

Subject: Anthropology

Production of Courseware
-Content for Post Graduate Courses

Paper No. : 01 Physical/ Biological Anthropology
Module : 10 Fossils and Dating Methods



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Description Of Module	
Subject Name	Anthropology
Paper Name	01 Physical/Biological Anthropology
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5. Summary

Learning objectives

Once you have studied this module you would be able to:

- Define and identify the fossils in archaeological context.
- Understand the process of fossil formation and related disciplines or sub disciplines.
- Understand the importance of fossil in palaeoanthropology as well as in anthropology.
- Understand the different methods of dating fossil both relative and absolute

1. Introduction

Palaeoanthropology is a subfield of biological anthropology that deals with the fossil record for humankind. Fossilized remains provide the direct evidence of human ancestry. So the discovery and study of fossils is indispensable for palaeoanthropology. The study of hominid fossils relies on many other disciplines or subdisciplines like geochronology, paleontology, osteology, Taphonomy, geology, anthropology and archaeology. Fossil remains are not only important to understand the phylogeny but also helpful in explaining and understanding the past events of man.

2. Fossil: Definition and process of fossilization

The word fossil is derived from the Latin word *fossils*, meaning 'dug from the earth'. Fossil is any trace or impression of an organism which existed in the past geological time period that has been naturally preserved in the earth's crust (Haviland, 1997).

The process of formation of fossil is known as fossilization. It involved the preservation of specific parts of an organism which once existed. The process includes the replacement of an organic component of an organism by minerals. When an organism dies the organic part decays rapidly and the inorganic part remains for a long time. The gaps left by the decomposing organic substances are filled with minerals of soils and water and became fossilized. Fossilization is depended on climate, geology and local soil condition. Wet and alkaline soil is suitable for fossil formation whereas in acidic tropical soil the soft and hard parts of the organism dissolve completely. Soft tissues are preserved in permafrost condition.

Taphonomy is the study of process of fossilization. It deals with the events of an organism after its death and until its discovery as a fossil including decomposition, transport, burial and other chemical, biologic, or physical activity which affects the remains of the organism. It also considers the geological and biological process that helps to know the context and condition of the fossilized remains.

The different parts of the body is fossilized in different rates. The bony parts which contain more minerals are suitable for fossilization rather the soft tissue like skin muscles etc. The hard tissues like bones and teeth are preserved well for their high mineral content. Teeth contain over 90 % mineral and the most commonly fossilized body parts. Other harder and larger bones like femur, humerus is more commonly fossilized than lighter bones. Fossilized skeletal part is very significant to the paleoanthropologists because it contains maximum evolutionary features of hominid evolution but limited in evidences (Poirier et. al. 1999). Hominid fossils of 2 million years ago are scantier than 50,000 years ago because of the fact that they were distributed widely in different geographical areas and in the later stage of human evolution it was found deliberate burials were practiced.

3. Importance of study fossil in palaeoanthropology

Fossil hominids are studied in different contexts. Relationship between form and function of early hominids in terms of structure of the bones, posture, locomotor patterns, and mobility of limbs, manual dexterity and dietary habits are reconstructed with the comparative anatomy. In palaeodemography different aspects like fertility, mortality, sex ratio, population size of prehistoric people are studied with the help of fossil remains. Palaeopathology is also dealt with the fossils to know the diseases, fertility and mortality rate, cause of death and life span of a prehistoric population. Fossils also have immense importance to reconstruct the prehistoric cultural practices, social structure, population migration and ethnic affiliation.

4. Dating of fossils

The discovery of a fossil is useless without proper dating. Dating is important for chronological arrangements of fossil found and reconstruct the bio-cultural history of early man. There are two techniques of dating- direct or absolute and indirect or relative. The absolute dating is also known as chronometric dating in which date is calculated in years BP. In relative dating the date of man's activity is determined in respect of other finding which has already been dated. All of the dating methods cannot date a fossil directly like Paleo magnetic dating, K-Ar dating. These are used to date the sediments or other objects associated with the hominid fossil finds and its deposition.

4.1. Relative dating

Relative dating involved the techniques by which an archeological finds are dated indirect or relative in respect of other findings, the date of which was known. Eg. Stratigraphy, FUN analysis. Before the advent of absolute methods of dating relative methods of dating was reliable method of dating ancient human remains including fossils and artifacts. Different geological and chemical methods are used as relative dating method. The commonly used relative dating are stratigraphy, FUN analysis, Faunal correlation.

4.1.1. Stratigraphy

The stratigraphy is the most well-known and widely used method to establish the relative sequence of the evidences. This method is based on geology. One stratum is differentiated from other in terms of composition, colour and contents. These strata are studied to get the Chrono-cultural sequence of different phenomenon. The stratigraphy is based on the law of super imposition that the lower strata are older than those of the higher strata. The fossils and artifacts are found from different strata are arranged chronologically to get the sequence of different culture and different stages of hominid

evolution in respect of time. All of the strata are not arranged chronologically because there are number of unconformities like various movements and rearrangement of the earth. Early hominids sites of South Africa were dated by relative chronology.

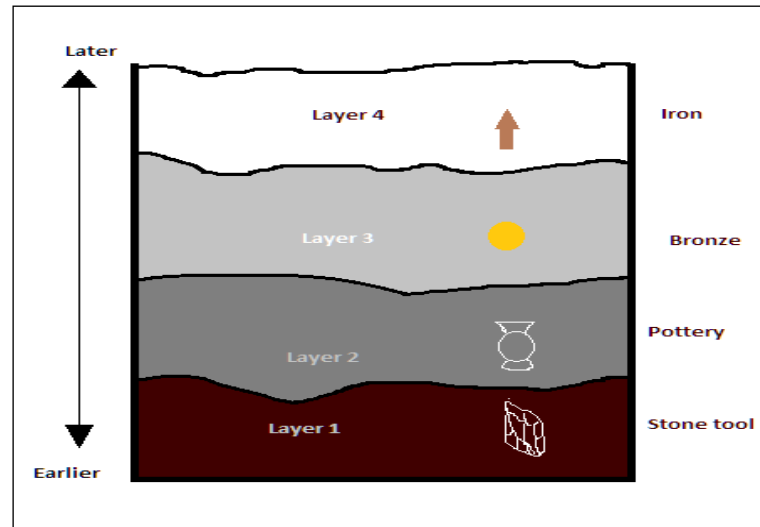


Fig. 1: Study of different stratum (layer)

4.1.2 Faunal correlation

The fossil remains in stratigraphical context can be dated by its form and structure (morphology). Analysis of faunal remains sometimes helps to establish relative chronological framework for sites where numerous fossils have been found. The new faunal forms emerged and spread with the extinction of older forms. Fossil vertebrates also are the determinants of Pleistocene environment. Mollusks and insects sometimes used as the indicator of past climate. The faunal remains of Elephas, Equas, Rhinoserous belonged to warmer climate are replaced by wooly mammoth, woolly rhinoceros, reindeer, bison in cold climatic condition.

4.1.3. Fluorine, Uranium and Nitrogen analysis

This dating method is applied to determine relative age of fossils found in same geological deposition. This method is based on the quantitative difference of concentration of fluorine, uranium and nitrogen in buried bones. The fluorine in the ground water combines with the calcium of the bones and forms a new compound fluoroapatite which can be measured and differs in fossilized bones found from different strata and remain same in the samples found in the same layer. The oldest bone contains the greatest amount of fluoroapatite and in case of the recently deposited youngest bone the amount is zero. The amino acids in collagen contain nitrogen break down. As the bone becomes older the amount of

nitrogen decreases. These two are complimentary in nature that the recent bones have higher nitrogen content and lower fluorine content and in case of fossil bones it is vice versa. Uranium from ground water percolates into the minerals content of bones through the replacing of calcium ion. The bones deposited for longer time period it absorb more uranium. The major problem is the variation of concentration of these elements in ground water in different areas. The famous Pildown problem was solved by the application of Fluorine method.

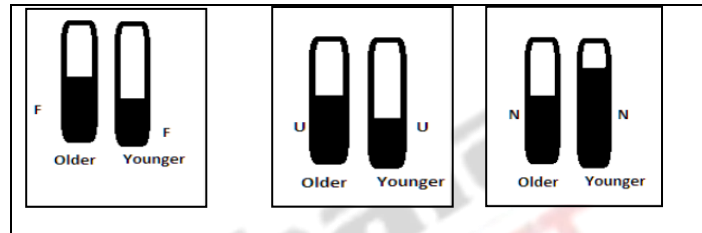


Fig 2: Determination of relative age of buried bones by FUN dating

4.2. Absolute dating

The absolute or direct method of dating includes those techniques which provide the date of the archaeological findings in years. The absolute dating is also known as chronometric dating. A number of absolute dating methods are used to date fossils directly or indirectly. Most of these absolute methods are radiometric dating. All these radiometric dating are based on the principle of decay rate of parent atoms into daughter atoms and the age is calculated by measuring the ratio of these two. Radiometric dating methods are essential to date the fossil hominids. The commonly used absolute datings are Carbon-14 dating, Potassium-Argon dating, Amino acid recimization, Fission track, Thermoluminescence, Uranium series dating, Palaeomagnetism. There are other dating methods but these are not directly associated with dating of fossils like dendrochronology.

4.2.1. Carbon-14 dating

It is the most widely used radiometric dating method. This dating method is based on the principle of the decay of C14 into nitrogen element. Neutrons produced by cosmic radiation react with nitrogen and produce 14C. The half-life period is 5,730 years. Unlike 14C, 12C is stable isotope. The 14C together with 12C combines with the oxygen present in the atmosphere and produce and enters into carbon dioxide. Carbon dioxide containing 14C and 12C in a constant ratio absorbed by plants and when eaten by animals enters into its body. After the death of the animals or plants the radioactive 14C begins to decay and 12C remains the same. By measuring the ratio of 14C and 12C the amount of 14C present in this can be calculated. The age of a specimen is calculated by emission rate of the half of the original radioactive materials 14C, approximately 5,730 years old. The 14C atoms are counted in the laboratory by using accelerator mass spectrometry (AMS).

The datable materials suitable for C14 dating are organic materials like charcoal, charred bones, shell, hair, wood and other organic substances. This is very effective method to date different organic artifacts and fossilized bones though there are number of errors like statistical errors indicating the \pm dates, error of the ^{14}C level of the sample and errors regarding the laboratory preparation of sample and management. The limitation of the method is range of time between 40,000 to 60,000 years but most of the hominid fossils are older than that. Recent development of the calibration date maximizes the datable range of the measurements based on tree ring and uranium thorium dates.

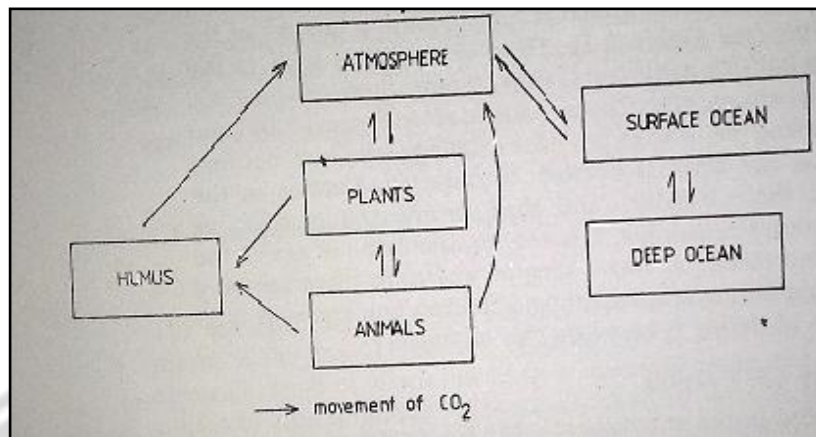


Fig 3: The carbon cycle (Parkes, 1986)

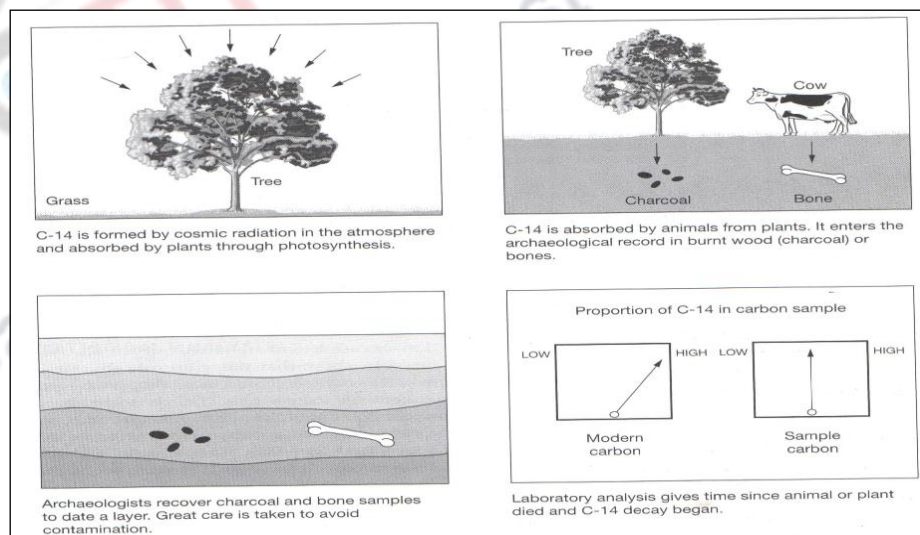


Fig 4: Method of radiocarbon dating (Grant et al. 2005)

4.2.2. Potassium-Argon dating

This chronometric dating method is more effective to date the fossils of the human history which ^{14}C fails to date. This dating technique developed by Arnold to date very old deposition of volcanic rocks, igneous rocks and minerals. K/Ar dating is applied to date the deposition in which the fossils are found but not directly the object. It is based on the principle of the decay rate of the ^{40}K to ^{40}Ar . The ^{40}K is radioactive in nature decays at particular rate to form the ^{40}Ar , which is stable in nature. Argon gas escape at high temperature and begin to accumulate when it cool down. 11 percent of every 100, ^{40}K becomes ^{40}Ar . By measuring the ratio of $^{40}\text{K}/^{40}\text{Ar}$ the rate of decay and time period is calculated in a spectrometer, which measures the concentration of ^{40}Ar . The half-life period of ^{40}K is 1,330 million years. The datable range is 500,000 to 3 billion years. This dating method is useful to date fossils where there are volcanic eruptions. So this dating method is extensively used for dating East African hominid fossils from Olduvai Gorge and Laetoli in Tanzania, Hadar in Ethiopia,

This dating method has number of limitations like the selection of suitable datable materials, statistical errors and management of the sample. Recent improvement of the method reduced the statistical errors and extends the datable range (Fagan, 1999). Recently $^{40}\text{Ar}-^{39}\text{Ar}$ methods have been developed to overcome the limitations of the K-Ar dating method.

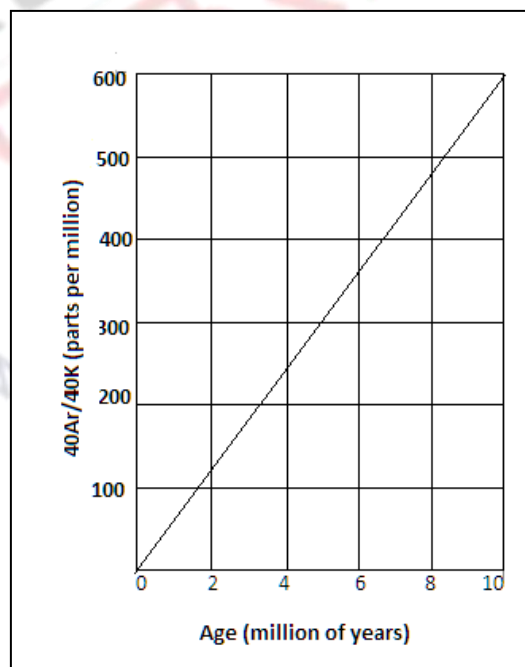


Fig 5: Changing ratio of $^{40}\text{Ar}/^{40}\text{K}$ over time (Jones et al. 1992)

4.2.3. Amino acid racemization

This chronometric method of dating is directly used to date fossil remains. Collagen is a kind of protein that remains in the fossilized bones for a longer time period. The amino acids which made the collagen have two forms i.e. L-amino acid (normal form) and D-amino acid (mirror image form). After death of an organism the L-amino acid transform to the non-protein D-amino acids over a long time period. This change is called racemization. The dating method is based on the principle of the amount of change, racemization that has been occurred in the buried fossilized bones.

The rate of racemization is not same in all the materials. In case of skeletal remains the datable range is 5,000 to 100,000 years. It is also help to date mollusks and ostrich egg shells, which are present in many human palaeontological sites. The datable range of ostrich egg shell from 40,000 to 180,000 years ago, the time when anatomically modern man appeared in the earth. The limitations of this dating method the racemization rate vary on the nature and extent of different amino acids and also depend on the temperature. Despite of all these limitations this method of dating is widely used to date fossils in Africa and Middle East (Poirer et al. 1999).

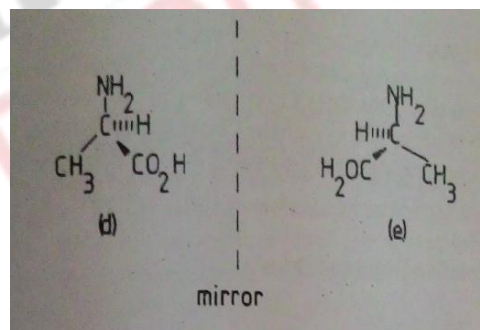


Fig 6: (d) L-amino acid (normal form), (e) D-amino acid (mirror image form) (Parkes, 1986)

4.2.4. Uranium series dating

Uranium series dating is a chronometric dating based on the decay chain of uranium i.e. ^{238}U and ^{235}U into various daughter elements and widely used for dating fossils. The different sets of daughter isotope sets used for dating i.e. ^{230}Th - ^{234}U (Th-U), ^{234}U - ^{238}U , ^{231}Pa - ^{235}U etc. Out of these sets Th-U method is widely used to date hominid sites that contain ancient rocks, stalagmites, bones, teeth, shell and calcium carbonate deposition. In fresh deposition of calcium carbonate no ^{230}Th is present because it is insoluble in water and the ratio of ^{230}Th - ^{234}U is zero. The ratio increases with the time when ^{234}U decays to ^{230}Th . The date of its equilibrium (1.0) is 350,000 years.

The datable materials of Uranium series are chemically or biologically precipitated calcium carbonate (CaCO_3) and also applicable to date teeth and bones are based on the principle of accumulation uranium from ground water after buried. For example living bones contains 0.1 ppm uranium whereas fossil bones contain up to 1000 ppm.

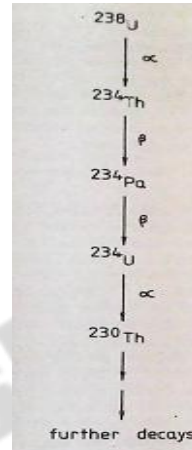


Fig 7: Radioactive decay of ^{238}U (Parkes, 1986)

4.2.5. Fission Track dating

Fission track dating is applied to date rock and stones in which fossil are found but not directly on the fossil. This method is based on the principle of counting the number of tracks that have been formed when uranium decays through fusion releases energy and damages crystalline structures. It creates a crystal lattice which are 15-20 micrometer long. These tracks are counted and dates are calculated. The datable range is long 20 years to 5 billion years. The advantage of this method is the rate of decay of ^{238}U is constant through time and tracks reproduced with 100 percent accuracy. This dating method was used to date Bed I at Olduvai Gorge, Tanzania, East Africa.

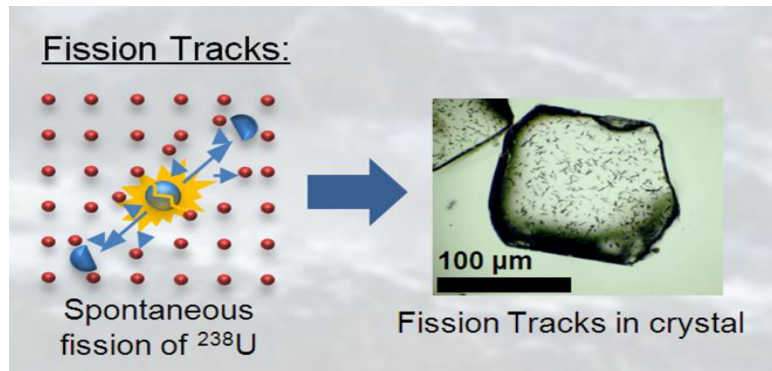


Fig 8: Fission tracks produced by Spontaneous fission of ^{238}U (Szameitat, 2013)

4.2.6. Thermoluminescence

This dating method is based on the principle that when a solid is heated its stored energy is released and emits light. The light emitted by temperature is termed as thermoluminescence. The trapped electron in a material is zero when heated. After last heating the trapped electron started to store in a sample. The age of the sample comprises the length of the time since the object was last heated. This is done by measuring the amount of total radiation in the sample and the amount of radiation in the sample receives in one year in particular environment (Conroy, 1997).

Age of a sample = accumulated radiation dose/ annual radiation dose

The datable range is present to 400,000 years ago and used to date burnt pottery, flint, shells and bones. The Neanderthal graves in Israel were dated more than 40,000 years ago (Fagan, 1999).

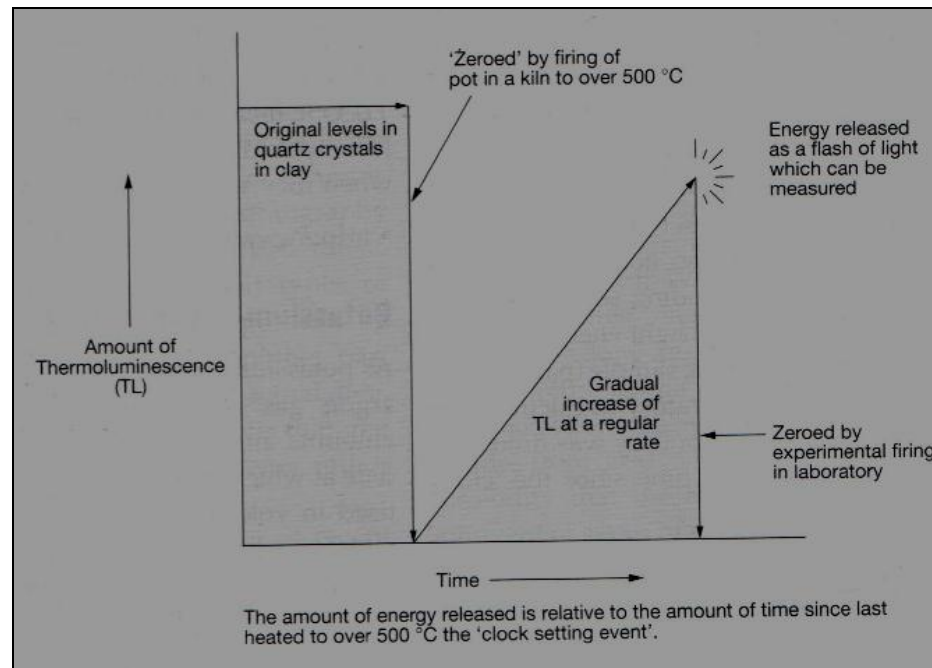


Fig 9: Method of thermoluminescence dating (Grant et. al, 2005)

4.2.7. Electric Spin Resonance (ESR)

This dating method is similar to TL method of dating but nondestructive in nature. In this method the density of trapped electron is determined by measuring their absorption of microwave radiation. The same formula of TL method of dating is used for the determination of age. This dating method is very significant in palaeoanthropology to date teeth enamel and bones of hominids. It was used to date middle Paleolithic skull from Qafzeh, Israel.

4.2.8. Palaeomagnetic dating

Palaeomagnetic dating is based on the principle of the change of earth's magnetic field over time in direction and intensity. These changes are recorded in lava, rocks, lake sediments, etc. Geomagnetic polarity lasts between 0.5 and 1 million years ago, which reversed between 0.5 and 2.5 million years ago and before 3.4 million years ago. The history of polarity changes have been determined over the past 4 million years helps to date different deposition in which fossils are found. This method of dating was applied to date number of site in East Africa like Olduvai Gorge in East Africa; Lake Turkana in Kenya; Omo in Ethiopia.

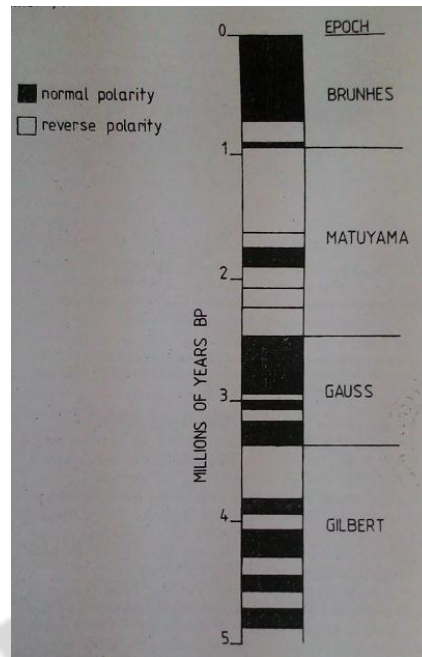


Fig 10: Magnetic polarity time scale (Parkes, 1986)

5. Summary

- The study of fossil is multidisciplinary in nature. Different natural and physical sciences are used to study the fossils and its formation process.
- The vital part of anthropology is human evolution which totally depends on the chances of getting hominid fossil.
- The different parts of the body are fossilized in different rates. So there are better chances of getting fossils of hard bones like skeletal parts, long bones and teeth.
- The development of hominid brain can be reconstructed by endocranial cast study. The long bones are very important for the development of locomotary pattern. Fossil evidences also help to know the different biological preconditions for capacity of making culture.

- Fossils are dated by number of relative and absolute methods of dating. The dating methods are useful to put the different events of biocultural evolution of man in chronological framework.
- All of the methods used for dating have number of limitations. Sometimes cross dating is used to minimize these limitations and to get more accurate date supported by number of different dating methods.

