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Jacob Whitman Bailey (1811-1857): Ehrenberg's Ambassador to America

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Abstract

Science in general, and microscopy in particular, lagged far behind Europe in early 19th century America. Jacob Bailey was one of the very few American microscopists. In eulogies he was called 'the Ehrenberg of America' and 'the founder of microscopical research'. He was a major figure in the scientific community of America in his time and instrumental in promoting microscopy and the study of microscopic organisms. His name maybe familiar to specialists who focus on diatoms, foraminifera, or radiolaria. However, Bailey's important contributions to protistology have received very little attention and he is rarely mentioned in histories of protistology. Here Jacob Bailey's life, his protistological works, as well as his roles in the development of microscopy in America and the 19th century debate over life in the deep sea, are reviewed.

***Keywords*:** History of protistology; Diatoms; Rhizaria; Microscopy; Deep sea; American naturalists

Contents

Introduction

It is rarely appreciated that in 19th century America, microscopical science lagged very far behind microscopy in Europe. For example, the Microscopical Society of London was formed in 1839 and began publishing the *Transactions of the Microscopical Society of London* in 1844. While in America, the first microscopical society to publish a journal was the State Microscopical Society of Illinois, founded in 1868, and its publication *The Lens*, lasted only 2 years, 1872-1873 (Brock 1989). The first American microscopical journal that endured dates from 1895, *Transactions of the American Microscopical Society* (Brock 1989). In the early 19th century America, there were no manufacturers of microscopes. Suppliers of scientific instruments did not carry microscopes (Padgitt 1975). Both microscopes and the literature, had to be imported at considerable cost from Europe by individuals. At this time, in the infancy of microscopy in America, one of the very few practitioners was Jacob Bailey.

Bailey was the 'Professor of Chemistry, Mineralogy and Geology' at the United States Military Academy in West Point (NY). He became quite well known in his time as the singular authority on microscopy and microscopic organisms in America. Unfortunately, his scientific career was short, beginning with his first publication at age 26 in 1837 and ending with an early death at age 46 in 1857. However, during his mere 20 years of scientific activity he authored many publications, and over 40 of these were on protistological or microscopical topics. Bailey introduced the pioneering German microscopist Christian Ehrenberg (1795-1876) to American scientists through a series of articles. Bailey published extensively on diatoms, authoring, for example, the first article devoted to the diatoms of America (Edgar 1977). He trained other notable scientists in the use of the microscope. Bailey conducted some of the pioneering studies of deep sea protists (Gooday et al. 2020) and even authored a charming paper on the infusoria of the Mississippi River, opining that given density of the fauna, the river water was likely nutritious (Bailey 1848a).

Nonetheless, Bailey is entirely missing from the usual histories of protozoology such as those of Saville Kent (1880-1881), Cole (1926), and Kudo (1954) or is

mis-characterized, for example, by Corliss (1978), who mentioned Bailey in passing as a micropaleontologist specializing in foraminfera and radiolaria. The relative obscurity of Jacob Bailey today may be due in part to the fact that he did not produce a substantial monograph, in contrast to later American workers such as Joseph Leidy (i.e., Leidy 1879) or Alfred Stokes (i.e., Stokes 1888). Bailey's work appeared only in articles. Furthermore, he often used titles only vaguely indicative of the full contents of the article such as "On the existence of siliceous? spiculae in the exterior rays of Actinia; and memoranda concerning the siliceous animalcules of Boston" (Bailey 1842a), a work which contains a description of a new diatom species he found in the Boston Harbor. Hence, many of Bailey's articles have perhaps simply been over-looked. Here an attempt is made to introduce the oft-neglected Jacob Bailey to protistologists of today. First a brief biography of Bailey, based largely on Gould (1858) and Coulter (1888), is presented in order to place in context both his life and his work in mid-19th century America. Then the progession of Bailey's protistological and microscopical studies will be described. A complete, annotated and detailed bibliography of Bailey's contributions, which includes his works in chemistry and botany, is available in Edgar (1977).

Biographical Sketch of Jacob Bailey

Jacob Whitman Bailey was born on April 29th, 1811 into a family of modest means. At age 12 he was put to work in a library/bookstore where he spent much time reading books on 'mineralogy' and 'conchology'. After a visit to the library of cadets from the United States Military Academy, at age 14, he "set his sites" on attending the academy in West Point (NY). In 1828, he was admitted as a cadet and graduated at age 21, fifth in his class, and became a commissioned officer of the United States Army. In 1835 Bailey married Maria Slaughter and their first child, Martha, was born, the first of four children. In 1838 his first son Samuel was born; his second son Loring was born in 1839, and his third son William in 1843. Both Loring and William would later become botantists of renown. They were both raised in West Point as in 1837 Bailey was called back to the Academy as 'Acting Professor of Chemistry'. It was then that Bailey published his first scientific article on the use of grasshopper legs as a

replacement for frog legs in classroom demonstrations of nerve stimulation (Bailey 1837). Bailey would remain at West Point for his entire career, named Professor of Chemistry, Mineralogy and Geology in 1838, and there his name became synonymous with microscopy, not only among the naturalists of America and the United Kingdom, (e.g. Mantell 1846), but also, interestingly, in the art world.

One of the most famous paintings of a microscope is "*The Microscope*". In the painting, Bailey was pictured by his colleague and friend Robert Weir (then a drawing instructor at West Point), at his microscope, with his wife, his daughter and two of his sons (Fig. 1). The painting of the happy family, one of the best known of Weir's works (Ahrens 1974), dates from 1849, just a few years before the Bailey family was subjected to tragedy. In 1852, a fire aboard the steamboat *Henry Clay* in the Hudson River took the lives of his wife and daughter. Bailey's loss is said to have been a heavy blow contributing to worsening a fragile health. Jacob Bailey died at the age of 46 in 1857, shortly before he was to have assumed the presidency of the American Association for the Advancement of Science. In obituaries and eulogies, Jacob Bailey was named the "Ehrenberg of America" (Gould 1857) and the "founder of microscopical research in America" (Grey 1857). It was said that few naturalists of the time purchased a microscope without first consulting Bailey (Gould 1858). Among those known to have received training in microscopy by Bailey are the pioneer American botantist John Torrey (Cassidy 1976) and Hamilton L. Smith, a diatomist, and the third president of the American Microscopical Society (Edlund & Stoermer 2013) . Bailey bequeathed his microscopical legacy, his collection of over 500 microscope slides, to the Boston Society of Natural History and many are today housed in the Farlow Herbarium of Harvard University.

Fig. 1. The left panel shows the 1849 oil painting by Robert Weir, "*The Microscope*", depicting Jacob Bailey at his microscope surrounded by his family, actual size 76 cm x 101 cm, presently in the Yale University Art Gallery. For more information on Weir and the painting see Ahrens (1974) and Fahlman (2011). The right panel shows the compound microscope in the painting, the Universal Microscope of Charles Chevalier, in the horizontal position; image of the microscope in the Golub Collection of the University of California, Berkeley.

The Contributions of Jacob Bailey to Protistology and Microscopy

Bailey's first paper on protists appeared in 1838. This early article contained his first published observations of living protists and is the first American article on diatoms (Edgar 1977). It was a study inspired by Bailey's examination of some samples that Ehrenberg had shared from German sites. The study is worth reviewing in some detail for what it reveals about scientific networks at the time, the constraints under which Bailey worked, and his penchant for giving his articles mis-leading titles. The 1838 article was entitled "On fossil infusoria, discovered in peat-earth, at West Point, N.Y., with some notices of American species of Diatomae" (Bailey 1838). His microscopical investigations of protists began then with the gift from John Torrey (an American botantist, former faculty member at West Point, and friend of Bailey's) of some sample containing fossil diatoms, originally collected by Ehrenberg. It had been brought to America by an Oxford Professor of Botany, Charles Daubeny. How a sample collected by

Ehrenberg came into the possession of Daubeny is not mentioned but he shared with Ehrenberg an interest in volcanoes. Regardless, the circuitous path of the sample that found its way to Bailey is indicative of odd routes and wide distribution of some samples during the times.

Despite the title of his 1838 paper, Bailey's article is largely on living, not fossil, diatoms. In Bailey's words: *"Having by means of this specimen* (Ehrenberg's sample) *become acquainted with the form of these singular creatures, I was led to search for living species of this family in various situations in this vicinity. I soon found that they were exceedingly abundant, occurring not only in small streams and stagnant pools, but also nestling in the wet moss on moist rocks"*. The plate accompanying the article showed both diatoms from deposits of diatomaceous earth found by Bailey, and diatoms he had observed alive. Bailey observed living diatoms in motion and said he could add nothing new to Ehrenberg's view that diatoms were animals. In this work, Bailey used a 'Raspail Chemical Microscope", akin to a dissecting microscope, allowing manipulation of the material on a glass stage. It was a very popular type of microscope in America for many years (Anon. 1878). However, it was a single lens microscope, explaining perhaps why the drawings in the plate appear rather crude (Fig. 2). Three of the eight pages of Bailey's article are a transcription of a summary of Ehrenberg's works published in the *London and Edinburgh Philosophical Magazine*. It was a translation into English of a review by Meyen (1837) of Ehrenberg's works, originally in German. It is only through such third hand reviews that Bailey knew of Ehrenberg's work. In contrast, in Europe, Ehrenberg's work had been widely known and discussed for years (e.g., Gairdner 1831) and had even begun to attract critics such as Dujardin (e.g., Dujardin 1836). Some of Ehrenberg's articles were published in entirety in English translations (e.g. Ehrenberg 1837). Bailey's 1838 article appears to be the first published in America mentioning Ehrenberg and presenting his views. Bailey ended his article stating that he had taken considerable pains to widely distribute specimens and giving a list of people, including himself, from which samples could be obtained. Thus, he ended his article saying he was going to do with his samples as Ehrenberg had, sharing them.

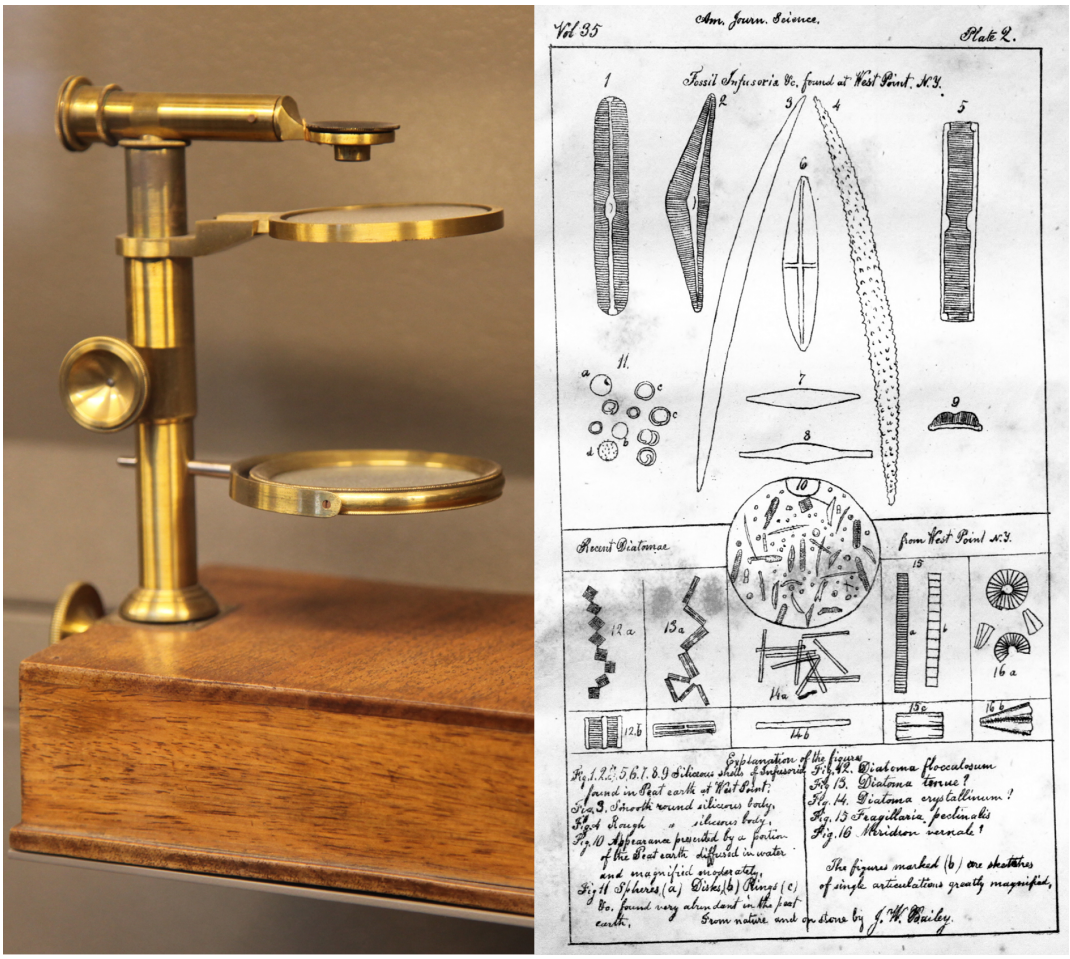

Fig. 2. Left panel: A Raspail Chemical Microscope made by Deleuil, the type of single lens microscope Bailey used to make the observations he reported in his 1838 paper. The image is of a *ca.* 1830 model in the collection of the *Conservatoire National des Arts et Métiers* (Paris). Right panel: The plate from Bailey's article. The top half shows diatom frustules from peat deposits. The central circle is a low magnification view of the peat deposit in a drop of water, and the bottom half shows living diatoms from ponds, etc. The plate is noted as a lithograph, printed from a stone drawn on by Bailey himself.

In 1841 Bailey published his first illustrations of foraminifera, found in a sample of 'Prairie Chalk' from the upper Mississippi (Bailey 1841a). He also published his first report devoted to "fossil infusoria" found in geological samples from a variety of locations in the state of Massachusetts (Bailey 1841b). In the article he mentioned that he now possessed the Chevalier microscope (shown here in fig. 1). The Chevalier microscope was a compound microscope, one of the best available at the time. However, he was still dependent on secondary sources with

regard to Ehrenberg's work. He based his identification of diatoms on the appendix of Mandl's *Traité de Microscopie* (Mandl 1839), a summary of Ehrenberg's classification scheme translated into French. Also in 1841, Bailey published a substantial article on diatoms and desmids, "Sketch of the Infusoria of the Family Bacillaria, with some account of the most interesting species which have been found in a recent or fossil state in the United States" (Bailey 1841c). The article included his own translations into English of Ehrenberg's characterizations from Mandl's book. The illustrations in the plates accompanying the article were of a much higher quality (e.g., Fig. 3) than those of Bailey's 1838 paper, likely reflecting the fact he now had a Chevalier microscope. Bailey continued his 'Sketch of Infusoria' in 1842. In the article, Bailey (1842b) states that he used Pritchard's *"History of Infusoria, Living and Fossil; Arranged According to 'Die Infusionsthierchen' of C.G. Ehrenberg*" (Pritchard 1841), a far more complete account of Ehrenberg's classifications than that in Mandl (1839), but still a second-hand account. However, by 1842 Bailey was in direct contact with Ehrenberg. He had sent Ehrenberg samples from America. Bailey reported on Ehrenberg's presentation to the "Royal Academy at Berlin" in an article entitled "Ehrenberg's Notices of American Infusoria" (Bailey 1842c). In Ehrenberg's 1843 monograph on the microscopic life of North and South America (Ehrenberg 1843), he named a new species of diatom for Bailey that he found in one of the samples, *Stauroneis baileyi*. Ehrenberg's monograph was summarized in considerable detail in an 1844 article by Bailey and Silliman which began with the laudatory sentence *"This important memoir by the illustrious Ehrenberg, is characterized like all the preceding works of the author, not only by marks of the most accurate research and indefatigible industry, but by the still higher merit of far-reaching philosophical views, and a just appreciation of the important bearings and applications of the facts which he has brought to light"* (Bailey & Silliman 1844). Thus, Ehrenberg's acolyte and ambassador to America was, in 1844, finally in possession of one of his monographs!

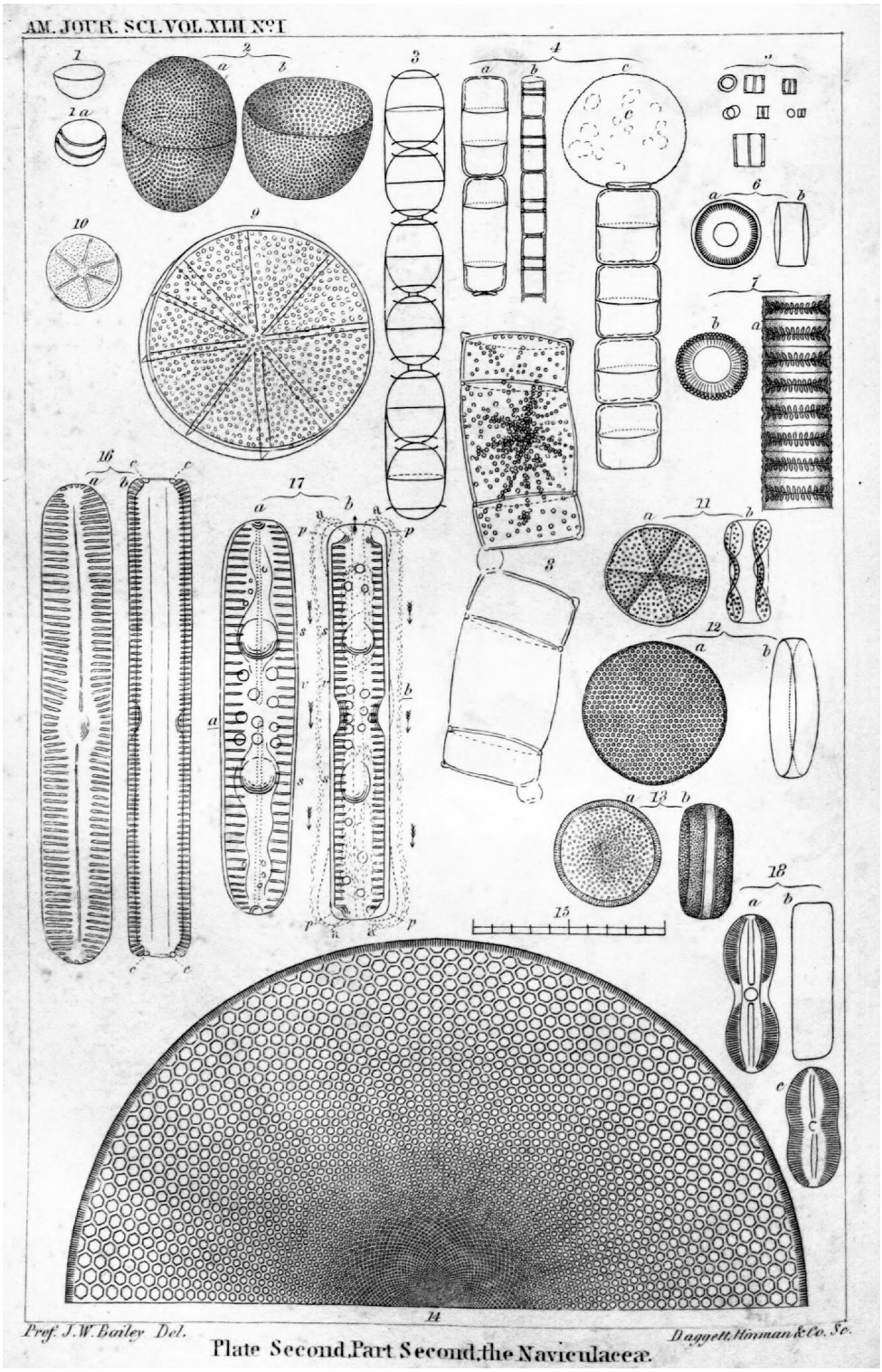

Fig. 3 One of the plates from Bailey's "Sketch of the Infusoria of the Family Bacillaria", part 1 (Bailey 1842c). Bailey used a camera lucida with his Chevalier compound microscope, a great improvement over the single lens Raspail microscope.

From the mid-1840's onward Bailey was sent samples for microscopic analysis from a wide variety of localities. At the 1843 meeting of the Association of American Geologists and Naturalists, he was given a sample of a deposit in Virginia (Bailey 1844). He received samples from the shores of a riverbank in Oregon from strata overlain by volcanic rock and found the remains of many common freshwater diatoms (Bailey 1845). A sample he received from Bermuda he found of such interest that he sent some of it to Ehrenberg along with sketches of the organisms he had found in the sample. Ehrenberg described new genera and species from the material, and for many crediting Bailey as "*the industrious American friend of microscopic research*" (der fleifsige amerikanische Freund mikroskopischer Forschung) with the first observations (Ehrenberg 1844). Bailey though also did some collecting himself. He reported on new species of desmids from ponds in the Catskill Mountains of New York (Bailey 1846). He also solicited samples from others and one sample he solicited turned out to be especially surprising.

Bailey thought that the sediments of the Mississippi River might contain fossil foraminifera washed into the river during flood events. He did not receive a sediment sample but rather a bottle of the water from a portion of the river in St. Louis used to supply drinking water for the city. The bottle had been carefully corked and by the time it reached Bailey in West Point, a full month had passed. Despite the passage of time, he found the water teeming with "*soft as well as siliceous-shelled infusoria*" (Bailey 1848a). He found, "in great abundance" species of *Coleps, Euglena, Fragillaria, Gallionella, Micrasterias, Navicula, Oxytricha, Stylonchia and Synedra*. One species, the diatom *Surirella campylodiscus*, was unknown at the time from the eastern United States, but had been described by Ehrenberg from Mexican material. Among Bailey's conclusions was: *"The inhabitants of St. Louis consider the water which they drink as remarkably wholesome, and so are surprised that strangers wish to have it filtered for their use. Whatever its effect on health may be, it is certain that it contains a sufficient amount of animal matter to be somewhat nutritious*." Bailey's description of the diversity of microorganisms found in the drinking water of St.

Louis thus predated Arthur Hassall's famous "Microscopic Examination of the Water Supplied to the Inhabitants of London" (Hassall 1850).

It was also in 1848 that Bailey received the visit of Charles Spencer, one of the first manufacturers of microscopes in America. Spencer, when shown the Chevalier 'achromatic' microscope in 1847, remarked that he thought he could make a better microscope. He had been making achromatic lenses for telescopes. Chromatic aberration, in which different portions of the light spectrum have different focal lengths, producing a blurred image, was a problem plaguing early microscope makers. The Chevalier was equipped with objectives described as achromatic but in reality there was significant aberration at high magnifications. (see https://golubcollection.berkeley.edu/optics/example_microscopes/167/opt167.html).

With his new objective, Spencer first visited Bailey in West Point as the authority on microscopy. Spencer knew that Bailey had slides with the diatom *Navicula hippocampus* as a microscope test object and wanted to have his new objective evaluated by Bailey using the diatom and most importantly, see how it compared to the Chevalier objectives. Bailey, in a letter published by the physician who had first shown the Chevalier microscope to Spencer, formally declared it to be far superior to the Chevalier, able to resolve structures on diatom frustules he had not previously seen (Gilman 1848). Bailey himself published an article describing the superiority of Spencer's objectives and proposing a new test object, *Navicula spenceri*, named by Bailey for Spencer, whose fine features were only discernable using Spencer's objective (Bailey 1848b). There followed a considerable polemic with English microscopists. They were incredulous that, in their words, a "*Yankee back-woodsman*" had made a superior objective (Bailey 1849). The arguments continued for some time. It became clear that using a slightly oblique illumination, rather than perfectly centered under the objective, was necessary to achieve maximum resolution with the wide aperture Spencer lens (Balley 1851a). Bailey specifically mentioned his use of the Spencer objective "*a new one of surpassing excellence*" in making sketches with a camera lucida of a new genus of rhizopods, *Pamphagus*, found in aquaria at West Point (Bailey 1853). Bailey was then very much a champion of Spencer's microscopes,

easily available and far cheaper than European microscopes. Consequently, in accounts of the history of microscopy in America, Bailey is generally given a key role (e.g., Gage 1964; Padgitt 1975).

Bailey became well known internationally by the 1850's. His studies of diatoms and microscope devices and test objects during the 1850's, published for the most part in the *American Journal of Science and Arts* and the *Smithsonian Contributions to Science* in America, were reproduced in entirety or summarized regularly in major journals in the United Kingdom such as the *Edinburgh New Philosophical Journal*, *Annals and Magazine of Natural History*, and the *Quarterly Journal of Microscopical Science* (see the 1997 Bailey bibliography of Edgar). However, Bailey's real claim to fame is his studies of microorganisms from deep sea soundings. The 1850's was the period when the first explorations of the deep sea were begun in preparation for laying telegraph cables as knowledge of the character of the deep sea bed was of importance. New sounding devices had been invented that allowed retrieval of superficial sediments and samples were sent to Bailey for microscopical analysis.

The first set of samples Bailey examined were from the coast of the South East United States, from depths ranging from 50 to 200 m. He found a surprising diversity of organisms (Fig. 4). Bailey reported that the material from depths between 100 to 200 m contained "*a truly wonderful development of minute organic forms, consisting chiefly of the Polythalamia*" (foraminifera). Bailey's complete results were published in the *Smithsonian Contributions to Knowledge* (Bailey 1851b) and summaries were published in the *American Journal of Science and Arts* (Bailey 1851c) as well as twice in the *Edinburgh New Philosophical Journal* (Bailey 1851d, 1852).

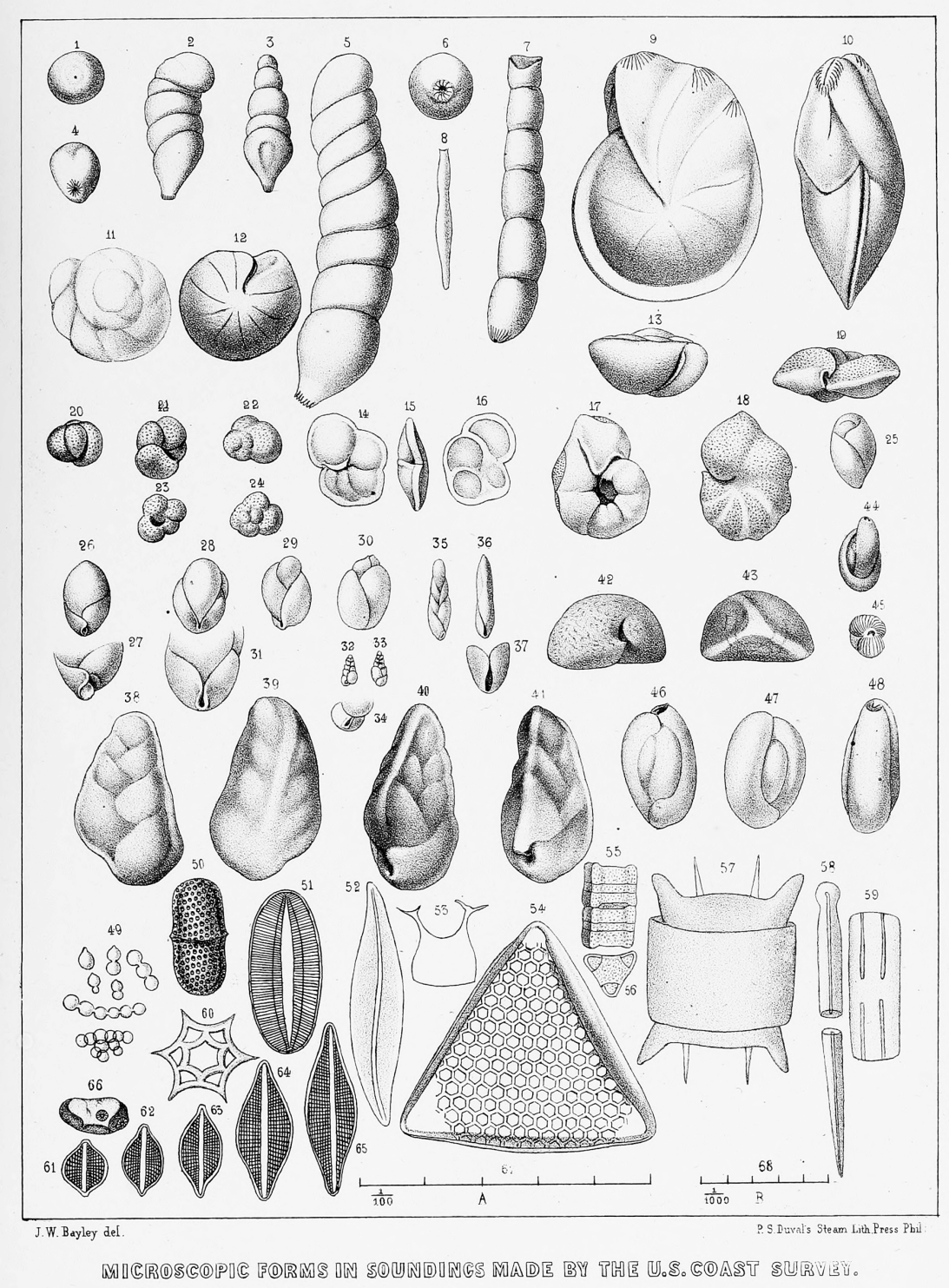

Fig. 4. From Baily 1851b showing the diversity of organisms found in sounding material from depths of 25 to 200 m off the South East coast of the United States. Note the dominance of large benthic foraminifera.

In 1854 Bailey reported on his examination of material from soundings in the North Atlantic Ocean obtained in July and August 1853, from sites ranging in depth from 2,000-4,000 m. In Bailey's words, the samples were "*the deepest ever submitted to microscopic examination*" (Bailey 1854). He found the material to be composed almost entirely of the shells of foraminfera, largely *Globigerina*, with a few skeletons of radiolaria, silicoflagellates and some diatoms. These results, in combination with those from his previous report (Bailey 1851a) led him to declare that the bottom of the North Atlantic Ocean, in sites ranging in depth between 200 and 4000 m, is covered by a mass of microscopic shells. His findings were described as "*astounding*" (Anon. 1855). Bailey also failed to find any foraminifera in water samples taken in surface waters leading him to pose the question of their origin: "*Do they live on the bottom at the immense depths where they are found or are they borne by submarine currents from their real habitat?*" At that time it was not realized that planktonic foraminifera are basically undetectable in seawater bottle samples due to their low abundances. A debate soon emerged as to the origin of the deep water foraminferal ooze (Rozwadowski 2001). Joining Ehrenberg were Thomas Huxley and George Wallich in the opinion that *Globigerina* lived on the deep sea bed. Bailey did not publicly dispute the view of Ehrenberg but in a private letter written in November of 1853 to M.F. Maury of the United States Naval Observatory (who had sent the samples to Bailey,) doubted that *Globigerina* was a deep sea benthic form. In Bailey's words: "*It is not probable that these animals lived at the depths where these shells are found, but I rather think that they inhabit the waters near the surface; and when they die, their shells settle to the bottom*" (Bailey's letter (pg 210-211 in Maury 1855).

The debate concerning the origin of the foraminferal ooze and nature of the microscopic life on the deep sea bed was eventually mixed up with debates on *Bathybius* and primordial life forms (e.g. Rehbock 1975; Rice et al. 1976). However, as Bailey passed away in 1857, he was not an active participant in any of the debates. Curiously, in some accounts, Bailey is stated to having taken a position, to having sided with Ehrenberg (e.g. Mills 1983) and in others to have

said that *Globigerina* lived at intermediate depths with its shells simply having sedimented (Wyville Thomson 1873).

Jacob Bailey's last major publication was his examination of sounding material from the Bering Sea near the Kamchatka Peninsula. He first published a brief report, a copy of a letter sent to Maury, who had asked Bailey to examine the samples from depths of 1,800 - 5,400 m. In the letter Bailey found the samples to be *"... **very** (italics in original) rich in the siliceous shells of diatomaceae which are in an admirable state of preservation- frequently with the valves united and even retaining the remains of the soft parts*." (Bailey 1856a). Notably, Bailey stated that he doubted the diatoms lived at such depths, but were rather transported from shallower depths, a correct opinion disputed as late as the 1880's (e.g., Smith 1880). Bailey was also still paying tribute to Ehrenberg as he stated that the microorganisms, in their species richness at high Northern latitudes, resembled the findings of Ehrenberg concerning the species richness of the deep waters of Antarctica. Shortly after, a full report was published (Bailey 1856b) containing descriptions of many new species and with a striking plate (Fig. 5). Bailey's report was cited extensively in Haeckel's first monograph on the radiolaria and Bailey was credited with several original descriptions (Haeckel 1862) as well as in his Challenger Reports on the radiolaria (Haeckel 1887). One of the forms Bailey described as new to science he named *Cadium marinum*, noting it as "Infusoria, Rhizopoda?" Curiously, it was not mentioned by Haeckel in his first monograph on Radiolaria nor in his Challenger report. It is today credited as the first phaeodarian species described (Nakamura & Suzuki 2015). Long after Bailey's death, Ehrenberg re-named the species for him as *Difflugia baileyi* (Ehrenberg 1872). Apparently then, neither Ehrenbergh nor Haeckel recognized it as a phaeodarian. Only Wallich (1869) had correctly placed it among the radiolaria of that time (Bütschli 1800-1882). It is now known as *Lirella baileyi*, renamed by Loeblich and Tappan (1961). Bailey's slides in the J.W. Bailey Collection at the Farlow Herbarium of Harvard University were used to identify type specimens of several radiolarian species he described (including the form now known as *Lirella baileyi* but as *Cadium marinum*) a full 150 years after his report appeared (Itaki & Bjørklund 2006).

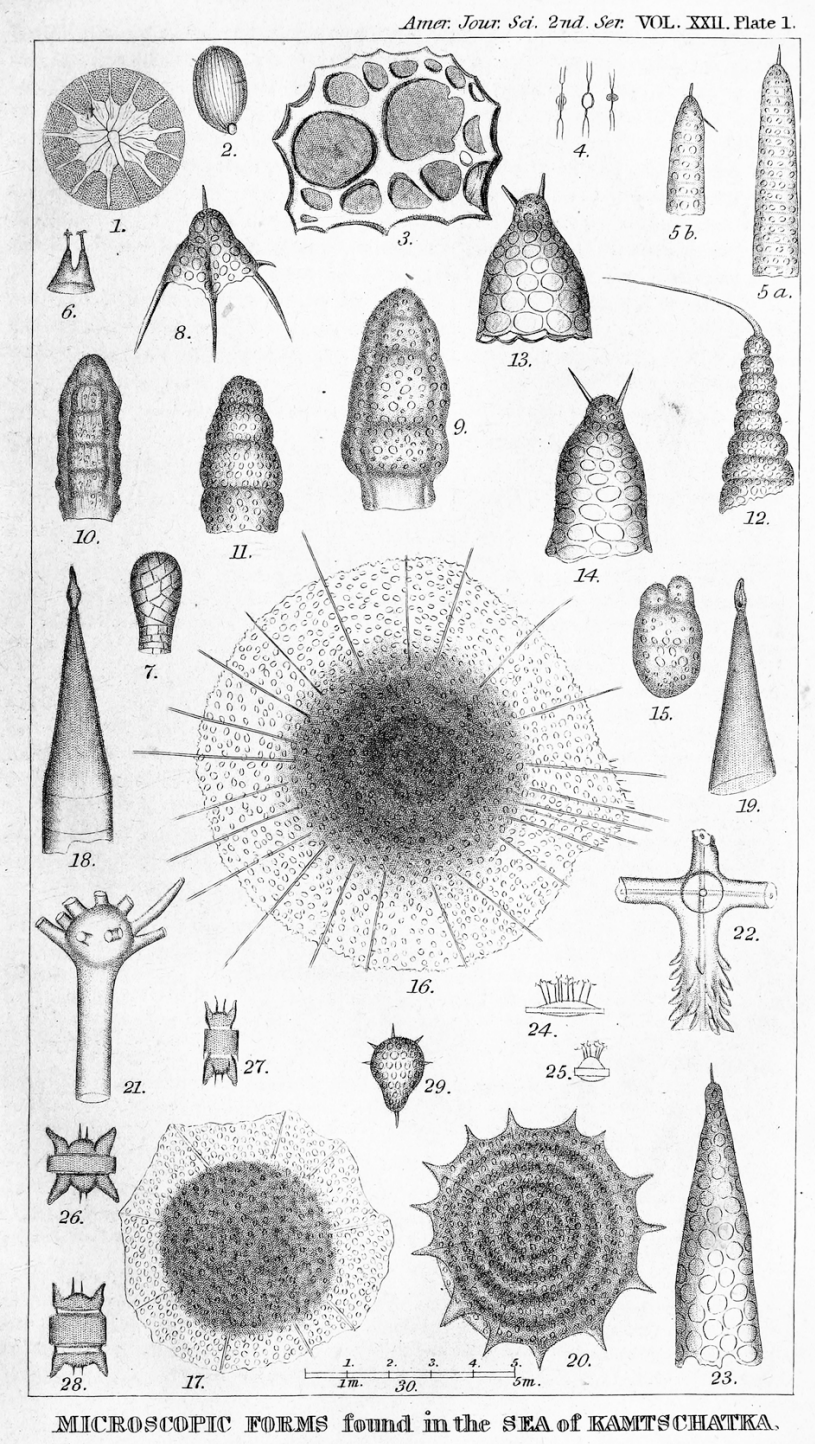

Fig. 5. The plate illustrating new forms Bailey found in soundings from deep water sites near the Kamchatka peninsula (Bering Sea). In the plate the figure 2 is the species he named *Cadium marinum*, now known as *Lirella baileyi*, with Bailey credited as having described the first phaeodarian (Nakamura & Suzuki 2015).

Conclusion

Jacob Whitman Bailey worked in an America where microscopes and scientific literature were nearly unavailable. Despite such handicaps, during his short life, he made major contributions to protistology. He described many new taxa of diatoms, foraminifera and radiolaria (A list of the 37 protist species currently credited to Bailey according to WoRMS is supplied as a supplementary file). He made significant discoveries with regard to the deep sea, promoted microscopy and introduced the work of Ehrenberg in America. While missing from histories of protistology, Bailey is featured in histories of oceanography, ironically, because of his work on deep sea protists (e.g. Rozwadowski, 2005; Schlee 1973). Hopefully this essay has served to place Jacob Bailey among the pioneers of protistology.

Supplementary File Information

An Excel file listing the species of protists whose first description is credited to Jacob Whitman Bailey according to the World Register of Marine Species (WoRMS) is supplied. The file was generated by first extracting species names associated with Bailey as the taxonomic authority and the status as "accepted". The file was then edited to remove non-protist taxa and also extraneous data columns. It is supplied as "WoRMS_Bailey_Protist_taxa_Jun5_2022.xls".

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