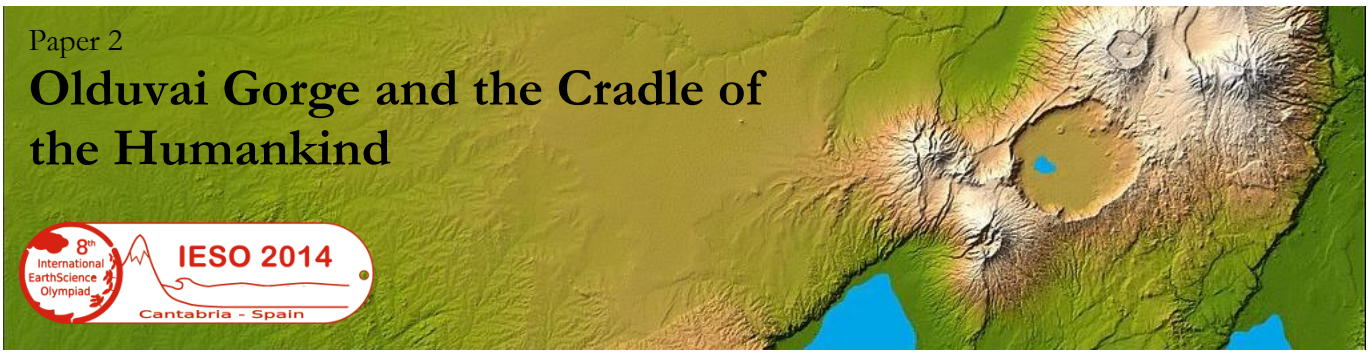
Paper 2

Olduvai Gorge and the Cradle of the Humankind



The Great African Rift Valley

Olduvai Gorge (in northern Tanzania) has often been called the "Cradle of Mankind" and is part of a UNESCO World Heritage Site since 1979. It is a site in Tanzania that holds the earliest evidence of the existence of human ancestors. Paleoanthropologists have found hundreds of fossilized bones and stone tools in the area dating back two millions of years, leading them to conclude that humans evolved in Africa. This site was occupied by *Homo habilis* approximately 1.9 million years ago, *Paranthropus boisei* 1.8 million years ago, and *Homo erectus* 1.2 million years ago.

From a geological point of view, Tanzania is part of a large Precambrian craton, composed of metamorphic and igneous rocks such as gneiss and granite, which is a fragment of an ancient continent. This basement, large and geologically stable, has evolved to the present flat landscapes, dotted with inselbergs in the outcrops of the more resistant metamorphic rocks. A good example of this is the great plain of the Serengeti, in northern Tanzania, dotted with isolated hills (inselbergs).
However, the Tanzania craton is crossed by a north-south fracture-system, known as the Great African Rift Valley. A rift is a great geological feature related to the breaking of a lithospheric plate and its separation into two tectonic plates. The Great Rift Valley of Africa is 4,000 km in length, from the Red Sea to Malawi, through Ethiopia, Kenya and Tanzania (Figure 1). The rift is largely found along a single line except in northern Tanzania where it divides into two branches. Africa began splitting some 30 million years ago, and the rift is still active, with fractures moving and volcanoes bringing magma to surface. With time, it will end up separating eastern Africa from the rest of the continent, with a new ocean in between, as has already occurred in the Red Sea.

The rupture of a continent has important consequences for the climate and landscape. The breaking process associates often with the intrusion of large volumes of magma in the crust, creating large raised areas, which represent an important climatic and ecological barrier. In spite its name; the Great African Rift is not exactly a valley (

Figure 2). In fact, it forms a series of highlands crossed by a line of depressions with huge lakes in the bottom (hence the name). Thus, the rift valley separates today the humid tropics to the West (forest) and dry tropical East (savannah). However, the growing of the rift is very slow, and has produced a progressive environmental shift, transforming tropical forest into savannah, leaving for some time isolated patches of forest. This change in vegetation could force some apes to move from one jungle area to another, across savannahs to where bipedism is an important advantage.

Figure 2. Plate Tectonics and West Africa structure.

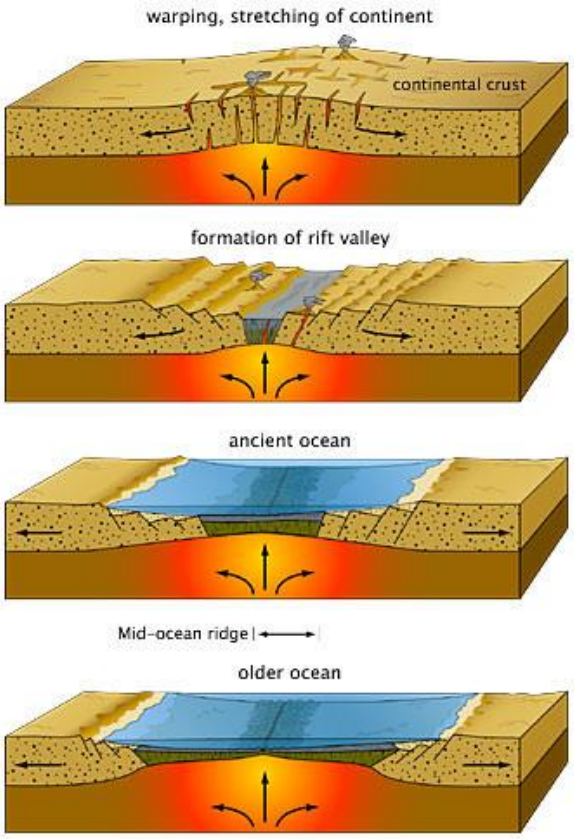


Figure 2. Evolution of a Rift. The Rift valley phase is represented by the current structure in African Rift Valley. The New Ocean Phase is represented by the Red Sea. The Mature Ocean Phase is represented by the Atlantic Ocean.

At the same time, large, shallow, and elongated lakes formed in the lowlands between elevations –Eyasi, Manyara and Natron lakes are located in northern Tanzania. Lakes get surface water, groundwater and, very often, hydrothermal waters. Under the influence of volcanic activity, there is a diversity of lake geometry and water-chemistry resulting in carbonated, salty and freshwater lakes. These lakes are wet places in the middle of arid savannah around.

Finally, the main volcanoes in northern Tanzania are Kilimanjaro, Meru and group Ngorongoro (8 volcanoes). Their emissions of lava and pyroclastic material (ash) during the Quaternary favored burial of the remains (bones) and artifacts (stone tools) generated by early hominids. Pyroclastic ashes added large amounts of calcium and magnesium into the medium, favoring a rapid process of fossilization. Some of these volcano-sedimentary deposits fossilized even the footprints of early Paranthropus bipeds, 3.5 Ma ago in Lemagrut slopes.

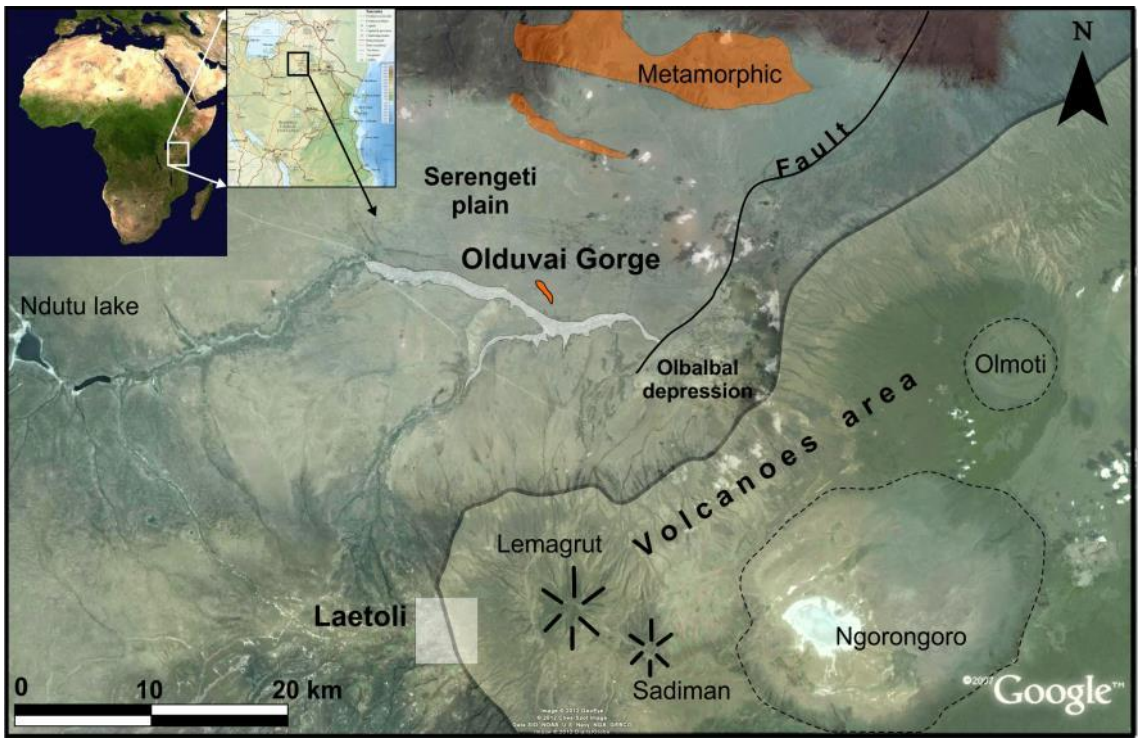


Figure 3. Olduvai Gorge, the Serengeti plains and the main volcanos around.

Olduvai Gorge

At the southern boundary of Seregueti, is the Olduvai Gorge beside the major Rift fault. Two million-year ago, this place was a large sedimentary basin with a shallow lake in the center (Olduvai lake). The basin's southern limits were the lava flows of Lemagrut and Ngorongoro; while the north limit was a large inselberg of metamorphic rock (quartzite) (Figure 3)

As the Olduvai Lake was fed by the waters of rivers descending from the slopes of volcanoes, during periods of drought, the size of the lake decreased dramatically and even got dry.

The sedimentation in the basin was the result of fluvial transport (material with transport marks and abrasion) and volcanic materials (ash, lapilli, bombs, etc). The volcanic coarser sizes (lapilli, bombs, etc.) correspond to pyroclastic surges, with high speed and temperature. However, the ash typically deposited as ashfall and volcanic dust transformed into clay, deposited on the lake bottom.

The availability of water and vegetation represented an attraction for animals in the region. The early hominids, came here for water and hunting, but also took advantage of the presence of basalt and quartzite, as raw materials for their stone tools. In addition, the chemistry of volcanic emissions influenced the composition of the lake water, increasing pH considerably, and helped the sedimentation processes and mineralization, to preserve animal remains and stone tools, forming archaeological deposits.

Scientists of several specialties have divided the sedimentary sequence of the basin into 4 main units (Beds I, II, III and IV). They represent the last 2 million-years of earth history and contain various hominid fossils that evolved in that time (*Paranthropus*, *Homo habilis*, *Homo ergaster*, *Homo sapiens*).

Bed I and II are the most interesting from a paleontological and archaeological view. During the sedimentation of Bed I (Figure 4), the great central lake was a landmark of the landscape, and the focus of activity for the first hominids. In the Bed II at (1.78-1.2 Ma. approx.), the climate became dryer and the lake divided into small ephemeral lakes, and rivers became also ephemeral. Over time, this basin accumulated 100 meters of sediments, to form the current great plain.

However, towards the end of the Pleistocene, large faults associated to the Eastern Rift caused a 100 m entrenchment of the Olduvai River. What started as a small groove (oriented WE, to reach the Olbalbal depression) became the current Olduvai Gorge, which cuts across the strata that filled the lake and provides access to the paleontological and archaeological remains they contain (Figure 5).

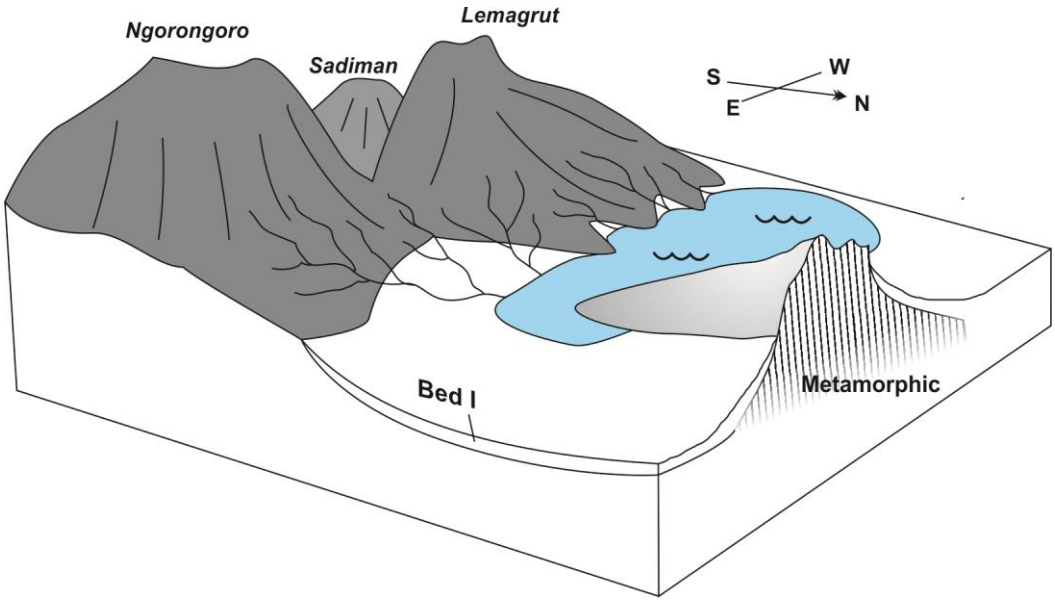


Figure 4. The Olduvai basin during the sedimentation of Bed I (2.0-1.78 Ma).

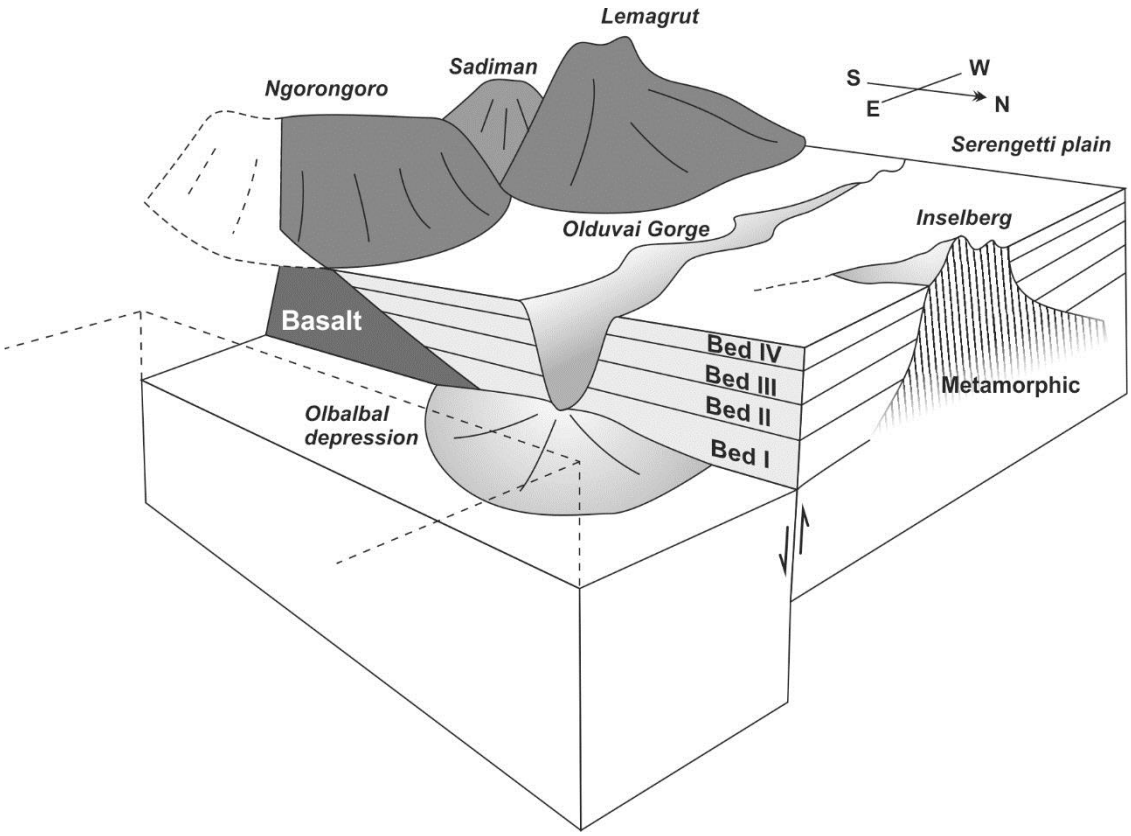


Figure 5. Diagram showing Olduvai Gorge today

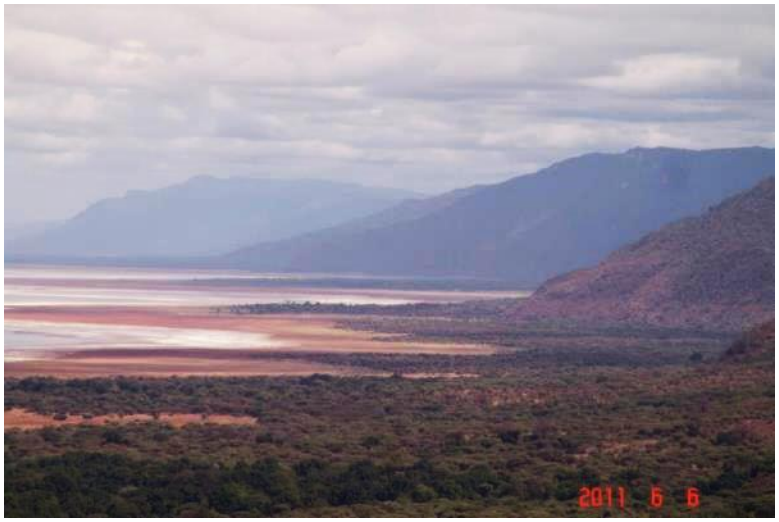


Figure 6. Lake Manyara in the African Rift (Tanzania)

Figure 7. Effect of pyroclasts today. Source: http://volcano-club.blogspot.com.es

Figure 8. Effect of pyroclasts in the past: hundreds of fossilized skeletons at Nebraska's Ashfall Fossil Beds.

1. Which of the options below best describes the impact of the opening of the African Rift on the emergence of bipedism in early hominids?
   a) The rainshadow effect transformed the forest into savanna.
   b) The volcanic activity caused a greater diversity of ecosystems.
   c) The emergence of numerous lakes.
   d) The formation of a continental north-south communication corridor.

2. Why are there so many archaeological sites in the African Rift Valley?.
   a) Because the emission of pyroclastic material that preserved the remains.
   b) Because there are numerous water resources around.
   c) Because there are many rocks to make stone tools.
   d) Because the presence of salts in the Rift's lakes.

3. Which rocks are best suited for making stone tools in Olduvai?
   a) Gneiss (glandular)
   b) Metamorphic quartzite foliated
   c) Slates (with garnet)
   d) Basaltic lava (or very fine grained microgranular)
   e) Basaltic lava (with large crystals of olivine)

4. In the stratigraphic column of Figure 9, the archaeo-paleontological site B is on lacustrine clays, covered by a pyroclastic surge with cross bedding. Site A is located on the top of this lapilli pyroclastic layer, covered by volcanic ash with parallel lamination. Where would and intact skeleton most likely be found?
   a) In any one, because the sediment density is very low.
   b) At Site A, because the ash was deposited at low speed.
   c) In the Site B, because the surge was deposited very quickly.
   d) None, because the high temperature of pyroclasts destroys the bones.

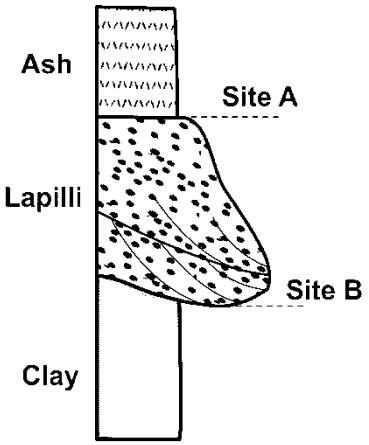


Figure 9. Stratigraphic column at sites A and B

5. Which type of material covered and preserved the Laetoli footprints?.
   a) Ashes
   b) Lapilli
   c) Tephra
   d) Lava
   e) Gravel
   f) Coarse Sand

6. Which type of geologic event occurred while the Parantropus' family walked by the slopes of Lemagrut?
   a) Tsunami (lake-type)
   b) Earthquake (magnitude 8 on the Richter scale)
   c) Strombolian Volcanism
   d) Hawaiian Volcanism

7. What can explain the excellent fossilized bones at Olduvai?
   a) The presence of shallow lakes with salt precipitation.
   b) The weathering of metamorphic rocks.
   c) The eruption of the volcano Oldoynio Lengai carbonatites.
   d) The presence of volcanic tuffs, in addition to calcium feldspar basalt.

8. Refering to Bed II, which process may explain why 90% of the fossil fauna was preserved in a fluvial environment?
   a) The arid climate reduces the size of the lakes and the fauna spend more time around the rivers.
   b) The climate is more humid and therefore the rivers are flowing.
   c) The fauna was better adapted to the riverbanks.
   d) The rivers are the main agent of transport and deposition of bones and archaeological remains.

Reffer to Figure 10 to solve the following questions:

9. Choose the most likely sedimentary environment (bottom of figure) for sites A and D (top of figure). [Choose the right answer in your answer sheet]

10. Choose the most likely sedimentary environment (bottom of figure) for sites C and B (top of figure). [Choose the right answer in your answer sheet]

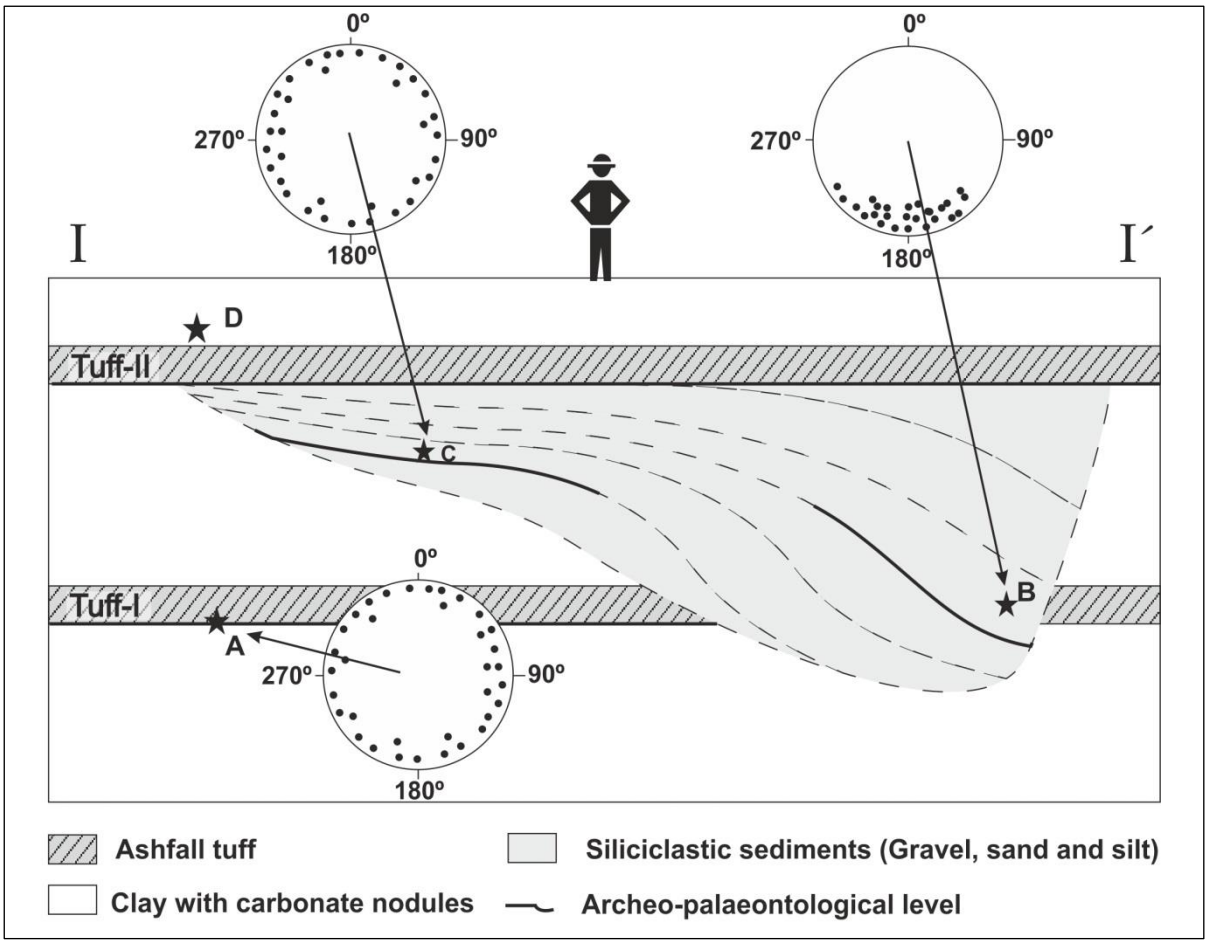
11. Considering the sedimentation environment and the orientation diagrams, what is the most likely site to find remains in with complete skeletons?
   a) A
   b) B
   c) C
   d) D

12. Taphonomy studies the post-sedimentary geological and biological processes on fossils. Given that 1.35 Ma ago the climate was very arid, where will you find better bones with the best evidences of manipulation by hominids?
   a) A
   b) B
   c) C
   d) D

One of main challenges in paleontology is determining the age of the fossils. Finds are meaningless unless we can date them, and dating is a complex process. From the very basic methods of the first geologists to modern techniques dating has evolved enormously.

13. Back to Figure 10, which of the following is the correct order of the age of the sites, from oldest to youngest?
   a) A > B > C > D
   b) B > C > D > A
   c) C > D > A > B
   d) D > A > B > C
   e) D > B > C > A
   f) A > C > B > D
   g) D > C > B > A
   h) D > B = C > A
   i) A > C = B > D
   j) Impossible to know

14. When you solved the previous question, you were using a method. Choose the two best options to describe the method you have just used.
   a) Absolute dating
   b) Correlative dating
   c) Relative dating
   d) Chrono-stratigraphic dating
   e) Radiometric dating
   f) Principle of Uniformity
   g) Principle of Superposition of Strata
   h) Principle of Cross Bedding
   i) Principle of Cross-Cutting



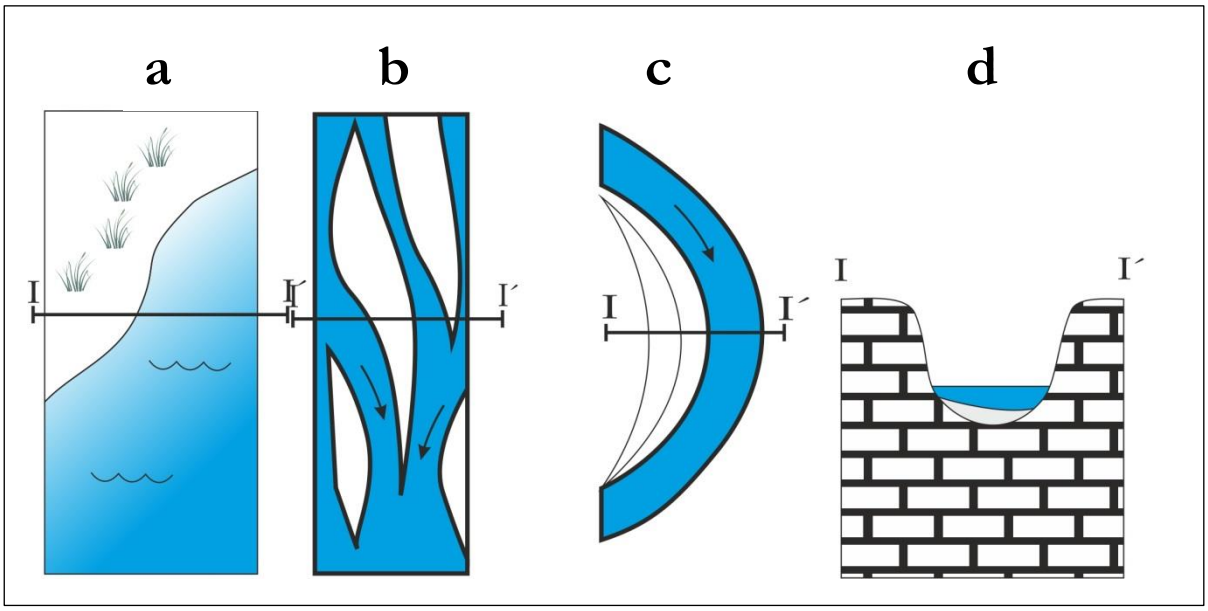


Figure 10. TOP: Geological section of the BK site (Bell's Korongo), located on the top of Bed II of Olduvai. The diagram shows the 4 archaeological levels (A, B, C and D). The circles represent the orientation diagrams of bones found in levels A, B and C. BOTTOM: Simplified representations of four sedimentary environment(a, b, c and d).

15. Which of the following radiometric series can be used in these paleo-archeological sites?
    a) K/Ar
    b) Ce/U
    c) Pb/Ca
    d) He/Ar

Geologic structures are also a clue for paleontological research. Figure 11 shows a simplified geological map; but even such simple scheme would help in paleo-archeological excavations.

16. What kind of fault is F1
    a) Normal
    b) Reverse
    c) Strike – Slip
    d) Rotation

17. What kind of fault is F2 if the fault plain dips 30º toward the east?
    a) Normal
    b) Reverse
    c) Strike – Slip
    d) Rotation

18. Choose the best explanation for the movement of F2.
    a) BL is uplifted in relation to BC
    b) BC is uplifted in relation to BR
    c) BR is uplifted in relation to BL
    d) Impossible to decide

19. These faults "cut" across a general structure than can be defined as…
    a) Diaper intrusion
    b) Lopolite intrusion
    c) Parallel bedding
    d) Cross bedding
    e) Symmetrical fold
    f) Asymmetrical fold
    g) Horst and graben

20. Dip values in the northern part of the map should be…
    a) Equal to the value in the south
    b) Bigger than in the south
    c) Smaller than in the south
    d) Impossible to know

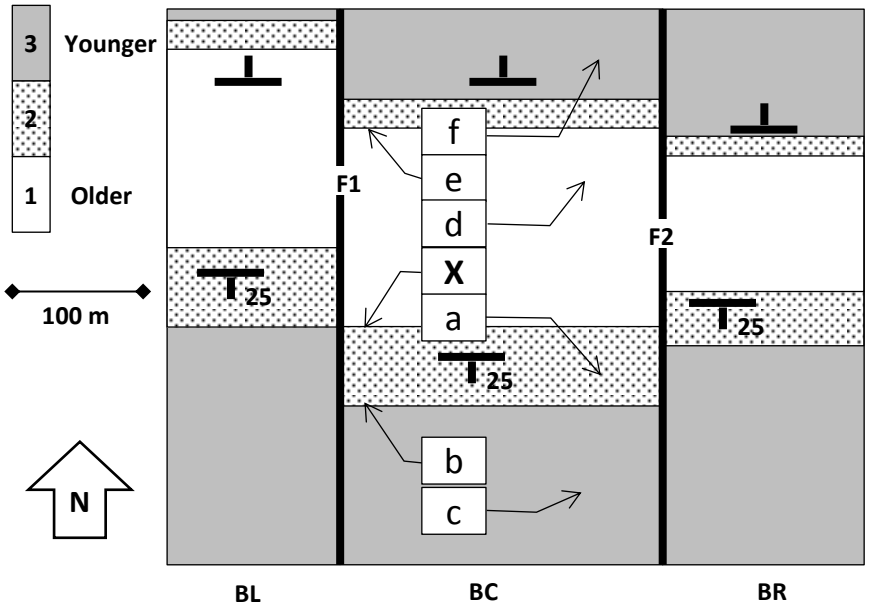


Figure 11. Simplified Geological Map of a folded paleontological site. F1 and F2 are fault. The three sedimentary units have been relatively dated, as shown in the column. The "T" symbols (and figures) give sense (and value) of strata tilting. BL=Block Left; BC=Block Center; BR=Block Right.

The contact marked with arrow **X** in Figure 11 is a paleontological site, where unit 2 covers the footprints that hominids and giraffes produced on unit 1. The scientists decide to explore the area and to dig in the places they consider possible sites.

21. Folding happened…
    a) At the same time that footprints
    b) Before footprints
    c) After footprints
    d) Impossible to deduce

22. Choose the points in which you can find fossils like those of site X.
    [Choose the right answer in your answer sheet]

23. Choose the point in which it is impossible to find in situ fossils like those of site X.
    [Choose the right answer in your answer sheet]

24. Where is the best location to dig to reach the same fossils that are in X, with a minimum excavation?
    a) In a
    b) In e
    c) a and f are equal
    d) It is impossible to find fossils in a or e
    e) Impossible to know

Biology, Earth Science and Astronomy are deeply interconnected. They are the basis for many advances in subjects as diverse as the exploration of planets, to the development of high efficiency agriculture.

The following question was part of the selection process for an Astronauts' School.

25. Based on the following data, which planet do you think is Jupiter?
[Choose in your answer sheet]

	Planet A	**Planet B**	**Planet C**	**Planet D**
Mass (kg)	5.69×10^{26}	8.68×10^{25}	1.90×10^{27}	1.02×10^{26}
Mean surface temperature (K)	88	59	120 (cloud tops)	48
Atmosphere	75% hydrogen 25% helium with trace amounts of water, methane, and ammonia	83% hydrogen 15% helium 2% methane	90% hydrogen 10% helium with trace amounts of water, methane, and ammonia	74% hydrogen 25% helium 1% methane
Satellites	18	15	16	8

You have been accepted as an astronaut for a mission and it's time to look at the other four planets nearby and see if any of them can support human life. The planet you're looking for needs to have moderate temperatures and liquid water.

26. Your instruments are showing you the readings below. Which one might be habitable?

	Planet E	**Planet F**	**Planet G**	**Planet H**
Mass (kg)	4.87×10^{24}	6.42×10^{23}	5.98×10^{24}	3.3×10^{23}

Mean surface temperature (K)	726	310	281	452
Atmosphere	96.5% carbon dioxide 3.5% nitrogen	95.3% carbon dioxide 2.7% nitrogen 1.6% argon 0.15% oxygen trace amounts of water	70% nitrogen 26% oxygen 2% argon trace amounts of carbon dioxide and water	no atmosphere
Satellites	0	2	1	0

http://evolution.berkeley.edu/evosite/evohome.html

Philogenics are basic in Evolutionary Biology. **Cladogrames** are phylogenetic representations to define **clades**—groups in which all organisms that are descended from a common ancestor. As an example, we can look more closely at reptiles and birds. Use this information to answer the following questions.

27. Choose the right answers that can be deduced from the table.
    a) Non-avian dinosaurs form a clade.
    b) Testudines, Squamata, Archosauria, and Crocodylomorpha all form four (4) clades.
    c) Turtles and Crocodiles share the same level of diversification.
    d) Birds and Snakes are closer than Birds and Crocodiles, from the point of view of evolution.
    e) Either "reptile" is not a valid phylogenetic clade or we have to start thinking of birds as reptiles.
    f) Dinosaurs are not extinct. Birds are, in fact, part of the clade Dinosauria.

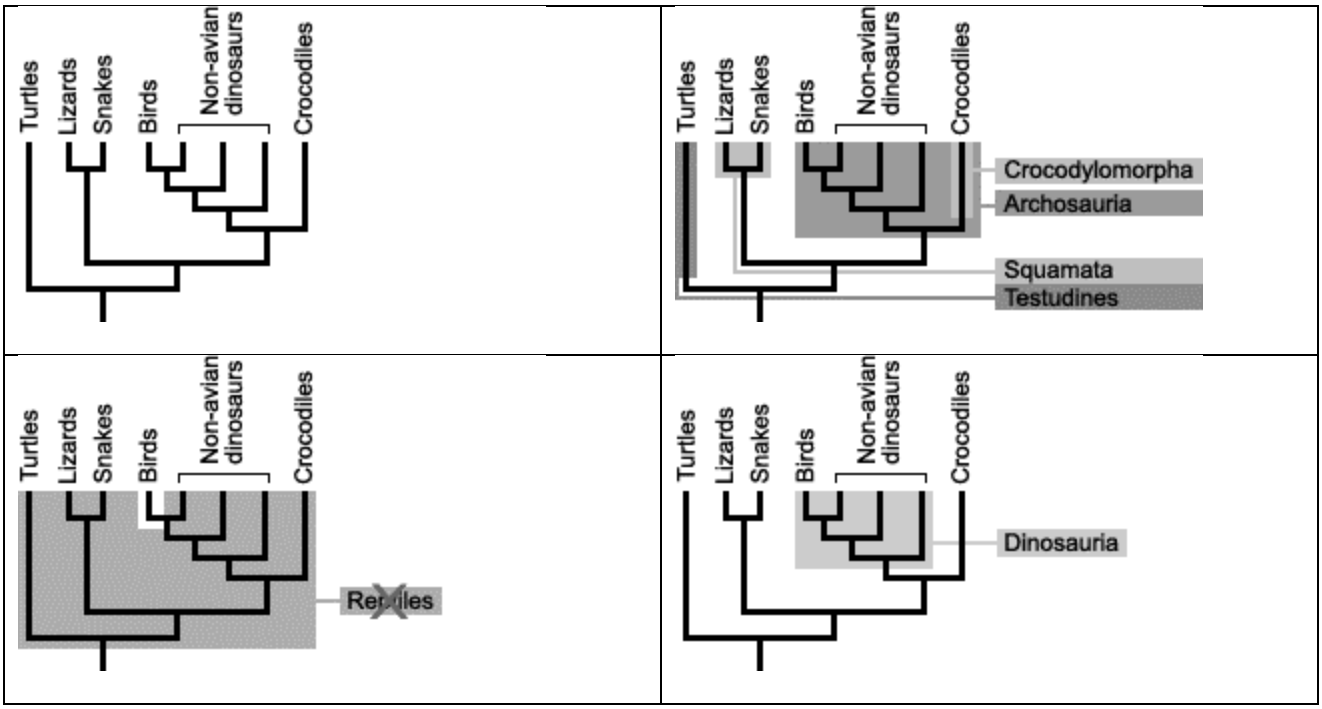


Figure 12. Section.

28. Choose the right sentences about Figure 12. The sections is…
    a) A sedimentary sequence.
    b) A soil
    c) A weathering profile
    d) An organic matter accumulation

29. Choose the right sentences about Figure 12.
    a) According to the principle of superposition of strata, A is younger than E
    b) According to the principle of superposition of strata, E is younger than B
    c) Except O, that is younger, all the other levels have the same age.
    d) Except C, that is younger, all the other levels have the same age.
    e) All the levels are contemporary.

30. Plants take nutrients only from horizon(s)…
    a) A
    b) B
    c) C
    d) O
    e) A+B
    f) All

31. In relation to Figure 12, mechanical agriculture practices, such as ploughing, disrupts…
    a) All levels
    b) Upper levels
    c) Lower levels
    d) None

32. In relation to Figure 12, intensive agriculture practices disrupts chemically…
    a) All levels
    b) Upper levels
    c) Lower levels
    d) None