Editorial

Mr M. Asoka T. de Silva

Archaeology – A Science and an Art

There is no doubt that archaeology in recent times has evolved into one of the most captivating disciplines of learning. It is both a science and an art. It is a science because it deploys precise analytical tools to decipher and unravel the vanished trails of antiquity. It is also an art because it recreates, restores, and resurrects the pristine glory of artifacts and monuments of a bygone era.

Readers of this number of *Vidurava* are certain to be enthralled by some of the recent findings and interpretations of archaeological excavations, both in Sri Lanka and in the venerated ancient City of Lumbini in Nepal, where conclusive evidence is now surfacing of the precise time and place of the birth of Prince Siddartha.

Recent excavations in the vicinity of the famed Fa Hien Cave (Fa Hien Lena or Pahiyangala Rock Cave) have revealed the existence of a sequence of human habitations dating back to 38,000 to 5,400 years, from fragmentary human remains. These have been considered to represent the earliest known anatomically modern human beings discovered in the whole of South Asia.

We are also informed that palaeo-climatic records based on radio-carbon dating of fossil remains of micro-organism, spores, pollen, etc found in peat and sedimentary material in Horton Plains have provided valuable clues that can revolutionize monitoring and observation of climate change phenomena.

The theme article provides interesting interpretations of the scientific and technological basis of many services and activities performed by our ancient ancestors. For instance, the author explains as to how the earliest human being sliced and shaped chert and quartz stones into usable implements with an indigenous knowledge base that incorporated scientific principles.

It is known that the iron smelting industry had been widespread in ancient Sri Lanka. There is a detailed account of the archaeology of iron smelting in ancient Sri Lanka by an author who pioneered investigations on the iron smelting industry at Alakolavava in the vicinity of Sigiriya. Her studies had revealed from carbon-dating of slag deposits from various parts of the country, that the industry may have begun in prehistoric times possibly beyond 2000 BC. The Department of Archaeology and the Post graduate Institute of Archaeology of the University of Kelaniya have carried out independent studies on this ancient industry, but the core issue that has generated debate and discussion has been the design layout of the furnace, and the ensuing structural changes, which facilitated the attainment of optimal temperatures for smelting.

Before concluding, it would be relevant to mention that Dr, Gill Juleff, the British archaeologist who pioneered studies on the west facing iron smelting furnaces at Samanalaweva, has in an article published in *"World Archaeologyt"* (Vol. 41 (4), Dec. 2009), drawn parallels with comparable iron smelting furnaces discovered in Burma (Myanmar), Cambodia and Japan. Accordingly, based on chronology and progressive structural adjustments in furnace designs in the respective countries, she has articulated a philosophy of evolution in furnace design, whereby transmission of technology across South Asia from Sri Lanka to Japan is speculated to have taken place through what is referred to as "Cultural Lineage" of inheritance.

Science and Technology in Ancient Sri Lanka

Prof. Raj Somadewa

Sri Lanka is a country with an ancient history. People who lived during that period faced but overcame various types of challenges for their survival. Included amongst these were the influences of various degrees of issues created by nature, as well as by the challenges associated with the management of socio-political changes which arise when a society continuously exists for a long period of time. In order to successfully face these, it becomes necessary to develop some sort of common social adaptations. History shows that Sri Lanka had such a tradition, and this note expects to discuss them.

Even though superficially the natural world appears to be a simple static admixture of matter and energy, in actual fact it constitutes a complex rhythmic series of events with regularity in change. We continuously face change, but if any condition remains unchanged for a considerable length of time then we sense it. When things remain unchanged we call it 'continuity'. A characteristic feature of living things is their adaptation to continuous conditions which exist for a long time. If there is an adaptation to a continuing condition, it becomes a necessity to adapt again if there is any change. As continuity and change are regular features in the natural world, in order to respond to these, it is necessary to understand the mechanism of how nature operates. In other words it is necessary to comprehend the basic principles which generate the respective conditions in the natural work, and then plan the practical strategies to respond to these conditions. The first of these approaches is considered as scientific thinking and the second as technology.

The moment we hear the terms science and technology, we get the idea or feeling that we have received them from the western world. This is the very reason why we are always compelled to think that science and technology are associated with what is regarded as modern. This is the reason why we question as to what extent is anything scientific if we are to accept it. Any knowledge which is not modern is considered outside and is echoed in this attitude. Rather than understanding the real truth we have been taught to believe that this is the truth. During the period when the modern scientific resurgence was taking place in Europe, most of the western countries which already had ancient civilizations with long scientific and technological traditions had declined due to various reasons. This made it easy to make us believe that modern science is an intellectual feat that developed and united Europe. Even though the required intellectual background for the birth of modern science developed in the thirteenth century, its direct translation began in the sixteenth and seventeenth centuries centered around countries in Europe.

Copernicus, Galileo Galeli, and Newton are the pioneers who were responsible for initiating this development which was based on Astronomy and Physics. The basis for the discoveries by these illustrious scientists was provided by the scientific method of Francis Bacon, and by the methodology introduced by the philosopher Rene Descartes. The methodology of Francis Bacon could be applied to survey of information, while that of Descartes was relevant to analysis and inference. This led to the development of a global perspective which was different from the philosophical background which provided the basis for the scientific ideas of the Aristotelian tradition, which existed in Europe up to that time. All these aspects taken together was regarded as modern science. In actual fact this concept is a creation of the Jewish - Christian intellectual tradition.

The method of Descartes was analytical, breaking up thoughts and problems into components and rearranging them in a logical sequence. This is the special idea that Descartes contributed to modern science. It is this analytical approach to modern science which enabled man to set foot on the moon. The famous statement 'There I stand' *"Cogito ergo sum"* made by Descartes has been discussed in all philosophical theories, and is regarded as the intellectual stand of Descartes with respect to the concept of mind and body. This thinking of Descartes emphasizes that the mind does not belong to the body, and the body does not belong to the mind. This Cartesian division is the central philosophical approach of modern science. Thus modern science learnt to view the world in a mechanical manner, due to this reason. Not only did rationality and analysis became the methodology of science due to the philosophy of Descartes, it also had an influence to spread authority and control over the world. This is why there is no similarity between the ancient scientific ideas that existed in the eastern countries and the intellectual horizon of modern science. The philosophical basis of scientific ideas that existed in the eastern countries during the pre-modern period was based on a unification of wisdom, understanding and natural order, while the methodology of modern science aimed at analysis. The methodology of oriental science concentrated on synthesis and integrated equilibrium. At least by the beginning of the second millennium B.C., the people of China, India, Sumeria and Egypt, which had great civilizations had already acquired and accepted the modern scientific views. By 2000 BC the Chinese knew the principles of the basis of producing bronze and also the technology to use it for practical purposes . Such bronze objects used in rituals have been discovered from tombs of the Shiya dynasty. By 3000 BC Sumerians had derived mathematical equations which could be applied to analyze complex phenomena. In fact the invention of the sexagesimal method (that is 60 seconds = 1 minute, 60 minutes = 1 hour, circle has 3600 etc.) depicts the glory of their advanced thinking capability. The Egyptian concept of mummification was recognized as a great embalming strategy. In order to undertake mummification practically, it is not only necessary to understand the factors that affect the changes in living matter in the natural world, but also there should be a clear understanding of the method to control these factors. This is relevant to the empirical strategy of controlling variables as employed in modern science. Our neighbour India also possessed an unchallenged scientific tradition in ancient times. Aryabhata, Bhashkara and Brahmagupta are three unique mathematicians of such a tradition. Trigonometry which is taught in modern mathematics had been used in India two centuries before the method was used in Europe.

Sri Lanka also had undergone socio-political transformations of various degrees after the 13th Century AD. As a result the institutional framework which maintained the inherent scientific knowledge of ancient civilization got disintegrated. It is in these circumstances that the colonial Euro-centric movement was successful in spreading the concept of modern science and technology in eastern countries. The extent to which such thinking had taken root in societies including those of Sri Lanka which have been subjected to colonization, made these societies to think that the local tradition used by them was not scientific. The missionary education method created a system of education for the colonies, that facilitated such thinking. The serious challenge that confront the society of this country, which has become the victim of such a situation is not the comprehension of modern science but liberation from the belief that modern science is the only salvation that will solve all our problems. One of the main tasks to be done to liberate from such imitative thinking is to recognize indigenous intellectual knowledge and understand and develop the underlying conceptual basis for their utilization or employment.

We will understand the nature of the local scientific tradition which existed in our ancient society by investigating a few of their applications. The rest of this document will attempt to look at these aspects.

The scientific ideas of the early period

Examining the material culture of the ancient Sri Lankan society provides an opportunity to understand the manner by which the people who lived then interacted with material in the natural world. There is sufficient evidence to indicate that by at least 2000 BC the society of this country had an understanding of the dynamics of the operations of the natural world. Historical and archaeological sources provide evidence for the tradition responsible for the organization and dissemination of the relevant knowledge. The word *'Achariya'* had been used in the inscriptions of 250 BC or close to that period. This word has been used to refer to the teachers who disseminated knowledge. The historical sources of this country, refer to the institutions called *'ashtamula'*. This refers to the eight intellectual schools which existed in this country about 2000 years ago. These institutions played a decisive role in maintaining suitable standards in the system of knowledge necessary for the society at that time.

In order to provide proof for this statement I have produced a limited number of examples which reflect scientific knowledge belonging to a few time-space dimensions.

Concepts of symmetry and dynamics of force

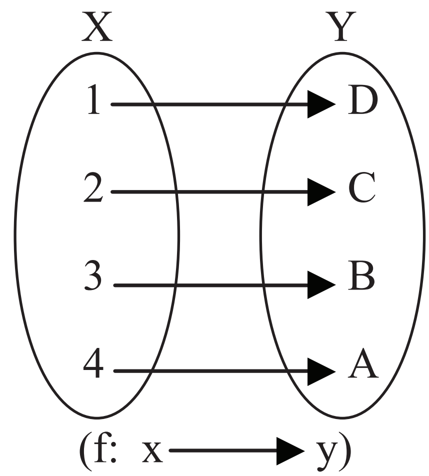
Symmetry is a principle of the natural world. It defines the equilibrium in a system. According to a strict definition, symmetry in one way is an indicator of harmony and visual balance. In another sense it is a mathematical admixture of patterned self-similarities.

A few stone implements which reflect a definite mathematically explainable symmetry have been discovered from several places in Sri Lanka (Image 1). These archaeological objects have been assigned to a period between 2400-1750 BC using radioactive dating techniques. Another similar stone implement has been dated to about 25,000 years of age.

The type of chert rock used to make these implements is a hard rock. If a model conceptualized by man is to be given to this rock which has a crystalline structure, then it is necessary to process it transcending the linear grid pattern conferred to it by nature. When a force is applied to a chert or quarts stone, it disintegrates along its crystal facets. However, the small stone implement shown in the photograph is a result of conscious effort made by man to overcome the natural forces inherent in the relevant rock. We can consider according to modern knowledge the mathematical basis accepted and practically applied by the people who lived in this country at least during the period of about 4400 years ago.

The symmetry of any phenomenon is dependent on the equilibrium of communication between the constituent sets of units. This feature is referred to by the term bijection. It is a mathematical concept. Bijection can be explained as follows:

Image 1: A Stone which reflects a definite mathematically explainable symmetry.



The mathematical sub-group of the symmetrical model of the stone implement shown in the photograph belongs to the type known as rotational symmetry. This example seeks to show the fact that even though not based consciously on mathematical concepts, man possessed the intuitive knowledge required to confer such mathematical relationships to matter. The development of the specialized cells called mirror neurons in the brain, provide the force necessary to generate such symmetry. It is said that these cells persuade the mind to imitate. These cells help to copy a thing correctly. The Acheulian hand axe invented by *Homo erectus* man is a clear example of how the instinct to think mathematically initiated in man. What I mean here is that the inherent ability to understand the basic principles of nature is a tendency related to the prehistoric development of the brain.

At this stage we must introduce and explain how a knowledge of physics had been used in an ancient construction innovation of this country. They are the ancient graves/tombs that have been dated to the period 1350 BC, or 3350 years ago, using radio active dating methods. These graves, found in the village of Ranchāmadama of the Ratnapura District, are elliptical in shape and built with sun dried clay bricks (Image 2). Generally the height of such a tomb is abovt 70 cm aboue ground level. The thickness of a wall is between 8-10 cm. The walls have been erected on the original natural rock in the site. Places with natural rock existing not beyond a depth from ground level have been selected, from which soil is removed and the walls of the tombs built perpendicular to the ground. Why have the people who lived 3350 years ago think of such an idea and acted accordingly? The only answer for this question is that they wanted to provide a practical solution to prevent the possibility of the clay walls collapsing to a side. Although this affirms to be a simple construction we know that there is an underlying scientific principle. The mathematical principles relating to resolution of forces make it clear that when a solid object stands alone on a flat surface it is possible to neutralize the vertical force by placing it perpendicular to the surface. The fact that the clay walls of the Ranchāmadama graves have remained intact and have not collapsed for over 3000 years is due to the manner in which these inhabitants followed the general laws of nature.

Image 2: A tomb found in Ranchāmadama.

It is the human skeletons and not the dead bodies that have been cremated in the above mentioned graves. Evidence from excavations have confirmed that the skeletal remains have been placed in the tomb and cremated after closing with a lid. It is clear that combustion cannot take place in a closed airtight space where the limited amount of oxygen can get depleted. Then how was combustion made possible inside these graves? Excavations have revealed that they have employed a suitable method to meet this requirement. A hole of about 10 cm in diameter had been made in one of the walls of the tomb and a tube made of burnt clay has been fixed in to it (Image 3). This shows that when combustion was in progress, a mechanism had been employed for air from outside to be supplied in an organized manner. This is a fine example to show the extent to which man had understood the relationship between combustion and air during that period. It appears that it is only in the 17th century that such a relationship between combustion and air had been discussed in detail in the western scientific thinking. The phlogiston theory of Yohan Joachim Betcher (1667 AD) can be considered a typical example in this respect. History of science shows that it was Antonio Lavosier (1843-1894) who explained in the 18th century that oxygen is a definite factor for combustion.

Image 3: A tube made of burnt clay was used to provide air to tomb.

The concept of time and space

There is an inscription on a natural rock in an ancient temple at Kirinda in the Hambantota District. It belongs to the second century AD. In this inscription there is a phrase that reads as *'aparimitha lokadathuya'.* The expression *'aparimitha lōkadāthuwa'*, which appears in the Sanskrit language, has been written in Sinhala Prakrit in this manner. At the time of writing this inscription people were aware that the 'world' is infinite. Modern scientific usage of the terms 'infinite universe' or 'expanding universe' embodies the same idea. The concept of infinite universe came into theoretical discussions only in the middle of the 20th century, and this should have been after the scientific researches of David Bohm (1917 - 1992).

Eastern tradition possessed a wide knowledge structure to describe the concept of time associated with that of space. According to the ancient vedic texts and ancient literary work the smallest unit for measuring time was mentioned as *'Paramanuwa'*. This was equivalent to 17 microseconds. A microsecond is equivalent to one millionth (1/1,000,000) of a second of modern usage. The scale to measure time ranged from that point to *'Maha manwantharaya'* (311.04 trillion years). This system to measure time was a cosmic one based on the movements of the sun and the moon.

The oldest inscriptions of Sri Lanka that refer to dates, belong to the second century AD. For this purpose the term *'Havajara'* has been used in the inscriptions. This is the Sinhala Prakrit expression of the Sanskrit word *'Sanvathsara'*. The word refers to a year that comprise of 12 lunar months. In the inscriptions of the 9th century AD of Sri Lanka, this system of dating based on the lunar months had been used very clearly. In these inscriptions it is seen that by taking the year of coronation of a particular king as a base, the date had been noted with reference to the elevant lunar month and the movement of the moon for 30 days. For example, the expression *'Wesanga masa pura dasawak davas'* refer to the 10th day of the waxing moon of the month of Wesak. In this concept of measuring time, the day has been further sub-divided into *'hōra'* hours and *'thithi'*.

An example of how the daily movement of the earth was used to measure *'hōra'* or the hour in modern usage has been discovered from the vicinity of the *'Mahāpāi'* alms-giving hall at Anuradhapura. It is a square slab of stone, with a small hole at the centre. The hole has been used to fix vertically an erect stick of wood or a similar structure. This stone slab situated near the stone 'rice canoe' meant for collecting food for the Buddhist priests, had been used to determine the time of day so that serving of the mid day meal to the priests could be completed before noon. Even though the shadow of the stick or rod fixed into the stone slab falls on the slab before noon, it completely disappears when the sun is just overhead or at noon (at 12.00 noon as used now). Although this is simple technology, the underlying basic principle is complex. This hour disc (time measuring device) has been used in the 8th century AD or close to that period.

Systematic measurements required to understand space has been used in our country during the ancient times. References to such measurement are seen in ancient writings *'Aangula' 'Waduriyana'* and *'Danda'* are some of them.

An iron rod used as a carpenter's measuring stick *'Wadu Riyana'* and owned by a craftsman named Godapola Galladda in the Kandy area had a length of 31 inches (according to modern usage) as recorded by Ananda Coomaraswamy, the famous Historian of Arts. *'Waduriyana'* is divided into 24 sections. Units such as *'Gauwa'* and *'Yoduna'* have been used to measure long distances. King Nissankamalla is known to have installed *'Gav kanu'* (mile posts) on major roads. These were known as *'Gāvuthakanu'*. Such *'Gāvuthakanu'* have been discovered at Katugahalge and Weligaththa.

Measurement of matter

Measurement of matter is essential for science. Once the behaviour of matter is understood, it becomes necessary to manage it quantitatively in order to interact with it. The ancient Sri Lankan society followed an organized system to measure matter. The unit *'Kalanda'* can be given as an example for measuring weight. It is used even today to measure certain types of herbal ingredients. A *'kalanda'* is equal to 4.66 grams according to modern usage. It is a unit of a wider table of units used in measuring weight. The table of weights as given in the text *'Abhidhanappadeepikawa'* is as follows.

4 *vēha*	=	*gunjā* 1
2 *gunjā*	=	*masaka* 1
2.5 *masaka*	=	*akha* 1
8 *akha*	=	*dharana* 1
5 *dharana*	=	*swarna* 1
2 *swarna*	=	*pala* 1
100 *pala*	=	*thulā* 1
20 *thulā*	=	*bhāra* 1
8 *vēha*	=	*manchādi* 1
20 *manchādi*	=	*kalan* 1

During an archaeological excavation of the ancient Abhayagiri temple in Anuradhapura, conducted under the Cultural Triangle project, a gold nugget was discovered. On this nugget the words *'randevisi kalandai'* had been inscribed in a script used in 9th century AD. During that period metal weight had been used as a unit of exchange. Since exchange was a decisive factor in managing the economy, it was extremely important to safe guard the standard of weight measurements.

Some evidence useful in understanding the system followed in ancient Sri Lanka with regard to accounting is found in inscriptions. Whole numbers as well as fractions were in usage. In the Perimiyamkulam inscription installed by King Vasabha (67-111 AD), the phrase *'sakotasin eka* *kotasa dini'* (one part of six parts was donated) can be seen. What is meant by this is, one part of six parts or 1/6. Numbers such as *'æka' (1) 'dhvi'*(2), *'thîni'*(3), *'chathara'*(4), *'dasa'*(10) indicating multiples of 10's, *'siyaka'*(100) and *'sathasahasa'* (100,000) have been in usage. Symbolized figures needed to display these numbers have been inscribed in these inscriptions.

Concept of hydrostatics and pressure

It is possible to give two historical examples to illustrate how the basic principles of hydrostatics and pressure have been put into practical use through technology. The first of these is the irrigational structure called the *'bisokotuwa'*. This structure is a sluice gate, which is an innovation to lead water out of water reservoirs (tanks) with tall bunds. The *'bisokotuwa'* has been constructed so as to generate the resistance necessary to control and manage the disastrous pressure caused by a body of water which is thousands of acre feet in area and over 100 feet in depth. It is not possible to provide a detailed account of the technology of this construction in this document. However, it can be realized that it is not possible to construct a *'bisokotuwa'* without calculating the massive pressure generated by such a huge body of fluid. *'Biso kotuwa'* was in use by 2nd century AD.

Another significant example illustrating the knowledge of hydrostatics is the discovery during the excavation of 'Kotavehera' in Dedigama of a metal elephant lamp which has a model of a man seated on a tusker. In this lamp the oil first fills into the elephant's abdomen.

Image 4: A metal elephent lamp found in 'Kotavehera' in Dedigama.

This the oil drips into the lamp through the sex organ of the animal. As the oil in the lamp decreases, an equal quantity of oil begins to drip into the lamp. The understanding of the scientific principle associated with this technology, requires an understanding of fluid dynamics. This technology of about the 10th century AD demonstrates the extent of the indigenous knowledge of the relevant subject.

There are various examples to show that in the interaction with nature, the people of ancient societies, not only in Sri Lanka, but also of other countries were conscious of the basic principles of nature, and worked accordingly. They acquired this knowledge through experience, and not by spending time in laboratories, controlling variables. The basis of this vision was to find the most practical approach to work in a harmonious relationship with nature. The need to live with an amicable understanding of nature was the basis of their existence.

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The Sun and its Role in Climate Change: a Record from the Horton Plains, Sri Lanka

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Understanding climate system

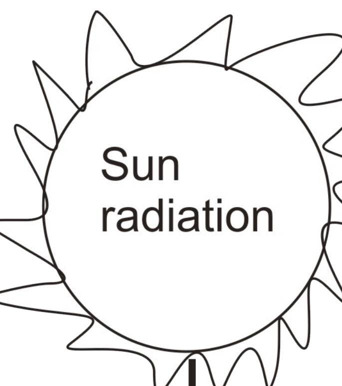
Earth is the only planet we know of that reinforce and allows the evolution of a large number of life forms, including macro and microorganisms, e.g. bacteria, algae, fish, elephants, plants and humans. This is ascribed to the rich abundance of water, which is part of the climate system of the earth, oxygen and carbon forming the basic ingredients of life. It is generally suggested that evolution of life started many million years ago, depending on the relationship between environment, climate, and organization of each group of life. This formation is largely supported by the earth's surface 'temperature'. In addition, scientists argue that 'water' had played a unique role in establishing the equable climatic conditions, as compared to the existing atmospheric conditions of our neighboring planets, i.e., Mars and Venus. To understand the general climate and environmental situations of the earth, one has to first compare the main components of the Venus and Mass as shown in (Table 1).

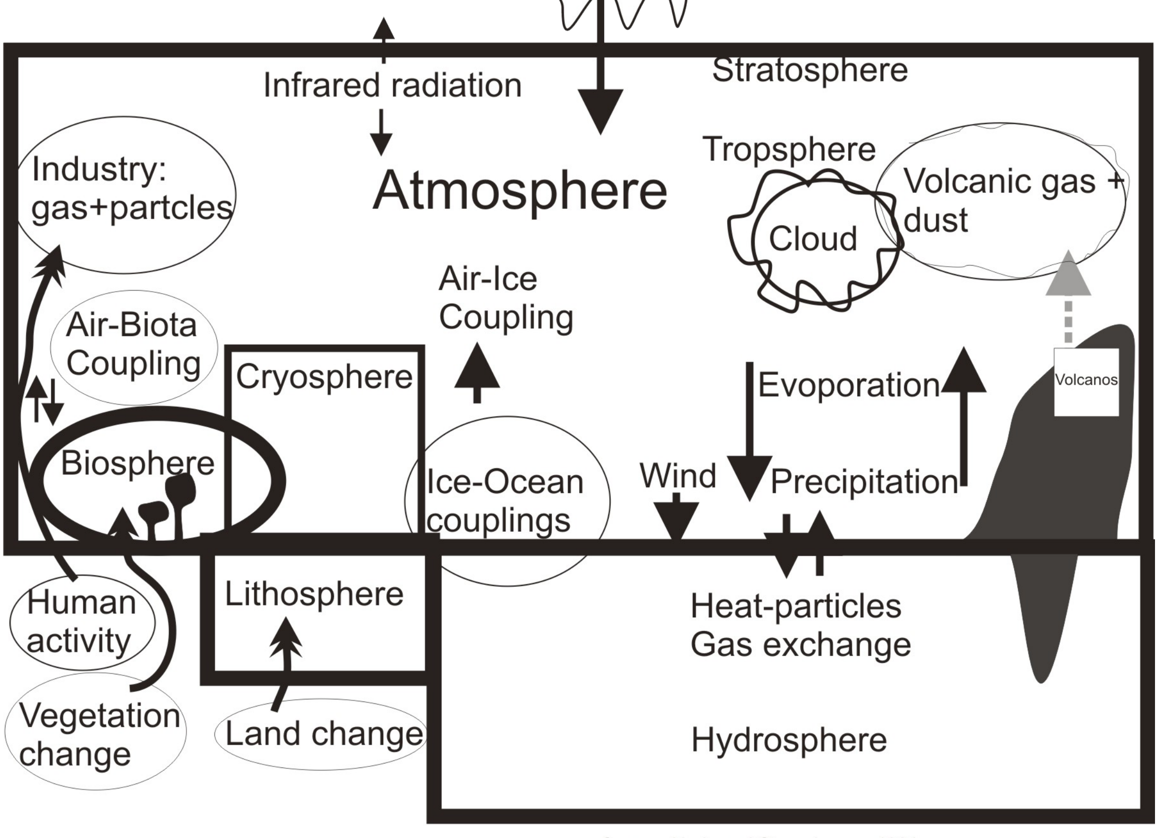
The climate system of the Earth is complex, and is represented by (1) atmosphere, (2) lithosphere (land), (3) hydrosphere (ocean and other water bodies), (4) cryosphere (ice and snow covered land and ocean), (5) biosphere (plant and animal life) and volcanos. The system outline is given in Figure 1, and it seems that all the main components of the system are interconnected. The sun is the major external source of energy for the system. The total power of the sun is about 3.86 x 1026 watts, which radiates out into space. Most of the radiation is in the visible and infrared part of the electromagnetic spectrum, with less amount of energy emitted into the radio, ultraviolet (UV) and X-ray bands. Solar radiation travels through the near vacuum of space from the sun to the earth. Terrestrial radiation is produced mainly as a result of

Table 1: Explains the atmospheric conditions of Venus and Mass compared to the Earth.

Planet	Mean surface temperature	Surface Pressure	Major constituents	Properties
Venus	476° C	90atm	$CO_2 > 90\%$	Very thick Co_2 clouds cover
Earth	15° C	1atm	$N_2 = 78\%$ $O_2 = 20\%$ $CO_2 = 0.03\%$	Around 50% H_2O cloud cover
Mass	-33° C	0.007atm	$Co_2 > 80\%$	Scattered thin H_2O cover

re-radiation of solar radiation. The energy is absorbed from the sun as the sun's spectrum but re-radiated from Earth at the much long-wavelengths (low energy radiation), associating with the temperature of Earth. Since the atmosphere is more absorptive to such long-wavelength terrestrial radiation, the atmosphere is largely heated. The atmosphere is the central component of the climate system of any planet. Water vapour, carbon dioxide and a number of other gas cover absorb the long wavelengths of radiation from the earth and act as a radiation blanket allowing little solar radiation through while trapping the long-wave radiation emitted from the lower atmosphere. This phenomenon is described as "greenhouse" effect. Ozone (O_3), on the other hand, absorbs only very short-wavelengths, mainly in the ultraviolet range, and therefore forms a shield of sorts, absorbing much of the harmful ultraviolet radiation before it can reach the earth. Note that the trace gasses that contribute to the greenhouse effect in the Earth's atmosphere are water vapor (H_2O), carbon dioxide (CO_2), ozone (O_3), methane (CH_4), ammonia (NH_3), nitric acid (HNO_3), nitrous oxide (N_2O), sulphur dioxide (SO_2), chlorofluorocarbons (or more generally chlorocarbons e.g. CF_2CI_2 - trade name Freon 12 and $CFCI_3$ - Freon 11), carbon monoxide (CO) and carbon tetrachloride (CCl_4) (IPCC list). Finally, a balance is maintained between incoming solar radiation and the amount of terrestrial radiation. This is referred to as the heat budget in the system. If this balance is disrupted, the Earth will become progressively colder (glacial/Ice Age condition) or warmer (interglacial/hot) at high latitudes, which corresponds to dry/arid or wet/humid conditions at low latitudes. It is important to note that the greenhouse effect in reasonable amounts is beneficial to the sustenance of life form on the Earth. Climate (aggregation of weather) is a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation and atmospheric particles in a given region over





Source: Haris and Stone-house, 1991

Figure 1: Components of Earth's Climate System.

long periods of time. In this regards, overall climate condition is marked by the heat-level in responding to the complex relationship between atmosphere, hydrosphere, cryosphere and biosphere (Figure 1).

It is possible to explain that the high temperature of Venus can thus be attributed to the thick carbon dioxide (CO_2) cloud cover that encompasses the whole planet and acts as a radiation blanket (Table 1). In contrast to Venus, the planet Mars has a thin CO_2 cloud-cover and thus has a low surface temperature. The composition of the Earth's atmosphere given in Table 1 helps to explain the moderate mean temperature of the Earth. The present average earth surface temperature of 15.5 °C (60 ° F) is considered to be close to the optimum for supporting life over the largest possible area on the globe.

Till the 19'th century (pre-industrial times), the primary way through which humans contributed to global climatic change was by acquisition of forest lands (deforestation) for agricultural purposes, e.g., expanding of wetlands with rice agriculture from 5,000 BP onwards, for timber and firewood collection by prehistoric humans. This had some impact to global climate system, but it was apparently minimal, except for local changes. In this procedure, carbon dioxide (CO_2) and methane (CH_4) may have increased affecting the global climate system. However, scientific evidence indicates that climatic changes are induced by severe human activities such as, industrialization, large scale land clearing/burning for agriculture purposes and mechanization of agriculture, which is defined as anthropogenic forcing in the climate system. On the other hand, global climate system is largely influenced by natural change, which is marked as natural forcing. Thus, climatic changes may take the form of increased/decreased global surface temperatures, substantial variation in precipitation patterns (arid or heavy rains), rise in sea-level, migration of fauna and desertification (increase aridity). Further, such climate changes will have significant impacts ecologically, economically and socially.

Causes of global climate change

Scientists argue that the number of causes for the changes can be identified in the geological past, covering the 250 million years, as follows.

Long-term natural forcing:

01. Effect of orbital parameter changes, as explained by Milankovitch cycles

(1): 100,000 year-eccentricity cycle. This depends on the shape of the earth's orbit; either circular pattern or elliptical pattern. Shape of the orbit controls the amount of solar radiation reaching the earth in terms of energy flux integrated over all latitudes. This cycle is responsible for creating severe and large-scale ice ages.

(2): 40,000-year obliquity cycle. This depends on the angle between earth's rotation axis and the plane of the earth orbit. Today it is 23.5° away from a vertical drawn to the plane of the orbit. It normally changes from 22.5° to 24.5° within this periodicity. When the North Pole points away from the sun, the northern hemisphere experiences winter while when it is close to the sun, the northern hemisphere experiences summer time. Effect of the obliquity cycle forced the insolation changes (i.e., solar radiation reached per unit area on the earth surface) and it may largely contribute to changes in the climate conditions on the earth surface. In general, the influence of the obliquity cycle is large at the poles and small at the equator making very significant climate change.

(3): 23,000-year precision cycle. Reason for this cycle is the overall effect of gravitational pull of the sun and moon on the equatorial belt of the earth. Owing to this effect, the earth's rotation axis wobbles and the North Pole describes a circle in space. Simultaneously, the elliptical orbit also rotates independently and more slowly. Scientists found that very significant peaks in the ice volume (Ice Ages) occurred at the periodicity of 23,000; 40,000 and 100,000 yrs.

02. Effect of changing pattern of the solar constant (i.e., power of the sun at the earth, is measured as watts per square meter: watts/m2). It generally increases over the life of the Earth, but it varies by 1-3%, because of the Earth's slightly elliptical orbit around the sun. Scientists have suggested that the sun may have varied in its power output within this range. Recent investigations also suggest that this variation apparently has connection with sunspot cycles.

03. Effect of large-scale plate tectonic activities, land-uplifting, ocean circulation and isostatic sea level changes.

04. Effect of the occurrence of volcanic eruptions. This action release large amount of volcanic dust, named as aerosol (e.g., various particles, heavy minerals and silica) into atmosphere disrupting energy balance in the system.

05. The complex interaction of atmosphere, the ocean and solar activities (e.g. sun-spots cycles), defined as El Nino and Southern Oscillation (ENSO) conditions.

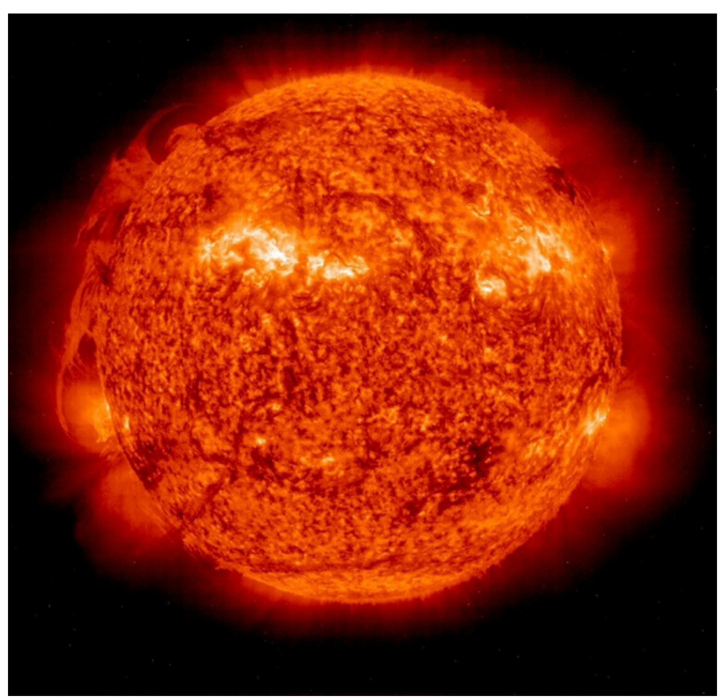
Short-term anthropogenic forcing

06. Greenhouse gas emission due to anthropogenic activities (e.g. CO_2 -fossil fuel burning) and other sources (e.g., CH_4 -wetland exposition).

07. Earth surface reflectivity (albedo) changes, with large-scale deforestation, land clearance and anthropogenic burning.

General context of the climate in South Asia

Global climate change has been attracting wide attention over the past two decades. Emphasis is now being placed on regionalization work, widely recognized to be an important step towards a better understanding of how the climate system varies naturally and also responds to changes in climate forcing. South Asia (e.g. Sri Lanka and India) is one of the most vulnerable regions to factors related to climate change. Billions of population in South Asia are critically dependent on Asian summer monsoon rainfall for their annual water requirements. It is obvious that the understanding of climate and environmental change is a major challenge for a sustainable development in the region. Simultaneous occurrences of catastrophic floods and devastating droughts are common features of the climate in the region. Such climatic extremes (e.g. hydro-climatic variables) show much spatial and temporal variability on different time-sales, e.g. inter-annual, decadal and multi-decadal. During the last few decades, repeated natural hazards such as floods, droughts, landslides, meteorological depressions, cyclones and coastal erosion, have affected Sri Lanka. Recently, unexpected severe rainfall deluged the south-western part of the country, resulting in massive damage to towns, schools, homes, communication and other infrastructures. In the sector of agriculture, the suicides of several



farmers coincide with repeated crop failures due to seasonal and annual droughts. The impact of this type of crop failures seems to have increased during the last decade and has seriously affected about 200,000 families in Sri Lanka. In addition, the increasing dryness in all parts of the country coincides with the spread of weeds in paddy fields (e.g. weedy rice) having negative effects on high-yielding cultivated rice fields. The present crisis in the sectors of agriculture, health, environment and hydropower generation can partly be related to decisions taken by policy makers without proper consideration of long- and short-term predictions based on palaeo-climatological and hydrometerological records on micro and macro time scales. Key uncertainties on micro and macro palaeoclimatic time scales remain to be solved in the tropics. It is said that knowledge on abrupt climate change, e.g. drought frequency, flood frequency, effect of ENSO conditions and ocean circulation in the tropics and the Southern Hemisphere is severely limited by lack of terrestrial palaeoeclimatic records. Understanding these climatic extremes varied in the past related to proxy data, but the nature of the proxy and their statistical calibration are incomplete. Climatologists are refining general circulation models (GCM) and various other climate models to predict the impact of future climate trends. The GCM´s and all other models require appropriate palaeoclimatic data to validate the climatic models in the region and global contexts, because direct observational series (instrumental data from meteorological stations/ Departments) are too short for these purposes.

Scientists are of the view that better understanding the sun and its role in climate changes is extremely important, but this is a difficult goal. It is important, because to properly assess the effect of human-induced climate change (anthropogenic forcing), an accurate quantification of the natural climate forcing (solar forcing) is urgently required. But, it is also a very difficult task, because,

(1) natural forcing (solar forcing) records are generally not well quantified

(2) the response of the climate system to various forcing is non-linear due to feed-back mechanisms

(3) lack of validated climate models

(4) some problem with proxy records used for climate reconstruction and their calibrations.

Thus, work for documenting and analysing solar forcing, past climate changes (palaeoclimate records), and climate modelling work in tropics are urgent task to be completed. For this purpose, scientific communities are largely required to formulate new research problems that address how past solar variation and many other anthropogenic variations have affected climate system and how this information can be used to construct solar-climate and anthropogenic-climate modelling. This modelling business may largely help for a better understanding of the complex processes that go on within the Earth/Climate system, and ultimately, developing our nation's socio-cultural and economic vitality for future.

Records from the Horton Plains

Sri Lanka is ideally situated for investigating the impact of atmospheric/oceanic events on the Asian (Indian) summer monsoon regime. This is because, the central Highlands (2,100-2,600 m above mean sea level) act as a physiographic barrier to moisture-laden monsoon winds, and is a natural climatological observatory tower in the Indian Ocean. Radiocarbon dated multi-proxy records (pollen: Figure 2, spores, phytoliths, diatom, magnetics, carbon and nitrogen isotopes and Sphagnum spp macrofossil) indicated that one of the very interesting geo-physical (peat and sedimentary) archives, located in the Horton Plains, in central Sri Lanka, has captured a 24,000 year old palaeoclimatic record. In our studies, we wish to emphasize that the number of periods of monsoon weakening lasted much longer than the periods of monsoon intensification during the past 24,000 years. The generalized trends in our records indicate that there is high-risk for monsoon rains in our part of the world in the future. If the monsoon downturn is prolonged as indicated in our records, the threat to agriculture, irrigation, hydropower generation, forestry and so many other sectors in socio-economic context, would be significant. To mitigate climate change-induced damage as described above, it is now the time for policy makers, politicians, and economic authorities to consider the best strategies and

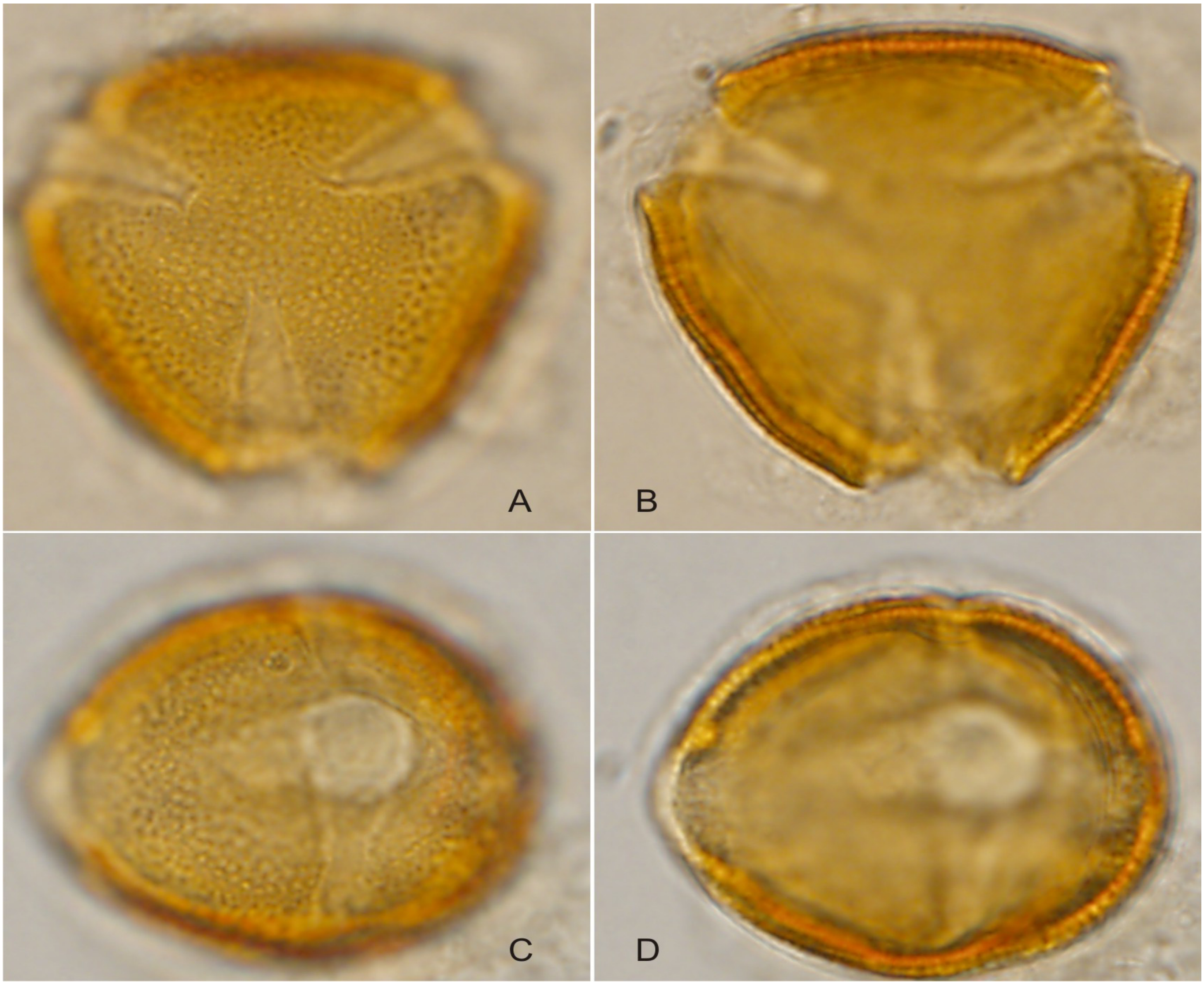


Figure 2: Radiocarbon dated pollen proxy of Calophyllum sp. found from the Horton Plains (15,000 years old fossil pollen records). A, B: 3CP-Polar views, C, D: 3CP-Equatorial views. Magnification: X1000.

practices for water management with sustainable development. For this purpose, understanding earth system science with the best knowledge relevant to climate science is essential.

Our palaeoclimate records will also throw some light into the pre-history of South Asia and the long term ecology of tropical ecosystems and their future trends. It is interesting that our records show that monsoon cyclicity is a long-term phenomenon as suggested by other scholars in South Asia, and that cyclicity operates at different periodicities, associating with orbital/sub-orbital forcing (solar forcing). This means that solar forcing appears to have predominated, compared to anthropogenic forcing. Several repeated short-term wet and dry episodes found from the sequence are very significant for understanding behavior of climate system in our part of the world. Reasons for these changes are still unclear. However, future research will allow us to understand the mechanism of these changes.

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Archaeology of Iron Metallurgy in Sri Lanka

Dr Rose Solangaarachchi-Bandujeewa

This article provides an overview of the archaeology of iron technology in Sri Lanka. Data on ancient iron metallurgy provided here are based on the data revealed from recently excavated iron production sites in the island and data from literary, ethnographical and metallurgical studies through other sub-disciplines of anthropology, which are strongly linked to the practice of archaeology of ancient iron technology.

Studies of Iron Metallurgy

The study of pre-modern iron metallurgy in Sri Lanka that had been started in the 19th centuryindicated that Sri Lankan iron and steel occupied a significant place in the south Asian iron technology complex. Although Sri Lanka's ancient chronicles and numerous epigraphs on stones provide evidence for using iron from early historic times, the ancient metallurgical knowledge of Sri Lanka is essentially incomplete due to the scarcity of research material published on archaeometallurgy. During the last decades of the 20th century, the archaeological discipline gradually shifted from an empirical and descriptive academic tradition which mainly focused on great monuments, ephigraphical works and art, to a discipline of archaeological material and analyses based on a multidisciplinary research approach connected with social sciences, natural sciences, and theoretical frameworks. As a result of new academic traditions, in the late 1980s major discoveries in the archaeological investigation of this subject were made at Dehigaha-ala-kanda (Alakolavava) and Dikyaya-kanda (Vavalavava) along the Kiri Oya Basin (KOB), in the Sigiriya-Dambulla Region of the dry zone, and at Samanalaweva on the banks of the upper Walave River in the intermediate zone. In Samanalaweva, the west-facing smelting site, was identified as using a wind-pressure technique without bellows for the smelting process. Evidence revealed from Dehigaha-ala-kanda and Dikyaya-kanda suggests that the smelters used a multiple/poly-tuyere system with bellows. However, in addition to these two sites, the existence of iron slag mounds throughout the island bear testimony to the fact that this technology was widespread. (Figure 1: Please see the back inner cover). The common indicator for smelting sites is the existence of iron slag, which is the main waste product of the smelting process.

Chronology

Until recently, the earliest known dates for the iron smelting technology was 10th-9th century BC, which was established through C^{14} dating from a slag sample extracted from an excavation in a protohistoric context, immediately above the Mesolithic layer from Aligala (998-848 BC) in Sigiriya, and from the excavation inside the citadel (930-800 BC)in Anuradhapura. Both samples indicated that the earliest archaeological evidence for the use of iron technology in the island which began with the agrarian protohistoric period in the Pre-Vijayan period. Slag samples dated 2400 BC, unearthed from recent excavations conducted in Beragala, pushes back the earliest date of the smelting technology in the island beyond the first millennium.

Radiocarbon Dating

Radiocarbon dates of excavated iron smelting sites in the Kiri Oya Basin; Dehigaha-ala-kanda, and Dikyaya-kanda have provided almost parallel data. Dikyaya-kanda samples were analyzed and calibrated at the Beta Analytic Radiocarbon Dating

Laboratory using latest INTCAL98 Radiocarbon Age Calibration database and the mathematical Pretoria calibration Procedures in C^{14} dates calibration for converting radiocarbon BP result to calendar years.

According to data, it seems that the main activities of iron smelting was conducted during Reigns of King Mahasen (269-296 A.D.) and his son King Kithsirimevan (269-324 AD), who ruled the area before King Kasyapa, the founder of the main construction period of Sigiriya Royal City of 5th century AD (477-495 AD). The period somewhere around 10th regnal year of King Kithsirimevan (296 AD) that is represented by the Vavalavava monastery rock inscription is also compatible with radiocarbon dates with main activity periods of both iron smelting sites.

Table 1: Radiocarbon dates for Dikyaya-kanda in the KOB.

Sample # & Beta Lab #	Measured Radiocarbon Age	Conventional Radiocarbon Age	2 Sigma Calibration (95% Probability)	1 Sigma Calibration (68% Probability)
SIT-22/04-01 201941	1900+60 BP	1860+60 BP	Cal AD 30 to 260 and Cal AD 290 to 320	Cal AD 80 to 230
SIT-22/04-02 201942	1780+40 BP	1780+40 BP	Cal AD 130 to 370	Cal AD 220 to 260 and Cal AD 290 to 320
SIT-22/04-03 201943	1790+40 BP	1760+40 BP	Cal AD 150 to 390	Cal AD 230 to 340
SIT-22/04-04 201944	1630+60 BP	1620+60 BP	Cal AD 260 to 290 and Cal AD 320 to 570	Cal AD 390 to 530

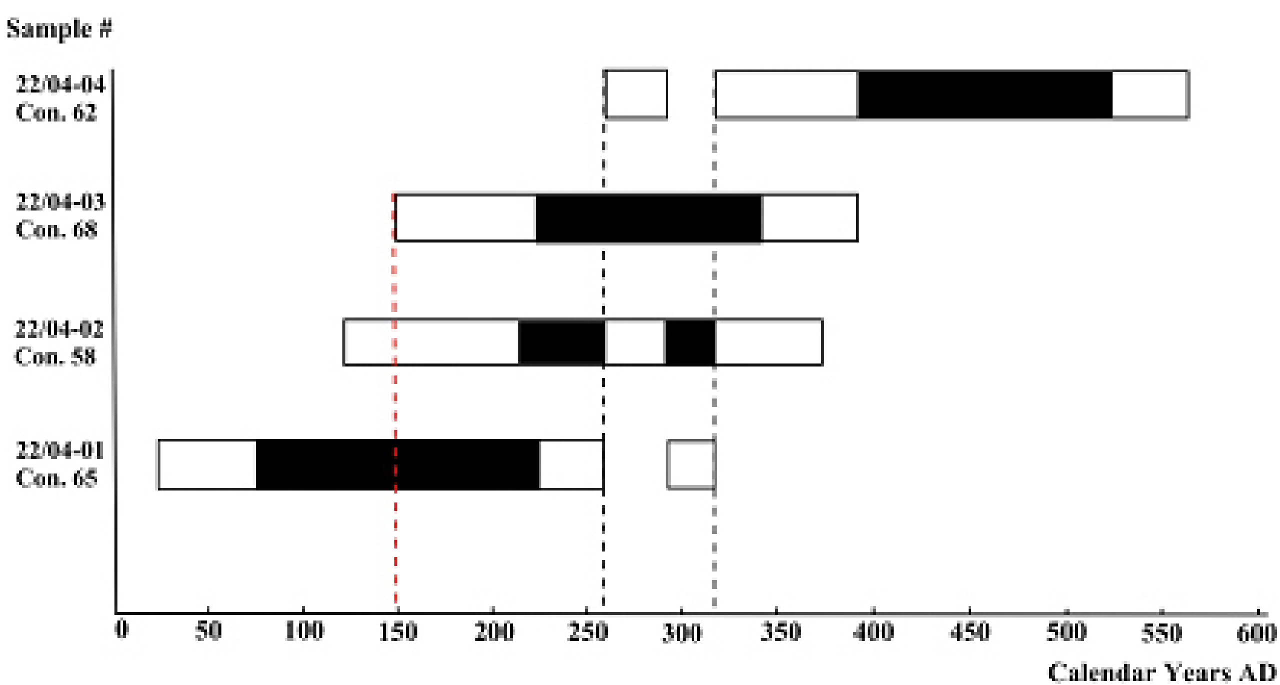

Figure 2: Diagram for Radiocarbon dates at Dikyaya-kanda in the KOB. Calibrated age ranges from cumulative probability, two sigma (95%) & one sigma (68%). INTCAL98 While hollow bars represent two sigma limits, solid bars represent one sigma limits.

Raw Materials: iron ore

The ancient iron smelters used haematite (Fe_2O_3), limonite ($Fe_2O_3.nH_2O$) and to a lesser extent magnetite (Fe_3O_4) ores as the principal raw material for their smelting process. Iron smelters at Samanalaweva also used limonite and haematite iron ores for the production process. The Anuradhapura Gedige site yielded some pieces of iron slag and limonite nodules indicating that these iron smelters also used limonite ore. But the X-ray diffraction confirmed that iron ore samples unearthed in the Kiri Oya Basin (Figure 3) are magnetite and the iron oxide content is around 90 wt.% (Table 2). The chemical analysis revealed all ore samples to have a very high purity.

The use of magnetite in bloomery furnaces has so far been identified only in a few exceptional cases in the world. Modern archaeometallurgists assume that the dense magnetite ore would be difficult to be reduced using this technique, because it would be impossible to attain the flame temperature high enough to reduce magnetite in these furnaces.

Before the production process, the pre-modern smelters roasted the ore to convert it into hematite, by removing much of the water content together with carbon dioxide and other volatile components like sulphur in the ore. The smelters also ground or pounded the ore making it suitable for putting it into the furnace.

A frontal bone, the bone of the human cranial vault, smeared with red ochre, which was found from Ravana Alla cave and two fractional human bones which were also coated with red ocher (haematite) and unearthed at Fa Hien cave (ca 5400 cal BP) are the earliest examples of the use of iron ore in Sri Lanka. This evidence suggests that iron ore was used in the lithic societies for ritualistic or funerary purposes even before identification of the metallurgical value of iron ore.

Table 2: Analysis chart of the iron ore samples at Dikyaya-kanda (Vavalavava) in the KOB.

		Atom%	
	SIT22-01	SIT22-02	SIT22-04
Fe	93.721	0	91.046
Na	0*	64.908*0*	
Mg	0.815*	0*	0*
Al	2.833	0*	0.919
Si	0.597	1.756	3.735
P	0.108*	5.322	2.771
S	0.243*	1.079*	0.017*
Cl	0.077*	7.177	0*
K	0.159*	0.762	0.017*
Ca	0.082*	0.402	0*
Sc	0.055*	0.231*	0.178*
Ti	0.72	4.715	0*
V	0*	6.768	0.111*
Cr	0.081*	0.178*	0.136*
Mn	0*	0.334*	0.11*
Sr	0.265*	0.144*	0.269*
Co	0*	6.226	0*
Ni	0244*	0*	0.158*

Area scan * = less than 2 sigma. Analyses report was done at the Arrhenius lab at the University of Stockholm under the supervision of Prof. Dag Noreus.

Furnace Construction

The most valuable part of studying the iron smelting process is to understand the structure of the furnace. The technological efficiency of the production process depended mainly on the furnace construction. Three factors are the basic requirements of the smelting process:

1) the speed of increasing the temperature;

2) attaining the temperature, and

3) the oxidation and reduction conditions inside the furnace, which depend on the furnace construction. The major raw materials used for the construction of furnaces excavated from smelting sites are clay, quartz grains and stone slabs. The height of a furnace when reconstructed with the remaining fragments seems to be about 2 m, while the thickness of the side walls was about 20-40 cm at the lower half, which decreased to about 3-4 cm at the top (Figure 4).

Taking into consideration the above as well as the height of the furnace, the furnaces appeared relatively broad, and had the shape of a rectangular bottle. The height and shape of the shaft showed its capability to control the

A B

Figure 3: Iron ore samples found in the KOB. A) Pieces of iron ore unearthed at Dikyaya-kanda. B) Block of iron ore collected at Dehigaha-ala east. Scale is given in inches.

temperature, while at the same time ensuring the strength of the furnace construction. The stone slabs also ensured the strength of the furnace by supporting the weight of the superstructure that was made of clay. The other probable reason is to determine the breaking margin of the front wall without harming the rest of the furnace construction when taking out the iron bloom (the final product) after the production process is completed. The furnace superstructures at both smelting sites can be categorized as bloomery furnaces.

Furnace Operation

Although the technique used in the smelting process varied greatly from area to area, the basic principle remained the same. The operation of the furnace depended mainly on the scientific basis of the iron metallurgy. The success of the furnace operation or the smelting process depended mainly on the presence of carbon monoxide (CO) which acted as an active reducing agent in the furnace. The extraction of iron from the ore occurred through reduction with charcoal at a high temperature, where charcoal acted as a fuel and a reducing medium. According to the characteristic atmospheric conditions and chemical reactions of the bloomery process, the features inside of the furnace can be divided into three major zones, namely, combustion, solution and reduction. According to the general method of furnace operation, the furnace is preheated at first and then filled with ore and charcoal in alternate layers. The air is supplied through tuyeres (clay nozzles/pipes attached to the furnace wall to direct the air produced by bellows) blown by bellows or natural draught for the process. The oxidation zone is created near the tuyeres. At a temperature between 1100°C-1300°C, carbon monoxide is formed by the combustion of particles of charcoal with the air blown through tuyeres. The main reaction of the combustion zone is the reaction of oxygen with carbon (C) produced from charcoal, and conversion of it into carbon dioxide (CO_2). This

A B C D E

Figure 4: Furnaces in the KOB. A) Unearthed two furnaces at Dehigaha-ala-kanda. B) Reconstructed drawing of the furnace at Dehigaha-ala-kanda. C)Well-preserved furnace at Dehigaha-ala-kanda;presently exhibited at the Sigiriya archaeology museum. D) A tuyere unearthed at Dikyaya-kanda.E)Furnace at Dikyaya-kanda.

carbon dioxide reacts with more charcoal to form the reduction gas, carbon monoxide (CO) in the solution zone.

Heat is the most important factor of the iron smelting process. In pre-modern furnaces, the ore was incompletely reduced because the temperature did not reach 1100°C-1300°C. Therefore reduction was completed in two stages. In the reduction zone ferrous oxide (FeO) was formed at first as a result of the ore (eg. Magnetite Fe_3O_4) reacting with carbon monoxide (CO). Secondly, ferrous oxide was partly reduced to iron as a result of the reaction with carbon monoxide, and partly turning the melt to slag together with the gangue or mainly silicates as fayalite (Fe_2SiO_4).

The fayalite compound melts at 1170°C absorbing the oxides of manganese, magnesium and aluminum present in the gangue. In some parts of South Asia there is evidence for the use of lime ($CaCO_3$) as a flux. In such cases the resulting slag also contains calcium silicate.

Unless the charcoal is broken into small pieces before charging, the distribution of carbon in the charge may not be sufficiently uniform, and unless the ore is adequately porous, it will not be completely reduced because the carbon monoxide will not be able to reach all parts of the ore. These two reasons caused the production of a small quantity of low quality output relative to the amount of raw material used. The other important point is that when too much enthusiasm is shown for the use of the bellows, or as another reason if too much oxygen is produced inside the furnace, especially due to the local absence of carbon, the already reduced iron may become reoxidized. This causes the whole process to be a failure.

As discussed above, the iron smelting process requires more critical conditions than copper, for a successful production. At least it requires a temperature of 1250°C to separate the useless gangue from the smelting charges in the furnace. Therefore it needs a good supply of oxygen to reach this high temperature. It is very difficult to maintain a reducing condition with a good supply of oxygen.

Ancient smelters were capable of controlling these critical points and complicated demands, and were able to produce high quality iron with the sustained experience of technological knowhow. They knew how to produce the desired quality of metal with their long experience, even though they may not have had a clear understanding of the chemical and metallurgical principles involved is the smelting technology.

Iron slags

An iron rich wüstite phase (FeO) was not found in the slag samples collected in the Kiri Oya Basin (Figure 5). But only the usual

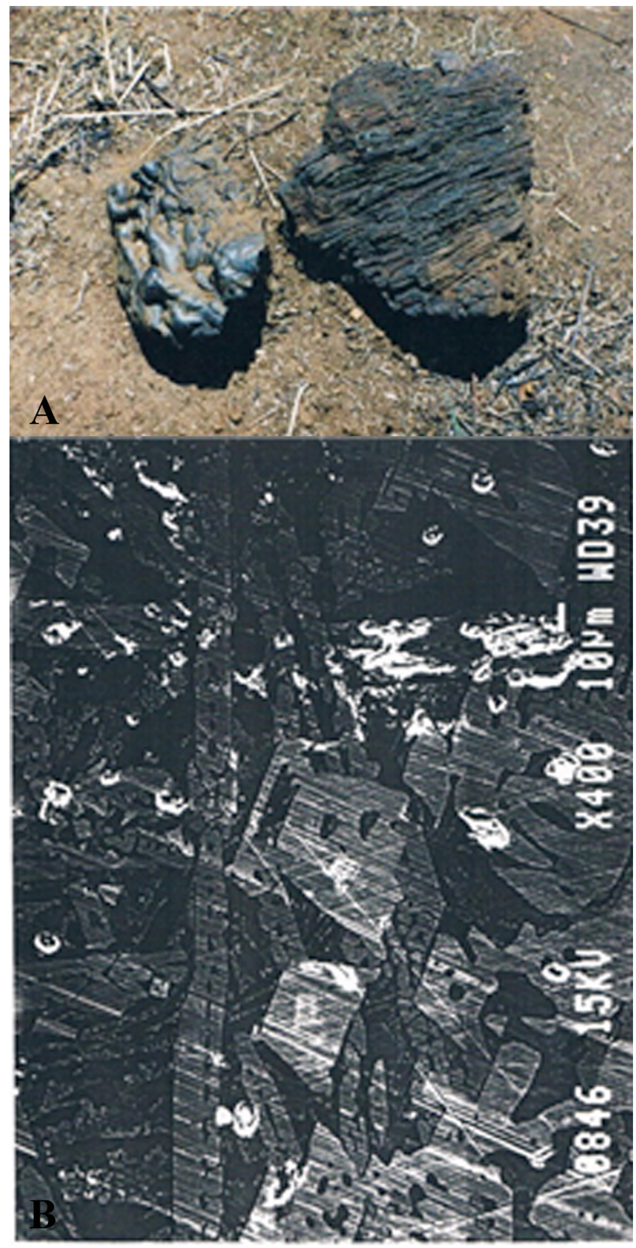

Figure 5: A) Different types of iron slag samples collected in the KOB.
B)Electron microscopy picture of a typical reduction slag at Dehigaha-ala-kanda.

A B

Figure 6: A)A crucible sample collected near paddy field near Balangoda Uggal Aluthnuwara Karagama Devalaya. (Presently exhibits at the Archaeology Museum of the Kelaniya University). B) Pieces of crucibles unearthed in the KOB.

fayalite phase (Fe_2SiO_4), which is an iron poor glassy phase. According to chemical analysis, the iron oxide contents in the slags in the Kiri Oya Basin were unusually low for bloomery slags.

Slags from both sites consisted of the lower iron oxide content of fayalite (Fe_2SiO_4) compound when compared with slag samples from other production sites which were situated around the area. This indicates that the yield of iron at the site had been very high. Considering the above data, it can be assumed that the smelters of KOB had the knowledge to select ore of good quality which could produce a high yield compared to the quantity of raw materials used, and the advanced smelting technology to achieve high quality
The brighter crystals with sharp edges are fayalite on a dark background of the glassy phase, and where the heavier elements are concentrated, will appear brighter on the pictures with this technique.

Crucible steel

The process of making steel was based on the principles of carburization of wrought iron in crucibles and these ingots were generally known as crucible steel or *wootz* steel. The ancient Islamic world used forged Damascus Swords from the high carbon crucible steel or Damascus Steel or *`Wootz Steel'* that was made in Southern India and Sri Lanka. Sri Lankan steel appeared in the book of al-Kindi who was a writer of the mid ninth century. According to him, four major sword-making centers of Yemen, Fars, Khorasan, and Mansura preferred using Serendib steel.

The procedure for producing steel from wrought iron is mostly recorded in most ancient smelting sites. The carbon content of steel is intermediate between that of cast iron and wrought iron. The percentage of carbon ranges from 0.1 to 2% in steel.

Very tiny (~ 10 g) piece of "steely iron" yielded at Dehigaha-ala-kanda confirmed that the furnaces at the site had fairly strong reducing conditions for producing `steely' iron and pieces of crucibles unearthed in the KOB also confirmed the existence of steel production in the region (Figure 6).Radiocarbon dating for the crucible pieces unearthed at the crucible steel site at Mamalgaha village near Balangoda Uggal Aluthnuwara Kataragama Devalaya, dated to 17 century AD which also confirmed Coomarswamy's eyewithness account for steel making technology around Samanalavava region in Sri Lanka.

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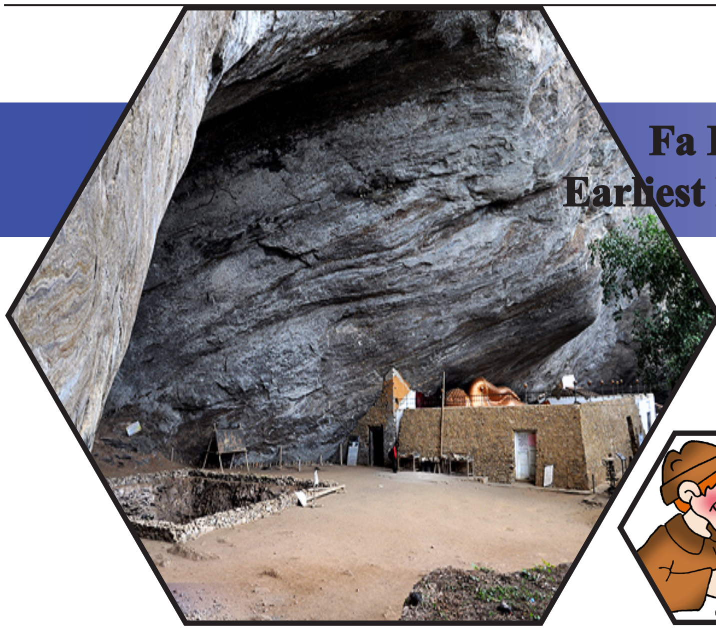


Fa Hien - Lena Prehistoric Cave, Earliest Modern Humans from South Asia

Dr H. Nimal Perera

Fa Hien-lena, one of the largest habitable rochshhelters in Sri Lanka, is situated in south-western Sri Lanka, at Yatagampitiya off the small township of Bulathsinhala near Horana in the Kalutara District, approximately 75 km southeast of Colombo (80 12' 55" E by 6 38' 55" N). Popular belief has it that the famed Chinese Buddhist monk Fa Hien sojourned there while on his pilgrimage to Adam's Peak.

The site lies in the foothills abutting the coastal plain and is a complex of interconnected rockshelters developed in a coarse crystalline gneiss cliff. The entrance faces east and is easily accessed along a short, fairly steep, path. From the entrance, one is afforded a view of Sri Lanka's central hills through the gem-bearing strike valleys of Ratnapura. The mouth has a width of c. 30 m and an average height above the cave floor of 20 m. The interior extends for c. 10 m into the cliff. Secondary lowland forest adjoins the cave complex, the primary rain forest having been cleared for plantations at the turn of this century.

Archaeologically, the site was initially recorded in 1968 by the then Assistant Commissioner of Archaeology of the Department of Archaeology of the Government of Sri Lanka, Dr S.U. Deraniyagala, when it was being used as a Buddhist cave temple. Subsequently it was reserved for future archaeological investigations once adequate resources become available. This did not materialize until 1986 when W.H. Wijeyapala, then Assistant Commissioner in charge of excavations, commenced excavations as part of stage 5 of Deraniyagala's prehistoric research design titled 'The systemic interaction of man and environment in prehistoric Sri Lanka', in which a series of rock-shelter excavations were conducted. Shelter A, the larger of the two at the site, was first excavated to a depth of over 6 m. It yielded a consistent mass of what appears to be roof-fall flakes or decaying bed-rock throughout the profile, without any indubitable trace of early human habitations.

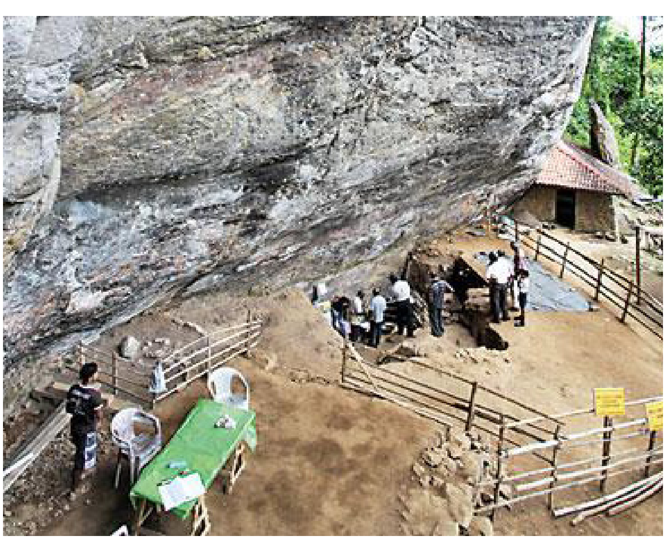
Shelter B, a smaller subsidiary shelter located approximately 20 m east of the main chamber (shelter A), proved to be far more productive. Excavations conducted in 1986, and subsequently in 2009-2012, have yielded a secure sequence of human habitation deposits dating to c. 38,000 to 5400 years ago (late Pleistocene to mid-Holocene). The lowermost deposit dated to c. 38,000 years ago produced a set of fragmentary human remains which are considered to be those of anatomically modern humans (Homo sapiens sapiens) by the eminent American bio-anthropologist Prof. Kenneth Kennedy and his team at Cornell University, the earliest known from the whole of South Asia. They were succeeded by a series of skeletal remains, the most recent being from a layer dated to c. 5400 years ago.

Some of the latter specimens had been coated with red ochre prior to interment.

The excavations revealed strong evidence of the technology employed by prehistoric man at Fa Hien shelter. The great majority of the artifacts are made of quartz, with a much smaller proportion made of organic materials such as bone, antler and shell. Compared to other rockshelters in Sri Lanka, the stone artifact component was found to be meager, the reason for which is unknown. They are overwhelmingly dominated by waste products from the manufacture of finished tools, often comprising small quart flakes of less than 2 cm in length. Noteworthy among the other lithic finds are grindstones smeared with red ochre and hammer-stones.
As with stone artifacts, bone and antler tools were present from the lowermost layers upwards. They comprised predominantly single- and double-ended bone and antler points, commonly with abraded or polished ends. They are small, and remarkable for their high degree of workmanship, notably a fine serration along the edge of one.

A large assemblage of faunal remains was found in the excavations, including molluscs, from the initial phase of habitation up to the final phase. They are well preserved and shed important light on the environments and subsistence patterns of hunters and gatherers in equatorial South Asia between c. 38,000 and 5400 years ago. Fa Hien's prehistoric inhabitants had foraged a broad spectrum of plant and animal resources derived from their rainforest environment.

It is noteworthy that remains of the miniscule lagoon habitat mollusc Potamides cingulatus have been found in the habitation deposits from as early as c. 20,000 years ago. This form occurs by the millions on lagoon flats in the inter-tidal zone. The only mechanism by which they could have reached Fa Hien-lena' is as inclusions in rock-salt which would have been transported from the lagoons situated in the southeast of the island over 100 km away.



Prehistorians believe that ornaments and exotic items are a form of symbolism associated with anatomically modern humans.

Beads of marine shell and shark vertebrae, shark teeth and a shell pendant from the earliest cultural layers were found in the Fa Hien-lena excavations. These findings indicate personal adornment in Sri Lanka from c. 38,000 years ago onwards. They are among the earliest dated markers of symbolic practices from (apart from Africa) anywhere in the world.

Fa Hien-lena rockshelter is of global importance for understanding the physical and cultural evolution of anatomically modern humans, particularly in the context of South cum Southeast Asia. Its deposits contain a sequence of habitations by equatorial rainforest hunter-gatherers from over 38,000 years ago; and they include their skeletal remains which constitute the earliest known modern humans from South Asia. They also demonstrate evidence of fully modern behaviour in their mortuary practices, stone tool technology and symbolic artifacts such as beads and red ochre.

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New Escalations of Lumbini

Mr Thusitha Malalasekera

Nepal is a kingdom situated at the foot hills of the Himalayas. Lumbini is located in a valley of the Rupandehi district which is about 300 kilometers to the south-west of Kathmandu, the capital city of Nepal. Historical sources indicate that ancient Lumbini was a beautiful garden park with trees laden with flowers. The Sal trees known by the scientific name *Shorea robusta* were plentifully, and were distributed throughout the garden. Hance it must have been an attractive garden providing ample enjoyment and leisure to the Kshathriya kings as well as their citizens.

When Mahamaya Devi the chief queen of King Suddhodhana, who was reigning in the city of Kimbulwath, was on her way accompanied by a retinue to Devgahanuwara (her birthplace) in order to deliver her baby, she desired to enjoy the environment of the garden as well as to take a rest. According to Buddhist history prince Siddhartha was born under a Sal tree in the Lumbini garden. It is generally accepted that Bodhisatva - Siddhartha was born on the Vesak (May) full moon day in the year 642 BC.

A large number of pilgrims visit Lumbini every year because Lumbini is believed to be the place of birth of Prince Siddhartha Gauthama who became Lord Buddha. Buddha in his Parinibbana Suthra named four places that should be venerated by the Buddhists. These were, Lumbini where his birth took place, Buddhagaya where he attained Buddhahood, Isipathana where the first sermon was delivered, and Kusinara where Parinibbana took place. One can understand how much Buddha liked the natural environment, endowed with a vanity flora and fauna.

According to historical records, Emperor Asoka of the Mauryan dynasty accompanied by his teacher Upaguththa visited Lumbini, the birthplace of the Buddha, it was a garden surrounded by a fertile and spectacular village. At the time of his visit Emperor Asoka had already

embraced Buddhism. King Asoka is known to have erected four stupas and a pillar (column), at the top of which was a stone figure of a horse. On this pillar the Emperor made the following inscription in Brahmi script in Pali language.

" King Piyadasi (Asoka) beloved of the gods came to the birthplace of Sakyamuni on a royal visit 20 years after his coronation, and venerated the place. He also constructed a stone wall and erected a pillar in order to pay respects to Buddha. The tax that should be paid to the King by the citizens of Lumbini was also reduced to 1/8th".

Later it became easy to locate Lumbini because of the Asokan pillar. There is evidence to indicate that various pilgrims had visited Lumbini up to the 15th century AD. Records show that Chinese travelers, specially Fa Hien (4th century AD) and Suen T-Seng (4th century AD) visited Lumbini. There is also historical evidence that a Malla King had been a pilgrim to this location.

However after the 15th century AD Lumbini became desolate and overgrown with forest and turned into ruins. Lumbini came into limelight again after the German archaeologist Dr A. Firtrer along with Khadga Samsher, the Governor of the region discovered the Asokan Pillar in 1896. Through various investigations and excavations carried out subsequently Mahadevi Viharaya, several sthupas, and the pond named 'Puskarni' situated to the the south of the Viharaya were discovered. There is a belief that Mahamaya Devi had a bath in this pond before giving birth to Prince Siddhartha. Lumbini was declared a world heritage in 1947, and since then all investigations are coordinated by the UNESCO office in Kathmandu with the assistance from the government of Nepal.

It is after this, that the strengthening and management project for conservation of Lumbini began under the leadership of UNESCO. The recent investigations associated with the Lumbini Sal garden in Nepal, has been the most talked about of the archaeological explorations carried out in the world. Archaeologists involved in these investigations have been successful in discovering archaeological structures that are as old as 6 centuries BC, which have conclusively established that the birth place of Gauthama Buddha - Prince Siddhartha had been in 6th century BC. What is of special significance is that these discoveries have conclusively assigned the birth of Prince Siddhartha to a particular century with certainty.

Although the sacred and venerated Lumbini Sal garden, considered as a UNECO World Heritage had been accepted from a long time ago as the place of birth of Prince Siddhartha, based on ancient texts and oral tradition, it is the current exploration that has provided definite evidence for this event. During these excavations, a hitherto undiscovered timber structure had also been found beneath many ruins of buildings made of brick. The open

space located at the center of this wooden structure (which is similar in plan to the structures above it), is believed by the archaeologists to be the birth place of Buddha.

Professor Robin Coningham of Durban University, UK, who is directing the archaeological explorations says that although many academics had believed that the birth of Buddha took place in the 3rd century BC basing their views on ancient texts and oral tradition, now for the first time evidence of a wooden building that existed in the 6th century BC in the Lumbini garden has been discovered.

The excavations at the Lumbini Sal garden in Nepal are conducted jointly by the governments of Japan (World Cultural Heritage Conservation Trust) and Nepal under the supervision of UNESCO. Further financial assistance and resources are supplied by the Universities of Durban and Sterling (U.K.), and the National Geographic Society Global Exploration Fund. This investigation team is led by Professor Robin Coningham and the well known archaeologist Kosh Prasad Acharya of Nepal.

The current archaeological excavations and investigations are expected to reveal a great deal of new information on the pre Asokan constructions before 3rd century BC. In this context, further attention is scheduled to be paid to the ancient Mayadevi Viharaya, and the monasteries in the east of the Sal garden which have so far not been investigated.

This investigation which was begun in 2010 continued research excavations of 'Maya Devi' Viharaya in 2011. It has been shown that another Viharaya existed at the location before the brick Viharaya was constructed by King Asoka. Since January 2013 the investigators have been attempting to collect data, evidence and information necessary to understand the nature of this ancient Viharaya. With the current explorations it has been possible to reveal that there were ancient human settlements in the Lumbini village, the oldest village in South Asia and situated to the South West of Mayadevi Viharaya.

Professor Robin Coningham and the archaeologist Kosh Prasad Acharya who made a statement in July 2013 regarding the new discoveries, said that as believed so far, Emperor Ashok in his efforts to spread Buddhism in this entire region had constructed the Viharaya in brick in Lumbini in 3rd century BC. They also stated that the current excavations have revealed the existence of a Viharaya constructed in brick and a timber structure beneath it constructed before the Asokan period.

Analysis of this archaeological information will provide new and clear information about the life of the Buddha, including his birth and how it took place. It will also provide new information as to whether the birth of the Buddha took place in the 6th century BC (and not in the 3rd century BC as believed by some) and whether Lumbini was a place of worship even before the birth of Buddha. The analysis of this new information and drawing conclusions will be a task for the future.

Mr Thusitha Malalasekera
(Compiled using information from the Internet)
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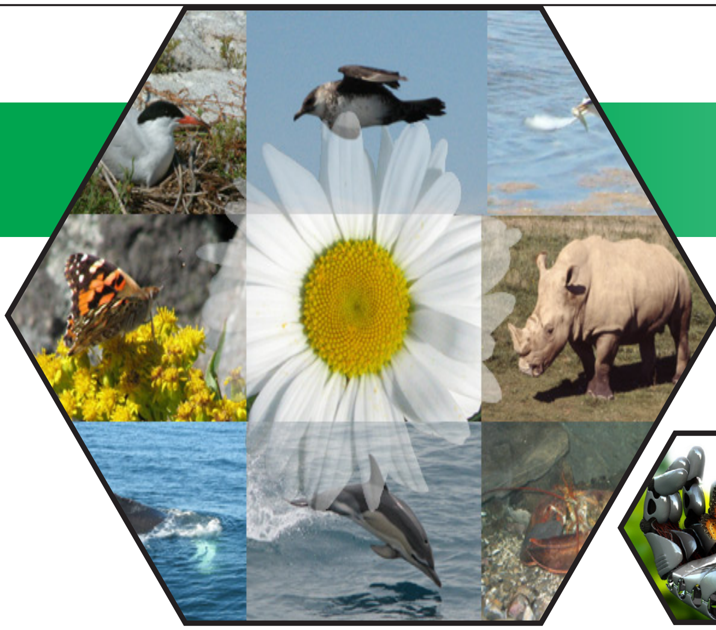


Biomimicry - Copying of The Nature

Dr Kumari Thilakaratne & Mr Umal Kuruppu

If I ask you "how would you reach the ground safely from the sky?" you would certainly say "By using a parachute, isn't it?". However, did you know that a gently swinging and falling cactus flower inspired mankind to solve that problem?

Comparing the products that have contributed to the developments in the field of technology, Nature's products - such as plants and creatures - are significantly advanced in their own aspects. Scientists have now admitted that the best way to find answers for our problems is by "studying nature". This unveiling of micro secrets in nature to produce new creations is called "Bio Mimicry".

For example, take the sky. An aeroplane that can fly higher than a bird can be compared to a giant student learning from a tiny bird teacher. Designers have utilized the shapes of the body, head, chest and the unique shape of wings of birds to design aircrafts.

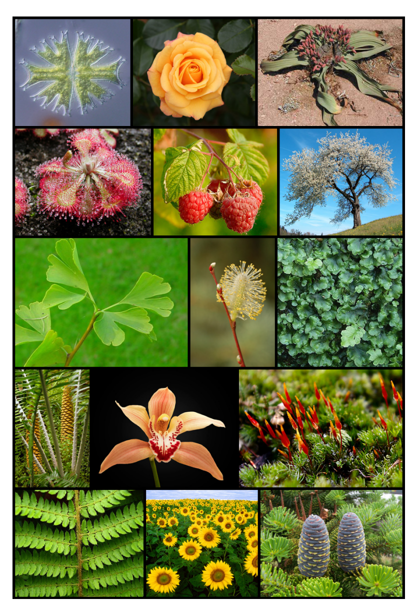
Although an aeroplane can fly higher, it cannot remain stationary in the sky. When people questioned nature as to how this happen, the answer came from the dragonfly. People observed that the motion of the dragonfly's wings helped it to stay in one place, and they blended that secret to the helicopter. Taking one step ahead, the latest aim of scientists at the Florida University is to study the flight of insects to develop an aircraft, smaller than six inches, which can be used in warfare.

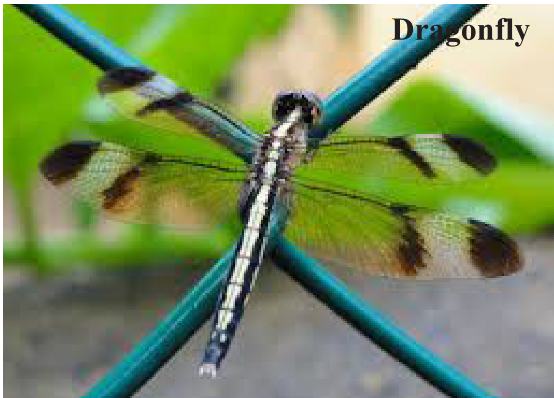
Another development is the new walking stick that has been developed using a bat's radar communication techniques. This has helped people with impaired vision to detect obstacles on roads, by informing the user well in advance using RADAR technology.

VELCRO tape is one of the oldest examples of Bio Mimicry. VELCRO tapes are common in things that we use daily, like clothes and bags, and it is designed by studying the seeds of sticky grass? or saramenia aleynia? and NAGADARANA. Though people see these seeds as a nuisance, Mr. George Mistral founded a business worth millions in 1951, simply by observing the seeds clinging to his dog's fur. He studied how the tiny hooks of these seeds cling to fur, fabric and leather.

Japanese scientists studied the ability of butterflies to change the colour of their wings and developed surfaces similar to them. It is another amazing creation of nanotechnology. It is not simply a painted surface, but one which is capable of changing colours by manipulating the direction of light reflection.

Though not yet seen in our country, you may have observed it in the media - the high speed electric trains (SHINKANSEN or Bullet Train) that are commonly used in countries such as China and Japan. During the era of





development of these trains, the greatest problem that engineers faced was the tremendous noise generated by the compression of air while passing through the tunnels. Can you believe that the engineers found the solution to this problem by observing the kingfisher? The unique shape of its beak allows it to move quietly through air as well as in water to hunt fish. Discovering this phenomenon, Japanese scientists produced the head of Shinkansen train in the shape of kingfisher's beak. This provided a perfect answer to the problem. As an unexpected advantage, it added 15% power saving and 10% extra speed.

We have learnt even more interesting lessons from the dwarf termite. This is not about their unity, but the nest. The dwarf termite is capable of creating architectural air vents to keep their nests cool. Inlet vents are made at lower levels allow to cool air in, and outlet vents are set at higher levels to allow warm air to rise by convection and escape. People have utilized the secret of dwarf termites to build mega buildings. You shouldn't be surprised if we call them "termite nests".

There are many things to learn from the behaviour of small insects such as cockroaches. Famous scientists study them because of the possibility of developing technological concepts using such studies. The glass sponge is a creature that lives in deep seas. It is made of a combination of weak chemical components but has a strong skeleton. Some might be troubled by the dwelling of pond skaters on the surface of water and another might be puzzled by the contribution of a shark's rough skin to its speed. Scientists are keen to investigate the secrets behind these phenomena because their curiosity may result in a new item of technology in the future.
Mother Nature is the creator of this amazing world. From the beginning of this world nature has endeavoured to find the most suitable and efficient answers, and the results are still visible today. Can mankind ever challenge her?

These are few examples out of the thousands of Bio Mimicry applications that have been brought to your attention, because you may also be able of contribute valuable ideas to developing new technologies.

Practise and train yourselves to observe nature with curiosity. It is certain that you will also be able to develop new concepts that would facilitate development of new technologies.

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