(Reedman *et al.*, 1985). More detailed work on the Bwlch Mine assemblage is currently in progress and further occurrences of antimony mineralization in North Wales are being investigated, particularly with a view to testing their epithermal nature and volcanic association.

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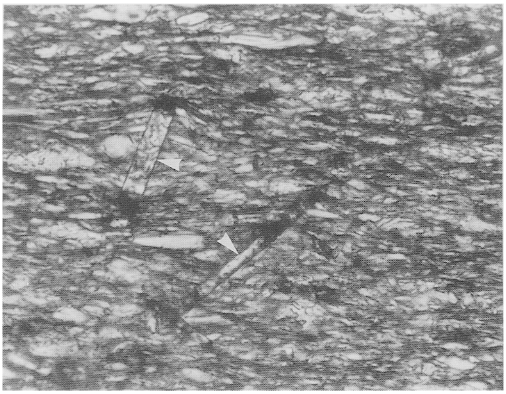
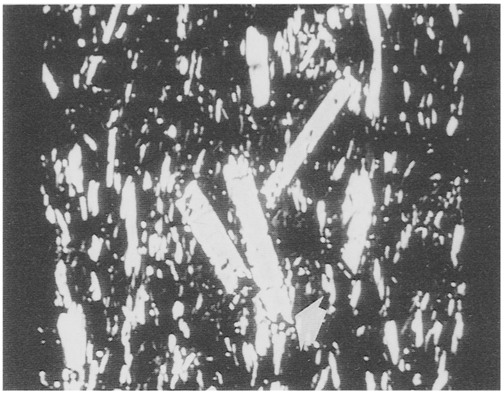
Chloritoid from low-grade pelitic rocks in North Wales

MN-RICH chloritoid has been found in low-grade metamorphic slates of Ordovician age near Rhyd-Ddu (NH 565528) in Snowdonia, Gwynedd, North Wales. To the author's knowledge this is the first reported occurrence of chloritoid in the para-tectonic Caledonides of the Welsh Basin and has important implications for the metamorphic history of the area which will be discussed elsewhere (Brearley, in prep.).

Chloritoid occurs in black slates of the Nant





FIGS. 1 and 2. FIG. 1 (*left*). Optical micrograph of chloritoid porphyroblasts in a sample of muscovite–chlorite slate from the Nant Ffrancon formation, Rhyd-Ddu, Snowdonia, Gwynedd, North Wales. Field of view = 250 μm. FIG. 2 (*right*). Backscattered electron image of a group of chloritoid crystals lying oblique to the cleavage plane. Note the development of the fan-tail morphology at the ends of some of the crystals (arrowed). Field of view = 200 μm.

Ffrancon formation and is found as small tabular porphyroblasts within a matrix of quartz, chlorite, muscovite and interlayered muscovite/paragonite (Fig. 1). The chloritoid porphyroblasts show only a limited size range with long axes between 30 and 100 μm and widths between 6 and 20 μm, but are always significantly larger than the groundmass phyllosilicates and quartz. Some of the crystals exhibit the classic fan tail morphology characteristic of chloritoids from other localities. Although chloritoid porphyroblasts are usually found as isolated single crystals, occasionally groups of three or more are found together as shown in the back-scattered electron image (Fig. 2), but this is rather atypical.

Chloritoid exhibits an interesting textural relationship with the aligned chlorites and white micas which define the cleavage in these rocks. Rarely is chloritoid aligned parallel to the cleavage plane: normally the crystals occur oriented with their long axes at an angle between 30° and 90° to the cleavage plane. There is no evidence of chloritoid overgrowing the cleavage, but in many cases the cleavage phyllosilicates are deflected around the porphyroblasts and in some cases pressure shadows are present on either side of the chloritoid crystals. These textural relationships strongly suggest that the chloritoid porphyroblasts predate the deformation event which produced the cleavage in these rocks. It is probable that the peak maximum metamorphic event in the area, when chloritoid porphyroblast growth occurred, preceded and was distinct from the development of the main Caledonian cleavage.

Representative electron microprobe analyses of chloritoid with structural formulae recalculated on the anhydrous basis of 12 oxygen atoms are shown in Table 1. The chloritoids are all Fe and Mn-rich and have a very restricted range of compositions between $Fe_{64}Mn_{29}Mg_7$ and $Fe_{68}Mn_{29}Mg_3$. No zoning is detectable in any of the crystals. MnO contents vary between 7 and 8.5 wt. % and MgO between 0.46 and 0.95. Chloritoids with high ottrelite components are not unusual in low-grade metapelites and have been reported previously by Kramm (1973) from greenschist rocks of the Venn-Stavelot Massif, Ardenne, and by Brindley and Elsdon (1974) in phyllites from County Wexford,

Table 1. Electron microprobe analyses of Rhyd-Ddu chloritoids

SiO_2	24.79	24.95	24.40	24.55	25.83
TiO_2	0.13	0.18	0.24	-	0.81
Al_2O_3	39.94	41.05	40.52	40.09	39.65
FeO	18.17	19.09	18.25	18.72	18.28
MnO	7.68	7.91	7.98	8.06	7.51
MgO	0.88	0.70	0.95	0.46	0.94
CaO	-	0.02	0.03	0.05	0.08
Na_2O	0.15	0.23	0.28	0.15	0.08
K_2O	0.12	0.02	0.05	0.05	0.08
Total	91.86	94.15	92.70	92.13	93.26
Formulae based on 12 [O] atoms					
Si	2.071	2.041	2.025	2.054	2.119
Ti	0.008	0.011	0.015	-	0.050
Al	3.933	3.957	3.964	3.955	3.834
Fe	1.269	1.305	1.267	1.310	1.254
Mn	0.543	0.548	0.561	0.572	0.522
Mg	0.110	0.085	0.118	0.057	0.114
Ca	-	0.001	0.003	0.004	0.007
Na	0.024	0.036	0.044	0.024	0.012
K	0.135	0.001	0.005	0.005	0.008
Atom%					
Fe	66.0	67.3	65.1	67.6	66.3
Mn	28.2	28.3	28.8	29.5	27.6
Mg	5.8	4.4	6.1	2.9	6.1

Ireland. The chloritoids from the latter locality are very similar to those reported in this study although they are significantly coarser grained. Ottrelite was also reported in Upper Devonian epizone slates from S.W. England by Hutchings (1889), but electron microprobe analyses by Primmer (1984, 1986) have shown that this phase is, in fact, a near Mn-free chloritoid with < 1.1% MnO.

The chloritoid-bearing rocks reported here lie close to the upper anchizone–epizone boundary in Snowdonia as determined by Merriman and Roberts (1986) and Robinson and Bevins (1986) using illite crystallinity measurements and metabasite assemblages. It is possible that of all the occurrences of chloritoid reported in the literature, e.g. as summarized in Halferdahl (1961), Hoschek (1967), and Deer *et al.* (1982), this is one of the lowest grade occurrences to date.

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Al-chlorite as a hydration reaction product of andalusite: a new occurrence

MOST chlorites are trioctahedral, i.e. they are composed of two trioctahedral layers. Although the possible existence of di,dioctahedral chlorite, which consists of two dioctahedral layers, has been suggested by Brindley and Gillery (1961) and Grim (1964), the occurrence and chemistry of such chlorite is not well understood. We describe a new occurrence of a near-end-member di,dioctahedral Al-chlorite as a hydration reaction product of andalusite.

The altered andalusite is from the pegmatite at Szabo Bluff, Scott Glacier, Antarctica (86° 29′ S, 144° 45′ W) (Stump *et al.*, 1981). Andalusite occurs as columnar, radiating, reddish-brown crystals segregated in the interior zone of the pegmatite (Burt and Stump, 1984). In addition to andalusite, the interior zone is composed of K-feldspar, milky quartz, platy albite, tourmaline, muscovite, and ilmenite and other oxides.

Ion-thinned specimens were studied with a JEOL 200CX 200 kV transmission electron microscope (TEM) with a top-entry stage for high-resolution imaging and with a Philips 400T 120 kV TEM with a side-entry stage for analytical electron microscopy (AEM). The Philips 400T is equipped with a Gatan 607 electron energy-loss spectrometer and a Tracor Northern TN-2000 multichannel analyser for electron energy-loss spectroscopy (EELS) and energy-dispersive X-ray analysis.

Optical-microscope observations indicate that andalusite is mainly altered to muscovite, primarily along irregular veinlets. Euhedral, dark-blue corundum occurs exclusively within muscovite aggregates, indicating that corundum is also produced by andalusite alteration. The occurrence of corundum is attributed to a local deficiency of silica in the fluid that caused the andalusite alteration (Rose, 1957; Burt and Stump, 1984).