Geology of the *Dakshin Gangotri* Landmass, Schirmacher Hill, Antarctica

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ABSTRACT

The nearest rock exposures to the Indian research station at the Princess Astrid coast of Queen Maud Land, Antarctica, is the *Dakshin Gangotri* range, which is about 16 km long with mean width of one km, trending in an almost East West direction. This landmass primarily exposes gneissic rocks of pre-cambrian age with intrusive younger dolerities.

Regional study of the gneissic complex indicates that two types of gneisses are widespread (i) re-constituted paragneiss and (ii) migmatitic gneiss. They contain segregation of feldspathic and pegmatite.

Mineral assemblages in the gneisses indicate that they were produced by regional metamorphism of pelitic and quartzo-feldspathic sediments under the sillimanite- almandine-orthoclase subfacies of the almandine -amphibolite facies and hornblende- granulite subfacies of the granulite facies of Fyfe *et al.* (1958).

INTRODUCTION

Dakshin Gangotri Landmass, also called the Schrimacher Hill Range of Queen Maud Land, forms the foothill zone of the mountain ranges of the Queen Maud Land, and lies almost midway of the coastal Indian Research Station towards north and Wohlthat mountain chain in south. This land-mass is 16 km long having a width of about a km (Fig. 1).

Besides the preparation of geological map of the entire *Dakshin Gangotri* landmass (Fig. 2), an area of 4.5 sq km was mapped on a large scale-1:10,000 scale-with the help of a plane table and telescopic alidade to bring out the nature of the graphite mineralisation and melasyenite intrusions (Fig. 3).

On the basis of (i) the mode of occurrence of the different rock types and their field disposition, (ii) lithologic associations, (iii) petrographical details, mineralogical and textural variations and *(iv)* the intensity of deformation, it has been possible to establish the following history of the area :

Post-Precambrian	Younger dolerite
Precambrians (Metamorphism, migmatisation and deformation).	Pegmatite, aplite and quartz veins, Metadolerite/melasyenite, amphibolite, biotite-hornblende bearing quartzo-feldspathic gneisses (including migmatites), and calc-silicate rock.

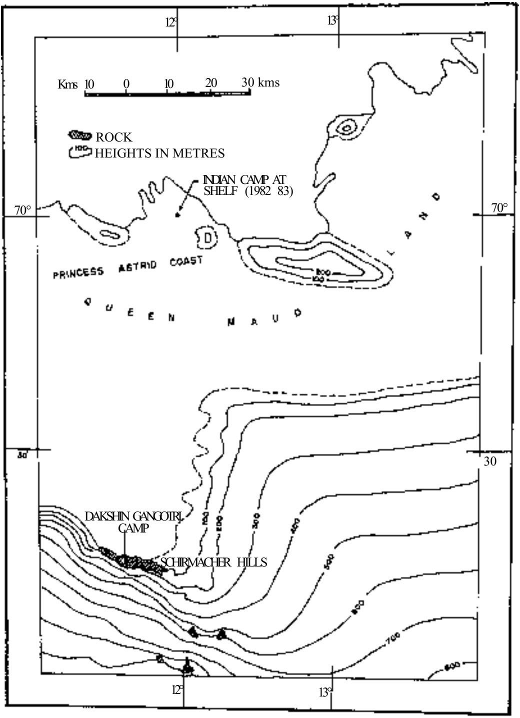

Fig 1 Location map of *Dakshin Gangotri* Landmass, Antarctica

BRIEF DESCRIPTION OF THE STRATIGRAPHIC UNITS

Biotite-hornblende-quartz-felspar gneisses

The biotite hornblende bearing quartzo felspathic gneisses form the metasedimentary country rock in the present area. These gneisses are distributed throughout the area and show NW-SE trend with the foliation plane dipping gently towards southwest. However, local variations are also noted.

Regional study of the gneisses indicates two contrasting types: (i) Reconstituted paragneiss which is less altered and (ii) the migmatitic gneisses with segregation of felspathic and pegmatitic veins.

The gneisses are medium-grained, light coloured and show gianoblastic texture with foliation due to orientation of biotite and hornblende. They comprise microcline, orthoclase, plagioclase, quartz, biotite and hornblende.

Migmatites: D. Microcline rich granoblastic gneiss with faint foliation.
C. Garnet bearing porphyroblastic gneiss with pegmatite veins.

Gneisses: B. Porphyroblastic gneiss with mafics showing clear foliation.
A. Microcline porphyroblastic gneiss.

Mineral assemblages in the gneisses indicate that they are produced by regional metamorphism of pehtic and quartzo-felspathic sediments-under the sillimanite-almandine-orthoclase-subfacies of Fyfe *et al.* (1958).

Calc-silicate rocks

These are exposed as isolated outcrops within the group C rocks (Fig. 4), with similar strike trend as then host gneisses suggesting a metasedimentary origin. They consist of alkali plagioclases (Fig. 5), microcline, quartz, epidote and chlorite and show schistose structure. Mineral assemblage, in the rock, indicates a regionally metamorphosed product of siliceous limestone at increasing temperature and sudden fall of pressure with decarbonation.

Amphibolites

These occur as veins, dykes and lenses of small dimension within the gneissic country rock with a north-westerly trend and show either a sharp or gradational contact with the host gneisses. Bands of amphibohte are ptygmatically folded in migmatitic outcrop. This rock is composed of hornblende, plagioclase, quartz with diposide and sphene, and shows granoblastic, gneissose and at places schistose texture. Relict sub-ophitic texture has also been observed. Well developed foliation and strong lineation of the amphibohtes reflect the subparallel orientation of prismatic grains of hornblende.

Field disposition and petrographic evidences such as sub-ophitic texture indicate that these amphibolites in the gneissic complex may have been derived from metamorphism of basic igneous rocks.

Metadolentes

These are exposed in different parts of the present area and cut across the strike of the foliation of the gneisses. These are dark coloured, medium grained rocks consisting of calic plagioclase, olivine, augite, hypersthene, hornblende and biotite. The relict ophitic sub ophitic and intergranular textures are well preserved.

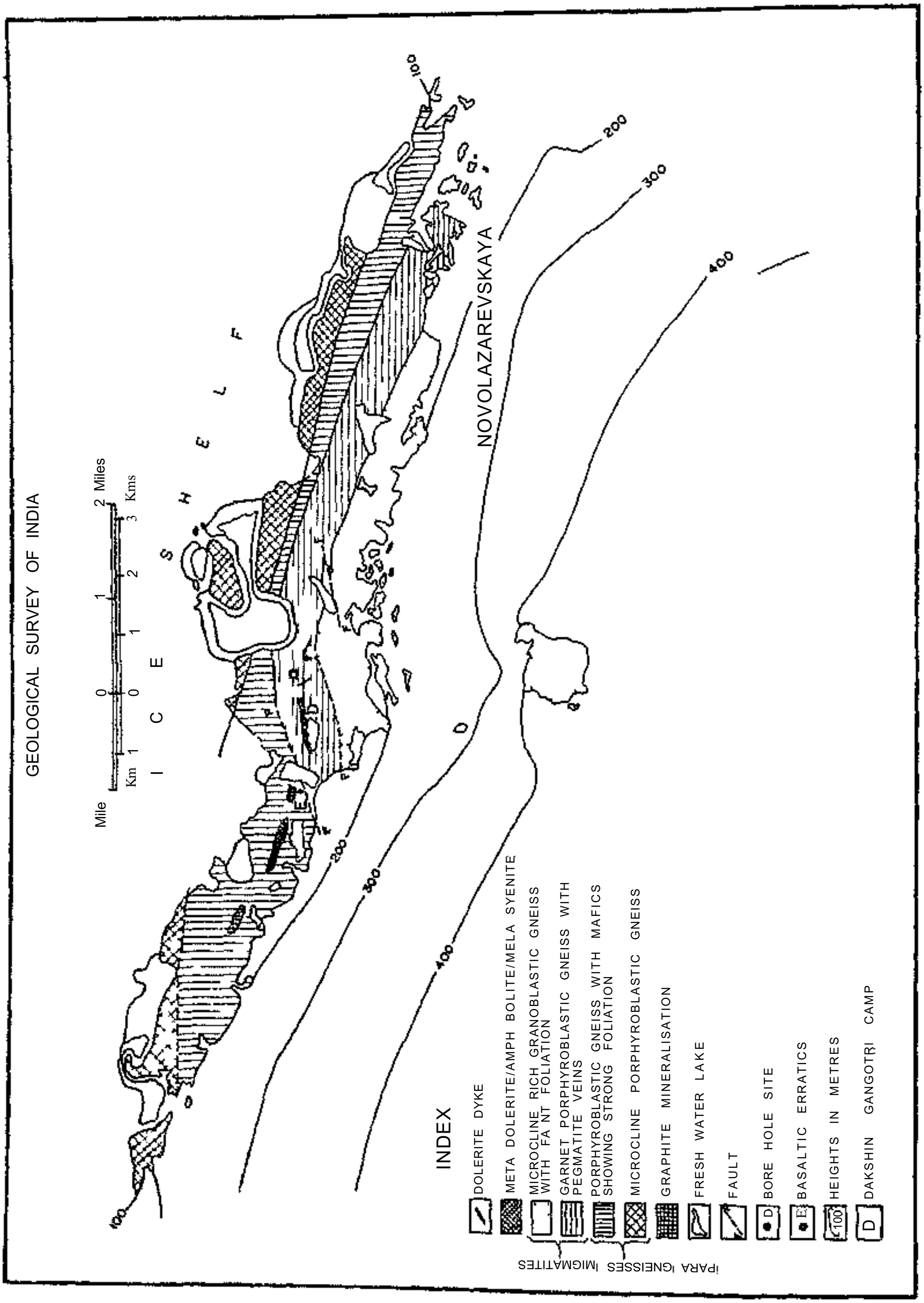

Fig 2 Geological map of the *Dakshin Gangotri* landmass Antarctica

Mineral assemblage, textural relationship, supported by field relations, indicate that these are the product of regional metamorphism of basic sills/dykes at elevated temperature, and water deficient conditions under hornblende-granulite sub-facies of granulite facies.

Melasyanite

This rock was come across along the western side of the landmass. It is a medium to coarse grained melanocratic rock consisting essentially of feldspar, quartz, biotite, orthopyroxenes and actinolite. The felspar is mainly cryptoperthite and microcline. Interstitial sphene and apatite are also present. The mineral constituents do not show sign of recrystallization. The presence of cryptoperthite as the predominant felspar is suggestive of the magmatic origin of these rocks. Test drilling was carried out on one of these outcrops and rock cores collected upto a depth of 7 m. These cores were examined by the Petrology Division, Northern Region, Geological Survey of India and their report is enclosed as Annexure-I.

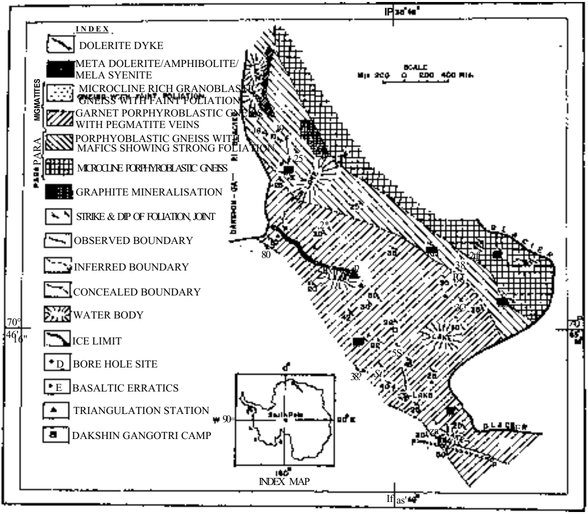

Fig. 3. Geological map around Dakshin Gangotri, Schirmacher Hill, Antartica

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f i, liitmu graph 1 A nb clustering of plagioclase m calc silicate rocks (Crossed n cols 61X)

Pegmatite and Quartz veins

These cut through the amphibolites and gneisses as irregular veins and minor dykes and also occur in concordant relationship with the gneisses Pegmatites are coarse grained pink coloured and consist of pink potash teldspar plagioclases quartz biotite and often magnetite Pegmatites are older than the unmetamorphosed dolerites is th do not cut across them At places foliation plane of the gneisses is occupied by thin quartzo feldspathic vein They have lenticular form and often follow joint planes In migmatitic outcrops pegmitites and quartzo feldspathic veins of variable thickness from few inches to few feet occur frequently Thcy cut across the foliation as bands and veins and are pigmatically foldcd Quartz veins are very thin and generally follow the foliation plane of the gneisses

Fig 6 Photomicrograph showing relict subophitic texture in the metadolerite (Crossed nicols, 61X).

Fig. 7 Photomicrograph showing css-cross arrangement of the plagioclase laths (Crossed nicols, 61 X)

The pegmatite and quartzo-feldspathic veins of migmatites may be interpreted as products of magmatic injection of silica rich quartzo-feldspathic melt derived from partial melting of the older metamorphic gneisses which appear to be residual melt of a granitic magma. According to Turner and Verhoogen (1960) pegmatites may be formed by crystallization from pegmatitic magma.

Dolerite dykes

These occur within the gneisses and are medium grained, dark coloured, comprising calcic-plagioclase, augite, pigeonite, opaques, and residual intergrowth of quartz and alkali-feldspar. The rocks show criss-cross arrangement of plagioclase laths (Fig. 6,7) and subophitic to ophitic and intergranular textures. These represent the younger group of rock and are possibly of Tertiary age.

STRUCTURES

Major part of the present area is formed by gneisses with variations in both megascopic character and field occurrences. However, they appear to form a single structural unit.

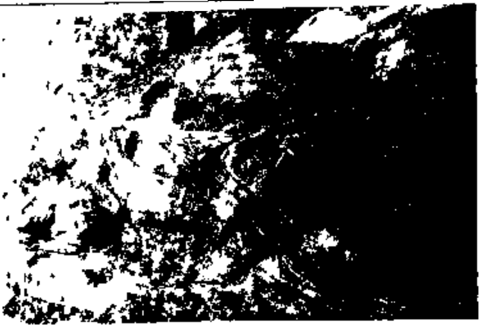
Structural elements : The S- and L- fabrics recognised in the area are bedding (S_1), axial plane schistosity (S_2), crenulation cleavage (S_3), gneissosity (S_g), mineral lineation (L_1), fold axis (F_1 & F_2). Other structural elements in the area include joints and minor faults.

Bedding (S_1): The general trend is NE-SW with moderately steep dip towards NW. The variation pattern of this element indicates that the earliest fold (F_1) is a non-cylindrical fold on S_1, plane with NE-SW axial trend, the fold axis being low plunging (10°) towards NE.

*Axial plane schistosity (S_2) :*Prominently developed in gneissic rock over the area with a regional trend of WNW-ESE and low dips towards SW. It is usually parallel to the bedding due to appressed nature of the minor folds. In the hinge zone of the minor folds, the bedding-schistosity relationship is either parallel (in F_2 folds) or at high angle (in F_1 folds). The nature of F_2 folding is similar to F_1 with NNW-SSE axial trend and distinct overturning towards NE.

Crenulation cleavage (S_3) : It is noticed as the axial plane S-plane of F_2 folds and puckers. The strike varies from NNW-SSE to WNW-ESE with steep to moderate dips towards NE.

Gneissosity (S_g): This plane is uniformly noticed in the rocks of this area. It is secondary in nature and is correlatable with the S_2 plane. It trends dominantly WNW-ESE with low to moderate dip towards SW. The gneissosity plane has closely followed bedding planes.



I- i l l otograph sho ng ov rturned F (olds at *Dakshin Gangotri*

Mineral lineation (L_1): The mineral lineation is widely developed and appears to have developed with F_1 folding. The variation in the attitude of the lineation is due to the rotation of the lineation on varying attitude of the schistosity surface due to F_2 folding.

Minorfold axes (F_1 and F_2): In general, minor folds are tight to appressed, lowplunging isoclinal overturned antiforms and synforms. Chevron pattern with sharp angular hinge is shown by some F_2 folds.

Structural Geometry: The preliminary structural analysis of the area has clearly indicated two phases of folding (F_1 and F_2). The first fold (F_1) recognised on bedding plane (S_1) is non-cylindrical, appressed, isoclinal antiform and synform with axial trend N80°W-S80°E and axis plunging 10°,N80° W. That axial plane schistosity is uniformly developed in the area and represents the regional trend.

The F_2 folding is cylindrical, appressed, isoclinal, overturned (Fig. 8) antiforms and synforms with axial trend N30° W S30° E and fold axis plunging 19°, S30°E . The axial plane is marked by the development of crenulation cleavage and the fold axis is corroborated by minor fold axis (F_2). The wanning stage of F_2 folding is indicated by the development of warps without the development of any axial plane and with axis parallel to the minor F_2 axis.

*Faults:*A few small faults have been noticed in the area. A major fault was observed in the southeast corner of the area showing a displacement of about half a kilometre.

Joints: A large number of joints are seen in the present area, but the most prominent joints observed are (i) trending E-W and dipping northerly, (ii) trending N10°E-S10°W and dipping vertically and (iii) parellel to tht strike of the rock.

MINERALISATION

At a number of locations in the *Dakshin Gangotri* hill, small pockets exhibiting leached and altered surfaces of oxidized ore bearing veins are seen. Sometimes, at places, the limonitic stains dominate giving these pockets the appearance of gossan. Except for such indications no *in situ* indications of base metal mineralisation were observed.

Within the porphyroblastic gneiss, a 300 m long zone of graphite mineralisation with an average width of 150 m was recorded, near the contact of this rock unit with its underlying formation, east of *Dakshin Gangotri* glacier. This zone was traced over a strike length of 300 m.

Frequent presence of pegmatites might indicate the setup for occurrence of pneumatolytic deposits. Large and well developed pegmatitic minerals were, however, noticed in the boulders. Zeolite and kyanite were observed in such boulders.

REFERENCES

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Turner, F. J. and J. Verhoogen, (1960). *Igneous and Metamorphic Petrology*. Second Edition. McGraw Hill Book Company Inc., 694 pp.

Annexure I

REPORT ON THE PETROLOGY OF DRILL CORE ROCK SAMPLE BROUGHT FROM ANTARCTICA BY SHRI V.K. RAINA, DIRECTOR, GLACIOLOGY DIVISION

One drill core sample of a dark coloured rock collected during the course of Second Indian Antarctica Expedition 1982 was received in the Petrology Division, Geological Survey of India, Northern Region, Lucknow on 12th April 1983, for identification.

Four thin sections, two along the length of the drill core and two transverse to it were prepared for petrography. These have been registered provisionally as Antc/P/1.

Megascopic Characters

The rock is medium to coarse-grained, melanocratic with large flakes of shining dark coloured mica along with black, and dark green stubby, prismatic crystals of amphibole and pyroxene. Sporadically grey felspars and quartz are observed in small quantities.

Microscopic characters

The rock is medium to coarse-grained, holocrystalline with a hypidiomorphic texture.

It comprises essentially of pale green actinolite, subhedral laths and flakes of brown biotite and anhedral crystals of cryptoperthite and microcline, with subordinate amount of hornblende, orthopyroxene and quartz. Accessory minerals are sphene, apatite and fine dusty iron oxides.

Biotite is pleochroic in shades of brown with some sections showing well developed cleavage. It comprises about 30%of the rock. A few laths contain minute zircons which exhibit pleochroic haloes.

Actinolite (25% of the rock) occurs as elongated, tabular plates having a pale green colour. In the cross sections it exhibits the typical amphibole cleavage in two directions. Actinolite is feebly pleochroic and the longitudinal sections show an extinction angle ranging from 10˚ to 19˚.

A few pale green coloured crystals exhibit faintly developed pyroxene cleavage and schiller structure due to dark inclusions. These are orthopyroxene which have been partially altered to amphiboles.

The felspars (40% of the rock) are represented by cryptoperthite and microcline occurring as large anhedral crystals. The cryptoperthite exhibits first order interference colours with some parts showing higher refractive index and higher order of interference colours, due to a higher birefringence. Microcline shows cross hatched twinning. The felspars are almost unaltered, only in few small patches these are observed to be replaced by carbonates. Plagioclase is absent.

Interstitial quartz occurs in small quantity constituting less than 5% of the rock.

A few minute prismatic crystals of colourless apatite, showing low first order grey polarisation colours and parallel extinction are scattered throughout the rock.

Granular sphene occurs in an anhedral form having a yellowish brown colour.

Observations

(1) The mineral constituents do not show any preferred orientation or sign of recrystallisation.

(2) The amphiboles appear to have been formed by the alteration of pyroxenes as is evident by the partially altered ortho-pyroxenes.

(3) The potash felspars are anhedral in shape because they have crystallised after the ferromagnesian minerals.[1]

(4) The presence of cryptoperthite as the predominant felspar is suggestive of the magmatic origin of the rock.[2]

Rock Identification:

The rock sent is provisionally identified as MELASYENITE.[3]

REFERENCES

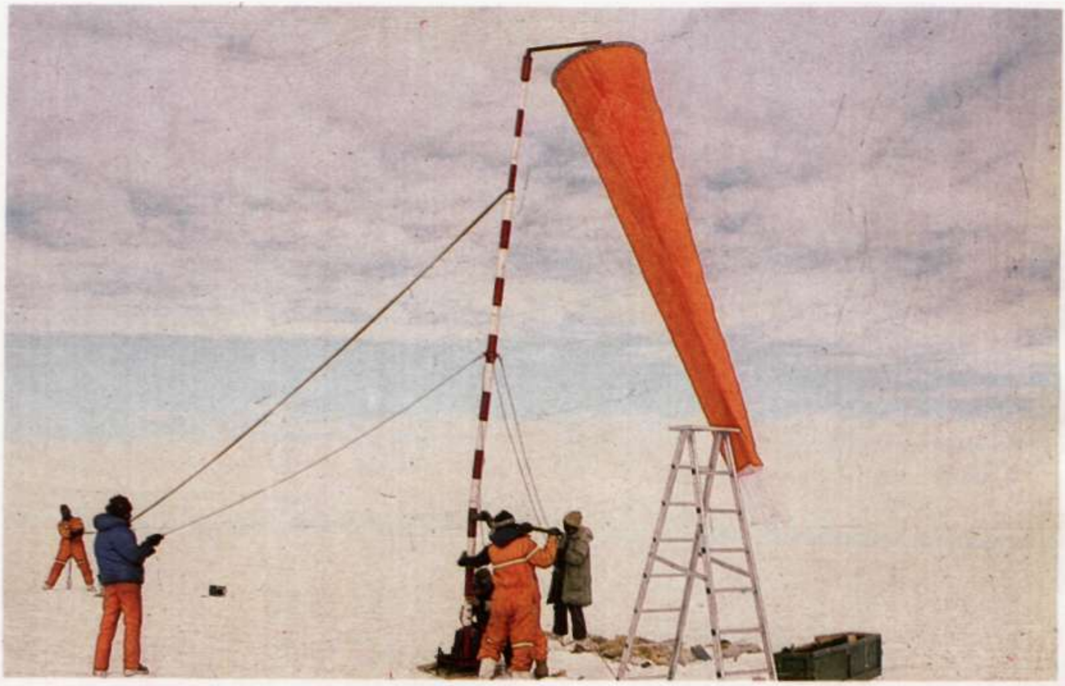
1 Jackson, K.C. (1970). *Textbook of Lithology.* 284 pp.

2 Williams, H., F J Turner and C.M. Gilbert, (1954) *Petrography: An Introduction to the Study of Rocks in Thin Sections,* 143 pp

3 Moorhouse, W.W. (1959). *The Study of Rocks in Thin Section,* 290 pp.

Indian flag flutters for the second time in the Antarctic base camp.

Construction work of a barrack commences in Antarctica.



Installing a windsock at the prepared ski-way.

Repair of the helicopter after a blizzard.

Inspection of the unmanned meteorological station established during the First Expedition and retrieval of meteorological data.

Collection of water samples from an Antarctic lake in Schirmacher hills.

Snow scooter with sledges used during the Second Expedition.

Triumphant return of the Second Expedition team to Goa.