lings and endophyte, the production of "synthetic" seedlings is not a simple operation. The age of the seedling, the suitability or otherwise of the rooting medium, the age of the fungus culture and the nutrient on which the endophyte is cultivated outside the plant are all critical factors, as are also doubtless such formal external conditions as temperature, moisture, and light.

REFERENCES.

- (1) CHRISTOPH, H. Untersuchungen über die mykotrophen Verhältnisse der "Ericales" und die Keimung von Pirolaceen. Beih. Bot. Centralbl. xxxviii, pp. 115-157 (1921).
- (2) RAYNER, M. C. Obligate symbiosis in *Calluna vulgaris*. Ann. Bot. xxix, pp. 97-133 (1915).
- (3) TERNETZ, C. Über die Assim. des atmosphär. Stickstoffes durch Pilze. Jahrb. f. wiss. Bot. (Pringsheim), xlv, pp. 353-408 (1907).

AN EOCENE MICROTHYRIACEOUS FUNGUS FROM MULL, SCOTLAND.

With Plate VIII.

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Well-preserved fossil fungi are of comparatively rare occurrence, and most of those so far described are found in petrified material. Names have certainly frequently been given to spots and markings on leaf impressions, which, however, rarely show any structure and are of very little botanical value. It is therefore of interest to be able to record the discovery in some Tertiary Rocks of Scotland of an unusually well-preserved epiphyllous fungus.

The Eocene interbasaltic beds of Mull contain a varied flora of ferns, conifers and dicotyledons mostly preserved as impressions. In a very few cases the actual leaf cuticles have remained practically unchanged in what has been called a "mummified condition," and by treatment with Schultze's mixture or some other reagent can be cleared and examined microscopically. This method of preservation is familiar to palaeobotanists, who have found the details of stomatal structure and cell outline valuable aids to classification, especially in the case of certain gymnosperms.

The microscopic fungus about to be described was found in the course of examining some linear coniferous leaves scattered on the surface of two slabs of rock in the Starkie Gardner Collection (Specimens V, 14846 and 7). With the object of

studying the leaves themselves, small fragments of the cuticle were detached from the rock and treated with nitric acid and potassium chlorate, followed, after washing, by ammonia. This process removes the carbonaceous matter and leaves a clear brown cuticle which can then be mounted in glycerine, the upper and under epidermis being first separated with needles. Some very small dark spots, which could not be seen before treatment, were then observed with the naked eye on the clear cuticle, and these proved on microscopic examination to be discoid bodies with a radiate structure which at once suggested a small epiphyllous fungus. I showed the specimens to my colleague, Mr J. Ramsbottom, who expressed the opinion that they probably belonged to the Microthyriaceae. In the subsequent study of this fungus I have continually received much help from Mr Ramsbottom and I am greatly indebted to him for his advice and assistance.

FIG. 1. Slab of rock with *Pityophyllum* sp., a coniferous leaf attacked by *Phragmothyrites*. Eocene, Mull. Brit. Mus. (N.H.), Geol. Dept. no. V. 14846. Nat. size.

Description of the material. The discoid bodies, which are regarded as the ascostromata (or "thyriothecia") of a Microthyriaceous fungus, occur singly, or rarely in conrescent pairs, on the upper surface of the leaf, and in some preparations are scattered over it in considerable numbers (cf. Pl. VIII, fig. 1). They are usually practically circular, and the largest specimen

is about 165μ in diameter. They have a regularly radiate structure and the margin is entire, or very slightly crenate, but never fimbriate. None of the specimens show a definite ostiole, but this may be due to immaturity, while on the other hand there is an appearance in some ascostromata of an irregular dehiscence such as occurs in some recent members of the family, e.g. *Asterina*, but appearances in fossils such as this are liable to be deceptive, and might be due to post-mortem or post-fossilization changes. There is no mycelium on the surface of the leaf, but stigmocysts (Pl. VIII, figs. 5 and 6) are abundant, and all stages of growth are to be found between them and the largest of the ascostromata. The stigmocysts (unicellular capitate hyphopodia) are circular and deeply crenulate, about $10-12\mu$ in diameter, and the clear central spot is usually distinctly seen.

No asci have so far been found, but Pl. VIII, fig. 7 shows a large 5-celled spore (? ascospore), 43μ in length and 25μ in breadth, which appears to be sending out delicate hyphae at each end. Another slide shows a similar spore, rather shrunken, with apparently only four cells. It seems quite probable that these spores belong to the same species as the ascostromata, though of course one cannot be absolutely certain. At any rate there is no other recognisable fungus on the leaves to which they might belong. There are a few detached fragments of hyphae and some spore-like bodies which may perhaps be mentioned here, but which may not even be of fungal nature.

The reference of a fossil fungus to its exact systematic position is not an easy matter, even when the material is so well preserved as in the present case. There are certain characters which are used in the classification of recent fungi which cannot be observed in a fossil, e.g. the colour of the spores, and moreover dissociated objects cannot always be proved absolutely to belong to the same species. In this instance one can at least feel fairly certain that the fossil is to be placed in the Microthyriaceae, though the exact generic reference is more difficult.

The Microthyriaceae and other "asterinoid" fungi have received considerable attention of late years, and their classification and relationships have been critically studied and revised by von Höhnelt, Theissen, Arnaud and others. Desmazières' genus *Microthyrium* (1841) was made the type of the family Microthyriaceae by Saccardo in 1883, and this family subsequently became the dumping ground for many heterogeneous forms which have since been excluded, while on the other hand detailed study has resulted in the separation of many new genera. The classification of Theissen (1913, 1 and 1913, 2) forms the basis of our present knowledge. He groups together

the Microthyriaceae, the Hemisphaeriaceae and the Trichopeltaceae in a new order, the Hemisphaeriales, which are all superficial, and are thus sharply marked off from the Dothideales, in which the ascostromata are developed beneath the cuticle. For the hemisphaerical fruiting bodies he adopts von Höhnel's term thyriothecium. The distinctive characters of the Microthyriaceae, with which we are particularly concerned here, are the radiate (very rarely linear) dimidiate thyriothecia, on the "inverse" method of whose development von Höhnel and Theissen lay great stress. They regard the thyriothecium as corresponding to the basal half of the spherical body such as occurs in related families (e.g. Perisporiaceae) which has become inverted against the leaf surface. The family is subdivided according to the presence or absence of a free mycelium, the number of cells and colour of the ascospores, the presence or absence of paraphyses, and so on. This classification is adopted with slight modifications by E. M. Doidge (1920) where a résumé of the general characteristics of the group will be found.

Arnaud (1918) proposes a somewhat different classification based on that of Spegazzini, and uses the term Microthyriaceae in a rather wide sense, while excluding, however, certain genera such as *Amazonia*. Arnaud gives the pycnidial forms a special name (Microthyriopsidaceae); the pycnidia resemble the thyriothecia as a general rule, and therefore we cannot be quite sure which we are dealing with in the present case. Certain spore-like bodies on the leaf cuticle might perhaps be conidia.

The form of the thyriothecia in the fossil is very similar to that of *Microthyrium* itself, while in this and allied genera the mycelium is absent or evanescent. Presuming the ascospore to belong to the same species as the fruiting bodies, a relationship is indicated to the genus *Phragmothyrium* of von Höhnel (1912, p. 347) which was instituted to include "*Microthyrium* species with more than 2-celled spores." *Amazonia* Theiss. is also phragmosporic (5-celled) but has a persistent mycelium and rather different thyriothecia with fimbriate margins. It is therefore suggested that the name *Phragmothyrites* be used for fossil forms belonging to the Microthyriaceae, the exact position of which is uncertain, but which appear to be most closely related to *Phragmothyrium* as defined by von Höhnel. The Mull specimen may be described as *Phragmothyrites eocaenica* n.sp. Thyriothecia circular, radiate, with entire margin, scattered singly (rarely conrescent) on the leaf surface; stigmocysts circular and deeply crenulate; ascospores (?) 5-celled; mycelium ? absent or evanescent. Occurring on coniferous leaves (*Pityophyllum* sp.) in beds of Lower Eocene age, Mull, Scotland.

I have only succeeded in finding a few other references to

fossil fungi belonging to this family. *Microthyrites disodilis* Pampaloni (1902, 1, p. 251; 1902, 2, p. 127, Pl. XI, fig. 1) occurs in the disodil of Melilli, Sicily, probably of Middle Miocene age. From Pampaloni's description, an affinity with the Microthyriaceae is quite possible, but the illustration leaves much to be desired. The material is said to consist of simple, scattered, shield-shaped perithecia, composed of polygonal concentric cells, and there is no reference to spores or mycelium. Altogether the record seems rather doubtful.

Engelhardt and Kinkel (1908, p. 185) record a few leaf-fungi from the Upper Pliocene of Klärbecken near Frankfurt-am-Main, and among them one which they refer with a query to a living species, *Asterina Ilicis* Ell., on leaves of *Ilex*. They describe circular thyriothecia (sometimes concrescent), 80–90 μ in diameter, with a crenate margin and a central ostiole when mature. Their drawing certainly closely resembles a Microthyriaceous fruit-body, and they state that an affinity to *Asterina* is indicated by the presence of a free mycelium ("Luftmyzel"), which however is not figured. They further record similar fruit-bodies on *Buxus* leaves, but smaller, with an entire margin, and without any free mycelium. Kräusel (1920, p. 338, text-fig. 7, p. 353) describes some similar bodies from the Miocene of Silesia, about 70 μ in diameter, found associated with *Sequoia langsdorffii* leaves, and apparently connected with hyphae. They are regarded as probably belonging to the Microthyriaceae. In neither of these cases were any spores found.

"Hyphae and haustoria of an *Asterina*-like fungus" occur on the cuticle of *Sequoia langsdorffii* from Tertiary beds (exact age unknown) of Ellesmere Land, lat. 77° N., and are described and figured by Nathorst (1915). The resemblance to the mycelium and stigmopodia of *Asterina* and other allied genera is certainly very striking. It is interesting to note that this fungus was discovered in the same way as *Phragmothyrites eocaenica* and the fungi described by Kräusel, by chemical treatment of a coniferous cuticle, and the preservation of the mycelium suggests that had *P. eocaenica* possessed a persistent mycelium it would also have been preserved.

The identification of the host plant presents some difficulties, but it is best referred to provisionally as *Pityophyllum* sp. (a name used for fossil coniferous leaves of uncertain affinity). A somewhat similar conifer, *Podocarpites campbelli* (Gard.), is a common fossil at Mull, but the leaves are usually larger and more acuminate. The scattered leaves of the present specimen, as shown in Text-fig. 1, may be compared with a figure of *Podocarpus suessionensis* Wat., given by Crié (1878, Pl. VII, fig. 32) of a specimen from the Eocene of Sarthe, but here again

it should be noted that the Mull leaves are not so acuminate. The identification even of leafy coniferous twigs is not easy, so that the attribution of detached leaves must be very uncertain. In the present instance, however, the cuticle preparations show to some extent the structure of the stomata, and these were kindly examined for me by Miss H. Bandulska, who made a series of comparative measurements. She believes that the stomata were of a type found in *Sequoia sempervirens* and some species of *Araucaria* and *Podocarpus*, the greatest resemblance being to those of *Podocarpus melangianus*. The host plant of *Phragmothyrites eocaenica* may therefore possibly be a *Podocarpus*. The question of its stomatal structure and identity will be dealt with more fully in another place. No other leaves from Mull yield cuticles, with the exception of *Ginkgo adiantoides* Ung. on which no traces of fungi have been found.

The presence of this epiphyllous fungus would seem to indicate fairly moist conditions of growth. The living Microthyriaceae are mainly tropical, but rainfall rather than temperature would appear to be the important factor influencing distribution. Arnaud (1918, p. 31, etc.) asserts that "asterinoid" fungi are confined to parts of the globe with more than one metre of rainfall per annum. Prof. A. C. Seward and Mr R. E. Holtum, who kindly allowed me access to a forthcoming paper on the Mull fossil plants, consider that the flora indicates a temperate climate, but warmer than that of the present day in the same latitude, and they speak of the possible presence of evergreen shrubs as another indication of a warm, fairly moist climate. They see no reason to modify Gardner's opinion that the beds are of Lower Eocene age.

In conclusion we may note that very few living species of Microthyriaceae have been recorded from Great Britain.

BIBLIOGRAPHY.

- ARNAUD, G.—Les Astérinées. Thèses présentées à la faculté des sciences de Paris. Montpellier, 1918.
CRIÉ, L.—Recherches sur la Végétation de l'Ouest de la France à l'Époque Tertiaire. Thèse présentée à la faculté des sciences. Paris, 1878.
DESMAZIÈRES, J. B. H. J.—Huitième Notice sur quelques plantes Cryptogames. Ann. Sci. Nat. sér. II, xv (Bot.), pp. 129–146, 1841.
DOIDGE, E. M.—South African Microthyriaceae. Trans. Roy. Soc. South Africa, VIII, pt. 4, pp. 235–282, 1920.
ENGELHARDT, H. and KINKELIN, F.—Oberpliocäne Flora und Fauna des Untermainales. Abh. Senckenberg. Naturf. Ges. XXIX, 1908.
GARDNER, J. S.—Mon. Brit. Eocene Flora, II, 1883–6. Pal. Soc. London.
HÖHNEL, F. VON.—Fragmente zur Mykologie, XIV, No. 725. Sitz. k. Ak. Wiss. Bd. 121, Abt. 1, p. 346, 1912.
KRÄUSEL, R.—Nachträge zur Tertiärflora Schlesiens, I. Jahrb. Preuss. Geol. Land. f. 1918, XXXIX, 1920.
NATHORST, A. G.—Tertiäre Pflanzenreste aus Ellesmere-Land. Rep. 2nd Norwegian Arctic Exped. in "Fram," 1898–1902, No. 35, 1915.

- PAMPALONI, L. (1).—Microflora e Microfauna nel disodile di Melilli in Sicilia. Atti della Reale Acad. dei Lincei, ser. 5, XI, pp. 248–253, 1902.
- PAMPALONI, L. (2).—I resti organici nel disodile di Melilli in Sicilia. Palaeontographia Italica, VIII, pp. 121–130, 1902.
- THEISSEN, F. (1).—Die Gattung Asterina. Abhandl. k. k. zool.-bot. Ges. Wien, VII, 1913.
- THEISSEN, F. (2).—Ueber Membranstructuren bei den Microthyriaceen als Grundlage für den Ausbau der Hemisphaeriales. Myc. Centralbl. III, pp. 273–286, 1913.

EXPLANATION OF PLATE VIII.

All the specimens are in the Geological Department, British Museum (Natural History). The photographs are by Mr F. W. Edwards.

- Fig. 1. *Phragmothyrites eocaenica* sp. n. Group of thyriothecia. $\times 80$. Slide V. 14847a.
- Fig. 2. *Phragmothyrites eocaenica* sp. n. A single thyriothecium. $\times 380$ (the largest observed). Slide V. 14847a.
- Fig. 3. *Phragmothyrites eocaenica* sp. n. Another thyriothecium. $\times 380$. Slide V. 14847a.
- Fig. 4. *Phragmothyrites eocaenica* sp. n. Two thyriothecia at an earlier stage of development. $\times 380$. Slide V. 14847a.
- Fig. 5. *Phragmothyrites eocaenica* sp. n. A stigmocyst. $\times 540$. Slide V. 14846b.
- Fig. 6. *Phragmothyrites eocaenica* sp. n. Group of stigmocysts beginning to grow. $\times 540$. Slide V. 14846a.
- Fig. 7. Presumed ascospore of *Phragmothyrites eocaenica* sp. n. $\times 540$. Note the delicate hyphae at each end. Slide V. 14846b.

A SINGULAR CORDYCEPS FROM STEPHEN ISLAND, NEW ZEALAND.

By G. H. Cunningham, Wellington, N.Z.

At the north-west extremity of Cook Strait, about three miles from D'Urville Island, the nearest land, lies Stephen Island, a small area one and a quarter miles in length and rising to a height of 900 feet above sea level. The island is for the most part open tussock country with, in the more sheltered localities, a few isolated patches of wind-swept forest.

Although only 370 acres in extent Stephen Island rejoices in the possession of a somewhat unique fauna. Here are found the tuatara, *Sphenodon punctatus* Gray, which occurs in thousands and appears to be slowly increasing in number; *Deinacrida rugosa* Buller, a huge weta, found in only one other locality; a Discoglossid frog, *Liopelma hamiltoni* McCulloch, a recently discovered species confined to this island, where its habitat appears to be the crevices under large boulders; and a now extinct wren, *Traversia lyallii* Roths.

With the single exception of the *Cordyceps* described below, the flora possesses no peculiar features, as there are no endemic species.