An occurrence of greenalite-chert in the Ordovician rocks of the southern uplands of Scotland.

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ROCKS composed mainly of the hydrated ferrous silicate greenalite are of very restricted geological and geographical distribution and, up to the present, have been recognized only from certain of the pre-Cambrian sedimentary iron-bearing formations of the Lake Superior region.[1] It is of interest, therefore, to record an additional occurrence, not only from another region but from a later geological system.

The material to be described in the present paper was collected by Mr. R. Eckford from the Arenig outcrop near Glenluce, Wigtownshire, where it occurs in association with spilitic pillow-lavas and basic gabbroic intrusions. In hand-specimen the rock is dark greenish-black in colour and weathers with a deeply iron-stained crust. It has a slightly brecciated appearance and the granular nature is quite apparent with the aid of a lens.

Under the microscope it presents a very characteristic appearance, and is found to be composed of numerous little, rounded, ellipsoidal or slightly irregular granules of a greenish mineral, sometimes partly or wholly replaced by spherulitic aggregates of dusty quartz, embedded in a fine-grained or somewhat variable matrix of cherty silica. The granules are separated from the cherty base by a narrow rim of dusty carbonate (chalybite), and this substance apparently gives rise also to the dusty staining of the secondary quartz aggregates.

The greenalite itself varies considerably in its properties. In thicker portions of the slice it is dark and opaque, quite isotropic, and greenish in reflected light. Here and there it is associated with some replacing

[1] C. R. Van Hise and C. K. Leith, The geology of the Lake Superior region. Monograph U.S. Geol. Surv., 1911, no. 52. C. K. Leith, R. J. Lund, and A. Leith, Pre-Cambrian rocks of the Lake Superior region. Prof. Paper U.S. Geol. Surv., 1935, no. 184.

magnetite. In thinner sections it is usually olive-green or less commonly brownish-green in colour and under crossed nicols exhibits a mottled patchy appearance due to an intimate mixture of isotropic and anisotropic portions. Under high powers the anisotropism may be seen to result from alteration of the isotropic granules to extremely

FIG. 1. Greenalite-chert from Glenluce, Wigtownshire. Greenalite (black) undergoing replacement by dusty quartz aggregates.

fine-grained fibrous aggregates of some greenish, slightly pleochroic mineral. The presence of the latter imparts a slight aggregate pleochroism which is occasionally marked in shades of olive-green and brown. There can be small doubt regarding the identity of the anisotropic portions with metagreenalite,[1] and although the material is too fine-grained to permit of definite optical determination, the pleochroism and general nature is suggestive of grunerite.

The isotropic granules are homogeneous and usually show narrow irregular cracks similar to the shrinkage cracks in gels. They were found to have a refractive index of about 1·675, and this value is in

[1] F. Jolliffe, A study of greenalite. Amer. Min., 1935, vol. 20, pp. 405–425. [Min. Abstr. 6–151.]

perfect agreement with the determinations made by Jolliffe on material from the Biwabik formation of Minnesota.[1]

Characteristically the granules are seen to be undergoing replacement by dusty quartz in the form of fine crystalline aggregates or spherulitic growths, and this silicification appears to lead ultimately to the production of the spherulitic cherts found here and there throughout the Southern Uplands. All stages in the replacement and recrystallization may be traced, but it is not known whether the process dates from the period of formation of the rocks or took place subsequently.

A typical specimen of the greenalite-chert has been analysed by Mr. W. J. Skilling, to whom the writer is much indebted, and the results are set out below.

SiO_2	71·08
TiO_2	0·13
Al_2O_3	0·55
Fe_2O_3	0·78
FeO	18·53
MnO	nil
MgO	0·18
CaO	trace
CO_2	0·44
Loss on ignition ...	6·40
Not determined ...	1·91
Total...	100·00

It is seen from this analysis that the green granular mineral must be essentially a pure hydrated ferrous silicate similar to the greenalite of the Mesabi range which has been shown by Leith[2] and Jolliffe (loc. cit.) to be a definite mineral species approximating to the composition $2H_2O.3FeO.4SiO_2$. It is unfortunate that the writer has been unable to obtain any of the Biwabik material for comparison, but the thin sections of the Glenluce rock are identical with the examples figured by Van Hise and Leith.[3]

Although the Scottish occurrences of greenalite-rocks have not yet been studied in detail, we may consider briefly certain of the genetical aspects of the problem.

The iron formations of the Lake Superior region now consist mainly of banded jaspers and ferruginous cherts derived from the oxidation

[1] F. Jolliffe, loc. cit., 1935, p. 410.

[2] C. K. Leith, The Mesabi iron-bearing district of Minnesota. Monograph U.S. Geol. Surv., 1903, no. 43, pp. 102–116.

[3] C. R. Van Hise and C. K. Leith, loc. cit., 1911, pls. XXXVII and XLIII.

of primary banded siliceous iron carbonate and greenalite-rocks, and the deposits as a whole represent chemical or in small part biochemical sediments. It is now unanimously agreed that the precipitation has been effected through the agency of inorganic processes, and Leith[1] succeeded in producing a precipitate similar to greenalite in composition and structure by a reaction involving alkaline silicates and ferrous salts. The main problem of the sedimentary iron formations, however, concerns the origin of the solutions from which these vast bodies of silica and iron were produced. Certain geologists believe that the iron and silica in solution were derived by intensive weathering of basic igneous rocks.[2] The difficulty in this case is that under such circumstances the iron is all in the ferric state and the precipitation of greenalite would necessitate reduction on a vast scale. If, however, the solutions derived their iron and silica directly from magmatic sources, either by magmatic emanations from igneous rocks poured out on the ocean floor or by rapid decomposition of basic igneous rocks due to their contact while hot with sea-water, the difficulty would not arise. Furthermore, there is a close association of such iron formations with contemporaneous submarine lavas and this feature affords additional evidence in support of the latter theory which is the one held by the majority of investigators.

The cherts and related rocks associated with the Arenig pillow-lavas of the Southern Uplands have usually been regarded as true radiolarian cherts formed by organic agencies, but the occurrence of greenalite in the Glenluce district and the abundance of ferruginous cherts and even small deposits of haematite on this horizon throughout the Southern Uplands suggests that chemical agencies similar to those which operated in the Lake Superior region may have played a greater part than has hitherto been suspected. Finally, the association of the greenalite-rocks with the Arenig pillow-lavas in Wigtownshire is at least suggestive that the iron and silica in question has been derived from igneous emanations rather than by processes of weathering.

[1] C. K. Leith in The geology of the Lake Superior region. Monograph U.S. Geol. Surv., 1911, no. 52, pp. 521–529.

[2] J. W. Gruner, The origin of sedimentary iron formations. Econ. Geol., 1922, vol. 17, pp. 407–460. [Min. Abstr. 3–136.]