ON THE OCCURRENCE OF SILLIMANITE IN THE GULA SCHIST GROUP, TRONDHEIM REGION

DAVID ROBERTS

Norges Geologiske Undersøkelse, Trondheim, Norway

ROBERTS, DAVID: On the occurrence of sillimanite in the Gula Schist Group, Trondheim Region. *Norsk Geologisk Tidsskrift*, Vol. 48, pp. 171-177, Oslo, 1968.

The local occurrence of sillimanite in the Cambrian Gula Schist Group of the Trondheim region is discussed. Potash feldspar is common in these sillimanite-bearing rocks but garnet, kyanite and staurolite, quite widespread elsewhere in this region, are significantly absent. Textural features indicate that most of the sillimanite crystallized largely at the expense of biotite during the first of three deformation episodes, with some growth continuing into the immediate post-F_1 static period. Reactions are suggested to account for the mineral paragenesis in these rocks which appear to be localized representatives of the highest temperature sub-facies of the almandine-amphibolite facies of regional metamorphism.

The Gula Schist Group, previously called the Röros Group (Wolff 1967), constitutes the oldest member of the Lower Palaeozoic metasedimentary and volcanic sequence in the Trondheim region, lying beneath the Stören and Hovin Groups. Detailed tectonic investigations in the Stjördalen valley area east of Trondheim (Roberts 1967) have shown that the Gula Schist Group forms the core of a complex fan-shaped anticlinal structure, both limbs of which are inverted. That the grade of metamorphism in general diminishes rapidly away from this central schist zone is a long-established observation (Kjerulf 1871), although detailed petrographical studies of the Trondheim region metasediments are largely confined to the work of Goldschmidt (1915) and C. W. Carstens (1928). A summary of the main features has been given by Strand (1960) who noted that the 'central' schists are representative of the (almandine-) amphibolite metamorphic facies. Hovin Group rocks generally, though not exclusively, belong to the greenschist facies.

Garnet, staurolite and kyanite occur frequently in rocks of the Gula Schist Group in the central part of the extensive Trondheim region, while in many places a hornblendic amphibole is the sole porphyroblastic mineral. In the Stjördalen profile and immediately to the north of this valley, garnet is the dominant index mineral: staurolite and kyanite here occur only rarely. The present note serves to report the common occurrence of sillimanite in a relatively narrow zone of schist adjacent to and in the approximate strike extension of the Gudå Conglomerate horizon (Fig. 1), and to comment briefly on the mineral assemblage and its petrological significance.

The sillimanite-bearing lithology is a dark grey to brownish-grey, medium-grained, pelitic or semi-pelitic schist (locally a gneiss) containing a profusion

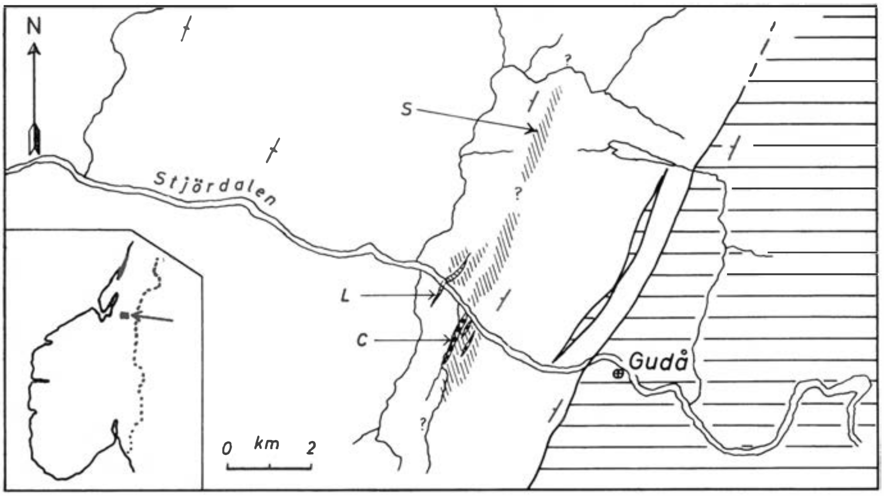


Fig. 1. Location of the sillimanite-bearing rocks. Stören Group indicated by horizontal lines. Gula Schist Group left blank. C—Gudå Conglomerate; L—diopsidic limestone; S—sillimanite-bearing schist zone. Key map: S. Norway.

of small creamy-grey coloured knots or pods which, owing to their greater resistance to weathering, often stand out conspicously on a weathered surface (Fig. 2): the pods are composed of fibrolitic sillimanite and variable amounts of quartz and late muscovite—essentially the *faserkiesel* of metamorphic petrologists. It has been shown elsewhere that the foliation in these schists was developed during the first of three main Caledonian fold episodes (Roberts 1967). The sillimanite pods, measuring up to 1.3 cm $\times$ 7 mm $\times$ 3-4 mm, lie within this F_1 foliation with their long axes paralleling the axial direction of the isoclinal first generation folds; many fine examples of their subsequent deformation around later fold closures can be demonstrated in the field.

In thin-section the lenticular pods consist of swarms, sheaves and sinuous mats of fibrous or acicular sillimanite and often display a central or irregular pale-brown coloration. Transverse fractures may be present. Needles of sillimanite rarely exceed 0.25 mm in length but slender prisms up to 0.5 mm have been noted, the longest individuals occurring in a thin-section cut 'ab' with respect to F_1. Where the fibrolitic mat is not so thick the sillimanite is seen to occur within a granoblastic mozaic of quartz grains. An important feature is the abundance of magnetite grains and blebs within the outer zone and on the margins of many pods (Plate 1A). Biotite is also present within the lenticles in various stages of breakdown and apparent replacement by sillimanite. Muscovite is frequently developed to different degrees depending on the precise nature of the metasediment, as porphyroblasts up to 2-3 mm in length which are clearly of relatively late development. They have grown chiefly at the expense of the sillimanite and, while generally orientated parallel or sub-parallel to the foliation, often extend out from the pods and enclose the groundmass fabric of the schist. In the more semipelitic lithologies relatively little sillimanite now remains within the muscovitized pods. Tourmaline metacrysts up to 1 mm in length have been noted in pods in two thin-sections (Pl. 1B and C); they have overgrown and developed apparently at the expense of the fibrous sillimanite mat. Sillimanite needles or sillimanite-bearing quartz grains are seen as inclusions in the tourmalines.

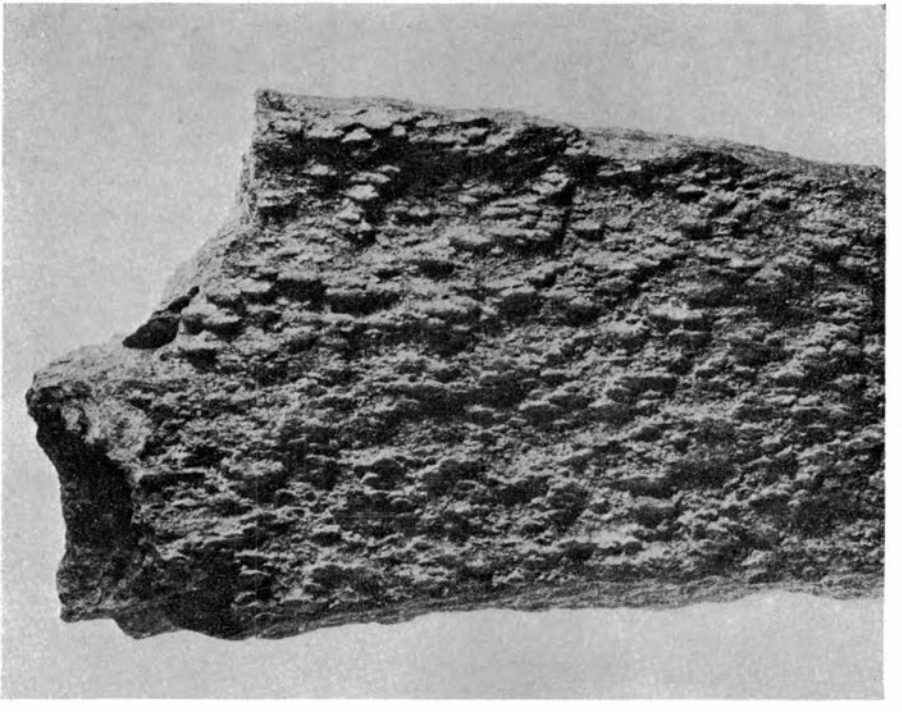
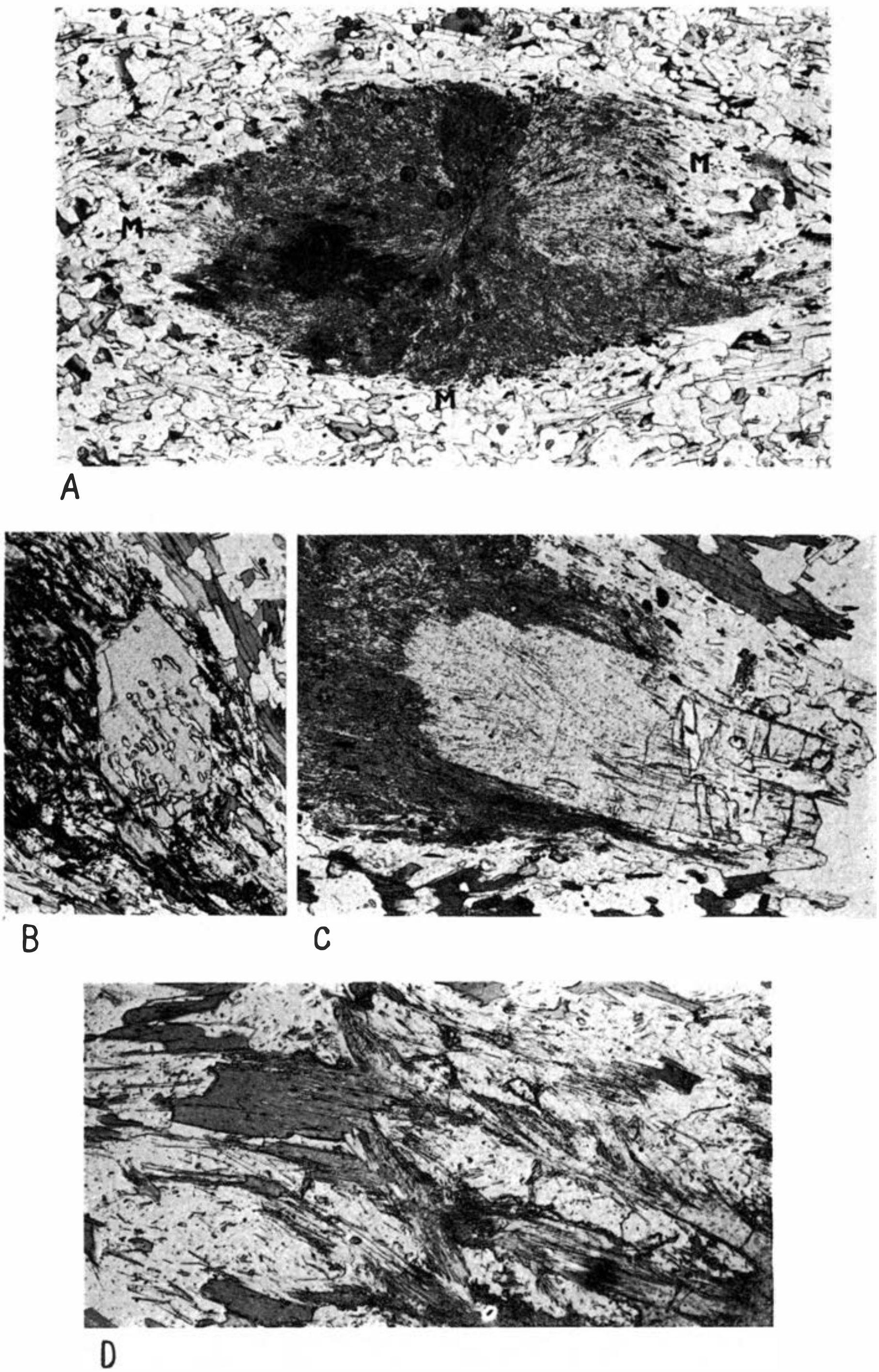


Fig. 2. Weathered surface of a typical sillimanite schist specimen showing the prominent faserkiesel. Natural size.

A generally lepidoblastic texture characterizes the groundmass of the pelitic schist with biotite present much in excess of muscovite, the latter more prominent in the semi-pelitic schists and gneisses. Quartz and plagioclase (An_{27-32}) are also major consituent minerals. Although garnet is common both to the west and east of the sillimanite-bearing schist zone, it has not been found in any of the rocks or thin-sections containing this particular alumino-silicate. Moreover, both kyanite and staurolite are also notably absent from these 'faserkiesel' schists. What is more significant is the presence of abundant xenoblastic porphyroblasts of potash feldspar (orthoclase), usually < 1 mm but occasionally up to 1.5 mm across. These contain inclusions of quartz, apatite, zircon and small biotites and, in some cases, many small granules of (?) magnetite. Myrmekite is not uncommon adjacent to the K-feldspar metacrysts which themselves are sometimes found to be perthitic.

Texturally, the sillimanite of these schists is intimately associated with biotite and appears to have developed principally from this mica (Plate I D).

PLATE I



Various stages in this breakdown can be recognised—even a pseudomorphing effect—and an associated 'decolorization' of the biotite is often discernible (Tozer 1955, Chinner 1961). While a simple development of sillimanite from the breakdown of biotite has been repudiated by some workers (Chinner 1961, Chakraborty and Sen 1967), the allied reaction

$$\underset{\text{Fe-biotite}}{KFe_3Si_3AlO_{10}(OH)_2} + \underset{\text{dissolved kyanite}}{Al_2O_3 + SiO_2} \rightleftharpoons \underset{\text{potash feldspar}}{KAlSi_3O_8} + \underset{\text{sillimanite}}{Al_2SiO_5} + 3FeO + H_2O$$

has much in its favour here since the products K-feldspar, sillimanite and magnetite are all present in the pelites in question. This reaction is catalysed by unstable kyanite, as alumina and silica in solution, such that sillimanite and magnetite appear instead of garnet (Francis 1956) .Considering the working possibilities of such an Al-Si-bearing solution, Chinner's (1961) proposal that channelways (e.g. shear planes) permitting the movement of the fluid phase were important locally is pertinent here, especially as F_1 shearing is very much in evidence in the vicinity of the Gudå Conglomerate with certain parts of the so-called 'Gudå Conglomerate Zone', in the writer's opinion, representative of a pseudo-conglomerate derived by intensive shearing of an isoclinally folded rapidly alternating quartzite/pelite lithology. The sillimanite schists are prominent within this zone.

Growth of the sillimanite, whether largely at the expense of biotite, by epitaxial nucleation on biotite, or assisted by a partial breakdown of muscovite (see below) was, however, syn-tectonic with respect to the F_1 deformation. It was initiated and proceeded during the development of the foliation (axial planar to F_1 folds), the recrystallization of the micas and the coarsening of the general fabric. with groundmass biotite and muscovite usually being deflected around the growing pods, but continued locally after biotite growth had ceased: the larger prisms in particular appear to be relatively late. An interesting feature is that the equant quartz within the pods is invariably appreciably less strained than that in the groundmass fabric. On textural evidence potash feldspar porphyroblastesis was also predominantly syn-kinematic, locally extending into the immediate post-F_1 phase. Sillimanite-ortho-

---

PLATE I

A) Pod of fibrolitic sillimanite with magnetite grains conspicuous in its outer zone: late muscovite (M) extends inwards enclosing fibrolite and outwards enclosing the groundmass fabric. The paler sectors faintly discernible within the pods represent individual muscovite metacrysts. Plane polarised light ×30.

B) Tourmaline metacryst overgrowing fibrolite and quartz. Sillimanite needles occur within the quartz grains enclosed by the tourmaline. Plane polarised light ×32.

C) Tourmaline metacryst (within a fibrolitic sillimanite pod) containing sillimanite needles which have retained their pre-tourmaline orientation. Late muscovite envelops both fibrolite and tourmaline. Plane polarised light ×65.

D) Fibrolite (bottom right) and acicular sillimanite developing principally at the expense biotite (dark grey). Plane polarised light ×128.

clase relations are nowhere seen. To account for the presence of perthite a reaction applicable here might be that proposed by Guidotti (1963):

$$\text{Muscovite} + \text{quartz} + \text{Na-rich plagioclase} \rightleftharpoons \text{sillimanite} + \text{Na-bearing potash feldspar} + \text{a more basic plagioclase} + H_2O$$

The anorthite content of the plagioclase of these schists, An_{27-32}, is certainly higher than that noted in most of the garnet-, kyanite- and staurolite-bearing metasediments of this region. However, in view of the close textural association of biotite with sillimanite the plausibility of this reaction is open to question in this particular case.

Another factor is the breakdown of groundmass muscovite in these schists and gneisses, and its probable contribution to the development of sillimanite and potash feldspar cannot, therefore, be overlooked. A reaction involving both the micas which could well be considered in this instance is that of:

$$\underset{\text{muscovite}}{KAl_2Si_3AlO_{10}(OH)_2} + \underset{\text{biotite}}{KFe_3Si_3AlO_{10}(OH)_2} + SiO_2 \rightleftharpoons 2\ \underset{\text{potash feldspar}}{KAlSi_3O_8} + \underset{\text{sillimanite}}{Al_2SiO_5} + 3\ FeO + 2\ H_2O$$

This is a variant of a more widely accepted reaction in which almandine-garnet appears together with the K-feldspar. Here, sillimanite and magnetite are present instead of garnet.

A complete mineral assemblage of these sillimanite-bearing rocks shows: sillimanite + K-feldspar + biotite + muscovite + quartz + plagioclase + magnetite + tourmaline + apatite ± zircon ± sphene; this is suggestive of derivation in the highest temperature sillimanite-almandine-orthoclase sub-facies of the almandine-amphibolite facies. Trondhjemites, granitization phenomena, venites and pegmatites (often tourmaline-bearing) are quite common features within the Gula Schist Group, not least within this sillimanite-potash feldspar schist zone, so that the process of migmatization can be assumed to have begun. With field relations suggesting that 'granitization' was both syn- and post-kinematic with respect to the F_1 deformation (Roberts 1967), a close temporal association is evident between this process and the formation of sillimanite. The preferential occurrence of tourmaline metacrysts within sillimanite pods is of interest here and a metasomatic origin is presumed with the aluminous faserkiesel proving an attractive site for the crystallization of the tourmalines: other criteria such as the presence and distribution of volatiles probably play a significant role in effecting this tourmaline-fibrous sillimanite association. The muscovite porphyroblasts which are often important constituents of the sillimanite pods post-date all other minerals and are of static crystallization. They are themselves deformed by the second and later folds.

In the absence of chemical analyses, certain of the suggestions bearing on the origin of the sillimanite in this area west of Gudå are, at this stage, necessarily of a speculative nature. It is hoped that a more extensive petrographical study will facilitate the drafting of a more accurate map of the distribution of the main metamorphic index minerals and the extent of the various sub-facies, and it is possible that more occurrences of sillimanite may well come to light. Sillimanite has previously been reported from the Trondheim region by Kisch (1962). This occurrence, however, is within the Stören Group, from an horizon bordering on a localized granulite zone adjacent to a major gabbroic complex in the S. W. Tydal district.

Norges Geologiske Undersøkelse, Postboks 3006,
7000 Trondheim, Norway.
March, 1968

REFERENCES

CARSTENS, C. W. 1928: Petrologische Studien im Trondhjemsgebiet. *Det Kgl. Norske Vidensk. Selsk. Skr.* (1928) *Nr. 1.* 96 pp.

CHAKRABORTY, K. R. & SEN, S. K. 1967: Regional metamorphism of pelitic rocks around Kandra, Singhbhum, Bihar. *Contr. Min. and Petrol. 16(3)*, 210-232.

CHINNER, G. A. 1961: The origin of sillimanite in Glen Clova, Angus. *Jour. Petrology, 2*, 312-323.

FRANCIS, G. H. 1956: Facies boundaries in pelites at the middle grades of regional metamorphism. *Geol. Mag. 93*, 353-368.

GOLDSCHMIDT, V. M. 1915: Geologisch-petrographische Studien im Hochgebirge des südlichen Norwegens III. Die Kalksilikatgneise and Kalksilikatglimmerschiefer des Trondhjem-Gebiets. *Vid. Selsk. Skr., I Mat.-Nat. Klasse, Nr. 10*, 37 pp.

GUIDOTTI, C. V. 1963: Metamorphism of the pelitic schists in the Bryant Pond Quadrangle, Maine. *Amer. Min. 48*, 772-791.

KISCH, H. J. 1962: Petrographical and geological investigations in the south-western Tydal region, Sør-Trøndelag, Norway. *Acad. Proefsch. Univ. Amsterdam*, 136 pp.

KJERULF, TH. 1871: Om Trondhjems Stifts geologi (I). *Nyt. Mag. for Naturv. 18.*

ROBERTS, D. 1967: Structural observations from the Kopperå - Riksgrense area and discussion of the tectonics of Stjørdalen and the N.E. Trondheim region. *Norges Geol. Undersök. 245*, 64-122.

STRAND, T. 1960: The Trondheim region and adjacent districts. *In* Holtedahl, O. (Ed.), *Geology of Norway. Norges Geol. Undersök. 208*, 202-220.

TOZER, C. F. 1955: Sillimanite in the Glen district, Co. Donegal. *Geol. Mag. 92*, 310-320.

WOLFF, F. C. 1967: Geology of the Meråker area as a key to the eastern part of the Trondheim region. *Norges Geol. Undersök. 245*, 123-146.