The Ordovician Graptolites of North-west Nelson, N.Z., Second Paper; with Notes on other Ordovician Fossils

By W. N. BENSON, R. A. KEBLE, L. C. KING, and J. T. MCKEE.

[*Read before the Otago Institute, September 12, 1933; received by the Editor, September 19, 1933; additions to the manuscript made during 1934-5; issued separately, March, 1936.*]

INTRODUCTION.

THE first paper under the above title (Keble and Benson, 1929) dealt with a series of graptolites, chiefly of Upper Ordovician age (according to the Victorian usage), collected by members of the official Geological Survey in the Mount Arthur District, which is on the main watershed in the central part of North-west Nelson, in the north-western portion of the South Island of New Zealand. Among them, however, were a few Lower Ordovician graptolites coming from an adjacent locality, the Aorangi Mine area near West Haven. During the last five years there have been several advances in graptolithology which affect the study of this region. Dr. Elles has discussed the sequence of the graptolite faunas in the Skiddaw Series in England, and has indicated their correlations. The occurrence and evolution of the *Didymograptus extensus-nitidus-hirundo* series and the *D. protobifidus-bifidus* series of transient forms has been made clear therein (Elles, 1933). The sequence of the Lower and Upper Ordovician graptolites in Victoria has been stated by Dr. Elles (1932), by Harris and Keble (1932), by Thomas and Keble (1933), by Harris (1935), and Thomas (1935), and the chronological evolution of the Isograptidae has been described by Harris

(1934). The sequence of the faunal zones in the Lower Ordovician rocks of south-western New Zealand has been determined, and many species have been added to the New Zealand graptolite-fauna (Benson and Keble, 1935). Moreover, nearly a score of additional collections have been made in North-west Nelson and almost all of the older material has been restudied. It is now possible, therefore, to give a corrected and extended account of the graptolites of this region. In so doing, special thanks must be expressed to Dr. Elles for her revision of the determinations of the graptolites of the Isaacson Collection, first examined by Dr. E. M. R. Shakespear nearly thirty years ago, and for checking the determinations of some of our recently collected material. Dr. W. J. Harris, who kindly examined our Isograptids from South-western New Zealand, has also helped us to classify some of these forms in our new collections. We are indebted also to Mr L. V. Ellis and Mr H. Service for collections from the neighbourhood of the Aorangi Mine area, and to the Director of the Geological Survey for the opportunity of examining the large collections made by Cox and Park about fifty years ago and for permission to use the Survey field-sheets of this area. Except for a few observations of dips by Service, the data shown on the accompanying map and section, from which the structure and formation-boundaries have been inferred, were obtained by Webb, Ongley, or Macpherson for the Geological Survey. We should acknowledge also a grant received from the Wellington Philosophical Society facilitating the visit of King and McKee to this region.

In the following account we have adopted for the various stratigraphical subdivisions of the Lower Ordovician which are equivalent to those occurring in Victoria, the Victorian nomenclature which has now been applied to the stratigraphy of the south-western portion of New Zealand, and we have abandoned, as involving unnecessary duplication, the series of New Zealand names proposed for use in this country (Keble and Benson, 1929; 1935).

The Aorangi Mine Area.

Historical.

The discovery of graptolites in New Zealand was first made shortly after gold-mining had started at the Perseverance Mine east of the Aorere River in 1866, or when the old Golden Ridge Mine was opened up in 1874, on the Golden Ridge by Slaty Creek, about fifteen miles to the west and southern end of West Haven (then termed the West Wanganui Inlet), in the extreme north-west of the South Island. Hutton (1878) exhibited specimens of forms known to occur in Australia, viz., "*Graptolites fruticosus*" and one compared doubtfully with "*G. gracilis*" (possibly *Goniograptus perflexilis*), which had been received by Ulrich from Nelson, and Hector, listing the Golden Ridge as "Fossiliferous Locality No. 431," noted the receipt of graptolites sent therefrom by Mr J. L. Moody, and remarked on the probable equivalence of the graptolitic slate here with that of the Victorian goldfields (Hector, 1879, *a* and *b*). In 1882 Hector noted the presence of other graptolites in slates collected from this spot during the geological examination by Cox

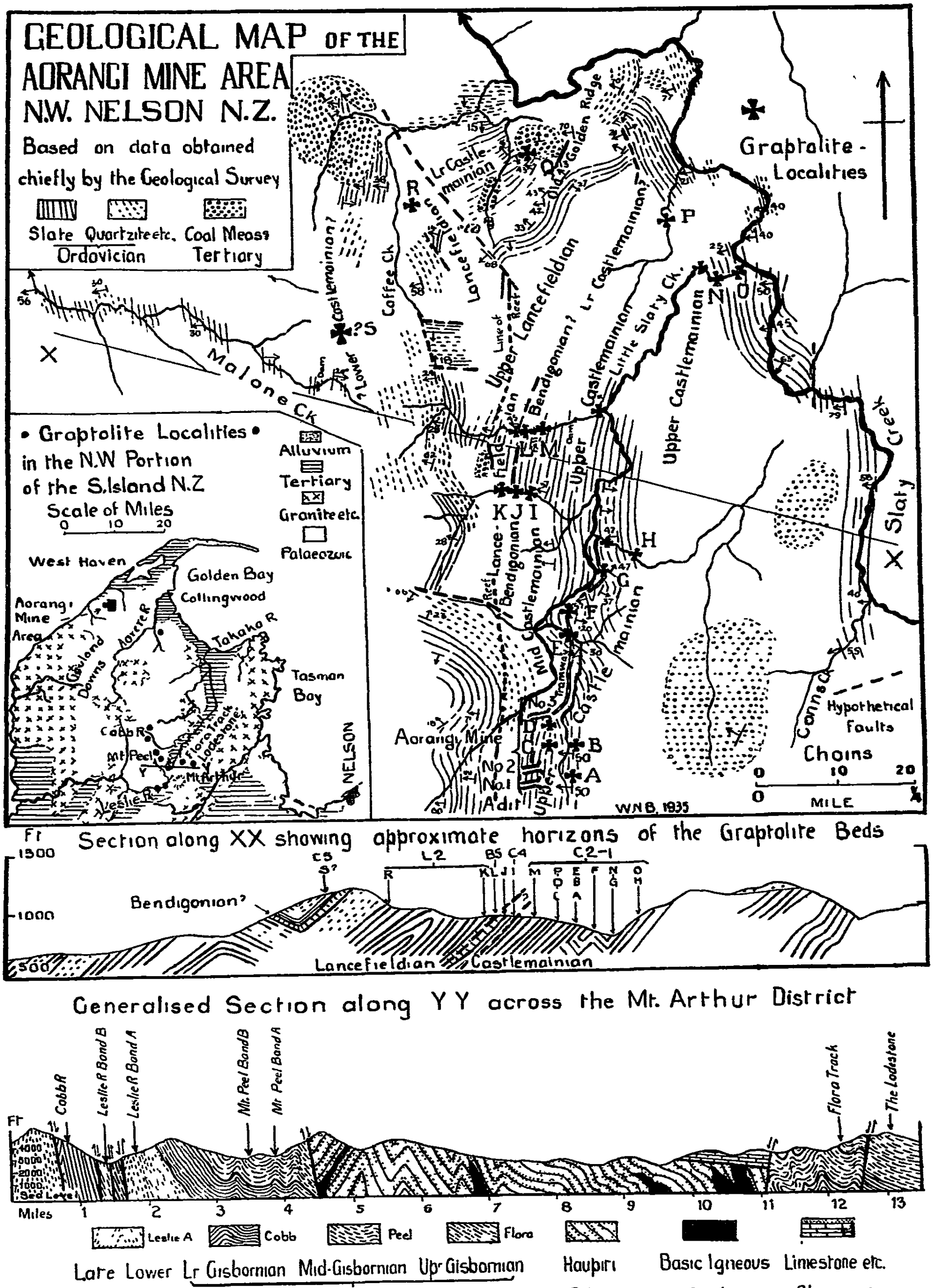

FIG. 1.—Geological map and sections of the Aorangi Mine and Mt. Arthur Areas based on the field studies of the Geological Survey, interpreted in accordance with the distribution of the graptolites.

(1882), listing it as "Fossiliferous Locality No. 547," and a year later commented on the probability that the collection betokened a Llandeilan age and an Arenig age for the underlying beds (Hector, 1883). Cox stated that the carbonaceous graptolitic slates were interbedded with grey slates and sandstones which dipped westwards at angles between 30° and 40°. Hutton (1885) commented on the apparent identity between certain of these graptolites and Australian Ordovician species, but did not mention any generic names. Hector (1886), again without mention of any determinations, published thirteen figures of New Zealand graptolites. These were reproduced by Park in 1910, and identifications were suggested for the forms illustrated. In 1889 Park made a comprehensive study of the Collingwood District, North-west Nelson. He stated that the auriferous bodies at Golden Ridge were lenticular or wedge-shaped masses of quartz in a narrow belt of crushed sooty black slates, and noticed that in the vicinity of the mine the slates "contained an abundance of finely preserved graptolites, and what are indistinct impressions of this zoophyte are also found in the Gouland Downs." He concluded that the slates were probably the equivalent of the "bituminous schists and carbon slates of the Baton River region," but did not in his map separate them from the less ancient fossiliferous limestones and blue slates of the Baton River area (Park, 1889, *a* and *b*). He made a large collection from the vicinity of the old Golden Ridge Mine, which is recorded as Fossiliferous Locality 740 (Hector, 1891). The collections from this region, namely, that marked as locality 431 which was added to Cox's larger collection 547, and Park's collection 740, were recently submitted to one of us (W. N. B.) for determination, with results recorded below (columns Q1 and Q2, p. 367).

In 1897 Frech noted that a specimen of *Didymograptus (Isograptus) gibberulus ("D. caduceus")* was preserved in the collections of the Breslau Museum (in which Hochstetter had placed a number of Australian graptolites, which Frech also mentioned). This specimen was derived from the Perseverance Mine, Bedstead Gully, on the eastern side of the Aorere River, about ten miles from its mouth, and fifteen miles east-south-east of the Aorangi Mine. Hochstetter (1864), who had visited this region in 1859, in describing the area, stated that he found no fossils there, but it may be surmised that the specimen had been found and sent to him during the decade 1866-76 while the Perseverance Mine was in operation.

In 1895 Dr. T. S. Hall, without mentioning any specific determinations of New Zealand graptolites, remarked on the similarity of the forms figured by Hector to those which characterise the Castlemaine Series of Victoria, and later (Hall, 1899) recorded the receipt of specimens of "*Didymograptus bifidus*" from North-west Nelson. In the same year Hutton (1899) published generic determinations of a number of New Zealand graptolites, recognising the presence of *Dichograptus, Tetragraptus, Phyllograptus,* and *Didymograptus.* In 1902 the Otago University Museum received through Mr A. Hamilton, from an undefined locality in North-west Nelson, though showing the lithological peculiarities of the rocks of the Golden Ridge mine, specimens which Dr. Elles has kindly determined for the writers as *Tetragraptus quadribrachiatus, T. reclinatus, Didymograptus protobifidus, D. suecicus,* and *Isograptus gibberulus (caduceus).*

The Collingwood region was examined by the Geological Survey in 1906-7 (Bell, Webb and Clarke, 1907), and the graptolites collected by Webb " from a band of carbonaceous argillite about eight inches thick not far from the Aorangi Mine " (i.e., about a mile south of the Golden Ridge Mine) were figured and determined provisionally by Clarke, whose determinations, revised to bring them into line with present usage, are listed below (List No. 5, p. 370).

A larger collection was obtained about the same time by Mr E. D. Isaacson, a mining engineer, and was sent to the British Museum, which shared it with the Sedgwick Museum, Cambridge. This collection was described by Dr. E. M. R. Shakespear (1908). These fossils, it was stated, came from " Slaty Creek " (probably Little Slaty Creek), " not far from the Aorangi Mine, where, interbedded among the unfossiliferous blue slates, there is a highly carbonised band a few inches thick." According to Isaacson, the fossils were obtained " almost anywhere in the line of the reef, both on the footwall and on the hanging wall." It is evident that an appreciable thickness of strata must have yielded the fossils collected by him, and, in spite of the words " a few inches thick " referring to one particular fossiliferous layer, his statement that they all came from one " band " must mean that they were found within a short distance on either side of the lode, and not that they were confined to a single narrow layer or faunal zone. Actually, Dr. Shakespear recognised two different faunal associations characteristically in different types of sedimentary rock. In Band (a) the rock is a rather coarse shale with an irregular fracture, while in Band (b) it is a finely granular smooth well-laminated slate. The list of forms occurring in these two bands, supplemented and revised by Dr Elles, is given below (Y, p. 367; No. 6, p. 370). Dr Shakespear compared the fauna of Band (a) with that of the *Tetragraptus* zone in New York State, or the *D. extensus* beds of the Skiddaw sequence, while that of Band (b) was compared with the lower part of the overlying *D. bifidus* zone of New York, or the *D. hirundo* of Great Britain.

In 1907 also Marshall made several collections of graptolites from near the Aorangi Mine, a mile south of the old Golden Ridge Mine. The more striking specimens were sent for identification to the late Dr. T. S. Hall, whose account thereof appeared in 1915.* Circumstances had unfortunately compelled Dr. Marshall to entrust the locality-labelling of these fossils to hands less careful than his own, and some confusion resulted, which Dr. Hall's experience of the Victorian fauna enabled him to detect. At Butcher's Gully, or Jacob's Ladder at the head of Malone Creek (probably near S on our map, though the precise locality cannot now be determined), Marshall had obtained an assemblage of forms apparently coeval

* Certain of these forms which were figured by Marshall (1912) as *Didymograptus murchisoni* and *Phyllograptus folius* would appear to be referrable to *D. protobifidus* in its larger C5 form, and to *P. angustifolius.*

with that in Isaacson's Band (b), for the most abundant and characteristic form in each case is the "*D. nanus*" of Dr. Shakespear or the "*D. bifidus*" of Dr. Hall, the form which has since been described as *D. protobifidus* by Dr. Elles (1933). After eliminating as foreign to the collection a large specimen of *Isograptus caduceus (gibberulus)* such as is nowhere known to occur *in situ* in association with *D. protobifidus,* Hall compared this assemblage with that of the lowest portion of the Castlemaine Series of Victoria. A list of its members (column S, p. 367) is given below. From the lowest adit (No. 3) of the Aorangi Mine (Locality D on map) Marshall obtained a collection believed by Hall to have been derived from the middle of the Castlemaine Series as then understood, but which seems now to be better placed with the higher portions of that series (see faunal list, No. 4, p. 370), while from the tramway between the mine and the battery (Locality E, F, or G on the map), a further collection was obtained containing large specimens of *Isograptus caduceus* from what was believed to be a higher horizon in the Castlemaine Series. There was obviously some mixing of specimens, however, for the counterpart of a slab from the adit was included among the collection from the tramway; from the latter a specimen of *D.* "*bifidus*" was eliminated as almost certainly foreign to the assemblage. The amended list of the fauna from Marshall's tramway locality is given below (No. 9, p. 370). Comparison between Dr. Shakespear's and Dr. Hall's lists showed that the latter would, on Victorian evidence, reverse the order that was assigned by Dr. Shakespear to Bands (a) and (b) recognised by her. As will appear below, the re-determination by Dr. Elles of the specimens examined by Dr. Shakespear in the light of her recent study of the Skiddaw sequence, confirms Dr. Hall's conclusion.

Several additional specimens obtained by Marshall from the underground workings of the mine have recently come to light in the Museum of the Geological Department of Otago University, Dunedin, but they have been so altered by mineralising solutions as to be quite indeterminable. Presumably Isaacson did not deal with specimens so closely associated with the ore-body as were these. Certain other graptolites found by Marshall from this region, and recently determined for the first time, are noted below.

During the re-survey of the Collingwood Division in 1920, Mr E. O. Macpherson obtained a small collection of graptolites from "graphitic slates" on the tramway track between the Aorangi Mine and the battery (Fossiliferous Locality 1273 in the Survey Register, and Locality G on our map). These were determined by Keble and Benson (1929), and their amended list is tabulated below (No. 8, p. 370). This assemblage is indicative of the highest portion of the Castlemaine Series.

In 1932 Mr L. V. Ellis obtained a number of graptolites from a point two or three chains south of No. 3 Adit, Aorangi Mine (Locality B on our map, Fig. 1).* This material was referred to Keble and Benson for determination. It had been carefully collected

* Fossiliferous Locality 1923 in the Survey Register.

from a narrow band of rather varied sediments of which the following particulars were noted, the several layers given in descending order.

Sample No. 1 (top), No. 2, and No. 3.	—Well bedded pale grey slates, in all	4½ inches.
No. 4.	—Imperfectly fissile pale grey slate ..	4½ inches.
No. 5.	—Slate like Nos. 1–3	9 inches.
No. 6.	—No specimen supplied	5½ inches.
No. 7.	Increasingly dark grey, becoming	2 inches.
No. 8.	sooty black in No. 10, which contains	2 inches.
No. 9.	nodules of pyrites. Fissility very	6 inches.
No. 10.	poor in No. 10.	4 inches.
No. 11.	—Fine grained and not very evenly-bedded slate	3 inches.
No. 12.	—Pale grey rather pyritous phyllite ..	8 inches.

The following forms were noted in these beds:—*Isograptus caduceus (gibberulus)* of small size (cf. var. *lunata*), in No. 1 and juvenile forms in Nos. 7 and 11; *I. caduceus* var. *victoriae,* the most abundant form in Nos. 1, 3, 5, 7, 9, 10 and 11; *I. caduceus* var. *maxima,* in Nos. 5 and 7; *Didymograptus nitidus,* in Nos. 7, 9, and 10; *Tetragraptus* cf. *amii,* in No. 11; *Cryptograptus circinus* in Nos. 10 and 11. In addition to these are specimens recalling those compared by Clarke to *Rastrites,* but seemingly more appropriately referred to *Goniograptus.* The whole collection (No. 2, p. 370) is uniform, and apparently was derived from about the same band as that which yielded the material studied by Clarke (No. 5, p. 370).

In March, 1933, Mr H. Service obtained three other collections from Little Slaty Creek. Near the battery two chains up Jimmy's Creek from its junction with Little Slaty Creek (Locality H on our map) there is a thickness of nearly sixty feet of graphitic slate followed by a hard grey micaceous quartzite, which outcrops strongly at a small waterfall five chains above the battery. *Isograptus caduceus* is the most abundant form in the slates (No. 11, p. 370). Beneath the bridge on the tramway-track (Locality E) the coarsely-laminated siliceous mudstone contains a layer of graphitic mudstone two inches thick which yielded a further collection (No. 7, p. 370). Finally at Locality A, six chains south of the Aorangi Mine Adit No. 3 and on the east side of the creek, yet another collection (No. 1, p. 370) was obtained. The fossils in these collections were determined by Benson.

Service sought without success for graptolites in Slaty and Conn's Creeks, half a mile east of Little Slaty Creek. The rocks are here grey imperfectly fissile slates with a chloritic sheen on strain-slip surfaces. Granite is exposed two miles further to the east. The absence of graptolites from this part of the Slaty Creek valley was confirmed by King and McKee in December, 1933.

In May, 1933, while sorting material in the Museum of the Geological Department, Otago University, Benson came on Marshall's long-lost collections of 1907, and noted beside the specimens which had been submitted to Dr. Hall, forms which had not hitherto attracted attention, indicative of derivation from other horizons. There were four slabs of smooth fine-grained black slate labelled " Creek Bed " or " Cutting " containing Bryograptids and the *Clonograptus* characteristics of the Upper Lancefieldian L.2 beds in the regions about Preservation Inlet. A fifth specimen, labelled " Creek Bed," displayed examples of *Tetragraptus approximatus,* which is very abundant in the basal Bendigonian beds in this southern district. These determinations were confirmed by Keble (No. X, p. 365). In view of this discovery, L. C. King and J. T. McKee visited the Aorangi area in December, 1933, located the beds from which these fossils must have been obtained, found two zonal assemblages not indicated in the earlier collections from this region, and showed the position of all but one of the already known zones. The stratigraphical information deducible from a consideration of the fossils obtained, and their places of origin, together with the records of dips and strikes, make clear for the first time that the structure of the region is that of an eastwardly overturned anticlinal fold (as shown on the section accompanying the map, Fig. 1), and permit some estimate of the relative thickness of the several zones, though this may have been obscured by strike-faulting.

The determination of the fossils collected by King and McKee was made by Benson, by whom also this manuscript was prepared after mutual discussion. Certain identifications, about which some doubt was felt, were kindly checked by Dr. Elles. Though many details might be added concerning the distribution of the several zones in this region, the general sequence of faunal assemblages seems now clear, and is in full accord with that occurring in the south-western portion of New Zealand.

Stratigraphy and Faunal Succession.

Lancefieldian. The watershed between Little Slaty Creek and Malone Creek seems to be composed of the lowest series in the Ordovician rocks, and forms the axial portion of an overturned anticline, the upper and lower limbs of which dip westwards at angles of about 40°, though near the apex the beds are almost horizontal. Fossils have been found in the upper limb at Locality R, the southernmost of three prospecting drives in the valley of Coffee Creek. They were also obtained from the lower limb at Locality K in a prospecting drive on the south side of a small creek which joins Little Slaty Creek just below the battery. The rock is a very fine-grained rather glossy slate, and contains a profusion of bryograptids. The four specimens obtained by Marshall, which were labelled " Creek Bed " or " Cutting " have the same lithology and fauna. The fossils in the last are recorded in column X in the following table, which indicates also the number of the different species recognised in each locality.

TABLE I.—UPPER LANCEFIELDIAN GRAPTOLITES.

Collection.	K	Q	X
Bryograptus (?) *antiquus* (T. S. Hall)	10	4	—
B. antiquus ? var. *inusitatus* B. and K.	1	1	×
B. hunnebergensis Moberg	11	6	×
B. simplex Tornquist*	2	1	×
Clonograptus tenellus var. *kingi* B. and K.	—	—	×
C. sp. indet.	2	—	—
Trochograptus (?) sp.	—	—	×
Tetragraptus decipiens T. S. Hall	3	5	—
T. decipiens var. *bipatens* K. and H.	—	—	×
Didymograptus taylori T. S. Hall	12	3	×

This association clearly belongs to that which characterises the beds at Preservation Inlet and Cape Providence, which have been compared with the L2 beds in Victoria. It will be seen that there is a thickness of at least 500ft. of Lancefieldian beds in the Aorangi area. It may be expected that the fauna of the immediately underlying L3 beds will eventually be found here.

Bendigonian. At Locality L in the gully immediately north of that containing Locality K, and in a cutting wherein the stream had been diverted near a small waterfall, a fossiliferous bed is displayed, wherein King and McKee obtained the following:—*Bryograptus* sp. indet. (4), *Tetragraptus approximatus* Nich. (8), *T. decipiens* (1), *T. fruticosus* (J. Hall) 4 br. (1), *T. quadribrachiatus* J. Hall (3), (and many stipes apparently belonging to this species), *Didymograptus taylori* (1); also an indeterminate fibrous form resembling *Strophograptus* or *Trichograptus,* but without obvious thecal openings. These fossils occur in a glassy slate resembling that of the L2 beds. This small assemblage is typical of the B5 or basal Bendigonian Zone. The profile on our map shows that the thickness of this bed cannot be much more than about a hundred feet, unless the apparent thickness has been much reduced by strike-faulting.

A Transitional Fauna. At Locality J, forty yards west of Locality K, on a western branch of Little Slaty Creek, King and McKee obtained the following:—*Bryograptus* sp. (1), *T. fruticosus* 3 br. (1), *D. extensus-nitidus* (2), *D. protobifidus* Elles (2), *Phyllograptus ilicifolius* var. *grandis.* E. and W. (2). These forms are too few to permit us to do more than refer the assemblage to the *D. protobifidus* Passage Beds as defined by Harris (Benson and Keble, 1935, p. 263). They must lie almost on the boundary of the Bendigo and Castlemaine Series, and, in any case, the thickness of strata characterised by this assemblage is so small that the boundary line between these series would pass through Locality J on our map.

Lower Castlemainian. No beds containing fossils referrable with certainty to the base of the Castlemainian were found by King and McKee. Hector's illustrations (1886) of fossils in Cox's collection from the old Golden Ridge Mine (Localities 431 and 457; Q on our map) make it clear that the basal zone C5 is present there, as

* The form mentioned by Chapman (1934, pp. 115-6) as *B. consobrinus* (a *nomen nudum*) was found later to be *B. simplex.*

will appear also from the detailed determination* of the fossils in these collections (column Q1 in Table II) and in Park's collection from the same spot (Fossiliferous Locality 740; column Q2 in Table II). Column Z shows the forms (several of which were kindly determined by Dr. Elles) in a small collection, probably from the same locality, placed in the Otago University Museum by Hamilton in 1902. Column S gives the determinations by Dr. T. S. Hall (1915) of a collection made by Marshall from Butcher's Gully or Jacob's Ladder at the head of Malone Creek. The first two names cannot now be localised, but probably indicate a spot near that of S on our map. Column Y gives the list of fossils obtained by Isaacson from "Band b" near the Aorangi Mine, and presumably near Locality D on our map. This material has been divided between the British Museum and the Sedgwick Museum, Cambridge, and was first studied by Dr. Shakespear (1908). The fossils were re-examined by Dr. Elles, by whose courtesy we are permitted to record the revised list.§ To these we have added for the sake of comparison column SWF giving the list of forms from the *early* Lower Castlemainian C5 beds at Localities 10 and 32 at Cape Providence and Coal Island respectively in South-west Fiordland (Benson and Keble, 1935). It is noteworthy that in all these determinations the forms recognised by Dr. Shakespear as *D. nanus* and by Dr. T. S. Hall as *D. bifidus* prove to be *P. protobifidus* Elles. In the table below x denotes an occurrence without indication of relative abundance, rr = very rare, r = rare, fc = fairly common, c = common, and cc = very common. The last column indicates the approximate relative abundance of the faunal elements in the lower C5 beds in North-west Nelson.

In order to complete our summary of the faunal succession in the Castlemaine Series, we may here recall that in South-west Fiordland there occurs in the upper part of the C5 beds on Cape Providence a late Lower Castlemainian assemblage that has not yet been noted in North-west Nelson. It differs from that just described in the decreased abundance of *Didymograptus protobifidus* and by the entry of its descendent form *D. bidens* Keble, and also by the increased abundance of *Isograptus caduceus (= gibberulus)* var. *primula* with which var. *lunata* now appears. The following are the chief elements of the fauna in an aggregate collection of 126 forms from two localities (Keble, 1927; Benson and Keble, 1935, p. 251). Many-branched forms (*Clonograptus* sp., *Goniograptus* sp., *Dichograptus octobrachiatus*) 5%; horizontal Tetragraptids (*T. amii, T. quadribrachiatus, T. whitelawi*) 6%; *T. pendens* (?) 2%; reclined Tetragraptids (*T. serra, T. similis*) 18%; horizontal Didymograptids (*D. adamantinus, D. extensus* and transients, *D. procumbens*) 12%; declined Didymograptids (*D. affinis, D. ellesi, D. gracilis*) 4%; dependent Didymograptids (*D. bidens, D. protobifidus*) 19%; *Isograptus caduceus* 23%; Phyllograptids 10%; *Diplograptus* sp. and *Strophograptus trichomanes* 1%.

---

* By Benson.

§ It has been necessary once more to use lithological criteria where the palaeontological association is insufficient to determine the zone from which any particular specimen was derived.

TABLE II.—LOWER CASTLEMAINIAN GRAPTOLITES IN NEW ZEALAND.

Collection.	SWF	Q1	Q2	S	Y	Z	%
Many-branched forms.							
Clonograptus sp.	1	—	2?	—	—	1	
Bryograptus cf. *lapworthi* Rued.	—	—	1?	—	r	—	
Goniograptus cf. *geometricus* Rued. ..	—	2	1	—	c	—	3
G. cf. *perflexilis* Rued.	—	23	2	—	—	—	
Dichograptus octobrachiatus J Hall ..	—	4	—	—	—	—	
Horizontal Tetragraptids.							
Tetragraptus amii Lapw. MS., E. and W.	13	10	6	×	×	—	2
T. harti T. S. Hall	2	5	—	×	—	1	
T. quadribrachiatus J. Hall	—	6?	—	—	rr	1	
Dependent Tetragraptids.							
Tetragraptus cf. *pendens* Elles	—	—	—	×	fc	—	
Reclined Tetragraptids.							
T. reclinatus Elles and Wood	—	2	1	—	—	1	
T. serra (Brongn.)	21	?	—	—	—	—	12
T. similis (J. Hall) (= *bigsbyi* J. Hall)	22	40	7	—	cc	—	
T. taraxacum Rued.	3	—	—	—	—	—	
T. spp. indet.							
Horizontal Didymograptids.							
Didymograptus extensus-nitidus transients	3	75	3	—	fc	—	
D. mundus T. S. Hall	3	—	—	—	—	—	
D. nitidus-hirundo transients	6	—	—	—	fc	—	15
D. similis Rued.	2—	—	—	—	fc	—	
D. suecicus Tullberg	—	—	—	—	—	1	
D. extensiform stipes indet.	×	7	18	×	×	×	
Declined Didymograptids.							
D. affinis Nich.	—	—	—	—	r	—	
D. gracilis Tornqt.	11	3	1	—	—	—	
D. simulans Elles and Wood	—	—	—	—	rr	—	
Dependent Didymograptids.							
D. artus Elles and Wood	2	—	—	—	—	—	
D. protobifidus Elles	98	497	72	cc	cc	17	56
Isograptus gibberulus Nich. (= *caduceus* Salter pars. var. *primula* Harris) ..	31	39	2	—	—	1	4
Phyllograptids.							
Phyllograptus angustifolius J. Hall ..	64	3	8	—	fc	—	
P. anna J. Hall	7	19	9	—	fc	—	
P. ilicifolius J. Hall	3	22	22	×	r	1	8
P. ilicifolius var. *grandis* E. and W. ..	—	—	—	—	×	—	
P. cf. *typus* J. Hall and spp. indet. ..	12	—	—	—	×	—	
Strophograptus trichomanes Rued. ..	—	3	1	—	×	—	

Middle Castlemainian. King and McKee obtained fossils* from Locality I, a bluff on the south side of the same creek as contained Locality J, and about forty yards further east. The collection was made from two layers twelve feet apart, the material from which was mixed. The assemblage of forms is, however, quite comparable with that in the Middle Castlemainian C4 and C3 beds in Victoria, and is larger than the small C4 assemblages obtained from Cape Providence (Benson and Keble, 1935, p. 251). It differs from that of the C5 beds by the entry of *Didymograptus dependulus* H. and K. (4%†) replacing *D. protobifidus,* by the increase of the Isograptids (37%), the small form *I. caduceus* var. *lunata* Harris being present as well as var. *primula,* while forms transitional to var. *victoriae* Harris also appear. There are also numerous extensiform Didymograptids such as *D. extensus-nitidus, D. patulus,* and *D. suecicus* (25%), together with horizontal Tetragraptids—*T. amii, T. harti,* and *T. quadribrachiatus* (8%), reclined Tetragraptids—*T. serra* and *T. similis* (12%), and Phyllograptids—*P. angustifolius, P. anna,* and *P. ilicifolius* var. *grandis* (12%); also *Bryograptus* sp., *Clonograptus* sp., and *Goniograptus* sp. So far there has not yet been found in the C4 beds in this region either *Tetragraptus woodi* Rued. or *Diplograptus* cf. *longicaudatus* Rued., which appear in the same zone on Cape Providence. It is apparent from the profile that the Lower and Middle Castlemainian beds cannot be more than about sixty feet thick each unless their apparent thickness has been considerably decreased by strike-faulting along the lower limb of the overfold. If there should actually be a considerable thickness of quartzite either between the Lower and Middle Castlemainian beds or between the Middle and Upper Castlemainian, such strike-faulting must have occurred.

Upper Castlemainian. The highest portion of the Castlemaine Series, which was represented at Cape Providence by a few pebbles only (Benson and Keble, p. 253) is the most fully represented portion of the Ordovician rocks in this area and contains the greatest variety of fossils. Collections have been made from twelve localities and comprise in all thirty different forms. The rocks composing this portion of the succession extend down the valley of Little Slaty Creek to its junction with Slaty Creek proper. The regularity of the westward dips is interrupted by several easterly-dipping bands. There is no obvious difference in character and fossil-content in the rocks on either side of the creek, so that either we have here a series that is quite uniform over a thickness of about five hundred feet or else a complicated synclinal fold is present, as is indicated in the profile accompanying our map. The confirmation of this structure would require more field-work than has been accomplished.

---

* Determined by Benson.

† These estimates of relative abundance are based on a collection of 54 determined forms.

Table III shows the forms that have been obtained from this zone at the various fossiliferous localities therein, which have been defined as under:—

1. Locality A. Six chains south of the Aorangi Mine No. 3 Adit, east side of creek; H. Service collector.*
2. Locality B. 2–3 chains south of No. 3 Adit, east side of creek; L. V. Ellis collector.§
3. Locality C. Between Adits 3 and 2; King and McKee collectors.*
4. Locality D. Adit No. 3. Marshall collector. Determinations by Dr. T. S. Hall.
5. Locality D?. "Near the Mine," Webb's collection. Clarke's determinations revised.
6. Locality D?. Slaty Creek Band (a), Isaacson's collection; Dr. Shakespear's determinations revised by Dr. Elles.
7. Locality E. Bridge on tramway; Service and also King and McKee collectors.*
8. Locality F. Tramway Track. Macpherson collector.§
9. Locality F?. Tramway Track; Marshall collector; Hall's determinations.
10. Locality G. Tramway Track, 5 chains south of the Battery; King and McKee collectors.*
11. Locality H. Jimmy's Creek, 5 chains above the Battery; H. Service collector.*
12. Locality M. On Creek tributary from the west to Little Slaty Creek, one chain below waterfall; King and McKee collectors.*
13. Locality N. Four chains above junction of Slaty and Little Slaty Creek. King and McKee collectors.*
14. Locality O. Near junction of Slaty and Little Slaty Creeks; King and McKee collectors.*
15. Locality P. Ten chains north-west of the junction of Slaty and Little Slaty Creek, by track; King and McKee's collections.*
16. Approximate relative abundance of faunal elements in zone (based on 140 determined specimens from Localities A, C, E, F, M, N, O, and P).

The following notes may be made concerning items in the list below (Table III):—

(a) "*Rastrites*" in the original statement.
(b) "*Loganograptus octobrachiatus*" in the original statement.
(c) Added by W. N. B., identified from Clarke's illustrations.
(d) "*Phyllograptus typus*" in the original statement.
(e) Determinations added by Dr. Elles.
(f) *D. caduceus* var. *manubriatus* in the original statement.

---

§ Determinations by Keble and Benson.

* Determinations by Benson.

TABLE III.—UPPER CASTLEMAINIAN GRAPTOLITES IN NORTH-WEST NELSON, N.Z.

Locality.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Many-branched forms.																6%
Bryograptus cf. *lapworthi* Rued.	—	—	—	—	—	?	—	—	—	—	—	—	—	—	—	
Clonograptus sp.	—	—	—	—	—	—	—	—	—	×	×	—	—	—	×	
Goniograptus crinitus T. S. H.	—	—	—	cf	—	—	—	—	—	—	—	—	—	—	—	
G. cf. *perflexilis* Rued	—	—	—	—	?	a	—	—	—	—	—	—	—	—	—	
G. spp. indet.	×	×	×	—	—	—	—	—	—	—	—	—	—	—	×	
Sigmagraptus laxus (T. S. H.)	—	—	—	cf	—	—	—	—	—	—	—	—	—	—	—	
Loganograptus logani J. Hall	—	—	—	—	—	×	—	—	?	—	—	—	—	×	—	
Dichograptus octobrachiatus J. Hall	×	—	—	×	b	×	×	×	—	×	—	—	—	—	—	
Horizontal Tetragraptids.																4
Tetragraptus amii E. and W.	—	×	—	—	—	×	×	—	—	—	—	—	—	—	—	
T. harti T. S. Hall	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×	
T. quadribrachiatus J. Hall ..	×	—	—	—	?	—	—	—	—	—	—	—	—	—	×	
Reclined Tetragraptids.																4
T. serra (Brongn.)	—	—	×	—	?	—	—	—	—	—	—	?	—	—	×	
Extensiform Didymograptids.																18
Didymograptus extensus J. Hall	—	—	×	—	×	×	×	—	×	×	—	×	—	—	×	
D. mundus T. S. Hall	—	—	—	×	—	—	—	×	—	—	—	—	—	—	—	
D. nitidus J. Hall	×	×	×	—	—	×	×	—	—	—	×	—	—	×	—	
var. *aorangiensis* K. and B.	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	
D. nitidus-extensus	—	—	—	—	—	e	—	—	—	—	—	×	—	×	×	
D. patulus J. Hall pars.	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	
D. suecicus Tullbg.	—	—	×	—	—	e	—	—	—	—	—	—	—	—	—	
Declined Didymograptids.																—
D. gracilis Tornqt.	—	—	—	—	—	e	—	—	—	—	—	—	—	—	—	
D. simulans E. and W.	—	—	—	—	—	e	—	—	—	—	—	—	—	—	—	
Isograptids.																56
Isograptus caduceus Salter pars.	—	—	—	×	×	×	—	×	×	—	—	—	—	—	—	
var. *lunata* Harris	—	×	×	—	c	—	×	—	—	—	×	×	—	—	×	
var. *victoriae* Harris	—	×	×	—	c	—	—	—	—	×	×	×	×	×	×	
var. *maxima* Harris	×	×	—	—	c	—	×	—	?	×	—	—	×	×	×	
I. hastatus Harris	—	—	—	—	—	—	—	f	—	—	—	—	—	—	—	
Phyllograptids.																6
Phyllograptus angustifolius J. Hall	—	—	×	—	—	—	—	—	?	—	—	—	—	×	—	
P. anna J. Hall	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	
P. ilicifolius J. Hall	—	—	×	—	d	—	—	—	—	—	—	—	—	—	—	
var. *grandis* E. and W. ..	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	
Cryptograptids.																6
Cryptograptus cf. *circinus* K. and H.	×	×	×	—	?	—	—	—	—	—	—	—	—	—	—	
C. hopkinsoni (Nich.)	—	—	—	—	?	e	?	—	—	?	—	—	—	—	?	
Diplograptids.																
Diplograptus cf. *inutilus* J. Hall	—	—	—	?	?	—	—	—	—	—	—	—	—	—	—	—

Several points of interest arise concerning these assemblages. The Isograptids have steadily increased during the Castlemainian Period both in size and in relative abundance. In the lower portion of the series they are scanty, and have hardly reached beyond the *primula* form. In the Middle Castlemainian they form nearly 40% of the total fauna, and have reached the *lunata-victoriae* stage, but in the Upper Castlemainian they comprise nearly 60% of the fauna, have reached the *maxima* stage, and have given rise to *I. hastatus,* though *victoriae* is the characteristically abundant variety. This accords with Dr. Harris' experience of the Castlemainian beds of Victoria (Harris, 1933, 1935). The course of evolution in the extensiform Didymograptids may also be seen in this region. The higher Bendigonian forms are not well displayed here, but we may recall that in Preservation Inlet the series has reached but little beyond the *nitidus* stage of development in the Upper Bendigonian (Benson and Keble, 1935, p. 283). Forms here in Middle and Upper Castlemainian beds reach the stage of *patulus* and rarely that of *suecicus,* and there is a late form of *suecicus* which has not yet reached the *praenuntius* stage (according to Dr. Elles' determinations). The succession thus agrees with that discussed by her in the Skiddaw rocks (Elles, 1933). The appearance of *Cryptograptus hopkinsoni* with these late forms is again in accord with the features of the Skiddaw sequence, though it has not yet been seen in Victoria. The complete absence of the dependent Didymograptids from the Upper Castlemainian is a feature in which the New Zealand succession accords with that in Victoria and contrasts with that in Britain, where, however, Dr Elles notes that the appearance of such Didymograptids is not general, but very local.

It is possible, as Hall suggested (1915), that the assemblage in column 4 may indicate an horizon rather below the highest Castlemainian Zone, and the same may hold in regard to the assemblages in columns 11 and 12. In none of these does *Isograptus* appear in the variety *maxima,* nor does *Cryptograptus* appear. Neither the collections available nor the field-evidence are sufficient to decide this. So also we note the lack of any examples of *I. caduceus* var. *maximodivergens* Harris, which Harris cites (1935) as the most characteristic member of the C1 Zone. However, the collections as a whole are indicative of an age comparable with that of the two highest zones C2–C1 in the Castlemaine Series in Victoria.

Structural Considerations.

While the stratigraphical succession of the fossiliferous beds has been satisfactorily determined, the general structure of the region remains obscure. Cox (1882) showed that the Ordovician rocks consist of slate and hard ridge-forming belts of "cherty sandstone." He noted that the thin band of graphitic slate at the Golden Ridge Mine (the C5 bed at Locality Q) was overlain by sandstone containing angular fragments "of the same rock" (? of slate), and traced this band along the ridge between Malone's and Little Slaty Creeks. Park (1889) confirmed this and showed that the auriferous deposits at the Golden Ridge had been formed in the fossiliferous graphitic band. Webb (Bell, Webb and Clarke,

1907) showed that beneath this graphitic band was a thin layer of quartzitic greywacke, which in turn rested on thick occasionally fossiliferous argillites. As a working hypothesis we may suggest that these lowest fossiliferous beds are the Lancefield and basal Bendigo Series, and that the succeeding quartzites mark a change of facies and some hiatus in deposition which continued through most of Bendigonian time. The succeeding deposition of argillites began at the close of Bendigonian time and continued into the base of the Castlemainian, comprising the transitional and graphitic C5 beds. Indeed, some contemporaneous erosion may have occurred, for King has noted the peculiar irregularity of the contact of the slate and quartzite. Further quartzites seem to have been formed in the Lower Castlemaine Series and been followed by the interlaminated Middle and Upper Castlemainian argillites and quartzitic greywackes.

If this be true, the general structure of the region may be expressed as an easterly overturned anticline and syncline, broken by strike-faulting. The soft thin graphitic Lower Castlemainian beds seem to have acted as an incompetent layer, and been dislocated by a thrust-fault in the overturned limb of the folds. As a result the Lower Castlemainian quartzites are concealed beneath the later Castlemainian beds in the syncline, and are faulted against the Bendigonian and Lancefieldian beds on the western side of Little Slaty Creek. The deposition of the auriferous quartz seems to have occurred during the shearing along the incompetent band, and to have been affected by the reducing action of the graphitic material. " The principal mineralised zone appears definitely confined to a narrow band of carbonaceous sometimes siliceous argillite never exceeding twenty feet in width. The vein-quartz is disposed in sheets, lenticular both in vertical and horizontal cross-section. These lensoid masses, which occasionally overlap, seldom exceed five feet in thickness. They occur at irregular intervals all along the zone of mineralisation, and are not confined to any particular position in the argillite band. . . . Differential movement is certainly recorded in crushed slickensided nature of the argillites, especially in the selvedges of the vein-walls " (Bell, Webb and Clarke, 1907). Explained in this manner, Isaacson's statement (Shakespear, 1908) that all his graptolites, including both Lower and Upper Castlemainian types, came from one band along the line of the lode, may be accepted as correct, provided that we conclude that this " band " was a heterogeneous strike-faulted mass of considerable width.

The map herewith, which has been reproduced by the courtesy of the Director of the Geological Survey, comprises all the data concerning the character, distribution, strike and dip of the formations recorded on the Survey's field-sheet, together with additional observations by Ellis, Service, King and McKee. It would indicate that though the general structure assumed in the transverse profile may be broadly true, the actual structure is complicated by additional strike-faults, oblique faults, and dip-faults, the effect of which cannot be determined from the available data. The thickly-bushed character of the region prevented the complete determination of its structure. In conclusion, it should be noted that the interpretation of the area about the Aorangi Mine as composed of *easterly* overturned anticlines and synclines is opposed to that suggested by Bell, Webb and Clarke for the Aorere area some ten miles to the south-east of the region here discussed, which envisaged the presence of westerly overturned folds.

THE MOUNT ARTHUR AREA.

During 1923 Messrs Grange, Macpherson and Sylvester, of the Geological Survey, discovered a series of graptolites in several localities in the highlands about Mount Arthur. The general structure of this region is indicated by the section YY (Figure 1) based on the data given in the maps published by the Geological Survey, which are to accompany the bulletin (No. 35) on the " Geology of the Motueka Subdivision, Karamea and Motupiko Divisions " now in preparation. The graptolites were described by Keble and Benson (1929). A few additional notes concerning these may now be given.

Late Lower Ordovician.

Near the head of the Leslie River (Band A, Fossiliferous Locality No. 1228) there were found a *Tetragraptus* resembling *T. similis*, a *Didymograptus* of the *euodus* type, and numerous indeterminate Dichograptid fragments. All that can be said of these is that the horizon is probably Lower Ordovician. Unless this fossiliferous horizon should eventually prove to be of Darriwillian age, that important division of the Victorian Lower Ordovician rocks is as yet unrepresented in New Zealand.

Upper Ordovician.

The Gisborne Series. The richly fossiliferous band at the head of the Cobb River was first recognised by the Geological Survey party. A collection made during the first visit to the area supplementary to that already examined has been since studied by one of us (W. N. B.), who has also determined the forms in a collection made by King and McKee, who revisited the Cobb River beds in 1932. They obtained, in addition to the forms already known, specimens of *Pterograptus elegans* Holms, which had not been previously recognised either in Australia or New Zealand, and some obscure forms resembling *Trigonograptus ensiformis* J. Hall. The former are described below. While naturally this additional material makes some alteration in the relative abundance of the thirty species recognised in these beds, the census given in the original description of the fauna (Keble and Benson, 1929, pp. 945-6) is sufficiently representative.

The fauna was at first considered to be comparable with the highest portion of the Darriwil Series of Victoria as then understood. There have since, however, been further studies of the Darriwillian, which call for modification of this view. Thomas and Keble (1933, p. 54) have shown that the " Ba 67 " beds of Victoria, with a fauna closely similar to that of the Cobb River beds, are appropriately considered as the basal member of the Gisborne Series, the lowest of the three divisions recognised by them in the " Upper " Ordovician rocks of Victoria. Harris (1935, p. 329), while in general accord with this view, suggests that the Cobb beds may be slightly older than those of Locality Ba 67. They fall, however, into the upper portion of his *Diplograptus* Series, which comprises the upper divisions of the Darriwillian (D2–D1) and the lower Gisbornian beds. The Gisbornian beds are about equivalent to the Glenkiln or Llandeilian Middle Ordovician strata of Great Britain, and the Cobb beds may perhaps be about equivalent to the *G. teretiusculus* zone of the British sequence.

The Mount Peel beds (Bands A and B, Fossiliferous Localities Nos. 1227 and 1229) together with the Lodestone beds (Fossiliferous Locality 1226) appear to be about coeval with the middle portion of the Gisbornian of Victoria, or perhaps the *Nemagraptus gracilis* zone of Britain. They are less richly fossiliferous than the Cobb beds, from which they differ in the entry of Dicellograptids and the disappearance of most of the Dichograptids and Glossograptids. It may be noted here that the varietal name *Diplograptus euglyphus* var. *distans* given in the list of specimens from Mt. Peel, Band A (Keble and Benson, 1929, p. 844), should be var. *sepositus.*

The still smaller collection from the Flora Track (Fossiliferous Locality No. 1232) differs from the last in the presence of *Climacograptus bicornis* J. Hall and *Dicranograptus* sp. An error was made in the table (*loc. cit.*, p. 848) in stating that Dicellograptids were not present in this bed. There are actually a few indeterminate specimens. This bed is probably coeval with the upper portion of the Gisborne Series of Victoria, and perhaps with the zone of *Climacograptus peltifer* in the British sequence. If the comparison of the *Dicranograptus* in the Leslie River bed (Band B, Fossiliferous Locality No. 1230) with *D. rectus* Hopk. should be significant, there seems to be no reason to consider that it belongs necessarily to a zone higher than that of the Flora Track beds. There is too little evidence for decision on this point.

In general it would appear that the fossiliferous rocks in the Mt. Arthur region (other than Band A on the Leslie River) are the equivalent of the various zones in the Llandeilan or middle division of the Ordovician rocks of Britain, or of the Gisbornian or lowest stage in the post-Lower Ordovician or, as usually termed, Upper Ordovician rocks of Victoria, in which no specifically Middle Ordovician division has yet been recognised.

Reference may here be made to the occurrence of poorly preserved graptolites in pebbles of dark phyllite in the bed of the west branch of the Owen River, a tributary of the Buller River, in the Murchison Subdivision, sixty miles south of the Aorangi Mine (Fyfe, 1927). These have not been seen by us.

A Diagrammatic Representation of the Development of Ordovician Graptolites in New Zealand.

The history of the graptolies is marked by the rise into prominence and subsequent decline of groups of forms representing successive stages in the evolution of the order. Each zone is indicated best by a concentration of forms in a certain stage of evolution (Elles, 1933). Within the past decade all of the available specimens of New Zealand graptolites (over 3000 determinable forms) have been examined or re-examined, and there now seems to be sufficient data to permit a general indication of the varying concentrations of the several faunal groups in the successive zones. Precise statement of this variation cannot be made, however, partly because of the uneven development of the fauna, richly present in some beds, sparsely in others, and partly because each zone is as yet known in but few localities. Nevertheless an approximate or qualitative

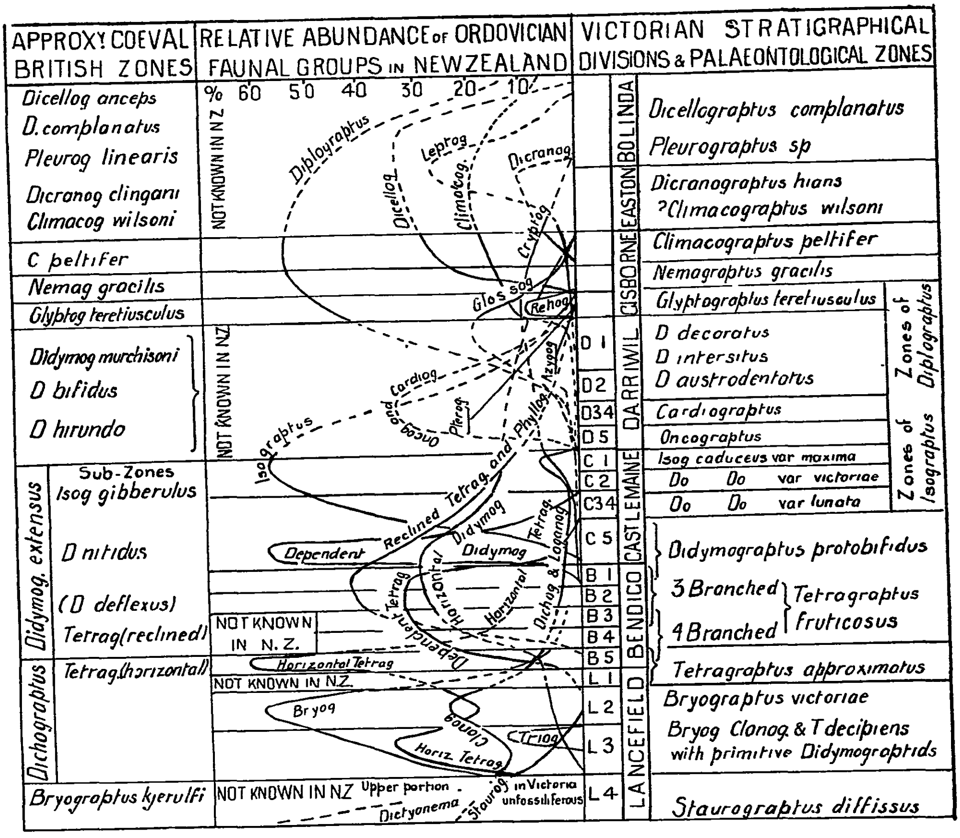

Fig. 2.—Diagrammatic representation of the increase and decrease of the relative abundance of the several groups of forms in the graptolite-fauna in the successive zones of the Ordovician rocks of New Zealand, indicated qualitatively by the rise and fall of the continuous lines. The broken lines afford similar information concerning the graptolite-fauna of Victoria during those portions of Ordovician time not represented by any known fossiliferous rocks in New Zealand. The widths of the several zonal divisions in the diagram have no relation to the thicknesses of the strata comprising the zones.

representation of the rise and decline of the several groups is, however, possible, and expresses the salient facts in a convenient fashion. Text-figure 2 is an attempt at such a representation. The continuous lines represent the variation in relative abundance of the several faunal grounds deduced from the New Zealand material only. (From a strictly quantitative point of view the development of Bryograptids, Clonograptids, and horizontal Didymograptids has been more or less underestimated in the zones in which they are most common, as many of these forms were specifically indeterminable.) The broken lines are based on Victorian evidence only for those portions of the Ordovician period not yet known to be represented by fossiliferous formations in New Zealand. The Victorian stratigraphical divisions are applied to the New Zealand sequence, and the corresponding palaeontological zones as listed by Thomas (1935) are indicated. Opposite thereto are placed the approximately coeval British zones taken with slight modification (for which one of us, W. N. B., must accept the responsibility) from the discussions of Dr Elles (1932, 1933) for the Lower Ordovician, and those based by Thomas and Keble (1933) on the results of more recent investigation of the Upper Ordovician rocks of Victoria.

Though the dendroid and many-branched Dichograptids occur in abundance in the earliest fossiliferous Ordovician rocks of Victoria (L4), the former are rapidly diminishing, and the latter appear to be subordinate to the horizontal Tetragraptids *(T. decipiens)* in the lowest New Zealand fossiliferous beds (L3). Both appear to increase in abundance in the L2 beds, but particularly the Bryograptids and Clonograptids, which, however, diminish very rapidly at the top of the Lancefieldian beds, while the horizontal Tetragraptids *(T. approximatus, T. quadribrachiatus)* attain their greatest expansion at the base of the Bendigo Series (B5)*, and thereafter diminish very rapidly.

A dependent Tetragraptid *(T. pendens)* appears sparingly in the highest Lancefieldian beds of Victoria, but the group expands very rapidly in the base of the Bendigo Series *(T. postlethwaitei, T. fruticosus)*, and the last of these continues with increasing abundance, but with reduction of stipes, until the close of that series, when it suddenly disappears, the group being represented sparsely by *T. pendens* only in the Lower Castlemainian. The reclined Tetragraptids *(T. serra, T. similis)* and Phyllograptids appear and rise into prominence in the B4 Zone, and continue with slow decrease in abundance until the close of the Darriwil Series. More important, however, is the simultaneous rise into prominence of the horizontal Didymograptids, which had been sparsely represented by a small form *D. taylori* as early as the L3 beds, in which the rare three-stiped form *Triograptus* made a brief appearance. They expand rapidly above the B5 Zone, and the members of the extensiform group characterise the remainder of the Bendigonian and Castlemainian beds. The dependent Didymograptids appear sparsely in B1 (*D. artus* and *D. protobifidus*), but the latter form rises suddenly into a dominant position in C5, and declines with almost equal rapidity, and the group is represented by *D. dependulus* only in C4. Neither in Victoria nor in New Zealand is there evidence

* For this reason the B5 beds are herein compared with the upper or horizontal *Tetragratus* subzone of the British *Dichograptus* zone, and the equivalent of the base of the British *D. extensus* zone is therefore drawn at the base of the B4 beds, rather than the base of the Bendigonian series as Dr Elles had suggested (1933).

of the continued development of the dependent stock through *D. bifidus* to *D. murchisoni* in beds equivalent to the Darriwil Series. In place of this evolutionary series so well displayed in Britain there is that of the Isograptids, which enter sparsely and in small forms into C5 and possibly the immediately underlying zone, expand both in size and abundance, and become the dominant forms in the highest Castlemainian beds.

For the history of the Darriwillian Period we are dependent on the Victorian record, for it is as yet unrepresented by fossiliferous rocks in New Zealand, and the British formations do not contain an analogous fauna. The Isograptids continue to abound, and give rise to the characteristic genera of *Oncograptus* and *Cardiograptus*, characterising the lower portion of this series. In the upper portion the most noteworthy feature is the great expansion of the Diplograptids, which may eventually mark the commencement of the Middle Ordovician beds (Harris, 1933, 1935; Thomas, 1935). When fossils again appear in New Zealand (in the lower portion of the Gisbornian), the Diplograptids are well established and the Glossograptids are already in their decline. Cryptograptids have continued their slow rise since their first appearance late in Castlemainian times; Climacograptids, Leptograptids, Dicellograptids, and Dicranograptids appear successively during the course of Gisbornian time. But for the subsequent history of the graptolites of the Australasian region reference must again be had to the Victorian record (Thomas and Keble, 1933). The Cryptograptids are the first to decline, the Leptograptids and Climacograptids follow, and but few Diplograptids extend beyond the Ordovician Period.

ORDOVICIAN FOSSILS OTHER THAN GRAPTOLITES.

Corals. Reference may here be made to the discovery of a few corals in the limestones a few miles north of the graptolite beds at the Lodestone, Mt. Arthur district. Dr. F. R. C. Reed compared these with *Palaeopora inordinata* Lonsd., an Upper Ordovician form. This form is closely allied to *Heliolites,* and occurs in the Bala limestone of Pembrokeshire*. Possibly the coral found by McKay (1879) in the limestone at the junction of the Dart and Wangapeka River ten miles south of Mt. Arthur may be of the same type. Park (1889, p. 232) noted the presence of broken remains of corals in the limestone on the west side of the Takaka River, at Sparrow's, nine miles from the mouth.

Crinoids. Indeterminable portions of crinoid stems were found in association with the corals in the localities noted above (Keble and Benson, 1929, p. 842, footnote).

Brachiopods. Though no trace of brachiopods has yet been found in the Ordovician rocks of Nelson, it may be recalled that Chapman (1934) has recognised two forms in those of Fiordland.

* There appears to be some uncertainty concerning the reported occurrence of this form in Helderbergian beds west of Baie des Chaleurs, Eastern Quebec, Canada.

Trilobites. Two species of trilobites have been recorded from Nelson Province (F. R. C. Reed, 1927). The form derived from the older Ordovician was found in a pebble about three miles east of the Aorangi Mine area, on a tributary of the Puturau River. No graptolites were found in association with it, but Dr. Reed described it as *Ogygites collingwoodensis* and compared it with the Lower Ordovician species *O. ("Basilicus "†) kuckersianus* Schmidt of Russia, *O. annamensis* Mansuy, and *O. yunnanensis* Reed, with which its relationship is most marked. Kobayashi (1934) adds that both *O. collingwoodensis* and *O. yunnanensis* lie very close to his new genus *Basiliella,* which characteristically is in the Middle rather than the Lower Ordovician of North America and Eastern Asia.

A second form of trilobite occurring on the watershed between the Taylor and the Wangapeka Rivers, about eighteen miles south of the Lodestone, has been described by Reed as *Dionide hectori.* Its nearest ally is *D. richardsoni* Reed from the Upper Bala beds of Girvan, Ayrshire. The genus is also known in North America and South-eastern Asia.

Phyllocarids. Nine species of phyllocarids have been described by Chapman (1934 a) from the Lower Ordovician beds of Fiordland. Traces of these organisms occur sparsely in the beds of the Aorangi Mine area. In the basal Castlemainian beds of Locality Q, the old Golden Ridge Mine, Benson recognised the following: *Rhinopterocaris maccoyi* (Eth. fil.) (11), *Caryocaris marri* Hicks (14), and *C. minima* Chapman (9). In the Upper Castlemainian beds (Localities C and N) *R. maccoyi* and *Lingulocaris* cf. *acuta* (Bulman) were noted, and a portion apparently of *Caryocaris wrighti* Salter was noted in a slab from an unknown locality in the same region. No definite indications of phyllocarids were seen in specimens from the Mt. Arthur region.

Notes on Graptolites Hitherto Unknown in New Zealand.

Tetragraptus reclinatus Elles and Wood, 1902. Text-figure 3.

T. reclinatus Elles and Wood, *Mon. Brit. Grapt.*, Part 1, 1902, p. 67, text-fig. 41, pl. 6, figs. 5 a-e.

The figured form was recognised by Dr. Elles on a specimen in the Otago University Museum, probably derived from the basal Castlemainian beds at the old Golden Ridge Mine. Two other examples were found among Cox's collection and one in Park's collection from the same spot (Locality Q). The species occurs in coeval beds, namely, Zone 4 in the Skiddaw Slates of Britain and extends into Zone 5.

† According to Kobayashi (1934) this should be referred to the genus *Pseudobasilicus* Reed.

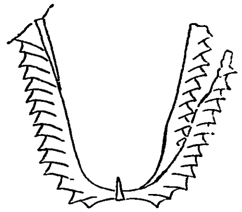

FIG. 3.—*Tetragraptus reclinatus* E. and W., probably from the C5 Zone at the Golden Ridge Mine, North-west Nelson; × 2.

FIG. 4. — *Didymograptus suecicus* Tullberg, probably from the C5 Zone at the Golden Ridge Mine, North-west Nelson; × 2.

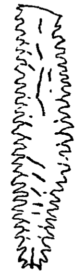

FIG. 6.

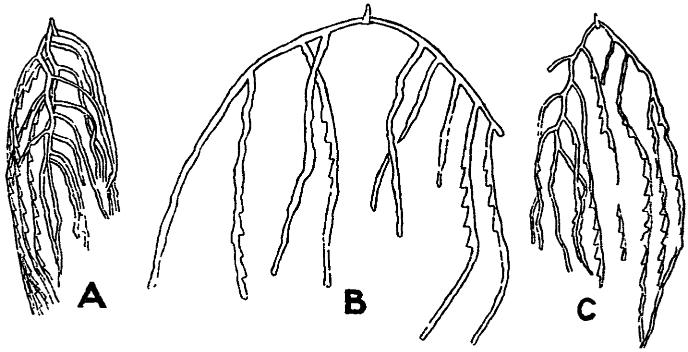

FIG. 5 a-c.—*Pterogratus elegans* Holm from the Lower Gisbornian beds at the head of the Cobb.

FIG. 6.—*Cryptograptus circinus* Keble and Harris, in L. V. Ellis' Sample 10 from the Upper Castlemainian beds at Fossiliferous Locality 1923, on Little Slaty Creek near the Aorangi Mine. × 2.

Didymograptus suecicus Tullberg, 1880. Text-figure 3.

D. suecicus Tullberg, *Geol. Foren. Fordhandl.*, vol. 5, 1880, p. 45, pl. 2, figs. 5-6.

Tornquist, *Lunds Universitetets Arskrift.*, Bd. 37, Afdeln 2, No. 5, 1901, p. 13, pl. 1, figs. 19-24.

Elles, *Summary of Progress Geol. Survey Grt. Brit.*, for 1932, 1933, Part 2, pp. 100, 111, fig. 10.

Dr. Elles regards this form as a transient in the evolving series *D. extensus-nitidus-patulus-suecicus-praenuntius,* occurring in the higher portion of the *D. extensus* zone at Skiddaw, and giving rise to *D. hirundo* in the succeeding zone. We are indebted to her for the recognition of example here figured, which was on the same specimen as the *T. reclinatus* noted above, i.e., from the basal Castlemainian. She also noted it among Upper Castlemainian forms in Isaacson's collection from the Aorangi Mine, and it was found also by King and McKee at Locality C near this mine.

Pterograptus elegans Holm, 1881. Text-figure 5 a-c.

Pterograptus elegans Holm, *Ofversight af Kongl. Vetenskaps Akademiens Forhandlingen,* 1881, pp. 77-80, figs. 1-4.

Coenograptus (Pterograptus) elegans Frech., *Lethaea Palaeozoica,* 1897, vol. 1, p. 585, fig. 157.

This form, hitherto unknown either in Australia or New Zealand, agrees in all essential features with Holm's description. The sicula, about 0·5 mm. long, gives off two thin primary stipes, declined at first, enclosing an angle of about 60° with the median plane, but becoming later pendent, parallel, and even convergent. The thecae on these are of the simple Dichograptid type spaced ten in a distance of 10 mm., with little or no overlap, inclined at 15° to the stipe, with straight ventral and apertural margins, the latter almost normal to the axis of the stipe. They are about 0·2 mm. wide at the base and 0·4 mm. at the aperture. From each of the seven proximal thecae of each primary stipe is given off a simple unbranched secondary stipe, such secondary stipes coming off alternately towards the front or back of the plane containing the two primary stipes. The thecae on the secondary stipes are of the same form and spacing as those on the primary stipes, and all thecae open inwards towards the more or less lensoid space enclosed by the polypary. Our material, which was collected by the Geological Survey and by King and McKee from the Cobb River bed, consists of one specimen compressed nearly perpendicularly to the plane of the primary stipes (Text-fig. 5 b*), one compressed obliquely thereto (Text-fig. 5 c), and the reverse and obverse of another (Text-fig. 5 a) compressed in a direction almost parallel to the plane of the primary stipes, so that the secondary stipes, hanging on either side, have been superposed on one another, the position occupied by the Brazilian member of this genus described by Bulman.† Our three figures, therefore, give an approximate idea of the three-dimensional shape of this graceful form. The angle enclosed by the adjacent secondary stipes is rather greater than that assumed to be characteristic of Holm's species and resembles that of the Brazilian form. This is perhaps the result of distortion, but is seen in both our outspread specimens. The maximum length of the primary stipes and the maximum breadth of the enclosed lensoid space are about 22 mm., the front-to-back width of that space about 8 mm. As in Holm's specimens the characteristic number of secondary stipes on a primary (seven) is seen on one side only of the sicula, as a result of the circumstances of preservation.

The specimen here illustrated by our Text-fig. 5 b, a faintly marked form, is that which was formerly compared by us to *Syndyograptus pecten* Rued. (Keble and Benson, 1929, pl. 107, fig. 30). but the distinctive material found by King and McKee necessitates its redetermination. It is possible also that the very distorted form previously described by us as *S. artus* may also be a Pterograptid on

---

* The preservation of this form is poor, and its reference to the species under discussion is tentative.

† O. M. B. Bulman, *Arkiv for Zoologi,* Band 22, No. 3, pp. 19-20, pl. 3, fig. 11, text-fig. 4. 1931.

account of the simple Dichograptid rather than Leptograptid form of its thecae, but it is impossible to determine satisfactorily the details of its branching.

Pterograptus elegans occurs (according to Frech, 1897) in the slates of the *D. murchisoni* zone in southern Sweden, but Dr. Elles informs us she has found it in the highest part of the *D. extensus* zone. The Brazilian member of this genus which is closely allied to *P. elegans,* if not identical therewith, occurs in the Upper Llanvirnian. In New Zealand, if the comparisons suggested in this paper are valid, the species occurs in the next succeeding zone, namely, the equivalent of the *G. teretiusculus* zone, where it is associated with *Diplograptus spiculatus* and *Glossograptus hincksi.*

Cryptograptus circinus Keble and Harris, 1934. Text-figure 6.

C. circinus Keble and Harris, *Mem. Nat. Mus., Melbourne,* No. 8, 1934, p. 177, text-fig. 5. pl. 21, figs. 6 a-e.

Three samples of a form agreeing in all essentials with this species were obtained by L. V. Ellis from the Upper Castlemainian beds in Little Slaty Creek. They are slightly larger than the Victorian form, reaching a length of 20 mm., and a breadth of 3·5. A short virgella and small apertural spines are present, the latter more marked on the proximal or basal thecae. The distal termination is not preserved. Thecae 13–14 in 10 mm. The species has so far been found only in the Upper Darriwillian in Victoria, so that its occurrence in New Zealand involves a downward extension of its known range. Probably this form was noted by Clarke (1908, figs. 17 or 18), but his data do not permit identification.

Cryptograptus hopkinsoni (Nicholson), 1869.

C. hopkinsoni Elles and Wood, *Mon. Brit. Grapt.,* Part 7, 1908, p. 299, pl. 32, figs. 15 a-b.

This species is smaller than the above form (length 10–20 mm., breadth 2 mm.) and has more widely spaced thecae (10 in 10 mm.) and more prominent spines. While rising into the *D. bifidus* zone, it is first noteworthy in the highest subdivison of the *D. extensus* zone of the Skiddaw slates. It was recognised by Dr. Elles in the material in the Isaacson collection derived from coeval beds in Little Slaty Creek, and seems also to be represented in material obtained there by Service and King. It is less narrow, but shorter, than the more widely ranging species *C. tricornis* Carr., which in New Zealand appears well developed in the Lower Gisbornian Cobb River beds in the Mount Arthur District.

BIBLIOGRAPHY.

BELL, J. M., WEBB, E. J. H., and CLARKE, E. de C., 1907. The Geology of the Parapara Subdivision, *N.Z. Geol. Surv. Bull.,* No. 3.

BENSON, W. N., and KEBLE, R. A., 1935. The Geology of the Regions adjacent to Preservation and Chalky Inlets, Fiordland, N.Z.; Part IV *Trans. Roy. Soc. N.Z.,* vol. 65, pp. 244-294.

CHAPMAN, F., 1934. On some Brachiopoda from the Ordovician of Preservation Inlet, New Zealand, *Trans Roy. Soc. N.Z.,* vol. 64, pp. 115-116.

——— 1934a. On some Phyllocarids from the Ordovician of Preservation Inlet and Cape Providence, New Zealand, *Trans. Roy. Soc. N.Z.,* vol. 64, pp. 105-114.

COX, S. H., 1883. On the District between Collingwood and the Big River, Collingwood County, *Rept. Geol. Explorations,* 1882, pp. 62-74.

ELLES G. L., 1932, In David, T. W. E., *Explanatory Notes accompanying a New Geological Map of the Commonwealth of Australia*, Sydney. p. 40, table.
——— 1933. The Lower Ordovician Graptolite Faunas with special reference to the Skiddaw Slates, *Summary of Progress. Geol. Surv. of Grt. Brit*, for 1932, Part II, pp. 194-199.
FRECH, F., 1897. *Lethaea Geognostica*, I, Lethaea Palaeozoica, p. 593.
FYFE, H. E., 1927. The Geology of the Murchison District, *Annual Rept. Geol. Surv. N.Z.*, No. 21, p. 5.
HALL, T. S., 1894. The Geology of Castlemaine with a subdivision of the Lower Silurian Rocks of Victoria, *Proc. Roy. Soc. Vict.*, vol. 7 (n.s.), pp. 55-88.
——— 1899. Graptolite Bearing Rocks of Victoria, *Geol. Mag.*, vol. 46, pp. 439-451.
——— The Golden Ridge Graptolites, *Trans. N.Z. Inst.*, vol. 47, pp. 410-411.
HARRIS, W. J., 1933. *Isograptus caduceus* and its allies in Victoria, *Proc. Roy. Soc. Vict.*, vol. 46, pp. 79-114.
——— 1935. The Graptolite Succession of Bendigo East, with Suggested Zoning, *Proc. Roy. Soc. Vict.*, vol. 47, pp. 314-337.
HARRIS, W. J., and KEBLE, R. A., 1932. Victorian Graptolite Zones with Correlations and Description of New Species, *Proc. Roy. Soc. Vict.*, vol. 44, pp. 25-48.
HECTOR, J., 1879. On the Geological Formations in New Zealand compared with those in Australia, *Journ. and Proc. Roy. Soc. N.S. Wales*, vol. 13, p. 80.
——— 1879 b. List of Fossiliferous Localities 127, *Rept. Geol. Explorations*, 1879, p. 12.
——— 1882. Progress Report, *Rept. Geol. Explorations*, 1882, p. xviii.
——— 1883. Progress Report, *Rept. Geol. Explorations*, 1883, p. xvi.
——— 1886. Outline of New Zealand Geology with Geological Map, *Catalogue of Exhibits Indian and Colonial Exhibition, London*, p. 82.
——— 1891. List of Fossiliferous Localities, *Rept. Geol. Explorations*, 1891, pp. 138, 145.
HOCHSTETTER, F. VON, 1864. Geologie von Neuseeland, *Novara Expedition. Geologischer Teil*, Bd. 1, Abt. 1, pp. 209-212, Vienna.
HUTTON, F. W.. 1878. An Exhibit of Graptolites from Nelson to the Otago Institute, *Trans. N.Z. Inst.*, vol. 10, p. 556.
——— 1900. The Geological History of New Zealand, *Trans. N.Z. Inst.*, vol. 32, p. 163.
KEBLE, R. A., 1927. Graptolites from Cape Providence, Chalky Inlet, Southland, *Trans. N.Z. Inst.*, vol. 58, pp. 157-9.
KEBLE, R. A., and BENSON, W. N., 1929. Ordovician Graptolites of North-west Nelson, *Trans. N.Z. Inst.*, vol. 60, pp. 840-865.
KOBAYASHI, T., 1934. The Cambro-Ordovician Formations and Faunas of South Chosen, Pt. 1, *Journ. Fac. Sci. Imp. Univ. Tokyo*, section II, vol. 3, pt. 8, pp. 464, 471-472, 486.
MARSHALL, P., 1912. *The Geology of New Zealand*, Govt. Printer, Wellington, N.Z.
McKAY, A., 1879. Report on the Baton R. and Whangapeka District, *Rept. Geol. Explorations*, 1878-9, pp. 121-131.
ONGLEY, M., and MACPHERSON, E. O., 1923. The Geology of the Collingwood Subdivision, Karamea Division, *N.Z. Geol. Surv. Bull.*, No. 25.
PARK, J., 1889. On the Geology and Mineral Resources of the West Wanganui Coalfield, *Rept. Geol. Explorations*, 1888-9, pp. 49-60.
——— 1889 (a). On the Geology of the Collingwood County, Nelson, *Rept. Geol. Explorations*, pp. 181-243.
——— 1910. *The Geology of New Zealand*, Whitcombe and Tombs, Christchurch.
REED, F. R. C., 1927. New Trilobites from the Ordovician of New Zealand, *Trans. N.Z. Inst.*, vol. 57, pp. 310-314.
SHAKESPEAR, E. M. R., 1908. On some New Zealand Graptolites, *Geol. Mag.*, dec. V, vol. 5, pp. 145-8.
THOMAS, D. E., and KEBLE, R. A., 1933. The Ordovician and Silurian of the Bulla-Sunbury Area, and Discussion of the sequence of the Melbourne Area, *Proc. Roy. Soc. Vict.*, vol. 45, pp. 33-84.
——— 1935. Ordovician, Geology of Victoria, Handbook for Victoria. *Aust. and N.Z. Assocn. Advt. Sci.*, pp. 96-105.