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Dear Carolee August 21, 2023

Thank you for your query regarding the Barbers Lake granite and the associated aggregate resources in the vicinity of Barbers Lake. I'm familiar with the area in question. Although I have not done a lot of detailed mapping around Barbers Lake itself, in the past I have sampled it for whole-rock geochemistry. In addition, in the last decade I have been doing detailed mapping in the areas just to the east (the Perth, Lanark and Carleton Place areas), and have collected information on a variety of rock units in those areas.

Some of my response is a bit technical, but some of the detail that I am supplying is needed in order to understand the strength and weaknesses of the available data.

First, in reviewing both Ontario Geological Survey Open File Report 5550 (p.15-16) and Aggregate Assessment Report 189, it is clear why the aggregate resources near Barbers Lake are of interest to multiple companies. These reports, especially the earlier report (OFR 5550; http://www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR5550), both indicate that these are among the best aggregate sources in Lanark County, with the proximity to main roads making them even more attractive. Thus, it is not a surprise that proposals for more extraction are being put forward.

Second, with respect to your main question. As you have already determined, the Barbers Lake granite is unusual among eastern Ontario granites in that has anomalous contents of uranium and thorium. The following sections provide details on the nature and extent of this radioactivity.

These anomalous contents of uranium and thorium are evident in the Federal gamma-ray spectrometric maps of the area (Geological Survey of Canada Open Files 4559 and 4560, respectively, links attached).

https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/downloade.web&search1=R=215115

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Both the Barbers Lake granite and the radioactive pegmatites located west of Highway 509 are clearly indicated on these maps. The shape of the Barbers Lake granite is well-defined on the map, and it does not look like radioactive debris from the granite has been more widely dispersed. Note that uranium and thorium contents are estimated values and are expressed as equivalent uranium and equivalent thorium. This is because the gamma-ray spectrometry measures a bismuth isotope generated during the decay of radioactive uranium and thorium isotopes, rather than directly measuring uranium and thorium content. Thus, they are estimates of U and Th content, not exact values.

Nonetheless, the gamma-ray results are supported by direct analysis of uranium and thorium on samples from the Barbers Lake granite itself. These have been reported in Ontario Geological Survey Miscellaneous Release—Data 311 (Cutts 2014). I have attached a data table from that document which shows the Barbers Lake data in yellow highlight. Uranium contents range from approximately 6 to 95 parts per million (ppm), with thorium contents ranging from 25 to 171 ppm. For comparison, contents for an average granite (global) are approximately 4 ppm uranium and 12-20 ppm (estimate of Kyser and

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Cuney 2009). I have found that most granites in central and eastern Ontario do indeed have uranium and thorium contents near these average values. Although not a complete data set, this can be seen in the table from MRD 311, where most of the other granites sampled have close to average values.

Note that uranium and thorium values in the table are reported by 2 different methods – x-ray fluorescence spectrometry (XRF) and inductively-coupled plasma mass spectrometry (IMC). The XRF method uses 10 g of crushed rock, has a higher upper detection limit, and is more representative in that it uses more material. The IMC method uses less than 1 g of powder which is then dissolved using acid into a solution that is then analyzed. It has a lower upper detection limit (why some Th values are indicated as >109 ppm), but has a much lower detection limit than XRF, which is better for samples with low U and/or Th contents. Using both methods provide a check that the sample dissolution process worked. This is seen in the data table by the fact that the results by both methods are the same within analytical error (approximately 5%).

Not all the Barbers Lake samples are highly anomalous, a few are close to the average granite values. Nonetheless, five samples collected along Highland Lane, including 3 samples that I collected personally on 12th Concession Road just north of Highland Lane, all have anomalous U and Th contents (31-90 ppm U, 38-171 ppm Th; none of the 3 samples I collected were pegmatitic). These five samples are all located 1 to 3 km southwest of the current Arnott Bros. pit.

Why the Barbers Lake granite has anomalous U and Th contents is unknown. Most other intrusions of the same age in eastern Ontario have average granite values (e.g., the Wolfe Lake, Rideau Lake and Foley Mountain intrusions near Westport, see the MRD 311 table). I can only speculate that it is related to the composition of the lower crust where the magma was produced, which subsequently rose toward the surface and crystallized as the Barbers Lake granite (pluton) a billion years ago.

Thirdly, estimating radon production and migration through various materials is difficult because it is a gas. Obviously, since it is produced by radioactive decay, having more U and Th around will result in greater radon gas production. This is probably why there are higher radon readings in the area.

Fourth, in terms of water quality, it is likely that there are 2 different water sources in the area to consider. The first would be deeper groundwaters, accessed by wells drilled into bedrock. The second would be shallow groundwater sources, likely hosted in aquifers in the Quaternary deposits that are part of the aggregate resources in the area. The below water table extraction referred to in the company proposals likely refers to these groundwater sources.

These 2 different sources make it harder to determine how the radioactivity in the Barbers Lake granite might interact with ground and surface waters. Regional lake sediment data for the area is limited to an old Geological Survey of Canada Survey from the late 1970s (Open File 747), and only includes uranium.

https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/downloade.web&search1=R=129708

The Barbers Lake area does not stand out as particularly anomalous in this study, although it is higher than some adjacent areas. Certainly, in areas where there are abundant carbonate rocks around, such as the host rocks to the Barbers Lake granite, uranium can more easily go into solution and be more mobile. That being said, in the Gooderham and Bancroft areas to the west, where there are more lake sediment data and more studies of uranium in water, uranium mobility is mostly clearly observed in areas where mining activities have occurred that have resulted in crushing of the radioactive host rock, and/or the creation of tailing areas. This makes sense, in that creation of greater surface area (breaking up of the original rock), allows for greater water-rock interaction and thus more uranium going into solution.

Thorium behaves differently and is less susceptible to mobilization into groundwater.

As a result of these complexities, aditional (sic) local data would be needed to more address the effect of the granite on groundwater sources more fully, regardless of any aggregate extraction activity.

Fifth, and probably most important, is trying to answer the question of determining any effects that the radioactive nature of the granite might have on the aggregate resource proposed for extraction. Some factors to consider are:

- The granite was glaciated approximately 10,000 years ago. This would have removed any in-situ weathering zones that had developed atop of the granite and would have exposed unaltered rock at surface. This would have reduced the risk of subsequent migration of unconsolidated radioactive materials.

  [I was not sure if the excepts from Dugdale's thesis related to weathered clay being developed on the granite was a generalized statement or was related only to the nature of the units at the bottom of Barber's Lake. Although in temperate and tropical climates granites can weather relatively quickly, geologically speaking, the fact that the area was recently (geologically) glaciated would suggest that no significant weathering zones (>5 cm thick) are present.]
- The aggregate deposits themselves are widely sourced and would not be expected to contain significant amounts of locally derived bedrock. Thus, they would not necessarily be radioactive even if situated near the granite. ***This would need to be confirmed, however***. Examination of the deposits present in the lowermost parts of the Arnott Bros. pit using a portable gamma-ray spectrometer would be a quick way of identifying if there are any areas of anomalous radioactivity in the aggregate material. Any anomalous deposits could be sampled and sent for geochemistry to determine the actual amount of uranium and thorium present.
- Even if the aggregate deposits themselves are not anomalous in terms of U and Th content, the interface between the granite and the aggregate deposits would still be an area of concern. Mechanical scraping of the bedrock, as well as exposure of the bedrock surface to air and water, could create dust and/or water hazards. This could be addressed relatively easily in the proposed plans by leaving a buffer zone a few metres thick above the bedrock. This zone would be excluded from any extraction or pit development activities.

In terms of next steps, assessing the aggregate materials directly for radioactivity levels would seem to be the next, most logical, step. As I suggested, this could be done relatively quickly and easily by a handheld gamma-ray spectrometer survey of materials in the existing pit. One would hope that the company(ies) would be interested in supporting such a survey, both as a means of establishing that their product is indeed safe, as well as meeting their obligations under the Ontario Occupational Health and Safety Act to ensure that their workers are not exposed to any potential hazards.

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Obviously, the Barbers Lake area presents a distinct challenge compared to aggregate development elsewhere in Ontario. Typically, one can evaluate the aggregate (Quaternary) resource separately from the character of the underlying bedrock (in this case Precambrian). This would be why the company proposals do not consider the nature of the bedrock. The fact that the underlying bedrock is radioactive, however, does mean that additional investigation is needed to determine what, if any, influence the bedrock may have on the potential aggregate resource. Without additional information, one cannot fully answer that question.

Yours truly

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