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HOCHSTETTER'S FOSSIL FORAMINIFERAL COLLECTIONS ON THE NOVARA EXPEDITION, 1857–1859

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ABSTRACT

Ferdinand Hochstetter was the geologist on the Austrian trans-global Novara Expedition (1857–1859). During these travels he collected sedimentary rock samples from three places that he recognised in the field to have rich foraminiferal faunas and on his return to Austria they were studied by three foraminiferal specialists. Conrad Schwager (1866) described 97 new species (79 currently accepted) from a Pliocene lower bathyal-abyssal fauna from Car Nicobar, India. This was the earliest description of cosmopolitan, deep-water Neogene foraminiferal species and thus includes descriptions of many species widely recognised today such as *Lobatula wuellerstorfi*, *Cibicidoides cicatricosus*, *Neogloboquadrina conglomerata*, *Pyrgo murrhina* and many of the more common elongate taxa that became extinct during the Last Global extinction in the Mid Pleistocene Climate Transition. Felix Karrer (1864) and Guido Stache (1864) described 19 foraminiferal species (16 currently accepted) from the early Miocene and 126 species (50 currently accepted) from the Oligocene of the North Island of New Zealand, respectively. Among the species described from Hochstetter's collections are the type species of 15 genera that are accepted today. Three species have been named *hochstetteri* from these localities. Because of their significance, all these new species from New Zealand and India were revised and typified in monographs by Hornibrook (1971) and Srinivasan & Sharma (1980), respectively.

INTRODUCTION

Like a number of prominent and now famous 19th century geologists from Europe (e.g., Alexander von Humboldt, Charles Darwin), Ferdinand von Hochstetter (Fig. 1) built most of his scientific reputation on the studies he undertook on a multi-year overseas expedition early in his career. Hochstetter was a key member of the scientific team on the circumglobal Novara Expedition of the Austrian Navy, 1857–1859 (Fig. 2). He was selected as the expedition's physicist and geologist at the age of 27, and nearing the end of the expedition he persuaded the leader to give him leave to carry out more detailed geological studies in New Zealand. He stayed nine months in New Zealand carrying out extensive field work in the provinces of Auckland and Nelson. When back in Austria, Hochstetter spent the next decade publishing the results of his work in New Zealand and on the *Novara* (e.g., Hochstetter, 1864, 1867). Today he is regarded by the geoscience community in New Zealand as 'the Father of New Zealand geology' (Johnston & Nolden, 2011).

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Seemingly a minor part of his activities during the expedition was Hochstetter's recognition of the presence of microscopic fossil foraminifera in sedimentary rocks he was examining. He collected samples of these from three locations – Car Nicobar, Bay of Bengal, India; Hobson/Orakei Bay, Auckland, New Zealand; and Whaingaroa/Raglan Harbour, New Zealand. What is outstanding is that this young, German-trained geologist with a major interest in volcanology, knew what foraminifera were and could recognise them in rocks in the field, presumably using a magnifying glass. He also carried a small bottle of acid for testing rocks for the presence of calcium carbonate – often foraminiferal tests.

On his return to Vienna in 1860, Hochstetter farmed out the study of foraminifera from these three localities to three Austrian or German foraminiferal specialists – Conrad Schwager, Felix Karrer and Guido Stache. According to the wishes of Hochstetter and the Novara Expedition, all the types of described fossils had to be placed in the Imperial-Royal Mineral Collections of the Austrian Court Museum (k. k. Hof-Mineralienkabinett des Wiener Hofmuseums), which later became the Natural History Museum, Vienna (Flügel, 1959). A search of the museum holdings in the late 1950s revealed that the types of foraminiferal species from the Hochstetter Novara collections described by Karrer (1864) and Stache (1864) were present but those described by Schwager from Car Nicobar were missing (Flügel, 1959). Flügel speculated that they may have been lost during shifts out of the museum of most of the collections during World War II.

These fossil foraminiferal faunas, formally described in the 1860s, contain many species that still have primacy and are widely used in foraminiferal studies today, or should be. Modern reviews of the taxonomies described by these three workers were undertaken just prior to the widespread use of scanning electron microscopes for imaging them, by Hornibrook (1971) for the New Zealand faunas and by Srinivasan & Sharma (1980) for the Car Nicobar fauna. Both revisions updated the generic placement of many of the species, made a few synonymies, established holotypes, lectotypes or neotypes and published beautiful line drawings of all recognised species.

Since these revisions, an archive of unpublished notes, maps and diagrams was 'discovered' in 2010 by one of us (SN) in the collection of Hochstetter's descendants in Switzerland. This material was then digitally copied, with the permission of the Hochstetter family, and made available for study and scientific research purposes. One important component of this archival estate holding was a series of Hochstetter's unpublished personal diaries from the Novara Expedition. These have since been donated to the Natural History Museum in Vienna, of which Hochstetter was the founding director from 1876. In this review we use this newly available material from Hochstetter's diaries and other unpublished ephemera to highlight the significant foraminiferal faunas he was responsible for collecting.

FIGURE 1. Ferdinand von Hochstetter, 1859, Auckland. (Photographer Bruno Hamel).

BRIEF BIOGRAPHICAL NOTES

FERDINAND VON HOCHSTETTER (1829–1884)

Christian Gottlieb Ferdinand Hochstetter was born in Esslingen, Germany. After initially studying theology at university, he shifted his focus to natural sciences and graduated with a doctorate in mineralogy from the University of Tübingen in 1852. He was then employed as a mapping geologist by the Imperial Austrian Geological Survey and by 1856 was teaching geology at the University of Vienna, before being appointed geologist and physicist on the Novara Expedition. On his return from the expedition he was ennobled by the King of Württemberg in 1860, becoming 'von' Hochstetter and late in life he was knighted by the Emperor of Austria and became Ferdinand Ritter von Hochstetter.

Two foraminiferal species were named for Hochstetter from his collections – one from Car Nicobar (*Nodosaria hochstetteri* Schwager, 1866) and one from Whaingaroa/Raglan Harbour (*Cristellaria (Marginulina) hochstetteri* Stache, 1864) and one subsequently from Car Nicobar (*Cibicides hochstetteri* Srinivasan & Sharma, 1980).

CONRAD SCHWAGER (1837–1891)

Conrad Joseph Johann Schwager was born in Protivín near Písek in Southern Bohemia, now Czech Republic. He was mostly educated in Prague and Munich where he was influenced by the lectures of foraminiferal micropaleontologist August Emanuel von Reuss. Later, he was employed as a paleontologist in the Geological Survey of Bavaria, 1865–1873, as an assistant and illustrator for Karl Alfred von Zittel before shifting employment to the Paleontological State Collections in Munich until his death. Schwager specialised in foraminiferal micropaleontology, describing and illustrating many new species and studying the structure of larger foraminifera. He published eight papers on foraminifera between 1865 and 1887. Thirty foraminiferal species and two genera have been named after him (Hayward et al., 2023).

FELIX KARRER (1825–1903)

Born in Venice and educated in Vienna, Karrer devoted himself to the study of geology and paleontology from 1857 onwards, with extensive studies of the Tertiary geology of the Vienna Basin, specializing in foraminiferal micropaleontology. He found time to work on Hochstetter's small foraminiferal fauna from the Orakei Greensand, Auckland in the early 1860s (Karrer, 1864). He published ten papers on foraminifera between 1862 and 1878. Twenty-eight foraminiferal species and four genera have been named after him, including *Plecanium karreri* Stache, 1864 from Whaingaroa/Raglan Harbour (Hayward et al., 2023).

GUIDO STACHE (1833–1921)

Karl Heinrich Hektor Guido Stache was born in Namysłów, Silesia, now Poland and became an Austro-Hungarian geologist and paleontologist. After graduation in 1857 he was employed at the Imperial Geological Institute in Vienna, becoming its director, 1892–1902. In addition to his geological and biostratigraphic field work in Europe, he devoted time to work on Hochstetter's foraminiferal collection from Raglan Harbour, New Zealand in the early 1860s (Stache, 1864). This was his only foraminiferal publication and shows a strong influence by his contemporary foraminiferal specialist in Vienna, August Reuss (see below). Seven foraminiferal species and two genera (taxa inquirenda) have been named after him (Hayward et al., 2023).

BRIEF NOTES ON PEOPLE WHO HAD SPECIES NAMED AFTER THEM

Bernhard Freiherr von Wüllerstorf-Urbair (1816–1883), Commodore of the Novara expedition who granted Hochstetter leave from the expedition to stay on in New Zealand and study its geology for an extra nine months. One foraminiferal species collected by Hochstetter was named after him: *Anomalina wuellerstorfi* Schwager, 1866.

Johann Ludwig Neugeboren (1806–1887), a pioneer of Transylvanian paleontology, who described nearly 100 species of foraminifera in 14 papers between 1850 and 1872. One foraminiferal species collected by Hochstetter was named after him: *Nodosaria neugeboreni* Schwager, 1866.

August Emanuel Rudolf von Reuss (1811–1873) was an Austrian geologist and paleontologist born in Bilin (now Bílina, Czech Republic), Bohemia. He trained as a medical doctor, but gave up that profession to become a geologist and paleontologist in 1849 and was appointed Professor of Mineralogy in the University of Vienna, 1863–1873. He studied a number of fossil groups specializing in foraminifera, describing hundreds of species between 1844 and 1874. One foraminiferal

FIGURE 2. Map of the circum-global route of the Novara Expedition, 1857–1859. (Hochstetter Collection Basel).

species collected by Hochstetter was named after him: *Gaudryina reussi* Stache, 1864.

Alexander Le Grand Campbell (1819–1890), a Scottish-born artist who arrived in Nelson, New Zealand in 1842 and met Hochstetter during his visit to Nelson, furnishing him with a selection of his watercolour landscape paintings. One foraminiferal species collected by Hochstetter was named after him: *Amphistegina campbelli* Karrer, 1864.

Julius von Haast (1822–1887), born in Bonn, Germany, and arrived in New Zealand the day before Hochstetter and joined him on many of his field trips and survey expeditions. Haast stayed on in New Zealand becoming a famous explorer, geologist and founding Director of Canterbury Museum, 1868–1887. One foraminiferal species collected by Hochstetter was named after him: *Cristellaria* (*Cristellaria*) *haasti* Stache, 1864.

George William Drummond Hay (1827–1881), land surveyor and Māori interpreter in Auckland and Coromandel, New Zealand. He accompanied Hochstetter, as interpreter, on a number of journeys in the North Island of New Zealand. One foraminiferal species collected by Hochstetter was named after him: *Textilaria hayi* Karrer, 1864.

James Mackay (1804–1875), a Scottish-born New Zealand farmer and politician, who arrived in Nelson in 1845, and hosted Hochstetter during a visit in 1859. One foraminiferal species collected by Hochstetter was named after him: *Rosalina mackayi* Karrer, 1864.

CAR NICOBAR COLLECTION

HOCHSTETTER'S DESCRIPTION

The *Novara* arrived off Car Nicobar on 22 February 1858 and anchored off the north-west coast. Scherzer (1862) wrote, "*On 25th February, at 10 A.M., the naturalists, accompanied by the officers in charge of the scientific apparatus, and the midshipmen, after very considerable difficulty, succeeded in effecting a landing on the island of Kar-Nicobar, in a bay protected by a coral reef between the villages of Moose [Mus]*

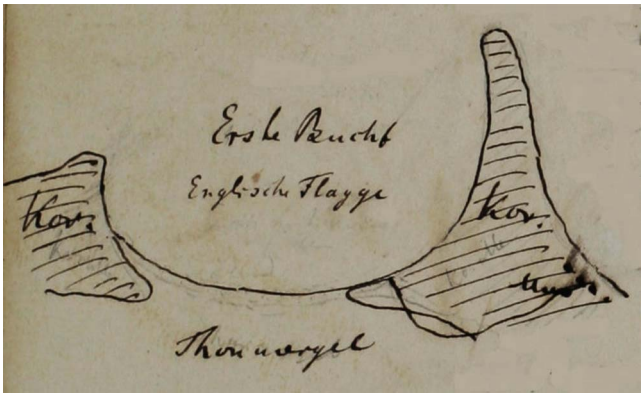

FIGURE 3. Hochstetter's diary sketch map, headed "Geological. First Bay" and in the bay "First Bay English flag". Left and right coral formations (cross hatched), and in the lower centre, clay marl is labelled (Hochstetter, 1858).

and Sàoui." . . . "*On 27th February, towards evening, after a stay of seven days on the north side of Kar-Nicobar, which had been spent in scientific operations of the most varied nature, we again set sail, and next morning cast anchor on the south side of the same island.*"

In his hand-written field diary Hochstetter wrote on 24 February 1858: "*Ich untersuche diese erste Bucht, in der man am besten auf der ganzen Küste von Car Nicobar anlegen kann an einem hinter Corallfels geschützten Platz. In dieser nördlichen Bucht, wo man mit Booten anlegen kann, tritt unter den Korallen ein bläulich weißer Thonmergel zu Tage, an der Stelle, wo er [am] mächtigsten auftritt, 20' mächtig nicht deutlich geschichtet, schmale Bänder, die horizontal liegen, sind z. Thl etwas dunkler heller gefärbt, andere eisenschüssig gelb. Ich habe aber nur einmal das gesehen, je ein Lager nur von wenigen Zoll. Ich konnte trotz eifrigsten Suchens keine Petrefakten finden, glaube aber daß der Thonmergel ganz voll Foraminiferen ist, einzelne Brauneisen Parthien darin, wahrscheinlich bloß zersetzte Basaltgerölle, z. Thl auch in Schwefelkies verwandelt. Der Thon liegt unter den Korallenbildungen*" (Hochstetter, unpublished 1858, p. 18; transcribed by SN). This is accompanied by a sketch location map (Fig. 3):

This passage translates as: I examined this first bay, the best place to moor on the entire coast of Car Nicobar, in a place sheltered behind coral rock. In this northern bay, where boats can berth, a bluish-white clay marl emerges under the corals. At the point where it is [most] thick, it is 20 feet thick, not clearly layered, narrow bands that lie horizontally, i.e., slightly darker, lighter coloured. At others ferruginous yellow. But I only saw this once, a deposit of only a few inches thickness. Despite my most diligent search, I was unable to find any fossils, but I believe that the clay marl is completely full of foraminifera, with individual limonite parts in it, probably just decomposed basalt rubble, and in places also transformed into pyrites. The clay lies beneath the coral formations (translation by SN).

In his description of the geology of Car Nicobar (Hochstetter, 1866; English translation by Stoliczka, 1869) Hochstetter wrote that the cliffs of parts of Car Nicobar are made of light grey clay which "*is a little calcareous, effervescing with acids*."..."*The clay deposit on the northern coast…is characterised as a marine formation by the numerous foraminifera which it contains*." This is a reference to First Bay, suggesting that this was the collection site of the material given to Schwager (Figs. 3–5). We have found no other documentation of the precise location, or stratigraphic position of samples Hochstetter collected. In his descriptions Schwager refers to occurrence in upper and lower clay layers implying there were two samples.

FIGURE 4. Hochstetter's 1858 unpublished geological map of Car Nicobar Island showing location of section from which his foraminiferal samples were obtained (red arrows added) on the northwest coast. Island is ~10 km across (Hochstetter Collection Basel).

LOCATION, STRATIGRAPHY, AGE AND PALEOENVIRONMENT

Srinivasan & Sharma (1969, 1973, 1974) undertook extensive stratigraphic field work and sampling at the three coastal sections of Neogene marl on Car Nicobar. Today this sedimentary rock is recognized as belonging to the Archipelago Group of Miocene-Pliocene age (Bandopadhyay & Carter, 2017). Srinivasan & Sharma (1973) placed it in Sawai Bay mudstone member of their Sawai Bay Formation and published a stratigraphic column through it in the cliffs of Sawai Bay (Srinivasan & Sharma, 1980, figure 2) which we deduce to be the place where Hochstetter collected his samples (~9°14′N, 92° 46′30″E). The member is ~250 m thick in this section and has a gentle dip towards the north-east (Srinivasan & Sharma, 1973).

The study of planktic foraminifera gave an age for these strata of middle zone N19 to lower zone N20 of Banner and Blow (1965) = Early to mid Pliocene age (~5–3.0 Ma) (Srinivasan & Sharma, 1980). The fauna contains many species that became extinct during the Last Global Extinction in the deep sea during the Mid-Pleistocene Transition, and many of these (e.g., *Anastomosa gomphiformis*, *Chrysalogonium rude*, *C. polystomum*, *Epelistoma crassitesta*, *Siphonodosaria insecta*,

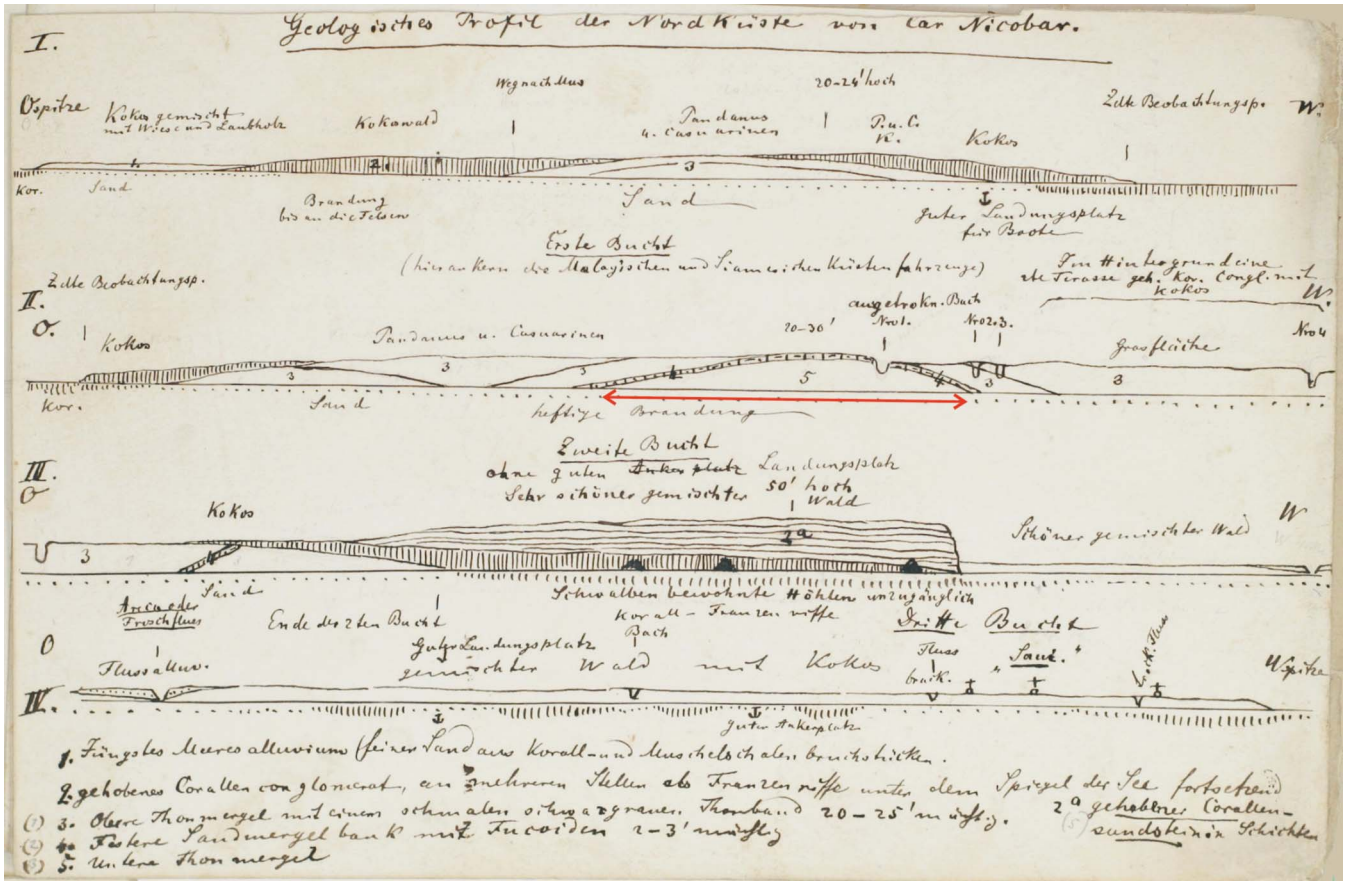

FIGURE 5. Hochstetter's 1858 unpublished manuscript geological profiles of the north west coast of Car Nicobar where he collected the foraminiferal-rich samples. (Hochstetter Collection Basel). This identifies what Hochstetter refers to as the first, second, and third bays [*Erste Bucht, Zweite Bucht, Dritte Bucht*] and uses numbers 1–5 to denote the geological formations:
1. Most recent marine alluvial deposits (fine sand comprising broken coral and seashells).
2. Uplifted coral conglomerates, in some places continuing as reefs below sea level.
2a. Uplifted coral sandstone layers.
3. Upper clay marl with a thin blackish-grey clay layer 20–25 feet thick.
4. Firmer sand marl beds with fucoids 2–3 feet thick.
5. Lower clay marls – source of the foraminiferal material (section II, red arrows added).

S. tauricornis, *Siphouvigerina hispida*) are characteristic of lower bathyal to mid abyssal (1000–4000 m) depths (Hayward et al., 2012).

Foraminiferal Fauna

Conrad Schwager (1866; Fig. 6) described 109 foraminiferal species including 97 that were new from Car Nicobar. In their revision of Schwager's fauna, Srinivasan & Sharma (1980) recognised 87 of these as valid. Today, with subsequent synonymies, 79 species are currently accepted as valid (WoRMS, Hayward et al., 2023; Appendix 1). As part of their detailed work on the Car Nicobar faunas, Srinivasan & Sharma (1980) identified a total of 204 benthic and 53 planktic foraminiferal species from these strata in three Car Nicobar sections (Sawai Bay, Passa bridge, and Kakana), not just the Sawai Bay section collected by Hochstetter.

Srinivasan and Sharma (1969, 1973, 1974; Fig. 7) picked "topotypic" material of most of Schwager's (1866) foraminiferal species. As no original types were known to be in existence (Flügel, 1959), Srinivasan & Sharma (1980) created neotypes for all 87 species they recognised as valid from the topotypic material they had collected and deposited them in the collections of the Department of Geology, Banaras Hindu University, Varanasi, India, and a set of topotypes was sent to the Natural History Museum, London. The only exceptions were *Globigerina conglomerata* Schwager, 1866, and *Globigerina seminulina* Schwager, 1866, for which Banner & Blow (1960) had already established neotypes.

Schwager's (1866) paper contained the name of the island in the title as Kar Nikobar. In his description of new species named after the island he retained the "k" in *Cristellaria nikobarensis*, but changed it in *Bigenerina nicobarica* and *Calcarina nicobarensis.* According to the ICZN code all these spellings are valid. In their revision of Schwager's foraminiferal taxonomy, Srinivasan & Sharma (1980) created two neotypes for one species name (*Biloculina lucernula* Schwager, 1866) allocated to two genera – *Pyrgo lucernula* (Schwager, 1866) and *Triloculina lucernula* (Schwager, 1866). Not surprisingly this is not acceptable according to ICZN and the latter of these two neotypes and combinations is rejected.

FIGURE 6. Conrad Schwager (1837–1891). (Photographer unknown).

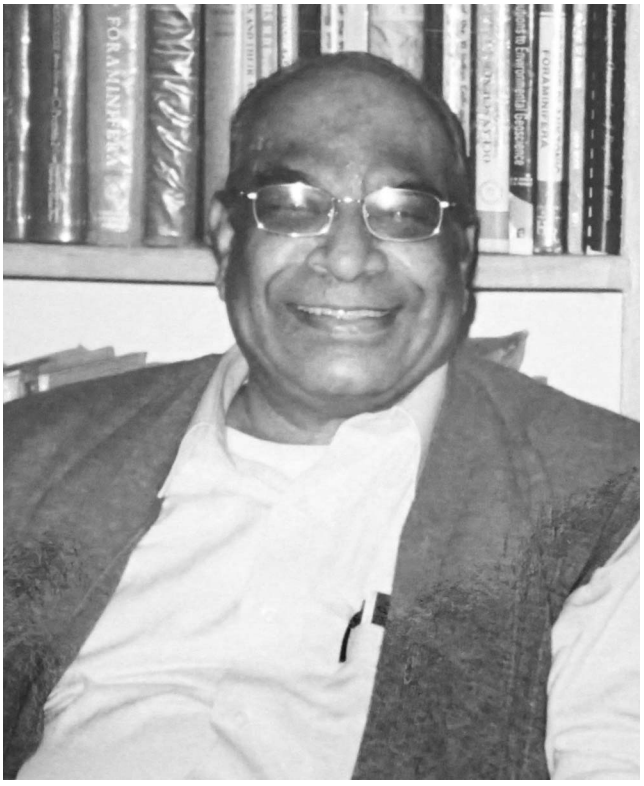

FIGURE 7. M.S. (Cheenu) Srinivasan (1938–2021). (Photographer James Kennett, 2004).

HOBSON/ORAKEI BAY COLLECTION

HOCHSTETTER'S DESCRIPTION

Hochstetter's first New Zealand diary contains no entries for the period when the Novara was in Auckland (22 Dec 1858–7 Jan 1859) and so we have no firsthand account of his collection from Hobson/Orakei Bay, Auckland, New Zealand (Fig. 8). We do know however that a party of scientists and officers from the *Novara* accompanied by a number of locals journeyed (possibly in boats from the *Novara*) a few kilometres east around the coast of the Waitemata Harbour on 23 or 24 Dec 1858. They must have stopped to visit both Judges Bay and the location near Orakei Basin where Hochstetter collected the "Orakei Greensand" sample.

We do have a brief description of this locality given by Hochstetter in his book on the Geology of New Zealand (Hochstetter, 1864, p. 39–42; English translation Fleming, 1959):

> *"Waitemata Beds. The steep shore cliffs of the embayed Waitemata Harbour (Auckland Harbour) show everywhere sections through a complex of chiefly horizontally bedded very regular strata consisting of alternating, light-coloured argillaceous marls and shaley sandier layers."…"The Waitemata Beds, despite their undoubted marine origin, are extremely poor in fossils. I have found only a single place where they generally occur, namely at Orakei Bay, east of Auckland… A very glauconitic muddy sand bed of ½ ft thickness, lying between thick sandstone beds, is quite full of Foraminifera, Bryozoa, and other (but always very small) fossils. The rock splits very easily along the bedding planes, from which the small fossils with their white shells then stand out clearly."…"Foraminifera: Mr T.R. Jones has determined the following species from parts of my collection that Heaphy sent to London*: *Nodosaria Raphanistrum* Linn. (fragments), *Vaginulina legumen* Linn. (common), *Polymorphina lactea* W. & J., *Cristellaria rotulata* Lam. (common), *Amphistegina vulgaris* d'Orb. (common), *Rotalia Schroeteriana* P. & J., *Miliola* (*Triloculina*). *Jones remarks that these species indicate a late Tertiary deposit. This however does not exhaust the wealth of Foraminifera in these beds. I refer to the fine work on this subject that Herr Felix Karrer has supplied for the paleontological part of this work*."

LOCATION, STRATIGRAPHY, AGE, AND PALEOENVIRONMENT

Hornibrook (1971) wrote "The exact locality at which Hochstetter collected the Orakei Bay Greensand is uncertain." He discusses several possible locations along the west shore of Hobson/Orakei Bay that various Auckland paleontologists and geologists speculated at the time was the likely locality, but that it was now removed or buried. Because of this, Hornibrook (1971) worked up samples (R11/f7555) collected by Professor J. A. Bartrum and Dr A.W.B. Powell in 1934, "where the sewer now enters and since buried under road construction debris." Dr P. F. Ballance (in Hornibrook, 1971) states that the Orakei Greensand is a 4–5 ft thick bed "with patchy concentrations of fossils near the base and a greenish colour due to concentration of andesitic volcanic detritus." He states that the bed can be traced in the sea cliffs for some

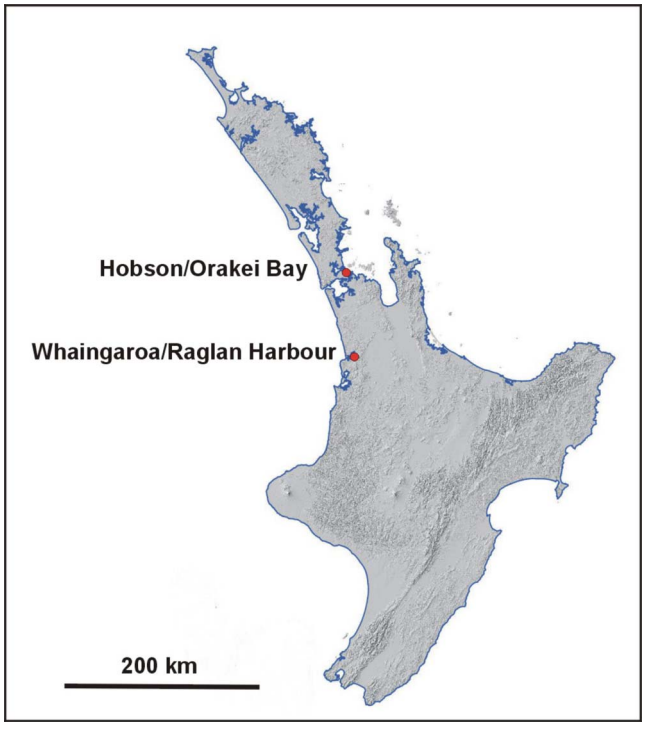

FIGURE 8. Map of northern North Island, New Zealand, showing locations of Hobson/Orakei Bay and Whaingaroa/Raglan Harbour where foraminiferal samples were collected by Hochstetter in 1859.

distance but not far into Hobson/Orakei Bay, where "the dip would appear to carry it to the shore platform in the vicinity of the sewer."

Recently an unpublished map by Heaphy (1859) has been discovered (Nolden & Hayward, 2023) which labels a point, about 50 m south of where the sewer line was built, with "fossiliferous rock 'H'" (Fig. 9). This map and rock samples were sent by Charles Heaphy to the Geological Society of London in 1859 to accompany a manuscript on the geological formation of Auckland (Heaphy, 1860). Sample H, is undoubtedly a sample collected by Hochstetter of the Orakei Greensand (Grenfell, 2023) and the one from which T. Rupert Jones (above) obtained and listed foraminifera (in Heaphy, 1860). The locality shown on Heaphy's map is precisely where Auckland geologists have recognised the Orakei Greensand for over 30 years (Kenny & Hayward, 1993). It is exposed as a 10–15 cm thick layer within the base of a 1 m thick sandstone bed in the foreshore and low cliffs of Hobson/Orakei Bay (36° 51′27.2″S, 174°48′33.2″E, New Zealand Fossil Record Number R11/f162; Fig. 10).

The sample comes from what is now called the Orakei Greensand Member of the East Coast Bays Formation of the Waitemata Group (Ballance, 1976). This formation is interpreted as turbiditic sandstones deposited in the lower bathyal-abyssal Waitemata Basin. The foraminifera in the sample contains *Haeuslerella hectori*, *Ehrenbergina marwicki*, *Globigerina woodi*, and lacks *Globorotalia praescitula* and *Globigerinoides trilobus*, giving it an age in the New Zealand Stage Otaian (Po, Early Miocene, 21.7–18.7 Ma; Raine et al., 2015). The diverse foraminiferal fauna (Hornibrook, 1971, p. 7–9) is dominated by large, robust specimens of the benthic foraminiferal genus *Amphistegina*, typical of inner shelf depths (0-50 m), and has 40% planktic foraminifera. The faunal assemblage is a mix of taxa from many different paleodepths from inner shelf (e.g., *Elphidium*, *Nephrolepidina*, *Pileolina*, *Porosorotalia*), outer shelf-upper bathyal (e.g., *Haeuslerella*, *Hoeglundina elegans*, *Ehrenbergina*) to mid bathyal or deeper (e.g., *Neugeborina*, *Osangularia*, *Siphonodosaria*, *Vulvulina pennatula*). Presumably these foraminiferal tests were sourced from the inner shelf origins of the turbidity current or were incorporated from the sea floor as the current passed.

FORAMINIFERAL FAUNA

Of the 19 foraminiferal taxa described by Felix Karrer (1864; Fig. 11) from this locality, 16 are currently accepted as valid (WoRMS, Hayward et al., 2023; Appendix 2). Two species are considered to be subjective junior synonyms of earlier described species and one a nomen dubium (WoRMS). All except two of Karrer's species are extinct with only *Gaudryina conversa* and *Lenticulina mamilligera* extant. In revising

FIGURE 9. Part of unpublished map of Charles Heaphy (1859) showing (with a "H") the location of the Orakei Greensand ("fossiliferous rock") sampled by Hochstetter in Hobson/Orakei Bay, Auckland (Nolden & Hayward 2023).

FIGURE 10. Orakei Greensand (beneath person) that was sampled by Hochstetter in December 1858. The coastal pohutukawa trees would have been flowering when Hochstetter was there (Photographer Bruce Hayward, December 2023).

Karrer's work, Hornibrook (1971; Fig. 12) repicked a complete fauna from close to the type locality (R11/f7555) in which he identified 125 species of foraminifera, many additional to those described by Karrer. He picked two sets of topotypes of the species of Karrer (1864) that he accepted and deposited one set in GNS, Lower Hutt, New Zealand and one set in the Natural History Museum, London, England. Hornibrook (1971) recognised some type specimens as still in existence in the Natural History Museum, Vienna, and labelled them holotype (if only one present) or selected one as a lectotype if there was more than one, or selected one from his topotypic material as a neotype if no types were found. In all he documented 5 holotypes, 10 lectotypes and 1 neotype.

FIGURE 11. Felix Karrer (1825–1903). (Photographer Théophile Le Comte, c. 1872).

FIGURE 12. Norcott de B. Hornibrook (1921–1994). (Photographer Lloyd Homer, c. 1975).

TABLE 1. List of species in Karrer's (1864) paper and their reidentifications by Jones & Parker (1864) together with additional taxa that Jones (1860) had previously identified from a sample from the same locality, also collected by Hochstetter, but sent to Jones by Heaphy.

Karrer (1864) species	Jones and Parker (1864) re-identifications
Amphistegina aucklandica Karrer	*Amphistegina vulgaris* d'Orbigny in Deshayes, 1830
Amphistegina campbelli Karrer	*Amphistegina vulgaris* d'Orbigny in Deshayes, 1830
Clavulina elegans Karrer	*Bigenerina Nodosaria* d'Orbigny, 1826
Critellaia mamilligera Karrer	*Cristellaria cassis* (Fichtel & Moll, 1798)
Robulus regina Karrer	*Cristellaria vortex* (Fichtel & Moll, 1798)
Dentalina aequalis Karrer	*Dentalina communis* (d'Orbigny, 1826)
Lingulina costata d'Orbigny	*Lingulina costata* d'Orbigny, 1846
Textilaria minima Karrer	*Lituola globigeriniformis* Parker and Jones, 1865
Nonionina simplex Karrer	*Nonionina umbilicata* d'Orbigny, 1826
Orbitoides incertus Karrer	*Orbitoides mantelli* (Morton, 1833)
Orbitoides orakiensis Karrer	*Orbitoides mantelli* (Morton, 1833)
Rotalia perforata Karrer	*Planorbulina haidingeri* (d'Orbigny, 1846)
Polystomella fichtelliana d'Orbigny	*Polystomella macella* (Fichtel & Moll, 1798)
Polystomella tenuissima Karrer	*Polystomella macella* (Fichtel & Moll, 1798)
Amphistegina ornatissima Karrer	*Polystomella* sp. (?)
Rotalia novozelandica Karrer	*Pulvinulina elegans* (d'Orbigny, 1826)
Rotalia mackayi Karrer	*Rotalia beccarii* (Linnaeus, 1758)
Textilaria hayi Karrer	*Textularia agglutinans* d'Orbigny, 1839
Textilaria convexa Karrer	*Textularia agglutinans* d'Orbigny, 1839
Vaginulina recta Karrer	*Vaginulina legumen* (Linnaeus, 1758)
Vaginulina neglecta Karrer	*Vaginulina legumen* (Linnaeus, 1758)
Additional:	*Cristellaria cultrata* (Montfort, 1808)
	Cristellaria rotulata (Lamarck, 1804)
	Globigerina bulloides d'Orbigny, 1826
	Nodosaria spinicosta (?) d'Orbigny, 1846
	Polymorphina lactea (Walker and Jacob, 1798)
	Uvigerina pygmaea d'Orbigny, 1826

T. Rupert Jones (1860) identified seven species from Hochstetter's sample sent to London by Heaphy (above) using European species names. Even before Karrer's taxonomic work (1864) appeared, Jones & Parker (1864) published a review of his work: "*Dr Karrer's nomenclature of Foraminifera permits nearly every difference of feature in individuals being taken as the basis for 'specific' distinction, which is still usual with some Rhizopodists; but if his 'species' be more strictly correlated with known forms according to the English plan (see Carpenter's 'Introduction') we shall find many old acquaintances on his beautiful plate of fossil Foraminifera from Orakei Bay, although he admits very few accepted names*." They then proceed to "correct" Karrer's identifications and list 22 species (Table 1). They conclude by stating that most are "*closely allied to Foraminifera now living, in warm seas, at depths of about 30 to 50 fathoms and more*." They recognise that two species are well known in Miocene strata. Jones & Parker (1864) also note that the sample "*yielded the numerous beautiful casts of Amphistegina figured and described in Dr Carpenter's 'Introduction to the Study of Foraminifera'*." (Carpenter et al., 1862).

This little spat was just another example of the major differences in the approach to foraminiferal classification of the English school of Jones, Parker, Williamson and Carpenter compared with the foraminiferal workers in the rest of Europe (Cifelli, 1990). The English school were 'lumpers' who recognised a limited number of cosmopolitan, long-ranging species whereas the others were 'splitters'. Today the splitters are considered more correct and Karrer's species are mostly accepted.

WHAINGAROA/RAGLAN HARBOUR COLLECTION

HOCHSTETTER'S DESCRIPTION

From 7 March to 24 May 1859, Ferdinand Hochstetter led an overland trek, mostly on foot, from Auckland southwards to the volcanoes in the centre of the North Island and back via the Bay of Plenty (e.g., Johnston & Nolden, 2011). On the 18 March Hochstetter fell into a disused kumara storage pit and twisted his knee and needed to rest up for several days before he was able to travel again. Thus, he spent three days at Haroto, the home of a Captain John Johnstone on a ridge above the southeast arm of Whaingaroa/Raglan Harbour. In his handwritten field diary Hochstetter wrote on 21 March 1859: "*Ich spürte zu meiner großen Freude eine wesentliche Besserung in meinem Knie, so daß ich nachmittags selbst bis zum Uferrand ging, um die Klippen zu sehen. In der Nähe des Hauses bestehen die circa 10–20' hohen Klippen am Waitetuna River aus grünen Thonmergeln, die kleine Fossilien verkalkt ziemlich häufig enthalten, darunter Foraminiferen aller Art, ich fand eine ausgezeichnet schöne Nautilusartige, ferner kleine Bivalven, [. . .] Die Mergelbänke mit den kleinen kalkigen Muscheln haben mehr ein alttertiäres eocänes Ansehen, als ein sekundäres*?" (Hochstetter, unpublished 1859, p. 68–69; transcribed by SN).

This passage translates as: *To my great joy, I felt a significant improvement in my knee, so that in the afternoon I walked to the coast to see the cliffs. Near the house there are approximately 10-20 feet high cliffs on the Waitetuna River made of green clay marls, which quite often contain calcified small*

FIGURE 13. The shore of Waitetuna Inlet, Raglan Harbour, in the approximate location where Hochstetter collected his Whaingaroa/Raglan Harbour sample in March 1859. (Photographer Bruce Hayward, February 2024).

fossils, including foraminifera of all kinds. I found an extremely beautiful nautilus-like one, as well as small bivalves . . . The marl banks with the small calcareous shells have more of an early Tertiary Eocene appearance than a Mesozoic one? (translated by SN).

Later in his book on the Geology of New Zealand (Hochstetter, 1864, translated into English by Fleming, 1959), Hochstetter wrote: "*At Whaingaroa Harbour. . .the eastern shore of the estuary, in particular the shore of Waitetuna Creek . . . consists of light grey, somewhat sandy clay marl, contains fossils, although sparsely. In company with my friend Haast, I here succeeded in collecting*" fossil molluscs and barnacle plates. "*These clay beds are very rich in Foraminifera, including the large and handsome Cristellaria haasti Stache. My friend Guido Stache has studied these Foraminifera, and the results of his work are presented in the paleontological part of this work*."

Location, Stratigraphy, Age and Paleoenvironment

The exact section of coast where the foraminiferal sample was collected by Hochstetter was identified in 1960 by David Kear of New Zealand Geological Survey (Hornibrook, 1971, p. 10). He located the site of Capt Johnstone's house on Te Kopapa Pt and the sample (R14/f8004; 37°47′30.0″S, 174° 57′50.1″E) he collected on the foreshore of Waitetuna Inlet (Fig. 13) just below where the house had been, contained a fauna identical to that described by Stache (1864). The sample comes from what has been designated the type section of the Whaingaroa Siltstone Formation by Kear & Schofield (1959) and the type section of the New Zealand Whaingaroan Stage by Finlay (1939).

The foraminiferal fauna contains *Rotaliatina sulcigera* and *Notorotalia stachei* and lacks *Subbotina angiporoides* which dates it as late Whaingaroan Stage (late Lwh; early Oligocene, 29.8–27.3 Ma; Raine et al., 2015). The diverse fauna (Hornibrook, 1971, p. 10–11) contains a large number of species of *Lenticulina* and other Vaginulinida, as well as specimens of bathyal-restricted *Siphonodosaria* and *Laticarinina pauperata*. It lacks typically inner-mid shelf (0–100 m depth) groups such as *Quinqueloculina*, Elphidiidae, or Glabratellidae and is consistent with a probable deep upper bathyal to shallow mid bathyal depth of deposition (400–800 m).

Foraminiferal Fauna

Of the 126 taxa described by Guido Stache (1864; Fig. 14) from this locality, 50 are currently accepted as valid (WoRMS,

FIGURE 14. Guido Stache (1833–1921). (Photographer Adolf Ost, Vienna. Alexander Turnbull Library PA2-1291).

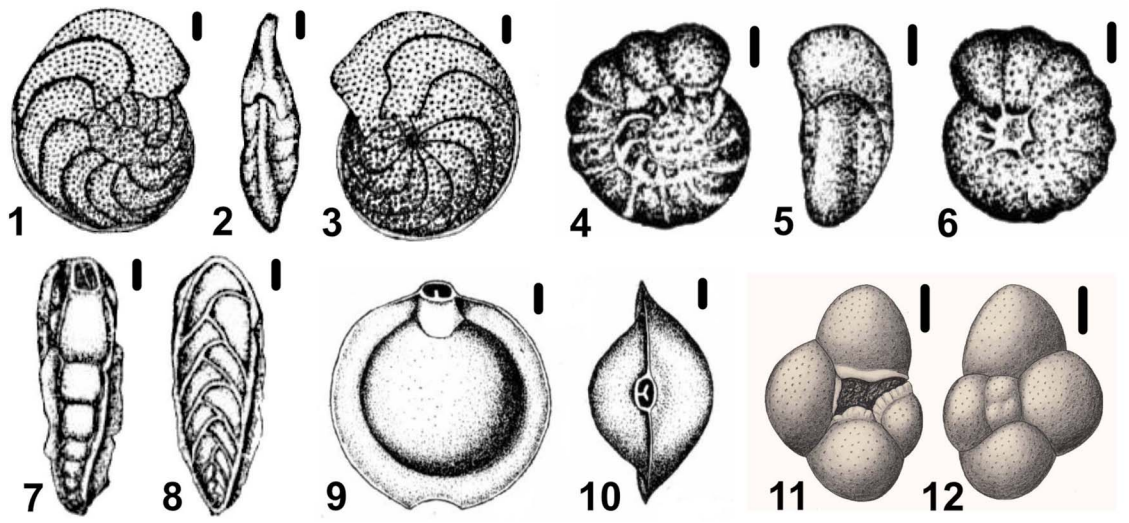

FIGURE 15. Images of neotypes of significant foraminiferal species described from Hochstetter's collections. Scale bars = 100 μm. **1–3** *Lobatula wuellerstorfi* (Schwager, 1866), neotype from Srinivasan and Sharma (1980). **4–6** *Cibicidoides cicatricosus* (Schwager, 1866), neotype from Srinivasan and Sharma (1980). **7–8** *Bolivinita quadrilatera* (Schwager, 1866), neotype from Srinivasan and Sharma (1980). **9–10** *Pyrgo murrhina* (Schwager, 1866), neotype from Srinivasan and Sharma (1980). **11–12** *Sphaeroidinellopsis seminulina* (Schwager, 1866), neotype (P44035) from Banner & Blow (1960), atypical four-chambered form.

Hayward et al., 2023; Appendix 3). The remainder have been considered to be subjective junior synonyms, mostly of other species described from this fauna by Stache (Hornibrook, 1971), or nomen dubium (9 species) because no substantiated type material has been identified as extant in the collections of the Natural History Museum in Vienna (Hornibrook, 1971). Stache (1864) described two new subgenera of *Cristellaria* with one still accepted as a valid genus—*Hemirobulina*. Just four species are considered to be subjective junior synonyms of species described earlier by other workers (Appendix 3). All species are considered to only occur as fossils. In the process of revising Stache's work, Hornibrook (1971) repicked the total fauna from the type locality and identified 96 species of foraminifera, many additional to those described by Stache. He picked two sets of topotypes of Stache's (1864) species that he accepted. One set was deposited in GNS, Lower Hutt, New Zealand and the other in the Natural History Museum, London, England. Where type specimens still existed in the Natural History Museum, Vienna, Hornibrook (1971) labelled them as holotype (if only one present) or selected one as a lectotype if there was more than one. Where no type specimens were found, he selected a neotype from his topotypes. In all Hornibrook (1971) documented 35 holotypes, 6 lectotypes and 8 neotypes.

SIGNIFICANCE OF THE FORAMINIFERAL FAUNAS COLLECTED BY HOCHSTETTER

The foraminiferal faunas from samples collected by Hochstetter in 1858–1859 constitute the first fossil foraminifera described from both India (Car Nicobar) and New Zealand. By chance they consist of foraminifera of three different ages: Oligocene (Whaingaroa/Raglan Harbour), Early Miocene (Hobson/Orakei Bay) and Pliocene (Car Nicobar), and three different depositional environments: lower bathyal-abyssal, oceanic (Car Nicobar), deep upper-shallow mid bathyal (Whaingaroa/Raglan Harbour) and mixed shelf and bathyal (Hobson/Orakei Bay).

The most significant of these faunas is the Pliocene fauna described by Schwager (1866) from Car Nicobar. This is because it was the first diverse, deep-water, fully oceanic

FIGURE 16. Type species from foraminifera described by Stache (1864) from samples collected by Hochstetter. All images from Stache (1864). Scale bars = 100 μm. **1** *Arenodosaria antipodum* (Stache, 1864). **2–3** *Hemirobulina arcuatula* Stache, 1864. **4** *Lagenoglandulina annulata* (Stache, 1964). **5–6** *Semivulvulina capitata* (Stache, 1864).

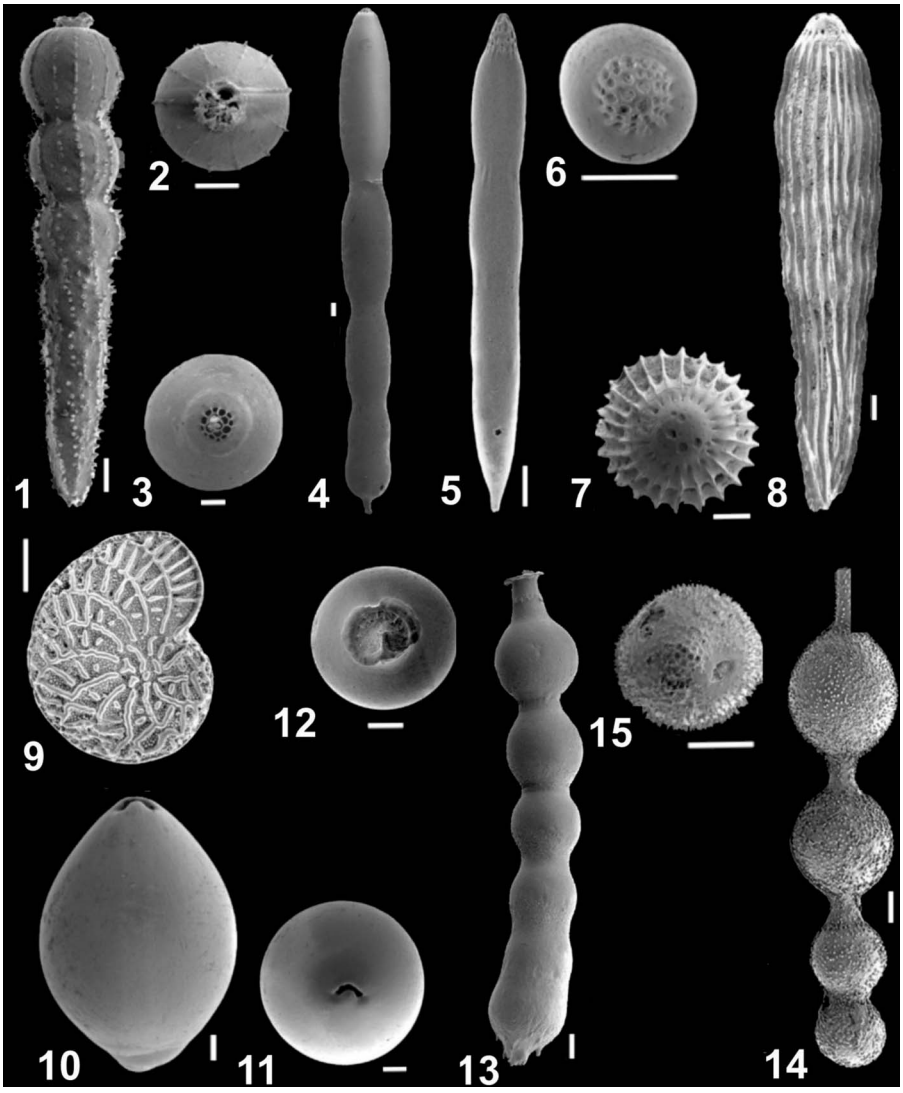

FIGURE 17. Illustrations of foraminiferal species described from samples collected by Hochstetter that have been designated the type species of new genera [specimen images (not types) from Hayward et al., 1997, 2012]. Scale bars = 100 μm. **1–2** *Anastomosa gomphiformis* (Schwager, 1866), ODP 1082A-11H-CC, Southwest Atlantic, Early Pleistocene. **3–4** *Chrysalogonium polystomum* (Schwager, 1866), ODP 1125A-16H-CC, SW Pacific, Early Pliocene. **5–6** *Cribroconica stimulea* (Schwager, 1866), ODP 1088B-2H-5, 127-131 cm, Southern Ocean, Early Pleistocene. **7–8** *Epelistoma crassitesta* (Schwager, 1866), ODP 1125A-16H-CC, SW Pacific, Early Pliocene. **9** *Discorotalia tenuissima* (Karrer, 1864), I38/f7607, Canterbury, New Zealand, Early Miocene. **10–11** *Ellipsoglandulina labiata* (Schwager, 1866), ODP 1123A-6H-5, 130-132 cm, SW Pacific, Early Pleistocene. **12–13** *Siphonodosaria insecta* (Schwager, 1866), ODP 758A-4H-CC, 5-7 cm, NE Indian Ocean, Late Pliocene. **14–15** *Lotostomoides asperulum* (Schwager, 1866), ODP 1120B-2H-5, 69-71 cm, SW Pacific, Late Pliocene.

Neogene fossil fauna described world-wide. It comprises a mix of cosmopolitan species that became extinct during the Last Global extinction (27 species), mostly during the Mid-Pleistocene Climate Transition (Hayward et al., 2012) and most of the remainder are cosmopolitan benthic taxa (50 species) that are still extant. Schwager (1866) and the Novara Expedition predated and therefore has primacy over the deep-water foraminifera described from around the world by Brady (1879a, b, 1881, 1884) from the Challenger Expedition (1872–1876). The reason why the Schwager foraminifera were among the first descriptions of deep, open-ocean Neogene foraminifera is that the majority of early described foraminifera were of modern, nearshore species, or fossil Neogene species from shelf and bathyal depths in enclosed sedimentary basins of Europe or the Mediterranean.

Molecular studies and modern morphological reviews of foraminiferal families tend to show that many deep-sea Cenozoic foraminiferal species have a cosmopolitan distribution whereas those that lived at upper bathyal and shelf depths have a mix of locally or regionally endemic and cosmopolitan species (Hayward & Holzmann, 2023). Thus, most of Schwager's deep-sea species are cosmopolitan and therefore of global significance, especially in the more recent paleoceanographic studies coming out of ocean drilling. This contrasts with shallower water Oligocene and Miocene foraminiferal faunas described by Karrer (1864) and Stache (1864) from mid bathyal to inner shelf environments around New Zealand. Many of these latter species are still recognised as valid in New Zealand where many may be endemic. Global taxonomic reviews in the future may show that some of these species were more

TABLE 2. Species described from Hochstetter's collections that are now the type species of accepted genera.2024-00006 Hayward & Nolden, Table 2.

Species from Hochstetter samples	Type species of [senior synonym of this original type species]
Clavulina antipodum Stache, 1864	*Arenodosaria* Finlay, 1939
[*Clavulina robusta* Stache, 1864]	
Cristellaria (*Hemirobulina*) *arcuatula* Stache, 1864	*Hemirobulina* Stache, 1864
Glandulina annulata Stache, 1864	*Lagenoglandulina* Silvestri, 1923
[*Glandulina subovata* Stache, 1864]	
Glandulina labiata Schwager, 1866	*Ellipsoglandulina* Silvestri, 1900
[*Ellipsoglandulina laevigata* Silvestri, 1900]	
Globigerina seminulina Schwager, 1866	*Sphaeroidinellopsis* Banner and Blow, 1959
[*Sphaeroidinella dehiscens subdehiscens* Blow, 1959]	
Nodosaria asperula Schwager, 1866	*Lotostomoides* Hayward and Kawagata, 2012
Nodosaria conica Schwager, 1866	*Scallopostoma* Hayward and Kawagata, 2012
[*Nodosaria aspera* Reuss, 1845]	
Nodosaria crassitesta Schwager, 1866	*Epelistoma* Hayward and Kawagata, 2012
Nodosaria gomphiformis Schwager, 1866	*Anastomosa* Hayward, 2012
Nodosaria insecta Schwager, 1866	*Siphonodosaria* Silvestri, 1924
[*Nodosaria abyssorum* Brady, 1881]	
Nodosaria polystomum Schwager, 1866	*Chrysalogonium* Schubert, 1908
Nodosaria stimulea Schwager, 1866	*Cribroconica* Hayward and Kawagata, 2012
Polystomella tenuissima Karrer, 1864	*Discorotalia* Hornibrook, 1961
Textilaria capitata Stache, 1864	*Semivulvulina* Finlay, 1939
Textilaria quadrilatera Schwager, 1866	*Bolivinita* Cushman, 1927

widespread than just New Zealand with some being subjective senior and others junior synonyms of species described from elsewhere.

SIGNIFICANT FORAMINIFERAL SPECIES DERIVED FROM HOCHSTETTER'S COLLECTIONS

Among the species described from Hochstetter's collections are some well-known and widely studied taxa (Fig. 15). *Lobatula wuellerstorfi* (Schwager, 1866) is the standard species used, when present, for benthic oxygen and carbon isotope studies in paleoceanography and paleoclimatology globally. Other common cosmopolitan deep-water benthic species in the Neogene, described from Hochstetter's collections include *Bolivinita quadrilatera* (Schwager, 1866), *Cibicidoides cicatricosus* (Schwager, 1866), *Lenticulina mamilligera* (Karrer, 1864), *Neolenticulina peregrina* (Schwager, 1866), *Siphouvigerina proboscidea* (Schwager, 1866), *Osangularia bengalensis* (Schwager, 1866), *Pyrgo lucernula* (Schwager, 1866), and *Pyrgo murrhina* (Schwager, 1866).

Schwager, Karrer, and Stache also described and named most of the more common elongate, cylindrical benthic foraminifera that became extinct in the Last Global extinction in the deep sea (Hayward et al., 2012), such as *Chrysalogonium deceptorium* (Schwager, 1866), *Cribroconica stimulea* (Schwager, 1866), *Ellipsoglandulina labiata* (Schwager, 1866), *Glandulonodosaria ambigua* (Schwager, 1866), *Mucronina compressa* (Schwager, 1866), *Obesopleurostomella brevis* (Schwager, 1866), *Orthomorphina perversa* (Schwager, 1866), *Pleurostomella alternans* (Schwager, 1866), *P. tenuis* (Schwager, 1866), *Siphonodosaria consobrina* (Karrer, 1864), *S. lepidula* (Schwager, 1866), *S. pomuligera* (Stache, 1864), *Staffia tosta* (Schwager, 1866), and *Stilostomella fistuca* (Schwager, 1866) and also the more common species that died-back in this period but have managed to survive through to today in low numbers, such as *Martinotiella variabilis* (Schwager, 1866), *Siphouvigerina hispida* (Schwager, 1866), and *Rectuvigerina striata* (Schwager, 1866). Schwager also described two planktic foraminifera that are still recognised as valid today: *Globoquadrina conglomerata* (Schwager, 1866) and *Sphaeroidinellopsis seminulina* (Schwager, 1866). Fifteen of the species described by Stache (1864), Karrer (1864), and Schwager (1866) now have importance as the type species of subsequently described genera (Figs. 16, 17; Table 2).

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APPENDICES

APPENDIX 1. List of species described from Hochstetter's Car Nicobar material by Schwager (1866) and their currently accepted names from WoRMS (Hayward et al., 2023). Most revisions are the work of Srinivasan & Sharma (1980) or Hayward et al. (2012).

Schwager (1866) name	Currently accepted name
Anomalina bengalensis	*Osangularia bengalensis* (Schwager, 1866)
Anomalina cicatricosa	*Cibicidoides cicatricosus* (Schwager, 1866)
Anomalina wuellerstorfi	*Lobatula wuellerstorfi* (Schwager, 1866)
Ataxophragmium laceratum	*Ruakituria magdalidiformis* (Schwager, 1866)
Ataxophragmium magdalidiforme	*Ruakituria magdalidiformis* (Schwager, 1866)
Ataxophragmium subovale	*Eggerella subovale* (Schwager, 1866)
Bigenerina nicobarica	*Vulvulina nicobarica* (Schwager, 1866)
Biloculina lucernula	*Pyrgo lucernula* (Schwager, 1866)
Biloculina murrhina	*Pyrgo murrhina* (Schwager, 1866)
Bolivina ligularia	*Bolivina ligularia* Schwager, 1866
Bolivina pusilla	*Bolivina pusilla* Schwager, 1866
Calcarina nicobarensis	*Calcarina nicobarensis* Schwager, 1866
Clavulina variabilis	*Martinottiella variabilis* (Schwager, 1866)
Cristellaria caelata	*Planularia caelata* (Schwager, 1866)
Cristellaria insolita	*Astacolus insolitus* (Schwager, 1866)
Cristellaria nikobarensis	*Lenticulina nikobarensis* (Schwager, 1866)
Cristellaria peregrina	*Neolenticulina variabilis* (Reuss, 1850)
Cristellaria perprocera	*Marginulina perprocera* (Schwager, 1866)
Cristellaria polita	*Lenticulina cushmani* (Galloway and Wissler, 1927)
Cristellaria sublenticularis	*Lenticulina sublenticularis* (Schwager, 1866)
Dimorphina striata	*Rectuvigerina striata* (Schwager, 1866)
Discorbina sacharina	*Globorotalia menardii* (d'Orbigny in Parker, Jones & Brady, 1865)
Fissurina capillosa	*Fissurina capillosa* Schwager, 1866
Fissurina staphyllearia	*Fissurina staphyllearia* Schwager, 1866
Frondicularia foliacea	*Mucronina compressa* (Costa, 1855)
Gaudryina baccata	*Karreriella baccata* (Schwager, 1866)
Gaudryina pavicula	*Arenodosaria pavicula* (Schwager, 1866)
Gaudryina solida	*Gaudryina solida* Schwager, 1866
Gaudryina subrotundata	*Karreriella subrotundata* (Schwager, 1866)
Gaudryina uva	*Eggerella uva* (Schwager, 1866)
Glandulina labiata	*Ellipsoglandulina labiata* (Schwager, 1866)
Glandulina solita	*Pseudonodosaria solita* (Schwager, 1866)
Globigerina conglomerata	*Globoquadrina conglomerata* (Schwager, 1866)
Globigerina seminulina	*Sphaeroidinellopsis seminulina* (Schwager, 1866)
Lagena caepulla	*Lagena caepulla* Schwager, 1866
Lagena castrensis	*Fissurina castrensis* (Schwager, 1866)
Lagena formosa	*Fissurina formosa* (Schwager, 1866)
Lagena seminiformis	*Fissurina seminiformis* (Schwager, 1866)
Marginulina subcrassa	*Astacolus subcrassus* (Schwager, 1866)
Marginulina subtrigona	*Astacolus subcrassus* (Schwager, 1866)
Nodosaria (Nodosaria) insolita	*Siphonodosaria tauricornis* (Schwager, 1866)
Nodosaria arundinea	*Neugeborina longiscata* (d'Orbigny, 1846)
Nodosaria brevicula	*Lotostomoides calomorpha* (Reuss, 1866)
Nodosaria costai	*Strictocostella scharbergana* (Neugeboren, 1856)
Nodosaria crassitesta	*Epelistoma crassitesta* (Schwager, 1866)
Nodosaria deceptoria	*Chrysalogonium deceptorium* (Schwager, 1866)
Nodosaria equisetiformis	*Chrysalogonium equisetiformis* (Schwager, 1866)
Nodosaria exilis	*Stilostomella parexilis* (Cushman & Stewart, 1930)
Nodosaria fistuca	*Stilostomella fistuca* (Schwager, 1866)
Nodosaria fustiformis	*Dentalina fustiformis* (Schwager, 1866)
Nodosaria glandigena	*Glandulonodosaria glandigena* (Schwager, 1866)
Nodosaria gomphiformis	*Anastomosa gomphiformis* (Schwager, 1866)
Nodosaria gracilescens	*Vaginulina protumida* (Schwager, 1866)
Nodosaria hircicornua	*Dentalina mutabilis* (Costa, 1855)
Nodosaria hispida	*Scallopostoma asperum* (Reuss, 1845)
Nodosaria hochstetteri	*Toddostomella hochstetteri* (Schwager, 1866)
Nodosaria holoserica	*Lotostomoides asperula* (Neugeboren, 1852)
Nodosaria inconstans	*Nodosaria pseudoinconstans* Srinivasan & Sharma, 1980
Nodosaria insecta	*Siphonodosaria insecta* (Schwager, 1866)
Nodosaria intertenuata	*Grigelis pyrula* (d'Orbigny, 1826)
Nodosaria koina	*Glandulonodosaria ambigua* (Neugeboren, 1856)

Appendix 1. Continued.

Schwager (1866) name	Currently accepted name
Nodosaria lepidula	*Siphonodosaria lepidula* (Schwager, 1866)
Nodosaria maculata	*Chrysalogonium rude* (d'Orbigny, 1846)
Nodosaria neugeboreni	*Laevidentalina haueri* (Neugeboren, 1856)
Nodosaria perversa	*Orthomorphina perversa* (Schwager, 1866)
Nodosaria polystoma	*Chrysalogonium polystomum* (Schwager, 1866)
Nodosaria protumida	*Vaginulina protumida* (Schwager, 1866)
Nodosaria recta	*Dentalina recta* (Schwager, 1866)
Nodosaria setosa	*Chrysalogonium rude* (d'Orbigny, 1846)
Nodosaria skobina	*Epelistoma crassitesta* (Schwager, 1866)
Nodosaria stiliformis	*Chrysalogonium deceptorium* (Schwager, 1866)
Nodosaria stimulea	*Cribroconica stimulea* (Schwager, 1866)
Nodosaria subradicula	*Amphicoryna scalaris* (Batsch, 1791)
Nodosaria subtertenuata	*Scallopostoma asperum* (Reuss, 1845)
Nodosaria tauricornis	*Siphonodosaria tauricornis* (Schwager, 1866)
Nodosaria tholigera	*Nodosaria tholigera* Schwager, 1866
Nodosaria tornata	*Glandulonodosaria ambigua* (Neugeboren, 1856)
Nodosaria tosta	*Staffia tosta* (Schwager, 1866)
Nodosaria tympaniplectriformis	nomen dubium
Plecanium laxatum	*Textularia laxata* (Schwager, 1866)
Plecanium lythostrotum	*Textularia lythostrota* (Schwager, 1866)
Plecanium solitum	*Siphotextularia solita* (Schwager, 1866)
Pleurostomella alternans	*Pleurostomella alternans* Schwager, 1866
Pleurostomella brevis	*Obesopleurostomella brevis* (Schwager, 1866)
Polymorphina labiata	*Pyrulina labiate* (Schwager, 1866)
Quinqueloculina eborea	*Quinqueloculina eborea* Schwager, 1866
Rotalia flosculiformis	*Oridorsalis umbonatus* (Reuss, 1851)
Rotalia nitidula	*Gyroidina nitidula* (Schwager, 1866)
Sphaeroidina murrhyna	*Globocassidulina murrhyna* (Schwager, 1866)
Textilaria globigera	*Bolivina variabilis* (Williamson, 1858)
Textularia praelonga	*Duquepsammia cubensis* (Cushman and Bermudez, 1937)
Textularia quadrilatera	*Bolivinita quadrilatera* (Schwager, 1866)
Uvigerina crassicostata	*Uvigerina crassicostata* Schwager, 1866
Uvigerina gemmaeformis	*Uvigerina gemmaeformis* Schwager, 1866
Uvigerina hispida	*Siphouvigerina hispida* (Schwager, 1866)
Uvigerina nitidula	*Uvigerina nitidula* Schwager, 1866
Uvigerina proboscidea	*Siphouvigerina proboscidea* (Schwager, 1866)

Appendix 2. List of species recorded and described from Hochstetter's sample from Hobson/Orakei Bay by Karrer (1864) and their currently accepted names from WoRMS (Hayward et al., 2023). Most revisions are the work of Hornibrook (1971).

Karrer (1864) name	Currently accepted name
Amphistegina aucklandica	*Amphistegina aucklandica* Karrer, 1864
Amphistegina campbelli	*Amphistegina campbelli* Karrer, 1864
Amphistegina ornatissima	*Porosorotalia ornatissima* (Karrer, 1864)
Clavulina elegans	*Clavulina antipodum* Stache, 1864
Cristellaria (Cristellaria) mamilligera	*Lenticulina mamilligera* (Karrer, 1864)
Cristellaria (Marginulina) neglecta	*Vaginulina neglecta* (Karrer, 1864)
Cristellaria (Robulina) regina	*Lenticulina regina* (Karrer, 1864)
Nodosaria (Dentalina) aequalis	*Siphonodosaria consobrina* (d'Orbigny, 1846)
Nonionina simplex	*Melonis simplex* (Karrer, 1864)
Orbitoides orakeiensis	*Nephrolepidina orakeiensis* (Karrer, 1864)
Orbitulites incertus	nomen dubium
Polystomella tenuissima	*Discorotalia tenuissima* (Karrer, 1864)
Rosalina mackayi	*Pararotalia mackayi* (Karrer, 1864)
Rotalia novozelandica	*Cibicides novozelandicus* (Karrer, 1864)
Rotalia perforata	*Cibicides perforates* (Karrer, 1864)
Textilaria convexa	*Gaudryina convexa* (Karrer, 1864)
Textilaria hayi	*Textularia hayi* Karrer, 1864
Textilaria minima	*Dorothia minima* (Karrer, 1864)
Vaginulina recta	*Vaginulinopsis recta* (Karrer, 1864)

Appendix 3. List of species described from Hochstetter's sample from Whaingaroa/Raglan Harbour by Stache (1864) and their currently accepted names from WoRMS (Hayward et al., 2023). Most revisions are the work of Hornibrook (1971).

Karrer (1864) name	Currently accepted name
Bulimina aperta	*Globobulimina pupula* (Stache, 1864)
Bulimina arcuata	*Haeuslerella textilariformis* (Stache, 1864)
Bulimina propinqua	*Globobulimina pupula* (Stache, 1864)
Bulimina pupula	*Globobulimina pupula* (Stache, 1864)
Bulimina textilariformis	*Haeuslerella textilariformis* (Stache, 1864)
Clavulina antipodum	*Arenodosaria antipodum* (Stache, 1864)
Clavulina antipodum var. alpha	*Arenodosaria antipodum* (Stache, 1864)
Clavulina antipodum var. beta	*Arenodosaria antipodum* (Stache, 1864)
Clavulina antipodum var. gamma	*Arenodosaria antipodum* (Stache, 1864)
Clavulina robusta	*Arenodosaria antipodum* (Stache, 1864)
Clavulina robusta var. alpha	*Arenodosaria antipodum* (Stache, 1864)
Clavulina robusta var. beta	*Arenodosaria antipodum* (Stache, 1864)
Cornuspira archimedis	*Ammodiscus archimedis* (Stache, 1864)
Cornuspira elliptica	*Ammodiscus archimedis* (Stache, 1864)
Cristellaria (Cristellaria) bucculenta	*Lenticulina taettowata* (Stache, 1864)
Cristellaria (Cristellaria) bufo	nomen dubium
Cristellaria (Cristellaria) callifera	*Lenticulina callifera* (Stache, 1864)
Cristellaria (Cristellaria) cilo	nomen dubium
Cristellaria (Cristellaria) colorata	*Lenticulina colorata* (Stache, 1864)
Cristellaria (Cristellaria) duracina	*Lenticulina taettowata* (Stache, 1864)
Cristellaria (Cristellaria) falcifer	*Lenticulina loculosa* (Stache, 1864)
Cristellaria (Cristellaria) glaucina	*Lenticulina foliata* (Stache, 1864)
Cristellaria (Cristellaria) gyroscalprum	*Lenticulina gyroscalpra* (Stache, 1864)
Cristellaria (Cristellaria) haasti	*Astacolus haasti* (Stache, 1864)
Cristellaria (Cristellaria) lactea	*Lenticulina foliata* (Stache, 1864)
Cristellaria (Cristellaria) larva	*Lenticulina loculosa* (Stache, 1864)
Cristellaria (Cristellaria) rotula	*Lenticulina loculosa* (Stache, 1864)
Cristellaria (Hemicristellaria)	*Hemirobulina* Stache, 1864
Cristellaria (Hemicristellaria) corculum	*Hemirobulina arcuatula* Stache, 1864
Cristellaria (Hemicristellaria) excavata	*Hemirobulina arcuatula* Stache, 1864
Cristellaria (Hemicristellaria) infrapapillata	*Vaginulinopsis hochstetteri* (Stache, 1864)
Cristellaria (Hemicristellaria) procera	*Hemirobulina arcuatula* Stache, 1864
Cristellaria (Hemicristellaria) verrucosa	*Vaginulinopsis hochstetteri* (Stache, 1864)
Cristellaria (Hemirobulina)	*Hemirobulina* Stache, 1864
Cristellaria (Hemirobulina) arcuatula	*Hemirobulina arcuatula* Stache, 1864
Cristellaria (Hemirobulina) compressa	*Astacolus compressus* (Stache, 1864)
Cristellaria (Hemirobulina) galeola	*Hemirobulina arcuatula* Stache, 1864
Cristellaria (Marginulina) angistoma	*Marginulina angistoma* (Stache, 1864)
Cristellaria (Marginulina) apiculifera	*Vaginulinopsis interrupta* (Stache, 1864)
Cristellaria (Marginulina) asprocostulata	*Vaginulinopsis interrupta* (Stache, 1864)
Cristellaria (Marginulina) cristellata	*Vaginulinopsis cristellata* (Stache, 1864)
Cristellaria (Marginulina) duracina	*Vaginulinopsis interrupta* (Stache, 1864)
Cristellaria (Marginulina) elatissima	*Vaginulinopsis interrupta* (Stache, 1864)
Cristellaria (Marginulina) hochstetteri	*Vaginulinopsis hochstetteri* (Stache, 1864)
Cristellaria (Marginulina) interrupta	*Vaginulinopsis interrupta* (Stache, 1864)
Cristellaria (Marginulina) mucronulata	*Vaginulinopsis interrupta* (Stache, 1864)
Cristellaria (Marginulina) opaca	nomen dubium
Cristellaria (Marginulina) pellucida	*Vaginulinopsis interrupta* (Stache, 1864)
Cristellaria (Marginulina) spinulosa	*Vaginulinopsis spinulosus* (Stache, 1864)
Cristellaria (Marginulina) tricuspis	*Vaginulinopsis interrupta* (Stache, 1864)
Cristellaria (Robulina) coronalunae	*Planularia halophora* (Stache, 1864)
Cristellaria (Robulina) cultrata var. antipodum	*Lenticulina pseudocalcarata* (Stache, 1864)
Cristellaria (Robulina) foliata	*Lenticulina foliata* (Stache, 1864)
Cristellaria (Robulina) halophora	*Planularia halophora* (Stache, 1864)
Cristellaria (Robulina) incrustata	*Lenticulina taettowata* (Stache, 1864)
Cristellaria (Robulina) lenticula	*Lenticulina lenticula* (Stache, 1864)
Cristellaria (Robulina) loculosa	*Lenticulina loculosa* (Stache, 1864)
Cristellaria (Robulina) oculus	*Lenticulina pseudocalcarata* (Stache, 1864)
Cristellaria (Robulina) pseudocalcarata	*Lenticulina pseudocalcarata* (Stache, 1864)
Cristellaria (Robulina) pusilla	*Lenticulina pusilla* (Stache, 1864)
Cristellaria (Robulina) taettowata	*Lenticulina taettowata* (Stache, 1864)
Dentalina deformis	*Siphonodosaria pomuligera* (Stache, 1864)
Dentalina marginata	*Vaginulina vagina* (Stache, 1864)

Appendix 3. Continued.

Karrer (1864) name	Currently accepted name
Dentalina obliquesuturata	*Marginulina obliquesuturata* (Stache, 1864)
Dentalina obscura	nomen dubium
Dentalina pomuligera	*Siphonodosaria pomuligera* (Stache, 1864)
Dentalina rotundata	nomen dubium
Dentalina scarificata	nomen dubium
Dentalina striatissima	*Nodosaria obliquecostata* Stache, 1864
Dentalina vagina	*Vaginulina vagina* (Stache, 1864)
Dentalina verticalis	*Vaginulina vagina* (Stache, 1864)
Frondicularia whaingaroica	*Mucronina monacantha* (Reuss, 1850)
Gaudryina capitata	*Gaudryina reussi* Stache, 1864
Gaudryina insecta	*Gaudryina reussi* Stache, 1864
Gaudryina megastoma	*Gaudryina reussi* Stache, 1864
Gaudryina novozelandica	*Gaudryina reussi* Stache, 1864
Gaudryina obliquata	*Gaudryina reussi* Stache, 1864
Gaudryina reussi	*Gaudryina reussi* Stache, 1864
Glandulina annulata	*Lagenoglandulina annulata* (Stache, 1864)
Glandulina aperta	*Pseudonodosaria aperta* (Stache, 1864)
Glandulina erecta	*Pseudonodosaria aperta* (Stache, 1864)
Glandulina napaeformis	*Lagenoglandulina annulata* Stache, 1864
Glandulina rimosa	*Lagenoglandulina annulata* Stache, 1864
Glandulina subovata	*Lagenoglandulina annulata* (Stache, 1864)
Glandulina symmetrica	*Pseudonodosaria symmetrica* (Stache, 1864)
Globigerina angipora	nomen dubium
Globigerina reticulata	nomen dubium
Guttulina fissurata	*Guttulina fissurata* Stache, 1864
Guttulina obliquata	*Guttulina fissurata* Stache, 1864
Guttulina pusilla	*Guttulina fissurata* Stache, 1864
Haplophragmium incisum	*Cyclammina incisa* (Stache, 1864)
Haplophragmium maoricum	*Cyclammina incisa* (Stache, 1864)
Lagena anomala	*Lagena anomala* Stache, 1864
Lagena tenuistriata	*Lagena tenuistriata* Stache, 1864
Lingulina decipiens	*Lingulina decipiens* Stache, 1864
Lingulina glans	*Pseudonodosaria aperta* (Stache, 1864)
Lingulina intustriata	*Pseudonodosaria symmetrica* (Stache, 1864)
Lingulina propinqua	*Pseudonodosaria aperta* (Stache, 1864)
Lingulina rimosa	*Arenodosaria antipodum* (Stache, 1864)
Nodosaria antipoda	*Siphonodosaria pomuligera* (Stache, 1864)
Nodosaria callosa	*Pyramidulina callosa* (Stache, 1864)
Nodosaria dubiosa	*Nodosaria dubiosa* Stache, 1864
Nodosaria obliquecostata	*Dentalina obliquecostata* (Stache, 1864)
Nodosaria striatissima	*Rectuvigerina striatissima* (Stache, 1864)
Nodosaria striatissima var. alpha	*Rectuvigerina striatissima* (Stache, 1864)
Nodosaria striatissima var. beta	*Rectuvigerina striatissima* (Stache, 1864)
Nodosaria striatissima var. delta	*Rectuvigerina striatissima* (Stache, 1864)
Nodosaria striatissima var. epsilon	*Rectuvigerina striatissima* (Stache, 1864)
Nodosaria striatissima var. gamma	*Rectuvigerina striatissima* (Stache, 1864)
Nodosaria striatissima var. zeta	*Rectuvigerina striatissima* (Stache, 1864)
Nodosaria subrhombica	nomen dubium
Nodosaria subsimilis	nomen dubium
Nodosaria substrigata	*Pyramidulina substrigata* (Stache, 1864)
Plecanium eurystoma	*Dorothia minima* (Karrer, 1864)
Plecanium granosissimum	*Dorothia minima* (Karrer, 1864)
Plecanium karreri	*Dorothia minima* (Karrer, 1864)
Polymorphina cognata	*Polymorphina lingulata* Stache, 1864
Polymorphina contorta	*Polymorphina lingulata* Stache, 1864
Polymorphina dispar	*Polymorphina pernaeformis* Stache, 1864
Polymorphina gigantea	*Polymorphina lingulata* Stache, 1864
Polymorphina incavata	*Polymorphina incavata* Stache, 1864
Polymorphina lingulata	*Polymorphina lingulata* Stache, 1864
Polymorphina marsupium	*Sigmomorphina pernaeformis* (Stache, 1864)
Polymorphina pernaeformis	*Sigmomorphina pernaeformis* (Stache, 1864)
Polymorphina sacculus	*Sigmomorphina pernaeformis* (Stache, 1864)
Rosalina fasciata	*Anomalinoides fasciatus* (Stache, 1864)
Rosalina latifrons	*Rosalina latifrons* Stache, 1864

APPENDIX 3. Continued.

Karrer (1864) name	Currently accepted name
Rosalina maorica	*Melonis maoricus* (Stache, 1864)
Rosalina orbiculus	*Anomalinoides orbiculus* (Stache, 1864)
Rosalina thiara	*Cibicides thiara* (Stache, 1864)
Rosalina thiara var. *elatior*	*Cibicides thiara* (Stache, 1864)
Rotalia maculata	*Cibicides maculatus* (Stache, 1864)
Rotalia naticoides	*Rotaliatina sulcigera* (Stache, 1864)
Rotalia paupercula	*Haplophragmium incisum* Stache, 1864
Rotalia soldanii var. *prominula*	*Gyroidinoides prominula* (Stache, 1864)
Rotalia sulcigera	*Rotaliatina sulcigera* (Stache, 1864)
Textilaria capitata	*Semivulvulina capitata* (Stache, 1864)
Textilaria carinata var. *antipodum*	*Semivulvulina capitata* (Stache, 1864)
Textilaria carinata var. *robusta*	*Semivulvulina capitata* (Stache, 1864)
Textilaria subrhombica	*Textularia subrhombica* Stache, 1864