Geothematic Mapping of the Italian
Programma Nazionale di Ricerche in Antartide
in the Terra Nova Bay Area

Introductory Notes to the Map Case

Editors
C. Baroni, M. Frezzotti, A. Meloni, G. Orombelli,
P.C. Pertusati & C.A. Ricci
This case contains four geothematic maps of the Terra Nova Bay area where the Italian Programma Nazionale di Ricerche in Antartide (PNRA) begun its activities in 1985 and the Italian coastal station Mario Zucchelli was constructed.

The production of thematic maps was possible only thanks to the big financial and logistical effort of PNRA, and involved many persons (technicians, field guides, pilots, researchers).

Special thanks go to the authors of the photos: Carlo Baroni, Gianni Capponi, Robert McPhail (NZ pilot), Giuseppe Orombelli, Piero Carlo Pertusati, and PNRA.

This map case is dedicated to the memory of two recently deceased Italian geologists who significantly contributed to the geological mapping in Antarctica: Bruno Lombardo and Marco Meccheri.

Recurrent acronyms

ASPA Antarctic Specially Protected Area
GIGAMAP German-Italian Geological Antarctic Map Programme
HSM Historical Site or Monument
NVL Northern Victoria Land
PNRA Programma Nazionale di Ricerche in Antartide
USGS United States Geological Survey

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INTRODUCTION

The first Italian Antarctic expedition left Lyttelton in New Zealand at the beginning of December 1985, onboard the research vessel Polar Queen, and arrived in Antarctica at Terra Nova Bay on 22 December 1985. Two of us (Massimo Frezzotti, Giuseppe Orombelli) took part to that first Italian Antarctic expedition. The bay took its name from the whaling ship Terra Nova which rescued Captain Robert Falcon Scott and his team during the "Discovery" expedition (1901-1904). The Italian expedition established a field camp in the ice free area above Tethys Bay. The first construction was a wooden shelter built by the field guides. The construction of the coastal station begun in December 1986 and was named Baia Terra Nova, later on changed in Mario Zucchelli (by the name of a prematurely deceased Italian programme manager).

The Terra Nova Bay area is included in the Mount Melbourne quadrangle of the 1:250 000 scale cartography of the United States Geological Survey (USGS) (74°00’ - 75°00’ S; 162°00’ - 166°30’ E). The sheet takes its name from the main geographic feature, Mt. Melbourne, a Quaternary quiescent volcano (2 710 m a.s.l.). The experience of the six members of the Northern Party of Scott’s 1910-1913 expedition (Victor Campbell, Mulray Levick, Raymond Priestley, George Abbott, Frank Browning, and Harry Dickason), forced to winterover as they missed the rendez-vous with the ship Terra Nova in March 1912, is well recorded in the geographic features dedicated to their memory: Campbell Glacier, Mt. Levick, Priestley Glacier, Mt. Abbott, Browning Pass, Mt. Dickason. The place where they winterovered, now a historical site (HSM n. 14), was a snow cave situated on the island for which they did not find any better word than ‘Inexpressible’.
Terra Nova Bay coast and Gerlache Inlet covered by seasonal sea ice, Mt. Melbourne volcano in the background (Photo C. Baroni).

The Polar Queen research vessel moored to the fast ice at Terra Nova Bay, December 1985 (Photo G. Orombelli).
The ice-free area where the first Italian expedition set up a camp in 1985-1986: eight tents and a wooden hut. In the same area, in 1986-1987, the permanent Italian station was built (Photo G. Orombelli).

The Italian station Mario Zucchelli in 2013, in the background the Mt. Melbourne volcano (Photo PNRA R. McPhail).
The USGS published 1:250 000 topographic reconnaissance maps of Victoria Land in the 1960s. These maps were compiled from ground survey (less the 3-4 geodetic points for each map) and tri-camera aerial photography (three cameras, operated simultaneously, with one vertical and two pointing obliquely sideways 60°) which provides 180° horizon to horizon coverage when the images are placed side-by-side. In spite of the huge effort expended on data collection and compilation, insufficient ground control hampered the preparation of “conventional maps”. Since the beginning of the exploration of the area it was clear that the 1:250 000 USGS topographic maps, based on aerial photographs taken from the mid-1950s to the mid-1960s, were not precise enough for field studies in glaciology, geomorphology, geology and for logistic purposes, as well as unreliable for the snow-covered areas without any rock outcrop.

Only in the mid-1970s, with satellite image maps, the accuracy of geometry became standard, but the orography was still of poor accuracy. Thus, considering the high quality of satellite images, a map based on satellite images was produced and published in 1991 (Borfeccchia & Frezzotti, 1991).

This case collects four maps produced within the framework of the Italian Programma Nazionale di Ricerche in Antartide:
- Geological 1:250 000 map of Mount Melbourne quadrangle
- Geomorphological and glaciological 1:250 000 map of Mount Melbourne quadrangle
- Satellite image mosaic of the Terra Nova Bay area, 1:250 000
- Satellite image map of the Northern Foothills and Inexpressible Island, 1:50 000

**GEOLOGICAL 1:250 000 MAP OF THE MOUNT MELBOURNE QUADRANGLE**

The map has been published in 2012, as part of the German-Italian geological Antarctic map programme (GIGAMAP), aimed to map the entire northern Victoria Land at the scale of 1:250 000. The initiative was coordinated by Piero Carlo Pertusati (Italy) and Franz Tessensohn (Germany). The scale of the mapping programme was preset by the only available detailed topographic map base for the 18 quadrangles which was kindly provided by the USGS.

The geology of Mount Melbourne quadrangle encompasses an Early Palaeozoic metamorphic and granitic basement, and a flat-lying cover spanning from Carboniferous – Permo-Trias to Quaternary time, with large stratigraphic gaps. The Early Palaeozoic basement consists of the Wilson Terrane, and includes two metamorphic complexes and the Granite Harbour Intrusive complex. The Wilson monometamorphic complex consists of low to high grade rocks formed during the Early Palaeozoic Ross orogeny; the Wilson polymetamorphic complex is constituted by granulite facies metasedimentary and metaigneous rocks affected by a previous metamorphic event of possible Neoproterozoic age; both complexes were intruded by large bodies of the Late Cambrian-Early Ordovician Granite Harbour Igneous Complex. The Wilson Terrane was deformed and underwent metamorphism in the Early Palaeozoic Ross Orogeny (Late Cambrian-Early Ordovician) with development of east-verging thrusts and folds developed under amphibolite- and greenschist
facies conditions. After the Ross Orogeny the area was uplifted and eroded. After the Devonian Admiralty – Gallipoli magmatic event, the area was further uplifted and eroded. On the resulting peneplain surface, the deposition of Carboniferous-Permian glacial deposits of Gondwanian pertinence occurred (Neall Massif Tillite). The basement and the tillite were covered by the Triassic sediments of the Section Peak Sandstone (Beacon Supergroup). These in turn were covered by large flows of Jurassic Kirkpatrick Basalt. The coeval Jurassic-Ferrar Dolerite formed sills chiefly along the basal Beacon horizon. The youngest event in the area was the emplacement of the Cenozoic McMurdo igneous complex, which consists of the older Meander intrusive suite and of the younger Melbourne alkali-volcanic suite. Many volcanic centres, belonging to the latter, strongly interacted with glacial activity, and conditioned the present landscape features, mainly along the coastal margin. More detailed explanatory notes and a references list are included in the coastal map.

**GEOMORPHOLOGICAL AND GLACIOLOGICAL 1:250 000 MAP OF THE MOUNT MELBOURNE QUADRANGLE**

This map is part of a series of geomorphological and glaciological maps of the coastal area which includes Mount Murchison to the north and Relief Inlet to the south. The geomorphological and glaciological features are represented on a georeferenced satellite image mosaic of the Mount Melbourne, Mount Murchison and Relief Inlet quadrangles, northern Victoria Land, Antarctica, at a scale of 1:250 000. Priestley and Revees outlet glaciers drain the East Antarctic Ice Sheet (i.e. the southern portion of the Talos Dome area) and part of the Victoria Land névé (Deep Freeze Range and Eisenhower Range). On the contrary, small ice caps and local névé resting on the Transantarctic Mountains feed the Campbell, Tinker and Aviator valley glaciers, pertaining to the northern Victoria Land ice field, a system of interconnected valley glaciers not draining the East Antarctic Ice Sheet. The main features related to present-day glacier morphology and dynamics are depicted. Glacier velocities and ice-front fluctuations were determined by analysis of aerial photographs and satellite images. Glacial and periglacial landforms and deposits, marine and coastal landforms, mass wasting, aeolian, weathering and structural landforms are identified and mapped. The chronological sequence of landforms and deposits, morphography and lithology is also indicated. Relict alpine topographic features and the elevation of the main trimlines of the area are depicted. Present and abandoned Adélie penguin colonies (Pygoscelis adeliae) are mapped. Additional information concerning human activity, such as cultural features, historic sites, and oversnow routes, is also indicated along with Antarctic Special Protected Areas (ASPA). Selected themes, such as lithology, along with areally extensive geomorphologic features, (i.e. main glacial troughs, relict alpine ridges and spurs, areally scoured terrain and the Mt. Melbourne stratovolcano) are shown at a smaller scale. Additional inserts report meteorological data from automatic weather stations operating since 1987.

The background for the map are three Landsat 4 Thematic Mapper (TM) satellite image mosaics. The mosaic consists of five TM images for Mt. Murchinson, three for Mt. Melbourne and two for Relief Inlet acquired during the 1990s. The TM images were digitally integrated using mosaicking tools to produce a map with the
Priestley Glacier, an outlet glacier draining the East Antarctic Ice Sheet, view upstream with the polar plateau in the background (*Photo C. Baroni*).

The Reeves Glacier draining the polar plateau (in the background) and feeding the Nansen Ice Sheet. Teall and Hansen nunataks emerge from the glacial surface, swept by katabatic winds as the Tarn Flat ice-free area in the foreground on the left. The Eisenhower Range and Skinner Ridge emerge on the right in the background (*Photo C. Baroni*).
dimensions of the USGS quadrangle. Landsat 4 TM mosaics were printed in false-colour composite (assigning red to band 4, green to band 3, and blue to band 2) at a 1:250 000 scale. The different albedo of snow, firn, and ice in the visible (band 3 and 2) and near-infrared (band 4) wavelengths allows differentiation of distinct glacier facies (e.g. snowcovered accumulation regions appear white in the images, whereas blue-ice covered ablation areas appear blue). The satellite image mosaic was georeferenced by identifying ground-control points measured during 1996 using dual-frequency Geodetic receiver and a GPS fixed station located at Mario Zucchelli Station, Terra Nova Bay. The USGS quadrangle contour lines were compiled using the triangulation system in the 1960s from U.S. Navy tri-camera aerial photographs taken between the 1950s and the 1960s on the basis of only few survey stations. The absolute positions of contour lines present considerable inaccuracies, and were corrected, wherever possible, using the georeferenced satellite mosaic.

**SATELLITE IMAGE MOSAIC OF THE TERRA NOVA BAY AREA, 1:250 000**

This map was produced and published in 1991. The mosaic map concerns the area of northern Victoria Land between the Drygalski and Parker ice tongues, including the Reeves and Priestley outlet glaciers and the basin of Campbell Glacier. The image ranges from 73°02’ - 75°29’ S to 160°04’ - 166°48’E, including the whole of Mount Melbourne and partially Sequence Hills, Mount Murchinson, Reeves Névé, Mount Joyce, and Relief Inlet USGS quadrangles. This mosaic has been made digitally from ten SPOT multispectral images acquired during 1988, 1989, and 1990. After radiometric and geometric processing, the mosaic was printed in false colour in a Lambert Conformal Projection. This map was one of first satellite image mosaic in Antarctica. The high quality of satellite images and the extreme environmental conditions in Antarctica make the remotely sensed images an essential instrument of analysis and support of the research and logistic purposes.

**SATELLITE IMAGE MAP OF THE NORTHERN FOOTHILLS AND INEXPRESSIBLE ISLAND, 1:50 000**

This map covers the area between 74°34’ - 74°58’ S and 163°33’ - 164°15’ E and was published in an issue of Terra Antartica Reports (Frezzotti et al., 2001). The map details an area of coastal hills on the northwestern side of Terra Nova Bay that lies to the east of Browning Pass and Nansen Ice Sheet and forms a sort of peninsula of the Deep Freeze Range. The satellite image map has been made by digital integration of a SPOT1 XS multispectral image mosaic recorded on 1988 and stereo-compilation reduction of TMA-air photos. Contour lines and spot elevations have been constructed from the photogrammetric processing of 28 vertical aerial photographs, taken on 1957, 1985, and 1993 at the scale of 25 000 and 50 000. The ground resolution of these photographs has been evaluated as being approximately 1 m. The satellite image mosaic was geo-referenced by identifying 17 ground control points determined by GPS measurements and used for aerial photo triangulation on the image. The map area was covered by 23 stereomodels, and natural points
were utilised as Ground Control Points. Cartographic editing included the drawing of: contour lines at 50 m intervals, 30 m elevation contours, bathymetric contours (every 50 m) re-drawn from Italian Istituto Idrografico della Marina (1989, 1991, 2000), over-snow routes, the location of relative elevations and photogrammetric elevations, construction and human activity (building, aircraft runway, radio mast, aerodrome, automatic weather station, historic monument), and Adélie penguin rookeries. Special attention was paid to the presentation of some coastal features (ice front, ice wall, rock wall and beach) and the fast ice limit. Meteorological data (wind and temperature) recorded at the automatic weather station “Eneide” in the period 1987-1999 are also reported. The Italian coastal station Terra Nova Bay (now Mario Zucchelli), the German station Gondwana and the snow cave where the Northern Party winterovered during 1912, are indicated on the map.

OTHER GEOTHEMATIC MAPS AND GEOPHYSICAL OBSERVATORIES

The geological map of the area between David and Mariner glaciers was published in 1987 (Carmignani et al., 1987). The cartographic base at the scale of 1:500 000 was obtained by a photographic reduction and adaptation of several USGS quadrangles. The map outlines the main features of the fundamental geological elements of the Transantarctic Mountains in that area: the crystalline basement, formed during the Palaeozoic Ross orogeny, and the cover sequences that formed in the time span from late Palaeozoic to Quaternary, even if with hiatus and unconformities. This map represents the first regional contribution to the geology of northern Victoria Land of the Italian PNRA and was the background for the following regional geological research and of the development of GIGAMAP.

The geomorphological map of the northern Foothills near the Italian station (Terra Nova Bay, Antarctica), at the scale of 1:20 000, was published in 1987 (Baroni, 1987). The detailed colour geomorphological map was surveyed at the scale of 1:10 000, in the vicinity of Mario Zucchelli Station (Terra Nova Bay) during the first expeditions of PNRA. The geomorphological survey and mapping were conducted following the principles and methods of the Italian geomorphological school, adapted to the Antarctic context. A pattern conditioned by the geological structure and by the glacial history can be outlined. Several zones parallel to the coast can be singled out: landscape features are conditioned by the geological structure and by glacial activity, responsible for shaping the hills and for depositing distinct Pleistocene and Holocene glacial complexes. Forms and deposits of marine origin or generated by the weathering of the bedrock stand out in the coastal belt. Abandoned penguin colonies assume a relevant role, reflecting the changes of environmental conditions that have characterized the Ross Sea during the last 8 000 years.

The total magnetic anomaly map of the central-southern part of Victoria Land, sheets A & B (Bozzo et al., 1996), is a compilation of about 50 000 km² of aeromagnetic surveys conducted south of Terra Nova Bay and covering portions of several USGS 1:250 000 scale quadrangles: Reeves Névé, Mount Melbourne, Mount Joyce, Relief Inlet, Convoy Range and Franklin Island. The survey was performed
within the framework of the German-Italian cooperation in aeromagnetic research in Antarctica. The topographic base was provided by USGS. Measurements have clearly indicated that all high magnetic susceptibility rock types produce magnetic anomalies, even if their outcrop is not extensive. The regional magnetic highs are attributed to the Palaeozoic granitoids, whereas the high frequency component of the magnetic anomalies are attributed to the Jurassic mafic magmatism. None of the formations of the metamorphic complex are responsible for intense magnetic signals (Bozzo & Meloni, 1992). Clear evidence of the transition of the Transantarctic Mountains to the East cratonic shield was not observed.

The textural seafloor map of the inner Terra Nova Bay (Brambati et al., 1991), at the scale of about 1:143 000 shows the distribution of the seafloor sediments of the area offshore the Mario Zucchelli Station between Campbell Glacier e Hells Gate. The base utilized for this compilation is the Bathymetric Chart n. 882, 1:50.000, *Istituto Idrografico della Marina*, 1991.

The geopetrographic map of the Terra Nova Intrusive Complex is attached to a paper on the Terra Nova Intrusive Complex in the Northern Foothills, published in Terra Antarctica Reports (Rocchi et al., 2003). The Satellite image map of the Northern Foothills and Inexpressible Island, 1:50 000, was used as topographic basis. The map shows the areal distribution and the relationships between the main lithological units of the Granite Harbour Intrusive Complex.

A geomagnetic observatory was installed at Terra Nova Bay (IAGA code TNB; geographic coordinates: 74.68° S, 164.12° E; corrected geomagnetic latitude: 80.0° S) in the vicinity of Mario Zucchelli Station during the 1986/1987 austral summer. Variations of the Earth’s magnetic field are recorded by means of three-axis fluxgate magnetometers, intensity is measured by means of Overhauser magnetometers (Meloni et al., 1994; Meloni et al., 2006). The observatory is still regularly running and absolute measurements are taken regularly when the station is open. Since 1996, 1-min data are routinely produced in INTERMAGNET standard. Several scientific studies have been made with TNB data mainly on secular variation and external magnetic fields (daily variation, pulsations, magnetic storms and impulses).

A Continuous Very Broad Band permanent seismographic station was installed at Terra Nova Bay (code TNV) starting operations in 1990. The primary seismometers are three-component Streckeisen STS-1/VBB sensors, data loggers are Quanterra Q4120 and Q680, which provide data with a resolution of 24 bits, corresponding to 144 dB dynamics. Accurate timing is provided by a GPS receiver. Several studies using this station have shown Earth mantle processes and seismic anisotropy. Shear-wave splitting techniques have shown a typical dominant NE-SW direction over the entire region, even if other anisotropy directions are present and related to regional tectonics (Morelli & Danesi, 2004).

During the 1990/91 summer expedition at Terra Nova Bay, an absolute gravity datum was determined. 166 measurements of symmetrical rise and fall of gravity acceleration brought to an absolute measurement of gravity. Assuming an error of 3-4 microgal, a final result for $g$ was obtained at 982 854 919 microgal (Cerutti et al, 1992). This is the first absolute gravity measurement in Antarctica. The
Inexpressible Island: Holocene raised beaches dated from present to about 8 000 years BP by organic remains from the abandoned penguin colonies (Photo C. Baroni).

Inexpressible Island, wooden sign dedicated to the six members of the Northern Party who winterovered in an ice cave in 1912 (Photo C. Baroni).
View on the Transantarctic Mountains (Shafer Peak): the Triassic continental sandstone of the Beacon Supergroup (pale yellow) lies on the peneplained Palaeozoic crystalline basement (dark) and is intruded by sills of Jurassic Ferrar Dolerite (red brown) (Photo P. Pertusati).

First Italian skidoo excursions (winter 1985-1986) on the sea ice fo Tethys Bay, a cove of the Gerlache Inlet. The camp was installed on the the saddle of the ice-free promontory. In the background the floating Campbell Ice Tongue (Photo G. Orombelli).
measurements at Terra Nova Bay have been repeated, even though not periodically, in the following years by NOAA (Mäkinen et al., 2007).

**LOCALITIES OF SPECIAL INTEREST**

In the Terra Nova Bay area there are many localities of special interest a selection of which is listed hereafter.

- **Eisenhower Range** - Fossil plants (trunks, branches and leaves) are present in the Beacon sandstone.

- **Deep Freeze Range** - The prograde sequence from low to high grade low P/high T metamorphism can be observed along a transect from Mt. New Zealand, Mt. Levick to Cape Glacier.

- **Mt. Emison** - Outcrops of charnockitic-enderbitic and metasedimentary granulites can be observed.

- **Campbell Glacier and Gondwana Station** - Outcrops of migmatites enclosing granulite facies relics are present.

- **From Mario Zucchelli Station to Tethys Bay** - Along the road and nearby coastal area Mt. Abbott mega K-feldspar bearing granite and metasedimentary septa are well exposed; near Tethys Bay the Strandline Glacier front advances on Holocene raised beaches; the glacier is monitored also for its frontal variations.

- **From Mario Zucchelli Station to Adélie Cove** - Along the track magmatic interaction between mafic and felsic facies of Granite Harbour Intrusives can be observed; several Holocene abandoned penguin rookeries (Pygocelis adeliae) are present, especially in the area of Campo Icaro (ornithogenic soils with penguin remains that document recolonization of the Antarctic coast after the Late Pleistocene ice sheet retreat); at Adélie Cove an Adélie penguin colony is present.

- **Mt. Melbourne area**: Outcrops of basaltic rocks of the Mc Murdo Igneous Complex with peridotitic inclusions from the Earth’s mantle can be observed; volcanic bombs are widespread on the lava outcrops; the presence of fumaroles is also to be mentioned.

- **Historical Site or Monument HSM n. 14, Inexpressible Island**: This is the site where the Northern Party of Scott’s second expedition (1910–13) spent the winter of 1912 in an ice cave excavated in March 1912; a wooden sign, plaque and elephant seal and emperor penguin bones remain at the site.

- **Inexpressible Island** - Holocene raised beaches document a relative maximum uplift of about 30 m of coastal areas following deglaciation after the last glacial maximum.

- **Hells Gate** - On the surface of this small ice shelf glacial deposits with marine shells (mainly barnacles), trapped by basal accretion at the grounding line, are present; marine remains are brought to the surface through ablation caused by strong catabatic wind.

- **Mt. Keinath, Mt. Crummer, Andersson Ridge, Harrow Peaks and other localities** - Pseudokarstic landforms and tafoni, produced by haloclastic processes and chemical weathering on granitic rocks, can be observed.
Introductory Notes to the Map Case

- **ASPA 161, Terra Nova Bay, Ross Sea (Italy)** - this is an important littoral area for well-established and long-term monitoring, with a high diversity at both species and community levels of high ecological and scientific value.

- **ASPA 165, Edmonson Point, Wood Bay, Ross Sea (Italy)** - The terrestrial and freshwater ecosystem is one of the most outstanding in northern Victoria Land. An exceptional diversity of freshwater habitats is present.

- **ASPA 173, Cape Washington and Silverfish Bay, Terra Nova Bay, Ross Sea (Italy, United States)** - These are areas with important or unusual assemblages of species, including major colonies of breeding native birds (snow petrels) or mammals (seals):
  1) **Cape Washington**, emperor penguin colony with around 20,000 breeding pairs comprising approximately 8% of the global emperor population and 21% of the population in the Ross Sea;
  2) **Silverfish Bay**, the first documented ‘nursery’ and hatching area for Antarctic silverfish is located approximately 20 km west of Cape Washington.

- **ASPA 175, High Altitude Geothermal sites of the Ross Sea region (Italy, New Zealand, United States)** - The area includes the active volcanoes Mt. Erebus, Mt. Melbourne, and Mt. Rittmann and are known to have unique biological communities developed around the fumarolic vents.

REFERENCES


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Direttore Scientifico: Carlo Alberto Ricci

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