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LATE ORDOVICIAN TO EARLY DEVONIAN GRAPTOLITE SEQUENCES IN AUSTRALIA

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Late Ordovician graptolites are commonest in the Australian states of Victoria and New South Wales, occurring in sediments which are either folded into complex structures or else interrupted by massive thickness of volcanics and associated with frequent facies changes. Thus it has not been possible to construct a series of zones which have either continuity or an established order of appearance. Present knowledge also suggests that differences occur between coeval faunas from volcanic and no-volcanic strata.

Silurian graptolites are most common and best preserved in New South Wales. The full sequence of graptolite zones devised in Britain cannot be recognized in Australia. This can be explained partly on failure of outcrop, and partly upon regional hiatuses. The most continuous Llandovery sequences are in areas with a widespread cover of Cainozoic volcanics and gravels. Nonetheless, the Llandovery zones so far recognized, principally *cyphus-gregarius* and *turriculatus-crispus*, are very wide-spread and occur in differing environments, so that non-representation of zones cannot be attributed wholly to collecting failure. These zones are among those most readily recognized throughout the world, which probably results from their being based upon distinct, easily identified species, and their comparatively long duration. The Wenlock zones are those most poorly represented, this being the part of the Silurian in New South Wales and eastern Victoria most affected by orogenic activity. In areas of central Victoria where sedimentation is believed to have been continuous throughout the Wenlock, the sediments have suffered extensive bioturbation and graptolites are absent. In addition, the extreme rarity of *Cyrtograptus* means that it is often very difficult to tie an assemblage with an overall Wenlock aspect to any particular zone.

The Late Silurian graptolites are those which are most widely distributed, and it has been possible to recognize most of the zones described from the Ludlow and Pridoli of Europe. Sedimentary sequences which cross the Siluro-Devonian boundary are common, but graptolites in Early Devonian strata are frequently in isolated beds separated by great thickness of non-graptolitic strata.

Key words: Graptolites, stratigraphy, Late Ordovician, Silurian, Early Devonian, Australia.

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INTRODUCTION

Critical surveys of the graptolite zones recognised in Australasia are limited in the post-war period to the works by Thomas (1960), and for the Ordovician only by Sherwin (1973), Beavis (1976), and Webby (1976).

A brief assessment of the Ordovician and Silurian zones recognised in New South Wales has been given by Packham (1969). This paper is an assessment of the status of graptolite zones in Australia, principally in New South Wales and Victoria, following new discoveries since the above reviews were compiled and written. It was clear from these earlier surveys that much revision was necessary for both the faunas and the concept of the zones. The Late Ordovician in particular was in a disordered state, while knowledge of Silurian faunas was very patchy.

LATE ORDOVICIAN

The Late Ordovician in Australasia has long been divided into the three "stages", in decreasing age, Gisbornian, Eastonian, and Bolindian. In contrast to the Early Ordovician stages, which are mostly concentrated

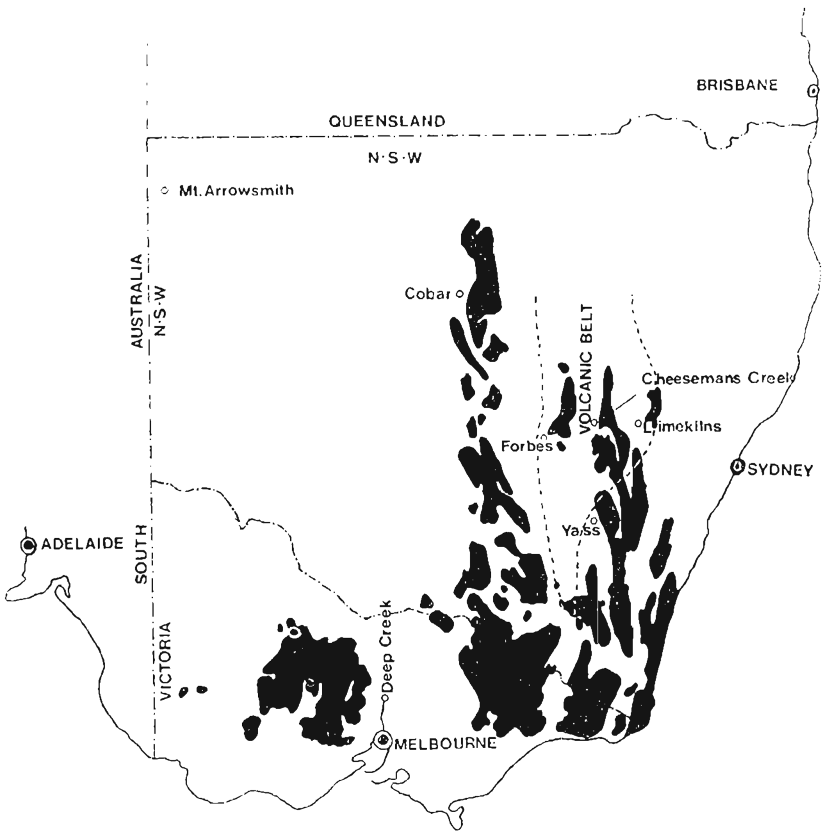

Fig. 1. Ordovician outcrops in New South Wales and Victoria. (modified from Webby 1976).

about a limited area of Victoria, the Late Ordovician is based upon assemblages from widely separated areas. Consequently it has yet to be demonstrated that these three "stages" do in fact succeed each other without either intervening gaps or significant overlaps. Very briefly, the problems associated with the Late Ordovician can be summarised as follows:

(1) Stratigraphy — the shales and siltstones in which the Late Ordovician graptolites occur are folded, but outcrops are often inadequate for mapping any continuity. Superposition of strata and hence of graptolites cannot be demonstrated always except over very short distances. While assemblages can be identified from widely separated areas, it is difficult to be absolutely certain of the exact order of appearance of some assemblages, particularly those which are close in age, but substantially different in the species represented. This problem of determining structure and stratigraphy in thick folded and faulted sequences of monotonous lithology applies equally to the non-volcanic Ordovician belts in New South Wales.

An inspection of the Late Ordovician-Early Silurian boundary beds exposed in Deep Creek, north of Melbourne, also showed that even existing mapping was in much need of revision, as the dips and trends observed were at odds with those published by Thomas and Keble (1933).

Much of the Ordovician in New South Wales is similar to that in Victoria, but in addition there are extensive areas of andesitic volcanics, with interbedded fossiliferous sediments. The stratigraphy in the volcanics is generally much better understood, as the structures in these regions are comparatively simple, but the variety of graptolite species present is somewhat limited. The size of many species is also noticeably small by comparison with those known from the non-volcanic regions. The volcanic areas are unsuitable for zonation, because the changes in fauna above and below a volcanic horizon are sometimes without any species in common.

(2) Taxonomy — workers on late Ordovician faunas will be well aware of the overdue need to revise many of the species, particularly with respect to the diplograptids. Most of the Ordovician graptolite species described from Australasia were illustrated by somewhat diagrammatic line drawings, often at natural size, and most descriptive work is over twenty years old, much of it even pre-war. Further work depends upon a thorough revision of European and American species, so as to avoid synonymies or incorrect attributions.

(3) Preservation — the late Ordovician graptolites of Australasia are normally found flattened, although some specimens in the silty and

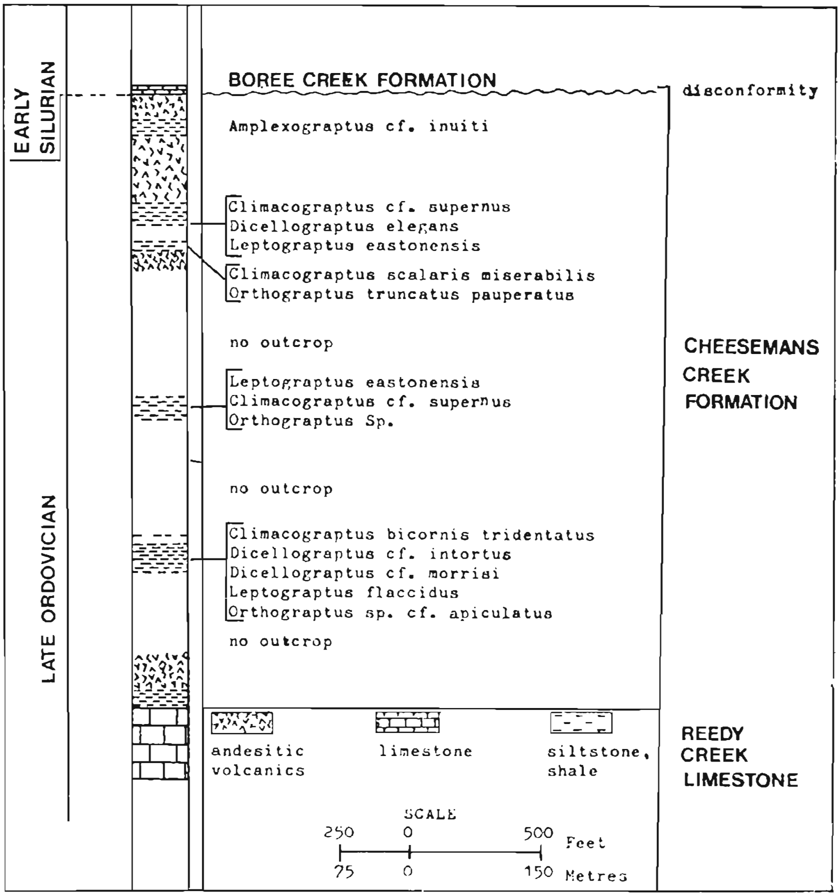

Fig. 2. Ordovician succession in Cheesmans Creek (modified from Sherwin 1971: 206).

volcanic sequences still maintain some relief as carbonised rhabdosomes. All others are flattened films which, although having clear outlines, are very difficult to interpret as far as any internal structures are concerned. One example is the difficulty in distinguishing *Climacograptus spiniferus* from *Climacograptus bicornis* on the basis of the development of basal spines. Another example is the difficulty in determining the nature of the spines at the proximal end of the *Climacograptus hastatus* group, which may account for past confusion of this species with *C. bicornis tridentatus*. The silty lithology in the upper part of the Bolindian beds has resulted in fine details of rhabdosomes being very obscure.

For these reasons only one measured section through Late Ordovician strata is shown, as this has at least undergone some recent revision. Most of the other reported assemblages need a detailed revision, but their usefulness is handicapped by uncertainty surrounding their order of superposition.

EARLY SILURIAN

The Silurian in Australia is much less of a problem than the Ordovician. The stratigraphy is much better understood because of the generally much less intense folding and more open structures. Most of the work dealing with Silurian graptolites, particularly as far as descriptive work is concerned, is of recent origin (Packham 1968; Sherwin 1974, 1975), so that it has been possible to take advantage of the prolific works which have appeared in recent years concerning the distribution, revision, and description of new species of Silurian graptolites. The cosmopolitan nature of Silurian graptolites, and the zones, used in a broad fashion, has been borne out in recent work.

Doubts associated with Australasian sequences which span the Ordovician-Silurian boundary have been summarised by Webby (1976). Subsequent work has not resulted in any further discoveries of better sections, but rather has cast doubt on those already known. Mention has been made of discrepancies in mapping of the boundary at Deep Creek in Victoria, but in addition Silurian graptolites there are exceedingly rare. The lithological uniformity of the Cotton Siltstone in central New South Wales certainly suggests an uninterrupted sequence, but this is difficult to demonstrate because of outcrop failure. Recent discoveries suggest that a Tasmanian sequence, previously considered late Ordovician in age, extends into the earliest Silurian (Baillie, Banks and Rickards, in press).

Generally speaking, Early Silurian (Llandovery) graptolites from Victoria are poorly preserved, and those of mid Silurian (Wenlock) age are very rare, although there is no evidence for any significant breaks in Victorian sequences within the Melbourne trough (Douglas and Ferguson 1976) which can be dated as Wenlock by inference. However, these beds have suffered markedly from bioturbation, which may account for the lack of graptolites had any ever been present.

Although many of the Llandovery graptolite zones have been recognised in the east Australian States, few examples are known where one zone can be shown to pass into another. The oldest and youngest Llandovery zones so far recognised, *Akidograptus acuminatus* and *Monograptus griestoniensis*, (Talent *et al.* 1975) are as far apart as Deep Creek in Victoria, and the Broken River district in northern Queensland, although a recent inspection has cast doubts upon the identity of the latter (R. B. Rickards, pers. comm.). In New South Wales the local zone of *Monograptus exiguus* frequently occurs in isolation. It has been noted elsewhere (Sherwin, in Pickett 1980) that the zones recognised in New South Wales in particular, and Australasia in general, are those which tend to be most commonly recognised throughout the world, either because they are defined by very distinctive species, or because of the long time span represented.

A peculiarity of diplograptids in the *cyphus*, *gregarius* (*triangulatus*), and *turriculatus* zones is the common occurrence of loss, excessive development, or reorientation of $Th1^2$ so as to produce a dimorphograptid appearance in otherwise normal species of *Climacograptus*, *Glyptograptus* and *Orthograptus* in the two older zones (Sherwin 1976), and *Petalograptus* in the *turriculatus* zone (Sherwin 1974). The effect is that of simultaneous akidograptid development in several lines of evolution.

MIDDLE — LATE SILURIAN

The Middle Silurian (Wenlock) graptolites have the poorest representation of any Silurian graptolites in Australasia. In Victoria the intense bioturbation of sediments of the appropriate age has been mentioned, while elsewhere there is a widespread regional hiatus (Talent *et al.* 1975). Recognition of Wenlockian zones is also hindered by the extreme rarity of *Cyrtograptus* in Australasia (Sherwin, *in* Pickett 1980).

Perhaps the portion of the graptolite zonation scheme to which the greatest contribution can be made from Australasia is from the late Wenlock to the Early Devonian. Much of this interval is represented by shales in which graptolites are well preserved as carbonised, or less commonly, as pyritic/limonitic rhabdosomes. A near complete sequence can be recognised from the *flexilis* zone to at least the top of the *transgrediens* zone.

The latter part of the Silurian in New South Wales and Victoria starts with basal conglomerates or coarse sandstones. The graptolites within these basal beds in the central west of New South Wales are typical late Wenlock species such as *Monograptus meneghini* (or possibly *pseudodubius*), *M. flumendosae*, and *M.* aff. *flemingi*, which, unaccompanied by any cyrtograptids, could conceivably extend from the *riccartonensis* to the *lundgreni* zone. Overlying this assemblage are shales which, extrapolated along strike, contain *M. jaegeri* and a small variety of *M. flemingi*. In the Forbes district of New South Wales *M. jaegeri* occurs with *M. ludensis*. Some 10—20 metres lower in the sequence *M. sherrardae* is common, along with *M. dubius* and fragmentary retiolitids, possibly *Gothograptus*. The "*nassa* interregnum" has yet to be identified, but these new discoveries mean that it is possible to place a definite late Wenlock age on *M. sherrardae*. It is interesting to note that strong dorsal curvature in late Wenlock monograptids is known also from Canada, where *sherrardae* like monograptids occur within a fault block surrounded by *testis* bearing sediments (Sherwin 1975). In Bolivia, Cuerda (1974) has described a *Monograptus* with affinities to *M. jaegeri*, but possessing a marked dorsal curvature throughout the rhabdosome. It would seem therefore that there is a case for recognising this particular development as a characteristic feature of the late Wenlock at an international level.

The British zones for the early Ludlow cannot be recognised with any exactitude, but this is possibly a result of existing uncertainties in England. For the latter part of the Ludlow and the Pridoli, the Bohemian zones apply reasonably well. The Bohemian species *M. butovicensis*, formerly identified by Brown and Sherrad (1952) as *M. roemeri*, is now known to occur in the Yass district of New South Wales. The species formerly identified as *M.* cf. *ultimus* (Packham 1968, Sherwin 1971), is now believed to be *M. tomczyki*. Recent work on the late Silurian in New South Wales can be summarised as follows:

Yass		Cheesemans Creek	
		M. aff. *thomasi* *M. transgrediens* *Linograptus* sp.	(750 m)
M. bouceki *M. transgrediens*	(85 m)	*M. bouceki*	(700 m)
M. formosus *M.* cf. *tomczyki*	(35 m)	*M. tomczyki*	(590 m)
Monograptus bohemicus subsp. (with *hercynicus* type sicula) *Linograptus posthumus posthumus*	(4 m)	*Monograptus bohemicus* subsp. (with *hercynicus* type sicula) *Linograptus posthumus posthumus* *"Monograptus scanicus"*	(450 m)
Monograptus bohemicus *Monograptus butovicensis* *"Monograptus scanicus" s.l.*		*Monograptus bohemicus* *Monograptus dubius*	(245 m)
		Monograptus jaegeri (occurs along strike) *?Gothograptus* sp.	
		Monograptus flemingi *Monograptus flumendosae* *Monograptus meneghini* or *pseudodubius*	

The figures appearing in parenthesis after each assemblage refer to the stratigraphic separation from the lowest asemblage in each column, which is taken as the datum. The Yass column is mostly after Jaeger (1967), Cheesemans Creek a revision of Sherwin (1971).

EARLY DEVONIAN

A summary of Early Devonian graptolite distribution in Victoria has been given by Douglas and Ferguson (1976). While several Early Devonian species have been found in Victoria, their wide separation by vast thicknesses of non-graptolitic strata makes it difficult to determine any reliable zonation scheme. In the case of such a species as *M. thomasi* it is difficult to form a definite opinion of age, as it is far separated from any other graptolite horizon, or even a reliably dated horizon of any sort.

In New South Wales Early Devonian graptolites are rare, and confirmed findings are limited to two small areas, at Cheesemans Creek and Limekilns. Even at the former locality the determination is based upon the *thomasi* like characteristics of a *Monograptus* accompanied by *M. transgrediens*. Specimens found at this locality are almost always in fragments. At the Limekilns locality Packham (*in* Strusz 1972: 445) has recorded *Monograptus* cf. *yukonensis* in black shales, immediately underlying limestones which contain a late Pragian — early Zlichovian conodont fauna (Pickett, *in* Strusz 1972: 445).

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