



## Measure 2 - Annex

# Management Plan

## for Antarctic Specially Protected Area No 168 MOUNT HARDING, GROVE MOUNTAINS, EAST ANTARCTICA

### 1. Introduction

The Grove Mountains (72°20'-73°10'S, 73°50'-75°40'E) are located approximately 400km inland (south) of the Larsemann Hills in Princess Elizabeth Land, East Antarctica, on the eastern bank of the Lambert Rift (Map A). Mount Harding (72°51'2 -72°57'2 S, 74°53'2 -75°1'22 E) is the largest mount around Grove Mountains region, and located in the core area of the Grove Mountains that presents a ridge-valley physiognomies consisting of nunataks, trending NNE-SSW and is 200m above the surface of blue ice (Map B).

The primary reason for designation of the Area as an Antarctic Specially Protected Area is to protect the unique geomorphological features of the area for scientific research on the evolutionary history of East Antarctic Ice Sheet (EAIS), while widening the category in the Antarctic protected areas system.

Research on the evolutionary history of EAIS plays an important role in reconstructing the past climatic evolution in global scale. Up to now, a key constraint on the understanding of the EAIS behaviour remains the lack of direct evidence of ice sheet surface levels for constraining ice sheet models during known glacial maxima and minima in the post-14 Ma period.

The remains of the fluctuation of ice sheet surface preserved around Mount Harding, will most probably provide the precious direct evidences for reconstructing the EAIS behaviour. There are glacial erosion and wind-erosion physiognomies which are rare in nature and extremely vulnerable, such as the ice-core pyramid, the ventifact, etc. These glacial-geological features have not only important scientific values, but also rare wildness and aesthetic values and the disorderly human activities would cause perpetual, unreparable damage to it.

The Chinese Antarctic Research Expedition (CHINARE) has visited the Grove Mountains for several times from 1998 to 2006, focusing on research on geological tectonics, glacial geology and landscape, meteorology, ice-cap movement and mass balance, surveying and mapping, especially on fluctuation of Antarctic icecap surface since the Pliocene, and these research results in some new discoveries. The Australian Antarctic Programme has for many years visited the Grove Mountains to conduct a range of geoscience and glaciology research and support activities. It currently maintains a continuous GPS station on Tianhe Range and expects to continue to access the region for research and operational purposes. Besides, Russian Antarctic Research Expedition has ever tripped there in 1958 and 1973 for a short stay, but whether they have arrived at this area is unclear.

### 2. Description of values

The Mount Harding area designated as the site for the specially protected area (Map A) has the precious physiognomies of glacier erosion preserved in the ice sheet of inland Antarctic, which is of great scientific, aesthetic and wilderness values. The aim of this protected area is to preserve its scientific, aesthetic and wilderness values.

#### 2(i) Scientific values

A lot of remains of ice sheet advance and retreat are preserved in Mount Harding, which are the direct evidence of the changes of cold and warm in the global environment since Pliocene. In this area, the scientists have found the rare extreme cold desert soil, the sedimentary rocks formed in the Neogene Period that are not consolidated completely, as well as the valuable spore pollen assemblages in those paleo-soils and sedimentary rocks. All of this implies there existed a warm climate event in this area; probably resulting in a large-scale retreat of the EAIS, and its margin might be even beyond the Grove Mountains, 400km south from its present coast of the EAIS.

The unique geomorphological features in this area includes the integral geologic-geomorphic remains and a series of special physiognomy, such as ice-core pyramid, ventifacts, ice-cored moraine (end moraine and lateral moraine), cold-desert soil, sedimentary erratics, pool of melted water, roche moutonnee, etc.

#### 2(ii) Aesthetic and wilderness values

A legacy of the various magnificent landscapes remains in this area, from pool of melted water, ice-core moraine, ice-core pyramid to ventifacts (photos 1-6).

Human beings have visited for many years this area, other area within Grove Mountains region to conduct for a range of scientific activities. It mainly includes scientists and support staff from China, Australia and Russia. In the future, especially during the 2007-2008 IPY, human activities perhaps will increase in this area.



### 3. Management objectives

The purpose of establishing a specially protected area for the remains of ice sheet advance and retreat around Mount Harding, Grove Mountains, East Antarctica, is to:

- Facilitate long-term scientific research while avoiding direct or cumulative damage to vulnerable geomorphological features;
- Allow compelling scientific research that cannot be carried out elsewhere;
- Authorize other scientific activities consistent with the management objectives;
- Allow visits for managerial purposes in support of the objectives of the Management Plan.

### 4. Management activities

Copies of the Management Plan (attached with maps) shall be made available at the Zhongshan Station (China), Davis Station (Australia), Progress Station (Russia), and the map of the protected area should be put up at conspicuous positions in the stations mentioned above (special restrictions of access to the protected area, and the equilibrium line separating the zone of net ablation from the inland zone of net accumulation, as well as a series of the special physiognomies unique to the inland ice sheet of East Antarctica within the protected area should be indicated in the map).

National Antarctic Programs operating in the region shall consult with each other and exchange information to ensure that activities in the Area are undertaken in a manner consistent with the aims and objectives of this Management Plan.

Visits should be paid to this area regularly (once every five years) so as to assess whether the objective of protection in this area is achieved and to ensure that various managerial measures are in place.

The Management Plan should be reviewed at least once every five years and, if necessary, updated or revised.

In case the Antarctic ice sheet continuously retreats so that the new remains of advance and retreat of EAIS are exposed in the vicinity of the protected area and the extent of remains of ice sheet advance and retreat expands, the boundary of the protected area should be updated periodically so as to include the newly exposed remains of ice cap advance and retreat in the area. This should be taken into consideration in examining the Management Plan.

### 5. Period of designation

Designated for an indefinite period.

### 6. Description of the Area

#### 6(i) Geographical co-ordinates, boundary marks, general climate condition in summer and physiognomy

The Area is irregular, and approximately rectangular in shape, with a width of about 10km from east to west, a length of about 12km from south to north and an total area of about 120km<sup>2</sup> (Map A).

The proposed ASPA boundary was defined to in order to ensure that the unique geomorphological features, formed in ice sheet advance and retreat in Mount Harding, can be specially protected as a whole.

#### Geographical Co-ordinates

The Specially protected Area of Mount Harding, Grove Mountains, includes the open blue-ice zone from the moraine on the west side of Mount Harding to the east side of the Zakharoff Ridge as well as a number of nunataks, detritus zone, and moraine etc. within it (Map B). Its geographical co-ordinates are: 72°512 -72°572 S, 74°532 -75°122 E.

#### Boundary marks

The western boundary of the Area is the moraine on the west side of Mount Harding, with its northern end turning eastward to the open blue-ice detritus zone on the east side of the Zakharoff Ridge via the north flank of the northern ridge of Mount Harding and the northern end of the Zakharoff Ridge, turning southwards to the northern end of Davey Nunataks, and then heading westwards to the southern end of the Xi Lake moraine to close the whole area. The geographical coordinates of the nine control points located at its boundary are counter clockwise: 1. 74°57'E, 72°51' S, 2. 74°54'E, 72°53' S, 3. 74°53'E, 72°55' S, 4. 74°54'E, 72°57' S, 5. 75°00'E, 72°57' S, 6. 75°10'E, 72°57' S, 7. 75°12'E, 72°55' S, 8. 75°11'E, 72°52' S, 9. 75°08'E, 72°51' S.

No markers or signs are currently in place to mark the boundary.

#### General climate condition in summer

With an average altitude of more than 2000 meters in the Grove Mountains, the daily temperature range and strong wind frequency are greater than those at Zhongshan Station. When affected by the warm-moist current from the north, snowfall would appear constantly in this area, while under the control of the east current, the weather would mainly be sunny. The trend of daily wind speed change is greater than that at Zhongshan Station, where the maximum wind speed appears at around 05:00 am; the lowest records are seen from 16:00 and 17:00 in the afternoon, and minimum wind speed might appears at about 17:00 pm. Same as Zhongshan Station, the Grove Mountains area is influenced by the katabatic wind, but with a greater force than Zhongshan Station.

From December 1998 to January 1999, the average highest and lowest air temperature in the Grove Mountains area were -13.1°C and -22.6°C respectively, and the estimated average daily temperature range could be -9.5°C. In this area, in January in particular, the air temperature and snow temperature saw an obvious change during a day, where the average air temperature was -18.5°C, and the snow surface temperature was about -17.9°C, that is, the average snow temperature was higher than the average air temperature.



## Physiognomy

Mount Harding in the central GMs is shaped as a crescent open to the north-west. Both the northern and southern ends are steep crests, protruding ~200m above the recent ice surface. The central segment of the ridge-line between two summits descends progressively until it reaches the ice surface in a central col, with a relic ice tongue hanging on the lee side. A stagnant field of blue ice, tens of km<sup>2</sup> wide, lies inside the crescent. All of this, shining each other with the vast blue ice, forms the magnificent, beautiful scene of ice-eroded ice field geomorphology.

The nunataks within the area may be divided into two groups. The one in the west is the tall nunataks represented by Mount Harding, and the other is a small part of the area including the low linear nunatak chain on the Zakharoff Ridge. The stoss slopes of rocky nunataks show smoothly abraded bedrock, with surfaces sparsely erratic till patches. The lee and lateral sides of the nunataks show generally sharp bluffs, resulting from both ice flow scraping and collapse along sub-vertical crevasses of rocks. The nunataks leave pair of "wake zone" of superglacial debris tens km in length on the ice surface, marking the path of present local ice flow.

The upper parts of the higher nunataks are usually jagged ridge populating with well-developed ventifacts on the summits, facing the dominant wind from the SE. The scarcity of glacial erosive imprints, also meters of depth inside the hard rock delved by wind-force blowing out indicate that these higher slopes are ice free since rather long time. But the lower parts of slopes beneath ~100m above ice surface have the features of recent glacial erosion such as fresh trimlines and erratics. Some of small nunataks are typical "roches moutonnées" resulted from the past ice flow overriding. This regional borderline between wind and glacial erosions are considered to represent a former height of ice surface since certain phase, probably early Quaternary glaciations, and the later rises of ice surface did not exceed this limit.

Mount Harding is the largest nunatak in the Grove Mountains. On the west side of the crescent ridge there is a large stretch of lake shaped stagnant blue ice plain (Kunming Lake, Xi Lake) and a dozen ice-cored pyramids (ice-cored cone) are visible at the juncture of the ice lake and the foot of the rocky nunataks.

The geological and glacial phenomena or landscapes that deserve special protection include (Map C).

Ventifact (photo 1, 2): As a result of long-term blow and erosion by fierce winds, there have developed a large number of ventifacts with peculiar shape around the southern summit of Mount Harding. These ventifacts are the typical wind-erosion physiognomy rarely seen on the earth and are subject to the perpetual damage by disorderly human activities.

Ice-core pyramids (ice-cored cones, photo 3): Along the northern and southern banks of "Kunming Lake" are scattered a dozen ice-core pyramids. These ice-core pyramids are cone shaped with a height of 20-40m and a base diameter of 50-80m. These pyramids are the best marks for directly measuring the pneumatolysis of blue ice and of great importance to the research on the material balance and evolutionary history of the EAIS. They are extremely vulnerable and any human climbing behaviour will lead to their perpetual alteration and destruction.

Floating ice-cored moraine (photo 4): On the north-west side of the stagnant blue ice pool lie some of linear floating moraine. These moraines are about 100m wide, 25-35m high and kilometres long. On the surface of the moraine there is a gravel bed with a thickness of 50-100 cm, below which is the blue ice. These exotic rock masses provide precious source material for studying the tectonics of the underlying base rocks of EAIS. The spore pollen assemblages contained in the sedimentary erratics are the key evidence of the large-scale retreat event of the EAIS during the Pliocene. Any walking or climbing activities will very probably cause the irreparable damage to these moraine dykes.

Cold-desert soil: Several cold-desert soil patches were found on the southern slope of Mount Harding above the regional erosion limit of 100m. The existence of such soils indicates also that the ice fluctuation has never been higher than this limit after the formation of soils because any higher rise of the ice would have scraped all of them away.

Microfossil assemblages in the sedimentary erratics: More than 25 species of Neogene microfossil of plant have been identified from such outwash sedimentary boulders. These spore and pollen assemblages provide useful information on the evolution of the EAIS since they are derived from a suite of glaciogenic strata hidden beneath the EAIS. Most of the pollen and spores are originated from local sources as in situ assemblages, representing a continental flora.

Pool of ice melted water (photo5): At the foot of the lee side of huge nunataks are often developed pools of ice melted water, large or small, each with an area from several dozen square meters up to a thousand square meters. The surface ice of these pools is extremely smooth and transparent, and the air bubbles are rich inside the ice from the bottom. The occurrence of the pool of ice melted water suggests the existence of a megathermal event.

Blue ice cliff: On the east side of the protected area are distributed blue ice cliffs or blue ice precipices, with the length of several thousand meters, usually 30-50m high, with a slope of 40-70°.

Roche moutonnées (photo 6): Typical roche moutonnées are distributed on the east and south sides of the protected area. They are peculiar in shape, have a large number of footprints of ice flow on their surfaces, and possess very high wilderness, aesthetic and scientific values.

Paleo-sedimentary basin (ice sheet leading edge): A paleo-ice erosion basin with the marginal sedimentary layer, at the front edge of ice sheet in the Pliocene is inferred to lie below the blue ice basin on the west side of Mount Harding. It is probably a brand-new type of subglacial lakes. Exploration of these paleo-sedimentary lake basins may yield the precious sedimentary records on the paleo-climatic and environmental changes during the Pliocene in this area.



## 6(ii) Geological condition

These nunataks consist mainly of upper amphibolite to granulite facies metamorphic rocks, syn- orogenic to late orogenic granite, and post tectonic granodioritic aplite and pegmatite. The absence of active structures and earthquakes, and the lack of Cenozoic volcanism suggest that this region, along with Prydz Bay, have been geologically stable at least since the Late Mesozoic Epoch. New geological evidence obtained from this area shows that in the inland East Antarctica there exists a huge "Pan-African" stage orogenic zone from the Prydz Bay, Grove Mountains to the Prince Charles Mountains, which should be the last segmented suture zone of the Gondwana land.

## 6(iii) Access to, and movement within or over, the Area

Access to the area may be gained overland by vehicle or by aircraft landing on snow- and ice- covered sites within or adjacent to the Area.

## 6(iv) Location of structures within and adjacent to the site

Australia maintains a continuous GPS station on Tianhe Ridge at 72°54'29.17479"S, 74°54'36.43606"E. The station consists of a GPS antenna mounted on a geodynamic survey pillar, three rugged cases containing batteries and GPS receivers, a solar panel frame holding four solar panels and a wind turbine. In addition there are three survey reference marks surrounding the GPS pillar, approximately 20m distant.

## 6(v) Location of other protected areas in the vicinity

There are no other protected areas nearby.

## 6(vi) Special Zones within the Area

There are no special zones proposed in this area.

## 7. Permit

Entry into the Area is prohibited unless a Permit issue by an appropriate national authority. Conditions for issuing a Permit to enter the Area are that:

- Scientific research activities that cannot be carried out in any place other than this area; and the applicant for a Permit who needs to collect rock specimens or samples shall make an application. Before the permit is issued, the applicant shall demonstrate to the appropriate competent authorities that the specimens or samples already collected from other parts of the world so far cannot fully meet the needs of the researches (tasks) proposed;
- Managerial activities for the purpose of realizing the objectives of the Management Plan, such as inspection, maintenance and review;
- The actions permitted are in accordance with the Management Plan;
- The actions permitted will not jeopardize the values of the Area;
- Those who are within the specially protected area must carry with them the Permit or its valid copy;
- The period of validity must be stated in the Permit;
- Report on the activities must be submitted to the national authorities issuing the Permit and in charge of polar issues.

### 7(i) Access to and movement within the Area

Entry by land vehicles such as snowmobile and aircraft should avoid destroying the local equilibrium line separating the zone of net ablation from the inland zone of net accumulation, paleo-soil distribution zone, ventifacts, blue-ice cliff, ice-core pyramid, and other geological and natural physiognomy of important scientific research and environmental values.

As there have many ice crevice in this area, it is recommend that entry by snowmobile would drive down the route along the two sides of which Chinese expedition has set colourful poles for the sake of safety.

Aircraft operations within the Area should be mindful of the mountainous terrain.

Climbing up the ice-core pyramids, walking on the floating moraine dyke and roches montannes is strictly prohibited.

### 7(ii) Activities allowed to be conducted in the Area, including restrictions on time and place

Scientific researches which have to be carried out in the Area (cannot be conducted in any other parts of the world or in other areas of Antarctica) and which must not damage the value of the Area.

Major management activities, including monitoring, inspection, maintenance or review.

Other activities in support of scientific research or management within the Area, or essential for operational support of activities within or beyond the wider Grove Mountains area.

### 7(iii) Installation, modification and removal of structures

No structures or facilities shall be erected in the Area except those for conducting essential scientific and managerial activities or for the purpose of scientific research, as specified in the Permit.

All the facilities to be set up and installed within the Area shall be specified in the Permit issued by the competent authority of the particular country. Where possible, such installations should avoid sensitive geomorphological features.

Their permitting country, year of installation, principal investigators or responsible persons shall be clearly indicated. When no longer needed, these facilities shall be removed in time and so shall other abandoned equipment or materials as far as possible.

### 7(iv) Location of field camps

For safety reasons, the camping sites must be selected in such a way as not to destroy or affect the special geological and natural physiognomy.

If not destroying the local and adjacent geological and natural physiognomy, Camping is allowed within the Area when necessary for purposes consistent with this Management Plan and where authorised in a Permit. In this area, the encampment near Mount Harding (No 9) and the encampment near Zakharoff Ridge (No 8) are the preferred camping site, shown in Map B. Camping should choose snow or ice surface or rock surface to avoid the remnants of ice sheet.



### **7(v) Restrictions on materials and organisms which may be brought into the site**

No depots of food or other supplies are to be left within the Area beyond the time period or activity for which they are required.

No live animals, plant material or micro-organisms shall be deliberately introduced into the Area. All necessary precautions shall be taken to prevent accidental introduction.

All material introduced shall be for a stated period, shall be removed at or before the conclusion of that stated period, and shall be stored and handled so as to minimise the risk of environment impacts.

### **7(vi) Taking of, or harmful interference with, native flora and fauna**

No native flora and fauna are present.

### **7(vii) The collection or removal of materials not imported by the permit holder**

Material may be Collected or removed from the Area only in accordance with a Permit and should be limited to the minimum necessary to meet scientific or management needs.

Material of human origin likely to compromise the values of the Area, and which was not brought into the Area by the Permit holder or otherwise authorised, may be removed unless the impact of the removal is likely to be greater than leaving the material in situ. If this is the case, the appropriate national authority must be notified and approval obtained.

### **7(viii) Disposal of waste**

At a minimum, all the wastes (non-human or human) should be managed in accordance with Annex III and not disposed of into freshwater streams or lakes, onto ice-free areas, or onto areas of snow or ice which terminate in such areas of high ablation.

### **7(ix) Measures that may be necessary to continue to meet the aims of the Management Plan**

None.

### **7(x) Reporting requirements**

After each Permit is issued, the responsible Permit holder shall prepare and submit a report on the activities conducted in the Area in the Visit Report form suggested by SCAR. The report shall be submitted to the competent authorities specified in the Permit as soon as possible, but no later than 6 months after the visit ends. Such reports shall be kept indefinitely and easily made available to the interested Parties, CCAMLR and COMNAP. If necessary, documentation of human activities within the area shall be provided to the above-mentioned parties.

The investigators should finish their investigation report within six months after the research activities are concluded. A copy of such report should be submitted to national authority so as to make revision and re-examination of the Management Plan in accordance with the requirements of the Antarctic Treaty. The report should include all the contents of the accepted Visit Report Form suggested by SCAR as well as other information as required according to the country's laws and regulations. The permit issuing authority should provide the information on these reports so that organizations such as SCAR, COMNAP and the interested countries may consult them.

## **8. Supporting documentation**

Australian Antarctic Division (AAD, 2007): Australian Antarctic Programme Approved Science Projects for season 2006/07, [http://its-db.aad.gov.au/proms/public/projects/projects\\_by\\_program.cfm?season=0607&PG\\_ID=5](http://its-db.aad.gov.au/proms/public/projects/projects_by_program.cfm?season=0607&PG_ID=5). Report on the 22<sup>nd</sup> CHINARE Scientific Activity [2005/2006] (2006), Chinese Arctic and Antarctic Administration.

Liu Xiaochun; Jahn Bor-ming, Zhao Yue, Li Miao, Li, Huimin; Liu Xiaohan (2006). Late Pan- African granitoids from the Grove Mountains, East Antarctica: Age, origin and tectonic implications. *Precambrian Research*, 145: 131-154.

Zhang Shengkai, E Dongchen, LiFei, et al (2006). The establishment of GPS network in Grove Mountains, East Antarctica. *Chinese Journal of Polar Science* 17(2):111-116.

CHENG Xiao, ZHANG Yan-mei(2006). Detecting Ice Motion with Repeat-pass ENVISAT ASAR Interferometry over Nunataks Region in Grove Mountain, East Antarctic—The Preliminary Result, *Journal of Remote Sensing* 10( 1):118-122. IPY-ACE core program, 2006

Dongchen E, Chunzia Zhou, Mingsheng Liao(2005). Application of SAR interferometry in Grove Mountains, East Antarctica. *SCAR Report*, 2005, 23: 42-46.

Dongchen E., Shengkai Zhang, Li Yan, Fei Li (2005). The establishment of GPS control network and data analysis in the Grove Mountains, East Antarctica. *SCAR Report*, 2005, 23: 46-49.

Aimin Fang, Xiaohan Liu, Xiaoli Li, Feixin Huang, Liangjun Yu (2005). Cenozoic glaciogenic sedimentary record in the Grove Mountains of East Antarctica. *Antarctic Science* 17(2): 237-240.

J. Taylor, M. J. Siegert, A.J. Payne, M.J. Hambrey, P.E. O'Brien, A.K. Cooper, & G. Leitchenkov (2004). Topographic controls on post-Oligocene changes in ice-sheet dynamics, Prydz Bay, East Antarctica, *Geology* 32 (3) :197-200.

FangAimin, Liu Xiaohan, Lee Jong Ik, Li Xiaoli, Huang Feixin (2004). Sedimentary environments of the Cenozoic sedimentary debris found in the moraines of the Grove Mountains, East Antarctica and its climatic implications. *Progress in Natural Science* 14(3): 223-234.

Huang Feixin, Liu Xiaohan, Kong Ping; Ju Yitai, Fang Aimin, Li Xiaoli, Na Chunguang (2004). Bedrock exposure ages in the Grove Mountains, interior East Antarctica. *Chinese Journal of Polar Research* 16(1):22-28.

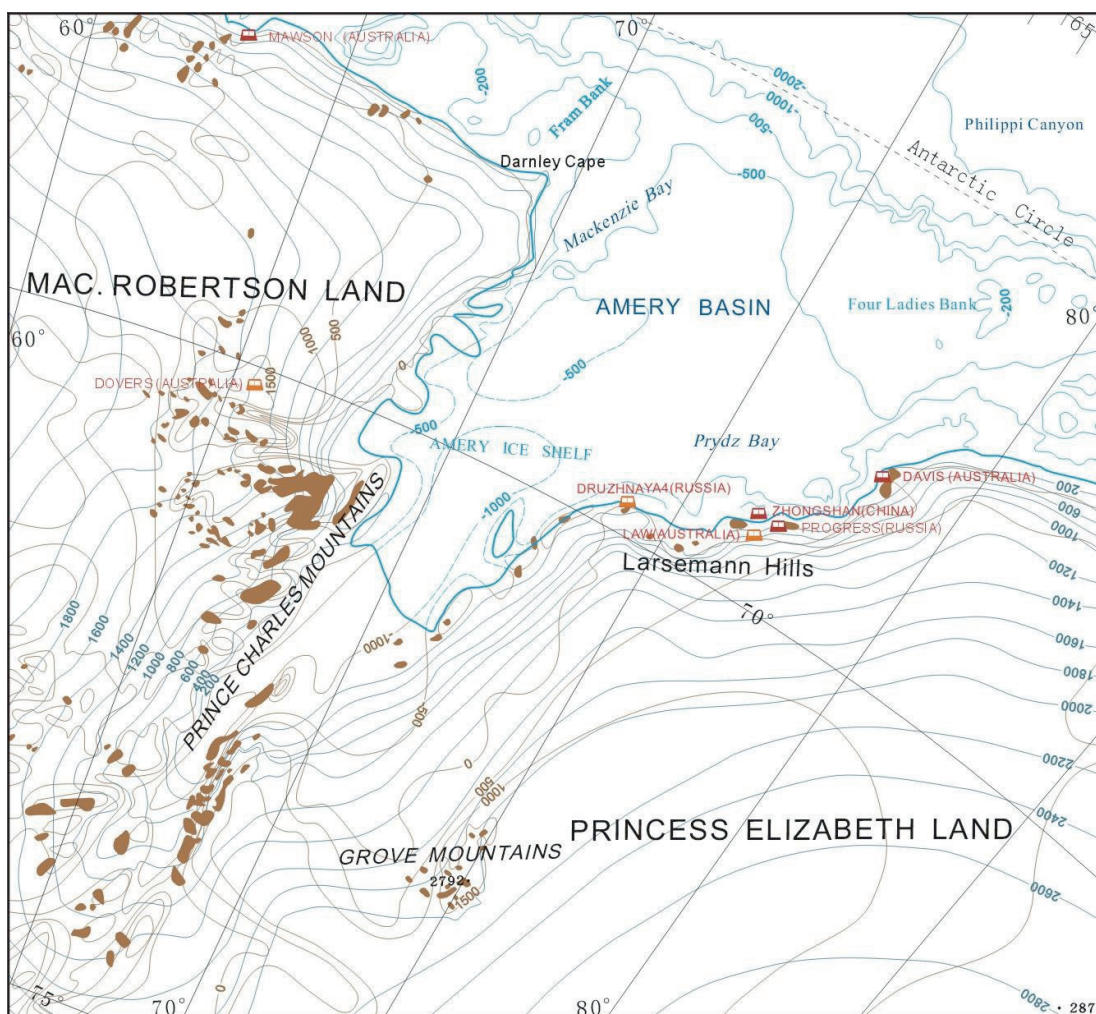


- Fang Aimin, Liu Xiaohan, Wang Weiming, Yu Liangjun, Li Xiaoli, Huang Feixin (2004). Preliminary study on the spore-pollen assemblages found in the cenozoic sedimentary rocks in Grove Mountains, East Antarctica. *Quaternary Sciences* 24(6):645-653. Report on the 19<sup>th</sup> CHINARE Scientific Activity [2002/2003](2003), Chinese Arctic and Antarctic Administration.
- X.H. Liu, Y. Zhao, X.C. Liu, & L.J. Yu, (2003) Geology of the Grove Mountains in East Antarctica—New Evidence for the Final Suture of Gondwana Land, *Science in China (D)*, 46 (4): 305-319.
- Zhao Y, Liu X H, Liu X C, Song B(2003). Pan-African events in Prydz Bay, East Antarctica, and their implications for East Gondwana tectonics. In: Yoshida M, Windley B F, Dasgupta S. (eds) *Proterozoic East Gondwana: Supercontinent Assembly and Breakup*. Geological Society, London, Special Publications, 206: 231-245.
- Liu X, Zhao Z, Zhao Y, Chen J and Liu X H (2003). Pyroxene exsolution in mafic granulites from the Grove Mountains, East Antarctica: constraints on the Pan-African metamorphic conditions. *European Journal of Mineralogy* 15:55-65.
- X.L. Li, X.H. Liu, Y.T. Ju & F.X. Huang(2003). Properties of soils in Grove Mountains, East Antarctica, *Science in China (D)* 46 (7):683-693.
- Qin Xiang (2003). A brief introduction to research on the snow and ice of the Grove Mountains, Antarctica, during the Third Chinese research expedition. *Bingchuan Dongtu*, 25 (4): 477-478.
- Cheng Xiao, Li Zhen, Massonnet, Didier [chairperson], Yu Shao, Zhang Yanmei(2003). Blue-ice domain discrimination using interferometric coherence in Antarctic Grove Mountains. 2003 EEE international geoscience and remote sensing symposium: July 21-25, 2003: Toulouse, France; International Geoscience and Remote Sensing Symposium, 2003, Volume 4: 2599-2601.
- Fang Aimin, Liu Xiaohan, Lee Jong Ik, Li Xiaoli, Huang Feixin (2003). The significance of Cenozoic sedimentary rocks found in Grove Mountains, East Antarctica. *Chinese Journal of Polar Research* 15 (2): 138-150.
- Li Xiaoli, Liu Xiaohan, Fang Aimin, Ju Yitai, Yan Fuhua (2003). Pliocene sporopollen in the Grove Mountains, East Antarctica, *Marine geology & Quaternary geology* 23(1):35-39.
- Johnston, Gary, Digney, Paul, Manning, John [editor](2002). Extension of the Australian Antarctic geodetic network in Grove Mountains. Third Antarctic geodesy symposium: July 18-20, 2001: Saint Petersburg, Russian Federation; SCAR Report 21: 34-37.
- Whitehead J M & McKelvey B C(2002). Cenozoic glacial sedimentation and erosion at the Menzies Range, southern Prince Charles Mountains, Antarctica. *Journal of Glaciology* 48 (2): 207-247.
- Liu Xiaochun, Zhao Yue (2002). Geological aspects of the Grove Mountains, East Antarctica——New evidence for the final suture of Gondwana Land. *Royal Society of New Zealand Bulletin* 35:161-166.
- Liu X H, Zhao Y, Liu X C, Yu L Z (2002). Geological aspects of the Grove Mountains, East Antarctica. *Science in China (Series D)* 32(6): 457-468.
- Yu Liangjun, Liu Xiaohan, Zhao Yue, Ju Yitai (2002). Preliminary study on metamorphic mafic rocks in the Grove Mountains, East Antarctica. *Chinese Journal of Polar Research* 14 (2): 93-104.
- Mikhalsky, E. V., Sheraton, J. W., Beliatsky, B. V. (2001). Preliminary U-Pb dating of Grove Mountains rocks: implications for the Proterozoic to Early Palaeozoic tectonic evolution of the Lambert Glacier-Prydz Bay area (East Antarctica). *Terra Antarctica* 8 (1): 3-10.
- B.C. McKelvey, M.J. Hambrey, D.M. Harwood (2001). The Pagodroma Group - a Cenozoic record of the East Antarctic ice sheet in the northern Prince Charles Mountains, Antarctica. *Antarctic Science*, 13 (4) :455-468.
- Liu X, Zhao Y and Liu X H(2001). The Pan-African granulite facies metamorphism and syn-tectonic magmatism in the Grove Mountains, East Antarctica. *Journal of Conference Abstracts, Cambridge Publications, Cambridge, United Kingdom*, 6:379.
- Sun Jiabing, Huo Dongmin, Zhou Junqi and Sun Zhaohui (2001). The digital mapping of satellite images by free of ground control and the analysis of land form blue ice and meteorites distribution in the Grove Mountains. *Chinese Journal of Polar Science* 13(1).
- Report on the 16<sup>th</sup> CHINARE Scientific Activity [1999/2000] (2000), Chinese Arctic and Antarctic Administration.
- Cheng Yanjie, Lu Longhua, Bian Lingen, Liu Xiaohan (2000). Summer weather characteristics on the Grove Mountain of Antarctica. *Chinese Journal of Polar Science* 11 (2): 123-130.
- Report on the 15<sup>th</sup> CHINARE Scientific Activity [1998/1999] (1999), Chinese Arctic and Antarctic Administration.
- Cheng Yanjie, Lu Longhua, Bian Lingen, Liu Xiaohan (1999). Summer weather characteristics of Grove Mountain area in East Antarctica. *Chinese Journal of Polar Research* 11(4): 291-300.
- Cheng Yanjie, Lu Longhua and Bian Lingen (1999). Summer weather characteristics of Grove Mountain area in East Antarctica. *Chinese Journal of Polar Science* 14(1):291-300.
- Guide to the Preparation of Management Plans for Antarctic Specially Protected Areas - Appendix to Resolution 2(1998).
- Domack E, et al (1998). Late Quaternary sediment facies in Prydz Bay, East Antarctica and their relationship to glacial advance onto the continental shelf. *Antarctic Science* 10(3):236-246.
- Barker P F, et al. (1998). Ice sheet history from Antarctic continental margin sediments: the ANTOSTRAT approach. *Terra Antarctica*, 5:737-760.
- D.E. Sugden, D.R. Marchant, Jr. N. Potter, R.A. Souchez, G.H. Denton, C.C. Swisher III, J.L. Tison (1995). Preservation of Miocene glacier ice in East Antarctica, *Nature* 376(3):412-414.
- D.E. Sugden, D.R. Marchani, & G.H. Destos, The case for a stable East Antarctic Ice Sheet the background, *Geografiska Annaler*, 75A, (1993) 151-153.



### Map A1. Position of Grove Mountains

Mapping Standard: Projection: Normal Stereographic Horizontal datum:WGS-84  
Manufacturer: Chinese Antarctic Centre of Surveying and Mapping, Wuhan University

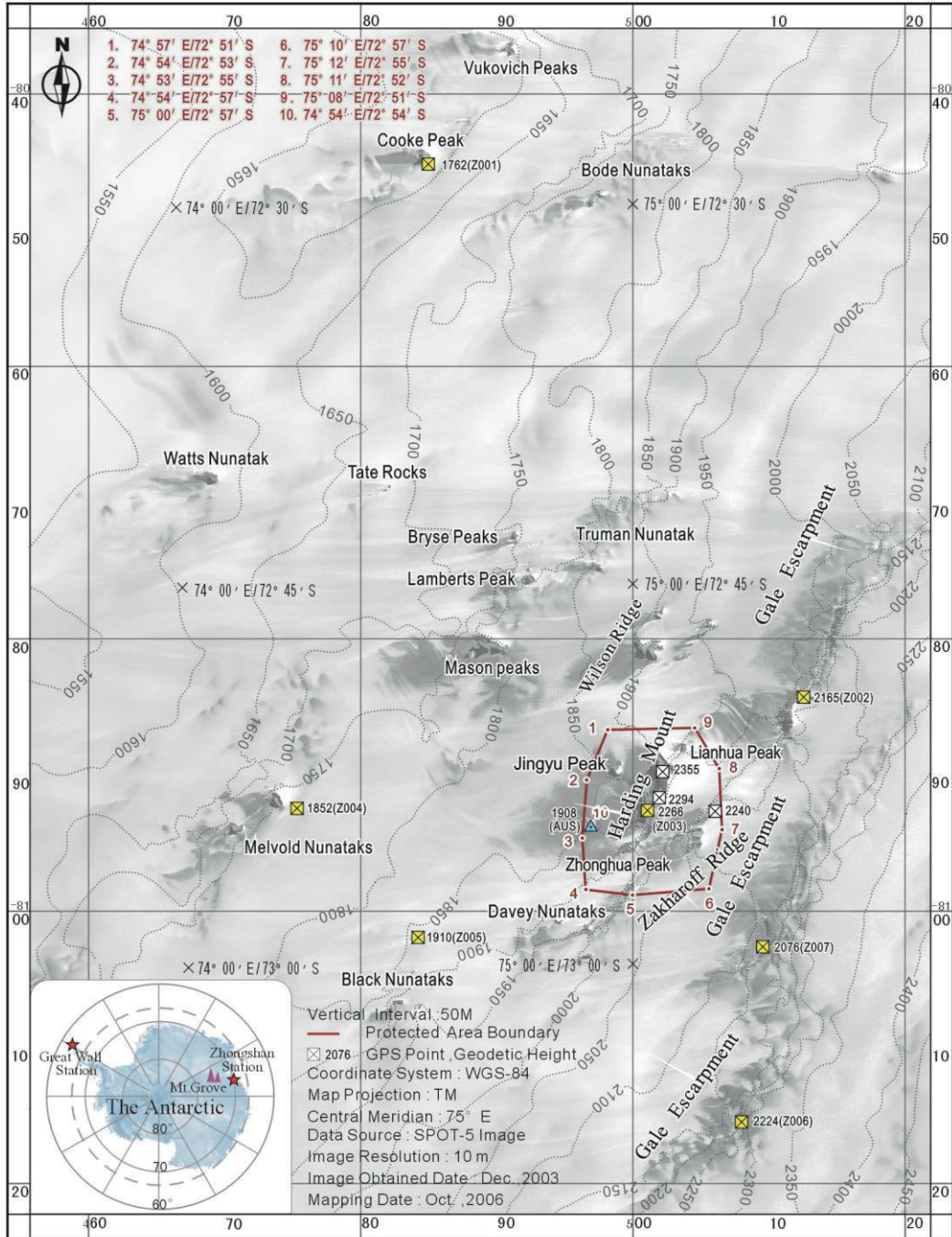




### Map A2. Grove Mountains Area, Antarctica

Mapping standards: Projection: TM, Horizontal datum: WGS-84  
Manufacturer: Chinese Antarctic Centre of Surveying and Mapping, Wuhan University

## GROVE MOUNTAINS



Mapping by: Chinese Antarctic Centre of Surveying and Mapping, Wuhan University.



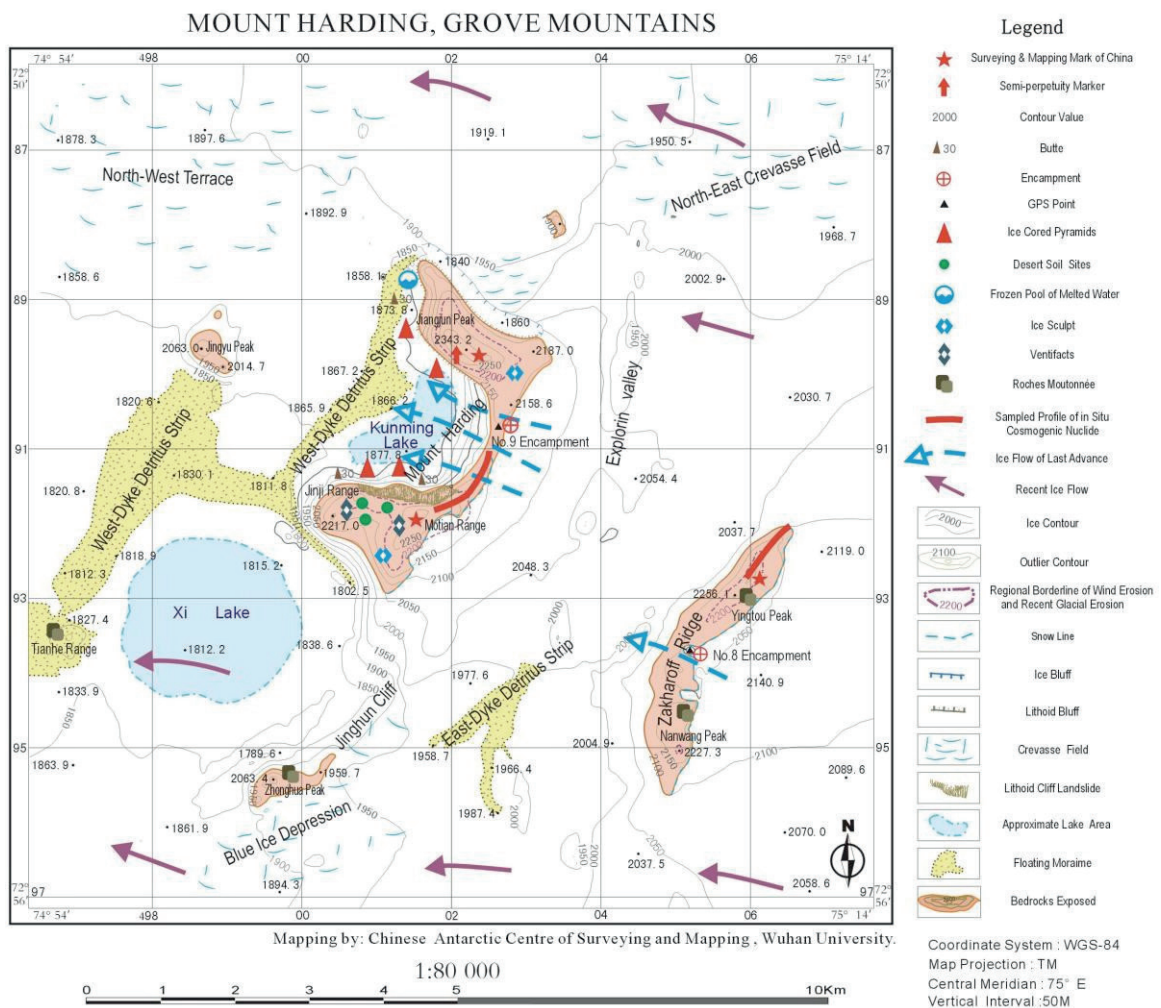




### Map B. Protected Area around Mount Harding, Grove Mountains, Antarctica

Mapping standards: Projection: TM Horizontal datum: WGS-84

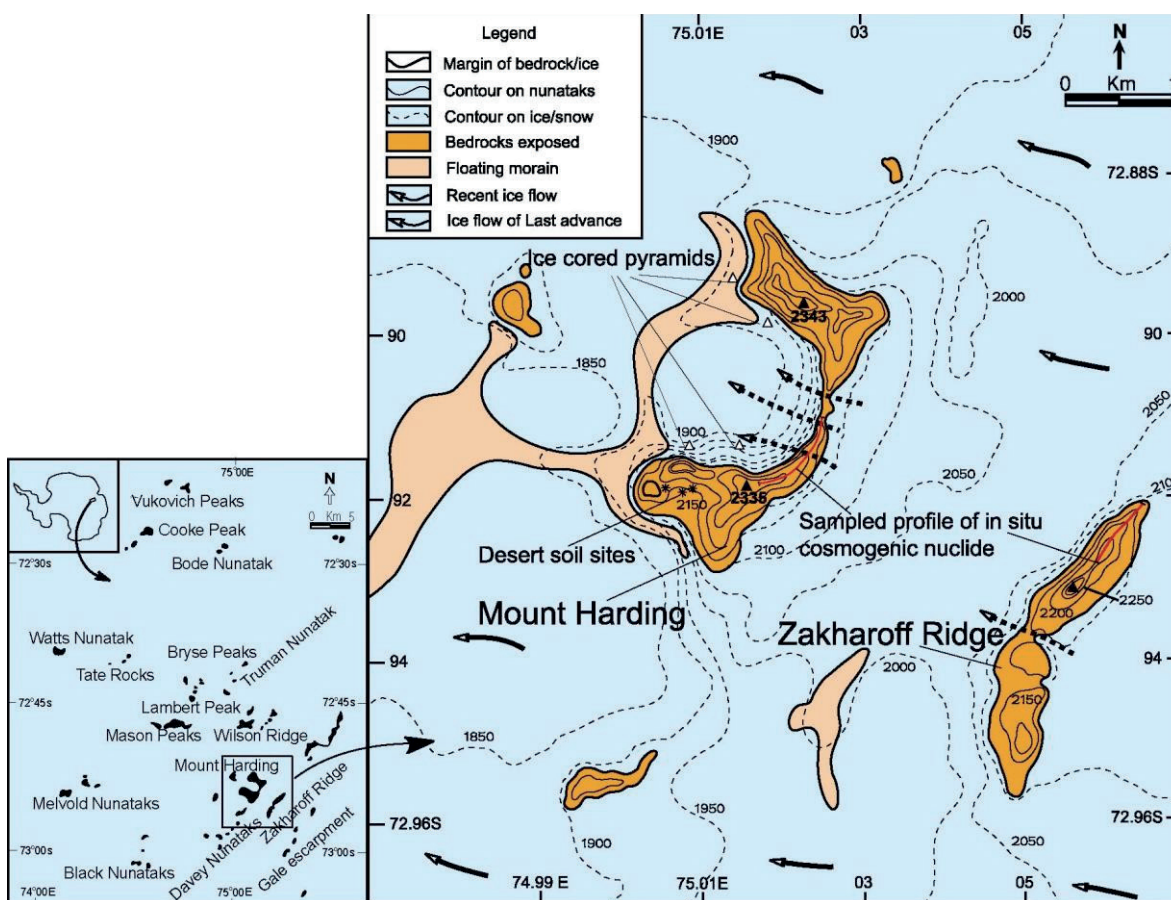
Manufacturer: Chinese Antarctic Centre of Surveying and Mapping, Wuhan University





### Map C. Location of Nunataks and Direction of Ice Flow around Mount Harding, Grove Mountains, Antarctica

Mapping standards: Projection: TM Horizontal datum: WGS-84  
Manufacturer: Institute of Geology and Geophysics, Chinese Academy of Sciences





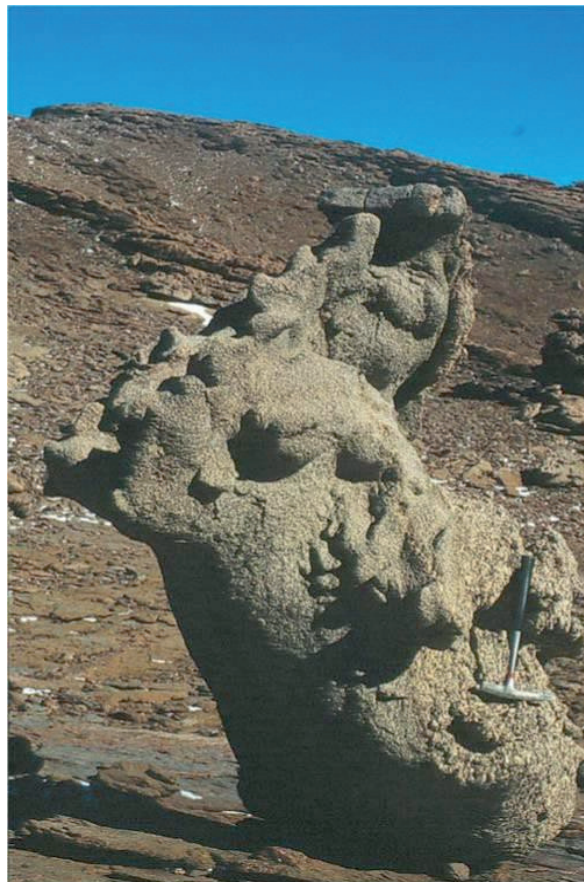
**Photo 1:**

Ventifact, taken on January 13<sup>th</sup>, 2003



**Photo 2:**

Ventifact, taken on January 13<sup>th</sup>, 2003





**Photo3:**

Ice-core pyramid, taken on January 12<sup>th</sup>, 2003



**Photo 4:**

Hanging moraine dyke, taken on January 14<sup>th</sup>, 2003





**Photo 5:**

Pool of ice melted water, taken on January 14<sup>th</sup>, 2003



**Photo 6:**

Roches montannees, taken on January 12<sup>th</sup>, 2003

