New insights into the evolution of the Mt. Melbourne Volcanic Field (Northern Victoria Land, Antarctica) from high-resolution aeromagnetic data

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Mt. Melbourne Volcanic Field

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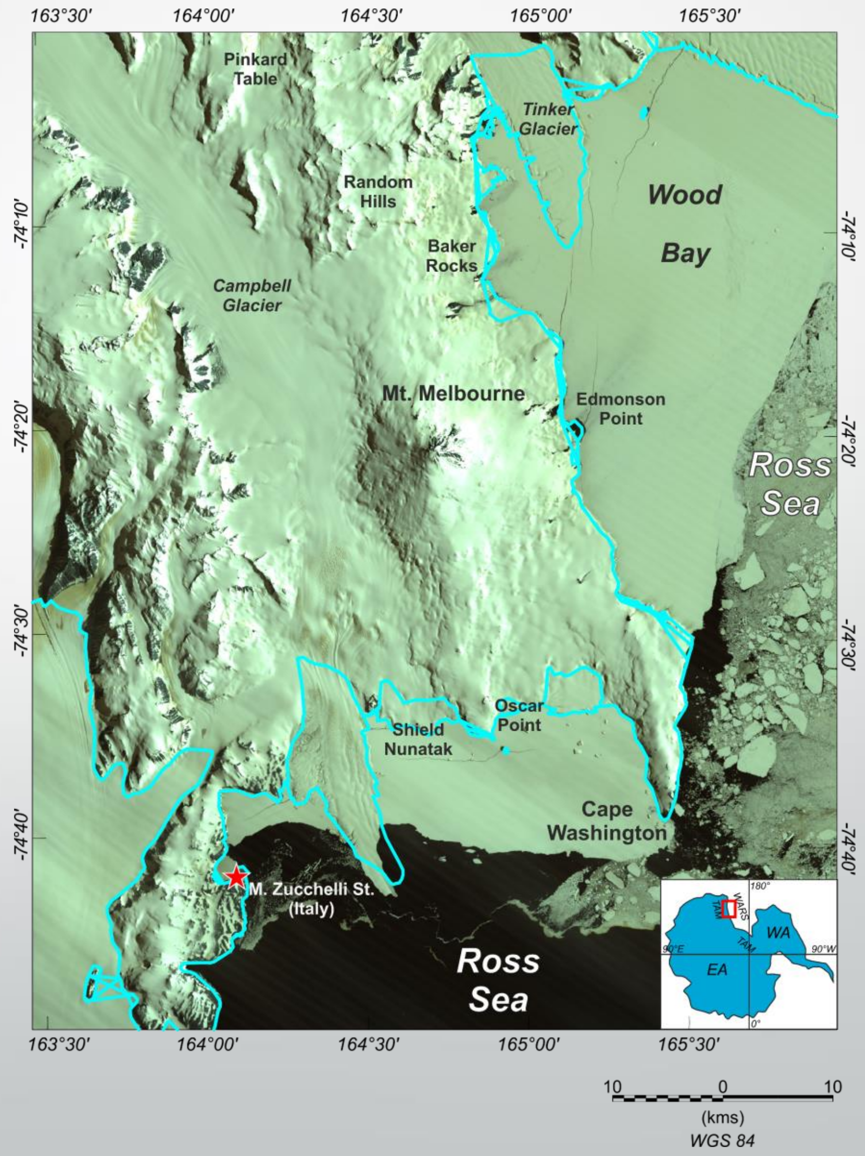
The Mt. Melbourne field is interpreted as a quiescent volcanic complex, located in Northern Victoria Land, Antarctica, at the boundary between the Transantarctic Mountains (TAM) and the West Antarctic Rift System (WARS).

The most recent activity could date between 100 (Lyon, 1986) and 200 (Nathan and Schulte, 1967) years ago. The presence of fumarolic ice towers and ground heating could attest the presence of near-surface cooling magma (Kyle, 1990).



Targets of the study

The **aims** of this study are:

i. to investigate the geophysical and geological structure of the main volcanic centres of the field, by means of potential field data forward modeling;
ii. to try to infer the evolution of the entire volcanic field.

The **future targets** will be:

i. to validate the geophysical models presented in this study, using them as "a priori" information in 2.5D Bayesian Monte Carlo inversion;
ii. to finally shed light into the geodynamic relationship among this volcanic site and the development of the TAM and the WARS.

From Wikimedia.org

Geodynamic setting

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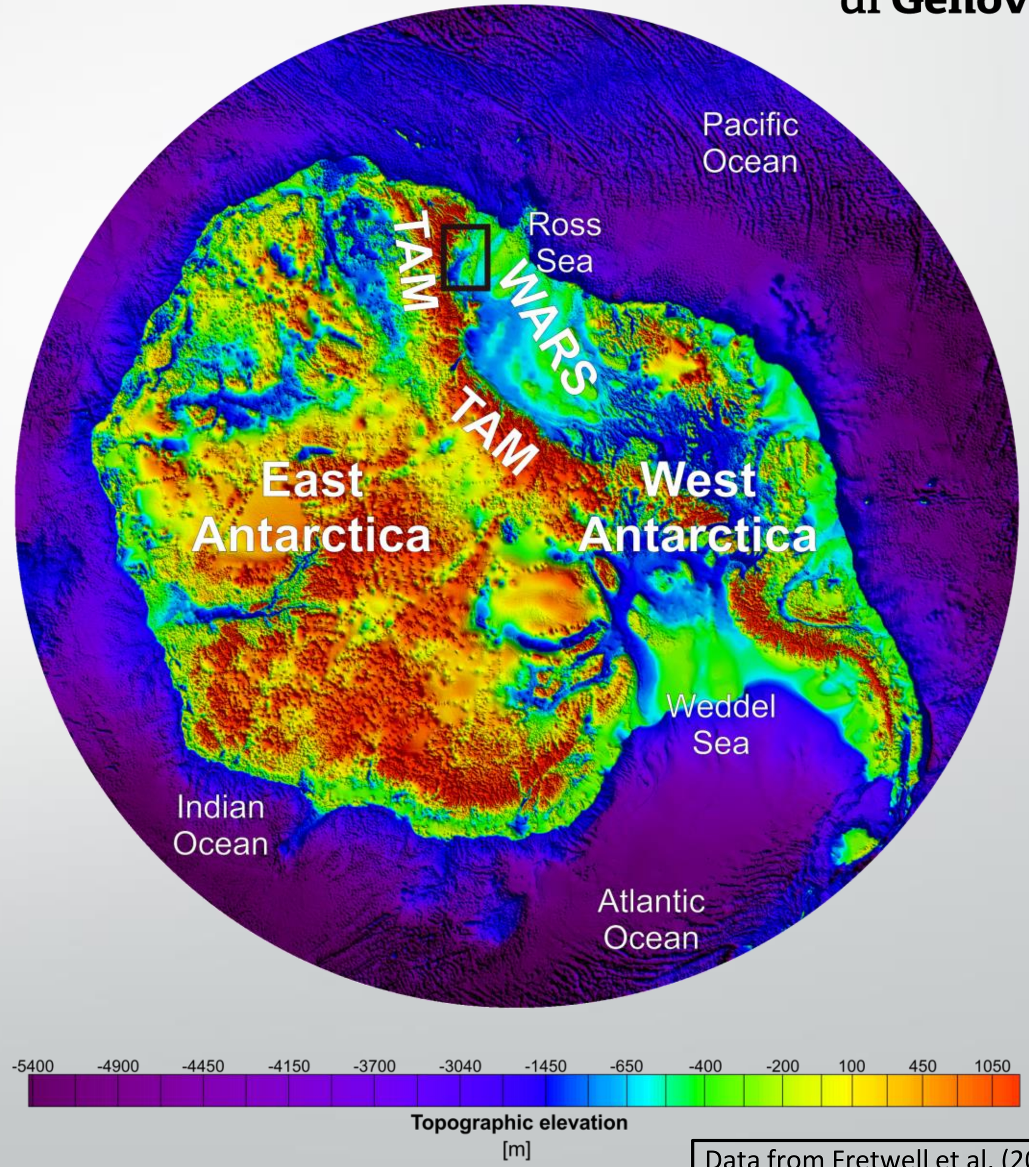
The geological and geophysical structure of this volcanic field, beyond its temporal evolution, remain poorly known, despite its key relevance to better comprehend the Cenozoic tectonic and geodynamic processes responsible for the opening of the WARS and the uplift of the TAM rift flank.

Recently, by means of 3D inverse modeling of P-wave velocity, Park et al. (2015) proposed a low-velocity anomaly beneath Mt. Melbourne possibly caused by edge flow of hot mantle material at the lithospheric step between the thick East Antarctic Craton and thin Ross Sea crust.



Data from Fretwell et al. (2013)

Geological and tectonic setting

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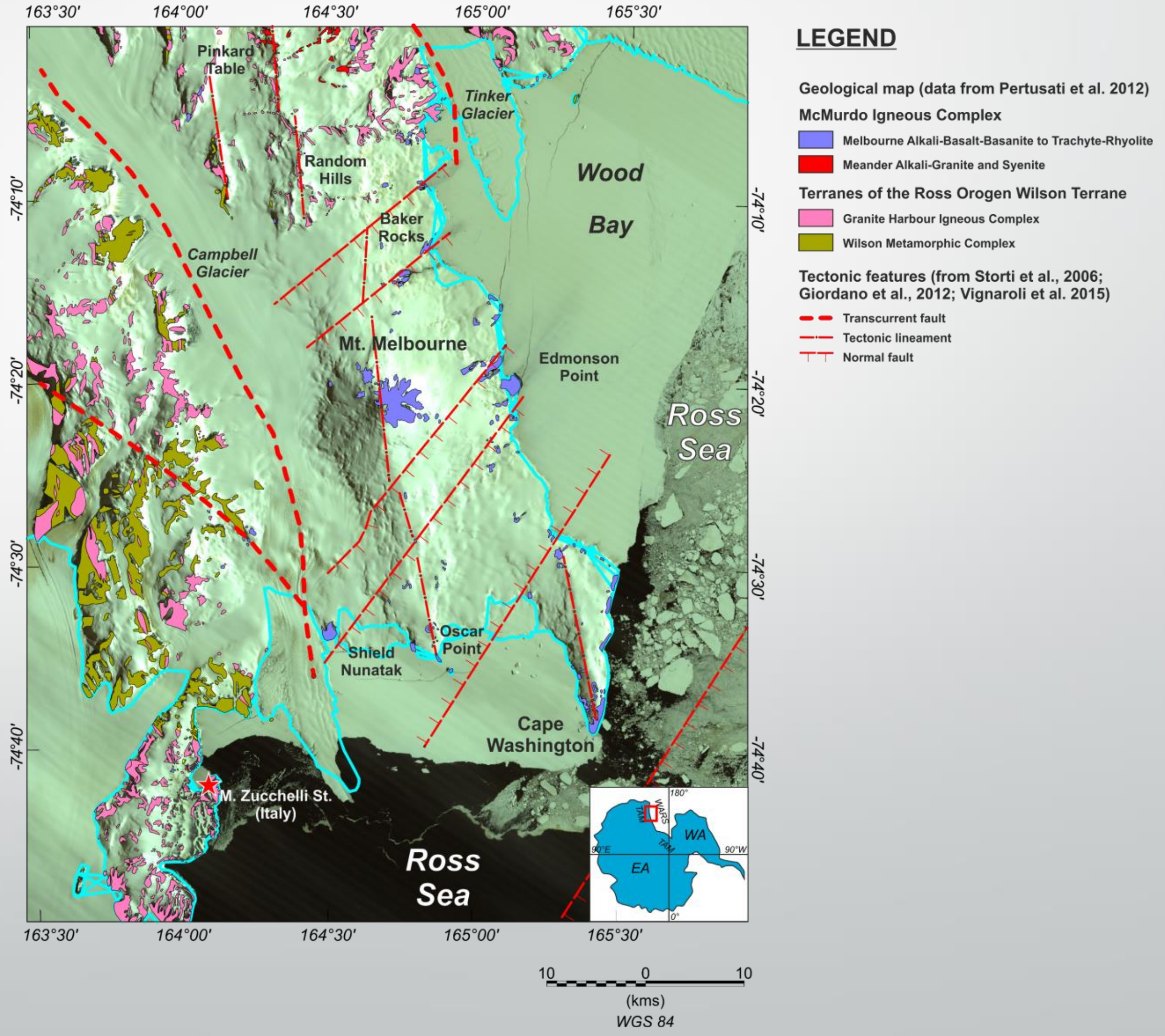
The Mt. Melbourne volcanic field is part of the Cenozoic McMurdo Igneous Complex and is underlain by the Wilson Terrane (part of the Ross Orogen).

It is flanked by major strike-slip fault systems including the Campbell Fault; N-S to NNW-SSE dissect Mt. Melbourne and Cape Washington and NE-SW faults parallel to the Ross Sea Rift margin have also been inferred.



New High-Resolution Aeromagnetic dataset

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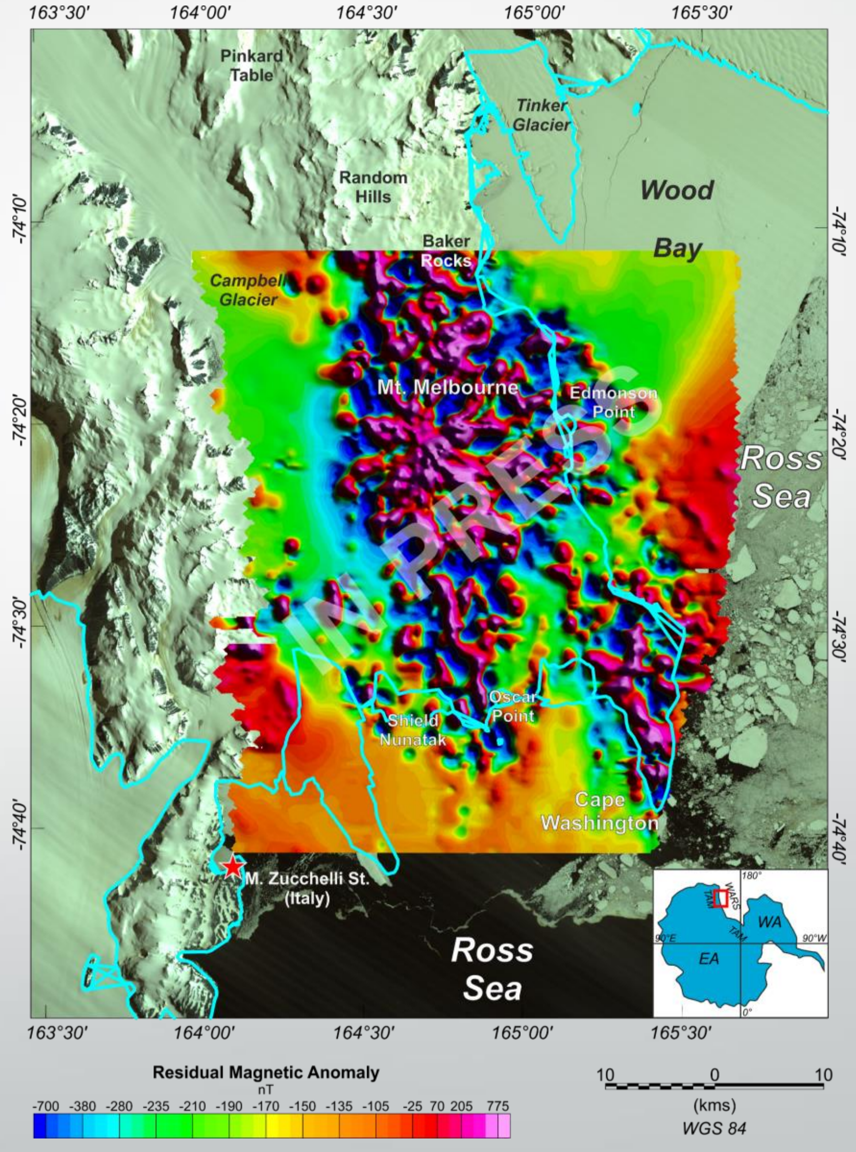
Here we present the results of a **newly processed High-Resolution AeroMagnetic dataset** (HRAM), collected in the austral summer 2002/2003 in the context of the Italian TIMM project (Programma Nazionale di Ricerche in Antartide - PNRA).

This represent one of the few HRAM collected in the entire Antarctic continent.

These new HRAM data represents a key tool for better investigate the geological and structural framework of this volcanic site.



New High-Resolution Aeromagnetic dataset

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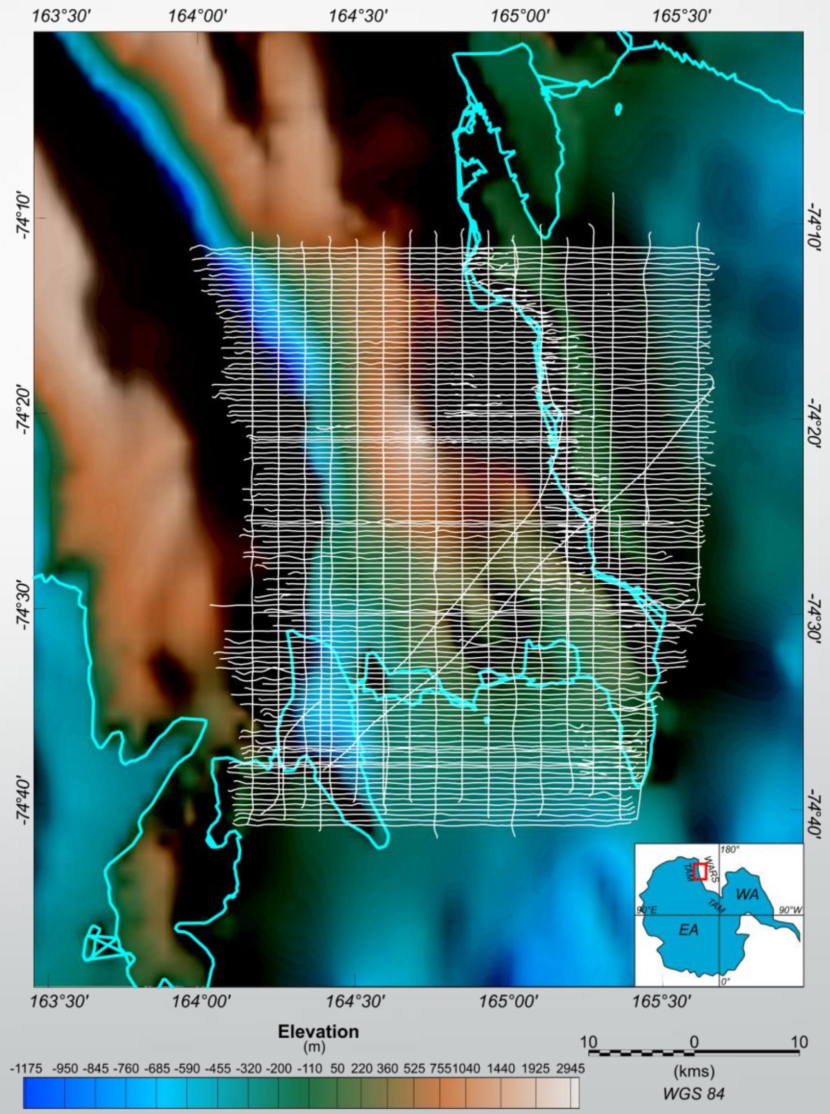
Survey technical description	
Type	Helicopter-borne survey
Magnetometer	MAC-3 Scintrex
Terrain clearance	1000 ft (draped survey)
Line spacing	500 m

Data processing	
Corrections performed	Base station Lag IGRF Levelling Microlevelling



Digital Enhancement

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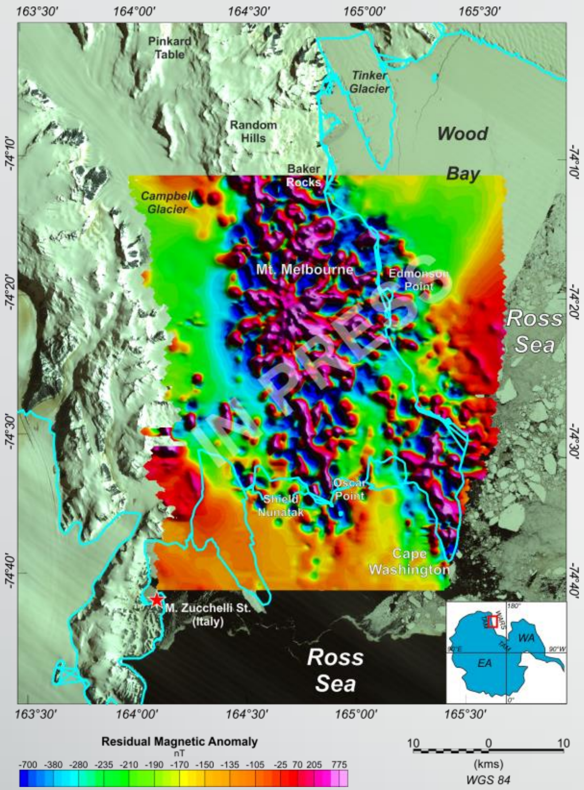
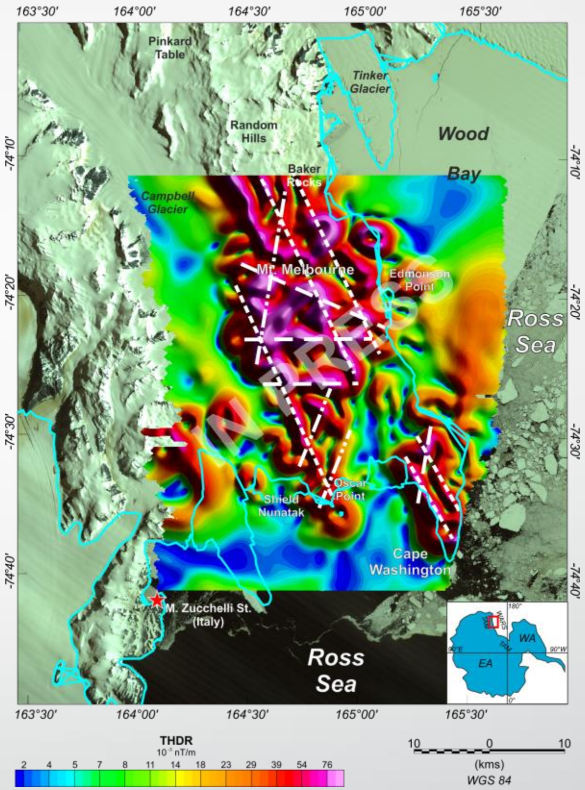


Residual magnetic anomaly



Total Horizontal Derivative applied to 2km upward-continued magnetic anomaly data

New data reveal with unprecedented detail NNW–SSE trending pervasive negative anomalies beneath both the Mt. Melbourne edifice and Cape Washington, superimposed by positive ones forming radial patterns.

The volcanic field seems affected by subglacial NNW-SSE, NNE-SSW and WNW-ESE to E-W trending structural systems.

New vs old structural information

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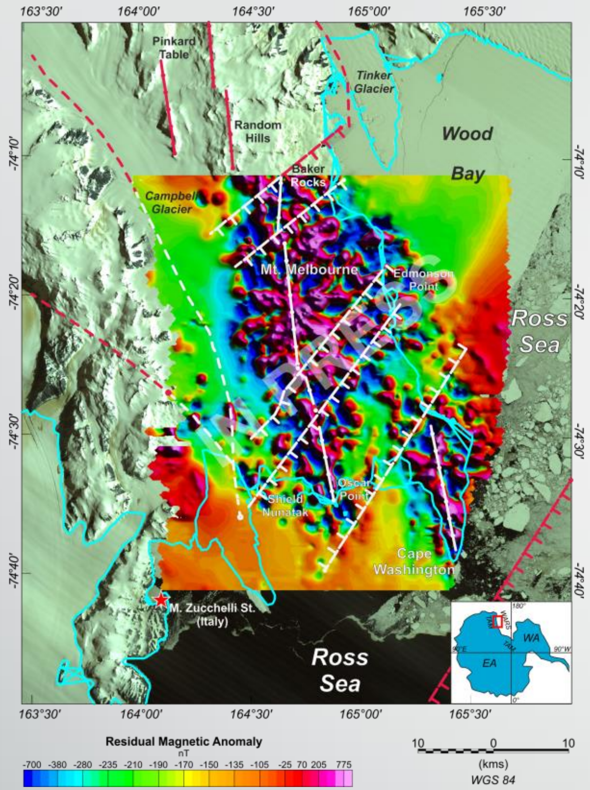
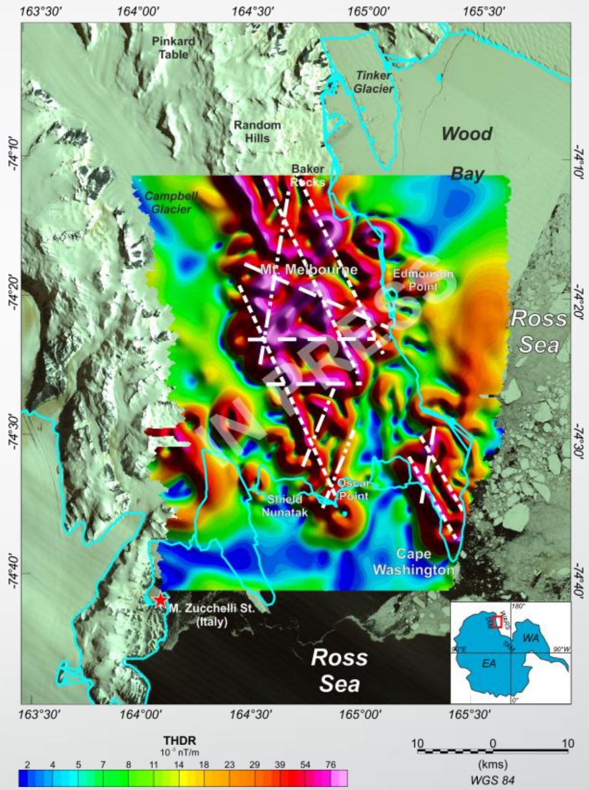


Structural information from literature



Our new structural information

Our new structural evidences result in partial agreement with the available tectonic information from literature (Storti et al., 2006; Giordano et al., 2012; Vignaroli et al., 2015).

Depth-to-source analysis

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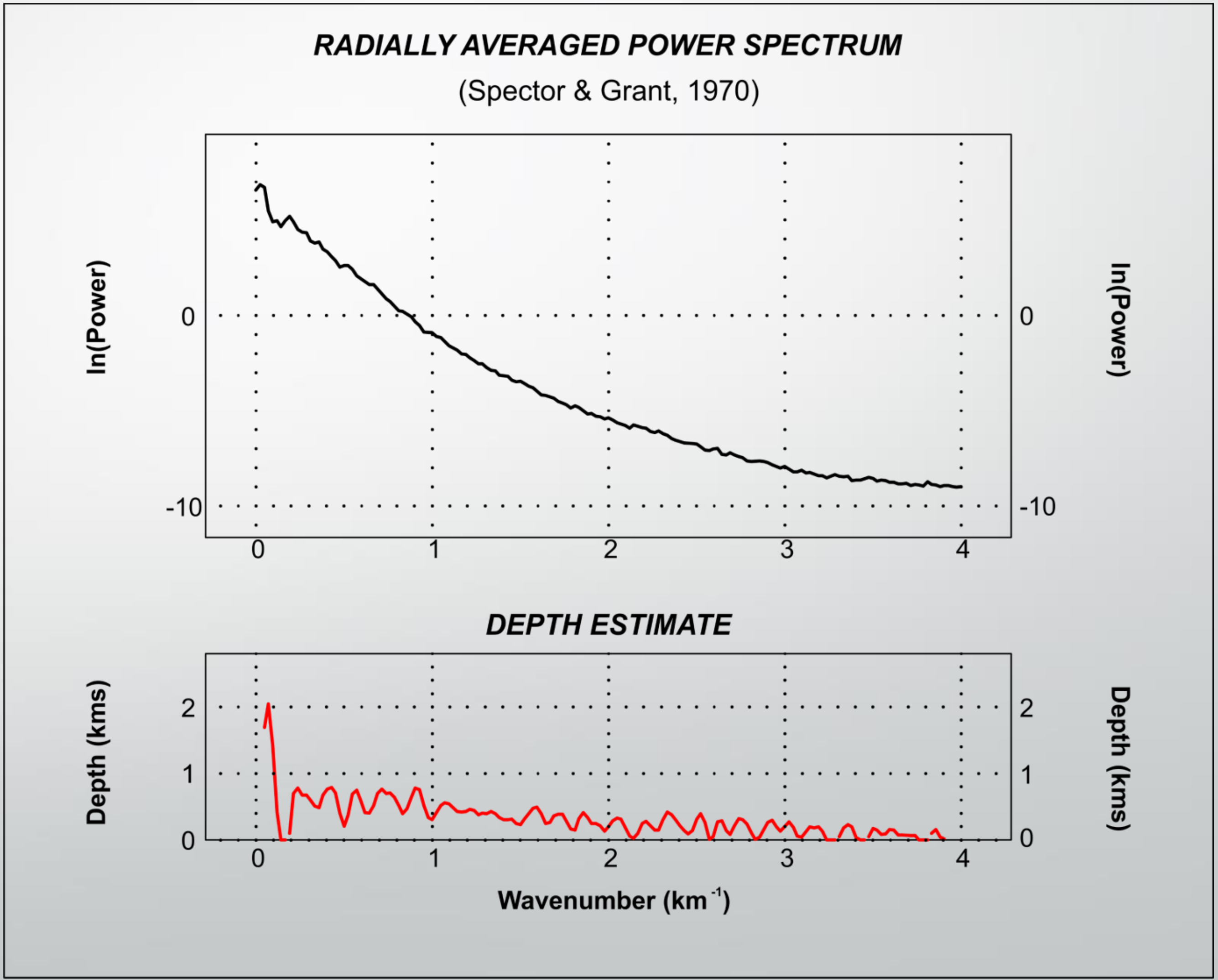
Power Spectrum technique
(Spector & Grant, 1970)

Note that the flight altitude (1000 ft) must be subtracted from the depth estimates to obtain the true depth source.

The **power** of the **magnetic signal** in the Fourier domain shows:

i. mainly superficial depth estimates, interpreted as the top of the recent volcanic flows (max depth estimates ~ 200 m);
ii. limited deeper depth estimates, possibly reflecting the interface between either the volcanic flows and the underlying basement or volcanic strata with different magnetic properties.



Magnetic Properties

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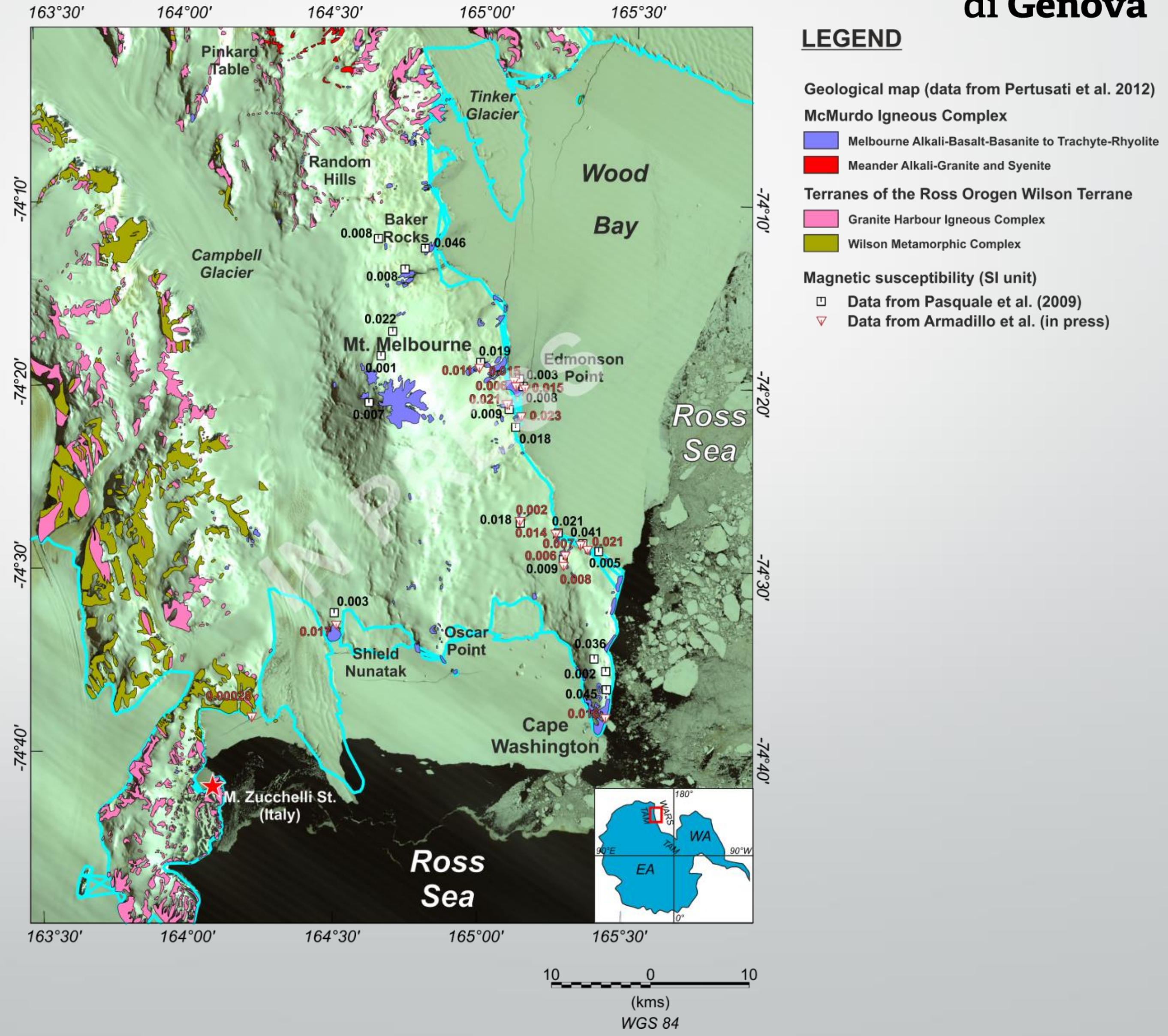
Magnetic susceptibility data available (published and unpublished) for the study area.

Values on volcanic rocks range from 2×10^{-3} to 46×10^{-3} SI unit (look at the map on the side).

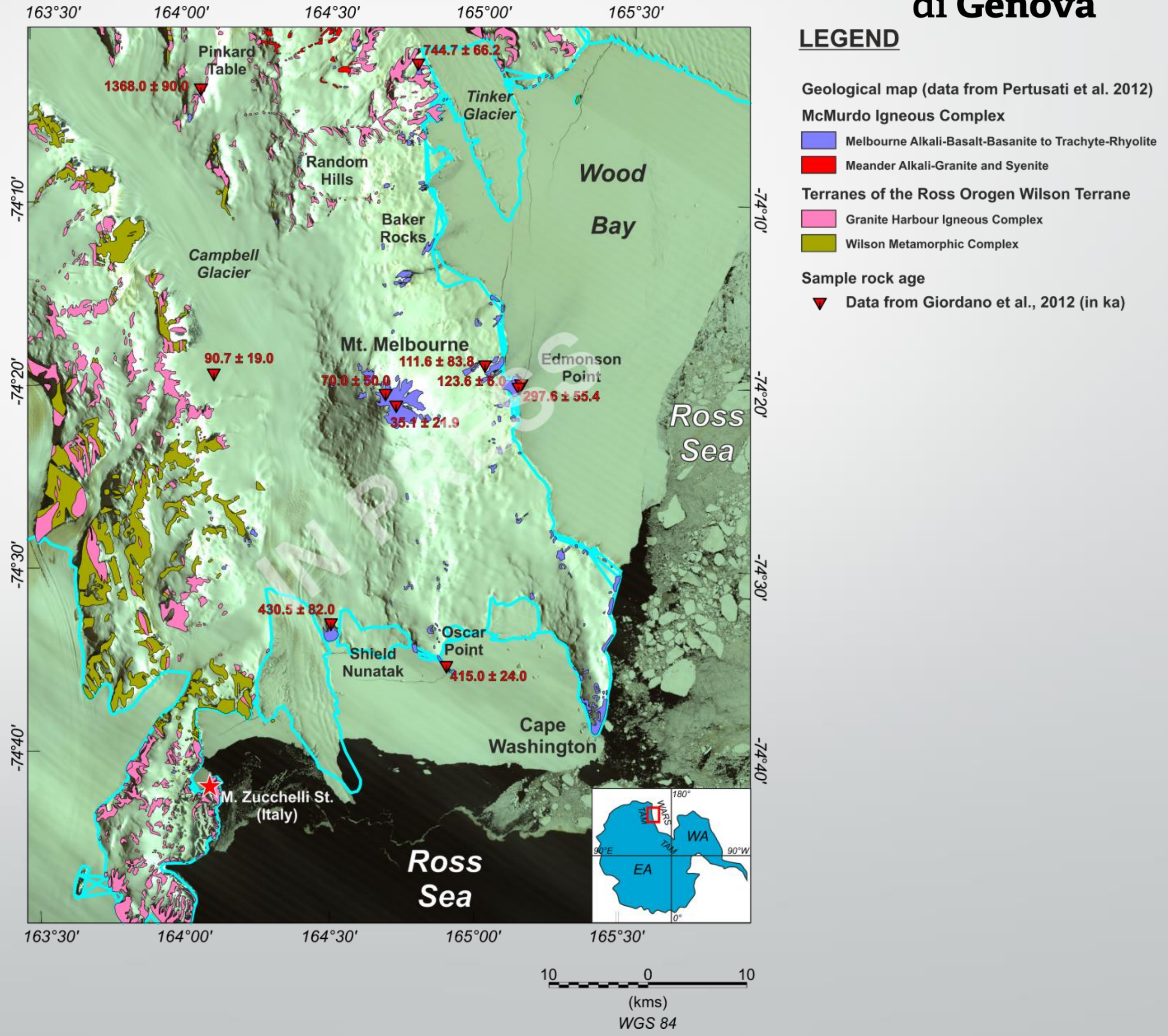


Outcrops ages

Outcrops ages (in ka) available for the study area from Giordano et al. (2012) (look at the map on the side).

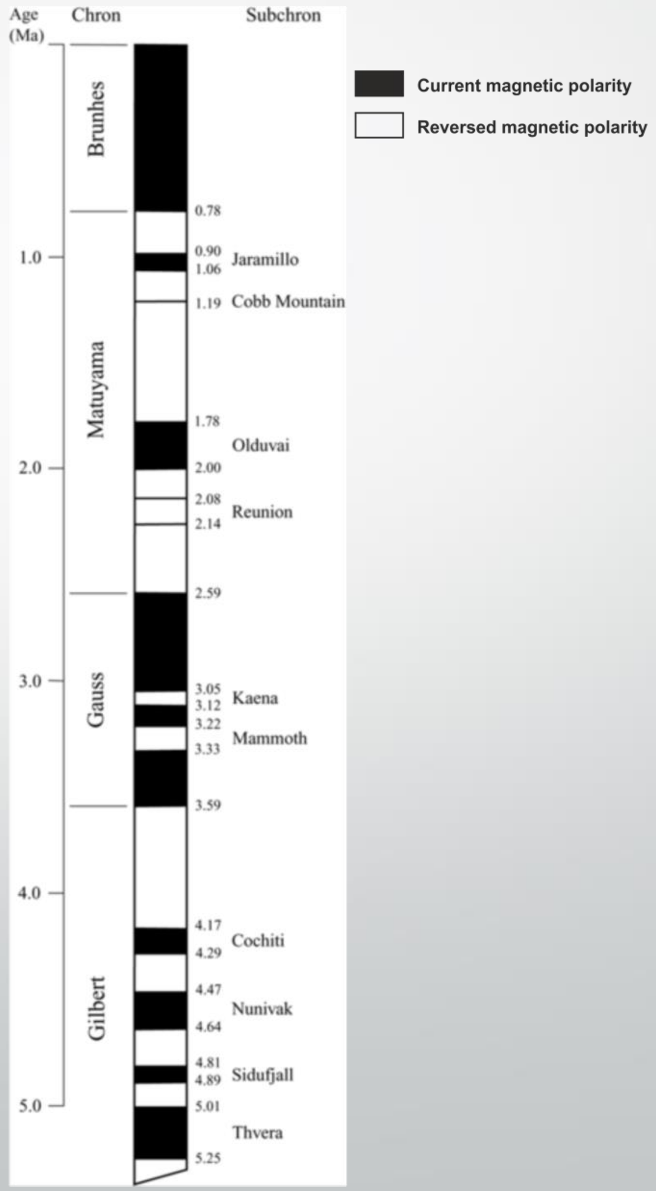
Other age estimates suggesting older age for the entire field are available from Armstrong (1978), Kreutzer (1988, unpublished report) Wörner and Viereck (1989), Armienti et al. (1991).

Considering the little agreement among the old and newly derived ages reported in Giordano et al. (2012), the **age of the buried volcanic rocks might be older** than the exposed rocks, as proposed hereafter from our new aeromagnetic data.



Outcrops ages

Age estimates are fundamental constrain information for the modeling of magnetic data, particularly in volcanic contexts in which magnetic remanence often dominate on magnetic susceptibility.
On the other hand, the polarity of the modeled magnetic remanence can be a powerful tool for volcanic (magnetic) rock age estimates.



Forward modeling

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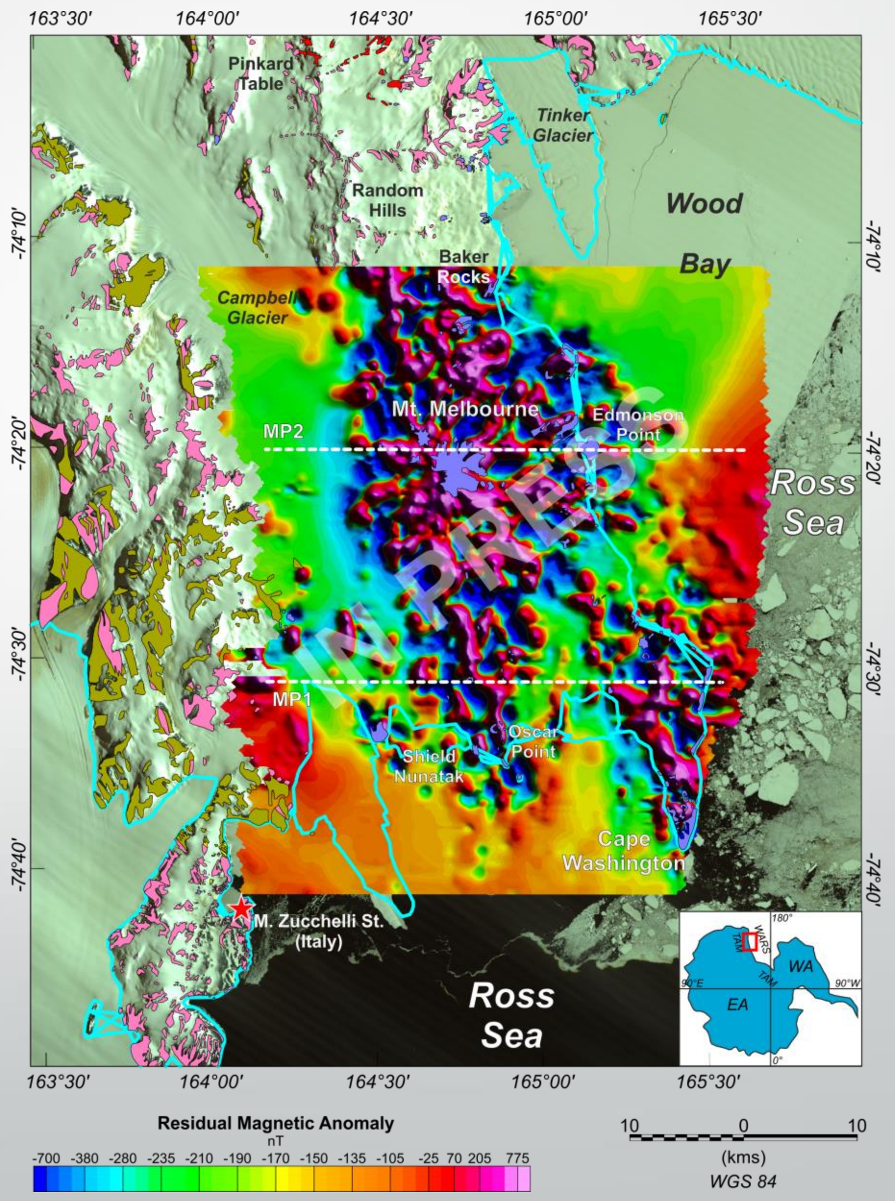
Profiles MP1 & MP2 were selected for our forward magnetic modelling across the Mt. Melbourne edifice and the Cape Washington shield.

We included available lithology, magnetic susceptibility and structural geology information to help constrain our new magnetic models.

The algorithm employed is that of Talwani et al. (1964) implemented in Geosoft® environment.



Modeled lithotypes

- Volcanic strata with current magnetization
- Volcanic strata with current magnetization
- Volcanic strata with current magnetization

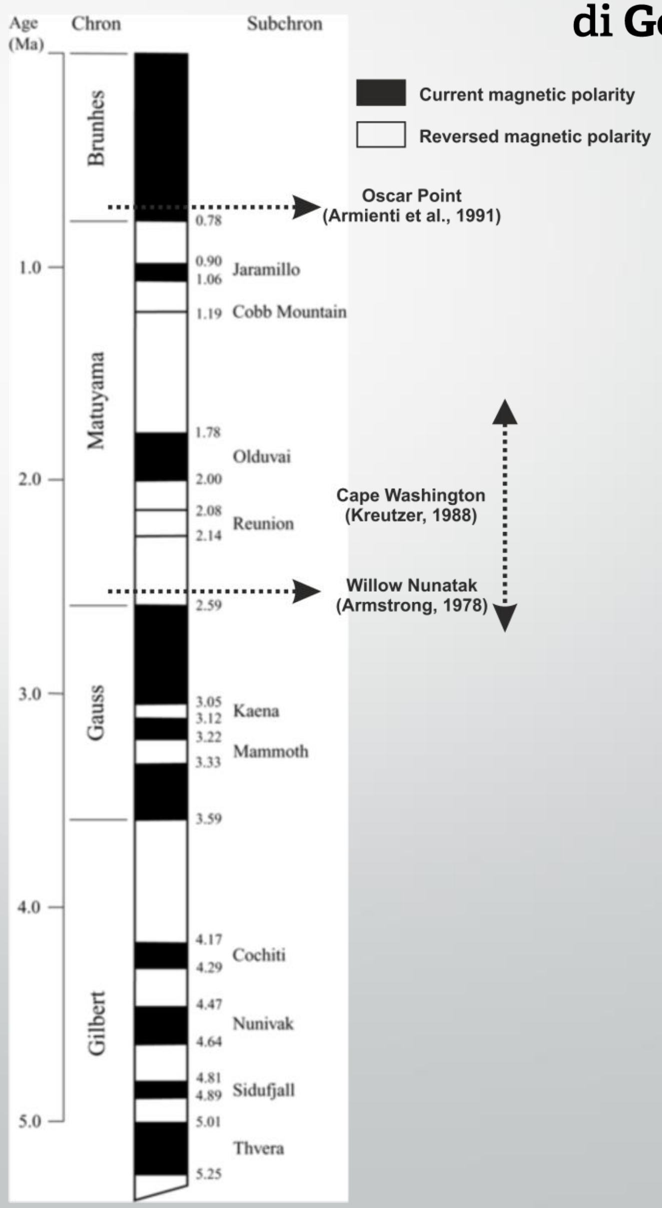
< 0.78 Ma

- Volcanic strata with reversed magnetizazion

0.78 - 2.59 Ma

- Metamorphic basement - Wilson Terrane

Armstrong (1978) suggests an estimated age of 2.5±0.1 Ma for an outcrop at Willow Nunatak, near Cape Washington.
Armienti et al. (1991) dated an outcrop at Oscar Point 0.71±0.18 Ma.
Kreutzer (1988) dated the Cape Washington basaltic shield as 2.7 to 1.67 Ma.
Lanza et al. (1991) notice the existence of reversely-magnetized basaltic bodies.
Therefore, there are geological evidences of basaltic strata with reversed magnetization.



Modeled lithotypes

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	Induced magnetization			Remanent magnetization		
	Value (SI)	Inclination	Declination	Value (A/m)	Inclination	Declination
Volcanic strata with current magnetization	$20x10^{-3}$	-83°	134°	2.2	-83°	134°
Volcanic strata with current magnetization	$41x10^{-3}$	-83°	134°	4.2	-83°	134°
Volcanic strata with current magnetization	$34x10^{-3}$	-83°	134°	3.1	-83°	134°
Volcanic strata with reversed magnetizazion				5.0	83°	-45°
Metamorphic basement - Wilson Terrane	$3x10^{-4}$	-83°	134°	N.A.	N.A.	N.A.

The above values have been used during forward modeling of magnetic anomaly data for profiles MP1 and MP2

Forward modeling – Cape Washington (MP1)

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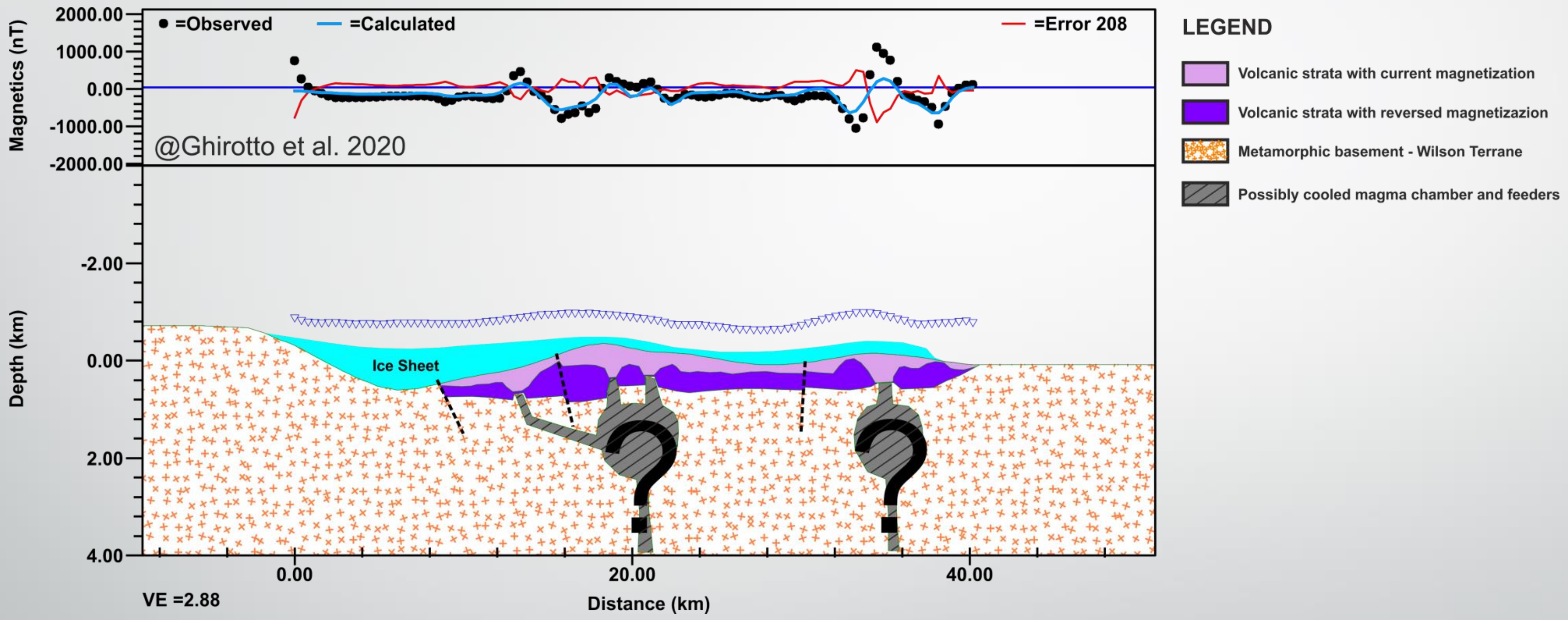

Recent volcanic flows (with current magnetization) show limited thickness, whereas ancient ones (with reversed magnetization) rise up at the topographic surface at some points, as suggested by older age estimates for this area.

Forward modeling – Mt. Melbourne edifice (MP2)

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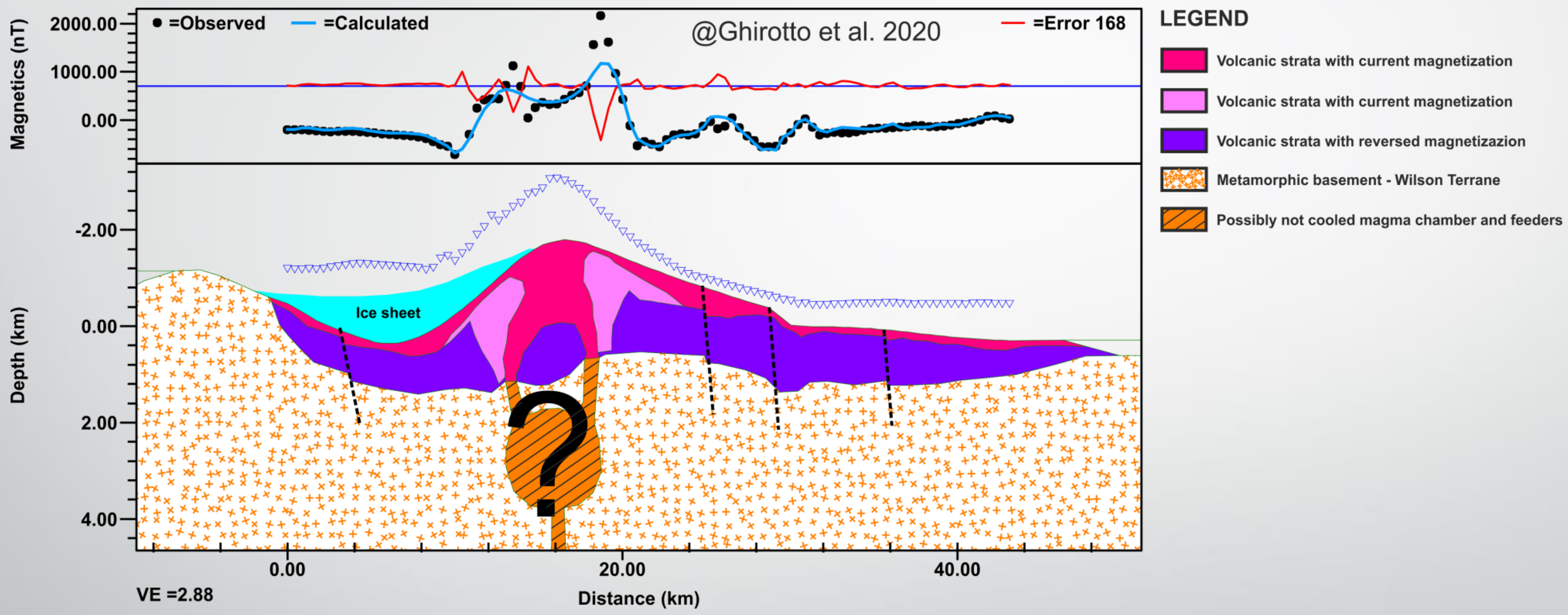

Recent volcanic flows show higher thickness and slightly different magnetic properties. Ancient volcanic strata do not rise up at the topographic surface but remain confined in the inner of the volcanic edifice. Hence, the putting in place of the volcanic edifice would be older than that suggested by Giordano et al. (2012).

Forward modeling – Mt. Melbourne edifice (MP2)

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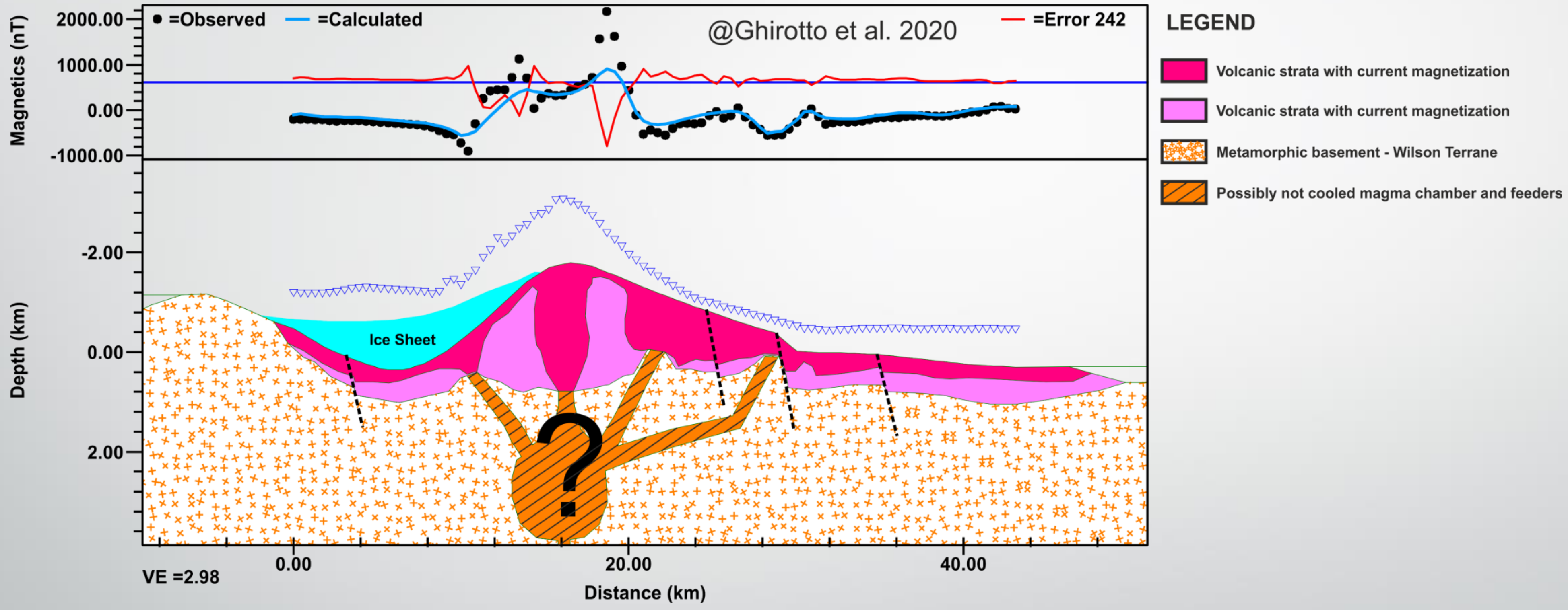

We tested an alternative model with no reversely magnetized volcanic flows (following the hypothesis of an Upper Pleistocene – Holocene building up of the volcanic edifice) but these appear to lead to a worse fit.

Next developments – Montecarlo inversion

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We will carry out **2.5D Monte Carlo inversion** using a **Bayesian approach** in order to test the models proposed. These models will provide “a priori” starting models.

Differently from traditional deterministic inversion methods, performing Monte Carlo ones will allow us to:

i. obtain a collection of models and their probabilities, each with related uncertainties and resolution estimates;
ii. increase geological plausibility of models directly constraining the variability of model parameters (i.e. magnetic susceptibility and remanence).

Combining together all the results obtained, we will try to shed light into the evolution of the Mt. Melbourne volcanic field and, at a regional scale, its geodynamic relationship on the development of the TAM and the WARS.

Conclusions

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i. High resolution aeromagnetic data reveal subglacial faults and magmatic patterns in the Mt. Melbourne volcanic field with unprecedented detail.

ii. Subglacial NNW-SSE, NNE-SSW and WNW-ESE to E-W trending structural systems have been detected, in partial agreement with previous results from literature.

iii. 2D forward models suggest that Mt Melbourne includes reversely magnetized flows overlain by younger flows with current polarity. This attests to the long-lived development of the volcanic field along the flank of the West Antarctic Rift System.

iv. 2.5D Bayesian Monte Carlo inversion will be performed to test hypothesized models.

THANKS FOR YOUR ATTENTION!!!

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British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL