Topographical mineralogy of the Bamble sector, south Norway

T.G. Nijland, J.C. Zwaan & L. Touret

Nijland, T.G., J.C. Zwaan & L. Touret. Topographical mineralogy of the Bamble sector, south Norway. — Scripta Geol., 118: 1-46, Leiden, December 1998.
T.G. Nijland, Rooseveltlaan 964, 3526 BP Utrecht, The Netherlands; J.C. Zwaan, Nationaal Natuurhistorisch Museum, Postbus 9517, 2300 RA Leiden, The Netherlands; L. Touret, Musée de Minéralogie, École des Mines, 60 Boulevard St. Michel, F 75806 Paris, France.

Key words: systematic mineralogy; Bamble; south Norway.
The Bamble sector of southern Norway is a classic high grade metamorphic gneiss region, which provided specimens to many mineralogical collections all over the world. The topographical mineralogy of this area is described and reviewed. All minerals known to occur in the area are listed according to Strunz' classification.

Contents

Introduction

The Bamble sector is a high grade metamorphic gneiss terrain in southern Norway (Fig. 1), whose present day geological features mainly resulted from multiple metamorphism and deformation during the Gothian (1.75-1.5 Ga) and Sveconorwegian (1.25-0.9 Ga) orogenies (e.g. Bugge, 1943; Touret, 1968; Starmer, 1985, 1991; Nijland, 1993; Visser, 1993a). This area has since long attracted geological and mineralogical attention. In most systematic collections of mineralogy (e.g. at the National Natural History Museum, Leiden, and the École des Mines, Paris), localities from southern Norway (besides the Bamble sector also the surroundings of Brevik and the Langesundfjord) are among those most often mentioned, together with other classic areas like Langbån (Sweden), Mont St Hilaire (Quebec) and Madagascar. The miner-

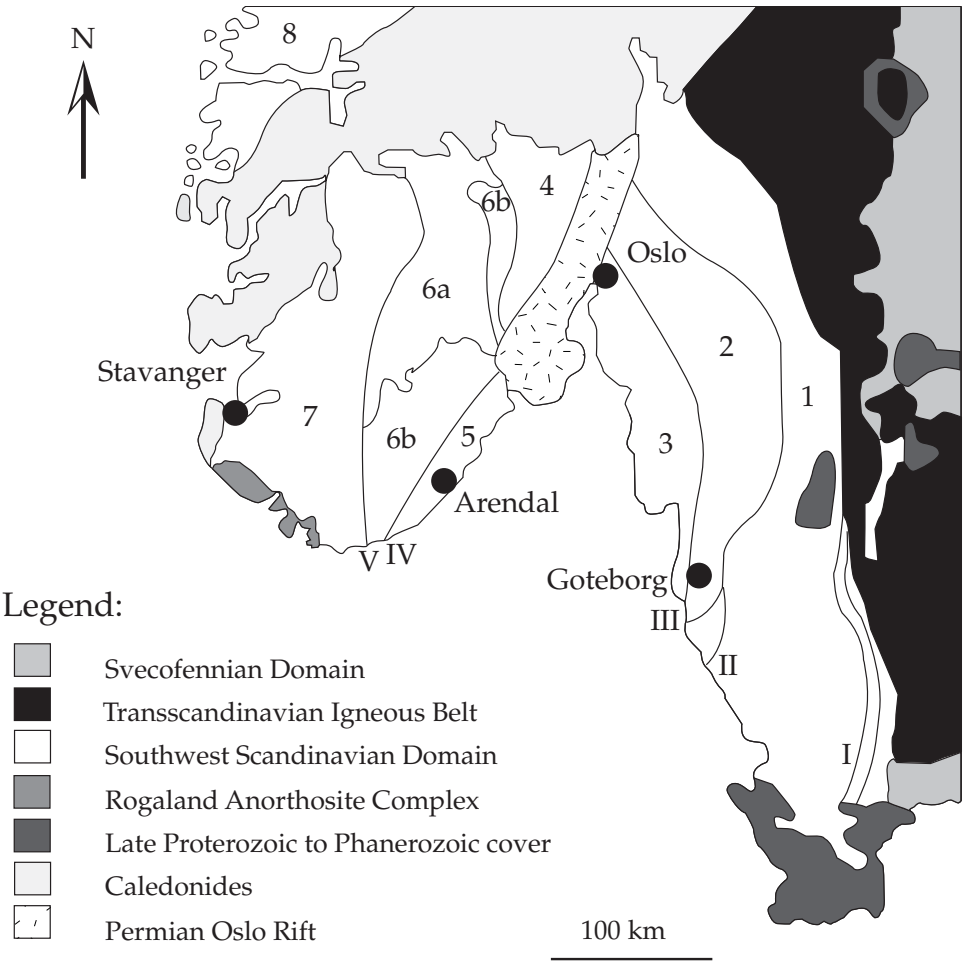

Fig. 1. Map of the Southwest Scandinavian Domain (Modified aftter Verschure, 1985). The individual terrains have been numbered: 1: Eastern Segment, 2: Median Segment, 3: Western Segment, 4: Kongsberg Sector, 5: Bamble Sector, 6a: Telemark Supracrustals, 6b: Telemark Basement Gneisses, 7: Rogaland/Vest-Agder Sector, 8: Western Gneiss Region. Tectonic lineaments: I: Protogine Zone, II: Mylonite Zone, III: Dalsland Boundary Thrust, IV: Kristiansand-Bang Shear Zone, V: Mandal-Ustaoset Line.

alogy of the latter island shows much similarities with that of the Bamble sector, as already recognized by Lacroix.

In the Bamble sector, two mining areas have been especially important, viz. those around Arendal and Kragerø. The skarns around Arendal represented one of the few places where large, idiomorphic crystals were readily available, because of iron-mining activities coinciding with the birth period of modern mineralogy. Among all these minerals, some have been of foremost importance because they have played major roles in the basic definition of mineral classes or have helped to precise their chemical

features. This holds, for example, for the pyroxenes, which group name was actually coined by Haüy (1799, p. 269) on a sample from Arendal, epidote (*arendalite, delphinite*), feldspars, scapolite (*wernerite, gabbronite*), and cordierite (*iolite, aspasiolite, dichroite, polychroite*), whose chemical composition was analysed by Scheerer (1848a). A comprehensive topographical mineralogy of this area was, however, not available, although this was partly compensated for by Neumann's (1985) overview of the mineralogy of entire Norway. The present paper aims to fill this gap, including both recent and old literature as well as unpublished data.

Short history of mining, geological and mineralogical interests in the Bamble sector

The Bamble sector, which is now a classic high grade gneiss terrane, has attracted geological and mineralogical attention since the early Middle Ages, when Viking sailors used gem quality cordierite crystals for navigation (Schlüter, 1994). This area is since long famous for its beautiful cordierite crystals, especially from the Tvedestrand area (e.g. Scheerer, 1848a; Lacroix, 1889; Hintze, 1897a), and is one of the most likely source areas for these navigation aids. In addition, Viking age utensils, made of *kleberstein* (talc) have been found near Vimme, south of Nelaug. These may have been derived from the small talc deposit in the same area (Moree & Nijland, 1996). Later, mining of both metallic and non-metallic ores became important. In 1860, the Ag-Pb-Zn deposit of Ettedalen (Espeland) was discovered, and Cu (at Bøylestad and Skyttemyr) and Ni (at Messel) have also been mined, but Fe ores have been of foremost importance. The oldest iron works date back to about 1540 (Vogt, 1908). In 1806, when Arendal had c. 1700 inhabitants, most of them merchants and sailors, there were 22 iron mines in the surroundings, some of them property of the crown, most privately owned (Hausmann, 1812). The iron ores were derived from two areas, Arendal and Kragerø. In the Arendal area, magnetite deposits associated with skarns were exploited (Klådeborg, Solberg, Barbudalen, Langsev, Tornsbudalen, Raneklev, Mørefær, Lærestveit, and Vågsnes and Alvekilen on Tromøy), as well as mineralizations associated with the Holt granite. In the Kragerø area, Fe-ore deposits were associated with metagabbros, for example on the islands of Langøy and Gumøy. Production declined from c. 1850 onward, but around the last turn of century, an elaborate iron industry, mainly fed with local ores, was operative. Through the Danish owners of many of the mines, notably A. Hofman, mineral specimens found their way to the major mineralogical collections of western Europe. The latest iron mine, Bråstad, was closed in 1975. Nowadays, well preserved skarn sections can be visited at Lofstad on Tromøy and Langsev-Barbudalen in Arendal.

Among the non-metallic ores, apatite was especially important. The large Ødegårdens Verk deposit was jointly exploited by the Compagnie Française de Mines de Bamle and Bamble AS. French mining activities in the area reflect the active scientific interest in the area by some of the great French geologists during the 19th century, among them Daubrée (1843), Michel-Lévy (1878a,b) and Lacroix (1889).

Granitic pegmatites have also been mined. One of the most prominent of these was the Narestø pegmatite, situated just above the shore of a small bay on Flosta, thus guaranteeing easy transport. Pegmatite exploitation was done on a very local scale, by farmers who derived additional income from it during winter times. The

pegmatites were quarried for feldspar, which was sent to the porcelain factories at Porsgrunn and in Scotland, while quartz was locally used (at Arendal Smelteverk in Eydehavn, and at Kristiansand) for the manufacturing of ceramics. Some of the radioactive minerals occurring in the pegmatites, notably the one at Auselmyra, were sold to Madame Curie at Paris.

Contemporaneously with Lacroix, W.C. Brøgger, who later in his life would write his famous monograph on the Fen area and become his country's minister of education, actively studied the geology and petrology of the area; he continued his studies during the first decennia of the 20th century (e.g. Brøgger & Reusch, 1875; Brøgger & vom Rath, 1877; Brøgger, 1906a, 1934a, b). During the first half of this century, the Bamble sector was actively studied by, amongst others, four Norwegian geologists who made it one of the classical amphibolite to granulite facies transition zones, and whose names all start with the 'B' of Bamble. Besides Brøgger, already mentioned, these are Barth (1925, 1929), A. Bugge (1928, 1936) and J.A.W. Bugge (1940, 1943, 1945). In the same period, the first age estimates became available, based on lead abundances (Bakken & Gleditsch, 1938). Radiometric age determinations (on specimens from the Narestø pegmatite) were performed as early as the mid-fifties (Holmes et al., 1955). Later, the area became under investigation by several research groups and individuals.

Summary of regional geology

The Bamble sector is part of the Southwest Scandinavian Domain (Fig. 1), the relatively late accreted part of the Baltic Shield (Verschure, 1985; Gaál & Gorbatschev, 1987). The continuation of the Bamble sector below the Skagerrak is obscured by the Skagerrak Graben, a continuation of the Oslo Rift. Inland, the Porsgrunn-Kristiansand Fault (PKF; also denominated as Great Breccia, Great Friction Breccia, or Kristiansand-Bang Shear Zone) is traditionally considered to separate the Bamble sector from the neighbouring Telemark gneisses (Bugge, 1928, 1936; Starmer, 1985, 1990, 1993). However, both the style of deformation (Falkum & Petersen, 1980; Hagelia, 1989) and distribution of Bouguer anomalies (NGU, 1971) indicate some kind of continuity of the Bamble sector over the PKF. Elaborate descriptions of the lithological relationships in the area have been compiled by Starmer (1985, 1990, 1991, 1993). There is no point in duplicating this work. Here we will just introduce the reader to the central part of the Bamble sector.

The oldest rocks recognized in the area so far are clastic metasediments. In the Arendal-Froland-Nelaug part of the Bamble sector, at least three different suites of supracrustals may be identified, whose mutual stratigraphic and age relationships have still to be solved:

1) The Hisøy-Merdøy Supracrustal Suite (HMSS), which occurs on the islands of Hisøy and Merdøy, the western tip of Tromøy and several smaller islands. Characteristic are decimetre- to metre-scale alterations of quartzitic rocks, with the relatively frequent occurrence of millimetre- to centimetre-thick sillimanite-garnet-biotite seams. Deposition of these sediments occurred prior to at least 1.37 Ga (Knudsen et al., 1997).

2) The Nidelva Quartzite Complex (NQC), which is exposed between the post-tecton-

ic Herefoss granite and the Nidelva river, and is characterised by the occurrence of massive, relatively pure quartzites, with minor intercalations of metapelites, nodular gneisses, cordierite-orthoamphibole rocks, and monomict, intraformational conglomerates. The lithological association and locally preserved primary sedimentary structures, like large metre-scale cross-bedding, small-scale cross-bedding, ripple marks, and desiccation cracks indicate a continental depositional environment (Nijland et al., 1993a). The well known corundum-bearing gneisses occurring north of Froland (Oftedahl, 1963; Nijland et al., 1993b) have been interpreted as metamorphosed kaolinite-bauxite weathering crusts (Serdyuchenko, 1968). The NQC has been deposited prior to 1.47 Ga (Nijland and coworkers, unpubl. data), and is likely to be correlated with the Coastal Quartzite Complex (CQC) in the Kragerø area (Starmer, 1985).
3) The Selås Banded Gneisses (SBG), which are constituted by a series of banded, migmatitic, quartzofeldspathic gneisses, with abundant thin intercalations of amphibolites, and sulphurous horizons. The rocks likely represent metagreywackes, and have been interpreted as of turbiditic origin (Touret, 1966, 1968, 1969). They have most likely been deposited before 1.51 Ga (Moorbath & Vokes, 1963). The well-known Ettedal (Espeland) Pb-Zn-Ag-deposit occurs within these rocks (Naik, 1975; Naik et al., 1976; Krijgsman, 1991a, b).

Carbonaceous rocks are rare in the Bamble sector, but minor marbles and skarns occur throughout the area. Especially the skarns, with their associated magnetite mineralisations and salient minerals, have attracted a lot of attention (Barth, 1925; Bugge, 1945, 1951, 1954, 1960).

Cordierite-orthoamphibole rocks occur throughout the area as small lenses and boudins (Bugge, 1940, 1943; Beeson, 1976, 1988; Visser & Senior, 1990; Visser, 1993a). They are a minor lithology qua volume, intercalated in both the HMSS and NQC, but are important with respect to unravelling the metamorphic history and sedimentary environment. Different occurrences have been interpreted as either meta-evaporites (Touret, 1979; Visser et al., 1991; Nijland et al., 1993a), or as metamorphosed volcanics which underwent alteration prior to metamorphism (Visser, 1993a, 1995).

The supracrustals have been reworked, metamorphosed and intruded during the Gothian and Sveconorwegian orogenies. Prominent intrusive rocks are the so-called 'hyperites' (Brøgger, 1934a), tholeiitic olivine-bearing gabbros that are often coronitic (de Haas et al., 1992a, 1993a, b). These intruded the area during both the Gothian and Sveconorwegian orogenies (de Haas et al., 1992b, 1993b). Some of these small gabbros show well developed primary igneous layering (Touret, 1968, 1969; de Haas et al., 1993a).

Several bodies of charnockitic to granitic augen gneiss have been emplaced during the Sveconorwegian orogeny (Hagelia, 1989; Andersen et al., 1994; Heaman & Smalley, 1994). These are surrounded by a few hundred metres wide granulite facies contact metamorphic aureoles (Hagelia, 1989; Nijland & Senior, 1991). Three of these, the Hovdefjell-Vegårshei augen gneiss (HVAG), the Ubergsmoen augen gneiss (UAG) and the Gjerstad augen gneiss (GAG) occur in a zone featured by intense mylonitic deformation, bordering the PKF. A fourth body, the Gjeving augen gneiss (GVAG) occurs in the coastal area. The rocks are Fe-rich, containing orthopyroxene among the most Fe-rich natural ones known (UAG; Lieftink, 1992), rare pigeonite (HVAG; Krijgsman, 1991c) and fayalite (HVAG; P. Hagelia, pers. com., 1996). Large,

discordant NW-SE trending bodies of granitic gneisses, often rich in magnetite, occur, and postdate at least one generation of layered gabbros. They may be correlated with the augen gneisses, or, alternatively, with the Holt granite, which is in fact a gneissic granite (Nijland, 1993).

Large scale low to medium temperature alteration affected both metasediments and metagabbros at a localised but regional scale, and involved the development of albite-actinolite-quartz (AAQ) assemblages (Brøgger, 1934a; Elliott, 1966; Kloprogge, 1987; Nijland et al., 1993c). These rocks have also been termed albitites, and are often enriched in Ti-minerals (titanite, rutile), in which case they have been termed *kragerrite* (Johannsen, 1937; Force, 1991). They are similar to the albite-rich rocks from the Kongsberg sector (Jøsang, 1966; Munz et al., 1994, 1995), which have been dated at 1.09 Ga (Munz et al., 1994). Earlier hydrothermal activity involved the emplacement of hydrothermal dolomitic marbles in the Kragerø area (Bugge, 1965) at c. 1.18 Ga (Dahlgren et al., 1993).

Late, not to low-grade metamorphic granitic sheets intruded the area during the Late Sveconorwegian, and have been dated at 1.06 Ga (Field & Råheim, 1979). In addition, two types of pegmatites occur in the area:
1) Large irregular bodies, often featured with enrichment in rare elements and providing many of the mineral specimens for which the area is well known, like the Gloserhei pegmatite in the Froland area and the Tangen pegmatite in the Kragerø area (e.g. Brøgger, 1906a; Åmli, 1975, 1977; Pl. 1, fig. a), and
2) Low angle pegmatites, which are much smaller, usually less than 2 m thick, that intruded along a joint system (Nijland, 1993). Type 1 pegmatites have been dated at c. 1.06 Ga (Baadsgaard et al., 1984). The post-tectonic Herefoss and Grimstad granites intruded the area at 0.93 (Andersen, 1997) and 0.99 Ga (Kullerud & Machado, 1991), respectively.

Late dykes (dolerites, lamprophyres, rhombporphyry dykes) which have intruded the Precambrian basement are prominent in the area. Most of these are related to Permian rifting in the Oslo region (Sundvoll & Larsen, 1991), whereas some intruded during the Tertiary (Støretvedt, 1968), and possibly Devonian and Eocambrian (Moree, 1994).

Metamorphism

A well developed regional amphibolite to granulite facies transition zone is situated in the area outlined above. This transition zone is characterized by the following, south facing, isograd sequence (Touret, 1971; Nijland & Maijer, 1993):

-Ms	Muscovite-out in quartzitic rocks
+Crd	Cordierite-in in metapelitic rocks
+Opx(1)	Orthopyroxene-in in amphibolites
+Opx(2)	Orthopyroxene-in in acidic gneisses
-All	Allanite-out in gneisses, metapelites and amphibolites
-Ttn	Titanite-out in gneisses, metapelites and amphibolites

The isograds are accompanied by increasing recrystallization of sillimanite from a fibrolitic habit to an euhedral prismatic habit. In addition, isopleths for Ti in hornblende and biotite from amphibolites increase with increasing metamorphic grade.

$Fe^{2+}/(Fe^{3+} + Fe^{2+})$ of both biotite and hornblende also varies with metamorphic grade (Nijland, 1993). Geothermobarometry indicates P,T conditions of c. 750°C and 7.1 kb in the amphibolite facies area (Nijland & Maijer, 1993) and c. 830°C, 7.4 kb in the granulite facies area (Nijland & Maijer, 1993; Knudsen, 1996). Peak metamorphism gave rise to the development of kornerupine-bearing assemblages in cordierite-orthoamphibole rocks (Visser & Senior, 1990; Visser, 1993a, 1995). Breakdown of cordierite in these rocks resulted in the development of lower temperature borosilicate assemblages, comprising dumortierite (Michel-Lévy & Lacroix, 1888; Visser & Senior, 1990, 1991) and rare grandidierite (Visser & Senior, 1990).

The (supposed) age of metamorphism in the Bamble sector became controversial during the eighties (e.g. Field & Råheim, 1979; Field et al., 1985). Since, detailed U-Pb zircon geochronology has demonstrated the presence of c. 1.1 Ga Sveconorwegian lower intercepts and overgrowths (Kullerud & Machado, 1991; Knudsen et al., 1997). This is corroborated by Sm-Nd mineral and mineral + whole rock isochron ages on granulite facies samples which ranges between 1.07 and 1.1 Ga (Kullerud & Dahlgren, 1993), although the closure temperatures of various minerals involved are not well constrained.

Topographical and systematic mineralogy

Minerals in the Bamble sector are largely confined to five modes of occurrence: 1) high grade metamorphic minerals, 2) minerals occurring in synorogenic intrusions and related ore deposits, 3) minerals in late orogenic granitic pegmatites, 4) minerals related to Late Sveconorwegian albitization, which resulted in albite-actinolite-quartz rocks and albitites, and 5) mineral occurrences related to post-Sveconorwegian activity. Below, minerals from all these occurrences are listed according to Strunz (1982). Only minerals currently recognized by the IMA are considered; in a few cases, some old names and/or varieties are mentioned, and set in italics. The main localities in the central part of the Bamble sector are depicted in Fig. 2. Spelling of place names etc. is (as much as possible) according to the one currently used on the 1:50,000 topographical map sheets by Norges Geografiske Oppmåling.

Elements

Metals

A specimen of native **copper**, labeled Arendal, is present in the collections of the Nationaal Natuurhistorisch Museum, Leiden (Pl. 1, fig. b).

Silver has been reported from carbonate veins in metasediments that were intruded by late dolerite dykes at Stølsvik on Hisøy (Vogt, 1884, 1886), at Landviksvannet near Grimstad (Vogt, 1884), and at Nødebro near Arendal (Scheerer, 1848b; Kjerulf & Dahll, 1861; Vogt, 1891). In addition, silver has been reported in samples from the Pb-Zn deposit at Tråk, in the eastern part of the Bamble sector, and from the old Cu-mine at Bøylestad near Froland (Neumann, 1985).

Gold has been reported as an accessory mineral from some of the iron ore

Fig. 2. Main localities (small towns etc.) in the central part of the Bamble Sector, as mentioned in text. The following localities have been indicated by numbers: 1: Auselmyra, 2: Gladstad, 3: Barbudalen, 4: Langsev, 5 : Solberg, 6: Klådeborg, 7: Arendal, 8: Vågsnes, 9: Lofstad, 10: Alve.

deposits in the Arendal area, viz. Nedenes (Pontoppidan, 1752), Barbudalen (Pontoppidan, 1752; Scheerer, 1845a), and Langsev (Scheerer, 1845a). Daubrée (1843) also reported gold from the Arendal area. In addition, it has been reported from the silver-bearing carbonate veins at Stølsvik on Hisøy (Vogt, 1884), from a pegmatite near Ranevik, Risør (Brøgger, 1906a), and from quartz veins at Lofthus near Lillesand and at Stabbestad on Skåtøy, off-shore from Kragerø (Neumann, 1985).

Metallic **iron** has been reported to occur in the ore zones associated with the Holt granite at Våland near Tvedestrand (Helland, 1904).

Metalloides and non-metals

Bismuth has been found in the ores from the Ettedal (= Espeland) Pb-deposit (Naik, 1975; Naik et al., 1976; Krijgsman, 1991a), and in the gold-bearing pegmatite at Ranevik near Risør (Brøgger, 1906a).

Graphite is a common accessory mineral in many rock types like marbles (Falkum, 1966; Touret, 1968), skarns (Kristiansand: Barth, 1925; Løddesøl: Bugge, 1945), gneisses (Touret, 1968; Field & Rodwell, 1968; Alberti & Comin-Chiaramonti, 1974; Beeson, 1975; Field & Starmer, 1982; Broekmans et al., 1994), and metapelites (Starmer, 1972, 1976). In addition, it has been reported from the Skyttemyr and Bøylestad Cu-deposits (Bugge, 1978). Coarse-grained hydrothermal graphite occurs in some quartz veins, especially in the Ubergsmoen area (Broekmans et al., 1994).

Sulphur has been reported from pegmatites at Tvedestrand (Andersen, 1926), Søndeled, Gjerstad, and Rosseland (Neumann, 1985).

Sulphides

Sulphides with Me:S > 1:1

Chalcosite has been reported from the skarns at Arendal (Bugge, 1954).

Bornite was reported from the surroundings of Arendal, Tvedestrand and Kragerø by Weibye (1847) who did not state its mode of occurrence. Bugge (1954) reported bornite from the skarns at Arendal, whereas Andersen (1931) mentioned in from the Hasalvik pegmatite in the Bamble community.

Argentite has been reported from silver-bearing carbonate veins associated with dolerites at Stølsvik on Hisøy (Vogt, 1884).

Hessite occurs as an accessory mineral in the ores from the Ettedal Pb-deposit (Naik, 1975; Naik et al., 1976).

Pentlandite occurs as a major phase in the Messel (Brickwood, 1986) and Nystein (Kuiperus, 1986) Ni-deposits, both of which are associated with gabbroic intrusions. Besides normal pentlandite, **cobaltian pentlandite** (with up to 9.9 wt.% Co) also occurs in the Messel Ni-deposit (Brickwood, 1986).

Sulphides with Me:S = 1:1

Sphalerite has since long been known from the Bamble sector (Arendal: Weibye, 1847; Brevik: Weibye, 1849), although its specific occurrence was not reported. It is an important mineral in several ore deposits, viz. the Ettedal Pb-deposit (Moorbath & Vokes, 1963; Naik, 1975; Naik et al., 1976; Krijgsman, 1991a), the Skyttemyr and Bøylestad Cu-mines (Bugge, 1978), and the Tråk Zn-Pb-deposit (Røsholt, 1967). In addition, it sporadically occurs in the skarns around Arendal (Bugge, 1954).

Chalcopyrite is a common mineral in the Bamble sector. It occurs as an accessory phase in the skarns around Arendal (Weibye, 1847; Bugge, 1940, 1954; Broekmans et al., 1994) and at Løddesøl (Bugge, 1945), in many amphibolites (Nijland et al., 1993d), and in Fe-rich felsic intrusions like the Ubergsmoen Augen Gneiss. It occurs also accessorially in several pegmatites, like those at Tangen (Andersen, 1931; Green,

1956), Lindtstøl, and Hella and Morefjær, both near Arendal (Andersen, 1931), in apatite-enstatite-phlogopite veins at Ødegårdens Verk (Brøgger & Reusch, 1875; Sjögren, 1883) and in apatite-hornblende veins at Noerestad near Risør (Solly, 1892). It is an important mineral in the Ettedal Pb-deposit (Moorbath & Vokes, 1963; Naik, 1975; Naik et al., 1976; Krijgsman, 1991a), the Messel (Brickwood, 1986) and Nystein (Kuiperus, 1986) Ni-deposits, the Skyttemyr and Bøylestad Cu-deposits (Bugge, 1978), the Tråk Zn-Pb-deposit (Røsholt, 1967), and the ore-zone in the Blengsvatn gabbro (van Linschoten, 1989). Chalcopyrite is also a common accessory in small quartz mobilisates together with tourmaline, scapolite, and siderite/ankerite, for example in the skarns at Lofstad and Arendal.

Tetrahedrite has been reported from the skarns around Arendal (Bugge, 1943).

Freibergite occurs as a minor phase in the ores from the Ettedal Pb-deposit (Naik, 1975; Naik et al., 1976; Krijgsman, 1991a).

Galena is a major mineral in the Ettedal Pb-deposit (Moorbath & Vokes, 1963; Naik, 1975; Naik et al., 1976; Krijgsman, 1991a,b), the Tråk Zn-Pb-deposit (Oftedal, 1959; Røsholt, 1967). It also occurs in the Skyttemyr and Bøylestad Cu-mines (Bugge, 1978).

Matildite has been reported as an accessory phase in ores from the Ettedal Pb-deposit (Oftedal, 1942).

Pyrrhotite has since long been known from the Bamble sector (e.g. Weibye, 1847). It occurs as an accessory mineral in marbles (Falkum, 1966), the skarns at Kristiansand (Barth, 1925, 1928), pegmatites (Hella near Arendal: Andersen, 1931), and amphibolites (Nijland et al., 1993d). It is a major constituent of the Ettedal Pb-deposit (Moorbath & Vokes, 1963; Naik, 1975; Naik et al., 1976; Krijgsman, 1991a,b), the Messel (Brickwood, 1986) and Nystein (Kuiperus, 1986) Ni-deposits, the Skyttemyr and Bøylestad Cu-deposits (Bugge, 1978), the Tråk Zn-Pb-deposit (Røsholt, 1967), the ore-zone in the Blengsvatn gabbro (van Linschoten, 1989), and the pyrrhotite deposit just west of Imeneskilen, NW of Grimstad (M.A.T.M. Broekmans, pers. com., 1995). In addition, it occurs in apatite-hornblende veins at Fogne and Hiåsen, both near Gjerstad, and Valeberg near Kragerø (Brøgger & Reusch, 1875), and at Noerestad near Risør (Solly, 1892). Pyrrhotite is also a common accessory in sulphureous banded gneisses with graphite, and in calcite ± scapolite ± biotite ± quartz alteration veins in gabbroic and amphibolitic rocks, e.g. at the quarry in the Vestre Dale Gabbro in the Froland area.

Millerite occurs as an accessory phase in the Messel Ni-deposit (Brickwood, 1986).

Nickeline occurs in Ag-bearing carbonate veins associated with dolerites at Stølsvik on Hisøy (Vogt, 1884; Oftedal, 1939) and Nødebro near Arendal (Scheerer, 1848b; Vogt, 1891). It also occurs in magnetite ores associated with gabbro on Langøy, off-shore of Kragerø (Scheerer, 1845b; 1848a,b; Kjerulf & Dahll, 1861).

Breithauptite occurs as an accessory phase in the Ettedal Pb-deposit (Naik, 1975; Naik et al., 1976).

Sulphides with Me:S < 1:1

Violarite has been reported as an accessory phase from the Messel (Brickwood, 1986) and Nystein (Kuiperus, 1986) Ni-deposits. **Cobaltian violarite** (5-19 wt.% Co) occurs together with violarite in the Messel deposit (Brickwood, 1986).

Bismuthinite is a rare mineral in the magnetite ores associated with gabbro on Langøy, off-shore of Kragerø (Vogt, 1918).

Pyrite is a common accessory in gneisses (Falkum, 1966; Beeson, 1975; Starmer, 1976), amphibolites (Falkum, 1966; Starmer, 1969a; Nijland et al., 1993d), metapelites (Starmer, 1976), marbles (Falkum, 1966), and albitites (Green, 1956). It occurs in the skarns at Kristiansand (Barth, 1925, 1928), Arendal (Bugge, 1940, 1954), and Løddesøl (Bugge, 1945). It is a constituent of the ores at the Messel (Brickwood, 1986) and Nystein (Kuiperus, 1986) Ni-deposits, the ore zone in the Blengsvatn gabbro (van Linschoten, 1989), the Skyttemyr and Bøylestad Cu-deposits (Bugge, 1978), and the Tråk Zn-Pb-deposit (Røsholt, 1967). It occurs in apatite-enstatite-phlogopite veins at Ødegårdens Verk (Brøgger & Reusch, 1875) and in apatite-hornblende veins at Fogne near Gjerstad (Brøgger & Reusch, 1875). Pyrite also occurs in many pegmatites, like those at Kalstad and Lindvikskollen (Green, 1956), Tangen (Andersen, 1931; Green 1956), Hella and Mørefjær, both near Arendal, Lindtstøl (Andersen, 1931), and Gloserhei (Åmli, 1975, 1977). **Nickeloan pyrite** occurs together with normal pyrite in the Messel Ni-deposit (up to 5.7 wt.% Ni: Brickwood, 1986).

Vaesite has been reported from a sulphide ore zone the Vissestad gabbro in the Bamble municipality (R. Morton, in Neumann, 1985).

Cobaltite occurs as an accessory mineral in the Messel Ni-deposit (Brickwood, 1986).

Willyamite has been found as an accessory mineral in the Ettedal Pb-deposit (Naik et al., 1976).

Ullmannite has been reported as an accessory phase from the Ettedal Pb-deposit, as is **cobaltian ullmannite** (Naik, 1975; Naik et al., 1976).

Marcasite occurs in the skarns at Løddesøl (Bugge, 1945) and Arendal (Bugge, 1954), and from the sulphidic ore zone in the Blengsvatn gabbro (van Linschoten, 1989). It has also been reported from Ag-bearing carbonate veins on Hisøy (Vogt, 1884, 1886).

Arsenopyrite has since long been known from the Arendal, Tvedestrand and Kragerø areas (Weibye, 1847; type of occurrence not specified). It also occurs in the Ettedal Pb-deposit (Moorbath & Vokes, 1963; Naik, 1975; Naik et al., 1976; Krijgsman, 1991a), and the Bøylestad and Skyttemyr Cu-deposits (Bugge & Foslie, 1922).

Gudmundite occurs as an accessory phase in the Ettedal Pb-deposit (Naik, 1975; Naik et al., 1976).

Molybdenite has been reported from the Bamble sector as long ago as the eighteenth century (Brünnich, 1777; Schumacher, 1801). It occurs as an accessory mineral in marbles (Falkum, 1966), skarns at Kristiansand (Barth, 1925, 1928) and Arendal (Bugge, 1943), and pegmatites, for example at Skogstad (Andersen, 1931). Molybdenite seems to occur especially in those pegmatites which are in contact with amphibolites. It also occurs in apatite-hornblende veins at Noerestad near Risør (Solly, 1892).

Skutterudite (*smaltite*) has been reported from the skarns around Arendal (Bugge, 1943).

Sulphosalts

Pyrargyrite occurs in ores from the Ettedal Pb-deposit (Naik, 1975; Naik et al.,

1976; Krijgsman, 1991a).

Stephanite occurs as an accessory mineral in the Ettedal Pb-deposit (Naik, 1975; Naik et al., 1976; Krijgsman, 1991a).

Boulangerite occurs as a rare phase in ores from the Ettedal Pb-deposit (Naik et al., 1976), where it coexists with argentian boulangerite (Naik et al., 1976; Krijgsman, 1991a).

Halogenides

Halogenides with Me:X = 1:2

Fluorite occurs in the skarns at Kristiansand (Barth, 1925, 1928) and Arendal (Weibye, 1847; Bugge, 1954), with calcite, quartz and prehnite in late veins (Broekmans et al., 1994), along late fractures, for example in the Ubergsmoen area, and as retrograde lenses in biotites in late dykes on Tromøy. Light green REE-bearing fluorite occurs in late fissures near Hynnekleiv.

Oxides and hydroxides

Spinels

Spinel-hercynite solid solutions were already reported from Arendal by Weibye (1847). Spinel occurs in the skarns at Kristiansand (Barth, 1925, 1928), Arendal (Bugge, 1940; Broekmans et al., 1994), and Lofstad on Tromøy (Broekmans et al., 1994). Spinel also occurs in corona structures in many gabbros (Bugge, 1940; Frodesen, 1968a; Starmer, 1969a; de Haas et al., 1992a), and in sapphirine-bearing rocks, like those at Hasleholmen (Lamb, 1981; Kihle & Bucher-Nurminen, 1992), Rangleåsen, Gladstad and Snaresund (Lamb, 1981), and in cordierite-orthoamphibole rocks (Visser, 1993a).

Gahnite occurs in skarns around Arendal (Scheerer, 1845a; Weibye, 1847).

Magnetite is a common accessory in gneisses (Bugge, 1940; Dietrich, 1960; Falkum, 1966; Comin-Chiaramonti, 1974), amphibolites (Falkum, 1966; Starmer, 1969a, 1976; Nijland et al., 1993d), marbles (Falkum, 1966), metapelites (Starmer, 1969b, 1972), quartzites (Starmer, 1976), skarns (Kristiansand: Barth, 1925, 1928; Arendal: Bugge, 1940; Broekmans et al., 1994; Løddesøl: Bugge, 1945), and in gabbros (Bugge, 1940; Frodesen, 1968b; Starmer, 1969a; Brickwood, 1986). V-bearing magnetite (up to 1.9 wt.% V_2O_3) occurs in the Messel Ni-deposit (Brickwood, 1986). Magnetite also occurs in the Tråk Zn-Pb-deposit (Røsholt, 1967), the Nystein Ni-deposit (Kuiperus, 1986), the sulphidic ore zone in the Blengsvatn gabbro (van Linschoten, 1989), and in veins on Langøy off-shore of Kragerø (Bugge, 1978). Large magnetite deposits are associated with the skarns around Arendal, and with the Holt granite. Several pegmatites, like those at Tangen (Bjørlykke, 1937; Green, 1956), Kalstad, Lindvikskollen, Sjåen (Green, 1956), Buøya (M.A.T.M. Broekmans, pers. com., 1995), and Gloserhei (Åmli, 1975, 1977) contain magnetite. **Titanomagnetite** occasionally occurs as an accessory phase in gabbros (Glaveris, 1970), amphibolites (Starmer, 1969a), and albitites (Green, 1956).

Ulvöspinel has been reported from one gabbro near Herre, in the Bamble community (Carstens, 1957). Magnetite in a granitic pegmatite on Buøya, near Tvedestrand, contains exsolution lamellae of ulvöspinel (M.A.T.M. Broekmans, pers. com., 1995).

Chrysoberyl has been found in the Lindtsøl pegmatite (Andersen, 1931).

Sesquioxides

Corundum is a major constituents of the corundum-bearing rocks at Kleggåsen, near Froland (Oftedahl, 1963; Nijland et al., 1993b; Pl. 2, fig. a). The beautifully red corundum crystals are too impure to be gem rubies, as they were designated by Oftedahl (1963). Large blue corundum crystals occur in partly molten metapelites at Maltemyra, south of Nelaug (Nijland, 1989). Corundum occurs as an accessory in albitites (Green, 1956), in sapphirine-bearing rocks at Hasleholmen (Lamb, 1981; Kihle & Bucher-Nurminen, 1992) and Rangleåsen (Lamb, 1981), and in cordierite-orthoamphibole rocks (Visser & Senior, 1990).

Hematite is a common (secondary) accessory in gneisses (Falkum, 1966), amphibolite (Falkum, 1966; Starmer, 1969a), quartzites (Starmer, 1976), and marbles (Falkum, 1966); it occurs more rarely in gabbros (Starmer, 1969a). Hematite also occurs in sapphirine-bearing rocks at Hasleholmen (Kihle & Bucher-Nurminen, 1992), the Tråk Zn-Pb-deposit (Røsholt, 1967), and in some pegmatites (Tangen: Green, 1956; Gloserhei: Åmli, 1975, 1977). Mirrors of hematite occur on fracture planes in albite-actinolite-quartz rocks, e.g. around the Uvatn, NW of Jåmmås, and in retrograded clinopyroxene-garnet skarns, e.g. at Vågsnes on Tromøy.

Ilmenite is a common minor mineral in albitites (Force, 1991) and gabbros (Frodesen, 1968b; Brickwood, 1986; de Haas et al., 1992a). Ilmenite occurs in the Nystein Ni-deposit (Kuiperus, 1986) and the Blengsvatn gabbro ore-zone (van Linschoten, 1989). Large masses of ilmenite, of over 100 kg, occur in metagabbroic rocks near the Ødegårdens Verk apatite deposit (M.A.T.M. Broekmans, pers. com., 1995). It sporadically occurs in pegmatites, notably those at Kalstad, Lindvikskollen near Kragerø (Green, 1956) and at the Buøya peninsula near Tvedestrand (M.A.T.M. Broekmans, pers. com., 1995). Ilmenite is a common accessory in gneisses (Comin-Chiaramonti, 1974), amphibolite (Starmer, 1969a, 1976; Nijland et al., 1993d), metapelites (Starmer, 1969a), cordierite-orthoamphibole rocks (Visser & Senior, 1990; Visser, 1993a), and quartzites (Starmer, 1976). It also occurs in apatite-enstatite-phlogopite veins at Ødegårdens Verk (Sjögren, 1883; Neumann et al., 1960), and apatite-hornblende veins at Hiåsen near Gjerstad, Lykkens and Valeberg, both near Kragerø, and Havredal in the Bamble community (Brøgger & Reusch, 1875). *Hystatite*, a species described from Arendal by Breithaupt (1830, p. 30), is a mixture of ilmenite with hematite and/or magnetite.

Högbomite occurs as a secondary phase in sapphirine-bearing rocks at Gladstad (Visser et al., 1992). A few crystals of högbomite have recently been identified as inclusions in ilmenite in a preiswerkite-biotite-tourmaline-scapolite rock from the Nidelva Quartzite Complex, in the Froland area.

Davidite has been reported from a pegmatite at Bringebærkastet on Langry, offshore of Kragerø (Neumann, 1985).

Betafite has been reported from the Tangen and Sjåen pegmatites (Green, 1956).

The variety *tangenite*, from the Tangen pegmatite (Gagarin & Cuomo, 1949, p. 10) represents a mixture, mainly composed by betafite.

Microlite has been found in the Mørkhøgda pegmatite, near Gjerstad (Bjørlykke, 1937).

Pseudobrookite was first mentioned from a pegmatite near Havredal in the Bamble community by Brøgger (1888), and subsequently reinvestigated by Smith (1969).

Dioxides

Quartz is a major rock forming mineral of most rocks in the Bamble sector. Several varieties, like smoky quartz etc., have been reported from many pegmatites. Small crystals occur in miarolitic voids in many pegmatites, e.g. at Moen near Tvedestrand. High purity quartz often occurs in association with albite-actinolite-quartz rocks. Rose quartz has been found in veins at the Solemsvatn in the Froland municipality.

Chalcedony has been found in the skarns around Arendal (Weibye, 1847).

Rutile is a common accessory in many rock types like quartzites (Bugge, 1940; Green, 1956; Starmer, 1976), amphibolite (Green, 1956; Frodesen, 1968b; Starmer, 1969a; Nijland et al., 1993d), cordierite-orthoamphibole rocks (Beeson, 1976; Starmer, 1976; Visser & Senior, 1990; Visser 1993a), the Froland corundum-rocks (Oftedahl, 1963; Nijland et al., 1993b), and skarns (Kristiansand: Barth, 1925, 1928; Løddesøl: Bugge, 1945). It also occurs as accessory mineral in some pegmatites, like the one at Gloserhei (Åmli, 1975, 1977). Rutile is present in some sulphidic ore zones associated with metagabbros, like those at Nystein (Kuiperus, 1986) and Blengsvatn (van Linschoten, 1989). It occurs in apatite-enstatite-phlogopite veins at Ødegårdens Verk (Brøgger & Reusch, 1875; Sjögren, 1883; Neumann et al., 1960; Lieftink et al., 1993, 1994), and apatite-hornblende veins at many localities (Brøgger & Reusch, 1875; Sjögren, 1883; Solly, 1892). Relatively large rutiles occur associated with albitites, e.g. at Lindvikskollen near Kragerø (Green, 1956; Bugge, 1978; Force, 1991) and in a small prospection pit northwest of Flaten. Dark purple-coloured oxygen-deficient rutiles rarely occur in graphitic gneisses, e.g. near Ubergsmoen, and altered metagabbro at Ødegårdens Verk.

Ilmenorutile has been found in several granitic pegmatites, like those at Auselmyra (Brøgger, 1906a; Neumann, 1961), Ramskjær near Søndeled (Schetelig, 1913; Andersen, 1931; Neumann, 1961), and Monbue on Tromøy (Schetelig, 1913; Neumann, 1961).

Anatase occurs in the skarns around Arendal (Bugge, 1943). It has also been observed as retrograde breakdown product of titanite in apatite-hornblende veins near Kragerø (Hamberg, 1886), in hydrothermal dolomitic marbles near Kammerfoss, Kragerø (Schei, 1904), and in charno-enderbitic gneisses from the Arendal area.

Columbite has been reported from several pegmatites in the Bamble sector, like those at Tangen (Andersen, 1931; Bjørlykke, 1937; Green, 1956; Neumann, 1961), Sannikdal (Milch, 1900), Ramskjær near Søndeled (Andersen, 1931), and Øvre Gjerstad (Neumann, 1961).

Euxenite has first been reported by Weibye (1847) from the Arendal area. It occurs in many pegmatites: Alve on Tromøy (Brøgger, 1906a), Ranevik near Risør (Brøgger, 1906a), Kalstad, Lindvikskollen and Sjåen, all near Kragerø (Andersen, 1931; Green, 1956), Tangen, also near Kragerø, Lindtstøl (Andersen, 1931), Gloserhei

(Åmli, 1975, 1977), Hella near Arendal (Andersen, 1931), Mørefjær (Andersen, 1931), and Lauvrak (M.A.T.M. Broekmans, pers. com., 1995).

Aeschynite-Y, known in the old Bamble literature as *blomstrandine*, has been found in pegmatites near Arendal (Brøgger, 1906a) and at Mørefjær (Andersen, 1931). Crystals with a high metallic lustre occur in the pegmatite at Gloserhei.

Yttrotantalite-Y has been observed in the Hella pegmatite near Arendal (Brøgger, 1906a; Andersen, 1931).

Fergusonite occurs in many of the granitic pegmatites in the Bamble sector, like those at Hella near Arendal (Forbes & Dahll, 1855; Andersen, 1931), Narestø on Flosta, Alve and Hampemyr on Tromøy (Forbes & Dahll, 1855), Arendal (Brøgger, 1906a), Ranevik near Risør (Brøgger, 1906a), Gryting near Risør (Hauser, 1908; Barth, 1927), Mørkhøgda near Gjerstad (Bjørlykke, 1937), Kalstad, Lindvikskollen near Kragerø (Green, 1956), and Rullandsdalen near Risør (Butler & Hall, 1960). The variety *risørite* (Hauser, 1908) was originally described as a separate mineral species from Gryting, near Risør, whereas *bragite*, now also discredited, was described from the Narestø pegmatite (Forbes & Dahll, 1855).

Samarskite has been found in granitic pegmatites at Ranevik near Risør (Brøgger, 1906a), Bjellåsen in the Froland community (Nilssen, 1970), Midtbø south of Ubergsmoen (D.J. Lieftink, pers. com., 1993), and at Lauvrak (M.A.T.M. Broekmans, pers. com., 1995).

Baddelyite has been found in the cores of zircons in metagabbros at Landvik, Grimstad, and Ravneberg near Risør (Dahlgren et al., 1990) and in the Jåmmåsknutene gabbro (C. Maijer, pers. com., 1992).

Uraninite, whose Y-bearing variety is known in the old Bamble literature as *cleveite*, occurs in several pegmatites: Garta near Arendal (Nordenskiöld, 1878), Auselmyra (Bakken & Gleditsch, 1938), Gloserhei (Åmli, 1975, 1977), and in a pegmatite cutting across the skarns at Alvekilen on Tromøy (M.A.T.M. Broekmans, pers. com., 1995).

Thorianite has been found as accessory mineral in the Levang gneiss (Neumann, 1985).

Hydroxides

Goethite occurs as accessory mineral in the Gloserhei pegmatite (Åmli, 1975, 1977), the Tråk Zn-Pb-deposit (Røsholt, 1967), and in the sulphidic ore zone associated with the Blengsvatn gabbro (van Linschoten, 1989).

Groutite has been discovered in the Klådeborg skarns near Arendal (J.A.W. Bugge, in Neumann, 1985).

Uranylhydroxides

Clarkeite has been found in one pegmatite near Gjerstad (A.O. Larsen, in Neumann, 1985).

Curite has been reported in samples from a pegmatite at Fone near Gjerstad in the British Museum of Natural History (Neumann, 1985).

Fourmarierite occurs in the Gloserhei pegmatite (Åmli, 1977).

Carbonates

Calcite is a common mineral in marbles, skarns, and late calcite veins from the entire Bamble sector. It also occurs as retrograde breakdown product in several other rocks.

Siderite has been reported from the Tråk Zn-Pb-deposit (Vogt, 1907; Røsholt, 1967).

Magnesite occurs associated with actinolite at Vegårshei (M.A.T.M. Broekmans, pers. com., 1995).

Dolomite is the main constituent of hydrothermal marbles in the surroundings of Kragerø (Bugge, 1965; Dahlgren et al., 1993). It also occurs as a primary phase in skarns at Lofstad on Tromøy (Broekmans et al., 1994) and in marbles near Flaten, Nelaug (Nijland, 1989; Broekmans et al., 1994). In addition, it has been reported by Reitan (1959) from carbonate-quartz veins at Rytterholmen, Kragerø.

Ankerite occurs in late veins in gneisses and amphibolites west of Arendal (Broekmans et al., 1994) and in skarns at Lofstad on Tromøy (M.A.T.M. Broekmans, pers. com., 1995).

Malachite has been reported from the Arendal and Tvedestrand areas by (Weibye, 1847), who did not further specify its mode of occurrence. It occurs as secondary mineral in Tråk Zn-Pb-deposit (Røsholt, 1967), and as weathering crusts on chalcopyrite in skarns at Lofstad on Tromøy (M.A.T.M. Broekmans, pers. com., 1995).

Parisite has been found in the Tangen pegmatite (R. Kristiansen, in Neumann, 1985).

Synchisite has been discovered in a pegmatite at Gryting near Gjerstad (R. Kristiansen, in Neumann, 1985).

Lokkaite has been found in the Tangen pegmatite (R. Kristiansen, in Neumann, 1985).

A specimen of **hydrotalcite** labelled Kragerø occurs in the collections of the Mineralogical-Geological Museum, Delft University of Technology.

Kamphaugite-(Y) has recently been discovered as a new mineral species, and was also reported from the Tangen pegmatite near Kragerø, where it occurs in cracks in quartz and feldspar (Raade & Brastad, 1993).

Borates

Cahnite was reported from the Klådeborg skarns, near Arendal by Bugge (1951).

Sulphates

Celestite possibly occurs in the Tråk Zn-Pb-deposit (Røsholt, 1967).

Baryte has been mentioned by Weibye (1847, 1849) from the basement near Brevig, possibly meaning the Tråk Zn-Pb-deposit, from which it was reported by Vogt (1907), and by Røsholt (1967). In addition, it occurs in some dykes on Tromøy (S.H. Dahlgren, pers. com., 1991).

Woodhouseite occurs as rare mineral in the apatite-enstatite-phlogopite veins at Ødegårdens Verk (Morton, 1961).

Phosphates

Whitlockite occurs as a rare mineral in apatite-enstatite-phlogopite veins at Ødegårdens Verk (Morton, 1961; Griffin et al., 1972).

Xenotime is present in many granitic pegmatites from the Bamble area, like those at Narestø (Brøgger, 1883; Blomstrand, 1887; Andersen, 1931; Neumann, 1961), Gloserhei (Åmli, 1975, 1977), Gryting near Gjerstad (Neumann, 1961), Austre Moland, Arendal (Neumann, 1961), Ramskjær near Søndeled (Andersen, 1931), Tråk (Røsholt, 1957), Lofstad on Tromøy (Brøgger, 1883), Lyngrot in the Froland municipality (Andersen, 1931), as well as in unspecified pegmatites in the Kragerø area (Betechtin, 1957). It also occurs in apatite-enstatite-phlogopite veins at Ødegårdens Verk (Neumann et al., 1960; Lieftink et al., 1994).

Monazite from Arendal was originally described as a separate species, *kryptolith*, by Wöhler (1846), which was subsequently shown to be identical with monazite. It occurs in many granitic pegmatites, among them those at Midtbø south of Ubergsmoen (Mallard, 1887), Risør (Schei, 1905), Gloserhei (Åmli, 1975, 1977), Narestø (Brøgger, 1906a; Andersen, 1931), Lyngrot (Andersen, 1931), Lauvland, Lauvrak, and Alvekilen (M.A.T.M. Broekmans, pers. com., 1995). In such granitic pegmatites, idiomorphic crystals of monazite are often associated with muscovite. Monazite also occurs as accessory mineral in gneisses and metapelites, in skarns at Vågsnes on Tromøy (Scheerer, 1848b), and in apatite-enstatite-phlogopite veins at Ødegårdens Verk (Neumann et al., 1960; Lieftink et al., 1994).

Wagnerite occurs in several apatite-hornblende veins, like those near Havredal (Helland, 1874; Brøgger & Reusch, 1875) and Haukedal (Neumann, 1985) in the Bamble municipality, and in apatite-enstatite-phlogopite veins at Ødegårdens Verk (Brøgger & Reusch, 1875; Neumann et al., 1960). It has also been reported from a pegmatite near Havredal (Smith, 1969). The now discredited variety *kjerulfine* was originally described from Kjørrestad (von Kobell, 1873, p. 272).

Apatite has been mined at several localities in the Bamble sector (Bugge, 1922). These so-called *apatite pegmatites* are either apatite-enstatite-phlogopite veins, which occur at Ødegårdens Verk (Helland, 1874; Brøgger & Reusch, 1875; Sjögren, 1883; Neumann et al., 1960; Lieftink et al., 1994), or apatite-hornblende veins, which occur at Fogne and Hiåsen near Gjerstad, at Ravneberg near Risør, in the obliterated Vuggens and Lykkens mines in Kragerø, at Havredal and Kaleberg near Kragerø (Brøgger & Reusch, 1875), at Landvik near Grimstad (Sjögren, 1883), at Noerestad, Risør (Solly, 1892), and Håvatn in the Froland municipality (Brøgger, 1934a). Apatite is also a common mineral in granitic pegmatites, like those at Kalstad-Lindvikskollen and Sjåen (Green, 1956), at Gloserhei (Åmli, 1975, 1977), where large euhedral green crystals occur, and at Hynnekleiv. It is a common accessory in quartzites (Green, 1956; Starmer, 1976), gneisses (Bugge, 1940; Dietrich, 1960; Falkum, 1966; Alberti & Comin-Chiaramonti, 1974; Beeson, 1975; Starmer, 1972), amphibolites (Green, 1956; Falkum, 1966; Frodesen, 1968b; Starmer, 1969a, 1976; Nijland et al., 1993d), metapelites (Starmer, 1969b, 1972), metagabbros (Bugge, 1940; Green, 1956; Frodesen, 1968b; Starmer, 1969a; de Haas et al., 1992a), cordierite-orthoamphibole rocks (Visser & Senior, 1990; Visser, 1993a), marbles (Falkum, 1966), and skarns (Kristiansand: Barth, 1925, 1928; Arendal: Bugge, 1940; Løddesøl: Bugge, 1945). Apatite occurs in

veins together with chalcopyrite, titanite, rutile, and calcite at the contacts of gabbros with their country rocks, like at Rønningen (Broekmans et al. 1994), and in actinolite-albite-quartz rocks, for example at Uvatn NW of Jåmmås. Apatites are generally F-rich varieties, especially in amphibolites (Nijland et al., 1993d), pegmatites and apatite-hornblende veins, like those at Håvatn. However, primary apatites in the apatite-enstatite-phlogopite veins at Ødegårdens Verk are near Cl-end members (Morton & Catanzaro, 1964, Lieftink et al., 1994); rarely, Cl-rich apatites also occur in amphibolites, for example near Ripåsen (Nijland et al., 1993d). The Cl-end member of apatite was first described from south Norway (Rammelsberg, 1860, p. 353). OH-dominated apatites tend to occur in alteration zones. The bluish-green variety *moroxite* was originally described from Arendal (Abilgaard, 1798, p. 349).

Carbonatehydroxylapatite, originally described as *dahllite* (Brøgger & Backstrøm, 1888), has been reported from the apatite-bearing veins at Ødegårdens Verk (Brøgger & Backstrøm, 1888; Neumann et al., 1960).

Bobierrite has been reported from the apatite-bearing veins at Ødegårdens Verk (Michel, 1893).

Vivianite occurs in the apatite-bearing veins at Ødegårdens Verk (Brøgger & Reusch, 1875) and in calcsilicate rocks from Froland (Beyer, 1992).

Silicates

Nesosilicates

Phenakite occurs in pegmatites from the surroundings of Kragerø, commonly as large prismatic crystals and twins together with quartz and albite. Large crystals have been found at Tangen (Hintze, 1897b; Backström, 1898; Andersen, 1931) and Kalstad-Lindvikskollen (Brøgger, 1906a; Green, 1956).

Eucryptite possibly occurs as minute flakes on spodumene in a Li-paragenesis in a pegmatite near Lien, at the Kilsfjord (Beyer, 1992).

Olivine is a common mineral in the metagabbros ('hyperites') from the Bamble sector (Green, 1956; Frodesen, 1968a,b; Starmer, 1969a; Glaveris, 1970; Brickwood, 1986; de Haas et al., 1992a). The Mg-end member forsterite also occurs in the skarns at Tromøy (Broekmans, 1992a; Broekmans et al., 1994) and Løddesøl (Bugge, 1945). The Fe-end member fayalite has so far been identified in samples from the monzonitic Morkheia Complex (Touret, 1967a) as well as in a syenitic sample of the Hovdefjell augen gneiss (P. Hagelia, pers. com., 1996).

Zircon is a common accessory in quartzites (Bugge, 1940; Green, 1956; Starmer, 1976), gneisses (Dietrich, 1960; Falkum, 1966; Starmer, 1972; Alberti & Comin-Chiaramonti, 1974; Beeson, 1975; Gupta, 1986), amphibolites (Green, 1956; Falkum, 1966; Starmer, 1976), skarns (Barth, 1925, 1928; Bugge, 1945), cordierite-orthoamphibole rocks (Starmer, 1976; Visser & Senior, 1990; Visser, 1993a), and metapelites (Starmer, 1969b; 1972). Crystals of variable size are common in most granitic pegmatites, like those at Lindvikskollen (Bjørlykke, 1937), Sjåen (Andersen, 1931), Tangen (Andersen, 1931; Green, 1956), and Gloserhei (Åmli, 1975, 1977). In feldspathic parts of some pegmatites, like those at Lauvland, Alvekilen and Hynnekleiv, zircon occurs as intergrowths of several crystals up to several centimetres in size, with a so-called azonite-

habit (pseudo-octahedra). The zircons have occasionally been called *alvite* or *malakon*. The discredited species *oerstedite* (Forchhammer, 1835, p. 630) represents an altered, reddish brown variety of zircon.

Thorite, occasionally called *orangite*, occurs in several of the well-known granitic pegmatites of the Bamble sector, like those at Lindtstøl (Andersen, 1931), Kalstad (Andersen, 1931), Lindvikskollen (Bjørlykke, 1937), Tangen (Andersen, 1931; Green, 1956), Gloserhei (Åmli, 1975, 1977), Auselmyra, and Midtbø (M.A.T.M. Broekmans, pers. com., 1995). An U-rich variety, called *uranothorite* in the older literature, has been reported from a not specified pegmatite in the vicinity of Kragerø (Gleditsch & Qviller, 1932). In addition, thorite occurs together with allanite in aggregates of mica in gneiss from Arendal (sample in the collections of the École des Mines, Paris).

Garnet is a common mineral in most rock types from the Bamble sector. It occurs in felsic gneisses (Falkum, 1966; Starmer, 1972; Alberti & Comin-Chiaramonti, 1974; Beeson, 1975), in amphibolites (Green, 1956; Falkum, 1966; Starmer, 1969a; Nijland et al., 1993d), in metagabbros (Bugge, 1940; Green, 1956; Pl. 2, fig. b), in metapelites (Starmer, 1969b, 1972, 1976), skarns (Barth, 1925, 1928; Broekmans, 1992a; Broekmans et al., 1994), and in some granitic pegmatites. Garnet is also present in spinel-biotite-orthopyroxene-rich rocks (Lamb, 1981; Kihle & Bucher-Nurminen, 1992) and in cordierite-orthoamphibole rocks (Beeson, 1976; Visser & Senior, 1990; Visser 1993a). Garnet in the skarns have been described as *colophonite (Kolophonit)* in old literature, a term attributed to D.L.G. Karsten by Haüy (in Lucas, 1806). Although generally considered as a variety of andradite, early analyses (Simon, 1807) of *colophonite* from Nordic origin have already shown them to be mixtures of grossular and andradite ($Al:Fe^{3+} \sim 3:2$). This is confirmed by modern analyses, although more spessartine-rich compositions also occur (with up to 11.5 wt.% MnO), for example at Skoletjern, just northwest of Arendal (Broekmans, 1992a). The latter garnets are both chemically and optically zoned, and have birefringent margins (Broekmans, 1992a), possibly due to a hydrogarnet-component, which is demonstrated to be present by IR-investigations (D. Visser, pers. com., 1997). In amphibolites and gneisses, garnets are generally almandine-pyrope mixtures, with minor amounts of grossular and spessartine components (Burrell, 1966; Nijland et al., 1993d).

Hydrogarnet occurs as small microscopic lenses and lamellae in biotite from various rock types (Visser, 1993b; Nijland et al., 1994), as well as in the skarns (see above). They are essentially hydrogrossulars with significant admixture of hydroandradite-component, and may contain considerable amounts of fluorine.

Sillimanite is well known from the entire Bamble sector (e.g. Weibye, 1847, 1849). Part was originally described as the separate species *bamlite* by Erdmann (1842, p. 19), on samples from the Bamble municipality. The mineral is common in metapelites (Macaudière & Touret, 1969; Starmer, 1972, 1976; Beeson, 1975) and quartzites (Bugge, 1940; Green, 1956; Starmer, 1976). In addition, it occurs in several rare rock types, like the Froland corundum-bearing rocks (Oftedahl, 1963; Nijland et al., 1993b) and spinel-biotite-orthopyroxene rocks at Hasleholmen (Lamb, 1981; Kihle & Bucher-Nurminen, 1992). In the Nelaug-Arendal area, its habit changes from fibrolitic to euhedral prismatic with increasing grade of metamorphism (Nijland & Maijer, 1993).

Andalusite only very rarely occurs in the Bamble sector. It has been reported from pegmatitic segregations at Fossingfjord, in the Bamble municipality proper

(Ramsay & Morton, 1971). Hagelia (1989) reported andalusite overgrowing sillimanite and kyanite from a metapelite near Eikås, NW of lake Nelaug. Rarely, it also occurs in cordierite-orthoamphibole rocks around the Blengsvatn (Visser & Senior, 1990) and biotite schists near Grandalstjern and Blakstad.

Kyanite, although generally considered scarce in the Bamble sector, has since long been known from the Kragerø (Weibye, 1847), Brevig (Weibye, 1847, 1849), and Risør areas (Forbes, 1857). It has now been identified in a range of cordierite-orthoamphibole rocks at Böylefossbru, Blengsvatn, Åmdalsmoen, Haugsjå (Visser & Senior, 1990, 1991), at Bjordammen (Touret, 1979; Visser et al., 1990; Visser & Senior, 1991), Søndeled and Gjerstad (D. Visser, pers. com., 1990, 1992), and metapelitic gneisses near Kristiansand (A.C. Tobi, in Jansen et al., 1985) and Eikås, NE of lake Nelaug (Hagelia, 1989) and some aluminous gneisses in the Froland area (Nijland & Maijer, 1993). Kyanite also occurs in veins intersecting the Froland corundum-bearing rocks (Oftedahl, 1963; Nijland et al., 1993b), and in pegmatitic segregations at Fossingfjord, Bamble municipality (Ramsay & Morton, 1971).

Staurolite is a rare mineral in the Bamble sector. It is known to occur as a relictic phase in cordierite-orthoamphibole rocks at three localities (Böylefossbru and Blengsvatn: Visser & Senior, 1990; Åmdalsmoen: this study), as well as in metapelites from the Hisøy-Torungen area (Knudsen, 1996) and in a biotite schist at Grandalstjern.

Topaz has been reported from the Tangen pegmatite, but the specimen has subsequently been identified as danburite (Neumann, 1985). Schneiderhohn (1961), however, mentions the occurrence of topaz as a common mineral in granitic pegmatites in the area.

Chondrodite occurs as an accessory mineral in marbles at Tveit (Falkum, 1966), and in the skarns at Kristiansand (Barth, 1925, 1928) and Arendal (Bugge, 1943).

Clinohumite has been reported from the Tveit marbles by Falkum (1966), the skarns at Barbudalen (Broekmans et al., 1994), and probably at Lofstad (M.A.T.M. Broekmans, pers. com., 1995). It was also reported from the skarns at Kristiansand by Barth (1925), who called it *Ti-olivine.*

Titanite is one of the minerals for which the Bamble sector has since long been famous (e.g. Weibye, 1847; Pl. 3, fig. a). Large crystals occur in granitic pegmatites, like those at Kalstad and Lindvikskollen (Green, 1956), in albitites (Green, 1956; Force, 1991) and as aggregates or envelope-shaped crystals in albite-actinolite-quartz rocks and altered metagabbro (Kloprogge, 1987; Maijer & Nijland, 1991; Nijland et al., 1993c). Accessorial titanite occurs in amphibolites (Green, 1956; Falkum, 1966; Frodesen, 1968b; Starmer, 1969a, 1976; Nijland et al., 1993d), marbles (Falkum, 1966), skarns (Barth, 1925, 1928; Bugge, 1940), metagabbros (de Haas et al., 1992a), gneisses (Dietrich, 1960; Nijland & Maijer, 1993), and cordierite-orthoamphibole rocks (Starmer, 1976). Titanite is also present in the apatite-enstatite-phlogopite veins at Ødegårdens Verk (Brøgger & Reusch, 1875; Sjögren, 1883) and in apatite-hornblende veins at Lykkens in Kragerø (Brøgger & Reusch, 1875), Landvik near Grimstad (Sjögren, 1883), Noerestad near Risør (Solly, 1892), and Håvatn in the Froland municipality. The Y-rich variety, *yttrotitanite*, has been reported from, among others, the granitic pegmatites at Kalstad (Andersen, 1931; Green, 1956), Lindvikskollen, Tangen, Sjåen (Green, 1956), Gloserhei (Åmli, 1975, 1977), and from the Arendal skarns (Oftedal, 1939). Bur was the type locality for the discredited variety *keilhauite* (Erdmann, 1844,

p. 355). Titanite from Gjerstad and Arendal was used by Hawthorne et al. (1991) in their study of alpha-decay damage in titanite. The titanites vary in colour from light caramel brown to very dark brown. Well-developed envelope-shaped crystals occur at the Håvatn mine.

Datolite has been found at the various skarn mines around Arendal (Weibye, 1847; Kjerulf & Dahll, 1861; Betechtin, 1957; Pl. 3, fig. b), which is the type locality for this mineral (cf. Clark, 1993). At Lofstad on Tromøy, it occurs in late veins with axinite, epidote, actinolite, and calcite (Broekmans, 1992b; Broekmans et al., 1994).

Gadolinite occurs in many of the rare mineral-rich granitic pegmatites, like those at Haneholmen near Tvedestrand (Scheerer, 1845a) Ranevik near Risør (Brøgger, 1906a), Lindvikskollen (Oftedal, 1972), and Lyngrot near Froland (Andersen, 1931). A large anhedral specimen has been collected from a granitic pegmatite that was intruded in the core of the layered gabbro at Flosta (M.A.T.M. Broekmans, pers. com., 1995).

Kornerupine is increasingly identified in cordierite-orthoamphibole rocks from the Bamble sector, both in the amphibolite and granulite facies areas. It occurs at Bjordammen (van de Wel, 1973), Hove on Tromøy (Hulzebos-Sijen et al., 1990), Böylefossbru (Visser, 1993a, 1995), Rød (Hulzebos-Sijen et al., 1990; Visser & Senior, 1991; Visser, 1992a), and at Færvik on Tromøy (Visser et al., 1991).

Dumortierite has since long been known from cordierite-orthoamphibole rocks at Tvedestrand (Michel-Lévy & Lacroix, 1888) and Hasleholmen (Bugge, 1943). Recently, it has been found in alteration assemblages after cordierite at Böylefossbru (Visser & Senior, 1990, 1991), Rød (Visser & Senior, 1991; Visser 1992b), Norum, Bjordammen, Haugsjå, Stutæsen, and Solbutjernane (Visser & Senior, 1991).

Magnesiodumortierite has recently been described as a new mineral species from the Italian Alps (Chopin et al., 1995); these authors note that one of the electron microprobe analyses of dumortierite presented by Visser & Senior (1991) qualifies it also as magnesiodumortierite. This specimen occurs in a sample from the Böylefossbru cordierite-orthoamphibole rock locality.

Grandidierite has only been found once in the cordierite-orthoamphibole rocks at Böylefossbru (Visser & Senior, 1990).

Kasolite has been identified in granitic pegmatites at Gloserhei (Åmli, 1975, 1977) and Gjerstad (Neumann, 1985).

Uranophane has been reported from a granitic pegmatite at Garta near Arendal (Nordenskiöld, 1884) and from the Gloserhei pegmatite, where **8-uranophane** also occurs (Åmli, 1975, 1977).

Sorosilicates

Axinite group minerals have been known from the skarns in and around Arendal for almost two centuries now (Schumacher, 1801; Hoffmann, 1811; Weibye, 1847). Recently, ferroan manganaxinite was found in late veins at the Lofstad skarn section on Tromøy, in which it occurs together with datolite and epidote (Broekmans, 1992b; Broekmans et al., 1994).

Hellandite occurs in granitic pegmatites. Besides from its type locality Lindvikskollen near Kragerø (Brøgger, 1903, 1906b; Green, 1956; Pl. 4, fig. a), it has been reported from the pegmatites at Tangen (Bjørlykke, 1939) and Auselmyra (Oftedal,

1948). It occurs as tablets, together with tourmaline, thorite and allanite (Winchell, 1951, p. 452).

Epidote occurs as a retrograde, accessory mineral in almost all rock types in the area, including marbles (Falkum, 1966), skarns (Weibye, 1847; Barth, 1925, 1928; Bugge 1940, 1945, 1954; Broekmans, 1992a; Broekmans et al., 1994), amphibolites (Green, 1956; Falkum, 1966; Starmer, 1969a), gneisses (Dietrich, 1960; Field & Rodwell, 1968; Beeson, 1975; Nijland & Maijer, 1993), and albitite (Green, 1956). Epidote also occurs in the Cu-deposits at Skyttemyr and Bøylestad in the Froland municipality (Bugge, 1978). The now discredited species *akanthicone* (d'Andrea, 1800) and *arendalite* (Karsten, 1800) had Arendal as type locality.

The epidote-group mineral **clinozoisite** has been found as an accessory mineral in marbles (Falkum, 1966), skarns (Broekmans et al., 1994), gneisses (Dietrich, 1960), and amphibolites (Starmer, 1969a).

Rare **piemontite** has been reported from the surroundings of Vegårshei (Touret, 1969).

Allanite is a common accessory in many rock types, like gneisses and amphibolites (Dietrich, 1960; Falkum, 1966; Beeson, 1975; Nijland & Maijer, 1993), but conspicuously absent in the most high grade part of the amphibolite-granulite facies transition zone at Arendal (Nijland & Maijer, 1993). It also occurs in many pegmatites, like those in the surroundings of Kragerø (Andersen, 1931; Bjørlykke, 1937), Gloserhei (Åmli, 1975, 1977), Lindtstøl, Narestø, Hella, Lyngrot, and Mørefjær (Andersen, 1931). It is present in the magnetite mineralizations in the surroundings of Arendal and Kragerø (Betechtin, 1957). An apparently anhydrous variety from the magnetite skarns at Neskilen was denoted as *bucklandite* by Lévy (1824a, p. 134). In the skarns at Barbudalen (Arendal), epidote is occasionally rimmed by an allanite with the pleochroism given by Winchell (1951, p. 452) for the P-bearing variety *nagatelite* (Broekmans, 1992a).

Zoisite occurs in some of the skarn localities near Kristiansand (Barth, 1925, 1928) and Arendal (Bugge, 1940) and occurs as an accessory mineral in some quartzites (Bugge, 1940).

Pumpellyite occurs as a late, retrograde mineral in the Arendal skarns (Bugge, 1954) as well as in many other rock types (Nijland & Maijer, 1993).

Vesuvianite was first reported by Weiss (1829, mentioned in Barth, 1963) from the skarns at Eg near Kristiansand (Vogel, 1887; Barth, 1963), and has subsequently been reported from the skarns near Arendal (Leonhard, 1841, p. 75; Weibye, 1847; Vogel, 1887; Bugge, 1940; Broekmans et al., 1994), from Kongsgårdskogen, Kristiansand (Barth, 1925, 1928, 1963), from Graslen in the Froland municipality, and Vegårshei (Barth, 1963).

Kainosite-(Y) has been found in the Tangen pegmatite (G. Raade, in Neumann, 1985) and Gryting near Gjerstad (R. Kristiansen, in Neumann, 1985).

Beryl has since long been known from the Bamble sector. It was, for example, mentioned by Weibye (1847), who did not specify its mode of occurrence. It occurs in several pegmatites, like those of Ramskjær near Søndeled (Andersen, 1931), Kragerø (Bjørlykke, 1937), Gloserhei (Åmli, 1975, 1977), and Skarpness in the Øyestad municipality (Neumann, 1961). According to Oftedahl (1963), beryl also occurs in the well known corundum-bearing rocks from Froland.

Cordierite from the Bamble sector is famous for its often large idiomorphic and beautifully blue crystals, which occurs at many localities around Arendal (Holm, 1824), Tvedestrand, Kragerø, and Brevig (Weibye, 1847). The mineral has been reported under a variety of names like *iolite*, *dichroite, aspasiolite*, and *polychroite*. The latter name particularly alluded to an altered specimen, originally described from Kragerø (Weibye, 1846, p. 286). Kragerø was also the type locality for *aspasiolite* (Scheerer, 1846, p. 323). Cordierite occurs in peculiar cordierite-orthoamphibole rocks, which occur in many small exposures in the area (Frodesen, 1968b; Beeson, 1975, 1976; Starmer, 1976; Visser & Senior, 1990, 1991; Visser, 1992b, 1993a; Pl. 4, fig. b), in biotite-orthopyroxene-rich rocks which often also contain sapphirine (Lamb, 1981; Kihle & Bucher-Nurminen, 1992), and in some metapelites (Starmer, 1972; Visser et al., 1994; Knudsen, 1996). Cordierite from the Bamble sector has been used in studies of the incorporation of volatiles into its structure (Zimmerman, 1981; Vry et al., 1990; Visser et al., 1994)

Tourmaline (Pl. 5, fig. a) occurs as an accessory in amphibolites (e.g. Frodesen, 1968b; Starmer, 1969b), albitites (Green, 1956), gneisses (e.g. Beeson, 1975), quartzites (e.g. Bugge, 1940; Starmer, 1976; Nijland et al., 1993a), skarns (Bugge, 1940, 1945), in cordierite-orthoamphibole rocks (Visser & Senior, 1990, 1991; Visser, 1993a), in the apatite-enstatite-orthopyroxene veins at Ødegårdens Verk (Brøgger & Reusch, 1875), and the apatite-hornblende veins at Hiåsen near Gjerstad (Brøgger & Reusch, 1875) and at Landvik near Grimstad (Sjögren, 1883). It also occurs in late, hydrothermally altered parts of the corundum-bearing rocks from Froland (Oftedahl, 1963; Nijland et al., 1993b). In addition, large crystals occur in many pegmatites, like those in the surroundings of Kragerø (Green, 1956), at Gloserhei (Åmli, 1975, 1977) and at Osedalen in the Froland area, where it has a triangular habit. Crystals in the pegmatite may be up to several decimetres across in size. Small pegmatites with extensively developed tourmaline-quartz symplectites occur just north of Ubergsmoen. *Aphrizite*, now considered to be a black variety of tourmaline, was originally described from Kragerø by d'Andrea (1800). The Li-tourmaline **elbaite** is reported to occur in a granite pegmatite near Lien, at the Kilsfjord west of Kragerø (Beyer, 1992), together with other Li-minerals. Tourmalinites are locally present in the Nidelva Quartzite Complex (Nijland et al., 1993a), and in the ore-bearing sequence at Ettedalen (Krijgsman, 1991a,b).

Inosilicates

Pigeonite is scarce in gabbroic intrusions in the area, and has so far only been reported from the Selåsfjellet gabbro (A. Senior, in de Haas et al., 1992a), from a gabbro on Tromøy (Bugge, 1940), and as inverted pigeonite in one sample from the Vestre Dale gabbro (de Haas et al., 1992a). It also occurs as a primary magmatic phase in some Phanerozoic dolerite dykes in the area, for example at Norum, east of Ubergsmoen.

Diopside to hedenbergite are the dominant end members in the composition of clinopyroxenes from calcsilicate rocks and skarns (Broekmans, 1992a). They have been described as augite in the old literature (e.g. Hintze, 1897a), but in fact, early analyses by Simon (1807) already confirm its diopsidic to hedenbergitic composition (SiO_2 50.25, Al_2O_3 3.50, Fe_2O_3 10.50, MnO 2.02, MgO 7.00, CaO 25.50, H_2O 0.50, total

99.37). Granular aggregates and masses from the skarns (Pl. 5, fig. b) have been termed *coccolite (Kokkolith)*, following de Andrada e Silva (1800, p. 32). Hedenbergitic clinopyroxene also occurs in several of the albite-actinolite-quartz rocks (Kloprogge, 1987; Maijer & Nijland, 1991).

Augite to ferro-augite are the predominant end members in the composition of clinopyroxenes from both primary (magmatic) and secondary mineral assemblages in gabbroic rocks from the area (de Haas et al., 1992a; Dam, 1995), as well as in amphibolites and gneisses.

Spodumene is reported to occur as a prismatic crystals in a granitic pegmatite near Lien, at the Kilsfjord west of Kragerø (Beyer, 1992).

Orthopyroxene is wide-spread in both felsic and basic rocks in the granulite facies area. Orthopyroxene also occurs in the granitic to charnockitic augen gneiss bodies and their aureoles, like those at Hovdefjell-Vegårshei, Ubergsmoen, Gjerstad, and Gjeving (Touret, 1967b, 1968; Hagelia, 1989; Nijland & Senior, 1991). At Ødegårdens Verk, large megacrysts occur in the apatite-bearing veins (Brøgger & Reusch, 1875; Lieftink et al., 1994) and other magmatic-deuteric veins. Orthopyroxenes in the Ubergsmoen augen gneiss are among the most Fe-rich varieties known, with 91% of ferrosilite component and up to 1.2 wt.% Al_2O_3 (Lieftink, 1992). In addition, magmatic orthopyroxene occurs in metagabbros throughout the Bamble sector. Orthopyroxenes from the Bamble community have been used in studies of mechanical behaviour of orthopyroxene (Riecker & Rooney, 1966), the presence of OH in orthopyroxene (Skogby et al., 1990, among others), and the terrestrial occurrence of orthopyroxenes with space group $P2_1/a$ (Luo et al., 1992).

Tremolite has already been reported from the Kragerø area by Weibye (1847). It occurs as a rare accessory in marbles (Falkum, 1966; Broekmans et al., 1994), skarns at Løddesøl (Bugge, 1945), Lofstad and Arendal (Broekmans, 1992a; Broekmans et al., 1994), in cordierite-orthoamphibole rocks at Hiåsen (Frodesen, 1968b), and in amphibolites (Frodesen, 1968b; Starmer, 1969a). Tremolitic amphibole is also present in the talc deposits at Vestre Vimme in the Nelaug area (Nijland, 1989; Moree & Nijland, 1996). In the zone along the Porsgrunn-Kristiansand Fault, tremolite occurs in veins together with calcite, where it replaces the assemblage dolomite + quartz (J.L.R. Touret, pers. com., 1997).

Actinolite occurs commonly as a retrograde phase in both felsic gneisses and metabasites (Nijland & Maijer, 1993). In addition, it occurs in great abundance in the so-called albite-actinolite-quartz rocks (Kloprogge, 1987; Maijer & Nijland, 1991) and albitites. Among these lithologies are rocks with large, dark green, often radial actinolite crystals in transparent quartz (*strahlstein;* Pl. 5, fig. c). Such rocks occur at many gabbro-metasediment contacts in the Froland area, for example around the Uvatn and near Styggetjern, both a few kilometres NW of Jåmmås.

Cummingtonite occurs as a replacement of olivine in several gabbros and basic dykes, and as a late, relatively high temperature degradation product of orthopyroxene in both basic and felsic rocks. It also occurs as an accessory in some cordierite-orthoamphibole rocks (Starmer, 1976; Visser, 1993b), and as exsolution lamellae in hornblendes from amphibolites (Nijland et al., 1993d). Near the northern tip of the Blengsvatn in the Froland municipality, peculiar rocks occur, almost entirely consisting of garnet and cummingtonite.

Hornblende is a common constituent of all metabasites in the area; it also occurs in several felsic gneisses. In addition, some hornblendites occur. Compositions range from hornblende s.s. to more edenitic, pargasitic, or hastingsitic varieties (Nijland, 1993).

Arfvedsonite is rare in the Bamble sector, and has so far only been encountered in late veins cutting a small metagabbro body in the vicinity of the Gloserhei pegmatite.

Anthophyllite and **gedrite** occur as major minerals in cordierite-orthoamphibole rocks (Frodesen, 1968b; Beeson, 1976; Starmer, 1976; Visser & Senior, 1990, 1991; Visser, 1992b, 1993a, 1995; Pl. 6, fig. a) and in biotite-orthopyroxene-rich rocks which are often sapphirine-bearing (Lamb, 1981; Kihle & Bucher-Nurminen, 1992). It occurs in some albitites and amphibolites (Green, 1956; this study).

Sapphirine occurs in biotite-orthopyroxene-rich rocks at Hasleholmen (Lamb, 1981; Kihle & Bucher-Nurminen, 1992), Snaresund (Touret & de la Roche, 1971; Lamb, 1981), Gladstad (Lamb, 1981), and Rangleåsen (Lamb, 1981). It also occurs in fine-grained symplectites in granulite facies migmatitic metapelites at the Hauglandsvatn in the Ubergsmoen area (Nijland et al., 1997).

Rhodonite has been reported from the Arendal skarns by Vogt (1910) and Bugge (1940), as well as from the Klådeborg skarns (Neumann, 1985).

Babingtonite is known from the Arendal skarns since long (Møller, 1826; Weibye, 1847; Kjerulf & Dahll, 1861; Vogt, 1910; Bugge, 1940; Pl. 6, fig. b), and Arendal is the type locality for this mineral (Lévy, 1824b, p. 275). Babingtonite from the Arendal skarns was used by Burns & Dyar (1991) in their crystal chemical study of this mineral.

Prehnite has been known from several localities in the Bamble sector since the early 19th century (Schumacher, 1801; Holm, 1824; Weibye, 1847). It is a common accessory in most rock types, due to low grade alteration (Nijland & Maijer, 1993), and also occurs in late calcite veins (Broekmans et al., 1994). Occasionally, it occurs as lenses parallel to the basal cleavage of biotite and graphite (Field & Rodwell, 1968).

Phyllosilicates

Apophyllite group minerals occur at several of the skarn exposures in the surroundings of Arendal (Schumacher, 1801; Weibye, 1847; Bugge, 1954).

Talc occurs as a secondary mineral in cordierite-orthoamphibole rocks (Visser et al., 1990) and in the apatite-enstatite-phlogopite veins at Ødegårdens Verk (Neumann et al., 1960; Lieftink et al., 1994). Museum collections commonly contain pseudomorphs of talc after orthopyroxene from this locality. A small talc deposit occurs near Vestre Vimme, in the Nelaug area (Nijland, 1989; Moree & Nijland, 1996), whereas another small quarry used to be in the vicinity of Vegårshei (J.L.R. Touret, pers. com., 1996).

Muscovite is still present as a primary phase in the western and northern part of the Bamble sector (Touret, 1971). Elsewhere, it occurs as a retrograde phase which developed at expense of sillimanite and feldspars in metapelites and some gneisses. Late muscovite poikiloblasts occur in some of the Late Sveconorwegian granitic sheets on Tromøy (Nijland & Maijer, 1993). Large muscovites are common in the granitic pegmatites (such as Lauvrak and Gloserhei); these muscovites occasionally

form large concave crystals, often with inclusions of monazite, xenotime, or zircon.

Fuchsite was reported from the Froland corundum-bearing rocks by Oftedahl (1963). However, reinvestigation by Nijland et al. (1993b) showed this mineral to be Cr-Fe-bearing muscovite.

Biotite is a common constituent of most rock types in the area. In most gneisses, granites and amphibolites, biotite crystals are a few millimetres in size, but pseudohexagonal crystals of over 1 m in diameter occur in several granitic pegmatites, for example at Moen, NW of Molandsvatnet. Biotite crystals elongate along one of the sides of the pseudohexagonal crystals, usually [100] (rarely [110]), the so-called *Riemen Glimmer* in German literature (Tröger, 1967, p. 503), are common in the granitic pegmatites, for example the Narestø pegmatite at Flosta. Biotite compositions in gneisses, metapelites and amphibolites vary from relatively Fe- to Mg-rich; occasionally, biotites may be Ti-rich, containing over 5 wt.% TiO_2 (Nijland, 1993).

Phlogopite occurs in some calcsilicate rocks and some ultramafics. It is also a major component of the apatite-enstatite-phlogopite veins at Ødegårdens Verk (Brøgger & Reusch, 1875; Neumann et al., 1960; Lieftink et al., 1994). These phlogopites have relatively high Na/K ratios (Lieftink et al., 1994). The dark mica in the skarns on Tromøy and around Arendal is also a nearly pure phlogopite (Broekmans, 1992b).

Zinnwaldite is reported as small crystals in the granitic pegmatite near Lien, at the Kilsfjord west of Kragerø (Beyer, 1992) in the sole Li-paragenesis known from this area.

Lepidolite occurs as small crystals in the sole Li-paragenesis known from the Bamble sector, in a granitic pegmatite near Lien, at the Kilsfjord west of Kragerø (Beyer, 1992).

Preiswerkite, a rare Na-Al mica, has recently been discovered in a rock mainly consisting of biotite, tourmaline and scapolite from the Nidelva Quartzite Complex in the Froland area.

Margarite occurs as an alteration product of plagioclase, kyanite and corundum in the Froland corundum-bearing rocks. These margarites contain significant amounts of Na and K substituting for Ca (Nijland et al., 1993b).

Volkonskoite has been reported by Nilssen & Raade (1973) from the hydrothermally altered zone in the Froland corundum-bearing rocks.

Chlorite is a common retrograde phase in many rock types in the area.

Serpentine-group minerals occur as late accessory phases in basic rocks, viz. amphibolites and metagabbros (Green, 1956; Starmer, 1969a), and in skarns (Barth, 1925; Bugge, 1940, 1945)

Chrysocolla has been reported from the Arendal area by Schumacher (1801), who did not specify its mode of occurrence.

Tectosilicates

Plagioclase is a constituent of most rock types in the area. The lamellar variety *cleavelandite* occurs in the pegmatites in the surroundings of Kragerø (Andersen, 1926; Green, 1956). *Aventurine feldspar*, i.e. feldspar with interspersed mica flakes, and especially *solstein*, i.e. feldspar with interspersed hematite flakes, are well known from the Bamble sector, and occurs also in several pegmatites at Arendal (Weibye, 1847; Cop-

ley & Gay, 1978, 1979), Bamble (Copley & Gay, 1978), Bjordammen (Copley & Gay, 1979), Havredal (Copley & Gay, 1979), and Kragerø (Weibye, 1847). The species denominated *tschermakite* from Bamble (von Kobell, 1874, p. 411) is an oligoclase-albite.

K-feldspar is a common constituent of many felsic gneisses, quartzites and pegmatites in the area. Commonly, the K-feldspar is a **microcline**. Idiomorphic crystals, often with perthitic exsolution, occur in many of the pegmatites. Very large, metre-sized K-feldspar crystals occur in the granitic pegmatites at Gloserhei, Hynnekleiv and Lauvrak (Pl. 6, fig. c). Graphic intergrowths of K-feldspar and quartz are common; fair specimens may be found at the Lauvrak pegmatites.

Danburite has been found in the Tangen and Sjåen pegmatites near Kragerø (Oftedal, 1963).

Scapolite has since long been known from the Arendal skarns (Schumacher, 1801; Hausmann, 1812). It is also common as a replacement of plagioclase in gabbros in the Bamble sector (Judd, 1889). This replacement happened extensively in many metagabbros and their surrounding amphibolites (Green, 1956; Frodesen, 1968a,b; Starmer, 1969a; Glaveris, 1970; Nijland et al., 1993d). Occasionally, all plagioclase has been altered to scapolite; these rocks have been termed *spotted gabbro (gefleckter Gabbro;* Brøgger & Reusch, 1875) or *ødegårdites* (Brøgger, 1934a). Scapolite replacing plagioclase also occurs in apatite-hornblende veins at Hiåsen, near Gjerstad (Brøgger & Reusch, 1875) and Noerestad near Risør (Solly, 1892), and in the apatite-enstatite-phlogopite veins at Ødegårdens Verk (Michel-Lévy, 1878a,b; Lacroix, 1889; Neumann et al., 1960; Lieftink et al., 1993, 1994). Associated with these veins is an odd rutile-phlogopite-scapolite rock, termed 'sand rock' by Brøgger (1934a); the scapolite in this rock is among the most Cl-rich varieties yet reported (Lieftink et al., 1993). Late replacing scapolite also occurs in the corundum-bearing rocks from Froland (Nijland et al., 1993b). Scapolite is a major component from some marbles (Falkum, 1966) and the skarns at Kristiansand (Barth, 1925, 1928), Arendal, Brastad (Bugge, 1940; Broekmans, 1992a; Broekmans et al., 1994), and Løddesøl (Bugge, 1945). Some pegmatites also contain large euhedral scapolite crystals, for example those at Garta, Buø, Hella, all in the Arendal area, Holt near Tvedestrand, Ramskjær near Risør, and Kragerø (Schetelig, 1915). Compositions vary from marialitic to meionitic. In addition, it occurs in veins with carbonates, tourmaline and sulphides cutting across a wide range of rock types. The species *gabbronite, wernerite* and *paranthine,* all originally described from Arendal by Schumacher (1801), d'Andrea (1800, p. 32) and Lucas (1806), respectively, have been discredited in favour of scapolite. The species *atheriasite*, described from Arendal by Weibye et al. (1850, p. 302), represents an altered scapolite.

Natrolite occurs in the skarns at Arendal (Bugge, 1943, 1954). It was also reported from the Kragerø area by Weibye (1847) who did not specify its mode of occurrence.

Mesolite has been reported from the skarns at Arendal (Hey, 1933; Bugge, 1954).

Scolecite occurs in the Raneklev skarns at Arendal (Bugge, 1954).

Thomsonite has been found in the skarns at Raneklev, Arendal (Bugge, 1954).

Analcime occurs in voids and late veins at many skarn localities in the Arendal area (Holm, 1824; Scheerer, 1845a; Weibye, 1847; Bugge, 1954).

Laumontite has been found in felsic gneisses at Østland near Kragerø (Sæbø &

Reitan, 1959).

Chabazite occurs in the skarns at Langsev and Raneklev, Arendal (Holm, 1824; Bugge, 1954).

Stilbite is known to occur in the Arendal skarns (Weibye, 1847; Bugge, 1954), and from late veins along road 407, where it is associated with epidote and other zeolites (M.A.T.M. Broekmans, pers. com., 1995).

The zeolite **stellerite** has been reported from the skarns at Arendal (Bugge, 1954). Small brown crystals of stellerite have been found at Lærestveit (M.A.T.M. Broekmans, pers. com., 1995).

Heulandite occurs at many skarn localities in the Arendal area (Weibye, 1847; Bugge, 1954). It has also been reported from gneisses near Kragerø (Sæbø & Reitan, 1959).

Acknowledgements

J.L.R. Touret, C. Maijer and M.A.T.M. Broekmans are thanked for their comments on an earlier version of the manuscript.

References

GFF: Geologiska Förening Stockholm Förhandlingar; NGT: Norsk Geologisk Tiddskrift; NGU: Norges Geologiske Undersøkelse.

Abilgaard, P.C., 1798. In: F.A. Reuss, 1802. Lehrbuch der Mineralogie. Teil 2: 349 (cited in Clark, 1993).

Alberti, A.A. & P. Comin-Chiaramonti, 1974. Hypersolvus granitic bodies in the Tromøy migmatites (Arendal district - southern Norway). — Boll. Soc. Geol. Ital., 93: 901-911.

Åmli, R., 1975. Mineralogy and rare earth geochemistry of apatite and xenotime from the Gloserheia granite pegmatite, Froland, southern Norway. — Am. Miner., 60: 607-620.

Åmli, R., 1977. Internal structure and mineralogy of the Gloserheia granite pegmatite, Froland, southern Norway. — NGT, 57: 243-262.

Andersen, O., 1926. Feltspat I. — NGU, 128a: 1-142.

Andersen, O., 1931. Feltspat II. — NGU, 128b: 1-109.

Andersen, T., 1997. Radiogenic isotope systematics of the Herefoss granite, south Norway: An indicator of Sveconorwegian (Grenvillian) crustal evolution in the Baltic Shield. — Chem. Geol., 135: 139-158.

Andersen, T., P. Hagelia & M.J. Whitehouse, 1994. Precambrian multi-stage crustal evolution in the Bamble sector of S. Norway: Pb isotopic evidence from a Sveconorwegian deep-seated granitic intrusion. — Chem. Geol., 116: 327-343.

Andersen, T., C. Maijer & R.H. Verschure, 1995. Metamorphism, provenance ages and source characteristics of Precambrian clastic sediments in the Bamble sector, south Norway: An Ar, Sr, Nd and Pb isotope study. — Petrol. (Moscow), 3: 321-339.

Andrada e Silva, J.B. de, 1800 — Allgemein. J. Chem., 4: 32.

Andrea, B.J. d', 1800. — J. Phys. Chem. Hist. Nat. Arts, Paris, 51: 240-244 (cited in Clark, 1993).

Baadgsaard, H., C. Chaplin & W.L. Griffin, 1984. Geochronology of the Gloserheia pegmatite, Froland, southern Norway. — NGT, 54: 111-119.

Bäckström, H., 1898. Fenakit från Kragerø. — GFF, 20: 295-303.

Bakken, R. & E. Gleditsch, 1938. Analyses of a single crystal of cleveit, Auselmyren, Norway. — Am. J. Sci., 236: 95-106.

Barth, T.F.W., 1925. On contact minerals from Precambrian limestones in southern Norway. — NGT, 8: 93-114.

Barth, T.F.W., 1927. The structure of risørite. — NGT, 9: 37-39.
Barth, T.F.W., 1928. Kalk- und Skarngesteine im Urgebirge bei Kristiansand. — N. Jahrb. Miner., Beil. Bd, 57A: 1069-1108.
Barth, T.F.W., 1929. Die Temperatur der Anatexis des Urgebirges in südlichsten Norwegen. — Centralbl. Miner. Geol. Pal., A (Miner. Petrogr.), 1929: 120-127.
Barth, T.F.W., 1963. Vesuvianite from Kristiansand, other occurrences in Norway, the general formula of vesuvianite. — NGT, 43: 457-472.
Beeson, R., 1975. Metasedimentary gneisses from the area between Songe and Ubergsmoen, Aust-Agder, south Norway. — NGU, 321: 87-102.
Beeson, R., 1976. The orthoamphibole-bearing rocks of the Söndeled-Tvedestrand area, Aust Agder, south Norway. — NGT, 56: 125-139.
Beeson, R., 1988. Identification of cordierite-anthophyllite rock types associated with sulphide deposits of copper, lead and zinc. — Trans. Inst. Min. Metall., B, 97: 108-115.
Betechtin, A.G., 1957. Lehrbuch der speziellen Mineralogie. — VEB Verlag Technik, Berlin & Porta Verlag, München: 1-683 (2nd ed.).
Beyer, H., 1992. Norwegen ist zwei Reisen wert. — Aufschluss, 43: 345-360.
Bjørlykke, H., 1937. Mineral paragenesis of some granite pegmatites near Kragerø, southern Norway. — NGT, 7: 1-16.
Bjørlykke, H., 1939. Feltspat V. De sjeldne mineraler på de norske granitiske pegmatittganger. — NGU, 154: 1-78.
Blomstrand, C.W., 1887. Analys af cer- och ytter-fosfater från södra Norge, ett bidrag till frågan om dessa mineraliers kemiska byggnad. — GFF, 9: 160-187.
Breithaupt, A., 1830. Übersicht der Mineral-Systematik.: 30.
Brickwood, J.D., 1986. The geology and mineralogy of some Fe-Cu-Ni sulphide deposits in the Bamble area, Norway. — NGT, 66: 189-208.
Broekmans, M.A.T.M., 1992a. Stable isotopic trends and mineral chemistry of carbon-bearing rocks from the Arendal area, Bamble sector, SE Norway. — Unpubl. MSc thesis, Utrecht Univ.: 1-68.
Broekmans, M.A.T.M., 1992b. Chemical and other properties of an axinite from a calcite vein in skarn, Arendal area, Bamble sector, SE Norway. — Unpubl. internal report, Utrecht Univ.: 1-15.
Broekmans, M.A.T.M., T.G. Nijland & J.B.H. Jansen, 1994. Are stable isotopic trends in amphibolite to granulite facies transitions metamorphic or diagenetic? - An answer for the Arendal area (Bamble sector, SE Norway) from Mid-Proterozoic carbon-bearing rocks. — Am. J. Sci., 294: 1135-1165.
Brøgger, W.C., 1883. Om uranbergerts og xenotim fra norske forekomster. — GFF, 6: 744-752.
Brøgger, W.C., 1888. Om en norsk forekomst av pseudobrookit i store krystaller. — GFF, 10: 21-24.
Brøgger, W.C., 1903. Über Hellandit, ein neues Mineral. — Nyt Mag. Naturvid., 41: 213-219.
Brøgger, W.C., 1906a. Die Mineralen der südnorwegischen Granit-Pegmatitgänge. I . — Nor. Vid. Ak. Oslo Skr., Mat.-Naturvid. Kl., 1906-6.
Brøgger, W.C., 1906b. Hellandit von Lindvikskollen bei Kragerö, Norwegen. — Z. Kristal. Miner., B42: 417-439.
Brøgger, W.C., 1934a. On several Archaean rocks from the south coast of Norway. II The south Norwegian hyperites and their metamorphism. — Nor. Vid. Akad. Oslo Skr., Mat. Naturvid. Kl., 1: 1-421.
Brøgger, W.C., 1934b. On several Archaean rocks from the south coast of Norway. I Nodular granites from the environs of Kragerö. — Nor. Vid. Akad. Oslo Skr., Mat. Naturvid. Kl., 8: 1-97.
Brøgger, W.C., & H. Bäckström, 1888. Über den Dahllit, ein neues Mineral von Ødegården, Bamble, Norwegen. — Ofv. Kong. Vid. Akad. Forh., 45: 493-496.
Brøgger, W.C. & G. vom Rath, 1877. Über grosse Enstatit-Krystalle, aufgefunden von W.C. Brøgger und H.H. Reusch bei Kjørrestad, Bamle. — Z. Kristal., 1: 18-30.
Brøgger, W.C. & H.H. Reusch, 1875. Vorkommen des Apatit in Norwegen. — Z. Deuts. Geol. Ges., 27: 646-702.
Brünnich, M.L., 1777. Forsøg til mineralogie for Norge. — Trondheim.
Bugge, A., 1928. En forkastning i det syd-norske grunnfjell. — NGU, 130: 1-124.

Bugge, A., 1936. Kongsberg - Bamble formationen. — NGU, 146: 1-117.
Bugge, A., 1965. Iakttagelser fra Rektangelbladet Kragerø og Den store Grunnfjellbreksje. — NGU, 229: 1-115.
Bugge, C., 1922. Statens apatitdrift i rationeringstiden. — NGU, 110: 1-34.
Bugge, C. & S. Foslie, 1922. Norsk arsenmalm og arsenik-fremstilling. — NGU, 106: 1-33.
Bugge, J.A.W., 1940. Geological and petrological investigations in the Arendal district. — NGT, 20: 71-112.
Bugge, J.A.W., 1943. Geological and petrological investigations in the Kongsberg - Bamble formations. — NGU, 160: 1-150.
Bugge, J.A.W., 1945. Løddesøl skarnforekomst. — NGT, 25: 35-47.
Bugge, J.A.W., 1951. Minerals from the skarn iron ore deposits at Arendal, Norway. I. Cahnite from Klodeborg Mine. — Kong. Nor. Vid. Sels. Forh., 17: 79-81.
Bugge, J.A.W., 1954. Minerals from the skarn iron ore deposits at Arendal, Norway. II. The zeolites. — Kong. Nor. Vid. Sels. Skr., 3: 1-18.
Bugge, J.A.W., 1960. Skarn iron ore deposits in the Arendal district. In: F.M. Vokes (ed.) Mines in south and central Norway. — NGU, 212m: 26-38.
Bugge, J.A.W., 1978. Kongsberg-Bamble complex. In: S.H.O. Bowie, A. Kvalheim & M.W. Haslam (eds.) Mineral deposits of Europe. Vol. 1. Northwest Europe. — Inst. Mining Metal. Miner. Soc., London: 213-217.
Burns, R.G. & M.D. Dyar, 1991. Crystal chemistry and Mössbauer spectra of babbingtonite. — Am. Miner., 76: 892-899.
Burrell, D.C., 1966. Garnets from upper amphibolite lithologies of the Bamble series, Kragerö, south Norway. — NGT, 46: 3-19.
Butler, J.R. & R. Hall, 1960. Chemical variations in members of the fergusonite-fourmanite series. — Miner. Mag., 32: 392-407.
Carstens, H., 1957. Investigations of titaniferous iron ore deposits. Part I. Gabbros and associated titaniferous iron ore in the west-Norwegian gneisses. — Kong. Nor. Vid. Sels. Skr., 1957-3: 1-67.
Chopin, C., G. Ferraris, G. Ivaldi, H.P. Schertl, W. Schreyer, R. Compagnoni, C. Davidson & A.M. Davis, 1995. Magnesiodumortierite, a new mineral from very-high-pressure rocks (western Alps). II. Crystal chemistry and petrological significance. — Eur. J. Miner., 7: 525-535.
Clark, A.M., 1993. Hey's mineral index. — Chapman & Hall, London: 1-852.
Comin-Chiaramonti, P., 1974. Iron titanium minerals in the Tromøy island (south Norway). — Atti Mem. Ac. Patavina Sci. Lett. Arti, 86: 243-247.
Copley, P.A. & P. Gay, 1978. A scanning microscope investigation of some Norwegian aventurine feldspars. — NGT, 58: 93-95.
Copley, P.A. & P. Gay, 1979. Crystallographic studies of some Norwegian aventurinised feldspars by optical, X-ray, and electron optical methods. — NGT, 59: 229-237.
Dahlgren, S., R. Bogoch, M. Magaritz & A. Michard, 1993. Hydrothermal dolomite marbles associated with charnockitic magmatism in Proterozoic Bamble shear belt, south Norway. — Contr. Miner. Petrol., 113: 394-409.
Dahlgren, S., L. Heaman & T. Krogh, 1990. U-Pb dating of coronitic metagabbros, hornblende-phlogopite-apatite pegmatites and albitites in the Proterozoic Bamble shear belt, south Norway. — Vol. Abstr. 2nd Symp. Baltic Shield, Lund, 1990: 29.
Dam, B.P., 1995. Geodynamics in the Bamble area during Gothian and Sveconorwegian times. A comparative petrological study of two gabbros. — Geol. Ultraiectina, 117: 1-114.
Daubrée, M.A., 1843. Mémoire sur les dépôts metallifères de la Suède et de la Norvège. — Ann. Mines, 4: 199-282.
Dietrich, R.V., 1960. Banded gneisses of the Randesund area, southeastern Norway. — NGT, 40: 13-63.
Elliott, R.B., 1966. The association of amphibolite and albitite, Kragerö, south Norway. — Geol. Mag., 103: 1-7.
Erdmann, A., 1842. — Kon. Vetenskaps. Akad. Handl., 1842: 19 (cited in Clark, 1993).
Erdmann, A., 1844. — Kon. Vetenskaps. Akad. Handl., 1844: 355 (cited in Clark, 1993).
Esmark, J., 1806. — Allgem. J. Chem., 16: 1 (cited in Clark, 1993).

Falkum, T., 1966. Geological investigations in the Precambrian of southern Norway. I - The complex of metasediments and migmatites at Tveit, Kristiansand. — NGT, 46: 85-110.

Falkum, T. & J.S. Petersen, 1980. The Sveconorwegian orogenic belt, a case of late Proterozoic plate collision. — Geol. Rundschau, 69: 622-647.

Field, D. & A. Råheim, 1979. Rb-Sr total rock isotope studies on Precambrian charnockitic gneisses from south Norway: Evidence for isochron resetting during a low-grade metamorphic-deformational event. — Earth Plan. Sci. Lett., 45: 32-44.

Field, D. & J.R. Rodwell, 1968. The occurrence of prehnite in a high-grade metamorphic sequence from south Norway. — NGT, 48: 58-61.

Field, D., P.C. Smalley, R.C. Lamb & C. Råheim, 1985. Geochemical evolution of the 1.6-1.5 GA-old amphibolite-granulite facies terrain, Bamble sector, Norway: Dispelling the myth of Grenvillian high-grade reworking. In: A.C. Tobi & J.L.R. Touret (eds.) The deep Proterozoic crust in the North Atlantic provinces. — Reidel, Dordrecht: 567-578.

Field, D. & I.C. Starmer, 1982. Graphite genesis in high-grade metamorphic rocks. — Nature, 298: 303-304.

Forbes, D., 1857. Gæologiske undersögelser over det metamorfiske territorium ved Norges sydkyst. — Nyt Mag. Naturvid., 9: 165-184.

Forbes, D. & T. Dahll, 1855. Mineralogiske iagttagelser omkring Arendal og Kragerr. — Nyt Mag. Naturvid., 8: 213-229.

Force, E.R., 1991. Geology of titanium-mineral deposits. — Geol. Soc. Am. Spec. Pap., 259: 24-56, 35-36.

Forchhammer, J.G., 1835. Oerstedit, ein neues Mineral. — Poggendorf. Ann. Phys. Chem., 35: 630.

Frodesen, S., 1968a. Coronas around olivine in a small gabbro intrusion, Bamble area, south Norway. — NGT, 48: 201-206.

Frodesen, S., 1968b. Petrographical and chemical investigations of a Precambrian gabbro intrusion, Hiåsen, Bamble area, south Norway. — NGT, 48: 281-306.

Gaál, G. & R. Gorbatschev, 1987. An outline of the Precambrian evolution of the Baltic shield. — Precamb. Res., 35: 15-52.

Gagarin, G. & J.R. Cuomo, 1949. — Communic. Inst. Nac. Invest. Cienc. Nat., 1: 10 (cited in Clark, 1993).

Glaveris, M., 1970. The occurrence of olivine hyperite at Odegardens Verk, Bamble, south Norway. — NGT, 50: 15-17.

Gleditsch, E. & B. Qviller, 1932. Investigation of uranothorite from the Arendal district, Norway. — Phil. Mag., 7: 233-243.

Green, J.C., 1956. Geology of the Storkollen-Blankenberg area, Kragerø, Norway. — NGT, 36: 89-140.

Griffin, W.L., R. Åmli & K.S. Heier, 1972. Whitlockite and apatite from lunar rock 14310 and from Ødegården Norway. — Earth Planet. Sci. Lett., 15: 53-58.

Gupta, L.N., 1986. Secondary and primary growths in the zircons from paragneisses and migmatites of Arvika (Sweden) and Nelaug (Norway) regions. — J. Geol. Soc. India, 28: 320-324.

Haas, G.J.L.M. de, T.G. Nijland, J.P.P. Huijsmans, C. Maijer & B.P. Dam, 1992a. The magmatic history of a gabbroic intrusion in the Bamble sector, Vestre Dale, Norway. — N. Jahrb. Miner., Mh., 1992: 221-240.

Haas, G.J.L.M. de, T.G. Nijland, A. Senior & B.P. Dam, 1993a. Preservation of whole rock chemical profiles and igneous structures during multiple high grade metamorphism (Flosta gabbro, Bamble, Norway). — Proc. Kon. Ned. Akad. Wetensch., 96: 389-410.

Haas, G.J.L.M. de, R.H. Verschure & C. Maijer, 1993b. Isotope constraints on the timing of the crustal accretion of the Bamble sector, Norway, as evidenced by coronitic gabbros. — Precamb. Res., 64: 403-417.

Haas, G.J.L.M. de, R.H. Verschure, C. Maijer & P.J. Valbracht, 1992b. Isotopic age determinations in south Norway. III. Rb-Sr isotope systematics of the coronitic Vestre Dale gabbro and its country rocks, Bamble, Norway. — GFF, 114: 417-422.

Hagelia, P., 1989. Structure, metamorphism and geochronology of the Skagerrak shear belt, as revealed by studies in the Hovdefjell-Ubergsmoen area, south Norway. — Unpubl. Cand. Sci.

thesis, Univ. Oslo: 1-236.
Hamberg, A., 1886. Anatas og titanit från apatitførekomsten vid Kragerø. — GFF, 8: 475-476.
Hauser, O., 1908. Risörite ein neues Mineral. — Z. Anorg. Chemie, 60: 230-236.
Hausmann, J.F.L., 1812. Reise durch Skandinavien in den Jahren 1806 und 1807. Zweiter Teil. — J.F. Römer, Göttingen: 132-184.
Haüy, R.J., 1799. — J. Mines, 5: 269.
Hawthorne, F.C., L.A. Groat, M. Raudsepp, N.A. Ball, M. Kimata, F.D. Spike, R. Gaba, N.M. Halden, G.R.Lumpkin, R.C. Ewing, R.B. Greegor, F.W. Lytle, T.S. Ecrit, G.R. Rossman, F.J. Wicks, R.A. Ramik, B.L. Sherriff, M.E. Fleet & C. McCammon, 1991. Alpha-decay damage in titanite. — Am. Miner., 76: 370-396.
Heaman, L.S. & P.C. Smalley, 1994. A U-Pb study of the Morkheia complex and associated gneisses, southern Norway: Implications for disturbed Rb-Sr systems and for the temporal evolution of Mesoproterozoic magmatism in Laurentia. — Geochim. Cosmochim. Acta, 58: 1899-1911.
Helland, A., 1874. Apatit i forekommende i rene stakke og gange i Bamle i Norge. — GFF, 2: 148-156.
Helland, A., 1904. Topografish-statistik beskrivelse over Nedenes amt. — Aschehoug & Co., Christiania.
Hey, M.H., 1933. Studies on the zeolites. Part. V. Mesolite. — Miner. Mag., 23: 421-447.
Hintze, C., 1897a. Handbuch der Mineralogie. Band II: Silicate, Titanate. — Veits & Co., Leipzig: 1-1841.
Hintze, C., 1897b. Über krystallisierten Phenakit aus Schlesien. — Z. Kristal., 28: 174-176.
Hoffman, C.A.S., 1811. Handbuch der Mineralogie. Band I. — Craz & Gerlach, Freiberg: 1-685.
Holm, C., 1824. Fortegnelse over de i omegnen af Arendal forekommende fossilier, meddeelt af C. Holm. — Mag. Naturvid., 3: 111-115.
Holmes, A., H.A. Shillibeer & J.T. Wilson, 1955. Potassium-argon ages of some Lewisian and Fennoscandian pegmatites. — Nature, 176: 390-392.
Hulzebosch-Sijen, N.M.P.E., D. Visser, M.H. Maarschalkerweerd & C. Maijer, 1990. Two new kornerupine localities in the Bamble sector, Norway. — Geonytt, 17: 58.
Jansen, J.B.H., R.J.P. Blok, A. Bos & M. Scheelings, 1985. Geothermometry and geobarometry in Rogaland and preliminary results from the Bamble area, South Norway. In: A.C. Tobi & J.L.R. Touret (eds.) The deep Proterozoic crust in the North Atlantic provinces. — Reidel, Dordrecht: 499-516.
Johannsen, A., 1937. A descriptiive petrography of the igneous rocks. Vol. III. The intermediate rocks. — Univ. Chicago Press, Chicago: 124-125.
Jøsang, O., 1966. Geologiske og petrografiske undersøkelser i Modumfeltet. — NGU, 235: 1-148.
Judd, J.W., 1889. On the processes by which a plagioclase feldspar is converted into scapolite. — Miner. Mag., 8: 186-198.
Karsten, D.L.G., 1800. Mineralogische Tabellen. (1st ed.)
Kihle, J. & K. Bucher-Nurminen, 1992. Orthopyroxene - sillimanite - sapphirine granulites from the Bamble granulite terrain, southern Norway. — J. Metam. Geol., 10: 671-683.
Kjerulf, T. & T. Dahll, 1861. Om jernertsener forekomst ved Arendal, Næs og Kragerø. — Nyt Mag. Naturvid., 11: 293-359.
Kloprogge, J.T., 1987. Albite-actinolite (hedenbergite) containing rocktypes in the Bamble area, southeast Norway. — Unpubl. MSc thesis, Utrecht Univ.: 1-33.
Knudsen, T.L., 1996. Petrology and geothermobarometry of granulite facies metapelites from the Hisøy-Torungen area, south Norway: New data on the Sveconorwegian P-T-t path of the Bamble sector. — J. Metam. Geol., 14: 267-287.
Knudsen, T.L., T. Andersen, M. Whitehouse & J. Vestin, 1997. Detrital zircon ages from southern Norway - Implications for the Proterozoic evolution of the southwestern Baltic Shield. — Contr. Miner. Petrol., 130, 1: 47-58.
Kobell, F. von, 1873. Ueber den Kjerulfin, eine neue Mineralspecies von Bamble in Norwegen. — J. prakt. Chem., N.F., 7: 272-275.
Kobell, F. von, 1874. Ueber den Tschermakit, eine neue Mineralspecies aus der Gruppe der Feldspäthe. — J. prakt. Chem., N.F., 8: 411-414.
Krijgsman, A., 1991a. Geology and ore-genesis of the Ettedalgrube, a Proterozoic Pb-Zn-Ag deposit in

SE Norway. — Unpubl. MSc thesis, Utrecht Univ.: 1-34.
Krijgsman, A., 1991b. Pb-Zn-Ag mineralization at the Ettedalgrube. — Exc. log to the 2nd SNF, Bamble, 1991: 40-41.
Krijgsman, A., 1991c. De geologie van het gebied rond het Hauglandsvann, Aust-Agder, Zuid-Oost Noorwegen. — Unpubl. MSc thesis, Utrecht Univ.: 1-131.
Kuiperus, G.T.J., 1986. Cu-Ni-Fe verertsingen in Oost-Bamble, Noorwegen. — Unpubl. MSc thesis, Utrecht Univ.: 1-34.
Kullerud, L. & S. Dahlgren, 1993. Sm-Nd geochronology of Sveconorwegian granulite facies mineral assemblages in the Bamble shear belt, south Norway. — Precamb. Res., 64: 347-360.
Kullerud, L. & N. Machado, 1991. End of a controversy: U-Pb geochronological evidence for significant Grenvillian activity in the Bamble area, Norway. — Terra Abstr., 3: 504.
Lacroix, A., 1889. Contribution à l'étude des gneiss à pyroxène et des roches à wernérites. — Bull. Soc. franç. Minér., 12: 83-350.
Lamb, R.C., 1981. Geochemical studies in the Proterozoic high-grade gneiss terrain, Bamble sector, south Norway. — Unpubl. PhD thesis, Univ. Nottingham.
Leonhard, G., 1841. Briefwechsel. — N. Jahrb. Miner. Geogn. Geol. Petrefakt., 1841: 75-76.
Lévy, A., 1824a. — Ann. Philos., 7: 134 (cited in Clark, 1993).
Lévy, A., 1824b. — Ann. Philos., 24: 275 (cited in Clark, 1993).
Lieftink, D.J., 1992. Geologie van het gebied rond Ubergsmoen, Bamble Sector, Zuid-Noorwegen. — Unpubl. MSc thesis, Utrecht Univ.: 1-122.
Lieftink, D.J., T.G. Nijland & C. Maijer, 1993. Cl-rich scapolite from Ødegårdens Verk, Bamble, Norway. — NGT, 73: 55-57.
Lieftink, D.J., T.G. Nijland & C. Maijer, 1994. The behaviour of REE in high temperature Cl-bearing aqueous fluids: Results from the Ødegårdens Verk natural laboratory. — Can. Miner., 32: 149-158.
Linschoten, P. van, 1989. Onderzoek naar de genese van twee ertszones in het Oygardsasen gabbrolichaam (Noordelijk deel Blengsvatn Gabbro), ZO Noorwegen. — Unpubl. MSc thesis, Utrecht Univ.: 1-37.
Lucas, J.A.H., 1806. Tableaux méthodique des espèces minéraux. — Paris.
Luo, G., J. Xue, H. Xu, H. Xu & M. Hu, 1992. Confirmation of the terrstrial occurrence of orthopyroxene with space group $P2_1/a$. — Am. Miner., 77: 115-120.
Macaudière, J. & J. Touret, 1969. La fibrolitisation tectonique: Un méchanisme possible de formation des gneisses nodulaires du Bamble. — Sci. Terre, 14: 199-214.
Maijer, C. & T.G. Nijland, 1991. Albite-actinolite-quartz rocks (AAQ): Result of extensive metasomatic alteration along gabbro-country rock contacts. — Exc. log 2nd SNF, Bamble,1991: 6-8.
Mallard, E., 1887. Sur la cryptolite de Norvège. — Bull. Soc. franç. Minér., 10: 236-238.
Michel, M.L., 1893. Sur une nouvelle espèce minérale de Bamle (Norvège). — Bull. Soc. franç. Minér., 16: 38-43.
Michel-Lévy, M.A., 1878a. Sur une roche à sphene, amphibole et wernérite granulitique des mines d'apatite de Bamble près Brevig (Norwège). — Bull. Soc. franç. Minér., 1: 43-46.
Michel-Lévy, M.A., 1878b. Note sur le gisement de l'amphibolite a wernérite granulitique d'Odegaard près Bamble (Norwège). — Bull. Soc. franç. Minér., 1: 79-81.
Michel-Lévy, M.A. & A. Lacroix, 1888. Minéralogie sur nouveau gisemant de dumortiérite. — C. R. Acad. Sci. Paris, 106: 1546-1548.
Milch, L., 1900. Mineralogische Mittheilungen. — N. Jahrb. Miner. Geol. Pal., 1900: 152-167.
Møller, N.B., 1826. Om nogle nøiere bestemte norske mineralier. — Mag. Naturvid., 7: 192-197.
Moorbath, S. & F.M. Vokes, 1963. Lead isotope abundance studies on galena occurrences in Norway. — NGT, 43: 283-343.
Moree, M., 1994. Relations between structural trends and ages of the mafic dikes in the Bamble Sector, southern Norway. — Vol. Abstr. 2nd Netherl. Earth Sci. Congr., Veldhoven, 1994: 91.
Moree, M. & T.G. Nijland, 1996. The Vimme talc deposit: field occurrence, whole rock chemistry & Pb isotopes. — Abstr. 7th SNF Excursion Numedal - Telemark - Bamble.
Morton, R.D., 1961. Contributions to the mineralogy of Norway. No. 9. On the occurrence of two rare

phosphates in the Ødegården Apatite mines, Bamble, south Norway. — NGT, 41: 233-246 .
Morton, R.D. & E.J. Catanzaro, 1964. Stable chlorine isotope abundances in apatites from Ødegårdens Verk, Norway. — NGT, 44: 307-313.
Munz, I.A., D. Wayne & H. Austrheim, 1994. Retrograde fluid infiltration in the high-grade Modum complex, south Norway: Evidence for age, source and REE mobility. — Contr. Miner. Petrol., 116: 32-46.
Munz, I.A., B.W.D. Yardley, D.A. Banks & D. Wayne, 1995. Deep penetration of sedimentary fluids in basement rocks from southern Norway: Evidence from hydrocarbon and brine inclusions in quartz veins. — Geochim. Cosmochim. Acta, 59: 239-254.
Naik, M.S., 1975. Silver sulphosalts in galena from Espeland, Norway. — NGT, 55: 185-189.
Naik, M.S., W.L. Griffin & L.J. Cabri, 1976. (Co,Ni)SbS phases and argentian boulangerite in galena from Espeland, Norway. — NGT, 56: 449-454.
Neumann, H., 1961. The scandium content of some Norwegian minerals and the formation of thortveitite, a reconnaissance survey. — NGT, 61: 197-210.
Neumann, H., 1985. Norges mineraler. — NGU Skr., 68: 1-278.
Neumann, H., O. Jøsang & R.D. Morton, 1960. Mineral occurrences in southern Norway. In: J.A. Dons (ed.) Excursions in Norway. — NGU, 212o: 1-18.
NGU, 1971. Areomagnetisk kart over Norge 1:250,000 Arendal. — NGU, Trondheim.
Nilssen, B., 1970. Samarskites, chemical composition, formula and crystalline phases produced by heating. — NGT, 50: 357-373.
Nilssen, B. & G. Raade, 1973. Contribution to the mineralogy of Norway, No. 54. On chromian montmorillonite (Volkonskoite) in Norway. — NGT, 53: 329-331.
Nijland, T.G., 1989. De geologie van het Nelaug gebied, Bamble sector, Zuid Noorwegen. — Unpubl. Msc thesis, Utrecht Univ.: 1-85.
Nijland, T.G., 1993. The Bamble amphibolite-granulite transition zone, Norway. — Geol. Ultraiectina, 101: 1-166.
Nijland, T.G., J.B.H. Jansen & C. Maijer, 1993d. Halogen geochemistry of fluid during amphibolite-granulite metamorphism as indicated by apatite and hydrous silicates in basic rocks from the Bamble sector, south Norway. — Lithos, 30: 167-189.
Nijland, T.G., F. Liauw, D. Visser, C. Maijer & A. Senior, 1993b. Metamorphic petrology of the Froland corundum-bearing rocks: The cooling and uplift history of the Bamble sector, south Norway. — NGU, 424: 53-61.
Nijland, T.G. & C. Maijer, 1993. The regional amphibolite to granulite facies transition at Arendal, Norway: Evidence for a thermal dome. — N. Jahrb. Miner., Abh., 165: 191-221.
Nijland, T.G., C. Maijer & J.L.M. van Haren, 1993c. Replacement of quartz by actinolite/clinopyroxene in graphic intergrowths in a deep-seated granite pegmatite (Mjåvatn, Norway). — Terra Abstr., 5: 480.
Nijland, T.G., C. Maijer, A. Senior & R.H. Verschure, 1993a. Primary sedimentary structures and composition of the high-grade metamorphic Nidelva Quartzite Complex (Bamble, Norway) and origin of the nodular gneisses. — Proc. Kon. Ned. Akad. Wetensch., 96: 217-232.
Nijland, T.G. & A. Senior, 1991. Sveconorwegian granulite facies metamorphism of polyphase migmatites and basic dikes, south Norway. — J. Geol., 99: 515-525.
Nijland, T.G., R.H. Verschure & C. Maijer, 1994. Catalytic effect of biotite: formation of hydrogarnet lenses. — C. R. Acad. Sci. Paris, 318, II: 501-506.
Nijland, T.G., J.L.R. Touret & D. Visser, 1997. Prograde sapphirine granulite islands in the amphibolite facies part of transition zone: Hauglandsvatn, southern Norway. — Vol. Abstr., Gen. Assembl. Eur. Geophys. Soc., Vienna.
Nordenskiöld, A.E., 1878. Cleveit, ett nytt yttro-uran mineral från Garta felsspatbrott nära Arendal. — GFF, 4: 28-32.
Nordenskiöld, A.E., 1884. Uransilikat från Garta felsspatbrott i granskapet af Arendal. — GFF, 7: 121-123.
Oftedahl, C., 1963. Contributions to the mineralogy of Norway. No. 19. Red corundum of Froland at Arendal. — NGT, 43: 431-443.

Oftedal, I., 1939. On the occurrence of tin in Norwegian minerals. — NGT, 19: 315-325.
Oftedal, I., 1942. Om betingelsene for oktaedrisk delbarhet hos vismutrisk blyglans. — NGT, 22: 61-68.
Oftedal, I., 1948. Oversikt over Norges mineraler. — NGU, 170: 1-48.
Oftedal, I., 1959. On the occurrence of tellurium in Norwegian minerals. — NGT, 39: 75-79.
Oftedal, I., 1963. Contributions to the mineralogy of Norway. No. 16. Danburite from the Kragerø District. — NGT, 43: 73-74.
Oftedal, I., 1972. Contributions to the mineralogy of Norway, No. 48. Calcium-rich gadolinite from Kragerø. — NGT, 52: 197-200.
Pontoppidan, E., 1752. Det første forsøg paa Norges naturlige historie. — Copenhagen.
Raade, G. & K. Brastad, 1993. Kamphaugite-(Y), a new hydrous Ca-(Y,REE) carbonate mineral. — Eur. J. Miner., 5: 679-683.
Rammelsberg, C.F., 1860. Handbuch der Mineralchemie. — W. Engelmann, Leipzig (1st ed).
Ramsay, C.R. & R.D. Morton, 1971. Hydrothermal retrogression of cordierite in the Bamble sector, south Norway. — N. Jahrb. Miner., Mh., 1971: 398-403.
Rath, G. vom, 1868. — Poggendorf. Ann. Phys. Chem., 113: 281.
Reitan, P.H., 1959. Pegmatite veins and the surrounding rocks. III. Structural control of small pegmatites in amphibolite, Rytterholmen, Kragerøfjord, Norway. — NGT, 39: 173-195.
Riecker, R.E. & T.R. Rooney, 1966. Shear strenght, polymorphism, and mechanical behavior of olivine, enstatite, diopside, labradorite, and pyrope garnet: test to 902EC and 60 kb. — U.S. Air Force Cambridge Res. Lab., Environm. Res. Pap., 216: 1-57.
Røsholt, B., 1967. The lead and zinc bearing veins at Tråk in southern Norway. — NGU, 250: 34-64.
Sæbø, P.C. & P.H. Reitan, 1959. An occurrence of zeolites at Kragerø, southern Norway. — NGU, 205: 174-180.
Scheerer, T., 1845a. Geognostisk-mineralogiske skizzer, samelede paa en Reise i Sommeren 1842. — Nyt Mag. Naturvid., 4: 126-164.
Scheerer, T., 1845b. Einiges über das Vorkommen und die Benutzung norwegischer Nickelerze. — Berg. hüttenm. Z., 4: 802.
Scheerer, T., 1846. Ueber eine eigenthümliche Art der Isomorphie, welche eine ausgedehnte Rolle im Mineralreiche spielt. — Poggendorf. Ann. Phys. Chem., 68: 319-375.
Scheerer, T., 1848a. Omen egen art af isomorphie, der spillen en omfettende rolle i mineralriget. — Nyt Mag. Naturvid., 5: 171-214.
Scheerer, T., 1848b. An det bidrag til kundskab om norske mineralier. — Nyt Mag. Naturvid., 5: 299-318.
Schei, P., 1904. On some new occrurrences of titanite from Kragerø. — Nyt Mag. Naturvid., 42: 35-38.
Schei, P., 1905. Notes on Norwegian minerals. — Nyt Mag. Naturvid., 43: 137-145.
Schetelig, J., 1913. Mineralogische Studien, I. — NGT, 2: 3-37 .
Schetelig, J., 1915. Skapolit fra Sudnorske pegmatitganger. — NGT, 3: 1-16.
Schlüter, J., 1994. Cordierit - Eine Navigationshilfe der Wikinger? — Aufschluss, 45: 67-72.
Schneiderhohn, H., 1961. Die Erzlagerstätten der Erde. Band II. — Gustav Fischer Verlag, Stuttgart: 61-84.
Schumacher, C.F., 1801. Versuch eines Verzeichnisses der in den Dänisch-Nordischen Staaten sich findenen einfachen Mineralien. — Copenhagen.
Serdyuchenko, D.P., 1968. Metamorphosed weathering crusts of the Precambrian, their metallogenic and petrographic features. — Proc. 23th Int. Geol. Congr. Prague, 1968, 4: 37-42.
Simon, 1807. Gehlen's J. Chem. Phys., 4: 405, 411.
Sjögren, H., 1883. Om de norska apatitförekomsterna och om sannolikheten att anträffa apatit i Sverige. — GFF, 6: 447-498.
Skogby, H., D.R. Bell & G.R. Rossman, 1990. Hydroxide in pyroxene: Variations in the natural environment. — Am. Miner., 75: 764-774.
Smith, D.G.W., 1969. Contributions to the mineralogy of Norway, No. 42. A reinvestigation of the pseudobrookite from Havredal (Bamble), Norway. — NGT, 49: 285-288.
Solly, R.H., 1892. Minerals from the apatite-bearing veins at Noerestad near Risör on the SE coast of

Norway. — Miner. Mag., 10: 1-7.
Starmer, I.C., 1969a. Basic plutonic intrusions of the Risør - Söndeled area, south Norway: The original lithologies and their metamorphism. — NGT, 49: 403-431.
Starmer, I.C., 1969b. The migmatite complex of the Risør area, Aust-Agder, Norway. — NGT, 49: 3-56.
Starmer, I.C., 1972. Polyphase metamorphism in the granulite facies terrain of the Risør area, south Norway. — NGT, 52 :43-71.
Starmer, I.C., 1976. The early major structure and petrology of rocks in the Bamble series, Söndeled-Sandnesfjord, Aust-Agder. — NGU, 327: 77-97.
Starmer, I.C., 1985. The evolution of the south Norwegian Proterozoic as revealed by major and mega-tectonics of the Kongsberg and Bamble sectors. In: A.C. Tobi & J.L.R. Touret (eds.) The deep Proterozoic crust in the North Atlantic provinces. — Reidel, Dordrecht: 259-290.
Starmer, I.C., 1990. Mid-Proterozoic evolution of the Kongsberg-Bamble belt and adjacent areas, southern Norway. In: C.F. Gower, T. Rivers & B. Ryan (eds.) Mid-Proterozoic Laurentia-Baltica. — Geol. Ass. Can. Spec. Pap., 38: 279-305.
Starmer, I.C., 1991. The Proterozoic evolution of the Bamble Sector shear belt, southern Norway: Correlations across southern Scandinavia and the Grenvillian controversy. — Precamb. Res., 49: 107-139.
Starmer, I.C., 1993. The Sveconorwegian Orogeny in southern Norway, relative to deep crustal structures and events in the North Atlantic Proterozoic supercontinent. — NGT, 73: 109-132.
Støretvedt, K.M., 1968. The permanent magnetism of some basic intrusions in the Kragerø archipelago, S. Norway, and its geological implications. — NGT, 48: 153-163.
Strunz, H., 1982. Mineralogische Tabellen. — Akad. Verlag, Leipzig: 1-621.
Sundvoll, B. & B.T. Larsen, 1991. Rb-Sr and Sm-Nd relationships in dyke and sill intrusions in the Oslo Rift and related areas. — NGU, 425: 25-41.
Touret, J.L.R., 1966. Sur l'origine supracrustale des gneiss rubanés de Selås (formation de Bamble, Norvège méridionale). — C. R. Acad. Sci. Paris, 262: 9-12.
Touret, J.L.R., 1967a. Sur la présence de mangérite à fayalite au NW de Gjerstad. — C. R. Acad. Sci. Paris, 263: 252-253.
Touret, J.L.R., 1967b. Les gneiss oeillés de la région de Vegårshei-Gjerstad (Norvège méridionale). I. Étude pétrographique. — NGT, 47: 131-148.
Touret, J.L.R., 1968. The Precambrian metamorphic rocks around the Lake Vegår (Aust-Agder, southern Norway). — NGU, 257: 1-45.
Touret, J.L.R., 1969. Le socle Précambrien de la Norvège méridionale (Région de Vegårshei-Gjerstad). — Unpubl. PhD thesis, Univ. Nancy, CNRS, AO 2902: 1-316.
Touret, J.L.R., 1971. Le faciès granulite en Norvège méridionale. I. Les associations minéralogiques. — Lithos, 4: 239-249.
Touret, J.L.R., 1979. Les roches à tourmaline-cordiérite-disthène de Bjordammen (Norvège méridionale) sont-elles liées à d'anciennes évaporites? — Sci. Terre, 23: 95-97.
Touret, J.L.R. & H. de la Roche, 1971. Contribution to the mineralogy of Norway, No. 45. Saphirine à Snaresund, près de Tvedestrand (Norvège méridionale). — NGT, 51: 169-175.
Tröger, W.E., 1967. Optische Bestimmung der gesteinsbildenden Minerale. Teil 2. Textband. — E. Schweizerbart'sche Verlag, Stuttgart: 1-822.
Verschure, R.H., 1985. Geochronological framework for the late-Proterozoic evolution of the Baltic Shield in south Scandinavia. In: A.C. Tobi & J.L.R. Touret (eds.) The deep Proterozoic crust in the North Atlantic provinces. — Reidel, Dordrecht: 381-410.
Visser, D., 1992a. On ammonium in upper-amphibolite facies cordierite-orthoamphibole-bearing rocks from Rød, Bamble sector, south Norway. — NGT, 72: 385-388.
Visser, D., 1992b. Gedrite breakdown in a gedrite-oligoclase rock, Blengsvatn, Bamble sector, south Norway. — N. Jahrb. Miner., Mh., 1992: 513-527.
Visser, D., 1993a. The metamorphic evolution of the Bamble sector, south Norway: A paragenetic and mineral chemical study of cordierite-orthoamphibole-bearing rocks with special reference to borosilicate-bearing mineral assemblages. — Geol. Ultraiectina, 103: 1-159.
Visser, D., 1993b. Fluorine-bearing hydrogarnets from Blengsvatn, Bamble sector, south Norway. —

Miner. Petrol., 47: 209-218.
Visser, D., 1995. Kornerupine in a biotite-spinel-garnet schist near Böylefossbru, Bamble sector, south Norway: Implications for early and late metamorphic fluid activity. — N. Jahrb. Miner., Abh., 169: 1-34.
Visser, D., J.T. Kloprogge & C. Maijer, 1994. An infrared spectroscopic (IR) and light element (Li, Be, Na) study of cordierites from the Bamble sector, south Norway. — Lithos, 32: 95-107.
Visser, D., C. Maijer & A. Senior, 1990. Retrograde talc-kyanite-quartz assemblage from Bjordammen, Bamble sector, south Norway. — Geonytt, 17: 119.
Visser, D., T.G. Nijland & C. Maijer, 1991. Orthopyroxene-cordierite-garnet-kornerupine-albite-bearing metaevaporites intercalated with enderbitic gneisses at Færvik School, Tromøya. — Exc. log 2nd SNF, Bamble, 1991: 60-64.
Visser, D. & A. Senior, 1990. Aluminous reaction textures in orthoamphibole bearing rocks: The P-T path of the high grade Proterozoic of the Bamble sector, south Norway. — J. Metam. Geol., 8: 231-246.
Visser, D. & A. Senior, 1991. Mg-rich dumortierite in cordierite-orthoamphibole-bearing rocks from the high-grade Bamble sector, south Norway. — Miner. Mag., 55: 563-577.
Visser, D., P.H.M. Thijssen & J.C. Schumacher, 1992. Högbomite in sapphirine-bearing rocks from the Bamble sector, south Norway. — Miner. Mag., 56: 343-351.
Vogel, H., 1887. Über die chemische Zusammensetzung des Vesuvian. — Thesis, Univ. Göttingen. Abstracted in Z. Kristal., 17: 216 (1890).
Vogt, J.H.L., 1884. Norske ertsforekomster. I. — Archiv Math. Naturvid., 9: 231-300.
Vogt, J.H.L., 1886. Hisø sølvgrube på Arendal, Norge. — GFF, 8: 64-70.
Vogt, J.H.L., 1891. Salten og ranen. — NGU, 3: 1-232.
Vogt, J.H.L., 1907. Über die Erzgänge zu Traag in Bamle, Norwegen. — Z. prakt. Geol., 15: 210-216.
Vogt, J.H.L., 1908. De gamle norske jernverk. — NGU, 46: 1-83.
Vogt, J.H.L., 1910. Norges jernmalmforekomster. — NGU, 51: 1-225.
Vogt, J.H.L., 1918. Jernmalm og jernverk. — NGU, 85: 1-181.
Vry, J.K., P.E. Brown & J.W. Valley, 1990. Cordierite volatile content and the role of CO_2 in high-grade metamorphism. — Am. Miner., 75: 71-88.
Weibye, P.C., 1846. Polychroilith, ein neues Mineral. — N. Jahrb. Miner. Geol. Geogn. Petrefaktenk., 1846: 289-292, Taf. IIIa.
Weibye, P.C., 1847. Bemerkungen über die geognostischen Verhältnisse der Küste von Arendal bis Laurvig im südlichen Norwegen. — N. Jahrb. Miner. Geol. Geogn. Petrefaktenk., 1847: 697-709, Taf. XI-XII.
Weibye, P.C., 1849. Beiträge zur topographischen Mineralogie des Distrikts Brevig. — N. Jahrb. Miner. Geol. Geogn. Petrefaktenk., 1849: 467-470 (abstract).
Weibye, P.C., N.J. Berlin, K.A. Sjögren & J.B. von Borck, 1850. Neue Mineralien aus Norwegen, Erster Theil. — Poggendorf. Ann. Phys. Chem., 79: 299-304.
Wel, D. van der, 1973. Contribution to the mineralogy of Norway, No. 53. Kornerupine: A new mineral to Norway. — NGT, 53: 349-357.
Winchell, A.N., 1951. Elements of optical mineralogy. Part II. Descriptions of minerals. — J. Wiley & Sons, New York: 1-551 (4th ed.).
Wöhler, F., 1846. Kryptolith. — Poggendorf. Ann. Phys. Chem., 67: 424.
Zimmerman, J.L., 1981. La libération de l'eau, du gaz carbonique et des hydrocarbures des cordiérites. Çinétique des méchanismes. Détermination des sites. Intérèt pétrogénétique. — Bull. Minér., 104: 325-338.

Revised manuscript received 16 October 1997.

Table 1. List of specimens from the Bamble sector, present in the collections of the Nationaal Natuurhistorisch Museum (National Museum of Natural History), Leiden.

Elements	
Metals	
Copper	22 630 (Arendal)
Sulphides	
Sulphides with Me:S < 1:1	
Pyrite	1543 (Arendal)
Oxides, hydroxides	
Spinels	
Magnetite	12 126, 12 954, 23 912, 23 951, 106 161, 106 194, 106 198 (all Arendal), 164 935 (Bråstad)
Sesquioxides	
Ilmenite	163 624 (Arendal)
Dioxides	
Quartz	2393 (*rose quartz*), 2483, 64 847, 69 373, 81 407, 105 158, 105 176, 105 391, 381 517 (all Arendal)
Rutile	2950, 105 185 (both Arendal)
Columbite	23 941 (Sannikdal)
Euxenite	164 637 (Arendal)
Aeschynite-(Y)	80 283 (Arendal)
Uranyl(hydr)oxides	
Fourmarierite	107 411 (Gloserhei)
Carbonates	
Calcite	24 110, 24 111, 24 325, 24 327, 24 342, 24 406, 24 462, 24 608, 64 847, 64 848, 64 852, 64 882, 69 391, 81 011 (all Arendal), 81 122 (Kragerø), 82 484, 105 138, 105 146, 105 148, 1051 54, 105 162, 105 163 105 167, 106 194 (all Arendal)
Phosphates	
Apatite	23 950, 23 951, 23 959, 105 138, 105 147, 105 164, 105 176, 105 445 (all Arendal)
Silicates	
Nesosilicates	
Zircon	80 279, 82 241 (both *alvite*, Kragerø)
Garnet	12 979 (almandine), 23 493, 24 188, 24 315, 24 316, 24 323, 24 325, 24 327, 24 333, 24 334, 24 342, 24 839, 64 831, 64 869, 64 943, 64 950, 69 391, 105 148 (andradite), 105 154 (andradite), 105 162 (andradite), 105 164 (andradite), 105 163 (andradite), 164 230 (almandine) (all Arendal).
Titanite	24 863, 64 823, 69 390, 69 391, 69 543 (*keilhauite*), 80 310 (*keilhauite*), 381 870 (all Arendal)
Datolite	24 110, 24 111, 64 833, 64 882, 105 167, 381 981 (all Arendal)
Sorosilicates	
Hellandite	80 707 (Kragerø)
Epidote	18 654, 18 655, 24 178-24 183, 24 185-24 188, 24 662, 64 847, 64 848, 64 852, 648 53, 64 856, 64 867, 64 869, 69 380, 69 391, 81 011, 105 139, 105 166, 381 506, 381 511, 381

	517 (all Arendal)
Vesuvianite	24 315, 24 316, 25 588, 64 943, 64 950, 81 257, 105 137, 105 172, 105 173, 105 180 (*cyprine*) (all Arendal)
Cordierite	24 561, 105 10, 105 158, 105 447 (all Arendal)
Tourmaline	24 116-24 118, 64 786, 420 796 (all Arendal)
Inosilicates	
Diopside	23 493, 24 604, 24 608, 82 484, 105 138, 105 145, 105 146, 105 148, 105 155, 105 156, 105 162, 105 164, 105 165, 105 167, 105 174, 381 903 (all Arendal)
Augite	12 126, 23 951, 64 823, 64 831, 64 833, 64 840, 412 151 (all Arendal)
Actinolite	64 826 (Arendal), 411 764 (Åmdalsmoen)
Hornblende	18 659, 24 697, 24 699-24 703, 37 523, 69 380 (all Arendal), 81 122 (Kragerø), 105 175, 106 194, 381 517, 412 271 (all Arendal)
Babingtonite	24 662 (Arendal)
Phyllosilicates	
Muscovite	10 158 (Arendal)
Biotite	24 402-24 404, 24 406, 24 410 (all Arendal)
Tectosilicates	
Plagioclase	24 816 (*aventurine*, Tvedestrand), 64 867 (oligoclase, Arendal), 69 380 (albite, Arendal), 105 199, 412 381 (both oligoclase, Arendal)
K-feldspar	24 816 (orthoclase, Arendal), 64 901 (orthoclase, Kragerø), 69 373 (microcline, Arendal), 381 444 (orthoclase, Arendal)
Scapolite	18 585, 24 830-24 834, 24 838, 24 839, 25 589 (all Arendal), 81 407 (*wernerite*, Arendal), 105 168, 105 391 (both Arendal), 105 548, 381 913 (both *wernerite*, Arendal)

Table 2. List of specimens from the Bamble sector, present in the collections of the Musée de Minéralogie, École des Mines, Paris.

Oxides, hydroxides	
Spinels	
Magnetite	859 (Arendal)
Sesquioxides	
Cordundum	15 740, 15 755, 18 734 (Blakstad, Arendal)
Ilmenite	5744, 16 517, 17 742 (all Froland), 19 653 (Arendal)
Dioxides	
Euxenite-(Y)	1366 (Arendal)
Aeschynite-(Y)	1371 (Arendal)
Phosphates	
Xenotime-(Y)	4855 (Narestø)
Silicates	
Nesosilicates	
Phenakite	3300 (Kragerø)
Thorite	5860 (Arendal)
Garnet	5879 (andradite, Arendal)
Sorosilicates	
Hellandite	16 374 (Lindvikskollen)
Allanite	3862 (Arendal), 16 407 (Kalstad, Kragerø)
Inosilicates	
Orthopyroxene	4546 (Kjørrestad), 4547 (Ødegårdens Verk), 16 515 (Kjørrestad)
Actinolite	4579 (Arendal)
Tectosilicates	
Plagioclase	4101, 4103 (both Arendal), 4106 (*solstein*, Tvedestrand), 4110 (Arendal)
Stilbite	3969 (Arendal)

Plate 1

Fig. a. Granitic pegmatite at Ossedalen, near Blakstad.
Fig. b. Native copper, Arendal (Coll. NNM Leiden, RGM 22 630). Height is c. 4.5 cm.

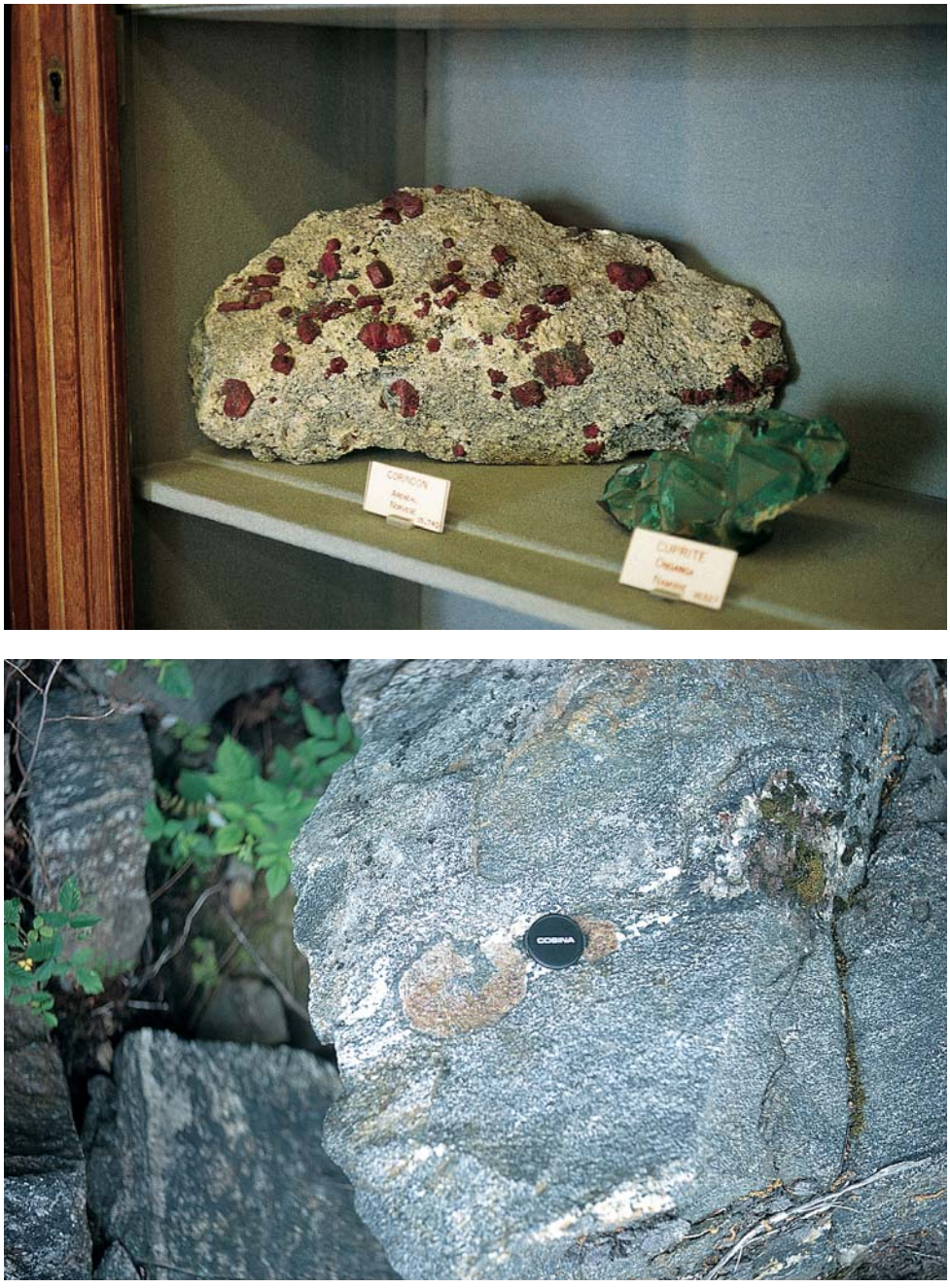

Plate 2

Fig. a. Corundum, Blakstad (Coll. École des Mines, 15 790). Length of sample is 57 cm.
Fig. b. Large garnet porphyroblasts in metagabbro, Flatenskole, south of Nelaug.

Plate 3

Fig. a. Titanite and calcite in garnet-epidote rock, Arendal (RGM 69 390).
Fig. b. Colourless to white datolite and calcite, Arendal (RGM 24 111). Length of crystals is 6 to 8 mm.

Plate 4

Fig. a. Hellandite, Kragerø (RGM 80 707). Lenght of crystal: 5 cm.
Fig. b. Cordierite-garnet gneiss, Færvik on Tromøy (cf. Visser et al., 1991).

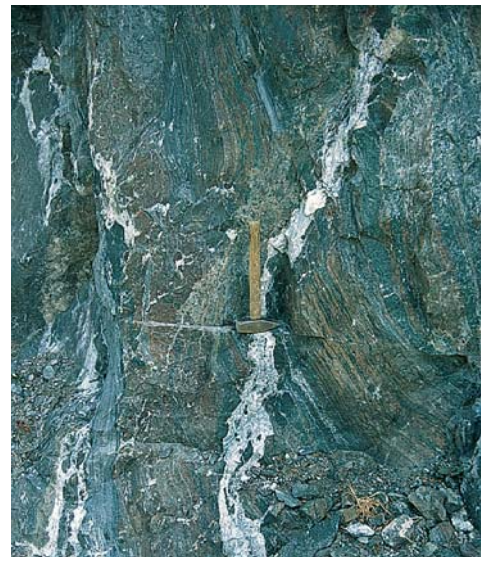

Plate 5

Fig. a. Dark green tourmaline with light green base, Arendal (RGM 420 796). Size 6.2 x 6 cm.
Fig. b. Clinopyroxene-garnet rocks within the skarns at Lofstad on Tromøy (cf. Broekmans et al., 1994).
Fig. c. Actinolite in quartz, small quarry near Uvatn (cf. Maijer & Nijland, 1991).

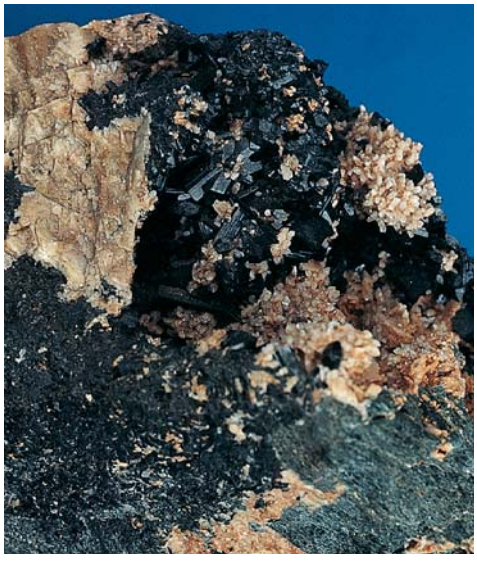

Plate 6

Fig. a. Anthophyllite rock, Bøylefossbru (cf. Visser & Senior, 1990; Visser, 1995).
Fig. b. Babingtonite, Arendal (RGM 24 662). Length of crystals is c. 3 mm.
Fig. c. Giant K-feldspar crystal, Lauvrak pegmatite.