Naturally occurring radioactive materials (NORM) in the Sedgwick Museum Collections

Sedgwick Museum of Earth Sciences

UNIVERSITY OF CAMBRIDGE MUSEUMS & BOTANIC GARDEN

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Some Sedgwick Museum facts

- Two sites (Public Museum & Collections Research Centre)
- Fossils = c. 1,000,000
- Rocks = c. 300,000
- Minerals = c. 50,000
- Microscope slides = 250,000
- Archive = 25m^3
- Provides a public museum
- Supports internal & external research and teaching

What things in the Museum collections are radioactive?

Fossils

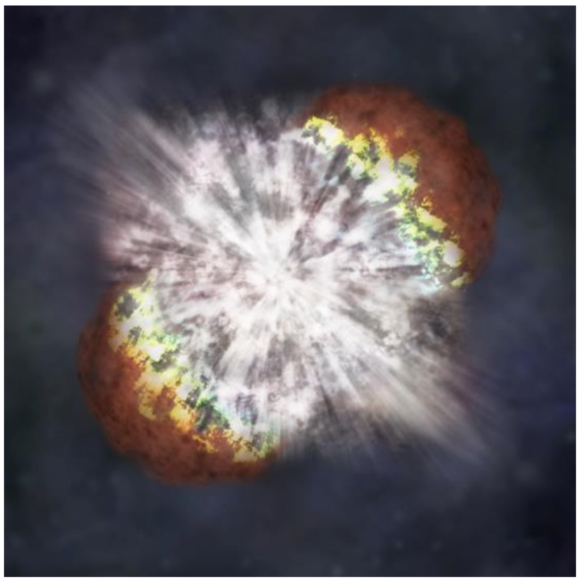
Rocks

Minerals

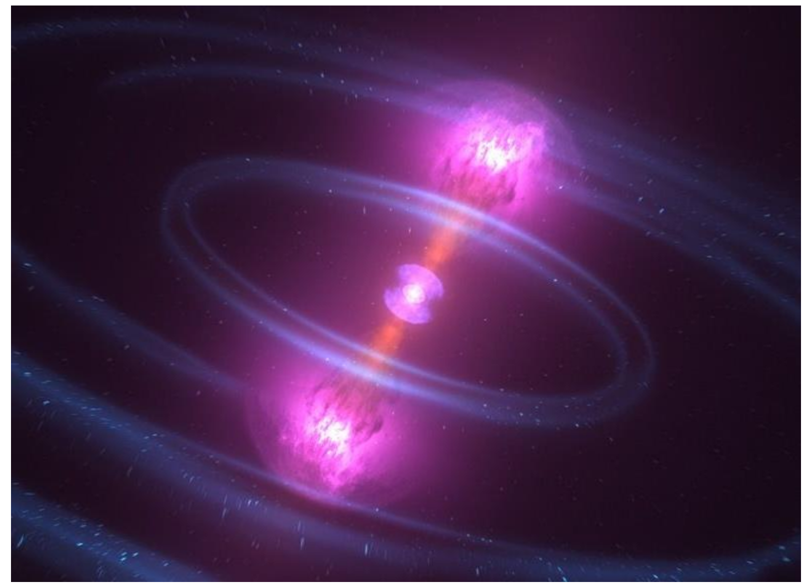
Lowest activity (1-10's of cps on contamination monitors, barely register on 'Type-R' dose-rate monitor)

Highest activity (1000's of cps on contamination monitors, up to c. 150-200 μSv/h on 'Type-R' dose-rate monitor.)

The commonest radioactive elements in our NORMs are probably uranium, thorium and their decay products, but where do they come from?



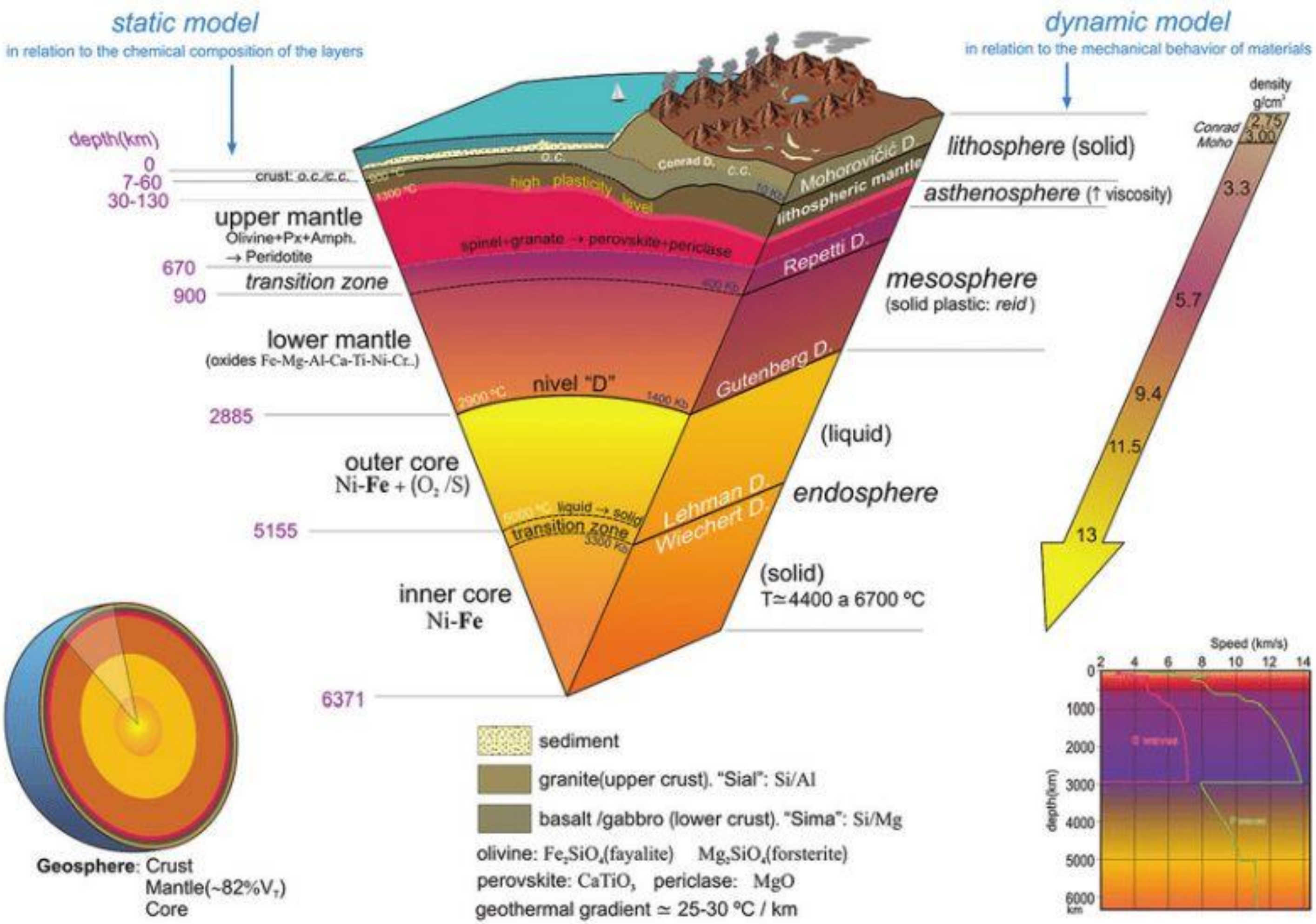
Supernovas?



Neutron-star collisions?

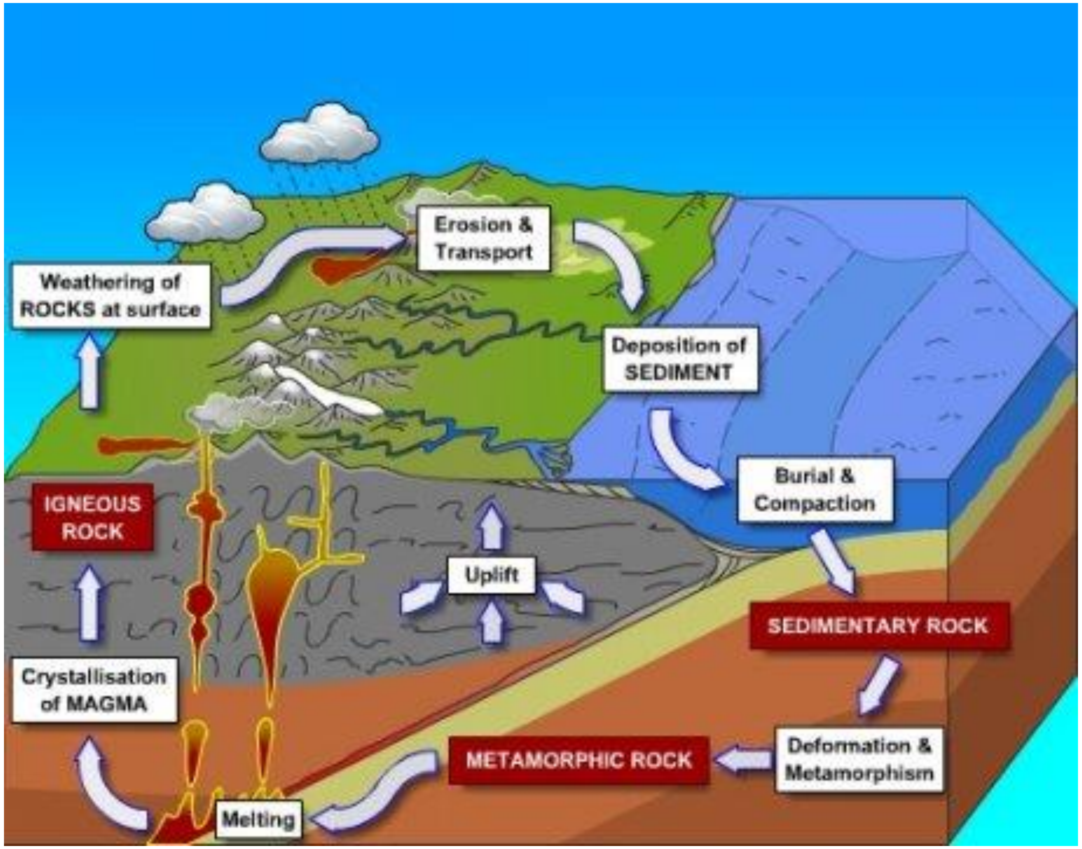
Images courtesy of NASA

The structure of the Earth



After Gervilla, F., González Jiménez, J. M., Hidas, K., Marchesi, C., & Piña, R. (2019).

How do elements like uranium & thorium get into rocks, minerals & fossils?



Elements such as uranium & thorium are leached from the Earth's mantle and concentrated in the Earth's crust. This happens through a rock recycling process known as the 'rock cycle'. These elements are not compatible with magma and so tend to fraction out into rocks such as pegmatites, or enter hydrothermal systems and form ore-bodies.

Image courtesy Geological Society of Glasgow.

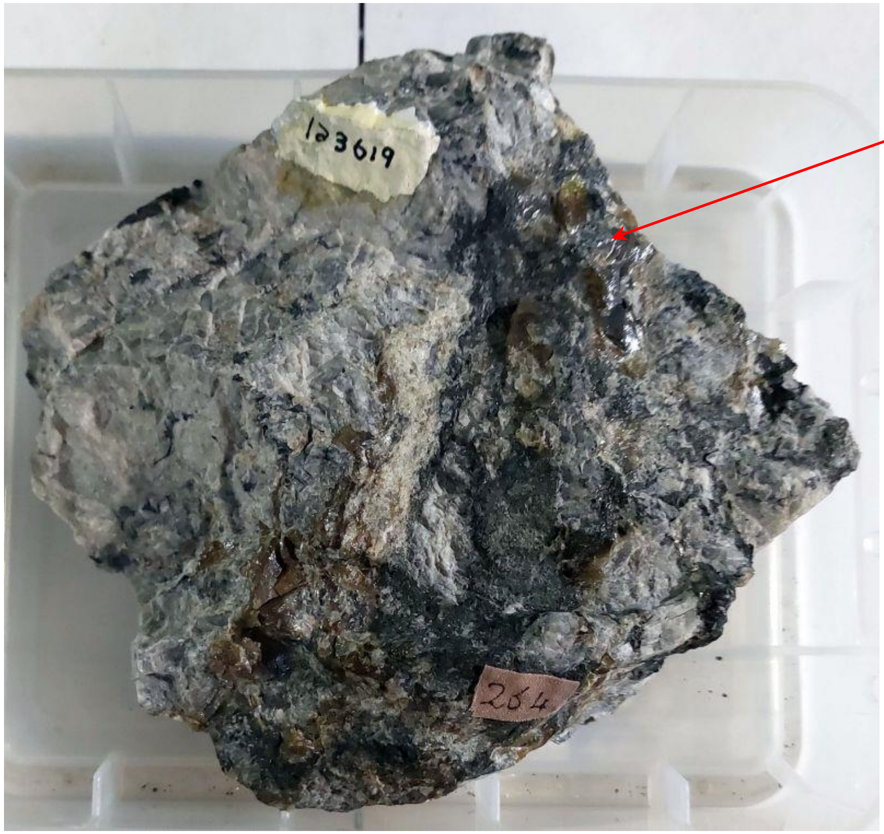
Table 1. Global ranges of uranium abundance in common rocks and waters

Igneous Rocks		**Sedimentary Rocks**	
Syenites and phonolites	0.1-26 ppm	Shales, clays, mudrocks	1-5 ppm
Granites and rhyolites	2-50 ppm	Black shales (organic-rich)	2-1250 ppm
Intermediate rocks	1-6 ppm	Phosphorite-black shales	≤700 ppm
Basalts and other mafic rocks	0.1-1 ppm	Sandstones	0.5-4 ppm
Ultramafic	0.001-1 ppm	Limestones, dolomites	<0.1-9 ppm
		Coals, lignites, peats	1-6000 ppm
Metamorphic Rocks		Pure evaporites	<0.1 ppm
Low-grade	<1-5 ppm	**Water**	
Medium-grade	<1-5 ppm	Oceanic seawater	0.3-3 ppb
High-grade	<1-7 ppm	Groundwater	<0.1-460 ppb

[based on data from Wedepohl, 1978a; Bowie, 1979; Basham et al., 1989; Ball and Milodowski, 1989; Basham and Kemp, 1993; Hobday and Galloway, 1999; U.S. Geological Survey, 1997;

From Tye, A. M., Milodowski, A. E., & Smedley, P. L. (2017).

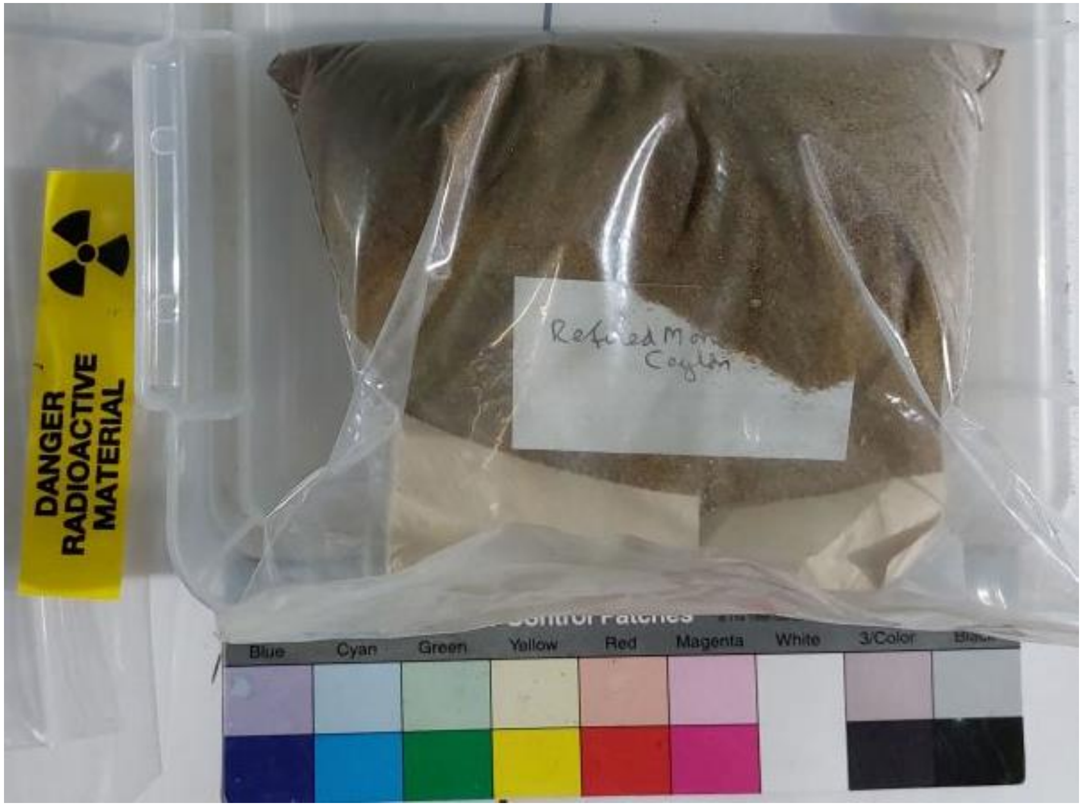
CAMSM 123619 Lovchoritte pegmatite from the Kola Peninsula NW Russia



A coarse-grained igneous rock with the exotic thorium containing mineral lovchoritte
$(\square,Ca,Na)_3(Ca,REE)_4Ti(Si_2O_7)_2[H_2O,OH,F]_4 \cdot H_2O$

Dose-rate 1.5 µSv/h at 0cm, 0 µSv/h at 30cm

CAMSM TN 4554 Monazite sand (concentrate) from Sri-Lanka



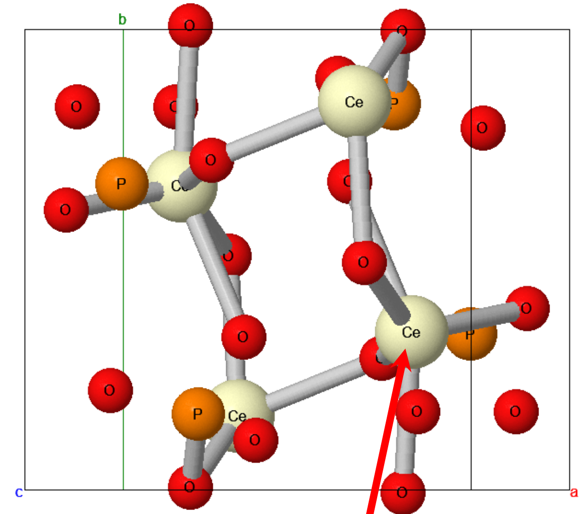


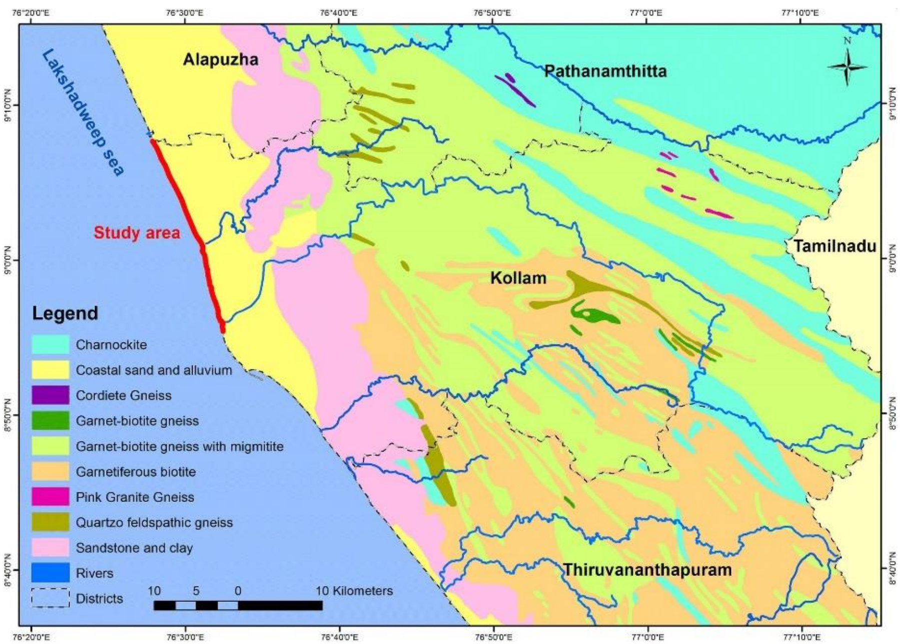
Image courtesy mindat.org

Or U, Th etc.

Monazite (Ce, LREE, Th, U, Ca)PO_4 , is a cerium phosphate mineral where thorium or uranium may be substituted for cerium. This sand contains crystals of monazite weathered from certain igneous and metamorphic rocks.
Mined as a ‘placer deposit’ e.g. beaches in India & Sri Lanka.

Dose-rate 45 µSv/h at 0cm, 1.5 µSv/h at 30cm.

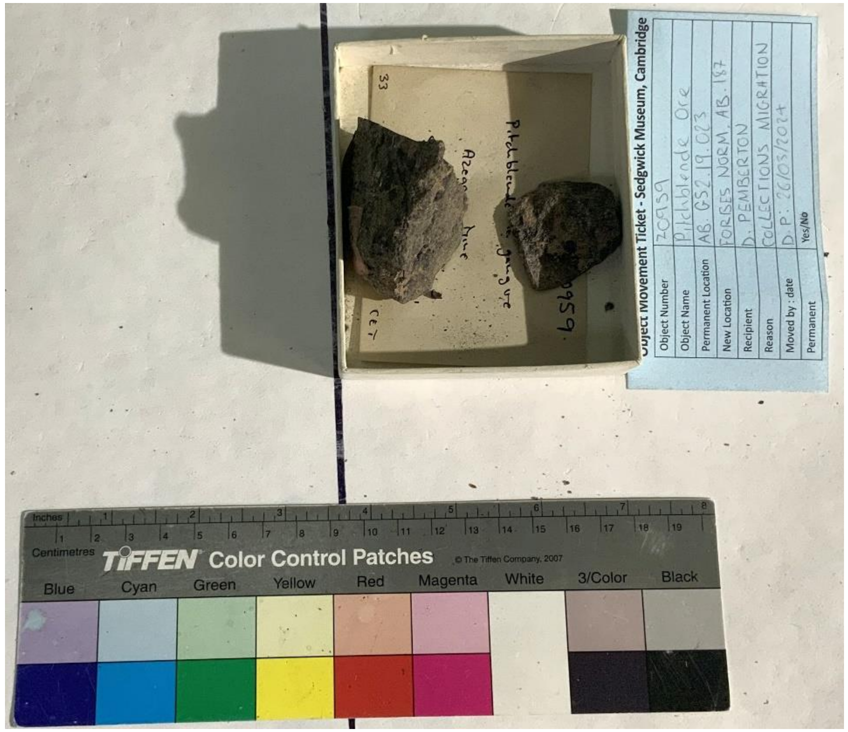
Monazite sand beaches



Monazite sand often accumulates in beach sand (0.1-1.5%) in places like Kerala India (above), Sri-Lanka and Brazil (up to 90 µGy/h), where it has been weathered from igneous and metamorphic rocks in the hinterland.

Geological map from Anitha, J. K., Joseph, S., Rejith, R. G., & Sundararajan, M. (2020)

CAMSM 70959 Uraninite (var. ‘pitchblende’) from Azegour Mine, Morocco



Uraninite UO_2 is a form of uranium oxide and one of the primary ores of uranium. It forms under hydrothermal conditions

Dose-rate at 0cm 28 µSv/h , 0.75 µSv/h at 30cm.

Formation of uranium ores

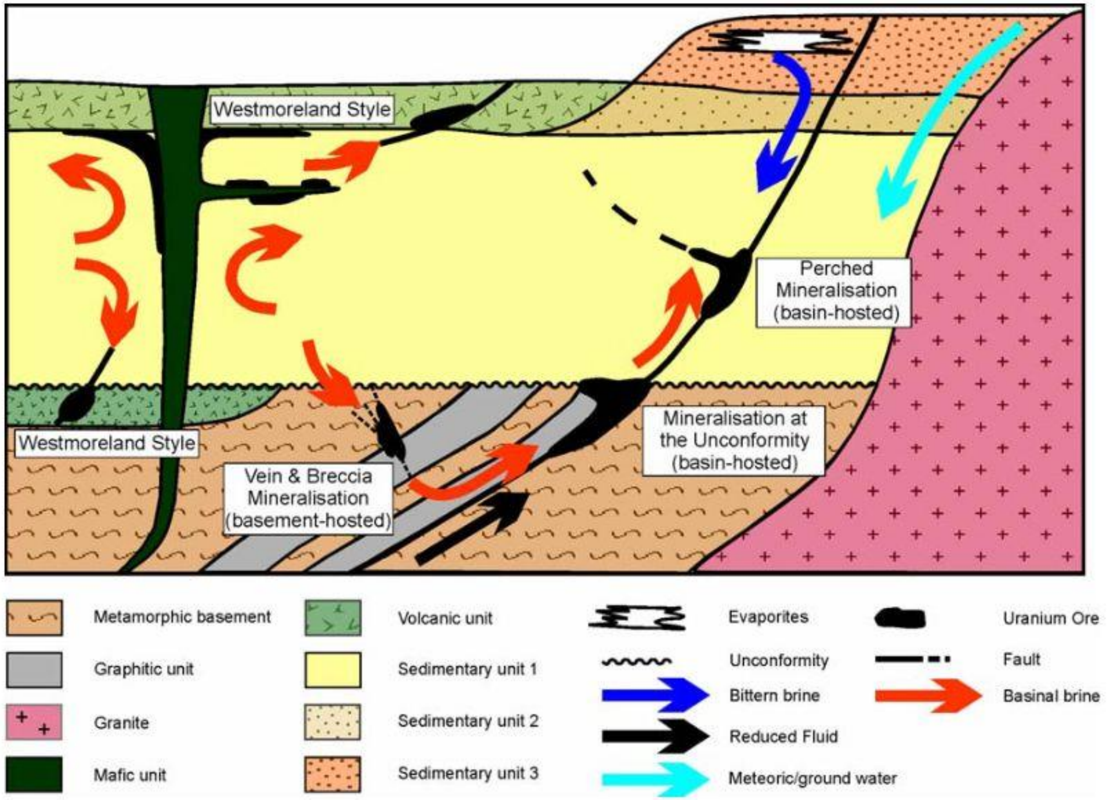


Figure 10: *Mineral system model for unconformity-related uranium deposits.*

Uranium is mobile when in an oxidised state, minerals such as uraninite form when uranium in oxidising hydrothermal fluids meets a reducing environment (e.g. by mixing with reducing fluids or migrating into a different rock type). Faults can form conduits between oxidising and reducing environments.

From Huston, D. L. (2020)

Why are some fossils radioactive?

Devonian (c.393,000,000 years old) fossil fish from the Orkneys. A few 10s of cps at surface

Dose-rate at 0cm <0.5 µSv/h , 0 µSv/h at 30cm.

What is the source of the radioactivity?

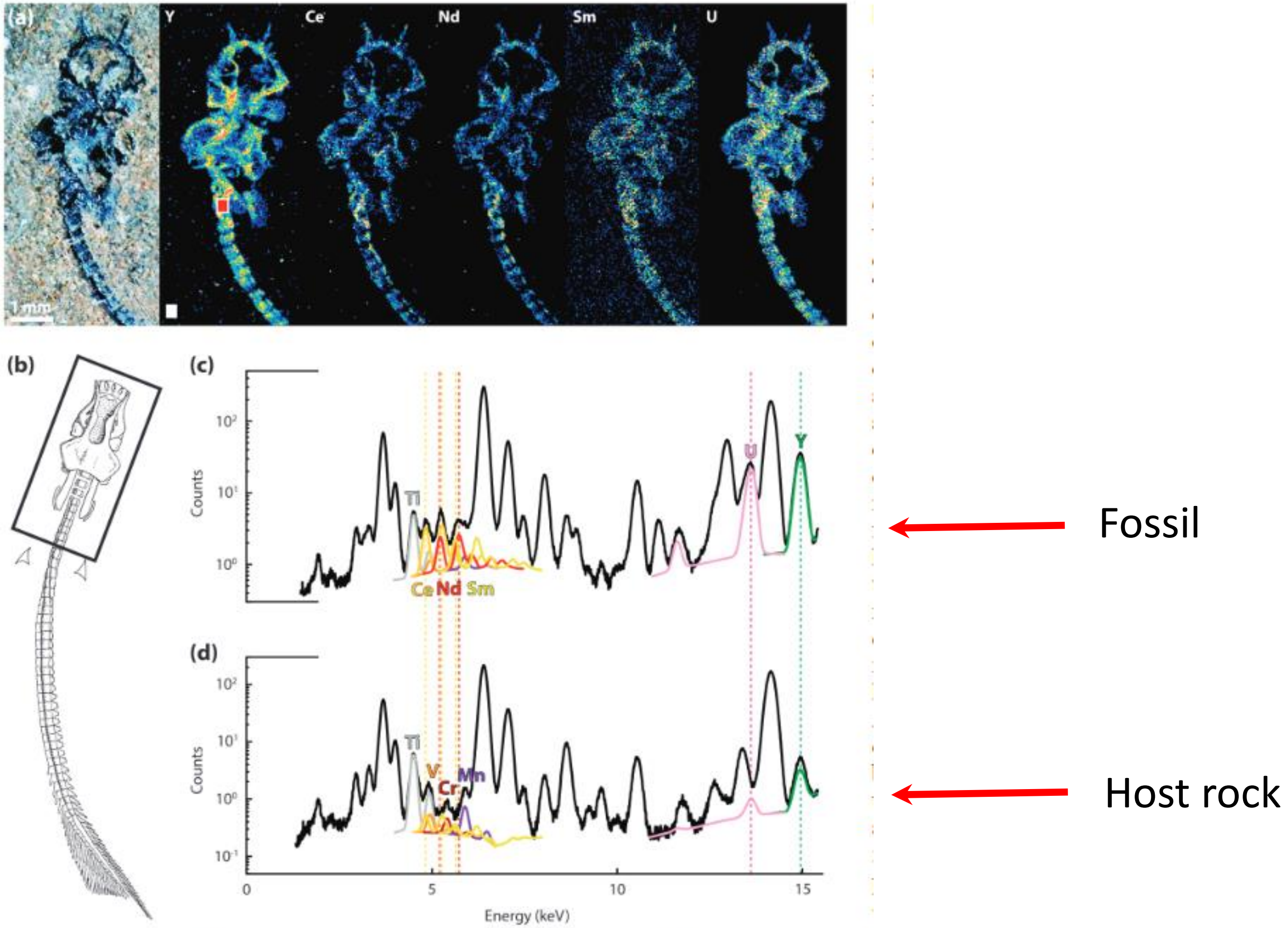


Figure 4: Synchrotron XRF mapping of trace elements in *Palaeospondylus gunni* (MNHN-GBP 92), an early vertebrate from the Middle Devonian (~390 Myr) of Scotland. (a) Light optical micrograph and distributions of yttrium; the REEs lanthanum, cerium, neodymium and samarium; and uranium that can be clearly mapped in this fossil (scan step: $30 \times 30 \mu m^2$, 28,231 pixels; distributions reconstructed from a full spectral decomposition of the data). (b) Reconstruction of the entire organism, with the box area corresponding to what is shown in (a). (c–d) Mean XRF spectra from the red (c) and white (d) box areas in the Y map (168 pixels), respectively characteristic of the fossil and the sedimentary matrix, showing contributions from transition metals and the elements mapped in (a).

From Gueriau, P. & Bertrand L. (2015)

A proposed model for the Orcadian lake environment

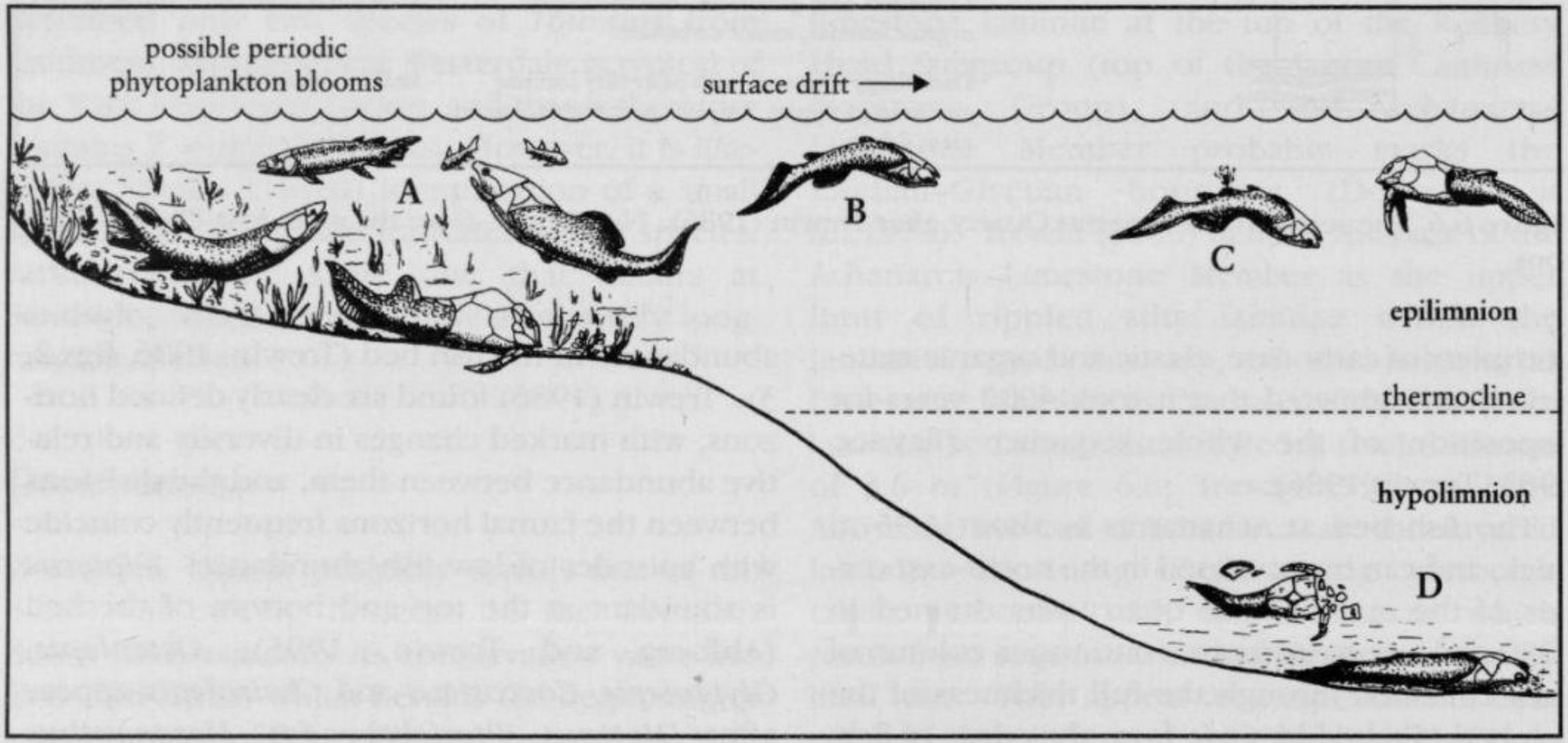


Figure 6.8 Particularly fossiliferous horizons with well-preserved fishes may result from mass mortality events induced by planktonic blooms. The axonic conditions extend throughout the shallow marginal areas (A); following this, carcasses drift into deeper water in a bloated conditions (B); after further decay (C), they sink through the thermocline and are preserved in laminites in the anoxic hypolimnion (D). The depth of the thermocline may have been no more than a few tens of metres (after Trewin, 1986).

From Dineley, D., and S. Metcalf (1999).

When and how did the fish become radioactive? #1

- According to BGS the fish beds, are rich in organic matter and contain up to 1,500 mg (1.5g) of U per kg
- BGS report uranium was present in the environment, weathered from basement & surrounding rocks that contained minerals such as monazite
- Uranium is mobile in oxidising environments and fixed in reducing environments
- It readily forms compounds with phosphate, some anaerobic reducing bacteria are capable of enzymatic uranium phosphate precipitation.
- Organic matter is an important sorbent for Uranium

When and how did the fish become radioactive? #2

- The fish died and sank to the bottom of a lake with v. slow sedimentation creating anaerobic, reducing conditions with a lot of decaying organic material.

- The fish have a skeleton and exoskeleton (bony scales) made of apatite $Ca_5(PO_4)_3(Cl/F/OH)$ and hydroxy apatite $Ca_5(PO_4)_3(OH)$ and are a potential source of phosphate.

- It would seem that in this case, the uranium became incorporated during the fossilisation process, rather than at a later date

A big surprise!

I was not expecting these Oligocene (c. 30,000,000 years old) fossils (mammals, crocodiles, turtles, fish etc.) from the Isle of Wight to be radioactive, but they are!
A few 10s of cps at surface

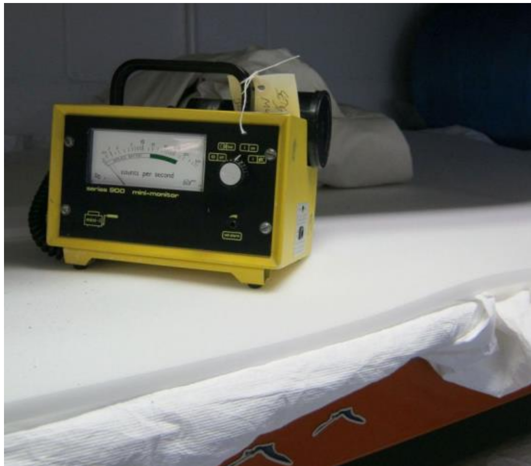
Dose-rate at 0cm <0.5 μSv/h , 0 μSv/h at 30cm.

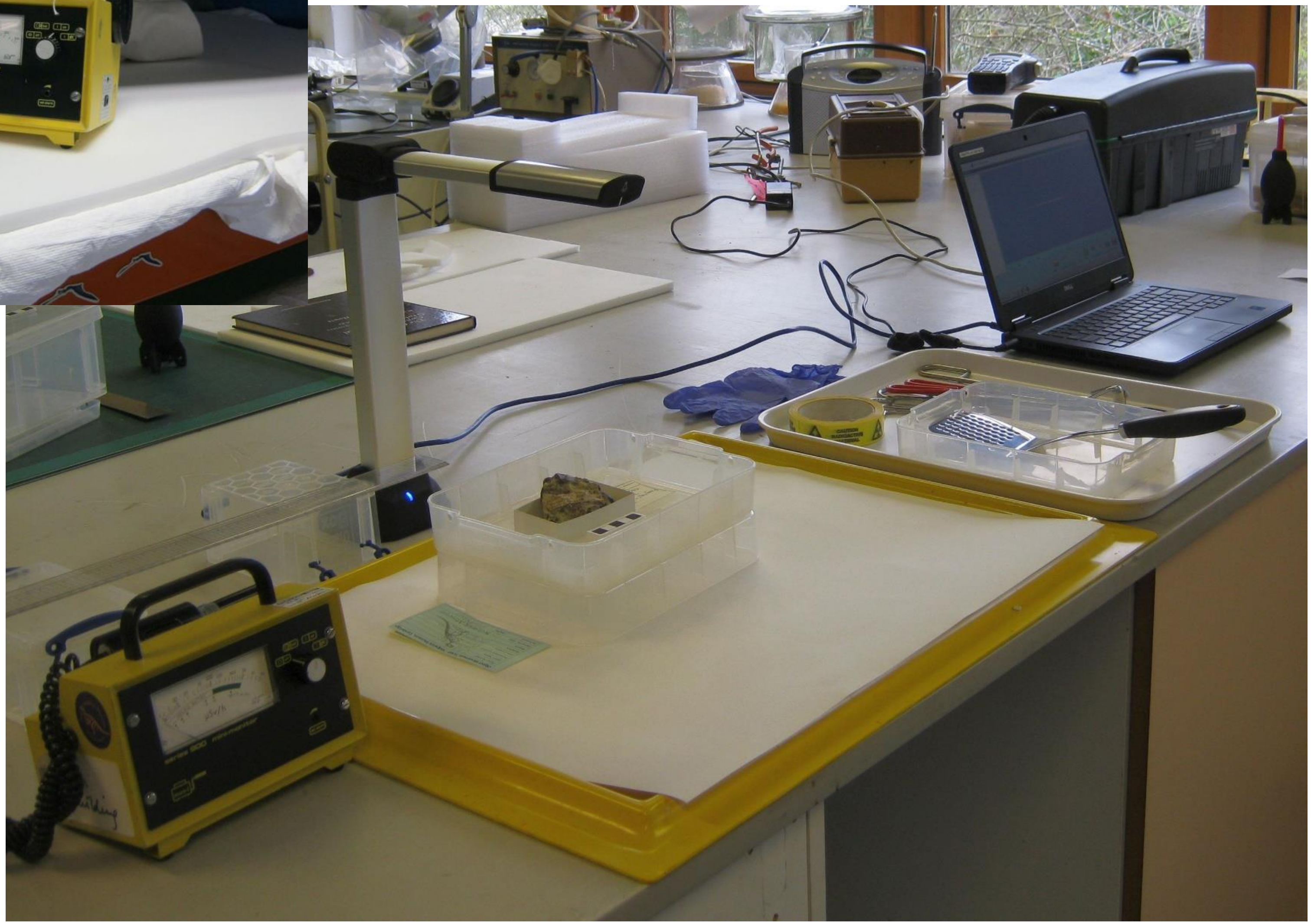
Current holdings of ‘Actionable’ NORMS

‘Actionable’ NORMS = 1 µSv/h at 0cm (Type-R dose-rate monitor)

- To date 414 items (+ 90 suspects in pipeline)
- Torbernite/metatorbernite ($Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$) = 119
- Autunite $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$ = 26
- Pitchblende/Uraninite UO_2 = 31
- Other (rocks, more obscure minerals etc.) = 143
- Unidentified = 54

Identification & Recording #1



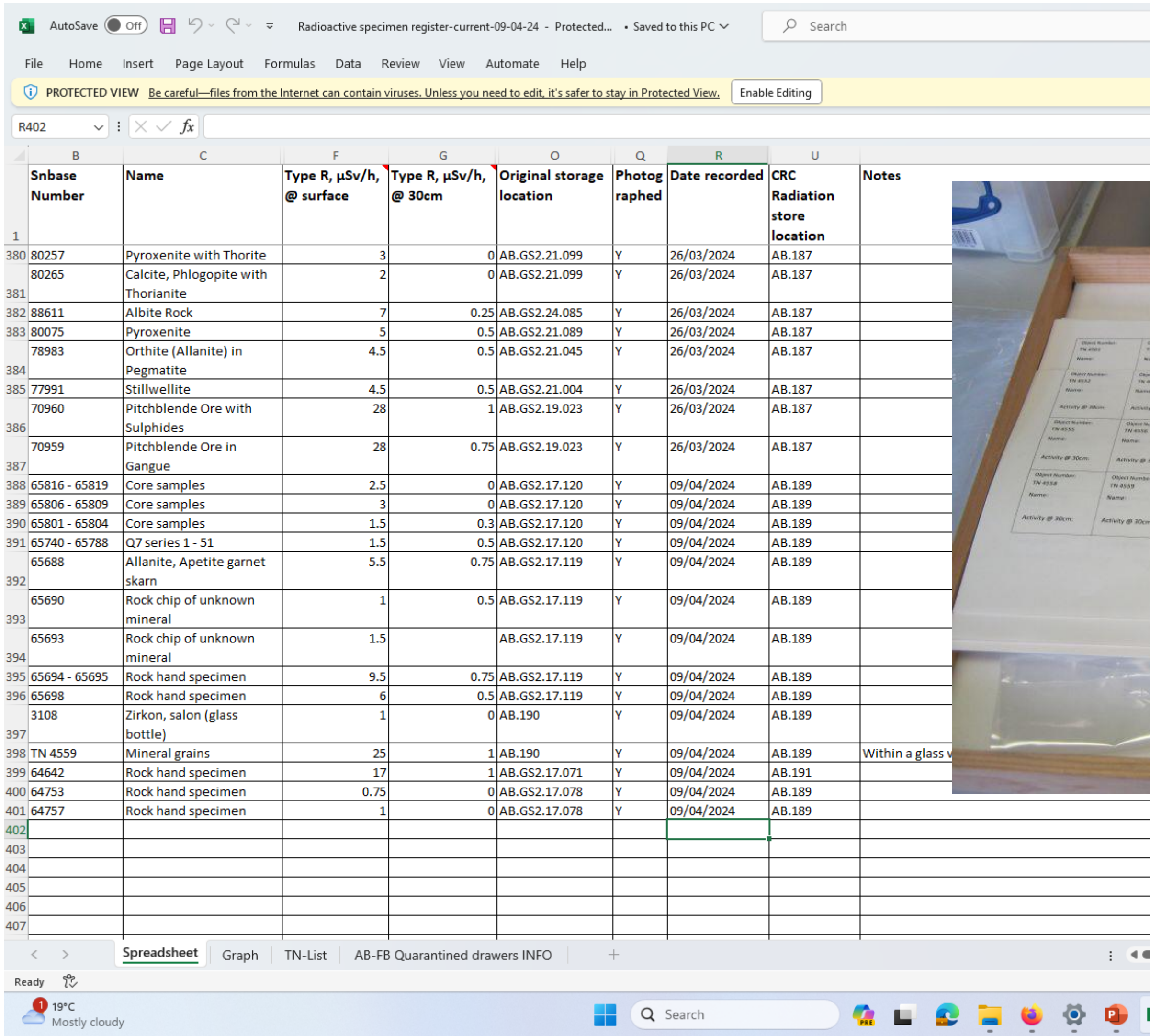


Basic set-up for handling and recording NORMs
Type-R monitor for dose-rate, EP-15 for contamination monitoring

NORM Handling

Some tools for keeping specimens at a distance

Identification & Recording #2



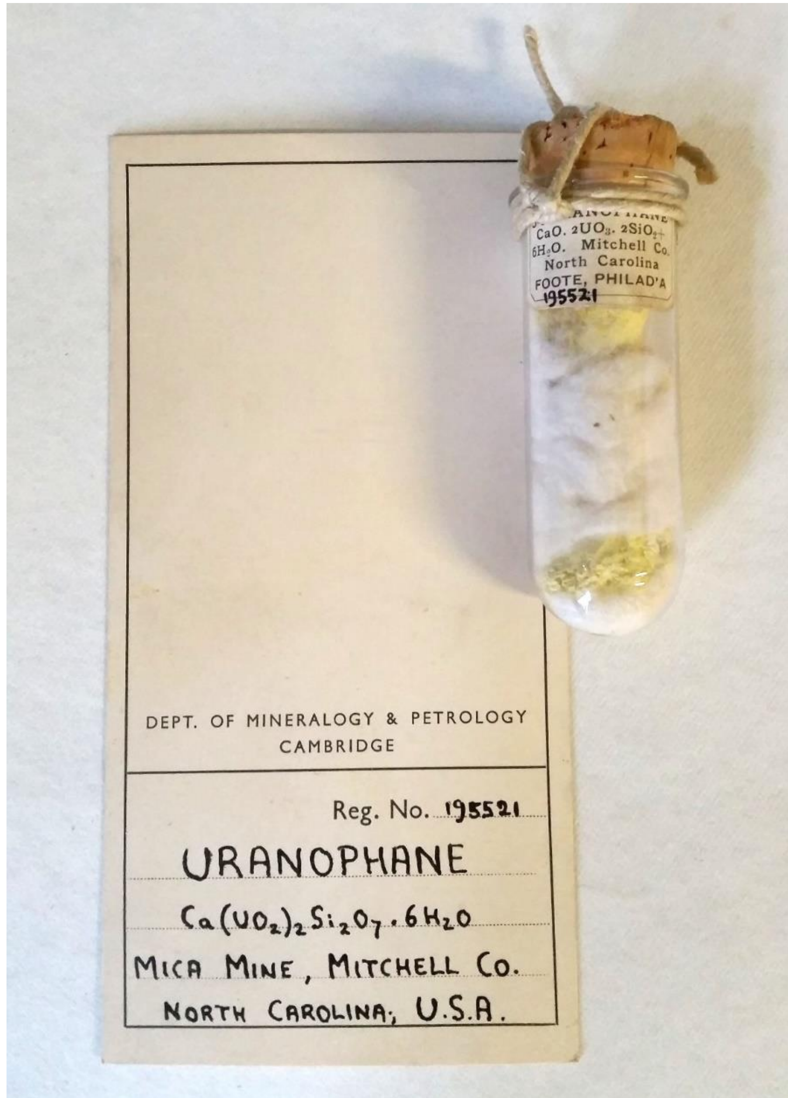
	B	C	F	G	O	Q	R	U	
1	Snbase Number	Name	Type R, µSv/h, @ surface	Type R, µSv/h, @ 30cm	Original storage location	Photographed	Date recorded	CRC Radiation store location	Notes
380	80257	Pyroxenite with Thorite	3	0	AB.GS2.21.099	Y	26/03/2024	AB.187	
381	80265	Calcite, Phlogopite with Thorianite	2	0	AB.GS2.21.099	Y	26/03/2024	AB.187	
382	88611	Albite Rock	7	0.25	AB.GS2.24.085	Y	26/03/2024	AB.187	
383	80075	Pyroxenite	5	0.5	AB.GS2.21.089	Y	26/03/2024	AB.187	
384	78983	Orthite (Allanite) in Pegmatite	4.5	0.5	AB.GS2.21.045	Y	26/03/2024	AB.187	
385	77991	Stillwellite	4.5	0.5	AB.GS2.21.004	Y	26/03/2024	AB.187	
386	70960	Pitchblende Ore with Sulphides	28	1	AB.GS2.19.023	Y	26/03/2024	AB.187	
387	70959	Pitchblende Ore in Gangue	28	0.75	AB.GS2.19.023	Y	26/03/2024	AB.187	
388	65816 - 65819	Core samples	2.5	0	AB.GS2.17.120	Y	09/04/2024	AB.189	
389	65806 - 65809	Core samples	3	0	AB.GS2.17.120	Y	09/04/2024	AB.189	
390	65801 - 65804	Core samples	1.5	0.3	AB.GS2.17.120	Y	09/04/2024	AB.189	
391	65740 - 65788	Q7 series 1 - 51	1.5	0.5	AB.GS2.17.120	Y	09/04/2024	AB.189	
392	65688	Allanite, Apetite garnet skarn	5.5	0.75	AB.GS2.17.119	Y	09/04/2024	AB.189	
393	65690	Rock chip of unknown mineral	1	0.5	AB.GS2.17.119	Y	09/04/2024	AB.189	
394	65693	Rock chip of unknown mineral	1.5		AB.GS2.17.119	Y	09/04/2024	AB.189	
395	65694 - 65695	Rock hand specimen	9.5	0.75	AB.GS2.17.119	Y	09/04/2024	AB.189	
396	65698	Rock hand specimen	6	0.5	AB.GS2.17.119	Y	09/04/2024	AB.189	
397	3108	Zirkon, salon (glass bottle)	1	0	AB.190	Y	09/04/2024	AB.189	
398	TN 4559	Mineral grains	25	1	AB.190	Y	09/04/2024	AB.189	Within a glass v
399	64642	Rock hand specimen	17	1	AB.GS2.17.071	Y	09/04/2024	AB.191	
400	64753	Rock hand specimen	0.75	0	AB.GS2.17.078	Y	09/04/2024	AB.189	
401	64757	Rock hand specimen	1	0	AB.GS2.17.078	Y	09/04/2024	AB.189	

Items are recorded in a spreadsheet and are issued a temporary ID if un-numbered

Examples

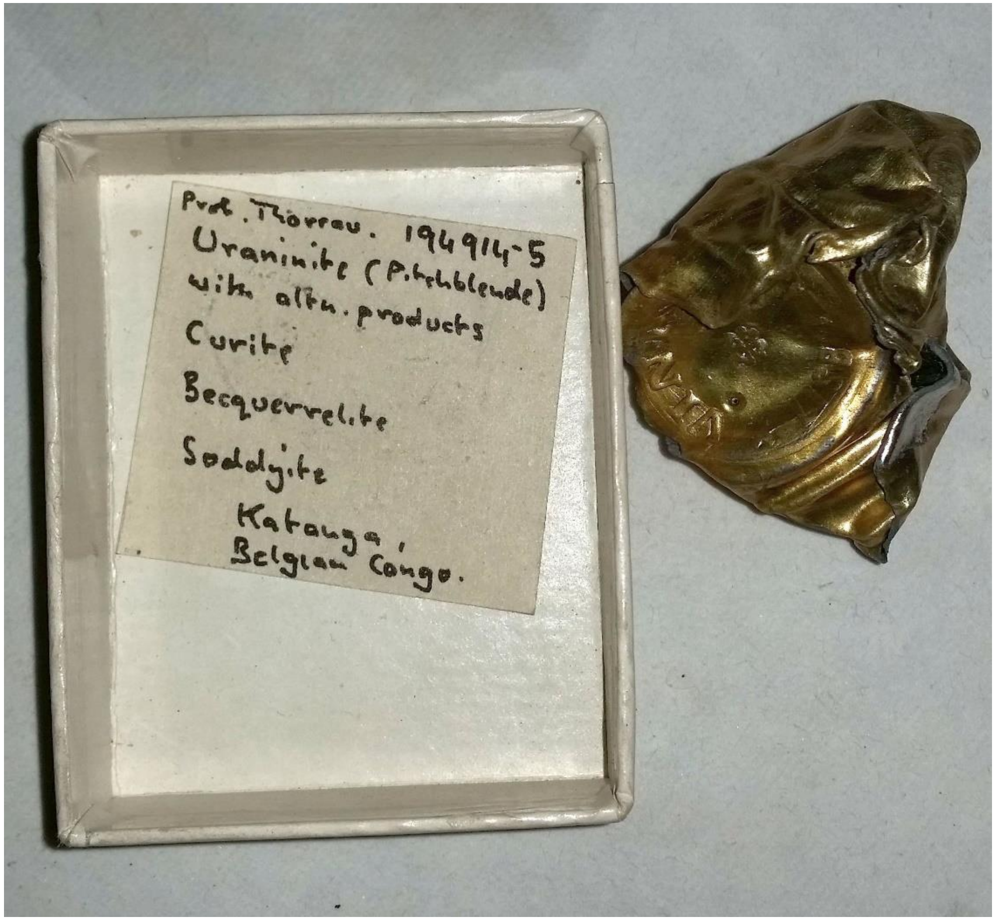
Crystal ‘micromounts’

Examples



Glass tubes

Examples



Wrapped in lead?

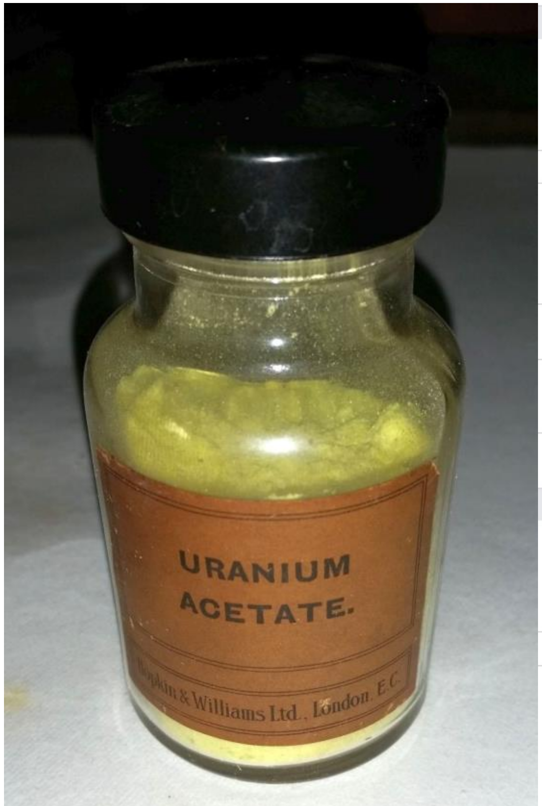
Examples

Open card trays (and in this instance poor condition)

Examples

Most radioactive to date CAMSM 1947.20 Uraninite (UO_2)
Dose-rate at 0cm 180 µSv/h , 15 µSv/h at 30cm.

Examples



Acute Toxic | Health Hazard | Environmental Hazard

Danger

H300+H330 (92.68%): Fatal if swallowed or if inhaled [Danger Acute toxicity, oral; acute toxicity, inhalation]
H300 (97.56%): Fatal if swallowed [Danger Acute toxicity, oral]
H330 (97.56%): Fatal if inhaled [Danger Acute toxicity, inhalation]
H373 (100%): May causes damage to organs through prolonged or repeated exposure [Warning Specific target organ toxicity, repeated exposure]
H411 (97.56%): Toxic to aquatic life with long lasting effects [Hazardous to the aquatic environment, long-term hazard]

P260, P264, P270, P271, P273, P284, P301+P316, P304+P340, P316, P319, P320, P321, P330, P391, P403+P233, P405, and P501
(The corresponding statement to each P-code can be found at the GHS Classification page.)

Aggregated GHS information provided by 41 companies from 4 notifications to the ECHA C&L Inventory. Each notification may be associated with multiple companies.
Information may vary between notifications depending on impurities, additives, and other factors. The percentage value in parenthesis indicates the notified classification ratio from comp
above 10% are shown.

Acute Toxic | Irritant | Health Hazard | Environmental Hazard

Danger

H301: Toxic if swallowed [Danger Acute toxicity, oral]
H315: Causes skin irritation [Warning Skin corrosion/irritation]
H319: Causes serious eye irritation [Warning Serious eye damage/eye irritation]
H335: May cause respiratory irritation [Warning Specific target organ toxicity, single exposure; Respiratory tract irritation]
H341: Suspected of causing genetic defects [Warning Germ cell mutagenicity]
H350: May cause cancer [Danger Carcinogenicity]
H361: Suspected of damaging fertility or the unborn child [Warning Reproductive toxicity]
H370: Causes damage to organs [Danger Specific target organ toxicity, single exposure]
H372: Causes damage to organs through prolonged or repeated exposure [Danger Specific target organ toxicity, repeated

Precautionary Statement Codes

P203, P260, P261, P264, P264+P265, P270, P271, P280, P301+P316, P302+P352, P304+P340, P305+P351+P338, P308+P316, P31
(The corresponding statement to each P-code can be found at the GHS Classification page.)

WTF?

Storage

Rock & Big Fossils Store: Radon average 84 Bq m^3

NORM Store: Radon average: 245 Bq m^3

Collections Research Centre, Madingley Rise Cambridge

References

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