

# **Barrytown Minerals Project**

## **Fast-track application**

### **Expert Report of John Phillip Bradley, PhD for the Coast Road Resilience Group**

### **Barrytown Radiation Geophysical Assessment**

September 26, 2026

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Appendix: Curriculum vitae of John Phillip Bradley, PhD

## 1. Introduction

1. My name is John Phillip Bradley. I am a geoscientist with the University of Hawaii. I am also an Affiliate Faculty Scientist at the National Center for Electron Microscopy at Lawrence Berkeley Laboratory in California.
2. I have more than 300 publications in the peer-reviewed scientific literature, including 25 in the international journals *Science* and *Nature* (11 as first author, 5 journal covers) and 3 in the *Proceedings of the National Academy of Science (PNAS)*.
3. I hold a MSc (1978) from the University of Canterbury in Christchurch. The subject of my thesis research was heavy minerals which I collected from rivers and beaches along the West Coast of the South Island <sup>1</sup>. My interest in pursuing heavy minerals research was a result of pre-university employment with a beach sand mining company in northern NSW, I also hold a PhD (1982) from Arizona State University.
4. During the past 40 years I have been employed in industry (Senior Research Scientist (McCrone Institute, Chicago), Government (Director, Institute for Geophysics and Planetary Physics, Lawrence Livermore National Security), and academia (Professor, University of Hawaii).
5. Much of my career has been associated with nuclear materials and radiation, including environmental aspects of radioactive materials disposal and radiation physics in space <sup>2</sup>. An abbreviated CV is appended to this report.
6. I was born in Greymouth and have visited the Barrytown Flats site the subject of this Fast-track application, as well as other sites with a similar rock composition

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<sup>1</sup> J. P. Bradley, C. J. Wilkins, W. Oldershaw, D. Smale, 1979. "A Study of Detrital Heavy Minerals in the Taramkau Catchment." *J. Roy. Soc. New Zealand* **9**, no. 2: 233–251. <https://doi.org/10.1080/03036758.1979.10419414.sssl>.

J. P. Bradley, M. P. Chew, C. J. Wilkins, 2002. "Transport and Distribution of Magnetite and Ilmenite on Westland Beaches of New Zealand; with Comment on the Accumulation of Other High- Density Minerals." *J. Roy. Soc. New Zealand* **32**, no. 1: 169–181. <https://doi.org/10.1080/03014223.2002.9517689>.

<sup>2</sup> Ref 3-6 A Abrajano et al., (two of them) and Bates et al

along the West Coast of New Zealand numerous times since childhood, throughout my university studies and following that. I have studied the naturally occurring radioactive minerals (NORMs) from the West Coast since the 1970s.

7. I was engaged by the Coast Road Resilience Group to prepare a report on the mineral sands at the site the subject of the Barrytown Minerals Project Fast-track proposal (Proposal).

## **2. Code of conduct**

8. I have read the Expert Witness Code of Conduct contained in the High Court Rules 2016 and agree to be bound by it.

## **3. Naturally occurring radioactive minerals (NORMS)**

9. NORMS can be found in rocks, rivers, beaches and soils throughout the world. Their radioactivity is due to the presence of fissionable elements like thorium and uranium made up of isotopes. For example, uranium has three isotopes (U-238, U-235 and U-234) and thorium has six, all of which are unstable to varying degrees, so over time they slowly decay into other radioactive elements, including radium and radon (a gas). The series of decays is known as the “decay chain” and it emits radiation. In other words, in addition to uranium and thorium, their radioactive decay products also emit radioactivity. Thus, the detected radioactivity is the sum of the contributions of the parent uranium and thorium isotopes plus their daughter isotopes in the decay chains. Thus, knowing only the amounts of uranium and thorium in a sample does not mean their total radioactivity is known.

## **4. NORMS at Barrytown**

10. NORMs are present in Barrytown and are present within the site which is the subject of this Proposal. This is public knowledge. In 1991, the New Zealand *Listener*

published an article about Barrytown entitled “Hot Sands”. The title refers to then already well-known radioactivity, and the article explores the local community’s concerns about the effects of large-scale mining<sup>3</sup>.

11. By any metric, the levels of radioactivity at Barrytown are significant and actionable. A 2008 airborne geophysics survey commissioned by the NZ Ministry of Economic Development, Crown Minerals, recorded strong above-background radioactivity over the Barrytown Flats, with a maximum above background of *"well over 4000 counts/second"*<sup>4</sup>. The Survey notes that such a high level of radioactivity at Barrytown is surprising because, *"ten centimeters of soil and/or alluvium is sufficient to extinguish the radiometric signal."* The highest response was observed at the location of former dredging activity, as seen in the map below showing the distribution (red areas on the map).

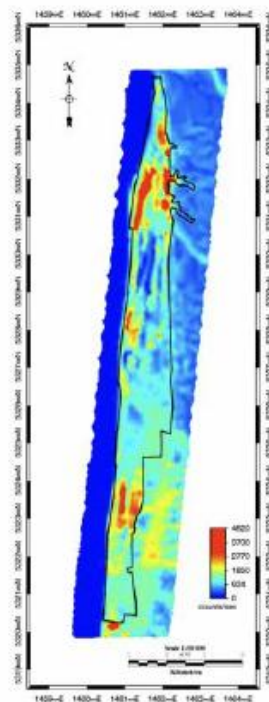


Figure 13: Total Count response

Figure 1: map showing radioactivity survey findings

<sup>3</sup> B. Ansley and B. Foster, 1991. Hot sands. *Listener and TV Times*. pp. 17-28.

<sup>4</sup> P. Vidanovich, 2008, p17. Barrytown airborne geophysics survey. *Min. Rep. Ser. MM4438*. Ministry of Economic Development, Crown Minerals. 73 pp (<https://geodata.nzpam.govt.nz/dataset/>)

12. In my professional opinion this is to be expected for the reasons stated in the Survey: "*This is to be expected since the mining removed the overlying outwash sediments, soils etc. revealing the heavy mineral sands beneath.* In other words, the airborne geophysics survey demonstrated that mining activity leads to increased radioactivity associated with heavy minerals.
13. This is confirmed by numerous publications in the peer-reviewed literature, at least three of which caution about the radiological health and regulatory implications of mining the radioactive heavy minerals at Barrytown <sup>5</sup>.
14. There are at least 10 different NORMS at Barrytown that have been documented in the peer-reviewed scientific literature spanning almost a century. Like the other heavy minerals, the Barrytown NORMs originated mostly in Westland rivers and streams, washed down to the coast and transported north by longshore drift, and finally concentrated by tide and wave action at Barrytown.
15. The most recent study of the NORMS in Barrytown is the paper entitled "*Radiological Properties of Heavy Minerals in the Beach Sand Placer at Barrytown, New Zealand*" authored by myself and colleagues at the Center for Advanced Materials Characterization at the University of Oregon <sup>6</sup>. The paper is published in the *New Zealand Journal of Geology and Geophysics (NZJG&G)*. Prior to acceptance by *NZJG&G*, it was reviewed by five independent reviewers within New Zealand.
16. We examined several samples from Barrytown, including a dredge sample from the heavy minerals collection of the late pioneering New Zealand geologist, C. O Hutton, archived at Stanford University in California, and a rare earth mineral

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<sup>5</sup> C. H. Wells and R. C. Haverkamp, 2020. Characterization of the Heavy Mineral Suite in a Holocene Beach Placer, Barrytown, New Zealand. *Minerals* **10**, 86–101; S. J. Tay, J. M. Scott, M. C. Palmer, M. R. Reid, C. H. Stirling. 2021. "Occurrence, Geochemistry and Provenance of REE-Bearing Minerals in Marine Placers on the West Coast of the South Island." *NZ. J. Geol. Geophys.* **64**, 89-106.

<https://doi.org/10.1080/00288306.2020.1736585>; and

J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) Radiological properties of heavy minerals in the beach sand placer at Barrytown, New Zealand. *NZ. J. Geol. Geophys.* **69**, 1-6. <https://doi.org/10.1002/jgo2.70050>.

<sup>6</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026)

concentrate produced by Westland Minerals <sup>7</sup>. To identify which NORMS are present and their radioactivity, the dredge concentrate (HMC) was passed through a device that uses magnetic susceptibility to separate the minerals into concentrates. Although some minerals have overlapping magnetic properties, individual magnetic fractions enriched respectively in ilmenite, garnet, zircon (plus gold) and NORMS were separated and the radioactivity of each was measured; one of the NORMS, zircon, magnetically separated out from the other NORMS (Table 1). Compositional and mineralogical examinations of NORMS grains were carried out using an electron microscope (Fig. 1).

| Line |               | Magnet setting (amps) | Solids (Bq/gm) | Radon (Bq/m3) |
|------|---------------|-----------------------|----------------|---------------|
| 1    | Bulk HMC      | 0                     | 0.22           | 505           |
| 2    | Ilmenite rich | 0.25                  | 0.06           | 127           |
| 3    | Garnet -rich  | 0.45                  | 10.03          | 392           |
| 4    | Zircon-rich   | >1.2                  | 12.24          | 1937          |
| 5    | NORMS-rich    | 0.75 - 1.2            | 53.26          | 7949          |

**Table 1:** Radioactivity of the heavy minerals (solids) and gas (radon). Values in red exceed regulatory and/or recommended safety thresholds. (The toxicities of Radon and NORMS are discussed in Section 6).

17. As shown in Table 1, radioactivity of the bulk (prior to separation) HMC and the ilmenite-rich fraction are below the New Zealand (10 Bq/gm) and International Atomic Energy Agency (1 Bq/gm)<sup>8</sup> thresholds for the solids, but radon is above the recommended level of 100-300 Bq/m3<sup>9</sup>. Unlike many other countries, New Zealand does not have a statutory safe limit for radon; these values are recommendations

<sup>7</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) Radiological properties of heavy minerals in the beach sand placer at Barrytown, New Zealand. *NZ. J. Geol. Geophys.* **69**, 1-6. <https://doi.org/10.1002/jgo2.70050>.

<sup>8</sup> IAEA. 2014. *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards* (GSR Part 3). ([https://nucleus-apps.iaea.org/nss-oui/Content/Index?CollectionId=m\\_3761d926-c16f-4477-a63b-741a9db1c16c&type=PublishedCollection](https://nucleus-apps.iaea.org/nss-oui/Content/Index?CollectionId=m_3761d926-c16f-4477-a63b-741a9db1c16c&type=PublishedCollection))

<sup>9</sup> Health New Zealand. 2026. Radon <https://www.healthnz.govt.nz/health-topics/keeping-healthy/healthy-homes-environments/hazardous-substances/radon>

from the World Health Organisation<sup>10</sup>. MoH<sup>11</sup> and WHO recommends to keep levels as low as possible<sup>12</sup>. (Table 1, line 1 & 2). The garnet-rich fraction is at the New Zealand threshold of 10 Bq/gm<sup>13</sup> for the solids (NORMS), and radon is 4 times the internationally recommended threshold (Table 1, line 3). Zircon concentrate exceeds both the New Zealand and IAEA thresholds for the solids and radon is approximately 4 times the recommended threshold level (Table 1, line 4). (Zircon contains between 1 and 5 weight percent uranium and thorium).

18. The highest readings are from the NORMS-rich fraction (Table 1, line 5) and examination of this fraction using electron microscopy showed it to be the richest in NORMS, including the minerals thorite, uranothorite, uraninite, and monazite. These four minerals are rich in thorium and uranium, the source of most of the radioactivity at Barrytown. The solids in the NORMS-rich fraction are 5 times the New Zealand limit and radon is almost 80 times the recommended threshold.

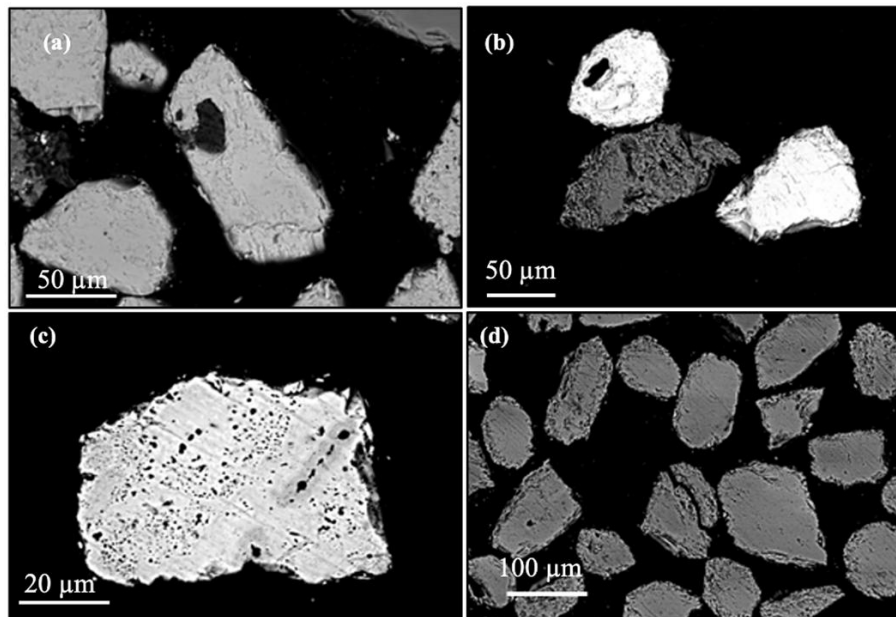


**Figure 2:** Scanning electron microscope images. (a) Monazite. (b) Thorite (c) Uranothorite. (d) Zircon. The ragged (etched) grain surfaces and interiors are a result of in-situ

<sup>10</sup> <https://www.who.int/news-room/fact-sheets/detail/radon-and-health>

<sup>11</sup> Health New Zealand. 2026. Radon <https://www.healthnz.govt.nz/health-topics/keeping-healthy/healthy-homes-environments/hazardous-substances/radon>

<sup>12</sup> *Ibid* Health New Zealand. 2026. Radon. <https://info.health.nz/health-topics/keeping-healthy/healthy-homes-environments/hazardous-substances/radon>

<sup>13</sup> Bq = Becquerel, a measurement of the activity of a radioactive substance or material, and 1 becquerel equals one radioactive decay (disintegration of an atomic nucleus) per second.

*weathering (leaching) and radiation damage (internal holes) within the saturated beach sand deposit at Barrytown.*<sup>14</sup>

19. The most radioactive NORMS are uranothorite, thorite, uraninite, monazite and zircon. Monazite is especially noteworthy because in addition to being radioactive, it contains uranium and thorium and is also rich in rare earth elements (~50 weight %). The rare earths are among the most sought-after critical metals. In the 1970's, Carpentaria Exploration investigated the economic potential of the monazite at Barrytown. The project did not proceed beyond a pilot-scale study, and while economics were a primary driver, the high radioactivity of monazite was another<sup>15</sup>. A "Radiation Hazard" sign has remained posted within the former pilot plant (Fig. 3). The market price of monazite *circa* 1970 was ~\$250/tonne, its current price today, depending on grade (purity), is between \$6000 and \$18,000/tonne.



**Figure 3:** Radiation hazard sign posted in the former pilot plant at Barrytown.

20. It is unclear from this application if the Proposal is also to mine and process rare earth minerals. Without this information, it would be difficult to assess the effects of the Proposal on the environment and take effective steps to address those effects.

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<sup>14</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) <https://doi.org/10.1002/jgo2.70050>

<sup>15</sup> Personal communication, Alan Beck, Carpentaria Exploration Ltd., *circa* 1977

## 5. Radon

21. Radon is a colorless, odorless gas, and a radioactive decay product of uranium, thorium and radium, the latter a highly radioactive metal produced together with radon during the radioactive decay of uranium and thorium.
22. Where there are NORMS there is radon. Radon levels fluctuate but radium doesn't fluctuate with radon because, whereas radium accumulates in groundwaters, radon accumulates in air. There is a strong seasonal effect with the highest radon levels in winter months when atmospheric pressures are low, causing a vacuum effect that pulls radon out of the ground to the surface. Ground water also affects atmospheric radon levels; in wet climates like Westland saturated soils and sands force radon both laterally and upwards to the surface.
23. Radon tends to accumulate in indoor spaces where it can seep into wells and buildings through foundation cracks and gaps.

## 6. Radon at Barrytown

24. The first such measurements of radon in this region of New Zealand are documented in the 2026 *NZJG&G* paper I co-authored<sup>16</sup>. The measurements were taken using commercially available home radon detectors that were installed by residents in the vicinity of the Barrytown Flats. A map of the locations compared to the Proposal site is included below.

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<sup>16</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) <https://doi.org/10.1002/jgo2.70050>

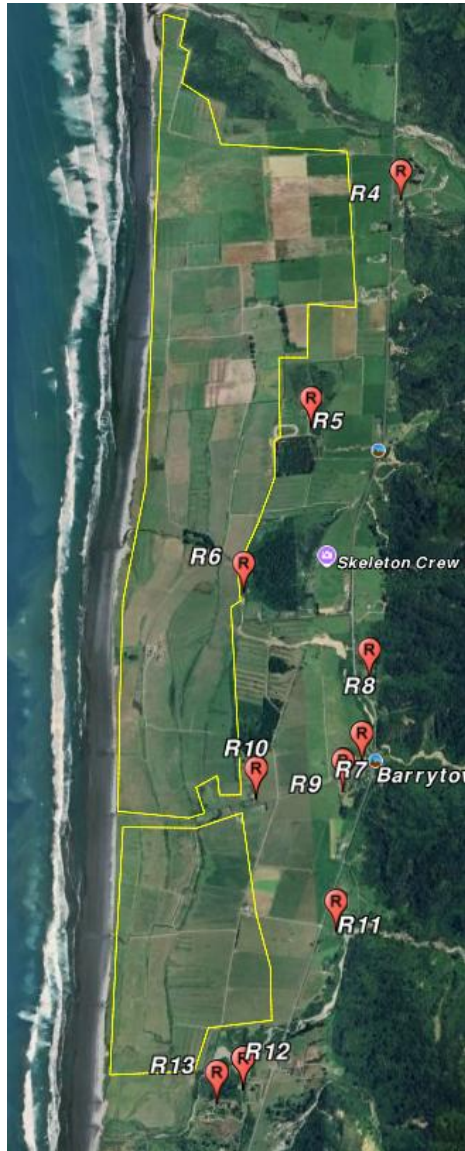


**Figure 4:** Map showing location of Radon measurement locations (red markers).

25. Indoor and underfloor measurements were taken, and the highest readings were obtained indoors. This is expected because radon is known to accumulate indoors, at the lower levels of dwellings, as it is heavier than air<sup>17</sup>. The median of all (indoor and underfloor) measurements is 63 Bq/m<sup>3</sup> (Fig. 5). These measured levels are conspicuously higher than those found in two previous studies of radon in

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<sup>17</sup> Health New Zealand. 2026. Radon <https://www.healthnz.govt.nz/health-topics/keeping-healthy/healthy-homes-environments/hazardous-substances/radon>

residences in the main population centers of New Zealand, where median radon levels were 18 to 23 Bq/m<sup>3</sup> <sup>18</sup>.

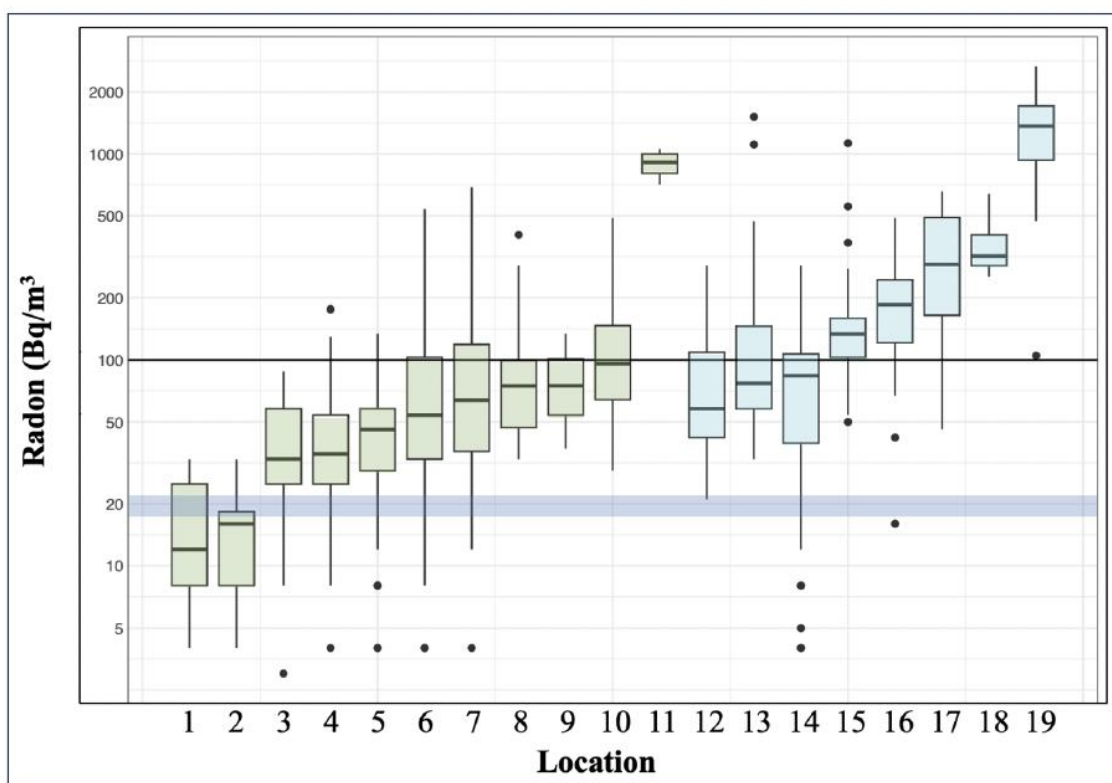


**Figure 5:** Box plot of accumulated radon incidence per 6-h (Bq/m<sup>3</sup>) from inside residential dwellings (locations 1–11, green) and below the dwelling floor levels (locations 12–19, blue). The boxes show median and interquartile range (25th and 75th percentiles), vertical lines are 1.5x interquartile range, and the dots show outliers. The median of all the data is 63 Bq/m<sup>3</sup> and the grey horizontal line indicates the range of median residential values recorded elsewhere in New Zealand, i.e. around 20Bq/m<sup>3</sup> (Health New Zealand, 2026). The horizontal black line marks the WHO recommended threshold reference level for mean radon exposure (100 Bq/m<sup>3</sup>).<sup>19</sup>

## 7. The radiation hazards at Barrytown

### Radon

26. It is well-established that NORMS and their radioactive decay products including radon pose a risk of chronic toxicity on a time scale of months to years, either by

<sup>18</sup> Health New Zealand. 2026. Radon <https://www.healthnz.govt.nz/health-topics/keeping-healthy/healthy-homes-environments/hazardous-substances/radon>

<sup>19</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) <https://doi.org/10.1002/jgo2.70050>

inhalation of gas and dust or by ingestion<sup>20</sup>. Recent findings even suggest that the risks have been underestimated<sup>21</sup>. Both uranium and thorium containing dust, and Radon adhering to dust, are vectors for inhalation. I discuss the risks from dust inhalation in a short video<sup>22</sup> I have prepared, where I use a Geiger counter to measure the radioactivity of an HMC sample from the West Coast similar to what would be present at the Proposal site.

27. Geography and climate are two important factors in risk assessment, and as discussed in Section 5 the climate and environment at Barrytown may be especially relevant. If the NORMS-containing sands are mined, handling and disposal would be additional risk assessment metrics.
28. Radon is already a potential hazard at Barrytown. It is colorless, odorless, airborne, and the second leading cause of lung cancer worldwide, with children and pregnant individuals most at risk from exposure<sup>23</sup>. The most surprising finding of the *NZJG&G* paper<sup>24</sup> is that the beach sand deposit at Barrytown is continuously venting radon gas into the atmosphere, and transient indoor radon “spikes” as high as 1000 Bq/m<sup>3</sup> have been recorded (Fig. 5).
29. New Zealand currently has no regulation concerning radon but the international limit beyond which it is recommended to “take action” is an average of 100 Bq/m<sup>3</sup><sup>25</sup>. The finding of the *NZJG&G* paper is that this limit has already sometimes been

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<sup>20</sup> ICRP 2014. Radiological Protection against Radon Exposure. *ICRP Publ. 126 Ann. ICRP* 43(3) 73pp <https://www.icrp.org/publication.asp?id=ICRP+Publication+126>; H. Zeeb and F. Shannoun (Eds), 2009. WHO handbook on indoor radon: a public health perspective. p110 <https://www.who.int/publications/i/item/9789241547673>; G. P. Verm, A. C. Patra, K. A. Dubey, S. K. Sha, and D. K. Aswal, 2026. Towards harmonized global approaches to NORM regulation: review of practices and policy perspectives. *Radiat. Environ. Biophys.* **6**, 57-66. <https://doi.org/10.1007/s00411-026-01209-8>. A further reference is: <https://www.westernhealthandsafety.com/naturally-occurring-radioactive-materials.html>

<sup>21</sup> S. G. Hewson, I. R Martin, M. Cattani, 2025. Are we underestimating exposures from NORM dust? *Ann. Work Expo Health* Sep 26;69(8):820-831. <https://doi.org/10.1093/annweh/wxaf043>.

<sup>22</sup> The video can be accessed here:

<https://drive.google.com/file/d/1Sfr2Yf57H4qKBs3BoQZC12xhjqBsd06z/view?ts=6ab84be8>

<sup>23</sup> <https://www.westernhealthandsafety.com/naturally-occurring-radioactive-materials.html>

<sup>24</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) <https://doi.org/10.1002/jgo2.70050>

<sup>25</sup> ICRP 2014. Radiological Protection against Radon Exposure. *ICRP Publ. 126 Ann. ICRP* 43(3) 73pp; H. Zeeb and F. Shannoun (Eds), 2009. WHO handbook on indoor radon: a public health perspective. pp110.

exceeded even without mining, and forms part of the existing environment at Barrytown.

### **Mitigation for radon**

30. Once actionable levels are detected indoors, radon is readily mitigated through simple measures like good ventilation, indoor fans, an underfloor vapor barrier and, most importantly, inexpensive home radon detector for continuous indoor monitoring.
31. Mitigation of radon first requires awareness of its presence. This includes year-round radon measurements, necessary because of wide seasonal variations which are typical.<sup>26</sup> In regions of Europe and North America, radon monitors are now mandatory in new commercial construction, highly recommended in homes, and measurements are mandatory in real estate transactions. Residents and businesses in and around Barrytown should be encouraged to install inexpensive radon detectors in dwellings.

### **Effects from the proposal on radon emissions**

32. Mining will only exacerbate that hazard, because excavating will agitate, decompact, and dewater the sands, expose their surfaces and enhance escape of radon into the atmosphere.
33. The Proposal does not acknowledge, much less address, radon, either as part of the existing environment or any effects the Proposal will have on radon levels or proposed mitigation action to address radon.

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<sup>26</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) <https://doi.org/10.1002/jgo2.70050>

## NORMs

34. The other potential hazard is the NORMS themselves which are found in the mineral sands that are proposed to be mined under the Proposal.
35. The New Zealand threshold for such material to be considered radioactive is 10 Becquerels per gram (10 Bq/gm) and the international threshold is 1 Bq/gm<sup>27</sup>. As shown in in Table 1, radioactivity of three of the five magnetic separates exceeds the New Zealand threshold<sup>28</sup>.
36. The finding that NORMS are being leached and dissolved in the saturated deposit is a key hazard assessment metric<sup>29</sup>, because it means their radioactive dissolution products are escaping into waterways.
37. High rainfall facilitates transport and migration of NORMS as undissolved sediments, where they too can contaminate waterways and wells.
38. The local hydrology may be an additional factor because waters high in organic matter like those on the West Coast are known to facilitate leaching (aqueous alteration) of minerals <sup>30</sup>, and the NORMS we examined in the electron microscope show clear evidence of leaching (aqueous alteration) (Fig. 2). Even monazite and zircon, known to be especially stable against leaching, show evidence of leaching. Radioactive metals like uranium and thorium were long assumed to be sparingly or relatively insoluble in water, but in a study funded by the US Department of Energy's Yucca Mountain project we found that leaching produces soluble (radioactive) colloids that enhance their dispersal into the environment <sup>31</sup>.

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<sup>27</sup> See MoH discussion on radon <https://www.healthnz.govt.nz/health-topics/keeping-healthy/healthy-homes-environments/hazardous-substances/radon>

<sup>28</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) <https://doi.org/10.1002/jgo2.70050>

<sup>29</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026) <https://doi.org/10.1002/jgo2.70050>

<sup>30</sup> J. I. Drever and G. F. Vance (1994) The role of soil acids in mineral weathering processes. In *Organic acids in Geological processes*, E. D. Pittman *et al.*, Eds. Springer Verlag berlin Heidelberg. pp 138-161.

<sup>31</sup> J. K. Bates, J. P. Bradley, A. Teetsov, C. R. Bradley, M. B. ten Brink, 1992. Colloid Formation during Waste Form Reaction: Implications for Nuclear Waste Disposal. *Science* **256**: 649–651.

## Effects from the proposal on NORMs leaching

39. The Proposal does not include a radiological analysis of uranium, thorium and radium in the as-received drill sample. Without such an analysis being available, it is not possible to assess the full range of effects of the Proposal, nor to identify ways in which these effects can be addressed.
40. TCM's analysis of groundwaters from the Barrytown deposit revealed elevated levels of dissolved heavy metals, including aluminum, arsenic, chromium, copper, nickel and zinc<sup>32</sup>. They concluded that removal of all the heavy minerals they detected (from the deposit as part of the Proposal) would cause an overall reduction in the dissolved metals concentrations.
41. In my expert opinion, this is an incorrect assumption. What will remain from the mineral sands once processing is undertaken and they are concentrated, is a more (not less) radioactive material. This is the material that is proposed to be used to fill in the mine void.
42. I have included a video<sup>33</sup> showing a live Geiger counter test of two samples of heavy mineral concentrate from the West Coast (not from the Proposal site, but from the same type of heavy mineral concentrations). The second sample you see me test in the video is similar to what the Proposal suggests will be deposited as a slurry into the mine void following extraction of ilmenite, garnet, zircon and gold. The Geiger counter reading of the second sample gives orders of magnitude higher readings of radiation, as can be heard and seen in the video.

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<sup>32</sup> Barrytown Sand Mine Fast Track Substantive Application Appendix L3 - Hydrological Assessment. Barrytown South Mineral Sand Project – Hydrological Effects Assessment. Final-B. Report No Z24011BTS-2-FIN. Komana Solutions Ltd.

<sup>33</sup> The video can be accessed using this link:

<https://drive.google.com/file/d/1Sfr2Yf57H4qKBS3BoQZC12xhjqBsd06z/view?ts=6ab84be8>

## **Unclear whether applicant analysed HMC sample**

43. TCM undertook pXRF testing of a sample from the Proposal site. It is unclear from the application and the supporting documents if that sample is a heavy mineral concentrate (HMC) – meaning a sample that has followed similar processing as that the Proposal is suggesting – or if the sample is simply an unconcentrated bore-hole sample (referred to as “as-received drill sample”).

## **No radiological analysis of as-received drill sample**

44. Given the fact that TCM detected uranium and thorium using pXRF in the as-received drill sample extracted from the Proposal site, and that the mineral samples show clear evidence of leaching and dissolution<sup>34</sup>, TCM should have instead carried out a radiological analysis<sup>35</sup> to actually determine radioactivity by measuring the isotopes of uranium and thorium, not wrongly assume only the least radioactive of the multiple uranium and thorium isotopes would be present in the sample, and not ignore their radioactive daughter isotopes, especially highly radioactive radium. Radium enters water supplies when groundwater dissolves surrounding sands, rock and bedrock, especially in regions with abundant granitic bedrock like Central Westland.
45. Without such analysis being available, it is difficult to assess the full range of effects of the Proposal and identify ways in which these effects can be addressed.

## **7. Radioactivity measurements reported in the Proposal are not credible**

46. The Proposal is for the applicant to excavate beach sand on the Southern Block at Barrytown, truck it by road to another location to extract ilmenite, garnet, zircon and gold, and then return the residual sand wastes, including NORMS which the

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<sup>34</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026)

<sup>35</sup> M. Lechermer and C. Ardouin, 2023 Peer Review of Radiological Assessment conducted by IHC Mining titled, “Radioactivity of BJV Material Tested Project 2019.” *ESR Radiation assessment review for WCRC*.

Proposal as lodged does not state will be extracted, back to the excavated mine site. I have reviewed the applicant's Statement of Evidence in relation to radiation<sup>36</sup>.

47. The stated purposes of the radioactivity measurements were to:

- (a) provide evidence on expected radiation levels in the ore body,
- (b) provide an outline of how the mining methodology proposed will impact radiation levels, and
- (c) confirm the conditions proposed are appropriate and ensure that any adverse effects are avoided.

48. The report concludes from their findings that radioactivity will not be an issue, but the findings are not credible because the instrument they used to measure radiation cannot detect radiation.

49. Radiation can be detected using alpha, (beta) and gamma spectrometry, but not x-ray spectrometry because x-ray spectrometry cannot detect radiation.

50. The report describes attempts to measure radioactivity by x-ray spectrometry using a hand-held device known as a portable x-ray fluorescence spectrometer (pXRF). This is not an appropriate "tool for the job" in this case, for the following reasons:

51. pXRF detectors are widely used in the mining industry, primarily in the field, for rapid "point and shoot" detection of elements like iron, titanium, zirconium, etc. in samples of ore bodies. pXRF can also detect uranium and thorium, however it does not provide a reading of radioactivity. Once uranium and thorium are detected, radioactivity can then be non-quantitatively inferred, although these calculations usually result in an understated measurement of radiation.

52. pXRF is blind to Radon, even by inference <sup>37</sup>.

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<sup>36</sup> Appendix L8A which forms part of the substantive Fast-track application.

<sup>37</sup> B. Marriott, 2025. What XRF can and can't analyze. <https://rigaku.com/products/xrf-spectrometers/learning/blog/what-xrf-can-and-cannot-analyze-a-guide-for-beginners>

53. However, if using x-ray spectrometry (and a pXRF) the approach is premised on the minerals (NORMS) being in a state of “secular equilibrium”, a prerequisite the report specifically acknowledges. Secular equilibrium means that the NORMS have not been disturbed (altered) since they formed within their parent rocks<sup>38</sup>. Heating and leaching (dissolution and (re)precipitation in water) are two geological processes that cause loss of secular equilibrium<sup>39</sup>. For example, uranium and thorium can be selectively leached from NORMS grains.
54. The report, however, fails to confirm that the NORMS are in a state of secular equilibrium. In my opinion, it is highly unlikely that the minerals which are the subject of this Proposal are in a state of secular equilibrium because they have been aqueously altered, most recently during the past ~10,000 years, sequestered within the organics-rich, saturated deposit at Barrytown. This is because the mineral deposit is below the water table.
55. The report acknowledges the impact of such aqueous alteration on secular equilibrium because it refers to it when describing the processes that the mineral sands will be subject to: *“No chemical or thermal processing of the ore takes place. Consequently, all materials are considered to be in secular equilibrium, and specific radioactivity levels are based on this premise.”*
56. Unfortunately, attempting to preserve secular equilibrium after a sample has been dug out of a waterlogged deposit is tantamount to *closing the barn door after the horse has bolted*.
57. Because the applicant failed to consider the impact of aqueous alteration on secular equilibrium these measurements of radioactivity using pXRF are not reliable.

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<sup>38</sup> B. Marriott, 2025. What XRF can and can't analyze. <https://rigaku.com/products/xrf-spectrometers/learning/blog/what-xrf-can-and-cannot-analyze-a-guide-for-beginners>

<sup>39</sup> A. Papadopoulos, G. Christofides, A. Koroneos, C. Papastfanau, 2013. Radioactive secular equilibrium in <sup>238</sup>U and <sup>232</sup>Th series in granitoids. *Applied Radiation and Isotopes* **75**, 95-104; S. Kigoshi, 1971. Alpha-Recoil Thorium-234: Dissolution into Water and the Uranium-234/Uranium-238 Disequilibrium in Nature. *Science* **173**, 47-48

58. It is surprising that the applicant did not opt to measure radioactivity directly using a hand-held (radioactivity) detector that costs less than \$100. Together with the choice of x-ray spectrometry to undertake these measurements, and the lack of analysis of the presence or absence of a state of secular equilibrium with respect to the mineral deposit which is the subject of this Proposal, this assessment raises questions around the level of expert input in this specialist area that the Proposal has relied on.
59. An expert witness submission to the 2024 TiGa Barrytown Sand Mining Consent Hearing, Greymouth by scientists from the New Zealand Crown Research Institute ESR (now PHF Science) also expressed skepticism about the use of TCM's pXRF<sup>40</sup>. It has been known for decades that aqueous alteration in natural groundwaters can profoundly alter uranium (and thorium) relative isotope abundances and the total radioactivity in unpredictable ways<sup>41</sup>. Thorium and uranium each have several different isotopes. For example, natural uranium (U) is a mixture of U-238, U-234 and U-235 plus numerous other daughter products, including radon and radium, that contribute heavily to the total radioactivity of uranium. Under secular equilibrium, more than 98% of the uranium will be U-238, the least radioactive of the three uranium isotopes.
60. As pointed out in the ESR Report [26], even with secular equilibrium pXRF still assumes only one uranium isotope (U-238) is responsible for (uranium) radioactivity. The radioactivity of U-238 alone is 12.40 kBq/gm, but the radioactivity of natural uranium, a mixture of U-238, U-234, U-235, is approximately 25.50 kBq/gm, and the total radioactivity of the more than 20 radioactive species in the uranium (radioactive) decay chain will be even higher. Therefore, the premise that only U-238 is responsible for the radioactivity guarantees an artificially low measurement of radioactivity.

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<sup>40</sup> Lecherman and Ardouin, 2024

<sup>41</sup> B. Marriott, 2025. What XRF can and can't analyze. <https://rigaku.com/products/xrf-spectrometers/learning/blog/what-xrf-can-and-cannot-analyze-a-guide-for-beginners>; A. Papadopoulos, G. Christofides, A. Korneos, C. Papastfanau, 2013. Radioactive secular equilibrium in <sup>238</sup>U and <sup>232</sup>Th series in granitoids. *Applied Radiation and Isotopes* **75**, 95-104; S. Kigoshi, 1971. Alpha-Recoil Thorium-234: Dissolution into Water and the Uranium-234/Uranium-238 Disequilibrium in Nature. *Science* **173**, 47-48.

## 9. Conclusion

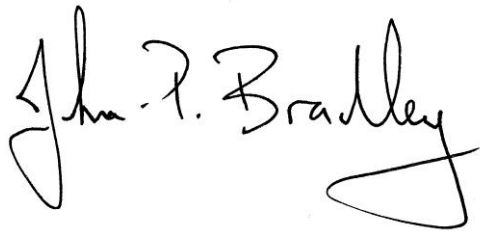
61. Radioactivity of the beach sand deposit at Barrytown proposed to be mined is substantially higher than ambient background levels because the deposit contains concentrated uranium and thorium-rich NORMS. The anomalously elevated radioactivity is in part a consequence of breakdown of the NORMS within the saturated deposit by ongoing aqueous leaching and dissolution, possibly a consequence of the high organic loading in the water and the high water table which covers (and affects) the NORMs deposit.
62. Radioactivity can be released into the environment via the atmosphere and water. It has been established that radon is continuously degassing from the deposit into the atmosphere and periodically accumulating in dwellings<sup>42</sup>. To my knowledge, water within and around the deposit has never been tested for dissolved radionuclides. The lack of such information makes it difficult to assess the Proposal's effects, and to identify and assess the effectiveness of measures that address those effects. In the absence of neither atmospheric radon data nor groundwater radionuclide (e.g. radium) data before mining even begins, there is simply no way to begin to meaningfully predict the impact of mining the Barrytown deposit.
63. The Proposal lacks a credible assessment of the radioactivity of the deposit, and it should be carried out prior to any work being undertaken; and an assessment of how the proposed activities will impact the radioactivity levels, including taking into account disposal of the most radioactive NORMS at Barrytown, thorite and uranothorite, and monazite, back into the mining void. This will then inform any mitigation measures that can be taken. Without this first step, there is insufficient information for me to meaningfully assess what is being proposed. Mineral sands are affected in different ways by various mining processes; therefore, a clear and detailed

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<sup>42</sup> *Ibid* J. P. Bradley, C. Smith, C., J. Chouinard, J. (2026)

explanation of those processes is also important to allow the effects to be assessed and assess any proposed mitigation.

64. If the Proposal is granted based on the information available at this stage, I recommend that the Panel incorporate into the consent conditions, requirements that align with the NORM management guides produced by the Western Australia Department of Local Government, Industry Regulation and Safety<sup>43</sup>, which provide detailed NORM management or, at a minimum, the New Zealand Ministry of Health NORM mining guidelines<sup>44</sup>. Suggested conditions, which I recommend are adopted, can be found in the CRRG conditions document at Appendix 6 to the legal submissions.

A handwritten signature in black ink, reading "John P. Bradley". The signature is written in a cursive style with a large, stylized initial 'J' and a long, sweeping underline.

Dr John P Bradley  
28 September 2026

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<sup>43</sup> Managing naturally occurring radioactive material (NORM) in mining and mineral processing: Guides

<sup>44</sup> Ministry of Health. 2026. *Compliance Guide: Management of Naturally Occurring Radioactive Material (NORM) in Mining and Mineral Extraction*. Wellington: Ministry of Health. (ORS G13)

## **John P. Bradley, PhD**

### **Current employment:**

Research Corporation of the University of Hawaii (RCUH), Honolulu, HI (50% appointment).

(Honorary) Affiliate Faculty, Advanced Electron Microscopy Center, University of Hawaii

(Honorary) Affiliate senior scientist, National Center for Electron Microscopy- Molecular Foundry, Lawrence Berkeley Laboratory, CA.

### **Prior employment:**

2014-2021

Research Professor, Hawai'i Institute of Geophysics & Planetology, School of Ocean, Environment, Science and Technology, University of Hawai'i, Honolulu, HI.

2002-2013

Director, Institute of Geophysics & Planetary Physics, Lawrence Livermore National Security LLC, Livermore, CA.

1996-2002

Adjunct Professor, School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, GA.

1992-2001

Executive Director, MVA Scientific Consulting, Inc., Norcross, GA.

1984-1992

Research Scientist, McCrone Associates, Inc., Westmont, IL.

### **Former Honorary Appointments:**

2005-2006

Committee on Mid-size Facilities, Board of Physics and Astronomy, The National Academies, Washington DC

2001-2006

Science Adviser, NASA STARDUST comet sample return mission

2006

Preliminary Examination Team, NASA Stardust mission

2010-2011

Deputy Principal Investigator – Science team lead: NASA Comet Odyssey proposed mission

External review committee memberships: DoE/BES SHARE facility (ORNL) and NCEM (LBNL)

## **Past advisory committee memberships:**

2013-2017

Center for Space and Earth Science, Los Alamos National Security, Los Alamos NM.

2015-2018

User Advisory Committee, Molecular Foundry, Lawrence Berkeley Laboratory, CA.

## **EDUCATION**

1976 B.Sc. Chemistry, University of Canterbury, Christchurch, New Zealand.

1978 M.Sc. Chemistry, University of Canterbury, Christchurch, New Zealand.

1982 Ph.D. Chemistry, Arizona State University, USA.

## **RESEARCH EXPERIENCE**

### **Government:**

US DoE – Materials analysis

USAF – Materials analysis

US Treasury - Materials analysis

USN - fluoride glasses (for seafloor fiber optics applications)

US Army – Chemical propellants.

NASA – space hardware, Astro-materials.

### **Industry:**

#### Soft Materials

Polymer battery separators, tire polymers, drug delivery polymers, biomedical polymer test devices, gel polymers, hard and soft contact lenses, biological tissue.

#### Hard materials

Optical fiber, solar cells, ceramics, solid-state multilayers, semiconductors, chalcogenides, electrodes (lead, nickel metal hydrides, LiMn oxides), metals and alloys, catalysts.

## **MEMBERSHIPS**

American Physical Society

Microscopy Society of America

Meteoritical Society (Fellow)

## **PUBLICATIONS – 335 [full list available on request]**

143 peer-reviewed papers, including 25 in *Science* and *Nature* (11 as first author, 5 journal covers) and 3 in the *Proceedings of the National Academy of Science (PNAS)*.

35 Conference Proceedings.

170 Conference abstracts.

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