NOMINATION OF MØNS KLINT

FOR INCLUSION ON THE UNESCO WORLD HERITAGE LIST

RESPONSE LETTER AND SUPPLEMENTARY MATERIAL, FEB. 2025

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View along the cliff profile, after a series of cliffslides in january 2024. On top a glimse of the GeoCenter Møns Klint

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Peninsula of chalk, created by the 2024 cliffslide

RESPONSE LETTER

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The IUCN letter regarding the interim evaluation of the nomination of Møns Klint for inclusion on the UNESCO World Heritage List has been well received. The letter highlighted the need for supplementary information, to further assess the site's eligibility under specific criteria, and to improve management planning. Key requests include expanding the comparative analysis, reviewing the boundaries, and strengthening the management and monitoring strategies.

In summary, we provide the following outline for our response in accordance with the recommendations and layout of the IUCN query:

A. Values under Criterion (viii) (see page 9)

1: Provide a detailed analysis and background for the comparative analysis, expanding beyond Northern Hemisphere Pleistocene sites (i.e. >2.4 million years) to include regions like Greenland, Svalbard, the Himalayas, and the Andes (enclosed in Appendix 1)
2: Address the nominated property as a three-dimensional glaciotectonic complex, not just in two-dimensional terms (enclosed in Appendix 1)
3: Submit geological and geomorphological maps of Møns Klint, highlighting three-dimensional features and supporting site monitoring (enclosed in Appendix 1)

B. Boundaries of the Nominated Property (see page 10)

4: Provide a map with revised boundaries and, as a consequence, propose a new and larger property based on the scientific boundaries of the glaciotectonic complex in its entirety
5: Provide a revised description of the new property and buffer zone, including potential effects on the justification and integrity of the site (enclosed in Appendix 2)

C. Protection and Management (see page 12)

6: Provide scientific data on chalk cliff erosion and climate change projections (Appendix 3)
7: Develop and provide a plan for long-term monitoring of erosion (Appendix 3)
8: Confirm the current and future deployment of geoscientists for site management (page 12)
9: Include the Geological Survey of Denmark and Greenland in the Scientific Advisory Board as well as representation of this Advisory Board to the World Heritage Steering Committee (page 14)
10: Provide financial projections and commitments for long-term management of the property and buffer zone, including a timeline, objectives, and roadmap for actions (page 12-14 and Appendix 3)

A. Values under Criterion (viii)

This request required an update of the comparative analysis, which has been accomplished by including three additional sites to the analysis, as well as a spatial dimension to the comparison of the nature and scale of sites (Criteria A). OBS: The scale of the proposed property of Møns Klint uses the new and enlarged proposed property of the site (see B. Boundaries of the nominated property page 3). Please find the updated analysis enclosed in Appendix 1, which has the following content:

The rationale behind our comparative analysis
Distribution of glaciotectonic complexes across the Earth
Pre-Pleistocene glaciations (>2.4 million years)
Glaciers in the Himalayas
Glaciotectonic complexes in Greenland

Table 2: List of pre-selected sites for comparative analysis (updated with three new sites)
Table 3: Criteria A – Nature and scale of sites (updated with an extra column: the spacial extent)
Table 4: Criteria B - Quality (integrity) of sites (updated with three new sites)
Table 5: Criteria C – Scientific impact and value of sites (updated with three new sites)
Table 6: Cumulative score of the criteria A-C
- Updated with the three newly added sites (Holmstrømbreen/Lago del Toro and Tihemboka), as well as the new scores on criteria A, including the spatial extent/perimeter.
- Across all criteria in the updated comparative analysis, Møns Klint still achieve the best score with a maximum of 36 point, with no change in the scientific justification as a result.

Descriptions of the three newly added sites to the comparative analysis
-Site 18. Holmstrømbreen, Svalbard
-Site 19: Lago del Toro ice lobe, Chilean southern Patagonia
-Site 20: Tihemboka Area, Murzuq Basin, Southwest Libya

Three-dimensional extent of Møn glaciotectonic complex
- References

Geological and geomorphological maps of Møns Klint
- 3D diagram showing Møns Klint (new LIDAR model and orthophoto) with DEM from terrain.
- Borehole/pre-quaternary principal diagram
- Soilmap and geomorphological map
- Comparison between Puggaards 1851 handheld drawing of Møns Klint and a new LiDAR recording (November 2024) of the cliff shown as orthophotographs of the same area.

B. Boundaries of the Nominated Property
Following the Field Mission and the investigations requested in the IUCN report, we have come to the conclusion that a revision of the boundaries - and an extension of the property of Møns Klint as UNESCO World Heritage - will improve the scientific completeness and integrity of the site.

We hereby propose a new property extending all the way to the Borre depression, and with a larger and more homogeneous buffer zone. Whereas the originally proposed property was concentrated around the most prominent features of Outstanding Universal Value (the exposed cliff profile and tallest marginal hill systems), the proposed new property encompass the entire glaciotectonic complex of Høje Møn, including all it's features.

The new property proposal (fig. 1, page 11) respects and aligns with the soil map limits for sediment types (fig. 2, page 13), and include important stratigraphical localities for quaternary deposits (green dots).

The industrial area of Klintholm Havn is excluded from the property, but included in the buffer zone, which now follows the Borre depression and extends towards the adjoining glaciotectonic areas on central Møn. The marine part of the buffer zone continues to follow the coastline one kilometer out into the Baltic Sea.

Size of the proposed new property: 4123 ha
Size of the proposed new buffer zone: 3628 ha
Total size of property and buffer zone: 7751 ha

Estimated population located within
The new nominated property: 471
The new buffer zone: 342

Please find an updated description of the proposed property, including the minor changes to the draft statement in Appendix 2, with the following content:

Textual description of the boundary(ies) of the nominated property
Criteria under which property is nominated (criteria viii)
Draft Statement of Outstanding Universal Value
a) Brief synthesis (*unchanged*)
b) Justification for Criteria (*unchanged*)
c) Statement of Integrity (*minor change marked in italic*)
e) Requirements for protection and management (*changes in italic)*

Summarized assessment of the new property
We find that the revised boundaries and the larger property help improve the integrity of the site as a - complete - glaciotectonic complex, even if the OUV and the Justification of the site is unchanged. Also, the larger buffer zone provides a more homogeneous protective zone around the new property.

Please find maps of the proposed new property and its relation to the buffer zone and all the protective designations in the area, enclosed in Appendix 4. All protective designations are the same as in the original Nomination Dossier.

Fig. 1. Map of the proposed new nominated property and buffer zone of Møns Klint

C. Protection and Management

A more detailed plan for the organization and level and source of finance has been conducted for the management of the Møns Klint site, following the requests of the IUCN. Besides from the following details the original Management Plan submitted with the Nomination Dossier, is still considered valid - however a new composition of the Steering Committee and the Scientific Advisory Board has been made. The revised boundaries and larger property will not propose any larger changes or challenges concerning the management or protection of the site.

Financial projections and commitments

Vordingborg Municipality has committed to employ a site-manager for the new UNESCO World Heritage Site, and to provide 335.000 EURO pr. year from 2025-2029, to run the new UNESCO secretariat, which will be combined with the existing UNESCO Biosphere Reserve of Møn/Nyord.

Of these fundings, 200.000 Euro are dedicated specifically to the World Heritage management, including salary for the Site Manager and a corresponding administrative staff member. They also cover the management obligation activities, centered around the five C's (credibility, communication, capacity building, conservation and community), as described in the Management Plan, annexed to the original Nomination Dossier.

WORLD HERITAGE BUDGET	Pr. year: 2025-2029
Site Manager	90,000 Euro
Adm. Staff member	40.000 Euro
Management activities	70.000 Euro
TOTAL	200,000 Euro

TIMELINE OF OBJECTIVES	YEAR
Employment of Site Manager/adm. staff Establishment of Geophysical Baseline for new monitoring strategy **APPENDIX 3**	2025
Running of Geophysical and Seismic monitoring - Year 1 New Strategic-Physical Action Plan for infrastructure on Høje Møn	2026
Running of Geophysical and Seismic monitoring - Year 2 New World Heritage Exhibition	2027
Conclusive report from the first three years of Geophysical and Seismic monitoring New Management Plan (2029-2032)	2028

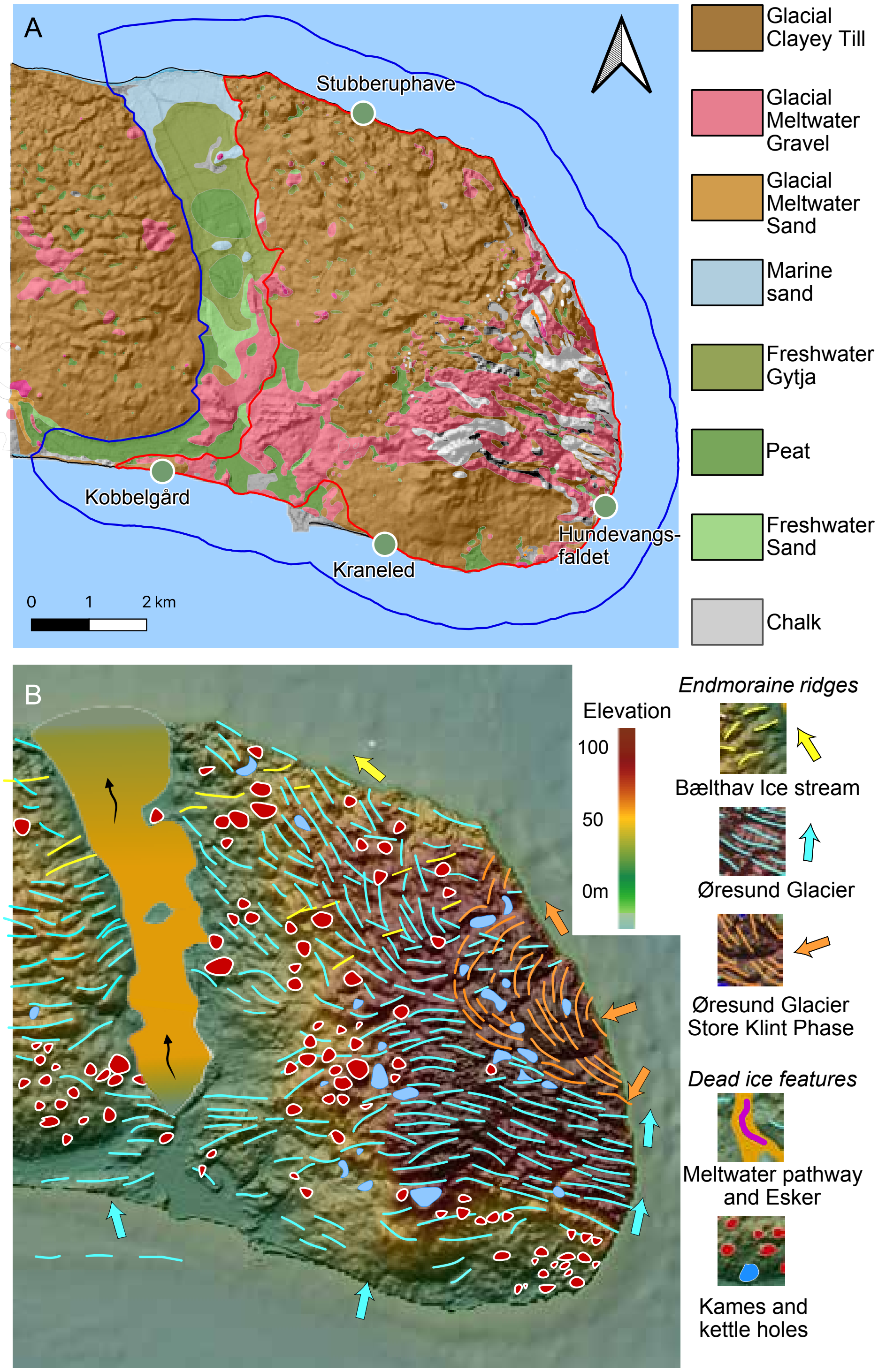

Fig. 2. The new proposed property on soil map (top) and geomorphological map (bottom)

Geoscientists in site management and future lines of action
The future site-manager will be employed on a scientific background, as the person needs to have qualifications in geology and/or geo-heritage. The site-manager will be in close contact with current geological capacity within the Municipality and the Danish Nature Agency, regarding management and protection of the site. The site-manager will moreover have direct access to specialized scientific knowledge on glaciotectonics, from the Scientific Advisory Board, which will be represented in the Steering Committee by Kurt H. Kjær, who has been responsible for conducting the comparative analysis and the glaciotectonic research.

New composition of Steering Committee
Mikael Smed, Mayor of Vordingborg Municipality
Peter Scavenius, Chairman of Geocenter Møns Klint
Signe Marie Rohde, Danish Agency for Culture and Palaces
Jane Skov Lind, State Forester, Danish Nature Agency
Carl Gustav Scavenius, Owner of Klintholm Estate
Kurt H. Kjær, University of Copenhagen, Globe Institute
Kathrine Olldag, Head of Center for Culture, Leisure and Development, Vordingborg Municipality
Nils Natorp, CEO, Geocenter Møns Klint
Eliza Jarl Estrup, Nomination coordinator

The Geological Survey of Denmark and Greenland (GEUS) has furthermore been integrated in the Advisory Board, and they are already deployed in conducting a new and comprehensive strategy for monitoring the conservation status of Møns Klint, as part of a larger project monitoring landslides and the erosional effects of climate change.

New composition of Scientific Advisory Board
Eliza Jarl Estrup, Geocenter Møns Klint
Jane Skov Lind, Danish Nature Agency, Storstrøm
Kurt H. Kjær, University of Copenhagen, Globe Institute
Kristian Svennevig, Geological Survey of Denmark and Greenland, GEUS
Nicolaj Larsen, University of Copenhagen, Globe Institute
Michael Houmark-Nielsen, University of Copenhagen, Globe Institute
Kristian K. Kjeldsen, Geological Survey of Denmark and Greenland, GEUS

Plan for long-term monitoring of erosion
A new strategy for establishing a base-line study of the cliff profile and for monitoring erosion and climate change has been planned in cooperation with the Geological Survey of Denmark and Greenland (GEUS). The plan is already partly funded and in its initial stage, and will be conducted by GEUS from 2025-2027. The strategy is enclosed in Appendix 3, which has the following content:

Scientific data on chalk cliff erosion and climate change projections
- References

Strategy for Monitoring Møns Klint Glaciotectonic Complex
- Long-term vision and objective
- Risk factors and threats
- Key monitoring indicators
- Monitoring methods
- Data collection and reporting
- Estimated costs

Summary and last remarks
Following the queries of the IUCN report, the proposed boundaries of the nominated property of Møns Klint have been revised, with a substantially larger property and a more homogeneous buffer zone as a result. The comparative analysis has been updated, adding perimeter and spatial extent as a comparative feature under criteria A, and also adding three new additional sites, representing two sites on the Southern Hemisphere and one on Svalbard to the analysis.

The updated comparative analysis, combined with the geomorphological map and the soil map (all presented in Appendix 1), has convinced us that the larger property and the complete glaciotectonic complex, to a large degree, improves the integrity of the site, while the justification of the site is substantially unchanged.

Møns Klint (still) represents an outstanding and superlative example of glaciotectonic mountain-building, that illustrates the profound effects of lowland glaciers on Pleistocene landscapes.

Mikael Smed

Chairman of Steering committee and Mayor of Vordingborg Municipality

The remains of the iconic viewpoint - Forchhammers Pynt, which crashed into the Baltic Sea in January 2024

APPENDIX 1

COMPARATIVE ANALYSIS VERSION 2.0.

COMPARATIVE ANALYSIS VERSION 2.0.

The rationale behind our comparative analysis

Glaciotectonic complexes and associated landforms are widespread across the Earth, and particularly well known from areas impacted by Pleistocene ice sheets (<2.4 million years). Glaciotectonic complexes are constructed through interaction between advancing glaciers and underlying sediments, resulting in deformation and structural changes. Their distribution is crucial for understanding past climate-ice interactions and environmental conditions, yet a major limitation is the absence of a comprehensive inventory of these features. Without a standardized catalog, researchers rely on localized data or ad hoc site selection, leading to potential biases and hindering systematic comparative analyses. To address this gap, we have proposed the Møns Klint to be the world's leading type-section when it comes to glaciotectonic complexes.

It has been customary practice among researchers to extract information from established international textbooks, synthesis articles, and conference proceedings, which leverage decades of peer-reviewed research to identify well-documented sites, ensuring credible and objective selection. All of which is essential for building a reliable dataset for comparative studies.

However, to achieve the highest standards for a World Heritage nomination, the Møns Klint glaciotectonic complex must be evaluated within a global context. Its outstanding universal value should be compared to similar sites of Pleistocene and Pre-Pleistocene (>2.4 million years) origin, that showcase glacial landforms and large-scale glaciotectonic complexes. This will encompass a diverse range of locations, including both onshore and offshore settings, to highlight Møns Klint's unique contributions to our understanding of one of Earth's most spectacular glacial processes. Establishing its global significance will underscore the site's role in advancing knowledge of glacial-tectonic processes and their impact on shaping glacial landscapes worldwide. We have therefore broadened our comparative analysis with three additional sites whereby addressing the southern hemisphere as well as Pre-Pleistocene glaciations. Thus, evaluating the significance of glaciotectonic structures globally and through time underline the reason for our choice of sites in the comparative analysis.

Distribution of glaciotectonic complexes across the Earth

The extent and preservation of glaciotectonic complexes between the hemispheres are largely influenced by the contrasting proportions of land and ocean at high latitudes. In the Northern Hemisphere, a significant portion of the landmass falls within the latitudinal zones affected by Pleistocene glaciation. Extensive lowland areas in North America, Europe, and northern Eurasia provided suitable substrates for glaciotectonic deformation, as the large Laurentide and Eurasian ice sheets, repeatedly advanced and retreated. These predominantly warm-based ice sheets, capable of deforming soft, unconsolidated sediments through basal sliding and subglacial meltwater processes, led to the development of well-preserved glaciotectonic structures, including fold-and-thrust ridges and push moraines. The abundance of exposed land that avoided the postglacial sea level rise allowed these features to remain relatively undisturbed by post-glacial processes, facilitating their long-term preservation and study.

In contrast, the Southern Hemisphere exhibits a markedly different land-ocean distribution, with a greater proportion of ocean covering the high-latitude zones affected by glaciation. The Antarctic Ice Sheet dominates the southern polar region, but its primary influence extends over the surrounding Southern Ocean rather than continental landmasses. Furthermore, the prevalence of cold-based ice in Antarctica, which primarily moves through internal deformation rather than basal sliding, results in minimal interaction with and deformation of the underlying substrate, reducing the formation of glaciotectonic complexes. The geological composition of the Southern Hemisphere also limits the extent of glaciotectonic deformation. Regions such as the Andes and Antarctica are characterized by resistant bedrock, which is less susceptible to deformation compared to the softer, more erodible sediments of the Northern Hemisphere lowlands. Additionally, the smaller glaciated land areas in the south have been subject to significant post-glacial erosion and reworking due to tectonic activity, fluvial processes, and marine transgressions, further diminishing the visibility and preservation of glaciotectonic features.

In summary, the greater abundance and preservation of terrestrial glaciotectonic complexes in the Northern Hemisphere is attributed to its favorable land-sea distribution, which provided extensive lowland areas conducive to glacial deformation and post-glacial preservation. In contrast, the Southern Hemisphere's dominance of ocean-covered areas at high latitudes, coupled with resistant geological substrates and cold-based ice dynamics, has resulted in fewer, smaller, and less well-preserved glaciotectonic complexes.

To some extent, the unequal distribution of glaciotectonic complexes between hemispheres is compensated by the presence of submarine glacial landforms. A comprehensive global analysis of submarine glacial landforms has produced a detailed inventory of well-preserved features (Dowdeswell et al. 2016). These landforms include Pleistocene terminal moraines, which often host glaciotectonic complexes and are typically located distally on continental shelves and in trough-mouth settings. These features formed along the margins of grounding ice shelves, tidewater glaciers, and terrestrial ice streams, where the interaction between ice and substrate led to the development of distinctive geomorphological structures. Postglacial sea-level rise has inundated these ice-marginal landforms, submerging them under ocean waters. This presents significant challenges for direct, hands-on field studies, as their underwater location limits physical accessibility and detailed examination using traditional geological methods. The logistical complexities and technological demands of studying these submerged features often result in them being considered less relevant in comparative studies of potential World Heritage sites. Despite these challenges, submarine glacial landforms are of critical importance to the broader understanding of glacial dynamics and geomorphology. They offer unique insights into the behavior of ice sheets in marine environments and the interactions between glaciers and ocean systems, including processes such as grounding-line retreat, sediment deposition, and subaqueous erosion.

Pre-Pleistocene glaciations (>2.4 million years)

Throughout Earth's history, polar and even global glaciation events have occurred multiple times (Hambrey & Harland 1981). The most well studied examples are the Neoproterozoic and Late Paleozoic glacial deposits and landforms, dispersed worldwide due to plate tectonic movement, offer valuable insights. These ancient glacial episodes are primarily evidenced by subaqueous, deep-water marine sediments. They may include diamictites containing outsized clasts and glacially sculpted drop stones, alongside with mass flows and turbidites sliding off continental shelf breaks. In contrast, descriptions of wave-influenced shallow water marine and fluvial coastal plain deposits, which often interbedded with one another, are less frequent.
Small-scale glaciotectonic deformations related to glacier dynamics and diamictites overlying pre-glacial rocks with glacially striated pavements are also reported. Subglacial morphologies such as tunnel valleys and mega-scale glacial lineation are occasionally documented (Eyles & Januszczak 2004; Eyles 2008). Proglacial deposits showing evidence of permafrost, wind abrasion, and infilled meltwater rivers are also sporadically noted (Le Heron et al. 2022; Soreghan et al. 2022). Despite the abundance and clarity of evidence

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from Pre-Pleistocene glaciations, records of large-scale glaciotectonism or extensive glaciotectonic complexes, comparable in scale to those identified in the comparative analysis, remain elusive and rare. Time dependent erosive forces and long-lasting breakdown of ancient landforms including glaciotectonic complexes have considerable reduced their preservation potential more than anything else.

Glaciers in the Himalayas

Himalaya has a great number of glaciers and small ice caps spread over the different mountain ranges, however there no large-scale glaciotectonic composite complex described from the region. Their absence in the Himalayas is foremost related to the region's steep topography, lack of extensive unconsolidated sediments, cold-based glaciers, rapid erosion, and active tectonics. Unlike the vast lowlands of the Northern Hemisphere, where soft sediments facilitated glaciotectonic deformation, the Himalayas' rugged terrain prevents the accumulation of deformable material. Cold-based glaciers, frozen to the bedrock, limit basal sliding, a key mechanism for glaciotectonic processes. Additionally, the region's resistant bedrock is less predisposed to deformation compared to the softer sediments found in other glaciated areas. Rapid erosion from fluvial and mass-wasting processes continuously reshapes the landscape, removing potential glaciotectonic features. Ongoing tectonic activity further complicates glacial processes, overshadowing glaciotectonic influences and driving landscape evolution. While some glacially influenced features, such as composite moraines and lake expansions exist, they are relatively small in scale. The combination of these factors prevents the formation and preservation of large-scale glaciotectonic structures, making the Himalayan glacial landscape somewhat distinct from other glaciated regions.

Glaciotectonic complexes in Greenland

The landscape in front of the present Greenland Ice Sheet shows glaciotectonic features e.g. the prominent push moraine forming the Flakkerhuk ridge, Scoresby Sund, East Greenland possesses many of the qualities required to be recognized as a significant glaciotectonic complex (Houmark-Nielsen, 1990; Tveranger et al., 1994). However, its morphology, tectonic architecture, and sedimentary context are not well documented, and further studies are necessary to raise this site to the level of other high-quality, potentially World Heritage sites. Additionally, its location in an Arctic fjord system with poor infrastructure and limited accessibility reduces its comparative ranking against other sites applying for World Heritage status.

On Holm Lands Isbræ in northeastern Greenland, Pedersen (2014) describes a sub-recent proglacially deformed complex in Greenland exhibit characteristic glaciotectonic features such as thrust faults and imbricate fans. Specifically, the Holm Lands Isbræ serves as an example of an active glaciotectonic complex where advancing ice has overridden and deformed underlying sediments, forming thrust-fault structures that contribute to the understanding of glaciotectonic processes in polar environments. However, no further documentation is provided, which excludes the site in a comparative analysis.

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Locality no. / Name	Country	Appearance in x out of 11 textbooks etc.	Primary material in composite ridges	Location
1. Møns Klint	Denmark	8	Chalk and late Quaternary strata	Coastal
2. Dammer Berge	Germany	7	Late Pleistocene Tertiary clay	Pits and drill cores
3. Norfolk	England	5	Quaternary with dislocated bedrock	Coastal
4. Dirt and Cactus Hills	Saskatchewan, Canada	5	Stratified glacial deposits	Drill cores
5. Fur formation	Denmark	3	Eocene diatomite with ash layers and glacial deposits glacial deposits	Coastal
6. Dinas Dinlle	North Wales	2	Stratified sediments	Coastal
7. Prophets Mountain	Missouri Coteau, USA	2	Glacial deposts and Cretaceous, Paleocene sedimentary rocks	Road cuts and drill holes
8. Muskauer-Faltenbogen	Germany and Poland	2	Oligocene and Miocene sediments	Pit sections and drill holes
9. Lamstedter Berge	Germany	2	Glacial deposits Tertiary marine clay	Sand pits and drill holes
10. Jasmund-Rügen	Germany	1	Chalk and Quaternary strata	Coastal
11. Mud Buttes	Alberta, Canada	1	Cretaceous sandstones, siltstones and mudstones	River bluffs and Badlands
12. Kanin Peninsula	Russia	1	Glacial and interstadial sediments	Coastal
13. Eyabakkajökull	Iceland	1	Loess, peat, tephra and glacial sediments	River
14. Bride Moraine	Isle of Man, Great Britain	1	Pleistocene deposits	Coastal
15. Blankenese-Hamburg	Germany	1	Pleistocene strata Pliocene sediments	Sand pits and drill holes
16. Utrecht ridge	Netherlands	1	Pleistocene strata	Sand pits and drill holes
17. Brandon Hills	Canada	1	Pleistocene strata	Sand pits and drill holes
18. Holmströmsbreen	**Svalbard**	**1**	**Holocene intertidal, outwash**	**River**
19. Torres del Paine	**Chile**	**0**	**Pleistocene strata**	**River**
20. Murzuq Basin	**Libya**	**1**	**Ordovician fluvial, deltaic,and shallow-marine sediments**	**River**

Table 2: *List of pre-selected sites for comparative analysis. Only, site 19. Torres del Paine does not appear in any international textbooks etc. However it holds a prominent role as a large-scale glaciotectonic complex in South America. Site 20 is mentioned in a textbook by Hambrey, M. J., Glasser, N. F., Christoffersen, P., & Hubbard, B. (2007). Glacial Sedimentary Processes and Products: The Late Ordovician Glacial Sedimentary System of the North Gondwana Platform. Blackwell Publishing Ltd. ISBN: 978-1-405-18300-0*

Our comparative analysis focuses on three major criteria that pre-selected site should fulfill to the highest possible level.

Criteria A

Nature and Scale of Site: display large-scale glaciotectonic structures such as folds and thrust faults, preferable in cross sections aligned with the former ice pressure. Further, contain documentation a constructed profile, a balanced cross section, a detailed description of internal architecture, and an interpretation of the progressive glaciotectonic deformation.

The cumulative score in Table 3 (page 26) shows the geological dimensions of the complexes and magnitude of disturbance during deformation of material by ice pressure. Five sites stand out within criteria A, i.e., Møns Klint, Dirt and Cactus hills, Fur formation, Muskauer-Faltenbogen and Jasmund on Rügen. All these locations have an impressive structural relief larger than 150 m and in the case of Møns Klint up to 250 m of deformed pre-quaternary chalk and glacial sediments displaced over several kilometers.
OBS: The newly added column in Table 3, covering the spatial extend and perimeter, uses the new and larger proposed property of Møns Klint (4123 ha).

Criteria B

The Quality (integrity) of Site: show well exposed outcrops exposing the structures over a long lateral extent, which is accessible and sustainable.

The total score in Table 4 (page 27), expresses the ability of a specific site to be of significant interest and be sustainable for a prolonged period.

Criteria C

Scientific Impact and Value of Site: have a research record documenting its scientific impact and value. The scientific work should document the relationship between the displaced material and the stratigraphy of displaced sediment packages. .

Table 5 (page 28) displays the score for scientific impact and value summarized the year when a specific site was recognized in the literature as a glaciotectonic complex, the completeness of the stratigraphical record and the overall scientific standing. Early recognized sites often have accumulated much knowledge and documentation as the research effort span over many years. Jasmund on Rügen being a notable exception that was recognized at the same time as Møns Klint in 1874 but was never globally accredited to the same extend as Møns Klint. Stratigraphic completeness signifies the association between deformation and sedimentation in all stages of the landform construction. Scientific standing shows an assessment of a specific site to be of influence in the research community.

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Locality no. / Name	Coastal height (above terrain, m)	Structural relief (m)	Length of exposure (km)	Lateral displacement (% / km)	Spatial extent: Area / Perimeter (Km2/Km)	Structural glaciotectonic documentation	Criteria A Score
1. Møns Klint	143	~250	c. 9	>5 km	**41/33**	Complete	12
2. Dammer Berge	Up to 143	115	<0.1	Several km	**23/27**	Complete	8
3. Norfolk	60	<100	< 5	>0.12 km	**22/37**	Complete	8
4. Dirt and Cactus Hills	120	215	Minor or none	>4 km	**497/126**	Incomplete	8
5. Fur formation	Up to 80	~150	<2	>5 km	**2.4/0.4**	Complete	10
6. Dinas Dinlle	25	60	1.8	54% shortening	**0.1/0.95**	Complete	7
7. Prophets Mountain	100	100	<0.5	NA	**18/18**	Partial	5
8. Muskauer-Faltenbogen	Up to 70	>200	<1	49% shortening	**150/50**	Complete	10
9. Lamstedter Berge	60	c.100	<1	NA	**131/54**	Partial	5
10. Jasmund-Rügen	161	c. 200	5	49% shortening ~5 km	**71/40**	Complete	12
11. Mud Buttes	120	>120	1.4	Unknown	**0.63/3.7**	Partial	6
12. Kanin Peninsula	80	>100	20-40	Unknown	**41/94**	Incomplete	5
13. Eyabakkajökull	25	c. 50	<1	27-39%	**13**	Complete	6
14. Bride Moraine	90	>90	5	NA	**0.4/2.9**	Partial	6
15. Blankenese-Hamburg	50	c. 150	<1	~50%	**2.6/8.4**	Partial	5
16. Utrecht ridge	50	Up to 100	<1	NA	**230/120**	Partial	7
17. Brandon Hills	100	<100	<0.5	NA	**8/40**	Complete	5
18. Holmstrømsbreen	**Up to 80**	**Up to 100**	**< 1**	**0.9 shortening**	0.5/3	**Complete**	**8**
19. Torres del Paine	**50**	**>50**	**2.5**	**NA**	27/30	**Partial**	**5**
20. Murzuq Basin	**80**	**>80**	**<2**	**NA**	80/NA	**Incomplete**	**5**

Table 3: Criteria A *- Nature and scale of pre-selected sites. Scores ranges from 1 to 12 with 12 being the highest level for the criteria A.*

Locality no. / Name	Visibility of glaciotectonics			Lateral extent of exposure			Quality of exposure			Total Score
	Expertise needed	Hard to recognize	Easy to recognize	<1 km	1 to 5 km	>5km	Pit, road cut and drill holes	River cut	Coastal cliff	
1. Møns Klint			4			4			4	12
2. Dammer Berge			4		2		1			7
3. Norfolk			4		2				4	10
4. Dirt and Cactus Hills		2		1			1			4
5. Fur formation			4		2				4	10
6. Dinas Dinlle			4		2				4	10
7. Prophets Mountain		2		1				1		4
8. Muskauer-Faltenbogen			4		2		1			7
9. Lamstedter Berge		2		1			1			4
10. Jasmund-Rügen			4			4			4	12
11. Mud Buttes	1				2		1			4
12. Kanin Peninsula	1					4			4	9
13. Eyabakkajökull			4	1				2		7
14. Bride Moraine			4		2				4	10
15. Blankenese-Hamburg	1			1				2		4
16. Utrecht ridge	1			1			1			3
17. Brandon Hills		2		1			1			4
18. Holmström-breen			**4**		**2**			**2**		**8**
19. Torres del Paine		**2**			**2**			**2**		**6**
20. Murzuq Basin		**2**			**2**			**2**		**6**

Table 4: Criteria B *- the quality (integrity) of the 20 pre-selected sites. Visibility of glaciotectonic deformation showing the internal architecture is rated on a scale from 1 to 4 with easy visibility even to the inexperienced eye giving the maximum of 4 points and sections where a guide is needed to point out the structure is given 1 point. The lateral extent of tectonic structures is rated on a scale where sites more than one kilometre is given a maximum of 4 points and sites of less than one kilometre is given 1 point. The quality of the exposure is rated based on the type of the exposure based on literature where sea cliff with ongoing erosion is given the maximum point of 4, and pit and road cuts a minimum of 1 point (evaluation adopted from Damholt and Surlyk, 2012).*

APPENDIX 1

Locality no. / Name	Year of glaciotec-tonic rec-ognition	Reference	Stratigraphy recorded	Scientific standing	Criteria C Score
1. Møns Klint	1874	Johnstrup, F. 1874: Über die La-gerungsverhältnisse und die He-bungs-Phänomene in den Kreidefelsen auf Mön und Rügen. Zeitschrift der deutsche geologische Gesellschaft 1874, 533–585.	Excellent pre- and post de-formational stratigraphy	High	12
2. Dammer Berge	1930	Dewers, F., 1930: Beiträge zur Kenntnis des Diluviums in der Umgebung des Dümmer Sees. Abhandlungen des Natur-wissenschaftlichen Vereins Bremen. 27 (1li, p. 1-46	Excellent pre- and post de-formational stratigraphy	High	10
3. Norfolk	1882	Reid, C. 1882: The Geology of the Cowury around Cromer. Memoirs of the Geologi-cal Survey of England and Wales.	Existing pre- and post defor-mational stratigraphy	High	12
4. Dirt and Cactus Hills	1959	Byers, A.R. 1959. Deformation of the Whitemud and Eastend formations near Claybank, Saskatchewan. Transactions of the Royal Society of Canada, Section 4, 53: 1 - 1 1.Christiansen, E.A. 196 1. Geology and groundwater	Poorly recorded	High	12
5. Fur formation	1940	Gry, H. 1940: De istektoniske Forhold i Moleret. Med Bemærkninger om vore dislocerede Klinters Dannelse og om den negative Askeserie. Meddelelser fra Dansk Geologisk Forening 9, 586–627.	Excellent pre- and post de-formational stratigraphy	High	10
6. Dinas Dinlle	1893	Reade, T.M. (1893). The drift beds of the Moe1 Tryfaen area of North Wales. Proceedings of the Liverpool Geological Society, 7, 36-97.	Excellent pre- and post de-formational stratigraphy	Middle	8
7. Prophets Mountain	1981	Bluemle, .I. P. 1981: Geology of Sheridan County, North Dakota. North Dakota Geol. Surv. Bull. 75: 1. 59pp.	Poorly		6
8. Muskauer-Faltenbogen	1929	Gripp, K. 1929: Glaziologische und geol-ogische Ergebnisse der Hamburgischen Spitsbergen Expedition. Abhandlungen der Naturwissenschaftlichen Verein Ham-burg 22, 147–247	Moderate recorded	High	8
9. Lamstedter Berge	1964	Henrici, H. 1964: Gutachtlicher abschluss-bericht zunn wasserversorgungsprojekt wingst Hanover: unpublished report Niedersächsishes landesamt für Boden-forschung.	Excellent pre- and post de-formational stratigraphy	Low	5
10. Jasmund-Rügen	1874	Johnstrup, F. 1874: Über die La-gerungsverhältnisse und die Hebungs-Phänomene in den Kreidefelsen auf Mön und Rügen. Zeitschrift der deutsche geologische Gesellschaft 1874, 533–585.	Excellent pre- and post de-formational stratigraphy	Middle	8
11. Mud Buttes	1927	Slater, G. 1927. Structure of the Mud Buttes and Tit Hills in Alberta. Geological Society America, Bulletin 38, p.721-730.	Poorly	Low	5
12. Kanin Peninsula	2006	Larsen et al., Early Weichselian palae-oenvironments reconstructed from a mega-scale thrust-fault complex, Kanin Peninsula, northwestern Russia. Boreas 35, 3	Excellent pre- and post de-formational stratigraphy	Low	3
13. Eyabakkajökull	1953	Todtmann, E.M., 1953. Am Rand des Eyjabakkagletchers, Sommer 1953. Jökull 3, 34–36.	Excellent pre- and post de-formational stratigraphy	Low	6
14. Bride Moraine	1931	Slater, G. 1931: The structure of the Bride Morainc, Isle of Man. Proc. Liverpool Ceol. SOC. 14, 186196.	Excellent pre- and post de-formational stratigraphy	Middle	8
15. Blankenese-Hamburg	1983	Wilke, H., & Ehlers, J. 1983: The thrust moraine of Hamburg-Blankenese. In: Glacial deposits in North-west Europe. A.A. Balkema.	Moderate pre- and post deformational stratigraphy	Low	5
16. Utrecht ridge	1916	Lorié, J., 1916. De geologische Bouw van de Geldersche Vallei II; benevens Beschri-jving van eenige nieuwe Grondboringen. Medeelingen van de Commissie voor geologisch onderzoek, nr 39. p.1-30. Verh. KNAW Tweede serie deel XIX, 1917.	NA	High	10
17. Brandon Hills	1988	Aber, J.S. 1988. Structural geology exercises with glaciotectonic examples. Hunter Textbooks, Winston-Salem, North Carolina, 140 p	Moderate pre- and post deformational stratigraphy	Low	6
18. Holmström-breen	**1927**	**Gripp, K. 1929. Glaciologische und geol-ogische Ergebnisse der Hamburgischen Spitzbergen-Expedition 1927. Abhan-dlungen des Naturwissenschaftlichen Vereins zu Hamburg, Volume 22, pages 147–247.**	**Excellent pre- and post de-formational stratigraphy**	**High**	**8**
19. Torres del Paine	**1932**	**CALDENIUS, C. 1932. Las glaciaciones cuaternarias en la Patagonia y Tierra del Fuego. Geografiska Annaler, 14, 1-64.**	**Excellent pre- and post de-formational stratigraphy**	**Low**	**3**
20. Murzuq Basin	**2008**	**Le Heron, D. P., & Craig, J. (2008). Glacio-genic reservoirs: Understanding lithofa-cies distribution and stratigraphic trap-ping mechanisms in the Late Ordovician glaciation of the Murzuq Basin, Libya. Petroleum Geoscience, 14(1), 55-66.**	**Excellent pre- and post de-formational stratigraphy**	**Middle**	**6**

Table 5: Criteria C assessment. *Scores ranges from 1 to 12 with 12 the highest level.*

ASSESSMENT

In summary, four sites fulfil the three criteria at a high level i.e., Møns Klint, Jasmund, Norfolk and the Fur formation all with a score above 30 points. However, across all criteria Møns Klint achieve the best score with a maximum of 36 point.

Of all 20 pre-selected sites, two are already properties on the UNESCO World Heritage List, however none of them due to their deformational history as a glaciotectonic complexes. The two sites on the List are the Jasmund National Park (Ancient Beech forests of Europe, serial nomination) and the Muskauer-Faltenborgen site. The last being valued for its cultural identity.

The coastal cliffs of Jasmund National Park on Rügen are, on the other hand, almost geologically identical with the white cliffs of Møn. However, the dimension of the cliff profile is smaller, including the lenght of exposure. Moreover, their status as an inscribed property as an ancient beech forest (serial nomination), currently refrain them from applying for further inscription on the World Heritage List.

Similarly, The Fur formation in Denmark is present as a site on the Danish tentative list, but as an important fossil locality, and not as a glaciotectonic complex.

Locality no. / Name	Score Criteria A	Score Criteria B	Score Criteria C	Score (total)
1. Møns Klint	12	12	12	36
10. Jasmund-Rügen	12	12	8	32
3. Norfolk	8	10	12	30
5. Fur formation	10	10	10	30
2. Dammer Berge	8	7	10	25
8. Muskauer-Faltenbogen	10	7	8	25
6. Dinas Dinlle	7	10	8	25
4. Dirt and Cactus Hills	8	4	12	24
14. Bride Moraine	6	10	8	24
18. Holmströmbreen	**8**	**8**	**8**	**24**
16. Utrecht ridge	7	3	10	20
13. Eyabakkajökull	6	7	6	19
12. Kanin Peninsula	5	9	3	17
20. Murzuq Basin	**5**	**6**	**6**	**17**
7. Prophets Mountain	5	4	6	15
11. Mud Buttes	6	4	5	15
17. Brandon Hills	5	4	6	15
9. Lamstedter Berge	5	4	5	14
15. Blankenese-Hamburg	5	4	5	14
19. Torres del Paine	**5**	**6**	**8**	**14**

Table 6: Cumulative score of the criteria A-C

Visitor on the beach, prospecting the large cliffslide from 2024

DESCRIPTIONS OF THE THREE NEWLY ADDED SITES TO THE COMPARATIVE ANALYSIS

Site 18. Holmstrømbreen, Svalbard

Geographic Description of Site

The site proposed is Holmströmbreen, a glacier located at the head of Ekmanfjorden in central Spitsbergen. The glacier surged into a proglacial tidalflat area, causing significant deformation that resulted in a push moraine complex extending 1.5 km beyond the glacier's maximum extent. The region encompasses various zones, including exposed glacier ice, ice-cored moraine, glacially pushed sediments, and proglacial outwash areas. Access to the area is possible by helicopter from Longyearbyen or by boat to the bottom of the fjord and subsequent walk across the tidal flat for c. 10 km.

Sediments and Stratigraphy

The sedimentary structure of the Holmströmbreen push moraine consists of six primary lithofacies, each representing distinct depositional environments temporal contexts.

The sediment succession, approximately 30 meters thick, reflects a dynamic environment shaped by glacial advances and retreats over a tidal flat setting. At the proximal extremity of the pushed zone lies subglacial till, a dense, overconsolidated diamicton with striated clasts, deposited directly beneath the glacier under high pressure. Overlying this are rhythmically bedded sands, silts, and clays (varves), formed in a proglacial lake. These layers result from turbidity currents depositing sand and silt, while clay settled from suspension in standing water. The sequence also includes glaciomarine mud, a consolidated blue-black deposit containing mollusk remains, indicating formation in a marine or intertidal setting during cold climates. This unit represents transitions between glacial and postglacial environments. Dominating much of the pushed belt is dark brown silty mud, interpreted as tidal flat deposits. The alternating layers of sand, silt, and clay, along with rooted plant remains and contraction cracks, suggest deposition in intertidal and supratidal zones. Above the mud deposits are fluvial sands, characterized by cross-laminations and ripples, indicative of active deposition in proximal fluvial channels. The coarsest material, sand and gravel, was deposited on proglacial outwash fans. These sediments exhibit imbrication and grading, reflecting high-energy meltwater outflows. Together, the stratigraphic arrangement highlights the interplay of glacial processes, water flow, and sedimentation in a shifting environment.

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Glaciotectonic Outline and Landscape Association

The Holmströmbreen push moraine complex provides a detailed example of the glaciotectonic processes that shape landscapes associated with surging glaciers. Its structural complexity reflects the dynamic interaction between ice movement, sediment deformation, and groundwater processes. The moraine's internal organization is divided into three structural zones, each characterized by distinctive deformation styles: 1. External Zone: This zone features open, parallel folds and small-scale thrusts. The folds generally have steep southern limbs, and deformation decreases progressively towards the distal edge of the moraine. This outer zone transitions imperceptibly into the undeformed foreland, marking the edge of the fold belt. 2. Intermediate Zone: Folding and thrusting become more intense in this zone, with highly asymmetric folds and significant overthrusting. Fold nappes with recumbent folds displaced along thrust faults are common. These structures reflect higher compressive stresses closer to the glacier front. 3. Internal Zone: Closest to the glacier, the internal zone is dominated by recumbent folds and nappes, some of which dip towards the glacier. These structures show evidence of intense deformation, including thrust planes and zones of high strain concentration. The sediments here exhibit significant lateral shortening and vertical thickening, consistent with high compressive forces transmitted from the advancing ice.

Holmstrømbreen, Svalbard. Credit: Kurt H. Kjær

The moraine evolved as the glacier surged forward, pushing and deforming overridden and adjacent proglacial sediments. Initial deformation occurred as low-amplitude folds at the distal end of the moraine, which later evolved into overturned folds and nappes as compressive forces increased. A decollement, a plane of detachment beneath the sediment mass, facilitated horizontal movement and deformation. The depth of this decollement lies at approximately 30 meters below surface, indicating that deformation was concentrated within a thin sedimentary nappe. The glacial push event also had a significant impact on meltwater drainage and sedimentation patterns. The compression of sediments created barriers that redirected meltwater, leading to the formation of syn-tectonic fluvial deposits in channels and fan systems. Over time, as the glacier ice downwasted and the moraine stabilized, post-tectonic drainage incised the folded sediments, leaving behind a highly dissected landscape.

Significance of the Site

The Holmströmbreen push moraine complex serves as a modern analog for similar glaciotectonic features found in areas once covered by Pleistocene ice sheets. Its detailed stratigraphy and structure provide valuable insights into the processes of sediment deformation, groundwater flow, and landform evolution in glaciated regions. This site highlights the interplay between glacial dynamics and sedimentary processes, offering a framework for interpreting the geomorphological and geological history of other glaciotectonic systems.

Boulton, G. S., van der Meer, J. J. M., Beets,D. J., Hart, J. K., & Ruegg, G. H. J. (1999). The sedimentary and structural evolution of a recent push moraine complex: Holmströmbreen, Spitsbergen. Quaternary Science Reviews, 18(3), 339–371. https://doi.org/10.1016/S0277-3791(98)00068-7

Site 19. Lago del Toro ice lobe, Chilean southern Patagonia

Geographic Description of Site

The study site is located within Torres del Paine National Park in Chilean Patagonia, specifically focusing on the Lago del Toro ice lobe. This area features dramatic contrasts in climate and topography, ranging from high precipitation zones adjacent to the Southern Patagonian Ice Field to semi-arid steppes eastward. The site includes multiple moraine belts formed during late-glacial glacier fluctuations. Access to the site is achieved by flight into Punta Arenas, the closest major airport, with international connections through Santiago. From Punta Arenas, travel by rental vehicle, bus, or guided transport to the park.

Sediments and Stratigraphy

The key area of interest for understanding the internal architecture is the "El Canal" stratigraphic section, spaning approximately 2.5 km in length, up to 750 m in width, and reveals sediment exposures c. 20 m high. This erosional channel provides an uninterrupted stratigraphic record of ice-marginal processes during the late-glacial period.

The sediments at El Canal are divided into eight lithofacies associations, ranging from subglacial to subaerial deposits, including: ice-proximal sediments i.e. tilted gravel and silt layers dipping at angles up to 10°, with some beds several decimeters thick. Glaciolacustrine sediments i.e laminated silts extend laterally for tens of meters, occasionally interrupted by dropstones (up to 10 cm in diameter). Grounding-line fan deposits i.e. gravelly clinoforms reaching heights of several meters, transitioning to finer sand and silt beds. The stratigraphy shows evidence of repeated glacial advances and retreats, with transitions from subaqueous deposits to moraine-building layers. Tephra analysis dates the moraines to approximately 14,150 ± 560 years BP.

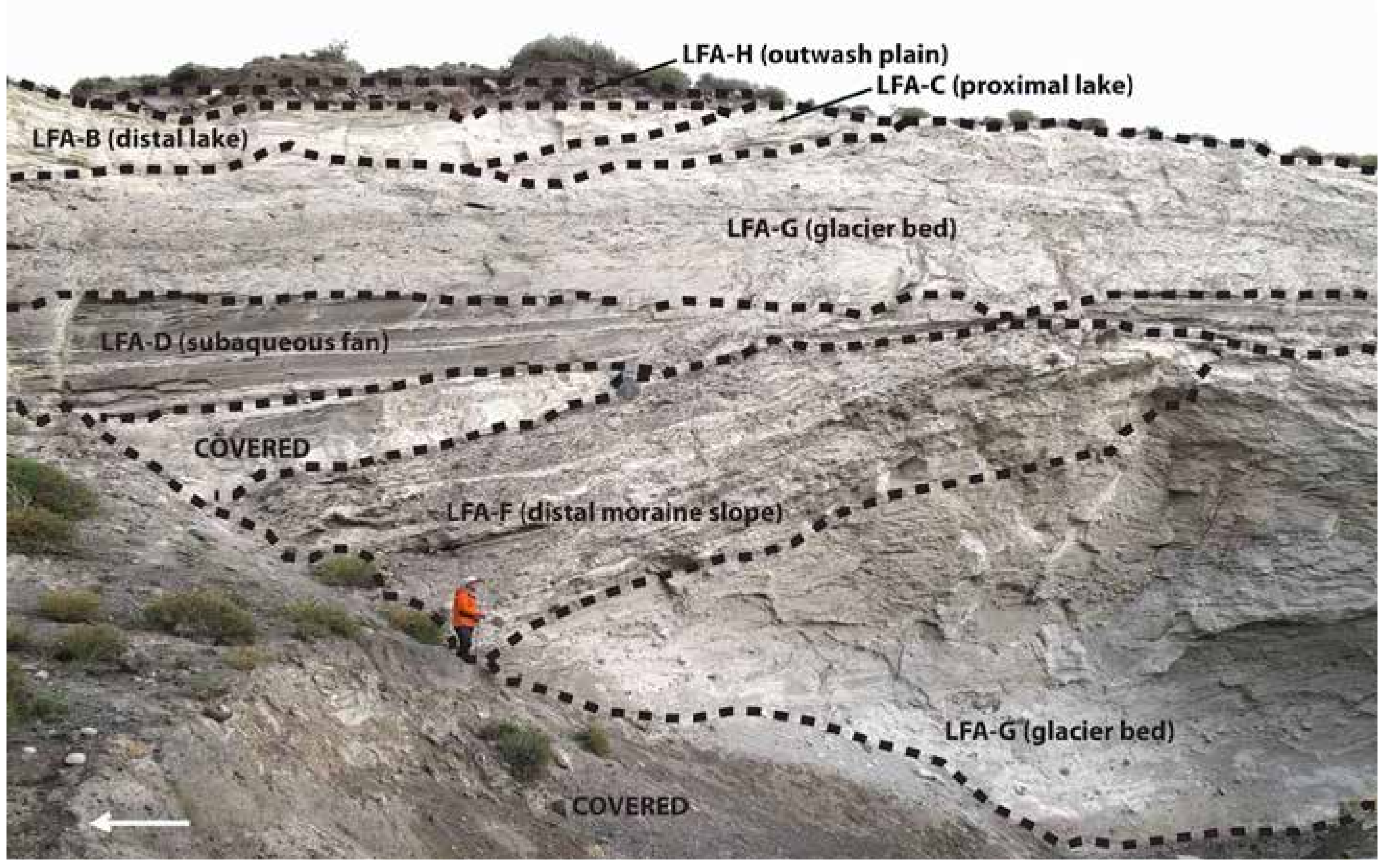
Glaciotectonic Outline and Landscape Association

The moraine-building processes in Torres del Paine involved ice pushing and glaciotectonic deformation associated firstly with ice advance: the glacier snouts compressed and deformed lake sediments, resulting in ductile and brittle deformation zones spanning up to 7 m vertically at El Canal. Secondly: moraine formation: moraine ridges range from 2–10 m in height and approximately 5 m in width, with saw-toothed and sinuous morphologies and thirdly landscape evolution: meltwater channels, up to 750 m wide, and glacial outwash plains were the result of meltwater transport and deposition. These landforms reflect the combined effects of ice advances and sediment reworking in a dynamic glaciolacustrine environment.

Significance of the Site

The Torres del Paine moraine system provides a valuable record of late-glacial dynamics, offering insights into past climate conditions, glacial processes, and chronological frameworks. Preserved sediments and stratigraphy reveal evidence of glacial activity during the Antarctic Cold Reversal, contributing to the understanding of climate fluctuations and ice-marginal processes. Structural deformations in the moraines shed light on subaqueous moraine construction, refining glaciotectonic models. Formation of the moraine reflects the relationship between regional glaciation and global climatic events at the end of the last ice age. The El Canal stratigraphic section, spanning 2.5 km in length and up to 20 m in height, serves as a well-preserved natural archive, facilitating studies of sediment deposition and ice dynamics. Its accessibility and scientific significance make it a key site for understanding late Pleistocene glaciation in Patagonia.

García, J.-L., Strelin, J. A., Vega, R. M., Hall, B. L., & Stern, C. R. (2015). Deglacial ice-marginal glaciolacustrine environments and structural moraine building in Torres del Paine, Chilean southern Patagonia. Andean Geology, 42(2), 190-212. https://doi.org/10.5027/andgoV42n2-a03



Lago del Toro, Torres del Paine, Chile. Source: García et al. (2015).

Site 20. Tihemboka Area, Murzuq Basin, Southwest Libya

Geographic Description of Site

The Tihemboka area, located in the northwestern Murzuq Basin of southwest Libya, spans approximately 40 kilometers in length and 20 kilometers in width. It is situated about 100 kilometers north of Ghat City. The Murzuq Basin is an intra-cratonic basin that formed on the northwestern part of the Gondwana supercontinent during the Lower Palaeozoic era, approximately 541 to 419 million years ago. This region preserves an extensive sedimentary record of end-Ordovician glaciation, characterized by multiple glacial erosion surfaces and depositional sequences. These sequences provide evidence of repeated ice-front advances and retreats, offering crucial insights into the pre-Pleistocene glaciotectonic history of the area. Access to the region is possible via Tripoli Airport, with further travel requiring domestic flights or overland journeys. Sebha Airport provides occasional flights closer to the study area, while local off-road transportation is necessary within the region due to its rugged terrain.

Sediments and Stratigraphy

The stratigraphy of the Tihemboka area consists of the Lower and Upper Glaciogenic units. The Lower were deposited during the Late Katian to Hirnantian stages of the Ordovician and encompass a complex interplay of glacial and interglacial deposits. These deposits include fluvial, deltaic, and shallow-marine sediments that document the alternating advance and retreat of ice sheets. The Upper Glaciogenics represent a sandstone-dominated depositional wedge that reaches thicknesses of up to 150 meters. These deposits formed during the final phase of the Hirnantian deglaciation and culminated in postglacial transgressive marine deposits, marking a critical transition in the geological history of the basin. The Upper Glaciogenics are further subdivided into three distinct depositional units. The lower proglacial delta unit consists of glaciofluvial braidplain deposits and mouth-bar systems, representing the advance of meltwater-driven sedimentation. The middle ice-marginal unit is characterized by the presence of tunnel valleys and glaciotectonic deformation, highlighting the dynamic interactions at the ice margin. The upper transgressive unit comprises fine-grained marine sandstones that signify the final postglacial transition and the progressive inundation of the region by rising sea levels. These sedimentary units collectively offer crucial insights into the glacial dynamics, ice-sheet behavior, and meltwater influences that shaped the Murzuq Basin during the late Ordovician period, providing valuable evidence for reconstructing past environmental and climatic conditions.

Glaciotectonic Outline and Landscape Association

The Tihemboka area features an extensive array of glaciotectonic structures, with large-scale folds and thrust ridges dominating the landscape. These features provide significant evidence of ice-sheet dynamics and sediment deformation under ice-sheet loading and advance. A prominent glaciotectonic fold-and-thrust belt extends over 10 kilometers and reaches thicknesses of up to 80 meters. This belt comprises fault-propagation folds, thrust faults, and nappes that indicate significant ice-driven deformation. The structures exhibit a north-northwest vergence, aligning with the dominant ice-flow direction, and primarily affect the lower proglacial delta unit, where sediments were compressed and folded by advancing ice. Fault-related growth structures and clastic dykes suggest syntectonic sedimentation. Subglacial shear zones, marked by intraformational striae, sheath folds, and normal microfaults, reflect high-pressure conditions with alternating compressive and extensional forces driven by fluctuating meltwater pressure. Tunnel valleys range from 30 to 50 meters deep and extend up to 1 kilometer in width, formed by overpressured subglacial meltwater flows, truncating existing glaciotectonic structures and underscoring the complex interactions between meltwater and ice. Additional ice-margin features, such as ice-keel scours, kettle holes, and glaciofluvial channels, provide further evidence of ice-margin stabilization and retreat, capturing key aspects of the basin's deglaciation history.

Murzug Bassin, Lybia. Source: Girard et al. (2015)

Significance of the Site

The Tihemboka ice-marginal wedge offers valuable insights into the dynamics of the end-Ordovician ice sheet and ancient glacial environments. Despite of old age the well-preserved sedimentary, structural and morphological records in this area enhance our understanding of the extent and climatic influences of the Gondwana ice sheet. Furthermore, they provide important data on glaciotectonic deformation processes, including subglacial and proglacial depositional settings. This site presents a unique opportunity to study pre-Pleistocene ice-sheet behavior and sedimentary processes, offering insights relevant to both ancient and modern glacial systems.

Girard, F., Ghienne, J. F., Du-Bernard, X., & Rubino, J. L. (2015). Sedimentary imprints of former ice-sheet margins: Insights from an end-Ordovician archive (SW Libya). Earth-Science Reviews, 148, 259–289. https://doi.org/10.1016/j.earscirev.2015.06.006

2. Address the nominated property as a three-dimensional glaciotectonic complex, not just in two-dimensional terms.

Three-dimensional extent of Møn glaciotectonic complex

The Møns Klint expose natural coastal erosion into a large three-dimensional structure that continues westward 4-5 km inland, terminated by a north-south trending depression in the landscape. The entire deformed area covers 41 km2 with a perimeter of 33 km. In comparison to other pre-selected sites, Møns Klint is within the five largest glacioteonic areas (table 3, page 26). The three-dimensional extent of the glaciotectonic complex behind Møns Klint encompasses a highly deformed landscape characterized by displaced chalk sheets, interbedded and superimposed with Pleistocene deposits, forming a complex geological structure that extends both laterally and vertically. The area consists of a series of parallel ridge hills, elongated depressions, and thrust sheets that have been displaced over significant distances (>5 km) by glacial forces.

The vertical structure of the complex is best observed in the cliff exposure at Møns Klint, which provides a cross-sectional view of the deformed strata. The cliffs are divided into three major sections: the proximal, central, and distal parts. In the proximal southern section, steeply imbricated chalk sheets, such as those at Hvidskud and St. Stejlberg, have been thrust northward over a basal décollement situated approximately 100 meters below sea level (Figure 11, side 42 in Nomination of Møns Klint dossier). The central section, characterized by an antiformal stack, represents the highest point of deformation, with sheets stacked upon each other and forming dramatic elevations such as Dronningestolen, which rises to 128 meters above sea level. Further inland, the terrain reached its highest elevation at Aborre hills at 143 meters. In the northern section, thrust faults dip more gently southward, with the tip of the thrust zone obscured by landslides and vegetation.

The complex interior architecture is displayed laterally into three distinct hill-systems that reflect different phases of ice movement and pressure. In the northern part, the ridges trend southeast-northwest, with a convexity toward the northeast, while the southern ridges follow an east-west trend with a convexity toward the southwest. A third hill-system around Store Klint trends north-south and is strongly convex to the east. These systems have been influenced by multiple ice advances, primarily from the northeast and southeast, which have superimposed their deformation patterns onto the landscape. In between the ridges, the presence of hummocky moraines and small lakes suggests that the area has experienced prolonged ice stagnation and passive melting possibly associated with syn-tectonic glacier ice (Figure 11 in Nomination of Møns Klint dossier). The ridge systems might be directly traced several km inland.

Beneath the Quaternary deposits, the undeformed Pre-Quaternary chalk surface is relatively uncomplicated, but varies from 25 to 40 meters below sea level. However, due to intense glacial displacement, the chalk is present 80 meters above sea level at High Møn and occurs close to the terrain surface in many places. Inland boreholes reveal the presence of large-scale chalk sheets, ranging in thickness from 20 to 40 meters and extending for several hundred meters. These sheets, in some cases, remain rooted in undisturbed Pre-Quaternary deposits, while others have been fully dislodged and transported and stacked by glacial forces. Offshore bathymetry south and east of High Møn reveals a large arch-shaped depression, possibly indicating the original source of the displaced chalk sheets. This depression, located up to 5 kilometers offshore, suggests an ice-marginal formation where thrusting originated and led to the hill-hole pair configuration of the glaciotectonic complex.

The interactions between ice advance and retreat cycles, which resulted in repeated depositional sequences, is observed in the borehole data over the 43 km2 area. Quaternary sediments, primarily clayey till and other diamict sediments, can reach thicknesses of 50-100 meters, and build up nearly 70% of the surface deposits on Møn. Despite the absence of larger chalk sheets within these deposits, deformation features such as folding and stacking are prevalent. The overall extent of the glaciotectonic complex behind Møns Klint is characterized by substantial lateral displacement, where thrust sheets were moved several kilometers northward. The depth to the basal décollement varies across the area, decreasing from the southern imbricate fan towards the antiformal stack in the central part, suggesting a progressive deformation pattern.

Thus, the glaciotectonic complex behind Møns Klint represents an intricately deformed landscape build of displaced chalk sheets and glacial deposits, extending from deep below sea level to significant elevations above it. The formation of the complex has been driven by multiple ice advances from different directions, leading to a distinct three-dimensional structure composed of imbricate fans, antiformal stacks, and foreland thrust sheets.

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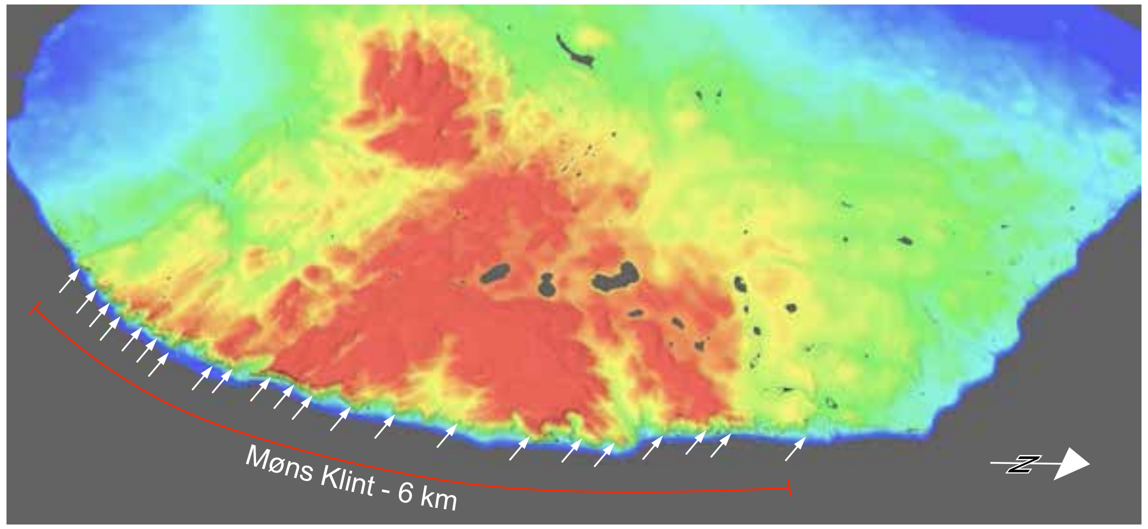
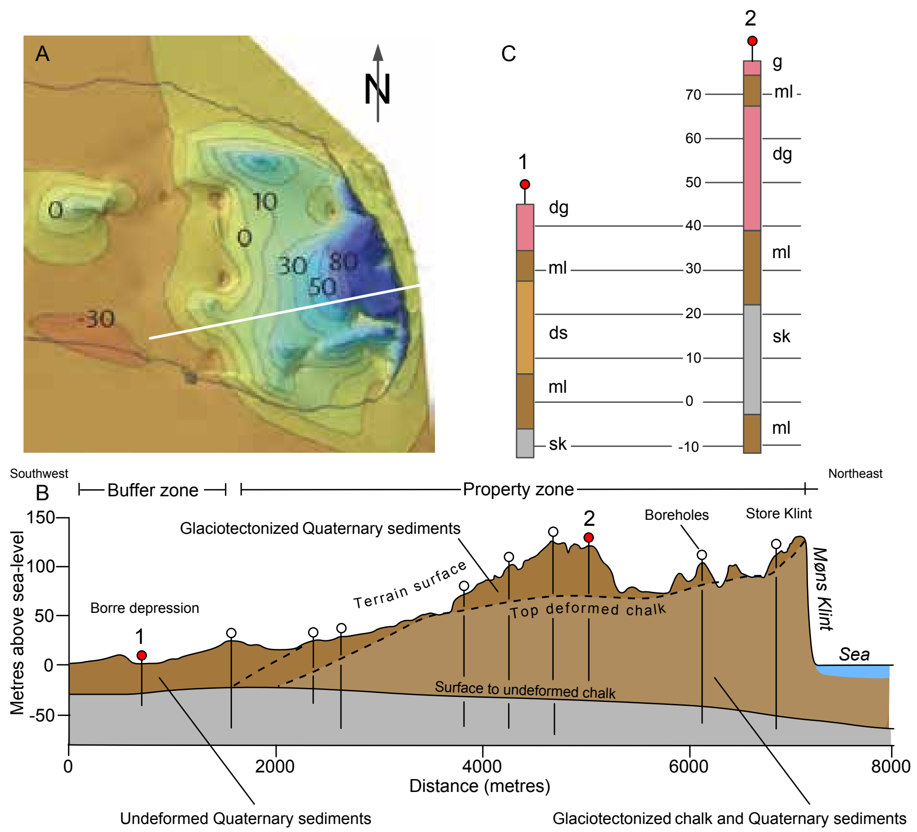
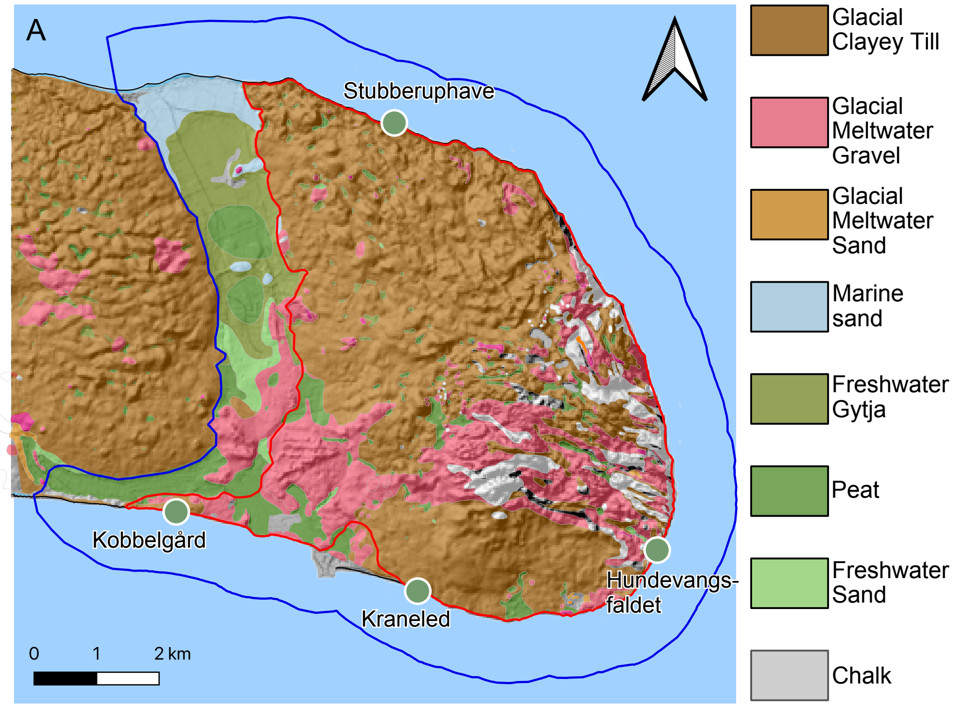
Geological and geomorphological maps of Møns Klint

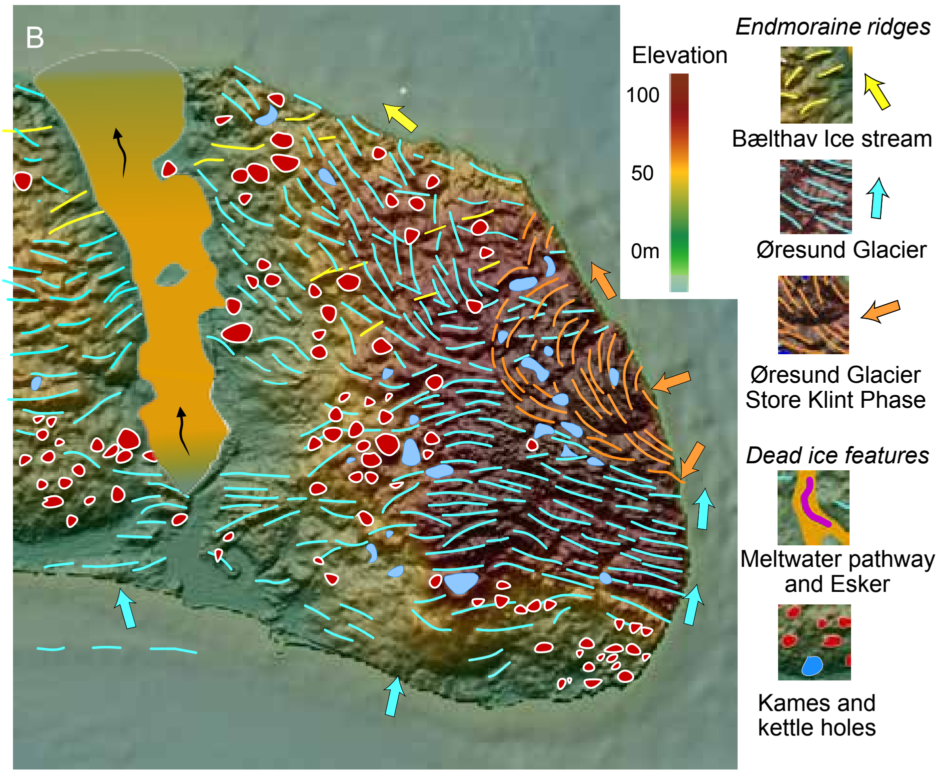


Møn, 3D Model. *Elevation model of eastern Møn covering the nominated property. View towards the west. Arrows mark the presents of ridges in the morphology that can be traced in prominent geological structure in the cliff section. It show a clear link between the interior achiecture and the landscape.*



Borehole/pre-quaternary principal diagram. A. *Spatial distribution of the Pre-Quaternary surface elevation including the glaciotectonized chalk sheets.* ***B.*** *Principal cross section - white line on inset A. The extent of glaciotectonized quaternary sediments and chalk as recognized in boreholes as well as glaciotectonized quaternary sediments only bordering to undeformed sediments. Top deformed chalk matches the contoured surface in inset A. The nominated property and buffer zone is outlined on the same cross section.* ***C.*** *Two principal type of boreholes used to reconstruct the top chalk deformed surface. g: gravel. ml: glacial clayey till. ds: glacial meltwater gravel. sk: chalk. Type 2 boreholes shows repetition of chalk with a sequence of quaternary sediments, which is a clear indication of large scale deformation. Type 1 boreholes does not allow this and other evidence is needed.*





Soilmap and geomorphological map. A. *Soilmap with exposed chalk, glacial and interglacial (Holocene) sediment.* ***B.*** *Geomophological map for the same area as the soilmap. The nominated property and buffer zone is overimposed on the soilmap and it is evident that both zone finds a counterpart in both the distribution of glaciotectonized ridges and soil types.*

Animation
Flyover along Møns Klint from south to north based on the LiDAR recording from November 2024.
https://moensklint.dk/lidarvideo/

Puggaard 1851 versus new LiDAR baseline

LiDAR 2024

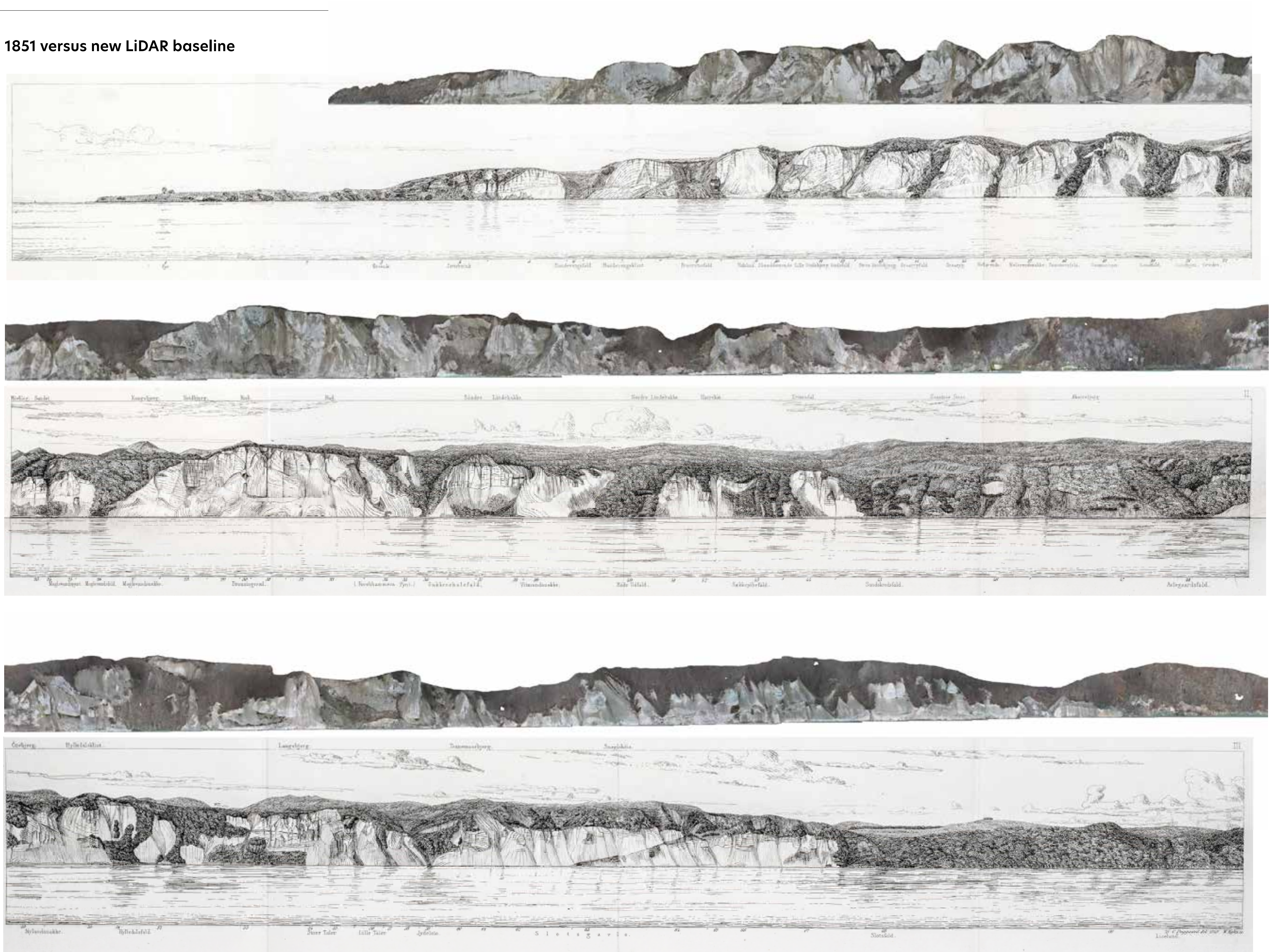
Puggaard 1851

LiDAR 2024

Puggaard 1851

LiDAR 2024

Puggaard 1851



Comparison between Puggaards 1851 handheld drawing of Møns Klint and a new LiDAR recording (Nov. 2024) of the cliff profile (viewed from the direction south to north), shown as orthophotographs of the same area. While there is general good agreement between the two recordnings there is new details of the interior achiecture revealed at the northern part of the cliff.

APPENDIX 2

BOUNDARIES AND INTEGRITY V.2.0

TEXTUAL DESCRIPTION OF BOUNDARIES, CRITERIA UNDER WHICH THE PROPERTY IS PROPOSED TO BE INSCRIBED AND DRAFT STATEMENT OF OUTSTANDING UNIVERSAL VALUE

REVISED, FEB. 2025

A view of the landscape behind the cliffs

BOUNDARIES AND INTEGRITY V.2.0

PLEASE NOTE:
The nominated property boundary presented and described in the original nomination dossier has been substantially extended to the west, and additionally to the north and south; with consequent adjustments to the buffer zone. The area extension equates to an 11.3 times increase to the Nominated Property and a 6 times increase to the buffer zone. The new nominated property now encompasses the entire multi-phase glaciotectonic complex on eastern Møn, illustrating the full three-dimensional primary field evidence for all structural deformations and disturbances to strata, together with directly associated erosional and depositional features. The nominated landscape now extends all the way to the Borre depression.

The new property proposal includes a significant additional length (2,3 km) of supporting cliff section together with the inclusion of the entire ice-shoved geomorphic maximum of eastern Møn and its associated fringing kame and kettle field topography. The boundary respects and aligns with the soil map limits for sediment types and includes important stratigraphical localities for quaternary deposits (green dots). The new buffer zone proposal follows the Borre depression and extends towards the adjoining glaciotectonic areas on central Møn, while the marine part continues to follow the coastline one km out into the Baltic Sea. The industrial area of Klintholm Havn is included in the buffer zone.

Textual description of the boundary(ies) of the nominated property:
The nominated property comprises *a complete, significant, multi-phase, glaciotectonic complex that illustrates all classic structural geological and geomorphological features. This includes 6 km* coastal chalk cliffs that have been deformed heavily by Pleistocene glaciers and thereafter exposed in a large-scaled cross section by erosional forces, *together with the system of landward ice-shoved hills and ridges and fringing kame and kettle topography.* The property boundary follows *the margins of the glaciotectonic complex, with the* chalk exposures of the cliff profile constituting the primary feature of the Outstanding Universal Value.

The central section *of the cliff profile*, comprising Dronningestolen and Forchhammers Pynt, constitute the most heavily deformed and tallest sections of the complex, and the most dramatic and spectacular viewpoints. The most prominent marginal hills provide important visual contributions to the understanding of glaciotectonic impact on landscape formation, as they represent the geomorphological landforms in the glacio-tectonic landscape. The tallest and most prominent of these hill systems are found at Aborrebjerg (143 m) in Jydelejet, and at the continuous ridge system of Siesø Bjerg and Timmesø Bjerg, within the forest of Klinteskoven.

The calcareous grasslands of Jydelejet, Høvblege and Hundevæng overdrev are furthermore included in the property, and provide visual contributions to the hilly inland structures of the complex, due to their lack of forest cover. The glaciotectonic features and hill systems decrease in size and intensity towards the west but are detectable all the way to the Borre depression. These are included in the property in their entirety to provide the complete understanding of the glaciotectonic complex.

Erosion from waves and weather continuously changes the exact profile of the cliffs, keeping the surface fresh, white and well exposed. The vertical boundary of the nominated property therefore follows the, at a given time, exact cliff profile exposure and location. Meaning that as the cliff profile migrates slowly inland, so follows the property boundary. The beach in front of the cliff profile is thus not included in the property, but part of the buffer zone.

The buffer zone surrounds the property and includes the Borre depression on the inland western side, extending towards the adjoining glaciotectonic area on central Møn. It also extends one kilometer into the marine section, following the coastline of the property. The industrial area of Klintholm Havn is included in the buffer zone.

The property and buffer zone are both extensively protected by many protective designations, in addition to strict national legislation, including the 'Beach Protection Line' and the 'Coastal Proximity Zone', veritably preventing construction and change of the landscape in an area of three kilometers from the coast, and thereby effectively protecting as well the property, but also the buffer zone and beyond, from any inexpedient development in the future.

Criteria under which property is nominated (itemize criteria)
Møns Klint is proposed to be inscribed under the criteria (viii) of Paragraph 77 of the Operational Guidelines for the implementation of the World Heritage Convention (2021), stating that the nominated properties shall:

(viii) be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;

The white cliffs and their hinterlands are proposed on the World Heritage list because they represent an outstanding and superlative example of glaciotectonic mountain building, that illustrates the profound effect of lowland glaciers on Pleistocene landscapes.

Draft Statement of Outstanding Universal Value

a) Brief synthesis (unchanged)
The property of Møns Klint is a coastal chalk cliff with exceptional geological and scenic qualities. The white cliffs consist of large sheets of Cretaceous chalk that has been bulldozed up into one of the world's largest glaciotectonic complexes during the last glaciation period, locally known as the Weichsel glaciation.

The complex in its entirety is one of the largest known well described glacial complexes in the world, and spans almost five kilometers inland, represented by parallel marginal ridge hills from three different glacio-directions. However, the uniqueness of the complex lies in the outstanding and large-scaled cross section of the complex, exposed in a spectacular cliff profile that reveals the inner architecture of the entire complex from south to north, and at the same time offers a magnificent visual experience for the viewer.
The coastal cliff profile on the easternmost tip of this extensive glaciotectonic complex contains the primary physiographical attributes, representing the outstanding universal value of the site. Erosional forces from waves

Size of the proposed new property: 4123 ha

Size of the proposed new buffer zone: 3628 ha

Total size of property and buffer zone: 7751 ha

Map of the nominated property and the buffer zone, including the position of the area in Denmark and in the World.

and weathering has exposed a spectacular cross-section, with an outstanding exposure of more than 6 km, and a structural relief extending 200 meters from the base to the top of the complex. The steep white cliffs, more than 120 meters above sea level, form jagged towers of whiteness above turquoise waters, stony black flint beaches, and crowned by green beech tree forests on top.

b) Justification for Criteria (unchanged)

Criterion viii: Møns Klint is an outstanding example of a major stage in the history of Earth: The glacial landscape formation and mountain building of the Pleistocene Epoch. It moreover represents significant geomorphic and physiographic features, in the form of a well exposed cross section through one of the world's largest glaciotectonic complexes, and it provides a unique testimony of the advances of specific glacial ice streams, including their extent, fast flow and dynamics. For the same reason, the site has played a key-role in the scientific history and acknowledgement of glaciotectonics, including important methodological contributions to the scientific discipline of glaciotectonism.

c) Statement of Integrity *(minor change)*

The Møns Klint property represents a *complete* and classic glaciotectonic complex, encompassed by a dramatic and scenic coastal landscape. The cliff profile covers the complete deformational history of a glacial advance, complete with a steep proximal imbricate section to the south, a central and highly deformed antiformal stack, and a distal section of thrust faults to the north.

The primary element of the complex is the exposed cross section: The cliff profile, which offers the most spectacular vistas and a unique insight into the complex glaciotectonic structures. However, to understand the true scale and evolution of the complex, also the marginal hills that continue back into the landscape are of scientific and visual importance. They provide an important overview of the morphological structures throughout the entire complex, including the number and direction of the glacial advances that created the glaciotectonic structures and formed the landscape. They thereby also provide an illustrative example of the classic glacio-landscape that Pleistocene glaciers have impacted and formed throughout the Northern Hemisphere, and that now cover immense parts of the continental lowland areas, corresponding largely to the fertile areas that house and feed a large portion of the Earth' population today.

e) Requirements for protection and management

The property consists of the entire glaciotectonic complex of eastern Møn, including the uniquely exposed and heavily deformed, large-sized cliff profile, and its prominent marginal hill systems, like Aborrebjerg and the Siesø Bjerg -Timmesø Bjerg system. The area has been iconic to Denmark for centuries, and thus well protected for its natural and scenic values for more than a century.

The 6 km coastline of the cliffs and cliffside edge (300 meters inland), is well protected by the national 'beach protection line', with no sections missing or being inaccessible. The hilly surroundings, including the calcareous grasslands, are likewise all protected by various national and international protective designations, including the 'Høje Møn protection' and the 'Natura 2000' conservation network. The innermost – and less hilly – section is mainly protected by the Coastal Proximity Zone, which protects any coastline in Denmark, within a zone of three kilometers, from development without dispensation.

Vordingborg Municipality has the overall responsibility for all development in the area, which is managed according to the national legislation and protective designations.

Natural management of the State owned part of the property, including the cliff profile and a large part of the forest and protected calcareous grasslands, lies with the Danish Nature Agency.

The Møns Klint cliff profile - viewed from the 2024 cliffslide peninsula on the beach.

APPENDIX 3

FUTURE STATE OF CONSERVATION AND MONITORING OF MØNS KLINT

FUTURE STATE OF CONSERVATION AND MONITORING OF MØNS KLINT

Scientific data on chalk cliff erosion and climate change projections

Coastal abrasion of the glacial landscape of Møn vas initiated when the Atlantic transgression peaked about 8.000 years ago. The bathymetry east of the present Møns Klint monitors a 2-4 km vide chalk platform adjacent to the cliff bordering a 30-meter-deep depression beneath which an unknown volume of Holocene deposits are present. The platform and depression may compose a hill-hole pair morphology often connected with glacio-tectonic complexes. If erosion over the past 8000 years has eroded 4 km cliff this implies an average retreat rate of the cliff face of about 50 cm per year. This is in accordance with calculations made by the Geological Survey (Pedersen & Møller 2004) suggesting an average retreat of the cliff face of ca 35 cm per year. The process of slicing off the cliff face takes place either as continued year-round weathering along the whole of the cliff face or major landslides. Landslides have in recent time occurred about every 5 years and account for local removal of significant volumes of cliff material over limited sections of the cliff as illustrated in Box 10 p. 130 of the Nomination Dossier.

The above-mentioned estimates are based on present day erosion rates and removal of cliff material by wave and current action. Whatever future climate fluctuations and sea level changes may cause of changes in these rates are unpredictable, but an ongoing sea level rise and increased storminess causing more frequent major erosional incidents may account for accelerated retreat rates (Rossius *et al.* 2025). However, even with doubled erosion rates the remaining 3-5 km inland continuation of the glacio-tectonic complex still leaves several millennia with exposure of this spectacular cliff site.

References

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-Rossius, J.E., Averes, T, Krämer, K & Winter, C. 2025: Event-driven erosion of a glacial till cliff. Geomorphology 109626.

STRATEGY FOR MONITORING MØNS KLINT GLACIOTECTONIC COMPLEX

Long-term Vision and Objective

The monitoring strategy should ensure that Møns Klint retains its Outstanding Universal Value (OUV) as a foremost example of glaciotectonic processes and associated composite landscapes. Sustainable management, based on scientific data and continuous assessment, is essential to preserving both the geological integrity and the authenticity of the site for future generations. This monitoring strategy must provide a robust framework for the preservation of Møns Klint by addressing its unique geological significance while anticipating potential risks from both natural processes and human activities that accommodate an expected increase in number of visitors.

Risk Factors and Threats

Natural Erosion and landslides

The proposed nomination area constitutes an active coastal area with high relief terrain behind an up to 126 m high cliff section dominated by hard chalk and soft quaternary deposits. On the northern and southern shore 10-30 m high cliff sections are exposed in soft Quaternary sediments. The coastal zone is characterized by normal erosion and occasional landslides. The landscape behind the coast is subject to solifluction of topsoil and few karsts depression related to dissolution of chalk. These processes must be quantified and their spatial extent known.

Human Activities

The OUV nominated area is foremost a culture landscape that is strongly influenced by centuries of agriculture and forestry as well as recreational activities. The sustainability of increasing numbers of visitors on both landscape and coastal cliff area is important to understand in further detail.

Climate Change

Climate change will raise sea levels due to ocean thermal expansion and melting ice sheets, but this rise will vary regionally. For instance, by 2100, Denmark may see a 25 cm difference between Esbjerg and Skagen, influenced by factors like land subsidence and water circulation. This will challenge coastal stability causing increased erosion and changes in formations. Storm surges will become more frequent and intense, heightening the risk of flooding and threatening infrastructure and ecosystems. Water discharge patterns will shift, potentially causing inundation, while saltwater intrusion may affect groundwater quality. Increased precipitation will elevate groundwater levels, raising landslide risks in prone areas.

Overall, the coastal areas of Møn are projected to face a combination of rising sea levels, increased storm surge frequencies, and changes in water systems, all of which require comprehensive adaptation strategies.

Key Monitoring Indicators

Baseline study

A baseline study for monitoring the glaciotectonic complex site involves gathering comprehensive data on the site's current conditions before any significant changes or developments occur. This initial data serves as a reference point for future comparisons, enabling the detection of any changes over time. Key indicators in the baseline study should include:

- Initial assessment of slope stability, especially in areas prone to landslides or erosion.
- High-resolution mapping of the physical landscape, including elevation, cliff formations, slopes, and coastal or inland features.
- Digital models (aerial photogrammetry or LiDAR) to capture the site's morphology in 1954 for the terrestrial landscape and 2003 for three-dimensional shape of Møns Klint.
- Baseline data on surface water bodies, stream gradients, and their interaction with geological features.

• Evaluating subsidence or uplift in the area through GPS and satellite measurements (In-SAR).
• The study might also include assessments of how geological features influence local ecosystems, like vegetation cover and habitat conditions, especially *on cliffs or slopes.*
• Remapping of the glaciotectonic structures using 3D imagery. *Status: funding secured for execution in 2025. Globe Institute, carried out a new LIDAR mapping of the coastal cliff in November 2024 and a new 3D model with orthophotos has been reconstructed. Using helicopter-based photogrammetry, GEUS will create high-resolution 3D models of the cliff surface. Both mapping effort*s will enable detailed geological mapping and monitoring of structural changes over time.
• Mapping of the Quaternary sediment and stratigraphy between the thrusted rafts.
• Sea-level impact. Tools such as "Klimatilpasningsportalen" and "Klima-Atlas" are already in place to provide local-level information on inundation, erosion, sea-level rise, storm surges, and changes in precipitation and temperature, though further integration of these processes need to be accessed for the property area to understand the impact.

Erosion and Natural Degradation
• Monitor the rate of cliff erosion due to wave action and weathering.
• Track changes in the exposed chalk layers to detect any shifts in structural relief.

Geological Features
• Conduct periodic assessments of the glaciotectonic formations, focusing on the integrity of the large-scale cross-section.
• Evaluate the impact of natural events (e.g., landslides or subsidence) on the clarity of geological features.

Vegetation Cover
• Monitor the extent of beech tree forests at the cliff top.
• Assess the relationship between vegetation growth and cliff stability.

Marine and Coastal Conditions
• Monitor water quality in the surrounding sea to track any ecological changes that might affect the visual and physical integrity of the site.
• Track sediment deposition on the stony flint beaches, assessing potential threats to beach stability.
• Track long-term changes in sea levels, storm frequency, and other climatic factors that could accelerate erosion or affect the high relief landscape within the glaciotectonic complex.

Human activity
• Monitor visitor numbers and assess the impact of tourism on the integrity of the site.

Monitoring Methods
Remote Sensing and Aerial Surveys
Interferometric Synthetic Aperture Radar. InSAR is a remote sensing technique that uses radar signals from satellites to monitor ground movement with high precision. It is particularly useful for detecting millimeter-level changes in the Earth's surface over large areas, making it a valuable tool for monitoring natural hazards like cliff collapses.

Global Navigation Satellite System. Using GNSS stations to monitor cliff collapse is a highly effective geodetic method to track the stability and movement of cliffs in real time. GNSS, often referred to as GPS, provides precise measurements of position by using a network of satellites. When applied to cliffs or other geologically unstable regions, GNSS can deliver critical data on ground motion, allowing for early warnings of potential collapse.

Status: funding secured for execution in 2025. *GEUS will at selected locations install GNSS (GPS) units to measure cliff deformations. These will only be placed in areas showing movement. If necessary, an exemption from conservation regulations will be sought. In addition, temporary seismic stations will be installed to record landslide activity, helping to identify when and where they occur.*

Repeat LIDAR survey. Use drones and satellite-based techniques to capture changes in cliff erosion, beach formation, and vegetation cover over time.

Ground Surveys and Geological Mapping
• Conduct regular geological surveys to document the condition of the glaciotectonic structures.
• Land-based geophysical Surveys. To understand the internal structure of the glaciotectonic complex at Høje Møn, we will conduct non-invasive geophysical surveys, including seismic and geo-electrical methods such as tTEM. Status: funding secured by GEUS to excecute between 2025-2027.
• Perform topographical mapping of the chalk cliff's cross-section to measure any changes in elevation and form.

Groundwater Monitoring
Groundwater meters will be installed to monitor water levels, which often influence landslide activity. Data will be available on Grundvandsstanden.dk. An existing meter at the visitor center currently provides low-quality data. *Status: funding secured for excecution in 2025.*

Photographic Documentation
• Set up fixed camera stations to capture time-lapse images of key features such as cliff faces, beaches, and forests.

Adaptive Management Strategies
Landslide hazard
• Consider controlled access to high-risk landslide zones.

Collaboration with Researchers
• Partner with geological institutions to conduct ongoing research on the glaciotectonic features of Møns Klint and its glaciotectonic complex.
• Facilitate scientific studies that focus on the Pleistocene geomorphic history and the site's role in understanding glaciotectonics.

Data Collection and Reporting
Monitoring Schedule
• Conduct annual review of key indicators such as erosion rates, geological integrity, and environmental health.

Stakeholder Involvement
• Involve local authorities, scientific communities, and conservation organizations in the monitoring and reporting process.

Reporting Framework
• Prepare an annual state-of-conservation report, detailing key findings and recommending adaptive management actions based on the monitoring data.

Estimated costs
The cost of a monitoring strategy for the site can vary significantly depending on which key monitoring indicators are selected. Several factors, such as:
1. Scope and complexity: The size of the area to be monitored and the complexity of its geology will have a major influence. For example, monitoring a large coastal area requires more equipment and resources than a smaller site.
2. Type of data and technology: Using advanced technologies like LiDAR, GPS monitoring, drones, and satellite data increases costs. Simple monitoring of erosion would cost less, while advanced solutions for landslides, for instance, would be more expensive.
3 Frequency of monitoring: Regular, continuous monitoring over a longer period will drive up costs. Periodic measurements or a one-time baseline study will be cheaper.
4. Expert assistance: Involving geological experts, engineers, and technical staff to analyze data and maintain equipment will also affect the price.

Establishment cost
Source of funding for the baseline study and establishment of the geophysical monitoring system should be integrated into a research project between Globe institute, GEUS and Geocenter Møn. Concretely, we envision that funding might be provided from a Geocenter Denmark grant with application deadline ultimo 2025.

Item	Cost per item (EURO)	Quantity	Note
Base station (GNSS)	27.000	1	Covered by existing GEUS grant
Rover stations (GNSS)	5.400	6-10	Covered by existing GEUS grant
InSAR Corner reflectors	4.000	2-3	North, south, west towards the forest
Salary GEUS	40.200	1	
Baseline study other	32.000	1	Covered partly by existing GEUS grant
Total cost	160.000		

The Geological Survey (GEUS) received funding for investigating landslides in Denmark and how climate change affects them. The project is part of a larger initiative running from 2025 to 2027.

Long-term monitoring and reporting cost
Three years after establishment and running of the geophysical monitoring, a solution will be in place for maintenance and analyses of the data on a long-term basis. The data coming from the monitoring is still of interest scientifically and new geological related project is anticipated to be developed. However, some basis funding must come from other sources. Cost: 25.000 EURO (GEUS salary). Cost for regular state-of-conservation reporting on key indicators and recommendation could be a task for a permanently employed Geocenter Møn UNESCO person working together with the scientific advisory board.

Møns Klint - viewed from the Gråryg staircase.

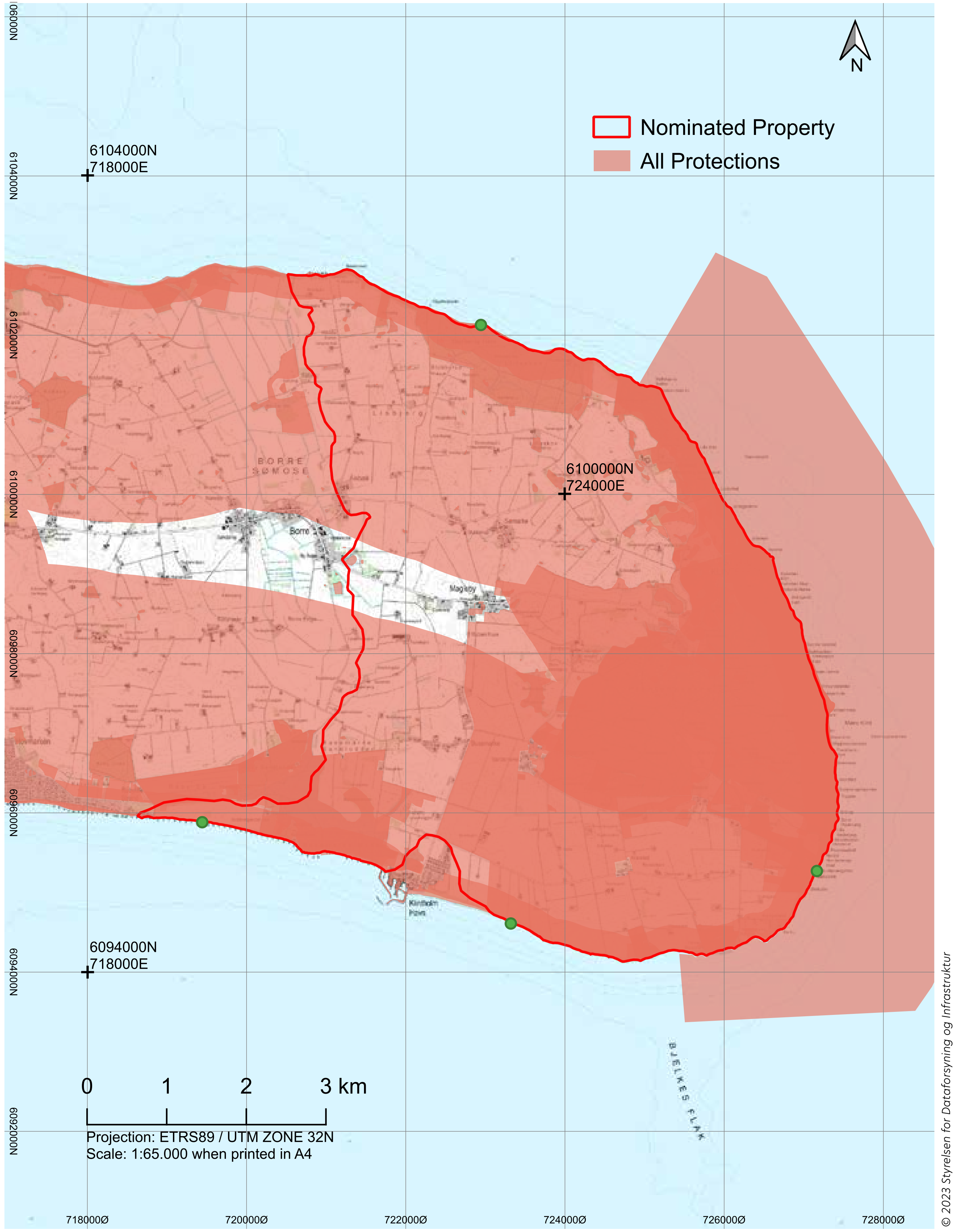
Flintstones on the beach

The dramatic cliffslide that took the remains of the famous cliff section "Sommerspiret" - January 2024

APPENDIX 4

MAPS OF THE NOMINATED PROPERTY (BUFFER ZONE AND PROTECTIONS)

Map 1. Nominated property and buffer zone



Map 2. Nominated property and its relation to All Protections

MAP 3

Map 3. Nominated property and its relation to the Beach Protection Line

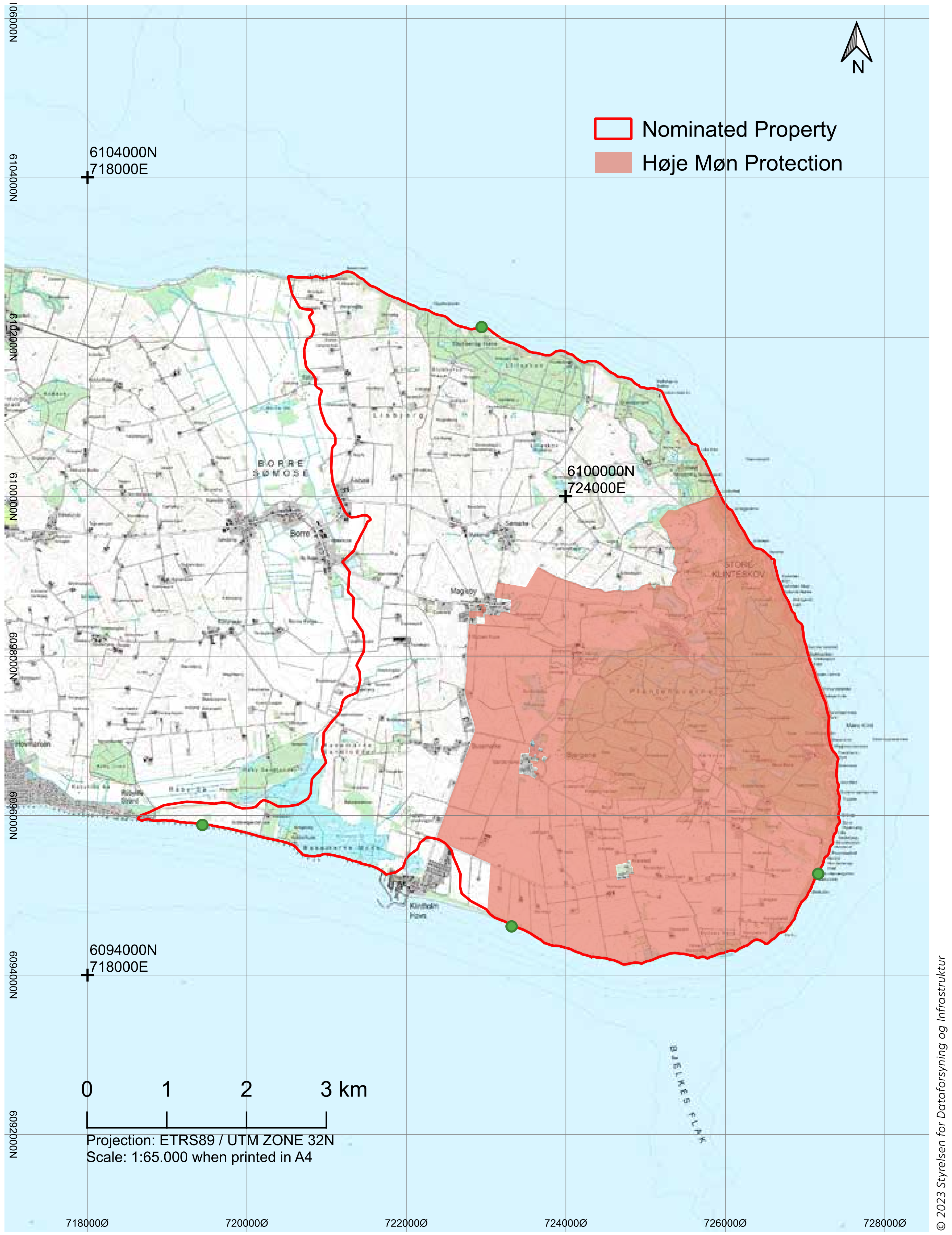
MAP 4

Map 4. Nominated property and its relation to the Coastal Proximity Zone

MAP 5

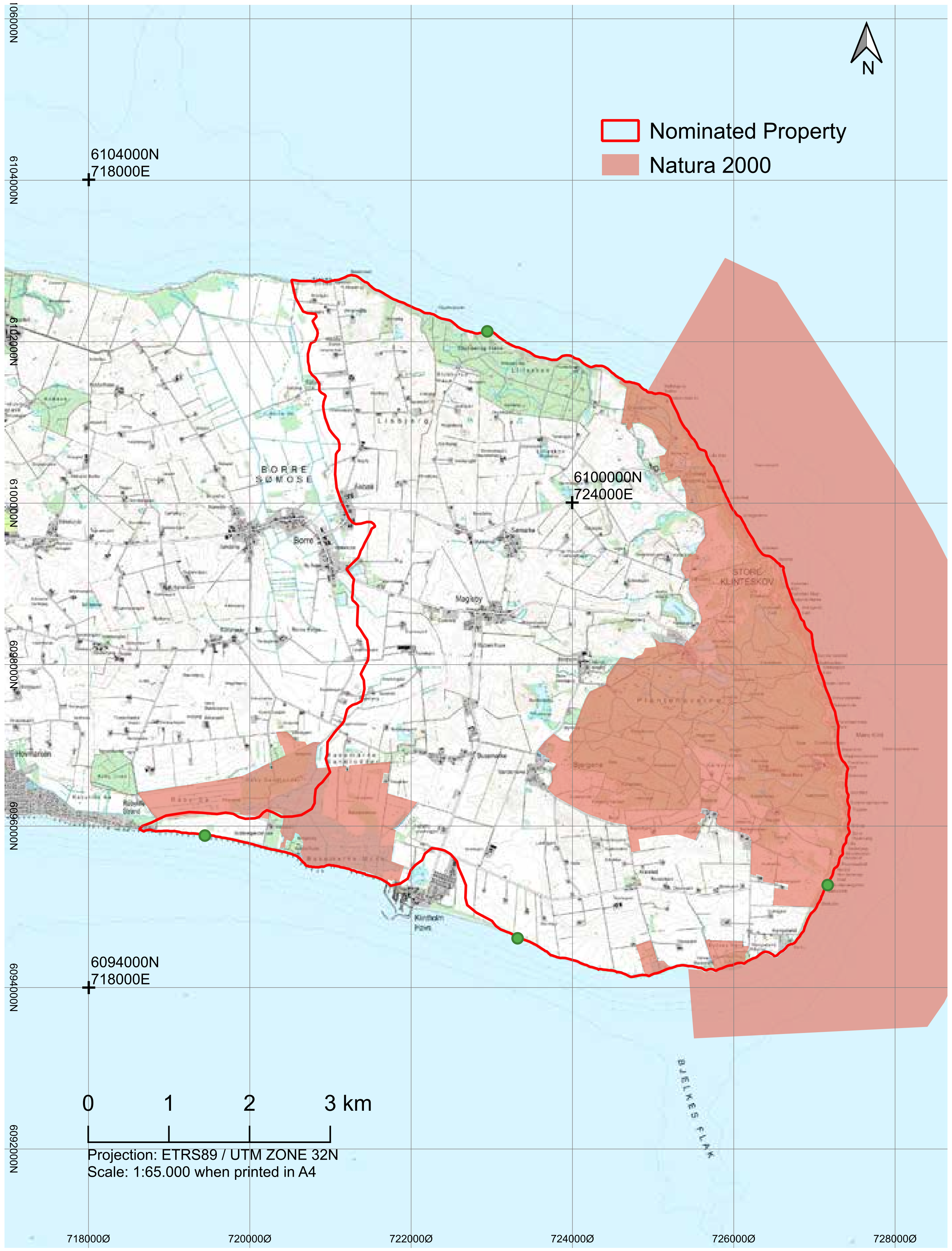
Map 5. Nominated property and its relation to Forest Act

MAP 6



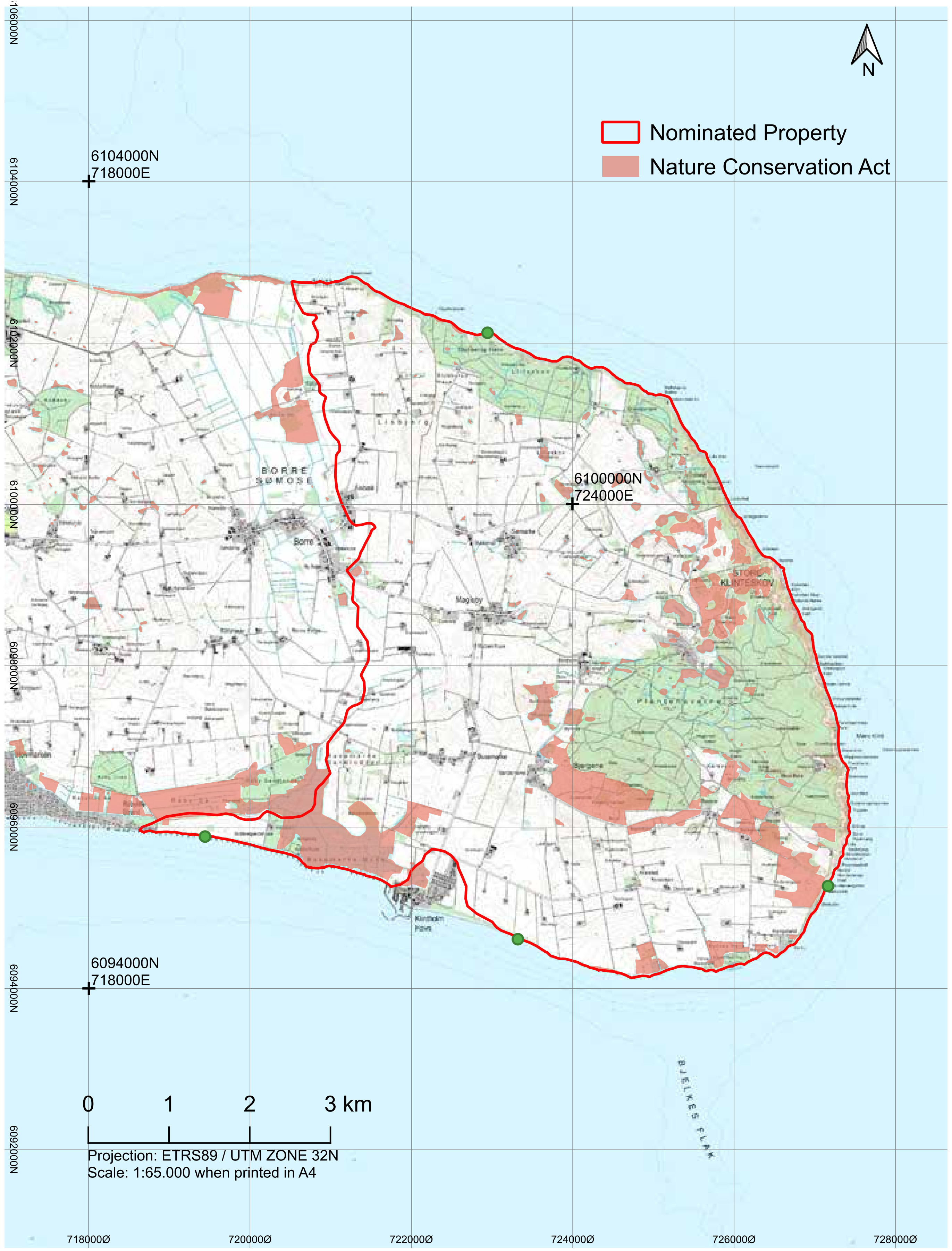
Map 6. Nominated property and its relation to the Høje Møn Protection

MAP 7



Map 7. Nominated property and its relation to Natura 2000

MAP 8



Map 8. Nominated property and its relation to the Nature Conservation Act

APPENDIX 5

IUCN INTERIM EVALUATION REPORT

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19 December 2024

IUCN Evaluation of Møns Klint – Interim Report and Request for Supplementary Information

Dear Ambassador,

Further to the above nomination to the World Heritage List, I am writing with information on progress with the IUCN evaluation. The IUCN World Heritage technical evaluation mission to Møns Klint was undertaken by Ms Sophie Justice and Ms Zsuzsa Tolnay. The evaluators greatly appreciated the excellent support, organisation and co-operation provided by your authorities in the preparation and implementation of the mission, and the kind welcome throughout the mission. Please convey our sincere thanks to all of the officials, scientists and contributors that assisted the mission.

Following the field evaluation mission, the IUCN World Heritage Panel is in the course of examining World Heritage nominations for natural and mixed properties, and cultural landscapes. This process will conclude in March/April 2025, following which the IUCN evaluation report will be issued to the UNESCO World Heritage Centre. The IUCN Panel examined in detail above-mentioned nomination, including reports of field evaluators and desktop reviews of external reviewers, as well as other references regarding the nominated properties.

The Panel greatly appreciated the State Party's efforts in relation to this nomination, and will be discussing the nomination again at its second meeting, to be held in March 2025. At this stage, the Panel noted a number of points that would require supplementary information. IUCN would therefore be highly grateful if the State Party authorities could provide the following elements of supplementary information to the Panel:

A. Values proposed under criterion (viii)

Regarding the proposed justification of criterion (viii), the Panel notes that the Global Comparative Analysis provided in the nomination dossier appears limited to Pleistocene sites in the Northern Hemisphere and to a two-dimensional assessment of lateral exposure. The Panel would therefore be grateful if the State Party could provide:

1. Further detail and background on the analysis underpinning the comparative analysis in the nomination dossier, if available, including an objective determination of the reduced geographic area used for the comparative analysis site selection. The Panel invites the State Party to consider expanding the global comparative analysis beyond Northern Hemisphere Pleistocene to include further areas, and different time periods where glaciotectonic features may be found – including sites with currently active glaciers. It was suggested by reviewers that this could include recent scientific studies on glaciotectonic features in regions such as Greenland, Svalbard, the Himalaya and the Andes. Whilst the Panel could not review all of the texts cited in selecting the sites included in the Comparative Analysis (Annex 5), it also noted that some of the books concerned include considerably fuller recognition of sites other than the Møns Klint, compared to the mentions of the nominated property, and also noted some sites (e.g. Svalbard) seem to be mentioned in the references but are not carried into the comparative analysis. As the comparative analysis requires to be global in scope, the Panel would also welcome confirmation that the methodology established is supported by a sufficient cross-section of international opinion, and would therefore be grateful if the State Party could confirm the means by which it verified that the method carries international support from the scientific community;

2. A supplementary comparative analysis addressing the nominated property and sites for comparison as three-dimensional glaciotectonic complex, i.e. assessing sites for their spatial coverage, and not only for their lateral extent and vertical development;
3. Geological and geomorphological maps of the nominated property illustrating the three-dimensional nature of the nominated property in relation to the proposed boundaries of the nominated property and its buffer zone, and to support the development of a geo-heritage inventory and ongoing site monitoring.

B. Boundaries of the nominated property

Based on the above, the Panel would be grateful for a technical review of the proposed boundaries of the nominated property and its buffer zone, considering the nominated property as a three-dimensional geological complex, providing:

4. a science-based rationale for the boundaries of the nominated property and its buffer zone as proposed, and the extent to which attributes of significance lie beyond the proposed boundaries, including a justification of the northern limit of the nominated property and its buffer zone;
5. scientific data, if available, mapping the erosion of the chalk cliff and projections in light of climate change and consideration of a potential revision of the boundaries.

C. Protection and Management

Whilst the Panel considers that the nominated property benefits from a strong protection system, the Panel has a number of questions regarding the need to strengthen conservation of geological heritage and would therefore be grateful if the State Party could:

6. provide a detailed plan for annual or biannual long-term monitoring of the erosion of the nominated property;
7. confirm the current and planned deployment of geoscientists for geo-heritage site management within the nominated property and its buffer zone;
8. confirm (a) that the Geological Survey of Denmark and Greenland would be included in the geological advisory board, and (b) that the geological advisory board would be represented in the World Heritage Steering Committee together with the local advisory board;
9. provide financial projections for the management needs of the nominated property and its buffer zone including commitments for long-term support;
10. confirm if the State Party would consider expanding the management plan to include a timeline, needs, measurable objectives and roadmap for action and if so, indicate actions and a timeline to address this need.

We would appreciate your response to the above points as soon as possible, in order to facilitate the evaluation process, but **no later than 28 February 2025**, as per paragraph 148 of the *Operational Guidelines*. Please note that any information submitted after this date will not be considered by IUCN in its evaluation for the World Heritage Committee. It should be noted, however, that while IUCN will carefully consider any supplementary information submitted, it cannot properly evaluate a completely revised nomination or large amounts of new information submitted at the last minute. Therefore, we kindly ask your authorities to keep their response concise and to respond only to the above requests.

Supplementary information should also be submitted officially in two copies to the UNESCO World Heritage Centre in order for it to be registered as part of the nomination. An electronic copy of all completed and submitted supplementary information to both the UNESCO World Heritage Centre, Mr Alessandro Balsamo (a.balsamo@unesco.org) and IUCN Headquarters, Mr Clemens Küpper (clemens.kupper@iucn.org) would also be greatly appreciated. Taking into account your response, IUCN will formulate its final recommendation to the World Heritage Committee.

In the interest of ensuring full transparency and dialogue regarding the IUCN evaluation process, we are happy to respond to any questions you may wish to raise regarding IUCN's work on the World Heritage Convention, including the above points. We would be pleased to organise a meeting via conference call. Please do not hesitate to contact Mr Clemens Küpper, Programme Officer, Nominations and Strategy (clemens.kupper@iucn.org), if you have any questions regarding this request, or if you would wish to arrange a conference call to discuss this request.

Please allow me to reiterate our thanks for your support and for the conduct of IUCN's recent mission. We thank you for your cooperation in providing this very important information, which will facilitate the Panel in making its recommendations.

In closing, I would like to thank you for your kind cooperation in the implementation of the World Heritage Convention, and I remain,

Yours sincerely,

Tim Badman
Director World Heritage

cc. Danish National Commission for UNESCO
UNESCO World Heritage Centre
IUCN Regional Office for Europe

Møns Klint in the summertime

MØNS KLINT

The spectacular cliff site of Møns Klint comprises a uniquely exposed cross-section through one of the worlds largest and most outstanding glaciotectonic complexes from the Pleistocene epoch. It represents the classic glaciotectonic site, and played a major role in the history of the discipline. This is the nomination file for the inclusion of Møns Klint as a UNESCO World Heritage Site.


N
Nominated Property
Buffer Zone
6104000N
718000E
6102000N
724000E
6094000N
718000E
0
1
2
3 km
Projection: ETRS89 / UTM ZONE 32N
Scale: 1:28.000 when printed in A2
BORRE SØMOSE
Borre
Magleby
Ålebæk
Sømarke
Lisbjerg
Lilleskov
Stubberup Have
STORE KLINTESKOV
Plantehaverne
Bjergene
Busemarke
Busemarke Mose
Klintholm Havn
Hovmarken
Råbylille Strand
Råby Sø
Råbylille Sø
Råby Sandlodder
Borre Enge
Mandemarke
Hampeland
Møns Klint
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