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ORDOVICIAN BIOSTRATIGRAPHY

OF

NORTH-WEST NELSON

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ABSTRACT

Eleven graptolite zones are recognised in New Zealand and are considered to represent most of the Ordovician Period. The most complete fossiliferous section, at Aorangi Mine in Northwest Nelson, is described in detail. New fossiliferous Ordovician sections at Wangapeka Valley and Hailes Knob, in Northwest Nelson, are described and the previously known sections at Cobb Valley (Northwest Nelson) and the Cape Providence - Preservation Inlet region (Southwest Otago) are discussed.

The New Zealand zones are correlated with those of Victoria, Australia, and the Victorian stage nomenclature is adopted for New Zealand. In upward sequence the stages and zones are: Lancefieldian (zones 1, Adelograptus, and 2, T.approximatus), Bendigonian (zone 3, T.fruticosus), Chewtonian (zone 4, D.protobifidus), Castlemainian (zones 5, I.c.lunata, and 6, I.c.maximodivergens), Yapeenian (zone 7, Oncograptus), Darriwilian (zones 8, P.etheridgei, and 9, D.decoratus), Gisbornian (zone 10, N.gracilis), Eastonian (zone 11, Orthograptus - lower part) and Bolindian (zone 11, Orthograptus - upper part?). Fossils of lowermost Lancefieldian and uppermost Bolindian age are not yet known in New Zealand. Diagnostic Silurian fossils are also unknown and the next youngest New Zealand fossils are Lower Devonian (Gedinnian?).

Previous work in the Aorangi Mine area is outlined, the geology illustrated by a map, and the stratigraphic column shown to include both older, and younger beds than were previously known. About 8500ft thick, the column comprises, in upward sequence, Webb Formation, Aorangi Mine Formation (with four informal members), Formation A (new and informal, with three members), and Formation B (new and informal). Graptolites are confined to the three younger formations and represent zones 1 to 10, ranging in age from Lancefieldian to Gisbornian. The structure is outlined and illustrated by cross-sections.

In Wangapeka Valley, argillites of the Wangapeka Formation contain zone 11 graptolites of Eastonian and lower Bolindian age, and are overlain by 1500ft of quartzite of the Ellis Formation, which has yielded no diagnostic fossils but which is inferred to represent at least part of the Silurian Period. Lower Devonian brachiopods, bivalves, corals and trilobites are known from the uppermost beds of the Ellis Formation, about 1550ft above its base.

At Hailes Knob, Mount Arthur Marble with fossils of uppermost Ordovician age is overlain by Hailes Knob Quartzite of probable Silurian age.

From the Aorangi Mine and Wangapeka areas, one hundred and thirteen graptolite species and subspecies, representing 35 genera, are described. They include one named new species and 49 new records for New Zealand. Stratigraphic

and geographic distribution elsewhere in the world is noted. The genera Isograptus Moberg and Paraglossograptus Mu are reviewed, and their New Zealand members described and discussed in detail. The important zonal species and subspecies are also described in detail; the remainder are briefly discussed. One hundred and six taxa are figured.

Fossil localities in the areas described are listed with their fossils in appendix I, and details of measured sections are given in appendix II. A summary of Lower Paleozoic fossil localities of Northwest Nelson is given in a supporting paper.

1. GENERAL INTRODUCTION

Geological Setting.

Northwest Nelson is the largest and most important region of fossiliferous Middle and Lower Paleozoic sedimentary rocks in New Zealand (fig.1). Distribution of the main rock groups of Northwest Nelson and of all recorded fossil localities is shown in fig.2, together with the N.Z.M.S.1 (1:63,360) map sheet boundaries and the location of areas mapped in detail in this thesis. A list of the fossil localities and of published references to fossils or localities is given by Cooper (1968, supporting paper) together with a brief account of the Middle and Lower Paleozoic fossils from elsewhere in New Zealand.

The older Paleozoic sediments form three north-trending, fault-bounded belts: a central belt of Cambrian volcanic and volcanogenic sediments; a western belt of Lower to Upper Ordovician sediments; and an eastern belt of Upper Ordovician to Devonian sediments. Low grade (chlorite zone) regional metamorphism is widespread; high grade metamorphism is confined to near granitic bodies. The rocks have undergone several phases of deformation (Grindley 1961) and fossiliferous sequences spanning two or more lithologic or biostratigraphic units are rare. Three fossiliferous areas have been studied by previous workers.

The first, the Cobb Valley - Mount Arthur area, in

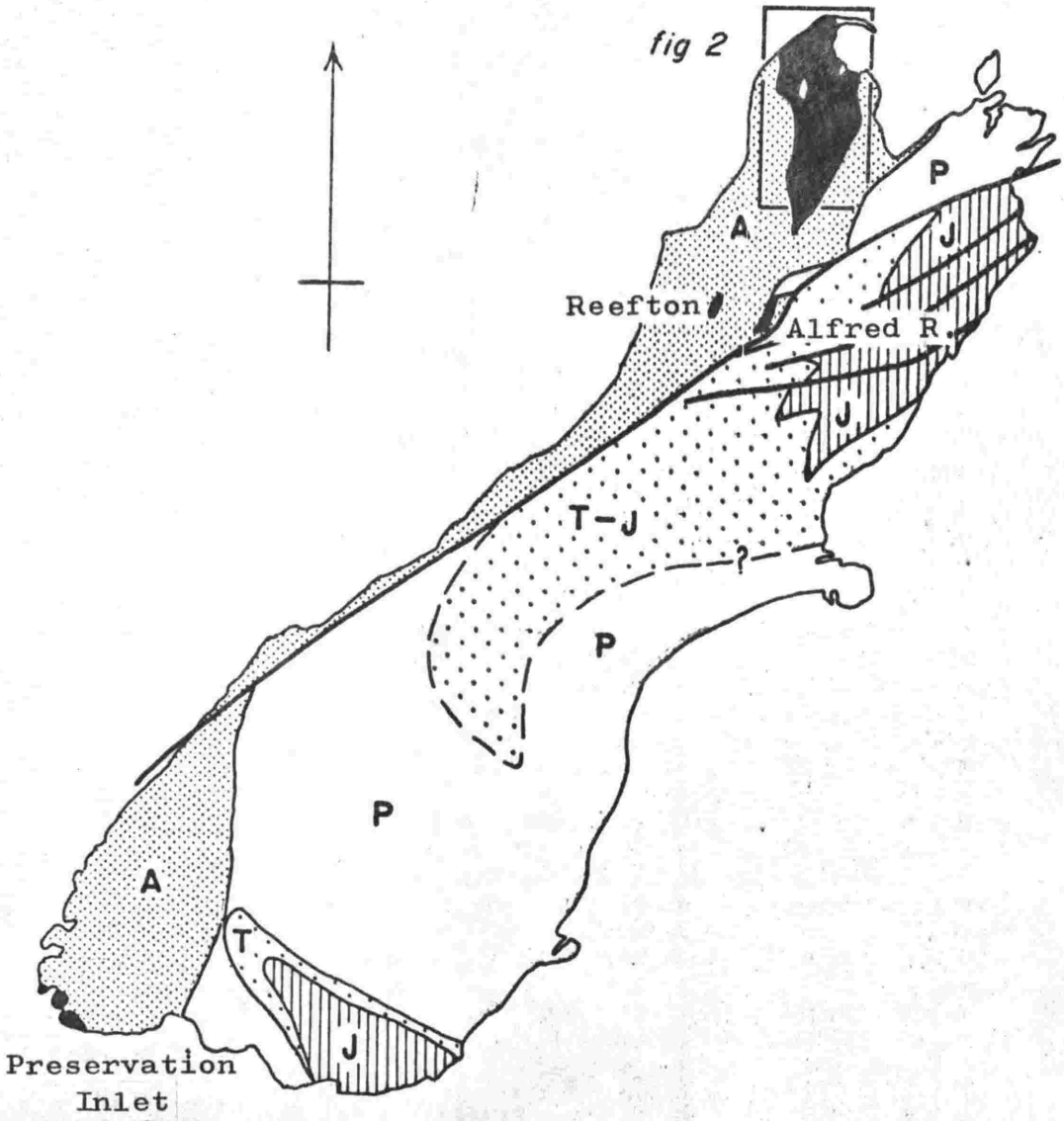
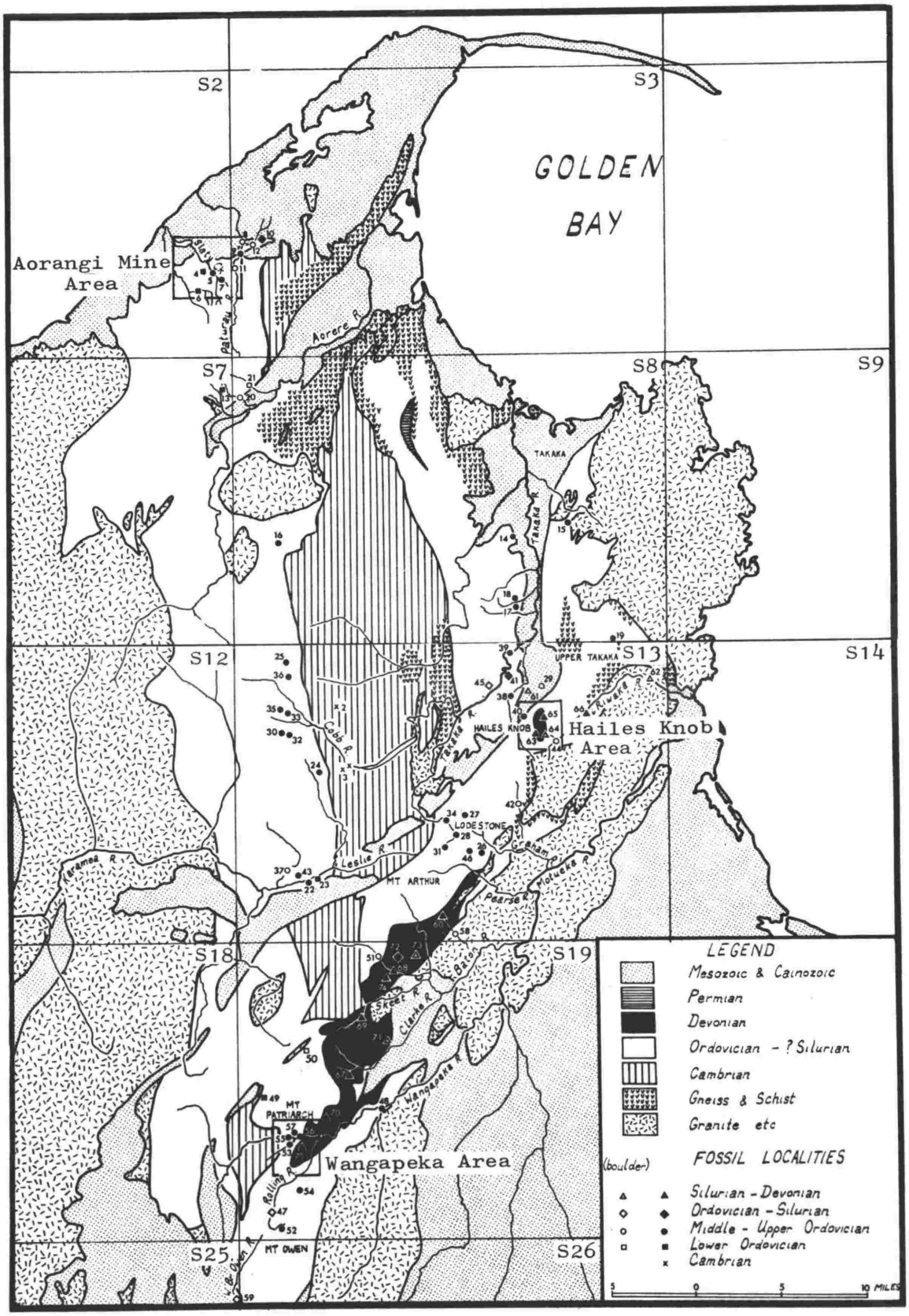


Fig.1. Locality map showing Lower and Middle Paleozoic fossiliferous rocks (black) together with generalised pre-Cretaceous units of the South Island. A, Paleozoic and ?Mesozoic granites and associated rocks, pre-Devonian unfossiliferous sedimentary, igneous, and metamorphic rocks. P,Permian; T,Triassic; J,Jurassic; P,T, and J being sediments, volcanics and schists of the New Zealand Geosyncline.

Fig.2. Distribution of main rock groups and of fossil localities of Northwest Nelson. Numbered localities are listed by Cooper (1968, supporting paper). The Aorangi Mine, Hailes Knob, and Wangapeka areas are indicated, together with N.Z.M.S.1 map sheet boundaries (S1, S3 etc). Geology mainly from Grindley (1961).


GOLDEN BAY
S2
S3
S7
S8
S9
S12
S13
S14
S18
S19
S25
S26
Aorangi Mine Area
Hailes Knob Area
Wangapeka Area
Aorere R.
Paturay R.
TAKAKA
Takaka R.
UPPER TAKAKA
HAILES KNOB
Cobb R.
Leslie R.
LODESTONE
MT ARTHUR
Graham R.
Motueka R.
Pearse R.
Baton R.
Skeet R.
Clarke R.
Wangapeka R.
MT PATRIARCH
Rolling R.
MT OWEN
LEGEND
Mesozoic & Cainozoic
Permian
Devonian
Ordovician - ? Silurian
Cambrian
Gneiss & Schist
Granite etc
FOSSIL LOCALITIES
(boulder)
Silurian - Devonian
Ordovician - Silurian
Middle - Upper Ordovician
Lower Ordovician
Cambrian
5 0 5 10 MILES

N.Z.M.S.1 map sheet S13, was mapped in 1926 by Henderson, Grange and Macpherson. Graptolites collected during mapping were described by Keble and Benson in 1929 and correlated with Victorian faunas from what are now known as the upper Darriwilian and lower Gisbornian stages. Further comments on the age and correlation of the graptolites were given by Benson and Keble in 1936. The area was recollected in more detail by Skwarko (1962) who largely substantiated the earlier age determinations and described many new forms.

The second area is at Baton River, in N.Z.M.S.1 map sheet S19. Devonian fossils were described by Shirley (1938) and assigned an "upper Siegenian or lower Emsian" age. Revised lists and determinations have since been published by Allan (1947), Boucot et al (1963), Willis (1965) and Wright (1968). The area was mapped in detail by Willis (1965).

The third area is at Aorangi Mine, in N.Z.M.S.1 map sheet S2. Previous work is reviewed with the detailed account given in this report. The relationship of the Cobb Valley and Baton River sequences to those discussed in this report are given in chapter 5.

Scope and Purpose of Work.

The aim of the present project has been, firstly, to establish a biostratigraphic subdivision of the Ordovician of Northwest Nelson based on the local sequence of fossils and, secondly, to establish New Zealand Ordovician time-stratigraphic divisions.

1. The fossil sequence was determined at each of three key fossiliferous areas - Aorangi Mine, Wangapeka Valley and Hailes Knob - by detailed mapping and collecting.

2. The three sequences were correlated with sequences described from elsewhere in New Zealand, particularly the Cobb Valley - Mount Arthur region, and the Preservation Inlet area of Southwest Otago.

3. New Zealand graptolite zones were established.

4. The New Zealand graptolite sequence was correlated with that of Victoria, and the Victorian stage classification adopted for New Zealand.

Six months were spent in the field, most time being spent in the Aorangi Mine area which was found to have the most complete and least complicated Ordovician sequence in New Zealand, extending from basal Ordovician to Upper Ordovician (in terms of the Victorian succession). The Wangapeka and Hailes Knob areas (see fig.2) were also examined; Upper Ordovician fossils were collected from Wangapeka Valley, and fossils ranging from Upper Ordovician to Devonian in age were collected from Hailes Knob. Systematic descriptions in this thesis are restricted to graptolites which were found to be of most use in zoning and correlation of the Ordovician.

Terminology.

Paleontological terms, collection numbers and locality numbers etc., are discussed in Part II of this thesis; other terms are used in general description.

In general New Zealand usage, the terms argillite,

siltstone, and slate largely conform to the definitions by Twenhofel (1937) and Pettijohn (1957 :342). Siltstone (and the finer grained equivalent, mudstone) and shale are the nonfissile and fissile products respectively of compacted silt- and clay-sized particles. Argillite is nonfissile indurated or incipiently metamorphosed siltstone or mudstone, while the fissile equivalent is usually termed slate. With increased metamorphism and recrystallisation argillite passes into slate and eventually to schist. Chert is highly siliceous, fine-grained or vitreous, and generally breaks with concoidal fracture.

Table I. Classification of pelitic rocks (modified from Twenhofel, 1937).

Particle Size	Compaction and Induration		Incipient metamorphism	Metamorphic equivalent
Silt and Clay →	Siltstone or mudstone	Non-Fissile →	Argillite ↘	
Silt and Clay ↘	Shale	Fissile →	Slate →	Slate → Schist

Quartzite, is used for compact quartz sandstone cemented with silica and corresponds to "orthoquartzite" of Krynine (1941), Pettijohn (1957) etc. Sandstones are distinguished by being less cemented and more porous.

Mesoscopic and macroscopic structures are of hand-specimen to outcrop size and larger-than-outcrop size respectively (Turner and Weiss, 1963).

Grid references given are in terms of the following map editions: N.Z.M.S.1, sheet S2(1965 edition), S3(1946 edition), S7(1965 edition), S8(1948 edition), S13(1950 edition) and S19(1963 edition).

The Ordovician is here divided as in Victoria (e.g. by Thomas 1960); Lower Ordovician includes the Lancefieldian, Bendigonian, Chewtonian, Castlemainian, and Yapeenian stages; Middle Ordovician includes the Darriwilian stage only; Upper Ordovician includes the Gisbornian, Eastonian, and Bolindian stages. The divisions are discussed in more detail in chapters 5 and 6.

Acknowledgements.

I wish to thank Professor H.W.Wellman and Dr A.J.Wright of Victoria University of Wellington, for criticising the original draught of this thesis. Professor O.M.B.Bulman of Cambridge University, and Dr D.Skevington of University College, London, examined some of the Nelson graptolite collections during their brief visits to New Zealand in 1967 and discussed some points of taxonomy with me, for which I am grateful. Dr F.F.Osborne of Laval University, Quebec, kindly gave me information about Point Levis, Quebec - the type locality of Isograptus caduceus Salter.

I have benefited greatly from the many discussions

with my colleagues, Drs A.G.Beu, I.G.Speden, and Mr M.R.Briggs, on various aspects of paleontology. The assistance of Mr Briggs in establishing techniques of photographing graptolites is especially appreciated. The text-figures and plates were finally reduced and copied by Mr T.Ulyatt, New Zealand Geological Survey, Lower Hutt.

For part of the field work I was assisted by Dr A.J. Wright, Professor H.W.Wellman and students, of Victoria University, and Mr G.W.Grindley, Mr D.G.Bishop, Mr D.S.Ker, and Mr M.R.Johnston, of the New Zealand Geological Survey, Lower Hutt. I am particularly grateful for the loan of large collections from Paturau River, made by Dr A.J.Wright during 1966-8. The hospitality of Dr and Mrs R.Roborgh of Riwaka, Mr and Mrs P.Bell of Wangapeka Valley, and Mr J.Sweeney of Aorangi Mine was most welcome.

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2. AORANGI MINE

Introduction and previous work.

The Aorangi Mine area lies 12 miles to the west of Collingwood township, and 6 miles south of Westhaven Inlet (or Wanganui Inlet), and extends from Paturau River in the east to Sandhills Creek and Lake Otuhie in the west, covering about 12 square miles. A Taitapu Timber Company road from Mangarakau township at the southern end of Westhaven Inlet gives access to within two miles of Aorangi Mine, and a disused pack track extends from the road to the old Aorangi Mine gold battery near the mine.

The northern and central parts of the Aorangi Mine area are drained by Slaty Creek and Little Slaty Creek, the south-western part by Sandhills Creek, and the eastern part by Paturau River. Topography is steep, being 500-800ft in relief, and most rivers are deeply entrenched. Dense rain forest originally covered the entire area but was largely cleared from the northern and central parts during the main period of gold mining, from about 1880 to about 1935. Much of the cleared central part is now covered by thick second growth making access difficult. The best outcrops, and the only stratigraphic sections, are exposed in the stream valleys and gorges.

This report deals only with the fossiliferous basement rocks. Cretaceo-Tertiary coal measures, quartz breccias, sandstones and mudstones cover the basement to the north and

west of the mapped area. To the east, south and west, the basement is unfossiliferous.

Gold mining began in the district about 1874 and continued sporadically until the 1930's (Bell, Webb and Clarke 1907 :89-94; Downey 1928 :33-5). Most of the gold was confined to thin, discontinuous, but relatively high grade ore shoots. Stamping batteries were sited at the mouth of Jimmy Creek - a tributary of Little Slaty Creek, in the lower Slaty Creek gorge, and near the mouth of Coffee Creek - a tributary of Slaty Creek, and auriferous quartz lodes were worked from many small mines and adits. The most productive lodes - those of the Aorangi, Anthill, and Golden Ridge mines - were confined to a north-south striking zone known as the "lode-line" or "gold reef", lying 10-20 chains west of Little Slaty Creek, and wholly within the Aorangi Mine Formation (Bell, Webb and Clarke 1907, fig.opposite page 89). Except for isolated prospectors, the area has been uninhabited since gold mining ceased and most of the adits and drives have collapsed.

Ordovician fossils, mainly graptolites, were mentioned or described by numerous workers between 1878 and 1936 (summarised by Benson et al 1936) but the first detailed map and discussion of the fossils was that given by Benson et al (1936). Graptolites were listed from 24 localities and correlated with the Lancefieldian to Castlemainian stages of Victoria (fig.16). Benson's interpretation of the structure is reproduced in fig.7b. Overturning of strata was not thought to be extensive, the rocks being considered to form

isoclinal folds. The interpretation is discussed in more detail and contrasted with the writer's interpretation in the section dealing with structure. Further graptolites were collected by Skwarko (1961), Bishop (1965), and Smith (1966), and showed the stratigraphic range of fossils to be wider than was previously thought (fig.17).

The writer spent several weeks mapping in detail and collecting fossils (maps 1 and 2 in pocket). Almost all previously known fossil localities have been recollected, and many new localities have been found. Ten graptolite zones are recognised and are summarised in table VI. The structure is re-interpreted (fig.7a,b) and the area is shown to contain the most complete sequence of Ordovician graptolites yet known in New Zealand.

Graptolite zones range in stratigraphic thickness from only 70ft in zone 4 to over 1800ft in zones 9 and 10. Zone boundaries appear to parallel lithostratigraphic boundaries within the mapped area and, as graptolites are absent from much of the mapped area, the most convenient units for mapping were found to be lithostratigraphic units, though fossils were also used for equating strata.

The base map of the Aorangi Mine area was constructed from vertical air photographs, by minor control plotting. The grid is based on Baldy and Paturau Trig stations (1949 geodetic datum) and is that to which grid co-ordinates of localities within the mapped area refer.

Table II. Lithostratigraphic units of the Aorangi Mine area.

Formation	Member	Thickness (ft) (approximate)		Fossils, zone	Age
B*	-	2000+	2000+	trilobites, graptolites, brachiopods; Zones 9-10	Gisbornian
A*	A3*	990	2380	graptolites; Zone 9	Upper Darriwilian
	A2*	340		graptolites; Zone 9	Upper Darriwilian
	A1*	1050		graptolites; Zones 7-8	Yapeenian? to Lower Darriwilian
Aorangi Mine	AM4*	800	2600 - 2900	graptolites; Zone 7	Yapeenian
	AM3*	1-300		graptolites; Zones 5-7	Lower Castlemainian to Yapeenian
	AM2*	4-500		graptolites; Zones 1-5	Middle Lancefieldian to Lower Castlemainian
	AM1*	1300		graptolite fragments	Lower Lancefieldian?
Webb	-	1300+	1300+	-	Upper Cambrian? to Lower Lancefieldian?
		TOTAL	8580+		

Lithostratigraphy.

The basement rocks form north-striking belts; fossils are confined to belts in the central and eastern parts of the mapped area. Lithologic units described below are all represented in the central part, and comprise an apparently continuous sequence dipping regionally to the west. Graptolites indicate a progressive decrease in age from Upper Cambrian or basal Ordovician in the west to Upper Ordovician in the east, the entire sequence being overturned. Graded beds and sole markings confirm the overturning at three localities in Slaty Creek. The graptolite sequence is discussed with the biostratigraphy, the lithostratigraphic sequence is discussed below. Four formations are recognised and comprise a total of 9 lithologic units. Thickness, fossils and age of the units are summarised in table II, names marked with an asterisk being new and informal.

Previous divisions.

Lithostratigraphic units of this thesis are equated with those of previous workers in table III. All rocks were included in the undivided Aorere Series, by Bell, Webb and Clarke (1907), and by Ongley and Macpherson (1923). In 1929 Keble and Benson named graptolite-bearing rocks near Little Slaty Creek the Aorangi Mine Bed. In 1961 Grindley mapped the same rocks - distinctive black slates and quartzites - as Aorangi Mine Formation. Grindley mapped all other rocks - that is those overlying the Aorangi Mine Formation together with the somewhat similar rocks underlying it - as

Aorere Formation. Bishop (1968) separated the underlying rocks as Webb Formation, and grouped the overlying rocks into two units. The first, the Roaring Lion Formation (a new name to replace Aorere Formation) corresponds to Formation A, member A1. The second, the Golden Bay Group corresponds to Formation A, members A2 and A3, and Formation B. The type area for each of the two units is the Cobb Valley - Roaring Lion Valley area, about 25 miles to the south. Formations of the two areas are insufficiently distinctive to be definitely equated however, and the Aorangi Mine units are here left in open nomenclature.

Table III. Previous lithostratigraphic divisions in the Aorangi Mine area.

Bell, Webb, Clarke 1907 Ongley, Macpherson, 1923	Grindley 1961	Bishop 1968	This paper	
			Member	Formation
Aorere Series	Aorere Formation	Undifferentiated Golden Bay Group		'B'
			A3	'A'
			A2	
		Roaring Lion Formation	A1	
	Aorangi Mine Formation	Aorangi Mine Formation	AM4	Aorangi Mine
			AM3	
			AM2	
			AM1	
	Aorere Formation	Webb Formation	Webb Formation	

Webb Formation.

Bishop (1968) erected the Webb Formation as follows: "indurated, pale grey, quartz-mica sandstone, siltstone and phyllite, commonly with a faint greenish cast, outcrop in Webb Stream and the middle reaches of Sandhills Creek. The type section, in the northern branch of Sandhills Creek (854 971-682972), extends through only the lower part of the section [formation?]". Rocks of the Webb Formation are confined to the western part of the mapped area.

Content. Pale, blue-grey siliceous spotted argillite, grey spotted sandstone, and quartz greywacke outcrop in the lower part of the North Branch of Sandhills Creek. Green to grey siliceous argillite, grey micaceous siltstone, and quartzite and sandstone with muddy flakes and lenses outcrop in Sandhills Creek, downstream from the North Branch, but are separated from beds in the North Branch by the Sandhills Creek Fault. The fine-grained beds are commonly strongly cleaved and spotted.

The base of the formation is not exposed within the mapped area. In the North Branch of Sandhills Creek, the upper 1300ft has been measured (column 3, fig. ~~15~~ 6), the full thickness probably exceeding 1500 feet.

Age. The Formation is unfossiliferous, but because it conformably underlies the Lower Ordovician Aorangi Mine Formation, it is thought to be Upper Cambrian or Lower Ordovician in age.

Aorangi Mine Formation.

In contrast to the Webb Formation of rather uniform lithology, the overlying Aorangi Mine Formation ranges widely in lithology and contains graphitic beds.

Original description. Grindley (1961) proposed the name Aorangi Mine Formation for "... dark graphitic argillites and interbedded quartzites [which]... at Aorangi Mine and Slaty Creek ... contain Lower Ordovician (Arenigian) graptolite faunas..." The Aorangi Mine Formation thus corresponds to the Aorangi Mine Bed of Keble and Benson (1929).

Definition and Age. Base of the Formation is here taken at the lowest black graphitic band in the sequence in the Aorangi Mine area; the top is taken at the top of the thick massive quartzite band in Slaty Creek (member AM4). Type section, nominated by Bishop (1968) extends from the head-waters of Anthill Creek along Anthill, Little Slaty, and Slaty Creeks, to the top of a small gorge in Slaty Creek, 26 chains upstream from the junction with Little Slaty Creek and thus does not include the lowest beds. A more complete, but less well exposed, and less accessible standard section is in the North Branch of Sandhills Creek, extending from approximately 1.75 miles upstream from its junction with the South Branch, to its junction with the major western tributary in its headwaters.

Graptolites indicate a Lower Ordovician (Lancefieldian to Yapeenian) age. Total thickness is about 2900ft in the

north and somewhat less in the south. Four informal members are recognised.

Member AM1. The lowest beds in the Aorangi Mine Formation are thick-bedded and massive quartzite and siliceous sandstone, with interbedded black slate, and distinctive laminated, siliceous slate. At Malone Creek, to the north, black and light grey, finely laminated slate predominates, while in Sandhills Creek to the south, quartzite and sandstone are most common. The member is well exposed in Sandhills Creek (section 3 in fig. 6), where it is approximately 1300ft thick. Graptolites from two localities were recorded by Smith (1966 :174), but the correct position of each is thought to be upstream from the points defined by the grid reference given by Smith, in beds mapped as member AM2 (see appendix I, localities S2/541,542). Diagnostic fossils are otherwise unknown from the member. Because it conformably underlies mid-Lancefieldian (La2) beds, it is probably lower to mid-Lancefieldian in age.

Member AM2. Overlying member AM1 are siliceous black slates and black chert with rare quartzite and sandstone bands. The siliceous black slates and cherts ("glassy slate" of Benson et al 1936 :365) are extremely hard and are generally poorly fissile, individual beds being about one half to six inches thick. Pyrite is common, occurring as small cubes or as discrete interbedded layers, one to three millimetres thick.

Graphitic sandstone ("greywacke" of Benson) and grey phyllite bands are common in the upper part of the member in Sandhills and Anthill Creeks, and finely fissile black shale bands are interbedded with hard slabby chert in the lower part of the member in Anthill Creek. Base of the member is exposed in Anthill Creek at the old mine drive where massive quartzite of member AM1 passes up into black slate.

The member is lithologically distinctive and is a good stratigraphic marker. Thickness at Anthill Creek is about 470ft, and at Sandhills Creek is about 400ft.

The gold-bearing 'lode-line' worked by the Aorangi, Anthill and Golden Ridge mines, corresponds to a horizon near the base of member AM2 or the top of member AM1. The nature of the gold ore is discussed by Bell, Webb and Clarke (1907 :89-94), and Downey (1928 :33-5).

The member is richly fossiliferous, graptolites having been found at many localities - those listed with a query probably, but not definitely, represent the member.

S2/522?	S2/564	S2/600	S2/613	S2/625
523?	565	601	614	626
524	570	602	615	627
525	577	603	616	628
526	579	604	617	641?
527	580	605	618	S3/552
528	586	606	619	

531	587	607	620
534?	588	609	621
541?	589	610?	622
542?	590	611	623
562	599	612	624

Graptolite zones 1 to 5 (see chapter on Biostratigraphy) are represented and indicate the middle and upper Lancefieldian, Bendigonian, Chewtonian and lower Castlemainian stages.

Member AM3. Medium-grained and fine-grained, pale blue-grey, massive, carbonaceous, micaceous argillite, interbedded with grey quartzites and black slates overlie member AM2. The member is well exposed in Little Slaty Creek and on the Aorangi Mine track where it contains the richest fossil localities in the area. Base of the member is exposed in Anthill Creek, two chains downstream from the high waterfall, and in the North Branch, Sandhills Creek, a few yards upstream from locality S2/617, black slates of member AM2 passing up into soft blue-grey argillites at both localities.

The member is apparently represented by only about 100ft of relatively soft, pale blue-grey, massive argillite in Sandhills Creek, but similar argillites are interbedded with black argillites and quartzites in a thicker sequence (approximately 300ft) in Slaty Creek, to the north.

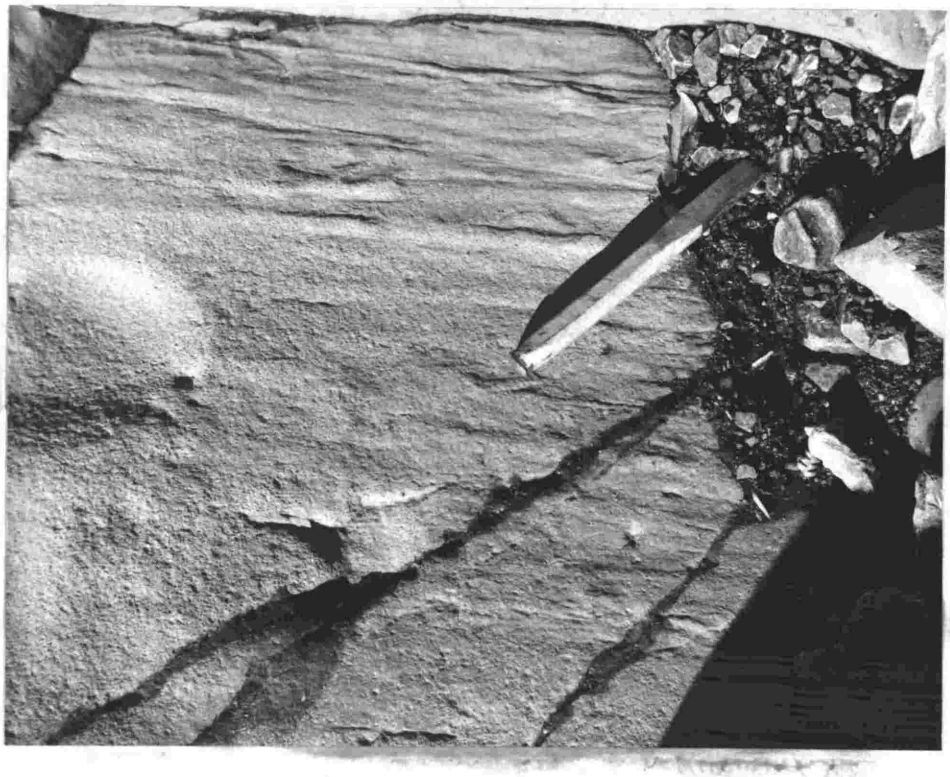


Fig.3. Groove casts on sole of fine sandstone bed overturned by nearly 180°. Aorangi Mine Formation, member AM4, Slaty Creek at Sweeney's hut.

Fig.4. Load structures in Formation A, member A3, in Slaty Creek a few chains upstream from its major eastern tributary. Argillite (dark coloured rock) forms flame structures in the base of overlying fine sandstone (pale coloured rock) in the upper and middle parts of the photo (see Potter and Pettijohn 1964, pl.53B). The graded bed below the hammer head indicates younging towards the top of the photo - to the east.

Graptolites from the following localities represent the upper part of zone 5, zone 6, and the lower part of zone 7 and indicate an upper Castlemainian to lower Yapeenian age for the member.

S2/529	S2/548	S2/557	S2/563
530	552	558	598?
532	553	559	608
533	554	560	629
535	555	561	632
545			

Member AM4. The youngest member of the Aorangi Mine Formation consists of two thick massive quartzite beds separated by alternating pale blue-grey, argillites and sandstones. The lower quartzite is moderately pyritic and both quartzites are ~~vary~~ very hard, forming deep gorges in the valleys of Slaty Creek and Sandhills Creek. The intervening argillites and sandstones in Slaty Creek include graded beds with scour casts (fig.3). In Sandhills Creek, the argillites and sandstones form a narrower band which includes thin beds of grey phyllite. Base of the formation is exposed in the North Branch, Sandhills Creek, a few yards upstream from locality S2/629, where bedded, dark blue-grey argillite of member AM3 passes up into massive quartzite. In Slaty Creek (S2/556), Sandhills Creek (S2/630), and Jimmy's Creek (S2/540), a thin band of black slate contains zone 7 graptolites indicating Yapeenian age. Other fossil

localities are S2/543, 544, 546, 566, 567, 576, 585?, 630 and 631. The member is about 800ft thick in Sandhills Creek, and probably somewhat thicker to the north, in Slaty Creek.

Relation to underlying beds. The predominantly argillitic beds of the Webb Formation pass up through dark sandstone into the more siliceous beds of the conformably overlying Aorangi Mine Formation in Sandhills Creek (see appendix II, column 3c). The contact is less well exposed in Shot Creek to the north.

Formation A.

Overlying the Aorangi Mine Formation are blue-grey sandstones and argillites, with a few bands of dark blue-grey or black graphitic slate and rare massive quartzites. Base of the Formation is exposed in Slaty Creek, five chains upstream from locality S2/556, and in the North Branch, Sandhills Creek, a few chains downstream from locality S2/631, massive quartzite of the Aorangi Mine Formation, member AM4 passing up into bedded sandstone in both creeks.

It is distinguished from the somewhat similar Webb Formation, by its thinner beds of alternating lithology, and by the presence of interbedded black slates and quartzites.

Grindley (1961) mapped the formation as part of the Aorere Formation; Bishop (1968) mapped the lower part only as Roaring Lion Formation. The beds are here regarded as an informal formation comprising three informal members.

Fig.5a. Bedded black slate and argillite at fossil locality S2/552 (beneath hammer) interbedded with thick beds of sandstone and argillite of the Aorangi Mine Formation, member AM4, on the track to Aorangi Mine.

Fig.5b. Disrupted thin-bedded siltstone band underlain by massive argillite (beneath hammer). Regional dip is shown by the massive sandstone band at left of photograph. Slaty Creek near Conn's Creek junction.

Fig.5c. Steeply plunging folds in Formation A, member A1, exposed in the Conn's Creek shear zone, a few chains up Conn's Creek from its junction with Slaty Creek.

Fig. 5a

Fig. 5b

Fig. 5c

Member A1. Thin alternating beds of spotted, blue-grey, micaceous argillite and grey sandstone, with massive, pale blue-grey, siliceous argillites and a single band of massive quartzite comprises the lower member of Formation A. A feature of the member is the relatively common intraformational deformation. Contorted argillitic beds, disrupted bedding (fig.5b), and slump folds, are seen in Slaty Creek, near its junction with Conn's Creek. The lower part of the member is folded, sheared, and quartz-veined along the Conn's Creek Shear Zone (fig.5c) which outcrops in Slaty Creek and in Conn's Creek. Beds on either side of the zone are of similar lithology, and fault displacement is not thought to be great.

Thin-bedded, blue-grey, spotted argillite and grey sandstone outcrop in a small tributary northwest of Mount Baldy and represent the northern-most outcrops of the member. Black phyllite bands are confined to the top of the member, near its contact with the overlying member A2 in Slaty Creek.

Thickness of the member in Slaty Creek is approximately 1050ft but to the south, between Sandhills Creek and the headwaters of Slaty Creek, the thickness is considerably less than this. Strike-faulting may have excluded some of the beds in the south, though slumping associated with contemporaneous deformation may account for some of the southward thinning.

Graptolites of zone 8, indicating lower Darriwilian age have been collected from the member at localities S2/547,

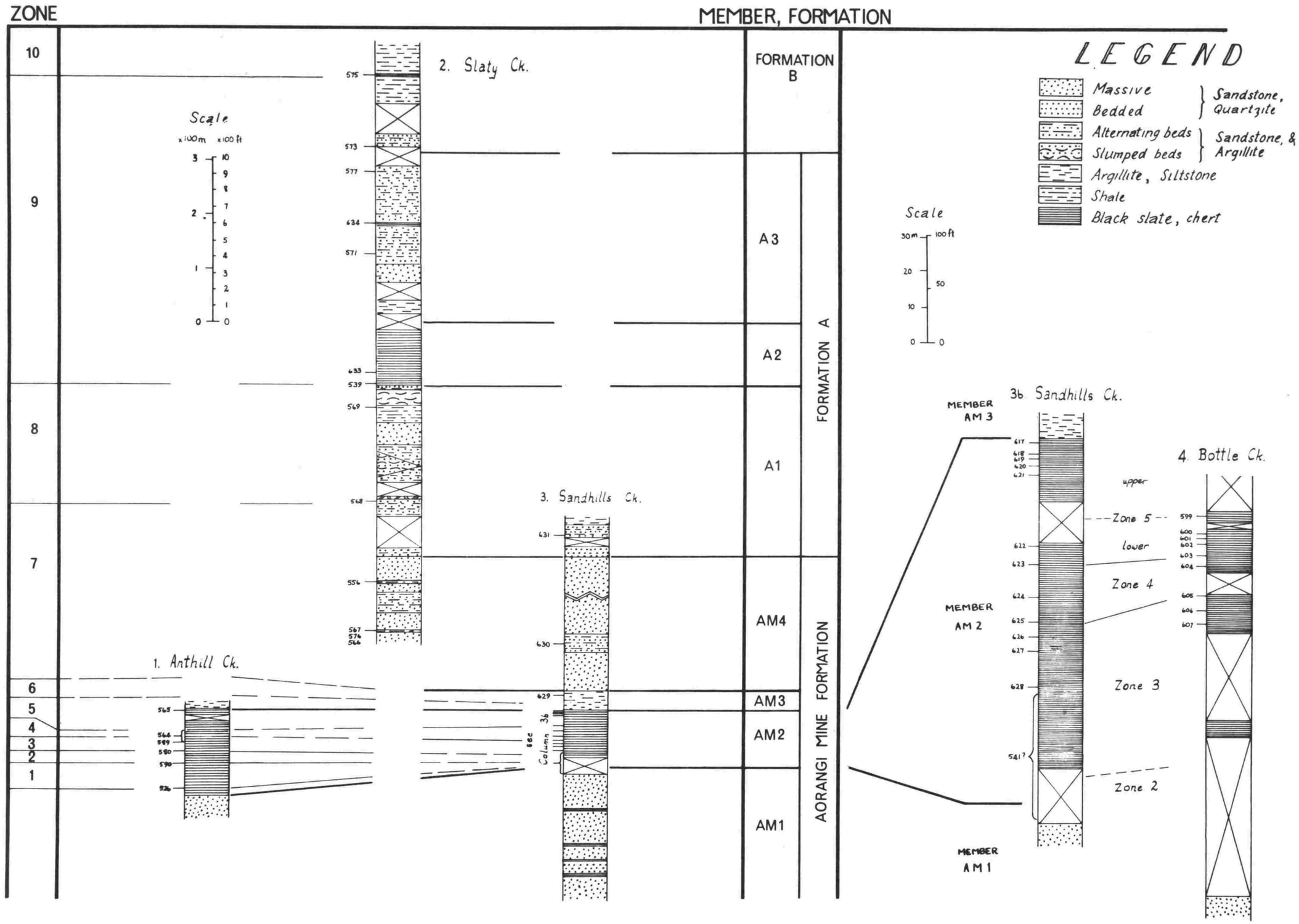
568, 569, 582 and 638, and zone 7 graptolites of Yapeenian age have been collected from the basal beds of the member in Sandhills Creek, at locality S2/631.

Member A2. A thick band of black spotted, hard, moderately to poorly fissile slate and argillite overlies member A1 in Slaty Creek, 11 chains upstream from the mouth of Conn's Creek. Thin bands of grey phyllite lie near the top of the member, which is locally strongly brecciated. Thickness is about 340ft. Zone 9 graptolites of upper Darriwilian age have been collected at 3 localities, S2/539,595,633.

Member A3. Overlying member A2 is a sequence of alternating 6 inch to 2ft bands of grey argillites and sandstones, graded beds, rare massive quartzites, and thin bands of black pyritic slates. The lowest exposed beds are massive argillites and these outcrop in Slaty Creek five chains downstream from its junction with the major eastern tributary, the actual contact with underlying black slates of member A2, outcropping further downstream, not being exposed. In the upper part of Slaty Creek, graded beds of sandstone and argillite with groove casts and other sole markings, are well exposed. In one outcrop (fig.4), flame structures and load casts (Pettijohn and Potter 1964 :pl.53B) and interlaminar deformation are prominent.

The member is about 990ft thick in Slaty Creek but may be somewhat thinner than this to the south, in the headwaters of Slaty Creek. Zone 9 graptolites from localities

Fig.6. Lithostratigraphic and biostratigraphic correlation of sections measured in Anthill Creek, Slaty Creek, Sandhills Creek and Bottle Creek, in the Aorangi Mine area. Sections 3b, Sandhills Creek and 4, Bottle Creek are drawn at enlarged scale at right. Fossiliferous horizons are indicated, together with their sheet (S2) fossil numbers. Location of the measured sections is shown in map 2 (in pocket); details of the sections are given in appendix II.


ZONE
MEMBER, FORMATION
10
9
8
7
6
5
4
3
2
1
Scale
x100m x100 ft
1. Anthill Ck.
2. Slaty Ck.
3. Sandhills Ck.
3b. Sandhills Ck.
4. Bottle Ck.
FORMATION B
A3
A2
A1
AM4
AM3
AM2
AM1
FORMATION A
AORANGI MINE FORMATION
MEMBER AM 3
MEMBER AM 2
MEMBER AM 1
upper
lower
Zone 5
Zone 4
Zone 3
Zone 2
LEGEND
Massive
Bedded
Sandstone, Quartzite
Alternating beds
Slumped beds
Sandstone, & Argillite
Argillite, Siltstone
Shale
Black slate, chert

S2/571 and 634 indicate an upper Darriwilian age.

Relation to underlying beds. In Slaty Creek, 26 chains upstream from the mouth of Little Slaty Creek and about five chains upstream from locality S2/556, massive quartzite of the Aorangi Mine Formation (member AM4) is conformably overlain by bedded quartzite with 1 inch bands of sheared argillite, representing the basal beds of Formation A. In the headwaters of Sandhills Creek a few chains downstream from locality S2/556, massive quartzite is conformably overlain by bedded graphitic sandstone. Contemporaneous deformation and strike-faulting have complicated the structure within the lower part of Formation A.

Formation B.

Content. The youngest Paleozoic formation comprises mainly siltstone and argillite, and is confined to the eastern part of the mapped area. Base of the formation is exposed in the major eastern tributary of Slaty Creek, about 18 chains upstream from its mouth, where quartzite and sandstone with thin argillites of Formation A pass up into thin-bedded quartzite and laminated argillite. Most of the formation between Slaty Creek and Paturau River is composed of distinctive laminated medium grey, and siliceous light grey argillite, individual laminae being 3-10mm thick. Further to the east in Paturau River, and probably overlying the laminated argillite, are green, grey-green and rarely pink siltstones and sandstones, generally poorly bedded and faintly

mottled, and locally strongly cleaved. Slump folds and disrupted bedding in Paturau River, particularly from two to three miles upstream from Thompson Creek, indicate contemporaneous deformation.

A lens of hard black cherty slate, 4ft wide, outcrops in a western tributary of Paturau River, 1 mile south of Rocky Creek. The rock closely resembles the distinctive black chert member (AM2) of the Aorangi Mine Formation and the lens may well have been derived by slumping during deposition. Black cherty slate is unknown elsewhere and the fossiliferous black chert pebbles mentioned below were probably derived from this, or a similar, included lens.

At the trilobite locality in Paturau River (S3/526), bedding in green and grey-green siltstone has been largely destroyed by contemporaneous animal borings, resulting in rather massive siltstone. The parent sediment may well have been laminated siltstone similar to that seen in the lower part of the Formation.

Zone 10 graptolites from dark slate bands near the base of the Formation in Slaty Creek (S2/575) and in Dam Creek (S2/592) indicate a basal Gisbornian age for the lower part. Graptolites associated with trilobites in Paturau River (S3/526), indicate a Gisbornian age for the upper part of the Formation. Black cherty slate pebbles in Paturau River with Lower Ordovician graptolites (S3/537,551) were probably derived from included lenses within the Formation

and represent older beds. The only other recorded fossil is a brachiopod impression in a boulder probably derived from this Formation (Cooper 1968, supporting paper). Structure has not been mapped in detail, and the full thickness of the Formation is uncertain, but minimum thickness is about 2000ft.

Relation to underlying beds. Contact with the underlying Formation A is exposed in the upper part of Slaty Creek, about one mile south of its major eastern tributary, where bedded quartzite and slate of Formation A pass conformably up into grey laminated siltstone of Formation B. A similar sequence outcrops in the major eastern tributary, about 18 chains upstream from its mouth, but the contact between the two Formations is not exposed.

Conditions of deposition.

No non-marine rocks are known and the entire sequence is presumed to be of marine origin. Conglomerates and other coarse-grained sediments are notably absent, and, except for small limestone lenses in Thompson Creek, Paturau Valley (Bishop 1965), shelly fossils and calcareous beds are unknown. Current bedding and other features generally regarded as typical of 'shallow-water' deposits are lacking and the beds are considered to have been deposited in quiet water below wave-base level.

During the late Cambrian to Lower Ordovician fine-grained clastic sediment was steadily supplied to a sinking

basin giving rise to the rather uniform lithology of the Webb Formation. The predominance of massive and bedded quartzites of the Aorangi Mine Formation marks a change to a more siliceous sediment supply during the Lower Ordovician. Black graphitic siliceous slate and chert of member AM2, about 400-500ft thick, spans 5 graptolite zones and represents a relatively long period of slow deposition. The abundance of carbon and of iron sulphide implies a reducing environment and the rocks undoubtedly belong to the problematical black shale facies (Pettijohn 1957 :622). On the other hand the much thicker member AM4, comprising mainly quartzites, lies wholly within a single graptolite zone, suggesting a sudden increase in the rate of deposition during the Yapeenian stage.

During the Middle Ordovician the sediment supply became less quartzitic and more micaceous resulting in thin-bedded argillites and sandstones with rare massive quartzites. Slumped and disrupted bedding imply relatively steep bottom gradients while graded beds and sole markings indicate turbidity currents. Assuming simple unfolding of the beds, orientation of the groove casts, measured at only two localities, indicates a NE-SW direction for the transporting current, agreeing with that indicated by groove casts in argillites of member AM4 (fig.3), in Slaty Creek. Except for member A2, black slates are rare.

The Upper Ordovician marks a change to steady deposition of fine-grained, mainly siliceous rhythmic sediments. Slumped bedding in Paturau River suggests local steep gradients.

The full sequence of about 8600ft is therefore thought to indicate a relatively deep water geosynclinal environment, lying some distance from the sediment source area.

Structure and Metamorphism.

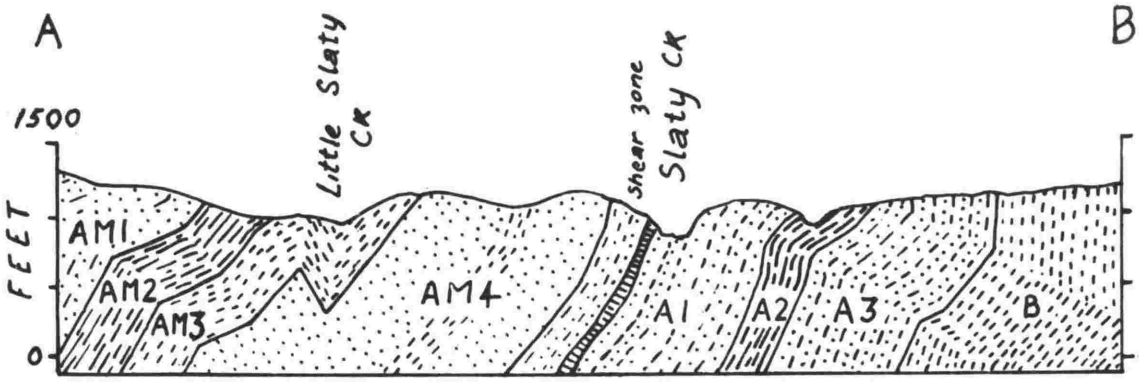
Structure of the Paleozoic rocks is shown in map 1 and in sketch cross-sections (figs 7 and 8). Previous interpretations of the structure differ from that described here, chiefly in the stratigraphic extent of overturned strata.

Previous interpretations. Benson et al (1936 :359,fig.1) presented a map showing lithology and attitude of beds and the position of graptolite localities in the region of Little Slaty Creek, Slaty Creek and Malone Creek. The structure of beds between Slaty Creek and the headwaters of Malone Creek was shown in a cross-section, and was based largely on graptolite determinations (Benson et al 1936 :364) together with observed lithology and dip. A north-trending isoclinal anticline with an overturned and faulted eastern limb lay in the western side of Little Slaty Creek Valley, and an adjacent syncline with an overturned western limb lay along the line of Little Slaty Creek itself. The oldest beds, exposed in the core of the anticline, were middle Lancefieldian while the youngest beds, in the core of the syncline, were upper Castlemainian. To the east of Little Slaty Creek, where no graptolites had been collected, the

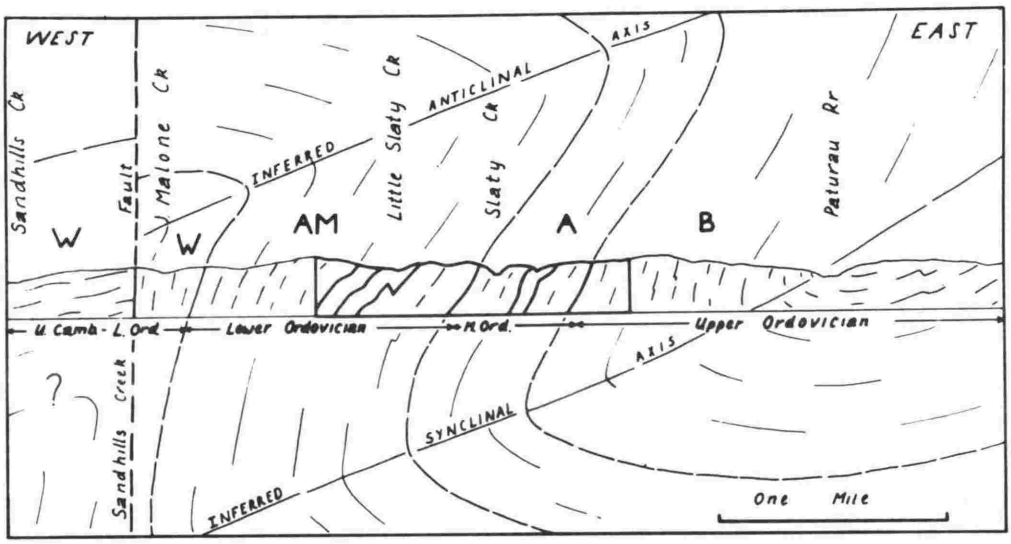
Fig.7. Sketch cross-sections from the headwaters of Malone Creek to Slaty Creek, near its junction with Conn's Creek, showing different structural interpretations. The section line is of similar length to that of fig.8 but lies further to the west, to coincide with that given by Benson et al (1936, fig.1). Horizontal and vertical scales are about ~~three~~ 3·4 inches to the mile. a) Dip of beds at the surface (writer's observations). b) Interpretation by Benson et al, in which beds exposed between Little Slaty Creek and a quarter of a mile to the west are overturned. Fossiliferous horizons are indicated. c) The writer's interpretation in which the entire section is overturned. Diagnostic fossiliferous horizons indicated.

La, Lancefieldian (zones 1 and 2 of this thesis); Be, Bendigonian (zone 3); Ch, Chewtonian (zone 4); Ca, Castlemainian (zones 4,5); Ya, Yapeenian (zone 7); Da, Darriwilian (zone 8). Fig.7b after Benson et al (1936, fig.1).

W.
Malone Creek
Little Slaty Creek
Slaty Creek
E.
Feet
1500
1000
500
0
a
? Ch
La
La Be
Ch
Ca
?
b
La ?
Coffee Creek Fault
La ?
La (Z 1,2)
Be (Z 3)
Ch (Z 4)
Ca (Z 5,6)
Ya (Z 7)
Shear zone
Da (Z 8)
c



a



b

Fig.8. Structural sections of the Aorangi Mine area.

a) Cross-section along line AB (see map 1). AM1 - AM4, Aorangi Mine Formation; A1 - A3, Formation A; B, Formation B. Horizontal and vertical scales same.

b) Diagrammatic section from Sandhills Creek to Paturau River, passing through line AB (heavy), inferred regional structure indicated. W, Webb Formation; A.M., Aorangi Mine Formation; A, Formation A; B, Formation B.

structure was unknown. To the west of the anticlinal axis, in the divide between Little Slaty Creek and Malone Creek, Chewtonian beds occupied the core of a second syncline, and were represented by a single graptolite locality, listed as "Locality S" by Benson et al (1936 :359,366).

Benson's cross-section is reproduced here in fig.7b for comparison with the writer's interpretation of structure in the same area. Fossiliferous horizons are indicated. The two interpretations agree in the regional westward dip of strata but differ in the inferred extent of folding. In particular the sequence of non-overturned beds ranging from Lancefieldian to Chewtonian in age in the divide between Little Slaty Creek and Malone Creek, shown by Benson et al, is not accepted here. The sequence was based largely on the Chewtonian age of graptolites from Benson's "Locality S" near the crest of the divide. The graptolites were collected by Professor Marshall in 1908 from "Butchers Gully or Jacob's Ladder at the head of Malone Creek" (T.S.Hall 1915a: 411). Benson et al state (1936 :366) "the first two names cannot now be localised, but probably indicate a spot near that of S on our map". The correct position of Marshall's locality is here thought to be a few chains to the northwest of that indicated by Benson, on the western side of the Coffee Creek Fault, where Chewtonian beds (member AM2) have been mapped. The full sequence exposed in the divide is considered to be overturned and dipping to the west.

The major syncline axis in Little Slaty Creek shown

by Benson et al probably corresponds to the minor syncline axis mapped by the writer in the same area.

In 1961 Grindley mapped the area as part of the 1:250,000 Golden Bay Sheet. The structure of beds between Malone Creek and Little Slaty Creek, indicated in his cross-section A-A', was largely as shown by Benson et al, the anticline west of Little Slaty Creek being named the Aorangi Anticline. Between Little Slaty Creek and Paturau River, structure shown was largely as mapped by the writer; the beds formed the overturned eastern limb of the Aorangi Anticline. A synclinal axis lay to the east of Paturau River in rocks mapped as Golden Bay Schist.

In the writer's interpretation several phases of deformation have affected the rocks. The earliest phase was penecontemporaneous, and is discussed above; subsequent deformation involved mainly folding. Three groups of folds are recognised and are summarised below. 1) large scale recumbent folds; 2) intermediate macroscopic folds; 3) minor folds associated with the Conn's Creek Shear Zone.

Group	Axial plane		Axial plunge	Associated shearing
	Dip	Direction of dip		
1	20-30°	270°	0°	?
2	90°	100°	5-10° S.	probably none
3	50-70°	270°	50-70° W.	strong

Faulting has been relatively minor and only two inferred faults have been mapped.

Large scale recumbent folds. In the central part of the mapped area a conformable sequence, about 8600ft thick, extending from the base of the Aorangi Mine Formation to the lower part of Formation B dips regionally to the west. Graptolites indicate that the rocks decrease in age to the east and the entire sequence is thus overturned. The beds are thought to comprise part of the overturned limb of a large, north-trending fold whose anticlinal axis lies to the west and whose synclinal axis lies to the east (figs 8a-b), axial planes dipping gently to the west. Graded beds and sole markings at three localities in Slaty Creek confirm the overturning (figs 3, 4). To the east and west of the central part, the structure is uncertain.

In the western part, west of the Sandhills Creek Fault, beds dip gently to the west and may represent the gently-dipping western anticlinal limb. In the eastern part, at Paturau River, beds dip moderately to the east and probably lie near the axial region of the syncline. East of the mapped area, in Thompson Creek, which joins Paturau River near the northeast corner of the mapped area, graptolite-bearing slate boulders (S3/550) have been found which closely resemble rocks and fossils from the base of Formation B in Slaty Creek (S2/575). The source of the boulders is unknown but lies within the upper catchment of Thompson Creek. The basal beds of Formation B are therefore probably re-exposed east of the syncline axis, possibly in the eastern limb of the syncline.

The age of recumbent folding is unknown but lies between Upper Ordovician and Upper Cretaceous or Lower Tertiary. No associated axial plane cleavage was seen.

Intermediate macroscopic folds. North-north-east trending macroscopic folds with amplitudes ranging from 50ft to about 600ft have been mapped at several localities, particularly in the North Branch of Sandhills Creek, and in Little Slaty Creek. Fold axes plunge gently to the south, and axial planes dip steeply. Comparable folds are likely to be common throughout the mapped area, particularly between Paturau River and the eastern tributaries of Slaty Creek. North-trending chevron folds with an amplitude of about one foot are exposed in a western tributary of Paturau River, about two miles south of Thompson Creek, and are probably of the same generation.

Moderately-developed to weakly-developed slaty cleavage, generally dipping steeply to the west or northwest, pervades pelitic rocks throughout the mapped area and probably represents the fold axial plane cleavage.

With their steeply dipping axial planes, the north-north-east macroscopic folds are incongruous with the large scale recumbent folds and belong to a different generation. Axial plane cleavage has not been destroyed or folded by the recumbent folds and the macroscopic folds are probably the younger of the two generations.

Conn's Creek Shear Zone. Tight mesoscopic folds (fig.5c) are associated with strong shearing, brecciation, and quartz veining in a zone exposed in Slaty Creek for a quarter of a mile downstream from the mouth of Conn's Creek, and in the lower part of Conn's Creek itself. Both fold axes and axial planes dip steeply to the west, the apparent sense of rotation (vergence) implying northward transportation of the eastern or younger block, relative to the western block. The zone is approximately concordant with bedding and lies within the lower part of member A1, Formation A. Graptolites from either side of the zone (section 2, appendix II) suggest that no significant amount of time is missing. Undisturbed beds on either side of the zone are lithologically similar, and it is thought that the sedimentary section has not been greatly altered by movement along the zone.

Much of the brecciation seen in other beds, particularly those of Formation A, member A2, and Aorangi Mine Formation, member AM2 (along the auriferous "lode-line"), has probably been produced by similar zones of shearing.

The steeply plunging folds of the Conn's Creek Shear Zone are incongrous with the recumbent folds and the intermediate macroscopic folds, both of which have a shallow plunge, and the zone probably represents a distinct period of deformation. Age of the deformation with respect to the other two groups of folds is unknown.

Faults. Faulting appears to be of relatively minor scale within the mapped area. Two inferred faults have been mapped - the Sandhills Creek Fault and the Coffee Creek Fault.

The Coffee Creek Fault trends east-north-east and offsets beds of the Aorangi Mine Formation by about a quarter of a mile in a relatively anticlockwise direction, at the ground surface. Rocks are locally intensely brecciated in Coffee Creek and in the gorge in Slaty Creek. The nature of movement along the Sandhills Creek Fault is unknown but it separates gently-dipping strata, from steeply-dipping strata of the Webb Formation.

The Coffee Creek Fault does not appear to have been folded and probably post-dates both the recumbent folding and the intermediate macroscopic folding. Its age with respect to the Conn's Creek shearing and folding is uncertain. The Sandhills Creek Fault is likely to be of similar age to the Coffee Creek Fault.

Metamorphism. Throughout the mapped area, pelitic rocks are weakly to strongly cleaved and locally spotted; they are represented by slates, phyllites, argillites and siltstones. Sandstones and quartzites are invariably indurated and compact, quartz veins are generally rare, and schists are unknown. Graptolites, represented by the casts of flattened rhabdosomes, generally have not been severely affected by metamorphism, and the rocks are considered to have undergone only incipient regional metamorphism.

Biostratigraphy.

Ten graptolite zones are here recognised in rocks of the Aorangi Mine area and are numbered 1 to 10. They are defined in terms of the stratigraphic ranges of selected species; relatively abundant widespread, and short-ranging species have been selected. The species are generally most abundant shortly after their first appearance and become rare towards the top of their range; their appearance is thus easier to detect than their disappearance. Zone boundaries are therefore placed at the successive points of appearance of selected species, the zones being the intervals between points.

Two species are thus required to define a zone and are its standards of reference. One, after which the zone is named, defines the base of the zone, and ranges within it; the other defines the top and lies wholly outside the zone. Three varieties of zones can thus be recognised. The first, the "successive appearance zone" of Vella (1963 :621), is that whose base is defined by a species which ranges through and beyond the zone, for example, the zone of Tetragraptus fruticosus at Aorangi Mine. The second is that whose base is defined by a species which disappears before the top of the zone, such as the zone of Didymograptus protobifidus. The third, the "range zone" of the American Code of Stratigraphic Nomenclature, is that whose upper boundary coincides with the disappearance of the species which defines the zone base. The nearest example at Aorangi Mine is the

zone of Isograptus caduceus lunata whose boundaries are defined by the evolutionary series Isograptus caduceus lunata - victoriae - maximodivergens, the transition from victoriae to maximodivergens marking the zone top.

The Aorangi Mine zones are discussed below and are correlated with graptolite sequences of Preservation Inlet, Cobb Valley, and Wangapeka Valley. Faunal diversity within each zone together with the faunal change across zone boundaries is shown in fig.9, and a list of zonally restricted species is given in table VI.

1. Zone of Adelograptus.

The oldest zone recognised at Aorangi Mine extends from the first appearance of anisograptids to the first appearance of Tetragraptus approximatus. The best section is exposed in Anthill Creek (section 1, appendix II), from locality S2/526 (first appearance of anisograptids) up to, but not including, locality S2/590 (first appearance of Tetragraptus approximatus), the zone being about 160ft thick. Adelograptus? antiquus and Adelograptus spp. are abundant, while Tetragraptus decipiens (4-stiped) and clonograptids are rare. Dictyonema pulchellum and Clonograptus aff. regularis are restricted to the zone, being represented by only one specimen each.

Indeterminate graptolite fragments are found at localities S2/597 (in Anthill Creek) and S2/583, 596 (in

Malone Creek) in beds lying considerably below the base of the zone.

An equivalent zone can be recognised in graptolite-bearing rocks at Preservation Inlet, from the section and faunal lists given by Benson and Keble (1935). At Cape Providence, localities 1,2,3,4, and 5 lie within the zone; at Kisbee Bay, localities 20,21,22, and 23; and at Coal Island, locality 28. As at Aorangi Mine Adelograptus? antiquus and A.spp. are common. Other fossils include clonograptids, Dictyonema macgillivrayi and Tetragraptus decipiens (4-stiped).

2. Zone of Tetragraptus approximatus.

The zone extends from the first appearance of Tetragraptus approximatus to the first appearance of T.fruticosus (4-stiped). Unfortunately the zone has not yet been found in a continuous section containing both defining fossils, but the best section is in Anthill Creek (section 1) from locality S2/590 (first appearance of T.approximatus) up to, but not including locality S2/580 (first appearance of zone 3 fossils including T.aff.serra, T.bigsbyi, Didymograptus similis, and D.cf.extensus). The zone is exposed in two true left tributaries of Little Slaty Creek at localities S2/577 and S2/612-616, its thickness in Anthill Creek being about 70ft.

Tetragraptus approximatus and T.decipiens (4- and 3-stiped) are abundant; the 3-stiped form of T.decipiens

and T.acclinans is restricted to the zone. Adelograptids and clonograptids are common.

The zone cannot be recognised at Preservation Inlet from the lists given by Benson and Keble (1935), but Skwarko (1958) records a graptolite assemblage from north of Cape Providence, at locality S165/507 (collection GS7021) which includes T.approximatus, T.quadribrachiatus, T.acclinans and T.decipiens, and which most probably represents the zone.

3. Zone of Tetragraptus fruticosus.

The zone extends from the first appearance of Tetragraptus fruticosus to the first appearance of Didymograptus protobifidus. In Sandhills Creek (section 3b) the zone extends from locality S2/628 (first appearance of T.fruticosus), up to, but not including locality S2/626 (first appearance of D.protobifidus). Fossils representing the previous zone are thought to come from unexposed strata underlying those at S2/628 (see appendix I, locality S2/541). The zone is also well exposed in Anthill, Bottle, and Little Slaty Creeks, its thickness in Sandhills Creek being approximately 150ft.

The zone marks the appearance in abundance of the dichograptid fauna, while anisograptids become rare. In addition to T.fruticosus, many species of Tetragraptus make their appearance, notably T.bigsbyi, T.harti, T.quadribrachiatus and T.serra. Phyllograptus anna, Didymograptus similis, D.ensjoensis and several forms of D.extensus type

appear. The zone also marks the last appearance of Tetragraptus approximatus and T.decipiens. Restricted species are Tetragraptus pendens, T.aff.pendens, T.aff. serra and Trichograptus fergusoni.

The order of appearance of the 4- and 3-stiped forms of T.fruticosus has not been definitely determined, no fossiliferous sequences containing both forms being known to extend below the first appearance of the species. In Sandhills Creek, the oldest outcropping fossiliferous beds have both forms (locality S2/628). The 4-stiped form disappears before the 3-stiped form in Sandhills Creek (section 3b) and probably also in Bottle Creek (section 4).

From Benson and Keble's work (1935), the zone can be recognised at Preservation Inlet at localities 6, 7 and 8 on Cape Providence, locality 24 at Kisbee Bay, and localities 29, 30, and 31 at Coal Island. The associated assemblage is similar to that at Aorangi Mine, except that the 4-stiped form of T.fruticosus appears before the 3-stiped form and does not overlap it.

4. Zone of Didymograptus protobifidus.

The zone extends from the first appearance of Didymograptus protobifidus to the first appearance of Isograptus caduceus lunata. In Sandhills Creek (section 3b) the zone extends from S2/625 (first appearance of D.protobifidus) up to, but not including locality S2/623 (first appearance of I.c.lunata), and is about 36ft thick.

The zone is also exposed in Anthill Creek (section 1), Bottle Creek (section 4), and in Little Slaty Creek. The well known locality at Golden Ridge (Hall 1915a) lies within the zone. D.protobifidus is abundant in the lower part of the zone but disappears before the top. Sigmagraptus laxus and Isograptus caduceus? primula are restricted to the zone. Phyllograptus ilicifolius, P.angustifolius angustifolius and Didymograptus extensus first appear and become common within the zone, Tetragraptus amii and T.reclinatus appear, but remain rare. T.fruticosus (3-stiped) ranges from the previous zone into the lower part only. T.serra, T.harti and T.bigsbyi are common.

From the lists given by Benson and Keble, the zone can be recognised at Cape Providence (localities 9,10,10a,11) and at Coal Island (locality 32), in the Preservation Inlet area. It is represented by a similar assemblage to that of Aorangi Mine.

5. Zone of Isograptus caduceus lunata.

The fifth and sixth Aorangi Mine zones are defined by subspecies of the evolutionary series, Isograptus caduceus lunata - victoriae - maximodivergens. The first appearance of I.c.lunata marks the base of zone 5, and the transition from victoriae to maximodivergens marks the top. The best section is exposed in Sandhills Creek from locality S2/623 for about 4 chains upstream, where the zone is about 115ft thick. The zone is also exposed in Anthill Creek (section

1), Bottle Creek (section 4) and in Little Slaty Creek.

I.caduceus is abundant, I.c.lunata in the lower part of the zone passing into I.c.victoriae in the upper part. Phyllograptus typus is confined to the zone. Graptoloid sp. 1 indet. appears with a burst near the base but becomes less common towards the top of the zone. Dichograptus, represented by D.octobrachiatus, D.octonarius, and D.maccoyi, and Didymograptus cf.eocaduceus make their first appearance. Making their last appearance are the anisograptids, Phyllograptus ilicifolius, P.anna, P.angustifolius angustifolius and Didymograptus extensus.

The zone is equivalent to the youngest rocks on Cape Providence recorded by Benson and Keble (locality 12).

6. Zone of Isograptus caduceus maximodivergens.

The first appearance of I.c.maximodivergens defines the base of the zone and the first appearance of either Oncograptus or Cardiograptus defines the top. The best section extends from the lower part of Anthill Creek, up Little Slaty Creek to the lower part of Jimmy's Creek. The zone is particularly fossiliferous at locality S2/552 on the Aorangi Mine Track, where it contains more than 29 taxa. It outcrops for about half a mile along strike in Little Slaty Creek. Thickness of the zone is of the order of 100-200ft in the Anthill Creek area. It is the most richly fossiliferous zone at Aorangi Mine, both in numbers of species (fig.9) and in numbers of individuals.

Members of Isograptus dominate the zonal assemblage, I.c.maximodivergens being the most common fossil. Other common forms are I.dumosus, I.hastatus and I.imitata, Tetragraptus cf.serra, T.aff.taraxacum, T.quadribrachiatus, Didymograptus sp.(extensiform) and Goniograptus. G.macer, T.aff.chapmani, T.headi, Trigonograptus cf.ensiformis are confined to the zone. Loganograptus, Didymograptus v-deflexus, Trigonograptus ensiformis, and Graptoloid sp.2 make their first appearance, while Dichograptus, Tetragraptus bigsbyi, T.reclinatus, Didymograptus cf.eocaduceus make their last appearance.

The zone has no known equivalent elsewhere in New Zealand.

7. Zone of Oncograptus.

The zone extends from the first appearance of either Oncograptus or Cardiograptus to the first appearance of Paraglossograptus etheridgei. The best section is exposed in the lower part of Little Slaty Creek and up Slaty Creek to, but not including, locality S2/568 (first appearance of Paraglossograptus etheridgei. The lower part of the zone is well exposed in the upper part of the North Branch of Sandhills Creek (section 3), in Jimmy's Creek, and in the gorge in Slaty Creek, downstream from Coffee Creek. The zone is particularly fossiliferous at localities S2/540 in Jimmy's Creek, and S2/545 in Slaty Creek. It is about 1170ft thick in the region of lower Little Slaty Creek.

The most common fossil as in the previous zone is

Isograptus caduceus maximodivergens, but I.spp.aff. manubriatus, I.aff.imitata, I.dumosus, Didymograptus v-deflexus and Graptoloid sp.3 indet. are also common. Oncograptus, Cardiograptus, Trigonograptus sp.nov., Glossograptus? crudus, Phyllograptus "nobilis", Goniograptus speciosus and I.spp.aff.manubriatus are confined to the zone.

Many forms make their last appearance, notably I.caduceus, Goniograptus, Tetragraptus serra, T.cf.serra, Didymograptus sp.(extensiform), D.v-deflexus, while few forms make their first appearance, the main one being ?Hallograptus inutilus.

The zone has no known equivalent elsewhere in New Zealand.

8. Zone of Paraglossograptus etheridgei.

The zone extends from the first appearance of Paraglossograptus etheridgei to the first appearance of Diplograptus? decoratus. In Slaty Creek the zone extends from locality S2/568 (first appearance of P.etheridgei) upstream to, but not including, the horizon represented by locality S2/539 (first appearance of D? decoratus), and is about 720ft thick (section 2). The zone is particularly fossiliferous at locality S2/582 in a small creek northwest of Baldy Trig.

The zone marks the appearance of the diplograptid fauna (as described by Bulman 1958) with the incoming of Paraglossograptus, Amplexograptus, and Glyptograptus, together

with ?Hallograptus and Glossograptus. Pseudobryograptus incertus, P.parallelus, Sinograptid sp., Glossograptus acanthus, Paraglossograptus etheridgei, P.zealandicus, Amplexograptus confertus, Glyptograptus austrodentatus austrodentatus, and G.cf.intersitus are confined to the zone. Most of the remaining dichograptids make their last appearance, including Loganograptus, Tetragraptus, Isograptus also Trigonograptus.

A single specimen of Glyptograptus austrodentatus ssp. in a pebble in 17 Mile Creek (S8/581) indicates that the zone is represented to the south in the Aorere River catchment.

9. Zone of Diplograptus? decoratus.

The zone ranges from the first appearance of Diplograptus? decoratus to the first appearance of Dicellograptus. In Slaty Creek the zone extends from locality S2/633 (first appearance of D? decoratus) upstream to the major true right tributary, and in the tributary up to, but not including, locality S2/575 (first appearance of Dicellograptus), its thickness being about 1850ft (section 2). It is exposed for a mile along strike in the upper part of Slaty Creek, and is most fossiliferous at localities S2/633 and S2/539.

Diplograptus? decoratus is confined to the lower part of the zone while Glyptograptus cf.teretiusculus first appears in the upper part. Phyllograptus angustifolius elongatus,

Table IV. Zonal distribution of Nelson graptolites described in Part II of this thesis. Those forms listed with an asterisk (*) are recorded for the first time in New Zealand.

	1	2	3	4	5	6	7	8	9	10	11
Dendroidea											
Dictyonema pulchellum	x	-	-	-	-	-	-	-	-	-	-
Anisograptis? sp.	x	-	x	-	-	-	-	-	-	-	-
Adelograptus? antiquus	x	x	-	-	-	-	-	-	-	-	-
A.clarki	x	-	-	-	-	-	-	-	-	-	-
* A.aff.pusillus	-	-	-	x	x	-	-	-	-	-	-
* Clonograptus aff.regularis	x	-	-	-	-	-	-	-	-	-	-
C.cf.kingi	-	-	x	-	-	-	-	-	-	-	-
C.sp.	x	x	x	-	x	-	-	-	-	-	-
Graptoloidea											
Goniograptus macer	-	-	-	-	?	x	-	-	-	-	-
*G.speciosus	-	-	-	-	-	-	x	-	-	-	-
G.thureaui	-	-	-	-	-	x	x	-	-	-	-
Loganograptus logani	-	-	-	-	-	x	-	x	-	-	-
L.logani cf.pertenuis	-	-	-	-	-	x	-	x	-	-	-
* Pseudobryograptus incertus	-	-	-	-	-	-	-	x	-	-	-
* P. parallelus	-	-	-	-	-	-	-	x	-	-	-
* Pterograptus? sp.nov.	-	-	-	-	-	-	-	-	x	-	-
Sigmagraptus laxus	-	-	-	x	-	-	-	-	-	-	-
*Trichograptus fergusoni	-	-	x	-	-	-	-	-	-	-	-
Dichograptus maccoyi	-	-	-	-	x	x	-	-	-	-	-
D.octobrachiatus	-	-	-	-	x	x	-	-	-	-	-
*D.octonarius	-	-	-	-	x	x	-	-	-	-	-
Tetragraptus acclinans	-	x	-	-	-	-	-	-	-	-	-
T.amii	-	-	-	x	-	x	x	-	-	-	-
T.approximatus	-	x	x	-	-	-	-	-	-	-	-
T.bigsbyi	-	-	x	x	-	x	-	-	-	-	-
T.sp.aff.chapmani	-	-	-	-	-	x	-	-	-	-	-
T.decipiens (4-stiped)	x	x	x	-	-	-	-	-	-	-	-
T.decipiens (3-stiped)	-	x	-	-	-	-	-	-	-	-	-
T.fruticosus (4-stiped)	-	-	x	-	-	-	-	-	-	-	-
T.fruticosus (3-stiped)	-	-	x	x	-	-	-	-	-	-	-
T.harti	-	-	x	x	-	x	-	-	-	-	-
*T.hesdi	-	-	-	-	-	x	-	-	-	-	-
T.pendens	-	-	x	-	-	-	-	-	-	-	-
T.cf.pendens	-	-	x	-	-	-	-	-	-	-	-
T.quadribrachiatus	-	-	x	x	x	x	x	x	-	-	-
T.reclinatus	-	-	-	x	x	x	-	-	-	-	-
T.serra	-	-	x	x	x	x	x	-	-	-	-
T.cf.serra	-	-	-	-	-	x	x	-	-	-	-
T.aff.serra	-	-	x	-	-	-	-	-	-	-	-

	1	2	3	4	5	6	7	8	9	10	11
T.aff.taraxacum	-	-	-	x	-	x	-	-	-	-	-
T.whitelawi	-	-	x	-	x	-	-	-	-	-	-
Phyllograptus anna	-	-	x	x	x	-	-	-	-	-	-
P.angustifolius angustifolius	-	-	-	x	x	-	-	-	-	-	-
*P.angustifolius elongatus	-	-	-	-	-	-	-	-	x	-	-
P.ilicifolius	-	-	-	x	x	-	-	-	-	-	-
*P."nobilis"	-	-	-	-	-	-	x	-	-	-	-
P.typus	-	-	-	-	x	-	-	-	-	-	-
Didymograptus extensus	-	-	-	x	x	-	-	-	-	-	-
D.cf.extensus	-	-	x	x	x	x	-	-	-	-	-
D.sp. (extensiform)	-	-	x	x	x	x	x	-	-	-	-
*D.cf.ensjoensis	-	-	x	-	-	-	-	-	-	-	-
D.cf.eocaduceus	-	-	-	-	x	x	-	-	-	-	-
D.protobifidus	-	-	-	x	-	-	-	-	-	-	-
D.similis	-	-	x	x	-	-	-	-	-	-	-
D.v-deflexus	-	-	-	-	-	x	x	-	-	-	-
*Cardiograptus morsus	-	-	-	-	-	-	x	-	-	-	-
*C? sp.	-	-	-	-	-	-	x	-	-	-	-
Isograptus caduceus primula	-	-	-	x	-	-	-	-	-	-	-
I. c. lunata	-	-	-	-	x	-	-	-	-	-	-
I. c. victoriae	-	-	-	-	x	-	-	-	-	-	-
I. c. maximodivergens	-	-	-	-	-	x	x	-	-	-	-
*I.dumosus	-	-	-	-	-	x	x	-	-	-	-
I.hastatus	-	-	-	-	x	x	-	-	-	-	-
*I.imitata	-	-	-	-	?	x	x	x	-	-	-
*I.aff.imitata	-	-	-	-	-	x	x	x	-	-	-
*I.sp.1 aff.manubriatus	-	-	-	-	-	-	x	-	-	-	-
*I.sp.2 aff.manubriatus	-	-	-	-	-	-	x	-	-	-	-
*I.sp.3 aff.manubriatus	-	-	-	-	-	-	x	-	-	-	-
*I.sp.4 aff.manubriatus	-	-	-	-	-	-	x	-	-	-	-
Oncograptus upsilon biangulatus	-	-	-	-	-	-	x	-	-	-	-
*Sinograptid sp.	-	-	-	-	-	-	-	x	-	-	-
Cryptograptus schaferi	-	-	-	-	-	-	-	-	x	-	-
Glossograptus acanthus	-	-	-	-	-	-	-	x	-	-	-
*G?crudus	-	-	-	-	-	-	x	-	-	-	-
G.hincksii	-	-	-	-	-	-	-	-	x	x	-
*Paraglossograptus etheridgei	-	-	-	-	-	-	-	x	-	-	-
*P.zealandicus	-	-	-	-	-	-	-	x	-	-	-
Leptograptus cf.flaccidus	-	-	-	-	-	-	-	-	-	-	x
Nemagraptus gracilis	-	-	-	-	-	-	-	-	-	x	-

	1	2	3	4	5	6	7	8	9	10	11
Dicranograptus nicholsoni	-	-	-	-	-	-	-	-	-	x	-
* D.cf.hians	-	-	-	-	-	-	-	-	-	-	x
Dicellograptus intortus	-	-	-	-	-	-	-	-	-	x	x
* D.patulosus	-	-	-	-	-	-	-	-	-	-	x
D.cf.sextans	-	-	-	-	-	-	-	-	-	x	x
D.sextans exilis	-	-	-	-	-	-	-	-	-	x	-
* Pseudoclimacograptus cf modicellus	-	-	-	-	-	-	-	-	-	x	-
* P.sp.	-	-	-	-	-	-	-	-	-	x	-
Climacograptus bicornis	-	-	-	-	-	-	-	-	-	-	x
* C.brevis	-	-	-	-	-	-	-	-	x	-	-
* C.caudatus	-	-	-	-	-	-	-	-	-	-	x
* C.hastatus	-	-	-	-	-	-	-	-	-	-	x
* C.cf.riddellensis	-	-	-	-	-	-	-	-	x	-	-
* C.tubuliferous	-	-	-	-	-	-	-	-	-	-	x
C.sp.	-	-	-	-	-	-	-	-	x	x	x
* Diplograptus? decoratus	-	-	-	-	-	-	-	-	x	-	-
Amplexograptus confertus	-	-	-	-	-	-	-	x	-	-	-
A.cf.confertus	-	-	-	-	-	-	-	-	-	x	-
Glyptograptus cf.teretiusculus	-	-	-	-	-	-	-	-	x	x	-
* G.cf.teretiusculus siccatus	-	-	-	-	-	-	-	-	x	-	-
* G.austrodentatus cf.austrodentatus	-	-	-	-	-	-	-	x	-	-	-
* G.cf.intersitus	-	-	-	-	-	-	-	x	-	-	-
G.sp.	-	-	-	-	-	-	-	x	x	x	x
* Orthograptus truncatus pauperatus	-	-	-	-	-	-	-	-	-	-	x
* O.sp. ex gr.calcaratus	-	-	-	-	-	-	-	-	-	-	x
* O.sp.	-	-	-	-	-	-	-	-	-	-	x
Trigonograptus ensiformis	-	-	-	-	-	x	-	x	-	-	-
T.cf.ensiformis	-	-	-	-	-	x	-	-	-	-	-
T.sp.	-	-	-	-	-	-	x	x	-	-	-
* T? sp.nov.	-	-	-	-	-	-	x	-	-	-	-
* ?Hallograptus inutilus	-	-	-	-	-	-	x	x	-	-	-
Retiograptus geinitzianus	-	-	-	-	-	-	-	-	-	x	-
* Graptoloid sp.1	-	-	-	-	x	x	-	-	-	-	-
* Graptoloid sp.2	-	-	-	-	-	x	-	-	-	-	-
* Graptoloid sp.3	-	-	-	-	-	x	x	-	-	-	-

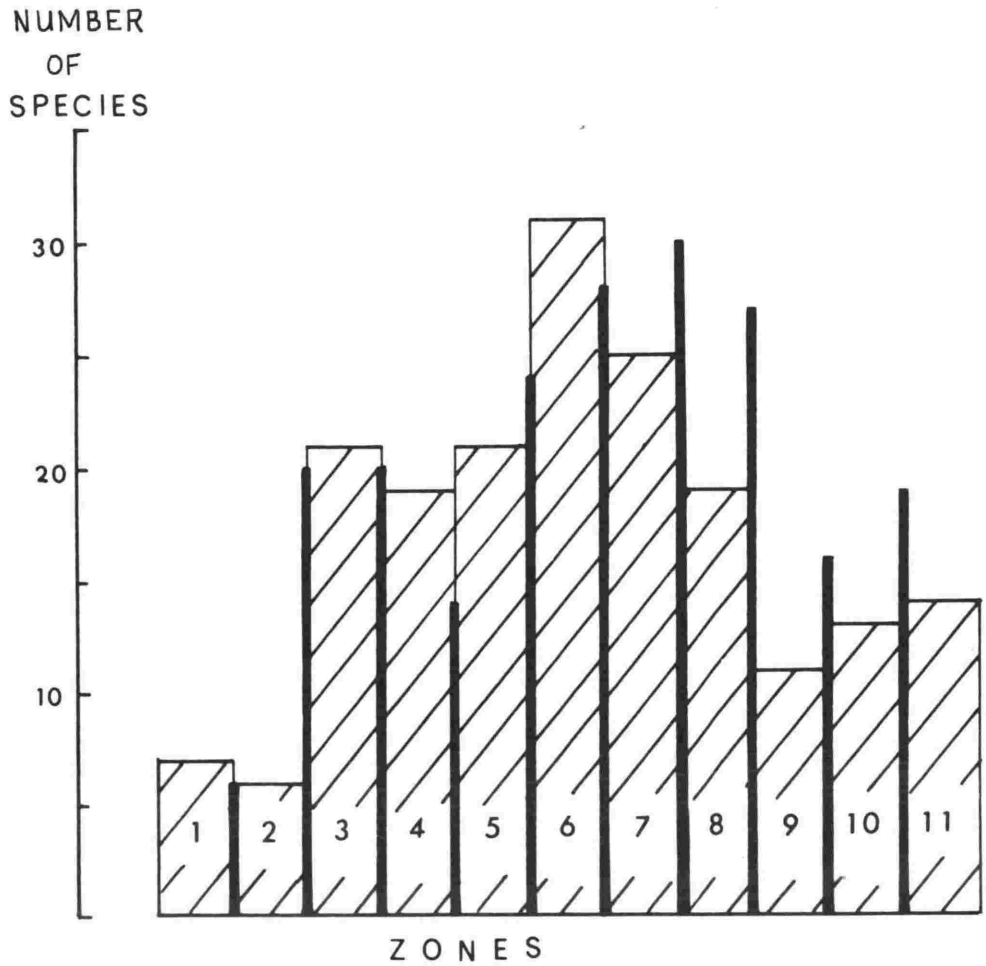


Fig.9. Faunal diversity (cross-hatched) and faunal change (heavy lines) in graptolite zones of the Aorangi Mine and Wangapeka areas. Faunal diversity is measured by the total number of species (and subspecies) in each zone; faunal change between two adjacent zones is measured by the sum of the number of outgoing species in the older zone and the number of incoming species in the younger zone.

and Pterograptus? sp.nov. - the only dichograptids - together with Cryptograptus schaferi, Climacograptus brevis, C.cf. riddellensis, and Glyptograptus cf.teretiusculus siccatus are confined to the zone. Glossograptus hincksii makes its first appearance, while the dichograptids make their last appearance. Small, poorly preserved diplograptids are particularly abundant in the lower part of the zone.

The well known "Cobb bed" in Cobb Valley contains the equivalent zone, described by Keble and Benson (1929) and by Skwarko (1962) as the "Glyptograptus teretiusculus zone". The earliest zone in the Cobb sequence, it does not contain Diplograptus? decoratus and probably corresponds to the upper part only of the Aorangi Mine zone. Paraglossograptus etheridgei is present (Skwarko 1962), extending its zonal range from that known at Aorangi Mine, but the common fossils, including Cryptograptus schaferi, Glossograptus hincksii and Glyptograptus teretiusculus agree well with the zonal assemblage at Aorangi Mine.

10. Zone of Dicellograptus.

The base of zone 10 is marked by the first appearance of Dicellograptus, the top is undefined. The best exposures are in the true right tributary of Slaty Creek upstream from locality S2/575 and in Paturau River and its western tributaries. The zone is most fossiliferous at localities S2/575, S2/592, in tributaries of Slaty Creek, and at S3/526

in Paturau River. Its thickness is of the order of 2000ft.

Dicellograptus appears with a 'burst' and is represented by mainly small forms, such as D.sextans exilis, in the lower part of the zone. Dicranograptus nicholsoni and Nemagraptus gracilis are sparsely represented, being confined to the upper part of the zone, while diplograptids are abundant throughout, and include Climacograptus spp., Glyptograptus cf.teretiusculus, Amplexograptus cf.confertus, and numerous unidentifiable forms. Pseudoclimacograptus, Retiograptus geinitzianus, and Amplexograptus cf.confertus are rare and confined to the zone.

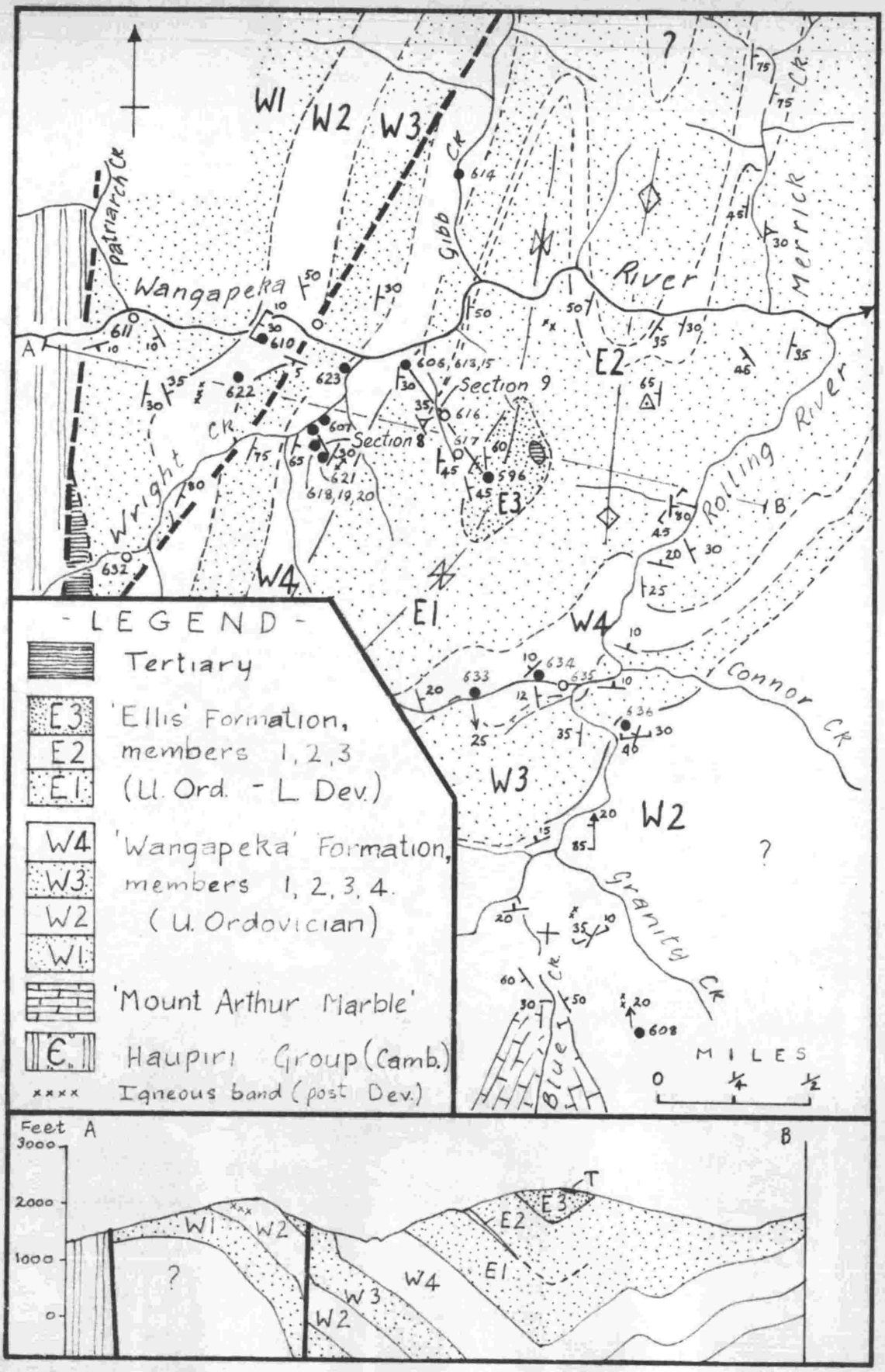
The zone is equivalent to the Nemagraptus gracilis zone of Cobb Valley (Skwarko 1962) though N.gracilis itself is uncommon in the Aorangi Mine area. Dicellograptus sextans, D.sextans exilis, D.cf.intortus, and Dicranograptus cf. nicholsoni all make their first appearance in this zone in the Cobb sequence, as at Aorangi Mine. Azygograptus, reported to be abundant at Cobb Valley by Skwarko (1962), is unaccountably absent at Aorangi Mine.

3. WANGAPEKA

Introduction.

Paleozoic fossils were first reported in the Wangapeka Valley area by Henderson, Grange and Macpherson (1924 :4-5), who noted poorly preserved graptolites in boulders in Nuggety Creek and in Wright Creek. Phyllite boulders with poorly preserved graptolites were found in Wangapeka River, one mile downstream from Rolling River by H.W.Wellman and the writer in 1962. In 1966 outcrops of dark argillite with relatively well preserved graptolites were found in the valley side south of Wangapeka River, 10 chains downstream from the mouth of Wright Creek by G.T. Hancox and A.J.Wright (Victoria University). A few miles to the south at Mt Owen, a graptolite collection from argillites was recorded as probably Eastonian in age by Johnston, Laird and Skwarko (1965). The writer visited the area during 1966-7 and collected graptolites from many localities in the valleys of the Wangapeka River, Rolling River, and Wright Creek. An area of about 8 square miles including part of the Wangapeka and Rolling River Valleys has been mapped (fig.10). The base map is an enlargement of N.Z.M.S.1 S19, 1:63,360 (1963 edition), modified by pace and compass traverses. Topography is particularly steep and relief is about 2000ft; outcrops are widely spaced and few stratigraphic sections can be measured.

Fig.10. Sketch map and cross-section of the Wangapeka River - Rolling River area showing hard rock geology. Fossil localities are indicated by solid circles, derived fossils by open circles; they are accompanied by their sheet (S19) fossil record number. Inferred faults are represented by heavy broken lines. The locations of the measured sections, 8~~a~~ and ~~8b~~ 9 (appendix II) are indicated. Dip, and cleavage symbols as in map 1, lineation indicated by arrows.


W1
W2
W3
W4
E1
E2
E3
Wangapeka
River
Patriarch Ck
Gibb Ck
Merrick Ck
Wright Ck
Rolling River
Connor Ck
Granity Ck
Blue Ck
Section 8
Section 9
A
B
- LEGEND -
Tertiary
'Ellis' Formation, members 1, 2, 3 (U. Ord. - L. Dev.)
'Wangapeka' Formation, members 1, 2, 3, 4. (U. Ordovician)
'Mount Arthur Marble'
Haupiri Group (Camb.)
Igneous band (post Dev.)
MILES
0
1/4
1/2
Feet
3000
2000
1000
0
T

The following stratigraphic sequence is therefore based on mapped sequences rather than on measured sections, and is tentative.

Stratigraphy.

Four broad lithologic units are recognised in Paleozoic rocks. The oldest unit lies to the west of the Wangapeka Fault; it was mapped by Grindley (1961) as Haupiri Group of Cambrian age and is not considered further. The remaining three units range from Upper Ordovician to Devonian in age and are tentatively equated with the Wangapeka, Ellis and Mt Arthur Marble formations of Grindley (1961).

Approximate thickness, fossils and age of formations and their members are summarised below. Names listed with an asterisk (*) are informal.

Mount Arthur Marble.

The marble which forms much of the Mount Owen massif, extends northwards into the mapped area in Blue Creek. Grindley (1961) mapped the marble as Mount Arthur Marble, equating it with marble and limestone at Mount Arthur, Pikikiruna Range and Takaka Valley. Definition of Mount Arthur Marble, as used here, is discussed in the following chapter.

Table V. Lithostratigraphic units of the Wangapeka Valley area.

Formation	Member	Thickness (ft) (approximate)		Fossils	Age
Ellis	E3*	200-250	1500 - 1600	corals, crinoids, brachiopods, bivalves, trilobites	Lower Devonian
	E2*	0-50		-	Silurian?
	E1*	1300		crinoid fragments	
Wangapeka	W4*	820	1970 - 2170+	graptolites zone 11	Eastonian-?Bolindian
	W3*	550		-	(Eastonian)
	W2*	600		graptolites zone 11	Eastonian
	W1*	0-200+		-	upper Gisbornian to lower Eastonian?
Mt Arthur Marble	-	1000+	1000+	-	Gisbornian to lower Eastonian?
	TOTAL	4470 - 4700+			

In Blue Creek the marble is fine-grained, light grey, hard and massive and is unfossiliferous. The total thickness of the formation is unknown, but it is likely to be thousands of feet. No fossils are known from marble in the Mount Owen area, but because it conformably underlies Wangapeka Formation it is thought to be probably Gisbornian to possibly lower Eastonian in age.

Wangapeka Formation.

Original description. Grindley (1961) erected the Wangapeka Formation with the statement - "the Mount Arthur Marble is overlain by dark argillites with interbedded quartzitic sandstone and rare limestone bands. Argillites predominate in the south [Wangapeka Valley area] and graded quartzitic sandstone in the north [Takaka and Waingaro Valleys] ..... Because the formation conformably underlies Lower Devonian rocks in Wangapeka Valley and overlies the Upper Ordovician Mount Arthur Marble it is considered to represent the Silurian Period." Type section, since designated by Grindley (in press), is Ellis River, a tributary of Baton River, about 15 miles to the north. Rocks mapped as Wangapeka Formation by Grindley extend discontinuously northwards from Wangapeka Valley for 45 miles, to Parapara River, and outcrop in the Takaka Valley area.

Definition and content. In Wangapeka Valley, dark carbonaceous argillites are interbedded with massive and

thick-bedded quartzites which resemble Grindley's (1961) overlying Ellis Formation and the position of the boundary

erous, but underlies Eastonian beds of member W2 and is thought to be lower Eastonian or upper Gisbornian in age.

Member W2. Dark blue-grey cleaved argillite and black slate overlie quartzite of member W1 in Wangapeka Valley, half a mile downstream from Patriarch Creek, and directly overlie Mount Arthur Marble in Blue Creek and Nuggety Creek. Thin bands of quartzite, muddy sandstone and calcareous argillite outcrop in Blue Creek near the base of the member which is about 600ft thick. Thin doleritic sills or flows outcrop on the Mount Owen track and on the ridge between Wright Creek and Wangapeka River.

Graptolites representing the lower part of zone 11 were found at localities S19/610,611,622,624, and 632 and indicate an Eastonian age for the member.

Member W3. Muddy sandstone and massive quartzite of member W3 overlie dark argillite of member W2 in Wangapeka Valley, a quarter of a mile upstream from Wright Creek, and in Rolling River, a quarter of a mile south of Connor Creek. The member is well exposed in the western bank of Rolling River (fig.11a), where the following section is seen.

Member W3	Feet
massive and thick bedded quartzite	50+
not exposed	ca80
massive quartzite with relict cross-bedding?	ca120
alternating bands of sandstone and argillite	25
dark argillite with thin quartzite bands	10
bedded quartzite with argillite bands and lenses (fig.12b)	29
massive quartzite	10
not exposed	c150
total,W3	c474

Member W2	
black argillite	50+
total,W2	50

Scree material on the Rolling River road derived from the member, contains distinctive boulders of dark, mottled, arkosic sandstone with irregular lenses and flakes of argillite. On the ridge between Wright Creek and Wangapeka River, pale massive quartzite has been extensively brecciated probably by the fault inferred to lie near Wright

Creek and Gibb's Creek. The member is unfossiliferous but is interbedded with the Eastonian members W2 and W4 and is therefore Eastonian in age. Total thickness is about 550ft.

Member W4. Dark graphitic argillite and slate overlies quartzite of member W3 in Wangapeka Valley near Wright Creek, and in Rolling River near Connor Creek, and comprise the youngest beds of the Wangapeka Formation. In Wright Creek thin calcareous bands and sandstones occur in the upper part of the member which is otherwise fairly uniform in composition.

Total thickness is about 820ft. A measured section through the upper part of the member in the valley of Wright Creek is given in appendix II.

The member contains abundant graptolites at several localities but preservation is generally poor.

Graptolites from the following localities represent the upper part of zone 11 and indicate an Eastonian to possibly Bolindian age for the member.

S19/606	S19/614	S19/621
607	615	623
608	618	633
609	619	634
613	620	635

Fig.11a. Contact between massive quartzites of member W3 (forming cliffs) and bedded siltstone and argillite of member W2 (showing just above bush), Wangapeka Formation, in Rolling River valley near Connor Creek.

Fig.11b. Minor contortion in dark argillites of member W2, Wangapeka Formation, in Rolling River valley, near Connor Creek.

Fig.11a

Fig.11b

Fig.12a. Section cut normal to bedding in hand specimen of muddy sandstone showing animal scour marks. Ellis Formation, member E1 on ridge between Rolling River and Wangapeka River.

Fig.12b. Thin, dark, argillite bands, interbedded with massive and bedded quartzite, in the base of member W3, Wangapeka Formation, in Rolling River valley near Connor Creek.

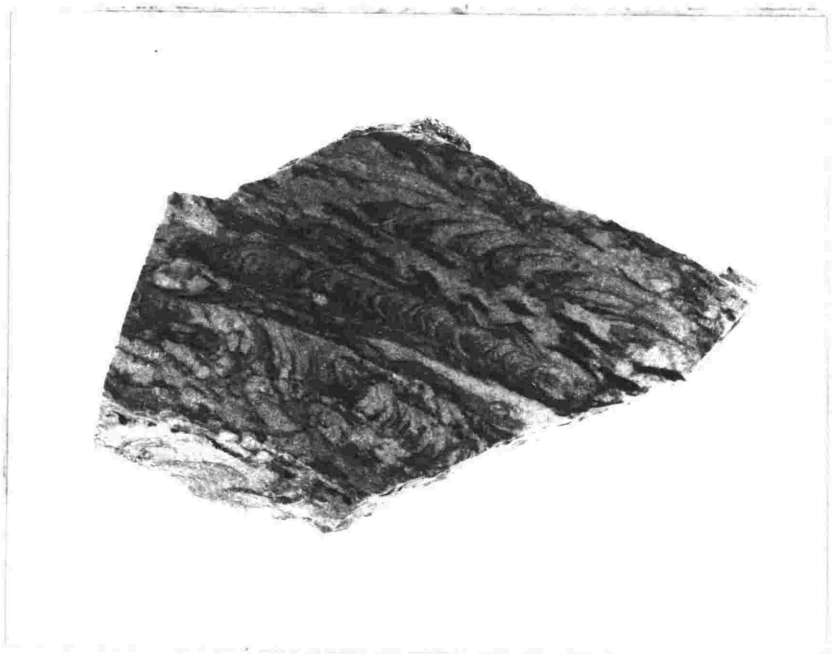


Fig. 12a

Fig. 12b

Relationship to underlying rocks. In Blue Creek, thin-bedded quartzite and argillite of member W2 are probably conformable with Mount Arthur Marble but order of superposition is not clear. In Nuggety Creek marble and argillite are in conformable contact but again, order of superposition is uncertain (D.S.Ker, pers.comm.). The two units are probably in part laterally gradational but from the strike of the contact in the region of Nuggety and Blue Creeks, together with the attitude of beds within member W2 near the contact, it is most likely that the member largely overlies the Mount Arthur Marble, the line of contact undulating in a series of northerly-plunging folds. Northerly plunge of two mesoscopic fold axes in the lower part of member W2 near the marble contact support this interpretation.

In Wangapeka Valley member W2 is underlain by member W1; member W1 is thus the stratigraphic equivalent of the Mount Arthur Marble in Blue Creek. Several authors have commented on the lensoidal nature of the Mount Arthur Marble elsewhere (see Fleming 1959 :247), and Johnston (in press) has mapped interdigitation of marble and quartzite in the Mount Arthur area, 15 miles to the north, where Mount Arthur Marble passes laterally into a non-calcareous facies.

Ellis Formation.

Original description and definition. Grindley (1961) erected the Ellis Formation as follows: "in the Wangapeka and Baton Valleys thick-bedded quartzites with thin beds of argillite contain brachiopods, corals, and crinoids of Lower Devonian age." The type area, subsequently designated by Grindley (in press), is Ellis Creek. As discussed above, the Ellis Formation is here restricted to the massive quartzites and sandstones which overlie dark carbonaceous argillite of the Wangapeka Formation between Rolling River and Wangapeka River. Three informal members are recognised and range in age from uppermost Ordovician? to Lower Devonian.

Member E1. The base of the member, and of the Formation is defined by the base of a 300ft thick band of pale-coloured, massive quartzite which forms prominent cliffs in the south side of Wangapeka Valley at the mouth of Wright Creek. The massive quartzite is overlain by 1000ft of predominantly quartzitic beds, the whole sequence comprising member E1. A measured section through the member in the south side of Wangapeka Valley is given in appendix II (section 9).

Siliceous and arkosic mottled sandstone with muddy streaks and bands a few millimetres thick, are common in the middle and upper parts of the member, and are interbedded with graded beds in Merrick Creek, and with current-bedded and calcareous sandstone in the measured section in Wangapeka Valley. Animal borings and scour marks are

particularly common (fig.12a).

Several boulders of leached calcareous sandstone containing fragments of crinoids and other indeterminate fossils were found in a small southern tributary of the Wangapeka, a quarter of a mile downstream from Wright Creek (localities S19/616,617), and were probably derived from member E1. Elsewhere fossils are unknown. Because the member conformably underlies member E3 of probable Lower Devonian age and conformably overlies Eastonian to ?Bolindian Wangapeka argillite (see below) it is thought to represent the upper Bolindian stage and the entire Silurian system, and thus to indicate a relatively long period of slow deposition. There are no continuous fossiliferous sections however, and the possibility of undetected disconformities remains.

Member E2. A band of strongly cleaved, pyritic, dark argillite outcrops at several localities on the Wangapeka track, between Rolling River and Wright Creek, and in Merrick Creek. The band is about 50-100ft thick and apparently thins to the south as it was not seen in the measured section (section 9) in Wangapeka Valley. It lies within the quartzites and sandstones of member E1 but is easily distinguished by its argillitic composition. The member is unfossiliferous, its age lies within the age range of member E1 - upper Bolindian or Silurian.

Member E3. The youngest member of the Ellis Formation comprises dark, thin-bedded shale overlain by bedded quartz sandstone and grit, and muddy calcareous sandstone, in all about 200-250ft thick. The beds are confined to a small area on the ridge crest between Wangapeka and Rolling Rivers, and occupy the core of a syncline. The attitude of beds within the member are concordant with those in the underlying member E1, and the two members are thought to be conformable.

Henderson, Grange and Macpherson (1924) collected fossils at several localities of which S19/596, on the ridge between Rolling River and Wangapeka River, lies within the mapped area. Corals, crinoids, brachiopods, molluscs, and trilobites, suggest a Gedinnian (basal Devonian) age (Wright 1967).

Relationship to underlying rocks. The base of the Ellis Formation is well exposed on the Rolling River Valley road, half a mile north of Connor Creek. Massive and thick-bedded Ellis quartzite passes down through a 10-20ft thick transition zone of 1ft beds of quartzite interbedded with 4-inch bands of argillite, to dark phyllitic Wangapeka argillite. In the south side of Wangapeka Valley near Wright Creek, member E1 concordantly overlies argillite of the Wangapeka Formation, though the actual contact is not exposed.

Structure.

Ordovician to Devonian strata form a relatively open, northeasterly-trending, synclinal structure which is folded in smaller, north-trending folds (fig. 10). South of the Wangapeka River folds plunge to the north while north of Wangapeka River they apparently plunge to the south, suggesting that they may have been cross-warped.

Although folds are relatively open, and steeply-dipping beds are rare, most rocks are strongly deformed in both hand specimen and outcrop scale. Argillites are commonly sheared and generally strongly cleaved, sometimes with finely contorted bedding. Mesoscopic folds and associated congruous drag folds are common. Quartzites are invariably fractured and commonly brecciated. Age of the folding and of smaller scale deformation is unknown.

The only major fault mapped is that inferred to separate the Cambrian Haupiri Group from Ordovician rocks, the nature of fault movement being unknown. A thin wedge of in-faulted mid-Tertiary beds in Wright Creek indicates that at least some fault movement has occurred since the mid-Tertiary. Minor normal faults too small to show in fig.10, with a throw of two to ten feet were seen at several localities and are probably common throughout the mapped area. The inferred fault in Wright and Gibb's Creeks is apparently accompanied by relatively minor off-setting but is probably associated with the brecciation of quartzite

beds on the spur between Wright Creek and Wangapeka River.

East of Rolling River, dark argillites of the Wangapeka Formation are weakly to moderately spotted and contain quartz veins up to three inches thick, both features probably being associated with the emplacement of the Separation Point Granite which outcrops 2 miles east of Rolling River.

Paleontology.

Diagnostic Paleozoic fossils comprise two groups : Upper Ordovician graptolites of the Wangapeka Formation, which constitute graptolite zone 11, and shelly fossils of the Ellis Formation.

Zone 11. Zone of *Orthograptus*. The base of the zone is taken at the first appearance of *Orthograptus*; the top is undefined, the youngest beds passing upwards into barren quartzites. Unfortunately no continuous sections through the zone are known, but the upper part is well exposed in the east bank of Wright Creek (section 8, appendix II).

Dicranograptus cf.*hians*, *Dicellograptus patulosus*, *Climacograptus caudatus*, *C.hastatus*, *C.tubuliferous*, *Orthograptus truncatus pauperatus*, *O*.sp.ex gr.*calcaratus* and large forms of *Orthograptus* are all confined to the zone. *Dicellograptus* cf.*sextans* and *D.intortus* are known from zone 10 of the Aorangi Mine area; *Leptograptus* and *Climacograptus bicornis* were recorded by Keble and Benson

(1929 :844-6) from the Cobb Valley - Mount Arthur area, in beds which probably correlate with zone 10.

In Australia (Thomas 1960), North America (Berry 1960) and Britain (Elles 1925), large orthograptids and climacograptids are first abundant in beds younger than those containing Nemagraptus gracilis, and the Orthograptus zone (11) is here considered to be younger than zone 10 (Dicellograptus and N.gracilis). It is separated from the nearest definite zone 10 correlatives, in Cobb Valley, by about 25 miles. The two zones have relatively few species in common and are only tentatively thought to be contiguous. Zone 11 is correlated with the Eastonian and possibly lower Bolindian stages of the Victorian Upper Ordovician (see chapter 5).

Between Wangapeka River and Rolling River zone 11 argillites are separated from Lower Devonian quartzites by approximately 1500ft of mainly quartzose sediments (member E1) from which no diagnostic fossils are known, and of which, part or all is inferred to represent the Silurian Period.

Lower Devonian. Corals, crinoids, brachiopods, molluscs and trilobites are known from locality S19/596 in Ellis quartzite on the ridge between Wangapeka and Rolling Rivers. The brachiopod Conchidium sp., of Shirley (1938) is now known to be Notoconchidium, suggesting that the beds are Gedinnian (Lower Devonian) in age (Wright 1968 :635). They are thus

probably slightly older than the more richly fossiliferous Baton River argillites to the north which are upper Siegenian or lower Emsian in age (Wright 1967 ~~Gill et al 1966~~).

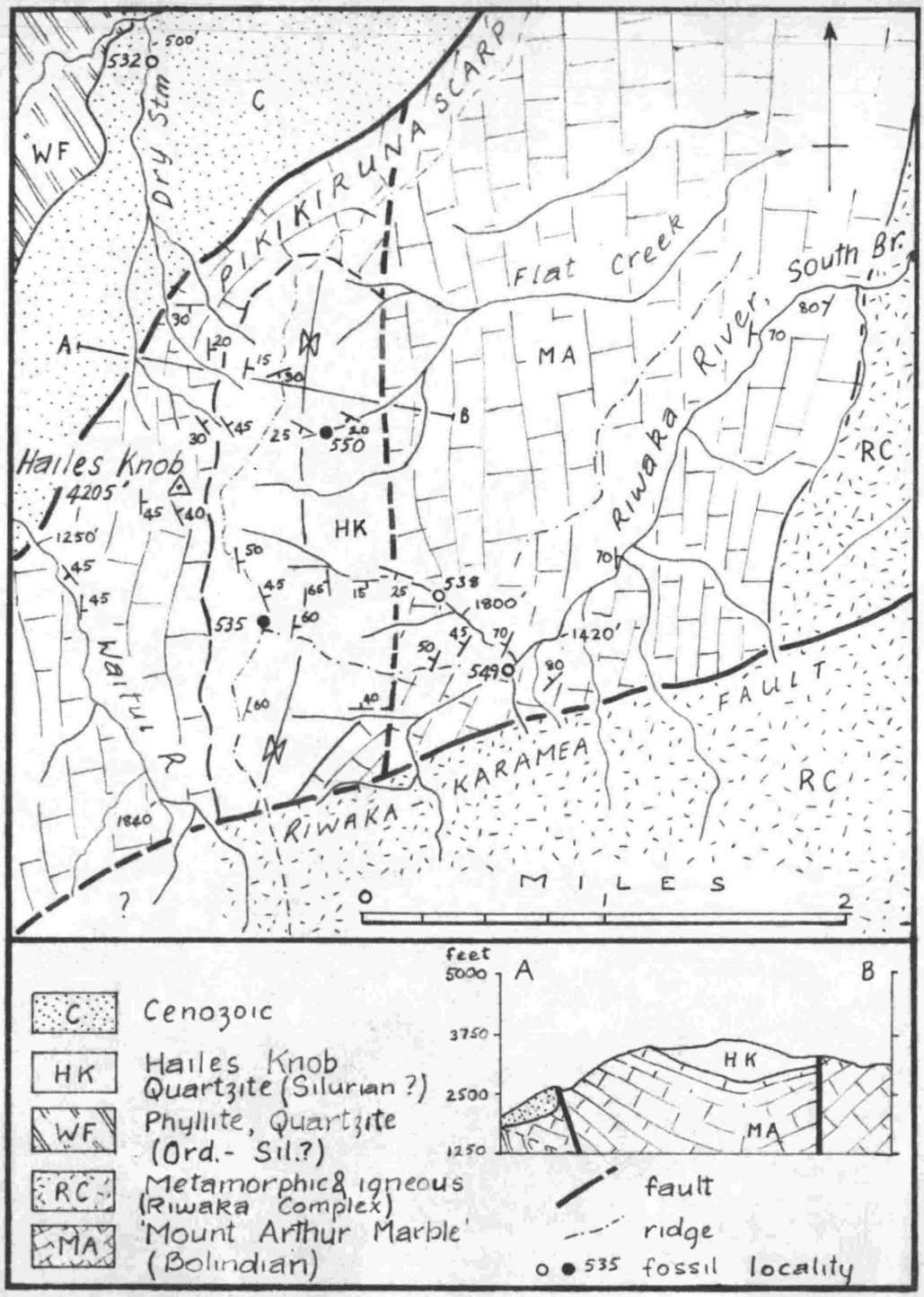
4. HAILES KNOB.

Stratigraphy.

Fossiliferous quartzite overlying Mount Arthur Marble at Hailes Knob (4205ft), near Upper Takaka, was first reported by Cooper (1965) who recorded brachiopod fragments on the ridge southeast of Hailes Knob. The area was briefly re-examined during the present work and a second fossil locality found, in the headwaters of Flat Creek. The geology of the area is shown in a sketch map (fig.13); the base map was constructed from vertical air photographs and ground traverses.

The best exposed and most accessible section through the marble and quartzite, and the only known exposure of the contact between the two formations, outcrops in the 2000ft high Pikikiruna scarp, in the headwaters of Dry Stream, one mile north of Hailes Knob. Less well exposed, and less accessible sections through the quartzite outcrop in the headwaters of Flat Creek, and on the ridge southeast of Hailes Knob. A measured section through the upper part of the limestone and through the full thickness of quartzite, exposed in Dry Stream, is given in appendix II (section 7) and is correlated with other Northwest Nelson sections in fig.15.

Fig.13. Sketch map from aerial photographs (4019/10,11) of the Hailes Knob area showing distribution of Hailes Knob Quartzite. Fossil localities are shown by solid circles, derived fossils by open circles; they are accompanied by the sheet (S13) fossil record number. The Hailes Knob column in fig.15 is constructed from outcrops between fossil locality S13/550 in the headwaters of Flat Creek, and the headwaters of Dry Stream, one mile to the west. The measured section (section 7, appendix II) is exposed in the headwaters of Dry Stream, ½ mile north of Hailes Knob Trig station. Spot heights are from the geological map of the Motueka subdivision (Henderson, Grange and Macpherson, 1959).


PIKIKIRUNA SCARP
Dry Stm
Flat Creek
South Br.
Riwaka River
Hailes Knob
4205'
HK
MA
RC
WF
C
Waitui R
RIWAKA
KARAMEA
FAULT
MILES
0
1
2
feet
5000
3750
2500
1250
A
B
C Cenozoic
HK Hailes Knob Quartzite (Silurian ?)
WF Phyllite, Quartzite (Ord.- Sil.?)
RC Metamorphic & igneous (Riwaka Complex)
MA 'Mount Arthur Marble' (Bolindian)
fault
ridge
o ● 535 fossil locality

Mount Arthur Marble.

The name "Mount Arthur Marble" has been generally applied by most previous workers to limestones and marbles of Northwest Nelson thought to be of Ordovician age. Wright (1968) has shown that limestones mapped as Mount Arthur Marble range in probable age from early Lower Ordovician at Mount Patriarch to late Upper Ordovician at Hailes Knob, and most probably represent more than one formation. The name Mount Arthur Marble is therefore restricted here to the massive marble and limestones forming Mount Arthur, the Pikikiruna Range and western Takaka Valley, and the Mount Owen massif.

At Hailes Knob at least 1000ft of black, fine-grained graphitic limestone with interbedded muddy and micaceous layers is exposed. Residues of acid solution samples commonly contain euhedral pyrite crystals. Interlaminar folding and contorted bedding are common at several horizons and fossiliferous boulders in Dry Stream derived from the formation are commonly strongly distorted and rarely cleaved. The beds have clearly undergone severe internal deformation, and the original thickness of the formation has probably been considerably altered. Base of the formation is not exposed.

Crinoid stem fragments are particularly common throughout the limestone, and poorly preserved tabulate corals and sponges are known from boulders (Cooper 1965). The limestone was equated by Cooper with that at Sam Creek, six

miles to the north, where the corals Plasmoporella cf. inflata Hill, Proheliolites goldfussi (Billings), and Favistella alveolata (Hall) suggest an uppermost Ordovician age (Bolindian). Limestone boulders derived from Hailes Knob contain the conodonts Scolopoda, Prioniodina cf. macrodentata, Ozarkodina, Cyrtoniodus cf. complicatus and Belodina (Wright 1968) suggesting a late Caradocian or Ashgillian (Bolindian) age. The limestone is therefore considered to be Bolindian at least in part, and may contain younger beds.

Hailes Knob Quartzite.

The name Hailes Knob Quartzite was proposed by Cooper (1965) for "grey quartzite and sandy slate overlying black limestone near Hailes Knob". The Formation is confined to the core of a small syncline and is fault-bounded to the east and south. Type section is exposed on the ridge leading southeast from Hailes Knob.

Massive and well bedded quartz sandstone and quartzite with rare phyllitic and argillaceous bands are exposed in the headwaters of Dry Stream. Near the top of the section the quartzite is strongly brecciated and contains lenses and pods of calcareous sandstone and grit (the "tuffaceous sandstone" of Cooper 1965), 3-6ft long. In the headwaters of Flat Creek a similar lens contains poorly

preserved fragments of brachiopods, corals and crinoids (S13/550). Argillitic beds and animal-bored muddy sandstones are more common in the ridge leading southeast from Hailes Knob. The horizon represented by the brachiopod locality S13/535 on the ridge is close to, or overlies, that of locality S13/550.

The base of the Formation is exposed in the headwaters of Dry Stream. Graphitic blue-grey Mount Arthur limestone passes conformably up into black phyllite and spotted argillite with calcareous bands overlain by well bedded quartzitic sandstone with mudstone flakes and calcareous bands, of the Hailes Knob Quartzite.

The brachiopod fragments include "ventral moulds of a plicate pentamerid" (A.J.Wright, pers.comm.). Pentameracea range from Upper Ordovician to Upper Devonian. Because Hailes Knob Quartzite conformably overlies Mount Arthur Marble which is uppermost Ordovician in part, it is thought to be probably Silurian in age.

Fig.14a. Interbedded quartzites and thin, sheared argillites near the base of the Hailes Knob Quartzite in the headwaters of Dry Stream. The contact with Mount Arthur Marble is exposed in the bed of Dry Stream to the left.

Fig.14b. Thick bedded quartzites dipping from upper left to lower right with a calcareous lens (beneath hammer) oriented normal to bedding. Upper part of Hailes Knob Quartzite, headwaters of Dry Stream.

Fig. 14a

Fig. 14b

5. NEW ZEALAND GRAPTOLITE ZONES

Previous divisions.

Previous correlations of New Zealand graptolite faunas are shown in two charts, which relate New Zealand sequences to the Victorian stages of Thomas (1960). In the first, fig.16, the ages are those the assemblages were considered to have when first described; in the second, fig.17, the ages have been revised in the light of present knowledge.

Sequences of two or more graptolite zones have previously been described from Preservation Inlet and Cape Providence in Southwest Otago, and from the Aorangi Mine area and the Cobb Valley - Mount Arthur area in Northwest Nelson, more than 430 miles to the north (fig.1). The two regions lie on opposite sides of the Alpine Fault and the distance between them is reduced to about 160 miles if the clockwise transcurrent offset of 300 miles along the Fault since the Jurassic (Wellman 1956) is allowed for.

Small collections of Lower Ordovician graptolites from Cape Providence, Preservation Inlet and the Aorangi Mine area were listed or described by several authors from 1879 to 1927 (see Benson et al 1936 :358-364). Their similarity with Victorian faunas was recognised (Hector 1879, Hall 1915a) and ages were determined by direct correlation with the Victorian sequence.

The first attempt at an over-all New Zealand zonal subdivision was that by Keble and Benson in 1929, and incorporated fossils from Southwest Otago, the Aorangi Mine area, and the Cobb Valley - Mount Arthur area. Five zones were distinguished: the Preservation, Golden Ridge, Douglas, Lodestone and Leslie zones in upward succession (see fig. 16). Several zones were subdivided, eight subzones being proposed.

The oldest zone, Preservation, was based on a single fauna from Preservation Inlet, described by Hall (1915b), and correlated with the L3 (now the La2) zone of Victoria. Although no younger fossils were known from the zone, it was considered to also comprise upper Lancefieldian and Bendigonian stages, including what is now termed in Victoria, lower Chewtonian, and to be contiguous with the following zone, Golden Ridge. The Golden Ridge zone was based on faunas at Cape Providence and at Aorangi Mine and was correlated with the whole of the Victorian Castlemainian stage, including what is now the upper Chewtonian. Subsequent work on the Southwest Otago sequence is discussed in the following section.

The three upper zones - Douglas, Lodestone and Leslie - were based on graptolites from several localities in the Cobb Valley - Mount Arthur area. The oldest, Douglas, was represented by the Cobb Bed graptolites which were correlated with the Ba67 fauna of Victoria, now known as upper Darriwilian (D4). Although older Darriwilian and Yapeenian

age fossils were unknown, the Douglas zone was considered to extend from the top of the preceding Golden Ridge zone. The overlying Lodestone zone was composed of graptolite-bearing beds at Flora Track, Mount Peel and Lodestone Peak and was correlated with what is now known as the Gisbornian stage. The youngest zone, Leslie, was represented by a single fauna from Leslie River and was thought to be Eastonian in age. Conformity of the Mount Peel and Cobb Beds was supported by field evidence, but the stratigraphic position of other localities was based on correlation of their fossils with those of the Victorian sequence (Keble and Benson 1929 :848). Thus, although New Zealand zone names were used, the succession of zones was largely determined by comparison with that of Victoria.

Following the discovery of more complete sequences at Southwest Otago and Aorangi Mine, Benson et al (1935,1936) abandoned the 1929 zone nomenclature in favour of that used in Victoria. Victorian zones and stages have since been revised by Harris and Thomas (1938b) and Thomas (1960) and are used accordingly below.

The Cobb Bed thus comprised the upper Darriwilian (D4) or Glyptograptus teretiusculus zone, the Mount Peel and Lodestone beds comprised the lower Gisbornian or Nemagraptus gracilis zone, and the Flora Track bed was grouped with the Leslie River bed to comprise the upper Gisbornian, or Climacograptus bicornis zone. The zone fossils

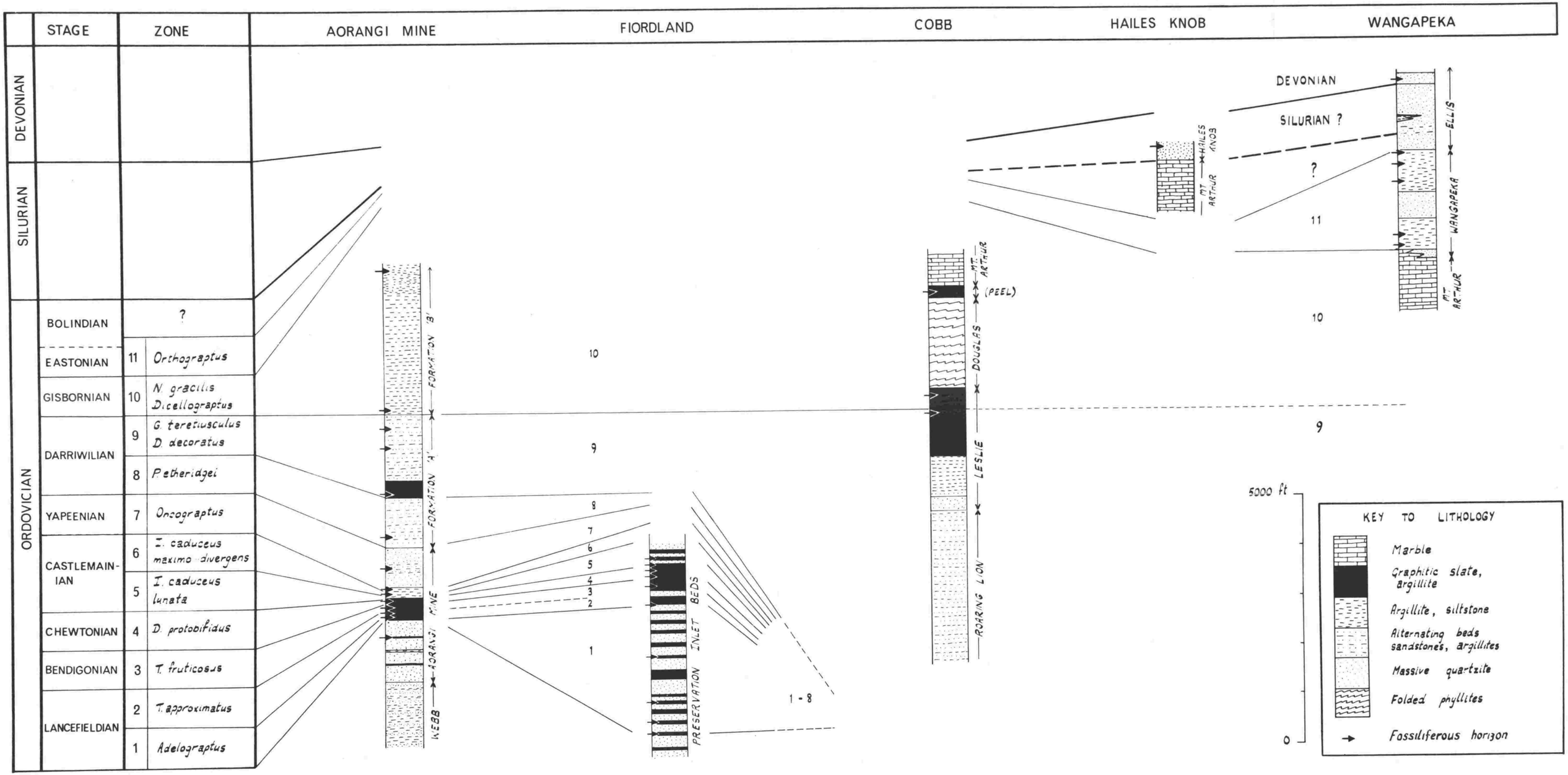
of the first two zones were unknown in New Zealand, and correlation was uncertain.

Nothing new was published on New Zealand graptolites for over 30 years. Then, in 1962, Skwarko described new collections from the Cobb Valley - Mount Arthur area. Glyptograptus teretiusculus was recognised in the Cobb Bed, confirming Benson and Keble's correlation with the G.teretiusculus zone of Victoria. Nemagraptus gracilis was discovered in strata stratigraphically inbetween the Cobb and Mount Peel Beds, thus establishing the new lower Gisbornian, or N.gracilis zone. The Mount Peel and Lodestone beds contained "no restricted zone species" and were listed as "middle Gisbornian". The Flora Track and Leslie River beds were not re-examined by Skwarko (1961 :217).

A small graptolite collection from Mount Owen, was listed by Johnston, Laird and Skwarko in 1965. Dicellograptus aff.divaricatus, D.aff.clingani, Climacograptus cf.bicornis, C.cf.exiguus and Retiograptus? sp.nov. were assigned a "probable Eastonian" age.

Most recently, Smith (1966) made a number of new collections in the Aorangi Mine area. One assemblage (V1043) included Oncograptus upsilon, and was referred to the Yapeenian (Ya1) of the Victorian sequence.

Fig.15. Correlation of New Zealand fossiliferous Ordovician sequences. Aorangi Mine, Hailes Knob, and Wangapeka columns compiled from data presented with this paper; Fiordland column from Benson and Keble (1935 :text-fig.1); Cobb column from Skwarko (1958, unpublished thesis held by Geology Dept., Victoria University of Wellington) and Grindley (1961). Indicated thickness of Cobb formations approximate.


STAGE
ZONE
AORANGI MINE
FIORDLAND
COBB
HAILES KNOB
WANGAPEKA
DEVONIAN
SILURIAN
ORDOVICIAN
BOLINDIAN
EASTONIAN
GISBORNIAN
DARRIWILIAN
YAPEENIAN
CASTLEMAINIAN
CHEWTONIAN
BENDIGONIAN
LANCEFIELDIAN
?
11 Orthograptus
10 N. gracilis D. cellograptus
9 G. teretiusculus D. decoratus
8 P. etheridgei
7 Oncograptus
6 I. caduceus maximo-divergens
5 I. caduceus lunata
4 D. protobifidus
3 T. fruticosus
2 T. approximatus
1 Adelograptus
FORMATION 'B'
FORMATION 'A'
AORANGI MINE
WEBB
PRESERVATION INLET BEDS
1 - 8
MT ARTHUR
(PEEL)
DOUGLAS
LESLIE
ROARING LION
HAILES KNOB
MT ARTHUR
DEVONIAN
SILURIAN ?
?
ELLIS
WANGAPEKA
MT ARTHUR
5000 ft
0
KEY TO LITHOLOGY
Marble
Graphitic slate, argillite
Argillite, siltstone
Alternating beds sandstones, argillites
Massive quartzite
Folded phyllites
Fossiliferous horizon

	Victorian Divisions			Keble and Benson, 1929		Benson and Keble, 1935,36.		Skwarko, 1958, 1961, 1962.		Smith, 1966. Johnston et al, 1965	This paper		
	Stage	Sub-stage	Zone		Zone								Zone
UPPER ORDOVICIAN	BOLINDIAN		Dicellograptus cf.complanatus										
			Pleurograptus linearis									Wangapeka Formation	
	EASTONIAN		Dicranograptus hians	Leslie River	LESLIE					Mt Owen (Johnston et al, 1965)			11
			Climacograptus baragwanathi										
	GISBORNIAN		Climacograptus peltifer	Flora Track	LODESTONE	Leslie River Flora Track		Mt Peel Lodestone			Formation B		
			Diplograptus multidens										10
			Nemagraptus gracilis	Mt Peel, Lodestone		Mt Peel, Lodestone		Cobb (upper)					
				Cobb Valley - Mount Arthur		Cobb Valley - Mount Arthur		Cobb Valley - Mt Arthur					
MIDDLE ORDOVICIAN	DARRIWILIAN	Da 4	Glyptograptus teretiusculus	Cobb Bed		Cobb Bed		Cobb (lower)			Formation A		9
		Da 3	Diplograptus decoratus										
		Da 2	Glyptograptus intersitus		DOUGLAS								8
		Da 1	G. austrodentatus										
LOWER ORDOVICIAN	YAPEENIAN	Ya 2	Cardiograptus										
		Ya 1	Oncograptus										7
	CASTLEMAINIAN	Ca 3	Isograptus caduceus maxima I. c. maximodivergens										6
		Ca 2	I. c. victoriae		Aorangi Mine	GOLDEN RIDGE					Aorangi Mine Formation		5
		Ca 1	I. c. lunata										
	CHEWTONIAN	Ch 2	I. c. primula Didymograptus protobifidus										
		Ch 1	D. protobifidus Tetragraptus fruticosus, 3-st.	Southwest Otago		Southwest Otago	Aorangi Mine	Southwest Otago	Aorangi Mine	Aorangi Mine (Smith, 1966)			4
	BENDIGONIAN	Be 4	T. fruticosus, 3-st.										
		Be 3	T. fruticosus, 3 & 4-st.										3
		Be 2	T. fruticosus, 4-st.			PRESERVATION							
		Be 1	T. fruticosus, 4-st.; Tetragraptus approximatus										
	LANCEFIELDIAN	La 3	T. approximatus										2
		La 2	"Bryograptus"										1
		La 1	Staurograptus and Dictyonema										

Fig.16. Chart of New Zealand Ordovician fossiliferous sequences arranged to show the ages, in terms of Victorian stages, adopted by previous workers. The Victorian zones are listed at left; those described by each author are indicated by a cross (x). Zones proposed by the writer are listed at right. The unshaded area signifies Victorian zones considered to be represented in New Zealand. The Victorian stages, substages and zones are as listed by Thomas (1960).

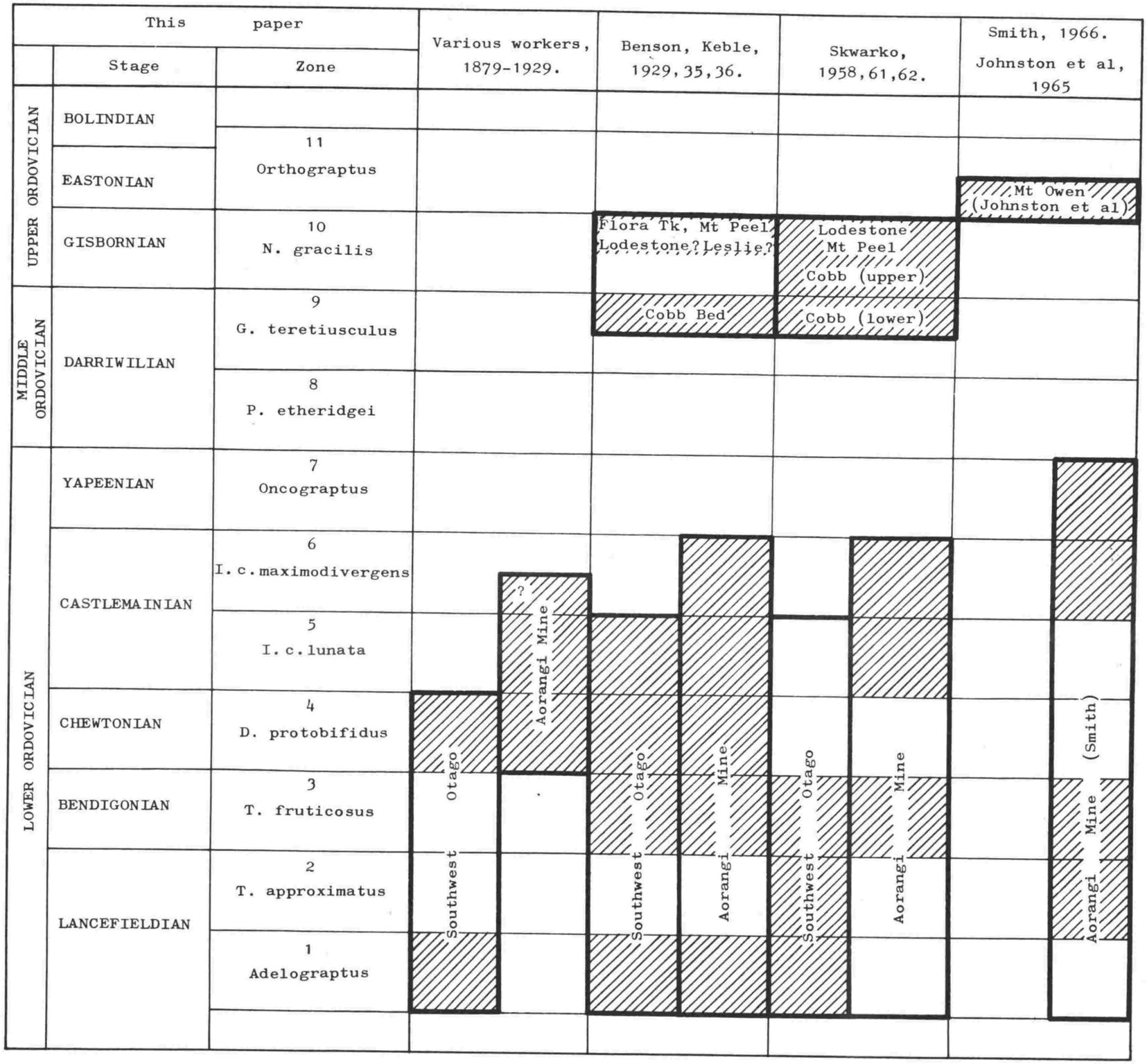


Fig.17. Chart as in fig.16, but arranged to show the ages of described "zones" (cross-hatched) in the light of present knowledge. Zones proposed in this paper are listed at left.

Zones (Benson, 1938)	La2 α				La2 β								Be1	Be4							Ch1							Ch2			Ch 3
Cape Providence	1	2	3	4			5						6							7	8		13/14		9	10	11			12	
Kisbee Bay						20				21	22	23	24																		
Coal Island									28							29	30				31								32		
Dictyonema macgillivrayi	·	X	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Clonograptus kingi	·	·	·	·	·	·	X	·	·	·	X	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
C.spp.	X	X	·	·	·	·	X	·	·	·	X	X	X	·	·	·	·	·	·	·	X	·	·	·	·	·	·	X	·	·	·
Adelograptus? antiquus	·	X	X	X	·	·	·	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
A. "hunnebergensis"	·	·	X	X	·	·	·	·	X	X	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
A. clarki & victoriae	·	·	X	·	X	X	·	·	·	X	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Goniograptus macer	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	·	·	X	·	·	·	·	·	·	·	·	·
Sigmagraptus laxus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	X	·	·	·	·	·	·	·	·	·	·	·
Tetragraptus acclinans	·	·	·	·	·	·	·	·	·	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
T. approximatus	·	·	·	·	·	·	·	·	·	·	·	·	X	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
T. bigsbyi	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
T. decipiens (4-st.)	X	X	X	X	·	X	X	·	X	X	X	X	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
T. fruticosus (4-st.)	·	·	·	·	·	·	·	·	·	·	·	·	X	X	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
T. fruticosus (3-st.)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	X	X	X	X	X	X	·	·	·	·	·	·	·	·	·	·
T. harti	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	X	·	X	·	·	·	·	·	X	·	·	·
T. pendens	·	·	·	·	·	·	·	·	·	·	·	·	·	X	·	X	X	X	X	·	·	·	·	·	·	·	·	·	·	·	·
T. whitelawi	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	·	X	·	·	·	·	·	·	·	·	·
Phyllograptus anna	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	·	·	·	·	·	X	·	·	·	·	·	·	·	·	·
P. angustifolius	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	X	·	·	·	·	X	·	·	·	·	·	X	·	X	X
P. ilicifolius	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	·	·	·	·	·	·	·	·	·	·	X	·
Didymograptus extensus	·	·	·	·	·	·	·	·	·	·	·	·	X	X	X	·	X	X	X	X	·	·	·	·	·	·	·	X	·	·	·
D. protobifidus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	X	X	X	·	·	·	·	·	·
D. similis	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	X	·	·	·	·	·	·	·	·	·	·	·	X	·	·	·
Isograptus caduceus primula	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X	X	·	·	·
I.c.lunata (?)	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	X
Equivalent Aorangi Mine zone	Zone 1												Z2	Zone 3													Zone 4				Z 5

Fig.18. Southwest Otago graptolites. Distribution of zonal species (heavy crosses) and other species useful for correlation with Aorangi Mine (light crosses) in collections made by Benson and Keble at Cape Providence, Kisbee Bay, and Coal Island. The zones distinguished by Benson (1938) are given at top, and equivalent Aorangi Mine zones are given at bottom. Fossil names are as revised in Part II of this thesis. (Data from Benson and Keble 1935, text-fig.1, tables I and II).

Correlation of New Zealand sequences.

The most complete graptolite sequence in New Zealand, that of the Aorangi Mine area, is correlated with fossiliferous sequences at Preservation Inlet, Cobb Valley, Hailes Knob and Wangapeka Valley (fig.15).

The graptolite sequence at Southwest Otago described by Benson and Keble in 1935 was determined from independent stratigraphic evidence at only three places - Kisbee Bay and Coal Island in Preservation Inlet, and south of the Arch Stack at Cape Providence. Fossiliferous horizons were shown in a composite stratigraphic column in text-fig.1 and are here reproduced in the same sequence in fig.18; the zones allotted by Benson and Keble are listed as in the revised list of Benson, 1938. The distribution of species regarded by Benson and Keble as zonal indicators is shown by heavy crosses, that of other useful correlation species, by light crosses. The equivalent Aorangi Mine zones are shown at the bottom of the figure.

The two oldest zones in Southwest Otago, La2a and La2b together extend from the oldest graptolites - Dictyonema, Adelograptus, Clonograptus, Tetragraptus decipiens - to the first appearance of Tetragraptus approximatus, and thus correspond to Aorangi Mine zone 1, Adelograptus. La2b is distinguished by the appearance "in abundance" of Adelograptus hunnebergensis and Clonograptus kingi. T.approximatus and T.fruticosus first appear together in the

collections made by Benson and Keble, and Aorangi Mine zone 2, T.approximatus, is apparently not represented. However, the zone was recognised by Skwarko in 1958 (as the Victorian zone La3) in a collection (GS7021) from north of the Arch Stack at Cape Providence, and its absence from the sequences described by Benson and Keble may well be due to insufficiently close sampling.

Benson and Keble's third and fourth zones together extend from the first appearance of T.fruticosus (4-stiped) to the first appearance of Didymograptus protobifidus and are thus equivalent to Aorangi Mine zone 3, T.fruticosus. The four-stiped variety of T.fruticosus is confined to the third zone - zone Be1 - and the three-stiped variety to the fourth zone - zone Be4.

The fifth and sixth Southwest Otago zones, Ch1 and Ch2, together range from the entry of D.protobifidus to the entry of Isograptus caduceus lunata and are equivalent to Aorangi Mine zone 4, D.protobifidus. Zone Ch2 is distinguished by the presence of I.c? primula.

In the Cobb Valley - Mount Arthur sequence the earliest zone, Glyptograptus teretiusculus, extends up to the incoming of Nemagraptus gracilis and Dicellograptus. It does not contain Diplograptus decoratus and corresponds to the upper part only of Aorangi Mine zone 9, D.decoratus. The common fossils, including Cryptograptus schaferi, Glossograptus hincksii and Glyptograptus teretiusculus agree well with those at Aorangi Mine.

The N.gracilis zone, with the zone fossil and abundant dicellograptids, corresponds to Aorangi Mine zone 10, Dicellograptus. D.cf.sextans, D.sextans exilis, and D.cf.intortus, are common to both areas. The stratigraphic column shown in fig.15 is based mainly on Grindley (1961) who mapped the G.teretiusculus, and N.gracilis zones as Leslie Formation, barren overlying strata as Douglas Formation, and the overlying Mount Peel Beds as Peel Formation. Marble overlying the Peel Formation in Cobb Valley was mapped as Mount Arthur Marble.

The youngest graptolite zone, Orthograptus, is known only from the Wangapeka area, and is thus the only zone not represented at Aorangi Mine. It is thought to be probably contiguous with zone 10, and its base - the first appearance of Orthograptus - is taken to represent the top of zone 10. The Mount Peel beds of the Cobb Valley - Mount Arthur area thus lie within the N.gracilis zone. A change in lithology to barren quartzite terminates the top of zone 11 in the Wangapeka Valley, the next youngest diagnostic fossils being Devonian and occurring 1500ft higher in the sequence.

The Hailes Knob section is only indirectly correlated with that at Wangapeka Valley. The tentative uppermost Ordovician age of conodonts from marble at Hailes Knob (Wright 1968) and of a coral assemblage from strata equated with the marble (Cooper 1965), suggest that the boundary between Mount Arthur Marble and Hailes Knob Quartzite approximates to

the Ordovician/Silurian boundary.

The eleven graptolite zones described in this thesis are therefore considered to represent the New Zealand graptolite succession, and are listed together with restricted species in table VI. The zone names are those of the Aorangi Mine and Wangapeka sequences, with the exception of Swarko's names, Nemagraptus gracilis (zone 10) and Glyptograptus teretiusculus (zone 9), which have priority. The zonal distribution of species discussed in Part II of this thesis is given in table IV.

Correlation with Victoria.

New Zealand zones are correlated with those of Victoria in fig.19. The stratigraphic ranges of New Zealand key species (those defining zone boundaries) are shown in heavy, solid lines and are compared with the ranges of the same species in Victoria (heavy broken lines). Other common New Zealand forms with restricted stratigraphic ranges are shown in light, solid lines, their range in Victoria being indicated by light broken lines.

The oldest New Zealand zone, Adelograptus, is correlated with the La2 zone of Victoria. Adelograptus, Clonograptus, Tetragraptus decipiens, Dictyonema pulchellum and D.macgillivrayi all make their first appearance in both areas. The subdivision of La2 into upper and lower parts

ZONE	KEY FOSSILS	RESTRICTED SPECIES
11. Orthograptus	Orthograptus spp. *	Orthograptus spp., Dicellograptus patulosus, Climacograptus caudatus, C. hastatus, C. tubuliferous.
10. Nemagraptus gracilis	Nemagraptus gracilis or Dicellograptus *	N. gracilis, Dicellograptus sextans exilis, Pseudoclimacograptus spp., Azygograptus novozealandicus.
9. Glyptograptus teretiusculus	Glyptograptus teretiusculus * or Diplograptus? decoratus	D.? decoratus, Climacograptus brevis, C. cf. riddellensis, G. teretiusculus siccatus, Cryptograptus tricornis.
8. Paraglossograptus etheridgei	Paraglossograptus etheridgei *	P. zealandicus, Glyptograptus austrodentatus, G. cf. intersitus, "Pterograptus" incertus, P. parallelus.
7. Oncograptus	Oncograptus sp. or Cardiograptus sp.	O. upsilon biangulatus, C. morsus, Isograptus spp. aff. I. manubriatus *, Glossograptus crudus, Phyllograptus "nobilis", Goniograptus speciosus, Trigonograptus ? sp.nov.
6. Isograptus caduceus maximodivergens	Isograptus caduceus maximodivergens *	Tetragraptus sp. aff. T. chapmani, T. headi, Goniograptus macer?
5. Isograptus caduceus lunata	Isograptus caduceus lunata * and I. c. victoriae *	I. c. victoriae, I. c. lunata, Phyllograptus typus.
4. Didymograptus protobifidus	Didymograptus protobifidus *	D. protobifidus, Isograptus caduceus ? primula.
3. Tetragraptus fruticosus	Tetragraptus fruticosus (3- and 4- stiped) *	T. fruticosus (4-stiped), T. pendens, T. cf. pendens, T. sp. aff. serra, Trichograptus fergussoni, Didymograptus cf. ensjoensis.
2. Tetragraptus approximatus	Tetragraptus approximatus *	Tetragraptus decipiens (3-stiped), Schizograptus waddickorum.
1. Adelograptus	Anisograptids *	Dictyonema pulchellum, D. macgillivrayi, Clonograptus aff. regularis.

* = particularly common or abundant forms

Table VI. New Zealand graptolite zones, with their key fossils - those that define their lower boundaries - and restricted species. Particularly common or abundant forms are listed with an asterisk (*).

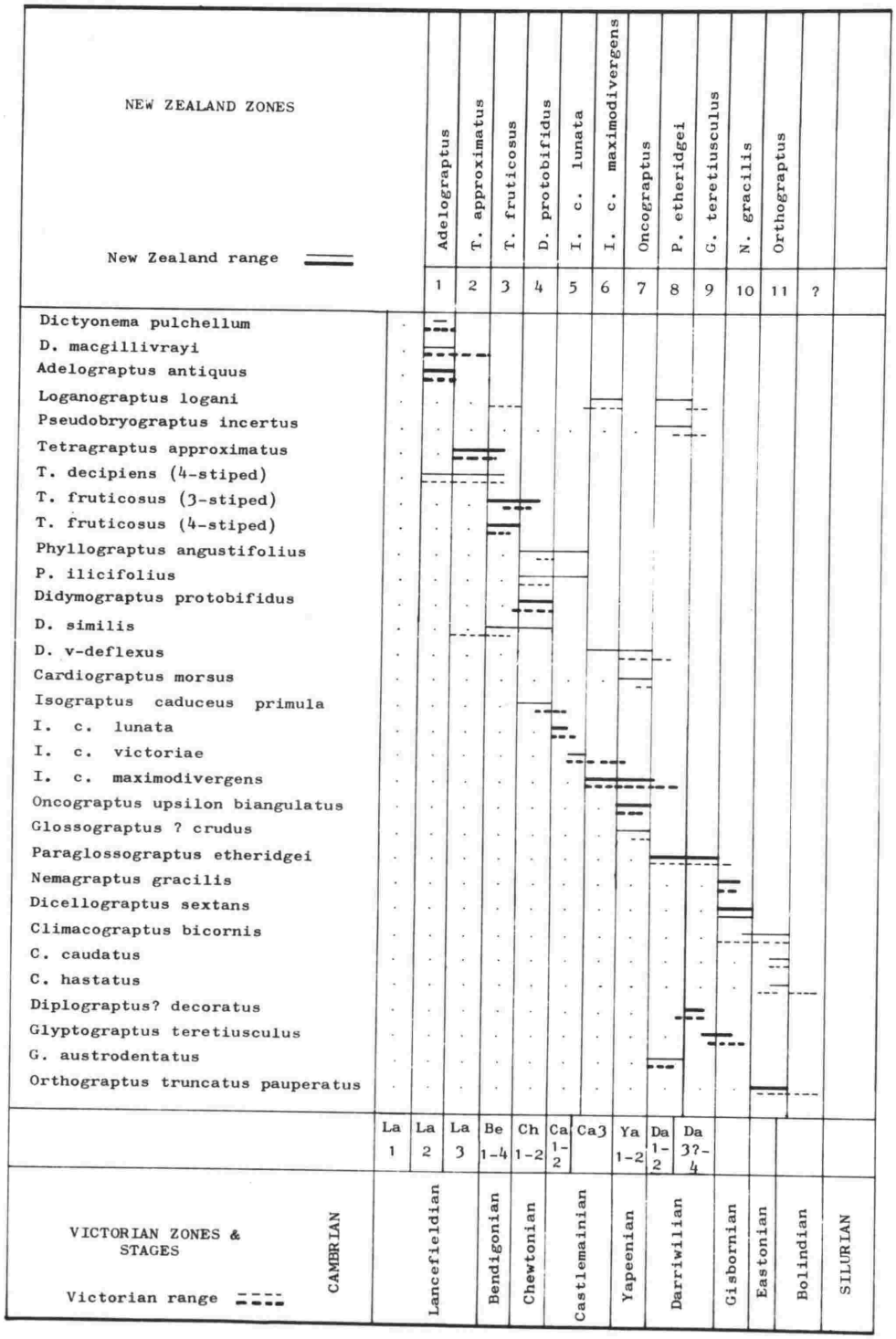


Fig.19. Correlation of New Zealand graptolite zones with those of Victoria, Australia. The ranges of New Zealand key species are shown in solid heavy lines, and of Victorian key species, in broken heavy lines. Other short-ranging, common species are shown in solid light lines (New Zealand range) and broken light lines (Victorian range). Victorian ranges from Thomas (1960).

(L2, L3 of Benson and Keble 1935) was abandoned by Harris and Thomas (1938). The previous Victorian zone, La1, containing only three species, Dictyonema campanulatum, D.scitulum and Staurograptus diffissus, is apparently known from only a single locality near Romsey, in Victoria. Equivalent fossils have not yet been found in New Zealand.

The New Zealand zone of Tetragraptus approximatus is correlated with La3; the incoming of Tetragraptus approximatus marking the base and becoming abundant in both Victoria and New Zealand. T.acclinans and Adelograptus are common to both regions.

The first appearance of Tetragraptus fruticosus marks the base of the third New Zealand zone, T.fruticosus, and of zone Be1 in Victoria. The four Victorian Bendigonian zones are defined by the ranges of T.approximatus and T.fruticosus (3- and 4-stiped forms).

Be4. T.fruticosus (3-stiped), absence of T.fruticosus (4-stiped).

Be3. T.fruticosus (3- and 4-stiped).

Be2. T.fruticosus (4-stiped), absence of T.approximatus.

Be1. T.fruticosus (4-stiped) plus T.approximatus.

In New Zealand, T.approximatus overlaps in range with the three-stiped form of T.fruticosus (at S7/516, Elliot Creek, Northwest Nelson), and the full range of T.fruticosus,

up to the appearance of Didymograptus protobifidus, is taken to represent a single zone, T.fruticosus, equivalent to all four Bendigonian zones of Victoria.

The zone of Didymograptus protobifidus is correlated with the two Chewtonian zones (Ch1-2). Thomas (1960 :9) stated that the base of Ch1 is "determined by the incoming of the dependent Didymograpti such as D.protobifidus". In Ch1 T.fruticosus (3-stiped) occurs with D.protobifidus but it is "one of the thinnest zones in Victoria, not exceeding 40-60 feet". In the following zone, Ch2, D.protobifidus becomes more abundant and T.fruticosus has disappeared. Isograptus caduceus ?primula appears near the top of the zone as in New Zealand.

Subspecies of Isograptus caduceus are useful zonal forms in both Victoria and New Zealand. In Victoria the three Castlemainian zones (Ca1-3), are defined thus: Ca1 contains the subspecies lunata, Ca2 contains victoriae, and Ca3 contains maxima and, in its upper part, maximodivergens. The New Zealand zone I.c.lunata, ranges from the entry of lunata to the entry of maximodivergens and is thus equivalent to Ca1, Ca2, and the lower part of Ca3. The I.c.maximodivergens zone is equivalent to the upper part of Ca3.

The first appearance of Oncograptus defines the base of the Yapeenian (zone Ya1) and of the seventh New Zealand zone, Oncograptus. Ya2 marks the entry of Cardiograptus, but the relative order of appearance of the two genera in

New Zealand is not known and the zone of Oncograptus embraces the total range of both genera. The zone is thus correlated with Ya1 and 2 of Victoria.

Diplograptids first appear, and glossograptids first become abundant, in New Zealand zone 8, P.etheridgei, and in the Victorian lower Darriwilian zones, D1-2. Paraglossograptus etheridgei, Glossograptus acanthus, Glyptograptus austrodentatus, together with abundant dichograptids - Loganograptus, Didymograptus, Tetragraptus - in the New Zealand zone strongly support its correlation with D1. The presence of Glyptograptus cf.intersitus, "Pterograptus" incertus, Amplexograptus confertus, however, suggest the D2 zone is also represented. The New Zealand zone differs from the equivalent Victorian beds in the almost total absence of Isograptus, and in the comparative rarity of Glyptograptus and dominance of Paraglossograptus.

Diplograptus? decoratus is confined to the lower part of the zone of G.teretiusculus in New Zealand and to the D3 zone of Victoria. Its associated assemblage however, is different in the two regions. The strong dichograptid element of the Victorian zone, including Didymograptus nodosus, D.cuspidatus, Atopograptus woodwardi, Brachiograptus etaformis, and Cardiograptus crawfordi, is not present in New Zealand, its place being taken almost exclusively by biserial forms - Cryptograptus schaferi, Glossograptus hincksii, Climacograptus brevis, Glyptograptus cf. teretiusculus siccatus - which suggest a higher horizon in

terms of the Victorian sequence. Part of the D3 zone is therefore probably represented by poorly fossiliferous beds in the upper part of the P.etheridgei zone at Aorangi Mine. The upper beds of the G.teretiusculus zone are most richly fossiliferous at Cobb Valley and have been correlated with the D4 zone (=Ba67 beds of Thomas and Keble 1933 :40) by Harris (1935 :329), Benson et al (1936 :373-4), and Skwarko (1962 :217).

The first appearance of the worldwide zone fossil, Nemagraptus gracilis provides an important horizon for correlation and occurs at the base of the Gisbornian stage (N.gracilis zone) in Victoria, and in the lower part of the N.gracilis zone of New Zealand. A more spectacular faunal incoming marking the base of the zone in both Victoria and New Zealand is the sudden influx of Dicellograptus. Represented initially by mainly small forms, such as D. sextans and D.sextans exilis, the genus is soon represented by numerous species. Most diplograptids and glossograptids of the previous zone persist in each region.

The almost complete absence of Dicranograptus and the Climacograptus bicornis group from New Zealand prevents close correlation with the Victorian upper Gisbornian (zone of Climacograptus peltifer and Diplograptus multidens) and Eastonian (Climacograptus baragwanathi zone and Dicranograptus hians zone).

The New Zealand N.gracilis zone, which here includes

the Mount Peel beds, is tentatively considered to correlate with all of the Gisbornian stage.

The youngest New Zealand zone, Orthograptus, contains abundant large orthograptids suggesting correlation with the Eastonian stage. Orthograptus of the calcaratus-group, Climacograptus tubuliferous, C.caudatus, Leptograptus cf. flaccidus and a single specimen of Dicranograptus hians strongly suggest that the upper Eastonian (Dicranograptus hians zone) is represented. Although Pleurograptus has not been found in the New Zealand zone, Climacograptus hastatus and Orthograptus truncatus pauperatus suggest that the lower part of the Bolindian stage also may be represented. The Orthograptus zone is therefore considered to correlate with the Eastonian stage and provisionally, with the lower Bolindian. The remaining part of the Bolindian stage is not represented by graptolites in New Zealand but may be represented by small assemblages of corals and conodonts from limestone in the Takaka Valley (Cooper 1965, Wright 1968b).

6. NEW ZEALAND ORDOVICIAN STAGES

Graptolites provide the only practical means of subdividing the Ordovician system in both Victoria and New Zealand. The Victorian Ordovician "stages" are, in practice, groupings of graptolite zones, but because they have proved to be widely applicable, and have survived almost unchanged during more than 30 years of intensive and detailed use, they are considered to at least approximate to time-stratigraphic units. The recent discovery of conodonts in the New Zealand Ordovician (Wright 1968) is important as it may eventually lead to an independent means of subdivision and correlation.

Although several Victorian zone boundaries cannot be accurately placed in the New Zealand succession, there is good overall agreement between the two sequences (fig.19). The basal Victorian zone, Staurograptus (La1) and the uppermost zone, Dicellograptus cf.complanatus (Thomas 1960 : 13) are apparently not represented by identifiable graptolites in New Zealand, but otherwise the sequence is thought to be substantially complete. In particular all Victorian stage boundaries can be readily located in the New Zealand sequence except for the boundaries between the three upper stages: Gisbornian, Eastonian, and Bolindian. The New Zealand sequence is least well known in this region and further work, particularly detailed collecting in the Wangapeka area, should improve the correlation of these

Table VII New Zealand graptolite zones and stages with suggested zone and stage mapping symbols, together with a list of reference areas - those in which the stages are best known and most fossiliferous.

ZONE	STAGE		REFERENCE AREAS
?			
Orthograptus Or	Bolindian QUb	Upper Ordovician	Wangapeka Valley area
	Eastonian QUe		
N.gracilis Ng	Gisbornian QUg		Cobb Valley, Aorangi Mine area
G.teretiusculus Gt	Darriwilian QMd	Middle Ordovician	Cobb Valley, Aorangi Mine area
P.etheridgei Pe			
Oncograptus Oc	Yapeenian QLy	Lower Ordovician	Aorangi Mine area
I.c.maximo-divergens Im	Castlemainian QLc		Aorangi Mine area
I.c.lunata Ic			
D.protobifidus Dp	Chewtonian QLh		Aorangi Mine area, Preservation Inlet area
T.fruticosus Tf	Bendigonian QLb		Aorangi Mine area, Preservation Inlet area
T.approximatus Ta	Lancefieldian QLl		Aorangi Mine area, Preservation Inlet area
Adelograptus Ad			
?			

boundaries.

It is therefore proposed to adopt the Victorian Ordovician stage nomenclature for the New Zealand sequence, as correlated in the previous chapter. Areas in which the stages are best known and are most fossiliferous are listed in table VII together with suggested stage and zone mapping symbols. Stage symbols are prefixed with 'Q', as was used for the Ordovician system in the "Geological Map of New Zealand, 1:250,000" (published by Dept. Sci. Industr. Res., Wellington), in order to avoid repetition of the already established symbols for other New Zealand stages (e.g. Finlay and Marwick 1947; Wellman 1959). Correlation of the Australasian stages with those of the standard British sequence is discussed in part II of this thesis.

Informal subsystemic division of the Ordovician into upper, middle and lower parts has been widely accepted in Victoria and New Zealand. The Lower Ordovician comprises the Lancefieldian, Bendigonian, Chewtonian, Castlemainian and Yapeenian stages; Middle Ordovician contains the Darriwilian stage only, and Upper Ordovician comprises Gisbornian, Eastonian and Bolindian stages (table VII). Because of the wide disparity between various uses of the terms Lower, Middle, and Upper Ordovician, both between Europe and Australia, and within Europe itself (Jaanusson 1960b), it is recommended that the terms be used only when qualified by reference to the area in which they apply.

PART II PALEONTOLOGY

General.

One hundred and thirteen graptolite taxa are discussed in this report. Detailed systematic descriptions are restricted to the more important zonal species and subspecies; the remaining forms are compared with their original descriptions, or with subsequent revised descriptions, their nomenclature being clarified where necessary. The stratigraphic distribution of taxa in Nelson is indicated, and their overseas distribution briefly discussed. "Associated" forms listed are those associated on the same bedding planes, not merely at the same locality. Collection numbers are prefixed according to the institution in which they are housed, as explained in appendix I. All forms except for seven are figured.

Figured specimens were photographed in alcohol by the writer using a Canonflex RM 35mm reflex camera, fitted with a Canon 50mm lens and bellows extension. For photographing very small specimens, a Leica 35mm lens was used. All line drawings were made by bleaching enlarged photographic prints on which the image had been outlined in indian ink.

Preservation.

Most Nelson graptolites are preserved as casts of flattened rhabdosomes lying on bedding planes in black, or dark blue-grey carbonaceous slate or argillite. The replacing mineral of the cast is usually silvery grey, white, or yellow in colour and has a platy structure. Small cubes of iron sulphide can be seen in a few specimens, and the rusty appearance of many graptolites suggests that it may be a common constituent. However, specimens from locality S2/552 on the Aorangi Mine track consist of a relatively thick film of white powdery material which was scraped off and analysed by X-ray diffraction and by infra-red spectrometer by Mr P.Brown, N.Z.Geological Survey, Lower Hutt. 50-60% of the material was found to be quartz, about 30% illite and most of the remainder, chlorite. Petrographic examination of thin rock sections containing graptolites by Mr Brown confirmed the presence of quartz in the replacing material, but the high quartz content of ~~value in~~ the analysed sample is surprising and is probably partly due to fragments of siliceous rock matrix adhering to the replacing material.

Thickenings of the original graptolite periderm, such as in spines, lists, or at interthecal septa, are generally represented in the cast by a thickening of the replacing material, enabling more than just the rhabdosome outline to be seen.

The association of flattened graptolites and black shales is common throughout the world, the rocks being known as the "graptolite facies" (Bulman 1955 :V16). It is generally assumed by graptolite taxonomists, though seldom stated, that the flattening process produces standard changes in rhabdosome dimensions, enabling detailed comparison between flattened specimens from different regions. Although this assumption has never been objectively proved, constant usage has shown it to be most probably generally true. Rhabdosome dimensions most likely to be affected by flattening are stipe width, stipe divergence angle, in multi-branched rhabdosomes whose stipes did not all lie in one plane and, possibly, thecal width, inclination etc. Details of thecal structure are generally obscured. Dimensions likely to be unaffected are thecal length, stipe length, and thecal spacing.

Comparison of flattened and unflattened specimens of the same species is more difficult. Packham (1962 :499) noted that the cross-sectional profile of British lower Silurian diplograptids preserved in relief was "such that assuming simple flattening of the periderm, the width of the graptolite would be increased by about 30%. Specimens thought to be of the same form, from different localities, confirm this assumption."

A few Nelson specimens are preserved in part relief and are found in two contrasting lithologies. The first is

medium blue-grey carbonaceous argillite of Formation A, member A1 at locality S2/568, in Slaty Creek, Aorangi Mine area. The rhabdosomes of several specimens of Glyptograptus austrodentatus cf. austrodentatus were replaced by, and in-filled with, pyrite before appreciable compaction occurred, and are now preserved with about half their original relief (pl.17, figs4,5). Rhabdosome width does not appear to be significantly different from flattened members of the same form at the same locality, differing from Packham's observation mentioned above.

The second lithology is grey-green, non-carbonaceous siltstone in the upper part of Formation B, at locality S3/526 in Paturau River, Aorangi Mine area. Several species are represented, most rhabdosomes being preserved as thin black carbonised films. A few are in nearly their full original relief, and are in-filled with siltstone matrix (specimen VG128, pl.16, fig.4). Unfortunately, the carbonised film was found to be too fragile to survive solution of the supporting rock matrix in hydrofluoric acid. Serial grinding of such specimens however, should be a useful means of determining their internal structure. Although unflattened, rhabdosomes have generally suffered some distortion during compaction, and unfortunately cannot be closely compared with flattened specimens of the same species.

Tectonic Distortion.

Paleozoic fossils at many localities in Northwest Nelson have been distorted by tectonic deformation (Wellman 1962b). Distorted graptolites at Cobb Valley were misidentified in 1929 by Benson and Keble who failed to recognise the distortion (Skwarko 1962 :218-9). Graptolites at a few localities in the Aorangi Mine area (S2/630) are slightly distorted; most are not used in specific descriptions although they are generally identifiable.

Two kinds of distortion affect flattened graptolites lying in the plane of bedding. The first involves differential distortion, and is usually obvious in bedding planes containing randomly oriented specimens of one species, from the relative lengthening and shortening of specimens lying in different directions. A single multibranched rhabdosome with stipes originally of equal thickness and thecal spacing, such as Goniograptus thureaui or Tetragraptus quadribrachiatus, will similarly indicate any differential distortion. Examples are found at locality S2/630, Aorangi Mine area, and in the Cobb beds (Skwarko 1962 :fig.2).

The second kind of distortion produces uniform expansion or contraction in all directions in the plane of bedding. This is difficult to detect unless great, but is probably present in some graptolite-bearing boulders in Dam Creek (S2/591).

Beds containing distorted graptolites are invariably cleaved. The relationship between slaty cleavage, bedding and distortion has been studied in Victorian graptolite-bearing slates by Hills and Thomas (1944). There was generally no dimensional change in the plane of bedding in a direction parallel to the line of intersection with cleavage. Where the angle of intersection between cleavage and bedding was greater than about 25°, specimens of graptolites were shortened in the direction normal to cleavage; where the angle was less than 25° specimens were lengthened normal to cleavage. The writer's observations of distorted graptolites in cleaved rocks in Northwest Nelson are consistent with those of Hills and Thomas.

Classification and Terminology.

The classification followed here is that proposed by Bulman (1955), modified by Jaanusson (1960a) and Bulman (1963b).

In this report, the term "population" is used as by Sylvester - Bradley (1951 :89), to include all fossils of one species found within a single "bed", or other convenient unit of strata. The term "subspecies" as used here embraces two categories. The first is that known in earlier graptolite publications as "variety" or rarely as "mutant". "Varieties"were generally given formal names and often designated with type specimens, and were apparently regarded as of subspecific status (in terms of the International Code

of Zoological Nomenclature, Article 45, 1964 edition). The second category comprises the subspecies of Isograptus caduceus which are regarded as populations within an evolving group and are discussed separately. The problem of relating graptolite subspecies to biological subspecies has been briefly discussed by Packham (1962 :523) and by Bulman (1963a :679).

The synonymy lists accompanying specific descriptions contain references to the original description, to subsequent revised or important descriptions, and to descriptions of material being placed in synonymy with the species for the first time.

Taxonomic names are prefixed with "cf." when the form is known to be distinct from, but closely related to an established taxon; names prefixed with "aff." are less closely related to an established taxon. Forms whose affinities are not positively known owing to incomplete or poor preservation are listed with a query. Where generic reference is uncertain, the genus name is followed by a query, and where generic and specific reference are both uncertain, the query is placed before the genus name, e.g., ?Hallograptus inutilus (Hall).

Most of the terms used in description here are in general usage; some require definition. Unless otherwise stated, all refer to flattened specimens.

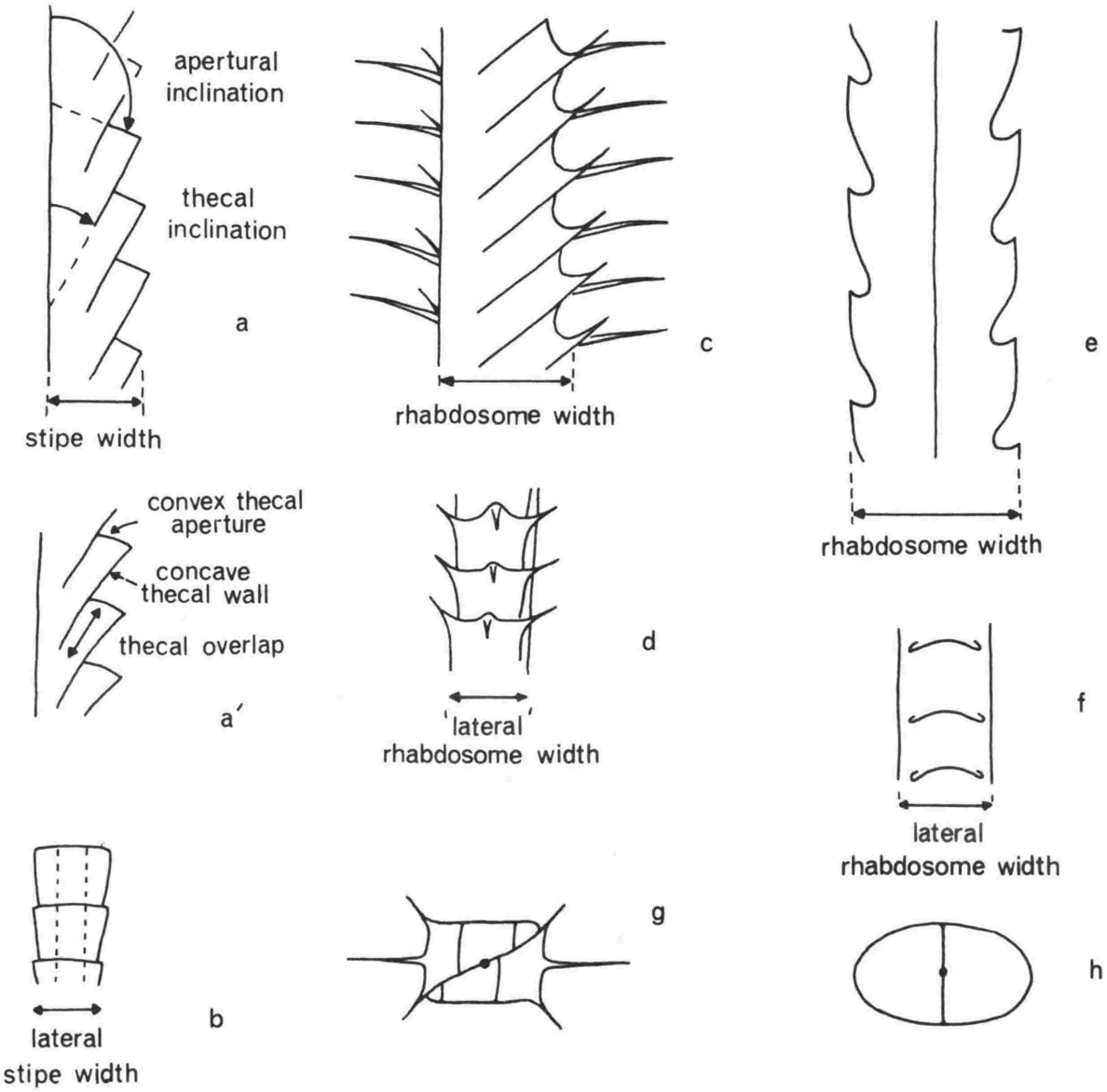


Fig.20. Idealised diagrams illustrating terms used in the description of flattened graptolites. a,a',b, monoserial rhabdosome (stipe) seen in profile view (a,a'), and ventral view (b). c - d, biserial, monopleural rhabdosome seen in "biprofile view" (c), and in "scalariform view" (d). e - f, biserial, dipleural rhabdosome seen in biprofile view (e), and scalariform view (f). g - h, cross-section of unflattened monopleural (g) and dipleural (h) rhabdosomes.

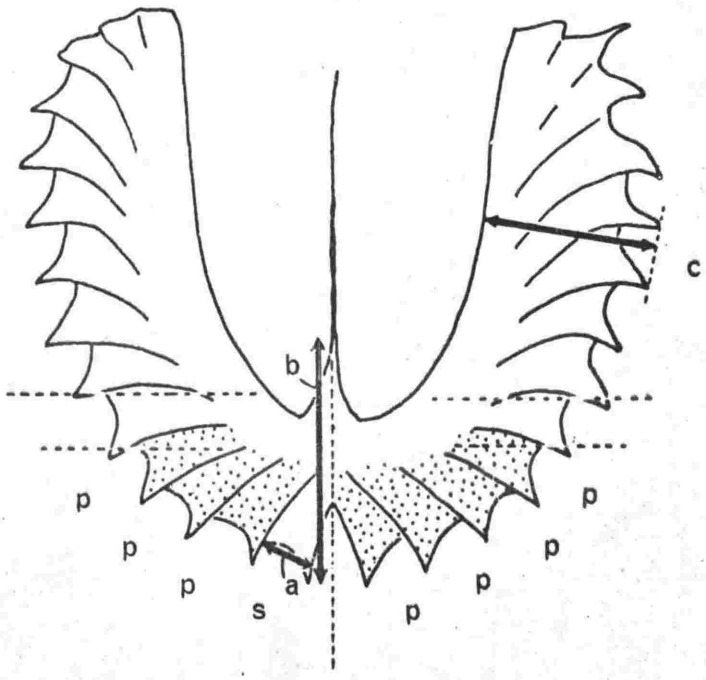


Fig.21. Measured characters of Isograptus caduceus (Salter). a, width of sicula at aperture. b, length of sicula. c, stipe width. p, pendant thecae. s, sicula. See text for discussion.

Stipe width, unless qualified, refers to the 'dorso-ventral' stipe width seen in profile view, including apertural denticles if any but excluding spines. "Lateral" stipe width is measured between the lateral stipe margins, as seen in dorsal or ventral view. (fig.~~19~~ 20a,a',b). Similarly, rhabdosome width in biserial forms is measured in biprofile view, lateral rhabdosome width in scalariform view (fig.~~19~~ 20, c-f).

Thecal inclination refers to the included angle between the ventral thecal margin and the dorsal stipe margin, as seen in profile view. Apertural inclination is measured between the apertural margin and the dorsal stipe margin on the distal side. Thecal width, sicular width etc., are as seen in profile view. Concave or convex ventral thecal margins refer to the outer surface of the ventral thecal margin as seen in profile view; concave or convex apertural margins similarly refer to the outer surface of the apertural margin (fig.~~19~~ 20a,a').

In the Nelson isograptids the sicula cannot be definitely distinguished from the first theca ($th1^1$) but because of their closely similar shape and size (see generic diagnosis of Isograptus) measurements of either one can be regarded, for the purposes of this discussion, as those of the sicula. Length of the sicula is measured from its apex to the tip of its denticle; the width at the aperture is measured from the ventral sicula wall to the ventral wall of the adjacent theca ($th1^2$, fig.~~20~~ 21).

The number of pendant thecae, has proved to be a useful and easily determined character in the description of Nelson populations of I.caduceus, and gives an indication of the degree of inclination of proximal thecae. The rhabdosome is oriented so that the midline - that which passes through the apex of the sicula and centrally between the free ventral margins of the sicula and first theca - is vertical. Pendant thecae are those whose apertural margins lie wholly 'below' the level of the dorsal thecal wall (interthecal septum), as illustrated in fig. ~~20~~ 21. The number of pendant thecae probably does not change significantly during flattening of the rhabdosome.

Modal values of measured characters are given in systematic description, the range of values being indicated in brackets.

A list of the taxa described or discussed is given in table IV, those forms accompanied by an asterisk (*) being recorded for the first time in New Zealand.

SYSTEMATIC DESCRIPTIONS

ORDER DENDROIDEA Nicholson, 1872

FAMILY DENDROGRAPTIDAE Roemer in Frech, 1897.

GENUS *Dictyonema* Hall, 1851.

Dictyonema pulchellum T.S.Hall, 1899
Fig.~~21~~ 22; pl.1, fig.2.

1899a *Dictyonema pulchellum* T.S.Hall :174, pl.18,figs 28-30.

1960 *Dictyonema pulchellum*;Thomas, pl.1, fig.5.

1961 *Dictyonema pulchellum*;Skwarko :102-3,fig.1.

Fig.22. *Dictyonema pulchellum* T.S.Hall. Distal fragment of large rhabdosome, x 1. GR101, locality S2/534, Aorangi Mine area, *Adelograptus* zone. Specimen figured by Skwarko 1960, fig.1.

Remarks. Hall's description was based on relatively immature specimens contained in a single slab from Lancefield. Mature, complete specimens have not yet been described, though Thomas (1960) figured a relatively mature form. Distal fragments of what was apparently a large rhabdosome

from Anthill Creek were figured and described by Skwarko (1961) as D.pulchellum, and are refigured here.

Horizon and localities. S2/526, 534. Associated form, Adelograptus? antiquus. Zone 1.

D.pulchellum is confined to the La2 zone, Lancefieldian stage, of Victoria and is unknown outside Australasia.

FAMILY ANISOGRAPTIDAE Bulman, 1950

GENUS Anisograptus Ruedemann, 1937

Anisograptus? sp.

Pl.1, fig.7.

Remarks. Anisograptus-like forms with asymmetrical proximal regions in which the sicula lies near the junction of two of the three main stipes, are listed as Anisograptus? sp. The proximal region is poorly preserved in all specimens and the origin of the primary stipes cannot be determined. The genus is therefore not yet definitely known in New Zealand.

Horizon and localities. S2/527, 615, 641; S7/516. Associated forms, Adelograptus? antiquus, Clonograptus aff. regularis. Zones 1 and 3.

Anisograptus is apparently absent from Victoria, but is known from the Tremadocian of North and South America and of Northwest Europe.

GENUS Adelograptus Bulman, 1941

Adelograptus? antiquus (T.S.Hall 1899)

Figs 24a-i; pl.1, figs 3,4.

1899a Leptograptus antiquus T.S.Hall :166-7, pl.17,figs 5,6.

?1899a Didymograptus pritchardi T.S.Hall :167, pl.17,figs 7, 9, pl.19,figs 8,10.

1935 Bryograptus (?) antiquus;Benson and Keble :266-7.

?1935 Bryograptus (?) antiquus var.inusitatus Benson and Keble :267-8, pl.30,figs 17,18.

?1938b D.pritchardi;Harris and Thomas, pl.1,fig.13.

1941 Adelograptus (?) antiquus;Bulman :116.

?1960 D.pritchardi; Thomas, pl.1,fig.14.

?1966a D.pritchardi; Berry :429-30, pl.45,fig.1; pl.46,fig.1; pl.47,figs 1,2.

Type material. Hall did not nominate a type specimen in his original description of L.antiquus. He figured only one specimen from Lancefield (Hall 1899a, pl.17,figs 5,6) though

he undoubtedly based his description on several specimens. It is not thought advisable to nominate a lectotype or propose a specific diagnosis until Hall's original specimens have been re-examined and refigured.

Original description. "Polypary of extreme tenuity. The two branches diverging at about 180° from the sicula, and slightly curving with the thecae on the concave side; these primary branches at times give off a secondary branch. Breadth of branches 0.1mm. Thecae 7 in 10mm, not in contact with one another; apertural margin straight or, when compressed in a different manner, slightly concave; incurved to the axis at an angle of 90°; outer margin slightly concave and inclined at an angle of 30°. Breadth from tip of theca to back of branch about 0.4mm."

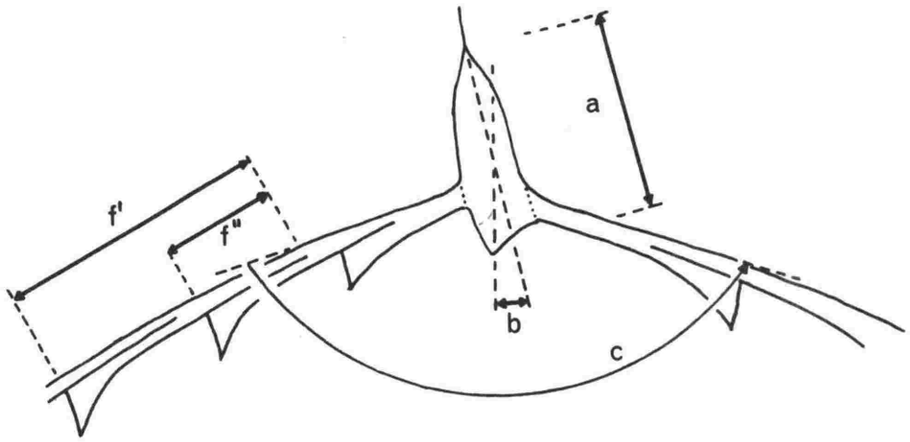
Description of Nelson material. The rhabdosome comprises two slender stipes each several centimetres long, gently curved, concave ventrally. The sicula is conspicuous but relatively slender being 0.2-0.3mm wide at the aperture. It bears a short fine nema, is usually slightly curved, and is generally inclined at an angle to the axis of symmetry of the rhabdosome, the apex always being directed towards the stipe developed from th1[1]. Length of the sicula ranges from 0.9 to 1.5mm, specimens with shorter siculae tending to have horizontal rather than declined stipes.

Table VIII Dimensions of Adelograptus? antiquus T.S. Hall

Specimen No.	Zfg6.2	VG14	VG15	Zfg6.7	VG16	Zfg6.1	VG17	VG18	VG19	Zfg6.6	VG13	Zfg6.5	VG20
a) sicula length (mm)	c1.1	1.2	0.9	1.0	1.5	1.05	1.1	1.4	1.5	1.3	1.5	1.2	1.5
b) sicula inclination°	21	35	30	10	3	2	10	30	5	5	7	10	7
c) stipe divergence°	170	160	150	140	140	132	130	120	120	120	115	115	108
d) stipe max. width (mm)	0.4	0.4	0.3	0.4	0.6	0.5	c0.4	0.5	0.5	0.45	0.5	0.45	0.5
e) thecae/5mm	4.0	?	?	5.0	?	4.8	4.0	3.5	4.2	?	3.8	4.8	?
f) thecal overlap	$\frac{1}{4}$+	$\frac{1}{4}$+	?	$\frac{1}{3}$+	$\frac{1}{3}$+	$\frac{1}{2}$	$\frac{1}{3}$+	$\frac{1}{3}$+	?	$\frac{1}{3}$+	$\frac{1}{3}$+	$\frac{1}{3}$+	$\frac{1}{2}$

Measurements on 13 specimens of A? antiquus indicating the variation in morphology of the species. Specimens are arranged in order of decreasing angle of stipe divergence.

Fig. 23. Diagram explaining measured characters in A? antiquus.



a, sicula length;

b, inclination of the sicula to the axis of symmetry of the rhabdosome;

c, divergence angle of the stipes;

f, thecal overlap, f"/f'.

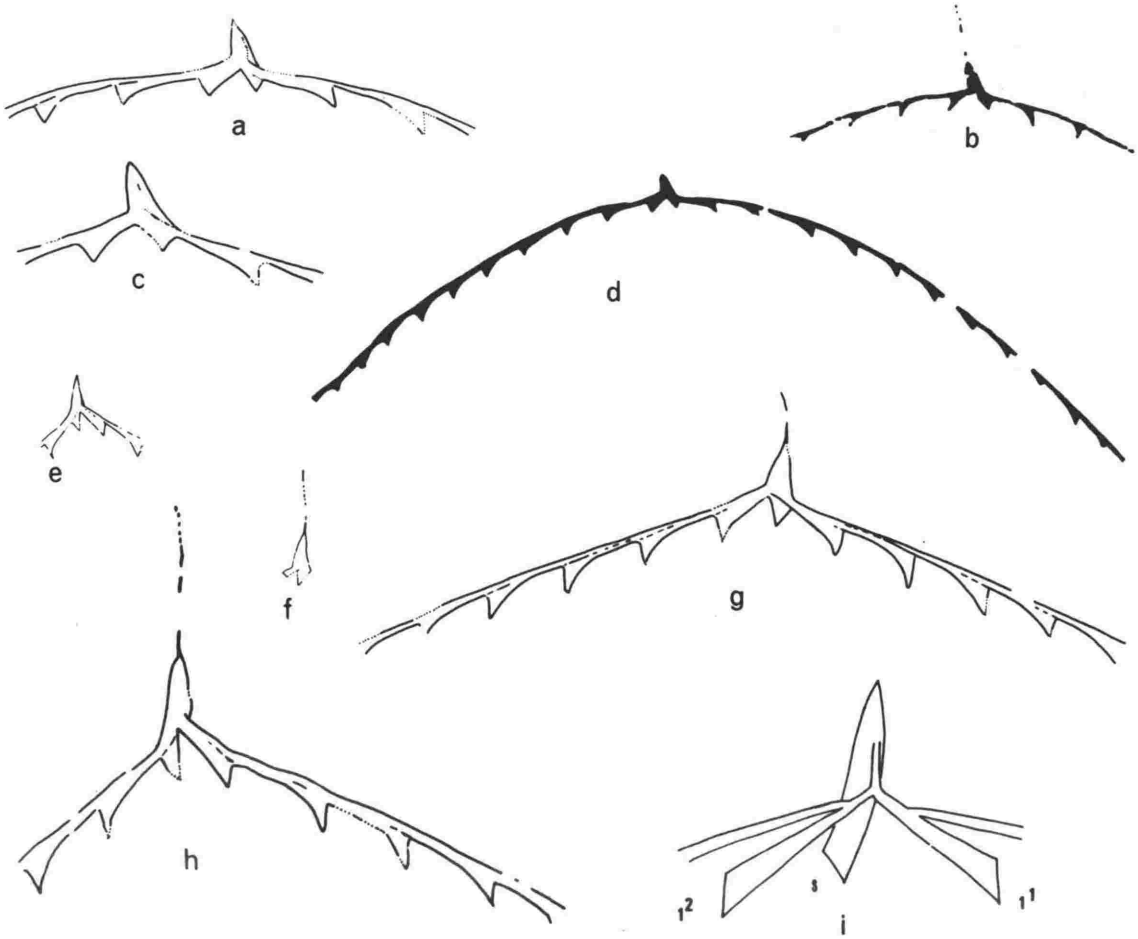


Fig.24. Adelograptus? antiquus (T.S.Hall). a,d. Proximal portion (a), and complete rhabdosome (d), Zfg6.2. b, VG24. c, proximal portion, VG15. e, proximal portion, VG20. f, sicula and partly formed theca 1^1, VG14. g, Zfg6.1. h, VG13. i, diagram illustrating probable arrangement of the sicula (s), first theca (1^1) and second theca (1^2). Figs a,c,g, and h, x 10; b,d,e, and f, x 5.

Specimens of figs a,d, and g, from locality S2/641; b,e,f, from locality S2/527; and c,h, from locality S2/526. Aorangi Mine area, Adelograptus zone.

The stipes diverge at angles ranging from 170° in specimens with 'horizontal' or extensiform stipes to 115° in declined forms. A stipe width of 0.3 - 0.6mm is reached by the first or second thecal pair - no further widening of the stipes being seen in the measured specimens. However, isolated stipe fragments up to 1mm wide, probably belonging to the species, suggest distal widening of the stipes. Longest measured stipes are 15mm, though maximum length is likely to have been several centimetres.

Thecae are long (ca 1.5 - 2.5mm), and only about ~~0.5~~ 0·05mm wide for the proximal three-fifths of their length, expanding rapidly near their apertures where their dorso-ventral width reaches 0.3 - 0.55mm. Dorsal walls are straight, ventral walls are sharply concave near the aperture, where they are sometimes extended into a 'lip' with the apertural margin. Thecal overlap of at least one half can be seen in one specimen (fig.24g). Apertural margins are straight or slightly concave, inclined 70 - 90° to the stipe axis. Thecal spacing measured in the proximal part of the stipes varies from 3.5 to 5.0 in 5mm (7 - 10 in 10mm). Spacing in detached distal stipe fragments ranges from 8 - 10 in 10mm. In a few specimens thecal spacing tends to be slightly irregular, though the average lies within the above range. No definite bithecae have been observed.

Structure of the proximal region. In their description of the species from Southwest Otago, New Zealand, Benson and Keble (1935 :267) refer to two short initial thecae which contrast strongly with the longer subsequently formed thecae, and to the presence of a short sicula, under 1mm long. Although flattened, several Nelson specimens are sufficiently well preserved to show some details of the proximal region to which the writer's attention was first drawn by Dr D. Skevington. The following interpretation is based mainly on specimens VG13, VG14, VG15 and VG20 (fig.24).

The sicula apparently grows to approximately its full length before growth of th1^1 is complete. The first formed theca originates from the upper part of the sicula, grows downwards alongside it to a point midway between the apex and aperture, then bends sharply away, giving off th1^2 at the point of flexure. Th1^2 grows down and across the sicula and gives rise to stipe^2, theca 2^1 arises immediately below the point of flexure on th1^1 and gives rise to stipe^1. The apertural portion of the sicula protrudes a little below the ventral margin of theca 1^2. The nature of development, whether right- or left-handed, is uncertain. Except for the apparent lack of bithecae, development is similar to that of Adelograptus? bulmani Spjeldnaes (1963).

The two short initial thecae of Benson and Keble correspond to the apertural portions only of the sicula and th1^1; all thecae are thus of approximately the same length.

Discussion. Considerable morphological variation is shown by the Nelson material which is thought to represent a single widely variable species. Measurements of the main variable characters in 13 specimens are listed in table VIII. Among the measured specimens are some (Zfg6.2) which unmistakably correspond to Hall's figures and descriptions of L.antiquus, differing only in having 8 rather than 7 thecae in 10mm. Other specimens (Zfg6.1, in the same slab) resemble Hall's and Berry's descriptions of Didymograptus pritchardi Hall, although none attains full stipe width of 0.8 - 0.9mm quoted by Berry.

Dimensions of A.antiquus given by Hall (1899a) and by Benson and Keble (1935), and of D.pritchardi given by Hall (1899a) and by Berry (1966a) in his redescription of Hall's type material, are summarised in table IX for comparison with those of the Nelson material.

Second-order branching, although rare and not seen in the Nelson specimens, is well established in both pritchardi and antiquus (Hall 1899a, Benson and Keble 1935, Berry 1966a). Hall stated "the species is easily distinguished from Didymograptus pritchardi with which it is associated and with which it is perhaps liable to be confused, by its more slender habit, and by the much more distant thecae which do not overlap". Benson and Keble have since recognised thecal overlap in A? antiquus and thecal spacing is here shown to be variable. Unfortunately, Berry did not comment on the

Table IX. Dimensions of Adelograptus? antiquus (given by Hall 1899[a], and Benson and Keble 1935) and of Didymograptus pritchardi (given by Hall 1899[a], and Berry 1966[a]) compared with Adelograptus? antiquus of this paper.

	A? antiquus		D.pritchardi		A? antiquus
	Hall	Benson & Keble	Hall	Berry	This paper
sicula length, mm	-	<1.0	-	1.4-1.5	0.9-1.5
sicula width at aperture, mm	-	-	-	0.25-0.3	0.2-0.3
stipe divergence angle from sicula	ca180°	180°	140°	135-145°	108-170°
stipe width, mm	0.1	0.5?	ca0.5	0.8-0.9	0.3-0.5
specimens with second-order branching?	"not very common"	"exceptional"	"not infrequent"	-	-
thecae/10mm	7	7	ca10	9.5	7-10(prox.)
thecal overlap, mm	none	0.2	ca0.5	0.4-0.5	0.5(max.)

relationship between the two forms in his re-examination of D.pritchardi (1966a:429-30). With its wide morphologic variation, the Nelson species is thought to definitely include A? antiquus and to possibly also include D.pritchardi.

Benson and Keble distinguished a variety of A? antiquus, var.inusitatus. From their description, it is virtually identical with the original species, but if the scale given for their illustrations (pl.30,figs 17,18) is correct, their figured specimens differ from their description, mainly in having much wider thecal spacing. Unfortunately the type specimens (Benson catalogue 468 (5,6)) cannot be traced and synonymy of the form remains in doubt. Ruedemann's North American species Bryograptus lapworthi is similar to A? antiquus, differing chiefly in the shape of its thecae.

L.antiquus was tentatively referred to Bryograptus by Benson and Keble (1935) and to Adelograptus by Bulman (1941), Bulman listing the form as ?Adelograptus antiquus. The Nelson material differs from Kinnegraptus Skoglund, in not bearing long thecal and apertural processes, and from Didymograptus McCoy in having potential for second-order branching. It is here tentatively retained within Adelograptus.

Horizon and localities. About 30 specimens have been examined; most are fragmentary or poorly preserved. Localities S2/522, 525, 526, 534, 590, 641. The species

is abundant in zone 1 and less common in zone 2. It has been recorded from Fiordland, by Benson and Keble (1935), and is common in the Lancefieldian (La2) of Victoria.

Adelograptus clarki (T.S.Hall, 1899)

Pl.1,fig.1.

1899a Bryograptus clarki T.S.Hall :165-6,pl.17,figs 3,4.

?1899a Bryograptus victoriae T.S.Hall :165,pl.17,figs 1,2.

1915b Bryograptus sp.; T.S.Hall :410-11,pl.8,figs 5,6.

1935 Bryograptus hunnebergensis; Benson and Keble (= B.pauxillus mom.nud. Benson and Keble, in Benson 1933 :403) :269-70, pl.30,figs 1-11, 14? 15?

1966a Adelograptus clarki; Berry :419-21, pl.44,figs 2,4.

Remarks. The type specimens of B.clarki described by Hall and by Berry are relatively immature, branching having reached the third-order only. Larger specimens from Nelson have fourth- and fifth-order stipes and resemble the Southwest Otago specimens figured as Bryograptus sp. by T.S.Hall in 1914.

A.clarki was synonymised with A.victoriae by Bulman (1941 :115), but Berry (1962 :420) re-examined the type material of both forms and concluded that A.clarki could be distinguished by the presence of lateral, rather than dichotomous, second-order division, and by its less declined

rhabdosome form. The nature of stipe division is difficult to determine in flattened material, such as that of Nelson and Victoria, and considerable variation in rhabdosome form is shown by Nelson specimens. A full description of the range of variation of each form is thus needed to resolve the question of their synonymy.

Horizon and locality. A clarki is a common form in zone 1, to which it is confined. Locality S2/527. Associated forms, Adelograptus spp.

A clarki was listed from Preservation Inlet by Benson and Keble (1935 :268) and ranges through the La2, La3 zones of the Lancefieldian stage of Victoria.

Adelograptus aff. A.pusillus (Ruedemann,1904)
Pl.2,fig.5.

aff.1904 Bryograptus pusillus Ruedemann :641-2,pl.4,figs 21,22.

aff.1947 Bryograptus pusillus; Ruedemann :299, pl.49,figs 3,4 (not figs 5,6).

Remarks. The Nelson form has a similar branching habit to that of A.pusillus, but the interval between successive

dichotomies is apparently considerably longer and the number of dichotomies greater, being at least 6 rather than 3 as in Ruedemann's specimen. The holotype of A.pusillus was illustrated by Ruedemann (1904 :pl.4,figs 21,22), the figures being reproduced in Ruedemann (1947 :pl.49,figs 3,4); the scale given for the earlier figures was apparently mistakenly changed in the later work.

The specimens figured by Ruedemann from the Glenogle Shale (1947 :pl.49,figs 5,6) as Bryograptus pusillus, belong to the genus Pterograptus (see Mu 1957 :422). Bryograptus pusillus was referred to Adelograptus Bulman, by Bulman (1941); Mu (1957 :422) subsequently suggested that the species belongs in Pseudobryograptus Mu. The Nelson form, with more than 3 orders of dichotomy, is excluded from Pseudobryograptus, and is therefore here referred to Adelograptus.

Horizon and localities. S2/564, 579, 624. Zones 4 - 5.

A.pusillus is known from the zone of Tetragraptus fruticosus of Texas (Berry 1960a) and the Deepkill Shale of New York (Ruedemann 1904).

GENUS Clonograptus Hall and Nicholson, 1873

Clonograptus aff. regularis (Tornquist, 1904)

Pl.1, fig.5.

aff. 1904 Dichograptus regularis Tornquist :20, pl.2, fig.19.

cf. 1904 Dichograptidae gen. et sp. indet; Tornquist, pl.2, fig.22.

aff. 1937 Herrmannograptus regularis; Monsen :192, pl.14, figs 3,8,9.

Remarks. The Nelson specimen differs from Dichograptus regularis as described by Tornquist and by Monsen, in having longer second-order stipes and in having fourth-order stipes. The specimen figured by Tornquist as "undetermined irregular Dichograptidae" (pl.2, fig.22) differs from the Nelson form only in having slightly thinner stipes.

Bulman (1955 :V33) synonymised Herrmannograptus Monsen with Clonograptus Hall and Nicholson.

Horizon and locality. One specimen, from locality S2/641. Associated forms, Adelograptus? antiquus, Anisograptus? sp. Zone 1.

C. regularis is found in the zone of Didymograptus balticus of Scandinavia.

Clonograptus sp.cf.C.kingi (Benson and Keble, 1935)

cf.1935 Clonograptus tenellus; Benson and Keble :271,pl.32, fig.4.

cf.1935 Clonograptus tenellus var.kingi Benson and Keble : 271-2,pl.32,figs 3,5.

Remarks. Nelson specimens have more slender stipes than those of Benson and Keble. The forms described by Benson and Keble as C.tenellus, and as C.tenellus var.kingi are regarded together as a distinct species by Bulman and Cooper (in press).

Horizon and locality. S2/628. Zone 3. Benson and Keble's material came from beds correlated with La2, and Be1, at Cape Providence and Preservation Inlet.

ORDER GRAPTOLOIDEA Lapworth, 1875

FAMILY DICHOGRAPTIDAE Lapworth, 1873

GENUS Goniograptus McCoy, 1876

Goniograptus macer T.S.Hall, 1899

Pl.3,fig.3.

1899b Goniograptus macer T.S.Hall :449-50, figs 9,10.

1939 . Goniograptus macer; Harris and Thomas :56,figs 4a-b.

Remarks. The Nelson specimens have slightly wider funicles (3mm) than that described by Hall (2mm) but closely resemble forms included by Harris and Thomas (1939) in G.macer.

Horizon and localities. S2/552, 611, 630. Associated forms, Isograptus caduceus maximodivergens, Tetragraptus aff.serra. Zone 6.

G.macer was described from Preservation Inlet by Benson and Keble (1935 :272,pl.30,fig.36; pl.32,figs 6,7). It ranges throughout the Bendigonian, and ?Chewtonian stages of Victoria (Thomas 1960 :16), considerably earlier than its first appearance in Nelson.

Goniograptus speciosus T.S.Hall, 1914

Pl.3,fig.1.

1914 Goniograptus speciosus T.S.Hall :110-1,pl.18,text-fig.1.

Remarks. The single Nelson specimen closely resembles Hall's description and figure (pl.18). Thecae in the Nelson form are less markedly denticulate than those shown by Hall's text-fig.1, a difference noted in other specimens from the

from the zone of Didymograptus protobifidus of Texas (Berry 1960a:49), and from a similar horizon at New York (Berry 1962a:703, as "G.thureaui postremus"). It is thus restricted to younger beds in Nelson than those elsewhere.

GENUS Loganograptus Hall, 1868

Loganograptus logani (J.Hall, 1858)

Pl.2,figs 1,2.

1858 Graptolithus logani J.Hall :115.

1902 Loganograptus logani; Elles and Wood :81-2,pl.2,figs 1a-g.

1947 Loganograptus logani; Ruedemann :286-7,pl.45,figs 11-13; pl.46,figs 1,2.

Remarks. Nelson specimens correspond well to the descriptions by Ruedemann and Elles and Wood. There is clearly some variation in stipe width, length, and particularly, in the number of stipes in the species. Most Nelson specimens have fewer than 16 main stipes.

Horizon and localities. S2/552,582. Associated forms,

Isograptus caduceus maximodivergens, Tetragraptus aff. chapmani, L.logani cf.pertenuis. Zones 6 and 8.

L.logani is known in the Bendigonian (Be1), Castlemainian (Ca3), and Darriwilian (D3) stages of Victoria, having a long but sporadic range.

The species is known from the Glyptograptus dentatus zone of New York (Ruedemann 1947), from the same zone at Levis, Quebec (Raymond 1914), and from the Arenigian of Britain (Elles and Wood 1902).

Loganograptus logani ssp.cf.L.logani pertenuis Ruedemann, 1904.

Pl.2,fig.6.

cf.1904 Loganograptus logani mut.pertenuis Ruedemann (pars) : 631-33, pl.9,fig.5.

cf.1947 L.logani mut.pertenuis; Ruedemann :287, pl.45,fig. 14 (not figs 15,16).

1960 L.logani mut.pertenuis; Berry :50,pl.12,fig.5.

Remarks. Ruedemann (1904 :pl.9,fig.5) referred to a specimen resembling L.logani but with more slender stipes (approximately 0.6mm wide) as "mut.pertenuis", apparently regarding it as of infrasubspecific rank. Ruedemann's specimen is less regularly branched than those of Nelson or of Texas (Berry

1960a:pl.12,fig.5).

Horizon and localities. 82/552,582. Associated forms, Isograptus imitata, I.caduceus maximodivergens. Zones 6 and 8.

The subspecies is known from the zone of Paraglossograptus etheridgei of Texas, and from the zone of Glyptograptus dentatus of New York.

GENUS Pseudobryograptus Mu, 1957.

Pseudobryograptus incertus (Harris and Thomas, 1934).

Pl.2,fig.8.

1935 Pterograptus incertus Harris and Thomas :289, fig.1, nos. 1,1a; fig.2, nos. 1-6.

Remarks. Nelson specimens match Harris and Thomas's description but include rhabdosomes with longer terminal stipes than those figured by Harris and Thomas. The species closely resembles Pseudobryograptus parallelus Mu (see below).

As diagnosed by Bulman (1955 :V76) Pterograptus excludes forms with third-order stipes, such as P.incertus; the species was therefore referred by Mu (1957) to his new genus Pseudobryograptus.

Horizon and locality. S2/582. Zone 8.

P.incertus is known from the Darriwilian (D2-3) of Victoria and from the zone of P.etheridgei of Texas (Berry 1960).

Pseudobryograptus parallelus Mu, 1957.

Pl.2,fig.4.

1957 Pseudobryograptus parallelus Mu :422, pl.3,figs 8,9; text-fig.8.

Remarks. Nelson specimens conform closely to Mu's specific description. Mu distinguished the species from P.incertus (Harris and Thomas) by its thinner stipes and longer thecae, but the two forms are found in the same beds at Nelson together with fragments of forms apparently intermediate between the two. A more complete description of populations containing the two forms is needed to determine their relationship.

Horizon and locality. S2/582. Zone 8.

P.parallelus was described from the Ningkuo Shale (D.hirundo zone), Western Chekiang, China (Mu,1957).

GENUS Pterograptus Holm, 1881.

Pterograptus? sp.nov.

pl.13,fig.10A.

Remarks. A few specimens of a peculiar asymmetrical pendant dichograptid have been found in zone 9, resembling a Pterograptus in which lateral stipes are given off from only one of the two primary stipes, the other remaining unbranched.

Horizon and localities. S2/539, 633. Associated forms, Cryptograptus schaferi, Glossograptus hincksii, Diplograptus? decoratus, Climacograptus brevis. Zone 9.

GENUS Sigmagraptus Ruedemann, 1904.

Sigmagraptus laxus (T.S.Hall, 1914)

Pl.2,fig.7.

1914 Goniograptus laxus T.S.Hall :113, text-fig.4.

1935 Sigmagraptus laxus; Benson and Keble :272-3, pl.32, figs 10,11, ?12.

Remarks. The Nelson specimen agrees well with Hall's description.

Horizon and locality. S2/564. Associated form, D.protobifidus. Zone 4.

The species was recorded from Preservation Inlet in Bendigonian beds by Benson and Keble, and is known from Bendigonian (Be3) to Castlemainian (Ca1) in Victoria.

GENUS Trichograptus Nicholson, 1876

Trichograptus fergusoni T.S.Hall, 1909

1912 Trichograptus fergusoni T.S.Hall :210,pl.26,figs 1,2.

1938 Trichograptus fergusoni; Harris and Thomas :72, pl.1, figs 6a-c; pl.4,fig.5.

Remarks. Two poorly preserved specimens from Nelson show the distinctive branching pattern of T.fergusoni.

Horizon and locality. S7/516. Associated forms, T.fruticosus (3- and 4-stiped forms). Zone 3.

T.fergusoni is known from the Bendigonian (Be1) to Chewtonian (Ch1) stage of Victoria, and from the zone of P.etheridgei of Texas (Berry 1960a).

GENUS Dichograptus Salter, 1863.

Dichograptus maccoyi Harris and Thomas, 1940.
Pl.3,fig.6.

1940 Dichograptus maccoyi Harris and Thomas :129,pl.1, figs 1a-d; pl.2,fig.2.

Remarks. Many names have been erected for slender forms of Dichograptus, some of which are likely to be conspecific. Because the Nelson specimens closely match the figures and description of D.maccoyi by Harris and Thomas, their name is used here.

Horizon and localities. S2/553, 600, 603. Associated form, Didymograptus cf.extensus. Zone 5.

D.maccoyi is known from the Bendigonian (Be2) of Victoria.

Dichograptus octobrachiatus (J.Hall, 1858).

1858 Graptolithus octobrachiatus J.Hall :122.

1865 Graptolithus octobrachiatus; J.Hall :96, pl.7,figs 1-7; pl.8,figs 1-4.

1902 Dichograptus octobrachiatus; Elles and Wood :77-9, pl.9; pl.10,figs 1a-e.

1947 Dichograptus octobrachiatus; Ruedemann :288-9, pl.46, figs 3-7.

Remarks. All Nelson specimens are incomplete or poorly preserved. The main stipes number from five to eight, agreeing with the descriptions by Elles and Wood and by Ruedemann. The central disc described by Hall and Ruedemann was not seen in any Nelson specimens.

Horizon and localities. S2/544,552,589,593,600,617. Zones 5 - 6.

D.octobrachiatus is an extremely widespread and long-ranging fossil. It is known from eastern and western North America, Europe, Scandinavia, China, and Australia, its stratigraphic range lying generally within the Arenigian or its equivalent. The species ranges from Bendigonian (Be1) to Darriwilian (D2) in Victoria.

Dichograptus octonarius (J.Hall, 1858).

Pl.3,fig.5.

1858 Graptolithus octonarius J.Hall :124.

1865 Graptolithus octonarius; J.Hall :95-6, pl.10,figs 1,2.

1940 Dichograptus octonarius; Harris and Thomas :129-30, pl.1,figs 2a-b; pl.2,fig.3.

Remarks. Hall based the species on a single specimen from Levis, Quebec. Specimens from Nelson and Victoria match Hall's specimen, particularly in the rapid widening of third-order stipes but vary considerably in rhabdosome form and stipe number. Australasian forms also have conspicuously "reclined" rhabdosomes; a feature not mentioned by Hall and indeterminable ~~indeterminate~~ from his figured specimen. Pending a redefinition of the species, the writer follows Victorian workers in referring Australasian forms to D.octonarius.

Horizon and localities. S2/528, 552, 599, 617. Associated forms, Dichograptus octobrachiatus, Isograptus caduceus victoriae, I.c.maximodivergens. Zones 5 - 6.

The species is known from the Castlemainian (Ca2) of Victoria.

GENUS Tetragraptus Salter, 1863.

Tetragraptus acclinans Keble, 1920.

Pl.5,fig.3.

1920 Tetragraptus acclinans Keble :198-9, fig.63; pl.33, figs 2a-c.

1960 Tetragraptus acclinans; Thomas :pl.1,fig.12.

Description. Primary branches form a funicle 2.1mm long, 0.6mm wide. Secondary stipes are gently curved, diverging at 100° proximally, 140° distally, giving the rhabdosome its characteristic shape. They are 37mm long, 1mm in lateral width at the first theca, and gradually widen to a maximum lateral width of 2.1mm at their distal ends. Thecae barely distinguishable, approximately 9 in 10mm.

Remarks. The Nelson material differs from Keble's description only in having a slightly shorter funicle (2.1mm, against 3mm in the Victorian material).

Horizon and locality. The single specimen, VG6, is from locality S2/577 at Aorangi Mine. Zone 2.

T.acclinans is known from the zone of T.fruticosus (4-stiped) of Texas (Berry 1960a:52); it ranges in Victoria

from Lancefieldian (La3) to Bendigonian (Be1).

Tetragraptus amii Lapworth, 1890

Pl.5,fig.7.

1865 Graptolithus bryonoides Hall (pars) :84-6, pl.4,figs 9,10.

1890 Tetragraptus amii Lapworth MS.

1902 Tetragraptus amii; Elles and Wood :60-1, pl.5,figs 4a-c.

Remarks. Nelson specimens agree well with the description by Elles and Wood. Australasian graptolite workers have been reluctant to accept Lapworth's name (Benson and Keble 1935 :274; Thomas 1960), preferring to use T.serra (Brongniart) sensu Tornquist (1904) instead, and to retain T.bryonoides (J.Hall) for those forms transferred to T.serra by Lapworth (Elles and Wood 1902 :61). Apparently no type specimen was designated for G.bryonoides Hall and the correctness of Lapworth's procedure is debatable. However, "Tetragraptus amii" has gained wide acceptance and is used here.

Horizon and localities. S2/545, 552, 556, 557, 560, 564, 586. Associated form, Isograptus caduceus maximodivergens. Zones 4,6, and 7.

Benson and Keble (1935 :274) recorded the species from Preservation Inlet and Benson et al (1936 :370) listed it from Aorangi Mine. T.amii ranges from Lower Bendigonian to Castlemainian in Victoria (recorded by Australians as "T.serra"). It is known from the T.fruticosus zone (4-stiped) to D.protobifidus zone of Texas (Berry 1960a:52), from the T.fruticosus zone (3- and 4-stiped forms) and D.protobifidus zones of New York (Berry 1962a:704), and from the I.gibberulus subzone and D.hirundo zone of the Skiddaw Group, England (Jackson 1962 :311).

Tetragraptus approximatus Nicholson, 1873.

Figs 25a-d; pl.4,fig.1.

1873 Tetragraptus approximatus Nicholson :136,fig.2.

1904 T.approximatus; Tornquist :6-7,pl.1,figs 11,12.

1920 T.approximatus; Keble :195-7, fig.61; pl.33,figs 1a-c.

1935 T.approximatus; Benson and Keble :275, pl.33,fig.22.

1937 T.approximatus; Monsen :156-8, pl.4,figs 8,20,21,25, 26?; pl.11,fig.4; pl.12,figs 4,5?

1938 T.approximatus; Harris and Thomas :74, pl.1,figs 17a-c; pl.4,fig.16.

1960a T.approximatus; Berry :52-3, pl.6,figs 1-3.

1962 T.(Etagraptus) approximatus; Lee and Chen; pl.3,figs 4-5.

1966 Tetragraptus approximatus; Smith :172-3,fig.1.

Description. The primary stipes form a funicle 1.8 (1.5-2.3)mm long, 0.5 (0.4-0.8)mm wide. The sicula cannot be seen. Second-order stipes reach 36mm in length, widening from 1.0mm (0.7-1.2) at the first theca to a maximum width of 1.6 (1.3-2.1)mm by about the 5th theca, narrowing slightly at the distal end. They are generally curved at their proximal ends, diverging initially at less than 180° but flexed back to give the rhabdosome its characteristic 'H' form (fig.25b,c). More rarely, the second-order stipes are straight and diverge sharply at 180° (fig.25a). Thecae are spaced 9.5 (9-10.5) in 10mm, are inclined 30-40°, and overlap about one half; ventral margins are slightly concave, apertural margins are normal to the stipe axis.

Remarks. The Nelson specimens show some variation in the width, curvature, and attitude of the second-order stipes, and in the length of the funicle. A few specimens from localities S2/577 and S2/590 are preserved with the second-order stipes converging distally or crossing each other (fig.25b).

The average maximum stipe width (1.6mm) and average length of the funicle (1.8mm) is less than that given by

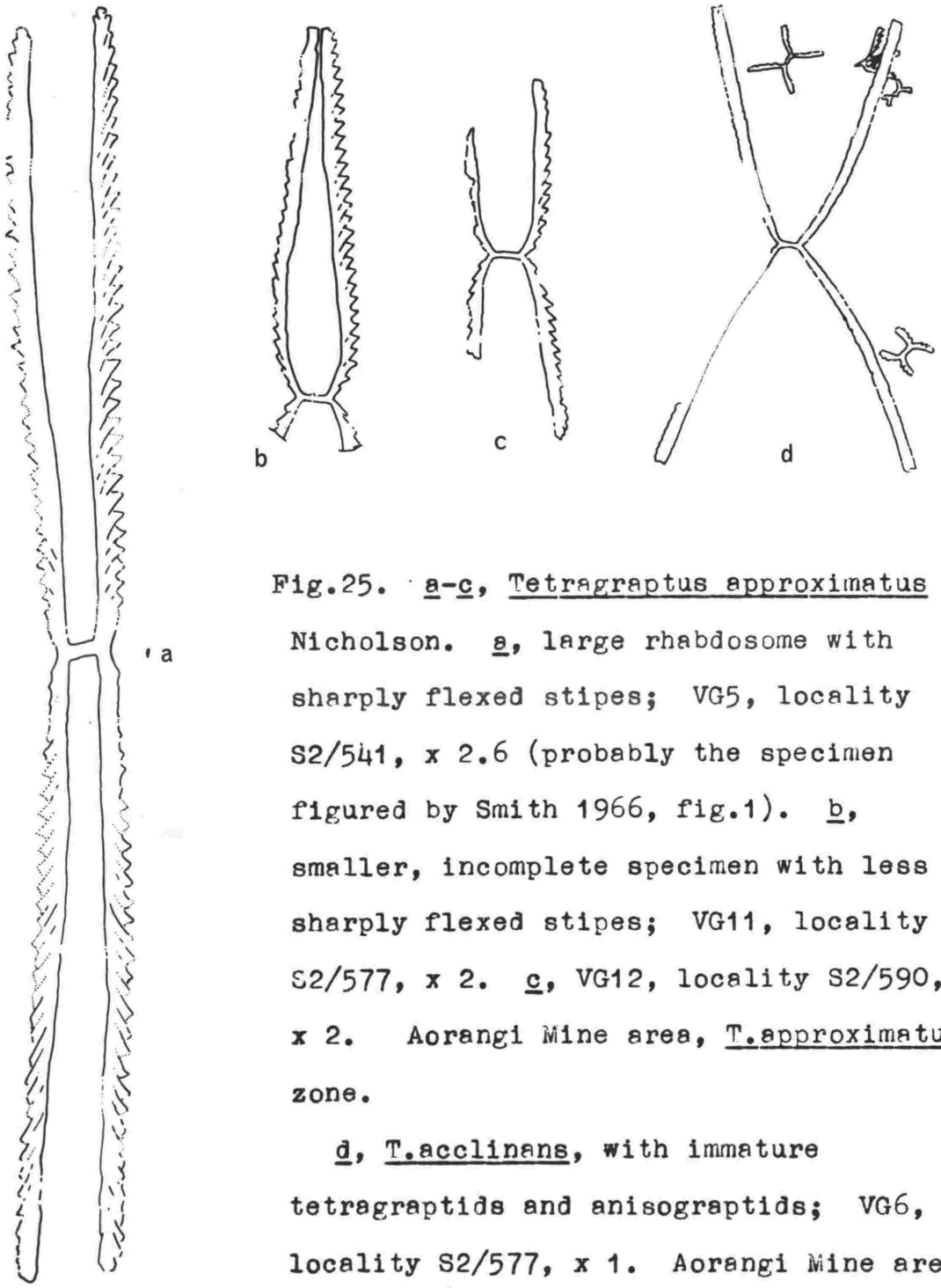


Fig.25. a-c, Tetragraptus approximatus Nicholson. a, large rhabdosome with sharply flexed stipes; VG5, locality S2/541, x 2.6 (probably the specimen figured by Smith 1966, fig.1). b, smaller, incomplete specimen with less sharply flexed stipes; VG11, locality S2/577, x 2. c, VG12, locality S2/590, x 2. Aorangi Mine area, T.approximatus zone.

d, T.acclinans, with immature tetragraptids and anisograptids; VG6, locality S2/577, x 1. Aorangi Mine area T.approximatus zone.

Nicholson ("one line" or 2.1mm and "one tenth of an inch" or 2.5mm respectively) in the original description. However, because the dimensions given were of "the largest specimen observed" in his collection (Nicholson 1873 :136) the smaller Nelson forms are here included in the species.

Ruedemann's figures of topotypes from Levis show considerable morphological variation ranging from forms with sharply flexed, relatively wide, second-order stipes, to forms with thinner more gently curved, second-order stipes resembling the specimen figured by Nicholson. Berry (1960a: 52-3) commented on the variation in curvature of the second-order stipes in Texas specimens.

Distribution and horizon. Localities S2/541, 577, 580, 590, 614, 616; S7/516. T.approximatus is the name-giving species to zone 2 in which it is particularly abundant. It ranges up into zone 3 at Elliot Creek (S7/516).

Benson and Keble (1935) and Skwarko (1958) reported the species from Fiordland, and Smith (1966 :172-3,fig.1) described and figured a specimen from Sandhills Creek, Aorangi Mine area. What is thought to be Smith's specimen is refigured here (fig.25a).

The species is known from the Lancefieldian (La3) and Bendigonian (Be1) of Victoria (Thomas 1960), from the Levis Shale, Quebec (zone A of Raymond,1914), from the Marathon region, Texas (zone of T.approximatus, Berry 1960a), from

Newfoundland (zone of T.approximatus and Clonograptus, Kindle and Whittington 1958), from Yukon (zone of T.approximatus, Jackson and Lenz 1962), from Sweden (zone of Tetragraptus phyllograptoides at Mossebo, Tornquist 1904), from China (lower Tonggao Shale at southern Gueizhou, Lee and Chen 1962), and from Taimyr, U.S.S.R. (Sokolov et al 1960 : 51). It appears to have a relatively short time range and is an important fossil for world-wide correlation.

Tetragraptus bigsbyi (J.Hall, 1858).

Pl.6,figs 2,5.

1858 Phyllograptus similis J.Hall :140.

1865 Graptolithus bigsbyi Hall (pars) :86-7, pl.16,figs 25,26,29,30 (not figs 22-24,27,28 = T.pseudobigsbyi Skevington 1965).

1963c Tetragraptus bigsbyi; Skevington :4-8,figs 1,3,5,6.

Remarks. The Nelson specimens agree well with Skevington's description of the lectotype, except in having a maximum stipe width of 2-3mm, rather than 3.1mm.

Horizon and localities. S2/552, 580, 588, 624. Zones 3,4,6.

Benson and Keble (1935 :278) recorded the form from Preservation Inlet and Benson et al (1936 :367) listed it

from Aorangi Mine.

T.bigsbyi sensu Hall 1865 has been reported widely, from North America, Britain, Scandinavia, China and Australia, its range generally lying within the Arenigian. In Victoria the species ranges from Bendigonian (Be2) to Castlemainian (Ca2).

Tetragraptus sp.aff. T.chapmani Keble and Harris, 1934.

Pl.7,fig.1.

aff.1934 Tetragraptus chapmani Harris and Keble: 169-70, pl.20,figs 3a-b.

Remarks. With their conspicuously denticulate thecae, second-order stipes in the Nelson form resemble those of T.chapmani. First-order stipes comprise only one theca each however, instead of three as in T.chapmani.

Horizon and locality. Common at locality S2/552. Associated form, Isograptus caduceus maximodivergens. Zone 6.

Tetragraptus decipiens T.S.Hall, 1899.

Figs 26a-g; pl.5,figs 1,2,5.

1899a Tetragraptus decipiens T.S.Hall :168-9, pl.17,figs 13-15; pl.18,figs 16? 17-19.

1920 T.decipiens; Keble :199-201, pl.34,fig.1a-e.

1935 T.decipiens; Benson et al :365.

1966 T.decipiens; Berry :423-4,pl.44,figs 5,10,11.

Description. The sicula is 1.3-1.8mm long, and about 0.5mm wide at the aperture. Two primary stipes diverge from near the sicular aperture, their initial dorso-ventral width being about 0.9-1.0mm and lateral width, about 0.5mm. Second-order stipes are given off at the level of the first thecal aperture. Two distinct forms are inferred to belong to the species; in the first, both primary stipes divide (the four-stiped form), while in the second only one primary stipe divides (the three-stiped form).

In the four-stiped form, the funicle is 1.9-2.3mm long. Second-order stipes range up to 7mm long, widening from about 0.5mm at the first theca to a maximum of 1.5mm at about the 6th theca, thereafter of constant width or tapering slightly. Their attitude is variable and some specimens appear to have been twisted during or prior to burial. Thecae are spaced 4 (3.7-4.2) in 4mm in the proximal region, are inclined at about 30°, are long and narrow, and overlap one half or more. Thecal ventral margins are straight or

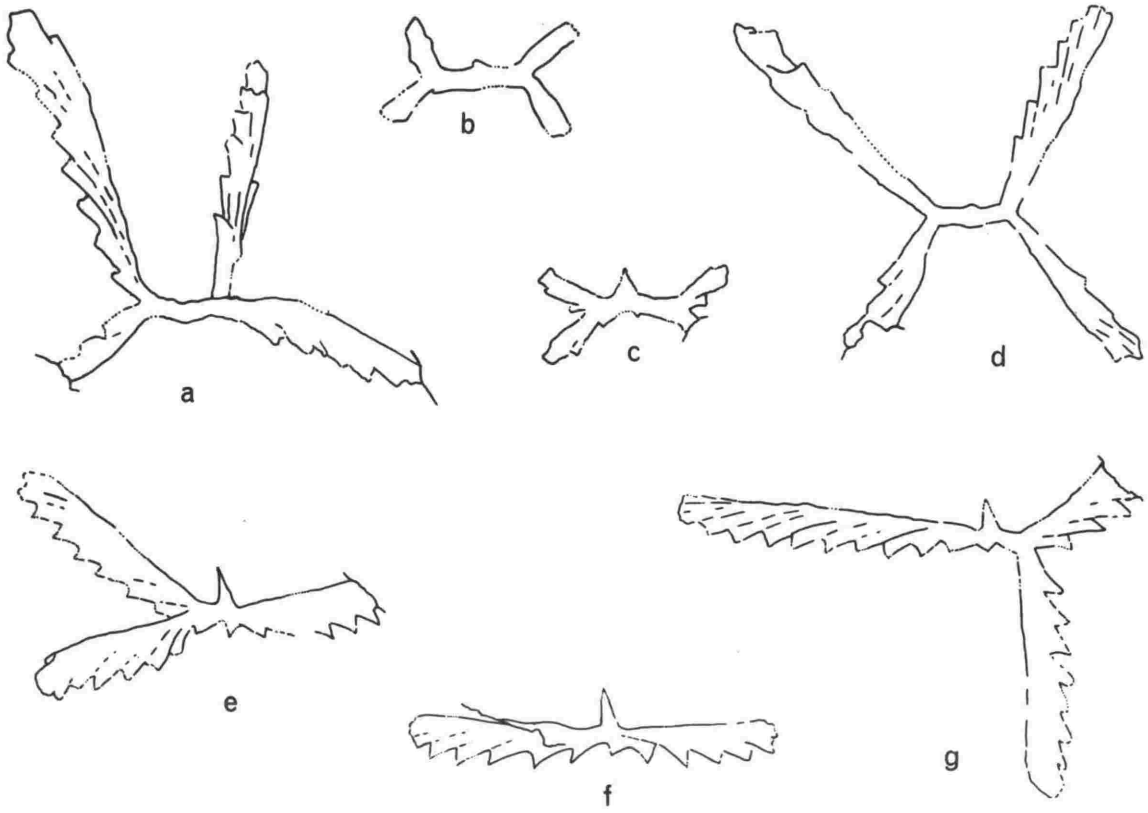


Fig.26. Tetragraptus decipiens T.S.Hall. a-d, four-stiped forms. a, VG2, locality S2/613, Aorangi Mine area. b, immature form, GR71, locality S7/516, Elliot Creek. c, immature form, GR72; locality S7/516, Elliot Creek. d, VG3, locality S2/613, Aorangi Mine area. a-d, from T.fruticosus zone. e-g, three-stiped forms. e, VG4, locality S2/590. f, specimen in which the two second-order stipes lie superposed; VG10, locality S2/577. g, VG9, locality S2/590. e-g, from Aorangi Mine area, T.approximatus zone.

All figures x 5.

slightly concave.

In the three-stiped form the two primary stipes diverge at approximately 180° from near the sicular aperture. One stipe divides dichotomously at the level of the first thecal aperture; the angle of divergence of the two second-order stipes is usually slightly less than 120° but varies according to the orientation of the rhabdosome prior to burial and compaction. All three stipes must have been approximately horizontal with respect to the sicula. They are generally 8-10mm in length, and are 0.9-1.0mm wide at the level of the first thecal aperture, increasing to a maximum of 1.1-1.4mm at the third or fourth thecal aperture. Lateral width is 0.6-0.8mm.

Thecae number 5.5-6.5 in 5mm and are inclined at 30-40°, with an overlap of slightly more than one half (about 0.6); ventral walls are slightly concave, apertural margins straight or almost straight and normal to the stipe axis.

Remarks. The three- and four-stiped forms are analagous to the three- and four-stiped forms of *Tetragraptus fruticosus*, and can be considered polymorphic variants of one species.

The four-stiped variant is most commonly preserved as small dumb-bell shaped forms (figs 26b,c) which probably represent immature specimens, and which show few, or no, details of structure. The few larger Nelson specimens (figs 26a,d) differ slightly from Berry's illustrations of

the types in the proximal tapering of the second-order stipes. From the measurements and figures given by Hall, Keble, and Berry, the four-stiped form shows appreciable variation. Keble noted that the second-order stipes were probably "declined" in life, and thus did not lie in one plane. 'Flattening' of such forms would produce variable stipe attitude as seen in the Nelson material.

In the three-stiped form the dichotomously dividing branch appears to be that based on th1^2 (specimen VG10). T.triograptoides Harris and Thomas 1938, from the lower Bendigonian of Victoria, and "Triograptus" otagoensis Benson and Keble, from the Lancefieldian of Preservation Inlet are similar 3-stiped tetragraptids, but differ from the Nelson form in having thinner stipes.

Horizon and Localities. Three- and four-stiped forms are found together at S2/577 in the Aorangi Mine area. Three-stiped forms only are found at S2/590, and four-stiped forms only are found at S2/524, 527, 577, 580, 612, 613; S7/516, 518, 519, and 520. Associated with both forms are T.approximatus, T.acclinans, and Adelograptus? antiquus. Zone 2 (3-stiped form); zones 1 - 3 (4-stiped form).

Benson et al (1936) recorded T.decipiens (four-stiped form) from the Aorangi Mine area together with the variety bipatens Keble and Harris. The material was neither described nor illustrated and the writer has not been able

to distinguish subspecies within the Nelson material. Benson and Keble (1935) also recorded both forms from Fiordland.

The species is common in the upper Lancefieldian (La3) and lower Bendigonian of Victoria, and is found in the zone of Adelograptus and Clonograptus of the Marathon sequence, Texas (Berry 1960a:54).

Tetragraptus fruticosus (J.Hall, 1858)

Figs 27a-c; pl.4,figs 2,5,7.

1858 Graptolithus fruticosus J.Hall :128.

1865 Graptolithus fruticosus; J.Hall :90-1, pl.5,figs 6-8; pl.6,figs 1-3.

1874 Graptolites (Didymograpsus) fruticosus; McCoy: 13, pl.1,figs 9-14.

1902 Tetragraptus fruticosus; Elles and Wood :61, pl.6, figs 2a-b.

1935 Tetragraptus fruticosus; Benson and Keble :275-6, pl.30,fig.41; pl.33,figs 25,27.

1947 Tetragraptus fruticosus; Ruedemann :304-5, pl.51, figs 25? 26-32.

1960a Tetragraptus fruticosus; Berry :54-5, pl.6, figs 7, 11,12; pl.7,fig.14; pl.8,figs 1,3; pl.9,fig.3.

Description. Sicula conspicuously large measuring 1.8-2.1mm long, and at least 0.5mm wide at the aperture. A long nema (up to 10mm) widens towards the sicula, making the apical margin of the sicula difficult to determine in many specimens. Two primary stipes diverge at about 90°, curve downwards for the first 5 or 6mm, then straighten, their distal portions diverging at between 30 and 70°.

Second-order stipes arise from near the apertures of the two initial thecae of the rhabdosome ($th1^1$, $th1^2$). Two distinct forms of the species are present : those in which one primary stipe divides, the three-stiped form (figs 27b,c), and those in which both primary stipes divide, the four-stiped form (fig.27a).

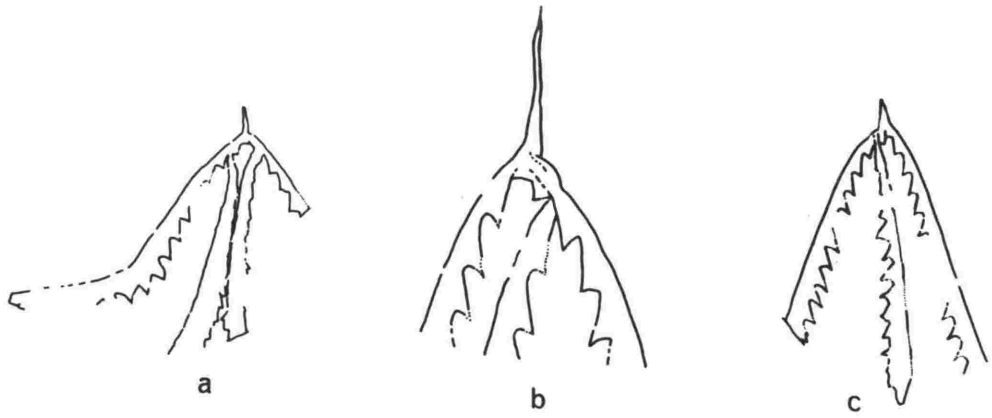


Fig.27. Tetragraptus fruticosus (J.Hall). a, four-stiped form x 2; VG23, locality S2/628. b, three-stiped form, x 5; VG21, locality S2/606. c, three-stiped form x 2; VG22, locality S2/626. All from Aorangi Mine area, T.fruticosus zone.

In most larger rhabdosomes of both forms the stipes recurve outwards distally, giving the characteristic bell-shaped outline to the rhabdosome (fig.27a). Stipes gradually widen throughout their length, from about 0.9mm in the proximal region to a maximum distal width ranging from 1.5-2.3mm

Thecae are spaced 7 to 8 in 10mm, the ventral walls are inclined at about 30°, apertural margins are concave and sharply denticulate.

Discussion. The Nelson specimens agree well with Hall's (1865) figures and with the description and illustrations by Elles and Wood (1902) and by Ruedemann (1947, excluding the specimen figured in pl.51, fig.25, which is nearer to T.pendens than T.fruticosus.)

In Nelson specimens of the three-stiped form, the second-order dichotomy always arises in the primary stipe developed from th1[1] (the shorter of the two initial thecae) and thus corresponds to the third-formed stipe of the four-stiped form. The three-stiped form could thus be derived from the four-stiped form by suppression of the fourth-formed stipe during development of the rhabdosome ("arrested development"), and the two forms can be considered as polymorphic variants of the one species. The four-stiped form generally appears before, and is superceded by, the three-stiped form (Benson and Keble 1935, Harris and Thomas

1938b, Kindle and Whittington 1958, Berry 1960a).

Judging from his illustrations, Ruedemann's species Tetragraptus clarkei is probably synonymous with T.fruticosus (Ruedemann 1947 :pl.50,figs 2-4,5?).

Horizon and localities. Four-stiped forms only are known from locality S2/628; three-stiped forms only are known from S2/606, 607, 626, 627; S7/519; while both forms are present at S2/524, S7/516,520. Zone 3 (3- and 4-stiped forms), and Zone 4 (3-stiped form only).

Both forms of the species were recorded from Aorangi Mine by Skwarko (1962) and are known from Fiordland (Benson and Keble 1935).

The species spans the Bendigonian stage in Victoria, the four-stiped form ranging from zones Be1 - Be3, the three-stiped form from zones Be2 - Be4. In Texas the four-stiped form ranges from the zone of T.fruticosus (4-stiped) to the zone of D.protobifidus; the three-stiped form ranges from the zone of T.fruticosus (3- and 4-stiped forms) to the zone of D.protobifidus (Berry 1960a:54-5). Both forms of the species are present in the Deepkill Shale of New York (Berry 1962a :707), and have about the same range, given as zone of T.fruticosus (3- and 4-stiped) to zone of D.protobifidus.

The species is also known from Quebec (Hall 1858;

Raymond 1914, "zone D") from Peel River, Yukon (Jackson 1964: 524) and northern Britain (Elles and Wood 1902).

Tetragraptus harti T.S.Hall, 1914.

Pl.5, fig.6.

1914 Tetragraptus harti T.S.Hall :113-4, text-figs 5,6.

1935 Tetragraptus harti; Benson and Keble :276, pl.33,figs 2,3, ?10.

1938 Tetragraptus harti; Harris and Thomas :73,pl.2,figs 14a-b; pl.4,fig.13.

Remarks. Specimens from zones 3 and 4 agree well with Hall's description, though they have slightly longer first-order stipes, as in those figured by Harris and Thomas.

Horizon and localities. S2/586, 606, 608, 626, 628. Zones 3-4,6.

T.harti was figured from Cape Providence, near Preservation Inlet, by Benson and Keble (1935), and listed from Aorangi Mine by Benson et al (1936 :370). It has a more restricted range in Victoria (Bendigonian, Be1-Be4). The species has been recorded from the Ningkuo Shale of China by Geh (1964 :393). An incomplete specimen from Norway was figured by Monsen (1937 :pl.4,figs 12,19) as T.cf.harti.

Tetragraptus headi (J.Hall, 1857)

Pl.7,fig.3.

1857 Graptolithus headi J.Hall: 127.

1865 Graptolithus headi; Hall :94-5, pl.6,fig.8.

1902 Tetragraptus headi; Elles and Wood :59-60, pl.5,figs 3a-b.

Remarks. Second-order stipes in the Nelson specimen reach 3.7mm wide; Elles and Wood (p.59) state that maximum stipe width in T.headi is 3.0mm, but their figure (pl.5,fig.3b) indicates that stipe width reached at least 3.5mm.

Horizon and locality. S2/552. Associated forms Trigonograptus ensiformis, Isograptus caduceus maximodivergens, Didymograptus sp. (extensiform). Zone 6.

T.headi was described from Levis, Quebec, where it is found in zone D2 (Raymond 1914 :529); it is found with Didymograptus hirundo and D.gibberulus in the Skiddaw Slates, England. Its presence in Victoria is doubtful (T.S.Hall, 1899b :6).

Tetragraptus pendens Elles, 1898.

Pl.4, fig.6.

1898 Tetragraptus pendens Elles :491, fig.13.

1902 Tetragraptus pendens; Elles and Wood :63-4, text-fig. 38; pl.6,figs 3a-d.

Remarks. The Nelson specimens have thecae with denticulate apertural margins but otherwise agree well with the descriptions by Elles (1898) and Elles and Wood (1902).

Horizon and localities. S2/628; S7/516. Zone 3.

T.pendens was recorded from Preservation Inlet by Benson and Keble (1935 :276-7), and T.cf.pendens was listed from Aorangi Mine by Benson et al (1936 :367). The species ranges from Bendigonian (Be1) to Chewtonian (Ch1) in Victoria, and is known from the T.fruticosus (4-stiped form) zone of Texas (Berry 1960a:55). Elsewhere, it is confined to younger beds. In New York it occurs in the D.bifidus zone of Ruedemann (1947 :306) though Berry (1962b :704) lists it from the D.protobifidus zone only. Raymond (~~1944~~ 1914 :529) lists it from zone C3 (D.bifidus), of Levis, Quebec; Jackson (1962 :312) records it from the D.nitidus subzone of the Skiddaw Slates.

Tetragraptus sp.cf. T.pendens Elles, 1898.

Pl.4, fig.3.

cf.1898 Tetragraptus pendens Elles :491.

cf.1902 Tetragraptus pendens; Elles and Wood :63-4, text-fig.38, pl.6,figs 3a-d.

Remarks. A larger rhabdosome and conspicuously denticulate thecae separate this form from that described by Elles. It has a similar pendant habit however, and is found in the same beds as T.pendens.

Horizon and locality. S2/628. Zone 3.

Tetragraptus quadribrachiatus (J.Hall, 1858)

Pl.3,fig.2; pl.7,fig.2.

1858 Graptolithus quadribrachiatus Hall :125.

1899b Tetragraptus projectus T.S.Hall :448,pl.22,figs 5,6.

1947 Tetragraptus quadribrachiatus; Ruedemann :307-8,pl.50, figs 15-18.

Remarks. Nelson specimens agree well with Ruedemann's description. One specimen (pl.7,fig.2) has a "central disc" - apparently a membranous film of periderm - and prominent

thecae, and matches the Victorian form T.projectus T.S.Hall (1899 :448). According to T.S.Hall T.projectus is distinguished by its narrow second-order stipes and by its prominent thecae. Similar forms were figured by Ruedemann (1947 :pl.50,figs 16,17) as T.quadribrachiatus however, and until J.Hall's species is revised, it is considered to include T.projectus.

Horizon and localities. T.quadribrachiatus is ubiquitous and long-ranging. At Nelson it is found at localities S2/540, 552, 557, 580, 582, 600, 603, 606, 615; S7/516, 519. Zones 3 - 8.

It has been recorded from North America, Britain, Scandinavia, China, U.S.S.R., and Australia, generally in rocks of Arenigian or, less commonly, Llanvirnian age.

Tetragraptus reclinatus Elles and Wood, 1902.

Pl.6, fig.1.

1902 Tetragraptus reclinatus Elles and Wood :67, pl.6,figs 5a-e.

1936 Tetragraptus reclinatus; Benson et al :378, text-fig.3.

Remarks. Nelson specimens agree well with the description by Elles and Wood. Of their figured specimens, those of plate 6, figs 5d-e most closely resemble the Nelson form.

Horizon and localities. S2/552, 563, 570, 586, 600, 601. Zones 4 - 6.

T.reclinatus was figured from the Aorangi Mine area by Benson et al (1936 :367, text-fig.3). The species is known from the D.protobifidus zone of Texas (Berry 1960a:56), from the Arenigian of England (Elles and Wood 1902) and from the lower Didymograptus Shale of Norway (Monsen 1937 :175).

Tetragraptus serra (Brongniart, 1828)

Pl.6,fig.9.

1828 Fucoides serra Brongniart : 71, pl.6,figs 7,8.

1902 Tetragraptus serra; Elles and Wood :65, text-fig.40, pl.6,figs 4a-f.

Remarks. Nelson specimens from zone 4 and 5 agree well with Elles and Wood's description of T.serra. They probably gave rise to the larger form of zone 6, T.cf.serra.

Horizon and localities. S2/528, 544, 545, 586 (specimen GR88), 605; S7/520. Zones 3 - 7.

Benson and Keble (1935 :278) listed the form from Preservation Inlet (Bendigonian and Chewtonian), and Benson et al (1936 :370) listed it from Aorangi Mine. Several different forms have been referred to T.serra, by workers

from both New Zealand and elsewhere and the species needs revision. "T.serra" has been recorded from Australia (as T.bryonoides J.Hall), North America, Britain, Belgium, Scandinavia and China, its range generally lying within the Arenigian. Its range in Victoria is from Bendigonian (Be3) to Darriwilian (Da3).

Tetragraptus cf. T.serra (Brongniart, 1828)
Pl.6, figs 7,11.

cf. 1828 Fucoides serra Brongniart :71, pl.6,figs 7,8.
cf. 1902 Tetragraptus serra; Elles and Wood :65, text-fig.40, pl.6,figs 4a-f.

Remarks. Although generally resembling T.serra, this form has wider, more rigid, and more reclined stipes. It is confined to zones 6 and 7 and is apparently closely related to T.serra which ranges from zones 3 to 7.

Horizon and localities. S2/532, 540, 552, 560, 567, 630. Associated forms, Isograptus caduceus maximodivergens, I.imitata, I.dumosus, Didymograptus sp. (extensiform). The species is conspicuously common in zone 6, and ranges up into zone 7.

Tetragraptus sp. aff. T.serra (Brongniart, 1828)
Pl.6, fig.10.

aff. 1828 Fucoides serra Brongniart :71, pl.6,figs 7,8.

1865 Graptolithus bryonoides Hall (pars.) :84-6, pl.4, figs 4,7 (not figs 1-3, 5-6, 8-11).

aff. 1902 Tetragraptus serra; Elles and Wood :65-7, text-fig,40, pl.6,figs 4a-f.

Remarks. The single specimen has rigid, apparently reclined stipes more than 6.5cms long, of T.serra type. It resembles the specimen figured by Hall (pl.4,figs 4,7) as Graptolithus bryonoides, and which were included by Elles and Wood in T.serra. The Nelson form differs however, from Elles and Wood's diagnosis and illustrations of T.serra particularly in its long, rigid stipes and distinct funicle.

Horizon and locality. S2/524. Zone 3.

Tetragraptus sp. aff. T.taraxacum Ruedemann,1904
Pl.6, figs 3,4,8.

aff. 1904 Tetragraptus taraxacum Ruedemann :663-4, pl.12, figs 17-26.

Remarks. With its conspicuous sicula, its long slender initial thecae (th1^1, 1^2) and its narrow reclined second-order stipes, the Nelson form resembles T.taraxacum Ruedemann, but is distinguished by a higher inclination and greater overlap of distal thecae. T.minutus Geh (1964: 400-401, pl.4,fig.12; text-figs 7a-b) appears to be a closely related form.

Horizon and localities. S2/552, 553, 560, 564, 609. Associated forms, Isograptus caduceus maximodivergens, I.imitata, I.hastatus, I.dumosus. Zones 4 and 6.

T.taraxacum was figured from Preservation Inlet by Benson and Keble (1935 :pl.33,figs 7,8). The species ranges from the zone of T.approximatus to the zone of D.protobifidus in Texas (Berry 1960a :56), and was listed from the zones of T.fruticosus and D.protobifidus of New York (Berry 1962a :704) though Ruedemann also recorded it from beds with Glyptograptus dentatus. Jackson listed the species from the G.dentatus zone of Northern Yukon (Jackson 1962 :39).

T.minutus is known from the Ningkuo Shale (Geh 1964: 401).

Tetragraptus whitelawi T.S.Hall, 1914.

1914 Tetragraptus whitelawi T.S.Hall :114, pl.17,fig.16.

Remarks. Although poorly preserved, the Nelson specimens have a "funicle" 8mm long and agree well with Hall's description of T.whitelawi.

Horizon and localities. S2/528, 626. Zone 4. The species ranges from the Bendigonian (Be4) to Chewtonian (Ch2) in Victoria.

GENUS Phyllograptus J.Hall, 1858.

Phyllograptus angustifolius angustifolius J.Hall,1858
Pl.8, fig.2.

1858 Phyllograptus angustifolius J.Hall :139.

1902 Phyllograptus angustifolius; Elles and Wood :100-01, pl.13,figs 7a-f.

Remarks. Nelson specimens closely match Elles and Wood's description.

Horizon and localities. S2/522, 531, 564, 570, 579, 586,

593, 605, 606, 607, 609. Associated forms, Isograptus caduceus lunata, Phyllograptus typus, Phyllograptus sp. Zones 4-5.

P.angustifolius was figured from Preservation Inlet by Benson and Keble (1935 :288-9, pl.33,figs 16? 19,20) and was recorded from the Aorangi Mine area by Benson et al (1936 :367,370). It is widely distributed elsewhere, being known from the Chewtonian (Ch2) of Victoria, from the zones of T.fruticosus (3- and 4-stiped), and D.protobifidus of Texas (Berry 1960a :57), from the D.protobifidus zone to the P.etheridgei zone of New York (Berry 1962a :704), from the Levis Shales of Quebec (Hall 1858), from the D.nitidus subzone to the D.hirundo zone of northern England (Jackson 1962 :312), from the P.densus and P.angustifolius elongatus zones of southern Norway (Monsen 1937), and from the Ningkuo Shale of South Anhui, China (Hsu 1934 :pl.3,figs 5a-c).

Phyllograptus angustifolius elongatus Bulman, 1931.
Pl.8, figs 3a-b.

1931 Phyllograptus angustifolius var.elongatus Bulman : 46-7, pl.3,figs 1,2.

Remarks. The Nelson specimen agrees closely with Bulman's

description.

Horizon and locality. S2/633. Zone 9.

The species is associated with Didymograptus bifidus - murchisoni transients in Bolivia (Bulman 1931 :47), and is the name-giving species to the P.angustifolius elongatus zone (3bδ) of southern Norway (Monsen 1937 :213).

Phyllograptus anna J.Hall, 1865.

Pl.4,fig.4; pl.8,fig.7.

1865 Phyllograptus anna Hall :124, pl.16,figs 11-16.

1902 Phyllograptus anna; Elles and Wood :101-2, pl.13, figs 6a-f.

Remarks. Nelson specimens agree well with Elles and Wood's description. A few specimens bear a short sicular spine (pl.4,fig.4), similar to that noted by Ruedemann in New York specimens (1947 :pl.53,figs 28,31).

Horizon and localities. S2/563, 564, 570, 586, 588, 593, 603, 604, 611, 625, 626, 628; S7/517. Associated forms Sigmagraptus laxus, Didymograptus protobifidus. Zones 3 - 5.

P.anna was listed from Preservation Inlet by Benson and Keble (1935 :289), and from the Aorangi Mine area, by Benson et al (1936 :267, 270). It is known from the T.fruticosus (3- and 4-stiped) zone to D.bifidus zone of Texas (Berry 1960a :57), from the T.fruticosus zone to P.etheridgei zone of New York (Berry 1962a :704), from the D."bifidus"and G.dentatus zones of Northern Yukon (Jackson and Lenz 1962 :38-9), from the subzone of D.nitidus to the zone of D.hirundo in England (Jackson 1962 :312), and from the zone of P.densus of Southern Norway (Monsen 1937 :217).

Phyllograptus ilicifolius Hall, 1858.

1858 Phyllograptus ilicifolius Hall :139.

1947 Phyllograptus ilicifolius; Ruedemann :317-8, pl. 53,figs 9-19.

Remarks. Although not well preserved, Nelson specimens agree well with Ruedemann's description.

Horizon and localities. S2/522, 562, 564, 586, 588, 593, 600. Zones 4 - 5.

The species was recorded from Preservation Inlet by Benson and Keble (1935 :289) and from the Aorangi Mine area by Benson et al (1936 :367,370). It is known from

the Chewtonian of Victoria, from Western and Eastern United States, Western and Eastern Canada, Great Britain, and Scandinavia, its stratigraphic range generally lying within the Arenigian.

Phyllograptus "nobilis" Harris and Keble, 1932.
Pl.10, fig.3.

1932 Phyllograptus nobilis Harris and Keble :41-2, pl.6, figs 3,4.

1966a Phyllograptus nobilis; Berry :424-5, pl.44,figs 6-9.

Remarks. Nelson specimens match the description of the type specimens by Harris and Keble and by Berry. The form is stratigraphically distinct from other species of Phyllograptus in Australasia but is morphologically similar to the earlier species, P.ilicifolius and P.angustifolius. It is here tentatively considered to be a distinct species.

Horizon and locality. S2/545. Zone 7.

The form is known from the Darriwilian (D3) in Victoria (Thomas 1960 :17), and from the G.cf.teretiusculus zone of Texas (Berry 1960a :58). It has also been recorded from the Basin Ranges, Western United States (Ross and Berry 1963 :84).

Phyllograptus typus J.Hall, 1858.

Pl.8, fig.1.

1858 Phyllograptus typus Hall :137.

1947 P.typus; Ruedemann :320-1, pl.53,figs 22-26.

Remarks. Nelson specimens have large rhabdosomes of variable shape, and agree well with Ruedemann's description of P.typus.

Horizon and locality. S2/579. Zone 5.

P.typus is known from the Bendigonian (Be4) of Victoria, from the zones of D.protobifidus and D.bifidus of Texas (Berry 1960a:58), from the same two zones of New York (Berry 1962a :704), and from Western and Eastern Canada (Ruedemann 1947 :320).

GENUS Didymograptus McCoy, in Sedgwick and McCoy, 1851.

Didymograptus sp.cf. D.ensjoensis Monsen, 1937.

Pl.9, fig.1.

cf. 1937 Didymograptus ensjoensis Monsen :107-8, pl.1,fig. 40; pl.7,figs 12-14.

cf. 1940 D.ensjoensis; Harris and Thomas :133, pl.1,figs

13a-b; pl.2,figs 15a-b.

Remarks. Nelson specimens show conspicuous widening of the stipes and agree with Monsen's description except that thecae are spaced 9-11 in 10mm rather than 8-9 as given by Monsen.

Horizon and locality. S2/628. Zone 3.

D.ensjoensis is known from the Bendigonian (Be1-2) of Victoria (Thomas 1960) and from the P.densus zone of southern Norway (Monsen 1937).

Didymograptus sp.cf. D.eocaduceus Harris, 1933.
Pl.9, fig.4; pl.11, fig.4.

cf. 1933 Didymograptus eocaduceus Harris :109,text-figs 64-67.

Remarks. Nelson specimens differ from Harris's description in having less strongly reclined stipes, and a larger sicula. Harris indicated a wide range of variation in rhabdosome form however and the Nelson specimens are compared with the species. The distinction between D.cf. eocaduceus and Isograptus Moberg is discussed below, under Isograptus.

Horizon and localities. S2/552, 550, 570, 579. Associated forms, Isograptus caduceus maximodiverrens, I.imitata. Zones 5 - 6.

D.eocaduceus is confined to the lower Bendigonian (Be1) in Australia (Thomas 1960), disappearing before the first appearance of the Nelson form.

Didymograptus extensus (J.Hall, 1858).

Pl.9, figs 2,5.

1858 Graptolithus extensus J.Hall :132.

1865 G.extensus; J.Hall :80-2, pl.2,figs 11-16.

1947 Didymograptus extensus; Ruedemann :331-2, pl.55,fig. 16; pl.56,figs 1,2.

Remarks. Nelson specimens agree well with Hall's (1865) figures and with Ruedemann's description.

Horizon and localities. S2/565, 586, 599, 603. Zones 4-5.

The species was recorded from Preservation Inlet by Benson and Keble (1935 :282-3), and "D.extensus - nitidus transients" were listed from the Aorangi Mine area by Benson et al (1936 :367,370). "D.extensus" has been recorded widely, from Australia (upper Lancefieldian to Chewtonian), North America, Europe, U.S.S.R., and China, its range

generally lying within the middle or lower Arenigian.

Didymograptus sp. (extensiform)

Remarks. Zones 3-7 contain a complex of extensiform didymograptids, including some forms with initially declined rhabdosomes. Some forms match described species and are so named here, but many appear to be intermediate between described forms and are listed as "D. spp. (extensiform)".

The whole group of extensiform didymograptids has long needed revision (see Bulman 1936b:74); a detailed study of the populations from which "species" have been described is likely to show that many of the supposed "species" are conspecific.

Didymograptus protobifidus Elles, 1933.

Figs 28a-e; pl.8, figs 4,5,6.

1933 Didymograptus protobifidus Elles :98, figs 1-3.

1935 D. protobifidus; Benson and Keble :285-6, text-figs 3a-b.

1937 D. protobifidus; Ripper :154-6, text-figs 1a-c, 2a-b, 3, 8a-d.

1960a D. protobifidus; Berry :63-4, pl.8, figs 5-9.

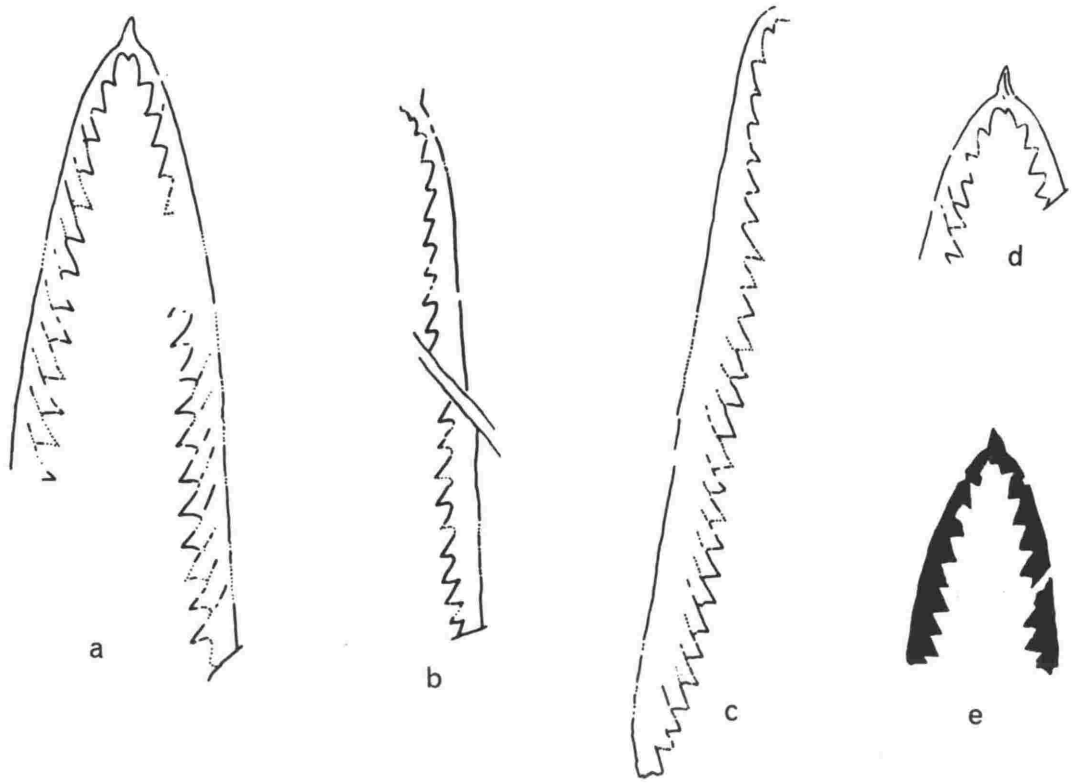


Fig.28. Didymograptus protobifidus Elles. a, incomplete rhabdosome of common form; GR1, locality S2/586. b, single stipe of narrow-stiped specimen; VG27, locality S2/564. c, single stipe of protobifidus-bifidus transient; VG25, locality S2/606. d, proximal portion of rhabdosome; VG26, locality S2/564. e, immature rhabdosome; VG28, locality S2/564. All specimens from Aorangi Mine area, D.protobifidus zone. All figures x 5.

Description. Siculs generally about 1mm long (0.7-1.4mm). Stipes up to 20mm long, diverging initially at about 90°, curved downwards reducing the divergence angle to 10-20° within the first 3-4mm. Stipes about 0.5mm wide proximally, gradually expanding to a maximum width, near their distal extremities, of 1.2-1.4mm.

Thecae in most specimens are spaced 12½ - 14 in 10mm. Thecal ventral walls are either straight or slightly concave, inclined generally at 30-35°, but ranging in a few specimens, up to 40-45°. Overlap is one half or slightly less, and apertural margins are normal to the stipe axis.

Discussion. The Nelson specimens agree well with Elles's description. Ripper (1937) noted that some Nelson specimens showed considerable widening of the stipes and a distal increase in thecal overlap, and represented transients between D.protobifidus and D.bifidus. Specimen VG25 (fig. 28c; pl.8,fig.4) is probably a similar transient.

Horizon and localities. S2/564, 586, 588, 605, 606, 609, 625. Associated forms, Sigmagraptus laxus, Phyllograptus spp. D.protobifidus is the name-giving fossil to the fourth zone at Aorangi Mine, in which it is particularly abundant and to which it is confined.

The species has been described and figured from Fiordland (Benson and Keble 1935 :285, text-fig.3a-b), and was recognised at Golden Ridge, Aorangi Mine area, (locality

82/490) by Benson et al (1936). It ranges from Bendigonian (Be4) to Chewtonian (Ch?) in Victoria (Thomas 1960), and is a zone fossil in the Chewtonian. It is confined to the zone of D.protobifidus in the Texas sequence (Berry, 1960a), and has been recorded from the zone of D.protobifidus and Tetragraptus fruticosus (3-stiped) of Newfoundland (Kindle and Whittington 1958), and from the zones of D.gibberulus, and D.hirundo of Britain (Elles 1933, Jackson 1962). Bulman (1950) has recorded the species from late Arenigian beds of Belgium.

Didymograptus similis (J.Hall, 1865).

Pl.9, figs 3,6.

1865 Graptolithus similis J.Hall :78-9, pl.2,figs 1-5.

1938 Didymograptus similis; Harris and Thomas :76, pl.2, figs 22a-b; pl.4,fig.20.

1947 Didymograptus similis; Ruedemann :347, pl.55,figs 37,38?, 39?, 40.

Remarks. Nelson specimens agree well with Hall's illustrations and with Ruedemann's description. A feature of Hall's figured specimens and of the Victorian and Nelson forms is the slightly reflexed dorsal stipe margin (noted by Harris and Thomas,1938a:76).

Horizon and localities. S2/585, 586, 628; S7/516, 519, 520. Zones 3 and 4.

The specimens figured by Benson and Keble as D.similis from Preservation Inlet (1935 :286, pl.30,fig.33; pl.31,figs 5,13) show only the proximal portion of the rhabdosome, and their record is considered doubtful. Benson et al (1936 :367) listed the form from the Aorangi Mine area, without description. The species ranges from upper Lancefieldian (La3) to Bendigonian (Be3) in Victoria (Thomas 1960). It is known from Texas (Berry 1960a :65), from New York (Berry 1962a :703) and Quebec (Raymond 1914 :529).

Didymograptus v-deflexus Harris, 1924.

Pl.10, figs 4,5.

1924 Didymograptus v-deflexus Harris :93-4, pl.7,figs 1,2.

1966a Didymograptus v-deflexus; Berry :430-1, pl.48,fig.1.

Remarks. Nelson specimens closely match Harris's description and illustrations. The specimen figured by Monsen (1937 : pl.10,fig.12) as "D.cf.deflexus" from the zone of P.densus of southern Norway is very similar to the Australasian species.

Horizon and localities. S2/540, 556, 557, 630. Associated forms, Isograptus sp.4 aff.manubriatus, I.caduceus maximodivergens. Zones 6 - 7.

The species ranges from Yapeenian (Ya1) to Darriwilian (D1) in Victoria (Thomas 1960), and has been recognised in the zone of Isograptus caduceus in Texas (Berry 1960a).

GENUS Cardiograptus Harris and Keble, 1916.

Cardiograptus morsus Harris and Keble, 1916
Pl.12, figs 3,6.

1916 Cardiograptus morsus Harris and Keble (in Harris) : pl.1, figs 1-4.

1924 Cardiograptus morsus; Harris :95-6.

Remarks. The few Nelson specimens have 11-13 thecae in 10mm rather than 9-11 as given by Harris (1924) but they otherwise closely agree with Harris's description. In view of the variability of C.morsus (see Harris 1933, figs 25-6) the Nelson specimens are here included in the species. Structure of the proximal region is not yet known in detail in Cardiograptus, but from specimen GR29 (pl.12,fig.6) it appears to be similar to that of Isograptus caduceus Salter.

Horizon and localities. S2/545, 546, 556. Associated form, Glossograptus crudus. Zone 7.

Cardiograptus morsus is a common form in the Yapeenian stage of Victoria (Harris 1933). It has been recorded from the I.caduceus zone of Texas (Berry 1960a: 66), and from the Glenogle Shale (I.caduceus zone) of British Columbia (Jackson 1964 : 528, fig.3,no.10).

Cardiograptus? sp.

Fig.29; pl.12,figs 1,2.

Remarks. Specimens with a Cardiograptus-like rhabdosome but with recurved proximal thecae are listed as Cardiograptus? sp. The first two or three thecae formed appear to grow downwards as in Oncograptus, but the thecal pair at about the level of $th2^{1-2}$ grow downwards then sharply outwards (fig.29).

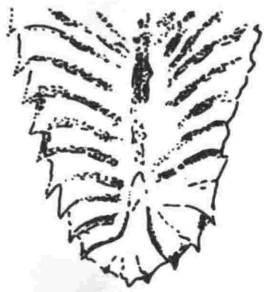


Fig.29. Cardiograptus? sp. Proximal end of specimen GR17 showing recurved proximal thecae, x 5; locality S2/545, Aorangi Mine area, Oncograptus zone.

A similar, though more accentuated feature, is illustrated by Mu and Lee (1958 :text-fig.5) and is used as a basis for distinguishing their genus Paracardiograptus. Until the proximal end structure in Cardiograptus is definitely known, the Nelson forms are tentatively retained within the genus.

Horizon and locality. S2/545. Associated form, Isograptus caduceus maximodivergens. Zone 7.

GENUS Isograptus Moberg, 1892.

Type species. Didymograptus gibberulus Nicholson, 1875 (?= D.caduceus Salter 1853) by original designation.

Diagnosis (emend.) Rhabdosome biramous, reclined; first theca arises near apex of sicula and attains almost identical proportions, in mirror image, to those of the sicula itself, the axis of rhabdosome symmetry passing between them. Subsequent development isograptid, proximal thecae relatively long and pendant. Prothecal folds generally absent.

Moberg's (1892 :346) original definition of Isograptus was vague; he misinterpreted the proximal end (Holm 1895 :19; Bulman 1932 :22) and his generic description is no longer usable. Bulman stressed the importance of the isograptid type of proximal end development as a generic character and in 1955 diagnosed the genus as follows: "[rhabdosome] reclined; thecae elongate with high inclination and large overlap, especially proximally; development isograptid, first few thecae growing entirely downward."

Skevington (1965 :44-5) pointed out the difficulty of distinguishing the genus from Meandrograptus Moberg and, in particular, the uncertain generic position of such species as I.manubriatus (T.S.Hall), I.hastatus Harris, and I.dumosus Harris in which distal thecae have low inclination and small overlap, and proximal thecae do not grow strictly downward. The generic position of Nelson specimens of I.caduceus lunata Harris, in which proximal thecae are only moderately inclined, is also uncertain.

Extremely diverse forms have been referred to Isograptus and it is difficult to find common characters uniting the group. Yet most authors would agree that the bulk of forms referred to the genus do constitute a distinct morphological group. From a study of the New Zealand isograptids and from the published descriptions of other species, several features of morphology appear to be present throughout.

1. The stipes are always reclined, usually strongly so.
2. Development, where known, is of isograptid type.
3. Proximal thecae are moderately, or highly inclined.
4. The sicula and the first theca attain almost identical proportions.

The first three characters are well known; the fourth needs discussion. The first theca ($th1^1$) arises near the apex of the sicula and grows down beside its ventral margin, attaining an almost identical outline in mirror image, to that of the sicula itself, a feature that misled Moberg (1892) into believing that the sicula was divided in two.

The axis of symmetry of the rhabdosome passes <u>between</u> the sicula and first theca, rather than <u>through</u> the sicula. Unfortunately, the feature cannot be definitely determined from Elles and Wood's figure of the type specimen of <u>I.gibberulus</u> (Elles and Wood 1902 :53; figs 33a-b), but it is well shown by Bulman's figures (1932 :24, text-figs 1a-b; pl.8,figs 1-4) of Swedish specimens of the type species (fig.30b). Similarly, all New Zealand members of the <u>caduceus</u> group, despite their variable shape, stipe width and thecal inclination, possess the proximal end symmetry. The problematical manubriate species of <u>Isograptus</u> are generally poorly known, but Bulman's illustrations (1968, figs 1,2) of a Texan specimen of <u>I.manubriatus</u> shows that the species has a similarly symmetrical arrangement of the sicula and first theca,

though the distal extremities of each are directed outwards, away from the midline of the rhabdosome.

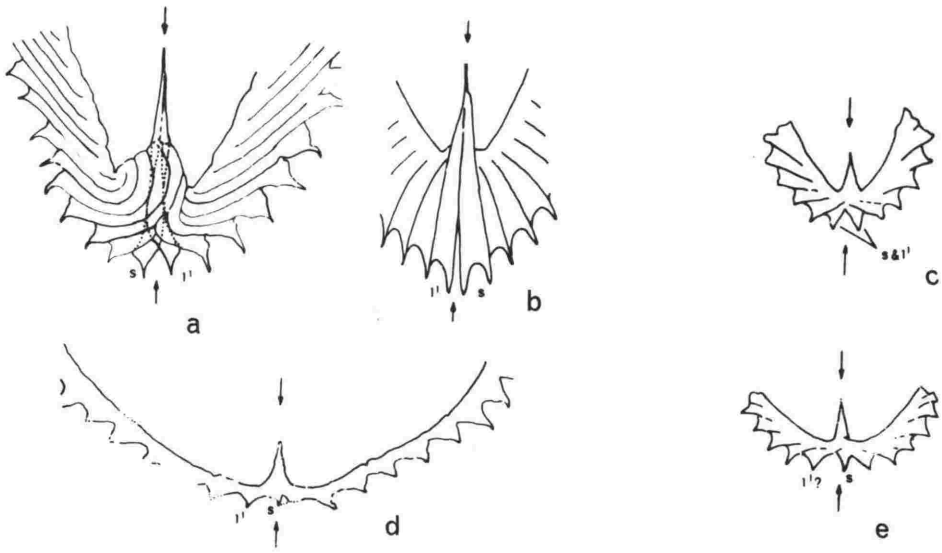


Fig.30. Proximal end symmetry in Isograptus (a,b,c) compared with that in reclined Didymograptus (d,e). s, sicula; 1^1, theca 1^1; arrows indicate axis of rhabdosome symmetry. a, Isograptus manubriatus T.S.Hall, from Marathon, Texas. After figure by Bulman (1968 :112, figs 1,2). b, I.gibberulus (Nicholson), from Sweden. After figure by Bulman (1932 (9) :25, text-fig.1). c, I.caduceus lunata Harris, from Nelson, VG31. d, Didymograptus hemicyclus Harris, from Victoria. After photograph of lectotype given by Berry (1966 :pl.49,fig.6). e, D.cf.eocaduceus Harris, from Nelson, GR109.

All figures approximately x 5.

The above diagnosis is therefore proposed and serves to distinguish the genus from reclined species of Didymograptus, such as D.hemicyclus Harris,1933 (re-figured by Berry 1966a : 427-8,pl.79,figs 5,6), but to include I.caduceus lunata Harris, in which proximal thecae have only moderate inclination and small overlap.

Meandrograptus Moberg is distinguished by the marked difference in shape between the sicula and first theca, the rhabdosome midline passing through the sicula (as shown by the type species, M.schmalenseei Moberg, figured by Bulman 1932, text-figs 2a-b, pl.2,figs 6-8), and by the prominence of prothecal folds (Skevington 1965 :44).

Species. Didymograptus caduceus Salter, 1853.

Didymograptus gibberulus Nicholson, 1875 (?= D. caduceus Salter).

Didymograptus forcipiformis Ruedemann, 1904.

Isograptus forcipiformis var.latus Ruedemann,1904.

Didymograptus caduceus var.manubriatus T.S.Hall,1914.

Isograptus caduceus var.primula Harris, 1933.

Isograptus caduceus var.lunata Harris, 1933.

Isograptus caduceus var.victoriae Harris, 1933.

Isograptus caduceus var.maxima Harris, 1933.

Isograptus caduceus var.maximodivergens Harris,1933.

Isograptus caduceus var.divergens Harris, 1933.

Isograptus caduceus var.imitata Harris, 1933.

Isograptus hastatus Harris, 1933.

Meandrograptus? geniculatus Skevington, 1965.

Isograptus caduceus var.norvegicus Monsen (pars), 1937 (?= I.c.lunata Harris).

Isograptus spinosus Spjeldnaes, 1953.

?Didymograptus ovatus J.Hall, 1902.

?Didymograptus caduceus mut.nanus Ruedemann, 1904.

?Didymograptus caduceus var.spinifer Keble and Benson, 1929.

?Isograptus caduceus var.tenuis Harris, 1933.

?Isograptus caduceus var.velata Harris, 1933.

?Isograptus caduceus var.pertensa Harris, 1933.

?Isograptus caduceus var.horrida Harris, 1933 (?= I.c. imitata Harris).

?Isograptus dumosus Harris, 1933.

?Isograptus caduceus var.armatus Ruedemann, 1947.

?Isograptus furcula Ruedemann, 1947 (?= I.caduceus divergens Harris, 1933).

?Isograptus lyra Ruedemann, 1947.

?Isograptus chinghaiensis Hsu, 1959

?Isograptus curvithecatus Hsu, 1959 (?= I.forcipiformis Ruedemann sensu lato).

?Isograptus schrenki Obut and Sokolevskaya, 1964.

?Isograptus manneri Keller, 1956? - original descriptions and illustrations not seen by writer.

In those forms listed with a query, the symmetry of the proximal region cannot be determined from the published figures or description, and their inclusion in Isograptus is tentative. Judging from his figures and description of I.caduceus var.gracilis Ruedemann (1904 :pl.57,figs 15,16) this form is most probably identical with I.hastatus Harris, 1933. I.horrida Harris apparently differs from I.caduceus imitata Harris only in having a spine on the sicula or first theca and, as Harris (1933 :92) implies, the two forms are probably synonymous. Isograptus chinghaiensis Hsu and Isograptus curvithecatus Hsu are based on a total of three "comparatively complete" specimens. Isograptus curvithecatus appears to be an intermediate between I.forcipiformis Ruedemann and its variety I.forcipiformis var.latus Ruedemann. The synonymy of other forms is discussed with the systematic descriptions below.

Discussion. The most notable feature of Isograptus in Australasia is the wide range of morphologic variation shown both within and throughout its member species and subspecies. A bewildering array of forms completely dominates the fauna of the Castlemainian and Yapeenian stages in Australia and New Zealand. The only attempt at a systematic subdivision of the genus was that by Harris (1933), who recognised 6 species (two of which were described as new) and 11 subspecies (all of which were described as new) in Victorian material. Many of Harris's taxa have since been

recognised outside Australasia, mainly in North America and considerable importance has been placed on the genus for correlation (Skevington 1963b). Many of the species need more precise definition; this however, must await re-study of Harris's type material, and recollection from the type localities. The main purpose of the present work is to demonstrate the biostratigraphic usefulness of the genus.

Two groups are distinguished within the genus in Nelson. The first, the "caduceus group", is composed of the subspecies of I.caduceus - namely primula, lunata, victoriae and maximodivergens, I.imitata and I.aff.imitata. Proximal thecae are either straight or are curved concave ventrally, so that their apertures are directed downwards. The second group, includes the "manubriate" species, in which thecal origins are concentrated near the sicula, and the distal portions of proximal thecae are curved convex ventrally, so that thecal apertures are directed outwards rather than downwards. Species include I.spp.aff.manubriatus T.S.Hall, I.dumosus Harris, and I.hastatus Harris.

Members of the caduceus group only are described in detail below.

Isograptus caduceus Salter, 1853.

1853 Didymograptus caduceus Salter (in Bigsby) :87,fig.1.

?1875 D.gibberulus Nicholson :271, pl.7,figs 3-3b.

Synonymy of other forms uncertain, pending a redescription of the nominal subspecies. For tentative synonymy, see Bulman 1932 :23.

Synonymy and Type specimens. The type specimens came from "Hudson River Group of Lauzon precipice", Quebec (Salter 1853 :87). They are now lost (Bulman 1932, 5:24; A.Rushton and P.Toghill, written communications, 1968), and Salter's original description and illustrations, reproduced here in fig.31, have proved to be inadequate. It is thus not surprising that confusion has surrounded the synonymy of the name almost since its inception.

DIDYMOGRAPSUS CADUCEUS, Salter. Fig. 1.

D. stipite filiformi longo; ramis retrorsum flexis, ferè parallelis; rachide utroque latiore, dentibus prominulis, appendice nullo.

This form is closely related to *D. geminus*, Hisinger; but the two branches are bent so much back, as to be nearly parallel, and the stalk is very long and threadlike.

From the Lauzon precipice.

Fig. 1.—*New species of Graptolite*, Didymograpsus caduceus, *Salter, from the Lauzon precipice (Hudson River Group).*

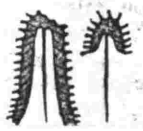


Fig.31. Photocopy of Salter's original description and illustrations of Didymograptus caduceus (from Salter, in Bigsby, 1853 (9) :82,fig.1; photographed from 'xerox' copy).

Argument has revolved around two main issues.

1. Whether the two figured specimens (syntypes) represent two-stiped (didymograptid) rhabdosomes as thought by Salter, or four-stiped (tetragraptid) forms. Advocating the latter view, Hall (1865 :42) contended that the figured specimens show two branches in profile, and one (the nema, or "stalk" of Salter) in dorsal view. McCoy (1875 :31)and T.S.Hall (1896 :69) have since shown that Hall's interpretation is unlikely to be correct. A tetragraptid rhabdosome was again advocated in a different interpretation proposed by Nicholson in 1875 (p.271), when erecting his new species Didymograptus gibberulus on British material:

> "It is very similar in general appearance to the fossil described by Mr Salter under the name of D.caduceus. The original specimen on which this species was founded (Quart.Journ.Geol.Soc. vol.IX. p.87), however, is beyond doubt an example of Tetragraptus bryonoides, Hall, or T.bigsbyi, Hall, in which two of the normal four stipes are concealed from view by the matrix. D.caduceus cannot, therefore, be retained ...."

Subsequently Elles and Wood (1901 :52,footnote) allowed that both Tetragraptus and Didymograptus were represented by Salter's original material - "the Tetragraptus seems to be identical with T.serra (Brongniart 1828), and the Didymograptus agrees exactly with the form described later by Nicholson as D.gibberulus". "Fig.1a" is listed

in their synonymy of D.gibberulus and presumably refers to the left hand figure of Salter, that with the longer stipes.

Three years later Ruedemann (1904 :695-8) discussed the synonymy of D.caduceus and concluded that "Salter's first two drawings and his description (1853,p.87) can apply only to the form later described as D.gibberulus by Nicholson "; thus considering Salter's species a true didymograptid. Ruedemann pointed out that "of the two drawings comprised in a later publication (1863,p.137, fig. 13a,13b) under this name [caduceus], the former is surely the Didymograptus, the latter represents probably a Tetragraptus bigsbyi". Some authors seem to have confused the British specimens figured in 1863 with the Canadian syntypes. For example, Harris (1933 :82) refers to them as "the two forms named Didymograptus caduceus .... by Salter in 1853". However, they have no status as types and should therefore be disregarded.

Finally, Bulman's statement (1932 :23,footnote) "it seems likely that the figures published by Salter in 1853 are referrable to a Didymograptus..." has not been disputed, and appears to have gained general acceptance. Both ~~Slater's~~ Salter's original specimens, then, are probably reclined didymograptids.

2. The second issue concerns whether D.caduceus Salter is synonymous with D.gibberulus Nicholson. As quoted above, Nicholson (1875) recognised that the two species were "very similar" but, for reasons shown above

to be probably erroneous, considered that Salter's name could not be used. Elles and Wood (1901 :52,footnote) admitted that Salter's Didymograptus "agrees exactly" with Nicholson's species, but preferred to "retain Nicholson's specific name rather than the earlier name of Salter, in order to avoid the possibility of any ambiguity." Ruedemann (1904 :697) regarded the two forms as conspecific.

Not sharing these views, Bulman, in his detailed description of Swedish specimens of gibberulus expressed the doubt that "it is still uncertain whether or not Nicholson's species is identical with Salter's", and he therefore used Nicholson's name, adding that "it is with the structure of I.gibberulus that we are familiar" (1932, footnote on page 23).

Salter's description gives only a vague outline of the species and no topotypes have been described. The identity of D.gibberulus is also not without some confusion. The three British specimens figured somewhat diagrammatically by Nicholson in 1875 (figs 3,3a-b) were refigured by Elles and Wood (1901,fig.33a, listed as "type specimen"; pl.II, figs 9b,9d) together with four other British specimens referred to the species. Bulman (1932) included all of Elles and Wood's forms within I.gibberulus but Monsen (1937 : 153-5) recognised two species - gibberulus and caduceus - among the forms figured by Elles and Wood, without specifying which forms belong to which species. The distinctive

Scandinavian form described and figured by Moberg (1892 : pl.8,figs 3-7), Tornquist (1901 :pl.3,figs 16-19) and particularly by Bulman (1932 :23;text-fig.1; pl.1,figs 1-5), although it does not closely resemble the type specimen, has come to be regarded as the "typical" form of gibberulus (Bulman 1936b :30; Skevington 1963b:301).

Together, the two forms are reported to be worldwide. Most North American workers have followed Ruedemann (1904) and used Salter's name, generally regarding the two forms as belonging to one species (references given by Ruedemann 1947 :350). Australian and New Zealand workers have followed McCoy (1875) in using Salter's name, regarding Nicholson's species as probably conspecific (McCoy 1875; Hall 1896; Harris 1933). European writers have generally used Nicholson's name, mainly restricting it to the "typical" form as figured by Moberg and Bulman, though several authors have recognised in addition, "varieties" of I.caduceus among European material (Monsen 1937; Blake 1962).

Clearly, both species need revision and a more detailed study of their morphologic variation before definite statements concerning their synonymy can be made. In particular, I.caduceus sensu stricto urgently needs to be redescribed and, preferrably, provided with a standard of reference by nomination of a neotype (International Code of Zoological Nomenclature, 1964 :Article 75). In the meantime the writer tentatively follows previous Australian workers

in referring Australasian forms to Isograptus caduceus (Salter). A full bibliography is not given here, but can be gained from the works quoted above, particularly from Bulman (1932).

Isograptus caduceus? primula Harris

Figs 32a-c, 36,nos 1-4; pl.11,figs 3,8,11.

1933 Isograptus caduceus var.primula Harris :90,figs 1,2.

1935 Isograptus caduceus var.primula; Benson and Keble :287.

1935 Isograptus caduceus var.lunata; Benson and Keble :288, pl.30,fig.30.

Description. The rhabdosome is small, and stipes are barely developed, bearing only 6-7 thecae in the largest specimen (fig.32c). The sicula bears a fine nema up to 8mm long. Measurements of the four complete specimens are given below; the thecae are slightly curved, concave ventrally, overlapping more than three-quarters, and highly inclined. Thecal apertural margins are concave and denticulate; the indentation formed by the free ventral margins of the sicula and first theca is relatively narrow and deep.

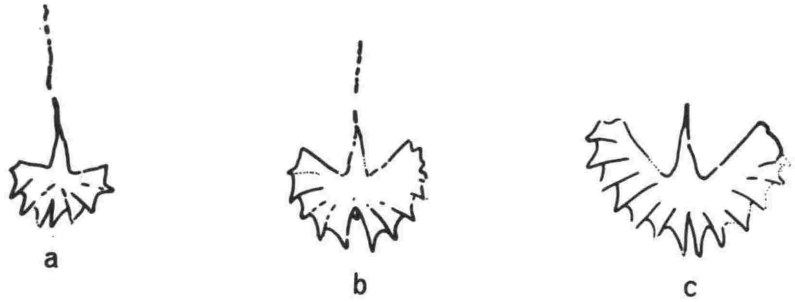


Fig.32. Isograptus caduceus? primula Harris.
a, smallest specimen, with barely developed stipes, GR5. b, intermediate form, VG33. c, largest specimen with more fully developed stipes, GR3. All from locality S2/586, Golden Ridge, Aorangi Mine area, D.protobifidus zone. All figures x 5.

Table X. Dimensions of Isograptus caduceus primula.

Spec. no.	Sicula		Maximum stipe width	Number of pendant thecae	Number of thecae per stipe
	length	width at aperture			
GR3	3.4	0.50	1.6	8	6-7
GR4	3.0	0.45	-	6+	3-4
GR5	2.6	0.40	-	5?	2-3
VG33	3.2	0.55	-	6+	3-4

Remarks. The three smaller Nelson specimens (GR4, GR5, VG33) match the smaller of the two specimens figured by Harris (1933 :112,fig.1). The larger Nelson specimen (GR3) differs from Harris's larger specimen (fig.2) in having wider stipes, but there is little doubt that the Nelson specimens all belong to one population and most closely match his "variety" primula.

I.c.? primula differs from I.c.lunata, of the succeeding zone, in having stipes which do not grow to more than 2 or 3mm long. Proximal thecae are inclined at a higher angle than in lunata, and there are more pendant thecae. Its short stipes serve to distinguish it from mature forms of other isograptids.

I.c.? primula is the earliest representative of Isograptus in the Victorian sequence and Harris considered it to be the first stage of a lineage giving rise to the large varieties of I.caduceus in the Castlemainian and Yapeenian stages. The subspecies is the earliest Isograptus in the Nelson sequence also, but is less obviously related to the succeeding subspecies, lunata, and its position in the caduceus lineage is tentative. I.c.? primula most closely resembles I.imitata and is probably the ancestor of that species (compare figs 36 nos 4 and 29). The large form (fig.32c) bears striking resemblance to the well known European species, I.gibberulus Nicholson and suggests that gibberulus and imitata may have had a common ancestor.

Horizon and localities. The four specimens are from locality S2/586, in the D.protobifidus zone. The subspecies is known from Australasia only. Benson and Keble (1935 : 287) reported the form from the C5 zone (=Ch2) of Preservation Inlet. The specimen figured by them as I.c.lunata (pl.2,fig.30) more closely resembles primula. I.c.? primula is known from the upper Chewtonian (Ch2) and lower Castlemainian (Ca1) of Victoria.

Isograptus caduceus lunata Harris, 1933.
Figs 33a-b; 36,nos 5-9; pl.11,figs 5,7,12.

1933 Isograptus caduceus var.lunata Harris :90,figs 3-6.

1947 Isograptus caduceus; Ruedemann (pars.) :350-1,pl.57, figs 10,11? only.

?1953 Isograptus lunata; Spjeldnaes :176,pl.1,fig.3; text-fig.1D.

1953 I.norvegicus; Spjeldnaes (pars.) :174,6,pl.1,figs 2, 4; text-figs 1b,c, (not pl.1,fig.6;text-fig.1f).

Description. The rhabdosome is of variable size, generally U-shaped. A nema is present in most specimens, the longest being 8mm long. The sicula bears a denticle or blunt spine and is 2-2.5mm (1.5-3.5mm) long. Width of the sicula at its aperture ranges from 0.5mm in forms with short

Fig.33. Isograptus caduceus lunata Harris. a, early growth stage of a large form, in which the sicula and first theca are almost fully developed, x 9. VG35, locality S2/593, Aorangi Mine area. b, mature stage of a small form, x 10. VG31, locality S2/579, Aorangi Mine area. Both from zone of I.c.lunata.

siculae to 0.8mm in forms with large siculae. As a general rule, the smaller rhabdosomes are those with the shorter and narrower siculae. The distal portions of the sicula and first theca are curved away from each other, their free ventral walls forming a wide, but not deep indentation. The origins of theca 1^2 and theca 2^1 cannot be seen, but the general aspect of the proximal end (figs 33a,b) suggests that development is of isograptid type (Bulman 1955).

The number of pendant thecae ranges from 2 to 6, most forms having 3 or 4 (see fig.38). Stipes are of even width, and range from 1.2mm wide and 4mm long in small forms, to 2mm wide and up to 9mm long in large forms (fig. 39). Stipes are always curved upwards, the degree of curvature and angle of divergence varying widely from specimen to specimen.

Thecal spacing, measurable in the large forms only, is 6 in 5mm. Thecal ventral walls slightly or moderately concave, thecal apertural margins concave and denticulate. Distal thecae are inclined from 25° at their origins, up to 75° near their apertures, while the corresponding inclination of proximal thecae is slightly greater.

Discussion. I.c.lunata is comprised of those members of I.caduceus in the lower part of zone 5 (approximately the lower 35ft), at Aorangi Mine. The Nelson specimens are considered to represent a population with a wide and

continuous range of morphologic variation, hardly any two specimens being identical.

The four type specimens figured by Harris (1933 :112, figs 3-6) indicate considerable variation also, his figures 5 and 6 closely resembling the common New Zealand forms. From his figures 3 and 4, it appears that some Victorian specimens have a greater number of pendant thecae than that shown by any Nelson forms, giving a 'crowded' aspect to the proximal region. The number of pendent thecae cannot be accurately determined from Harris's figures however, and no direct comparison can be made without re-examining the types.

In a few Nelson specimens (fig.36 no,5) the stipes taper distally and the sicula and first theca are relatively long, giving the rhabdosome a v-shape rather than U-shape. The specimens approach the later species I.imitata and are thought to probably represent forms transitional between primula and imitata. The common form of lunata however, (fig.36,no.7) is that which gave rise to the I.caduceus victoriae - maximodivergens lineage (fig.44).

Some of the small Nelson specimens with few pendant thecae resemble in general aspect D.eocaduceus Harris or D.hemicyclus Harris. They are readily distinguished by the symmetrical arrangement of the sicula and theca 1^1 (fig. 30).

Distribution. The specimen from Preservation Inlet figured by Benson and Keble (1935 :pl.30,fig.30) as I.c.lunata belongs to primula. Specimens from the Deepkill shale listed by Ruedemann (1947 :pl.57,figs 10,?11) as I.caduceus closely resemble New Zealand members of I.c.lunata, though the subspecies was not recorded by Berry (1962a) in his revision of the biostratigraphy of the Deepkill shale.

The form described by Spjeldnaes (1953) as "Isograptus lunata" from "Layer III" of the upper part of the Lower Didymograptus Shale (3b) at Slemmestad, Oslo, differs slightly from the larger Nelson forms in having more pendant thecae, and in the angle of thecal inclination being generally higher. His figures (particularly figs 1b-c, pl.1,figs 2, 4) of I.norvegicus Monsen from "just below" Layer III closely match the intermediate and small Nelson members of lunata (see fig.36, nos 5,7).

Range of the species in Victoria is given by Thomas (1960 chart,p.18) as lower Castlemainian (Ca1-2).

Localities and horizon. S2/562, 563, 570, 579, 593, 600, 601, 602, 603, 623. Zone 5 (lower).

Isograptus caduceus victoriae Harris, 1933.

Fig.34; 36,nos 10-15.

1933 Isograptus caduceus var.victoriae Harris :90,figs 7-10.

Description. The rhabdosome is of variable size, generally U-shaped, and commonly bears a long stout nema. The sicula ranges in length from 2 to 4mm, in most forms being 3-3.5mm long and 0.8mm wide at the aperture. A prominent denticle takes up $\frac{1}{4}$ to $\frac{1}{6}$ of the total sicula length. The indentation between the free ventral walls of the sicula and the first theca is wide and deep. In many specimens this is partly 'filled in', presumably by a web of periderm. Most rhabdosomes have 5-7 pendant thecae in the proximal region.

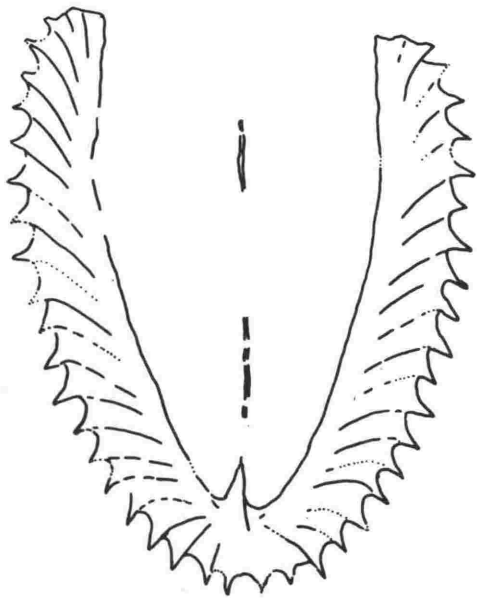


Fig.34. Isograptus caduceus victoriae Harris. Mature, moderately large, slightly distorted rhabdosome, the relative shortening direction being lower left to upper right, x 5. VG43, locality S2/599, Aorangi Mine area, I.c.victoriae zone.

The stipes are of even width, except for the distal 3 or 4mm where the thecae are incompletely developed. They curve upwards, the distal portions generally diverging at 310°- 350°, in some specimens becoming parallel or even convergent. Stipe width in most forms is 2.0 - 2.5mm, but ranges from 1.0-3.0mm, generally being greatest in rhabdosomes of largest overall size. Greatest stipe length is 12mm.

Thecae are spaced 11 in 10mm in the mid-portions of the stipes. They are moderately to strongly curved, distal thecae being inclined from 20° at their origins to 90-100° near their apertures. The inclination of proximal thecae is not easily measured but is greater. Apertural margins are strongly concave, and are extended into prominent denticles at their junctions with ventral thecal margins.

Discussion. I.c.victoriae is ~~comprised~~ composed of those specimens of I.caduceus in the upper part of zone 5 (approximately the upper 60ft of member AM2) at Aorangi Mine. The population represented differs from that of I.c.lunata in the lower part of the zone, in containing generally larger forms with a greater number of pendant thecae (figs 36,38, 39). In victoriae, thecae attain a higher angle of inclination and have more overlap than in lunata; the most common or "typical" forms of each subspecies are easily

distinguished, but the smallest members of victoriae are of similar size to the largest members of lunata. The few large forms from the highest fossiliferous horizon of the zone (locality S2/565) approach I.c.maxima Harris and are only tentatively included within victoriae.

Harris's four figured specimens (p.112,figs 7-10) indicate a similar range of morphology to that shown by the Nelson material.

Distribution. I.c.victoriae has been recorded from the lower part of the Fort Pena Formation (zone of Isograptus caduceus) in the Marathon sequence of Texas, by Berry (1960a), but the specimen figured by him (pl.11,fig.7) more closely resembles the later subspecies maximodivergens (see fig.36, no. 12); it is associated with Cardiograptus morsus, I.c.divergens, I.c.maximodivergens, and Oncograptus upsilon, all of which first appear at a later horizon than that of victoriae in Australasia. Ross and Berry (1963) recorded I.caduceus cf. var.victoriae from the Palmetto Formation, Basin Ranges, Western U.S.A. Kindle and Whittington (1958) recorded the form from Newfoundland; I.c.var.victoriae was listed from the top of their section at Martin Pt, and I.c.cf.var. victoriae from locality (5) at St Paul's Inlet.

I.c.cf.var.victoriae has been listed from Rioux Quarry, near Cowansville, Southern Quebec, by Riva (1966 : 221), together with "I.cf.caduceus". Jackson (1964 :525, fig. 1) recorded the subspecies from near the base of the zone

of I.caduceus, at the type locality of the Road River Formation in the Richardson Mountains, Northern Yukon, and Jackson, Steen and Sykes (1965) listed it from Cloudmaker Mountain (zone of I.caduceus) in north-eastern British Columbia.

Horizon and localities. S2/528, 529, 531, 565, 599, 610, 617, 618, 619, 620, 621. All are from the upper part of zone 5. It has also been collected from S7/517 at Elliot Creek from beds correlated with zone 5.

Isograptus caduceus maximodivergens Harris, 1933.
Figs 35a-f, 36,nos 16-24; pl.11,figs 1,2.

?1931 Didymograptus (Isograptus) caduceus Salter emend.var.; Bulman :42-3, text-fig.17.

1933 Isograptus caduceus var.maximodivergens Harris :91, fig.13.

1947 I.walcottorum Ruedemann (pars.) :354,pl.57,figs 26? 29? 30-36 (not figs 27,28).

1960a I.caduceus var.maximodivergens; Berry :67, pl.11,fig. 11.

1963 I.caduceus cf. I.c.var.maximodivergens; Ross and Berry: 93, pl.5,fig.14.

1964 I.caduceus var.maximodivergens; Jackson,fig.3,no.9.

Description. The rhabdosome is large, U- to V-shaped, and

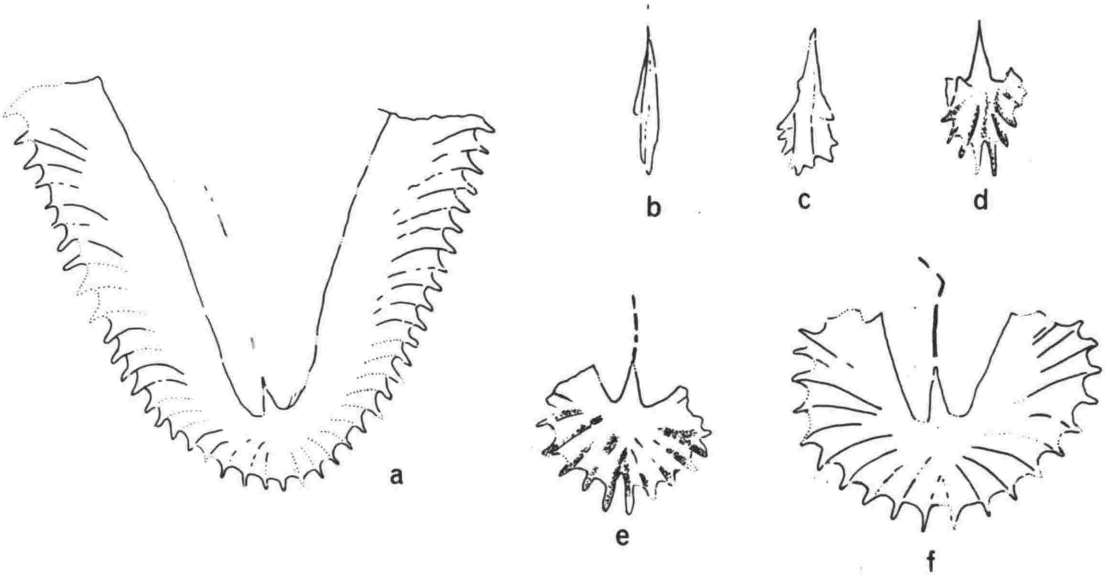


Fig.35. Isograptus caduceus maximodivergens Harris.
a, incomplete, mature rhabdosome; x 3. VG65;
b-f, growth stages; x 5. b, sicula and initial bud; VG69. c, later stage; VG34. d, stage in which the sicula and first theca have nearly reached their full length; VG68. e, stage in which the proximal thecae are almost fully formed, with the indentation between the sicula and first theca still open. f, stage in which the proximal region is fully formed and the ventral indentation has been filled by a web of periderm. All specimens from locality S2/552, Aorangi Mine area, I.c.maximodivergens zone.

commonly bears a short nema. The sicula ranges from 3.5-6.0mm long, but in most forms is 4.0-5.0mm long and 0.6-0.8mm wide at the aperture. In many mature specimens from zone 7 the sicula and proximal portion of the nema are enmeshed in a web, the "axilar film" of Harris, which generally extends to the dorsal stipe margins (fig.36,nos 22,24). Probably a thin sheet of periderm, the web is not present in early growth stages and is apparently formed only after maturity of the rhabdosome has been reached. The indentation formed by the free ventral margins of the sicula and the first theca is partly bridged by a similar web of periderm leaving in most forms, an excavation only slightly deeper than that formed by a thecal aperture. Formation of the web follows shortly after the proximal thecae are fully developed (figs 35e,f). The number of pendant thecae in the proximal region ranges from 7 to 12, most forms having 8 or 9 (fig.38).

Stipe width is remarkably variable, both within individual specimens, and from specimen to specimen. Stipes are generally narrowest at their points of maximum flexure, in the proximal region, and widest in the middle third of their length. Proximal width is generally about three-quarters maximum width which is 4-5mm in most forms (fig.39). The stipes of a few exceptional specimens widen and narrow repeatedly along their length.

The direction of growth of the stipes is also variable both within, and between specimens. Following the sharp initial concave curvature, the dorsal stipe margins

generally show a gentle convex recurvature, after which they become straight or, less commonly, gently flexuous. In a few specimens from zone 6, the dorsal stipe margins retain concave curvature throughout their growth, becoming almost parallel. The stipes of most specimens from zone 7 are straight and sharply flexed in the proximal region. Divergence angle generally ranges from about 350° to about 310°.

Thecae are spaced 9-10 in 10mm and are strongly curved, inclination ranging from about 20° at their origins up to 90-100° near their apertures. They overlap almost their entire length. Thecal apertures are strongly concave and are prominently denticulate.

Discussion. Specimens of *Isograptus caduceus sensu lato* from zones 6 and 7 comprise two distinct groups, *I.c.maximodivergens*, and *I.imitata* (fig.36). Most specimens in the first group resemble Harris's figure of var.*maximodivergens* (Harris 1933,fig.13); however a few forms from zone 6, in which stipe width is nearly constant (fig.36,no.17), more closely match his figure 12, *maxima*, while others from zones 6 and 7 (fig.36,nos 21 and 22) resemble his figs 14 and 17, *divergens*. They are linked with the most common form by intermediates, and are regarded here as 'variants', or members, of a variable population centred around forms which correspond to *maximodivergens*, rather than as distinct subspecies.

Few fossils have been found in strata from which the subspecies maxima might be expected (lower part of member AM3 at Aorangi Mine) - according to its stratigraphic position in Victoria (Thomas 1960) - and it is probable that the apparent absence of populations of this subspecies from Nelson is the result of non-preservation, or incomplete sampling. Previous records of I.c.maxima from Nelson are based on few specimens (Benson and Keble 1936; Skwarko 1962) and are indefinite.

The subspecies is distinguished from the earlier form, victoriae, from which it has descended, by its larger overall size, its broader stipes, and by the initial increase in stipe width.

The initial divergence angle of stipes in a few specimens from zone 6 (fig.36,no.21) is 360°, becoming less distally with the convex curvature of the dorsal stipe margin. The specimens are particularly interesting as they approach the Oncograptus rhabdosome with an initial biserial portion, and accord with Harris's suggestion (1933 :95-6) that Oncograptus was derived from I.c.maximodivergens. Bulman's evidence (1936a) for a 'primitive' pre-minutus stage of development in Oncograptus however, apparently contradicts Harris's suggestion, and the derivation of Oncograptus is still uncertain.

Distribution. Ruedemann's figures of I.walcottorum from the

Glenogle shale, British Columbia, and from Nevada (Ruedemann 1947 :pl.57,figs 26-36) agree with Harris's figure of I.caduceus var.maximodivergens (Berry 1960a :67), with the exception of figs 27 and 28 which probably represent manubriate species of Isograptus. Turner's I.gibberulus var.a (1960 :82, pl.9,fig.6) from Argentina, which is stated to bear "certain similarities to I.walcottorum" probably also belongs to maximodivergens.

Harris (1933) records maximodivergens from the upper Castlemainian and Yapeenian of Victoria. Berry (1960a : 67, pl.11,fig.7) described the form from zone 8 in the Marathon Sequence, Texas, and Ross and Berry (1963 :93, pl.5, fig.14) recorded it from the Basin Ranges (Phi Kappa Formation).

Bulman (1931 :42-3,text-fig.17) has described and figured an incomplete specimen which probably corresponds to maximodivergens, from the "lower Llanvirnian" beds of Korpa, Bolivia. The specimen was associated with Didymograptus murchisoni var.geminus.

Jackson (1964 :fig.3,no.9) figured a specimen from the "I.caduceus Zone, Glenogle Formation", British Columbia, which closely resembles Nelson members of the subspecies from zone 7. I.caduceus cf.maximodivergens has been listed by Kindle and Whittington (1958) from Newfoundland (from Bed 13 on Cow Head Peninsula, and from locality (5) at St. Paul's Inlet).

Fig.36. Isograptus caduceus (Salter), and related forms. All specimens from Aorangi Mine, all figures x 2. Figures of the subspecies primula, lunata and victoriae are arranged with the most common forms in the centre of each group, the smallest forms at left, largest forms at right.

1-4, I.caduceus?primula Harris. 1, GR5. 2, VG33. 3, GR4. 4, GR3. All from locality S2/586.

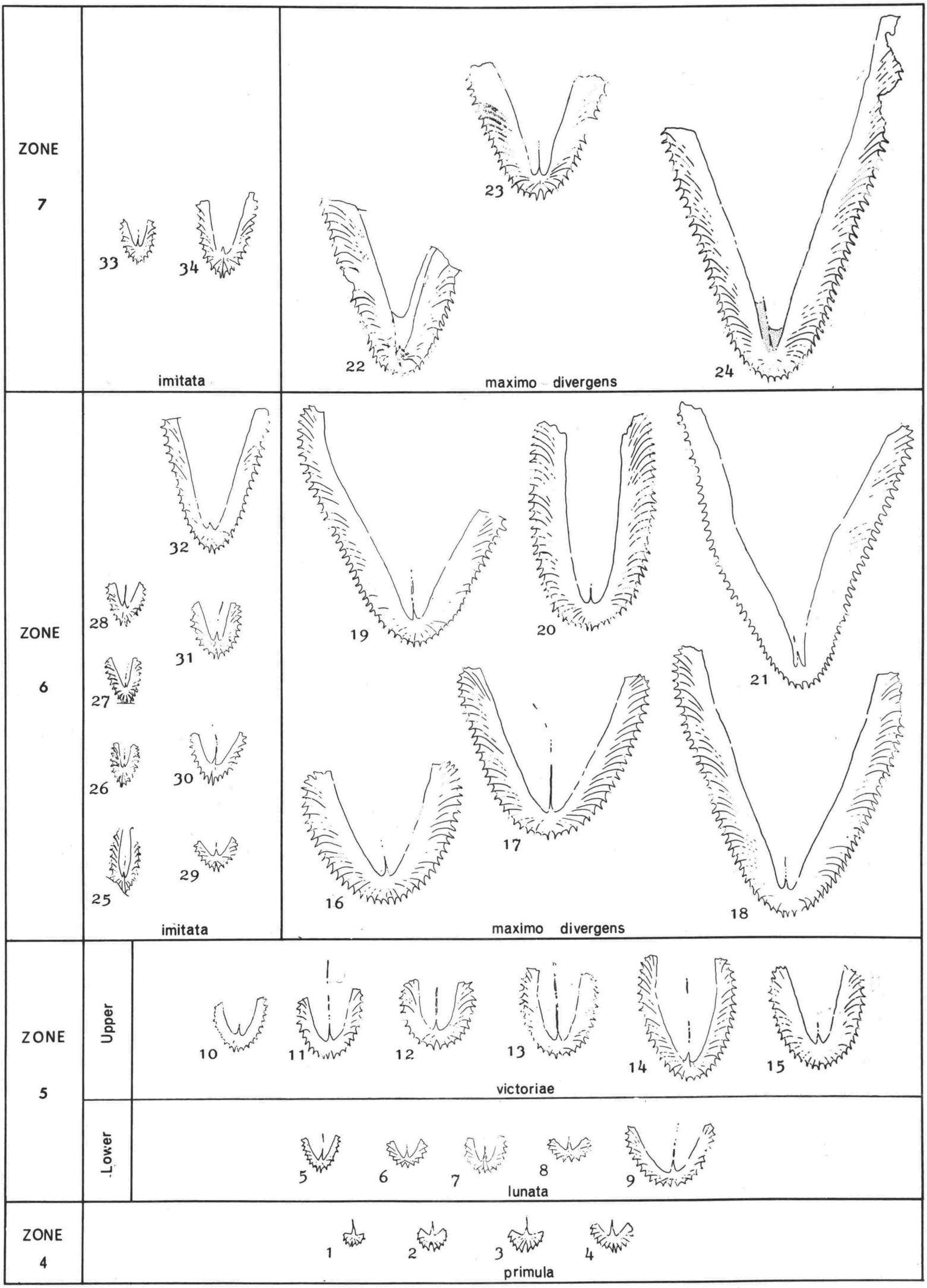
5-9, I.caduceus lunata Harris. 5, VG107, locality S2/593. 6, VG31, locality S2/579. 7, VG37, locality S2/562. 8, VG136, locality S2/602. 9, VG39, locality S2/562.

10-15, I.caduceus victoriae Harris. 10, VG36, S2/565. 11, VG45, slightly distorted - relatively shortened from upper left to lower right. 12, VG42, locality S2/599. 13, VG44, slightly distorted - relatively shortened from upper right to lower left. 14, VG43, locality S2/599. 15, large form, VG41, locality S2/565.(?=I.c.maxima Harris).

16-24. I.caduceus maximodivergens Harris. 16, VG48. 17, VG51. 18, VG54. 19, VG49. 20, VG47. 21, VG52. 16-21, from locality S2/552. 22, VG64, locality S2/540. 23, VG50, locality S2/545. 24, VG46, locality S2/540.

25-30,33, I.imitata Harris. 25-26, "forcipiformis" variants, locality S2/552. 25, VG55. 26, VG62. 27, specimen with thickened ventral thecal margins, VG56, locality S2/552. 28-30, common forms, locality S2/552. 28, VG58. 29, VG59, typical form. 30, VG61. 33, GR8, locality S2/540.

31-32,34, I.aff.imitata. 31, VG57, locality S2/552. 32, VG60, locality S2/552. 34, VG133, locality S2/540.


ZONE 7
33
34
imitata
22
23
24
maximo divergens
ZONE 6
32
28
31
27
26
30
25
29
imitata
19
20
21
16
17
18
maximo divergens
ZONE 5
Upper
10
11
12
13
14
15
victoriae
Lower
5
6
7
8
9
lunata
ZONE 4
1
2
3
4
primula

Horizon and localities. S2/530, 532, 533, 535, 540, 544, 545, 546, 548, 552, 553, 557, 558, 559, 560, 561, 576, 584, 587, 598, 608, 629, 630; S7/517. Associated forms, Tetragraptus cf.serra, T.aff.taraxacum, T.aff.chapmani, Goniograptus macer, G.thureaui, Didymograptus sp. (extensiform), Isograptus imitata, I.aff.imitata, I.dumosus, I.hastatus, and I.spp.aff.manubriatus. I.c.maximodivergens is the most common form in zones 6 and 7, to which it is confined.

Isograptus imitata Harris, 1933.

Fig.36,nos 25-30,33; figs 37a-b; pl.11,figs 6,9,10.

1933 I.caduceus var.imitata Harris :92-3, figs 55-9.

1961 I.forcipiformis var.harrisi Skwarko :106,fig.4.

Description. The rhabdosome is generally V-shaped and small, the greatest dimension being under 1cm. The sicula commonly bears a thin short nema, and ranges in length from 2.0-4.2mm, most forms having siculae 2.5-3.5mm long, and 0.4mm wide at the aperture. The indentation between the free ventral walls of the sicula and first theca is narrow and deep, and both the sicula and first theca bear conspicuous apertural denticles up to 1mm long. The number of pendant thecae ranges from 2 to 6, but most forms have

4 or 5 (fig.38). The stipes, after their sharp initial flexure, remain straight or only slightly curved, generally diverging at 300-330° giving the rhabdosome its characteristic 'V' shape. They are widest in the sicular region, and taper distally, measuring about 1.5mm wide at the level of the 3rd or 4th theca.

Thecae are spaced about 5½ in 4mm. The initial one or two thecae of each branch are relatively long and nearly straight, and are followed by shorter, curved thecae which are highly inclined to the stipe axis. Distal thecae are less curved and are inclined at lower angles. Thecal apertures are concave and markedly denticulate.

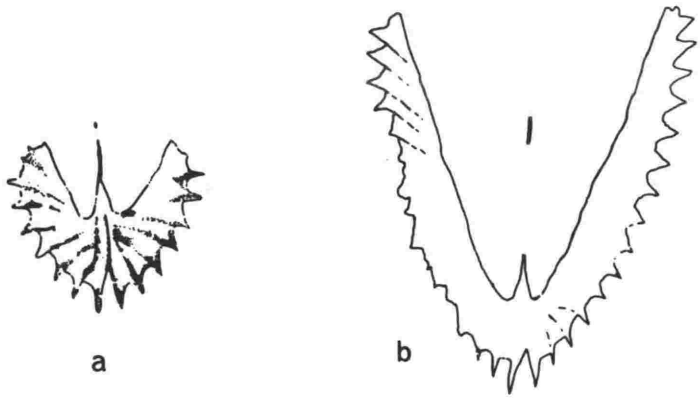


Fig.37. <u>Isograptus imitata</u> Harris. <u>a</u>, immature rhabdosome, in which proximal thecae are clearly outlined; VG30. <u>b</u>, mature, incompletely preserved rhabdosome; VG88. Both specimens from locality S2/552, Aorangi Mine area. <u>I.c.maximodivergens</u> zone. Both figures x 5.

Discussion. Specimens referred to I.imitata from zone 6 are considered to represent a variable population, the most common forms of which (fig.36,nos 29,30) agree well with Harris's illustrations of the type specimens (Harris 1933, figs 55-9). The most distinctive feature of the form is the shape of its stipes - they are widest in the sicular region, and taper distally. The typical, though not invariable, V-shape of the rhabdosome together with its small size also distinguishes it from subspecies of I.caduceus in Nelson, and it is here given full species rank. I.imitata varies considerably in shape, and variants approach several described species.

Specimens from zone 7 have a more rounded ventral margin in the proximal region and resemble in general shape, Ruedemann's illustrations of I.caduceus mut.nanus Ruedemann (1904 :698, pl.15,figs 8,9). The Nelson specimens differ in having more fully developed stipes.

In a few specimens from zone 6 proximal thecae are longer than average and stipes are sharply flexed and more reclined (see fig.36,nos 25-8). The periderm appears to be thickened in the region of the ventral thecal margin, and the ventral indentation between the sicula and first theca is almost completely closed. In general shape the specimens approach I.forcipiformis Ruedemann (1904 :pl.15, figs 10-13) and support Ruedemann's statement (1904 :699) that forcipiformis is a derivative of Isograptus of the caduceus type.

Specimen VG30 (fig.37a) from zone 6, with more pendant thecae than average, is the closest match to the well known European species I.gibberulus Nicholson (compare figures by Bulman 1932,pl.8,figs 3,4), yet described from Australasia. It is distinguished by having fewer thecae in the proximal region and by the lower inclination of distal thecae. The similarity between I.imitata and I. gibberulus was noticed independently by Dr D.Skevington (pers.comm.) and the writer.

While the contemporaneous form I.c.maximodivergens, can be readily related to preceding subspecies of I.caduceus, I.imitata's ancestry is not so easily traced. Harris regarded it as a "catagenetic variety" of I.caduceus and implied that it evolved from an earlier subspecies (victoriae or lunata). In general accordance with Harris's view, the writer tentatively considers it to have descended from I.c.? primula in zone 4, through such forms as the V-shaped specimen of I.c.lunata (fig.36,no.5)in zone 5, becoming a distinct species in zone 6 (see fig.~~43~~44).

Skwarko's description and illustration of I.forcipiformis var.harrisi Skwarko (1961 :106,fig.4) from the Aorangi Mine area Nelson, agree~~s~~ well with larger members of I.imitata. Under the 1964 International Code of Zoological Nomenclature, varieties published after 1960 are to be regarded as of infrasubspecific rank; "var.harrisi" is here included in I.imitata.

Distribution. The species has not been recognised outside Australasia, but its full range may not be so restricted. In South America, Turner (1960 :83-4, pl.9,figs 10,11?) described a similar form as Isograptus gibberulus var.c from "Lower Llanvirnian" beds. His figure 10 closely matches Nelson members of I.imitata from zone 7.

Horizon and localities. S2/535, 540, 545, 552, 553, 559, 561, 568, 629. Associated forms, I.c.maximodivergens, Goniograptus thureaui, Tetragraptus cf.serra, I.aff.imitata. Abundant in zone 6, common in zone 7, and one specimen from zone 8.

Isograptus aff. I.imitata Harris, 1933
Fig.36,nos 31-32,34.

aff.1933 Isograptus caduceus var.imitata Harris :92-3,figs 55-9.

1962 I.caduceus var.divergens; Blake :231-2, pl.1,figs 8-9; pl.2,figs 7, ?8.

1963 I.caduceus cf. I.c.var.divergens; Ross and Berry : pl.5,fig.22.

Description and Remarks. Associated with I.imitata in zones 6 and 7 is a small group of forms which differ slightly

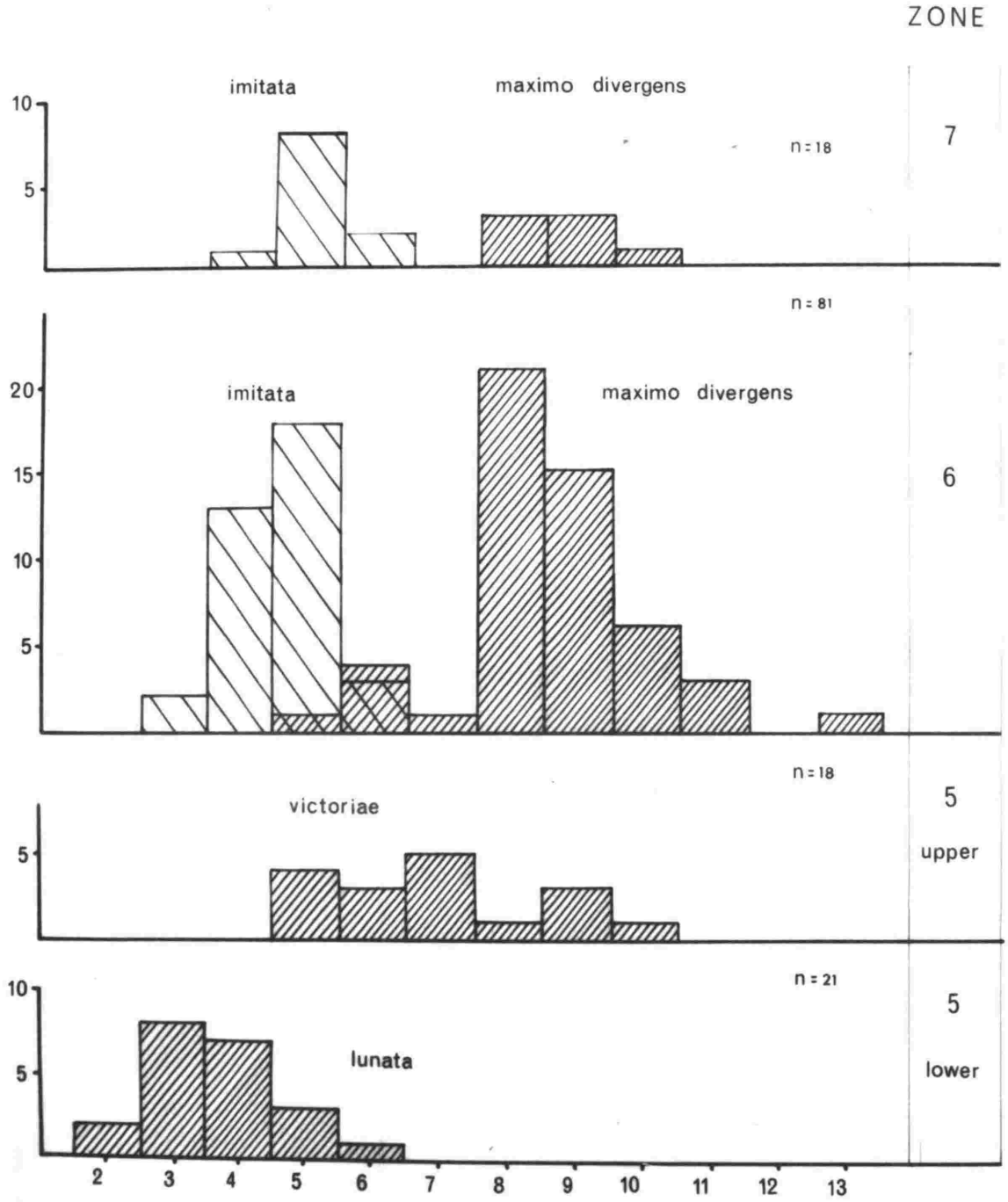
from the main population in bearing relatively broad, long straight stipes, which are parallel-sided after their sharp initial flexure. Average stipe width is 2.0-2.5mm, maximum length being 15mm. Thecae are spaced 10 in 10mm. As in I.imitata, the stipes are widest in the proximal region, a feature which distinguishes the form from I.c.divergens Harris, in which the stipes are conspicuously narrow in the proximal region (Harris 1933, figs 14-18).

The specimen figured by Ross and Berry (1963 :pl.5, fig.22) as I.c.divergens, from Pine Valley quadrangle, Nevada, has stipes which are widest at their proximal ends, and thus cannot be referred to divergens. The specimen matches those Nelson forms of I.aff.imitata with narrow stipes.

Blake (1962 :231-2, pl.1,figs 8,9; pl.2,figs 7,8) figured four specimens from the Bogo Shale of the Trondheim region, Norway, as I.caduceus var.divergens Harris. From his figures the stipes appear to be widest at their proximal ends, and match I.aff.imitata, rather than I.c.divergens. The Bogo Shale fauna was correlated with the Didymograptus hirundo zone of Britain by Skevington (1963a); a somewhat younger British equivalent has since been advocated by Berry (1968).

Horizon and localities. S2/535, 540, 547, 552, 560, 630. Associated forms, I.imitata, I.caduceus maximodivergens. Common in zones 6 and 7, one specimen from zone 8.

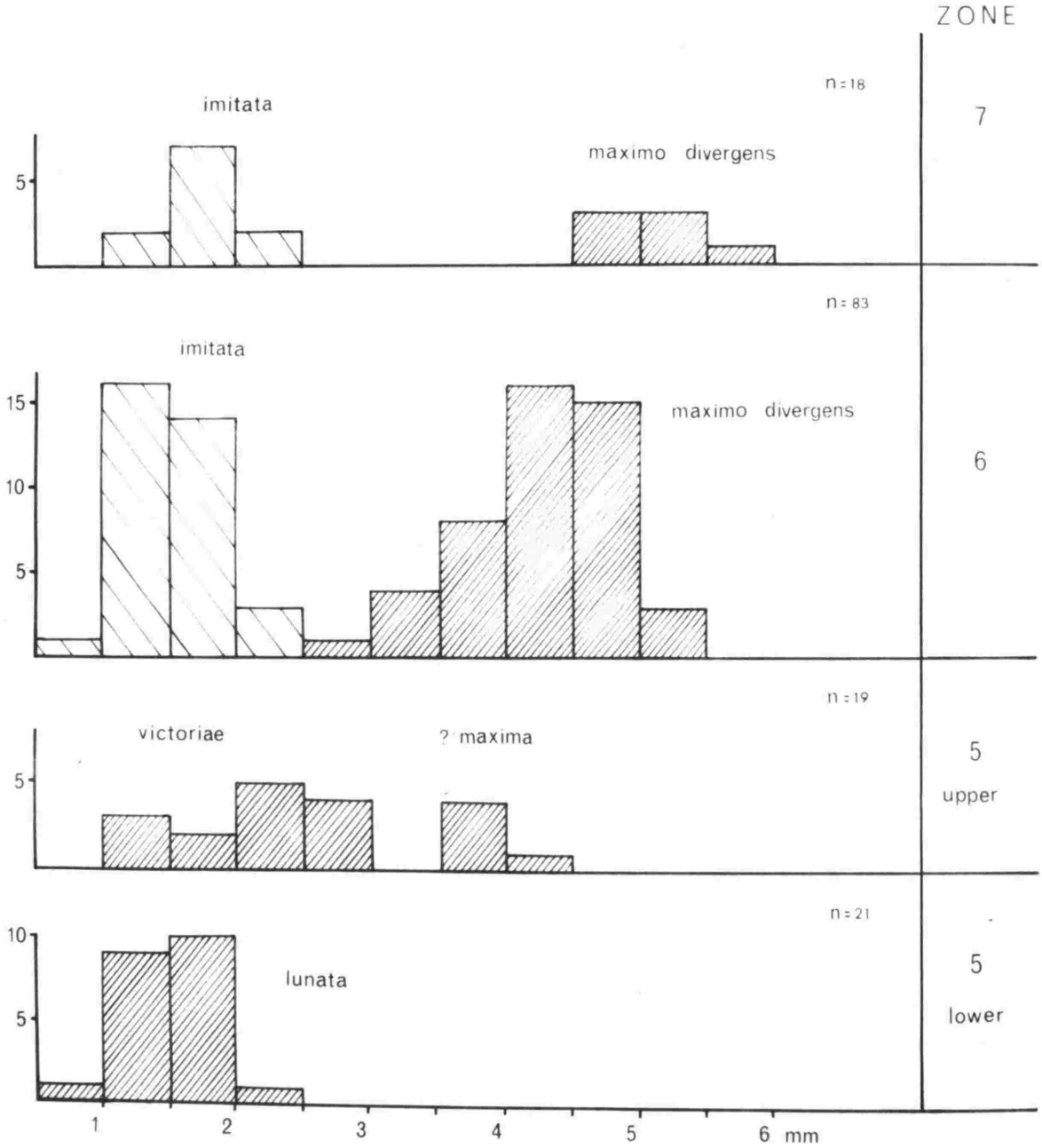
Fig.38. Frequency distribution of the number of pendant thecae in Isograptus caduceus (Salter) and I.imitata Harris, in zones 5,6, and 7.



Number of pendant thecae

Fig. 38

Fig.39. Frequency distribution of maximum stipe width measurements in Isograptus caduceus (Salter) and I.imitata Harris, in zones 5,6, and 7.



Maximum stipe width

Fig.39

Fig.40. Frequency distribution of sicular length measurements in Isograptus caduceus (Salter) and I.imitata Harris, in zones 5, 6, and 7.

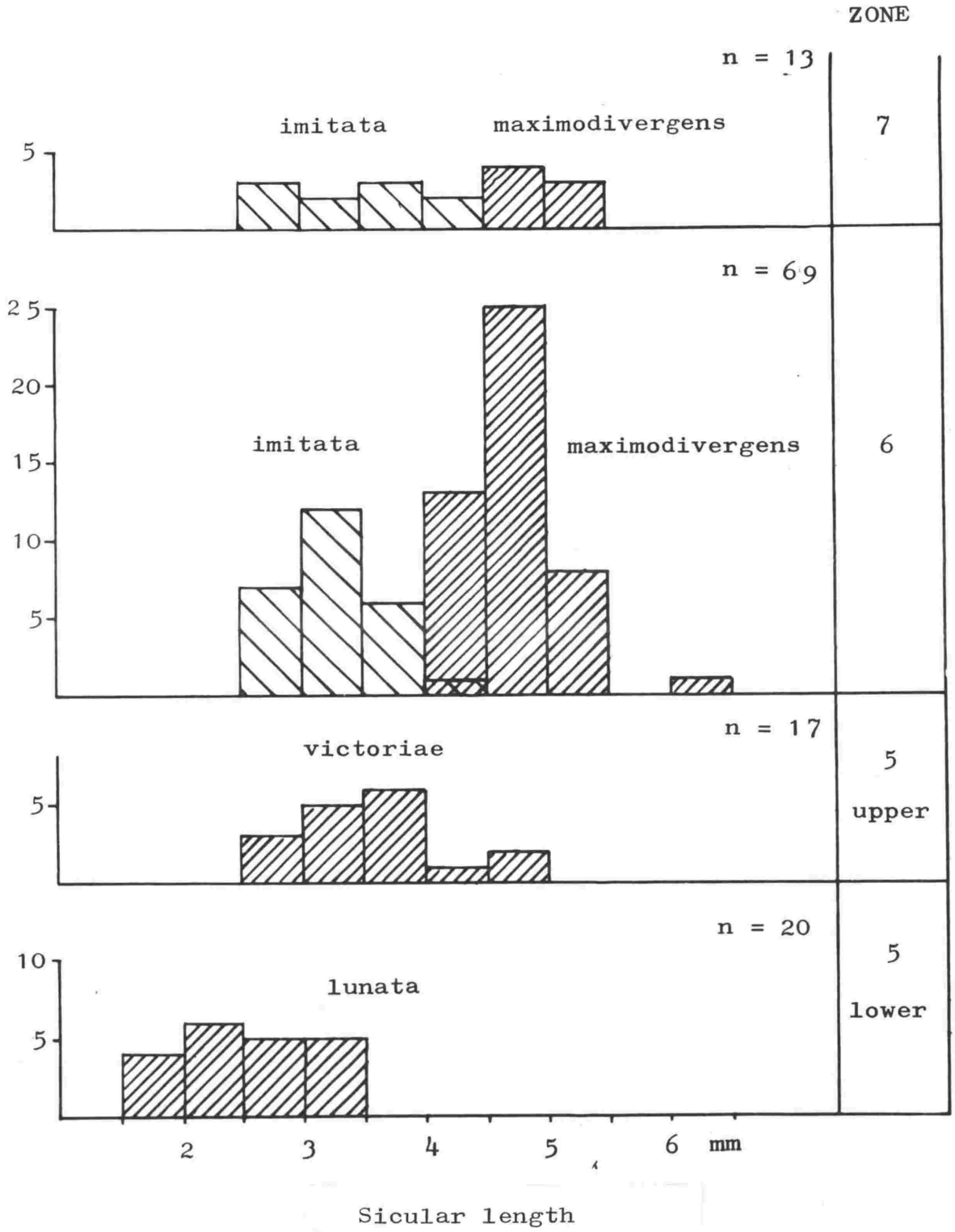

ZONE
n = 13
imitata
maximodivergens
7
5
n = 69
25
20
15
10
5
imitata
maximodivergens
6
n = 17
victoriae
5
upper
5
n = 20
10
5
lunata
5
lower
2
3
4
5
6
mm
Sicular length

Fig.40

Fig.41. Relation between sicular length and the number of pendant thecae in Isograptus caduceus (Salter) from zones 5,6, and 7. Same specimens as in fig.40.

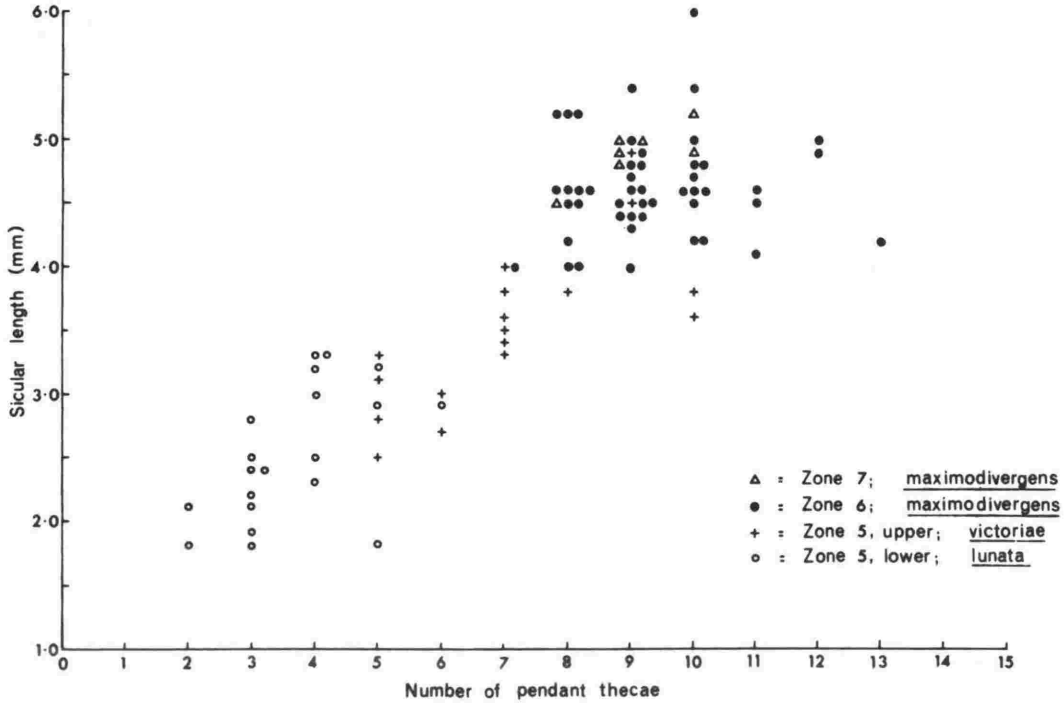

6·0
5·0
4·0
3·0
2·0
1·0
Sicular length (mm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Number of pendant thecae
△ : Zone 7; maximodivergens
● : Zone 6; maximodivergens
+ : Zone 5, upper; victoriae
○ : Zone 5, lower; lunata

Fig.41

Fig.42. Relation between sicular length and maximum stipe width in Isograptus caduceus (Salter) from zones 5,6, and 7. Same specimens as in fig.40.

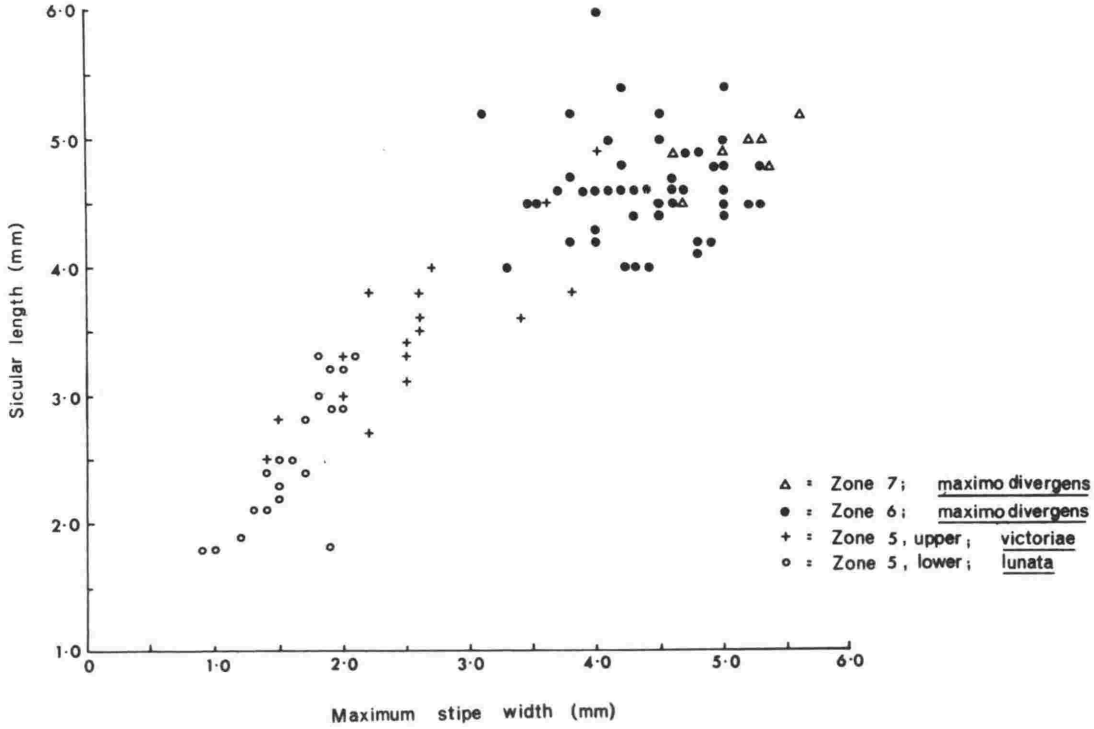

6·0
5·0
4·0
3·0
2·0
1·0
Sicular length (mm)
0
1·0
2·0
3·0
4·0
5·0
6·0
Maximum stipe width (mm)
△ = Zone 7; maximo divergens
● = Zone 6; maximo divergens
+ = Zone 5, upper; victoriae
○ = Zone 5, lower; lunata

Fig. 42

Fig. 43. Relation between the number of pendant thecae and maximum stipe width in 91 specimens of <u>Isograptus caduceus</u> (Salter) from zones 5,6, and 7.

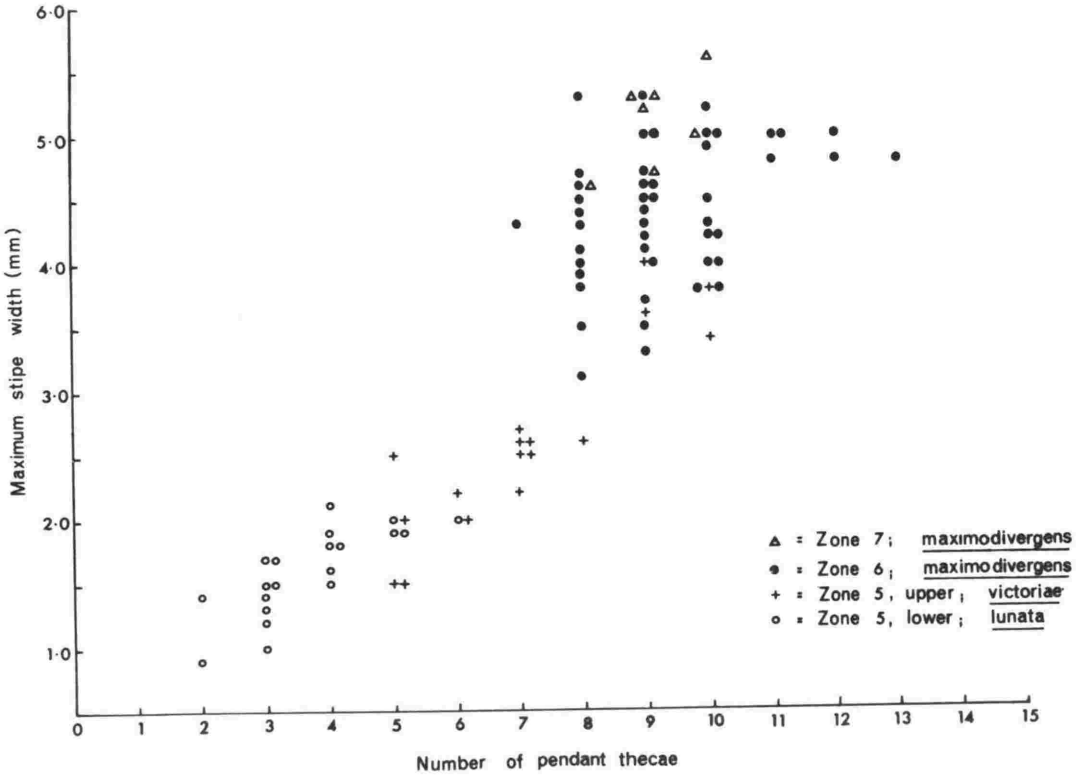

6·0
5·0
4·0
3·0
2·0
1·0
Maximum stipe width (mm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Number of pendant thecae
△ = Zone 7; maximodivergens
● = Zone 6; maximodivergens
+ = Zone 5, upper; victoriae
○ = Zone 5, lower; lunata

Fig. 43

The Phylogeny of the I.caduceus group

The inferred phylogeny of the Isograptus caduceus group, set out in fig.44, is based on the present work and on Harris's (1933) description of the Victorian sequence.

I.c.? primula is the earliest subspecies and the probable ancestor of the whole group. The remaining forms evolved along two main lines.

The first is that giving rise to imitata and is based on the close similarity between the small form of imitata and the large form of primula. An intermediate stage is probably represented by those forms of lunata with V-shaped rhabdosomes and distally tapering stipes, such as VG107 (fig.36,no.5). The passage from primula to lunata (of VG107 type) was thus apparently immediately followed by rapid 'lateral' [illegible]

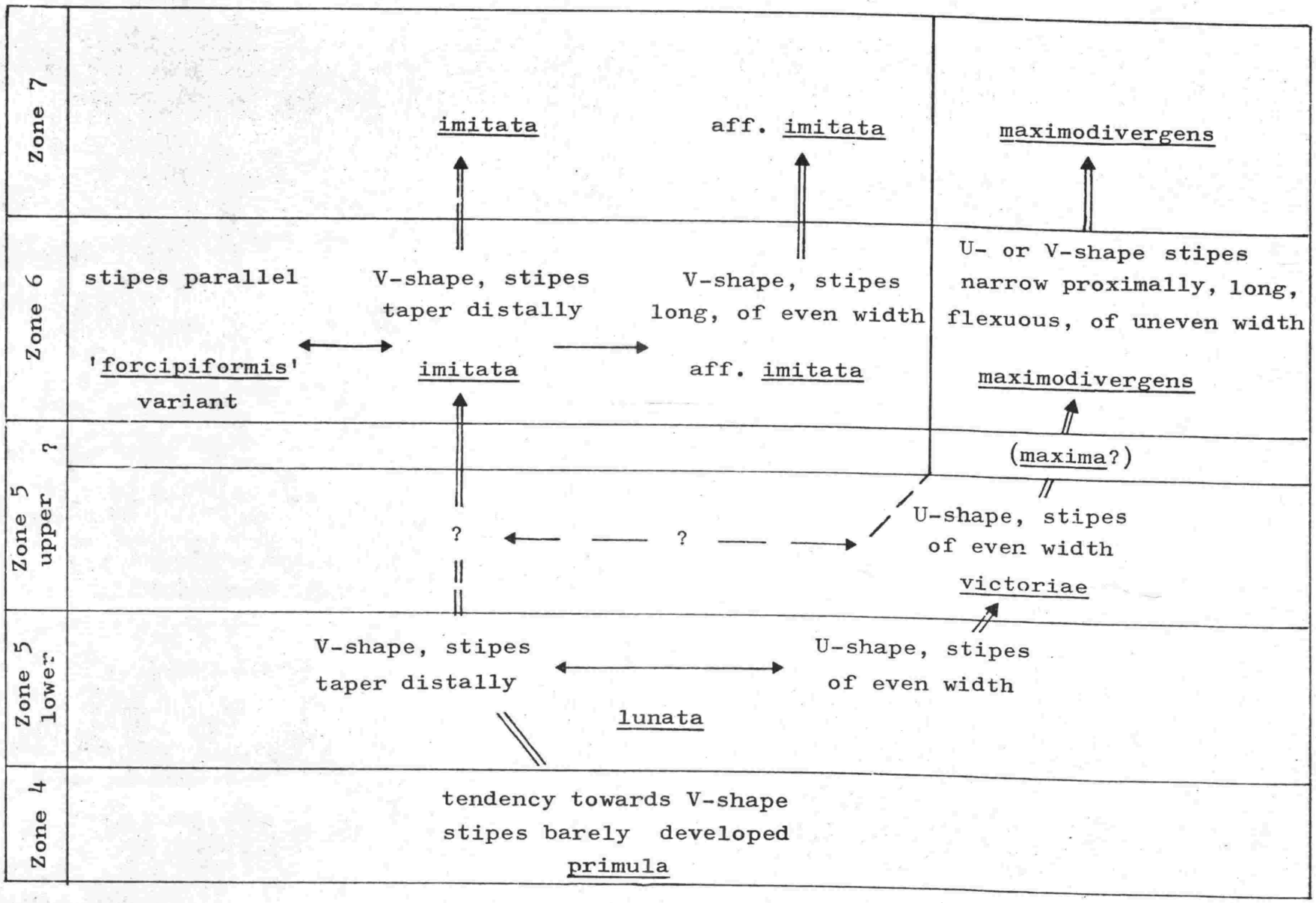


Fig. 44. The phylogeny of Isograptus caduceus (Salter).

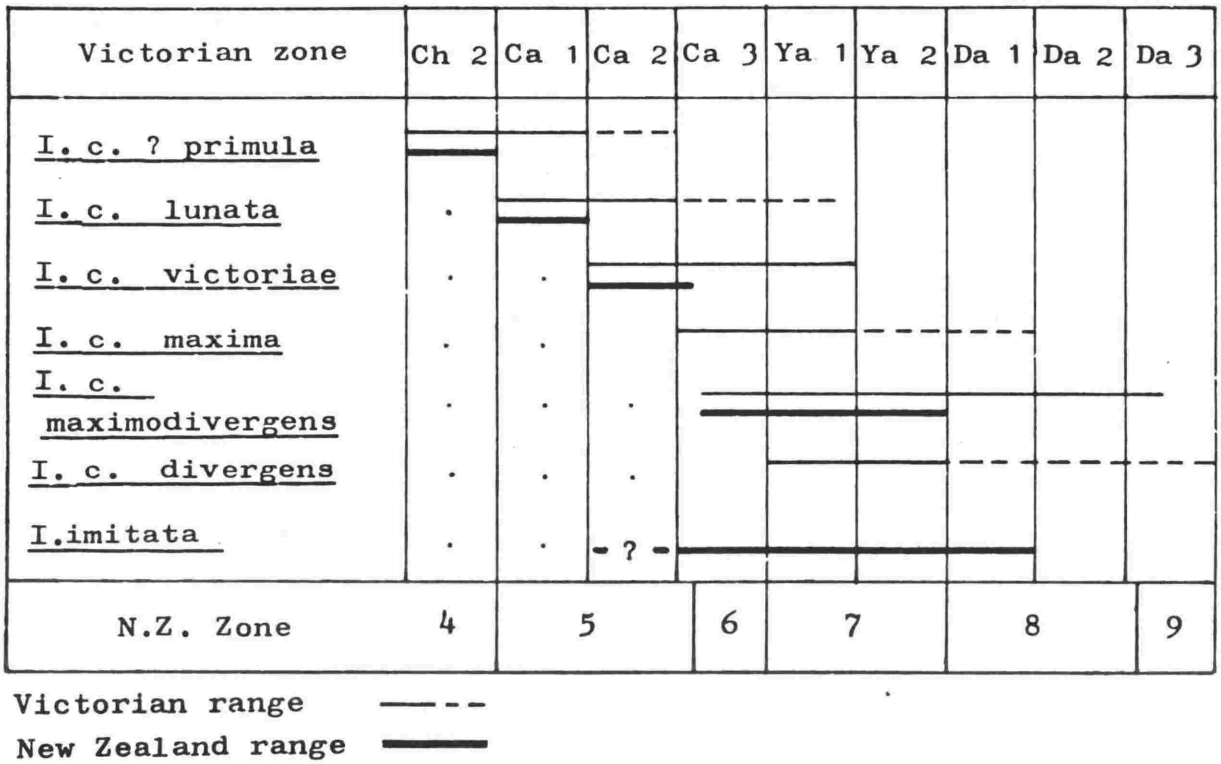


Fig.45 Comparison of the stratigraphic ranges given for members of the I.caduceus group in Victoria by Thomas (1960), and in Nelson by the writer.

correspond to the "chronological subspecies" of Sylvester-Bradley (1951). They are represented by a relatively large number of specimens in Nelson of which 138 have been measured for maximum stipe width, sicula length and number of pendant thecae, being characters which best reflect the overall increase in rhabdosome size from lunata to maximo-divergens. The progressive increase in value for each character in successive populations is shown in the frequency distribution diagrams (figs 38-40). Correlation between characters is good (figs 41-43); they provide a convenient means of measuring evolution in the series and should prove useful for stratigraphic correlation with sequences bearing I.caduceus elsewhere in the world.

The concept of successive populations with wide, sometimes overlapping ranges of variation ("biospecies" of Cain 1954) differs from Harris's view of morphological varieties ("morphospecies" of Cain 1954). Thus, a single Nelson population can include two of Harris's morphological types; for example the smallest forms here referred to victoriae match his var.lunata, while intermediate and larger forms match his var.victoriae. The stratigraphic ranges given by Thomas (1960) for the Victorian "varieties" are consequently greater than those given by the writer for the same forms in Nelson (fig.45).

Distribution outside Australasia. The Australasian isograptids have been recorded widely throughout the world but the

relative stratigraphic sequence of members of the caduceus group is poorly known outside Australasia.

In the Marathon Sequence Texas, the earliest member, I.c.lunata, appears in the highest beds of the Marathon limestone (zone 7), and extends into the overlying Alsate shale (lower part of zone 8, Berry 1960a :66). The forms victoriae, maxima, maximodivergens, and divergens, are listed from the lower Fort Pena Formation (upper part of zone 8), but their relative order of appearance within the zone is not stated. The replacement of lunata by the larger subspecies agrees with the Australasian sequence and suggests that the boundary between Berry's zones 7 (D.bifidus) and 8 (I.caduceus) lies within the Nelson zone of I.c.lunata, in the lower Castlemainian stage (table XI).

At Slemmestad, near Oslo, several species of Isograptus were described by Spjeldnaes (1953) from the upper few metres of the Lower Didymograptus Shale.

Zone 3bε, Layer 2

I.gibberulus Nicholson

Layer 3

I.lunata Harris (?=I.c.lunata)

Zone 3bδ

I.norvegicus Monsen (pars = I.c.lunata)

Zone 3bγ

I.spinosus Spjeldnaes

The earliest species, I.spinosus Spjeldnaes from zone 3bγ, has no known equivalent in Australasia but included in the succeeding form, I.norvegicus Monsen in zone 3bδ, are specimens which are here referred to I.c.lunata and which according to Spjeldnaes grade into the youngest form, I.gibberulus (Nicholson) in zone 3bε, through a "continuous series of development". The transition from norvegicus to gibberulus involves an increase in thecal length and overlap, a slight increase in stipe width and a marked increase in thecal inclination, and in the number of pendant thecae, and suggests that gibberulus evolved from a lunata-like ancestor in much the same way as its Australian counterpart - imitata - did. The 3bδ/3bε boundary, which also marks the appearance of the zone fossil Didymograptus hirundo (upper Arenigian), is thus thought to lie within the upper part of Nelson zone 5 (Ca2,see table XI) agreeing with the correlation proposed by Harris and Thomas (1938b: 68), and Skevington (1963b) but in marked conflict with that proposed by Kindle and Whittington (1958 :328) and advocated by Berry (1960b,1967,1968 etc), in which 3bε (or upper Arenigian) is correlated with upper Bendigonian (Nelson zone 3) or lower Chewtonian (Nelson zone 4).

In conclusion, the succession of subspecies of the I.caduceus group is poorly known outside Australasia, but in the only two regions in which the sequence of two or more subspecies is known - Texas and Norway - it agrees with that in Australasia.

Table XI. Correlation of New Zealand zones 1-9, with *Isograptus*-bearing sequences of Victoria, Texas, Western Canada, Newfoundland, Norway and Great Britain. In correlating zones 5 to 8 (upper Arenigian to Llanvirnian) emphasis has been placed on the first appearance of *Paraglossograptus etheridgei* (open triangles), *Glyptograptus dentatus* or its allies (solid triangles), and the horizon of transition from *Isograptus caduceus lunata* (or equivalent) to the later, derived, subspecies or species (asterisk). Heavy vertical lines represent the total range of *Isograptus*. The heavy horizontal line marking the top of zone 9 (Llandeilian) represents the first appearance of *Nemagraptus gracilis*, the heavy line at the base of zone 2 (Arenigian) indicates the first appearance of *Tetragraptus approximatus*.

Data from the following sources: New Zealand, Keble and Benson (1929), Skwarko (1961), this thesis; Victoria, Harris and Thomas (1938b), Thomas (1960); Texas, Berry (1960a); Western Canada, Jackson (1964); Newfoundland, Kindle and Whittington (1958), Whittington and Kindle (1963); Norway, Monsen (1937), Størmer (1953), Spjeldnaes (1953); Britain, Elles and Wood (1914), Jackson (1962).

AUSTRALASIA			NORTH AMERICA			EUROPE			
NEW ZEALAND		VICTORIA	TEXAS	WESTERN CANADA	NEW-FOUNDLAND	NORWAY		BRITISH STANDARD SEQUENCE	
9 Glyptograptus teretiusculus	DARRIWILIAN	Da 4	Glyptograptus 10 cf. teretiusculus	Glyptograptus euglyphus	Middle and Upper Table Head Formation	4a α	Ogygiocaris-bronni beds	Glyptograptus teretiusculus	LLANDEILIAN
		Da 3		?			Upper Didymogr. Shale	Didymograptus murchisoni	LLANVIRNIAN
8 Paraglossograptus etheridgei		Da 2	Paraglossogr. 9 etheridgei	Paraglossogr. etheridgei		3c	Orthoceras Limestone (Bogo Sh.)	Didymograptus bifidus	
		Da 1							
7 Oncograptus	YAP-EENIAN	Ya 2	Isograptus 8 caduceus	Isograptus caduceus	Isograptus caduceus	3b γ	Lower Didymograptus Shale	Didymograptus hirundo	ARENIGIAN
		Ya 1							
6 I.c. maximodivergens	CASTLE-MAINIAN	Ca 3						Isograptus gibberulus	
5 Isograptus caduceus lunata		Ca 2							
		Ca 1	7 D. bifidus	Didymograptus protobifidus	?	3b β-δ		Didymograptus nitidus	
4 Didymograptus protobifidus	CHEW-TONIAN	Ch 2	6 Didymograptus protobifidus		Didymograptus protobifidus & Tetragraptus fruticosus (3)				
		Ch 1							
3 Tetragraptus fruticosus	BENDIGONIAN	Be 4	5 Tetragraptus fruticosus (3+4)	Didymograptus extensus				Didymograptus deflexus	
		Be 3							
		Be 2	4 Tetragraptus fruticosus (4)		Tetragraptus fruticosus (4)				
		Be 1							
2 T. approximatus	LANCEFIELDIAN	La 3	3 T. approximatus	T. approximatus	T. approximatus	3b α	T. approximatus	?	
1 Adelograptus		La 2	2 Clonograptus	Bryograptus Clonograptus	Clonogr. Bryogr. Dictyonema	3a	Ceratopyge Lst.	?	
		La 1	1 Anisograptus	Staurograptus	Staurograptus Dictyonema		Ceratopyge Shale	Anisograptids + Dictyonema	TREMADOCIAN
				Dictyonema		2e	Dictyonema Shale	Dictyonema flabelliforme	

Table XI. Correlation of Isograptus-bearing sequences.

Isograptus dumosus Harris, 1933.

Pl.12,figs 7,8,12.

1933 Isograptus dumosus Harris :94, text-figs 37-9, pl.6, figs 2a-c.

Remarks. Specimens from zone 6 (pl.12,figs 7,8) closely match Harris's text-figures, those from zone 7 (pl.12,fig. 12) are larger but otherwise similar.

Horizon and localities. S2/533, 540, 552, 560, 561, 608, 630, 631; S7/517. Associated forms, Isograptus caduceus maximodivergens, I.hastatus. Zones 6,7.

I.dumosus is known from the Yapeenian stage of Victoria, and has been reported from the Basin Ranges, U.S.A., by Ross and Berry (1963 :94).

Isograptus hastatus Harris, 1933

Pl.12, figs 9,11.

1914 Didymograptus caduceus var.manubriatus T.S.Hall (pars.) pl.17,fig.13.

1933 Isograptus hastatus Harris :104, text-figs 33-6.

1947 Isograptus caduceus var.gracilis Ruedemann :351, pl.57,figs 15,16.

Remarks. Nelson specimens agree well with Harris's figures and description. Ruedemann's figures of I.caduceus var.gracilis Ruedemann, from the Glenogle Shale closely match the Victorian species.

Horizon and localities. S2/528, 533, 552, 553, 557, 560, 608. Associated form Isograptus caduceus maximodivergens. I.hastatus is the earliest of the manubriate species to appear in the Nelson sequence. It is abundant in zone 6, one specimen is known from zone 5.

The species ranges through the Yapeenian stage in Victoria, and is known (as I.c.var.gracilis Ruedemann) from the Glenogle Shale, British Columbia.

Isograptus manubriatus (T.S.Hall, 1914)

Generic affinities.

In a recent discussion of the generic affinities of I.manubriatus, Skevington (1968) concluded that the species is more closely related to Meandrograptus Moberg, 1892 than to Isograptus Moberg, 1892. However, the symmetrical arrangement of the sicula and initial theca (1^1) in I.manubriatus (see Bulman 1968 :212,fig.1) as in the closely similar Swedish species Meandrograptus? geniculatus Skevington 1965, suggest that both species belong to

Isograptus, as defined here. The sicula in the type species, Meandrograptus schmalenseei Moberg (see Bulman 1932, text-figs 2a-b, pl.2,figs 6-8) is relatively long and straight, and the initial pair of thecae (1^1 and 1^2) turn sharply away from it, the axis of rhabdosome symmetry passing through the sicula. In M.schmalenseei, as in other species referred to Meandrograptus by Skevington (1965 :44) - M.leptograptoides (Monsen, 1937) and M.mobergi (Tornquist, 1901) - the distal portions of the initial thecae, and the entire length of all subsequent thecae are inclined at a relatively low angle (about 30° or less) to the stipe axis, contrasting markedly with those of I.manubriatus and M? geniculatus. The two species are probably best regarded, together with the other "manubriate" species, dumosus and hastatus (Harris 1933 :93), as comprising a divergent group within Isograptus, with the proximal symmetry and highly inclined proximal thecae of Isograptus, and the proximal concentration of thecal origins, the prothecal folds, and the low inclination of distal thecae of Meandrograptus.

Isograptus spp.aff. I.manubriatus (T.S.Hall,1914)

Discussion. A wide variety of large manubriate isograptids are found in zone 7. Although none closely matches the

specimen figured by Hall (1914 :pl.17,fig.12), or Harris (1933 :pl.6,figs 1a-1i), each bears the typical features - a proximal concentration of thecal origins, outwardly-directed apertural portions of proximal thecae, and low inclination of distal thecae. Four informal 'forms' are recognised here; it is unlikely that each will prove to be a distinct species.

The specimen figured by Keble and Benson (1929, pl. 104,fig.10) as "I.ovatus" from Cobb Valley probably belongs to the I.manubriatus group.

Isograptus sp.1 aff. I.manubriatus (T.S.Hall,1914).
Pl.13,fig.1.

Remarks. The stipes are relatively wide, straight and diverge at a high angle, their proximal portions enclosing the sicular 'wedge'. They taper distally, giving an ovate outline to the rhabdosome.

Horizon and locality. S2/540. Associated form, Isograptus caduceus maximodivergens. Zone 7.

Isograptus sp.2 aff. I.manubriatus (T.S.Hall,1914).
Pl.13,figs 2,6.

Remarks. The stipes are approximately parallel-sided, diverging at a smaller angle than those of I.sp.1 aff. manubriatus, and are curved upwards.

Horizon and localities. S2/540, 630. Zone 7.

Isograptus sp.3 aff. I.manubriatus (T.S.Hall,1914).
Pl.13,fig.8.

Remarks. The sicular "wedge" is large and prominent; the stipes are nearly straight, are narrower than those of I.sp. 2 aff.manubriatus, and diverge at a smaller angle.

Horizon and localities. S2/540, 630. Zone 7.

Isograptus sp.4 aff. I.manubriatus (T.S.Hall,1914).
Pl.13,figs 3,7.

Remarks. Stipes are relatively narrow and parallel-sided, and curve upwards. They diverge at a relatively low angle,

approaching that of "Meandrograptus" tau Harris (1933 : text-figs 47-9). The sicular wedge is large and prominent.

Horizon and locality. 82/540. Zone 7.

GENUS Oncograptus T.S.Hall, 1914.

Discussion. The specimen on which Skevington (1968, specimen of fig.2c) apparently based his evidence for the conspecificity of Oncograptus upsilon (the type species of Oncograptus) with Cardiograptus morsus and Isograptus manubriatus is incomplete and appears to be more closely related to a Cardiograptus of the type listed here as Cardiograptus? sp. The proximal aspect of the Nelson Oncograptus (see pl.12, fig. 5) resembles that of I.caduceus rather than of I.manubriatus. The genus is here regarded as valid.

Oncograptus upsilon biangulatus Harris and Keble, 1916.
Pl.12, figs 4,5,10.

1916 Oncograptus biangulatus Harris and Keble (in Harris): pl.1, figs 7-9.

1924 O.biangulatus; Harris :96.

1933 O.upsilon var.biangulatus; Harris :95-6, text-figs 23,24.

1936a O.sp; Bulman :text-fig.1.

1966 O.upsilon; Smith :173,fig.2.

Remarks. Nelson specimens resemble the narrow form; O.biangulatus Harris and Keble, which Harris (1933) made a "variety" of the wider O.upsilon Hall. A thin web of periderm joins the dorsal margins of the proximal 3 or 4mm of the uniserial stipes in most Nelson specimens.

Horizon and localities. S2/540, 630. Associated forms, I.spp.aff. manubriatus, Didymograptus v-deflexus. Zone 7.

Oncograptus upsilon biangulatus is a zone fossil in the Yapeenian (Ya1, 2?) of Victoria, and is known from the I.caduceus zone of Texas.

FAMILY SINOGRAPTIDAE Mu, 1957

Gen. et sp. indet.

Pl.10, fig.2.

Remarks. An isolated stipe fragment preserved in part relief has an undulating dorsal margin of the type associated with prothecal folds, and otherwise simple dichograptid thecae. The stipe widens from 0.25mm at its narrowest end to 0.5mm at its widest end.

The general form of the thecae, in profile view,

resembles that described in Cymatograptus Jaanusson, 1964 (p.420, 424).

Horizon and localities. 82/568, 592. Zone 8.

Sinograptids are known from the Victorian Darriwilian (Bell 1961 :67-70), from China, North America and Scandinavia.

FAMILY CRYPTOGRAPTIDAE Hadding,1915.

GENUS Cryptograptus Lapworth, 1880.

Cryptograptus schaferi Lapworth, 1880.
Pl.13, figs 4,10B.

1880 Cryptograptus tricornis var.schaferi Lapworth, pl.5, figs 28a-b.

1908 Cryptograptus tricornis var.schaferi; Elles and Wood: 299, text-figs 201a-b, pl.32,figs 13a-c.

1931 Cryptograptus tricornis var.schaferi; Bulman :65-6, text-figs 31a-b, pl.6,figs 1-5; pl.7,fig.3.

Remarks. Nelson specimens agree well with Elles and Wood's description. C.tricornis var.schaferi was raised to

specific rank by Bulman (1933 :352).

Horizon and localities. 82/539, 595, 633. Associated forms, Climacograptus brevis, Glossograptus hincksii, Pterograptus? sp.nov. Zone 9.

C.schaferi has been described from Cobb Valley, Nelson, by Keble and Benson (1929 :859, pl.106,figs 23a-d, e?) as "Cryptograptus tricornis" and by Skwarko (1962 :225, text-fig.4, figs 10a-c). The range given by Skwarko is from upper Darriwilian (zone 9) to lower Gisbornian. The species is widely distributed being known from South America, North America, Great Britain, Scandinavia?, U.S.S.R.?, China and Australia. Its range in Victoria is from mid-Darriwilian (D3) to basal Eastonian (Thomas 1960).

FAMILY GLOSSOGRAPTIDAE Lapworth, 1873 (emend.)

GENUS Glossograptus Emmons, 1855.

Glossograptus acanthus Elles and Wood,1908

Pl.13, fig.11.

1908 Glossograptus acanthus Elles and Wood :314, text-figs 208a-b, pl.33,figs 4a-c.

1935 Glossograptus acanthus; Harris and Thomas :302-3,

fig.3,nos 13-16.

Description. Nelson specimens agree well with Elles and Wood's description. The apertural margins however, appear to be slightly thickened by lists.

Horizon and localities. S2/547, 568, 582. Zone 8.

G.acanthus ranges in Victoria from Darriwilian (Da1) to Gisbornian. It is known from the zone of Paraglossograptus etheridgei of Texas (Berry 1960a :70-1), and from the upper Arenigian and Llanvirnian of Britain (Elles and Wood :314).

Glossograptus? crudus Harris and Thomas, 1935.
Fig.46; pl.13,fig.9.

1935 (?)Glossograptus crudus Harris and Thomas :303-4,fig.1, no.13; fig.2,nos 15-17.

1962 Glossograptus crudus; Beavis :485-6,figs 1a-b.

Remarks. Nelson specimens agree well with the description by Harris and Thomas. Beavis described pyritised specimens from Victoria with monoserial rhabdosomes indicating that the species belongs to the Family Glossograptidae Lapworth. Glossograptus, as diagnosed by Bulman (1955) and by Jaanusson

(1960a), bears apertural spines, and thus excludes forms such as ?G. crudus. The species most closely resembles members of Glossograptus, however, and is tentatively included within the genus here.

Fig. 46. Glossograptus? crudus Harris and Thomas. Mature, poorly preserved, complete rhabdosome; x 5. GR31, locality S2/556, Aorangi Mine area. Oncograptus zone.

Horizon and localities. S2/545, 556, 632. Associated form, Cardiograptus morsus. Zone 7.

G? crudus is the earliest glossograptid in the Nelson sequence. It is restricted to the Yapeenian (Ya2) in Victoria.

Glossograptus hincksii (Hopkinson, 1872)

Pl.13, fig.10C.

1872 Diplograptus hincksii Hopkinson :507, pl.12, figs 9a-d.

1908 Glossograptus hincksii; Elles and Wood :309-12, text-figs 205a-f, pl.33, figs 2a-j.

1956 Glossograptus hincksii; Lemon and Cranswick :20-4, text-figs 5a-f, 6, 7, pl.1, figs 13, 14.

Remarks. Nelson specimens are preserved in outline only but agree well with the description by Elles and Wood and with the wider forms described by Lemon and Cranswick.

Horizon and localities. S2/592, 633. Associated forms, Cryptograptus cf.schaferi, Pterograptus? sp.nov. Zones 9-10.

G.hincksii has been described from the Cobb Valley region by Keble and Benson (1929 :859, pl.106,figs 24a-h), and by Skwarko (1962 :226-7, text-fig.4, figs 11a-b). The range given by Skwarko is upper Darriwilian (zone 9) to mid-Gisbornian (Mount Peel beds, zone 10). The species is widely distributed, being recorded from South America, North America, Britain, Scandinavia, U.S.S.R.(Taimyra), China (S.Anhui), and Australia. Its range in Victoria is from Darriwilian (Da4) to upper Gisbornian.

GENUS Paraglossograptus Mu (in Hsu, 1959)

Type Species. P.typicalis Mu, MS 1958, by subsequent designation (Mu,1963).

In his description of the new genus, Hsu (1959) did not nominate a type species. In 1963, Mu (p.364) gave the following indication; "the genus Paraglossograptus Mu, in Hsu (1959) with P.typicalis Mu (text-fig.15) as the type occurring in great number in the lower part of Amplexograptus confertus zone of the Shihuigou shale is characterised

by the development of lacinia." Berry's (1966a :431) nomination of P.latus Hsu as type species is therefore redundant.

The original description of the type species, P.typicalis Mu, has not been seen by the writer; the figure given by Mu (1963 :364,fig.15a) is taken as a basis for comparison.

Diagnosis. Rhabdosome biserial, with prominent virgula; some (possibly all) species with monopleural stipe arrangement. Periderm attenuated and lists commonly developed. Thecae resemble those of Glossograptus, and bear one or more slender to robust apertural spines. Lacinia delicate to robust, in regular or irregular meshwork, confined to discrete longitudinal rows in some species.

Species.

?Graptolithus tentaculatus Hall, 1858

Lasiograptus (Thysanograptus) etheridgei Harris,1924

Lasiograptus (Hallograptus) proteus Harris and Thomas, 1934

Paraglossograptus regularis Hsu, 1959 (?= L.(T.) etheridgei Harris)

Paraglossograptus latus Hsu, 1959 (?= L.(T.)etheridgei Harris)

Paraglossograptus multifibratus Hsu, 1959 (?= L.(T.) etheridgei Harris)

Paraglossograptus multifibratus var. longus Hsu, 1959

Paraglossograptus typicalis Mu, 1962

Paraglossograptus intermedius Mu, Geh, and Yin, 1962

Paraglossograptus zealandicus sp. nov.

Discussion. The main features of Paraglossograptus outlined by Hsu (1959 :187-8) were : a) biserial rhabdosome "similar to that of Glossograptus"; b) attenuated periderm and development of lists; c) conspicuous virgula; d) presence of lacinia formed from "branching" apertural spines and e) general presence of proximal spines.

In 1963 Mu (p.355) stated that Paraglossograptus has a monopleural rhabdosome, contrasting with the dipleural rhabdosome of the otherwise similar genera, Hallograptus and Lasiograptus. Jaanusson (1960a:336) pointed out that Lasiograptus (Thysanograptus) etheridgei Harris belongs to Paraglossograptus Mu. In re-examining Harris's type specimens, Berry (1966a :431-2) was unable to determine whether stipe arrangement was monopleural or dipleural. He noted that the construction of the lacinia was irregular both within and between specimens, and recorded the presence of a clathrial framework in the proximal region similar to that of Cryptograptus (described by Bulman, 1945). Berry also noted lists developed at the apertural margins. The new Nelson species, P. zealandicus, has particularly robust apertural spines and a barely developed lacinia which is confined to discrete vertical rows, and is supported on

relatively slender lateral apertural? spines.

Paraglossograptus most closely resembles Glossograptus Emmons, particularly in the monopleural rhabdosomes of at least some of its species, in the outline of the rhabdosome and of the spinose thecae, and in the attenuated periderm and development of lists. It differs chiefly in bearing a lacinia, and in the general absence of prominent apertural spines. The lacinia, in most species, is readily seen, but P.intermedius Mu, Geh, and Yin and P.zealandicus sp.nov. have a relatively simplified lacinia, and specimens in which it is obscured are difficult to distinguish from Glossograptus. The two genera are probably closely related but, pending a general review are here regarded as distinct genera within the family Glossograptidae.

Members of Paraglossograptus are distinguished from Cryptograptus Lapworth by their spinose thecae and their lacinia. Hallograptus Lapworth has similar spinose thecae and attenuated periderm but, as diagnosed by Bulman (1955), excludes forms with lacinia or monopleural stipe arrangement (see also Ross and Berry 1963 :154-5). Lasiograptus Lapworth is distinguished by its amplexograptid thecae (or "lasiograptid thecae" of Jaanusson 1960a:303-5, text-fig.2). Neurograptus Elles and Wood has a more delicate, fibrous lacinia and is not known to include forms with monoserial rhabdosomes.

Hall's original description of Graptolithus tentaculatus (Hall 1858 :134) has not been seen by the

writer but from his 1863 description and figures (p.116-7, pl.14, figs 6-8), the species probably belongs to Paraglossograptus as suggested by Mu (1963 :355). Lasiograptus (Hallograptus) proteus Harris and Thomas, also belongs to the genus as diagnosed here. The original description of Paraglossograptus intermedius Mu, Geh and Yin, has not been seen by the writer, but from the illustrations given by Mu (1963 :364, fig.15b) the species clearly belongs to the genus.

The genus has been reported from North America, China and Australasia, its stratigraphic range generally lying within uppermost Arenigian, Llanvirnian and Llandeilian stages of the standard British Sequence (see table XI).

Paraglossograptus etheridgei (Harris, 1924)
Figs 47a-g; pl.14, figs 4,5,9.

1924 Lasiograptus (Thysanograptus) etheridgei Harris :98-99, pl.7, figs 3-7.

1935 Lasiograptus (Thysanograptus) etheridgei; Harris and Thomas :306, fig.2, nos 28-9.

?1959 Paraglossograptus regularis Hsu :188-9, pl.5, figs 1-4.

?1959 Paraglossograptus latus Hsu :189, pl.5, figs 5,6.

?1959 Paraglossograptus multifibratus Hsu :190, pl.5, figs 7,8.

1960a Hallograptus etheridgei; Berry :95, pl.12,fig.6, 9b; pl.13,fig.4.

1962 Lasiograptus etheridgei; Skwarko :236,fig.5,no.14.

1966a Paraglossograptus etheridgei; Berry :432-5, pl.48, figs 3,5,6.

Description. Mature rhabdosomes range in length from 15mm to more than 22mm, and in maximum width (exclusive of lacinia and spines) from 3.0mm to 4.1mm. A stout virgula can generally be seen in the distal part of the rhabdosome and extends beyond the distal margin for several millimetres. The rhabdosome widens gradually from a blunt proximal end to its maximum width which is reached about 5 to 10mm from the proximal end. The distal part either tapers slightly or remains parallel-sided, most narrow rhabdosomes being parallel-sided.

The replacing mineral in all Nelson specimens is unevenly distributed, suggesting localised thickening and attenuation of the original periderm. The apertural margins were apparently strengthened by a list, which supported the apertural spine.

Thecae are spaced 11 - 12.5 in 10mm and generally resemble those of Glossograptus, with the ventral margin of the aperture extended into a spine. In the proximal region the spines are relatively straight and free ("normal" apertural spines of Hsu 1959 :187), while in the mid and

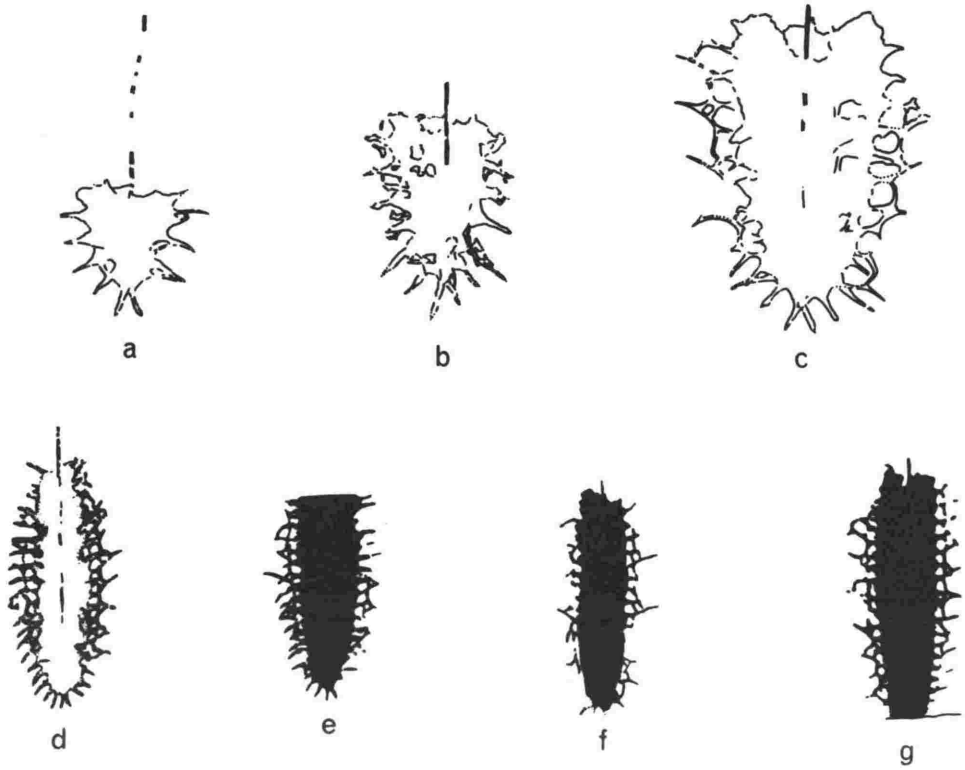


Fig. 47. Paraglossograptus etheridgei (Harris). a-c, growth stages; x 5. a, VG74. b, VG77. c, VG73. d-g, mature rhabdosomes; x 2. d, complete, large rhabdosome, VG72. e, incomplete, large rhabdosome, VG76. f, complete, small rhabdosome, VG78. g, incomplete, large rhabdosome, VG75. All specimens from locality S2/582, Aorangi Mine area, P.etheridgei zone.

distal portions of the rhabdosome most spines bifurcate, or are bent, and merge into the lacinia ("twisting apertural spines"). However there is no consistent pattern of spine arrangement within, or between rhabdosomes.

The lacinia is similarly irregular, comprising a loose meshwork supported on short or long apertural spines. The meshwork itself is composed of robust to delicate threads.

Dimensions of eight specimens are given in table XII.

Table XII. Dimensions of Paraglossograptus etheridgei (mm)

Specimen no.	Maximum width	Distal tapering	Length	Thecae/10mm
VG71	3.5	none	21+	?
VG72	3.7	pronounced	16	11-12
VG75	4.0	slight	16+	11.0
VG76	4.1	slight?	14+	12.0
VG78	3.1	none	15	c10.5
VG85	c4.0	slight?	20+	?
VG86	c4.1	slight	22+	?
VG87	3.0	slight	16+	?

Discussion. The Nelson specimens vary considerably in outline, and in maximum width. Forms with a maximum width

of 4.0-4.1mm closely resemble the descriptions and figures of the type specimens given by Harris (1924), and by Berry (1966a). The narrower forms, which otherwise resemble the typical forms, may represent a different orientation of the rhabdosome prior to flattening. Berry (1966a :434-5) noted similar variation among Victorian specimens, and all forms are here included within the species.

Poor preservation does not allow determination of the Cryptograptus-like list structure about the sicula described by Berry.

The Chinese forms described by Hsu (1959 :188-90, figs 3,4; pl.5,figs 1-12) as P.regularis, P.latus and P.multifibratus all appear to be very similar to P.etheridgei. They are based on a total of 4 specimens and are distinguished mainly by their rhabdosome width, thecal spacing and construction of lacinia. In view of the variability of each of these characters in P.etheridgei, the Chinese forms are here tentatively placed in synonymy.

Horizon and localities. S2/547, 568, 569, 582. Associated form, ?Hallograptus inutilus. Zone 8.

Skwarko recorded the form from the Glyptograptus teretiusculus zone in the Cobb Valley area, Nelson. The specimen figured by him (1962, text-fig.5,no.14) from zone 10, N.gracilis ("Locality G.S.7373"), has been examined by

the writer. It is obliquely distorted, bears almost no lacinia, and is only doubtfully identifiable. The range of the species into the Gisbornian stage in Nelson is therefore not considered definite.

The species ranges from Darriwilian (Da1) to lower Gisbornian in Victoria, being common in the Da1 zone (Thomas 1960 :10). Berry (1960a) has figured the form from the zone of "Hallograptus" etheridgei in the Marathon sequence, Texas. Morris and Kay (1966) listed the species from the Middle Table Head Formation at Black Cove, Newfoundland, but their figured specimen apparently bears thecae spaced only 5 in 10mm and is distinct from etheridgei. Jackson (1964 :fig.3,no.6) figured a specimen which is slightly wider than, but otherwise similar to, Australasian members of the species, from the zone of Paraglossograptus etheridgei in the Road River Formation, Yukon. Berry (1962a) lists the species from the Deepkill Shale of New York ("zone of H.etheridgei") and Riva (1966) noted it in collections from zone D of the Levis Shale, Quebec.

Paraglossograptus zealandicus sp.nov.

Figs 48a-b; pl.14,figs 1-3.

Holotype. Specimen VG80, from locality S2/582. Paratype, specimen VG79, locality S2/582.

Figured material. VG79, VG80, VG81, VG82.

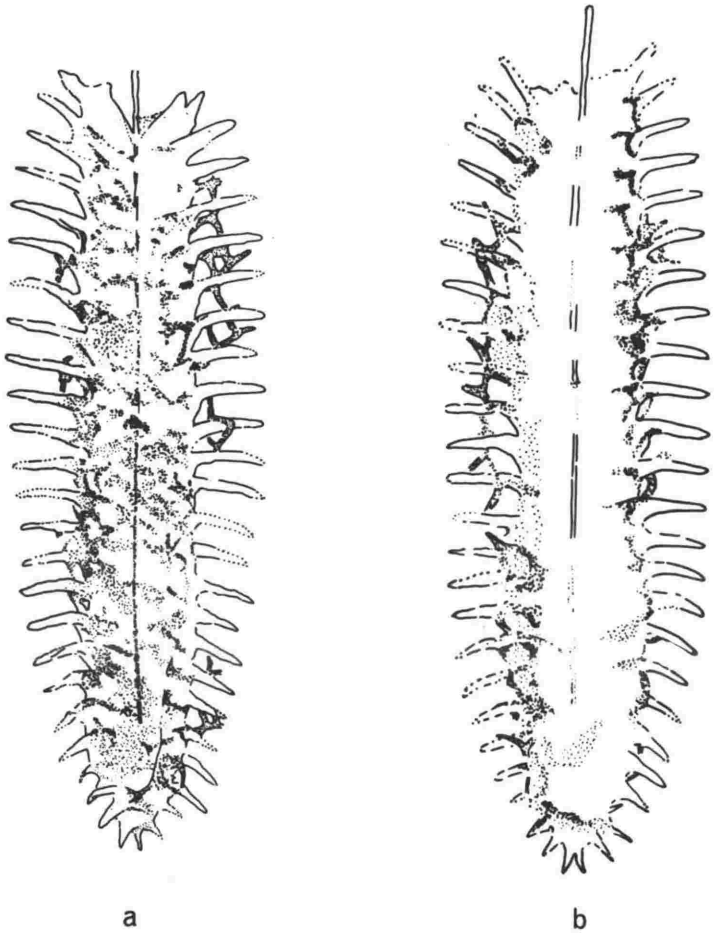


Fig.48. Paraglossograptus zealandicus sp.nov. a) holotype; x 5. VG80. b) paratype; x 5. VG79. Both specimens from locality S2/582, Aorangi Mine area. P.etheridgei zone.

Diagnosis. Rhabdosome parallel-sided or with slight distal taper, 3.1-3.5mm wide, with blunt proximal end and prominent virgula. Thecae bear long robust apertural spines and are spaced 10.5-12.5 in 10mm in the mature part of the rhabdosome. The lacinia is barely developed being confined to discrete rows and supported on slender upwardly-directed, lateral apertural(?) spines.

Description. Complete rhabdosomes are 19-21mm long and bear a stout virgula, which can be traced to within 3mm of the proximal end, and which projects beyond the distal margin by up to 10mm. Rhabdosomes widen rapidly from a blunt proximal end, attaining their maximum width of 3.1-3.6mm within the first 10mm. Thereafter, they either remain parallel-sided, or taper slightly as in P.etheridgei, to a distal width of 2.0-2.2mm. Attenuation of the periderm and development of lists is less marked than in P.etheridgei.

Thecae are spaced 10.5-12.5 in 10mm, the apertural margin of each passing smoothly into a long robust horizontal spine. In the proximal region, spines are relatively short, but in the mid and distal portions of the rhabdosome they reach 2.0mm long and 0.4mm wide at their bases, and resemble those of Glossograptus acanthus Elles and Wood.

In addition to the main apertural spines, a pair of more slender, upwardly-directed 'lateral' spines arise from about the level of each thecal aperture. One or two thin

connecting bars ("dissepiments" of Hsu,1959) join adjacent successive spines and represent a much simplified lacinia. Excavation of the enclosing shale of several specimens showed that the lateral spines probably projected from the lateral margins of the thecal apertures, the arrangement of spines being similar to that of Glossograptus hincksii (Hopkinson) as described by Jaanusson (1960a:320,text-fig.5).

Table XIII. Dimensions of Paraglossograptus zealandicus sp.nov. (mm.)

Specimen no.	Length	Maximum width	Distal width	Thecae/cm
VG79	21	3.6	3.5	10.5
VG80	19	3.4	3.4	11
VG81	16+	3.4	c2.2	12
VG82	19+	3.1	2.0	12.5
VG83	16+	3.0	?	12

Discussion. The long robust apertural spines and simplified lacinia are the most distinctive features of the Nelson species. Specimens in which the lacinia cannot be seen resemble Glossograptus acanthus Elles and Wood but are distinguished by their parallel-sided, rather than ovate

outline. From the figure and comments given by Mu (1963: 364, fig.15b), Paraglossograptus intermedius Mu, Geh and Yin, has more slender spines, a slightly wider rhabdosome, and a more fully developed lacinia. P.zerlandicus is distinguished from P.proteus (Harris and Thomas) mainly by its longer, more robust spines, its wider rhabdosome, and the absence of a long proximal spine.

The specimen from the Glenogle Shale, British Columbia, figured by Ruedemann (1947 :pl.77, fig.13) as Lasiograptus (Hallograptus) echinatus (Ruedemann) appears to have a similar simplified lacinia, but the spine arrangement cannot be determined from the published figure.

Horizon and localities. S2/568, 582. The form is confined to zone 8 at Aorangi Mine.

FAMILY LEPTOGRAPTIDAE Lapworth, 1880

GENUS Leptograptus Lapworth, 1873

Leptograptus sp.cf. L.flaccidus (J.Hall, 1865)

Figs 49a-b, pl.14, fig.10

cf. 1865 Graptolithus flaccidus J.Hall :143, pl.2, figs 17-19.

cf. 1903 Leptograptus flaccidus; Elles and Wood (s.l.) : 106-112, pl.14-15.

Remarks. Nelson specimens range from forms with very slender rigid stipes, such as those of L.flaccidus macer Elles and Wood (fig.49a) to forms with gradually widening curved stipes resembling those of L.flaccidus macilentus Lapworth (fig.49b). Poor preservation of the specimens does not allow the structure of the proximal region or details of thecae to be seen.

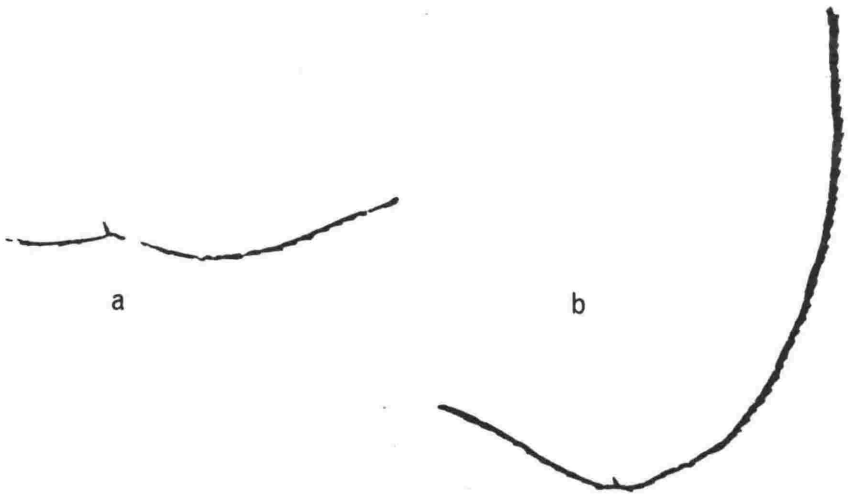


Fig.49. Leptograptus cf.flaccidus (Hall). a) form with very slender stipes such as those of L.flaccidus macer Elles and Wood. VG113, locality S19/624, Wangapeka Valley. b) form with gradually widening stipes such as those of L.flaccidus macilentus Lapworth. VG125, locality S19/610, Wangapeka Valley. Both specimens x 2. Zone of Orthograptus.

Horizon and localities. S2/606, 607, 609, 610, 624. Zone 11.

The specimens figured by Keble and Benson (1929 : 862-3, pl.107,fig.31) as L.flaccidus var.angustus Keble and Harris, from Cobb Valley, cannot be traced; the locality given was G.S.1231 (S13/482). Skwarko (1962) recollected the locality proving its upper Darriwilian age (zone of Glyptograptus teretiusculus) but failed to find further specimens of Leptograptus. In view of the indefinite figures and description given by Keble and Benson, the presence of the genus in the Glyptograptus teretiusculus zone is questioned.

GENUS Nemagraptus Emmons, 1855.

Nemagraptus gracilis (J.Hall, 1847)

Fig.50, pl.15,fig.3.

1847 Graptolithus gracilis J.Hall :274, pl.74,figs 6a-d.

1903 Nemagraptus gracilis; Elles and Wood :127-9, pl.19, figs 1a-f.

1962 Nemagraptus gracilis var.aoteoroaensis Skwarko :228, text-fig.4, fig.15.

Remarks. Although poorly preserved the Nelson specimens have the distinctive rhabdosome form of N.gracilis.

Fig.50. Nemagraptus gracilis (Hall). Incomplete and fragmentary rhabdosome; x 2. VG102, locality S3/526, Paturau River, Aorangi Mine area. Dicellograptus zone.

Skwarko's varietal name aoteoroaensis (Skwarko 1962: 228) is not available under the International Code of Zoological Nomenclature (1961 Article 15). Skwarko recognised that his form was "closely related to typical N.gracilis" and it is grouped accordingly here.

Horizon and locality. Two specimens are known from S3/526. Zone 10.

Nemagraptus gracilis is cosmopolitan and is widely regarded as indicating the base of the Caradocian stage of the standard British sequence.

Skwarko's specimens are from the Nemagraptus gracilis zone of Cobb Valley.

FAMILY DICRANOGRAPTIDAE Lapworth, 1873

GENUS Dicranograptus J.Hall, 1865

Dicranograptus nicholsoni (Hopkinson, 1870)

Fig.51, pl.15,fig.6.

1870 Dicranograptus nicholsoni Hopkinson :357,pl.16,fig.3.

1904 D.nicholsoni; Elles and Wood :171-3, pl.25,figs 1a-h.

1945 D.nicholsoni; Bulman :36-40, text-figs 18-20; pl.3, figs 1-11.

Remarks. A single fragment representing the biserial portion of the rhabdosome, is preserved in part relief and shows the shape of the thecae. It agrees well with Elles and Wood's description and particularly with Bulman's description and illustrations of specimens from Laggan Burn.

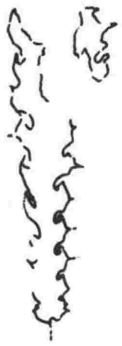


Fig.51. Dicranograptus nicholsoni (Hopkinson). Incomplete biserial portion of rhabdosome; x 5. VG100, locality S3/526, Paturau River, Aorangi Mine area. Dicellograptus zone.

Horizon and locality. S3/526. Zone 10.

D.nicholsoni is worldwide; its range in Victoria is from lower Gisbornian to upper Eastonian.

Dicranograptus sp.cf. D.hians T.S.Hall, 1905

Pl.15,fig.10.

cf.1905 Dicranograptus hians T.S.Hall, pl.6,fig.6.

cf.1955 D.hians; Harris and Thomas :9-10, text-figs 16-18.

Remarks. The Nelson specimen has a short biserial portion and a pair of prominent lateral spines on the initial two thecae. It resembles the description and figures of D.hians by Hall, and Harris and Thomas, except in lacking thecal spines after the initial pair.

Horizon and locality. S19/607. Zone 11.

D.hians is known from the upper Eastonian of Victoria.

GENUS Dicellograptus Hopkinson, 1871

Dicellograptus intortus? Lapworth, 1880.

Pl.15,fig.4.

? 1880 Dicellograptus intortus Lapworth :161, pl.5,fig.19a.

? 1904 D.intortus; Elles and Wood :146-7, text-figs 90a-d; pl.20,figs 4a-f.

Remarks. In general rhabdosome form, the Nelson specimens agree with Elles and Wood's description of D.intortus; the rhabdosomes are poorly preserved however, and show no thecal details.

Horizon and localities. S2/592; S19/607. Zones 10-11.

D.cf.intortus was reported from Cobb Valley by Skwarko. "D.intortus" (Thomas, 1960 :pl.7,fig.98) ranges in Victoria from lower Gisbornian to lower Eastonian.

Dicellograptus patulosus Lapworth, 1880.

Pl.15,fig.1.

1880 Dicellograptus patulosus Lapworth :162, pl.5,fig. 18a-f.

1904 D.patulosus; Elles and Wood :147-8, text-figs 91a-e; pl.21,figs 5a-e.

Remarks. Nelson specimens agree well with Elles and Wood's description of D.patulosus except that maximum stipe width is 0.5mm rather than 1.0mm as stated by Elles and Wood. However, from their figures (pl.21,figs 5c,5e) forms with narrow stipes such as those of the Nelson specimens were also included within the species.

Horizon and localities. S19/607, 621. Zone 11.

D.patulosus ranges in Victoria (Thomas 1960, pl.7, fig.97) throughout most of the Gisbornian and Eastonian stages. It is known from the zone of N.gracilis of Texas (Berry 1960a :76) and is common in the zone of Climacograptus peltifer and Mesograptus multidens in the Glenkiln Shales of Scotland (Elles and Wood 1904 :148).

Dicellograptus sp.cf. D.sextans (J.Hall, 1843)

cf.1847 Graptolithus sextans J.Hall :273, pl.74,figs 3a-e.

cf.1904 Dicellograptus sextans; Elles and Wood (s.l.) : 153-5, pl.21,figs 1a-e.

Remarks. With their relatively wide axils, the Nelson specimens resemble Hall's figures rather than the description by Elles and Wood.

Horizon and localities. S2/574, S3/526, S19/614. Zones 10-11.

D.sextans was recorded from Cobb Valley in "lower to middle" Gisbornian beds by Skwarko (1962 :231), and is found in the Gisbornian of Victoria. It has been recorded widely, occurring mainly in rocks of Caradocian or equivalent age.

Dicellograptus sextans exilis Elles and Wood,1904
Pl.15,fig.7.

1904 D.sextans var.exilis Elles and Wood :155, text-fig. 97, pl.21,figs 2a-d.

Remarks. Nelson specimens agree well with the figures by Elles and Wood.

Horizon and locality. S2/592. Zone 10.

D.sextans exilis was recorded by Skwarko from Cobb Valley in "lower to middle" Gisbornian beds. It is known from the zones of N.gracilis and C.bicornis of Texas (Berry 1960a :77), from the C.bicornis zone of New York (Berry

1962a, table 4), from the N.gracilis zone of northern Yukon (Jackson and Lenz 1962 :40), and from the N.gracilis and C.peltifer zones of Britain (Elles and Wood 1904 :155).

FAMILY DIPLOGRAPTIDAE Lapworth, 1873

GENUS Pseudoclimacograptus Přibyl, 1947

Pseudoclimacograptus sp.cf. Amplexograptus modicellus Harris and Thomas, 1935.

Fig.52, pl.14,fig.~~8~~6.

cf. 1935 Amplexograptus modicellus Harris and Thomas :300, fig.1,nos 10a-f; fig.3,nos 17-20.

Remarks. Several small, thin, and generally poorly preserved diplograptids from Formation B in zone 10 with rhabdosomes under 1cm long and 1mm or less wide, resemble Harris and Thomas's description of A.modicellus. The supra-genicular walls of thecae in the proximal 3mm are generally convex, the apertures being slightly introverted. The shape of more distal thecae is not known but the Nelson forms are

most probably referrable to Pseudoclimacograptus Přibyl, as diagnosed by Jaanusson (1960a:325) and by Bulman and Rickards (1968 :2). Harris and Thomas noted that the "free ventral edges are slightly convex" in A.modicellus; from their figures, convexity is less marked than in Nelson specimens.

Horizon and localities. S3/526. Zone 10.

A.modicellus ranges from uppermost Darriwilian (Da4) to lower Gisbornian in Victoria.

Pseudoclimacograptus spp.indet.

Figs 53a-b; pl.14,figs ~~0~~-7-8.

Remarks. Small diplograptids with strongly or slightly curved supra-genicular walls and introverted thecal apertures are common in the lower part of zone 10. They

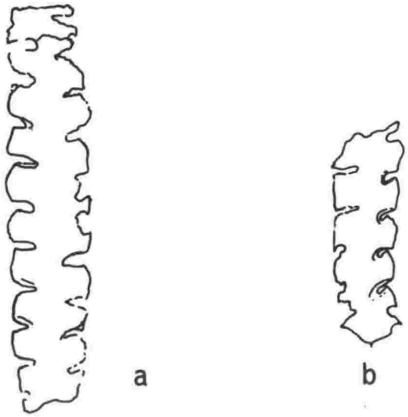


Fig.53. Pseudoclimacograptus sp. a) incomplete rhabdosome showing convex supragenicular walls and slightly introverted thecal apertures. GR91; locality S2/592, Aorangi Mine area. b) proximal portion of rhabdosome showing convex supragenicular walls and introverted and slightly introtorted thecal apertures. GR58; locality S3/526, Paturau River, Aorangi Mine area. Both from zone of Dicellograptus. Both figures x 10.

are generally poorly preserved, but from the shape of their thecae they belong to the genus Pseudoclimacograptus Přibyl. Several taxa are likely to be represented.

Horizon and localities. S2/575, S3/526. Zone 10.

GENUS Climacograptus J.Hall, 1865

Climacograptus bicornis (J.Hall, 1847)

Pl.16,figs 9,10.

1847 Graptolithus bicornis J.Hall :268, pl.73,figs 2a-b, ?2c-s.

1906 C.bicornis; Elles and Wood :193, pl.26,figs 8a,8c-f, ?8b.

1947 C.bicornis; Bulman :59-62, text-figs 30,31,32a-c; pl.8,figs 9,10; pl.9,figs 10-13.

Remarks. Nelson specimens are poorly preserved but agree well with the description by Elles and Wood. The basal spines are generally long and stout, corresponding to the later rather than the earlier form of the species (Elles 1925 :341; Thomas 1960 :12).

Horizon and localities. S19/606, 613. Zone 11.

C.bicornis ranges from lower Gisbornian to upper Eastonian in Victoria. It is confined to the zone of C.bicornis in Texas (Berry 1960a :79), and is known widely in North America, Europe, U.S.S.R., and China, its range generally lying within the Caradocian or equivalent strata.

Climacograptus brevis Elles and Wood, 1902

Fig.54; pl.16,fig.3.

1902 Climacograptus brevis Elles and Wood :192-3, text-figs 125a-b; pl.27,figs 2a-f.

1947 C.brevis; Bulman :62, text-figs 33a-c; pl.9,figs 1-9.

Remarks. Although poorly preserved, the Nelson specimens agree well with the description by Elles and Wood, and by Bulman.

Fig.54. Climacograptus brevis Elles and Wood. Complete rhabdosome; x 10. GR63; locality S2/568, Aorangi Mine area. D.decoratus zone.

Horizon and localities. 82/539, 633. Associated forms, Glyptograptus teretiusculus siccatus, Cryptograptus schaferi. Zone 9.

C.brevis is known from the upper Gisbornian of Victoria and from the zone of N.gracilis and of C.peltifer - M.multidens in Britain (Elles and Wood 1918). The species is known from upper Caradocian beds in Sweden (Hadding, 1915a) and Belgium (Bulman, 1950).

Climacograptus caudatus Lapworth, 1876.

Fig.55; pl.16,fig.7.

1876 Climacograptus caudatus Lapworth, pl.2,fig.48.

1902 C.caudatus; Elles and Wood :202-3, text-figs 133a-d.

Remarks. Nelson specimens are poorly preserved but with their rhabdosome dimensions and outline, their long virgella and virgellar body, they match the description by Elles and Wood. Lapworth's description has not been seen by the writer.

Horizon and locality. S19/620. Zone 11.

C.caudatus ranges from upper Eastonian to lower Bolindian in Victoria. It is known from the zones of O.truncatus intermedius, and O.quadrimucronatus in Texas,

Fig.55. Climacograptus caudatus Lapworth. Proximal portion of rhabdosome showing virgellar body; x 5. GR106; locality S19/620, Wangapeka Valley. Zone of Orthograptus.

from Pleurograptus linearis zone beds in Belgium (Bulman 1950 :5-6), and from the zone of D.clingani in southern Scotland.

Climacograptus hastatus T.S.Hall, 1902

Fig.56; pl.16,fig.1.

1902 Climacograptus hastata T.S.Hall :54-5, pl.14,figs 1-3.

1955 C.hastatus; Harris and Thomas :pl.7,figs 8,9.

1966a C.hastatus; Berry ("var.3") :170-1, text-fig.2.

Remarks. Hall's original description has not been seen by the writer, but Berry (1966a) has recently redescribed the species, recognising eight infrasubspecific varieties. The single Nelson specimen most closely resembles Berry's "variety 3".

Fig.56. Climacograptus hastatus T.S.Hall. Proximal portion of rhabdosome showing a single pair of proximal spines; x 5. VG119; locality S19/606, Wangapeka Valley; Orthograptus zone.

Horizon and locality. S19/606. Zone 11.

According to Berry, "C.hastatus var.3" is confined to a single Eastonian locality in Victoria ("locality 24, Wellington River", of Harris and Thomas 1955).

Climacograptus sp.cf. C.riddellensis Harris, 1924

Pl.16,fig.8.

cf. 1924 Climacograptus riddellensis Harris :100-1, pl.8, figs 11,12.

cf. 1966a C.riddellensis; Berry :439-40, pl.50,figs 1-5.

Remarks. Nelson specimens agree well with Harris's and with Berry's descriptions except that apertural excavations, as outlined by the apertural and infra-genicular lists, are less curved, deeper, and more nearly horizontal than in the Victorian forms.

Horizon and locality. S2/595. Zone 9.

C.riddellensis is known from the Darriwilian (Da4) and Gisbornian stages of Victoria (Harris 1935; Thomas and Keble 1933).

Climacograptus tubuliferous Lapworth, 1876.

Pl.16,fig.2.

1876 Climacograptus tubuliferous Lapworth, pl.2,fig.49.

1902 C.tubuliferous; Elles and Wood :203-4, text-figs 134a-b; pl.27, figs 8a-d.

Remarks. Nelson specimens agree well with Elles and Wood's description. The distal "vessicle" can be traced through the distal 2.5cms of the rhabdosome, and extends 2cms beyond the rhabdosome margin, reaching a maximum width of 3.5mm. Lapworth's description has not been seen by the writer.

Horizon and localities. S19/620,621. Zone 11.

C.tubuliferous is known in Victoria (Thomas 1960 : pl.9,figs 125, 126b) in the upper Eastonian. It is found in the zone of O.quadrimucronatus of Texas (Berry 1960a :83) and in the Basin Ranges, Western United States (Ross and Berry 1963 :132, pl.10,figs 1,2). It is known in Britain in the zone of D.clingani (Elles and Wood 1902).

GENUS Diplograptus McCoy, 1850

Diplograptus? decoratus (Harris and Thomas, 1935)
Pl.17,fig.1.

1935 (?)Mesograptus decoratus Harris and Thomas :298-300, fig.3,nos 31-38.

1947 Climacograptus antiquus var.bursifer; Ruedemann (pars.), pl.71,fig.54.

1963 Diplograptus decoratus "var. multus" Ross and Berry : 135-6, pl.10, figs 9,10,15.

1966 Diplograptus decoratus; Morris and Kay : text-fig. 4N,P,Q,R.

Remarks. The only complete Nelson specimen has a lanceolate rhabdosome 5.4cms long, widening from 0.9mm proximally to a maximum width of 3.5mm in its mid portion, and tapering markedly to a distal width of 1.7mm. Thecae are of "amplexograptid" type throughout, spaced 13.5 in 10mm proximally, 12 in 10mm distally. The virgula can be traced through the mid and distal portions of the rhabdosome and extends just beyond the distal margin where it bears a heart-shaped "vessicle". The dimensions of incomplete specimens closely match, or are slightly less than those given above.

The Nelson forms most closely resemble the two specimens figured by Harris and Thomas in fig.3, no.34. They differ from the Victorian specimens in the more pronounced distal tapering of their rhabdosomes and their more conspicuously "amplexograptid" distal thecae. Harris and Thomas (p.298) stated that distal tapering was common and (p.299) that rhabdosome form was extremely variable in the species; ~~and~~ the Nelson forms are here referred to decoratus, pending a review of the species.

Specimens closely matching the Nelson form have been figured by Ross and Berry as D.decoratus "var.multus" var.nov., from the Basin Ranges, Western U.S.A., and Ruedemann (1908 :440,fig.409, and 1947 :pl.71,figs 53,54) figured the distal portions of comparable tapering rhabdosomes from Nevada with heart-shaped virgular appendages. Similar but wider specimens were figured by Morris and Kay as D.decoratus, from Newfoundland.

Because of their "amplexograptid" rather than "orthograptid" distal thecae, the Nelson specimens are only doubtfully retained within Diplograptus (see diagnosis in Bulman 1955 :V85).

Horizon and localities. S2/539, 633. Zone 9.

The species is confined to the Darriwilian (Da3) in Victoria (Thomas 1960). Morris and Kay's specimens were found in beds with Cardiograptus crawfordi and Glossograptus hincksii (1966, text-fig.4 I), considered to be Llanvirnian in age. Ross and Berry's material ranges in age from the zone of P.etheridgei to the zone of G.teretiusculus, in terms of the Texas zones (Berry 1960a).

Diplograptus spp.indet.

Pl.17,figs 2,6.

Remarks. Indeterminate specimens of Diplograptus range from

forms with wide rhabdosomes such as those of D? decoratus to forms with more slender rhabdosomes and more widely spaced distal thecae, such as those of D.crassitestus Ruedemann (1947 :pl.71,figs 3-9). All material is poorly preserved and is listed as "Diplograptus sp."

Horizon and locality. S2/592. Zone 10.

GENUS Amplexograptus Elles and Wood, 1907

Amplexograptus confertus (Lapworth, 1875).
Fig.57.

1875 Climacograptus confertus Lapworth, in Hopkinson & Lapworth :655, pl.34,figs 4a-c, 4e-f, ?4d.

1907 Amplexograptus confertus; Elles and Wood :269-70, text-figs 185a-c; pl.31,figs 18a-e.

1935 Amplexograptus confertus; Harris and Thomas :300-1, fig.1, nos 14a-b; fig.3,nos 21-26.

Remarks. Nelson specimens generally agree with Lapworth's figures and with Elles and Wood's description though thecae are slightly more widely spaced, as in the Victorian forms described by Harris and Thomas. The proximal end in Nelson

specimens is blunt resembling that figured by Harris and Thomas (fig.1,no.14a), with a pair of short basal spines.

Fig.57. Amplexograptus confertus (Lapworth). Immature rhabdosome; x 10. GR94; locality S2/582, Aorangi Mine area, P.etheridgei zone.

Horizon and locality. S2/582. Zone 8.

"A.confertus" is reported to be worldwide but, as Jaanusson (1960a:352) points out, many records are unreliable. The species ranges in Victoria from Darriwilian (Da2) to lower Gisbornian. Its horizon in Britain, given by Elles (1922 :270) is lower Llanvirnian (zone of D.bifidus).

Amplexograptus sp.cf. A.confertus (Lapworth,1875)

cf. 1875 Climacograptus confertus Lapworth, in Hopkinson & Lapworth :655, pl.34,figs 4a-c, 4e-f, ?4d.

cf. 1907 Amplexograptus confertus; Elles and Wood :269-70, text-figs 185a-c; pl.31,figs 18a-e.

cf. 1935 A.confertus; Harris and Thomas :300-1,fig.1,nos 14a-b; fig.3,nos 21-6.

Remarks. Specimens resemble A.confertus Lapworth except in having rhabdosomes which range from 2.0-2.5mm in maximum width rather than 2mm or less as given by Elles and Wood (1908 :269) and by Harris and Thomas (1935 :301).

Horizon and localities. S2/572, 575. Zone 10.

GENUS Glyptograptus Lapworth, 1873

Glyptograptus austrodentatus cf.austrodentatus Harris and Keble, 1932.

Figs 58a-b; pl.17,figs 4,5.

cf.1932 Diplograptus (Glyptograptus) austrodentatus Harris and Keble :39, pl.5,figs 4,5; text-figs 1-4.

cf.1935 Diplograptus (Glyptograptus) austrodentatus; Harris and Thomas :295, fig.3,nos 1-5.

cf.1963a Glyptograptus austrodentatus austrodentatus; Bulman: 679-80, text-figs 6a-e; pl.97,figs 6-9,12,15.

Remarks. Most of the Nelson material is flattened and

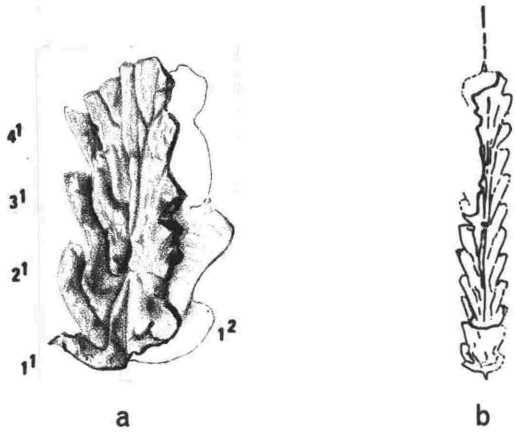


Fig.58. Glyptograptus austrodentatus cf. austrodentatus Harris and Keble. a), proximal portion of pyritised specimen in part relief, obverse view, showing the initial four thecae of stipe^1(th1^1 - 4^1) and the probable streptoblastic nature of development. Thecae of stipe^2 are not preserved but the outline of theca 1^2 can be seen from its mould in the rock; x 20. GR56. b), incomplete mature rhabdosome pyritised in low relief, showing relatively straight distal interthecal grooves; x 5. GR51. Both specimens from locality S2/568, Aorangi Mine area, P. etheridgei zone.

poorly preserved but one boulder from locality S2/568 in Slaty Creek contains several fragmentary pyritised specimens, of which two are relatively well preserved in semi-relief.

Specimen GR56 (fig.58a) is preserved in obverse view. The sicula is not clearly outlined and its apertural portion is missing but theca 1^1 can be distinguished, growing vertically downwards for at least 0.7mm before turning sharply outwards. Theca 1^2 has broken away, but from the impression remaining, its apertural margin lay slightly beyond the level of that of $th1^1$. The initial portion of $th2^1$ cannot be seen but from the position of its metathecal portion, and of the $th2^1/3^1$ interthecal groove, it is almost certain that development was of the streptoblastic type, confirming Bulman's (1963a:680) suggestion for Victorian specimens. The apertural portion of $th2^1$ is somewhat introtorted and introverted.

Specimen GR51b (fig.58b), also in obverse view, shows the interthecal grooves of most distal thecae to be relatively straight, resembling those of G.intersitus Harris and Thomas. Introtorsion and introversion of $th2^1$, is less marked than in specimen GR56. Thecae are spaced 7 in 5mm.

All rhabdosomes are under 1cm long. They differ from G.austrodentatus austrodentatus as described by Bulman in having less sigmoidally curved distal thecae and narrower rhabdosomes. Nelson forms are 1.0-1.1mm wide proximally,

and widen to a maximum width of 1.2-1.4mm, whereas Victorian forms widen from an initial width of 1.3mm to a maximum width of 1.6-1.9mm. The Nelson specimens may well represent transitional forms between G.austrodentatus austrodentatus and the succeeding Victorian species, G.intersitus Harris and Thomas.

Horizon and localities. S2/568, 582. Zone 8.

G.austrodentatus austrodentatus is known from the Darriwilian (Da1) of Victoria. G.austrodentatus (sensu lato) has been recorded from Texas, Quebec, N.E.Europe, Scandinavia, and China, its range generally lying within upper Arenigian to Llanvirnian stages.

Glyptograptus sp.cf. G.intersitus Harris and Thomas,1935
Fig.59; pl.17,fig.8.

cf. 1935 Glyptograptus intersitus Harris and Thomas :296-7,
fig.1,nos 11a-e; fig.3,nos 7-10.

Remarks. The few Nelson specimens are poorly preserved but have thecae with relatively straight free ventral walls and a gradually tapering rhabdosome matching the description by Harris and Thomas. Thecal apertures have a convex outline in profile view and are slightly introverted, unlike those

of the Australian types; dorso-ventral width of distal thecae appears to be greater in Nelson specimens than in those of Australia.

Fig.59. Glyptograptus cf. intersitus Harris and Thomas. Incomplete, mature rhabdosome, partly pyritised; x 7.5. GR70; locality S2/568, Aorangi Mine area, P.etheridgei zone.

Horizon and localities. S2/568, 582. Zone 8.

G.intersitus in Victoria ranges from zone Da2 (G.intersitus zone) to zone Da3 of the Darriwilian stage (Thomas 1960).

Glyptograptus sp.cf. G.teretiusculus (Hisinger, 1840)

cf. 1840 Prionotis teretiusculus Hisinger :5, pl.38,fig.4.

cf. 1908 Diplograptus (Glyptograptus) teretiusculus; Elles and Wood :250-2, text-figs 171a-d, pl.31,figs 1a-e.

Remarks. The Aorangi Mine specimens are similar in rhabdosome form to G.teretiusculus as described by Elles and Wood, and in the form of their thecae to G.cf.teretiusculus of Jaanusson (1960a:pl.3,figs 10,11). They are distinguished by their greater rhabdosome width and more widely spaced thecae. Distal thecae have relatively straight ventral walls and low inclination and resemble those of the problematical "Diplograptus spiculatus" Keble and Benson 1929 (see Skwarko 1962 :234).

Horizon and localities. S2/575, 592, 634; S3/526. Zones 9 - 10.

G.teretiusculus was recorded by Skwarko (1962 :235) from Cobb Valley and stated to be abundant in the G.teretiusculus zone, and rare in the N.gracilis zone. Forms comparable with the species have a similar distribution in the equivalent zones at Aorangi Mine. G.teretiusculus is worldwide, its range generally lying within Llandeilian to Caradocian.

Glyptograptus sp.cf. G.teretiusculus siccatus Elles and Wood, 1908.

Fig.60; pl.17,fig.9.

cf.1908 Glyptograptus teretiusculus var.siccatus Elles and

Wood :253,text-figs 173a-b, pl.31,figs 3a-d.

Remarks. Nelson rhabdosomes are slightly wider in the proximal region than those figured by Elles and Wood but otherwise agree well.

Fig.60. Glyptograptus cf.teretiusculus siccatus Elles and Wood. Immature rhabdosome; x 10. VG111; locality S2/633, Aorangi Mine area, D.decoratus zone.

Horizon and locality. S2/633. Zone 9.

G.teretiusculus siccatus has been recorded from the Gisbornian stage of Victoria (Thomas 1960, table p.19) and from the N.gracilis zone of Texas (Berry 1960a :89). It is known from the zones of N.gracilis and C.peltifer of Britain (Elles and Wood 1918, table A).

GENUS Orthograptus Lapworth, 1873

Orthograptus truncatus pauperatus Elles and Wood, 1907

Fig.61; pl.18,figs 2,3,8.

1907. Diplograptus (Orthograptus) truncatus var.pauperatus Elles and Wood :237-8, text-fig.157a-d, pl.29, figs 7a-e.

Remarks. Nelson specimens agree well with the figures and description by Elles and Wood.

Fig.61. Orthograptus truncatus pauperatus Elles and Wood. Incomplete specimen; x 10. VG127; locality S19/606, Wangapeka Valley, Orthograptus zone.

Horizon and locality. S19/606. Zone 11.

The subspecies ranges from Bastonian to Bolindian in Victoria (Thomas 1960). In Britain it ranges from upper Caradocian to Ashgillian (Elles and Wood 1914, table A). Bulman (1950) has listed it from Caradocian beds of Belgium.

Orthograptus sp. ex gr. O.calcaratus Lapworth

Fig.62; pl.18,figs 4,5,7.

Remarks. Large specimens of Orthograptus up to 7cms in length and 2.8mm in maximum width are abundant in zone 11. The proximal extremity bears two short lateral spines and a short virgellar spine and the apertural portion of the initial theca is particularly wide, giving a markedly assymmetrical outline to the proximal region in biprofile view (fig.62). The extended virgula of specimen GR113 terminates in a small "disc", 2.3mm in diameter (pl.18,fig. 5). Although distal thecae in a few specimens appear to have been spinose as in members of the O.quadrimucronatus group, the overall rhabdosome form, thecal spacing, and

Fig.62. Orthograptus ex gr.calcaratus Lapworth. Proximal portion of specimen figured in plate 18, figs 4,7, showing assymmetrical outline of proximal end; x 10. VG122; locality S19/620, Wangapeka Valley, Orthograptus zone.

proximal end most closely resemble species included by Elles and Wood in the O.calcaratus group.

Horizon and localities. S19/606, 607, 621, 624. Zone 11.

Orthograptus sp. (large form)

Pl.18, figs 1,6.

Remarks. Rhabdosomes attain 13cms in length; they are only about 1mm wide for their initial 1cm, but reach a maximum width of 3.5mm, 3-4cms from their proximal end. A pair of fine basal spines is seen in a few specimens.

The slender proximal portion distinguishes the Nelson form from described species of Orthograptus.

Horizon and localities. S19/606, 607, 609, 610, 614, 620, 621, 635, 637. Zone 11.

FAMILY DIPLOGRAPTIDAE Incertae Sedis

GENUS Trigonograptus Nicholson, 1869

Trigonograptus ensiformis (J.Hall, 1858)

Pl.19,figs 5,8.

1858 Graptolithus ensiformis J.Hall :133.

1865 Reticlites ensiformis; J.Hall :114-5, pl.14,figs 1-5.

1908 Trigonograptus ensiformis; Elles and Wood :302-3, text-figs 202a-c, pl.35,figs 1a-c.

Remarks. Nelson specimens vary widely in rhabdosome shape and size but all are approximately lanceolate in outline and generally agree with the description by Elles and Wood.

Horizon and localities. S2/552, 589. Zones 6,8.

T.ensiformis is worldwide and has been reported from beds ranging in age from Arenigian to Caradocian.

Trigonograptus? sp.nov.

Pl.19,fig.3.

Remarks. A few flattened specimens of a peculiar Trigonograptus-like form from zone 7 are distinguished by having part of their rhabdosome margin serrated like those of forms described here as Graptoloid spp. gen. et spp. indet. Preservation is insufficiently good to determine whether more than two rows of thecae are present.

FAMILY LASIOGRAPTIDAE Lapworth, 1879

GENUS Hallograptus Lapworth, 1877

?Hallograptus inutilus (J.Hall, 1865)

Fig.63, pl.13,fig.5.

1865 Diplograptus inutilus J.Hall :111, pl.13,fig.14.

1904 Diplograptus inutilus; Ruedemann :721, pl.16,figs 13, ?12.

?1908 Lasiograptus (Hallograptus) mucronatus var.inutilus; Elles and Wood :322, pl.33,figs 7a-e, text-fig.211.

Remarks. The type specimens of Diplograptus inutilus, figured by Hall, consist of the distal portions only of two rhabdosomes from Levis, Quebec. The distal portions of

Fig.63. ?Hallograptus inutilus (Hall). Incomplete rhabdosome showing the Cryptograptus-like aspect of the proximal end; x 5. GR49; locality S2/582, Aorangi Mine area, P.etheridgei zone.

Nelson specimens agree well with those figured by Hall, particularly the right-hand specimen of fig.14. Neither of the two topotypes figured by Ruedemann shows clear details of the proximal end.

Nelson specimens bear a pair of slender basal spines, and the general aspect of the proximal end resembles that of a Cryptograptus, such as C.tricornis (Carruthers), rather than that of Hallograptus. The species is therefore only tentatively referred to Hallograptus.

Cryptograptus hopkinsoni (Nicholson) figured by Elles and Wood (1908, pl.32,figs 14a-d) is a similar, but broader species.

Horizon and localities. S2/556, 582. Associated form, Paraglossograptus etheridgei. Zones 7-8.

The species has not been recorded from Victoria, but is known from zone D2 of Quebec (Raymond 1914 :table p.530), from the Deepkill Shale, New York (Berry 1962a :705), from the Arenigian and Llanvirnian stages of Great Britain (Elles and Wood, 1914), and is probably represented in Norway (Spjeldnaes 1953 :181; Blake 1962 :234).

FAMILY RETIOLITIDAE Lapworth, 1873

GENUS Retiograptus J.Hall, 1859.

Retiograptus geinitzianus J.Hall, 1859

Pl.16,fig.11.

1859 Reteograptus geinitzianus J.Hall :518

1908 Retiograptus geinitzianus; Elles and Wood :316-7, pl.34,figs 7a-d.

Remarks. The single specimen from zone 10 agrees well with the description by Elles and Wood.

Horizon and localities. S2/575, 592. Zone 10.

R.geinitzianus was recorded by Skwarko (1962 :237-8) from Cobb Valley, Nelson. The species is worldwide and apparently long-ranging. It is well known in beds of Caradocian age though it is confined to the Silurian (Keilorian) in Victoria.

Graptoloids of unknown Generic affinity.

Peculiar multiserial graptoloids with long narrow rhabdosomes and deeply serrated lateral margins are common in the lower part of zone 5, in zone 6, and at one locality in zone 7. They superficially resemble Phyllograptus in bearing what appear to be highly inclined thecae with a high degree of overlap. Whether there are more than two

rows of thecae cannot be determined, specimens being invariably poorly preserved. Until better-preserved material is found, the specimens are grouped into three "species" which, from general appearance, seem to form a related group.

Graptoloid sp.1 gen.et sp.indet.

Pl.19,fig.6.

Remarks and horizon. First appearing with a 'burst' in the lower part of zone 5, the form designated "sp.1" is a useful stratigraphic marker at Aorangi Mine. Rhabdosomes measure about 2.2mm wide in 'profile' view, and 1.7cms in length, and have deeply serrated margins. Thecae are spaced 12-13/cm. Although apertural margins are conspicuous, thecal outlines cannot be traced within the rhabdosome and their shape and inclination are unknown.

The form is found at localities S2/552, 562, 599, 603, 610, and 622, and ranges through zone 5 and into zone 6 where it is superseded by Graptoloid sp.2.

Graptoloid sp.2 gen.et.sp.indet.

Pl.19,fig.4.

Remarks and horizon. This form is wider and longer than

"sp.1" but otherwise closely resembles it. In 'profile' view the rhabdosome measures about 3.4mm wide and 3cms long; thecae are spaced 11-12 in 10mm. Thecal outline and rhabdosome orientation are uncertain.

The form is confined to zone 6, in which it is relatively uncommon. It is found at localities S2/532, 552, and 560.

Graptoloid sp.3 gen.et sp.indet.

Pl.19,figs 1,2.

Remarks and horizon. The youngest form is longer than either of the preceding forms, measuring about 3mm wide and at least 4.2cms long. Thecae are spaced about 9 per cm. In most specimens, what appear to be interthecal boundaries extend from the ventral stipe margin to the midline of the rhabdosome. Specimen GR22 (pl.19,fig.2) is preserved in slight relief, and suggests that the boundaries are actually apertural margins which extend to the midline, each theca enclosing the succeeding one. The second interpretation involves a reversal in rhabdosome orientation from that of the first, and would distinguish the group from the genus Phyllograptus.

APPENDIX 1 - LIST OF FOSSIL LOCALITIES

Paleozoic fossil localities of the Aorangi Mine, Elliot Creek, Hailes Knob and Wangapeka Valley areas are listed below in order of one-mile (1:63,360) sheet districts, locality numbers being in numerical order within each sheet. Details of localities and grid references are given. In locality descriptions, "right" and "left" bank, tributary, etc., refer to true right and true left, i.e. right-handed and left-handed when facing downstream. Grid references not prefixed with the relevant one-mile sheet edition are in terms of the revised grid shown in map 2. The lithologic unit containing the fossiliferous beds is named, and, where no reference is included, the name is that introduced in this report. The collector, unless otherwise stated, was the writer, between 1965-1968.

A list of fossils examined by the writer follows the locality details. Where a single locality is represented by more than one collection, the distribution of taxa throughout individual collections is indicated. Collection numbers are prefixed as follows:

G.S. - , collections held by the Geological Survey, Lower Hutt.

V - , collections held by the Geology Department, Victoria University of Wellington.

O.U. - , collections held by the Geology Department, Otago University.

Zfg - , collections held by the Canterbury Museum.

The relative order of abundance of taxa is given; r = rare, c = common, and a = abundant. Reference to published faunal lists is given after the collector's name, and published fossils not re-examined by the writer in the original collections are noted with comments. Phyllocarid crustacean fragments are found at most graptolite localities, particularly those of zones 1 - 5. They are invariably poorly preserved and have not been included in the faunal lists.

The biostratigraphic zone given for each locality is that indicated by the fossils alone, the probable age being followed by the possible age range, in parentheses.

S2/490 "Golden Ridge Claim, Taitapu, Collingwood". Collections have been made from the vicinity of Golden Ridge by numerous workers since the locality was first discovered about 1878. The graptolites in several collections are listed by Benson et al 1936 (p.367). Probably most come from locality S2/586, Coffee Creek, and a complete faunal list is given under that number.

S2/522 Boulder near Golden Ridge Mine. Probably derived from Aorangi Mine Formation, member AM2. Collector S.K.Skwarko 1959. Collection G.S.7481.

Adelograptus? antiquus	(r)
Phyllograptus angustifolius angustifolius	(r)

Phyllograptus ilicifolius	(c)
Didymograptus sp. (extensiform)	(c)
Isograptus caduceus ssp.	(r)

ZONE 4 (possible range, zones 4-5).

S2/523 Boulder in Little Slaty Creek 300 yards upstream from battery. (Probably close to locality S2/563). Probably derived from Aorangi Mine Formation, member AM2. Collector S.K.Skwarko 1959. Collection G.S.7482.

Adelograptus sp.	(c)
Clonograptus sp. (large form)	(c)
Tetragraptus decipiens (4-stiped)?	(r)

ZONE 1 (possible range, zones 1-3).

S2/524 Ten feet inside Aorangi Mine north-south adit. Aorangi Mine Formation, member AM2. Collector S.K.Skwarko (see Skwarko 1961 :101-2). Collection G.S.7483.

Clonograptus sp.	(r)
Goniograptus cf. thureaui	(c)
Tetragraptus fruticosus (3-stiped)	(c)
T. fruticosus (4-stiped)	(r)
T. decipiens (4-stiped)	(r)
T. aff. serra	(r)
Phyllograptus cf. anna	(c)
Didymograptus sp. (extensiform)	(c)

Skwarko also listed:

Clonograptus cf.rigidus

Didymograptus cf.asperus

"D.cf.missilis"

ZONE 3.

S2/525 Anthill Creek at Anthill Mine adit. Aorangi Mine Formation, member AM2. Collector S.K.Skwarko 1959. Collection G.S.7484.

Adelograptus? antiquus	(c)
A.sp.	(c)

ZONES 1 - 3.

S2/526 Thirty yds downstream from Anthill Mine adit, in Anthill Creek, grid ref. 869992. Aorangi Mine Formation, member AM2. Collector S.K.Skwarko (see Skwarko 1961 : 100-1); recollected R.A.Cooper 1966-7.

		Collections V1580	G.S.7485
Dictyonema pulchellum	(r)	-	x
Adelograptus? antiquus	(c)	x	x
A.sp.	(c)	x	x

Skwarko also lists Bryograptus cf.hunnebergensis but the identification is questioned by Bulman and Cooper (in press).

ZONE 1.

S2/527 Forty yds downstream from Anthill Mine adit, in Anthill Creek. Aorangi Mine Formation, member AM2. Collector S.K.Skwarko 1959; recollected R.A.Cooper 1965-7.

		Collections V2651	G.S.7486
*Adelograptus? antiquus	(c)	x	x
*Adelograptus clarki	(c)	-	x
*Anisograptus? sp.	(r)	x	x
Clonograptus sp.	(c)	x	-
Tetragraptus decipiens (4-stiped)	(r)	-	x

* (loose boulder, probably derived from base of member AM2). ZONE 1 (possible range, zones 1-3).

Other fossils in place, ZONES 1 - 3.

S2/528 One chain below waterfall, in Anthill Creek ½ chain downstream from S2/565. Aorangi Mine Formation, member AM2. Collector S.K.Skwarko 1959. Collection G.S.7487.

Goniograptus sp.	(r)
Dichograptus octonarius	(c)
Tetragraptus serra	(r)
T.whitelawi	(r)
T.sp.	(r)
Didymograptus cf.extensus	(r)
D.sp. (extensiform)	(c)

Isograptus caduceus victoriae (a)

I.hastatus (r)

ZONE 5.

S2/529 Two and a half chains up Jimmy's Creek, from its junction with Little Slaty Creek, close to "Loc. H" of Benson et al. Aorangi Mine Formation, member AM3. Collector S.K.Skwarko 1959. Collection G.S.7488.

Didymograptus sp.(extensiform) (c)

Isograptus caduceus victoriae (c)

ZONE 5.

S2/530 Approximately 1 chain up Jimmy's Creek from its junction with Little Slaty Creek. Aorangi Mine Formation, member AM3. Collector S.K.Skwarko 1959. Collection G.S.7489.

Isograptus caduceus cf.victoriae (r)

I. c. maximodivergens (c)

ZONE 6.

S2/531 Two chains upstream from no.3 adit, in Little Slaty Creek, approximately Benson's "Loc.B". Aorangi Mine Formation, member AM2. Collector S.K.Skwarko 1959. Collection G.S.7490.

Phyllograptus angustifolius angustifolius	(c)
P.sp.	(r)
Didymograptus cf.extensus	(c)
Isograptus caduceus victoriae	(c)
I. c. cf.victoriae	(c)

ZONE 5.

S2/532 Eight chains upstream Little Slaty Creek from Aorangi Mine battery. Aorangi Mine Formation, member AM3. Collector S.K.Skwarko 1959. Collection G.S.7491.

Dichograptus sp.	(r)
Tetragraptus cf.serra	(r)
Didymograptus sp.(extensiform)	(c)
Isograptus caduceus maximo-divergens	(c)
I. cf.hastatus	(r)
Graptoloid sp.2. Gen. et sp.indet.	(r)

ZONE 6.

S2/533 Fifteen yards in from mouth of Morning Star Mine adit, east of Coffee Creek. Aorangi Mine Formation, member AM3. Collector S.K.Skwarko 1959. Collection G.S.7492.

Didymograptus sp.(extensiform)	(c)
Isograptus caduceus maximo-divergens	(c)

I.dumosus	(r)
I.hastatus	(r)
Trigonograptus cf.ensiformis (figured, Skwarko 1960 : 104,fig.5).	(r)

ZONE 6.

S2/534 Boulder at junction of Anthill Creek and Little Slaty Creek. Probably derived from Aorangi Mine Formation, member AM2. Collector S.K.Skwarko (see Skwarko 1961 : 100-1). Collection G.S.7493.

Dictyonema pulchellum	(c)
Adelograptus? antiquus	(c)
A.sp.	(r)
Tetragraptus cf.decipiens(4-stiped)	(r)
Bryograptus cf.hunnebergensis? (see S2/526)	(r)

ZONE 1.

S2/535 At the junction of Anthill Creek and Little Slaty Creek. Aorangi Mine Formation, member AM3. Collector S.K.Skwarko 1959. Collection G.S.7494.

Didymograptus sp.(extensiform)	(c)
Isograptus caduceus maximo-divergens	(c)

I.imitata	(r)
I.aff.imitata (=I.forcipiformis var.harrisi Skwarko 1961 :106, fig.4)	(r)
Trigonograptus cf.ensiformis	(r)

ZONE 6.

S2/539 Slaty Creek, 16 chains downstream from junction with true right tributary, immediately upstream from narrow gorge. Grid ref. 882987. Formation A, member A2. Collectors D.G.Bishop and R.A.Cooper 1965-66; recollected R.A.Cooper 1967.

		Collections V1571	G.S.9537
Pseudobryograptus sp.	(r)	x	x
Pterograptus? sp.nov.	(r)	-	x
Didymograptus sp.(of affinis type)	(r)	-	x
Cryptograptus schaferi	(a)	x	x
Glossograptus cf.hincksii	(c)	x	x
Diplograptus? decoratus	(c)	x	x
Climacograptus brevis	(c)	x	x

ZONE 9.

S2/540 Five chains upstream from waterfall in Jimmy's Creek, south bank. Grid ref. 873981. Aorangi Mine Formation, member AM4. Collector G.Smith 1963 (see Smith 1966 :174);

recollected R.A.Cooper 1965-7.

		Collections V1043	G.S.9949
Goniograptus speciosus	(r)	-	x
G.thureaui	(c)	x	x
Tetragraptus cf.serra?	(c)	-	x
T.quadribrachiatus	(r)	x	x
Phyllograptus? sp.	(r)	-	x
Didymograptus v-deflexus	(c)	x	x
D.spp.	(c)	x	x
Isograptus caduceus maximo-divergens	(c)	x	x
I.dumosus	(c)	x	x
I.imitata	(c)	x	x
I.sp.aff.imitata	(r)	x	x
I.sp.1 aff.I.manubriatus	(c)	x	x
I.sp.2 aff.I.manubriatus	(a)	x	x
I.sp.3 aff.I.manubriatus	(c)	x	x
I.sp.4 aff.I.manubriatus	(c)	-	x
Oncograptus upsilon biangulatus	(c)	x	x
Trigonograptus sp.	(r)	x	x

Smith (1966 :174) also listed Isograptus caduceus victoriae (?=Isograptus imitata of this paper).

ZONE 7.

S2/541 "One chain downstream from large plunge pool in Sand-

hills Creek, ½ mile south of Aorangi Mine. Grid ref. 868974." Collector G.Smith (Smith 1966 :174). Collection V1044.

The description of this locality is indefinite, there being several large plunge pools in this region of Sandhills Creek. The position defined by the grid reference lies in beds of member AM1, from which no diagnostic fossils have been found elsewhere. However, for reasons discussed under S2/542, the true position of this locality is likely to be some distance upstream, probably in beds of member AM2 which, further to the north, contain the fossils listed below.

Tetragraptus approximatus	(c)
T. cf. quadribrachiatus	(c)

ZONE 2.

Smith also lists Didymograptus extensus, and Goniograptus thureaui, neither of which were seen by the writer in Smith's collections.

S2/542. "In Sandhills Creek, five chains upstream from S2/541. Grid ref. 870973." Collector G.Smith (Smith 1966 :174). Collection V1045.

From the stated grid reference, this locality should be immediately below beds containing zone 3 fossils at locality S2/628 in member AM2. The fossil listed below would thus be anomalous. The position of locality

S2/541 is indefinite and because beds containing the listed fossil outcrop about six chains further upstream (S2/621), the grid reference is considered doubtful.

Isograptus caduceus cf. maximo-divergens (listed by Smith as I. c. victoriae).

ZONE ?6.

S2/543 "Upstream from S2/542, and 7 chains below the junction of the East and West branches of Sandhills Creek. Grid ref. 878971". Aorangi Mine Formation, member AM4. Collector G. Smith (Smith 1966 :174), Collection V1046.

Graptolite fragments indet.

Smith lists Isograptus caduceus victoriae

ZONE indeterminate.

S2/544 "Seven chains upstream from S2/543, 2 chains up the west bank tributary of the west branch of Sandhills Creek. Grid ref. 877965". Collector G. Smith (Smith 1966 :174). Aorangi Mine Formation, member AM4. Collection V1047.

Dichograptus octobrachiatus	(r)
D. cf. maccoyi	(r)
Tetragraptus serra?	(r)
Isograptus caduceus cf. maxima	(c)

I. c. maximodivergens	(a)
I.cf.imitata	(r)

ZONE 6 (possible range, zones 6-7).

Smith also lists Isograptus caduceus victoriae (probably = I.cf.imitata).

S2/545 South bank, Slaty Creek, 4 chains upstream from Slaty Creek battery, which is just upstream from Taitapu Timber Co. gravel pit. Grid ref. 860009. Aorangi Mine Formation, member AM3. Collector G.Smith (Smith 1966 : 174); recollected R.A.Cooper 1965-7.

		Collections V1048	G.S.9950
Tetragraptus amii?	(r)	-	x
T.serra	(r)	-	x
Phyllograptus "nobilis"	(c)	x	x
Isograptus caduceus maximodivergens	(a)	x	x
I.cf.dumosus	(c)	x	x
I.imitata	(r)	x	x
Cardiograptus morsus	(r)	x	-
Cardiograptus? sp.	(c)	x	x
Glossograptus? crudus	(r)	-	x
?Hallograptus cf.inutilus	(c)	-	x
Trigonograptus sp.	(c)	x	x
T? sp.nov.	(r)	-	x

Graptoloid sp.3. Gen. et sp.indet. (c) x x

ZONE 7.

Smith also lists

Phyllograptus anna (?= P."nobilis")

Didymograptus extensus

I.c.victoriae (?=I.imitata)

S2/546 South wall, Slaty Creek, at top of first gorge above Lake Otuhie, opposite old gold battery. Grid ref. 868003. Aorangi Mine Formation, member AM4. Collector G.Smith (Smith 1966 :174); recollected R.A.Cooper 1967. Collection V1321.

Cardiograptus sp. (probably C. morsus) (r)

Smith's collections contain two distinct "assemblages" preserved in different lithologies.

"Assemblage" 1, dark blue-black micaceous slate.

Cardiograptus morsus

Isograptus caduceus maximodivergens?

I.sp.

"Assemblage" 2, black siliceous slate.

Tetragraptus serra?

T.cf.reclinatus

Phyllograptus angustifolius elongatus?

P.typus

Isograptus caduceus lunata

Recollections made by the writer correspond to "assemblage" 1 in lithologic and fossil content; the origin of "assemblage" 2 is not clear. The locality lies immediately to the west of Coffee Creek Fault and Smith's collections may include material derived from the fault zone, or from the eastern side of the fault. The fossils of "assemblage" 1 are accepted as representing the locality.

ZONE 7.

S2/547 Northwest of Baldy 1,058 ft., in the bed of the first west bank tributary of Slaty Creek upstream from Lake Otuhie. Formation A, member A1. Grid ref. 865017. Collector G.Smith (Smith 1966 :174); recollected R.A.Cooper 1967. Collection V1322.

Isograptus caduceus cf.maximodivergens	(c)
I.aff.imitata	(r)
Glossograptus acanthus	(c)
Paraglossograptus etheridgei	(c)
Glyptograptus austrodentatus ssp.	(c)

ZONE 8.

Smith lists Phyllograptus anna, Didymograptus extensus and Isograptus caduceus victoriae; none of which were noticed in Smith's collections by the writer. The occurrence of any would be anomalous in zone 8, and their presence is questioned.

S2/548 South bank of Slaty Creek, opposite the Slaty Creek battery; upper 6 inches of slate band. Grid ref. 860009. Aorangi Mine Formation, member AM3. Collector G.Smith (Smith 1966 :174); recollected R.A.Cooper 1967. Collection V1323.

Isograptus caduceus maximo-divergens	(c)
I. c. maxima?	(r)
I.sp.	(c)

ZONE 6 (possible range, zones 6-7).

Smith lists I.c.victoriae (probably the form listed above as I. c. maxima?) and Didymograptus extensus.

S2/552 On track to Aorangi Mine where it crosses the first stream after leaving Slaty Creek. Grid ref. 874997. Aorangi Mine Formation, member AM3. Benson et al (1936) locality "P"; recollected G.Smith 1963, R.A.Cooper 1965-7.

		Collections V1493	G.S.9952
Goniograptus macer	(c)	x	-

G. thureaui	(r)	x	x
Loganograptus logani	(c)	x	x
L. logani cf. pertenuis	(r)	x	x
Dichograptus octobrachiatus	(r)	-	x
D. octonarius	(r)	-	x
Tetragraptus cf. serra	(c)	x	x
T. reclinatus	(r)	x	x
T. aff. taraxacum	(c)	-	x
T. bigsbyi	(r)	x	x
T. amii	(r)	-	x
T. headi	(r)	-	x
T. aff. chapmani	(c)	-	x
T. quadribrachiatus	(c)	x	x
T. cf. harti	(c)	x	x
T. spp. (small)	(c)	x	x
Didymograptus cf. eocaduceus	(c)	x	x
D. sp. (extensiform)	(c)	x	x
D. cf. extensus	(c)	x	x
D. cf. v-deflexus	(r)	-	x
Isograptus caduceus maximo-divergens	(c)	x	x
I. dumosus	(c)	x	x
I. hastatus	(c)	x	x
I. imitata	(c)	x	x
I. aff. imitata	(c)	x	x
Trigonograptus ensiformis	(r)	-	x

T.cf.ensiformis	(r)	-	x
Graptoloid sp.1. Gen. et sp.indet.	(c)	x	x
Graptoloid sp.2. Gen. et sp.indet.	(c)	x	x
Graptoloid sp.3. Gen. et sp.indet.	(r)	-	x

ZONE 6.

S2/553 Jimmy's Creek, true right bank, five to six chains upstream Little Slaty Creek battery. Grid ref. 873987. Aorangi Mine Formation, member AM3. Collector G.Smith 1963?; recollected R.A.Cooper 1966-7. Collections V1554, V1601.

Dichograptus maccoyi	(r)
Tetragraptus aff.taraxacum	(r)
Didymograptus sp. (extensiform)	(r)
Isograptus caduceus victoriae?	(r)
I. c. maximodivergens	(c)
I.hastatus	(r)
I.imitata	(r)

ZONE 6 (possible range, zones 6-7).

S2/554 Little Slaty Creek; 1 chain downstream from Jimmy's Creek junction. Grid ref. 872988. Aorangi Mine Formation, member AM3, Not collected.

Isograptus caduceus ssp. (one specimen)

ZONES 5 - 8.

S2/555 Little Slaty Creek, ½ chain downstream from S2/554. Grid ref. 872988. Aorangi Mine Formation, member AM3. Collection V1556.

Trigonograptus sp. (one specimen)

ZONES 6 - 9.

S2/556 Slaty Creek, 18 chains upstream from Little Slaty Creek junction. Fossils confined to 2 inch band of black graphitic slate in outcrop of blue-grey argillite on left bank. Grid ref. 876993. Aorangi Mine Formation, member AM4.

		Collections V1558	G.S.9953
Tetragraptus cf. *serra*?	(r)	-	x
T. amii	(r)	-	x
Didymograptus v-deflexus	(c)	x	x
Isograptus caduceus divergens?	(r)	-	x
I. sp.	(r)	x	x
Cardiograptus morsus	(c)	-	x
Glossograptus? crudus	(c)	x	x
?*Hallograptus inutilus*	(c)	-	x
Trigonograptus sp.	(r)	x	x

ZONE 7.

S2/557 Little Slaty Creek, 5 chains upstream from the big waterfall on true left bank. Grid ref. 874996. Aorangi Mine Formation, member AM3. Collection V1560.

Tetragraptus amii	(r)
T.quadribrachiatus	(r)
Didymograptus sp. (extensiform)	(c)
D.v-deflexus?	(r)
Isograptus caduceus cf. victoriae?	(r)
I. c. maximodivergens	(c)
I.hastatus	(r)

ZONE 6 (possible range, zones 6-7).

S2/558 Little Slaty Creek, 8 chains downstream from junction with Anthill Creek; west of minor fault. Grid ref. 873993. Aorangi Mine Formation, member AM3. Not collected.

Isograptus caduceus maximo-divergens	(r)

ZONE 6 (possible range, zones 6-7).

S2/559 Little Slaty Creek, 8 chains downstream from junction with Anthill Creek; east of small fault. Grid ref. 873993. Aorangi Mine Formation, member AM3. Collection V1561a.

Tetragraptus sp.	(r)

Isograptus caduceus ? ssp. (small)	(r)
I. c. maximodivergens	(c)
I.imitata	(r)

ZONE 6 (possible range, zones 6-7).

S2/560 True left tributary of Little Slaty Creek. In headwaters, approximately 35 chains south of battery. Outcrop between two waterfalls. Grid ref. 871981. Aorangi Mine Formation, member AM3. Collection V1562.

Tetragraptus harti?	(r)
T.amii	(r)
T.cf.serra	(c)
T.aff.quadribrachiatus	(r)
T.aff.taraxacum	(r)
Didymograptus cf.eocaduceus	(r)
D.sp.(extensiform)	(a)
Isograptus caduceus maximo-divergens	(c)
I.dumosus	(r)
I.aff.imitata	(c)
I.hastatus	(r)
Graptoloid sp.2. Gen. et sp.indet.	(r)

ZONE 6.

S2/561 Minor true right tributary of Little Slaty Creek, 15 chains south of battery, about 4 chains upstream from junction with Little Slaty Creek. Grid ref. 872985. Aorangi Mine Formation, member AM3. Collection V1563.

Tetragraptus cf. *reclinatus*	(r)
Didymograptus sp. (extensiform)	(c)
Isograptus caduceus maximo-divergens	(c)
I. dumosus	(r)
I. imitata	(r)

ZONE 6 (possible range, zones 6-7).

S2/562 At base of 60ft waterfall in true left tributary of Little Slaty Creek, 1 chain from Little Slaty Creek. Lower 10ft of section (see also S2/570,579). Grid ref. 870985. Aorangi Mine Formation, member AM2. Collection V1564a.

Isograptus caduceus lunata	(a)
Tetragraptus cf. *reclinatus*	(r)
Phyllograptus ilicifolius	(c)
Graptoloid sp. *1*. Gen. *et* sp. indet.	(r)

ZONE 5.

S2/563 Little Slaty Creek, 15 chains upstream from Jimmy's Creek, near minor fault. Grid ref. 871986. Aorangi Mine Formation, member AM3. Collection V1565.

Tetragraptus reclinatus	(c)
Phyllograptus anna	(r)
P.sp.	(r)
Didymograptus sp.(extensiform)	(c)
Isograptus caduceus lunata	(c)

ZONE 5.

S2/564 Anthill Creek, Aorangi Mine. Fallen block derived from fallmaker band of black siliceous slate at high waterfall. Grid ref. 870992. Aorangi Mine Formation, member AM2. Collection V1566a.

Adelograptus aff.pusillus	(c)
Sigmagraptus laxus	(c)
Tetragraptus aff.taraxacum	(c)
T.amii	(r)
Phyllograptus angustifolius angustifolius	(c)
P.anna	(r)
P.ilicifolius	(c)
Didymograptus protobifidus	(c)

ZONE 4.

S2/565 Anthill Creek, ½ chain downstream from waterfall, ½ chain upstream from S2/528. Grid ref. 870992. Aorangi Mine Formation, member AM2. Collection V1566b.

Dichograptus cf. maccoyi	(c)
Didymograptus extensus	(c)
D. spp. (extensiform)	(c)
Isograptus caduceus victoriae	(c)
I. c. maxima?	(c)

ZONE 5.

S2/566 Slaty Creek, 3 chains downstream from the junction with Little Slaty Creek. Grid ref. 876997. Aorangi Mine Formation, member AM4. No collection.

Graptolite fragments indet.

S2/567 True right bank Slaty Creek opposite junction with true left tributary at Sweeney's Hut. Grid ref. 874000. Aorangi Mine Formation, member AM4. Collection V1568.

Tetragraptus cf. serra	(r)
Isograptus caduceus cf. maximo-divergens	(c)

ZONE 6 (possible range, zones 6-7).

S2/568 Slaty Creek, 30 chains downstream from Conn's Creek

junction. Fossils in slip on true left bank. Grid ref. 878992. Formation A, member A1.

		Collections V1569	G.S.9965
Isograptus imitata	(r)	-	x
I.sp.	(c)	x	x
Sinograptid sp.	(r)	-	x
Glossograptus acanthus	(r)	-	x
Paraglossograptus etheridgei	(c)	x	x
P.zealandicus	(c)	x	x
Glyptograptus cf.intersitus	(c)	x	x
G.austrodentatus cf.austrodentatus	(c)	x	x
Trigonograptus sp.	(r)	-	x

ZONE 8.

S2/569 Slaty Creek, 5 chains upstream from Conn's Creek junction. Grid ref. 880986. Formation A, member A1. Collection V1570.

Tetragraptus harti?	(r)
Paraglossograptus etheridgei	(c)

ZONE 8.

S2/570 At base of 60ft waterfall in true left tributary of Little Slaty Creek, 1 chain from Little Slaty Creek. From

10 - 20 ft above base of exposure (see also S2/562,579). Grid ref. 870985. Aorangi Mine Formation, member AM2. Collection V1564b.

Phyllograptus angustifolius angustifolius	(r)
P.anna	(r)
Tetragraptus reclinatus	(r)
Didymograptus sp.(extensiform)	(c)
D.cf.eocaduceus	(r)
Isograptus caduceus lunata	(a)

ZONE 5.

S2/571 True right tributary Slaty Creek, 1 chain upstream junction with Slaty Creek, at top of waterfall. Grid ref. 884986. Formation A, member A3. Collection V1572.

Glossograptus cf.hincksii	(c)
Cryptograptus cf.schaferi	(r)
Climacograptus sp.	(c)
Amplexograptus confertus?	(c)
Glyptograptus sp.	(c)

ZONE 9 (possible range, zones 8 - 10).

S2/572 True right tributary Slaty Creek, 15 chains upstream junction with Slaty Creek. Grid ref. 886985. Formation B (lower part). Collection V1573.

Didymograptus sp.	(r)
Amplexograptus cf. confertus	(c)

ZONES 8 - 10.

S2/573 True right tributary Slaty Creek, 3 chains upstream S2/572. Grid ref. 886985. Formation B (lower part). Collection V1574.

Climacograptus sp.	(r)
Glyptograptus sp.	(r)

ZONES 8 - 11.

S2/574 Boulder, true right tributary Slaty Creek, 3 chains upstream S2/573, probably derived from near S2/575. Grid ref. 886985. Collection V1575.

Dicellograptus cf. sextans	(r)
D. sextans cf. exilis	(r)

ZONE 10.

S2/575 True right tributary of Slaty Creek, 9 chains upstream S2/573. Grid ref. 887984. Formation B (lower part).

		Collections V1576	G.S.9969
Dicellograptus spp.	(c)	x	x
Climacograptus sp.	(r)	x	x

Pseudoclimacograptus sp.	(c)	-	x
Amplexograptus cf. confertus	(c)	x	x
Glyptograptus cf. teretiusculus	(r)	-	x
Retiograptus geinitzianus	(r)	-	x

ZONE 10.

S2/576 True left bank Slaty Creek at junction with true left tributary, opposite Sweeney's hut. Grid ref. 874999. Aorangi Mine Formation, member AM4. Collection V1577.

Isograptus caduceus maximo-divergens	(c)

ZONES 6 - 7.

S2/577 Top of high waterfall in true left tributary at head of Little Slaty Creek. Grid ref. 869979. Aorangi Mine Formation, member AM2. Collection V1578.

Bryograptid sp.indet.	(r)
Tetragraptus decipiens (3-stiped)	(c)
Tetragraptus decipiens (4-stiped)	(r)
T. approximatus	(c)
T. acclinans	(r)
Didymograptus sp.	(r)

ZONE 2.

S2/578 Boulder in Little Slaty Creek, downstream from Aorangi Mine adit, at large plunge pool. Grid ref. 871983. Collection V1579.

Adelograptus? sp.	(a)
Tetragraptus cf. decipiens	(r)

ZONES 1 - 3.

S2/579 Base of 60ft waterfall in true left tributary of Little Slaty Creek, one chain from Little Slaty Creek. 10 - 20ft above base of section (see also S2/562,570). Grid ref. 870985. Aorangi Mine Formation, member AM2. Collection V1564c.

Adelograptus aff. pusillus	(r)
Tetragraptus cf. reclinatus	(r)
Phyllograptus angustifolius angustifolius	(c)
P. typus	(c)
Didymograptus eocaduceus?	(r)
D. sp. (of protobifidus type)	(r)
Isograptus caduceus lunata	(a)

ZONE 5.

S2/580 Anthill Creek, true left bank 24 yards downstream from second waterfall (about 4.7 chains downstream from Anthill Mine adit). Grid ref. 869992. Aorangi Mine

Formation, member AM2.

		Collections V1589	G.S.9954
Tetragraptus decipiens (4-stiped)	(c)	x	x
T.bigsbyi	(c)	x	x
T.aff.serra	(r)	-	x
T.quadribrachiatus	(c)	x	x
T.approximatus	(c)	x	x
Didymograptus similis	(c)	-	x
D.cf.extensus	(c)	x	x

ZONE 3 (possible range, zones 2-3).

S2/581 Anthill Creek, ½ chain downstream from S2/565. Grid ref. 870992. Not collected.

Isograptus caduceus ssp.

ZONES 5 - 9.

S2/582 Boulders in creek, northwest of Baldy Trig., 1 chain from S2/547. Derived from cliffs above right bank. Grid ref. 865018. Formation A, member A1.

		Collections V1596	G.S.9951
Loganograptus logani	(c)	x	x
L.logani cf.pertenuis	(c)	x	x

Pseudobryograptus incertus	(c)	x	x
P.parallelus	(r)	-	x
Tetragraptus quadribrachiatus	(r)	x	x
Didymograptus spp.	(c)	x	x
Isograptus caduceus ? ssp.	(r)	-	x
Glossograptus acanthus	(c)	x	-
Paraglossograptus etheridgei	(c)	x	x
P.zealandicus	(c)	x	x
Glyptograptus austrodentatus cf. austrodentatus	(r)	-	x
G.cf.intersitus	(c)	-	x
Amplexograptus confertus	(c)	x	x
?Hallograptus inutilus	(c)	x	x
Trigonograptus ensiformis	(r)	-	x
T.sp.	(r)	x	x

ZONE 8.

S2/583 Malone Creek, 35 chains downstream from junction ~~with~~ of main branch; outcrop on right bank. Grid ref. 852005. Aorangi Mine Formation, member AM1. Collection V1597.

Graptolite fragments indet.

Age indeterminate.

S2/584 Coffee Creek, at junction of main branches. Grid ref. 868001. Aorangi Mine Formation, member AM4? Collection V1598.

Isograptus caduceus maximo-divergens	(r)
Oncograptus or *Cardiograptus* (juvenile)	(r)
Pseudotrigonograptus sp?	(r)

ZONE 7.

S2/585 Spoil heap above waterfall at mouth of Coffee Creek, true left bank, one chain from creek. Grid ref. 868002. Derived from Aorangi Mine Formation, member AM4. Collection V1600.

Cardiograptus sp.	(r)
Isograptus sp.	(r)

ZONE 7.

S2/586 "Old Golden Ridge" locality, 40 chains up true right branch of Coffee Creek, from junction with left branch. Grid ref. 869998. Aorangi Mine Formation, member AM2.

		Collections V1602	G.S.740, 547
Tetragraptus amii	(r)	-	x
*T.*cf.*bigsbyi*	(c)	x	-
T.decipiens?	(r)	-	x
T.harti	(r)	-	x

T.reclinatus	(c)	x	x
T.serra	(c)	x	x
T.cf.whitelawi	(r)	-	x
Phyllograptus anna	(r)	x	x
P.angustifolius angustifolius	(c)	x	-
P.ilicifolius	(c)	x	-
Didymograptus extensus	(c)	x	-
D.protobifidus	(a)	x	x
D.similis	(r)	x	-
Isograptus caduceus ? primula	(r)	x	x

ZONE 4.

S2/587 On Aorangi Mine track where it leaves creek, north of saddle, between Slaty and Little Slaty Creeks. Grid ref. 873997. Aorangi Mine Formation, member AM2. Collection V1603.

Isograptus caduceus maximodivergens

ZONE 6 (possible range, zones 6-7).

S2/588 Two to three chains up true left tributary of Anthill Creek, which joins Anthill Creek 3 - 4 chains downstream from high waterfall. Grid ref. 870992. Aorangi Mine Formation, member AM2. Collection V1604.

Tetragraptus bigsbyi	(c)
Phyllograptus anna	(r)

P.ilicifolius	(c)
Didymograptus protobifidus	(c)
D.sp.cf.extensus	(r)

ZONE 4.

S2/589 Top of high waterfall in Anthill Creek. Grid ref. 869992. Aorangi Mine Formation, member AM2. Collection V1903.

Dichograptus octobrachiatus

Tetragraptus serra?

ZONES 3 - 6.

S2/590 At second waterfall up Anthill Creek. Grid ref. 869992. Aorangi Mine Formation, member AM2. Collection V1904.

Adelograptus? antiquus	(c)
Tetragraptus approximatus	(c)
T.decipiens (3-stiped)	(c)

ZONE 2.

S2/591 Boulders in Dam Creek, traced upstream to S2/592 which is their probable source. Formation B? Collection V1906. Graptolites generally distorted.

Dicellograptus sp.(of D.sextans exilis type)	(a)

Diplograptids indet. (c)

ZONE 10 (possible range, zones 10-11).

S2/592 Junction of branches in headwaters of west branch of Dam Creek. Grid ref. 885993. Formation B (lower part). Graptolites in some beds strongly distorted.

		Collections V1907	G.S.9976
Sinograptid sp.indet.	(r)	-	x
Glossograptus hincksii	(r)	-	x
Nemagraptus sp?	(r)	-	x
Dicellograptus sextans exilis	(c)	x	x
D.intortus?	(c)	-	x
Diplograptus sp.	(r)	-	x
Diplograptid spp.indet.	(c)	x	x
Glyptograptus cf.teretiusculus	(r)	-	x
Retiograptus geinitzianus	(r)	-	x

ZONE 10.

S2/593 Boulder in Coffee Creek, true right branch, 5 chains upstream from junction. Grid ref. 869000. Collection V1908.

Dichograptus octobrachiatus	(r)
Tetragraptus serra?	(r)

Phyllograptus anna	(r)
P.angustifolius angustifolius	(r)
P.ilicifolius	(r)
Didymograptus cf.extensus	(r)
Isograptus caduceus lunata	(r)

ZONE 5.

S2/594 One chain up north branch of headwaters of eastern tributary, Slaty Creek. Grid ref. 890983. Formation B (lower part). Collection V1915.

Graptolite fragments indet.

S2/595 Slaty Creek, left bank, 45 chains downstream from true right tributary. Fossils in outcrop and scree at base of small waterfall on left bank. Grid ref. 882978. Formation A, member A2.

		Collections V1916	G.S.9977
Glossograptus sp.	(r)	-	x
Cryptograptus schaferi	(r)	-	x
Climacograptus spp.	(c)	x	x
Climacograptus cf.riddellensis	(c)	x	x
Glyptograptus sp.	(c)	x	x

ZONE 9 (possible range, zones 8-10).

S2/596 Malone Creek, at small waterfall in headwaters of right branch. Grid ref. 862996. Aorangi Mine Formation, member AM1.

Adelograptus sp?

Graptolite fragments indet.

ZONE indeterminate.

S2/597 Headwaters of Anthill Creek. Outcrop one chain upstream from junction of three small branches, west of old building site in clearing. Grid ref. 866992. Aorangi Mine Formation, member AM1. Collection V1918.

Dendroid sp.indet.

Phyllocarids (small)

AGE indeterminate.

S2/598 Immediately upstream of small clearing in valley of Beaton Creek, 25 chains upstream from junction with Coffee Creek. Grid ref. 868999. Aorangi Mine Formation, member ?AM3. Collection V1919.

Isograptus caduceus maximo-divergens (c)

I. sp. (c)

ZONE 6 (possible range, zones 6-7).

S2/599 40 chains up Bottle Creek, at east end of black chert band, ½ chain downstream from plunge pool. Section 4. Grid ref. 869999. Aorangi Mine Formation, member AM2. Collection V1920.

Dichograptus octonarius	(c)
Didymograptus extensus	(c)
Isograptus caduceus victoriae	(c)
Graptoloid sp.1,	(a)

ZONE 5.

S2/600 Bottle Creek; section 4; 15ft stratigraphically below S2/599. Grid ref. 869999. Aorangi Mine Formation, member AM2.

		Collections V1921	G.S.9980
Dichograptus maccoyi	(r)	-	x
Tetragraptus quadribrachiatus	(r)	-	x
T.reclinatus	(c)	x	x
Phyllograptus cf.angustifolius	(r)	x	x
P.ilicifolius	(c)	x	x
P.cf.typus	(r)	-	x
Didymograptus cf.extensus	(r)	-	x
Isograptus caduceus lunata	(c)	x	x

ZONE 5.

S2/601 Bottle Creek, section 4. 18ft stratigraphically below S2/599. Grid ref. 869999. Aorangi Mine Formation, member AM2. Collection V1922.

Clonograptus sp?	(r)
Dichograptus octobrachiatus	(r)
Tetragraptus reclinatus	(r)
Phyllograptus sp.	(c)
Isograptus caduceus lunata	(c)

ZONE 5.

S2/602 Bottle Creek, section 4. 22ft stratigraphically below S2/599. Grid ref. 869999. Aorangi Mine Formation, member AM2. Collection V1923.

Isograptus caduceus lunata (one specimen)

ZONE 5.

S2/603 Bottle Creek, section 4. 35ft stratigraphically below S2/599. Grid ref. 869999. Aorangi Mine Formation, member AM2. Collection V1924.

Clonograptus sp.	(c)
Dichograptus maccoyi	(r)
Tetragraptus quadribrachiatus	(c)
Phyllograptus anna	(c)
Didymograptus extensus	(r)

D.spp. (extensiform)	(c)
D.sp. (of protobifidus type)	(r)
Isograptus caduceus lunata	(r)
Graptoloid sp.1	(c)

ZONE 5.

S2/604 Bottle Creek, section 4. 45ft stratigraphically below S2/599. Grid ref. 869999. Aorangi Mine Formation, member AM2. Collection V1925.

Tetragraptus sp.	(c)
Phyllograptus anna	(c)

ZONES 3 - 5.

S2/605 Bottle Creek, section 4. 75ft stratigraphically below S2/599. Grid ref. 869999. Aorangi Mine Formation, member AM2. Collection V1926.

Dichograptus sp. (minute form)	(r)
Tetragraptus serra	(c)
Phyllograptus angustifolius angustifolius	(c)
Didymograptus protobifidus	(c)
D.sp. (extensiform)	(c)

ZONE 4.

S2/606 Bottle Creek, section 4. 85ft stratigraphically below S2/599. Grid ref. 869999. Aorangi Mine Formation, member AM2. Collection V1927

Tetragraptus fruticosus (3-stiped)	(c)
T.harti	(c)
T.quadribrachiatus	(c)
T.serra?	(c)
Phyllograptus angustifolius angustifolius	(c)
Didymograptus protobifidus	(c)

ZONE 4.

S2/607 Bottle Creek, section 4. 100ft stratigraphically below S2/599. Grid ref. 869999. Aorangi Mine Formation, member AM2. Collection V1928.

Tetragraptus fruticosus (3-stiped)	(c)
Phyllograptus angustifolius angustifolius	(a)
Didymograptus cf.protobifidus	(c)

ZONE 4.

S2/608 Aorangi Mine Track, at point where it crosses Little Slaty Creek, below Jimmy's Creek junction. Grid ref. 872990. Aorangi Mine Formation, member AM3. Collection V1929.

Tetragraptus harti	(r)
Didymograptus sp. (extensiform)	(c)
Isograptus caduceus maximo-divergens	(a)
I.dumosus	(c)
I.hastatus	(c)

ZONE 6 (possible range, zones 6-7).

S2/609 Half a chain up minor, dry, true right tributary, one chain upstream Little Slaty Creek from Aorangi Mine adit. Grid ref. 871983. Aorangi Mine Formation, member AM2.

		Collections V1947	V1947a
Tetragraptus serra?	(r)	-	x
T.aff.taraxacum	(r)	x	-
Phyllograptus cf.anna	(c)	-	x
P.angustifolius angustifolius	(c)	x	-
Didymograptus protobifidus	(c)	x	-

V1947 = boulder derived from nearby. ZONE 4.

V1947a = in place. ZONES 3 - 5.

S2/610 Boulder, 27 yards upstream Little Slaty Creek from S2/609. Grid ref. 871982. Aorangi Mine Formation, member AM2? Collection V1948.

Didymograptus cf. extensus	(r)
Isograptus caduceus victoriae	(c)
Graptoloid sp. 1	(c)

ZONE 5.

S2/611 4½ chains upstream Little Slaty Creek from S2/609. Grid ref. 871982. Aorangi Mine Formation, member AM2. Collection V2041.

Goniograptus macer	(c)
Tetragraptus serra?	(r)
Phyllograptus anna	(c)
Didymograptus cf. extensus	(c)

ZONE 5.

S2/612 At top of high waterfall at mouth of true left tributary of Little Slaty Creek, 10 chains south of Jimmy's Creek. Grid ref. 869986. Aorangi Mine Formation, member AM2. Collection V2042.

Tetragraptus decipiens (4-stiped)

ZONES 1 - 3.

S2/613 True left tributary of Little Slaty Creek. 5ft stratigraphically below S2/612. Grid ref. 869986. Aorangi Mine Formation, member AM2. Collection V2043.

Tetragraptus decipiens (4-stiped) (c)

Didymograptus sp? (r)

ZONE 3.

S2/614 True left tributary, Little Slaty Creek, 8ft stratigraphically below S2/612. Aorangi Mine Formation, member AM2. Collection V2044.

Clonograptus sp. (r)

Tetragraptus approximatus (c)

ZONE 2 (possible range, zones 2-3).

S2/615 True left tributary, Little Slaty Creek, 12ft stratigraphically below S2/612. Grid ref. 869986. Aorangi Mine Formation, member AM2. Collection V2045.

Anisograptid sp.

Tetragraptus quadribrachiatus (r)

ZONES 2 - 3.

S2/616 True left tributary, Little Slaty Creek, 17ft stratigraphically below S2/612. Grid ref. 869986. Aorangi Mine Formation, member AM2. Collection V2046.

Tetragraptus approximatus (r)

ZONE 2 (possible range, zones 2 - 3).

S2/617 North branch of Sandhills Creek, at junction with true right tributary, eastern limit of member AM2. Grid ref. 872973. Aorangi Mine Formation, member AM2. Collection V2047.

Clonograptus sp.	(r)
Dichograptus octobrachiatus	(r)
D.octonarius	(c)
Didymograptus sp. (extensiform)	(r)
Isograptus caduceus victoriae	(c)

ZONE 5 (upper)

S2/618 North branch Sandhills Creek, 6ft stratigraphically below S2/617. Section 3b. Grid ref. 872973. Aorangi Mine Formation, member AM2. Collection V2048.

Loganograptus logani cf.pertenuis?	(r)
Isograptus caduceus victoriae	(c)

ZONE 5 (upper).

S2/619 North branch Sandhills Creek, 9ft stratigraphically below S2/617. Section 3b. Grid ref. 872973. Aorangi Mine Formation, member AM2. Collection V2049.

Didymograptus sp. (extensiform)	(c)
Isograptus caduceus victoriae	(c)

ZONE 5 (upper)

S2/620 North branch Sandhills Creek, 13ft stratigraphically below S2/617. Section 3b. Grid ref. 872973. Aorangi Mine Formation, member AM2. Collection V2050.

Isograptus caduceus victoriae	(a)

ZONE 5 (upper).

S2/621 North branch Sandhills Creek, 18ft stratigraphically below S2/617. Section 3b. Aorangi Mine Formation, member AM2. Collection V2051.

Dichograptus cf. octonarius (5-stiped form)	(r)
Isograptus caduceus victoriae	(c)
I. c. victoriae?(= distorted maxima or maximodivergens?)	(r)

ZONE 5 (possible range, zones 5 - ?7).

S2/622 North branch Sandhills Creek, at first sharp bend downstream from S2/617. Section 3b. Grid ref. 871972. Aorangi Mine Formation, member AM2. Collection V2052.

Didymograptus sp. (extensiform)	(r)
Graptoloid sp.1	(c)

ZONES 5 - 6.

S2/623 North branch Sandhills Creek, 10ft stratigraphically below S2/622. Section 3b. Grid ref. 871972. Aorangi Mine Formation, member AM2. Collection V2053.

Phyllograptus sp.	(r)
Didymograptus sp. (extensiform)	(r)
Isograptus caduceus lunata	(c)

ZONE 5 (lower).

S2/624 North branch Sandhills Creek, 30ft stratigraphically below S2/622. Section 3b. Grid ref. 871972. Aorangi Mine Formation, member AM2. Collection V2054.

Adelograptus aff. *pusillus*	(r)
Tetragraptus bigsbyi	(c)
T. cf. *reclinatus*	(c)

ZONES 3 - 6.

S2/625 North branch Sandhills Creek, 50ft stratigraphically below S2/622. Section 3b. Grid ref. 871973. Aorangi Mine Formation, member AM2. Collection V2055.

Phyllograptus anna	(a)
Didymograptus protobifidus	(r)

ZONE 4.

S2/626 North branch Sandhills Creek, 70ft stratigraphically below S2/622. Section 3b. Grid ref. 871973. Aorangi Mine Formation, member AM2. Collection V2056.

Tetragraptus fruticosus (3-stiped)	(c)
T.harti	(c)
T.whitelawi	(c)
Phyllograptus anna	(r)

ZONE 3.

S2/627 North branch Sandhills Creek, 100ft stratigraphically below S2/622. Section 3b. Grid ref. 871973. Aorangi Mine Formation, member AM2. Collection V2057.

Clonograptus sp.	(r)
Tetragraptus fruticosus(3-stiped)	(r)
Phyllograptus cf.ilicifolius	(r)

ZONE 3.

S2/628 North branch Sandhills Creek, at large plunge pool, where stream makes sharp left turn, 130ft stratigraphically below S2/627. Section 3b. Grid ref. 871973. Aorangi Mine Formation, member AM2. Collection V2058.

Clonograptus cf.kingi	(c)
Goniograptus sp. (perflexis type)	(r)
Tetragraptus cf.bigsbyi	(r)

T.fruticosus (4-stiped)	(c)
T.harti	(r)
T.pendens	(c)
T.cf.pendens	(r)
T.cf.reclinatus	(r)
T.sp. (of pygmaeus type)	(r)
Phyllograptus anna	(r)
Didymograptus cf.ensjoensis	(c)
D.similis	(c)
D.sp. (extensiform)	(c)

ZONE 3.

S2/629 North branch Sandhills Creek, 2.7 chains upstream from S2/617. Section 3. Grid ref. 872973. Aorangi Mine Formation, member AM3. Collection V2059.

Isograptus caduceus maximo-divergens	(r)
I.imitata	(r)
Trigonograptus ensiformis?	(r)

ZONE 6 (possible range, zones 6-7).

S2/630 North branch Sandhills Creek, 30 chains upstream from S2/629. Section 3. Grid ref. 876971. Aorangi Mine Formation, member AM4. Collection V2060. Graptolites tectonically distorted.

Goniograptus cf. macer	(r)
Phyllograptus sp.	(c)
Tetragraptus cf. quadribrachiatus	(c)
T. cf. serra (small form)	(c)
Didymograptus v-deflexus	(c)
D. sp. (extensiform)	(c)
Isograptus caduceus maximo-divergens	(c)
I. dumosus	(c)
I. aff. imitata	(c)
I. sp. 2 aff. manubriatus	(c)
I. sp. 3 aff. manubriatus	(c)
Oncograptus upsilon biangulatus	(c)

ZONE 7.

S2/631 North branch Sandhills Creek, 18 chains upstream from S2/630. Section 3. Grid ref. 878971. Formation A, member A1. Collection V2061.

Didymograptus sp. (extensiform)	(r)
Isograptus dumosus	(c)
Oncograptus sp.	(r)

ZONE 7.

S2/632 Left bank Slaty Creek, 7 chains upstream battery at bottom of gorge, at junction with true left tributary.

Grid ref. 861008. Aorangi Mine Formation, member AM3. Collection V1599.

Glossograptus crudus?	(r)
?Hallograptus cf. inutilus	(r)

ZONE 7.

S2/633 Slaty Creek, 12 chains upstream Conn's Creek junction, outcrop in slip on left bank. Section 2. Grid ref. 882986. Formation A, member A2.

		Collections V2066	G.S.9966
Pterograptus? sp.nov.	(r)	x	-
Phyllograptus angustifolius elongatus	(r)	-	x
Cryptograptus schaferi	(c)	x	x
Glossograptus hincksii	(c)	-	x
Climacograptus brevis	(c)	x	x
Diplograptus? decoratus	(r)	-	x
Glyptograptus cf. teretiusculus siccatus	(c)	x	x

ZONE 9.

S2/634 True right tributary of Slaty Creek, 9 chains upstream from junction with Slaty Creek. Outcrop in right bank, and in centre of creek. Section 2. Grid ref. 884985.

Formation A, member A3. Collection V2067.

Didymograptid sp.	(r)
Climacograptus sp.	(c)
Glyptograptus cf. *teretiusculus*	(c)

ZONE 9 (possible range, zones 9-10).

S2/638 Boulders, Conn's Creek, 17 chains upstream from junction with Slaty Creek. Grid ref. 877984. Derived from Formation A, member A1. Collection V2637.

Glossograptus sp.	(r)
Glyptograptus sp.	(r)

ZONES 8 - 10.

S2/641 "No. 2 level tram, Aorangi Mine". (Probably loose boulder near no.2 adit, Aorangi Mine.) From lithology, almost certainly derived from base of member AM2, Aorangi Mine Formation. Collector Mr S.A.A.Fry, Dec.,18, 1935. Collection Zfg6.

Clonograptus aff. *regularis*	(r)
Adelograptus? *antiquus*	(c)
Anisograptus? sp.	(r)

ZONE 1 (possible range, zones 1-3).

S3/526 Paturau River, 20ft talus slope on right bank, ½ mile upstream from junction with Thompson Creek. Grid ref. S3/907011. Formation B (upper part). Collectors D.G.Bishop, R.Ryburn, D.S.Ker (Bishop 1965); recollected A.J.Wright, R.A.Cooper, etc., 1966-1968.

		Collections V1593	G.S.9504
Nemagraptus gracilis	(r)	x	-
Dicellograptus cf. sextans	(c)	x	-
D. cf. sextans exilis	(c)	x	x
D. sp.	(c)	x	x
Dicranograptus nicholsoni	(r)	x	-
Climacograptus sp.	(c)	x	x
Pseudoclimacograptus cf. modicellus	(r)	x	x
P. sp.	(c)	x	x
Glyptograptus cf. teretiusculus	(c)	-	x
G. spp.	(c)	x	x
Retiograptus sp.	(r)	x	-

Three species of trilobites are associated with the graptolites (A.J.Wright pers.comm.) one of which matches Ogygites collingwoodensis Reed, described from a boulder downstream from this locality (Reed 1927).

ZONE 10.

S3/537 Boulder in Paturau River, 25 chains upstream from Thompson Creek. Grid ref. 908017. Collector B.Stainton. Collection V1590.

Tetragraptus cf. *reclinatus* (one specimen)

ZONES 3 - 6. In lithology, the pebble closely resembles rocks of the distinctive member AM2, Aorangi Mine Formation; however, no rocks of this member are known to outcrop within the Paturau catchment, and the origin of the pebble is unknown.

S3/538 Boulder, Paturau River, 2 miles upstream from Thompson Creek. Grid ref. 903002. Formation B? Collection V1944.

Diplograptid sp.indet.

ZONES 9 - 10 (possible range, zones 8 - 11).

S3/540 Thompson Creek, 40 chains upstream from its junction with Paturau River. Outcrop of dark shale on true left bank. Grid ref. S3(1946)/917220. Formation B (?lower part). Not collected.

Diplograptid fragments.

S3/550 Thompson Creek, boulder upstream from lower limestone locality. Derived from Formation B? Collector E.O'Fee.

Collection V2699.

Dicellograptid fragments

ZONES 10 - 11.

S3/551 Pebble in Paturau River, at bridge on logging road. Grid ref. S3(1946)/905041. Derived from Aorangi Mine Formation, member AM2? (see S3/537). Collector G.Smith 1963? Collection V1049.

Phyllograptus sp.

ZONES 3 - 8.

S7/516 Five to fifteen yards downstream from second waterfall in left branch, Elliot Creek, Aorere Valley, approximately one mile upstream from ford. Grid ref. S7(1965)/886866. Aorangi Mine Formation, member AM2. Collectors V.U.W. students 1963, 1967; recollected R.A.Cooper, G.W.Grindley, M.R.Johnston etc., 1965-8.

		Collections V1588	G.S.9475
Anisograptid sp.indet.	(r)	x	x
Trichograptus fergussoni	(r)	-	x
Tetragraptus approximatus	(r)	-	x
T.fruticosus (3- and 4-stiped)	(c)	x	x
T.decipiens (4-stiped)	(c)	x	x

T.pendens	(r)	-	x
T.quadribrachiatus	(c)	x	x
Didymograptus similis	(c)	x	x
D.sp. (extensiform)	(c)	x	x

ZONE 3 (presence of T.approximatus suggests basal zone 3).

S7/517 Boulders, Elliot Creek, between ford and second waterfall. Collectors H.W.Wellman, V.U.W.students, 1963; recollected R.A.Cooper etc., 1965-8.

	Collections V2156	G.S.9511
Single boulder		
Isograptus caduceus maximodivergens	x	-
I.dumosus	x	-
Trigonograptus sp.	x	-

ZONE 6 (possible range, zones 6-7).

Separate boulders

Goniograptus cf.thureaui	(r)	x	-
Tetragraptus cf.harti	(r)	x	x
Phyllograptus anna	(r)	x	-
Isograptus cf. caduceus ? primula	(r)	x	-
I. c. victoriae	(c)	x	x

ZONES 3 - 6 (possible range, zones 3-7).

S7/518 At bottom of lower waterfall in left branch, Elliot

Creek. Outcrop in centre of creek. Grid ref. S7(1965)/884862. Aorangi Mine Formation, member AM2?

		Collections V1584	G.S.9970
Clonograptus sp.	(r)	x	x
Tetragraptus decipiens (4-stiped)	(c)	x	x
Bryograptid fragments	(c)	x	x

ZONES 1 - 2 (possible range, zones 1-3).

S7/519 Elliot Creek, left branch, 22 chains upstream from upper waterfall. Grid ref. S7(1965)/887867. Collection V1585.

Goniograptus sp.	(r)
Tetragraptus decipiens (4-stiped)	(c)
T.fruticosus (3-stiped?)	(r)
T.quadribrachiatus	(c)
Didymograptus similis	(r)

ZONE 3.

S7/520 Elliot Creek, left branch, 15 chains upstream from upper waterfall, 7 chains downstream from S7/519. Grid ref. S7(1965)/887866. Collector R.A.Cooper 1965-6; recollected R.A.Cooper and V.U.W.students 1967. Collection V1586.

Tetragraptus fruticosus (3-stiped)	(c)
T.fruticosus (4-stiped)	(r)
T.serra	(c)
Phyllograptus cf.anna	(r)
Didymograptus cf.extensus	(r)
D.similis	(c)

ZONE 3.

S7/521 At junction of the main branches of Elliot Creek, east bank. Grid ref. S7(1965)/885863. Not collected.

Graptolite fragments indet.

S7/522 Elliot Creek, 5 - 6 chains upstream minor true left tributary, approximately 60 chains downstream from junction of main branches. Boulder in scree. Grid ref. S7(1965)/886861. Collection V2063.

Tetragraptus decipiens (4-stiped) (r)

ZONES 1 - 2 (possible range, zones 1-3).

S7/523 Elliot Creek, 1 - 2 chains upstream S7/522. Grid ref. S7(1965)/886861. Collection V2064.

Anisograptid fragments

ZONES 1 - 3.

S7/524 Left branch, Elliot Creek, approximately 5 chains upstream S7/519. Grid ref. S7(1965)/886867. Collection V2065.

Adelograptus sp.

ZONE indeterminate (possible range, zones 1-3).

S8/581 17 Mile Creek, Aorere Valley. Four pebbles at intervals from bridge to one mile upstream. Collectors P.Wellman 1963; recollected R.A.Cooper, G.W.Grindley, M.R.Johnston, 1965. Collection V2155.

Glyptograptus austrodentatus ssp. (one specimen)
Graptolite fragments

ZONE 7.

S8/582 Boulder, Denton Creek, 1 chain upstream from bridge. Grid ref. S8(1950)/944873. Collection V2154.

Phyllograptus sp.

ZONES 2 - 6.

S13/535 On ridge crest, one mile E.S.E. of Hailes Knob. Grid ref. S13(1950)/213510. Hailes Knob Quartzite. Collector R.A.Cooper (Cooper 1965). Collection V977.

Brachiopods indet.

AGE indeterminate.

S13/549 South Branch Riwaka River, opposite Mosses Hut, and opposite Wilkinson's Flat. Grid ref. S13(1950)/234506. Mount Arthur Marble. Collection V1594.

Crinoid fragments

Corals?

AGE, Middle Ordovician or younger.

S13/550 Small narrow dry gully on east side of divide 0.6 miles @ 075°T from Hailes Knob trig. Fossils in bottom of gully, about four chains below bush line, and approximately 2 chains downstream from first outcrop coming down valley. Approximately 150ft below divide. Grid ref. S13(1950)/217527. Hailes Knob Quartzite. Collector R.A.Cooper 1966; recollected R.A.Cooper, A.J.Wright, 1967. Collection V1905.

Brachiopods

Corals

Age and Comments: "Hailes Knob fossil collections are

dominated by ventral moulds of a plicate pentamerid; other material has not been identified. The range of Pentameracea is Upper Ordovician to Upper Devonian" - A.J.Wright (pers.comm.).

S13/551 Road cutting, Cobb Valley Hydro road, ½ mile downstream from Sam Creek, 2 miles upstream from bridge. Grid ref. S13(1950)/172565. Beds mapped as Wangapeka Formation by Grindley (1961). Collection V1909.

Fragments of graptolites?, resembling Mastigograptus simplex (Walcott).

Age indeterminate.

S19/596 On ridge between Rolling River and Wangapeka River, about 47 chains southwest of Trig I, 1811ft. Grid ref. S19(1963)/967088. Ellis Formation, member E3. Collectors Henderson, Grange and McPherson 1924-6 (fossils listed in Shirley 1938 :498, and Wright 1968 :635); recollected G.W.Grindley 1961, A.J.Wright, R.A.Cooper 1967. Collection V1971.

Fossils include:

Corals (Pleurodictyum)

Crinoids

Brachiopods ("probably" Notoconchidium)

Molluscs

Trilobites

Age, lower Devonian (?Gedinnian). "In Victoria and Tasmania Notoconchidium is either early Devonian or late Silurian." (A.J.Wright pers.comm.).

S19/606 Boulders in scree, 180ft above terrace at top of large scree slope, 12 chains downstream from Wright Creek in Wangapeka Valley. Derived from beds of S19/613, Wangapeka Formation, member W4. Grid ref. S19(1963)/963095. Collectors G.Hancox, A.J.Wright 1965; recollected R.A.Cooper 1967.

		Collections V1592	G.S.10013
Leptograptus cf.flaccidus	(r)	x	x
Dicellograptus sp.(of angulatus type)	(r)	x	x
Climacograptus bicornis	(c)	x	x
C.hastatus	(r)	x	-
C.spp.	(c)	x	x
Glyptograptus sp.(small form)	(c)	x	x
Orthograptus truncatus pauperatus	(c)	x	x
O.sp.(ex gr. calcaratus)	(c)	x	x
O.sp. (large form)	(r)	x	x

ZONE 11.

S19/607 Wright Creek, at upper end of terraces on right bank. Outcrops in stream and 20ft above stream. Grid ref. S19(1963)/958092. Wangapeka Formation, member W4. Collectors R.A.Cooper, D.S.Ker, 1967; recollected R.A.Cooper 1967.

		Collections V1910	G.S.10012
Leptograptus cf.flaccidus	(c)	x	x
Dicellograptus intortus?	(c)	-	x
D.patulosus	(c)	x	x
D.spp.	(c)	x	x
Dicranograptus cf.hians	(r)	-	x
D.sp.	(r)	-	x
Climacograptus spp.	(c)	x	x
C.cf.caudatus	(c)	x	-
Glyptograptus sp.	(c)	x	x
Orthograptus sp. (ex gr.calcaratus)	(c)	x	x
O.spp.	(c)	x	x

ZONE 11.

S19/608 Knob north of saddle on Mt Owen track, about 15 chains south of trig V, 1514ft. Grid ref. S19(1963)/977 065. Wangapeka Formation, member W4. Collectors R.A.Cooper, D.S.Ker, 1967. Collection V1911.

Climacograptus sp. (one specimen)

ZONES 9 - 11.

S19/609 Boulders in large scree slope in Wright Creek, 6.5 chains upstream from S19/607. Scree on right bank, derived from beds of S19/618-621. Grid ref. S19(1963)/957091. Wangapeka Formation, member W4.

		Collections V1912	G.S.10014
Leptograptid fragments	(c)	x	x
Leptograptus cf. *flaccidus*	(c)	-	x
Dicellograptus spp.	(c)	x	x
Climacograptus cf. *caudatus*	(r)	-	x
C. cf. *tubuliferous*	(r)	-	x
C. sp. (broad form)	(c)	x	x
Orthograptus sp.	(c)	x	x

ZONE 11.

S19/610 Boulders on Wangapeka track, 30 chains upstream from Wright Creek junction. Derived from bluffs 50 to 200ft above track. Grid ref. S19(1963)/954095. Wangapeka Formation, member W2.

		Collections V1913	G.S.10015
Leptograptus cf. *flaccidus*	(c)	x	-
Dicellograptus sp.	(c)	x	x
Climacograptus sp.	(c)	x	-
Amplexograptus confertus?	(r)	-	x
Orthograptus sp.	(r)	x	-

ZONE 11.

S19/611 Fossils in quartzite boulders on Wangapeka track, opposite junction with Patriarch Creek. Grid ref. S19(1963)/946097. Probably derived from Wangapeka Formation, member W1. Collection V1914.

Indeterminate fossil fragments

S19/612 Wangapeka track, scree 2 to 3 chains west of S19/610. Derived from cliffs above track. Grid ref. S19(1963)/954097. Derived from Wangapeka Formation, member W2. Collection V1930.

Leptograptus sp.	(r)
Dicellograptus sp.	(c)

ZONES 10 - 11.

S19/613 Outcrop above terrace on right bank Wangapeka R, 12 chains downstream from junction with Wright Creek, 180ft above terrace. Grid ref. S19(1963)/963095. Wangapeka Formation, member W4. Collection V1931.

Dicellograptus sp. (of *angulatus* type)	(c)
Climacograptus bicornis	(c)
C. cf. *tubuliferous*	(r)

ZONE 11.

S19/614 Gibb's Creek, outcrop ½ mile upstream from its mouth. Grid ref. S19(1963)/966107. Wangapeka Formation, member W4. Collector A.J.Wright 1967. Collection V1930.

Leptograptus sp.	(r)
Dicellograptus cf. *sextans*	(r)
Climacograptus sp.	(c)
Orthograptus sp. (large form)	(r)

ZONE 11.

S19/615 Outcrop about 220ft above terrace in Wangapeka Valley, 12 chains downstream from Wright Creek junction, 35ft stratigraphically above S19/613. Grid ref. S19(1963)/963095. Wangapeka Formation, member W4.

		Collections V1933	G.S.10016
Glyptograptus sp.	(c)	x	x

ZONES 8 - 11.

S19/616 Boulders in hillside above S19/613, approximately 630ft above terrace, Wangapeka Valley, 12 chains downstream from Wright Creek. Probably derived from Ellis Formation, member E1. Grid ref. S19(1963)/964095. Collection V1934.

Indeterminate fossil fragments

S19/617 Boulders on hillside above S19/613, 1170ft above terrace in Wangapeka Valley, 12 chains downstream from Wright Creek. Probably derived locally from Ellis Formation, member E1. Grid ref. S19(1963)/964091. Collection V1935.

Crinoid fragments

S19/618 Outcrop 350ft above Wright Creek, right bank, 50 chains upstream from Wangapeka River. Grid ref. S19 (1963)/957091. Wangapeka Formation, member W4.

		Collections V1936	G.S.10017
Dicellograptus sp.(of elegans type)	(r)	-	x
Climacograptus sp. (large form)	(r)	x	x
C.sp. (small form)	(c)	x	x

ZONES 10 - 11.

S19/619 Four hundred ft above right bank of Wright Creek, 50 chains upstream from junction with Wangapeka, approximately 100ft above S19/618. Grid ref. S19(1963)/ 957090. Wangapeka Formation, member W4. Not collected.

Diplograptids indet. (c)

S19/620 Fifteen ft above S19/619, right bank Wright Creek, 50 chains upstream from Wangapeka River. Grid ref.

S19(1963)/957090. Wangapeka Formation, member W4.

		Collections V1938	G.S.10018
Dicellograptus sp. (of angulatus type)	(r)	-	x
D.sp. (of elegans type)	(r)	x	x
Climacograptus tubuliferous	(r)	-	x
C.caudatus	(c)	x	-
C.sp.	(c)	x	x
Orthograptus sp. (large form)	(c)	x	x
O.sp. (ex gr.calcaratus)	(r)	x	-

ZONE 11.

S19/621 500ft above right bank of Wright Creek, 50 chains upstream from junction with Wangapeka River, 100ft above S19/621. Grid ref. S19(1963)/958089. Wangapeka Formation, member W4.

		Collections V1939	G.S.10019
Dicellograptus patulosus	(r)	-	x
D.sp. (of sextans type)	(c)	x	-
Climacograptus tubuliferous	(r)	x	-
C.sp. (of antiquus type?)	(c)	x	x
Orthograptus sp. (ex gr.calcaratus)	(c)	x	x
O.sp. (large form)	(c)	x	x
O.spp.	(c)	x	x

ZONE 11.

S19/622 Ridge between Wright Creek and Wangapeka River, about 55 chains from junction. Grid ref. S19(1963)/953093. Wangapeka Formation, member W2. Collection V1940.

Dicellograptus sp?	(r)
Climacograptus sp.	(c)

ZONES 10 - 11.

S19/623 At base of ridge between Wright Creek and Wangapeka River, about 16 chains from junction. In locally derived scree. Grid ref. S19(1963)/959095. Wangapeka Formation, member W4. Collection V1941.

Climacograptus sp.	(r)

ZONES 9 - 11.

S19/624 Left bank Wangapeka, 30 chains upstream from the junction with Wright Creek. Boulders derived from outcrops between two prominent bluffs. Grid ref. S19 (1963)/958098. Wangapeka Formation, member W2. Collection V1942.

Leptograptus cf. flaccidus	(c)
Dicellograptus sp. (of angulatus type)	(c)
Orthograptus sp. (ex gr. calcaratus)	(c)

ZONE 11.

S19/632 Upper Wright Creek. Boulder in slip on right bank. Grid ref. S19(1963)/946084. Wangapeka Formation, member W2? Collection V2068.

Diplograptid fragments

ZONES 8 - 11.

S19/633 Small western tributary of Rolling River, opposite Connor Creek. Outcrop in creek bed 25 chains upstream from Rolling River. Grid ref. S19(1963)/967075. Wangapeka Formation, member W4. Collection V2633.

Diplograptid fragments

ZONES 8 - 11.

S19/634 Western tributary of Rolling River, opposite Connor Creek. Cliffs above left bank 10 chains upstream from Rolling River. Grid ref. S19(1963)/970077. Wangapeka Formation, member W4. Collection V2634.

Climacograptus sp.	(c)
Orthograptus cf. truncatus	(c)

ZONE 11.

S19/635 Western tributary of Rolling River, opposite Connor Creek. Boulders in creek bed about 8 chains upstream from Rolling River. Grid ref. S19(1963)/971077.

Wangapeka Formation, member W4. Collection V2635.

Leptograptids	(r)
Dicellograptus sp. (large form)	(r)
Orthograptus cf. truncatus ssp.	(c)
O. sp.	(c)

ZONE 11.

S19/636 Outcrop on roadside, ½ chain north of prominent slip on road up Rolling River, 1½ miles from junction with Wangapeka River. Wangapeka Formation, member W2. Grid ref. S19(1963)/975074. Collection V2636.

Climacograptus? sp.

S19/637 Boulders in Loveridge Creek, 2-5 chains upstream from junction with Baton River. Grid ref. S19(1963)/048288. Beds mapped as Wangapeka Formation by Grindley (1961). Collectors R.A.Cooper, M.R.Johnston, 1968. Collection G.S.9905.

Climacograptus sp. (large form)

Orthograptus sp. (large form)

ZONE 11.

S19/638 True right bank of Baton River, 2 chains downstream from northern tributary, 15 chains downstream from

Loveridge Creek. Grid ref. S19(1963)/050282. Collectors R.A.Cooper, M.R.Johnston, 1968. Collection G.S.9906.

Dicellograptus sp.

ZONES 10 - 11.

S19/639 Outcrops on track on north bank of Baton River, 10 chains downstream S19/638. Grid ref. S19(1963)/051281. Collectors R.A.Cooper, M.R.Johnston 1968. Collection G.S.9907.

Graptolite fragments indet.

APPENDIX 2 - STRATIGRAPHIC SECTIONS

The following stratigraphic sections have been chain-and-compass traversed. Sections 1 to 6 are exposed in stream valleys in the Aorangi Mine area and are shown in Map 2; section 7 is exposed in a dry gully in the Pikikiruna scarp, near Hailes Knob (fig.13); sections 8 and 9 are exposed in the valleyside in the Wangapeka Valley area (fig.10).

Section 1, Anthill Creek

Top of section 4 chains downstream from high waterfall in Anthill Creek. Grid ref. 871992.

	Feet.
Aorangi Mine Formation - member AM3	
pale, blue-grey, massive argillite, pyritic argillite, and rare bands of quartzite	20+
not exposed	60
pale and dark, blue-grey, massive argillite	40
TOTAL, member AM3	120+
Aorangi Mine Formation - member AM2	
black fissile and cherty slate	15
Collection S2/565	
black and dark blue-grey fissile slate	15
massive pale quartzite	6

pale blue-grey siliceous argillite with black shale bands	11
not exposed	20
black cherty and fissile slate	53
Collection S2/564 (approximate position at high waterfall)	
black cherty slate	50
Collection S2/589	
black cherty slate locally brecciated	50
Collection S2/580	
black cherty slate with rare quartzite bands	110
Collection S2/590	
black cherty slate with rare quartzite bands	110
Collection S2/526	
black cherty slabby slate	30
TOTAL, member AM2	470
Aorangi Mine Formation - member AM1	
massive pale quartzite	25+
TOTAL, member AM1	25+

Base of section one chain upstream from old Anthill Mine drive. Grid ref. S2/868992.

Section 2, Slaty Creek

Top of section in eastern tributary of Slaty Creek, approximately thirty five chains upstream from its confluence with Slaty Creek. Grid ref. S2/887984.

Formation B	Feet.
grey, finely laminated (2-10mm) argillite	350+
medium- to dark-grey slate	10
Collection S2/575	
grey, finely laminated argillite	160
not exposed	180
alternating 1-2ft beds of quartzite and dark banded argillite	80
Collection S2/573	
not exposed	110
TOTAL, Formation B	890+

Formation A - member A3	
fine-grained sandstone and quartzite with 1-4inch bands of dark argillite	30
Collection S2/577	
alternating bands of grey or black siliceous argillite, sandstone, and quartzite	310
black slate	15
Collection S2/634	
interbedded grey pyritic quartz-sandstone,	

quartzite, graded beds, and rare, black and grey argillite bands	180
Collection S2/571	
alternating graded beds, quartzites, argillites	60
massive, pale quartzite	110
not exposed	100
massive, blue-grey to grey argillite	90
not exposed	100
TOTAL, member A3	995

Formation A - member A2

massive, black, siliceous argillite, slate and sandstone, spotted and locally brecciated	250
Collection S2/633	
black, massive, and thick-bedded slate	70
Collection S2/539	
black, massive, and thick-bedded slate	20
TOTAL, member A2	340

Formation A - member A1

grey quartz-sandstone in 3-inch beds with thin sheared phyllites with graptolite fragments	20
blue-grey argillite, with micaceous sandstone bands, slumped and disrupted bedding	100
Collection S2/569	
pale and dark, blue-grey massive and bedded argillite	100

massive, pale quartzite	130
alternating bands of blue-grey spotted argillite and sandstone, locally with slumped and disrupted bedding	225
not exposed	90
sheared and folded, blue-grey argillite and sandstone	25
Collection S2/568	
thin (2-4inch) alternating bands of pale and dark, blue-grey, micaceous argillite and sandstone	90
not exposed	200
alternating bands of quartzite (1ft.thick) with thin sheared argillitic layers	50
TOTAL, member A1	1030

Aorangi Mine Formation - member AM4

massive, pale quartzite	150
thin alternating beds of black slate and sandstone	15
Collection S2/556	
massive and thick-bedded quartzite	50
alternating and graded beds (6inches to 2ft thick) of blue-grey argillite and sandstone	120
massive, pale, blue-grey and grey quartzite	105
massive and thick-bedded, fine to coarse-grained, pale, blue-grey argillite	15
Collections S2/566,567,576	

massive quartzite (exposed in Little Slaty Creek)	50+
TOTAL, member AM4	505+

Base of section in Slaty Creek, at junction with minor true left tributary, opposite Sweeney's Hut. Grid ref. S2/874999.

Section 3a, North Branch, Sandhills Creek; lower part

Top of section continued in section 3b

Aorangi Mine Formation - member AM1	Feet.
grey, massive, quartz sandstone	20
not exposed	50
pale, brecciated, massive quartzite	200
laminated chert	5
grey, coarse-grained sandstone and greywacke	200
black, cherty slate, contorted	10
pale grey massive sandstone	90
black slate and laminated chert	5
dark grey bedded sandstone and quartzite	60
black, siliceous slate and laminated chert	20
pale grey massive quartzite	90

not exposed	70
massive quartzite	10
laminated chert	20
grey, massive quartzite	180
black, laminated slate	20
dark grey,bedded,mottled sandstone and quartzite	170
black, and laminated slate	10
TOTAL, member AM1	1230

Webb Formation

dark mottled sandstone	170
not exposed	220
grey quartzite	100
blue-grey spotted siltstone and argillite with sandstone bands	250
grey, phyllitic siltstone	45
not exposed	75
grey greywacke	50
dove grey, siliceous argillite and fine-grained sandstone	210
not exposed	150
grey, spotted, siliceous sandstone	150
grey, siliceous argillite	170
grey,spotted,siliceous,thick-bedded sandstone	150+
TOTAL, Webb Formation	1740+

Base of section, 16 chains upstream North Branch, Sandhills Creek, from junction with South Branch. Grid ref. S2/858970.

Section 3b, North Branch, Sandhills Creek; middle part

Top of section continued in section 3c

Aorangi Mine Formation - member AM2	Feet.
black graphitic sandstone	3
Collection S2/617	
black slate and sandstone, with grey phyllite bands	10
Collection S2/618	
black sandstone, with thin slate and phyllite bands	5
Collection S2/619	
black sandstone, rare slate and phyllite bands	6
Collection S2/620	
black, cherty slate with sandstone bands	8
Collection S2/621	
sheared blue-grey graphitic sandstone and argillite	25
not exposed	38
black slate and phyllite	3
Collection S2/622	
black slate and sandstone	16
Collection S2/623	
hard black cherty slate with sandstone bands	30
Collection S2/624	

hard black chert, laminated chert, and thin sandstone bands	22
Collection S2/625	
siliceous black slate and chert	13
Collection S2/626	
hard, cherty slate with thin fissile bands	12
Collection S2/627	
hard, black, siliceous, blocky chert with rare fossiliferous fissile bands	33
Collection S2/628	
hard, black cherty slate (in 2-6inch beds), sandstone and rare phyllitic bands	74
Approximate location of Collection S2/541	
not exposed	50
TOTAL, member AM2	348

Section continued in section 3c.

Section 3c, North Branch, Sandhills Creek; upper part

Top of section 10 chains upstream from junction of major tributaries in headwaters of Sandhills Creek. Grid ref. 879967.

	Feet.
Formation A - member A1	
blue-grey massive argillite	50+
blue-grey, pyritic, spotted argillite with sandstone bands	70
Collection S2/631	
not exposed	50
dark, carbonaceous, speckled sandstone	60
TOTAL, member A1	230+
Aorangi Mine Formation - member AM4	
dark grey, massive quartzite and sandstone (thickness approximate, section line broken)	470
dark sheared phyllite and siliceous argillite, carbonaceous sandstone, rare black slate	50
Collection S2/630	
dark phyllite, argillite and sandstone	50
not exposed	30
pale grey, massive quartzite	200
TOTAL, member AM4	800
Aorangi Mine Formation - member AM3	
dark, fine-grained sandstone	20
Collection S2/629	
pale, blue-grey, massive, pyritic, micaceous argillite	100
TOTAL, member AM3	120

Section continued, section 3b.

Section 4, Bottle Creek

Top of section in Bottle Creek, seven chains upstream from its junction with Little Slaty Creek. Grid ref. S2/870989.

Aorangi Mine Formation - member AM2	Feet.
bands of hard and soft black slate	5
Collection S2/599	
black slate	5
not exposed	5
black slate	5
Collection S2/600	
hard slabby black slate	5
Collection S2/601	
hard siliceous black slate	5
Collection S2/602	
black slate	10
Collection S2/603	
black slate	10
Collection S2/604	
black slate	5
not exposed	20
hard black slate	2
Collection S2/605	
hard black slate	13
Collection S2/606	

hard black slate	10
Collection S2/607	
black slate	10
TOTAL, member AM2	110

Base of section in Bottle Creek, 11 chains upstream from its junction with Little Slaty Creek. Grid ref. S2/869989.

Section 5, headwaters of Slaty Creek

Top of section 8 chains up true left fork in headwaters of Slaty Creek. Grid ref. S2/887963.

	Feet.
Formation B	
grey laminated argillite	380
black sheared slate	20
grey laminated argillite	280
dark spotted shale	25
grey argillite and grey laminated argillite	440
TOTAL, Formation B	1145
Formation A, member A3	
dark grey folded slate	20
black, strongly cleaved argillite	15
bedded grey quartzite	130
black graphitic sandstone and argillite	35

dark quartzite	50+
TOTAL, member A3	250+

Base of section 39 chains downstream from forks in headwaters of Slaty Creek. Grid ref. S2/882967.

Section 6, Slaty Creek, lower gorge

Top of section at downstream end of Slaty Creek lower gorge. Grid ref. S2/861009.

	Feet.
Aorangi Mine Formation - member AM4	
pale grey, pyritic, fine-grained, massive quartzite	150+
not exposed	20
TOTAL, member AM4	170+
Aorangi Mine Formation - member AM3	
dark blue-grey massive siliceous argillite	10
Collection S2/632	
not exposed	40
Collection S2/545	
banded (4") dark and pale blue-grey, graphitic argillite and slate, with thin sandstone bands	50
blue-grey, massive, medium-grained and coarse-grained graphitic sandstone and argillite	40
grey quartz sandstone	15

blue-grey, massive, graphitic argillite	15
Collection S2/548	
pale and dark blue-grey, massive argillite and sandstone	30+
TOTAL, member AM3	200+

Base of section 8 chains downstream from Slaty Creek lower gorge. Grid ref. S2/859010.

Section 7, Hailes Knob

Top of section approximately 300ft below crest of Pikikiruna scarp in headwaters of Dry Stream. Grid ref. S13(1950)/209529.

Hailes Knob Quartzite	Feet.
mainly massive grey siliceous sandstone and quartzite with rare phyllitic bands and flakes	100+
massive and bedded quartzite with extensive local fracturing	60
Approximate horizon of Collection S13/550	
grey hard sandstone and quartzite with brown calcareous pods and lenses	40
grey hard massive quartzite and greywacke	100
quartzite with muddy and phyllitic layers and rare calcareous bands. Strong local shearing	45

well bedded quartzite and sandstone with mudstone flakes and thin sheared phyllite bands and calcareous bands	35
black phyllitic spotted schist with calcareous bands, strongly cleaved	20
TOTAL, Hailes Knob Quartzite	400
Mount Arthur Marble	
not exposed	20
graphitic blue-grey flaggy limestone, with minor contorted bands and with rare thin bands of graphitic schist	1000+
TOTAL, Mount Arthur Marble	1020+

Base of section exposed in western face of Pikikiruna scarp, approximately 1700ft below crest of ridge. Approximate grid reference S13(1950)/203533.

Section 8, Wright Creek, Wangapeka Valley

Top of section 750ft above Wright Creek in south side of valley, 30 chains upstream from the junction with Wangapeka River. Grid ref. S19(1963)/958087.

Ellis Formation - member E1	Feet.
massive quartzite, locally brecciated	65+
TOTAL, member E1	65+

Wangapeka Formation - member W4

not exposed	225
grey slate and phyllite with rare black argillite bands	95
not exposed	40
dolerite sill or flow	8
black argillite	47
grey argillite, phyllite, rare sandstone bands	60
dark slate and argillite	43
not exposed	40
grey argillite	10
Collection S19/621	
dark slate and argillite	95
Collection S19/620	
dark argillite	10
Collection S19/619	
dark sandstone	12
black argillite with bands of leached sandstone	95
Collection S19/618	
black argillite and sandstone	5
well bedded black slate and argillite with thin bands of grey phyllite	295
TOTAL, member W4	1080

Base of section about 50ft above stream bed in south side of Wright Creek valley, 30 chains upstream from the junction with Wangapeka River. Grid ref. S19(1963)/957091.

Section 9, Wangapeka River

Top of section at ridge crest between Wangapeka and Rolling Rivers, about 2500ft above sea level, ¾ mile south-west of Trig I. Grid ref. S19(1963)/967088.

	Feet.
Ellis Formation - member E3	
hard pale sandstone with calcareous bands	30
Collection S19/596	
sandstone and argillite	40
not exposed	50
thin banded dark shale	40
TOTAL, member E3	160
Ellis Formation - member E1	
blue-grey mottled muddy sandstone	50
not exposed	300
hard white quartzite	10
not exposed	150
leached calcareous sandstone with fossil fragments	10
not exposed	60
pale hard massive quartzite	200
dark, mottled, muddy sandstone, cross-bedded, with muddy lenses and bands	180
massive, hard quartzite	310
TOTAL, member E1	1270

Wangapeka Formation - member W4

not exposed	60
grey phyllite with black shale bands	7
Collection S19/615	
not exposed	8
dark phyllite	12
dark, cleaved argillite	10
Collection S19/613	
dark, cleaved argillite with bands of black slate and grey phyllite	30
TOTAL, member W4	127

Base of section 180ft above terrace in south side of Wangapeka Valley, 12 chains downstream from the junction with Wright Creek. Grid ref. S19(1963)/963095.

APPENDIX III

(Supporting Paper)

Lower and Middle Paleozoic Fossil Localities

of North-West Nelson

TRANSACTIONS

OF THE

ROYAL SOCIETY OF NEW ZEALAND

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Lower and Middle Paleozoic Fossil Localities of North-west Nelson

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Abstract

THE Lower and Middle Paleozoic fossil localities in North-west Nelson are arranged in 75 locality-groups, which are shown on a map and are listed in a table giving sheet fossil numbers, important fossils, lithologies, inferred ages, and references. Fossils (including Porifera, Coelenterata, Polyzoa, Brachiopoda, Mollusca, Arthropoda, Echinodermata, and Graptolithina) indicate Middle Cambrian, most of the Ordovician, and Lower Devonian ages.

New fossil localities are recorded from the Aorangi Mine area, Paturau River, Elliot Creek, Rameka Creek, Cobb Road, North Branch of Graham River, Graham and Pearse Valleys, Baton Valley, and Wangapeka Valley. Stratigraphic ranges and geographic distributions of the fossils are discussed and brief mention is made of Lower and Middle Paleozoic fossils from elsewhere in New Zealand.

INTRODUCTION

THE Lower Paleozoic fossils of North-west Nelson were reviewed by Benson and Keble (1936) and the Middle Paleozoic fossils by Shirley (1938). Many new fossils and fossil localities have since been found, most of which are as yet unrecorded. This paper records all known fossil localities—about 230 in all—of definite or probable Lower and Middle Paleozoic age in North-west Nelson.

The most common and widely distributed fossils are graptolites, which are now known to represent most of the Ordovician period. They are currently being studied by the writer. Porifera, Coelenterata, Polyzoa, Brachiopoda, Mollusca, Arthropoda, and Echinodermata are also represented.

The Ordovician is here divided according to the stages used in Victoria (Thomas, 1960); Lower Ordovician includes the Lancefieldian, Bendigonian, Chewtonian, Castlemainian, and Yapeenian stages; Middle Ordovician includes the Darriwilian stage only; Upper Ordovician includes the Gisbornian, Eastonian, and Bolindian stages.

A locality map, Fig. 1, shows the distribution of fossiliferous Lower and Middle Paleozoic strata throughout New Zealand.

LIST OF FOSSIL LOCALITIES (Table I)

Individual fossil localities are registered in the New Zealand national fossil record catalogue with sheet fossil numbers. Each fossil locality is normally allocated

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a single locality number, but re-collections from a few places have been given separate numbers. For example, the numbers S13/484 and S13/526 probably both refer to the well-known "Trilobite Rock" locality in Cobb Valley.

In order to show them in Fig. 2, the 230 fossil localities have been grouped into a total of 75 "locality-groups", which are listed in Table I (by consecutive numbers prefixed with "LG"), together with sheet fossil numbers, collection numbers, grid references, important fossils, general localities, lithology, age, and references.

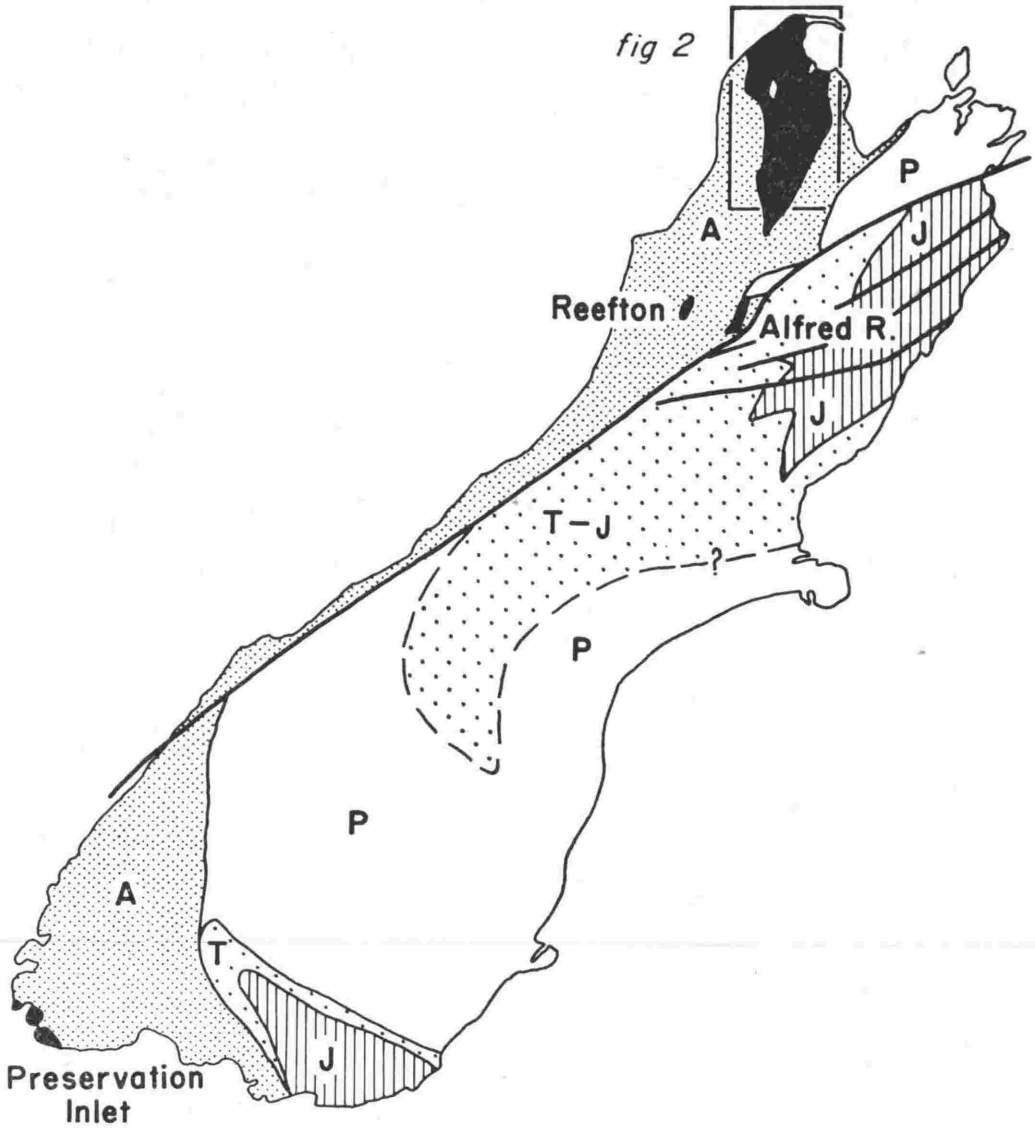

Fig. 1.—Locality map showing Lower and Middle Paleozoic fossiliferous rocks (black), together with generalised pre-Cretaceous units of the South Island. A, Paleozoic and ?Mesozoic granites and associated rocks, pre-Devonian unfossiliferous sediments, and metamorphic rocks. P, Permian; T, Triassic; J, Jurassic; P, T, and J being sediments, volcanic rocks, and schists of the New Zealand Geosyncline.

Grid references give the position of a fossil locality near the centre of each locality-group, and are based on the following map editions: N.Z.M.S.1, sheet S2 (1965 edition), S3 (1946 edition), S7 (1965 edition), S8 (1948 edition), S13 (1950 edition), and S19 (1943 edition).

Only the more important fossils are listed. Graptolite names are revised, but the names of other fossils are as published.

General locality is given for quick reference. Lithology is followed by the name of the formation in which the beds were placed by Grindley (1961), with the exception of Hailes Knob Quartzite (Cooper, 1965).

The ages of the fossils—Cambrian, Ordovician, Silurian, and Devonian—are indicated by the symbols "C", "O", "S", and "D", and are subdivided into Upper, Middle, or Lower, indicated by "U", "M", and "L", when known. The age symbols are enclosed in parentheses when the age is inferred from stratigraphy, and cannot be determined directly from the fossils. Important references are numbered as in the list of references at the end of the paper; those publications in which the fossils are listed or described are indicated by underlined numbers. Most of the fossil locality-groups are shown in the 1:250,000 geological map of Golden Bay (Grindley, 1961), and a few are mentioned in the text accompanying the map. Only Grindley's text references are given in Table I.

Two reported localities require special mention. Of the first (listed as LG 14, in Table I) Benson and Keble (1936: 249) state: "The coral obtained by Park (1889) further northwards from the Takaka Valley, eight miles from its mouth, was compared by Dr F. R. C. Reed (1927) to *Paleopora* (*Heliolites*) *inordinata* Lonsd., a form occurring in the Bala Limestone of Pembrokeshire . . ." The Bala Limestone is Upper Ordovician, and Grindley (1961) used the coral as evidence for an Upper Ordovician age for the Mount Arthur Marble. Unfortunately, no coral is mentioned in the paper by Reed, and the actual identity of Park's coral is uncertain. However, the Upper Ordovician age is confirmed by the recent discovery of further corals in the same formation a few miles to the south (Table I, LG 17 and LG 18).

The second of these localities is "Perseverance Mine, Bedstead Gully, on the eastern side of the Aorere River", which, according to Benson *et al.* (1936: 360), was the source of a specimen of *Didymograptus gibberulus* Nich. (= *Isograptus caduceus* (Salter)) in the Breslau Museum. Because only unfossiliferous, strongly schistose rocks are known from Bedstead Gully (G. W. Grindley, pers. comm.), it is not included in Table I.

NOTES ON NEW FOSSIL LOCALITIES

New fossil localities are discussed below, in order of One Mile Sheet districts.

S2. *Aorangi Mine, Slaty Creek,* and *Sandhills Creek,* south of Westhaven Inlet (LG 4–LG 7 in Table I). Graptolites from over 35 new localities near Aorangi Mine indicate an apparently continuous sequence about 6,500ft thick, ranging from early Lower Ordovician to early Upper Ordovician in age. Graptolites from this area were previously described as Lower Ordovician only (Keble and Benson, 1929; Benson *et al.,* 1936; Skwarko, 1961; Smith, 1966). The fossiliferous beds—black graphitic slate and blue-grey non-graphitic argillite—are interbedded with banded quartzite and argillite and thick beds of massive quartzite. Most lie within the Aorangi Mine Formation as mapped by Grindley (1961). Two of the new localities were found by D. G. Bishop (N.Z. Geological Survey) and the writer during 1966; the remainder were found by the writer during 1966 and 1967. Zonal graptolites include *Adelograptus* cf. *victoriae* (T. S. Hall), *Tetragraptus*

TABLE I.—LIST OF CAMBRIAN TO DEVONIAN FOSSIL LOCALITIES OF NORTH-WEST NELSON.

LG Number	Sheet Fossil Number	Collection Number	Grid Reference	Fossils	General Locality	Lithology, Formation	Age	Reference
CAMBRIAN								
LG 1	S13/474, 477 483-4, 526	GS/4928-9, 7393	020481	trilobites (incl. Ptychagnostus nathorsti, P. punctuosus), sponges, monoplacophoran, calyptotomatid, gastropod, ostracod branchiopods, brachiopods	'Trilobite rock' and Thorne Ck, Cobb Vy	limestone, Tasman	MC	6, 7, 31
LG 2	S13/476		002538	trilobites	Lockett Ra.	limestone, Tasman	(MC)	7
LG 3	S13/475		011478	trilobites	Trilobite Ck, Cobb Vy	limestone, Tasman	(MC)	7
ORDOVICIAN								
LG 4	S2/490, 522-35, 540, 545-6, 548, 552-67, 576-81, 583-90, 593, 596-616	V/1043, 1048, 1321, 1323, 1493, 1554-6, 1558, 1560-8, 1577-80, 1589, 1595, 1597-1600, 1602-4, 1903-4, 1908, 1917-29, 1947-8, 2041-6 GS/431, 547, 740, 7481-94	874997	Adelograptus cf. clarki Tetragraptus approximatus, T. fruticosus, Didymograptus protobifidus, Isograptus caduceus victoriae, I. c. divergens, Oncograptus upsilon, phyllocarids undet.	Aorangi Mine and Slaty Ck area	dark argillite and black chert, Aorangi Mine	LO	4, 15, 22, 30, 32
LG 5	S2/539, 547, 568-9, 571-3, 582, 595, 633-4	V/1322, 1569-74, 1596, 1916, 2066-7 GS/9537	882987	Glyptograptus intersitus, Paraglossograptus etheridgei, Diplograptus decoratus	Slaty Ck	dark argillite, Aorangi Mine	MO	t. p.
LG 6	S2/541-4, 617-31	V/1044-7, 2047-61	872973	Tetragraptus fruticosus, Didymograptus protobifidus, Isograptus caduceus maxima	Sandhills Ck	black chert, dark argillite, Aorangi Mine	LO	t. p.
LG 7	S2/574-5, 591-2, 594	V/1575-6, 1906-7, 1915	887984	Amplexograptus cf. confertus, Dicellograptus sextans exilis	Slaty Ck	dark slate, Aorangi Mine	UO	t. p.
LG 8	S3/527	GS/9505	912024*	Ogygites collingwoodensis	Paturau R.	siltstone, Aorere	UO?	8, 23, 26
LG 9	S3/526	V/1593 GS/9504	909012	Ogygites collingwoodensis, Glyptograptus cf. teretiusculus, Dicellograptus sextans exilis	Paturau R.	siltstone, Aorere	UO	8
LG 10	S3/525	V/1943 GS/9492	925025	brachiopod, trilobites, undet. conodonts	Thompson Ck	limestone, ?	O	8
LG 11	S3/537	V/1590	908017*	Tetragraptus cf. reclinatus	Paturau R.	black chert, ?	LO	t. p.
"	S3/538	V/1944	903002*	diplograptid frags. indet.	Paturau R.	dark slate, Aorere?	UO	t. p.

LG Number	Sheet Fossil Number	Collection Number	Grid Reference	Fossils	General Locality	Lithology, Formation	Age	Reference
"	S3/ -		899025*	brachiopod undet.	Paturau R.	siltstone, Aorere?	?	t.p.
LG 12	S3/540	V/1946	970220*	diplograptids, Dicellograptus sp.	Thompson Ck	dark slate, Aorere?	UO	t.p.
LG 13	S7/516-24	V/1584-8, 2063-5, 2156 GS/9475, 9511	886866	Tetragraptus approximatus, T. fruticosus, Isograptus caduceus victoriae	Elliot Ck	black chert and sandstone, Aorangi Mine?	LO	t.p.
LG 14	S8/485	GS/744	207693	Paleopora inordinata ?	Takaka Vy	limestone, Mt Arthur	UO	4, 13, 15
LG 15	S8/548, 554, 561	V/879 GS/7192, 9342	246739	brachiopod impressions	Rameka Ck	marble, Mt Arthur	(UO)	t.p.
LG 16	S8/549-51	GS/7478-80	947711	Cryptograptus schaferi, Climacograptus antiquus, Glyptograptus teretiusculus	Douglas Ra.	black slate, Leslie	MO	31
LG 17	S8/552	V/653	195640	Plasmoporella cf. inflata, Favistella alveolata, sponges indet.	Sam Ck	limestone, Mt Arthur	UO	13
LG 18	S8/555, 559	V/880, 985	185650	Proheliolites goldfussi	Cotton Ck	limestone, Mt Arthur	UO	13
LG 19	S8/556-8	V/974-5, 980	302609	corals, sponges indet.	Takaka Hill	marble, Mt Arthur	(UO)	13
LG 20	S8/581	V/2155	905864*	Glyptograptus cf. intersitus	17 Mile Ck	phyllite, ?	MO	t.p.
LG 21	S8/582	V/2154	944873*	Phyllograptus sp.	Denton Stm	phyllite, ?	O	t.p.
LG 22	S13/478, 490, 548	V/1583 GS/1230	974366	Dicellograptus sp., Dicranograptus cf. rectus	Leslie R. ('B')	black shale, Leslie	UO	22, 31
LG 23	S13/479, 491	GS/1228	981367	Tetragraptus bigsbii?	Leslie R ('A')	black shale, Leslie	LO?	22, 31
LG 24	S13/480-1	GS/1227, 1229	998479	Dicellograptus spp., Amplexograptus confertus, Dicranograptus cf. nicholsoni, Archaeolafoea serialis	Mt Peel ('A' & 'B')	dark shale, Peel	UO	22, 31
LG 25	S13/482, 520	GS/1231, 7372	955591	Glyptograptus teretiusculus, Glossograptus hinksii, Amplexograptus confertus, Cryptograptus schaferi, Climacograptus antiquus	Lockett Ra. Cobb	black slate, Leslie	MO	22, 31
LG 26	S13/485, 537, 554, 557	V/981, 1661, 1664 GS/444	166393	corals, crinoids indet.	Graham Vy	limestone, Mt Arthur	(UO)	13
LG 27	S13/486, 525, 552	V/1662 GS/1226, 7377	143428	Dicellograptus sextans exilis, Leptograptus sp., Glyptograptus sp.	Lodestone Pk	phyllite, Flora	UO	15, 22, 31
LG 28	S13/487	GS/1232	123423	Dicellograptus sp., Amplexograptus confertus	Flora Track	phyllite, Flora	UO	31
LG 29	S13/488	GS/5927	? *	corals indet.	Upper Takaka	limestone, Mt Arthur ?	(UO)	13
LG 30	S13/512, 522	GS/7364, 7374	955515	Glyptograptus teretiusculus, Amplexograptus confertus, Cryptograptus schaferi, Glossograptus hinksii	Peel Ra.	black shale, Leslie	MO	31

LG Number	Sheet Fossil Number	Collection Number	Grid Reference	Fossils	General Locality	Lithology, Formation	Age	Reference
LG 31	S13/513-4	GS/7365-6	122395	graptolites indet.	Mt Arthur Ra.	phyllite, Flora	(UO)	31
LG 32	S13/515, 523	GS/7367, 7375	965517	Nemagraptus cf. gracilis, Dicellograptus sextans, Azygograptus cf. fasciculatus	Peel Ra.	black shale, Leslie	UO	31
LG 33	S13/516, 519	GS/7368, 7371	957537	Nemagraptus exilis linearis, Dicellograptus sextans, Azygograptus cf. fasciculatus	Chaffey Ridge	black shale, Leslie	UO	31
LG 34	S13/517	GS/7369	118426	graptolites indet.	Flora Track	phyllite, Flora	(UO)	31
LG 35	S13/518	GS/7370	963534	Climacograptus modestus, Pterograptus elegans, Cryptograptus schaferi	Chaffey Ridge	dark shale, Leslie	MO	22, 31
LG 36	S13/521	GS/7373	966565	Nemagraptus gracilis aotearoaensis, Dicellograptus divaricatus, Azygograptus cf. fasciculatus, Triarthrus sp.	Lockett Ra.	black slate, Leslie	UO	31
LG 37	S13/524	GS/7376	945365*	Climacograptus antiquus	Hodge Stm	black shale, Leslie	M-UO	31
LG 38	S13/530	V/970	192557	Streptelasma sp.	Waitui R.	limestone, Mt Arthur	(UO)	13
LG 39	S13/531	V/971	187596	Streptelasma sp.	Takaka R.	limestone, Mt Arthur	(UO)	13
LG 40	S13/532-3, 536	V/972-3, 978	203525	corals, sponges indet., conodonts	Hailes Knob	limestone, Mt Arthur	(UO)	13
LG 41	S13/539	V/984	185582	graptolites indet.	Takaka R.	phyllite, Wangapeka	O-S	36
"	"	"	"	crinoids indet.	Takaka R.	limestone, Mt Arthur	(O-S)	36
LG 42	S13/542-3	GS/9317-8	190450*	crinoids, sponges indet.	Nth. Br. Graham R.	limestone, Mt Arthur	(UO)	t.p.
LG 43	S13/546-7	V/1581-2	968366	Dicellograptus sp., Cryptograptus schaferi, Glossograptus hinksii	Leslie Vy	black shale, Leslie	(UO)	-
LG 44	S13/549	V/1594	234506*	corals indet.	Riwaka R.	limestone, Mt Arthur	(UO)	-
LG 45	S13/551	V/1909	172565	graptolites?	Cobb Rd	grey shale, Wangapeka	(O-S)	t.p.
LG 46	S13/555-6	V/1665, 2040	157386	graptolites indet.	Graham & Pearse Vys	phyllite, Flora	M-UO	t.p.
LG 47	S19/479		932019*	graptolites	Nuggety Ck	slate? Wangapeka?	O-S?	17
LG 48	S19/487-8	GS/445-7	046127	corals, crinoids	Wangapeka Vy	limestone, Mt Arthur	(UO)	25
LG 49	S19/513	GS/7653	929141	Dionide hectori, conodonts	Mt Patriarch	argillite, Patriarch	LO	15, 24, 26
LG 50	S19/515	GS/7655	976190*	trilobites	Blue Duck Stm	argillite, Patriarch	LO	15
LG 51	S19/576, 589	V/861,	053278*	Dicellograptus sp.	Baton R.	black phyllite, Wangapeka	UO	t.p.
LG 52	S19/591	GS/9192	944004	Dicellograptus aff. clingani, Climacograptus cf. bicornis	Nuggety Ck	slate, Wangapeka	UO	21
LG 53	S19/607, 609, 618-21, 632	V/1910, 1912, 1936-9, 2068	956094	Dicellograptus spp. Leptograptus spp., Climacograptus spp.	Wright Ck	black slate, Wangapeka	UO	t.p.

LG Number	Sheet Fossil Number	Collection Number	Grid Reference	Fossils	General Locality	Lithology, Formation	Age	Reference
LG 54	S19/608	V/1911	977063	graptolites	Mt Owen Track	dark shale, Wangapeka	UO	t.p.
LG 55	S19/610, 612, 622-4	V/1913, 1930, 1940-2	954099	Dicellograptus sp., Climacograptus sp.	Wangapeka Vy	dark shale, Wangapeka	UO	t.p.
LG 56	S19/613, 615	V/1931, 1933	962096	Climacograptus bicornis, Leptograptus spp.	Wangapeka Vy	dark shale, Wangapeka?	UO	t.p.
LG 57	S19/614	V/1932	965107	diplograptids undet.	Gibb Stm	dark shale, Wangapeka	UO	t.p.
LG 58	S19/625	-	? *	graptolites indet.	Stony Ck	phyllite, ?	M-UO?	36
LG 59	S26/495	-	? *	graptolites indet.	West Br. Owen R.	slate? ?	O-S?	16
LG 60	S13/529	V/860	113310	trilobites, brachiopods, corals, cephalopod	Price's clearing	argillite, Baton	(D)	37
LG 61	S13/532	V/972	203535*	brachiopods, crinoids	Dry Stm	quartz grit, Hailes Knob	(S)	13
LG 62	S13/534	V/976	335571*	brachiopods indet.	Riwaka R.	quartzite, Onekaka Schist	(S)	13
LG 63	S13/535	V/977	213510	brachiopods undet.	Hailes Knob	sandstone, Hailes Knob	(S)	13
LG 64	S13/538	V/982	231511*	brachiopods indet.	Sth. Br. Riwaka R.	quartzite, Hailes Knob	(S)	13
LG 65	S13/550	V/1905	217527	brachiopods, corals undet.	Hailes Knob	quartz grit, Hailes Knob	(S)	13
LG 66	S13/558		275542	brachiopod indet.	Riwaka Vy	quartzite, Onekaka Schist	(S)	13
LG 67	S19/481, 631	GS/448,	?	brachiopods, crinoids	Clarke R.	quartzite, Ellis?	(S-D)	28
LG 68	S19/491, 566-573 578, 580-1, 586-8	V/855-7, 863, 865-6, 899-901 GS/128, 5878	059273	Pleurodictyum megastomum, brachiopods (incl. Mutationella, Howellella, Fascicostella, Cyrtina), pelecypods, gastropods, sponges, cephalopods, trilobites, crinoids	Baton Vy and Haines Stm	mudstone, calcareous argillite, Baton	D D	2, 15, 28, 38
LG 69	S19/514, 575, 597	GS/7654,	033230	brachiopods, corals	Skeet R.	argillite? Baton?	(D)	38
LG 70	S19/516	GS/7656	989119	brachiopods	Wangapeka Vy	quartzite, Ellis?	(S-D)	28
LG 71	S19/574	V/858	060020*	brachiopods	Fowler Ck	argillite, Baton	(D)	38
LG 72	S19/577	V/862	067280	trilobites	Haines Stm	argillite, Ellis	(S-D)	38
LG 73	S19/579, 585	V/864, 898	068287*	brachiopods, trilobites, corals	Paddy's Stm	argillite, Baton	D	38
LG 74	S19/582, 590	V/867, 903	055263	brachiopods	Moran Ck	argillite, Baton	D	38
LG 75	S19/596, 616-7	V/1934-5, 1971	976095	Pleurodictyum, brachiopods, trilobites, molluscs	Rolling R. - Wangapeka R. ridge	quartzite, Ellis	D	28

Reference numbers refer to list of references at end of paper; underlining of numbers indicates that the fauna is described or listed in the reference cited. C, Cambrian; O, Ordovician; S, Silurian; D, Devonian; U, upper; M, middle; L, lower; ages in parentheses based on stratigraphy.

* Boulder; t.p., locality described in this paper; indet., indeterminate; undet., undetermined.

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approximatus (Nich.), *T. fruticosus* (Hall), *Didymograptus protobifidus* Elles, *Isograptus caduceus victoriae* Harris, *I. caduceus divergens* Harris, *Oncograptus upsilon* T. S. Hall, *Glyptograptus intersitus* Harris and Thomas, *Paraglossograptus etheridgei* (Harris), *Diplograptus decoratus* Harris and Thomas, *Amplexograptus* cf. *confertus* (Lapw.), *Dicellograptus sextans exilis* Elles and Wood.

S3. *Paturau Valley* (LG 11, LG 12, in Table I). Two to three miles north-east of Aorangi Mine several fossiliferous pebbles have been found in Paturau River and in its tributary Thompson Creek. A pebble of black chert containing a specimen of *Tetragraptus* cf. *reclinatus* Elles and Wood, indicating a Lower Ordovician age, was found by B. Stainton (Victoria University) in May, 1966, in Paturau River, a few chains upstream from the mouth of Thompson Creek. Pebbles of dark slate containing Middle or Upper Ordovician diplograptids were found in Paturau River two miles upstream from Thompson Creek, by the writer in January, 1967. At the same time he found slate pebbles containing specimens of diplograptids and of the typically Upper Ordovician genus *Dicellograptus* in Thompson Creek, a few chains upstream from its mouth. The pebbles in Thompson Creek were traced upstream to outcrops of dark slate containing graptolite fragments in the east bank, 40 chains from the mouth, but the source of the Paturau River pebbles—both those found by the writer and those found by Stainton—remains unknown.

A pebble of grey slate containing the impression of an articulate brachiopod of uncertain age was found in Paturau River at the mouth of Thompson Creek by D. C. Mildenhall (Victoria University) and D. G. Bishop, in March, 1967. Its source is unknown.

Several fossils have already been reported from these two streams. The trilobite *Ogygites collingwoodensis* Reed, from a boulder in Paturau River, was described by Reed in 1927 (LG 8, in Table I). A fauna of trilobites and graptolites from grey siltstone boulders and outcrops in Paturau River, two miles upstream from Thompson Creek (LG 9, in Table I), was reported by Bishop in 1965. The fauna includes specimens of *Dicellograptus* cf. *sextans exilis* Elles and Wood and *Ogygites collingwoodensis* Reed (A. J. Wright, pers. comm.) suggesting an Upper Ordovician age.

A lens of limestone in Thompson Creek one mile upstream from its mouth contains fragments of small shells (Bishop, 1965) and conodonts of probable Ordovician age (A. J. Wright, pers. comm.). Unfortunately its stratigraphic relationship with the graptolite-bearing dark slate farther downstream is unknown.

S7 and S8. *Elliot Creek, Aorere Valley* (LG 13, LG 20, LG 21, in Table I). Black slate boulders containing graptolites were found in Elliot Creek by H. W. Wellman and students of Victoria University during a field trip in May, 1963, and traced to outcrops at a 20ft waterfall about two miles upstream from the Aorere Valley Road. At the same time an incomplete specimen resembling *Glyptograptus intersitus* Harris and Thomas, of Middle Ordovician age, was found in a pebble in 17 Mile Creek, one mile to the north-east.

A single pebble containing a poorly preserved specimen of *Phyllograptus* was collected from Denton Stream, near the road bridge a few miles to the north-east of Elliot Creek, by the writer in 1965. Graptolites were later collected from several localities in Elliot Creek and its tributaries. The fossiliferous rocks range from hard, siliceous, black slate to massive, moderately soft, blue-grey argillite. Important zonal graptolites include *Tetragraptus approximatus* (Nich.), *T. fruticosus* (Hall), and *Isograptus caduceus maxima* Harris, suggesting that much of the Lower Ordovician is represented. The fossiliferous rocks and fossils closely match those in the lower part of the sequence at Aorangi Mine and Slaty Creek, 10 miles to the north.

S8. *Rameka Creek* (LG 15, in Table I). Poorly preserved brachiopod impressions were found by J. E. Braithwaite, of Lime and Marble Ltd., Mapua, in April, 1964, in outcrops of dark crystalline limestone one chain north of a logging track,

half-a-mile south of the junction of the logging track and Rameka Creek, about five miles south-east of Takaka. Boulders of similar limestone containing indeterminate crinoid fragments were found in Rameka Creek and in Dry River, to the north, by members of Victoria University field trips during 1961 and 1962. The limestone was mapped as Mount Arthur Marble (Upper Ordovician) by Grindley (1961).

S13. *North Branch, Graham River* (LG 42, in Table I). Indeterminate coral and crinoid fragments collected from marble boulders in the north branch of Graham River, near Mount Crusader, by D. J. Stanton, of the Cawthron Institute, Nelson, in 1963. The boulders are probably derived from rocks outcropping in the headwaters of the north branch which were mapped as Mount Arthur Marble (Upper Ordovician) by Grindley (1961). Corals were earlier reported by McKay (1879) from crystalline limestone in the south branch of Graham River (LG 26, in Table I).

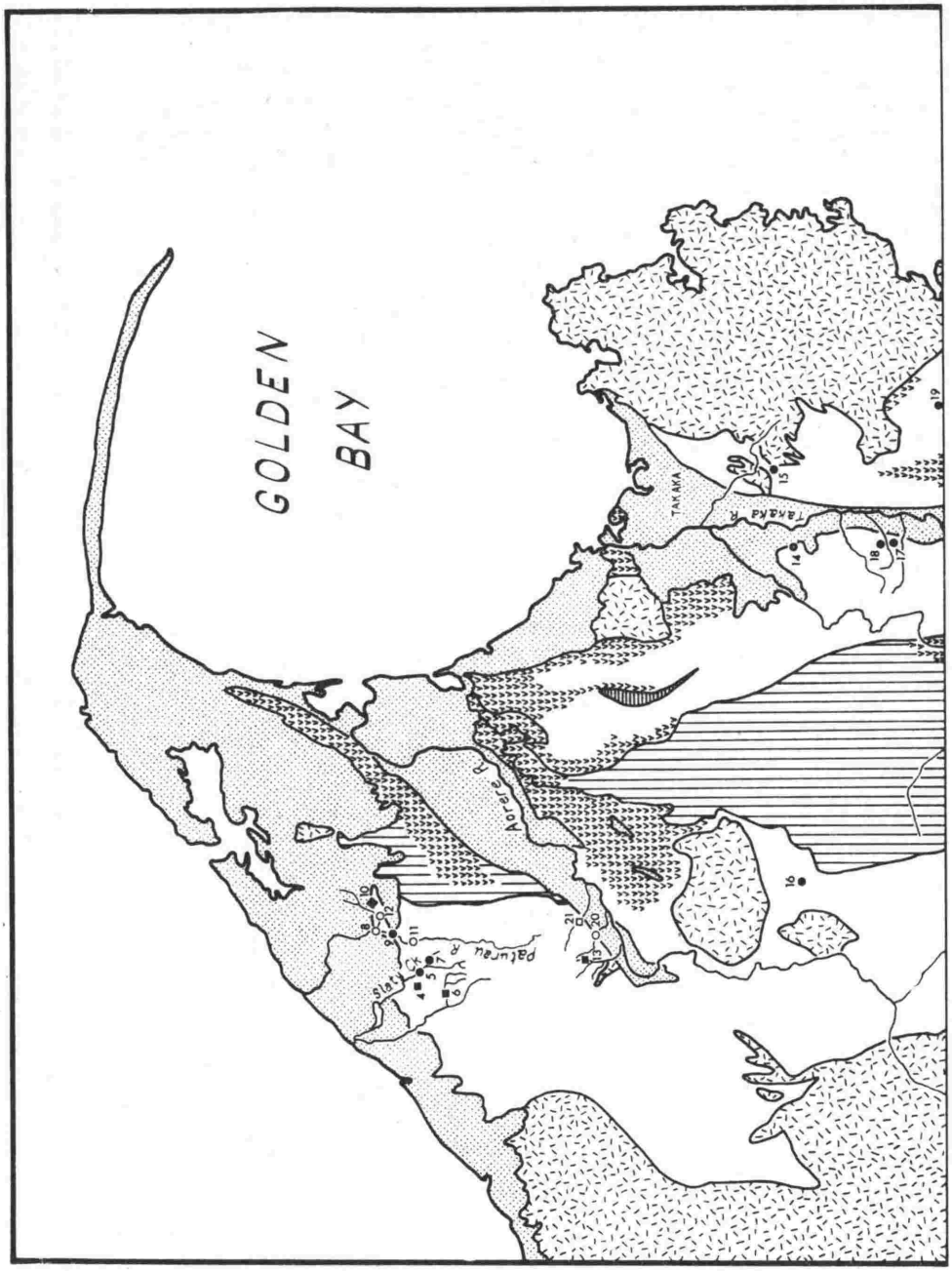
S13. *Cobb Road* (LG 45, in Table I). Poorly preserved fragments of what are probably graptolites were found by the writer in May, 1966, in phyllitic grey shale in a road-cutting half-a-mile north-east of Sam Creek, on the road to Cobb Power Station. One-and-a-half miles to the east, Wellman (1962) reported poorly preserved graptolites in the east bank of Takaka River (LG 41, in Table I). The rocks at both localities were mapped by Grindley (1961) as Wangapeka Formation. If the fossils are actually graptolites they indicate an Ordovician to basal Devonian age.

S13. *Graham Valley Area* (LG 46, in Table I). Poorly preserved, indeterminate diplograptid graptolites were found in spotted, black, cleaved slate on the ridge between Graham and Pearse Valleys, and in boulders in the Pearse Valley, by M. R. Johnston (Victoria University), who is at present mapping the area. They are Middle or Upper Ordovician in age, probably Upper Ordovician—the same age as the nearby graptolites of Mount Lodestone (LG 27) described by Keble and Benson (1929) and by Skwarko (1962).

S19. *Baton Valley* (LG 51, in Table I). Poorly preserved graptolites, including a large specimen of *Dicellograptus* sp. and diplograptid forms, were found in boulders of dark, strongly cleaved slate in Baton River between White Creek and Loveridge Creek, and also in Loveridge Creek, by H. W. Wellman, I. Willis, and the writer during the summer of 1961. Further graptolite fragments occur in nearby outcrops in the northern bank of Baton River (H. W. Wellman, pers. comm.) in rocks mapped by Grindley (1961) as Wangapeka Formation and considered to be of Silurian age. In Victoria, the larger forms of *Dicellograptus* are confined to the Upper Ordovician, and if the outcrops mentioned by Wellman are the source of the boulders containing this fossil, an Upper Ordovician age is likely for the Wangapeka Formation at this locality.

In Baton River Grindley has mapped a conformable sequence between the Wangapeka Formation and the well known fossiliferous Devonian Baton Formation, but according to Willis (1965) the sequence is faulted.

S19. *Wangapeka Valley* (LG 52–56, in Table I). Poorly preserved graptolites were reported in slate and phyllite boulders in two creeks in Wangapeka Valley–Nuggety Creek (LG 47) and Wright Creek (LG 53)—by Henderson, Grange, and Macpherson (1924). Phyllite boulders with poorly preserved graptolites were found in Wangapeka River, one mile downstream from Rolling River junction, by H. W. Wellman and the writer in 1962. In 1965 outcrops of dark argillite with well-preserved graptolites were found in the valley side south of Wangapeka River, 10 chains downstream from the mouth of Wright Creek, by G. T. Hancox and A. J. Wright (Victoria University).


GOLDEN
BAY
TAKAKA
TAKAKA R.
Aorere R.
Paturau R.
Slate Cr.
M
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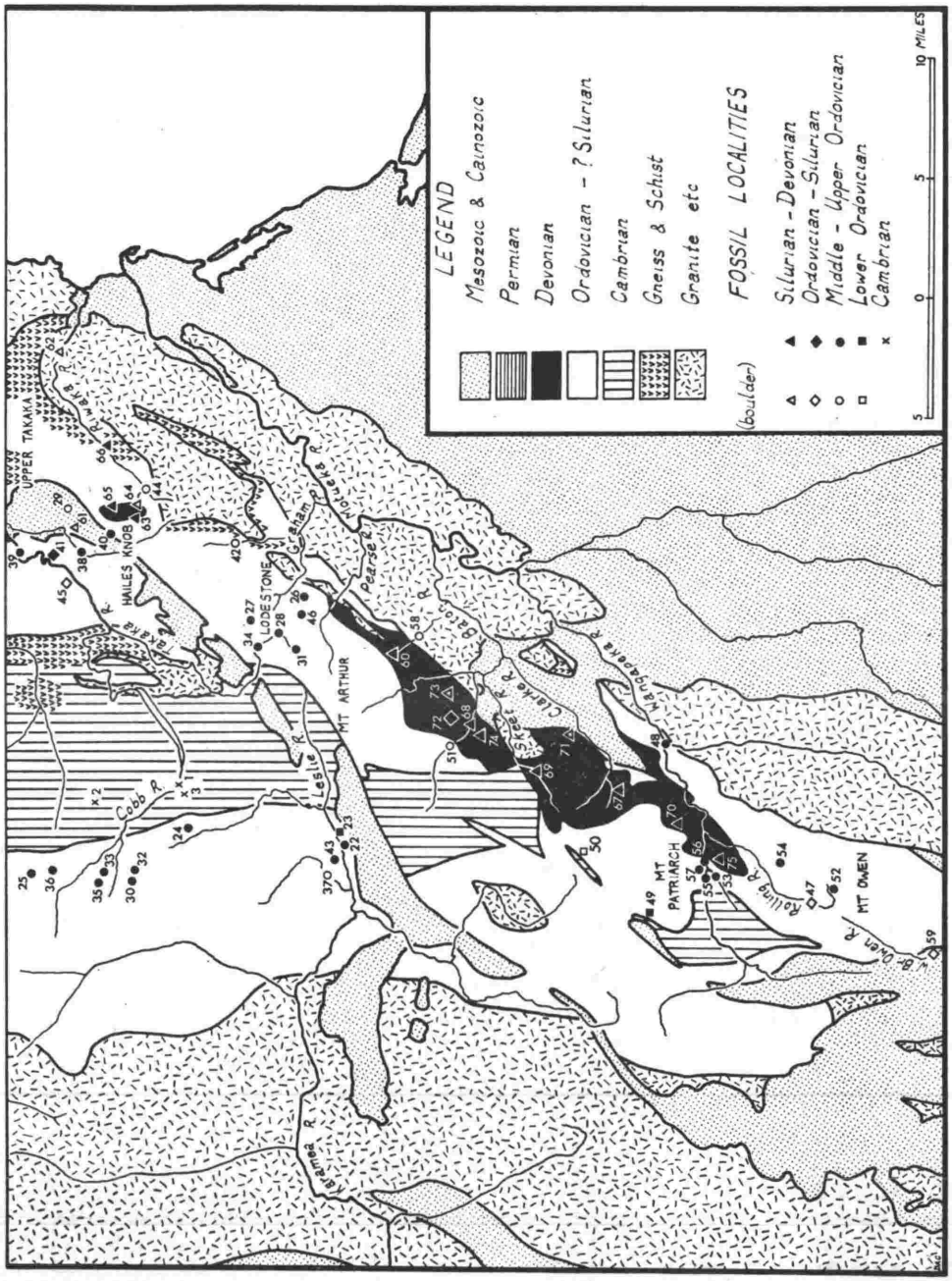

FIG. 2.—Distribution of Cambrian to Devonian fossil localities in North-west Nelson. Geology from Grindley (1961) and Waterhouse and Vella (1965).

The writer and D. S. Ker (N.Z. Geological Survey) have since found several more graptolite localities in the Wangapeka River and its tributaries. The fossiliferous beds are dark cleaved argillites and, from their lithology, are probably part of Grindley's Wangapeka Formation. The graptolites include *Climacograptus bicornis* (Hall), *Dicellograptus* spp., *Orthograptus* spp., and *Glyptograptus teretiusculus* (Hisinger), and indicate an Upper Ordovician age.

Upper Ordovician graptolites have also been recorded from similar beds at Mount Owen (LG 54, in Table I) by Johnston, Laird, and Skwarko (1965).

STRATIGRAPHIC RANGE AND GEOGRAPHIC DISTRIBUTION

The fossils comprise three distinct age groups. The oldest consists of the late Middle Cambrian fossils from Cobb Valley (Benson, 1956). Five fossiliferous limestone lenses have been found within rocks of the Haupiri Group. Fossils include trilobites, brachiopods, gastropods, a monoplacophoran, a calyptotomatid, ostracods, branchiopods, fragments of sponges and crinoids, and annelid tubes.

The second age group spans the Ordovician Period. Lower Ordovician graptolites are known from the Aorangi Mine area (Benson and Keble, 1936; Skwarko, 1961; Smith, 1966) and from Elliot Creek, Aorere Valley (this paper), and a trilobite from Mount Patriarch has been thought to be Lower Ordovician by Kobayashi (1940). Middle and Upper Ordovician graptolites are known from the Aorangi Mine area (this paper), and from the Cobb Valley–Mount Arthur area (Keble and Benson, 1929; Benson and Keble, 1936; Skwarko, 1962). Upper Ordovician graptolites are known from Mount Owen and Wangapeka Valley (Johnston, Laird, and Skwarko, 1965; this paper). Upper Ordovician corals, sponges, stromatoporids, and crinoid fragments are recorded from the Upper Takaka area (Benson and Keble, 1936; Cooper, 1965), and corals and crinoids of probable Upper Ordovician age are reported from the Graham and Wangapeka Valleys (McKay, 1879). The trilobite from Paturau Valley described by Reed (1927) as probably Lower Ordovician is now thought to be Upper Ordovician. A fauna of brachiopods, corals, and crinoids from quartzite at Hailes Knob (Cooper, 1965) is Upper Ordovician or possibly Silurian.

No definitely Silurian fossils have yet been found in New Zealand, and the third age group comprises the Lower Devonian fossils between Baton River and Wangapeka Valley. The fossils are brachiopods, pelecypods, gastropods, sponges, corals, polyzoans, trilobites, and crinoid fragments, and have been described by Shirley (1938), revised lists being given by Allan in 1947 and Willis in 1965.

No Middle Devonian, Upper Devonian, or Carboniferous fossils are known in North-west Nelson, but it is of interest to note the recent discovery of a mid-Permian fauna of polyzoans, brachiopods (including *Stropholosia minima* Maxwell and two spiriferids), pelecypods, gastropods, and crinoids at Parapara Peak (Waterhouse and Vella, 1965). Further important fossil localities may yet be found.

Geographic distribution of fossil localities is shown in Fig. 2. Although much of the Middle Cambrian to Lower Devonian is represented by fossiliferous rocks, large areas of sedimentary rocks inferred to be of this age-range are without evident fossils. The unfossiliferous rocks are mostly siliceous and non-graphitic; they include siltstones, sandstones, massive quartzites, argillites, and tuffaceous beds. In contrast the fossiliferous rocks are predominantly muddy, graphitic, or calcareous. The relative paucity of fossil localities in the more inaccessible west and central parts of the sedimentary belt (Fig. 2), however, probably partly reflects the lack of detailed mapping in these areas.

OTHER NEW ZEALAND FOSSIL LOCALITIES

The remaining New Zealand Lower and Middle Paleozoic fossil localities are confined to three separate areas. The first, near Reefton, contains the well known Devonian beds, fossiliferous at several localities and horizons. The beds have been mapped most recently by Suggate (1957) and the fossils have been described by Allan (1935; 1947), Hill (1956), Boucot *et al.* (1963), and Gill *et al.* (1966). The fossils are brachiopods, including *Acrospirifer coxi* (Allan), *Pleurothyrella venusta* Boucot *et al.*, *Reeftonia marwicki* Allan, *Maoristrophia neozelanica* (Allan), molluscs, polyzoans, echinoderms, trilobites, ostracods, and corals. Hill considered the corals to indicate a Couvinian (Middle Devonian) age, whereas the brachiopods, which come mainly from lower in the sequence, suggest an Emsian (Lower Devonian) age (Gill *et al.*, 1966).

The second area lies between Alfred River and Station Creek, near Maruia Springs Junction. Wellman (1962) has recorded Upper Ordovician graptolites in boulders of strongly cleaved argillite from Alfred River and poorly preserved graptolites in boulders in Station Creek, 10 miles to the north. The fossils from Alfred River include diplograptids and the typically Upper Ordovician genera *Dicellograptus* and *Dicranograptus*.

The third area of localities includes the graptolite-bearing strata at Preservation and Chalky Inlets and at Cape Providence, Fiordland. Benson and Keble (1935) have described the graptolites and a sponge, and revised earlier descriptions; Skwarko (1958) has listed some graptolites in later collections from Cape Providence and described some new material. The graptolites indicate that much of the Lower Ordovician is represented. Brachiopods and phyllocarids (Crustacea) were described by Chapman (1934a; 1934b).

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Plate 1.

Fig.1. Adelograptus clarki (T.S.Hall). Complete rhabdosome, adelograptid fragments superposed, x 3. GR73, locality S2/527, Aorangi Mine. Adelograptus zone.

Fig.2. Dictyonema pulchellum T.S.Hall. Distal part of large rhabdosome, x 1.5. GR101, locality S2/534, Aorangi Mine. Adelograptus zone.

Figs 3,4. Adelograptus? antiquus (T.S.Hall). Fig.3, complete rhabdosome, x 5, Zfg6.2. Fig.4, proximal portion of broken rhabdosome, x 10, Zfg6.1. Locality S2/641, Aorangi Mine. Adelograptus zone.

Fig.5. Clonograptus aff.regularis (Tornquist), x 1.25. Zfg6.3, locality S2/641, Aorangi Mine. Adelograptus zone.

Fig.6. Bryograptus? sp. Proximal fragment, x 5. VG135, locality S2/526, Aorangi Mine. Adelograptus zone.

Fig.7. Anisograptus? sp. Complete rhabdosome; s,sicula. x 3. GR74, locality S2/527, Aorangi Mine. Adelograptus zone.

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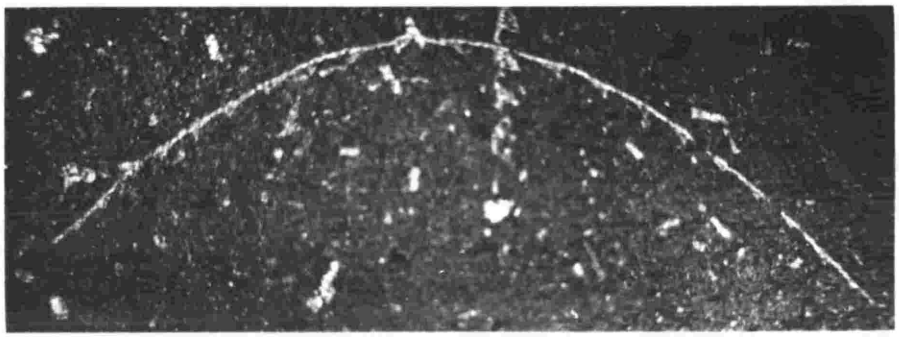

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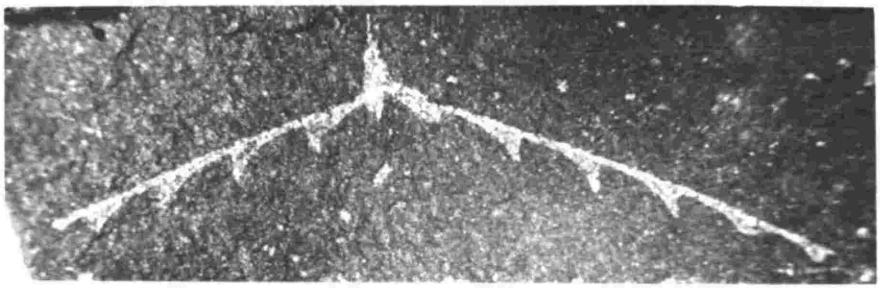

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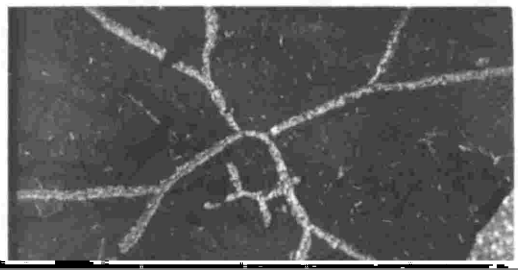

Plate 2.

Figs 1,2. Loganograptus logani (J.Hall). Fig.1, rhabdosome with superposed fragments of Isograptus and Tetragraptus, x 2. GR44, locality S2/582. I.c.maximodivergens zone. Fig.2, incomplete leached rhabdosome with superposed specimen of Glyptograptus austrodentatus? and dichograptid stipes, x 2. GR47, locality S2/582. P.etheridgei zone. Aorangi Mine.

Fig.3. Pterograptus? sp. x 2. GR66, locality S2/633, Aorangi Mine. D.decoratus zone.

Fig.4. Pseudobryograptus parallelus Mu. x 5. GR50, locality S2/582, Aorangi Mine. P.etheridgei zone.

Fig.5. Adelograptus aff.pusillus (Ruedemann), x 5. VG106, locality S2/579, Aorangi Mine. I.c.lunata zone.

Fig.6. Loganograptus logani cf.pertenuis Ruedemann. Incomplete rhabdosome showing 4th-order stipes, x 2.1. GR33, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.7. Sigmagraptus laxus (T.S.Hall). x 3. VG103, locality S2/564, Aorangi Mine. D.protobifidus zone.

Fig.8. Pseudobryograptus incertus (Harris and Thomas). Incomplete rhabdosome, x 2. GR77, locality S2/582, Aorangi Mine. P.etheridgei zone.

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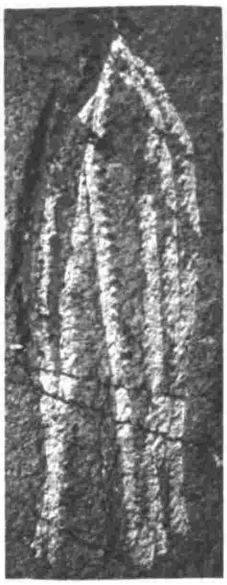

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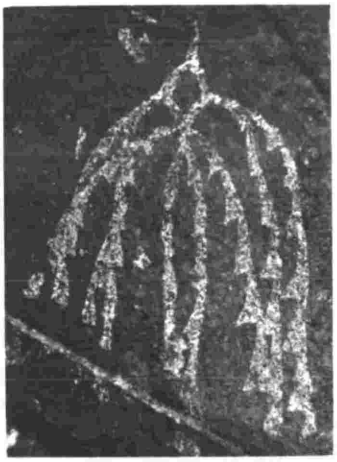

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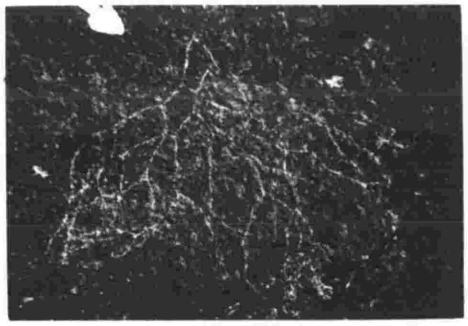

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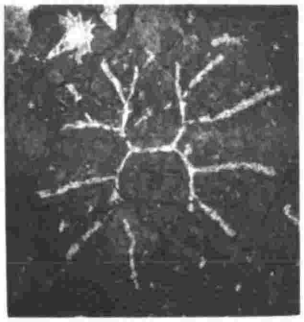

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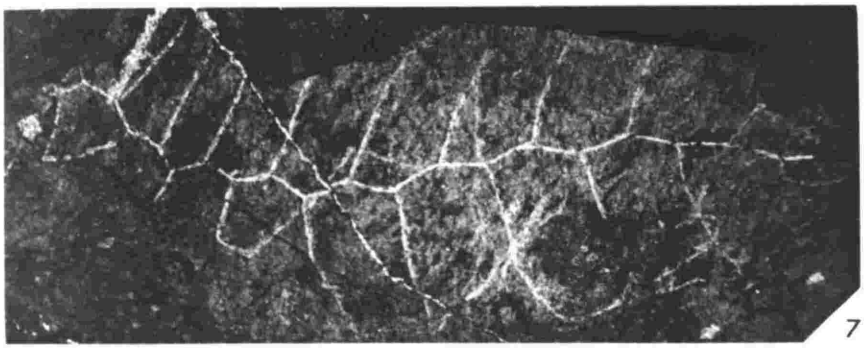

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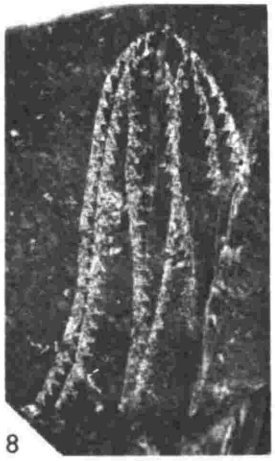

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Plate 3.

Fig.1. Goniograptus speciosus T.S.Hall. Incomplete rhabdosome, x 1.5. GR14, locality S2/540, Aorangi Mine. Oncograptus zone.

Fig.2. Tetragraptus quadribrachiatus (J.Hall). Poorly preserved rhabdosome, x 1. GR76, locality S7/516, Elliot Creek. T.fruticosus zone.

Fig.3. Goniograptus macer T.S.Hall. Complete rhabdosome, x 2. GR36, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.4. Goniograptus thureaui (McCoy), Incomplete rhabdosome, x 2. GR43, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.5. Dichograptus octonarius (J.Hall). Complete seven-stiped rhabdosome, x 2. VG91, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.6. Dichograptus maccoyi Harris and Thomas. Incomplete rhabdosome, x 5. GR80, locality S2/600, Aorangi Mine. I.c.lunata zone.

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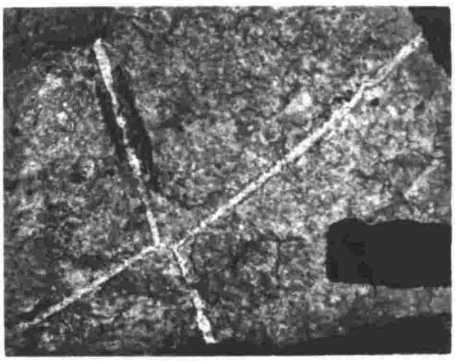

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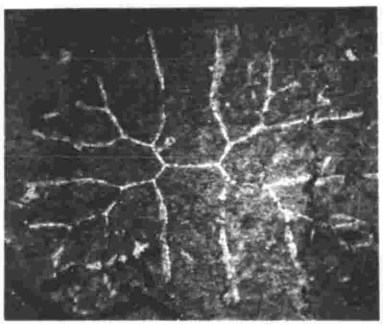

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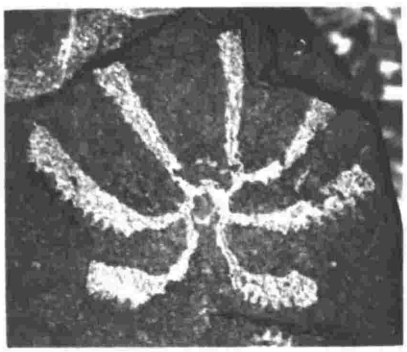

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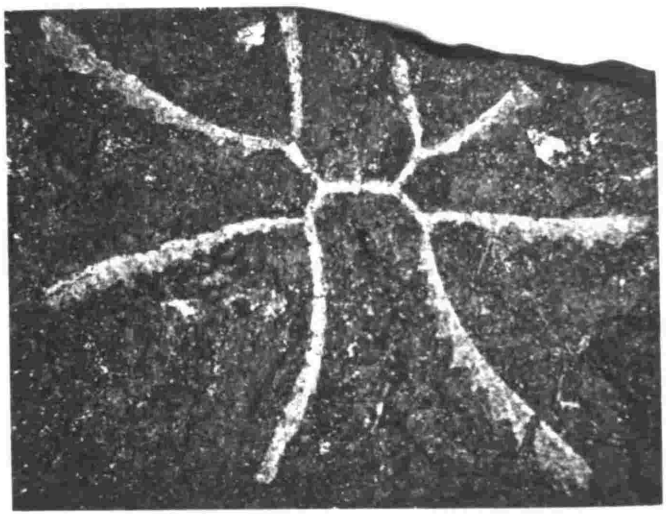

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Plate 4.

Figs 1,8. Tetragraptus approximatus Nicholson. Fig.1, complete rhabdosome, x 1.5. VG5, locality S2/541. Fig.8, incomplete rhabdosome, with bent stipes, x 2. VG134, locality S2/590. Aorangi Mine. T.approximatus zone.

Figs 2,5,7. Tetragraptus fruticosus (J.Hall). Fig.2, proximal portion of 3-stiped form, x 5. VG21, locality S2/606, Aorangi Mine. D.protobifidus zone. Fig.5, incomplete 4-stiped form, x 2. VG23, locality S2/628, Aorangi Mine. T.fruticosus zone. Fig.7, 3-stiped form, with Phyllograptus anna, x 2. VG22, locality S2/626, Aorangi Mine. T.fruticosus zone.

Fig.3. Tetragraptus cf.pendens Elles. Complete rhabdosome, x 5. VG110, locality S2/628, Aorangi Mine. T.fruticosus zone.

Fig.4. Phyllograptus anna J.Hall. x5. GR81, locality S2/586, Aorangi Mine. D.protobifidus zone.

Fig.6. Tetragraptus pendens Elles. x 5. VG109, locality S2/628, Aorangi Mine. T.fruticosus zone.

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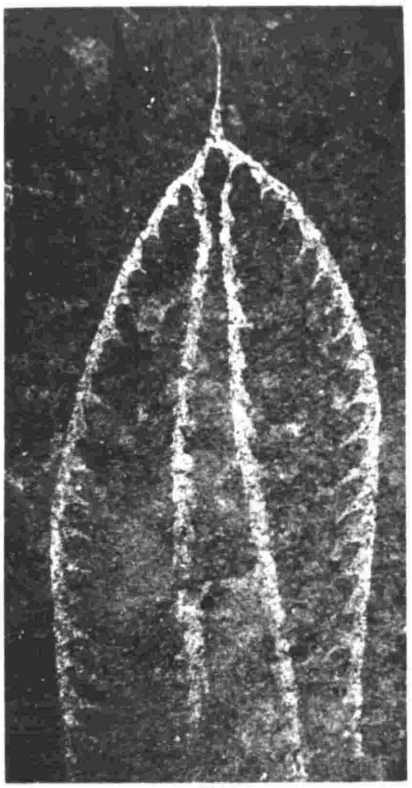

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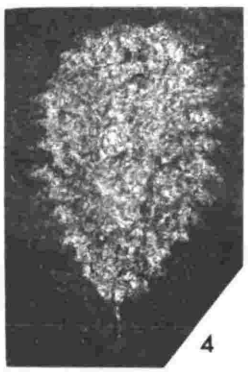

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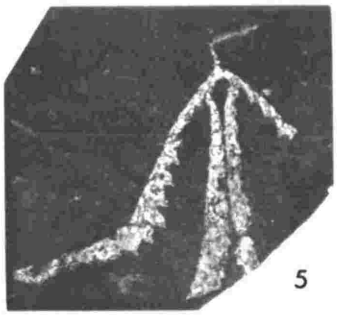

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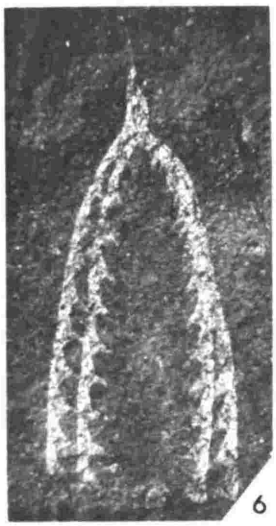

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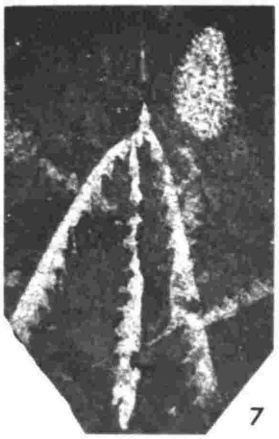

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Plate 5.

Figs 1,2,5. Tetragraptus decipiens T.S.Hall (3-stiped form). Fig.1, rhabdosome in which the two second-order stipes lie superposed, x 7.5. VG10, locality S2/577. Fig.2, incomplete rhabdosome, x 5. VG9, locality S2/590. Fig.5, incomplete rhabdosome, x 5. VG4, locality S2/590. Aorangi Mine. T.approximatus zone. The three specimens, figs 1,2, and 5, are figured by Bulman and Cooper (in press,pl.1)figs 2,4, and 1, respectively.

Fig.3. Tetragraptus acclinans Keble. Incomplete rhabdosome, x 1. VG6, locality S2/577, Aorangi Mine. T.approximatus zone.

Fig.4. Tetragraptus decipiens T.S.Hall (4-stiped form), x 5. VG2, locality S2/613, Aorangi Mine. T.approximatus zone. Figured by Bulman and Cooper (in press, pl.1,fig.3).

Fig.6. Tetragraptus harti T.S.Hall. Immature rhabdosome, x 5. GR78, locality S2/586, Aorangi Mine. D.protobifidus zone.

Fig.7. Tetragraptus amii Lapworth. Incomplete rhabdosome, x 2. GR53, locality S2/552, Aorangi Mine. I.c.maximo-divergens zone.

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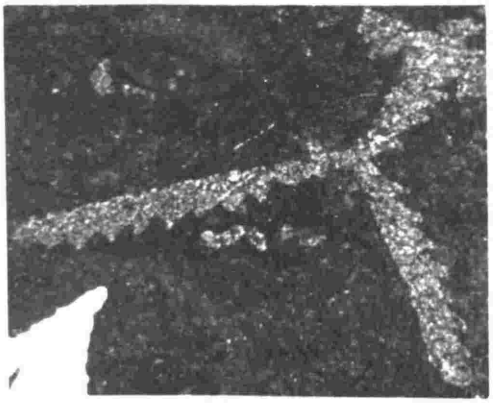

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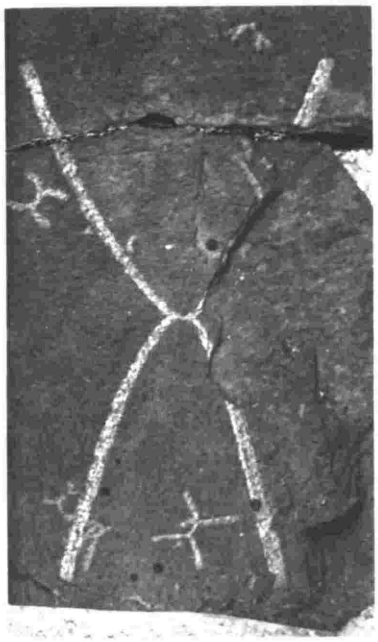

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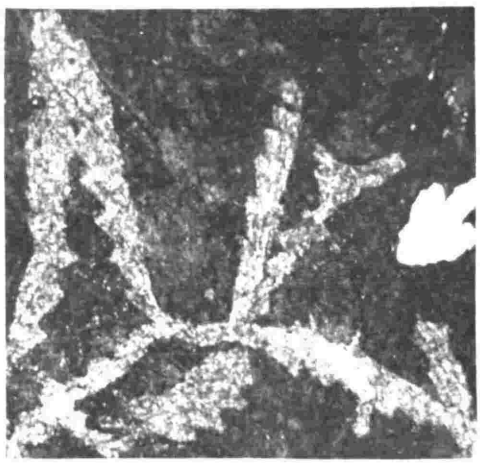

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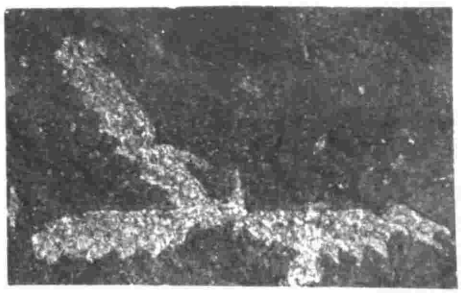

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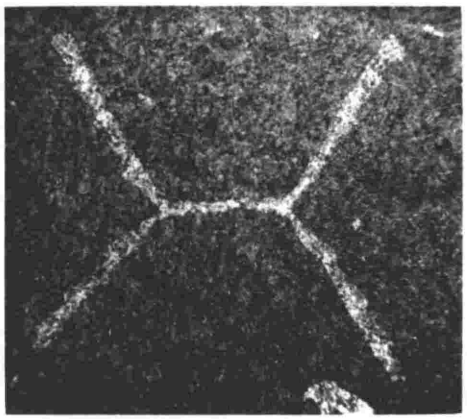

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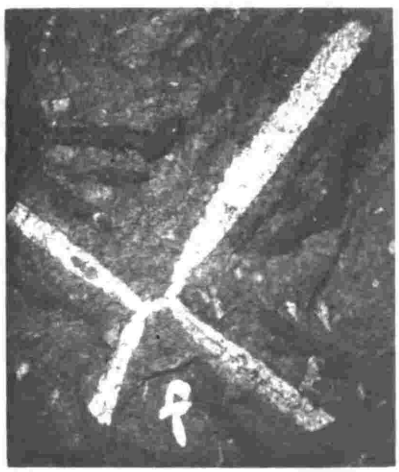

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Plate 6.

Fig.1. Tetragraptus reclinatus Elles and Wood, x 3. GR79, locality S2/600, Aorangi Mine. I.c.lunata zone.

Figs 2,5. Tetragraptus bigsbyi J.Hall. Fig.2 x 5, VG8. Fig.5, x 5, VG92. Both from locality S2/580, T.fruticosus zone.

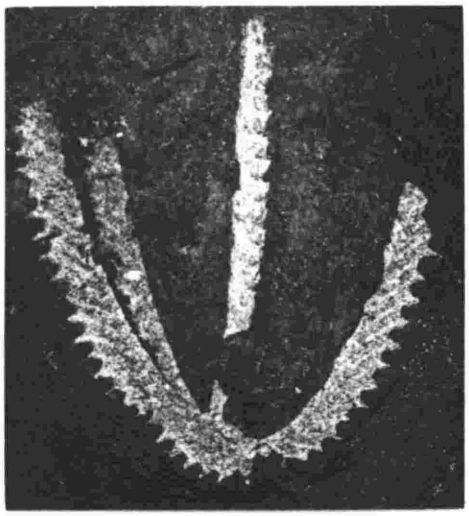
Figs 3,4,8. Tetragraptus aff.taraxacum Ruedemann. Fig.3, rhabdosome in which the stipes have been bent during flattening, x 5, GR38. Fig.4, x 5, GR40. Fig.8, x 5, GR39. All from locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.6. Tetragraptus sp. Specimen with stipes resembling those of T.serra, or T.bigsbyi, but with a distinct "funicle". x 3. GR45, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Figs 7,11. Tetragraptus cf.serra (Brongniart). Fig.7, early growth stage, x 4, GR41. Fig.11, mature rhabdosome, with juvenile specimens of I.c.maximodivergens. x 2, GR52. Both from locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.9. Tetragraptus serra (Brongniart), x 2. GR88, locality S2/586, Aorangi Mine. D.protobifidus zone.

Fig.10. Tetragraptus aff.serra (Brongniart), x 1.5. GR97, locality S2/580, Aorangi Mine. ?T.fruticosus zone.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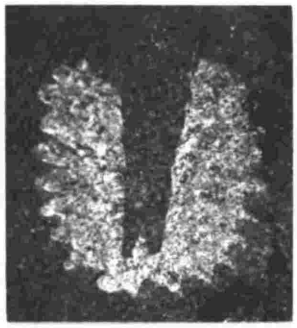
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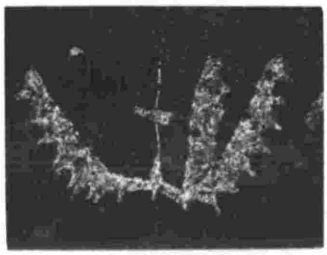
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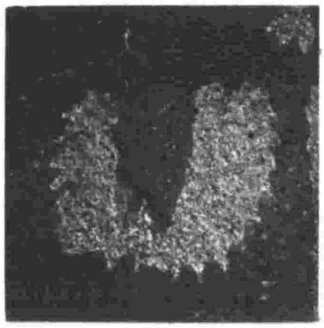
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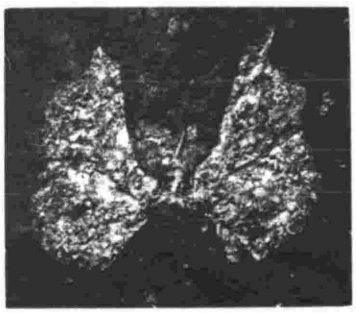
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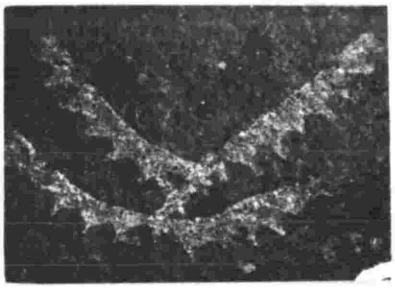
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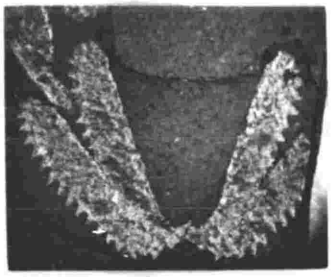
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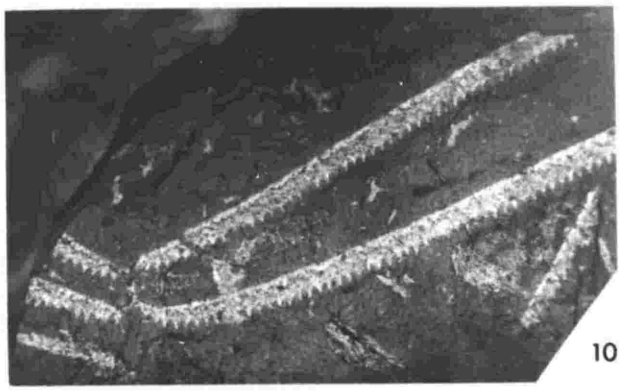
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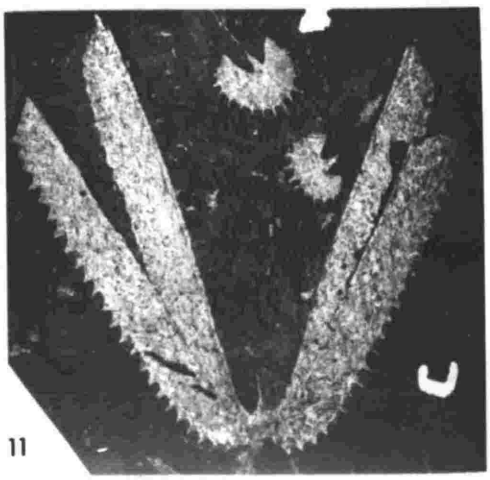
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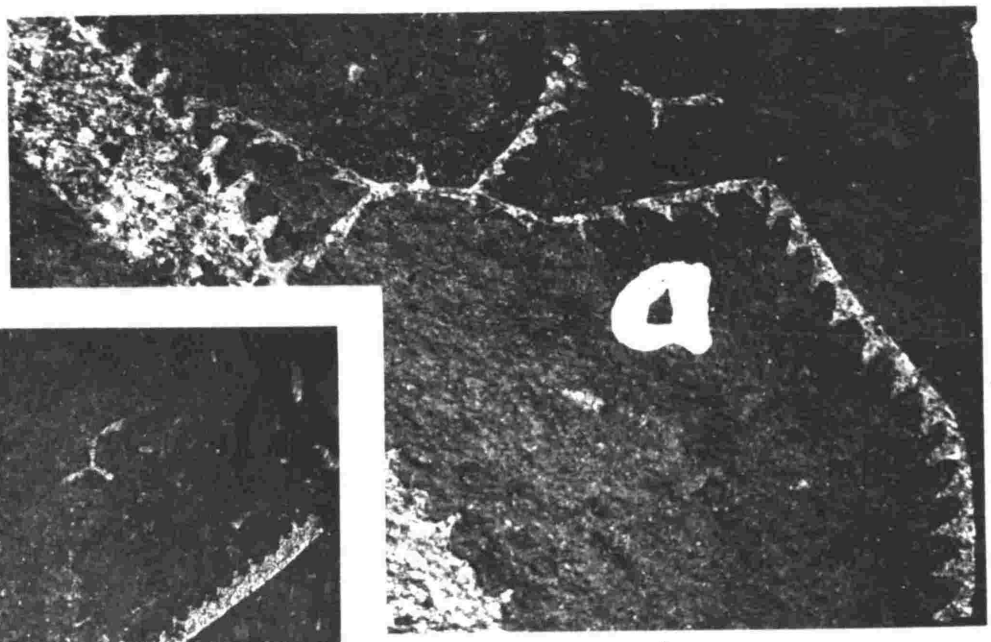
Plate 7.

Fig.1. Tetragraptus aff. chapmani Keble and Harris. Proximal part of rhabdosome, x 5, with slight tectonic distortion, the relative shortening direction being from top to bottom of page. ~~vertical~~. VG93.

Fig.2. Tetragraptus quadribrachiatus (J.Hall). Specimen showing the "central disc", and corresponding to T.projectus T.S.Hall, x 2. GR34.

Fig.3. Tetragraptus headi (J.Hall). Incomplete rhabdosome, x 1.5. GR35.

All from locality S2/552, Aorangi Mine. I.c.maximodivergens zone.



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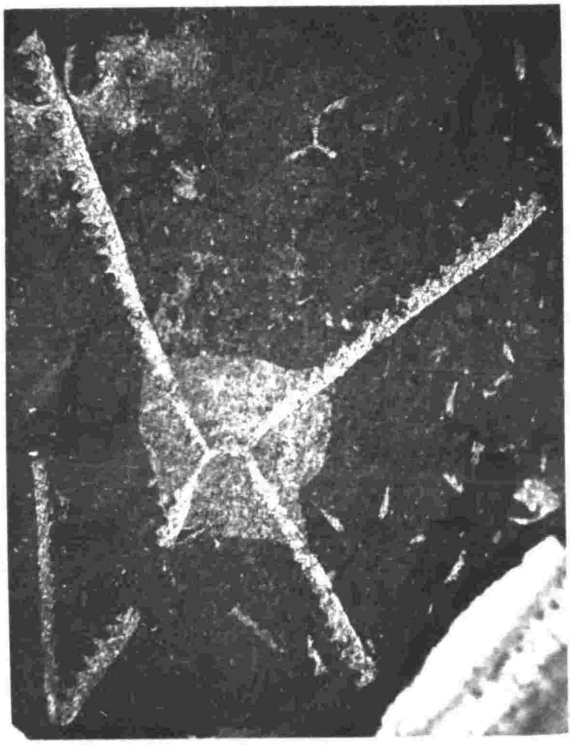

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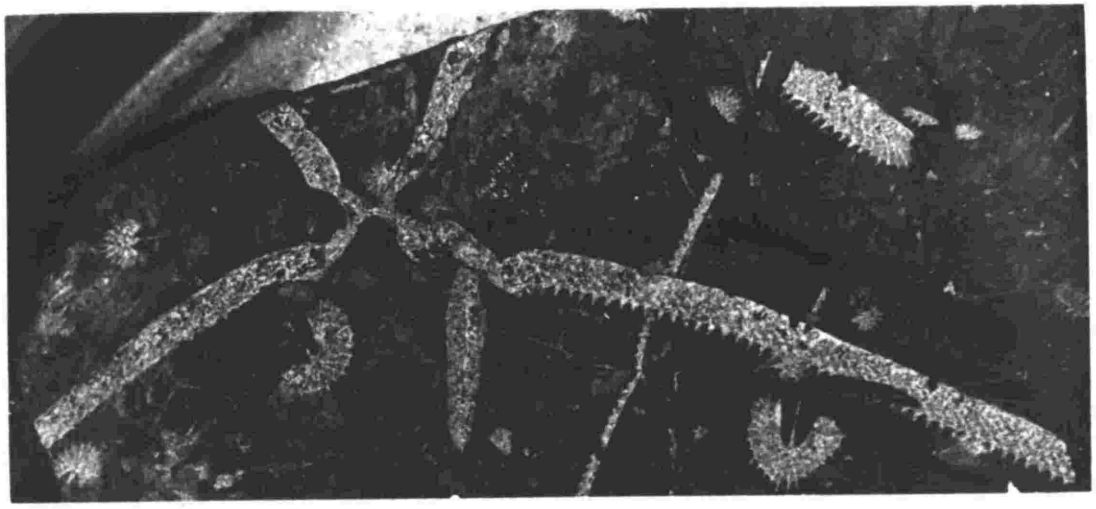

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Plate 8.

Fig.1. Phyllograptus typus Hall, x 3. VG98, locality S2/579, Aorangi Mine. I.c.lunata zone.

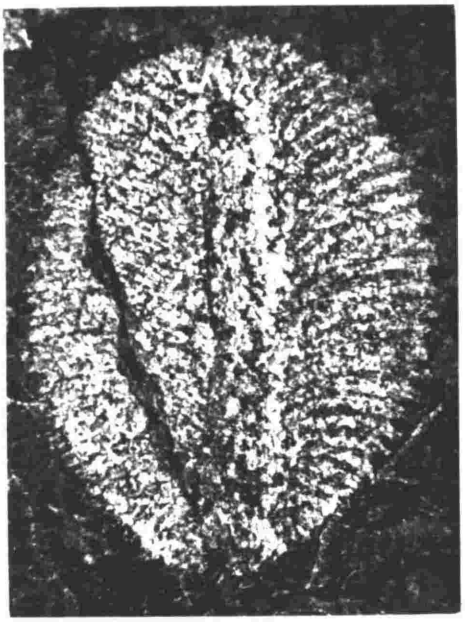
Fig.2. Phyllograptus angustifolius angustifolius J.Hall, x 3. VG99, locality S2/579, Aorangi Mine. I.c.lunata zone.

Fig.3a-b. Phyllograptus angustifolius elongatus Bulman. Fig.3a, proximal portion of broken rhabdosome. Fig.3b, distal portion of counterpart of same rhabdosome lying adjacent to its original position with respect to the proximal portion. x 3. GR62, locality S2/633, Aorangi Mine. D.decoratus zone.

Fig.4. Didymograptus protobifidus - bifidus transient. Incomplete rhabdosome, x 5. VG25, locality S2/606, Aorangi Mine. D.protobifidus zone.

Figs 5,6. Didymograptus protobifidus Elles. Fig.5, mature rhabdosome, x 5. GR1, locality S2/586. Fig.6, immature rhabdosome, x 5. VG28, locality S2/564. Both from Aorangi Mine, D.protobifidus zone.

Fig.7. Phyllograptus anna J.Hall, x 6. VG104, locality S2/564, Aorangi Mine. D.protobifidus zone.



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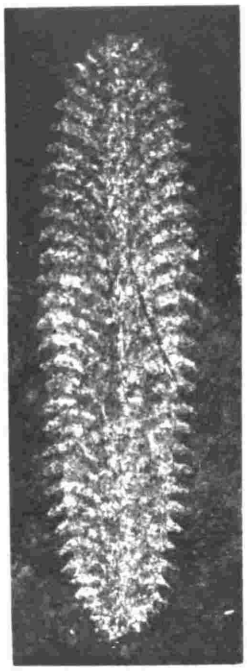

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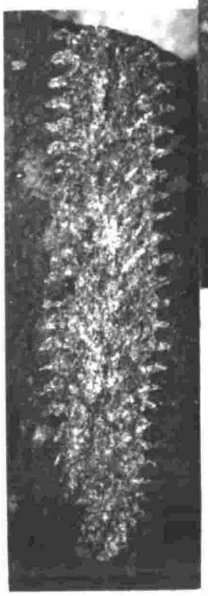

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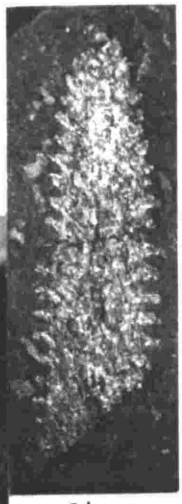

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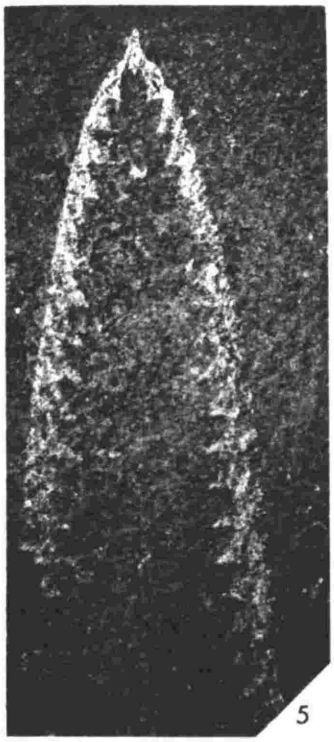

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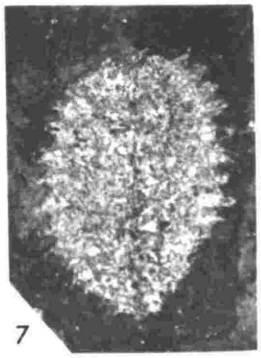

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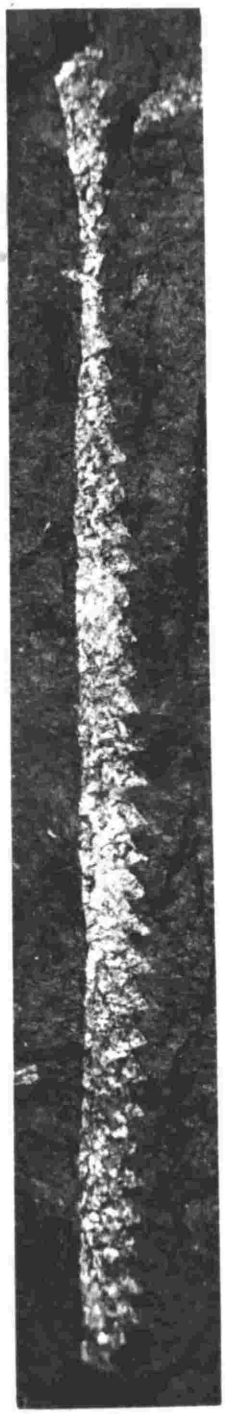
Plate 9.

Fig.1. Didymograptus cf.ensjoensis Monsen. Rhabdosome with one complete stipe, x 5. VG108, locality S2/628, Aorangi Mine. T.fruticosus zone.

Figs 2,5. Didymograptus extensus (J.Hall). Fig.2, rhabdosome with one complete stipe, x 5. Fig.5, same, x 2. VG105, locality S2/565, Aorangi Mine. I.c.lunata zone.

Figs 3,6. Didymograptus similis (J.Hall). Fig.3, complete rhabdosome, x 5. GR83, locality S7/516, Elliot Creek. T.fruticosus zone. Fig.6, complete rhabdosome, x 5. GR82, locality S2/586, Aorangi Mine. D.protobifidus zone.

Fig.4. Didymograptus cf.eocaduceus Harris, x 10. VG97, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.



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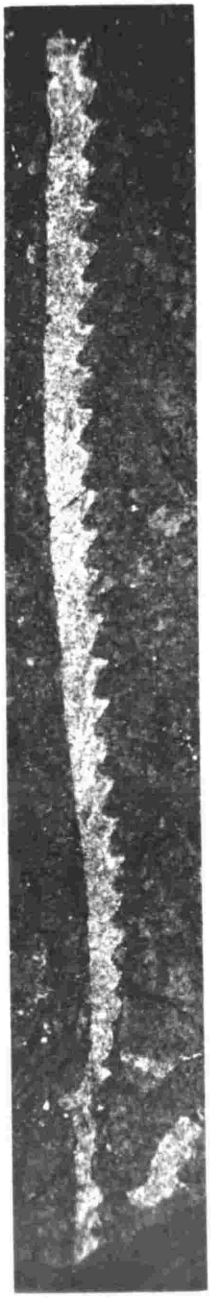

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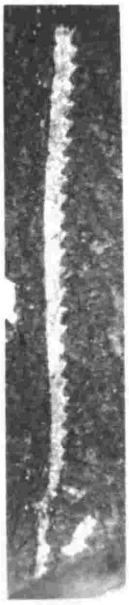

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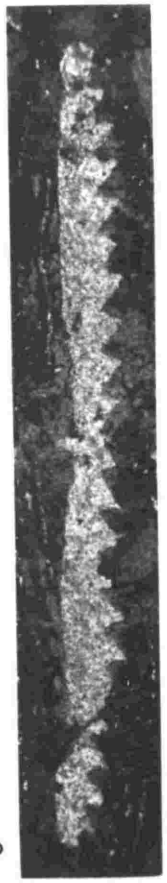

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Plate 10.

Fig.1. Didymograptus sp. (extensiform), x 2. GR42, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.2. Sinograptid sp.indet. Stipe fragment, x 10. GR68, locality S2/568, Aorangi Mine. P.etheridgei zone.

Fig.3. Phyllograptus "nobilis" Harris and Keble. Two rhabdosomes, x 3. GR18, locality S2/545, Aorangi Mine. Oncograptus zone.

Figs 4,5. Didymograptus v-deflexus Harris. Fig.4, broken rhabdosome, x 2, GR19. Fig.5, x 3.7, GR20. Both from locality S2/545, Aorangi Mine. Oncograptus zone.

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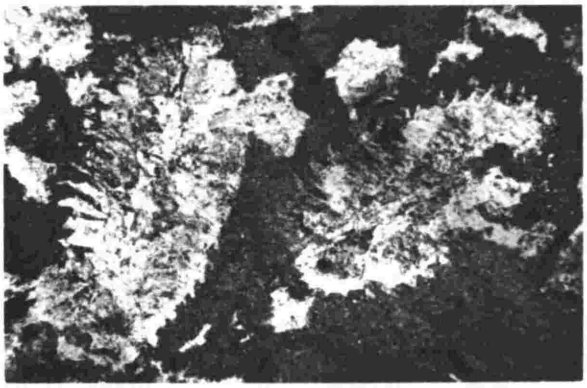

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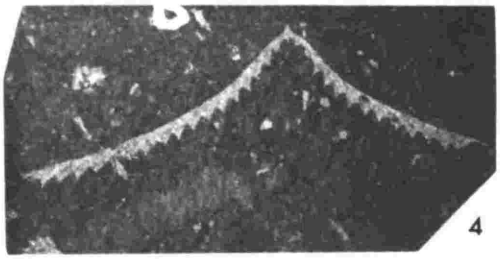

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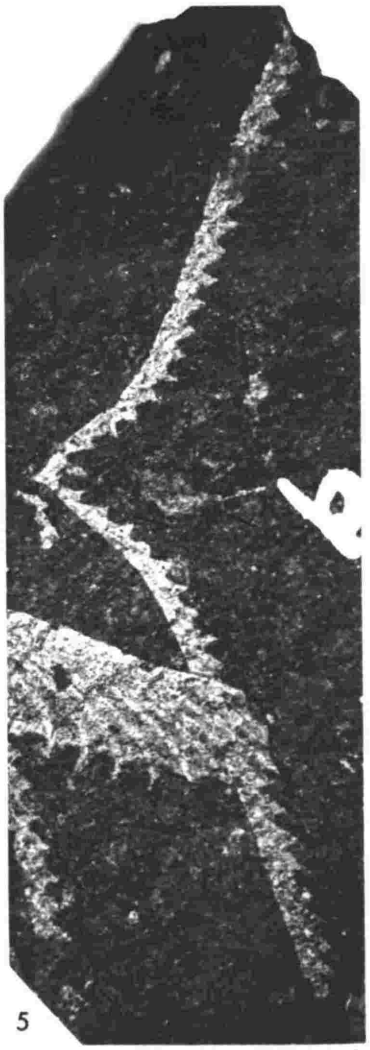

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Plate 11.

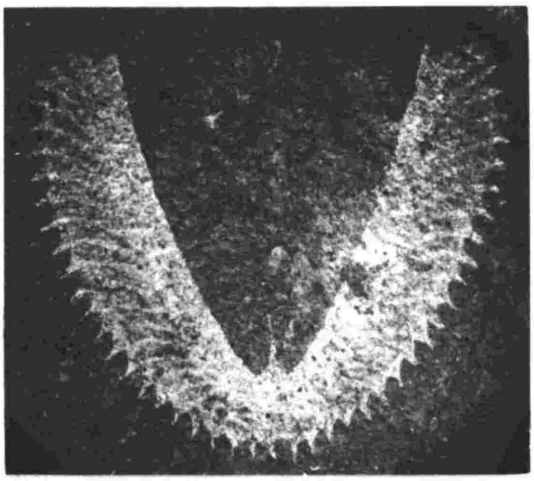
Figs 1,2. Isograptus caduceus maximodivergens Harris. Fig.1, mature rhabdosome from I.c.maximodivergens zone, x 3. VG48, locality S2/552. Fig.2, proximal portion of mature rhabdosome from Oncograptus zone, showing "axilar film" or web of periderm, overlying a specimen of Didymograptus v-deflexus, x 2. VG70, locality S2/540. Both from Aorangi Mine.

Figs 3,8,11. Isograptus caduceus? primula Harris. Fig.3, small rhabdosome, x 5, GR5. Fig.8, intermediate rhabdosome, x 5, GR4. Fig.11, large rhabdosome, x 5, GR3. All from locality S2/586, Aorangi Mine. D.protobifidus zone.

Fig.4. Didymograptus cf.eocaduceus Harris, x 5. VG97, (specimen of pl.9, fig.4).

Figs 5,7,12. Isograptus caduceus lunata Harris. Fig.5, growth stage of the common form, x 5. VG35, locality S2/593, Aorangi Mine. Fig.7, mature rhabdosome with relatively long sicula and initial thecae, x 5. VG107, locality S2/593, Aorangi Mine. Fig.12, mature rhabdosome, x 5. VG37, locality S2/562, Aorangi Mine. All from I.c.lunata zone.

Figs 6,9,10. Isograptus imitata Harris. Fig.6, immature rhabdosome, x 5. VG30, locality S2/552, I.c.maximodivergens zone. Fig.9, mature rhabdosome, x 5. VG88, locality S2/552, I.c.maximodivergens zone. Fig.10, mature rhabdosome from Oncograptus zone, x5. VG133, locality S2/540.All Aorangi Mine.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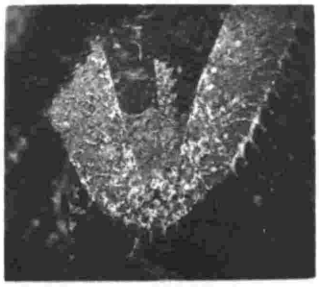
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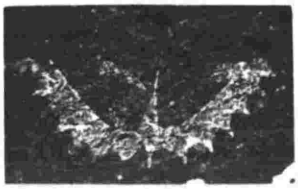
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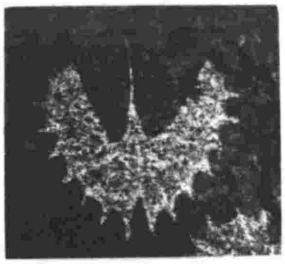
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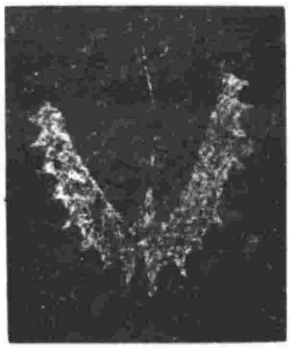
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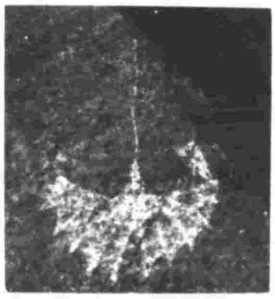
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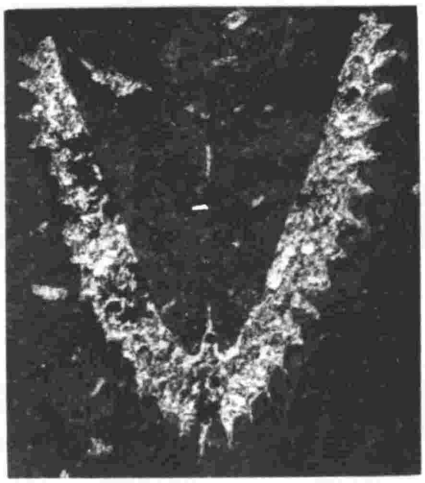
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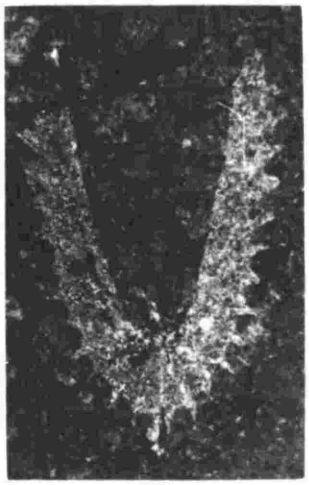
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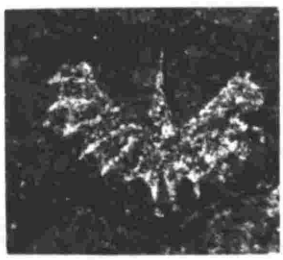
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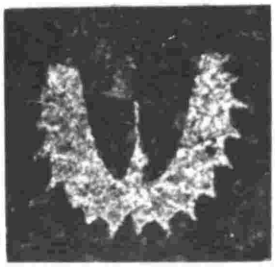
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Plate 12.

Figs 1,2. Cardiograptus? sp. Fig.1, full rhabdosome x 3. Fig.2, proximal portion of same rhabdosome, showing recurved proximal thecae, x 6. GR17, locality S2/545, Aorangi Mine. Oncograptus zone.

Figs 3,6. Cardiograptus morsus Harris. Fig.3, distal portion of incomplete mature rhabdosome, x 3. GR29. Fig.6, proximal portion of incomplete, immature rhabdosome, lying in the same bedding plane as GR29. x 3.5, GR30.

Figs 4,5,10. Oncograptus upsilon biangulatus Harris and Keble. Fig.4, immature stage in which the apex of the sicula is still exposed, x 3, VG90. Fig.5, immature form at a slightly later stage in which the sicula is no longer exposed, x 3, GR7. Fig.10, mature rhabdosome, x 3, GR6. All from locality S2/540, Aorangi Mine. Oncograptus zone.

Figs 7,8,12. Isograptus dumosus Harris. Fig.7, mature rhabdosome from the I.c.maximodivergens zone, x 5. GR27, locality S2/552. Fig.8, immature rhabdosome from the I.c. maximodivergens zone, x 5. VG89, locality S2/552. Fig.9, mature rhabdosome from the Oncograptus zone, x 5. GR28, locality S2/540. All from Aorangi Mine.

Figs 9,11. Isograptus hastatus Harris. Fig.9, mature rhabdosome with damaged proximal ventral margin, x 5, VG94. Fig.11, immature rhabdosome, x 10, VG95. Both from locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

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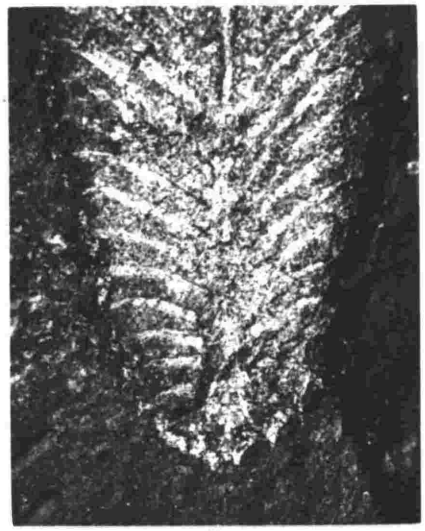
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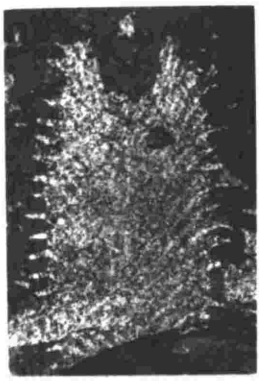
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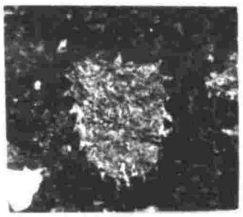
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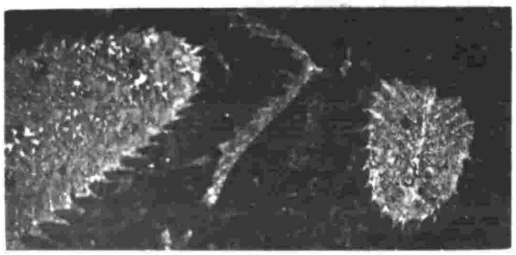
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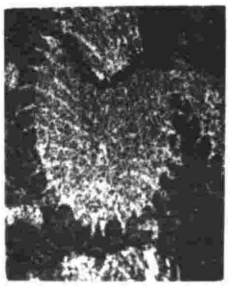
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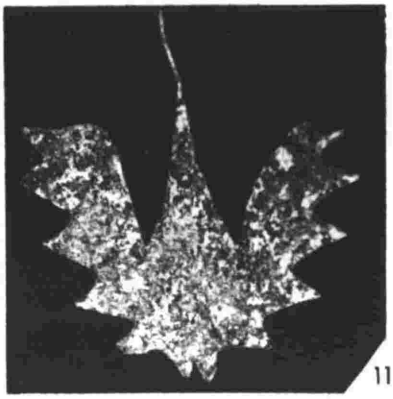
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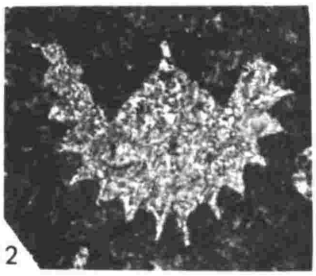
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Plate 13 (continued).

Fig.10A. Pterograptus? sp.nov. Incomplete rhabdosome showing three second-order (lateral) stipes arising from one first-order stipe, the other first-order stipe remaining unbranched. x 5. VG112, locality S2/633, Aorangi Mine. D.decoratus zone.

Fig.10C. Glossograptus hincksii (Hopkinson). Two rhabdosomes lying superposed. x 5. Locality S2/633, Aorangi Mine. D.decoratus zone.

Fig.11. Glossograptus acanthus Elles and Wood. x 2.3. VG84, locality S2/582, Aorangi Mine. P.etheridgei zone.

Plate 13.

Fig.1. Isograptus sp.1 aff.manubriatus (T.S.Hall). Mature rhabdosome, x 3. GR13. Locality S2/540, Aorangi Mine. Oncograptus zone.

Figs 2,6. Isograptus sp.2 aff.manubriatus (T.S.Hall). Fig.2, mature rhabdosome, x 3. GR11, same locality as fig.1. Fig.6, immature rhabdosome, x 6. GR12, same locality as fig.1.

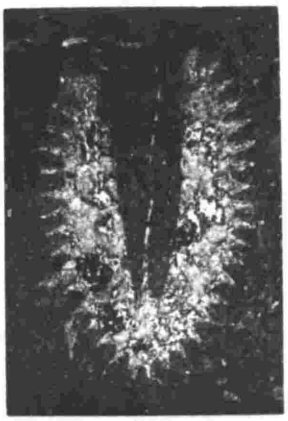
Figs 3,7. Isograptus sp.4 aff.manubriatus (T.S.Hall). Fig.3, mature rhabdosome, x 3. VG63, same locality as fig. 1. Fig.7, immature rhabdosome, x 6. GR9, same locality as fig.1.

Figs 4,10B. Cryptograptus schaferi Lapworth. Fig.4, x 5. GR64, locality S2/633. Fig.10B, x 5. Locality S2/633. Both from Aorangi Mine, D.decoratus zone.

Fig.5. ?Hallograptus inutilus (J.Hall). Mature incomplete rhabdosome, x 5. GR49, locality S2/582, Aorangi Mine. P.etheridgei zone.

Fig.8. Isograptus sp.3 aff.manubriatus (T.S.Hall). Mature rhabdosome, x 3. GR10, locality S2/540, Aorangi Mine. Oncograptus zone.

Fig.9. Glossograptus? crudus Harris and Thomas. Mature rhabdosome, x 5. GR31, locality S2/556. Oncograptus zone.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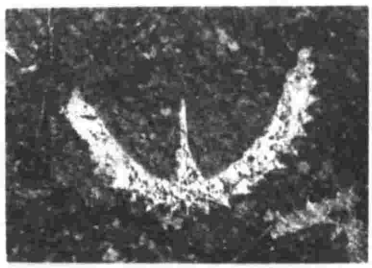
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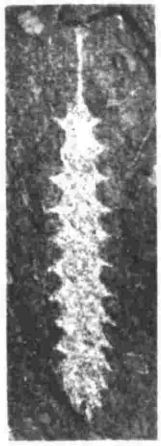
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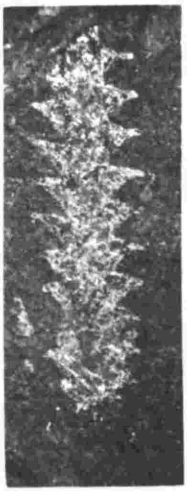
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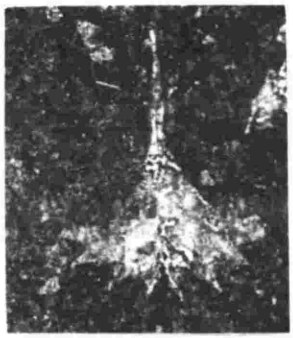
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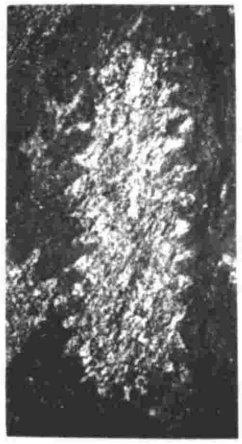
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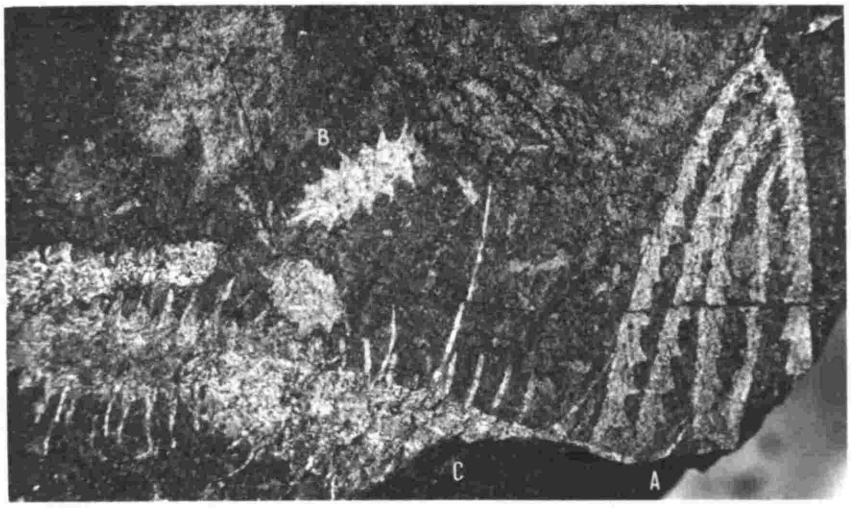

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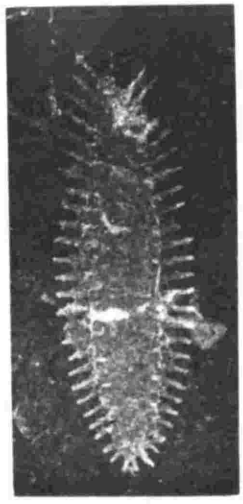
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Plate 14.

Figs 1,2,3. Paraglossograptus zealandicus sp.nov. Fig.1, incomplete rhabdosome, x 3. VG82, locality S2/568. Fig.2, nearly complete rhabdosome, x 3. VG81, locality S2/568. Fig.3, holotype, x 3. VG80, locality S2/582. All from Aorangi Mine, P.etheridgei zone.

Figs 4,5,9. Paraglossograptus etheridgei Harris. Fig.4, incomplete rhabdosome, x 3. VG71, locality S2/582. Fig.5, full rhabdosome, x 3. VG72, locality S2/582. Fig.9, immature rhabdosome, x 5. VG73, locality S2/582. All from Aorangi Mine, P.etheridgei zone.

Fig.6. Pseudoclimacograptus cf. modicellus (Harris and Thomas). Proximal part of incomplete rhabdosome, x 16. GR58, locality S3/526, Aorangi Mine. Dicellograptus zone.

Fig.7. Pseudoclimacograptus sp. Fragment of rhabdosome, x 10. GR91, locality S2/592, Aorangi Mine. Dicellograptus zone.

Fig.8. Pseudoclimacograptus sp. Proximal part of incomplete rhabdosome, x 10. GR92, locality S2/592, Aorangi Mine. Dicellograptus zone.

Fig.10. Leptograptus cf.flaccidus (J.Hall). Incomplete large rhabdosome, x 3. VG125, locality S19/610, Wangapeka Valley. Orthograptus zone.

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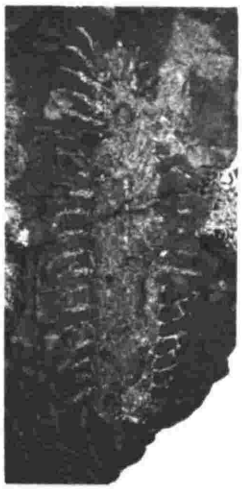
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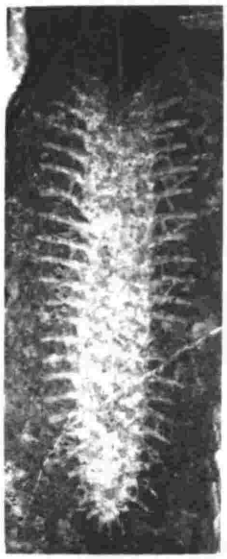
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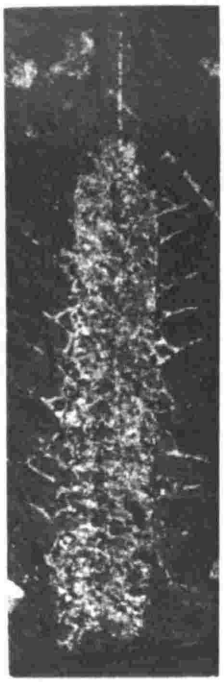
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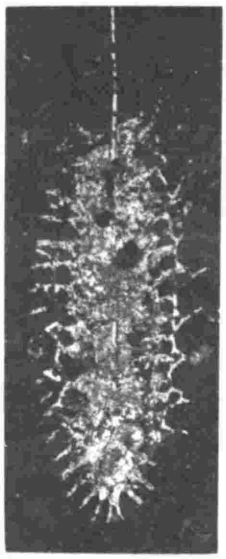
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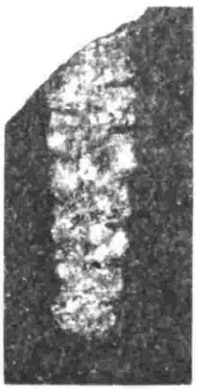
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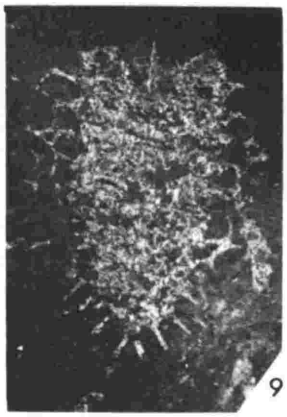
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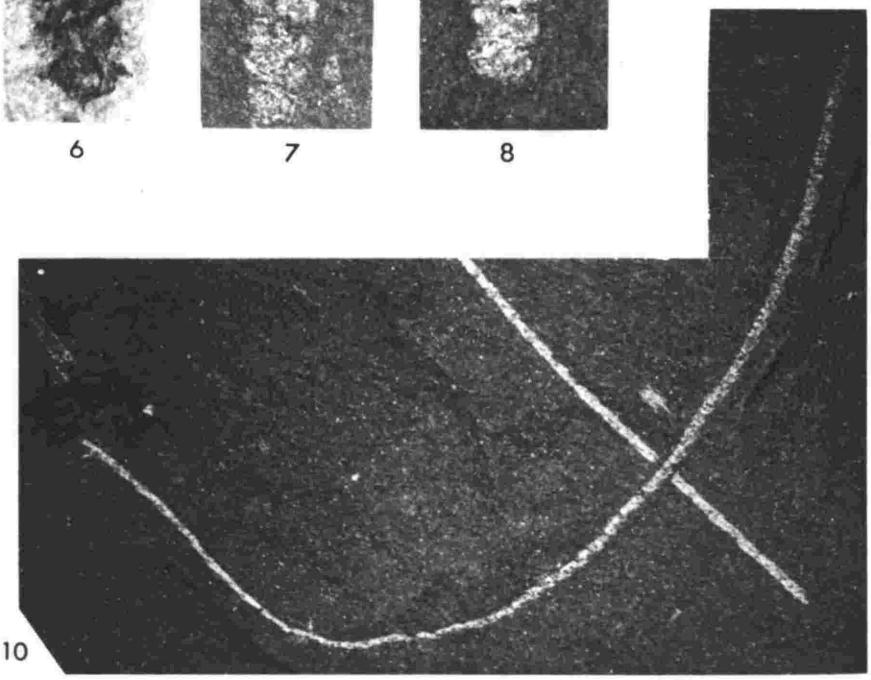
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Plate 15 (continued).

Fig.9. Dicellograptus sp. Rhabdosome in part relief with part of lateral wall of left-hand stipe removed, showing interthecal septa, x 6. VG129, locality S3/526, Aorangi Mine area. Dicellograptus zone.

Fig.10. Dicranograptus cf.hians T.S.Hall. Immature rhabdosome, x 7.5. GR107, locality S19/607, Wangapeka Valley. Orthograptus zone.

Plate 15.

Fig.1. Dicellograptus patulosus Lapworth, x 3. VG126, locality S19/621, Wangapeka Valley. Orthograptus zone.

Fig.2. Dicellograptus sp. x 5. GR86, locality S2/592, Aorangi Mine. Dicellograptus zone.

Fig.3. Nemagraptus gracilis (J.Hall). Fragmentary rhabdosome, x 3. VG102, locality S3/526, Aorangi Mine area. Dicellograptus zone.

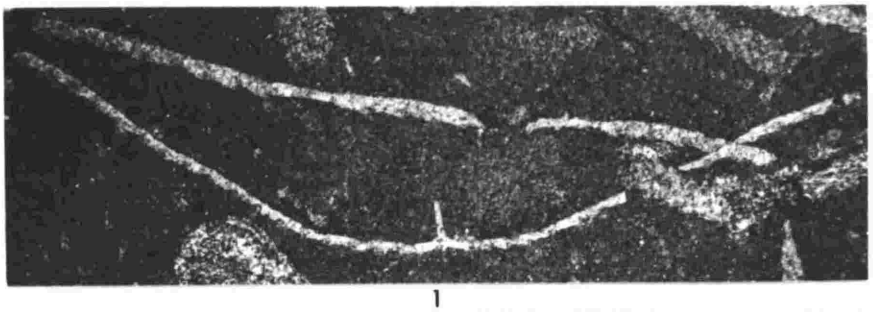
Fig.4. Dicellograptus intortus? Lapworth, x 3. GR103, locality S19/607, Wangapeka Valley. Orthograptus zone.

Fig.5. Trigonograptus ensiformis? (J.Hall), x 3. GR67, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.6. Dicranograptus nicholsoni (Hopkinson). Fragmentary biserial part of rhabdosome, x 7.5. VG100, locality S3/526, Aorangi Mine area. Dicellograptus zone.

Fig.7. Dicellograptus sextans exilis Elles and Wood. Broken mature rhabdosome and immature rhabdosome, x 5. GR84, locality S2/592, Aorangi Mine. Dicellograptus zone.

Fig.8. Dicellograptus sp. x 10. GR85, locality S2/592, Aorangi Mine. Dicellograptus zone.



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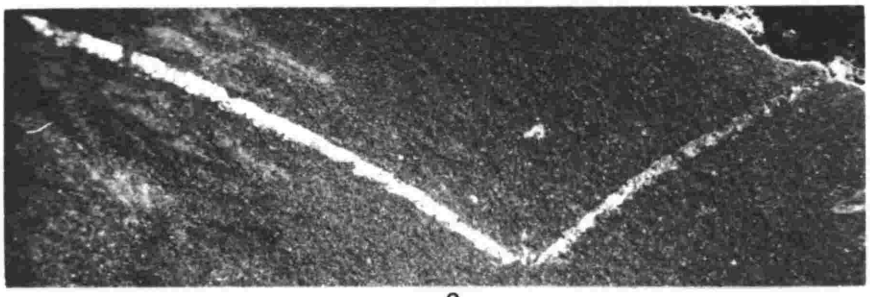

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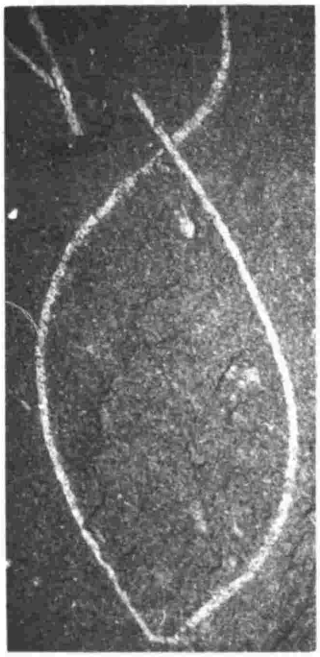

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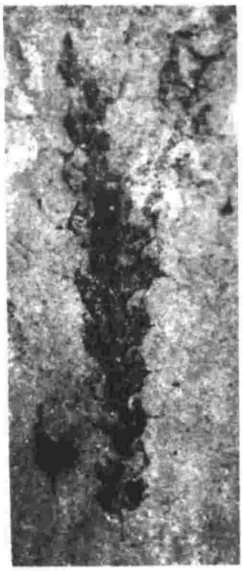

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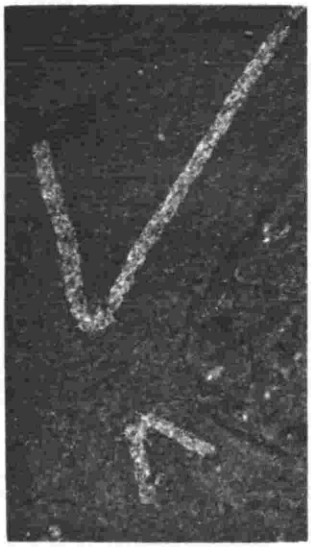

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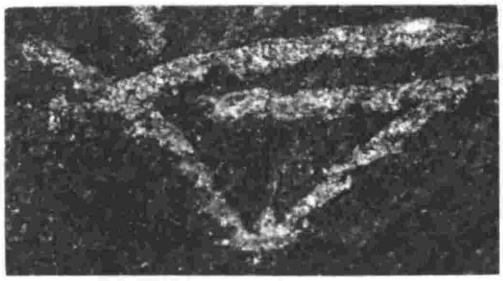

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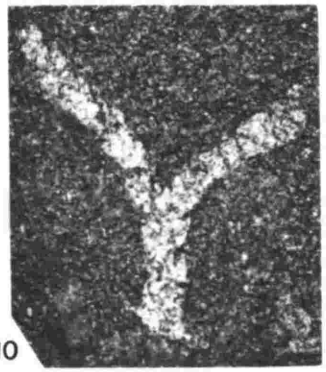

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Plate 16.

Fig.1. Climacograptus hastatus T.S.Hall. Rhabdosome showing long virgella and single pair of proximal spines, x 3.5. VG119, locality S19/606, Wangapeka Valley. Orthograptus zone.

Fig.2. Climacograptus tubuliferous Lapworth. Distal part of incomplete rhabdosome, showing virgular body. x 2.5. VG124, locality S19/621, Wangapeka Valley. Orthograptus zone.

Fig.3. Climacograptus brevis Elles and Wood, x 7.5. GR63, locality S2/568, Aorangi Mine. D.decoratus zone.

Figs 4,5. Climacograptus sp. Fig.4, very long, deformed rhabdosome in three-quarters relief, x 3, VG128. Fig.5, rhabdosome in part relief with most of the uppermost lateral rhabdosome wall removed, showing interthecal septa. x 3, GR61. Both from S3/526, Aorangi Mine area. Dicellograptus zone.

Fig.6. Climacograptus sp. Incomplete rhabdosome, x 5. VG115, locality S19/618, Wangapeka Valley. Orthograptus zone.

Fig.7. Climacograptus caudatus Lapworth. Incomplete rhabdosome, x 3. VG118, locality S19/620, Wangapeka Valley. Orthograptus zone.

Fig.8. Climacograptus cf.riddellensis Harris, x 3. GR98, locality S2/595, Wangapeka Valley. Orthograptus zone.

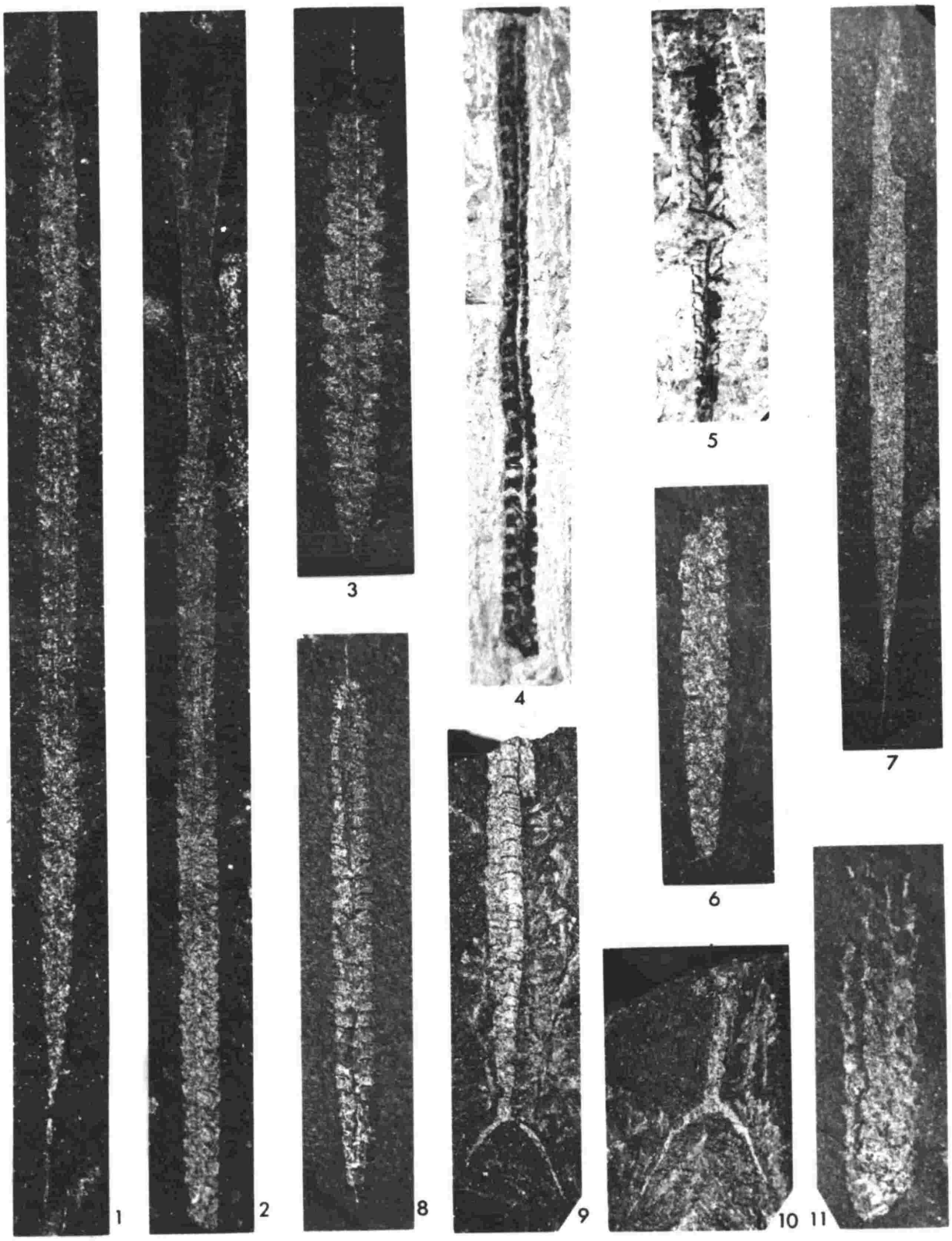
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Plate 16 (continued).

Figs 9,10. Climacograptus bicornis (J.Hall). Fig.9, proximal portion of incomplete rhabdosome, x 3. VG116, locality S19/606, Wangapeka Valley. Orthograptus zone. Fig.10, proximal portion, x 3. VG117, locality S19/606, Wangapeka Valley. Orthograptus zone.

Fig.11. Retiograptus geinitzianus J.Hall, x 7.5. GR105, locality S2/592, Aorangi Mine. Dicellograptus zone.

Plate 17.

Fig.1. Diplograptus? cf. decoratus (Harris and Thomas). Complete mature rhabdosome x 3. GR65, locality S2/633, Aorangi Mine. D.decoratus zone.

Figs 2,6. Diplograptus sp. Fig.2, x 5.2, GR90. Fig.6, x 3, GR89. Locality S2/592, Aorangi Mine. Dicellograptus zone.

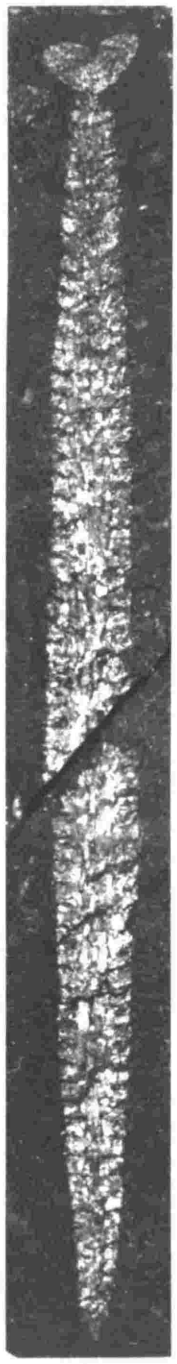
Figs 3,7. Glyptograptus aff.teretiusculus (Hisinger). Fig.3, distal fragment of broken rhabdosome in part relief, x 3. Fig.7, proximal part of same rhabdosome, x 3.5. GR99, locality S3/526, Aorangi Mine area. Dicellograptus zone.

Figs 4,5. Glyptograptus austrodentatus cf.austrodentatus Harris and Keble. Fig.4, incomplete pyritised rhabdosome, in part relief, x 10. GR51, locality S2/568. Fig.5, proximal part of incomplete pyritised rhabdosome, in half relief, x 20. GR56, locality S2/568. Both from Aorangi Mine. P.etheridgei Zone.

Fig.8. Glyptograptus cf.intersitus Harris and Thomas. Proximal part of rhabdosome, x 10. GR70, locality S2/568, Aorangi Mine. P.etheridgei zone.

Fig.9. Glyptograptus cf.teretiusculus siccatus Elles and Wood, x 10. VG111, locality S2/633, Aorangi Mine. D.decoratus zone.

Fig.10. Glyptograptus sp. Two incomplete rhabdosomes, x 5. GR57, locality S3/526, Aorangi Mine area. Dicellograptus zone.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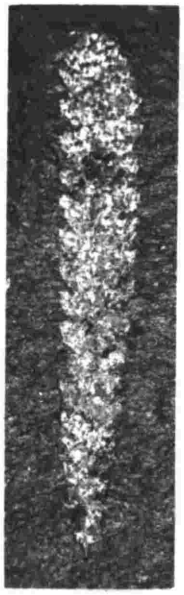
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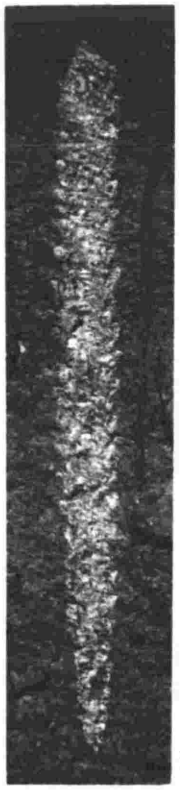
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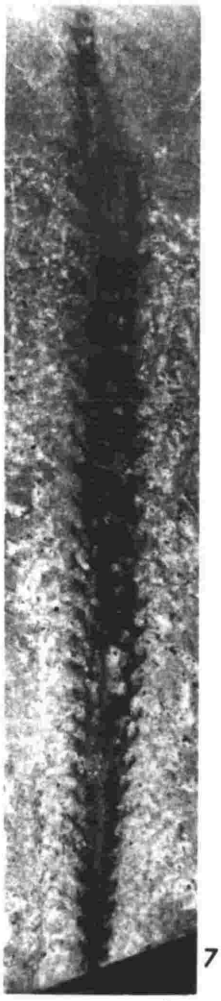
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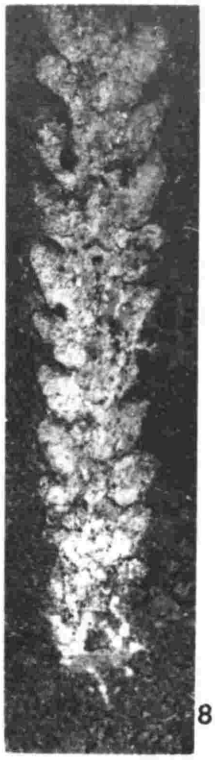
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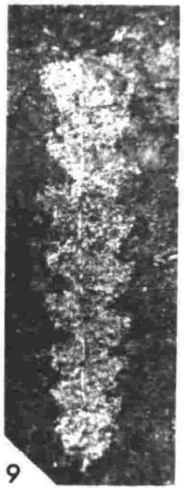
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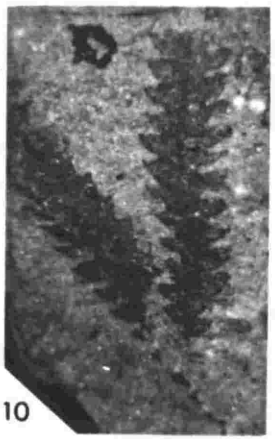
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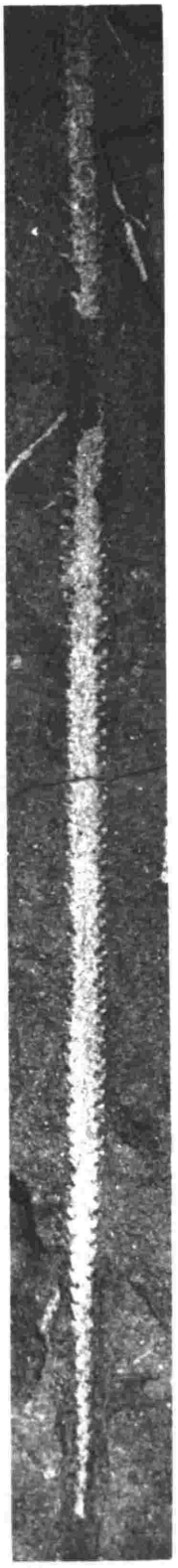
Plate 18.

Figs 1,6. Orthograptus sp. (large form). Fig.1, incomplete long rhabdosome, x 1.5. Fig.6, proximal part of rhabdosome in same bedding plane (inked in), x 3.1. VG123, locality S19/621, Wangapeka Valley. Orthograptus zone.

Figs 2,3,8. Orthograptus truncatus pauperatus Elles and Wood. Fig.2, incomplete rhabdosome, x 7.5, VG127. Fig.3, broken rhabdosome, x 7.5, VG114. Fig.8, complete mature rhabdosome, x 5, VG120. All from locality S2/606, Wangapeka Valley. Orthograptus zone.

Figs 4,5,7. Orthograptus ex gr. calcaratus Lapworth. Fig.4, x 3, VG122. Fig.5, group of rhabdosomes, one of which has a disc-shaped virgular body, x 2, VG121. Fig.7, proximal part of specimen of fig.4, x 10. All from locality S19/620, Wangapeka Valley, Orthograptus zone.

NB. Fig. 4 inadvertently reversed from negative.



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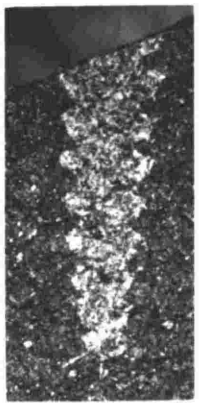

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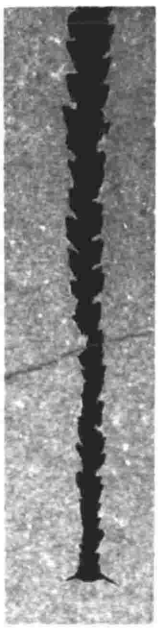

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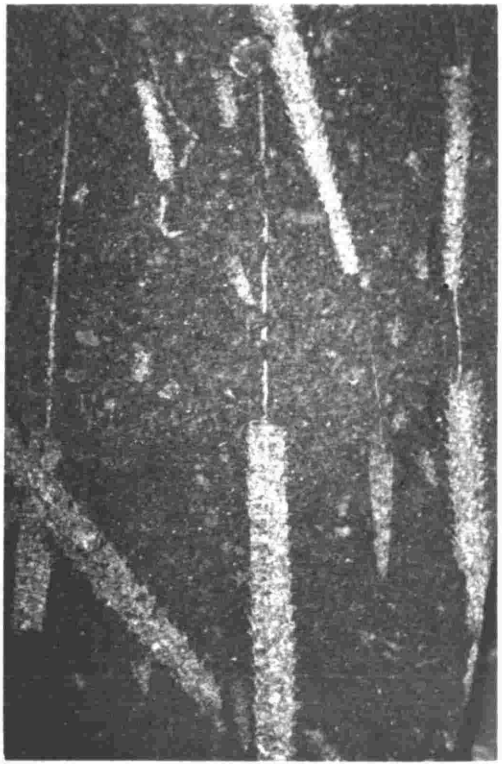

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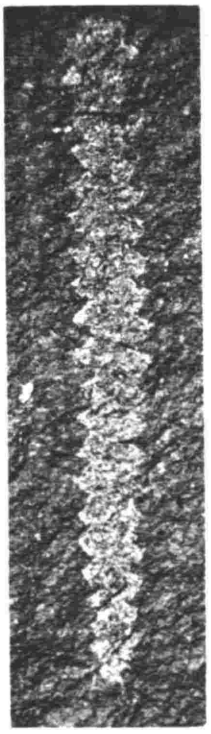

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Plate 19.

Figs 1,2. Graptoloid sp.3 indet. Fig.1, incomplete mature rhabdosome, oriented as in fig.2, x 2.8, GR25. Fig.2, incomplete mature rhabdosome, in part relief. The direction of rhabdosome growth was determined from the orientation of the thecae, the apertural margins of which extend to the mid-line of the rhabdosome. x 3, GR22. Both from locality S2/545, Aorangi Mine. Oncograptus zone.

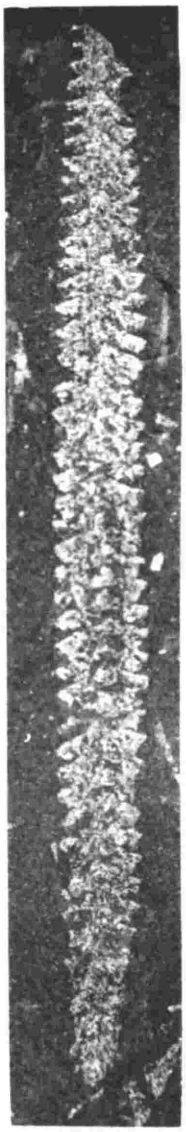
Fig.3. Trigonograptus? sp.nov. Incomplete rhabdosome oriented as in fig.2, x 3. GR21, locality S2/545, Aorangi Mine. Oncograptus zone.

Fig.4. Graptoloid sp.2 indet. Complete rhabdosome and incomplete rhabdosome, x 3. GR26, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Figs 5,8. Trigonograptus ensiformis (J.Hall). Fig.5, immature rhabdosome, x 5. VG96, locality S2/552, Aorangi Mine. I.c.maximodivergens zone. Fig.8, incomplete mature rhabdosome, x 3. GR24, locality S2/545, Aorangi Mine. Oncograptus zone.

Fig.6. Graptoloid sp.1 indet. Group of rhabdosomes, x 3. GR110, locality S2/552, Aorangi Mine. I.c.maximodivergens zone.

Fig.7. Trigonograptus cf.ensiformis. Slender rhabdosome, x 3. GR96, locality S2/582, Aorangi Mine. P.etheridgei zone.



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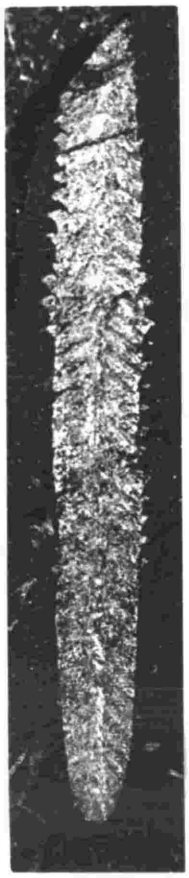

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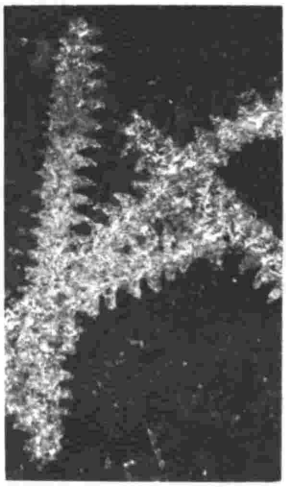

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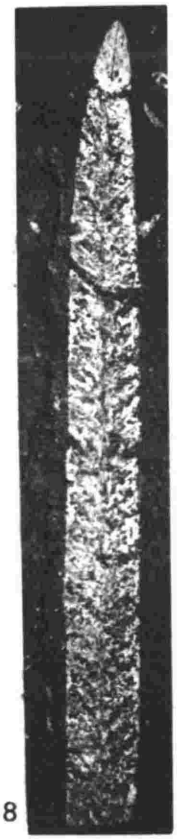

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