# Radioactive fossils: What? Where? Why?....

# And how to reduce the risk to health.


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**Figure 1**. The GMC-300E plus Geiger Muller Counter Data Logger used for examining specimens for radioactivity, here placed on a radioactive dinosaur bone giving a reading of 7.29 μSv h (7.29 microsieverts per hour).



## Abstract


Most curators and collection managers responsible for a geological collection will be aware of the risk posed by rocks and minerals which emit ionising radiation and will have put measures in place to reduce the risk to collection users. However, fewer people are aware that fossils can be radioactive too. A fossil may be radioactive if it has been exposed to uranium-bearing fluids during diagenesis and fossilisation processes. Any groundwater moving from the radioactive deposit to or through another nearby porous deposit can contaminate the rocks and fossils with radioactive elements. Over time the skeletons or other remains being fossilised incorporate these elements into their structure. The processes of fossilisation can even concentrate the levels of radioactive elements so that some fossils may be more radioactive than their host rock. The more massive the fossil, e.g. a large dinosaur bone, the greater the potential for a higher level of radioactivity, and a greater risk to humans. Whilst most radioactive fossils may not present a danger to health through direct absorption of radiation unless there is prolonged exposure at close quarters (e.g. hundreds of hours), the main risk is posed by the ingestion or inhalation of small radioactive particles from the specimen. Here, we describe what measures can be taken to reduce these risks and also provide a (non-exhaustive) list of locations around the world known to yield radioactive fossils which we hope can be augmented by others.


## Health risks posed by radioactive fossils.

The products of radioactive decay that present a hazard to health are radon gas, alpha radiation, beta radiation and gamma radiation. This can cause both deterministic (or threshold) and stochastic (or probabilistic) health effects. Deterministic health effects are predictable, occur above a certain threshold and increase proportionally with amount of radiation exposure. For example, very high radiation doses above certain thresholds predictably cause burns in everyone exposed. Stochastic effects are those caused by radiation which appear in some people and not others, e.g. some cancers. Because these effects are unpredictable, it is impossible to set safe thresholds for exposure (Goodman 2010).

The 'dose' of radiation received from a specimen will depend on several factors, including how radioactive the specimen is, contact time with the source, distance from the source, the body part exposed to radiation, what PPE was worn and what task was undertaken. However, external adsorption of radiation from the specimen is only one way to be exposed to this risk. Although alpha particles can be easily stopped from penetrating the body by a few centimetres of air or a piece of paper, once ingested, or inhaled they are potentially very damaging to living cells. The greatest risk is posed by specimens deteriorating and shedding material.

Regulations will vary from country to country but they will impose a responsibility for institutions to establish procedures and rules for the safe detection, handling, use, storage or disposal of its radioactive material, and to maintain records to show that this has been done. Speak to your local Radiation Protection Advisor or similar for guidance.

However, these regulations rely on people being aware that they are actually responsible for material that is radioactive. Not only are some collection care professionals unaware that fossils can be radioactive, an increasing number of dinosaurs and other fossils are being handled by auction houses, galleries, shops and private collectors who are completely unaware of the potential threat to health that such specimens may pose. This is not a theoretical risk: Some recent interactions with such organisations have revealed that people have been put at significant risk by handling, cleaning, conserving and mounting specimens whilst wearing no PPE nor taking any other precautions (see below) - oblivious to the fact that the specimens were in fact highly radioactive (described in paper in progress). More education is required to highlight the risks to health that such specimens may pose. Nevertheless, radioactive fossils - even dinosaur skeletons - may still be displayed in public areas as long as the risks are assessed and understood, regulations are followed and suitable precautions are taken.

**Table 1.** Localities that are known to yield radioactive fossils. Note: not all fossils from the following locations will be radioactive, but some will. Often, the greater the mass of the fossil, the higher the level of radiation being emitted. ***This is not an exhaustive list***!

| Country | Location | Age of deposit | Type of fossil |
|---|---|---|---|
| **Africa** | | | |
| Morocco | Phosphate lagerstätte | Cenomanian | Sedimentary phosphates, and bones / teeth of vertebrates |
| Southern Africa | Karoo Sequence | Late carboniferous to early Jurassic | |
| Zambia | Upper Luangwa Valley | Lopingian | Tetrapods, esp therapsids |
| Tanzania | Tendaguru Formation southeastern Tanzania | Late Jurassic | Dinosaurs (other taxa not monitored) |
| South Africa | Adelaide subgroup (i.e. the Permian part) of the Beaufort Group of the Karoo Basin | Lopingian | Therapsid tetrapods |
| Egypt | Fayum basin | Palaeogene | Crocodylus |
| Kenya | Rusinga | Miocene | |
| **America, North** | | | |
| USA | South Carolina | phosphate deposit fossils | |
| USA | Hell Creek Formation, Carter County (Montana) | Late Cretaceous | Dinosaurs etc |
| USA | Wyoming, Idaho, Colorado and Utah (including the Morrison Formation) | Upper Jurassic etc | Dinosaurs etc |
| USA | Cedar Mountain Formation (Utah) | Early Cretaceous | |
| USA | Hagerman Lake Beds (Idaho) | Pliocene | |
| Canada | Cypress Hills Formation (Alberta) | Eocene to Miocene | |
| **America, South** | | | |
| Argentina | Santa Cruz Formation | Miocene | mainly mammals |
| Chile | Santa Cruz Formation | Miocene | mainly mammals. No avian fossils demonstrated activity. |
| Chile | Bahía Inglesa Formation (southern Atacama) | Miocene-Pleistocene | Marine vertebrates |
| **Asia/Middle East** | | | |
| India | Gujarat | | |
| Mongolia | | | |
| India & Nepal | Siwalik Hills / Shivalik Hills / Churia Hills | Miocene/Pliocene | Mammals and tortoises |
| India | Jabalpur | Upper Cretaceous Lameta Formation | dinosaurs |
| Iran | Maragha | Turolian, Upper Miocene | mammals |

The contents of this table are to be considered work in progress. We welcome comments, additions, corrections and suggestions. We intend that a more comprehensive article on this subject will be published in a peer-reviewed journal in due course.

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|---|---|---|---|
| **Australasia** | | | |
| Australia | Camfield Beds, Bullock Creek (Northern Territory) | Miocene | Terrestrial and aquatic vertebrates |
| Australia | Namba Formation, Lake Tarkarooloo (South Australia) | Oligocene-Miocene | Terrestrial and aquatic vertebrates |
| Australia | Mannum Formation, Wongulla (South Australia) | Miocene | Marine vertebrates |
| Australia | Batesford Limestone, Batesford Quarry (Victoria) | Miocene | Marine vertebrates |
| Australia | Bochara Limestone, Grange Burn (Victoria) | Miocene | Marine vertebrates |
| Australia | Black Rock Sandstone/Sandringham Sands, Beaumaris (Victoria) | Miocene-Pliocene | Marine and terrestrial vertebrates |
| Australia | Jan Juc Formation, Jan Juc (Victoria) | Oligocene | Marine vertebrates |
| Australia | Jemmy's Point Formation, Lakes Entrance (Victoria) | Pliocene | Marine vertebrates |
| **Europe** | | | |
| UK | Gault deposits of Southern England | Cretaceous | |
| UK | Kimmeridge | Jurassic | Coprolites |
| Scotland | Orcadian basin (Caithness, Orkney, Thurso, Shetland) | Middle Devonian (Old Red sandstone) | Fish |
| Germany | Southern Bavaria, Molasse-Becken, various. Localities e.g. Massenhausen, Mühldorf and Mehring | Miocene, Upper (Upper Freshwatermolasse (UFM) | Freshwater vertebrates, silicified wood |
| Germany | Hesse, Mainzer Becken | Oligocene-Miocene | marine vertebrates |
| The Netherlands | Breda Formation, Aalten Member, Miste Bed, in Winterswijk-Miste (Gelderland) | Miocene | phosphorites |
| Switzerland | Montchaibeux (Jura canton) | Jurassic? | Prodeinotherium |
| France | St Gerand-le-Puy in | Miocene | Crocodile |
| France | Faluns d'Anjou | Miocene | mammals |
| France | Sansan site (Gers) | Miocene | mammals |
| France | Sables de l'Orléanais | Miocene | mammals |
| France | Gannat (Allier), | Oligocene | mammals |
| France | Robiac (Gard), | Oligocene | mammals |
| France | Autun basin | Permian | fish and amphibians |
| France | Neuville-aux-Bois, Loiret | Miocene | |
| France | Chevilly, Loiret | Miocene | |
| France | Montaigu-le-Blin, Allier | Miocene | |
| France | Usclas-du-Bosc, Saint-Julien-du-Bosc, Tuilières, Viala and Bosc: all from the Lodève basin, Hérault | Permian | |

## Reducing the risk to health

As not many people realise that fossils may be naturally radioactive, some collection users are being put at risk. For specific information on managing radioactive specimens see Price *et al* (2013) but in general the risks posed can be lowered in many ways. **Education:** spreading awareness of the fact that fossils can be radioactive, not just rocks and minerals. **Identifying specimens*:*** Specimens from sites known to yield radioactive fossils (Table 1) should be assessed with a radiation monitor (e.g. Fig 1). Not all specimens from these sites will be radioactive and not all sites that yield radioactive fossils are listed. **PPE**: The inhalation or ingestion of radioactive particles presents a potentially higher risk than adsorption of radiation through handling of specimens. Radioactive fragments lodged inhaled or ingested can affect live cells for a prolonged period of time. It is therefore essential that appropriate PPE is worn when handling radioactive specimens and should then be disposed of responsibly. **Consolidation:** Consolidation of the surface of a radioactive fossil with an appropriate reversible conservation polymer (e.g. Paraloid B72 in acetone) will help to strengthen the surface and reduce the chances of small particles becoming loose and being inhaled or ingested. **Reducing surface damage**: Radioactive specimens should be stored or mounted upon a soft cushioning material such as Plastazote foam. This will reduce the chances of small particles becoming loose. Specimens should be handled gently and be moved within their permanent storage media (e.g. box/crate/drawer/tray) rather than being handled directly, to reduce damage to surfaces. **Reducing handling of the specimen**: Any conservation or preparation of the specimen should be minimal, not just to reduce handling but to maintain the integrity of the surface. The work should take place in a clean area so that any small particles dislodged can be seen and collected and either kept, well labelled, or disposed of responsibly. **Storage**: Keep specimens away from public areas, offices and workrooms. Having a designated store is useful if there is enough material to warrant it, but ventilation may be required. **Radon gas:** This is emitted by radioactive specimens, presenting an inhalation hazard if in sufficient concentration e.g. if many radioactive specimens are stored together, or large radioactive fossils are present in a small area. If stored in a sealed box/bag this must be opened in a well-ventilated area (preferably a fume cupboard). Monitoring for radon gas should be considered where radiation levels are well above background. **Labelling and documentation:** Any specimen with a reading above the background level should be documented and labelled as being radioactive and be placed into a container with a lid, or in a sealed bag.

## References


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