Legacy Radionuclides from nuclear testing at Montebello, Australia—Island soils, biota and dose assessments

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With much thanks to:

Emma Davis, Jen Harrison, Nick Howell, Andrea Johansen, Colleen Sims, Sangeeth Thiruvoth,, Lida Mokhber-Shahin, Scott Whiting

Science. Ingenuity. Sustainability.

There are three former British nuclear weapons testing locations in Australia

Bikini Atoll, Marshall Islands

Montebello Islands

Emu

Maralinga

Moruroa

US Dept of State Geographer
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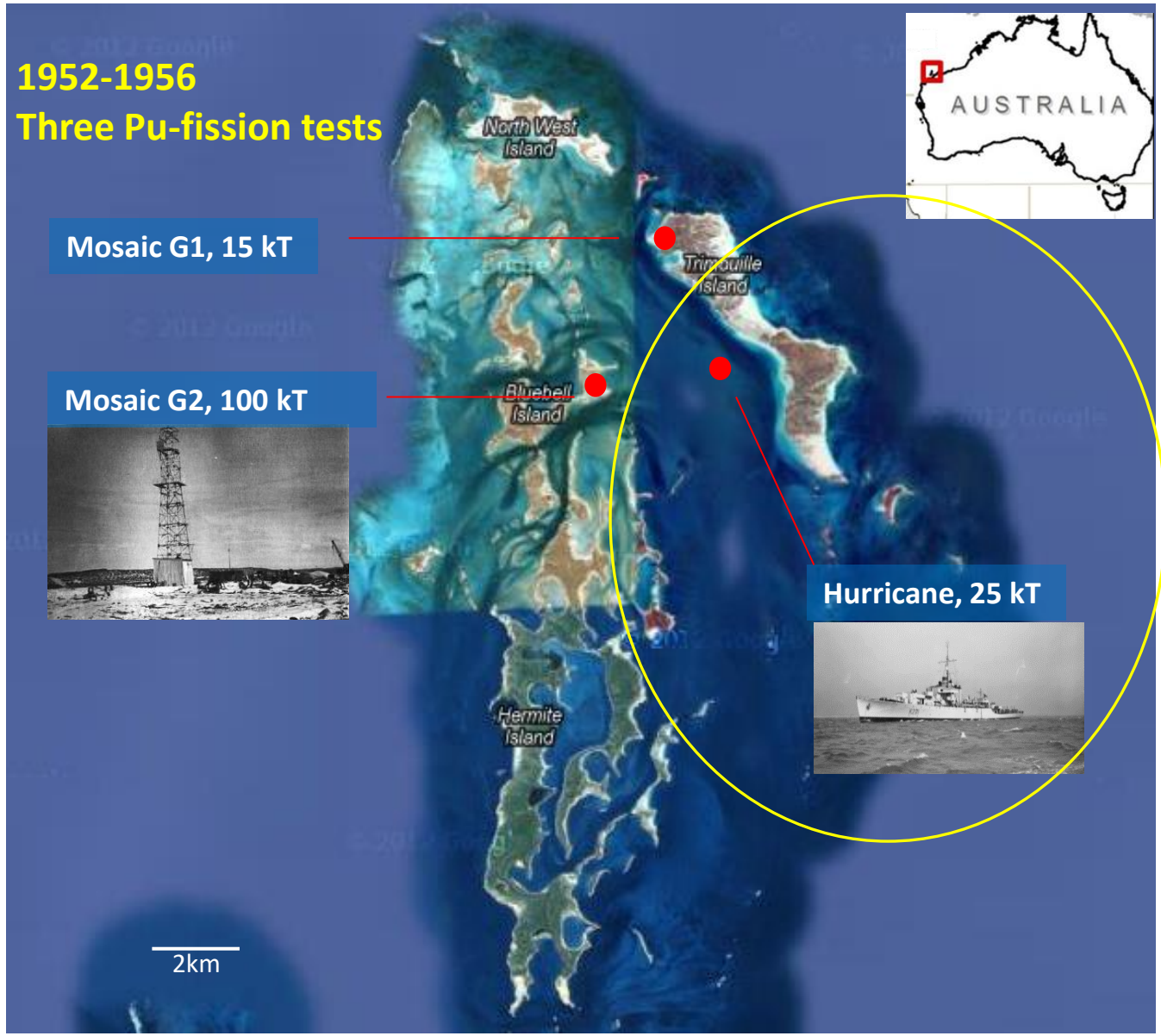
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth
Eye alt 6956.02 km

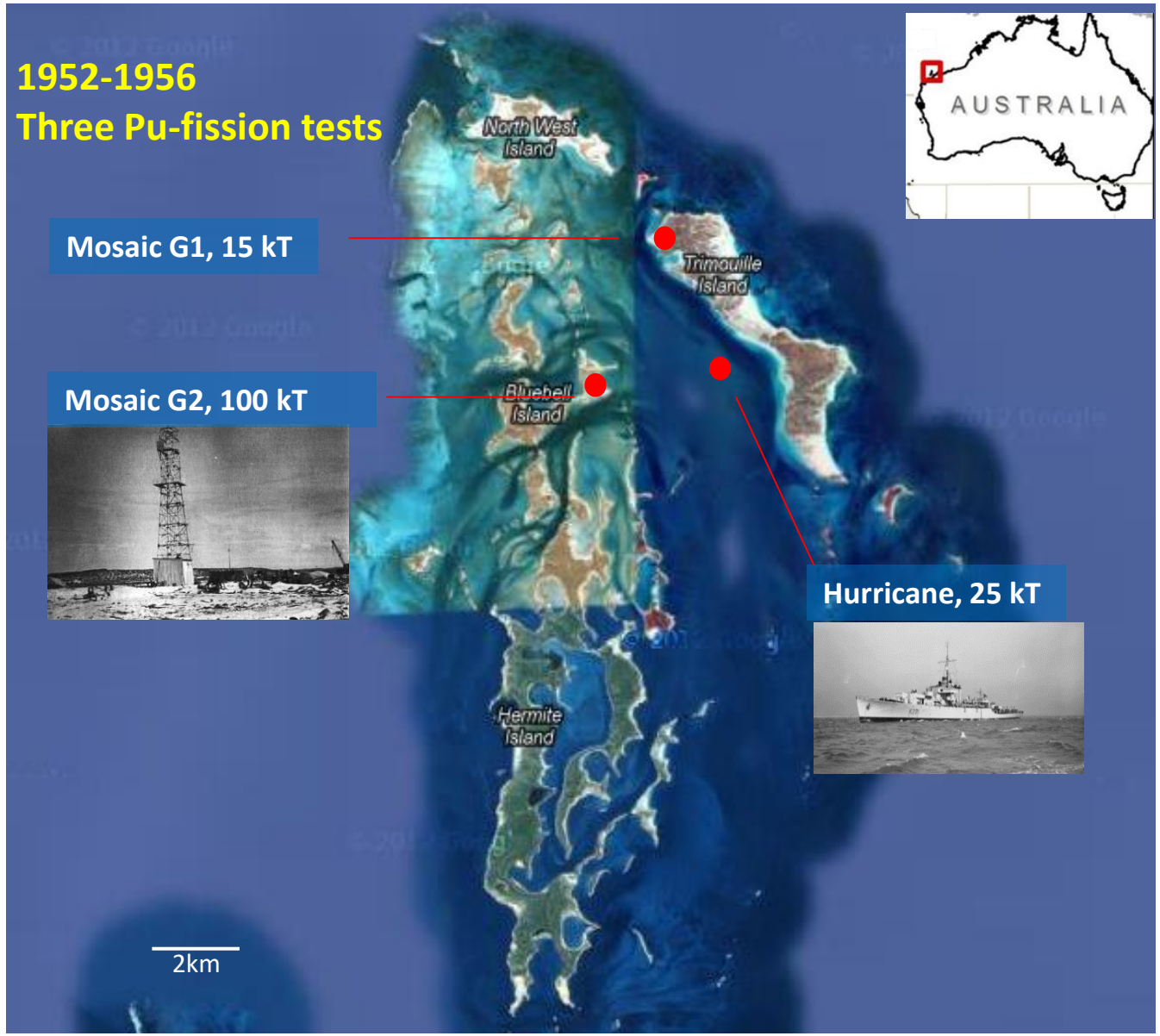
Google ear

ANSTO

Montebello Islands

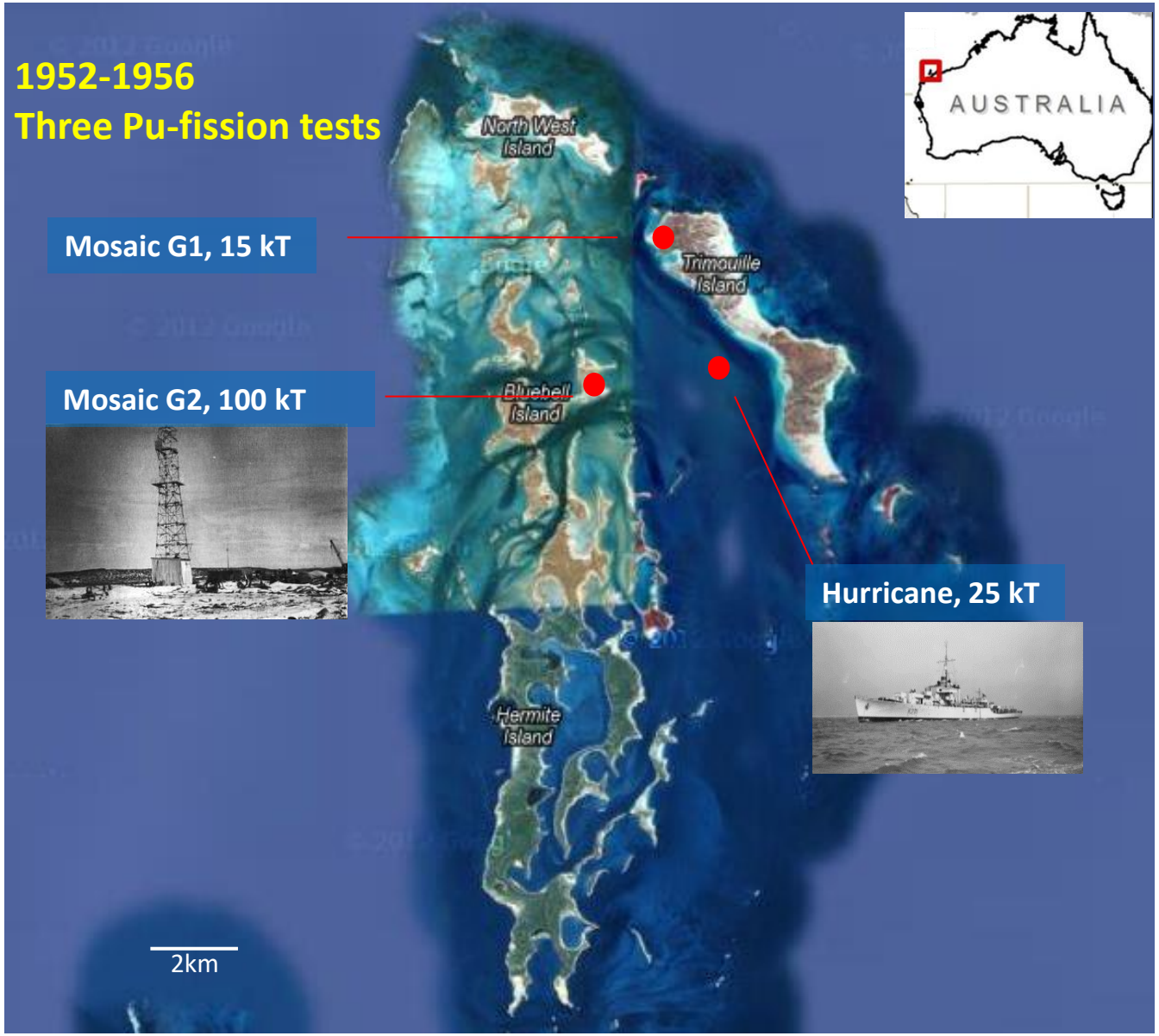


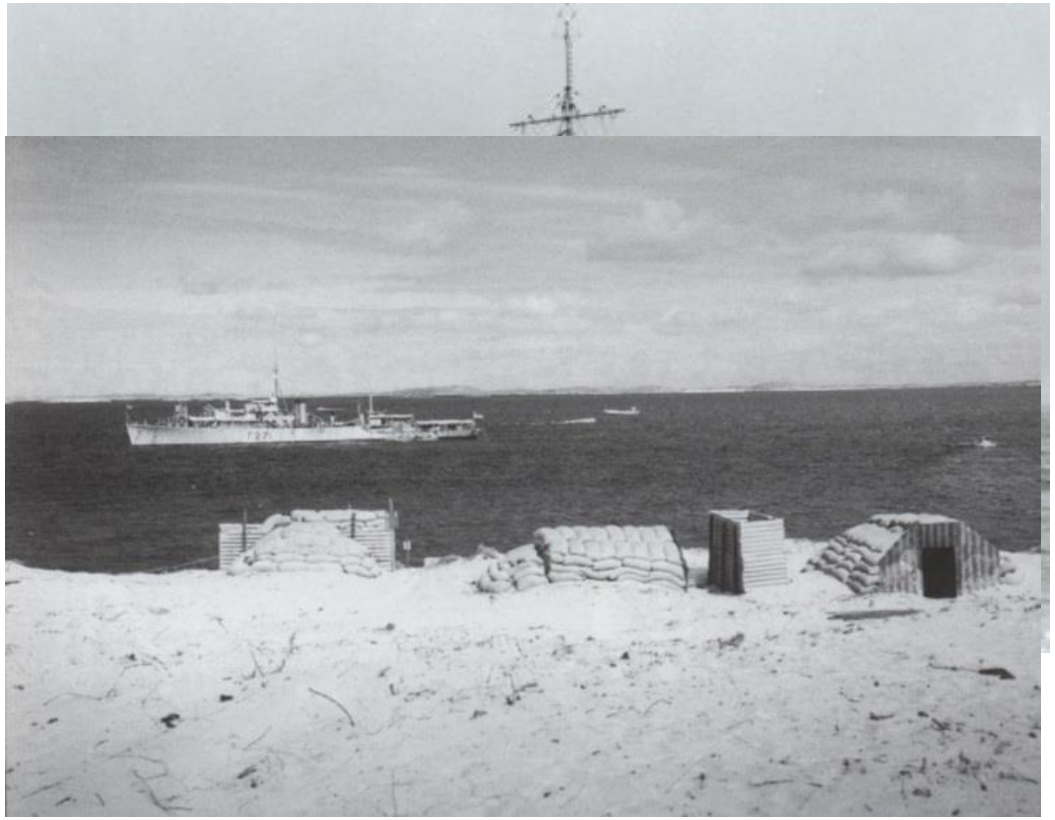
Montebello Islands



Montebello Islands

1952-1956
Three Pu-fission tests





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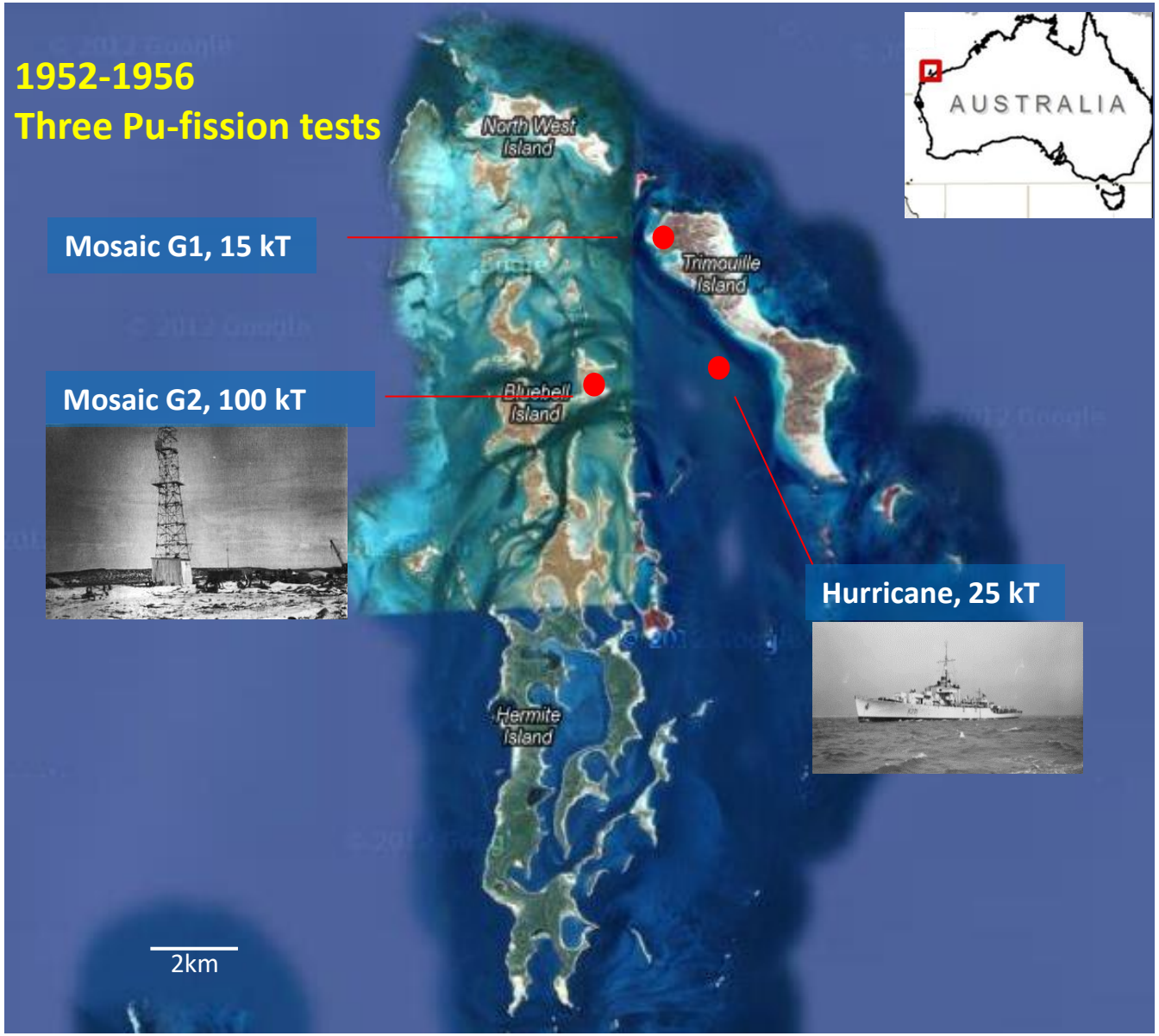

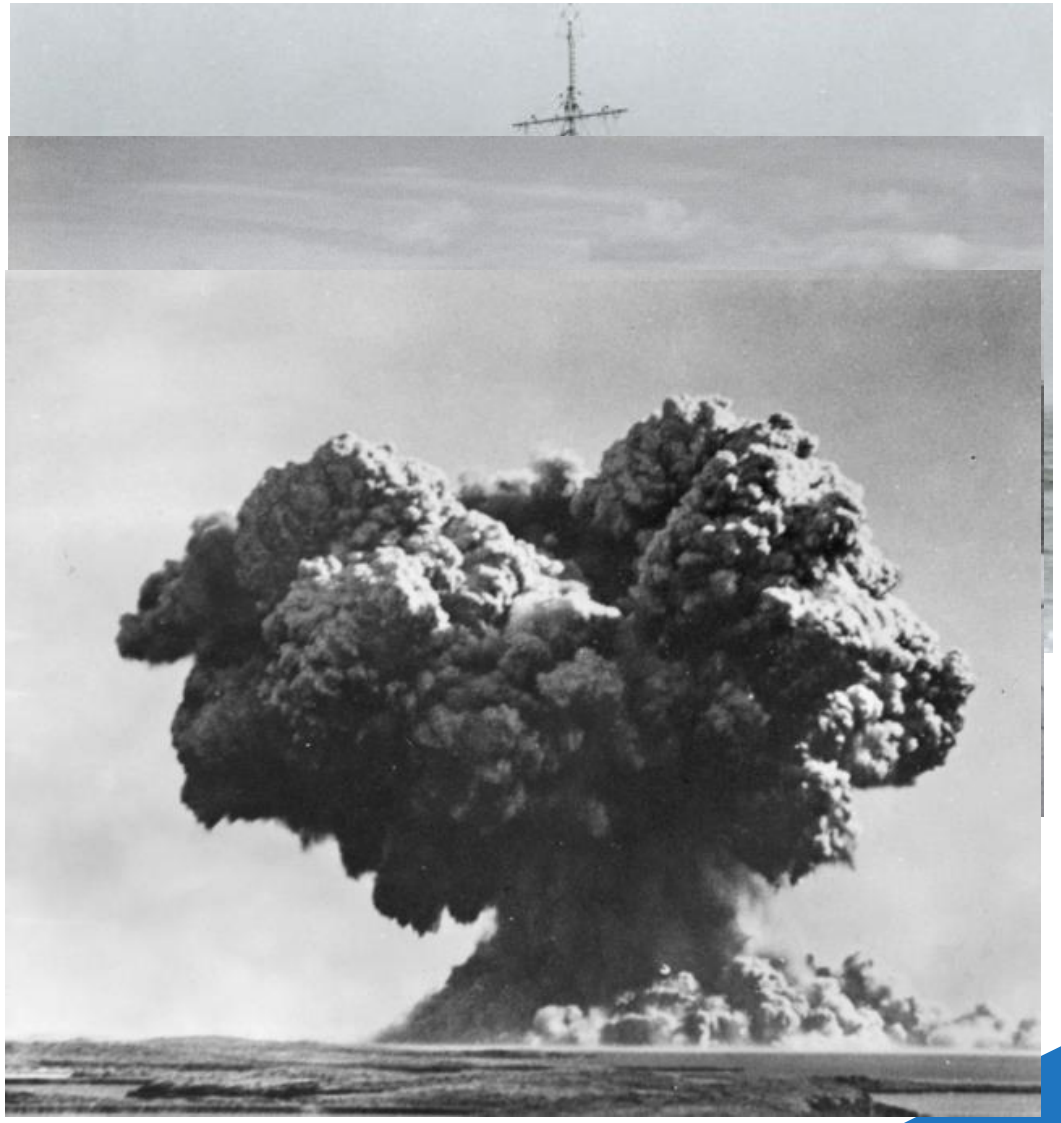

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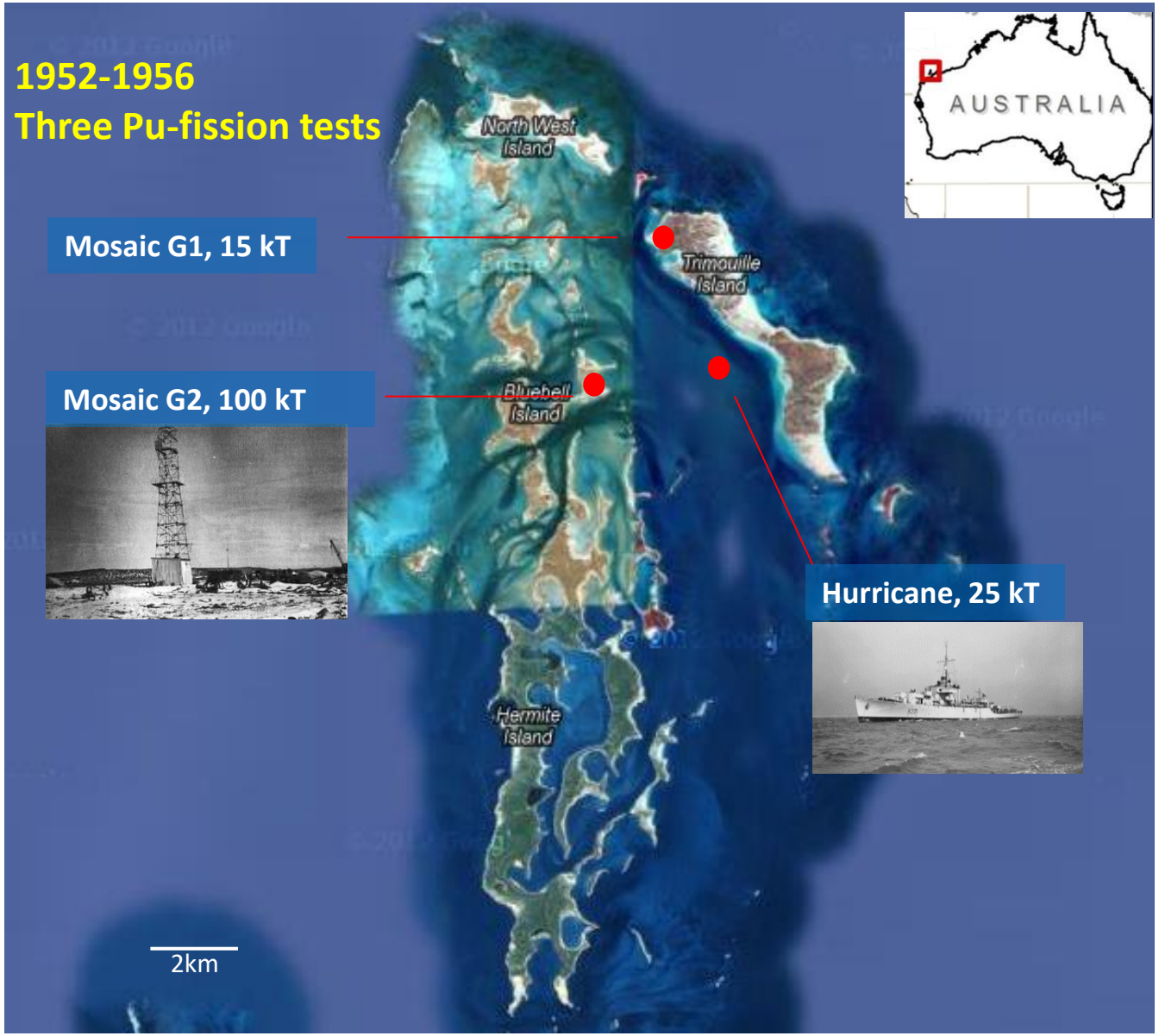
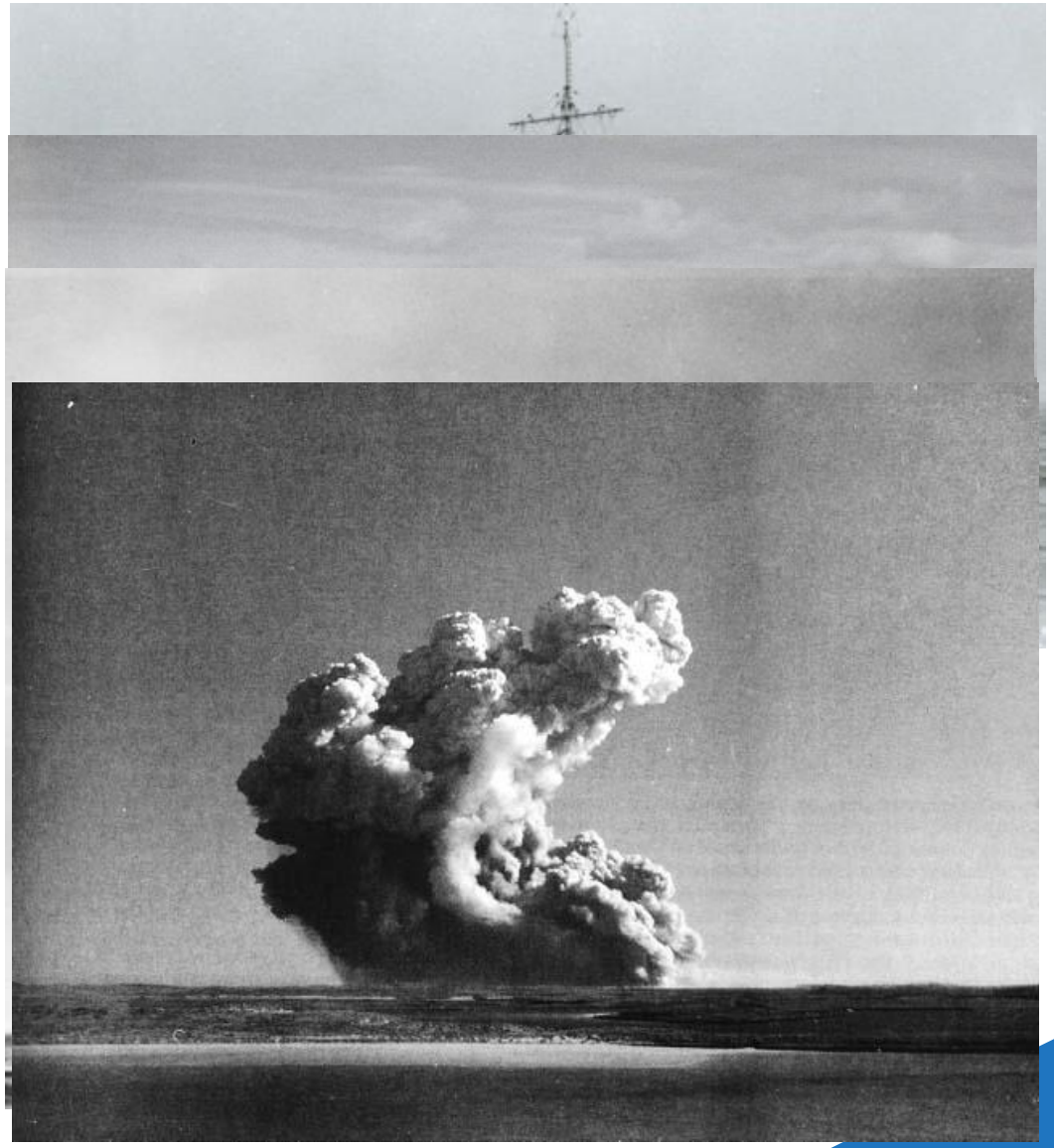


Mosaic G1, 15 kT

Mosaic G2, 100 kT

Hurricane, 25 kT



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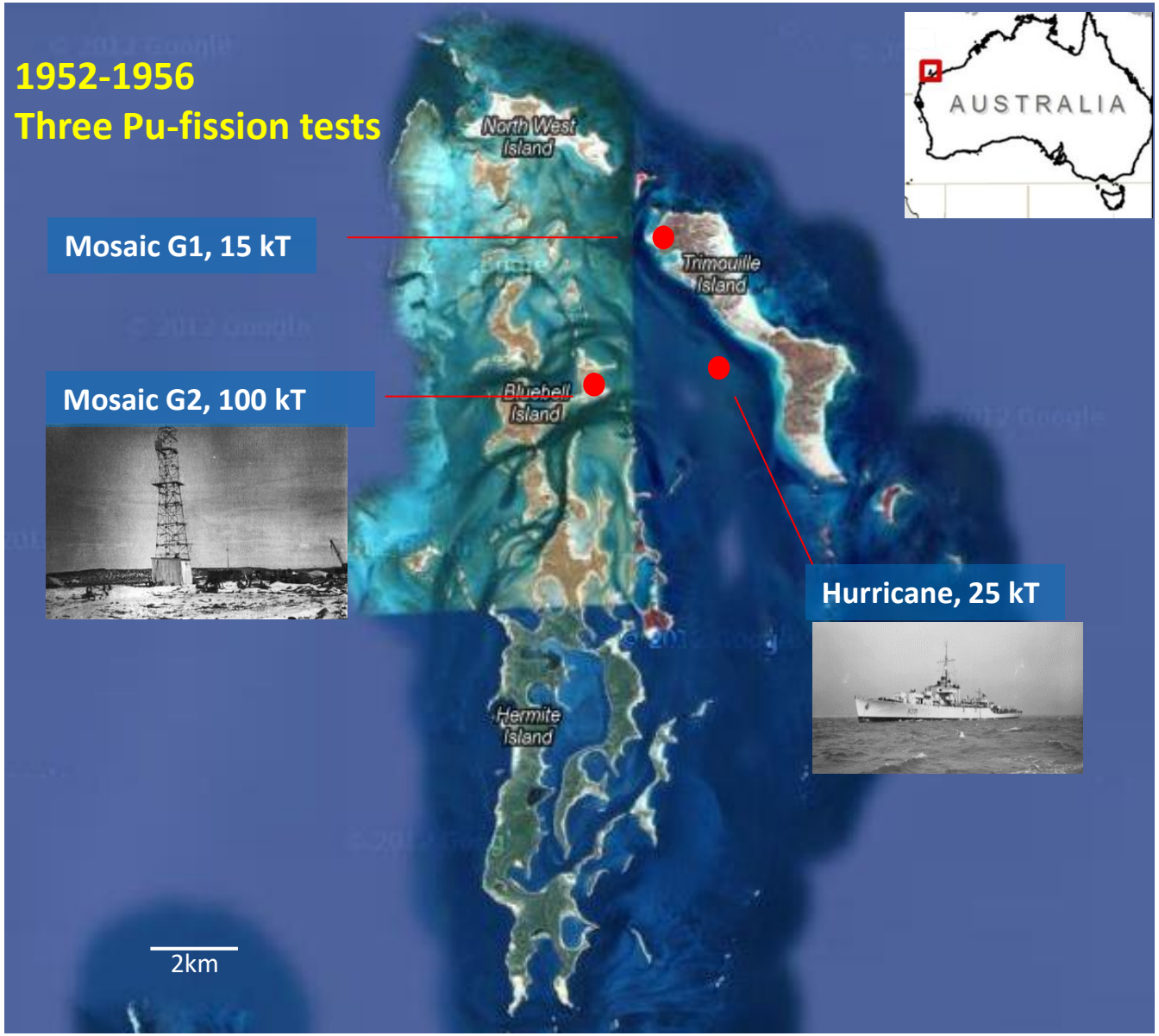

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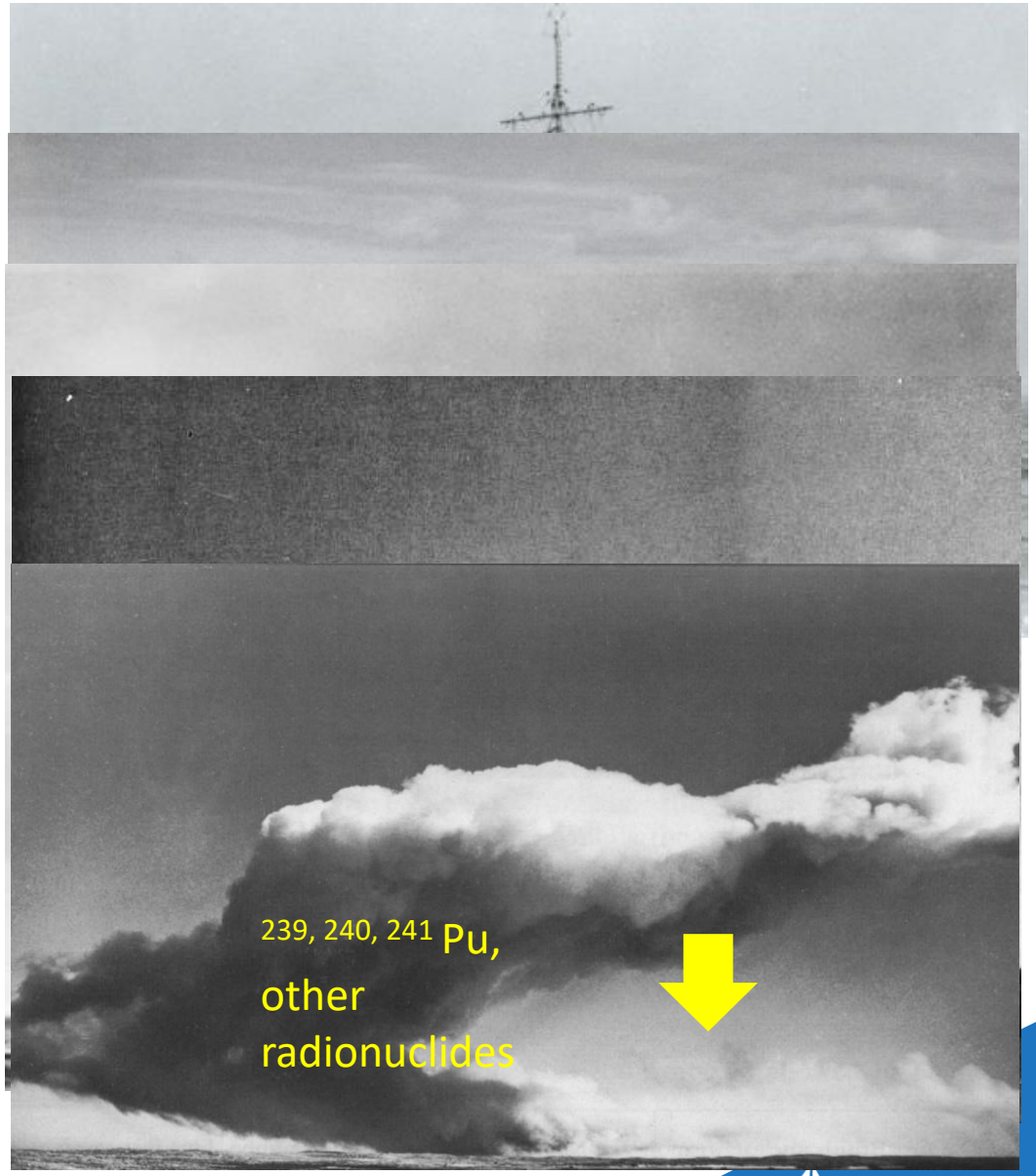
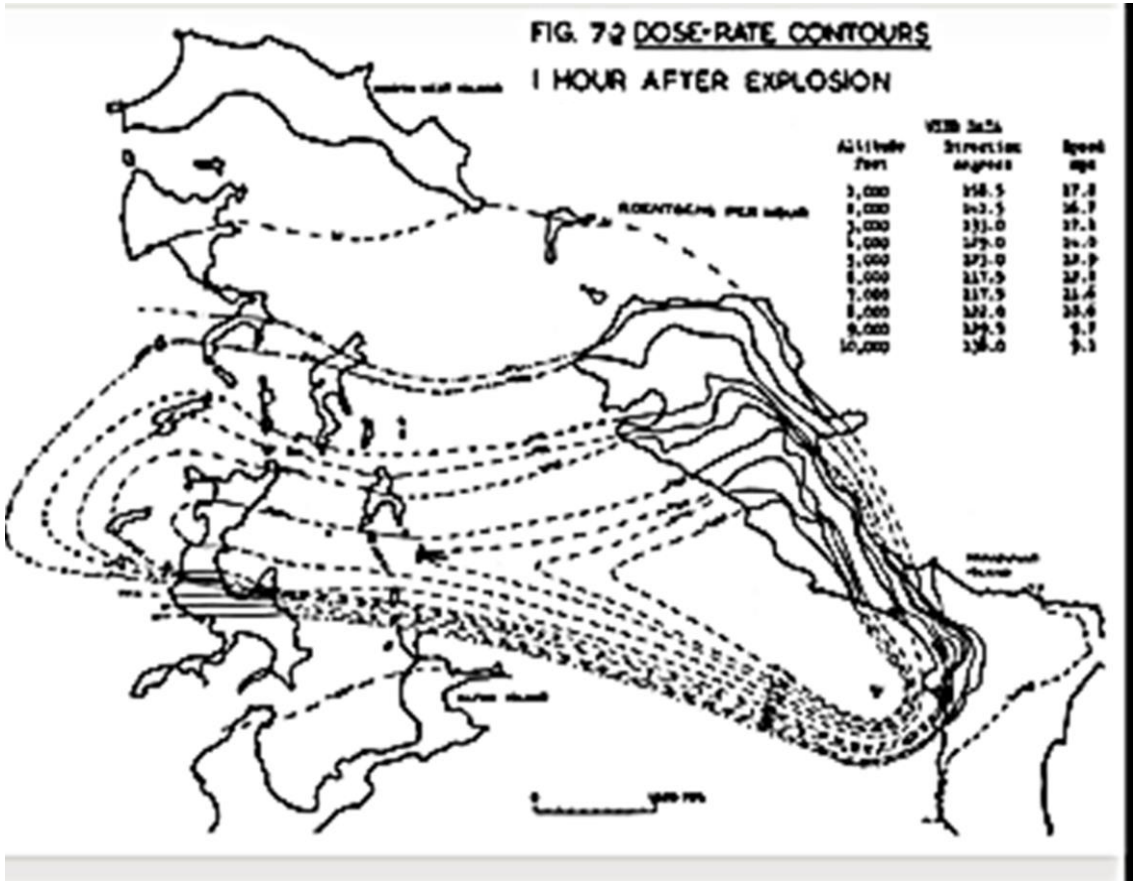
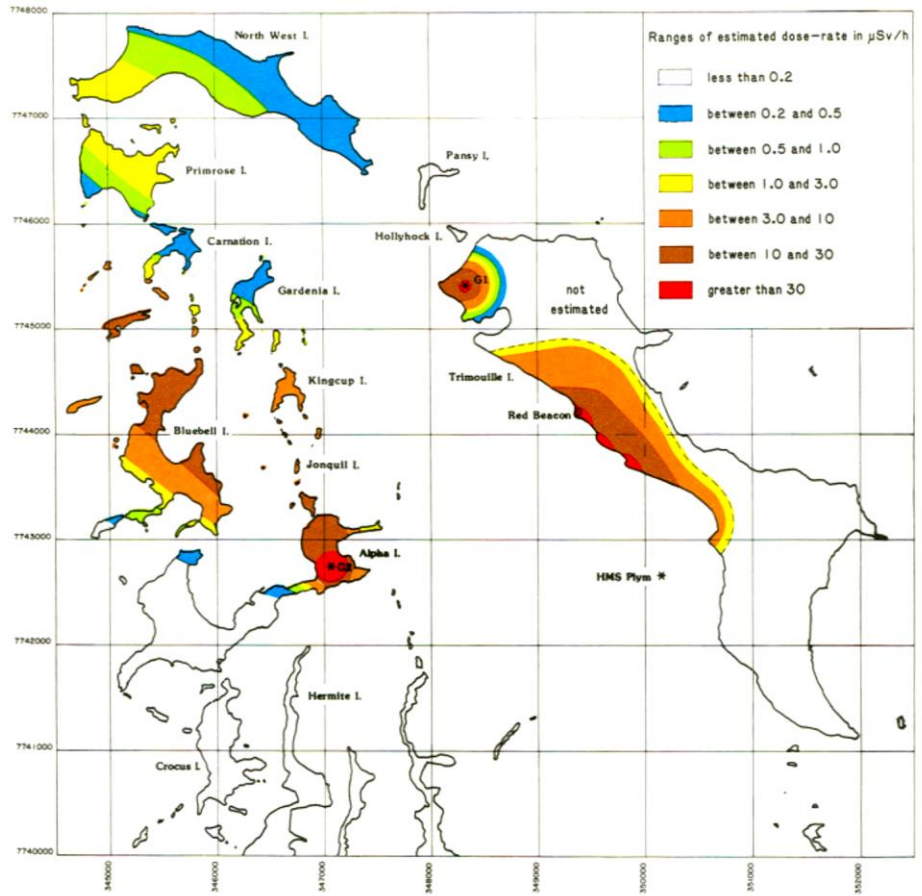


Montebello Islands – Some historical information on gamma dose rates

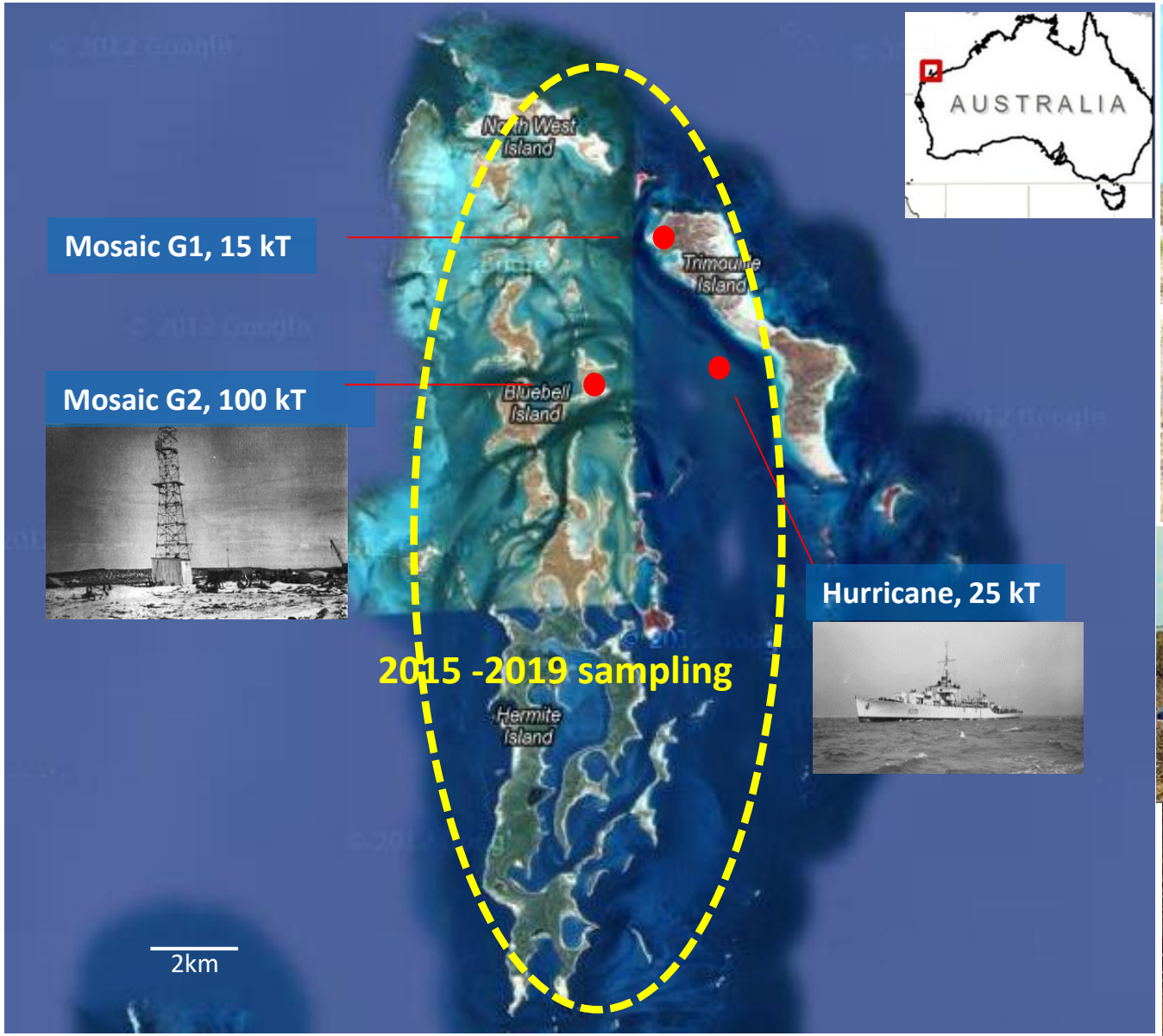


1952 gamma survey, 1-hr after the Hurricane test (1st test from ship).

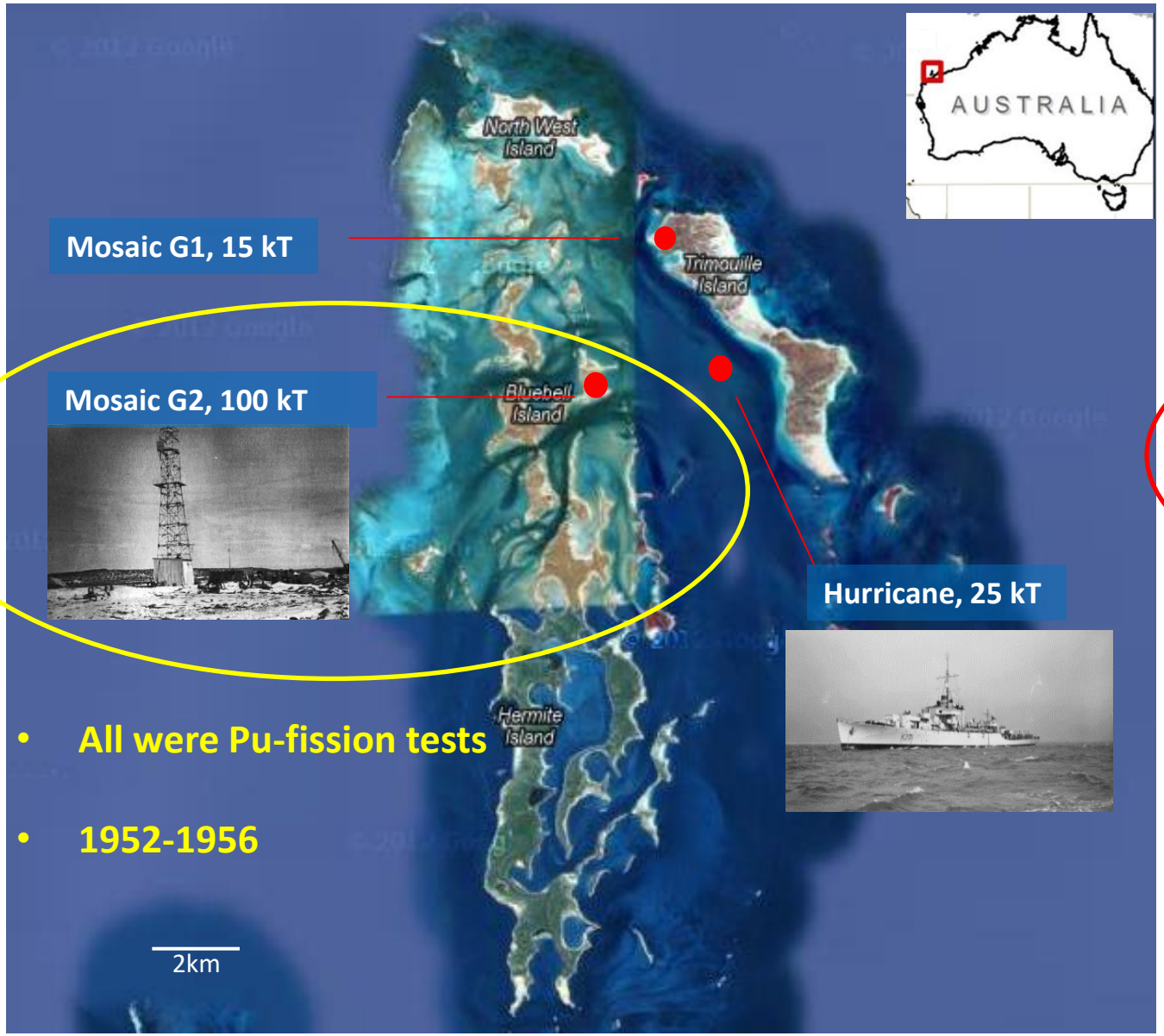


1962 gamma survey (ARL, 1982) of residuals from all three tests.

Montebello Islands – Field work 2015, 2019



Montebello Islands



- All were Pu-fission tests
- 1952-1956

Montebello Islands:

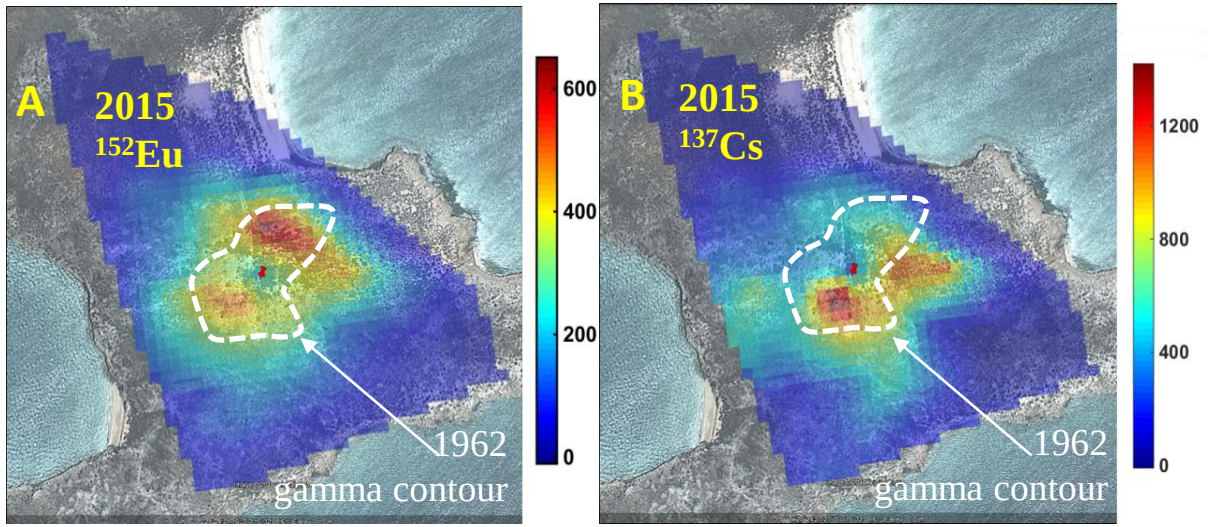
We sought to answer:

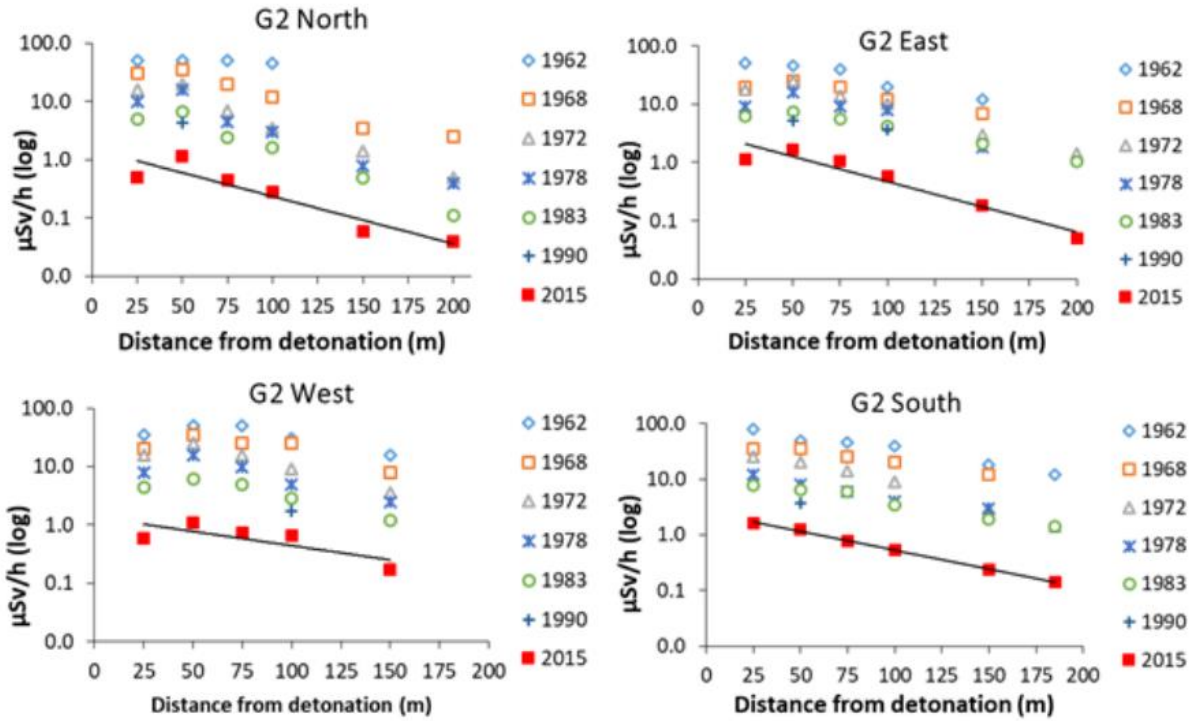
- How much weapons test-Pu and other radionuclides remain after 60 yrs?
- Is it cycling into the biosphere?
- Impacts of the residual Pu today?

Mosaic G2- Gamma over time

Relative movement of ^{152}Eu and ^{137}Cs over time

Decreases in gamma dose rates with time and distance at the Mosaic G2 site as measured 1 m above the soil surface.





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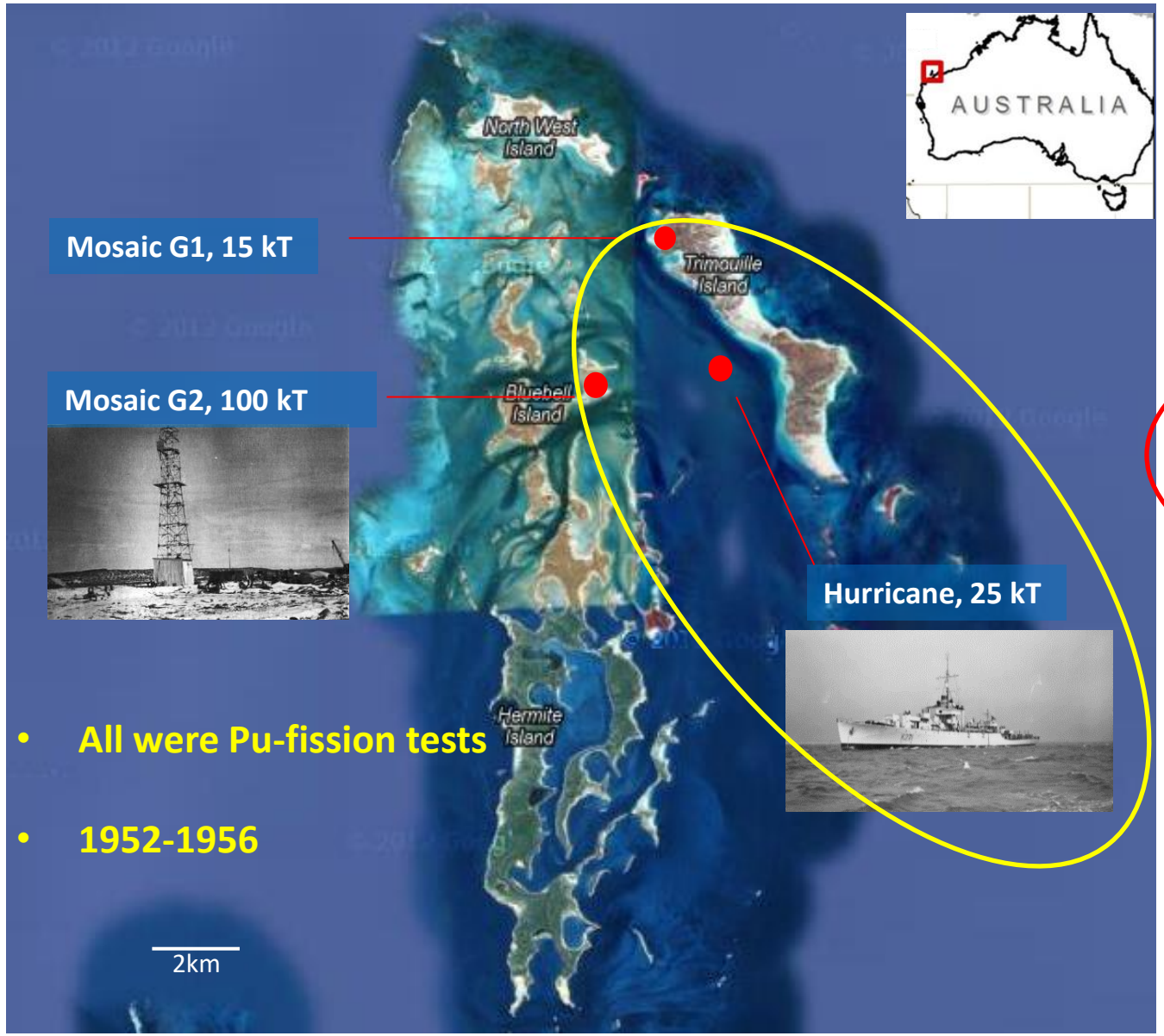

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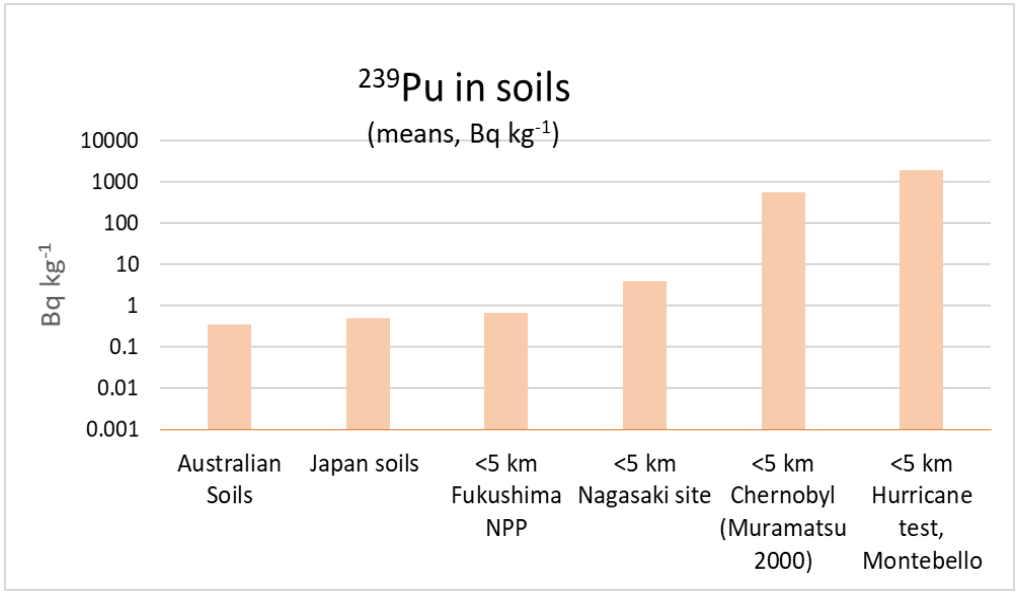
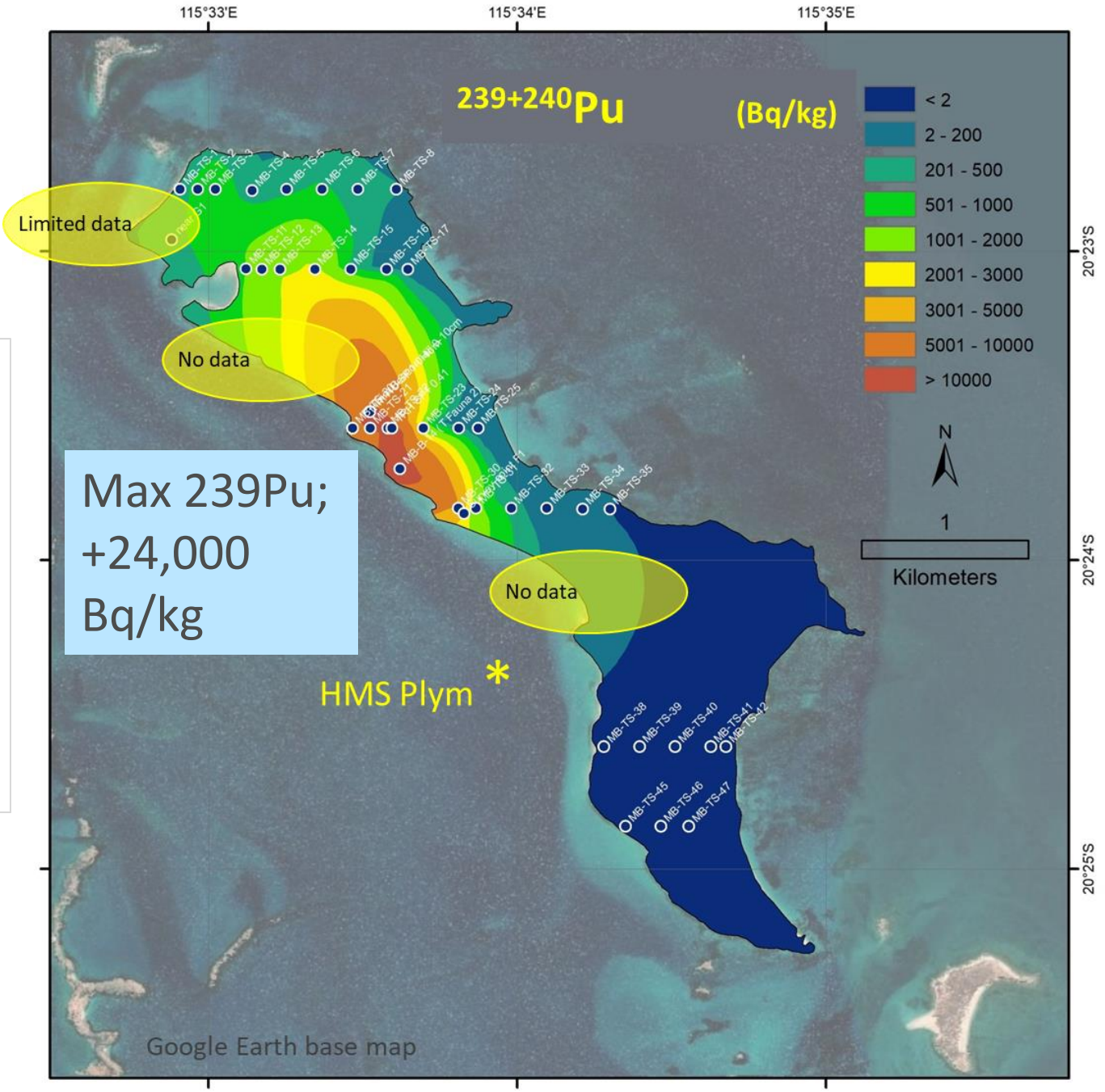
Pu persitsts on Trimouille Island from the Hurricane test

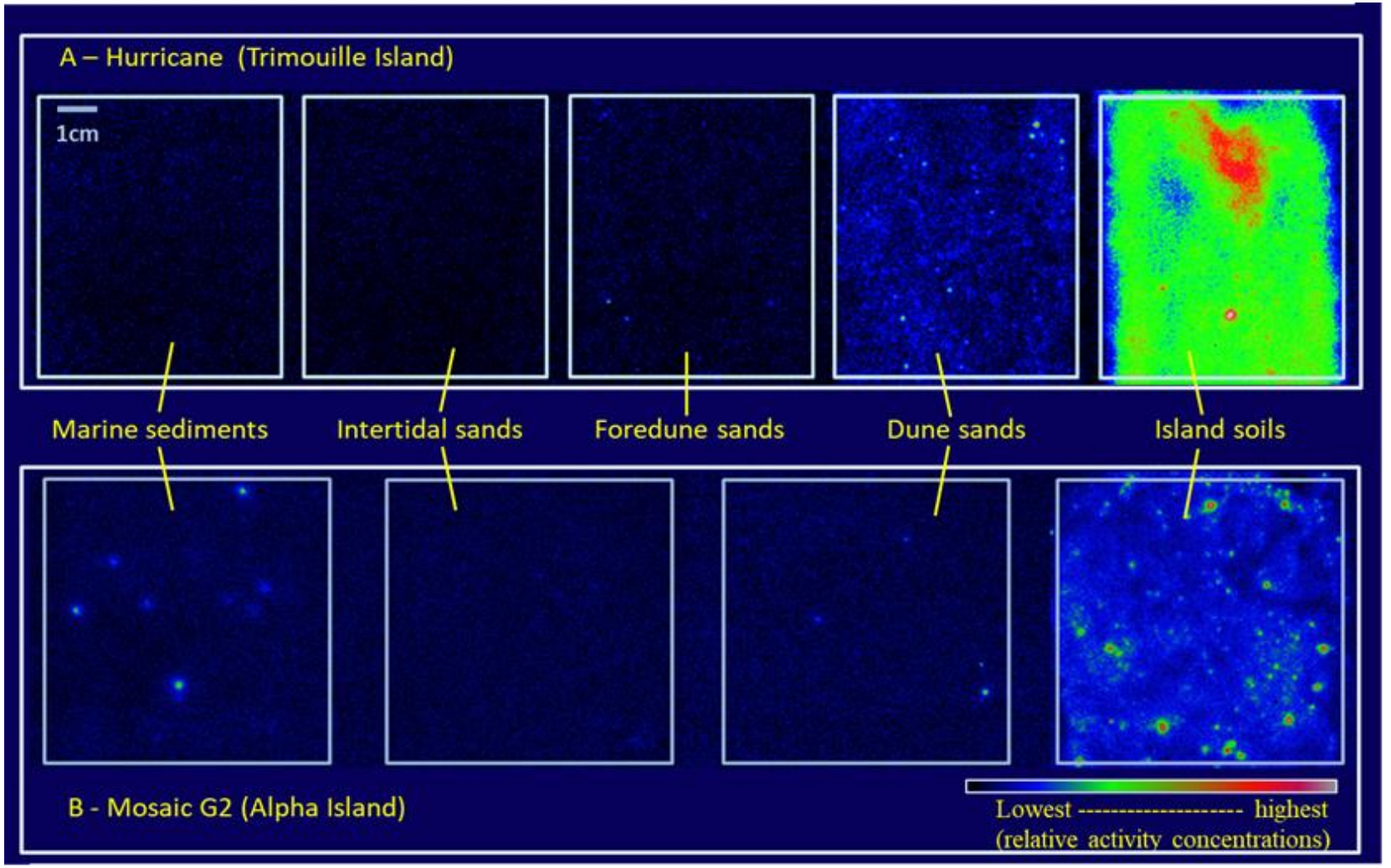
Rough-scale comparison of <5 km Pu activity concentrations w/Chernobyl.

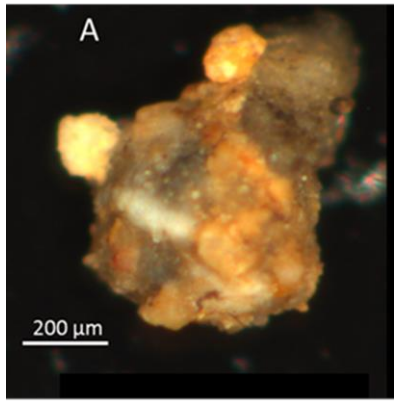


Of course the Bq/kg values vary with distance and direction



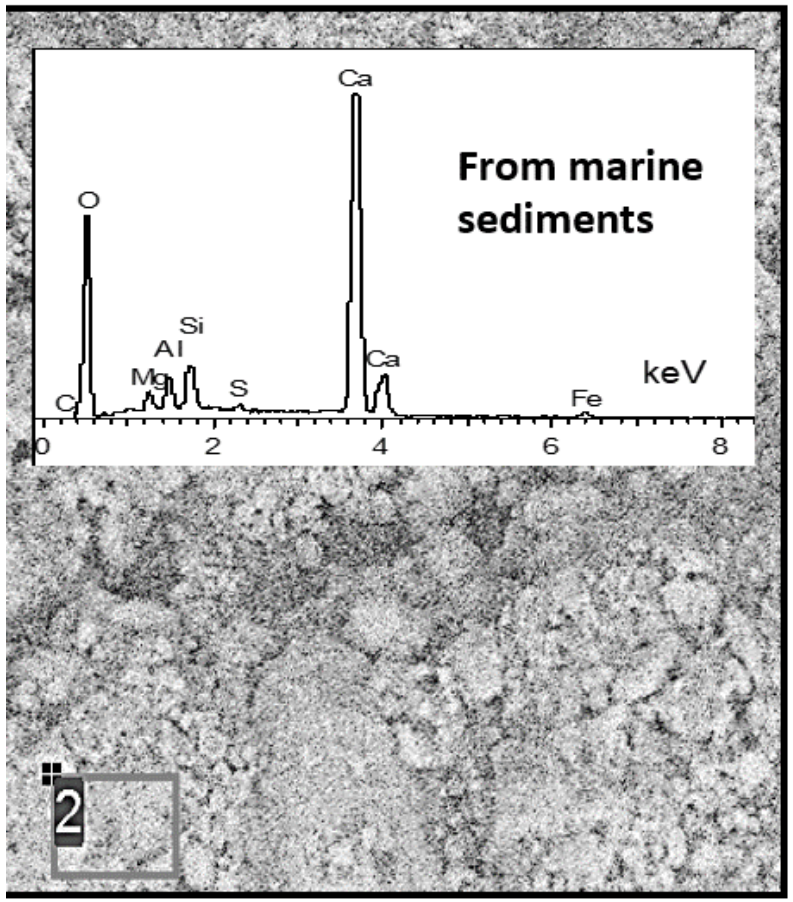
Bq/kg along transects (marine sediments-to-terrestrial soils, Hurricane (ship) vs Mosaic G2 (tower)

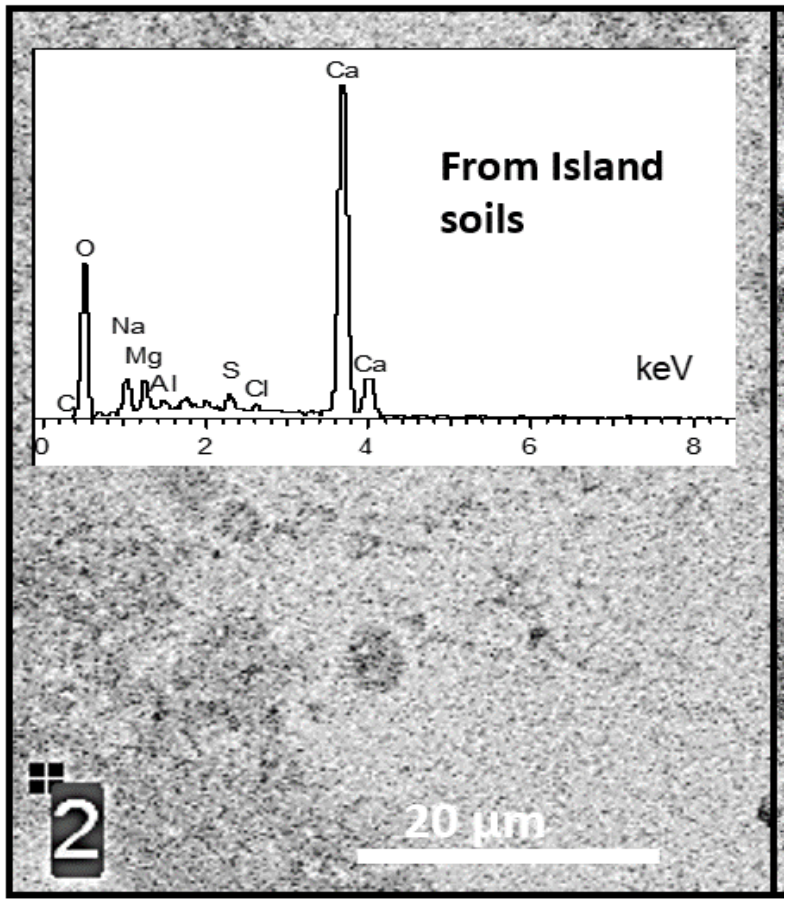


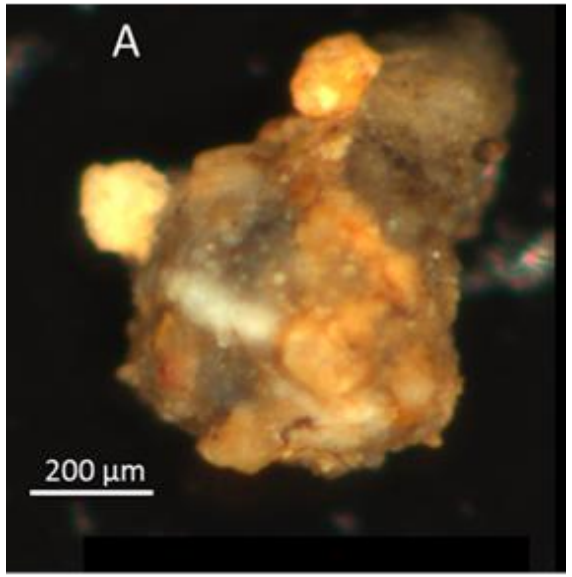


Autoradiography of soils from two nuclear test deposition areas in the Montebello islands, Australia. Top (A) is from the Hurricane deposition site near Red Beacon Hill on Trimouille Island. The bottom (B) is from the Mosaic G2 site, Alpha Island (from Johansen et al. 2019).

SEM on two Mosaic G2 (tower) particles: retrieved from terrestrial vs marine







Protective coatings and composition (Fe vs Ca vs Si) are important for persistence/weathering; long-term shedding of radionuclides into the general environment.

SEM backscatter electron image and SEM-EDS spectra from the surface coatings of PT-3 from island soils (left,) and a similar comparison particle retrieved from nearby marine sediments (right). Both particles are from the same Mosaic G2 test, Montebello Islands and have very similar compositions, but differ in the amount of weathering. Small areas are shown here, and these are representative of the broader surrounding surface areas.

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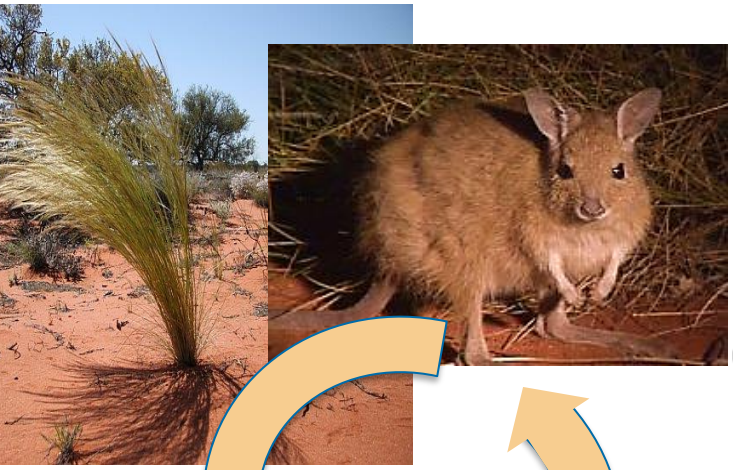
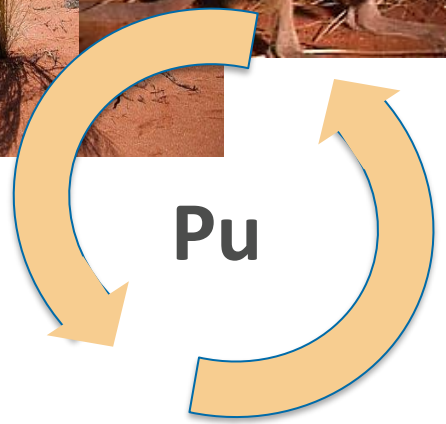
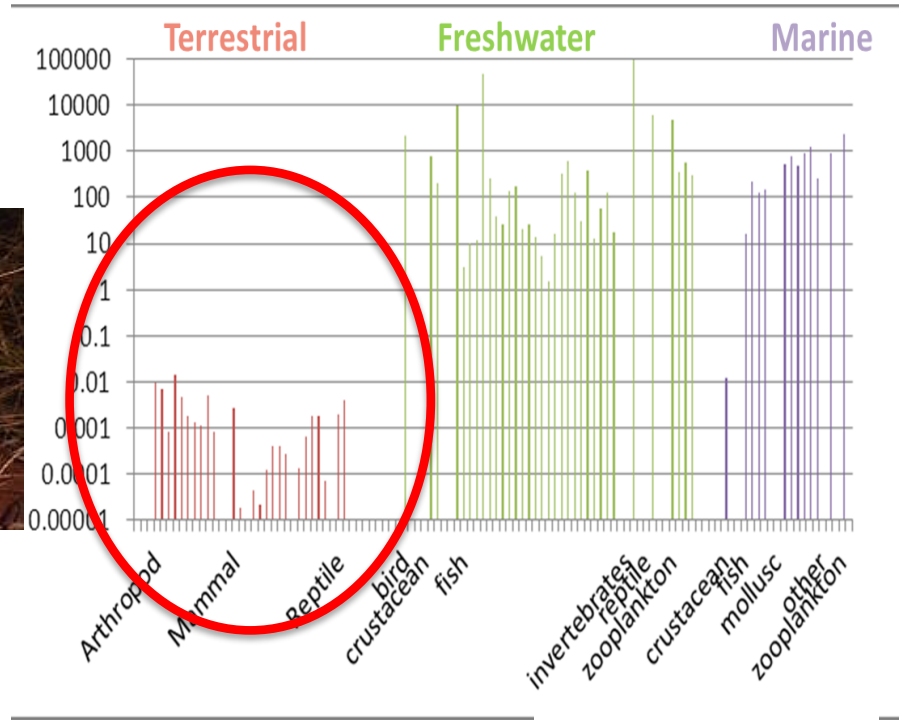
Montebello Islands – Biota uptake





Ratio of Pu in Animals to Pu in Soil or Water



Johansen et al., 2012

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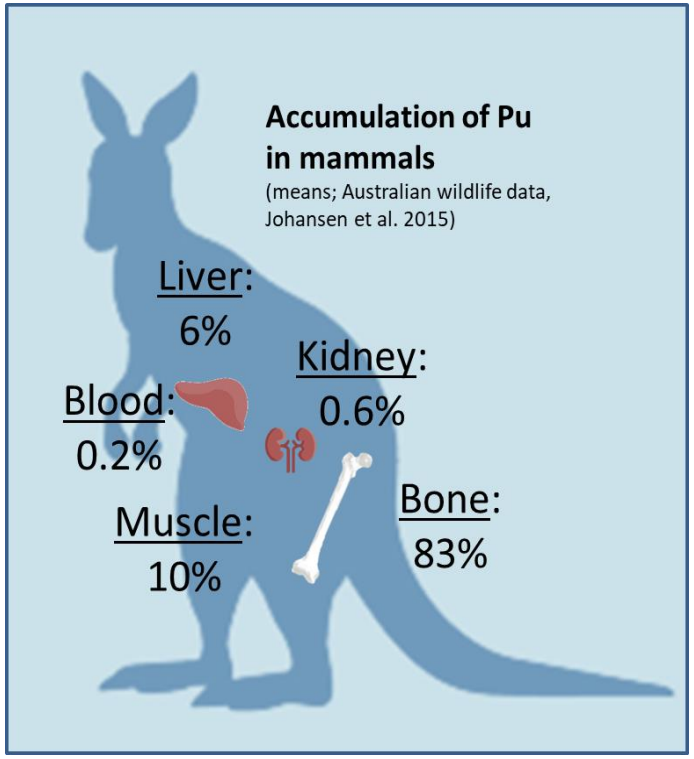
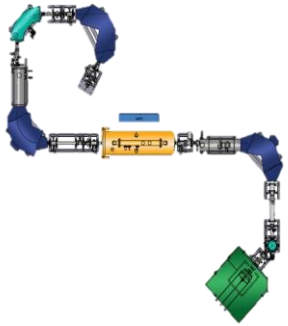


Data from Johansen et al., 2015

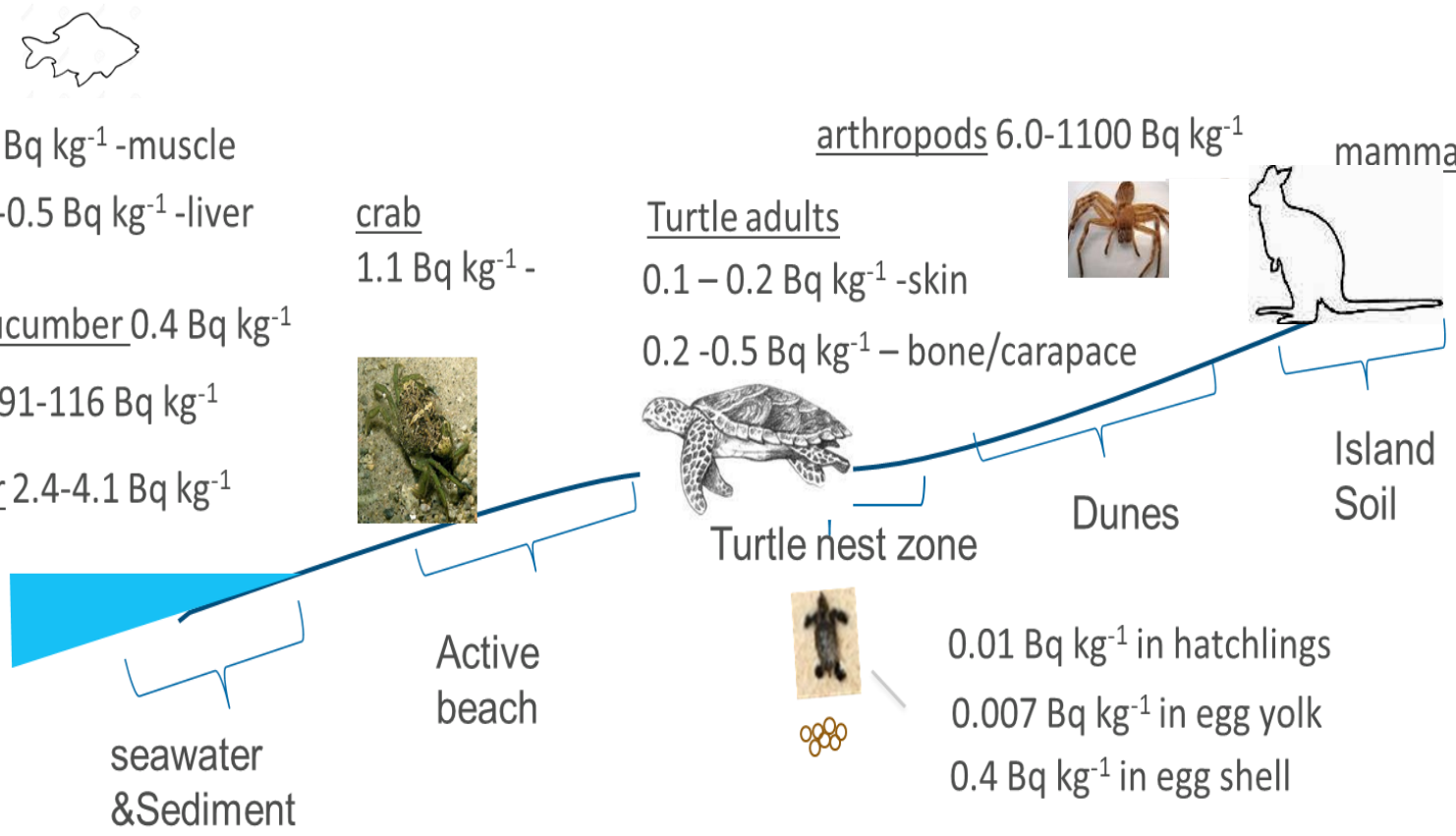
VEGA 1MV AMS system: Actinide Specialised



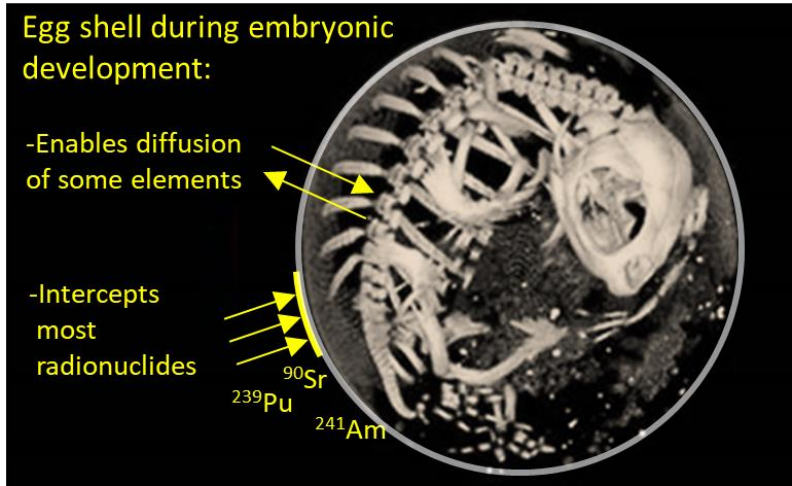
Using Pu isotopes to evaluate uptake in biota at the Montebello Islands former Nuclear test sites

Montebello Islands – Pu from 1950s testing persists in all local biota example

Pu in biota



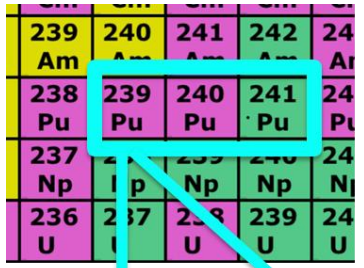
Using data in biota and human-health dose assessments (ERICA and RESRAD).

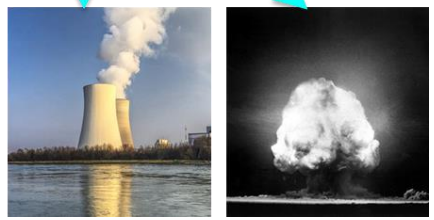


How do we know where the Pu came from?

Sort out the Pu sources using:

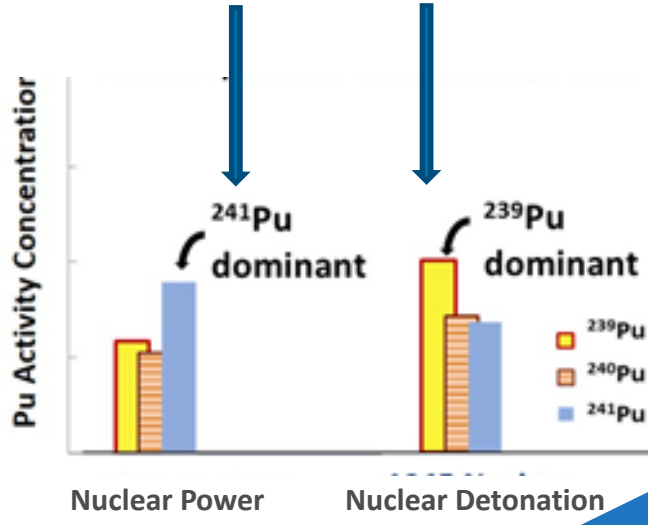
- ^{239}Pu
- ^{240}Pu
- ^{241}Pu



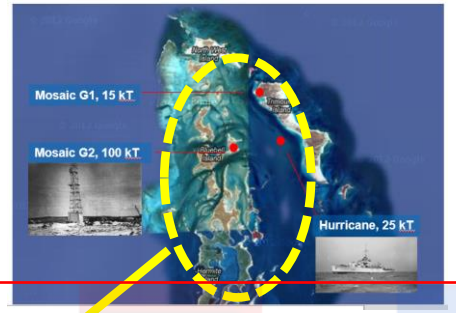


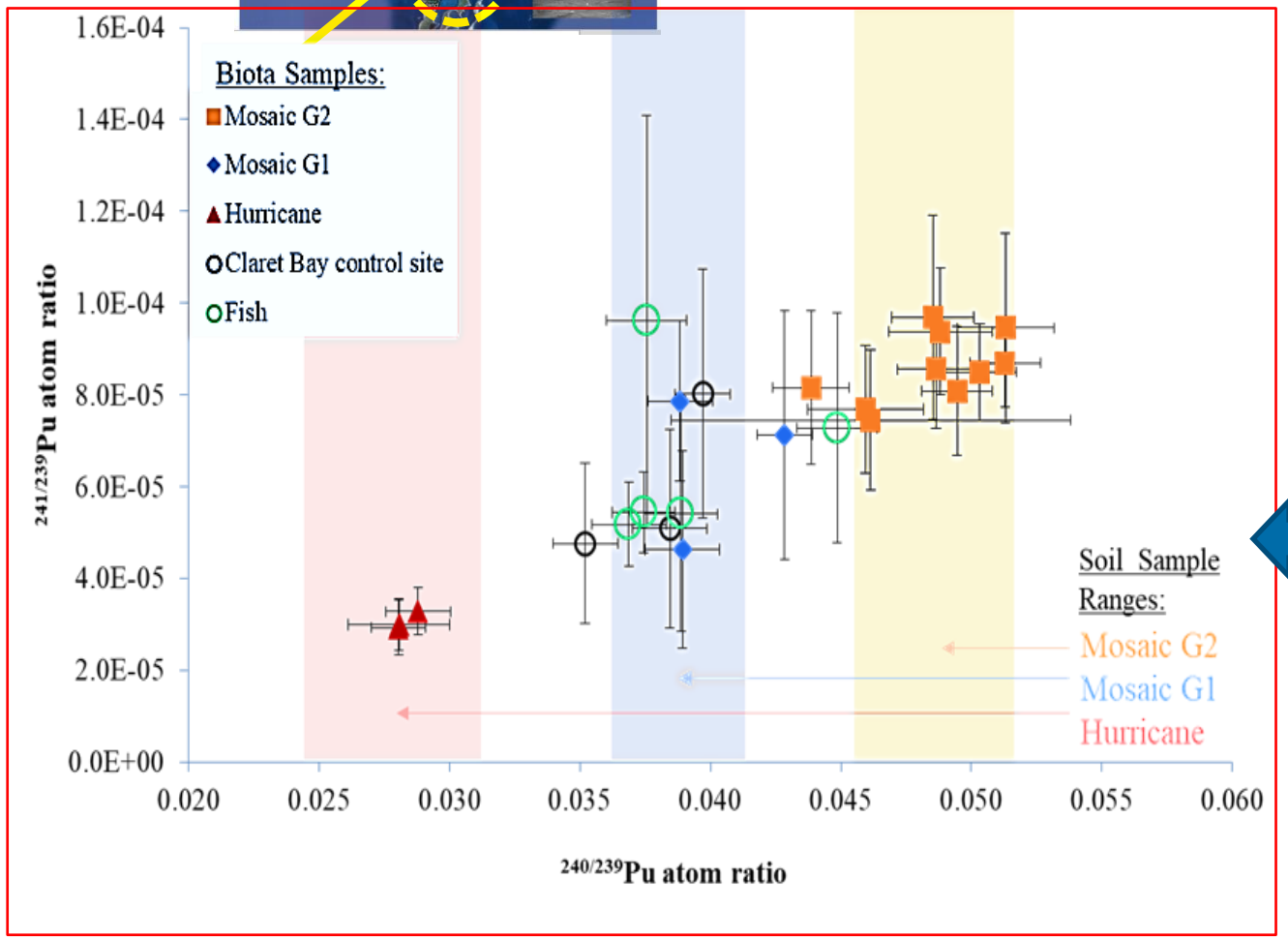
Determine atom ratios:

- $^{240}Pu/^{239}Pu$
- $^{241}Pu/^{239}Pu$



nuclear test sources are distinct.





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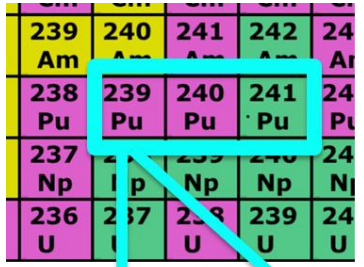

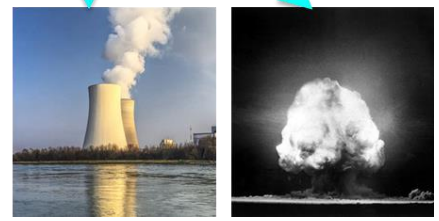

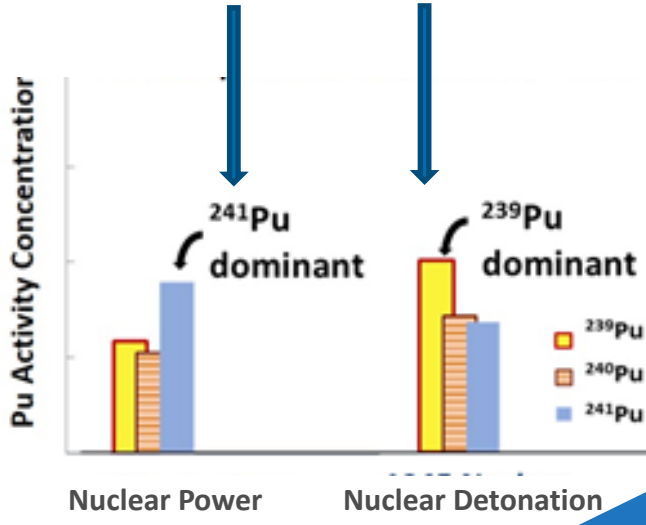

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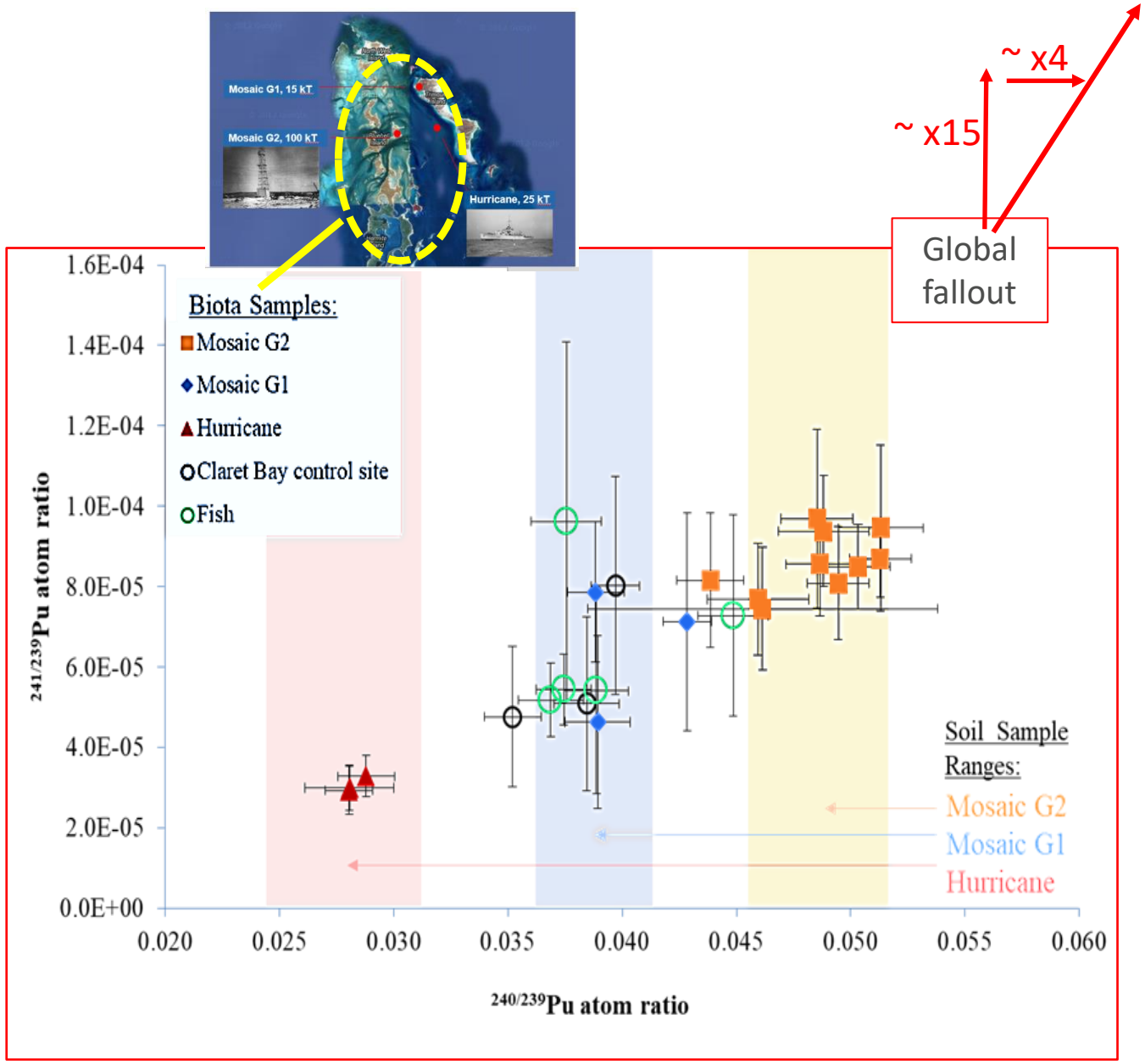

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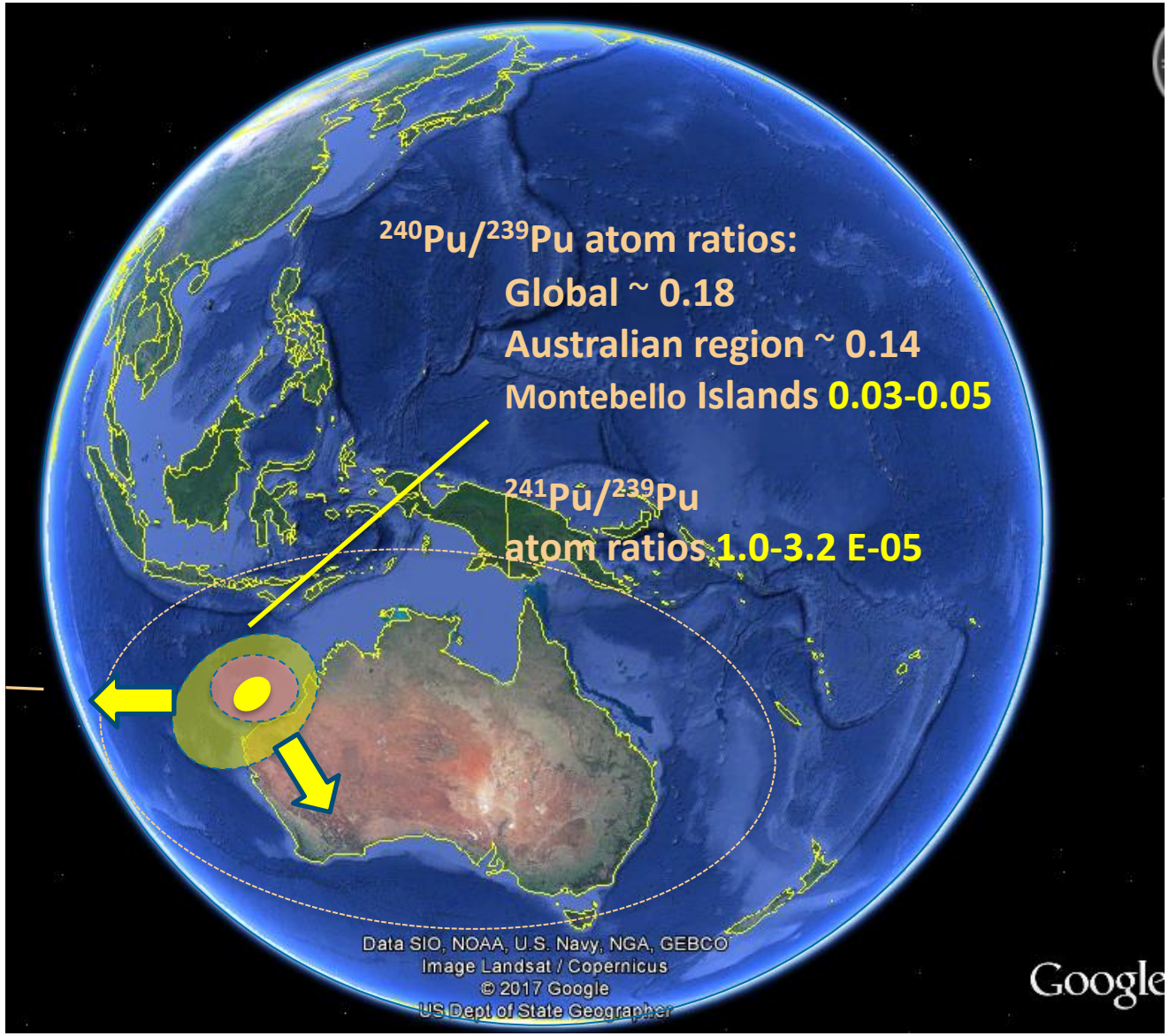
At Montebello:

- Local scale: Pu isotopes from the three nuclear test sources are distinct.
- The Pu in all marine and terrestrial organisms is predominantly from weapons tests (~ > 90%)
- Large scale: Relative to global fallout, the $^{241}Pu/^{239}Pu$ atom ratios had greater separation.



Distinct Pu isotope source:

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- The Pu in all marine and terrestrial organisms is predominantly from weapons tests (~ > 90%)
- Large scale: Relative to global fallout, the $^{241}Pu/^{239}Pu$ atom ratios had greater separation.
- Larger scale: The combined Pu isotopic signature of the Montebello sources is very low relative to hemisphere/global values.

Sources: Livingston et al., 1975; Kelly et al. 1999; Tims et al., 2013, Child and Hotchkis, 2013, Johansen et al. 2019,2020.

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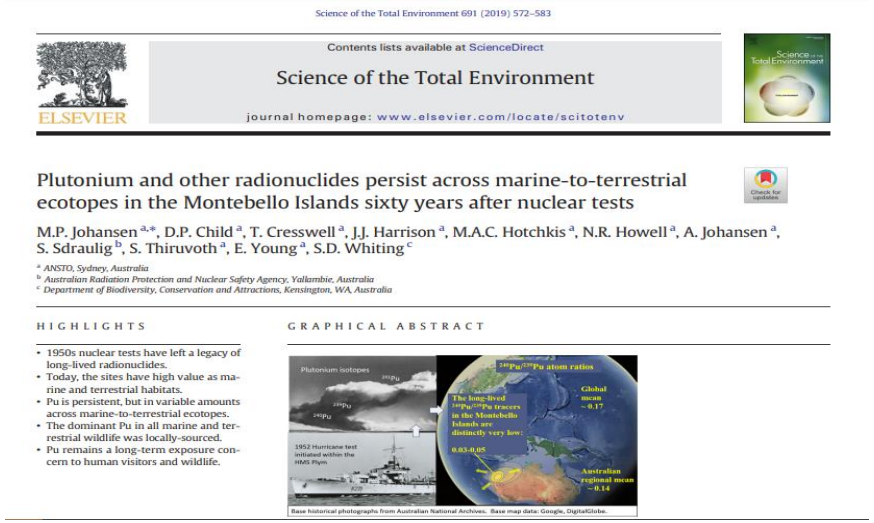
At Montebello:



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Plutonium and other radionuclides persist across marine-to-terrestrial ecotopes in the Montebello Islands sixty years after nuclear tests

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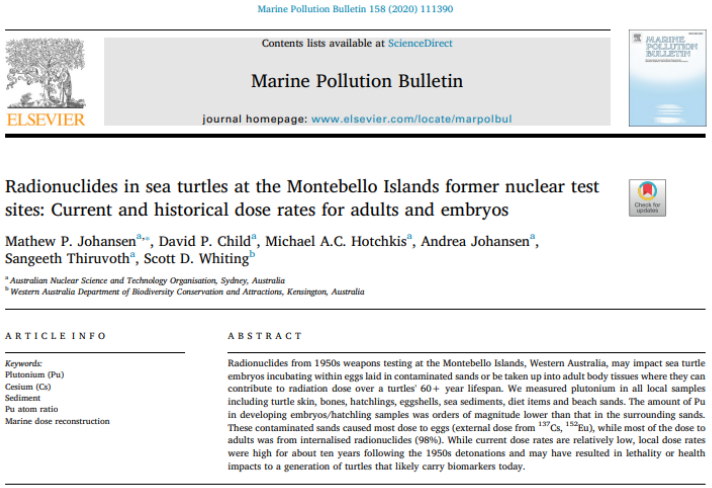
[a] ANSTO, Sydney, Australia
[b] Australian Radiation Protection and Nuclear Safety Agency, Yallambie, Australia
[c] Department of Biodiversity, Conservation and Attractions, Kensington, WA, Australia

HIGHLIGHTS

- 1950s nuclear tests have left a legacy of long-lived radionuclides.
- Today, the sites have high value as marine and terrestrial habitats.
- Pu is persistent, but in variable amounts across marine-to-terrestrial ecotopes.
- The dominant Pu in all marine and terrestrial wildlife was locally-sourced.
- Pu remains a long-term exposure concern to human visitors and wildlife.

GRAPHICAL ABSTRACT

Base historical photographs from Australian National Archives. Base map data: Google, DigitalGlobe.



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Radionuclides in sea turtles at the Montebello Islands former nuclear test sites: Current and historical dose rates for adults and embryos

Mathew P. Johansen [a,*], David P. Child [a], Michael A.C. Hotchkis [a], Andrea Johansen [a], Sangeeth Thiruvoth [a], Scott D. Whiting [b]

[a] Australian Nuclear Science and Technology Organisation, Sydney, Australia
[b] Western Australia Department of Biodiversity Conservation and Attractions, Kensington, Australia

ARTICLE INFO

Keywords:
Plutonium (Pu)
Cesium (Cs)
Sediment
Pu atom ratio
Marine dose reconstruction

ABSTRACT

Radionuclides from 1950s weapons testing at the Montebello Islands, Western Australia, may impact sea turtle embryos incubating within eggs laid in contaminated sands or be taken up into adult body tissues where they can contribute to radiation dose over a turtles' 60+ year lifespan. We measured plutonium in all local samples including turtle skin, bones, hatchlings, eggshells, sea sediments, diet items and beach sands. The amount of Pu in developing embryos/hatchling samples was orders of magnitude lower than that in the surrounding sands. These contaminated sands caused most dose to eggs (external dose from ^{137}Cs, ^{152}Eu), while most of the dose to adults was from internalised radionuclides (98%). While current dose rates are relatively low, local dose rates were high for about ten years following the 1950s detonations and may have resulted in lethality or health impacts to a generation of turtles that likely carry biomarkers today.

- Pu persists at all sites, with:
  Mosaic G1<Mosaic G2i<<Hurricane
- Sensitive AMS Pu measurements were made on a variety of tissues (pref bones, but also on wide range of challenging samples).
- Outcomes were best when applying both ^{240}Pu/^{239}Pu and ^{241}Pu/^{239}Pu atom ratios.
- Provided new reference data for use in ocean and atmospheric tracer studies.
- Answered questions on dose rates to the biota and humans.
- Supported health and safety practices for researchers, public and decision makers.

Thank you.

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