# Europlanet TA Scientific Report

**PROJECT LEADER**

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| **Project number: 20-EPN-007** |
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| **Home Institution: Cardiff University** |
| **TA Facility visited: GGIF, Vrije Universiteit, Amsterdam** |

## Project Title: **Investigating mantle heterogeneity through high spatial resolution mineral Pb and Nd isotopic analyses**

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

The traditional approach of measuring the isotopic compositions of mid-ocean ridge basalts (MORB) is problematic because MORB is homogenised prior to eruption, and therefore does not record the full heterogeneity of the mantle source. To overcome this problem, we developed low-concentration coupled Pb-Nd isotope analysis of minerals at high spatial resolution to assess the isotopic heterogeneity of melts delivered to Earth's oceanic crust and hence that of the depleted upper mantle. We acquired small volume Pb and Nd isotope analyses from minerals in gabbroic cumulates from fast-spreading oceanic crust at Hess Deep using the Thermo Scientific TRITON *Plus* at the Vrije Universiteit in Amsterdam. We measured minerals from 27 samples (Nd from 25 cpx and 19 plag, Pb from 18 plag) covering the full stratigraphic depth (4350 m to 25 m) of the Hess Deep oceanic crust. Our study reveals that Pb isotopes from primitive plagioclase domains show greater heterogeneity than Nd isotopes from plagioclase and clinopyroxene, validating the new coupled Pb-Nd isotopic approach. The Pb data do not vary systematically with depth but do show a departure in $^{207}Pb/^{204}Pb$ away from the NHRL and across the main trend of East Pacific Rise MORB that may indicate cumulate-melt mixing throughout the crust or the involvement of an exotic mantle source.

**Full Scientific Report on the outcome of your TNA visit**

**Introduction:** Traditionally, the isotopic compositions of mid-ocean ridge basalts (MORB) have been used to map the geochemical heterogeneity of the upper mantle. However, there is a major problem with this approach: MORB is homogenised prior to eruption, and therefore does not record the full heterogeneity of the source. To overcome this problem, we targeted cumulus minerals from gabbros [1] from the fast-spreading Hess Deep (East Pacific Rise) [2] and developed the first coupled Pb-Nd isotope analysis of cumulus plagioclase. This new method has two advantages over the use of Nd alone: (i) the relative variation in Pb isotope ratios significantly exceeds that of Nd; Pb isotope analysis should therefore be a more sensitive tracer of mantle heterogeneity; (ii) in providing three isotopic ratios, Pb enables a range of compositional endmembers to be distinguished.

**Methods:** For this project we acquired small volume Pb and Nd isotope analyses from minerals in gabbroic cumulates from Hess Deep using the Thermo Scientific TRITON *Plus* at the Vrije Universiteit in Amsterdam. Prior to isotopic analyses, we used an scanning electron microscope to element map all samples to identify the most primitive domains in plagioclase and clinopyroxene crystals (Fig.1). The trace element concentrations (including Pb and Nd) of plagioclase and clinopyroxene were then measured by LA-ICP-MS. Small volumes of the most primitive domains of the selected minerals were then micromilled (Fig. 1) (based on Pb and Nd concentrations). We recovered 280-720 pg Pb and 0.5-2.9 ng Nd from plagioclase, and 2.3- 6.7 ng Nd from clinopyroxene. Pb and Nd were then separated using ion exchange columns at Cardiff University. Due to the small sample volumes, it is vital that the procedural blanks were low, and these were tested and refined at Cardiff. Nd blanks were between 0.62 pg (full Nd procedure) and 4 pg (including Pb and Nd chemistry). Full procedural Pb blanks were between 4.5 and 10 pg.

Clinopyroxene Nd isotopes were measured on $10^{11}$ Ω resistors, whereas the plagioclase samples, with lower concentrations of Nd were run using $10^{13}$ Ω resistors. For plagioclase analyses, the $10^{13}$ Ω resistors were attached to the masses of 143, 144, 146 and 150, the rest (145, 147, 148) were measured on the $10^{11}$ Ω [3]. Pb isotopes were measured using a $10^{13}$ Ω resistor for the detection of $^{204}$Pb in combination with $10^{11}$ Ω resistors for the other isotopes [4]. All data were collected over 4 analytical sessions using remote access.

**Results:** We measured primitive mineral domains from 27 samples (Nd from 25 cpx and 19 plag, Pb from 18 plag) covering stratigraphic depth from 4350 m to 25 m (Fig. 2). Plagioclase and clinopyroxene $^{143}$Nd/$^{144}$Nd values show limited variation and cover a similar range (0.51307 to 0.51322), which is largely within the precision of the measurements (±7-77 ppm 2SE). In contrast, plagioclase Pb isotopes show greater heterogeneity, far beyond that of analytical uncertainties ($^{208}$Pb/$^{204}$Pb=17.70-18.09 ±0.0014-0.0258 2SD, $^{207}$Pb/$^{204}$Pb=15.43-15.57 ±0.0014-0.0214 2SD, $^{206}$Pb/$^{204}$Pb=37.42-37.68 ±0.0042-0.0662 2SD). The Pb isotopes do not show any clear systematic trends with depth through the section. The Pb data show a negative trend with respect to $^{206}$Pb/$^{204}$Pb vs. $^{207}$Pb/$^{204}$Pb (Fig. 3a), which trends away from, rather than follow the Northern Hemisphere Reference Line (NHRL) [5] and the main isotopic trend of the East Pacific Rise (EPR).

**Key findings:**

- Lead isotopes from primitive plagioclase domains show greater heterogeneity than plagioclase and clinopyroxene Nd isotopes, validating the new coupled Pb-Nd isotopic approach developed here.
- The departure of $^{207}$Pb/$^{204}$Pb away from the NHRL and across the main trend of the EPR may indicate mixing with an exotic mantle source.

**References:** [1] Lambart, S. et al. (2019), *Nat. Geosci*. 12, 482-486. [2] Lissenberg, C.J. et al. (2013), *Earth Planet. Sci. Lett.* 361, 436-447. [3]. Koornneef, J. M. *et al.* (2014), *Anal. Chim. Acta* 819, 49-55. [4]. Klaver, M. *et al.* (2016), *J. Anal* 31, 171-178. [5] Hart, S. (1984), *Nature* 309, 753–757.

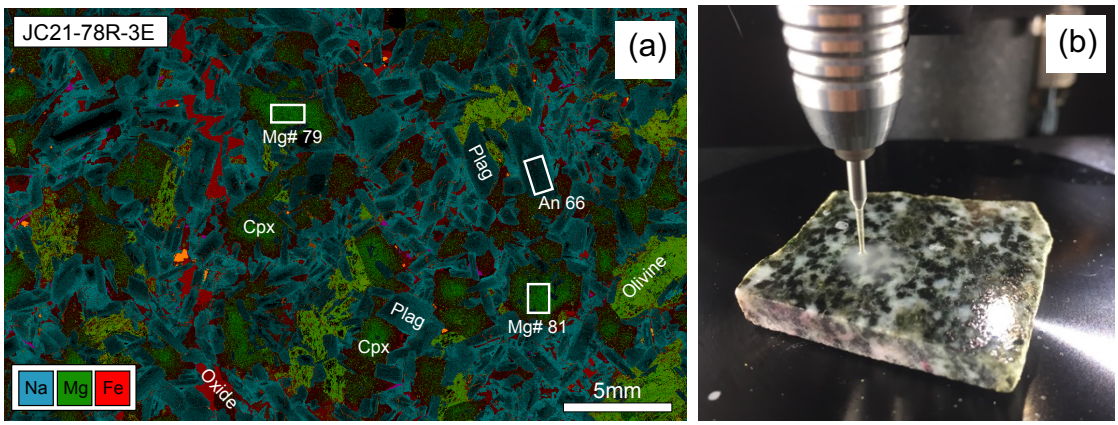


**Figure 1.** (a) EDS-SEM element map of polished thin section billet showing anorthite zoning in plagioclase (black-blue) and Fe-Mg zoning (red-green) in clinopyroxene. Primitive cores are selected for micromilling (white boxes) and for trace element analysis by Laser Ablation ICPMS. (b) Micromilling selected mineral domains on polished blocks. The sample slurry is pipetted into beakers with MQ water.

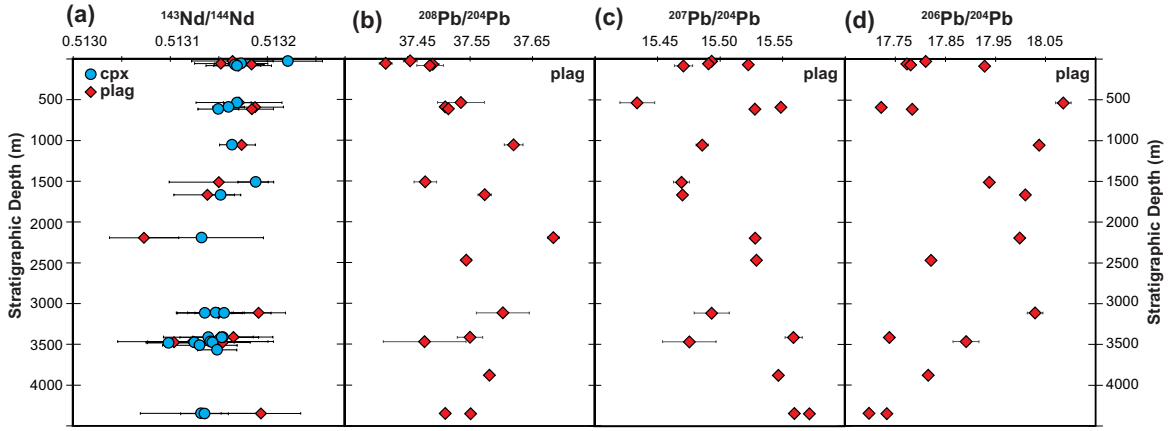


**Figure 2.** A compilation of all data collected for this study showing the variation in clinopyroxene Nd isotopes (a) and plagioclase Nd (a) and Pb (b-d) isotopes with depth through the fast-spreading oceanic crust at Hess Deep.

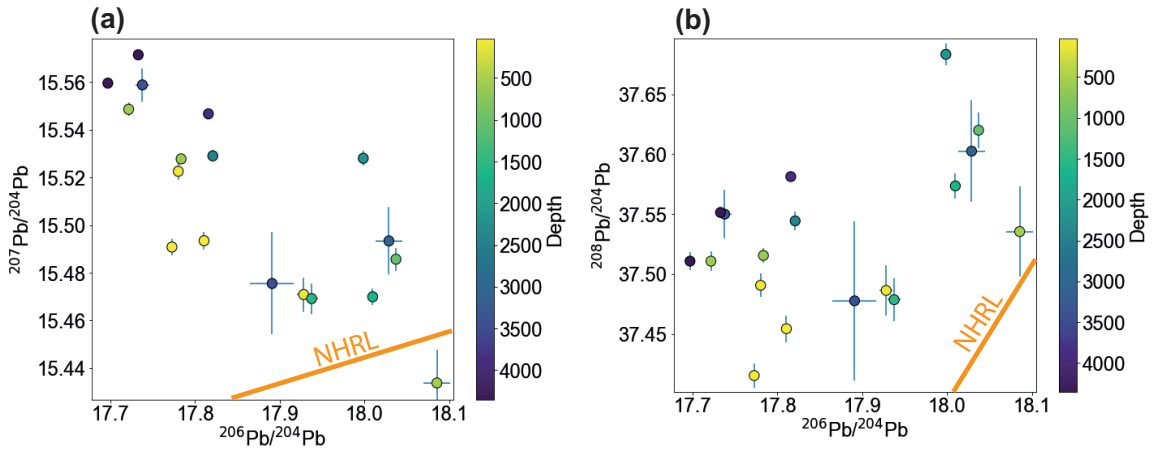


**Figure 3.** Plagioclase $^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$ (a) and $^{206}Pb/^{204}Pb$ vs. $^{208}Pb/^{204}Pb$ (b). Symbols are coloured by depth in section. The Northern Hemisphere Reference Line is plotted (orange line).

# - Give details of any publications arising/planned (include conference abstracts etc)

Two publications are planned using the data obtained in this study. The first paper will focus on the isotopic and trace element variation with depth through the Hess Deep crustal section. The second paper will focus on the Pb isotope record from Hess Deep to determine the sources of the observed heterogeneity and how these compare with published data along the length of the East Pacific Rise.

# - 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: N/A<br><br>Arrived: N/A | 22-02-22 | N/A | | 10 days remote access | 09-12-2022 | Departed: N/A<br><br>Arrived: N/A |

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

| **Host Name** | **J.M. Koornneef** |
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| **Date** | **16-12-2022** |

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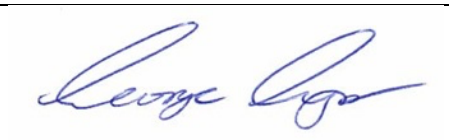
| **Project Leader Signature** |  |
| **Date** | **15/12/2022** |