SATELLITE IMAGE MAPPING OF THE LARSEMANN HILLS, ANTARCTICA

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ABSTRACT

The Larsemann Hills is an ice free oasis on the continental margin of Antarctica. Approximately 250 square kilometres in area it has a coastline of 15 kilometres abutting Prydz Bay in the Davis Sea. As one of the four major ice free oases in the five thousand kilometres of coastline in Eastern Antarctica, it has considerable scientific importance. Topographically the area consists of ice free,low rounded hills and adjacent small islands. Associated with the deglaciation of the land areas has been the development of a complex lake system which melts during the short Antarctic summer. The accummulation of strata of algal gythra overlaying lake bed sediments provides a chronology reflecting the environmental history of the lakes since deglaciation. Studies of these sediments and raised sea level benches enables a history of the climate and environment of the local area to be established.

Due to its scientific importance there is a strong demand for detailed topographic mapping of this unique area. Mapping however, as in the whole of Antarctica, is technically

topographic data from the line map will be used as a basis for a GIS to integrate the scientific data of other scientific disciplines to support the environmental management plan of the area. There are now three Scientific Base Stations in the Larsemann Hills, one from Australia, one from the USSR and the other from China, and careful environmental management by all expeditions is of considerable importance.

Due to the technical difficulty and costs involved in conventional mapping in Antarctica, the combination of stereoscopic line mapping, multi-spectral image mapping, and GIS technology is seen as providing the best total mapping solution for remote areas with significant environmental importance such as the Larsemann Hills.

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TOPOGRAPHIC DESCRIPTION

The Larsemann Hills (69°30'S, 76°30'E) is a series of islets and rocky peninsulas dissected by steep sided valleys which are structurally contorted. The topography reflects at least three glacial stages involving two periods of valley deglaciation after retreat of the Antarctic ice-cap. The bedrock geology consists chiefly of gneisses and granites with mafic rocks being locally abundant.

More than two hundred freshwater lakes are scattered through the bare rocky hills. These lakes can be broadly classified as supreglacial ponds, proglacial lakes (some permanently frozen), small closed rock basins, and colluvium dammed ponds. Meltwater streams are well developed in high summer and secondary drainage networks exist. Large sorted stone circles are common in outwash fans. Morainic deposits are virtually absent, though erratic blocks are scattered thinly throughout the hills.

Stornes Peninsula, at the western end of the Hills, is heavily dissected with a relief of about 140 metres. Numerous deep closed rock basins also occur and relatively unweathered rockslabs surround the lake basins. Surficial deposits are thin and of restricted extent; they include snowpatch gravels, sandy deltas and talus. Glacial ice movement has been from southwest to northeast, along structural trends. Glacial striations are uncommon though fine scratches can be seen on rocks in the Stornes Peninsula.

HISTORY OF THE REGION

The Larsemann Hills was first sighted during the Lars Christensen series of Norwegian whaling/exploring expeditions to the coastal waters of the Antarctic in the 1930's. In the 1934/35 summer season, Captain Klarius Mikkelsen was in command of the Norwegian ship "Thorshavn", delivering fuel to the factory ships and back-loading oil from the whaling fleet. He encountered the Eastern Antarctic coastline in the vicinity of the West Ice Shelf and traced the coast westerly for nearly 500 kilometres to the edge of the Amery Ice Shelf (69°40'S, 74°00'E). Nearly one hundred kilometres of this coast was free from snow and ice and included two ice free oasis areas, the Larsemann Hills and the Vestfold Hills. No landing was made at the Larsemann Hills but on 20 February 1935 a party of eight which included Captain Mikkelsen and his wife landed by lifeboat in the Vestfold Hills. Mrs Caroline Mikkelsen probably became the first woman to land in Antarctica and a mountain on the edge of Prydz Bay was named after her to commemorate the event.

Lars Christensen was aboard the "Thorshavn" for his fourth visit to Antarctica in the summer of 1936/37. He planned a series of aerial reconnaissance flights taking oblique aerial photographs to confirm the Norwegian whaling exploration of the past ten years. In January 1937 his aircraft flew the length of the Ingrid Christensen coast, passing over the Larsemann Hills. Two

seasons later Lincoln Ellsworth's 1938/39 Antarctic Expedition was also in Prydz Bay and undertook aircraft flights distantly sighting the Larsemann Hills. At the same time Sir Hubert Wilkins, captain of the expedition ship "Wyatt Earp", made landings at the nearby Svenner and Rauer groups of islands.

In the 1946/47 summer trimetrogon photography of much of the coastline of Eastern Antarctic was taken during the 'Operation Highjump' expedition of the United States of America. This photography from seaplanes included some oblique photography of the Larsemann Hills, but no ground control was established or any maping produced at that time.

AUSTRALIAN FIELD ACTIVITIES

The Australian National Antarctic Research Expedition (ANARE) established Mawson, its first Antarctic station, in 1954, and subsequently Davis station was established in the Vestfold Hills in 1957. Working from these stations Australian surveyors began to establish a series of astro fixes as control for mapping. In August 1957 the first ground visit to Larsemann Hills was made by an ANARE survey party to establish a mapping control point. Landing on the winter sea ice in a single engine 'Beaver' aircraft an astrofix was taken and a small cairn built on the feature then shown as Sigdöy (now Fisher Island).

The second visit to the Larsemann Hills area was made the next summer by an ANARE party led by Phillip Law from the expedition ship "Thala Dan" in February 1958. Several islands were visited and two separate landings made on the Stornes Peninsula and a prominent rocky hill was climbed. See Figure 1.

Ten years later in the 1967/68 summer, an ANARE trig station was established on Blundell Peak, one of the highest points in the Larsemann Hills, as the terminal point in a Tellurometer traverse extending westerly down the Ingrid Christensen Coast to the Amery Ice Shelf. Next summer the trig point was re-occupied and the survey traverse extended easterly to the Vestfold Hills thus establishing a continuous line of geodetic trig points from Mawson station to Davis station. That year a blue ice, fixed wing landing strip was used for operations by a turbocharged 'Beaver' aircraft operating from the ANARE summer base at Sandefjord Bay.

ANARE scientists next visited the area in the summer of 1979/80 by helicopter, and lived in a temporary base of polar pyramid tents. On 5 February 1986 a party of fourteen ANARE scientists and support staff visited the Larsemann Hills for four days to conduct a scientific survey and select a site for a summer field station. Using helicopters and supported by the "Nella Dan" which carried the main group and equipment, they established a single 'apple' hut at what has now become 'Law' Base.

During the winter of 1986, ANARE members from Davis visited the site several times by ground transport during visits to the nearby Emperor penguin rookery at Amanda Bay to check on the condition of the Australia hut. Later that year, in October and November, three groups from Davis established additional huts for the field station. On the first of these expeditions, the

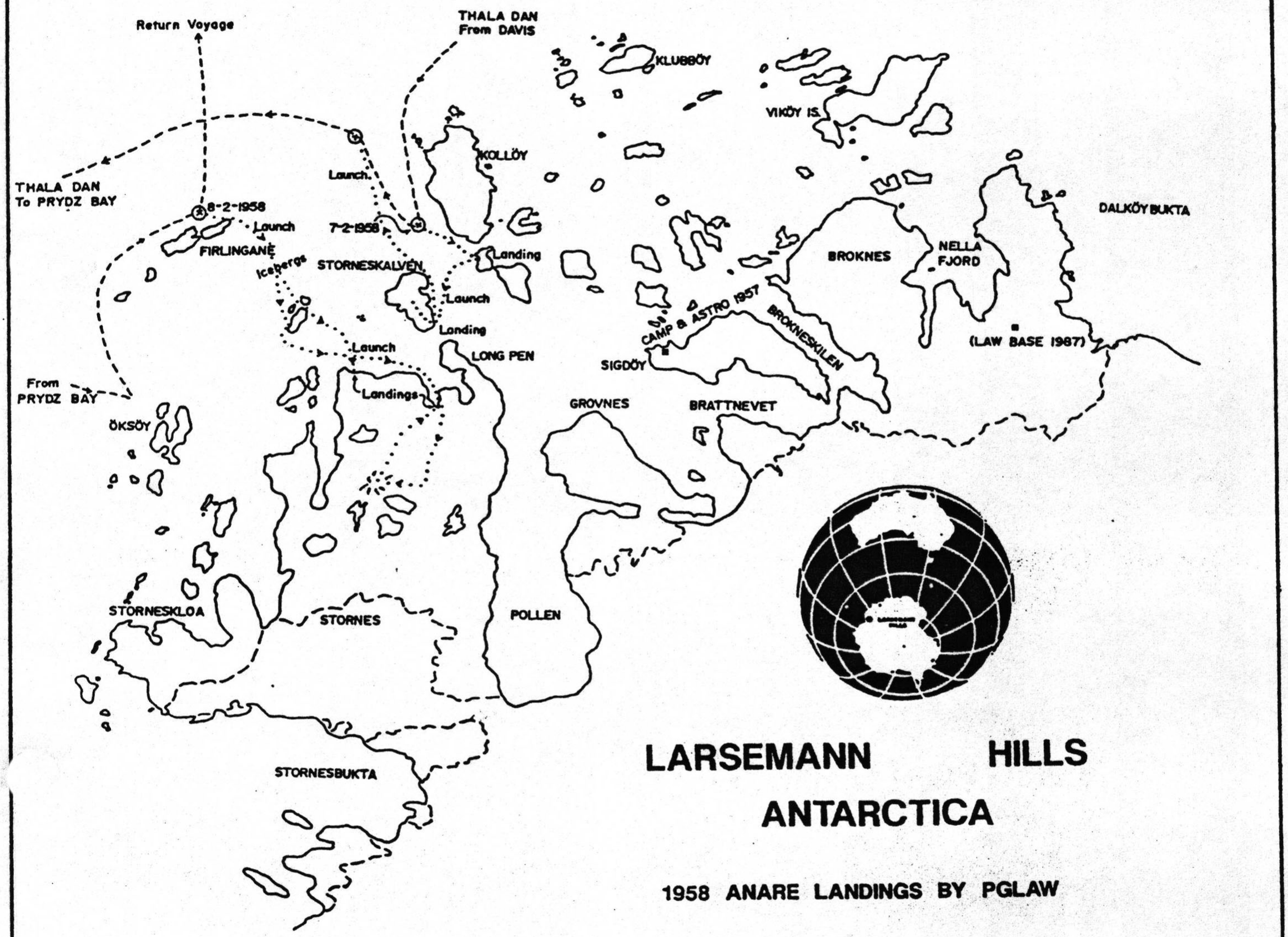
Return Voyage
THALA DAN
From DAVIS
KLUBBÖY
VIKÖY IS.
KOLLÖY
Launch.
THALA DAN
To PRYDZ BAY
8-2-1958
Launch
7-2-1958
FIRLINGANE
Icebergs
STORNESKALVEN
Landing
DALKÖY BUKTA
BROKNES
NELLA
FJORD
Launch
Landing
CAMP 8 ASTRO 1957
BROKNESKILEN
(LAW BASE 1987)
Launch
LONG PEN
SIGDÖY
From
PRYDZ BAY
Landings
GROVNES
BRATTNEVET
ÖKSÖY
STORNESKLOA
STORNES
POLLEN
STORNESBUKTA
LARSEMANN HILLS
ANTARCTICA
1958 ANARE LANDINGS BY PGLAW

FIGURE 1

damaged remains of a Soviet made wood-panelled hut and equipment were discovered in the area that has subsequently become the USSR 'Progress' Base.

The next ANARE visit to Larsemann Hills occurred when a party of summer scientists were unable to reach their original destination in the Bunger Hills due to adverse sea-ice conditions. Eighteen personnel from the "Nella Dan" landed on 18 January 1987 by helicopter and occupied the newly establish Law Base until 27 February. The location of three survey stations were determined by satellite Doppler techniques.

In the 1988/89 summer the USSR established a new base site, which was called 'Progress Two' base, and scientists from the Peoples Republic of China also established a wintering base 'Zhong Shan'. There are now three bases in close proximity to each other in the Larsemann Hills.

TOPOGRAPHIC MAPPING

Mapping of the Larsemann Hills, as of the whole of Antarctica is technically difficult and costly due to its remoteness,the lack of aerial photography, the shortage of ground control and the logistic problems encountered in gaining access to the site.

The first map of the Larsemann Hills was published in 1946 by H.E. Hansen on behalf of the Norwegian Whalers Association. Part of a series of twelve charts it was plotted at 1:250 000 scale from oblique aerial reconnaissance photographs taken during the Lars Christensen 1936/37 expedition. The only other existing mapping in the area was a reconnaissance map published by the USSR in 1972 at a scale of 1:100 000.

On 19 February 1988 a cloud free overpass was made and imagery recorded by the SPOT 1 Satellite at the WRS reference point 278-495. This scene covered the Larsemann Hills and the adjoining areas of Prydz Bay. The imagery was scanned in multispectral four channel mode with 20m pixel resolution using the HRV2 sensor on the spacecraft.

The Australian Surveying and Land Information Group (AUSLIG) purchased the imagery from SPOT Image under its national distribution agreement later in 1988. The imagery was digitally enhanced using a DIPIX image analysis system, and scaled to the Doppler survey points established early in 1987. To provide an interim topographic product for use by ANARE scientists, a four colour image map at a scale of 1:25 000 was printed in a large format sheet, suitable for folding.

DIGITAL ENHANCEMENT OF IMAGERY

The multispectral digital data was first transferred from magnetic tape to the hard disk of the DIPIX ARIES III image analysis system at AUSLIG in Canberra. The total scene contained 3383 pixels and 2992 lines in three spectral bands. A subset of the total scene covering the Larsemann Hills area was extracted from the whole scene, representing an area 30 kilometres by 20 kilometres in extent.

The scene was rectified to WGS72 values for UTM Zone 43 using ground control points which could be identified in the image. These ground control points were then used to create a first order transformation file. This file was used in the resampling of the image to the UTM grid with a 10 x 10 metre pixel size. A cubic convolution resampler was used.

The image was digitally enhanced to make the rock areas more readily distinguishable from the snow/ice and sea-water, while retaining some detail in the inland snow/ice areas. A linear spectral stretch was determined and applied to the image. This was undertaken by creating colour look-up tables which were applied to each band of the image, creating a modified composite image which displayed the contrast enhanced topographic information.

The final image was written to magnetic tape by the DIPIX system. This tape was then read into the MICROBRIAN image system which in turn was used to format the image in a form suitable for output to a photographic film writer.

MERGING PHOTOGRAPHIC DATA WITH SATELLITE DATA

Further to the digital enhancement of the SPOT digital data an additional experiment was carried out to merge information from an aerial photograph into the SPOT digital data. A photograph of 'Law' Base taken from a helicopter on a 6 cm x 6 cm colour slide was merged with the spectral data obtained from the satellite. The slide was scanned with an EIKONIX digital scanner through red, green and minus blue clear filters. This produced three layers of information for merging to satellite data (three bands). The image was then registered to the satellite image and resampled to the same pixel size. An appropriate spectral stretch was applied to blend the slide sourced image to the satellite image. The two images were merged by tiling the green filtered image to Band 1, the red filtered image to Band 2 and the clear filtered image to Band 3. (Bands 1, 2 and 3 being the satellite data layers.)

The result indicated that image data of various resolutions could be integrated successfully but the result was considerably dependent on the resolution of the output device used.

CARTOGRAPHY

The computer enhanced digital image for the Larsemann Hills was written to colour negative film at the Australian Centre for Remote Sensing, using an Optronics film writer with a 50 micron aperture, at a scale of 1:200 000. A contact film positive was produced and subsequently colour separated into four colours on a SCITEX 350 Response colour scanner with an output resolution of 150 dots to the inch.

Major feature names were added using drop out techniques in dark areas for clarity. The layout was cartographicaly designed to produce a double-sided fold up map on a 720mm x 1036mm format. The front cover was illustrated with an identifying photograph of the Australian 'Law' Base and the back panel of the map carried a short history of the area. Copyright arrangements

were made with SPOT Image for use of the imagery. The image map was printed as an interim product to meet pressing needs of the client, the Australian Antarctic Division. The bulk map stock will be stored flat and untrimmed so that a line map can be printed on the reverse side when it is subsequently prepared. This line map will be stereoscopically plotted using SPOT panchromatic 10 metre imagery. Panchromatic, stereoscopic imagery was acquired by the SPOT satellite on 13 and 14 February 1989 and consists of a 21° degree left oblique and a 29° right oblique. It is planned to use established control by ground survey, using GPS techniques in the 1989/90 Antarctic summer.

CONCLUSION

Antarctic mapping by conventional techniques can be a very costly and time consuming process . The application of high resolution space imagery, both multi-spectral and stereoscopic panchromatic, offers considerable savings in cost and in production time. For different purposes, a range of custom combinations of coloured image map, enhanced image or a stereoplotted line map will be appropriate. In the case of the Larsemann Hills this data will also provide the basis for a Geographical Information System to provide a register of scientific information as an important component of an environmental management plan for this unique Antarctic rock oasis.

REFERENCES

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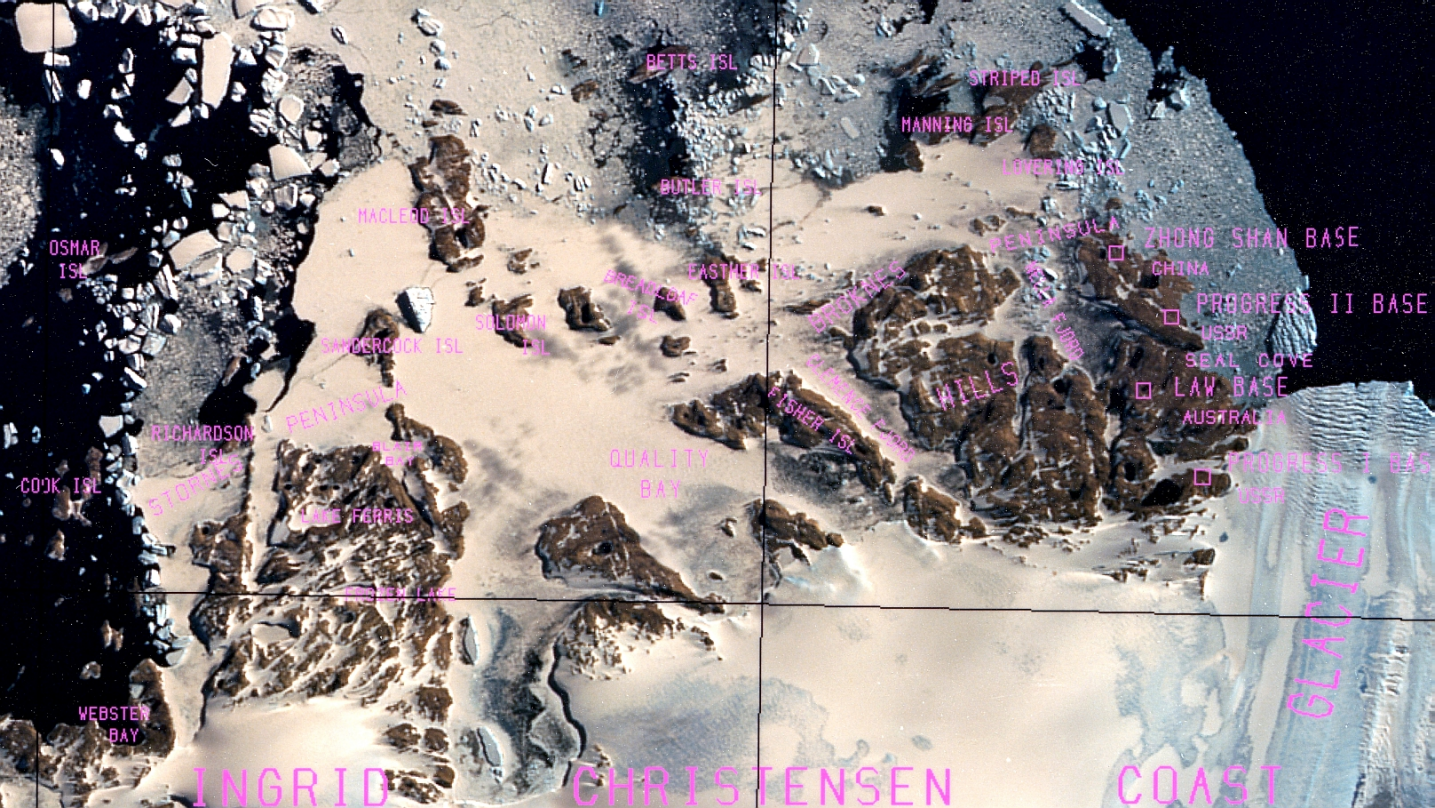
BETTS ISL
STRIPED ISL
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LOVERING ISL
BUTLER ISL
MACLEOD ISL
OSMAR ISL
PENINSULA
ZHONG SHAN BASE
CHINA
EASTMEN ISL
BROKNES
PROGRESS II BASE
USSR
SOLOMON ISL
SANDERCOCK ISL
SEAL COVE
WILLS
LAW BASE
AUSTRALIA
FISHER ISL
RICHARDSON ISL
PENINSULA
QUALITY BAY
PROGRESS I BAS
USSR
COOK ISL
LAKE FERRIS
WEBSTER BAY
GLACIER
INGRID CHRISTENSEN COAST