Ardipithecus ramidus, *Australopithecus afarensis*, *Australopithecus garhi*, *Homo erectus*, and *Homo sapiens idaltu*. The combined geologic and fossil evidence suggests that the broad nature of the rift floor and episodic volcanic and tectonic activities confined to different portions of the Middle Awash region created multiple ecological sectors that were inhabited by different species of vertebrate animals during rift evolution.

The 6.5 Ma volcanic record is dominated by distal silicic fallout deposits, some widespread throughout northeast Africa and the adjoining ocean basins, with identified or postulated sources within the Ethiopian volcanic province. Local Middle Awash region sources are responsible for substantial basaltic input, including major effusive activity between 5 to 5.5 Ma and <3.9 Ma and major strombolian and phreatomagmatic activity between 4.2 to 4.4 Ma and 5.5 to 6 Ma. While many of the silicic tephra contain chemically homogenous glass, multiple glass populations suggestive of eruption from zoned magma chambers are commonly observed, particularly in the 4.5, 2.5, and <1 Ma time periods. Moreover, three very distinctive mixed magma explosive eruptions are documented at 3.85, 4.4, and 5.6 Ma. The timing of these eruptions corresponds to hightened regional/local basaltic magmatism, which may in turn be linked to episodes of increased tectonic activity and marginal basin development in the transition region between the northern Main Ethiopian and Afar rifts. We will present a chronostratigraphically controlled geochemical summary of the Middle Awash volcanic record and discuss the primary magmatic and tectonic controls on this volcanism.

Title in publications

209-2 **8:25 AM** Brown, Francis H.

GEOLOGICAL DEVELOPMENT OF THE OMO-TURKANA BASIN DURING THE PLIOCENE AND PLEISTOCENE EPOCHS

BROWN, Francis H. and BROWN, Francis H., Geology and Geophysics, Univ of Utah, 135 S 1460 E, Rm 209, Salt Lake City, UT 84112-0112, fbrown@mines.utah.edu

Pliocene and Pleistocene deposits of the Omo-Turkana Basin extend from 6°N latitude to about 2°N latitude (~450 km), and laterally from about 35.5°E to 36.5°E. Sediments are brought to the basin by the Omo River which rises in Ethiopia, and by the Turkwel and Kerio Rivers which rise in Kenya and Uganda. Pliocene deposition began ~4.3 Ma ago, and is recorded in the Mursi, Nkalabong, Usno, and Shungura Formations in southern Ethiopia, and by the Koobi Fora, Nachukui, Lothagam, and Kanapoi Formations in neighboring Kenya. The composite stratigraphic thickness of exposed Pliocene strata is on the order of 400 m. The stratigraphy of the basin is well integrated through tephrostratigraphic correlations, and deposits are well-dated through 40Ar/39Ar and K/Ar analyses of lavas and reworked ash layers. In addition the paleontological record in the basin is tied firmly to marine records in the Gulf of Aden. Paleoclimatic changes are recorded not only through isotopic compositions of paleosols but also in the distribution of strata of particular ages. Pleistocene strata have a composite thickness of about 400 m, but there is a gap in the record from about 0.7 Ma to 0.2 Ma. Seismic work in the greater basin suggests that a more complete record exists beneath Lake Turkana, where combined Pliocene and Pleistocene strata appear to be ~4000 m thick. Pleistocene history is recorded in the Shungura, Koobi Fora, Nachukui, Kibish, and Galana Boi Formations. Of particular interest is that the locus of deposition in the basin appears to have controlled to some extent by the same climatic factors that are responsible for development of sapropels in the eastern Mediterranean Sea. For example, deposition of the Kibish Formation near the northern end of the basin is episodic, and new dates suggest that each episode of deposition can be correlated with particular sapropels in the Mediterranean sequence. As the sapropels are related to Nile discharge, this is understandable because the Omo River shares a drainage divide with the Blue Nile. Tectonic and volcanic events have also played a role in the development of the basin during the Pliocene and Pleistocene.

209-3 **8:45 AM** Feibel, Craig S.

SEDIMENTARY PATTERNS IN THE PLIOCENE HADAR FORMATION, AFAR RIFT, ETHIOPIA

FEIBEL, Craig S., Geological Sciences and Anthropology, Rutgers Univ, 131 George St, New Brunswick, NJ 08901-1414, feibel@rci.rutgers.edu and CAMPISANO, Christopher J., Anthropology, Rutgers Univ, 131 George St, New Brunswick, NJ 08901

The sedimentary strata of the Hadar Formation preserve a high-resolution record of environmental character and change from the late Pliocene, roughly 3.5 – 2.3 Ma. Detailed analysis of the fluvial and lacustrine strata indicates that tectonic and climatic signals are evident in patterns of sedimentary character and shifts in accumulation history. Aspects of the Pliocene

208-13 11:15 AM Kelty, Thomas K.

STRUCTURE AND CRUSTAL SHORTENING OF THE SUBHIMALAYAN FOLD AND THRUST BELT, WESTERN ARUNACHAL PRADESH, NE INDIA

KELTY, Thomas K., Geological Sciences, California State Univ, Long Beach, 1250 Bellflower Blvd, Long Beach, CA 90840-3902, tkelty@csulb.edu, YIN, An, Earth and Space Sciences, Univ of California, Los Angeles, Los Angeles, CA 90095-1567, and DUBEY, C.S., School of Geology, Univ of Delhi, Delhi, India

The Subhimalayan fold and thrust belt of western Arunachal Pradesh (AP) includes Miocene and younger sedimentary rocks that comprise northward dipping thrust sheets, structurally below the Main Boundary Thrust (MBT) and above the Main Frontal Thrust (MFT). Balanced cross sections are constructed at various locations along a 100-km segment of the AP Subhimalayan fold and thrust belt. Comparison of these sections reveals structural configurations that are remarkably consistent perpendicular and parallel to the fold and thrust belt. Three regionally significant faults are developed from north to south and are the: (1) MBT, (2) Tipi Thrust and (3) MFT. Within the AP Subhimalayan zone the structures can be lumped into two tectonostratigraphic units: (1) the MFT-Tipi Thrust unit and (2) the MBT-Tipi Thrust unit. The structures of the fold and thrust belt between the MFT and Tipi Thrust in most locations consists of a northerly dipping (10° to 30°) monocline consisting of the Subansiri and Kimin Formations. This part of the fold and thrust belt is interpreted to be the hanging wall flat above the MFT. There are also large folds developed between the Tipi Thrust and MFT. The Tipi Thrust is interpreted to flatten into a decollement that is regionally extensive and located at the base-Neogene unconformity. The decollement is developed in the AP Subhimalayan zone over a distance of at least 300 km. It is likely that the same stratigraphically controlled, regional decollement exists at the base of the Siwalik or top of pre-Tertiary basement as far west as Nepal. The depth to the detachment in both Nepal and western part of AP is approximately 5 km.

An estimate of the amount of shortening within the AP Subhimalayan fold and thrust belt is obtained from restored balanced cross sections. The minimum shortening of about 6 km occurs between the MFT and Tipi Thrust and >6 km between the MBT and Tipi Thrust. This interpretation includes a dramatic four-fold stratigraphic thickening of the Dafla Formation across the Tipi Thrust. Structural thickening caused by thrust imbrication is an alternative interpretation. Given the minimum estimate of shortening of 12 km assuming northward thickening of the Dafla Formation, a slip rate of 8 mm/yr is estimated for motion on the MFT. If the Dafla Formation has a constant thickness, the slip rate could be as high as 20 mm/yr.

208-14 11:30 AM Myrow, Paul M.

STRATIGRAPHIC CONSTRAINTS UPON THE NATURE AND TIMING OF THE HIMALAYAN CAMBRIAN–ORDOVICIAN EVENT

MYROW, Paul M.[1], HUGHES, Nigel[2], SNELL, Kathryn E.[1], HEIM, Noel A.[3], SELL, Bryan[2], and PARCHA, S.K.[4], (1) Geology Department, Colorado College, 14 E. Cache La Poudre St, Colorado Springs, CO 80903, pmyrow@coloradocollege.edu, (2) Earth Sciences, Univ of California, Riverside, 1432 Geology Building, Riverside, CA 92507, (3) Department of Geology, University of Georgia, Athens, GA 30605, (4) Wadia Institute of Himalayan Geology, Dehra Dun, 248001

Cambrian strata of the west-central Himalaya provide a critical record of the early history of the orogen. In the Tethyan Himalaya of India, Middle Cambrian carbonate platform deposits of the Karsha Formation are overlain by the Kurgiakh Formation, a shale and sandstone succession previously interpreted to record deep-water flysch deposits. The carbonate-to-siliclastic transition is hypothesized to represent a tectonic transformation from a passive margin to an active deep marine, foreland basin setting that was adjacent to a newly developed arc-trench system. This interpretation is problematic for three reasons. First, the interpretation of sandstone beds of the Kurgiakh as turbidites with classic Bouma sequences is incorrect since these strata contain evidence of shallow-marine, storm-influenced deposition within shoaling deltaic cycles. Secondly, paleocurrent data in overlying Ordovician conglomeratic molasse(?) range from eastward with a subordinate northwest mode in the Zanskar Valley, to north and northeast in the Spiti Valley. Such transport directions are inconsistent with standard models of foreland basin development. Finally, our improved biostratigraphic database suggests that the carbonate-to-siliciclastic transition may have significantly predated the main phase of Cambrian–Ordovician orogenesis. Earliest dated Ordovician deposits in the west-central Himalaya are no older than Middle Ordovician and the Kurgiakh is latest Middle Cambrian. Thus, tectonic uplift and erosion could have occurred as much as 20-30 million years after deposition of the Kurgiakh Formation, and therefore Kurgiakh deposition may have significantly predated the Cambrian–Ordovician orogenic event. These data are inconsistent with recent models for the Himalayan C-O event that includes significant thrust-induced subsidence and southward sediment transport.

SESSION NO. 209, 8:00 AM

Wednesday, November 10, 2004

T106. Geological Context of Early Humans from Ethiopian Rift Basins (*GSA Archaeological Geology Division, GSA Sedimentary Geology Division; GSA Limnogeology Division*)

Colorado Convention Center, 102

209-1 8:05 AM Hart, William K.

BIMODAL VOLCANISM AND RIFT BASIN DEVELOPMENT IN THE MIDDLE AWASH REGION, ETHIOPIA

HART, William K., Dept. of Geology, Miami Univ, 114 Shideler Hall, Oxford, OH 45056, hartwk@muohio.edu, WOLDEGABRIEL, Giday, Earth Environmental Sciences Division, Los Alamos National Lab, EES-6/MS D462, Los Alamos, NM 87545, RENNE, Paul R., Berkeley Geochronology Ctr/UC Berkeley, 2455 Ridge Road, Berkeley, CA 94709, and WHITE, Tim D., Dept. of Integrative Biology, Univ. of California, 3060 VLSB, Berkeley, CA 94720

The Middle Awash region of Ethiopia is located along a volcanic and tectonic transition zone between the northern sector of the Main Ethiopian Rift and the Afar Rift. It is characterized by a wider rift floor (>100 km) than observed in any other part of the East African Rift south of the Afar Depression and preserves evidence of bimodal effusive and pyroclastic activity over the past 6.5 Ma. These volcanic materials are associated with sediments from numerous fluvio-lacustrine depositional systems and have been utilized to provide absolute age control on abundant vertebrate taxa, including important homind fossils such as *Ardipithecus kadabba*, *Ardipithecus ramidus*, *Australopithecus afarensis*, *Australopithecus garhi*, *Homo erectus*, and *Homo sapiens idaltu*. The combined geologic and fossil evidence suggests that the broad nature of the rift floor and episodic volcanic and tectonic activities confined to different portions of the Middle Awash region created multiple ecological sectors that were inhabited by different species of vertebrate animals during rift evolution.

The 6.5 Ma volcanic record is dominated by distal silicic fallout deposits, some widespread throughout northeast Africa and the adjoining ocean basins, with identified or postulated sources within the Ethiopian volcanic province. Local Middle Awash region sources are responsible for substantial basaltic input, including major effusive activity between 5 to 5.5 Ma and <3.9 Ma and major strombolian and phreatomagmatic activity between 4.2 to 4.4 Ma and 5.5 to 6 Ma. While many of the silicic tephra contain chemically homogenous glass, multiple glass populations suggestive of eruption from zoned magma chambers are commonly observed, particularly in the 4.5, 2.5, and <1 Ma time periods. Moreover, three very distinctive mixed magma explosive eruptions are documented at 3.85, 4.4, and 5.6 Ma. The timing of these eruptions corresponds to hightened regional/local basaltic magmatism, which may in turn be linked to episodes of increased tectonic activity and marginal basin development in the transition region between the northern Main Ethiopian and Afar rifts. We will present a chronostratigraphically controlled geochemical summary of the Middle Awash volcanic record and discuss the primary magmatic and tectonic controls on this volcanism.

209-2 8:25 AM Brown, Francis H.

GEOLOGICAL DEVELOPMENT OF THE OMO-TURKANA BASIN DURING THE PLIOCENE AND PLEISTOCENE EPOCHS

BROWN, Francis H. and BROWN, Francis H., Geology and Geophysics, Univ of Utah, 135 S 1460 E, Rm 209, Salt Lake City, UT 84112-0112, fbrown@mines.utah.edu

Pliocene and Pleistocene deposits of the Omo-Turkana Basin extend from 6°N latitude to about 2°N latitude (~450 km), and laterally from about 35.5°E to 36.5°E. Sediments are brought to the basin by the Omo River which rises in Ethiopia, and by the Turkwel and Kerio Rivers which rise in Kenya and Uganda. Pliocene deposition began ~4.3 Ma ago, and is recorded in the Mursi, Nkalabong, Usno, and Shungura Formations in southern Ethiopia, and by the Koobi Fora, Nachukui, Lothagam, and Kanapoi Formations in neighboring Kenya. The composite stratigraphic thickness of exposed Pliocene strata is on the order of 400 m. The stratigraphy of the basin is well integrated through tephrostratigraphic correlations, and deposits are well-dated through 40Ar/39Ar and K/Ar analyses of lavas and reworked ash layers. In addition the paleontological record in the basin is tied firmly to marine records in the Gulf of Aden. Paleoclimatic changes are recorded not only through isotopic compositions of paleosols but also in the distribution of strata of particular ages. Pleistocene strata have a composite thickness of about 400 m, but there is a gap in the record from about 0.7 Ma to 0.2 Ma. Seismic work in the greater basin suggests that a more complete record exists beneath Lake Turkana, where combined Pliocene and Pleistocene strata appear to be ~4000 m thick. Pleistocene history is recorded in the Shungura, Koobi Fora, Nachukui, Kibish, and Galana Boi Formations. Of particular interest is that the locus of deposition in the basin appears to have controlled to some extent by the same climatic factors that are responsible for development of sapropels in the eastern Mediterranean Sea. For example, deposition of the Kibish Formation near the northern end of the basin is episodic, and new dates suggest that each episode of deposition can be correlated with particular sapropels in the Mediterranean sequence. As the sapropels are related to Nile discharge, this is understandable because the Omo River shares a drainage divide with the Blue Nile. Tectonic and volcanic events have also played a role in the development of the basin during the Pliocene and Pleistocene.

209-3 8:45 AM Feibel, Craig S.

SEDIMENTARY PATTERNS IN THE PLIOCENE HADAR FORMATION, AFAR RIFT, ETHIOPIA

FEIBEL, Craig S., Geological Sciences and Anthropology, Rutgers Univ, 131 George St, New Brunswick, NJ 08901-1414, feibel@rci.rutgers.edu and CAMPISANO, Christopher J., Anthropology, Rutgers Univ, 131 George St, New Brunswick, NJ 08901

The sedimentary strata of the Hadar Formation preserve a high-resolution record of environmental character and change from the late Pliocene, roughly 3.5 – 2.3 Ma. Detailed analysis of the fluvial and lacustrine strata indicates that tectonic and climatic signals are evident in patterns of sedimentary character and shifts in accumulation history. Aspects of the Pliocene Hadar landscape, important as habitat to the *Australopithecus afarensis* populations well-represented in the fossil record, can also be reconstructed from the sedimentary sequence.

A composite sequence of some 175 m of sedimentary strata is exposed in the badlands of Hadar. An interlocking framework of isotopic age control on volcanics (8 dated levels), magnetic polarity transitions (4 chron or subchron boundaries), geochemically characterized vitric tephra (N≥ 22) and numerous lithostratigraphic markers provides tight temporal control on the sequence. A distinct shift at ca. 2.9 Ma, marked by a dramatic change in accumulation rates, stratigraphic completeness, and facies character demonstrates a major tectonic reorganization within this segment of the Main Ethiopian Rift. This likely reflects the initiation of down-rift translation of the primary terminal depocenter. The earlier high-accumulation rate (ca. 30 cm/ky) phase of Hadar Formation history is largely responsible for the geologically and palaeontologically rich early record at Hadar. The subsequent tectonic reorganization is reflected in the down-rift migration of lacustrine facies, and a shift in fluvial character to successive cut-and-fill cycles dominated by coarse (conglomeratic) lithologies.

Within the early phase of accumulation at Hadar, a strong cyclicity to the fluvial system, and regular intercalations of lacustrine or lake margin facies, reflects significant periodicity in the control of sedimentary character. This control is interpreted to be dominantly climatic in nature. After 2.9 Ma the stratigraphic record becomes much more complex. In spite of the abundant tephra markers in this latter time interval, highly localized stratigraphic preservation associated with cut-and-fill cycles makes interpretation of driving forces here more difficult, though climatic factors may still dominate.

209-4 9:05 AM Quade, Jay

THE GEOLOGY OF GONA

QUADE, Jay, Geosciences, Univ of Arizona, Tucson, AZ 85721, jquade@geo.arizona.edu, SEMAW, Sileshi, CRAFT CENTER, Indiana Univ, 419 N. Indiana, Bloomington, IN 47405, SIMPSON, Scott, Dept. of Anatomy, Case Western Reserve Univ, School of medicine, Euclid Ave, Cleveland, OH 44106, RENNE, Paul, Berkeley Geochronology Center, 2455 Ridge Road, berkeley, CA 94709, LEVIN, Naomi, Dept. of Geology and Geophysics, Univ of Utah, 717 Browning Building, Salt Lake City, UT 84112, and MCINTOSH, William, Dept. of Geoscience, New Mexico Inst. of Mining and Technology, Socorro, NM 87801

Gona archives nearly 6 million years (from ~6 to <0.5 Ma) of deposition and hominid prehistory. The oldest fossil-bearing formations are exposed in the western side of the project area, west of the As Duma Fault. Radiometric and paleomagnetic dates place the youngest of these sediments between 4.5 to 4.0 Ma, whereas the oldest may be 5-6 Ma, based on biostratigraphic constraints. The sediments were deposited by small rivers and lakes confined between large expanses of Dahla Series basalts. All these deposits are richly fossiliferous and have yielded abundant hominid remains, including those of *Ardipithecus ramidus*.

Extension beginning 4-3.4 Ma activated the east-dipping As Duma normal fault and the Awash graben to the east. Sediments all associated with the paleo-Awash river and fringing alluvial fans poured into the graben, first as the Hadar Formation (3.4 to 2.9 Ma) and later the Busidima Formation (2.7 to <0.5 Ma). Low-gradient rivers and lakes covered the area during Hadar Formation time, whereas higher-energy axial river and alluvial fan deposits compose the Busidima Formation. Radiometric and paleomagnetic constraints place the base of the Busidima Formation at ~2.7 Ma and the top above the Brunhes/Matuyama boundary (0.78 Ma). The Silbo Tuff (0.74 Ma) known from Kenya and the Gulf of Aden is also present just above this paleomagnetic boundary. The Busidima Formation contains a rich archeological (Oldowan (2.58-1.7 Ma) and Acheulian (1.7 to <0.5 Ma)) record largely associated with paleo-Awash Rivers deposits.

209-5 **9:20 AM** Levin, Naomi

EARLY PLIOCENE ENVIRONMENTS AT GONA, ETHIOPIA

LEVIN, Naomi, Dept. of Geology & Geophysics, Univ of Utah, 135 S. 1460 East Rm 719, Salt Lake City, UT 84112, nlevin@mines.utah.edu, QUADE, Jay, Department of Geosciences, Univ of Arizona, Tucson, AZ 85721, SIMPSON, Scott, Dept. of Anatomy, Case Western Reserve Univ, School of medicine, Euclid Ave, Cleveland, OH 44106, and SEMAW, Sileshi, CRAFT Stone Age Institute, Indiana Univ, 1392 W. Dittemore Road, Gosport, IN 47433-9531

The western margin area of the Gona Paleoanthropolgical Research Project in Afar, Ethiopia, is composed of both fluvial and lacustrine sediments, and contains abundant fossils, including those of *Ardipithecus ramidus*. We use the carbon and oxygen isotopic composition of paleosol carbonates, fossil teeth and aragonitic shell from these sediments to characterize early Pliocene (4.3-4.5 Ma) environments at Gona. $\delta^{13}C$ values of paleosol carbonates and tooth enamel indicate environments with a mix of C_3 and C_4 vegetation wherein the majority of large mammals had C_4-dominated diets. $\delta^{18}O$ values of paleosol carbonates, fossil teeth and aragonitic shell are too low to have formed under the present climate conditions at Gona and likely indicate more rainfall and different circulation patterns in the early Pliocene.

209-6 **9:35 AM** Campisano, Christopher J.

INTEGRATING DEPOSITIONAL ENVIRONMENTS, PALEOGEOGRAPHY, AND FAUNAL ASSEMBLAGES: A NEW VIEW OF HADAR PALEOENVIRONMENTS ACROSS SPACE AND TIME

CAMPISANO, Christopher J., Anthropology, Rutgers Univ, 131 George St, New Brunswick, NJ 08901-1414, cjcampi@rci.rutgers.edu.

For almost three decades, the site of Hadar, Ethiopia has remained one of the most important paleoanthropological sites in the world. In addition to its extraordinary fossil hominin record, the Hadar Formation also contains an enormous amount of geological and paleontological information pertaining to mid-Pliocene East African paleoenvironments and mammalian evolution. Traditionally, faunal assemblages are used to reconstruct the "average" paleohabitat that existed. While such approaches can elucidate general paleoenvironments and their change over time, they often homogenize the diversity of habitats that existed across a landscape at any one particular time. This study takes an alternative, high-resolution approach to compare catalogued faunal assemblages from Hadar using tightly constrained depositional units and geography as controls.

Using this methodology, distinct faunal and paleoenvironmental communities can be distinguished within sub-members that are usually treated as one unit. For example, two distinct paleoenvironments are recognized within the KH-2 sub-member (~ 3 Ma). The eastern region is comprised primarily of a forest dwelling faunal assemblage with taphonomic and geologic data suggesting a low-energy proximal floodplain. This is interpreted to be a gallery forest dominated environment between meanders in the ancestral-Awash River. A very different pattern exists in the western region where the faunal assemblage shows a mosaic habitat of forest and more open environments while the geology indicates proximal to distal floodplains leading outward from the edge of a fluvial cut-bank. Together this indicates a limited gallery forest giving way to more open environs away from the river. In this particular scenario, *A. afarensis* appears more common in the mosaic environment, or is at least not tethered to the forested ones.

Additional analyses from other sub-members also display degrees of spatial variation, primarily amongst habitat-specific bovid tribes used to distinguish forest, wet-grassland, and arid habitats. Temporal variation between sub-members for the most part agrees with earlier analyses. This combined geo-paleontological approach may provide an additional level of resolution in identifying early hominin habitat preference across paleolandscapes.

209-7 **9:50 AM** Wynn, Jonathan G.

GEOLOGY AND STRATIGRAPHY OF SEDIMENTS BELOW THE SIDI HAKOMA TUFF IN THE DIKIKA RESEARCH AREA, LOWER AWASH VALLEY, ETHIOPIA

WYNN, Jonathan G., School of Geography and Geosciences, Univ of St. Andrews, Irvine Building, St. Andrews, KY16 9AL, United Kingdom, jonathan.wynn@st-andrews.ac.uk, ROMAN, Diana C., School of Earth Sciences, Univ of Leeds, Leeds, LS2 9JT, and ALEMSEGED, Zeresenay, Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology Max Planck Institute for Evolutionary Anthropology, Deutcher Platz 6, Leipzig, 04103, Germany

New geological research from the Dikika Research Area, Lower Awash Valley, Ethiopia, provides a cohesive stratigraphic record of sedimentation and evolution spanning the range of >3.8 to <0.6 Ma, complementing records of surrounding research areas. Most sediments exposed at Dikika belong to the Hadar Formation (>3.4 to <2.3 Ma), famous for its many paleoanthropological finds. However, the definition of the this geological unit was developed in the 1970s at Hadar as the prospecting for hominids expanded from initial discoveries. Current research further afield from Hadar is demonstrating that the Hadar Formation definition needs to be further expanded or better delimited, not only to include or exclude strata above and below, but also to better articulate the tectonic implications of regional sedimentation patterns. While strata from Gona, western Hadar, and Asbole are expanding the younger end of the depositional sequence, the eastern Dikika area exposes variably thick sedimentary sections (~10 to 40+ m) below the Sidi Hakoma Tuff (SHT; ~3.4 Ma), thereby attributable to the defined Basal Member. Along a low ridge in the southern Dikika Area, the Ikini Tuff outcrops in a fault block where it is doubly upthrown by two intersecting normal faults. Major and trace-element abundances in glass shards from this tuff indicate a strong correlation to the Wargolo Tuff in the Turkana Basin, and to the VT-3 in the Middle Awash Region (~3.8 Ma). Furthermore, sections in the eastern and southern portion of the Dikika Area lie directly on tens of meters of basalt, which forms the local sedimentary basement. The upper several meters of these basalts exhibit the C horizon of a deeply weathered paleosol, overlain by juvenile sediments derived from the basalt, including poorly sorted sandstones with abundant angular basaltic rock fragments and other initial weathering products such as reworked calcite vugh-fills and zeolites. These sandstones are overlain by, and in some places partially interfinger with, lacustrine clays, which typify the Basal Member elsewhere. The lacustrine sequence thickens northwards across NE-trending faults, some of which are syndepositional, as indicated by growth faults. These exposures document the early evolution of this segment of the rift basin, the implications of which will be discussed.

209-8 **10:05 AM** Roman, Diana C.

DEVELOPMENT OF AN INTERACTIVE ONLINE DATABASE OF EAST AFRICAN TEPHRAS

ROMAN, Diana C., School of Earth Sciences, Univ of Leeds, Leeds, LS2 9JT, droman@earth.leeds.ac.uk and WYNN, Jonathan G., School of Geography and Geosciences, Univ of St. Andrews, St. Andrews, KY16 9AL

Correlation of primary and secondary tephra deposits based on volcanic glass compositions is one of the most important tools currently in use for applying stratigraphic and chronological constraints to hominin and other fossil fauna from the Ethiopian Rift. Successful correlation of a new tephra to local or extrabasinal tephras requires a complete database of published and unpublished tephra analyses that includes information on chemical composition and variability, analytical methods, location, and stratigraphic and chronological information.

Creation of a database for tephra correlation is time-consuming, and there is potential for incompleteness. A single comprehensive and universally accessible database is a favorable alternative. To this end, we are developing an online database that currently contains over 500 published and unpublished analyses of tephras from Ethiopia and Kenya and includes interactive tools for searching the database and submitting new data. Each analysis entry contains information on major and trace element composition, tephra name and correlates, location, and age, as available, and includes information on analytical techniques and the source of the data. The database search engine allows the user to request analyses based on a paper reference, tephra name, range of major element compositions, or range of ages.

The online database has been used to identify local and extrabasinal correlates to tephras from the Asbole-Dikika Research Area, Ethiopia. Using the database, a list of candidate correlates was compiled for each Asbole-Dikika tephra using a composition-range search, and narrowed down based on calculated similarity coefficients and stratigraphic knowledge. This process efficiently identified correlations between Asbole-Dikika tephras and the Sidi Hakoma Tuff (3.4 Ma), the Wargolo Tuff (3.8 Ma), and the AST-3 tuff (2.7 Ma), as well as a locally extensive tephra horizon known as the Bironita Tuff (correlating to tephras dated 0.55-0.72 Ma).

209-9 **10:20 AM** Haileab, Bereket

PLIO-PLEISTOCENE VOLCANIC CENTERS IN THE ETHIOPIAN HIGHLANDS, DISTINGUISHED USING MAJOR AND TRACE ELEMENT ABUNDANCES FROM TEPHRA LAYERS IN THE TURKANA BASIN

HAILEAB, Bereket, Geology, Carleton College, One North College Street, Northfield, MN 55057, bhaileab@carleton.edu.

Slightly over 4 Ma, crustal extension accompanied by plume generated thermal erosion at the base of the lithosphere formed the present day Turkana Basin located in Southern Ethiopia and Northern Kenya. These processes resulted in thinning, subsidence and sedimentation into the newly formed basin. Basaltic magma of theolitic composition ponded at the base of the thinned crust eventually erupted as a flood basalt covering the thin layers of sediments in the basin. Rifting continued to the present, resulting in one of the most active basins in the region, filled with sediments that include many volcanic ashes and mammalian fossils such as some of the most famous hominid fossils discovered so far. While the Turkana Basin was forming, tectonic and volcanic activities in the Ethiopian highlands were actively producing the Main Ethiopian Rift and igneous rocks most notably a large volume of silicic rocks. Evidence of this silicic volcanism is well preserved in the sediments within the Turkana basin in the form of distal tephra layers. Today, in the Turkana basin over 130 chemically and stratigraphically distinct volcanic ashes between 4.1 and 0.7 Ma have been identified. Several of these are known from many localities quite distant from the Turkana Basin. Chemical analyses of glass separated from these tephra layers were used to identify tuffs derived from the same eruption and correlate the different formations of the Turkana basin with other basins in the region. Here, relations between the compositions of tephra from individual eruptions are used to group tephra that were probably erupted from the same source. Major and incompatible trace element abundances and ratios show variable values, which allow several compositionally distinct magmatic groups to be distinguished. Twelve groups of tephra are established on the basis of more extensive ash layers found in the basin. Each of these groups is present in the section over a restricted stratigraphic interval, corresponding to only a few hundred thousand years. Representatives of more than one group are found in the same stratigraphic interval, showing that more than one source volcano were active at any given time.

209-10 **10:35 AM** Buffler, Richard T.

GEOLOGIC SETTING OF THE ABDUR ARCHAEOLOGICAL SITE, SOUTHERN RED SEA COAST, ERITREA, AFRICA

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Stone tools discovered within uplifted marine terraces along the southern Red Sea coast of Eritrea, near the small village of Abdur, are dated to 125+/- ka. These tools represent the earliest well-dated evidence for human occupation of coastal marine environments. The Abdur Archaeological Site (AAS) lies along the northern extension of an active section of the Danakil rift system. It is located on the Buri Peninsula along the eastern shoreline of the Gulf of Zula. Three main stratigraphic units are defined: 1. The Buri Sequence is a series of marginal marine, estuarine and fluvial sediments consisting of limestones, mudstones, sandstones and conglomerates with ash and pumice beds. Ar-Ar dating of pumice and tephras put the time of deposition from at least 0.90 +/- 0.04 to less than 0.72+/-0.01 Ma. These layers were faulted, folded and eroded prior to the deposition of the overlying Abdur Reef Limestone (ARL). A few MSA obsidian tools were found in this unit. Extensive artifacts and a hominid skull have been reported from similar age fluvial deposits to the south along the base of the Eritrean Escarpment. 2. The Abdur Volcanic Complex is a small basaltic shield complex that forms the highlands along the eastern part of the AAS. Basaltic lavas from this center overlie the Buri Sequence and, in turn, are overlain by the ARL. Basalt samples dated at 1.27 +/- 0.01 Ma and 0.44+/-0.02 Ma, however, indicate that the Complex has been tectonically and magmatically active prior to, during and after the deposition of the Buri Sequence. 3. The Abdur Reef Limestone consists of a basal transgressive lag deposit overlain by an extensive build-up of mollusks, echinoderms, bioclastic sands and corals up to 4m thick. It is uplifted and tilted 1-2 degrees in a seaward direction and is faulted in places. The ARL is the remnant of a shallow marine reef system deposited approximately 125,000 years ago (MIS 5e) along the margins of the Abdur volcanic highlands and across large areas to the north. Acheulian bifacial hand axes typically occur within the basal lag deposits, while MSA-type obsidian flakes and blades are found mainly in sandy nearshore and beach environments, representing a late example of the Acheulian/MSA transition and the earliest well-dated example of early human adaptation to marine food resources.

209-11 **10:50 AM** Arrowsmith, J. Ramon

GEOLOGICAL MAPPING AND TEPHROSTRATIGRAPHY OF THE HADAR FORMATION NEAR 11.25 N AND 40.75 E (AFAR REGION, ETHIOPIA)

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Fossil-bearing strata of the Hadar Formation crop out in a belt bounded on the southwest by the Ourda River, by the Awash River to the south and east, and by the Mille-Elowha Road to the north and west. Geological investigations from two field seasons permit us to present a basic stratigraphic framework (including tephra) for these Plio-Pleistocene units. 250 m of gently north-dipping strata are exposed within the south-central zone (Middle Ledi). Late Quaternary plateau gravels overly them in an angular unconformity of a few degrees. All units but the plateau gravels are cut (<20 m) by the few north-northwest and north-northeast striking normal faults (<2 km long). The strata are dominated by silty claystones with ubiquitous carbonate nodules. The lower 50 m of section is marked by gastropods, limestones, and lignites (lacustrine). The following ~50 meters comprises mudstones and discontinuous km-scale sand bodies several meters thick (floodplain and fluvial). The central 100 m of section alternates from red to brown sands and mudstones (floodplain) to silvery and yellowish mudstones with occasional fish fossils (lacustrine). The uppermost 35 m are green and brown silty claystones interbedded with at least one sand and pebble conglomerate package (floodplain and fluvial). They were the most productive for fossil recovery. Outcrop patterns and comparison with published field descriptions indicate that the base of the section is defined by the Sidi Hakoma Tuff while the top of the section is probably marked by BKT-2 tephra. We traced the upper tuff for >40 km across outcrops spanning the Adayitu-Mille Road. The thickest (8 m) and most diverse components crop out 8 km northeast of Adayitu, extending the trend of eastward thickening and increasing diversity noted in Hadar. Two additional tephra units are so far uncorrelated by field observations. The first is a grey to light tan, ledgy, discontinuous, ashy tuff encased within packages of pebble conglomerates and dark brown mudstones. The second crops out along the Mille River near its confluence with the Weranso. There, an 8 meter section exposes 16 tuffaceous layers. These field observations provide spatial breadth and new tephra descriptions for depositional basin models and the characterization of regional faunal variation as a function of changing paleoenvironment.

SESSION NO. 210, 8:00 AM

Wednesday, November 10, 2004

T117. Innovative Approaches to Teaching "Geology of National Parks": Tales from the Classroom, Field, Page, Web, and Beyond (*GSA Geoscience Education Division, National Association of Geoscience Teachers*)

Colorado Convention Center, 603

210-1 **8:15 AM** Mathis, Allyson C.

PARKS ARE CLASSROOMS: A PARK RANGER'S PERSPECTIVE

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National parks provide exciting opportunities for geoscience education, particularly for integrating the earth sciences with other academic disciplines and with recreational and experiential opportunities. Many national parks were established in recognition of their geologic resources, and even more national parks contain important geologic resources related to their primary significance. "Geology of national parks" courses take advantage of the "natural classroom" aspects of parks. Incorporating interpretive principles into these educational programs helps ensure the quality, and the lasting impact, of these educational experiences. Interpretation is a philosophy of communication that aims to relate to the whole person and to reveal the significances of resources instead of conveying only factual information. Successful interpretation can be described as "PAIRing people with parks" and includes mastery of 4 different components: presentation techniques, knowledge of the audience, interpretive methods, and resource information. Using interpretive themes as a tool while designing courses, field trips, or other educational material may be the single most effective method to add to the interpretive value of the instruction of geology of national parks. Interpretive themes can organize course material into individual take-home messages. Using interpretive methods, such as tangible-intangible links and "demystifying geology," can make geology more relevant, particularly to non-majors, and can help students understand the links between landscape and geologic processes, and the other natural and cultural resources of parks. Focusing on the origin of unique landscape features, Earth systems relationships, and the history of geologic research in parks, may also help elicit the compelling stories within park's geologic resources. Tying parks together, either via their geographic proximity or similar geologic resources, is also an effective strategy in instructing larger geologic concepts.

210-2 **8:30 AM** Ormand, Carol J.

KEEPING IT REAL: MAKING THE GEOLOGY OF THE NATIONAL PARKS RELEVANT FOR NON-SCIENCE MAJORS

ORMAND, Carol J., Department of Geology, Wittenberg Univ, Springfield, OH 45501, cormand@wittenberg.edu.

Many students enroll in introductory level geoscience courses to fulfill institutional science requirements. Making the course material relevant to these non-science majors is essential to attracting and keeping their interest. There are many ways to make courses about the geology of our national parks relevant. Three that work well for me are local field trips that exhibit features similar to national parks, incorporating scientific articles on the geology of parks we study in class, and investigating real data and real questions in extended lab exercises.

In central Ohio, most national parks are too far away to visit. However, our local geology exhibits features formed by the same processes as more famous parks, on a smaller scale. So while we study Mammoth Cave National Park, we take a field trip to Ohio Caverns. When we study the Grand Canyon, we visit Clifton Gorge. As students learn about Glacier National Park, they examine glacial deposits in Springfield, Ohio. While none of our local geologic features are as spectacular as those in the parks we study, the students want to know how these local features formed.

Many of my students are surprised, and intrigued, to learn that geoscientists do not yet have all of the answers. I include structured reading assignments on current research in the national parks we study in class. Using articles or excerpts from Geology, GSA Bulletin, GSA Today, Science, or Nature, I ask students to identify the question being investigated, the methods used to study the question, the data collected, and the author(s) interpretation of the data. While keeping students interested in the parks we study, these guided reading assignments also reinforce for students what it means to do science.

I have also designed or modified several extended lab exercises that ask students to grapple with real data and real questions. In these exercises, my students work to answer questions such as 'If the Pacific Plate were stationary, which would be bigger: Hawaii or Olympus Mons?', 'How faithful is Old Faithful?' and 'When will the glaciers be gone from Glacier National Park?' I find that students become quite caught up in these questions, and want to know the "real" answers. At this point, the students are "hooked."

210-3 **8:45 AM** Burns, Scott F.

USING MUSIC , VIDEOS AND FIELD TRIPS TO ENHANCE GEOLOGY OF NATIONAL PARK CLASSES

BURNS, Scott F., Geology, Portland State Univ, P. O. Box 751, Portland, OR 97207, burnss@pdx.edu.

Teaching a class in the Geology of the National Parks can be exciting and challenging. My classes are large so my exams have to be primarily multiple choice. I want the students to write, though. I use extra credit exercises to get them to write more. I have a collection of videos on the national parks that are from public broadcasting programs and also commercial video companies. I have the students write summaries on the videos which are on reserve in the library. They get 5 percentage points for each hour video (minimum of one page writeup). I also have the students grade the video which gets them to critically look at the videos. The final three lines of the summary are the evaluation. These exercises really get the students to see professional videos on the parks and write up what they have seen! I also give extra credit to students who visit a national park during the term. They get 10 percentage points for a day trip. We also visit one park as a class, Mt. Rainier. I also introduce each lecture with a song of the day which relates to the park. I will have copies of the song list at the presentation.

210-4 **9:00 AM** Lillie, Robert J.

PARKS AND PLATES: THE USE OF PLATE TECTONIC CONCEPTS TO TEACH A COURSE ON GEOLOGY OF NATIONAL PARKS

LILLIE, Robert J., Department of Geosciences, Oregon State Univ, Wilkinson Room 104, Corvallis, OR 97331-5506, lillier@geo.oregonstate.edu.

Introductory geology courses commonly employ a plate tectonic framework to help students understand Earth materials and processes. The same framework can be used to interpret the processes responsible for the development of the inspiring landscapes of our national parks, monuments, and seashores. Plate tectonics provides students the opportunity to appreciate the big things they see on Earth's surface, to understand basic geologic processes, and to look for similarities and differences in the landscapes they see in different parks. For example, steep-sided composite volcanoes are found in parks in the Pacific Northwest and Alaska because they formed at subduction zones, while Hawaiian parks reveal broad shield volcanoes developed over an oceanic hotspot. The spectacular mountains, valleys, beaches, and rock formations in national parks, monuments, and seashores, commonly form at plate boundaries or hotspots. Students can see what happens where plates diverge by studying continental rift features in parks in the Basin and Range Province, as well as the passive continental margin morphology revealed in national seashores along the East Coast. Convergent plate boundary processes can be examined through accretionary-wedge and volcanic-arc features seen in subduction zone parks in the Pacific Northwest and Alaska; students can then be shown that parks in the Appalachian Mountains reveal a zone of continental collision that developed as plate convergence closed an ocean basin. The plate tectonic framework also allows for interpretation of park features in ancient settings, such as rock layers in Grand Canyon National Park deposited along a passive continental margin, and granite in the Sierra Nevada that formed during subduction.

210-5 **9:15 AM** Reese, Joseph F.

PARKS FROM SPACE: ALTERNATIVE VIEWS OF AMERICA'S PARKLANDS USING REMOTE SENSING IMAGERY AND ASTRONAUT PHOTOGRAPHS

REESE, Joseph F., Geosciences, Edinboro Univ of Pennsylvania, Cooper Hall, Edinboro, PA 16444, jreese@edinboro.edu.

Remotely sensed imagery and astronaut photographs give a distinctly alternative and spectacular perspective of some of our continent's most recognizable landscapes – those in America's parklands. Views of National Parks from Space provide a clear link between local geologic setting and regional landscape formation. By coupling views of well known federal lands (i.e., Grand Canyon, Mt. St. Helens) from Space with those from closer to the ground and with maps and cross sections, we can readily distinguish North American physiographic / tectonic provinces (i.e., Colorado Plateau, Cascades) by their surface expression and characterize these regions geologically.

Views of parks from Space present the parklands at scales typically not seen in National Park Geology courses. These views are used to introduce the regional geology of a particular park or set of parks and to provide an effective regional backdrop after details of a park's geologic setting have been discussed. Questions addressing views are also incorporated into park-specific homework exercises. Regional-scale landforms related to deformation and mountain-building, volcanism, deposition, and erosion are easily observed, interpreted, and contrasted. Associated geologic processes and their modern and ancient large-scale products are beautifully documented. Integrating these views with more typical air and ground photos provides a continuum of scales to observe and study Park geology. Many views are visually stunning as well as educational and, with their aesthetic appeal, serve to enhance student curiosity and interest in Park geology.

Space Shuttle and International Space Station crews supply photographs of Earth's surface, whereas ASTER, MODIS, Landsat 7 and others provide remotely sensed imagery of the Earth. Increasingly, these alternative park views are being used in USGS websites such as the Cascades Volcano Observatory and published printed materials on parks. Visual resources that catalog views of parks from Space and make them available electronically include NASA's "Earth Observatory" (http://earthobservatory.nasa.gov) and "The Gateway to Astronaut Photography of Earth" (http://eol.jsc.nasa.gov) and JPL's ASTER website (http://asterweb.jpl.nasa.gov).

210-6 **9:45 AM** Norton, Kevin P.

USING COMPUTER MODELING TO STIMULATE INTEREST AND LEARNING IN LARGE LECTURE COURSES

NORTON, Kevin P., School of Science, Penn State Erie - The Behrend College, Station Road, Erie, PA 16563-0203, kpn1@psu.edu.

National Parks Geology is a large, 100+ student, lecture course at Penn State Erie - The Behrend College. This course satisfies a general science requirement, and as a result the students are of diverse backgrounds. In an effort to engage these mostly non-science majors, GSA - Denver (Wednesday, Nov. 10, 2004)

NO.	TIME	DESCRIPTION (*SPONSORS*)	LOCATION
208	8 a.m.	T87. Recent Advances in Himalayan Geology *(GSA Structural Geology and Tectonics Division)*	708/710/712
209	8 a.m.	T106. Geological Context of Early Humans from Ethiopian Rift Basins *(GSA Archaeological Geology Division; GSA Sedimentary Geology Division; GSA Limnogeology Division)*	102
210	8 a.m.	T117. Innovative Approaches to Teaching "Geology of National Parks": Tales from the Classroom, Field, Page, Web, and Beyond *(GSA Geoscience Education Division; National Association of Geoscience Teachers)*	603
211	8 a.m.	T136. Electronic Student Response Technology in the Geoscience Classroom: Is it a Valuable Teaching and Learning Tool? *(National Association of Geoscience Teachers; GSA Geoscience Education Division)*	601
212	8 a.m.	Environmental Geoscience (Posters) I	Exhibit Hall
213	8 a.m.	Geophysics/Tectonophysics/Seismology (Posters)	Exhibit Hall
214	8 a.m.	Quaternary Geology (Posters) II	Exhibit Hall
215	8 a.m.	Tectonics (Posters)	Exhibit Hall
216	8 a.m.	T39. Current Perspectives in Environmental Biogeochemistry (Posters) *(GSA Hydrogeology Division; GSA Geobiology and Geomicrobiology Division)*	Exhibit Hall
217	8 a.m.	T79. Pre-EarthScope Synthesis of the Rocky Mountains IV (Posters) *(GSA Structural Geology and Tectonics Division; GSA Geophysics Division; Friends of the Ancestral Rocky Mountains; EarthScope)*	Exhibit Hall
218	8 a.m.	T81. Regional Geology of the Northern Rockies: A Session Honoring Betty Skipp (Posters) *(GSA Structural Geology and Tectonics Division; GSA Sedimentary Geology Division; SEPM—Society for Sedimentary Geology)*	Exhibit Hall
219	8 a.m.	T84. Terrane Translation, Orogenesis, and Plate Interactions in the Late Mesozoic to Early Cenozoic North American Cordillera, and Implications for Paleogeographic Reconstructions (Posters) *(GSA Geophysics Division; GSA Structural Geology and Tectonics Division)*	Exhibit Hall
220	8 a.m.	T96. Records of Late Quaternary Climatic Change from the Americas: Interhemispheric Synchroneity or Not (Posters) *(GSA Quaternary Geology and Geomorphology Division)*	Exhibit Hall
221	8 a.m.	T97. Geologic History and Processes of the Colorado River (Posters) *(GSA Quaternary Geology and Geomorphology Division)*	Exhibit Hall
222	1:30 p.m.	Economic Geology II: Copper Deposits	102
223	1:30 p.m.	Engineering Geology	201
224	1:30 p.m.	Geoscience Education II	603
225	1:30 p.m.	Paleontology X: Early Life	108/110/112
226	1:30 p.m.	Paleontology XI: Species Concepts and Phylogenetic Relationships	104/106
227	1:30 p.m.	Paleontology XII: The Ecologic Context of Taxonomic Turnover	111/113
228	1:30 p.m.	Public Policy: Decisionmakers, and the Public: Challenges in Communication	607
229	1:30 p.m.	Quaternary III	703
230	1:30 p.m.	Stratigraphy II: Glacial and Bedrock Stratigraphy	107/109
231	1:30 p.m.	Tectonics III: UHP Terranes, Ribbon Continents, Appalachians, and Mid-Continent	709/711
232	1:30 p.m.	T2. Upcoming Revolutions in Observing Systems: Implications for Hydrogeology *(GSA Hydrogeology Division)*	203
233	1:30 p.m.	T7. The Occurrence, Storage, and Flow of Groundwater in Mountainous Terrain *(GSA Hydrogeology Division; U.S. Geological Survey; American Geophysical Union Hydrology Section)*	205
234	1:30 p.m.	T35. Assessment and Characterization of Geologic Formations for Long-Term CO_2 Storage (Sequestration) *(GSA Geology and Public Policy Committee)*	207
235	1:30 p.m.	T47. Ocean Chemistry through the Precambrian and Paleozoic II *(GSA Sedimentary Geology Division)*	Ballroom 4
236	1:30 p.m.	T81. Regional Geology of the Northern Rockies: A Session Honoring Betty Skipp *(GSA Structural Geology and Tectonics Division; GSA Sedimentary Geology Division; SEPM—Society for Sedimentary Geology)*	702/704/706