Paleogene fossils in erratic blocks from Averøy and Frei, Nordmøre, Norway

Smelror, M.[1]*, Ossó, À.[2]

[1] *Geological Survey of Norway, Postboks 6315 Sluppen, NO-7491 Trondheim, Norway.*
[2]*Josep Vicenç Foix, 12-H, ler-1a, 43007, Tarragona, Catalonia.*

** corresponding author: Morten.Smelror@NGU.no*

Two erratic blocks found on Averøy and Frei in Nordmøre contain fossils of Paleocene-Oligocene age. A yellowish sandstone block found at the shore on Tjønnøya at Averøy contains a fossil decapod *Palaeocarpilius* sp., a genus previously known from the Eocene and Oligocene of the Tethys. A brownish sandstone block found 60-65 m above present sea-level in Frei contains fossil plants leaves (alder and beech), and common terrestrial and rare marine palynomorphs. The recovered dinoflagellate cysts point to a Late Paleocene age for this erratic rock. The two erratic blocks found on Nordmøre derived from sediments deposited in marine, warm-water, near-shore environments. Possibly, the erratic blocks originate from relatively shallow water sediments deposited in the Northern Norwegian-Danish Basin (Skagerrak area) in Late Paleocene to Oligocene times.

Smelror, M. & Àlex Ossó. (2016) Paleogene fossils in erratic blocks from Averøy and Frei, Nordmøre, Norway. *Norges geologiske undersøkelse Bulletin*, **455**, 1-10.

Introduction

In December 2012, Mrs. Anne Lise Tømmervåg contacted geologist Arne Solli at the Geological Survey of Norway about the finding of a block with plant fossils at island Frei in Nordmøre (Fig. 1). The fossils were preserved in an erratic sandstone block (Fig. 2) which was discovered beneath the roots of a pine-tree on her property at Åneslia, some 60-65 m above the present sea-level. The rock with the plant fossils was sent to NGU and a small piece of the sandstone was picked out for palynological analysis. The sampled yielded a fairly rich micro-flora of Paleogene pollen, spores and some rare marine micro-plankton.

The bedrock in the area comprises high-grade Precambrian gneisses (Råheim 1972), and the Quaternary cover is very thin at the location of the finding. A short survey at the site in July 2014 did not add further discoveries.

Late February 2015, Mr. Alf Marius Røsand contacted NGU about a rock containing a fossil crab found by Mr. Johannes Johnsen Ormset some 15 years ago, among boulders on the shore of the small islet Tjønnøya at Averøy (Fig. 1) This is a relatively large fossil crab preserved in yellowish, calcareous sandstone. Upon closer examination, it was identified to be a carpiliid crab of the genus *Palaeocarpilius* A. Milne Edwards, 1862 as commonly found in the Middle- Late Eocene to Early Miocene in the Tethyan Realm (Figs. 3.1, 3.2).

Erratic blocks with Mesozoic fossils and coal are found at several locations along the Norwegian Coast (Ravn and Vogt 1915, Oftedal 1972, Fürsich and Thomsen 2005, Bøe et al. 2008, 2010, Petersen et al. 2013). Most of them originate from nearby offshore or in-shore sedimentary basins (Bøe et al. 2008, 2010), but some blocks may have been transported over longer distances by the sea-ice. To the authors' best knowledge, the Paleogene fossils found at Averøy and Frei are the first on-shore records of Early Tertiary fossils in Norway (excluding Svalbard). The present paper gives a concise description of the fossils and correlates the macrofossil fossil assemblages with comparable assemblages described elsewhere in Europe and the micro-floras with time-equivalent assemblages reported from the Norwegian Shelf. Possible paleogeograhic implications of the recoveries of the erratic fossils are also discussed.

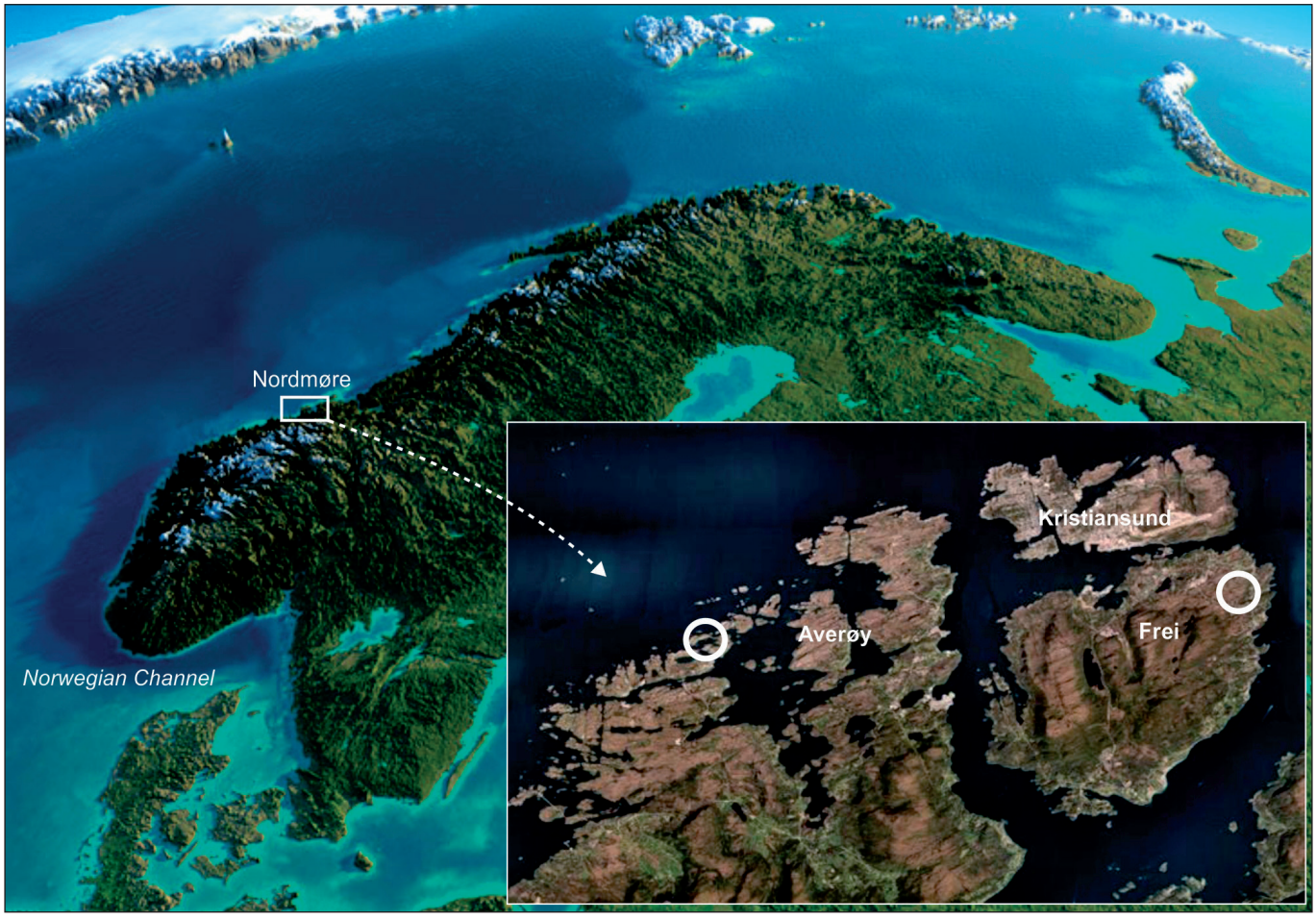

Figure 1. Location map of Early Tertiary erratic blocks found on Averøy and Frei, Nordmøre.

Figure 2. Erratic sandstone with fossil plant leaves found at Åneslia, Frei (Photo: Anne Lise Tømmervåg). The size of the block is approximate 25×40 cm.

Fossil Decapod from Averøy

The decapod specimen found on Averøy is fairly complete, with most of the carapace, chelae and some remains of legs present (Figs. 3.1, 3.2). The carapace is wider than long, measuring 10.5×7.0 cm. Although the carapace surface is heavily degraded and most of the cuticle is missing, from closer examination of photos, it is observed that the specimen preserves still the main diagnostic characters such as: carapace low length/width aspect ratio, strongly vaulted longitudinally; triangular front strongly downturned with medial notch; rounded, small and entire orbits, strongly arched anterolateral margin armed with lobes or teeth; well-marked short transverse ridge starting from last anterolateral spine; shorter and concave postero-lateral margin; short and straight posterior margin; robust and smooth chelae with remains of tubercles on upper margin and short dactily. This set of characters allows us to assign it with confidence to the genus *Palaeocarpilius* A. Milne-Edwards, 1862 (Carpiliidae, Carpilioidea).

Notwithstanding, most specific diagnostic characters are absent in the Averøy specimen, which complicates identification at species level. Nevertheless, it appears very close to two *Palaeocarpilius* species such as *P. macrochelus* (Desmarest 1822), well-known in the Late Eocene-Oligocene of northern Italy, Hungary and Romania, and P. aquitanicus A. Milne-Edwards, 1862 from the Early Oligocene of northern Italy and south-west France. However, differences among those two species are very subtle and concern only the number of tubercles of upper margin of chelae and the number or shape of anterolateral lobes or teeth, which are not well preserved in the Averøy specimen (see Beschin and De Angeli 2006). Therefore, the Averøy fossil decapod is determined as *Palaeocarpilius* sp.

The genus *Palaeocarpilius* is known from Middle Eocene to Miocene strata and was an inhabitant, as many other fossil and extinct members of the family Carpiliidae Ortmann 1893, of warm and generally shallow waters often associated with carbonate reefs in the Tethys Realm. The records of different *Palaeocarpilius* species and other related genera formerly attributed to *Palaeocarpilius* (see Feldmann et al. 2011) in south-west France (Milne-Edwards 1862), northern Italy (Beschin and De Angeli 2006, among others), Hungary (Lörenthey and Beurlen 1929), Romania (Schweitzer et al. 2009), Libya (Collins and Morris 1973), Emirates (Ossó pers. obs.), Pemba Island of Tanzania (Stubblefield 1927), India

Figure 3. Erratic block with the fossil crab Palaeocarpilius *found on Tjønnøya, Averøy (3.1) and close up frontal view of the crab (3.2). The size of the carapace is 10.5×7.0 cm.*

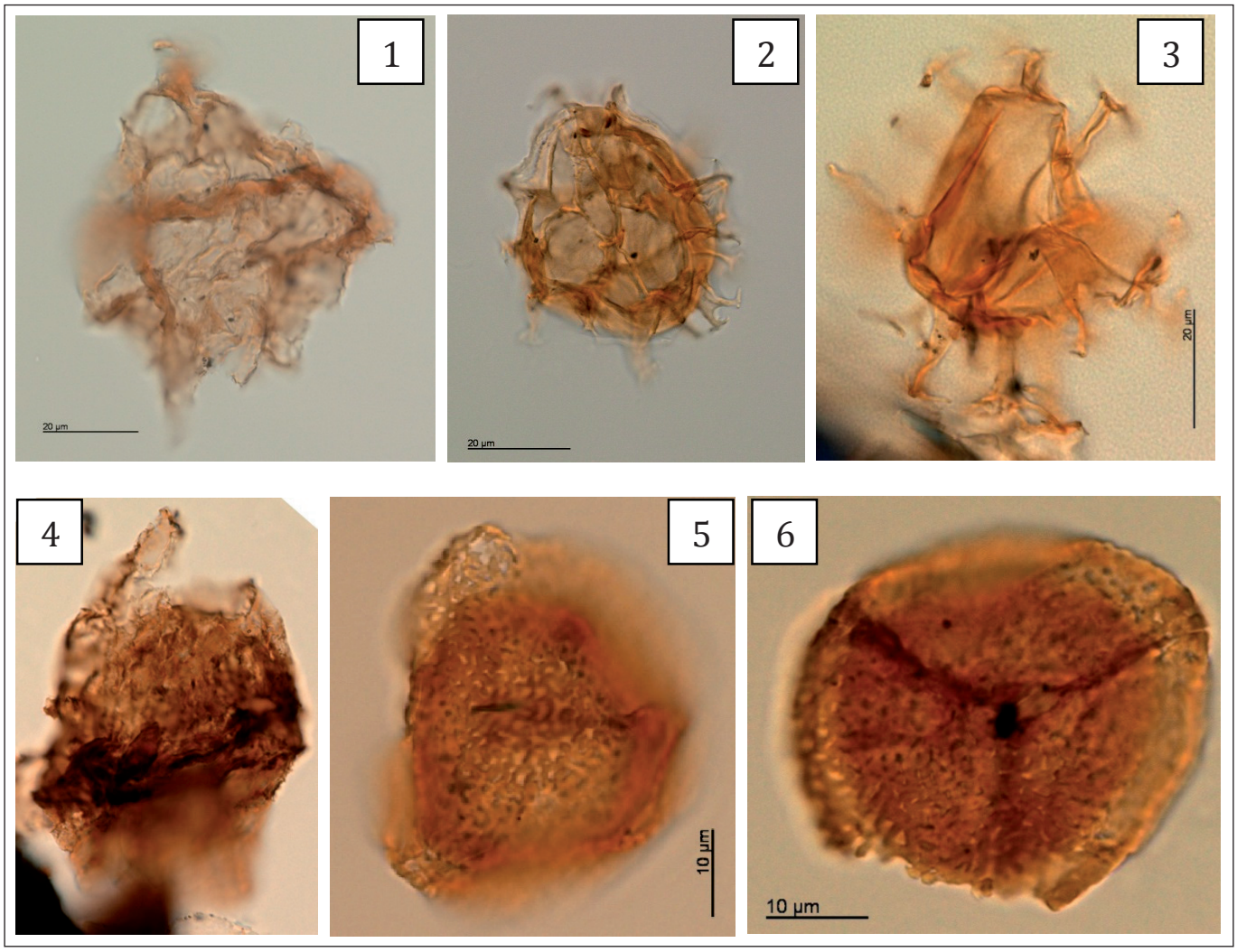

Figure 4. Palynomorphs recovered in erratic blocks found on Averøy calcareous sandstone (Picture 3) and Frei sandstone (Pictures 1, 2, 4, 5 & 6): 1- cf. Phelodinium *sp., 2-* Spiniferites *sp., 3-* Achomosphaera *sp., 4-* Deflandrea speciosa*, 5- Spore indet, 6-* Stereisporites (Distgranisporis) granuloides.

(Ralte et al. 2009, Vega et al. 2010, Rai et al. 2013) and Japan (Imaizumi 1939) show the clear Tethyian affinity of this genus. Furthermore, *Palaeocarpilius* also reached the south-east coast of North America and Gulf of Mexico (Rathbun 1935, Lewis and Ross 1965). The record of *Palaeocarpilius* in the Paleogene of the Norwegian Shelf represents the most septentrional record for the genus, which may have reached the Norwegian Sea from the Western Tethys trough the rising Paratethys. Connection between the North Sea and the Norwegian Sea and the western Tethys, existed during the Late Eocene-Early Oligocene via the Danish-Polish trough and the Rhine Graben, which favored the migration of warm-water faunas (Rögl 1998).

Palynomorphs in the Averøy sandstone

Palynological analysis of a piece of the sample from Averøya also containing the crab fossil showed that the yellowish calcareous sandstone is almost barren of palynomorphs and any other particulate organic matter. The limited amount of palynodebris contained in the sample comprises dominantly small, black coaly fragments. Among the palynodebris, only a single specimen of the dinoflagellate cyst *Achomosphaera* sp. was recorded (Fig. 4.3).

Fossil leaves in the Frei sandstone

The grey-reddish sandstone found in Frei contains several fossil plant leaves from alder and beech (Fig. 2). This flora appears similar to floras described from the Early Tertiary in North Sea-North Atlantic provinces (Cleal et al. 2001, Golovneva 2000, Uhl et al. 2007, Kvaček 2010, Kvaček and Manum 1993).

Palynomorphs in the Frei sandstone

Palynological analyzes of the sandstone yielded common pollen and spores, together with some marine palynomorphs (dinoflagellate cysts) (Fig. 4).

The terrestrial palynoflora includes: *Baculatisporites* spp., *Echinatisporites* sp., *Laevigatosporites ovatus*, *Laevigatosporites* spp., *Leiotriletes* spp., *Lycopodium annotinioides*, 1 spp., *Osmuda claytonites*, *Picea* sp., *Pinus* spp., *Rugulatisporites* spp., *Sciadopitypollenties serratus*, *Sphagnium steroides* and *Stereisporites granuliodes*. Fungal remains are also present.

The assemblages of dinoflagellate cysts includes: *Areosphaeridium* cf. *arcuatum*, *Cerodinium speciosum*, *Deflandrea* spp., cf. *Phelodinium* sp., *Spiniferites mirabilis*, *Spiniferites ramosus* and *Spiniferites* spp. The presence of *Cerodinium speciosum* suggests a correlation to the Late Paleocene Zone 2 of Heilmann-Clausen (1985) and the *Cerodinium speciosum* Interval Biozone (Csp Biozone) of Powell (1992).

Possible origin of the erratics

Ice-rafted boulders and debris are found all along the Norwegian coast and on the shelf. On-land boulders and gravel eroded from the Precambrian and Caledonian basement rocks are common within the cover of Upper Quaternary deposits. The strong glacial erosion by the large ice sheets has led to scarcity of old Quaternary deposits (Mangerud 2004, Olsen et al. 2013), and Neogene and Paleogene deposits have not been identified in Norway. Local basins with Mesozoic deposits are found in some fjords and near-shore areas (Bøe et al. 2008, Bøe et al. 2010), but Tertiary sedimentary rocks appear to be missing in the near-shore basins.

There is no evidence of any pre-Quaternary deposits preserved in the fjord adjacent to the island Frei and Averøya, but seismic data suggest a basin with Mesozoic rocks in Edøyfjorden to the northeast (Bøe and Bjerkeli 1989, Bøe at al. 2010). Possibly, Upper Paleozoic, Mesozoic and/or Tertiary sediments are preserved within faults and fractures parallel to the Møre-Trøndelag Fault Complex in Frøyfjorden (Bøe et al. 2005, Bøe et al. 2010). Pollen of Late Cretaceous or younger age has been found in reddish-brown breccia in the Frøya tunnel beneath Frøyfjorden (Bøe et al. 2005). Erratic boulders with Jurassic and Early Cretaceous fossils are found on the outer islands at Frohavet, but to our knowledge no Tertiary sedimentary rocks have been reported among these findings.

Along the Møre-Trøndelag coast, the boundary between sedimentary and crystalline rocks is located 10-40 km west of the outer islands; the Mesozoic and Cenozoic strata have been cut by erosion. Due to basin-ward subsidence and extensive erosion of the inner part of the shelf, combined with uplift of the coastal areas and the mainland, the sedimentary rocks sub-crop more or less parallel to the coast and decrease in age westwards (Rokoengen et al. 1988, Ottesen et al. 2009).

The bedrock offshore Møre comprises dominantly Mesozoic and Cenozoic sediments. There, the continental shelf is narrow compared to the Haltenbanken area further north. Offshore 25 km northwest of Kristiansund, between the Frøya High and the island of Smøla, there is a basement high, Gripetarane (Bøe & Skilbrei 1998). This topographic high is surrounded by Jurassic strata, which are covered by thicker Cretaceous deposits to the west. A further 35 km offshore to

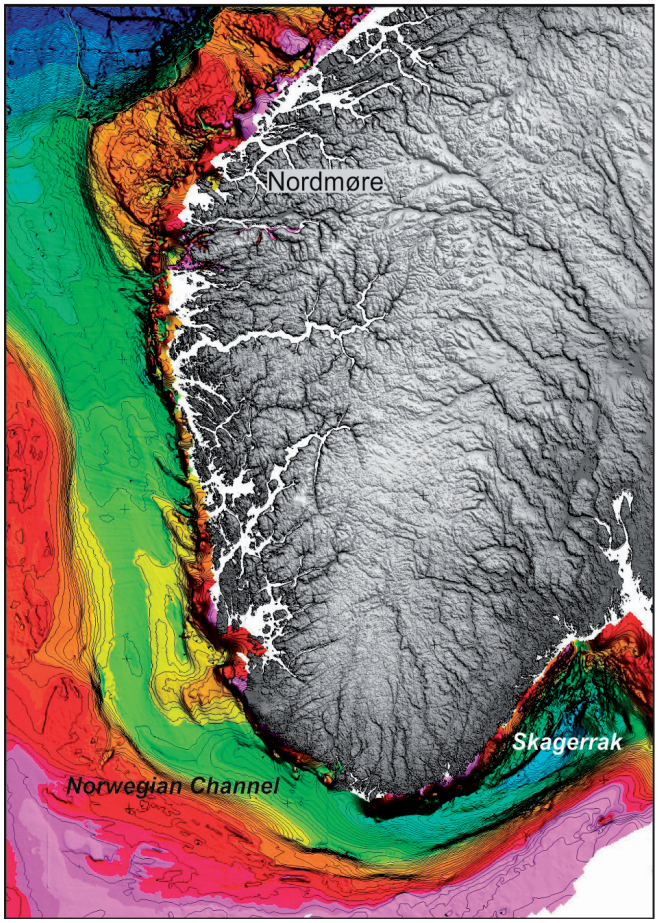

Figure 5. Overview color shaded-relief map of the Norwegian shelf from Skagerrak to the Møre Margin, showing the deepened Norwegian Channel. Based on present knowledge of ice-transported rocks found along the coast of Norway, it seems possible that the erratic blocks found on Nordmøre originates from relatively shallow water Lower Tertiary sediments in the Skagerrak area. (Map by Dag Ottesen).

the northwest, Paleogene volcanic rocks pile up through the succession of Mesozoic and Tertiary sediments (Bugge et al. 1980, Bøe & Skilbrei 1998). In the areas between Gripetarane and the outcropping volcanic Lower Tertiary sedimentary rocks appear to cover the underlying Mesozoic succession.

Triassic, Jurassic and Cretaceous sediments are well-documented in the eastern part of the Møre Basin, i.e. the Sløre botn Subbasin (Smelror et al. 1994, Jongepier et al. 1996). Paleogene strata have been recovered in wells in the Sløre botn Sub-Basin and other localities along the southern portion of the Møre Basin margin (Vergara et al. 2001). Across much of the Halten Terrace and Frøya, High Paleogene strata are absent.

Offshore Møre, the shelf comprises WNW-ESE-trending depressions separated by shallow banks. The troughs presented drainage routes for ice streams during several glaciations (Ottesen et al. 2001, 2005, 2009). Outside the island of Smøla, the ice drainage was directed towards the northern part of the Storegga slide area in the south-west. The bathymetric data reveals another ice stream south of Gripetarene directed towards northwest and merging the ice stream off Smøla (Ottesen et al. 2001).

It cannot be precluded that erratic blocks found on Frei and Averøya originate from nearby Late Paleocene – Oligocene strata, even though no such rocks appear to be present in these areas today. Alternatively, the erratic blocks may have been transported by drifting sea-ice for longer distances along the Norwegian Coast (Fig. 5). Debris is usually concentrated in a 1 - 3 m layer at the base of a glacier. When such layers are preserved in calved icebergs, the layers with eroded material most often melts within a few tens to hundreds of kilometers of the ice-margin where they generated (Andrews 2000). However, findings of ice-rafted chert and rhomb porphyry originating from the Oslo region and the Skagerrak area along the Norwegian coast up to Steigen and Andøya have been known for more than a hundred years (e.g. Vogt 1900, Rekstad 1926). These ice-transported erratic are all found below the upper marine limits. Rekstad (1925) reports erratic from the island of Træna and mention further that blocks of chert are caught in the fishermen's gear at the sea-bed off Nordland (Sklinna, Myken) down to around 200 fathoms (i.e. approximately 110 m).

Rekstad (1926) and Reite (1968) refer to records of ice-rafted rhomb porphyry at Møre, including records at Gjermundnes (Vestnes), at Romsdalsfjorden inside of Molde, and at the outer part of Storfjorden. Kaldhol (1912, 1946) reports recoveries of more than one thousand exotic erratic rocks only at Gjermundnes, predominantly chert, but also rhomb porphyry and larvikite. Rekstad (1926) mentioned that together with the ice-rafted rhomb porphyry, also other rocks are most likely to come from the Oslo Region, such as nordmarkite and erratic blocks with Silurian fossils.

During the Quaternary glaciations, the largest ice stream followed the Norwegian Trench along the southern and western coast of Norway, and ended where the ice calved in the Norwegian Sea west of Måløyplatået (King et al. 1996, Ottesen et al. 2001). The first idea of a major glacier in the Skagerrak area flowing along the Norwegian coast was introduced over one-hundred and thirty years ago by Helland (1885). Several later studies have provided supporting evidence for this major ice stream starting in Skagerrak between Denmark and Norway and ending outside western Norway at 62°N (Longva and Thorsnes 1997, Rise and Rokoengen 1984, Larsen et al. 2000, Sejrup et al. 2000, 2003, Ottesen et al. 2001, 2009, Hjelstuen et al. 2005, 2012) (Fig. 5).

The ice stream in the Norwegian Channel drained much of the southern part of the Scandinavian Ice Sheet (Mangerud 2004, Olsen et al. 2013). It ran parallel with the coast and was the longest on the Norwegian Shelf. The age of the Norwegian Channel is at least 1.1 million years (Sejrup et al. 1995). It has been excavated by ice streams during two major glaciations during Saalian-Weichselian times (Larsen et al. 2000, Mangerud 2004). Based on current morphology, Hjelstuen et al. (2012) estimated that the volume of erosion from the Norwegian Channel has been 10 000 km^3, while Hall et al. (2013) find that 42 000 km^3 of rock must have been removed from the inner shelf of southern Norway. During the main erosion phases, older glacial deposits would have been reworked and re-deposited. On Jæren, along with erratic originating from the Oslo Region, blocks of porphyry from Dalarna in central Sweden, as well as rapakivi and quartz-porphyry most likely coming from the southern part of Åland were also recovered (Rekstad 1926).

Paleogene sedimentary rocks are found on the shelf between Denmark and Norway, and it is possible that the erratic blocks found on Averøya and Fri are from this area. Rekstad (1926) suggested that the erratic from the Oslo Region found along the coast of Norway were transported north-eastwards by sea-ice along with the Norwegian current when the coast became ice-free during de-glaciations. Erratics with Paleogene and Mesozoic fossils commonly found in the Quaternary on-land and offshore Jæren, and reworked Tertiary and Cretaceous palynomorphs are also recorded in Quaternary clay offshore Lista (Smelror pers. obs.). In the Skagerrak area, including the Norwegian Channel, Quaternary deposits truncates and rest with a regional unconformity on Mesozoic and Tertiary sediments.

In eastern North Sea Basin fine-grained, hemi-pelagic, deep-marine sediments were deposited during Late Paleocene to latest Eocene times (Heilmann-Clausen et al. 1985, Michelsen et al. 1998, Rasmussen et al. 2008). The eastern and northern limits of these clay deposits are unknown, due to later erosion (Japsen et al. 2007). During times of Late Cenozoic uplift of the Scandinavian mainland, the basin margins were exhumed and eroded. The amount of uplift increased towards the present-day coasts of Norway and Sweden, and

quantitative studies of exhumation indicate that up to 1 km of sediment may have been removed (Jensen and Schmidt 1992, Japsen et al. 2007).

On a paleographic map presented by Japsen et al. (2007), the southern parts of Norway and Sweden are covered by Lower Eocene deposits. These interpretations are based on the recovery of deep marine faunas in Eocene sediments close to the Sorgenfrei-Tornquist Zone, with no signs of a near-shore fauna. The successive Late Oligocene palaeogeographic map of Japsen et al. (op. cit.) shows an uplifted Skagerrak area, with the coastline extending down to the present north-western coast of Jylland.

The Early Paleocene and Eocene paleogeographic maps of Rasmussen et al. (2008) suggest land areas over southern Norway and Sweden and the present northern Skagerrak. Rasmussen et al. (2008) point out that the present limit of the Eocene deep water sediments towards the Fennoscandian Shield is erosional, caused by Neogene uplift and Quaternary glaciations, and consequently their interpretations of coastline positions are rather speculative. Japsen et al. (2007) argue that Eocene deep-sea faunas and the presence of reworked dinoflagellate cysts and clasts of Eocene muds inter-bedded in the Miocene deltaic sediments in Denmark clearly indicate the presence of marine Eocene deposits in the Scandinavian hinterland.

The presently studied erratic blocks from Averøy and Frei were both deposited in an open marine environment, but the plant-fossils and abundant terrestrial palynomorphs in the block from Averøy suggest a relatively near-shore setting. Further, the fossil carpiliid crab (*Palaeocarpilius* sp.) in the erratic boulder from Averøy is typical of warm and shallow waters. Thus, it is possible that the erratic blocks found on Nordmøre both originate from relatively shallow water sediments deposited in the Northern Norwegian-Danish Basin (Skagerrak area) in Late Paleocene-Oligocene times.

Conclusions

Two erratic blocks found on Averøy and Frei in Nordmøre contain fossils of Late Paleocene-Oligocene age. A yellowish sandstone block found at the shore on Tjønnøya at Averøy contains a fossil crab *Palaeocarpilius* sp. previously known from the Eocene to Miocene of the Tethys, and presents the northernmost record of this genus. A brownish sandstone block found 60-65 m above present sea-level in Frei contains fossil plants leaves (alder and beech), and common terrestrial and rare marine palynomorphs. The recovered marine fossils point to a Late Paleocene age for this erratic sedimentary rock. The erratic blocks come from sediments deposited in marine, warm-water, near-shore environments. Based on present knowledge of ice-transported rocks found along the coast of Norway, it seems possible that the erratic blocks found on Nordmøre originate from relatively shallow water sediments deposited in the Northern Norwegian-Danish Basin (Skagerrak area) in Late Paleocene to Oligocene times.

References

Andrews, J.T. (2000) Icebergs and iceberg rafted detritus (IRD) in the North Atlantic: facts and assumptions. *Oceanography*, **13**, 100-108.

Beschin, C. and De Angeli, A. (2006) Il genere *Palaeocarpilius* A. Milne-Edwards, 1862 (Decapoda, Brachyura, Carpiliidae) nel Terziario del Vicentino (Italia Settentrionale). *Studi e Ricerche*, **13**, 11-23.

Bugge, T., Prestvik, T. and Rokoengen, K. (1980) Lower Tertiary volcanic rocks off Kristansund – Mid Norway. *Marine Geology*, **35**, 277-286.

Bøe, R. and Bjerkeli, K. (1989) Mesozoic sedimentary rocks in Edøyfjord and Beitstadfjorden, central Norway: implications for the structural history of the Møre-trøndelag Fault Zone. *Marine Geology*, **87**, 287-299.

Bøe. R. and Skilbrei, J.R. (1998) Structure and seismic stratigraphy of the Gripetarane area, Møre basin margin, mid-Norway continental shelf. *Marine Geology*, **147**, 85-107.

Bøe, R., Mørk, M.B.E., Roberts, D. and Vigran, J.O. (2005) Possible Mesozoic sediments in faults and brecciation zones in Frøyfjorden, Mid Norway. *Norges geologiske undersøkelse Bulletin*, **443**, 29-35.

Bøe, R., Smelror, M., Davidsen, B. and Walderhaug, O. (2008) Nearshore Mesozoic basins off Nordland, Norway: Structure, age and sedimentary environment. *Marine and Petroleum Geology*, **25**, 235-253.

Bøe, R., Fossen, H. and Smelror, M. (2010) Mesozoic sediments and structure onshore Norway and in the coastal zone. *Norges geologiske undersøkelse Bulletin*, **450**, 15-32.

Cleal, C. J., Thomas, B. A., Batten, D. J. and Collinson, M. E. (2001) Mesozoic and Tertiary palaeobotany of Great Britain. Joint Nature Conservation Committee, Peterborough. *Geological Conservation Review Series*, **22**, xviii + 335 pp.

Collins, J.S.H. and Morris, S.F. (1973) A new crab from the Middle Eocene of Libya. *Palaeontology,* **16** (2), 283-292.

Desmarest, A.G. (1822) Histoire naturelle des Crustacés fossiles. Les Crustacés proprement dits: 67-154. Paris (Levrault).

Feldmann, R.M., Schweitzer, C. E., Bennett, O.A., Franţescu, O.D., Resar, N. and Trudeau, A. (2011) New Eocene Brachyura (Crustacea: Decapoda) from Egypt. *Neues Jahrbuch für Geologie und Paläontologie – Abhandlungen*, **262**, 323-353.

Fürisch, F. and Thomsen, E. 2005: Jurassic biota and biofacies in erratic from the Sortland area, Vesterålen, northern Norway. *Norges geologiske undersøkelse Bulletin*, **443**, 37-53.

Golovneva, L. (2000) Early Palaeogene floras of Spitsbergen and north Atlantic floristic exchange. Acta University of Carolina, Geology, **44**, 39-50.

Hall, A.M., Ebert, K., Kleman, J., Nesje, A. and Ottesen, D. (2013) Selective glacial erosion on the Norwegian passive margin. *Geology*, **41**, 1203-1206.

Heilmann-Clausen, C., Nielsen, O.B. and Gersner, F. (1985) Lithostratigraphy and depositional environments in the upper Palaeocene and Eocene of Denmark. *Bulletin Geological Society of Denmark*, **33**, 287-323.

Helland, A. (1885) Om jordens løse afleiringer. *Meddelelse fra Den naturhistoriske Forening i Christiania*, 27-42.

Hjelstuen, B.O., Sejrup, H.-P., Haflidason, H., Nygård, A., Ceramicola, S. and Bryn, P. (2005) Late Cenozoic glacial history and evolution of the Storegga Slide area and adjacent slide flank regions, Norwegian continental margin. *Marine and Petroleum Geology*, **22**, 57-69.

Hjelstuen, B.O., Nygård, A., Sejrup, H.P. and Haflidason, H. (2012) Quaternary denudation of southern Fennoscandia – Evidence from the marine realm. *Boreas*, **41**, 379-390.

Imaizumi, R. (1939) *Palaeocarpilius laevis* sp. nov. from the Tappocho Limestone of Saipan Mariana Group. *Jubilee Publication in the Commemoration of Professor H. Yabe, M. I. A. Sixtieth Birthday*, 1: 221-226.

Japsen, P., Green, P.F., Nielsen, L.H., Rasmussen, E. and Bidstrup, T. (2007) Mesozoic-Cenozoic exhumation events in the eastern North Sea Basin: a multi-disciplinary study based on palaeothermal, palaeoburial, stratigraphic and seismic data. *Basin Research*, doi:10.1111/j.1365-2117.00329.x

Jensen L.N and Schmidt B.J. (1992) Late Tertiary uplift and erosion in the Skagerrak area; magnitude and consequences. *Norsk Geologisk Tidsskrift*, **72**, 275–279.

Jongepier, K., Rui, J.C. and Grue, K. (1996) Triassic to Early Cretaceous stratigraphy and structural development of the northeastern Møre basin margin, off Mid-Norway. *Norsk Geologisk Tidsskrift*, **76**, 199-214.

Kaldhol, H. (1912) Flyttblokker fra Kristianiatrakten og Danmark på Gjermundnes I Romsdalen. *Kongelige Norske Videnskabselskab Skrifter*, **Nr.2**, 12pp.

Kaldhol, H. (1946) Bidrag til Møre og Romsdals kvartærgeologi. Hellesylt. 150pp.

King, E.L., Sejrup, H.P., Haflidason, H., Elverhøi, A. and Aarseth, I. (1996) Quaternary seismic stratigraphy of the North Sea Fan: glacially fed gravity aprons, hemipelagic sediments and large submarine slides. *Marine Geology*, **130**, 293-315.

Kvaček, Z. (2010) Forest flora and vegetation of the European early Palaeogene – a review. *Bulletin of Geosciences*, **85**, 63 – 76.

Kvaček, Z. and Manum S.B. (1993) Ferns of the Spitsbergen Palaeogene. *Palaeontographica B*, **230**, 169-181.

Larsen, E., Sejrup, H.-P., Janocko, J., Landvik, J., Stalsberg, K. and Steinsrud, P.I. (2000) Recurrent interaction between the Norwegian Channel ice Stream and terrestrial-based ice across southwest Norway. *Boreas*, **29**, 185-203.

Lewis, J. E. and Ross, A. (1965) Notes on the Eocene Brachyura of Florida. *Quarterly Journal of the Florida Academy of Sciences*, **28**, 233-244.

Longva, O. and Thorsnes, T. (Eds.) 1997: Skagerrak in the past and the present – an integrated study of geology, chemistry, hydrography and microfossil ecology. *Norges geologiske undersøkelse Special Publication*, **8**, 100 pp.

Lörenthey, E. and Beurlen. K. (1929) Die fossilen Dekapoden der Länder derUngarischen Krone. *Geologica Hungarica, Series Palaeontologica*, **3**, 421 pp.

Mangerud, J. (2004) Ice sheet limits in Norway and on the Norwegian continental shelf. *In* Ehlers, J. and Gibbard, P. (Eds.), *Quaternary Glaciations – Extent and Chronology, Part I Europe*, pp. 271-294. Elsevier, Amsterdam.

Michelsen, O., Thomsen, E., Danielsen, M., Heilmann-Clausen, C., Jordt, H. and Laursen, G.V. (1998) Cenozoic sequence stratigraphy in the eastern North Sea. *In* de Graciansky, P.C. et al. (Eds.), *Mesozoic-Cenozoic Sequence Stratigraphy of Western European Basins*. Society of Economic Paleontology and Mineralogy, Special Publication, 60, pp. 91-118.

Milne-Edwards, A. (1862) Monographie des Crustacés de la famille Cancériens. *Annales des Sciences Naturelles*, (Zoologie), (4), **18** [1862]: 31-85.

Oftedahl, C. (1972) A sideritic ironstone of Jurassic age in Beitstadfjorden, Trøndelag. *Norsk Geologisk Tidsskrift*, **52**, 123-134.

Ortmann, A. (1893) Abtheilung: Brachyura (Brachyura genuina Boas), II. Unterabtheilung: Cancroidea, 2. Section: Cancrinea, 1. Gruppe: Cyclometopa. Die Decapoden-Krebse des Strassburger Museums, mit besonderer Berücksichtigung der von Herrn Dr. Döderlein bei Japan und bei den Liu-Kiu-Inseln gesammelten und zur Zeit im Strassburger Museum aufbewahrten Formen, VII Theil: *Zoologische Jahrbücher, (Systematik, Geographie und Biologie der Thiere)*, **7**, 411-495.

Ottesen, D., Rise, L., Rokoengen, K. and Sættem, J. (2001) Glacial processes and large-scale morphology on the mid-Norwegian continental shelf. *In* O.J. Martinsen & T. Dreyer (Eds.), *Sedimentary Environments Offshore Norway – Palaeozoic to Recent*. NPF Special Publication, **10**, 441-449.

Ottesen, D., Dowdeswell, J.A. and Rise, L. (2005) Submarine landforms and the reconstructions of fast-flowing ice streams with a large Quaternary ice sheet: the 2,500 km-long Norwegian-Svalbard margin (57°N to 80°N). *Geological Society of America Bulletin*, **117**, 1033-1050.

Ottesen, D., Rise, L., Andersen, E.S., Bugge, T. and Eidvin, T. (2009) Geological evolution of the Norwegian continental shelf between 61°N and 68°N during the last 3 million years. *Norwegian Journal of Geology*, **89**, 251-265.

Petersen, H.I., Øverland, J.A., Solbakk, T., Bojesen-Kofoed, J.A. and Bjerager, M. (2013) Unusual resinite-rich coal found in northeastern Greenland and along the Norwegian coast: Petrographic and geochemical composition. *International Journal of Coal Geology*, **109-110**, 58-76.

Powell, A.J. (1992) Dinoflagellate cysts of the Tertiary System. *In* Powell, A.J. (Ed.), *A stratigraphic Index of Dinoflagellate Cysts.* British Micropaleontological Society Publication Series, Chapmann & Hall, London, pp. 155-251.

Rai, J., Mishra, V. P., Sahni, A., Singh, A. and Vega F. (2013) On some Paleogene and Neogene crabs of Kachchh, Western India. *Bulletin of the Mizunami Museum*, **39**, 39-45.

Ralte, V. Z., Lalchawimawii, J., Malsawma J. and Tiwari R. P. (2009) Decapod fossils from the Bhuban Formation, Surma Group, Aizawl, Mizoram. *Earth Science India*, **2** (III), 196-210.

Rasmussen, E.S., Heilmann-Clausen, C., Waagstein, R. and Eidvin, T. (2008) The Tertiary of Norden. *Episodes*, **31**, 66-72.

Rathbun, M.J., (1935) Fossil Crustacea of the Atlantic and Gulf Coastal Plain. *Geological Society of America, Special Papers*, **2**, 1-160.

Ravn, J.P.J. and Vogt, T. (1915) Om en blok av Neocom fra Hanø i Vesteraalen. *Norsk Geologisk Tidsskrift*, **3**, 32 pp.

Reite, A.J. (1968) Lokalglaciasjon på Sunnmøre (On the Mountain Glaciation of Sunnmøre, West Norway). *Norges geologiske undersøkelse*, **247**, 262-287.

Rekstad, J. (1925) Træna. Beskrivelse til det geologiske generalkartet. *Norges geologiske undersøkelse*, **125**, 36 pp., pls. I-IV.

Rekstad, J. (1926) Flyttblokker langs Norges kyst. *Norsk Geologisk Tidsskrift*, **Bind VIII 1924-1925**, 74-78.

Rise, L. and Rokoengen, K. (1984) Surficial sediments in the Norwegian sector of the North Sea between 60°30'N and 62°N. *Marine Geology*, **56**, 287-317.

Rögl, F. (1998) Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). *Annalen des Naturhistorischen Museums in Wien*, **99 A**, 279-310.

Rokoengen K., Rise, L., Bugge, T. and Sættem, J. (1988) Berggrunnsgeologi på midtnorsk kontinentalsokkel. Kart i målestokk 1: 1 000 000. *Continental Shelf Institute Publication*, **118**.

Råheim, A. (1972) Petrology of high grade metamorphic rocks of the Kristiansund area. *Norges geologiske undersøkelse Bulletin*, **279**, 1-75.

Schweitzer, C.E., Feldmann, R. M. and Lazăr, I (2009) Fossil Crustacea (excluding Cirripedia and Ostracoda) in the University of Bucharest Collections, Romania, including two new species. *Bulletin of the Mizunami Museum*, **35**, 1-14.

Sejrup, H. P., Aarseth, I., Hafiidason, H., Løvlie, R., Bratten, Å, Tjøstheim, G.,

Forsberg, C. F. and Ellingsen, K. L (1995) Quatemary of the Norwegian Channel: glaciation history and palaeoceanography. *Norsk Geologisk Tidsskrift*, **75**, 65-87.

Sejrup, H.-P., Larsen, E., Haflidason, H., Berstad, I.M., Hjelstuen, B.O., Jonsdottir, H., King, E.L., Landvik, J.Y., Longva, O., Nygård, A., Ottesen, D., Raunholm, S., Rise, L. & Stalsberg, K. (2003) Configuration, history and impact of the Norwegian Channel Ice Stream. *Boreas*, **32**, 18-36.

Sejrup, H.-P., Larsen, E., Landvik, J., King, E.L., Haflidason, H. and Nesje, A. (2000) Quaternary glaciations in southern Fennoscandia: evidence from southwestern Norway and the northern North Sea. *Quaternary Science Reviews*, **19**, 667-685.

Smelror, M., Jacobsen, T., Rise, L., Skarbø, Verdenius, J.G. and Vigran, J.O. (1994) Jurassic to Cretaceous stratigraphy of shallow cores on the Møre Basin Margin, Mid-Norway. *Norsk Geologisk Tidsskrift*, **74**, 89-107.

Stubblefield, C.J. (1927) Lower Miocene Crustacea from Pemba Island. *Reports on the Paleontology of Zanzibar*, 1927: 118-120.

Uhl, D., Traisen, C., Griesser, U. and Denk, T. (2007) Fossil leaves as paleoclimate proxies in the Palaeogene of Spitsbergen (Svalbard). *Acta Palaeobotanica*, **47**, 89-107.

Vega, F. J., Tiwari J. K. and Bajpai S. (2010) Additions to *Palaeocarpilius rugifer* Stoliczka from the Oligocene of Kutch, western India. *Bulletin of the Mizunami Fossil Museum*, **36**, 45-49.

Vergara, L., Wreglesworth, I., Trayfoot, M. & Richardsen, G. (2001) The distribution of Cretaceous and Paleocene deepwater reservoirs in the Norwegian Sea basins. *Petroleum Geoscience*, **7**, 395-408.

Vogt, J.H.L. (1900) Søndre Helgeland. *Norges Geologiske Undersøkelse*, **29**, 105 pp.