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AERIAL THERMAL INFRARED SURVEY, RABAUL AREA, PAPUA NEW GUINEA, 1973

by

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SUMMARY

An airborne thermal infrared survey of the Rabaul caldera was carried out in May 1973 to try to detect previously unknown hot spots, both on land and within the waters of the harbour. All imagery was acquired before sunrise at wavelength intervals of 3.5-5.5 micrometres and 8-14 micrometers (μm). Both sets of imagery showed the location and extent of all known thermal areas, but no new areas were discovered. Because of its greater contrast, the longer wavelength record displayed the details of the terrain better than the shorter wavelength record. An airborne radiometer provided general information on the temperatures of sea and land, its broad field of view (2 degrees) combined with its response time (50 millisec) resulted in averaging of the surface temperatures of the small thermal areas.

INTRODUCTION

The town of Rabaul, on the northeastern end of the island of New Britain, New Guinea, is built on the shores of Simpson Harbour, within a breached volcanic caldera.

The latitude is 4 degrees south, and the climate humid tropical. The northwest monsoon season generally begins in December and continues to March, followed by a period of relatively calm weather until the south-east season starts in June. The average annual rainfall is approximately 2000 mm.

Two important volcanic centres in the caldera have been active in recent times. Vulcan erupted in 1937 with simultaneous minor activity at Tavurvur, and Tavurvur erupted again between 1941 and 1943, (Taylor, 1973). A volcanological observatory had been established on the caldera rim in 1939, and a program of volcanic surveillance begun (Fisher, 1940). During the war the observatory was destroyed but was rebuilt in 1952, and since then the surveillance instrumentation has been undergoing development and is now of a high standard (Taylor, 1973). The temperatures of vapours from fumaroles and water from thermal springs in the vicinity of Tavurvur are recorded each week (Table 2). The thermal infrared survey was undertaken to find out whether previously unknown hot spots could be detected, particularly springs that might issue from the sea-bed within Simpson Harbour and the shallower waters of Blanche Bay.

DETAILS OF SURVEY

The Bureau of Mineral Resources let a contract to Qasco Air Surveys to survey the area with a Daedalus optical-mechanical infrared line scanner owned by the University of Newcastle. The scanner is capable of recording the output from either a 3.5-5.5 μm (Indium-antimonide) or 8-14 μm (Mercury-cadmium-telluride) detector on magnetic tape. The information on the tape was later recorded on film by a tape-to-film conversion unit at the University of Newcastle.

The versatility of the scanner provided an opportunity to compare the effectiveness of the 8-14 μm band with that of the 3.5-5.5 μm band in the particular environmental conditions, in which ground and sea temperatures were in the range 20-30^{o}C (293-303^{o}K) and the temperatures of some fumaroles ranged up to 99^{o}C (372^{o}K). Theoretically the 8-14 μm band should be superior because a black body at ordinary temperatures (300^{o}K) emits its maximum radiant power at a wavelength of 9.7 μm, whereas in the 3.5-5.5 μm band the temperature at which a black body emits its maximum radiant power is much higher, about $600^{o}K(327^{o}C)$ (Wolfe, 1965); therefore this band can be expected to be less suitable than the longer wavelength interval for studying materials at ordinary temperatures. Although over an extended wavelength interval real bodies behave differently from black bodies, most natural materials approximate the behaviour of black bodies, particularly in the 10.5-12.5 μm interval (Hovis, 1970; Moxham, 1971). Also Moxham (op. cit., p.116) points out that at ordinary temperatures the radiance (radiant power per unit solid angle per unit projected area) in the 8-14 μm band is about an order of magnitude greater than that in the 2-6 μm interval, although the change in radiance for a given temperature change is much greater in the shorter wavelength band. He goes on to state 'for overall volcanological work, where interest may extend over a wide range of temperatures, the 8-14 μm region is probably more suitable ....'

Despite the theoretical advantage of this interval for the Rabaul work, it was decided that valuable experience would be gained by using both detectors.

The preferred imaging time is pre-dawn, because then the daily heating effect of the sun is at a minimum, and any thermal anomalies will show up most strongly against the background.

The survey was carried out during the period May 3 to May 11, 1973, but flying had to be limited to the time of day after first light and before sunrise because of restrictions in night flying in the vicinity of Rabaul (Lakunai) Airport; consequently daily imaging time was approximately 30 minutes.

The main area of survey is a rectangle 10 km by 15 km including Rabaul, Simpson Harbour, Blanche Bay and adjacent land, and a supplementary coastal strip 21 km in length to the north of Rabaul, extending from Talili Bay in the west to Nordup in the east (see map, Figure 1). The selection of the flying altitude is usually a matter of compromise between the requirement of good resolution which demands a low altitude, and economy of operation which demands broad coverage and therefore a high altitude. In the Rabaul area the relief of the terrain is an additional problem; e.g. the northeast slope of the Mother rises from sea level to an altitude of 673 m in a distance of just over 1 km. The rectangular area was flown at 914 m (3000 ft) to achieve sufficient terrain clearance, and coastal runs at 731 m (2400 ft). The thermal resolution of the detectors is $0.3^{o}C$, (Prof C.D. Ellyett, pers. comm.) with an instantaneous field of view of 2.5 milliradians; i.e. for an altitude of 914 m (3000 ft) the detectors view a square of 914 x .0025 m = 2.28 m (7.5 ft) on a side. To reduce electronic noise and thus increase sensitivity, the detectors are cooled to 77°K with liquid nitrogen.

The scanner was fitted with a roll stabilizer (type DFI 252) that provides electronic compensation for aircraft roll to the scanner imagery by reference to a gyroscope.

Other equipment included a Barnes PRT 5 airborne radiometer that records surface temperatures with a specified accuracy of ± 0.5°C on a strip chart. The radiometer was attached to the port side of the aircraft near the nose, and directed vertically downward. It has a field of view of 2 degrees i.e. from an altitude of 914 m (3000 ft) it looks at a circle 32 m (105 ft) in diameter. During daylight hours the location of the radiometer trace can be determined by reference to photographs taken by a 35 mm motorized Nikon tracking camera equipped with a 28 mm f.2.8 lens; each time the intervalometer fires, a pulse is recorded on the side of the radiometer strip chart. During the first run each day there was usually insufficient light to expose the film, and the tracking camera photo centre points seem to have been located on the imagery by finding two points at which marked temperature changes occur, e.g. where the ground track crosses the coast, and scaling between them. It would improve the accuracy of locating these points if in future surveys the firing of the intervalometer made a mark on the scanner record as well as on the radiometer chart. The reading on the chart is calibrated before and after flight by presenting to the radiometer aperture a black body at a known temperature. The construction of the black body is illustrated below. It consists of a metal cylinder that can be filled with water through a hole on the side which also can house an accurate mercury-in-glass thermometer; within the cylinder and integral with it near its top is a cone, the outside of which is in contact with the water in the cylinder; the inside of the cone, which the radiometer 'sees', is blackened. In use the cylinder is a push fit on to the body of the radiometer.

Navigation

Because flying took place after first light, navigation was by visual reference to ground features, and the coastlines in the area made this a relatively simple task. The aircraft, an Aero Commander 680 F, was fitted with a Decca Doppler navigation system, but this did not provide useful information on runs partly over land and partly over (calm) water, a state of affairs that applied to most of the survey area. When the aircraft flew over the water, which was always calm in the early morning, the Doppler readings of ground speed and heading ceased to be accurate because of the lack of adequate reflections of signal from the smooth water surface.

Because of the need for up to date aerial photography, which by comparison with the imagery enables details of the latter to be related precisely to ground features, complete vertical photographic coverage of the caldera was obtained at 1:15 000 scale on MS Ektachrome film with an RC 8 camera between 0830 and 1015 hrs on May 5, and between 0800 and 0940 hrs on May 6; during these intervals the sun's elevation ranged from somewhat less than 30 to somewhat more than 50 degrees.

RESULTS

General

All the imagery was acquired after first light and before sunrise during a period of eight days; the actual times are shown in Table 1. The grey tones of the imagery (Figs 2 and 3) give an indication of relative temperature of the terrain. The hotter areas are light toned and the cooler areas relatively dark.

8-14 μm band (Fig. 2)

The most noticeable features of the imagery are light and dark bands at right angles to the flight lines, which are caused by an instrumental effect due to amplification of the detector output practically to the maximum to extract as much information as possible on temperature variations of the water surface (Prof C. Ellyett, pers. comm.).

Neglecting these it can be seen that the sea is generally warmer than the land at this time of day.

However at several points along the coast of Simpson Harbour and Blanche Bay darker plumes can be observed; these are considered to be caused by cooler fresh water entering the sea. On the west side of Simpson Harbour, large plumes visible in the vicinity of Malaguna 3, Rapolo and in the small bay south of Vulcan could be due to surface run off from the comparatively large catchment areas behind these villages, but because of the porous nature of many of the volcanic rocks in the area, allowing the water to penetrate, they are more likely to be due to groundwater run off (Meinzer, 1923). Another large cool plume is visible in Runs 6 and 7 about 1 km east of Davaon trig point, off the southern shore of Karavia Bay; these runs were flown on the morning of May 7. Smaller plumes issue from the shore in the town area. Thirty three points (8 mm) of rain fell at Rabaul airstrip in the 24 hours before imaging began, but no rain was recorded at the airstrip during the entire survey (Table 4). The imagery of Runs 8 and 9 was acquired four days later, on the morning of May 7, and cool water outflow from the same localities can be observed on Run 10 acquired on May 11.

Bright areas within the water, principally in Matupi Harbour, are caused by hot water from thermal springs. The main activity is at the head of Matupi Harbour, with other hot zones at the southeast end of the airstrip, and west of Tavurvur; the water in Sulphur Creek is slightly warmer than the harbour water, and north of Vulcan Crater a small body of water isolated from the harbour by a narrow sand bar is also warmer than the harbour water.

On the land Rabalankaia is outlined by concentric bright rings (R.4A) that can be seen on the aerial photographs Run E/8396-7 to correspond with areas of bare ground on the crater floor and walls. It is concluded that the bright returns on the imagery are produced by warm ground. Similarly, small areas of bare ground between Rabalankaia and Matupi Harbour show as hot spots on the imagery.

The bright, rather complicated pattern at Tavurvur corresponds in part to bare ground, but exceptions are dark tones bare areas that image cool, for example the northeast slope and the upper southwest flank. Light tones areas on the lower southwest flank are warm in only a few places. Also imaging cool are the floors of the four individual craters within the main crater rim, and the floor of one small parasitic cone on the southwest flank of Tavurvur. Figure 4 gives the location of all thermal areas detected in the Matupi Harbour area by infrared imaging in the 8-14 µm band. Details of the imagery were plotted onto aerial photograph overlays, using a 'zoom transfer scope' which enabled the different scales to be quickly matched and distortions in the imagery eliminated.

All bitumen roads are warm in relation to their surroundings, and within the town area, tennis courts, probably sealed with bitumen, show up as relatively hot (R6; tracking camera photo 25). A point of interest in this area is that two concrete cricket pitches, can just be discerned against the cooler background of the playing fields.

The north coastal runs 15 to 18 show obvious flows of cool water into Talili Bay near Ratung and Pilapila, though there are other small flows in many places.

3.5-5.5 um band (Fig. 3)

In general the contrast is less in this band than in the 8-14 µm interval, and as a result details of the terrain are less apparent. The obvious features of the imagery are the dark zones along one side of each strip; strips 1 to 10 were flown from south to north, but 15 to 18 were flown round the coastline from west to east, and it can be seen that the dark zone remains on the starboard side of each strip irrespective of aircraft heading; it is concluded that the dark zones are caused by some instrumental factor.

Dark plumes indicating cooler water can be observed in the vicinity of Malaguna 3 and Rapolo on run 10, along the coast south of Vulcan on Runs 8 and 9, and east of Davaon trig. point in Karavia Bay on Run 6. Run 7 is very low in contrast in this area, and the indications of cooler water are barely discernible. Runs 8 and 9 were flown on May 10, a week after the rain recorded at Rabaul, and three days after the longer wavelength imagery; the size of the plumes is comparable in both sets of imagery, and this is regarded as support for the idea that the origin of the cool water is groundwater runoff rather than surface runoff. The north coastal runs, 15 to 18, are of little use for detecting water outflow from the coast because of very low contrast; small flows of cooler water entering Talili Bay can be seen on Run 15.

All the 'hot spots' visible on the long wavelength record can be seen on the 3.5-5.5 µm imagery, but on the latter the details of the background are less well shown because of the lack of contrast.

Radiometer

The approximate scale of the imagery in the central part of the strips (Figs 5 & 6) is 1:38 000, i.e. 1 mm on the imagery is equivalent to 38 m on the ground. The field view of the radiometer is 2 degrees (.0349 radians), and thus at any instant from the operating altitude of 914 m, the instrument will integrate the temperatures over an area of 914 x .0349 = 32 m, i.e. over an area of about 1 mm in diameter on the imagery. It is evident, however, that the radiometer traces show less variation in temperature than one would expect from the tonal variations on the imagery of the same area. For example on Run 3A, 8-14 µm band (Fig. 5), over Tavurvur the radiometer records only three peaks, whereas the imagery suggests more variation; also the maximum temperature recorded by the radiometer is only just above that of the sea, whereas the brightness of the imagery suggests that the temperature should be considerably greater. It is concluded that the averaging effect on the record is due to the broad instantaneous field of view of the instrument combined with the effective elongation of this field of view in the direction of the ground track because of the response time of the radiometer (50 millisec). At a ground speed of 150 knots (280 km/hr) the aircraft moves nearly 4 metres in this time.

On Run 4A, 8-14 μm band, the radiometer detected thermal activity close to and on the northern shoreline of Matupi Harbour (Fig. 6) which also imaged brightly in both infrared bands. The radiometer detected thermal areas close to points 29, 33 and 34 (Fig. 9) whose temperatures, measured the day before the run was flown, were 90°C, 72°C and 74°C respectively. As these temperatures are not surface temperatures the actual temperatures that could be detected by the radiometer would be lower, though probably not as low as the maximum recorded by this instrument.

Run 3A in the 8-14 um band did not pass over any temperature measuring points but it did pass over several brightly imaging areas in the northern craters and slopes of Tavurvur (Fig. 5). Temperatures from points in Tavurvur craters (pts. 1-11) ranged from 89°C to 99°C when measured the day before run 3A was flown. Temperatures of fumaroles in the areas passed over by the radiometer would probably fall within this range but as these temperatures were measured by inserting a thermometer into the throat of the fumarole, actual surface temperatures which could be detected by the radiometer would be lower. However, it seems unlikely that surface temperatures would be as low as the maximum of 27.5°C registered by the radiometer. The tone of infrared imagery in that area compared with the tone of the sea on the northern and southern sections of run 3A is much brighter. The radiometer recorded the temperature of the sea in those areas as 27°C whereas its maximum over the brightest section of imagery on Tavurvur was only 0.5°C higher. As the radiometer was about 2400 ft (731 m) above Tavurvur craters, the area which it sensed had a minimum diameter of 25 m. It is unlikely therefore that it passed over any thermally homogeneous areas of that size but instead passed over smaller fumarole fields surrounded by cooler ground. It therefore probably averaged out the infrared radiation received from the small patches of fumaroles and surrounding areas of cooler ground to give the recorded maximum temperature of 27.5°C.

The complete radiometer records are shown in Figures 7 and 8.

Known thermal activity

Known thermal activity within the Rabaul caldera is confined to mild fumarolic emission in the craters and on the slopes of Rabalankaia and Tavurvur. Thermal waters seep into the bay mostly from areas below the high-tide mark along the shoreline of Matupi Harbour, the northern shoreline of Vulcan and in Sulphur Creek.

Weekly temperature checks are made of these thermal areas. Table 2 gives temperatures recorded in May, 1973, during the time of the infrared survey, from the various points in the caldera (Fig. 9).

Temperatures of the fumaroles have remained generally steady over the past 23 years since regular measurements were initiated after the war, and have rarely risen much above 100°C. Thermographs of fumarolic temperatures show no diurnal variation in temperature except for one small fumarole (4A) in Tavurvur crater which exhibited a regular rise and fall of up to 37°C over a twelve hour period ... a phenomenon which may be related to tidal rhythms. Heavy rainfall can produce sharp falls in fumarolic temperatures but recovery of temperatures to original levels occurs within several hours of cessation of rainfall. This factor did not affect imaging of fumarolic areas as the weather in the area was fine for at least 48 hours before imaging commenced (Table 4).

Temperatures taken along the shoreline of Tavurvur (pts. 17A, B), Vulcan (pts. 22-24), Sulphur Creek (pts. 51-55), and along the northern shoreline of Matupi Harbour (pts. 29-45, 36-40, 57-60) fluctuate widely depending on tidal conditions. Latter (1966) considers that the amount of recent rainfall and the consequent height of the water table also influences temperatures. All these points, except point 33, lie below the high-tide mark and therefore may be expected to have temperatures lower than inland points. Infrared imaging of these points was done when the tide was near the high-tide mark and falling, and therefore most of these points were under water (Table 3). As the infrared sensor records radiation emitted from the water's surface, actual temperatures at the surface would be several degrees lower than those shown in Table 2. Thermal activity at htthe sites is usually produced by warm to hot mineralized waters seeping through sand accompanied at some points at the northern end of Matupi Harbour, by gas ebullition.

Thermal areas along the north coast of Vulcan (23, 24) and along the coast immediately to the south of Tavurvur do not show up on the infrared imagery. Thermal springs in these areas have a comparatively small flow and relatively low temperature, and it is concluded that the sea masked the temperature effects.

Thermal activity contributes to the slightly brighter image of the small body of water north of Vulcan, as point 22 on its western edge recorded temperatures of

$44^{\circ}C$ three days before imaging in the 8-14 μm band and $40^{\circ}C$ one day after imaging in the 3.5-5.5 μm band.

CONCLUSIONS

The thermal infrared scanner successfully mapped the location and extent of most of the known thermal areas with the exception of a few springs below high water level, and it is concluded that there are no other major 'hot spots' within the surveyed area. Of the two infrared records, the 8-14 μm imagery is preferred for this sort of general volcanological work, because of its better contrast, although had only the 3.5-5.5 μm detector been available the mapping of thermal areas could still have been satisfactorily achieved.

The radiometer contributed little useful information to the study of the thermal areas; in the writers' opinion the use of a radiometer of this type in similar aerial surveys in future would be worthwhile only in situations in which the thermal areas are larger than the instantaneous field of view of the instrument at the operational altitude. Small or patchy fumarolic areas commonly found on slopes and in craters of volcanoes would probably not be suitable, but the temperature of large areas of warm surface water produced by subaqueous thermal activity could probably be accurately measured.

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TABLE 1

TIMES OF SURVEY

3.5-5.5 μm

Date	Run	Time	Air speed	Altitude
May 8	15	0530-0531)	140 knots	2400 feet above sea level
	16	0533-0535)	"	"
	17	0536-0539)	145 "	
	18	0541-0542	"	
	1	0546-0550	"	3000 "
	2	0555-0559	"	"
	10	0605-0609	"	"
9	4	0528-0532	155 "	3000 "
	5	0537-0541	150 "	"
	6	0555-0559	"	"
10	7	0527-0531	155 "	3000 "
	8	0540-0544	"	"
	9	0550-0554	"	"
	3	0600-0604	160 "	"
	3A	0609-0611	"	"

8-14 μm

Date	Run	Time	Air speed	Altitude
May 4	15	0525-0526	140 "	2400 "
	16	0527-0530	"	"
	17	0531-0533	"	"
	18	0535-0536	"	"
	1	0541-0545	145 "	3000 "
5	2	0525-0529	145 "	3000 "
	3	0535-0540	150 "	"
	4	0546-0550	"	"
	5	0556-0601	"	"
7	6	0526-0530	145 "	3000 "
	7	0539-0543	150 "	"
	8	0550-0553	"	"
	9	0559-0603	"	"

TABLE 1 (contd.)

Date	Run	Time	Air speed	Altitude
May 11	3A	0523-0524	150 knots	3000 feet above sea level
	10	0539-0543	"	"
	4A	0547-0549	145 "	"

TABLE 2

GROUND TEMPERATURES OF THERMAL AREAS, RABAUL

Point		27/4/73	4/5/73	11/5/73	18/5/73
Tavurvur	1	99	99	99	99
	2	99	99	99	99
	3	99	99	99	96
	4A	89	89	97	95
	4C	99	99	99	97
	5	98	99	99	99
	6	99	99	99	99
	7	99	99	99	99
	8	97	89	87	85
	9	99	89	90	93
	10	94	90	89	93
	11	98	91	91	92
	14	99	99	99	99
	15	99	99	99	99
	16	99	99	99	99
	17A	75	68	69	67
	17B	75	75	75	75
	18	99	99	99	98
Vulcan	22	45	44	40	40
	23	56	53	40	62
	24	57	54	-	47
Rapindik	29	89	90	91	91
	30	72	76	80	88
	31	83	84	85	83
	32	74	77	81	82
	33	68	72	75	67
	34	74	74	75	69
	35	99	98	99	99
	36	51	65	55	65
	37	63	65	66	65
	39	53	-	46	49
	40	61	66	50	62

TABLE 2 (contd.)

Point		25/4/73	2/5/73	9/5/73	16/5/73
Rapindik	57	54	50	52	58
	58	48	49	42	47
	59	57	59	51	57
	60	55	55	51	51
Sulphur Ck	51	42	40	34	47
	52	58	50	46	48
	54	49	50	45	49
	55	45	38	35	38
Rabalanakaia	41	99	99	99	98
	42	99	99	99	99
	43	99	99	99	99
	44	99	99	96	99
	45	99	99	99	99
	46	99	99	99	99
	47	99	99	99	99
	48	99	99	99	99
	49	96	97	89	97
	50	84	89	87	86
	56	99	96	96	95

TABLE 3

TIMES AND HEIGHTS OF HIGH AND LOW WATERS AT RABAUL,
MAY 4-11, 1973,
extracted from Australian National Tide Tables, 1973.

Date	Local Time	Tide heights in metres
May 4	0306	1.7
	1207	0.8
5	0326	1.7
	1256	0.8
6	0349	1.7
	1349	0.8
7	0411	1.7
	1551	0.9
8	0431	1.6
	1811	0.9
9	0448	1.6
	1859	1.0
10	0457	1.5
	1928	1.0
11	0428	1.4
	1240	1.1
	1428	1.1
	1935	1.1

TABLE 4

WEATHER CONDITIONS AT RABAUL AIRSTRIP DURING INFRARED IMAGING RUNS, extracted from Meteorological Bureau records

Date	Run Nos. and time	General weather description during run times	Rainfall during 0500-0600 hrs	Rainfall previous 24 hrs to 0500 hrs	Wind Speeds and Direction 0500-0600 hrs	Relative Humidity 0500-0600 hrs
May 4	15-18, 1, (8-14 μm) 0525-0545 hrs	Fine	0	33 pts	calm	0500 hrs 98% 0600 hrs 98%
May 5	2-5, (8-14 μm) 0525-0556 hrs	Fine	0	0	0500 hrs 2 knots at 100° true; 0600 hrs - calm	0500 hrs 82% 0600 hrs 85%
May 7	6-9 (8-14 μm) 0526-0603 hrs	Fine with some smoke haze	0	0	calm	0500 hrs 100% 0600 hrs 100%
May 8	1,2,10, 15-18 (3.5-5.5 μm) 0531-0609 hrs	Fine with some smoke haze	0	0	calm	0500 hrs 100% 0600 hrs 100%
May 9	4,5,6, (3.5-5.5 μm) 0528-0559 hrs	Fine with some haze	0	0	calm	0500 hrs 100% 0600 hrs 100%
May 10	7,8,9,3,3A (3.5-5.5 μm) 0527-0611 hrs	Fine	0	0	calm	0500 hrs 94% 0600 hrs 94%
May 11	3a,4a,10 (8-14 μm) 0523-0549	Fine with shallow fog patches	0	0	calm	0500 hrs 100% 0600 hrs 100%

TABLE 5

TEMPERATURE OBSERVATIONS

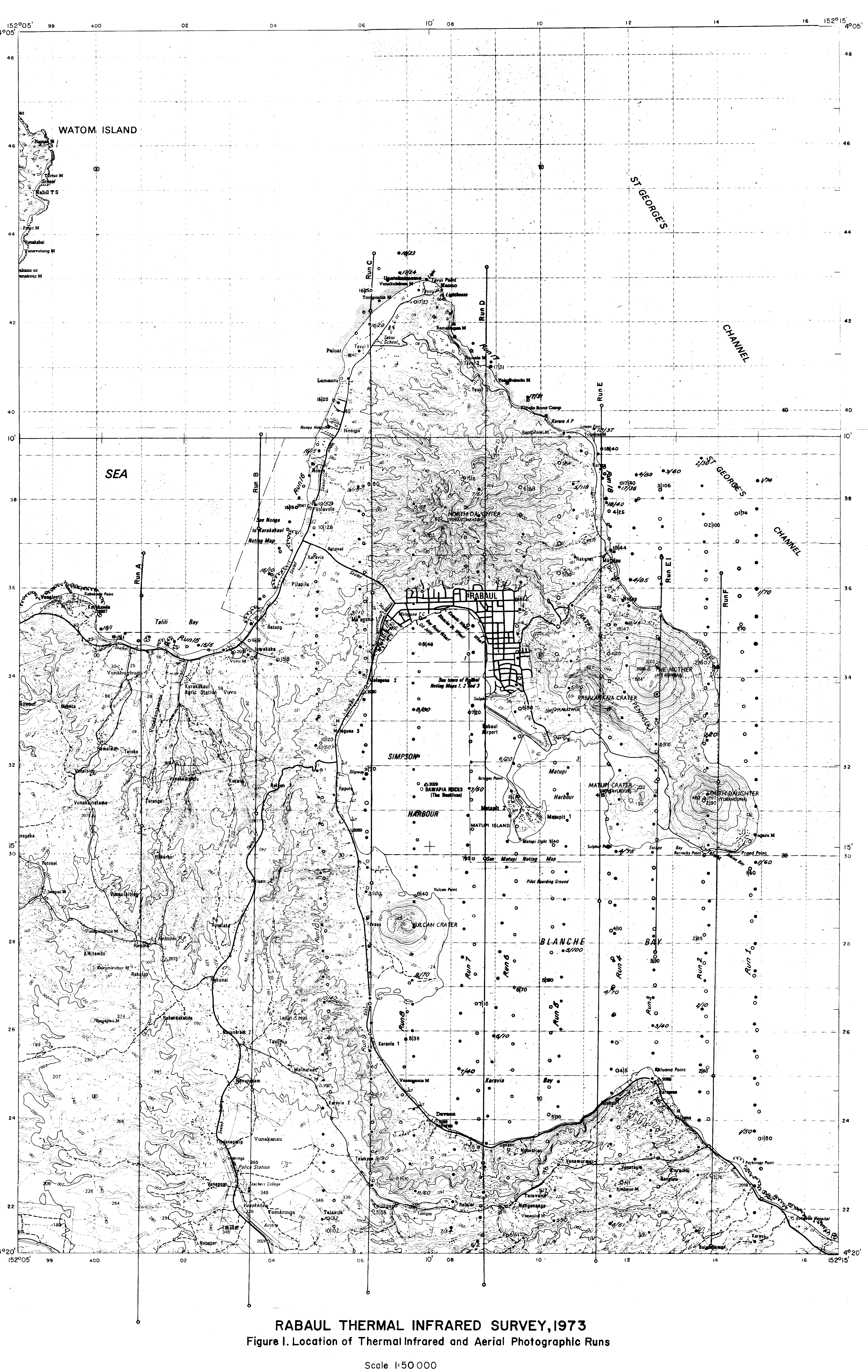
Date 1973	Place	Time	Air Temp. $^{\circ}C$ 1 metre above ground		Remarks
May 3	Rabaul airport	0445	26		Calm, light rain
		0500	26		
		0530	26		wind, easterly, 5-10K
		0540	25		Low cloud, rain
		0547	24.5		
					No imaging done because of low cloud
4	Rabaul airport	0430	24.5		Clear, calm
		0500	23.5		" "
		0523	23.5		" "
		0545	23.5		" "
		0555	25		" "
					Imaging of runs 11 to 14 and run 1 with 8-14 micrometre detector
5			Air	Water	
	Rabaul Yacht Club jetty, Simpson Harbour	0415	25	27.5	Clear, calm
	Rabaul airport	0445	25		Light air from ESE, becoming overcast
		0515	25.5		
		0530	25.5		
		0545	25		Sun obscured by cloud in east
		0600	25		
	Yacht Club jetty	0700	27.5	28.5	
					Imaging of runs 2 to 5 with 8-14 μm detector

TABLE 5 (contd.)

Date 1973	Place	Time	Air	Grass	Water	Remarks
May 7	Yacht Club jetty	0415	25.5		27	Clear, calm
	airport	0430	25	24.5		Light air from E
	"	0510	24.5	24		
	"	0530	24.5	24.5		
	"	0540	24	24		Sun slightly obscured by cloud
	"	0610	24.5	24.5		
	Yacht Club jetty	0640	25.5		27.5	
						Imaging of runs 6 to 9 with 8-14 µm detector
8	Yacht Club jetty	0415	25		28	Calm, patchy high cloud in SE
	airport	0430	24	24		
	"	0500	24	24.5		Ground fog 1-2 m thick on airstrip NW of airport buildings
		0536	24	24		
		0550	24	24		Light air from E; sun obscured by cloud
		0600	24	24		
	Yacht Club jetty	0645	25		27	
						Imaging of runs 11 to 14 at 2400' asl and runs 1, 2 and 10 at 3000' asl with 3.5-5.5 µm detectors
May 9	Yacht Club jetty	0415	25		28	
	airport	0435	24	24		Clear, calm
	"	0505	24.5	24		
	"	0520	24	24		Patchy ground fog on airstrip
	"	0537	24	24		
	"	0550	24.5	24.5		
	"	0600	24	24		

TABLE 5 (contd.)

Date 1973	Place	Time	Air	Grass	Water	Remarks
May 9	Yacht Club jetty	0630	25		27.5	
						Imaging of runs 4 to 6 with 3.5-5.5 μm detector
May 10	Yacht Club jetty	0455	25		28	
	airport	0520	24	23		Light breeze from E, patchy cloud
		0603	25.5	26		
						Imaging of runs 7 to 9, 3 & 3A with 3.5-5.5 μm detector
May 11	airport	0512	26	26		Calm, some ground
		0555	25	25		fog on airstrip; patchy light cloud
	Yacht Club jetty	0630	26		28.5	
						Imaging of runs 3A, 4A & 10 with 8-14 μm detector



RABAUL THERMAL INFRARED SURVEY, 1973

Figure 1. Location of Thermal Infrared and Aerial Photographic Runs

Scale 1:50 000

1 0 1 2 3 4 5 Kilometres

○ ○ ○ 10|102 } Thermal infrared run and tracking camera photo number { 3·5–5·5μm wavelength interval

● ● ● 10/32 } { 8·0–14·0μm " "

o——Run A——o Aerial photographic runs

To accompany Record 74/97

PA/470

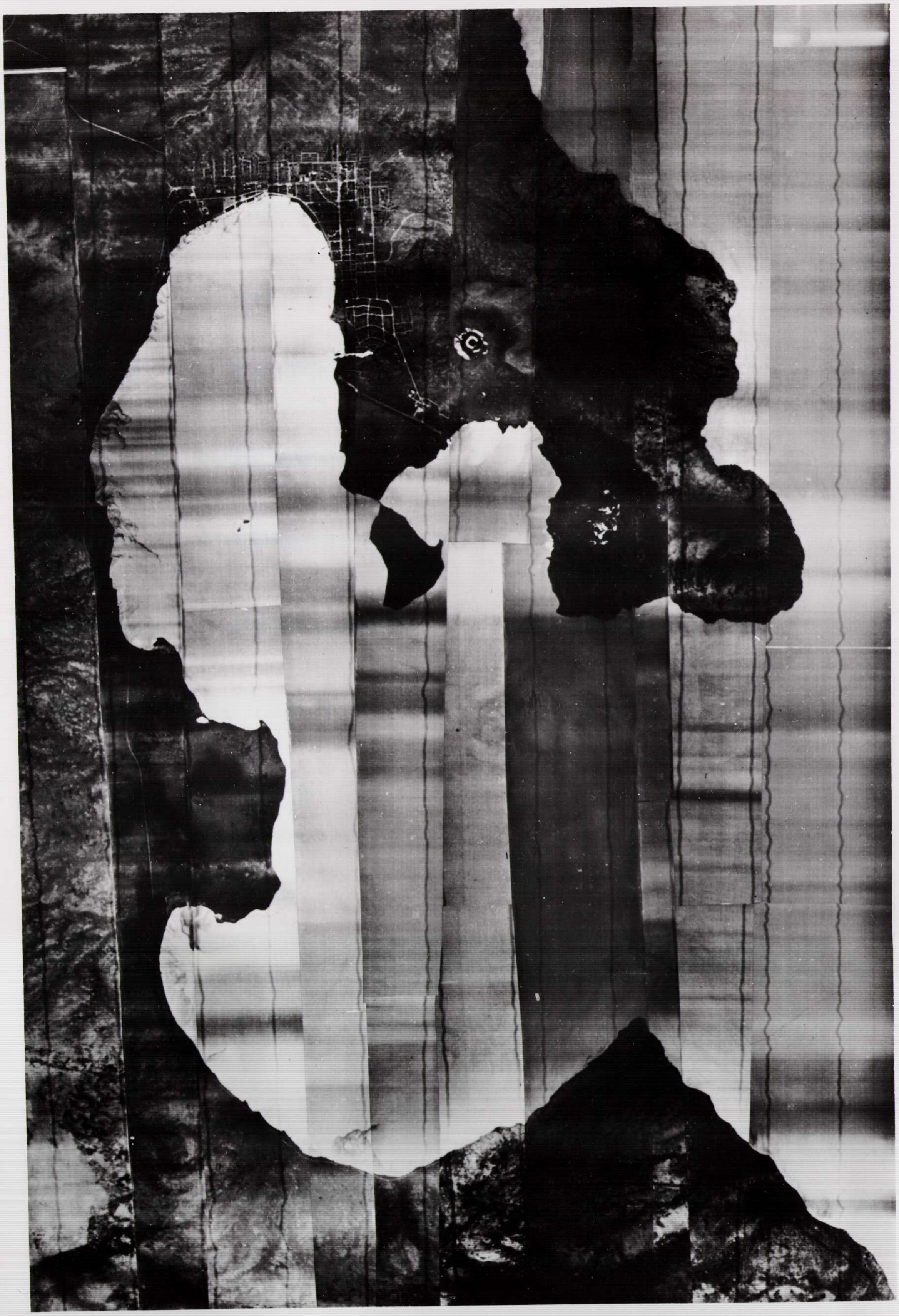
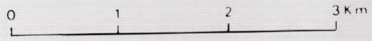


Fig 2 Mosaic of thermal infrared runs, 8 - 14 µm, Rabaul Caldera

Compiled by Qasco Air Surveys



To accompany Record 1974/97

Fig 3 Mosaic of thermal infrared runs, 3·5–5·5 µm, Rabaul Caldera

Compiled by Qasco Air Surveys

0 1 2 3Km

To accompany Record 1974/97

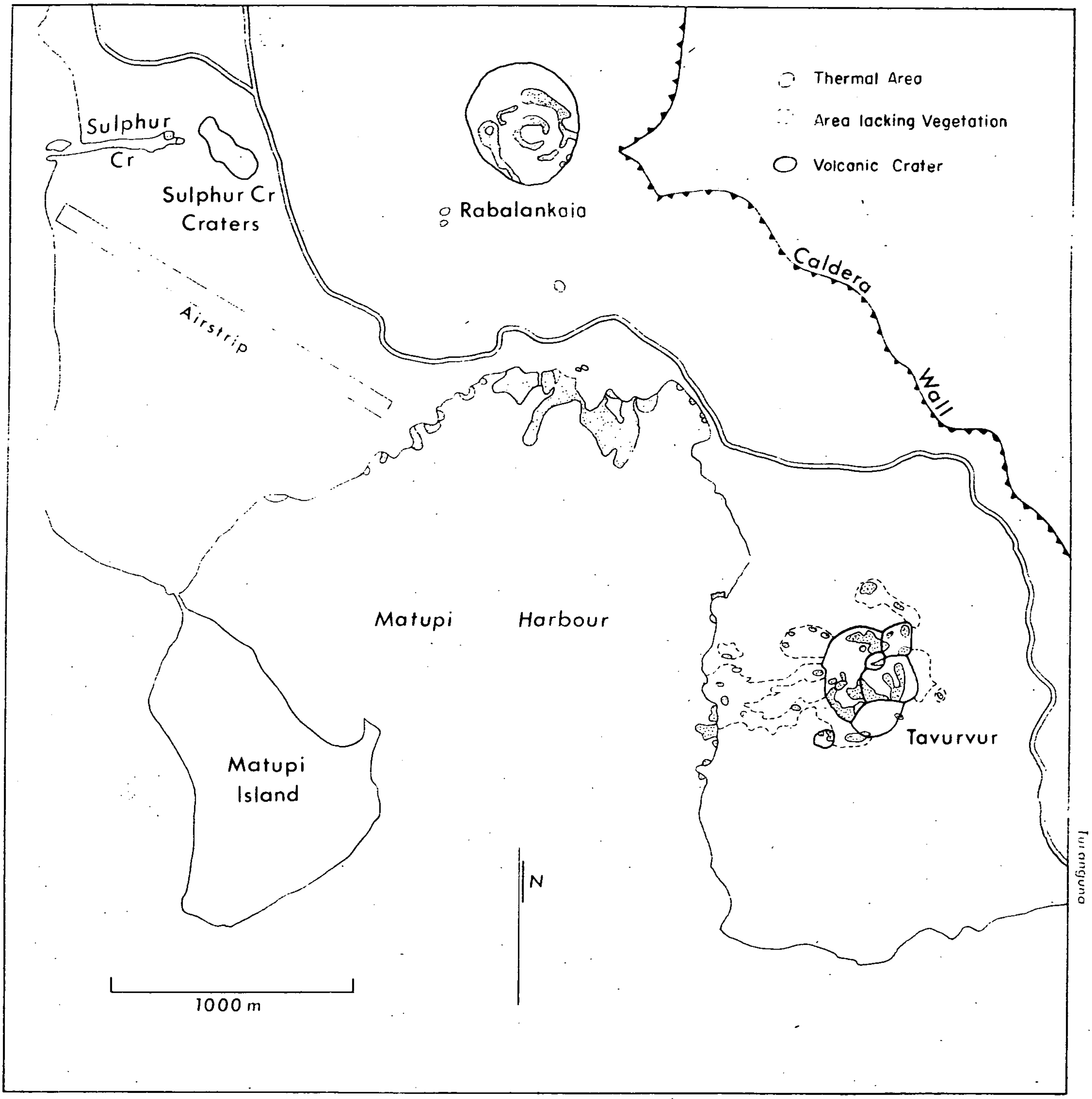


Fig. 4 Thermal Anomalies of Matupi Harbour Area from I.R. Imagery (8 - 14µm), May 1973

To accompany Record 1974/97

PA / 460

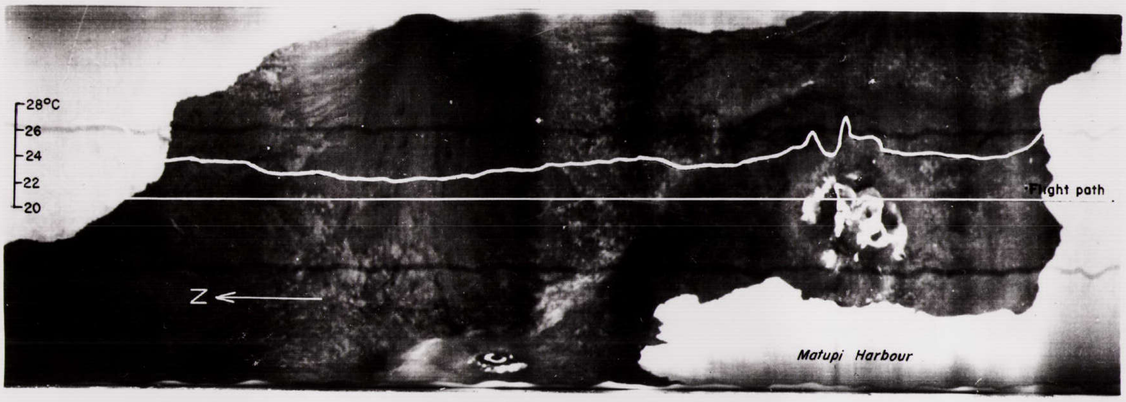


Fig 5 Infrared imagery (8 - 14µ) of Tavurvur matched with the radiometer results. Run 3A flown at 0523 - 0524 hrs, south to north, 11th May, 1973, flying height 3000' asl; aircraft speed 150 knots

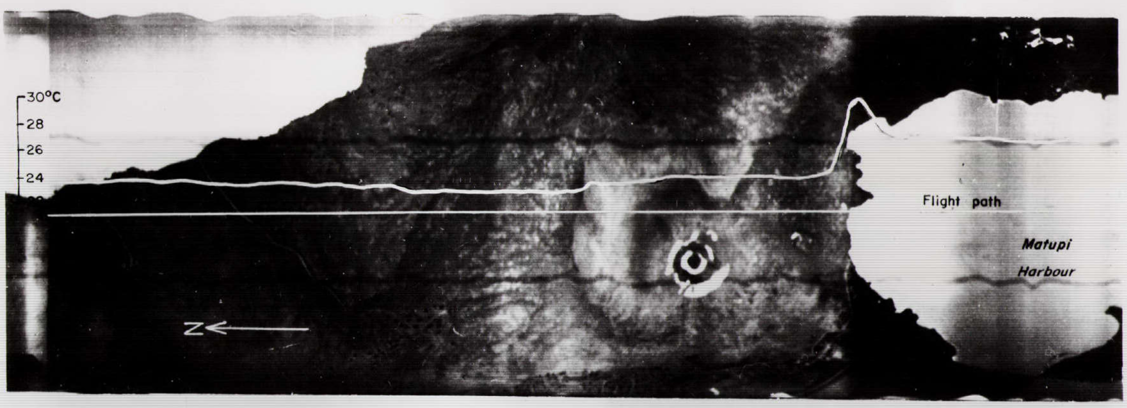


Fig 6 Infrared imagery (8-14µ) of Rabalankaia matched with the radiometer results. Run 4A flown at 0547-0549 hrs, south to north, 11th May, 1973, flying height 3000' asl; aircraft speed 145 knots.

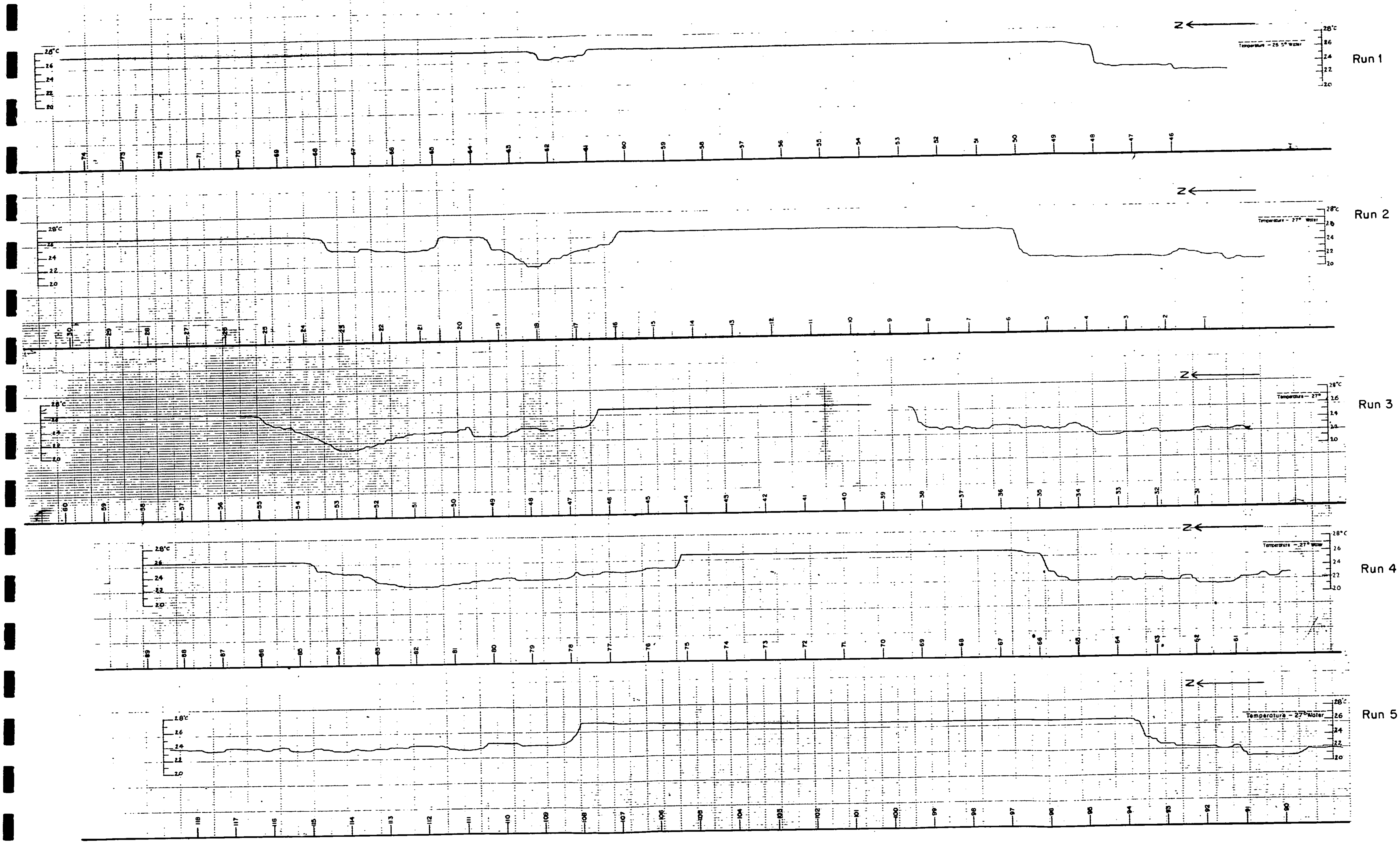


Fig. 7a Runs 1-5 (8-14μm).

To accompany Record 1974/97

PA/472

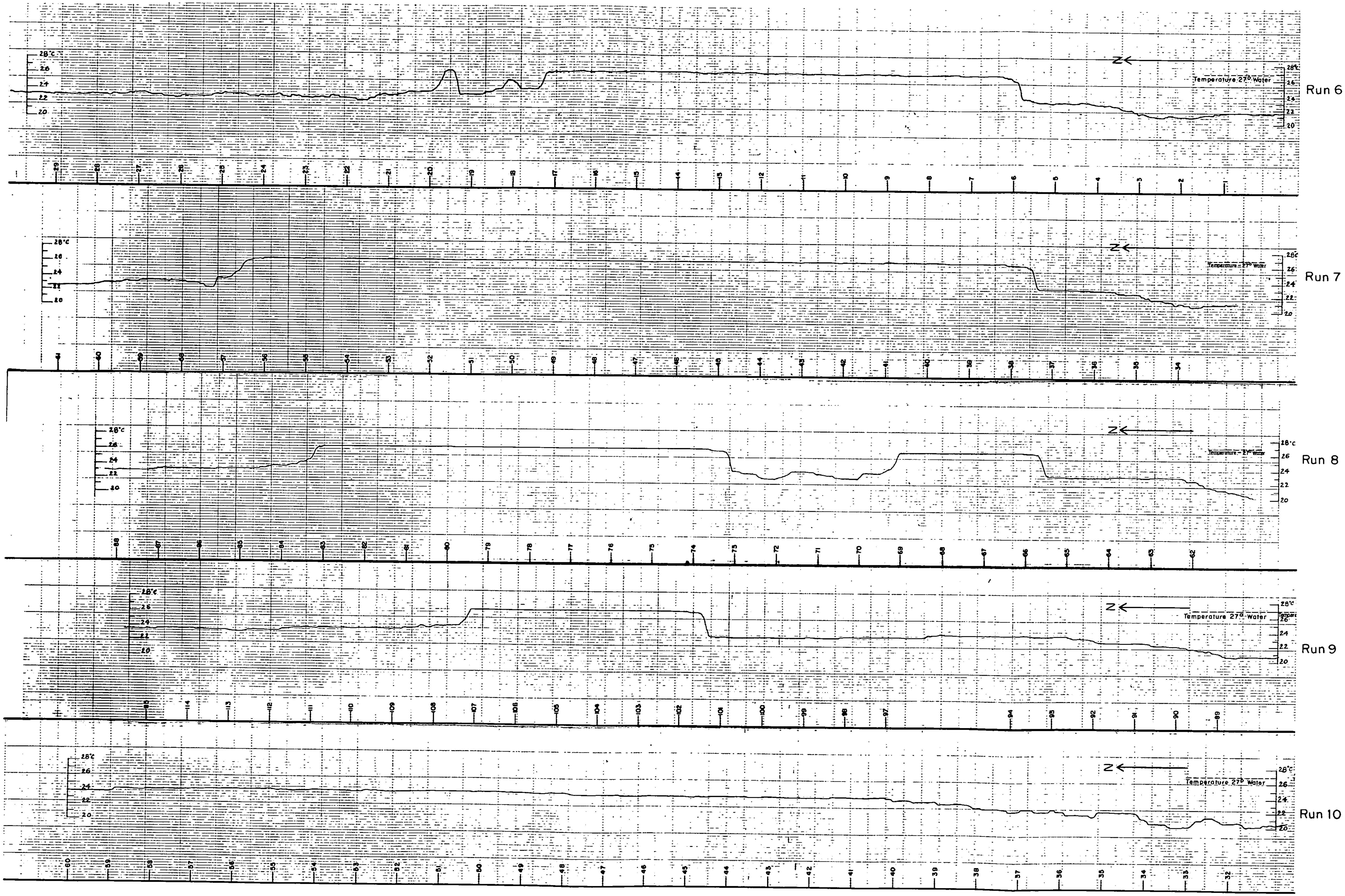


Fig. 7b Runs 6 - 10 (8-14μm)

To accompany Record 1974/97

PA/473

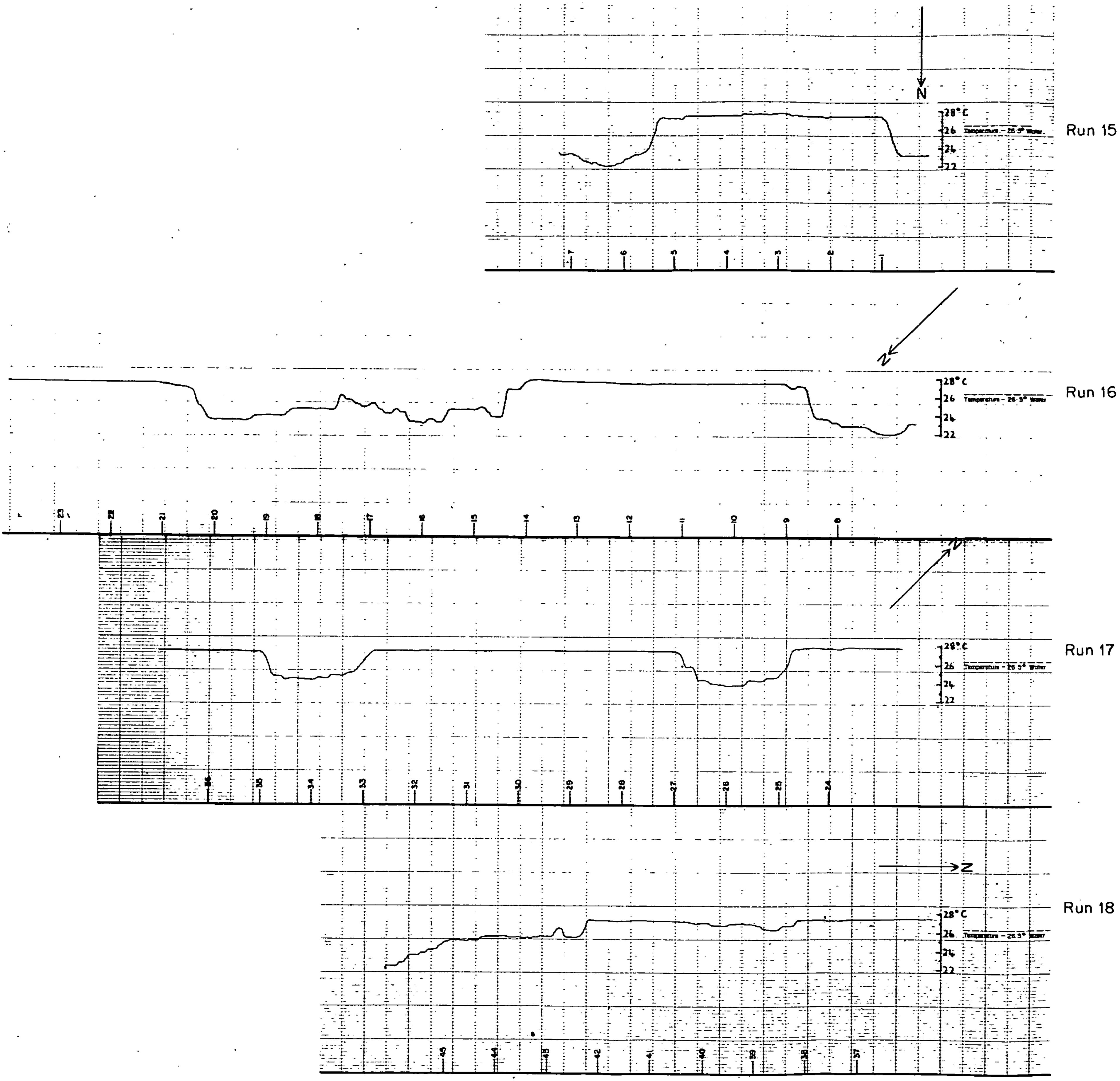
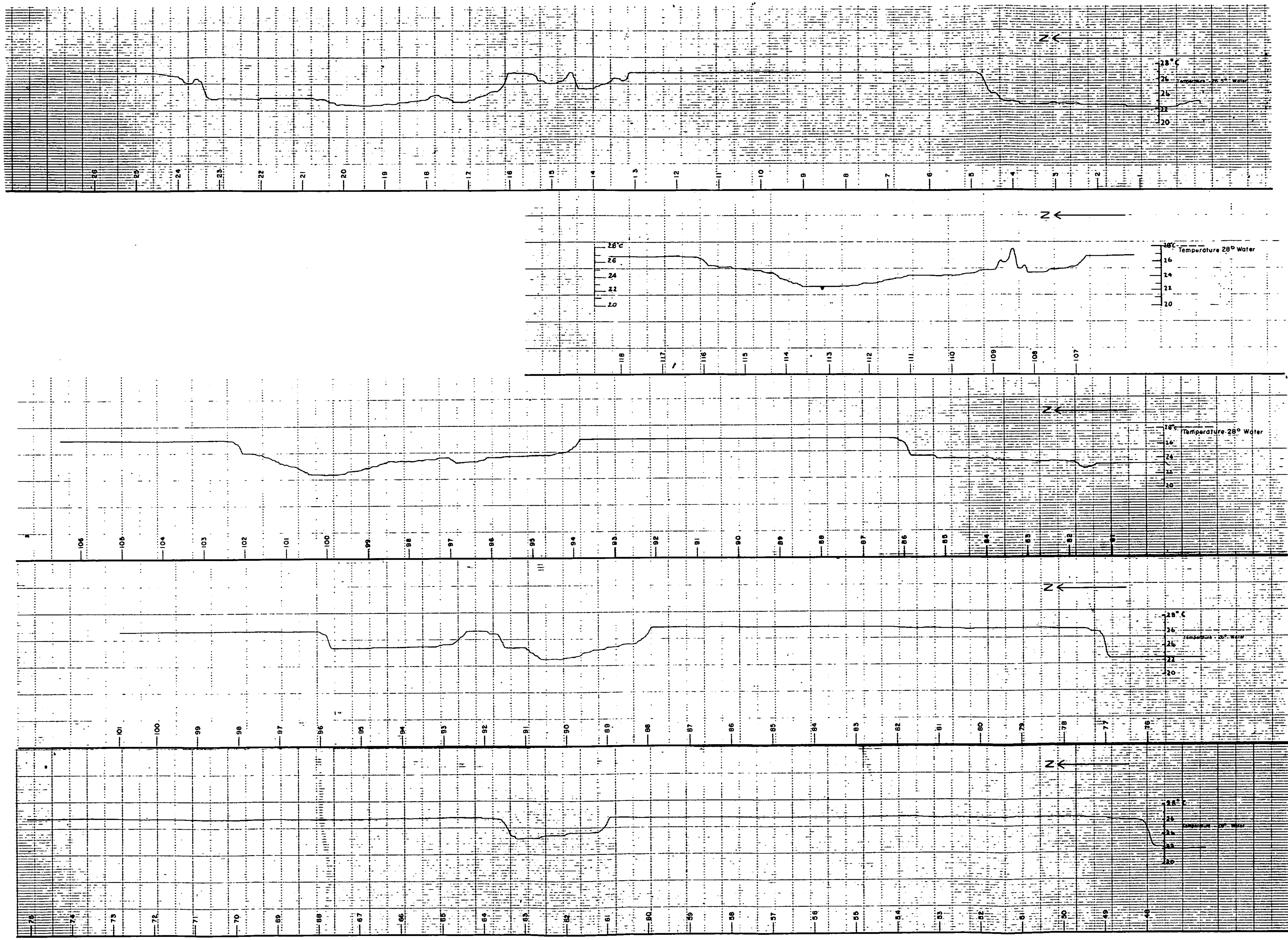


Fig. 7c Runs 15-18 (8-14μm).



To accompany Record 1974/97

Fig. 8a Runs 1–4 (3·5 – 5·5μm).

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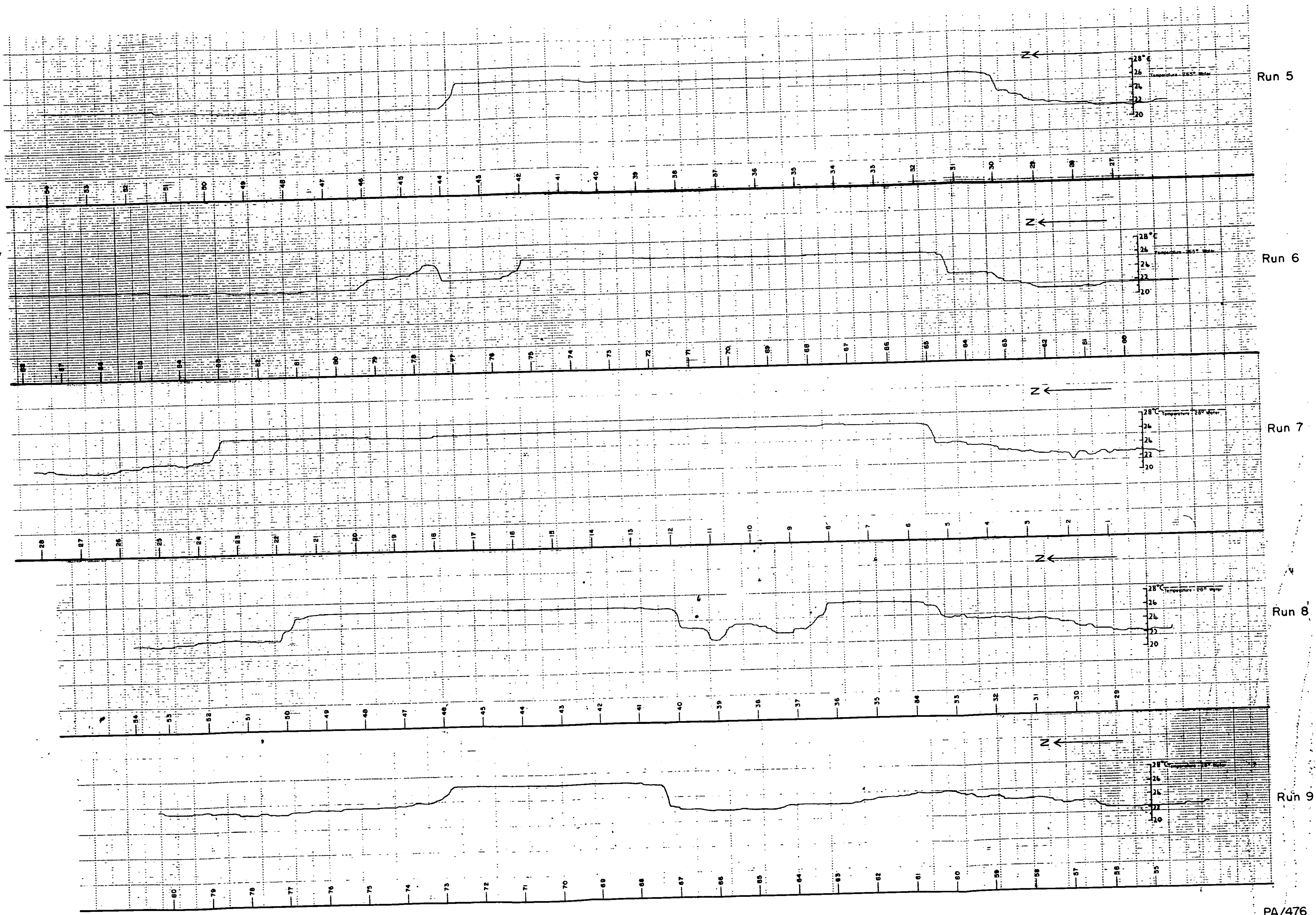

Fig. 8b Runs 5 – 9 (3·5 – 5·5 μm).

To accompany Record 1974/97

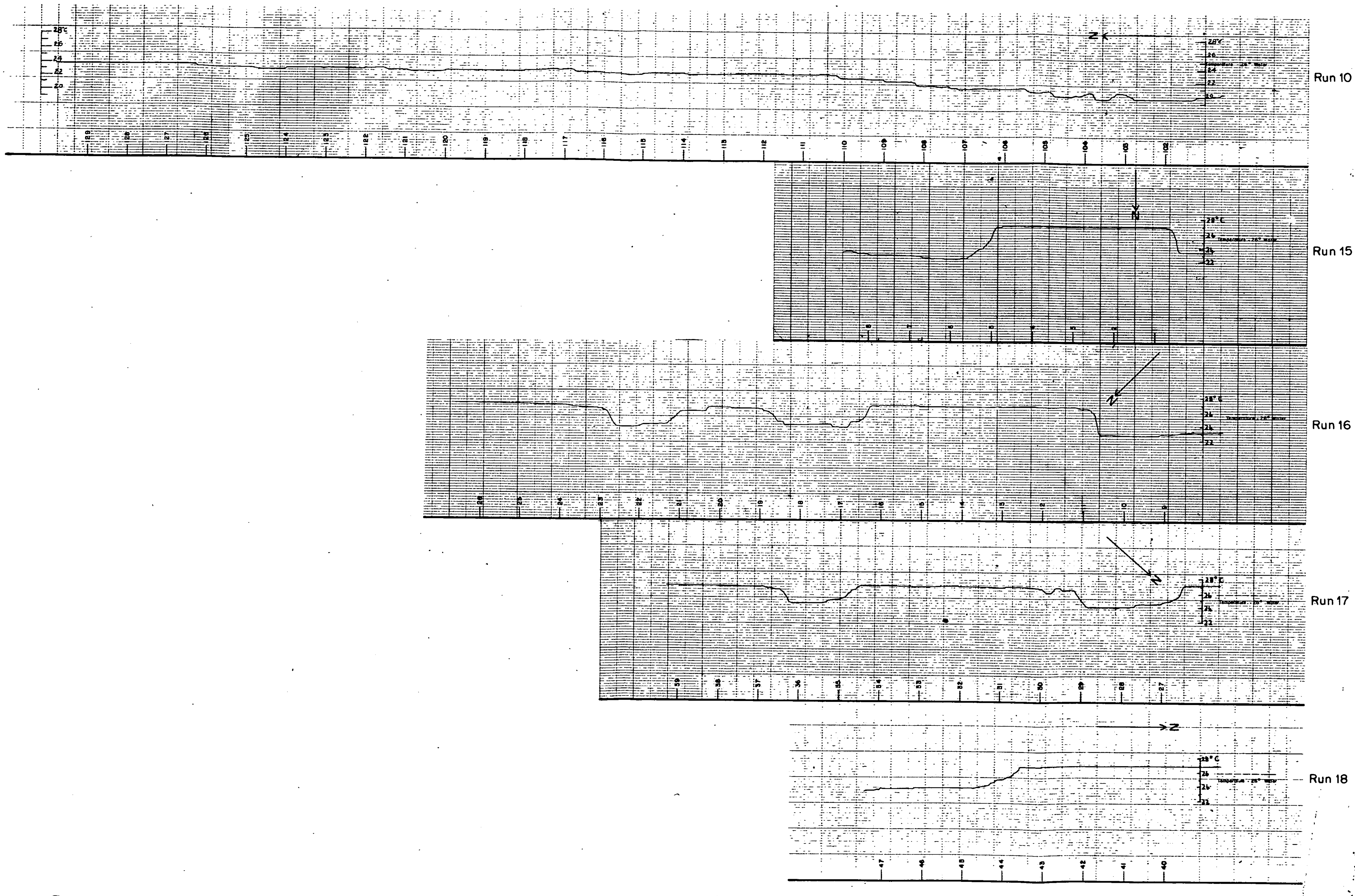

Fig. 8c Runs 10, 15 – 18 (3·5-5·5μm).

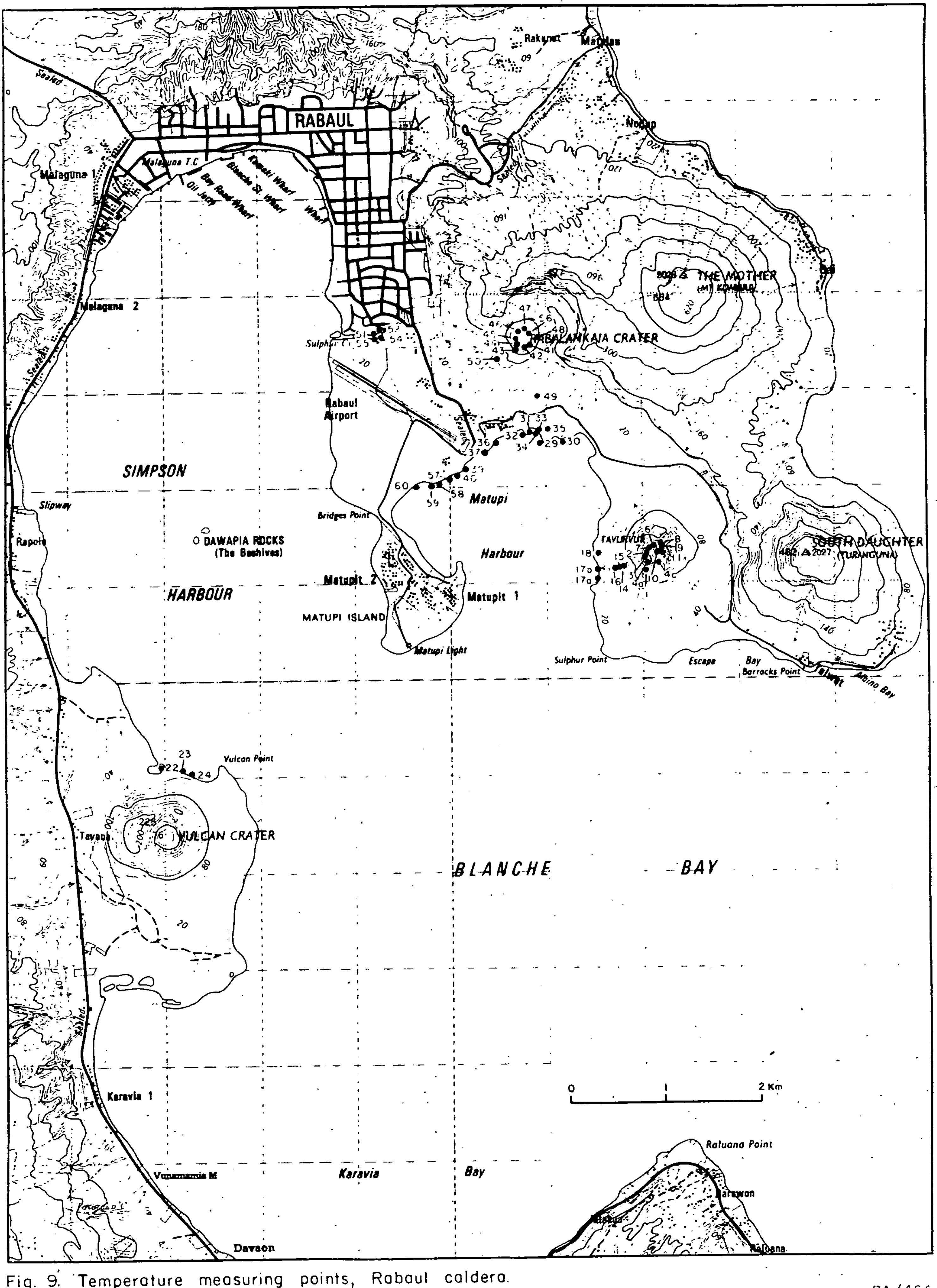

Fig. 9. Temperature measuring points, Rabaul caldera.

To accompany Record 1974/97

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