

### Acknowledgements

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## Some observations on the former sea levels of Marion Island

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*Investigation of raised beaches together with mathematical extrapolation from a river long profile suggest two definite former sea levels with the possibility of a third. True raised beaches were found at c. +3 m and c. +6 m with extrapolated levels of +5,9 m and +10,8 m. Stone roundness and flatness indices were used as additional aids to differentiation of various levels. Comparison is made with former sea levels found on other sub-Antarctic islands.*

*'n Ondersoek van strandterrasse met behulp van wiskundige ekstrapolering van 'n rivierlangse profiel af dui op twee besliste vroeëre seevlakke, met die moontlikheid van 'n derde. Egte strandterrasse is by c. +3 m en c. +6 m gevind met geëkstrapoleerde vlakke van +5,9 m en +10,8 m. Klippe se rondheids- en platheidsindekse is as verdere hulpmiddels by die onderskeiding van die verskillende vlakke aangewend. 'n Vergelyking word getrek met vroeëre seevlakke wat op ander sub-Antarktiese eilande gevind is.*

### Introduction

As part of the study of the Quaternary history of Marion Island (46°54'S, 38°45'E) an investigation of former sea levels was undertaken. Observations by Verwoerd (1971) had shown no evidence for former levels and he suggested that this may be due to the "differential tectonic settling of the volcano . . . so that they were drowned". The volcanic nature of Marion is such that many of the recent black lava flows, which line the coast, could be morphologically mistaken for a former marine level owing to their bench-like form. However, despite the problems of possible tectonic disturbance and the extensive lava flows a number of distinct raised beaches could be recognised at several locations around the island.

Two main methods were used to determine the former marine levels, namely direct observation (and subsequent survey) and mathematical extrapolation from the long profile of a river. As an aid to direct observation use was made of stone roundness and flatness indices to help differentiate the

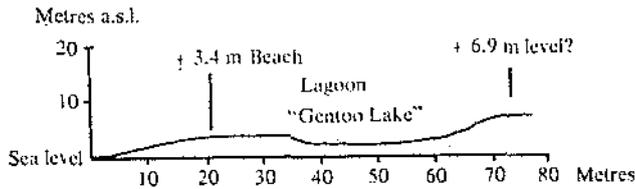


Fig. 1. Surveyed profile of the raised beach at Transvaal Cove.

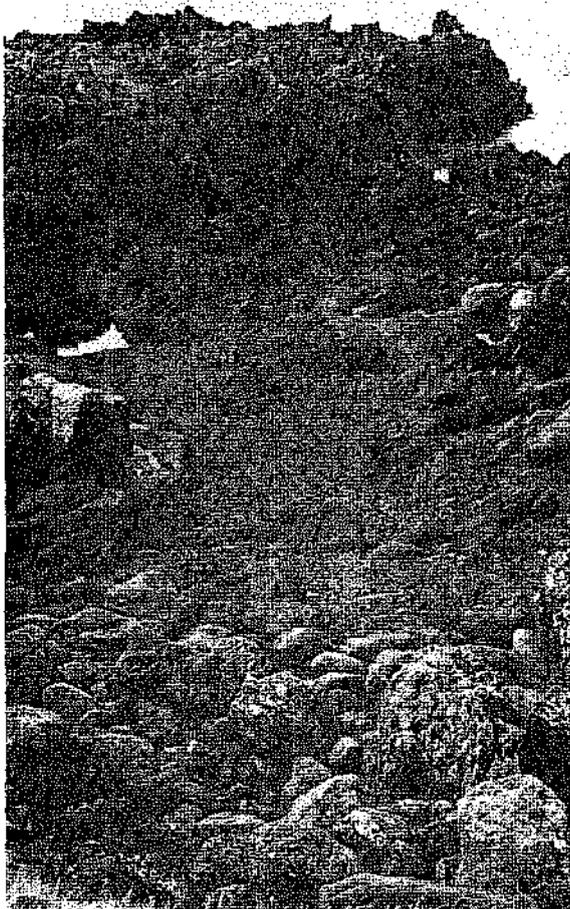
various levels. One river was surveyed and used in the calculations, the results of which are in good accord with those found for the actual beaches.

## Results

### True raised beaches

True raised beaches were observed at a number of locations around the island. At all sites wave-smoothed rocks, wave-rounded pebbles and boulders, and wave-cut cliffs at the back of the beach were observed. At Transvaal Cove (Fig. 1) and Trypot Beach raised beaches were surveyed and heights of +3,4 m and +2,9 m, respectively, were found. A further level of +6,9 m was indicated at Transvaal Cove but the lack of rounded pebbles and boulders suggests that this may represent a lava flow rather than a true marine-cut level. Just to the north of Cabbage Point a classic raised beach sequence (Fig. 2) from +3,3 m to +6,1 m was found and surveyed (Fig. 3). The lower beach started above a wave-cut cliff and rose, across a pebble-bould beach, to a cliff-backed level at +6,1 m.

Fig. 2. A view across the raised beach sequence to the north of Cabbage Point.



At this location stone roundness ( $P_i$ ), using Cailleux's equation  $P_i = (2r/a) \times 1000$  and flatness ( $F_i$ ), using  $F_i = [(a + b)/2c] \times 100$  indices were determined for both levels. The following results were obtained:

+3,3 m level	+6,1 m level
$P_i = 422,9$ ( $s = 125,6$ )	$P_i = 381,2$ ( $s = 121,3$ )
$F_i = 448,1$ ( $s = 61,0$ )	$F_i = 492,0$ ( $s = 117,6$ )
$n = 100$	$n = 100$

The above figures clearly indicate differentiation between the two levels, with the greater roundness and lower flatness indices at the +3,3 m level. In addition,  $P_i$  indices given below were also calculated for the present beach and the +2,9 m level at Trypot Beach:

Present beach	+2,9 m level
$P_i = 557,5$ ( $s = 120,3$ )	$P_i = 417,1$ ( $s = 119,5$ )

Again a clear-cut distinction is seen between the two levels but it is interesting to note that the mean  $P_i$  index is similar for the +2,9 m level and the +3,3 m level (417,1 and 422,9 respectively). However, owing to the variations in the structures of the lavas at the two locations the resulting beach deposits can only be assumed with 80 per cent certainty to come from the same population (Mann Whitney  $U$ -test with level of significance of  $U$  calculated using  $z$ -score). Thus there appears to be evidence to indicate two levels, c. +3 m and c. +6 m, above the present-day beach.

These two levels were observed at several locations around the island (Fig. 4). Between Transvaal Cove and Trypot Beach a small beach was found at +6,1 m cut in the black lava and backed by a 3-m cliff. The whole coastline from Cabbage Point up to Skua Ridge shows a c. +3 m level with occurrences of the +6 m level. The two levels were also observed at the following locations: Watertunnel Stream, Goodhope Bay, Kildalkey Bay, Bullard Beach, Ships Cove, Fur Seal Bay, and around the edges of Cape Davis. Both levels are thought to occur at Kaalkoppie and Swartkop Point but observations here were limited.

An interesting observation of what may be 'fossil' seal wallows, which are now well above the present sea level, was made. Four large (up to 800 m<sup>2</sup>) abandoned wallow complexes were found which are no longer used by the seals and in which plant regeneration has reached an advanced stage. The locations of these wallows suggest that they were in active use at the time of higher sea levels when the present wallow areas would have been under water. Above Transvaal Cove, where at the present time there is a large concentration of seals on the +3 m beach and up to +6 m, there is an abandoned wallow area recognisable at +10 m a.s.l. A similar type of area occurs at the back of Trypot Beach at approximately +7 m a.s.l., whilst immediately to the back of the raised beach sequence shown in Fig. 2 there is a 'fossil' wallow which even shows an old 'crawlway' from the beach top into the wallow. Logically the seals must have used wallows at higher elevations at times of higher sea levels and the situations described above appear to be good evidence.

### River long profile

The long profile of the Van den Boogaard River, close to

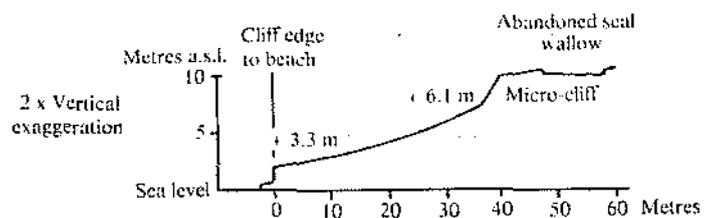


Fig. 3. Surveyed profile of the raised beach sequence for the unnamed beach to the north of Cabbage Point.

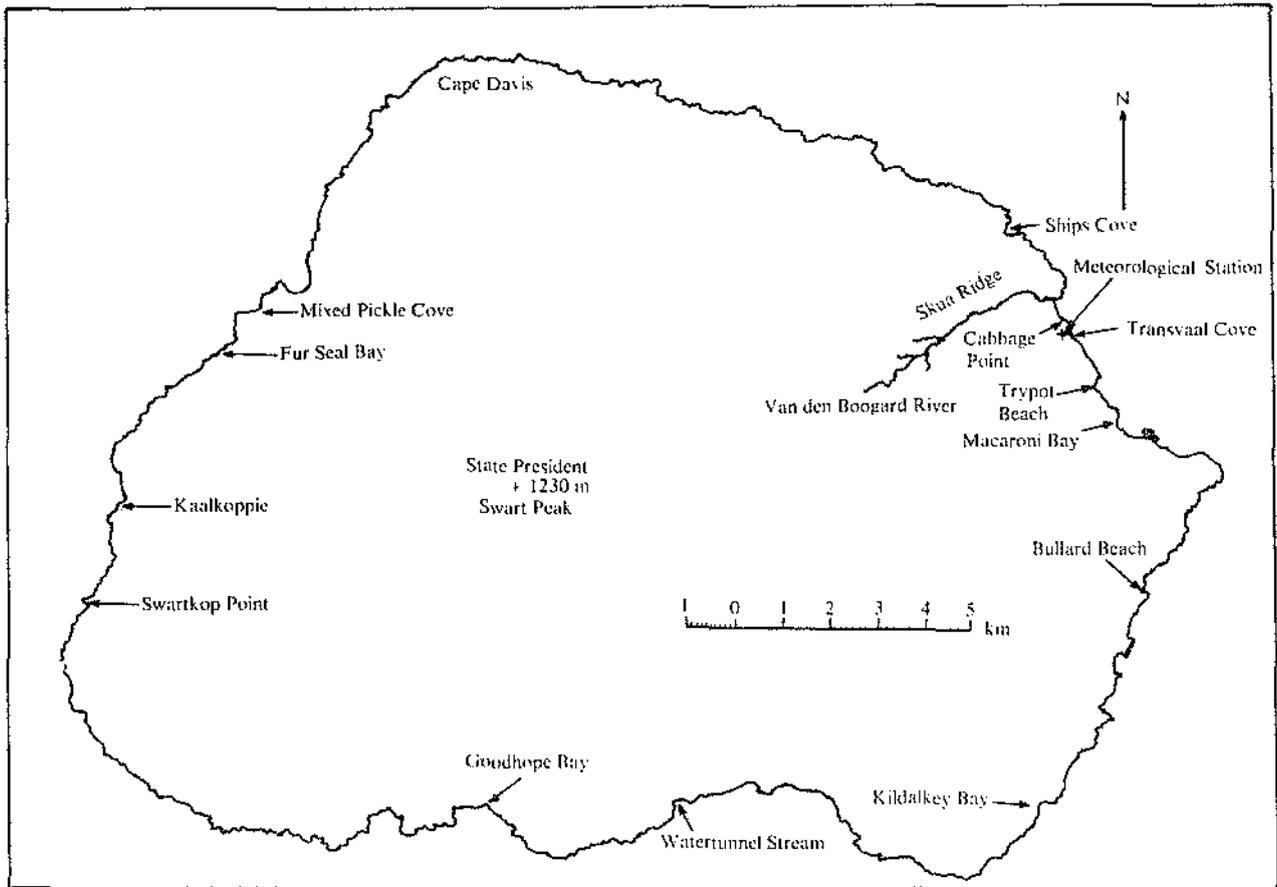


Fig. 4. Map of Marion Island to show the named locations where raised beaches have been found.

the Meteorological Station, was measured by means of a Kern level. From the long profile obtained a number of distinct nick-points were discernable (Fig. 5). Whilst an exponential curve (Table 1), with a coefficient of determination ( $r^2$ ) of 0,83, best fitted the whole profile a linear equation was found to fit each segment best.

A line generated for the seaward segment (1st segment) suggests a former level of +5,9 m with an  $r^2$  of 0,98 (Table 2). The inland (2nd) segment, when projected, gives an extrapolated level of +10,9 m with an  $r^2$  of 0,95 (Table 3). Thus two levels, +5,9 m and +10,9 m, are suggested. The former is

of great interest as it is so very close to the values found for the true raised beaches, namely c. +6 m. With the close correspondence of this extrapolated level to those actually found it is tempting to assume that the +10,9 m value may also be indicative of a former level. In fact a wave-cut platform at Macaroni Bay does reach to +10 m and may be related to this extrapolated level.

### Conclusions

It would appear that there are two distinct former sea levels on Marion Island with the possibility of a third; namely at

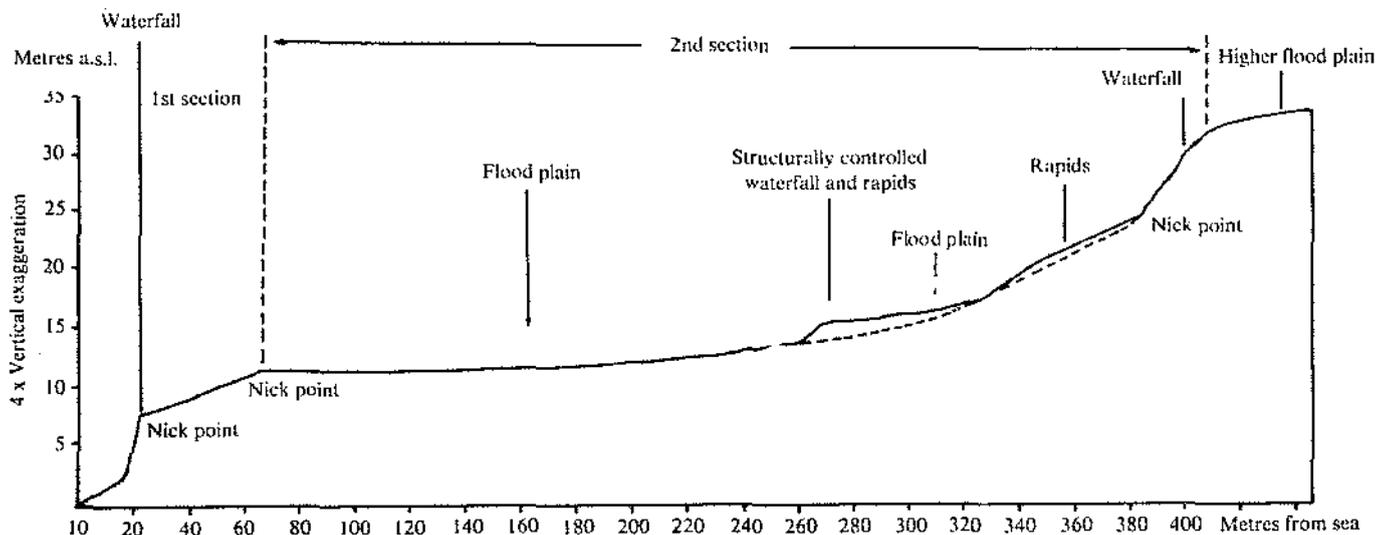


Fig. 5. Levelled profile of the Van den Boogard River from which the former sea levels were extrapolated.

Table 1

Exponential curve generated for the whole of the measured profile of the Van den Boogaard River

x	y
70	11,2
100	11,3
140	11,4
180	11,6
200	11,8
280	13,8
320	16,5
340	18,1
380	24,0
400	30,0

$x =$  distance inland from present sea level (metres)  
 $y =$  height above present sea level (metres)

constants:  $a = 7,853$   
 $b = 0,00269$   
 $r^2 = 0,8228$   
 $y = 7,853 \exp(0,00269 x)$

Table 2

Linear regression of seaward section of long profile of river

x	y
70	11,2
60	10,0
50	9,3
40	8,8
30	8,0
20	7,5

$x =$  distance inland from present sea level (metres)  
 $y =$  height above present sea level (metres)

$a_0 = 5,92$   
 $a_1 = 0,07$   
 $r^2 = 0,98$   
 $y = 0,07 x + 5,92$

Extrapolation of former marine level:

x	$\hat{y}$
10	6,63
5	6,28
0	5,92

c. +3 m, c. +6 m and c. +10,9 m. A +3 m level has been noted on Kerguelen and Crozet where it is considered to be of eustatic origin (Nougier, 1970). It has also been suggested (Bellair, 1969) that this +3 m level relates to the Climatic Optimum ( $\sim 5500$  B.P.). Nougier (pers. comm.) has noted a +6 m level on Kerguelen, Crozet and St. Paul-Amsterdam and suggests that the +11 m level can be recognised on Crozet. Sugden and John (1973) found both c. +3 m and c. +6 m levels in the South Shetlands but obtained dates for these levels of c. 300 B.P. (A.D. 1650) and 750 to 500 B.P. (A.D. 1200 to 1450) respectively. Araya and Hervé (1966) noted +2,7 m and +5,4 m levels on Elephant Island in the South Shetlands. Finally, Everett (1971) describes levels of +6,1 m and +10,6 m for Livingston Island.

Unfortunately no specific dates are available for the Marion levels so it is difficult to correlate them with those found on other islands or to suggest whether they are related to the Climatic Optimum or the more recent dates of Sugden and

Table 3

Linear regression of inland section of long profile of river

x	y
70	11,2
100	11,3
140	11,4
180	11,6
200	11,8

$x =$  distance inland from present sea level (metres)  
 $y =$  height above present level (metres)

$a_0 = 10,86$   
 $a_1 = 0,0043$   
 $r^2 = 0,95$   
 $y = 0,0043 x + 10,86$

x	$\hat{y}$
60	11,12
50	11,08
30	10,99
10	10,91
0	10,86

John (1973). However, despite the doubts of Verwoerd (1971) it would appear that raised beaches can be recognised around the island and that their accordance in height suggests that Marion has been tectonically stable during and since their formation. A detailed investigation of the former sea levels of Marion Island, especially if dates can be produced, would be most profitable for a better understanding of the post-glacial sea level changes of the southern hemisphere.

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