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THE SCANDINAVIAN CALEDONIDES
A REVIEW

TRYGVE STRAND

Institutt for Geologi, Universitetet i Oslo, Oslo, Norway

On the occasion of the Geological Congress of 1960 arranged by the Nordic countries, descriptions of the geology of the Scandinavian Peninsula have been edited in English and have thus been made available to a wide circle of readers. The descriptions of the Caledonides, which like the other main geological units of the peninsula are divided between Norway and Sweden, have appeared separately in the parts falling within each of the two countries. Thus the present short digest of the geology of the Scandinavian Caledonides may be useful also as an introduction to the literature on the Norwegian and Swedish parts, which show some discrepancies, at least in the nomenclature.

The Caledonides form the western part of the Scandinavian Peninsula; the greater part on Norwegian territory. The eastern Caledonian margin is formed by a range of nappes overthrust upon autochthonous Cambro-Ordovician sediments, which in turn rest upon the peneplaned surface of the Precambrian rocks of the Baltic shield. Between 61° 40′ and 68° 20′ N the eastern part of the chain is on Swedish territory, a strip of land more than 800 km long and with a mean width of about 100 km. Between 68° 30′ and 69° N again a narrow marginal strip is partly on Swedish and partly on Finnish territory. There is no western border of the Scandinavian Caledonides; the rocks that disappear beneath the sea along the west and north coast belong to central parts of the orogenic belt.

Stratigraphy.—Among the sediments of the Caledonian cycle, of Eocambrian and Cambro-Silurian age, it is possible to distinguish distinct types of facies, deposited in different parts of the geosynclinal realm and characteristic of distinct parts of the tectonic succession of nappes.

The deposits of the so-called eastern facies were laid down upon the eastern foreland or in the eastern, miogeosynclinal part of the depositional troughs. Beneath the marine Cambro-Silurian deposits of this facies are the thick, mainly psammitic deposits of the Sparagmite super-group in parts of southern Norway and Sweden and the sandstone and dolomite formations in Finnmark, the northeasternmost part of Norway. Eocambrian is used in Scandinavia as a chronostratigraphical term for the deposits in question. Some geologists consider the younger part of the Eocambrian to be indeed of Lower Cambrian age, while Asklund in Sweden has coined the term Varegian for the same part of the sequence. It must be emphasized that Eocambrian deposits are found also in sequences that can not be referred to the eastern facies type, for example, the highly metamorphic psammitic rocks in the west parts of Finnmark.

The marine Cambro-Silurian deposits of the eastern facies are most fully developed in the Oslo region in Norway and in the eastern part of Jemtland (between 63° and 64° N) in Sweden, as alternating formations mainly of shale, marlstone, and limestone. To the west the amount of calcareous material decreases and there is a corresponding increase in the amount and grain size of the clastic material. Although the rocks are wholly unmetamorphic and richly fossiliferous in the east, they become low grade metamorphic to the west. Volcanic intercalations and typically also Caledonian intrusives are absent in the deposits of the eastern facies type.

A second main type of facies is represented by eugeosynclinal deposits and has been called the western facies. The eugeosynclinal deposits can indeed be referred to two distinct facies, that of the Trondheim region and the Nordland facies. The sediments of the Trondheim region have thick intercalations of basic and also of acid volcanic rocks at various stratigraphic horizons, especially in the Lower and Middle Ordovician. The stratigraphy of the deposits of this facies has been established in the northwest part of the Trondheim region in Norway (district centering about 63° N, 10° E) and in a part of Vesterbotten in Sweden (district centering about 65° N, 15° E), based in each area on a number of fossiliferous formations of Middle Ordovician to Silurian age. In these districts the metamorphism is low grade or almost absent, while in other districts the grade of metamorphism is high. In Sweden the terms Köli and Seve schists are being used for the low-grade and high-grade rocks, respectively. The sediments of the Trondheim region facies contain a multitude of intrusive bodies of varying size, peridotites-serpentinites, gabbros and trondhjemites.

The sediments of the Nordland facies, a sequence of several thousand meters, consist of a lower division mainly of pelites and an upper division with thick limestones and dolomites. Volcanic intercalations are present, but up to the present little is known of their extent and importance. Sedimentary iron oxide ores, found at a number of horizons, are further characteristic. The Nordland sediments are generally strongly metamorphosed, and fossils have never been found in them.[1] But apparently they are in a normal stratigraphic succession above the Eocambrian deposits of western Finnmark.

Great parts of the eugeosynclinal sediments are positively known to form nappes, and there is no reason to believe that any of them are in autochthonous positions. Parts of the Caledonian nappes are built, however, of crystalline rocks of Precambrian (pre-Eocambrian) or unknown age.

The Caledonide nappes.—In most districts the autochthonous Cambro-Silurian is present only as a thin sequence, forming a narrow border zone between the Archean and the overlying nappes and varying in thickness from little or nothing up to about 200 meters, only the Cambrian or, more rarely, the lower part of the Ordovician being represented. The Cambro-Ordovician sequence in the Hardangervidda district in southern Norway (about 60° N, 7° E) must be considered as autochthonous, as it lies in regular succession above the Archean basement. The same is the case with the Cambro-Silurian

[1] The Upper Ordovician or Silurian fossils recently detected in Magerøy, Finnmark, do not seem to be in sediments of the Nordland facies. They are considered to have a stratigraphic and tectonic position similar to the unmetamorphosed Cambro-Ordovician sediments of the Digermul peninsula of the Tana district (Reitan, in Holtedahl, Føyn, and Reitan, 1960, p. 57).

sequence of the Oslo region, but here as in other districts folding by *décollement* involved a gliding of the sediments above the Archean basement. In Finnmark a thick autochthonous Eocambrian sequence with fossiliferous Cambrian and lowermost Ordovician deposits at the top is found east of meridian 27° E. In the eastern part of Finnmark these rocks are practically unfolded near the border of the Archean.

Very characteristic of the eastern part of the Scandinavian Caledonides are nappes or thrust sheets, which have moved relatively eastward or southeastward on flat thrust-planes, often very close above the undisturbed peneplaned Archean basement. The nappes are, however, not composed of flat-lying rocks, as in many cases they are known to have schuppen structures.

It may be convenient to divide the nappes in two main groups. In a first group, in a lower tectonic position, are nappes composed of rocks of Eocambrian and Cambro-Silurian rocks of the eastern, miogeosynclinal sequence. In some cases rocks from the Archean substratum of the sediments form parts of the nappes. The lower nappes in the present group, occurring near the Caledonian margin, are unmetamorphosed, while rocks of the higher nappes are metamorphosed and deformed.

In a second group, in a high tectonic position, are nappes composed of sediments of the western eugeosynclinal sequences and of crystalline rocks that in some cases are known to belong to the substratum of the sediments.

Along the Caledonian margin from Hallingdal in Norway (60° 40′ N, 9° E) to Vesterbotten in Sweden (about 65.5° N) extends a range of nappes of sandstones of the uppermost part of the Sparagmite super-group (Ringsaker sandstone ("quartz sandstone") in Norway, Vemdal quartzite and Ström quartzite in Sweden). The range of the "quartzite nappes" is interrupted by the Cambro-Silurian district of Jemtland in Sweden.

In the southern part of Vesterbotten (64° 45′ N) the Blaik nappe of quartzites and sparagmites with wedges of Archean rocks is considered a western continuation of the Ström quartzite nappe. North of 67° N in Sweden, nappes of Archean rocks are in a similar position as the "quartzite nappes" further south, directly above the autochthonous sediments. The nappes are of rocks similar to those in the Archean substratum ("syenite nappe") and schuppen of the nappe have overlying Cambrian sediments of the same type as in the autochthonous sequence (the "Hyolithes zone"). In Finnmark, between 25° and 27° E, unmetamorphosed Eocambrian sandstones and dolomites form a nappe above the autochthonous sediments along the Caledonian margin: the observed length of the thrust perpendicular to the strike is nearly 30 km.

In the area surrounding the area of the Valdres sparagmite in southern Norway, Cambro-Ordovician phyllites and quartzites of the eastern facies are stratigraphically in a normal succession above the allochthonous Ringsaker sandstone and must thus be in an allochthonous position.

In Jemtland in Sweden, north of 63° N, Cambro-Silurian sediments cover large areas, the greater part of the rocks are allochthonous and form a number of nappes thrust above the autochthonous part. Especially in the Ordovician part of the sequence the upper nappes of western derivation contain

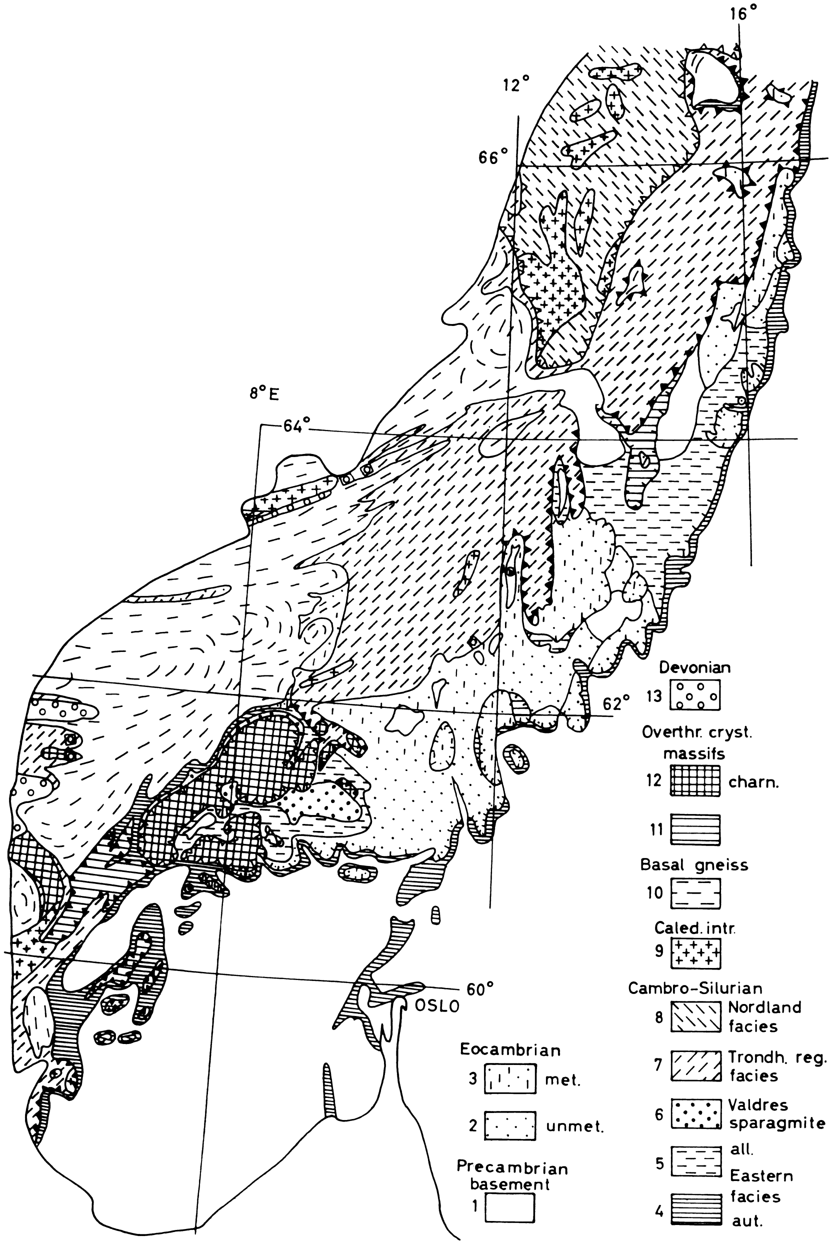
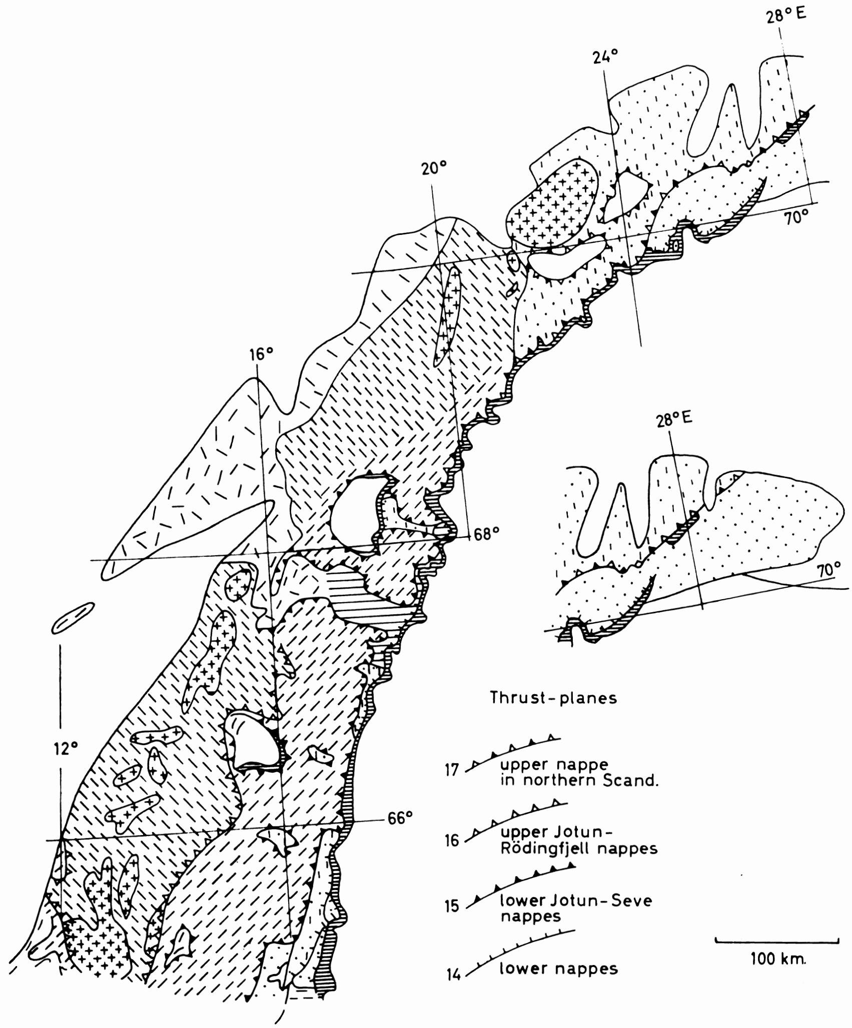


Fig. 1. Geologic-tectonic map of the Scandinavian Caledonides, somewhat schematic and simplified. See explanation on page 166.



less lime and more coarse terrigeneous material than do the autochthonous sequence and the lower nappes of eastern derivation. The Offerdal conglomerate, whose stratigraphic position is near the Ordovician-Silurian boundary, may be equivalent to the Valdres sparagmite in southern Norway. The youngest sediments present in the allochthonous sequences are of early Wenlock age.

Next above the "quartzite nappes" are a number of nappes of deformed and metamorphosed Eocambrian sparagmites, quartzites, and dolomites and of strongly mylonitized granitic rocks probably of Precambrian age. The sediments of this group of nappes are intruded by numerous dikes and sills of olivine dolerite ("Ottfjell diabase"), sometimes metamorphosed to chloritic rocks. The rather high degree of metamorphism and the intrusion by magmatic rocks give the nappes of this group a position transitional to the overlying nappes of eugeosynclinal facies. The Kvitvola nappe in the eastern part of the Norwegian Sparagmite district near the international border (about 62° N., 11 to 12° E) is built mainly by light-colored feldspathic sandstones (called "light sparagmites" in Norway). "Light sparagmites" of similar types have a wide distribution in the northern part of the Sparagmite district of Norway, sometimes metamorphosed into augen-gneisses. Most of these rocks are certainly allochthonous, but it is doubtful whether they all form one tectonic unit together with the Kvitvola nappe. The tectonics of the Sparagmite district presents many unsolved problems.

The Kvitvola nappe continues into Sweden under the name of the Serv nappe and forms a flat-lying sheet about 100 km long in north-south direction south of the 63rd° parallel. The same nappe occurs also further north between 65° and 66.5° N. Beneath the Serv nappe in the southern districts are augen-gneisses, coarse-grained granitic rocks with feldspar augen. Granitic rocks, for the most part strongly mylonitized, build the Offerdal nappe (or "granite mylonite nappe") extending for 150 km to the north-northeast. In the southern parts of Jemtland it rests on allochthonous Cambro-Silurian rocks and carries

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Explanation of Figure 1

1. Precambrian basement, Precambrian rocks not affected by Caledonian movements, or at least without any radical change in mineral composition and structure.

2—3. Eocambrian: the Sparagmite super-group and the sandstone-dolomite formations in Finnmark.

2. Unmetamorphosed rocks: the "quartzite nappes" and parautochthonous rocks in the southern and middle districts; the sandstone and dolomite formations of Finnmark (the northeasternmost part of Norway), allochthonous in the west, autochthonous in the east.

3. Metamorphic rocks, all or most of them allochthonous: the Kvitvola-Serv nappes, the Stalon nappe, and the main nappe in western parts of Finnmark.

4—8. Cambro-Silurian.

4. Eastern facies, autochthonous.

5. Eastern facies, allochthonous.

6. Valdres sparagmite, in central southern Norway.

7. Eugeosynclinal Trondheim region facies, probably all the sediments allochthonous, in the lower Jotun nappe in southern Norway and the Seve nappes in Sweden.

8. Eugeosynclinal Nordland facies, in the Rödingfjell nappe in northern Norway.

9. Caledonian intrusive rocks, comprising the gabbros, diorites, trondhjemites, and other rocks of the opdalite-trondhjemite kindred, the granites of Nordland, and also the basic massifs of Lyngen and Finnmark.

10. Basal gneiss, below Cambro-Silurian sediments in the central parts of the orogenic belt, "Caledonized" Precambrian rocks, and Caledonian migmatites.

11—12. Crystalline rocks in the nappes, of Precambrian or unknown age.

11. Schists and gneisses in the nappes of Hardangervidda, metamorphosed supracrustals (with intrusives) in the Bergsdalen nappes, augen-gneisses, and granite mylonites in the Offerdal nappe, "syenite nappe" in northern districts.

12. Charnockitic rocks of the Bergen-Jotun kindred in the lower and upper Jotun nappes in southern Norway.

13. Old Red Sandstone deposits of Lower and Middle Devonian age.

14. Thrust-planes of the nappes of the lower structural unit—sediments of miogeosynclinal facies.

15. Thrust-planes of the lower Jotun and Seve nappes, lower part of upper structural unit—sediments of eugeosynclinal facies.

16. Thrust-planes of the upper Jotun and Rödingfjell nappes, upper part of upper structural unit—sediments of eugeosynclinal facies.

17. Thrust-plane of upper nappe (upper structural unit) in the northern parts of Scandinavia.

an outlier of the Serv nappe on its back. The Stalon nappe, extending between 64° 40′ and 66° N in Vesterbotten, consists of metamorphosed sparagmites and has a position analogous to the Serv nappe.

Turning now to the upper Caledonian nappes with sediments of a eugeosynclinal facies, we shall first consider the conditions in central southern Norway. A sheet of charnockitic rocks, known as the upper Jotun nappe, here extends 180 km in direction northeast-southwest (the strike direction) and 85 km northwest-southeast (including a gap due to erosion), resting upon underlying sediments. Northeast of this huge nappe, at about 61° 50′ N, 9° E, smaller massifs of the same general type of charnockitic rocks are normally overlain by a sedimentary sequence of the Trondheim region facies. The said charnockitic massifs with their sedimentary cover form a nappe thrust above Cambro-Ordovician phyllites and quartzites of the eastern facies, in parts of the area upon underlying Eocambrian sparagmites. This nappe unit is known as the lower Jotun nappe. The Valdres sparagmite in the central part of southern Norway is a formation chiefly of arkoses (sparagmites) rich in microcline, but including quartzite conglomerates, with an upper division of meta-graywackes rich in albite, epidote, chlorite, and amphibole, indicating a derivation from gabbroid rocks. It can be shown that the Valdres sparagmite contains material from the overthrust charnockitic massifs, from the common occurrence among its feldspar grains of perthites characteristic of these rocks, in some cases even from boulders in its conglomerates. An early Silurian sandstone in the northern part of the Oslo region contains grains of perthites of the same types as those found in the Valdres sparagmite. There is no known source of the perthites in question other than the charnockitic rocks in the overthrust massifs in central southern Norway, which must thus have been moved to their present geological surroundings before the beginning of Silurian time.

The position of the Valdres sparagmite is above the lower Jotun nappe and below the upper Jotun nappe, as has been found everywhere that the three units are found in one and the same section (fig. 2). Thus the *mise-en-place* of the lower Jotun nappe must have been in a Taconic phase before the deposition of the Valdres sparagmite. Judging from fossils found in a number of places, none of the marine sediments below the Valdres sparagmite (and below the nappes) should be younger than early Middle Ordovician. The rocks of the lower Jotun nappe must be assumed to have undergone erosion before and during the deposition of the Valdres sparagmite, and only comparative small remnants of the original nappe are now present. In a later phase the upper Jotun nappe was overthrust above the Valdres sparagmite.

In the Hardangervidda-Rogaland district (about 59.5° N, 7° E) a sheet of gneisses and crystalline schists, greatly dismembered by erosion, forms a nappe above autochthonous Cambro-Ordovician phyllites. In the southwest part of the same district, at the Boknfjord near Stavanger, sediments of the Trondheim region facies and igneous rocks intruded into them are in a similar tectonic position above the phyllites and are probably a part of the same nappe as the gneisses and schists in the areas to the northeast. The sediments of the Boknfjord thus have the same facies as the sediments of the lower Jotun nappe and may be a part of the same tectonic unit.

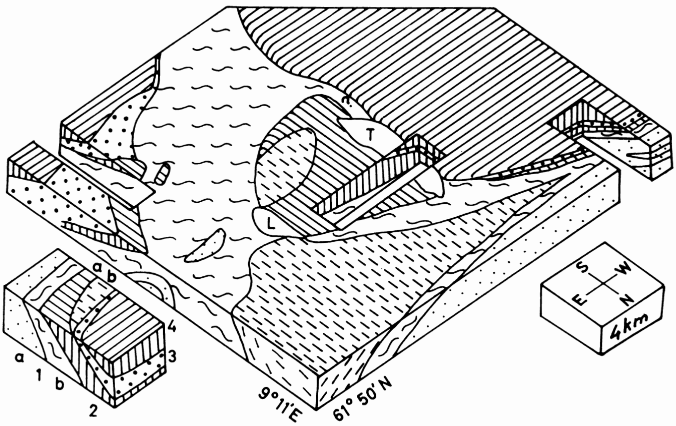

Fig. 2. Tectonogram of a district south of the Otta valley in central southern Norway, to show the relations between the Valdres sparagmite and the lower and upper Jotun nappes. L—Lake Lemonsjøen, T—Lake Tesse.

1a,b. Eocambrian sparagmites and Cambro-Ordovician phyllites and quartzites—sediments of eastern facies below the great nappes.

2a,b. Crystalline basement rocks and sediments of the Trondheim region facies of the lower Jotun nappe.

3. Valdres sparagmite, represented by meta-graywackes rich in albite, epidote, and chlorite, containing boulders of trondhjemites and other rocks—the "Gabbro conglomerate".

4. Charnockitic rocks of the upper Jotun nappe.

To the southwest of the continuous massif of the upper Jotun nappe and east of the city of Bergen are the Bergsdalen nappes, consisting in all of four sheets of quartzites and volcanic rocks, metabasalts, metadacites, and metarhyolites of assumed Precambrian age—with intruded diorites and granites. The Bergsdalen nappes are below the upper Jotun nappe and must thus have been thrust earlier than that large nappe. Further, according to sections recently published by Kvale (1960), the rocks of the Bergsdalen nappes are overlain by sediments and volcanics of the Trondheim region facies occurring southwest of the Bergsdalen rocks at the Hardangerfjord. Might it be that the sediments and volcanics in question form one tectonic unit together with the Bergsdalen nappe? In any case the sediments of the eastern and of the Trondheim region facies occur very near to each other at the Hardangerfjord, and it is a reasonable assumption that the areas of deposition of the two very different facies of sediments were farther apart. It thus seems possible to correlate the Bergsdalen nappes with the lower Jotun nappe.

In the midst of the Bergen arcs (at the west coast between 60° and 61° N) is a massif of charnockitic rocks, underlain at both sides by sediments of the Trondheim region facies. The charnockitic Bergen massif is most probably to be correlated with the upper Jotun nappe, but it is greatly influenced by the movements that led to the formation of the Bergen arc structures. Sediments of the Trondheim region facies are also found below the Devonian deposits north of Bergen.

In southern Norway between 62° and 64° N is the large area of axial depression of the Trondheim region with Cambro-Silurian sediments of the facies typified in that area. Little is known at present of the tectonics of the Trondheim region, and future research may well show that more than one tectonic unit is present in that large area. In the southwestern part of the region, the sediments are in direct connection with the sediments of the lower Jotun nappe in the northern part of Gudbrandsdalen, while at the eastern side they are in connection with the rocks forming the Seve nappe in Sweden. There is thus no reason to consider the sediments of the Trondheim region to be in an autochthonous or parautochthonous position.

To continue our review of the eugeosynclinal nappes we have to turn to Jemtland in the southern part of the Swedish Caledonides, a classical area of nappe tectonics. It was here that A. E. Törnebohm in the 1880's found the clue to the understanding of Caledonian tectonics and to the solution of the "mountain problem" of the Scandinavian geologists. In the Jemtland region we have already described the "quartzite nappe" of late Eocambrian sandstones, the nappes of Cambro-Silurian sediments of eastern facies, the granite mylonite nappe, and the Serv nappe of metamorphosed light sparagmites. At the top of this tectonic sequence is the large Seve nappe. The eastern and lower part of this large unit consists of the Seve schists: highly metamorphosed and even migmatized schists and gneisses and intrusive rocks, including large masses of amphibolites (in some regions, therefore, the nappe has been called the "amphibolite nappe"). The upper part of the nappe is of less highly metamorphosed sediments, the Köli schists. The difference between the Seve and Köli rocks is considered to be mainly one of different metamorphic grade, though Asklund considers that basement rocks of the Köli sediments may be contained in the Seve. As already mentioned, the sediments of the Seve nappe in Jemtland are in connection with the sediments in the Trondheim region at the Norwegian side. Further north in Vesterbotten (about 65.5° N) the stratigraphy of the Seve nappe sediments is established by a number of fossiliferous formations of Upper Ordovician and Silurian age. The Seve nappe has been recognized as far north as Lake Tornetresk (69° N), where the Caledonian margin cuts the national border just north of the lake. In the Swedish Sulitelma district (67° N), the Seve nappe has been shown to consist of three thrust sheets and thus to be a composite tectonic unit.

As indicated on the legend of the map (fig. 1), the Seve nappe has been correlated with the lower Jotun nappe in southern Norway. This may be justified as far as both have a similar position in the tectonic sequence and contain sediments of the same general facies. While there are good indications, at least, that the lower Jotun nappe was moved to its present tectonic position in a Taconic phase, this cannot have been the case with the Seve nappe. The latter in Jemtland has been thrust above fossiliferous Silurian rocks and also contains Silurian sediments. Although it is possible that nappe structures were formed in the Seve nappe in a Taconic phase, as claimed by G. Kautsky, the final *mise-en-place* of the nappe cannot be earlier than late Silurian.

The Rödingfjell nappe is a name given to a nappe of highly metamorphic rocks above the Seve nappe. The nappe was first recognized on Swedish ground, but the main part of the nappe is in Norway; it is built by highly metamorphic sediments of the Nordland facies with numerous granite massifs.

On Norwegian ground the thrust-plane below the Rödingfjell nappe has been mapped as far north as 66° 20′. In the south the outcrop of the thrust-plane of the Rödingfjell nappe bends to the west at 64° 20′ N and continues to the northwest towards Foldenfjord. Northwest of that fjord, at 65° N, 12° E, the massif of the Bindal granite, heavily mylonitized in its lower part, stands up as a wall above underlying micaceous gneisses and meta-basalts; further to the north the thrust-plane disappears below the sea. This interpretation implies a minimum of about 100 km for the length of transport of the Rödingfjell nappe. The Rödingfjell nappe can be correlated with the upper Jotun nappe in southern Norway in so far as both form an uppermost tectonic unit. North of the Sulitelma district (67° N) a boundary between the Rödingfjell and the underlying Seve nappes has not been determined. Sediments of the Nordland facies, typical of the Rödingfjell nappe, are known to occur in the district just south of Tromsø (at 69.5° N).

In the most northeastern part of the Caledonides large masses, mostly of highly metamorphic rocks, lie overthrust above the autochthonous Cambrian to the southeast and above the unmetamorphosed Finnmark sandsone and dolomites to the east. Future research may show the presence of more than one tectonic unit among the thrust rocks in this large area, only small parts of which have been closely examined until now. East of the 22nd meridian the overthrust rocks consist mostly of metamorphic psammitic rocks containing also tillites and certainly of Eocambrian age. To all appearance they are normally below the mainly pelitic rocks to the west of them, of assumed Cambro-Silurian age. In the northwest parts the psammitic rocks are highly metamorphosed and granitized, parts of the complex consisting of coarse-grained gneisses. In this part of the Caledonides are the large massifs of gabbroid rocks with banded structures in Lyngen and in Vest-Finnmark.

Basal gneisses and basal massifs.—At the southeast margin of the Caledonides there is a very sharply marked unconformity between the Precambrian basement and the overlying Eocambrian and younger sediments. Likewise at the northwestern side of the areas occupied by Cambro-Silurian sediments in southern Norway gneisses underlie the sediments, but here with a perfect conformity. In some districts it is even difficult to find any distinct boundary between the gneisses and the overlying sediments. So far it might be possible to interpret the so-called basal gneisses as Precambrian rocks that had acquired new structures during the Caledonian orogeny. But in some areas sediments of the Caledonian cycle pass into underlying gneiss by an increasing feldspathization of the sediments. Bands of quartzite often accompanied by limestone and lime silicate rock strike through parts of the gneiss area. In one case a quartzite extending at least 50 km out into the gneiss area has been shown to be in connection with an Eocambrian quartzite occurring at the border of the gneiss with the overlying sediments. Further, peridotites occurring as numerous bodies in parts of the gneiss region can in no way be distinguished from the peridotites in the Trondheim region sediments. Thus parts of the gneisses must be migmatites of Caledonian origin. In the Oppdal district west of the Trondheim region basal gneiss and overlying Eocambrian flagstones and Cambro-Ordovician "Trondheim schists" form large folds, sometimes approaching the Pennine type of tectonics. This type of tectonics is reported also in the districts to the west of the Oppdal district.

In northern Norway a basal massif of coarse-grained granite appears beneath the sediments in the Tysfjord culmination (68° N, 16° E). The Tysfjord granite is similar to Archean granites occurring 20 km to the east in the Rombak window; on the other hand bands of granitic gneiss closely similar to the Tysfjord granite occur in the sediments above the granite basement. The most likely interpretation seems to be that the Archean Tysfjord granite was "rejuvenated" during the Caledonian orogeny. A complex of banded gneisses in the Vesterålen-Lofoten archipelago, west of the Tysfjord culmination, contains inclusions of micaschists, limestones, and sedimentary iron ores. To the west the metamorphic grade increases and reaches the granulite (charnockite) facies, and the said gneisses thus pass into the coarse-grained highly crystalline rocks that give the wild rugged topography to the western Vesterålen and Lofoten islands.

Age of deformation.—Lower and Middle Devonian sandstones and conglomerates of Old Red Sandstone facies occur in southern Norway in two districts at the west coast and in a very small area near the national border at 62.5° N. They lie with profound unconformity above the strongly folded and metamorphosed Cambro-Silurian rocks. In the island of Hitra the age of the unconformity is fixed by the occurrence of *Dictyocaris*, indicating a Ludlowian or Downtonian (uppermost Silurian) age, in the basal part of the sequence above a Caledonian diorite. Thus the main Caledonian orogeny in the central parts of the mountain chain was ended before the beginning of Devonian time. In the Oslo region, a marginal part of the orogenic belt, the folding took place later, as the continental Ringerike sandstone of Ludlowian-Downtonian age is here conformable with the underlying marine sequence, and the folding must be early Devonian or later. A correlation of the phases thus indicated with the Ardennian and Erian phases established in other regions is near at hand. A Taconian phase is strongly indicated in southern Norway. Conglomerates in the Trondheim region sequence indicate disturbances with uplift and erosion between the lower and middle and between the middle and upper part of the Ordovician and between the Ordovician and the Silurian. More than one phase of folding has been proved by painstaking structural studies carried out in a few areas. It is also known that the thrust-planes of the large nappes have been affected by later movements. The movements leading to the formation of the Bergen arc structures (at the west coast of southern Norway) were later than the formation of the nappes but older than the deposition of the Devonian sandstones. Furthermore, the Devonian sediments along the west coast were subjected to rather intense folding and thrusting after deposition. A problem presenting itself is the degree to which the post-Middle Devonian earth movements manifested themselves outside the areas with Devonian sediments. They seem to be restricted to western districts, as the Devonian sediments in the eastern area at Røragen have been tilted but not folded, the tilting being ascribed to faulting, probably of Permian age.

The picture that can be given of the Scandinavian Caledonides is an incomplete one, as the western part of it and its western foreland is now beneath the sea. Marginal faults along the Norwegian coast have been assumed by O. Holtedahl on the basis of study of submarine topography.

The Scandinavian Caledonides have all the attributes of a fully developed orogenic belt: strong volcanism occurred in the geosynclinal phase, large sheets of sediments and even of the underlying basement were cut out and moved as nappes for distances of 200 km or perhaps even more, and plutonic processes led to magmatism and strong metamorphism and migmatization. Probably no other part of the world shows a stronger manifestation of Caledonian orogeny. Perhaps as a consequence of this, the later history of Scandinavia is mainly one of vertical uplift and fracturing (exception being made for some marginal districts). This is in contrast to the Caledonian regions in the British Isles and in Spitzbergen, which show a rich history of late Paleozoic and younger subsidence and sedimentation.

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