Holocene Cultural and Environmental Reconstruction of the Yeha Area, North Ethiopia

Mulugeta Feseha[1], Tekle Hagos[2], Teclehaimanot Gebreselassie[3], Ahmed Hassen[4], Zerihun Woldu[5], Krawielicki Julia[6], Negar Haghipour[6] , Birhan Teka[7], Friat Angesom[7], Hadgu Zeru[7], Negasi Awetehegn[7], Hayelom Tafere[7] and Welu Gebresilassie[7]

Abstract

The formation of modern state in Ethiopia was initiated some 900-500 BC in northern Ethiopia, Yeha, a town located within the mountain chains of Adwa. Because of its historical and archeological importance, several research works have been conducted on this site for many years. As a continuation of this and in a more comprehensive way a multidisciplinary research team was engaged in a research to reconstruct the ancient environment and culture of the Yeha area using multiple archaeological, historical, and geological methods including: archaeological surveys and excavations; radiocarbon dating; stratigraphic and depositional environment interpretation and biomarker analysis; and interpretation of settlement areas. The outcome of the research indicates that the indigenous inhabitants of Yeha seem to have been living in the area since ~5,000 Years BP as cattle herders and cultivators. Furthermore, the climate of the Yeha region around ~3500Yrs BP, which was wet with an average temperature of 17.5°C, had created a favorable condition for settlement that led to the formation of a centralized stratified society at Yeha at about 3500BP.

Keywords: Cultural, environment, Holocene, reconstruction, stratified society, Yeha

[1] Paleoanthropology and Paleoenvironment Program, Addis Ababa University;
[2] Department of Archeology and Heritage Management, Addis Ababa University;
[3] Department of History, Addis Ababa University;
[4] Institute of Ethiopian Studies, Addis Ababa University;
[5] Department of Plant Sciences, Addis Ababa University;
[6] Geological Institute, ETH Zurich;
[7] Department of Archeology, Aksum University;

1. Introduction

Several research works have been carried out on the archeological site of Yeha that include: ancient vegetation reconstruction, archeological excavations and historical reconstruction. However, except the works done by Kathryn et al. (2000), the overall environmental condition that prevailed in Yeha and its surrounding areas between 900 BC - 500 BC is not comprehensively investigated. What the environment of Yeha looked like and what was the impact of the environment on cultural evolution of the site is not yet fully addressed. Hence, this research focuses on reconstruction of ancient vegetation, climate and culture of the region. It considers: i) geological and biomarker research on the depositional history and ancient environment; ii) radiometric dating of organic materials and cultural materials; iii) archaeological and historical research and reconstruction; and iv) the integration of the ancient environmental and cultural evolution of the Yeha region, which is the origin of complex society and the formation of the first state in the region.

2. Objective

The objective of this research is to reconstruct the cultural and environmental evolution of the Yeha region from environmental, archeological and historical studies.

3. Geographical Location

Yeha is located in northern Ethiopia at 39°1′43″ east and 14°17′36″ north. It has basin topography with surrounding mountain chains of phonolitic and trachytic volcanic rocks (Miruts et al. 2017). The Temple of Yeha is located at the center of the town. It has preserved several archeological localities in its vicinities including: *Grat Beal Geubri* which is a ruined complex of an old palace, a temple, Sabaean inscriptions; and Ethiopian Orthodox Tewahedo Church monastery of *Aba Afitse*. In addition, several archeological sites are found in Yeha including: a rock art, cemetery, settlement and several historical handicraft centers. The topography of the area and locations of the archeological localities are shown in figure-1 below.

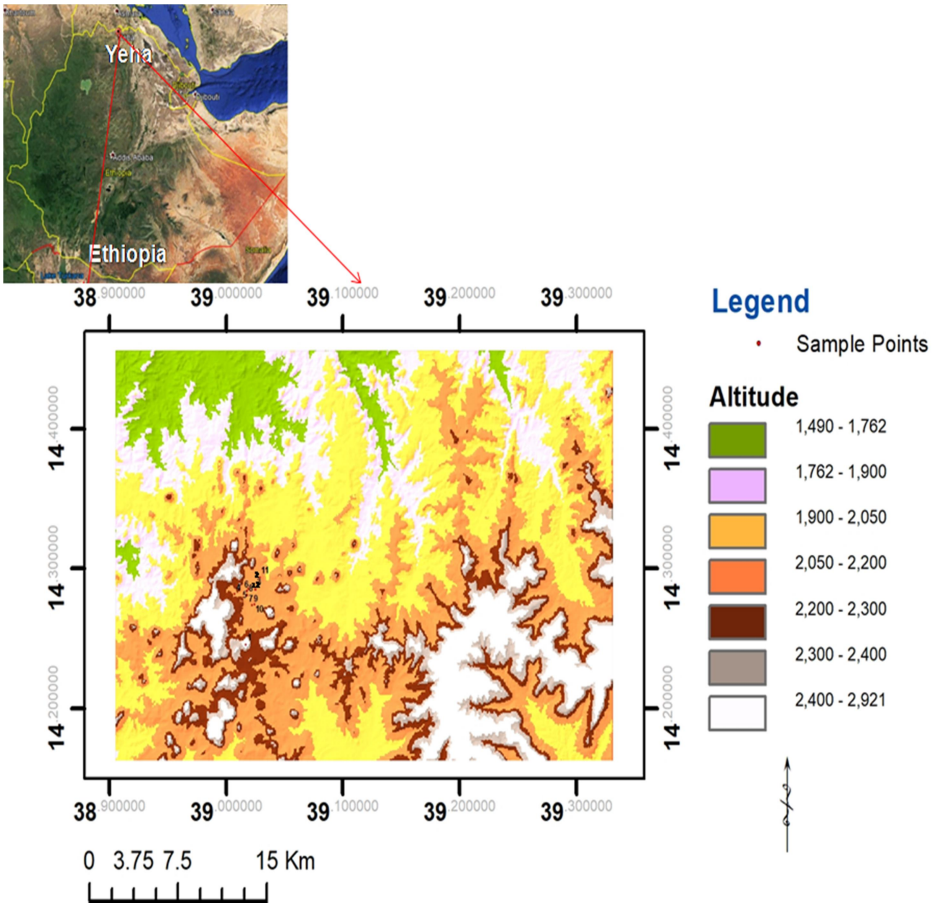

Fig.1. Map showing the topography of Yeha located in northern Ethiopia and its mountain chain surroundings. The dots with corresponding numbers represent the following locations: 1- Emba Tsegurom cave art , 2-Sawne stratigraphic section, 3-Harawa stratigraphic section, 4- Mai Mekolo stream source, 5-Da'ero Michael Burial, 6- Gebe'ta settlement , 7- Haguado smelters locality, 8- Abi Adi cemetery, 9- Tseratsur settlement , 10- Mingirgar Muslim settlement, 11- Enda Galie pottery site and 12- Yeha Temple.

Fig.2. Photo showing the Yeha basin and its surroundings

4. Archeological Researches

Archaeological investigations have been carried out at the site of Yeha for the last decades. But comprehensive research on ancient cultural and environmental reconstruction using multiple proxies at Yeha is not yet carried out. The summary of the archaeological researches carried out so far and the current archaeological research that is taking place in the vicinities of Yeha are presented below.

4.1. Previous Researches

The site of Yeha located in the northern tip of Ethiopia, in Tigray National Regional State, was known to scholars and travelers since at least the 6th century AD (Bent 1893), although, the name Yeha is as old as 8th century BC as proven by the inscription found on an altar found in *Addi* Akawih near the town of *Wukro*, 60 km north of the city of Mekelle (Japp et.al. 2011). The six century Byzantine Ambassador to Aksum, Nonnosus, mentioned the same site as Ava/Ave which was later identified by some scholars such as Bent as Yeha (Bent 1893). Nonnonsus might have wrongly spelt *Aba Afistie* as Ava/Ave, as Yeha was known as *Aba Aftsie* since the 6th century AD. Furthermore, Yeha is considered as the only site with rich archaeological remains including a palace and pre-Christian religious

ceremonial center, which is located 53 km to the east of the World Heritage site of Aksum, and is considered to be the capital city of Ethiopia before Aksum.

In the 16th century AD, the Portuguese Catholic priest Francisco Alvarez visited the site of Yeha in 1520 and reported that there was a high skill of water control at the site of Yeha and that the fields were "all irrigated by channels of water made of stone" descending from the mountains **(**Beckingham and Huntingford, 1961, 141). In the 16th century AD, when Alvarez visited the place, the site of Yeha was already known as *Aba Aftsie*. Furthermore, Alvarez reported that the Great Temple of the moon god (*almaqah*) had already begun to fall into ruins in the 16th century AD **(**Beckingham and Huntingford 1961).

In the 18th century AD, the Scottish explorer James Bruce (1790) visited the site of Yeha in 1769. In the beginning of the 19th century AD, the British traveler Henry Salt, also visited Yeha in 1810 and copied the Sabaean inscriptions at Yeha (Salt 1814).

In the late 19th century AD, Theodore Bent, the British archaeologist carried out the first archeological investigations at the site of Yeha in 1893. He measured, documented and photographed the archaeological ruins of Yeha. Bent identified different archaeological localities in Yeha that require future archaeological excavations, and confirmed the remotest date and the great archaeological potential of the site of Yeha. He also argues that according to classical sources, Yeha was the capital city of Ethiopian Todlodytica (name of the ancient people who were leaving in Yeha) before the foundation of Aksum (Bent 1893). However, it is unclear as to who were the Todlodytica whether they are similar with the current inhabitants of the region, the *Tegaru (*the Tigrigna speaking populations of the area*)*. In fact, the inscriptions discovered at the site of Yeha also mention that the population of ancient Yeha was divided into two families of populations: the Reds and the Blacks which may refer to the Semitic and the Cushitic, respectively (Bernand *et.al.* 1991-2000; Sergew 1972). The same scholar argues that the place mentioned as Ava by

6th century travelers was Yeha. Bent, who came from the port of Adulis following the Aksumite trade routes by land, was the first scholar to confirm that Yeha was a trade route centre in the early first millennium AD between the Aksumite metropolis, Aksum, and the port of Adulis located in the Red Sea Coast near the port of Massawa in what is now Eritrea. Bent used the following authoritative statement: "the ruins of Yeha are definitely located along the ancient road between the port of Adulis and Aksum" (Bent 1893, 143).

The German Aksum Expedition led by Enno Littman stayed in the town of Yeha from 11 – 13 April 1906 for three days at the beginning of the 20th century AD (Phillipson 1997; 1998). This team has documented the inscriptions reported by Henry Salt: the ruins of *Grat Beal Geubri* and the Great Temple of Yeha, using photographs. The Enno Littman team made excellent reconstructions of the palace of Grat Beal Guebri and the Great Temple of Yeha that do not have any parallel with modern ones (Littman et.al. 1913).

In 1955, the French archaeologist, Jean Doresse, discovered a baptistery to the southeast of the interior of the Great Temple which proves that the temple was converted to a church or a monastery, probably after the coming of The Nine Saints (Anfray 1963). From 1973-74, intensive archaeological surveys around Yeha were conducted by an American Archaeological Expedition under the direction of Joseph Michels (Michels 2005) who documented several Yeha period sites at Yeha and its surroundings as part of his grand archaeological survey project entitled 'Archaeological Surveys between Yeha and Shire regions'. In the 1960s and 1970s, two large scale archaeological excavations were undertaken by the Institute of the Ethiopian Archaeology under the direction of the French archaeologist, Francis Anfray, at the palace of *Grat Beal Geubri* and at the *Daero Mikael* rock cut tombs to the north east and south west of the Great Temple of Yeha, respectively.

The first major structure that was excavated in 1960 by Francis Anfray was the underground rock cut tombs at the locality of *Dae'ro Mikael*. A series of rock-cut graves with vertical shafts that lead to one or more tomb-chambers were excavated by Anfray. In addition, 300 grave goods including pottery, copper-alloy sickles, 13 bronze

seals with zoomorphic shapes such as lions and Walia ibex, and other tools were retrieved in these 17 underground vertical rock cut shaft tombs at *Daero Mikael* (Fattovich 2009; Japp et al. 2011). The Italian archaeologist, Rudolfo Fattovich, who was an assistant to Anfray on the course of the investigation of these tombs, undertook a detailed study of the pottery collections from the same tombs. He also studied the potteries that were collected from test excavations that he conducted at the locality of *Gual Edaga (found adjacent to the Yeha temple)* at the same time (Anfray 1972). Fattovich, based on his study on the pottery collection, argues that the earliest pottery from *Gual Edaga* and the potteries from some of the tombs from the *Daero-Mikael* represented low-status settlement dating prior to 8th century BC that could be associated to the indigenous communities before the coming of the Sabean immigrants while some of them represented elite cemetery that may have been contemporary to the second phase of the construction of the Palace of *Grat Beal Geubri* and the Great Temple (Fattovich 2009).

The second major excavation took place under the direction of Anfray in 1971 at the Palace of *Grat Beal Geubri* that was initially systematically investigated in 1906 by the German Aksum Expedition. On the course of the excavations, Anfray uncovered several monolithic pillars and stairs which lead to the main Palace of *Grat Beal Geubri*. This excavation showed that there were two phases of construction of the Palace of *Grat Beal Geubri*. The earliest one was destroyed by fire and was replaced by complex building that is characterized by monkey head style and by corners of monolithic pillars (Anfray 1972). Excavation conducted below the podium of the *Grat Beal Geubri* retrieved the earliest pottery contemporary to the pottery of *Gual Edaga* that also represent the earliest settlement of indigenous communities of Yeha dating prior to the 8th century BC (Fattovich 2009). It seems that this palace was the only structure in Yeha and its surroundings to be built on fertile cultivated land as the building required deep foundation that could be excavated easily to carry huge load above the surface of the earth. However, Anfray did not completely excavate the whole building complex as it can be

understood from the recent excavations undertaken by the German researchers.

In the 1990s a French Archaeological Mission under the direction of Christian Robin conducted an archaeological clearance inside the Great Temple. He completely exposed the floor of the Great Temple. The potteries he uncovered below the foundation of the Great Temple have similarities with the styles of the South Arabians (Fattovich 2009). He also found an earlier structure of a small temple on the north eastern chamber of the Great Temple that date to the 8th century BC (Robin and de Maigret 1998). After the destruction of this temple it was replaced by the surviving Great Temple at about late 8th century BC or early 7th century BC (Fattovich 2009). He also reported that the ruins of small temple were reused to build the new church of *Aba* Afitse in the 1940s, as it can be understood from the ibex engraving and block of dressed stones that have been part of the small temple are integrated in the walls of the same modern church (Robin and de Maigret 1998, 740; Littman et al. 1913)

Researchers from the German Archaeological Institute (DAI) under the Direction of Gerlack Iris have been conducting archaeological investigations at the Palace of *Grat Beal Geubri*, at the rock cut tombs of *Abiy Addi* and also near to the Great Temple and restoration works at the Great Temple since 2009 (Japp *et.al*. 2011).

The first archaeological locality where the DAI have been conducting archaeological excavations is the palace of *Grat Beal Geubri.* This team continued archaeological excavations at the same place which was not completed by the French archaeologists. The team undertook large scale archaeological excavations in the same place and determined the shape and size of the palace which is square in shape measuring 46 m by 46 m. The excavations of the same team showed that the palace stood on a podium that is 4.5 m high, and that the podium of the Palace of *Grat Beal Geubri* was constructed with stones. Wooden beams were also excavated by the same team in the same structure. In addition, the excavation showed that the front façade of the palace is well planned and built as proved by the six surviving monolithic pillars. Charcoal sample taken from the surviving wooden beam from the base of the podium was dated by

radio Carbone (^{14}C) to 8th century BC according to the researchers of the German Archaeological Institute (Japp et.al. 2011).

The German team gives too much emphasis to diffusion approach than to the internal dynamism. The same team compared the Great Temple of Yeha and the *Grat Beal Geubri* Palace with those found in Yemen and argues that what is found at Yeha is attributed to the civilization of the Sabaeans. On the other hand, the same researchers did not get any comparison of the rock-cut tombs of *Abbiy Addi* in Yemen and argue that the same tombs are indigenous and date prior to the coming of the Sabaeans to Yeha in the early first millennium BC (Japp *et.al.* 2011).

4.2. Current Research

Since 2016 a multidisciplinary research team from Addis Ababa and Aksum Universities, led by Mulugeta Feseha, has been conducting a research outside the town of Yeha, in the rural areas that surround the same town. This team consists of geologists, historians, archaeologists, ecological botanist, and museum experts. The objective of this research team is to reconstruct the ancient environment and culture of the Yeha region during the Holocene.

4.2.1. Historical data

It is not straight forward to make precise historical statements about the ancient inhabitants of northern Ethiopia before the emergence of the Yeha state. In order to search for ancient settlement sites and excavate for archeological evidences, it was important to interview a group of selected informants from the residents. For this purpose, oral traditions were collected in 2018/19 and the results demonstrate that the Nilo-Saharan followed by the Cushitic/Agaws were the earliest inhabitants at Yeha and its surroundings before the coming of the Sabaeans to the Northern Horn in general and to Yeha and its surroundings in particular in the early first millennium BC. The Sabaean presence in the Northern Horn is supported by later period linguistic evidences found at the sites of Yeha, Hawelti, and Matara and at Aksum dating between the first millennium BC and the early first millennium AD (Sergew 1972).

In the early first millennium BC (Sergew 1972), it is assumed that people from South Arabia, the Sabaeans, migrated westwards across the Red Sea and eventually intermingled with the people of the Horn of Africa, probably with the Agaw, and became the Semitic peoples of Ethiopia. Taddesse (1988, 6) says that "The Agaw stand out as some of the most ancient inhabitant of northern Ethiopia." There are historical indications that the Sabaeans are assumed to have settled in peace to secure a better and peaceful life. The indigenous people are said to have developed the indigenous title for their leaders *Mukarib* equivalent to king, until they later adopted a Sabaean title MLK (head or chief) in un-vocalized Sabaean inscription discovered at the site of Yeha and in other pre-Aksumite sites.

What we see nowadays as prominent elements of the Yeha civilization in northern Ethiopia is the product of the fusion of several peoples. Those successive migrations of the above indicated peoples and others of the Northern Horn have made the current ethnic composition and diversified culture of the study area. These important traditions were gathered from different knowledgeable elders with their background of Church education and others who have been transmitting oral history from generation to generation, as well as the available archaeological facts accessed and identified for further analysis. Our research has compared the oral information with the available archaeological evidence, most of which have shown amazing correspondence with the available literature. When compared with some old literature the ancient place names, water sources for irrigation and terrains very well fit the existing ones as indicated in the description of the archaeological localities discussed throughout this paper.

It can be inferred that Yeha was selected as a settlement because of its climatic condition and the availability of adequate water from its high mountains used for irrigation of the entire fertile Yeha valley using carved stone canals.

Fig.3. Photo showing key informants: interviewed elders at Yeha (left) and old water canals of Yeha, which is still used for modern town water supply.

4.2.2. Archaeological Evidence

The team followed the suggested ancient settlement sites by the informants and conducted intensive archaeological surveys in the rural areas of Yeha and documented several Yeha period settlements on the hills that surround the town of Yeha as elaborated in 4.2.2a-2d.

4.2.2a. *Inda'a Gali'e*

This pottery site is located at 39°1′43″ east and 14°17′36″ north in a flat land on the top of the Èntäkobo hill at *Addi Qäshi* which is part of the mountain chains that surround the Yeha basin. It is located about 5 kms to the northeast of the Yeha Temple. The terrain is rocky and highly degraded. It is covered by shrub land vegetation composed mainly of *Euphorbia candelabrum, Euclea schimperi, Becium sp, Acacia etbiaca, Maytenus senegalensis and Dodonaea angustifolia*. This locality was documented by Michels in 1974 (Michels 2005) as consisting of sparsely distributed Yeha period potteries on its surface. This site indicates that settlements and production areas of the Yeha period were influenced by the topography of the area. Unlike the palace of *Grat Beal Geubri and Gual Edaga,* most of the Yeha period settlement/pottery sites and shrines at Yeha are located on hill tops reserving the fertile plains for cultivation. This argument can be

substantiated by the location of the locality of *Inda'a Gali'e* as it is located in uncultivated land.

The team surveyed the same locality in 2018 and observed that pottery fragments are scattered all over the same locality.

Fig.4. Photos showing the locality of *Inda'a Gali'e* (left) and fragments of pottery (right) found in that locality.

4.2.2b. *Dingure*

The second archeological locality that is found in uncultivated land in a foot hill is *Dingure*, located at 39°1′19″ east and 14°1′24″ north. This locality is characterized by the distribution of several disturbed stones that may have been part of the Yeha period buildings. Several fully decorated potteries were accidentally discovered by farmers in the area while working in the farm. It appears that this locality might have been a pottery production area (*kiln*) as it can be understood from the provenience of the same remains. These potteries may have been produced for grave goods of the elites.

Fig.5. Photos of potteries at Dingure locality. Hammer (at left top photo), camera lid (at top right photo and standard scale at bottom right photo are placed for scale).

4.2.2c. Tseratsur (*Inda- Hantal)*

The archaeological locality of *Tseratsur* is located at about 39°1′19″ east and 14°16′25″ north in a gentle slope, 6 km south of Yeha, at the edge of southward facing hill overlooking the surrounding valley. The soil in the same locality is degraded and the vegetation cover includes: *Euphorbia candelabrum, Cordia africana, Croton macrostachyus, Olea eurpaea,* and is heavily dominated by *Acacia etbiaca* trees. It is one of the localities where the team conducted intensive archaeological surveys and test excavations. The landscape of this locality preserves an evidence of material remains of the Yeha civilization represented by orange ware pottery, dressed stone slabs, waterspout (1.35 m in length, 0.34 m wide and 0.10 m deep) and fragments of dressed stones with Sabaean inscriptions.

Fig.6. Photo of a Monumental pillar with a depression at the center at Tseratsur.

In addition, three bases of monumental pillars are also found in the same locality. The two base pillars are found inside a modern house while the third one is located outside the same house. The pillars are round in shape with shallow depression at the middle. One of the pillars that is found outside the modern house measures 90 cm by 95 cm while its centre depression is 31cm by 48 cm in size. It appears that these base pillars may have been remains of a third temple of the Yeha period in rural area (Fattovich 2012; Japp.et.al. 2011).

Fig.7. The landscape (top left), Sabaean inscriptions (top right), waterspout (bottom left) and dressed stone slabs (bottom right) at Inda Tseratsur.

The structure at the locality of Tseratsure is located in a strategically commanding point overlooking its surrounding valleys possibly to control the Yeha period or Aksumite trade routes that connected Yeha with the Nile Valley and the Red Sea during the Yeha and Aksumite times (Hatke 2013).

The team conducted test excavations in 2019 in two trenches at the same locality (TS-1 and TS-2) that measured 2 m by 1 m up to the depth of 75 cm and 87 cm below modern surface, respectively, to the east and west of a modern house to determine the horizontal extent

and vertical depth of the structure (temple?). Archeological excavation was conducted in the two trenches following an arbitrary level at the interval of 15cm up to the maximum depth of 87cm.

Fig.8. Photos of Test pit at TS-1

Both trenches showed that the structure/temple does not extend outside the modern house and that it was built on a shallow foundation as the bedrock was exposed at 70 cm below modern surface in trench one (TS-1).

Fig. 9. Photo of Test pit at TS-2

Furthermore, the test excavation conducted at trench two (TS-2) near the disturbed dressed slabs and water spout uncovered a collapsed wall which is 0.83 m wide with shallow foundation at the depth of 52 cm below modern surface. Excavation was terminated in this trench at the depth of 87 cm below modern surface level as the wall did not continue below the same depth. It appears that these dressed and disturbed pillars do not have connection with this collapsed wall as it can be understood from the poor construction technology of the wall as compared with the Yeha period building architecture. It is concluded that the overall structure of this temple is confined within the modern house as it can be understood from the result of the test

excavations in both trenches. This condition makes it too difficult to examine the ancient temple as it stands now.

4.2.2d. *Emba Tsegurom*

This rock art site is found in two rock shelters facing eastwards located at 39°17′24″ east and 14°24′56″ north, 10 km south of Yeha along the Adwa-Adigrat road in phonolitic-trachytic volcanic rocks. The rock shelters where the paintings are found are located at the top of the cliffy terrain, which is part of the phonolitic-trachytic volcanic mountain chain that surrounds the Yeha basin. The cliff is covered with bushy vegetation and grasses.

Fig.10. Photo showing the site of *Emba Tsegurom* (top left corner) and its paintings

The Emba Tsegurom archeological site is the first rock art site to be discovered in 2017 around Yeha. The paintings in these two rock shelters fall into the two phases of the Ethiopian-Arabian styles: the Surre-Hanakiya and the Dahathami phases that had been conventionally established by Cervicek (1971), Clark (1976; 1977) and Brandt and Carder (1987). The paintings in the rock shelters are located on top of a hard rock in a steep hill not easily accessible. They are executed in three colors: black, brown and white. The earliest naturalistic paintings appear to be executed in black followed by semi-naturalistic ones that are painted in brown color while the latest ones are executed in white. The earliest naturalistic paintings can be categorized to the Surre-Hanakiya phase of the Ethio-Arabian Style dating to 5000 BP (Cervicek 1971; Clark 1976, 1977; Brandt and Carder 1987). These naturalistic paintings portray, bull head, arrow and a rabbit. The semi naturalistic paintings can be categorized to the early phase of the Dahathami of the Ethio-Arabian Style dating to 3000 BP and portray, serpent, elephant and a circular figure that is difficult to decipher at the moment. It is interesting to see an elephant depicted in these paintings of *Emba Tsegurom* that confirms the 6th century AD report of Nonnosus who saw elephants grazing at Ava/Aba during the 6th century AD. The depiction of a large serpent with an opening mouth in the same paintings can be associated with the traditional belief that the first Ethiopian king and god was a serpent whose name was Arwe and that virgin girls, sheep, goat and milk were offered to the same (Sergew 1972). Furthermore, a serpent is also depicted on 3rd century AD Aksumite stela number 7 showing the importance of the same before the introduction of Christianity to the Aksumite court in the 4th century AD (personal observation, June 2019).

The latest paintings can be categorized to the later Dahathami phase of the Ethio-Arabian Style that date between about 3000 BP (Cervicek 1971) possibly up to the early Aksumite times. They portray herding scene of long horned humpless cattle, hunting scene, cultivation scene, riding scene on horses/mules, fighting scene with arrow and shield. The fighting depicted in these paintings seems to confirm the oral tradition that there were confrontations among the inhabitants of Yeha during the Yeha period. In addition, images of bull heads are displayed in the early phase of the paintings which are

uncommon in the rock arts of Ethiopia that are widely distributed in many parts of the country (Tekle 2011). Bull head carved on quartz and made on pottery figurines has been common on the *Ona* Culture found in the town of Asmara and its surroundings. The bull head image was considered as a symbol representing the belief system of the *Ona* Communities who resided in what is now central Eritrea during the early first millennium BC. In fact, it was this symbol that was taken as an evidence by some archaeologists to argue that the *Ona* Culture is different from the then existing culture of northern Ethiopia (Curtis, 2009). Thus, the discovery of the bull head in the paintings of *Emba Tsegurom* is one of the arguments to disprove the proposition that the *Ona* Culture in Eritrea is different from the Yeha Culture of northern Ethiopia. This proposition can also be substantiated by the image of a bull head that is displayed on the altar of the Temple of *Addi AKawih* near the town of Wukro that date to 8th century BC (personal observation 2016).

5. Stratigraphy and Paleoenvironment Data

Data was collected from two stratigraphic sections to understand the depositional environment and to interpret the ancient vegetation and climate of the area.

5.1. Depositional environment interpretation

Two stratigraphic sections that preserve pottery, bone fragments, burned ash and a stone tool were studied from *Sawne* (14°17′7.08″ N and 39°1′31.8″E) and *Haraw* (14°17′6.3″ N and 39°1′30.8″E) localities. These localities are found along the river valley, about 3kms north of the Yeha temple. The two stratigraphic sections of *Sawne* and *Haraw* preserve plant and cultural remains. Samples of sediments and organic materials were collected for depositional environment, climate and vegetation interpretation; and radiocarbon dating. The sediments of Sawne are deposited in a point bar fluvial deposit and the bottom part of the same section contains conglomeratic bed that is rich in charcoal, ash, bones and pottery fragments which represent the activities of the ancient humans. Organic materials from this horizon was dated to 3543 ± 84 Yrs BP

(see annex 1 and Sample_1 in figure 11) indicating that by this time period the communities of Yeha have already evolved to a complex system of society as it can be understood from the pottery remains as they are indicators of stratified communities. Similarly, the Haraw sediment section is deposited in flood plain origin anoxic poorly drained environment. The sediments of Haraw contains a single stone tool (scraper) which is dated to 3644 ± 88 Yrs BP (see annex 1 and sample H5 in figure 11). This material is also found in stratified societies such as those of the Aksumites of the first millennium AD.

The sediments in stratigraphic sections mentioned above were deposited by flooding in humid condition and have provided evidence of cultural remains. The presence of these cultural remains suggests that the communities at Yeha had evolved to a complex system of society since 3500 BP.

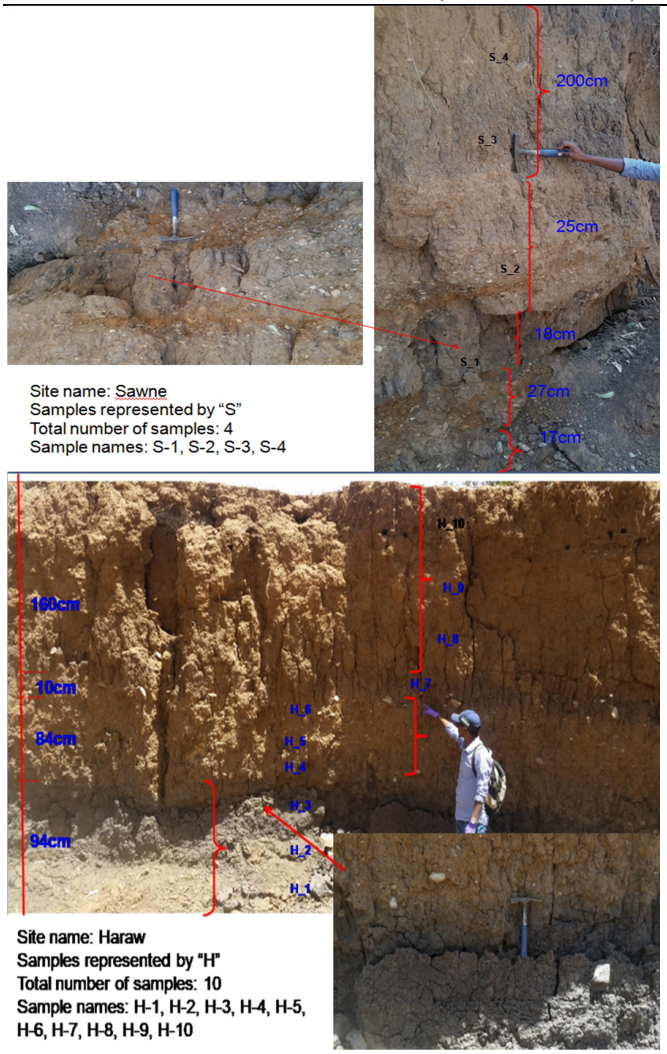

Fig.11. Photo of the Sawne section (left) and Haraw section (right). Thickness (in cm) and location of sample numbers in the section is presented.

Fig.12. Photos showing bone (top left), pottery (top right), charcoal (bottom left) and ash bed (bottom right) at the base of the Sawne sedimentary section.

Fig.13. A scraper found at the level where H5 sample was collected in the Haraw section.

5.2. Paleoenvironmental data

Data derived from organic carbon in the paleosols of the *Sawne* and *Haraw* stratigraphic sections shows strong shifts during the climatic transition period at the end of the African humid period (AHP) ~3500 years BP, including: total organic carbon (TOC), carbon to nitrogen ratio (C/N), reconstructed soil pH and temperature. The AHP from the early to mid-Holocene interrupted the general aridification trend in Africa. It has been related to the northward shift of the inter-tropical convergence zone (ITCZ) associated with an intensified monsoon (Liu et al. 2017; Tierney et al. 2008). Based on data from

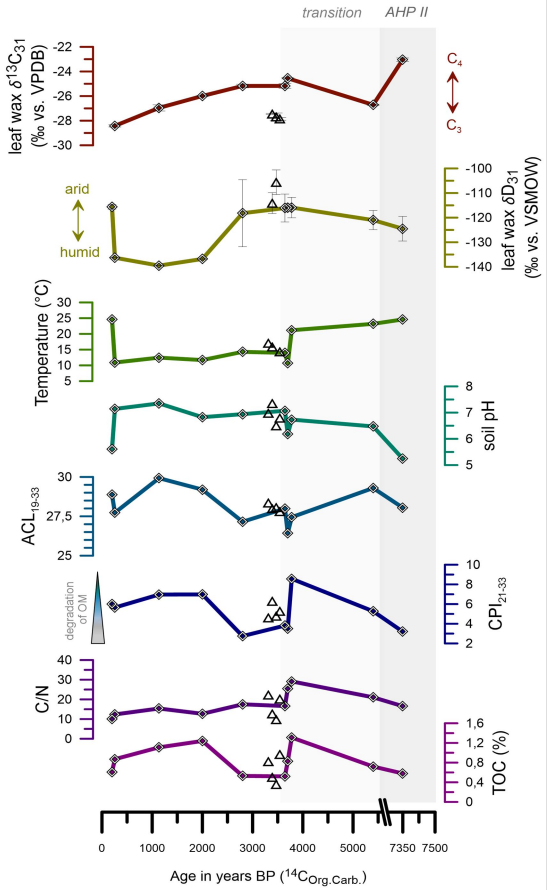

Figure 14: Geochemical data for Haraw site (diamonds) and Sawne site (triangles) with indication of the African humid period and transition into modern climate. Total organic carbon (TOC), carbon over nitrogen ratio (C/N); *n*-alkane carbon preference index (CPI); *n*-alkane chain length index (ACL); bacterial community changes in the soil (BIT); reconstructed mean annual temperature based on brGDGT data (MAT); *n*-alkane hydrogen isotopic values (δD_{31}); *n*-alkane carbon and isotopic values ($\delta^{13}C_{31}$) are depicted.

the coast of Tanzania three phases displaying decreasing humidity have been found: AHP I from the early Holocene to ca. 8 ka, AHP II until ca. 5.5 ka and a transition period until ca. 3.5 ka before the modern cool and arid climate (Liu et al. 2017; Loomis et al., 2012; Tierney et al. 2008). The record shown in the Yeha study is dominated by the termination and transition of the AHP, leading the continent into a cooler and dryer climate. The proxies for past eco-hydrology are derived from bulk organic material in the paleosol and molecular fossils (biomarkers) of plant leave-waxes (*n*-alkanes) and lipids of soil bacteria (*br*GDGTs) (Junginger et al., 2013; Sachse et al. 2012). The high variability of the plant wax average chain length ($ACL_{nC19-33}$) indicates (Eglinton et al. 1967) vegetation community shifts, especially around the end of the AHP transition and in the youngest

samples. This shift is also reflected in the plant wax carbon isotopic record ($\delta^{13}C_{wax}$), showing a gradual transition from enriched values during the AHP II to highly depleted values during and after the mid-late Holocene transition. This indicates a gradual change from C_4 to C_3 plants (Magill et al. 2013a; 2013b), i.e. from grasslands to open woodlands during the middle Holocene, possibly related to a shift to cooler temperatures as also observed in reconstructed annual temperatures. Additionally, hydrological conditions ($\delta D_{wax)}$ reflect the environment shift from arid (enriched values in hydrogen isotopes) to rather humid or wet after the AHP transition.

Furthermore, the C/N ratio shows a sharp drop during the transition period, indicating that the soil became less fertile. Also, a slight increase in alkalinity of the soil in addition might be a sign of a change in nutrient input or nutrient recycling, possibly related to a change in land use. In summary, the biomarker record shows a gradual change from an arid and warm climate to cold (with average temperature of 17.5°C) and wet conditions with soil conditions becoming less profitable for land use over the course of the Holocene.

6. Combined Archaeological, Historical, Settlement and Environmental Analysis and Results

The origin for the formation of the complex society that culminated as Yeha state can be traced back to the 3rd millennium BC with the coming of cattle pastoralist from the Sudan (Harrower 2015) as it is indicated from the rock paintings of *Emba Tsegurom* dating to 5000 BP (Cervicek 1971).

The dating of the rock art of *Emba Tsegurom* falls within the time range of the whole Yeha civilization**.** The dating of these rock arts also coincides with environmental change that took place during the Holocene from dry to wet seasons that resulted in the creation of an environment that had sufficient rainfall, water and grass that was conducive for food production such as domestication of cattle and cultivation as shown in the paintings of *Emba Tsegurom* and for the beginning of permanent settlement and state formation as attested by the Palace of *Grate Beal Geubri*, Great Yeha Temple, the Temple of

Inda Tseratsur, the rock cut tombs of Daero Mikael Shaft Tombs and Abbiy Addi, the Sabaean inscriptions found in proper Yeha and *Inda Tseratsur* and the potteries found at *Dingure and Daero Mikael.*

Conclusion

This research has used historical, archeological, and geological data to reconstruct the cultural and environmental history of the Yeha area. The earliest settlers of Yeha seem to have lived at the rock shelters which are located at the top of the Mountain of *Emba Tsegurom* as indicated in the paintings of the same dating to about 5000 BP probably before the establishment of the Yeha State. The Sabaeans together with the indigenous communities might have formed a highly stratified society who made their capital at Yeha as proved by the palace of *Grat Beal Geubri*, elite cemetery, and the Great Temple dated between the 8^{th} and 7^{th} centuries BC according to pottery evidence and radio carbon date (Fattovich 2009; Japp et.al. 2011).

The biomarker record in the Yeha sediments (Figure 14) depicts the climate of the Yeha region, at around 3500 Yrs BP, shows a gradual change from an arid and warm climate to cold (with average temperature of 17.5°C) and wet conditions, which was favorable and attractive for settlement. Along with this climatic change the plant community was transformed from grassland predominantly composed of C_4 species to woodland, predominantly C_3 species as reflected in carbon isotopic values (Figure 14). Moreover, the middle-late Holocene transition had a strong impact on lowering/ reducing the volume of water levels in lakes (Costa et al. 2014; Foerster et al. 2012; 2015) resulting in the movement of early societies in east Africa from lowlands to high lands in search of better climate and water (Garcin et al. 2012; Maria etal. 1998; Marshall et al. 2011; Tierney et al. 2008). Especially the climate established at Yeha at about 3500 BP with an average temperature of 17.5°C, better vegetation and water supply might have favored settlers that became the basis for the foundation of the Yeha Civilization. Furthermore, there are several archeological evidences in the neighboring areas of Yeha that support the fact that other nearby areas were inhabited by stratified communities such as *Ona Addi* in Goulo Makada (northeast of Yeha) dating to 1600 BC; Seglamen to the south of the town of

Aksum dating to 1200 BC, and Mai Addrasha near the town of Enda Slassie (west of Aksum) dating to 1200 BC.

Thus, it can be concluded that the late Holocene transition has influenced the movement of early societies living in the low lands to the nearby highland areas as it was shifting from dry condition in the mid Holocene to humid condition in the late Holocene for better water availability, food and vegetation resources that ultimately led to the formation of a complex society at Yeha dating to about 3500 BP.

Acknowledgments
This research was supported by the financial support of Addis Ababa University and Aksum University. Laboratory analysis was carried out by the generous support of the Geological Institute, ETH Zurich, Switzerland and the Lyell Centre, Edinburgh. The staffs of the Archeology of Aksum University which could potentially purse their PhD based on the new findings of the Yeha data are always extremely helpful for the successful fieldworks in Yeha. We strongly acknowledge the continuous support and commitment of the Aksum University Management and staffs. Field permit was given by the Authority for Research and Conservation of Cultural Heritage of Ethiopia. We also thank the administration and the community of Yeha for offering their valuable information and for all the boundless support they always offered. Our fieldworks wouldn't have been fruitful without their support.

References

Anfray, F., 1963. Une campagne de fouilles à Yĕḥā (Février-mars 1960). *Annale's D'Ethiopie*, 5:171-232.

Anfray, F., 1972. Fouilles de Yeha. Annales d'Ethiopie 9: 45-56.

Beckingham, C. F., and Huntingford, G. W. B., 1961. The Prester John of the Indies: A true relation of the lands of the Prester John, being the narrative of the Embassy to Ethiopia in 1520 written by Father Francisco Alvares. London: Hakluyt Society.

Bent, T.,1893. The Sacred City of the Ethiopians. London: Longmans and Green

Bernand, E., Drewes, A. J., and Schneider, R. 1991-2000. Receuil des inscriptions de l'Éthiopie despériodes pré-axoumite et axoumite. Paris: Académie des Inscriptions et Belles Letters.

Brandt S.and Carder N.1987. Pastoral rock art in the Horn of Africa: making sense of udders of Cows, World Archaeology, 19 (2): 194-213.

Bruce, J., 1790. Travels to discover the source of the Nile in the years 1768-1773, Dublin.

Castañeda, I. S., Schouten, S., Pätzold, J., Lucassen, F., Kasemann, S., Kuhlmann, H., and Schefuß, E., 2016. Hydroclimate variability in the Nile River Basin during the past 28,000 years: *Earth and Planetary Science Letters*, v. 438, p. 47-56.

Cerviceck, P., 1971. Rock paintings at Laga-Oda (Ethiopia), Paideuma, 17: 121-136.

Clark, D., 1976. The domestication process in Sub-Saharan Africa with special reference to Ethiopia. In Origins d'elevage et de la domestication, 56-115.

Clark, D., 1977. The origins of domestication in Ethiopia, Proceedings of the 8th Pan African Congress of Pre-history and Quaternary Studies, 268-270.

Curtis, M. C., 2009. Relating the Ancient Ona culture to the wider northern Horn: Discerning patterns and problems in the archaeology of the first millennium BC. African Archaeological Review, 26, 327–350.

Eglinton, G., and Hamilton, R. J., 1967. Leaf Epicuticular Waxes: Science, v. 156, no. 3780, p. 1322-1335.

Fattovich, R., 2009. Reconsidering Yeha, c. 800–400 BC, African Archaeological Review: 26:275–290.

Fattovich, R., 2012.The Northern Horn of Africa in the First Millennium BCE: local traditions and external connections, Rassegna di Studi Etiopici Nuova Serie 4: 1-60.

Foerster, V., Junginger, A., Langkamp, O., Gebru, T., Asrat, A., Umer, M., Lamb, H. F., Wennrich, V., Rethemeyer, J., and Nowaczyk, N., 2012. Climatic change recorded in the sediments of the Chew Bahir basin, southern Ethiopia, during the last 45,000 years: Quaternary International, v. 274, p. 25-37.

Foerster, V., Vogelsang, R., Junginger, A., Asrat, A., Lamb, H. F., Schaebitz, F., and Trauth, M. H., 2015. Environmental change and human occupation of southern Ethiopia and northern Kenya during the last 20,000 years: Quaternary Science Reviews, V. 129, p. 333-340.

Garcin, Y., Melnick, D., Strecker, M. R., Olago, D., and Tiercelin, J.-J., 2012. East African mid-Holocene wet–dry transition recorded in palaeo-shorelines of Lake Turkana, northern Kenya Rift: Earth and Planetary Science Letters, v. 331, p. 322-334.

Hatke, G., 2013. Aksum and Nubia, warfare, Commerce and Political fictions in Ancient NorthEast Africa Africa, New York University Press and Institute for the Study of the Ancient World.

Harrower, M., 2015. Political and Religious Change at Baita Semati and Ancient Geographies of the Yeha Region, field report.

Hopmans, E. C., Weijers, J. W., Schefuß, E., Herfort, L., Damsté, J. S. S., and Schouten, S., 2004. A novel proxy for terrestrial organic matter in sediments based on branched and isoprenoid tetraether lipids: Earth and Planetary Science Letters, v. 224, no. 1-2, p. 107-116.

Hopmans, E. C., S. Schouten and J. S. S. Damsté, 2016. The effect of improved chromatography on GDGT-based palaeoproxies. Organic Geochemistry, 93, 1-6.

Huguet, C., E. C. Hopmans, W. Febo-Ayala, D. H. Thompson, J. S. S. Damsté and S. Schouten (2006). An improved method to determine the absolute abundance of glycerol dibiphytanyl glycerol tetraether lipids. Organic Geochemistry, 37, 1036-1041.

Japp ,S., Gerlach.,I, Hitgen, H and Schnelle, M., 2011. Yeha and Hawelti: cultural contacts between Saba and D'MT – New research by the German Archaeological Institute in Ethiopia Proceedings of the Seminar for Arabian Studies 41: 145-160.

Junginger, A., and Trauth, M. H., 2013. Hydrological constraints of paleo-Lake Suguta in the Northern Kenya Rift during the African humid period (15–5 ka BP): Global and planetary change, v. 111, p. 174-188.

Kathryn A. Bard, Mauro Coltorti, Michael C. DiBlasi, Francesco Dramis, and Rodolfo Fattovich, 2000. The Environmental History of Tigray (Northern Ethiopia) in the Middle and Late Holocene: A Preliminary Outline, African Archaeological Review, Vol. 17, No. 2.

Littmann, E., Krencker, D., and von Lüpke, T., 1913. Deutsche Aksum-Expedition. Berlin: Reimer.

Liu, X., Rendle-Bühring, R., Kuhlmann, H., and Li, A., 2017, Two phases of the Holocene East African Humid Period: Inferred from a high-resolution geochemical record off Tanzania: Earth and Planetary Science Letters, v. 460, p. 123-134.

Loomis, S. E., Russell, J. M., Ladd, B., Street-Perrott, F. A., and Damste, J. S. S., 2012. Calibration and application of the branched GDGT temperature proxy on East African lake sediments: Earth and Planetary Science Letters, v. 357, p. 277-288.

Magill, C. R., Ashley, G. M., and Freeman, K. H., 2013a. Ecosystem variability and early human habitats in eastern Africa: Proceedings of the National Academy of Sciences, v. 110, no. 4, p. 1167-1174.

Magill, C. R., Ashley, G. M., and Freeman, K. H., 2013b. Water, plants, and early human habitats in eastern Africa: Proceedings of the National Academy of Sciences, v. 110, no. 4, p. 1175-1180.

Maria J. Machado, Alfredo Pe´rez-Gonza´lez, Gerardo Benito, 1998. Paleoenvironmental Changes during the Last 4000 yr in the Tigray, Northern Ethiopia, QUATERNARY RESEARCH v. 49, No. QR981965, 312–321.

Marshall, M. H., Lamb, H. F., Huws, D., Davies, S. J., Bates, R., Bloemendal, J., Boyle, J., Leng, M. J., Umer, M., and Bryant, C., 2011. Late Pleistocene and Holocene drought events at Lake Tana, the source of the Blue Nile: Global and Planetary Change, v. 78, no. 3-4, p. 147-161.

Marzi, R., Torkelson, B., and Olson, R., 1993. A revised carbon preference index: Organic Geochemistry, v. 20, no. 8, p. 1303-1306.

Michels, J. W., 2005. Changing Settlement Patterns in the Aksum-Yeha Region of Ethiopia, 700 BC – AD 850. Oxford: Archaeo Press.

Miruts Hagos, Christian Koeberl and Fred Jourdan, 2017. Geochemistry and Geochronology of Phonolitic and Trachytic Source Rocks of the Axum Obelisks and Other Stone Artifacts, Axum, Ethiopia, *Geoheritage*, 9:479–494.

Naafs, B., Gallego-Sala, A., Inglis, G., and Pancost, R., 2017. Refining the global branched glycerol dialkyl glycerol tetraether (brGDGT) soil temperature calibration: Organic Geochemistry, v. 106, p. 48-56.

Phillipson D.W., 1997. The Monuments of Aksum, Addis Ababa University Press, Addis Ababa**.**

Phillipson, D. W., 1998. Ancient Ethiopia: Aksum, its antecedents and successors. London: British Museum.

Robin C. and de Maigret A., 1998. Le Grand Temple de Yéha (Tigray, Éthiopie), après la première campagne de fouilles de la mission française (1998). Comptes rendus de l'Académie des Inscriptions et Belles-Lettres 142:738-798.

Sachse, D., Billault, I., Bowen, G. J., Chikaraishi, Y., Dawson, T. E., Feakins, S. J., Freeman, K. H., Magill, C. R., McInerney, F. A., and Van der Meer, M. T., 2012. Molecular paleohydrology: interpreting the hydrogen-isotopic composition of lipid biomarkers from photosynthesizing organisms.

Salt, H., 1814. A Voyage to Abyssinia, and travels into the interior of that Country, executed under the orders of the British Government in the years 1809 and 1810. London: Rivington.

Sergew Hableselassie, 1972. Ancient and Medieval Ethiopian History to 1270. Addis Ababa University.

Taddesse Tamrat. 1988. Process of Ethnic Interaction and Integration in Ethiopian History: the Case of the Agaw, Journal of African History, 29: 5-18.

Tekle Hagos, 2011. The Ethiopian Rock Art: the Fragile Resources, Authority for Research and Conservation of Cultural Heritage, Addis Ababa.

Tierney, J. E., Russell, J. M., Huang, Y., Damsté, J. S. S., Hopmans, E. C., and Cohen, A. S., 2008. Northern hemisphere controls on tropical southeast African climate during the past 60,000 years: Science, v. 322, no. 5899, p. 252-255.

Annex 1.

Laboratory analysis

Ancient vegetation and climate study using biomarker analysis and radiocarbon dating from organic matter was carried out from the Yeha sediments. Laboratory analysis was carried out at the Geological Institute, ETH Zurich, Switzerland and the Lyell Centre, Edinburgh and the detailed work in each step is described below.

a. Lipid analysis

The samples were collected in the spring 2017 through a trench on the stratigraphic horizons below the weathering surface wearing purple nitrile gloves. Large sample sizes were taken to allow removal of the outside and material in contact with modern roots. Finally, the sediment was crushed with mortar and pestle (ca. 80 g), freeze-dried and total lipid extract gained through microwave-accelerated extraction (MARS; DCM/MeOH 9:1 v/v, 30 min. at 100°C). The resulting lipids were saponified with KOH in MeOH (0.5M, 2h at 70°C) and a neutral phase collected from adding MilliQ water with NaCl and back-extracting with hexane. It was then separated into four fractions over a silica-gel column using hexane (1), DCM (2), DCM:MeOH (1:1 v/v) (3) and MeOH (4). GDGTs were obtained from fraction (3) and passed with hexane: isopropanol (99:1 v:v) over a 0.45 μm PTFE filter. Additionally, the internal standard $C_{46}$was added (Huguet et al. 2006). GDGTs were measured at ETH Zurich on an Agilent 1260 high performance liquid chromatograph with atmospheric pressure chemical ionization coupled to a quadrupole mass spectrometer (HPLC–APCI–MS) using the method described in Hopmans, Schouten and Damsté (2016) at ETH Zurich. The proxies were calculated using equations previously described in the literature with Roman numerals referring to structures of GDGTs (Hopmans et al. 2004).

BIT = (Ia + IIa + IIIa)/(Ia + IIa + IIIa + Cren) (Hopmans et al. 2004)

CBT' = ^{10}log [(Ic + IIa' + IIb' + IIc' + IIIa' + IIIb' + IIIc') / (Ia + IIa + IIIa) (De Jonge et al. 2014).

pH = 7.15 + 1.59 * CBT' (De Jonge et al. 2014).

MBT'_{5Me} = (Ia + Ib + IIc)/ /(Ia + Ib + IIc + IIa + IIb + IIc +IIIa) (Naafs et al. 2017)
$MAAT_{soil5me}$ (global soil calibration, °C) = 39,09*MBT'_{5Me} – 14.5 (Naafs et al. 2017)

N-alkanes within the polar fraction were separated with glass-pipette silica-gel column impregnated with silver-nitrate over hexane (1) and DCM (2). The polar fraction (1) was then separated by applying a molecular sieve of zeolites which were dissolved in HF, followed by liquid/liquid-extraction of *n*-alkanes with hexane. Quantification of *n*-alkanes was done with a *n*-C_{21-40} standard on a gas chromatograph with flame ionization detector (GC-FID; Agilent Technologies 7890A) at ETH Zurich. To calculate individual n-alkane distributions we applied the average chain length (ACL) as a weighted average of the various carbon chain lengths and carbon preference index (CPI) as a measure of the relative abundance of odd over even chain lengths. In the following equations C_n describes the concentration of each *n*-alkane with *n* carbon atoms (Marzi, Torkelson and Olson 1993):
$ACL_{19\ to\ 33} = \Sigma(C_n * n)/ \Sigma(C_n)$
$CPI = [\Sigma_{odd}(C_{21\ to\ 33}) + \Sigma(C_{23\ to\ 35})]/(2\Sigma_{even}C_{22\ to\ 34})$

Compound-specific stable isotopic values (both carbon and hydrogen) were measured on a gas chromatograph isotope ratio mass spectrometer (GC-IRMS; Trace 1300 Delta V Plus) at the Lyell Centre, Edinburgh. Values were determined relative to reference gas calibrated to VPDB for carbon isotopes and VSMOW for hydrogen isotopes. They are expressed in permil (‰) units:

$\delta^{13}C = 1000\ (R_{sample}/R_{std} - 1)$, $R = {}^{13}C/{}^{12}C$
$\delta D = 1000\ (R_{sample}/R_{std} - 1)$, $R = {}^{2}H/{}^{1}H$

External standards of n-alkanes with known isotopic composition (Mix B, Schimmelmann standards) were used throughout sample runs to ensure accuracy. Carbon isotopic values of plant waxes are enriched towards the late Holocene *(mean $\delta^{13}C_{31}$ = -27.2 ‰, standard deviation = 0.14‰)*. Hydrogen isotopic values of plant waxes become more depleted after the AHP transition period *(meanδD_{31} = -121‰, standard deviation = 3.6‰).*

b. Bulk measurements and dating of total organic carbon

First, the ground sediment was decarbonated using Ag-boats in a desiccator under HCl vapor (70°C, 3 d) and then neutralized with NaOH (70°C, 3 d). Second, samples were wrapped in tin boats to measure total organic carbon (%C), total nitrogen (%N) and C/N-ratio against an atropine and peptone standard on a Vario MICRO cube elemental analyzer (EA). Finally, for ^{14}C dating the appropriate amount of organic material was calculated and the preparation repeated (10 to 20 mg sediment) with an atropine and oxalic acid standard. The samples were then combusted again in an EA and the resulting CO_2 was collected, graphitized with an automated graphitization equipment system (AGE) and ^{14}C isotopes measured on a mini radiocarbon dating system (MICADAS) at the Laboratory for Ion Beam Physics (ETH Zurich). AMS ^{14}C dates were converted to calendar age using OxCal software.

Table 1 Radiocarbon data (in yrs BP + error margin) of total organic matter in each sedimentary layer.

Sample #	Age (y)	± (Y)
H1	7349	103
H3	3778	90
H5	3644	88
H8	1136	76
H9	257	71
S1	3543	84
S4	3313	83