# 2016 Heard Island Expedition Project Description

## Definition

**TITLE**

### THE VOLCANIC HISTORY OF HEARD ISLAND

**Abstract**

Heard Island is one of only two active subaerial volcanic locations in Australian Territory, the other being the nearby McDonald Islands. Located in the southern Indian Ocean, the island is heavily glaciated and subject to high winds, snow, and wet conditions. Due to its remote location and difficult conditions little detail is known about the geology of the island including the timing, processes and products of the volcanic eruptions that have occurred there.

As a unique and dynamic volcanic environment, Heard Island is worthy of a detailed volcanology study in its own right. The island currently erupts almost annually but there is no understanding of the volcanic structure, plumbing system or volcanic hazards. The geology and volcanism on Heard Island provides the context for all flora, fauna and marine environments and related research on and around the island. In terms of broader significance its location on the Kerguelen Plateau; Heard islands represents an opportunity to examine the products of the Kerguelen Plume, a volcanic hotspot that has been active for 130 million years.

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| **Principal Investigator** | Ms. Jodi Fox | University of Tasmania |
| **Co-Investigator** | Prof. Jocelyn McPhie | University of Tasmania |
| **Co-Investigator** | Dr. Rebecca Carey | University of Tasmania |
| **Co-Investigator** | Prof. Patrick Quilty | University of Tasmania |
| **Co-Investigators** | Gavin Marshall, Fred Belton, and the onsite Team | Cordell Expeditions |

## Context

**Background**

Heard Island is the southern most subaerial exposure of the Kerguelen Plateau, a Large Igneous Province (LIP) of geological, oceanographic and biological significance (Quilty, 2006). The basalts of the Kerguelen Plateau are geologically significant both because of their very large volume and inferred duration of their eruption. The apparent source of the magma, the Kerguelen Plume or hotspot has likely been active for the last 130 Ma (Coffin et al., 2002; Quilty and Wheller, 2000). This is one of the longest known eruptions of basalt from a single source (Coffin et al., 2002).
Most of the Kerguelen Plateau is sub-marine and as such what is known of it has been derived from remote sensing methods such as radar bathymetry and via dredging and samples collected from Ocean Drilling Program legs (Quilty, 2006). Improving understanding of the geology of Heard Island and the processes that have taken place there provides the opportunity to gain insight into the geology and history of the Kerguelen Plateau.

This research is being conducted in the context of several other national and international studies involving Heard Island and the Kerguelen Plateau. All or some of the principle investigators of this proposal are researchers in four other projects related to Heard Island and the Kerguelen Plateau.

*Heard Earth-Ocean-Biosphere Interactions*: A RV Investigator (CSIRO) research cruise (INV2016_V01) to the Kerguelen Plateau and Heard Island to investigate submarine

volcanism (Departs 8 January 2016). (Fox and Carey).

*Australian Antarctic Science Grant:* Project 4316 The geological evolution of Heard Island, Australian Sub-Antarctic. Recently funded isotopic dating of a small number of lavas from historical Heard Island collections. (Fox and Carey)

*Geologic Development of Heard Island, Central Kerguelen Plateau:* Isotopic dating of historical samples from Heard Island with collaborators Dr Jane Barling (UK), Prof. Patrick Quilty (AUS) and Prof. Robert Duncan (USA) (Research completed and paper accepted for publication, included in reference list). (Fox)

*Towards an understanding of the volcanic history of Heard Island:* Part of a University of Tasmania PhD project. (Research completed and paper prepared for submission) (Fox, Carey and McPhie)

## Motivation and goals

Heard Island's geological and volcanic history is poorly understood. There is much work to be done in understanding the formation and volcanic history of Heard Island, from the formation of the Laurens Peninsula Limestone through to the eruption of modern day lavas. For each geological unit on Heard Island, the same questions remain largely unanswered that have been considered by geologists since first visits to Heard Island.

- What types of environments were each unit deposited in?
- What were the processes that produced each geological unit?
- What was the duration of deposition of each unit?
- How old are the geological units on Heard Island?
- When did volcanism start on Heard Island?
- Has volcanism on Heard Island been continuous or intermittent?

There are no scheduled geological expeditions to Heard Island by Australian government scientific bodies in the near future. This expedition and the proposed project represent the first opportunity in at least 12 years to obtain new geological samples and photographs that can be used by the principle investigators and be shared with the broader Australian and international scientific community. The collection of volcanic rocks and rocks that may or do contain fossils will provide valuable information that will contribute to answering the unresolved geological questions on Heard Island.

This project proposes to collect rock samples for petrology isotopic dating and geochemical analysis for the purpose of understanding the timing and source of volcanic activity on Heard Island. If rocks hosting fossils are observed these will also be sampled to assist with dating. This information will also be used to ground truth an as yet unpublished geological map that has been prepared from satellite imagery and historical data. The goal is to sample from new locations and to increase the body of limited detailed knowledge currently available about the distribution of lavas on Heard Island and hence unravel the volcanic history of Heard Island.

## Description

### Onsite

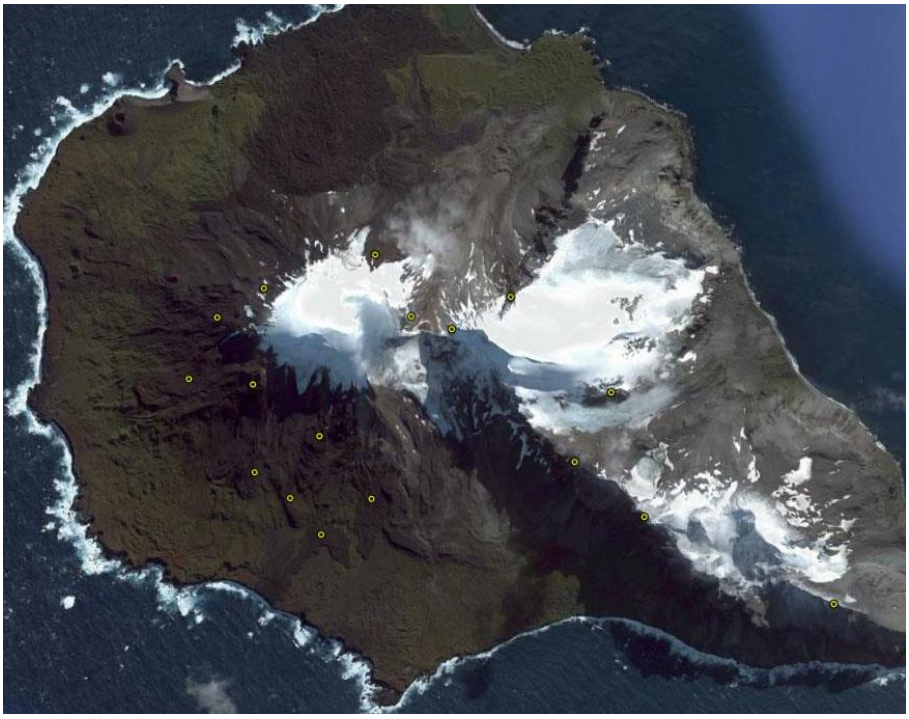
***Equipment***

Geologist's hammer, safety glasses, specimen bags, indelible markers, GPS unit, GPS camera, satellite phone

***Location(s)***

Collection of specimens will be attempted at the following locations:

1. Slopes of the three small peaks of the Laurens Peninsula and at Spit Bay. Priority will be to sample locations where few or no specimens have been obtained by previous teams. High priority sample sites on the Laurens Peninsula are indicated by the yellow markers in the following image:



2. Volcanic rocks at Spit Bay.
3. Opportunistic sampling of rocks that may host fossils.
4. Pumice from Elephant Spit believed to be from the 1992 eruption of nearby McDonald Islands.

Access requirements for the above locations: Laurens Peninsula (Wilderness Zone), Elephant Spit (Wilderness Zone), Oil Barrel Point (Visitor Zone)

***Procedure***

Rocks collected will be *in situ* and around fist size with the exception of scoria, pumice, or shingle on beaches. Specimens normally will be collected when there is a transition between rock types, particularly at contacts.

### Records

***Photo-documentation***

General area of samples including an introduced object to indicate scale, close up of sample being taken. Camera will record GPS data.

***Logging***

Specimens will be photographed before and after collection, GPS coordinates recorded, specimens bagged and labelled.

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| *Nonliving specimens* | All specimens will be free of organic material |
| *Live specimens* | None |

## Post-expedition procedure

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| *Destination(s) of records* | Geological Samples will be catalogued and held at the University of Tasmania, Earth Sciences Rock Store and will be accessible for future work.<br><br>The AAD website concerning the Quarantine Act 190 states that "Geological samples collected from the Australian Antarctic Territory for approved programs do not require a quarantine permit, but the consignment must be notified to AQIS and may be inspected by a Quarantine Officer on arrival in Australia. A Department of Agriculture import permit is not required. The consignment must be clean and free from biosecurity risk material. To demonstrate compliance with this requirement you must present the following on a Manufacturer's declaration, Exporter declaration, Supplier declaration or Commercial invoice. Each consignment must be packed in clean and new packaging."<br><br>In accordance with the above, Cordell Expeditions will ensure that all rock specimens are clean, packed in new and clean packaging, and notified to AQIS. A written declaration will be provided that describes compliance with these requirements. |
| *Processing of records* | Planned work includes isotopic dating and geochemistry, whole rock geochemistry and petrology as appropriate |
| *Publication(s) expected* | Publication in scientific journals. Presentations at domestic and international conferences. Shared information with a broader public audience via web pages and media. Production of an updated geological map of Heard Island. All results, data and publications will be shared with the AAD and Geoscience Australia |
| *Definition of success* | A significant number of specimens collected on the Laurens Peninsula and near Spit Bay would constitute a successful outcome to the field work, even if a number of the proposed collection sites cannot be reached. |

## Supplementary material

### Suppl. 1 Geology of Heard Island

Heard Island consists of two land areas joined by a narrow isthmus. The main area of the island is around 18km in circumference and reaches a height of 2745m at Mawson Peak (Stephenson et al., 2006). Mawson Peak is located on top of the edifice known as Big Ben and has produced lava flows as recently as June 2015. To the north west of Big Ben is the smaller part of Heard Island, Laurens Peninsula. Laurens Peninsula is ca. 7km in circumference with its highest point being Mt Dixon as 715m (Stephenson et al., 2006). The slopes of Big Ben are almost completely covered in glaciers and snow throughout the year whilst Laurens Peninsula is less extensively glaciated and snow covered (Kiernan and McConnell, 1999).

Heard Island stratigraphy has been divided into 3 units on the basis of field outcrop observations; Laurens Peninsula Limestone, the Drygalski Formation and the Younger Volcanic Rocks (Stephenson et al., 2006). There is no published map of the geology of Heard Island.

Laurens Peninsula Limestone (LPL) outcrops most extensively on Laurens Peninsula and is interpreted to also be the basement rocks of Big Ben although no direct evidence of this has yet been found (Stephenson et al., 2006). The limestone is light coloured and thinly bedded, predominantly nano ooze carbonate with rarer argillaceous limestone, likely deposited in an open ocean environment during cool conditions (Quilty and Wheller, 2000). Lambeth (1952) documented mafic sills and dykes in the LPL. Barling (1991) also noted concordant dolerite sills which were folded along with the limestone and that the upper surface of the LPL is an erosional, planed surface.

Quilty and Wheller (2000) correlate the LPL with a carbonate succession that is widespread across the Kerguelen Plateau. This succession has been intercepted during several Ocean Drilling Programs and overlies the Kerguelen Plateau basalts (Stephenson et al., 2006). It is assumed that on Heard Island the LPL also directly overlies the basaltic lavas of the Kerguelen Plateau (Quilty, 2006).

The Drygalski Formation is a diverse formation and includes volcaniclastic rocks, interbedded basaltic lava flows and some mafic intrusives (Stephenson et al., 2006). The origin of the clastic rocks has not been fully established. Stephenson (1964) was convinced that the deposition of the vast range of clasts in the clastic rocks and striated pebbles and boulders were indicative of glacial activity. Another interpretation is that they are lahar deposits (Dott, 1964; Willett, 1964). The Drygalski Formation contains pillow lavas well above modern sea level that were interpreted by Stephenson et al. (2006) as evidence for sub-aqueous eruption and later broader uplift of the island. Barling (*pers com* 2013) believes that there is a possibility that the pillow lavas are actually the result of sub-glacial eruption. These conflicting interpretations highlight the need for further investigation of the role of glacio-volcanic eruption in the deposition of the Drygalski Formation.

The Younger Volcanic Rocks consists of lavas, volcaniclastic and pyroclastic rocks (Quilty and Wheller, 2000; Stephenson et al., 2006). Barling et al. (1994) divided the younger lavas into the Laurens Peninsula Series (LPS) and the Big Ben Series (BBS) based on isotopic and geochemical studies. The BBS includes the basanite, basalt, and trachybasalt lavas of Big Ben and its various satellite or parasitic cones (Stephenson et al., 2006). Based on estimates regarding the shape and size of Big Ben, Clarke et al. (1983) estimated that the first lavas of Big Ben were produced only several hundred thousand years ago. This estimate is unreliable as lava effusion and glacial erosion rates are not well known (Stephenson et al., 2006). Collerson et al. (1998) states that volcanic eruption of Big Ben started 1.2 Ma but does not provide a rationale for this date.

The LPS series includes the Laurens Peninsula lavas and consists of trachytic lavas overlain by recent basaltic lavas (Quilty & Wheller 2000). Clarke et al. (1983) dated a lava at the base of Mt Dixon as being approximately 10 000 years old using K-Ar techniques. Many of the lavas on Laurens Peninsula appear quite fresh with little signs of weathering leading to speculation that some could be as young as several hundred years old (Quilty and Wheller, 2000; Stephenson et al., 2006).

Barling et al. (1994) found that the LPS series were istopically distinct from the BBS, having lower strontium ratios and higher neodymium and lead ratios than the BBS and favoured a binary mixing model at mantle source as an explanation. In contrast Quilty and Wheller (2000) suggested that the lavas of the BBS are the primary products of the Kergeulen Plume with some local mixing with a portion of sedimentary crust that may have been subducted prior to the formation of Gondwana. Quilty and Wheller (2000) concluded that the LPS lavas are likely the result of local mobilisation of enriched lithospheric mantle (Quilty and Wheller, 2000).

Around the circumference of Heard Island are small scoria and tuff cones and some associated lava flows thought to be younger than 10,000 years old (Stephenson et al., 2006). The relationship of these cones to other volcanic features is unclear, although they have been thought to be parasitic in origin (Kiernan and McConnell, 1999; Stephenson et al., 2006) and possibly monogenetic (Wheller *pers com* 2012). Recent analysis of sea floor bathymetry has revealed clusters of small volcanic cones across the Kerguelean Plateau (Leser, 2012). It is possible that these cones and the small cones on Heard Island were erupted contemporaneously, suggesting a regional volcanic event as their source rather than a parasitic relationship to the main eruption centre at Big Ben.

On Heard Island, the basaltic volcanic cones such as those at Azorella Peninsula and South Barrier are described as being dissected or eroded by the sea so that only half the cone remains (Quilty and Wheller, 2000; Stephenson et al., 2006). It is possible that these cones may actually be intact littoral cones. Littoral cones form when hot lava enters the sea causing hydrovolcanic explosions that can blast juvenile pyroclastic material back onto the land forming half cones (Moore and Ault, 1965).

## Suppl. 2 Previous geological work at Heard Island

Heard Island was visited briefly and sporadically by geologists from the late 1800s until 1948, who reported evidence of heavy glaciation and recent volcanic activity and eruption. Tyrrell (1937) completed the first significant petrography study of rocks collected by Sir Douglas Mawson during the 1929 BANZARE visit to Heard Island. Between 1948 and 1949 an Australian National Antarctic Research Expedition (ANARE) team wintered on the island. As part of this expedition, Lambeth (1952) undertook field and petrographic work and published a stratigraphic interpretation of the island. Stephenson (Stephenson, 1964, 1972) spent one summer season on Heard Island and expanded on Lambeth's work and updated unit descriptions.

Fleming (1957) described and dated a new species of fossil *Chlamys* collected from a rock scree Heard Island in 1953. Based on field relationships it was determined that the likely source of the fossil, *Austrochlamys heardensis* was the Drygalski Formation (then known as the Drygalski Agglomerate) although none have ever been found *in situ (*Quilty et al., 2004). Based on morphological comparisons with similar species Fleming (1957) determined the fossil to be Late Miocene to early Pliestocene, implying a similar age for the Drygalski Formation. Later work by Quilty et al. (1983) and Truswell et al. (2005) on the palynology and microfossils of the Drygalski Formation has narrowed the age of the formation to Late Miocene. Quilty et al. (2004) provided further description of *A. heardensis* based on samples dredge from the sea to the north of Heard Island but did not redefine an age for the

specimens.

Barling et al. (1994), Clarke et al. (1983) and Wheller and Barling (1992) collected igneous rock samples from Heard Island for isotopic and petrographic studies during various short ANZARE visits to Heard Island. These studies were focused on understanding the relationship between coherent volcanic rocks on Heard Island and the Kerguelen Plateau and identifying whether they have a common source. Attempts were also made to date a limited number of the samples using K-Ar methods. This work identified two lava series on Heard Island that shared a common mantle source, the Kerguelen Plume, and that each series has undergone different pre-eruption processes. (Barling 1994).

Since publication of these results in the early 1990s there has been no further geological field work conducted on Heard Island. Two articles summarising current knowledge of the geology and volcanology of Heard Island have been published more recently (Quilty and Wheller, 2000; Stephenson et al., 2006).

## References


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## Evaluation

### HIMI Management Plan

The present project is sanctioned by Items **A10** and **A12** of **Table 2, Section 5.5** of the HIMI MP:

> **A10)** Systematic geological mapping and monitoring of volcanic activity.
>
> **A12)** Research into oceanographic features and processes that strongly influence the distribution of marine species ad seabirds. [Note: Strictly, the volcano is not an "oceanographic" feature. However, it obviously "strongly influences the distribution of marine species and seabirds." Surprisingly, there is no entry in Table 2 that strictly includes volcanic activity as influences the marine species and seabirds. We believe there should be such an entry, hence we include this entry here.]

Section 5.5 of the HIMI Management Plan provides the following:

> Research within the Reserve is required for the integrated and ecologically sustainable management of the broader HIMI region. … Scientifically robust evidence is needed to make effective conservation management decisions. … Research and monitoring activities must be undertaken in accordance with the research and monitoring priorities identified in Table 2 and the Australian Antarctic Science Strategic Plan. … Research also facilitates the fulfilment of public reporting requirements.

In combination with the remarks about Table 2 (above), we interpret this statement to mean that the research described in this document is consistent with the AAD mission for management of the HIMI.

The HIMI Management Plan further provides

> … the policies … require … that: any biological resources taken are not intended to be used for commercial purposes; … that samples will not be given to other people … without permission … [Parts of this excerpt are omitted solely for space requirements in this document, and are not meant to be omitted in the agreement.]

We do affirm that this project has no commercial interest or activity, and that Cordell Expeditions guarantees conformance with the above statement, both in words and meaning.

### Priority

Given the high-quality of this investigation and the great likelihood of yielding new information, this project ranks as high priority for the 2016 Expedition.

### Specimens

The entire project is predicated on obtaining geological specimens, particularly at locations that have never before been sampled.

### Risks

The primary risk to personnel is that of travelling on foot in a remote wilderness zone on the Laurens Peninsula. Field personnel will be equipped with satellite communications, GPS, emergency rations, first aid kit, and emergency bivouac bag. Each team member has undergone wilderness first aid training and has prior experience with wilderness travel in poor weather conditions. Field operations and potential incidents are addressed by the Cordell Expeditions Heard Island Risk Management Plan.

The primary risk to the Reserve is the impact of field personnel on the

environment while traversing the landscape, impact of collecting specimens, and cross contamination from other ice-free regions. Field personnel will avoid damage to vegetation at collection sites and avoid trampling vegetation when alternative routes exist on bare ground. Personnel will avoid walking single file and avoid traversing vegetated hillsides when possible in order to minimize erosion. All waste will be removed. All equipment used in any other ice free zone of the island will be carefully inspected and cleaned to avoid cross contamination. No wildlife will be approached. Historical artifacts will be left undisturbed.

# JODI M. FOX

Position: PhD Candidate
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**Education**

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| B.Sc. (Hons) Geophysics, University of Tasmania | 2007 |
| B. Nursing University of Tasmania | l994 |

**Non-Academic Positions**

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|---|---|
| Undergraduate Demonstrator | 2013- |
| Exploration and Mine Geologist | 2008-2012 |
| Zircon analysis Lab-assistant | 2006 |

**Fields of Specialization**

Base metal exploration
Physical volcanology

**Honors and Awards**

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|---|---|
| AusIMM Education Endowment Fund Scholarhip | 2006-2007 |
| Zinifex Academic Award | 2005 |

**Professional Activities**

Delegate – Goldschmidt Conference, 2013, Florence, Italy.
Delegate and Presentor – International Association for the Volcanology and Chemistry of the Earth's Interior (IAVCEI) Scientific Assembly, 2013, Kagoshima, Japan.

**Publications**

Duncan, R.A., Quilty, P.G., Barling, J and Fox, J.M., accepted manuscript (2015) , Geologic Development of Heard Island, Central Kerguelen Plateau, Australian Journal of Earth Sciences, unpublished.

Fox, J.M., 2015, New lava flow on Heard Island, LAVA Newsletter, Geological Society of Australia, February, Vol 26.

Fox, J.M., 2014, Heard Island Eruption Update, LAVA Newsletter, Geological Society of Australia, February, Vol 25.

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**Collaborations**

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