Protected geosites in an urban area of Norway, inventories, values and management.

Abstract:

The Oslo area has a rich geodiversity, a long history of scientific investigations and several protected geosites. Many of the protected geosites were protected some 30 years ago and have until recently not been followed up with monitoring and systematic management. This paper presents a work where 35 protected geosites have been assessed regarding their state of preservation and their management need. The geosites are mostly small areas protected for their paleontological and stratigraphic heritage. They are situated along the shoreline of the Oslo fjord as well as in small quarries and road cuts. The urban setting leads to a significant pressure towards the geodiversity in the area both when it comes to urbanization as well as recreational use.

The investigation has shown that the state of the geosites is reasonably good, but overgrowing requires a need for management in many places. It is also a need for upgrading the signposting of the sites with more site-specific information material.

A Gap analysis shows some gaps in the protection system, especially linked to more recent defined stratotypes and major structural landforms such as the Oslo Graben fault line. It is also a need to be more aware of the general impact of the geodiversity of the area for landscape character and thus in local land-use planning.

Keywords:
Geosites, Protection, Management plan, GAP analysis

Introduction

The geoconservation history of the Oslo area, SE Norway, goes back to 1919 when the island of Tofteholmen was protected (Erikstad 2012). This is a small island south of Oslo that consists of a volcanic neck of Permian age. In the 1970's geology was included in nation-wide inventories of nature conservation values in Norway. As a part of this work, an inventory report was made by scientists, affiliated with the University of Oslo linked to research in the Paleozoic sedimentary rock succession of the Oslo Region. A large portion of the geosites then identified was protected in a conservation plan for fossils in this area (15.01.1988). The plan comprises 65 geosites, protected as natural monuments and nature reserves. The number of protected geosites in the area is, however, higher, as single geosites have been protected both before and after this major protection plan, and by including geological values in biological or more general protection areas.

The area around the Oslo fjord is among the areas in Norway with the highest population density and building pressure on a level that can be found as a normal situation for large parts of Europe. The Oslo Fjord is also a major recreation resource that put a significant pressure on the nature in these areas.

In the 1980's formal protection of nature was not systematically followed up with well-developed management activities. All areas, however, have been sign-posted and it has been a low-intensity policing of the areas. Clearing of vegetation has until recently not been systematically performed and have partly been non-existing, especially in the first decades after the protection. The state of the geological values has not been systematically monitored.

A systematic inventory of the state of 35 protected geosites in the counties of Oslo, Akershus and Buskerud around the inner part of the Oslo fjord has been carried out as a basis for management plans for the protected areas. It has also been performed an analysis of the geological relevance of the protection system and a gap analysis of geological values that are not protected. This paper presents and discusses some core findings of this research project.

The Oslo Region

The Oslo Region is a geological structure that varies in width from 40 to 70 km and extends approximately 115 km both north and south of Oslo (Fig. 1). The region is fault controlled (the Oslo Graben) and covers an area of roughly 10 000 km^2. It is bordered by Precambrian rocks to the east and west, and by the Caledonian nappes to the north. The Oslo Region also extends out into the sea to the south (the Skagerrak Graben). The Lower Palaeozoic succession is approximately 2.500 m thick and contains alternating shales, silt- and sandstone, and carbonates often rich in fossils (Worsley and Nakrem 2008). The rocks were folded, faulted and thrusted during the Caledonian orogeny, as well as rifted during the Late Palaeozoic rifting phase. Local and regional thermal metamorphism is evident due to the Late Palaeozoic magmatic activity. The area has attracted international scientific research for almost 200 years and a good documentation of the geological history of the area as well as the discovery and first description of several species (Tab.1) is developed. Figure 2 shows some selected fossils from the area demonstrating the great variety and scientific importance of the fossil faunas encountered in the studied area. The Cambrian units are defined, albeit north of the areas covered in the present paper, in Nielsen and Schovsbo (2007), the Ordovician succession by Owen et al. (1990) and the Silurian by Worsley et al. (1983). The units are in some subsequent papers slightly modified, and the database of all units can be retrieved from the Norwegian Geological Survey (http://aps.ngu.no/pls/oradb/geoenhet_SokiDb.Startapp).

The Upper Paleozoic succession of the Oslo Region was lithostratigraphically described in Henningsmoen (1978) and units within the Carboniferous Asker Group were erected. Proper definitions of type sections and boundary definitions are still lacking for this interval, and it is necessary to follow this up according to modern international standards.

The landscape has been formed during several ice age events, leaving a moderately glacially sculptured Oslo Fjord and abundant remnants of glacial erosional landforms such as glacial striae, roches moutonnées, plastically sculptured forms etc. The deglaciation of the late Weichselian ice-cap has been especially important when it comes to the distribution of surficial deposits. The major Younger Dryas Ice-marginal features cross the Oslo Fjord just south of the investigation area, which stretches north to some of the youngest ice-marginal features, found in South-East Norway just south of Lake Mjøsa (Sørensen 1979). The Aker moraines dated to 10000 yr. BP (Gjessing 1980) crosses through the northern urban areas of Oslo. Glacioisostatic response of the Earth’s crust has resulted in a late glacial highest shoreline, which reaches its maximum elevation in Oslo reaching 220 m.a.s.l. Below this limit glaciomarine clays occur typically in flat and concave terrain positions forming an agricultural landscape intersected by gullies. Several places well-developed shorelines can be found and the glasioisostatic rebound is well documented by pollen studies in lakes and mires in the area (Hafsten 1958).

A geoheritage framework of the area (excluding the Precambrian) can, based on present knowledge, be linked to the following features: 1) The Early Paleozoic sedimentation period, 2) the Caledonian folding, 3) the Carboniferous-Permian rift with fault lines calderas, lavas and magmatic rocks and 4) the relatively recent ice age impacts including Holocene landforms and shore displacements.

Most of the protected areas are linked to natural shore outcrops. Natural erosion is low and many sites are small. Even if they principally are exposure sites they have been regarded as integrity sites (Prosser et al. 2006) by the management. Some of the sites are, however, found in small abandoned quarries or road- and railway cuts.

Materials and methods

Old reports prepared for different inventory schemes have been studied together with general geological literature including collection databases at the Natural History Museum (University of Oslo), archives and field visit reports. The scientific and management literature seen together gives insight in the inventory process, use of value criteria and management priorities. This has been supplemented by an analysis in two scales identifying gaps in the protection system relative to a simple understanding of the geoheritage framework. Such gap analysis (see for example Jennings 2000 and Sharples 2014) is increasingly used in conservation network assessment and planning. In this paper, we have both made a gap analysis of the stratigraphic sites relative to the stratigraphic logs of the area and a more general analysis based on suggested geoheritage frameworks for bedrock geology and structures and Quaternary geology.

The overall status of the geosites has been documented through aerial photo interpretation and a detailed recording of the state of defined geological values was recorded by field visits. 35 protected localities were visited during the 2012 field season, and a few were re-visited in 2013 (Erikstad et al. 2013). The following observations were made for each locality:

- Overview and detail photos were taken
- Degradation of the site was noted
    - Natural degradation (sea, ice, scouring, over-growth)
    - Human degradation (active destruction, wear and tear due to the use of the site for public recreation, walking/paths, fire places)
- Management assessment
    - Quality / presence of sign posts, information panels
    - Assessment of the extent of each protected site relevant to the protection aim

A literature survey was conducted to map geographic positions of lithostratigraphic type sections for the stratigraphic sites. Such type sections, where lithostratigraphic formations and members are defined, are considered to be of great importance for future scientific use.

Results

<u>Inventories, values and criteria</u>

The old nature conservation inventory of the 1970's was not completed to form a contemporary systematic inventory covering the whole country for a comprehensive geological framework. It is dominated by suggestions from concerned geologists and dominated by Quaternary sites (Erikstad 2012). It contained, however, a comprehensive report and a systematic scientific inventory of the stratigraphic record of the Paleozoic sedimentary rocks in the Oslo region. This inventory was used as a basis for selecting geosites for the fossil protection plan of the area. The main aim of the inventory was to document the whole record of sedimentary rocks with its stratigraphic and fossil content within the selected geosites. In this respect both uniqueness as well as representativeness formed important criteria elements in the selection process. Both scientific and educational value were assessed. All educational criteria were specifically linked to the stratigraphic and fossil character of the sites with important elements linked to the possibilities to study the geological development over time.

For parts of the geology supplementary inventories have later been launched, notably a large scheme linked to Quaternary sites for all Norwegian counties resulting in the documentation of nearly 1000 geosites (Erikstad

2012). This was a nation-wide inventory done separately for each county by scientific personnel. Also here criteria were used to secure both the unique and the representative with especial emphasis on documenting different geographical patterns as well as the development of glaciation features over time. Both scientific and educational criteria were used together with additional value given for common experience, but limited to the site's scientific value and information potential.

One protected area is also included in this study representing a protection plan for minerals in southern Norway. This was linked to a specific scientific unpublished inventory by John Brommeland in 1980, resulting in 16 protected sites in South Norway in 1984.

Priority in the overall strategies of geosite selection has not only been given to the best sites, the sites with greatest geological values. The pressure on the different types of sites has been lifted up as a main reason for giving priority to these specific parts of a Norwegian geoheritage framework. The priorities governing this work in the late 1900's were specified in a nature conservation governmental white-book in 1983 (Erikstad 1984). Other important parts of the geoheritage framework linked to the Carboniferous-Permian rifting in the Oslo region including lava and deep eruptive rocks have their primary locations outside the most urbanized areas and have not been regarded as being under the same type of threat. Many of these sites have been included in larger protected areas such as large nature reserves and landscape protection areas. Central parts are situated within the main recreation areas around Oslo that are managed according to special legislation giving a higher level of protection than stated in the normal land-use planning. The same is true for Precambrian rocks to the outside the Oslo graben structure although one of the 35 localities included in the survey belongs to this category. No comprehensive inventory of geosites belonging to this category of geoheritage exists and as it geographically is marginal to the investigated area, it is not covered in this paper.

Gap analysis of the Paleozoic sedimentary record

The protected geosites in this investigation cover the stratigraphic record within the area. It is supplemented by protected geosites north, west and south of the investigation area to form a complete stratigraphic record. These geosites fill in the upper part of the coverage as well as on other vital segments in the record. The inventory however is old and was performed before development of new lithostratigraphic units, with corresponding type localities e.g. Owen et al. (1990). Several of these type locations are not protected (see Fig. 3).

General gap analysis

The general coverage of protected areas relative to the coverage of bedrock types has been assessed by a GIS analysis based on the geological maps of the Geological Survey of Norway (Tab. 2). The rocks representing the Oslo-region graben are relatively well represented in the protection system. This, however, is more a general representation analysis of the general geodiversity, rather a gap analysis based on a geoheritage framework. Such a framework has been developed separately for the Quaternary heritage and the bedrock heritage of the area. It is based on the characteristic representation of the different elements and their scientific importance (Tab. 3 and 4).

The most prominent gaps are linked to the main fault line forming the east coast of the Oslo Fjord and representing the eastern border of the graben system. This is poorly represented in the protection system and some of the best localities are under a high land-use pressure that may form a real threat to the geological values in these sites.

Several of the elements of a more local importance are not systematically represented in the protection system. The knowledge about their state or threats towards them is not well developed. It is quite clear that the general pressure on land does deteriorate the geological information found in the landscape. Examples of this are elements like glacial striae, roches moutonnées, Permian intrusives etc.

State of the geosites

The investigated protected geosites have in general terms their geoheritage values intact. A general high land-use pressure has not led to the destruction of these sites and their geological values, although some has been in the focal point of major construction schemes. On a smaller scale, some problems were detected. These are especially linked to the common use of fires in the area, partly linked to gardening and partly recreational use of fires and disposable grills. Placed directly on bare rock these result in cracking and destruction of details in rock structures, content and form may be affected negatively. The same sort of damage can also be observed by small-scale building activities linked to garden walls, paths and landing stages along the coastline. Various forms of graffiti on exposed rock surfaces are also observed during field work in the current project. Such vandalism is difficult to remove from porous rocks and may exist for years.

The main problem in the protected areas that especially affects the possibilities to demonstrate their geological heritage is that many sites start to be overgrown. This is both a question of moss and lichens, but also bushes and shrubs. Several sites have an acute need for cleaning and tests have been initiated to develop and improve the management concerning these problems (Fig. 4).

Some of the most important sites are situated along the shoreline of the Oslo Fjord. The lime-rich bedrock here together with a favorable climate and the glasioisostatic land upheaval have made these shores to a hotspot when it comes to species diversity with a very high proportion of Norwegian red listed vascular plants in very small areas. The most important habitat is called "Open lime-rich shallow-soil lowland system in the boreonemoral zone" (Lindgaard and Henriksen 2012) and are red listed as a nature type in Norway under the category of vulnerable (VU) (IUCN criteria). The area is in great overlap with sites of major geoheritage value both within and outside the protected areas. Hence, management conflicts may arise when it comes to decisions on removal of vegetation from rock surfaces. The red listed nature type is however an open habitat, also threatened by reforesting and invasion of shrubs and bushes. This nature type is normally found in a distinct zonation from rock outcrops at the shoreline through to open species-rich habitats over to forest. Normally it is possible to develop management strategies that facilitate both geological and biological heritage needs in this setting (Fig. 5).

Information and dissemination

All protected geosites are signposted, some also with a general information poster outlining the general geology of the area and the protection system and geosites linked to it. In some places private initiatives have also contributed with special posters, giving more specific information linked to the site. During our study it has been documented a need for better information. Especially there is a need for better interpretation material (site specific information boards with illustrations, publications etc.) that makes the protection understandable for local people and visitors.

Discussion

The analysis has documented the great importance of the protected geosites in the Oslo region. They have a clear scientific value and also educational value used regularly on all teaching levels. Scientific use of the sites occurs on a regular basis. To do research in the protected geosites one has to follow the rules of conducts which are specified for each and every site. This means that activities such as sampling and collecting are not allowed. It is, however, possible to apply for dispensation from this rule for scientific research. One of the conservation aims is to facilitate research and most applications are accepted. During the completion of the current project several researchers contacted us regarding field work and collection of samples in the protected geological sites. The nature conservation office in each affected county or in some occasions the municipality is handling such applications, and there is a near contact between that office and scientists affiliated with the Natural History Museum (University of Oslo). As a general rule the applicant has to justify why field works must take place inside the protected areas, the collection of samples must be carried out with as little damage as possible and photo documented reports must be handed in when the project is completed. The application and dispensation procedures and the reporting of the activities going on can however, be improved.

Scientific and educational value criteria are closely linked and criteria based on the regional representativeness of stratigraphy and geographical changes in the traits of the geological units as well as the regional pattern of deglaciation features underline this. All use of educational criteria in selecting areas for protection is based on scientific assessments. On a lower level a multitude of sites exist that can be documented as important for education on local schools and for a general public, demonstrating regional patterns (such as stria, dykes and foldings) and forming central elements in the landscape character of the area.

It has recently been questioned (Brilha 2016) if such sites represent what we call geoheritage and should not be labeled geosites, but rather separated under the term geodiversity sites. The word “heritage” in this context is not normally limited to features or objects of a specified high value. The British Dictionary defines the term “the evidence of the past, such as historical sites, buildings, and the unspoilt natural environment, considered collectively as the inheritance of present-day society”. UNESCO (2015) defines heritage as a “set of tangible and intangible values, and expressions that people select and identify, independently of ownership, as a reflection and expression of their identities, beliefs, knowledge and traditions, and living environments, deserving of protection and enhancement by contemporary generations and transmission to future generations”. The term is in other words used to cover a range of values, not only the top end, which is also underlined by the UNESCO term “World heritage”, the objects/features which are unique and have a global value.

Limiting the terms geoheritage to the top end of the scientific value scale, will introduce a risk of underestimating local values and thereby weaken the possibility to include geology in local land-use planning and landscape strategies. Heritage should in this setting be used on different levels of value and the term can be rather flexible for the justification on geoheritage initiatives in different settings and within different strategies. The link between the heritage in the everyday landscape and the national and global values is vital to disseminate the importance of geological values within nature management (Erikstad 2013). The values must, however, link to a geoheritage framework and have a scientific content within this framework.

Sites that have not been designed with a value have in a Nordic tradition (Johansson 1999) been labeled geotope parallel to the neutral biological term biotope, but as the term geotope in a German tradition is used synonymous to “Geosite” this is problematic internationally. An alternative is using the term “geodiversity element” which also has the advantage to be expanded into a setting like “geodiversity landscape element” indicating a use of geodiversity in local land assessments in a broader setting than pure geosite assessments.

The overall positive state of the geosites in the investigation is encouraging. It shows that the protection system works, and handles the land pressure in the area. The justifications of the protected geosites are sound. They represent a clear top-level selection of sites representing the geoheritage framework of the area. The protection system should however, be supplemented based on the performed gap analysis and by the inclusion/addition of some recently found localities of high quality and of special geoheritage value.

The lack of implementation of management in some areas has led to a plant overgrowing problem that increases with time. This problem affects the possibilities to use the sites for demonstration and education. It does, however, not affect the basic scientific value of the site. It may be a sound strategy in areas with high land-use pressure to give priority to securing the physical presence of a site even if resources for active management are limited as has been done for many of the investigated sites. For these the time has now come, however, to address this need for active management and one of the primary recommendations in the management plan is to clear vegetation where necessary, to facilitate the scientific and educational use of the sites. This work is now continuously ongoing and clearing of vegetation has already been done in several of the investigated sites. As a part of this work tests of sand- and dry ice blasting of rock surfaces in road cuttings and old quarries have also been carried out (Fig 4). It is also important to promote public awareness by preparing sign posts and information panels in more areas and improve the existing ones with more detailed and site-specific information. This will also increase local “ownership” to the areas and make the cooperation between public, landowners and management better.

Conclusion

The protected geosites in the investigated area are well justified and form a protected system of high quality regarding the geoheritage framework of the area. The protected units are linked to protected areas outside the investigated area, especially stratigraphic and fossil geosites in the rest of the Oslo Region. The gap analysis and management assessment should be expanded to cover these areas. The gap analysis has revealed the need for additional protection, especially linked to non-protected type locality sites, some recently discovered unique sites of special documented value and sites linked to the main fault-line of the Oslo graben.

A larger emphasis should also be given to sites of local value and geodiversity elements that are important for landscape character. This will improve the general land-use planning in a way that the overall geodiversity-based landscape character can sustain its geological quality for the future and is an important element in future strategies to secure the local geoheritage.

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References

Brilha J (2016). Inventory and Quantitative assessment of Geosites and Geodiversity Sites: a Review. Geoheritage 8(2): 119–134.

Erikstad L (1984) Registration and conservation of sites and areas with geological significance in Norway . Norwegian Journal of Geography 38: 199-204

Erikstad L (1994) The building of an international airport in an area of outstanding geological diversity and quality. In: O´Halloran D, Green C, Harley M, Stanley M, Knill J (eds) Geological and Landscape Conservation. Geological Society, London, pp 47-51.

Erikstad L (2012) Norway. In: Wimbledon WAP, Smith-Meyer S (eds) Geoheritage in Europe and its Conservation. ProGEO, Oslo, pp 246-253.

Erikstad L (2013) Geoheritage and geodiversity management – the questions for tomorrow. Proceedings of the Geologists' Association 124: 713-719.

Erikstad L, Hoel OA, Nakrem HA, Markussen JA (2013) Forvaltningsplan for geologiske verneområder i Buskerud, Oslo og Akershus med tilleggsvurderinger. (Management plan for geosites in Buskerud, Oslo and Akershus with additional assessments,) Fylkesmannen i Oslo og Akershus, Miljøvernavdelingen, rapportnummer 5-2013, 135 pp (In Norwegian).

Gjessing J. 1980. The Aker moraines in southeast Norway. Norwegian Journal of Geography 20: 9-34.

Hafsten 1958 Application of pollen analysis in tracing the Late Quaternary displacement of shorelines in the inner Oslofjord area. Norwegian Journal of Geography 16: 74-99

Henningsmoen G (1978) Sedimentary rocks associated with the Oslo Region lavas. In: Dons JA, Larsen BT (eds) The Oslo Palaeorift. A Review and Guide to Excursions. Norges Geologiske Undersøkelse Bulletin 337: 17-24.

Jennings, M. D. (2000) Gap analysis: concepts, methods and recent results. Landscape Ecology 15: 5-20.

Johansson, C.E. (ed) (2000) Geodiversitet i Nordisk Naturvård (Geodiversity in Nordic Nature Conservation). Nord 2000:8 Nordisk Ministerråd, Copenhagen, 149pp.

Larsen BT, Olaussen S, Sundvoll B, Heeremans M (2008) The Oslo Rift and North Sea in the Carboniferous and Permian, 359-251 million years ago. In: Ramberg I, Bryhni I, Nøttvedt A, Rangnes K (eds) The Making of a Land. Geology of Norway. Norsk Geologisk Forening, Trondheim, ISBN 978-82-92-39442-7, pp 260-303.

Lindgaard A, Henriksen S (2011) The 2011 Norwegian Red List for Ecosystems and Habitat Types. Norwegian Biodiversity Information Centre, Trondheim.

Nakrem HA, Rasmussen JA (2013) Oslo district, Norway. In: Calner M, Ahlberg P, Lehnert O, Erlström M (eds) The Lower Palaeozoic of southern Sweden and the Oslo Region, Norway. Field Guide for the 3rd Annual Meeting of the IGCP project 591. Sveriges geologiska undersökning Rapporter och meddelanden 133: 58–85 (+references).

Nielsen AT, Schovsbo NH (2007) Cambrian to basal Ordovician lithostratigraphy in southern Scandinavia. Bulletin of the Geological Society of Denmark 53: 47-92.

Owen AW, Bruton DL, Bockelie JF, Bockelie TG (1990) The Ordovician successions of the Oslo Region, Norway. Norges Geologiske Undersøkelse, Special Publication 4: 54 pp.

Prosser C, Murphy M, Larwood J (2006) Geological conservation – a guide to good practice. English Nature, Peterborough, UK.

Sharples, C. (2014) A Thematic Gap Analysis of the Tasmanian Geoconservation Database: Glacial and Periglacial Landform Listings in the Tasmanian Wilderness World Heritage area. Nature Conservation Report Series 14/4, 81pp. http://dpipwe.tas.gov.au/Documents/Sharples2014_TGD_GapAnalysis_GlacialPeriglacial_final.pdf. Accessed 29.09.2016).

Sørensen 1979. Late Weichsealian deglaciation in the Oslofjord area. Boreas 8: 241-246.

UNESCO (2015) Recommendation concerning the protection and promotion of museums and collection, their diversity and their role in society." http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CLT/images/FINAL_RECOMMENDATION_ENG_website_03.pdf. Accessed 29.09.2016.

Worsley D, Aarhus N, Bassett MG, Howe MPA, Mørk A, Olaussen S (1983) The Silurian succession of the Oslo Region. Norges Geologiske Undersøkelse Bulletin 384, 57 pp.

Worsley D, Nakrem HA (2008) The Lower Palaeozoic – Cambrian, Ordovician and Silurian – the sea teems with life; 542-416 Ma. In: Ramberg I, Bryhni I, Nøttvedt A, Rangnes K (eds) The Making of a Land. Geology of Norway. Norsk Geologisk Forening, Trondheim. ISBN 978-82-92-39442-7. 148-177.

Figure Captions

Figure 1. Geological map of the Oslo region. (Larsen et al. 2008)

Figure 2. Selected fossils from the Oslo Region. (Museum number prefix PMO refers to the paleontological collections of the Natural History Museum, Oslo).

A: *Mixopterus kiaeri*, a 70 cm long eurypterid from the Upper Silurian, Ringerike district, Norway. PMO H2044

B: *Toxochasmops extensus*, a phacopid trilobite from the Upper Ordovician of the Asker district. PMO 94322

C: *Catenipora oriens*. A Lower Silurian tabulate coral from Oslo. PMO 42944

D: *Cnemidactis osloensis*. An asteroid from the Middle Ordovician, Asker district. PMO 202.380

E: *Pterolepis nitidus*. An anapsid fish from the Upper Silurian of the Ringerike district. PMO E1063

F: *Asaphus expansus*. A Middle Ordovician trilobite from Oslo. PMO 61493.

Figure 3. Stratigraphic diagram relative to the coverage of protected geosites in the study area.

Figure 4. Vegetation removal with wet sandblasting and dry ice has been tested as part of a systematic management procedure in selected geosites.

Figure 5. Zonation in a geological reserve with high biodiversity valley. (A) Bare rock outcrops at the shoreline washed by waves and affected by ice drifting is the most geological accessible and valuable. (B) a shallow soil zone between shoreline and (C) the forest. This zonation can be used as a guideline assessing the balance between geoheritage and biodiversity in many protected areas with mixed values.

Table captions:

Table 1.

Number of new species described in the Oslo region given by taxonomic units. Numbers are based on the collection databases of the Natural Historic Museum, University of Oslo.

Table 2.

Protection coverage for rock types in the area according to geological map units (Geological Survey of Norway).

Table 3.

Suggested framework for Quaternary geology of the investigated area

Table 4.

Suggested framework for the bedrock and bedrock structures of the investigated area.

Table 1. Number of new species described in the Oslo region given by taxonomic units. Numbers are based on the collection databases of the Natural Historic Museum, University of Oslo.

Taxonomic unit	Number
Algae (macro)	3
Bivalves	8
Brachiopods	79
Bryozoans	15
Cephalopods	63
Conodonts	4
Corals (cnidarians)	32
Early jawless fish	5
Echinoderms	21
Eurypterids	8
Foraminiferans	3
Gastropods	19
Graptolites	82
Ichno-fossils (trace fossils)	1
Molluscs (others)	16
Ostracodes	52
Palynomorphs	5
Plants	2
Problematica	2
Sponges	6
Trilobites	204

Table 2, Protection coverage for rock types in the area according to geological map units (Geological Survey of Norway).

Code	Rock unit	Area	area %	protected	protected%
2	Sandstone	246118	**1.90**	6277	**1.02**
3	Conglomorate, sedimentary breccia	4091	**0.03**	450	**0.07**
4	Breccia	67943	**0.52**	210	**0.03**
5	Mylonite, phyllonite	379	**0.00**	0	**0.00**
7	Sedimentary rocks (unspecified)	5344	**0.04**	128	**0.02**
8	Schist, sandstone, limestone	302950	**2.34**	10573	**1.72**
9	Sandstone, Schist	358114	**2.77**	11274	**1.84**
10	Limestone, schist, marl	481352	**3.72**	15553	**2.54**
11	Limestone, dolomite	66999	**0.52**	205	**0.03**
21	Granite, granodiorite	2166385	**16.74**	59290	**9.66**
22	Diorite, monzodiorite	34750	**0.27**	0	**0.00**
23	Syenite, quarts syenite	2585733	**19.98**	150207	**24.48**
24	Monzonite, quarts monzonite	2621795	**20.26**	260136	**42.40**
26	Rhyolite, rhyodacite, dacite	157973	**1.22**	1469	**0.24**
27	Rhomb porphyry	1786623	**13.81**	53919	**8.79**
28	Metabasalt	197790	**1.53**	14301	**2.33**
29	Volcanic rocks (unspecified)	301277	**2.33**	13816	**2.25**
35	Gabbro, amphibolite	38307	**0.30**	0	**0.00**
61	Quartsite	15582	**0.12**	0	**0.00**
62	Mica gneiss, mica schist, meta sandstone, amphibolite	116354	**0.90**	0	**0.00**
65	Phylite, mica schist	594575	**4.59**	7354	**1.20**
66	Calcareous mica schist , calc-silicate gneiss	69	**0.00**	0	**0.00**
70	Marble	215514	**1.67**	8314	**1.36**
82	Dioritic to granitic gneiss, migmatite	344707	**2.66**	0	**0.00**
85	Augen gneiss, granite, foliated granite	141460	**1.09**	0	**0.00**
87	Banded gneiss (amphibolite, hornblende gneiss, mica gneiss), partly migmatitic	89561	**0.69**	0	**0.00**

Table 3 Suggested framework for Quaternary geology of the investigated area

	Description	Comments
Characteristic features of national and international importance	• The Ås-Ski and Hauerseter stages • Large delta deposits, glasilacustrine deposits, kettle hole systems at the Hauerseter stage • Late glacial highest shoreline localities • Marine clays with gullies and quick clay slides • Large recent delta deposits	Large protected areas around the Hauerseter stage (Erikstad 1994) covers large raised delta deposits, kettle holes and clay landscapes. Ecological nature reserves covers large recent delta deposits.
Characteristic features of national and international importance of regional and large local importance	• Other ice margin stages • River channel forms such as meanders • Eolian deposits and fossil sand dunes	An area of Fossil sand dunes is protected near the Hauerseter stage
Supplementary characteristic features contributing to the geodiversity of the area.	• Eskers • Potholes • Erratics • glacial striae, roches moutonnées • Drumlins • Remnants on pre-Quaternary deep weathering	

Table 4. Suggested framework for the bedrock and bedrock structures of the investigated area.

	Description	Comments
Characteristic features of national and international importance	• The main fault line along the eastern shores of the Oslo fjord. • Permian and lavas forming plateau hills west of the inner Oslo Fjord • Caldera structures in the Oslo Graben	Protected areas covers large areas of lava incl. cliffs with cross sections. The major calderas have most of their area within the specially managed (protected) recreational areas around Oslo.
Characteristic features of national and international importance of regional and large local importance	• Permian deep eruptive rocks • Permian lavas (through the total sequence of eruptions)	Large parts within the specially managed (protected) recreational areas around Oslo.
Supplementary characteristic features contributing to the geodiversity of the area.	• Permian dykes and sills • Volcan remnants	Often small outcrops under heavy land use pressure.

Figure

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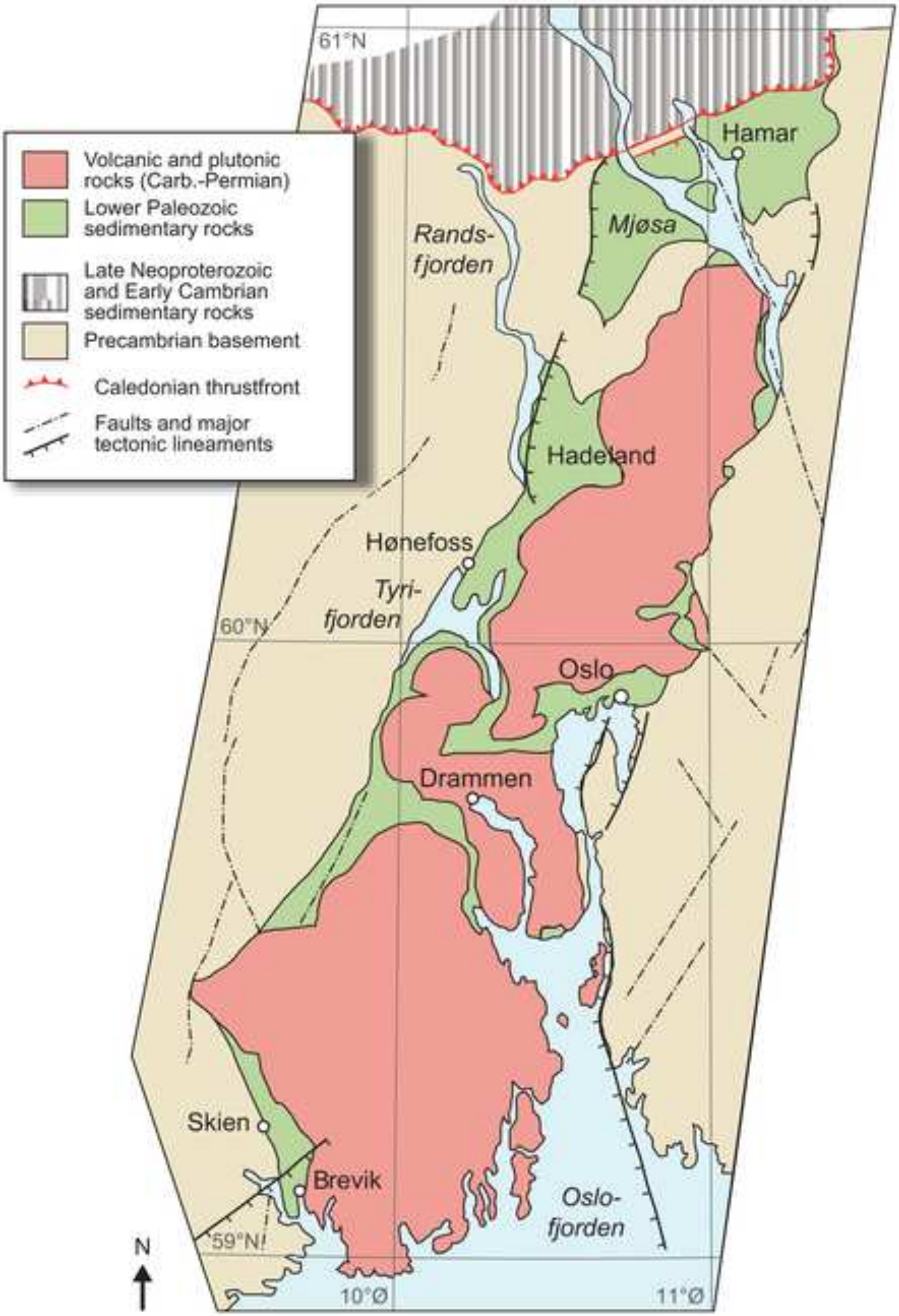

Figure

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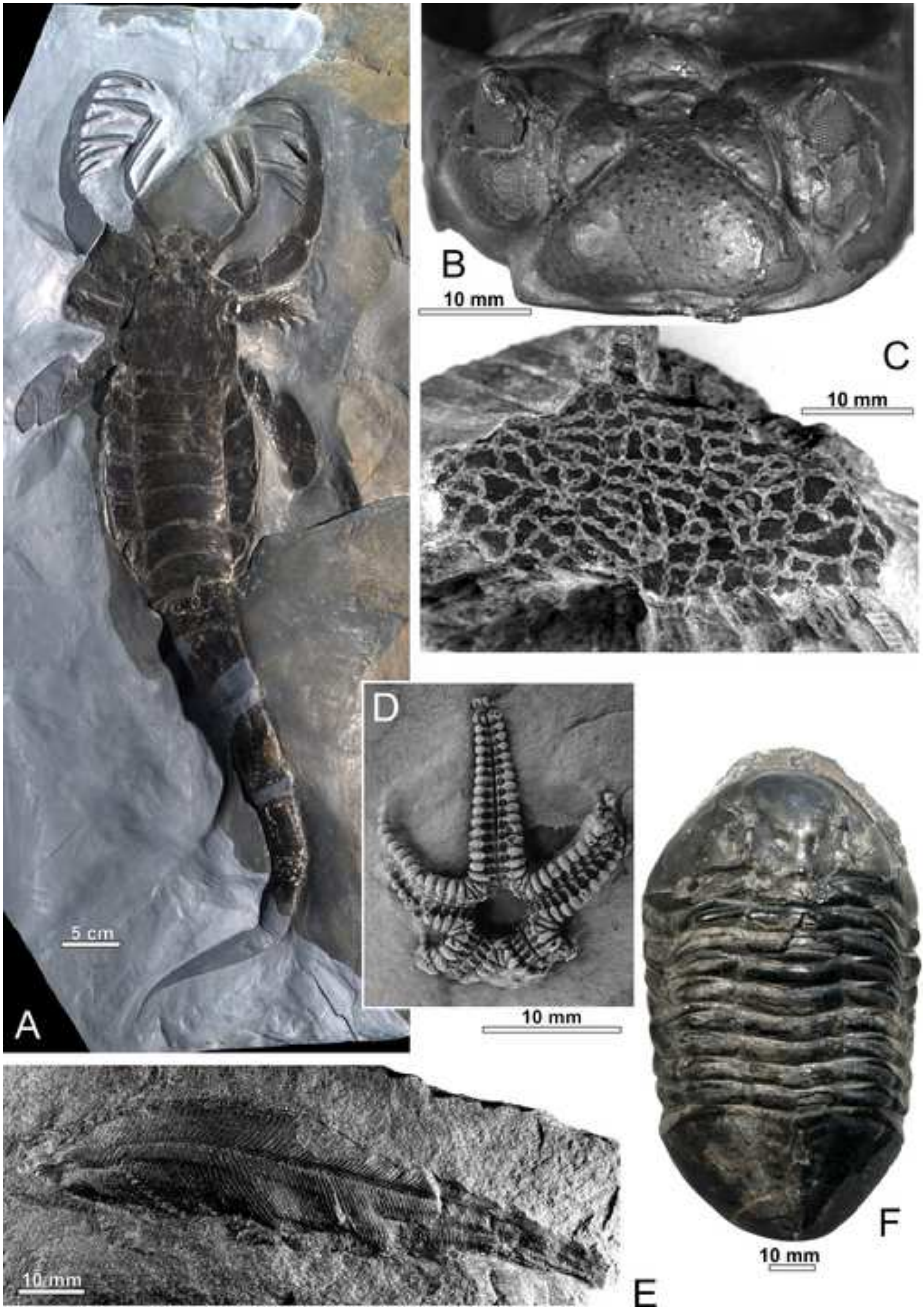

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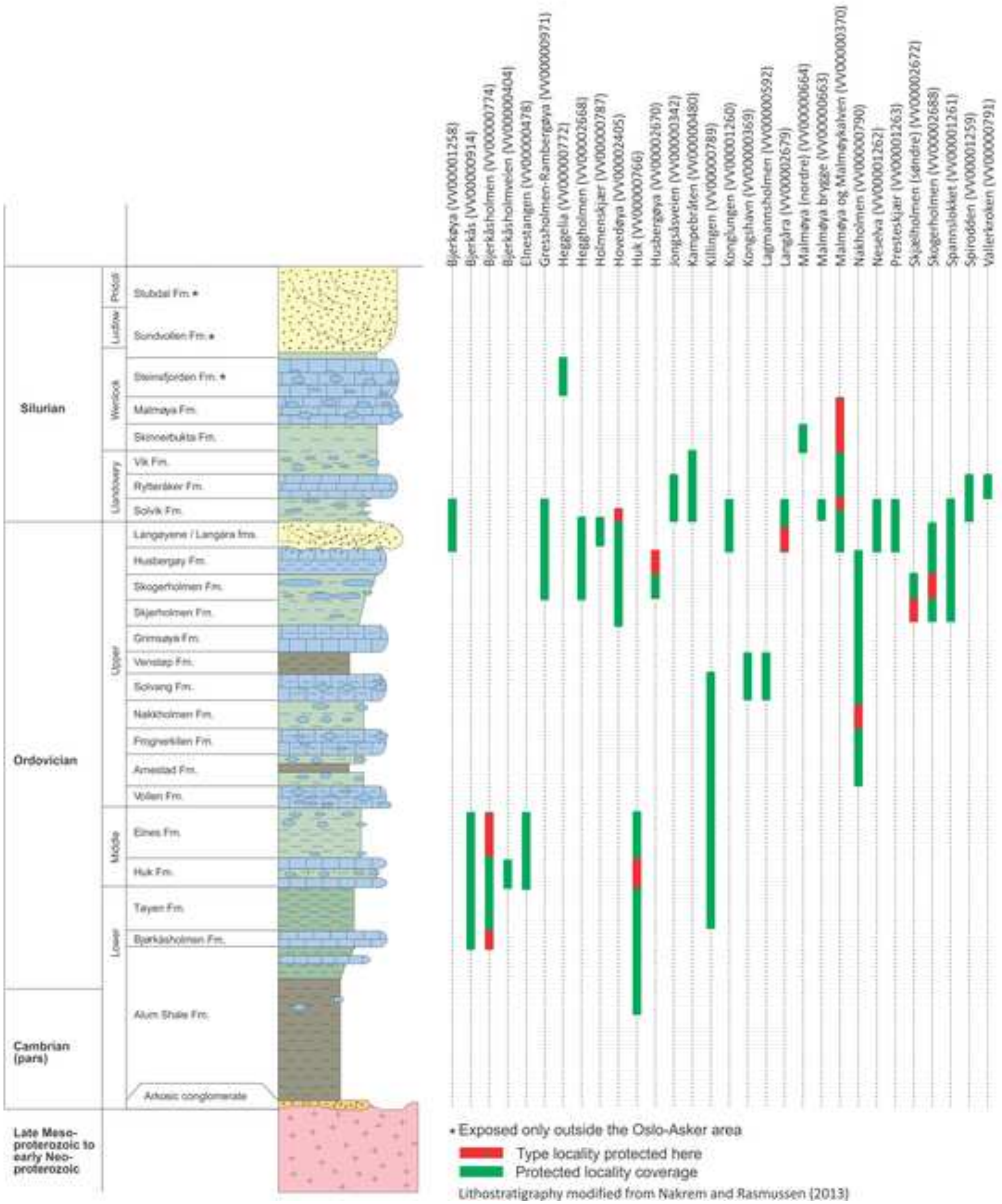

Figure

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