Finding a needle in a haystack

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The common usage of the quote "No pressure, no diamonds", attributed to a 19th century Philosopher Thomas Carlyle, suggests that many people at least understand that diamonds are formed under high pressure. However, to the non-expert, little is known about where on Earth these precious minerals are formed.

Undoubtedly, diamonds were not formed where they are found today. They can only form at pressures over a hundred times greater than those attainable in the world's deepest diamond mine (Cullinan diamond mine, South Africa). In other words, diamonds are formed at depths of over 150 km below the surface, whereas the deepest diamond mine is only about 1 km deep. How then do diamonds get to shallow depths so that we can find them?

Together with intact fragments of the deep Earth, diamonds were conveyed vertically to shallow depths by buoyant rising molten rock (known as magma), which solidified and became the "primary" host rock of diamonds. This rock type is known as a kimberlite, named after the town of Kimberly in South Africa, where it was first identified. These primary hosts can be subjected to erosion, whereby the diamonds, together with other sediments, end up downstream in riverbeds, shorelines, or the ocean floor. When exploration geologists go on treasure hunts for primary diamond deposits, they start by looking for these now-"frozen" conveyors.

Unfortunately, not all of these conveyors carry diamonds because some originated from shallow depths where pressures are not high enough for diamonds to form. As geologists, we are tasked with coming up with ways to discriminate conveyors that likely host diamonds and those that would not.

As diamonds only constitute a tiny fraction (less than 0.001%) of the fragments conveyed to the surface, the odds of finding a diamond through sieving the mass deposited by the conveyors at the surface are as good as those for finding a needle in a haystack, or even less. On average, only two grams of diamonds will be found in a hundred thousand kilograms of host rock.

As a result, the economically unimportant minerals that form with the diamonds but occur at greater abundance are used as indicators to constrain the depth of origin. Samples of the same mineral, one from great depths and another from shallow depths, can be distinguished based on their chemical compositions. Conveyors that originated from depths greater than 150 km are likely to contain diamonds, whereas those that are from shallow depths will not contain any diamonds.

While the minerals traditionally used as indicators occur in greater abundance than diamonds, they still constitute a small fraction of the conveyed mass. However, there is one mineral, called olivine, that occurs in much greater abundances, constituting about 40-50% of the primary host rock of diamonds. Recently, a tool that translates the chemistry or composition of the olivine grains to their depths of origin was developed. As a result, we can use olivine to extract information about the depth at which it formed, allowing us to evaluate if it was formed with diamonds.

In our study, we test the applicability of this new method as a probe to determine whether various conveyors across southern Africa transported material from depths greater than 150 km to shallow levels. We expect conveyors that are known to host diamonds to be dominated by olivine grains that originated from correspondingly great depths - where diamonds are formed.

Preliminary results from two conveyors situated in central South Africa (namely Finsch and Roberts Victor) shows that Finsch is constituted by a greater proportion of olivine grains from depths at which

diamonds are formed than Roberts Victor. This is consistent with the occurrence of a greater abundance of diamonds at Finsch and lower quality and quantity of diamonds at Roberts Victor. Ongoing work will shed more insights into the subject. The success of this method would result in less sampling and effectively decrease the cost of diamond exploration programs. More land will therefore be explored at a lower cost. More exploration generally translates to more discoveries of economic diamond deposits, which benefits the economy of the country and communities through creation of jobs and business opportunities.