Mapping Surveys in the Prince Charles Mountains of Antarctica

by John Manning, 2012

1. Introduction

The Prince Charles Mountains (PCM) are a group of inland features in East Antarctica. They extend over 500 kilometres from 70 S to beyond 74 S latitude and 60 E to 70 E longitude. Morphologically they are usually divided into two regions North and South. The northern area comprises many ranges of jagged peaks and mountain glaciers, which drain into the floating Amery ice shelf. The southern PCM consist of a number of block mountain massifs, with large glaciers, which flow into the Lambert Glacier, which is bordered on its eastern flank by the 160 km wall of the Mawson Escarpment. The Lambert Glacier the world's largest which in turn feeds into the Amery Ice shelf. The most northerly rock exposures related to the morphology of PCM protrude above the polar ice cap as outliers at Depot Peak some 300 kilometres almost due south from the Mawson scientific base on the coast of Mac.Robertson Land. The first range of the Prince Charles Mountains lies out of sight another 150 kilometres further south.

The existence of the Prince Charles Mountain features was first detected on the Operation Highjump trimetrogon photography flown by the USN in the summer 1946/47. Being well inland the mountain features were not visible from the exploration ships or from coastal aircraft flights by the earlier explorers; Douglas Mawson in the BANZARE expeditions and the Norwegian Lars Christensen's whaling/exploring factory ships of the 1930s. Phillip Law as Director Antarctic Division gained access to Operation Highjump oblique photographs in 1953 to help select possible sites for the establishment of Mawson station. In the far distance inland on the trimetrogon oblique photography, he noticed a small dark outline. Following the establishment of the Mawson station in 1954 and coastal exploration to the east and west, a major southern exploratory journey was made in the summer to explore the feature seen on the photography.

2. The exploration era

The 1954 southern exploratory journey consisted of three men; Robert Dovers leader and surveyor; Bob Summers, medical doctor; and Bruce Stinear geologist. Departing

Mawson 13th December with one dog team and one wartime tracked weasel vehicle they ventured south into the unknown interior. Two weeks later they sighted a dramatic rock feature with four peaks on 24th December where Dovers observed an astrofix at the site (69 01 53S 64 33 47E). From the top of peak 4 of the Depot Peak mountain block he sighted five other small features some 70 kilometres to the south– later named the Stinear Nunataks. The following day they were able to drive the weasel and dog team to the top of peak 7 of the Stinear Nunataks and Dovers recorded in his report:

> A most interesting surprise awaited us here as soon as we topped the crest we saw a great range of mountains leading away to the southeast. Up to this time we had not the least suspicion of the existence of this range. It was a magnificent spectacle and a very fitting climax to the journey. (Dovers 1954)

At the Stinear Nunataks, Dovers observed two astrofixes : peak 7 (69 40 35 S, 64 41 36E) and peak X (69 42 10S and 64 26 51E) as a base line for mapping the features sighted to the south by theodolite intersection and returned to Mawson. It had been a dramatic journey and Dovers had become seriously ill with intestinal problems, which required much fortitude by all to return safely to Mawson on 7th January 1955.

The following year John Bechervaise and six companions began a major field journey on 14 November 1955, south from Mawson with two weasel tracked vehicles to the mountains sighted by Dovers. Using the route established the previous year they sighted the Prince Charles Mountains on 25 November and established a base and depot close to the mountains where a prominent feature was named Mt Bechervaise as a gateway marker to the Northern Prince Charles Mountains. Surveyor Bob Lacey observed an astrofix at the Southern Depot site (70 09 31S, 64 47 05E) and another near Mt Macklin (69 57 25S, 64 36 43E). After exploring the nearby mountains the return journey was made with only one weasel, the other had been abandoned, though its damaged engine was brought back. Mawson was reached on 7 December. Again the limits of men and equipment had been sorely tested without any possible back up support.

This depth of available support changed to a degree in 1956 when the ANARE 1956 wintering party included a RAAF flight of two pilots and support crew with a DHC2 Beaver aircraft and a rebuilt Auster 201 aircraft, which had been damaged at Mawson in 1954. This dramatically changed the exploration capability of the party and a

protective aircraft hangar was built at Mawson for sea ice landing operations. 1956 was an outstanding year for exploration with field survey and extensive aerial photography flown using a tri camera setup in the Beaver aircraft. The lighter Auster aircraft was used for support flights and for heighting the terrain using a radar altimeter. The general instructions of Phil Law in the 1956 ANARE Operations Manual were for:

> "The general survey of the PCM ... particular interest centres on the eastern wall of these mountains and the question of whether arms of the Amery Ice shelf extend as far as this."(1956 ANARE operations manual)

In April 1956 pilot John Seaton made a flight due south down the 63rd meridian deep inland to beyond latitude 72 south. (Wilson 1991, p40). This approached the southwest extent of the Prince Charles Mountains and in the distance sighted a massive mountain block of what was to be later named Mt Menzies. Other exploratory flights were made in the autumn to the northern edge of the Prince Charles Mountains. As surveyor Kirkby put it this was "mapping from scratch with only a blank sheet of paper", it was completely unknown territory

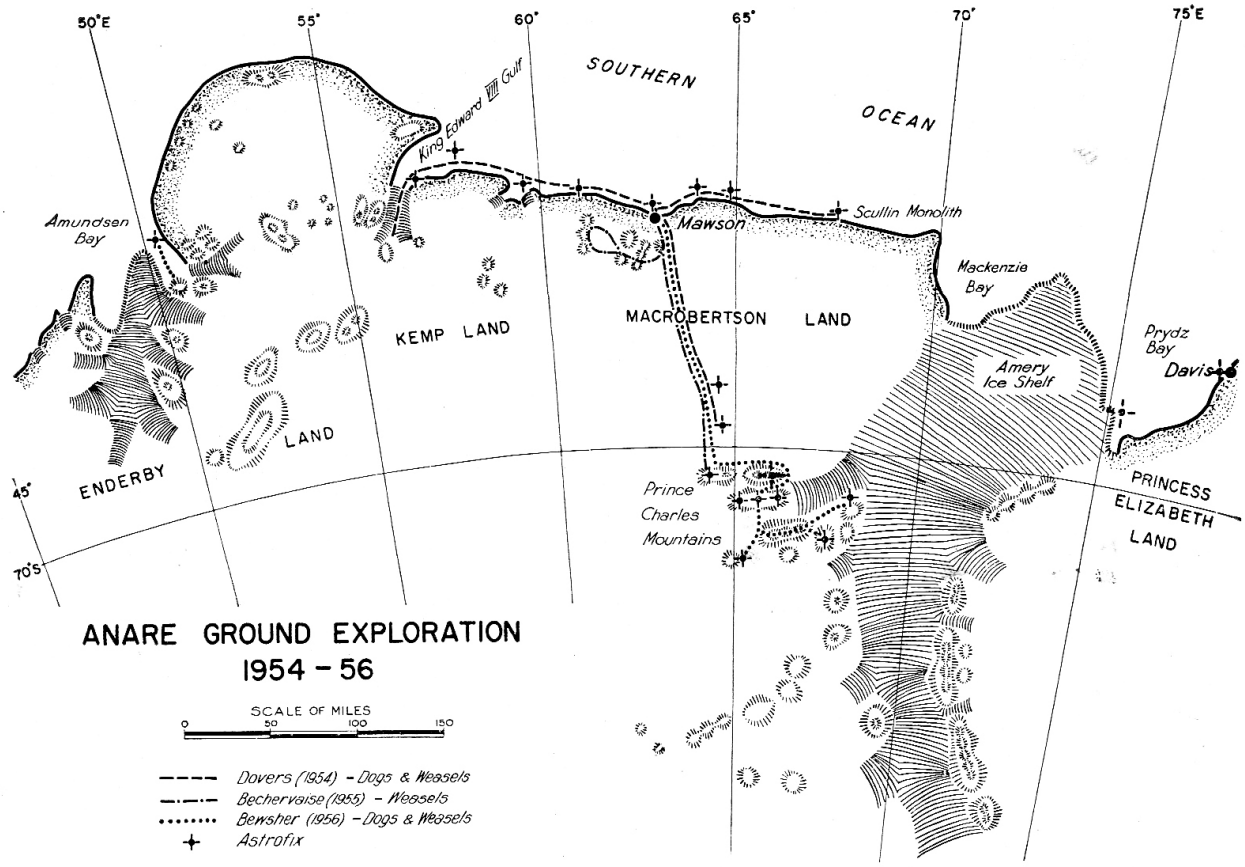

Figure 1 : Early survey exploration from Mawson (Law and Bechervaise 1957)

On 4th November an exploratory flight was made to the northern ranges of the Prince Charles Mountains to plan a summer ground traverse and a bumpy landing was made at a site close to Mt Jacklyn, 50 kilometres east from Mt Bechervaise. Eight supply flights were made to establish what was then called the 250-mile depot. With this supply depot in place a party of five left Mawson on 19th November with two weasels and one dogteam and reached the 1955 Southern Depot on 10 December along the previously established route. From that depot it took two days travel to reach the depot at Jacklyn. This 1956 party was led by Bill Bewsher from the Melbourne Mountaineering Club, it included Lyn Gardner mechanic, John Hollingshead radio operator, Peter Crohn geologist who had travelled the ground route to Mt Bechervaise when he wintered the previous year, and Syd Kirkby surveyor Leaving the Jacklyn depot they encountered difficult travel in unknown crevassed country (Bewsher 1988 and 1989). On 20th December it was decided that the country was too difficult for the weasels and Bewsher, Crohn and Kirkby set out with dog team and supplies for two weeks, traversing the Porthos range, the Scylla glacier and the northern part of the Charybdis glacier. They returned to the Weasel depot, ten days later on 30 December. A second dog-sledging trip led by Peter Crohn with Hollingshead replacing Bewsher was made across the Charybdis glacier to the edge of the Amery ice shelf and then looping back to the weasel depot. A third dog journey was arranged, which included some man hauling of stores from the Weasel depot to a new depot (the moraine depot) on 16th January, which the dog team reached the following day for resupply. Bewsher then changed over with Hollingshead to enable the dog team to progress through the Aramis range to its south western end and undertake an astrofix below Mt Bewsher and a round of survey photos from the summit of this virgin area (Kirkby 1991 and 1991a). The survey party then made their way back through their previous moraine depot and met the Weasel party at the 250-mile depot on 29th January eventually returning to Mawson on 10 February after eighty-four days in the field. This was a most productive exploratory survey trip undertaking astrofixes and geological survey, unravelling the glacial flows into the Amery ice shelf and reaching the shore of Beaver Lake. The work of the geologist and the surveyor was outstanding and astrofixes were observed at seven sites Jacklyn 70 15 39S 65 53 07 E, Mt Kirkby, 70° 25' 21S 65° 8' 21E, Mt Gardner 70 25 18S 65 51 03E, Mt McCarthy 70 25 52S 66 30 32E, Mt Loewe 70 31 16S 67 45 19E, Mt Hollingshead 79 49 59S 66 12 18E and Mt Bewsher 70 53 49S 65 27 58E. These provided reconnaissance ground control for long strips of tri met aerial photography flown by the Beaver aircraft by

Seaton and Leckie. The results from this party and the overall work of the 1956 party, particularly the aircrew, who also flew aerial photography over completely unknown terrain, were outstanding. A great example of this was the exploratory photographic flight was on the 28th November when John Seaton flew to the limits of aircraft endurance discovering the Lambert Glacier in a photographic run down its eastern extremity along the Mawson Escarpment to 74ºS before making a loop to the west towards Mt Menzies and returning to Mawson through the Jacklyn depot (Wilson 1991, p49-50). He sketched the terrain of the Lambert Glacier and the southern Prince Charles Mountains, which is shown in the 1:2 million map of the Prince Charles Mountains below in figure 2.

RAAF replaced their wintering Antarctic flight crew each year for the next four years and aerial photography and observation of astrofixes for reconnaissance mapping continued not only in the PCM but also broadly across the terrain accessible from Mawson and Davis stations. In 1957 a major over snow seismic traverse using D4 caterpillar tractors was made to the deep south 600 kilometres miles from Mawson as part of the IGY to establish a route to the deep inland. Led by geophysicist Keith Mather, further progress to the south was blocked by the southwest arc of the southern Prince Charles Mountains and an astrofix was taken near the end of the traverse at Goodspeed nunataks (72 57 03S, 66 32 30E). While the ground traverse took place surveyor Morrie Fisher with aircraft support observed astrofixes at Mount Stinear 73 04 06S. 66 32 38E), Mount Johnston, Fisher Massif (71 39 44S, 67 23 32E) and Beaver lake 70 49 59S, 68 13 12E where he noticed tidal motion of the surface ice on Beaver lake.

1958 also was a very successful year for exploration and mapping from Mawson with a focus on Enderby Land and major dog teams traverse from Amundsen Bay to Mawson. Surveyor Knuckey was very productive observing some sixteen astrofixes through the year, although only two of which were in the PCM. Wilson Bluff (74 16 40 S 66 56 10E) Clemence Massif (72 17 40S 68 30 00E), an additional astrofix was also observed at Jennings Lake on the eastern side of the Amery ice shelf, and another in the remote Grove Mountains (72 53 04S 74 53 48E).

Figure 2 : First map of the Prince Charles Mountains (Division of National Mapping 1957)

The geology and survey work for mapping during the next two years was directed mainly to towards Enderby Land from Mawson and only one ground astrofix was observed (by Syd Kirby, again wintering at Mawson), this was on the Lambert Glacier near the southern end of the Mawson Escarpment (73 33 11S 68 13 25E) in December 1960. In the spring a major tractor traverse with two D4s and a weasel vehicle was made generally along the old traverse route of 1957 where a base and a depot was established at Binders Nunatak that was then supplied by aircraft from Mawson. From that base a vehicle geological survey was made to the mountains to the east though crevassed dangerous country. Many photographic and radar altimetry flights were made in the DC3 throughout the year despite continuing engine problems, but following the loss of both aircraft in December 1960 RAAF withdrew their wintering Antarctic flight support. This had an impact on further work deep in the PCM, although a further geological exploration to the area was made in 1961 when Geologist Dave Trail, Dave Keyser and Jim Seavers drove a dogteam along the 1960 tractor train route to the depot at Binders base in the southern PCM for re-supply. From there they crossed the heavily crevassed Fisher Glacier and climbed to the summit of Mt Menzies, a major unsupported round trip of 1000 kilometres.

At this time the PCM region which extended from its northern outliers of Depot Peak to the southernmost astrofix at Wilson Bluff and the far out isolated Grove Mountains was positioned by sixteen astrofixes, a credit to the ANARE exploratory teams. These surveys were supported by widely separated trimetrogon photographic runs which enabling the main features to be roughly plotted from oblique photos and from ground panoramic photos and theodolite rays from the astrofix points. After each expedition the work of the year was transferred to base compilations at a scale of 1: 1 million and in some areas 1:100 000. Most of the features had been sighted and even very roughly positioned by sketch but it was a huge area and the loss of the aircraft marked a change in the further mapping in the PCM. The focus on ANARE exploration and scientific work over the next four years now moved to the glaciology investigations of the Amery Ice shelf by ground survey traverse teams. This was a major initiative in its own right and is not addressed in this paper.

3. The application of new geodetic technology

Globally in the early 1960s a new wave of surveying technology emerged followed micro radar developments being applied to distance measurement. Norway and South Africa cooperated in using the South African Tellurometer invention in Dronning Maud land during IGY in 1957. BAS trialed Tellurometers in 1959 on sub Antarctic islands whilst the USGS began distance-measuring traverses in Victoria Land in 1961. Australia also trialed the use of Tellurometers in 1962 with surveyor David Carstens measuring a coastal quadrilateral figure in the Framnes Mountains in the 61/62 Mawson changeover and surveyor Syd Kirkby measuring a similar one in the Windmill Islands in 62/63 at Wilkes. This distance measurement based technology had been applied widely to the rapid geodetic survey of Australia, and precision techniques and specification for second order surveys developed there were then applied in Antarctica. In 1964/65 a combined geological and survey of four field teams of two, supported from Mawson base and from the *Nella Dan* in King Edward Gulf, commenced a trial geodetic quality traverse west across Kemp Land connecting to the Tellurometer work in the Framnes mountains commenced by Carstens three years previously. Five new stations were established on features previously only positioned by astrofixes (Kirkby 1966). This project had helicopter and fixed wing support and used the *Nella Dan* as a mobile base for operations to reduce distance to be flown to the survey points. Whilst problems were encountered with the aircraft and the equipment, this application of the technology indicated the way ahead.

A further big step in technological application was made in 1965 when surveyor Max Corry who had participated in the Kemp Land survey, wintered at Mawson. His task was to carry the geodetic survey from the Framnes Mountains some 300 kilometres inland over the featureless ice plateau to the Depot Peak outlier nunataks of the PCM. This oversnow application had only been attempted once before in the Ross Ice Shelf by a German glaciology team in 1962 (Hoffman 1963). Corry used the autumn in 1965 to establish a fuel depot and undertake a route reconnaissance. The second order standard geodetic traverse was then completed the next spring with seventeen legs required over the moving ice cap (Corry 1966). This was a remarkable survey innovation and a significant breakthrough in technological application.

The following year surveyor John Quinert and the 1966 wintering team extended a new vehicle route further into the PCM from the 1955 southern depot, past Mt Bechervaise and established a new depot below Moore Pyramid. Surveyor Quinert extended Corry's Tellurometer traverse from Depot Peak through the Stinear Nunataks establishing a new terminal point on Mt Wishart, a small nunatak ringed by higher mountains in the central ranges. They left stores, fuel and a caravan at this Moore Pyramid depot. The modern geodetic survey line had now reached PCM proper, and the new techniques developed by Kirkby, Carstens and Corry were proving successful.

The ANARE 1967 year at Mawson saw consolidation of the coastal geodetic framework in the Framnes Mountains and on nearby islands and an oversnow geodetic traverse to the Gustav Bull Mountains and Scullin Monolith to the east. In the winter high precision astronomic observations were carried out at Bechervaise Island over a period of two months to establish an origin for the new geodetic network The Corry traverse to the inland mountains over the moving ice cap was then repeated to compensate for the ice movement at stations during the surveys.

4. The major PCM geodetic framework

The consolidation of survey work in the vicinity of Mawson base and the carriage of the geodetic traverses far inland triggered a new approach to regional surveys between the Bureau of Mineral Resources, Division of National Mapping and the Antarctic Division. It was no longer logistically feasible for wintering teams to be able to get to the work areas of the PCM and work effectively in the mountains using ground transport alone. 1968 also saw a new direction when an ambitious team of four wintered on the Amery Ice Shelf for glaciology studies. Led by Max Corry they undertook geodetic traverses and spirit levelling down the Amery ice shelf as far inland as Beaver Lake, and drilled an ice core deep into the ice shelf. During the establishment phase of the winter camp, surveyor Max Corry, aware of the successes and shortcomings of the 1964/65 Kemp Land survey and applying his experiences with the subsequent oversnow inland traverse, commenced a summer survey from the *Nella Dan* supported by three Hiller turbine helicopters. This resulted in a line of survey traverse stations from the Larsemann Hills westward along the Ingrid Christensen coast and down the eastern edge of the Amery Ice Shelf to the Reinbolt

Hills. 1968 also signalled the end of wintering of a surveyor for mapping at Mawson, and the major task for the winter party became the establishment of a depot of aircraft fuel and stores at the Moore Pyramid camp as a base for further PCM exploration and mapping.

The ensuing summer 1968/69 saw the *Nella Dan* deployed to pick up Corry's Amery party while establishing a fixed summer camp on the ice shelf for aircraft operation to support geodetic and geological work. Aircraft support was provided by a Turbo Beaver aircraft and turbine helicopters. From this base at Sandefjord Bay on the eastern edge of the Ice shelf, the hanging survey traverse established by Corry the previous summer, was extended in two directions –eastwards along the coast to Davis station and southwards down the eastern side of the Amery Ice Shelf across the Lambert Glacier and then through the PCM to occupy the terminal point of Quinert's 1966 traverse at Mt Wishart. A continuous geodetic quality traverse now extended from Davis to Mawson with a single traverse line through the Northern PCM and Tellurometer connections to Corry's survey work on the Amery ice shelf.

A new regional pattern of operations now emerged to extend the geodetic network widely over the features of the PCM. The 1969 winter party successfully replaced the supply of aviation fuel at Moore Pyramid and in the summer 1969/70 it was occupied as a summer aircraft operation base. But constant bad weather and focus on geological operations limited survey work to the occupation of just a few stations and little control for mapping was achieved. However the following summer 1970/71, despite the limitations of the base camp site being ringed by mountains, and local bad weather patterns, the geodetic framework was extended through the northern PCM across the Lambert glacier to the Mawson Escarpment. This survey was supported by a Pilatus Porter (a turbine short take off and landing fixed wing aircraft), flown by squadron leader Doug Leckie, and three Hughes 500 turbine helicopters. These were carried south on the *Nella Dan* to the vicinity of Mawson where a suitable ice floe was used on which to re-assemble the aircraft and refit the wings. With the backup of the fixed wing, personnel and equipment were ferried to Mawson using the helicopters. From Mawson the summer parties were flown into the unoccupied fuel depot previously established by the Mawson wintering party. Temporary polar pyramid tents were then established as an operational base to place parties in small tents in the mountains. Tellurometer and theodolite surveys were undertaken and extensive

geology investigations were made using helicopters during transit to the next survey site. The geological work was also supplemented by specific day sorties for detailed examination. With the good progress made through the northern mountains it was decided to move the main base camp to Mt Cresswell in the Southern PCM whilst Moore Pyramid remained as a staging station for aircraft to refuel enroute to the southern base. This required an escalation of the logistic support needed from the wintering teams to resupplying Moore Pyramid as well as establishing a new heavy vehicle route along the line of the old 1957 route and into the blue ice field under Mt Cresswell through heavily crevassed country. This saw an upgrade to more powerful D5 tractors as prime movers but the task was dangerous and only achieved with difficulty and was a tribute to the expertise of the men involved. For the next three summers intensive summer surveys were carried out through the southern PCM from the Cresswell base and fuel was delivered by the wintering teams each year. Geologists from BMR and survey teams from National Mapping established a geodetic network and a regional geological survey. In addition eleven glaciology sites far from the mountains were accurately positioned from the network and re-measured to determine input flow rates into the Amery drainage basin. Additionally the mapping task included fixing the position of the southernmost rock feature of the region, Komsomolskiy Peak, which had been reported beyond the southern PCM by Soviet Expeditions in 1957. The survey framework also included a geodetic traverse line to the outliers of the remote Grove Mountains east of the Mawson Escarpment. (Johnston et al 2002a). Vertical aerial photography was flown over most of the rock features using colour and black and white film for mapping and geological survey. This was achieved by flying the Pilatus porter aircraft at the maximum achievable altitude (approaching 20 000 ft). There was no loss of life in the surveys although surveyor Andrew Turk was injured when a helicopter crashed while attempting a landing on an unknown rock ridge at Burke Nunatak in 1974. In February 1974 the Cresswell camp was packed up for the last time and the focus of the intensive summer surveys moved to Enderby Land.

The advent of satellite positioning systems in the 1970s saw it’s the first application in the Enderby Land surveys in 1976 using Transit Doppler techniques, but it was not until 1988 that GPS was trialed in Antarctica when Wild WM101 and single frequency Magnavox MX 4000 receivers were used for aircraft navigation during ice depth sounding flights in the PCM. Precise dual frequency GPS units were then employed in

1989 when Australia, on behalf of SCAR, coordinated a feasibility trial of geodetic GPS techniques on the Antarctic continent (Govind et al 1990). This produced the first substantial GPS baselines between Australia and Antarctica (Morgan and Tiesler 1991) and sixteen GPS positions were subsequently observed on rock sites to provide additional local control for SPOT and Landsat space imagery in the PCM region (Manning et al 1990). The use of high precision GPS to monitor movements of the rock feature was taken much further in the outstanding work was done by Gary Johnstone from Geosciences Australia and Paul Tregonning from the School of Earth Sciences, Australian National University which saw the installation of permanent GPS equipment at Cresswell Wilson Bluff Mawson Escarpment south and Komsomolskiy peak and Grove Mountains for geophysical research. (Johnstone et al 2002), (Tregoning et al 1990 and 2000)

5. Australian Antarctic mapping program

The Australian Antarctic Division held original responsibility for Antarctic mapping but this was transferred to the Division in 1958 when Bruce Lambert, Director of National Mapping and member of the Antarctic Executive Planning Committee, accepted responsibility for Antarctic survey and mapping. He became the chairman of the SCAR Working Group on Geodesy and Cartography, which Australia then chaired until 2004 when SCAR was reorganized. Antarctic Division employed the early wintering surveyors, but from 1958 they were employed by National Mapping when an Antarctic Mapping Branch was established in the Rialto building under Commander D'Arcy Thomas (Tommy) Gale. Exploration of the whole Australian Antarctic Territory was addressed and provisional maps were compiled and published along the coastline of the AAT and coastal mountain regions. But while provisional maps of some areas of the PCM had been produced in 1958 the massive area of the Prince Charles posed technical and severe resources problems in order to produce fully contoured topographic maps.

Geodetic survey had established a strong positional framework throughout the Prince Charles Mountains and most rock features were covered by block aerial photography, but the conversion of this amount of material to printed maps would require a massive amount of dedicated resources. At this time the restrictions on the resources available for fundamental mapping of Australia forced the Division of National Mapping to reduce, rather than increase, its Antarctic mapping compilation focus in

the 1980s. This resulted in the transfer of responsibility for mapping to the Antarctic Division in 1988 together with a sizeable increase in budget for mapping to resource this work. Under a user pays arrangement payment for this work was initially tied to the Division of National Mapping for two years. A new era of publications began with the use of new applied technology with satellite imagery and GPS precise positioning. National Mapping and its successors (AUSLIG and Geosciences Australia) retained the geophysical and geodetic responsibilities.

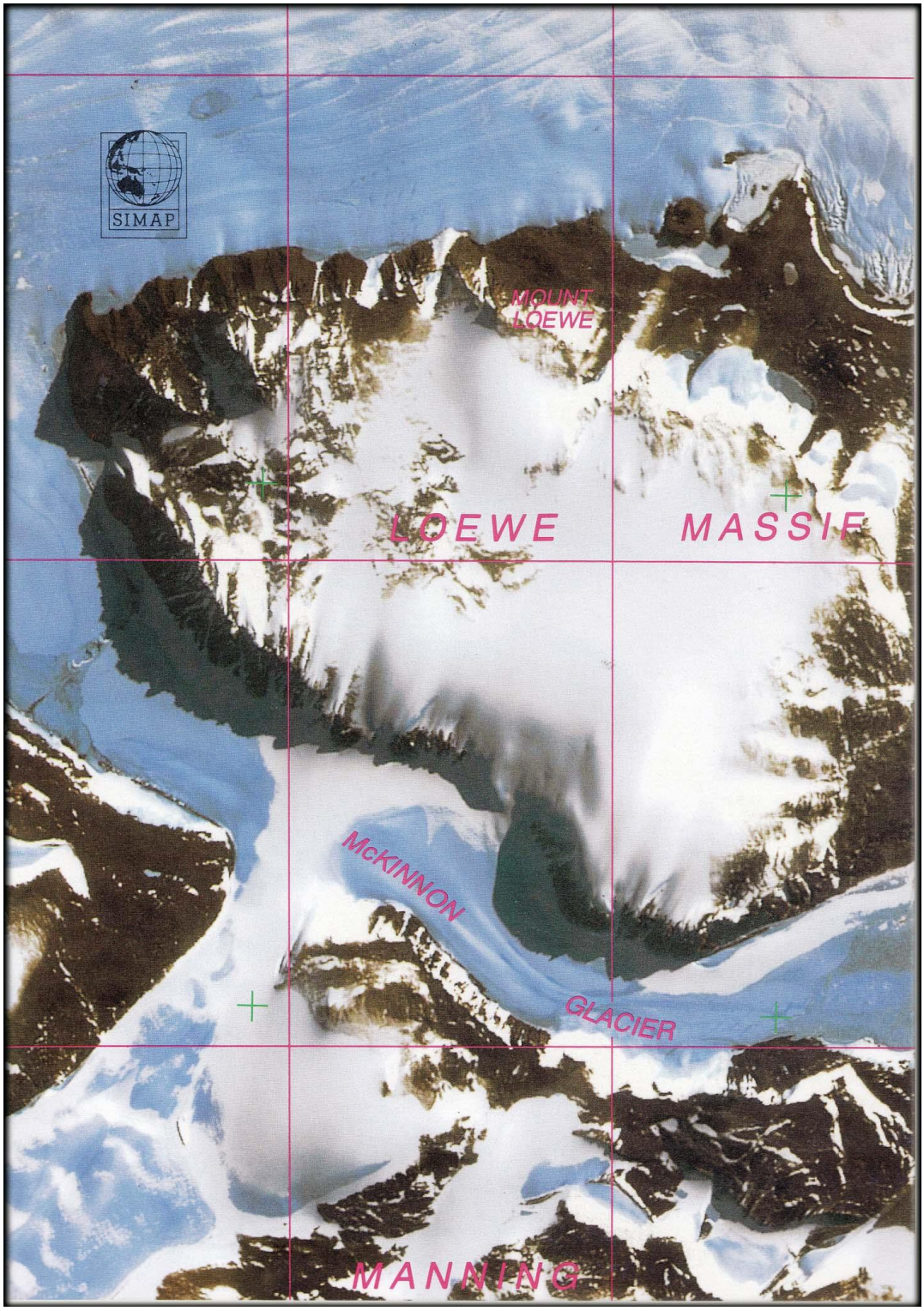

Figure 3 : Section of the 1:100 000 Beaver Lake Satellite Image Map

Satellite imagery was the basis for a new series of satellite maps of the coastal and inland areas of the PCM. Notable advances were made in printing and computer enhancement of imagery technology by ACRES such as shown in the Beaver Lake map (Manning 1990) and the Mawson Escarpment maps published at a scale of 1:100 000. The Beaver Lake sheet was taken further with printing of a contoured line map of the reverse side using photogrammetric techniques and incorporating information from Soviet maps published earlier. Although the scientific research focus has moved from resource mapping to environmental mapping and climate change such as the dynamics of the Amery ice shelf. The age of satellite imagery now enables digital display of imagery such as can be viewed through Google earth or high-resolution commercial satellites. Viewing the PCM area in this way is a spectacular example of modern mapping technology, which can be integrated with information from other disciplines.

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Surveyors who worked in the Prince Charles Mountains From 1954 to 1974

1. Astro fix period 1954-1960

1954 Dovers
1955 Lacey
1956 and 1960 Kirkby
1957 Fisher
1958 Knuckey
1959 Armstrong

2. Geodetic framework 1965-1975

1965 Corry (coastal mountains to depot peak oversnow traverse)
1966 Quinert (depot peak outlier to Mt Wishart NPCM)
1967 Manning (coastal mountains to depot peak oversnow traverse)
67/68 Rubeli, Corry, Hamm (coastal traverse)
68/69 Manning, Fox, Rubeli
69/70 Rubeli, Hutchison, Burke
70/71 Manning, Edwards, Ely
71/72 Manning, Burke, Greenall, Skinner
72/73 Manning, Cowling, Helmore
73/74 Manning, Turk, Mulholland, Wood