Unlocking the secrets of the Southern Prince Charles Mountains

In the frozen desert of Antarctica, there lies a mountain range that holds within its lofty peaks and its roots buried deep beneath the ice, a story of the Earth that spans thousands of millions of years. These are the Southern Prince Charles Mountains with rocks over 3.4 billion years old that formed the mighty supercontinents of Rodinia approximately 1000 million years ago, and Gondwana 500 million years ago. Here also is found a great rift valley that hosts the world's largest glacier – the Lambert Glacier. This valley was formed as Gondwana was ripped apart in an event that transported remnants of the supercontinent to form new continents such as Australia and as far away as Africa and Asia.

Despite their importance, much of the Southern Prince Charles Mountain range remained unstudied, due to remoteness and inaccessibility. A few trips had been made there, by Australia in 1960, 1974 and 1998, and by Russia between 1983 and 1991. These expeditions collected enough information to indicate that this is indeed a scientifically critical location, but not enough to provide as many answers as they did questions. In 2000, Professor Chris Wilson from the University of Melbourne and Dr Norbert Roland of the German Federal Republic Geological Survey [Bundesanstalt für Geowissenschaffen und Rohstoffe (BGR)] proposed an expedition to unlock the secrets of these mountains.

GARY KUEHN

Remote geological field parties supported by Squirrel helicopters.

During the 2002–03 Austral summer, an expedition of twenty scientists from five Australian, one Russian, and six German research institutions joined forces with the Australian Antarctic Division to undertake a complete study of the formation of these mountains and their preserved record of the Earth's history. It was christened the Prince Charles Mountains Expedition of Germany-Australia (PCMEGA).

The PCMEGA program has been one of the most comprehensive onshore geoscience projects ever undertaken under the auspices of the Australian Antarctic Program. The work involved several programs, including Australia's first major airborne geophysical investigations into the subglacial structure of the Antarctic continent, its glacial evolution and the impact of climate change. Other programs investigated the geological architecture of the bedrock geology and the control that this geology has on shaping the geomorphic evolution of the continent. A comprehensive sampling program was undertaken to establish the age and evolution of the continent and its relationship to other fragments when they were assembled as part of the supercontinent Gondwana.

Good weather and logistical support enabled an extremely productive field season. Twenty-four sites were investigated in detail, incorporating field camps at Mt Stinear, Cumpston Massif, Clemence Massif, Mt Dummit, Wilson Bluff, Mt Ruker, Mt Rubin and various light-weight camps along the Mawson Escarpment. Detailed observations and maps at 1: 10,000–1:50,000 were made of the ancient bedrock outcrops and early Cenozoic-Recent weathering, glacial, fluvial, biological and lacustrine landforms and sediments. Four tons of hard rock samples were collected for mineralogical and geochemical investigations and age dating, with four hundred sediment samples collected to determine past geomorphic processes and sediment depositional pathways and for cosmogenic exposure age dating.

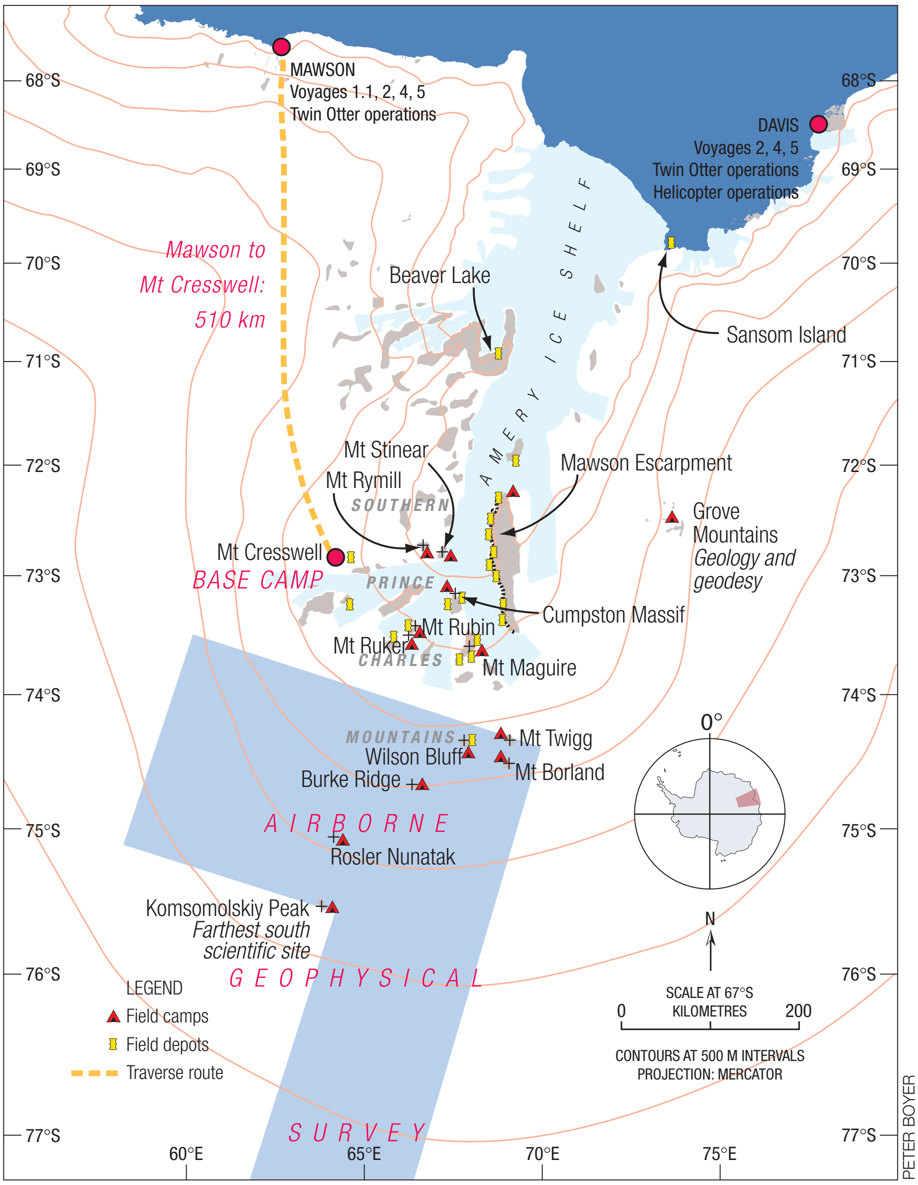
One of the most interesting features of the Southern Prince Charles Mountains is the presence of a remarkably widespread and ancient land-surface that marks the summit of much of the range. The enigmatic flat plateau-like surfaces of these mountains piercing the Antarctic ice sheet hints at the region's older history. This is a history that has since been disrupted by faulting and uplift, erosion and glaciation.

Over the next two years, detailed investigations using a range of isotopic techniques, in conjunction with structural analysis, will be necessary to determine the magnitudes and rates of the processes that shaped this part of the continent. This will permit reconstructions of key components of the tectonics of Antarctica since before the break-up of Gondwana. Because only a small percentage of the continent is exposed from beneath several thousand metres of ice, the research will use the ice-penetrating radar, as well as subsurface geophysical data collected as part of the PCMEGA program, to establish a regional picture of the crustal geometry and development.

The airborne geophysical program involved a Twin Otter fixed-wing aircraft flying in a surveyed grid over an area of 81,000 square kilometres. This has produced over 30,000 kilometres of high-quality airborne gravity, magnetic and ice-penetrating radar data that has enabled the scientists to map the underlying geology in the sub-glacial basement at depths of up to 3.5 kilometres below the current ice surface, and identify the shape and distribution of the sub-glacial mountains. Importantly, they have been able to locate and identify part of the Gamburtsev Mountains, a major sub-glacial mountain range buried by 1600 metres of ice that acts as a major glacial drainage divide underneath the centre of the east Antarctic ice sheet some 1000 kilometres inland from the continental margin.

As a major bonus to the geophysics program there was the acquisition of some additional 20,000 kilometres of geophysical data from the upper reaches of the Lambert Glacier and its tributary glaciers. This data was acquired during the Twin Otter's daily flights over known areas of outcropping rock from Mount Cresswell to the survey area. The additional high-quality ice radar data and its precise GPS surveyed positions will provide important information on the volume of ice flowing through the Lambert-Amery ice drainage system and any mass-balance calculation of ice volumes. The additional gravity and magnetic data obtained during these flights is also critical as it can be directly correlated with the petrophysical properties of the rocks collected during the geological investigations.

Rock samples were also collected along and across the tops, and in numerous vertical profiles, of many of the 1000 metre high nunataks that penetrate the ice sheet. These mountainside profiles will provide information about Antarctica's history that could otherwise only be recovered by drilling deep



boreholes. In essence, individual samples record a portion of the history of the rock column over vast expanses of time (greater than 500 million years). The spectacular three-dimensional exposure in the Southern Prince Charles Mountains also enabled an assessment of the recent structural development of fault blocks that now confine the world's largest glacier – the Lambert Glacier.

The PCMEGA team included two geodesists from Geoscience Australia and one from the University of Dresden in Germany. They were responsible for establishing gravity and GPS stations to record long-term uplift, or isostatic rebound, of the Antarctic continent, as a result of ice sheet volume changes. The GPS data collected from all sites will be processed to generate sub-centimetre coordinates. These positions will provide a base data set for the study of tectonic plate movement. The geodesists were also able to record surface flow rates of the Lambert and its tributary glaciers and re-surveyed the position of 20 nunataks, using the highly accurate GPS survey methods. Additional tasks completed during the geodesy campaign included the establishment of a ground calibration grid for the ICESAT satellite launched on the 13th January 2003, and the placement of a Doppler Orbitography Ranging Interfermetric System (DORIS) beacon on the Lambert Glacier to measure the movement upstream (south) of the glacier's grounding line near Cumpston Massif.

The scientists of PCMEGA will be busy over the next months and even years, processing and interpreting the huge amounts of data they collected. In a mere two months, this group accomplished more than the previous expeditions were able to accomplish over several trips. By combining their intellectual and financial resources, they were able to execute a complete study that will expand our knowledge of the processes that have shaped our Earth over billions of years.

Chris Wilson, University of Melbourne