of geological history.

1 INTRODUCTION

Svalbard offers excellent exposures of a number of geological features, including deep-time paleoclimate, siliciclastic-carbonate-mixed sedimentology, different structural styles (extensional and compressional tectonics, magmatism) and active use of geology (petroleum, coal, gold, geothermal and CCS exploration, coal production). In addition, it serves as an important analogue to the rest of the Barents Shelf (Worsley, 2008), and is thus routinely visited by petroleum geologists working in this area. The vegetation-free outcrops allow excellent quality of outcrops. However, the field season is notoriously short with snow cover for ca. 9 months of the year at sea level and a long dark season. In addition, fieldwork in Svalbard is expensive, logistically challenging and may also be hampered by wildlife (e.g. polar bears). This applies both for research and teaching activities.

Over the past 5 years, the University Centre in Svalbard (UNIS) based in Longyearbyen started systematically collecting digital outcrop models across the Svalbard archipelago, and sharing these via the open-access Svalbox geoscience portal (Senger et al., 2020). The majority of digital outcrop models are acquired using structure-from-motion photogrammetry (Westoby et al., 2012), relying on processing many overlapping photographs. In recent years, drone-based photographs have been primarily used, providing excellent bird's eye perceptions. Digital outcrop models provide an opportunity to extend the field season, and also allow safe (virtual) access to otherwise inaccessible outcrops (e.g., steep cliffs, coastal outcrops) often from remote locations. Digital outcrop models also open up for more quantitative research on, for instance, sedimentology, structural geology or seismic modelling (e.g., Anell et al., 2016; Nesbit et al., 2018).

Digital outcrop models nonetheless also rely on integrating the technological advances in their acquisition and visualisation, with the geological knowledge about the area. We foresee that virtual field trips that use digital outcrop models as input for building storylines that incorporate key geological know-how from a given area provide an opportunity for enhanced digital geoscience teaching – at UNIS but also at other educational institutions. In this contribution, we illustrate this concept by presenting a digital outcrop model of the renowned Festningen section, and a complementary virtual field trip.

2 FESTNINGEN DIGITAL OUTCROP MODEL

2.1 Acquisition and processing

The digital outcrop model of Festningen used structure-from-motion photogrammetry, relying on acquiring a large number of overlapping photographs. The photographs were acquired using a UAV (Mavic 2 Pro, 20MP Hasselblad camera). During acquisition, the maximum drone speed was set to 1 meter/second (i.e., "tripod mode"), and photographs were taken automatically at set time intervals (e.g. 1 photo every 5 seconds ≈ meters). In total, 3757 photographs were aligned using photogrammetric processing steps, including sparse and dense cloud generation, point confidence calculations and confidence-based trimming (3% confidence), meshing and texturing, that resulted in a 7 km long digital outcrop model. Georeferencing relied on the drone-mounted GPS, and the resulting digital outcrop model is well aligned with the regional terrain model (estimated total camera error: 4.12 m). The digital outcrop model offers a pixel resolution of 7.27 mm/pixel and covers 0.67 km2.

2.2 Visualisation and sharing

The Festningen digital model is available for free via the Svalbox geoscience data portal (Senger et al., 2020). The model can be found via the map (www.svalbox.no/map) or via the digital outcrop library (http://www.svalbox.no/portfolio/dom_2020-0001-festningen/). Limits on file size in the SketchFab model repository mean that the model needs to be decimated prior to sharing. We have therefore also shared the model on the V3Geo repository, which allows a compilation of several smaller models into one large one – and in future also model interpretation. The Festningen model on V3Geo is accessible here: https://v3geo.com/model/226

The digitization of Festningen was presented to the broader geoscientific community in January 2021 as part of the (digital) Geological society of Norway Winter Meeting (Senger et al., 2021) – the talk is also available as an online video: https://www.youtube.com/watch?v=7WRJFnhPcoE. Following the success at the winter meeting, an invited digital field trip to Festningen was also organized at the DIGEX 2021 conference in February 2021. A data science paper on the acquisition of the Festningen model is currently in preparation.

3 VIRTUAL FIELD TRIP

Virtual field trips (VFTs) focus on building storylines upon the different data sets available on the Svalbox platform. All VFTs are accessible for everyone via http://www.svalbox.no/virtual-field-trips/. The most recent trips are build within ArcGIS' StoryMaps interface, allowing text to be easily merged with maps, figures, 3D models (including digital outcrop models), 360° imagery, audio snippets and videos.

3.1 Storyline approach

The virtual field trip to Festningen, "Discover the fossilized world of Festningen", is available at:

https://storymaps.arcgis.com/stories/5efc4f9559c348f796e643b965a5b5e9

The VFT focusses on the fauna and flora evolution from the Carboniferous to the Cretaceous, with a chapter for each of the geological eras. The main focus is on how the fauna and flora changed as both the global climate changed and Svalbard drifted northwards through Earth's climatic zones. Concise text is merged with excellent figures, and further information is provided in hyperlinked references and

other sources. The VFT is designed to be followed individually by the audience, and is openly accessible to anyone.

In addition to the "Discover the fossilized world of Festningen" VFT, a general VFT was generated to introduce the geology of Svalbard. This is also available via http://www.svalbox.no/virtual-field-trips/, or the direct StoryMaps link:

https://storymaps.arcgis.com/stories/36cf2935a6754422bba794edeea05b9f

3.2 Educational material

In addition to the VFT, we have generated educational material that can be used by educators worldwide to guide their students in using the Festningen VFT to learn more about the Carboniferous-Cretaceous geological evolution, and what the rock record can tell us about past climate change.

One of the key resources is the excellent traditional field guide by Mørk and Grundvåg (2020) available via https://www.geologi.no/organsisasjon/om-ngf/nyheter-ngf/item/1080-geoguide7

3.3 Further work

Clearly, the Festningen locality is relevant to a broader range of geoscientists rather than just palaeontologists. At the moment, complementary VFTs are being made focussing on the deep-time paleoclimate record in Svalbard, and also on the petroleum systems of Svalbard. Furthermore, efforts are underway to digitize more and more of Svalbard's outcrops and exponentially update the Svalbox database for making the high Arctic outcrops accessible to the general public.

4 SUMMARY

The Digital Festningen project build on a high-resolution digital outcrop model of the renowned Festningen section in western Spitsbergen to generate a virtual field trip to the site. Thematically, the field trip focused on the evolution of fauna and flora within the 300 million year span recorded at Festningen. Both the model and the virtual field trip are openly available via the Svalbox geoscientific data portal (www.svalbox.no).

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