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# SOME WORKING HYPOTHESES AS REGARDS THE GEOMORPHO- LOGY OF SOUTH SWEDEN.

By *HANS W:SON AHLMANN.*

The geomorphological development of South Sweden is difficult to investigate partly because it dates from very ancient time, and partly because it has had few clearly distinguished cycles or epochs. The different elements in the topography are indistinct and blend together. The absence of different geological formations also renders analysis difficult. These circumstances were among the causes of my geomorphological studies in Norway,<sup>1</sup> whose topography is much more pregnant than that of Sweden, and whose geomorphological development, owing to great changes at a relatively late date, is less difficult to investigate than that of Sweden, but is nevertheless not so different from that of this country that certain resemblances in the general development may not be expected to occur. Consequently what we have learnt and observed in one country may be employed in studies in the other. The following conceptions of certain features in the geomorphology of South Sweden are based on studies in the field and of maps, with the use of certain results obtained in South Norway which I have set forth in my treatise about Norway: they must be regarded as working hypotheses, as the morphological investigations of this part of Sweden must be said to be still in a preliminary stage.

The morphologico-geological development of South Sweden, apart from Scania, may — in accordance with the now current conception of geology — be briefly summarized as follows. At the beginning of the Cambrian period a subaerial cycle had been developed to the peneplain stage. The Cambrian sea burst in over a low and level plain, the sub-Cambrian denudation surface. During the Cambro-Silurian period a not very thick covering of sediment was deposited over the greater part of the country. After that period the country was again exposed to a very long subaerial denudation, which has left behind in our time only sporadic remains of the Cambro-Silurian strata and no sure remains of rocks from any other submarine period. Nevertheless changes of level may have oc-

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<sup>1</sup> Geomorphological Studies in Norway, *Geografiska Annaler* Vol. 1, Stockholm 1919.

curred especially during the latter part of the Cretaceous period and the tertiary period. After this we have the Glacial Period, setting a stamp upon the landscape which is clearly marked and characteristic, but nevertheless relatively insignificant compared with the marks that the Glacial Period left on areas with a more broken initial topography than occurred in Sweden.

For a morphologist it is one of the first and weightiest tasks to search out the importance of the late Cretaceous and Tertiary changes of level, as these formed a distinct epoch in the process of development and revived the morphological work.

The development of South Norway is like that of South Sweden on the whole, with the exception of the fact that during the later part of the Silurian period there begins to be formed a considerable mountain chain, the Caledonian, on which the forces of denudation after the Devonian period had a magnificent field of work, which has not yet been accomplished. As the Tertiary changes of level in Norway were considerably greater than those in Sweden, this phase of the morphological development was marked much more sharply and clearly. The erosion of the ice during the Glacial period also left behind it quite different results in the strongly dissected Norway than in the flatter Sweden. One of the main objects of my studies in South Norway was the morphological part played by Tertiary changes of level in bringing about the present topography of the country. The results that I attained may be summarized in the following way. Before the Tertiary elevation of the land South Norway was worn down nearly to sea level: only in its central parts did there rise a mountain complex developed to maturity as the last remains of the Caledonian mountain chain. With the Tertiary elevation of the land the forces of denudation were rejuvenated and the elevated land-block began to be dissected in the edges by river erosion. Owing to the great elevation of the land, that erosion worked rapidly and formed considerable valley-systems, which gradually penetrated deeper and deeper into the mountain body. During the Glacial period the fluvial valley systems were transformed to troughs and rock-basins and the contacts of the valley-systems to the land-block, which had already been markedly steep, were still further intensified. That part of the land-block over which the valley-generation, introduced at the raising of the land, had not yet made its way, I call »the central unbroken part of the land-block». The denudation on this central unbroken part of the land-block has proceeded so far that the sub-Cambrian peneplain surface has been exposed and now forms a part of the denudation surface which comprises great parts of the Hardangervidda.

The elevation of the land seems to have been greatest in the NW parts of South Norway, which is now occupied by the Jostedal plateau. In the central part of South Norway, Hardangervidda, the surface of denudation now lies at about 1,000—1,400 m., and consequently we may estimate the rising of the land at

least at this amount. From here the upper surface of the land slopes towards the east, but is interrupted by the Kristiania area, so that we can obtain no direct connection with Sweden. But the raising of the land in the Kristiania district must have been substantially less than in the districts above mentioned.

In Sweden the sub-Cambrian denudation-surface plays an almost greater part in the present topography than in Norway. It is probable that the sub-Cambrian denudation surface in Scandinavia at the time when the Cambrian sea broke over it formed a continuous surface. At the places where this surface is exposed, in fact, it is very homogeneous; and it has been maintained that the sub-Cambrian fauna in large areas is so unique that it is probable that the sea broke rapidly over areas that are homologous in relation to the old shore line. The present position of the sub-Cambrian surface of denudation, therefore, gives an idea of the changes of level in Scandinavia since the Cambrian period.

Whether the sub-Cambrian surface of denudation lay at about the same level in Sweden-Norway at the beginning of the land elevations in late Cretaceous and Tertiary times is uncertain, even though there are certain circumstances that point in that direction.

The extent of the sub-Cambrian surface of denudation in Sweden can be determined geologically by the exposed rocks that underlie the Cambrian sandstone (as, for instance, at Kinnekulle,<sup>1</sup> at Stolan at the north end of Billingen, and Lugnås), by the remains of Cambrian sandstone outside the Cambro-Silurian regions proper (as, for instance, in the Kalmar district), by the calculation of the thickness of the Cambro-Silurian strata under a certain exposed guiding layer (as, for instance, has been done at Billingen),<sup>2</sup> and finally by the Cambrian sandstone courses in the fractures of the Archaean rock more or less far outside the Cambro-Silurian areas. Such sandstone courses are met with in Dalsland on the western shore of Lake Vänern,<sup>3</sup> in Värmland at Näset and near Karlstad (according to information kindly supplied by R. Sandegren), and in Småland on the Loftahammar,<sup>4</sup> Ankarsrum<sup>5</sup> and Mönsterås<sup>6</sup> sheets of the Ordnance Map

<sup>1</sup> G. Holm och H. Munthe: Kinnekulle. Sveriges Geol. Undersökning, Ser. C. No. 172, Stockholm, 1901.

<sup>2</sup> H. Munthe: Beskrivning till kartbladet Sköfde. » » » Ser. Aa. No. 121, Stockholm 1905.

<sup>3</sup> A. Gavelin: Om underkambriska sandstensgångar vid v. stranden av Vänern, Sveriges Geol. Undersökning, Ser. C. No. 217, Stockholm 1909.

<sup>4</sup> A. Gavelin: Beskrivning till kartbladet Loftahammar. Sveriges Geol. Undersökning, Ser. Aa. No. 127, Stockholm 1904.

<sup>5</sup> Fr. Svenonius: Beskrivning till kartbladet Ankarsrum. » » » Ser. Aa. No. 126, Stockholm 1905.

<sup>6</sup> H. Munthe och H. Hedström: Beskrivning till kartbladet Mönsterås. Sveriges Geol. Undersökning, Ser. Ac. No. 8, Stockholm 1904.

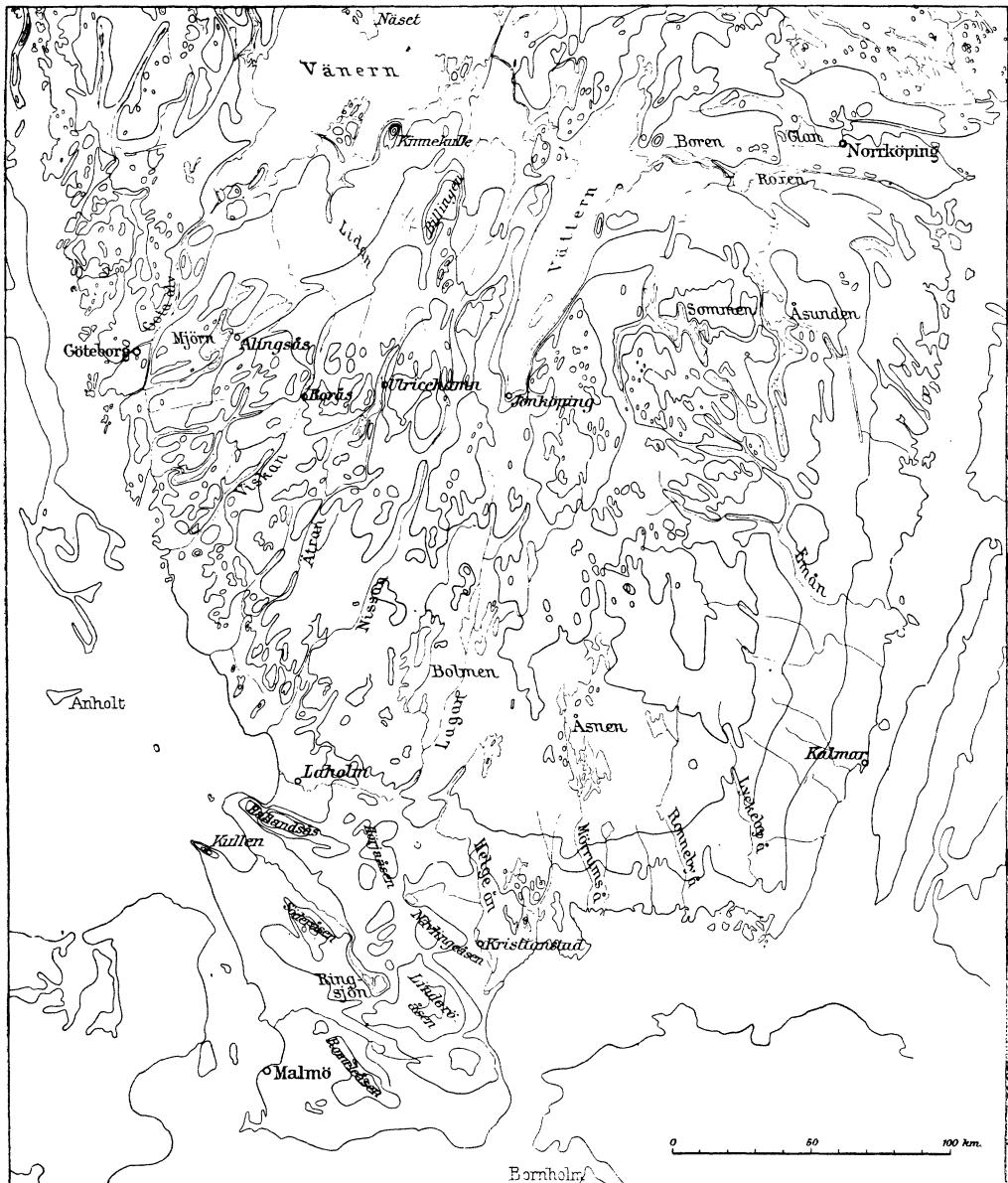
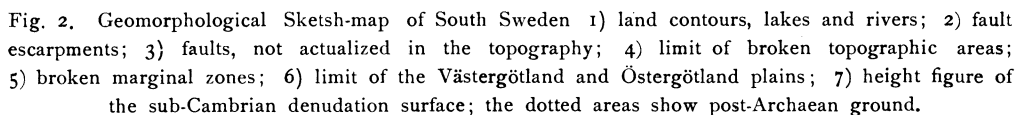


Fig. 1. Geographical Sketch-map of South Sweden showing land contours, principal lakes and rivers; height-curves and depth-curves with an equidistance of 300 Swedish feet.



The ground underlying the Kristianstad plain continues towards the north and the east, where remains of Cretaceous rocks are found sporadically.

The elevation of the geologically established points of the sub-Cambrian denudation surface are set out in Fig. 2. Morphologically, the sub-Cambrian surface of denudation can be established by the evenness of the terrain within and near the geological points shown on the map. G. De Geer<sup>1</sup> first demonstrated this morphological fact, and S. De Geer<sup>2</sup> has since shown it on his maps.

As is generally known, and as is very well demonstrated by S. De Geer's maps, the regions of the sub-Cambrian surface (Fig. 2) include the Västgöta plain with the Vänern area, the Östgöta plain, and the Kalmar plain: with which are associated in the south the Cretaceous Kristianstad plain and the Scanian plain, consisting of rocks belonging to the Cambro-Silurian series and of younger formations. The sub-Cambrian denudation surface of the Västgöta plain is divided by fractures into ribs or low horsts and has a slight rise towards the south from 44 m. above sea-level at Kinnekulle to 165—180 m. above sea-level at Vartofta (Fig. 2). Within the Vänern region the surface lies even, or only very slightly bowl-shaped, at about 40—50 m. above sea-level. The limit of this plain area is everywhere well marked, not only at the places where fractures have long since been considered to occur, but also, and that not least, in the south towards the broken terrain round Ulricehamn (see Fig. 1). The parts of the Östgöta plain that are covered by Cambro-Silurian rocks are level. The sub-Cambrian surface of denudation, as an immediate continuation of this plain, on the other hand, rises gently towards the south and passes without any sharp boundary into the broken terrain of northern Småland (Fig. 1). The same holds good of the Kalmar Sound area; the sub-Cambrian surface that forms an immediate continuation of the level plain immediately adjacent to Kalmar Sound, rises evenly up to the level surface that covers southern and central Småland. The Kristianstad plain, which is covered by Cretaceous rocks, is limited in the south by the faults; its continuation to the north passes by a slight slope into the Småland plateau; its continuation eastwards into the level littoral of Blekinge, on the other hand, is more sharply delimited towards the plateau country in the north. The Scanian plain assumes a special position owing to its thick strata of different geological age and its faults with considerable slip. The Laholm

<sup>1</sup> G. De Geer: Über die Beziehung unserer Seenplateaus zu der einstmaligen Abrasionsflächen, Nord. naturf. och läkaremötet i Helsingfors 1902. Forh. Sek. 4.

<sup>2</sup> S. De Geer: Landforms in the surroundings of the great Swedish lakes. Sveriges Geol. Undersökning, Ser. Ba. No. 7, Stockholm 1910.

S. De Geer: Södra Sveriges Landformer. Sveriges Geol. Undersökning, Ser. Ba. No. 9, Stockholm 1917.

plain, north of the Halland ridge, continues along the coast of Halland, bounded on the east by a marked slope up to the Småland plateau and here and there interrupted by marked isolated heights (Fig. 1). North of Varberg the coastal plain ceases, and its place is taken by the very much broken terrain of Bohuslän.

Above these above-named flat regions rises central Småland like a shield, forming an unbroken continuation of the sub-Cambrian denudation-surfaces of the plains of Östergötland, Kalmar and Kristianstad; it is marked off by a limited border or transition zone from the plains of Västergötland and Halland, and by a less marked limit towards the coastal district of Blekinge and the plain of southern Scania. The situation and position of the surrounding sub-Cambrian surface of denudation, in relation to the Småland plateau, is shown by the height-figures (Fig. 2).

Central Småland, as S. De Geer insists, is for the most part to be conceived as a plateau. The lakes form only flooded depressions, and the watercourses are not localized to individual valleys but run in irregular courses between the low heights. Its elevation above sea-level is 150—200 m. In the northern part, on the boundary to Västgötaland and about the southern part of Vättern, the land rises somewhat more and is more broken. The border area between the Småland plateau and the Halland plain is very much dissected by valleys; the somewhat less marked transition to the Blekinge coastal regions is also dissected, though to a smaller extent. The north-eastern part of Småland is also broken in detail, but not in the same way with a marked zone as in the other places. Thus round the central unbroken Småland plateau there lie broken marginal zones at the places where the transition to the surrounding flat low regions is marked by more or less distinct slopes. The broken marginal zone round the central Småland plateau is specially marked on the map in Fig. 2.

The morphological conditions just mentioned are well illustrated by the longitudinal curves of the watercourses (Fig. 3). Those watercourses have an extremely gentle fall and run through one or more shallow lakes upon the plateau; they have a steep course, with rapids and falls through the broken marginal zones, and then resume their gentle slope when they come out on the peripheric low plains that lie below. The Lagan and Ätran rivers represent the Halland rivers with the three distinct sections clearly distinguished and typically formed. With these watercourses is naturally associated the Göta river, whose gentle course is interrupted at Trollhättan by the well-known falls that lead up to Vänern. The Mörrum and Ronneby rivers have curves with a similar threefold division, but the steep middle section is smaller. In contrast to these three-divided curves stands that of the river Emå, which throughout the whole of its course



risers by small steps owing to the fact that it runs in a capricious course, through the humpy rocky ground and the uneven moraine covering, down towards the Kalmar plain. The relations of the watercourses to the broken marginal zone between the plateau country and the Västgöta plain are different, in that the Ätran and the Viskan here break through the high region. The Ätran rises immediately to the east of Ulricehamn and runs first in a normal direction north-

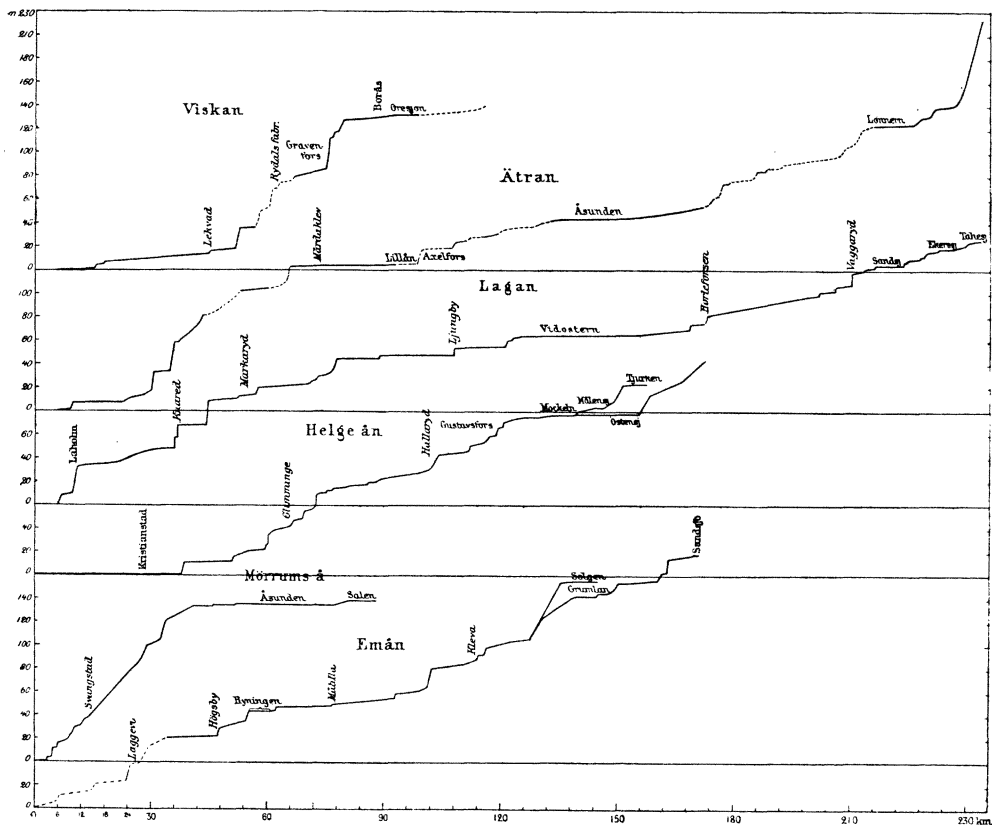


Fig. 3. Longitudinal profiles of some of the most important watercourses in South Sweden.

wards and then, immediately south of Vartofta, bends abruptly towards the south and breaks through the higher mountain region of Ulricehamn in the well-marked valley that ends in Lake Åsunden.

S. De Geer points out the dissimilarity in morphological respects between the Småland plateau, which is full of shallow lakes, and the clay plains without lakes lying outside it. With regard to the Halland marginal zone he says that "even in the east of Halland the Småland plateau is divided up into lappets by valleys 50—60 m. deep". "Here we have a really broken terrain, whose entire

morphology shows that the rock-ground is traversed by numerous zones of weakness or fracture which were carved out by the erosion of the inland-ice." As I have already pointed out, a reference to the presence of zones of weakness or fracture only gives no explanation whatever of the origination of valleys within them. In order that a zone of weakness may be able to be transferred into a valley it is necessary that it should lie in such a situation in relation to a base of erosion that running water has the opportunity to carry out the work of erosion. The size and depth of the valley depend primarily on the situation of the base of erosion. The erosion of running water is the active factor; the zone of fracture or weakness is passive and is of moment only for guiding the erosion and for facilitating its work. There seems to me to be no reason for assuming the inland ice as an erosive factor in the Halland border zone. Throughout the whole of the very slightly broken terrain of South Sweden the inland-ice seems to have confined itself to renovating and intensifying the small unevennesses in the topography which were already laid out in pre-glacial times. My investigations in Norway have indeed confirmed the view that glacial valley erosion requires an initial fluvial valley-generation. A valley formed exclusively by glacial erosion in terrain which was previously free from valleys, I know neither from my own investigations nor from the literature of the subject. Especially does it seem to me inconceivable that the open, wide, and "mature" Halland valleys with their typical subaerial character can be the work of the inland ice. All empirical observations tell against such an assumption. Consequently, in my opinion, the reason why these valleys and the marginal zone as a whole were formed is the coming into existence of the height of erosion between the Kattegat as base and the Småland plateau.

To me, therefore, the most important problem for our conception in the morphology of South Sweden is to find the reason of the origin of the low-lying base of erosion that caused the running water to break up the Småland plateau country into the margins by the formation of valleys. Thus the problem is the same as in South Norway. Has the Småland plateau been elevated in relation to its environment and has thereby a low-lying base of erosion arisen?

The circumstances telling in favour of changes in level are most distinct on the Halland marginal zone, with Archaean plain on the one side and the Kattegat with its Danien on the bottom on the other. Högbom<sup>1</sup> also points out, with regard to the Trollhätte falls the probability that the course of the Göta river was shortened "eher durch die in tertiärer Zeit stattgefundenen Senkung des Kattegatgebiets als nur durch eine Landhebung". He further points out that the level

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<sup>1</sup> A. G. Högbom: *Fennoskandia, Handbuch der Regionalen Geologie*. Bd. IV:3 Heidelberg 1913.

terrain of the Småland plateau surface indicates that during a period before the change of level it lay in close proximity to the general base of erosion. Thus elevation of the land must have been at least a considerable factor in the shortening of the Göta River. The probability that changes of level have taken place along the Halland coast is greatly strengthened by the relation of the region to the Scanian faults. The Halland coast forms an immediate continuation of these Scanian faults, and G. De Geer<sup>1</sup> considers that the sharply marked channels in the floor of the Kattegat, running parallel and immediately outside the Halland coast, are tertiary fault-depressions belonging to the southern line of faults in Scania. G. De Geer also considers that it is easier to imagine the horsts as elevated above their extensive surroundings than to imagine the latter as being sunk. At the same time he expresses the surmise that these local elevations stood in causal connection with the submergences that took place in the Kattegat and Skagerack. If these circumstances be placed in connection with the morphological facts, we have good reason to assume that changes of level took place along the marginal zone along the Halland littoral. This zone is so narrow that faults probably took place within it, or at least zones of weakness in the form of fractures — i. e. shear zones — arose in conjunction with the changes of level. The level surface of the Småland plateau, and its relation to the broken Halland marginal zone shows that the final result of the changes of level was the elevation of the land area in relation to the marine area outside it. These changes of level introduced a new fluvial cycle, which, with the sea-level as the base of erosion, elaborated the valley-system that was predestinated by the lines of weakness in the marginal zone, and which transformed the peripheral parts of the elevated land-block into the present broken marginal zones.

Blekinge, as has been previously mentioned, has a less marked marginal zone than Halland. The valleys are shallow, but yet marked, and the marginal zone stands in sharp contrast to the quite unbroken plateau country that lies within it. Here too a land-elevation must have taken place and a new fluvial cycle been begun. Although the change of level has not been localized to so narrow a zone as in Halland and consequently the transition zone has not been so marked, yet it stands out clearly enough as the slope up to the high-lying plateau area. The Kristianstad plain, which stands out as an area of depression in relation to the fault escarpements in S., the Lindarö ridge and the Nävlinge-Hörja ridge, is therefore limited towards the north by a slope that is even tectonically conditioned.

The uniformity of the Småland plateau throughout its area is also evidence that it is elevated in relation to the Kalmar plain. Here, however, the elevation

<sup>1</sup> G. De Geer: Om tiden för Skånehalvöns första uppkomst. Geologiska Föreningens Förhandlingar, Bd. 40, Stockholm 1918.

of the land has not taken place on the lines of any definite zone, but makes itself felt only through the gradual rise of the land surface towards the west. The slope is so slight that the running water across it has not attained such speed and power that marked valleys have yet arisen and a broken marginal zone been formed, with the exception of the special fault valleys between Vetlanda and Virserum.

From Halland in the west to Kalmar Sound in the east, therefore, the morphological effects of the elevation of the land gradually abate. Accordingly the elevation was probably greatest, or at least localized to its narrowest zone, in the west and "dies out" gradually towards the east. Outside Kalmar Sound the elevation of the land seems even to continue in the depression which is now occupied by the Baltic. On Öland, as is well known, the Cambro-Silurian series dips towards the east, showing that the sub-Cambrian surface of denudation continues the same slope as on the adjacent mainland; on Gottland the sub-Cambrian level is not met with until about 387 m. under the surface of the sea; after that it again rises, so that in Estland it is found about 200 m. under sea-level, and at Petrograd at 180—190 m. If the present level of the sea be regarded as the datum line, therefore, the coastal line of the Kalmar plain would be the boundary between the positive and the negative moving.

As has been previously mentioned, the marginal zone between the Småland plateau and the Västgöta plain differs from the other marginal zones owing to the valleys which break through the high district of Ulricehamn. The first named marginal zone is sharply marked, especially in the Alingsås—Borås—Ulricehamn district, where the difference between the hilly broken and lake-filled marginal zone and the level lakeless ground of the Västgöta plain is extremely striking. The difference is so great, and the boundary so sharp, that one may suspect the presence of faults. The presence of an east-west fault system in this district is shown by the geologically demonstrated faults having that direction south of Falbygden. The uniform rock-ground round the marginal zone makes it difficult to demonstrate geologically the existence of faults. The great and sudden change in morphological formation and in orographical conditions, however, hint that changes of level have taken place here, possibly along a dislocation-zone.

When these changes took place it is difficult to determine. It may possibly be thought that the transition between the marginal zone and the plain was sharpened by the eroding away in relatively recent times of the Cambro-Silurian rock, which covered the Västgöta plain even outside the remains which still survive. In that case one might imagine that the valleys have come into existence through the erosion of watercourses that had flowed over a Cambro-Silurian plain sloping towards the south west on the level of the Alingsås—Borås—Ulricehamn uplands.

This supposition is contradicted, however, by the fact that the sub-Cambrian subsoil of the Västgöta plain slopes in the opposite direction, towards the north. Moreover, it is difficult to imagine how such a valley is to arise through the erosion of a river flowing from such an extremely easily denuded rock as the Cambro-Silurian to a rock-ground that is so extremely difficult to erode as the Archaean. The slope of the sub-Cambrian level of denudation, and the position of the Alingsås—Borås—Ulricehamn uplands in relation to the uniform Småland plateau which slopes towards the south, tells in favour of the view that changes of level along this marginal zone took place in connection with the elevation of the whole Småland plateau. The broken terrain on the border of the Västgöta plain should thus correspond to the other broken marginal zones with regard not only to morphological position but also probably to mode of origin. Nevertheless the slope down to the Västgöta plain may probably have been further steepened in recent times through the eroding away of the remains of the Cambro-Silurian series.

In any case, however, it is a difficult problem to solve definitely how these valleys came into existence. For this purpose it is of importance that the largest watercourses rise on the south side of the mountain country that is pierced through, and that that side was also as steep as the northern one towards the Västgöta plain, especially if the remains of the Cambro-Silurian rock remained there for a long time. Consequently the erosion on the southern side has probably been greater than on the northern side, and therefore the valleys there have cut their way back more quickly and captured bit by bit the watercourses running towards the north. This, of course, is a circumstance which has often been described and is one which amongst other things is well represented in Norway in the relation between the fjord valleys of the Westland and the great fluvial valleys of the Eastland. The erosion of the inland-ice, which worked from north to south, probably enlarged the gap afterwards.

Just as the broken marginal zones of the Småland plateau on their western and southern border diminish in size and steepness from Halland to Blekinge, so also does the northern zone diminish from the Ulricehamn district towards the east. Round Lake Vättern the broken terrain is caused by the local base of erosion within the fault basin of Lake Vättern.

As is shown by S. De Geer's map, and according to what is pointed out in the text thereto and according to what has been said above in this article, the north-eastern part of Småland is occupied by a broken region, although there is no transition zone to the low-lying plain outside it. The slope of the land both towards the north and towards the east is slight. The reason for the broken terrain cannot be the same, therefore, as with regard to the marginal zones previously mentioned. S. De Geer states with regard to this region, as with regard

to the broken marginal zone, that it is the presence of specially marked lines of weakness that has given rise to this broken terrain. Thus the same question remains to be answered as before: what force has actualized the lines of weakness? Ice erosion I consider to have been equally incapable of creating by itself the broken terrain within this region in NW. Småland as within the broken marginal zones. The general view is that typical faults occur only within Västgötland, Östgötland and Scania, or, in other words, in regions where younger geological formations are prominent, and where the sub-Cambrian surface of denudation is especially well marked. It is a priori peculiar that faults should only occur within those region. The fact of the matter may be that only those faults are known which have been able to be demonstrated geologically. Faults in regions with a uniform Archaean ground are difficult or impossible to demonstrate geologically; and consequently it has been considered that faults do not occur at all. Within that portion of the broken region in NE Småland that projects like a wedge towards SW (see fig. 2), three marked features stand out especially in the terrain: namely the series of escarpments, arranged in a straight line from Lake Algunnen in SW to Virserum in the east; the valley between Vetlanda and Målilla; and the valley between Brusaholm and Hultsfred. Of these the first-named series of escarpments possesses such morphological properties that there is ample reason to assume a fault. The Vetlanda—Målilla valley is so strongly marked between high steep sides and is so essentially different from other valleys up on the Småland plateau that it not only reminds one of a dislocation-depression but may really be one. The same probably holds good also of the Brusaholm—Hultsfred valley. The broken terrain around these valleys would thus be a consequence of their quality of local bases of erosion for the neighbourhood.

The broken region in the south of Östergötland has no such marked and large valleys as those recently mentioned: the whole region is, as it were, a mosaic of short valleys and irregular hollows between low heights with relatively steep sides. The difference between this area on the one side and the broken marginal zone and the above-mentioned districts on the north of Småland on the other is considerable. Nor is it to be regarded as any sort of marginal zone similar to the others, for its relation both to the areas that lie within and to those that lie without is entirely different. The presence of zones of weakness in the rock-ground in this Östgöta tract is evident, both through observations of fractures in the rock-ground and through the straight borders of the depressions. The topography is also quite analogous with that in other parts of Sweden and Norway and North America, which are considered to have arisen through long continued sub-aerial denudation, succeeded by glacial denudation which swept

away the products of weathering and "renovaded" the initial topography by intensifying slopes and precipices.

The morphological conditions and the attempts to explain them which have been brought forward in the above, lead to the following conclusions as regards certain features in the topographical development of South Sweden. The Småland plateau forms a sub-aerial surface of denudation, which in late Cretaceous times or the early Tertiary period was worn down to the immediate proximity of the general base of erosion and gradually passed into the sub-Cambrian denudation surfaces that extended round it and either lay bare or were covered with minor remains of the Cambro-Silurian series. Only in the north-west, in the Ulricehamn district, did low uplands rise. In connection with the late Cretaceous and Tertiary faults in Scania and in other places round the borders of Fennoscandia the Småland surface of denudation is elevated and passed into a low-lying plateau. The adjoining parts of the sub-Cambrian plains took part in this elevation. The centre of elevation lay in the west, and here also the changes of level were localized along the narrow zones. The elevation of the land introduced a new fluvial cycle or generation which within the marginal zones of the plateau country began to actualize the fracture zones into valleys. By this process broken marginal zones came into existence, which increased in breadth the deeper the running water cut the valleys. The greater the amount of elevation, and the more marked the zone for the actual change of level, the more distinct became the broken marginal zone. Within these zones are found the broken fall-curve sections of the South Swedish watercourses, which give rise to the waterfalls of great energy. The elevation abates towards the east, and at Kalmar Sound it is zero, if the present division between land and water is taken as the base line. Nor does any broken marginal zone occur here, but the plateau country passes without a break into the evenly sloping sub-Cambrian surface of denudation. Outside the present coast-lines are provided submarine channels, which show that these areas have partly lain above the surface of the water and have been exposed to fluvial erosion. During certain parts of Quaternary time the land had demonstrably lain higher than now; and it is probable that this was also the case in pre-glacial times.

Within the broken marginal zone lies the unbroken part of the Småland plateau where there are no marked or individual valleys and over which the watercourses make their way in irregular and capricious courses with only a slight fall, and where the flat depressions are flooded and so become shallow lakes. The internal limit of the sub-Cambrian denudation surfaces is difficult to determine morphologically, as the transition is so gradual. Whether the whole of the plateau country once belonged to the sub-Cambrian denudation surface is not a

priori obvious. Just as it is probable that in the central parts of South Norway areas once lay above the Cambro-Silurian sea, so too this may have been the case with Central Småland.

During the glacial period the area was renovated owing to the fact that the covering of loose weathered material was swept away and the unevennesses in the underlying rock were thereby brought to life; valleys and breaks in the topography running in a direction parallel to the ice movement were intensified. Nevertheless the result of the glacial erosion was small on the whole owing to the unpronounced nature of the initial topography.

There is an obvious resemblance between the conception of South Sweden that I have here propounded and that which I have previously set forth with regard to South Norway. Similar central unbroken land-blocks, surrounded by broken marginal zones, are found in both areas as the result of land elevations from early Tertiary time. The elevation of the land has also been greatest in the west. Whether the plateau surface of South Sweden forms an immediate continuation of that of South Norway, and whether there is an unbroken slope from the Jostedal region in the west (with a height of about 2,000 m.) to the Baltic in the east (with no elevation at all, but rather a depression), is uncertain owing to the complicated and not yet investigated terrain between the western border of the Kristiania area and the Göta River.

But the resemblances between South Sweden and South Norway do not justify any conclusions based on analogy between the one area and the other with regard to all morphological phenomena. Thus, for instance, the relation of the South Swedish plateau country to the surrounding sub-Cambrian denudation surfaces is different from that which prevails in Norway. In Sweden no mountain foldings have taken place, but here the sub-Cambrian underlying rock lies in about the same position as during its first stage. In Norway, on the other hand, undisturbed sub-Cambrian denudation surfaces probably remain only on the central unbroken land-block: outside the west coast they have taken part in the great Caledonian mountainfolding. The relation of the valleys to the coastal plain as well as to the inland is also quite different in Norway and in Sweden. Glacial erosion was also quite different in Norway and in Sweden, owing to the great dissimilarity of the initial topography.

#### NOTES ON THE FIGURES.

Fig. 1 forms a diminished and generalized copy of the orographical map of the Ordnance Survey Department (Scale 1: 500,000).

Fig. 2 is based on Fig. 1. The fault escarpments, the limits of broken topographic areas and the limits between Archaean and post-Archaean ground from S. De Geer's maps. Faults, not actualized in the present topography, after geological maps; the broken marginal zones laid out after fig. 1. Fig. 3 is based on the topographical maps published by the Ordnance Survey Department (Scale, 1: 100,000) and on the longitudinal profiles of watercourses drawn up by the Hydrographical Bureau.

10 *Geografiska Annaler. Uppsats 1920, häft. 2.*