# THE GILLBERGA SYNFORM (PRECAMBRIAN BASEMENT, SW VÄRMLAND, SWEDEN); LITERATURE SYNOPSIS AND PRELIMINARY NOTES ON ITS RE-INTERPRETATION

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The current interpretation of the geology of the Precambrian basement of SW Sweden is summarized and a short review of the available literature on a restricted part of that basement, the Gillberga synform, is given.

Preliminary results of recent investigations in the Gillberga area are presented. It is suggested that the rock complex in the area consists of a pile of 3 major thrust sheets which consist in part of rocks that may represent cataclastic equivalents of the rocks found in the basement on which the lower thrust sheet rests. Many rocks which in the present paper are interpreted as cataclastic rocks were formerly mapped as supracrustal rocks (Åmål Quartzite Formation).

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The current interpretation of the geology of the Precambrian basement of SW Sweden is based on compilations by the Swedish geologist N. H. Magnusson and his co-workers (Magnusson et al., 1958; Magnusson, 1960 a, b, 1965; Magnusson et al., 1963; Lundegårdh, 1966, 1967). This interpretation is summarized in table 1 and fig. 1. The six rock stratigraphic units distinguished cover large areas and are composed of a variety of rocks. Although detailed descriptions of rocks and rock relations are available for many restricted areas, a factual account of the rock variation within the whole body of each of the outlined units, and a discussion of why the various rock members are grouped into units as they are, are wanting. Consequently, the available regional geological map (Magnusson et al., 1958) reproduced in fig. 1 should be regarded with some reservations.

Many of the (age) relations between the rock units given in table 1 should be considered as equivocal. For example, the relation between: the Pre-Gothian Group and the Åmål-Kroppefjäll Granite Formation (see the discussion in Gorbatschev, 1971, p. 23–25, 55–59), the Stora Le–Marstrand Formation and the Gothian and Pre-Gothian Group (see the discussion

Table 1. Summary of the current geological interpretation of SW Sweden. After Magnusson et al. (1958), Magnusson (1960a, b; 1965), Magnusson et al. (1963), Lundegårdh (1966, 1967). The various units are considered as rock-stratigraphic units and therefore rock-stratigraphic terms like supergroup, group, subgroup, formation and member have been employed rather than terms like series, system and cycle which figure in the earlier papers. The established geographical denominations in the rock unit names have not been changed. All radiometric ages are after Magnusson (1960a), unless stated otherwise.

1. *Pre-Gothian Group, consisting mainly of gneisses and amphibolites. Locally gran-*itoid and gabbroid rocks, and quartzites, marble and metapelites do occur. Radiometric age determinations (total rock, K/Ar) render analytical ages of 940 to 1060 m.y. However, these ages are – like all other known K/Ar whole-rock ages in SW Sweden, on rock older than the Bohus Granite, see below – not interpreted as true age but are related to overprinting by a later tectonic-metamorphic event. In fact, Magnusson "... is convinced that the gneisses are the oldest rocks in Sweden" (Magnusson, 1965, p. 23).
2. *Gothian Group,* renders analytical ages (whole rock, K/Ar) of 1065–1130 m.y., and is subdivided into:
   a. *Åmål Quartzite Formation* – metasediments and metavolcanics – resting nonconformably upon the Pre-Gothian Group (Magnusson, 1965, p. 10);
   b. *Åmål-Kroppefjäll Granite Formation* – geisses and granitoid rocks and some amphibolites and gabbroid rocks – is considered to represent rocks that have been intruded into, and thus be younger than, the Åmål Quartzite Formation (Magnusson, 1965, p. 9).

   *The Stora Le-Marstrand Gneiss Formation* – schists, quartzites, metabasites and gneisses, with analytical ages (whole rock, K/Ar) of 1040 to 1066 m.y. – is preliminarily classified with the Gothian Group where it would be older than the Åmål Quartzite. Formation. It is considered possible, however, that it belongs to another, older group (Svecofenian), see Magnusson (1965, p. 10).
3. *Dalslandian Group,* consists of
   a. *Dal (and Kappebo) Formation* – metasediments and metavolcanics, one analytical age determination (whole rock, K/Ar), on a slate: 1025 m.y. – which overlies nonconformably the Gothian Group;
   b. *Bohus Granite (Formation),* which is supposed to be (slightly) younger than the Dal Formation, separated from it by an orogenic (-metamorphic) episode, the *Dalslandian orogeny.* It is this event that, according to Magnusson and his school, overprinted the whole-rock K/Ar ages of the older Precambrian rocks in SW-Sweden to give analytical values of approx. *1000–1100 m.y. Granitic* dykes thought to be connected with the Bohus Batholith cut the Dal Formation. Radiometric age determinations (whole-rock, K/Ar, and Pb/U on minerals from associated pegmatites) give values of 920 and 1010 m.y., respectively 1000 m.y.

Recent geochronology work has been done by O'Nions and others on rocks from the Kragerø (Bamble) area in S Norway, facing SW Sweden across the Skagerrak (see inset map in Fig. 1). In that area the Precambrian basement is in many respects similar to that found in SW Sweden, albeit that formal stratigraphic correlations have not been undertaken. Based on analytical ages on zircons and sphenes (U-Pb) and whole rocks (Rb-Sr), O'Nions & Baadsgaard (1971) concluded that the thermal maximum of the Dalslandian (synonym: Sveco-Norwegian) metamorphism in the area was reached at 1170 $\pm$ 50 m.y. ago, a slightly higher value than "1100 m.y." claimed earlier by O'Nions, Morton & Baadsgaard (1969). Analytical ages of micas and amphiboles separated from the same rocks are consistently lower (1114 $\pm$ 32 – 970 $\pm$ 30 m.y., O'Nions, Morton & Baadsgaard, 1969, p. 174–175) and are interpreted as cooling ages, due to successively later closure of the K/Ar systems.

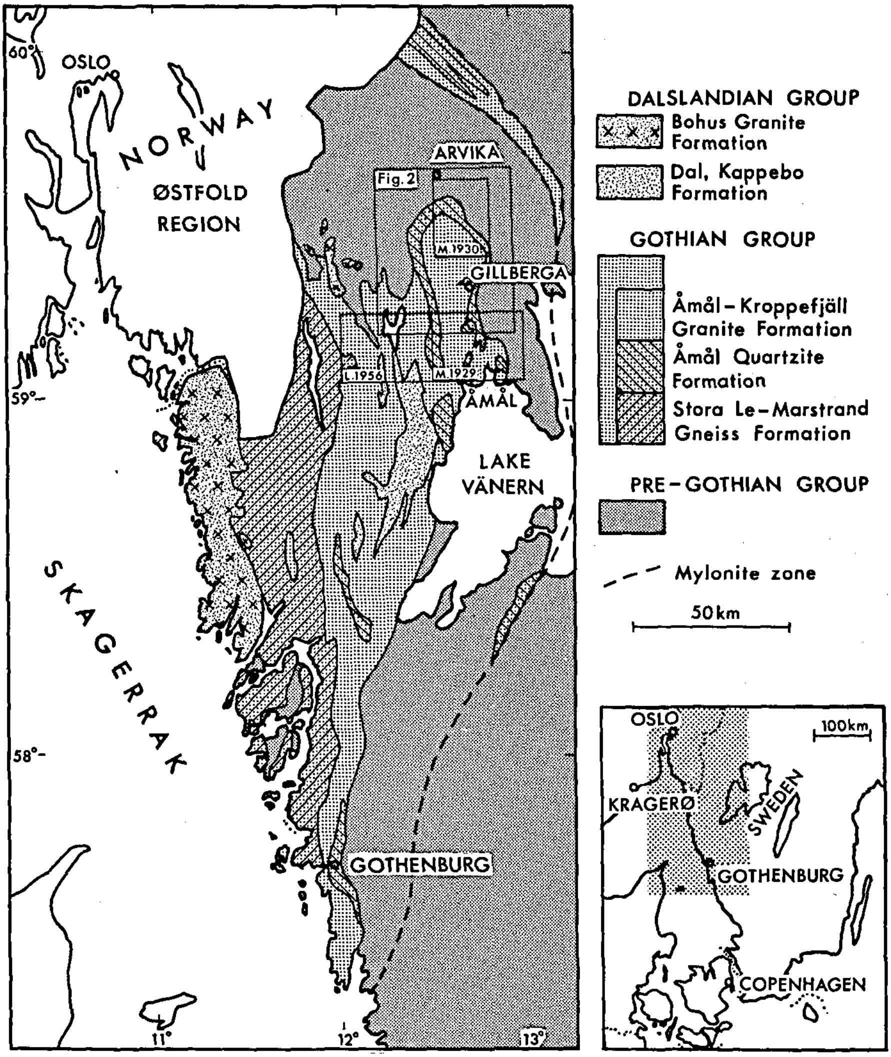


Fig. 1. Geological sketch map of SW Sweden showing the current interpretation, after Magnusson et al. (1958). The rock-stratigraphic classification used is explained in table 1. The course of the mylonite zone is according to Magnusson (1960b, fig. 1, p. 6) and Gorbatschev (1971, fig. 1, p. 5). Erratum: for fig. 2 read fig. 3.

in Gorbatschev, 1971, p. 55, 58), and the Åmål-Quartzite Formation (the Kappebo Formation) and the Åmål-Kroppefjäll Granite Formation (see the discussion in Heybroek, 1950, p. 136–138 and Gorbatschev, 1971, p. 6–21, 35–39, 57–59). The current chronological correlation of the Gothian Group with "Gothian" granitic rocks and supracrustals in SE Sweden should be regarded as dubious.

In spite of the objections that can be made to the current classification, its rock-stratigraphic basis may be used as a reference basis, in the framework of which new data are reported. No other regional classification system is available, and renewed investigations have as yet not got far enough to warrant the erection of a new classification scheme. In order to emphasize the rock stratigraphic aspect of the classification system as it is used in this paper, rock stratigraphic terms like supergroup, group, subgroup, formation and member have been employed rather than terms like system, series or cycle. This was earlier proposed by Zeck (1971, p. 308), and is in accordance with proposals by the American Commission on Stratigraphic Nomenclature (1970).

As the formations involved are rather inhomogeneous and consist of metamorphic rock complexes, to which in general formal rock-stratigraphic classification is seldom applied, it seems appropriate to use consumate formation names, comprising a geographical and a lithological name followed

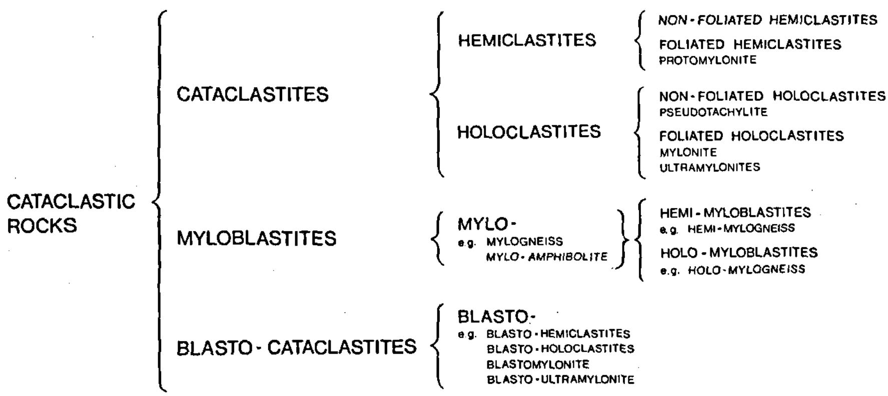


Fig. 2. (After Zeck, 1974). A schematic diagram presenting the classification and nomenclature of *cataclastic rocks:* rocks that show signs of a phase of ruptural deformation. A. three-fold subdivision is proposed: *cataclastites,* in which the cataclasis is the final major imprint, not followed or accompanied by noteworthy recrystallization; *myloblastites,* which show the effects of roughly simultaneous recrystallization and ruptural deformation; and *blasto-cataclastites,* original cataclastites which recrystallized in part in a later and separate stage. Various types of cataclastites are distinguished on the basis of the degree of cataclasis (hemiclastites ≡ incomplete cataclasis; holoclastites ≡ more complete cataclasis) and the presence or absence of a cataclastic foliation. The names of all types of myloblastites are formed by adding the prefix *mylo-* to the name of their fully crystalloblastic counterpart. The names of all types of blasto-cataclastites are formed by adding the prefix *blasto-* to the name of the corresponding cataclastite. Note that the denomination *cataclastic rock* has a general meaning free from any implication whatsoever as to the presence or relative timing and importance of effects of recrystallization in the rock; analogously: *hemiclastic rock* (cataclastic rock with incomplete cataclasis) and *holoclastic rock* (cataclastic rock with more complete cataclasis).

by Formation. For example, using "Åmål-Kroppefjäll Granite Formation" consisting mainly of gneisses, granitic rocks, amphibolites and gabbroic rocks (table 1) appears more satisfactory than simply using "Åmål-Kroppefjäll Granite". The classification and nomenclature of mechanically degraded rocks that is used in this paper follows Zeck (1974) and is outlined in fig. 2.

A restricted area of the SW Swedish basement is discussed below in greater detail. The area is outlined in fig. 1 and comprises the major part of the Gillberga synform, a well known feature in the Swedish regional geology. A synopsis of the available literature on the area is given, followed by a preliminary report on recent investigations in the same area. The fieldwork which forms the basis for these investigations is part of the mapping program staged by the Geological Survey of Sweden (SGU) in SW Sweden (progress report: Gorbatschev, 1971). The present paper puts on record a few points in which other solutions are preferred than those which form the current interpretation. A detailed account of the geology of the area will be given by S. Malling elsewhere.

## Results of previous geological investigations in the Gillberga synform

The earliest, more detailed geological investigations concerning the Gillberga synform were reported by Törnebohm, who presented a time stratigraphic map of Central Sweden (Törnebohm, 1883), the part of which that covers the Gillberga synform being reproduced in fig. 3 a. The relatively simple, open synform structure of the area was established, which was to be confirmed by all subsequent investigations. All rocks, including the granitic and gabbroic rocks, were interpreted as supracrustals formed under marine conditions; foliation where present was looked upon as a sedimentary structure. The rock pile (legend of fig. 3 a) was considered as an undisturbed stratigraphic succession decreasing in age upwards.

The 1901 edition of the 1:1,500,000 geological survey map of Sweden (Sveriges Geologiska Undersökning, 1901 a) pictures the Gillberga area somewhat differently (fig. 3 b), but the main features of the stratigraphic classification, especially its time-stratigraphic nature, were preserved. However, it

Fig. 3. Geological sketch maps of the Gillberga area, according to different sources, (a) Törnebohm (1883), (b) Sveriges Geologiska Undersökning (1901a), (c) Magnusson et al. (1958), and (d) the version preferred by the present authors. The latter interpretation is further explained by fig. 4, a tectonic map, and fig. 5, the section A-B indicated on the map (d). Due to the appreciable differences between the topographical basis of the earlier, 1883 and 1901, geological maps and modern topographical maps which are used as a mutual base for the present figures, (a) and (b) should be regarded as approximate reproductions of the original maps.

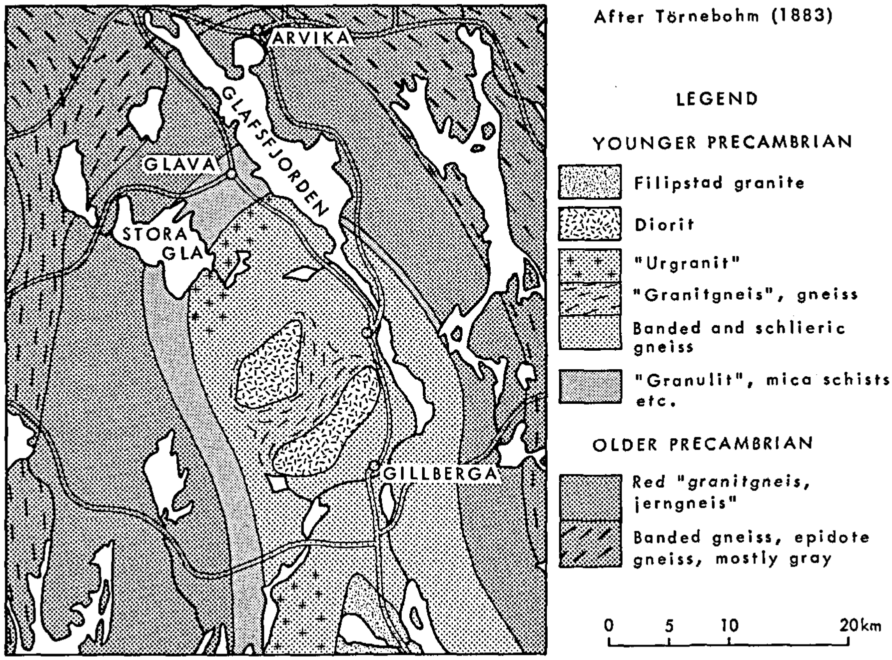
ARVIKA
GLAFSFJORDEN
GLAVA
STORA GLA
GILLBERGA
After Törnebohm (1883)
LEGEND
YOUNGER PRECAMBRIAN
Filipstad granite
Diorit
"Urgranit"
"Granitgneis", gneiss
Banded and schlieric gneiss
"Granulit", mica schists etc.
OLDER PRECAMBRIAN
Red "granitgneis, jerngneis"
Banded gneiss, epidote gneiss, mostly gray
0 5 10 20km

Fig. 3 a.

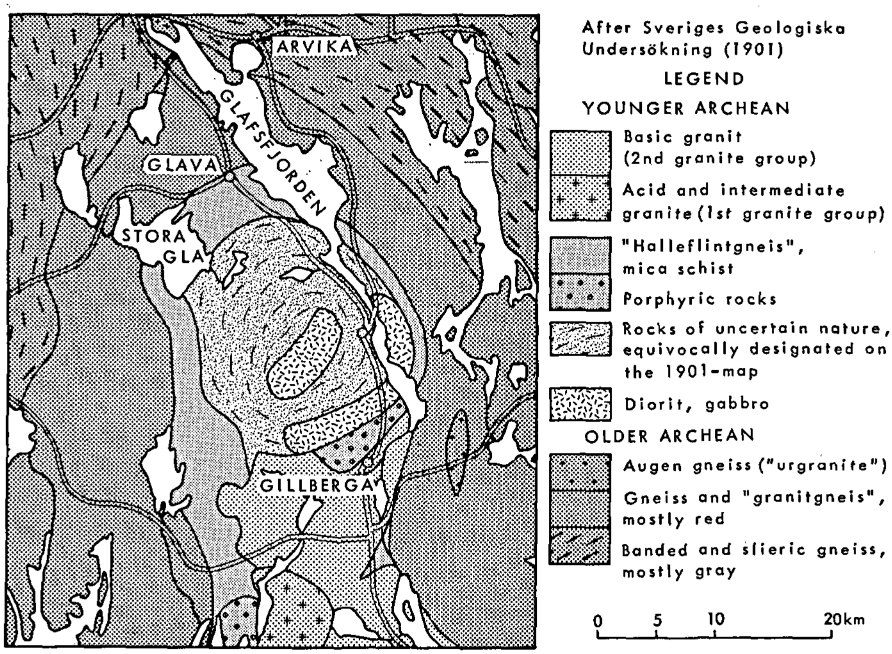
ARVIKA
GLAFSFJORDEN
GLAVA
STORA GLA
GILLBERGA
After Sveriges Geologiska Undersökning (1901)
LEGEND
YOUNGER ARCHEAN
Basic granit (2nd granite group)
Acid and intermediate granite (1st granite group)
"Halleflintgneis", mica schist
Porphyric rocks
Rocks of uncertain nature, equivocally designated on the 1901-map
Diorit, gabbro
OLDER ARCHEAN
Augen gneiss ("urgranite")
Gneiss and "granitgneis", mostly red
Banded and slieric gneiss, mostly gray
0 5 10 20km

Fig. 3 b.

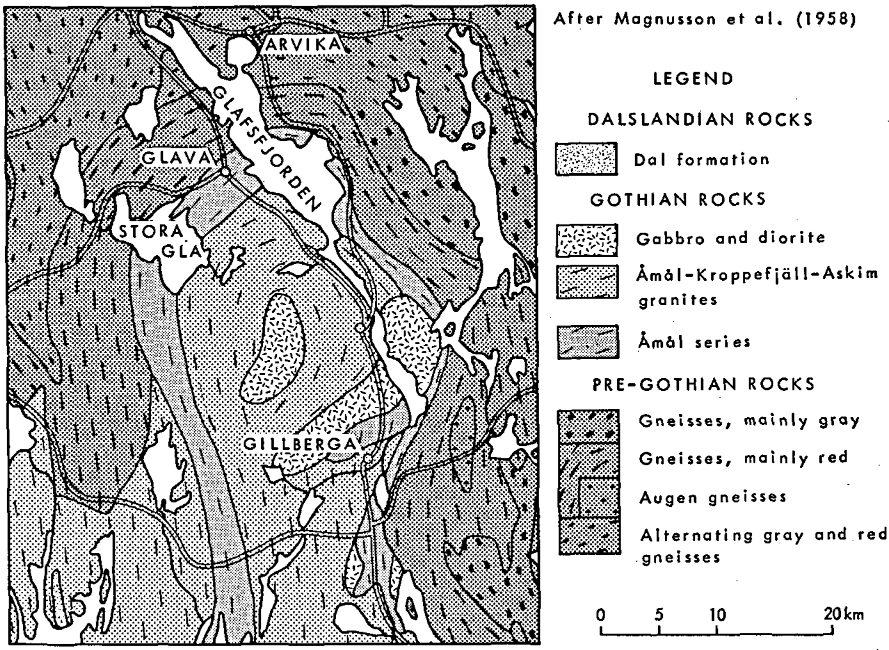
After Magnusson et al. (1958)
ARVIKA
GLAFSFJORDEN
GLAVA
STORA GLA
GILLBERGA
LEGEND
DALSLANDIAN ROCKS
Dal formation
GOTHIAN ROCKS
Gabbro and diorite
Åmål-Kroppefjäll-Askim granites
Åmål series
PRE-GOTHIAN ROCKS
Gneisses, mainly gray
Gneisses, mainly red
Augen gneisses
Alternating gray and red gneisses
0 5 10 20km

Fig. 3 c.

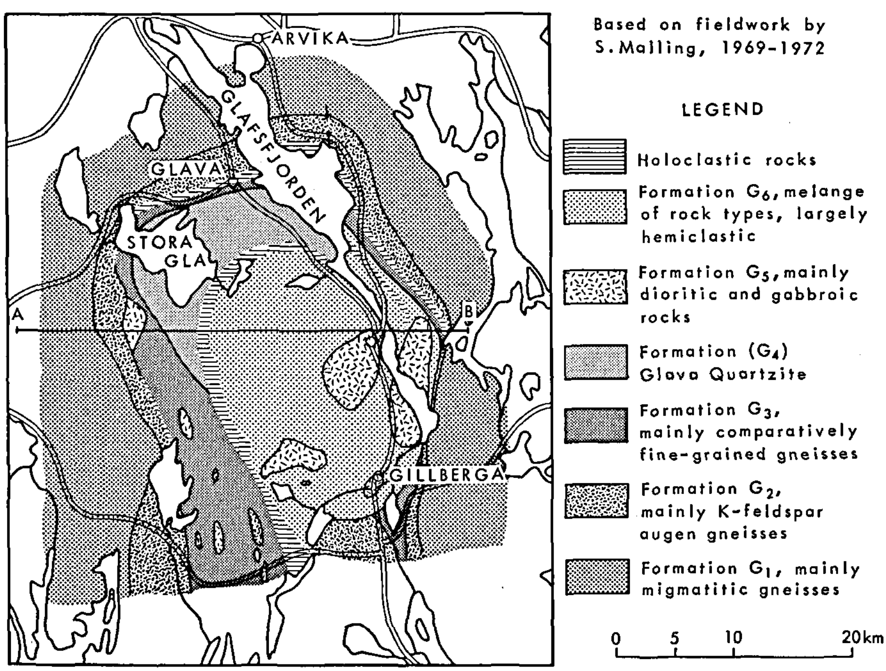
Based on fieldwork by S. Malling, 1969-1972
ARVIKA
GLAFSFJORDEN
GLAVA
STORA GLA
GILLBERGA
A
B
LEGEND
Holoclastic rocks
Formation G6, melange of rock types, largely hemiclastic
Formation G5, mainly dioritic and gabbroic rocks
Formation (G4) Glava Quartzite
Formation G3, mainly comparatively fine-grained gneisses
Formation G2, mainly K-feldspar augen gneisses
Formation G1, mainly migmatitic gneisses
0 5 10 20km

Fig. 3 d.

was now thought feasible that part of the granitic rocks were plutonic and that part of the gneisses and amphibolites were metamorphic rocks (Sveriges Geologiska Undersökning, 1901 b).

Holmquist (1906) suggested that the major part of the gneisses which make up the bulk of the area represent ortho-gneisses showing a foliation and banding of metamorphic origin. The parent material for these gneisses would locally be found preserved in the form of lens-shaped bodies of granitic rocks. Locally within the ortho-gneisses para-gneisses would occur, representing metamorphic equivalents of rocks such as feldspar quartzites. Some granitic rocks would show intrusion contacts to the para-gneisses and thus postdate them (Winge, 1900). Holmquist (1906) considered the rocks in the area to be of roughly the same age, but varying as to the degree of metamorphism. There was said to be a gradual increase in the degree of metamorphism going from the rocks in the central part of the Gillberga synform, which showed a predominance of cataclastic structures, towards the underlying rocks outside, which were crystalloblastic rocks that had been deformed plastically. One and the same metamorphic-tectonic event was suggested to be responsible for the array of metamorphic changes. However, with reference to De Geer (1899), the possibility was mentioned that part of the basement had been influenced by two metamorphic-tectonic events of quite different age, one of them Algonkian (Dalslandian).

New fieldwork in the area was carried out by N. H. Magnusson in the 1920's. Magnusson mapped two areas (fig. 1) and reported the results of his investigations in two papers (Magnusson, 1929, 1930). The interpretation of the rock genesis is similar to that given by Holmquist (1906); that is to say, one event, not specified further, was thought to be responsible for the metamorphic-tectonic development of the area. A new element brought into the discussion was the claim that the toplayer of the Pre-Gothian Group directly underneath the Åmål Quartzite Formation rocks (cf. figs. 1 & 3 c) would represent a metamorphosed weathered land surface (meta-palaeosol), implying a major unconformity. Further, at the bottom of the Åmål-Kroppefjäll Granite Formation a layer of cataclastic rocks was reported which could represent the basis of a large overthrust mass.

Larsson (1956) reported work on the map sheet Vårvik, immediately W of the Säffle sheet mapped by Magnusson, see fig. 1. In the main, Magnusson's stratigraphic classification was followed. However, not one but four metamorphic-tectonic events were recognized. The strength of the events was said to vary over the mapped area, thus in the N-part of the area, and presumably also in the Gillberga area further N, the metamorphic-tectonic development of the area would have taken place in the Dalslandian event. The Dalslandian metamorphism in these parts was said to be high-grade, resulting in the production of migmatitic gneisses.

Fig. 3 c shows the current interpretation of the geology of the Gillberga area, as it appears from the regional geological model given by Magnusson et al. (1958) and Magnusson (1960 b), see fig. 1 and table 1. In the main, it reflects the above-mentioned interpretations by Magnusson (1929, 1930) and Larsson (1956). However, three events were now held responsible for the metamorphic-tectonic development of the area. During the first the Pre-Gothian rocks would have gone through a major phase of recrystallization (producing gneisses etc) before the supposed weathering took place. During the second "the Gothian rocks were altered for the first time", while "at the same time the existing gneissic Pre-Gothian rocks were extensively recrystallized". A third metamorphic-tectonic event would have taken place after formation of the Dalslandian supracrustals. It was suggested that in the area where the Dalslandian rocks were exposed large scale overthrusting would have taken place during this latter event, with "mechanical effects generally prevailing over chemical transformations". In the area N of the Dalslandian rocks, including the Gillberga area, these overthrusts were said to be absent. The suggestion by Magnusson (1930) that zones of cataclastic rocks found in the Gillberga area outline thrust planes was not commented upon and was presumedly discarded. It is of interest to note that a 300–400 km long mylonite zone was indicated in the Pre-Gothian Group (see fig. 1).

## Preliminary results of the present investigations in the Gillberga synform

The preliminary results of the present investigations are summarized in figs. 3 d, 4 & 5. The earlier proposed, simple, large open synform structure of the area was confirmed. However, when observed in more detail fig. 3 d shows many differences from the earlier maps for two reasons. In the first place, other mapping units have been defined. This proved to be necessary as the earlier stratigraphic classification did not fit our field observations, mainly because of the recognition of the wide-spread occurrence of cataclastic rocks and the more detailed nature of the present investigations. Further, the topographic base used in the present study differs from those of the earlier maps; it is much more detailed, and many new roads make the area more accessible.

### Rock formations distinguished in the present study

*Formation $G_1$* consists mainly of usually reddish coloured (migmatitic) gneisses and migmatites of granodioritic (to granitic bulk) composition. Non-migmatitic types are more abundant closer to the boundary with the overlying rock unit ($G_2$). At many places relatively fine-grained (Ø ~ 0.1–0.5 mm), leuco-

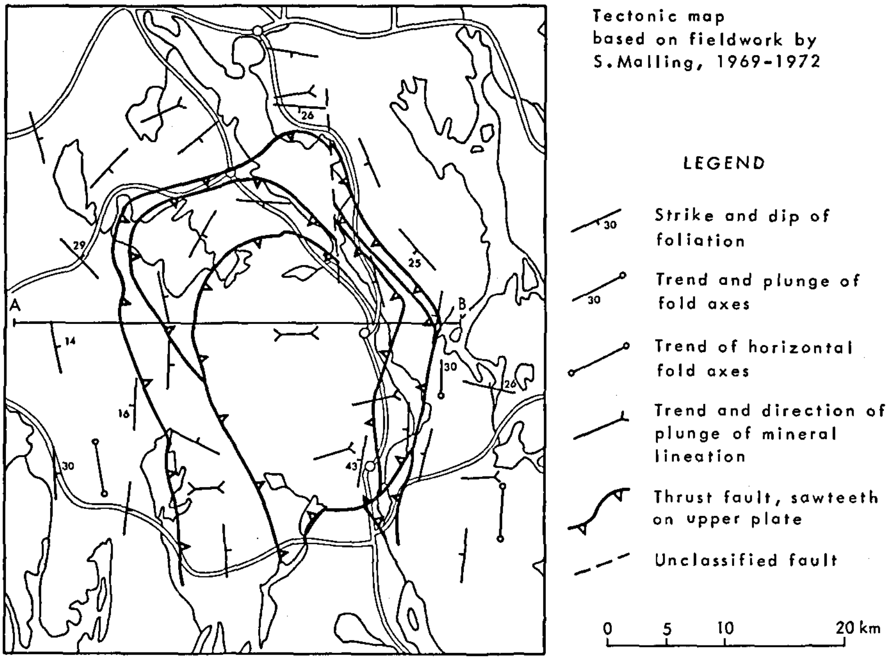


Fig. 4. Tectonic sketch map of the *Gillberga synform*, using the same topographical basis as in fig. 3.

cratic, reddish to pink coloured layers occur, parallel to the common layering and with a thickness varying between 0.1 and 5 m. Basic material occurs as foliation-parallel amphibolitic layers as well as irregular clods which do not show marked foliation though often an amphibole lineation. The rocks do not show signs of ruptural deformation. At least two deformation phases can be recognized. During the older phase the prominent foliation and layering would have been formed. Small isoclinal fold hinges with axial planes parallel to the foliation are locally found. In a later deformation phase half open fold structures were formed. The mineral assemblages of the rocks may be classified in two groups of paragenesis (cf. Zeck, 1971, p. 308–311): a main one comprising minerals like quartz, plagioclase ($An_{25-35}$), K-feldspar, biotite, hornblende and possibly white mica and epidote, and a second, quantitatively less important one comprising quartz, albite, epidote, titanite, chlorite, white mica and in many rocks prehnite and pumpellyite (cf. descriptions by Zeck, Andersen & Leonardsen, 1971).

*Formation $G_2$* consists mainly of K-feldspar augen gneiss. The rock is usually red, in many places rather rich in biotite and amphibole. Basic material is present in a few foliation-parallel amphibolite layers. EW amphibole lineations are locally present. The mineralogy of both the quartzo-feld-

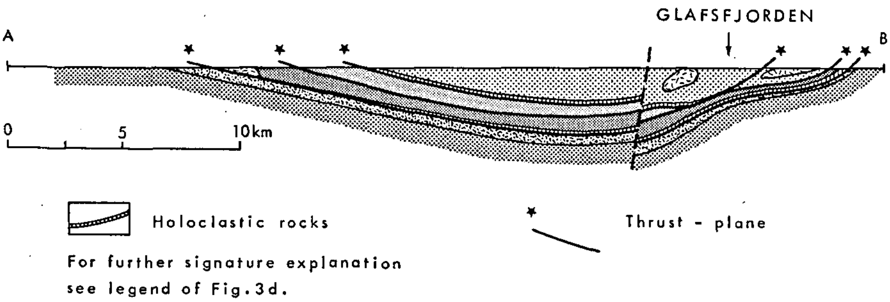


Fig. 5. Section A-B indicated on the geological map of fig. 3 (d) and the tectonic map of fig. 4.

spathic and the basic rocks is very similar to the corresponding rock types in Formation $G_1$; the remarks made there apply also here.

*Formation $G_3$* consists mainly of leucocratic, reddish, compact rocks. Foliation is at many places poorly developed. Amphibolite layers are of common occurrence. The mineralogy of the rocks is similar to that of the corresponding rock types of Formation $G_1$. The interpenetrative foliation, outlining the large synform structure, and an EW amphibole lineation in the foliation plane are the only structural elements observed. Locally, migmatitic gneisses, very similar to those found in Formation $G_1$, but hemiclastic, are found enclosed in the finer grained rocks in bodies up to 5 km long, elongated parallel to the foliation, and with gradational boundaries towards the surrounding rocks. Other large, correspondingly elongated bodies of contrasting lithology occur, but as a rule show sharp boundaries to the surrounding rocks, and consist of rocks very similar to those found in Formations $G_2$ and $G_4$. In many of these bodies the internal foliation is at a considerable angle with the foliation in the surrounding rocks. It is thought possible that this rock formation consists in the main of cataclastic equivalents of Formation $G_1$ and $G_2$.

*Formation $G_4$: Glava Quartzite Formation* consists mainly of (feldspar-bearing) quartzites, semi-schists, schists and gneissic rocks. At some quartzite exposures well developed current bedding structures were found indicating a normal, non-inverted position of the rocks. At many localities, the rocks show signs of ruptural deformation of variable strength. At the base of the formation the ruptural deformation is strong and prominent at most localitites.

*Formation $G_5$* consists mainly of (quartz) diorite, hornblende gabbro and some melano hornblende gabbro. At many exposures an amphibole lineation can be recognized. As a rule foliation is absent or poorly developed. Within the basic rocks irregular veins and pods of quartzo-feldspathic material occur. All rocks involved show as a rule signs of ruptural deformation.

*Formation $G_6$* consists of a melange of many rock types. All rocks involved are cataclastic, mostly hemiclastic, comprising a) hemiclastic granitic rocks rich in angular amphibolite inclusions, b) gneisses very similar to those of Formation $G_1$ and $G_3$, c) gneisses which show some similarity to those of Formation $G_2$ and d) holoclastic rocks, mainly holo-myloblastites. The structural pattern resulting from measuring foliation planes where available is incoherent.

Zones of *holoclastic rocks*, mainly holo-mylogneisses, could be mapped out at many formation boundaries. Two main zones of holoclastic rocks have been mapped: a lower one, defining the base of the middle thrust sheet, and an upper one defining the base of the upper thrust sheet. The mechanical degradation in the upper one seems more pronounced. In both zones ruptural deformation seems stronger in the W part in the area S of lake Stora Gla than in other parts of the same zone.

At the present stage of the investigations it is difficult to correlate the rock units distinguished in the present study with those figuring in the current regional classification system summarised in fig. 1 and table 1. The unconformity between the Pre-Gothian Group and the Gothian Group, which is a crucial aspect in this classification, and which rests on the recognition of a meta-palaeosol at the top of the Pre-Gothian Group, could not be confirmed by our investigations. Note in this respect that the unconformity hypothesis rests solely on a supposedly consistent higher muscovite content at this stratigraphic level, no other indication, e.g., the (local) occurrence of conglomerates or an angular unconformity were found (see also Holmquist 1906, p. 205). As also the rocks within the Gillberga synform are similar to those outside, it seems that in the litho-stratigraphic classification of the rocks in the Gillberga area there is no need to distinguish between a Pre-Gothian Group and a Gothian Group. Strictly lithologically, part of the rocks within the Gillberga synform could consist of sheared, cataclastic, equivalents of the rocks outside the synform.

One formation, $G_4$, the Glava Quartzite Formation, distinguishes itself from the surrounding gneisses by its quartzitic composition. Obviously it is this formation which corresponds to what in the current model has been called Åmål Quartzite Formation. However, we do not want to exclude the possibility that it belongs to the Dalslandian Group. The extent of Formation $G_4$ on the geological map (fig. 3 d) is much less than that of the Åmål Quartzite Formation on earlier maps (fig. 3). Large parts of what by earlier authors has been mapped as supracrustal rocks are in the present study interpreted as cataclastic rocks. In general, it seems not uncommon that holoclastic rocks are mistaken for metavolcanics or metasediments, see Higgins (1971).

The present authors suggest that it is probable that more rock units in the Precambrian basement of SW Sweden, which currently are interpreted as supracrustals (often as prophyric volcanics) will turn out to be holoclastic rocks. Reconnaissance work by the present authors in the basement of SW Sweden and the adjacent part of SE Norway, since 1970, has shown that cataclastic rocks are wide-spread. It seems feasible that several important, usually roughly N–S trending zones of cataclastic rocks are present in the area. Typical holoclastic rocks are for example exposed in a long road cut along the Örje-Mysen road (E 18) about 0.5 km N af Örje. Recent, preliminary work seems to indicate that these rocks are part of a larger, roughly N–S striking cataclastic belt (cf. Skjernaa, 1972).

## The structure of the Gillberga synform

The structural model preferred by the present authors is presented in figs. 3 d, 4 & 5. It consists of a pile of three thrust sheets. The model employs three deformational events: (a) one (or more) folding phase(s) affecting the Pre-Gothian rocks, (b) the emplacement of the thrust masses, and (c) the formation of the large open N-axial synform.

At many places the rocks figuring in the Gillberga synform show an influence of cataclasis, usually overprinted by a relatively weak phase of recrystallization. Narrow zones of holoclastic rocks can be mapped. The major zones are indicated on figs. 3 d, 4 & 5, situated at mapping unit boundaries, and it is taken that they outline the major thrust planes. However, similar, but narrower zones of lesser extent and parallel to the major ones are present and they may indicate subordinate thrust planes.

The lower thrust mass rests on Formation $G_2$ which in turn is underlain by Formation $G_1$. Whereas in Formation $G_1$ the double folded nature of the second folding is locally visible, in Formation $G_2$ fold axes are only very rarely observed. It is suggested that a folding pattern similar to that in $G_1$ has been present in $G_2$, but that (sub-)horizontal shear movements in connection with the emplacement of the thrust masses have resulted in a general flattening and obliteration of pre-existing structures. The lower thrust mass consists mainly of Formation $G_3$. A rather prominent zone with holoclastic rocks was found at its base. Large rock inclusions interpreted as fragments of Formation $G_1$, $G_2$ and $G_4$ are explained as tectonic inclusions. The middle thrust sheet consists mainly of Formation $G_4$ and further, at the east, of Formation $G_6$ which consists for a large part of a melange of rocks allocated to Formation $G_1$, $G_2$ and $G_3$. The relations between the various bodies of rocks in this formation are complicated and subject to further study. The third thrust mass consists entirely of this complex Formation $G_6$.

The three thrust masses are not necessarily independently emplaced. It is possible that they all three or that two adjacent ones travelled together over a considerable distance. An indication for the place of origin of the overthrusted material is given by the E–W direction of the mineral lineation. This lineation is interpreted as an a-lineation, and thus indicating that the thrust masses came from the E or the W. (Note that Magnusson, 1929, reported ENE–NE trending mineral lineations in the rocks of the Säffle sheet). The distance over which the thrust masses have travelled will be difficult to determine. There is perhaps the possibility that the thrust masses stem from the large, roughly N-S striking mylonite zone which is said to run ca. 20–25 km E of the Gillberga synform (see fig. 1); such according to a model similar to that proposed by Bryant & Reed (1970, fig. 106, p. 170) for the Blue Ridge in the North American Appalachians.

It is of interest to mention that Heybroek & Zwart (1949) confirmed earlier results by A. E. Törnebohm by giving evidence for the occurrence of large horizontal overthrusts of basement gneisses over Dalslandian Group rocks, with displacements of the order of 5–10 km. Larsson (1956) reported the occurrence of large overthrusts in the Vårvik map sheet, and also Magnusson (1960 b) mentioned "nappes of Gothian rocks" thrust over younger Dalslandian rocks, in the same geological belt more to the S.

## Metamorphic-tectonic model for the Gillberga area

The metamorphic-tectonic model preferred by the present authors in this preliminary stage of the investigations bears similarity to that given by Magnusson (1960 b), but employs two main events. The first event is characterized by a plastic deformation under (continuous) crystallization producing only or mainly amphibolite facies parageneses, while foliation and metamorphic layering were formed. This process would result in the formation of gneisses and amphibolites and, at the deepest level, of migmatitic gneisses and migmatites. Rocks formed by this event would be found best preserved in Formation $G_1$ at some distance from the lower thrust plane, preservation becoming poorer closer to the thrust plane. Perhaps this event was terminated with an inherent retrogressive metamorphic phase (cf. Zeck, 1971, p. 311–312).

The second event is characterized by the mise-en-place of the thrust sheets. During this event mechanical degradation figured prominently. Recrystallization connected to this event produced amphibolite to greenschist facies parageneses and E-W directed mineral lineations. Mainly, or wholly after the main, cataclastic phase directly concomitant with the mise-en-place of the thrust sheets, (minor) recrystallization might occur, producing low grade parageneses (prehnite-pumpellyite facies, Zeck, 1971, and possibly greenschist facies and/or a facies transitional between these two facies). The influence of this second event is best seen in Formation $G_3$ and $G_6$, and in the zones of holoclastic rocks (see fig. 3 d). The parallel orientation of the foliation in Formation $G_1$ and $G_2$ with the foliation in the rest of the rock pile could be effected in this second event.

The age of the second event seems to be Dalslandian, because (a) other authors have described similar thrust plate structures as characterize the second event involving established Dalslandian meta-sediments in the same geological belt more to the S (see above), and because (b) the final metamorphic-tectonic phase in the Precambrian basement of S Norway, which in many respects is similar to the basement in SW Sweden, was radiometrically dated as Dalslandian (1170 $\pm$ 50, see table 1). However, an older (and even younger) age of the thrusting is not excluded. A radiometric dating programme is being planned to settle the question.

The first event is older and might belong to the Svecofennian ($\sim$ 1700 my BP), thus conforming to the model established for S Norway (O'Nions & Baadsgaard, 1971).

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## Dansk sammendrag

Der gives en gennemgang af Sydvestsveriges prækambriske grundfjelds geologi samt en kort gennemgang af den tidligere litteratur om en afgrænset del af dette grundfjeld (Gillbergaskålen). Foreløbige resultater af igangværende undersøgelser i Gillberga området præsenteres. Det foreslås, at bjergartkomplekset i området består af en stabel af 3 overskudte masser, der muligvis repræsenterer kataklastiske æquivalenter til de bjergarter, der findes i grundfjeldet på hvilket den nederste overskudte masse hviler. Mange bjergarter, der tidligere ansås for at være suprakrustale (Åmål Kvartsit Formationen), er i nærværende arbejde tolket som kataklastiske bjergarter.

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