

THE FIRST OCCURRENCE OF GRANDIDIERITE IN NORWAY

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Iron–magnesium–aluminium borosilicate grandidierite has been found in a K-rich metasediment at Vestpolltind, Hinnøya, northern Norway. This is only the third certain locality for this mineral. It occurs together with orthoclase, quartz, garnet, biotite, rutile and ilmenite. The K-rich metasediments are associated with granulite-facies Mn-bearing iron formations, and seem to be of submarine origin. P-T estimates for the metamorphism in the area give ~ 10 kb and 850–900°C.

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Occurrence

Grandidierite, $(\text{MgFe})\text{Al}_3\text{BSiO}_9$, occurs on Vestpolltind, at the head of Øksfjorden, Hinnøya, northern Norway in a metamorphosed K-rich sediment together with orthoclase, quartz, garnet, biotite, ilmenite and rutile.

The chemical composition of the rocks is:

71.20 % SiO_2 ; 1.42 % TiO_2 ; 14.40 % Al_2O_3 ; 0.04 % Fe_2O_3 ; 0.62 % FeO ; 0.02 % MnO ; 0.71 % MgO ; 0.12 % CaO ; 0.40 % Na_2O ; 10.38 % K_2O ; 0.02 % P_2O_5 .

No other boron minerals have been recognized in the area.

Description

The grandidierite from Vestpolltind occurs as euhedral prismatic crystals from less than 0.1 mm to 1.5 mm long and up to 0.1 mm across. It constitutes less than 1 modal % of the rock. Under the binocular microscope the mineral has an aquamarine colour, and shows good cleavage parallel to (100). It has relatively strong pleochroism with α blue, β colourless and γ blue-green.

The X-ray powder pattern is identical with that of grandidierite from Madagascar (locality: Andrahomana, film no. 6436 in the X-ray film file at Mineralogisk–geologisk museum, Oslo). The mineral was analysed with an ARL–EMX electron microprobe, using a polished thin section of the rock. Various natural and synthetic standards were used; the counting rates were corrected for dead time and background, and for fluorescence/absorption by the method of Bence & Albee (1969). Boron was only determined qualitatively.

Table 1. Chemical composition of grandierite and contents of 1/4 unit cell calculated to O = 9.

	1	2	3	4	5		1	2	3	4	5
SiO ₂	20.05	20.4	19.8	20.1	20.3	Si	1.00	1.03	0.99	1.00	0.99
TiO ₂	—	0.05	—	—	—	Ti	—	—	—	—	—
Al ₂ O ₃	53.68	49.2	50.6	50.9	52.3	Al	3.15	2.92	2.95	2.99	3.01
FeO*	6.81	6.7	4.7	5.0	1.1	Fe	0.28	0.28	0.19	0.21	0.04
MnO	0.18	0.3	0.05	0.1	—	Mn	0.01	0.01	—	—	—
MgO	9.44	10.5	12.0	11.6	14.0	Mg	0.70	0.79	0.88	0.87	1.02
CaO	—	0.2	0.3	—	0.1	Ca	—	0.01	0.02	—	0.01
B ₂ O ₃	~ 10**	11.2	11.3	11.2	10.9	B ³⁺	0.86	0.97	0.97	0.96	0.93
Total	~100	98.55	98.75	98.9	98.7						

1. Vestpolltind, Hinnøy (Ø15/72).

2. Blanket Bay, Cuvier Island.

3. Landing Bay, Cuvier Island.

4. Ampamatoa, Madagascar.

5. Vohiboly, Madagascar.

Data for 2, 3, 4 and 5 from Black 1970.

* Total iron calculated as FeO.

** Assumed value.

These analyses are compared with analyses of grandierites from Madagascar and Cuvier Island (Black 1970) in Table 1. The data for the Vestpolltind grandierite are based upon analyses of 15 grains; there are no grain-to-grain variations in composition.

The high Al₂O₃ and low B₂O₃ content of the grandierite from Vestpolltind is notable. It seems that Al is substituting for B, although Stephenson & Moore (1968) report Al in six- and fivefold coordination, and B in threefold coordination in grandierite. The lack of a quantitative determination for B requires that this suggestion be only tentative.

Genesis

None of the previous records of grandierite have yielded clear evidence of its genesis (Black 1970).

It has been suggested (McKie 1965) that grandierite could have crystallized from a boron enriched magma, but the Cuvier and the Vestpolltind grandierites are clearly not magmatic minerals. The Cuvier Island grandierite occurs in a hypersthene–cordierite–biotite–spessartine–andesine–pyrrhotite–orthoclase–rutile–magnetite hornfels (Black 1970). At Vestpolltind grandierite occurs together with orthoclase–quartz–garnet–biotite–rutile–ilmenite.

Other mineral parageneses in the area are:

Orthoclase–biotite–scapolite–garnet–piemontite–magnetite.

Orthoclase–plagioclase–orthopyroxene–clinopyroxene–quartz–biotite–magnetite–ilmenite.

Orthoclase–quartz–biotite–magnetite.

Orthoclase–biotite–garnet–magnetite.

Orthoclase–quartz–sillimanite–biotite–hematite.

All of these rocks lie between two sequences of iron formations. On one side the iron formation is a jasper banded hematite ore with small amounts of jacobsonite, and on the other side it is a quartz banded magnetite ore. The jasper is partly recrystallized.

In the area there is also a large mangeritic intrusion, crystallized under high P–T-conditions, and between this mangerite and the metasediments that enclose the iron formations there are granulite-facies basic rocks. The mangerite, dated at 1700 ± 20 m.y. by Rb/Sr (Griffin et al. 1974), is the youngest of these rocks.

Calculations based upon coexisting ilmenite_{ss}–magnetite_{ss} (Buddington & Lindsley 1964) and orthopyroxene–olivine (Williams 1971, Smith 1972) give a temperature estimate of 1000–1050°C and a pressure of 9–11 kb for the crystallization of the magma (Krogh 1975).

Temperature calculations based upon coexisting clinopyroxene–orthopyroxene (Wood & Banno 1973) from one of the metasediments lying close up to the grandidierite-bearing rock, give a temperature of 850–900°C. This temperature estimate is similar to those obtained from other parts of the granulite-facies Lofoten–Vesterålen terrane (Krogh 1975). The regional high-pressure granulite-facies metamorphism is Rb/Sr dated at ca. 1850 m.y. (Taylor 1974). The thermal effect from the later mangerite intrusion does not seem to have any significant effect on the mineral assemblages.

Both on Cuvier Island and at Vestpolltind the origin of the boron is uncertain. In both places it may be related to boron metasomatism, but the grandidierite may also have crystallized from boron enriched aluminous sediments. Harder (1959, 1961) and Fredrickson & Reynolds (1960) have shown that the major part of the boron content in clays and shales is fixed in illites, and that illites irreversibly take up relatively high amounts of boron from diluted boron solutions.

The reaction

illite + B₂O₃ + chlorite + quartz → orthoclase + grandidierite + H₂O
could then have taken place instead of the reaction

illite + quartz → orthoclase + sillimanite + H₂O.

Grandidierite may thus have occurred instead of sillimanite, due to the presence of boron, magnesium and iron.

The first reaction gives a simplified picture of what has happened. Other phases (e.g. muscovite) may have been formed at intermediate stages during the prograde metamorphism to granulite facies assemblages. But if the system has remained closed with regard to boron, the reaction serves to illustrate the chemical controls on the mineralogy of the sediments and their metamorphic equivalents.

The presence of boron, chert (jasper) and manganese-rich iron ores indicates a submarine origin for these metasediments.

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