

Digitising the Past: Digital tools to support rock art research and dissemination

Ashely Green^{1,2}, Christian Horn^{1,2}, and Rich Potter^{1,2}

¹ Department of Historical Studies, University of Gothenburg, Renströmsgatan 6, 41255 Gothenburg, Sweden

² Svenskt Hällristningsforskningsarkiv, University of Gothenburg, Renströmsgatan 6, 41255 Gothenburg, Sweden

Abstract

As digital applications in cultural heritage and rock art research continue to grow, resources from the Svenskt Hällristningsforskningsarkiv (SHFA) support such work by providing access to valuable data and tools. The SHFA archive includes data from the 17th century onwards and continually digitises the most recent documentation work. In collaboration with the Gothenburg Research Infrastructure for Digital Humanities we have created a platform to share this data with researchers and the public. The SHFA also provides tools and additional resources to visualise and enhance 3D data with Topography Visualisation Toolbox (TVT, <https://tvt.dh.gu.se/>). This empowers amateurs and professionals working with 3D recordings to improve their results. These visualisations can be used in deep learning workflows which drives the development of AI approaches in archaeology. In this paper, we provide an overview of SHFA's resources, their use in and beyond rock art research, their role in data dissemination, and future developments.

Keywords

Digital archaeology, data dissemination, visualisation, research infrastructure

1. Introduction

Digital approaches to rock art (including petroglyphs and paintings) documentation and analysis have been increasingly used over the last 15 years. From documentation to dissemination, digital methods have continued to improve rock art research and further our understanding of how rock art was created, the people who created it, its role in past societies, and how it can be viewed in modern times [1–3]. Digital methods largely encompass digitisation of traditional rock art documentation, 3D recordings (e.g., photogrammetry and laser scanning), statistical and geostatistical analysis, machine and deep learning, and dissemination platforms. Digital documentation, whether using Reflective Transformation Imaging (RTI), Structure from Motion (SfM) photogrammetry, or laser scanning, allows for additional analysis and extraction of carving patterns and motifs [4–6]. The use of geostatistical and GIS methods allows for both regional and large-scale analysis of rock art distribution and its role or positioning in the landscape [7–9]. Machine learning and deep learning approaches have been used recently in rock art research for both the identification and classification of motifs [10–13]. All of these methods and approaches culminate in the digital dissemination of rock art documentation and associated interpretations and metadata, as rock art requires explanation and interpretation. Digital tools, such as augmented reality (AR) [14], virtual reality (VR), and web-based platforms [15] provide data and access for researchers and the public.

Since 2007, the Svenskt Hällristningsforskningsarkiv (SHFA; Swedish Rock Art Research Archives) has led the development and implementation of digital methods and tools in rock art research. The SHFA has been a research infrastructure at the University of Gothenburg since 2017. It is responsible for documenting, archiving, and disseminating international rock art. Through collaboration and participation in research projects, the SHFA have developed tools, methodologies, and platforms to aid rock art researchers.

This paper presents an overview of the methods and tools from the SHFA and their current applications in rock art research, with a forward look on digital developments and applications beyond rock art research.

Huminfra Conference 2025, Stockholm, 12-13 November 2025.

✉ ashely.green@gu.se (A. Green); christian.horn@gu.se (C. Horn); richard.potter@gu.se (R. Potter)



© 2025 Copyright for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

2. Tools

2.1. TVT

Topography Visualisation Toolbox (TVT; <https://tvt.dh.gu.se/>) is a set of tools that were originally developed to highlight the shallow carvings common in Bronze Age rock art in West Sweden [16]. However, it has continued to have broader applications within the cultural heritage sector. The tool works on similar principles to local relief modelling and difference maps for LiDAR data, but it provides additional features to generate the best possible visualisations of 3D documentation of planar surfaces (see **Figure 2**). It was developed for easy batch processing and user friendliness. This includes the base knowledge needed for both professionals and amateurs as not everyone is accustomed to programming or specialist software such as GIS software [17]. While it would be beneficial, not all archaeology departments employ technicians with coding experience to produce advanced visualisations. For researchers that simply want to produce visualisations, TVT provides an easy-to-use solution with a user-friendly interface, shown in **Figure 1**, to interact with the tools. The app is provided for Windows and MacOS, and the code is open source [18].

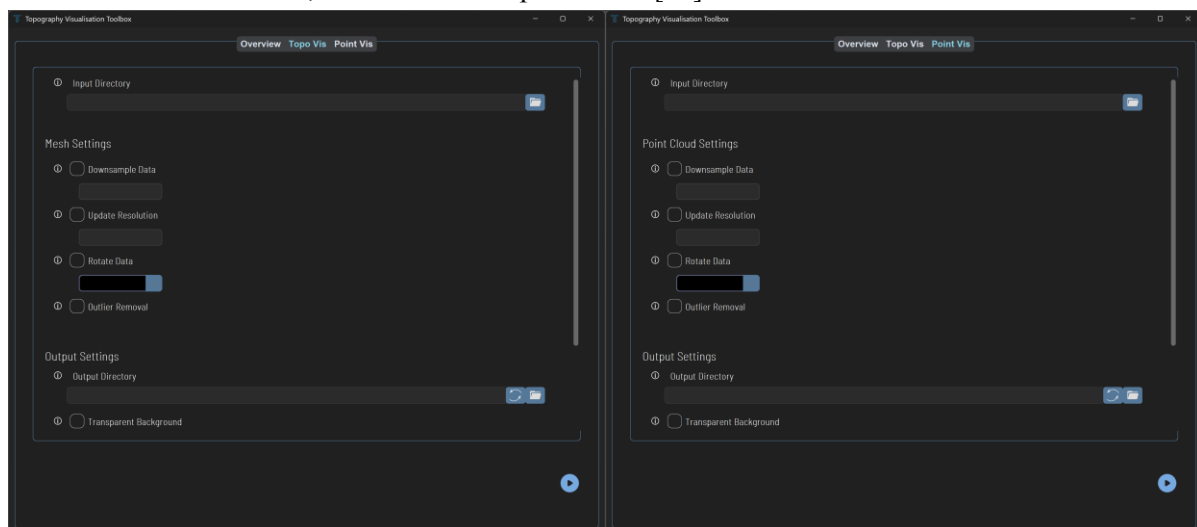


Figure 1: TVT app and tool GUIs for Windows.

At the core of TVT are two visualisation tools called Topo Vis and Point Vis. Topo Vis visualises 3D models, while Point Vis takes point data. Topo Vis includes additional processing steps to transform the mesh geometry into point data. Both use a difference map approach with additional contrast enhancements to highlight small changes in topography, for example carvings that are millimeters deep. Subtle traces like carvings are often obscured by larger changes in the local topography of the rock art panels. Difference maps help to remove larger, overpowering features, and thus, improve the visibility of the carvings. Users can select a range of optional settings, for example, when their data are scaled to metres rather than millimetres, as often occurs in photogrammetry 3D models, then they can use the *Update Resolution* setting to improve the visualisations. The 3D data (meshes or point clouds) must be stored in an input folder which allows for easy batch processing. The tools generate 16 visualisations and a summary of the data and processing settings which are saved automatically. Input and output folder locations can be easily adjusted in the app. The output files are shown in **Figure 2** and they include:

- depth map, texture map, normal map, derivative map
- topographic maps at two scales in greyscale and colour
- topographic maps with contrast enhancement using scikit-image's Contrast Limited Adaptive Histogram Equalization (CLAHE) function at two scales in greyscale and colour
- topographic maps which are a blend between the topographic map and enhanced topographic map at two scales in greyscale and colour

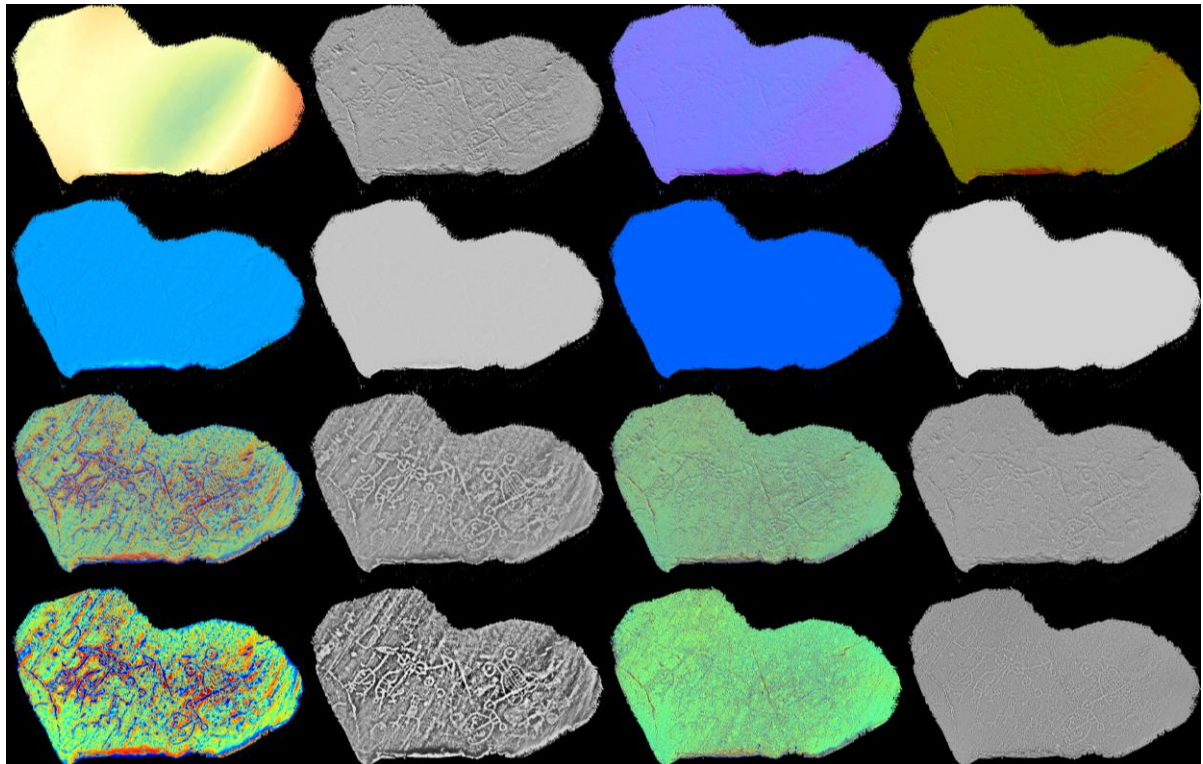


Figure 2: Example of TVT visualisations of a laser scan of the rock art panel Brastad 18:1. These visualisations demonstrate the potential uses of TVT to highlight shallow, small, and eroded carvings which are difficult to see in the original model. Original model by Ellen Meijer, visualisations by Ashely Green.

Depending on the data and the documented surface some of these visualisations will be more useful than others. The user will have to decide which visualisation(s) shows features in their data best. Processing the same data using the same settings in the same version of TVT will produce consistent results.

2.2. Tools for Deep Learning

Artificial intelligence (AI) approaches are growing in archaeology [19]. Rock art studies and other fields make use of geospatial data for these approaches, as such it is important to provide methods to generate training data in a streamlined workflow and subsequently test and understand the limits and challenges of these data in AI approaches. A toolbox for ArcGIS GIS software was developed to improve the workflow for exporting annotated data in YOLO OBB format [20] directly from the software. RockArtAITools [21] includes a script tool which tiles images and exports the clipped bounding box annotations. The tool allows users to draw their annotations directly in ArcGIS or import vectors from external sources, such as a Heritage Environment Record or national heritage board. The minimum bounding rectangle of the vector annotations are used in processing, so users can provide either rectangular bounding boxes or defined polygons in the tool. This tool builds on the existing annotation export tools provided by Esri, and more functionalities will be added for further AI applications.

2.3. SHFA Website and Database

The SHFA first launched a web platform around 2010. The updated SHFA database and website were developed in collaboration with the Gothenburg Research Infrastructure in Digital Humanities (GRIDH) in 2022 and officially launched in 2023. To date, the publicly available data includes nearly 27000 images and over 100 3D models from Sweden, Norway, Denmark, Spain, and Italy.

Development of the updated website was planned for four modules, with the first three completed as of 2024 and the final module available in late 2025.

The SHFA web resource is comprised of a PostgreSQL/PostGIS relational database in the Django framework and a website. REST APIs are used to retrieve data for the frontend. All images and 3D models in the database are related to a site, and associated 3D models and visualisations are grouped using a common identifier. Metadata stored for images includes:

- Image identifiers (numeric id and uuid)
- Location of the higher resolution IIF display image
- Site identifiers and the site location information (e.g., coordinates, municipality, country)
- Group of panels or region an image belongs to
- Collection of images based on a common institution, region, or creator
- Original creator(s) and their affiliation(s)
- Year the image was taken or created
- Image type (e.g., photo, 3D visualisation, orthophoto, night photo) and subtype for visualisations
- Keywords to describe the motifs and image content, their associated terms in the Getty Art & Architecture Thesaurus controlled vocabulary, and whether the keyword describes a figurative motif
- Dating tags to describe archaeologists' interpretations of the motifs
- Visualisation group identifier

In addition to the metadata recorded for images, for 3D models we also record:

- Method
- Camera specifications, including focal length and crop factor, for SfM models
- Date and weather conditions for fieldwork
- Model dimensions, vertices, faces, and number of photos (for SfM models)
- Geology of the panel

The main website [22] uses the Vue3 framework, while the 3D model viewer [23] is separate from the main website to preserve compatibility with the 3DHOP library [24]. All resources are provided in Swedish and English. The main website (<https://shfa.dh.gu.se/>) is responsive and uses the split.js library to display three panels of data which increase in detail from left to right, as in **Figure 3**. The first panel contains the three search options – a free-text search, and advanced search, and a geographic/map search using OpenLayers [25]. The middle panel contains the search results. Once one of the search results is selected, the third panel is displayed.

The third panel contains the image metadata and, if available, a description of the site from the national heritage board or similar. Many fields in the metadata section are also clickable to trigger a new free-text search. All images that have an associated 3D model are indicated with a '3D' icon on the thumbnail in the search results gallery and a link to the model viewer is provided in the image metadata panel.

The 3D models are displayed in GRIDH's Multimodal Viewer [23], which uses open source libraries such as 3DHOP [24], Openseadragon [26], and OpenLime [27]. The model's metadata is displayed alongside the interactive 3DHOP and IIF viewer, as in **Figure 4**. Users can change the lighting, navigate the model, measure the model, and, where available, turn the texture on/off.

Users can share a link to specific position in the 3D model viewer, for example to allow colleagues to easily discuss the same motif. Users can also share links to individual images and for a free-text search. Both the image and 3D model metadata sections include a suggested citation to allow users to easily align with the CC-BY copyright on all content. Images are downloadable and retain authorship, date, and id information in the filename.

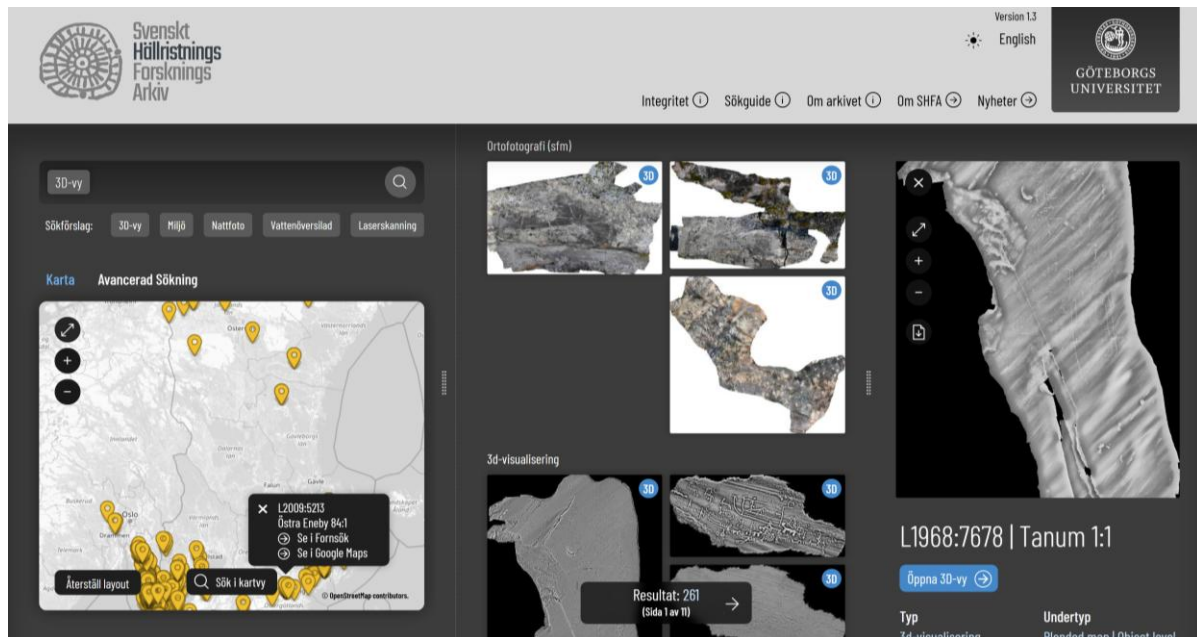


Figure 3: The SHFA website displaying the three-panel layout, highlighting the free-text and map search options, availability of 3D models, and the Openseadragon [26] IIIF image viewer.

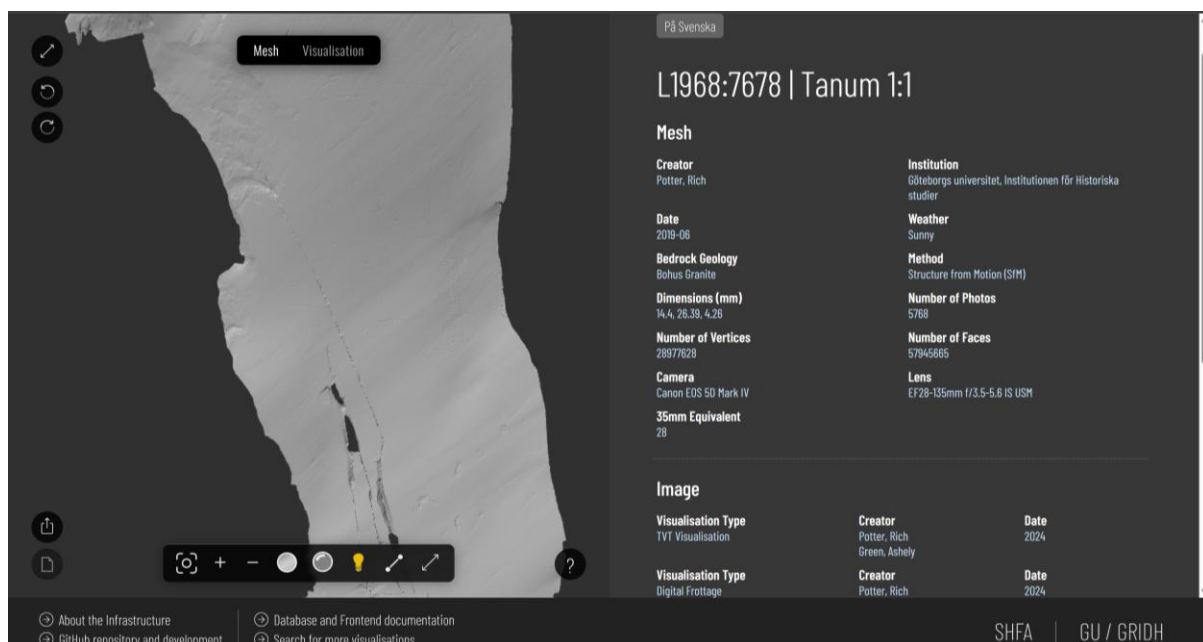


Figure 4: An example of the 3D model viewer and associated metadata.

3. Research & Impact

The SHFA and the tools it developed continue to support high-quality rock art research and other studies in which rock art serves as data. TVT enables researchers to produce visualisations of their 3D data quickly. Even considering the niche nature of TVT, it has had 172 downloads since 2024. TVT has been used by several other research groups with outputs published since 2022. The tools have been used successfully in research on Swedish, Norwegian, and US rock art, Iberian megaliths, Mesolithic and Early Neolithic material culture, Bronze Age cairns, for example. In these case studies, TVT not only provided material for research, but also the images to communicate the results to the readership. The visualisations offer a low-cost, readable format for displaying the data in publications as storage space is still a considerable cost factor and few publishers allow for embedding the full high-resolution 3D models in publications.

SHFA's main website aims to support research and dissemination on a broader scale than a tool aimed at the narrower segment of people engaging in 3D documentation. Within this scope, the launch of the new website can be seen as a huge success when considering what has been achieved since then. Beyond traditional rock art research, SHFA has supported such socially relevant research as difficult heritage studies, pedagogy, and library and information science among others [28–30]. It also has a significant role in aiding higher education by supporting theses on BA, MA, and PhD level.

Matomo is also used for analytics on the SHFA website. From this we can note the number of visits, interactions with the site, approximate location of visitors, and keyword search rates. As of September 2025, the new website has had over 30000 visits originating from 105 distinct countries. Visitors performed over 43000 searches. The top five search terms were in our suggested searches (skepp (ship), nattfoto (night photo), människofigur (human figure), djur (animal), hållristningsmiljö (rock art environment)), so we will implement randomized suggestions in 2025 to improve the user experience when revisiting the site. The statistics demonstrate consistent use of the SHFA archive and a growing use internationally.

Another measurement of the impact of the SHFA website and its tools is publications making use of these opportunities. For this, it should be kept in mind that the CC license under which we operate only demands that the publications cite the author of the images or documentations that are published. While we encourage authors to acknowledge SHFA in their publications, we depend on them doing so voluntarily and in a manner that can be tracked by search engines. Moreover, not all publications can be tracked. In total, at least 24 publications name TVT as a tool that was used since its first publication under its original name ratopoviz (rock art topography visualization) in 2022. This is a great achievement considering that TVT is a specialist tool without a large advertising footprint. SHFA has been mentioned since the launch of the new website in at least 80 publications. There is an increase of 50% from 2023 (22) to 2024 (33). While we cannot and should not expect a consistent increase in publications year-on-year, so far in 2025 we were able to identify 25 publications with SHFA material. These publications include at least 28 articles in scientific journals, 21 chapters in edited volumes, 16 theses, six monographs, five edited volumes, and four other publications such as fieldwork reports.

4. Discussion and Conclusion

The tools and platforms provided by the SHFA emphasise user-friendliness. Thereby lowering entry bars to access, for example, powerful visualisations for 3D data, deep learning in a GIS environment, or data. This benefits and furthers rock art research and the wider cultural heritage sector. By offering open-source tools and images under a less restrictive CC-BY license we aim to continue supporting the development of digital methods and workflows for rock art research. Further development of the SHFA website will focus on data summary tools and integration of external data, such as palaeoshoreline models from Sveriges geologiska undersökning (SGU) and site descriptions for international site (e.g., from Riksantikvaren for Norwegian panels). We will continue to share our data with Riksantikvarieämbetet and ARIADNEplus. These features will enhance the ability for researchers to use data hosted by SHFA in their projects and combine it with other datasets.

Acknowledgements

This work was funded by Riksbankens Jubileumsfond (grant no. IN18-0557:1, M21-0018) and the Swedish Research Council (grant no. 2020-01097, 2020-03817). We extend our thanks to all individuals working at the SHFA for supporting the progress that we have made. We also thank Jonathan Westin, Tristan Bridge, Aram Karimi, and Siska Humlesjö at GRIDH for their work in developing the SHFA database and website.

References

- [1] M. Carrero-Pazos, R. Döhl, J.J. van Rensburg, P. Medici, A. Vázquez-Martínez, Rock Art Research in the Digital Era: Case Studies from the 20th International Rock Art Congress IFRAO 2018, Valcamonica (Italy), 2022. <https://doi.org/10.30861/9781407360119>.

- [2] A. Green, C. Horn, Svenskt HällristningsForskningsArkiv Launches New Website, *Curr. Swed. Archaeol.* 32 (2024) 236–239. <https://doi.org/10.37718/CSA.2024.17>.
- [3] C. Horn, M. Peternell, J. Ling, A. Green, R. Potter, Rock Art in Three Dimensions: Comments on the Use and Possibilities of 3D Rock Art Documentation, in: M. Hostettler, A. Buhlke, C. Drummer, L. Emmenegger, J. Reich, C. Stäheli (Eds.), *3 Dimens. Digit. Archaeol. State---Art Data Manag. Curr. Chall. Archaeol. 3D-Doc.*, Springer International Publishing, Cham, 2024: pp. 87–108. https://doi.org/10.1007/978-3-031-53032-6_6.
- [4] M. Díaz-Guardamino, Rock Art Technology, Digital Imaging and Experimental Archaeology: Recent Research on Iberian Late Bronze Age Warrior Stelae, *Complutum* 34 (2023) 145–162. <https://doi.org/10.5209/cmpl.85238>.
- [5] R. Potter, R. Rönnlund, J. Wallensten, An evaluation of Substance Painter and Mari as visualisation methods using the Piraeus Lion and its runic inscriptions as a case study, *Herit. Sci.* 11 (2023) 226. <https://doi.org/10.1186/s40494-023-01071-7>.
- [6] M. Carrero-Pazos, B. Vilas-Estévez, A. Vázquez-Martínez, Digital imaging techniques for recording and analysing prehistoric rock art panels in Galicia (NW Iberia), *Digit. Appl. Archaeol. Cult. Herit.* 8 (2018) 35–45. <https://doi.org/10.1016/j.daach.2017.11.003>.
- [7] T. Barnett, J. Valdez-Tullett, L.M. Bjerketvedt, F. Alexander-Reid, M. Hoole, S. Jeffrey, G. Robin, A Multiscalar Methodology for Holistic Analysis of Prehistoric Rock Carvings in Scotland, *Herit. Sci.* 12 (2024) 86. <https://doi.org/10.1186/s40494-024-01183-8>.
- [8] J.L. Schaefer, A comparison of rock art and bluff shelter spatial distributions in the eastern Arkansas Ozarks, Southeast. *Archaeol.* 41 (2022) 1–15. <https://doi.org/10.1080/0734578X.2021.2017636>.
- [9] M.L. Wienhold, D.W. Robinson, GIS in Rock Art Studies, in: B. David, I.J. McNiven (Eds.), *Oxf. Handb. Archaeol. Anthropol. Rock Art*, Oxford University Press, 2019: p. 0. <https://doi.org/10.1093/oxfordhb/9780190607357.013.12>.
- [10] J. Kowlessar, J. Keal, D. Wesley, I. Moffat, D. Lawrence, A. Weson, A. Nayinggul, Reconstructing rock art chronology with transfer learning: A case study from Arnhem Land, Australia, *Aust. Archaeol.* 87 (2021) 115–126. <https://doi.org/10.1080/03122417.2021.1895481>.
- [11] A. Jalandoni, Y. Zhang, N.A. Zaidi, On the use of Machine Learning methods in rock art research with application to automatic painted rock art identification, *J. Archaeol. Sci.* 144 (2022) 105629. <https://doi.org/10.1016/j.jas.2022.105629>.
- [12] C. Horn, O. Ivarsson, C. Lindhé, R. Potter, A. Green, J. Ling, Artificial Intelligence, 3D Documentation, and Rock Art—Approaching and Reflecting on the Automation of Identification and Classification of Rock Art Images, *J. Archaeol. Method Theory* 29 (2022) 188–213. <https://doi.org/10.1007/s10816-021-09518-6>.
- [13] C. Horn, A. Green, V.W. Skärström, C. Lindhé, M. Peternell, J. Ling, A Boat Is a Boat Is a Boat...Unless It Is a Horse – Rethinking the Role of Typology, *Open Archaeol.* 8 (2022) 1218–1230. <https://doi.org/10.1515/opar-2022-0277>.
- [14] J. Westin, A. Råmark, C. Horn, Augmenting the Stone: Rock Art and Augmented Reality in a Nordic Climate, *Conserv. Manag. Archaeol. Sites* 23 (2021) 258–271. <https://doi.org/10.1080/13505033.2023.2232416>.
- [15] A. Green, T. Bridge, C. Horn, S. Humlesjö, A. Karimi, J. Ling, J. Westin, Accessing centuries of documentation - Resources to improve access to Swedish rock art documentation and metadata, in: *Proc. Huminfra Conf. HiC 2024*, Linköping University Electronic Press, Linköping, 2024: pp. 154–160. <https://doi.org/10.3384/ecp205021>.
- [16] A. Green, C. Horn, R. Potter, Topography Visualisation Toolbox: Project and Software Summary, (2025). <https://tvt.dh.gu.se/> (accessed August 20, 2025).
- [17] R. Potter, D. Pitman, L. Shaw, C. Horn, Everyone Has to Start Somewhere: Democratisation of Digital Documentation and Visualisation in 3D, *Open Archaeol.* 11 (2025) 20250054. <https://doi.org/10.1515/opar-2025-0054>.
- [18] A. Green, O. Ivarsson, R. Potter, C. Horn, Topography Visualisation Toolbox (TVT), (2025). <https://doi.org/10.5281/zenodo.15479454>.
- [19] S.H. Bickler, Machine Learning Arrives in Archaeology, *Adv. Archaeol. Pract.* 9 (2021) 186–191. <https://doi.org/10.1017/aap.2021.6>.
- [20] G. Jocher, J. Qiu, Ultralytics YOLO11, (2024). <https://github.com/ultralytics/ultralytics>.

- [21] A. Green, R. Potter, C. Horn, RockArtAITools, (2025). <https://arcg.is/191Gjn1> (accessed April 30, 2025).
- [22] J. Westin, T. Bridge, A. Karimi, A. Green, S. Humlesjö, SHFA Frontend + Backend, (2025). <https://github.com/gu-gridh/shfa-frontend> (accessed October 9, 2025).
- [23] J. Westin, T. Bridge, A. Green, J. Beck, gu-gridh/multimodal-viewer, (2025). <https://github.com/gu-gridh/multimodal-viewer> (accessed August 20, 2025).
- [24] M. Potenziani, M. Callieri, M. Dellepiane, M. Corsini, F. Ponchio, R. Scopigno, 3DHOP: 3D Heritage Online Presenter, *Comput. Graph.* 52 (2015) 129–141. <https://doi.org/10.1016/j.cag.2015.07.001>.
- [25] openlayers/openlayers, (2025). <https://github.com/openlayers/openlayers> (accessed August 20, 2025).
- [26] I. Gilman, A. Kishore, C. Thatcher, M. Salsbery, A. Vandecreme, T. Pearce, OpenSeadragon, (2024). <https://github.com/openseadragon/openseadragon> (accessed August 20, 2025).
- [27] cnr-isti-vclab/openlime, (2025). <https://github.com/cnr-isti-vclab/openlime> (accessed August 20, 2025).
- [28] G. Andersson, E. Bylin, Vetenskaplig publicering inom humaniora: En jämförelse av två fördelningsmodeller, 2024. <https://urn.kb.se/resolve?urn=urn:nbn:se:hb:diva-32493> (accessed September 4, 2025).
- [29] M. Legnér, Difficult Heritage or Objects of Science?: The Material Legacy of Nazi German Rock Art Research in Sweden, in: P.B. Larsen, M. Křížová (Eds.), *Eur. Univ. Legacies Probl. Herit. Contemp. Pract.*, Edinburgh University Press, Erscheinungsort nicht ermittelbar, 2025: pp. 197–220.
- [30] L. Almqvist Nielsen, Prehistoric history in Swedish primary school education: pupils' expression of empathy after visiting a cultural heritage site, *Educ. 3-13* 53 (2025) 378–392. <https://doi.org/10.1080/03004279.2023.2191631>.