SVASTIK

SVASTIK STORIES

INDIAN TRADITIONAL KNOWLEDGE THROUGH THE LENS OF SCIENCE

Volume II

A CSIR-NIScPR PUBLICATION

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Foreword

The Team SVASTIK is extremely happy to bring the second volume of the book, ***SVASTIK Stories: Indian Traditional Knowledge through the Lens of Science***, for the benefit of our esteemed readers. The first volume of this book was released by Hon'ble Dr. Jitendra Singh, Minister, Government of India in the International Conference on Communication and Dissemination of Traditional Knowledge organised by CSIR-NIScPR held during February 14-15, 2023 at New Delhi. We have moved on with our efforts since then and have communicated many more episodes using social media platforms. This volume contains 20 of these SVASTIK stories.

The national programme, SVASTIK, was launched on August 25, 2021. The inspiration behind this programme was a call by Hon'ble Prime Minister and President of CSIR Society, Shri Narendra Modi, to test the scientific validity of Indian traditional knowledge and to communicate to the society wherever there exist scientific basis. The Team SVASTIK has been working relentlessly to take this message forward. The mission is pretty much challenging since our country possesses a treasure trove of traditional knowledge and practices that span across diverse disciplines of science and technology. SVASTIK is indeed fortunate to have association of so many subject experts from diverse areas.

So far, SVASTIK has covered themes relating to metallurgy, chemistry, mathematics, sustainable agriculture, hydrology, traditional food, architecture, medicinal chemistry, shipbuilding, education, trade and commerce, so on and so forth. Creative contents based on these themes are communicated on social media platforms in English, Hindi and many Indian languages. In a very short span of time, SVASTIK received phenomenal public interest, which is growing day by day. Presently, the reach is over 3 million through SVASTIK social media handles.

We are confident that the second volume of the book will be received enthusiastically by our readers, just like the first one. The SVASTIK project will continue its mission of exploring the scientific validation of traditional knowledge and making it known to the public at large.

The team SVASTIK, consisting of the members of the Steering Committee and the expert sub-committees together with NIScPR, deserves applause for their invaluable contributions to making this project a reality. I take this opportunity to express my sincere appreciation for the dedication and relentless work of Dr. Charu Lata and the team, which ensured flawless execution of the project. Finally, I would like to place on records our heartfelt gratitude to Dr. Ranjana Aggarwal, Director, NIScPR, whose dynamic leadership and guidance were instrumental in ensuring the project's success.

Wishing you an enriching reading experience full of new insights and perspectives.

Prof B.N. Jagatap
Chairperson RC, CSIR-NIScPR
& Steering Committee, SVASTIK

March 19, 2024

Message

In the contemporary changing world, documentation of traditional knowledge and intangible cultural heritage is needed without delay for its immediate maintenance, fortification, management and communication while contributing to the sustainable growth of the nation.

I take pride in sharing that CSIR-NIScPR has launched a national initiative **#SVASTIK (Scientifically Validated Societal Traditional Knowledge)** to disseminate scientifically proven Indian traditional knowledge to society in response to the Hon'ble Prime Minister's clarion appeal. #**SVASTIK** aims to preserve India's rich heritage, foster a scientific mindset, and give citizens faith in the scientific worth of our indigenous practices and knowledge. Thus far, 55 scientifically validated India's traditional knowledge stories have been disseminated with the motive to reach every segment of society. The dissemination has been done in English and 17 Indian languages on various social media platforms including X (formerly Twitter), Facebook, Instagram and LinkedIn with the name **@NIScPR_SVASTIK**.

A popular science book based on the disseminated Indian traditional knowledge stories "**SVASTIK Stories: Indian Traditional Knowledge through the Lens of Science (Vol. I)**" which was brought out last year, is gaining wide popularity among diverse stakeholders. The second volume of this SVASTIK popular science book supported by rigorous scientific validation is now being released. The present treatise embodies a collection of twenty chapters offered by eminent authors to acquaint a wide audience with the significance of the indigenous knowledge system in our country. The authors strongly and authoritatively highlight and discover various TKs of our society and bring out the scientific evidence behind them. Under one cover, the present volume features with abundance of unique materials and wide-ranging analysis which is extremely stimulus, useful and surely serves the interest of policymakers, scholars, researchers of cultural studies, and readers interested in TKs and cultural history.

I would like to express my sincere gratitude to the members of the Steering committee, members of various sub-committees, and all concerned institutions and experts for their remarkable support to this initiative. Last but not the least, I congratulate the SVASTIK team for their yeoman service in compiling such a timely book presenting the state-of-the-art in the area of traditional knowledge and making **#SVASTIK** a brand to disseminate scientifically validated TK to diverse sections of the society.

Prof Ranjana Aggarwal
Director
CSIR-NIScPR, New Delhi

March 19, 2024

SVASTIK Stories

INDIAN TRADITIONAL KNOWLEDGE THROUGH THE LENS OF SCIENCE

Volume II

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India is endowed with a rich legacy of traditional knowledge and practices touching several spheres of life and traversing several S&T domains. Our traditional practices exist in synergy between human needs and nature, often balancing resources and requirements in a local context. However, with time, India has been witnessing erosion in people's faith towards our traditional knowledge.

Recognising the importance of this subject matter, Hon'ble Prime Minister and President of CSIR Society, Shri Narendra Modi exhorted that information related to scientific validation of the traditional knowledge/practices need to be communicated effectively to the public. The Council of Scientific and Industrial Research (CSIR) was directed to spearhead the efforts to collaborate with the relevant partners from across the country and implement the national initiative on 'Communicating India's scientifically validated traditional knowledge'. CSIR-National Institute of Science Communication and Policy Research (CSIR-NIScPR) has been assigned as the nodal organisation to implement this national initiative.

This popular book has a collection of 20 profusely illustrated scientifically validated TK stories, covering a wide range of subject areas, and targeting not only the students but also the public as readers. This book is the manifestation and part of the national initiative - SVASTIK. The primary objective of SVASTIK is to conserve the practice of the Indian traditions, inculcate scientific temper and infuse confidence in citizens regarding the scientific value of our traditional knowledge/practices. Under this initiative, we are disseminating the TK/practices having scientific basis in different Indian languages with the aim to reach and benefit different sections of the society.

You can reach SVASTIK through @NIScPR_SVASTIK on all popular social media platforms.

Wootz/Damascus Steel and Evidence from South Indian Antiquity

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The legacy of Wootz steel and its influence on Damascus steel swords endure as testaments to ancient South India's metallurgical expertise. Archaeological findings and historical records substantiate the region's pivotal role in steel making. Here, the author attempted to elucidate its technological advancements as well as its historical cultural relevance.

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The history and antiquity of iron and steel in the Indian subcontinent is quite remarkable. The Iron Pillar which stands in the Qutab Minar complex in Delhi is celebrated as the 'rustless wonder' owing to properties of corrosion resistance. It is in fact the earliest known massive iron forging in the world standing at about 7.375 m high and 41.6 cm in diameter. The inscription in Gupta Brahmi script in Sanskrit on the pillar of the late 4th century to early 5th century CE is of the period of the Gupta king Chandragupta II.

However, the ancient Indian prowess in steel making is somewhat less known, whereby the Indian subcontinent has been renowned for the making of high-quality steel known in southern India as *ukku*. Wootz, the Europeanised version of *ukku* refers to a high-grade high-carbon steel. It was specially produced in southern India as attested by several European travellers' accounts from around the 16th -17th centuries (Bronson, 1986). As indicated in this paper, archaeometallurgical studies by the author point to finds of high-carbon steel going back to the South Indian Iron Age from the early to mid-first millennium BCE. As such, wrought iron which was used in the Delhi iron pillar is an alloy that consists of very little carbon of less than 0.04% carbon; and in earlier times in much of the ancient world it was mainly only low carbon steels that were known, of iron alloyed with less than about 0.4% carbon. However, wootz steel was a special kind of high-grade high-carbon steel with about 1.5% carbon alloyed to iron which gave special properties of strength, formality and cutting edge.

As indicated in the writings by 17th century traveller Tavernier, thousands of ingots wootz steel were sent from the port of Masulipatnam in the region of Golconda (in modern Telangana) to Persia and West Asia to make the fabled Damascus blades. The blades made of Damascus steel (Figure 1), with the intricate alternate light and dark pattern had been a curio of interest in itself in Europe. It was believed to have been used in the Medieval Crusades, with its legendary properties said to have been demonstrated by the Egyptian ruler Saladin during the truce with King Richard; where he is said to have cut a gauze kerchief with the fine cutting edge of the Damascus blade as fictionalised in the book Talisman by Walter Scott. When it was recognised from travellers' accounts such as by Voysey in Golconda and Buchanan in Mysore in the 19th century that steel ingots made by crucible processes from southern India had formed the raw material for Damascus blades, interest in wootz surged. Ingots of Wootz (Voysey, 1831) (Figure 2) were shipped by the British East India Company to England for scientific study to understand the specific properties. Indeed, Tavernier commented that steel traded from the Coromandel coast of

Figure 1: Wootz/Damascus steel blade with typical light and dark wavy pattern

Figure 2: Wootz steel ingot in Science Museum London

southern India was the only sort that Persian artists could damascene to make Damascus blades by etching in vitriol; implying some regional prowess in making such true ultra-high carbon steels.

As pointed out by metallurgist Cyril Stanley Smith (1960), the Oriental Damascus steel blade, made by forging Indian wootz steel with a high carbon content of 1.5-2%, with the typical ‘watered silk’ pattern was one of the earliest structures to have been studied under the microscope. The properties of wootz ingots/Damascus steel were enthusiastically investigated and debated during the 19th-20th century by several European scientists including Michael Faraday with the aim of industrial production and leading to several innovations and discoveries such as the making of alloy steels (Srinivasan & Ranganathan, 2004). Interest further intensified from 80’s following the metallurgical studies by Wadsworth and Sherby (1980) who patented a class of materials known as Ultra-High Carbon Steels (UHCS) which were found to have properties of advanced materials such as superplasticity or high formability at high temperatures. It was then noted that their composition and structure were in fact like Damascus/Wootz steel.

Indeed, archaeometallurgical investigations and metallurgical studies made by the author, on remnants of steel-making crucibles (Figure 3) collected from surface surveys of a production site from antiquity in Tamil Nadu, Mel-siruvalur, indicated that the remnants closely matched UHCS or ultra-high carbon steels of about 1.5% carbon steel composition, with a typically etched micro-structure of darker lamellar pearlite surrounded by a light cementite network along honey-comb-shaped prior austenite grains (Figure 4) which would usually form at the liquidus of 1400°C but could come down to 1200°C under highly reducing conditions. This micro-structure also indicated how the high-carbon steel could have been manufactured in south Indian antiquity by essentially carburising wrought iron under highly reducing conditions by packing the charge with carbonaceous organic matter in crucibles, and firing over long temperatures until it became viscous enough to absorb more carbon to get ultra-high carbon steel. The above micro-structure also explains how the wavy light and dark patterns of the Damascus blade could have emerged from the forging and etching of the UHCS wootz ingot resulting in alternating wavy dark pearlite and light cementite. The properties of superplasticity would also explain how the blades were extensively forged into elaborate curved shapes as seen in various armouries such as Indian and Persian. In recent times, Reibold and his coworkers (2006) proposed that the ‘*damask*’ pattern of alternating light and dark wavy lines that the Damascus blades were known for also consisted of carbon nanotubes, heightening the materials science interest.

Figure 3: Wootz steel making crucible fragments from Mel-siruvalur, Tamil Nadu

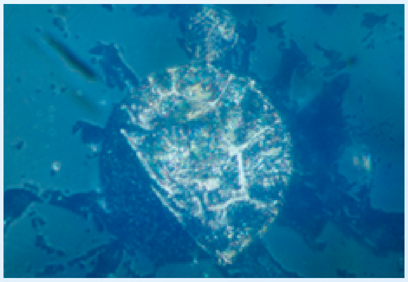

Figure 4: Micro-structure of crucible fragment from Mel-siruvalur showing remnants of ultra-high carbon hypereutectoid steel of 1.5% carbon

As such, the fame of Indian iron and steel goes back to antiquity. The accounts of Quintus Curtius from the 1st century CE mentioned that during the campaign of Alexander of Macedonia in the Indus region he was presented 'ferrum candidum' or bright iron (Edgerton, 1896; Srinivasan & Ranganathan, 2004). The 12th century accounts of the Arab Edrizi which were quoted by Henry Yule in his book related to the travels of the Venetian Marco Polo, mentioned that it was not possible to find a blade that could surpass the edge from Indian steel. The fame of Hinduwani, the term used by Arabs to describe Indian steel also led to the fabled accounts of 'Ondanique' attributed to the quixotic traveller to the East from Venice, Marco Polo. Going back earlier, the 'Natural History' by the Roman Pliny mentions that iron from the '*Seres*' was imported into the Roman world, which some scholars like Warmington have argued may be identified with the Southern Indian kingdom of the Cheras in ancient times. In general archaeological evidence had been sketchy due to the lack of systematic studies. However, more and more archaeometallurgical evidences have come to light in recent years which establishes more concretely the antiquity of wootz steel and from studies by the author from sites in southern India as indicated further.

Excavations were undertaken at an iron age megalithic site at Kodumanal, Tamil Nadu which is close to Karur, the Chera capital of the Sangam era (6th *c.* BCE-3rd *c.* CE) and they revealed furnaces with vitrified crucibles (Figure 5) and iron slag (Rajan, 1990) with recently obtained AMS dates of 5th century BCE. A vitrified crucible fragment from Kodumanal excavated by K Rajan and studied by the author showed processing remains related to ferrous metallurgy (Srinivasan & Griffiths, 1997; Srinivasan, 2007). Figure 5 is an elemental distribution map of this crucible fragment from Kodumanal (Figure 6), examined using EPMA-WDS by the author confirming the presence of ferrous remnants. Kadebakele is an Iron Age site near the World Heritage site of Hampi in Karnataka excavated by K Morrison and C. Sinopoli with the State Archaeology Department of Karnataka. Metallography undertaken by the author on a specimen of a small intact iron ring (acc. No. 900, 22E-28 N, Level 7) radiocarbon dated to 800–440 BCE yielded a through pearlitic structure of at least 0.8% carbon steel, appearing like cast steel produced from crucible processes (Srinivasan *et al.*, 2009). Roman accounts of the 'Periplus of the Erythrean Sea' refer to the flourishing port of Muziris or Muciri on the Malabar coast. An iron nail from Pattanam a site in Kerala identified with the Muziris revealed a microstructure typically associated with ultra-high carbon wootz steel containing about 1.5% C as studied by the author in collaboration with Kerala Council of Historical Research and P Cherian (Srinivasan, 2007).

Figure 5: Ferrous processing tuyeres and crucible fragment from Kodumanal, Tamil Nadu (5th century BCE)

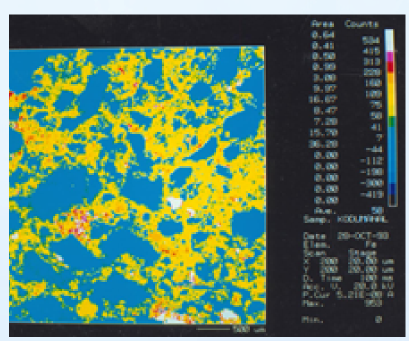

Figure 6: Elemental concentration map confirming ferrous metal remnants in crucible fragment from Kodumanal (5th century BCE)

The Sangam Tamil poetess Auvaiyar (3[rd] *c.* BCE-3rd *c.* AD) wrote several bardic poems that evoke warring chieftains and their spears (*ekku*). *Ukku* may derive from the Sangam Tamil word *uruku*, meaning boiling over as indicated in the Tamil lexicon (Srinivasan, 1996). Indeed, the Greek alchemist Zosimos in the 3[rd] *c.* AD mentioned that the Indians made steel for swords by melting soft iron in crucibles (Craddock, 1995). This also recalls the wootz production mechanism indicated from the crucible remnants at Mel-siruvalur of carburisation of low-carbon wrought iron in a viscous or molten state to hypereutectoid high-carbon steel as described by Srinivasan (1994, 2007) since the crucibles were also found close to trenches with iron smelting slag and debris. The prills of metallic remnants trapped in the vitrified matrix of the crucible had a consistent micro-structure of ultra-high carbon steel of about 1.2-1.5% carbon as seen in the pearlitic colonies in prior austenite grains and surrounded by cementite needles (Figure 4).

The process of carburisation of wrought iron to steel has also been described as the Mysore process at southern Indian sites such as Gatihosahalli following the process described by Buchanan (1807) (as noted in studies by Rao (1970), Craddock (1998) and Srinivasan (2017)). Wood also made significant observations on crucible steel processes in the Salem and Arcot districts of Tamil Nadu (Wood, 1893). But Wood's observations on crucible processes in Salem and Arcot districts in Tamil Nadu suggest that only iron was charged and the crucible containing the ingot was not fast cooled in water as in the Mysore process, so that it forms a distinct process. The structures from Mel-Siruvalur suggest that the ingot was slowly cooled, as seen from the formation of fine lamellar pearlite within the equiaxed prior-austenite grain. This may be inferred as the 'Tamil Nadu process' as described previously in the accounts of Wood which suggests that the charge consisted of iron (indicative of a process of carburisation of iron), and is distinct from the Mysore process where fast cooling or quenching was reportedly observed (Srinivasan, 2017).

Crucibles from sites identified by Srinivasan in Karnataka at Machnur and Tintini had a similar vitrified vessel fabric of carbonaceous material packed with a refractory quartz rich exterior (Srinivasan & Griffiths, 1997). Large slag heaps of archaeometallurgical debris related to the production of wootz steel have also been found in the region of northern Telangana which had been visited by Voysey and Tavernier (which were studied through a collaborative UKIERI project between the author and Dr Gill Juleff, and with S Ranganathan, Jaikishan, Jens Anderson and Brian Gilmour). Interestingly however, the crucible remnants from sites from Telangana here indicated remnants of cast iron prills or remnants: which perhaps pointed to a later Deccani process as indicated in SEM-EPMA investigations (Srinivasan *et al.*, 2011). The Deccani process has been described as co-fusion production of high-carbon steel, whereby cast iron which has a high carbon content of 4% carbon is fired with low-carbon wrought iron to get steel of an intermediate composition of about 1.5% to 2% carbon steel. An interesting finding from the EPMA investigations on Telangana crucibles reported in Srinivasan *et al.* (2011) undertaken at Cambourne School of Mines by the author Jens Andersen was the presence of traces of zirconium minerals in the crucible fabric, which is a refractory material found in sandy soils may have made the crucibles more refractory to withstand the high temperatures needed for crucible steel making processes. The above findings also point to the diverse and intriguing aspects that still need to be unpacked concerning the various regional processes of wootz steel production and their local antiquity.

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