The geology of the Leirpollen area, Tanafjord, Finnmark

By

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Abstract.

900 metres of sedimentary rocks, including Eocambrian tillites, have been mapped on 1 : 50,000 and 1 : 25,000 scales around Leirpollen and correlated with the Vestertana Group which outcrops on the Digermul Peninsula. The rocks consist almost entirely of clastic sediments; volcanic rocks are absent and carbonates extremely rare. The Vestertana Group begins with two tillite formations which appear to be absent in the east. The upper part of the group consists of cleaved mudstones, siltstones, orthoquartzites and greywacke sandstones. Body fossils have not been found but trace fossils are present and are common in the upper part of the group.

The rocks are folded with axes trending approximately SSW—NNE. The intensity of the folding decreases towards the east. In the extreme west of the area some overturned synclines occur and are associated with steeply-dipping reverse faults.

Introduction and geological background.

The Leirpollen area (Maps, next page and end of paper.) lies immediately the east of the mouth of the Tana River at the head of Tanafjord on the north coast of Finnmark, between longitudes 28°10′ and 29° east and between latitudes 70°15′ and 70°30′ north.

The area was first described by Holtedahl (1918) and the general features of the geology were elucidated. In 1933 and 1934 the western part of the area was visited by Føyn (1937) who established the presence of an uncontormity beneath the Lower Tillite. In 1933 the area had been mapped on the scale of 1 : 100,000 by Rosendahl (1945). Since 1950 five parties from Oxford University, under the direction of Dr. H. G. Reading, have visited East Finnmark, working mainly on the Digermul Peninsula. The stratigraphic sequence for the Digermul Peninsula was worked out in detail and in 1964 J. D. Collinson made a brief visit to the Leirpollen district. The purpose of this paper is to

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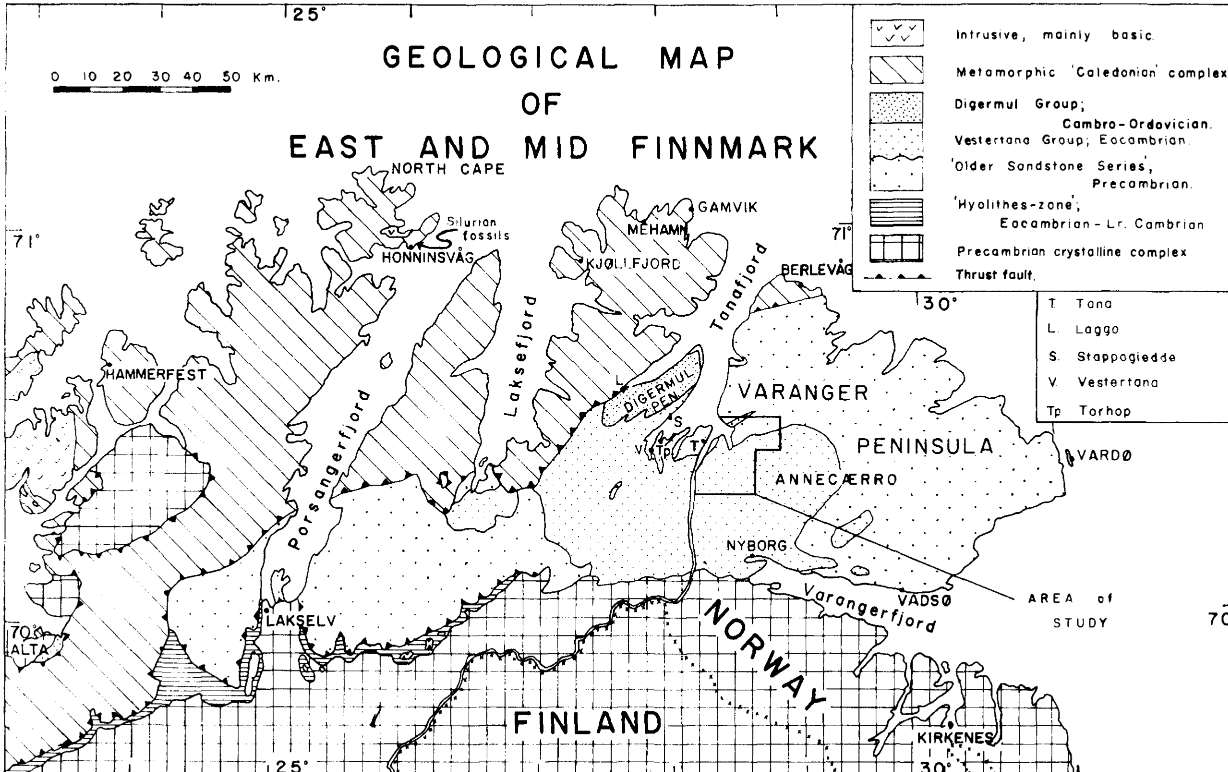
GEOLOGICAL MAP
OF
EAST AND MID FINNMARK
0 10 20 30 40 50 Km.
Intrusive, mainly basic.
Metamorphic 'Caledonian' complex.
Digermul Group; Cambro-Ordovician.
Vestertana Group; Eocambrian.
'Older Sandstone Series', Precambrian.
'Hyolithes-zone', Eocambrian - Lr. Cambrian
Precambrian crystalline complex
Thrust fault.
T. Tana
L. Laggo
S. Stappogiedde
V. Vestertana
Tp Torhop
25°
30°
71°
70°
NORTH CAPE
Silurian fossils
HONNINSVÅG
HAMMERFEST
ALTA
LAKSELV
Porsangerfjord
Laksefjord
KJØLLFJORD
MEHAMN
GAMVIK
Tanafjord
BERLEVÅG
DIGERMUL PEN.
VARANGER
PENINSULA
ANNECÆRRO
VARDØ
NYBORG
VADSØ
Varangerfjord
AREA of STUDY
NORWAY
FINLAND
KIRKENES

present the results of an expedition from Oxford which went to the Leirpollen area in the summer of 1965 with the aim of remapping the area using the detailed stratigraphical section obtained from Digermul.

1 : 50,000 scale A.M.S./M 711 maps were used, supplemented in the western part of the area by 1 : 25,000 scale aerial photographs.

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Stratigraphy.

The Older Sandstone Series is overlain with slight unconformity by the Vestertana Group (Eocambrian), which outcrops around the shores of Vestertanafjord and is there about 1450 metres thick. It passes conformably up into the Digermul Group which contains Cambrian and Tremadocian fossils (Reading, 1965). Within the Leirpollen area no rocks above the Lower Breivik Member of the Vestertana Group occur and the local thickness measured, from the base of the Lower Tillite Formation, was 900 metres. No body fossils were found but trace fossils were fairly common, particularly in the higher horizons.

Older Sandstone Series.

The uppermost 250 metres were studied in order to ascertain the nature of the unconformity beneath the Vestertana Group. The following succession is seen in the north-west of the area:

Vagge Quartzite	15 metres
Vagge Shale	90 metres
quartzite	over 200 metres

Towards the south-west the unconformity beneath the Lower Tillite Formation cuts down through the above succession and in the extreme south-west removes 130 metres of strata and rests on the quartzite below the Vagge Shale. An angular unconformity of 1—2 degrees was calculated, agreeing with that found by Føyn (1937).

Vestertana Group.

Lower Tillite Formation.

The thickness of the formation varies from 50 metres in the south-west to 8 metres in the north-west and it is apparently absent in the east. The rock is generally massive but stratification is sometimes present, taking the form of thin lenses of sand. It is unsorted, containing particles ranging from clay-grade to large cobbles. The bulk of the rock is composed of material finer than coarse sand, which is light-grey when fresh and weathers to dark-grey or brown. The coarser fraction consists of angular, sub-angular or rounded blocks of dolomite, metamorphic rocks, grey mudstone and quartzite. Dolomite makes over 50 per cent of the blocks which are frequently dissolved out leaving characteristic cavities. The Lower Tillite Formation is generally homogenous throughout its thickness but in the west of the area the formation contains a band of slates and mixed sediments 3—5 metres thick.

Nyborg Formation.

This formation is well exposed in the west of the area where it separates the two tillite formations. The thickness is commonly 15—20 metres, increasing to 90 metres in the south-west (Hanaelven valley). The formation thins towards the east but there is no accompanying facies change; it retains its character as a quiet-water sediment. This suggests that a pre-Upper Tillite Formation unconformity is responsible for the thinning.

The lower limit of the formation is taken at the abrupt disappearance of tillite blocks at the top of the Lower Tillite Formation. This is generally followed by a grey lithic sandstone 2-3 metres thick which grades quickly up into purple shales, but on the north-western slopes of Lammeskallfjell the Lower Tillite Formation is overlain by a dolomite 1.5 metres thick. The bulk of the formation consists of purple shales and lighter-coloured siltstones, the siltstones being commoner in the higher horizons. Immediately beneath the Upper Tillite Formation the beds are generally sandy laminated siltstones showing cross-lamination, but some massive lithic sandstones occur.

Upper Tillite Formation.

The Upper Tillite outcrops extensively in the western part of the area. It is commonly 9-15 metres thick with a maximum of 50 metres. It was not found in the east and is probably absent. It is an unsorted rock, so similar in most respects to the Lower Tillite Formation that it is difficult to distinguish them on lithology alone. Føyn (1937) states that in general the Upper Tillite Formation contains fewer dolomite and more crystalline blocks than the Lower Tillite Formation. In this area this distinction does not seem to hold. The blocks consist of dolomite, including pisolitic and striated varieties, with subordinate quartzite, gneiss, vein-quartz, mudstone, siltstone, chert, conglomerate, acid igneous rocks, and one block of pegmatite containing galena and pyrite was seen. Faint stratification, represented by the parallel orientation of small pebbles, is sometimes depressed under large blocks, suggesting that they have been dropped in from above. In some places there is evidence of reworking by currents.

Lateral variation of the succession in the east of the area

Along the northern margin of the main outcrop of the Vestertana Group, the Older Sandstone Series rocks form steep cliffs and the boundary between the Older Sandstone Series and the Vestertana Group is often obscured by quartzite screes. The bedrock is seen in only a few places.

West of Hanglefjell the two tillite formations are seen with the Nyborg Formation at the most only 15 metres thick. The succession in this part is thus similar to that seen in the west of the area near the Tana River but the units are essentially thinner and there is evidence of much tectonic crumpling of the beds.

5 kilometres to the east the following succession occurs:

4.	Blue-green and red-violet slate member	over 200 m.
3.	Purple mudstones (Nyborg Formation?)	15 m.
2.	Laminated grey silty sandstone	8 m.
1.	White quartzites of Older Sandstone Series	over 100 m.

The two tillite formations and possibly the Nyborg Formation appear to be absent. None of these formations was found at any place further to the east. Their absence could be explained by structural dislocations similar to the reverse faults in the west of the area. However, the present authors favour a stratigraphical explanation and believe the Lower Tillite and Nyborg Formations have been removed by a pre-Upper Tillite unconformity; the evident thinning of the tillites and Nyborg (the latter with no facies change) point to this conclusion. The Upper Tillite Formation itself, which sometimes shows shallow-water features, was eroded prior to the deposition of the Stappogiedde Formation due to the shallowing of the basin or the existence of land in this region immediately after the deposition of the Upper Tillite.

It is thought that the unconformity is only a local feature. In the west of the area the contact between Nyborg and Upper Tillite Formations is gradational, suggesting that there is no unconformity in this region.

Stappogiedde Formation.

Following the terminology of Reading (1965) this is divided into three members:

3. Red quartzitic sandstones with greywacke sandstones and mudstones.
2. Blue-green and red-violet slate.
1. Quartzitic sandstones*).

1. *Quartzitic sandstone member:* This outcrops frequently in the western part of the area but was not seen in the east. Its thickness varies irregularly from 5-55 metres. It consists of massive grey orthoquartzites, 2-8 metres thick, alternating with thin-bedded lithic sandstones and siltstones. Medium-scale cross-bedding is common. The upper part shows increasing amounts of fine material and grades up into the overlying member.
2. *Blue-green and red-violet slate member*: This is at least 250-300 metres thick. A thickness of 550 metres was calculated for the eastern part of the area but this apparent increase is probably due to undetected folding.

The lower 10-100 metres are dark purple mudstones, with, in the north, one band of white orthoquartzite 1.7 metres thick. Bands of light-green occur within the purple and are both parallel and transverse to the bedding, suggesting post-depositional reduction of the ferric to ferrous iron.

The upper part of the member consists of blue-green or grey mudstones containing laminae and thin lenses of siltstone. Ripples and channels occur, the channels being filled with muddy siltstones similar to the sediments they cut. The highest horizons become finer and purple mudstones again occur.

Red quartzitic sandstone member: This consists of three bands of red quartzitic sandstone separated by two bands of greywacke sandstones with mudstone alternations. The local thickness is between 230 and 250 metres.

3rd red quartzitic sandstone	10— 12 metres
Greywacke sandstones and mudstones	30— 40 metres
2nd red quartzitic sandstone	30— 40 metres
Greywacke sandstones and mudstones	45— 55 metres
1st red quartzitic sandstone	80—100 metres

The bases of the bands of greywacke sandstones and mudstones are abrupt. The greywacke sandstones occur as thin (10-14 cm.) graded beds with sharp bases, and are interbedded with silty mudstones. Horizontal and vertical burrows are present. The greywacke sandstones become thicker and the ratio of sandstones to mudstones increases towards the top of the bands. The transi-

*) The sandstone terminology of this paper follows Pettijohn (1957) with the addition that "quartzitic sandstone" is a bulk term including both orthoquartzites and lithic sandstones.

tion into the overlying red quartzitic sandstone is lithologically gradual although the actual colour-change is usually abrupt. However, on the west side of the Hanaelven valley there is at the base of the 1st red quartzitic sandstone a massive pale-grey orthoquartzite, 1.5-3.0 metres thick, overlying siltstones; this is found only in this valley and a fluviatile origin is suggested. Similar massive "white" quartzites occur more widely near the base of the second red quartzitic sandstone and at the top of the third, where a 3-4 metre bed forms a distinctive mapping horizon. In general the red quartzitic sandstone bands consist of red orthoquartzites and lithic sandstones with a small proportion of mica and decomposed felspar grains. Channels, medium-scale cross-bedding and ripple-marked surfaces are present.

The member thus shows a succession of coarsening-upward cycles. Each cycle begins with silty mudstones and greywacke sandstone alternations, the latter becoming thicker and more abundant upward. These pass gradually into the red quartzitic sandstone bands which contain little fine-grained material. There is a sharp base beneath the succeeding cycle.

Breivik Formation.

Rocks of this formation are stratigraphically the highest beds seen in the Leirpollen area. They consist of medium-grained lithic sandstones, orthoquartzites and greywacke sandstones, all interbedded with silty mudstones. The lithic sandstones and orthoquartzites occur as parallel-sided units 5-200 centimetres thick and showing cross-stratification and scoured bases. The greywacke sandstones occur as thin graded units 2-10 centrimetres thick with sharp, occasionally conglomeratic, bases and abundant horizontal burrows.

Reading (1965) has divided the formation into two members but probably only the lower member occurs here since the characteristic Upper Breivik Member lithology of the Digermul of thin mudstones and greywacke sandstones, without lithic sandstones and orthoquartzites, is absent. In addition the maximum observed thickness is only 230 metres, compared with 220-255 metres for the Lower Breivik Member on the Digermul.

Structure

The major structural elements consist of pitching folds with varying axial directions. In the south-west the axes trend NNE-SSW. These change to NE-SW in the east and north, while in the extreme north-east of the area the trend of the steeply dipping rocks adjacent to the Older Sandstone Series appears to be NW-SE. Intensity of the folding increases towards the west where folds are often asymmetrical, with axial planes dipping west. In the region of Annecaerro the beds are practically horizontal. Much minor folding occurs in the Stappogiedde Formation in the west of the area.

Three large reverse faults occur in the area of greatest deformation. They follow the trends of the folds and are thought to be contemporaneous with them. The two western examples, on the river-cliffs of the Tana and at Lavvonjargga may possibly be the same fault; in both these cases the Older Sandstone Series is brought up against overturned younger rocks. In all cases the fault-planes dip in a westerly direction. Small reverse faults are found in the noses of some minor folds, where sandstone beds have deformed by fracturing but adjacent fine-grained beds show plastic deformation.

Normal faults are fairly common throughout the area and generally have an E-W trend. However, in most cases the throws are too small to justify their representation on the map.

Flow cleavage, increasing westwards, was found to be parallel to the major and minor fold axes.

Geomorphology

In the north of the area the Older Sandstone Series rocks form high hills, up to 600 metres high, covered with a surface of bare rock and screes. The Vestertana Group underlies lower ground to the south. where an extensive plateau surface occurs at 340-380 metres. this is deeply dissected by wooded valleys. In the north-flowing Julelven tributaries there is a striking correlation between anticlines and stream valleys.

The whole area shows abundant evidence of the action of land-ice in the recent past; overdeepened valleys, with hanging tributaries, and large erratic blocks of tillite and crystalline rocks, the latter derived from the Precambrian basement in the south, are common. Drumlins are found on Hanglefjell. Many valleys on the plateau are dry, or only carry snow melt-water in the early summer.

Deep incision of valleys, terraces at many levels and raised beaches above the fjord appear to indicate that a large lowering of base-level was the most recent geological event in the area.

Conclusion

The Leirpollen area shows a succession of clastic sediments 1150 metres thick. The lowest 250 metres comprise the upper part of the Older Sandstone Series. The remainder is in the Vestertana Group, placed in the Eocambrian by Reading (1965) who, however discusses, (pp. 186-187) the possibility that the uppermost portion, the Breivik Formation, may be of Lower Cambrian age.

The Vestertana Group can be correlated in detail with the succession described by Reading (1965) from the Digermul Peninsula.

Two tillite formations were found in the area. NE of Leirpollen a thin typical Nyborg lithology was found between two tillite horizons. The tillite by the Leirpollen Bridge is considered to be the Upper Tillite. Two faulted tillite horizons are present in the extreme west of the area and in the extensive but hitherto unrecorded exposure in the upper Hanaelven valley. Reading (1965) accepts a marine glacial origin for the tillites on the evidence of lithology, lateral extent and constancy of the two tillite horizons. The lithological evidence from the Leirpollen area supports this view. However, in the east of the area unconformities beneath both tillites and removal of the Upper Tillite by a possible unconformity beneath the Stappogiedde Formation suggest that the margin of the basin lay in this area, and that erosion alternated with periods of deposition.

The Nyborg Formation (90 metres) is thinner than in the centre of the Tana district where a minimum of 200 metres was recorded, and in the Leirpollen area no turbidites were found in this formation.

The Stappogiedde Formation (500-600 metres) shows a considerable increase in thickness compared to the Digermul area where it totals 330-475 metres. The increase is in the two upper members of the formation. The basal member of the Stappogiedde Formation contains shallow-water quartzites and conglomerates, but quiet water conditions seem to have prevailed during the deposition of the blue-green and red-violet slate member. The topmost member of the formation contains three bands of red quartzitic sandstones with many shallow-water features, alternating with greywacke-sandstones and mudstones in a series of coarsening-upwards cycles.

The Breivik Formation, consisting of greywacke-sandstones, quartzites and mudstones outcrops extensively in shallow synclines underlying most of the high ground in the south.

The greywacke-sandstones in the Stappogiedde and Breivik formations may have been deposited by turbidity currents, but the closely associated orthoquartzites and lithic sandstones were probably deposited by traction currents. The basin of deposition was thus probably essentially shallow, but occasionally became deeper, allowing deposition of fine-grained sediments and turbidites. Current directions in the greywacke-sandstones of the Stappogiedde Formation show a south to north movement, but are more variable in the red quartzitic sandstones.

Trace-fossils are common in the higher formations. They first occur in the blue-green and red-violet slate member and increase in abundance upwards.

No body fossils were found. The oldest fossils found in the Digermul succession are of Lower Cambrian age. They occur in the Duolbasgaissa Formation of the Digermul Group, about 700 metres above the highest horizon mapped in the Leirpollen area.

The structural history is similar to that on the Digermul, but over the greater part of the area deformation is less intense. It comprises folding along NNE-SSW axes, with contemporaneous reverse-faulting or thrusting in the west. There was a later episode of minor normal faulting along E-W lines. Dating of these events is impossible due to the absence of younger rocks.

The investigation has shown that the map of Rosendahl (1945) is substantially correct. Nevertheless, there are important modifications: Rosendahl was of the opinion that only one tillite occurred at Leirpollen, but two were found. Only one red quartzite sandstone was recorded from the area by Rosendahl but three have now been proved as on the Digermul. The Breivik Formation outcrops more extensively than is shown on Rosendahl's map; the white quartzite detritus on Annecaerro is considered to be derived from this formation, and not from the Duolbasgaissa Formation as suggested by Rosendahl.

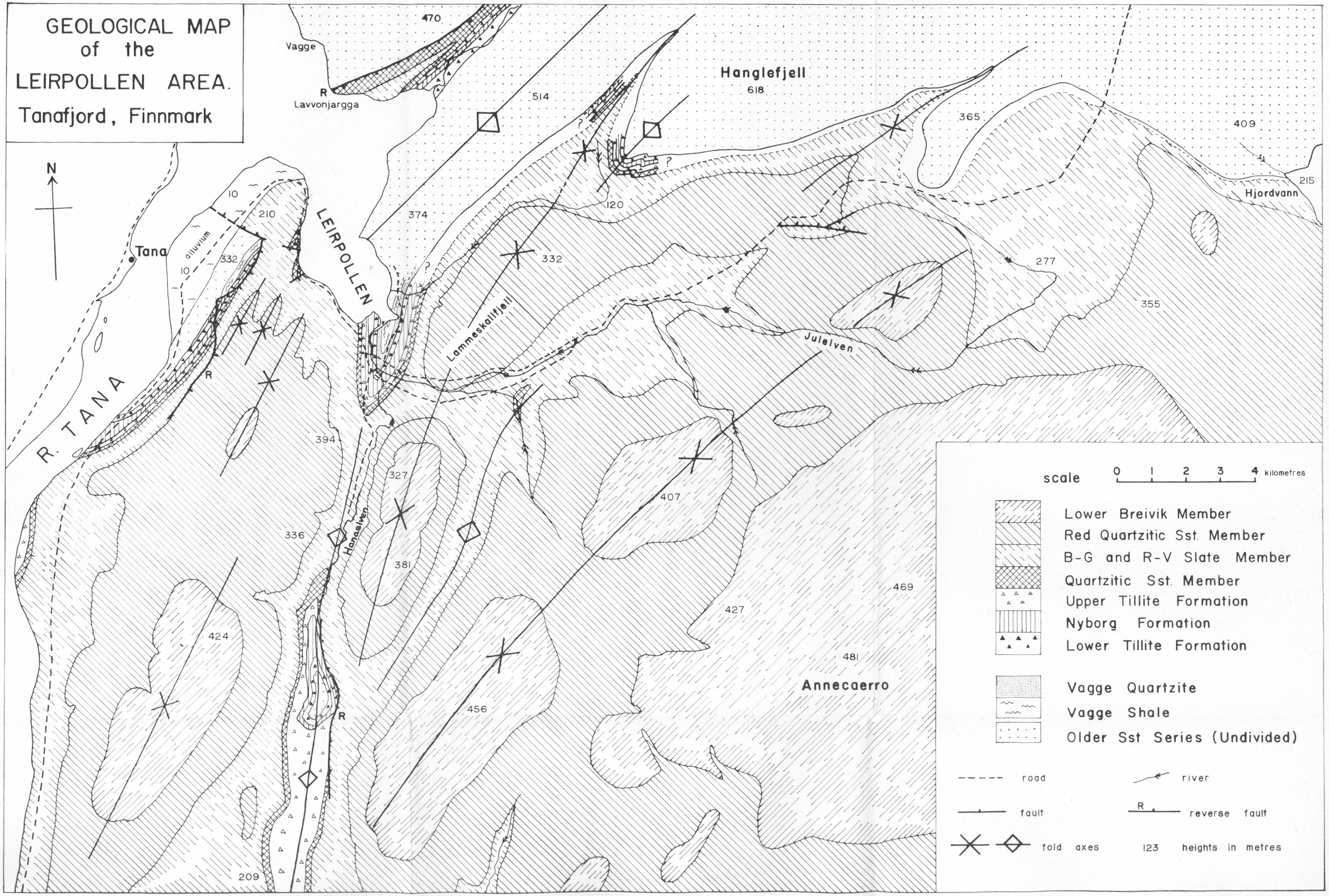
SAMMENDRAG

De geologiske forhold i Leirpollen-området, Tanafjord, Finnmark.

Berggrunnen i området omkring Leirpollen består av sandsteiner, morenekonglomerater (tillitter) og leirsteiner. Karbonat-bergarter (dolomitt) er svært sjeldne og det finnes ikke vulkanske bergarter i området. Lagrekken er i området i alt 1150 m tykk. Den er en del av de sedimentbergarter som forekommer på strekningen fra Varangerhalvøya over Tana, Laksefjordvidda og videre til SV for Porsangerfjorden.

Den laveste delen av lagrekken i Leirpollen-området, omkring 250 m, hører til den såkalte "eldre sandsteinslagrekke". Den hører i alder til yngste prekambrium. Mellom den eldre sandsteinslagrekke og den øvre del av lagrekken er det et brudd som representerer en erosjonsperiode.

Den øvre delen, som altså er omkring 900 m tykk, svarer til den del av lagrekken som H. G. Reading har kalt Vestertana-gruppen i sin beskrivelse av bergartene på Digermulhalvøya vest for Tanafjorden (1965). Vestertana-gruppen er inndelt i 5 formasjoner, nemlig (nedenfra og oppover): Undre tillitt, Nyborg-formasjonen, Øvre tillitt, Stappogiedde-formasjonen og Breivik-formasjonen. Av den sistnevnte formasjonen er omkring 230 m representert i Leirpollen-området, d.v.s. ca. halvparten av Breivik-formasjonen i Digermulhalvøya. Det geologiske tidsrom som Vestertana-gruppen hører til, kalles eokambrium, som kan oversettes med "kambriums demring".


GEOLOGICAL MAP
of the
LEIRPOLLEN AREA.
Tanafjord, Finnmark
N
470
Vagge
R
Lavvonjargga
514
Hanglefjell
618
365
409
215
Hjordvann
120
374
LEIRPOLLEN
10
210
Tana
alluvium
332
10
332
277
355
Lammeskalfjell
Julelven
R. TANA
R
394
327
407
336
Hanaelven
381
469
427
424
481
Annecaerro
R
456
209
scale
0 1 2 3 4 kilometres
Lower Breivik Member
Red Quartzitic Sst. Member
B-G and R-V Slate Member
Quartzitic Sst. Member
Upper Tillite Formation
Nyborg Formation
Lower Tillite Formation
Vagge Quartzite
Vagge Shale
Older Sst Series (Undivided)
road
river
fault
R
reverse fault
fold axes
123 heights in metres

Spor etter krypende eller gravende organismer i form av horisontale og vertikale rørformede dannelser i bergartslagene, er i Leirpollen-området funnet fra og med Stappogiedde-formasjonen og oppover. Sporene blir mer og mer tallrike oppover i lagrekken. Ingen rester av organismene selv, altså egentlige fossiler, ble funnet der.

De to tillittformasjonene inneholder blokker av grunnfjell og av dolomitt. En regner med at tillittene er dannet ved at blokkene er falt ned fra flytende is. Siden det er to tillittformasjoner, må en regne med to istidsperioder.

Mellom de to tillittformasjonene ligger Nyborg-formasjonen som i Leirpollen-området er opptil 90 m tykk. Den består av skifrig rød leirstein og moleir-stein. Det synes å ha vært et brudd i lagrekken mellom den øverste delen av Nyborg-formasjonen og øvre tillitt.

Stappogiedde-formasjonen begynner med 40 m kvartsittisk sandstein. Derover følger 300 m blågrønn og rødfiolett leirstein og moleir-stein med noen få sandsteinsbenker i. Det øverste ledd i Stappogiedde-formasjonen er omkring 240 m tykt, det består av en veksling av rød kvartsittisk sandstein og mer gråaktige sandsteiner og leirstein.

Av Breivik-formasjonen er som før nevnt bare den undre halvpart representert i området. Den er karakterisert ved en sterk veksling av kvartsitter og andre slags sandsteiner og av leirsteiner.

Bergartene i området er blitt foldet under den kaledonske fjellkjede-dannelse. Foldenes retning er fra SV til NØ. Graden av deformasjon øker mot V i området, der en kan se skjeve folder som er veltet over, og hvor det også har skjedd forkastninger med store oppskyvninger. Mindre forkastningsbevegelser langs linjer som går i retning V-Ø, har også forekommet.

Den endelige utformning av landskapet er skjedd under og etter kvartærtidens istider, altså i en geologisk sett meget sen periode av jordhistorien. Virkningen har vært til dels nedsliting av berggrunnen på grunn av ismassenes bevegelse, og dels en avleiring av løse jordlag — morenemateriale og elveavsetninger — som nå dekker berggrunnen i større eller mindre grad.

References.

Føyn, S., 1937. The Eo-Cambrian series of the Tana district, Northern Norway. Norsk Geol. Tidsskr., 17, pp. 65—164.

Holtedahl, O., 1918. Bidrag til Finmarkens geologi. Norges Geol. Unders., 84, pp. 1—314.

Pettijohn, F. J., 1957. Sedimentary rocks. Harper and Brothers, New York, pp. 1—618.

Reading, H. G., 1965. Eocambrian and Lower Palaeozoic geology of the Digermul Peninsula, Tanafjord, Finnmark. Norges Geol. Unders., 234, pp. 167—191.

Rosendal, H., 1945. Prækambrium-eokambrium i Finnmark. Norsk Geol. Tidsskr., 25, pp. 327—349.