Airborne geophysics in the Antarctic

Dr Fausto Ferraccioli discusses how airborne geophysics can be used to uncover the geology of Antarctica and explore some of the Earth's final frontiers

How did you come to develop an interest in airborne geophysics?

I actually fell into this field by chance. It all began 20 years ago in Italy; I was at university and my professor was working in aeromagnetics in Antarctica. I found it really fascinating that a plane could be flown over ice to discover the geology that's underneath. After that, there was no going back. Airborne geophysics is like a black hole – once you've entered it, you'll never get out!

Could you elucidate what an airborne geophysical survey entails? What technology is commonly utilised?

We use three different techniques: aeromagnetics, airborne gravity and radar. Aeromagnetics provides a glimpse into the geology that lies beneath the ice. This is because rocks (particularly crystalline rocks) are magnetic; therefore we can map magnetic anomalies to trace the geology from the limited outcrops along the coast through the interior of the continent. With gravity, we study the density of rocks. Airborne gravity is particularly good at looking at larger features (for example, the crust under mountain ranges or beneath basins) and can also give us an indication of how strong the crust is, which is important when trying to understand the processes that led to, for example, mountain building or basin formation. Finally, radar gives a view from the ice surface through to the structures in the ice and the bedrock topography that lies beneath, and can also give an insight into the hydrology (the way that water flows under the ice).

Which of your previous discoveries do you consider to be your greatest achievement?

I would definitely consider my greatest achievement to be the Antarctica's Gamburtsev Province (AGAP) project, where several nations worked together to explore the least understood mountain range on Earth. This had a lot of visibility both in terms of scientific output and media interest. This was not a project about ice sheet stability or climate change, but rather pure curiosity-driven research. Our attitude was very much: 'Let's uncover the last frontier on Earth and try to understand how the ice sheet was born in the first place, and how mountain building may have influenced that process'.

The British Antarctic Survey (BAS) has a long history of collaborative research. How significant is this to your work? Is a multidisciplinary approach important to the success of your aerogeophysics group?

International collaboration is absolutely fundamental: no single nation can really tackle a continent that is as hostile and difficult to work in as Antarctica. Even now in the 21st Century, exploring these regions remains a big challenge. Most Antarctic research stations are situated along the coast, so exploring the interior requires the establishment of deep field international camps. It goes beyond logistics, however. Working with researchers from different nations provides access to an entirely new set of skills and expertise. I've found, at least for my own personal development, that working with and learning from all these different researchers from different countries has been a highly rewarding experience. Hopefully they've learnt something from me as well!

A multidisciplinary approach is also vital. We work with scientists who are interested in the ice sheet and its short- and long-term behaviour, including climate modellers, ice sheet modellers, geomorphologists and geologists, to name just a few.

For me, one of the best things about Antarctic research is that it's collaborative, international and multidisciplinary. This approach has been key to the success of all of the major projects that I have been involved in the last 10 years.

What is the most rewarding or exciting aspect of your work?

The greatest reward is definitely the publication of results, as that's the end of several years of work in setting up these projects and processing the data. Nevertheless, the greatest excitement comes from setting up the campaign itself; meeting all these different challenges and going beyond what one might think is possible.

Geophysical glimpses beneath Antarctic ice sheets

The Aerogeophysics Group at the **British Antarctic Survey** are unearthing valuable information about the ice sheets and underlying geology of Antarctica. Such insights are of vital importance to the successful modelling of past and future changes on the continent

AIRBORNE GEOPHYSICS CAN be used to explore some of the most remote regions on Earth. By flying over regions in specially adapted planes, geophysicists are able to conduct large-scale surveys using a combination of aeromagnetic, gravitational and radar technologies. "Together, the three datasets give us new views from the ice surface right down to the base of the crust," highlights Dr Fausto Ferraccioli of the British Antarctic Survey, who has been conducting airborne geophysical surveys over Antarctica for the past 20 years. Such insights can be significant both in improving understanding of Antarctica's geology and for modelling past and future ice sheet behaviour.

BUILDING BASINS AND MAKING MOUNTAINS

Ferraccioli was part of the research team responsible for the discovery of the Ferrigno Rift – a subglacial basin the size of Wales in the Bellingshausen Sea sector of West Antarctica that is connected to the warming ocean. The presence of this basin indicates that this largely unexplored region of the West Antarctic Ice Sheet (WAIS) could be vulnerable to accelerated future ice loss. Since WAIS is currently losing ice faster than any other part of the Antarctic, information that can be used to more accurately predict the ice sheet's future behaviour is of immense value. This discovery was made using both airborne and ground geophysics, through the use of radio-echo sounding technology.

Airborne geophysics can also be used to investigate the formation of subglacial mountain ranges, as a study of the origins of the Gamburtsev Subglacial Mountains in East Antarctica – conducted by Ferraccioli along with an international team as part of International Polar Year (2007-08) – demonstrated. "Mountain building is a critical factor in the initiation of the Antarctic ice sheet," Ferraccioli enthuses. "Even during major retreats that have occurred repeatedly over geological timescales over Antarctic subglacial basins, the ice sheet remained comparatively stable across these high elevation mountain ranges."

ICE STREAM INVESTIGATIONS

Currently, Ferraccioli is involved in an investigation of basal boundary conditions for the Institute and Möller (IIS/ MIS) ice streams of West Antarctica. Until now, these streams have been largely unexplored. "Historically, it's been a difficult region to reach," Ferraccioli elaborates. "Furthermore, satellite data suggests that this is not a hotspot of change at present." The researchers established field camps in the region from which they could conduct their surveys. The airborne radar data have already been made available on BEDMAP II (an open access database of all Antarctic bedrock topography data), whilst the team's final results and point observations will be made publically available in April 2014.

It was during this project that the researchers, using satellite images and airborne radar measurements, discovered 250 m high channels beneath the Antarctic ice shelf. Of particular importance is the fact that these channels are thought to have been created by water flow beneath the grounded ice sheet, and may perhaps also impact the ice shelf's stability. "This discovery, together with evidence for much deeper subglacial basins beneath the IIS/MIS ice streams, suggests that this region could also be prone to future changes," explains Ferraccioli.

THE FINAL FRONTIER

As the IIS/MIS project comes to a close, Ferraccioli and his colleagues can now turn their attention to their next big challenge: "At the moment we are involved in a major new international project: exploring the Recovery region in the interior of East Antarctica, in between the Gamburtsev Subglacial Mountains and the Weddell Sea," he elucidates. "It's a real frontier – true terra incognita – and yet it's of great significance because this part of the ice sheet contains approximately 3 m of sea level rise." The international team have already conducted an extensive airborne geophysical survey during the field season of 2012-13, and more are planned for 2015-16. The findings from these surveys will help establish whether this part of the East Antarctic ice sheet is potentially less stable than often thought, and will provide fundamental new geological knowledge on how East Antarctica was assembled.

Airborne geophysics has the power to improve knowledge in remote regions, and it is imperative that we do not underestimate its value – especially at a time when the ice sheet in some parts of Antarctica is retreating with alarming rapidity. "On short-term timescales we know that the main drivers of Antarctic ice sheet change are the warming ocean and climate," concludes Ferraccioli. "However, it is necessary that we understand subglacial landscapes and geology if we are to make accurate predictions as to how ice sheets actually work and, hence, what contributions these can make to both past and future global sea level rise."

INTELLIGENCE

USING AIRBORNE GEOPHYSICS TO INVESTIGATE THE ANTARCTIC

OBJECTIVES

To use airborne geophysics to understand the structure and evolution of the Antarctic continent and to comprehend how geological boundary conditions influence ice sheet behaviour.

KEY COLLABORATORS

UK: **Drs Tom Jordan**, **Carl Robinson** & **Hugh Corr**, British Antarctic Survey • **Professor Martin Siegert**, University of Bristol • **Dr Robert Bingham**, University of Edinburgh • **Dr Neil Ross**, Newcastle University • **Dr David Rippin**, University of York • **Dr Anne Le Brocq**, University of Exeter • **Dr Stewart Jamieson**, University of Durham

USA: **Professor Robin Bell**, Lamont Doherty Earth Observatory • **Dr Carol Finn**, U.S. Geological Survey • **Drs Donald Blankenship** & **Duncan Young**, University of Texas

Australia: **Professor Alan Aitken**, University of Western Australia • **Professor Peter Betts**, Monash University

Germany: **Dr Detlef Damaske**, Federal Institute for Geosciences and Natural Resources • **Professor Mirko Scheinert**, Technical University of Dresden

Denmark: **Professor Rene Forsberg**, Technical University of Denmark

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FUNDING

Natural Environment Research Council (NERC)

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FAUSTO FERRACCIOLI obtained a PhD in geophysics at the University of Genoa, Italy, in 2000. In 2002 he moved to the UK, where he has been the Aerogeophysics Group Leader at the British Antarctic Survey for the past 11 years. He has been at the forefront of major international aerogeophysical exploration projects, particularly over the Gamburtsev Subglacial Mountains as part of the International Polar Year.

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