ART. XXIII.—*Fauna of the Hampden Beds and Classification of the Oamaru System.*

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Plates XV–XVII.

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DESCRIPTIONS OF NEW SPECIES OF FOSSIL MOLLUSCA FOUND AT HAMPDEN.

Circulus inornatus n. sp. (Plate XV, fig. 15.)

Shell minute, round, 2½ mm. in diameter. Spire almost plain, consisting of three whorls only. Whorls increasing rather quickly in size and suture strongly incised. Aperture of a broadly oval form. Surface quite smooth. Umbilicus moderately wide.

A single specimen, in good condition. The entire absence of sculpture distinguishes this from the other New Zealand species.

Type in the Wanganui Museum.

Cerithidea minuta n. sp. (Plate XV, fig. 11.)

Shell minute, 5 mm. by 2 mm. Spire tapering and composed of five whorls which are slightly convex. Aperture oval, extending very slightly over the base, and produced anteriorly into a short canal. Sculpture: About nine low rounded radial ribs on each whorl, which are crossed by four elevated sharp spiral ridges: these are more pronounced on the radial ribs than elsewhere. Suture not deep and without a border. Body-whorl with about twelve spiral ridges, which decrease on the base and extend almost into the aperture.

One specimen only, in good condition. I can find no record of *Cerithidea* being found at a lower horizon than that of the Awamoa beds.

Type in the Wanganui Museum.

Cerithiella tricincta n. sp. (Plate XV, fig. 2.)

Shell small, 10 mm. by 3 mm., with a narrow turreted spire. Spire of ten whorls, each of them distinctly convex, and slowly decreasing in diameter. Suture very deep. Whorls with spiral and radial ornamentation. Three raised spiral rounded ridges on each whorl, the lowest of them the most prominent. They are crossed by seven radial ridges on the half-whorl. At the points of intersection of the radial and spiral lines there are distinct rounded knobs. Body-whorl not preserved. Columella smooth.

Suter remarks that this species is closely related to *C. fidicula* Suter The sculpture of the present species is, however, far coarser, and there are fewer radial lines. The diameter of the whorls also decreases more rapidly.

One specimen only, imperfect, and embedded in the matrix.

Type in the Wanganui Museum.

Turritella rudis n. sp. (Plate XVII, fig. 3.)

Shell small, the largest specimen 15 mm. by 6 mm. Sharply conical. Whorls narrow. In a small specimen 7 mm. long there are eleven whorls. Each whorl with some broad spiral ribs more or less broken into rounded or blunt nodules in large numbers. In the higher whorls there is generally only one of these ribs, nearly median in position, but in the lower whorls there are generally four. The spaces between these ribs have a number of fine spiral lines. There are no axial riblets. Suture deep.

Several specimens, in good condition. The species is closely related to *T. ornata.*

Type in the Wanganui Museum.

Submargarita ? tricincta n. sp. (Plate XV, fig. 14.)

Shell small, turbinate, slightly conic above. Whorls 3½ to 4. Spire very small; protoconch depressed. The last whorl comparatively very large, slightly angulated by the last three spiral riblets. The lower riblet defines the basal area, which is contracted and slopingly convex. Sculpture: On the body-whorl, in addition to the three principal riblets, there are on the base a number of minute threadlets which vanish on approaching the basal margin. Between the basal and middle principal spirals are about five minute threadlets. The space above is narrower and has two or three threadlets. Between the upper principal spiral and the suture is a fairly wide area, sloping, slightly convex, and with four or five threadlets; irregular growth-striae cut the threadlets into minute gemmules. The apex is somewhat eroded, and sculpture, if any, is not determinable. Sutures somewhat impressed. Aperture rounded; outer lip slightly effuse, more marked on the basal area. Columella narrow above, then expanding into a stout freely projecting plate which unites with the basal lip. Parietal wall thinly calloused, minutely perforate. Beneath the outer calcareous layer the shell is somewhat iridescent. Height, 5·25 mm.; breadth, 5 mm.

This species was submitted to the late Mr. Suter, and he suggested its inclusion in *Submargarita.* There is one example only, and it appears to be adult and not the juvenile of *Turbo* or *Astraea.*

Type in the Wanganui Museum.

This description was kindly written by Mr. Murdoch.

Erato antiqua n. sp. (Plate XV, fig. 7.)

Shell small, 4½ mm. by 3½ mm. Broadly oval, but slightly produced anteriorly. Aperture almost linear, but rather wider in the anterior than in the posterior portion. Outer lip much thickened, with numerous denticles. Spire completely covered by the body-whorl and a posterior callosity. Surface quite smooth and polished.

One specimen only, in good condition. The small size and absence of a distinct spire distinguish this species from *E. neozelanica* Suter. This is the only other species of the genus which has been found in New Zealand.

Type in the Wanganui Museum.

Epitonium tenuispiralis n. sp. (Plate XVII, fig. 6.)

Complete shell not available. Four whorls of the spire only, which measure 10 mm. by 5 mm. The whorls taper rather rapidly. Radial ribs slightly rounded, prominent, about fourteen on each whorl. Interstices rather wider than the ribs. Both ribs and interstices are crossed by a large number of exceedingly fine spiral lines.

Although the specimen is extremely fragmentary, the very distinct sculpture justifies its description under a specific name.

Type in the Wanganui Museum.

Turbonilla antiqua n. sp. (Plate XV, fig. 10.)

Shell small, and only the lower four whorls remain in the single specimen which was found. Length, 8 mm.; width, 1½ mm. The whorls taper very gradually, and the entire shell must have a considerable length relative to its breadth. Whorls nearly flat in outline, but suture rather deep. About twenty-two straight transverse ribs on each whorl, but no spiral sculpture. On the body-whorl the transverse ribs do not extend over the base. Columella with a slight umbilicus. Inner lip thickened at its base with a small fold. Outer lip rather thick. The gradual taper of the whorls and the fold on the columella distinguish this species from those that have been described in New Zealand.

Type in the Wanganui Museum.

Dicroloma zelandica n. sp. (Plate XV, fig. 16.)

Shell of moderate size. Length, 28 mm.; breadth, 9 mm. Spire of five convex whorls rapidly decreasing in size. Suture shallow. Beak not complete, but apparently about two-thirds the length of the shell. The whorls with numerous slightly raised spiral threads; there are twelve on the penultimate whorl: these are crossed by numerous low radial lines which are strongly bent backwards in the middle. Body-whorl with spiral striation more distinct, but no radial lines can be distinguished. At the very beginning of the body-whorl a keel starts to develop a little above the crown of the convexity of the whorl. A little farther forward another keel is developed slightly below the crown of the convexity. The two keels are separated by four spiral lines. The two keels rapidly increase in prominence, and where they reach the outer lip they extend into two large wings. The anterior wing is at first directed forward in direct continuation of the keel; 10 mm. distant from the outer lip it bends through a right angle and, extending for 9 mm., it terminates apparently near the end of the beak. The other keel also ends in a wing, which at first proceeds outward in a continuation of the direction of the keel, then bends gradually downward, and ends about 15 mm. from the penultimate whorl.

Several specimens have been found, but none of them show the aperture and wings in a good state of preservation. The first one that was found was small, but was worked out of the matrix in a satisfactory state. Unfortunately, it was completely smashed when it was sent through the post to Mr. Suter. Another specimen (Plate XV, fig. 16), found in 1918, showed the spire fairly complete, but the greater part of the wings is absent, though the impression of them is quite clear in the matrix. The impression has been coloured white in order to show more clearly in the photograph. The beak also was detached, and a small amount of the material has been lost. I think, however, that there is no doubt as to the generic position, and in this Mr. Murdoch agrees with me. The species is probably closely allied to *D. myurus* Desl. (Cossmann, *Essais de Paléoconchologie comparée*, vol. 6, p. 85, pl. 6, fig. 1). The genus *Dicroloma* has not hitherto been definitely recorded from a higher horizon than the Upper Jurassic (Portlandian), though a doubtful species, highly imperfect, is mentioned by Dickerson from the Tejon of California.

Type in the Wanganui Museum.

Fusinus altus n. sp. (Plate XVI, fig. 5.)

Shell of moderate size, narrowly fusiform. Length, 60 mm.; width, 17 mm. Spire of seven whorls, gradually tapering; each whorl strongly convex, adorned with twelve broad transverse ribs which extend to the anterior but not to the posterior suture: they are much stronger on the suture than elsewhere. About twelve strong spiral striae on each whorl, but they are much stronger near the carina than elsewhere. There are often much smaller striae intercalated between the larger ones Aperture not complete, but moderately wide. Outer lip with well-marked internal ribs. Beak long, with spiral striation similar to that of the rest of the shell.

This species is rather slender, but approaches more closely to *F. kaiparaensis* than to any other. The radial ornamentation, however, is much less pronounced, and the carina is much less marked. The shell is also considerably narrower.

A single specimen, not well preserved.

Type in the Wanganui Museum.

Latirus dubius n. sp. (Plate XVI, fig. 6.)

Shell of moderate size, 33 mm. by 10 mm., narrowly fusiform. Spire of four whorls, each of them strongly convex. Aperture incomplete, but terminating in a short canal which is bent sharply upwards. Inner lip wide, and extending forward beyond the columella for two-thirds of its length. Columella with two well-developed folds. Outer lip wanting. On each whorl a number of radial ribs—generally fourteen: these are moderately high and rounded, and extend from suture to suture. On the upper third of each whorl a number of fine spiral lines. On the lower two-thirds of each whorl there are five strong spiral lines which are much raised where they cross the radial ribs. Between the strong spirals there are a number of fine spirals similar to those in the upper part of the whorl.

One specimen only, rather imperfect. I have some hesitation in following the late Mr. Suter's advice and classing this species in the genus *Latirus*.

Type in the Wanganui Museum.

Belophos incertus n. sp. (Plate XV, fig. 3.)

Shell small, shortly fusiform, 15 mm. by 9 mm. Spire of four whorls, rapidly decreasing. Each whorl with about 22 radial ridges, which are slightly raised and somewhat prominent on the carina. Carina quite prominent, and whorls almost shouldered; suture impressed. About five small threads between the carina and the anterior suture. Body-whorl with radial ridges far less pronounced than those on the spire, and towards the aperture they degenerate into growth-lines. Spiral lines numerous and distinct, especially towards the end of the siphon. Aperture semi-lunar. Outer lip thin but arched. Inner lip without any callosity. Columella slightly bent backwards.

The genus *Belophos* has not previously been recorded from New Zealand, but it has been found in the Eocene of Australia.

A single specimen, in good condition.

Type in the Wanganui Museum.

Volutoderma zelandica n. sp. (Plate XVII, figs. 4, 5.)

Shell small. Length, 12 mm.; width, 5 mm. Spire incomplete; portions of the first and second whorls alone remain. Whorls rather rapidly decreasing. Aperture prolonged anteriorly into a moderately long siphon which is bent backward towards its extremity. Each whorl with a distinct ridge bordering the posterior suture. Six prominent costae on each whorl, which are most pronounced near the keel; they extend forward to the anterior suture, but do not reach the posterior one. Five small spiral ridges on each whorl crossed by numerous growth-lines. On the body-whorl the costae are little more than tubercles on the carina. The growth-lines are numerous and distinct, but spiral lines are visible near the end of the siphon only. Columella with one prominent plait. The growth-lines indicate that there is a moderately deep sinus between the suture and the keel. The aperture is too imperfect in the specimens to show this feature. I am indebted to the late Mr. Suter for provisionally classifying this species.

Two specimens, somewhat imperfect, in the Wanganui Museum.

Marginella aveniformis n. sp. (Plate XV, fig. 8.)

Shell small, 6 mm. by 2½ mm., narrowly oval. Spire of three whorls, rapidly decreasing. Aperture about two-thirds the length of the shell. Spire short; whorls convex in outline, but suture only slightly marked. Surface perfectly smooth and polished. Aperture narrow, with a slight anterior canal. Columella with four narrow folds, the two posterior of which are nearly at right angles to the columella, but the two anterior ones are highly oblique. Outer lip swollen, and furnished with a number of denticles on its inner margin.

A single specimen, in good condition. The spire is longer than that of other New Zealand species.

Type in the Wanganui Museum.

Turris politus n. sp. (Plate XVII, fig. 9.)

Shell small, 10 mm. by 4 mm., with a polished surface. Spire consists of six strongly keeled whorls. Seventeen small rounded tubercles on the carina of each whorl. Growth-lines extend upwards from the tubercles, and where they intersect the raised anterior border of the suture there is another series of much smaller tubercles. There are no spiral markings on the portion of the whorl between the posterior suture and the keel. On the keel there is a small spiral furrow which intersects all the tubercles. There are four other small furrows between the keel and the anterior suture. On the body-whorl the furrows in front of the keel are more numerous. Aperture imperfectly preserved.

Two specimens, in fair condition, but the aperture is imperfect. Suter remarks that this species is closely related to *T. complicatus* Suter. The species, however, is considerably smaller, the tubercles are much less prominent, and the spiral ornamentation in front of the carina is distinct.

Type in the Wanganui Museum.

Turris margaritatus n. sp. (Plate XVII, fig. 2.)

Shell small. Length, 15 mm.; width, 5 mm. Spire consists of six strongly-keeled whorls. Aperture less than half the length of the shell. The keel has eighteen bead-like tubercles on each whorl, but rather flattened in front. The whole whorl is finely striated spirally. Body-whorl with a moderate anterior canal. The growth-lines, which are quite distinct, indicate that the anal notch is rather deep, but the specimens have not the aperture sufficiently well preserved to show it. The portion of the body-whorl in front of the keel has large as well as fine striations.

The number of tubercles on the keel and the number of fine spiral striations distinguish this from the other New Zealand species.

Five specimens, in a fair state of preservation.

Type in the Wanganui Museum.

Turris reticulatus n. sp. (Plate XVII, fig. 8.)

Shell small, 15 mm. by 6 mm., but the greater part of the anterior canal is wanting. Spire of six whorls, strongly keeled. Each whorl with a number of strong spiral lines behind and in front of the keel. On the penultimate whorl there are ten of these lines above and five below the keel; the second from the upper suture and that on the keel are by far the strongest. On the keel there are sixteen well-developed tubercles, which are rather larger radially than longitudinally. Well-marked growth-lines pass through the tubercles and reach the upper suture. Where they cross the second spiral line below the suture they give rise to small tubercles, which are far more prominent on the upper whorls than on the lower. The intersection of the growth-lines and the spirals give rise to an appearance that is almost reticulate. The anterior part of the body-whorl has more marked spiral lines and very numerous growth-lines. Columella smooth, but aperture not fully preserved.

One specimen only, not very well preserved.

Type in the Wanganui Museum.

Surcula gravida n. sp. (Plate XVI, fig. 4.)

Shell large, fusiform, 70 mm. by 28 mm. Spire of moderate length and composed of five whorls. Whorls convex and sharply keeled, but no tubercles on the keel. Aperture about half the length of the shell, but lips imperfectly preserved. Anal sinus deep, not sharp, but well rounded. Ornamentation: A distinct border in front of the suture. A number of rather prominent spiral lines both above and below the suture. On the penultimate whorl there are eleven of these in front of the keel and nine behind it. On the body-whorl the spiral lines in front of the keel are less prominent, and there are no spiral lines on the beak.

This species approaches, though rather distantly, to *S. hamiltoni* (Hutt.). The spiral angle, however, is 40°, in place of 25° in *S. hamiltoni*. The ornamentation is quite different. There are tubercles on the keel of *S. hamiltoni* and no spiral lines above it, and there are no spiral lines on the beak.

A single fairly perfect specimen, though a little compressed.

Type in the Wanganui Museum.

Surcula marginalis n. sp. (Plate XVII, fig. 10.)

An imperfect specimen only. Seven whorls remain on the spire, and there is a protoconch of three whorls. In the first six whorls there are eighteen tubercles on the keel, but the last whorl is smooth. Sutures prominently bordered in front. All portions of the whorl have prominent spiral striations, including the tubercles. As shown by the growth-lines the anal sinus is moderately sharp, but less so than in *S. hamiltoni* Hutt.

This species is closely related to *S. hamiltoni*, but differs from it in having the prominent border of the suture, more numerous tubercles, and a much more abundant spiral ornamentation both above and below the keel.

A single imperfect specimen.

Type in the Wanganui Museum.

Surcula equispiralis n. sp. (Plate XVI, fig. 3.)

Specimen imperfect, not showing the aperture. Length, 20 mm.; width, 7 mm. The remaining part of the spire consists of six whorls, which are slowly tapering, and each one is clearly convex. Each whorl with about twelve nodular elevations on the carina. These are slightly extended transversely, but do not reach either suture. They are inclined forward anteriorly. There are many fine spiral lines developed equally on all parts of the whorl. Suture bordered in front by a raised ridge, which is marked spirally like the rest of the whorl.

Mr. Suter remarks that this species is nearest to *S. pareoraensis* Suter. The nodules, however, are much more prominent, the suture more distinctly bordered, and the spiral ornamentation more prominent than in that species.

A single specimen, imperfect, but showing the sculpture very distinctly.

Type in the Wanganui Museum.

Surcula torticostata n. sp. (Plate XVII, fig. 7.)

Shell small, and the specimens quite imperfect, 13 mm. by 4 mm. Spire long and slender; six convex whorls showing in the best specimen. Suture impressed with a well-marked border anteriorly. Whorls with eighteen radial ridges, which extend from suture to suture and are strongly twisted forward at the anterior end. A series of very fine spiral striae cover all parts of the whorls. Aperture not preserved in any of the specimens, but the fairly distinct growth-lines show that the anal notch was broad and rounded.

Four specimens, which show the ornamentation clearly, but the anterior part of the shell is not preserved.

Type in the Wanganui Museum.

Terebra sulcata n. sp. (Plate XVI, fig. 2.)

Shell of moderate size, 30 mm. by 8 mm. Spire gently tapering, and consisting of six very slightly convex whorls. Sculpture consisting of large sharp transverse ribs, which are slightly bent backwards in the middle. There are twenty of these ribs on the body-whorl, and they are nearly as prominent on the body-whorl as on the higher whorls.

The only specimen is incomplete, though the sculpture is distinct. Mr. Suter says that the species approaches more closely to *T. biplex* than to any other species.

Type in the Wanganui Museum.

Sarepta solenelloides n. sp. (Plate XV, figs. 4, 5, 6.)

Shell of moderate size, 30 mm. high, 15 mm. long, and 10 mm. thick. Shape oval and slightly inequilateral, the anterior end being a little longer and more acute. Dorsal margin sloping slightly downward on both sides of the umbo, which is situated a little behind the middle of the hinge-line and points slightly posteriorly. Ventral margin gently curved, and passes gradually to the posterior margin, which is rounded. Hinge-line not quite straight, with about seventeen teeth on each side of the umbo, below which there is a large alivincular pit. Pallial line simple. Lunule large but narrow. A broad but very shallow groove extends from the umbo to the anterior margin. The sculpture consists of a series of fine concentric grooves with relatively flat and wide ridges between them.

In my previous paper (*Trans. N.Z. Inst.*, vol. 49, p. 464, 1917) this shell is classified as a species of *Malletia*, a genus which it closely resembles in external form. However, it has the hinge of *Yoldia*, the pallial line of *Nucula*, and the external form of *Malletia*—peculiarities that Fischer cites as characteristic of *Sarepta*. Several specimens were obtained, some in good condition.

Type in the Wanganui Museum.

It may be that this is the species recorded by Hutton from these beds under the name *Malletia funiculata*, but his specimens seem to have disappeared, and the name is a *nomen nudum*.

Sarepta tenuis n. sp. (Plate XV, fig. 9.)

Shell very small, but thick for its size. Height, 3 mm.; length, 4 mm. Shape broadly oval. Inequilateral, with a slight anterior extension. Hinge-line a little curved, with seven inclined teeth in front of the umbo and three behind it. Shell somewhat tumid. Umbo prominent. Concentrically striated with shallow grooves leaving low rounded ridges between them.

A single specimen, in good condition. Differs from *S. obolella* in its shape, its small size, and its concentric ornamentation.

Type in the Wanganui Museum.

Limopsis hampdenensis n. sp. (Plate XV, figs. 12, 13.)

Shell small, sub-rhomboidal, inequilateral, somewhat inflated; sculptured with small rounded concentric riblets about the same width as the interspaces and sensibly granular. On the posterior end from a line with the umbo are numerous well-marked radiating riblets giving the area a distinctly cancellated surface. The disc shows several well-marked periods of rest. Umbones nearer to the anterior end and prominent, slightly projecting beyond the almost straight dorsal margin. Anterior end short, slightly convex, the curve almost uniform with that of the basal margin. Posteriorly the dorsal margin almost twice the length of the anterior portion, the end truncated, sharply descending, a little oblique, nearly straight, and forming a curve on uniting with the broad upward-sweeping basal margin. Hinge slightly curved; a narrow triangular pit beneath the apex, and a few small denticles below the teeth, gradually getting larger as they proceed outwards, anteriorly four or five, posteriorly six or seven, and more oblique. Anterior muscle-scar small and immediately below the hinge-margin, the posterior lower and much larger. The interior shows faint radiations, the margin worn but in places slightly crenulate. Height, 3·5 mm.; length, 4 mm.; diameter of a single valve approximately 1·25 mm.

Type in the Wanganui Museum.

The description is derived from two right valves, and the measurements from the larger of the two. It is a minute form compared with others recorded from the New Zealand Tertiaries.

Mr. Murdoch was good enough to write this description.

Trigonia areolata n. sp. (Plate XV, fig. 1; Plate XVII, fig. 1.)

Shell small, ovate, inequilateral, slightly extended posteriorly. One valve 14 mm. high and 15 mm. long; another 17 mm. high and 18 mm. long. Interior of the shell highly nacreous. Beaks rather prominent, distinctly prosogyrous. Dorsal margin descending rapidly in front, and posterior margin evenly rounded; posterior ventral margin nearly circular; anterior margin at first well rounded, then ascending gradually to the umbo. Sculpture a series of broad rounded ribs except over the area. There are fifteen of these ribs, which are distinctly broader than the grooves which separate them. Grooves crossed occasionally by irregular fine lines of growth. Ventral margin slightly crenated. Near the ventral margin on the interior surface the grooves have a few irregular striations in the direction of their length. The posterior "area" constitutes about one-fourth of the surface of the valve. Close to its border it has one rib-like elevation extending from the posterior margin one-third of the distance to the umbo. Another much broader rib near the posterior margin of the area, also extending about two-thirds of the distance to the umbo. A series of fine transverse ridges cross the area. The right valve shows one large cardinal tooth, which, however, shows no trace of striation The posterior part of the hinge has not been preserved.

Two right valves only, both with somewhat incomplete hinge. The nacreous internal surface and the posterior area appear to make it necessary to refer this shell to the genus *Trigonia*. The smooth tooth, however, as well as the prosogyrous character, are most anomalous. Suter suggests that there may be a subgenus of *Trigonia* possessed of this peculiarity, but there is no mention of this in the available literature. Cossmann in his work *Sur l'evolution des Trigonies* does not mention a single species which has these two characters.

Trigonia densicostata n. sp. (Plate XVI, fig. 1.)

Shell rather large, 50 mm. high and 65 mm. long. Interior surface highly nacreous. Umbo indistinct but apparently pointed forward. Dorsal margin nearly straight, but soon descending and sweeping with a rounded curve to the ventral margin, which is not complete but appears to bend round evenly to the posterior margin, which is also incomplete. Sculpture: A large number of fine, rather sharp radiating ridges which are rather narrower than the intervening grooves. The ribs are nearly equal, and they can be distinctly seen on the interior surface of the shell. Hinge-line incomplete, but with one prominent pointed tooth somewhat resembling that in *T. areolata* Marshall, described above.

The generic position of this shell is very doubtful. In my former list it was referred to *Cardium (Papyridina)*, but Suter afterwards referred it with the greatest hesitation to *Pseudomonotis*. It is described here merely in order that it may be possible to refer to it by name, but it will shortly be forwarded to Mr. H. Woods for identification. In the meantime it may be said that the species does not belong to any other genus of Tertiary or Recent mollusca hitherto found in New Zealand.

One specimen only, somewhat imperfect.

Type in the Wanganui Museum.

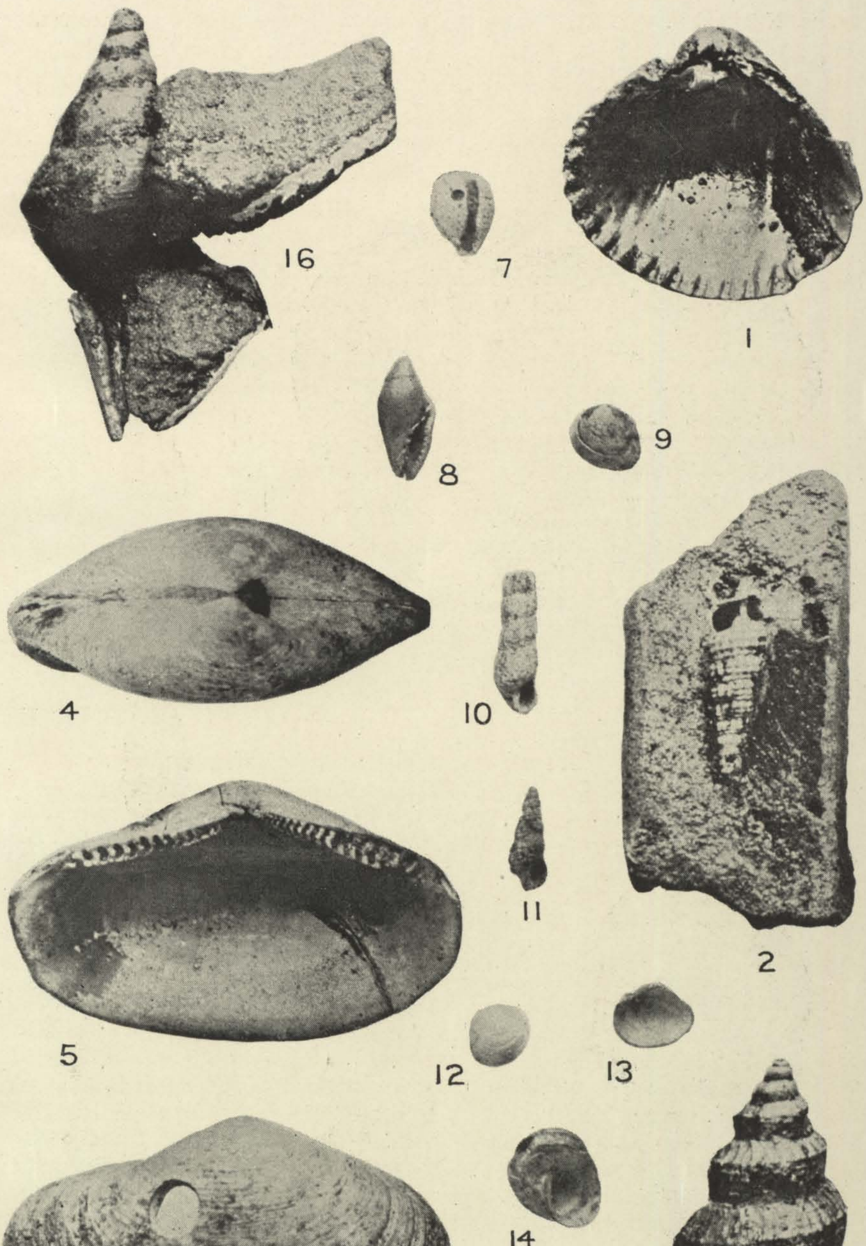

Fig. 1.—*Trigonia areolata* n. sp. × 2½.
Fig. 2.—*Cerithiella tricincta* n. sp. × 2½.
Fig. 3.—*Belophos incertus.* × 2½.
Figs. 4, 5, 6.—*Sarepta solenelloides.* × 2½.
Fig. 7.—*Erato antiqua.* × 2½.
Fig. 8.—*Marginella aveniformis.* × 2½.
Fig. 9.—*Sarepta tenuis* n. sp. × 2½.
Fig. 10.—*Turbonilla antiqua* n. sp. × 2½.
Fig. 11.—*Cerithidea minuta* n. sp. × 2½.
Figs. 12, 13.—*Limopsis hampdenensis.* × 2½.
Fig. 14.—*Submargarita tricincta* n. sp × 2½.
Fig. 15.—*Circulus inornatus* n. sp. × 2½.
Fig. 16.—*Dicroloma zelandica* n. sp. × 2.

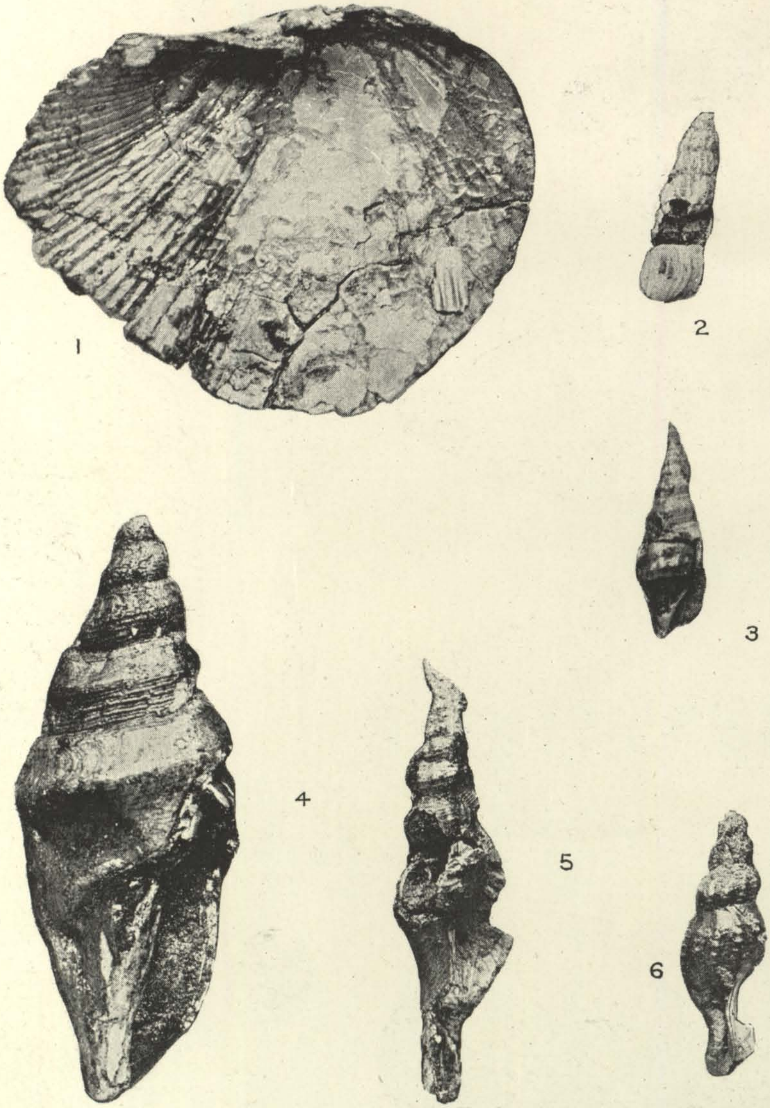

FIG. 1.—*Trigonia densicostata* n. sp. × 1½.
FIG. 2.—*Terebra sulcata* n. sp. × 1½.
FIG. 3.—*Surcula equispiralis* n. sp. × 1½.
FIG. 4.—*Surcula gravida* n. sp. × 1½.
FIG. 5.—*Fusinus altus* n. sp. × 1½.
FIG. 6.—*Latirus dubius* n. sp. × 1½.

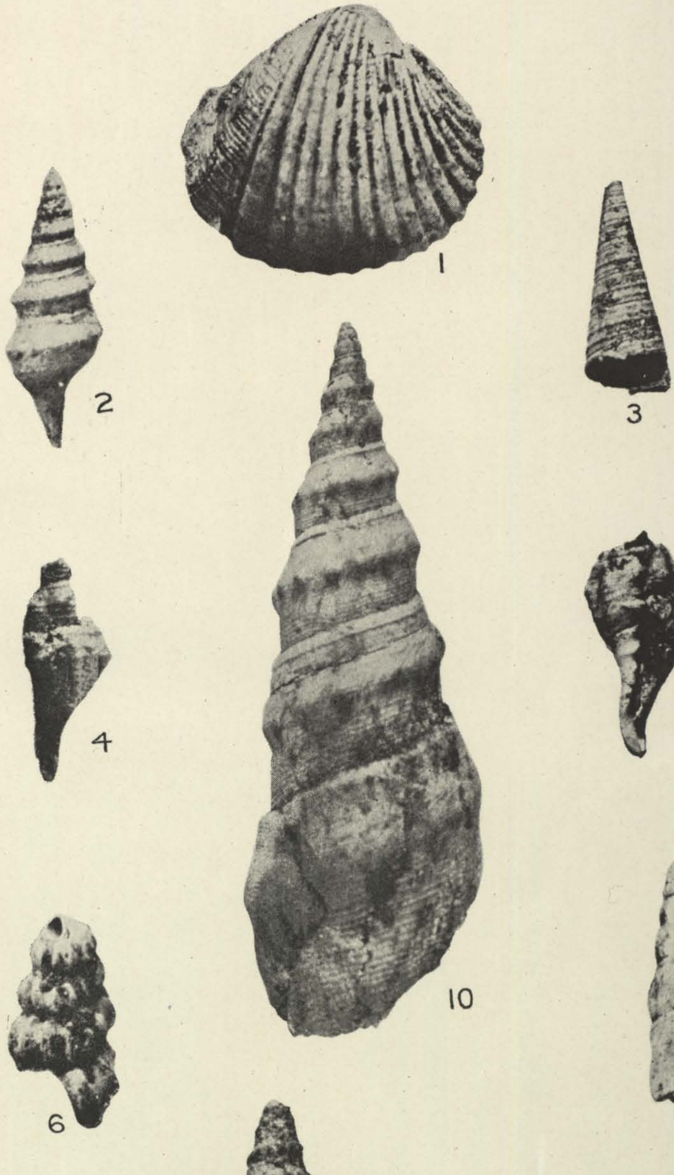

Fig. 1.—*Trigonia areolata* n. sp. × 2½.
Fig. 2.—*Turris margaritatus* n. sp. × 2½.
Fig. 3.—*Turritella rudis* n. sp. × 2½.
Figs. 4, 5.—*Volutoderma zelandica* n. sp. × 2½.
Fig. 6.—*Epitonium tenuispiralis* n. sp. × 2½.
Fig. 7.—*Surcula torticostata* n. sp. × 2½
Fig. 8.—*Turris reticulatus* n. sp. × 2½
Fig. 9.—*Turris politus* n. sp. × 2½.
Fig. 10.—*Surcula marginalis* n. sp. × 2¼.

LIST OF HAMPDEN MOLLUSCA.

The following list contains all the species of Mollusca that have been collected by me at Hampden—*i.e.*, the species that have been described above and a few species that were found during 1918.*

Aturia sp.
Architectonica n. sp.
Clio aff. *urenuiensis* Suter
Circulus inornatus n. sp.
Cerithidea minuta n. sp.
Cerithiella tricincta n. sp.
Turritella symmetrica Hutton
Turritella ornata Hutton
Turritella rudis n. sp.
Struthiolaria cincta Hutton
Struthiolaria minor Marshall
Sinum (Eunaticina) elegans Suter
Submargarita tricincta n. sp.
Ampullina waihaoensis Suter
Ampullina suturalis Hutton
Natica zelandica Q. & G.
Erato antiqua n. sp.
Cymatium minimum Hutton
Galeodea senex Hutton
Epitonium rugulosum lyratum (Zittel)
Epitonium tenuispiralis n. sp.
Turbonilla antiqua n. sp.
Dicroloma zelandica n. sp.
Fusinus solidus Suter
Fusinus altus n. sp.
Exilia waihaoensis Suter
Latirus dubius n. sp.
Siphonalia nodosa Martyn
Siphonalia turrita Suter
Belophos incertus n. sp.
Alectrion sp.
Volutoderma zelandica n. sp.
Cymbiola (Miomelon) corrugata Hutton
Ancilla novae-zelandiae Sowerby
Marginella avenoides n. sp.
Turris duplex Suter
Turris nexilis bicarinatus Suter
Turris complicatus Suter
Turris politus n. sp.
Turris regius Suter
Turris margaritatus n. sp.
Turris reticulatus n. sp.
Surcula hamiltoni Hutton
Surcula gravida n. sp.
Surcula marginalis n. sp.
Surcula equispiralis n. sp.
Surcula torticostata n. sp.
Surcula serotina Suter
Surcula sp.
Bathytoma sulcata Hutton
Terebra costata Hutton
Terebra sulcata n. sp.
Gilbertia tertiaria Marshall
Bullinella enysi Hutton
Dentalium mantelli Zittel
Dentalium pareoraense Suter
Cucullaea alta Sowerby
Sarepta solenelloides n. sp.
Sarepta obolella (Tate)
Sarepta tenuis n. sp.
Arca novae-zelandiae E. A. Smith
Limopsis hampdenensis n. sp.
Limopsis zitteli Ihering
Trigonia areolata n. sp.
Trigonia densicostata n. sp.
Lima angulata Sowerby
Atrina sp.
Ostrea wuellerstorfi Zittel
Cardium sp.
Pecten huttoni Park

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* Further collecting at Hampden resulted in obtaining a good specimen of *Dicroloma zelandica*, which shows the aperture perfectly, though the distal portions of the wings are wanting. The following additional species were collected:—

Euthriofusus spinosus.
Seila cfr. *bulbosa.*
Epitonium cfr. *gracillimum.*
Surcula, 2 n. sp.
Fusinus n. sp.
Siphonalia n. sp.
Trochus ? sp.
Borsonia sp.

None of these specimens seems to have a Recent occurrence, and if that is the case the percentage of Recent species in the formation sinks to 9·1. The number of species in the Hampden fauna is unusually large compared with the number of specimens that can be found. The Recent species are in nearly all cases represented by a single specimen. *Arca novae-zelandiae, Turritella symmetrica, Sarepta obolella, Natica zelandica,* and *Lima angulata* are identified from bad single specimens only. (May, 1919.)

The Age of the Hampden Beds.

The main features of the Hampden beds were described in a former paper, in which a brief reference was made to their geological position* and to the opinions that had been expressed in regard to them by various geologists. Further collecting has been done and a more complete examination of the specimens has been made since then, with the result that eight additional species can now be recorded from these beds. Of these eight species only one is Recent; thus the percentage of Recent species is only slightly affected, and remains at 10·3.

The specimen which was previously classed as *Malletia* sp. is now found on examination of some perfect examples to be a new species of *Sarepta.* It is much larger and has a much thicker shell than any other species of *Sarepta* that has been previously recognized in this country.

One of the additional species is *Struthiolaria minor* Marshall, which has previously been recorded from Wangaloa only. Further examination of *Trigonia* sp. shows that although it has an area with a sculpture quite different from that on the rest of the shell, and is thus in no way related to the Recent or Tertiary species of *Trigonia,* it yet apparently has teeth that are destitute of the striations which are so characteristic of this genus. Mr. Suter advised that it should be sent to England for further comparison and examination.

The specimen previously classed as *Papyridea* sp. is now found to be certainly not a species of that genus, and in fact it is quite clear that it does not belong to any genus that has hitherto been recognized among the Recent or Tertiary species of Mollusca of New Zealand. Mr. Suter considered that it was a Pteriid, and suggested that it might belong to *Pseudomonotis.* The shell has a marked nacreous lustre, while its dentition suggests a relationship to the species classed as *Trigonia areolata* Marshall, and its ornamentation has no marked resemblance to any New Zealand genus. It is here provisionally classed with the genus *Trigonia.* Mr. Suter remarked that it was not possible to do justice to this species in New Zealand, where comparatively little literature was available and few specimens from other parts of the world were available for comparison.

An additional specimen of *Dicroloma* was obtained, but unfortunately it also is incomplete; but in the matrix in which it is embedded there are definite impressions of the wings, and the species is now placed in the genus *Dicroloma* with some confidence. It is most unfortunate that so many of the species that are found in this locality should be in such a poor state of preservation.

The list of species that have been found at Hampden given above shows that altogether some sixty-eight species have been obtained. Of these as many as twenty-nine—a percentage of 42·7—are regarded as new. This very large proportion in itself suggests that the beds belong to an horizon from which little collecting has been done in New Zealand. Since nearly one thousand species of Mollusca have now been recorded from the Tertiary rocks of this country, it is clear that the Hampden beds cannot be one of the ordinary Tertiary horizons, from nearly all of which fairly large collections have now been made.

Of other Hampden species that have also been found in other localities the following are noteworthy. *Gilbertia tertiaria* Marshall is thought by

* P. Marshall, *Trans. N.Z. Inst.,* vol. 49, p. 463, 1917.

Cossmann to be possibly identical with *G. paucisulcata* Marshall from Wangaloa. In addition the following species occur in both of these beds: *Cucullaea alta* Sow., *Turritella symmetrica* Hutton, *Bullinella enysi* Hutton, *Dentalium mantelli* Zitt., *Struthiolaria minor* Marshall.

I have previously stated that in my opinion the Wangaloa beds are the oldest Tertiary horizon that has yet been recognized in this country, and that the occurrence of *Perissolax* and *Pugnellus* shows that there were some Cretaceous Mollusca still in existence. In addition *Gilbertia* and *Heteroterma* suggest an extremely early Eocene or perhaps a Paleocene age as an equivalent. The further fact that the percentage of the Recent species sinks as low as 8 again supports the view as to the antiquity of these beds. This opinion as to their great antiquity is supported by Trechmann* and by Thomson.† The percentage of Recent species in the Hampden beds is about the same as in the collection from Wangaloa, but the Recent species are not the same in the two localities.

In addition the antiquity of the Hampden beds is shown by the presence of the genera *Gilbertia*, *Volutoderma*, *Trigonia*, and *Dicroloma*. These genera, however, with the exception of *Gilbertia*, are not the same as those of high antiquity in the Wangaloa collection. This difference in details may, however, be due to the different lithological nature of the strata, and therefore, in all probability, of the station at which deposition of the strata took place. The Wangaloa beds are quartz sands with a small amount of glauconite. The Hampden beds, on the other hand, are formed of an extremely unctuous mud, in which, however, there is a large amount of glauconite.

I believe that in the present state of our knowledge of the range of genera and species in the older Tertiary rocks both in space and in time it is unreasonable to insist on the occurrence of considerable numbers of identical genera and species of fossils for the correlation of horizons, for we cannot at present make proper allowance for the differences that are due to station. On the other hand, the outcrops of these older Tertiary rocks are so isolated from one another that in view of the generally accepted belief in the great overlap in their stratigraphical relations it is very undesirable—if, indeed, possible—to classify all the Tertiary rocks on a basis of purely stratigraphical considerations, as has lately been attempted by Thomson.

For these reasons it is in the opinion of the author far better to base the classification of these rocks on the general affinities of the fossil fauna contained in them. This may be most conveniently effected by comparing the faunas in such a way as to show the percentage of species that are common to the various strata, and in particular by paying special attention to the percentage of Recent species that occur in the various collections that have been made. The Recent fauna is particularly suitable for this comparison, since it contains species that have littoral occurrence as well as those which occur in water of moderate depth. This comparison may, however, tend to suggest rather too great an age for those strata which were deposited in deep water, because the molluscan fauna of our deep-water areas is still most imperfectly known.

Thomson, indeed, now suggests that the geographical separation of the outcrops of our Tertiary formations is due to minor diastrophic

* C. T. TRECHMANN, *Geol. Mag.*, dec. 6, vol. 4, p. 296, 1917.
† J. A. THOMSON, *Trans. N.Z. Inst.*, vol. 49, p. 402, 1917.

movements instead of overlap. Of this there is at present no proof whatever. Certainly the continuity of the Tertiary strata between the Waihao and Shag Point gives no suggestion of such a series of movements as would be required to account for the different age of the lowest strata of the series of younger rocks (Oamaru system) in different parts of that district.

A further comparison of the Hampden fauna with that of other horizons in the Oamaru district is also of interest. This comparison should begin with those strata that are oldest. In my opinion the oldest from which collection has been made (with the exception of the Hampden and of the Shag Point beds) is the Bortonian of Park. That is also the opinion of Park, who says, "The Bortonian is the lowest marine fauna of the Oamaruian in North Otago, if not in New Zealand."* The list of Mollusca, however, which he gives is relatively small, for it contains only forty-three species. In another respect also it is rather strikingly different from all the other collections that have been made in North Otago, as it contains twenty species—nearly half of the total—of lamellibranchs. This may be due to a shallower-water station or to the imperfect preservation of the smaller species of gasteropods.

The beds from which this collection was made are composed of a quartz sandstone which must have been deposited under conditions quite different from those under which the Hampden beds were deposited. Under these circumstances it would not be expected that the faunas from these two localities would show very great resemblance even if they were of the same age. In actual fact but little resemblance can be discovered. It is, however, noticeable that *Sinum elegans* Suter and *Surcula serotina* Suter occur in both formations, and that these species have been found in the lower formations of the Oamaru district only.

The horizon that appears to me to be next in the order of age in the Oamaru district is that of the greensand of Waihao. Collections from this horizon were listed in 1914,† but the collections were very small. Out of thirty-three species some 12 per cent. were found to be Recent. Six of these species, however, have been found in the Hampden and Waihao beds only up to the present time. These are—*Ampullina waihaoensis* Suter, *Exilia waihaoensis* Suter, *Turris duplex* Suter, *Turris regius* Suter, *Turris complicatus* Suter, and *Surcula serotina* Suter. The last of these has been found in the Bortonian also.

The occurrence of these species in the two beds is of special importance when it is realized that all of them are absent from the Awamoa and Target Gully localities, in which large collections have been made, numbering 87 and 212 species respectively. These two localities topographically lie directly between the Hampden and Waihao greensand deposits. The Waihao greensands lie stratigraphically between the quartz sands with coal—probably the Bortonian beds of Park—and the Oamaru or Ototara limestone horizon. Another stratum which occupies the same local stratigraphical position and has the same lithological nature is the Wharekuri bed; but this lies farther to the west, and on the assumption of the correctness of the theory of continuous overlap the Wharekuri beds, which lie farther to the west, would be of greater age than the Waihao greensands, which are situated twenty miles farther to the east and in a region, therefore,

* J. Park, *N.Z. Geol. Surv. Bull. No. 20*, p. 34, 1918.
† P. Marshall, *Trans. N.Z. Inst.*, vol. 47, p. 385, 1915.

submerged at an earlier date as the sea margin gradually advanced westwards. Actually the Wharekuri beds contain 18·7 per cent. of the species that are found in the Hampden beds, and this is a larger percentage than is found in any other of the beds in the Oamaru district.

CLASSIFICATION OF THE OAMARU SYSTEM.

These comparisons between the Hampden fauna and that of other localities within the Oamaru area is of special interest in view of criticisms that have lately been made by Thomson,* and of classifications that have been proposed by Park,† and of statements which have been made by Morgan.‡

In various publications I have insisted that the series of rocks that rest on the Hokonui formation, or on rocks that are older than these, belong to one period of continuous deposition. The upper limit of this formation has been placed by me as certainly not below the base of the Wanganui rocks, and perhaps as high as the upper limit of this formation. This whole system of rocks I have called the Oamaru system.

This suggestion to classify all the younger rocks in a single system has been constantly opposed by Park, who has written, " To the young geologist there is always something attractive and alluring about a Cretaceo-Eocene succession." Since 1904 he has been pointing to one horizon after another as obviously the plane of division between the Cretaceous and the Tertiary, but in each case he has been forced to withdraw from his position. His latest statement, after being forced to retreat from his position of 1912, is: " A settlement can only be reached by a detailed geological survey of the middle Waipara and Weka Pass districts."§ This is the result after fifteen years of effort to find a plane of disjunction in a small area where continuous sections are remarkably clear in stream-valleys running generally at right angles to the strike.

Morgan, in discussing this proposal to classify all these younger rocks in one system, writes: " This proposal has not been fruitful in any respect save in the promotion of discussion and in the temporary thickening of the cloud of confusion involving an admittedly difficult problem." It is only necessary to add that it has stimulated research in such a way that it is now definitely known that the planes that were previously thought to be breaks between different geological formations are merely stratigraphical planes in a series of continuous deposition.

Thomson, on the other hand, agrees with the proposal to regard all the sediments above the Hokonui system up to and including the Wanganui system as a single formation " which were called by Marshall and his colleagues the younger rock-series of New Zealand, and named by Marshall the Oamaru system. Previous classifications had not brought out the close diastrophic relationship of this group of rocks, and in this respect the paper in question marked a great advance."

Thomson objects to the use of the name " Oamaru " for this rock-system. He lays stress on the fact that the name had been previously used for a rock-system in New Zealand, and he says also that the strata are not

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* J. A. THOMSON, *Trans. N.Z. Inst.*, vol. 48, pp. 28–40, 1916; also vol. 49, pp. 397–413, 1917.

† J. PARK, *N.Z. Geol. Surv. Bull. No. 20*, 1918.

‡ P. G. MORGAN, *10th Ann. Rep. N.Z. Geol. Surv.*, Parl. Paper C.–2B, p. 28, 1916.

§ J. PARK, *Trans. N.Z. Inst.*, vol. 49, p. 393, 1917.

fully developed in the Oamaru district. My reasons for wishing to retain the name " Oamaru " for this system are as follows :—

(1.) Historical: (*a*) The locality is the one from which the first collection of fossils in New Zealand was made; and (*b*) Hutton's Oamaru system included nearly all the strata in the district, and his Oamaru system includes the majority of the rocks classed in the Oamaru system by me. The retention of the name will serve to keep alive the memory of the man who did so much spade-work in the palaeontology and stratigraphy of New Zealand.

(2.) Palaeontological: The fossils in the Oamaru area have been far more fully collected, studied, and classified than in any other region where the system of rocks is well developed.

(3.) In the Oamaru district there is a fuller development of the various strata of a fossil-bearing nature than elsewhere. Between Shag Point, Wharekuri, and the Waihao River the strata are continuous, and so far as known they are not disturbed by any minor diastrophic movements. A nearly complete series of fossiliferous strata is now known :—

Awamoa	36·8 per cent.	Recent species.
Target Gully	34 ,,	,,
Otiake	24 ,,	,,
Wharekuri	23 ,,	,,
Waihao Valley greensands ..	10–15 ,,	,,
Bortonian	18 ,,	,,
Hampden (early Tertiary) ..	10·3 ,,	,,
Shag Point (Senonian).		

At Mount Harris there are beds which are stratigraphically still higher, but satisfactory collections have not yet been made from them. In no other district where the strata have such a full development have so many fossils been collected from such a variety of horizons. Confusion with Hutton's Oamaru system is easily avoided, for it has already fallen into disuse.

Thomson* has lately proposed to call my Oamaru system the Notocene system. This appears to me to be a very unfortunate suggestion. The suffix " cene " has a definite and satisfactory meaning when used in the ordinary names of the divisions of the Tertiary era. This meaning of " recent " ceases to have any point when used in the word Notocene. The word " noto " should mean either that this is the farthest southern point where such rocks have been found or that the formation is common to southern latitudes. Neither of these is the case, for younger rocks and their contents have been fully described from Seymour Island. There are also well-known and wide occurrences of young rocks in South America and in Australia, and these cannot be included under the same name as the New Zealand formations. The name Notocene would thus be scientifically misleading, and it is at once pretentious and inexact. If it is desired to use a name that has no special locality origin, and if hybridism is not an offence, I would suggest " Maoricene " ; or if a name with a special and exact meaning is required " Notonesinene " might be used, as this might well be taken to mean " The young rocks of southern islands."

However, as I have already said, the retention of the name " Oamaru " is desirable for the reasons—(1) it is historical; (2) it helps to emphasize

* J. A. Thomson, *Trans. N.Z. Inst.*, vol. 49, p. 398–413, 1917.

the memory of the pioneer in the Tertiary palaeontology of New Zealand; (3) Oamaru is the district where nearly the whole system is developed; (4) the rocks are there more richly fossiliferous in the various horizons than elsewhere, and fuller collections have been made from them.

My classification of the divisions of the Oamaru system has also been criticized because it is based on the percentage of Recent species contained in the faunas of the different beds. It appears to me that any classification of the divisions of the strata must be based on at least one of the following considerations: (1) The occurrence of easily recognizable and widely extended lithological horizons, or on a similar succession of strata in different localities; (2) the occurrence of genera or species of fossils that have a relatively short range in time and are also widely distributed areally; (3) the general features and relationship of the faunas in the different strata.

The first of these considerations appears to me to be incapable of general application to the Oamaru system. The rocks of the system have probably a great overlap, and consequently deposits that are strikingly different from one another lithologically may be strictly contemporaneous.

In Thomson's opinion the areas of deposition have been affected by local diastrophic movements.* I can reasonably hold that no proof has been given of these supposed local distrophic movements in New Zealand, and I can quote the Oamaru district, at least, as one in which the Tertiary strata are continuous over a large district without any indication of being affected by local diastrophic action.

Thomson's divisions of his Notocene appear to be based entirely on the lithological characters of certain beds near Oamaru itself. The descriptions that he gives of them are as follows:—

Awamoan (uppermost stage)—Blue clay of All Day Bay.
Hutchinsonian—Hutchinson Quarry beds and concretionary band.
Ototaran—Limestone.
Waiarekan—Waiareka tuffs and Enfield-Windsor greensands = Ngapara greensands.
Ngaparan—Coal-measures, sands, conglomerates, and coal-seams.†

These purely stratigraphical divisions are poorly enough defined from a lithological standpoint, and no mention whatever is made of any palaeontological characters that they may have. It appears almost impossible to correlate any other beds with them. Endless confusion would be caused, too, by attempts to place the various beds at Oamaru in them. Actually, so far as lithological characters are concerned, this classification is almost the same as that proposed by myself and colleagues in 1911, but this lithological classification was then stated to be proposed merely because the palaeontological researches up to that time did not, in our opinion, provide satisfactory material for the classification of the strata, and for that reason we refrained from giving stage names for the strata. Now, however, there is, in my opinion, sufficient material to allow me to frame a classification that is based on palaeontological research.

In making use of our present knowledge of palaeontology the first point that requires notice is that the fossil Mollusca that have been found in each of these divisions of a lithological nature extend in large numbers—25 to

* J. A. THOMSON, *Trans. N.Z. Inst.*, vol. 49, pp. 400–1, 1917.
† J. A. THOMSON, *Trans. N.Z. Inst.*, vol. 48, pp. 34, 35, 1916.

50 per cent.—into the divisions above and below. It is therefore necessary to exercise the greatest care in selecting those species which are to be regarded as the distinctive species of any one horizon. Even yet our knowledge is probably not quite sufficient to allow us to do so in all cases with great confidence. But even where this is so it does not justify us in neglecting the large amount of palaeontological knowledge we now have, as is actually done by Thomson.

As stated before, endless confusion would be caused by attempts to place the various beds near Oamaru in the stages as defined by Thomson. What, for instance, is the position of the Wharekuri beds? There is no Ototara limestone near them, and there is no Waiareka tuff, and there are no beds that in any way resemble the blue clays of the Awamoa stage. In our old classification of 1911 they had already a definite place, though it was regarded as provisional only. Park without any hesitation classes them in the Hutchinsonian because, he says, they lie below his Waitaki stone and above his lignitic beds.* This is at best a guess, and Thomson, with all other geologists except Park, refuses to recognize any difference between the Ototara and Waitaki limestones. Palaeontological results, however, can here be utilized with advantage, for seventy-five species of Mollusca have been found in the Wharekuri beds. If the general relationship of this fauna and the percentage of Recent species can be taken as a guide it can be clearly shown that the horizon is lower than that of the Ototara limestone and higher than the Bortonian of Park.

The reason for all of this is that Thomson maintains that the fauna of each locality is still imperfectly known, and he will not accept any fauna as characteristic until repeated visits to a locality fail to result in the collection of additional species. He states that he has examined ten thousand specimens of brachiopods from all parts of New Zealand, and says that until a similar investigation has been made of the Mollusca no rock grouping can rightly be based upon them. Actually I have examined far more than ten thousand specimens of Mollusca at Target Gully alone, and many times this number of specimens in other parts of New Zealand. More than eight hundred species of Tertiary Mollusca that occur in New Zealand have now been described, and the number of species recorded from several localities is now more than sixty. Surely our knowledge is now sufficient to allow us to adopt a palaeontological basis for our grouping of the rocks of the Oamaru system.

The basis of classification that has been found satisfactory in all parts of the world is dependent upon the occurrence of genera or species which have a restricted range in time. Unless a clear sequence of fossiliferous strata is found in any locality, or unless some rough grouping of the rocks is first obtained, the range of species is in general rather hard to determine. There will, however, always be some species that have a restricted range in any one fossiliferous locality, and by comparing those species that have a short life in different localities a classification can soon be arranged.

Attempts which have been made to do this in New Zealand have not up to the present time proved very successful. The more accurate identification of fossils and the more extensive collecting of recent years have, however, now made it possible. Some of our genera in particular are specially suited for this. *Struthiolaria* appears to me to be one of the best.

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* J. Park, *Bull. N.Z. Geol. Surv. No. 20,* p. 84, 1918.

The species are numerous, and their ornamentation distinct and varied, and many of the species appear to have a short range.

There can now be no doubt that the genus *Struthiolaria* is derived from *Pugnellus* Conrad, or from that modification that has been called *Conchothyra* by McCoy. *Conchothyra parasitica* McCoy occurs at the Selwyn Rapids and other places in rocks of Senonian age, and at the Waipara in rocks probably of the same age it is represented by *Pugnellus waiparaensis* Trechmann, a closely related species, while at Wangaloa, in rocks that are of very early Tertiary age, *Pugnellus australis* Marshall occurs, a species quite closely related to *P. waiparaensis*. At Hampden and Wangaloa there is *Struthiolaria minor* Marshall, a species that has a callosity extending over the greater part of the spire. *Pugnellus australis* Marshall is thought by Cossmann to be quite probably a *Struthiolaria*. *S. calcar*, *S. spinosa*, and *S. tuberculata* have a restricted range in the middle part of the Oamaru system, while *S. canaliculata* occurs in the portion that is commonly compared with the Upper Miocene, and *S. frazeri* is found in beds that are possibly the equivalent of the Lower Pliocene, and two species extend up to the Recent period.

Fusinus is another genus that can probably be used in the same way, for *F. solidus* is found in the Hampden beds, and in other rather higher but still old Tertiary beds. At Wharekuri *F. pulcher* occurs. *F. carinatus* occurs in beds that are rather low in the system in Canterbury, while *F. climacotus* is found at Enfield and Target Gully. In the north *F. morgani* and *F. kaiparaensis* are also species that appear to have a restricted range. *F. spiralis* occurs in Wanganui and Recent beds.

Exilia is a genus that is said by Cossmann to be characteristic of the Eocene period. In New Zealand *E. waihaoensis* is found in the Hampden beds and at Waihao, *E. dalli* extends to the top of the Oamaru limestone, and a third species is found in beds of a low horizon at Enfield.

Surcula is a genus that is well represented, and many of the species have a restricted range. Thus *Surcula hamiltoni* is found at Hampden, Wharekuri, and Kakahu. *Surcula serotina* is confined to the beds of low horizon at Hampden and Waihao and at Borton's. Many of the other species have a sufficiently restricted range to allow them to be used as index fossils.

There are many other genera, such as *Pecten*, *Cardium*, *Venericardia*, *Natica*, *Crassatellites*, and *Siphonalia*, that have species which by reason of their common occurrence, distinctness, and short range in time are eminently suitable for indicating the age of certain horizons.

The relation of various faunas to the Recent fauna and to one another gives another basis for correlation that may be used with the greatest advantage in studying the divisions of the Oamaru system. Thomson compares it with Lyell's original basis for the classification of the European Tertiaries, and says that the great geologist adopted this method because the European fossiliferous Tertiary beds were discontinuous. Surely that is also so in New Zealand, for otherwise we should not still at the present day be worrying about the stratification succession in them after forty years of effort. The fact that Lyell included the Brachiopoda in his comparisons does not affect the question. In New Zealand the brachiopods occur so sporadically and in such a small number of species compared with the Mollusca, and the species are so hard to identify with certainty, that they are far less satisfactory for purposes of correlation. Nobody would slavishly follow Lyell to the extent of requiring in New Zealand the same percentages for the different divisions of the Tertiary sediments as those that were used by him. It would be inadvisable to include the Brachiopoda in any New Zealand comparisons, because it so often happens that no brachiopods are to be found in the beds that contain molluscan fossils.

A further objection to this method is based on the possibility of the migration of faunas to New Zealand at different times. Our knowledge of the fauna is probably sufficient now to enable us to express a definite opinion on this subject, and it can be stated with some confidence that we have every reason for thinking that at no time has an introduction of a considerable number of species to our Tertiary molluscan fauna taken place. It is certainly a fact that a statement of the number of Recent species in the different fossil faunas will more speedily discover whether there has been such a migration than any other method of research.

It is now generally admitted that there is no stratigraphical break in the series of Tertiary rocks, and also that there is none in the faunal succession that is represented in them, for, as I have previously quoted, Thomson and Morgan state "Each Tertiary fauna seems to merge gradually into the succeeding one"*; and the late Mr. Suter has written the following in a letter to me: "There is no doubt that our molluscan fauna has gradually decreased, and also that the Tertiary forms gradually merge into one another." If this is the case it will certainly be extremely hard, if not impossible, even when our Tertiary fauna is completely known and the range of species definitely recorded, to find a horizon at which any important number of species disappear simultaneously. It is distinctly better under these circumstances to characterize the beds as containing certain percentages of Recent species.

This statement of the proportion of Recent species will, however, not provide a secure basis for comparison with European horizons. The small size of New Zealand and the fact that the more recent researches and the number of autochthonous species in its fauna and flora all show that the land has been isolated from other countries since, at the latest, the late Cretaceous, except possibly in the post-Tertiary, suggest that the organic changes must have been relatively slow. This belief is further supported by the knowledge that there has been no great variation of climatic conditions: that is, though the climate has been warmer and colder, it has not been tropical at any time, nor has there been anything that has approached the arctic cold of the Great Ice Age of Europe.

Again, it must be emphasized that our strata were deposited under the most different conditions of depth of water and of proximity to the shore-line, so that it is almost certain that in different parts of the area conglomerates, greensands, and limestones were contemporaneous formations. Such different lithological horizons would necessarily have also very different palaeontological facies, and a very great deal of work must be undertaken before we can be reasonably certain of their contemporaneity if we rely upon the occurrence or absence of index fossils. On the other hand, the Recent fauna contains species that live under all these different conditions, and it therefore affords a basis for comparison with the fauna of every lithological facies of the Tertiary strata.

It follows that if there is in New Zealand a continuous succession of our Tertiary molluscan species and an unbroken series of Cainozoic strata, and if the contemporaneous strata have a great variety of lithological facies,

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* Preface to *Palaeontological Bulletin No. 5*, 1917.

then this country is a typical one in which a calculation of the percentage of Recent species in representative collections from different strata affords the most satisfactory means of gauging the relative age.

It is not reasonable to refuse to use the percentage criterion because the present collections have not exhausted the fauna of any locality. In most cases sixty or seventy species are sufficiently representative of a fauna, and it is usually found that the percentage of Recent species in a collection of forty species in New Zealand strata remains practically the same even when large additions are subsequently made to it. At Target Gully, Oamaru, when the collection was 69 species the percentage of Recent species was 32·8; when 126 species, 36·3 per cent.; when 155 species, 33 per cent.; and when 212 species, 33·4 per cent. In calculating these percentages allowance has been made for erroneous identifications which were made in the earlier lists when they were first published.

Of course, it must be realized that the personal equation in the identification of species may cause a considerable variation in the percentage of Recent species when the identification is made by different authorities. Probably by the time that this has had much effect we shall be able to substitute definite species as indicating a special horizon in place of these percentages. At present it must be noted that in the Target Gully fossils Cossmann cannot agree that the species identified by Suter as *Chione mesodesma* and *C. oblonga* are actually the same as these Recent species. It is noticeable also that the relatively large *Natica zelandica* which is found Recent and in the Wanganui beds differs greatly in size from the consistently small form which is found in the Target Gully and Wharekuri beds and in other beds of that series near Oamaru. Again, the *Malletia australis* of Wharekuri is notably different from the Recent and Wanganui specimens, while specimens from Awamoa have characters intermediate in many respects Mr. Murdoch, too, assures me that in his opinion the *Crassatellites obesus* from Target Gully is quite a different species from that which is still living.

In summarizing the above I should say that the following facts appear to me to justify the use of the percentage method in the present state of our knowledge in classifying the strata of the Oamaru system in New Zealand: (1) There is a continuous succession of strata belonging to this system, which extends from perhaps the equivalent of the European Senonian to the Pliocene; (2) the faunas of the various Tertiary horizons gradually merge into one another; (3) contemporaneous strata differ so greatly lithologically and have been deposited under such very different bathymetric conditions that comparisons of species are in the light of our present knowledge unsatisfactory; and (4) the actual range of species is not yet sufficiently well known to allow of definite index fossils being stated as distinctive of different horizons.*

The table below, which has been prepared with great care, shows the faunal relations between the various beds near Oamaru. It also shows some comparisons between the Oamaru strata and those of the Trelissick beds of Canterbury, and also those of the Pakaurangi Point, Kaipara Harbour, North Auckland. It is difficult to frame a table that will give

* In reference to the use of the percentage of Recent species for defining the age of the Tertiary periods the most comprehensive of lately published text-books of geology says, "A wider knowledge of the marine Tertiary molluscs has shown that this classification has permanent value." (L. V. PIRSSON and C. SCHUCHERT, *Text-book of Geology*, p. 914.)

the actual faunal relationships between the different strata in a distinct manner when the collections which have been made in the different localities vary much in the number of species. For instance, when a comparison is made between the Otiake and the Target Gully faunas one is comparing a collection of 61 species with one of 212 species. One would naturally expect that a high percentage of the former would be found in the latter. On the other hand, only 28 per cent. of the Target Gully species could occur in the Otiake collection. On the whole, it appears to be the best plan to take each collection separately and calculate what percentage of the species that occur in each of the other localities is found among the species that occur in the stratum which is being considered. A comparison is also made with the fauna of the Recent beds and of the fauna that has been recorded from the Wanganui beds. In the latter some 200 species are recorded by Hutton, but the collection that he describes has been made from a large number of horizons, though all of them are younger than the strata at Oamaru and younger than those of the Trelissick Basin. It appears to me probable that no single horizon at Wanganui will yield more than 150 species of fossil Mollusca, even when fully collected. Of the Recent Mollusca it seems that no more than 400 of the recorded species could be expected to occur under the conditions of depth of water in which the Oamaru deposits were laid down. This, at any rate, is the assumption that is made, and in all of the percentage calculations it is assumed that the Recent fauna consists of 400 species only.

The various beds from which collections have been made may be described as follows:—

(1.) Hampden: On the coast about three miles north of the township of Hampden, or about fifteen miles south of Oamaru. The beds are unctuous green marls with a good deal of glauconite. Perhaps some 1,000 ft. above the base of the Oamaru system in that locality.

(2.) Wharekuri: Typical glauconite sands. Exposed on the left bank of the Waitaki River six miles from Kurow, about thirty miles north-west of Oamaru.

(3.) Otiake: Close to the right bank of the Waitaki River, four miles south-east of Kurow, or twenty-five miles north-west of Oamaru. The rocks are gritty polyzoan limestones which are higher in the series than the Wharekuri beds and probably rest directly on them. It is very generally admitted that this is the horizon of the Oamaru or Ototara limestone.

(4.) Target Gully: These are about half a mile from the Oamaru Railway-station, close to the Eden Street bridge. The beds are greyish sands with a little glauconite. The beds rest some 30 ft. above the Oamaru or Ototara limestone.

(5.) Awamoa: Near the coast about four miles south of Oamaru. The beds are a blue mudstone, which is admitted to be a higher horizon than the Target Gully beds.

In addition some comparisons are made with the Bortonian beds of Park* and also with the fauna of two beds in the Trelissick Basin, which have lately been fully listed by Speight,† and with the Pakaurangi fauna of North Auckland.

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* J, Park, *N.Z. Geol. Surv. Bull. No. 20*, p. 34, 1918.

† R. Speight, *Trans. N.Z. Inst.*, vol. 49, pp. 346, 348, 1917.

—		Hampden, 68 Species	Wharekuri, 75 Species	Otiake, 61 Species.	Target Gully, 212 Species.	Wanganui, 200 Species.	Recent, 400 Species.	—
Hampden, 68 species		..	14	8	16	7	7	Number of species found also in Hampden fauna.
		..	18·7	13·3	7·5	3·5	·1·7	Percentage of species found also in Hampden fauna.
Wharekuri, 75 species		14	..	31	41	18	16	Number of species found also in Wharekuri fauna.
		20·6	..	50·2	19·3	9	4	Percentage of species found also in Wharekuri fauna.
Otiake, 61 species		8	31	..	43	19	15	Number of species found also in Otiake fauna.
		11·8	41·3	..	19·7	9·5	3·8	Percentage of species found also in Otiake fauna.
Target Gully, 212 species		16	41	43	..	71	71	Number of species found also in Target Gully fauna.
		23·5	54	67	..	35	18	Percentage of species found also in Target Gully fauna.
Awamoa, 87 species		11	30	25	59	35	34	Number of species found also in Awamoa fauna.
		16	40	41	28	17·5	9	Percentage of species found also in Awamoa fauna.
Trelissick (1), 87 species		4	13	13	27	27	33	Number of species found also in Trelissick (1) fauna.
		5·9	17·3	21·3	12·7	13·6	8·2	Percentage of species found also in Trelissick (1) fauna.
Trelissick (2), 66 species		6	10	11	31	17	21	Number of species found also in Trelissick (2) fauna.
		8·8	13·3	18	15·1	8·5	5·2	Percentage of species found also in Trelissick (2) fauna.
Pakaurangi, 113 species		11	21	18	48	24	23	Number of species found also in Pakaurangi fauna.
		16·2	28	29·5	22·6	12·0	6	Percentage of species found also in Pakaurangi fauna.
Bortonian, 43 species		5	12	5	17	11	8	Number of species found also in Bortonian fauna.
		7·3	16	8·2	7·5	5·5	2	Percentage of species found also in Bortonian fauna.

	Number of Lamellibranchs.	Total Number of Species.	Percentage of Lamellibranchs.
Hampden	14	68	20
Wharekuri	30	75	40
Otiake	19	61	31
Target Gully	60	212	28
Awamoa	24	87	28
Trelissick (1)	57	87	66
Trelissick (2)	40	66	60
Pakaurangi	39	113	34
Bortonian	18	43	42

The relations of the different faunas as shown by this table must give a very definite idea of the relative ages of the strata. The conclusion to which it leads is in perfect accord with that at which I had previously arrived by employing the criteria of stratigraphy and of the percentage of Recent species.

The percentage of the species of the Hampden fauna which occurs in each of the other strata is relatively low, and clearly points to the considerable antiquity of the Hampden fauna. So far as the other localities are concerned, the percentage of the Hampden species gradually decreases from the Wharekuri to the Recent. On the other hand, the percentage of the Target Gully and of the Awamoa species gradually decreases from the Wharekuri to the Recent. However, these beds are more closely related to the Otiake beds below them than to the Wanganui beds above them. This obviously points to the probability or certainty that there are intervening beds of an intermediate age which will show a complete faunal gradation. In fact, the upper and lower strata in the Wanganui district are very different in age, as is clearly shown by the fact that the higher beds at Castlecliff contain about 90 per cent. of Recent species, while the beds at Waipipi, near Waverley, contain little more than 65 per cent. This, however, is a matter that will be worked out more fully subsequently.

The Bortonian, Trelissick, and Pakaurangi faunas are also tabulated in order that they may be more definitely compared with that of the beds near Oamaru. The Bortonian is clearly seen to approach most nearly to the Wharekuri strata, and this fact in itself shows quite clearly that the basal beds at Borton's are much younger than the basal beds in the Shag Point - Hampden portion of the Oamaru basin.

The Trelissick formations do not enter so readily into a comparison with the strata near Oamaru. The character of the fauna is somewhat different, as is clearly shown by the fact that there is a high percentage of lamellibranchs in it. At the same time the upper bed shows a closer approach to the Otiake stratum than to any other in the Oamaru district. This is significant, for the lower Trelissick bed is the middle of the limestone horizon in the Canterbury area, while the Otiake bed has the same position in the local series of Oamaru. The upper Trelissick bed, which rests directly on the surface of the limestone, is shown by the table to be much more closely related to the fauna of the Target Gully beds, which also have the corresponding position with reference to the Oamaru limestone that the Trelissick (2) beds have to the limestone (Amuri limestone) in that locality.

The fauna of the Pakaurangi beds is also shown to be more closely related to that of the Target Gully beds than to any other beds of the local Oamaru area, though there is a fairly close affinity with the fauna of Otiake—the Oamaru limestone horizon. This again agrees closely with the stratigraphical position that I have assigned to them. As stated elsewhere, the Pakaurangi beds, in my opinion, rest conformably on the hydraulic limestone, which I have correlated with the Oamaru limestone* (Otiake beds), and are therefore the local equivalent of the Target Gully beds. In applying the table to this matter it must be realized that only 53 per cent. of the Target Gully fauna could occur in the Pakaurangi beds, as is shown by the actual numbers of the species that have been collected. On the other hand, 100 per cent. of the Otiake fossils could occur in it.

The considerations that have been stated in this paper seem to me to justify the proposal to use the palaeontology of the strata near Oamaru as a basis for the correlation of the Oamaru system of rocks, and I would

* Thomson (*Trans. N.Z. Inst.*, vol. 48, p. 49, 1916) objects to the correlation of the hydraulic limestone of North Auckland with the Amuri limestone. It is a fact, however, that the hydraulic limestone rests on strata which contains a Senonian fauna and is covered by strata which contains a Tertiary fauna — the criterion given by Thomson for the stratigraphical position of the Amuri limestone.

now suggest the following divisions of the system in amplification of that proposed by me in a former paper* :—

OAMARU SYSTEM.

Probable European equivalent, Senonian to Pliocene.

Castlecliff Series (80–90 per cent. of Recent species).

Characteristic fossils: *Bezanconia huttoni*, *Calliostoma ponderosum*, *Actaeon ovalis*.

Until full collections have been made from these beds it is a little difficult to fix the boundary-line between them. At present it seems to me to be best placed at the horizon of the Moa bed, one mile south of the Nukumaru Beach.

The beds of the whole system certainly show a complete faunal gradation throughout, and it is therefore impossible to select fossil species that are entirely absent from the series above and below. In several cases the species that have been cited are found also in other series. It is thought, however, that they are more characteristic of the series under which they are mentioned than of the others.

Nukumaru Series (70–80 per cent. of Recent species).

Characteristic fossils: *Melina zealandica*, *Lutraria solida*, *Lucinida levifoliata*, *Ataxocerithium perplexum*, *Struthiolaria frazeri*.

A full list of species from this series has not yet been published, but it is hoped that this will be done next year. This series probably includes the Matapiro and Petane beds.

Waipipi Series (60–70 per cent. of Recent species).

Characteristic fossils: *Ostrea ingens*, *Pecten triphooki*, *Cardium spatiosum*, *Lima waipipiensis*, *Diplodon ampla*.

Collections from this locality are not yet completed. It is probable that localities near Hawera and in the higher portions of the Wanganui River contain a fauna that will fill in the gap between the Waipipi and the Target Gully series. The probability of this is shown by the collection made by Park from the Paparoa, on the Upper Wanganui River.†

The Greta and the Awatere beds and those at Castle Point may occupy a position intermediate between the Target Gully and the lower beds of the Wanganui coast-line—the Waipipi series. The collections that have been made up to the present are not sufficiently extensive to settle this matter definitely.

Target Gully Series (30–40 per cent. of Recent species).

Characteristic fossils: *Venericardia pseutes*, *Terebra orycta*, *Vexillum rutilidomum*, *Murex octogonus*, *Calyptraea maccoyi*, *Turbonilla oamarutica*, *Murex angasi*, *Chama huttoni*, *Fusinus climacotus*.

Nearly all species, however, are found in higher or in lower strata as well as in the Target Gully beds. In addition to species previously recorded from these beds I wish now to record *Venericardia bollonsi*, *Ficus subtransennus*, *Loripes concinna*, *Drillia laevis*, *Nucula sagittata*, *Leda semiteres*.

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* P. MARSHALL, *Trans. N.Z. Inst.*, vol. 48, p. 119, 1916.

† J. PARK, *Reports Geol Explorations during 1886–87*, p. 173, 1887

The strata called elsewhere in this paper "Trelissick (2)," the Pakaurangi beds, and the sandy beds of the lower Waipara Gorge should probably be placed here.

Ototara Series (25–30 per cent. of Recent species).

Characteristic fossils: *Pecten athleta, P. hochstetteri, P. williamsoni, Ostrea nelsoniana, Lima laevigata.*

This series is more definitely marked lithologically than palaeontologically, for it consists mainly of the limestone stratum which has such a general occurrence throughout New Zealand and but seldom contains molluscan fossils. Nearly all the fossils that have been found in this limestone have been found in higher and in lower horizons as well.

Wharekuri Series (20–25 per cent. of Recent species of Mollusca).

Characteristic fossils: *Surcula serotina, Borsonia mitromorphoides, Fusinus maorianus, Exilia dalli, Crassatellites subobesus, Niso neozelanica, Polinices huttoni, Turritella ambulacrum.*

Since my previous publication on the Wharekuri beds the following additional species of Mollusca have been collected: *Turris subaltus* n. sp., *Cucullaea australis, Terebra orycta, Terebra sulcata* Marshall, *Crassatellites subobesus* n. sp., *Panope orbita, Divaricella cumingi, Argobuccinum?* sp., *Cardium waitakiense, Marginella harrisi, Typhis maccoyi, Borsonia mitromorphoides, Chione* sp., *Siphonalia subnodosa, Zenatia acinaces, Fusinus maorianus.*

The Waihao greensands are probably to be placed in this series.

Wangaloa Series (0–20 per cent. of Recent Species of Mollusca).

Characteristic fossils: *Gilbertia, Perissolax, Heteroterma, Dicroloma, Volutoderma, Struthiolaria minor, Pugnellus australis.*

Waipara Series (Senonian).

Characteristic fossils: *Trigonia hanetiana, Inoceramus australis, Conchothyra parasitica, Belemnites lindsayi, Kossmaticeras, Baculites, Mosasaurus.*

Art. XXIV.—*Occurrence of Fossil Moa-bones in the Lower Wanganui Strata.*

By P. Marshall, M.A., D.Sc., F.G.S.

[*Read before the Wanganui Philosophical Society, 7th December, 1918; received by ditor, 30th December, 1918; issued separately, 16th July, 1919.*]

Plate XVIII.

No occurrence of fossil remains of the larger species of moa has yet been recorded. Such records as there are of fossil moa-remains were collected by Hutton (*Trans. N.Z. Inst.*, vol. 24, p. 141, 1891). Since the publication of that paper no further record has been made. If it be true, as I have often advocated, that the area of New Zealand has practically been isolated since the Upper Cretaceous period, the development of the numerous species of moa must have taken place within the limits