Providing reliable chronologies for later human evolution: Direct dating of bone by U-series disequilibrium

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The direct dating of bone beyond the limit of radiocarbon (50 ky) is something of a holy grail for archaeologists and palaeontologists. Bone forms the primary archive in the quest for understanding the origins of Modern Humans, but until recently it has proved impossible to obtain reliable absolute ages.

U/Th dating has the potential to provide a chronology back to 400 ky, but there are many problems with the method when applied to bones (and teeth). Unlike primary precipitates (e.g. calcite), bone is an open system and takes up U from the burial environment. It is the understanding of this uptake process that ultimately defines the reliability of the U-series method for bone.

We show that traditional descriptions of U uptake in bones and teeth, namely Early and Linear uptake (EU and LU), cannot be considered reliable, and can lead to gross over- or under-estimations in the calculation of a date. Yet, many such dates are included in the consensus view of the chronology of later human evolution.

We present a method of U-series dating of bone based on Millard & Hedges (1996) Diffusion-Adsorption model (D-A) of U-uptake. The D-A model is used to predict how changes in the geochemistry of the burial environment lead to phenomena such as leaching of U from the bone, or recent U uptake which would give erroneous U-series dates calculated using traditional assumptions.

The D-A model predicts the rate of U uptake and also the distribution ('profiles') of elemental U and U-series isotopes across a bone section. We show how these profiles reflect the overall U uptake history of a bone, and can be used to identify and reject bone that have undergone 'complex' U uptake schemes. We present measurements of U and U-series isotope profiles measured using ICP-Ms and TIMS. We show how by selecting bones that fit the straightforward cases of uptake according to the D-A model, on the basis of these measured profiles, we can calculate U-series dates with much improved reliability.

References

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MORB-like $^3He/^4He$ ratios in olivines from the back-arc of the South American Central Volcanic Zone

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The first comprehensive noble gas isotope survey of the South American Puna Plateau (21° – 27° S) is reported. We sampled geothermal gases and fluids, and collected samples from Pliocene to Recent phyric lava flows with different geochemical characteristics.

The $^3He/^4He$ ratios in fluid inclusions of olivines and pyroxenes from the Puna ($5.2 < R/R_a < 8.3$) are the highest values reported from South America so far and are comparable to South Atlantic MORB ratios (7.83 ± 0.53 R_a). They differ significantly from ratios observed in the Western Cordillera (Hilton et al., 1993). This He isotopic composition suggests a MORB-like He source beneath the Puna Plateau. The Ne isotope composition is a further indication that a mantle reservoir very similar to that of MORB exists beneath the Puna. The MORB signature occurs independently of rock chemistry and the area in which the rocks are taken.

The observed range of $^3He/^4He$ values may be explained by variable ingrowth of radiogenic ^4He in the magma chambers (magma aging). A timespan of 10,000 – 80,000 years is calculated to be sufficient to produce the range of isotopic compositions by this process. High He concentrations in the crushed samples ($0.5 – 18.1 * 10^{-8}$ cm^3 STP/g) indicate their provenance from a less degassed reservoir, which would be less susceptible to contamination with a radiogenic He source.

The highest $^3He/^4He$ ratios in the Puna olivines indicate that these crystals must have grown prior to magma contamination with K-U-Th-rich crustal material. Assimilation of crustal melts of up to 25% (Kay et al., 1994), as is stipulated by Sr-Nd-systematics, must have occurred after olivine crystallisation. Also the presence of quartz in the volcanic rocks from the back-arc indicates no equilibrium between olivine and melt.

References

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