Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN-039
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Project Title: Deep carbon- and water-rich (C-O-H) fluids record associated geodynamic processes and impacts on planetary continental lithospheres through time.

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

'Fibrous' diamonds, a fast-growing form of diamonds that often encapsulate carbon- and water-rich (C-O-H) fluid microinclusions, are a primary target for studies of C-O-H mantle fluids and how these fluids influence deep mantle processes. However, only a small amount of diamond (normally <1 mg) and even smaller amounts of C-O-H fluid microinclusions can be sampled and analyzed using conventional laser ablation approaches and mass spectrometry measurements. In the present project, we implemented a novel diamond-in-liquid laser ablation technique that was developed to overcome the sample size limitation, combined with ultra-low blank column chromatography and 10^{13} Ohm resistor TIMS analyses, to provide the first high-precision Sr-Nd-Pb isotopic compositions of C-O-H mantle fluids in diamonds from the Kaapvaal Craton in southern Africa. We successfully processed and analyzed 12 samples from De Beers Pool, 5 from Finsch and 6 from Koffiefontein mines, as well as standards and blanks. We finished processing the collected data which show exciting Sr-Nd-Pb relationships that vary between diamonds carrying different C-O-H fluids and micro-mineral inclusions. We still need to complete some data processing and calculations, as well as correlate the isotopic ratios with trace element compositions to fully understand the results and their geological significance. Nonetheless, we are certain that the outcome of this Europlanet project will have a major impact on our understanding of the origin and evolution of C-O-H mantle fluids, the transport of mobile components between different mantle (and crustal) reservoirs, and the role of deep C-O-H fluids in the global circulation of volatiles through Earths' history.

Full Scientific Report on the outcome of your TNA visit

We encourage you to add figures to your report, which should be approx. 1 page of text plus figures.

Here we report the results of a novel custom-made system for diamond-in-liquid laser ablation, combined with ultra-low blank column chromatography and 10^{13} Ohm resistor TIMS analyses to provide the first high-precision Sr-Nd-Pb isotopic analyses of high density C-O-H mantle fluids (HDFs) in diamonds from the Kaapvaal Craton.

In a pioneering study at VU Amsterdam, during a previous Europlanet project, we validated the efficiency of the laser-ablation method and established a new analytical protocol for high-precision isotopic measurements of microinclusions-bearing diamonds. However, the techniques needed improving: 1) the laser-ablation procedure needed adjustments to reduce the blank levels, so diamond with low-density microinclusions could also be analyzed. 2) the protocol and analyses for determining the Pb isotope compositions, which are key traces in geodynamics, needed to be optimized. We accomplished these goals in the present Europlanet project: we reduced the blank levels to <1% for Sr on average, <0.2% for Nd and <1.5% for Pb, so samples with 2 ng Sr, 40 pg Nd and 200 pg Pb can be easily analyzed at VU Amsterdam; which effectively allowed us to accomplish meaningful Pb isotope compositions for all 23 samples, Sr isotope compositions for 22 of the samples (95%) and Nd isotope compositions for 21 of the samples (90%). It is important to note, that the analyzed samples that failed are due to unfortunate incidents during column chemistry (the samples spiled during chromatography); so we are confident our sample preparation procedure and analyses can now provide Sr-Nd-Pb isotope data for many microinclusions-bearing diamond samples, including those with a low density of microinclusions.

In the present study, we focused on diamonds from the Kaapvaal Craton to better understand the large isotopic variation observed in C-O-H mantle fluids from this well-charactrized region. We successfully processed and analyzed 12 samples from De Beers Pool, 5 from Finsch and 6 from Koffiefontein mines. We finished processing the collected data that show exciting Sr-Nd-Pb relationships which vary between diamonds carrying different C-O-H fluids and micro-mineral inclusions: 1) the Sr and Nd isotopes of both silicic and carbonatitic fluids have unradiogenic $^{143}Nd/^{144}Nd$ and radiogenic $^{87}Sr/^{86}Sr$ compared to bulk Earth (i.e. $^{143}Nd/^{144}Nd$=0.51265, $^{87}Sr/^{86}Sr$=07046, Fig. 1). In contrast, most saline HDFs (+/- associated micro-mineral inclusions) have Nd isotope compositions within ± 0.0004 of bulk Earth but extend to more radiogenic Sr isotopes that reach $^{87}Sr/^{86}Sr$=0.7587. There are also marked variations for Pb isotopes (Fig. 2).

We need to complete some data processing and calculations, as well as correlate the isotopic ratios with trace element compositions of the samples to fully understand the results and their geological significance. These data will provide major new constraints on the origin and evolution of different types of deep C-O-H mantle fluids. We are certain that the new results accomplished in this Europlanet project will open the opportunity to understand the complex history of fluid transport events in the Kaapvaal lithosphere, the type of fluid involved, and relate these deep mantle events to the regional tectonics and magmatic history. Moreover, it will have a major impact on our understanding of the origin and evolution of C-O-H mantle fluids, the transport of mobile components between different mantle (and crustal) reservoirs, and the role of deep C-O-H fluids in the global circulation of volatiles through Earth's history.

We plan to present the new and exciting outcome of the project at international conferences and published it in high-ranked refereed journals.

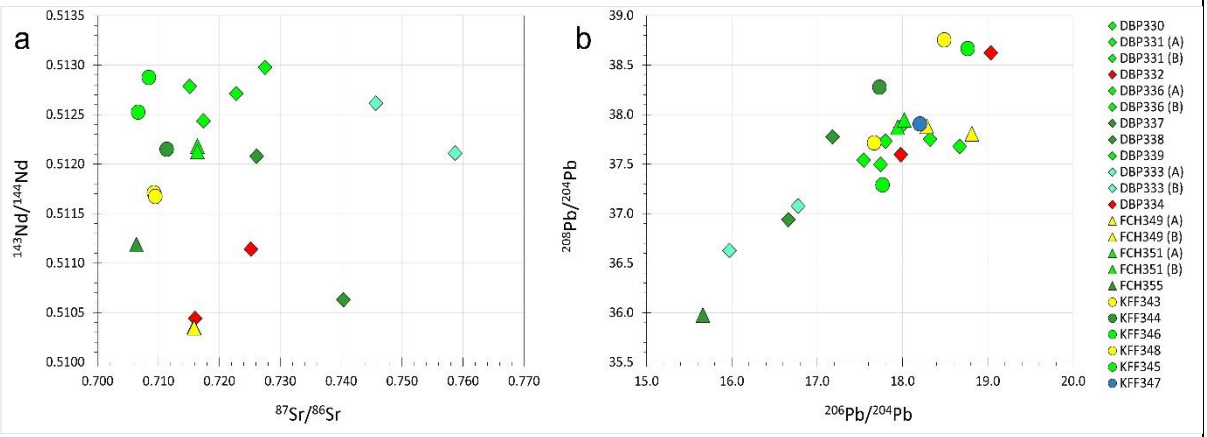

Fig. 1: (a) Nd and Sr isotope compositions of C-O-H mantle fluids in diamonds from the Kaapval craton (silicic fluids – red; carbonatitic fluids – yellow; saline fluids – green and blue shades). (b) Pb isotope variations.

- Give details of any publications arising/planned (include conference abstracts etc) - We plan to present the new results first at the coming 'fifth International diamond school' that will take place between February 20-25 in Brixen, Italy.

- Host confirmation

Please can hosts fill in/check this table confirming the breakdown of time for this TA project:

Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Departed: First visit: 07-12-21 Second visit: 21-08-22 Arrived: First visit: 07-12-21 Second visit: 21-08-22	First visit: 07-12-21 Second visit: 22-08-22	0	10 10	0	First visit: 18-12-21 Second visit: 03-09-22	Departed: First visit: 19-12-21 Second visit: 04-09-22 Arrived: First visit: 20-12-21 Second visit: 04-09-22

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	Vrije Universiteit Amsterdam
Host Signature	GR Davies
Date	24-11-2022

- Project Leader confirmation

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YES

Project Leader Name	Yaakov Weiss

Project Leader Signature	
Date	November 21, 2022