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THE LATE QUATERNARY DEPOSITS OF BLAKES OPENING AND THE MIDDLE HUON VALLEY, TASMANIA

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[Plate 1]

CONTENTS

A 10–12 m sequence of late Quaternary deposits from a large river bank section is described. Morphologic, stratigraphic, sedimentologic, palynologic and radiometric analyses demonstrate the presence of both pre-Last Glacial age glacigenic deposits and Last Glacial age fluviatile terrace and alluvial fan deposits.

The pre-Last Glacial age till and outwash gravels are associated with 10–30 m high morainic ridges at Blakes Opening and occur throughout the middle Huon and lower Picton valleys. These deposits are strongly chemically weathered and are believed to belong to the Penultimate or to an earlier glacial age.

At Blakes Opening the glacigenic deposits are overlain by a stratified sequence of organic-rich fluviatile sands and silts deposited by the Huon river, and by alluvial fan deposits derived by erosion from the adjacent moraines. Most of the fluviatile sands and silts are of early to middle Last Glacial age (70000–30000 B.P.) and the alluvial fan deposits are mainly of late Last Glacial age. The surface soil, an iron podzol, is of Holocene age.

Pollen analysis of the organic sands and silts revealed that the vegetation had altered from Wet Sclerophyll *Eucalyptus* forest to Temperate Rain Forest which reverted to Wet Sclerophyll *Eucalyptus* forest. Although the influences of possible habitat changes and frequency of firing on the vegetation are discussed, it is concluded that the changes were primarily climatically induced.

The vegetation changes probably represent a sequence of climatic changes from drier and colder conditions to moister and warmer conditions with a return to drier and colder conditions. Radiocarbon dating suggests that the moister warmer phase may represent an interstadial of mid Last Glacial age.

Observations of glacial and periglacial landforms and deposits in the wider area suggest that during the early glaciation thick valley glaciers occupied the middle Huon and lower Picton valleys, whereas, during the Last Glacial Stage only local cirque and short valley head glaciers were developed at high elevations on Mount Picton and on the South Picton Range.

1. Introduction

Blakes Opening is a fire opening of sedgeland and ti-tree scrub in the tall open (Wet Sclerophyll) forests of the middle Huon valley (figures 1 and 2). The opening is about 3 km^2, extends from 70 to 240 m above State Datum, and lies between the Huon River and the northern slopes of Mount Picton (1327 m). Except for the summit areas over 1000 m on Mount Picton to the south and on the Weld Range (1320 m) to the north, the middle Huon and surrounding areas of Manuka Creek and Picton valley are covered with thick forest which makes systematic mapping of the landforms impossible. The landforms and deposits described in this paper represent the most important deposits of the south bank of the Huon between Tahune Bridge and Blackslate Creek which are accessible from the Yoyo Track. Similar forms and deposits are also described from the lower Picton valley, and Farmhouse Creek, which are accessible from the new road to Farmhouse Creek and the bush track that leads from Farmhouse Creek to the Cracroft River.

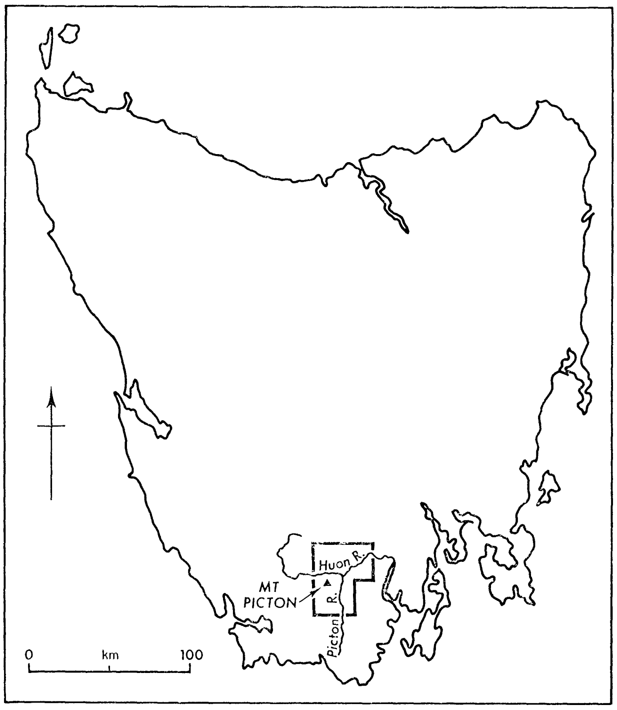


Figure 1. Location of middle Huon and lower Picton valleys, Tasmania.

Field investigations during 1973–5 demonstrated the occurrence of an important group of moraine ridges at Blakes Opening, associated outwash gravel terraces upstream and downstream from the morainic deposits, and strongly weathered till deposits at Blakes Opening (figure 3, plate 1) and in the Picton valley. All these deposits were found outside the limits of glaciation previously recorded for this region (Lewis 1924; Derbyshire *et al.* 1965). Lewis suggested that the upper Huon, Mount Anne and Lake Pedder areas to the west were first glaciated by an extensive ice cap which was about 400–600 m thick. During the decay of the ice cap meltwaters contributed abundant outwash gravels and formed extensive plains in the upper Huon valley and Lake Pedder areas. They also contributed outwash gravels to the Weld valley.

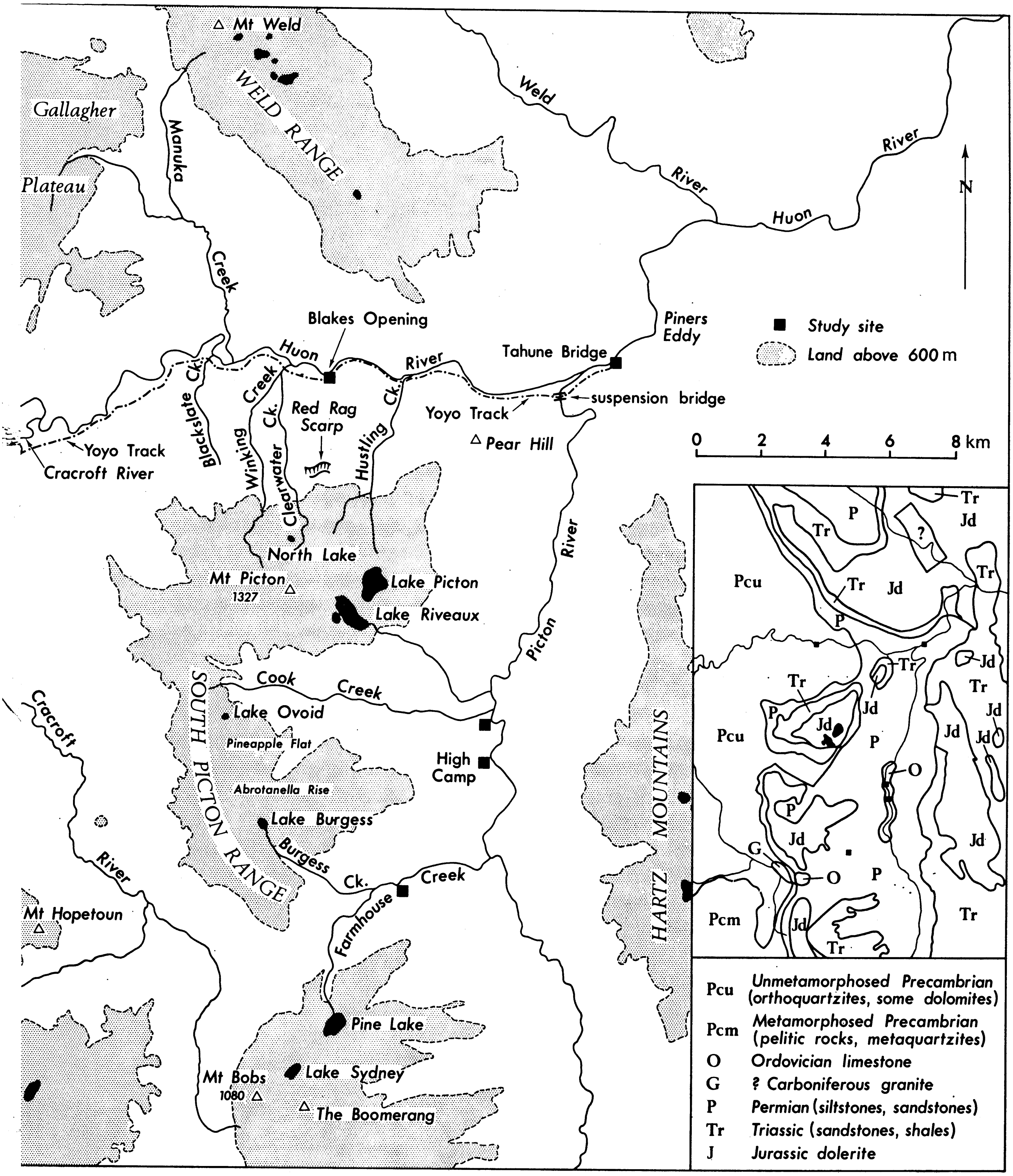


FIGURE 2. Topography and geology of middle Huon and lower Picton valleys.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

He considered that the ice cap stage was succeeded by later stages when valley and cirque glaciers were present on Mount Anne, Mount Mueller, the Frankland, Arthur, Weld and Snowy ranges, but he does not record any specific evidence of glaciation from the middle Huon valley. Derbyshire *et al.* recorded cirque moraines of late Last Glacial age enclosing lakes Picton and Riveaux and some of the small tarns east of the South Picton Range. It was also suggested that an older cirque glacier had occupied the head of Winking Creek northwest of Mount Picton. Although multiple glaciation was tentatively suggested for the upper Huon valley and Mount Picton area of southern Tasmania no glacial evidence was known from the middle Huon or Picton valleys. Also, no deposits containing organic remains were known prior to the present study.

The geology of this region has never been systematically mapped and the rock types are known only in broad outline. Most of the upper Huon valley is underlain by unmetamorphosed quartzites of Precambrian age. These first crop out about 3 km west of Blakes Opening (figure 2). At Blakes Opening Precambrian dolomite with agate crops out in the bed of the Huon and on Red Rag Scarp to the south (Hughes 1957). Most of the high ground south of the Huon, including the summits of Mount Picton and Mount Riveaux, is formed of Jurassic dolerite. Further south the South Picton Range is composed mainly of dolerite with the eastern slopes and most of the Picton valley underlain by Permian mudstones. North of the Huon, the Gallagher Plateau consists of Precambrian quartzites while the eastern part of the Manuka valley and the Weld Range is formed in Jurassic dolerite. At Tahune Bridge Permian mudstones occur locally on the floor of the valley.

The weathered till deposits and outwash gravels found at Blakes Opening are overlain by organic-rich fluviatile silts and sands, that contain abundant wood and charcoal, and by alluvial fan gravels. The organic constituents permit the dating and establishment of a late Quaternary stratigraphy at this site. Because of this, the age relationships of the older and younger landforms and deposits of the region can be more reliably determined than was possible previously. There is evidence for a pre-Last Glacial glaciation of the valleys separated from a late Last Glacial age cirque glaciation by a long interval during which strong chemical weathering occurred. There is also evidence that the organic rich fluviatile deposits, which contain both Wet Sclerophyll and Temperate Rain Forest floral assemblages, were deposited during the early and middle part of the Last Glacial Stage, and that the large alluvial fans were mainly formed during the late or maximum part of the Last Glacial Stage. It is the purpose of this paper to present and evaluate the stratigraphic, sedimentary, palynologic and ^{14}C data from the Blakes Opening site, to interpret the landforms and deposits of the local area in the context of this stratigraphic framework, and to indicate the possible wider significance that the sequence of deposits has for the study of late Quaternary glaciations and environments in Tasmania and in the mid-latitudes of the southern hemisphere.

2. Geomorphology and stratigraphy

The topography at Blakes Opening is characterized by a series of dissected north–south trending morainic ridges which extend from the foot of Red Rag Scarp to the south bank of the Huon River east of Clearwater Creek. The ridges vary from 10 to 30 m in height, have slopes of 5°–25° inclination, contain several almost enclosed peat floored depressions, and are composed of a complex of quartzite and agate-rich till, gravels, sands and silts which were deposited in association with the front of a former valley glacier. Although some of the original depositional morainic topography is still preserved in largely undissected form, the lower slopes have been dissected by minor streams. These have flat floored channels that grade to several large alluvial fan surfaces which coalesce to form the broad terrace south of the Huon River.

An extensive section (figure 4) in the river cliff below the shelter hut revealed a complex sequence of till with associated dolerite erratics and laminated silts, outwash gravels, fluviatile sands and silts with organic-rich deposits, and alluvial fan deposits. The stratigraphy is as follows from the river bed to the surface:

(i) The local rock is a greyish white (N 8/0) coloured Precambrian dolomite with abundant lace patterned agate. It is exposed in the river bed beneath the section and for 100–200 m downstream.

(ii) The lowest Quaternary deposit is from 1 to 3 m in thickness and consists of a variety of till deposits with associated laminated silts and dolerite erratic blocks (figure 3, plate 1). The character of the deposits was best seen between 100 and 120 m on the section shown in figure 4. At the base there was 0.5 m of angular fragmental lace agate detritus with a sandy matrix. This fractured gravelly deposit has the character of a deformation till (Dreimanis 1976) and is overlain by 1–2 m of light olive grey (5GY 7/1) coloured clay till (Standard Soil Color Chart 1965) which when oxidized alters to a yellow-orange (7.5YR 7/8) colour. This till has a field pH of 4.5 and contains large blocks of Jurassic dolerite, rounded to subangular ice-smoothed boulders and pebbles of quartzite, sandstone and occasional lace agates. The siliceous rocks are unweathered but all the dolerites up to 30 cm size are completely chemically decomposed and occasional larger blocks of 1–1.5 m diameter have been totally altered. The till also contains a small proportion of decomposed dolomite pebbles from which the calcium and magnesium carbonate content has been completely removed. Samples of weathered dolomite (figure 4, location 1) and weathered dolerite (location 2) were analysed by X-ray diffraction which revealed a very strong quartz peak for the dolomite and a very strong kaolinite peak with a trace of quartz for the dolerite. There were no other significant constituents in either sample.

The till matrix contains more clay (33.8 %, table 1) than silt (18.8 %) or sand (26.7 %). The strongly weathered dolerite and dolomite cobbles indicate that part of the clay matrix is of secondary origin and has resulted from weathering of the larger clasts in the till within the zone of groundwater fluctuation. The heavy silty-clay matrix has itself assisted the chemical decomposition of the larger clasts by its retention of moisture.

A fabric analysis (Curray 1956) of the A-axes of elongated pebbles between 2–5 cm size was carried out in the field. The results showed a preferred mean orientation of 30° with a magnitude of 50% which when tested by χ^2 is significant at the 99.9% level. This strong pebble fabric is not oriented in the direction of ice movement but is a transverse fabric which approximately coincides with the alignment of the adjacent moraine ridges and is almost at right angles to the eastward direction of ice movement through the middle Huon valley. The direct association of this till with beds of laminated meltwater silts up to 0.5 m in thickness with individual laminae 2–5 mm thick, and with small gravity faults which truncate the laminated beds suggests that in was probably formed as meltout or flow till (Boulton 1972; Dreimanis 1976), the faults indicating collapse due to the melting of ice. Since the till has probably been affected by collapse, and possibly also by flowage during its deposition, the transverse fabric determined clearly relates to some secondary factor and not to the direction of ice flowage.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

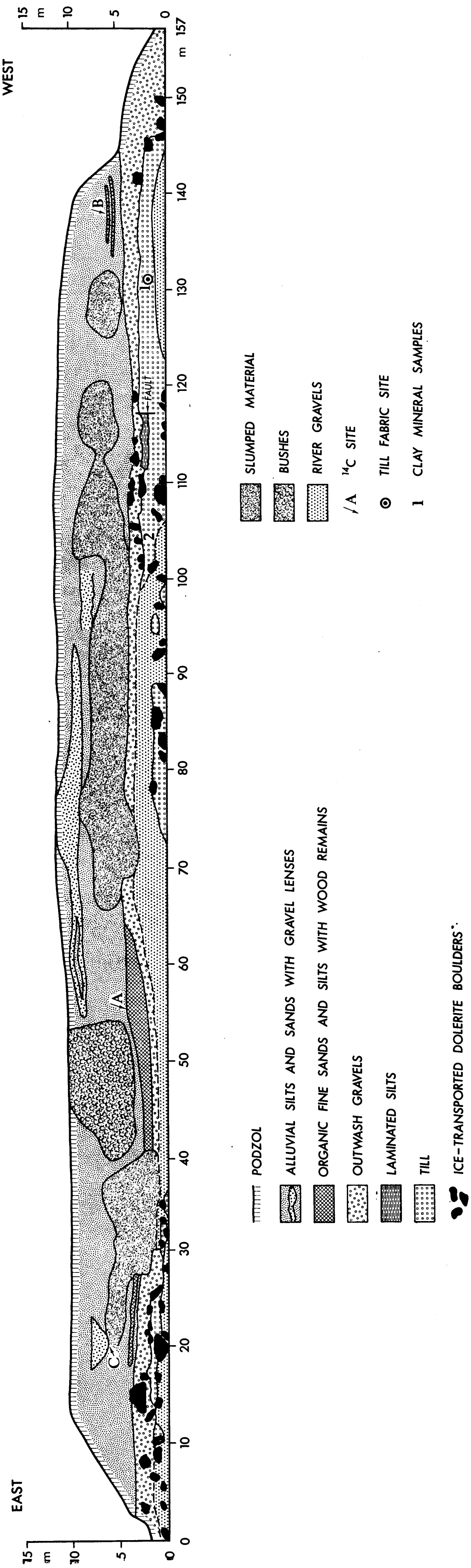


Figure 4. Riverbank section at Blakes Opening. ^{14}C samples D, E and F were located in sequence below A.

TABLE 1. GRAIN SIZE DISTRIBUTIONS OF QUATERNARY SEDIMENTS IN THE MIDDLE HUON AND PICTON VALLEYS

sample and location	cobbles and large pebbles (> 1 cm)	granules and small pebbles (1 cm–2 mm)	very coarse sand (2–1 mm)	coarse sand (1–0.5 mm)	medium sand (0.5–0.25 mm)	fine sand (0.25–0.125 mm)	very fine sand (0.125–0.0316)	silt (0.0316–0.0039 mm)	clay (< 0.0039 mm)
Blakes Opening, till	6.6	14.0	5.7	5.1	4.5	3.5	7.9	18.8	33.8
Blakes Opening, alluvial gravel	52.5	45.0	0.5	0.3	0.3	0.2	0.2	0.4	0.6
Blakes Opening, alluvial sands	10.3	9.0	0.7	0.6	6.0	27.6	20.4	11.2	14.2
Blakes Opening, alluvial silts	—	—	0.1	0.2	1.3	6.4	31.6	41.0	19.3
Farmhouse Creek, till	—	0.2	0.48	1.6	5.6	9.2	21.2	28.9	30.8
High Camp, till	4.6	15.3	6.2	5.0	5.5	5.1	11.7	24.8	21.3

The A-axes of pebbles from an oriented block of till were measured using a goniometer. The results showed a strong primary mode in the direction 285–105° with a secondary mode in the direction 335°–155°. The primary mode lies at right angles to the local slope direction of 10°, the direction of minimum orientation of long axes, and 15° from the west–east axis of the valley (E. Derbyshire, personal communication). This analysis supports a generally west to east ice flow in the valley. Its considerable deviation from the mean direction of the field analysis emphasizes the probable complexity of processes involved in deposition of the till.

Locally between 100 and 105 m on figure 4 a deposit of 0.5–1 m of angular quartzite and agate blocky till with very little matrix overlies the meltout or flow till. The upper bed has the character of a supraglacial till that has lost most of its matrix by eluviation during ice ablation. It is closely associated with many large dolerite boulders of 1–3 m diameter which occur on the surface of the till and within the base of the overlying quartzite outwash gravels. The dolerite boulders were transported to the site by ice and are currently being concentrated on the bed of the Huon River by erosion of the till deposits and outwash gravels. The largest boulders measure $4.5 \times 3 \times 1.8$ m^3. Despite the frequent occurrence of floods of over 10 m height above normal flows these blocks are not presently moved by the river.

(iii) Extensive fluvioglacial gravels between 1 and 5 m in thickness directly overlie the till deposits and locally have a lag horizon of ice-transported dolerite boulders at their base. The bulk of the outwash gravel consists of white, yellowish-brown and pinkish coloured moderately rounded quartzites of 5–50 cm in diameter (figure 5, plate 1). The outwash cobbles are imbricated upstream which indicates that the meltwaters flowed eastwards through the Huon valley. They occur extensively in adjacent sections for at least 3 km upstream and downstream of the site. The surfaces of the dolerite boulders are weathered to 1–3 cm depth, but because of the porosity of the gravels the dolerite is much less weathered than in the underlying till. The high quartzite content, the absence of dolomite and the scarcity of agate in the outwash gravels shows that these deposits were transported to the site from further west in the Huon and were not derived from the strictly local rocks. Erosion of these quartzite outwash gravels is supplying the present coarse bedload of the Huon River which is slowly transported downstream and in several places (figure 4) is redeposited over the older outwash gravels downstream from the site.

(iv) The contact between the outwash gravels and the overlying fluviatile organic-rich sands and silts is very sharp at A (figure 5, plate 1), but at B and between 20 and 30 m on figure 4 unweathered river gravels and sands overlie uncomformably the outwash gravels and underlie the organic beds.

The organic-rich beds in the basin shown at A vary from brownish grey (10YR 6/1) and greyish yellow (10YR 5/2) medium grained sharp river sands with granules, and brownish black (10YR 2/2) organic fine sands and silts with compressed wood fragments, branches and locally abundant charcoal below 595 cm (figure 3), to predominantly greyish yellow brown (10YR 5/2) silty sand and clayey sand with yellowish brown (10YR 5/6) mottles and abundant fragmental charcoal above 595 cm. That the lower fluviatile sands and silts began to accumulate in the still waters of a backswamp in a forested environment is proven by the presence of *Myriophyllum* in the lowest three pollen spectra of profile A and by the presence of fossil tree stumps in growth position on the surface of the outwash gravels near the eastern end of the section.

The boundary between the lower fluviatile gravels, sands and silts deposited by the Huon

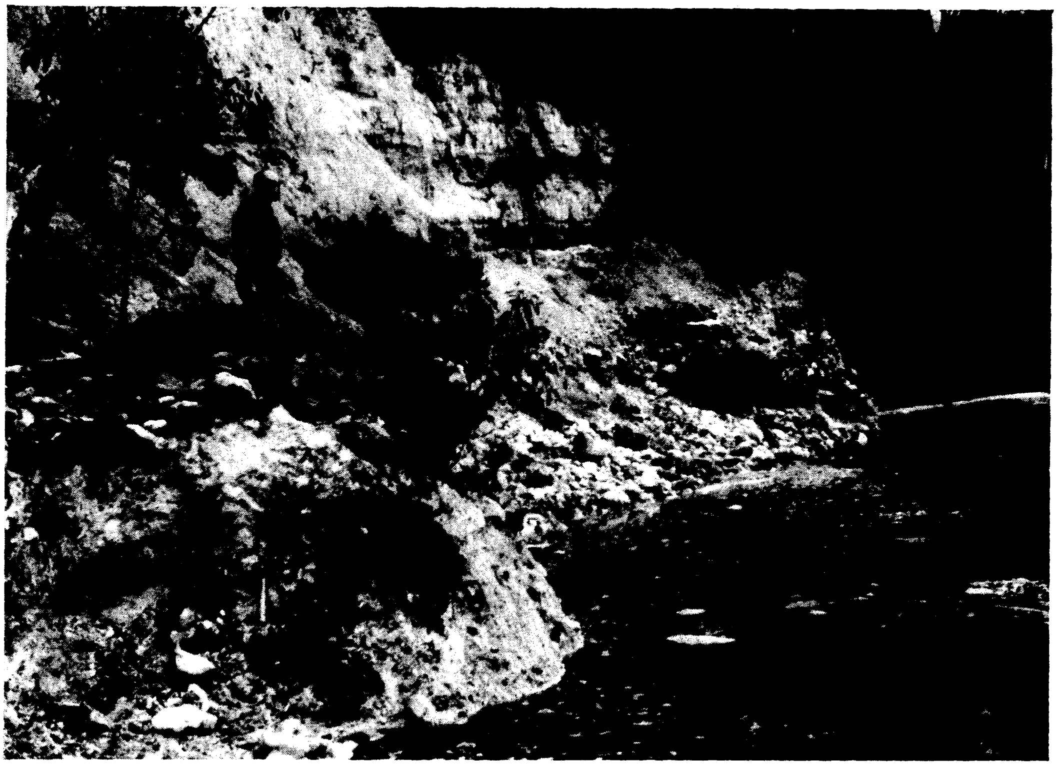


FIGURE 3. Part of the riverbank section at Blakes Opening showing weathered till deposits and a dolerite erratic in the foreground, and outwash gravels overlain by fluviatile gravels and sands containing the organic horizons of profile B in the background.

FIGURE 5. The sharp unconformable junction between the coarse quartzite outwash gravels and the overlying organic-rich silts and clays 10 m east of profile A.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

and the predominantly overlying alluvial fan gravels, derived by erosion from the Blakes Opening moraines, is difficult to determine because of slumping of the section and because the fluviatile terrace deposits grade up into the alluvial fan gravels. The higher beds of the former interdigitate with the lower beds of the latter which constitute most of the upper 3–5 m of the section. The interdigitation of the deposits demonstrates that the terrace was mainly constructed by fluvial deposits derived contemporaneously from different sources.

(v) The alluvial fan deposits are unweathered and consist predominantly of yellowish brown (10YR 5/6) silts (41 %, table 1) with sporadically distributed charcoal. The silts contain much fine sand (31.6 %) and substantial clay (19.3 %). There are only occasional granules and pebbles. The deposits are massive, are locally gleyed, exhibit yellow brown to orange brown mottles, have a pH of 4.5–5, and crack on drying out. Some of the beds consist of yellowish brown alluvial sands with about 55 % sand, 19 % pebbles and granules, 11 % silt and 14 % clay (table 1). The pebbles in the sample are of angular to subrounded form, consist of grey agate and quartzite, and vary from 7 to 31 mm in length. Cross sections of channel fills of alluvial gravels with very little matrix occur locally. Their pattern demonstrates the radial distribution from the SSW of the alluvial fan deposits onto the accumulating terrace. The gravels consist almost entirely of subrounded agate and quartz with occasional fragments of completely weathered unidentifiable rocks.

The pebble content of the sand and gravel lenses within the alluvial deposits indicates derivation from a quartzite and agate source. This mixed quartzite and agate lithology, with no unweathered dolerite pebbles, is consistent with the interpretation that they were derived by erosion of the morainic deposits at Blakes Opening after these deposits had been affected by a long period of chemical weathering.

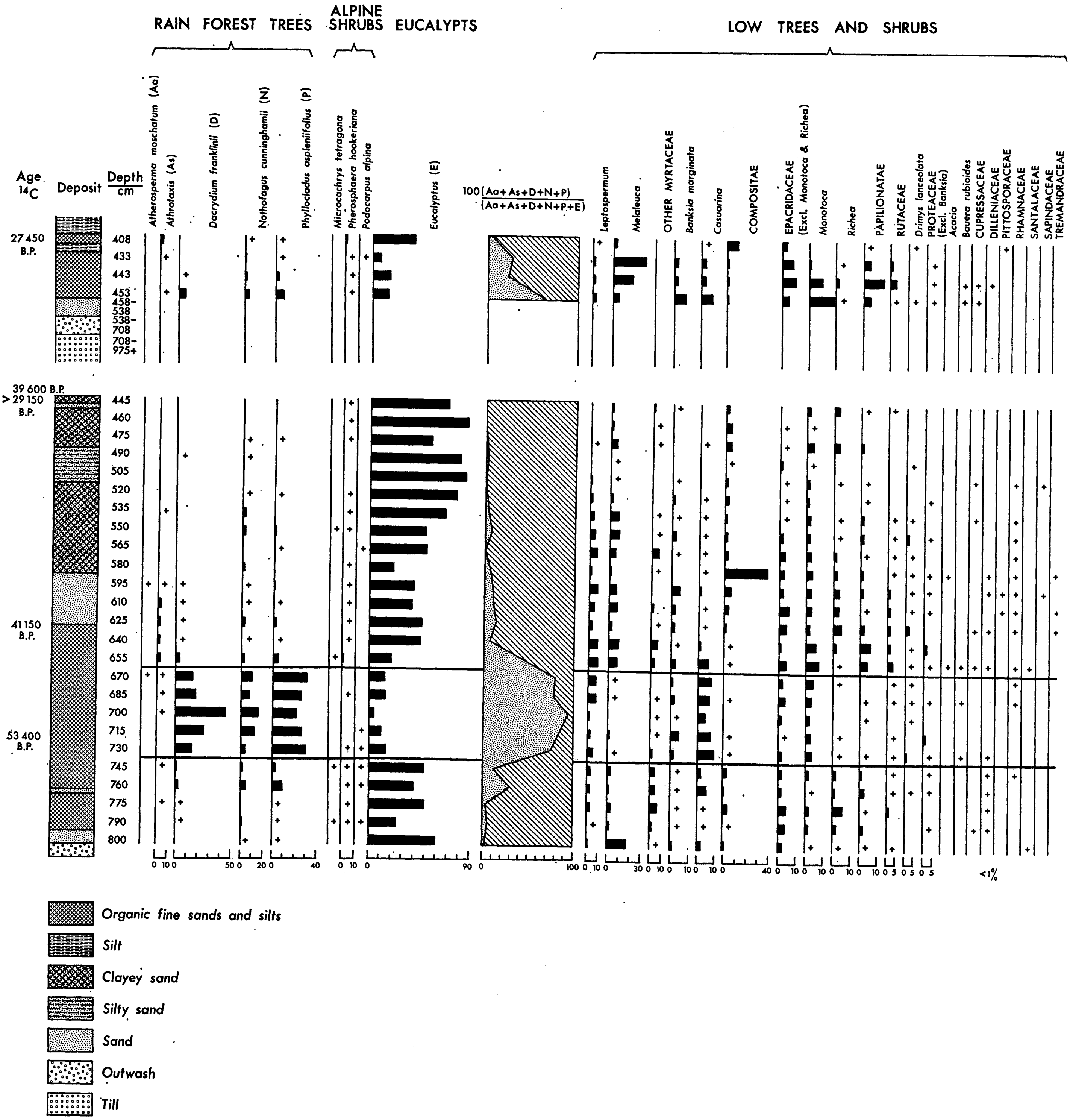
(vi) The soil profile on top of the section is a moderately developed iron podzol of 0.5 m depth.

3. Pollen

The organic rich fluviatile deposits were sampled for pollen at 15 cm intervals between 445 cm depth and the top of the quartzite outwash gravels at 800 cm depth at site A. Samples were also taken at 408 cm and between 433 and 458 cm in a short profile at site B. The pollen samples were prepared by the Faegri & Iversen technique (1964) and relative counts based on a sum of 300 grains of all tree, shrub and herb taxa were made. As there was not adequate reference material for identification of fern spores these were not counted. Although the distinctive spore of the treefern *Dicksonia antarctica* was noted as traces not exceeding 1 % on several horizons it was arbitrarily excluded from the sum. The taxonomic nomenclature follows Curtis (1956, 1963, 1967). The results are shown in the relative pollen diagrams of figure 6.

There is a marked contrast in the present vegetation at Blakes Opening between the higher and drier south bank terrace formed on alluvial and outwash gravels and the lower and wetter point bar and backswamp depressions of the northern side (table 2). On the southern terrace the tall open forest (Specht 1970) is dominated by *Eucalyptus obliqua* (85.2 %) with *Acacia mucronata* (5.8 %) and *Phebalium squameum* (3.5 %) as important subsidiary components. *Monotoca glauca*, *Melaleuca squarrosa*, *Leptospermum scoparium*, *Ziera arborescens*, *Bauera rubioides* and *Banksia marginata* occur in small quantities up to 1 % relative cover.† *Gahnia grandis* is the most important ground layer species. On the low ground of the northern bank *Eucalyptus obliqua* was

† Measurement of basal area at 1 m height was taken to represent the relative cover.



reduced to 45% with abundant *Pomaderris apetala* (22.4%), *Acacia dealbata* (14.1%), *A. melanoxylon* (2.8%), *Nothofagus cunninghamii* (8%), and *Atherosperma moschatum* (5.9%). *Phebalium squameum*, *Anopterus glandulosus* and *Dacrydium franklinii* occur in small amounts. *Dicksonia antarctica* is important in the understory, but this species is not included in the calculation of representation factors or *R*-values as it was excluded from the pollen sum.

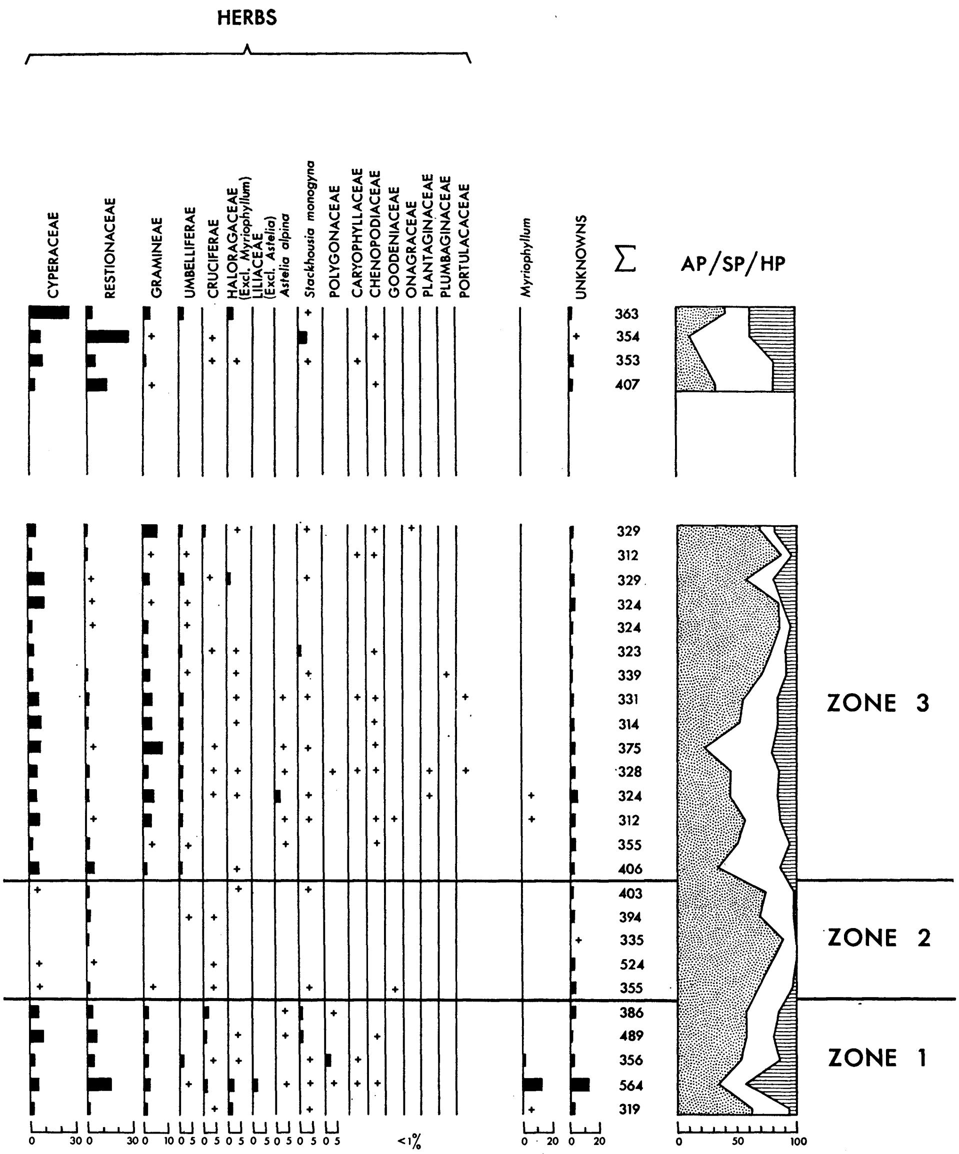


FIGURE 6. Pollen diagram for profiles at sites A and B.

The validity of the relative pollen analysis for fluvial deposits in a forested environment as discussed here depends on many factors of which the chief are: first, that the airfall and transported pollen from the catchment is reasonably representative of the local area pollen rain for the time of deposition of the sedimentary horizon concerned; secondly, that there has been non-selective preservation of the pollen; and thirdly, that the pollen percentages reflect the composition of the vegetation in the local area. Although it is recognized that alluvial deposits may contain significant quantities of transported, eroded and derived pollen it has also been shown that the pollen assemblages obtained from surface alluvial sediments can closely reflect that of adjacent terrestrial vegetation assemblages despite water transport (Grichuk 1967). The low concentration of pollen and relatively high numbers of eroded grains on horizons 445, 505, 535, 580, 595, 775, 790 and 800 cm depth in profile A, and on horizons 408 and 443 cm depth in profile B suggests a significant input of transported and derived pollen in these horizons. The high concentration and good preservation of pollen on all other horizons indicates that the major part of the pollen input is probably of local vegetation origin and that it accumulated with the fine organic sands and silts that constitute the backswamp deposits.

As there are no studies that consider the relationship between vegetation composition and pollen rain in Tasmania, the local vegetation of the south bank and the north bank was measured to relate the relative cover to the modern pollen rain for the purpose of determining *R*-values (Davis & Goodlet 1960; Davis 1963, 1969) for guidance in interpreting the pollen diagram. The method used was to measure the 'basal areas' at 1 m height of the four nearest trees or shrubs in the forest in each quadrant from surveyed points located on a 10 m square grid over the area. At each point a small surface litter/soil sample was taken for pollen analysis. The samples from the south bank and north bank were analysed separately to give independent *R*-values (table 2).

Table 2. Some *R*-values for Blakes Opening

	South Bank			North Bank		
	veg. (%)	pollen (%)	*R*	veg. (%)	pollen (%)	*R*
Rainforest Trees						
Atherosperma moschatum	—	—	—	5.9	0.4	0.06
Dacrydium franklinii	—	0.3	—	†	0.4	—
Nothofagus cunninghamii	—	3.2	—	8.0	4.2	0.52
Phyllocladus aspleniifolius	—	0.6	—	—	0.8	—
Eucalyptus obliqua	85.2	15.3	0.18	45.0	43.6	0.97
Low trees and shrubs						
Leptospermum scoparium	0.6	0.6	1.0	—	—	—
Melaleuca squarrosa	0.9	2.2	2.4	—	0.8	—
Acacia spp.	5.8	5.4	0.93	16.9	0.8	0.3
Anopterus glandulosus	†	—	—	0.43	0.38	0.9
Monotoca glauca	1.0	36.3	36.3	—	—	—
Pomaderris apetala and elliptica	—	1.3	—	22.4	40.8	1.82
Rutaceae *Phebalium squameum and Ziera arborescens*	3.6	19.8	5.5	1.0	3.4	3.4
Cyperaceae *Gahnia grandis*	2.8‡	0.6	0.21	0.3‡	0.4	1.2

† < 0.1%.
‡ Percentage cover of *Gahnia grandis* divided by an arbitrarily chosen factor of 10.

Most of the occasionally represented pollen species had variable *R*-values and are of little help in interpretation. Pollen of *Dacrydium*, *Nothofagus* and *Phyllocladus* may be represented in small quantities without being present at the site. The *R*-values for *Eucalyptus* vary from 0.2 to 1.0 and the variation seems to be related to the nature of the understory trees and shrubs. On the south bank, where *Acacia*, *Monotoca* and *Phebalium* form a dense understory, *Eucalyptus* is markedly under-represented with *Monotoca* and *Phebalium* being strongly over-represented.

On the north bank, where the understory consists predominantly of *Pomaderris* and the tree-fern *Dicksonia antarctica*, *Eucalyptus* has an *R*-value of 0.97 and is proportionately represented even though *Pomaderris* is over-represented. The limited data suggest that the contribution of the canopy species *Eucalyptus obliqua* to the pollen rain is reduced where a thick understory of shrubs and lesser trees is present and that even with a relatively open understory *Eucalyptus* is unlikely to be over-represented in the diagrams. Although it is possible to adjust relative pollen diagrams by using the *R*-values (Davis 1963; Andersen 1973) the high forest component and relatively low herb component in the pollen diagrams indicates that the composition of the local vegetation is more likely to be adequately represented than would be the case in more open environments in which relatively large non-local components frequently occur. The presence of only one *Eucalyptus* species and the more restricted range of species in the modern forest than in the fossil assemblages makes recalculation of the diagrams by using *R*-values impossible. For this reason no adjustment of the relative diagrams has been made but the knowledge of the local relative representation of modern groups, that are apparently analogous to some of the fossil groups, is used for interpreting the diagrams.

The pollen diagram for profile A can be divided into three zones, two of which are dominated by *Eucalyptus* species; the other by Temperate Rain Forest species (figure 6). In zone 1 *Eucalyptus* varies from 24 to 60 % and is associated with undershrubs belonging mainly to the Myrtaceae and Epacridaceae. The presence of *Myriophyllum* between 775 and 800 cm indicates that deposition commenced in standing water on the backswamp and the Cyperaceae and Restionaceae components are indicative of a local damp habitat. The rainforest and alpine pollen content is small and indicates that these species are unlikely to have been present in any quantity at the site. The rainforest pollen was probably transported from further west and the alpine pollen probably originated on the adjacent mountains. The composition suggests that open *Eucalyptus* forest (Wet Sclerophyll) was the regional low ground vegetation during this time. The moderate values of shrub and herb pollen suggest that fire openings probably occurred within the forest.

Zone 2 is represented by a marked decrease in *Eucalyptus* to 5–17 % with a marked increase in rainforest species to 49–82 % and *Casuarina* to 4–9 %. Although the decrease of the former and increase of the latter groups may appear to be in part statistical they are not primarily so, because above 760 cm pollen is very abundant in the sediments but between 775 and 800 cm it is sparse. Thus, the increase of pollen input occurs at the lithological boundary and prior to the main expansion of the rainforest species which occurs within the sedimentary unit. The sharp reduction in *Eucalyptus* is accompanied by the marked reduction of some shrubs and most herbs. The almost complete exclusion of a herbaceous ground flora and reduction in understory shrubs, with high values for the rainforest species, indicates that the flora of the valley was predominantly rainforest during this time and that fewer openings existed than during zone 1 times. From the pollen curves it is noted that the peak values for *P. aspleniifolius* bear an inverse relationship with the peak values for *D. franklinii* and *N. cunninghamii*. This relationship indicates that *P. aspleniifolius* increased rapidly relative to *D. franklinii* and *N. cunninghamii* as rainforest developed, was relatively suppressed as *D. franklinii* and *N. cunninghamii* became dominant, and increased relatively again as *D. franklinii* and *N. cunninghamii* declined before the rainforest was replaced by open *Eucalyptus* (Wet Sclerophyll) forest.

At the commencement of zone 3 rainforest species decrease to less than 12 %, *Eucalyptus* species increase rapidly to 20 % and then maintain percentages between 38 and 87 throughout the remainder of the profile, except on horizon 580 cm where the value is relatively depressed to 21 % by the very high value of 38 % for Compositae. During the first half of zone 3 values for the low trees and shrubs of the understory are quite high but these decline after the maximum is attained on horizon 580 cm to low values above 520 cm. Herbs also expand at the commencement of zone 3 and maintain values between 6 and 20 %. If the *R*-values of the modern pollen rain are accepted as a guideline for interpretation, then the association of low values of *Eucalyptus* during the first part of zone 3 with high values of *Monotoca*, Rutacaea and *Melaleuca*, as well as other understory shrubs, suggests that the input of *Eucalyptus* pollen may have been relatively reduced by over-representation of the understory trees and shrubs, but the reduction in understory trees and shrubs during the later part of the zone would have given a relatively increased representation of *Eucalyptus*. If, as seems to be the case, *Eucalyptus* is not over-represented in the diagram then the lowland vegetation association that existed throughout the zone was an open *Eucalyptus* (Wet Sclerophyll) forest with a much thicker understory component during the earlier part than during the later part.

The marked rise of *P. aspleniifolius* prior to the maximum development of the Temperate Rain Forest dominant species *D. franklinii* and *N. cunninghamii* is notable. The expansion of *P. aspleniifolius* before the rise of *N. cunninghamii* has been observed also at the base of the Temperate Rain Forest succession in a pollen diagram near Lake Margaret in western Tasmania where it clearly reflects a climatic change from alpine to relatively warm humid conditions. The pollen evidence suggests that *P. aspleniifolius* may be a 'pioneer' rainforest species which indicates the occurrence of warm humid conditions earlier than the slower spreading and growing 'climax' species (Colhoun, unpublished).

Short though the zone may be, the relationship between the rainforest species indicates that the biostratigraphic changes at Blakes Opening probably represent the occurrence of an interstadial climatic oscillation. Before this interpretation be accepted it is necessary to consider other possibilities.

It could be argued that the different pollen assemblages of zones 1, 2 and 3 reflect different local habitats, and that the variation between the greater percentage of rainforest pollen in the surface samples from the low-lying point bar and backswamp deposits of the north bank and the surface samples of the higher, drier, West Sclerophyll forested south bank demonstrates such local variation. However, the pollen percentages for the rainforest species between 670 and 730 cm depth are very much higher than for any of the surface samples. This suggests that even if geomorphological changes in the habitat may have partly contributed to the vegetation changes they were unlikely to have produced as great a change as recorded, and that rainforest vegetation was more generally distributed in the area during zone 2 times than it is today.

One of the most important ecological factors that affects the distribution of Temperate Rain Forest and Wet Sclerophyll forests in Tasmania, and the extent of the ecotone, is the frequency of firing. The middle Huon valley occurs within the climatic-ecological zone of Temperate Rain Forest which Jackson (1965, 1968) suggests requires rainfall in excess of 1032 mm per annum with summer monthly totals of over 50 mm, and attains a climax in areas of over 1420 mm. However, the area is presently extensively occupied by tall open *Eucalyptus* forest maintained by firing. While it is possible that the expansion of the rainforest of zone 2 could have been facilitated by the occurrence of a long period when firing was very infrequent, the abundance of charcoal on most horizons within the fluvial deposits and in the overlying fan silts and sands does not indicate the occurrence of any period of infrequent firing followed by a period of increased firing which might have allowed replacement of the rainforest by *Eucalyptus* forest.

In this region, which has a precipitation gradient that declines very steeply eastwards into the lower Huon valley, it is much more likely that during the Last Glacial Stage, when temperatures were markedly colder than present, a climatic trend towards wetter, warmer conditions followed by a trend towards drier, colder conditions would cause the ecological balance to sequentially favour a change to rainforest followed by a reversion to *Eucalyptus* forest than either changes of the local habitat or of frequency of firing.

The pollen spectra obtained from profile B were taken from deposits which lie on a higher and younger level than any of the deposits analysed in profile A. Except for the uppermost horizon, the spectra are dominated by low trees, shrubs and herbs with only 8–38 % of *Eucalyptus* spp. and 1–17 % of rainforest species. The high shrub values of *Melaleuca*, Epacridaceae and Papilionatae with significant quantities of Cyperaceae and Restionaceae indicate that extensive areas of scrub and damp sedgeland probably occurred in the valley as a vegetation mosaic with areas of open *Eucalyptus* forest or woodland. Although the pollen spectra of profile B are characterized by a greater percentage of rainforest types than during most of zone 3 in profile A the deposit is not thick enough and the pollen changes not complete enough to make any interpretation of changing vegetational conditions during this time.

4. Dating

Six samples were submitted for ^{14}C dating. The first was charcoal from 445 cm depth that occurred in the uppermost organic-rich horizon of the fluviatile silty-fine sand in profile A. This sample was assayed at > 29150 B.P. (GaK-5587) but it was not an infinite determination. A second charcoal sample from this horizon was submitted to Groningen University for assay in a large counter. The assay was finite and gave a radiocarbon age of 39600 ± 1000 B.P. (GrN-7695). Further samples of wood from 625 to 30 cm and from 720 cm depth were similarly assayed at 41150 (+1450, −1250) B.P. (GrN-7999) and 53400 (+1700, −1400) B.P. (GrN-8277) respectively. In addition a sample of charcoal collected from 408 cm in the surface horizon of the organic deposits of profile B gave an assay of 27400 ± 2900 B.P. (GaK-5588), and a sample of charcoal from alluvial silts below the channel gravel filling at C gave an assay of 29340 (+3080, −2220) B.P. (GaK-5589).

The ^{14}C dating indicates that the surface iron podzol developed on a stable forested surface during the Holocene, and the date of 29340 B.P. from the alluvial silts at site C shows that accumulation of the alluvial fan gravels had commenced by this time. The stratigraphy and unweathered character of these deposits strongly suggests that the bulk was formed during the later part of the Last Glacial Stage when the effects of strong fluvial action, accentuated by snowmelt, eroded the till and stratified drift deposits of the morainic ridges at Blakes Opening. The date of 27400 B.P. from the surface of the organic-rich fluviatile sands and silts in profile B shows that organic-rich fluviatile deposits laid down by the Huon River continued to accumulate at least for a while after the alluvial fan gravels began to form.

The dates of 39600 B.P., 41150 B.P. and 53400 B.P. indicate that the accumulation of the organic sands, silts and clays occurred in a forested environment over a long period during the middle and early part of the Last Glacial Stage. The overlap between the 39600 and 41150 B.P. assays at one standard error indicates that sedimentation of the sands, clayey sands and silty sands in the upper part of the fluviatile deposits was probably much more rapid than the deposition of the organic fine sands and silts of the lower part. Thus, the pollen records of zones 1 and 2 probably have time spans equal to or exceeding that of zone 3. Viewed in temporal terms the rainforest climatic oscillation may not have been as brief as suggested by the mere 70 cm of sediment. The radiocarbon dates support a probable age of over 41150 B.P. to somewhat more than 53400 B.P. for this interstadial oscillation. Considering the possible range of error involved close to the limits of non-isotope enriched radiocarbon assays these determinations agree remarkably well with assays of 44700 ± 1500 B.P. (GrN-7690) and 48400 (+1900, −1600) B.P. (GrN-7691) at Pulbeena Swamp in northwestern Tasmania where cool, moist interstadial climatic conditions are inferred to be associated with the development of grassy *Eucalyptus* woodland between early and late Last Glacial age cold, dry grassland phases (Colhoun, Mook & van de Geer 1979). If, as seems reasonable, the *Eucalyptus* zones 1 and 3 at Blakes Opening correspond approximately with the Pulbeena grassland phases then zones 1 and 2 are of early and middle Last Glacial age and a broad tripartite division of the Last Glacial is suggested. Such a division is consistent with the widely-quoted marine O^{18}/O^{16} isotope record of Shackleton & Opdyke (1973) and with palynological and palaeosol evidence for a mid Last Glacial interstadial in the northern hemisphere (Dreimanis & Raukas 1975), although the authors consider that, because of the very limited nature of the Blakes Opening record, it may be premature to make such universal correlation.

5. Southern hemisphere comparisons

Unfortunately there are few terrestrial deposits of approximately the same age from similar environments in the mid-latitude regions of the Southern Hemisphere with which the organic deposits at Blakes Opening can be compared.

In South Island, New Zealand partial pollen records of late Last Interglacial (Oturian) age and late Last Glacial (Otiran; post *ca.* 23300 B.P.) age are known but there are no records of early and middle Last Glacial age (Suggate 1965; Suggate & Moar 1970; Dickson 1973).

In southeastern Australia an initial pollen record from Lake George near Canberra suggests that a cool temperate forest phase (zone D of Singh, pp. 371–2 in Bowler *et al.* 1976) occurred after approximately 50000 B.P. and may have lasted until *ca* 22000 B.P. This forest phase is preceded and succeeded by non-forest phases (Zones E and C). It could be considered a stratigraphic and climatic interstadial similar to the oscillation recorded at Blakes Opening but the dating is very tentative. Although the oscillations at both sites may be approximately of middle Last Glacial age the boundaries have not been dated closely enough to permit definitive correlation.

Heusser (1974, 1976; Heusser & Flint 1977) has described pollen sequences in Chile from organic-enriched sediments associated with glacial deposits from sections at Pan American Highway, Rió Ignao, Rupanco and Taiquemó. The major pollen change at Pan American Highway indicates grassland succeeded by forest dominated by *Nothofagus dombeyi* and a ^{14}C assay indicates an age of over 39000 a (I-4170 and I-5032). At Rió Ignao the pollen indicates a cycle of change from grassland through shrubland to a maximum forest phase of *N. dombeyi*, *Drimys* and Myrtaceae before a retrogression, shown by an increase of non-arboreal taxa, near the top of the deposit. A ^{14}C assay of 56000 (+2000, −1700) B.P. (Q-61) is presented as a minimal age for the forest phase. Heusser interprets the Pan American Highway section as representing part of the Last Interglacial and the Rió Ignao sections as an interstadial early in the Last Glacial Stage although the diagrams are very similar.

At Rupanco three pollen zones occur which are successively characterized by Gramineae–Tubuliflorae–Umbelliferae (Ll); *N. dombeyi*–Myrtaceae–Gramineae (L2); and Gramineae–Tubuliflorae (L3). Zone L3 is ^{14}C dated between 19450 ± 350 B.P. (I-5679) and 23750 ± 620 B.P. (I-5680) but there is a long hiatus between the lowest spectrum in this zone and the uppermost spectrum of zone L2 which is dated at 36300 ± 2600 B.P. (I-6564).

At Taiquemó the basal pollen zone (5) indicates a cool montane forest association dominated by *Nothofagus* with significant *Fitzroya* type and *Podocarpus nubigenus*. During this zone *Fitzroya*

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

increases and *P. nibigenus* decreases which suggests decreasing temperatures. A marked increase of Gramineae–Compositae in the succeeding zone (4) reflects greater cooling. The base of zone 5 has been ^{14}C assayed at 42700 ± 1200 B.P. (QL-1011) and an assay of 42400 ± 1000 B.P. (QL-1012) has been obtained from the lower part of the zone.

An enriched ^{14}C assay from Rió Ignao of 62600 (+1300, −1100) B.P. (QL-61) supports an early Last Glacial interstadial age for the forest phase and further work at Pan American Highway suggests that the forest phase there represented is still older than that at Rió Ignao (Heusser, personal communication). The dating of the Rupanco sequence strongly supports an interstadial interpretation for zone L2, and the date of 36300 B.P. for its upper spectrum points to a possible mid-Last Glacial age. Similarly, pollen zone 5 of the Taiquemó sequence may also represent an interstadial phase of mid-Last Glacial age.

Although Heusser emphasizes the difficulty of correlating such sections within Chile and clearly any wider correlation is still more difficult, nevertheless, the *N. dombeyi*–Myrtaceae forest oscillation in the Rupanco section and the *Nothofagus*, *Fitzroya* and *P. nubigenus* association in the Taiquemó section probably occurred about the same time as the Temperate Rain Forest oscillation at Blakes Opening. The question of whether or not these forest associations represent different local vegetational responses in far distant localities to a mid-Last Glacial interstadial climatic oscillation that occurred throughout Southern Hemisphere mid latitudes will only be answered when many more deposits of similar character have been discovered and analysed.

The strongly chemically weathered character of the dolerite boulders in the outwash gravels that directly underlie the organic sands, silts and clays at Blakes Opening, and the almost complete decomposition of the dolerite in the till, indicates that a long phase of weathering occurred after the ice retreated from the middle Huon valley before the unweathered organic-rich deposits accumulated. The simplest interpretation is that the phase of chemical weathering mainly represents the Last Interglacial Stage. However, it is not impossible, given the high degree of chemical alteration of the deposits and the relative brevity of moist, warm climatic conditions during the Last Interglacial, that a longer time span is represented. In either case the presence of the outwash gravels, the weathered till deposits and the moraines at Blakes Opening indicates a glaciation of pre-Last Glacial age. This glaciation probably correlates with the highly weathered surface glacial deposits of the middle part of the Forth valley (Paterson 1965) and may be of Penultimate Glacial Age or older.

6. Glaciation of the middle Huon and lower Picton valleys

The data described from Blakes Opening demonstrate that ice of pre-Last Glacial age occupied the middle part of the Huon valley. Although Lewis (1924) advocated multiple glaciation of the upper Huon valley to the west, Derbyshire *et al.* (1965) indicated that most of the ice was probably of late Last Glacial age. Since it is now known that the strongly weathered glacial drifts at Blakes Opening and in the Forth valley (Paterson 1965; Colhoun 1976) are old, it is possible to differentiate between highly chemically weathered pre-Last Glacial and the virtually unweathered Last Glacial age drifts in Tasmania.

The evidence to be described suggests that valley glaciers occupied the middle Huon and lower Picton valleys during an earlier glaciation and that only cirque glaciers occurred in the area during the Last Glaciation. The ice of the older glaciation appears to have been thicker and more extensive than the ice of the Last Glaciation. The maximum extent of the suggested

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

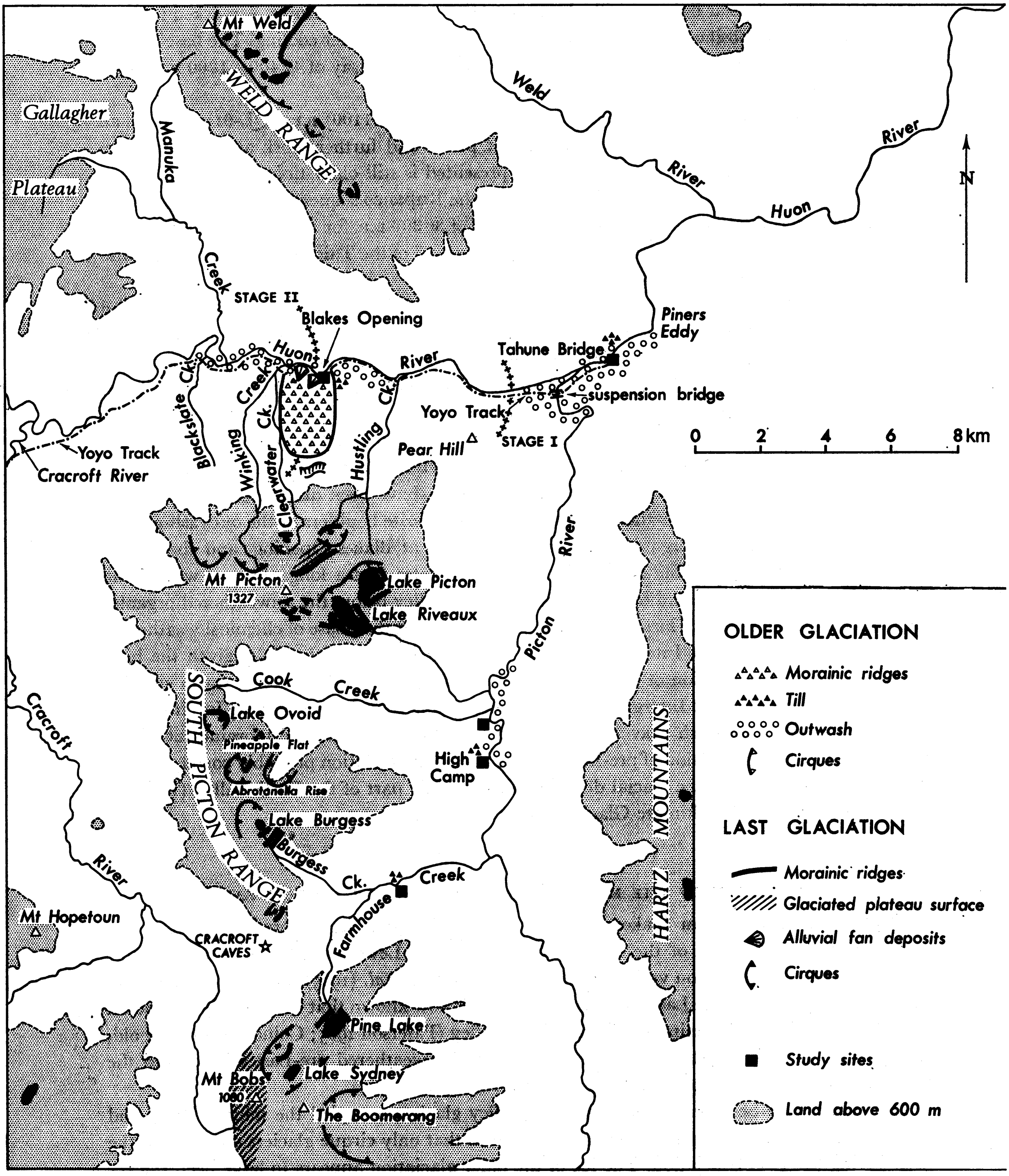


FIGURE 7. Glacial morphology of middle Huon and lower Picton valleys.

confluent lower Picton–middle Huon valley ice is not known but may have extended to Tahune Bridge (figure 7). The outwash terraces that occur east of the dolerite gorge between Pear Hill and the Weld Range, and the moraines at Blakes Opening indicate two stages of ice retreat in the middle Huon.

Upstream from Blakes Opening between 2 and 12 m of strongly imbricated, heavy calibre (2–50 cm diameter) outwash gravels form the discontinuous thick terrace deposits of both sides of the Huon. The matrix consists of medium-coarse sand and granules, is strongly oxidized and cemented with iron. These terraces have been traced as far as Blackslate Creek but certainly extend further west. Locally the gravels overlie strongly water eroded rock terraces, but there is no evidence of morainic materials or of older deposits in this part of the valley floor. The main source of ice that flowed eastwards past Blakes Opening was the Gallagher Plateau east of Mount Anne, off which ice flowed into both the Huon and Manuka Creek valleys. East of Manuka Creek the ice did not extend above 600 m, and did not submerge the Weld Range which has very thick dolerite screes on its southwestern slopes and tors on its summit ridge. Thick dolerite screes occur above Red Rag Scarp on the northern face of Mount Picton. These, and the large tor-like joint determined summits of both Mount Picton and Mount Riveaux, indicate that the ice did not exceed 600 m on the southern side of the valley. The small amount of dolerite compared to the quartzite and agate in the moraines at Blakes Opening indicates that the dolerite of Mount Picton contributed little to the glacial drifts which are composed mainly of dolomite from the valley floor and quartzites from the upper part of the Huon valley.

Local cirque and valley glaciers developed at the heads of Winking and Hustling Creeks on the northern slopes of Mount Picton above the limits of the middle Huon valley ice. These glaciers flowed northwards and probably became confluent with the Huon ice. But the ice which occupied the basin of North Lake and the small lake to the south may have remained as independent small cirque glaciers.

The surface of the main Huon ice must have declined steeply as it flowed eastwards into the narrow dolerite gorge between Pear Hill and the southeastern slopes of the Weld Range. The ice did not override Pear Hill and must have been contained within the valley below *ca.* 400 m. Downstream from the gorge to the junction of the Picton River an extensive terrace of outwash gravels occurs at 70 m and has a virtually horizontal surface. A lower terrace adjacent to the Huon is cut 10–15 m into the main terrace, and a higher gravel terrace remnant occurs above the main terrace at 75–77 m adjacent to the northern slope of Pear Hill. The terraces converge towards the narrow gorge which represents the apex from which they were discharged. It seems likely that the gravels were deposited and subsequently terraced rapidly during the glacial retreat, and that little modification of this part of the valley floor has taken place subsequently.

Between the suspension footbridge over the Picton River and Tahune Bridge the valley floor is 1–1.5 km wide. In this area deposits of coarse, predominantly quartzite, gravels occur as a thin (1–3 m) sheet overlying sporadically distributed till-like deposits that occur on eroded surfaces of Permian mudstones. A section in the outwash gravels 300 m southwest of Tahune Bridge shows that they have been very strongly weathered and the sandy matrix has been strongly cemented with iron and iron-pan horizons to 1–1.5 m depth. At the base of the gravels large blocks (1–2 m) of quartzite and dolerite occur. The surface of the dolerites is weathered to 2–4 cm depth and one of the blocks exhibits a P-form eroded by high velocity water flow. The surface of the gravel terrace is virtually undissected by subsequent erosion. Similar gravels extend northeast from Tahune Bridge to Piners Eddy but the terrace surface has been dissected by minor streams which have narrow valleys 1–3 m deep. Although the gravels in this section of the Huon valley exhibit many of the characteristics of outwash deposits, a glacial origin is difficult to prove as *in situ* till deposits have not been found.

Sections exposed on either side of the Huon at Tahune Bridge (figure 8) suggests that the older ice may have extended to this locality. On both sides of the river the weathered light grey Permian (5YR 7/1) sandy-siltstone has been locally shaven off and undercut by erosion. The siltstone is overlain by up to 5 m of a deeply chemically weathered yellowish-brown (10YR 5/6) coloured, sandy-clay deposit with a blocky subangular structure and moderately developed clay skins around the quartzite and dolerite cobbles. This deposit has a pH of 5.0. Dolerites of 0.3 m diameter show weathering skins of 2–3 cm depth and all dolerite pebbles < 10 cm in diameter are completely decomposed. Although no striated cobbles were found the deposit may represent an old weathered till.

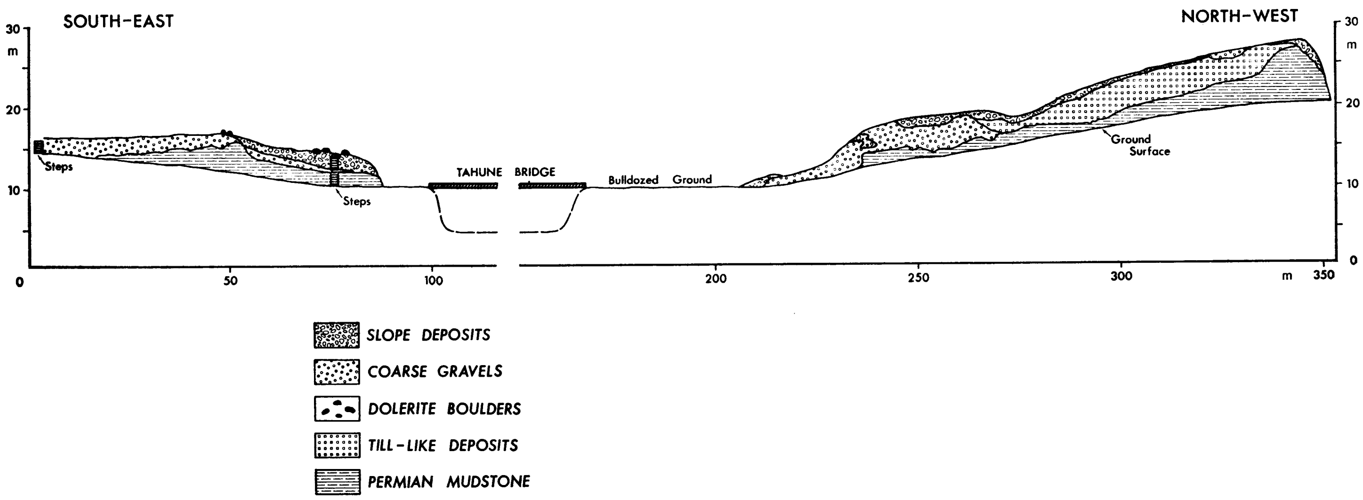


FIGURE 8. Section at Tahune Bridge, Huon valley.

Irregular terraced deposits of gravel occur adjacent to and locally above the weathered till-like deposit. The matrix of the gravels is bright yellowish-brown (10YR 6/6) in colour. The gravels vary from 1 to 25 cm in size, are subangular to moderately rounded, and are 95% quartzite. Some cobbles appear to have ice-smoothed surfaces that have been only minimally modified by water action. The 5% dolerite content is very strongly weathered, boulders having weathering skins of 2–3 cm depth and cobbles of < 10 cm diameter being totally decomposed. The matrix varies between medium sand and granules, is strongly oxidized and cemented with iron, and shows strong clay skins surrounding the cobbles. The surface of both the weathered sandy-clay deposits and quartzite gravels has been disturbed by solifluction processes and human activities which have produced strongly weathered bright reddish-brown (5YR 5/8) slope deposits of 1–3 m thickness. The 1.5 m dolerite boulders southeast of the bridge appear to have been ice-transported to the site like the 3–5 m dolerite boulders in the river bed east of the bridge.

Evidence for an older glaciation of the lower Picton valley has been found at three sites between Farmhouse Creek and the confluence of Cook Creek, and extensive gravel terraces extend north of Cook Creek as far as the narrowing of the floor of the Picton valley at grid reference 755202 on Sheet 8211 of the 1:100000 scale map (figure 7).

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Extensive till deposits occur in the south bank of Farmhouse Creek at 220 m. The till is from 1 to > 2 m in thickness, is light olive grey (2.5GY 7/1) in colour and becomes yellowish-brown (10YR 5/6) when oxidized. The till matrix has a pH of 4–4.5 and is very rich in fine sand (21 %), silt (29 %) and clay (31 %). The boulder and cobble content consists of approximately 80 % dolerite, 10 % quartzite and occasional weathered mudstones. Some of the quartzites are striated and many are faceted. Dolerites up to 0.5 m in diameter are completely weathered to clay and larger boulders have weathering rinds 2 cm thick. The whole floor of Farmhouse Creek is filled with large dolerite boulders up to 3–4 m long which have been derived from the till and are too large for the present stream to transport. Coarse quartzite and weathered dolerite gravels also occur in the banks of the stream. Locally both the till and outwash are overlain by 1–1.5 m of modern yellow brown alluvial fine sand and silt.

A section at High Camp (figure 7) on the west bank of the Picton shows a sequence of deposits the stratigraphy of which closely parallels that described for Blakes Opening. At High Camp till overlies Ordovician Gordon Limestone which is exposed in the bed of the Picton. It consists of 4 m of bright yellowish-brown (10YR 6/8), silt (25 %) and clay (21 %) rich till with numerous cobbles and small pebbles, and has a pH of 6. The till is compact and is strongly weathered with clay skins around the cobbles and pebbles. The cobble and pebble content consists mainly of quartzites with some weathered mudstones. Some cobbles were striated. A till fabric analysis gave a mean orientation of 355° with a magnitude of 56 % which when tested by χ^2 is significant at the 99.9 % level. If the deposit is a subglacially-deposited till and the fabric reflects the direction of ice movement then it suggests a northward flow of ice through the lower Picton valley towards its confluence with the middle Huon.

A 20 cm horizon of disturbed organic stained clay occurs on top of the till. The organic content is extremely low and the horizon did not contain any pollen. This horizon appears to result from perching of humic materials in the surface layers of the till. It is overlain by coarse quartzite gravels with some dolerites which have 1 cm thick weathering skins. These gravels appear to be outwash gravels and are overlain by 10 m of small subangular to subrounded quartzite gravels with weathered mudstones of 2–10 cm size. These deposits are light grey (5GY 8/1) in colour, have a silty matrix, a pH of 3.5–4, and locally show an openwork structure. These deposits closely resemble the alluvial fan deposits at Blakes Opening and may similarly be alluvial gravels of Last Glacial age.

Half a kilometre south of Cook Creek a 3 m section shows extensive outwash gravels overlying weathered laminated clays and Gordon Limestone which crops out in the river bed. The gravels consist of dolerite boulders 15–90 cm in size with a few quartzite cobbles up to 30 cm in diameter. One 80 cm dolerite boulder was striated and many of the dolerites and quartzites showed distinctly faceted forms. Some of the quartzites had surface chattermarks, and some of the large dolerites at the base of the section overlying the impermeable clay were completely chemically decomposed. Clay skins occurred around the cobbles and boulders, and the deposit had an iron-enriched weathered yellowish-brown (10YR 5/6) coloured sandy matrix. There was sharp unconformity with the underlying pale yellow (5Y 8/6) to bright yellowish-brown (2.5Y 6/6) clay which was sheared and contorted. The clay is locally laminated, is strongly weathered with a pH of 3, contains weathered mudstone fragments, and overlies Gordon Limestone. The clay is so highly weathered that it was difficult to determine its mode of origin. While it could have been deposited as englacial or supraglacial laminated sediments and therefore would probably be of similar age to the overlying gravels, the deposit may be of quite different origin.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

The evidence of the strongly weathered till and thick outwash gravels in the banks of the Picton River and Farmhouse Creek supports the interpretation that this area was glaciated by a broad valley glacier of pre-Last Glacial age. Some of the ice may have accumulated in the cirques on the eastern slopes of the South Picton Range but the main source was probably further south in the area of Mount Bobs and The Boomerang.

The deep armchair-shaped hollow between the east-trending arms of The Boomerang shows no evidence of having been occupied by ice during the Last Glaciation but was probably an important source area during the earlier glacial phase. The valley glacier in Farmhouse Creek appears to have had its primary source in the Lake Burgess cirque but ice from Mount Bobs probably also contributed.

Ice-abraded dolerite surfaces and moraine topography indicate that during the Last Glaciation the summit plateau of Mount Bobs had a carapace of ice, and that a valley glacier flowed towards the northeast as far as Pine Lake; a distance of 3.5 km.

Southeast of Mount Picton and east of the South Picton Range there are numerous cirque basins and many of these contain tarns bounded by steep morainic ridges. Lake Picton and Lake Riveaux are the largest and have steep headwalls that have been ice-eroded into the largely unglaciated summit. A cirque at the western head of Hustling Creek has a tarn bounded by a steep morphologically undegraded 30–40 m high moraine. At the breach in the moraine ridge an extensive fan of dolerite boulders of 0.5–2 m in size occurs, and represents the blocks that could not be removed by the meltwater that flowed northwards from the ice. This is the only cirque moraine on the northern side of Mount Picton which is undegraded and is certainly of Last Glacial age. On Mount Picton a ridge extends northeastwards at the 1160 m contour and is oriented at right angles to the northwest winds. This ridge acted as a small snowfence to the lee of which a shallow mass of ice accumulated on the northeastern shoulder of the mountain. A narrow sinuous moraine ridge 5–7 m high bounds the southeastern side of this former ice mass, which judging from the markedly reduced quantity of dolerite scree within its area of occurrence seems to have been present during the Last Glaciation.

Further south moraine ridges bound Lake Ovoid, Lake Burgess, the lake slightly above 690 m at the southern end of the South Picton Range and the small lakes at Abrotanella Rise and Pineapple Flat east of the range. These fresh ice-eroded cirque basins and undegraded morainic ridges clearly indicate that numerous small cirque glaciers were formed immediately leeward of this north–south trending snowfence during the Last Glaciation. From the evidence presented for older ice in the lower Picton valley it is reasonable to suggest that during an earlier, more severe and more extensive glacial phase the cirques leeward of the South Picton Range snowfence would have been more important local sources of ice than they were in the Last Glaciation when glaciers were much more localized.

7. Conclusions

The till deposits and outwash gravels recorded in juxtaposition to the morainic ridges at Blakes Opening on the Huon, near Cook Creek and at High Camp on the lower Picton, and in the banks of Farmhouse Creek, show that ice occupied the middle Huon and lower Picton valleys. The source of the former was probably an ice cap centred on the Gallagher Plateau and of the latter a local ice cap situated leeward of the north–south oriented snowfence–water-

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

shed of the South Picton Range and its southerly extension to Mount Bobs (figure 7). The maximum extent of this valley glaciation has yet to be determined in the Huon valley, but easterly flowing Huon ice and northerly flowing Picton ice may have extended to Tahune Bridge. During the general recession two retreat/readvance stages occurred when ice fronts occupied the gorge between Pear Hill and the Weld Range, and stood at Blakes Opening.

The strong chemical weathering of the deposits suggest that this early glaciation was of pre-Last Glacial age. This interpretation is supported by the palynological evidence and ^{14}C dates from the overlying alluvial silts and sands at Blakes Opening. The characteristics of the deposits are similar to the glacial deposits described from the Mersey and Forth valleys in northwestern Tasmania (Paterson 1965; Colhoun 1976) and to the buried glacial deposits at Henty Bridge in western Tasmania (Banks, Colhoun & Chick 1977) which are also of pre-Last Glacial age. This phase of glaciation may correlate with the Waimean Stage of New Zealand (Suggate 1965) and is probably of Riss/Illinoian age. Most of the strong chemical weathering is considered to have occurred during the Last Interglacial when the area probably had a humid temperate climate and forest vegetation cover.

The organic rich fluviatile sands and silts which comprise the lower middle portion of the terrace at Blakes Opening were formed mainly as flood plain and local backswamp deposits of the Huon River. Their location and thickness suggests that the middle Huon River has occupied virtually its present channel since the decay of ice during the early glaciation.

The pollen contained in the organic-rich fluviatile deposits began to accumulate in a backswamp environment and records vegetation changes, from West Sclerophyll *Eucalyptus* forest to Temperate Rain Forest succeeded by reversion to West Sclerophyll *Eucalyptus* forest. These changes were probably caused by climatic changes during the middle Last Glacial Stage. The pollen/vegetation changes appear to reflect a change from cooler, drier conditions to the warmer, moister conditions of an interstadial which were succeeded by cooler, drier conditions. The magnitude of these climatic changes need not have been large, as the region today occurs within the West Sclerophyll–Temperate Rain Forest ecotone, but the changes may have been widespread.

The silts, sands and gravels of the alluvial fan deposits, that comprise the upper part of the terrace have resulted from stream erosion of the extensive area of morainic deposits at Blakes Opening mainly during the later part of the Last Glacial Stage when climatic conditions were probably more rigorous and geomorphic processes more vigorous than during the early to middle part of the Last Glacial Stage. It is probable that a reduced vegetation cover facilitated greater erosion and deposition at this time but direct evidence bearing on this has not been ascertained from this site.

The morphologically fresh moraines adjacent to Mount Picton and the South Picton Range show that only local cirque glaciers and thin plateau summit carpaces of ice were formed in this area during the Last Glacial Stage. This ice did not extend below 600 m. The orographic snowline was probably at approximately 800 m elevation and was at least 200 m higher than the snowline during the earlier glaciation which probably lay at about 500–600 m. On the basis of present day temperature means, the level of cirque floors and the difference in altitude between glacial source areas and the maximum known extents of ice, an estimate of the depression of snowline for the earlier glaciation is 1300 m and for the later glaciation 1100 m with reductions in mean temperature of approximately 8 °C and 6.5 °C respectively. Although precipitation conditions cannot easily be considered, the crude temperature estimates suggest that slight

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

differences would produce large responses and that the markedly more extensive earlier glaciation may have been only slightly colder.

The thick scree aprons adjacent to the frost riven summits of Mount Picton, the Weld Range and parts of the South Picton Range demonstrate the effects of former processes of strong frost weathering and mass movements in the periglacial environment of the unglaciated parts of the mountain summits and slopes. Although these deposits are presently stabilized their chemically unweathered character suggests that they were mainly formed during the later part of the Last Glacial Stage.

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PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

FIGURE 3. Part of the riverbank section at Blakes Opening showing weathered till deposits and a dolerite erratic in the foreground, and outwash gravels overlain by fluviatile gravels and sands containing the organic horizons of profile B in the background.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

IGURE 5. The sharp unconformable junction between the coarse quartzite outwash gravels and the overlying organic-rich silts and clays 10 m east of profile A.