Looking into the world of our early ancestors, using clay clues

300 meter high outcrop of lake clays exposed on the side of Olduvai Gorge. The stair-like excavation at the outcrop base allowed detailed sampling of ancient lake deposits. The chemical composition of these clays records what the climate was like nearly two million years ago.

The details within rocks can inform us about major climatic events, which have influenced the evolution of life on the planet. **Professor Gail Ashley** from Rutgers University has investigated ancient lakes in East Africa to see what they can tell us about past climate, in a major international collaboration. She now leads a field team in East Africa, who are investigating the environments that influenced our early human ancestors, the hominins.

Climate change has become a global concern today. We can look at past climate patterns, and use these to predict how the future of our planet may unfold. Unravelling climate change history is not only important to understand our planet, but also for its influence on our early ancestors – the hominins.

Professor Gail Ashley is uncovering what the environment was like for our early ancestors, as she interprets the past environments of the Quaternary period (dating back to 2.6 million years ago). She has been investigating whether this fluctuating past climate can be shown in the mineral make-up of ancient lake sediments. Analysing the minerals is important because many lake sediments lack the fossils that would normally tell us about climate change.

This research is part of a global collaboration project ACACIA (Ancient Climate and the Authigenic Clay Index of Aridity), that seeks to find out about the past environment and climate of the East African Rift System through ancient lake clays. The large project co-led by Prof Ashley not only focuses on clay mineralogy and past climate, but looks to track where rivers and springs had once been. By identifying the locations of these drinkable freshwater sources, the team is investigating how they relate to early hominin activity. Prof Ashley exclusively leads the effort to apply the research to other environments beyond lakes, such as wetlands. The water and food that these sites would have provided must have played a part in evolution of our early ancestor, the Homo genus, across Africa.

EAST AFRICA

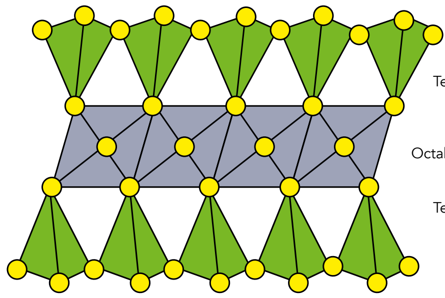
The East African Rift is a deep trench that is home to Olduvai Gorge (in Tanzania), which is one of the most important sites in the world for understanding human evolution. It contains some of the very first records of early hominin bones and stone working tools. In this area, it is generally assumed that our early ancestors thrived, before dispersing elsewhere across the planet.

Although there has been a wealth of scientific research on the hominin species in East Africa, a mystery remains as to how the climate and environment has influenced these early ancestors. Particularly since many of the 'fossil free' ancient lake basins have previously been considered ambiguous for interpreting climate history. As East Africa is near the equator, temperature would have remained relatively stable. While the temperature did not change dramatically, it was the humidity and aridity of the environment that resulted from climate change. These cycles of wetness and dryness would have influenced the surrounding plant and animal life, as well as the lives of our early ancestors.

ACACIA – THE INTERNATIONAL COLLABORATION

To uncover these changes in climate and environment, Prof Ashley is seeking answers from ancient lake basins across East Africa, as part of the international ACACIA project. This project encompasses an international

The underlying idea of ACACIA is that the chemistry of smectite (group) clay minerals records the ambient climate. Thick sequences of clay can show a changing climate. Sediment deposited in lakes over time can change their mineral structure and gradually change their chemical composition. The proportion of magnesium (Mg^{++}) in the octahedral layer (sheet) increases when the lake water becomes more salty when the climate is drier. The proportion of Mg^{++} in the octahedral layer decreases when lake water is "fresher" when climate is wetter.



field team (from Canada to Kenya) that are experienced in East Africa, in partnership with Proyecto Olduvai at Olduvai Gorge and the Olorgesailie Drilling Project at Olorgesailie.

The motivation driving the research is to fill in the missing records of past climate and environment that exist across the invaluable East African Rift System. To do this, their key aim is to investigate whether ancient lake clays can be used to represent the chemical composition of past climate and environment.

Sediment samples have been extracted from the Olduvai (Tanzania) and Olorgesailie (Kenya) Basins, and analysed with modern analytical techniques. This way, the researchers could uncover the chemical make-up of the sediment particles contained within the ancient lake clays. X-ray diffraction shows mineral structures, while other sophisticated techniques such as the electron microprobe technique reveal the various proportions of elements contained in the sediment particles. With these observations, the researchers have been pointing out the times in history when the lakes experienced drier, or wetter climates.

ACACIA field team 2015. Left to right: Ibrahim Mathiyas, Francis, Paul, Kevin Garrett, Gail Ashley, Daniel Deocampo, Joseph Masoy, and Nathan Rabideaux.

CLAYS AS CLUES

Clays are sensitive to a changed environment, as their structure alters according to the chemistry of the water they are in contact with. In lake basins, the chemistry of the water is influenced by the surrounding soil and rock types, as well as the climate. When there is more evaporation than rainfall, the salt level (salinity) increases, and so does the alkalinity of the water. Such conditions make an ideal 'potion' for triggering chemical changes, that cause mineral alteration, or the formation of new minerals (named authigenic minerals). The minerals in authigenic clays could be used to indicate past humidity or aridity in ancient lakes.

Prof Ashley first began analysing the minerals of ancient lake clays in 1995 with previous PhD student, now fellow colleague and collaborator, Dr Daniel Deocampo (Georgia State University). By applying modern techniques such as X-ray diffraction and electron microprobe analysis, they helped confirm that authigenic clays are reliable indicators for past climate. To investigate this further, the team observed modern lakes in arid environments. In these settings, where evaporation leads to high salt levels in the water, they found a greater abundance of magnesium.

This higher proportion of magnesium is thought to have resulted from a changed mineral structure. For example, when looking at the structure of smectite (a key family of authigenic clays), the proportion of magnesium in the octahedral sheet is thought to increase as more salt is introduced into the lake water, or decrease as fresh water comes in. When high levels of magnesium are found in ancient lake sediments, this can suggest the waters were salty, as a result of an arid climate.

WHAT THE FUTURE HOLDS

So far, the ACACIA project has largely focused on using the clay mineralogy of ancient lake sediments to understand past climate change. By marking out key climatic changes recorded in authigenic clay minerals, we can see how certain environments have changed over time, inevitably affecting our early ancestors.

Now, Prof Ashley is looking further afield, to see whether we can find climate clues in the sediments of other wet environments, such as springs and groundwater-fed wetlands. Wetlands are prone to accumulate clays, as sediments settle in still, ponded water. These settings would have been important habitats for our ancestors, due to the availability of water and food resources. If wetlands were to dry up as a result of climate change, this would have driven the hominins to re-settle elsewhere. Prof Ashley is addressing this idea as she investigates where freshwater rivers and springs once were. She now leads a research team in East Africa, who are investigating the connection between fresh water resources and early hominin behaviour.

Prof Gail Ashley is investigating the connections between early hominin activity in relation to the presence of freshwater in East Africa

Q&A

Q&A with Prof Gail Ashley

Why is the East African rift such a key area of interest for your research?

The rift is often called "The Cradle of Mankind" as it contains the oldest and most complete fossil and cultural records. There is no substitute for water and thus knowing about available water resources seems key to understanding the context of hominin evolution and dispersal out of Africa. My goal is to reconstruct the ancient environments associated with archaeological sites. I hope to identify where and what water sources were available. The spacing of water sources (widely separated or closely spaced) must have been a factor in natural selection by either isolating groups of hominins or allowing free mixing.

How has hominin activity changed in response to an altered environment and climate?

Climate during the time of hominin evolution varied in wet and dry cycles on a time scale of ~ 20,000 years. During dry periods, lakes became alkaline, rivers seasonal and only groundwater that is protected from evaporation persisted. Vegetation changed with the reduction of forests and expansion of grasslands. Hominins and other animal groups "followed the water" and during dry periods likely moved to higher ground making only brief forays into the rift valley. The plants and small animals that hominins consumed likely changed with the new habitat. Successful hominins were those that could adapt to the continuously changing environment.

Could the tool of using lake clay minerals as climate indicators be used for research beyond East Africa?

The ACACIA approach of using the composition of authigenic clay minerals as climate indicators is not restricted to East Africa, it can be used worldwide in all arid regions (i.e., receiving 100-300 mm or rainfall a year). As 40% of the modern Earth's surface is considered dryland, it is likely that ancient landscapes would have similar proportions at some time during their history. Although, not yet attempted, the ACACIA approach could be used in cold dry deserts, such as the Arctic and Antarctic and perhaps even used on planetary bodies, like Mars.

Q&A with Dr Daniel Deocampo

What have been the main challenges faced in the ACACIA project?

A major challenge is teasing out the complex history from when a clay particle settled at the bottom of the lake, to the moment we dug it up two million years later. When that particle settles out, it carries information about the environment when it formed, but after it is buried, things can change – so when analysed today, it can be difficult to know if we are making observations of the environment two million years ago, or if we are seeing the effect of something else that happened more recently, like the movement of groundwater, weathering from rainwater and the elements, or the impacts of organisms that live in the sediment.

What are you working on next?

I am applying what we have learned at Olduvai to lake sediment studies in other basins throughout East Africa. My lab is carrying out mineral analysis in support of several projects where we have drilled deep into ancient lake sediments and obtained sediment cores. We are piecing together the environmental history of the East African Rift to try to understand how climate and environmental change over the past five million years affected human evolution and the development of stone technology. This is part of the Smithsonian Institution's Olorgesailie Drilling Project, and the International Continental Drilling Program's Hominin Sites and Paleolakes Drilling Project. We are working directly on materials from regions in both Kenya: Olorgesailie, Lake Magadi,Lake Baringo , Lake Turkana , and in Ethiopia Chew Bahir and Afar cores.

Detail

RESEARCH OBJECTIVES

Professor Ashley and her team are investigating the historical context of the past climate and vegetation during the Quaternary epoch, a time of rapid climate change, and how this has played a vital role in the adaptation and evolution of our early ancestors.

FUNDING

- NSF-EAR
- National Geographic

COLLABORATORS

- Georgia State University
- Natural History Museum, London
- Miami University of Ohio
- Auburn University
- University of Western Ohio
- Waco University

BIO

Prof Ashley received a PhD in geology at University of British Columbia. Specialising in sedimentology, she initially worked in Alaska and Antarctica. She was president of three scientific societies: SEPM, GSA and AGI. She now leads a research team in East Africa studying the paleoenvironment and water resources of early hominins.

CONTACT

Professor Gail M Ashley
Dept. of Earth and Planetary Sciences
Rutgers.
The State University of New Jersey
610 Taylor Road
Piscataway, NJ 08854
USA

E: gmashley@eps.rutgers.edu
T: 1-848-445-2221
W: http://sas.rutgers.edu/

Dr Daniel M Deocampo
Department of Geosciences
Georgia State University
P.O. Box 3965
Atlanta, GA 30302
USA

E: deocampo@gsu.edu
T: +1 404-413-5759
W: http://geosciences.gsu.edu/