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ISOTOPES IN TREE RINGS -

STANLEY RIVER COLLECTIONS, 1981/82

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ISOTOPES IN TREE RINGS - STANLEY RIVER COLLECTIONS, 1981/82

Abstract

Field activities at Stanley River in the western Tasmanian rainforest are described. These involved collection of material for dendroclimatological and isotopic studies on tree-ring material, supported by measurement of the tree environment and physiology. Attention is focussed on Huon pine (*Lagarostrobos franklinii*) and Celery-top pine (*Phyllocladus aspleniifolius*), and full documentation of the collected material is presented.

Preliminary results establish both species as suitable for ring width dating. Radiocarbon dating of old logs demonstrates a potential for a ring-width chronology reaching back 13,000 years BP, and geomorphological studies elucidate the river characteristics over this period.

Stable carbon isotope measurements on leaf and branch material exhibit strong systematic variations which can account for some of the isotope variations seen in tree rings; measurements of the light environment and gas exchange characteristics of the leaves confirm the relevance of a physiological model describing carbon isotope fractionation in leaves. Measurements of the composition of air in the rainforest canopy lend further support to the model by demonstrating the relative unimportance of isotopic variations in air as an influence on the tree ring values. New data on trace gases in forest air are included.

Contents

(including initials of major contributors to sections or subsections)

1. Introduction

Tree ring properties such as width, density, structure and isotopic composition are thought to be influenced by environmental conditions at the time of growth. Thus reconstruction of past climatic conditions or past atmospheric composition from tree rings has received considerable attention in the literature, mostly involving northern hemisphere temperate zone species (e.g. Fritts 1976).

In the Australasian region, preliminary tree ring studies have recently been the subject of a comprehensive review by Ogden (1982), see also Dunwiddie (1982). For Australian species most attention has centred on Tasmanian softwoods, resulting in published chronologies for *Athrotaxis cupressoides* (Pencil pine), *Athrotaxis selaginoides* (King Billy pine) and *Phyllocladus aspleniifolius* (Celery-top pine), spanning the last 500 to 1000 years (Ogden 1978, La Marche *et al.* 1979[a]). A preliminary temperature record for Tasmania has been reconstructed from these and other data (La Marche and Pittock 1982).

In the Stanley River expeditions two species have been sampled, Huon pine* and Celery-top pine. Huon pine is thought to be the longest lived tree in Australia. It is restricted to rainforests in the west and south west of Tasmania and is largely confined to a narrow zone along banks of water courses, or to river flats (Pedley *et al.* 1980). These areas all lie within, or in the case of the eastward flowing Huon River, have headwaters within, the line enclosing the lowest coefficient of variability of annual rainfall in Tasmania (Watson and Wylie 1972). This close association with high soil moisture content, and absence of rainfall variations, suggest a relatively small variation of annual ring growths due to climatic variations. Also in these dense rainforest situations, fluctuations in ring width will be influenced by local competition effects. Thus, until now, dendrochronological attention has been diverted to species distributed over more climatically-variable areas. Celery-top pine is found throughout Tasmanian rainforests, including Huon pine areas, and has been shown to exhibit common ring width patterns over this range (La Marche *et al.* 1979[a]) though it rarely reaches a comparable age.

The decision to focus primarily on Huon pine was influenced by the following considerations:

(i) Distinct annual growth rings are a characteristic of Huon pine and this with a degree of sensitivity to climatic variation, implies that cross dating and chronology building are possible.

(ii) It has been suggested that the presence of the fire-sensitive Huon pine in a forest is an indication of a community stable over thousands of year (Millington *et al.* 1979). Like most mature Celery-top pines, many Huon pines have foliage at or above the canopy level of competing rainforest species (see Plate 1). Thus emergent trees

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* Huon pine has been identified as *Dacrydium franklinii*: Quinn (1982) proposes *Lagarostrobos franklinii* as a revised classification.

PLATE 1

Huon Pine (SRT 50) exposed by recent clearing, illustrating foliage at canopy top only.

can be selected in which local influences might be expected to be small over long periods.

(iii) The environment of Huon pine is typified by an unusual lack of moisture stress. This has significance in relation to isotopic studies of tree ring material where recent progress in the understanding of carbon isotopic fractionation (Farquhar *et al.* 1982[a]) suggests appreciable effects due to moisture stress.

(iv) A long tree-ring chronology in the southern hemisphere is of considerable interest with the possibility of important geographical variations in some tree-ring parameters e.g. in ^{14}C (Suess 1980) and ^{13}C (Francey 1981).

(v) The longevity of some trees (a 2138 ring specimen exists) should be of considerable benefit in studying climatological phenomena with long characteristic timescales. Measurements of the ^{14}C activity of dated wood spanning thousands of years is also of relevance to the calibration of radiocarbon dates and to the study of solar and geomagnetic variation (Barbetti and Flude 1979, Stuiver and Quay 1980, 1981).

(vi) Huon pine timber is well known for its durability (Penny 1910). This property to resist decay raises the possibility of extending a ring sequence well beyond 2000 years using overlapping chronologies from fallen or buried logs.

Recent hydro-electric development has provided ready access to Huon pine stands on the Stanley River in an area previously little disturbed by human activity. Slight selective logging has occurred close to the river banks over the last century. Current logging operations permit easy access and provide convenient sources of bulk material from stumps and log ends. Recent mineral exploration has resulted in a grid of strip-lines through the forest, greatly facilitating systematic exploration and sampling over an area of several square kilometres. The area provides examples of Huon pine and Celery-top pine in a range of habitats. Prevailing winds from the ocean cross about 23 km of predominantly open heathland to reach the site; this is relevant in assessing the degree of biospheric influence on ambient CO_2 levels and isotopic ratio.

This technical report provides an overview of, describes the techniques employed in, and presents basic data arising from, activities conducted at the Stanley River expedition site. A large amount of trunk wood (cores and cross sections) was collected to provide a statistical basis for a ring width chronology for the site, and to permit selection of dated wood for a variety of analyses and studies. The initial major objectives were threefold:

(i) an elucidation of the environmental influences on carbon isotopic fractionation in trees with the eventual aim of reconstructing past atmospheric CO_2 variations;

(ii) a study of carbon-14 variations in wood with emphasis on variations over millenia; and

(iii) an assessment of the potential of Huon pine for climate reconstructions using ring width data.

The necessity for a multidisciplinary response to these objectives has led to other significant contributions, in particular those relating to the stream geomorphology, the physiology of Huon pine and the composition of sub-canopy air.

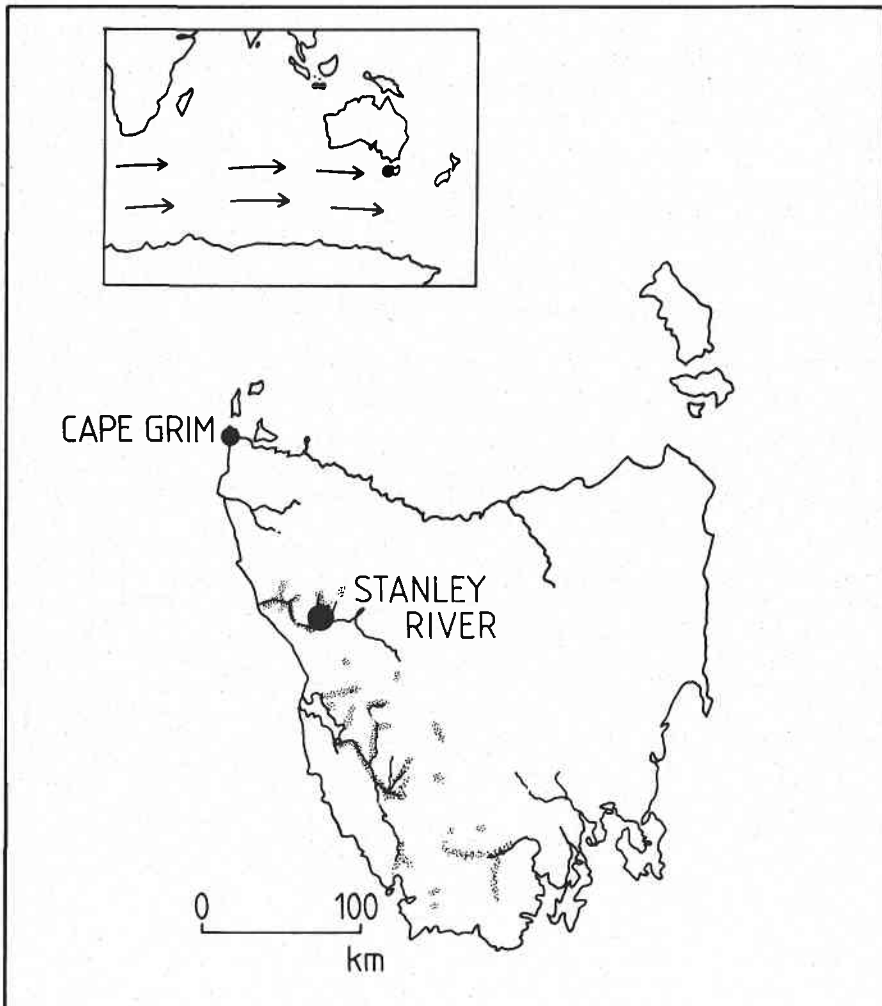


Figure 1 The site of the Stanley River expedition shown near the intersection of the Pieman River (running E-W) and Stanley River (N-S). The distribution of Huon Pine is indicated by shading. The inset illustrates the location in relation to predominant wind patterns and in the context of large scale pollution.

2. Site and Expedition Details

The west coast of Tasmania provides excellent access to air masses representing the southern oceans (see Figure 1). The expedition site on the Stanley River (a tributary of the Pieman River) is at the northern extent of the present range of Huon pine (Millington *et al.* 1979). A description of the distribution, history, abundance, habitat, and growth characteristics of Huon pine in the Pieman area is given by Pedley *et al.* (1980).

The expeditions were focussed on three areas, A, B and C, shown in Figure 2. Area A in particular was clearly marked by narrow grid strips cut through the rainforest, typically at 100 m intervals. This pre-existing coordinate system, with "grid north" rotated 33 degrees anti-clockwise from true north, and 45 degrees from magnetic north, is used throughout to identify tree and log locations.

Commercial logging of selected Huon pine trees is continuing in area A.

In February 1981 the main emphasis was on coring live trees and cutting cross-sections from recently logged stumps to establish a modern chronology. Preliminary measurements on atmospheric composition and physiological responses of leaves were carried out, and some leaf material and seedlings collected for further testing.

A minor expedition was mounted in April 1981, on the basis of preliminary ^{14}C dating of a small piece of wood from a log emerging from the river bank. Samples of wood were collected from a selection of old logs in, or emerging from, the bank of the Stanley River. In addition a preliminary study of the geomorphology of the river, including probing the floodplain for buried logs, was conducted.

In February 1982 an excavator was used to unearth several old logs from up to 4 m below a Stanley River floodplain. Geomorphological studies continued. Cross sections were collected from excavated logs and from old logs in the creek bed. Other field workers concentrated on establishing profiles of carbon dioxide and carbon isotopes in air within the rainforest canopy, measurements of gas exchange in leaves and collection of leaves for isotopic analysis.

Supplementary information was gathered in September 1982 and April 1983.

A full list of participants, their allegiance and interest, is shown in Appendix A, and a full summary of all wood and other samples collected and site details are included in the six tables of Appendix B. Figures 3 and 4 are enlargements of areas A and B respectively of Figure 2 and show the grid location of all samples.

The Februaries of 1981 and 1982 were exceptionally dry. During part of the 1981 expedition bush fires raged 20-30 km to the south and on occasions atmospheric sampling occurred in the plume of these fires. In February 1982, no fires were evident during the expedition but fire swept through the region about one week later. Fortunately some undisturbed areas of rainforest were not burnt.

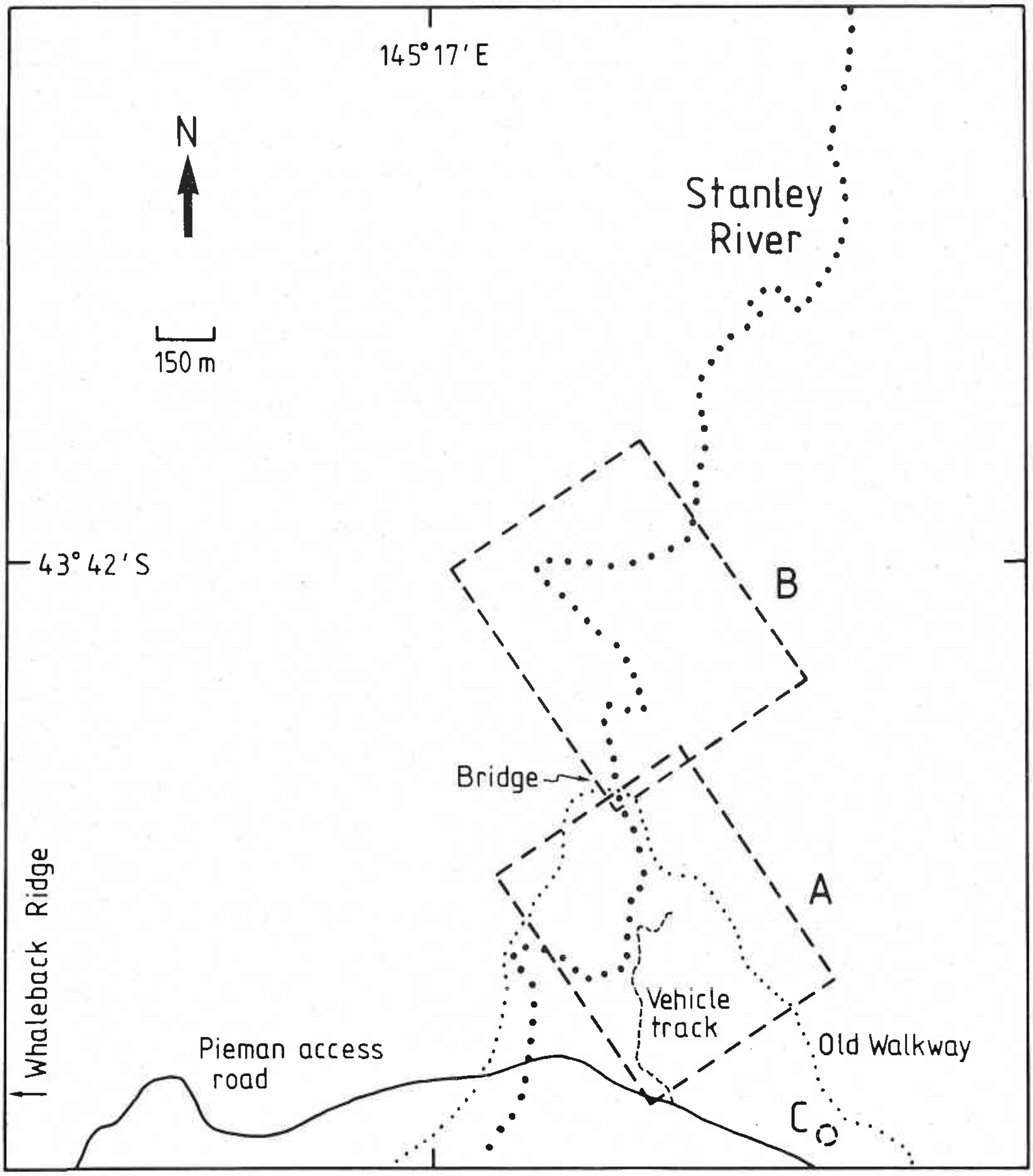


Figure 2 The three areas A,B,C, encompass the expedition activities. Two are shown as enlargements in Figures 3 and 4.

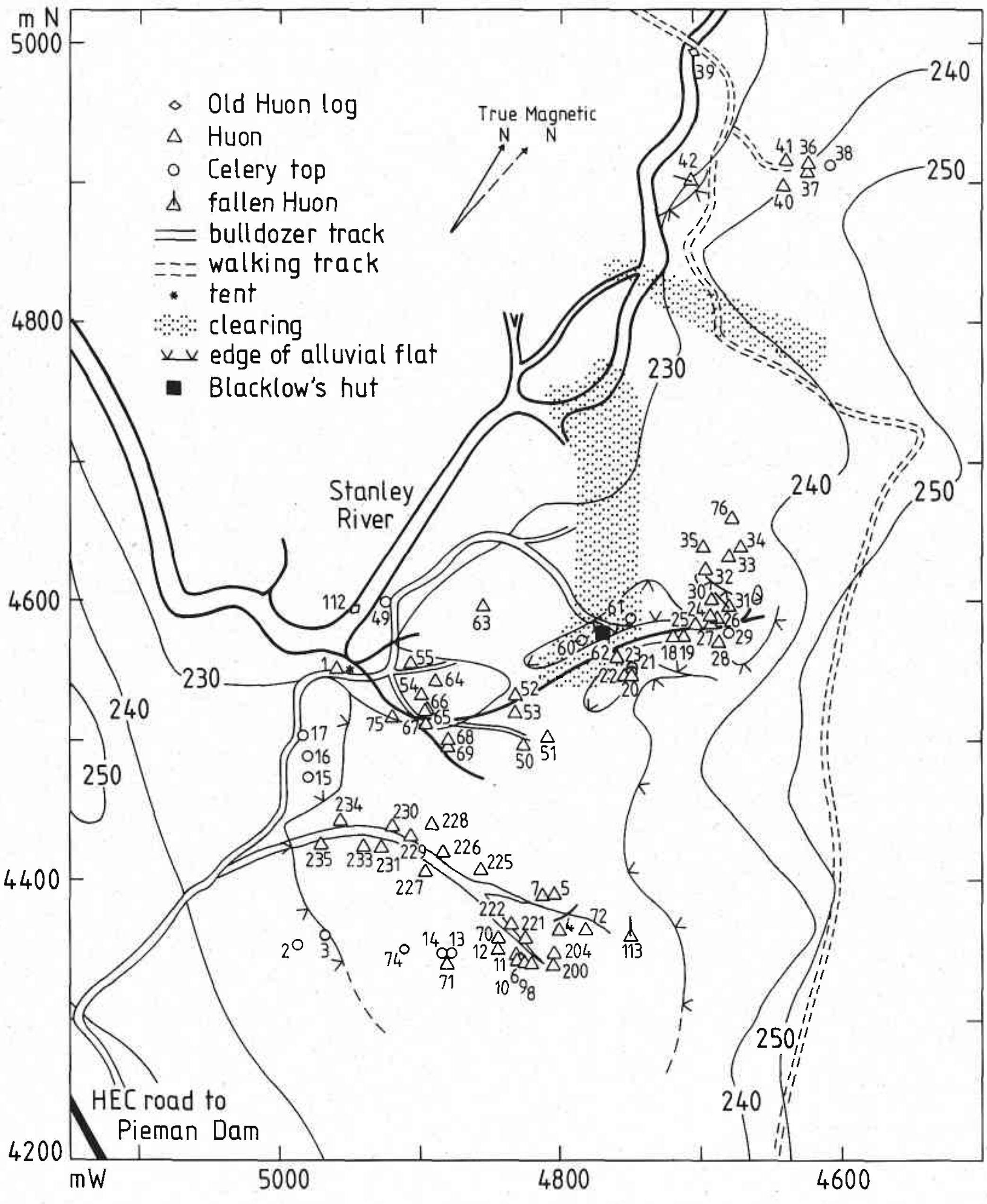


Figure 3 An enlargement of area A (Figure 2) showing main geographic features and the location of samples and activities as detailed in the figure legend. Coordinates are in metres with respect to a pre-existing grid system (see Section 2).

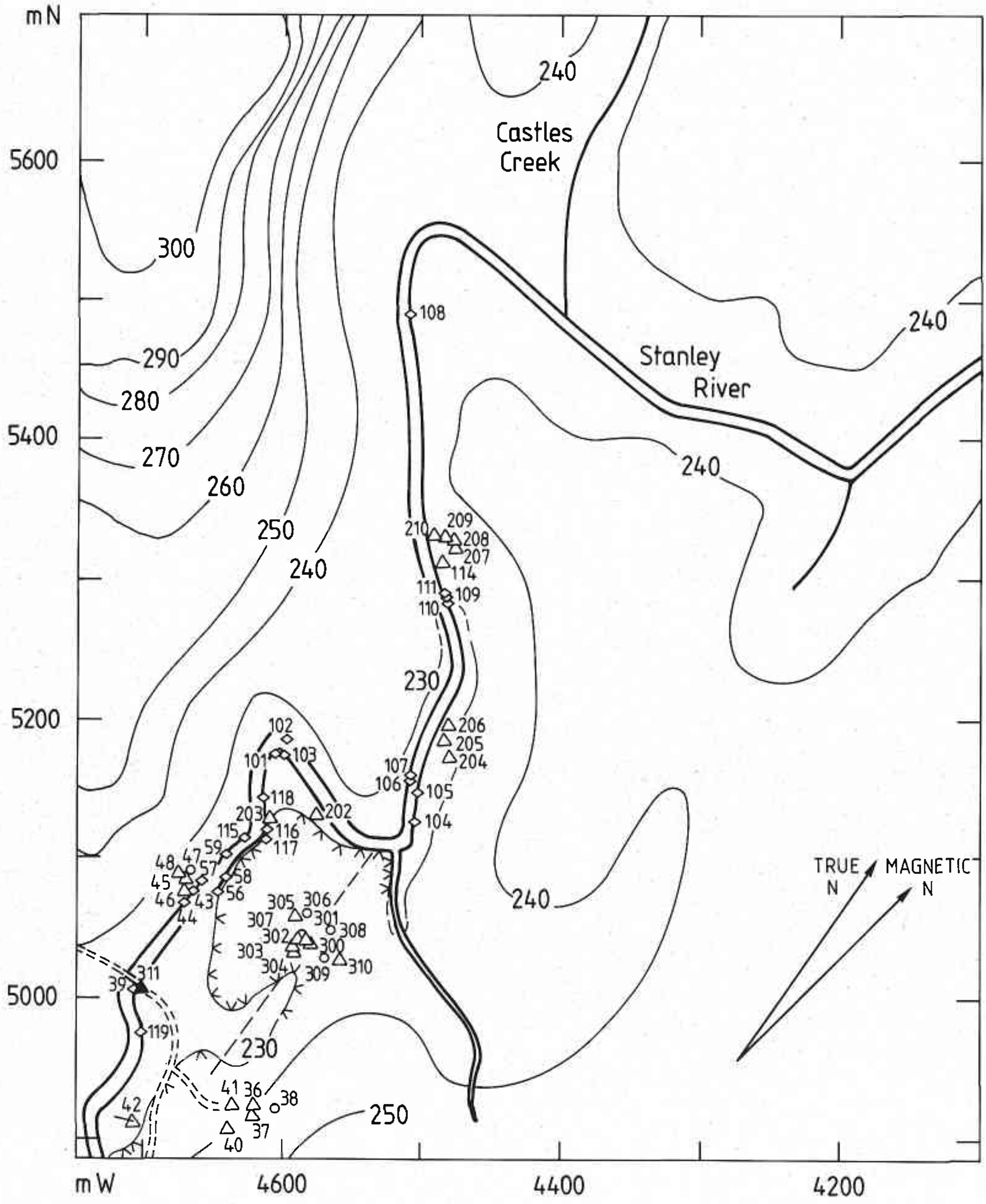


Figure 4 An enlargement of area B (Figure 2). For details of symbols and coordinates see Figure 3.

3. Preliminary Dendrochronology and Dendroclimatological Prospects (TB, JED, BK)

The distinct annual rings and apparent great age of some specimens of Huon pine harvested at the time of the Lake Gordon inundation indicated that a long Huon pine chronology might be built. This was supported early in our investigations by the cross-dating of certain common years with established Celery-top pine (*Phyllocladus aspleniifolius*) chronologies (La Marche *et al.* 1979[a]). There is not always synchroneity in growth between these species as, infrequently, a narrow ring in Huon pine may occur in the year following the formation of a narrow ring in Celery-top, suggesting that growth may be limited by a common antecedent cause but that the two species respond to it differently.

As a general rule, individual missing or false rings are rare in Huon, more commonly short sequences of rings "wedge out" leaving lenticular bands of growth, especially low in the butt.

Other difficulties with Huon include compression wood, which is common at the centre and may be spirally arranged, and merging rings. The habit of Huon pine in overhanging stream banks or in coppicing from fallen trees ensures that many stems have some eccentric growth. With age, as vigour declines, many trees have sections of moribund vascular cambium where rings merge into unicellular latewood bands. These sections may resume normal growth later but intersection of such a sequence with an increment borer generally renders a core undatable.

Notwithstanding these problems, it has been possible to date 114 cores from 44 Huon trees satisfactorily, with the earliest wood sampled with the 40 cm corer commencing in 880 A.D. (SRT 114). Table B1 shows the dating success for individual cores. Many of the Huon cross-sections have been dated (Table B3) yielding years of origin between 1700 and 1174 A.D. This collection is being augmented as forest operations continue in the area.

A diameter versus age relationship derived from Huon core measurements suggests that larger cross-sections yet to be logged are older than those sampled so far, though their use in extending the chronology will depend on how whole they are in the centre.

A simple linear relation provided the best estimate of age (years) and took the form

$$\text{Diameter} = 8.86 + 0.08\ \text{Age}$$

where diameter is in cm under bark. Measurements were made on cores, where radii were measured to the earliest annual ring boundary still perpendicular to the axis of measurement. In all, 122 radii from 41 trees were included with $r = 0.88$. In general terms these trees grew about 1 mm in diameter per year but the data show a range of growth rates from <0.3 - 2 mm/year for sustained periods. As the largest diameter used in developing the relationship was 94 cm, somewhat less than that for the largest cross-sections of Table B3, extrapolation gives an expectation of ages exceeding 2000 years for these pieces.

In the next section, Table 3 gives radiocarbon dates for some excavated logs and approximate age spans have been assigned to these samples using a different relationship. Data were available for 57 cores from 26 younger trees at Riveaux, 200 km to the south and these have been pooled with the Stanley River material to provide a wider diameter and age class range. The relation is

$$\text{Diameter} = 10.68 + 0.08\ \text{Age}$$

where n = 67 trees and r = 0.84.

Many of the rings noted as narrow for the Stanley River chronology are found to be narrow for Huon pine from Lake Gordon and the Picton River to the south. There appears to be sufficient coherence for a regional Huon pine chronology. Conformity with chronologies from other species also reinforces dating certainty. For example, the rings for the growing seasons 1696/1697 (see Plate 2) and 1887/1888 are narrow and conditions for growth, or their precursors, in those years appear to have been harsh for conifers across the State. *Athrotaxis selaginoides, A. cuppressoides* and most of the *Phyllocladus* site chronologies (La Marche *et al.* 1979[a]) show narrow rings in these instances.

While many Huon pine seedlings establish on fallen mossy logs giving them the later appearance of straddling the log, the same affect can occur with vegetative propagation from fallen Huon stems. Here small branches of an original fallen "mother" regain the canopy as "daughter" stems, providing a datable sequence from the present through the previous generation. These, with the abundance of well-preserved material stratified in the creek banks and the ages ascribed to logs by radiocarbon dating (next section) suggest that a long continuous chronology can be built.

Compilation of such a series may be more difficult than for species such as Bristlecone pine (Ferguson 1969) and oak (Pilcher *et al.* 1977) which have yielded long chronologies, as there is less variation in ring-width from year to year to facilitate cross-dating and assignment of age. This is borne out by the high coefficient of kurtosis displayed by Huon pine ring-width distributions which emphasises that there are few exceptional ring-widths, large or small, in these series. Huon pine has been discounted as a potential dendroclimatological tool (Dunwiddie and La Marche 1980) because of this lack of high frequency variation in ring-width.

However, quantitative statistics of ring-width series assessing potential for climate reconstruction are compared in Table 1 to those of other species. Data are presented for three measures, mean sensitivity (a measure of year-to-year variation, Fritts 1976), standard deviation, and the first order serial correlation of some published chronologies. Minimum criteria for these are discussed for Western North American sites by Fritts and Shatz (1975) and their results for a 102 site chronology series lead the table. Data from other chronologies for species inhabiting more mesic, cool temperate to Arctic sites follow. In a statistical sense, Huon pine compares favourably with the other species, all of which have provided climatic reconstructions.

Huon has a lower mean sensitivity and standard deviation than the paragon western North America group, perhaps reflecting the constancy of water availability. The few trees upslope from the river banks (denoted site type III in Table B1) show greater sensitivity and higher frequency variation in ring-width than the norm for Huon pine.

The high coefficient of serial correlation in Huon indicates that the

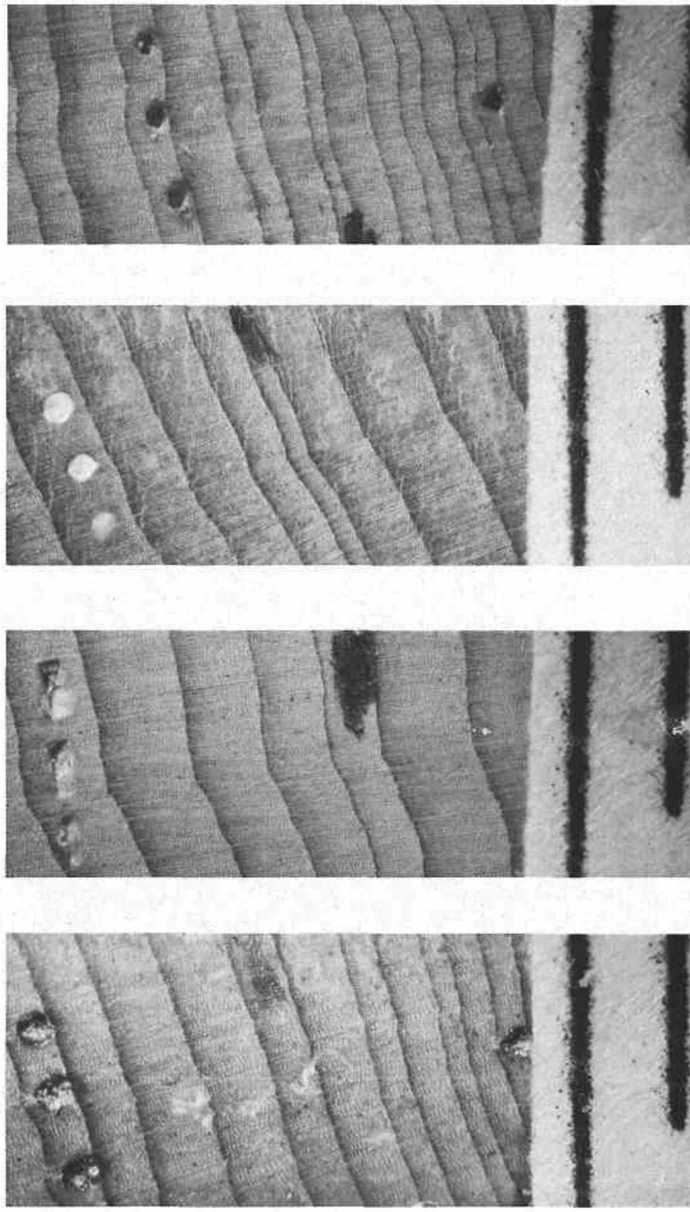


PLATE 2

Matching ring-width patterns from Tasmanian trees.

a: Huon Pine (SRT 26 core B), Stanley River.
b: Celery Top Pine (SRT 38 core B), Stanley River.
c: Huon Pine, Picton River, Southern Tasmania.
d: Celery Top Pine, Bathurst Harbour, South-West Tasmania.

The three pin-holes mark 1700 AD. All cores show a distinctly narrow ring for the 1696/1697 growth season.

TABLE 1

Comparisons of Huon pine ring width statistics with chronology statistics for other sites and species used for climatic reconstructions.

	Mean Sensitivity	Standard Deviation	1° Serial Correlation
W. North America (Fritts & Shatz 1975)	0.37	0.39	0.42
E. & Central U.S.A. (De Witt & Ames 1978)	0.18	0.24	0.50
Alaska and Yukon (Cropper & Fritts 1981)	0.16	0.25	0.62
Hudson Bay (Jacoby & Ulan 1982)	0.15	0.17	0.44
New Zealand (Norton 1981) *Libocedrus*	0.18	0.33	0.70
(La Marche *et al.* 1979[3])			
Phyllocladus	0.31	0.26	0.00
Other species	0.15	0.23	0.63
Tasmania (La Marche *et al.* 1979[4])			
Phyllocladus	0.29	0.28	0.26
Athrotaxis	0.13	0.20	0.65
Huon pine	0.20	0.24	0.53

variation is generally of low frequency. In comparison the serial correlation for Celery-top chronologies is low, but longer term oscillations are disguised in this species by a tendency for a narrow ring to follow a wide one, injecting a negative first order correlation into the overall figure. This tendency is probably caused by diversion of assimilates for biennial flowering.

Trees of both species noted to have all foliage exposed at canopy top exhibit even radial growth without fluctuations from episodes of competition. Concentration on such trees on site type III will increase the potential of Huon pine for dendroclimatological reconstructions, and permit extension of the Celery-top chronology. Celery-top from these sites is generally older than average (e.g. 550 years for SRT 309) and very sensitive but with a higher proportion of missing rings. Huon pine is less sensitive than Celery-top, with fewer narrow marker rings, but also fewer missing rings. The capacity to use both species in conjunction provides a sound chronology that further collections will undoubtedly extend.

4. Preliminary ^{14}C Dating (MB, SMcP, RBT)

4.1 Pretreatment Methods

As there were no previous radiocarbon analyses on Huon pine, we have developed a simple but effective pretreatment method to isolate material formed at the time of ring growth. Research workers with other species of trees have sometimes isolated pure cellulose, but the preparation time is lengthy. A quicker, simpler method was sought.

Any pretreatment for Huon pine must, in particular, be able to remove the mobile oils and resins which are primarily responsible for its resistance to decay. Following suggestions put forward by Head (1979 and pers. comm.) it was thought that a series of solvent extraction steps would ensure removal of these substances. Linking this to the deVries method (deVries *et al.* 1958) of sequential acid, alkali and acid extractions, which is well known to be quite successful in removing more polar contaminants, seemed a suitable approach to try. The residue from this method would be essentially cellulose and high molecular weight lignins.

The method devised consists of sequential soxhlet extractions with a 2:1 benzene:ethanol mixture, then pure ethanol and finally water, followed by sequential boiling and filtration in 2M hydrochloric acid, then 2% sodium hydroxide (repeated if large amounts of coloured material are extracted) and finally 0.1% phosphoric acid. The residue is then washed with distilled water until it is neutral.

To test the ability of this method to yield a residue essentially free of more modern contaminants, a Huon pine, felled in 1974 in the Gordon River area, was selected.

Wood from the 1941-45 AD growth rings, which in this tree had already undergone the sapwood-to-heartwood transition, was treated and various fractions analysed. The results are given in Table 2 and are discussed in McPhail *et al.* (1983). Briefly, it can be seen that the solvents extract considerable material with high ^{14}C activity, indicating that most of it was formed after the rise in atmospheric ^{14}C from 1956 onwards (Polach and Singh 1980). The alkali extract has ^{14}C activity lower than that of the solvent indicating a greater proportion was formed before 1956 AD . The acid extract has very different $\delta^{13}C$ and much lower $\Delta^{14}C$, indicating a different composition and formation predominantly before 1956 AD. The result for the fully treated residue ($-16 \pm 6‰$) (see Table 2) is in satisfactory agreement with published results for the pre-1956 northern hemisphere (Stuiver and Quay 1980).

Table 2 also gives results for identical wood not treated with solvents. Some of the oils and resins apparently find their way into the alkali extract, but the wood residue $\Delta^{14}C$ indicates incomplete removal of post-1955 components. This effect has also been found with other types of wood (Olsson, 1980).

TABLE 2

Pretreatment tests on Huon pine

Fraction	Yield (% of total CO_2)	$\delta^{13}C$ PDB (°/oo)	$\Delta^{14}C$* (°/oo)	SUA- Lab. No.
Method: solvent/acid/alkali/acid				
benzene:ethanol extract (oils, resins, etc.)	8	-24.8	318 ± 18	5002
acid extract (hemicellulose, some lignin, various other compounds)	18	-20.1	-2 ± 9	5006
alkali extract (lignin, some hemicellulose, various other compounds)	3	-25.1	107 ± 37	5007
wood residue	71	-22.9	-16 ± 6	5005
Method: acid/alkali/acid				
acid extract	14	-20.1	21 ± 11	5001
alkali extract	7	-25.0	226 ± 21	5003
wood residue	79	-22.6	-5 ± 6	5000

(* See Stuiver and Polach 1977)

4.2 *Driftwood and Buried Logs*

Many logs can be seen along the river bed and banks, particularly upstream from the old walkway bridge (Figure 4). Radiocarbon ages have been determined for some of these (Table 3), with the initial aim of finding their age distribution and guiding further fieldwork.

Conventional radiocarbon ages (Stuiver and Polach 1977) are given in years b.p. (before 1950 AD), while calibrated ages (Klein *et al.* 1982) are denoted by B.P. Estimated "age-spans" for the logs are based on the number of rings when known, the position of the rings (usually <30) used for ^{14}C analysis and the calibrated age; where ring counts have not been made, the numbers in brackets are estimated from the diameter-age regression specified in Section 3.

The oldest Huon pine trunk so far discovered (SRT 39) has 484 rings spanning a period around 6900 to 7400 years ago. The older Celery-top pine has 252 annual rings with (uncalibrated) radiocarbon age of 12390 ± 80 years, near the outer part, and 12870 ± 90 near the centre. The radiocarbon age difference of 480 ± 120 years is much larger than the *ca.* 150 years difference in ring ages, and is being investigated further.

TABLE 3

Radiocarbon ages and calibrated radiocarbon ages for sections of preserved logs collected at Stanley River, also from the Bird River track

Stanley River Tree No.	Number of Rings in Section	SUA Lab No.	$\delta^{13}C$ (±0.1°/₀₀)	^{14}C Age (yr b.p.)	Calibrated Age (yr B.P.)	Age Span (approx. yr B.P.)
Huon Pine						
39	484	5004	-22.9	6190 ± 60	7080 ± 190	6900-7400
43	470+	5011	-22.1	1580 ± 60	1530 ± 170	1500-2000
56	(600)	5021	-22.7	630 ± 60	620 ± 70	(450-1050)
58	(400)	5015	-22.8	100 ± 60	150 ± 140	(50-450)
59	653+	5012	-24.7	1980 ± 60	1930 ± 190	1800-2450
101	400+	5013	-22.2	1210 ± 70	1180 ± 140	1100-1500
103	(200)	5016	-23.7	120 ± 60	150 ± 150	(0-200)
105	(500)	5014	-24.4	1190 ± 70	1180 ± 140	(1100-1600)
110	500+	5010	-21.4	2050 ± 50	2110 ± 200	1700-2200
115	(400)	5023	-24.0	3680 ± 40	4050 ± 210	(3900-4300)
151	(200)	5024	-24.0	4900 ± 50	5590 ± 240	(5550-5750)
158	200+	5025	-21.2	3750 ± 40	4190 ± 270	4100-4300
161	400+	5019	-22.4	4670 ± 70	5370 ± 240	5300-5700
162	300+	5020	-22.6	5500 ± 50	6210 ± 270	6150-6450
163	(500)	5027	-22.3	4090 ± 40	4610 ± 240	(4550-5050)
Celery-top pine						
154	322	5018	-21.4	4080 ± 70	4600 ± 240	4600-4900
157	252	5022	-23.1	12390± 80	beyond range	
157X	inner log	5028	-26.7	12870± 90	beyond range	
160	160+	5026	-22.2	4410 ± 50	5090 ± 230	5050-5200
Bird River Track						
Huon pine						
-	559	5017	-23±1	1290 ± 70	1210 ± 140	950-1500

PLATE 3

Excavation 2 on the Stanley River flood plain. SRT 161 (5300-5700 years B.P.) is shown at the bottom of the trench, with a section removed.

Other logs which are flat-lying and partly buried under the modern riverbank (SRT 43, 56, 59, 110, 115) have ages from a few hundred to around 4000 years. One log projecting outwards and upwards from the riverbank (SRT 105) is more than a thousand years old, as is a curved water-worn piece of driftwood (SRT 101). Another trunk (SRT 58) protruding from the river bank has a recent date; it has been cut above the water-line with an axe, presumably within the last hundred years. A small, curved, dead tree (SRT 103), which had grown out of the bank also has a recent age.

It is worth noting that the two recent dates (100 ± 60, 120 ± 60) were obtained on wood approximately 150 and 100 rings (respectively) from the outer, weathered surfaces. Northern hemisphere results for the period 1700-1900 AD are between 80 and 200 yr. b.p. (Stuiver 1982), in agreement with our two results.

Results from the 1981 collection led us to excavate a trench in flood plain sediments during the 1982 field season, in the hope of locating more timber older than two thousand years (see Plate 3). This trial excavation of limited extent was quite successful, as nine logs (>20 cm diameter) of Huon and Celery-top pine, many smaller pieces of wood and even some leatherwood (*Eucryphia lucida*) and lancewood (*Phebalium*) were sampled. The first dates from Excavation 1 indicate a 12390 ± 80 year old Celery-top log, separated horizontally by about 2 m and vertically by about 40 cm from logs dated at 3750 ± 40 and 4410 ± 50 years (SRT 158, 160). The older Celery-top log is of great scientific interest, as its 252 ring section will provide isotopic data during the transition between glacial maximum (18,000 yr. b.p.) and mid-Holocene warm periods. The >8,000-year difference in ages is discussed in Section 5.

5. The Geomorphology of the Stanley River Floodplain (GN)

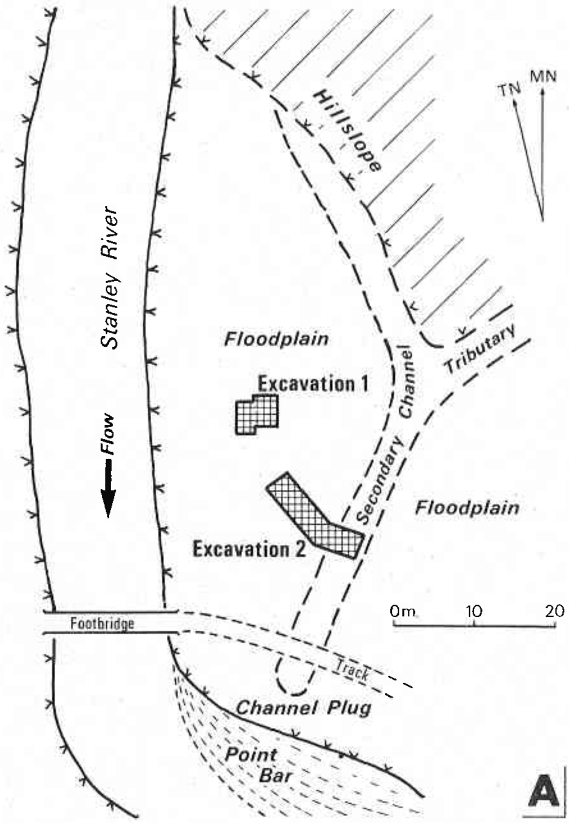
5.1 The Site

At the study site the floodplain is divisible into two distinct parts. Upstream of the walking bridge (Figure 4) it is restricted by a narrow valley and is discontinuously located along a laterally stable and partially bedrock-confined channel. Downstream of the bridge the valley opens out into a wide basin partially infilled with unconsolidated alluvium. Here the channel appears actively meandering, for it is sinuous and exhibits point bars, bank erosion and chute cutoffs. The floodplain here is relatively wide, but unfortunately its stratigraphy has been partially disturbed by tin mining both last century and early this century.

Because of its geomorphic stability as a site for locating buried timber, only the floodplain upstream of the walking bridge (Figures 4 and 5) has been excavated at this stage; consequently, the following description and interpretation is restricted to this location.

5.2 The Channel

Immediately upstream of the walking bridge, the Stanley River has a well defined channel approximately 20 m wide with a mean depth of 2.35 m, and a maximum depth at bankfull flow of 4.2 m. The channel slope, measured over a distance of 340 m upstream of the bridge, is 5.9 m/km. The bed is



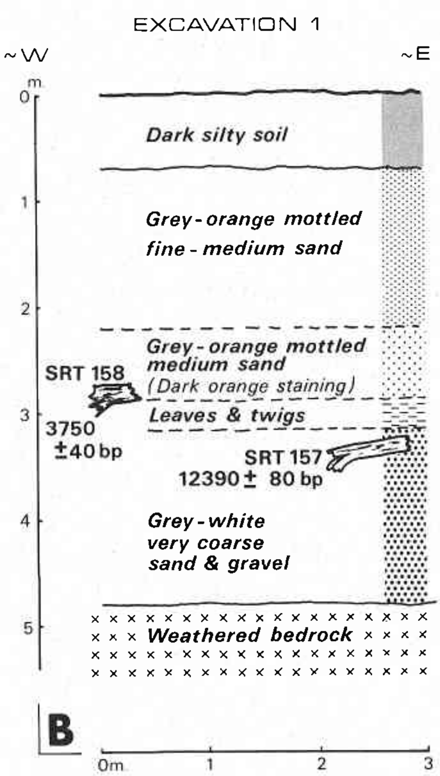


Figure 5
A: Map of floodplain (surveyed with tape and compass) showing location of excavations relative to the river and the secondary channel.

B: Stratigraphy of north wall of excavation 1.

C:(over page) Stratigraphy of north east wall of excavation 2. Log outlines drawn in a stippled fashion were located near the opposite wall or centre of the trench.

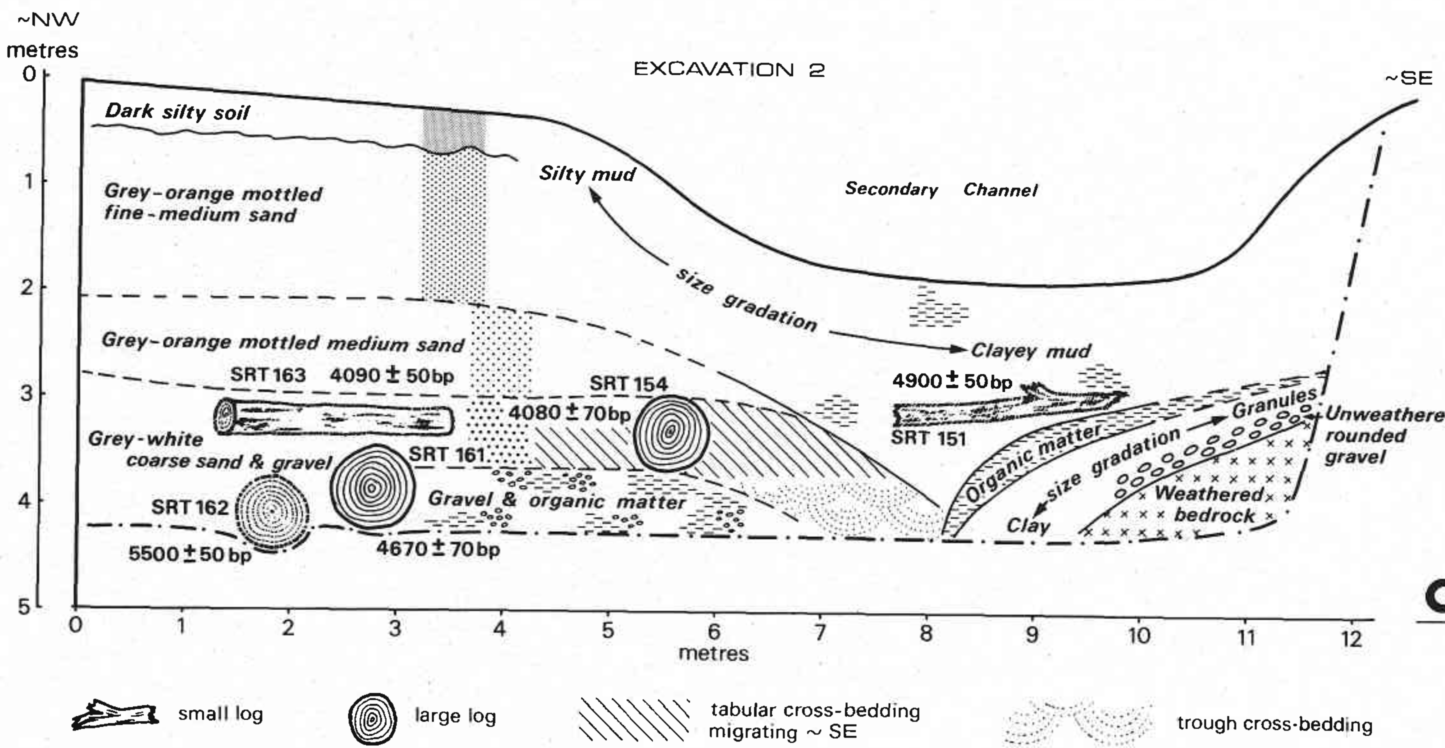


Figure 5 Part C

coarse to very coarse sand with some granules (0.5-4 mm) derived from the coarse-grained Devonian granite and granite porphyry of the catchment. This sediment rests on a lag deposit of large granitic boulders, sometimes up to several metres in diameter. These boulders add greatly to the channel roughness.

The stream banks are very steep and covered with moss, logs and seedlings, particularly those of Myrtle (*Nothofagus cunninghamii*). Also growing on the banks, and important for channel protection, are medium-sized Huon pine. Living Huon trees and partially buried stumps and trunks act as natural rip-rap, greatly increasing bank strength and boundary flow-resistance. Further resistance to flow is provided by the profusion of logs which criss-cross the channel, sometimes in the form of jams. This combination of bank protection and impeded flow is reflected in the absence of any significant bank erosion and in the unusual straightness of much of the upper Stanley River.

An estimate of channel roughness in terms of Manning's n is between 0.10 and 0.13, providing an estimated bankfull discharge of between 40-60 cumecs (m^3/s).

5.3 Floodplain Sediments and Stratigraphy

Along much of the study reach a 20-30 m wide floodplain is situated on the east side of the river, supports dense rainforest, and has an undulating surface about 4-5 m above bedrock. The coarse crystalline rocks of the catchment provide very little fine sediment for floodplain deposition. Consequently, 90% (by weight) of the floodplain alluvium is sand and granules with the remainder silt and clay. The vertical profile grades from fine sand (0.2 mm) mixed with 12-15% silt and clay near the surface, to very coarse sand (1-2 mm) and only 3-5% silt and clay at a depth of 3m, to very coarse sand and gravel with no silt and clay over a weathered granite bedrock surface at 4.5-5.0 m. Although the channel sediments are a clean white-grey colour, those in the floodplain show signs of weathering and are stained orange. In some locations there are well developed iron pans at approximately 1 m below the surface, whereas pronounced iron staining at 2-3 m is very widespread.

Floodplain stratigraphy and evolution at the study site were assessed from two trenches dug with a caterpillar-tracked excavator (Figures 4 and 5a, Plate 3). Excavation 1 was a roughly square hole dug to a depth of 4-5 m (Figure 5b). Excavation 2 was a 14 m long trench dug roughly perpendicular to the river channel, but with a slight "dog-leg" near the mid point. It extends from a secondary channel on the floodplain to a point about half way across the floodplain towards the main channel (Figures 5a, 5c) and was excavated to a depth of 4 m below the highest point on the floodplain, although in places the excavation was continued down to bedrock at about 5 m.

At the eastern end of excavation 2, the sediments beneath the secondary channel consisted of clay mud and abundant organic detritus over a layer of coarse unweathered gravels on an inclined but weathered bedrock surface (Figure 5c). Further west, the depth of the excavation increased out of the secondary channel and into the floodplain proper. Near the surface in a westerly direction, clay muds give way to silt and fine sand, while below this there is a sharp but inclined contact between overlying mud and underlying medium to coarse sand containing large Huon and Celery-top logs and smaller pieces of drift wood. These sands contain well defined flow structures in the form of cross-stratified trough and tabular large-ripple sets with a mean depositional orientation away from the main channel and towards the secondary channel.

Excavation 1 represents a fairly typical floodplain section for this site (Figure 5). The uppermost 0.5 m consists of a dark grey/brown silty soil which changes at a very sharp but convoluted boundary to grey/white orange-mottled fine to medium sand to a depth of 2.1 m. To a depth of 2.9 m is pale medium sand with a dark orange staining at the base, beneath which there are 10-20 cm of well-preserved leaves and twigs. From 3 to 4 metres are abundant logs in a matrix of very coarse sand and granules, and from 4-5 m is very coarse sand and gravel.

5.4 The Development of the Floodplain

The present river channel upstream of the bridge is laterally very stable. This is surprising given the steep channel slope and the relatively uncohesive nature of the bank sediments. The stability is evidenced by the lack of any bank erosion, the absence of point bars, the straight, steep sided and canal-like channel, the very large diameter Huon pine and Myrtle growing on the floodplain, and the growth habit of Huon pine on the river banks. New generations of pine propagate from the limbs of previous generations which appear to have slumped down the bank and now lie partially buried by bank sedimentation. Three such generations were traced near SRT 57, testifying to the continuous regeneration of Huon pine on a relatively stable river bank. The lineages along this reach indicate that there has been little channel migration in the last millenium.

However, prior to this period of stability, the floodplain stratigraphy shows evidence of lateral channel-migration. The oldest Huon log yet discovered, (SRT 39, 6190 ± 60 years b.p.), is projecting from the present channel bank beneath the bridge 10 m to the west of the floodplain trench (Figures 4, 5). Fifteen to nineteen metres in an easterly direction from this log, in excavation 1, logs SRT 162, 161 and 154 have been dated at 5500 ± 50, 4670 ± 70 and 4080 ± 70 years b.p. respectively. These logs, and the flow structures in the trench, suggest that the Stanley River migrated from west to east during the mid-Holocene, until it arrested against weathered bedrock exposed at the eastern end of excavation 2. Following this, there appears to have been an episode of avulsion, with the abandonment of the secondary channel and the incision of a new stream course roughly at the position of the present river. This new channel appears to have exhumed SRT 39.

Since formation of the present channel, and possibly for some time before, the Stanley River has been laterally very stable. The youngest wood yet dated within the floodplain is SRT 158 found at 3 m depth on the western side of excavation 1 (3750 ± 40 yrs b.p.), (Figure 5b), indicating that channel stabilisation has taken place since then. This log also demonstrates that the floodplain at this point has accumulated 3 m vertically in the same period of time. Lateral stability has been associated with substantial vertical accretion.

One problem is the location of a 2 m length of Celery-top (SRT 157) found in excavation 1 at a depth of 3.4 m. It has an outer radiocarbon age of 12390 ± 80 years b.p. yet was only 2 m away from SRT 158 and SRT 160, dated at around 4,000 years. The presence of bark still on the roots of this tree suggests it has not been exhumed and redeposited. Until resolved, the discovery of SRT 157 emphasises that any stratigraphic interpretation must be regarded as hypothetical at this stage.

5.5 *Summary*

From the evidence collected so far, the most logical interpretation at the excavation site is as follows:

(1) Prior to about 4,000 years ago when most of the timber was buried, the Stanley River had a relatively shallow and laterally active channel;

(2) Since this time, the channel has stabilised, except for a major avulsion which cut a new channel at roughly the river's present position;

(3) With stabilisation, the floodplain has vertically aggraded about 3 m, resulting in the present deep channel with steep banks.

6. Carbon Isotope Measurements on Leaf and Branch Material (RJF, RMG, NGR)

6.1 *Leaf Sampling Strategy*

The measurement of stable carbon isotopes in tree-rings has often been quoted as the most promising method of reconstructing past variations in atmospheric carbon dioxide isotope ratios. Such knowledge provides important constraints on models used to predict the consequences of fossil fuel combustion and forest clearing (Peng *et al.* 1983).

Large differences in $^{13}C/^{12}C$ trends exist between trees from different regions (Francey 1981). Suggestions of regional modification of atmospheric isotope values have been used to explain $^{13}C/^{12}C$ tree-ring differences by some authors (Mazany *et al.* 1980, Freyer and Belacy 1981), and similar arguments have been used to explain the "juvenile effect", a ^{13}C depletion in the innermost rings of trees. In general, previous authors attempting atmospheric reconstructions have assumed that the isotopic fractionation which occurs when CO_2 is assimilated by a plant is constant, and/or that variations other than those reflecting the large scale atmosphere are averaged out by combining data from many isolated trees.

The leaf and branch sampling described here was aimed at elucidating environmental influences on the fractionation occurring in the leaves of Huon pine, and possible further fractionation in carbon as it is transported from the leaves to tree-rings. A quantitative model of carbon isotope fractionation by leaves during photosynthesis by Farquhar *et al.* (1982[b]) is discussed in relation to tree-ring studies by Francey and Farquhar (1982), and these papers influenced the collection of material at Stanley River. In particular sampling emphasized variations in light environment and in atmospheric mixing around leaves. A schematic showing relative positions of samples with respect to these situations is given in Figure 6.

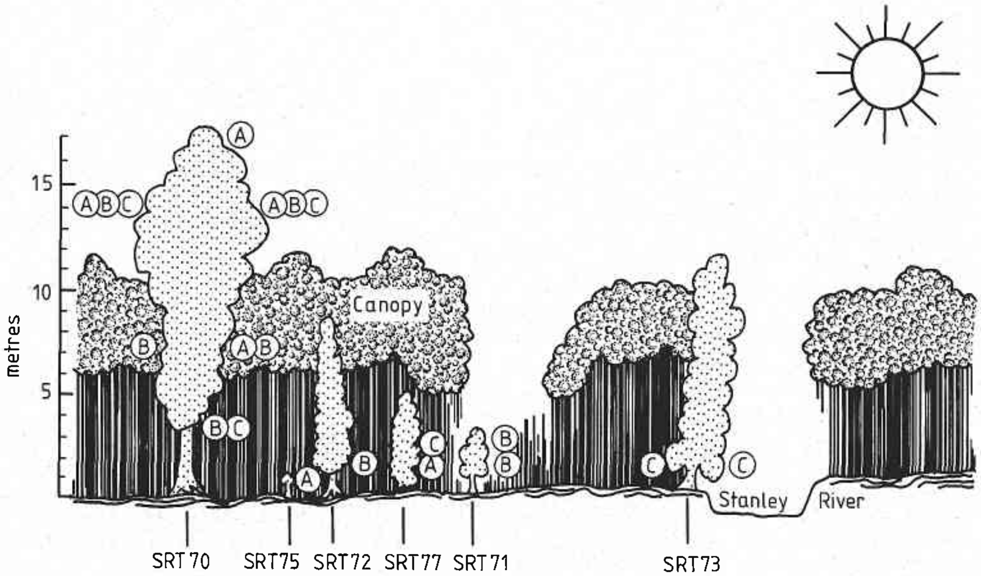


Figure 6 A schematic indicating the location and shading of leaf and branch samples collected for $\delta^{13}C$ analyses. Letters indicate activities described in Table 6.

6.2 Carbon Isotope Variations within One Branch

Before comparing $^{13}C/^{12}C$ values between branches it is important to assess the representativeness of material from any one branch. Plate 4 shows a typical branchlet of Huon pine. The "needles" are really thin stems ensheathed by overlapping bract-like leaves arranged in a spiral (Plate 5). Three adjacent leaves form approximately one whorl of the spiral around the stem.

A branch in a shaded position of SRT 70, 6 m above ground was harvested in February 1981. Terminal shoots were selected and side branches removed. Inspection of the stem suggested a distinction between regions of functional leaves (green and full, current seasons growth?), senescing leaves (darker green, with brown tipped leaves), and non-functional leaves (brown/grey flaky surface), with each section typically 50-100 mm length.

Starting from the tip, successive 5-whorl sections of functional leaves were cut from 13 separate stems. Dry weight of each 5-whorl section was 2-3 mg requiring pooling of replicate stems to produce the 20-30 mg required for combustion and analysis. The 13 stems were sorted in two

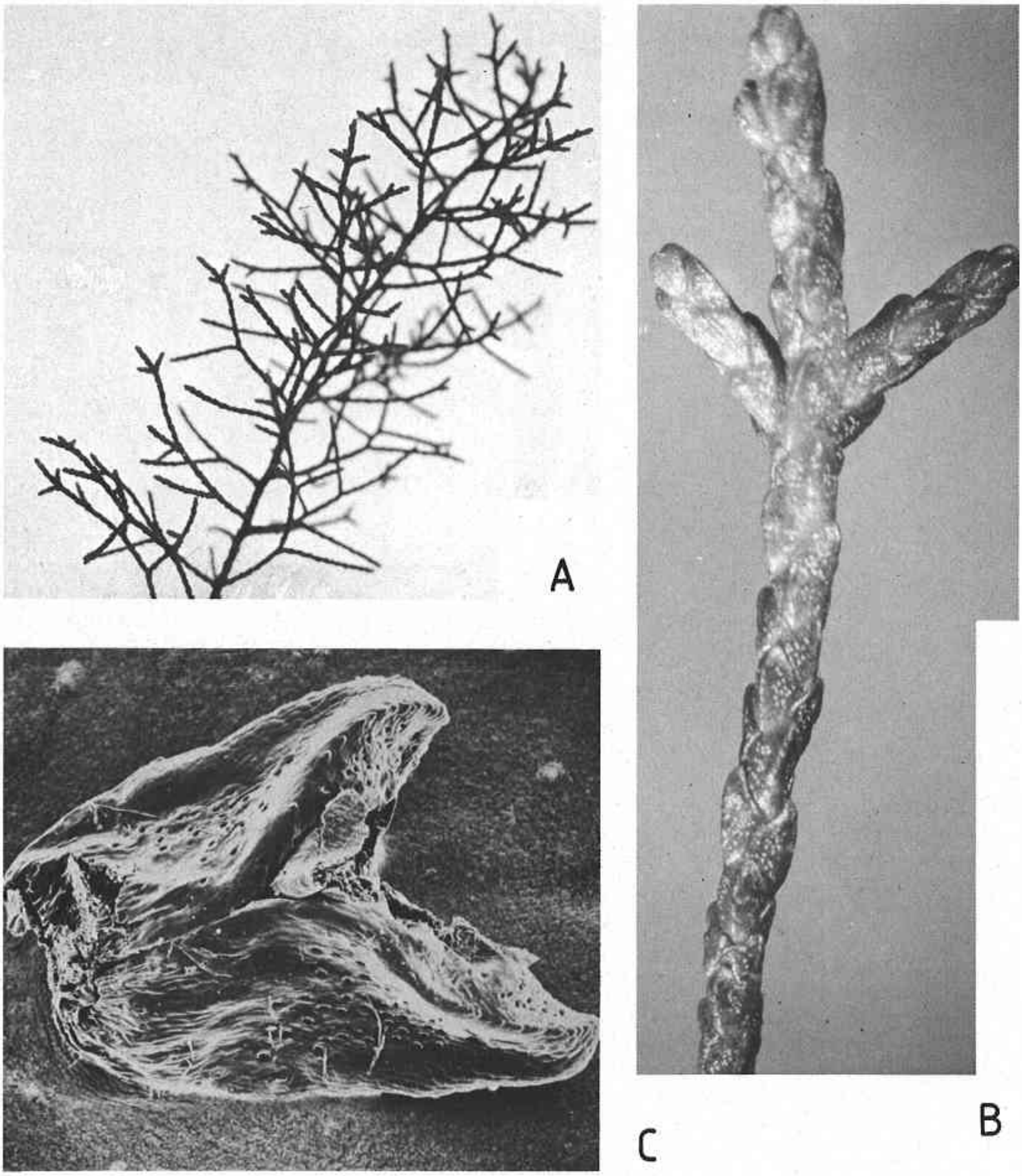


PLATE 4 A: A branchlet of Huon pine.

B: A stem tip of Huon pine showing the spirally-arranged, appressed, "functional" leaves. (scale is in mm.)

C: A pair of Huon pine leaves (magnification x 55) showing stomata.

groups, the first group having 10-12 five-whorl sections of functional leaves, the second group with 6-9 sections. The corresponding 5-whorl sections for each group were combined and evenly mixed before analysis. The $\delta^{13}C$ values are given in Table 4, where

$$\delta^{13}C = \left[\frac{^{13}C/^{12}C \text{ sample}}{^{13}C/^{12}C \text{ PDB}} - 1 \right] \times 1000 \ ^{o}/_{oo}$$

Further details of the combustion and measurement technique, including correction and conversion of isotope ratios to the PDB scale are given in Section 9.3.3 and in Francey *et al.* (in prep.). The $\delta^{13}C$ gradients from the tip are large and systematic, with a significant absolute difference between the groups.

Four replicates of stem regions with senescing leaves from the same branch were divided into 6 equal sections. For two replicates, a small equal portion (5 mg) of each section was combined to obtain an average $\delta^{13}C$ from the "senescing" stems, giving values of -27.26 and -27.60°/₀₀, both marginally more positive than the last sections of the "functional" stems. Small equal portions (5 mg) from corresponding sections (1 to 6) of each 4 replicates of the "senescing" stems were combined to give $\delta^{13}C$ values shown in Table 11. These values are consistent with the two 6-section averaged values above, and are relatively constant along the stem.

As an independent assessment of these effects, a further four stems from the SRT 70 6 m branch, were first divided into the "functional leaf", "senescing leaf" and where available, non-functional leaf categories and each split into 6 sections of equal length. Adjacent sections were paired and combined with corresponding sections from two of the stems to provide 6 samples over the first two categories, and the second pair of stems similarly pooled over 3 categories to give 9 samples. The resulting

TABLE 4

The strong gradient in $\delta^{13}C$ along the stem (from the tip) in 5 whorl stem sections with "functional" leaves. Group 1 combines 10 to 12 sections from 6 stems and group 2, 6 to 9 sections from 7 stems. All stems are from a 6 m height shaded branch of SRT70. $\delta^{13}C$ values are in $^{o}/_{oo}$ with respect to PDB.

Section	Group 1 (10-12 sections) (6 stems)	Group 2 (6-9 sections) (7 stems)
1 (Tip)	-29.19	-28.89
2	-29.26	-28.89
3	-29.18	-28.75
4	-28.99	-28.60
5	-28.73	-28.37
6	-28.70	-28.17
7	-28.54	-27.97
8	-28.36	-27.92
9	-28.21	-27.58
10	-27.94	-
11	-27.80	-

TABLE 5

The insignificant gradient in $\delta^{13}C$ along the stem for equal length sections of stem with "senescing" leaves. Stems are from the 6 m shaded branch of SRT 70.

Section	$\delta^{13}_{PDB}C$ (°/₀₀)
1	-27.21
2	-27.70
3	-27.42
4	-27.28
5	-27.34
6	-27.37

TABLE 6

The overall gradient in $\delta^{13}C$ along the stem from the tip for combinations of stem sections, representing 3 equal length divisions of each stem in each of the 3 categories of "functional", "senescing" and "non-functional" leaves. Stems are from the 6 m shaded branch of SRT 70. Total dry weight of the combined stem sections is also shown.

Leaf Category	Sections	Stems 1, 4 Dry weight (mg)	Stems 1, 4 $\delta^{13}_{PDB}C$ (°/₀₀)	Stems 2, 3 Dry weight (mg)	Stems 2, 3 δ^{13}_{PDB} (°/₀₀)
Functional	1,2	(28)	-29.24	(25)	-28.64
	3,4	(36)	-28.93	(42)	-28.31
	5,6	(66)	-28.13	(88)	-27.37
Senescing	1,2	(38)	-27.55	(81)	-26.84
	3,4	(48)	-27.45	(83)	-26.66
	5,6	(59)	-27.19		-26.94*
Non-Functional	1,2	(121)	-27.01		
	3,4	(115)	-26.98		
	5,6	(118)	-26.95		

(*stem 2 only)

analyses are summarized in Table 6. The total dry weights of sections from which the samples were formed are also shown. The gradient in $\delta^{13}C$ is largely confined to the stem sections with functional leaves.

6.3 Carbon Isotope Variations from Branch to Branch

On the basis of the previous section, considerable care was exercised in comparing $\delta^{13}C$ of leaf material from different branches. From the material collected off SRT 70 in February 1981, the tip-most 10-whorls were sampled at four positions on the tree, as illustrated (Figure 6), at 17 m (exposed, north facing), 14 m (exposed, north east facing), 14 m (shady, west facing) and 6 m (shaded, south facing). At each position approximately 30 mg (dry weight) replicate samples were obtained from the tips of individual branchlets or tufts. Selected replicates were combusted whole for analysis. The results are shown in Table 7.

Also included are single measurements of stems with "non-functional leaves" from the four positions, and the derived difference between these values and the mean tip value. There are strong position-sensitive $\delta^{13}C$ variations with the exposed values less negative than shaded values for both tips and stem. This is particularly important at the two 14 m level locations where atmospheric mixing should be practically identical. The difference between tips and stem appears to be largely independent of position.

In conflict with the last statement, however, are the results for a small (5 m high) completely shaded sapling (SRT 77), sampled in February 1981. Four stems were each divided into 10-whorl sections starting at the tip, providing 5 to 7 section series. Corresponding sections were combined from all four replicates to provide the results of Table 8. Apart from section 7 for which only one small replicate was available, the monotonic increase in $\delta^{13}C$ is still evident but of smaller magnitude than seen on SRT 70, see Tables 4, 6.

Confirmation of these results was sought in February 1982 with more extensive sampling of SRT 70, plus other trees. The results are summarised in Table 9. The $\delta^{13}C$ of the first 10 mm (approximately) of the tip are compared to that of stem wood of approximate diameter 5 mm (typically some 200 mm from the tip) on selected branches. Also included are $\delta^{13}C$ for cellulose extracted from tip and stem for the exposed branch on SRT 70.

For these trees, a large relatively consistent $\delta^{13}C$ difference is observed throughout. The magnitude of the difference is slightly larger than that in Table 7, presumably as a result of the different sampling technique. There is a suggestion of a slightly larger difference at the higher levels of SRT 70.

The $\delta^{13}C$ values for cellulose exhibit a larger difference between tip and stem than for the corresponding whole material; most of the difference comes from the change in stem rather than tip values. This is consistent with the expectation of a larger proportion of isotopically lighter lignin in the whole stem compared to the tips.

The very negative values for the 8 m sapling are consistent with the dense shading and the magnitude of these $\delta^{13}C$ are only exceeded by the

TABLE 7

The variation in $\delta^{13}C$ with branch location on SRT 70. Locations vary in height above ground and exposure to the sun. The $\delta^{13}C$ variation is similar for 10 whorl tip sections and for corresponding stem sections with "non-functional" leaves.
Brackets indicate stem replicate number.

		$\delta^{13}_{PDB}C$ (°/₀₀)	
Position	10 Whorl Tips	Stem with Non-functional Leaves	Difference
17 m: N, exposed	-27.51 (4)		
	-27.85 (14)		
	-27.31 (16)	-25.36 (9)	2.20
14 m: NE, exposed	-27.02 (1)		
	-27.51 (4)		
	-27.61 (6)	-25.75 (5)	1.63
14 m: W, shady	-28.49 (1)		
	-28.10 (3)		
	-26.67 (5)		
	-28.18 (7)		
	-28.38 (9)	-26.15 (1)	2.01
6 m: S, shady	-28.66 (1)		
	-29.41 (2)		
	-29.67 (3)	-27.01 (1,3)	2.24

TABLE 8

The small gradient in $\delta^{13}C$ along the stem from the tip in 10 whorl sections of deeply shaded sapling SRT 77.
Brackets indicate stem replicate numbers combined for analysis

Section	$\delta^{13}_{PDB}C$ (°/₀₀)
1 (1, 2, 3, 4) [tip]	-31.72
2 (1, 2, 3, 4)	-31.71
3 (1, 2, 3, 4)	-31.55
4 (1, 2, 3, 4)	-31.54
5 (1, 2, 3, 4)	-31.47
6 (1, 2, 3)	-31.34
7 (1)	-31.66

SRT 77 values. The very small tip to stem gradient for SRT 77 (see Table 8) is unique in this data set. It is interesting that the ^{13}C values for Celery-top pine leaf tips (see Table 10) correspond closely to ^{13}C of Huon pine tips from comparable situations (Table 9).

6.4 Discussion

Despite the preliminary nature of the sampling, very strong systematic stable carbon isotope effects are evident in these data. The magnitude of the effects, spanning up to 9°/₀₀, dwarf the anticipated atmospheric signal due to fossil fuel combustion which is of order 0.05°/₀₀ per year at present. Light level obviously plays a major role, but neither light level nor atmospheric composition can explain the tip to stem gradient.

A fuller discussion and attempted interpretation of these data, coupled with measurements on the light environment, atmosphere composition and gas exchange characteristics (in following sections) is the subject of a separate paper.

TABLE 9

The variation in $\delta^{13}C$ with branch location for SRT 70 (repeat), SRT 71 and SRT 72. Locations vary in height above ground and exposure to the sun. Results are for tip sections (approx. 10 mm) and for corresponding sections with non-functional leaves (approx. 200 mm from tip). Results for cellulose extracted from tip and stem sections of the 16 m, full sun, SRT 70 branch are also included.

	$\delta^{13}_{PDB}C$ (°/₀₀)		
Tree/Position	Tip	Stem	Difference
SRT 70: Mature tree with foliage above and below canopy			
: 14 m; N, full sun	-27.33, 27.76	-24.35, -24.31	3.22
as above, CELLULOSE	-26.97	-22.67	4.30]
: 14 m; SW, shaded	-29.12	-26.54	2.58
: 6.9 m; SW, morning sun	-28.53	-25.74	2.79
: 6.9 m; SW, full shade	-29.74	-27.11	2.63
: 3.5 m; NE, morning sun	-29.32	-26.93	2.39
SRT 71: 2 m high sapling, well exposed to sunlight			
: 2 m; NW, sunny	-27.22	-24.83	2.39
: 1 m; NW, sunny	-28.27	-26.14	2.13
SRT 72: 8 m high sapling, completely shaded under dense canopy			
: 1 m; S, deep shade	-31.00	-28.60	2.40

TABLE 10

$\delta^{13}C$ and $\Delta^{14}C$ of Celery-top Pine leaves from above and below the canopy

Tree (Analysis)	Relation to Canopy	$\delta^{13}_{PDB}C$ (°/₀₀)	$\Delta^{14}C$ (°/₀₀)
SRT 74: (SUA 5008)	below	-29.6	286 ± 9
SRT 2: (SUA 5009)	above	-24.0	293 ± 7

6.5 *^{14}C Measurements of Leaf Material (MB, SMcP, RJF)*

As an aside to the direct measurements of sub-canopy atmospheric composition (Section 9) a measurement of the radiocarbon content of leaves was employed as a means of placing limits on the contribution of CO_2 from decaying litter mass. Depending on the age and amount of the decaying material, the ^{14}C content of tree-rings formed from sub-canopy air might not accurately reflect atmospheric levels.

For this purpose, leaves of Celery-top pine were selected, since the cluster of leaves corresponding to current season's growth on these trees is easily identified, and provides sufficient bulk for ^{14}C determinations.

The method exploits the steadily declining $\Delta^{14}C$ of the free atmosphere at about 16°/₀₀ year since the peak of atmospheric nuclear bomb testing around 1965. It is assumed that any seasonal variations in $\Delta^{14}C$ are removed by the seasonal sampling of the trees, and that the carbon turnover time for litter-mass in this environment is 1-2 years (Atjay *et al.* 1979).

Table 10 shows $\delta^{13}C$ and $\Delta^{14}C$ for new leaves from SRT 74, a 2 m sapling situated under dense closed canopy on the alluvial flat, and from the top of SRT 2, a 22 m high tree on a hill slope with all foliage above the canopy.

The leaves were washed in distilled water and combusted to CO_2 for a $\delta^{13}C$ determination. The CO_2 was then converted to benzene for $\Delta^{14}C$ determination. SUA 5008 was a small sample requiring dilution with inactive CO_2 for benzene synthesis and ^{14}C measurement. These samples were measured sequentially in the same vial and ^{14}C counter, and the $\Delta^{14}C$ values are normalised to $\delta^{13}C$ = -25°/₀₀ and expressed relative to the 0.95 NBS oxalic acid standard after correction for decay between 1950 and 1981 AD (Stuiver and Polach 1977). For comparison with published $D^{14}C$ values (Polach and Singh 1980) 5°/₀₀ should be added to the $\Delta^{14}C$ values of Table 10.

If the sub-canopy CO_2 (at approximately 2 m) is a mixture of CO_2 of contemporary activity (taken as 293 °/₀₀) and CO_2 with $\Delta^{14}C$ in the range 309 to 325°/₀₀ (based on a 16°/₀₀yr^{-1} atmospheric decline and 1-2 year littermass decay), then the one sigma upper limit of the sub-canopy $\Delta^{14}C$ represents an upper limit of about 8% of sub-canopy CO_2 originating from littermass.

7. Meteorological and Light Environment Data

7.1 Climatological Data

The tree-ring data represent integrated records of environmental influences, so that it is important to relate conditions at the time of measurement to those expected over a longer term. Meteorological observations are scarce in the Stanley River area, but some data for the last decade exist for two stations approximately 20 km north and south of the site. Table 11 gives details on the sites of Bureau of Meteorology stations relative to the tree-ring site.

Monthly mean daily maximum and minimum temperatures are given in Table 12, monthly rainfall amounts in Table 13, and cloud amounts in Table 14. Included in Table 14 is information on monthly averages of daily sunshine duration at Savage River only.

TABLE 11

Details of the Stanley River site relative to nearby meteorological stations.

Location	Latitude	Longitude	Elevation	Distance from West Coast	Years of Records
Savage River	41° 30S	145° 11E	352 m	33 km	1966-82
Stanley River site	41° 42S	145° 18E	230 m	23 km	-
Zeehan	41° 53S	145° 20E	172 m	14 km	1969-78

7.2 Meteorological Observations at the Stanley River Site (NGR, DB, HSG)

Basic meteorological observations were made at various times throughout the expeditions, most frequently at times corresponding to air sampling events. These are summarized in Tables 15 and 16 for 1981 and 1982 respectively. The site of the observation is identified for comparison with Figures 2, 3 and 4. The "ridge" site refers to Whaleback Ridge, an exposed treeless ridge 2.5 km west of the river and 220 m above the valley floor.

7.3 Light Environment at the Stanley River Site (RMG)

Two quantum sensors (LI-COR Instruments, Lincoln, Nebraska, Model LI 1905) sensitive in the photosynthetically active wave-band 400-700 nm, were used. One was located near 4200 mN, 5150 mW (Figure 3) on the top of a grass-covered hill, about 50 m above, and overlooking the Stanley River Valley. The second was placed in each of two positions under the forest canopy.

TABLE 12

Means, standard deviations (in brackets) and years of available data of the monthly means of maximum and minimum daily temperatures at Savage River and Zeehan

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Daily Mean Max. Temperature (°C)	Savage River (1966-82)	19.6 (1.7) 13	20.3 (1.1) 13	17.5 (1.4) 14	14.6 (1.1) 15	12.0 (1.0) 16	10.2 (0.9) 16	9.2 (0.5) 16	9.9 (0.6) 16	11.1 (1.0) 17	13.4 (1.1) 16	15.2 (1.2) 16	17.0 (1.5) 15	14.3 (0.4) 10
	Zeehan (1969-78)	20.8 (1.5) 10	21.5 (1.7) 10	19.2 (1.5) 10	16.2 (1.1) 9	13.8 (0.8) 9	11.7 (0.8) 10	10.9 (0.6) 10	11.6 (0.8) 10	12.8 (1.1) 10	15.0 (0.9) 10	16.7 (0.8) 9	18.1 (1.5) 9	15.8 (0.3) 8
Daily Mean Min. Temperature (°C)	Savage River (1966-82)	9.5 (1.2) 14	10.4 (1.2) 14	8.6 (1.6) 14	7.4 (1.3) 15	5.7 (1.3) 16	4.2 (0.9) 15	3.5 (0.8) 16	3.5 (1.1) 17	4.1 (1.1) 17	5.4 (0.8) 16	6.8 (0.9) 16	7.9 (1.1) 15	6.5 (0.6) 10
	Zeehan (1969-78)	9.7 (0.5) 10	10.3 (1.5) 10	8.7 (0.9) 10	7.4 (0.5) 9	5.5 (1.3) 9	2.9 (0.9) 10	3.5 (0.8) 10	3.5 (0.7) 10	4.4 (1.3) 10	5.6 (0.6) 10	6.9 (0.9) 9	8.6 (0.7) 8	6.5 (0.2) 7

TABLE 13

Means, standard deviations (in brackets) and years of available data of the total monthly rain amount at Savage River and Zeehan

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Total Rainfall (mm)	Savage River (1966-82)	95 (41) 13	82 (44) 13	114 (47) 13	174 (33) 14	212 (112) 15	186 (56) 14	256 (75) 14	247 (60) 14	203 (81) 16	158 (66) 16	144 (68) 15	135 (78) 14	1978 (188) 8
	Zeehan (1969-78)	114 (38) 10	96 (48) 10	127 (56) 10	236 (41) 10	271 (120) 10	203 (77) 10	315 (117) 10	275 (60) 10	213 (81) 10	182 (70) 10	147 (58) 9	190 (76) 9	2396 (228) 9

TABLE 14

Means, standard deviations (in brackets) and years of available data of the number of cloudy days per month, the number of clear days per month and the monthly means of daily sunshine duration for Savage River and Zeehan

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Number of Cloudy Days (> 6/8 cloud)	Savage River (1966-81)	13.0 (3.5) 13	11.1 (2.4) 13	14.4 (3.6) 13	16.2 (3.4) 14	16.5 (5.1) 15	15.9 (4.0) 15	17.8 (6.7) 15	16.8 (6.7) 16	20.2 (3.3) 16	17.6 (4.6) 16	15.8 (5.6) 16	15.0 (6.3) 15	184 (26) 11
	Zeehan (1969-78)	9.8 (4.7) 10	8.5 (2.7) 10	12.1 (13.3) 10	14.5 (12.3) 10	16.7 (5.2) 9	12.9 (4.5) 10	19.5 (4.2) 10	15.9 (2.8) 10	17.1 (3.2) 10	15.6 (3.9) 10	14.2 (3.3) 9	15.9 (3.8) 9	173 (19) 8
Number of Clear Days (< 2/8 cloud)	Savage River (1966-81)	5.2 (3.4) 13	3.8 (2.4) 13	3.5 (2.7) 13	2.3 (1.9) 14	2.1 (1.6) 15	2.1 (2.3) 15	1.3 (1.5) 15	1.4 (1.5) 16	0.8 (1.0) 16	1.6 (1.7) 16	2.3 (2.1) 16	2.5 (2.2) 15	27 (13) 11
	Zeehan (1969-78)	4.6 (3.2) 10	3.6 (2.5) 10	4.1 (2.7) 10	2.0 (1.9) 10	1.6 (1.9) 9	2.8 (2.5) 10	1.3 (1.5) 10	1.1 (1.4) 10	1.5 (1.4) 10	1.7 (1.3) 10	2.2 (1.3) 9	2.1 (2.4) 9	29 (9) 8
Mean Daily Sunshine Duration (hr)	Savage River (1966-81)	7.5 (1.3) 9	7.8 (0.5) 8	5.2 (0.8) 10	4.1 (0.8) 11	3.3 (1.2) 12	2.8 (0.7) 12	2.7 (0.8) 11	3.6 (0.8) 12	3.9 (0.9) 14	5.0 (0.8) 15	6.0 (0.9) 13	6.3 (1.1) 10	5.0 (0.5) 4

TABLE 15

Meteorological observations at the Stanley River site in 1981

Date	Time (AEST)	Site*	Height (m)	T_d(°C)	T_w(°C)	Wind Speed (ms^{-1})	Wind Direction (deg from N)	Pressure (mb)	Cloud (eighths)	Weather
3 Feb 81	1645	T	1	30	19	-	-		2 Sc	fine
4 Feb 81	0825	T	1	16.2	16.0	calm	-	980	8 Cu	drizzle
	1200	S1	1	16.2	15.8	calm	-	-	8 St	intermittant drizzle
	1202	S1	3	15.5	14.7	"	-	-	8 St	
	1315	S1	1	15.1	14.8	"	-	-	8 Sc	overcast
	1317	S1	3	15.1	14.7	"	-	-	8 Sc	
	1400	T	1	15.0	15.2	calm	-	985	-	mist (smoke)
5 Feb 81	0920	T	1	12.0	11.9	calm	-	990	-	mist (smoke)
	1010	R	1	13.3	11.4	2	110-140	-	8 Cu Sc	misty
	1133	S1	1	15.9	14.4	light/variable	-	-	7 Cu Sc	clearing
	1148	S1	5	17.6	13.7	" "	-	-	"	
	1151	S1	1	16.2	14.0	" "	-	-	"	
	1310	H	1	19.7	14.5	light	135	-	6 Cu Sc	fine, sunny
	1352	T	1	20.4	15.5	calm	-	998	3 Sc	fine, clear
	1515	S1	1	18.0	14.5	light/variable	-	-	3 Cu	fine, sunny
6 Feb 81	0915	S1	1	12.0	10.4	calm	-	991	5 Cu Sc	misty
	0954	S1	1	15.0	13.0	light/variable	-	-	4 Cu	fine, sunny
	0956	S1	5	17.0	14.0	" "	-	-	"	
	1445	T	1	18.6	11.5	0.5	SW	990	0	fine
7 Feb 81	0900	T	1	13.4	12.4	calm	-	989	6 Cu Sc	fine, mist lifting
8 Feb 81	0830	T	1	20.2	17.0	1, gusty	WSW	-	1 Cu, 1Ci	fine
9 Feb 81	0940	T	1	16.4	16.0	calm	-	972	8 Cu Sc	rain

* T (tent sub-canopy) 4575N, 4950W; S1 (sub-canopy) 4670N, 4680W; H (helipad) 4670N, 4770W; R (ridge), see text.

TABLE 16

Meteorological observations atthe Stanley River site in 1982

Date	Time (AEST)	Site*	Height (m)	Temperature Td(°C)	Temperature Tw(°C)	Wind Speed (ms^{-1})	Direction	Cloud Eighths	Weather
12 Feb 82	1040	S2	1	19.0	16.7	calm	-	0	fine
	1310	R	1	-	-	2	NW	1 Cu, 1 As	fine
	1415	S2	1	23.9	17.8	calm	-	1 Cu	fine
	1830	S2	1	20.4	17.8	calm	-	1 Cu, 1 Ci	fine
13 Feb 82	0831	S2	1	17.5	16.6	slight breeze	-	0	fine
	0937	S2	1	20.1	17.8	calm	-	0	fine
	1105	S2	1	23.9	19.3	slight breeze	-	0	fine
	1222	S2	1	26.4	19.7	calm	-	0	fine
	1326	R	1	28.4	18.6	7		1 Cu	fine
	1430	S2	1	27.8	20.9	slight breeze	-	0	fine
	1650	S2	1	26.8	20.4	calm	-	1 Cu	fine
	1810	S2	1	25.3	20.1	calm	-	0	fine
14 Feb 82	0853	S2	1	20.6	18.3	light breeze	-	1 Cu, 1 Ac, 1 Ci	fine
	1012	S2	1	25.7	18.7	light variable	-	1 Cu, 1 Ac, 1 Ci	fine
	1130	R	1	32.1	18.1	7	NE	1 Cu, 1 Ac, 1 Ci	fine
	1232	S2	1	31.5	19.3	fresh breeze	-	1 Cu Sc, 1 Ac	fine

* S2 (sub-canopy) 4360N, 4800W; R (ridge), see Section 8.2.

The quantum sensor in the open site was attached to a printing integrator set to print every 10 minutes. The complete record of this sensor is shown in Figure 7. As indicated by Table 15, it was raining on February 4 up until mid-morning and overcast all day. The other three days were sunny with some scattered cloud. Peak and day-long average photosynthetic photon flux densities (PPFD) are given for each day (of approximately 14.2 hours). With respect to cloud cover it can be seen from Table 14 that the overcast conditions of 4 February 1981 can be expected about 10 days in February, while the fine days of 5-8 February 1981 (and 12-14 February 1982) can be expected on only 3-4 days of February.

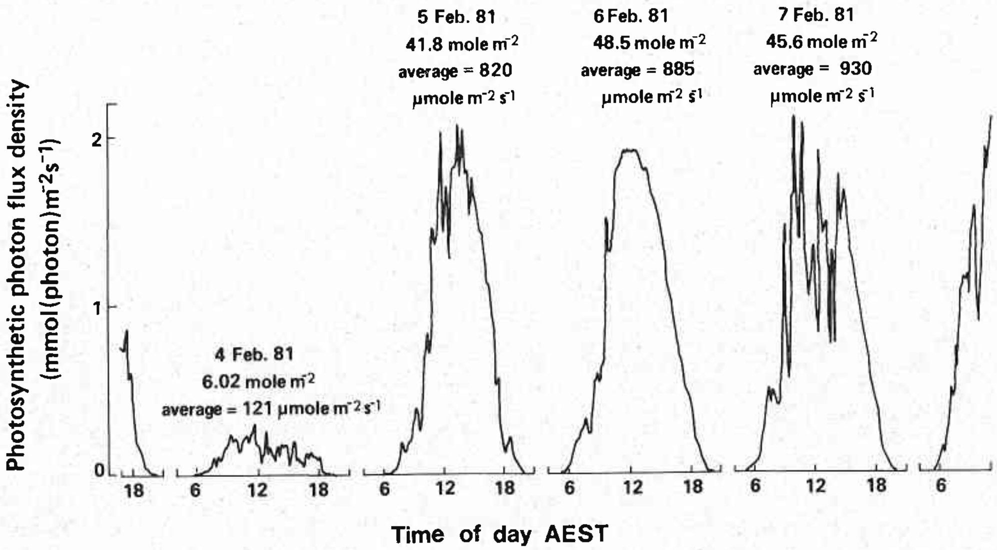


Figure 7 The photosynthetically active photon flux density (PPFD), based on ten minute integrals, on a well-exposed site close to the Stanley River, February 1981.

The sub-canopy sensor was attached to an integrator which required visual recording and resetting. This recording was done several times a day when other tasks permitted. It was not practicable to make after-dark recordings to establish dawn to dusk integrals. Generally recordings were taken to be synchronous with the printing of the hill top integrator.

Location 1 for the sub-canopy sensor was under mature Huon pine SRT 76, at 4670 mN, 4680 mW (Figure 3). There was very little vegetation on the ground due to dense shade, though there were some tree saplings. Location 2 was on a fallen Huon log in the swampy flats at 4525 mN, 4925 mW in Figure 3. The sensor was positioned adjacent to a 15 cm tall Huon "seedling" growing out of the log. Both locations were shady but had occasional sun flecks. The average PPFD above and below the canopy at each location, and percent transmission of photosynthetically active quanta to the forest floor, are given in Table 17.

TABLE 17

Transmission of solar photosynthetically active quanta to the forest floor.

	Time over which light integrated (AEST)	Average photon flux density (daylight hours) ($\mu mol\ m^{-2}\ s^{-1}$)		
		Above canopy	Forest Floor	Percent Transmission
		Location 1 (Near SRT 76)		
Heavily overcast	0940; 4 Feb 81 to 1020; 5 Feb 81	88	1.23	1.4
Bright; little cloud	1031; 5 Feb 81 to 1031; 6 Feb 81	919	6.10	0.6
		Location 2 (Near SRT 75)		
Cloud free	1121; 6 Feb 81 to 1201; 6 Feb 81	1981	62.1	3.3
Bright; little cloud	1121; 6 Feb 81 to 1121; 8 Feb 81	964.5	21.5	2.2

On the overcast rainy day in the first location 1.4% of the diffuse incident photons reached the forest floor. On the second day at this location, bright conditions meant that most of the light came in direct rather than diffuse form and the transmission was reduced to 0.6%.

At the second location conditions were less shaded; over three bright days 2.2% of the incident radiation penetrated the forest canopy. Over the period of maximum radiation close to noon on February 6, the high elevation of the sun led to a 50% greater penetration of light - namely 3.3%.

Thus the highest hour-long PPFD which the 15 cm seedling is ever likely to experience is about 60 $\mu mol\ m^{-2} s^{-1}$ (Table 17 line 3) which in plant physiological terms is very low indeed. Since 6 February 1981 was unusually bright and clear the hour-long average PPFD at the forest through the daylight hours of the summer months is likely to be very much less than 60 $\mu mol\ m^{-2}\ s^{-1}$, i.e. between 1 $\mu mol\ m^{-2}\ s^{-1}$ (Table 17, line 1) and 20 $\mu mol\ m^{-2}\ s^{-1}$ (Table 17, line 4) with the typical day being closer to the low end of that range.

The highest instantaneous PPFD observed was when a sunfleck was dancing over the sensor. Then the meter needle flicked around with a mean value in the region of 150 $\mu mol\ m^{-2}\ s^{-1}$.

8. Stomatal Conductance and Gas Exchange Measurements

8.1 Introduction

The aim of these measurements, in conjunction with the leaf and branch sampling for $^{13}C/^{12}C$ analyses (Section 6) was to elucidate the environmental influences on fractionation of carbon as it is removed from the atmosphere and stored in trees. As noted in Section 6.1, a quantitative model of carbon isotope fractionation by leaves developed by Farquhar *et al.* (1982[b]), influenced the Stanley River activities. In brief the model expresses the relative isotopic ratio of photosynthate, $\delta_p^{13}C$ as

$$\delta_p^{13}C \approx \delta_a^{13}C - a - (b-a)\ c_i/c_a \qquad (8.1)$$

where c_a, $\delta_a^{13}C$ represent the concentration and isotopic composition respectively of CO_2 in air surrounding the leaf; c_i is the CO_2 concentration in the intercellular spaces of leaf mesophyll; a(= 4.4°/$_{oo}$) and b(≈ 30°/$_{oo}$) are constants representing discrimination due to diffusion through the stomata and in the carboxylation reaction, respectively.

Farquhar *et al.* (1982[b]) give additional terms, thought to be small, to account for photo- and dark-respiration, and for possible gradients in CO_2 from the intercellular spaces to the site of carboxylation. To paraphrase Farquhar (1980), "factors which reduce CO_2 assimilation rate through effects primarily on the mesophyll capacity for photosynthesis (e.g. very low light intensities and deficiencies of certain mineral nutrients) will increase c_i/c_a and reduce $\delta_p^{13}C$; factors which reduce CO_2 assimilation rates primarily through reduction of supply of CO_2 through the stomata (for example, large vapour pressure deficits) will decrease c_i/c_a and increase $\delta_p^{13}C$".

In February 1981 a ventilated diffusion porometer was used to obtain preliminary information on the stomatal behaviour of Huon pine. In February 1982 a portable gas analysis system was used in the field to obtain stomatal conductance, assimilation rate and c_i/c_a.

8.2 Stomatal Conductance Measurements February 1981 (RMG, NGR)

Measurements were made with a ventilated diffusion porometer designed for flat leaves. For the Huon pine, we poked the branchlets (still attached to the branch) into the measuring compartment on sunny days (so that there was no surface moisture) and started the system running within seconds. Repeated measurements were made on each branchlet without removing it from the chamber in order to ascertain the time-course of stomatal closure in response to darkness inside the measurement cuvette. For Huon pines we found closure to start immediately, in contrast to the more typical behaviour of an unidentified broad-leaved plant on the forest floor (Figure 8). Whereas the broad-leaf exhibited a 4 to 5 minute lag followed by stomatal closure within 20 minutes, for the Huon closure started immediately but was not complete after an hour. Leaves having high stomatal conductance showed rapid initial closure, while those with low conductance showed a slow rate of closure. A conductance was estimated for each needle by taking a series of 6 to 8 determinations over the first five minutes after insertion, and extrapolating the time-course to t=0 (Figure 8, curves A and B).

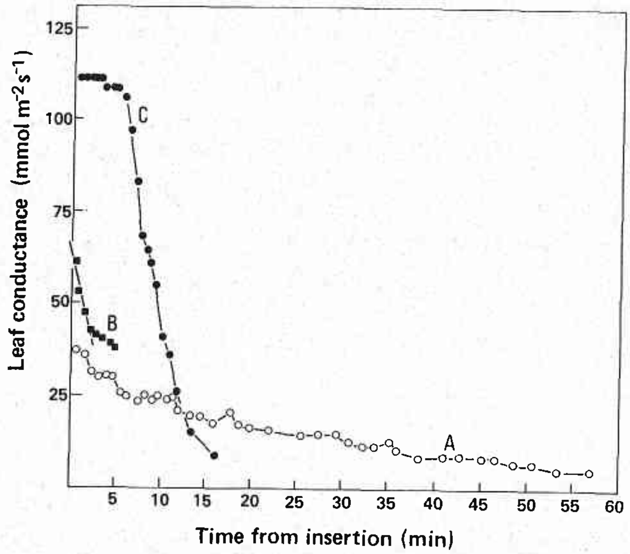


Figure 8 Time-course of lead conductance after darkening by insertion into a ventilated diffusion porometer.

A: Attached Huon pine branchlet growing in a well-exposed site and illuminated at about 2000 μmole m^{-2} s^{-1} immediately before measurement.

B: An example of the extrapolation procedure, based on a 5 minute time-course, to obtain the stomatal conductance of Huon pine at the moment of insertion into the porometer.

C: An unidentified attached broad leaf growing in a moderately exposed site and illuminated at about 70 μmole m^{-2} s^{-1} immediately before measurement.

To calculate these conductances required an estimate of leaf area. When the branchlet was removed from the instrument, its point of entry into the chamber was marked with a piece of adhesive tape and the branchlet was stored in a plastic bag. Later the length and diameter of the branchlet was determined with ruler and micrometer gauge in the laboratory. Specification of diameter is problematic because the branchlet, being made up of numerous tiny, closely appressed leaves, is bumpy. We determined the "thickness" when the micrometer first gripped ("loose diameter"). The estimates of stomatal conductance presented in this section are based on leaf areas calculated as the surface area of cylinders with measured length and "loose diameter".

The ventilated diffusion porometer was calibrated for infinite "stomatal" conductance using dead Huon pine branchlets soaked in water.

At the time of measurement in the field the light intensity was determined using a small portable exposure meter, reading in foot candles but calibrated in μmol m^{-2} s^{-1} against a quantum sensor in sunlight (12000 foot candles corresponding to about 2000 μmol m^{-2} s^{-1}).

Branchlets were selected from a range of positions - from seedlings or mature trees, from low in the forest to high in the canopy, from various

TABLE 18

Stomatal conductance of Huon Pine branchlets determined, by extrapolation, at the moment of insertion into a ventilated diffusion porometer

Tree	Branchlet No.	Approx. location on grid mN	mW	Date	Time (AEST)	Branch attached or detached	Approx. height from ground (m)	PPFD μmol m^{-2} s^{-1}	Leaf conductance mmol m^{-2} s^{-1}
SRT 76	5	4670	4680	5 Feb 81	1300	A	1	6	29
"	6	"	"	5 " "	1320	A	1	27	57
78	7	4570	4750	5 " "	1340	A	2	1700	28
"	8	"	"	5 " "	1400	D	2	1700	38
75	9	4525	4925	6 Feb 81	1300	A	1	15	98
"	10	"	"	6 " "	1310	A	.5	27	49
"	11	"	"	6 " "	1320	A	.75	23	24
"	12	"	"	6 " "	1330	A	1.5	33	26
"	13	"	"	6 " "	1340	A	1.5	16	27
"	14	"	"	6 " "	1420	D	1.5	67	8
"	15	"	"	6 " "	1430	A	0.5	67	12
77	17	4390	4925	6 " "	1600	A	5	833	25
"	18	"	"	6 " "	1610	A	5	633	27
"	19	"	"	6 " "	1625	A	5	80	16
70	20	4350	4825	7 Feb 81	1200	A	1.6	250	66
"	21	"	"	7 " "	1210	A	1.6	233	41
"	22	"	"	7 " "	1220	A	1.6	141	39
"	23	"	"	7 " "	1230	A	1.6	250	57
"	24	"	"	7 " "	1320	D	1	200	89
"	25	"	"	7 " "	1430	D	3	122	21
"	26	"	"	7 " "	1440	A	3	108	27
"	27	"	"	7 " "	1450	D	3	250	40
"	28	"	"	7 " "	1500	A	3	333	26
"	30	"	"	7 " "	1530	D	11.1	1800	31
"	31	"	"	7 " "	1540	D	11.1	1800	30
"	32	"	"	7 " "	1550	D	11.1	1800	33
SRT 70	33	"	"	7 Feb 81	1600	D	11.1	1800	25

degrees of shading, from locations that were permanently well-illuminated on the edge of clearings to locations that were permanently shady. When samples were taken from high in the canopy, the light intensity was first measured and then a piece of branch was clipped off and dropped down to the porometer operator below who quickly started the measurements. Pre-testing of this procedure indicated that it did not influence the results.

The measurements are presented in Table 18. No clear pattern of conductances could be discerned with respect to position of the leaf in the canopy. Above 300 μmol m^{-2} s^{-1} stomatal conductance was approximately constant (independent of light intensity) at an average value of 29 ± 1.5 μ mol $m^{-2}s^{-1}$. Below 300 μmol m^{-2} s^{-1} a wide range of stomatal conductances was found to be unrelated to light intensity, with values both as high as 90 and as low as 8 μmol $m^{-2}s^{-1}$ being recorded at PPFD less than 50 μmol $m^{-2}s^{-1}$.

In general the stomatal determinations at or below about 60 μmol $m^{-2}s^{-1}$ yielded conductances equal to or greater than values obtained in bright light. At these low light levels, typical of the sub-canopy levels in the brightest conditions (Table 17), the rate of mesophyll photosynthesis would have been close to zero (Section 8.3) suggesting that c_i/c_a would be close to unity. In terms of the Equation 8.1 this is consistent with the low values of $\delta^{13}C$ associated with inner rings (juvenile wood) relative to outer wood (Francey and Farquhar 1982).

8.3 Measurement of Gas Exchange Characteristics, February 1982 (TDS, BW, WC, GDF)

8.3.1 Portable gas exchange system

Three mass flow controllers (Tylan, Model FC260) were used to make "air" from E (80*l*) cylinders of N_2, O_2, and 1% CO_2-in-air.

The flow meters were calibrated by passing the exit gas through a bubbler for humidification and then calculating the volume (assuming 95% saturation) from measurements with a soap bubble flow meter. The rate of flow of this air determined the humidity in the chamber.

Evaporation rate (E) was calculated as:

$$E = \frac{u}{a} w$$

where u is total flow rate of air out of the chamber (moles s^{-1}), w is the mole fraction of water in the air stream, and a is the leaf area (m^2), taken as the projected area of a stem section (note that in Section 8.1, total surface area of a cylindrical section of stem is used for similar purposes).

The decrease in CO_2 concentration as a result of assimilation by the leaf was compensated for by injecting 1% CO_2-in-air directly into the chamber with a fourth flow controller. Assimilation rate (A) was calculated as:

$$A = \frac{u_1 \ (C_1 - C_o)}{a} - E\ C_o$$

where u_1 is the flow of CO_2-enriched air, C_1 is the mole fraction of

CO_2 in the CO_2-enriched air, and c_o the mole fraction of CO_2 in the air leaving the chamber. The evaporation rate term is necessary because water lost from the leaf dilutes the CO_2 in the air stream.

Other gas exchange parameters were calculated according to Caemmerer and Farquhar (1981).

Carbon dioxide was measured with a BINOS-2 infra red gas analyser (Leybold-Heraeus, West Germany).

The compensation method of assimilation rate measurement eliminates the need for an accurate calibration of the gas analyser in the field. In practice the assimilation rate was not perfectly compensated and the difference in CO_2 mole fraction before and after the chamber was included in the calculation of assimilation. The mole fraction of CO_2 in the air entering the chamber was calculated from the flows of gas through the mass flow controllers.

The mole fraction of water in the air stream leaving the chamber was calculated from the measurement of relative humidity using a Humicap sensor (Vaisala, Finland) kept at 35°C. The humidity sensor was calibrated in the field using the technique of Parkinson *et al.* (1980).

The temperature of the aluminium chamber was controlled by Peltier heating/cooling devices (180W installed capacity; Melcor, U.S.A.) using circuitry which compared the signal from a precision reference with the signal from a temperature sensor (AD/590, Analog Devices, U.S.A.). Branchlet temperature was measured with an AD 2036 (Analog Devices, U.S.A.) scanning thermocouple thermometer.

Illumination in the field was from the sun and from a quartz-iodide light source. The system was run from a 12V battery and proof of its portability came when we used the system 14 metres high in the Huon pine tree SRT 70.

8.3.2 Results

Additional photosynthetic photon flux densities (PPFD) were determined with a portable quantum sensor (Lambda LI 185A, Lambda Instruments Corp., U.S.A.) and 20 whorl sections of branch tip were harvested for $\delta^{13}C$ analysis (using the ANU combustion apparatus and Micromass 602D mass spectrometer, c.f. Section 6.2) from various locations on Huon pine trees SRT 73, SRT 70. Gas exchange measurements were conducted at two of these locations as summarized in Table 19.

The phosphorous and total Kjeldahl nitrogen contents of the leaves are also included in Table 19 as potential correlating factors with photosynthetic rate.

The response to quantum flux of two branches on SRT 73 is shown in Figure 9. Branch HP 9 was exposed to sun for 4 hours per day due to the break in the canopy over the river, whereas branch HP 10 was in deep shade all day. Note that proximity to the river for these branches implies substantial differences in light level and atmospheric mixing compared to leaves at similar height under the undisturbed canopy.

TABLE 19

Leaf tip samples used for gas exchange measurements in February 1982. Results for samples HP9, HP10 are shown in Figure 9, and for samples HP5, HP6 in Figure 10. The $\delta^{13}C$, phosphorus content, nitrogen content and dry weight per unit area of harvested tips are included

Tree	Sample No.	Location	$\delta^{13}C_{PDB}$ °/°°	N content m mol m^{-2}	P content m mol m^{-2}	Dry weight/area g m^{-2}
SRT 73	HP 9	1 m, 4 hrs sun	-29.12	250	1.5	414
	HP 10	1 m, deep shade	-30.16	170	0.8	322
SRT 70	HP 1	1 m, 3 hrs sun	-29.68	140	1.1	371
	HP 2	"	-29.25	160	0.9	380
	HP 3	"	-28.86	190	1.6	402
	HP 4	"	-29.26	194	1.2	414
	HP 5	14 m, sun	-27.77	200	1.3	535
	HP 7	"	-27.72		1.4	546
	HP 6	14 m, shade	-28.58	160	1.3	506
	HP 8	"	-28.95		0.7	457

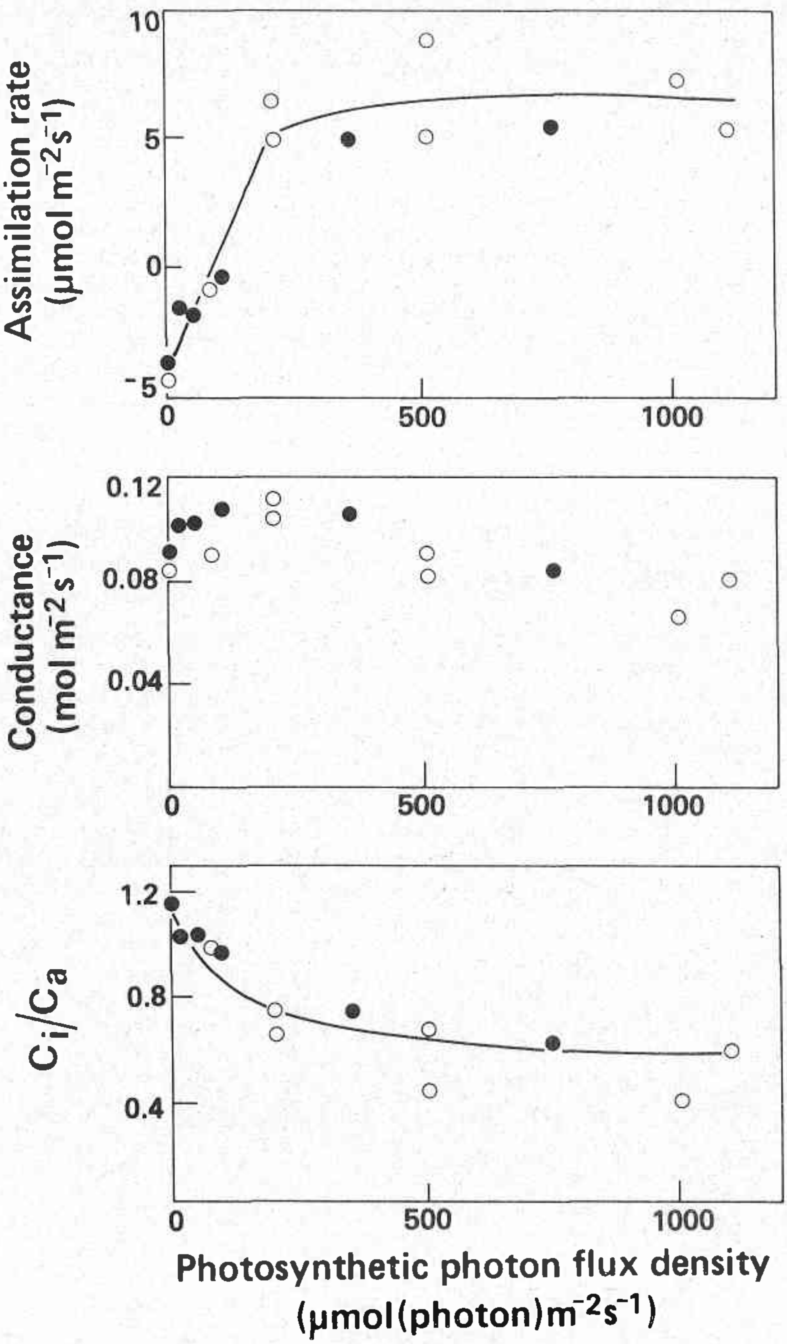


Figure 9 Gas exchange characteristics of exposed (open symbols HP9) and shaded (closed symbols HP10) branches of Huon pine SRT 73. Measurements of CO_2 assimilation rate and stomatal conductance to water vapour diffusion as a function of PPFD, are used to derive the variation of c_i/c_a with PPFD.

In both branches the CO_2 assimilation rate increased with quantum flux up to about 200 μmol m^{-2} s^{-1}. Conductance to water vapour diffusion did not vary with quantum flux. Since c_i is primarily a function of conductance and CO_2 assimilation rate, the ratio of c_i/c_a varied inversely with assimilation rate.

Figure 10 shows the time course of CO_2 assimilation rate for sun and shade branches of SRT 70 at 14 m, well above canopy top. The shade branch received 50 to 150 μmol m^{-2} s^{-1} throughout the day of measurement but had a steadily declining CO_2 assimilation rate. Since conductance did not vary, this represents a decline in the assimilation capacity of the mesophyll tissue. The sun branch was shaded for a short time around 1300 AEST. At 1400 hours the branch was again in full sun (~1500 μmol m^{-2} s^{-1}), but the capacity for CO_2 assimilation was much reduced. By 1500 hours the branch had a negative carbon balance.

8.4 Discussion

The gas exchange measurements confirm the lack of sensitivity of stomatal conductance to irradiance as observed in 1981, and the dependence of c_i/c_a on CO_2 assimilation rate for Huon pine, foreshadowed by the preliminary measurements (Section 8.2).

The $\delta^{13}C$ of leaf tips harvested during the gas exchange measurements correspond closely to similar measurements (Tables 13, 15) with the possible exception of HP 9. This is the exposed sample from SRT 73 which appears too negative by comparison with the tip $\delta^{13}C$ of SRT 71 (Table 15) with quite similar exposure.

Using equation 8.1, the variation of c_i/c_a in Figure 9, for example, implies $\delta^{13}C$ variations which are of a sign, and ample magnitude, to explain the variations in $\delta^{13}C$ between exposed and shaded locations. As mentioned in Section 6.4, a full comparison and interpretation of these results requires consideration of temporal and spatial variations in these values as well as the possible variations in atmospheric $\delta^{13}C$, and is the subject of a separate publication.

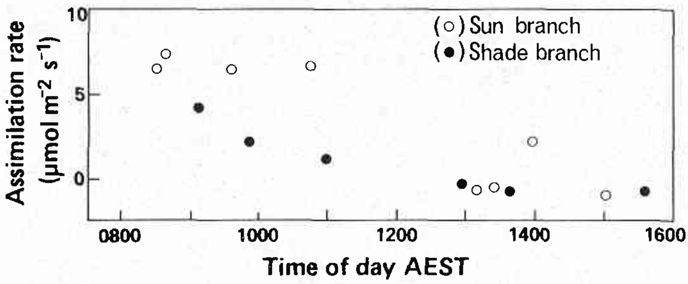


Figure 10 The variation in net photosynthesis rate throughout a day for a sun branch (open symbols) and shade branch (closed symbols) of Huon pine SRT 70.

9. Composition of Sub-canopy Air (PJF, DB, HSG, RJF, GIP)

9.1 Introduction

The primary aim of the air sampling was to investigate the space and time variability of carbon dioxide level and $^{13}C/^{12}C$ ratio around the growing Huon pine. This is important in aiding the interpretation of carbon isotope ratios in the plant material (see Sections 6.1, 8.1).

The air samples have been analysed for other trace gases, namely Freon-11 (CCl_3F), methane (CH_4) and carbon monoxide (CO). CCl_3F is present in the atmosphere purely as a consequence of human activities, and its concentration in clean tropospheric air of the mid latitudes is well established (e.g. Fraser *et al.* 1983). Concentrations significantly above background levels are a clear indication of anthropogenic contamination of the air sample on a local or regional scale (e.g. Fraser *et al.* 1977), and suggest that observed levels of other trace gases subject to direct anthropogenic influence (e.g. CO_2) should be treated cautiously.

The CH_4 and CO observations form part of a general study of the behaviour of these trace gases in forest environments. However, elevated CH_4 and CO levels have been observed in the plumes and ground level environment of forest fires (Crutzen *et al.* 1979) and as it happened, these measurements help characterize the air mass environment experienced during the February 1981 expedition, when substantial forest and scrub fires were prevalent around the Stanley River site throughout the expedition. CH_4 is present in the atmosphere largely as a result of anaerobic decay of plant material; while CO results from *in situ* oxidation of CH_4 by the hydroxyl radical (OH), as well as from natural and anthropogenic combustion processes and emissions from vegetation. The CH_4 and CO levels in background air in Tasmania have recently been established (Fraser *et al.* 1981, Fraser P.J. unpublished) and can be used to interpret observations made during the Stanley River expeditions.

9.2 Sampling Methods

In February 1981 only, a portable non-dispersive infra-red gas analyser (IRGA) was operated in the field to give carbon dioxide concentration. At the same time, and in 1982, air was trapped in flasks for subsequent laboratory analysis. Details of the flask type, trapping method, number per expedition and analysis type are given in Table 20. Laboratory analyses involved an IRGA, gas chromatograph (GC) and mass spectrometer (MS).

Figure 11 is a schematic of the air sampling arrangement used for the *in situ* IRGA measurements (February 1981), all 1/2 L glass flasks and most of the 5 L glass flasks.

A rope and pulley fixed to a tree branch at, or above, competing canopy top enabled a flexible air intake of 3/8" o.d. Dekabon '1300' tubing (Olex Cables Ltd., U.S.A.) to be positioned at selected heights. Using a metal bellows (MB) pump, air was pumped through a water trapping/surge damping flask, a granular magnesium perchlorate packed drying tower and a dust filter, (Swagelok, U.S.A.). A pressure/relief valve set at 55 kPa (110 kPa in the 1982 expeditions) for pump-valve protection also determined the

TABLE 20

Details of the flask type and atmospheric trapping methods used on various expeditions. The type of analyses conducted on the sample is included

Flask Type	Air Pressure (full) (kPa)	Filling Method	Expedition & No. of Flasks	Analyses
½ L Glass (G ½)	55 110	MB Pump	Feb 81: 22 Feb 82: 73 Sep 82: 41	IRGA: CO_2 GC: CO_2, CO, CH_4, CCl_3F
1.5 L Stainless Steel (SS)	2700	Cryogenic	Feb 82: 3	GC: CO_2, CO, CH_4, CCl_3F MS: $^{13}C/^{12}C$
5 L Glass (G 5)	55 110 0 0	MB Pump " Vacuum "	Feb 81: 5 Feb 82: 12 Feb 81: 2 Feb 82: 3	MS: $^{13}C/^{12}C$

amount of air collected in the flasks. At a selected height the intake lines and flasks were well flushed (5-10 minutes) with representative air before filling or analysis.

A second portable pump unit (Beardsmore *et al.* 1978) was available for collecting air samples in glass flasks at other locations.

The flexible intake line and drying tower, initially flushed by the pump, were also employed in filling the 1.5 L stainless steel flasks. Here the cryogenic filling method involved immersion of the flask in liquid nitrogen for 10-15 minutes (Rasmussen *et al.* 1982) during which time approximately 40 L of ambient air was collected.

The 'vacuum' method of filling 5 L glass flasks (lent by Dr. A.R. Chivas, Australian National University) simply involved placing the evacuated flask in an exposed position (upwind of the operator) and opening the inlet tap until pressure equilibrium was attained.

9.3 Measurement Techniques

All analyses of air samples collected in flasks were carried out at CSIRO, Division of Atmospheric Research.

9.3.1 Infra-red gas analyser (IRGA) for CO_2

The analysis of air samples in glass flasks in the laboratory, using an IRGA, is described by Beardsmore *et al.* 1978. The 1981 field operation was more unusual and is described in some detail in the Figure below.

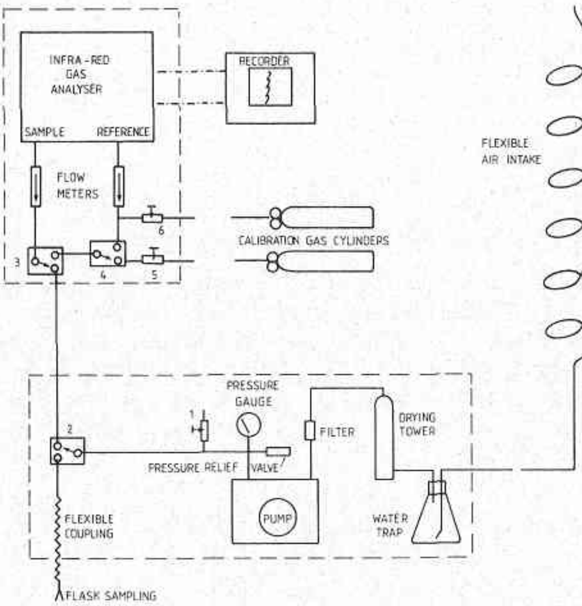


Figure 11 Sampling system used for analysis and collection of air samples. The *in situ* infra-red gas analyser was employed in February 1981 only. Flasks were filled through the flexible coupling, with the exception of 'cryogenic' flasks which were filled from the intake line after the drying tower.

The portable system, comprising a UNOR 5B IRGA infra-red gas analyser (H. Maihak A.G., S/No. 5-0599) with flow meters, gas switching (2,3,4) and flow control (1,5,6) valves, obtained its 230 volt, 50Hz power from an inverter driven by 12V accumulators.

The analyser was operated in the differential mode with a flowing reference gas. Cylinders of CO_2 in N_2 mixtures, with known CO_2 concentrations close to the free atmospheric value, were used for frequent calibrations throughout the experiment. The output signal was recorded on a 5 inch portable potentiometric chart recorder.

As it was necessary to turn the analyser off overnight to conserve power, a two hour warm up period was needed for the IRGA each day. During initial flushing of the intake line the system was calibrated; a zero signal was obtained by applying the calibration gas with higher CO_2 concentration to both sample and reference cells of the analyser. Keeping this gas flowing through the reference cell and switching the second calibration gas through the sample cell gave a second output signal. Using the pre-determined CO_2 concentration of the two calibration gases a scale factor could then be established (Beardsmore *et al.* 1978). Valves 2 and 3 were then operated to admit the dried air stream to the sample cell. Intervals between analyses of air from selected heights were employed to recalibrate the analyser and collect air samples in flasks.

The analyser signal was read at 36 second intervals on the chart record (Figure 12). In a sampling period, the mean value of these signals was compared with those of the calibration gases, before and after, to obtain an apparent concentration, C_A. True concentration, C_T, was then obtained by correcting for the 'carrier gas error' (Pearman 1980, Pearman *et al.* 1983) using a function of the form:

$$C_T = C_A\ (A + B\ C_A).$$

For the 1981 *in situ* analyser (S/N 5-0599), A = 0.988166, B = -1.9332 x 10^{-5}, while for the UNOR (S/N 631693) employed on the glass flasks in 1981, A = 0.983194, B = +2.8702 x 10^{-5} and in 1982 (S/N 631478), A = 0.985441, B = +0.2778 x 10^{-5}. All absolute concentrations are expressed in the WMO 1981 CO_2 Calibration Scale.

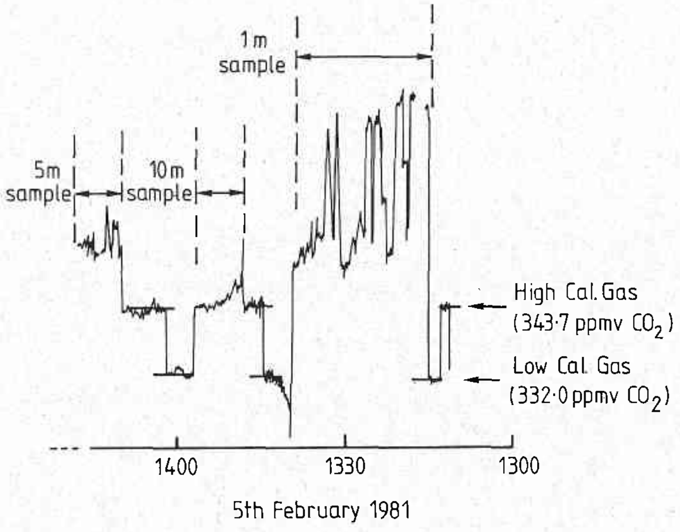


Figure 12 An example of the trace from the *in situ* CO_2 IRGA used in February 1981. Time is plotted (backwards) on the x-axis and analyser outputs equivalent to CO_2 concentrations on the y-axis. The gas switching sequence from approx. 1312-1416 AEST is shown. The intermittent nature of sub-canopy mixing at low wind speeds is evident at 1 m. CO_2 concentrations in the air samples were obtained by averaging the values of successive 36 second intervals of the analyser output trace.

9.3.2 Gas chromatograph measurements of CO_2, CO, CH_4, CCl_3F

All air samples were analysed using gas chromatographic (GC) techniques, CCl_3F with an electron capture detector (ECD), and CH_4, CO, CO_2 using a flame ionization detector (FID). The experimental procedures used are described elsewhere (Fraser and Pearman 1978, Rasmussen and Khalil 1981). The calibration gas (0-067) used for the GC analysis was supplied by R.A. Rasmussen of the Oregon Graduate Centre. It was a sample of clean air (1000 L at STP) contained in a stainless steel vessel (40 L) which had been internally electropolished to minimise the effect of the steel surface on trace gas composition. The concentrations of the relevant trace gases in 0-067 are: CCl_3F, 181.5 pptv (parts per 10^{12} by volume); CH_4, 1583 ppbv (parts per 10^9 by volume); CO, 105 ppbv; and CO_2, 341.80 ppmv (parts per 10^6 by volume, WMO 1981 CO_2 Calibration Scale).

9.3.3 Mass spectrometer measurements of $^{13}C/^{12}C$

The stable carbon isotope ratio of the flask air was obtained by first extracting all of the CO_2 from the air sample, and then admitting this CO_2 to a Micromass 602D mass spectrometer for determination of $^{13}C/^{12}C$ relative to a CO_2 gas cylinder standard.

The CO_2 was extracted by first freezing the flask with liquid nitrogen and then slowly pumping off all of the non-condensable gases. The liquid nitrogen was then replaced with a dry-ice/alcohol bath, to retain water vapour while the CO_2 was transferred to the mass spectrometer inlet system.

The fractional difference of the mass 45/mass 44 ratio, relative to that of the reference gas, is measured by the Micromass 602D. This was corrected for a $C^{12}O^{16}O^{17}$ contribution to mass 45, on the basis of a mass 46/mass 44 measurement (Mook and Grootes 1973). The fractional difference, expressed in parts per thousand, is referred to as $\delta^{13}C$ (Section 6.2). The corrected value was converted to a $\delta^{13}_{PDB}C$ on the basis of measurements of the CSIRO reference gas relative to international isotope standards TKL and NBS-19 (Goodman and Francey, unpublished) giving, for the reference gas,

$$\delta^{13}_{PDB}C = -6.26°/_{\circ\circ}$$

$$\delta^{18}_{PDB}O = -13.27°/_{\circ\circ}$$

9.4 *Results*

The concentrations of trace gases observed during the first two expeditions are listed in Table 21 (February 1981) and Table 23 (February 1982). Table 22 gives February 1981 CO_2 concentrations measured with the *in situ* analyser. Table 24 lists February 1982 CO_2 values from the IRGA only, as the gas pressure in these flasks was insufficient for both types of analysis. Table 25 lists trace gas concentrations measured by GC in September, 1982. For comparison, the concentrations observed for the same species collected in flasks under the baseline conditions at the Australian Baseline Air Pollution Station, Cape Grim (Baseline 1976, 1978) are given in Table 26, including the stable carbon isotope ratio.

In Table 27, stable carbon isotope measurements of the Stanley River sub-canopy air are summarized. Note that no isotope results are included for February 1981. This is due to uncertainties arising from the laboratory extraction of CO_2 from the 5 L flasks, during which difficulties were encountered in controlling liquid nitrogen levels during pump off of the major constituents of the air. Improved liquid nitrogen containers were employed in extracting air from the 1982 flasks, however some fractionation was still evident. In what follows the $\delta^{13}C$ have been corrected for fractionation during extraction on the basis of the measured $\delta^{18}O$ value in the CO_2. This correction assumes that the actual $\delta^{18}O$ in the trapped air is relatively constant and that fractionation in the two isotopes is related in a known fashion.

Support for the first assumption comes from the extensive measurements of Keeling (1961) in forest air, in which the magnitude of differences from the site mean for daytime (0800 - 2000 hours) values was $\Delta\delta^{18}O = 0.23 \pm 0.33°/_{oo}$. Cape Grim isotope measurements over 5 years in baseline (oceanic air) and non-baseline (continental air) also support this assumption. The Cape Grim results, which also include examples of incomplete trapping due to low liquid nitrogen levels in traps, also strongly support the second assumption with $\Delta\delta^{13}/\Delta\delta^{18} = 2.0 \pm 0.3$ (Francey, unpublished). Of most relevance to the present application is the distribution of mean measured $\delta^{18}O$ with height (excluding two points $>5\sigma$ from the mean) of $12.7 \pm 1.0°/_{oo}$, 1 - 2 m; $12.9 \pm 1.4°/_{oo}$, 8 m; $13.0 \pm 1.5°/_{oo}$, 14.3 m; and $12.6 \pm 1.1°/_{oo}$ on the exposed ridge - no systematic effects are evident to indicate a local (rather than experimental) source of variation.

TABLE 21

Trace gas concentration in ½ litre glass flasks filled February 1981. Site details are given in Tables 15, 16. CO_2 concentrations are in the WMO 1981 CO_2 Calibration Scale

Date	Time (AEST)	Site	Height (m)	CCl_3F (pptv)[1]	CH_4 (ppbv)	CO (ppbv)	CO_2(GC) (ppmv)	CO_2 (IRGA) (ppmv)
4 Feb 81	1342	S1	10	-	-	-	-	347.5
	1413	S1	5	181	1567	982	348.2	345.5
	1418	S1	5	-	-	-	-	348.4
	1443	S1	1	183	1583	1309	353.1	352.4
5 Feb 81	1009	R	2	180	1539	763	339.7	341.9
	1013	R	2	179	1537	783	352.1	342.8
	1017	R	2	179	1553	832	340.8	342.1
	1309	H	3	507	1526	499	338.9	336.7
	1315	H	3	189	1510	376	341.8	335.1
	1320	H	3	183	1521	324	340.7	336.9
6 Feb 81	0855	R	2	210	1490	141	332.6	336.4
	0900	R	2	211	1512	188	331.0	337.0
	0905	R	2	208	1512	165	328.4	336.9
	1002	S1	10	202	1517	454	335.1	340.6
	1015	S1	5	198	1505	417	332.6	337.8
	1030	S1	1	242	1509	494	342.5	347.4
	1108	S1	10	198	1566	502	355.5	339.0
	1122	S1	5	232	1520	456	336.8	339.3
	1134	S1	1	-	-	-	343.7	
	1111	H	3	189	1507	435	333.6	338.4
	1115	H	3	192	1532	516	335.6	338.9
	1119	H	3	190	1502	441	333.5	339.1

1. ppmv: 1 part in 10^6 by volume.
ppbv: 1 part in 10^9 by volume.
pptv: 1 part in 10^{12} by volume.

TABLE 22

Carbon dioxide concentrations measured at site S1 (see Table 15) with the *in situ* IRGA in February 1981. Concentrations are in the WMO 1981 CO_2 Calibration Scale

Date	Mean Time (AEST)	Height above ground (m)	CO_2 (ppmv)
4 Feb 81	1143	10	359.5
	1211	5	350.8
	1247	1	350.0
	1328	10	344.0
	1400	5	350.2
	1431	1	354.0
	1459	10	347.8
	1523	5	345.1
	1545	1	354.9
5 Feb 81	1011	10	343.6
	1040	5	346.2
	1111	1	>355
	1143	10	338.2
	1159	5	343.2
	1232	1	352.7
	1254	10	338.8
	1321	5	340.5
	1351	1	350.9
	1406	10	335.5
	1437	5	341.8
	1502	1	353.1
	1516	10	334.9
	1526	5	336.3

No corrections for a N_2O contribution to the mass spectrometer output have been made, so that a further assumption in the present context is that the correction is constant for all situations, from Cape Grim to ridge top to forest floor. The correction is small (+ 0.3°/₀₀ in $\delta^{13}C$ for a N_2O concentration of 0.3 ppmv, Keeling *et al.* 1979) and N_2O is very constant in the troposphere with very small sources and sinks (Roy 1979).

In recent tests on clean air the repeatability measured in $\delta^{13}C$ of CO_2 from 11 five litre flasks was ± .05°/₀₀ (Francey, unpublished). The additional uncertainty on individual measurements introduced by the above factors is estimated at ± 0.3°/₀₀.

9.5 Discussion

9.5.1 Freon-11

The 1981 CCl_3F measurements indicate one obviously contaminated flask (507 pptv on 5 February) possibly due to incomplete flushing of the sampling apparatus. The remaining flasks on 4, 5 February 1981 show an average concentration of 183 (± 4) pptv, marginally above the Cape Grim baseline

TABLE 23

Trace gas concentrations in glass and stainless steel flasks (see Table 20) filled February 1982. Site details are given in Tables 15, 16. CO_2 concentrations are in the WMO 1981 CO_2 Calibration

Date	Time (AEST)	Site	Height (m)	Flask	CCl_3F (pptv)	CH_4 (ppbv)	CO (ppbv)	CO_2(GC) (ppmv)	CO_2(IRGA) (ppmv)
12 Feb 82	1043	S2	8	G 1/2	202	1505	53	338.4	336.9
	1201	"	8	"	199	1505	49	337.5	335.7
	1359	"	1	"	201	1488	–	350.9	355.2
	1430	"	14	"	201	1482	–	338.0	335.6
	1445	"	14	SS	205	1518	66	338.2	336.3
	1534	"	8	G 1/2	197	1480	–	339.0	337.3
	1545	"	14	"	196	1483	–	339.8	338.7
	1655	"	1	"	–	1528	61	361.6	370.6
	1708	"	8	"	196	1517	55	339.2	337.8
	1713	"	8	"	193	1515	58	339.7	338.6
	1725	"	14	"	195	1520	57	339.8	338.7
13 Feb 82	0825	"	1	"	193	1502	–	376.2	393.0
	0836	"	8	"	193	1524	–	344.2	346.9
	0847	"	14	"	194	1524	–	339.7	338.8
	0954	"	8	"	195	1524	–	339.2	337.9
	1010	"	14	"	197	1515	–	338.9	337.3
	1050	"	0.3	"	199	1526	–	348.3	352.0
	1100	"	1	"	199	1512	–	348.2	352.2
	1110	"	8	"	195	1502	–	338.4	336.0
	1115	"	8	"	195	1502	–	338.2	336.3
	1126	"	14	"	195	1502	–	337.7	336.3
	1225	"	0.3	"	3300	1486	–	355.0	361.4
	1239	"	8	"	233	1493	–	337.8	335.8
	1254	"	14	"	213	1479	–	338.3	336.7
	1330	R	2	"	203	1528	–	338.9	337.6
	1335	R	2	"	201	1528	–	338.1	337.4
	1411	S2	1	"	204	1479	–	347.9	351.1
	1432	"	14	"	198	1479	–	338.8	337.6
	1543	"	1	SS	1364	1502	103	359.2	367.3
	1600	"	1	G 1/2	212	1515	–	342.2	342.5
	1622	"	14	"	245	1524	–	339.4	338.3
	1703	"	8	"	205	1529	–	340.4	340.0
	1713	"	14	"	204	1540	–	339.4	338.4
	1754	"	1	"	208	1567	–	374.1	391.3
	1805	"	8	"	200	1512	–	339.9	340.1
	1815	"	14	"	198	1512	–	338.1	338.6
14 Feb 82	0857	"	1	"	269	1555	–	383.1	404.6
	0918	"	8	"	244	1531	–	340.9	341.1
	0928	"	14	"	218	1555	–	340.1	339.8
	0933	"	14	"	233	1524	–	341.1	339.2
	1018	"	8	"	220	1520	–	339.0	338.6
	1026	"	8	SS	242	1528	71	340.1	338.9
	1050	"	14	G 1/2	217	1515	–	338.7	338.1
	1135	R	2	"	203	1547	–	338.7	338.4
	1226	S2	8	"	203	1515	–	340.6	340.0
	1318	"	8	"	196	1512	–	340.8	340.8

TABLE 24

Carbon dioxide concentrations collected in ½ litre glass flasks at sites S2, R (see Tables 15, 16) in February 1982. Concentrations were determined with an IRGA and were expressed in the WMO 1981 CO_2 Calibration Scale

Date	Time (AEST)	Site	Height above ground (m)	CO_2 (ppmv)
12 Feb 82	1027	S2	14	337.7
	1059	"	1	384.5
	1150	"	14	335.4
	1214	"	0.3	360.9
	1415	"	8	335.9
	1523	"	1	350.6
	1650	"	1	372.4
	1834	"	0.3	371.6
	1845	"	8	349.9
	1856	"	14	346.4
	1938	"	1	394.5
	2049	"	8	369.3
	2100	"	14	363.2
13 Feb 82	0938	"	1	361.8
	1131	"	14	335.8
	1421	"	8	337.3
	1610	"	8	338.8
	1652	"	1	356.7
14 Feb 82	0902	"	1	389.9
	0913	"	8	341.2
	1006	"	1	354.9
	1215	"	1	349.1
	1239	"	14	339.3
	1309	"	1	349.2
	1327	"	14	337.3
12 Feb 82	1309	R	2	336.4
	1316	"	2	336.7

value of 177 (± 1.5) pptv. This is possibly explained by small levels of contamination associated with the rubber and plastic materials used in the sampling intake. On 6 February, the consistently elevated level averaging 207 (± 17) pptv, suggests a regional scale pollution event.

In February 1982 two of the flasks were heavily contaminated (3300 pptv, 1364 pptv, on 13 February) suggesting a local source of CCl_3F, possibly associated with people working at the site. It is possible that this contributes, along with regional pollution, to the general enhancement of February 1982 CCl_3F values above the Cape Grim value of 189 (± 1) pptv; the Stanley River values (excluding the two obviously contaminated flasks) average 198 (± 4) pptv before midday of 13 February and 218 (± 20) pptv thereafter. In September 1982 two flasks (at 1002, 1011 on 28th) show enhanced CCl_3F levels. Excluding these, the average level is 195 ± 1 pptv.

There is no significant correlation of CCl_3F with height, although three of the four 1982 contaminated flasks were taken at ground level. These flasks also exhibit enhanced CO_2 concentrations which is also noticeable for the first flask on 14 February 1982. Excluding these flasks, there is no significant correlation between CCl_3F and CO_2, and no obvious influences of site (river flat or ridge) are apparent.

TABLE 25

Trace gas concentrations in 1/2 litre glass flasks collected in September 1982 near 4350 mN, 4900 mW. CO_2 concentrations were determined with a GC only and are expressed in the WMO 1981 CO_2 Calibration Scale

Date	Time AEST	Height above ground (m)	CCl_3F (pptv)	CH_4 (ppbv)	CO (ppbv)	CO_2 (GC) (ppmv)
27 Sep 82	0910	5	194.7	1553	44	340.3
	0919	5	193.8	1558	45	341.3
	1012	1	196.6	1567	54	346.0
	1020	5	196.0	1558	49	340.4
	1105	1	195.7	1558	48	342.3
	1118	5	196.2	1553	44	340.3
	1205	5	194.9	1551	45	339.6
	1212	1	195.5	1561	49	342.4
	1218	1	194.9	1548	56	344.5
	1305	1	195.5	1566	55	343.3
	1313	5	195.7	1551	49	340.6
	1320	5	194.7	1545	48	339.3
	1405	5	194.7	1558	45	338.7
	1414	1	196.9	1555	50	343.4
	1421	1	194.7	1564	51	346.0
	1504	1	195.3	1550	52	344.5
	1513	5	-	1569	-	338.9
	1519	5	196.9	1577	43	338.8
	1605	5	194.2	1556	43	343.9
	1612	1	195.3	1562	49	345.4
	1617	1	194.6	1567	44	345.0
	1705	1	194.7	1575	48	347.1
	1712	5	197.4	1566	-	337.4
	1717	5	194.4	1548	43	341.0
	1835	5	197.3	1558	49	342.4
	2005	5	195.1	1555	47	345.0
	2134	5	195.3	1551	46	344.3
	2335	5	194.2	1551	46	347.4
28 Sep 82	0035	5	-	1550	49	346.9
	0205	5	195.3	1558	46	348.3
	0335	5	194.7	1553	47	348.2
	0534	5	195.1	1558	40	342.5
	0804	5	195.7	1553	44	341.0
	0812	1	195.3	1551	44	349.5
	0910	5	194.7	1553	44	340.3
	0919	5	193.8	1558	45	341.3
	1002	5	202.9	1551	41	341.6
	1011	1	205.1	1564	48	345.4
	1100	1	195.5	1562	48	343.3
	1109	5	194.9	1562	40	340.0
	1120	5	194.2	1556	47	340.9

TABLE 26

Average baseline trace gas concentrations and carbon isotope ratios at the Baseline Air Pollution Station, Cape Grim (see Figure 1). CO_2 concentrations are in the WMO 1981 CO_2 Calibration Scale

Date	CCl_3F (pptv)	CH_4 (ppbv)	CO ppbv)	CO_2 (ppmv)	$\delta^{13}_{PDB}C$ (°/₀₀)
Feb 81	177.0 ± 1.5	1491 ± 18	27 ± 3	336.8 ± 0.8	-
Feb 82	188.6 ± 0.8	1515 ± 20	30 ± 6	338.1 ± 0.2	-7.6 ± 0.1
Sep 82	-	1551 ± 6	42 ± 5	340.0 ± 0.5	-7.6 ± 0.1

TABLE 27

Carbon isotope measurements of forest canopy air in February 1982. Site details are given in Tables 15, 16 and flask details in Table 20

Date	Trapping Times (AEST)	Site	Height (m)	Flask	$\delta^{13}_{PDB}C$ (°/₀₀)
12 Feb. 82	1027-1028	S2	14	G5 (110)	-7.65
	1043-1044	S2	8	G5 (110)	-7.46
	1059-1100	S2	1	G5 (110)	-9.60
	1311	R	1.5	G5 (0)	-7.63
	1359-1400	S2	1	G5 (110)	-8.13
	1445-1455	S2	14	SS	-7.51
13 Feb. 82	0954-0955	S2	8	G5 (110)	-7.64
	1010-1011	S2	14	G5 (110)	-7.62
	1225-1226	S2	0.3	G5 (110)	-8.88
	1239-1240	S2	8	G5 (110)	-7.51
	1254-1255	S2	14	G5 (110)	-7.51
	1333	R	1.5	G5 (0)	-7.38
	1543-1553	S2	1	SS	-8.67
	1622-1623	S2	14	G5 (110)	-7.64
14 Feb. 82	1006-1007	S2	1	G5 (110)	-8.43
	1026-1036	S2	8	SS	-7.68
	1050-1051	S2	14	G5 (110)	-7.60
	1131	R	1.5	G5 (0)	-7.69

9.5.2 Methane

During the 1981 expedition the average CH_4 concentration at Stanley River was 1527 (± 25) ppbv, higher than the 1491 (± 18) ppbv observed at Cape Grim in February 1981. The average enhancement of CO_2 levels at Stanley River above baseline, as defined by the Cape Grim February average, was approximately 3 ppmv, and the CH_4 levels were enhanced by approximately 40 ppbv. This ratio is in agreement with the work of Crutzen *et al.* (1979) who have studied the composition of forest fire plumes. This suggests that the source of these enhanced levels of CO_2 and CH_4 was forest combustion.

During the 1982 expedition CH_4 concentrations at Stanley River averaged 1514 (± 21) ppbv, not significantly different from the 1515 (± 20) ppbv at Cape Grim for February 1982, in contrast to the 1981 observations. No significant correlation of CH_4 with sample height is present in the data.

One obvious feature of the CH_4 data collected during this summer period is the local minimum concentration observed around mid-afternoon (Figure 13), and the minimum concentration (1480 ppbv) is below the average concentration observed at Cape Grim for February. This suggests that a local CH_4 sink exists. Two possible sinks are (i) generation of enhanced levels of OH radical during periods of maximum irradiation leading to enhanced destruction via the reaction $CH_4 + OH \rightarrow CH_3 + H_2O$; (ii) net CH_4 destruction at the soil surface around mid afternoon as has been observed for swamp soils under drought conditions (Harriss *et al.* 1982). There is a suggestion from the data the early morning CH_4 concentration may be above background, arising from a net source (presumably forest soil) during the night.

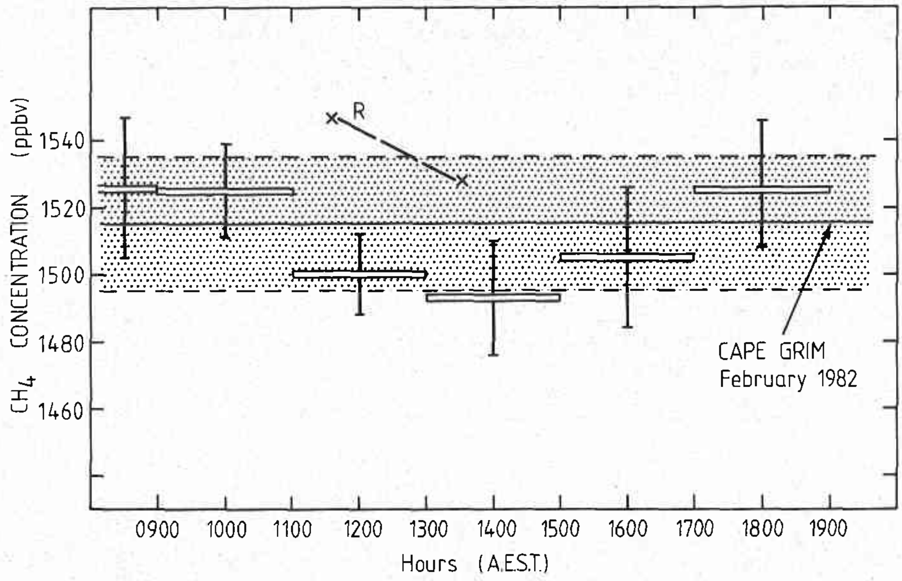


Figure 13 The diurnal variation in methane concentration observed in the rainforest at heights 0.3-14 m between 12-14 February 1982. The methane concentrations on Whaleback Ridge (R) and in baseline air at Cape Grim (Table 31) are also shown, the latter indicated by a mean value and shading at ± 1 standard deviation of the 1982 February data.

A significant fraction of the observed diurnal cycle in CH_4 concentrations could be due to enhanced turbulent mixing in the afternoon compared to evening and morning.

The September 1982 values show no evidence of a diurnal cycle, with the average value of 1556 (± 7) ppbv not significantly different from the Cape Grim value of 1551 (± 6) ppbv. The slightly higher levels at 1 m, of 1560 (± 9) ppbv, suggest a surface source of CH_4.

Diurnal CH_4 cycles have not been previously reported in forest environments. This phenomenon will be further investigated using other forest data and attempts will be made to model the results in terms of possible local sources and sinks.

9.5.3 Carbon monoxide

During the 1981 experiment CO levels at Stanley River averaged 550 (± 270) ppbv while Whaleback Ridge averaged 480 (± 340) ppbv. The highest CO levels were observed on February 4 (approximately 1300 ppbv in the Stanley River Forest) and the lowest (approximately 160 ppbv on Whaleback Ridge) on February 6. These CO levels are higher than those observed at Cape Grim during February 1981 (27 ± 3 ppbv) by a factor of 20. Crutzen *et al.* (1979) have shown that, in a forest fire environment, for every 1 ppmv of CO_2 above background, CO levels are enhanced by approximately 160 ppbv. The average CO_2 enhancement was approximately 3 ppmv, so CO levels around 500 ppbv, as observed, are in line with their observations. Once again this suggests that the enhanced CO levels are due largely to the adjacent forest fires.

Unfortunately, due to instrumentation problems, few CO observations were made during the February 1982 experiment. The average CO concentration observed at Stanley River was 64 (± 16) ppbv. The highest observation of 103 ppbv (SSO-3), was one of the samples heavily contaminated with CCl_3F. It is possible that CO contamination occurred as well. If this sample is not considered then the average concentration was 59 (± 7) ppbv, a factor of 2 above the February 1982 average concentrations at Cape Grim (30 ± 6 ppmv). These data indicate that the forest environment is a source of CO, but it is not clear whether it emanates from the soil or the vegetation.

In September 1982, the 5 m samples were constant throughout the 26 hour period, with average value 45 (± 3) ppbv very close to the Cape Grim average of 42 (± 5) ppbv. The daylight 1 m average values, at 50 (± 4) ppbv, is significantly enhanced indicating a surface source.

9.5.4 Carbon Dioxide

CO_2 levels were measured by gas chromatography, using a single calibration gas, and the resultant data from both experiments were unsatisfactory. For the 1981 data the precision of the CO_2 measurements was approximately ±5 ppmv, at least an order of magnitude less than that obtained using the IRGA method. For the 1982 data the precision was improved considerably (± 0.5 ppmv), but the use of only one calibration gas resulted in large systematic errors at high concentrations. For example, the error in assigning a CO_2 concentration of around 400 ppmv was approximately 20 ppmv (the error using the IRGA method was 1 ppmv associated with the fact that the instrument was calibrated in the range 340 to 360 ppmv and the response of the instrument to changing CO_2 concentrations is slightly non-linear). These large errors in the GC technique are due to instrument problems and should not be viewed as typical of the precision or accuracy of CO_2 measurements that can be made with such instrumentation.

In summarizing and discussing the CO_2 results here, emphasis is placed on the IRGA values. The three flasks with enhanced CCl_3F values (Section 9.5.1) are excluded as is the first value with the *in situ* analyser (Table 22, 1143 hours, 4 February 1981) in which it appears as if the inlet system was not sufficiently flushed, and that at 1111 hours, 5 February 1981, which was off the instrument scale (> 355 ppmv).

An indication of a 'typical' CO_2 environment for a plant may be inferred from the remaining values which are pooled in Figures 14, 15. Figure 14 shows the mean and standard deviation (with the number of samples in brackets) of CO_2 concentrations in 2 hour periods throughout the day, for two height intervals, 0.3 - 5 m and 8 - 14 m, through the forest canopy. Below 5 m height there is a generally enhanced level of CO_2 before 0900 AEST and after 1700 AEST (during most of the day, 1000 - 1600 inclusive, a mean level of 349 ± 8 [n = 30] ppmv, is observed); at the higher levels a relatively constant 340 ± 5 (n = 39) ppmv between 0900 and 1900 AEST is observed, with a suggestion of slightly enhanced levels before 0900 AEST.

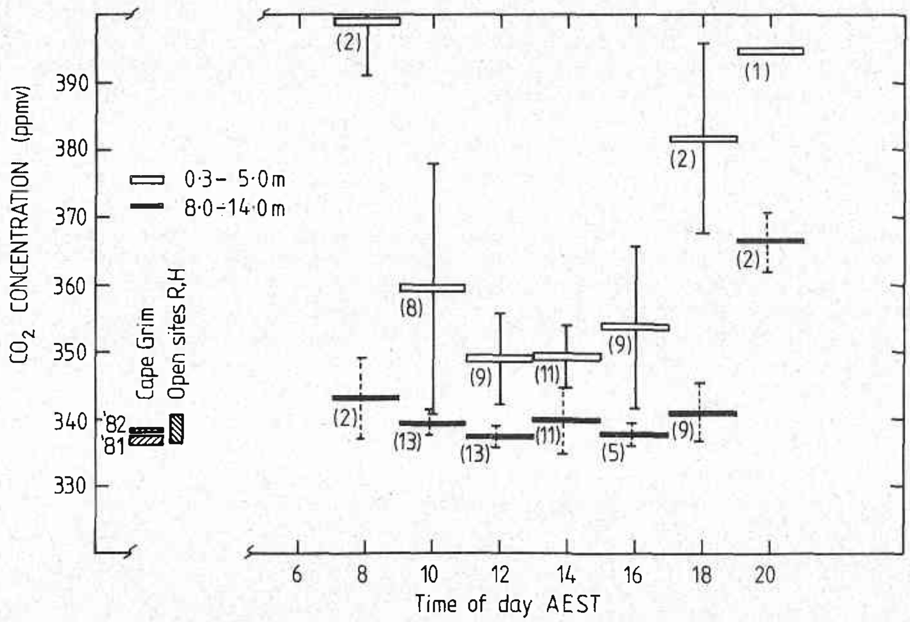


Figure 14 The mean diurnal (daytime) variation in CO_2 concentration in two height intervals (0.3-5 m and 8-14 m) in the Stanley River rainforest. Canopy foliage is typically 8-12 m. For comparison the 1981 and 1982 February average Cape Grim values (in baseline air) and the range of values observed on Whaleback Ridge (R) and in the open helipad area (H) are included. Observations from the months of February in both 1981 and 1982 have been averaged within 2 hour intervals to give a mean and standard deviation (number of samples is given in brackets).

In averaging the February 1981 and 1982 data no account has been taken of the relatively small annual increase in CO_2, shown in the Cape Grim values in both Figures. The daylight forest canopy values above 8 m are not significantly different from the measurements taken 2 or 3 m above ground in the exposed Whaleback Ridge (R) or helipad (H) sites.

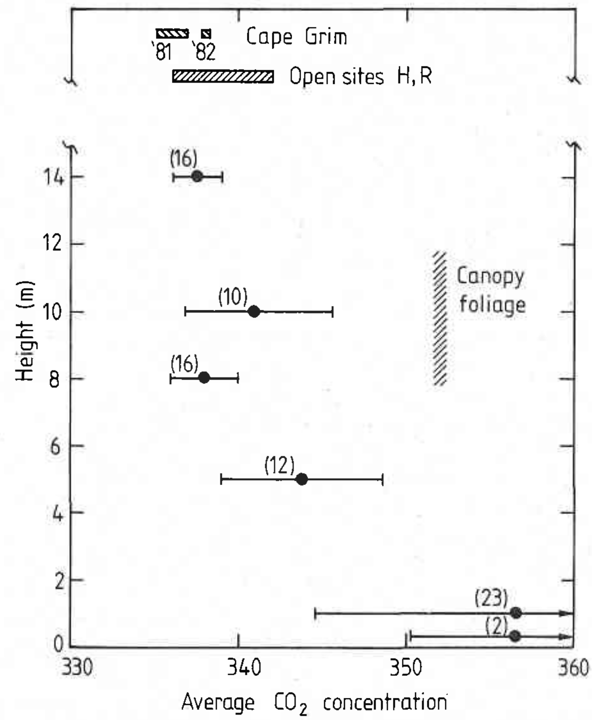
Figure 15 gives a more detailed account of the CO_2 variation with height through the forest canopy, in which samples taken between 0900 and 1700 AEST have been averaged for each measurement height.

The warm and very still conditions existing during these measurements (Tables 15, 16) suggest that the mean concentrations here are unlikely to be substantially exceeded by long-term average concentrations over the growing period, and in fact may represent an upper limit. The contribution of CO_2 from forest fires in 1981 (Section 9.5.2) reinforces this suggestion.

General confirmation of the diurnal cycle and vertical gradient can be found in the September 1982 GC measurements (Table 25).

Figure 15

The 0900-1700 AEST values of Figure 14 are averaged for each sampling height. Other details are as in Figure 14.



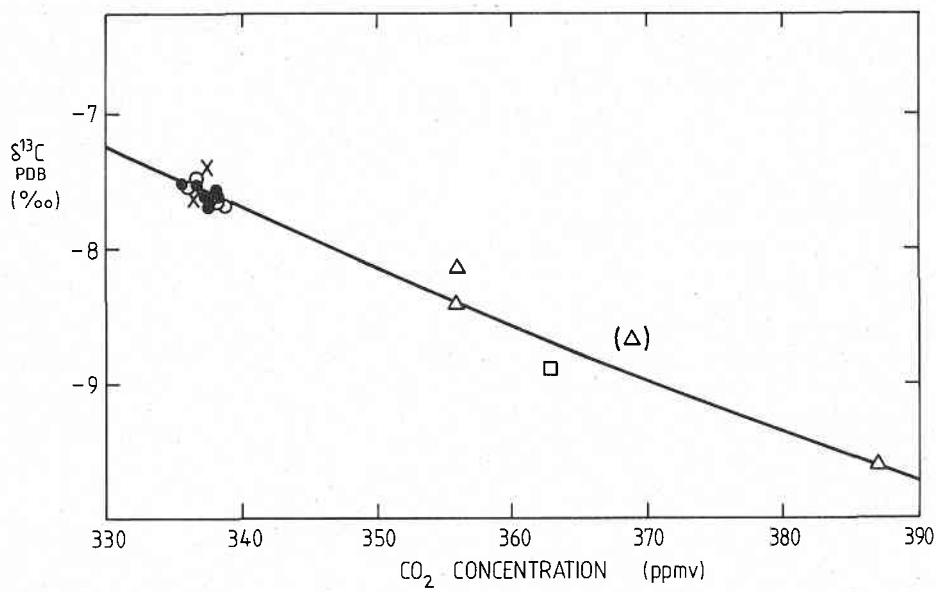


Figure 16 The $\delta^{13}_{PDB}C$ of air samples from the Stanley River rainforest at (□) 0.3 m, 1 m (△), 8 m (○) and 14 m (●), also at Whaleback Ridge (x), in February 1982, plotted against CO_2 concentration (IRGA). A line of best fit (see text) is given.

9.5.5 Stable carbon isotope ratios

The $\delta^{13}_{PDB}C$ values of Table 27 are plotted as a function of CO_2 concentration (IRGA values) in Figure 16. The bracketed value corresponds to the sample, collected in a stainless steel container at 1 m on 13 February 1982, which exhibited an enhanced CCl_3F value and is not included in the following analysis.

A linear regression of $\delta^{13}C_{PDB}$ (‰) versus the inverse of concentration (C, in ppmv) yields

$$\delta = -23.4\ (\pm\ 0.8) - \frac{5349\ (\pm\ 258)}{C}\ ‰ \quad . \qquad (9.1)$$

The relationship is very similar to that previously observed near vegetation (Keeling 1961) and is interpreted in terms of simple two component mixing between ambient air and CO_2 respired from vegetation.

If the 1982 Cape Grim Baseline CO_2 concentration of 338.1 ppmv is entered in this equation the resulting δ is -7.6‰, very close to that measured at Cape Grim (Table 32). Note that neither δ^{13} are corrected for N_2O (see Section 9.4). This confirms that the daytime measurements at Stanley River, above about 8 m, are representative in terms of both CO_2 concentration (to within a few ppmv) and isotopic composition (to within about 0.2‰) of the large scale troposphere.

The constant term of Equation 9.1 is an estimate of the average isotopic ratio of respired CO_2, i.e.

$$\delta^{13}_{PDB}C\ (\text{respired}) = -23.4\ (\pm\ 0.8)\ ‰ \quad .$$

In the context of the large ^{13}C depletions (~4‰, Section 6.3) observed in sub-canopy foliage it is noteworthy that even at 1 m height beneath dense rainforest canopy, Figure 15 indicates an average daytime CO_2 concentration of around 358 ppmv, which from Figure 16 implies a $\delta^{13}_{PDB}C$ of -8.5‰, less than 1.0‰ from the free atmosphere value.

10. Summary

The paper presents detailed information on the site, techniques, material collected and measurements made, in the Stanley River expeditions. Full analysis of material and data will take many years, involving several disciplines and this paper has been prepared as a foundation reference for future work.

The main long-term objectives of the expeditions are environmental reconstructions from tree ring parameters, unavoidably involving a considerable degree of empiricism. A philosophy of the expeditions has been to provide a broad base of information upon which empirical deductions can be inferred and tested, in particular by collecting sufficient material for analyses of many parameters on the same sample. In addition, with respect to carbon isotope ratios in tree rings, emphasis has been placed on elucidating the physical and physiological processes which influence carbon isotope variations in trees and their environment.

The early discovery of the unexpected abundance of old preserved logs in the Stanley River focussed attention on the geomorphology of the river bed, both as an indication of previous tree habitats and as an aid to locating further old logs of particular ages.

Of fundamental importance to most tree ring studies is the ability to date collected samples by ring counting. In Section 3 preliminary evidence is presented on the suitability of the selected species, Huon pine and Celery-top pine, for ring width dating. Modern chronologies of 1,000 years for Huon pine and 300-400 years for Celery-top pine are already well developed for this site.

The sensitivity of the species as dendroclimatological tools are investigated by a statistical comparison with species successfully employed elsewhere. The results are encouraging, and methods of enhancing sensitivity by selection of Huon pine habitat are suggested.

Section 4 describes the development of a successful pretreatment of Huon pine wood (with its unusual chemical preservatives) for carbon-14 dating. This involves complete removal of all mobile fractions so that measured activities are appropriate only to the year of growth of the rings analysed. Preliminary tabulation of radiocarbon ages of old logs yields dates spanning the last 12,000 years, and offers the potential of a continuous ring width chronology spanning much of this period.

The geomorphology of the river in the area of these old logs is described in Section 5. Preliminary probing led to excavations in the flood plain of the river, and the recovery of much old timber. Radiocarbon dating of these and nearby logs has provided a history of river channel evolution (and tree habitat) over 12,000 years.

Sections 6, 7, 8 and 9 are primarily concerned with elucidating the influences on carbon isotope fractionation in the trees. Section 6 details large systematic variations in the stable carbon isotope ratio $^{13}C/^{12}C$. These are of two types, a strong gradient ($\sim$ 2-3 ‰) of increasing ^{13}C going from the tips of leaf stems towards the woody branches, and a large ^{13}C depletion ($\sim$4-5‰) in both leaves and branch wood going from bright exposed situations to shaded situations.

The physical environment above and below the rainforest canopy is described in Section 7, with the emphasis on the light environment. The stomatal and gas exchange measurements in Section 8 provide field information on the parameter c_i/c_a, the ratio of internal to external CO_2 concentrations in a leaf. Variations in c_i/c_a, due mainly to light level, are shown to be reflected in $^{13}C/^{12}C$ ratio of the plant material. Details on the technique, based on determinations of c_i/c_a in the field, are given.

Measurements on the composition of sub-canopy air are described in Section 9. Profiles of carbon dioxide concentration and $^{13}C/^{12}C$ ratio confirm the relative unimportance of carbon isotope variations in air as an influence on the tree values. Interpretation has been aided by measurements on Freon-11, methane and carbon monoxide in the air samples as indicators of contamination from anthropogenic sources or forest fire plumes. A previously unreported diurnal variation in methane level is revealed.

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APPENDIX A

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2 *Main Programs*

(Underlining indicates participation in the field).

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Mr. Trevor Bird, Mr. George Dolezal, Mr. Bernard Kunda, (CSIRO-DFR).

Radiocarbon Research:

Long-term (millenia) variations - Dr. Mike Barbetti, Dr. Steve McPhail, Dr. Richard Temple (SU).

Mid-term (recent centuries) variations - Mr. Henry Polach, Radiocarbon Dating Laboratory, Australian National University (ANU), Dr. Minze Stuiver, University of Washington, Dr. Allan Chivas, Research School of Earth Sciences (ANU).

Short-term (recent decades) variations - Dr. Chris Radnell, Dr. Paul Damon, University of Arizona.

Stable Isotope Research:

Carbon-13: Dr. Roger Francey, Mr. Geoff Richards, Dr. Graeme Pearman, Dr. Randyl Flynn (CSIRO-DAR).

Hydrogen-Oxygen: Dr. Allan Chivas (RSES-ANU).

Atmospheric Composition:

Carbon Dioxide: Mr. David Beardsmore, Dr. Graeme Pearman (CSIRO-DAR).

Carbon-13: Mrs. Helen Goodman, Dr. Roger Francey, (CSIRO-DAR).

Other Trace Gases: Dr. Paul Fraser (CSIRO-DAR).

Plant Physiology:

Light and stomatal measurements: Dr. Roger Gifford (CSIRO Division of Plant Industry).

Gas exchange measurements: Dr. Graham Farquhar, Dr. Tom Sharkey, Mr. Brian Weir, Mr. Win Coupland (ANU, Department of Environmental Biology).

Geomorphology:

Dr. Gerald Nanson, Mr. Kevin Mills, University of Wollongong.

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APPENDIX B

MATERIAL COLLECTED (RJF, MB, TB, JED)

Figures 3 and 4 are enlargements of areas A and B respectively of Figure 2. Symbols are coded in Figure 3. Numbers correspond to tree numbers summarised in Tables B1 - B6.

In Tables B1 - B6:

GRID LOCATION refers to the coordinate system discussed in Section 2. Most trees from area B lie beyond the established grid system and their positions (in brackets) are approximate, being interpolated from their relative positions on the site map.

DBH is a measurement, sometimes an estimate, of the tree "Diameter at Breast Height".

RADIAL DIRECTION OF CORE is the magnetic bearing from the tree centre along a core. Note that underlining is used to distinguish a different trunk in the case of multi-stemmed trees.

YEAR DATED TO refers to the earliest year (A.D.) which could be assigned to a ring by cross-dating. Where an asterisk follows the year, it denotes that a substantial number of rings precede this year but that for various reasons, such as presence of a knot, rot, or cracks, they have not been dated. Remarks such as "sapwood too tight" mean that rings are very narrow or are merged so that there is a suspicion that multiple rings may be missing from this section of the radius.

SITE CLASSIFICATION identifies tree locations

- (I) within a few metres of the river bed,
- (II) on a river flat/flood plain,
- (IIwc) as in (II) but with the tree base in a shallow water course, and
- (III) on well drained rocky slopes, typically 10 m above river level.

FOLIAGE indicates that foliage is

- (a) mostly sub-canopy,
- (b) at canopy top but with a significant amount sub-canopy,
- (c) within 2-3 m of canopy top only, and
- (d) predominantly above mean canopy top.

Brackets indicate uncertainty resulting from recent clearing.

TRUNK indicates the number of main vertical trunks, and prefix L indicates growth obviously stemming from a fallen log.

DIAMETER and THICKNESS of cross sections are also given where relevant.

TABLE B1 Cores collected from live Huon pines

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DBH (mm)	RADIAL DIRECTION OF CORE (degrees) AND YEAR DATED TO A	B	C	D	SITE TYPE	FOLIAGE TYPE	TRUNK TYPE
SRT-1	4 Feb 81	4551	4958	1215	300° 1418	30° 1558	90° 1720*	120° 1436	I	c	2
4	5 " "	4363	4800	1620	310° 994	340° sapwood rings	280° tight	-	IIwc	c	3
5	5 " "	4388	4805	475	270° 1748	150° 1697	65° 1684	-	II	b	1
7	5 " "	4388	4812	370	95° 1744	15° 1649	-	-	II	b	1
8	5 " "	4340	4821	780, 780	60° 1356	280° 1238	340°	-	II	c	2
9	5 " "	4344	4828	330	330° 1708	50° 1706	-	-	II	b	L1
10	5 " "	4342	4829	420	15° 1693	125° 1708	-	-	II	b	L1
11	5 " "	4345	4829	430	145 1647	1757	-	-	II	b	L1
12	5 " "	4350	4845	340, 560	325° 1700*	195° 1661	335° 1665	-	II	b	L2
18	6 " "	4573	4720	1200	70° sapwood tight	210° 952	315° 983	-	IIwc	b	1
19	6 " "	4574	4712	900,1000	300°	315° 919	-	-	IIwc	c	2
20	6 " "	4548	4750	1540	215° cores E,F,G also	330° taken but all	35° too tight	205°	II	c	1
24	6 " "	4589	4694	690	330° 1520	260° sapwood tight	0° 1439	-	IIwc	b	1
25	6 " "	4582	4703	1600	10° 1100	300° wedging out	225° too tight	DEFG also undateable	IIwc	c	3
26	6 " "	4587	4688	940	260° 1393	360° 1493*	170° 1242	-	IIwc	b	2
27	7 " "	4582	4693	590	240° too tight	280°	10° 1324	-	IIwc	b	1

TABLE B1 continued

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DBH (mm)	RADIAL DIRECTION OF CORE (degrees) AND YEAR DATED TO A	B	C	D	SITE TYPE	FOLIAGE TYPE	TRUNK TYPE
28	7 Feb 81	4570	4687	440	140° 1806	35° 1761	290° 1771	-	II	c	2
30	" "	4600	4692	282	120° 1800*	30° 1701	-	-	II	b	2
32	" "	4622	4696	2000	340° tight at 1800	85° 1359	5° 1600*	295 sapwood tight	II	b	2
33	7 " "	4632	4680	1130	145° 1632	80° 1228	295° 924	-	II	(c)	3
34	7 " "	4638	4672	550	80° 1462	280° 1550*	340° 1570*	-	II	(c)	1
35	7 " "	4638	4698	510	315° 1616	250° tight at 1870	105° 1540	-	II	c	1
36	9 " "	4915	4625	580	115° 1450*	210° 1420*	290° 1480	-	III	c	1
37	9 " "	4908	4625	1630	235° 1278	120° 1409	340° 1240	-	III	d	1
40	9 " "	4898	4642	1330	70° 1393	315° 1500*	200° 1223	-	III	d	1
41	9 " "	4917	4640	580	135° 1600*	250° 1688	340° 1774	-	III	b	1
45	9 " "	(5070	4670)	370	285° 1620	210° 1625	140° 1671	-	I	b	2
46	9 " "	(5080	4670)	400	270° 1721	110° 1772	360° 1720	-	I	b	1
48	9 " "	(5090	4670)	405	320° 1800	110° 1750*	180° 1753	-	I	d	1
50	9 " "	4496	4826	600	180° sapwood tight	275° E dated to 1550	20°	Cores B,D,E,F, show centre rot	II	c	2
51	9 " "	4502	4809	1220	0° 1600*	110° 1700*	350° 1800*	170° Cores A-H taken, all undateable but old. X-sect being obtained	II	b	>3
54	9 " "	4532	4900	780	55°	260° 1317	150°	-	II	b	1

TABLE B1 continued

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DBH (mm)	RADIAL DIRECTION OF CORE (degrees) AND YEAR DATED TO A	B	C	D	SITE TYPE	FOLIAGE TYPE	TRUNK TYPE
55	10 Feb 81	4555	4907	690	70° 1632	140° 1500	210° 1510	-	II	b	2
114	10 " "/ 26 Sep 82	(5310	4480)	1890	80° 1078	150° 880	240° 1198	-	IIwc	d	2
202	26 Sep 82	(5130	4570)	1500	0° 1700	90° 1653	- rotten shell	-	I	d	2
203	26 Sep 82	(5130	4610)	770	180° rot	0° 1800*	280° too tight at 1800	200°	I	d	1
204	26 Sep 82	(5170	4480)	1470	330° 1730 rot	75° 1208	270° 1800*	190° 1700*	II	d	2
205	26 " "	(5180	4480)	545	30° 1485	330° 1505	1569	-	I	d	1
206	26 " "	(5190	4480)	1035	340° 1261	150° 1200	270° 1229	-	II	d	1
207	26 " "	(5320	4470)	602	0° 1597	120° 1607	1561	1608	II	c	1
208	26 " "	(5330	4480)	560	240° 1714	180° 1655	-	-	IIwc	b	1
209	26 " "	(5330	4480)	480	350° 1555	250° 1615	-	-	II	b	1
210	26 " "	(5330	4490)	750	60° 1689	300° 1657	160° 1582	-	II	d	1
211	27 " "	(3793	4608)	455	90° 1785	210° 1741	-	-	II	b	1
212	27 " "	(3789	4628)	490	300° 1514	200° 1602	-	-	II	b	1
213	27 " "	(3789	4634)	410	180° 1533	280° 1645	-	-	II	b	L1
214	27 " "	(3788	4635)	760	260° 1355	360° 1261	100° 1264	-	II	c	L1

TABLE B1 continued

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DBH (mm)	RADIAL DIRECTION OF CORE (degrees) AND YEAR DATED TO A	B	C	D	SITE TYPE	FOLIAGE TYPE	TRUNK TYPE
215	27 Sep 82	(3788	4646)	380	340° 1624	60° 1610	-	-	II	b	L1
216	27 " "	(3795	4655)	350	120° 1620	230° 1612	-	-	II	b	1
217	27 " "	(3780	4625)	460	180° 1672	300° 1602	-	-	II	c	L1
218	27 " "	(3787	4634)	615	360° 1565	150° 1528	270° 1713	-	II	c	L1
219	27 " "	(3795	4627)	1095	180°	210°	320°	260°	II	d	1
					----------------All too tight----------------						
220	27 " "	(3780	4626)		Four cores, three too tight and one uncertain				II	b	1
300	30 Apr 83	(5030	4580)	480,400	70° 1611	135°	315°	215° 1431	III EFG exist	c	2
301	30 Apr 83	(5040	4580)	550,340	230° 1610	320°	-	1431	III F-1493, G-1546	d	2
302	30 " "	(5040	4590)	360	220° 1589	140° 1589	-	-	III	b	1
303	30 " "	(5030	4590)	1390	180°	112° 1814*	20°	-	III	d	1
304	30 " "	(5030	4590)	590	135° 1545	20° 1546	115° too tight	-	III	d	1
305	30 " "	(5060	4590)	430	310° 1750	50° 1750	195° 1799	75° 1799	III	b	L1
310	30 " "	(5020	4560)	660	265° 1586	25° 1595	-	-	III	d	1
311	30 Apr 83	5000	4705	(950)	80° 1838-1339	dead stump logged at turn of century standing over SRT 39			I		

TABLE B2 Cores collected from live Celery-top pines

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DBH (mm)	RADIAL DIRECTION OF CORE (degrees) AND YEAR DATED TO A	B	C	D	SITE TYPE	FOLIAGE TYPE	TRUNK TYPE
SRT-3	4 Feb 81	4360	4967	830	360° 1682	270° cores fractured	130°	180° 1612	II/III	d	1
13	5 " "	4347	4878	350	250° 1610	-	-	-	II/III	d	1
14	5 " "	4347	4885	380	125° 1800*	-	-	-	II/III	d	1
15	6 " "	4473	4980	540	200° 1708	110° 1683	-	-	III	d	1
16	6 " "	4488	4980	840	165° 1664	295° rings wedged out	-	-	III	d	1
17	6 " "	4504	4984	410	280° 1890	135° sapwood tight	-	-	III	c	1
21	6 " "	4548	4750	340	130° 1608	265° 1578	-	-	II	c	1
23	6 " "	4551	4749	540	260° 1616	335° 1578	-	-	II	c	1
29	7 " "	4577	4680	450	50° 1550	0° 1681	1602	1550	IIwc	c	3
38	9 " "	4912	4610	630	330° 1620	275° 1589	100° 1566	-	III	d	1
47	9 " "	(5090	4660)	480	210° wedging <1880	350° 1679	-	-	(I)	d	1
49	9 " "	4598	4925	650	30° 1702	150° 1668	310° 1644	-	II	b	1
306	30 Apr 83	(5060	4580)	650	55° many wind shakes	-	-	-	III	d	1
307	30 " "	(5040	4580)	610	70° 1512	355° 1506	-	-	III	d	1
308	30 " "	(5050	4560)	870	340°	260° 1507	-	-	III	d	1
309	30 " "	(5030	4570)	540	45° 1536	1448	-	-	III	d	1

TABLE B3 Cross-section cut from Huon pine stumps or commercially harvested logs

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DIAMETER (mm)	YEAR DATED TO	THICKNESS (mm)	SITE	COMMENT
SRT-6A	5 Feb 81	4340	4825	1080		200,100	II	fallen tree, alive,
6B	5 " "	"	"	650		250	"	host to 300 mm DBH myrtle
6C	5 " "	"	"	300		400,150	"	sloping branch
22	6 " "	4548	4752	1250		200	II	felled 79/80
31A	7 " "	4595	4680	500	1670	200	II	vertical off-shoot
31B	7 " "	"	"	1000	1174	100	"	fallen log, cut 79/80
31C	7 " "	"	"	450	1700	150	"	vertical off-shoot
40A	30 Apr 83	4898	4642	900		70	III	cross-sections from below
40B	30 " "	"	"	900		60	"	crown after logging
42	9 Feb 82	4906	4707	1000		100,100	I	fallen log
52	Nov 81	4532	4832	1100		180	IIwc	fallen tree, from sawmill
53	Nov 81	4520	4832	1300		200	II	fallen tree, from sawmill
62	7 Feb 81	4560	4760	650	1668	150	IIwc	felled 79/80
63	7 " "	4595	4855	640		200	II	felled 80/81
64	8 " "	4543	4890	1500		200	II	felled 1900?
65	8 " "	4520	4897	630		150	IIwc	felled prior 1979?
66	8 " "	4522	4897	450		100	IIwc	felled prior 1979?
67	8 " "	4512	4896	650		100	IIwc	felled 79/80
68	8 " "	4499	4880	350	1474	200	IIwc	felled 79/80
69	8 " "	4496	4880	470	1580	100	IIwc	felled 79/80
113	-	4360	4750	2000		-	II	sawmill to provide

TABLE B3 continued

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DIAMETER (mm)	YEAR DATED TO	THICKNESS (mm)	SITE	COMMENT
200A	28 Sep 82	4345	4800	1000		55	II	cross-sections from base
200B	28 " "	"	"	910		60	"	and top of logged downer
201	28 " "	4350	4805	540		90	II	felled 1982
221	28 " "	4355	4820	460		110	II	felled 1982
222A	28 " "	4365	4830	340	1680	60	II	felled 1982
222B	28 " "	"	"	320		60	"	felled 1982
223	28 " "	4380	4795	350		55	II	branch sect. of large rotten tree burnt and falling in 1982
225	28 " "	4400	4860	520	1485	60	II	logged 79/80, stump burnt 1982, many are 1/2 sections only
226	28 " "	4410	4880	570	1490	60	II	
227	28 " "	4400	4895	430		75	II	" " " " "
228	28 " "	4440	4890	460	1350	55	II	" " " " "
229	28 " "	4435	4910	520	1380	90	II	" " " " "
230	28 " "	4445	4920	490		60	II	" " " " "
231	28 " "	4425	4930	370		90	II	" " " " "
233	28 " "	4420	4940	230	1480	70	II	" " " " "
234	28 " "	4440	4950	530		85	II	" " " " "
235A	28 " "	4420	4960	610		70	II	" " " " "
235B	28 Sep 82	"	"	370		70	II	rotten in centre

TABLE B5 Cross sections or samples of preserved logs, collected along the river bed from excavations in the flood plain.

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DIAMETER (mm)	X-SECTION THICKNESS (mm)	SITE TYPE	SPECIES
SRT- 39	11 Feb 81	5000	4705	750	(200g)	I	Huon
"	Feb 82	"	"	"	6 x 1000	"	"
43	9 Feb 81	(5070	4660)	520	300,100 (200g)	I	Huon
44	9 " "	(5070	4670)	810	200,100	I	Huon
56	11 Apr 81	(5070	4650)	600	(200g)	I	Huon
57	11 " "	(5080	4660)	800	(200g)	(I)	Huon
58	11 " "	(5080	4640)	400	(200g)	I	Huon
59	11 " "	5100	4640)	900	(200g)	I	Huon
"	Feb 82	"	"	"	100,70	"	"
101	11 Apr 81	(5170	4600)	1000	(200g)	(I)	Huon
102	11 " "	(5180	4600)	700	(200g)	(I)	Huon
103	11 " "	(5170	4600)	270	(200g)	I	Huon
104	11 " "	(5120	4500)	1000	(200g)	I	Huon
105	11 " "	(5140	4500)	500	(200g)	I	Huon
106	11 " "	(5160	4510)	1700	(200g)	(I)	Huon
107	11 " "	(5160	4510)	750	(200g)	I	Huon
108	12 " "	(5490	4510)	300	(200g)	(I)	Celery
109	12 " "	(5280	4480)	300	(200g)	I	Huon
110	12 " "	(5280	4480)	300?	(200g)	(I)	Huon
111	12 " "	(5290	4480)	700	(200g)	(I)	Huon
112	12 " "			1800	(200g)	(I)	Huon

TABLE B5 continued

TREE NUMBER	COLLECTION DATE	GRID m N	LOCATION m W	DIAMETER (mm)	X-SECTION THICKNESS (mm)	SITE TYPE	SPECIES
115	Feb 82	(5110	4630)	450	75,75	I	Huon
116	" "	(5120	4610)	550	75,60	I	Huon
117	" "	(5130	4610)	500	65,100	I	Huon
118	" "	(5140	4610)	900	100,75	I	Huon
119	1 May 83	4970	4700	250	50	I	Huon
150	12 Feb 82	5020	4680	160	70,70	Excav. 1	Phebalium
151	" "	5000	4680	270	(3)	Excav. 2	Huon
152	" "	5000	4680	360	(4)	" "	Huon
153	" "	5000	4680	> 300	100,100	" "	Huon
154	" "	5000	4680	500	75,100 (+2)	" "	Celery
155	" "	5000	4680	200	50,75	" "	Celery
156	" "	5020	4680	250	70,80	Excav. 1	Eucryphia
157	" "	5020	4680	300	70,70	" "	Celery
158	" "	5020	4680	150	(2)	" "	Huon
159	" "	5020	4680	150	(2)	" "	Eucryphia
160	" "	5020	4680	130	(2)	" "	Celery
161	" "	5010	4680	500	110,70	Excav. 2	Huon
162	" "	5000	4680	500	90,90	" "	Huon
163	" "	5000	4680	> 500	75,75	" "	Huon
164	12 Feb 82	5000	4680	350	(200g)	" "	Huon

APPENDIX C

SUPPLY OF WOOD SAMPLES

The amount and variety of well documented wood samples far exceeds the immediate analysing resources of the participating laboratories. We are happy to consider requests for wood if they are accompanied by a short (~ 1 page) description of the intended research. This information helps us select the most appropriate wood sections and avoids unnecessary duplication of research.

Requests should be directed to one of the principal investigators (Appendix [A]).

At infrequent intervals an attempt will be made to circulate brief status reports on research results.