

# A world of copper: globalizing the Industrial Revolution, 1830–70\*

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## Abstract

*For most of human history the smelting of metallic ores has been performed immediately adjacent to the ore body. In the 1830s the copper industry that was centred on Swansea in the UK departed abruptly from that ancient pattern: Swansea smelters shipped in ores from very distant locations, including sites in Australasia, Latin America, and southern Africa. Swansea became the hub of a globally integrated heavy industry, one that deployed capital on a very large scale, implanted British industrial technologies in some very diverse settings, and mobilized a transnational workforce that included British-born ‘labour aristocrats’, Chinese indentured servants, and African slaves. This paper explores the World of Copper between its inception c. 1830 and its demise in the aftermath of the American Civil War. It asks what the experience of this precociously globalized industry can contribute to some current concerns in global history.*

**Keywords** Australia, Britain, copper, Industrial Revolution, Latin America, nineteenth century

Writing in 1848, the French technocrat Frédéric Le Play was in no doubt that Europe’s (and for that matter the world’s) copper industry had just undergone an epochal change. Throughout human history, Le Play maintained, the smelting of metals had been ‘rigorously determined’ by geology. Ores were smelted in close proximity (‘almost always less than 10 kilometres’) to the mines from which they were extracted, using local timber for fuel. This was a universal law to which every one of Europe’s old-established copper-producing regions, from Norway to Andalusia, adhered. And yet, Le Play observed, in the ‘last twenty

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We have drawn freely upon discussions with a large number of historians, archaeologists, museum professionals, and mining enthusiasts. We do not expect all of them – indeed, perhaps any of them – to agree with the inferences that we have drawn or the conclusions that we have reached. The text is our responsibility and only ours. We are grateful to Stephen Hughes for his help with illustrations and to Martin Critchley for designing the map. Needless to say, we have benefitted greatly from the advice of the *Journal’s* referees and editors.

years this old order of things has changed remarkably'. The British copper industry, or more specifically the smelters of the Swansea district in south-west Wales, no longer relied upon ore deposits that were conveniently local. All of a sudden, the Welsh copper sector seemed to know 'no limits other than those of the globe itself'. Swansea received ores 'from the island of Cuba, from Mexico, from Colombia, from Peru, from Chile, from Australia and from New Zealand'.<sup>1</sup> Swansea copper thus became a truly transoceanic phenomenon, involving mining and processing complexes on different continents and the mobilization of capital, labour, and technology across immense distances.

As Le Play recognized, this was a startling development. Although metals and metallic wares had been traded over great distances since antiquity, metallic ores had not.<sup>2</sup> Yet now, in the 1830s and 1840s, furnace materials were brought to Swansea Bay from very remote locations; in 1848 Le Play itemized those from the Caribbean, the Pacific coast of South America, and Australasia. In the 1850s the supply lines became still more diverse: new contributions came from Namaqualand in southern Africa, from Algeria, from the Iberian Peninsula, from the United States, and from Newfoundland. A new world of copper had come into being. It turned upon a small patch of south-west Wales but its reach was authentically global. This was the World of Copper, here given initial capitals to distinguish it from more enclosed copper-producing zones – some venerable (such as Saxony) and some new (such as the Altai mountain range on the fringes of the Russian empire) – that stayed loyal to older organizational forms and lacked Swansea's global scope.<sup>3</sup>

The World of Copper was certainly novel. But what significance does it have for the study of global history? For one thing, it was properly global; that is to say, it directly embraced every continent. As such, it provides a counterpoint to much recent scholarship that focuses upon Asia.<sup>4</sup> The see-saw relationship between the eastern and western ends of Eurasia during the passage to modernity has been a hallmark of the new global historiography of the last two decades. Debate has revolved around questions of how the balance of power is to be assessed or shifts in power accounted for. This is a discussion to which the history of copper can certainly contribute, for control over the lucrative Indian market was contested by European and Japanese copper producers between the seventeenth and nineteenth centuries.<sup>5</sup>

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- 1 Frédéric Le Play, *Description des procédés métallurgiques employés dans le Pays de Galles pour la fabrication du cuivre*, Paris: Carilian-Goeury et Von Dalmont, 1848, pp. 6–7.
  - 2 Jack Goody, *Metals, culture and capitalism: an essay on the origins of the modern world*, Cambridge: Cambridge University Press, 2012; David Killick and Thomas Fenn, 'Archaeometallurgy: the study of preindustrial mining and metallurgy', *Annual Review of Anthropology*, 41, 2012, pp. 559–75, esp. pp. 560–2.
  - 3 See A. Snowden Piggot, *The chemistry and metallurgy of copper, including a description of the principal copper mines of the United States and other countries*, Philadelphia, PA: Lindsay & Blakiston, 1858, pp. 193–285, for an inventory of production zones in the mid nineteenth century.
  - 4 Maxine Berg, *Luxury and pleasure in eighteenth-century Britain*, Oxford: Oxford University Press, 2005; Prasannan Parthasarathi, *Why Europe grew rich and Asia did not: global economic divergence, 1600–1850*, Cambridge: Cambridge University Press, 2011; Kenneth Pomeranz, *The great divergence: China, Europe, and the making of the modern world economy*, Princeton, NJ: Princeton University Press, 2000.
  - 5 Huw Bowen, 'Sineus of trade and empire: the supply of commodity exports to the East India Company during the late eighteenth century', *Economic History Review*, 55, 3, 2002, pp. 466–86; Kristof Glamman, 'The Dutch East India Company's trade in Japanese copper, 1645–1736', *Scandinavian Economic History Review*, 1, 1, 1953, pp. 41–79; Ryuto Shimada, *The intra-Asian trade in Japanese copper by the Dutch East India Company during the eighteenth century*, Leiden: Brill, 2006.

However, the World of Copper can speak to much more than that. It can illuminate how very varied portions of the globe, and not just those abutting the Indian Ocean and the North Atlantic, were drawn into an increasingly integrated world economy. It can illuminate so much because of its multi-dimensionality. The World of Copper was an articulated production network that spanned hemispheres; it was a set of migration streams; it was a field of technological hybridization; it was a web of credits and remittances; and it was a shipping network of unexampled range.

The Swansea-centric World of Copper can also reinstate metals in our narrative of global modernity. Many of the most striking historiographical advances of recent years have come through the study of globally traded goods that were intended to add to domestic comfort or figure in acts of exotic consumption: Indian cottons, Chinese ceramics, or foodstuffs such as sugar or tea. Metals, unless they come in an especially bijou form, do not register in this new historiography. The bulk production of copper, like heavy industry in general, has been ‘crowded out’ of the picture. This is of a piece with a more general eclipse of the Industrial Revolution as an explanatory framework for the coming of the modern world. Classical conceptions of the Industrial Revolution, which stressed its rapidity, its reliance upon revolutionary technological innovations, and its essential Britishness, no longer command attention.<sup>6</sup> Far from being the harbinger of modernity, the British Industrial Revolution is now painted as an odd, thoroughly atypical phenomenon. The rival notion of an ‘industrious revolution’, which privileged consumption over production, which was driven by shifts in labour allocation rather than technological change, and which has no distinctively British component, has its champions (and its critics).<sup>7</sup> The World of Copper, however, stands as a reminder that the older narrative has some hard-to-ignore features that were often decisive vectors of global industrialization. The ‘Welsh process’ of copper smelting was one. It is time, in other words, to re-inscribe coal-burning, heavy industry into global history.<sup>8</sup>

The World of Copper can also engage in dialogue with current interpretations of global development that centre on the British empire. Recent scholarship has focused on how British colonial rule or British cultural affinities moulded migration and capital flows, giving rise to an ‘imperial globalization’.<sup>9</sup> The World of Copper tests the firmness of imperial boundaries by raising questions about how migration patterns and capital investment flowed both within and beyond the ‘Anglo-World’. The World of Copper, after all, did not just set

6 E. J. Hobsbawm, *The age of revolution: Europe, 1789–1848*, London: Weidenfeld & Nicholson, 1962; David Landes, *The unbound Prometheus: technological change and industrial development in western Europe from 1750 to the present*, Cambridge: Cambridge University Press, 1969.

7 Jan de Vries, *The industrious revolution: consumer behavior and the household economy, 1650 to the present*, Cambridge: Cambridge University Press, 2008; C.A. Bayly, *The birth of the modern world, 1780–1914: global connections and comparisons*, Oxford: Blackwell, 2004.

8 Our emphasis differs from that expressed in the editor’s introduction to Maxine Berg, ed., *Writing the history of the global: challenges for the twenty-first century*, Oxford: Oxford University Press, 2013, where the persistent gravitational pull of the Industrial Revolution is identified as a continued historiographical distortion.

9 Gary B. Magee and Andrew S. Thompson, *Empire and globalisation: networks of people, goods and capital in the British world, c.1850–1914*, Cambridge: Cambridge University Press, 2010; James Belich, *Replenishing the earth: the settler revolution and the rise of the Angloworld, 1783–1939*, Oxford: Oxford University Press, 2009; Carl Bridge and Kent Fedorowich, eds., *The British world: diaspora, culture and identity*, London: Frank Cass, 2003.

down in areas under formal British rule; it established branches in parts of other European empires (such as Cuba) and newly minted independent states (such as Chile). It is true that it exported distinctively British technological packages (such as Cornish ore-dressing techniques), but British technologies were often hybridized or installed alongside traditional practices. The World of Copper may have pivoted upon Swansea, but to apply a well-worn core and periphery model, in which capital and technological expertise flow outwards from a metropolitan hub, is not necessarily appropriate. There were some unequivocal examples of new technologies emanating from the core, but there were also instances of low-tech but adaptable practices that travelled laterally: the Chilean mules and mule-drivers shipped across the Pacific to carry ore across the scrub of South Australia stand witness to that.<sup>10</sup> Likewise, finance for the Chilean ore trade came from merchant houses in Calcutta, as well as from London. Above all, the World of Copper can contribute to an authentically global history of labour. An extraordinary array of workers was set in motion by Swansea copper: among those put to work alongside British operatives were enslaved Africans, Chilean indigenes, Chinese indentured labourers, and a multinational maritime workforce.

The exploration of the World of Copper that follows below has four parts. First, its chronology is set out and its shifting shape described. Secondly, its governance is analysed: methods of corporate control are identified and the tensions that hummed between rival centres of power are mapped out. Thirdly, the pathways followed by the global copper trade's main citizens, its workers, are traced. Part four analyses how the World of Copper that came into being in the 1830s collapsed in the aftermath of the American Civil War. A concluding section asks how the World of Copper can be construed within wider patterns of industrial development that stretch from the seventeenth century to the late nineteenth.

## The World of Copper: taking shape

Global copper smelting underwent a major reconfiguration *c.*1830 as the Swansea district broke decisively with the geological determinism that had hitherto prevailed, and South Wales became the 'central smelter for minerals from East and West'.<sup>11</sup> In truth, Swansea had always been an anomaly of sorts. The great centres of early modern smelting in central Europe or Scandinavia were wood-dependent but the Swansea district relied from the outset on mineral coal for energy.<sup>12</sup> The viability of coal-fired smelting methods had first been demonstrated in the Bristol region in the 1680s.<sup>13</sup> In the early eighteenth century, however, smelters began to drift westwards into Wales, to Neath (where copper smelting with coal commenced in the 1690s) and then to the lower Swansea valley (where the first smelter was built in the 1710s). The relocation is readily explained. A new-style reverberatory

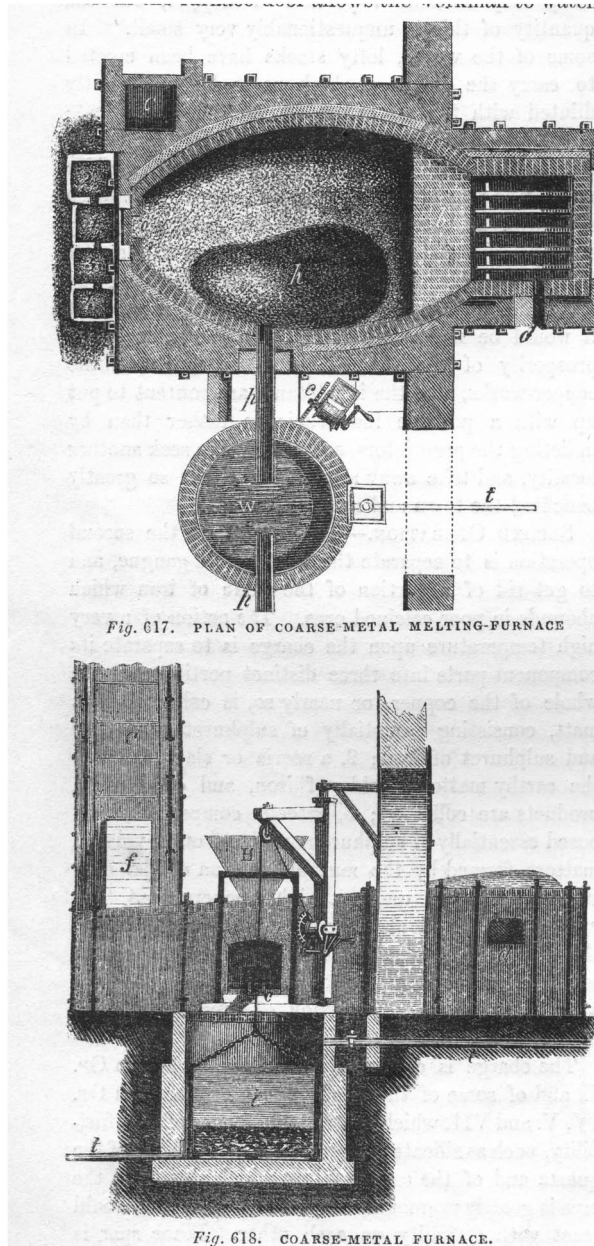
10 J. B. Austin, *The mines of South Australia, including an account of the smelting works in that colony*, Adelaide: Platts, 1863, p. 100; Mel Davies, 'Land transport and the South Australian copper and smelting industries', *Revista de Historia Social y de las Mentalidades* (forthcoming).

11 Le Play, *Description des procédés*, p. 387: 'fonderie centrale des minerais des deux océans'.

12 George Grant-Francis, *The smelting of copper in the Swansea district of South Wales, from the time of Elizabeth to the present day*, London: H. Sotheran & Co., 1881.

13 Peter W. King, 'Sir Clement Clerke and the adoption of coal in metallurgy', *Transactions of the Newcomen Society*, 73, 2001–02, pp. 33–52.

**Figure 1.** The reverberatory furnace in plan and side-view. Source: Charles Tomlinson, ed., *Cyclopaedia of useful arts, mechanical and chemical, manufactures, mining and engineering*. Vol. 1: *abattoir to hair-pencils*, London & New York: George Virtue, 1852, p. 432.



furnace (see Figure 1) consumed several tons of coal in smelting one ton of ore, so it made sense to ship ore from Cornwall, which boasted Britain's richest copper reserves, and whose mines were seldom more than 10 kilometres from the sea, to the nearest available

coal measures.<sup>14</sup> These were at Swansea, where the South Wales coal basin outcropped. This, so the great Swansea industrialist Henry Hussey Vivian (1821–94) reckoned, set Wales apart from the rest of the world, where charcoal-fired blast furnaces were the norm: ‘South Wales against the world!’<sup>15</sup>

This was the Swansea trinity: coal – reverberatory furnaces – seaborne ore. It proved an astonishingly successful formula. Given a ready supply of fuel, reverberatory furnaces could be multiplied endlessly; and so they were, until Wales dominated global copper smelting to an extraordinary degree. Victorian Swansea was hailed as ‘Copperopolis’ for good reason. In the first half of the nineteenth century Wales consistently accounted for over 40% of the world’s smelted copper, and often more than 50%. The lower Swansea valley became choked with furnaces. Works that had been established in the eighteenth century were extended, and new works of prodigious size – such as Hafod (1810) and Morfa (1835) – were laid out alongside them.<sup>16</sup> The workforce was correspondingly large; contemporary estimates went as high as 4,000 (‘exclusive of colliers’) in the 1860s.<sup>17</sup>

Sustaining this industrial complex called for huge quantities of ore. In principle, ore could have been shipped in from anywhere provided it was of sufficient richness to cover the cost of transport. But before the 1830s that did not happen. Supplying Swansea’s smelters remained a Cornish monopoly, save for contributions from North Wales (Parys Mountain) and Ireland (mines in counties Wicklow, Waterford, and Cork). This was a maritime operation of some sophistication in its own right, a World of Copper in embryo, but it was unable to expand beyond the Bristol Channel and Irish Sea, for reasons that were political. Tariff restrictions excluded ore from outside Britain and Ireland. Once significant alterations

14 The reverberatory furnace was fundamental to the ‘Welsh Process’ practised at Swansea. It had three essential features, shown in Figure 1 from right to left in plan and side-view: (i) the fire-grate in which coal was burnt, (ii) the hearth in which mineral material was roasted, smelted, or refined, and (iii) a flue (‘f’ in the side-view) leading to the stack. The height and narrowness of the chimney stack created a powerful draught that swept flame and combustion gases from the fire-grate across the hearth. The sloping roof of the hearth served to deflect (or ‘reverberate’) radiant heat down onto the mineral charge.

The reverberatory furnace’s great attraction lay in the degree of control that it offered the smelter – control that was not available to the users of blast furnaces. The raising or lowering of the damper on the stack enabled furnacemen to modulate the reduction process with speed and some delicacy. Moreover, the progress of the operation could be directly observed via the furnace door, through which furnacemen could also manipulate the mineral charge.

Reverberatory furnaces varied in size and function. The largest of these low brick structures were used for the calcining of ore, a preliminary roasting in which volatile sulphurous matter was burnt off. According to one Swansea copper master, calciner hearths were ‘commonly from 17 to 19 feet in length from the bridge to the flue, and from 14 to 16 in width’. The furnaces in which the subsequent smelting and refining operations were carried out were much smaller, ‘not exceeding 11 or 11½ feet in length by 7½ or 8 feet in the broadest part’ (John Henry Vivian, ‘An account of the process of smelting copper as conducted at the Hafod copper works, near Swansea’, *Annals of Philosophy*, new series, 5, 1823, p. 114).

The furnace shown here was used for the second operation in a sequence of ten. Calcined ore was deposited in the furnace via the hopper marked ‘H’ in the side-view. The smelting process yielded a liquid copper matte that gathered in a depression in the hearth floor (‘h’ in the plan). This was tapped into a tank of water (‘W’ in the plan and shown in section in the side-view). The matte granulated in contact with the water. Winched clear of the tank in baskets, it was dried and carted off to a different furnace for the third operation.

15 Henry Hussey Vivian, *Copper smelting: its history and processes*, New York: The Scientific Publishing Co., 1881, p. 18.

16 Stephen Hughes, *Copperopolis: landscapes of the early industrial period in Swansea*, Aberystwyth: Royal Commission on the Ancient and Historical Monuments of Wales, 2008.

17 John Scoffern, William Truran, William Clay, Robert Oxland, William Fairbairn, W.C. Aitkin, and William Vose Pickett, *The useful metals and their alloys*, London: Houlston & Wright, 1866, p. 551.

**Figure 2.** The World of Copper, 1830–60. The map shows the principal sources of furnace stuff for the British copper industry in the middle of the nineteenth century. It is not exhaustive: mining districts whose contributions were small, intermittent, or no more than experimental are omitted. For the sake of clarity the mining districts of England and Wales are not shown. Source: created by ERA-Maptec Ltd. (Ireland).



were made in the tariff regime, however, as happened in the late 1820s, foreign ores could enter the British market on a competitive basis.<sup>18</sup>

With this, the World of Copper opened up (see Figure 2). Its first phase, from *c.*1830 to the mid 1840s, was dominated by Latin American ores, from Gran Colombia, Chile, and Cuba. Of these, the Cuban contribution was the most important: it outgrew the trade in Chilean ores and outlasted mining at Aroa in modern Venezuela, which was abandoned in 1844.<sup>19</sup> The Cuban mining sector was revolutionized when two British-owned companies, the Cobre Company and the Royal Santiago Mining Company, began to exploit the lode at El Cobre in the east of the island. Old workings that had been derelict for over a century were rejuvenated by British capital and Cornish deep-mining methods, and with great success. Shipped to Swansea from the deep-water anchorage at Santiago de Cuba, El Cobre's ores would account for over half of the foreign ores entering Britain *c.*1840.<sup>20</sup>

18 Edmund Newell, 'Copperopolis': the rise and fall of the copper industry in the Swansea district, 1826–1921', *Business History*, 32, 3, 1990, pp. 75–97, esp. pp. 78–80.

19 Edmund Newell, 'The British copper ore trade in the nineteenth century, with particular reference to Cornwall and Swansea', PhD thesis, University of Oxford, 1988, p. 82.

20 Chris Evans, 'El Cobre: Cuban ore and the globalization of Swansea copper, 1830–70', *Welsh History Review*, 27, 1, 2014, pp. 112–31; Inés Roldán de Montaud, 'El ciclo cubano del cobre en el siglo XIX, 1830–1868', *Boletín Geológico y Minero*, 119, 3, 2008, pp. 361–82.

Over the course of the 1840s, however, the World of Copper was reshaped as the exploitation of Australasian ore deposits began. The new colony of South Australia played a central role. As pastoralists advanced north from Adelaide they hit upon mineral outcrops, first at Kapunda in 1842 and then at Burra Burra in 1845. The discoveries at Burra Burra (or 'the Burra') proved seminal. The bonanza enjoyed there by the South Australian Mining Association (SAMA) prompted a prospecting frenzy that transformed Australia's fortunes. Copper was quickly overshadowed by the gold rush of the early 1850s, but beyond the helter-skelter Victorian goldfields there was a steady spread of copper mining: Western Australia in 1851, New South Wales in 1858, and Queensland in 1862.

These developments ensured that the raw materials processed by Britain's mid-Victorian copper industry were a rich multinational blend. In 1848 the Hafod works, Swansea, smelted a mix that included the local (ores from the Fowey Consols mine in Cornwall and Wheal Friendship in Devon), the distant (Cuban ores), and the super-distant (ores from Burra Burra).<sup>21</sup> There was no disadvantage in such a miscellany. On the contrary, it worked very much to the benefit of Swansea's smelters. Smelting by blast furnace, the norm in continental Europe, was a single-stage process that was suited to using a homogeneous mineral charge. The Welsh process, by contrast, was a multi-stage operation involving several different reverberatories, each one housing a different stage in the reduction process. It depended upon heterogeneity for its success; each element of the mineral charge triggered one in a sequence of chemical reactions that would eventually yield pure copper. Supply chains that snaked around the world actually complemented the World of Copper's signature technology.

The appearance of Australian ores in the late 1840s heralded a new diversity in the global market for copper. Cuban mining lost its dominance as the rich carbonates and oxides that had been brought to the surface in El Cobre's early days gave way to less valuable sulphides at lower depths. Chilean ore exports to Britain were resilient though, even resurgent, and as the 1850s wore on there were other entrants besides the Australians. There were some inevitable false starts and blind alleys. The geological surveying of Jamaica yielded next to nothing, while mining in the Virgin Islands was no more than spasmodic.<sup>22</sup> However, the first of what was to be a steady series of consignments from Namaqualand, on the Cape Colony's Atlantic coast, arrived in the mid 1850s. The first supplies from Newfoundland followed, and some ore even made its way from landlocked locations such as Ducktown, Tennessee.<sup>23</sup> Not all new material could boast the high copper content of the ores from the Burra or El Cobre mines. Pyritic ores from around Huelva, on Spain's Atlantic coast, for example, were low grade, but as they yielded both copper and 'purple ore' (an iron oxide

21 John Percy, *Metallurgy: the art of extracting metals from their ores, and adapting them to various purposes of manufacture*, London: John Murray, 1861, p. 322.

22 Douglas Hall, *Free Jamaica, 1838–1865: an economic history*, New Haven, CT: Yale University Press, 1959, pp. 138–52; Roger Burt, 'Virgin Gorda copper mine, 1839–1862', *Industrial Archaeology Review*, 6, 1, 1981, pp. 56–62.

23 John M. Smalberger, *Aspects of the history of copper mining in Namaqualand, 1846–1931*, Cape Town: C. Struik, 1975, p. 127, table A; Charles K. Hyde, *Copper for America: the United States copper industry from colonial times to the 1990s*, Tucson, AZ: University of Arizona Press, 1998, p. 20; Otis E. Young, 'Origins of the American copper industry', *Journal of the Early Republic*, 3, 1983, p. 132; Patricia Bernard Ezzell, 'Burra Burra Copper Company', *The Tennessee Encyclopedia of History and Culture*, <http://tennesseencyclopedia.net/entry.php?rec=162> (consulted 24 July 2013).



that could be sold on to iron manufacturers) they were economically viable; sufficiently viable, in fact, to account for 9% of British copper ore imports in the 1850s.

The World of Copper was now at its fullest extent. Far-flung though its transactions had become, they had acquired a certain regularity and routine. Its way stations, from Coquimbo, gateway to the Chilean north, to Port Wakefield, were familiar to a generation of seafarers and itinerant industrial workers. Indeed, citizens of the World of Copper had acquired a reflexive awareness of their globality. An inlet on Kawau Island, New Zealand, where copper mining began in 1845, was christened Swansea Bay, and when investors in Tennessee sought to revamp their Ducktown mines in the late 1850s they could think of no better name for themselves than The Burra Burra Copper Company. Indeed, allusion to the now fabled ‘Monster Mine’ in South Australia seems to have been *de rigueur* among hopeful mine promoters in the 1850s, for the Cape Colony had its own ‘New Burra Burra Mining Company’.<sup>24</sup>

## Patterns of corporate control

How was the World of Copper to be governed? It had a central hub in south-west Wales but its provinces were very varied. They were to be found in all sorts of topographical and climatic settings and they harboured a great diversity of political and institutional structures. The relationships between different parts of the World of Copper were equally varied. Some provinces were controlled directly from Britain. Other parts, however, experienced a far more autonomous existence; their relationship with the Swansea district was indirect or discontinuous.

Cuba presents the clearest case of direct British control.<sup>25</sup> The companies that redeveloped the mines at El Cobre were almost entirely in British hands. Cuban involvement was restricted to a clutch of local merchants whose value lay in their political lubricity, not their command of capital. Ownership resided with distant British shareholders, for both the Cobre and the Santiago companies were joint-stock corporations that tapped huge sums on the London money markets. The 1836 share issue that reconstituted the Cobre Company produced a leviathan valued at £480,000. The Santiago Company was a significantly smaller operation, but its flotation in 1838 still realized £210,000. Both companies were directed by men from the City of London’s moneyed elite. The Cobre Company was headed by Charles Pascoe Grenfell (1790–1867), a director of the Bank of England. The affairs of the Santiago Company were steered by the super-financier Isaac Lyon Goldsmid (1778–1859) and William Thompson (1793–1854), one-time lord mayor of London and MP for the City between 1826 and 1832. Both companies also had copper masters on their boards. The Cobre Company’s Charles Pascoe Grenfell was not just a banker, for he was the proprietor of the Middle Bank and Upper Bank copper works in the Swansea valley. Michael Williams, of the Santiago Company, was both a Cornish mine adventurer and a partner in the Morfa works, Swansea. Present too were shipping magnates such as John Pirie, founder of the P&O line, who could bring their own expertise to bear on enterprises that were maritime as much as they were mineral.

24 G. T. Bloomfield, ‘The Kawau copper mine, New Zealand’, *Industrial Archaeology*, 11, 1, 1974, pp. 1–10; Smalberger, *Aspects*, Table C (folded in after p. 143).

25 Evans, ‘El Cobre’.

On-the-spot management was also in British hands. The Cobre mine was overseen by John Hardy, Jr, a merchant who doubled as the British consul at Santiago de Cuba. With huge resources at their disposal, the Cobre and Santiago companies deployed the most advanced hard-rock mining technologies of the time, those of Cornwall, and technicians (also Cornish) who were familiar with the highly distinctive steam-power systems of the English south-west.<sup>26</sup> Set to work on lodes that were on average three times the richness of those found in Cornwall, this technological package proved enormously remunerative. A British visitor in 1839 spoke of the ‘princely revenue’ that accrued to the Cobre Company, a net monthly profit of £12,000.<sup>27</sup>

Direct intervention by British investors was made necessary in eastern Cuba by the atrophy of local mining in the eighteenth century, whereas in Chile, by contrast, local mining traditions were strong. There was a well-established framework for mineral exploitation inherited from the colonial era. Staking a claim was a simple matter and, provided the mine was worked fairly regularly, the *minero* was secure in his possession. Because the barriers to entry were so low, most mines were very modest. Many miners struggled to meet the barest running costs, which left them dependent upon advances from local merchants and landowners (*habilitadores*). Fixed capital was kept to a minimum. In the mid nineteenth century ‘steam power had not even been dreamed of [in Chilean mining] ... and even whims, or horse-power drawing machines, were looked upon as costly and probably unsuccessful innovations’.<sup>28</sup> A copper mine visited by Charles Darwin was drained by labourers clambering up the shaft with water-filled leather pouches on their backs.<sup>29</sup> At another mine he watched ore-carriers, shuddering with exertion, climb a zigzag of crudely notched tree trunks to reach the surface. This was typical of the traditional mining sector, not least because the availability of alternative employment opportunities in agriculture created seasonal fluctuations in the labour supply, and made it likely that expensive equipment would be underutilized.

Technologically, the Chilean mining sector stood still, yet the early nineteenth century saw a veritable revolution in what was produced and the markets to which it was despatched. In the colonial era, silver and gold were the pre-eminent metallic exports. Bullion was shipped up the Pacific coast to Callao, the port of Lima, a route that reflected Chile’s political subordination to the Viceroyalty of Peru. Some Chilean copper was exported to Spain after direct trade was authorized in the mid eighteenth century, but the value of those exports remained low.<sup>30</sup> Such copper as exited the Spanish sphere went across the

26 See Alessandro Nuvolari, *The making of steam power technology: a study of technical change during the British Industrial Revolution*, Eindhoven: Technische Universiteit Eindhoven, 2004, for the peculiarities of the Cornish steam tradition, and Jonathan Curry-Machado, ‘“Rich flames and hired tears”: sugar, sub-imperial agents, and the Cuban phoenix of empire’, *Journal of Global History*, 4, 1, 2009, pp. 33–56, for the impact of predominantly non-Cornish steam technologies in Cuba’s sugar sector.

27 David Turnbull, *Travels in the west. Cuba; with notices of Porto Rico, and the slave trade*, London: Longman, Orme, Brown, Green, and Longmans, 1840, p. 14.

28 Quoted in John Mayo, ‘Commerce, credit and control in Chilean copper mining before 1880’, in Thomas Greaves and William Culver, eds., *Miners and mining in the Americas*, Manchester: Manchester University Press, 1985, p. 33.

29 Charles Darwin, *Journal of researches into the natural history and geology of the countries visited during the voyage round the world of H.M.S. Beagle*, London: John Murray, 1913, p. 277.

30 Marcello Carmagnani, *Los mecanismos de la vida económica en una sociedad colonial: Chile 1680–1830*, Santiago: Dirección de bibliotecas, archivos y museos, 2001, pp. 55, 61.

Pacific to Asian markets. These arrangements held firm until Chilean independence paved the way for new commercial relationships to be put in place.

Here, as in other parts of Latin America, the British led the way. The speculative boom-and-bust that convulsed South American mining in 1824–25 was inauspicious, but Chile's copper reserves represented a solid opportunity, one tied into British industrialization, which merchant houses in Valparaíso were keen to exploit. The export of metals and minerals now became more copper-hued, and the principal export route now looped around Cape Horn. Ore exports to Britain took off in the mid 1830s, rising from 411 tons in 1833 to 12,993 tons five years later.<sup>31</sup> There was little outside investment in mining itself though. Traditional funding mechanisms continued to underpin the sector, both in the central belt around Santiago and Valparaíso, and in the rapidly growing Norte Chico. British merchant houses rarely intervened, concentrating instead on assembling cargoes for the 'Swansea-fitted' barques that would carry ore to the North Atlantic.

Outside capital was deployed in the smelting of ore, however. British mining companies in Cuba had not ventured into the reduction of ore because they were so closely connected to Swansea smelters. There was no such inhibition in Chile. Smelting on the Welsh model would allow foreign capitalists to process sulphide ores that the comparatively crude local reduction methods could not digest. Charles Lambert (c.1794–1876), the French-born agent of a British mining association, introduced the reverberatory furnace to Chile in the 1830s, establishing a modern smelting plant near La Serena in the Norte Chico.<sup>32</sup> Others, mostly Anglo-Chilean partnerships, followed. Joaquín Edwards founded an 'English works' at Lirquén in Coquimbo province in 1843; the construction of plant for the Mexican & South American Company at Herradura, also near Coquimbo, began four years later.

The emergence of a modern smelting sector in the 1840s was eased by the development of a domestic coal industry in the southern province of Concepción, and the relaxation of restrictions on imported British coal, which together made reverberatory furnaces viable.<sup>33</sup> The development of new smelting capacity in Chile, fuelled by Welsh coal and *carbón de piedra* from Concepción, now seemed opportune. Industrial modernity could take root. Even so, the growth of smelting was not confined to streamlined processing plants on the Welsh pattern. Copper production also grew in the central provinces, the industry's old heartland, but it did so on the basis of traditional wood-burning technology and without external investment. So it was that in Chile, unlike Cuba, mining continued along time-honoured lines. A good deal of the ore was directed to customers overseas, just as in the Cuban case, but significant volumes were smelted locally, using both traditional and modern methods.

In Australia and South Africa the World of Copper assumed yet another form. Technologically advanced mining complexes were put in place but under local rather than British tutelage. The mining frontier in South Australia and Namaqualand in the 1840s and

31 *Accounts relating to the import and export of copper, copper ore, brass and copper manufactures*, British Parliamentary Papers 637, 1847, p. 2.

32 Claudio Veliz, 'Egaña, Lambert, and the Chilean mining associations of 1825', *Hispanic American Historical Review*, 55, 4, 1975, pp. 637–63.

33 Luis Valenzuela, 'The Chilean copper-smelting industry in the mid-nineteenth century: phases of expansion and stagnation, 1834–1858', *Journal of Latin American Studies*, 24, 3, 1992, pp. 507–50; Luis Ortega, 'The first four decades of the Chilean coal mining industry, 1840–1879', *Journal of Latin American Studies*, 14, 1, 1982, pp. 1–32.

1850s advanced across territories that were populated by aboriginal hunter-foragers, but the respective colonial capitals, Adelaide and Cape Town, each had a resident capitalist class eager for investment possibilities. Mineral exploitation was the best of all prospects: it opened up local resources while fostering the closer integration of the colony with the global economy. Nothing was more pleasing to local boosters. Cape Town could aspire to be more than a victualling stop for the shipping that passed between the North Atlantic and the Indian Ocean, and Adelaide could be more than the half-built headquarters of a near-bankrupt colonial experiment. Not even the most sanguine projectors could have foreseen the bounty at the Burra, however. The SAMA, established in 1845, paid fifteen dividends, each of 200%, in the first five years of its existence.<sup>34</sup> Nothing in Namaqualand could match that, although incorrigibly optimistic investors set off a speculative spiral in the mid 1850s, hoping that the quality of the ore could offset the remoteness of the deposits (1,000 metres above sea level and far inland from a barren coast with no harbour facilities).

Australian ores were shipped to Swansea Bay, naturally enough, but Adelaide's business class was from the outset keen to assert its independence of Swansea's smelting companies. Thus, the SAMA made an abortive attempt to smelt Burra Burra ore at the pithead with a German-style blast furnace in 1846–47, a misstep that probably reflected the SAMA partners' ignorance of contemporary metallurgical practice.<sup>35</sup> Collaboration between the SAMA and the Patent Copper Company (PCC), which had works at Spitty Bank near Llanelli, produced a more satisfactory outcome. The PCC established a works in the Welsh manner at Kooringa, adjacent to the Burra mine, where six reverberatories were lit in 1849. This was where low-grade material would be smelted; the richer Burra Burra ores would go to Spitty.<sup>36</sup> The decision of the PCC to split its operations between 'core' and 'peripheral' locations, using both imported coal and local timber to fuel its Kooringa works, heralded the slow fraying apart of the Swansea-centric system that had flourished in the 1830s and 1840s. The World of Copper would henceforth take on a more complex, multi-focal structure.

## Modes of labour

The arrival of the barque *Richardson* at Port Adelaide in October 1848 was greeted in the South Australian press as a turning point in the short history of the colony. The ship, which had cleared Swansea five months earlier, was laden with materials to be carted up-country and assembled at Kooringa, 'affording the colonists all necessary means and appliances for converting the crude ores of the colony, into merchantable metals'. The contents of the *Richardson*, the *South Australian Register* averred, were 'destined to revolutionise the mining efforts' of South Australia.<sup>37</sup> So they would, but only when combined with the *Richardson*'s passengers, who comprised a complete workforce for a Welsh-style smelting works.

34 Jason Shute, *Henry Ayers: the man who became a rock*, London: I.B. Tauris, 2010.

35 Peter Bell and Justin McCarthy, 'The evolution of early copper smelting technology in Australia (Part I)', *Journal of Australasian Mining History*, 8, 2010, p. 3.

36 Mel Davies, 'Balanced costs: inland copper smelting location and fuel in South Australia 1848–76: were they so naive?', University of Western Australia, Department of Economics, working paper 05–25, 2005, pp. 1–17.

37 *South Australian Register*, 4 October 1848.

Thomas Henry Williams, the PCC's designated manager, travelled out in relative style, as befitted a son of Michael Williams, the Swansea copper master and director of the Royal Santiago Mining Company in Cuba. The assayer and the clerk for the projected Kooringa works also took cabins, but most of the workforce travelled in steerage: twenty-five men who had engaged themselves to work for seven years. They had been recruited in Wales: from Cwmavon, on the Swansea district's eastern edge, and from Loughor (Llwchwr in Welsh), where the PCC had its Spitty Bank works. In acknowledgement of the fact, the township built for them at Kooringa was christened 'Llwchwr'.<sup>38</sup>

In terms of copper, Australia was a *tabula rasa*. Everything needed for modern industry, animate and inanimate, had to be brought in. It was taken for granted that copper smelters should be Welsh or at least schooled in the Welsh process. It was equally axiomatic that Cornwall was a reservoir of hard-rock mining expertise. The expansion of the World of Copper therefore had a major effect on the labour market in both the Cornish mining and the Welsh smelting sectors. As regards Cornish mining, the price that ores from the English south-west fetched in Swansea trended downwards in the 1840s as growing volumes of foreign minerals entered the market. At the same time, work opportunities overseas started to multiply. The outcome was a major dispersal of mining labour. 'It is a fortunate thing for the colony', a South Australian newspaper announced as early as 1844, 'that there is here a large force of Cornish miners.'<sup>39</sup> Indeed, Cornish toponyms already dotted the Adelaide Hills, Cornish work practices prevailed, Cornish technologies were adopted, and Cornish mining terminology was universally used.<sup>40</sup> Cultural preferences followed suit. It was reported in 1848 that the feast of Piran, patron saint of Cornish miners, was celebrated at the Burra with 'wrestling matches, the favourite amusement of Cornwall'.<sup>41</sup>

The imprint of Welsh smelting was not quite so profound. The numbers employed in extracting ore were necessarily greater than the numbers engaged in smelting it. Even so, the Australian smelting sector was significant. The works at Wallaroo, one of dozen such works scattered across South Australia and New South Wales in the early 1860s, was hailed as 'the most extensive in the colony, and the largest, I believe, out of Swansea'. It had four calcining furnaces, twenty-two smelting reverberatories and three refining furnaces. 'About 150 hands are employed here, besides wood-carters.'<sup>42</sup>

Cornish miners and Welsh smelters prevailed in Australasia because they had no conceivable rivals. Indigenous peoples were too few in number and too intermittent in their engagement with the labour market. The field was clear for British workers, who enjoyed high wages, cultural esteem, and (from the 1850s) political rights. Nowhere else in the World of Copper did they occupy so commanding a position. In Chile they found themselves confined to more marginal spaces, even in death, when their bodies were consigned to spiritual quarantine in the *cementerio inglés*. Robert Charles Jones, a Welsh missionary who

38 Greg Drew, 'The Leyshon Joneses: father and son Welsh smeltermen who dominated the South Australian smelting industry from 1848–1877', unpublished paper for World of Copper workshop, Burra, South Australia, 24–26 September 2012.

39 *South Australian*, 22 March 1844.

40 Philip Payton, *The Cornish overseas*, Fowey: Alexander Associates, 1999, pp. 166–201.

41 *South Australian*, 14 March 1848.

42 Austin, *Mines of South Australia*, pp. 98–9.

wandered through the Protestant plot at Guayacán in 1874, found that Swansea and Cwmavon had ‘sent many a speck of dust to rest quietly in this place’.<sup>43</sup> That Welsh smelters were interred in a cemetery reserved for aliens speaks of their ambivalent position in Chile: they represented the world’s hegemonic commercial and technological power, but were essentially sojourners, restricted to specialist enclaves. ‘The little Guayacan colony of workmen from this country’, *The Times* of London reported, were ‘nearly all from Wales’. Between forty and fifty of them were employed at the works of Urmeneta & Errázuriz; the Welsh played a decisive role in this modern, coal-fired establishment, but even within its confines they were a minority since the workforce totalled ‘about 300 hands’.<sup>44</sup>

For the Welsh, Chile was a jarringly foreign environment, but it must be remembered that the Norte Chico could also be an unfamiliar experience for their Chilean co-workers. The northern mining region churned with immigrants, the vast majority of whom came from within Chile, not far-distant Britain. Mining settlements (*placillas*) sprang from the soil, flourished briefly, and then withered as the lode they exploited began to taper off. Labour was nomadic, responding to the wax and wane of geological good fortune. Andean mining was also transhumant, for *placillas* built at altitude were often abandoned in the depths of winter; others were deserted during the sowing season and at harvest time. The Norte Chico was therefore an unstable place: a frontier zone whose population leapt upwards during the mining boom in the middle third of the nineteenth century. At the end of that period, as the mining sector sagged, the region’s ever-mobile population adjusted. Many continued their quest for work by heading for the newly opened silver mines of Caracoles in Bolivia or the nitrate fields of southern Peru. Others were reabsorbed wholly into the agricultural sector as the Norte Chico ruralized in the last decades of the century.<sup>45</sup>

Namaqualand also relied upon a mixed workforce, partly European and partly African. When the speculative tumult of the 1850s subsided, just three substantial mining concerns remained, the largest of which was recast as The Cape Copper Mining Company in 1862. This new firm marked a juncture between local capital (hitherto inexpertly applied) and British expertise, for behind The Cape Company stood John Taylor & Sons of London, the leading mining consultancy of the age.<sup>46</sup> European workers, Cornishmen for the most part, set the technological parameters. That, at least, is the conclusion to be drawn if the prevalence of Cornish terminology is any guide. When miners at O’okiep hacked their way through non-mineralized rock they were said to engage in ‘tut-work’, just as in Cornwall, and were paid for the volume of material they handled; those who extracted the precious ore were ‘tributers’, who were paid, in accordance with Cornish practice, on the value of what they raised.<sup>47</sup> They were well rewarded, as befitted their status as industrial aristocrats.

43 Quoted in Bill Jones, ‘Labour migration and cross-cultural encounters: Welsh copper workers in Chile in the nineteenth century’, *Welsh History Review*, 27, 1, 2014, p. 133.

44 *The Times*, 20 January 1874.

45 Luis Ortega, ‘Fragilities of a frontier zone: townships and villages in the copper mining districts of Chile 1830–1875’, unpublished paper for World of Copper workshop, Burra, South Australia, 24–26 September 2012.

46 Smalberger, *Aspects*, p. 69; Edmund Newell, ‘Taylor, John (1779–1863)’, *Oxford Dictionary of National Biography*, Oxford University Press, 2004, <http://www.oxforddnb.com/view/article/27059> (consulted 28 August 2013).

47 Smalberger, *Aspects*, p. 105; Payton, *Cornish overseas*, pp. 347–9.

Most of those who worked in Namaqualand's mines, however, lacked the inestimable benefits of white skin and British citizenship. A good deal of the underground work and all surface tasks were performed by 'Native labourers': juveniles and women who undertook the laborious task of moving and 'dressing' the ore. The African labour force was drawn from across the south of the continent: 'Damaras, Zulus, Hottentots, Bushmen, &c'.<sup>48</sup> Their rewards were meagre. The African workers, in the lofty opinion of one European observer, were mostly 'from tribes unacquainted with civilization' and therefore, when viewed through the racial optic of the time, naturally unindustrious.<sup>49</sup> Stern discipline was necessary if such disadvantages were to be overcome. Happily for the mining companies, draconian legal mechanisms were at their disposal. Slavery had been abolished at the Cape in the 1830s as part and parcel of a programme of emancipation in Britain's wider Atlantic empire, yet no sooner had outright slavery been abolished and the enslavement of native peoples moderated than a new legal code was introduced to pinion African labourers to their tasks. Masters and Servants legislation of an unusually restrictive stripe was introduced in 1841, inaugurating a 'labour-repressive economy where workers may not have been slaves, but they were certainly not free'.<sup>50</sup> Further legislation, enacted in the mid 1850s as the copper mania in Namaqualand gathered strength, handed still more powers to employers.<sup>51</sup> The World of Copper put in place what would later become a defining feature of the Witwatersrand and of South African mining as a whole – the division between a privileged white industrial elite and a subordinate black proletariat.

Racial divisions in the Cuban mining sector were still starker, for the British companies made heavy use of slave labour, the default option in mid-century Cuba. Deep mining began with the inevitable troupe of Cornishmen: the 'present establishment', Santiago Company shareholders were assured, 'consists of one superintendant [*sic*], one head and two sub-mine captains, thirty eight miners, one head blacksmith, [and] one head carpenter, all from Cornwall'.<sup>52</sup> But it was an unspoken assumption that this cadre would be supported by a far larger auxiliary labour force. Indeed, hundreds were needed to carry out the more mundane operations – the endless de-watering of the mines, the crushing and grading of the ore, haulage of every description, and fetching feed for the many hundreds of draught animals used in haulage. 'Englishmen in general, including Officers' accounted for only 80 of the Cobre Company's 651-strong workforce in December 1836.<sup>53</sup> Enslaved Africans made up most of the balance. El Cobre was a mountain village populated by free people of colour before the advent of the British companies. In little more than a decade it was transformed into a giant

48 Quoted in Smalberger, *Aspects*, p. 107.

49 Quoted in *ibid.*, p. 106.

50 Nigel Worden and Clifton Crais, 'Introduction', in Nigel Worden and Clifton Crais, eds., *Breaking the chains: slavery and its legacy in the nineteenth-century Cape Colony*, Johannesburg: Witwatersrand University Press, 1994, p. 6.

51 M. K. Banton, 'The Colonial Office, 1820–1855: constantly the subject of small struggles', in Douglas Hay and Paul Craven, eds., *Masters, servants, and magistrates in Britain and the empire, 1562–1955*, Chapel Hill, NC: University of North Carolina Press, 2004, pp. 262–4.

52 *Morning Chronicle*, 19 March 1838, p. 1.

53 The National Archives (henceforth TNA), FO 84/201, 'Summary of the distribution of the operatives employed at the Royal Consolidated Cobre Mines', enclosed in John Hardy, Jr to Lord Palmerston, 27 December 1836.

mining complex dominated by freshly (and illegally) imported captives from the Bight of Biafra – a feature that the British companies did not draw to the wider world’s attention.<sup>54</sup>

Stabilizing the workforce at El Cobre was problematic, however. The European contingent was instantly depleted by yellow fever. Late in 1838 a British guest of the Cobre Company reported that ‘a year before our arrival, there had been two hundred Englishmen from Cornwall; but a single sickly season had carried off the half of them, including two of the captains’.<sup>55</sup> There was little exaggeration in this. The losses at El Cobre were so severe that Cornish miners began to think better of journeying to a tropical charnel house. In their stead, the Cobre and Santiago companies had to drum up recruits in North and South Wales, enlisting ‘ignorant Welshmen who would be more properly described as labourers than miners’.<sup>56</sup> The mining companies’ resort to slave labour also shrank back in the face of island-wide unrest on the part of the enslaved in the 1840s. A sense of self-preservation jolted the Cuban authorities into enforcing their own previously disregarded embargo on slave importation. With the supply of African labour now tightening, the Cobre Company, like many Cuban slave-owners, looked further afield. They found what they wanted in China’s Guangdong province, the main recruiting ground for the nascent ‘coolie trade’ of the 1840s. Nearly 125,000 Chinese labourers were sold in Havana between 1848 and 1874, most of them destined for the sugar zone in the west of the island; some *colonos asiáticos* went to eastern Cuba though, to the shafts and galleries of the Cobre mines.<sup>57</sup> They joined the most variegated and polyglot of the World of Copper’s workforces.

## The World of Copper in eclipse

The World of Copper was in constant motion, shifting in form as new fields of mineral exploitation were opened up and new harbours added to the roster visited by copper barques. In the 1830s and 1840s such shifts had generally been outwards and the World of Copper had been firmly defined by the centripetal pull of the Swansea district. In the 1850s and 1860s those features became less pronounced.

The success of the Swansea district, which was based upon the bringing together of seaborne ore and locally sourced coal, was something that others might emulate. The Baltimore & Cuba Copper Company was established in 1846 to do just that. Its works was built on the waterfront of what was then the second-ranked port in the United States, at which foreign ores could be unloaded and to which Pennsylvanian coal could be brought by rail. As the company’s name suggested, it was intended that ore should be shipped into Baltimore from Cuba. In the event, Cuban supplies did not live up to the hopes of the company’s promoters, but ores were also brought in from Chile, as well as from locations up and down the eastern seaboard of the United States. Reverberatory furnaces were installed

54 Chris Evans, ‘*Carabalí* and *culíes* at El Cobre: African slaves and Chinese indentured labourers in the service of Swansea copper’, *Revista de Historia Social y de las Mentalidades* (forthcoming); Chris Evans, ‘Brazilian gold, Cuban copper and the final frontier of British anti-slavery’, *Slavery & Abolition*, 34, 1, 2013, pp. 118–34.

55 Turnbull, *Travels in the west*, p. 9.

56 TNA, FO 72/634, Charles Clarke to Joseph Crawford, 27 April 1843.

57 Mary Turner, ‘Chinese contract labour in Cuba, 1847–1874’, in Hilary Beckles and Verene Shepherd, eds., *Caribbean freedom: economy and society from emancipation to the present*, Princeton, NJ: M. Wiener Publishers, 1996, pp. 132–40.



and a ‘whole colony of smelters was imported from Wales’ to work them.<sup>58</sup> In this way, Baltimore was projected as the Swansea of the Chesapeake.

The promoters of the Baltimore & Cuba Copper Company, closely followed by the founders of the Baltimore Copper Smelting Company (1850), envisaged a straightforward replication of the Welsh model in the New World.<sup>59</sup> More threatening from a Welsh perspective was an adaptation of the Welsh smelting process that would allow it to roam freely, detached from its original geological and maritime moorings. The Welsh process was lavish with fuel, which was why smelting in the British Isles had clustered in coal-rich South Wales, but every adjustment that saved on coal (or allowed the substitution of a different energy source) loosened Swansea’s grip on the World of Copper. Abridgements of the Welsh process, of which there were several at mid century, paved the way for a dispersal of smelting worldwide.<sup>60</sup> The Swansea copper master John Henry Vivian specified eight separate processes in his description of the Welsh process in the 1820s.<sup>61</sup> The chemist James Napier, writing in the 1840s, described a six-stage process.<sup>62</sup> Napier’s own patent process was even more abbreviated. His patrons, the PCC, claimed that they could smelt Burra ores in an operation with just two stages.<sup>63</sup> It was on this basis that the PCC, under the leadership of Henry William Schneider, built its plant at Kooringa. The same considerations led the Mexican & South American Company, another Schneider-led enterprise, to adopt the Napier process at its Herradura works near Coquimbo.<sup>64</sup>

It was also possible to disaggregate the Welsh process spatially, performing an initial reduction of the ore near to its place of excavation and completing the final stages at Swansea. The World of Copper therefore became one in which regulus (a copper matte with a metallic content of 40–50%) circulated as well as ore. The trade in regulus had a strong Chilean flavour. Chile had a native smelting tradition, mines that were almost entirely in Chilean hands, and a merchant class that was not beholden to Swansea’s smelters. There was every incentive to retain preliminary processing within Chile. By the 1850s British imports of Chilean regulus, which averaged over 26,000 tons annually in that decade, exceeded the import of Chilean ores (a little over 20,000 tons annually). Indeed, the British market absorbed 80% of Chile’s regulus export.<sup>65</sup>

Regulus production was slower to emerge elsewhere. Even so, the benefits were clear enough, especially at times when ore prices were falling or ore was declining in quality. In such

58 Vivian, *Copper smelting*, pp. 33–4.

59 *Exposition of the Baltimore and Cuba Smelting & Mining Company*, Baltimore, MD: Robert Neilson, 1845.

60 Snowden Piggot, *Chemistry and metallurgy*, pp. 331–7.

61 John Henry Vivian, ‘An account of the process of smelting copper as conducted at the Hafod copper works, near Swansea’, *Annals of Philosophy*, n.s. 5, 1823, pp. 113–24.

62 James Napier, ‘On copper smelting’, *London, Edinburgh and Dublin Philosophical Magazine and Journal of Science*, 4th series, 4, 1852, pp. 45–59, 192–201, 262–71, 345–55, 453–65; 4th series, 5, 1853, pp. 30–9, 175–84, 345–54, 486–93.

63 Davies, ‘Balanced costs’, p. 3.

64 Valenzuela, ‘Chilean copper-smelting industry’, p. 522.

65 Manuel Llorca, ‘Chilean exports of copper to Wales during the nineteenth century: their impact on the Chilean and Welsh economies’, *Revista de Historia Social y de las Mentalidades* (forthcoming).

circumstances the value of the metal might be insufficient to justify the cost of freighting the rocky matrix in which it was locked. These factors led the Cobre Company to begin making regulus in 1862–63; the Cape Copper Mining Company followed suit in 1864–66.<sup>66</sup>

This pointed the way towards a new international division of labour, in which South Wales played a more restricted part. Swansea was no longer the ‘central smelter for minerals from East and West’ that Frédéric Le Play had explored in the 1840s. Primary smelting became dispersed and Swansea’s global role was rejigged; it was recast as a specialist centre for the refining of copper matte, especially argentiferous matte. If the silver content warranted the cost, matte would be taken to Swansea, however rough the terrain or demanding the route. Thus, argentiferous matte was carried down by mule from the mountains of Sonora to Mexico’s Pacific coast, and thence to Swansea Bay. Matte from the smelter at Black Hawk, Colorado, which yielded over 100 ounces of silver in every ton, was despatched to the Hafod works of Messrs Vivian, notwithstanding the immense distance that had to be covered just to reach the Gulf coast.<sup>67</sup>

These processes, once initiated, were ineluctable and foretold slow disintegration for the World of Copper that had flourished in the 1830s and 1840s. Such was the spatial logic at work; yet, in actual fact, that logic was not given the opportunity to unfold. The global system that had been so heavily skewed towards Swansea did not ebb quietly; it dissolved with sudden speed in the late 1860s. The demise of the World of Copper was precipitated by a crisis in the global market in the era of the American Civil War. Copper had been an important materiel for the belligerent parties in North America, and the high price that it commanded stimulated an extension of production and an inevitable crash at the war’s end.

The crash in prices became sustained because of the opening up of new deposits deep in the North American interior. Although Lake Superior copper had been mined since the 1840s, smelting on Michigan’s Upper Peninsula did not begin until 1860. When it did, it marked the true beginnings of the US copper sector, and a rapid-fire reordering of global production. Several mainstay features of the old World of Copper disappeared. Cornish mining, the foundation stone upon which the World of Copper had first been raised, slumped, never to recover. Chilean mining was also hit hard, its problems compounded by the onset of war between Chile and Spain in 1865, and the complete derangement of commerce and credit that followed. Elsewhere, the Cobre Company was wound down in 1868–69, and the entire Cuban copper mining industry disappeared with it. Deep mining at the Burra also came to a stop in 1868. That was far from the end of copper in South Australia, for Burra’s demise overlapped with the sinking of new mines on the Yorke Peninsula, but ores were now consumed locally in the furnaces at Wallaroo, not packed off to Swansea Bay.<sup>68</sup>

Once Michigan producers had acquired their own smelting capacity they saw little need to participate in an international division of labour of the sort pioneered by South Wales.

66 *Consolidated Copper Mines of Cobre: report of Mr Petherick, F.G.S.*, London: George Unwin, 1863, pp. 9–10; Smalberger, *Aspects*, p. 69.

67 Samuel Truett, *Fugitive landscapes: the forgotten history of the U.S.–Mexico borderlands*, New Haven, CT: Yale University Press, 2006, p. 80; James E. Fell, Jr, *Ores to metals: the Rocky Mountain smelting industry*, Boulder, CO: University Press of Colorado, 2009, pp. 30–4.

68 Philip Payton, *Making Moonta: the invention of Australia’s Little Cornwall*, Exeter: Exeter University Press, 2007.

Indeed, because the Great Lakes deposits were of ‘native copper’ – copper found naturally in its metallic form, threaded through host strata – they had no need of the Welsh process. The Michigan producers were engaged in melting, not smelting. The basket of ores used in the prolonged, multi-stage reduction process that characterized the World of Copper was of no use to them. As copper prices trended downwards in the 1860s, the companies of the Upper Peninsula pressed for the exclusion of foreign materials, arguing that they could supply all the copper that America needed and some to spare. They were rewarded with the US tariff act of 1869, passed at the behest of Michigan representatives, which raised formidable barriers against the entry of foreign copper and foreign ores. Needless to say, this was fatal for the east coast producers, who depended upon the inflow of furnace stuff from overseas.<sup>69</sup> Baltimore’s future as the Swansea of the eastern seaboard was to be thwarted. Henceforth North American copper would follow a continental rather than an oceanic path of development.

By the 1870s the US mining frontier had reached the Rocky Mountain West, where new forms of industrial gigantism took hold. The great centres of late nineteenth-century copper (such as Butte, Montana) drew upon a Cornish and Welsh heritage but rapidly transcended it, opting for smelting and refining methods that were rooted in the blast furnace traditions of continental Europe (such as the waterjacket furnace) or which did not depend upon coal at all (such as the Manhes converter, a French twist on the Bessemer process used in steel production). Even where elements of the old Welsh process were retained, they took on a new, vastly inflated form. Writing in 1910, a US metallurgist compared ‘the small Swansea type’ of reverberatory that had been introduced to the American West in the 1870s ‘to the furnaces now in use’. From the vantage point of the early twentieth century, those early furnaces appeared puny, with a hearth area of just 105 square feet. Under open Western skies the reverberatory furnace assumed monstrous proportions. By 1910 the typical calciner hearth in the United States covered 1,967 square feet.<sup>70</sup>

Copper output continued to grow in Britain until the 1890s, but even here production networks were reconfigured, both spatially and technologically, in the second half of the nineteenth century. The headlong expansion of dock accommodation at Liverpool – in strong contrast to congested and outmoded berthing facilities in south-west Wales – allowed for a revival of copper smelting in the Mersey valley, where the industry had flourished in the eighteenth century.<sup>71</sup> Liverpool offered ore-shippers a faster turnaround, and a much wider choice of return cargoes, than Swansea. Moreover, the inflow of pyritic ores from the Iberian Peninsula, which were used in the chemicals industry and from which copper emerged as a by-product, meant that the metal was produced in regions such as the north-east of England, where there was no prior tradition of copper smelting.<sup>72</sup>

69 Jonathan Leitner, ‘Red metal in the age of capital: the political ecology of copper in the nineteenth-century world-economy’, *Review: A Journal of the Fernand Braudel Center for the Study of Economies, Historical Systems, and Civilizations*, 24, 3, 2001, pp. 411, 416–17.

70 Edward Dyer Peters, *The practice of copper smelting*, New York and London: McGraw-Hill Book Co., 1911, p. 326.

71 Robin Craig, ‘The copper ore trade’, in David Alexander and Rosemary Ommer, eds., *Volumes not values: Canadian sailing ships and world trades*, St John’s, Newfoundland: Memorial University of Newfoundland Maritime History Group, 1979, pp. 277–302; W.H. Jones, *History of the port of Swansea*, Carmarthen: W. Spurrell & Son, 1922.

72 Newell, ‘British copper ore trade’, pp. 36–41.

It would be a mistake to think that the Swansea district sank into torpor. Leading firms such as Vivians were well aware of what was globally current, and were quick to install Manhes converters at their Hafod works.<sup>73</sup> However, the huge amounts of capital sunk in still-effective ‘Welsh’ smelting works inhibited the take-up of new methods across the Swansea district as a whole. Indeed, there was little incentive to write off old plants when the new methods’ principal savings lay in labour and coal, factors of production that were both relatively cheap in Swansea.

World-leading developments were still possible in South Wales. Electrolytic refining, which made its debut at the Pembrey Works outside Llanelli in 1869, was a prime example. Yet electrolytic methods had no organic connection to South Wales. Ominously, they could be practised wherever electricity was available, and soon were. Electrolytic refining was readily transferable to the American Mountain West, where the potential for harnessing hydroelectric power was immense, and it was highly compatible with the new, monumental style of copper smelting to be found there. ‘The process of electrolytic refining’, wrote E. D. Peters, the oracle of contemporary American metallurgy, ‘is of such a nature that it cannot well be connected with an ordinary smelter. It requires cheap power, highly trained chemists and electricians, and a general scale of operations too large to be in harmony with any but an exceptional smelting plant.’<sup>74</sup>

## The global history of copper

The copper masters of south-west Wales had brought a World of Copper into being at the end of the 1820s with a boldness that awed Frédéric Le Play. The speed of that transformation should not, however, obscure the fact that the Swansea smelting district had been able to boast an international profile ever since its first emergence in the 1690s. The early British copper industry had a pronounced orientation towards overseas markets. Initially, these were Atlantic and intimately connected with the circuits of Atlantic slavery. Copper and brass articles were exported to Africa as trade goods, while copper vessels were vital for the making of sugar and rum by enslaved workers in the Caribbean.<sup>75</sup> Later, especially from the 1760s, India became a major export market.<sup>76</sup> British-made copper could serve such widely spread and expansive markets because it captured a pyrochemical energy that was unique to metal processing in the British Isles.<sup>77</sup> Coal-fuelled, multi-stage smelting on the Welsh model diverged fundamentally from the charcoal-burning, single-stage

73 R. O. Roberts, ‘The smelting of non-ferrous metals since 1750’, in Arthur H. John and Glanmor Williams, eds., *Glamorgan county history. Vol. 5: industrial Glamorgan from 1700–1970*, Cardiff: Glamorgan County Council, 1980, pp. 74–5.

74 Peters, *Practice of copper smelting*, p. 533.

75 Chris Evans, *Slave Wales: the Welsh and Atlantic slavery, 1660–1850*, Cardiff: University of Wales Press, 2010, pp. 31–41; Nuala Zahedieh, ‘Colonies, copper, and the market for inventive activity in England and Wales, 1680–1730’, *Economic History Review*, 66, 3, 2013, pp. 805–25.

76 Bowen, ‘Sinews of trade’.

77 The centrality of mineral energy to British industrialization is the theme of E. A. Wrigley, *Continuity, chance and change: the character of the Industrial Revolution in England*, Cambridge: Cambridge University Press, 1998, and R.C. Allen, *The British Industrial Revolution in global perspective*, Cambridge: Cambridge University Press, 2009.

Eurasian and African norm. The singularity was still remarked upon two centuries later: ‘South Wales against the world!’<sup>78</sup>

Coal and the reverberatory furnace proved a richly productive combination, one that propelled the British Isles from the outer margins of European copper smelting to international prominence over the course of the eighteenth century. Britain, which had been dependent upon cupreous imports from northern Europe in the seventeenth century, became the major player in Asian, African, and American markets. The Dutch were assailed in Atlantic markets, and Japanese copper was rudely evicted from the South Asian markets that it had dominated through most of the early modern era. Plainly enough, the coal and reverberatory dyad gave command over markets far and wide, but the transnational potential of Swansea copper as a production system was corseted by the mercantilism of eighteenth-century British imperialism – only ores from within the Hiberno-British archipelago were eligible for smelting.

For the World of Copper to take shape, the highly regulated world economy favoured by Hanoverian policy-makers had to be undone. That was achieved with a post-Napoleonic settlement that saw the British state begin to propound (and where possible enforce) a more liberalized international economic order. This breakout from the old mercantilist exoskeleton was piecemeal and not always untroubled. British producers were convinced that changes to Britain’s tariff regime in 1842 undermined their hegemony in the world market by encouraging ore-exporting countries to develop their own smelting capacity.<sup>79</sup> The evidence is ambivalent, however, and it may be that the sprouting up of modern copper works in Chile, Australia, and the United States over the course of the following decade owed more to local factors. Whatever the case, such diversification was not immediately fatal to the World of Copper, which retained its essential coherence into the 1850s.

What did prove deadly was a reordering of the global economy in the aftermath of the American Civil War. The opening up of Michigan’s copper deposits was but the signal for a wider transformation. The pushing of the American mining frontier deep into the continental interior, coupled with the topping out of a tariff wall in 1869, was a matter of global moment, not a question of US domestic development. This was a model of nationally bounded, protectionist industrialization that stood apart from the now languishing World of Copper. The international cotton industry, which underwent an even more dramatic convulsion of its own in the 1860s, provides an apt point of comparison. Before the outbreak of the civil war, cotton from the American South was traded freely under British tutelage. That arrangement was liquidated by wartime embargoes and the Cotton Famine that ensued. The famine, in turn, prompted the extension of cotton cultivation into virgin zones, such as Turkestan or Maharashtra, to service national or imperial cotton industries that had been deprived of supplies from the international market. As one historian of cotton has written, ‘The political economy of continental industrialization now won out over the political economy of Atlantic trade.’<sup>80</sup>

78 Vivian, *Copper smelting*, p. 18.

79 British Parliamentary Papers, 1847–48 (186). *Copper duties. Copies of all memorials in reference to the copper duties, which have been presented to the Treasury or other departments of government since July 1847.*

80 Sven Beckert, ‘Emancipation and empire: reconstructing the worldwide web of cotton production in the age of the American Civil War’, *American Historical Review*, 109, 5, 2004, p. 1435. See also Bayly, *Birth of the modern world*, pp. 162–3.

To rephrase this in a manner more appropriate for the copper industry, the political economy of continental industrialization ousted the political economy of British-sponsored globalism.

The continental model was now the one to follow, not the oceanic. The revival of copper production in Japan under the Meiji Restoration was carried forward on just this basis: tariff protection and gargantuan technologies imported from the American West, not from Swansea Bay. This was an organizational model that rested upon vertical integration. The Anaconda Company of Butte exemplified the new approach, integrating ‘vertically into timber, water, transportation, smelting and refining’.<sup>81</sup> The separation of functions that had characterized the World of Copper, where smelting concerns and the mines that supplied them had been separately owned rather than brought within a single corporate envelope, no longer held. Vertical integration, often accompanied by horizontal amalgamation, demanded the deployment of quite staggering sums. The Amalgamated Copper Company, which had Anaconda as its core, was floated in 1899 with a capital value of US\$75 million. Alongside this, the World of Copper suddenly appeared quaint.

As the corporate form of the copper industry changed, so did its human dynamics. In the World of Copper’s heyday the Cornish and the Welsh were the most intrepid of industrial travellers. If we are to speak of a nineteenth-century ‘British World’, it cannot be said that the Cornish, still less the Welsh, counted for much in raw numbers; but if we view miners and itinerant smelters as fulfilling a more specialized function, as dauntless frontier scouts, then they assume a far greater importance. And if, as some recent work suggests, the growth of an ‘Anglo-World’ was a convulsive, boom-driven process, then those who headed to mineral frontiers were not quite so aberrant as at first they might seem; they, rather than sober homesteaders, were archetypal.

Be that as it may, the World of Copper coincided with the British World only partially. As a spatial entity, it was defined by geology. That underlying materiality, which neither politics nor culture could affect, took industrial migrants to places far beyond the confines of the British cultural sphere. And, as a temporal entity, the World of Copper rose and fell within a comparatively brief spell. Whereas the Anglo-World continued to unfold and flourish into the mid twentieth century, the World of Copper terminated in the 1860s, and with that the logic governing the movement or settlement of its erstwhile citizens shifted. Cornish miners continued to be exceptionally mobile. Indeed, the collapse of copper mining in Cornwall in the 1860s led to a fresh burst of out-migration by ‘Cousin Jacks’, enabling Cornishmen to maintain their position as the arbiters of global best practice in mining for some decades to come. Their model of selective underground extraction (the careful removal of a metalliferous vein from its rock matrix) continued to prosper until the spread of non-selective open-cut mining techniques in the early twentieth century. Non-selective techniques, involving the wholesale removal of low-grade ore bodies by what have aptly been called ‘mass destruction’ methods (a mining analogue of Fordist mass production), broke decisively with the *modus operandi* of the World of Copper. The Cornish of the early twentieth century could claim no privileged place in excavated bowls of the sort that now

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81 Christopher Schmitz, ‘The rise of big business in the world copper industry 1870–1930’, *Economic History Review*, 39, 3, 1986, p. 396.

began to pock Utah, vast industrial amphitheatres shaken by dynamite and the rumble of giant rock-shifting vehicles.<sup>82</sup>

The hold that Welsh workers had once exercised over the World of Copper was also long gone by this time. The superintendent of an Australian copper smelter in 1870 might still be a Welsh patriarch who had, as a young man back in the 1830s or 1840s, tended a furnace in the Swansea district, but by 1910 his successor ‘was far more likely to be a young American with a German surname and an engineering diploma from Arizona or Michigan’.<sup>83</sup> For others still, whose lives had been decisively changed by contact with British industrialization, the collapse of the World of Copper brought a radical change in prospects. The remaining enslaved miners at El Cobre were emancipated by the nationalist rebels who stormed the town in 1868, only to be conscripted straight into the insurgent army.<sup>84</sup> The fate of the *colonos asiáticos* who worked alongside them is not known.

Much else is unknown. The World of Copper was a system of production. As such, its geography can be mapped with some degree of certainty. The markets that were served by the Swansea district, on the other hand, are not so easily delineated. In part, that is because the marketing of copper products is poorly documented. The difficulty is compounded because the history of copper production and the history of its consumption do not mesh. Production was modernized at the start of the eighteenth century, but the modern, industrial consumption of copper – embodied in the tubing of steam locomotives, in telegraphic cabling, in the roller-printing of cotton, and in the generation and transmission of electrical power – was of little importance before the final third of the nineteenth century.

That requires exploration and explanation, for it is at odds with much recent literature. Advocates for an ‘industrious revolution’ maintain that modern habits of consumption precede and stimulate modern modes of production. In the all-important cotton sector, for example, the circulation of Indian fabrics in the Atlantic world prompted import substitution and technological change in Europe. Here, consumption induced changes in production. Yet copper follows a different course: supply-side innovation trumps demand-led change. World output of smelted copper rose from an estimated 2,500 tons in 1700 to 17,200 tons in 1800, and then to over 53,000 tons in 1850, with most of the increase attributable to the multiplication of reverberatory furnaces operated in the Welsh manner. But this was a period in which conspicuously new uses of copper were rare. The coppering of ships’ hulls from the 1780s onwards was a significantly new source of demand for rolled copper, but there appear to have been few others. Well over a century separated major changes in production from equally eye-catching changes in consumption. A global history of copper must address that lengthy pause. ‘Traditional’ markets were clearly buoyant. Indeed, they were keenly fought over: Australian producers entered the Indian market in the 1850s, as soon as they had the capacity to do so, tussling with their

82 Timothy J. LeCain, *Mass destruction: the men and giant mines that wired America and scarred the planet*, New Brunswick, NJ: Rutgers University Press, 2009, pp. 129–37.

83 Peter Bell and Justin McCarthy, ‘The evolution of early copper smelting technology in Australia (Part II)’, *Journal of Australasian Mining History*, 9, September 2011, p. 31.

84 TNA, FO 72/1222, copy of the emancipation decree of 31 December 1868.

Swansea rivals.<sup>85</sup> By attending to these markets, to those in East Asia and Africa, and to the complex interlocking of ‘old’ and ‘new’ consumption in the world economy, a genuine contribution to the global history of industrial modernity can be made.

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85 See the sales ledgers of the English & Australian Copper Company (State Library of South Australia, BRG 30/1), and J. E. Vivian and Edward Younger, *Remarks on the position and prospects of the copper trade in England as affected by the war between Spain and Chili*, London: Effingham Wilson, 1866, pp. 8, 11.