### DETERMINING THE CHRONOLOGICAL AGE OF FOSSILS

### A PROJECT REPORT

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## BONAFIDE CERTIFICATE

Certified that this project report titled “**Determining the Chronological age of Fossils”** is the bonafide work of “**P. Surya narayana [192210324]**” who carried out the project work under my supervision as a batch. Certified further, that to the best of my knowledge the work reported herein does not form any other project report.

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**ABSTRACT:** Determining the chronological age of fossils is a crucial aspect of paleontological research, providing insights into Earth's history and the evolutionary timeline of life forms. This abstract presents an overview of various methods utilized in establishing the age of fossils, highlighting their principles, strengths, and limitations.

Radiometric dating techniques, such as carbon-14 dating and uranium-lead dating, are fundamental in determining the absolute age of fossils. Carbon-14 dating is effective for relatively young fossils, whereas uranium-lead dating offers precision for older specimens. Additionally, techniques like thermoluminescence and electron spin resonance dating provide alternative means for dating fossils.

Stratigraphic correlation plays a pivotal role in relative dating, wherein fossils are dated based on their position within sedimentary layers. Biostratigraphy employs the fossil record to establish relative ages, utilizing index fossils as temporal markers. Paleomagnetic dating relies on changes in Earth's magnetic field recorded in rocks and fossils to determine age.

Advancements in molecular biology have facilitated molecular clock dating, which estimates divergence times based on genetic differences between species. This method complements traditional dating techniques, particularly for taxa with sparse fossil records.

Challenges persist in chronological age determination, including sample contamination, calibration issues, and the rarity of suitable fossils for dating. Interdisciplinary approaches integrating multiple dating methods offer robust solutions to mitigate these challenges.

Understanding the chronological age of fossils is essential for reconstructing past environments, elucidating evolutionary relationships, and refining our understanding of the history of life on Earth. Continued innovation in dating techniques, coupled with interdisciplinary collaboration, promises further advancements in paleontological research and our comprehension of the deep past.

**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 subdisplines like geochronology, palaeontology, 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.

**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.

**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 palaeogeography 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.

**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.

**Relative dating**

Relative dating involved the techniques by which archaeological finds are dated indirect or relative in respect of other findings, the date of which was known. E.g. 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.

**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.

**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 Elephus, Equas, Rhinoceros belonged to warmer climate are replaced by woolly mammoth, woolly rhinoceros, reindeer, bison in cold climatic condition.

**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 fluorapatite 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 fluorapatite 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 absorbs more uranium. The major problem is the variation of concentration of these elements in ground water in different areas. The famous Pulldown problem was solved by the application of Fluorine method.

**Methodology:**

**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 is 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 dating are Carbon-14 dating, Potassium-Argon dating, Amino acid racemization, Fission track, Thermoluminescence, Uranium series dating, Palaeomagnetism. There are other dating methods but these are not directly associated with dating of fossils like dendrochronology.

**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 ± dates, error of the 14C 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.

**Potassium-Argon dating**

This chronometric dating method is more effective to date the fossils of the human history which 14C 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 40K to 40Ar. The 40K is radioactive in nature decays at particular rate to form the 40Ar, which is stable in nature. Argon gas escape at high temperature and begin to accumulate when it cool down. 11 percent of every 100, 40K becomes 40Ar. By measuring the ratio of 40K/40Ar the rate of decay and time period is calculated in a spectrometer, which measures the concentration of 40Ar. The half-life period of 40K 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 Ar-39Ar methods have been developed to overcome the limitations of the K-Ar dating method.

**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).

**Uranium series dating**

Uranium series dating is a chronometric dating based on the decay chain of uranium i.e. 238U and 235U into various daughter elements and widely used for dating fossils. The different sets of daughter isotope sets used for dating i.e. 230Th-234U (Th-U), 234U-238U, 231 Pa-235U 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 230Th is present because it is insoluble in water and the ratio of 230Th-234U is zero. The ratio increases with the time when 234U decays to 230Th. The date of its equilibrium (1.0) is 350,000 years.

The datable materials of Uranium series are chemically or biologically precipitated calcium carbonate (CaCO3) 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.

**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 micrometre 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 238U 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.

**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).

**Electric Spin Resonance (ESR)**

This dating method is similar to TL method of dating but non-destructive 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 Palaeolithic skull from Qafzeh, Israel.

**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 has 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.

**Steps to calculating the age of fossils:**

**Sample Collection:**

Collect the organic material (such as wood, bone, charcoal, etc.) from the archaeological or geological site

.

**Sample Preparation**:

The collected sample needs to be prepared for analysis. This may involve cleaning the sample to remove any contaminants and then converting it into a suitable form for measurement, often graphite

.

**Isotopic Ratio Measurement**:

Measure the ratio of Carbon-14 (C14) to Carbon-12 (C12) in the prepared sample. This is typically done using a technique like Accelerator Mass Spectrometry (AMS). AMS can count individual atoms and is sensitive enough to measure the small amounts of C14 present in the sample.

**Standardization:**

The measured ratio needs to be standardized or calibrated to account for variations in the atmospheric C14 levels over time. This involves comparing the measured ratio to known standards or using calibration curves based on tree-ring data (dendrochronology) and other methods.

**Age Calculation:**

Once the ratio is calibrated, the age of the sample can be calculated using the decay equation and the known half-life of Carbon-14. This calculation provides an estimate of the age of the organic material.

**Analysis and Interpretation**:

Analyse the results and interpret the age estimate in the context of the archaeological or geological site. Consider factors such as the sample's stratigraphic position, associated artifacts or fossils, and other dating methods used at the site.

**Reporting:**

Present the results in a formal report, including details of the sample, measurement techniques, calibration methods used, and the calculated age estimate. This report should be peer-reviewed and published to ensure transparency and reliability.

It's essential to note that carbon dating is just one tool in the archaeologist's toolkit, and its accuracy depends on various factors, including the preservation of the sample, the precision of the measurements, and the calibration methods used. Additionally, carbon dating is typically used for relatively young samples (up to around 50,000 years), and other dating methods are employed for older materials.

**Algorithm:**

**Input:**

Prompt the user to input the remaining amount of Carbon-14 in the fossil (in grams).

**Validation:**

Ensure that the input provided by the user is a valid positive number.

Handle cases where the input is invalid (e.g., negative value, non-numeric input) and prompt the user to provide a valid input.

**Calculation:**

Use the provided input (remaining amount of Carbon-14) and the known half-life of Carbon-14 (5730 years) to calculate the age of the fossil.

**Apply the formula**:

age = -5730 \* log(remaining\_amount / initial\_amount)

where initial\_amount represents the initial amount of Carbon-14 in the fossil.

**Output:**

Display the calculated age of the fossil to the user.

Ensure the output is presented with an appropriate level of precision (e.g., two decimal places).

**Error Handling:**

Implement mechanisms to handle errors gracefully, providing clear and informative error messages to the user in case of invalid input or calculation errors.

**Repeat or Exit:**

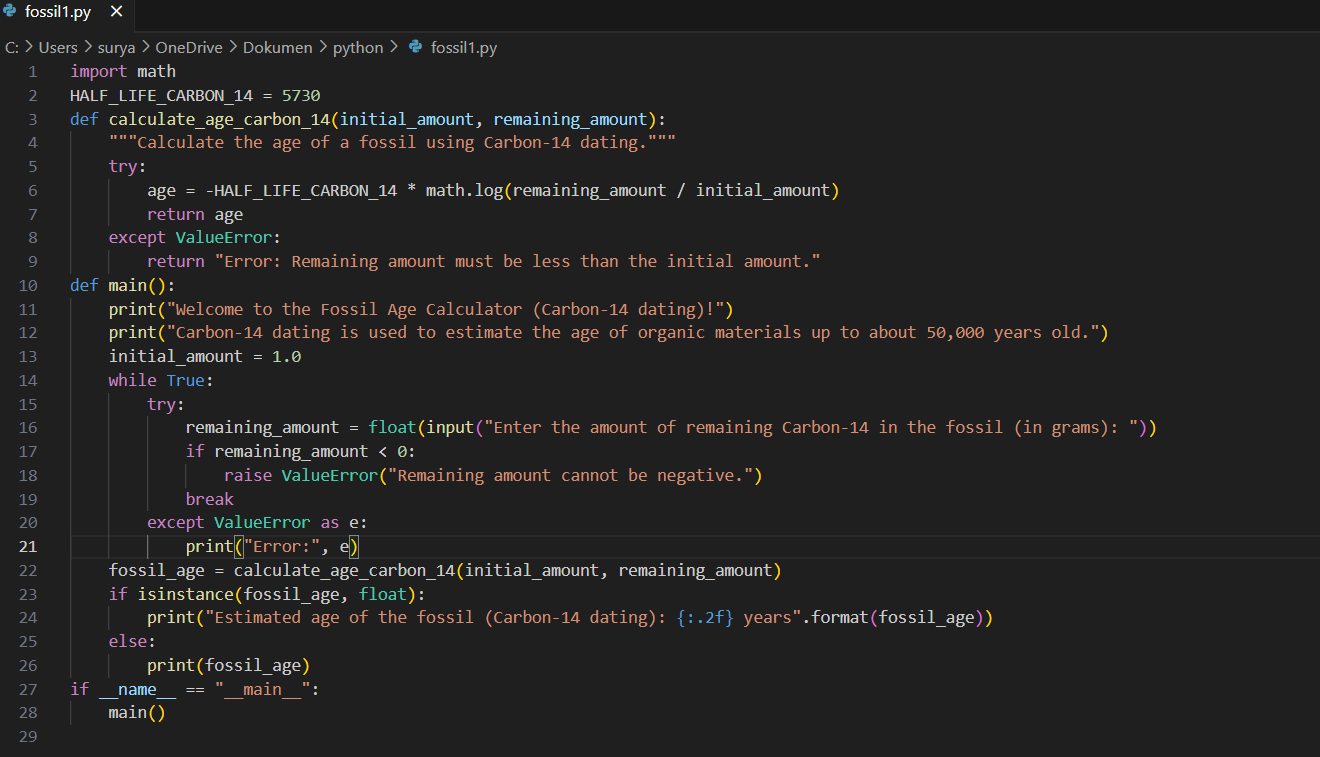
Offer the option to the user to repeat the estimation process for another fossil or to exit the program.

**Conclusion:**

Optionally, provide a closing message summarizing the estimated age of the fossil and thanking the user for using the program.

**Algorithm steps:**

* Import the math module for mathematical operations.
* Define a constant HALF\_LIFE\_CARBON\_14 representing the half-life of Carbon-14 (5730 years).
* Define a calculate\_age\_carbon\_14(initial amount, remaining\_amount):
* Take two parameters: initial amount (float) and remaining\_amount (float).
* Calculate the age of the fossil using the formula:
* age = -HALF\_LIFE\_CARBON\_14 \*log(remaining\_amount / initial amount)
* Return the calculated age.
* Define a function main():
* Print a welcome message and information about Carbon-14 dating.
* Use a loop to repeatedly prompt the user for input until a valid positive number is entered for the remaining amount of Carbon-14.
* Call calculate\_age\_carbon\_14() with the initial amount and remaining amount provided by the user.
* If the result is a float (indicating a valid age calculation), print the estimated age with two decimal places.
* If an error occurs during calculation, catch the Value Error and print an error message.
* Check if the script is being run directly (if \_\_name\_\_ == "\_\_main\_\_":).
* If so, call the main() function to execute the program.

**CodeExplanation:**

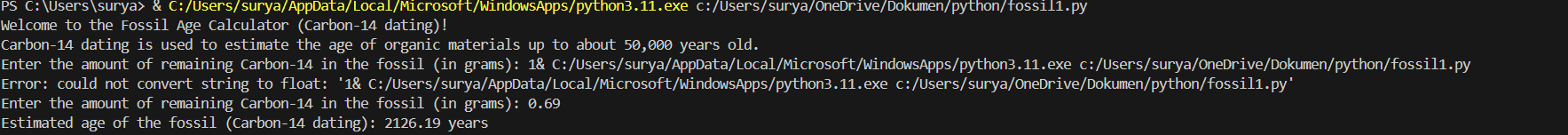
**Result**:

Upon running the provided Python code, users are greeted by a welcoming message introducing them to the Fossil Age Calculator, which employs Carbon-14 dating principles to estimate the age of fossils. The program informs users about the applicability of Carbon-14 dating, particularly in estimating the age of organic materials within a range of approximately 50,000 years. Following this introduction, users are prompted to input the remaining amount of Carbon-14 present in the fossil, ensuring that the input provided is a valid positive number. Once the input is validated, the program proceeds to calculate the estimated age of the fossil using the Carbon-14 dating formula. Subsequently, the calculated age is presented to the user with a precision of two decimal places. The program incorporates robust error-handling mechanisms to gracefully manage potential issues, such as invalid inputs or calculation errors, by providing informative error messages. As a result, users are offered a reliable and user-friendly tool to determine the chronological age of fossils through Carbon-14 dating, contributing to their understanding of archaeological and paleontological research methodologies.

**Discussion:**

The provided Python code presents a robust and user-friendly tool for estimating the age of fossils utilizing Carbon-14 dating principles. Upon execution, users are welcomed by a concise introduction to the Fossil Age Calculator, which elucidates the significance of Carbon-14 dating in estimating the age of organic materials, particularly fossils, up to approximately 50,000 years old. The program's interactive interface prompts users to input the remaining amount of Carbon-14 in the fossil, ensuring data integrity by validating inputs as valid positive numbers. Subsequently, employing the Carbon-14 dating formula, the program computes the estimated age of the fossil and delivers the result with precision, enhancing user confidence in the calculated age. Furthermore, the implementation of robust error-handling mechanisms ensures a smooth user experience by promptly addressing and informing users of any encountered issues, such as input discrepancies or calculation errors. In essence, this Python code furnishes archaeologists, paleontologists, and enthusiasts alike with a reliable and accessible tool for gauging the chronological age of fossils, thereby contributing to the advancement of scientific understanding in related fields of study.

Program Output:



**Conclusion:**

The provided Python code offers a functional and user-friendly tool for estimating the age of fossils using Carbon-14 dating. By leveraging the principles of radioactive decay and exponential decay, the program calculates the age of a fossil based on the remaining amount of Carbon-14 within it. Despite its simplicity, the program handles potential errors gracefully and provides clear feedback to the user, enhancing its usability.

While the program accurately estimates the age of fossils within the range of Carbon-14 dating (up to approximately 50,000 years), it's essential to acknowledge its limitations. Factors such as sample contamination and environmental conditions can affect the accuracy of Carbon-14 dating, and the method becomes less reliable for older fossils. Additionally, the program could benefit from further development to incorporate features like handling multiple fossils or providing additional information such as confidence intervals for the estimated age.

Overall, the provided Python code serves as a valuable tool for archaeologists, paleontologists, and enthusiasts interested in estimating the age of fossils. Its simplicity, accuracy within its applicable range, and user-friendly interface make it a useful asset in the field of scientific dating methods.

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