

plateau, each little waterfall illustrating in its own small way many of the characteristics so magnificently displayed by its gigantic forerunner and originator. Another equally impressive line of evidence is afforded by the gradual falling away of the angle of slope in the Batoka Gorge itself as it is followed down from its present termination at the Falls. Here, as everyone may see, its walls, carved out as it were but yesterday, are approximately perpendicular, but even here they are already beginning to crumble down under the influence of the weather; at the distance of a few miles below the Falls, where they have been longer exposed to this influence, the average inclination falls to not more than 60° , and still farther eastward to 45° or less; and finally, in the lower parts of the Gorge, instead of the familiar wall-like lines of crags, we find that the river is bounded only by rugged hillsides whose average slope from crest to base is often not more than 30° .

The processes that have operated during the immeasurable past must continue also into the immeasurable future, so long as the Zambesi continues to thunder seaward over the edge of its upland basin. Imperceptible though the rate may be when measured by the short span of our human life, yet surely is the river gnawing its path backward into the heart of the continent; and the geologist, noting how already at the rapids above the Leaping Water the trench is deepening that draws down more and more of the flood at the expense of the shallower portions of the Falls, may look forward with confidence to a future when either here or along some still lower trench at present undeveloped the main trough of the river will become fixed. The present lip of the Falls will then be left dry to form another 'Knife-edge' around which the torrent will swirl in turmoil as it passes away from its new place of descent at some line of crags at present submerged under the placid waters of the upper river.

II.—THE MOUNT TORLESSE ANNELID.

By F. A. BATHER, M.A., D.Sc., F.G.S., British Museum (Natural History).

AMONG the geological specimens obtained by Mr. H. T. Ferrar, while the "Discovery" was visiting New Zealand, are seven rock-fragments containing tubular shells, and an eighth with some obscure markings. They are labelled as follows:—

No. 17.	Annelid tubes?	Mt. Torlesse.	H. T. F.	Dec. 8th, 1901.
No. 18.	"	"	"	"
No. 19.	"	"	"	"
No. 20.	Scaly markings.	"	"	"
No. 21.	Annelid.	Mueller Glacier.	Presd. Capt. Hutton,	F.R.S.
No. 22.	Annelid tubes?	Kowai River.	"	"
No. 23.	"	Wilberforce River.	"	"
No. 24.	"	Gorge of the Ashley.	"	"

Specimen No. 20 may at once be dismissed with the remark that it is merely an irregular imprint, showing no structure; even the "scaly markings" of the label appear due to incipient cleavage of the

micaceous shale bearing the imprint. It may represent the "obscure plant remains" of Hector (1885, p. 339).¹

The other specimens are all representatives of the fossil, or rather fossils, long known to the geologists of New Zealand as "the Mount Torlesse Annelid." This fossil is so abundant in certain dark-coloured slates and sandy shales, as to have procured for them and their associated sandstones the name of "the Mount Torlesse Annelid Beds" or "the Annelid Beds." These beds are usually regarded as the uppermost division of the Maitai Series, since they appear to be conformable with the underlying limestones, slates, and sandstones of that series. The fossils found in the Maitai Limestone, the basement bed of the series, as quoted by Mr. A. M'Kay (1879 and 1881) and by Captain F. W. Hutton (1885) are obviously Carboniferous, and, if correctly identified, should be regarded as Lower Carboniferous. Unfortunately the country in which the undoubted Annelid Beds occur is much disturbed, so that the stratigraphical evidence as to their relations is not free from uncertainty, and other beds have, it is now known, been confused with them in several cases (see, for example, Von Haast, 1885). Unfortunately also, the supposed Annelids are the sole fossils found in the beds. Thus the opinion published by Mr. M'Kay in 1881 still expresses the truth, namely, that "the placing of these Annelid beds in their correct position is unquestionably the most difficult problem that has yet to be dealt with in perfecting the classification of the older sedimentary rocks of New Zealand." "Much therefore," he continues, "depends upon the presence, absence, or correct identification of the annelid, which importance it must retain until other and more determinate forms are discovered" (op. cit., p. 90). Mr. M'Kay consequently proceeded to give a brief description, but up till now no figure has been published, and no comparison has been made with other fossils.

The material, as recognised by Mr. M'Kay, contains two quite distinct forms, which, however, are said to be found in precisely the same strata. One of these is straight (Nos. 17, 18, 19, 21, 24), the other curved (Nos. 22, 23). The former is the most widely distributed, being especially abundant and well preserved at Ashley Gorge, whence comes our specimen No. 24. The latter, according to M'Kay (1881, p. 91), is found only on the west coast of the South Island. The Kowai River, however, whence comes our No. 22, is on the east coast, disembodying a little north of Port Lyttelton. With this exception, the localities quoted by Von Haast (1872 A-B), M'Kay (1881), Hector (1885 and 1892) may be supposed to refer to the straight form. It is pointed out by M'Kay that, although this fossil is called the annelid of Mount Torlesse, and although a long list of localities for it has been published, "it is nowhere spoken of as actually having been collected from Mount Torlesse." Hector, however (1885, p. 339), quotes it from "the south-eastern end of Mount Torlesse," while Mr. Ferrar found it to be "quite abundant near the summit of the hill."

¹ See end for List of Papers referred to.

THE STRAIGHT FORM. (Figs. 1-3.)

Mr. M'Kay (1881, p. 90) described this as "a tapering tubular calcareous¹ body, varying from one to three inches in length, the greater diameter of the larger specimens being not more than a quarter of an inch. In most cases when they occur between the bedding planes of the rock they are found flattened by the pressure of the overlying stratum, but when found vertical or highly inclined to the bedding planes they preserve their cylindrical form. In their fossil condition the walls of the tube are sufficiently thick to have resisted any ordinary amount of pressure exercised by the overlying beds, and therefore it may be doubted if they have always been as calcareous as they now are." Mr. M'Kay believes that the animals "were during life fixed to one place," and that the vertical "is their natural position."

To the preceding little can be added beyond more precise measurements. The greatest length of any of our specimens (No. 24, Fig. 1a) is 71 mm. (a little less than 3 inches), but this is obviously incomplete, being truncated at the smaller end by a slickensided joint-face, while the larger end has been broken off. At the smaller end, which is much flattened, the mean diameter is $(2.3 + 1.4) \div 2 = 1.85$ mm. ($= \frac{5}{8} \frac{1}{4}$ in.). At the larger end the mean diameter is $(2.9 + 1.9) \div 2 = 2.4$ mm. The rate of tapering, therefore, is very slight, and the same is the case in other specimens. Since all the specimens are flattened in the plane of bedding, the lumen appears as little more than a dark line. A section of another individual in No. 24 gives the following measurements:—Greatest diameter, 4.7 mm. Least diameter, 1.3 mm. Greatest width of the compressed lumen, 2.7 mm. Thickness of tube-wall, on one side of lumen, .3 mm.; on the opposite side, .8 mm.; at one end, 1.3 mm. Probably this last measurement is exaggerated, and the lumen was really longer in this direction. Before compression, therefore, the tube at this level may have had a diameter of about 3.5 mm. with a wall .8 mm. thick, and a lumen 2.7 wide, or just under four-fifths of the total diameter. These measurements should be checked from individuals preserved in a vertical position, such as unfortunately do not occur in the material under examination; but assuming their approximate correctness, it can scarcely be maintained that such a tube with its infilling of fine mud ought, however "calcareous," to have resisted the considerable pressure to which it has been submitted—a pressure which the rock-specimens themselves, as well as the published sections of the country, show to have been by no means "ordinary pressure exercised by the overlying beds." Consequently, there is no reason to suppose that the tube-wall was ever more horny than calcareous. As a matter of fact Mr. M'Kay's argument starts from an erroneous assumption: the substance of the fossil is not a carbonate or any salt of lime, but a chalcedonic form of

¹ Hector (1885, p. 339) also says "a calcareous tubular body." None of the specimens submitted by Mr. Ferrar are calcareous, but all, from all localities, are silicified throughout.

silica. In section the fossils are generally somewhat hour-glass or dumb-bell shaped, but this is an ordinary effect of compression, and there is no trace of lateral ridges such as characterise *Serpulites*. Unequal compression and a slight tendency to cleavage in the rock have produced inequalities of thickness, but the general impression produced is that the tubes were remarkably straight and not curved as in *Serpula*. The surface appears to have been smooth, but, if anything, irregularly and finely striate longitudinally rather than polished (Fig. 1c). There are no transverse annulations, wrinkles, or striæ, but specimen 19 shows a slight transverse swelling at one level (Fig. 2). The evidence at hand does not show whether the tube was closed or open at the smaller end. Probably it was not operculate at the broader end, or traces of the opercula would have been found.

Owing, perhaps, to its silicification, no microscopic structure can be detected in a thin transverse section of the tube (Fig. 3).

The specimens of rock, of which an average sample measures $100 \times 62 \times 18$ mm., contain as a rule traces of more than one individual, but they are not very closely associated. Since there are in the rock no other solid bodies to which they can have been attached, it must be inferred that the tubes were free and isolated. While the evidence of the vertical specimens suggests that they were sedentary and embedded in the mud, the still greater number of specimens in the plane of bedding leads one to enquire how and when they left their vertical station.

The systematic position of this fossil is far from clear. There seems, indeed, no reason to doubt the unanimous ascription of it to the *Polychæta tubicola*, at least with as much reason as *Serpulites*, *Cornulites*, and similar forms; but the genus is not so obvious. Captain Hutton (1885) has suggested that certain annelids from the Upper Maitai beds of the Dun Mountain¹ are "perhaps *Cornulites*." The present specimens, however, assuming that they are of the same species, do not support that view, since they are devoid of annulations and taper much less rapidly.

From *Serpulites*, as defined by Mr. R. Etheridge, fil. (1880, p. 304), this species differs in the absence of the lateral ridges and in its straightness. The genus *Serpula*, as defined by Linnæus (*Syst. Nat.*, 1758, p. 786), had "Testa univalvis, tubulosa, adhærens, sæpe isthmis integris passim intercepta." It is true that the first species mentioned by him, *Serpula seminulum*, "recedit a congeneribus quod libera sit nec adhæreat aliis corporibus," but this species cannot be taken as the genotype, and it seems justifiable to follow R. Etheridge, fil. (1880, p. 362) in regarding adherence as a necessary criterion of the genus. Another feature almost universally ascribed to *Serpula* is the irregular contortion or enrolment of the tube. On both these counts the Mt. Torlesse annelid is not a *Serpula*.

¹ Accounts of the Maitai beds of the Maitai River and Dun Mountain district near Nelson have been given by M'Kay (1878 and 1879), who, however, mentions only "Annelid tracks" and a shell like *Inoceramus*. But these beds were not then correlated with the Annelid slates and sandstones of Westland and Mount Torlesse, which were placed in an underlying Rimutaka series (see Hector, 1878).

The annelids secreting firm calcareous tubes do not, however, appear to furnish any other genus with which comparison would be profitable, and in general appearance this fossil most nearly resembles certain fossils rightly or wrongly assigned to *Serpula*. It is not the Mesozoic or Cainozoic species that it in any way resembles, but certain Palæozoic species, and of all these the resemblance appears closest to the Carboniferous fossil named *Dentalium indistinctum* by Fleming (1825) and *Serpula compressa* by J. de C. Sowerby (1829). That species, however, which certainly agrees with *Serpula* in its irregular curvature, and probably in its partial attachment, further differs from the Mount Torlesse fossil in the more rapid tapering and its relative tenuity of its tube-wall, notwithstanding the fact that the wall is described as "thick." It is thick relatively to the Palæozoic serpuloids, which therefore need not further be brought into comparison.

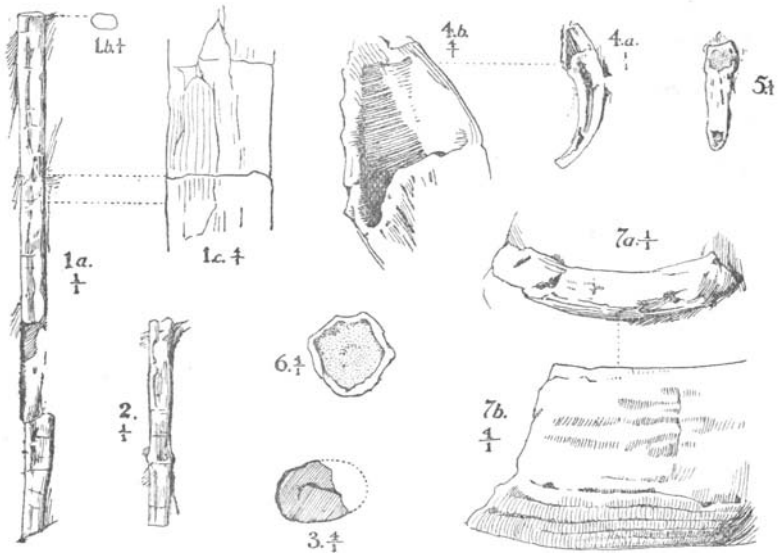
It is probable, and has thus far been assumed, that the tube of this fossil, though now chalcedony, was originally a firm calcareous secretion, a view confirmed by the composition of the other Mount Torlesse fossil. There is, however, just the possibility that the tube was an aggregate of sand-grains as in *Terebella*. The tubes of the various species of that genus differ from the present fossil in their irregular growth, while the calcareous sand-grains of which they are composed are certainly coarser than any which could possibly have entered into the composition of the New Zealand fossil. A much closer resemblance is presented by tubes from the Yakutat Slates of Alaska, recently described by Mr. E. O. Ulrich (1904, p. 132) as *Terebellina Palachei*, gen. et sp. nov.; indeed, some of his figures (pl. xi, figs. 2, 5) might almost serve as illustrations of our specimens. *Terebellina* is thus diagnosed:—"Long, subcylindrical, gently curved and rather thick-walled tubes, acuminate below; surface obscurely striated transversely. Tubes composed of cemented minute siliceous grains." These grains are "essentially the same as those of the arenaceous shale in which" the fossils "are found," but are "of more uniform and larger average size in the tubes than in the matrix." The length, the very gradual tapering, and the thickness of the wall ("about two-thirds of the diameter is taken up by the central hollow") are all points of resemblance to our fossil. It is further noteworthy that in Alaska as in New Zealand these peculiar worm-tubes serve to correlate exposures of slate of undetermined age in widely separated localities, and that the only other fossils are supposed fucoids and, in one locality, a peculiar concentrically ribbed *Inoceramus*-like shell. The Alaskan shell is named *Inoceramya* by Mr. Ulrich, to express his opinion that it is intermediate between *Posidonomya* and *Inoceramus*. On the evidence of all these fossils Mr. Ulrich assigns the Yakutat Slates to a Liassic age. But, although it would be important as well as curiously interesting to identify the Mt. Torlesse annelid with *Terebellina*, this course does not appear possible. Apart from the absence of any structure suggesting a similar constitution of the tube-wall,

there are differences in the absence of curvature and in the signs of a longitudinal rather than a transverse striation.

We come then to the conclusion—particularly unfortunate for the stratigrapher—that the straight annelid of Mt. Torlesse cannot be ranged with any established genus. Although further information is desirable, still it may be well to draw attention to the fossil by giving it a name:—

TORLESSIA, gen. nov.

A tubicolous Polychæt, of which the tube is unattached, straight, very slightly tapering, circular or elliptical in section, and with relatively stout, unridged, (originally) calcareous walls (*circa* one-tenth diameter); habitat, vertical in marine mud.



TORLESSIA MACKAYI and *DENTALIUM* HUTTONI.

1. *Torlessia Mackayi*, No. 24. *a*, natural size; *b*, section; *c*, portion of surface, to show striae, $\times 4$ diam.
2. *T. Mackayi*, No. 19. Natural size.
3. *T. Mackayi*, No. 19. Transverse section from another individual, $\times 4$ diam.
4. *Dentalium Huttoni*, No. 22. *a*, a shell lying on its side, nat. size; *b*, larger aperture of same, showing ridges, $\times 4$ diam.
5. *D. Huttoni*, No. 22. Another shell lying with the smaller curve uppermost, nat. size.
6. *D. Huttoni*, No. 22. Section of another shell as seen on the surface of the stone, probably not quite transverse, and partly crushed, $\times 4$ diam.
7. *D. Huttoni*, No. 23. *a*, the largest individual on the stone, nat. size; *b*, a portion showing the ridges, $\times 4$ diam.

Genotype, *TORLESSIA* MACKAYI, n.sp.

Surface smooth or with faint longitudinal striation; description as above.

The association of Mr. Alexander M'Kay's name with this species requires no justification, as this is one of the rare cases in which the adoption of a personal name conveys a meaning which is not misleading.

Holotype: Specimen No. 24 of Mr. Ferrar's list (Fig. 1). Nos. 17, 18, 19, and 21 also belong to this species.

Horizon: Probably not below Upper Carboniferous and not above Trias (see Von Haast, 1887).

Localities: Ashley Gorge (holotype), Mueller Glacier, Mt. Torlesse, and many other places in New Zealand, especially Hutt and Selwyn counties (see Hector, 1885 and 1892).

THE CURVED FORM. (FIGS. 4-7.)

This has not hitherto been described. It is represented by specimens 22 and 23, both collected by Captain Hutton. No. 22, from the Kowai River, is a water-worn pebble from which one quarter has been broken away. The substance of the pebble is a very hard dark-grey shale, weathered greenish. It is 19 mm. thick, 80 mm. long, and 63 mm. wide. On one of the flat surfaces, occupying an area about 52 mm. long \times 50 mm. wide, are the remains of nineteen individuals, of which the most complete measures 19.3 mm. along the chord of the curve (Fig. 4). No. 23, from the Wilberforce River, is a fragment of hard black shale, iron-stained, slightly contorted, slickensided at one end, and with numerous cracks filled with silica. It is 14 mm. thick, 96 mm. long, and about 40 mm. wide. One flat surface is slightly water-worn and displays the remains of three individuals, of which the most complete measures 28.5 mm. along the chord of the curve (Fig. 7). In both specimens the substance of the fossils is silicified.

The above numbers suggest that these animals were more gregarious than *Torlessia Mackayi*.

In No. 22 the shells lie in all positions: most are in the plane of bedding, either on their sides, or with the concave curve up, or with it down; a few, of which only a transverse section is seen, appear to lie at an angle to the plane of bedding. Those which lie in the bedding-plane are compressed, and the side that happens to lie uppermost is usually pressed inwards so as to make the transverse section approach a semicircle or even a crescent. That this is an effect of pressure is further shown by the fact that the transverse sections mentioned above are more circular in outline.

The individual, 19.3 mm. long, on specimen 22, lies on its side, having the uppermost side crushed in, as above described, over the middle of its course, but partly broken away at the ends. The larger, convex curve has a radius of 12 mm. (a trifle over that of a shilling). The smaller, concave curve has a radius of about 7.6 mm., but is not so nearly a segment of a true circle. The outside diameter of the tube at a little distance from the larger end is about 4.3 mm., but since this end is broken, the diameter at the wider aperture cannot have been less than 5.3 mm.,

from which perhaps a little should be deducted for the flattening. At the smaller end the outside diameter is 1.6 mm. The thickness of the tube-wall at the larger end is not less than .3 mm.; at the smaller end it was rather thinner. It is doubtful whether the transverse section was circular; it may have been slightly polygonal. The inner wall of the tube is smooth, but the outer wall was covered with about fourteen slight but distinct longitudinal ribs (Fig. 4b). These are almost or entirely worn away from the exposed surfaces, but are seen in section, and often on the impressed portions of the outer wall.

The three fragments preserved in specimen 23 all appear to have belonged to individuals rather larger than those in No. 22. They are much worn, and the tubes appear to have been filled with a greenish chalcedony rather than with shale. The ribs are shown in each of them, and very plainly in the largest, where three of them occupy a width of 1.2 mm. (Fig. 7b).

Of this form also, the systematic position is not free from doubt. Hitherto it has generally been regarded as the tube of an annelid, but to this there are certain objections. The shell, for instance, seems rather too stout and too regularly curved. Its general shape reminds one of *Cornulites*, to which Captain Hutton referred some tubular fossil (loc. cit. supra), but it is ribbed, not annulate. If an annelid it would be suggestive of a far later age than that to which stratigraphical evidence would assign it. Short, curved annelid tubes with longitudinal ribs do not seem to occur before the Lias, in which epoch there lived "*Serpula*" *quinquecristata*, Goldf., "*S.*" *tetragona*, J. de C. Sow., and *S. quadrilatera*. *Serpula heptagona*, Sow., from the Barton Beds of the Upper Eocene, is a similar form. But the most suggestive are the tubes from the Maestrichtian Chalk, now referred to Denis de Montfort's rather problematical genus *Pyrgopolon* (1808), e.g. *P. deforme* (Lam.) and *P. cipliana*, Ryckholt. But none of these real or supposed annelid tubes has the same regularity of shape as appears to have been possessed by the present fossil. And if not an annelid, the conclusion is inevitable that it is the shell of a Scaphopod, probably of the genus *Dentalium* (sens. lat.). Since that genus, or some close ally thereof, has persisted from Devonian times to the present, this conclusion, while throwing no fresh light on the age of the rocks, is at least in harmony with other evidence. Several species of *Dentalium* or its subgenus *Entalis* have been recorded from Carboniferous rocks. Since the habitat of *Dentalium* is in marine mud, this conclusion further agrees with the evidence afforded by *Torlessia*. The fact that the stereom has been converted into silica renders inapplicable the argument from its arragonite or calcite constitution, and also prevents the investigation of its microscopic structure.

The tubes show no trace of slits at either end, so that it is legitimate to leave them in the genus *Dentalium*, even as now restricted (see Simroth, 1895, p. 458). Among the species of *Dentalium* (sens. lat.), both recent and fossil, the one to which the present form seems to bear most resemblance is *D. formosum*, Adams

and Reeve, from the China seas, since that tapers rather rapidly and has longitudinal ribs of about the same degree of coarseness. That species, however, has an apical fissure, is much straighter, and marked with transverse lines of growth. None of the Carboniferous species are so coarsely marked as the present one. It seems necessary, therefore, to establish :—

DENTALIUM HUTTONI, n.sp.

A *Dentalium* (or allied genus) of which the shell tapers rapidly (from 25 to 7·5, length being taken as 100) and is strongly curved (radius of outer curve being *circa* 12 mm.), with about fourteen distinct longitudinal ribs.

Here too the name of the collector and donor of the specimens described, the lamented New Zealand geologist who himself alluded to them in his published writings, seems highly appropriate for the trivial appellation.¹

Holotype: Specimen No. 22 of Mr. Ferrar's list (Fig. 5).

Horizon: Said to be the same as that of *Torlessia Mackayi*.

Localities: Kowai River (holotype), Wilberforce River (No. 23), and west coast of the South Island (*fide* M'Kay), all in New Zealand. Perhaps this is the same species as was found in the Maitai Series of the Taipo ranges by S. H. Cox (1877, p. 78) and referred by him to *Dentalium*; but it is not, of course, the same as any of the *Dentalium* from much later rocks recorded by M'Kay (1877, pp. 101, 110, 116, 117).

I am indebted to my colleagues Mr. Edgar Smith and Mr. G. C. Crick for kindly looking at these obscure fossils, and for raising no objection to the systematic position here proposed for them.

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III.—ON THE PROBABLE PELEAN ORIGIN OF THE FELSITIC SLATES OF SNOWDON, AND THEIR METAMORPHISM.

By J. R. DAKYNS, M.A., and EDWARD GREENLY, F.G.S.

PART I: By J. R. DAKYNS, M.A.

THERE are several kinds of acid volcanic rocks in Wales. In the neighbourhood of Snowdon there are at least five kinds, as follows:—

1. There are undoubted lavas, showing lines of viscous flow and sometimes vesicular, and weathering into cubical blocks. Such may be seen on Crib Goch and on Crib Yddysgl, on Cerrig Cochion, and elsewhere. These rocks are rarely cleaved.

2. There are rocks like the last as to fracture and mode of weathering, but which are neither viscous nor vesicular. They are probably masses of felsitic dust or mud. Such may be seen in Cwm Llan.

3. There are also massive felstones, rudely cleaved, such as form Moel Meirch and Clogwyn Llwyd.

4. There are the so-called ashes of various kinds, usually well-bedded and often highly cleaved.

5. Lastly, there are highly cleaved felsitic rocks, which show no lines of viscous flow, are generally unbedded, and which are in many places fragmentary. They are markedly different from the undoubted uncleaved lavas with which they are in some places associated; and though not readily to be distinguished from cleaved lavas they are so often obviously fragmentary that I cannot but consider them to be mainly of clastic origin.

With reference to these rocks Mr. Greenly wrote to me immediately after the meeting of the British Association at Southport