National Report

Antarctic Earth Science Program of China

2014-2015

To the 34th SCAR SSG-Gs

Chinese Arctic and Antarctic Administration (CAA)

2016.8

Major Progress and Results of Scientific Research during 2014

(1)Geological expedition and research on the Antarctic continent

The Vestfold Block is an Archean/ Palaeoproterozoic cratonic fragment, with several mafic dyke swarms of Proterozoic age. The study reveals that the dykes from the southwest of the block experienced heterogeneous granulite facies metamorphism, characterized by spotted or fractured garnet-bearing aggregates in garnet absent groundmass. The garnet-absent groundmass typically preserves an ophitic texture composed of lathy plagioclase, intergranular clinopyroxene and Fe–Ti oxides. Garnet-bearing domains consist mainly of a metamorphic assemblage of garnet, clinopyroxene, orthopyroxene, hornblende, biotite, plagioclase, K-feldspar, quartz and Fe- Ti oxides. Chemical compositions and textural relationships suggest that these metamorphic minerals reached local equilibrium in the centre of the garnet-bearing domains. Thermodynamic calculations in the model system NCFMASHTO (Na_2O–CaO–FeO–MgO– Al_2O_3–SiO_2–H_2O–TiO_2–Fe_2O_3) yield P-T estimates of 800 ℃ and c. 9.1 kbar. Ion microprobe U–Pb zircon dating reveals that the NW-and N-trending mafic dykes were emplaced at 1764 ± 25 and 1232 ± 12 Ma respectively, whereas their metamorphic ages cluster between 957 ± 7 and 938 ± 9 Ma. The identification of granulite facies mineral inclusions in metamorphic zircon domains is also consistent with early Neoproterozoic metamorphism. Therefore, the south-western margin of the Vestfold Block is inferred to have been buried to depths of ~30–35 km beneath the Rayner orogen during the late stage of the late Mesoproterozoic/early Neoproterozoic collision between the Indian craton and east Antarctica (i.e. the Lambert Terrane or the Ruker craton including the Lambert Terrane). The lack of penetrative deformation and intensive fluid–rock interaction in the rigid Vestfold Block prevented the nucleation and growth of garnet and resulted in the heterogeneous granulite facies metamorphism of the mafic dykes.

The work was supported by the Polar Key Programmes (CHINARE2013-02-05) and the result was published in the *Journal of Metamorphic Geology*.

(2)The investigations of the Paleo-climate event and the Cenozoic history of the East Antarctic Ice Sheet in the Grove Mountains area

The Cenozoic history of the East Antarctic Ice Sheet (EAIS) becomes one of the most scientific hot points recently. The glacial geology, the ages of cold desert soils, the depositional environment of younger moraine sedimentary boulders and their spore pollen assemblages combine to imply a possible significant shrinkage of the Ice Sheet before the Middle Pliocene Epoch, with the Ice Sheet margin retreating south of the Grove Mountains (~400 km south from its present coastal position). Exposure age measurements of bedrock indicated that the elevation of the ice surface in the Grove Mountains region subsequently rose at about mid-Pliocene to at least 200 m higher than today′s levels. The ice surface then progressively lowered, with some minor fluctuations. Such point of view was widely interested by the SCAR meetings and the Open Scientific Conference held in New Zealand

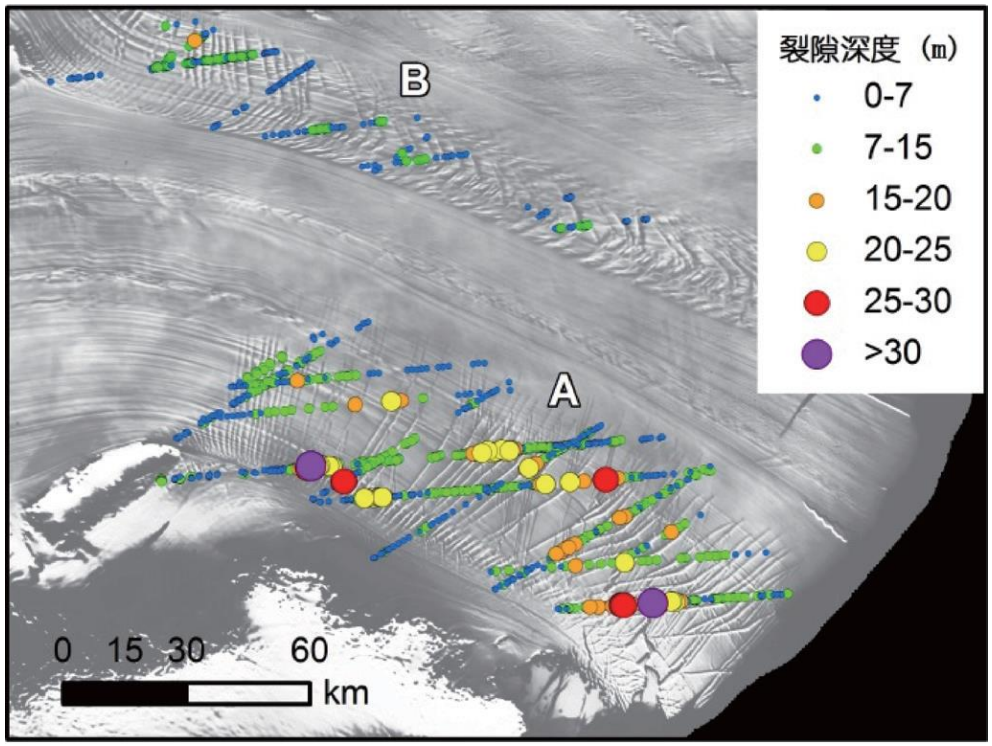
2014.

This study was supported by the Polar Key Programmes.

(3)Detection of crevasses over polar ice shelves using Satellite Laser Altimeter

The research group presented a method of crevasse detection using the ICESat-1/GLAS data. A case study was taken at the Amery Ice Shelf of Antarctica to verify the accuracy of geo-location and depth of crevasses detected. Moreover, based on the limited crevasse points, the research group developed a method to detect the peak stress points which can be used to track the location of the crack tips and to identify the possible high-risk area where an ice shelf begins to break up. The spatial and temporal distribution of crevasse depth and the spatial distribution of peak stress points of the Amery Ice Shelf were analyzed through 132 tracks in 16 campaign periods of ICESat-1/GLAS between 2003 and 2008. The results showed that the depth of the detected crevasse points ranged from 2 to 31.7 m, which were above the sea level; the crevasse that advected downstream to the front edge of an ice shelf had little possibility to directly result in breakups because the crevasse depth did not show any increasing trend over time; the local stress concentration was distributed mainly in the suture zones on the ice shelves.

This work was supported by the Polar Key Programmes and the NSFC. The result was published in *Science China*.

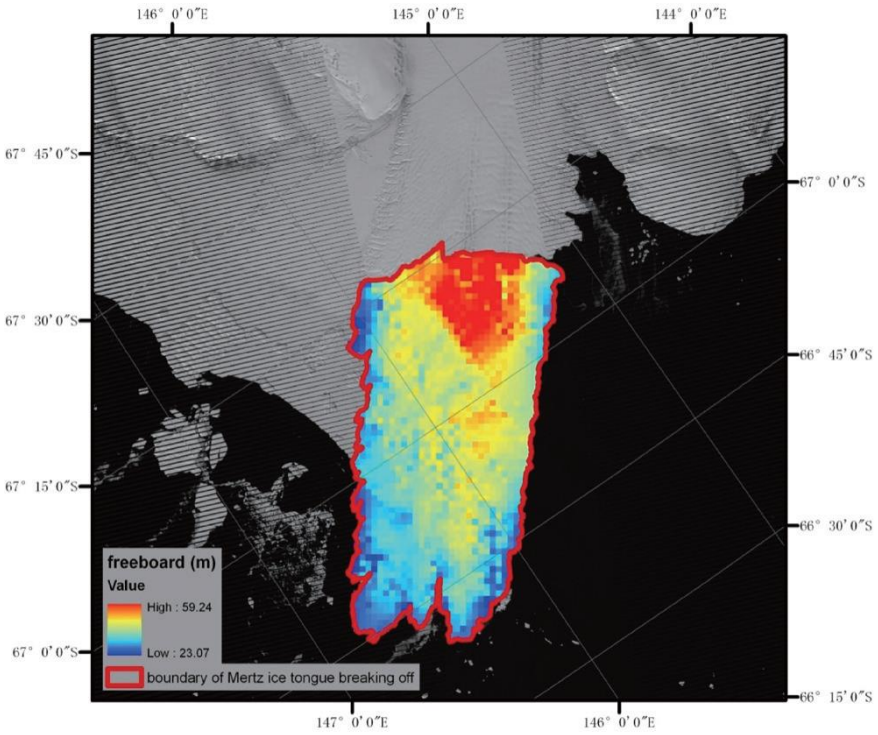


Spatial distributions of GLAS crevasse depths of the Amery Ice Shelf from 2003 to 2008 overlaid on MOA image

(4)Freeboard map and ice loss of the disintegrated Mertz Ice Tongue

The total ice loss is approximately 2560±5 km^2 after analysis using remote sensing data. The freeboard map of this disintegrated iceberg was generated for the first time after data preprocessing, data separation by track, sea level extraction, freeboard calculation, relocation and freeboard exclusion for those fallen in deep crevasse, using a time-series ICESat/ GLAS data from 2003 to 2009 with Kriging method. The freeboard varied from 23.1 m to 59.2 m. With assumption of hydrostatic equilibrium (assuming a snow layer depth of 1m, a snow density of 360 kg/m^3, an ice density of 915 kg/m^3 and a sea water density of 1024 kg/m^3), the minimum, maximum and average ice thickness were calculated to be 210 m, 550 m and 383 m respectively. The total ice loss is approximately 8.96×10^{11} tons. This is the first time that the freeboard and ice loss of the Mertz ice tongue are calculated using long time series of laser altimetry data.

This research was supported by the NSFC and the Polar Key Programmes and the result was published in *Remote Sensing of Environment*.



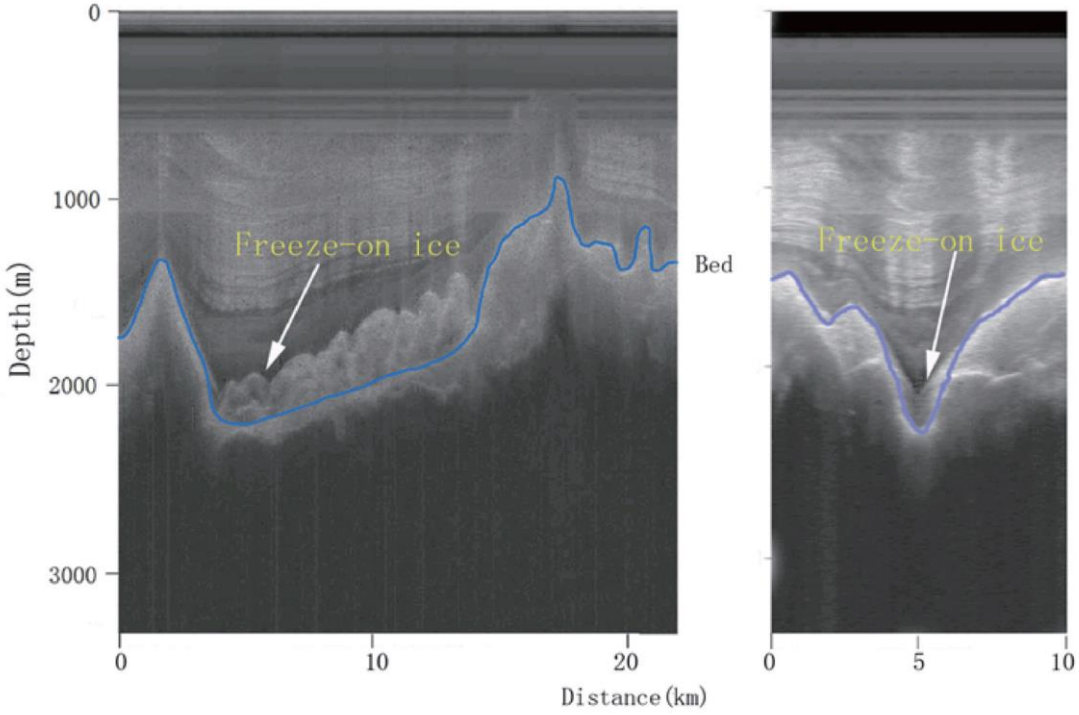
Freeboard Map of the Disintegrated Mertz Ice Tongue

(5)Key process of polar ice sheet and its response to climate change

The research group used the SAR and optical remote sensing images to extract the velocity field of Lambert Glacier-Amery Ice-shelf. Using the field data, a high resolution map with temporal and spatial variations in the typical areas of the ice sheet was completed. The group derived the mass balance, refreezing process from the radar data, with process research. Along the flowlines from the radar lines, a three-dimensional parallel ice sheet model (PISM) was applied to simulate the flow field of the Amery ice shelf.

Institute of Electronics of the Chinese Academy of Sciences (CAS) and the PRIC developed a new radar system to explore the subglacial conditions between the Zhongshan station and Dome A. The radar dataset along the profile was collected using a new ground-based radar system with a high frequency of 150 MHz. A typical example of a freeze-on ice structure was revealed in the radar images, similar to that found in the Dome A region. Six dated radar isochrones layers were traced from the radar profile with a length of 216 km at Dome A. The depth-age relationships were extended from Vostok ice core to Dome A. The D-J model was used to infer the spatial and temporal variation of Dome A over the last ~160,000 years. The result showed accumulation rates of ice increase gradually from south to north along the radar profile.

The study was supported by the Polar Key Programmes.



Radar images of the freeze-on ice in the ice-sheet profile along the Zhongshan station and Dome A

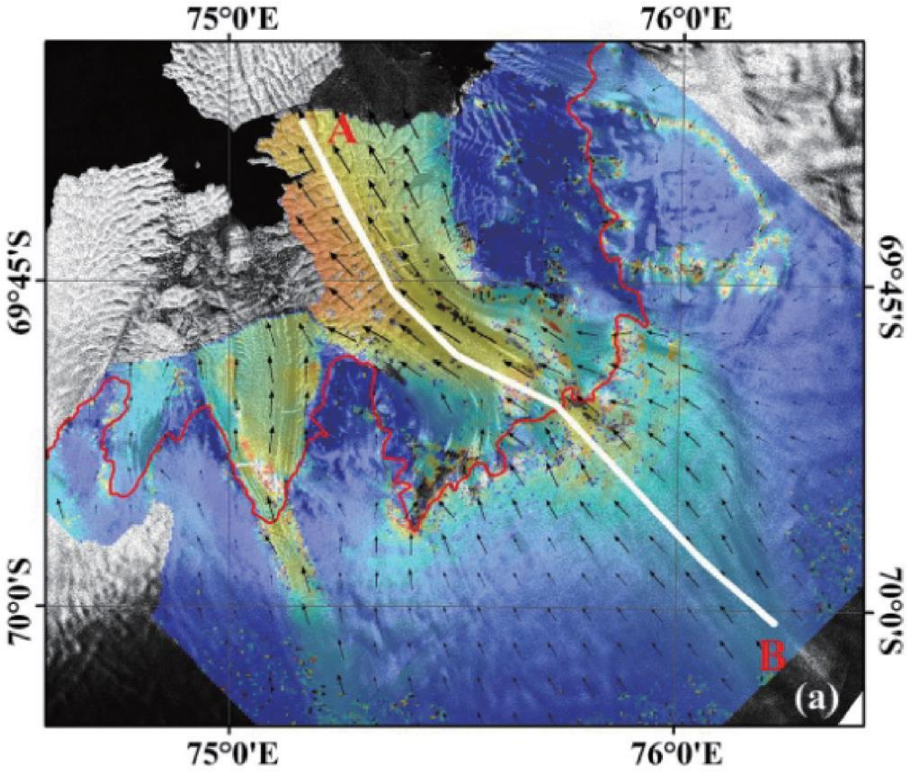
(6)Research on ice-flow velocity in East Antarctica

Using the GPS data collected during the 29th CHINARE, the latest DEM of the Dome A area was generated. Combined with GPS data in 2008, the ice velocity and strain field in Dome A area were obtained. The ice velocity varied from 3.1±2.6 cm/a to 29.4±1.2 cm/a. The study also found that ice velocity was related to terrain slope.

The seasonal and interannual ice velocity changes of Polar Record Glacier were studied using ERS-1/2, Envisat and PALSAR data. Ice velocities in the grounding zone did not show clear seasonal or interannual changes. Velocities in winter were 19% less than velocities during summer at the front of the glacier tongue.

These researches were supported by the Polar Key Programmes, the 863 Program and the 973 Program. The results were published in *Journal of Glaciology*, *Journal of Geodesy*,

Annals of Glaciology and *IEEE Transactions on Geoscience and Remote Sensing*.

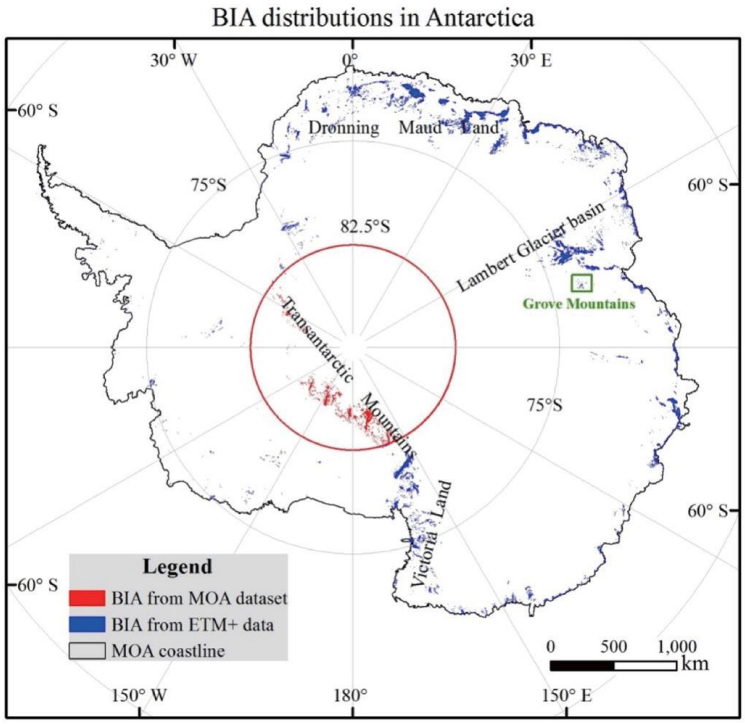


Ice velocity of Polar Record Glacier based on ERS-1/2 tandem data

(7)Mapping of Blue Ice Areas in Antarctica using ETM+ and MODIS data

Blue Ice Areas (BIAs) and their geographical distribution in Antarctica were mapped using Landsat-7 ETM+ images obtained during austral summers of 1999-2003 covering the north area of 82.5° S, and the snow grain size image of MODIS-based Mosaic of Antarctica (MOA) dataset acquired during the 2003- 2004 austral summers from 82.5° S to the South Pole. The results estimated BIAs to occupy 234,549 km_2, or 1.65% of the continent. The BIAs were scattered widely over coastal or mountainous regions of the continent but were generally located in Victoria Land, the Transantarctic Mountains, Dronning Maud Land and the Lambert Glacier basin. The surface slope of most of the BIAs was less than 5 degrees, and only 5.5% of the BIAs had slopes of more than 5 degrees, primarily located in the Transantarctic Mountains and Victoria Land. The ice velocities of approximately 92.92% of the BIAs were less than 500 meters per year, while ~84% of BIAs exhibited ice velocity of less than 200 meters per year, mainly located in the Ross, Shackleton, Amery, Riiserlarsen and Ronne Ice Shelves closely associated with glacier dynamics. The BIAs product has been distributed by National Snow and Ice Data Center of USA.

This research was supported by the Polar Key Programmes and the NSFC and the result was published in Annals of Glaciology.

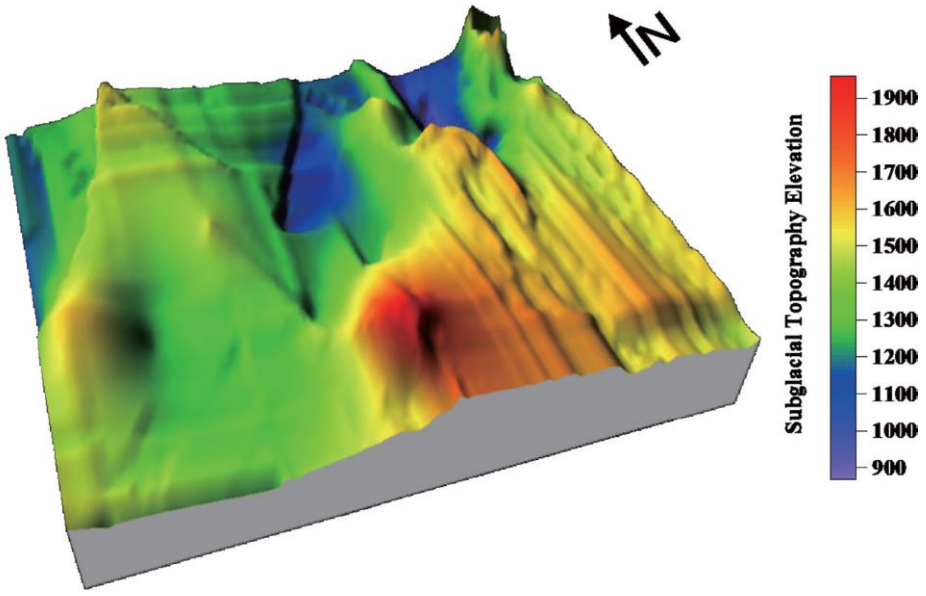


Blue Ice Areas distribution in Antarctica

(8)Subglacial topography investi-gation in the Grove Mountains

In the last decade, approximately 400 subglacial lakes were found, and at least half of them were interconnected. This discovery helped scientist understand the interaction between sea and ice deep in the Antarctic, thus it became the most popular field in international Antarctic research. During the 30th CHINARE (2013-2014), the subglacial topography was detected with ice radar by the Grove Mountain Team. The survey line was more than 200km. The preliminary data shows that there are at minimum nineteen subglacial sedimentary basins. Furthermore, it also shows that in that area, two subglacial lakes may exist.

This study was supported by the Polar Key Programmes.

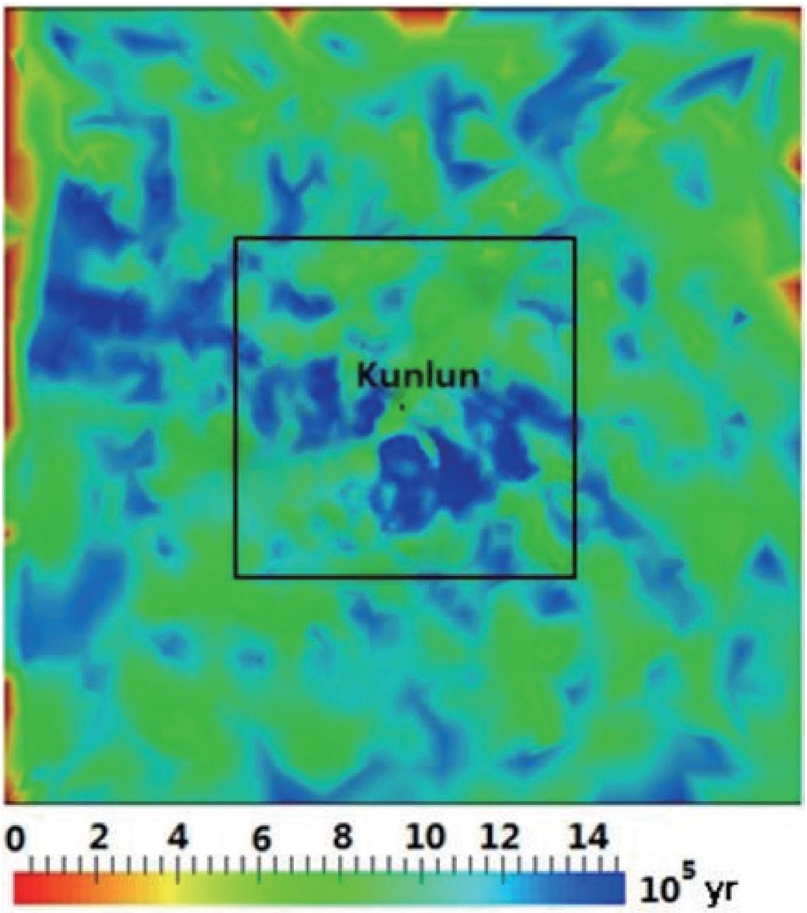


Subglacial topography of some areas in Grove Mountain

(9)A modeling study of the ice age at the Dome A region

A study of modeling flow, temperature and the age of the ice was made by applying a three-dimensional, thermomechanically coupled full-Stokes model to a 70×70 km^2 domain around the Kunlun station, using isotropic non-linear rheology and different prescribed anisotropic ice fabrics that vary the evolution from isotropic to single maximum at different depths. This work predicts that Dome A is a location where ice older than 1 million years can be found, though there may be uncertainties as large as 500 000 years in the basal age by a comparison with dated radar isochrones in the upper one third of the ice sheet cannot sufficiently constrain the age of the deeper ice. The simulation finds strongly variable basal ages across the domain since the ice varies greatly in thickness; any basal melting effectively removes very old ice in the deepest parts of the subglacial valleys; and it suggests that Dome A is a dynamic region where basal conditions are sensitive to small changes in surface forcing, such as thickness changes of tens of meters, which can switch bedrock locally from melting to freeze-on, driving changes in hydrology and latent heat distribution; and perhaps the unusual basal accretion noted in the radar surveys. It is therefore possible that the Kunlun site would provide both a highly resolved record of the past 700 000 years from vertical drilling, and a longer but lower resolution record from off-nadir drilling.

The study was supported by the 973 Program and the result was published in *The Cryosphere*.



Age–depth relationship of the ice at 95% depth in the 70×70 km^2 domain (central 30×30 km^2 region is boxed) using 60mWm−2 heat flux and surface temperature of −58.5° C.

(10) Progress in the deep ice core project at Dome A, East Antarctica

A major breakthrough in deep ice core project of Dome A was made during the 29th CHINARE (2012-2013). Major facilities of the deep ice core drilling workshop, including the drill slot, operating compartment, maintenance compartment and ice core processing area, were established. In addition, the deep ice-core drilling system was installed, and all the auxiliary equipment was connected and commissioned. After filling the hole with drilling fluid (n-butyl acetate), three runs of 'wet' ice-core drilling were carried out. An integrated ice core, with the length of 3.84m, was recovered in the first run. In total, ice core with the length of 10.9m was recovered during the 29th CHINARE. The diameter of the ice core was 95mm with the mean density of 0.88g/cm^3. It is interesting that a distinct volcanic ash layer was found at the depth of 124 m, suggesting a large volcanic eruption occurred ca. 4000 B.P.

The study was supported by the Polar Key Programmes and the SOA Project for Public Good.

The ice core recovered at the first run of the Dome-A Deep Ice Core Project

(11) Study on uncertainty of Antarctic sea ice concentration and thickness

This study explored the uncertainty of Antarctic sea ice contraction and thickness based on passive microwave data and satellite altimeter data. Antarctic sea ice concentrations at ice edges from pseudo ship observations, MODIS and passive microwave observations were compared to verify the accuracy of sea ice concentration products. The influence of parameters to sea ice thickness retrieval from satellite altimeter data was investigated through sensitivity analysis and compared with in situ observations.

This work was supported by the Polar Key Programmes and the results were published in Annals of Glaciology and Scientometrics.

(12) Polar research robots applied in Antarctic Ice Sheet

Depending on past test results in Antarctica, the capability of the polar research robots was improved mainly in communication、autonomous moving and adaptability under polar conditions. The Chinese developed the deep ice penetrating radar system, as an important instrument installed on the snow-surface roaming robot. According to field investigation results, the system can reach a penetrating depth of more than 3500, which totally meet the need of ice sheet measurement. Another important instrument of FMCW shallow ice penetrating radar system was also improved, and would be used to detect shallow ice structure during the 31st CHINARE.

This study was supported by the Antarctica Science Program.

Polar snow-surface long-distance roaming robots and renewable energy snow-surface robots

(13) Site selection for Antarctic rese arch stations based on GIS and FAHP

Site selection of is of great importance to the safety, function and operation of the Antarctic research stations. The aim of this study was to build a criteria system and to conduct a site selection process with aid from geographical information systems (GIS) and the fuzzy analytical hierarchy process (FAHP). In considering the natural environment and building conditions, fifteen factors were used as multiple evaluation sub-criteria and grouped into four main criteria: topography, environment, scientific research fields and logistical support requirements. Comparisons were made between potentially suitable areas and the locations of existing stations and camps to demonstrate fitness-for-use of the allocation results.

The research was supported by the Polar Key Programmes and the result was published in *Antarctic Science*.