On the tectonic relations of the Devonian complex of the Röragen area, East Central Norway.

By

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Abstract.

In 1961, by chance, the author observed folded strata within the Devonian complex at Röragen. As the complex was earlier believed to be faulted only, the author revisited the area in 1962. In the present paper the field relations are described shortly, and the author concludes that the complex has been emplaced by folding and (in part) by thrusting. The orogeny which affected the Devonian strata belonged probably to a late phase of the Caledonides, described and termed the Svalbardian phase by Th. Vogt (1928). The present conclusions are not in accordance with the general earlier concepts (V. M. Goldschmidt, 1913).

Previous work.

The conglomerates of the small Devonian area surrounding Lake Röragen, east of Röros (fig. 1), were noticed early by Norwegian geologists due to their exotic appearance compared with the metamorphic rocks of the surroundings.

V. M. Goldschmidt investigated and mapped the area in 1913, an outstanding work at that time. He discovered an abundance of plant fossils in shale beds in the lower part of the group. A. G. Nathorst, who examined Goldschmidt's collection, found that the fossils probably belonged to Middle Devonian (Goldschmidt, 1913).

In 1914 T. G. Halle spent two weeks at Röragen, collecting more fossils. In his profound paper (Halle, 1916) the material from Röragen was compared with the Devonian flora generally known at that time, and he came to the conclusion that the Röragen flora must be regarded as belonging to Lower Devonian.

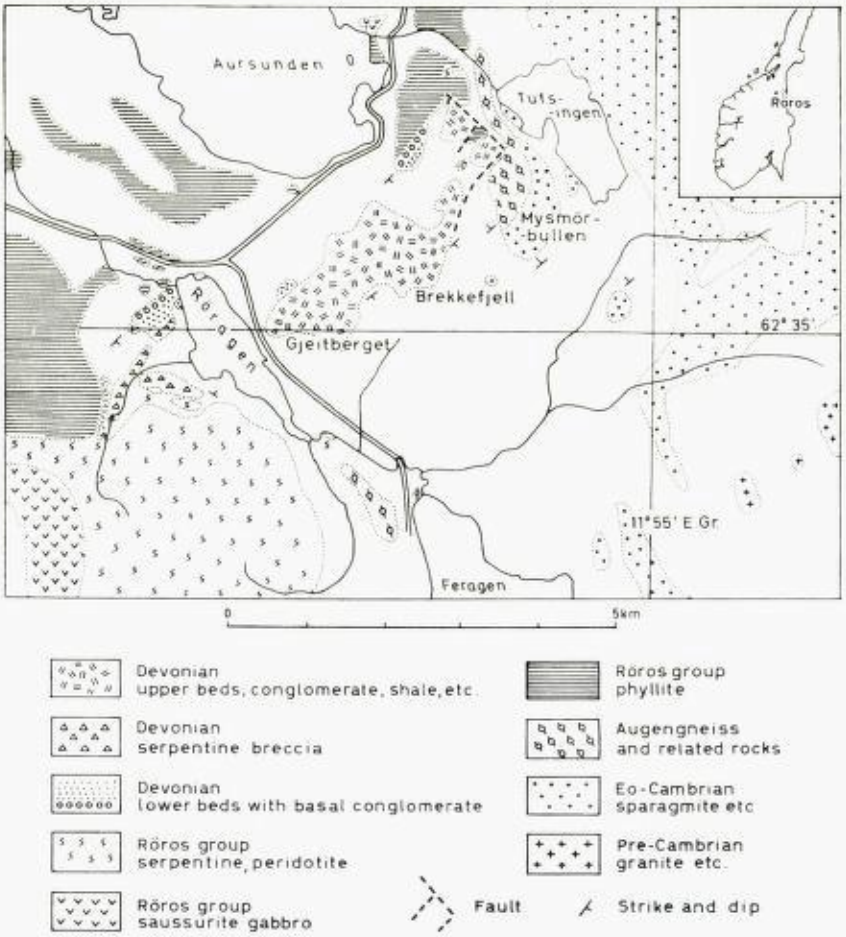


Fig. 1. Sketch map of the Devonian area of Röragen and its surroundings. Simplified copy of Goldschmidt's map of 1913.

Kartskisse over Röragens devonske kompleks med omgivelser. Forenklet kopi av Goldschmidts kart av 1913.

The area has been visited later by O. A. Höeg (1936), and by O. Holtedahl (1953, 1960).

The Devonian strata, occupying an area of approximately six kilometers by two, dip generally 45–50° SE, in part considerably steeper. In order to explain the tectonic emplacement of the complex, Goldschmidt discussed two alternatives, namely by folding and by faulting. Goldschmidt dis-

counted the existence of any folds in the Devonian strata, and, consequently, he concluded that they were dislocated by faulting. On his map two sets of faults were constructed along the eastern margin. In his opinion the area was tilted towards these faults, more or less like a rigid body.

With one exception this hypothesis has remained uncontradicted until recently. In the oral discussion following a lecture at a meeting in Oslo about seven years ago, Chr. Oftedahl mentioned having observed shear planes in the Röragen Devonian, and he considered the rocks to be partly affected by the Caledonian orogeny during a late phase (the "Svalbardian phase").

Recent investigations.

By chance the present author walked across the area one day in 1961 and happened to notice folded beds, apparently within the Devonian complex. In 1962 the author spent a day there in order to look more closely into the matter. It appeared that, in the area between the Brekkefjell and the Mysmörbullen hillocks, the Devonian strata are folded. It appeared also that the little corner, interpreted as Röros-phyllite by Goldschmidt and situated between two faults as a horst along the eastern margin of the Devonian on his map of 1913, actually consists of Devonian strata of alternating shale and phyllite conglomerate. The fragments are not easily discerned, but give the rock a lustrous, phyllite-like appearance, a circumstance that may have caused the mistake.

Upon closer examination the contact between Devonian beds and their phyllite basement was found at the northern end of the area. At the very contact there is a local mylonite, dipping 40° SE, nearly conformable with the strata below. Along the northwestern margin the contact is visible in the depression north of Brekkefjell. Goldschmidt's observation here is certainly correct. The basal conglomerate of the Devonian rests normally with an angle of unconformity upon folded phyllite of the Röros group (Cambro–Silurian). A little north of this place the contact is exposed but for a narrow gap. The Devonian strata are nearly vertical and seemingly conformable with the phyllite below.

Along the southeastern margin the contact is covered by drift. The narrowest gap between outcrops of Devonian and its substratum is approximately 15 metres, seen north of Mysmörbullen.[1] Benches of

[1] See appendix.

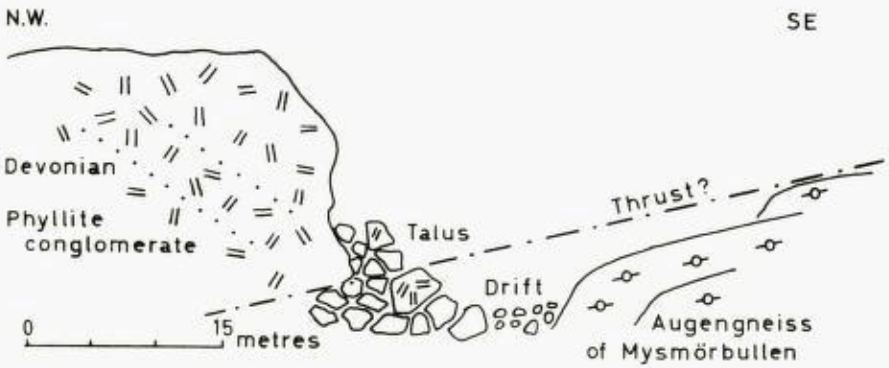


Fig. 2. Cross section of the southeastern margin of the Devonian area, north of Mysmörbullen.
Skjematisk profil av Devon-områdets grense i sydøst, nord for Mysmørbullen.

augengneiss, without any sign of brecciation, are dipping gently NW towards the foot of a steep hillock of Devonian phyllite-conglomerate. The contact is covered by a talus of tumbled conglomerate blocks. If a fault were present in the covered gap, one should expect traces of a fault breccia, either in the adjacent rock sides or in the boulders. No indication of a fault could be seen, however, and one would rather suggest a thrust contact, not a fault (Fig. 2).[1]

In the course of reconnaissance it became obvious that Goldschmidt's observations, however excellent, were inadequate in part, and his conclusion as to the tectonic emplacement of the Devonian by vertical faulting ought to be revised.

A few samples were taken for microscopic examination, in particular from the lustrous, folded shale beds north of Brekkefjell.

The present investigations can be summarized as follows:

1). Between Brekkefjell and Mysmörbullen the Devonian beds are folded (Fig. 3). This observation is contrary to Goldschmidt's statement. Amplitudes of folds are of a size between one meter and one decimeter. The orientation of fold axes varies considerably, and does not at all coincide with structural elements in the basement rocks. Common orientations are: plunge variable towards SE, and plunge c. 25° SSW. However, there seems to be no simple system of fold axes.

2). The little area, indicated as Röros-phyllite on Goldschmidt's map and

[1] See appendix.

Fig. 3. Folded shale bed in upper conglomerate on northeastern slope of Brekkefjell. Structure reminiscent of drag folds. View towards SW.

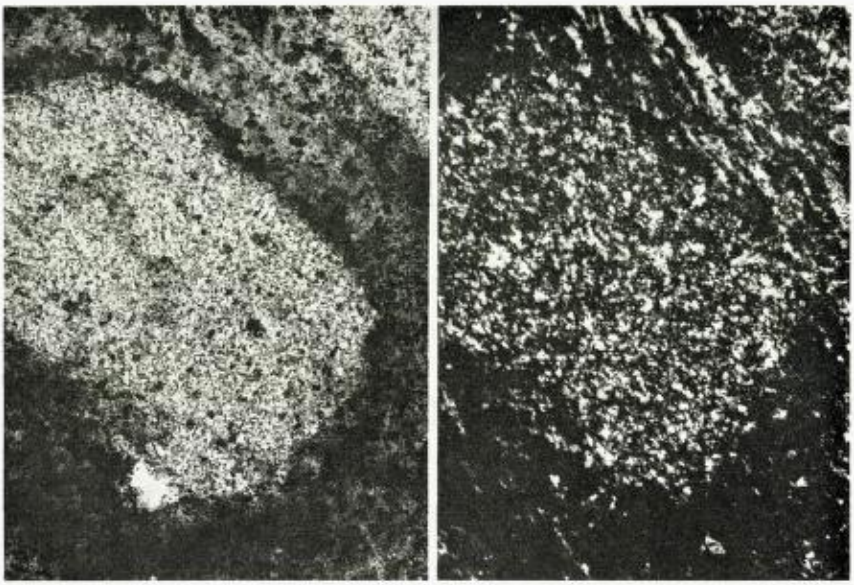
Foldet skiferlag i det øvre konglomerat i nordskråningen av Brekkefjell. Strukturen minner om drag-folder. Sett mot SW.

limited by two faults, consists of Devonian beds, in contrast to his interpretation. The northern fault certainly does not exist, and the southern one, along the contact with augengneiss, is more likely a thrust dipping gently NW. See point 5 below.

3). At the northern point of the Devonian area a local mylonite forms the contact with the phyllite. The orientation of the thin mylonite is remarkable as it is dipping 40° SE. Goldschmidt denied any tectonical disturbance along the primary contact.

4). Along the northwestern margin the contact is normal with a distinct angular unconformity, visible in one place. In another place the basal beds of the Devonian are steeply inclined. This is principally in accordance with Goldschmidt's view.

5). The contact all along the southeastern margin is obscured by drift, but in one place there is a narrow gap. Goldschmidt postulated a vertical



a *b*

Fig. 4. Thin section of Devonian phyllonite at northeastern foot of Brekkefjell. Fragment of phyllite with recrystallized outline. New minerals are: sericite, chlorite and quartz. 50×. a. Ordinary light. b. Polarization filters crossed.

Tynnslip av devonsk fyllonitt i nordøstskråningen av Brekkefjell, nederst. Bruddstykke av opprinnelig fyllitt, med omkrystallisert korngrense. Nydannete mineraler er: sericitt, kloritt, kvarts. 50×. a. Vanlig lys. b. Kryssete polarisasjonsfiltre.

fault there. More likely there is a thrust between the Devonian phyllite conglomerate and the augengneiss (Fig. 2).[1]

6). The lustrous, folded "shale" beds on the northeastern slope of Brekkefjell were examined in thin sections. A distinct recrystallization is visible with the formation of quartz, sericite and chlorite (Fig. 4). The flaky minerals give the rock type in question a phyllite-like appearance, and is, in fact, a phyllonite. In a small crag between Brekkefjell and Mysmörbullen folded beds of quartzite occur (Fig. 5). Thickness of quartzite beds are 5–10 centimeters, the interbedded phyllitic layers are a few millimeters thick only. The rock type is not mentioned by Goldschmidt.

In the author's opinion the recrystallization effects indicate a low-

[1] See appendix.

Fig. 5. Steeply inclined, thin-bedded quartzite in crag northeast of Brekkefjell. Vertical wall facing NE. Local shear plane above hammer.
Complicated set of fold axes on southeastern slope of crag (outside photo).

Steilt stående lag av tynnbenket kvartsitt i en fjellknatt nordøst for Brekkefjell. Steil vegg som vender mot NE. Lokalt skjærplan like over hammeren. Komplisert system av foldningsakser i fjellknattens sydøstskråning (utenfor fotografiet).

grade metamorphism, even though it has been proved in sections from folded beds only. However, a systematic microscopic study might possibly reveal similar effects in unfolded beds, indicating a general metamorphism of a very low grade.

7). The major upper part of the Devonian is built up by conglomerates. In Gjeitberget and Brekkefjell the common rock is a "schieferbreccie", i.e. a conglomerate with angular boulders of schistose or slaty rock types. According to Goldschmidt, Röros-phyllite constitutes the majority of the boulders. This is a very simplified account, because the fragments in question are of types different from the phyllite of the surrounding area. Various quartzitic, low-grade schistose rocks of reddish and greenish colours dominate, especially chert-like types, that do not originate from any of the known formations in this part of Norway. Most probably the

fragments derive from formations, later removed by erosion, which once made up the upper structural units of the Caledonides. In certain beds occur abundant quartzitic and sparagmitic boulders which are very similar to the Eo-Cambrian rocks of the basement complex south and east of Röragen. This is in accordance with Goldschmidt's statement, as well as the occurrence of a local serpentine conglomerate, or breccia, in the southern part of the Devonian area. A local, steeply inclined fault separates the breccia from the serpentine body (within the Röros phyllite) from which the fragments derived. The true phyllite conglomerates mentioned above, however, dominated by Röros phyllite fragments, are rather exceptions in the field.

Concluding remarks.

In disagreement with Goldschmidt's simple conception of vertical faulting, the present author considers the tectonic emplacement of the Devonian complex of the Röragen area to be far more complicated, and that the problem should be investigated in connection with a regional study of the various Devonian complexes in Norway. However, a few suggestions concerning the Röragen area may throw some light upon the question of the tectonic structure in relation to the Caledonides in general:

a). In accordance with Goldschmidt the Devonian sediments, representing denudation products of the Caledonides ("molasse"), were brought into a subsiding depression during a late phase of Caledonian orogeny. It seems reasonable to agree with Goldschmidt and Holtedahl that the stratigraphy and character of the Devonian indicate that the sediments were deposited in a subsiding basin. Holtedahl (1960, p. 295) emphasizes that "crustal movements must have taken place during the period of deposition", and concludes that "a relative uplift of the adjacent pre-Devonian grounds" resulted in the successive erosion of ever deeper strata. Hence the variable petrographic composition of the boulders.

The crustal movements causally connected with the development of the basin may have been rather complex, and faulting was probably an important factor. Seen in a wide perspective however, the movements most reasonably were related to Caledonian orogeny during a late phase.

b). After the consolidation of the sediments, the Devonian complex was in part folded and tilted, and probably thrusted for some distance,[1] by

[1] See appendix.

forces acting transversally, not by simple faulting. Most probably the phyllite substratum along the northwestern margin was affected at the same time and partly folded (anew) with the Devonian. One has to remember that the primary contact in that part of the area is undisturbed. At the northern end there is a local thrust at the contact. To make it more complicated, at the southern margin there seems to be a steeply inclined fault contact between the serpentine and the serpentine breccia.

The structural elements induced upon the Devonian sediments during their thrusting and folding, as for example the orientation of fold axes, are entirely different from the various tectonic structures within the more deep-seated Caledonian complexes. One is inclined to take gravitational sliding into account in order to explain the shallow effects. However, even if the transversal forces acted only upon the upper tectonic units, orogenic movements must still be the principal cause. Some of the major Caledonian structures, outside the Devonian area, probably got their present shape during this phase.

Thrusted Devonian complexes have been recorded from other parts of Norway, for instance from the Örlandet area (Th. Vogt, 1928, p. 111), and the Kvamshesten complex (see O. Holtedahl, 1960, p. 200). In that way the Devonian complex of Röragen seems to be more closely related to the other Devonian complexes of Norway than was earlier accepted. It is rather tempting to classify the latest traceable orogeny here described, within the Devonian, as *Svalbardian*, this term being used in the original sense of Th. Vogt (1928, p. 113).

Appendix.

During a joint excursion in 1963, Johs. Færden and the author found a new contact locality at the northerly eastern margin, where slightly folded Devonian beds are resting on Röros phyllite. The contact itself is moderately inclined and undulating, and scarcely affected by tectonic disturbances. Consequently, if a thrust exists, as indicated in Fig. 2, it eventually occurs below the Röros phyllite (the Röros group). As the phyllite is lacking in the locality north of Mysmörbullen, the theory may be forewarded that the denudation had reached the augengneiss level at the time of Devonian sedimentation. The assumption of a thrust does not exclude such a possibility.

Sammendrag.

Röragenfeltets devonske bergarter tiltrakk seg tidlig de norske geologers oppmerksomhet på grunn av deres avvikende utseende sammenlignet med de omgivende metamorfe bergarter. V. M. Goldschmidt undersøkte og kartla området i 1913, og oppdaget plantefossilene der. Nathorst, som undersøkte fossilene, mente å kunne henføre dem til mellem-devon (Goldschmidt, 1913), mens T. G. Halle, som foretok supplerende undersøkelser ved Røragen i 1914, mente bestemt å kunne henføre lagene til undre devon (Halle, 1916).

Goldschmidt mente å føre bevis for at devonlagene var sunket ned i nivå med omgivelsene ved vertikalforkastninger, særlig fordi lagene ikke noe sted var foldet. Den skrå lagstilling tilskrev han at feltet var sunket skrått inn mot forkastningene, som er angitt på hans kart av 1913.

Denne oppfatning har stått uimotsagt inntil nu, med en eneste undtagelse. Chr. Oftedahl nevnte for omtrent syv år siden under en diskusjon efter et foredrag i Norsk geologisk forening at han hadde iakttatt skjærplan gjennemsette devonlagene i Gjeitberget, og trakk herav den slutning at de seneste kaledonske fjellkjedebevegelser (den svalbardiske fase) hadde berørt disse lagene.

Nærmest ved et tilfelle kom nærværende forfatter til å gå en tur over devonfeltet i 1961, og la merke til foldete lag som øyensynlig tilhørte devonlagene. I 1962 kunne dette stadfestes under et nytt besøk i feltet, denne gang også med en mere omhyggelig rekognosering av grensene for devonfeltets nordlige halvdel.

Det viste seg at devonlagene langs grensen i nordvest ligger primært med en vinkeldiskordans på sitt underlag bestående av foldete fyllittlag tilhørende Røros-gruppen, slik som også Goldschmidt beskrev dem. Nordvest for Goldschmidts lokalitet står lagene nesten vertikalt. Ved nordspissen ligger devonlagene noe forskjøvet henover fyllittunderlaget, og her dannes selve kontakten av et lokalt skyveplan som faller 40° mot sydøst, en retning som ellers er ukjent i denne del av landet. Langs den sydøstre grense er kontakten hele veien dekket av løsmasser.[1] Det sted hvor bergartene er nærmest i kontakt med hverandre skiller 15 meter ur mellem blotningene. Det er her Goldschmidt har postulert en forkastning. Imidlertid er det mere sannsynlig at kontakten utgjøres av et skyveplan, og at devonlagene er skjøvet hen over øyegneis (Fig. 2). Forkastningsbreksjer eller andre tegn til vertikalforkastninger finnes ikke.

[1] Se tillegg.

De foldete devonlag forekommer særlig i nordøstskråningen av Brekkefjell, og mellem dette og Mysmørbullen. Se fig. 3. og 5. I forbindelse med foldningen har disse lag gjennemgått en svak rekrystallisasjon med nydannelse av sericitt, kloritt og kvarts. Dette gir bergarten et fyllitisk utseende, ikke bare langs lokale glidespeil, men gjennem hele bergarten, som derved er blitt omdannet til en fyllonitt (Fig. 4.).

Foldninger av denne type, og med ledsagende omkrystallisasjon, kan ikke godt tenkes å være oppstått som følge av vertikalforkastninger alene, men må skyldes transversale bevegelser, helst under en orogenese. Forholdene kan enklest forklares ved å anta at devonlagene er blitt foldet sammen med sitt fyllittunderlag (jfr. den primære kontakt og de steilt stående lag i nordvest), og at det hele er skjøvet noe inn over øyegneisunderlaget (Fig. 2).

Dette tektoniske brudd har mere enn lokal interesse fordi det viser at der har foregått skyvebevegelser også efter konsolideringen av devonlagene. Man må derfor ha lov til å regne med visse jordskorpebevegelser, knyttet til en sen fase av den kaledonske fjellkjede, som er yngre enn innsynkningen av bekkenet (bassinet) – hvor devonlagene ble sedimentert. Disse fjellkjedebevegelser må videre ha berørt de eldre komplekser utenfor devonfeltet, særlig Røros-skifrene, og det er vel mulig at visse hovedstrukturer i den kaledonske fjellkjede kan være blitt utformet på den samme tid.

De strukturelementer som denne siste fase har efterlatt seg i devonlagene, gjenfinnes imidlertid ikke i det kompetente underlag. Foldningsaksene i devonlagene har således helt andre retninger (der er intet enkelt system) enn f. eks. linjestrukturene i øyegneisen, og skjærplan med fall mot SE er helt ukjent ellers. Foldningene synes derfor ikke å ha grepet dypt ned i jordskorpen. Det faller naturlig å tenke på glidninger nedover et skråplan, såkalt «gravitational sliding». Men for at slike glidninger skal kunne oppstå, må der åpenbart ha foregått jordskorpebevegelser efter at devonlagene var konsolidert. I storformene kan disse jordskorpebevegelser derfor allikevel ha vært dyptgripende.

Efter de seneste iakttagelser synes Røragen-feltets Devon å stå de øvrige norske devonfelter nærmere i strukturell henseende enn man tidligere var klar over. Det er da fristende å klassifisere de orogene bevegelser som førte til foldning av Røragen-lagene som *svalbardiske*, dennee term brukt i samme forbindelse som opprinnelig av Th. Vogt (1928).

Tillegg.

Under et felles besøk i 1963 fant Johs. Færden og forfatteren en ny lokalitet nordligst langs østsiden hvor svakt foldete devonske lag hviler på fyllitt av Røros-gruppen. Selve kontakten er svakt bølgende, ikke særlig steil, og lite tektonisk forstyrret. Følgelig, hvis der eksisterer et skyveplan, slik som antydet på Fig. 2, må det gå under Røros-gruppens fyllit. Fordi fyllitten mangler ved lokaliteten nord for Mysmørbullen er det mulig at denudasjonen var nådd helt ned til øyegneisnivået da devonlagene ble avsatt. Antagelsen av et skyveplan utelukker ikke en slik mulighet.

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