 DOI: 10.24425/academiaPAS.2022.143447

DARIUSZ NAST

Measuring the radiation emitted by the shell of a Cretaceous ammonite

In Search of Radioactive Fossils

Fossils are a source of great interest, even fascination. They offer evidence of the past existence of living things, somewhat different from life as we know it today. Yet not many fossil-hunters realize that these traces of a bygone past are often a source of radiation.

Magdalena Długosz-Lisiecka

Institute of Applied Radiation Chemistry
Łódź University of Technology

Daniel Tyborowski

Faculty of Biology and Environmental Sciences
Cardinal Stefan Wyszyński University
in Warsaw

There's plenty we can learn by reading rocks – indeed quite literally so, using modern, even unique spectrometric techniques. A high-resolution gamma-ray spectrometer equipped with an active and passive background reduction system is a perfect instrument for analyzing low concentrations of radioactive isotopes. High-precision measurements offer many possibilities for interpreting the material being studied, in this case rocks and fossils. Gamma-ray spectrometry allows us to measure the content of most of the radioactive isotopes present in the human environment – in water, in the air, and in the Earth's crust. The energy of gamma radiation determines the radioactive isotope type, and the area below the peak on the spectrometric spectrum determines the activity of the isotope. Qualitative and quantitative information and isotope ratios are the basic radiometric indicators that determine the characteristics of the material under study.

Each material has a characteristic isotopic composition that could be described as its fingerprint. While it is true that isotopes will not allow us to determine the type of the biological organism embedded in the rock matrix, they will definitely tell us a lot about the geological environment. Well-known applications of isotopes include isotopic dating, including in particular carbon-14 dating, which is used for organic matter. However, the fossils that are of interest to scientists are millions of years old, sometimes hundreds of millions. This renders carbon-14 dating useless, as the isotope it is based on has a a half-life of just 5730 years. There are other methods of isotopic dating, but it is not dating that really concerns us here.

Radiation

Each element exists in nature in several variants called isotopes. Isotopes of a specific element have the same number of electrons (negatively charged particles), which orbit the atomic nucleus, and the same number of protons (positively charged particles) in their nuclei. Next to protons, the atomic nucleus also contains neutrons (particles with a neutral charge). Their number allows us to differentiate between specific isotopes of each chemical element. Some isotopes decay at a higher and others at a lower rate. The ones whose decay time is below the age of the Earth (about 4.6 billion years) are called radioactive isotopes. During their decay, they release energy in the form of ionizing radiation.

Radiometric analyses of various geological samples have revealed certain natural regularities. The relations between certain isotopes may exhibit a linear correlation: if there is a lot of U-238, there is usually also a lot of the chemically similar Th-232. It is likewise natural that isotopes belonging to the same radioactive series are strongly correlated. This does not necessarily hold true for isotopes that belong to different series, but the tendency remains for reasons related to the similar chemistry of the parent isotopes (which means specifically U-238, U-235, or Th-232). These tendencies only become disrupted in anthropogenic, non-natural processes, and this is called isotope separation, which means the removal of certain isotopes as opposed to others and their potential further concentration. This means that by studying the isotopic composition of selected samples of materials, we can tell if they have natural origins or were formed as a result of human activity. We know that some rocks and fossils have a greater content of radioactive isotopes, and this is usually true for all natural isotopes from radioactive series.

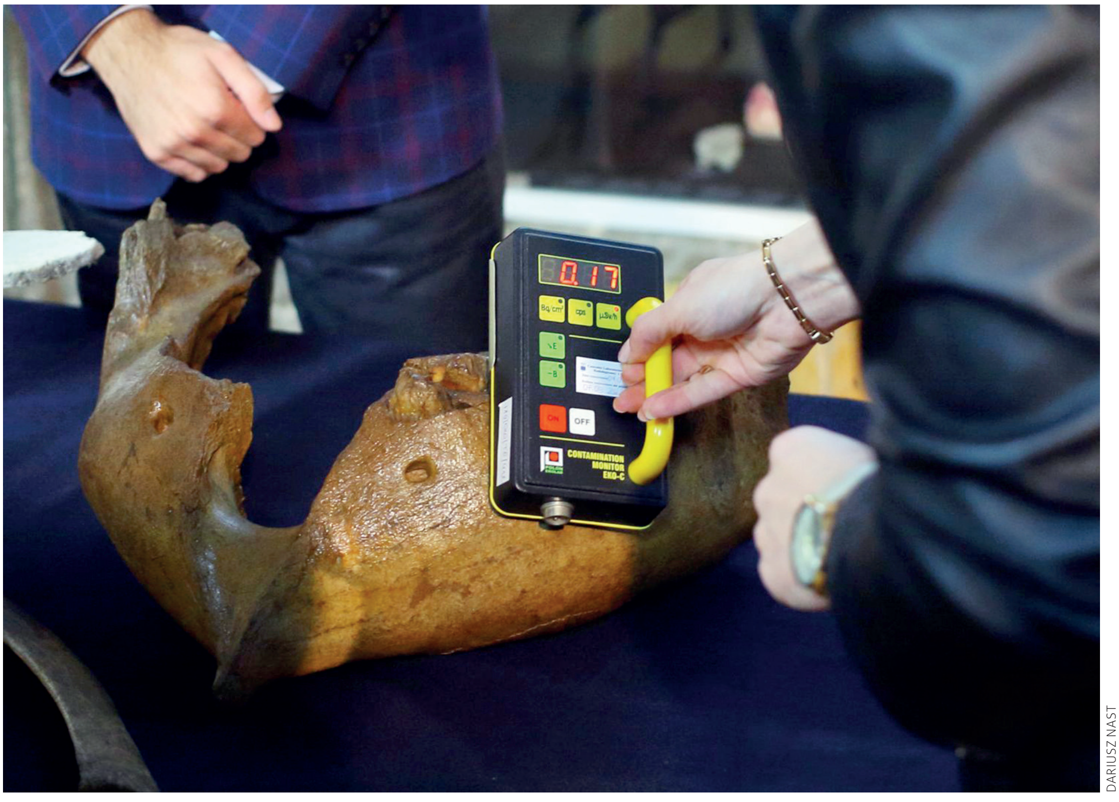
It turns out that the decomposing remains of organisms and the considerable accumulation of bacteria that accompany the decomposition of organic matter promote the formation of phosphates. Phos-

MAGDALENA DŁUGOSZ-LISIECKA

A Jurassic ammonite from France. The specimen preserved through the phosphatization of the originally carbonate shell

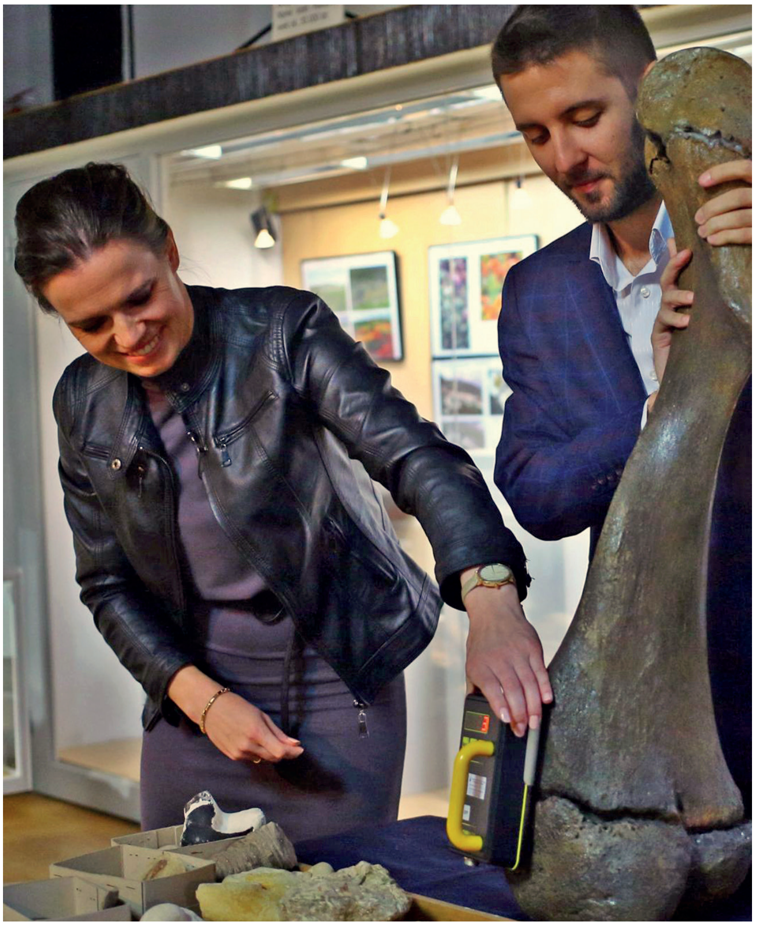
Magdalena Długosz-Lisiecka, PhD, DSc
is an Associate Professor, lecturer, and researcher employed at the Institute of Applied Radiation Chemistry, Łódź University of Technology. She specializes in the radiometric analysis of environmental samples. She uses the isotopes she studies as tracers of processes taking place in nature.
magdalena.dlugosz@p.lodz.pl

Daniel Tyborowski, PhD
is a paleontologist and geologist. He conducts research in the field of paleoecology and functional morphology of Jurassic marine vertebrates. He uses CT and geochemical methods to study the life and appearance of extinct fish and marine reptiles. A popularizer of the Earth sciences and a lecturer at the Faculty of Biology and Environmental Sciences, Cardinal Stefan Wyszyński University in Warsaw.
paleodanieltyborowski@gmail.com



Measuring the radiation emitted by the mandible and a molar of a Pleistocene woolly mammoth

DARIUSZ NAST



Measuring the radiation emitted by a long bone of a Pleistocene woolly mammoth

DARIUSZ NAST

phate minerals have a tendency to impregnate and even ideally preserve soft and hard organic tissues. Elemental phosphorus combines easily with uranium, which is readily available in sediments, which promotes the natural process of the concentration of uranium compounds in phosphatized fossils. If the decomposition process is long, and if phosphorus and uranium are abundant in the surroundings of the organic remains, these are perfect conditions for the effective accumulation of radioactive uranium isotopes. Certain conditions are conducive to the accumulation of large amounts of the parent isotopes U-238 and U-235 and later in the long history also their decay products. Every rock contains uranium isotopes, but these are not always concentrations of around kBq of activity in 1 kg of mass. One kilogram of sedimentary rock typically contains the natural decay products of U-238, namely Th-234 or Ra-226, at an activity concentration of 20–40 Bq. A dinosaur tooth embedded in limestone can contain U-238 at levels up to 10 times higher, and this is thanks to apatite, which is a natural phosphate mineral.

Fossils

Phosphorites are types of rocks famous for their use in the production of fertilizers. As a natural source of phosphorus from the remains of organic matter, phosphorites contain naturally accumulated uranium

MAGDALENA DŁUGOSZ-LISIECKA

Measuring the radiation emitted by a tooth of a Cretaceous marine reptile (mosasaur). The specimen comes from phosphate-rich sediments from Morocco

and its decay products. If these phosphorites contain fossils, they are an example of very radioactive natural objects exhibiting isotope concentrations higher than the surrounding bedrock.

The world literature provides us with very few examples of the identification of radioactive fossils. Usually, however, these are descriptions of vertebrate teeth and bones or invertebrate shells, which means hard components that naturally contain phosphorus.

The latest research by a Polish team from the Institute of Applied Radiation Chemistry of the Łódź University of Technology and the PAS Museum of the Earth shows that soft fossil structures may contain enriched contents of radioactive isotopes too. The researchers found that the process of sorption was possible in specific taphonomic windows thanks to fossils. Phosphatization, or the process of replacing original tissue with phosphate material, is one of the most important mechanisms leading to the fossil preservation of soft parts of the body, such as muscles and skin. The recent research by the Polish team has shown that phosphatization promotes not only the preservation of soft anatomy, but also the formation of radioactive fossils. It therefore appears that we could search for fossils using a radiometer. In theory, this is possible! But not easy.

To reliably measure the content of radioactive elements in fossils, we must carry out long-term measurements with background reduction and high-precision isotope identification. A simple radiometer can only show if a given radiation flux is greater or smaller, at close proximity at that. Fossils, even those with elevated contents of selected radioactive elements, pose no radiation hazard. They are a natural curiosity, but they should not be seen as a problem or danger. Humans also have radioactive elements in their bodies.

Here, we should ask one question: what is the spatial distribution of radioactive fossils in the world? It turns out that unique paleontological sites (the aforementioned taphonomic windows, also known as "fossil lagerstätten"), which contain scientifically valuable specimens preserved through phosphatization, can be found all over the globe. Fossils from Morocco are widely known. But such fossils can be found also in Europe, South America, Asia, and Australia. Morocco alone has huge deposits of phosphate rocks that contain beautiful and well-preserved fossilized teeth and bones of mosasaurs, plesiosaurs, bony fish and sharks, as well as the remnants of giant sea turtles, pterosaurs, and dinosaurs. The area appears promising for the study of radioactive fossils. Due to their mineral composition, or a large content of phosphates, what we deal with in most cases are specimens that show elevated radioactivity on closer examination. The radioactivity of fossils is linked to the process of fossilization, which means indirectly also to the place of their formation at the bottom of ancient oceans. ■

Further reading:

Długosz-Lisiecka M., Tyborowski D., Krystek M., Radioactive fossils: The uranium anomaly and its paleobiological implications, *Chemosphere* 2021, doi.org/10.1016/j.chemosphere.2021.131444.

Jaworowski Z., Pensko J., Unusual Fossil Bones from Mongolia, *Nature*, 1967.

Koul S.L., Uranium in fossil bones, *Radiation Effects Letters*, 1979.