Erratics of the Danish Maastrichtian and Danian Marine Limestones

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A material of thirty erratics from the Maastrichtian and Danian marine limestones in Denmark falls into four categories: quartzes, rocks from a composite crystalline complex, volcanic rocks and lithified sedimentary rocks. The author suggests that the erratics were mainly derived from the Fenno-Scandian Border Zone in Scania. The erratics show an increase in size from the Maastrichtian to the Danian which is likely to be related to the progressive approach of the coastline with regression.

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In Maastrichtian and Danian time the area now covered by Denmark was occupied by a relatively shallow shelf sea, 100–200 m deep. In the Maastrichtian sedimentation was almost exclusively of pelagic nature, resulting in a thick pile of unlithified coccolithic mudstones (micrites). In the Danian the sea gradually became shallower and a variety of biogenic sedimentary carbonates were deposited, dominated by coccolithic mudstones and bryozoan wackestones and, in the Middle Danian, with a scattered development of coral-bryozoan complexes.

All the mentioned sedimentary rock types have an extremely low content of terrigeneous material, mainly in the form of rare grains of aeolian quartz (Surlyk, 1972). However, isolated finds of pebbles of crystalline rocks, lithified sediments and quartzes have long attracted the attention of geologists.

Hawkes (1951) gave a description of some 400 extraneous stones from the English chalk. When in the title and in the following description I speak of similar stones from deposits in Denmark as "erratics", I have followed Hawkes (1951, p. 257) who stated: "An erratic is a stone which has been transported and deposited by some agent other than those which have laid down the fine sediment in which it occurs."

Erratics of this kind have been described earlier from various localities and countries; I shall restrict my references to Godwin-Austen (1858), Lyell (1871), Ball (1888), Cayeux (1897), Martin (1897), Stebbing (1897), Double (1931) and Hawkes (1943).

Although labels in the Mineralogical Museum of the University of Copenhagen show that erratics from the Maastrichtian and Danian deposits in Denmark have been collected for at least 75 years, only few references to these have appeared in literature (Hennig, 1899; Rosenkrantz, 1920 and Troedsson, 1924). I have examined 30 specimens, kept in the museum in Copenhagen, and one more which belongs to Mr. Gorm Jensens's private geological collection in Fakse.

The material originates from localities on Sjælland, eastern Denmark, except for erratics No. 10, 11 and 13 (compare table 1). Twelve of the erratics, mainly quartzes, came from uppermost Maastrichtian strata; the rest have been found in deposits of Danian age.

The Danian deposits in Denmark are divided into four zones, in ascending order A, B, C and D (Ødum, 1927). One erratic, no. 13, belongs to zone B and four from the Copenhagen area to zone D. Rosenkrantz (1920) mentioned the scarce occurrence of small pebbles from the lower "Crania-limestone" (zone D) in the Copenhagen south harbour; a rounded quartzite the size of a hazel nut is referred to on his p. 13 (Rosenkrantz, 1920).

Table 1

No	Erratic type of rock (or mineral)	Age of host rock	*Lithological character of* still adherent rock
1	Grey quartz	Maastrichtian	Chalk
2	Greyish green quartz	»	»
3	Brownish quartz	»	»
4	White Quartz	»	»
5	White quartz	»	
6	Grey quartzite	»	
7	White quartz	»	
8	White quartz	»	
9	Quartzitic green sandstone	»	
10	White quartz	»	
11	White quartz	»	
12	Dark phosphoritic (?) sandstone	»	Chalk
13	Brownish quartz	Danian, zone B	
14	Biotite schist	» zone C	
15	Grey gneiss or granite	» » »	Lithified coral limestone
16	Grey sandstone	» » »	Coral limestone
17	Green glauconitic sandstone	» » »	Strongly recrystallized coral limestone
18	Biotite gneiss or granite	» » »	
19	Biotite schist	» » »	Recrystallized coral limestone
20	Light brownish opal	» » »	Strongly recrystallized coral limestone
21	Dark grey mica schist	» » »	Bryozoan limestone
22a	Dark rhyolite	» » »	Strongly recrystallized coral limestone
22b	» »	» » »	»
23	Grey fine grained gneiss	» » »	»
24	Light grey schist	» » »	Bryozoan limestone
25	Grey gneiss	» » »	Strongly recrystallized coral limestone
26	Limy sandstone	» zone questionable	Bryozoan limestone
27	Light greenish quartz	» zone C	Calcarenite
28	Gabbro (or coarse dolerite)	» zone D	»
29	Quartz	» » »	»
30	Dark greenish quartz	» » »	Fine grained calcarenite
31	Grey quartz	» » »	» » »

The only known specimen from the small island Saltholm in Øresund is also from zone D; the rest came from the big Fakse quarry where zone C is developed in a coral limestone facies. Floris (1967, and personal communication) estimates the water depth of the Fakse bioherm to about 50–75 m and the temperature of the sea to 15°–18°C. The relatively large amount of erratics found in the Fakse quarry is probably to some extent due to the intensive search for fossils at the locality through the last hundred years.

The finding place of one erratic, no. 26, is uncertain. It either came from Fakse as the majority or from a limestone pit at Karlstrup about 20 km south of Copenhagen, where the zones A, B and C are exposed.

Description of material

The greater part of the erratics are rounded or subangular (figs 1 & 2); one has irregular, broken outlines (fig. 3). The size of the erratics is summarized in fig. 4.

Two of the small quartzes possess a marked "polish" which either may be due to wind action prior to deposition in the marine environment (Dorr, 1966), or possibly may be a token of their having been gastroliths (Godwin-Austen, 1858; Brown, 1904; Wimann, 1916; Troedsson, 1924 and Hawkes, 1951).

The material of the erratics can be divided into the following four petrological groups.

Quartzes (fifteen in all). Because of the wide distribution and the long geological life of that mineral it is not possible to indicate any special locality of provenance.

Rocks from a composite crystalline complex, including mica schist, biotite schist, biotite gneiss, microcline granite and a single

No	Size in millimetres	Locality
1	20 × 12 × 5	Stevns Klint, north of Kulsti Rende
2	4 × 2, partly covered	» » south of ladder Kulsti Rende
3	7 × 5 » »	» » north » » » »
4	3 × 3 » »	» » » » » » »
5	3 × 2 × 2	» » » » » » »
6	11 × 6 × 3	»
7	5 × 3 × 2	»
8	4 × 3 × 2	»
9	10 × 7 × 6	» » 200 m north of Kulsti Rende 2 m above sea level
10	64 × 45 × 20	Lindholm, North Jylland
11	25 × 20 × 12	» » »
12	11 × 8 × 4 partly covered	Stevns Klint
13	6 × 4 × 2	Karleby Klint, Djursland, East Jylland
14	70 × 25 × 15 fractured	Fakse quarry
15	20 × 16 × 6	» »
16	60 × 45 × 30 fractured	» » 25 m beneath surface
17	12 × 8 × 5 fractured	» »
18	45 × 16 × 12 fractured	» »
19	14 × 8 × 2	» »
20	15 × 14 × 10 fractured	» »
21	20 × 12 × 8	» »
22a	20 × 20 partly covered	» » } Two slices of the same pebble
22b	20 × 17 » »	» » }
23	30 × 20 × 12 fractured	» »
24	47 × 18 × 5	» »
25	38 × 30 × 23	» »
26	30 × 13 × 10	Fakse or Karlstrup?
27	11 × 7 × 4	Frederiksholm, Copenhagen
28	70 × 55 × 35 fractured	In contact with basal conglomerate, Saltholm
29	6 × 3.5 partly covered	Knippelsbro, Copenhagen harbour
30	8 × 7 × 6	Djævleøen, » »
31	21 × 20 × 10	» » »

gabbro (which could perhaps be a dolerite from the central part of a broad dyke). These rocks are all known to occur in the Precambrian of southwest Sweden of to-day.

Volcanic rocks are only represented by a rhyolitic pebble and an isolated, nutsized opal. Rhyolite erratics are also known from the English chalk (Hawkes, 1951). The opal could have come from a weathered basalt in Scania; recent age determinations of the basalts here have proved that they are not of Eocene age as hitherto believed but that the oldest of them are Middle Jurassic in age, up to 140 my (Printzlau and Larsen, 1972).

Sedimentary rocks: one pebble is a small, almost black, perhaps phosphoritic sandstone, the rest have light colours; they comprise green quartzitic sandstone, glauconitic sandstone, calcareous sandstone and shale, none of them contains visible fossils. The rocks undoubtedly came from a sequence of lithified sediments subjected to erosion in a not too distant coastal area.

Mode of transport

Godwin-Austen (1858) suggested four possible agencies of transport for erratics of this kind (a to d), to these I have made an addition in brackets to (d) and added one more (e).

(a) Floatation by ice.
(b) In the roots of trees, as driftwood.
(c) Attached to sea-weed (see also Ball, 1888 and Cayeux, 1897).
(d) In the bodies of reptiles (and perhaps birds, see below).
(e) Random swallowing by voracious animals.

(a) Transport by ice, including shore ice, can be excluded in the present case on account of the palaeoclimate (Voigt, 1965).

(b) Transport in the roots of trees is nowadays observable in places where driftwood in larger amounts is washed ashore. Nathorst (1900, p. 222) gave a photograph from

Fig. 1. Pebble of dark grey mica schist in situ in bryozoan limestone (no. 21). × 0.5. Fakse quarry, Middle Danian.

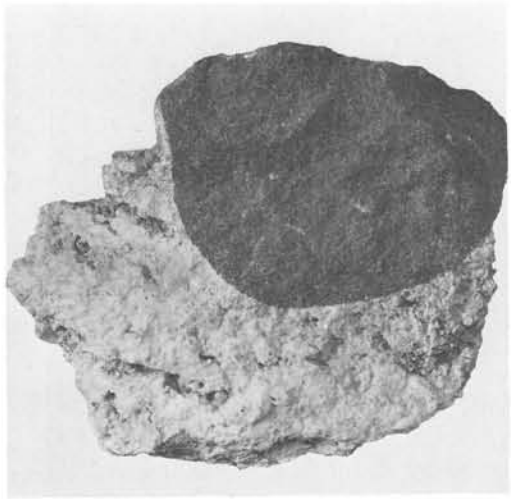

Fig. 2. Pebble of grey sandstone in situ in coral limestone (no. 16). Almost nat. size. Fakse quarry, Middle Danian.

Fig. 3. Rhyolitic pebble (no. 22) with broken outlines, in situ in highly lithified coral limestone. × 0.5. Fakse quarry, Middle Danian.

East Greenland showing a large stone in a tree root. Personally I have seen a big trunk of *Larix* sp. with entangled roots in which two larger stones were held, one as big as a head, in Moskusoksefjord also in East Greenland. The East Greenland driftwood comes from northern Siberia, quite a long distance to be carried! Heavily soaked with seawater, however, much driftwood sinks to the bottom instead of being washed ashore.

(c) Several recent types of algae use stones for their attachment, an example is shown in fig. 5. Such stones can move around easily due to the buoyancy of the plants, especially species with air bladders. Waterworn stones of the size of a child's fist, with attached algae, can to-day be washed ashore with an onshore wind; with an off-shore wind such algae-carried stones may be moved out unto deeper water and come to rest here (see also Hennig, 1899).

(d) The rather numerous smaller erratics may have been transported in animals.

In several cases plesiosaurian bones have been found in connexion with collections of

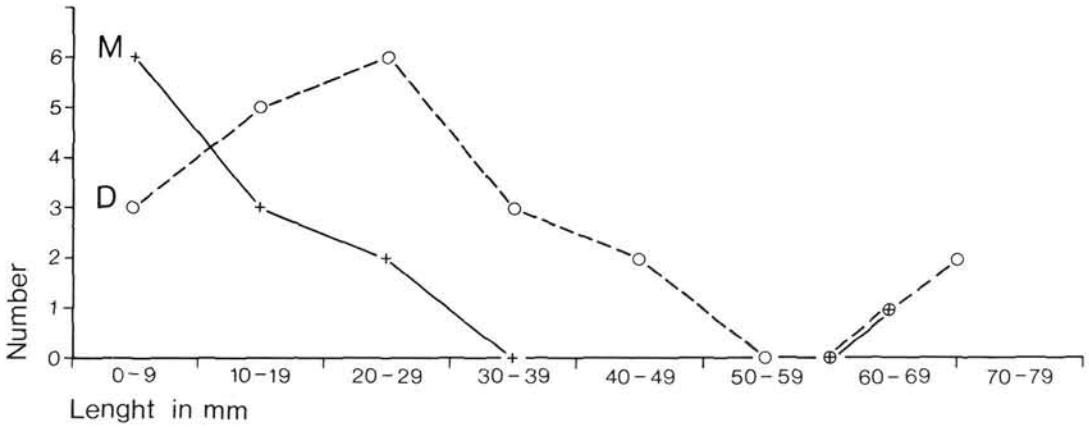

Fig. 4. Size-frequency curves for the erratics. The Danian erratics (D) are seen to be considerably larger than those from the Maastrichtian (M).

stones in fine grained sedimentary strata. In such cases it seems safe to assume that these stones were gastroliths. From England a collection of about 150 small stones were found in a chalk pit near Rochester within a radius of few feet. Hawkes (1951 p. 264) comments on this find as follows: "There can be little doubt that these Rochester stones are gastroliths derived from one drifting carcase. They give the impression of having suddenly been emptied out of a bag – a stomach bag – on to the sea floor". From the "Mucronata chalk" (Upper Campanian or Lower Maastrichtian biocalcarenites) in northeast Scania Wiman (1916) reports a similar find. From the Danian limestone at Limhamn Troedsson (1924) makes mention of gastroliths in connexion with the find of *Thoracosaurus scanicus*. Further, Voigt (1964) has reported on gastroliths.

Since birds are also known to have existed at the time in question, gizzard stones could perhaps be taken into consideration too. (In the gizzard of a Greenland ptarmigan, killed on Ella Ø in East Greenland during the winter 1931–32, I have counted about 400 small stones, almost exclusively consisting of quartz). See also Hoskin, Guthrie and Hoffmann (1970).

(e) The small number of Danish erratics were all found as single stones occurring at random, and only two had a definite polish. As isolated crocodile teeth have been found in Fakse and in the Copenhagen area, these reptiles must have been present, and the occurrence of gastroliths is therefore a possibility. It would be natural to think, however,

Fig. 5. Stone with attached seaweed. Recent. The maximal length of the stone is ca. 10 cm.

that the greater part of the small pebbles had been swallowed together with food, accidentally, by such animals as fish, a thing which can easily happen for voracious animals with a good appetite. Some years ago a basalt stone weighing 600 grammes was found in the stomach of a cod off the west coast of Greenland (P. M. Hansen, personal communication).

Conclusion

It lies near at hand to assume that the rocks represented by the erratics were derived from a coastal strip along the north-eastern shore of the Upper Cretaceous-Lower Tertiary sea. This coast was eroded into the Precambrian shield, partly represented by the Scanian horsts of the Fennoscandian Border Zone. Along the horst flanks sedimentary rocks of both Palaeozoic and Mesozoic age were exposed. Consequently, coastal erosion would be expected to have produced a beach gravel composed of these rocks. However, it cannot be excluded that a contribution could also have been yielded for instance by driftwood transport from a southern shore region, in present Poland and central Germany.

The number of erratics is small and the size-frequency curves of fig. 4 are therefore rather tentative. They show two things, however: the size of the Maastrichtian pebbles is smaller than that of the Danian, and that while the bulk of the material consists of small pebbles there are also a few larger cobbles, 60–70mm in their longest direction. These may have been transported by a different agent from the small ones, perhaps by driftwood or seaweed. It is considered that the small pebbles were possibly picked up randomly by voracious animals along with their food, perhaps in the littoral belt. Later they were deposited on the seafloor together with the excreta of the animals or after their death. The increase in size of the erratics from the Maastrichtian to the Danian at roughly speaking the same geographical location (Stevns and Fakse) is likely to be a consequence of the increasing proximity of the coastline as a result of regression.

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Dansk sammendrag

I danske aflejringer fra Maastrichtien og Danien findes der nu og da små sten af »fremmed« oprindelse. I Mineralogisk Museums samlinger findes der 30 af dem, så at sige alle fundet i dette århundrede. Stenmaterialet består af: 1) kvartser, 2) bjergarter fra et krystallinsk kompleks, 3) bjergarter af vulkansk oprindelse og 4) sedimenter. Det er sandsynligt, at bjergarterne overvejende stammer fra et datidigt kystområde, der ikke lå særlig langt borte fra fundstederne; man kan først og fremmest tænke sig Sydvestsverige og den fennoskandiske randzone i Skåne. Forfatteren forestiller sig, at stenene for størstedelens vedkommende er blevet slugt af grådige dyr – mest fisk – sammen med deres føde, når de har fourageret i kystområdet. Stenene er siden enten udstødt sammen med ekskrementerne eller er efter dyrenes død endt på havbunden. På steder med omtrent samme geografiske beliggenhed som Stevns og Fakse ser man, at stenene tiltager i størrelse fra Maastrichtien til Danien; dette må sandsynligvis tages som udtryk for, at kysten kommer nærmere og nærmere under regressionens forløb. Enkelte større sten med dimension på 60–70 mm er måske blevet transporteret ved hjælp af drivtræ.

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