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Eulysites and related rock types from Loch Duich, Ross-shire.

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OUR knowledge of the rare rock type eulysite (A. J. Erdmann, 1846) comes almost wholly from Swedish occurrences and hitherto no examples have been recognized from Britain. It is therefore of interest to place on record a new occurrence of eulysites and related rocks from among Lewisian rocks of the Glenelg area, Scotland.

The rocks shortly to be described come from the vicinity of Totaig on Loch Duich between Totaig and Letterfearn, little more than half a mile from the first described occurrence of eclogite in Britain.[1] These eulysitic rocks crop out on the hillside immediately south-west of Druideig Lodge. About 200 yards south-west of the lodge coarse garnet-paragneisses form outcrops associated with grunerite- and cummingtonite-garnet-gneisses, and a similar interbanded association is found at higher levels. At the summit of the knoll, darker and more massive rock types, consisting chiefly of pyroxene-garnet-magnetite and fayalite-pyroxene-garnet-magnetite assemblages heavily stained with black hydrated oxide of manganese, are developed.

The paragneisses of this area form part of the broad band of metamorphosed argillaceous sediments which accompany the bands of

[1] J. J. H. Teall, On an eclogite from Loch Duich. Min. Mag., 1891, vol. 9, p. 217.

Glenelg limestone—striking NNE. towards Loch Duich between Totaig and Letterfearn. The general characters of the paragneisses in the area have been described by Clough in the Survey Memoir.[1]

South-west of Druideig Lodge the garnet-gneisses form strikingly coarse aggregates chiefly of garnet and quartz. Microscopically they are seen to be composed of garnet, quartz, oligoclase, biotite, and muscovite, while Clough has recorded examples containing conspicuous kyanite. The garnets of the coarser types are seen to be in process of replacement by chlorite. It is with these typical paragneisses that the rocks of eulysitic facies now to be described occur.

These iron-rich rocks may be divided into three groups according to their mineralogical contents:

(1) Eulysites proper containing abundant fayalite.

(2) Hedenbergite-garnet-rocks.

(3) Grunerite-garnet-rocks.

(1) *Eulysites.*—The eulysites proper are massive rocks of high density (4·0) often conspicuous in the field by their bluish-black weathering surfaces, the colour being due to hydrated oxide of manganese. Fresh fractured surfaces are dark and somewhat resinous lustred, due to the abundance of fayalite which under a low-power lens is seen to have in thin flakes a honey-yellow colour. In the granular matrix of fayalite occur larger dark green-black crystals of pyroxene, whilst granular red garnet and magnetite are sporadically distributed.

Under the microscope, the constituents seen are fayalite, hedenbergite, iron-hypersthene, garnet, magnetite, and apatite. Some grunerite of secondary development may appear in some of the rocks. The chief constituents, fayalite and pyroxene, form granoblastic aggregates and seldom show good crystal shape. The fayalite ($\frac{1}{2}$ mm. average grain-size) shows fair (010) and poor (100) cleavages. Lamellar twinning of the type familiar in magnesian olivine is not uncommon. The low optic axial angle and pale yellow colour show that this mineral is near fayalite in composition, but the high content of MnO in the analysis of the rock makes evident further that it is a *manganfayalite.* A feature which is characteristic of these and other eulysites is the aggregation of magnetite grains fringing the fayalite crystals.

Monoclinic pyroxene is readily distinguished among the fayalite aggregates by its lower relief, light green colour and more perfect

[1] Geology of Glenelg, Mem. Geol. Surv. Scotland, 1910, p. 26.

cleavage. The grain-size is more variable and may reach in porphyroblasts a diameter of 3 mm. or more. A fine salite striation is not uncommon and magnetite dendrites are not infrequently present in the larger crystals.

An iron-rich hypersthene forming independent grains associated with fayalite and monoclinic pyroxene appears in significant amounts in some of the eulysites. The properties of this hypersthene are referred to on p. 334.

The garnets (spessartine-almandine) are conspicuous by a characteristic yellow-pink tinge. Less abundant than either fayalite or pyroxene, they show considerable variation in grain-size ($\frac{1}{2}-3$ mm.) and are xenoblastic. Enclosures are few but include magnetite, apatite, and less frequently fayalite and pyroxene.

Magnetite, like garnet, is uneven in its distribution. It may be concentrated in narrow zones giving in places a banded structure to the rock. In these it forms xenoblastic grains wrapping around fayalite or intergrown with garnet. That this banding expresses original compositional differences is suggested by a like orientation of bands with variable pyroxene and fayalite contents.

Grunerite can usually be detected in small amount and in some examples is conspicuous. It is readily distinguished by its almost colourless appearance in thin section, fibrous character, and multiple (100) twinning. Its secondary development is made clear from the occurrence of it in veins and the manner of its development from monoclinic pyroxene, and also from fayalite.

A typical member of these eulysites has been analysed (table I, col. 1). The rock contains, in order of abundance, fayalite, hedenbergite including some iron-hypersthene, magnetite and garnet, apatite. A typical section of this rock is illustrated in fig. 1 *b*. The notable feature of this analysis is the high MnO content (12·55 %) and high sum of iron oxides (40·33 %). Rocks of comparable chemical composition are indicated in the table, but a discussion of these analyses is deferred to a later page (p. 340).

Eulysitic rocks rich in iron-hypersthene.—Iron-hypersthene has been already referred to under the description of the eulysites. A few rocks, however, contain it in abundance. The mineral is present in association with fayalite or with monoclinic pyroxene, and in one rock—a hypersthene-grunerite-garnet type—it forms the major constituent.

In specimen no. 221 it forms independent grains as well as parts of zoned crystals of porphyroblastic monoclinic pyroxene. In these the orthorhombic mineral may appear as irregular areas within the porphyroblast or form an outer shell. Some of the monoclinic pyroxene has the distinctive properties of an enstatite-augite, with 2V small, positive, and low double refraction; but a hedenbergitic variety with the characteristics of the pyroxene of the eulysites is also present. This occurrence of an enstatite-augite is comparable with the examples recorded by Geijer[1] among the eulysites of north Sweden.

Another rock (no. 50) is a coarse-grained type built up of hypersthene with small amounts of grunerite and garnet. Crystals of hypersthene reach up to 6–10 mm. in length and have fine schiller plates of brown translucent ilmenite. The rock has been subject to stress with the development of fine lamellar twinning in the hypersthene. Between the large plates of hypersthene occur granulitic zones of finer-grained orthorhombic pyroxene (fig. 2 *b*). There are a few scattered grains of green hedenbergitic pyroxene and manganiferous garnet. Grunerite occurs in veins and bands replacing the iron-hypersthene, and it appears clear that eventually a grunerite-rock might well develop from a rock of this type.

The pyroxene of this rock has been subject to analysis and an account of its composition and optical properties has recently been published.[2] The mineral contains FeO 35·39, MnO 6·29, and MgO 7·02 %; optically negative, 2V 68°, α 1·738, β 1·749, γ 1·755.

(2) *Hedenbergite-garnet-magnetite-rocks.*—Like the eulysites proper, these rocks are also manganiferous and yield on weathered surfaces a blue-black crust. On fresh fractures the rocks are dark-coloured with conspicuous pyroxene like that of the eulysites, magnetite, and pink garnet. The last may give, as in the eulysites, a faint banded character to parts of the rock, though this is seldom conspicuous.

Under the microscope, the chief constituents are seen to be hedenbergite, magnetite, garnet, and apatite. Fayalite is present in some examples and with it a link between these rocks and the eulysites proper is established. Iron-hypersthene and secondary grunerite are also developed.

The pyroxene is a green hedenbergite with a characteristic salite striation. The grain-size is variable, porphyroblasts up to 4 mm. in diameter being associated with aggregates of smaller crystals of

[1] P. Geijer, Årsbok Sveriges Geol. Undersökning, 1925, ser. C, no. 324 (for 1923), pp. 4 and 9.

[2] N. F. M. Henry, Min. Mag., 1935, vol. 24, p. 221.

$\frac{3}{8}-\frac{1}{2}$ mm. diameter. That it is a hedenbergitic type is made clear from the optical properties $\gamma : c = 48°$, $\gamma = 1{\cdot}740$, and the paucity of alumina in the rock analyses. Garnet is in xenoblasts with the same

TABLE I.

	1.	2.	3.	4.	5.	6.	7.	8.
SiO_2 ...	32·85	38·12	37·06	33·30	46·46	46·12	49·43	48·8
TiO_2 ...	0·20	0·03	0·16	0·36	—	nil	nil	—
Al_2O_3 ...	3·02	2·01	0·80	4·24	0·24	0·56	nil	—
Fe_2O_3 ...	9·88	1·10	3·01	23·62	0·64	6·44	8·16	—
FeO ...	30·45	24·00	46·36	28·58	26·28	30·93	30·52	43·9
MnO ...	12·55	20·29	5·01	0·38	0·21	—	0·17	—
MgO	5·84	5·80	4·37	2·25	3·10	5·35	4·77	—
CaO	3·95	7·87	2·47	0·63	1·87	nil	0·18	—
Na_2O ...	trace	0·11	0·37	0·67	—	nil	nil	—
K_2O	trace	0·16	0·30	0·65	—	nil	nil	—
H_2O+ ...	nil	0·18	0·20	4·03	1·15	6·13	6·24	7·3
H_2O- ...	0·30	—	—	1·24	0·07	1·34	0·51	—
P_2O_5	0·78	0·44	0·38	0·42	0·13	nil	—	—
CO_2	—	—	—	—	19·96	nil	0·43	—
&c.	—	0·10	0·08	0·13	0·11	0·38	—	—
	99·82	100·21	100·57	100·50	100·22	99·85*	100·41	100·0
Sp. gr. ...	4·034	3·95	4·212	3·316	—	—	2·87	—

1. Eulysite, Druideig Lodge, Loch Duich, Ross-shire. Analyst, W. H. Herdsman.

2. Eulysite, Stora Utterwicks Hage, Tunaberg, Sweden. J. Palmgren, Bull. Geol. Inst. Upsala, 1917, vol. 14, p. 196. [M.A. 1–252.]

3. Eulysite, Mansjö Mt., Loos, Sweden. H. von Eckermann, Geol. För. Förh. Stockholm, 1922, vol. 44, p. 254. [M.A. 1–396.]

4. Magnetite-stilpnomelane-rock ('Schwarzfels'), Trondhjem region, Norway. C. W. Carstens, Geol. För. Förh. Stockholm, 1924, vol. 46, p. 248.

5. Cherty iron carbonate rock (Gunflint beds), north side of Gunflint Lake, Minnesota. R. D. Irving and C. R. Van Hise, Monogr. U.S. Geol. Surv., 1892, no. 19, p. 192.

6. Greenalite-rock, Cincinnati mine, Mesabi district, Minnesota. C. K. Leith, Monogr. U.S. Geol. Surv., 1903, no. 43, p. 108. *The total includes also insoluble $(Al_2O_3+Fe_2O_3)$ 2·60.

7. Greenalite-rock, Biwabik, Mesabi iron range, Minnesota. F. Joliffe, Amer. Min., 1935, vol. 20, p. 416.

8. Greenalite (and metagreenalite). Calculated composition. F. Joliffe, ibid., p. 418. [M.A. 6–151.]

tinge as in the garnet of the eulysites, pointing to a manganiferous almandine. Magnetite is an important constituent forming irregular grains wrapping around the pyroxenes. These rocks usually carry grunerite, which is often clearly secondary after pyroxene. The material is always much lighter coloured than the pyroxene; optically negative, γ 1·690, $\gamma : c = 15°$.

An analysis has been made of one of these rocks with the results given in table II, col. 1. This rock contains, in addition to pyroxene (hedenbergite), garnet, magnetite, and apatite, some iron-hypersthene and fayalite, as well as a small amount of secondary grunerite.

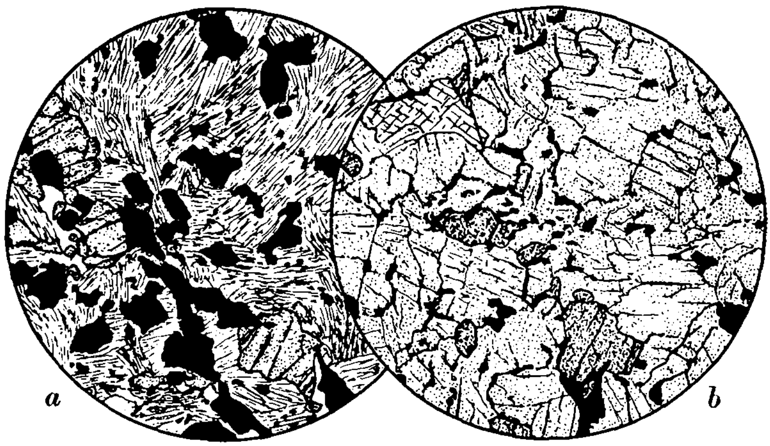

FIG. 1. *a*. Grunerite-garnet-magnetite-schist, Druideig Lodge. *b*. Eulysite, Druideig Lodge, showing fayalite, garnet, hedenbergite, and magnetite. ×20.

Hedenbergite is the most abundant constituent. A section of this rock is illustrated in fig. 2 *a*. Analysis shows again a high MnO content (7·5 %). Among the Swedish occurrences the most comparable analysis is that of a pyroxene-rich eulysite from Tunaberg (table I, col. 2). This has CaO 7·87 %. In table II the Loch Duich rock is compared with an average analysis of a Lake Superior cherty iron carbonate sediment.

(2 *a*) *Grunerite-garnet-magnetite-rocks with residual pyroxene.*—Associated with the pyroxene-garnet-rocks just described there occur types rich in grunerite but bearing a green pyroxene. These are dark dense-grained rocks in which pyroxene porphyroblasts are still visible, but the groundmass contains much grunerite. The production of grunerite at the expense of hedenbergite is best seen in the porphyroblasts themselves.

Irregular fragments of pyroxene are set in a matrix of fibrous grunerite. Ultimately pyroxene completely disappears and its place is taken by a divergent aggregate of grunerite grains occupying the space of former pyroxene.

In the groundmass the evidence of secondary development is not so clear. The grunerite appears often as idioblastic grains without sign of direct replacement. Nevertheless the strong evidence displayed in the porphyroblasts and that of the cross-cutting veins

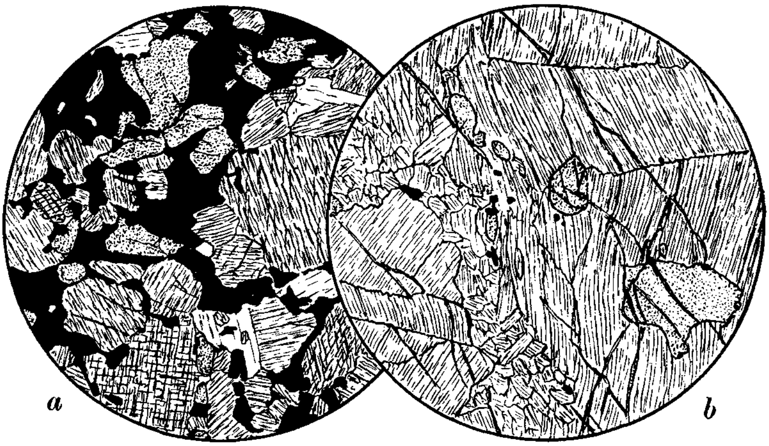

FIG. 2. *a*. Hedenbergite-garnet-magnetite-rock, Druideig Lodge. *b*. Iron-hypersthene-garnet-grunerite-rock, Druideig Lodge, showing zones of granulitic hypersthene between larger stressed crystals of the same mineral. ×20.

through the eulysitic rocks suggest that grunerite formation is subsequent to that of pyroxene and eventually at its expense.

In these rocks, therefore, is to be traced a succession of stages from a hedenbergite-garnet-magnetite assemblage to one in which the last traces of pyroxene are disappearing, and a corresponding removal of lime during the transformation.

(3) *Grunerite-(cummingtonite)-garnet-schists.*—Rocks bearing grunerite without pyroxene come under this category. They show some variety of appearance and composition. In the first place, they are more common than the eulysitic and pyroxenic types, and occur in association with the garnet paragneisses at lower levels on the hill-side above Druideig Lodge.

In hand-specimens they appear as a rule as coarser-grained rocks than the eulysites and the dominant amphibole varies much in colour from light clove-brown (cummingtonite) to dark green or black (grunerite). The lighter coloured amphiboles are cummingtonitic, positive in double refraction; the darker, gruneritic and negative in sign. Magnetite is a very variable constituent, but is more abundant in the gruneritic types. Quartz, a mineral conspicuous by its absence from the eulysites, appears often here as an interstitial constituent.

TABLE II.

	1.	2.
SiO_2	34·80	42·89
TiO_2	0·20	trace
Al_2O_3	3·82	0·12
Fe_2O_3	18·60	2·03
FeO	19·70	18·45
MnO	7·50	0·25
MgO	4·34	7·07
CaO	10·02	8·16
Na_2O	trace	—
K_2O	trace	—
H_2O+	0·25	1·45
H_2O-	0·15	
P_2O_5	0·78	0·09
CO_2	nil	19·20
&c.	—	0·13
	100·16	99·84
Sp. gr.	3·854	—

1. Hedenbergite-garnet-magnetite-rock, Druideig Lodge, Loch Duich, Ross-shire. Analyst, W. H. Herdsman.
2. Average ferrous carbonate rock, Gunflint, Minnesota. C. Zappfe, Econ. Geol., 1912, vol. 7, p. 162.

A short description of a rock selected for analysis (table III, col. 1) will give the essential petrography of this group of rocks. Grunerite forms long prisms reaching 2–3 mm. in length. Greyish to colourless in section, it shows abundant multiple twinning on (100). The mineral is optically negative and has an extinction $\gamma : c = 15°$. This forms the major constituent; magnetite is next in abundance, followed by garnet, quartz, and apatite. Xenoblastic garnet has the characteristic yellowish-pink tinge of the manganiferous varieties (fig. 1 *a*).

The analysis shows considerable similarity to that of the eulysite of table I, col. 1, both in its low lime content and sum of iron oxides + MnO + MgO. A much higher Fe_2O_3 content of the grunerite-rock is due to the larger content of magnetite.

In table III the rock is compared with a cummingtonite-garnet-schist from the Loch Maree area. This rock is also a manganiferous type and is tentatively referred to in the Survey Memoir as an altered manganiferous sediment. It is of interest to note that this rock, like the Loch Duich rock, is also involved in the Lewisian.

While the grunerite-rocks with residual pyroxene and massive texture give clear evidence of their origin, the rocks referred to here show no signs that they were at any time pyroxenic types. Their

TABLE III.

	1.	2.	3.	4.	5.	6.
SiO_2 ...	37·00	51·89	49·70	46·94	46·25	37·11
TiO_2 ...	0·18	—	—	—	—	0·22
Al_2O_3 ...	2·82	7·21	1·35	0·66	0·92	2·41
Fe_2O_3 ...	20·61	2·36	3·10	4·51	30·62	17·51
FeO ...	19·44	18·68	37·19	33·72	16·92	26·13
MnO ...	5·93	7·08	0·93	0·31	1·01	1·21
MgO ...	8·79	9·18	5·72	6·64	2·13	3·70
CaO ...	2·55	0·93	0·68	3·22	1·69	0·75
Na_2O ...	trace	0·31	trace	0·16	—	0·09
K_2O ...	trace	0·81	—	—	—	0·62
H_2O+ ...	1·20	1·33	1·40	0·67	0·42	2·57
H_2O- ...	0·30				—	0·95
P_2O_5 ...	1·27	—	0·12	0·07	0·07	0·09
CO_2	nil	—	—	2·79	—	6·16
&c.	—	0·54	—	—	—	0·73
	100·09	100·32	100·19	99·69	100·03	100·25
Sp. gr. ...	3·582	3·38	—	—	—	—

1. Grunerite-garnet-magnetite-rock, Druideig Lodge, Loch Duich, Ross-shire. Analyst, W. H. Herdsman.
2. Cummingtonite-garnet-schist, $\frac{5}{12}$ mile SW. of outlet of Loch Bad-na-Sgalaig between Loch Maree and Gairloch. Mem. Geol. Surv. Great Britain, N.W. Highlands, 1907, p. 83.
3, 4, 5. Grunerite-magnetite-schists derived from ferrous carbonate rocks, Marquette district, Michigan. C. R. Van Hise, Monogr. U.S. Geol. Surv., 1897, no. 28, p. 338.
6. Grunerite-magnetite-slate (derived from greenalite-rock), Mesabi district, Minnesota. C. K. Leith, Monogr. U.S. Geol. Surv., 1903, no. 43, p. 144.

schistose textures indicate that they are completely recrystallized rocks. That they should be traced back eventually to rather similar original assemblages from which the eulysites are derived is, however, made clear by their chemical composition.

Origin of the Eulysites.—In referring to the best known of the eulysites—those of Tunaberg—Rosenbusch[1] cautiously expressed the opinion that these rocks were perhaps garnet-rich varieties of wehrlite. Högbom[2] concluded that the same rocks were metasomatic products of limestone. At a later date (1917) Palmgren[3] made a

[1] H. Rosenbusch, Elemente der Gesteinslehre, 1910, p. 217.
[2] A. G. Högbom, Handb. reg. Geologie, 1913, vol. 4, Abt. 3, p. 21.
[3] J. Palmgren, Bull. Geol. Inst. Upsala, 1917, vol. 14, p. 109.

detailed study of the Tunaberg occurrence. He described them as crystalline schists but left undecided their original character.

The rock type styled 'collobrierite' from Collobrières, NE. of Toulon, was described by Lacroix[1] as a new type of ferriferous crystalline schist composed of fayalite, grunerite, and magnetite. It has obviously close petrographical relations with the Tunaberg eulysites.

Eulysites were subsequently described by von Eckermann[2] from Mansjö Mt., Loos, Sweden. In this memoir he referred to the Mansjö eulysites as consolidation products of a water-rich halogen-bearing pegmatitic residual magmá; but in his latest memoir[3] they are reinterpreted as derived from sediments rich in iron ores, though their mineralogical content has been influenced by secondary processes at contacts.

In 1924 Carstens[4] drew attention to the similar chemical composition of the eulysites and the 'Schwarzfels' of the Ordovician of the Trondhjem district, and he suggested that the eulysites, like the 'Schwarzfels', were derived from oolitic iron-ore or lake-ore sediments and probably represented higher grade metamorphosed products of such chemical deposits.

In describing the eulysitic iron-ores of north Sweden, Geijer[5] referred them to metamorphosed chemical sediments stating that 'the iron was probably deposited as a ferrous compound either silicate (greenalite) or carbonate'. Finally, Harker[6] classifies the eulysites as regionally metamorphosed siliceous and otherwise impure iron-ores (ferruginous deposits).

The composition and field relations of the Loch Duich rocks is in harmony with the view that they are derived from some type of ferruginous sediment, but the high grade of metamorphism they have experienced has destroyed all signs of primitive textures.

The paucity of alumina as shown in the analyses shows that these rocks did not contain original clay material. On the other hand, the presence of considerable amounts of lime—especially in the hedenbergite-garnet-magnetite types—suggests that $CaCO_3$ as such or combined in ankerite or ferrodolomite formed part of the original

[1] A. Lacroix, Bull. Soc. Franç. Min., 1917, vol. 40, p. 62.
[2] H. von Eckermann, Geol. För. Förh. Stockholm, 1922, vol. 44, p. 253.
[3] H. von Eckermann, ibid., 1936, vol. 58, p. 165.
[4] C. W. Carstens, ibid., 1924, vol. 46, p. 248.
[5] P. Geijer, Årsbok Sveriges Geol. Undersök., 1925, ser. C, no. 324 (for 1923).
[6] A. Harker, Metamorphism, 1932, p. 237.

materials from which the eulysitic rocks were derived. The presence of lime perhaps tends to favour the view that the development of iron silicates like fayalite resulted from reactions between iron-bearing carbonates and silica. There is nothing in the field evidence to suggest derivation from limestone metasomatically changed to $FeCO_3$ prior to metamorphism.

In considering further the nature of the iron-rich sediment from which the eulysites are derived, attention may be drawn to the following sediment types:

(*a*) Silica–iron carbonate.

(*b*) Silica–greenalite.

(*c*) Silica–iron oxide.

The researches of Van Hise, Leith,[1] and others have shown that the iron ores of the Lake Superior region have developed from chemical sediments of types (*a*) and (*b*), and regional metamorphism of these cherty iron carbonate or cherty greenalite rocks has produced grunerite-magnetite-schists (cf. table III, analyses 3–6). When rocks of this type have been brought into contact with later basic intrusions (e.g. the Duluth gabbro), fayalite has been abundantly produced and the resulting rocks have mineralogical features in common with some eulysites.

Silica–iron carbonate assemblages are also known among bog-iron-ores, and a sediment of this character should also be given consideration more especially as bog-iron-ores are known in cases to be manganiferous. Modern examples of bog-iron-ores containing iron carbonate as well as limonite are provided by the 'Rasen Eisenstein' of Ederveen, Netherlands, described by Van Bemmelen[2] and his associates. Here the iron ores containing notable percentages (6–37) of ferrous carbonate associated with ferric oxide have been found in a sandy matrix. Analyses show also a $MnCO_3$ content rising to 4 %.

As regards assemblages of the composition silica–iron oxide (*c* above) Ramdohr[3] has described fayalite and fayalite-quartz-rocks which are referred to thermal metamorphism of primary haematite-quartz-ores in the aureole of the Brocken massif. As far as I am aware, this is the only example yet described in which a reaction between iron oxide, e.g. magnetite and quartz to produce fayalite, has been confidently expressed. The conditions demanded are clearly those in

[1] C. R. Van Hise and C. K. Leith, Monogr. U.S. Geol. Surv., 1911, no. 52.

[2] J. M. Van Bemmelen, Zeits. Anorg. Chemie, 1900, vol. 22, p. 319.

[3] P. Ramdohr, Neues Jahrb. Min., 1927, Beil. Bd. 55, p. 333.

which the iron is actively reduced to the ferrous state—a condition which appears to be seldom realized if we consider the common magnetite-quartz paragenesis of rocks consolidating or recrystallizing at high temperatures.

While a sedimentary origin for the Loch Duich rocks appears clear, some doubt must exist as to the original character of the iron-bearing material. Chemically they can be matched, as the comparative analyses show, with either original greenalite or original ferrous carbonate rocks.

The production of fayalite or grunerite by interaction of ferrous carbonate and quartz or from a ferrous silicate offers perhaps less difficulty than their formation from materials like limonite or magnetite. The formation of fayalite through reaction of magnetite and quartz would require the presence of some active reducing agent. Carbonaceous material in a sediment might fill this role, but if so, evidence of it has disappeared.

The rather limited range of silica and iron oxide contents expressed in the three analyses (32–37 %) and (40–43 %) respectively might appear to favour the view that a ferrous silicate like greenalite had formed the greater part of the original rocks. The mineral greenalite with loss of water would give as an extreme composition SiO_2 53, Fe oxide 47 %.[1] The presence of significant lime (rising to 10 %) is, however, very suggestive of the presence of carbonates; and the coexistence of iron carbonates (chalybite with ferrodolomite or calcite) together with quartz, as in the Lake Superior cherty iron carbonate rocks, would yield on loss of CO_2 mixtures of similar bulk composition as these eulysites. The presence of considerable manganese is also more suggestive of derivation from original oxide or carbonate.

We can therefore only at present conclude that carbonates formed part at least of the original rocks, but whether they formed the major source of the iron of the eulysites remains uncertain.

The writer is much indebted to Dr. Alfred Harker for his kindness in executing the drawings of figs. 1–2, which accompany the text.

[1] Direct confirmation of these figures is much to be desired. Joliffe's results include metagreenalite and are obtained indirectly. Gruner (Amer. Min., 1936, vol. 21, p. 205) states that X-ray powder photographs of greenalite resemble those of serpentine.