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EVIDENCE OF PLEISTOCENE GLACIATION IN EAST PAPUA

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Despite earlier recognition (Detzner, 1921) it was not until 1960 that evidence of Pleistocene glaciation was described in detail from Australian New Guinea, when the glacial features of Mt Wilhelm (4,509 m) were dealt with by Reiner (1960). Later Bik (1967) found evidence of Pleistocene glaciation on Mt Giluwe and Mt Hagon, two extinct volcanoes 4,367 m and 3,777 m high respectively, which lie southwest of Mt Wilhelm.

From a study of air photographs followed by field work the present author has discovered signs of relatively extensive Pleistocene glaciation on the Owen Stanley Range in East Papua.

PHYSIOGRAPHIC SETTING

The Owen Stanley Range forms the high, rugged backbone of East Papua. The highest mountains of the range are Mt Victoria (4,036 m) and Mt Albert Edward (3,990 m) (Figure 1), both of which show evidence of former glaciation. The two mountains are markedly different in appearance.

Mt Victoria is a long and narrow northwest trending ridge with little dissected and very steep side slopes (Plate I). Although it reaches 4,036 m there is only a small area above the 3,500 m contour line which is regarded as the approximate lower limit of the summit area. It is drained by a system of sub-parallel streams, minor tributaries of the Mambare River in the north and the Udovo River in the south.

In contrast Mt Albert Edward is an extensive plateau with two asymmetric summit ridges forming the central and the northern crests, which rise a few hundred metres above the plateau (Figure 2, Plate II). The central crest subdivides the plateau into a southern and a northern part. Except in the southwest, where the plateau slopes gradually down to an intermontane basin which forms the head of the Giumu River, the plateau is bounded by steep slopes. Most of the plateau area lies well above the 3,500 m contour line.

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Mt Albert Edward is drained by a radiating system of large and small rivers rising in the summit area. In the southeast, east, and northeast the rivers form the headwaters of the Chirima and Aikora Rivers and have small catchments and steep gradients with many rapids and waterfalls. In the west Mt Albert Edward is drained by the Guimbu River and its tributaries which seem to be more mature as their gradients are less steep and generally not broken.

![Figure 1. Location map.](image)

Mt Albert Edward is formed of mica schist, the foliation of which strikes 300° and dips 60 to 70° to the northeast. The schist is well exposed on the asymmetric summit ridges.

Mt Victoria is part of the same tectonic unit as Mt Albert Edward and air photo interpretation indicates that it probably also consists of schist.

**EVIDENCE OF GLACIATION ON MT ALBERT EDWARD (FIGURE 2)**

_Cirques._ The most marked signs of a former glaciation on Mt Albert Edward are cirques with very steep to precipitous back walls, overdeepened floors, and well-developed rock thresholds blocking lakes and swamps. The largest cirques are southwest and west of the two summit ridges where their back walls are formed by the outcrop slopes of the schist and are up to 250 m high (Plate II).

The cirques northeast and east of the summit ridges and on the plateau are less spectacular although they are also well preserved. The back walls of these cirques are less steep and rock outcrops are less prominent. Northeast and east of the summit ridges this is due to the cirques being formed on the dip slopes of the foliation of the schist. On the plateau areas it is due to the cirques being over-ridden by ice during the maximum glaciation. The cirque floors are dammed by low rock thresholds and are mostly occupied by small swamps or shallow lakes. The cirque floors are at altitudes between 2,600 and 3,750 m.

Key to Figure 2: 1. Summit ridges; 2. High and very steep cirque back walls along summit ridge; 3. Relatively low and moderately steep cirque back walls; 4. Glacial rock thresholds and steps; 5. Moraines of maximum glaciation; 6. Recessional moraines; 7. Maximum extent of glaciation; 8. Form lines, approximate intervals 250 m but 200 m between 3000 and 3700 m; 9. Lakes; 10. Swamps.

![Figure 2. Glacial features on Mt Albert Edward. Capital letters show locations of features referred to in the text or illustrated in the plates. This map was prepared from the Rumia sheet (SC 55-3), 1:250,000 series of the Royal Australian Survey Corps, 1966, and aerial photographs. All heights, except for the main peak, are corrected altimeter readings. Key on opposite page.](image)
Rock basins. Rock basins not associated with cirques are common on the flatter parts of the southern and northern plateau. These basins are mostly occupied by swamps, although some are occupied by lakes. Many of the basins are connected to one another by small streams.

Glacial valleys. On Mt Albert Edward there are several U-shaped valleys or troughs, of which the largest and deepest are situated southwest and west of the central crest. They are up to 150 m deep, 250 m wide, and up to 2.5 km long.

Plate II. The southwest side of the central crest of Mt Albert Edward showing large cirques, the back walls of which are formed of steeply dipping schist. The two lakes (A, B) are marked on Figure 2.

The glaciated valleys are in marked contrast to the non-glaciated V-shaped valleys below the glaciated area and their limits indicate the maximum extent of the glaciation (Plate III). Steps of up to 100 m occur in most of the glaciated valleys, especially in the higher parts. Some hanging tributary valleys are present but are not well developed.

Other erosional features. Glacially smoothed and rounded surfaces are common throughout the formerly glaciated area, and are particularly well developed in the northwestern part of the central crest (Plate II). However, there are no striated surfaces present probably because the schist, being strongly foliated, is unfavourable for the preservation and even the development of striations.

Moraines. During the maximum glaciation an area of about 90 km² was covered by a more or less continuous ice cap through which the highest parts of the summit ridges protruded. On the two plateaux several short lobes of ice diverged from the ice cap into the adjacent valleys and terminated between 3,400 and 3,450 m. Moraines formed by these lobes are preserved as smooth narrow ridges with sharp crests in the southeastern and northwestern parts of the southern plateau (Plate III). The ice cover along the central and northern crests seems to have been more irregular and thicker than on the plateau areas. Some valley glaciers, up to 2.5 km long and 150 m thick, were developed. They overdeepened the valleys more effectively than did the glaciers on the plateaux, probably because they were supplied with more abundant rock debris derived from outcrops in their steep catchments.

Moraines of the maximum glaciation are not well preserved in the larger valleys but here the maximum extent of the glaciation can be estimated from the downstream limit of the U-shaped valleys (Plate III). Well-preserved moraines marking the maximum extent of the glaciation are present, however, in some smaller valleys. Three of these valleys, all descending from the northern crest,
were examined in the field (G, H, I on Figure 2). The moraines there form long and narrow ridges with even and sharp ridge crests. In two of the valleys the moraines form single ridges, in one valley there is a double moraine ridge. The inner sides slope somewhat more steeply than the outer sides. The ridges are up to 80 m above the valley floors, but this does not represent the true thickness of the moraine, as the lower part of the ridge consists of solid bedrock. Near the snouts of the former glaciers the heights of the ridges do correspond more closely to the thickness of the moraines, which were here only up to 20 m thick.

The moraine material was exposed at one locality by a small landslide (Plate IV). It consists of boulders of different sizes lying in a fine matrix. The boulders are not well rounded except at the corners and are not striated; however it can be clearly seen that the rock surfaces have been polished by glacial activity. The matrix material is compacted and unweathered except near the surface.

The soils developed on the moraines consist of a horizon, 25-40 cm thick, of dark brown clay and peat overlying an irregular ferruginous band, up to 6 cm thick, which forms the transition to the underlying moraine material. No differences were observed in the soils and weathering profiles developed on the different moraines examined.

Recessional moraines are rare or absent in the larger valleys. A good succession of recessional moraines however is developed in one of the small valleys in the northern half of the southern plateau. The moraines are well preserved because of the low gradient of the valley. Here there are three distinct sets of moraines, about 500 m apart, each consisting of one to three moraine ridges (Plate V). The moraines are 2 to 6 m thick and are composed of unsorted material. Some large boulders are scattered on their crests. The soil profiles developed on these moraines are similar to those on the moraines of the maximum glaciation.

THE PLEISTOCENE SNOWLINE ON MT ALBERT EDWARD

The Pleistocene snowline can be reconstructed by several empirical methods most of which were developed in the European Alps at the end of last century. The two most widely used and generally accepted methods are those of Penck and Brückner (1909) and Höfer (1879). According to Penck and Brückner the altitude of the lowest cirques corresponds closely to the snowline, while according to Höfer the snowline is represented by the arithmetic mean of the altitude of the terminal moraine and the mean altitude of the catchment area of the former glaciers.

On Mt Albert Edward both methods give similar results as the altitudes of the lowest cirques are at 3,600 to 3,650 m which is the same height as the arithmetic mean of the mean altitude of the catchment area, 3,800 m, and the altitude of the lowest moraines, 3,400 to 3,450 m. The snowline so calculated is at the same height on all sides of the mountain although the snowline might be expected to have been lower on the western and southwestern slopes of the crests where the large cirques are located. However, the distribution and size of the cirques on Mt Albert Edward appears to have been controlled by rock structures and not mainly by climatic geomorphological factors as in higher latitudes.

PERIGLACIAL FEATURES ON MT ALBERT EDWARD

Present day periglacial activity on Mt Albert Edward seems to be restricted to the formation of terracettes, which occur on slopes of over 10° at altitudes above 3,700 m. They are common on or near ridge crests. The terracettes have vertical to overhanging faces 15 to 40 cm high. Small areas in front of the faces are bare of vegetation while the areas behind the faces are vegetated. Terracettes similar to those on Mt Albert Edward have been reported from many alpine areas of the world (Troll, 1944). They seem to be mainly formed by the action of needle frost (pilkkrae) which causes undercutting of the faces and retreat upslope as a result.

Plate IV. Moraine material exposed in a valley on the west side of the northern crest, Mt Albert Edward. (Position indicated by G on Figure 2).

The extent of the Pleistocene periglacial zone is difficult to determine because of the dense forest which covers the areas where periglacial features might be preserved. The only exposures seen are along the bridle path connecting Woltau and Longai. They show that a marked change in the soil and weathering profile
occurs at approximately 3,000 m. Below 3,000 m there is a thick soil profile probably autochthonous, consisting of 50 cm of black peat over up to 1.50 m of yellow-brown clay and clay loam with few rock fragments over 1 m of reddish brown clay and clay loam also with few rock fragments, over weathered schist. Above 3,000 m the soil profile is much thinner and consists of a horizon 40 to 50 cm thick of black peat overlying unsorted rock fragments possibly representing solifluction rubbles up to 50 cm thick over weathered schist. This indicates that the lower limit of Pleistocene solifluction activity might be situated at about 3,000 m.

Plate V. Recessional moraines (K, L) in one of the small valleys in the northern half of the southern plateau, Mt Albert Edward. (Position shown on Figure 2).

**Evidence of Glaciation on Mt Victoria**

Although Mt Victoria is nearly 50 m higher than Mt Albert Edward it exhibits only a few glacial features. These include two well-developed cirques leading down into two short glacial valleys that form the headwaters of the Visani River, a tributary of the Mambere River north of the main peak (Plate I). Neither of the two glaciers exceeded 1 km in length. Moraines representing the maximum glaciation are not well preserved except for a medial moraine which forms a prominent straight ridge with a sharp and even crest between the two valleys.

* This section is based on photo interpretation only.

In the westernmost of the two valleys two recessional moraines are preserved. They are approximately 4 to 5 m high and about 250 m apart (Plate I).

There are also some small cirques on the flanks of the summit ridge and both flanks of the main ridge appear to have been smoothed by glacial erosion down to somewhat below the present forest line.

Because of the lack of reliable height information except for the main peak it is not possible to reconstruct the altitude of the Pleistocene snowline accurately. It appears likely that the snowline was 50 to 100 m higher than on Mt Albert Edward.

**Discussion**

The Pleistocene snowline on Mt Albert Edward, which is 3,600 to 3,650 m, agrees well with results obtained in other areas of New Guinea (Reiner, 1960; Verstappen, 1964; Bik, 1967). It also agrees with the observation that there are no signs of former glaciation on Mt Suckling (3,676 m), the third highest mountain of the Owen Stanley Range (D. H. Blake, personal communication). According to Verstappen (1964) the present-day snowline on Mt Juliana and Mt Wilhelmia in West Irian is at approximately 4,600 m. This can be regarded as an approximate value for the present-day snowline above Mt Albert Edward. The Pleistocene depression of the snowline would thus be in the order of 1,000 m.

Assuming that the temperature gradient in New Guinea during the Pleistocene was similar to the present one and that there was no significant change in precipitation, the depression of the snowline by 1,000 m would mean a lowering of temperature of about 5 to 6°C for the mountain areas.

The more extensive glaciation and the lower snowline on Mt Albert Edward in comparison to Mt Victoria is due to Mt Albert Edward having a much larger area available for snow accumulation.

The present-day lower limit of periglacial activity is 3,700 m and this agrees with temperature observations made by the author on Mt Albert Edward where night frosts occurred regularly on clear nights at 3,600 m. During cloudy nights the temperatures were between 2 and 3°C. Observations on Mt Wilhelm over longer periods have given similar results (McVean, 1968) and have also shown that there is hardly any seasonal variation in temperature. Little can be said about the depression of the periglacial zone except that it probably did not exceed 700 m, but it might have been less.

**Conclusions**

The two highest mountains of the Owen Stanley Ranges, Mt Albert Edward and Mt Victoria, were glaciated during the Pleistocene. On Mt Albert Edward the ice covered an area of about 90 km² while on Mt Victoria the glaciated area did not exceed 15 km². Because of the freshness of the glacial features it is assumed that they originate from the last glaciation. No clear evidence for an
older glaciation has been found, but the size of some of the cirques on Mt Albert
Edward and the amount of overdeepening and glacial erosion is more than one
might expect from the modest size of the glaciers and it seems unlikely that they
were formed during just one period of glaciation.

The retreat of the glaciers from their maximum extent was interrupted by at
least three readvances which led to the accumulation of low moraines.

The Pleistocene snowline on Mt Albert Edward was at 3,600 to 3,650 m;
on Mt Victoria it appears to have been slightly higher. The Pleistocene depression
of the snowline was about 1,000 m, which implies that in the mountains mean
temperatures were about 5° to 6°C lower than at present, assuming that the
temperature gradient during the Pleistocene was similar to the present one.

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