

Donald B. Wagner, *Ferrous Metallurgy*, Volume 5, Part 11 of Joseph Needham's *Science and Civilisation in China*, Cambridge: Cambridge University Press, 2008, 512 pp.

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Tracing the development of the iron and steel industry in China from earliest times to the mid-twentieth century, this book has been written by a scholar and researcher at the Nordic Institute of Asian Studies, University of Copenhagen, who is well known for his publications dealing with Chinese science, technology, history, archaeology, and language.

Covering a wide range of economic, geographic, and technical contexts that deal comprehensively with China's ferrous metallurgical past, this is a singular and sleek volume that is a welcome addition to the remarkable series pioneered by Joseph Needham on science and civilization in China.

This volume, as suggested by Christopher Cullen (the series' present editor and director of the Needham Research Institute), has been ably written by a recognized authority in the field "at a time when the question why one should study the technical history of China seems a clear failure to appreciate the obvious." (p. xxviii)

The author has constructed and presented his arguments in ten chapters. The first two provide an introduction and introductory orientation to the topic; the subsequent five follow and elucidate the developments and accomplishments of the iron and steel industry in China chronologically and dynastically from its earliest use through the Han, Tang, Song, and Ming periods; the penultimate chapter discusses China's modern contributions to siderurgical technology; and the final one offers an epilogue. Despite the occasional appearance of detailed summaries of archaeological research findings, his arguments and language are clear and precise and

the volume contains numerous figures, diagrams and sidebars, which enhance its readability and provide additional clarity for the non-specialist reader.

Wagner informs us that iron ore and production was known as early as 3000 BC, but, since ferrous metallurgical properties and how to control them had to be developed by artisans, there was a time delay in iron becoming an important metal. The Hittites, who had established themselves in eastern Turkey, were among the early exploiters of iron and were working the metal by eighteenth century BC. Diffusion of the use of iron and the process of making iron began about 1200 BC and it spread widely east and west. By the eighth century BC, if not before, it was established in northwest China. The “direct method” (the use of ore directly to produce solid sponge iron that was subsequently worked to extrude impurities and wrought into useful shapes of iron) was common at this point in both East and West. It remained the starting point for iron production in the West until the fourteenth century. Things were dramatically different in China: first, the Chinese learned to melt and pour cast iron into useful shapes by the fifth century BC and malleable cast iron was in use in China by the third century BC, almost two millennia before Europeans began to cast rudimentary cannon balls in the seventeenth century. Furthermore, during this period, cast iron implements became widely available in China in contrast with Europe where the choice in farm implements was between wood and scarce and expensive wrought iron. Second, the Chinese produced wrought iron from molten cast iron by removing carbon from iron by the first century BC—a process that was by no means simple, since furnaces were not available to reach the melting point of pure iron. Chapter 8 deals with developments in iron making technology in the late Ming periods and, based on a treatise written in 1637 by Song Yingxing that described two contemporaneous Chinese steelmaking processes: “co-fusion” (where carbon from molten cast iron is caused to diffuse into wrought iron) and “puddling” (where carbon is removed from molten cast iron by oxidation causing the iron, at the temperatures involved, to become semi-solid). This latter process was the one of choice for making steel in the West from the time of its invention by Cort in 1784 to its radical improvement by Hall in 1830, until both were eventually and subsequently superseded by the Bessemer and Siemens processes. The penultimate chapter deals with modern Chinese contributions to global siderurgical metallurgy, which offers incisive examinations concerning blast furnaces or “indirect smelting” (the production of cast iron in a blast furnace, which is decarburized to wrought iron by fining) and discussions about the Bessemer and Höganäs processes and whether Chinese ferrous technology

may have had earlier connections or not with similar metallurgical technological developments in Europe.

I only have two minor reservations about this volume. The first is that I detect or opine that to insure the high-level and outstanding quality of the individual volumes in and pending production in the *Science and Civilisation in China* series' franchise, manuscripts by outstanding authoritative author's, as in this case, appear to face unusually rigorous organizational and formatting constraints. Obviously, this insures the high-standard and quality of an individual volume to the collective work. But, it appears to limit an individual author's creative presentation of results. The second reservation is specific to this volume. I observe that either by the choice of the author or editor, Chapter 2 (Introductory orientations: the traditional Chinese iron industry in recent centuries) advances—well beyond mere synthesis—all of the major points that are to be found in the next eight chronologically organized chapters. I found that this produced a somewhat stilted outcome in reading and following the arguments found in this admirable work. When reading a chapter after Chapter 2, I found myself being forced to return to the section in that chapter that synthesized a process or technology that was being referred to in the chapter that I was reading.

Placing these minor reservations aside, Donald Wagner's *Ferrous Metallurgy* is a highly creditworthy addition to the remarkable *Science and Civilisation in China* series and it is a comprehensive and scholarly treatise on Chinese ferrous metallurgy that should be read and consulted by both scholars and general readers.