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Synonymy and stratigraphic ranges of *Belemnopsis* in the Heterian and Ohauan Stages (Callovian–Tithonian), southwest Auckland, New Zealand

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Abstract *Belemnopsis stevensi*, *Belemnopsis maccrawi*, and *Belemnopsis* sp. A (Challinor 1979a) are synonymous; *B. stevensi* has priority. New belemnite material from Kawhia Harbour and Port Waikato, together with graphical study methods, indicates that many small fragmentary specimens associated with *B. stevensi* in the lower part of its stratigraphic range are probably the same taxon. *B. stevensi* has been found only in the Middle and Upper Heterian Stage (Lower Kimmeridgian) at Kawhia and only in the Lower Ohauan Stage (Upper Kimmeridgian) at Port Waikato. This apparently disjunct distribution is attributed to poor exposure in the relevant sections. ***Belemnopsis kiwiensis*** n.sp., *Belemnopsis* cf. sp. B, *Belemnopsis* sp. B, *Belemnopsis* sp. D, and *Belemnopsis* spp. are associated with *B. stevensi* near the lowest known point in its stratigraphic range. The distribution of stratigraphically useful belemnites within the Heterian and Ohauan Stages is: *Conodicoelites* spp. (Lower Heterian; correlated with Lower Callovian); *Belemnopsis annae* (Lower and Middle Heterian; Lower Callovian/Lower Kimmeridgian); *Belemnopsis stevensi* (Middle Heterian/Lower Ohauan; Kimmeridgian); *Belemnopsis keari* (Upper Heterian; Kimmeridgian); *Belemnopsis trechmanni* (Upper Ohauan; Upper Kimmeridgian/Middle Tithonian). The apparently extreme range of *Belemnopsis annae* remains unexplained. **Klondyke Sandstone** (new) is recognised as the basal member of Moewaka Formation (Port Waikato area).

Keywords *Belemnopsis kiwiensis* n. sp.; *Belemnopsis*; synonymy; Heterian; Ohauan; Callovian; Oxfordian; Kimmeridgian; Tithonian; belemnite zones; Kawhia; Port Waikato; Klondyke Sandstone; new stratigraphic names; new taxonomic names

INTRODUCTION

The first detailed research on the belemnites of New Zealand was that of Stevens (1965). In part of that work, Stevens described belemnites of the Heterian and Ohauan Stages (Kimmeridgian, Stevens 1997), based mostly on collections from the southern shore of Kawhia Harbour (Fig. 1, 2), and housed at New Zealand Geological Survey (now part of the Institute of Geological and Nuclear Sciences). Stevens described several species of *Conodicoelites* from the lower Heterian Stage, *Belemnopsis keari* ranging from near the base to near the top of the stage, and *Belemnopsis alfurica* (Boehm) from the Upper Heterian and Lower Ohauan Stages.

Challinor (1974, 1979a,b, 1980) restudied the belemnites of these stages, based partly on his own collections from Kawhia Harbour and Port Waikato, and partly on collections

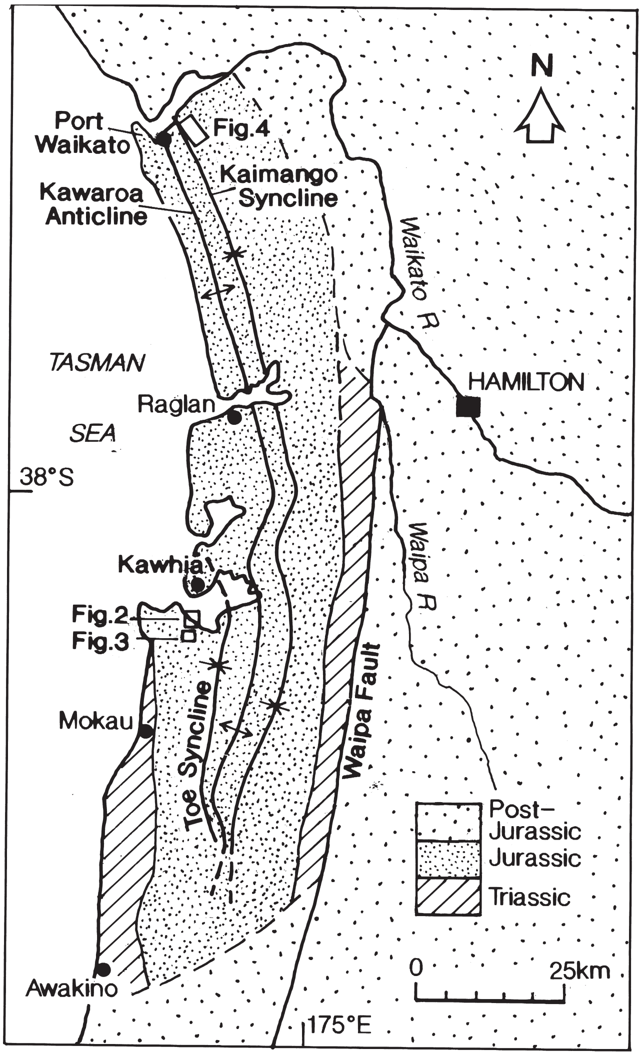

Fig. 1 Approximate surface extent of Kawhia Regional Syncline, west coast, North Island, New Zealand. Its boundary is indicated to the north and south by dashed lines, and to the east by the Waipa Fault. In some areas, Tertiary and younger cover strata within the boundary are omitted. Jurassic rocks occupy the centre of the syncline, Triassic rocks flank to east and west. Major fold axes are indicated. Locations of study areas (Fig. 2–4) are shown. Adapted from Kear (1978, fig. 4.64).

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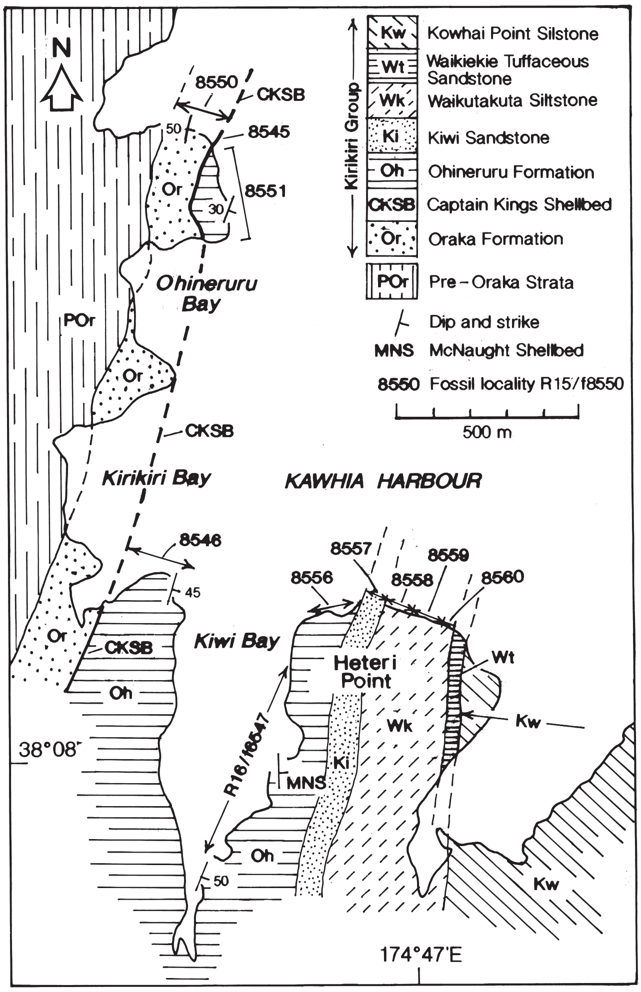


Fig. 2 Geology and fossil localities near Heteri Point, Kawhia Harbour. Map based on Fleming & Kear (1960, map 3 modified). Fossil localities mentioned in text are indicated. The prefix R15/f has been omitted (e.g., R15/f8550 = 8550). *Conodicoelites* sp. and *Belemnopsis annae* occur at f8550, *Belemnopsis annae* at f8550, f8545, f8546, and f8551, *Belemnopsis stevensi* appears at R16/f6547 and continues through f8556, f8557, f8558, f8559, and f8560. *Belemnopsis keari* appears in f8559, and continues into f8560. *Belemnopsis kiwiensis* and *B.* cf. sp. B are present in R16/f6547. MNS = McNaught Shellbed.

on loan from the University of Auckland and New Zealand Geological Survey. He described *Belemnopsis stevensi* from the lower Ohauan at Port Waikato (1974), found *B. keari* to be a composite taxon (1979a), and redescribed specimens from the lower part of its range as *B. annae*, those from the middle and some from the upper part as *B. maccrawi*, and found *B. keari* s.s to be restricted to the uppermost Heterian (upper Waikutakuta Siltstone; for stratigraphy see Fig. 2, 5, and below). Challinor did not recognise *Belemnopsis alfurica* in New Zealand and considered the specimens so identified by Stevens (1965) to belong in *B. keari* s.s. (1979a,b). He later described *Dicoelites kowhaiensis* and *Belemnopsis rarus* from the lower Ohauan Stage at Kawhia (Challinor 1980).

Despite this research work, a number of problems remained. These included: (1) the relationship of the morphologically similar *Belemnopsis stevensi* and *B. maccrawi*; (2) determination of the stratigraphically lowest occurrences of *B. maccrawi* in the Kawhia Harbour sequence; and (3) the true nature and relationships of *Belemnopsis* sp. A, sp. B, sp. C, sp. D, and many small fragmentary juvenile *Belemnopsis*, all associated with *Belemnopsis maccrawi* at the stratigraphically lowest known point in its range at Kawhia Harbour. The stratigraphic range of *Belemnopsis stevensi* at Port Waikato remained uncertain. These uncertainties led to the present study. Fieldwork for this paper was undertaken in the Kawhia region (Fig. 1, 2, 3) and near Port Waikato (Fig. 1, 4)

Belemnopsis stevensi, *B. maccrawi*, and *Belemnopsis* sp. A are now considered identical (see taxonomy below) and hereafter are discussed as *Belemnopsis stevensi*. Riegraf (1999) considered the generic name *Belemnopsis* to be invalid, and should be replaced by *Pachybelemnopsis* Riegraf, 1980. Riegraf's forensic arguments may be valid but I would argue that to follow his conclusions, some 110–125 taxa discussed in c. 90 publications (Riegraf 1999) would be renamed, and this would introduce great confusion where none exists at present. Therefore, the older names continue to be used in this paper.

FIELDWORK, STUDY AREAS, AND STRATIGRAPHY

A little additional fossil material has become available from the Kawhia area since 1980. Some is from previously known localities in the coastal section on the southern shore of Kawhia Harbour (Fig. 2, 5), and some from new inland localities to the south (R16/f246, R16/f216).

Very little new material is available from the Port Waikato region. A major change in land use has taken place in the area since the 1970s and a pine forest is now established over much of the area studied. Stream characteristics have changed. Old exposures are weathered and partly revegetated and consequently not all could be recognised. Few new exposures were found.

Lithostratigraphic units and type sections for the Upper Jurassic were established on the southern shore of Kawhia Harbour by Fleming & Kear (1960). Formations relevant to this study are detailed in Fig. 2, 3, and 5. They form the Kirikiri Group of Fleming & Kear (1960), and are predominantly mudstones and siltstones with less common fine sandstones. All are well exposed at Kawhia Harbour. The Temaikan/Heterian boundary (Marwick 1953) is located 20–23 m above the base of the Oraka Formation (Hudson 1999), and the Heterian/Ohauan boundary near the base of the Waikiekie Tuffaceous Sandstone (Meesook & Grant-Mackie 1995).

In the Port Waikato region, Kirikiri Group is divided into two formations (Waterhouse 1978): a stratigraphically lower Pakau Formation, and an overlying Moewaka Formation (Fig. 4). Moewaka Formation consists of a basal coarse unit overlain by grey to light brown well-bedded siltstone (Waterhouse 1978). The coarse unit crops out on Klondyke Road at New Zealand Map Series NZMS 260 grid reference R13/701243 and extends eastwards. It consists of weathered yellow to brown siltstone, sandstone, grit, and fine conglomerate, coarsens downsequence, and is 100–130 m thick at this location. These outcrops correlate with sandstones and grits exposed on Moewaka Stream and Moewaka Track (grid ref. c. R13/716219). *Malayomaorica malayomaorica* appears at the top of the coarse unit at

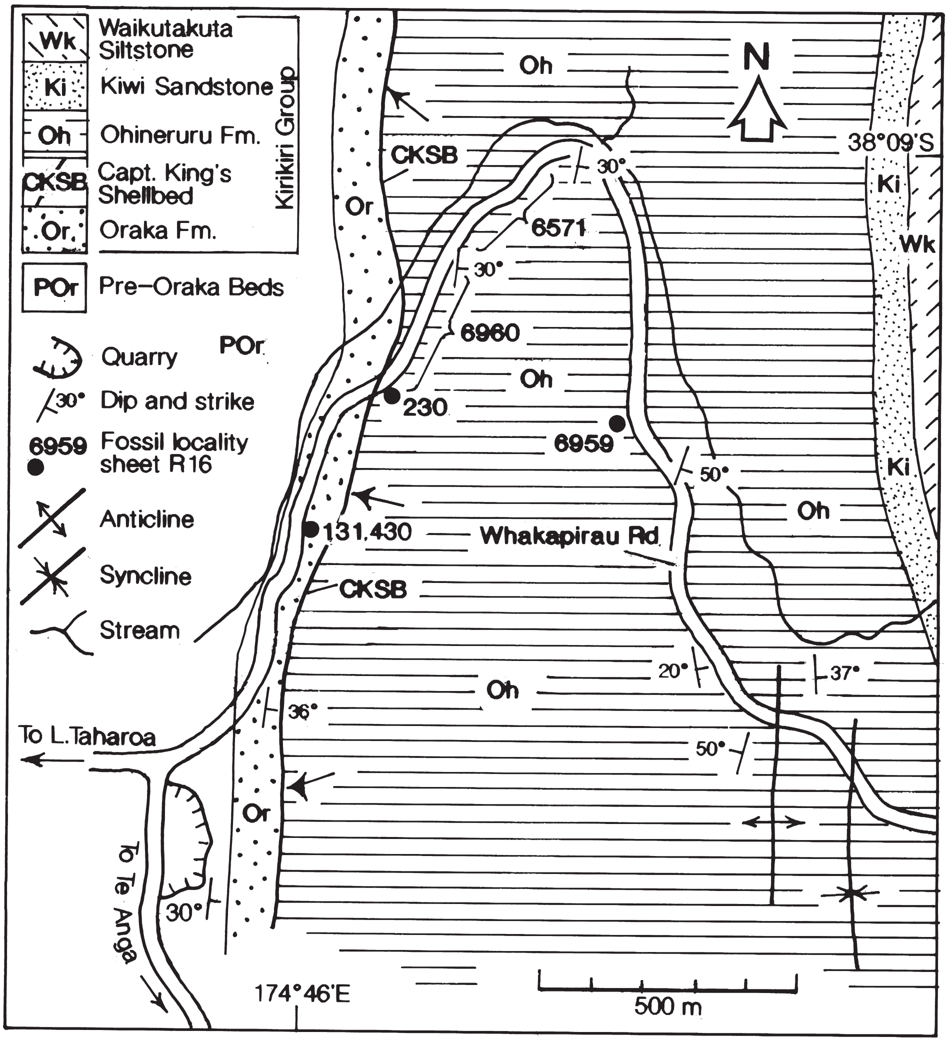


Fig. 3 Geology and fossil localities on the western part of Whakapirau Road, c. 2 km south of Kawhia Harbour (Sheet R16, NZMS 260). Map based on Francis (1977), Meesook & Grant-Mackie (1995), and additional mapping by the author. *Conodicoelites* is present at f131 and f430, *Belemnopsis annae* at f230, f6960, and f6571, and *Belemnopsis stevensi* at f6959. Arrows indicate position of outcrops of Captain King's Shellbed (CKSB) located by Francis (1977).

locality R13/f6610 (Purser 1961), but the unit appears to lack *Conodicoelites*, and may correlate approximately with the upper part of the Oraka Formation to basal Ohineruru Formation at Kawhia Harbour. The coarse unit is here named the **Klondyke Sandstone**, basal member of Moewaka Formation, and its type section is located on Klondyke Road between grid references R13/701243 and 703267.

Waterhouse (1978) mapped the base of Moewaka Formation at grid reference c. R13/719218 on Moewaka Stream, and that position is accepted here as an approximation. At Klondyke Road, however, Klondyke Sandstone is located east of the mapped base of Moewaka Formation. The base of Klondyke Sandstone is regarded here as indicating the base of Moewaka Formation, and the Pakau/Moewaka Formation boundary at Klondyke Road is therefore considered to be located c. 400 m east of, and stratigraphically well below, the position adopted by Waterhouse (1978). The position adopted for the base of Klondyke Sandstone in Fig. 4 is approximate; exposures lower in the sequence may also be present but unexposed or unseen both on Klondyke Road and Opuatia Stream.

Moewaka Formation contains the Heterian/Ohauan boundary (Purser 1961) in its middle part, and, near the base, fossils that in the Kawhia Harbour section span the Early/Middle Heterian boundary (see below). The sections studied are located at Moewaka Stream, lower Te Karamu Stream, the upper part of Waihikura and Okahu Streams, and at Klondyke Road (Fig. 4). Exposure is relatively poor in the stream sections and nearly all exposures are weathered.

The Kawhia Harbour section is located on the western limb of Toe Syncline (Fleming & Kear 1960). The Port Waikato sections, located on the eastern limb of Kaimango Syncline (Fleming & Kear 1960) to the east of Toe Syncline (Fig. 1), are mostly finer grained than those at Kawhia, and may represent a more offshore facies than that at Kawhia Harbour.

STRATIGRAPHIC DISTRIBUTIONS

The first belemnites found within the studied stratigraphic interval are *Conodicoelites* spp., which appear near the base of the Heterian Stage at Kawhia Harbour (upper Oraka Formation; Stevens 1965). No additional detailed data have been published since 1965 and the morphology of the relevant taxa is not discussed further here. The stratigraphic range and formal zone of *Conodicoelites* are discussed below. It has not been recorded from the Port Waikato region.

Belemnopsis annae first appears in the Oraka Formation where, according to Stevens (1965), it is associated with *Conodicoelites* spp. Small specimens, apparently *B. annae*, were found during collecting for this work at locality R15/f351, in the upper Oraka Formation (in beds d4 of Fleming

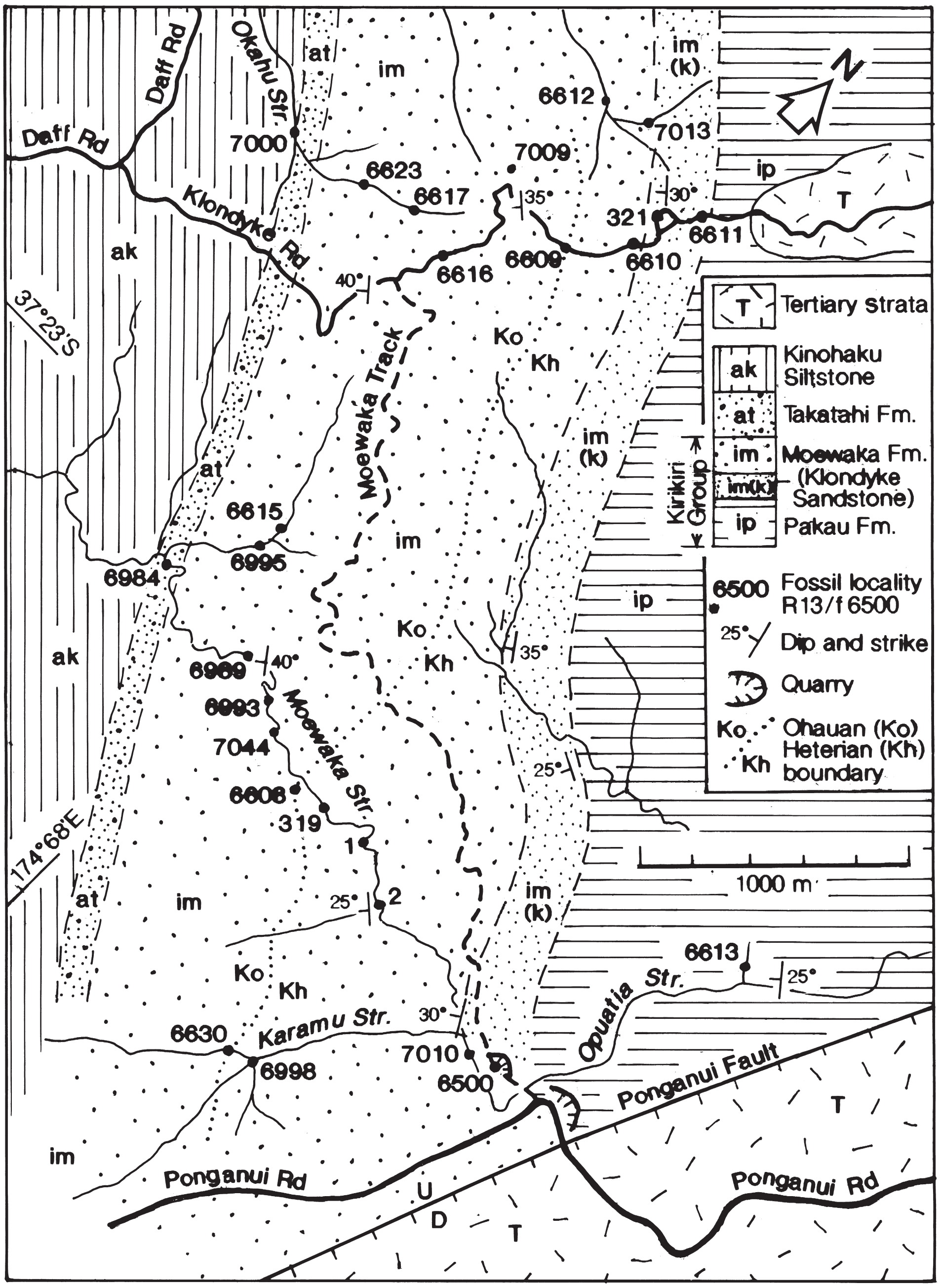


Fig. 4 Geology and fossil localities near Moewaka Stream and at Klondyke Road, Port Waikato. Map based on Purser (1961, map 2), Waterhouse (1978), Challinor (1974), and additional mapping by the author. Purser recorded *Retroceramus haasti* at f6630, f6608, f6609, f6615, f6616, f6617, and f6623 (apparently its highest point). *Belemnopsis annae* occurs at f6500, f7010, f6610, f321, and f7013. *Belemnopsis keari* is present at f1, f6998, and probably f6609. *Belemnopsis stevensi* occurs at f6989, f6993, f6995, and f7009. Fragments of very small specifically indeterminate *Belemnopsis* are present at f2. Takatahi Formation is apparently lensoidal (Challinor 1974, 2001), has been sighted only at Okahu Stream in the western part of the map, and is mapped to the south by projection along the strike. The Upper Ohauan fossil *Belemnopsis trechmanni* occurs at f6984 and f7000 (Challinor 2001).

& Kear 1960, 15–30 m below the formation top). This appears to be above the upper limit of *Conodicoelites*, and additional specimens were collected from the Whakapirau Road section (Fig. 3), again apparently above the upper limit of *Conodicoelites*. These new specimens do not alter the morphologic concept of the taxon (see Challinor 1979a).

Only small specimens of *Belemnopsis annae* are known from the lower part of its range at Kawhia Harbour (Oraka Formation and Captain King's Shellbed, Fig. 5), with large specimens (e.g., Challinor 1979a, fig. 3–16), so far found only in the lower Ohineruru Formation in the type section (R15/f8546, f8551, Fig. 2), and at Whakapirau Road (R16/f230, f6571, f6960, Fig. 3). *B. annae* appears to extend 100–150 m into the Ohineruru Formation (Fig. 5). Francis (1977) mapped Captain King's Shellbed at three localities in the area covered by Fig. 3 (arrowed), but the formation is largely unexposed or difficult of access at Whakapirau Road, and was not re-collected during this work.

Large specimens of *B. annae* are known from within and just above the Klondyke Sandstone at Port Waikato (R13/f7010, Moewaka Stream; R13/f7013, Waihikura Stream; R13/f6610, f321, Klondyke Road; and R13/f6500, Moewaka Quarry; Fig. 4). If, as seems likely, the *Belemnopsis* recorded by Purser (1961) from R13/f6611 are *B. annae* (they cannot be located at the University of Auckland), the *Belemnopsis annae* zone would extend through c. 100 m of beds at Port Waikato. The taxon appears to be confined to the Early and early Middle Heterian.

Challinor (1979a), originally thought that *Belemnopsis annae* possibly extended into the upper Ohineruru Formation at Kawhia (R16/f6547), based on a strongly ventrally

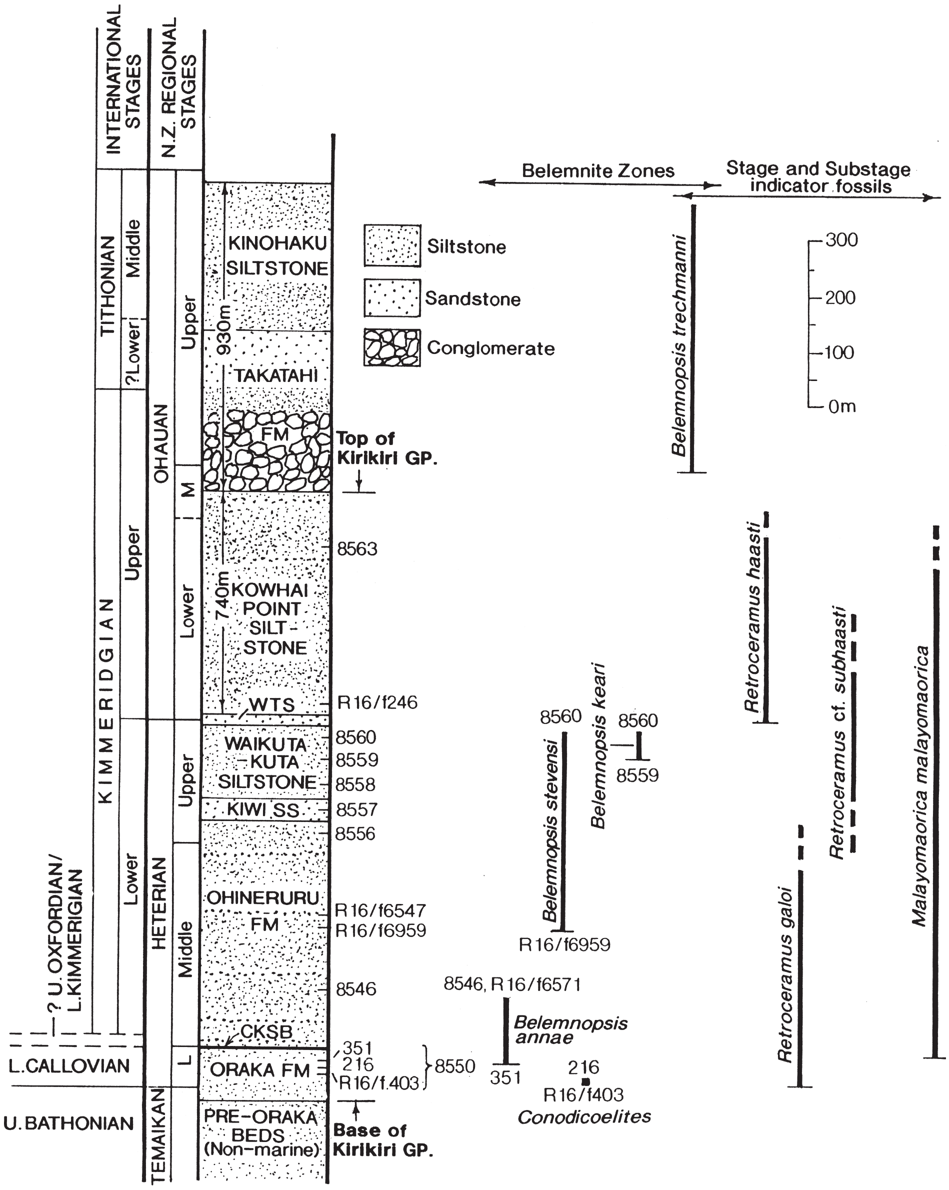


Fig. 5 Stratigraphic column for Kirikiri Group based on type sections at Kawhia Harbour (adapted from Fleming & Kear 1960, fig. 4). Correlations between New Zealand regional stages and international stages follow Westermann et al. (2002), and Stevens (1997). An unconformity is hypothesised at the base of Captain King's Shellbed (CKSB), see text. Fossil Record numbers without sheet prefix (e.g., 216, 8563) are located within Sheet R15, NZMS 260. Known ranges of *Belemnite* zones in the Kawhia region are indicated. Fossil record numbers at the range bar limits indicate first and last occurrences where these are known. The *Belemnopsis stevensi* Zone extends well into the Lower Ohauan in the Port Waikato region. CKSB (1–2 m thick), Kowhai Point Siltstone, Takatahi Formation, and Kinohaku Siltstone are not shown to scale.

eccentric apical line in some small fragments. This is now considered to be a misinterpretation resulting from the occurrence of a wide ventral groove in some specimens of *B. stevensi* (see below).

Belemnopsis stevensi ranges from R16/f6547 and f6959 in the Ohineruru Formation, to the top of the Waikutakuta Siltstone at Kawhia (Fig. 5), and has not been found above the top of the Heterian in that region. It appears to be present in highest numbers just below the base of the Kiwi Sandstone.

Many small belemnites were found at Kawhia at about the level of R15/f6547 and R16/f6959 (Fig. 5). About 50 small fragmentary specimens 3–7 mm in diameter were found at R16/f6959 and c. 60 similar specimens at f6547. The smaller specimens are needle-like and lack clear diagnostic features, but do not differ significantly from *Belemnopsis stevensi*, and are included in that taxon (see below). Most of the larger specimens (5–7 mm diam.) are clearly *B. stevensi*. However, a few specimens that together span the stratigraphic range of R16/f6547 are relatively narrowly grooved, and most are approximately equidimensional or compressed in cross-section. Their status is uncertain.

Localities R16/f6547 and f6959 contain a diverse, but sparse belemnite assemblage, apart from *B. stevensi*. Both contain the earliest known *Belemnopsis stevensi*, as well as *Belemnopsis kiwiensis*, *B.* cf. sp. B, *B.* sp. B (f6547), and *B.* sp. D (f6959).

In contrast, *B. stevensi* from Port Waikato are mostly adult forms and were found only in the middle Moewaka Formation (R13/f6989, f6993, f6995, f7009, Fig. 4), above the Heterian/Ohauan boundary. This apparently disjunct range is almost certainly due to collection failure. Exposure is poor in the lower Kowhai Point Siltstone at Kawhia Harbour (Lower Ohauan) and in the Moewaka Formation. On present evidence, *Belemnopsis stevensi* ranges from the Middle Heterian well into the Lower Ohauan Stage.

Additional specimens of *Belemnopsis keari* are now available from Kawhia, but the concept of the taxon (Challinor 1979a) remains unchanged. Its short range at Kawhia Harbour (confined to the Waikutakuta Siltstone) is apparently mirrored at Port Waikato, where it has been found only at localities R13/f1, f6998, and probably f6609, closely below the earliest localities at which Purser (1961) identified *Retroceramus haasti* (R13/f6630 lower Te Karamu Stream, f6608 Moewaka Stream, and f6609 Klondyke Road, Fig. 4). A number of plastic casts prepared from natural belemnite moulds were obtained from R13/f6609 on Klondyke Road. They are identified as *Belemnopsis* cf. *keari*, and are associated with *Retroceramus* cf. *haasti* and a *Retroceramus* with much less prominent sculpture (Challinor 1974). *Belemnopsis keari* is possibly confined to the topmost Heterian.

No additional morphological information has become available on *Dicoelites kowhaiensis*, but its known stratigraphic range has been extended by discovery of a single specimen at locality R16/f246 (lowermost Kowhai Point Siltstone, see Meesook & Grant-Mackie 1995, fig. 1) south of Kawhia Harbour. It is accompanied at R16/f246 by *Malayomaorica malayomaorica*, *Retroceramus haasti* (Meesook 1989), and a finely ribbed ammonite (?*Kossmatia*). Its stratigraphic range encompasses at least the lower and middle Kowhai Point Siltstone (R16/f246–R15/f8563, Fig. 5) but it is too sparsely distributed to be useful as a zonal fossil. No further specimens of *Belemnopsis* sp. B. or *B*. sp. D similar to the originals have been found.

HETERIAN/OHAUAN BOUNDARY

Fleming & Kear (1960) defined the Heterian/Ohauan boundary by the first appearance of *Retroceramus haasti* (Hochstetter). At Port Waikato, Purser (1961) placed the boundary at localities R13/f6630, f6608, and f6609 (Fig. 4). Purser found the stratigraphically highest *R. haasti* at f6623 on Okahu Stream, c. 100 m below the position adopted for Takatahi Formation by Challinor (2001 and in this paper). The Heterian/Ohauan boundary appears to be diachronous, and is younger in the southern part of the area studied compared with that in the north.

Retroceramus species within the Heterian and Ohauan Stages are not well understood (Meesook & Grant-Mackie 1995). King (1994) has shown that a number of separate forms stratigraphically intermediate between *galoi* s.s. and *haasti* s.s. are present in the North Island Jurassic. During this work, *Retroceramus* cf. *galoi* was found at Moewaka Stream (R13/f319) not far below Purser's *R. haasti* locality R13/f6608. Earlier, *R*. cf. *haasti* and a much more finely sculptured *Retroceramus* were found together at R13/f6609 on Klondyke Road (Challinor 1974, fig. 22, 23), and it is possible that Purser's Heterian/Ohauan boundary is based at some localities on specimens that are not *haasti* s.s., resulting in the apparently diachronous boundary mentioned above.

However, the distribution of *Belemnopsis keari* at Port Waikato (R13/f1, f6698, and probably at f6609) with respect to that of *Retroceramus haasti*, closely mirrors that at Kawhia Harbour (i.e., closely below the first appearance of *R. haasti*), suggesting that the position of Purser's boundary is not greatly in error.

It is possible that the specimens of *Belemnopsis keari* found so far at Port Waikato are from different points in its stratigraphic range. It ranges through the upper 60 m of the 130 m thick Waikutakuta Siltstone at Kawhia Harbour according to Challinor (1979a), but through the whole formation according to Meesook & Grant-Mackie (1995, fig. 4), although specimens supporting the latter distribution were not found in the Meesook collections at the University of Auckland. Some of Purser's *Retroceramus haasti* specimens may be misidentified, and others may be from different stratigraphic positions. Another possibility is that *Belemnopsis keari* extends into the lower *Retroceramus haasti* zone, and the apparent diachronism may be a result of accidents of collection and/or exposure. As this anomaly has not been resolved, Purser's boundary is accepted here, and *Belemnopsis keari* is regarded as confined to the topmost Heterian.

STAGE CORRELATIONS

These correlations are based on the stratigraphic sequence at Kawhia Harbour (Fig. 5). The base of the Heterian Stage and of the Lower Heterian Substage is marked by the first appearance of *Retroceramus galoi* (Boehm), and is currently placed 20–23 m above the base of the Oraka Formation (Hudson 1999). The Middle Heterian, based on the first appearance of *Malayomaorica malayomaorica* (Krumbeck) (MacFarlan 1975), includes the Captain King's Shellbed and most of the Ohineruru Formation. The Upper Heterian is recognised by the first appearance of *Retroceramus subhaasti* (Wandel) (MacFarlan 1975), and the Middle/Upper Heterian boundary is located in the upper part of the Ohineruru Formation.

The overlying Ohauan Stage (Marwick 1953) is defined by the first appearance of *Retroceramus haasti* (Hochstetter), and the base is located near the base of the Waikiekie Tuffaceous Sandstone (Meesook & Grant-Mackie 1995). The Middle Ohauan is an interval zone between the last appearance of *Retroceramus haasti* and the first appearance of *Belemnopsis trechmanni* Stevens, the latter indicating the base of the Upper Ohauan Stage (Meesook & Grant-Mackie 1995). This is located in the lower part of the Takatahi Formation in the type section (Challinor 1996).

The international correlations of New Zealand stages adopted here follow Westermann et al. (2002) for the Lower Heterian, and Stevens (1997) for the Middle Heterian–Ohauan.

Westermann et al. (2002, fig. 4) date the Oraka Formation at Kawhia as Late Bathonian and Early Callovian (Fig. 5), based on two assemblages of eurycephalitine ammonites. The Oraka Formation in the Awakino region is thicker (Hudson 1983), the same ammonite assemblages occur beneath its lower part, with two younger assemblages (Lower and Middle Callovian) in the Oraka Formation above (Westermann et al. 2002, fig. 4). The Oraka Formation and unnamed underlying formations near Awakino are dated as Bathonian to probably Middle Oxfordian by Westermann et al. (2002, fig. 4). They speculate that a Mid–Late Oxfordian unconformity may exist between these formations and the overlying Captain King's Shellbed, although no physical evidence of a break has been found. At Kawhia Harbour, this possible unconformity would span the late Lower Callovian to Mid–Late Oxfordian (Westermann et al. 2002, fig. 4).

Both Stevens (1997), and Westermann et al. (2002), correlate most of the Ohineruru Formation with the Lower Kimmeridgian, although their taxonomic interpretation of the relevant ammonites differs. The age of the basal Ohineruru Formation is not completely clear. Stevens (1997), regarded it as being of Early Kimmeridgian age, Westermann et al. (2002), as Late/latest Oxfordian to Early Kimmeridgian.

Stevens (1997, fig. 61) correlated the Kiwi Sandstone and Waikutakuta Siltstone with the Lower Kimmeridgian, the Kowhai Point Siltstone and lower half of the Takatahi Formation with the Upper Kimmeridgian, the upper Takatahi Formation possibly with the Lower Tithonian, and the Kinohaku Siltstone with the Middle Tithonian.

FORMAL BELEMNITE ZONES

The stratigraphic distribution of belemnites in the Heterian Stage is better known in the Kawhia region than at Port Waikato. At this time, the upper part of the known stratigraphic range of *Belemnopsis stevensi* has not been demonstrated at Kawhia and the lower part not demonstrated at Port Waikato. The time ranges of *Condicoelites* and *Belemnopsis annae* in southwest Auckland are not fully known.

Conodicoelites occurs in the Oraka Formation at both Kawhia (R15/f216, f217, R16/f403), and Awakino, but the ages and taxonomic relations of the two groups of specimens are uncertain at this time. The lowest occurrences of *Belemnopsis annae* in the Kawhia region (small specimens in the upper Oraka Formation, currently interpreted as members of the taxon), are, according to the stage correlations of Westermann et al. (2002), of Early Callovian age. This implies that the taxon ranges through almost two full stages (Lower Callovian to Lower Kimmeridgian, Fig. 5). This is an extremely long range, and raises uncertainty on the taxonomic status of specimens from the Oraka Formation. Undescribed *Belemnopsis* species, including *Belemnopsis* cf. *annae*, occur in the Oraka Formation near Awakino, associated with the eurycephalitine ammonite fauna 4 (Middle Callovian, Westermann et al. 2002).

The zones of *Conodicoelites* and *Belemnopsis annae* (Fig. 5) are provisional, based mostly on data from Kawhia, and are included here to complete this study as far as is possible at this time. It is the intention to investigate the ranges of these taxa, and the taxonomic status of the included specimens, in a further study.

The following formal belemnite zones (Fig. 5) best represent the distribution of stratigraphically useful belemnites within the Heterian and Lower Ohauan Stages.

***Conodicoelites* Zone.** Age: Early Heterian (Early Callovian).

Conodicoelites is present in the middle Oraka Formation at Kawhia Harbour (Stevens 1965) and to the south at Whakapirau Road. Hudson (1983, 1999) recorded the taxon in the Oraka Formation in several Lower Heterian sections between Kawhia and Awakino. C*onodicoelites* has not been recorded at Port Waikato. The Temaikan/Heterian boundary is located in the lower Oraka Formation at Kawhia Harbour (Hudson 1999); *Conodicoelites* appears above this point, and in this paper the zone is regarded as being confined to the Early Heterian.

***Belemnopsis annae* Zone.** Age: Early and early Middle Heterian (?Early Callovian to Early Kimmeridgian).

The known range of *Belemnopsis annae* at Kawhia apparently includes the upper Oraka Formation, Captain King's Shellbed, and lower c. 150 m of the Ohineruru Formation. It appears to range through c. 100 m of beds at Port Waikato.

***Belemnopsis stevensi* Zone.** Age: Middle Heterian to Early Ohauan (Kimmeridgian).

Belemnopsis stevensi has been recorded from the upper c. 200 m of the Ohineruru Formation and throughout the Kiwi Sandstone and Waikutakuta Siltstone at Kawhia Harbour. It has been found at Port Waikato only in the middle Moewaka Formation.

***Belemnopsis keari* Zone.** Age: Late Heterian (Kimmeridgian).

Belemnopsis keari occurs throughout the upper half (possibly all) of the Waikutakuta Siltstone at Kawhia and in the middle Moewaka Formation at Port Waikato. It is known from Pomarangei Road, Marakopa district (its type locality), and Maungakohe Junction and Taumatatotara Road, Kawhia South. The *Belemnopsis keari* Zone is co-extensive with the middle part of the *Belemnopsis stevensi* Zone.

***Belemnopsis trechmanni* Zone.** Age: Late Ohauan (Kimmeridgian/Tithonian).

This zone is discussed fully in Meesook & Grant-Mackie (1995) and Challinor (1996, 2001).

TAXONOMY

Methods

Study and descriptive methods used here broadly follow Challinor & Skwarko (1982) with terminology and some techniques from Stevens (1965), and Jeletzky (1966). Terminology is summarised in Challinor (1999 fig. 5, 2001 fig. 12). Indices used herein are redefined or defined below.

$$\text{Index A} = \frac{\text{transverse diameter of guard} \times 100}{\text{sagittal diameter}}$$

$$\text{Index Z} = \frac{\text{distance from dorsal surface to apical line} \times 100}{\text{distance from ventral surface to apical line}}$$

$$\text{Index W} = \frac{\text{width of ventral groove} \times 100}{\text{transverse diameter of guard}}$$

$$\text{Index D} = \frac{\text{depth of ventral groove} \times 100}{\text{sagittal diameter of guard}}$$

The philosophy and approach used in this paper are set out in Challinor (1999, pp. 369–373).

Systematic descriptions

The material studied is held at University of Auckland, Institute of Geological & Nuclear Sciences, Lower Hutt, and in my own collections (shortly to be deposited at University of Auckland). Fossil locality numbers (R13/f6500, R15/f8556, R16/f6959) are those of the New Zealand Fossil Record File within sheets R13 (Onewhero), R15 (Kawhia), and R16 (Marakopa), New Zealand Map Series NZMS 260, 1:50 000. Specimens with numbers prefixed C are part of the collection of type and figured specimens of the University of Auckland; numbers prefixed TM, CE, are from IGNS Type Collections and Cephalopod Register.

Order BELEMNITIDA Zittel, 1895
Suborder BELEMNOPSEINA Jeletzky, 1965
Family **BELEMNOPSEIDAE** Naef, 1922
Genus ***Belemnopsis*** Bayle, 1878

Belemnopsis stevensi Challinor, 1974. Fig. 6–36, 50–56; Table 1.

1965 *Belemnopsis alfurica* Stevens, *N.Z. Geol. Surv. Pal. Bull. 36*: part; pl. 5, fig. 10–12 only.

1965 *Belemnopsis keari* Stevens, *N.Z. Geol. Surv. Pal. Bull. 36*: part; pl. 3, fig. 7–9; pl. 4, fig. 1–3 only.

1974 *Belemnopsis stevensi* Challinor, *New Zealand Journal of Geology and Geophysics 17*: 235–269, fig. 8–13.

1979a *Belemnopsis maccrawi* Challinor, *New Zealand Journal of Geology and Geophysics 22*: 111–115, fig. 22–42.

1979b *Belemnopsis maccrawi* Challinor, *New Zealand Journal of Geology and Geophysics 22*: 267–275.

1979a *Belemnopsis* sp. A Challinor, *New Zealand Journal of Geology and Geophysics 22*: 119, fig. 66–67.

LOCALITIES AND MATERIAL: Kawhia specimens: Locality R15/f8556. 107 specimens or fragments. Includes C1252 (former holotype of *B. maccrawi*), C1253a, C1260 (formerly *Belemnopsis* sp. A). R15/f8557, 4, includes C1255. R15/f8558, 12, includes C1253b, C1256, C1257a,b. R15/f8559, 6. R15/f8560, 3. R15/f8558–f8560, 12, not precisely localised. R16/f6547, 76, includes C1255. R16/6959, 59. Port Waikato specimens: R13/f6989, 4. R13/f6993, 4, includes TM5368, TM5369, TM5370. R13/f6995, 1. R13/f7009, 1. In total 289 specimens and/or fragments. About 100 are moderately sized to large specimens; the remainder are fragments of small to very small specimens. About 60 specimens consist of half or more of the guard, the remainder are smaller fragments.

HOLOTYPE: TM5368, Challinor 1974, fig. 8, 9 (Fig. 10, 11).

TYPE LOCALITY: Locality R13/f6989, Moewaka Stream, Port Waikato.

AGE: Middle Heterian to Early Ohauan (Kimmeridgian).

STRATIGRAPHIC AND GEOGRAPHIC RANGE: *Belemnopsis stevensi* occurs in the Ohineruru Formation, Kiwi Sandstone, and Waikutakuta Siltstone in the Kawhia region, and in the upper Moewaka Formation at Port Waikato.

DESCRIPTION:

About 300 specimens of *Belemnopsis stevensi* are available but most are fragmentary, and many are of young specimens (diam. 3–6 mm). Only 24 specimens are complete enough to provide length measurements and almost half of these are incomplete, requiring some degree of estimation. Statements of length and length/diameter ratios should be regarded as indicative only. Some measurements are available from fragments; as a result, measures of maximum diameter, relationship between diameters and position of the apical line are more accurate, as are those of ventral groove length, width, and the relation of groove to guard length.

External features

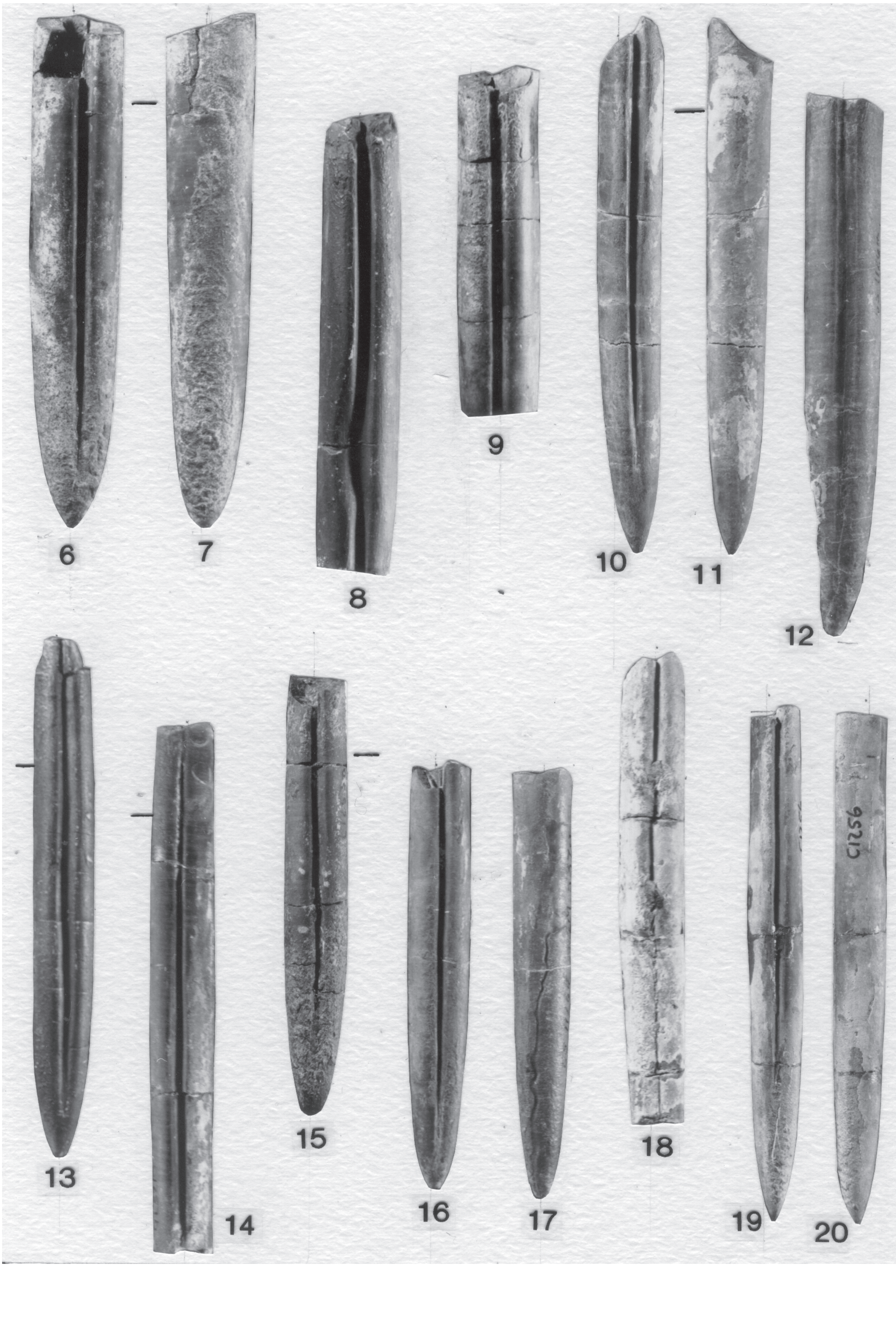
The guard is elongate and moderately robust. The postalveolar length is 59–105 mm ($\bar{x}$ 75 mm, σn–1 10.7 mm) and 4.4–13.6 times maximum diameter ($\bar{x}$ 7.7, σn–1 2.6). Specimens >10 mm in diameter have postalveolar length/diameter ratios of c. 6 and this is an approximation for adult specimens. The alveolar region of *B. stevensi* is approximately cylindrical and robust and much of it is often preserved. Total length to maximum diameter ratio for these specimens is c. 7–9.

The outline is symmetrical and either non-hastate or very slightly hastate (Fig. 6, 9). The widest point on the guard is variable in position but in fully mature specimens is usually located close to, and sometimes anterior to, the protoconch (Fig. 6, 12). In slightly hastate or non-hastate specimens the sides of the guard at first converge slowly towards the apex, then more rapidly over the terminal 20 mm, producing an elongate apical region (Fig. 6, 10). In some specimens, particularly those that are not fully mature (Fig. 19), the widest point is located between the protoconch and midway along the postalveolar guard. These specimens are slightly hastate and the sides converge gradually and slightly towards the anterior break. Hastation appears to be maximally developed in some half-grown specimens (Fig. 26–32) and may be quite marked. Very young specimens are rarely complete enough to reliably indicate their shape, but many fragments are only slightly hastate or almost parallel sided, suggesting that the young guard is slender, elongate, and only slightly hastate (Fig. 33, 34).

Profile is usually non-hastate and asymmetric (Fig. 7, 11, 17). The apex is subcentrally placed and occasionally weakly mucronate (Fig. 10, 19); the ventral surface at first curves smoothly away from the apex, then remains approximately parallel to the midline of the guard (Fig. 11, 17). The dorsal surface curves more strongly away from the apex than does the ventral surface, and either continues to diverge gradually from the midline producing a weakly conical profile (Fig. 7, 11) or remains subparallel to guard midline. In the latter case the anterior half of the guard is

Fig. 6–49 Belemnite guards. Specimens figured in ventral view, or in ventral and left lateral view (ventral groove facing camera, or facing left), or in transverse section. Ventral and lateral views ×1; transverse sections approximately ×3 or ×4. A horizontal bar marks the approximate position of the protoconch. Catalogue numbers printed in bold type indicate specimens plotted in Fig. 50–56. ➤

Fig. 6–20 *Belemnopsis stevensi*. **6**, **7, C1252**, R15/f8556, Ohineruru Formation. **8**, C1928, (plastic cast), R15/f8556, Ohineruru Formation. **9**, **C1253b**. R15/f8558, Waikutakuta Siltstone. **10**, **11**, **TM5368**, R13/f6989, Moewaka Formation. **12**, **TM5369**, R13/f6989, Moewaka Formation. **13**, **C1254** (plastic cast), R15/f8556, Ohineruru Formation. **14**, **C1257b**, R15/f8558, Waikutakuta Siltstone. **15**, **C1253a**, R15/f8556, Ohineruru Formation. **16**, **17**, **TM5370**, R13/f6989, Moewaka Formation. **18**, C1915, R16/f261, Taumatatotara West Road, Ohineruru Formation. **19**, **20**, **C1256**, R15/f8558, Waikutakuta Siltstone. **C1256** (Fig. 19, 20), is a late pre-adult guard, the remainder are fully adult. Note lack of transverse hastation in some specimens (**C1252**, **TM5368**, **TM5369**) and slight transverse hastation in others (**C1253a**, **C1253b**, **C1254**, **C1256**); consistent lack of sagittal hastation in most adults; variation in ventral groove characters (C1915, **TM5369**, C1928). **C1252**, **C1253a**,**b**, **C1254**, **C1256**, were illustrated as *Belemnopsis maccrawi* in Challinor (1979a).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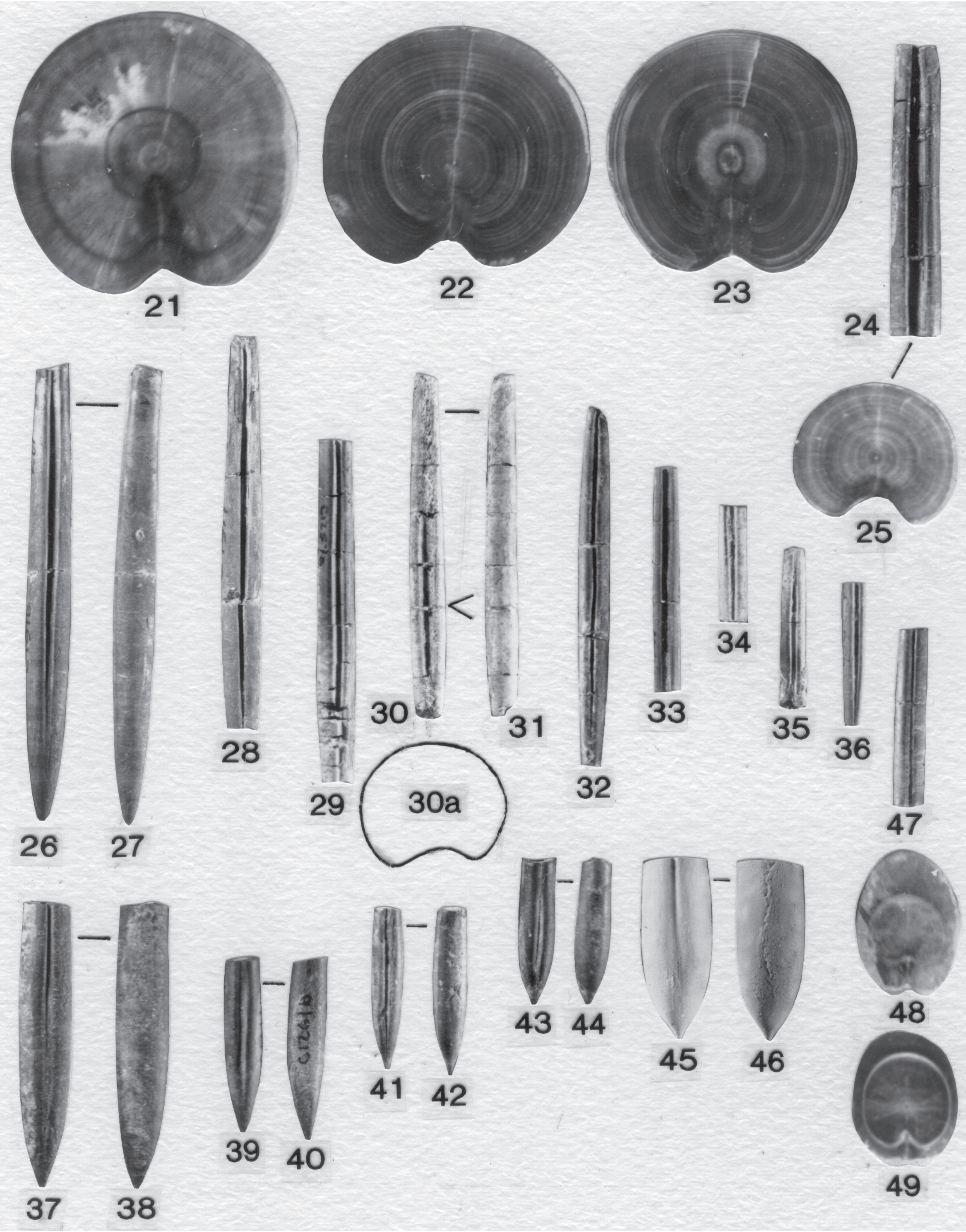

Fig. 21–36 *Belemnopsis stevensi*. **21**, **C1919**, R15/f8556, Ohineruru Formation. Transverse section near midguard (A = 102), ×3. **22**, **C1922**, R15/f8556, Ohineruru Formation. Transverse section near midguard (A = 112), ×3. **23, C1918**, R15/f8556, Ohineruru Formation. Tranverse section near protoconch (A = 103), ×3. **24**, **25**, **C1260** (original specimen of *Belemnopsis* sp. A, Challinor 1979a), R15/f8556, Ohineruru Formation. **24**, Ventral view. **25**, Transverse section at apical end (A = 120), ×3. **26**, **27**, **C1916**, R16/f261, Taumatatotara West Road, Ohineruru Formation. **28**, **C1917**, R16/f261, Taumatatotara West Road, Ohineruru Formation. **29**, **C1257a**, R15/f8558, Waikutakuta Siltstone. **30**, **30a**, **31**, **C1920**, R15/f8557, Kiwi Sandstone. Wide grooved specimen, see discussion in text. A tick marks the position of Fig. 30a, a sketch of the cross-section (A = 115) illustrating wide shallow ventral groove; ×4 approx. **32**, **C1255**, R16/f6547, Ohineruru Formation. **33**, **C1921**, R15/f8558, Waikutakuta Siltstone. **34**, C1923, R16/f6547, Ohineruru ➤

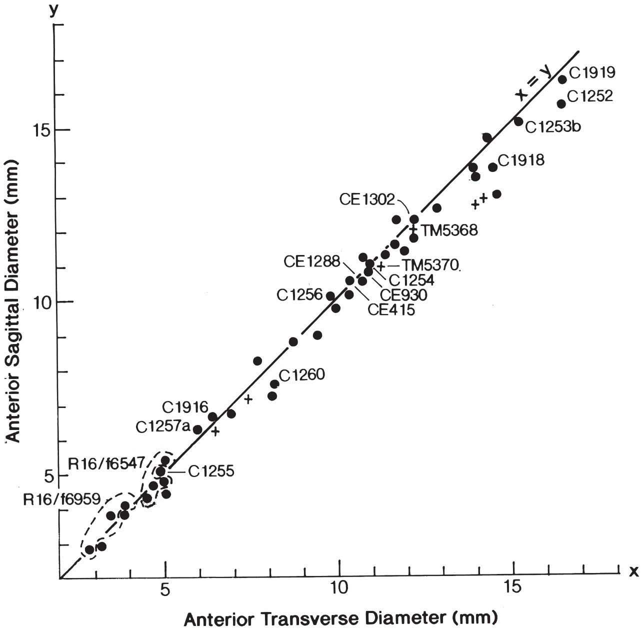

Fig. 50 Relationship between guard diameters in *Belemnopsis stevensi* measured in the anterior region of the guard. Note position of observations from R16/f6547 and f6959. CE415 is from outside the study areas (within Sheet R14, Te Akau). In Fig. 50–56, crosses represent data from Port Waikato, closed circles from the Kawhia area unless otherwise stated.

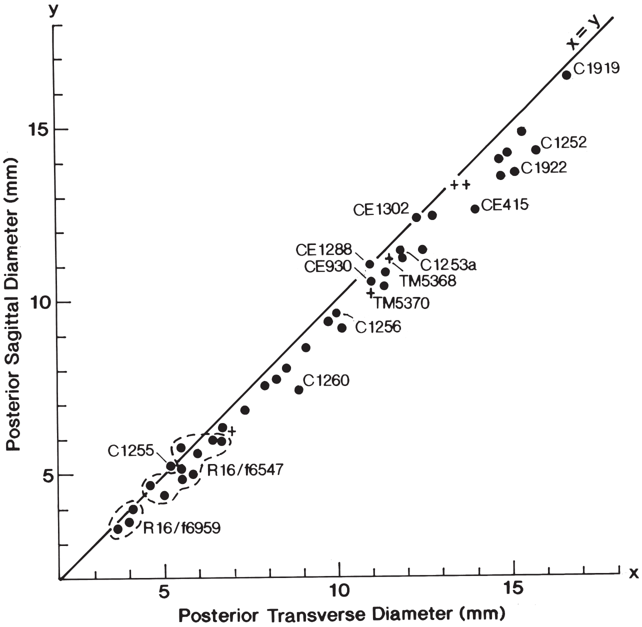

Fig. 51 Relationship between guard diameters in *Belemnopsis stevensi* measured in the posterior region of the guard. Note position of observations from R16/f6547 and f6959. CE415 is from outside the study areas (within Sheet R14, Te Akau).

approximately cylindrical. Maximum sagittal diameter is located at the guard anterior (Fig. 7, 11, 17).

Cross-section measurements were made near the protoconch and approximately midway down the post-alveolar guard (in similar positions to those indicated in Challinor 2001, fig. 12). The cross-section is usually slightly depressed near the protoconch and more depressed near the midguard (Fig. 21–23, 25, 50, 51; Table 1) and is more variable in this feature than in many New Zealand belemnites (cf. Challinor 1996, 1999, 2001). It is oblate posteriorly with rounded dorsal and lateral surfaces and a more flattened ventral surface (Fig. 22, 25). It is more quadrate anteriorly, often with slightly flattened ventrolateral surfaces corresponding to the position of the lateral line depressions (Fig. 21, 23).

The median ventral groove is variably developed. In rare instances it is moderately strongly developed anteriorly but narrow and shallow posteriorly (Fig. 18). It is strongly developed in most specimens (Fig. 6, 8, 12), wide and deep, commences at the anterior break and extends well down the guard, terminating 10–15 mm from the apex. In occasional specimens it is very wide, and in extreme cases its width is c. 50% of the guard transverse diameter (Fig. 24, 25, 30a). It is much wider and deeper in relation to guard diameters in many small specimens than in adults (Fig. 52–54).

Lateral lines are weakly developed but often faintly visible, particularly in young specimens. They commence on the dorsolateral surface of the guard near the apex, run obliquely down across the flanks, becoming centrally placed near the midpoint. They continue onto the anterior stem and alveolar region as wide, very shallow depressions. They are closer together, more deeply incised, and more visible in the apical region. Their presence as widely separated shallow furrows near the alveolus occasionally produces the ventrolateral flattening mentioned above.

Internal features

The apical line is ventrally placed (Fig. 21, 22, 25, 55, Table 1, Z = 118), becoming more so posteriorly. In a few small specimens it is quite strongly ventrally placed (e.g., Z = 125). In these, the ventral groove is wider than usual, effectively placing the ventral surface closer to the apical line than in

Formation. **35**, C1924, R16/f6959, Ohineruru Formation. **36**, C1925, R16/6959, Ohineruru Formation. **Fig. 37–42** *Belemnopsis kiwiensis* n. sp. **37**, **38**, C1929, holotype, R16/f6547, Ohineruru Formation. **39**, **40**, C1261b, R16/f6547, Ohineruru Formation. **41**, **42**, C1930, R16/f6547, Ohineruru Formation. **Fig. 43**, **44** *Belemnopsis* cf. *B.* sp. B. C1931, R16/6547, Ohineruru Formation. **Fig. 45**, **46** *Belemnopsis* sp. B. C1261a, R16/f6547, Ohineruru Formation (original specimen of Challinor 1979a). **Fig. 47** *Belemnopsis sp.* C1926, R16/f6547, Ohineruru Formation. **Fig. 48**, **49** *Belemnopsis* sp. D. **48**, C1927, R16/f6959, Ohineruru Formation. **49**, C1932, R16/f6959, Ohineruru Formation. Note slight hastation in small specimens of *Belemnopsis stevensi* (Fig. 32, 33) and increasing hastation with increasing size of pre-adult (Fig. 26–31). Fig. 33–35 are typical of the small specimens at the level of R16/f6547 and f6959. Many smaller fragments of smaller guards occur at these localities, particularly f6959. C1926 (Fig. 47) is a small specimen with a relatively narrow groove and approximately equidimensional cross-section identified as *Belemnopsis* sp. C1927 and C1932 (Fig. 48, 49) illustrate the less compressed early growth stages of *Belemnopsis* sp. D. **C1255**, **C1257a** were illustrated as *Belemnopsis maccrawi*; C1261b as *Belemnopsis* sp. C in Challinor (1979a).

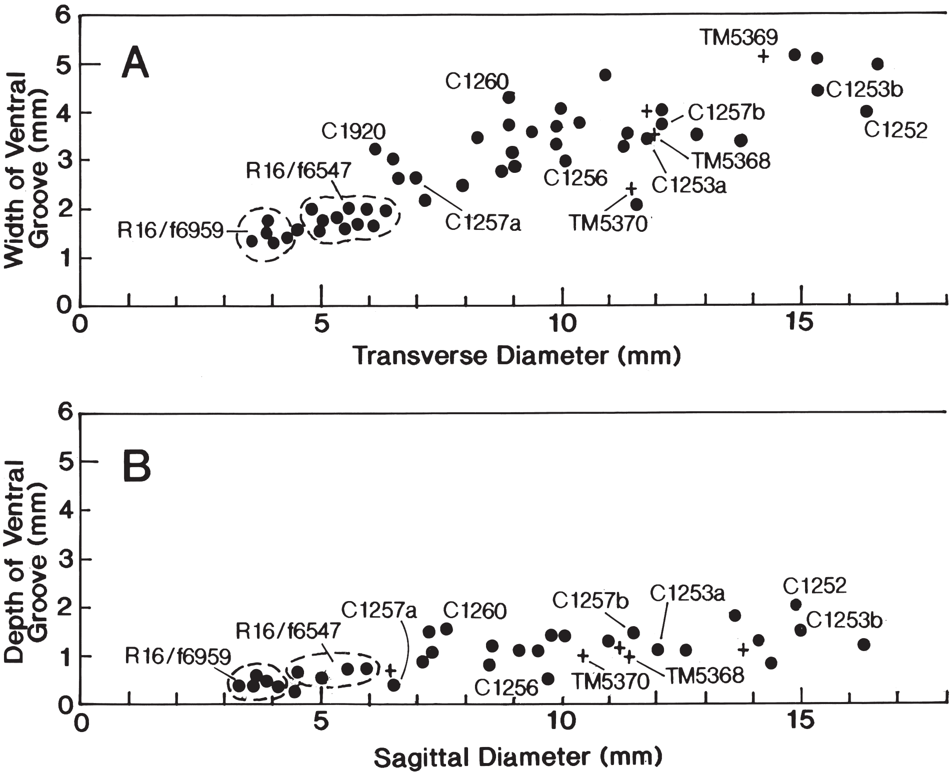

Fig. 52 **A**, Width of ventral groove in *Belemnopsis stevensi* plotted against guard transverse diameter. **B**, Depth of ventral groove plotted against guard sagittal diameter. Note approximately collinear position of observations from R16/f6547 and f6959 with other data.

normally grooved specimens. A long chord passes closer to the centre of a circle than does a short chord, and a wide ventral groove produces the same effect. A wide groove also contributes to depression of the cross-section. The protoconch is slightly ventrally placed and the dorsoventral alveolar angle is c. 25° (based on few specimens).

Several prominent growth stages are usually visible in transverse sections, (Fig. 21–23, 25) particularly one with a diameter of c. 6–8 mm. A prominent growth stage at about this stage of development is present in many New Zealand belemnites and has been interpreted as a change in growth pattern from a mostly longitudinal to a mostly diametral direction (Challinor 2001). A splitting surface is visible between apical line and ventral groove in transverse sections, is often surrounded by a discoloured region, apparently due to pore fluids migrating along it (Fig. 21, 23), and can sometimes be seen externally at the base of the ventral groove. It extends down the guard for about one-half of the guard length.

ONTOGENY:

The guard of *Belemnopsis stevensi* is characterised by an elongate, slender, slightly hastate early growth stage c. 3–5 mm in diameter, a mid-growth stage c. 6–8 mm in diameter which is weakly to strongly hastate (Fig. 26–32), and later growth stages which become progressively less hastate, cylindrical, and finally often conical. A dorsoventral longitudinal section (which provides information only on sagittal hastation) exhibits a slightly hastate early growth stage 3–4 mm in diameter and 74 mm long, a cylindrical mid-growth stage 7.5 mm in diameter and 87 mm long, both within a cylindrical adult guard of 14 mm diameter and 102 mm postalveolar length. Growth in length clearly dominates early and mid stages of development. Some young specimens (e.g., C1916, Fig. 26, 27) closely resemble some *Belemnopsis keari* (e.g., Challinor 1979a, fig. 45, 46) and could readily be so identified. As with most belemnite taxa, several specimens should be used as a basis of identification whenever possible.

SYNONYMY:

When *Belemnopsis maccrawi* was first described from Kawhia it was clear that it strongly resembled *B. stevensi* from Port Waikato. G. R. Stevens (pers. comm. 1979) considered them to be possible chronosubspecies or perhaps identical. After much consideration it was decided to describe the Kawhia material as a separate taxon (Challinor 1979a). This option was chosen because *B. stevensi* appeared always to be non-hastate when fully adult. Specimen TM5369 (Fig. 12) possessed a ventral groove wider than that of *B. maccrawi* (the relationship of *maccrawi* to *Belemnopsis* sp. A was not then known) and the two appeared to differ in stratigraphic range (upper Heterian for *maccrawi*, lower Ohauan for *stevensi*). A more detailed study and the availability of more specimens have shown this view to be incorrect.

Bivariate plots of diametral relationships (Fig. 50, 51), the index W and transverse diameter (Fig. 53), the index D and sagittal diameter (Fig. 54), and maximum diameter and postalveolar length (Fig. 56), all suggest identity. So also do plots of direct groove width and depth against guard transverse and sagittal diameters (Fig. 52). These plots, together with a general morphological similarity and a better understanding of growth pattern, are now regarded as confirming identity.

Many specimens from R16/f6959 and f6547 at Kawhia are fragments of small to very small guards. Few similar-sized firmly identified specimens of *B. stevensi* are available

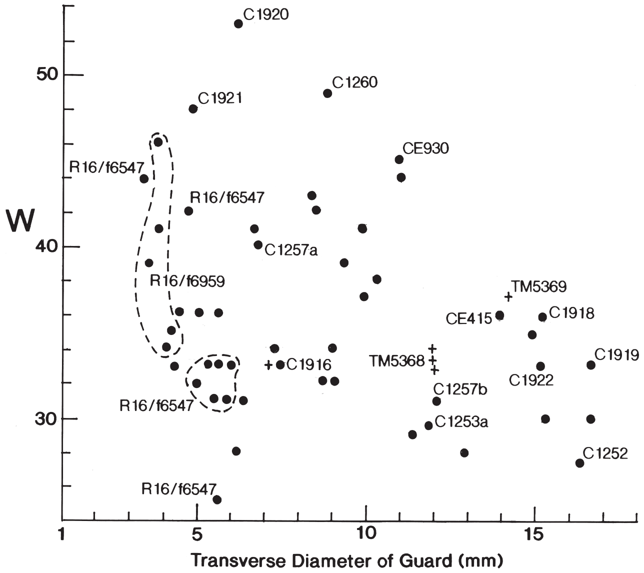

Fig. 53 Width of ventral groove in *Belemnopsis stevensi* expressed as a percentage of guard transverse diameter (the index W), plotted against true transverse diameter of guard. Note extreme relative width of the ventral groove in some specimens of small diameter and decrease in relative groove width with increasing guard diameter. C1260 figured as *Belemnopsis* sp. A. by Challinor (1979a). Specimen TM5370 (Fig. 15, 16) lies below the graph field (W = 21, transverse diameter = 11.4 mm). CE415 is from outside the study areas (within Sheet R14, Te Akau).

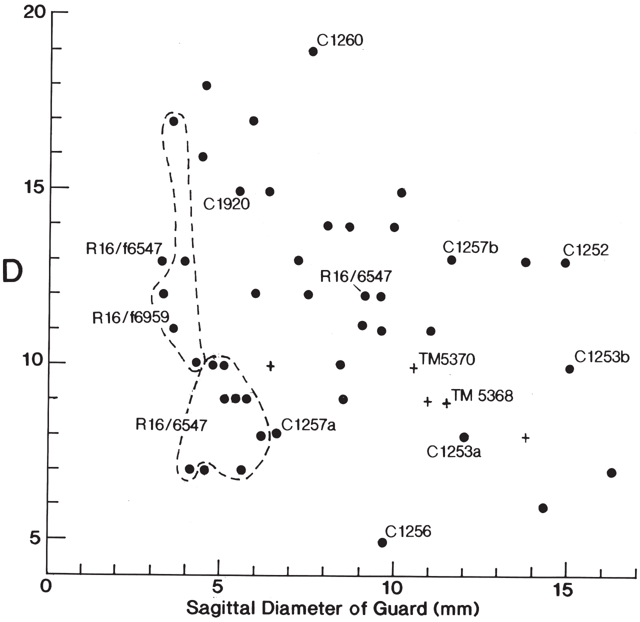

Fig. 54 Depth of ventral groove in *Belemnopsis stevensi* expressed as a percentage of guard sagittal diameter (the index D), plotted against true sagittal diameter of guard. Note extreme relative depth of groove in some specimens of small diameter and decrease in relative groove depth with increasing guard diameter. C1260 figured as *Belemnopsis* sp. A. by Challinor (1979a).

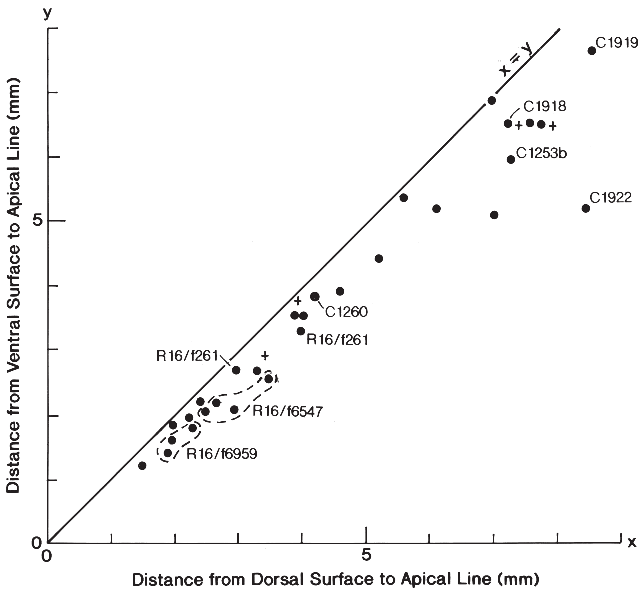

Fig. 55 Position of the apical line in *Belemnopsis stevensi*. Anterior and posterior regions not differentiated. Data for R16/f261 is from Taumatatotara West Road c. 8 km south of the southern edge of Fig. 3.

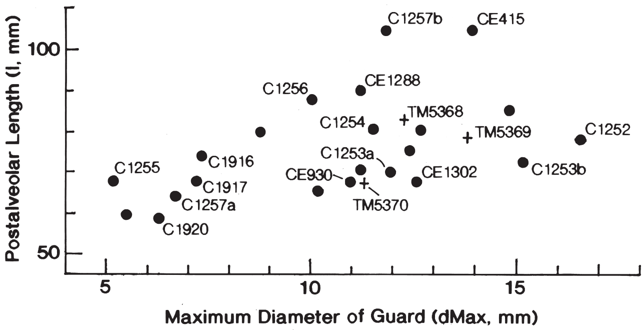

Fig. 56 Relationship between postalveolar length and maximum transverse diameter in *Belemnopsis stevensi*. CE415 is from outside the study area (within Sheet R14, Te Akau).

for comparison. These small specimens are identified as *B. stevensi* by relative width and depth of ventral groove, absolute width and depth of groove, diametral relationships, apical line position (Fig. 50–55), and general appearance. It is often difficult to be confident when identifying young belemnite specimens, particularly when they are fragmentary (Challinor 1999), but these data are fairly convincing.

The status of a large acrylic cast originally figured as *Belemnopsis* sp. (Challinor 1974, fig. 2, 3), from R13/f7009, Port Waikato, and later compared with *B. maccrawi* (Challinor 1979b), remains uncertain, and it is more symmetrical in profile than most *B. stevensi*.

The additional specimens now available also establish the synonymy of *Belemnopsis stevensi* and *Belemnopsis* sp. A. When the latter was described, only one specimen was recognised (C1260, Fig. 24, 25), and it was the only such widely grooved specimen known (apart from the relatively narrower but still widely grooved TM5369 from Port Waikato). Others are now available (C1920, Fig. 30, 30a, 31; C1921, Fig. 33). The groove in C1920 is extremely wide, relatively shallow, and is arcuate in cross-section. Its anterior one-third is filled with a hard sandy matrix, and only its deepest part is in shadow. Its outer limits are indicated by faint dark longitudinal shadows posterior to the matrix infilling and situated c. 1.5 mm in from, and parallel to, the guard flanks (Fig. 30). A sketch of the cross-section is illustrated in Fig. 30a.

Figure 53 plots the index W (groove width as a percentage of guard width) against guard transverse diameter. It illustrates the extreme variability of *Belemnopsis stevensi* in this feature, and that a continuum exists between relatively weakly grooved and strongly grooved conditions (at least in pre-adult guards). The new specimens also indicate that extreme relative groove width, like more normally proportioned grooves, occurs in both strongly hastate (Fig. 30) and weakly hastate (Fig. 24) pre-adult guards. Fully adult specimens with a comparable relative groove width are rare (e.g., CE930, Fig. 53), perhaps indicating that the condition does not often persist into late development.

Measurements of groove width are easily obtained from sectioned guards using a binocular microscope with a low powered graduated eyepiece. They are less easily obtained from entire specimens, and sectioning complete guards for this purpose alone is not warranted. Measurements can be obtained from complete specimens by illuminating the guard with low-angle lighting, and measuring the width between the shadows produced by the crests of the curves between the ventrolateral surface of the guard and the upper walls of the groove. Depth measurements can be obtained with a small rule graduated in millimetres by placing the end of it directly into the groove. Such measurements are approximate and much less accurate than those from sectioned specimens, but they are adequate for the purposes of this paper. They have the additional advantage that approximate groove widths can be obtained from published photographs if the illumination is suitable. Data from CE930 (Stevens 1965, pl. 5, fig. 10–12) were obtained from the illustration.

Stevens (1965) figured three specimens from the Waikutakuta Siltstone here included in *Belemnopsis stevensi*. He included two (CE1288, Stevens 1965, pl. 4, fig. 1–3; CE1302, pl. 3, fig. 7–9) in *B. keari* Stevens (but tabulated their dimensions under *B. alfurica*), and one (CE930) in *B. alfurica* (Boehm). All are large, robust, strongly grooved, slightly hastate or cylindrical guards and are plotted in Fig. 50, 51, and 56. CE930 is particularly strongly grooved (guard width 11 mm, groove width c. 5 mm), and is relatively the most widely grooved adult known from Kawhia. Although the specimens have not been directly examined, they are here included in *B. stevensi*, based on the illustrations and dimensions tabulated by Stevens (1965). Stevens also figured CE415 (from Kirikiri Group, Te Akau region) as *B. keari* Stevens. This specimen may also be a member of *B. stevensi*, although it is more hastate than most adults. Data from all four specimens are concordant with other data points in Fig. 50, 51, 53, and 56, supporting their inclusion in *Belemnopsis stevensi*.

Table 1 Statistical data of *Belemnopsis stevensi*.

	n	$\bar{x}$	σn–1
A (anterior)	10	1.9	4.6
A (posterior)	87	107.3	4.7
Z	35	118	8.0

***Belemnopsis kiwiensis* n. sp.** Fig. 37–42, Table 2

1979a *Belemnopsis* sp. C. Challinor, *New Zealand Journal of Geology and Geophysics 22*: 118, fig. 70, 71.

LOCALITY AND MATERIAL: 5 specimens from locality R16/F6547, near the horizon of McNaught Shellbed, upper Ohineruru Formation, Kawhia Harbour.

AGE: Middle Heterian (Lower Kimmeridgian).

HOLOTYPE: C1929, Fig, 37, 38. Locality R16/f6547.

STRATIGRAPHIC AND GEOGRAPHIC RANGE: *Belemnopsis kiwiensis* has been found only at R16/f6547 in the upper Ohineruru Formation.

DESCRIPTION:

Only five specimens are known. All are complete from apex to protoconch and all retain part of the alveolar region. All were collected as float and are thought to have been derived from siltstones exposed immediately adjacent to McNaught Shellbed (Fig. 2.) Three specimens are in good condition, but two are somewhat abraded as a result of wave action. In view of the small number of specimens, it was not appropriate to prepare sections, and this description is therefore confined to external features. Postalveolar length is estimated.

The largest specimen (Fig. 37, 38) is assumed to be adult. All others are considerably smaller (Fig. 39–42) and the description may be more accurate for immature specimens, although the large specimen does not appear to differ greatly from most of the remainder.

External features

The guard is small (total length preserved ranges from 29 to 51 mm, postalveolar length 27–45 mm) and robust (postalveolar length 4.1–4.9 times max. diam.).

The outline is symmetrical and hastate. The widest point on the guard is anteriorly placed, usually about two-thirds the distance from apex to protoconch (Fig. 37, 39). The apical region is elongate, tapering slowly towards apex, more rapidly terminally (Fig. 37, 39, 41). The apex is acute and weakly mucronate. Anteriorly the sides contract slightly towards the alveolar break, and the guard is slightly to moderately hastate.

The profile is slightly hastate. The ventral surface converges slightly towards the dorsal surface, commencing at a point one-half to two-thirds the distance from apex to protoconch (Fig. 40, 42). The dorsal surface remains subparallel to the midline of the guard.

The cross-section is variable in shape. It is subquadrate and usually flattened near the protoconch (A = 96–105), dorsal and ventral surfaces are moderately rounded, lateral surfaces more flattened. Posteriorly it is more compressed (A = 97–102) and more regularly rounded. Statistical data (Table 2) suggest it is somewhat more flattened anteriorly (mean A = 100.7) than posteriorly (mean A = 98.3), reverse to the situation in most *Belemnopsis*, although this anomaly may be due to sampling inadequacies.

The median ventral groove is moderately strongly developed (Fig. 37, 39, 41) and extending from anterior break to within 5 mm of the apex. It is narrower at guard anterior, widest at about midguard, and narrows and shallows toward the apex.

DISCUSSION:

Knowledge of guard ontogeny is limited but its shape does not appear to change much during development. *Belemnopsis kiwiensis* resembles the Lower Ohauan *Belemnopsis rarus* (Challinor 1980), and the two could be confused. Both are similarly sized small belemnites (although C1929 is larger than any known *B. rarus*), with similar ventral grooves, and a similar length to diameter ratio (Challinor 1980). But *B. rarus* is more hastate, the widest point on its guard is posteriorly placed, and its cross-section is consistently depressed.

Table 2 Statistical data of *Belemnopsis kiwiensis*.

	n	$\bar{x}$	σn–1
A (anterior)	5	100.7	3.7
A (posterior)	5	98.3	2.3

***Belemnopsis* cf. *Belemnopsis* sp. B.** Fig. 43, 44, Table 3

LOCALITIES AND MATERIAL: One specimen from locality R16/f6547, near the horizon of McNaught Shellbed, upper Ohineruru Formation, Kawhia Harbour.

AGE: Middle Heterian (Lower Kimmeridgian).

STRATIGRAPHIC AND GEOGRAPHIC RANGE: Known only from R16/f6547.

DESCRIPTION:

Guard small, short, and robust. Ratio of total length to maximum diameter c. 4; postalveolar length to maximum diameter c. 3. Outline symmetrical and hastate. Widest point at about midguard. Apical regions converge to produce a blunt, centrally placed, mucronate apex. Flanks converge to produce slight transverse hastation; difference between maximum and minimum anterior transverse diameter c. 0.4 mm. Sagittal hastation is greater than transverse; difference between anterior diameters 0.5 mm. Cross-sections slightly depressed (A = 105). Ventral groove prominent, extends from alveolar break to c. 4 mm from apex; deep and moderately narrow in alveolar region, deep and wide over much of guard. Faint traces of lateral lines are preserved on the alveolar regions.

DISCUSSION:

Although the specimen is juvenile it already strongly resembles *Belemnopsis* sp. B (Fig. 45, 46), in hastation, cross-section, and apical configuration. In length to diameter ratios it is already similar (Table 3) and, had it followed the usual pattern of increasing robustness typical of *Belemnopsis*, may have become almost identical at maturity (assuming that *Belemnopsis* sp. B is itself a mature guard). It differs in ventral groove characters, however, so much that specific separation is suggested, particularly as the groove in *Belemnopsis* usually becomes more prominent with maturity. In the absence of further examples of both *Belemnopsis* sp. B and this specimen, it is not possible to evaluate groove differences, and the status of the specimen remains unclear. Its stratigraphic horizon is thought to be c. 50 m above that of *Belemnopsis* sp. B, but both specimens are float and some transport may have occurred.

Table 3 Length/diameter ratios in *Belemnopsis* cf. sp. B and *Belemnopsis* sp. B.

	Belemnopsis cf. Sp. B	*Belemnopsis* sp. B
Total length/ maximum diameter	4.1	2.7
Postalveolar length/ maximum diameter	3.1	2.2

***Belemnopsis* spp.** Fig. 47

LOCALITIES AND MATERIAL: A number of fragments of uncertain affinity from the lower part of R16/f6547.

AGE: Middle Heterian (Lower Kimmeridgian).

STRATIGRAPHIC AND GEOGRAPHIC RANGE: Known only from R16/f6547.

DISCUSSION:

The figured specimen is narrowly grooved, slightly depressed in cross-section (A = 104), and slightly hastate. Most of the others have similar features. They may be atypical *Belemnopsis stevensi*, early growth stages of known taxa (e.g., *Belemnopsis* sp. D, Fig. 48, 49), or unrecognised taxa.

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REFERENCES

Challinor, A. B. 1974: Biostratigraphy of the Ohauan and Lower Puaroan Stages (Middle Kimmeridgian to Lower Tithonian), Port Waikato Region, New Zealand, with description of a new *Belemnopsis*. *New Zealand Journal of Geology and Geophysics 17*: 235–269.

Challinor, A. B. 1979a: The succession of *Belemnopsis* in the Heterian stratotype, Kawhia Harbour, New Zealand. *New Zealand Journal of Geology and Geophysics 22*: 105–123.

Challinor, A. B. 1979b: Recognition and distribution of Heterian *Belemnopsis* in southwest Auckland. *New Zealand Journal of Geology and Geophysics 22*: 267–275.

Challinor, A. B. 1980: Two new belemnites from the lower Ohauan (?middle Kimmeridgian) Stage, Kawhia Harbour, New Zealand. *New Zealand Journal of Geology and Geophysics 23*: 257–265.

Challinor, A. B. 1996: Belemnites from the upper Ohauan Stage at Kawhia Harbour, New Zealand. *New Zealand Journal of Geology and Geophysics 39*: 211–223.

Challinor, A. B. 1999: Belemnite biostratigraphy of the New Zealand Late Jurassic Mangaoran (Early Puroan) Substage and the Puaroan Stage revisited. *New Zealand Journal of Geology and Geophysics 42*: 369–393.

Challinor, A. B. 2001: Stratigraphy of Tithonian (Ohauan–Puaroan) marine beds near Port Waikato, New Zealand, and a redescription of *Belemnopsis aucklandica* (Hochstetter). *New Zealand Journal of Geology and Geophysics 44*: 219–242.

Challinor, A. B; Skwarko, S. K. 1982: Jurassic belemnites from Sula Islands, Moluccas, Indonesia. *Paleontology Series 3*. Geological Research and Development Centre, Indonesia. 89 p., 21 pl.

Fleming, C. A; Kear, D. 1960: The Jurassic sequence at Kawhia Harbour, New Zealand. *New Zealand Geological Survey Bulletin 67*. 55 p.

Francis, D. A. 1977: The upper Jurassic Captain King's Shellbed in the Kawhia-Mahoenui region, southwest Auckland. Unpublished MSc thesis, lodged in the Library, University of Auckland, Auckland, New Zealand.

Hudson, N. 1983: Stratigraphy of the Ururoan, Temaikan, and Heterian Stages; Kawhia Harbour to Awakino Gorge, south-west Auckland. Unpublished MSc thesis, lodged in the Library, University of Auckland, Auckland, New Zealand.

Hudson, N. 1999: The middle Jurassic of New Zealand: a study of the lithostratigraphy and biostratigraphy of the Ururoan, Temaikan and lower Heterian Stages (?Pliensbachian to ?Kimmeridgian). Unpublished PhD thesis, lodged in the Library, University of Auckland, Auckland, New Zealand.

Jeletzky, J. A. 1966: Comparative morphology, phylogeny and classification of fossil Coleoida, Mollusca. *Article 7, Paleontological Contributions of the University of Kansas, 1–162*. 25 pl., 15 fig.

Kear, D. 1978: *In*: Suggate, R. P. *ed*. The geology of New Zealand. Wellington, Government Printer. 2 vol., 820 p.

King, D. 1994: A biometric study of some North Island Upper Jurassic retroceramid bivalves. Unpublished MSc thesis, lodged in the Library, University of Auckland, Auckland, New Zealand.

MacFarlan, D. A. B. 1975: Mesozoic stratigraphy of the Marakopa area. Unpublished MSc thesis, lodged in the library, University of Auckland. Auckland, New Zealand. 176 p.

Marwick, J. 1953: Divisions and faunas of the Hokonui System (Triassic and Jurassic). *New Zealand Geological Survey Paleontological Bulletin 21*. 141 p., 17 pl.

Meesook, A.; Grant-Mackie, J. A. 1995: Upper Jurassic stratigraphy, south Kawhia region, New Zealand. *New Zealand Journal of Geology and Geophysics 38*: 361–373.

Purser, B. H. 1961: Geology of the Port Waikato region. *New Zealand Geological Survey Bulletin 69*. 36 p.

Riegraf, W. 1999: Taxonomic status of the belemnite genus *Belemnopsis* Bayle 1878. *Palaontologische Zeitschrift 7*: 59–76.

Stevens, G. R. 1965: The Jurassic and Cretaceous belemnites of New Zealand and a review of the Jurassic and Cretaceous belemnites of the Indo-Pacific region. *New Zealand Geological Survey Paleontological Bulletin 36*. 231 p.

Stevens, G. R. 1997: The Late Jurassic ammonite fauna of New Zealand. *Institute of Geological & Nuclear Sciences Monograph 18*. 216 p.

Waterhouse, B. C. 1978: Geological map of New Zealand, Sheet N51—Onewhero 1:63 360. Lower Hutt, New Zealand. Department of Scientific and Industrial Research.

Westermann, G. E. G., Hudson, N.; Grant-Mackie, J. A. 2002: New Jurassic Ammonitina from New Zealand: Bathonian–Callovian Eurycephalitinae. *New Zealand Journal of Geology and Geophysics 45*: 499–525.