THE DRIFT BEDS OF WESTERN SKÅNE IN SOUTHERN SWEDEN

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Abstract. Just like the northern parts of the European continent, the southernmost province of Sweden (Skåne) shows traces of several land ices. They have passed across this province in different directions at different times, either following the Baltic basin and Öresund (from the NE.-E.-SE. to the SW.) or crossing the southern Swedish highlands from the N. or NE. Thus, the boulder composition changes from drift bed to drift bed. Stratified inter-moraine beds occur, but they are in general non-fossiliferous and therefore it is difficult to get a good stratigraphic comparison across the southern part of the Baltic to northern Germany or even to Denmark. This work gives a short summary of the opinions of former authors as to the glacial development and adds some new facts on the stratification of drift beds and inter-moraine sediments.

Skåne, the southernmost province of Sweden, differs in its geology in many respects from the Fennoscandian part of Sweden. Whereas Fennoscandia mostly consist crystalline Archaean rocks, Skåne, especially the part SW. of its NW.-SE. diagonal, is built up of sedimentary rocks from the Cambrian to the Tertiary. As regards the Quaternary stratigraphy, this south-western part is more closely connected with Denmark and northern Germany. In "Fennoscandian" Sweden, there is in general only one till bed, while in south-western Skåne there are several drift beds with inter-morainic sediment layers, in places several metres thick.

The outlines of our knowledge of the older Quaternary stratigraphy of this province were drawn in the mid 1860s in the works of O. Torell and L. Holmström. The details were added by the geological mapping of the province from 1860s to just after the end of the nineteenth century. The first of the Scanian geological map sheets (scale 1:50 000, Geological Survey of Sweden, series Aa), Aa Båstad, was issued in 1877. The last four were issued after the turn of the century. The ever last was Aa 142 Sövdeborg, issued in 1920 but in the main mapped a decade earlier. Later works by Danish and Swedish authors have made additions to and diversified the earlier pictures.

In this paper I shall give a summary of these works, concluding with some observations as to the Quaternary drift stratigraphy of western Skåne that have emerged from the geological mapping carried out in the last few years.

Even before the theory of the Ice Age was delineated in Sweden by O. Torell, the Danish scientist A.S. Oersted (1844) had observed in the shore cliffs on the western coast of Skåne, north of Landskrona, folded, non-fossiliferous sediments alternating with stone-bearing clays (boulder clays).

In his classic work *Observations in Scania on Traces of the Ice Age* (1865) Holmström thought that the drift belonged to a single Ice Age. Torell (1872, p. 57) found that the sediments below the drift bed must have been deposited before the advance of the ice stream that, when it receded, left its till or boulder clay upon the sediments. However, he did not say anything about the direction from which the ice stream came that brought the drift to the cliff, but he mentioned that the drift bed contained Cretaceous limestones and flint (from south-western Skåne).

A. G. Nathorst (1872) and Holmström (1873) describe profiles in southern Skåne containing *upper boulder clay* with Cretaceous limestones, *sediments,* in places with fresh-water molluscs, *lower boulder clay* (or till) with boulders of crystalline rocks, Silurian clay stones, Cambrian sandstones, etc. and *lower sediments.*

As regarded the shore cliffs N. of Landskrona, Torell (1872) was able to distinguish two different drift beds: a superior, yellow one and an inferior, grayish-black boulder clay. However, he still seemed to maintain his view that they both belonged to the same ice stream, even though this could have oscillated and changed direction during different time periods or phases. He thought that the same interpretation was applicable to the successions observed by Nathorst and Holmström.

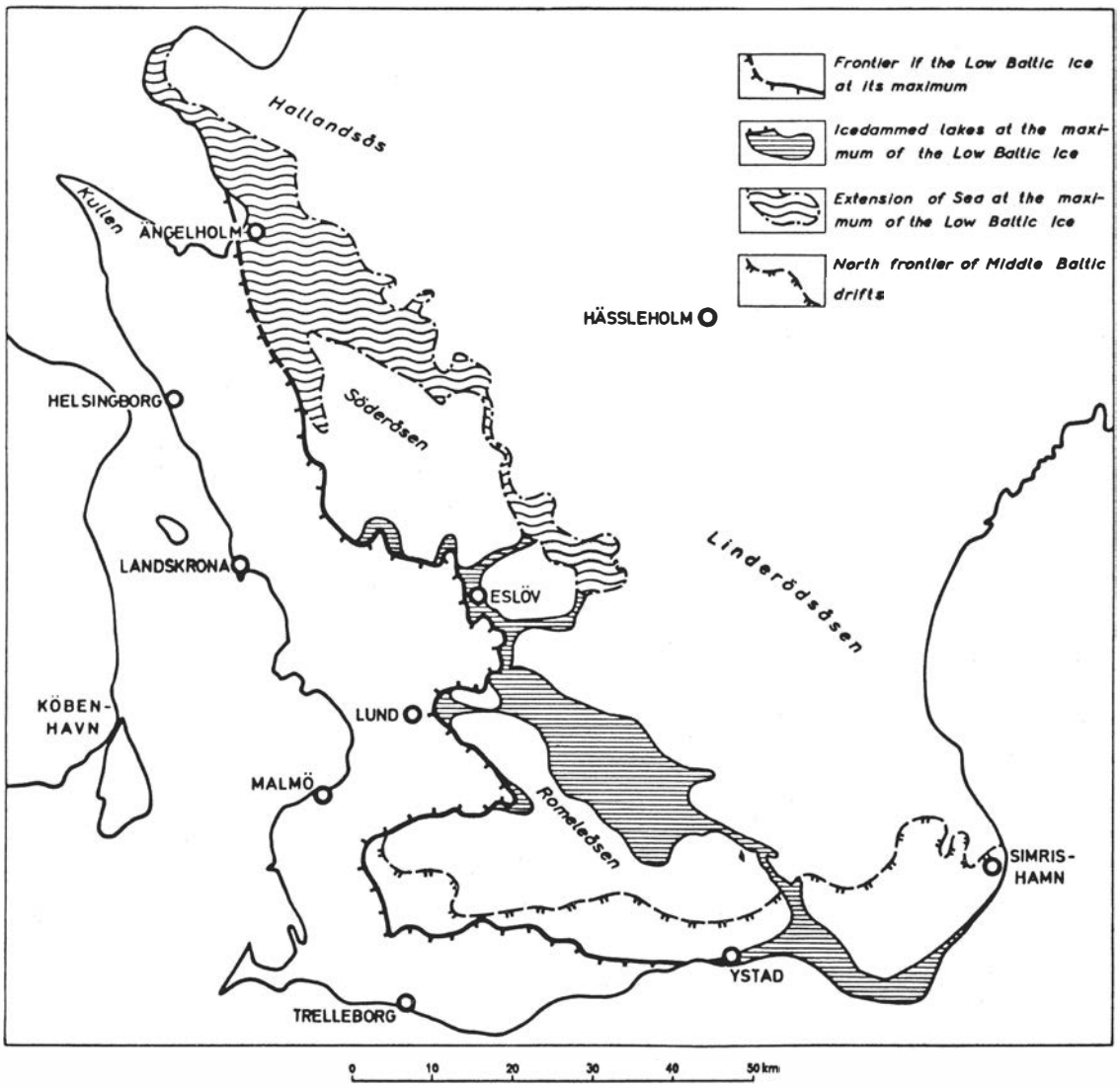

Fig. 1. The right frontier of the Low Baltic Ice in southern and western Skåne and the probable extension of the sea and the ice-dammed lakes at its maximum. Compiled from G. Ekström and K. Nilsson.

In the 1870s in Germany and Denmark, observations had been made on stratigraphic successions in which sediments were underlain and overlain by drift beds. Under the influence of these observations, Nathorst called the Scanian sediments in a similar position *interglacial* and thus also the sediments in Skåne, containing fresh-water molluscs. Holmström was more restrictive and only called them *glacial fresh-water deposits,* stressing their connection with an ice front and a cold climate, whereas the German interglacial fossils indicated a rather good climatic amelioration.

In Sweden, the introduction of the monoglacial concept began by these works being controverted.

In his work 1873 (p. 23), Holmström considered that sediments below the lower drift could be followed around the northwestern corner of the Romele horst into the Vomb plain between this horst and the Silurian heights in the NE. The sediments are non-fossiliferous, but he supposed them to be fresh-water sediments and hoped to find fossils that would make stratigraphic connections with clays in western Skåne possible.

In his book *Om den skandinaviska landisens andra utbredning* (On the Second Extension of the Scandinavian Land Ice) (1884), G. De Geer maintained that

there had been more than one Ice Age. This work was the source of a great dispute for 15 years between De Geer and the extreme monoglacialist N.O. Holst. The main problem was concentrated on the age and stratigraphic position of the Lomma clay (Lomma is a village 10 km NNE. of Malmö). De Geer (1887) regarded this clay as belonging to "the middle glacifluvial deposits" (*mellersta hvitåbildningarna*), that means, it was older than the youngest drift bed (=interglacial, *sensu* Nathorst). Holst admitted (1895) that the land ice in this region "both during the first and during the last phase had had its own movement with a deviating direction". However, according to Holst, this fact could not be interpreted as meaning that, between periods of different ice movements, there had been "an interglacial phase". Unfortunately for De Geer, the Lomma clay in the type locality is not covered by the younger drift bed. To Holst, this meant that the sedimentary Lomma clay must be Late Glacial. Fossils of *Gadus saida* (the polar cod) indicated that the clay was marine and high Arctic.

It was not until 1899 that the problem of the Lomma clay was solved by Holmström, who carried out systematic borings from Åkarp to Lomma, a section 4 km long. He then stated that, between the upper part of the sedimentary clay (De Geer's cement clay) and the inferior part (De Geer's brick clay), there was a non-stratified clay with small stones and pebbles of Danian limestones and flint, locally called "lime clay". Holmström followed this stratum sideways and found it to be the youngest drift. Thus, the upper part of the sedimentary Lomma clay was Late Glacial, whereas the inferior clay was inter-morainic. According to De Geer (1887, p. 48) the *Gadus saida* skeletons had been found "mainly in the lower parts of the brick clay" and thus belonged to an interstadial phase.

Holmström, however, designates "the common Lomma clay" as "brick clay" and says (1899, p. 242): "In the intermorainic clay no organic remains have been found, nor even fish fossils." From this, it must be concluded that the Late Glacial Lomma clay (upper part) is marine, but nothing is said about the deposition milieu of the intermorainic clay. But still there is an uncertainty, because De Geer and Holmström use opposite technical terms for the two types of clay. Holmström is probably the more reliable author in this case, as he had long experience of these clays and their use and knew what their technical names stood for.

Some years earlier, on the basis of a renewed investigation, Holmström (1896, p. 308) had had to correct his opinion as to the presence of fresh-water molluscs below the superior drift bed (Holmström's *öfre krosstenslera*). This *öfre krosstenslera* was in fact a complex, probably a mixture of real superior drift clay and early sedimentary clays ("plateau clays"), which by solifluxion had been brought into a secondary position upon Late Glacial lake clays containing molluscs such as Sphaerium and Pisidium. Their intermorainic age was thus out of the question.

As early as 1865, Holmström was clearly aware that ice streams had passed over Skåne with different directions of movement at different times. He based his opinion upon the ice striae and the distribution of erratic boulders. Unfortunately, neither the "iron gneisses" of western Sweden nor the sedimentary rocks of Skåne are adapted for the carving or conservation of ice striae. The gneisses are strongly tectonised, the sedimentary rocks are soft and lightly weathered, and the cover of Quaternary deposits is rather thick and continuous. However, Holmström was able to distinguish three different ice streams:

1. *The Old Baltic Stream,* passing over Skåne from the E. or SE. towards the W. or NW.
2. *The Great Ice Stream* from a northerly direction.
3. *The Younger Baltic Stream.* This extended only over the southern and western parts of Skåne, turning from the NE. over W. to the NW., thus rounding the southeastern and southwestern corners of the province, and pushed northward in the recent Öresund. (In Danish literature it often is called the Öresund glacier.)

During the geological mapping of Skåne in the last few decades of the 19th century, so many facts were collected on ice striae, erratics, etc. that Holmström (1904) was able to make a new survey:

1. *The Old Baltic Stream* from the E. or SE., which gradually passed over into
2. *The Meridian Stream* with a direction from N. to S. This in turn was succeeded by
3. *The High Baltic Stream,* which only passed across the middle and southern parts of Skåne, at first from the NE., later from the ENE. and finally once more from the NE., as it melted and its front withdrew. It was followed by
4. *The Low Baltic Stream,* from the same direction as no. 3 in the above scheme.

When the geological mapping of Skåne was concluded with the map sheet Aa 142 Sövdeborg, its author H. Munthe (1920, p. 65) summarized his picture of the geological development, based on ice striae, erratics, and the stratigraphy and extension of the sediments of ice-dammed lakes, as follows:

1. *The Old Baltic Ice* succeeded by
2. *The Northeastern Ice* (= Holmström's Meridian and High Baltic Streams). During one phase of the melting

this ice was divided into two wings:

(a) a right wing, retiring in northern and central Skåne and

(b) a "*Middle Baltic*" left wing, at first advancing in southernmost Skåne but later on retiring during an *interstadial period.*

3. After some time the ice re-advanced on two fronts:

(a) The *Younger Northeastern Ice* across central Skåne and

(b) *The Low Baltic Ice* (or Southwestern Ice).

Munthe's conception of the situation at the maximum of this last ice advance with the extent of the ice, bare land, ice-dammed lakes and the sea will be seen in Table 2 in his 1920 work. The ice front in stage 3(a) ran from the southern end of the Söderåsen horst towards the SE. in the direction of Ystad. Between this front and the eastern boundary of 3 (b), Munthe supposes an ice-dammed lake surrounding the Romele horst (called the Inferior Romele Ice Lake). The lake was dammed at its northwestern corner by the Low Baltic Ice and the drainage was situated *between* the two ices from Eslöv via Svalöv to Vegeå River with its mouth in the Glacial Sea, W. of Söderåsen. Munthe assumes that the frontier of the Low Baltic Ice ran from Svalöv to the W. over the Glumslöv - Rönneberga Hills, N. of Landskrona, vaguely in the direction of Helsingborg.

It was of great importance for the view of the Quaternary developments to fix the *maximal* extension of the Low Baltic Ice and its drift bed. G. Ekström (1934) performed around Svalöv a detailed investigation of the front which here is very clear, with the northeastern drift bed, fine sandy, rich in crystalline boulders and pebbles and local Silurian material on the one side and on the other the Low Baltic boulder clay, in places with a clay content of more than 40 per cent and characterized by Danian limestones and flint. Extramarginal lake sediments occur in several places along the front and thus separate the drift beds in the field. Such sediments occur even *below* the younger drift. Pollen analyses of the sediment indicate almost exclusively secondarily re-deposited pollen grains. Bones of Mammalia, probably the wild horse, have been found in the inferior part of the younger drift.

Under the leadership of Ekström in the 1930s and 1940s agrogeological detail mapping was performed from Svalöv in the N. to the Romele horst in the S. From here the boundary was traced by Ekström more comprehensively to the southeastern corner of Skåne (Fig. 1) and also from Svalöv towards northwestern Skåne. Here, from Tågarp northwards, the boundary is less distinct, because of the dilution of the characteristic Low Baltic drift with material picked up by the ice from the northeastern drift and/or from the Rhaetic-Liassic rocks. Ekström called this drift bed "the northwestern-drift", not a very good designation (cf. the southwestern-drift *coming* from the SW. and the northeastern-drift *coming* from the NE.).

Ekström (1936, p. 74) let the frontier of the Low Baltic Ice run from Svalöv via Sireköpinge, Ekeby, Billesholm, and Åstorp (at the northwestern-end of Söderåsen) and from there in an arc up into the southern part of the Bjäre peninsula, N. of the Skälderviken bay. Ekström considered that the central parts of Skåne had been bare land at the time of the maximal extension of the Low Baltic Ice (the Southwestern Ice).

G. Wennberg, who found it curious that a Low Baltic Ice on the southern coast of Skåne could force heights of only about 20 m above the recent sea-level but pushed forward more than 100 km along Öresund and here reached heights of 60—70 m, attacked (1949) the Ice Age problem from a glaciodynamic point of view and on a mainly monoglacialistic basis. The idea was undoubtedly interesting, but the conclusions were in many respects very peculiar. Wennberg drew the front of the Low Baltic Ice from Svalöv to the southern foot of the Glumslöv Hills. These hills, which are built up of fine sandy sediments or sandy clay, he supposed to have been deposited subglacially or between the Low Baltic Ice and the remainder of the Northeastern-Ice that, according to Wennberg, covered the whole interior of Skåne as a dead ice.

Whereas the works so far reported were mainly based upon observations on or near the soil surface, H. Möller (1959) also treated samples from well drillings in the neighbourhood of Lund. He stated that in this area there are thick and widespread sediments, in part clays with high contents of the clay fraction, covered by the Low Baltic drift and resting upon the northeastern drift bed. This signifies that there must have been an icefree period, perhaps short and with a high Arctic climate (no fossils), before the advance of the Low Baltic Ice.

K. Nilsson (1959) also bases his work on the ice streams and ice movements in southwestern Skåne to a great extent upon well drillings, besides the counting of erratics. Along and parallel to the Romele horst, there is a valley in the Cretaceous rock floor called the Alnarp valley (Holst, 1911). It runs in Skåne from the middle part of the southern coast towards the NW. to the coast of Öresund between Malmö and Landskrona. The valley bottom is in general situated 60 to 100 m below sea-level. It is entirely filled up with Quaternary deposits. The deepest parts consist of older drift beds (the "Old Baltic drift") and interjacent sediments. These are covered by younger drift beds, by

Nilsson collectively named "younger deposits". They are

(a) drift beds (and sediments) from the Meridian Ice Stream, deposited SW. of the Romele horst by an ice from the NNE, with basalt boulders from central Skåne and

(b) younger Baltic beds, deposited by the same ice as (a), when its direction was E. to W. Three separate phases are distinguished, each characterized by its erratics. When the ice cap had become so thin that the Romele horst (summit 186 m) protruded as a nunatak, there was dead ice on the lee (southwestern) side of the horst, which gave rise to the recent western hill landscape. The youngest phase we recognize as the Low Baltic Stream, with many Baltic rock types (for example, limestones from Gotland and Öland, rapakivi from Åland), Cambrian sandstones and Silurian claystones from southeastern Skåne and, above all, Maastrichtian limestones and flint.

Unlike Möller, Nilsson did not think that he had found an interstadium just before the advance of the Low Baltic Ice.

In 1971, K. Nilsson published a work on a core drilling made in 1964 in the southern part of the Alnarp valley, through the Quaternary deposits. The Cretaceous limestone floor was situated 95 m below sealevel. Just above the Cretaceous rock there were

1. Three metres of clay or silt sediments covered by
2. a drift bed, 27 m thick, tough, rich in Cambrosilurian pebbles, especially Cambrian sandstones. Its upper surface nearly equals the normal bottom level of the Alnarp valley.
3. A series of glacial or glaciofluvial sediments, containing mainly Cretaceous material, whereas the Cambrosilurian is rather low. No drift bed with the same composition has been found. A varved clay at the top of the series indicates an ice-free period.
4. A drift bed, 8 m thick, with predominantly Cambrosilurian material, whereas the Cretaceous material is low. Clay contents 20–25 per cent.
5. Sandy - silty sediments, a few metres thick.

6a. A heavy clay with a 94 per cent clay fraction.
6b. Coarse, upwards finer, sandy - silty sediments.
6c. Varved clay.

The series 6a–6c is in all about 25 m thick. This succession of layers and Nilsson's statement that there were Jurassic and Cretaceous coal fragments on the layer surfaces of the fine sand and silt make a parallel probable with the normal sedimentary series in the northwestern parts of the Alnarp valley, described by N.O. Holst (1911).

7. A drift bed, 10 m thick, in which the contents of crystalline rocks increases upwards. Cretaceous types are rather moderate in frequency. Nilsson interprets this bed as the Middle Baltic drift bed (*sensu* Munthe). It would be better to call it "the Northeastern drift".
8. Boulder clays form the main part of the uppermost 25 m. Clay contents 15 to 40 per cent. Between the boulder clays there are sediments, in part heavy clays.

It is of the greatest value that, by a core drilling, it has been possible to take *in situ* samples and directly to observe the details of the stratification. Micro-fossil investigations by U. Miller (1971) show a rich pollen flora, but the genera and species indicate that they represent all ages from the Jurassic to the Quaternary Interglacials and thus they have been secondarily deposited here.

One of the difficulties in paralleling and interpretating the drift beds and glacial sediments in Skåne has been the absence of fossilbearing sediments (marine or terrestrial), with the exception of the Lomma clay containing *Gadus saida*. The discovery of organic material in a stone quarry in Stenberget on the Romele horst, 175 m above sealevel and 25 km E. of Malmö, was therefore very opportune. It was made in the spring of 1971 during an excursion of geologists from Lund under the guidance of K. Nilsson. The material is being studied under the leadership of Professor B. Berglund. A radiocarbon dating shows an age of > 40 000 years. Pollen grains in peat and clay gyttja preliminarily indicate the Eem Interglacial. The sediments rest upon a till bed protected against erosion by a protruding tectonic ridge of the gneiss rock. Ice striae on the rock surface below the till bed indicate an ice movement that turns from the E. or ENE. to the NE. The sediments are covered by a younger drift bed.

The works here reported and given in the list of references are only the most basic ones. For a more complete list, see, for example, G. Wennberg (1949, pp. 1–2), H. Möller (1959, pp. 6–7), and K. Nilsson (1959, pp. 5–8).

As I mentioned before, Ekström pictured the boundary between the northeastern and the southwestern drifts as running from Tågarp to the N. through Ekeby and Skromberga towards Billesholm. The mapping in the last few years has verified this picture. In a clay quarry (Rhaetic) in the northern part of Skromberga, only the northeastern drift is represented; it is characterized by Rhaetic-Liassic sandstones and clays with boulders of gneisses, amphibolites and dolerites but with no Cretaceous elements. The drift bed, about 4–5 m thick, is a fine-sandy, light boulder clay (Swed. lättlera, grovlera).

Three kilometres further to the S., in another quarry, the younger drift bed also occurs; it is represented by a brownish-red clay, a solifluction-like boulder clay type characterized by the local Keuper rock. Flint and Danian limestones have been found, but only rarely.

NW. of Ekeby, the boundary is again very distinct, as meltwater has eroded a deep rivulet valley along the ice front from Billesholm to Bjuv, where the drainage met the glacial Sea. Below the highest sea level at + 50 m, the southwestern drift bed is generally buried below glacial clay. But well drillings at several places have revealed its presence, as, for instance, at Rögle, 10 km SW. of Ängelholm. At a place 7 km further to the E., no Danian boulders have been found in the till, in spite of the fact that they are often to be found in and on the glacial clay upon the till. In a stone quarry at the eastern end of Mt Kullaberg, Danian limestones and flint are rather frequent in the surface gravel and in the till at +25 m, and on the summit of this horst (+187 m) there has been found flints, together with Liassic clay ironstones and Cambrian sandstones. Mr. Erik Lagerlund is at present investigating whether they were transported by the Low Baltic Ice or some older ice or perhaps came from the NW.

According to Ekström, the Southwestern Ice reached the southern coast of the Bjäre peninsula. The rather large quantity of Danian flint in the postglacial beach ridges seems to verify this opinion. In a gravel pit at Ljungby, 10 km NW. of Ängelholm, there is, in the southern wall, a flint-bearing, calcareous drift bed resting on stratified glaciofluvial sand and gravel, containing, as far as is known, no Danian flint. Here we are close to the "fork" between the Southwestern Ice and the Northeastern Ice, which, according to Mörner (1969, p. 70), were contemporaneous.

In northwestern Skåne there is in general only one drift bed, that of the Southwestern Ice. It is also generally rather thin. This younger ice mixed in its "own" drift from the S. or SW. also that of the older drift bed(s), and, in places, also a good deal of Liassic or other sedimentary rocks. In some places these predominate to such an extent, that it is hard to decide whether the soil should be called drift or loose, glacially tectonized rock.

But inter-moraine sediments have also been observed. In the northeastern parts of Helsingborg (Ringstorp, Drottninghög, Brohus, Björka, Långeberga) coarse glaciofluvial sediments, several metres in thickness, occur, covered by 1–2 m of the Low Baltic drift. These inter-moraine sediments seem to have come from the NE. (no Danian material) and their stratification is disturbed. In general, they rest directly upon the sedimentary rock floor, but northeastern drift has also been observed.

The cliffs between Helsingborg and Landskrona have been mentioned before. A penetrating investigation of the lithostratigraphy of the drift beds and the sediments has been performed by L. Adrielsson (1971). Two drift beds with material from the SW. can be distinguished, separated by about 1 m of fine sand and silt. The lower drift is only represented by a pavement of greatly weathered boulders and pebbles. When a real drift occurs, it seems to have been affected by solifluction or wave action.

During the building of the E 6 highway, 2–3 km E. of the coast, there were good opportunities for studying the stratification of the inter-moraine sediments. Here they are greatly folded and disturbed by an ice pressure that, as far as could be judged, came from the N. or NE. No flint or limestone material could be observed, but the presence of clay ironstone and coal of the Rhaetic-Liassic and the reddish colour of the clay fraction (Triassic or Lias β) make it probable that this fine material came from the N. or NE. as a glaciofluvial transport and was deposited in a wide basin under calm conditions. Thus they seem to have been deposited before the Northeastern Ice advance or during an interstadium of this ice age, as they were later folded by an ice from this direction. Thus these sediments are older than the sediments resting between the two Southwestern drift beds.

In the great limestone quarry at Limhamn, SW. of Malmö, B. Ringberg (verbal report) has stated that there are 1 1/2–2 m of fine sandy to gravelly, undisturbed sediments below an upper drift bed, resting on an older bed. This in turn rests upon the Danian limestone rock, with ice striae bearing S. 85°E. (oldest), but most of the bearing N. 30°E. The boulders on the surface of the older drift are in part greatly frost weathered.

In the clay pit at the Hög brickyard, 10 km NW. of Lund, the southwestern drift bed is only 1 m thick and is greatly frost weathered and characterized by solifluction. It rests upon 1 m of sand and under this there are about 7–8 m of a beautifully stratified, stone-free clay. Below this clay a well digging has revealed a hard, stony clay (Northeastern drift).

Also on the southern coast of Skåne, at Maglarp, 10 km W. of Trelleborg, the examination of gravel pits has shown that a superior drift bed of typical Low Baltic boulder composition rests upon 10 m of stratified sand and fine sand, on the surface of which ice wedges and boulders with striations bearing S. 20°E., have been observed.

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