

NOTES ON THE BELEMNITE CONTENT OF THE HETERIAN AND OHAUAN STAGES AT KAWHIA HARBOUR, NEW ZEALAND

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Abstract

The belemnite content of the Heterian and Ohauan stages at Kawhia Harbour is described. Six major species or groups are differentiated, each of which ranges through several hundred feet of strata. Other minor elements are also present. *Belemnopsis keari* Stevens is shown to be present in only a restricted group of beds in the upper part of the Waikutakuta Siltstone, and *Belemnopsis alfurica* (Boehm) may be present in the upper Waikutakuta Siltstone. A system of informal belemnite zones is suggested. The belemnite succession is well defined throughout most of the Heterian stage, but poorly defined in the Ohauan, and further work is required in the upper and lower parts of this stage.

INTRODUCTION

The discussion in this paper is based on the examination of over 600 belemnite guards collected by the writer from the southern shores of Kawhia Harbour during 1967 and 1968. Approximately 250 of these are complete, or almost complete specimens. The sites from which fossil material was collected commence on the eastern shore of Totara Peninsula at N73/307064 (Grid references in terms of N.Z.M.S. 1 mile series) and extend eastwards following the coastline to N73/365047, a point three-quarters of a mile west of Waiharakeke Bridge, and span most of the Heterian and Ohauan stages. Opinions expressed on biostratigraphy are based on specimens found *in situ* unless otherwise stated, as it is held that loose fossils collected from the beaches and shore platform can give a most misleading impression of stratigraphical ranges. However, loose fossils are used as a basis for discussion where specimens were not found *in situ*, and are also used to provide a fuller appreciation of the morphology of the various species collected.

The methods of examination and description used are some of those described by Stevens (1965, pages 38-47) and consist mainly of the examination and measurement of external features of the guard. The following criteria were found useful:—

Measurement of maximum transverse diameter	... ..	dtM
Measurement of minimum transverse diameter	... ..	dtm
Measurement of maximum saggital diameter	... ..	dsM
Measurement of minimum saggital diameter	... ..	dsm
Index of transverse hastation	= $\frac{dtM}{dtm} \times 100$	Ht
Index of saggital hastation	= $\frac{dsM}{dsm} \times 100$	Hs
Index of flattening (at dtM)	= $\frac{dtM}{dsM} \times 100$	A
Position of dtM		
Particulars of the ventral groove		
Gross outline in ventral aspect	(outline)	
Gross outline in lateral aspect	(profile)	

Reference to Figure 1 will explain the descriptive terminology used in this paper.

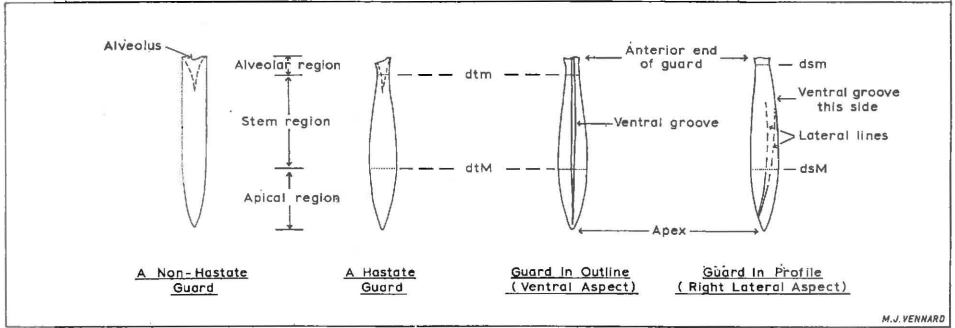


Figure 1. Diagrams illustrating the descriptive terminology of belemnite guards.

It was frequently found difficult to obtain exact measurements — successive micrometer readings of the same dimension of a guard often differing by up to 0.1 mm., due probably to small projections and irregularities on the guard's surface. This applies particularly to measurements at the anterior end of the guard, which is often slightly crushed or corrugated. However, the error introduced by this factor is probably not significant.

No investigation of internal structure has been undertaken apart from examination of the transverse sections of broken guards.

No attempt is made to fully describe any of the specimens collected, a task for which the writer is not qualified, and the brief descriptions given are used solely to differentiate between specimens, and to aid discussion.

Stevens (1965, page 135) has suggested a series of informal belemnite zones for the New Zealand Upper Jurassic, based on the limited material then available. These zones are in the nature of *teitzones* (Donovan 1966, page 55) and those suggested for the Heterian (Kh) and Ohauan (Ko) stages are as follows (and see Figure 2):—

- (i) A zone of *Belemnopsis keari* Stevens, ranging from lower Kh to towards the top of the stage (base of Captain King's Shellbed, to the upper part of Waikutakuta Siltstone).
- (ii) A zone of *Belemnopsis alfurica* (Boehm), ranging from upper Kh (top of Waikutakuta Siltstone) into lower Ko (middle of Kowhai Point Siltstone).
- (iii) First *uhligi*-complex zone (*Belemnopsis aucklandica trechmanni* Stevens) ranging from middle to upper Ko (although the lower part of this zone may be missing at Kawhia as the time-equivalent strata, the Takatahi formation, are apparently unfossiliferous).

However, several undescribed species have been collected by the writer, and these suggest a different succession from that outlined above.

Fleming and Kear (1960) have described the geology of the area in detail and Figures 2 and 3 are from that source.

## HETERIAN STAGE

The Heterian stage at Kawhia Harbour as mapped by Fleming and Kear (1960) consists of five formations: Oraka Sandstone, Captain King's Shellbed, Ohineruru Formation, Kiwi Sandstone, and Waikutakuta Siltstone (see Figure 2).

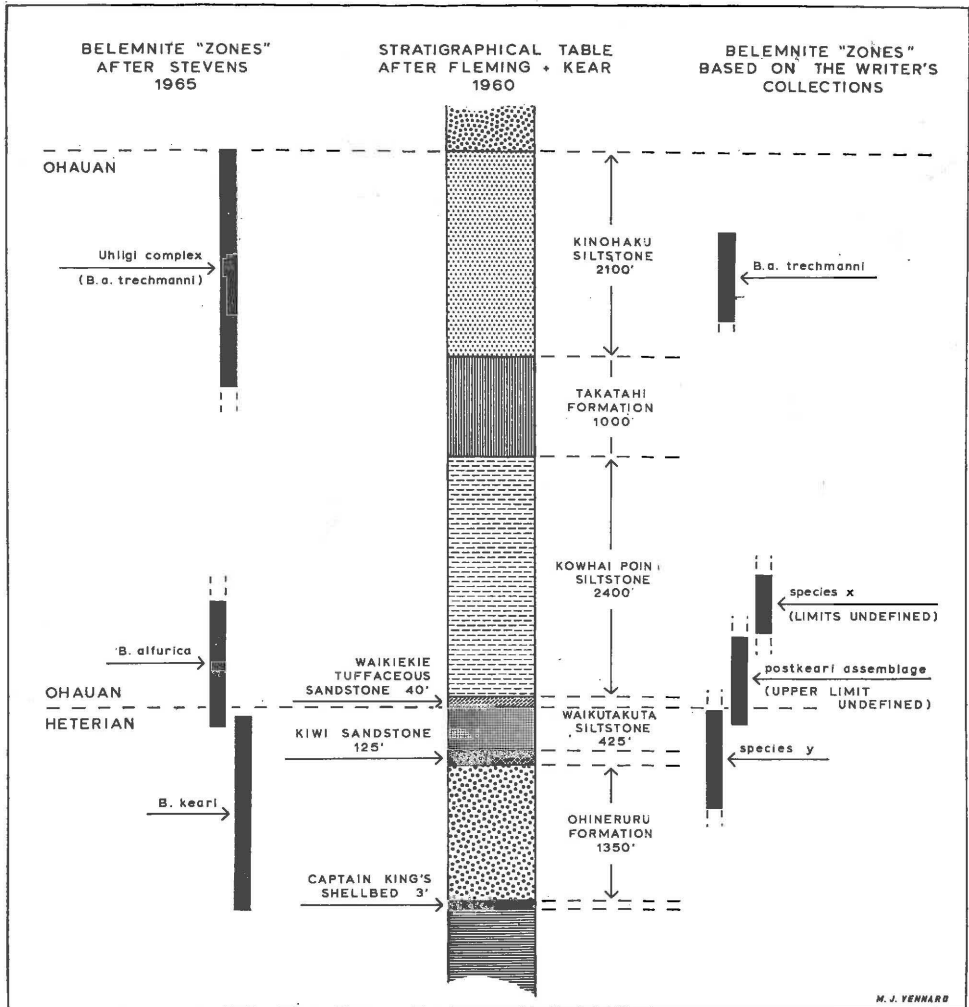


Figure 2. Stratigraphical Table and Belemnite "Zones" for Heterian and Ohauan Stages at Kawhia Harbour.

### Lower Heterian

The oldest belemnites discussed are a species of *Belemnopsis* of lower Heterian age collected from Captain King's Shellbed, and from the lower few feet of Ohineruru Formation. The guards from Captain King's Shellbed at Captain King's, Totara Peninsula, although abundant, are difficult to extract from the hard sandstone matrix, but six more or less complete specimens were obtained. These all

Table 1. Dimensions of guards from Captain-King's Shellbed. (Dimensions in mm.)

dtM	dtm	dsM	dsm	Ht	Hs	A
7.6		6.62				114.8
5.73	4.5	5.5	4.37	127	126	104
7.26	5.5	6.6	5.42	132	122	110
7.03	5.4	6.55	5.4	130	121	107.5
6.66	4.95	6.15	4.86	135.4	126	108
7.75		6.9				112

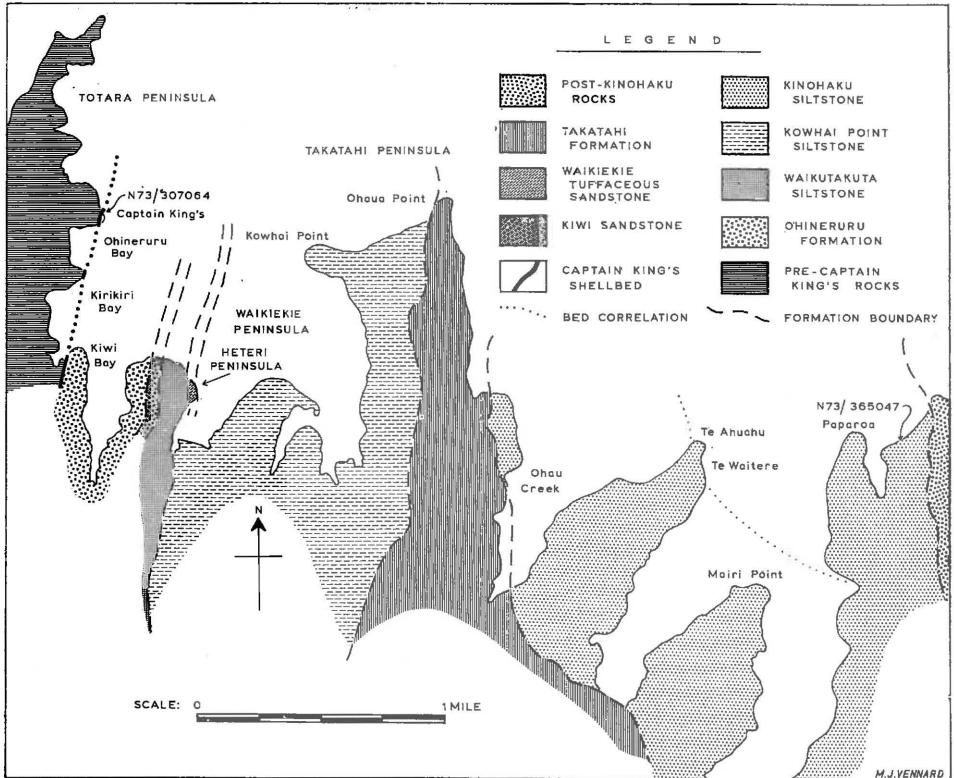


Figure 3. Geological Map of part of southern shores of Kawhia Harbour (from Fleming and Kear, 1960 (modified)).

lack part of the anterior stem, and the alveolar region. Those from the base of the Ohineruru Formation consist of leached fragments. Table 1 gives some indication of the dimensions of the more complete guards. These guards all have a more or less straight ventral surface, show two internal growth stages, have an apical line which is in some cases very eccentric, and most have lateral lines preserved. In addition, 30-40 fragments were examined and show similar features to those described. There is some indication that the degree of hastation, depression of the cross section, and eccentricity of the apical line all increase with development of the second growth stage. Guards from the Captain King's Shellbed are frequently distorted and abraded, and have their surfaces badly pitted. Remnants of the hard matrix are difficult to remove without damaging the specimen. For this reason the measurements and brief description given should be regarded as approximate only. This applies particularly to measurements of *dsm* and *dtm* and to the hastation indices derived from them.

Another outcrop of the Captain King's Shellbed occurs in the easternmost point of the promontory between Kirikiri and Ohineruru Bays (N73/306058). Here, belemnites occur abundantly throughout about 6 feet of strata, but are present only as moulds. The range of diameters of the guards is similar to that at Captain King's, i.e. up to a maximum of about 9 mm.

It has been suggested that the abundance of guards in the Captain King's Shellbed may be the result of the stranding of a swarm of juvenile *Belemnopsis keari* (Stevens 1965, page 76) but if this is the case then the guards should be concentrated in one plane in the bed. In fact they occur abundantly throughout the

total thickness (3 feet) and in reduced numbers in the basal 3 feet of the overlying formation. Assuming a more or less constant rate of deposition, this thickness of sediment must represent a considerable period of accumulation (some thousands of years at least) and the possibility that all these guards are juveniles seems remote. Dr G. R. Stevens has recently suggested (pers. comm.) that new collections have cast doubt on the identification of these guards as juvenile *B. keari*. The suggestion is here made that these belemnites are a species, referred to as *Belemnopsis* sp. z, characterised by a slender guard with two, or perhaps occasionally three, internal growth stages. This suggestion is supported by the observation that some 1600 feet of sediment, containing at least one other *Belemnopsis* species (see below) separate the belemnites of the Captain King's Shellbed from the next occurrence of *B. keari* passing upwards in the Kawhia sequence.

Apart from the basal beds mentioned earlier, the lower part of the Ohineruru Formation has few belemnites, and the next specimens collected came from a narrow sandstone bed about 1200 feet below the top (this *may* be bed f4 of Fleming and Kear 1956, p. 26). This bed crops out in the point between Kiwi and Kirikiri Bays, and northwards along the strike at N73/306058 (in the shore platform) and again in the shore platform at N73/308064 (immediately east of the reference section of the Captain King's Shellbed and *ca.* 160 feet above). Relatively common belemnite moulds were found at all three sites, but only two calcareous specimens were obtained, both from the most southerly part of the shore platform at Captain King's (N73/308062).

One of these is a stem fragment showing two growth stages, and has a markedly eccentric apical line. The fragment is hastate, and has transverse and saggital diameters of 7.32 and 6.68 mm. respectively. The second guard is a juvenile showing one growth stage, and has an eccentric apical line, although this is not as marked as in the previous specimen. It is in two pieces, one consisting of most of the stem and the alveolar region, and the other of most of the apex. A third section, estimated at 12 mm. in length is missing, and this section probably contains both dtM and dsM. The estimated total length of the guard is 107 mm., and its other dimensions are given in Table 2. The ventral surface is less curved than the dorsal, the ventral

Table 2. Dimensions of the guard from the Lower Ohineruru Formation.  
(Dimensions in mm.)

dtM	dtm	dsM	dsm	Ht	Hs	A
*6.16	4.3	*5.27	4.03	*143	*130	*116.8
			* Estimate.			

groove is wide and deep, and extends from alveolus almost to the apex (within 10 mm.) and faint lateral lines are apparent. Both of these specimens are identified as *Belemnopsis* sp. z.

It is considered that the small number of specimens collected is not sufficient to give a reliable indication of the belemnite content of the lower Heterian Stage. If Fleming and Kear's bed f4 mentioned above has not been located, its belemnite content could be invaluable in helping to elucidate the sequence in the lower Ohineruru Formation.

From 1200 feet to about 400 feet below the top, the Ohineruru Formation is either lacking in belemnites or poorly exposed, although indeterminate belemnite moulds are present at N73/307045 (south-west coast of Kiwi Bay).

#### *Middle and Upper Heterian*

The top 400 feet of the Ohineruru Formation has yielded specimens of a previously unrecognised belemnite. Several well preserved guards, some complete, were first collected from the north-west coast of Heteri Peninsula (N73/311052).

at a horizon near the top of the formation and *ca.* 12-15 feet below the base of the Kiwi Sandstone. The writer was unable to identify these guards as a known species, and they were sent to Dr G. R. Stevens for examination. He has advised that fragments of similar guards had been collected in the past, and had been thought to be *Belemnopsis keari* Stevens, but that the writer's discovery of complete guards has shown this view to be incorrect.

Similar specimens were collected from slightly lower in the formation (at 50, 60 and 100 feet), and juvenile guards were found at 300 and 400 feet on the south-west coast of Heteri Peninsula (N73/308046). Subsequently both adult and juvenile guards were found at two levels within the Kiwi Sandstone (100 and 115 feet below the top), and at 16 horizons throughout the Waikutakuta Siltstone (including 351, 296, 259, 210, 150, 135 and 55 feet below the top).

The species is characterised in the adult by a large robust guard (probably well over 100 mm. long and 16 mm. in diameter in a large specimen) with weak transverse hastation. Saggital hastation is frequently absent, and in adult guards the dorsal surface commonly diverges towards the alveolus. (See specimens 2, 3, Figure 4.) This increase in anterior saggital diameter is possibly the result of divergence of the dorsal and ventral surfaces to accommodate the phragmacone, but there is no sign of lateral divergence. Except for this possible slight divergence anteriorly, the ventral surface is straight and parallel to the dorsal for most of its length. At about two-thirds of the distance from alveolus to apex the ventral surface sometimes converges slightly towards the dorsal for a short distance before resuming an approximately parallel course, and finally curves towards the apex. This feature seems common enough to be diagnostic. The cross section is nearly equidimensional ( $A = 104$ ), the ventral groove is wide and deep, and extends from alveolus almost to the apex. (See specimens 4, 7, Figure 4.) Lateral lines are present in most guards. The dorsal surface of the apical region is more strongly curved than the ventral, and the apex is subcentral.

This species is referred to as *Belemnopsis* sp. y. Some dimensions are given in Table 3, and the numeral in the final column refers to Figure 4, which illustrates these specimens.

Table 3. Measurements of *Belemnopsis* sp. y guards.  
(Dimensions in mm.)

dtM	dtm	dsM	dsm	Ht	Hs	A	Location	No.
5.45	4.75	5.42	5.00	114.00	108.00	100.0	Ohineruru Fm. 300ft from top	1
14.75*	14.25*		15.00*	103.50*		98.3*	Ohineruru Fm. 50ft from top	2
12.00	11.30		12.35*	106.00		98.5	Ohineruru Fm. 12ft from top	3
11.40*	11.00*	11.00*	11.00*	104.00*	100.00*	104.0*	Ohineruru Fm. 12ft from top	4
15.45	14.95		15.25	103.30		101.3	Ohineruru Fm. 12ft from top	5
11.39		11.05				103.0	Kiwi S.S. 115ft from top	6
6.84	6.00	6.55	6.34	114.00	103.30	104.4	Waikutakuta ZS 351ft from top	7
12.16	11.10	11.56	11.32	109.50	102.00	105.0	Waikutakuta ZS 259ft from top	8
12.64	12.15	11.95	11.95	104.00	100.00	105.0	Waikutakuta ZS 135ft from top	9
10.42	9.50		10.12	109.50		103.0	Waikutakuta ZS 55ft from top	10

\* Approximate.

Although only eight calcareous specimens were found in the Kiwi Sandstone, this species is probably at its most abundant in the lower part of this formation. Numerous blocks of sandstone litter the beach at N73/311052, and are derived from a 3-foot massive bed about 20 feet above the base of the formation. *Belemnite* moulds are very common in these blocks, and appear to be *Belemnopsis* sp. y. This could be proved by making latex casts using the technique outlined by Stevens (1965, page 13). One fragmentary *B.* sp. y. guard was extracted with difficulty from the bed mentioned above.

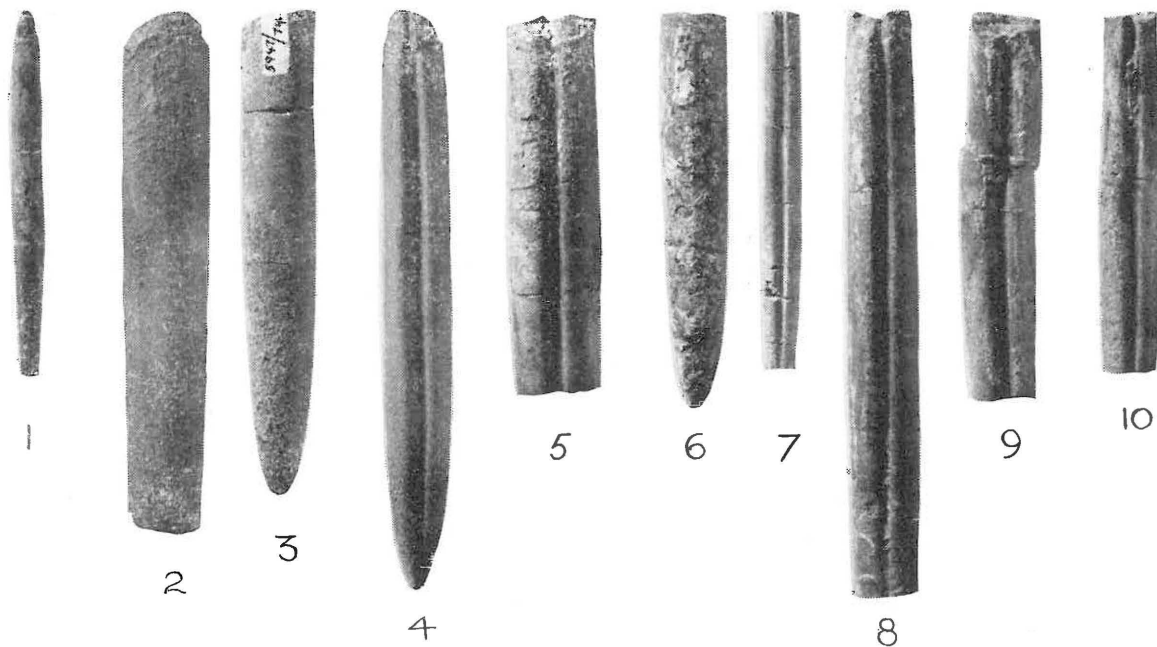


Figure 4. *Belemnopsis* sp. y.  $\times \frac{3}{4}$   
 1, 2, 3, 6, left lateral (i.e. groove facing left). 4, 5, 7, 8, 9, 10, ventral.  
 (Numbers 2 and 4 are casts. The originals are at Geological Survey, Lower Hutt.)

Poorly preserved moulds present in the group of beds designated g2 (Fleming and Kear 1960, page 29) were not identifiable.

One further guard was collected from about 100 feet below the top of the Kiwi Sandstone (beds g2 of Fleming and Kear 1960). This specimen is moderately hastate (in both a transverse and a saggital sense) and has an extremely wide groove, and may be similar to that specimen from 100 feet below the top of the Ohineruru Formation (see below).

The horizon at the top of the Ohineruru Formation from which the first *Belemnopsis* sp. y guards were collected also yielded 33 fragments from very young specimens. All show only one growth stage, and are from 3 mm. to 5 mm. in diameter. These probably represent only eight or ten guards, and were collected from within an inch of each other. Of these 33 fragments, 26 show a depressed cross section (e.g. have dimensions of 4.5 x 4 mm., 3.78 x 3.24 mm., 3.39 x 3.05 mm.) and the remainder are approximately equidimensional. Thirteen show hastation, and the balance are cylindrical. Other young guards showing cylindrical characteristics were found at N73/308046 (ca. 400 feet below the top of the formation) and this suggests that there may be considerable variation in the shape of the cross section and in the degree of hastation in young *Belemnopsis* sp. y.

Two further specimens from the Ohineruru Formation are worthy of comment. One was *in situ* 100 feet below the top, and the other was loose. Both are stem fragments without alveolar and apical sections, and in each case dtM can be measured. Sagittal and transverse hastation are both slight to moderate. Both guards are probably adolescent.

Each of these guards has a very wide and deep groove. The first specimen has a maximum transverse diameter of 8.97 mm., and the groove is approximately 4.5 mm. wide at this point, while the second has a maximum width of 8.29 mm., and the groove is approximately 3.5 mm. across. Both have a very depressed cross section ( $A = 116$ , and  $112.5$ ) but this is due at least in part to the width of the ventral groove. (The wide groove removes a large section of the guard's circumference.) These *may* represent another species, and if so this could account for some of the variation in young guards from this location. Alternatively, some young *Belemnopsis* sp. y guards may retain a depressed cross section and show moderate hastation at the adolescent stage.

Apart from these guards with a very wide ventral groove, which may represent a second species, *Belemnopsis* sp. y is the only belemnite present in the upper 400 feet of the Ohineruru Formation, in the Kiwi Sandstone, and in the lower 275 feet of the Waikutakuta Siltstone.

#### *Upper Heterian*

Belemnites are sparse in the lower 275 feet of the Waikutakuta Siltstone, but 150 feet from the top they increase noticeably, with guards occurring in abundance from 115 feet to 45 feet below the top. The fossils are not distributed evenly throughout this thickness of strata, but are concentrated in certain beds, with the intervening beds containing a much lower content. The maximum concentration occurs at approximately 85 feet, with subsidiary maxima at 110, 71, and 55 feet, and above 51 feet the numbers decrease. No belemnites were found above 45 feet from the top.

This increase in fossil content at 150 feet is due to the appearance of a second group of belemnites. These are not evolutionary products of *Belemnopsis* sp. y as this species can still be found unchanged in the top 150 feet, and their sudden appearance indicates migration into the area at this time. Specimens from this group show a wide variation in the degree of transverse and sagittal hastation (see Figures 5 and 6) and in the shape of the cross-section, and have previously been identified as *Belemnopsis keari* Stevens, and *Belemnopsis alfurica* (Boehm). Dr G. R. Stevens (pers. comm.) now doubts the occurrence of true *B. keari* in the Waikutakuta Siltstone. He is of the opinion that guards showing similar hastation and cross section indices to those of the *B. keari* holotype (which comes from Pomarangei Road, to the south of Kawhia Harbour) have probably not been found in this formation at Heteri Peninsula, although this requires checking.

Several guards collected by the writer, however, appear to be very similar to true *Belemnopsis keari*, and although their dimensions are not identical with those of the holotype, they fall well within the range of measurements regarded as defining the species (Stevens 1965, page 78). Some of them lack the almost straight ventral surface of typical *Belemnopsis keari* (Stevens 1965, page 75). The measurements of several specimens are given in Table 4, and those of the holotype are included for comparison. The numeral in the final column refers to Figure 5 which illustrates these specimens.



Table 4. Guards within the range of measurements of *B. keari*.  
(Dimensions in mm.)

dtM	dtm	dsM	dsm	Ht	Hs	A	Location	No.
10.50	7.80	8.50	7.50	134.60	113.30	123.5	Holotype	
15.37		13.75				111.8	Waikutakuta ZS	1
	8.90	7.66	6.25*	127.00*	122.00*	116.2	150ft from top Waikutakuta ZS	2
	8.12	7.26	5.75	138.80	126.00	111.8	85ft from top Waikutakuta ZS	3
	11.65	10.02	8.76	134.60	114.30	116.2	(top half) Waikutakuta ZS	4
							108ft from top	

\* Approximate — Specimen slightly exfoliated at anterior.

The Indonesian species *Belemnopsis alfurica* (Boehm) has also been identified in the upper Waikutakuta Siltstone (Stevens, 1965, p. 79) but in the writer's collections only three guards have been tentatively ascribed to this species. Stevens (1965, pp. 79, 80) lists the dimensions of Indonesian specimens and New Zealand specimens collected from the Waikutakuta Siltstone, but the writer suggests that two of the New Zealand specimens, CE 1302 and CE 930, may be *Belemnopsis* sp. y., although this suggestion is made without examination of the actual guards. CE 1302 is illustrated by Stevens (1965 plate 3) as *B. keari* presumably in error. Comparison of Stevens' tables indicates that most of the Indonesian specimens have significantly lower indices of transverse and saggital hastation than the New Zealand specimens (e.g. Ht = 106, Hs = 100) and this is particularly marked if specimens CE 1302 and CE 930 are omitted from the table of New Zealand specimens.

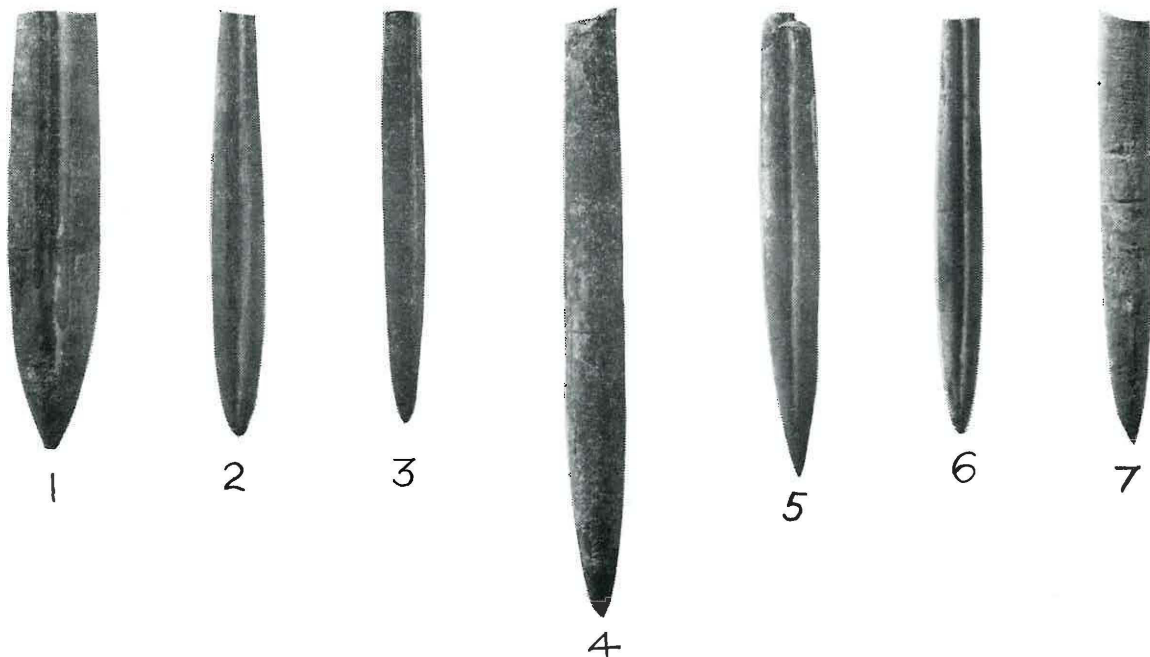


Figure 5. "Post-keari" assemblage guards which fall within the ranges of measurement of *B. keari* and *B. alfurica*.

×  $\frac{3}{4}$

<p><i>B. keari</i> 1, 2, ventral 3, 4, left lateral</p>	<p><i>B. alfurica</i> 5, 6, ventral 7, left lateral</p>
-----------------------------------------------------------------	-----------------------------------------------------------------

The writer has collected only three complete guards which fall within the range of measurements of *Belemnopsis alfurica* (as defined by Stevens 1965 p. 78, table 4) and these specimens have been provisionally so identified. A few incomplete guards may also fall within this range. The dimensions of the three specimens are given in Table 5, and the numeral in the final column refers to the illustrations in Figure 5.

Table 5. Guards within the range of measurements of *B. alfurica*.  
(Dimensions in mm.)

dtM	dtm	dsM	dsm	Ht	Hs	A	Location	No.
9.08	8.55	8.92	8.45	106.00	106.00	101.8	Waikutakuta ZS 0 - 125ft from top	5
7.58	6.82	7.15	6.85	111.00	104.40	106.0	Waikutakuta ZS 55ft from top	6
9.05	8.67	8.90	8.20	111.30	108.00	101.7	Waikutakuta ZS 51ft from top	7

All of these guards may lack several millimetres of stem, and if so the hastation indices will be greater than those given. New Zealand specimens of *Belemnopsis alfurica* taken as a group, do appear to have a higher degree of hastation, and a more depressed cross section than the Indonesian specimens listed by Stevens.

Of 90 specimens collected from the top 150 feet of the Waikutakuta Siltstone, only 18 have been assigned to the three species *Belemnopsis keari*, *Belemnopsis alfurica*, or *Belemnopsis* sp. y. The remaining guards form a group with wide variation in the shape of the cross section, and in the degree of hastation, at one extreme approaching *B. keari*, and at the other *B. alfurica*. Specimens commonly show hastation indices well within the limits of *B. keari*, but a cross section index within the range of *B. alfurica*. In view of this continuous range of dimensions the writer suggests that this group, plus the few guards resembling *B. keari* and *B. alfurica* which were collected, forms a single population. This population is at a stage of rapid evolutionary diversification, the parent species was *Belemnopsis keari*, and that most of the members of the group are postmutations (Morley Davies 1965, p. 265) of this species.

For convenience this whole group is referred to as the "post-keari" assemblage. The measurements of selected transitional "post-keari" guards are given in Table 6 and the numeral in the final column refers to Figure 6 which illustrates these specimens.

Table 6. Measurements of Selected Transitional "post-keari" guards.  
(Dimensions in mm.)

dtM	dtm	dsM	dsm	Ht	Hs	A	Location	No.
10.81	8.45	9.90	8.55	128.00	115.80	109.0	Waikutakuta ZS 113ft from top	1
10.98	7.91	10.07	8.47	138.80	118.80	109.0	Waikutakuta ZS 115ft from top	2
9.55	8.10	8.80	7.85	118.00	112.00	108.5	Waikutakuta ZS 85ft from top	3
8.45	6.28	7.78	6.43	134.50	121.00	108.6	Waikutakuta ZS 85ft from top	4
7.35	5.87	6.53	6.15	125.00	106.00	112.5	Waikutakuta ZS 55ft from top	5
9.58	7.77	9.02	8.10	123.30	111.30	106.2	Waikutakuta ZS 55ft from top	6
10.55	8.50	9.65	8.57	124.00	112.60	109.3	Waikutakuta ZS 55ft from top	7
7.41	5.85	7.23	6.08	126.60	119.00	102.5	Waikutakuta ZS 85ft from top	8

Innumerable belemnite fragments may be collected from the water line below the Waikutakuta Siltstone, particularly at the eastern end of the beach, and are derived from the beds in about the top 100 feet. Considerable along-shore transport of fossil material occurs in this area, and broken guards from the top of the Waikutakuta Siltstone are common on the eastern side of Heteri Peninsula (at N73/315050) and one or two similar fragments were found at N73/311052 (north-west coast of Heteri, below the top beds of the Ohineruru Formation). Similarly, fragments apparently derived from the *Belemnopsis* sp. y beds just below the Kiwi Sandstone, were collected from the west coast of Heteri Peninsula (N73/309050) where there are very few outcrops. The use of loose fossil material to give an indication of stratigraphical ranges in this section would be most misleading.

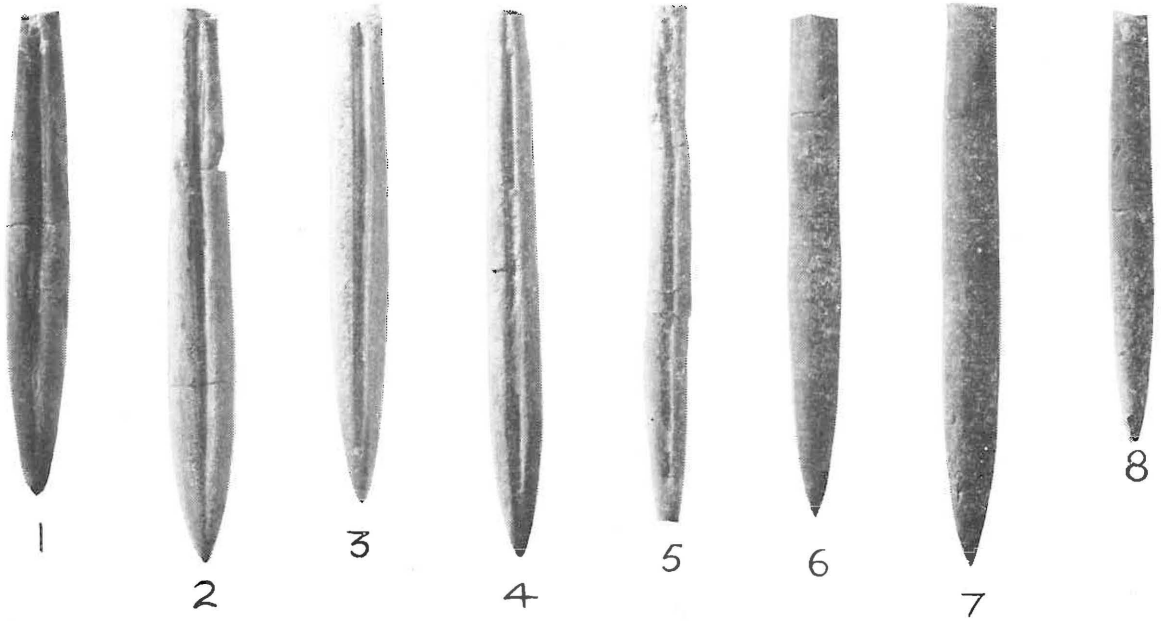


Figure 6. Selected transitional "post-keari" guards.  
 1, 2, 3, 4, 5, ventral  $\times \frac{3}{4}$  6, 7, 8, left lateral

### OHAUAN STAGE

Fleming and Kear (1960) have placed the boundary between the Heterian and Ohauan stages at Kawhia at the top of the Waikutakuta Siltstone, and have included four formations in the Ohauan Stage (Figure 2): Waikiekie Tuffaceous Sandstone, Kowhai Point Siltstone, Takatahi Formation, and Kinohaku Siltstone.

#### Lower Ohauan

The Waikiekie Tuffaceous Sandstone appears to be completely lacking in fossils. The lower part of the Kowhai Point Siltstone, some 500 feet thick, contains relatively abundant *Inoceramus* and *Buchia* (Fleming and Kear 1960, p. 32) but no belemnites are mentioned, and none were found by the writer. This section is very poorly exposed, and outcrops are limited to the occasional appearance of more resistant beds through the mud of the shore platform north-east of Heteri Peninsula. Unless they were abundant, belemnites in this section would be difficult to detect.

Belemnites are comparatively rare in the well exposed reference section of the Kowhai Point Siltstone (N73/320061 to N73/326062) and in exposures at the

northern end of Waikiekie Peninsula. Although about 8 hours were spent in a careful examination of the outcrops, only five incomplete guards were found *in situ*. Broken guards, however, are not uncommon amongst the beach pebbles below high water mark at Kowhai Point (N73/322060) and for a short distance eastwards on both the northern and southern shores of the promontory. Most of them are small and fragmentary, and many are corroded and otherwise damaged by wave action, but a few larger and reasonably well preserved pieces were found. A total of about 100 specimens was collected, most of them stem fragments, but six specimens include the apex, and one includes the alveolus. These specimens suggest that there are at least three belemnites present in the Kowhai Point Siltstone.

“Post-keari” guards are probably still present at Kowhai Point itself, or in the shore platform, although no members of this group were found *in situ*. But the isolation of the site may almost eliminate the possibility of transport of fossil material from lower in the sequence. Five “post-keari” specimens were collected (specimens 4, 5, 6, Figure 7), three of which include part of the stem and the apex, one includes the anterior stem and alveolus, and the other is a stem fragment. Only two of the specimens which include the apex are measurable, and their dimensions are given in Table 7.

Table 7. Dimensions of “post-keari” assemblage guards from Kowhai Point. (Dimensions in mm.)

dtM	dsM	A	A at anterior of fragment	Length
9.10	8.07	112.7	104	33
5.54	5.23	106.0	103	27

The cross section of the largest specimen changes rapidly from quite depressed at dtM (A = 112) to slightly depressed (A = 104) at the anterior end of the fragment (a distance of about 15 mm.) and in all three specimens it appears that dtM is well towards the apex. The alveolar fragment suggests that the cross section may be slightly depressed or equidimensional in this region. All specimens show moderate transverse and slight saggital hastation, and have a well marked ventral groove, which extends to within a few millimetres of the apex, but the groove in the stem fragment mentioned above is markedly wider and deeper than in the others. The profile is symmetrical, and lateral lines are not evident.

The “post-keari” assemblage forms only a small part of the belemnite population at Kowhai Point (about 5%) and is probably approaching its upper stratigraphical limit at this point.

The dominant species in the Kowhai Point Siltstone is a belemnite characterised by an extremely long and slender guard (specimens 7 - 10, Figure 7), and about 80% of the fragments collected by the writer can probably be assigned to this species. Nearly all of the specimens collected are portions of the stem region, but two apices were found, both of which have been assigned to this species, although the only direct evidence for this is their slenderness, and the fact that they are extremely attenuate. The guard appears to be quite hastate, with the flanks and the dorsal and ventral surfaces converging anteriorly, but showing little curvature. The cross section is compressed throughout, the ventral groove is well defined, but narrow, and appears to be fairly persistent (although neither of the apices shows a groove). A noticeable feature of most of these specimens is the presence of well defined and prominent lateral lines which parallel both the dorsal and ventral surfaces of the guard at about the mid line of the flanks. These extend for the full length of most of the fragments found. These guards are notable for the high proportion (8-10%) of specimens showing healed fractures and other pathological conditions, but in view of their slenderness this is not unexpected.

Representatives of this species were found *in situ* at the northern end of Waikiekie Peninsula (N73/321051) and at the western tip of Kowhai Point, and a loose specimen was found on the western shore of Takatahi Peninsula (N73/326055). Dr G. R. Stevens (pers. comm.) advises that Mr J. Grant-Mackie of Auckland University has collected similar specimens from the extreme eastern tip of Waikiekie Peninsula, so this belemnite probably extends through at least 600 feet of the Kowhai Point Siltstone (1525 feet to 900 or 1000 feet from the top). This species is referred to as *Belemnopsis* sp. x.

The remaining belemnite from Kowhai Point is again represented only by fragments, although one specimen contains the apex and part of the stem region (specimen 1, Figure 7). Again this species was not found *in situ* with the possible exception of one fragment collected from about 50 yards eastwards of the westernmost tip of Kowhai Point, and on the northern coast. The guard appears to have slight or moderate transverse hastation, but little saggital hastation. The ventral groove is shallow but becomes more prominent towards the anterior. The cross section is roughly circular in the stem and apical regions, and compressed anteriorly. Faint lateral lines may be seen in some of the fragments to run diagonally across the flanks from the dorsal to the ventral surface of the guard. This species is referred to as *Belemnopsis* sp. w.

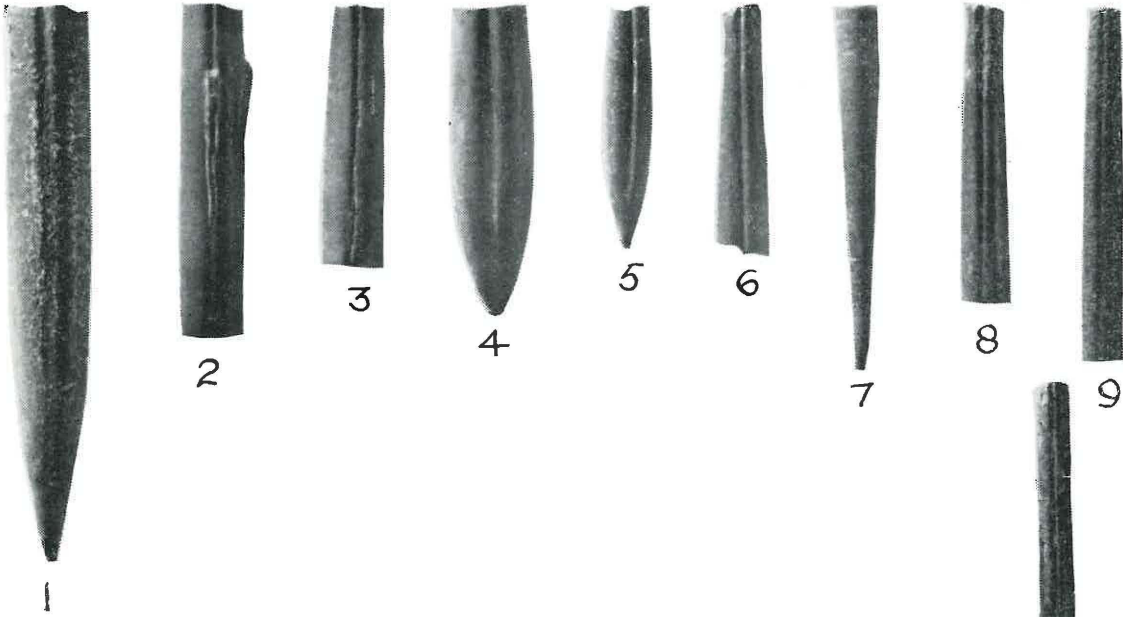


Figure 7. Fragmentary guards from the Kowhai Point Siltstone.

1, 2, 3, *B. sp. w*      4, 5, 6, "post-keari" assemblage  $\times 1\frac{1}{4}$       7, 8, 9, 10, *B. sp. x*  
 (all ventral aspect)

(Number 1 is a cast. The original is at Geological Survey, Lower Hutt.)  
 NOTE — The scale of this figure is larger than that of Figures 4, 5, 6, and 8.

It must be emphasised that the fragmentary nature of most of the specimens from Kowhai Point complicates their identification, and several suggestions could probably be advanced. For example, both sp. x and sp. w could represent different parts of the same belemnite, those fragments designated sp. x representing the anterior part, and those designated sp. w the posterior part of the guard, but this explanation does not account for the very attenuate apices mentioned under sp. x.

The belemnite content of the Kowhai Point Siltstone is at present very poorly defined, and until complete specimens are found *in situ* the position will remain obscure. The upper 650 feet of the Kowhai Point Siltstone is unexposed, and its belemnite content, if any, is unknown.

#### *Middle and Upper Ohauan*

No belemnites have been collected from the Takatahi Formation at Kawhia, although Fleming and Kear (1960, p. 33) record undetermined *Belemnopsis* casts from this formation on the western coast of Takatahi Peninsula, 65 chains south of Kowhai Point (N73/326046). Kowhai Point Siltstone crops out at sea level at this site, but the fossils were found in loose conglomerate boulders, apparently derived from the overlying Takatahi Formation which forms the ridge above.

The non-appearance of belemnites in this section is probably due to insufficient collecting, as the Takatahi Formation in the Te Akau area to the north of Kawhia contains the subspecies *Belemnopsis aucklandica trechmanni* Stevens. The earliest collections of this subspecies at Kawhia are younger, and come from the lower Kinohaku Siltstone.

*Belemnopsis aucklandica trechmanni*, the only belemnite found by the writer in the lower half of the Kinohaku Siltstone, is common from 1875 feet to about 850 feet below the top. The maximum concentration occurs at 1800 feet, at the northern end of the promontory on the eastern side of Takatahi Peninsula, and 37 specimens, most either complete, or consisting of a large part of the guard, were collected. Ten specimens were *in situ* and came from two beds, one of which is in the north-easternmost part of the promontory (N73/337049), and the other is in the shore platform due eastwards, and about 50 feet higher in the sequence. The remainder were loose on the foreshore. Complete guards were found on the north-west coast of Te Waitere Peninsula (N73/341042) and numerous fragments were collected from the shore for about 200 yards eastwards. A number of fragments were found at the site of the Mairi Ammonite Bed (N73/355035), eastern coast of Mairi Peninsula, 1150 feet from the top of the Kinohaku Siltstone. Broken guards are common from about 50 yards to 100 yards westwards of Te Ahuahu (Lemon Point) (at approx. N73/350047), and were found to be eroding from the shore platform at about 1000 feet below the top of the formation. One or two complete guards were collected from the cliffs behind the wharf at Te Waitere.

*Belemnopsis aucklandica trechmanni* is described and illustrated by Stevens (1965, pp. 88 to 91, plates 9-12), and the writer's specimens from the lower Kinohaku Siltstone (specimens 8-10, Figure 8) are similar in all essentials. Typical *B. a. trechmanni*, however, was not found above the horizon of the Kinohaku Belemnite Bed (ca. 700 feet from the top) and the writer suggests that this species does not occur higher in the formation.

Small belemnites are fairly common in the top 700 feet, and quite a number were collected from several locations. Most of them came from roadside exposures, from sites at N73/365047 (three-quarters of a mile westwards from Waiharakeke Bridge), at the north-western tip of Paparoa (N73/360044 to 362048), and on the western side of the same promontory (N73/360041 to 360043). Many of these can be identified as *Belemnopsis spathi* Stevens (which is described and illustrated by Stevens 1965, pp. 92-94, plate 13), but the writer has been unable to identify a number of specimens.

The dimensions of these unidentified guards are given in Table 8, and they are illustrated in Figure 8, Numbers 1 to 7. (Numbers 8 to 10 are typical *B. a. trechmanni* from the lower half of the Kinohaku Siltstone). Specimens 2 to 7 may be

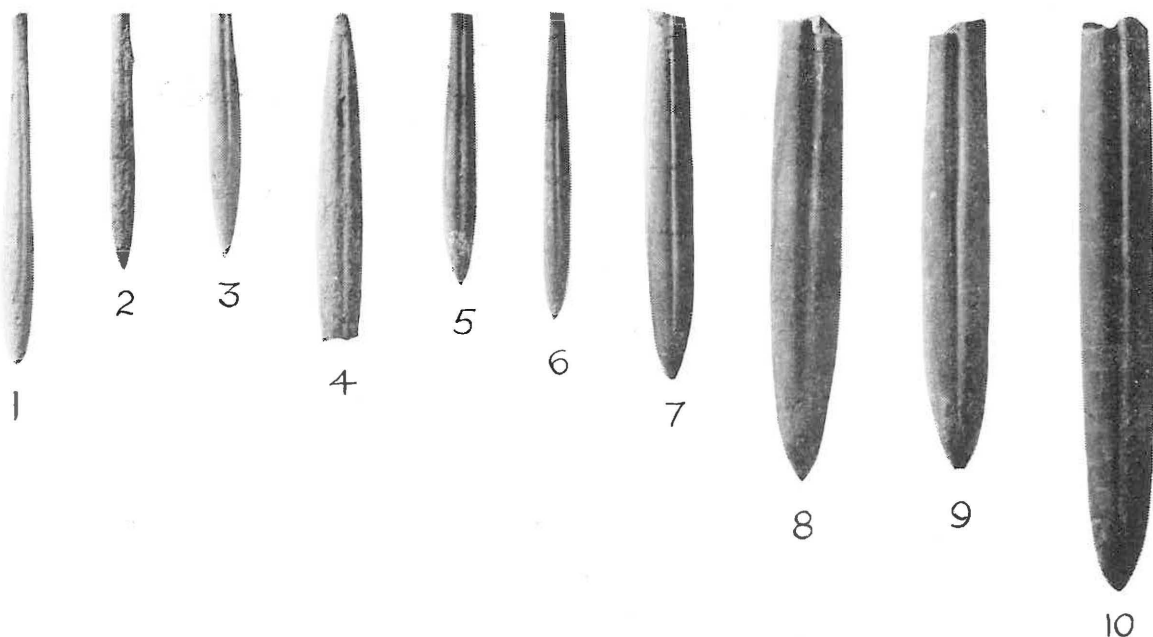


Figure 8. *B. a. trechmanni* and undetermined guards from the Kinohaku Siltstone.

1, 2, 3, 4, 5, 6, 7, undetermined guards  $\times \frac{3}{4}$   
 (all ventral aspect) 8, 9, 10, *B. a. trechmanni*

juvenile *B. a. trechmanni* but if this is so then juveniles of this species are markedly hastate, rather than slightly hastate anteriorly as suggested by Stevens (1965, p. 91). However, they differ from typical members of the subspecies in a number of other important characteristics as well. Most of them have a rather narrow ventral groove, and this is very marked in specimen Number 7 where the groove is almost slitlike at the anterior end of the guard although it widens and shallows in the posterior stem and apical regions. In most, the apical region curves smoothly and regularly towards the apex, although the apical region of specimen Number 7 gives some indication of a more sudden final curve near the actual apex similar to that shown by *B. a. trechmanni* (Stevens 1965, p. 90). The apex is sometimes mucronate but

Table 8. Dimensions of unidentified guards from upper Kinohaku Zs.  
 (Dimensions in mm.)

dtM	dtm	dsM	dsm	Ht	Hs	A	Location	No.
4.67	2.70	4.78	3.08	173.00	155.00	97.7	Kinohaku ZS 625 - 690ft from top	1
4.33	2.70	4.10	2.70	168.00	152.00	105.5	Kinohaku ZS 500 - 625ft from top	2
5.50	4.24	5.28	4.44	129.70	119.00	104.0	Kinohaku ZS 250 - 350ft from top	3
7.64	3.95*	7.40	4.23*	193.00*	175.00*	103.0	Kinohaku ZS 500 - 625ft from top	4
5.56	3.95	5.13	4.10	141.00	125.00	108.0	Kinohaku ZS 850ft from top	5
4.85	2.92	4.80	3.13	166.00	153.00	101.0	Kinohaku ZS 250 - 350ft from top	6
8.71	5.85	8.12	6.34	149.00	128.00	107.0	Kinohaku ZS 500 - 625ft from top	7

\* Approximate — specimen abraded anteriorly.

frequently not, and lateral lines are present in some specimens. The position of dtM is well towards the apex in most of these guards (in specimen Number 7 dtM is at a point approximately 2/3 of the distance from anterior to apex) and all of them are rather small and slender, although specimens Number 4 and Number 7 are rather larger and perhaps represent adult guards. There may be important differences between specimens 4 and 7 in the nature of their ventral grooves, as the groove in specimen 4 appears to be wide and shallow, but this may be due to abrasion as the guard is damaged.

If juveniles of *B. a. trechmanni* occur in the top 700 feet of the Kinohaku Siltstone, then it seems logical to expect the presence of adult guards. However, examination of the literature available to the writer has revealed no record of their collection, but of course this does not prove that they are absent. In view of the probable absence of adult *B. a. trechmanni*, and noting the appearance of the guards described briefly above, it is suggested that a second species is represented by guards Numbers 2 to 7 in Figure 8. These specimens are probably postmutations of *B. a. trechmanni*, the original species having undergone changes which include a decrease in mean size, and an increase in hastation.

The remaining specimen in Figure 8, Number 1, is a juvenile guard which appears to be fundamentally different to Numbers 2 to 7. As Table 8 indicates, this guard has a compressed cross section throughout, and is very long and slender with its maximum diameters in a markedly posterior position. The ventral groove is very weak, and probably does not persist very much further towards the apex than the position of dtM. The apex is blunter than those of specimens 2 to 7.

The only belemnite with a compressed cross section known to be present in the Kinohaku Siltstone is *Hibolites minor* (Hauer), a specimen of which was collected in 1859 by Hochstetter from Te Ahuahu (ca. 850-1000 feet from the top of the formation). Specimen Number 1 may be a juvenile of this species.

## CONCLUSIONS

From the evidence presented above it will be seen that belemnite species or groups replace one another at intervals throughout the Heterian and Ohauan stages, most major species or groups ranging through a thickness of sediment of the order of 1000 feet.

Provided more or less complete adult guards are available, it is relatively easy to identify the belemnites mentioned in this paper, but much more difficult to determine juvenile or fragmentary material. The main external differences between the various species may be restated briefly as follows:—

*Belemnopsis* sp. z guards are of small or moderate size, are markedly hastate, have a depressed cross section, a moderately incised persistent ventral groove, and normally show well developed lateral lines. They become more hastate as the second growth stage develops.

*Belemnopsis* sp. y guards are large and robust, with weak hastation, a slightly depressed cross section, a prominent persistent ventral groove, a more or less straight ventral surface, and normally have lateral lines preserved. Juveniles are hastate, and become less so with development.

“Post-keari” assemblage guards are variable in their degree of hastation, and shape of cross section, and most are of moderate to large size (with a few very large specimens). The ventral groove is prominent and persistent, and lateral lines are normally weak or absent. Those members resembling *B. alfurica* may be distinguished from *B. sp. y* by their shorter and more slender guards, their symmetrical profiles, and by the weakness of their lateral lines.



The appearance of complete guards of *B. sp. w* and *B. sp. x* from the Kowhai Point Siltstone, is not known, but *B. sp. x* fragments are readily identified by their slenderness and prominent lateral lines.

Unidentified guards present in the top part of the Kinohaku Siltstone (Figure 8) are easily distinguished from typical *B. a. trechmanni* by their much smaller size, their marked hastation and narrower ventral grooves, by the posterior position of dtM, and by the smooth curve of the apical region.

The nature of the distribution of "post-keari" guards in the upper part of the Waikutakuta Siltstone (i.e. the apparent tendency for guards to be more hastate, and to have a higher index of flattening, in the lower part of this section) suggests that the population may be evolving towards a less hastate form (i.e. from guards similar in shape to *Belemnopsis keari* to guards similar in shape to *Belemnopsis alfurica*). However, this may be illusory and due to accidents of collection, for of the two measurable "post-keari" guards from Kowhai Point, one has a very depressed cross section, and four of the five specimens are quite hastate.

If local range zones (*teitzones*) are to be established for the Heterian and Ohauan stages at Kawhia Harbour, then only two zones appear to be sufficiently well defined at present (see Figure 2).

- (i) A zone of *Belemnopsis sp. y* extending from the middle of the Ohineruru Formation to the top of the Waikutakuta Siltstone (Middle to Upper Heterian).
- (ii) A zone of *Belemnopsis aucklandica trechmanni* extending from the lower part to the middle part of the Kinohaku Siltstone (Upper Ohauan).

In addition a "post-keari" assemblage zone could be established once the upper limit of the group is located (presumably at about the horizon of Kowhai Point), and *Belemnopsis sp. x* may be useful in establishing a further zone once its range is defined.

Further collecting is needed to complete the picture, particularly in the lower Heterian (lower Ohineruru Formation), the lower Ohauan (Kowhai Point Siltstone), and at the top of the Ohauan (upper Kinohaku Siltstone).

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## REPOSITORY OF MATERIAL

The fossil material on which this paper is based is at present located at 141 Russell Road, Huntly, New Zealand, and is available for examination.