Masters of tidology: The cultivation of the physical sciences in early Victorian Liverpool

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> In the first place, pray do not omit to mention what the Liverpool people, the members of the Athenaeum and the Corporation, have done for Tidology; I do not see that any of the public prints have noticed it. I gave you a written memorandum about it.[1]

William Whewell, Master of Trinity College, Cambridge from 1841 to 1866 and a central figure in Victorian science, goes to great pains in the above quotation to solicit Henry Phillips, the secretary of the newly-formed British Association for the Advancement of Science, to note in print the contributions of Liverpool to his investigation of the tides. To an historian of early Victorian England, this may seem quite odd. Liverpool was not known for its science during this period. Indeed, in an age of unprecedented specialisation in the sciences, it was known for quite the opposite.

Whewell was perhaps the premier evaluator and definer of science during the early Victorian era, and a zealous coiner of new terms.[2] He had coined the word 'scientist' a year earlier in 1833, consciously narrowing the group of practitioners that could legitimately participate in the new endeavour. Whewell overtly excluded theology,

[1] William Whewell to Henry Phillips, 7 Oct. 1834, British Association for the Advancement of Science, Phillips Correspondence, Bodleian Library, Oxford.

[2] Richard Yeo, *Defining science: William Whewell, natural knowledge, and public debate in early Victorian Britain* (Cambridge, 1993); Jack Morrell, 'The judge and purifier of all', *History of Science*, 30 (1992), pp. 97–114; Joan Richards, 'Observing science in early Victorian England: Recent scholarship on William Whewell', *Perspectives on Science*, 4 (1996), pp. 231–47.

economy, and the moral sciences, and helped move science away from the gentlemanly amateur and toward the devoted professional.[3] His introduction of the new term also suggested a hierarchy of the sciences. Whewell confidently and consistently portrayed astronomy as the 'queen of sciences,' the only perfect science. The closer other subjects approached the *methods* of astronomy, the more 'scientific' they became. As Sydney Ross has noted, 'science and the scientists grew out of the physical sciences'.[4]

Whewell fits squarely into a broader movement in the early Victorian era in his attempt to define science, its practice, and its practitioners. Yet, it is difficult to see where Liverpool fits into this movement. From the founding of the School of Tropical Medicine, Liverpool's history in science has been associated more with medicine than with the physical sciences.[5] Moreover, as historians have noted, Liverpool went through a *cultural* transformation in the first half of the nineteenth century, but without—and even in direct reaction against—a systematic cultivation of the natural sciences.[6] As the Literary and Philosophical Societies ('Lit and Phils') of northern cities such as Manchester, Birmingham, Leeds, and Newcastle all began to focus heavily on the natural sciences—on the 'Phil' rather than the 'Lit'—only Liverpool leaned steadfastly the other way.

William Roscoe is undoubtedly responsible for the more general and literary focus of the Liverpool Lit and Phil. President of the Society from 1817 to 1831, Roscoe was a classicist, not a scientist. E. A. Bryant, a past-president of the Society, referred to this period in the Society's history as the 'golden age of Roscoe', where literary conversation accompanied by porter and oysters established a mode of procedure that endured well into the nineteenth century. 'Perhaps

[3] Robert K. Merton, 'De gendering man of science: The genesis and epicene character of the word "scientist"', in Kai Erikson, ed., *Sociological visions* (Lanham, Maryland, 1997), pp. 225–53.

[4] Sydney Ross, 'Scientist: The story of a word', *Annals of Science*, 18, no. 2 (1962), pp. 65–85.

[5] Helen J. Power, *Tropical medicine in the 20th century: A history of the Liverpool School of Tropical Medicine, 1898–1990* (London, 1999).

[6] Guy Kitteringham, 'Science in provincial society: The case of Liverpool in the early nineteenth century', *Annals of Science*, 39 (1982), pp. 329–48; Arline Wilson, 'The cultural identity of Liverpool, 1790–1850: The early learned societies', *Transactions of the Historic Society of Lancashire and Cheshire (THSLC)*, 147 (1997), pp. 55–80.

we may trace to Roscoe personally,' reflected Bryant, 'the influence that led to a first predominance of literary and general subjects in the society's programmes'.[7] Guy Kitteringham has argued that the 'majority of Liverpool's higher classes attached no especial importance to science; for them it was merely a part of a general intellectual and literary culture'.[8] The gentlemen of Liverpool, Arline Wilson more recently concurred, 'chose to make their bid for legitimacy through a general and intellectual culture' that focused heavily on literature and the arts.[9] Thus, Liverpool not only failed to cultivate the physical sciences; it also played no role in their definition or their specialisation.

In this paper, I will suggest that we historians have been looking in the wrong place. This has been partly owing to the ultimately successful definition of the 'scientist' offered by the Victorians themselves (such as Whewell), and partly owing to the preoccupation of present-day historians on great men (such as Roscoe) and great institutions (such as the Liverpool Lit and Phil). Liverpool did indeed go through a cultural renaissance in the first half of the nineteenth century, but it was not solely general and literary. Liverpool was directly and innovatively involved in a particularly prominent type of science practised in the early Victorian era: long term, large scale projects in what today we would call physical oceanography, what contemporaries would have termed either physical astronomy or nautical science. The 'cult of individuality' has, however, masked the participation of the lesser sorts—the harbour masters and dock yard engineers, the tide table makers and Admiralty surveyors—those figures who actively participated in physical astronomy in Liverpool but were pushed out by the defining process taking place in Cambridge and London in the first quarter of the nineteenth century. An approach that examines the involvement of these lesser sorts as part of the larger scientific *process* will link the practice of science in Liverpool to the commercial and maritime interests of the port, and more fully demonstrate the wide and varied participation in science that ultimately represents early Victorian natural science.

[7] E. A. Bryant, 'The Lit and Phil—A retrospective', a handwritten monograph in Liverpool Record Office (Liv. RO) Hq 1021: 'Papers, chiefly on psychology, delivered to the Literary and Philosophical Society of Liverpool on 22 March 1937'.

[8] Kitteringham, 'Science in provincial society', p. 348.

[9] Wilson, 'Cultural identity,' p. 65.

Liverpool was a commercial town rising steadily in the eighteenth and early nineteenth centuries. Absorbed, as an early observer noted, in a 'nautical vortex', the science practised was linked directly to that part of early nineteenth-century Liverpool that represented the lifeblood of the city: its port.[10] As a port, it continuously confronted one of the major difficulties of any commercial city on Britain's west coast: exceedingly high tides. Whether wealthy or a worker, most people in Liverpool were concerned with the ebb and flow of the sea, and a few excelled in what was one of Whewell's less successful coinages. These people of Liverpool were masters of 'tidology'.

The national context

During the last quarter of the eighteenth century and the first quarter of the nineteenth century, natural history, especially botany, rose to become the premier science in Britain and its possessions. Joseph Banks, President of the Royal Society of London for over forty years from 1778 to 1820, incessantly fostered its promotion.[11] Although natural history continued to rise in popularity throughout the nineteenth century, there also developed an increasing interest in subjects pertaining to the physics of the earth. This included terrestrial magnetism, oceanic tides and currents, meteorology, and other physical sciences of immediate practical value to the field of navigation. Susan Faye Cannon termed this change in focus to the geophysical sciences 'Humboldtian science', in honour of the polymath, world traveller, and influential statesman, Alexander von Humboldt.[12] Humboldtian science relied on simultaneous observations made across wide areas of the earth's

[10] As quoted in M. J. Power, 'The growth of Liverpool', in John Belchem, ed., *Popular politics, riot and labour: Essays in Liverpool history 1790–1940* (Liverpool, 1992), p. 21.

[11] David Philip Miller, 'Between hostile camps: Sir Humphry Davy's presidency of the Royal Society of London, 1820–1827', *British Journal for the History of Science*, 16 (1983), p. 3; also David Philip Miller, 'Sir Joseph Banks: An historiographical perspective', *History of Science*, 19 (1981), pp. 284–92; D. L. Mackay, 'A presiding genius of exploration: Banks, Cook and empire 1767–1805', in R. Fischer & H. Johnston, eds, *Captain James Cook and his times* (London, 1979), pp. 21–39. For the rise and continued popularity of natural history, see N. Jardine, J. A. Secord & E. C. Spary, eds, *Cultures of Natural History* (Cambridge, 1996).

[12] Susan Faye Cannon, *Science and culture: The early Victorian period* (New York, 1978).

surface over long periods of time.[13] It was a defining feature and a particularly prominent type of science practised in the early Victorian era. As David Phillip Miller has argued, 'participation in an ongoing train of research of this type became increasingly the hallmark of the serious scientific investigator'.[14]

Because Humboldtian initiatives were usually centred in London or Cambridge, early histories viewed this type of science through a 'centre-periphery' model. All too often, the periphery was subordinate to the centre and merely offered the observational data needed by the scientists back in London.[15] In recent decades, however, the centre-periphery model has come under increasing scrutiny.[16] More sophisticated approaches now view the complexity of the exchange of information between the centre and periphery as unidirectional rather than diffusionist. Not only did investigations in the periphery advance the science at the centre (as this case study will demonstrate), but different peripheral areas exchanged information without the intermediary of the centre.

As Humboldtian studies prospered in the second quarter of the nineteenth century, the study of the tides was one of the first research frontiers. In 1830, John William Lubbock, a London banker and Cambridge graduate, resurrected the theoretical study of the tides in Britain from over a century of relative neglect. His chosen method of analysis required long-term observations of the tides. His first break came in the form of a letter from Isaac Solly, the Chairman of London Dock, who informed Lubbock that records of the tides had been kept at London Dock since its opening in 1805. Twenty-five years of continuous observations, night and day, had been registered—just the observational data Lubbock needed to compute the mathematical laws of the tides for the port of London.

Lubbock's initial success suggested to him that he could find a general theory to predict the tides for all of the ports in Britain. The same conclusion was reached by William Whewell, Lubbock's former

[13] John Cawood, 'Terrestrial magnetism and the development of international collaboration in the early nineteenth century', *Annals of Science*, 34 (1977), p. 576.

[14] David Philip Miller, 'The revival of the physical sciences in Britain, 1815–1840', *Osiris*, 2 (1986), p. 124.

[15] See, for example, Nathan Reingold & Marc Rothenberg, eds, *Scientific colonialism: A cross-cultural comparison* (Washington, D.C., 1987).

[16] For a full account of these advances, see Roy Macleod, ed., *Nature and empire: Science and the colonial enterprise*, *Osiris*, 15 (2000).

tutor at Trinity College, Cambridge. Whewell entered tidology in 1833, and like Lubbock, began with the tides in the River Thames. Using the same London Dock observations, Whewell ascertained the effects of the parallax and declination of the moon and sun on the tides.[17] He accomplished this for only one port, however, a port admittedly peculiar in its tidal action, located miles up the Thames. Philosophically and methodologically, this would not do.

Along with the desire to find other long-term observations of the tides to compare with those at London Dock, Whewell's interests also turned to short-term observations to determine the more general problem of the tides as they progressed in the oceans. With the help of the British Admiralty, especially Sir Francis Beaufort the Hydrographer to the Admiralty, Whewell eventually set up a 'great tide experiment' in 1835 where the time and height of the tides were measured every fifteen minutes for a fortnight in over nine countries and their possessions. Over 650 tidal stations participated, including over 300 stations in England and Scotland, and over 200 stations in Ireland. This was a prototypical Humboldtian venture. Owing to their reputation and connections, Whewell and Lubbock resurrected the study of the tides as a worthy research frontier. They made tidology a hot topic. It is within this national context of tidal studies that we may now turn to the local context in Liverpool.

The local context

At the local level in Liverpool, the emphasis on the study of the tides was more immediate and useful. Tidal studies could indeed contribute to the science of physical astronomy, but more importantly, as maritime commerce increasingly defined the ever-expanding city, such studies could also advance the commerce and thus the prosperity of the town. As Thomas Baines, author of the *History of the commerce and town of Liverpool*, proudly boasted in 1852, 'the commerce of Liverpool extends to every port of any importance in every quarter of the globe'.[18] Its prosperity was directly related to

[17] William Whewell, 'On the empirical laws of the tides in the Port of London', *Philosophical Transactions of the Royal Society of London* (hereafter *Philosophical Transactions*), 124 (1834), pp. 15–46.

[18] As quoted in John Belchem, 'Liverpool in 1848: Image, identity and issues', *THSLC*, 147 (1997), pp. 1–26, p. 2.

its geographical position. The port's easy approach from the manufactures in the interior of northern England, along with its direct access to the Atlantic, made it the principal seat of commerce with both Ireland and the New World.[19]

During the late eighteenth century, Liverpool overtook Bristol as the leading port on England's west coast.[20] As Michael Power suggested, the charter granted to Liverpool in 1695 provided an early boost. 'It established a council which actively promoted political, ecclesiastical, and economic improvements, and is notable for building a pioneering wet dock'.[21] In the second half of the eighteenth century, while those responsible in Bristol—the Society of Merchant Venturers and the Corporation of Bristol—were slow to act, the Liverpool Corporation invested large sums of money in the development and maintenance of its port. Such innovative economic and engineering foresight established Liverpool as the most important port in England second only to London.[22]

Owing to the extreme difficulties of navigating its approaches, historians have noted Liverpool's geographical position and heavy investment in its docks as essential to its ascendancy in the eighteenth and nineteenth centuries. As early as 1682, King Charles II had his hydrographer Captain Greville Collins survey the coasts and channels of Liverpool. Collins's survey of the Dee and Mersey highlighted the obstacles to shipping caused by the tides. Indeed, at that time, Liverpool was almost inaccessible. The Formby Channel was not buoyed while the Rock Channel was dry at low water, causing 'ships [to] lie aground before the town of Liverpool'.[23] These problems persisted well into the nineteenth century. Graham

[19] Thomas Baines, *History of the commerce and town of Liverpool, and of the rise of manufacturing industry in the adjoining counties* (London, 1852), p. 749.

[20] W. E. Minchinton, ed., *The growth of English overseas trade in the seventeenth and eighteenth centuries* (London, 1969), p. ix; Kenneth Morgan, 'Bristol and the Atlantic trade in the eighteenth century', *English Historical Review*, no. 424 (1992), p. 626.

[21] Michael Power, 'Creating a port: Liverpool 1695–1715', *THSLC*, 149 (2000), pp. 51–72, p. 51.

[22] Power, 'The growth of Liverpool'.

[23] As quoted in Jos. Brooks Yates, 'Memoir on the rapid and extensive changes which have taken place at the entrance to the river Mersey, and the means now adopted for establishing an easy and direct access for vessels resorting thereto,' an 'Appendix' to William Williams Mortimer, *The history of the Hundred of Wirral, with a sketch of the city and county of Chester* (London, 1847), p. 25.

H. Hills, staff-commander in the Royal Navy and marine surveyor in Liverpool, noted that 'the harbours are for the most part tidal harbours, suited only to small craft, and that throughout these coasts there is a remarkable deficiency of harbours accessible at all times of tide'.[24] Joseph Yates had acknowledged similar detriments to navigation in the early Victorian era. 'The intricacy of the access to the River Mersey is well known,' Yates acknowledged. 'It arises from the accumulation, outside of its embouchure, of numerous beds of sand, which are frequently, and suddenly, changing their position and elevation, to the great horror and confusion of navigation'.[25]

Technological innovations in shipbuilding only added to the 'horror and confusion'. In May 1815, steam navigation was first introduced on the Mersey, and by 1837, so many steamers were using the port of Liverpool that two docks were appropriated exclusively for the use of steam vessels.[26] The first steamer to cross the Atlantic from Liverpool was the *Royal William* in 1838, only a short time after the *Great Western* made the first all-steam powered voyage from England to New York. The much larger class of ship occasioned by steam and the use of iron in steamers' hulls further limited coastal and river navigation and made the approaches to the Liverpool docks all the more treacherous. Moreover, the enormous number of vessels using the port grew steadily. By 1830, over 11,000 vessels were navigating the Mersey each year, two-thirds of them during high water hours.[27] The approaches were a jumbled mass of confusion, as vessels large and small vied for position to dock and unload their wares during the few hours of high tide.

The sheer number of vessels, their expanding size and weight, and the ultimate importance of their trade to the city of Liverpool, made the city not only a 'nautical vortex,' but a nautical vortex that ebbed and flowed twice a day. Understanding and thereby harnessing that twice-daily ebb and flow required the industry and talent of many of those who made their livelihood through the port. These included

[24] Graham H. Hills, *Navigation of the approaches to Liverpool, with some account of the tides, currents, & soundings of the Irish Sea, with a chart of Liverpool Bay* (5th edn, Liverpool, 1871).

[25] Yates, 'Memoir'.

[26] Baines, *History of the commerce and town of Liverpool*, pp. 558, 640.

[27] J. F. Smith, Gordon Hemm & Alderman A. Ernest Shennan, *Liverpool, past, present, future* (Liverpool, 1948), p. 8.

harbour-masters and tide table calculators, dockyard engineers and Admiralty surveyors. They studied the tides not necessarily for the benefit of science, but because their jobs and livelihood demanded it. They were practical men and contributed to the knowledge of the tides in spite of and often in defiance to the natural philosophers—the newly-defined 'scientists'—at the centre. Even before the scientists in London and Cambridge resurrected the theoretical study of the tides in the early 1830s, Liverpool had become a centre of tidal study and analysis.

Liverpool's tidologists

Liverpool possessed a forgotten history of tidal studies begun in the late eighteenth century that was not 'rediscovered' until the first meeting of the British Association for the Advancement of Science in 1831. The rediscovery was indirect, however, as neither tidology nor the Liverpool Lit and Phil was represented directly at this inaugural meeting. The organisers of the British Association seemed to have overlooked the burgeoning city. As the physician James Hunter Lane of Liverpool lamented, 'no communication [had] been had with any of the institutions' of Liverpool.[28] Likewise, in the flourishing field of tidology, neither Lubbock nor Whewell attended the meeting. From this first gathering of natural philosophers, however, an important development occurred that would quickly advance both tidology and Liverpool in the eyes of science.

During the meeting, William Scoresby, an initial and active member of the British Association, informed Vernon Harcourt, the President of the Association, that very accurate observations of the tides existed for the port of Liverpool that spanned the last thirty years of the eighteenth century. Harcourt immediately forwarded this news to Lubbock who was just beginning his theoretical studies of the tides. Lubbock was extremely anxious to receive further information concerning the observations, information that soon came from the pen of James David Forbes. Forbes could not give specifics, but did intimate to Lubbock that he and Scoresby were having some difficulty procuring the observations.[29] They were

[28] As quoted in Jack Morrell & Arnold Thackray, *Gentlemen of science: Early years of the British Association for the Advancement of Science* (Oxford, 1981), p. 67.

[29] J. D. Forbes to John William Lubbock, 21 Nov. 1831, John William Lubbock Papers, Royal Society of London (hereafter Lubbock papers), F91.

housed in the Athenaeum Library and could not be removed, consistent with the policy of the Athenaeum of not allowing any book or manuscript to leave its library.

Though both Forbes and Scoresby were distinguished gentlemen of science, the Athenaeum was still reticent to lend the manuscript. This disgusted Lubbock, who thought 'the Liverpool people ought to entrust them to us without putting us to the expense of having them copied, they must know that they would be in safe hands'.[30] William Whewell was a bit more understanding—and proactive. He suggested to Lubbock that one of their hired calculators, Joseph Foss Dessiou at the Admiralty Hydrographic Office, be sent up to Liverpool. 'Indeed I think it is well worth your ascertaining whether you might not take Mrs. Lubbock to Liverpool,' prodded Whewell. 'It is quite as good a sight as Birmingham . . . [and] you might see the rail-way and travel along it to Manchester'.[31]

Lubbock had little time or interest in travelling to Liverpool, and after months of inaction, Whewell suggested that they make personal appeals to the Athenaeum through Joseph Yates, a central figure in Liverpool's scientific culture. 'He has taken a great deal of interest and a great deal of trouble about the business from the first,' Whewell noted, 'and would, I think, urge our request as well as he could'.[32] Meanwhile, Lubbock concluded that only through the strong arm of the British Association would anything get done, and requested that the Association demand the document 'in the most urgent manner'.[33] Separate solicitations were made by Whewell and Lubbock, and an additional request was sent in the name of the British Association (also in the hand of Lubbock), all going through their local emissary, Joseph Yates. This finally produced the desired results. Yates had a key to a box holding the manuscript sent to Joseph Dessiou at the Hydrographic Office, followed the next day by the actual manuscript itself.[34] Whewell felt the manuscript to be so important that he wrote personally to Francis Beaufort, the Hydrographer to the Admiralty, asking him to 'take charge of the above article . . . to which the owners at Liverpool attach such great

[30] Lubbock to Whewell, 7 Jul. 1833, William Whewell Papers, Trinity College Cambridge (hereafter Whewell papers), R.6.20/214.

[31] Whewell to Lubbock, 27 Jul. 1833, Lubbock papers, W272.

[32] Whewell to Lubbock, 13 Oct. 1833, Lubbock papers, W275.

[33] 18 Oct. 1833, Lubbock papers, L440, outgoing letters.

[34] Yates to Dessiou, Nov 1833, Lubbock papers, Y5.

value'.[35] Whewell also requested that Beaufort respond personally to the Athenaeum. 'I consider these papers as very valuable independent of any extrinsic value which the owners might sign to them, and the loan of them a fortunate circumstance for the progress of our knowledge of the tides'.

The 'very valuable' tidal observations that had lain unused for over forty years, and that had taken over two years to acquire, were those made by William Hutchinson. Hutchinson was a merchant navy man who worked his way up from cabin boy to one of the leading privateers, alongside Fortunatus Wright, in late eighteenth-century Liverpool. He was appointed dockmaster of the Liverpool Docks in 1759, a position he held for forty years. The dockmaster was responsible for the overall operation of the dock, especially the safe passage of ships in and out of the port, including the approaches to the locks, docks, and bridges.[36] As dockmaster, therefore, Hutchinson took an interest in everything to do with the safety of the port. And this, in turn, led him to an interest in all scientific subjects pertaining to the sea. As Philip Woodworth has aptly demonstrated, Hutchinson was on friendly terms with several astronomers and mathematicians then resident in Liverpool, and revelled in the enlightened spirit of the burgeoning town.[37] He was the inventor of reflecting mirrors for lighthouses, erecting the first one of its kind at Bidston in 1763. He also experimented with lifeboats, artificial respiration, and performed intricate experiments with miniature ships to determine their centre of gravity as part of a more elaborate study of scientific shipbuilding.[38] His work went far beyond his official duties as dockmaster and demonstrates that his own interests were both practical and scientific, a distinction certainly not made by Hutchinson and others at the time.

[35] Whewell to Beaufort, 15 Nov. 1833, Sir Francis Beaufort Papers, Royal Hydrographic Office, Taunton (hereafter Beaufort papers) misc file no. 23, folder no. 6.

[36] Alan Johnson, *Working the tides: Gatemen and masters on the River Mersey* (Docklands History Project, 1988), p. 7

[37] Phillip Woodworth, 'Three Georges and one Richard Holden: The Liverpool tide table makers', *THSLC*, 151 (2002), pp. 19–52, pp. 23–24.

[38] Gomer Williams, *History of the Liverpool privateers and letters of marque, with an account of the Liverpool slave trade* (London, 1897), p. 144; Editor's introduction, Philip L. Woodworth, ed., *The journals of William Hutchinson*, (Wakefield, 2000), microfilm, copy in Liv. RO.

As dockmaster in a dangerous port, he also was in a good position to witness many shipwrecks owing to the 'common method' the seafarer used to ascertain the tides. He had personally experienced 'very narrow escapes, both in America, and on our own coasts' through the use of these outdated methods. Hutchinson, therefore, focussed at length on the practice of sailing with regard to the extreme tides in Britain in his *Treatise on practical seamanship* first published in 1777. One is struck by the seemingly incomparable difficulties in navigating the coasts of Great Britain. Hutchinson warned that 'every prudent diligent officer, should endeavour to get all the help he can come at from tide tables, books, charts &c, to make himself as well acquainted as possible with the tides, and should take all favourable opportunities to try and remark their ebbing and flowing'.[39] This was all the mariner could do, but it was usually not enough. The 'tables, books, and charts' were based on the 'common method' Hutchinson had just warned against.

With these dangers in mind, Hutchinson began taking readings of the tides in 1768, a register that he faithfully kept until 1793, or 'twenty-five years, seven months and ten days'.[40] Whewell was especially anxious to have Hutchinson's Liverpool observations discussed (what we would term 'reduced'). Whewell had earlier established certain mathematical formula for the tides for a single port, London, and wanted to use the Liverpool observations for 'testing and improving the formulae to which I was led by the London observations'.[41] He turned to the British Association for help.

As the numbers attending the meetings reached into the thousands within only a few years, the British Association found itself embarrassingly prosperous. Under Whewell's recommendation, the Association began offering research grants to be allocated to indi-

[39] William Hutchinson, *A treatise on practical seamanship* (London, 1777, new edn 1979), pp. 32, 132, 99.

[40] The manuscript, entitled 'Observation of the Tides, science of high water, height of the Tides, state of the barometer and Thermometer . . .taken (daily) at the [Custom] House Dock Gates Liverpool from 1762 to 1793, a period of 25 years 7 months 10 days by Mr. Hutchinson Dock Master', is housed in the Liverpool Central Library. Merseyside Maritime Museum holds several of Holden's Tide Tables.

[41] William Whewell, 'Researches on the tides—fourth series. On the empirical laws of the tides in the Port of Liverpool', *Philosophical Transactions*, 126 (1836), p. 1.

viduals with established research programs. As Roy MacLeod has remarked, the '"Humboldtian sciences" of the earth and its environment (such as geodesy, terrestrial magnetism, meteorology, radio-telegraphy, seismology and tidology) were specially cultivated, often through the efforts of particular individuals'.[42] In 1833 the BAAS offered its first official research grant (£200) for the 'discussion of observations of tides, and the formation of tide tables'.[43] Whewell used the money to have the newly-acquired Liverpool observations reduced, and turned his own investigations to a comparison of them with his earlier studies of the London tides.

Whewell was exuberant with his results. The researches on the Liverpool tides, Whewell boasted,

> have both confirmed, in general, my formulae, and have given me the means of very much improving them. The corrections for lunar parallax and declination, which, as far as they depended on the former investigation [on the port of London], might be considered as in some measure doubtful, and probably only locally applicable, have been so fully verified as to their general form, that I do not conceive any doubt now remains on that subject.

Whewell concluded that it 'is impossible to doubt, under these circumstances, that the theoretical formula truly represents the observed facts'.[44] Whewell would use similar arguments in his *Philosophy of the inductive sciences* (1840) when discussing the manner in which scientific hypotheses should be tested. According to Whewell, a hypothesis should not only explain the observed facts, it also should 'foretel [sic] phenomena which have not yet been observed; at least all phenomena of the same kind as those which the hypothesis was invented to explain'.[45] That his conclusions, derived from the port of London, fit so well with the observations 'of the same kind' at Liverpool, was for Whewell a sure sign that he had advanced the theoretical study of the tides.

The observations of Hutchinson were not, however, the sole preserve of the scholars in Cambridge. Indeed, their most productive use had been made by the tide table calculators living in Liverpool.

[42] Roy MacLeod, 'Introduction: On the Advancement of Science', in Roy MacLeod & Peter Collins, eds, *The Parliament of Science: The British Association for the Advancement of Science, 1831–1981* (Northwood, 1981), p. 24.

[43] Morrell & Thackray, *Gentlemen of science*, p. 515.

[44] Whewell, 'On the tides in the port of Liverpool', pp. 2–3.

[45] William Whewell, *The philosophy of the inductive sciences, founded upon their history*, 2nd edn (London, 1842), vol. 2, p. 62.

Tidology is in the end the most practical of sciences; its aim is to produce accurate tide tables. But the creation of tide tables, like all other tables in physical astronomy, is both an end and a means. While the professed *end* is the creation of accurate tables for the safety of navigators, these same tables are the only *means* by which natural philosophers are able to test the accuracy of their theories. Thus, when Whewell entered tidology, he was especially anxious to obtain accurate local tide tables from around Great Britain to verify his initial hypotheses through a comparison with observation. What surprised Whewell was that, in the creation of accurate tables, 'persons of much less elevated position' had moved far beyond the theorists in Britain.[46] Whewell was referring to the tide table calculators of Liverpool; in particular, Whewell had the tables of George Holden in mind.

When Whewell and Lubbock finally received Hutchinson's tide observations after two years of wrangling, the first several pages of the manuscript were missing. William Hutchinson had offered the first five years' (3,000) observations to Richard and George Holden to compile their 'Liverpool Tide Tables,' first published in 1770. The Reverend George Holden, perpetual curate of a chapel in Tatham Fells, framed the rules by which the tide tables were calculated.[47] His brother, Richard Holden, a mathematics teacher in the town of Liverpool, formed the theory upon which the rules were founded.[48] George and Richard Holden never divulged these rules or the theory they were based upon. They were private property.[49] They passed the rules and theory down to George's son, and by the 1830s, they were in the charge of George's grandson, Mr George Holden, the prolific writer and celebrated theologian from Liverpool.

[46] William Whewell, 'On the empirical laws of the tides in the Port of London, with some reflexions on the theory', *Philosophical Transactions*, 124 (1834), p. 15.

[47] J. R. Rossiter, 'The history of tidal predictions in the United Kingdom before the twentieth century', *Proceedings of the Royal Society of Edinburgh (B)*, 73 (1971/2) pp. 19–20.

[48] G. Holden to William Whewell, 19 Apr. 1834, Whewell papers, R.6.20/205. For an excellent discussion of the Holdens and the history of their tide tables, see Woodworth, 'Three Georges and one Richard Holden'.

[49] For a discussion of the 'ownership' of observational data during this period, see William J. Ashworth, '"Labour harder than thrashing": John Flamsteed, property and intellectual labour in nineteenth-century England', in Francis Wilmoth, ed., *Flamsteed's Stars: New perspectives on the life and work of the first Astronomer Royal 1646*-1719 (Woodbridge, 1997), pp. 199–216.

In the 'Preface' of their tide tables for the year 1773, the Holdens remarked on the erroneous nature of other tide tables. 'As their theory hitherto remained defective, so their methods of calculation, founded thereupon, have succeeded no better'.[50] The Holdens' improved theory was based on the Bernoulli equilibrium theory of the tides, and their tables were quite exceptional in their accuracy. Indeed, they were so accurate that William Whewell tried repeatedly to discover the methods they used. Holden's grandson, George Holden, assured Whewell that 'so far from having any objection to communicate to you my method of calculating the Liverpool T. Tables, I shall be most happy to shew you the whole'.[51] But he informed Whewell that he could not do so in the compass of a letter, and confined his explanation to the most general of remarks. Holden did offer to submit all the rules and tables for Whewell's inspection in a future letter, but stressed that it must be for Whewell's inspection alone. He did not want to make the process public for monetary reasons. The Corporation of Liverpool paid him £50 for the tables each year, a sum equal to what he made as Curator of a free school in Maghull. If his methods were ever published, Holden would lose half his income.

When Whewell replied and promised his secrecy, Holden thought better of his generosity and rescinded his offer. Holden informed Whewell that the observations used by his grandfather in constructing his tables were lost (the missing pages of the document noted above), and again confessed that he was bound by pecuniary interest to keep the methods to himself. 'Nevertheless every man should rejoice at the progress of science; and if I can in any way contribute to it by shewing you my Rules etc, I shall be most happy to do so'.[52] Whewell, however, would have to come to Liverpool and talk to Holden in person. Whewell perhaps realised he would never get the information he wanted, and he never made the journey to Liverpool. He was sympathetic to the entrepreneurial interests of the tide table calculators, perhaps owing to his own humble beginnings.

Holden's tide tables were exceptionally accurate and relatively sophisticated. They included, for instance, corrections for the moon's parallax and declination and reflected a practical understanding of Bernoulli's advances on Newton's equilibrium theory.

[50] Quoted in Hutchinson, *Practical seamanship*, p. 100.
[51] G. Holden to Whewell, 27 Sep. 1833, Whewell papers, R.6.20/204.
[52] Holden to Whewell, 19 Apr. 1834, Whewell papers, R.6.20/205.

They did not, however, correct for the diurnal inequality. This was an important omission. The diurnal inequality is the difference in time and height between the successive high tides in the morning and the evening, and is relatively pronounced in Liverpool. As ships grew in size and weight, the difference between the two high tides each day became pertinent. Holden's tables, however, gave only the heights of the tides between 6am and 6pm, a real disadvantage. As the number of vessels docking at Liverpool in the 1830s reached over a thousand each month, an 'immense number of vessels' had to dock in Liverpool at night.[53] Competition with Holden's tide tables became inevitable.

Holden's secrecy may have been one of the reason behind the success of his fiercest competitor: the 'Liverpool Commercial Almanack and Tide Tables,' by Mr Smith and calculated by Alexander Brown. Lubbock, from a different social background than Whewell, resented the secretive nature of the tide table calculators, and readily offered Brown, at his request, the numerical tables Lubbock had calculated to produce accurate tide tables for Liverpool, presumably to force the hand of George Holden. In his reply of thanks to Lubbock, Brown added that he 'stated in that part of the Almanac referring to the tides that I have employed your tables in the computation'.[54] This is one instance among many when the theorists and tide table makers formed a mutually beneficial relationship. For his part, Brown received a ready-made apparatus for the construction of his tables, complete with the latest theoretical work advanced by one of the main authorities on the subject from London. His tables included the high and low water for both night and day tides, an advance upon the Holden tables, and he could boast in print that his tables were based upon the work of the Secretary of the Royal Society of London.[55] Lubbock's work, in turn, was being used to heighten the accuracy of local tide tables. He was acknowledged for his efforts and he could use this as a means to attain further funding from the British Association and ultimately from the British Admiralty. More importantly for Lubbock, he could use Brown's creation of tide tables—extremely time-consuming numerical reductions—to test the accuracy of his own theory.

This mutually beneficial relationship is expertly demonstrated in

[53] Joseph Yates to Joseph Foss Dessiou, Sept. 1835, Lubbock papers, Y6.

[54] Alexander Brown to Lubbock, 12 Mar. 1840, Lubbock papers, B493.

[55] Brown to Lubbock, 12 Mar. 1840, 21 Mar. 1840, Lubbock papers, B493, B494.

the set of tide tables that preceded Brown's and were also in competition with the Holden tables. These were the tables calculated by the Liverpool resident Thomas Bywater. Bywater was first introduced to the study of the tides through a paper he read on the subject written by Whewell for the *Nautical Magazine*.[56] Bywater then obtained Lubbock's methods for preparing tide tables from a paper that Lubbock had sent to David Wylie, the secretary to the Liverpool Lit and Phil.[57] As a basis for his own tables, he acquired several months of tide observations from Jesse Hartley, the Liverpool dock engineer, and applied those observations to Lubbock's and Whewell's theoretical work. Like Alexander Brown, Bywater acknowledged his debt to Lubbock and Whewell in his published tables, and the two philosophers always sent Bywater a copy of their theoretical publications. Bywater, in turn, sent his tables to Lubbock and Whewell as a 'practical proof' of their method's 'great utility'.[58] By offering both observations and tables to the theorists, Bywater was hoping for an equally beneficial return.

As Bywater had 'deviated from the plan' adopted by Whewell and Lubbock, he wrote to Whewell as his first set of tables were going to press, intimating that he would cause the printing to be stopped to give time for Whewell's suggestions.[59] Whewell spent some time and energy on Bywater's tables, writing back with several suggestions. Bywater replied as a sign of deference that whatever his own endeavours deserved, 'the chief merit belongs to yourself for bringing the subject before the public in such a manner as to render a further investigation of the tides at Liverpool a question of peculiar local importance'.[60] He again asked Whewell for his opinion concerning the tables, and also asked about the tables produced by Joseph Dessiou, a calculator working under the guidance of Whewell and Lubbock at the Hydrographic Office. Bywater was particularly concerned with Dessiou's work on the diurnal inequality. Whewell answered Bywater's request for Dessiou's latest tables, but had to admit that they were not as satisfactory as he had anticipated. In his fifth series of researches on the tides, 'On the

[56] Thomas Bywater to Whewell, 14 Nov. 1835, Whewell papers, R.6.20/146.
[57] Wylie to Lubbock, Mar. 1836, Lubbock papers, W503.
[58] Bywater to Lubbock, 14 Nov. 1835, Lubbock papers, B627.
[59] Bywater to Lubbock, 14 Nov. 1835, Lubbock papers, B627; Bywater to Whewell, 21 Nov. 1835, Whewell papers, R.6.20/147.
[60] Bywater to Whewell, 16 Dec. 1835, Whewell papers, R.6.20/148.

solar inequality and on the diurnal inequality of the tides at Liverpool' published in the *Philosophical Transactions* in 1836, Whewell was unable to account for the laws of the diurnal inequality, and could only haphazard a guess as to its mathematical form. Bywater compared his own observations with Whewell's theoretical work, however, and could write to Whewell that 'the line of diurnal variation (which you have particularly alluded) was so strongly marked through the whole of these observations and referred so clearly to the varying position of the moon that it left no doubt in my mind respecting the principle on which this Diurnal difference depended'.[61] Through his own calculations, Bywater formed an improved tide table that included the diurnal inequality in the table's predictions of the heights and times of high water.

When sending his new tables to Whewell, Bywater emphasised that one of the Whewell's problems might be with the transit of the moon that he had used in his calculations.[62] While grappling with this difficulty, Whewell wrote to Lubbock referring to the diurnal inequality at Liverpool. 'It appears to me quite clear', wrote Whewell, 'that the theoretical and the observed curve would approach very near by putting the epoch of the former about 3 hours forward'.[63] Whewell then acknowledged that 'This is very nearly what I collected from Bywater's results'. Whewell returned to the subject of the diurnal inequality in his seventh series, 'On the diurnal inequality of the height of the tide, especially at Plymouth and at Singapore' published in the *Philosophical Transactions* in 1837. Whewell ended his paper with an examination of all reports of the diurnal inequality he could accumulate, including those at Liverpool from Thomas Bywater. From all of these observations, Whewell was able to determine the mathematical law of the diurnal inequality, his most prized conclusion in his twenty-five year research project on the tides.

Whewell's work on the diurnal inequality demonstrates the importance of local tide table calculators in the theoretical discussion of the tides. Thomas Bywater, as early as 1835 while Whewell was just beginning to work on the diurnal inequality, included this inequality in his tide tables for Liverpool, tested Whewell's theoret-

[61] Bywater to Whewell, 21 Nov. 1835, Whewell papers, R.6.20/147.

[62] Bywater to Whewell, 16 Dec. 1835, Whewell papers, R.6.20/148; Bywater to Lubbock, 21 Dec. 1835, Lubbock papers, B629.

[63] Whewell to Lubbock, 1 Apr. 1837, Whewell papers, O.15.47/225.

ical conclusions in his own predictions of the tides, and offered advice to iron out the discrepancies.[64] Whewell and Lubbock in turn offered their papers to Bywater and allowed him to include their names in his tables. This mutually beneficial relationship between tide table makers and theorists necessarily included a third party, however, as neither group actually gathered (or had others gather) the actual observations. This crucial role was played by military men, usually under direct orders from Francis Beaufort at the Hydrographic Office. It included dockyard engineers and Admiralty surveyors, men such as Jesse Hartley and William Denham, whose jobs required that they have such observations made.

Bywater had noted to both Whewell and Lubbock that he had acquired most of his observations from the Liverpool docks, observations that Jesse Hartley, the dockyard engineer, had instigated.[65] Hartley worked his way up from a stonemason to the position of Dock Engineer to Liverpool by 1824. As his biographer Nancy Ritchie-Noakes has demonstrated, Hartley's engineering works in Liverpool were a major factor in the rise of Liverpool's exceptional dock system. In 36 years as civil engineer to the docks, applauds Ritchie-Noakes, 'he constructed or altered every dock in the city; he added no less that 140 acres of wet docks and some 10 miles of quay space'.[66]

No sharp distinction existed at that time between engineers and scientists. Indeed, that distinction was in the process of being made. Hartley followed the latest scientific developments in England, especially as they pertained to dock engineering. He was both an experimenter and inventor, and introduced several of his inventions to the Dock Trustees, including an illuminated tide gauge for dock entrances.[67] Hartley's favourite scientific interest, however, was tidology. As a civil engineer responsible for the construction of docks and other engineering projects, Hartley would have had to take tide measurements as a routine part of his engineering projects.

[64] Bywater to Lubbock, 5 Dec. 1835, Lubbock papers, B628.

[65] Bywater to Whewell, 21 Nov. 1835, Whewell papers, R.6.20/147.

[66] Nancy Ritchie-Noakes, *Jesse Hartley: Dock Engineer to the Port of Liverpool, 1824–1860* (Merseyside County Museum, 1980), p. 5.

[67] Housed in the Maritime Museum, this plan was not a gauge to register the tides, but rather a means by which the height of the tide could be illuminated, using Hutchinson's reflectors, to help pilots ascertain the tide. Though never built, it was to be about twenty feet tall. Merseyside Maritime Museum, Liverpool, Mersey Docks & Harbour Board Collection, MDHB 3450 PM15.

But he also used these observations to advance the scientific understanding of the tides. In addition to offering observations to local tide table calculators, including Bywater and Brown, Hartley also was well situated to help the natural philosopher back in London. He had earlier requested that the Dock Trustees require the dockmasters of the several docks in Liverpool to make observations of the heights of high water.[68] He sent the observations directly to Lubbock with the hopes that the observations would be of some scientific use, 'which indeed is the end which I had in view in causing the heights of the Tides to be taken'.[69] In addition, he organised the observations into tables for each month at three different docks from July 1827 to August 1835. The dockyard attendants, however, had failed to include the *time* of high water, and Lubbock found the measurements of little use.[70] Before the end of the month, however, Hartley had corrected this oversight and was having the time of high water registered 'by watches carefully regulated by a proper time piece by men of strictly moral rectitude'.[71] Thus, through the combined effort of Hartley the engineer, and Bywater and Brown the tide table makers, Lubbock and Whewell had a constant stream of both observations and tables from Liverpool to use and compare with their theoretical results.

Hartley, while engineering the construction of Brunswick Dock in 1832, had worked closely with Lieutenant William Denham with whom he shared an interest in the study of the sea. Denham was a salty seaman who entered the Royal Navy at the age of nine. By age seventeen he was on board the *Shamrock* under the command of Captain Martin White, surveying the English Channel and the coasts of Ireland. During these formative years he learned the basics of surveying and first took up the interest in nautical science. In 1827, he was given his first command, the *Linnet*, a ten-gun ship, to survey the Bristol Channel.[72] He would not complete this survey, however, as the tides of Liverpool soon beckoned.

The great tides off the west coast of England caused frequent and sudden changes to the access of the river Mersey. The two main approaches, the Formby and Rock Channels, deteriorated at a rapid

[68] Wylie to Lubbock, Sept. 1835, Lubbock papers, W500.
[69] Hartley to Lubbock, 19 Sept. 1835, Lubbock papers, H258.
[70] Hartley to Lubbock, 19 Sept. 1835, Lubbock papers, H258.
[71] Hartley to Lubbock, 30 Nov. 1835, Lubbock papers, H260.
[72] Andrew David, *The voyage of HMS* Herald (Carlton, Victoria, 1995), p. 3.

rate, and by 1830 the port was closed to river navigation for four hours out of every twelve.[73] As this cut sharply into the commercial viability of the port, the city council approached the Admiralty, and Denham was ordered to quit his survey of the Bristol Channel and begin a survey of the River Mersey.[74] Denham was chosen owing to his interest in the scientific study of the sea, particularly the study of the tides. Earlier, in 1829, he had erected several tide gauges on the southern coast of Wales to detect the effects of winter storms on the rise of the tides, and he had also experimented with the effects of the tides on ships by setting them adrift during the ebb tide of a river.[75] He came to Liverpool with orders to instigate a technical and scientific project to determine the effects of the tides on the approaches to the port. For the next seven years, Denham undertook the most comprehensive survey of the Mersey and its approaches that had until then been accomplished.

When he began his survey of the Mersey, the deterioration of the approaches gained his foremost attention. His first order of business was to have tide observations made at several of the principal docks. He had the Dock Trustees erect tide gauges, and observations were carried out for several months between 1832 and 1833. He sent these measurements to Whewell and Lubbock in the hopes that they would be helpful for their theoretical researches.[76] When tide tables for the port of Liverpool were calculated at the Hydrographic Office from these measurements, Beaufort returned the new tables to Denham so that he could observe 'how far it deviates from the truth'.[77] Denham was both collecting data and testing theory. Significantly, however, these early observations also allowed Denham to contribute his own theoretical insights and practical conclusions. From a close study of these observations, Denham first voiced his theory that the half tide level should be used as the zero point for all surveying work done by the Ordnance and Hydrographic Surveys. Moreover, his meticulous soundings and surveying of the port revealed a new channel, which he and Hartley dredged,

[73] A. S. Mountfield, 'Admiral Denham and the approaches to the port of Liverpool', *THSLC*, 105 (1953), pp. 123–36, p. 124.

[74] Mountfield, 'Admiral Denham', p. 123.

[75] Denham to Beaufort, 16 Oct. 1829, Beaufort papers, Surveyor's letters, 3a, Denham 1829–32, Letter no. 9.

[76] John Lord to Beaufort, 19 Jun. 1841, Lubbock papers, L361.

[77] Beaufort to Denham, 21 Dec. 1836, Beaufort papers, out-letters, Letter book 7.

buoyed, and beaconed. The new channel, christened Victoria Channel, allowed ships easy access to the port at all hours of the day, including low water. As Joseph Yates noted in 1843, 'The access to the harbour is far better than at any former period . . . For vessels of ordinary dimensions it is practicable at all times; for large ships it is the earliest entrance to the port by three hours'.[78] Denham gathered the observations, gave them freely to the scientists, checked their predictions, and contributed his own theoretical investigations on the mean level of the sea. All this while attending to his own surveying work, which produced a new channel that added to the prosperity of the port.

Owing to his work with the river Mersey, the Dock Trustees unanimously appointed Denham as the first Marine Surveyor of the port at a hefty salary of £700 per year. He held that position until 1839, the same year he was elected as a Fellow of the Royal Society of London for his accomplishments in nautical science. By then, he was a regular on the scientific scene. Denham reported on his surveying, and particularly the new channel and its value for the trade of Liverpool, at two consecutive meetings of the British Association. His scientific approach to surveying shines through. He carefully calculated the amount of earth deposited each tide, and the direction and velocity of the sediment as it entered and left the estuary. From these calculations, he could determine the time and extent of dredging needed to keep the new channel open. It was also at these British Association meetings that Denham first published his theory of the half-tide mark.

Denham collected all his materials from his survey of the Mersey to publish his *Sailing directions from Point Lynas to Liverpool with charts, coasts views, river sections, tidal courses and tide gauge tables for navigating the Dee and Mersey* in 1840. He sent the book to Lubbock owing to Lubbock's 'time, expense, and researching light' that he bestowed on the tides, as well as 'how such espousal as yours can encourage the toilsome collection of data'.[79] But Denham was feigning his position as a mere collector. In his text, Denham mixed both theory and practice, of interest to both scientists and seamen. He produced a valuable tide table for mariners and calculated the half tide level for the philosophers. Lubbock was so impressed with

[78] Yates, 'Memoir', p. 27.
[79] Denham to Lubbock, 24 Apr. 1841, Lubbock papers, D110.

Denham's work that he asked if he could submit the lot to the Royal Society. Denham, of course, thought that to be a splendid idea. 'In fact the matter is in your possession with my very satisfactory conviction that it will not be dormant'.[80] When the Ordnance Survey of Great Britain began, the mean tide level at Liverpool was selected as the datum plane for all the levels throughout the country.[81] Denham never gave up his interest in science, especially the tides, or his work's connection with commerce, the mariner, and the scientist. His subsequent voyage as commander of the HMS *Herald* to the southwest oceans resulted in significant collections in botanical and ornithological material and earned him a knighthood.[82]

Many Admiralty surveyors stationed in Liverpool with similar interests to Denham followed. Samuel Haughton published numerous papers on the tides, the first several in the *Journal of the Royal Dublin Society* on the tides of the Irish Sea. He also published a *Manuel of tides and tidal currents*, a text written for the navigator to teach the basics of the theories of tides, and to apply those general principles to the Irish and English Channels. He focussed heavily on the port of Liverpool. The diurnal inequality and the direction of the stream was further investigated by Frederick William Beechey, later Rear Admiral, during his extensive survey of the approaches to Liverpool, and published in the *Philosophical Transactions* in 1848 and 1851.[83] Beechey connected the tides of the Irish Sea with those of the Bristol and English Channels 'to reconcile and reduce to a system' all the past work of both naval surveyors and scientists. 'But it is not to the navigator alone that these observations will, I hope, be found useful; they will, I think, be interesting to men of science'. They were useful and interesting to both, and by combining the work of surveyors and scientists, Beechey was following the lead of many before him.

80 Denham to Lubbock, 7 May 1841, Lubbock papers, D111.

81 Richard Veevers, 'On the tides and datums of the Lancashire coast', *THSLC*, 49 (1897), pp. 171–75, p. 171.

82 David, *The Voyage of HMS* Herald.

83 F. W. Beechey, 'Report of observations made upon the tides in the Irish Sea . . .', *Philosophical Transactions*, 138 (1848), pp. 105–16; F. W. Beechey, 'Report of further observations upon the tidal streams of the North Sea and English Channel . . .', *Philosophical Transactions*, 141 (1851), pp. 703–18.

Conclusion

Owing to the researches by John William Lubbock, then secretary of the Royal Society of London, and William Whewell, a leading light in early Victorian science, the study of the tides became a highly regarded topic of research in the early Victorian era. And because of the importance of the tides to the prosperity of its port, Liverpool became a centre of that research. It would be misleading, however, to view the contribution of the Liverpool people simply through the eyes of Lubbock and Whewell in London and Cambridge. According to such a framework, the narrative would be one of the scientists, in the midst of defining their field, successfully transforming the 'traditionary secrets' of tide-table makers and the 'practical workings' of the surveyor into 'scientific knowledge' for the good of physical astronomy. Art in the periphery would have given way to science in the centre. Such a narrative would misrepresent the complex exchange of information among the individuals involved.

Before Lubbock and Whewell resurrected the study of the tides from over a century of relative neglect in Britain, the people of Liverpool had not been idle. Liverpool possessed the longest continuous tidal observations of any city in Britain. Moreover, the commercially-inclined tide table calculators, without the help or the impetus of the scientists, created tide tables that were by far the most accurate in the country. They included sophisticated analysis that incorporated the moon's declination and parallax into their predictions. And when the theorists did step in, the calculators marched ardently astride. As quickly as Lubbock and Whewell published their latest results, tide-table makers from Liverpool incorporated those results into their predictions. They were the first, for instance, to include the diurnal inequality into their tide tables. These tide-table makers were the first to bring the necessary data to the natural philosophers and the first to apply the results to the construction of tables and thus to the testing of theory.

The tide table calculators, moreover, were not the only figures in Liverpool to advance the science of tidology. Dockyard engineers such as Jesse Hartley and Admiralty surveyors such as William Denham brought recognition to the science and the city. Hartley and Denham instigated observations and offered them freely to the tide table calculators in Liverpool and the theorists in London and Cambridge. Denham, furthermore, advanced upon the findings of the theorists, extending their work into important areas concerning the mean level of the sea. All of these individuals, from calculators to engineers to surveyors, were doing their job while actively becoming involved in tidal studies. They would have accomplished this with or without the impetus from the theorists. Their efforts expertly demonstrate the lack of any distinction they placed on theory and practice, though that distinction was being made at that time by the scientists in Cambridge and London. That the scientists ultimately succeeded in this endeavour should not obscure the reality that the contributions of these associate labourers were an instrumental part of the investigation of the tides in the early Victorian era.

Liverpool did in fact go through a cultural renaissance during the first half of the nineteenth century, but it was not simply one of a general and literary nature. Liverpool was directly involved in the predominant type of scientific investigation in the early Victorian era. This goes far in explaining why Liverpool received some notoriety in the burgeoning scientific community. Though the Liverpool Literary and Philosophical Society had been founded in 1812, it were not part of the first meeting of the British Association in 1831. Tidology, likewise, had no voice. Yet by 1837, both Liverpool and tidology occupied pride of place. In the autumn of that year, despite a strong challenge from Manchester, Liverpool finally succeeded in its application to host the British Association meeting, and Whewell made sure that the study of the tides attained the highest priority. Liverpool was a central node in Whewell's tidology, and after accepting the office of Vice President of the Association several months before the meeting, he worked diligently to acquire additional monies for the acquisition, reduction, and continuation of tidal observations in Liverpool.

Thomas Stuart Traill gave the inaugural address to a packed house on a Monday evening to open the British Association meeting in Liverpool.[84] Traill had lived in Liverpool for twenty-eight years, and though he had left the city by 1837, he was the first honorary Secretary of the Liverpool Lit and Phil and a founder of the Liverpool Mechanic's Institute. After congratulating the members for their laudable desire to 'promote social intercourse among men of science,' he moved directly to a discussion of the city's scientific

[84] 'Address by Professor Traill, MD', *Report of the seventh meeting of the BAAS, held at Liverpool in September 1837*, 6 (1838).

accomplishments. He focused almost exclusively on the study of the tides. He boasted that the latest theoretical developments 'had chiefly for their original basis the very valuable tide observations made in this port, many years ago, by Mr. Hutchinson, a dock-master'. He could also point out that the diurnal inequality, Whewell's prized possession, 'was first marked in the tide tables constructed by a young ingenious townsman, Mr Bywater'. And he further noted that one of 'our eminent associates,' Captain Denham, 'has recorded his most important general inference (drawn from a connected series of observations on the tides, which the liberality of the Dock Trustees of Liverpool enabled him to carry on)—that there is one invariable mean height, common to neap and spring tides—The Half Tide Mark—a point from which engineers, geologists, and navigators will henceforward commence their calculations, and adjust their standards of comparison'. Traill's bravado was not unwarranted. Tidology, and with it, Liverpool, had made their mark on science.

Notice, however, that Traill did not speak of the great luminaries in Liverpool (such as Roscoe) or in Cambridge (such as Whewell), but of the lesser sorts—the harbour masters and dock yard engineers, the tide table makers and Admiralty surveyors—those associate labourers who were being pushed out by the definitions being applied to the term 'scientist' at that time. By the second quarter of the nineteenth century, Liverpool had become the major port in England, second only to London. The type of science it fostered followed suit. A lively tidology developed, advanced by people not considered 'scientists' by today's standards, in places more closely linked to the commercial and maritime interests of the city than the porter and oyster gatherings of its scientific society. Thus, this paper underscores the importance of looking not only at local histories of science that reach beyond London and Cambridge, but also at the local contributors of that science often obscured by both their contemporaries and our histories. In the process, we come to a better representation of the type of science practised in early Victorian England, where the strong collaboration between the Admiralty, the scientists, and the multitude of harbour masters, dockyard engineers, surveyors, and tide table calculators uncovered the workings of nature.

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