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Multi-disciplinary Approach of Archaeology

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Use of Minerals, Rocks and Clay as Geoarchaeological Materials: an Overview

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Abstract

Geoarchaeology is a multi-disciplinary approach, which uses the techniques and subject matter to examine topics which share the archaeological knowledge and thought. During the archaeological excavation, the geoarcheologists engage with soil strata and sediment or deposits. For this purpose, different macroscopic and microscopic techniques are used to obtain good results. Accordingly, using such techniques, a geoarchaeologist or a group tries to analyze minerals, rocks and clay from excavations to reveal the old humans and their civilizations, artifacts and fossil remains. Thus, based on physical, chemical and biological approaches, the geoarchaeologist/archaeologist tries to realize the palaeoclimatic changes, which incorporated with human and cultural evolutions from glacial and interglacial periods to date.

In Sri Lankan submerged planated surface (present continental shelf), salient features are submerged forest,

rock and shelter caves and old river courses. Also, along the coastline and coastal zone, beachrock shoals, corals, shell beds, submerged lagoons and river mouths, emerged coastal sand ridges, sand dunes, wind blown sand ridges have formed due to the palaeo sea level fluctuations during the Pleistocene and Holocene epochs. Besides, from 2nd planated surface (coastal plain) to 4th planated surface (hilly and mountainous terrain), it is possible to identify wetlands, mounds, rock and shelter caves as palaeo settlement sites. However, a proper investigation using geoarchaeological methods and techniques were not conducted yet by archaeologists. So then, archaeologists should pay attention to conduct research emphasizing genealogical techniques and methodologies using radiometric datings, on minerals, rocks and clay objects found through archaeological methods to obtain scientific results from Sri Lanka.

Introduction

The subject Archaeology is the scientific study of human activity through the recovery and analysis of materials and culture. The archaeological record consists of artifacts, architecture, biofacts or ecofacts, and cultural landscapes. Such records are uncovered as buried materials and surface material from palaeo sites in different regions of the Earth. In this manner, the subject archaeology can be considered as a combination of social sciences and a branch of the humanities and also pure science subjects.

An artifact is an object made by human beings, especially with a view to subsequent use. It is a handmade object, as a tool, or the remains of one, as a shard of pottery, characteristic of an earlier time or cultural stage, especially such an object found at an archaeological excavation. Likewise, any mass-produced, usually inexpensive object reflecting contemporary society or popular culture. Throughout of these developments, from Palaeolithic time *to date*, the cave men developed their shelter as a huge designing and constructing buildings by modern humans.

In archaeology a biofact or an ecofact is organic material found at an archaeological site that carries archaeological significance. Biofacts are natural objects found with artifacts or features such as big animal horns/ bones, charcoal, plants, and pollen. Biofacts are handled by humans; however, once the manipulation occurs, biofacts transform into artifacts.

Except some biofacts, from palaeo shelter to modern architectural designs and artifacts, these are made from geologic materials such as minerals, rocks, and clay. A mineral is a naturally occurring chemical compound, usually of crystalline form and abiogenic in origin. A mineral has one specific chemical composition, whereas a rock can be an aggregate of different minerals or mineraloids. Rock or stone is a natural substance, a solid aggregate of one or more minerals or mineraloids. For example, granite, a common rock, is a combination of the minerals quartz, feldspar and biotite found from archaeolocal sites.

Clay is a fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter and are plastic due to their water content and become hard, brittle and non–plastic upon dried and baked to make bricks, pottery, and ceramics. From tiny beads to huge pottery, tiles and ceramics represent as clay objects also show the development of Palaeolithic cultures in the ancient world to present.

Archaeology and geoarchaeology

The word geoarchaology encompasses the all sub disciplines of archaeology due to use of minerals rocks and clay. As a subject, geoarchaeology is a multi-disciplinary approach, which uses the techniques and subject matter of geography, geology and other Earth Sciences to examine topics, which inform archaeological knowledge and thought (Figure 1). Hence, geoarchaeologists study the natural, physical processes that affect archaeological sites such as geomorphology, the formation of sites through geological processes and the effects on buried sites and artifacts due to post-deposition. Thus, the geoarchaeologists' work frequently involves studying soil, soil layers (stratigraphy) and sediments as well as other geographical concepts to contribute an archaeological study. Geoarchaeologists may also use drawings, computer cartography, geographic information systems (GIS) and digital elevation models (DEM) in combination with disciplines from human and social sciences and earth sciences dealing with the physical constitution of the earth and its atmosphere.

Geoarchaeology is important to society because it informs archaeologists about the geomorphology of the soil, sediments and the rocks on the buried sites and artifacts they are researching on. By doing this, we are able to locate ancient cities and artifacts and estimate the age or time using radiometric datings. All these reveal that an archaeologist needs to follow a compulsory stream of science subjects, social sciences and humanities (Figure 2 and 3).

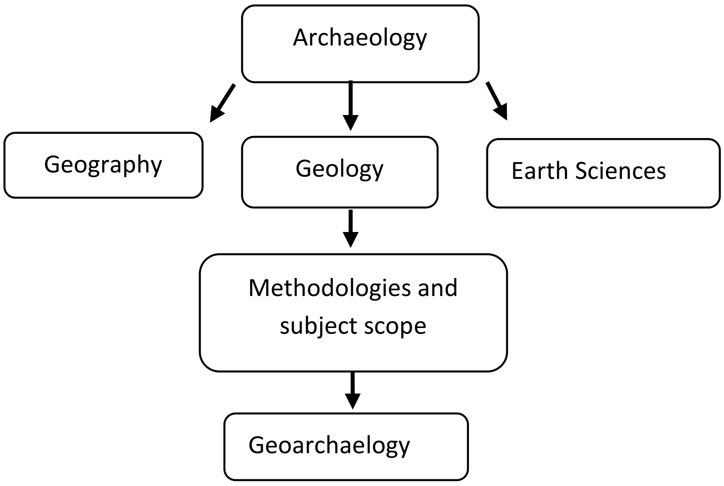


Figure 1. The subject geoarchaeology is a multi-disciplinary approach

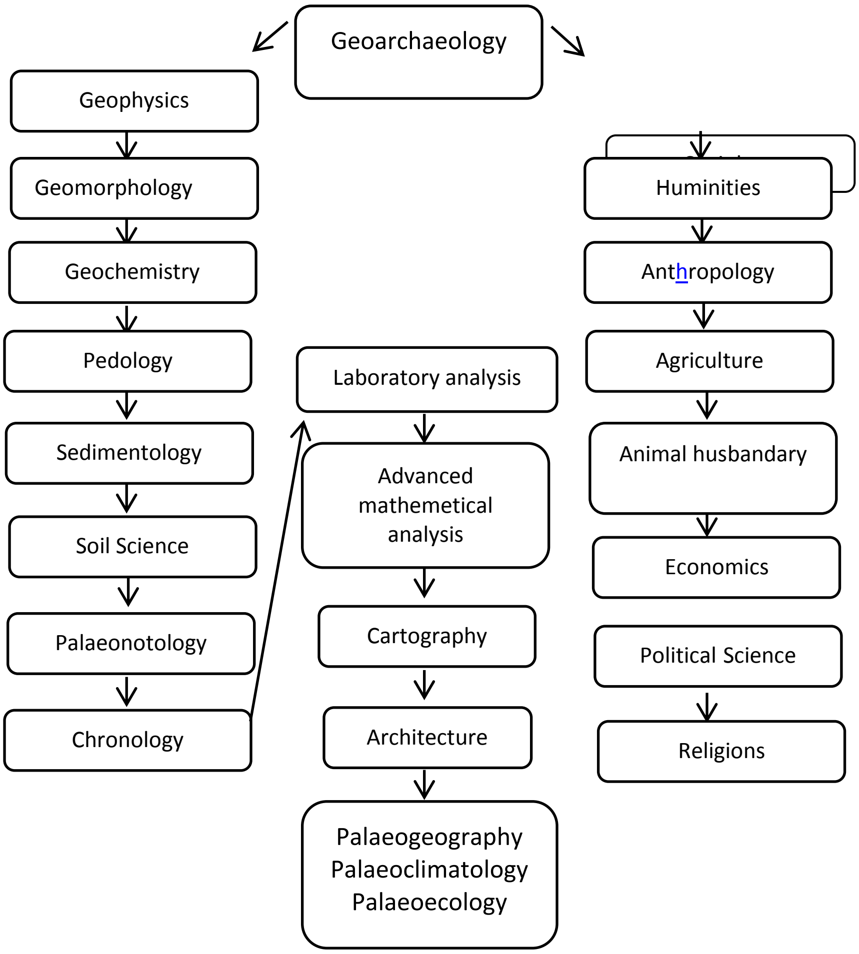


Figure 2. An archaeologist needs a multidisciplinary approach to get a sound knowledge in archaeology subject.

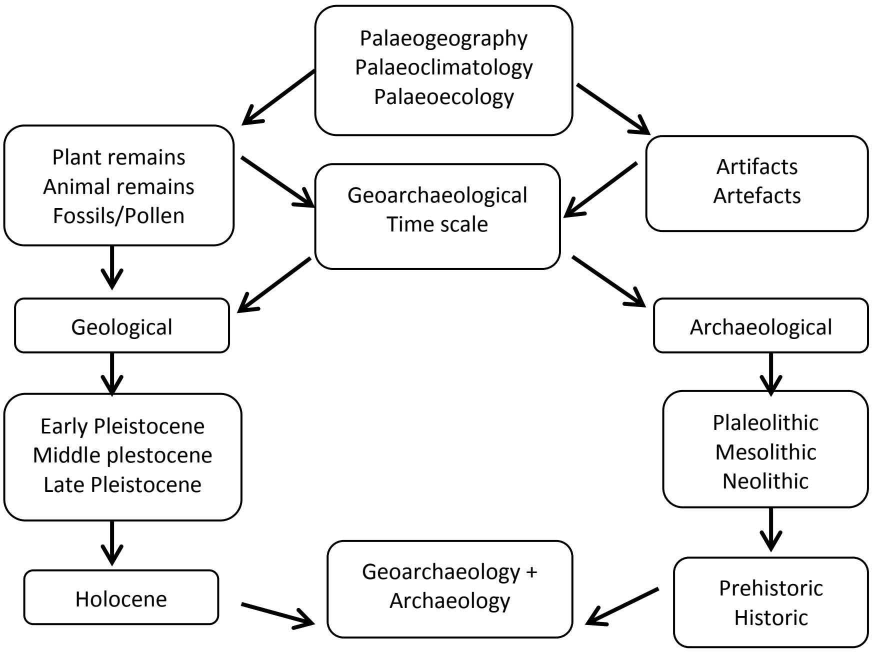


Figure 3. Geological, archaeological timescales needed to understand proper excavations.

Without exposing with others or other subjects, national and international collaborations, the graduates from archaeology subjects have become historians.

Techniques used in geoarchaeological research

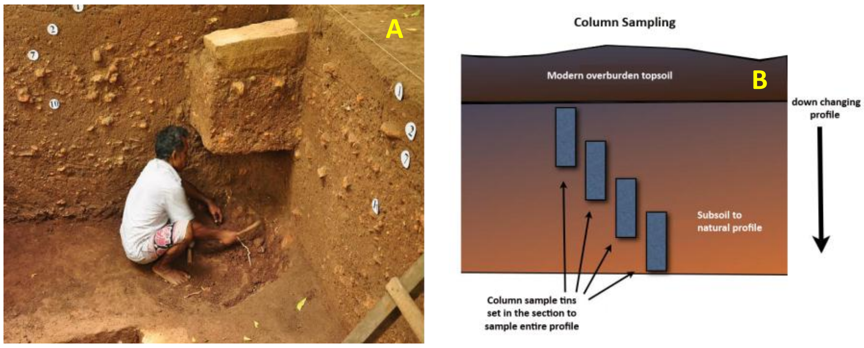
Column sampling

Column sampling is a technique of collecting samples (tiny samples of minerals, rocky artifacts and clay objects) from an archaeological section for analyzing and detecting the buried processes down the profile of a section. Narrow metal tins are hammered into the section in a series to collect the complete profile for the study (Figure 1B). If more than one tin is needed, they are arranged offset and overlapping one side so the complete profile can be rebuilt off-site in laboratory conditions. Column (Row) sampling techniques select a subset of important columns (or rows) of the original matrix, often randomly (sometimes deterministically) with respect to a well-defined probability distribution; and show that sampled matrix is a good approximation to original one (Jeff and Mina (2015).

Loss on ignition testing

Loss on ignition is a test used in inorganic analytical chemistry, particularly in the analysis of minerals. It consists of strongly heating a sample of the material at a specified temperature, allowing volatile substances to escape, until its mass ceases to change. Loss on ignition testing for soil organic content in soil samples. Samples taken from a known place in the profile collected by column sampling are weighed then placed in a fierce oven which burns off the organic content. The resulting cooked sample is weighed again and the resulting loss in weight is an indicator of organic content in the profile at a certain depth. These readings are often used to detect buried soil horizons.

A buried soil's horizons may not be visible in section and this horizon is an indicator of possible occupation levels. Ancient land surfaces, especially from the prehistoric era can be difficult to discern so this technique is useful for evaluating an areas potential for prehistoric surfaces and archaeological evidence. Comparative measurements down the profile are made and a sudden rise in organic content at some point in the profile combined with other indicators is strong evidence for buried surfaces. Factors such as sample size, exposure time, position of samples in the furnace and the laboratory measuring affected LOI results, with LOI at 550 °C being more susceptible to these factors than LOI at 950 °C. We, therefore, recommend analysts to be consistent in the LOI method used in relation to the ignition temperatures, exposure times, and the sample size and to include



Photograph: An excavation pit at Kaparamula, Abayagiri Vihara Project, CCF, Anuradhapura, 2014 (A) and offset column sampling of the soil profile (B).

Magnetic susceptibility analysis

The magnetic susceptibility of a material is a measure of its ability to become magnetised by an external magnetic field (Dearing, 1999). The magnetic susceptibility of a soil reflects the presence of magnetic iron-oxide minerals such as maghaematite; just because a soil contains a lot of iron does not mean that it will have a high magnetic susceptibility. Magnetic forms of iron can be formed by burning and microbial activity such as occurs in top soils and some anaerobic deposits. Magnetic iron compounds can also be found in igneous and metamorphic rocks. The relationship between iron and burning means that magnetic susceptibility is often used for:

- Site prospection, to identify areas of archaeological potential prior to excavation.
- Identifying hearth areas and the presence of burning residues in deposits.[2]
- Explaining whether areas of reddening are due to burning or other natural processes such as gleying (waterlogging).

The relationship between soil formation and magnetic susceptibility means that it can also be used to:

- Identify buried soils in depositional sequences.
- Identify redeposited soil materials in peat, lake sediments etc.

Using the Bartington MS2 System to determine Environmental Magnetic Susceptibility (Dearing 1999) analysis, the magnetic susceptibility can be divided under two parts: measurement and interpretation. Under measurement, he explains the Magnetism and Environmental Materials, Getting started with the MS2B Sensor, Working in the laboratory - sensors MS2B, MS2C, MS2E, MS2G, MS2 κ/T 20, Surface measurements in the field - sensors MS2D, MS2F and MS2K 27, Sub-surface measurements in the field – sensor MS2H, calibration, accuracy and precision and use of Software for the MS2. Similarly, under interpretation, Room temperature susceptibility, Frequency-dependent susceptibility, Low and high temperature susceptibility, Weak samples etc. were explained.

It is evidently clear that the soil represents a great storehouse of information for archaeology hence the connection between the two fields, thus soil science and archaeology should be tightened. Further research should be done to drastically minimize the main drawbacks of soil total phosphorus analysis. Soil magnetism should be deeply explored as it holds the key to reliable archaeological investigations (Vranováet al 2015). The authors mention that the prehistoric alterations in the local archaeological soil body profiles documented by archaeological and biochemical evidences and related to microbial and biochemical changes induced by paleoenvironmental amendments and settlement dynamics rotations can be studied from soil scientific points of view.

Phosphate and orthophosp hate content with spectrophotometry

Phosphorus (P) in soils has long been of interest to archaeologists because of its potential to inform them about the presence of past human occupation and to offer clues regarding the type and intensity of human activity (Holliday and Gartner, 2007). Soil P dynamics are quite complex, however. Phosphorus is a common allotropic element with many possible natural and cultural sources. It enters the soil through a variety of direct and indirect pathways. Phosphorus forms bonds with soil particles, primarily through biologic immobilization, chemical precipitation, and sorption. The precise form of Porg and Pin present in the soil, the strength of P bonds, and the loci of fixation within a soil horizon, depend largely on-site environmental factors.

Phosphate in man-made soils derives from people, their animals, rubbish and bones. 100 people excrete about

62 kg of phosphate annually, with about the same from their rubbish. Their animals excrete even more. A human body contains about 650g of PO4, (500g-80% in the skeleton), which results in elevated levels in burial sites. Most is quickly immobilized on the clay of the soil and ‘fixed’, where it can persist for thousands of years. For a 1 ha site this corresponds to about 150 kg PO4 ha-1yr-1 about 0.5% to 10% of that already present in most soils. Therefore, it doesn’t take long for human occupation to make orders of magnitude differences to the phosphate concentration in soil. Phosphorus exist in different ‘pools’ in the soil 1) organic (available), 2) occluded (absorbed), 3) bound (chemically bound). Each of these pools can be extracted using progressively more aggressive chemicals. Some workers (Eidt especially), think that the ratios between these pools can give information about past land use, and perhaps even dating. Phosphate concentrations can be plotted on archaeological plans to show former activity areas, and is also used to prospect for sites in the wider landscape.

Whatever the method of getting the phosphorus from the soil in solution, the method of detecting it is usually the same. This uses the ‘molybdate blue’ reaction, where the depth of the colour is proportional to phosphorus concentration. In the lab, this is measured using a colorimeter, where light shining through a standard cell produces an electric current proportional to the light attenuation. In the field, the same reaction is used on detector sticks, which are compared to a colour chart.

Particle size analysis

Grain size analysis is a fundamental tool for classifying unconsolidated materials and sediments, sedimentary rocks, and sedimentary environments. Quantitative analysis of the percentages of different particulate sizes yields one of the most fundamental physical properties of clastic sediments and sedimentary rocks (López 2017). The author mentions that grain size analysis is an analytical technique typically conducted within the earth sciences and implemented as a routine laboratory study. Other disciplines, such as archaeology and geoarchaeology, also use it regularly. It is a sedimentological analysis carried out in order to determine the size of the different particles that constitute a particular unconsolidated sedimentary deposit, sedimentary rock, archaeological locus, or soil unit. The main goal of this procedure is to determine the type of environment and energy associated with the transport mechanism at the time of deposition; this is done by inference from the sizes of the sediment particles analyzed and their distributions

The particle size distribution of a soil sample may indicate the conditions under which the strata or sediment were deposited. Particle sizes are generally separated by means of dry or wet sieving (coarse samples such as till, gravel and sands, sometimes coarser silts) or by measuring the changes of the density of a dispersed solution (in sodiumpyrophosphate, for example))of the sample (finer silts, clays). A rotating clock-glass with a very fine-grained dispersed sample under a heat lamp is useful in separating particles.

The fractions received can be further investigated for cultural indicators, macro- and microfossils and other interesting features, so particle size analysis is in fact the first thing to do when handling these samples.

Trace element geochemistry

Trace element variations in an archeological carbonate deposit from the antique city of Ostia: Environmental and archeological implications describe by (Carlut et al 2009). Similarly, Trace Element Analysis of Obsidian Artifacts has been described by Ughes and Ortiera 2007). Also, Trace element geochemistry in archaeological sites clearly emphasized by Jenkins (1989).

The author emphasizes that man can leave a geochemical imprint on an archaeological site in several ways. In common with other components of the biosphere, there is a selective enrichment of elements in his body tissues which, upon death and burial, may lead to detectable anomalies. Of elements concentrated in this way P is the most obvious, but Sn could be another possibility worth further investigation. There has been particular geochemical impact due to the progressive use of such metals as Ag, Au, Cu, Pb and Zn during successive cultural stages. Anomalies may thus arise due to recognizable transported ore, slags or artefacts, although there has also often been cryptic redispersion of the metals within a site.

Trace element geochemistry is the study of the abundances of elements in geological materials that do not occur in a large quantity in these materials. Because these trace elements' concentrations are determined by a large number of particular situations under which a certain geological material is formed, they are usually unique between two locations which contain the same type of rock or other geological material.

Geoarchaeologists use this uniqueness in trace element geochemistry to trace ancient patterns of resource-acquisition and trade. For example, researchers can look at the trace element composition of obsidian artifacts in order to "fingerprint" those artifacts. They can then study the trace element composition of obsidian outcrops in order to determine the original source of the raw material used to make the artifact.

Clay mineralogy analysis

Geoarchaeologists study the mineralogical characteristics of pots through macroscopic and microscopic analyses. They can use these characteristics to understand the various manufacturing techniques used to make the pots, and through this, to know which production centers likely made these pots. They can also use the mineralogy to trace the raw materials used to make the pots to specific clay deposits.

Ostracod analysis

Naturally occurring Ostracods in freshwater bodies are impacted by changes in salinity and pH due to human activities. Analysis of Ostracod shells in sediment columns show the changes brought about by farming and habitation activities. This record can be correlated with age dating techniques to help identify changes in human habitation patterns and population migrations.

Mineral objects

From archaeological excavation sites plenty of mineral and mineraloid objects are found. Among these calcium carbonate, limestone, glass/ceramics silica sand, talc, lithium, borates, soda ash, feldspar, linoleum calcium carbonate, clay, wollastonite, kaolin clay, sodium sulfate, lime, soda ash, titanium dioxide, gypsum, phosphates etc. are valuable things.

Photographs: Minerals, rocks and clay objects found from Kaparamula excavation pit, Abhayagiri Vihara Project (CCF Anuradhapura), August 2014.

Geoarcheologcal research in Sri Lanka

In Sri Lankan submerged planated surface (present continental shelf), salient features are submerged forest, rock and shelter caves and old river courses. Also, along the coastline and coastal zone, beachrock shoals, corals, shell beds, submerged lagoons and river mouths, emerged coastal sand ridges, sand dunes, wind blown sand ridges have formed due to the palaeo sea level fluctuations during the Pleistocene and Holocene epochs (Katupotha, 1995; 2013). Besides, from 2nd planated surface (coastal plain) to 4th planated surface (hilly and mountainous terrain), it is possible to identify wetlands, mounds, rock and shelter caves as palaeo settlements (Katupotha 2013). However, proper investigations using geoarchaeological methods and techniques are not conducted by archaeologists yet. So then, archaeologist should pay attention to conduct research emphasizing geoarchaelogical techniques and methodologies as well as radiometric datings, on minerals, rocks and clay objects found to obtain scientific results from Sri Lanka.

In Sri Lanka, thousands of Palaeolithic to Neolithic sites are extended from continental shelf and coastal zone to Central Hill Country. But, archaeologists and others have undertaken their research over the kings, kingdoms, religious activities, foreign trades, foreign invaders etc (Katupotha, 2009; 2015). Using minerals, rocks and clay objects through such events, archaeologicats try to reveal activities from Iron Age **(**1200–230 BC) to the Age of Imperialism (c. 1700 – mid 20th Century). However, emphasizing multi-disciplinary approaches, geoarcheological research have undertaken by palaeonotogists, geologists, sedimentologists, anthropologists, mineralogists, entomologists as well as cultivators, and their observations blooms on stone tools emphasizing lower palaeolithic period to upper Palaeolithic period.

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