Technical Note

NGI

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From:	Norwegian Geotechnical Institute
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Title: **Geotechnical study of Moss-Halden and Minnesund-Heimdal**

Due to feasibility studies for several new high-speed lines across Norway for railway transport, NGI has been asked by JBV to focus on bedrock and quaternary geological conditions along proposed routes for these new railroads in phase 2 "Line by Line Study". The total study includes the corridors:

- Oslo – Gøteborg
- Oslo – Stockholm
- Oslo – Trondheim
- Oslo – Bergen
- Oslo – Kristiansand/Stavanger

This technical memo will look at geological conditions and engineering geological challenges in particular along the lines Oslo – Gøteborg and Oslo – Trondheim.

1 OSLO - GØTEBORG

The focus in this paragraph lies on the new line through the county of Østfold between the towns of Moss and Halden as the proposed line north of Moss toward Oslo will follow the existing line. Østfold is situated southeast of Oslo and provides Norway with its southern most boundary to Sweden. The town of Moss is situated some 50 km to the NW of Halden and the Swedish border.

1.1 Geology in general

Geologically, the whole area belongs to the Precambrian basement in eastern Norway, and the Østfold Complex and Iddefjord granite in general. The rocks of these two complexes comprise mainly of different gneisses and granites with varying mineralogical compositions.

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1.2 Engineering geological challenges

According to Løset (2006), the area to the east of the Oslo Fjord is influenced by several fault zones or large zones of weakness that are orientated approximately N-S. Due to the orientation of the smallest horizontal main stress being perpendicular to these zones, this may cause somewhat open joints and potential water inflow to underground excavations. Weathering of the rock and water circulation in joints increases the possibility of running into clay minerals in zones of weakness. Swelling clays have been encountered when excavating through southern parts of the area.

1.3 Quaternary geology

In Norway there is vast evidence of several larger or intermediate ice ages. The last period started about 100.000 years ago and was at its maximum 18-20.000 years ago. At that time, Norway was entirely covered with several kilometres of ice. During the glacier melting and withdrawal toward the north about 8.500 years ago, the glacier cap melted leaving large end-moraines at its foot during pauses. At the same time, almost the entire southeast part of Norway was subdued under the sea. This has resulted in that the marine frontier is situated 195 m.a.s.l which means that marine sediments below this height may be expected in the area today. Please see Figure 1.1 for map on ice margin deposits and Figure 1.2 for the profiled structure of an end-moraine.

The proposed/imaginary route of the high-speed line is situated slightly to the southwest of the end moraine named Raet, on the eastern side of the fjord. Southwest of the proposed line the terrain consists mainly of rock depressions filled with fine sediments, like silt and clays. The clays are mainly quick and normally consolidated.

1.4 Foundation aspects

The planned railway line will follow a route that crosses soft soil areas between hard rock ridges. The soft soil may in many cases turn out to be marine clays with quick properties and low values of over-consolidation.

This implies that the railroad foundations at the sections of soft soil have to be designed with precision to reduce potential settlements, a procedure that will be both expensive and extensive.

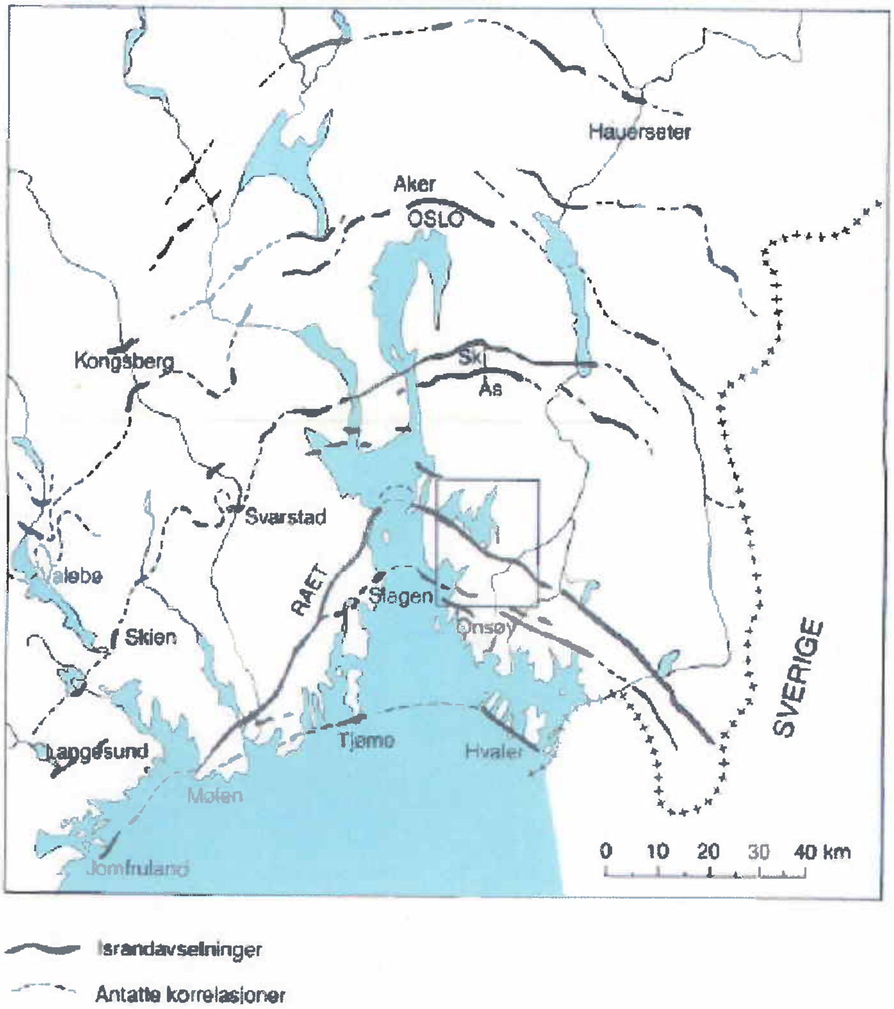

Figure 1.1: Ice margin deposits in the Oslofjord area.

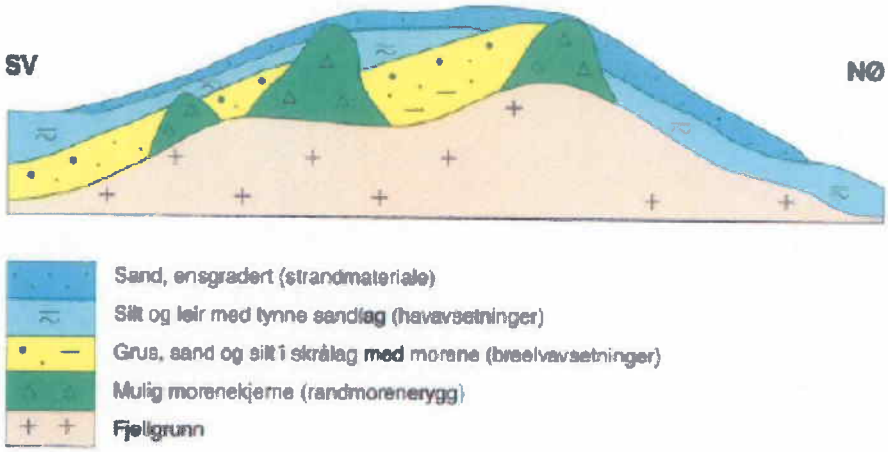

Figure 1.2: The structure of an end moraine, seen in profile.

2 OSLO - TRONDHEIM

The focus in this paragraph lies on the new line through the counties Akershus, Hedmark and Sør-Trøndelag between the towns of Minnesund to Heimdal, as the proposed line north of Oslo toward Minnesund and south of Trondheim toward Heimdal will follow the existing lines. Roughly, the line is proposed to run from Minnesund and pass through Hedmark up to Elverum. From Elverum the line will follow Østerdalen northbound passing Rena and Koppang toward Tynset. North of Tynset the line cuts to the northwest through Tunndalen and over Kvikneskogen. From there, the line descends to Kvikne and continues along river Orkla. The line is then proposed to go through a tunnel to Sokndal and continue to the follow the valley via Støren, along river Gaula and up to Heimdal south of Trondheim.

Akershus, Hedmark and Sør-Trøndelag are roughly the three counties one has to pass through when travelling in an approximate straight N-S line between Oslo and Trondheim. The proposed line and focus of the geotechnical attention in this paragraph starts at Minnesund (north of Oslo) and ends at Heimdal (south of Trondheim) and covers an approximate distance 500 km.

2.1 Geology in general

This proposed line is of fair distances and crosses many geological regions. For that reason the line has to be divided into sections based on their geological belonging.

2.1.1 Minnesund – approximately to Rena

Geologically, this area belongs to the northern part of Precambrian basement in eastern Norway. The rocks of the basement comprise mainly of different gneisses and granites with varying mineralogical compositions, in addition to gabbroic intrusions and meta-sedimentary rocks of the Solør complex.

2.1.2 Rena – approximately Tynset

This area varies geologically and consists of miscellaneous rocks belonging to the two main lower nappe complexes / allochtones thrust in over the Precambrian basement and autochthonous meta-sediments, also known as the Sparagmite region. The nappes consist roughly of sandstones, quartzites, shales and mica-schists. The nappe complexes are sub-divided into sub-nappes by large thrust- and vertical faults, and the rocks within a sub-nappe may be folded and faulted extensively.

2.1.3 Tynset – Støren

Entering the upper allochtone and the lower Trondhjem nappe, the rocks exhibit changes in their mineralogical compositions and tectonic history compared to the nappes below. Generally, the rocks of the Gula-nappe consist of quartz rich mica schists, phyllites, amphibolites and banded quartzites and exhibit a higher degree of metamorphosis than the over laying rocks. Granitic trondhjemites also exist.

2.1.4 Støren - Heimdal

The rocks of the middle Trondhjem nappe are mainly of sedimentary or volcanic origin and exhibit varying degrees of metamorphosis. Phyllites, clay slate and greenstone of the Støren group in addition to Cambro-Silurian sedimentary rocks constitute the upper Trondhjem nappe.

2.2 Engineering geological challenges

2.2.1 Minnesund – approximately to Rena

Faults and zones of weakness are generally orientated NW-SE and contribute to belts of varying rock defined by these zones. In general, the bodies of rock in between the zones of weakness are considered to be of good quality, but chemical and mechanical alteration in addition to water inflow may cause instabilities in tunnels, Løset (2006).

2.2.2 Rena – approximately Tynset

The spragmites are generally hard and stiff rocks, and may exhibit extensive fracturing. High contents of quarts may give large bit wear. Large water inflows may be expected in highly fractured zones. Clays are abundant along joints as a result of chemical and mechanical alteration, Løset (2006).

2.2.3 Tynset – Støren

Thrust faults and adjacent zones of weakness may cause problems in the Trondhjem nappe especially in low-metamorphic rocks. Clusters of joints may contain abundant clay and chlorite filling, Løset (2006).

2.3 Quaternary geology

The line will pass through different geological areas. Around Minnesund the line will cross glaciofluvial and/or glaciolacustrin deposits. Around Hamar there are areas with the same material lying over till material.

Between Hamar and Elverum the quaternary material consists mainly of till. The valley from Elverum and up to around Atna is the area where the ice from the previous ice age resided at its final stage of withdrawal. The sediments in the valley consist mainly of glaciofluvial material along the sides of the valley and fluvial material around the river, Glåma. The glaciofluvial material consists mainly of sand and gravel while the fluvial material consists of more fine material such as silt and fine sand. Higher up in the flat valley sides, there are till deposits.

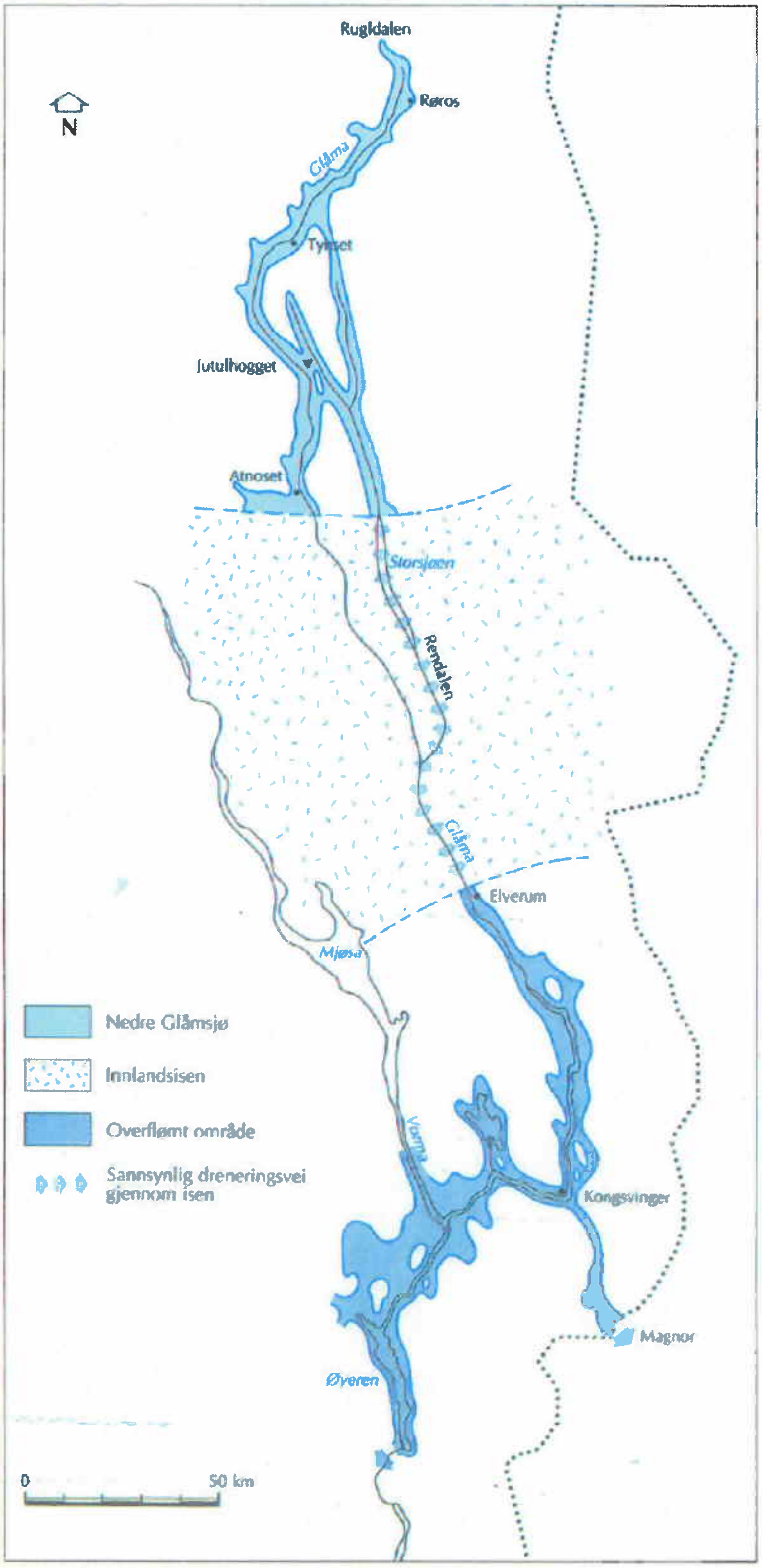

Figure 2.1: Residing ice during its withdrawal toward the north.

North of Atna glacier lakes formed under the residing ice giving the sediments characteristic grain size distributions of coarse and fine glacier lake material. Along the sides of the valley one can expect the coarser material and along the valley floor one can expect finer material such as fine to coarsely grained silty or clayey sediments. In Østerdalen these fine grained sediments are known as "kvabb". This soil material is used for agricultural purposes in the valley.

This fine material is very sensitive to frost heaving and can give problems for the foundation. This problem applies for the section between Atna and north to Tynset where the rail line leaves the valley and turns northwest into Tunndal. In Tunndal "kvabb" also exists. From Tunndal the line climbs up the V-shaped valley. The valley is covered with a thin cover of till. Between Tynset and Kvikneskogen the line passes an area with lakes. It is assumed that the lake material is till. North of Kvikneskogen the topography descends relatively quick from around 700 m.a.s.l to 500 m.a.s.l at Kvikne.

Kvikne is situated in a U-shaped valley with a flat area at its floor, where the valley sides consist of silt and fine sand material. At Kvikne, there is planed a 15 km long tunnel trough metamorphic slates. For information, there is a TBM tunnel for waterpower through Finnfjell, between Ullsberg and Berkåk.

Further on along Orkdal, the valley is a V-shaped and there are considerable amounts of till deposits. The exciting main road, Rv 3, has large problems with landslides and rock falls on the north side of the valley.

Finally, the rail line will change direction and continue to Gauldalen. Between Sokndal and Støren the valley is covered with a thick layer of till and glaciofluvial/fluvial material. Existing railroad passes today on the west side of Sokan where there have been many problems with frost heave and frost sliding.

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