Eocambrian and Lower Palaeozoic geology of the Digermul Peninsula, Tanafjord, Finnmark.

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Abstract.

The stratigraphical succession of the Digermul Peninsula consists of about 3 000 metres of conformable clastic sediments with carbonates and volcanic rocks absent. It has been divided into two groups. The lower, Vestertana Group, is about 1 450 metres thick and starts with two tillite formations. It includes slates, ortho-quartzite and greywacke sandstones. No body fossils have been found in the group but trace fossils are abundant. The upper, Digermul Group, is about 1 500 metres thick and consists of alternate units of sandstones and shales. The sandstones are mainly orthoquartzites. Fossils, including trilobites and brachiopods, occur at several horizons and an age ranging from Lower Cambrian to Tremadocian has been established.

The principle structure is a major south eastwards facing overturned syncline within which there are many minor folds and thrusts. A major overthrust of the "Caledonian" metamorphic complex from the NNW followed the formation of this structure. The last event was normal faulting along W–E and WNW–ESE lines. A few post-folding quartz dolerite dykes also occur.

Introduction.

The Digermul Peninsula lies on the north coast of Norway between longitudes 27° 35′ and 28° 15′ east and between latitudes 70° 30′ and 70° 45′ north (Figs. 1 and 2). It protrudes from the head of Tanafjord, splitting it into two, with Langfjord on the northwest and the main Tanafjord and Vestertanafjord on the southeast.

No roads or paths exist and habitations are restricted to a few farms at Laggo at the head of Langfjord and at Stappogiedde on the southeast coast. Much of the peninsula is margined by steep cliffs which in many

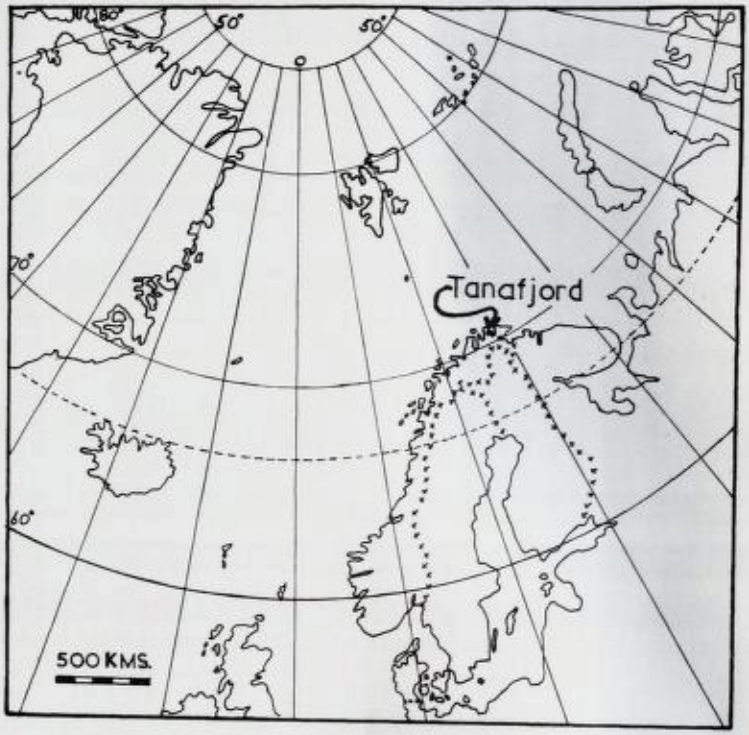

Fig. 1. Sketch map showing relation of Tanafjord to other arctic regions.

places rise abruptly from the sea to a height of 450 metres. The slope inland is more gradual in those parts where metamorphic rocks occur and along the southeastern shore of the peninsula. The centre of the peninsula is essentially a peneplane about 500 metres high, covered by frost shattered boulders and dissected along the southeast side by steep narrow valleys and along the northwest coast by broad glaciated valleys.

The writer first visited the Digermul Peninsula in 1950, while a student. In 1959 he returned with the purpose of mapping the whole peninsula and establishing a stratigraphical succession if possible dated by fossils. This was accomplished and a number of trilobite faunas obtained.

In 1961 and 1963 parties of undergraduate students from Oxford mapped some areas in greater detail. Dr. Gunnar Henningsmoen visited the area in 1960 and 1963 with F. Nikolaisen to collect more fossils and

Fig. 2. Geological map of East and Mid Finnmark
(largely after Holtedahl and Dons, 1960).

the author returned again in 1964 to make a detailed description of the sedimentary rocks.

Mapping was done using 1:50,000 N.A.T.O. maps, enlarged to 1:25,000, as base maps, supplemented by compass traverses and by plane table surveys of Kistedalen and Hånsvikdalen. Aerial photographs were available only for a small area to the southwest of Stappogiedde. Since the survey was made and geological map completed aerial photographs have become available for the whole peninsula.

The purpose of this paper is to present the broad outlines of the geology. Details of the sedimentology will be published later.

The author is indebted to a large number of people for the completion of this work; to Dr. K. S. Sandford who first suggested visiting the Tana region, to Professor O. Holtedahl and Dr. Sven Føyn who have constantly aided with advice and encouragement from their wide knowledge of Finnmark geology, Dr. Føyn himself revisiting the Digermul in 1964; to Dr. Gunnar Henningsmoen who has so kindly undertaken all the palaeontological identifications and who has also helped with discussion and criticism.

For assistance in the field the author would like to thank R. Pattinson and J. K. Russell, his companions in 1959, in particular for their detailed mapping of Kistedalen and for finding the first Tremadocian fauna in Finnmark; to M. E. Fox, M. F. Tuke and S. W. Richardson who made an accurate map of Hånsvikdalen in 1961; to J. D. Collinson, D. M. Cruden, D. M. D. James and B. R. Rosen who began mapping to the southwest of Stappogiedde; to D. R. V. Beynon, J. D. Collinson and R. G. Walker who accompanied the writer in 1964 and not only extended and improved the original map but measured and photographed innumerable stratigraphical sections.

No acknowledgements would be complete without thanking the people of Tanafjord, in particular those at Laggo and Stappogiedde for their hospitality and readiness to help with boats under all conditions of weather.

Field expenses in 1959 were defrayed by the Norges Geologiske Undersøkelse. A generous award from the Scientific Affairs Division of N.A.T.O. allowed the 1964 visit and paid for subsequent laboratory work. To both these bodies and to the many other contributors who made these investigations possible, the author is extremely grateful.

The manuscript has been greatly improved by the critical reading of Drs. Sandford, Henningsmoen, Føyn, Walker and Oxburgh.

Geological background.

The outlines of the geology of Finnmark were established by Holtedahl (1918, 1931) who gives a summary of current knowledge in the Geology of Norway (1960, p. 116–125). This work also includes an account of the structure of Finnmark by Strand (p. 270–277).

East Finnmark is made up of a wedge of sediments lying between an overthrust metamorphic "Caledonian" complex to the north-northwest and the Fennoscandian basement of Precambrian crystalline rocks to the south (Fig. 2). The metamorphic "Caledonian" complex consists of phyllites, schists, and quartzites. It is probably approximately equivalent to the sedimentary wedge for at Berlevåg on the north coast of the Varanger Peninsula the thrust which separates them dies out and there is a transition from metamorphosed into unmetamorphosed sediments (Holtedahl, 1918, p. 270; Føyn, 1937, p. 158).

The stratigraphical sequence of the sedimentary wedge can be divided into three parts: –

3. *Digermul Group*, c. 1500 m. – sandstones and shales containing Cambrian and Ordovician fossils.
2. *Vestertana Group*, c. 1450 m. – sandstones and shales with two tillite formations at the base.

   Slight unconformity
1. *"Older Sandstone Series"*, 1200 m. – sandstones and shales with dolomite in the upper part.

The "Older Sandstone Series" (Føyn, 1937) or "Dolomite-bearing sandstone division" (Holtedahl, 1918, 1960) or "Older Eocambrian Division" (Føyn, 1960) has been described by Holtedahl (1918, 1931, 1960) and Føyn (1937, 1960). It does not outcrop on the Digermul Peninsula and has not been examined by the author. Above it comes an unconformity first discovered in Varangerfjord by Holtedahl (1918) and confirmed in the Tana district by Føyn (1937). The angular discordance is small (estimated at 1° to 2° by Føyn) and its recognition is due primarily to the absence of the higher divisions of the Older Sandstone Series towards the southwest.

The Vestertana and Digermul Groups were described by Føyn (1960) as the "Younger Eocambrian Division" and divided by him (1937) into two, a "Tillite-bearing Sandstone Series" (Holtedahl, 1918) including the present Duolbasgaissa formation and a "Fossiliferous Stage", equivalent to the present Kistedal Formation.

Føyn spent the summers of 1933 and 1934 in the Tana district. He mapped the region around the head of Tanafjord and established that there were two tillite horizons. Toward the end of his field work he encountered fossils on the beach at Laggo, and so made excursions into the Digermul Peninsula up the valleys of Bokselven, Hånsvikdalen, Kistedalen and Digermuldalen (Fig. 6), finding fossils, mainly brachiopods, in situ. The fossils were identified by Strand (1935) as probably Middle Cambrian. These were the first fossils to be found in Finnmark other than in the narrow "Hyolithes Zone" of Lower Cambrian age between the metamorphic complex and basement in west Finnmark (Fig. 2).

Føyn also crossed the peninsula to examine the sequence between Stappogiedde and Duolbasgaissa and to link up the fossiliferous beds with the tillite-bearing sandstones; he proved that the tillites lay below the Cambrian. At the same time in a general section of the strata above the tillites on the Digermul Peninsula he showed that there were about 2200 metres of sandstones and shales above the subtillite unconformity. He also established the essentials of the structure.

In 1950 the writer found one specimen of *Paradoxides* in a loose rock in Kistedalen showing that part of the sequence was undoubtedly Middle Cambrian (Holtedahl, 1952). In 1959 the major part of the peninsula was mapped and a stratigraphical sequence measured which suggested that there were 4600 metres of sediments above the unconformity. Trilobite horizons confirmed various ages in the upper part of the column ranging from the top of the Lower Cambrian to the Tremadocian. Whilst the succession has remained unchanged, the 1964 visit has led to a reduction in the estimated thicknesses of some structurally deformed formations making the present total about 3000 metres for the strata above the unconformity.

Stratigraphy.

Vestertana Group.

The Vestertana Group is about 1450 metres thick and includes 5 formations from the Lower Tillite to the Breivik Formation. These outcrop around Vestertanafjord (Fig. 2) where structural complexities are at a minimum and the whole group is best exposed. Body fossils have not yet been found in this group, but trace fossils are abundant. The general sequence is shown in Fig. 3.

Lower Tillite Formation.

This formation does not outcrop in the Digermul Peninsula and is only found on the tiny island of Areholmen. It was visited south of Trollfjord on the east side of Tanafjord, at the point northeast of Torhop and at Vestertana (Fig. 2). Føyn (1937) showed that it is a badly sorted rock containing pebbles and boulders up to 2 metres in diameter of dolomite, Precambrian crystalline rocks, especially granites and gneisses, and some quartzitic sandstones in a matrix of silt and clay. Dolomite boulders predominate except towards the south where the proportion of crystalline boulders is higher. Some bands of sorted pebbles occur and traces of stratification are frequent. The thickness is rather variable, ranging from 7 to 50 metres.

Nyborg Formation.

This was named by Holtedahl (1960, p. 118) after a locality at the head of Varangerfjord (Fig. 2) for strata between the two tillite formations. It has been described by Føyn (1937, 1960) as "red brown sandstones and red and green shales." Lying between the two massive tillite formations, much of it is disturbed by asymmetrically overturned folds and its true thickness is different to measure. It is at least 200 metres and possibly 400 metres thick,

The lower part is extensively exposed in the Tana District, but was seen by the author only on the shore opposite Vestertana and at Torhop (Fig. 2). It consists of reddish purple or green silty mudstones interbedded with sandstone bands 5–30 cms thick which are occasionally graded and show ripple cross-lamination and small scoured surfaces. Current directions are somewhat variable but suggest flow towards the west or northwest.

The upper 100 metres of the Nyborg Formation is exposed along the coast at Stappogiedde on the Digermul Peninsula. The lowest beds seen are graded grey-green greywacke[1] sandstones, with ripple cross-laminated

[1] Throughout this paper sandstone terminology follows Pettijohn (1957). "Greywacke" indicates a sandstone which in the field appears to have a high proportion of detrital matrix. Thin section examination to date shows that the greywackes fall within McBride's (1962) definition and include more than 15 % chlorite-sericite matrix, more than 10 % unstable fine-grained rock fragments and more than 5 % felspar. "Orthoquartzite" indicates a sandstone with a high proportion of quartz, cemented with

(Note cont. p. 176)

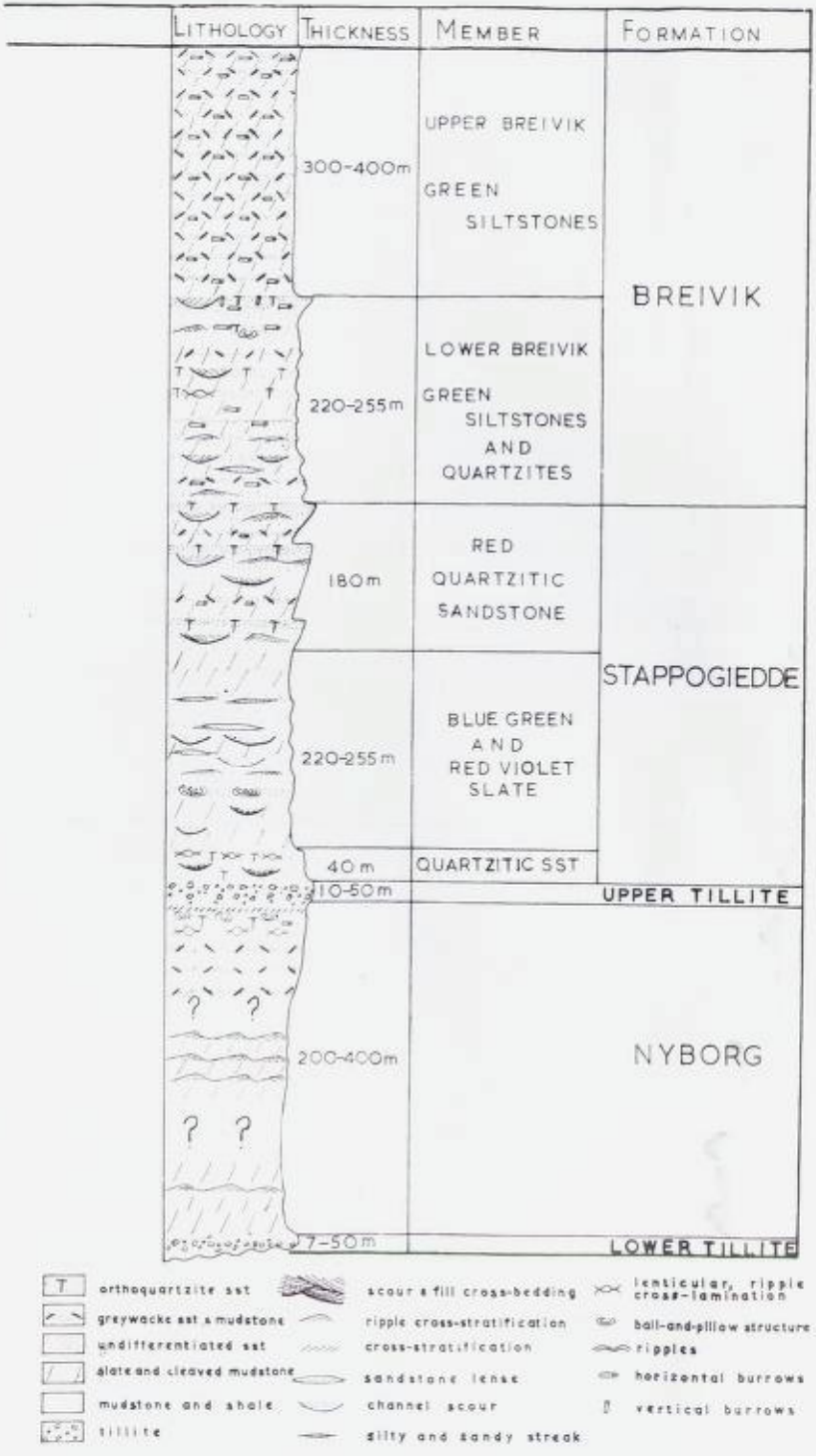

Fig. 3. Stratigraphical section of the Vestertana Group.

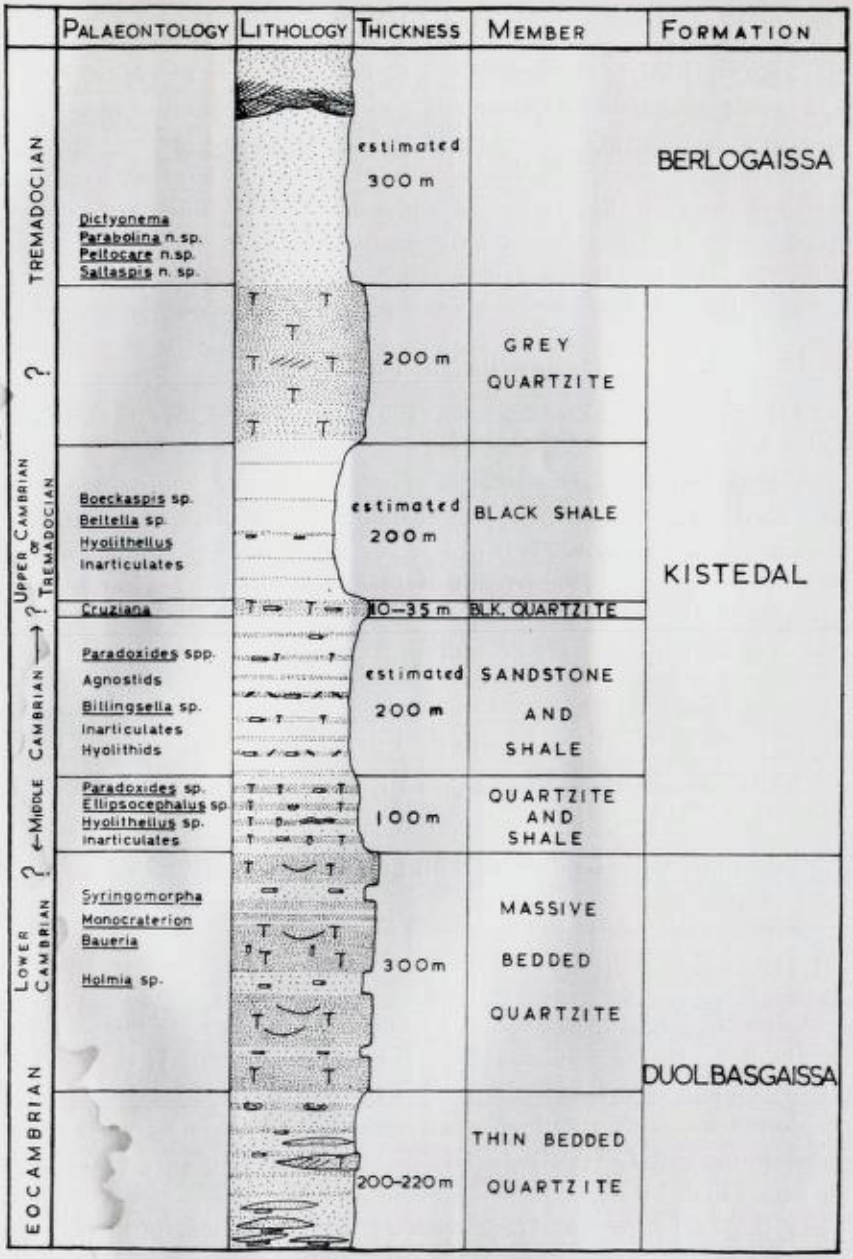

Fig. 4. Stratigraphical section of the Digermul Group.
Palaeontology by G. Henningsmoen.

tops, interbedded with mudstones and interpreted as turbidites. Flute and prod marks indicate current flow to the north. The turbidites pass up into lenticular ripple cross-laminated siltstones and lithic sandstones with variable current directions. Horizontal burrows are first seen with certainty here. Finally, 25 metres below the Upper Tillite, come purple and grey orthoquartzites and lithic sandstones with cross-bedding and ball-and-pillow structures (Potter and Pettijohn, 1963, p. 148).

Upper Tillite Formation.

This has been described by Føyn (1937) who showed that its thickness varies from 10–50 metres with the greatest thickness south of the head of Vestertanafjord. It contains fewer dolomite and more numerous crystalline fragments than the Lower Tillite and, while it is stratified, it lacks the sorted horizons. It is exposed around Stappogiedde where it is about 15 metres thick, unsorted, with blocks up to 3 metres in diameter. Some of the larger blocks have deformed the sediments beneath them and suggest that they have been dropped from above.

Stappogiedde Formation.

This is exposed along the southeast coast of the Digermul Peninsula and is from 330–475 metres thick. It is divided into three members:

3. Red quartzitic sandstones with greywackes, sandstones and mudstones.
2. Blue-green and red-violet slate.
1. Quartzitic sandstone.

Quartzitic sandstone member is the same as the "dark coloured" shale and "light coloured sandstone" of Føyn (1937, 1960). It is about 40 metres thick and consists of orthoquartzites and lithic sandstones and conglomerates with small channel scours, cross-bedding and ripple cross-lamination. Lenticular, ripple cross-lamination occurs toward the top where shale bands, occasionally present below, become more common. Thus the sequence from cross-bedded orthoquartzites upwards into

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silica. "Lithic sandstone" includes a wide range of intermediate sandstone types with an abundance of labile components. In addition to Pettijohn's terms, "quartzitic sandstones" has been used as a bulk term to include both orthoquartzites and lithic sandstones.

lenticular, ripple cross-lamination is the reverse of that seen in the top of the Nyborg Formation.

Blue-green and red-violet slate member has a thickness of 220–255 metres. The lower 25–50 metres is red-violet in colour and the remainder blue-green. There is a gradual transition upward from the quartzitic sandstone member beneath and some lenticular, ripple cross-lamination occurs in the first few metres. The base is taken at the bottom of the first thick (over 50 cms) red-violet slate horizon. For 70–80 metres the beds are very fine-grained with bedding obscured by cleavage and only detectable by slight colour variation. There are very occasional lenses up to one metre thick, of sandstone and conglomerate which contrast sharply with the surrounding slate. About 100 metres of somewhat coarser beds follow, with cleaved mudstones dominant but containing a variety of sandstone and siltstone lenses including the sandy and silty streak facies of de Raaf et al. (1965). The cross-lamination shows, in these irregular lenses, variable current directions. Some bands of isolated ripples have a cross-lamination which indicates a northerly flowing current. Bands of cross-laminated orthoquartzites occur with spectacular ball-and-pillow structures and there are also many channelled horizons, the channels filled by silty mudstone similar to the sediments they cut. The top 50 metres show a return to the lower part of the member, consisting of slates, mainly grey-green, but occasionally red-violet.

Red quartzitic sandstone member consists of three resistant and feature forming bands of red quartzitic sandstone including orthoquartzites and lithic sandstones separated by bands of greywacke sandstone in mudstone. The total thickness measured is everywhere close to 180 metres although that of individual units varies considerably:

3rd red quartzitic sandstone	12–15 metres
Greywacke sandstones and mudstones	25–37 »
2nd red quartzitic sandstone	30–43 »
Greywacke sandstones and mudstones	33–48 »
1st red quartzitic sandstone	50–80 »

The greywacke sandstones occur as thin parallel-sided graded units interbedded with mudstones. There are very rare flute and groove casts and animal trails are abundant on the base of each unit. The sandstones become thicker upwards and pass gradually into the quartzitic sandstone bands which are mainly red or purple but locally grey. These sandstones show scouring, channelling and cross-bedding. The 1st and 2nd red

quartzitic sandstones are followed abruptly by greywackes and mudstones. Thus this member contains a series of coarsening upwards cycles which pass upwards from mudstones and greywacke sandstones interpreted as turbidites into quartzitic sandstones probably deposited in shallow water.

Breivik Formation.

The name of this formation was first published by Føyn (1960) and Holtedahl (1960). It had been selected by Reading (1959) for the "green siltstones" of Føyn (1937) from a locality on the Digermul Peninsula. The thickness of this formation is about 550 metres, but an accurate measurement of the upper part is difficult because it is generally rather folded. It is distinguished from the formations above and below by the presence of grey-green sandstones, siltstones and cleaved mudstones. It is divided into two members of somewhat different character, a Lower Breivik Member with abundant orthoquartzites and lithic sandstones and an Upper Breivik Member where these are absent.

Lower Breivik Member follows the 3rd red quartzitic sandstone without a sharp junction and its base is taken at the top of the last red sandstone. The member is 220–255 metres thick and consists of interbedded sandstones and cleaved mudstones. The sandstones fall into two types, occurring in bands from 5–20 metres thick. The dominant type is composed essentially of horizontally, sometimes lenticular, bedded lithic sandstones and orthoquartzites (each bed about 5–30 cms and up to one metre thick) showing scouring, ripple cross-lamination and cross-bedding. Horizontal and vertical burrows are seen. The other type of sandstone band is less common and is made up of graded greywacke sandstones interbedded with mudstones. The sandstones have sharp bases with horizontal burrows and internal ripple cross-lamination which indicated current flow from north to south. In addition to these two clearly defined types there are also bands where orthoquartzites, lithic sandstones and greywackes are intimately interbedded with the mudstones. No recurrent pattern of sedimentation is visible in this member, the bands occurring randomly. In the top 30 metres however, the beds coarsen upwards in the same manner as they do in the red quartzitic sandstone member from almost pure mudstones into a 10 metre orthoquartzite unit. The latter is the most conspicuous band in the member.

Upper Breivik Member is clearly separated from the lower member by

a sharp break between its basal cleaved mudstone and the orthoquartzite just mentioned. This junction is easily mapped over the whole peninsula and has been found near the main Finnmark highway over 30 kilometres to the southwest of Breivik. The Upper Breivik Member is between 300 and 400 metres thick and consists of cleaved mudstones with thin (1–5 cm) graded greywacke sandstone and siltstone layers which have horizontal and cross-lamination. Small loadmarks and abundant burrows occur on the bases of the sandstones. The cross-lamination indicated current flow from north to south.

Digermul Group.

The Digermul Group is about 1500 metres thick and so far as is known occurs only on the Digermul peninsula. No rocks as young as this have been found elsewhere in Finnmark except for strata containing Silurian (Llandoverian?) fossils near Honningsvåg (Henningsmoen, 1960). Rosendahl (1945) however thought the equivalents of the Duolbasgaissa quartzite occurred at Annecaerro (Fig. 2) in the southern part of the Varanger Peninsula, but a reconnaissance visit by Mr. J. D. Collinson in 1964 showed that the quartzitic sandstones capping Annecaerro are the equivalents of those in the Lower Breivik Member. Vertical trace fossils "pipes" and body fossils found in the group indicate an age ranging from Lower Cambrian through Middle and possibly Upper Cambrian into the Tremadocian. The general sequence is shown in Fig. 4.

Duolbasgaissa Formation.

This formation was previously named "Digermul formation" (Føyn, 1960; Holtedahl, 1960) using Reading's (1959) report. However, at Dr. Føyn's suggestion it has been renamed Duolbasgaissa Formation after the highest point in the peninsula. Below this point almost all the formation is exposed in a 300 metre escarpment. Føyn had earlier (1937, pp. 110–112) used the terms "Stage of Duolbasgaissa" and "Duolbasgaissa Sandstone" to mean a lithostratigraphical unit. The term "Digermul" is now used for the group which contains the Duolbasgaissa, Kistedal and Berlogaissa Formations and makes up about 75% of the surface outcrop of the peninsula. The Duolbasgaissa Formation is between 450 and 550 metres thick and is characterised by orthoquartzite sandstones; fine-grained sediments are extremely rare. The formation is divided into two

members, a lower, thin-bedded quartzite member and an upper, massive-bedded quartzite member.

Thin-bedded quartzite member is 200–220 metres thick but is difficult to measure because the base is usually obscured by scree. It consists of orthoquartzites and lithic sandstones interbedded with siltstones and occasional cleaved mudstones. The orthoquartzites are often purple, occasionally cross-bedded and show very rare ball-and-pillow structures. One massive white quartzite, 20 metres thick, occurs at Breivik and lenses out to the southwest. The lithic sandstones are normally thin-bedded, from 2–30 cms thick. The most characteristic feature of the member is the abundance of large intersecting trails, 2 cms in diameter, on the bases of the orthoquartzites. The base of the member is taken at the horizon where the large trails first appear. This horizon coincides approximately with the incoming of the first purple orthoquartzite but the boundary of the Breivik Formation with the Duolbasgaissa Formation is not a sharp one.

Massive-bedded quartzite member is about 300 metres thick but no section was found where both top and bottom were clearly visible. It caps the spectacular escarpments of the Digermul Peninsula and extends over the scree covered centre. The dominant feature of this member is the occurrence of thick (5–50 metres) orthoquartzite bands, white, purple or grey and commonly cross-bedded and channelled. In most sections there are four major quartzite units separated by bands, 15–30 metres thick, of thinly bedded orthoquartzites and lithic sandstones and shales similar to those in the thin-bedded quartzite member. Vertical pipes (e. g. *Skolithos*) are first seen about 100 metres above the base of the member and Dr. Henningsmoen has found a few specimens of an olenellid (*Holmia* sp.) near the middle, thus establishing its Lower Cambrian age.

Kistedal Formation.

This is a rather heterogeneous formation and includes orthoquartzites, black shales and lithic sandstones between the top of the highest thick (more than 5 metres) orthoquartzite of the Duolbasgaissa Formation and the bottom of the thin-bedded sandstones of the Berlogaissa Formation. Its thickness is difficult to measure because the incompetent members are structurally very disturbed and the present estimate of 700 metres is rather less than that quoted by the author (1959) and used by Professor

Holtedahl for publication in his Geology of Norway (1960). The formation is named after the valley in the north of the peninsula where it is best exposed, in spite of being overturned.

Quartzite and shale member is about 100 metres thick and consists of thin-bedded (2–30 cms) grey, purple and white orthoquartzites and lithic sandstones interbedded with uncleaved mudstones and siltstones. A characteristic feature of the sandstones is the abundance of ripples at some horizons and the presence of vertical and horizontal trace fossils. The highest purple orthoquartzite marks the top of the member. Trilobites were found near the base of the member indicating an age low in the Middle Cambrian (Fig. 4).

Sandstone and shale member is composed mainly of thin-bedded (1–10 cms) greywacke and lithic sandstones and grey shales with some black shale bands. The sandstones are occasionally graded with rippled, cross-laminated tops and horizontally burrowed bases. Small overturned asymmetrical folds are common and it is impossible to measure the thickness of this member accurately. It is estimated at 200 metres. This is the member in which Føyn first found the inarticulate and articulate brachiopods described by Strand (1935). Several fossiliferous horizons were found by the author; some contained trilobites which proved a Middle Cambrian age (Fig. 4).

Black quartzite member is 10 to 35 metres thick. It makes a conspicuous horizon of considerable value for mapping and for determining the structure of the Kistedal Formation. It is made up of mainly thin-bedded (1–10 cms) black orthoquartzites with very occasional thicker beds and very thin black siltstone or mudstone partings. Mudflake conglomerates occur and the whole member is characterised by superb horizontal burrows including *Cruziana* trails on the bases of many of the quartzites. No body fossils have been found.

Black shale member is composed mainly of black micaceous, sometimes very thinly laminated, mudstones with thin-bedded (1–5 cms) lithic sandstone bands which occasionally have sharp burrowed bases. The thickness of 200 metres is not certain because of structural complexity. Fossils are rare but brachiopods and one horizon of trilobites have been found; the latter indicated a late Cambrian or early Tremadocian age (Fig. 4).

Grey quartzite member is made up entirely of orthoquartzites, mainly thick-bedded (20–100 cms) with no fine-grained partings. 125 metres were measured in the scarp above Kistedal. The base, however, is hidden

by scree and the unit is probably 200 metres thick. Cross-bedding and scoured surfaces are very rare, the whole member being remarkedly flat bedded and lacking in sedimentary structures. Neither body fossils nor burrows have been found.

Berlogaissa Formation.

This formation outcrops in a small area near Berlogaissa in the core of the Digermul syncline and is the highest stratigraphical unit. It is very disturbed structurally by isoclinal folds and by faults which are difficult to detect in spite of the good exposure. The thickness is estimated very roughly at 300 metres, considerably less than the author's previous estimate (Holtedahl, 1960). Petrographically it consists of dark grey to black, thin to medium-bedded (3–30 cm) sandstones which vary from orthoquartzites to greywackes. Sedimentary structures are very difficult to detect and over most of the outcrop were not seen. There is, however, some very well developed scour and fill cross-bedding high up in the formation. Very occasional black shale layers occur containing beautifully preserved Tremadocian trilobites and graptolites (Fig. 4).

Igneous.

Føyn (1937) reported a gabbroic rock 2 kms NE of the mouth of the Kistedal river. This occurs as a post-folding dyke, running at 130°. Loose boulders of similar material were found on the shore at 2 and 3 kms NE of Hånsvikdal and about 3 kms north of Breivik. A petrographical examination by Mr. J. D. Collinson shows that both the dyke material and the loose boulders are similar, consisting of strongly zoned augite and plagioclase with abundant iron ore and also quartz. This indicates a tholeiitic quartz dolerite rock.

Structure.

The major structure of the Digermul Peninsula is a large south eastwards facing overturned syncline running in a NE–SW direction and plunging gently north eastwards (Fig. 6). The fold axis swings to almost N–S at the northern tip of the peninsula and towards the SW. The metamorphic complex is thrust over the sediments from the NNW and

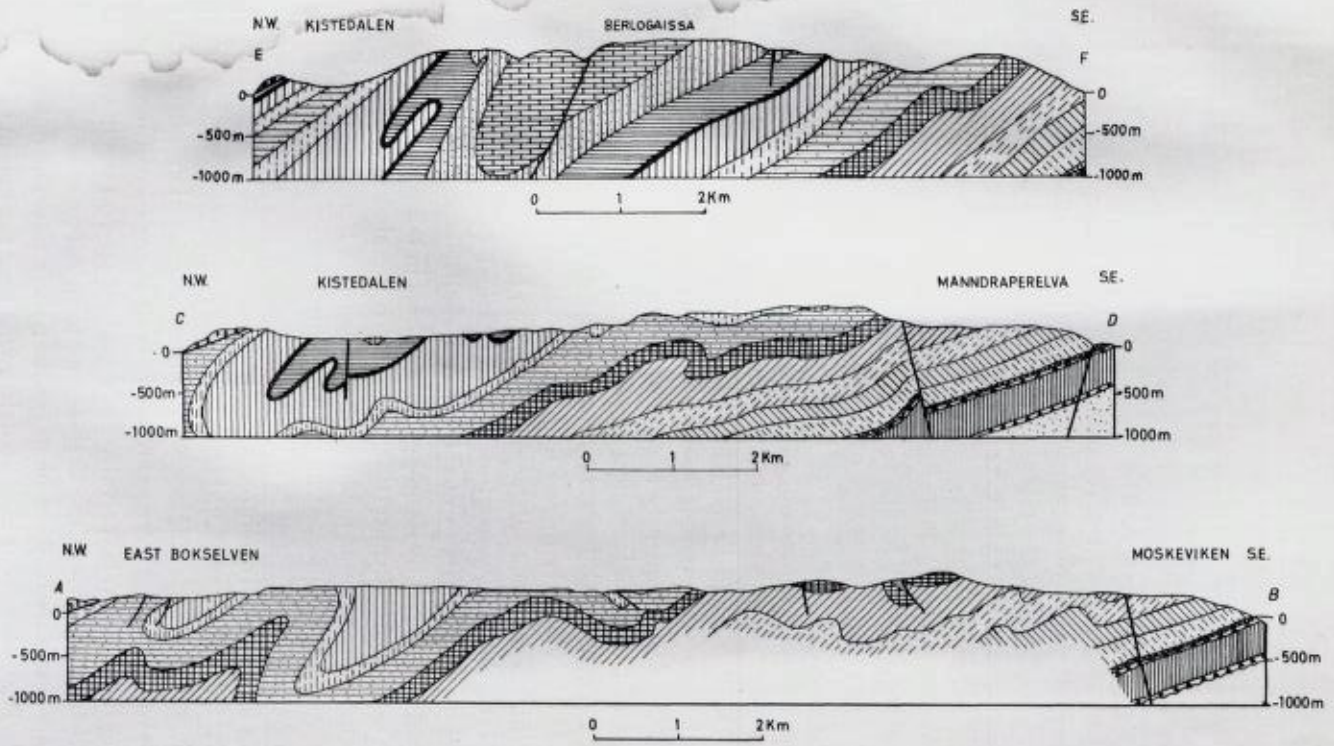

Fig. 5. Structural sections across the Digermul Peninsula from NW to SE.

truncates them along a thrust dipping at 18°. The thrust plane is clearly visible in gorges in both branches of Bokselven. Since the trace of the thrust diverges from the fold axis of the sediments, additional folds appear to the SW (Fig. 6). Most of the folds face SE but in Hånsvikdal there is a broad anticline with complementary folds on either flank (Figs. 5 and 6, section A–B).

Flow cleavage is well developed in the Vestertana Group, along the south eastern side of the peninsula, where it lies parallel or nearly parallel to the axial planes of the folds. In the Digermul Group cleavage occurs only locally, adjacent to thrust planes.

Structural style varies according to lithologies and stratigraphical depth. The competent Upper Tillite and the quartzitic sandstone bands in the Stappogiedde Formation are folded on a regional scale but locally not greatly disturbed. Mudstones of the Nyborg and Stappogiedde Formations are converted into slates with folding apparent only where there are interbedded thin sandstones or siltstone layers. Here they tend to be isoclinally folded with the minor fold axis parallel to the major fold axis.

The Duolbasgaissa Formation is the major structural feature of the Peninsula and its orthoquartzites are strongly folded and overturned towards the SE. Frequently the lower limb of the Z folds are shattered or thrust and the Duolbasgaissa Formation rides disharmonically on the Breivik Formation, which acts as a plane of décollement. The Kistedal Formation is violently folded with the wavelength of the folds related to the thickness of the sandstone beds. The black quartzite member is folded into tight asymmetrical almost isoclinal folds. (Fig. 5, section C–D). The grey quartzite member has a similar structure but the scale of folding is larger. The incompetent members in the Kistedal Formation display asymmetrical concertina folds which are almost isoclinal.

Insufficient study was made of the Berlogaissa Formation to ascertain the structure, but, squeezed in the core of the syncline, it has numerous tight, isoclinal, concertina folds with perhaps a few thicker sandstones showing more open structure.

Apart from thrusts, faulting is of minor importance. Some orthoquartzites have high angle faults probably relaxation phenoma. No definite wrench faults were seen. There is an abundance of normal faults trending E–W and WNW–ESE. They are best seen on the Stappogiedde coast where they govern the drainage pattern. A few are marked on the map and many more were observed but their position not accurately located. They also occur in Kistedalen. One near the mouth of the valley

cuts an overturned anticline and the displacement indicates that the fault is normal. On the Stappogiedde coast they form clefts in the cliffs and their fault planes can be observed to dip at about 70°–80°.

Summary and history of area.

The Digermul Peninsula displays a continuous succession of completely conformable clastic sediments 3,000 metres thick which extend from the Eocambrian tillites through the Cambrian to the Tremadocian. Volcanics, limestones and dolomites are absent except for dolomites eroded from the underlying "Older Sandstone Series" and present as derived blocks in the tillites.

The succession starts with two tillite formations, the lower resting with slight unconformity on sediments of the "Older Sandstone Series". A marine glacial origin for the tillites is accepted because 1) they are completely unsorted and yet well stratified 2) they extend as contiuonus mappable horizons as far as exposure allows, for over 50 kms in each direction 3) except towards the source area to the south, where only one occurs, there are two distinct tillite formations, never more. A slide or slump hypothesis is ruled out by the lithology, and their lateral extent makes a derivation from contemporaneous fault scarps impossible. In the Digermul area deposition was probably from floating ice.

Most of the sedimentary sequence consists of scoured cross-bedded and flat-bedded orthoquartzites and lithic sandstones with thin-bedded greywacke sandstones and shales. The former were evidently deposited in shallow water, probably marine but possible continental. The latter frequently show grading and sedimentary structures characteristic of turbidites and are particularly well seen in the Nyborg Formation and in the greywacke sandstones and mudstones of the red quartzitic sandstone member. Sandstones and siltstones in the Upper Breivik Formation may also be turbidites. A turbidite origin is more difficult to envisage for other thin-bedded sandstones, especially those in the Digermul Group. Bottom currents, operating perhaps in some depth of water, were probably an important factor in sedimentation of the sandstones of this group and also for many of the thin-bedded orthoquartzites in the Lower Breivik Formation.

Thus the basin was essentially a shallow water one which deepened temporarily to allow sedimentation by turbidity currents to proceed below the depth of surface currents. Transitions from surface current to turbid-

ity current and bottom current deposition were rapid and at times these three types of deposition were so intimately associated that it is almost impossible to separate them.

Current flow directions measured in the shallow water sandstones are variable. In the turbidites they show movement from the south in the Nyborg and Stappogiedde Formations. This is consistent with the regional pattern of thinning towards the Fennoscandian shield to the south, and supports a southerly derivation. In the Breivik Formation current flow in the muddy sandstones was from north to south. Insufficient flow directions were measured in the Digermul Group to give any flow pattern.

Within the Tana district all formations are continuous units which can be mapped as far as the outcrop allows. There are variations within each unit, especially in the Nyborg Formation, but nevertheless each member is recognizable and traceable for considerable distances. To the south and west there is substantial thinning and the "Hyolithus zone" and Alta district successions are about one tenth of the thickness of the Tana district and correlation is extremely difficult (Føyn, 1964).

To the NNW lies the metamorphic complex described and named the Laksefjord Group by Føyn (1960). It consists of thick (up to several hundred or even thousands of metres thick) units of phyllites, quartzites and conglomerates. It is tempting to consider the metamorphic complex as the basinward equivalents of the Tanafjord sediments and whilst this is very probable no precise correlation can be made.

The Vestertana Group shows the increasing importance of trace fossils from a rare phenomenon in the Nyborg Formation to abundance in the Breivik Formation. Vertical burrows begin in the Stappogiedde Formation and become more abundant upward, particularly in the Duolbasgaissa Formation. Body fossils are first known from the Duolbasgaissa Formation, indicating a Lower Cambrian age and there seems to be a more or less complete succession of Cambrian faunas through the Digermul Group into the Tremadocian.

No proof of the age of any part of the Vestertana Group has been obtained in the Digermul Peninsula, but Føyn (personal communication) has shown that the zone of the Lower Cambrian fossil *Platysolenites antiquissimus* in the "Hyolithes Zone" southeast of Lakselv belongs to beds which he is inclined to correlate with the Breivik Formation. This suggests that the upper part of the Vestertana Group is Lower Cambrian. However, until fossils are found in the Breivik Formation and its age

proved, it is preferable to place the whole group in the Eocambrian and to put the Cambrian-Eocambrian boundary just below the lowest known zonal fossil in the Duolbasgaissa Formation. Further discoveries should lower this boundary. The term Eocambrian is used here for all strata lying conformably below proved Cambrian beds, i.e. down to the base of the Lower Tillite. This is the sense to which Føyn (1964 and personal communication) now restricts the term. In the past, however, the "Eocambrian" has also included the "Older Sandstone Series".

Dating of the structural history is impossible because of the absence of later sediments in the region and because of the lack of isotopic age dates. The sequence of events is as follows:

1) Major asymmetrical folding and thrusting along a NE–SW trend.
2) Overthrusting of metamorphic complex from the NNW.
3) Normal faulting along W–E and WNW–ESE lines.

The age of the quartz dolerite dykes is uncertain except that they post-date the folding. Føyn (1960) states that similar diabase dykes in the metamorphic complex post-date the folding but are earlier than the overthrusting.

Summary.

Eocambrian and Lower Palaeozoic geology of Digermulhalvøya, Tanafjord, Finnmark.

The Digermulhalvøya exposes a continuous conformable succession of sedimentary rocks, 3,000 metres thick, which extends from Eocambrian tillites through the Cambrian into the Tremadocian. The sedimentary succession consists entirely of sandstones and shales. Limestones, dolomites and volcanic rocks are absent. It is part of the sedimentary wedge of East Finnmark in which late Precambrian, Eocambrian and Cambro-Ordovician sediments lie unconformably upon Precambrian crystalline basement rocks to the south and are overlain by a thrusted metamorphic "Caledonian" complex to the NNW.

The succession has been divided into two groups. The lower, the Vestertana Group, is 1450 metres thick and is considered to be Eocambrian because it lies conformably beneath the Lower Cambrian and because to date no definite zonal fossils have been found in it. The upper, the Digermul Group, is 1500 metres thick and is found only in the Digermulhalvøya. It contains abundant trilobites and brachiopods which

indicate an age from Lower Cambrian near the base, through Middle and Upper Cambrian, to Tremadocian.

The sedimentary sequence begins with two tillite formations which contain scattered boulders of Precambrian crystalline rocks and dolomites eroded from the underlying "Older Sandstone Series" and Precambrian basement. The two tillite formations are separated from each other by 200–400 metres of the Nyborg Formation which consistes of red and green silty mudstones, greywackes sandstones and orthoquartzites. Cross-lamination shows current flow from south to north. The tillites are considered to have been deposited from floating ice and indicate two extensive glacial periods.

The Stappogiedde Formation starts with 40 metres of quartzitic sandstones and passes up into 220–255 metres of red-violet slates and siltstones with occasional sandstones. The topmost member, 180 metres thick, is composed of alternations of red quartzitic sandstones and greywacke sandstones and mudstones.

The Breivik Formation is characterized by the presence of grey-green cleaved mudstones and is divided into two members. The Lower Breivik Member is variable and contans orthoquartzites, greywackes and other sandstones interbedded with mudstones. Current flow measured on the greywackes shows movement from north to south. The Upper Breivik Member contains cleaved mudstones and thin greywacke sandstones and siltstones.

The Digermul Formation is largely composed of orthoquartzite sandstones, particularly in the upper part and it dominates the scenary forming spectacular cliffs and escarpments. In the upper part Dr. Henningsmoen has found the lowest horizon of trilobites, indicating a Lower Cambrian age.

The Kistedal Formation begins with quartzites and shales and passes gradually up into sandstones and shales. Ripples and cross-lamination are common and there are many horizons of trilobites which prove a Middle Cambrian age. In the middle of the formation there is a black quartzite, 10–35 metres thick with abundant *Cruziana* trails which makes an excellent mapping horizon. Above it come highly folded black shales with trilobites which may be either late Cambrian or early Tremadocian. The highest member is a thick, 200 metre, grey quartzite.

The Berlogaissa Formation forms the highest stratigraphical unit and, except for the Silurian fossils found near Honningsvåg, is the youngest formation known from Finnmark. Its thickness is difficult to estimate

because it is strongly folded and faulted. It consists mainly of black sandstones, but bands of orthoquartzite sandstones and occasional black shales occur. In the latter graptolites and trilobites have been found proving the formation to be Tremadocian.

The area has been folded and thrust along a NE–SW trend. Subsequently the metamorphic "Caledonian" complex was thrust over the area from the NNW. At a late date normal faulting occured along W–E and WNW–ESE lines.

Sammendrag.

Eokambrisk og tidlig paleozoisk geologi i Digermulhalvøya, Tanafjord, Finnmark.

Digermulhalvøya består av sandsteiner og skifre som danner en sammenhengende lagrekke, 3000 m tykk. Avleiringen av denne lagrekken begynte i eokambrisk tid med tillittene (morenekonglomerater) og fortsatte gjennom eokambrisk og kambrisk tid til opp i undre ordovicium. Kalksteiner, dolomitter og vulkanske bergarter mangler. Geologisk er Digermulhalvøya en del av Øst-Finnmarks sedimentære bergartsområde, et område som har form som en kile med spissen mot sørvest. Bergartene i dette område er sen-prekambriske, eokambriske og kambro-ordoviciske sedimentbergarter; de hviler diskordant på et underlag av prekambriske krystallinske bergarter i sør, mens de i nord-nordvest grenser til et kompleks av metamorfe "kaledonske" bergarter som er skjøvet over dem.

Forfatteren har delt lagrekken på Digermulhalvøya i to formasjonsgrupper. Den undre, *Vestertanagruppen*, er ca. 1450 m tykk og ansees for å stamme fra eokambrisk tid. Den ligger nemlig under lag som inneholder underkambriske fossiler, mens det i den selv ikke er funnet fossiler som er brukbare til å tidfeste lagene. Den øvre gruppen, *Digermulgruppen*, er ca 1500 m tykk og finnes ikke noe annet sted enn på Digermulhalvøya. Den inneholder rikelig med trilobitter og brakiopoder, som viser at avsetningen har skjedd i et tidsrom som strekker seg fra underkambrium for de laveste lagene og gjennom mellom- og overkambrium opp i underordovicium.

Vestertanagruppen er igjen delt i fem formasjoner, nemlig undre tillitt, Nyborg-formasjonen, øvre tillitt, Stappogiedde-formasjonen og Breivikformasjonen. De to *tillittformasjonene* inneholder ujevnt fordelt blokker av dolomitt og sandstein og av krystallinske bergarter, blokker som skyldes erosjon av den underliggende "Eldre sandsteinserie" og av det krystallinske prekambriske underlag. Tillittene tolkes som dannet ved

at materialet i dem er avsatt fra flytende is, og de tas som tegn på at det den gang var to glasiale perioder.

De to tillittformasjonene er skilt fra hverandre ved den 200–400 m tykke *Nyborg-formasjonen*, som består av røde og grønne sandige leirsteiner, gråvakker (leirholdig sandstein) og rene kvartsitter. Skråskiktning viser at det under avleiringen har vært strøm fra sør mot nord.

Stappogiedde-formasjonen begynner med ca. 40 m kvartsittisk sandstein og går så over i 220–255 m rødfiolett og blågrønn skifer og sandig skifer med enkelte sandsteiner. Det øverste ledd i formasjonen er 180 m tykt, sammensetningen av dette ledd veksler mellom rød kvartsittisk sandstein, grå leirholdig sandstein og leirstein.

Breivik-formasjonen er karakterisert ved tilstedeværelsen av grågrønn leirstein med skrå oppspalting. Den undre halvpart av formasjonen har en nokså variert sammensetning, idet den inneholder rene kvartsitter, gråvakker og andre sandsteiner i veksling med leirstein. Strømningsstrukturer i gråvakkene viser at det under avleiringen har vært transport av materiale fra nord mot sør. Den øvre halvpart av formasjonen består av leirstein med skrå oppspalting, tynne gråvakker og sandige skifre.

Digermul-gruppen er inndelt i tre formasjoner: Duolbasgaissa, Kistedal og Berlogaissa. Den underste av dem, *Duolbasgaissa-formasjonen*, består vesentlig av kvartsittiske sandsteiner, særlig i den øvre del. Disse motstandsdyktige bergartene har hatt en dominerende innflytelse på utformingen av landskapet og står nå fram med stupbratte skrenter. I den øvre del av Duolbasgaissa-formasjonen fant Dr. Henningsmoen den underste trilobithorisont, med en trilobitt som tyder på at alderen er underkambrisk.

Kistedal-formasjonen begynner med kvartsitter og skifre og går oppad gradvis over i sandsteiner og skifre. Strømrifler og skråskiktning er alminnelige. En rekke trilobitthorisonter viser med sikkerhet at lagene er av mellomkambrisk alder. Midt i formasjonen er det en svart kvartsitt, 10–35 m tykk, med mengder av fossile krypespor av Cruziana-typen, den er en førsteklasses ledehorisont ved kartleggingen. Over den følger en sterkt foldet svart skifer med trilobitter som kan tilhøre enten øverste kambrium eller underste ordovicium. Det øverste ledd i Kistedal-formasjonen er en 200 m tykk grå kvartsitt.

Berlogaissa-formasjonen er den øverste stratigrafiske enhet og er, når en unntar lagene med siluriske fossiler nær Honningsvåg, den yngste formasjon som er kjent fra Finnmark.

Det er vanskelig å bedømme tykkelsen av Berlogaissa-formasjonen da

GEOLOGICAL MAP OF THE DIGERMUL PENINSULA

0 1 2 3 4 Km

EXPLANATION OF SYMBOLS

Fold axis, anticline
syncline
anticline with N-flank overturned
syncline with N-flank overturned

Stratigraphical boundary
Fault, general
, thrust or reverse
Strike and dip of bedding 30
overturning proved 30

Dyke

Spot height, metres Δ 513
Line of section
Grid lines indicate the Universal Transverse Mercator grid, zone 35

DIGERMULEN
Digermulddalen
Im. Liver
LAGGO
Langfjord
Bokselven
NOVA Δ 573
Hjørnedalselven
Kistedalen
BERLOGAISSA Δ 635
BREIVIK
Hamnaperelva
AREHOLMEN
GUOHOLMEN
DUOLBASGAISSA Δ 668
Skotelven
Mærelven
STAPPOGIEDDE
LARSHOLMEN
BADNAGGAISSA Δ 630
MOSKEVIKEN
Kasmuelven
A
B
C
D
E
F
7845
7835
7830
7825
520
525
530
535
540
545

LAKSEFJORD GROUP

DIGERMUL GROUP	Tremadocian	BERLOGAISSA FORMATION	Black sandstone; Grey quartzite
	U. Cambrian	KISTEDAL FORMATION	Black shale; Black quartzite
	M. Cambrian		Sandstone and shale
	L. Cambrian	DUOLBASGAISSA FORMATION	Quartzite and shale; Massive bedded quartzite; Thin bedded quartzite
VESTERTANA GROUP	M 1000	BREIVIK FORMATION	Grey-green siltstone; Grey-green mudstone and quartzite
	500	STAPPOGIEDDE FORMATION	Red quartzitic sandstone, greywacke & mudstone; Blue-green and red-violet slate
		UPPER TILLITE	Quartzitic sandstone; Tillite
	0	NYBORG FORMATION	Quartzitic sandstone, greywacke and red slate
		LOWER TILLITE	Tillite

OLDER SANDSTONE SERIES

Phyllites

Fig. 6. Geological map of the Digermul Peninsula.

den er sterkt foldet og forkastet. Den består vesentlig av svarte sandsteiner, men det opptrer også rene kvartsitter og leilighetsvis svarte skifre. I slike svarte skifre ble det funnet graptolitter og trilobitter som viser at formasjonen er underordovicisk

Området har vært utsatt for foldning og forskyvninger med strøkretning sørvest–nordøst. Deretter fulgte en overskyvning av det metamorfe, "kaledonske" kompleks fra nord-nordvest. På et senere tidspunkt har det funnet sted normalforkastninger langs linjer med V–Ø og VNV–ØSØ-retninger.

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