40,000 Year record of food plants in the Southern Kimberley Ranges, Western Australia

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An important Pleistocene-Holocene sequence was discovered when Carpenter's Gap Site 1 was excavated in 1992 and 1993 by Sue O'Connor (O'Connor 1995). The site is located in Windjana Gorge National Park, in the Napier Range, which lies at the southern edge of the Kimberley region (Fig. 1). Carpenter's Gap Shelter 1 has an archaeological sequence spanning at least 40,000 years, from the late Pleistocene to the present. A unique feature of this site is the extensive macrobotanical remains preserved: over 2000 seeds and plant parts from one square metre have been recorded. The Bunuba Aboriginal people, traditional owners for this area, consider this rockshelter to be an important cultural landmark. There is supporting evidence, from the petroglyphs and pictographs within this rockshelter, and the rockshelter's continuing role within Bunuba Aboriginal culture, of considerable time depth and continuity to the human occupation and use of this site.

This paper describes the macrobotanical materials from the site with some taphonomic considerations. The changing patterns of deposition are considered as potential indicators of both evidence of cultural use from the Pleistocene occupations through to the Holocene, and as general environmental indicators.

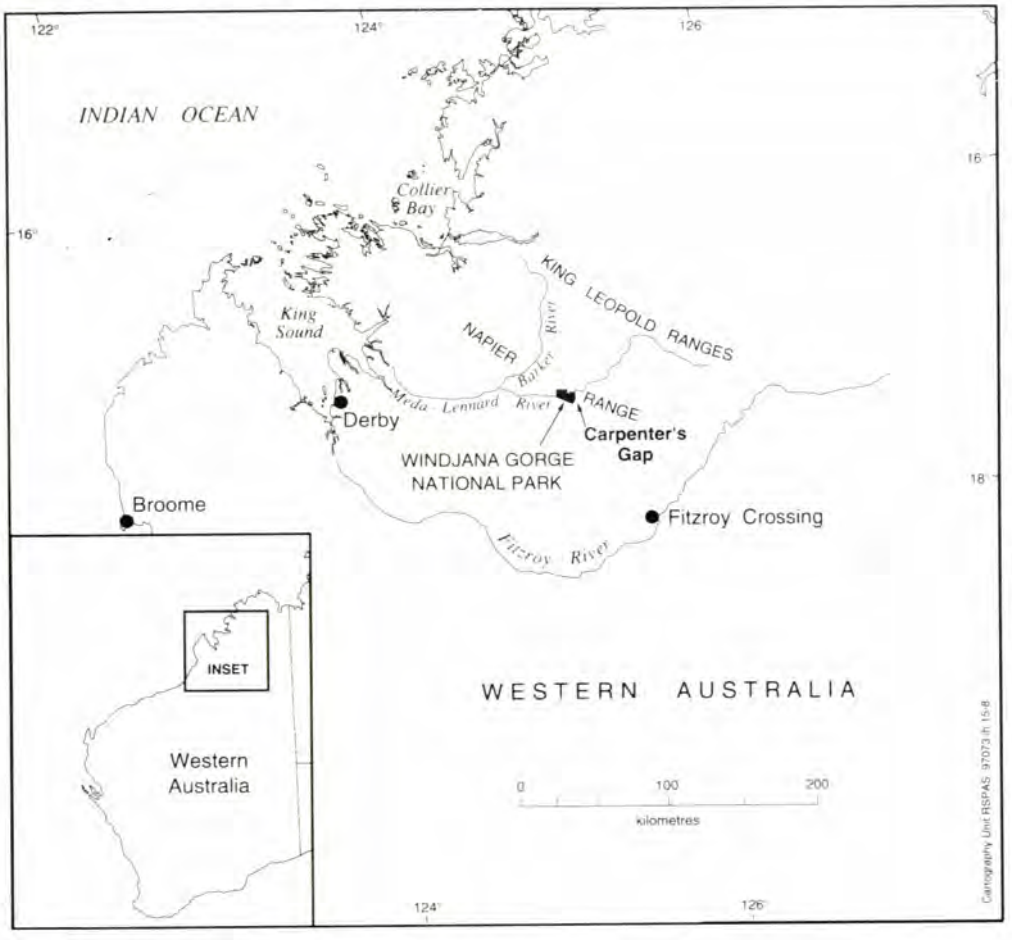

Figure 1 Map of site area.

The southern Kimberley region

The Kimberley region, in northwestern Australia, is defined by the King Leopold and Halls Creek orogens, dated to 2150 Ma, that bound the Kimberley basin around the southern border (Griffin and Grey 1990:232). On the southwest fringe of the King Leopold orogen lies the Napier Range, the remnant of the forefront and inter-reef facies of a Devonian reef built around 350 million years ago (Goudie et al. 1990). The reef trends in a NW-SE direction, approximately 120 km long and up to 5 km wide, rising 100-150 m in height. It is composed of sandstone, siltstone and coral limestone (Playford n.d.). South of the range lies the savannah which gives way within 100 km to the Great Sandy Desert. The Kimberley region is within the tropics and is subject to monsoon effects. The site area receives a total of 600 mm rainfall per year limited to the winter months, November to March (Bureau of Meteorology 1995) (Fig. 1).

Vegetation description

There are three main vegetation classes in the region today. Most of the plains surrounding the ranges are covered in ephemeral and annual grasses with scattered *Eucalyptus, Melaleuca* and Proteaceae. Pockets of rainforest or broadleaf vine thicket, grow in fire shadows and where there is access to additional water (Russell-Smith and Dunlop 1987: 265; McKenzie 1991:1). These exist along permanent watercourses and seasonal washes that cut across the savannah; and, in the Napier range, where there is seepage from the limestone. Occasionally the seepage is enough to run down to the savannah below, creating a vine thicket-filled wash within a fire shadow (Russell-Smith and Dunlop 1987:253, 263, 306), such as occurs adjacent to the site. The third vegetation class, low tree and shrub savannah, with *Triodia*

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spp., *Adansonia gregorii* and *Terminalia* spp. is an intermediate between these two formations, occupying the dry gravel slopes of ridges, and eroded hillslopes associated with the ranges (Whyte 1968:103).

There is a narrow strip of tropical tall hummock grass savannah growing around the base of the Napier Range on all sides, up to 100 m wide. The grasses, *Plectrachne* spp. and *Cymbopogon proceris*, are 1-2.5 m tall, with a few herbaceous weeds, growing along the base of the talus slope. This area benefits the most from any precipitation runoff from the range and therefore tall grasses are supported together with the scattered trees *Cochlospermum fraseri* and *Adansonia gregorii*. The majority of the savannah is composed of ephemeral grasses with scattered *Eucalyptus*.

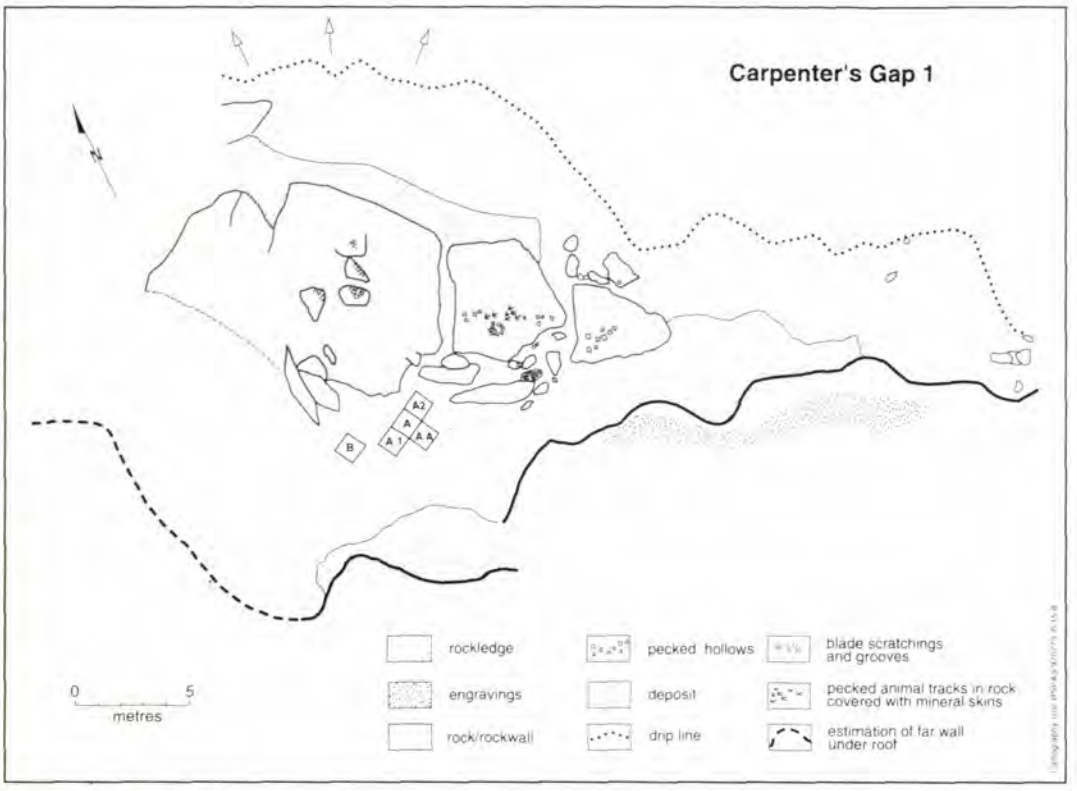

Figure 2 Planview of site.

Carpenter's Gap rockshelter

Carpenter's Gap Site 1 is a rockshelter in the Napier Range, facing northeast (Fig. 1). The site is approximately 3 km from the Lennard River to the north that has cut the Windjana Gorge through the Napier Range limestone. The rockshelter is within a natural embayment in the ridge, protecting it from weather extremes coming from the north or south. Direct access to the rockshelter is due northeast. The front of the shelter has a large rockfall lying across the mouth, further protecting the interior from weather. The shelter is situated approximately 25 m above the savannah, with a steep talus slope below and limestone cliff above.

The excavation

The excavation is located behind the screen of protective roof fall across the front of the rockshelter (O'Connor 1995). This has helped retain sediment deposits and may have aided the preservation of organics. The area that contains sediment to any appreciable depth is quite small, situated just behind the rockfall. Square A, a 1 m^2 was excavated down to bedrock in 2 cm spits to a depth of approximately 1.04 m at the deepest point (Fig. 2).

The range of artefacts recovered from the site, and Square A, indicate that a wide range of activities took place here over an extended time. As with the botanical remains, the upper spits, from spit 11 to the surface, provided the bulk of flaked stone and bone that was recovered. No basal grindstones were recovered from the site. The largest category of artefacts recovered were retouched and unretouched stone flakes with some retouched points in the upper Holocene levels. The materials are mostly of clear rock quartz with some hornfels. A wide range of faunal remains including those of medium and small-sized macropods, rodents and fish were recovered. Emu shell, freshwater mussels and snailshell were also recovered. Spits 6, 7 and 8 extended through several hearths and contained the largest quantity of fish bone (McConnell and O'Connor 1995; McConnell 1996).

Flotation also recovered a mass of very small fish bone, pieces of fish scales and burned bits of mammal bone, visible only when sorted under the microscope (McConnell and O'Connor 1995). A significant amount of the mammal bone in most spits is burnt.

Radiocarbon dates

Radiocarbon dates from charcoal in Square A have been obtained. Dates range from 650±90 BP from spit 2, near the surface, to 39,220±870 at spit 49, near the base of fill (Table 1) (O'Connor 1995). These are uncalibrated dates, so there is an underestimation of age gradually amounting to around 1000 years at 7000 BP and 2-3000 years at 20,000 BP. The date inversion at spits 17 and 20 is within one standard deviation of error. Figure 3 diagrams the association between spit and estimated age derived from ^{14}C dating. It presents a relative chronology showing the rates of soil accumulation, given that each spit represents a constant 2 cm depth. The varying slope of the line gives some indication of the relative accumulation of sediments through the varying time periods. This diagram shows three periods of rapid soil accumulation, or possibly accumulation mixed with deflation interspersed with two periods of more gradual soil accumulation, shown by the gradual sloping section.

Lab No.	Spit	Approx. depth (cm)	Mat.	Date
Wk-3075	2A	4	char.	650 ±90
ANU 10030	8A1	16	char.	3300 ±60
ANU 10027	13A1	26	char.	16,050 ±150
AMS NZA 3800	17A	35	char.	20,760 ±170
AMS NZA 3801	20A	40	char.	18,940 ±170
AMS NZA 3802	40A	80	char.	39,700 ±1000
AMS 11777	45A	90	Term.	30,700 ±650
AMS NZA 3803	49A	100	char.	39,220 ±870

Table 1 ^{14}C dates.

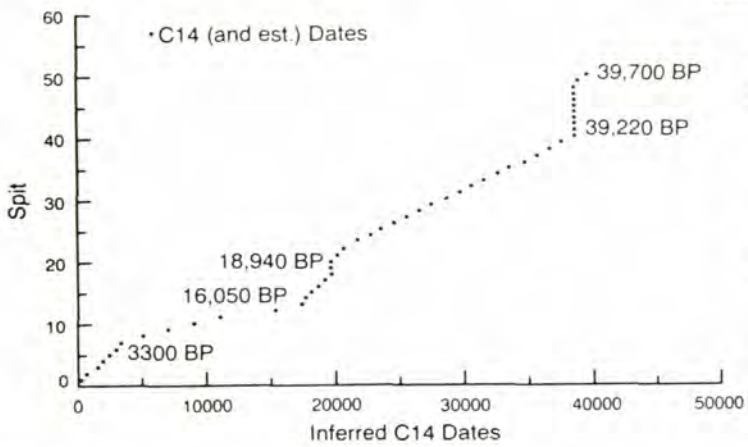

Figure 3 Association of spit with inferred ^{14}C ages in Square A.

Botanical analysis

The material considered in this study included the bulk sediment samples from each spit in Square A. These were weighed, screened in water and the light fraction was collected in 0.1 mm mesh and examined under a light microscope (Pearsall 1989). The heavy fraction was collected in a 1 mm mesh screen. The 3 and 6 mm samples that had been screened at the site were dry sorted and then floated. All fractions, light, heavy, 3 mm and 6 mm were examined for botanical remains. A brief comparison of methods showed that dry sorting leaves approximately 5% of botanical material unsorted, while flotation separates close to 100% of botanical remains and captures the seed fraction that is smaller than 3 mm. The total amount of botanics per 100 g sediment was calculated. The JEOL 6400 scanning electron microscope was used to make a microscopic examination of seeds and plant parts, to make a photographic record of remains and to perform a spectrum analysis for carbon of the seeds and other materials recovered, to establish whether the materials which appeared burned had in fact been charred.

Botanical remains

Figure 4 shows the major plant remains recovered from Square A. The condition of the materials examined was quite good, with surfaces intact and over 90% whole seeds. Seeds were identified using vouchered comparative material collected in Western Australia by Kings Park Botanical Garden, Perth, denoted here by (KPBG), the CSIRO herbarium collections in Canberra (CSIRO), the Anbangbang site material (ANBB) (Clarke 1987) and McConnell's[2] field collections made in the Windjana Gorge National Park (K-KM). In each case at least two sources, and usually more, could be used to identify materials. Dr Mike Lazarides of the CSIRO assisted with the identifications of the grasses and sedges.

Terminalia spp. L.

The most frequently recovered seed type is *Terminalia* of the Combretaceae family. Superficially the seeds look like a peach pit as they are elliptical, and bisymmetrical, with a deeply rugose surface. Trees provide fruits, a drupe, in the wet season, January to April. Several kernels from the *Terminalia* seeds were also recovered from spits 3 and 36. Eating the kernels has been recorded for *T. arostrata, T. catappa, T. cunninghamii* (western Great Sandy Desert), *T. grandiflora* (Groote Eylandt) (Scarlett 1985:8; Roth 1984 [1901]: 107; McGlew and Hilton 1987:48; Specht and Mountford 1958:496), (KPBG #5337/92). Roth reports that four species of fruit were eaten in northern Queensland but only one is eaten raw (*Terminalia platyphylla*), implying the others were cooked before eating (Roth 1984[1901]:107).

The bark of the *Terminalia carpentariae* provides a glue. The red inner bark is scraped off and collected in a basket, mixed with water and pounded into a waterproof cement that is used to caulk canoes. The trunk exudes a gum that can be eaten immediately or heated in a fire, pounded and then soaked where it becomes a jelly (Specht and Mountford 1958:496). *Terminalia* fruit contain some protein and carbohydrates but are exceptionally high in vitamin C, providing 3792 mg per 100 g raw edible portion (Miller et al. 1993). Carpenter's Gap Site 1 seeds bear the closest resemblance to the following seeds, although identification is not certain and there may be other varieties and species present. (KPBG #367/86 – *T. platyphylla* F. Muell; KPBG #5372/92 – *T. latipes* Benth (also called *T. ferdinandiana* Exell.).

Ampelocissus acetosa (F. Muell.) Planchon

This member of the Vitaceae family is also common in the site. The seeds, in size around 6 x 5 mm are globular to ovoid, with a wide calyx attachment scar and an indented apex. The surface is ribbed from the apex to the calyx. The thick, woody seed has two complete ovary chambers. The vine produces fruit called the native grape in vine thickets January-May. In several cases in the Holocene spits, flesh was still attached to the seed. Water can be obtained from the hollow stems and the tuberous tap root can be baked and eaten in an emergency (Specht and Mountford 1958: 493). The fruit provide protein, carbohydrates and potassium and magnesium (Miller et al. 1995) (CSIRO #8003232; ANBB U17 NE4).

Vitex glabrata R. Br.

Seeds of this species of the Verbenaceae family were also common in the site. The ovoid seeds range in size around

2 McConnell is currently seeking additional late Pleistocene sites in northern Australia with systematically sampled levels that may contain cultural macrobotanical materials, to be incorporated into a Ph.D. Please contact the author at email: kmcconne@coombs.anu.edu.au.

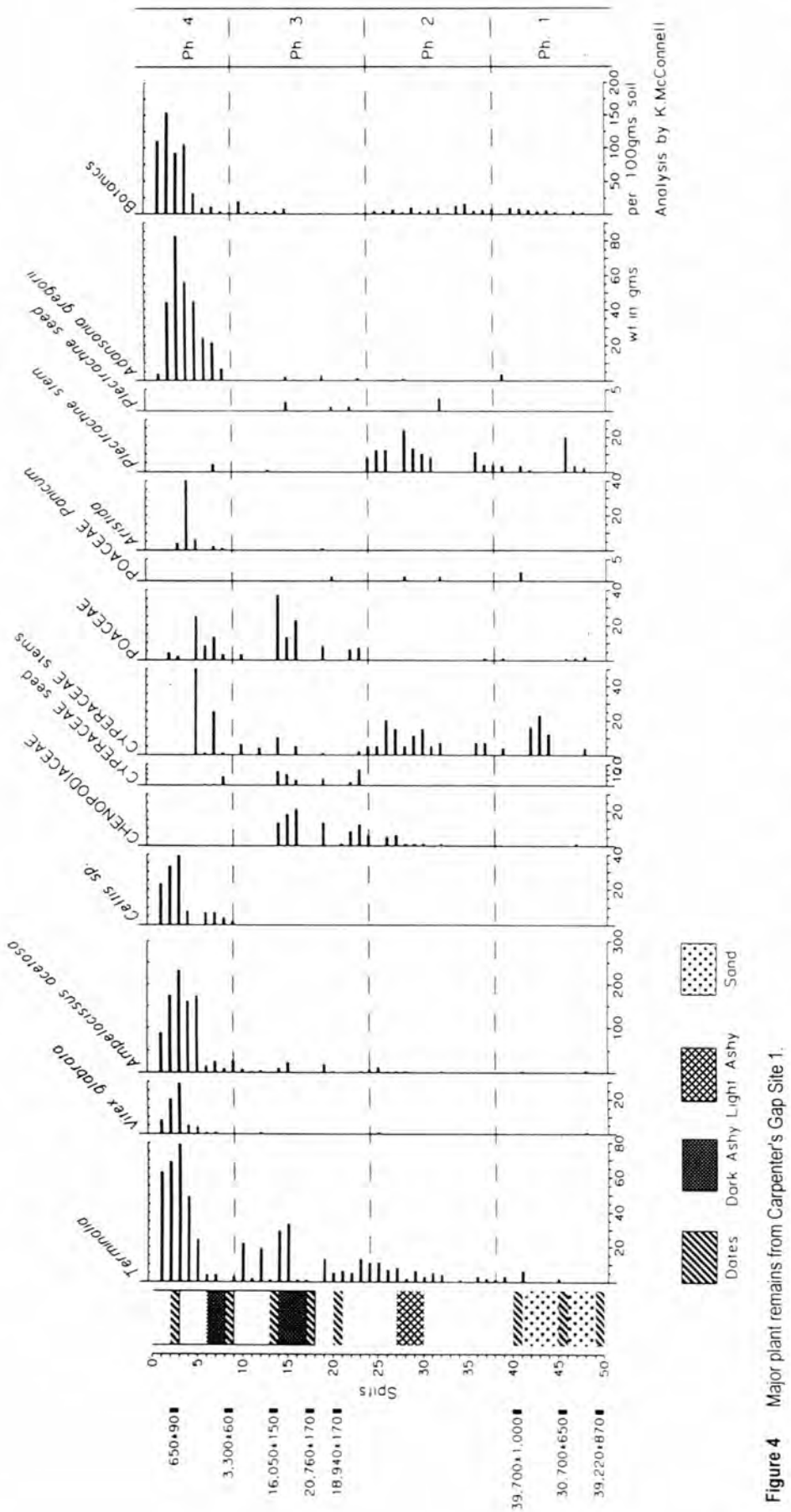

Figure 4 Major plant remains from Carpenter's Gap Site 1.

5 x 4 mm, fairly constant. A distinguishing characteristic is the slight sharp protuberance on the wide ovoid apex and the prominent ring and large opening around the calyx scar. The seam that divides the seed along a bisymmetrical axis is indented and the surface is slightly rugose. The tree grows from 4-20 m high on sandstone, or other rocky terrain (Crawford 1982). The fruit, ripe December-February, is a drupe, dark purple to black when ripe (Wheeler et al. 1992:793). Crawford reports that the Bremorai who live in the far north Kimberley around Kalumburu distinguish between two trees that are not separated botanically. One produces black fruit in January that must be baked before eating, while the other produces green fruit in March that are eaten raw and the tubers are roasted and eaten. Both Crawford (1982) for the Bremorai; and Scarlett (1985) for the Kija who live around Turkey Creek in the Eastern Kimberley, report that *Vitex glabrata* constituted one of the staple fruits during the wet season, with a surplus often being available. The fruits can be pounded and formed into large round cakes, wrapped in paperbark and stored for later use (Scarlett 1985:7). The fruit provides carbohydrates and protein with some vitamin C (Miller et al. 1995) (CSIRO #8003232; ANBB U17 NE4).

***Celtis philippensis* Blanco**

Sometimes misspelt as *Celtis philippinensis*, this tree is widespread in northern hemisphere tropical and temperate regions, with only one species growing in the Kimberley Region (Wheeler et al. 1992:75). A member of the Ulmaceae family, seeds were recovered in fairly large numbers from the recent Holocene spits. The globular whitish seed, 6 x 6 mm, has a reticulate-areolate surface with prominent ridges from the calyx to the apex. The calyx scar is everted forming a prominent lip. The shrub or trees grow in vine thickets with fruits in January-September. The flesh of the fruits is eaten.

There is a great range in size in this species; however the distinctive surface treatment remains the same (CSIRO #358398 from W.A.; #194658 from New Guinea; K35KM).

Chenopodiaceae Paul G. Wilson

From spits 14 to 23 approximately 108 Chenopodiaceae seeds were recovered. Seed size is around 1 mm. One type from spit 14 has a reticulate surface, capped with waxy reticulate particles; another type from spit 15 has a ruminate surface, indicating possibly two different species. Some of the comparative materials used are: (KPBG #1765/102/79 – *C. inflatum)*, (CSIRO #390144 – *C. auricomum)*, (CSIRO #268200, 7910465 – *Einadia nutans)*, (CSIRO #105411 – *Dysphania kalpari)*, (CSIRO #53648 – *Rhagodia eremaea*), (CSIRO #299028 – *Atriplex semibaccata*), (CSIRO #105431 – *Atriplex spongiosa*).

Sclerolaena sp. fruits are a fairly large, woody pod (3 mm in length) with two long horn-like projections (3 mm in length) (Wheeler et al. 1992:103-5). They occurred throughout the excavation in low numbers. *S. lanicuspis* also of the genus Chenopod is commonly called the Spinach burr, in recognition of the use of the young green leaves as a spinach substitute. Taken in conjunction with the other related taxa, and the ethnographic information, it was included with the Chenopods (KPBG #1723/303/86).

The Amaranthaceae are included with the Chenopodiaceae as these closely related genera thrive in similar conditions and are utilised similarly. The archaeological finds are smooth, lenticular seeds recovered from spit 19 and spit 23. The archaeological finds are very similar to vouchered collections from the Kings Park Botanic Garden, Perth, of *A. pallidiflorus* (KPBG #170/92) and *A. interruptus* (CSIRO #301105).

Poaceae

Remains from grasses could be divided into three groups based on location within the archaeological record.

Plectrachne sp. Henrard

From the lowest spits basal stems or culms from a large-sized bunch grass believed to be *Plectrachne* sp. were recovered in large numbers. Each stem measures from 6 to 17 mm in length and 1 to 2 mm in width. Only the culms were recovered. These are all fairly uniform in length and thickness. Identification by M. Lazarides, CSIRO. (KPBG #294/357/89 – *Plectrachne pungens*) (K10KM).

Unburned seeds of *Panicum* sp. and a closely allied genus were recovered from spits 16, 19 and 21. A *Triodia* sp. Eragrostoid type – one of the spinifex grasses, was also recovered from the mid spits. These are large-seeded grasses and there are many ethnographic examples showing them to be utilised for food (Latz 1995; Crawford 1982). From the upper spits unburned *Triodia pungens* florets and seed, and *Aristida* sp. awns were recovered. There is very little overlap between the presence of *Triodia* spp. inflorescences in the upper 10 spits, labelled *Aristida* sp., and *Plectrachne* spp. basal stem fragments in the lower spits labelled *Plectrachne*.

Cyperaceae

Aquatic plant stems were recovered in sizeable numbers from throughout Square A. They have been identified as Cyperaceae or a related family such as Potamogetonaceae (M. Lazarides, pers. comm.). They are circular in cross-section, with large xylem elements situated in a ring around the centre, and smaller phloem elements surrounding these (Mauseth 1988:113, 130). In a few of the Holocene spits (5, 7, 8) much larger diameter split reeds were recovered. These may possibly belong to *Typha dominguensis* or bulrushes.

Two different seeds or nuts of the Cyperaceae family were recovered identified tentatively as *Fimbristylis* spp. (David Albrecht, pers. comm.). Type A has a smooth surface, possibly *Fimbristylis tristachya* R.Br. Type B, possibly *Fimbristylis depauperata* R.Br. with a scalariform surface, is found growing around swamps, along watercourses and in seepage areas (Wheeler et al. 1992:1070-5). Another seed type has been identified as Cyperaceae possibly *Cyperus* sp. by the pithy culm and the symmetrical appearance (M. Lazarides, pers. comm.) (K3KM, K13KM).

Adansonia gregorii F. Muell.

Adansonia gregorii F. Muell. of the family Bombacaceae, was found in large quantities in spits 8 to the surface, with isolated finds in spits 23 and 39. The tree grows across the northwest as far as the Northern Territory. The white pulp around the seeds is high in carbohydrates, protein and potassium (Miller et al. 1995). The densely hairy pods, 2 to 4 mm thick and from 80-140 x 50-90 mm in size, are very distinctive, as are the large, thick calyx and stem fragments. The seeds are large, 10 x 7 mm, black and reniform, thin-walled and brittle and do not survive well (KPBG #788/86), (K6KM).

Summary

The majority of the botanical material consists of a relatively few genera and species dominating the record at different times (Fig. 4). Those which appear first in the archaeological record, *Plectrachne,* are perennial tall tropical grasses which grow in arid regions, many species found in dune fields; Cyperaceae are small sedges found growing in wetlands (Latz 1995; Wheeler et al. 1992). The shrub and grassland taxa Chenopodiaceae/Amaranthaceae, the perennial grasses (*Panicum*) and the Cyperaceae seed are concentrated in the upper to mid section. The deciduous tree fruits such as *Terminalia* and *Celtis* together with vine fruits *Ampelocissus* and *Vitex*, are found in significant numbers in the top 9 spits but appear in low numbers in the lower mid sections.

Some taphonomic considerations

Weights of lithic artefacts from square A indicate a good correlation between the presence of lithics and botanical remains. This implies that the bulk of botanical remains are related to human occupation of the site, either directly, as food or useful materials brought to the rockshelter, or as material incidentally brought in with other items.

The selective pattern to burned botanical remains is one indicator of a cultural and not a natural agent (Minnis 1981; Murphy 1992). The SEM spectrum analysis test for the presence of carbon seems to indicate that a low reading represents an unburned sample. A sample *Terminalia* seed burned in the lab shows 20 cps (counts per second). *Ampelocissus*

acetosa from spit 4 was not burned, still brown and woody in appearance, as was the *Terminalia* seed from spit 24. These two show carbon levels of 10-15 cps. In contrast, the Chenopodiaceae recovered from spit 15 returned high carbon counts of 60 cps and the Poaceae floret recovered from spit 23 measured carbon at 40 cps (Fig. 5).

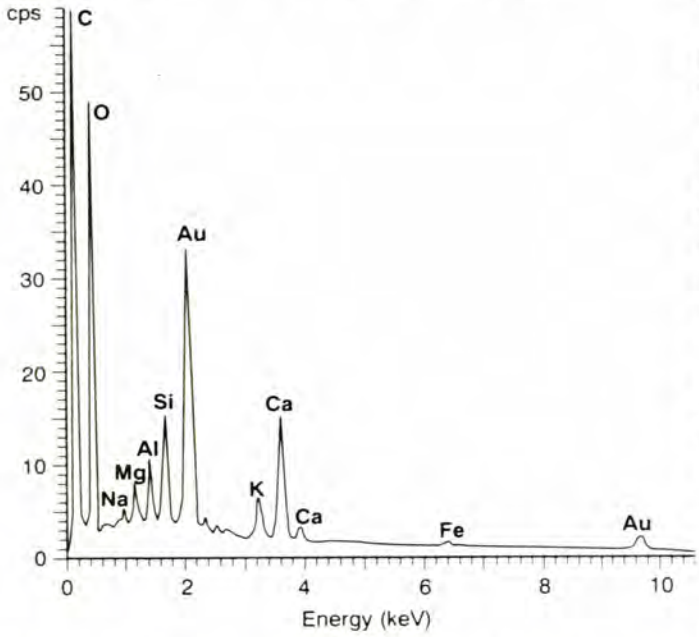

Figure 5 Spectrum analysis of Chenopodiaceae showing amount of carbon present.

In spits 9 to 23, charred seed forms a significant proportion of botanical remains (Fig. 6). In spit 14, all the *Cyperaceae* stem and *Poaceae* stems were burned. All (17) of the grass seed was burned, while of the glumes present, one was burned, eight were not. This pattern is repeated in spits 22 and 23 where the grass seed has been burned and the glumes have not. Walsh (n.d.) and Latz (1995) have recorded the dehiscing of grass seed by passing burning branches under the stems. This aids in separating the seed from the stem and speeds processing. This method of cleaning small seed can also be used for Chenopodiaceae and Amaranthaceae seed.

Terminalia seed is also burned in the early Holocene to late Pleistocene spits. From spit 25 through to spit 9 over 95% of all *Terminalia* seed from each spit is burned. This contrasts with other levels where the reverse is true, 95% of seed is unburned. The kernels recovered from these spits may be from the species *T. catappa*, and *T. grandiflora* which are eaten.

The *Aristida* sp. inflorescences recovered from the upper spits are believed to be wind blown deposits, as the grass grows today on the savannah and talus slopes. It is a dryland annual, with no known cultural use (Wheeler et al. 1992). No evidence of burning or selection through processing was noted. *Aristida* sp. are common across the Kimberley region as invaders of bare or overgrazed land (Petherham and Kok 1983:36-47).

Murphy (1992) completed a study of many factors related to the movement of botanical materials within a site rockshelter. Over one year, leaves and twigs did not move more than 4 m away from the original position but there was a marked movement of reproductive parts into crevices by animals using them for food. It was also noticed that leaves became buried and were later uncovered over the course of one year (Murphy 1992:87, 91, 94). Her work showed that wind deposition of woody species can be indicated by the presence of branchlets in deposits (Murphy 1992:111). In addition, the absence of gnaw marks, and the presence of only useful plant parts (reproductive fruits and seeds), are characteristic of cultural deposition (Murphy 1992:111).

These taphonomic studies seem to indicate that the majority of botanical material in Carpenter's Gap rockshelter was culturally deposited. Judging by the lengthy, contiguous record and the stable rockshelter environment, the remains are believed to be representative of the range of species present in the landscape. Gaps in the record are interpreted as absence and not selective decay. The comparison with lithic weights indicates cultural presence, and gives some comparative basis for rates of decay. The SEM tests show that small seeds, like *Chenopodium*, can be tested to see if they are in fact burned. The pattern of burned remains indicates a selective agent which can be compared to ethnographic examples using fire for the processing of foods and other useful plants.

Interpretation of botanical remains

There is no proof for prehistoric cultural use of plant material, especially when dealing with remains that are tens of thousands of years old. The best indication for the cultural use of a taxon, that is known from ethnographies to be either useful or a food source, is presence over an extensive time period. The case for cultural use is strengthened if similar patterns can be found within a range of taxa. Patterns in the burning of botanical remains also provides some evidence for cultural impact (Minnis 1981; Hillman 1984). Two types of information are available from a quantified study of macrobotanical remains: cultural (dietary) patterns and palaeoenvironmental (Pearsall 1989; Minnis 1981).

Indications of importance within the diet can sometimes be inferred from the quantity of remains and their continued presence through time. Environmental changes and cultural responses can be correlated by comparing the types of plant remains recovered from one set of spits, representing one time period, with another set of spits representing another time period. Normally, plants can only be exploited to any appreciable degree if they constitute a sizeable percentage of the vegetation formation. In the absence of agriculture, where human engineering creates artificial environmental conditions that may result in a biased botanical data set, this premise seems reasonable. Unless one could argue for the systematic transportation of food plants over long distance, the inhabitants could only exploit the vegetation that is growing in sufficiently large quantities to repeatedly and continuously forage. The phrase, 'sufficiently large quantities' has been quantified by various researchers (Cleland and Johnston 1933; O'Connell et al. 1983; Veth and Walsh 1988; Jones and Meehan 1989; Edwards and O'Connell 1995). It refers to the abundance of a food plant needed to enable prolonged gathering. This, in turn, is reflected in the archaeological

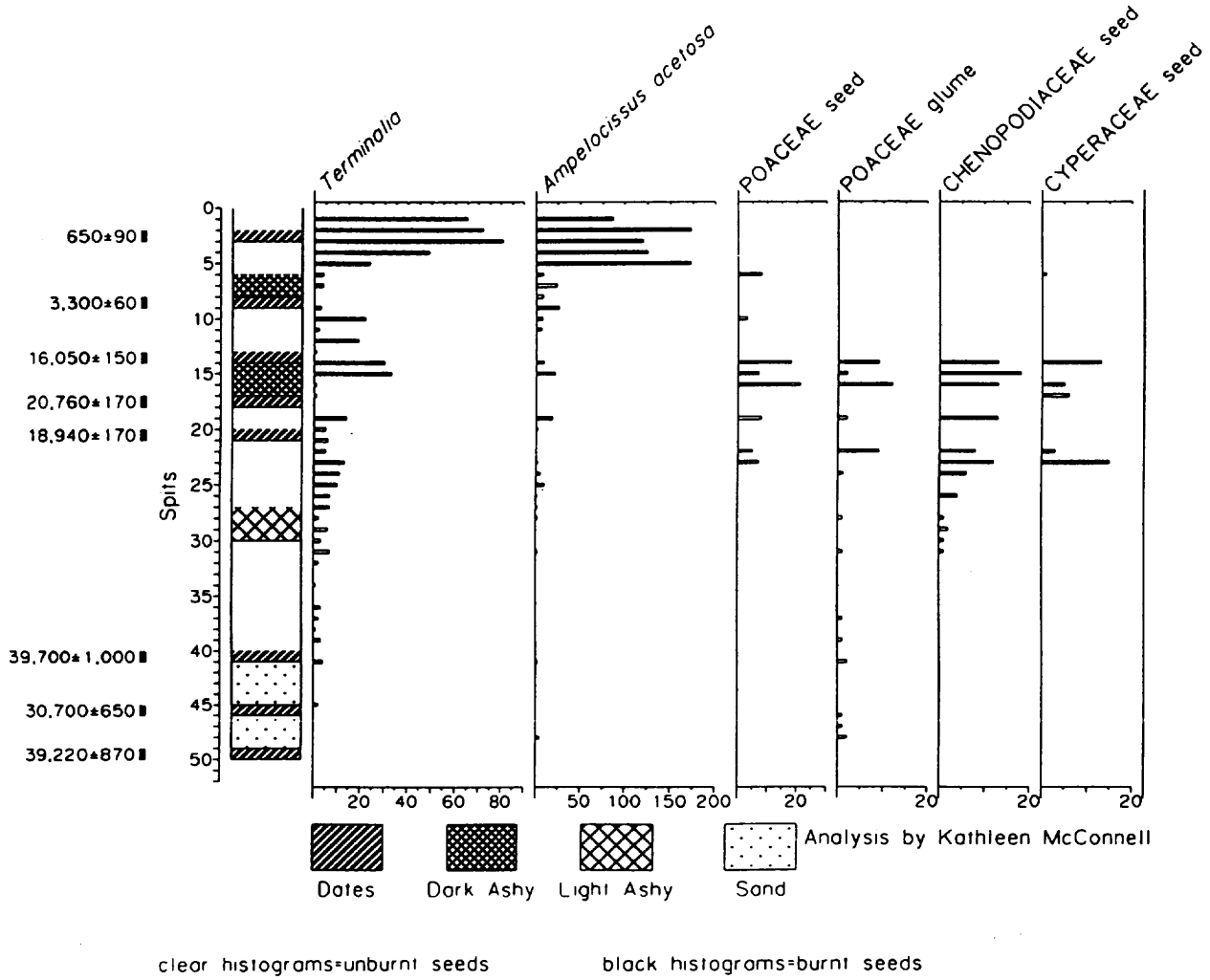

Figure 6 Graph comparing burned seed to unburned seed for all spits.

record in the continuity and abundance of the plant remains, including carbonised materials.

When a particular taxon or suite of taxa dominate an environment, extrapolations and inferences may be made about the environment, using current ecological models. Due to the economic limits placed on the transportation of large amounts of food, recovery of items from a site indicates proximity to that site. Rather than transport large amounts of food on a daily basis, it may be more acceptable to move closer to the food source, at least temporarily. This is a strategy which Australian Aboriginal people are known to have employed (Cleland and Johnston 1933; Crawford 1982; Goddard and Kalotas 1985; Latz 1995).

Only a few taxa from Carpenter's Gap meet these criteria; they are both durable and potentially useful, or food sources, so as to provide potential cultural information. There are some observations that can be drawn by evaluating only the taxa that meet this criteria.

Four peaks in the quantity of botanical remains occur in spite of an expected steady decrease in quantity with depth due to taphonomic factors (Fig. 4). The presence of ethnographically useful flora extends through a contiguous series of spits. On the basis of presence over an extensive time period the peaks in the quantity of botanical remains may be interpreted as representing phases of human activity at the site, assuming the excavation is typical of the site as a whole.

Phase 1 extends from spits 51 to 39 with a peak of activity at spit 47. It was characterised by the use of wood, charcoal and the grassland taxa, Cyperaceae and *Plectrachne* stems. Phase 2 encompasses spits 38 to 25. It is characterised by *Plectrachne* and Cyperaceae stems but with some use of deciduous fruits – *Terminalia* spp., *Ampelocissus acetosa,* and *Vitex glabrata.* Phase 3 extends from spit 24 to spit 10. The third phase is characterised by shrub, grass and water weeds: seeds of Chenopodiaceae/Amaranthaceae, Poaceae (*Panicum* species) and *Potamogeton* spp. There are little or no *Plectrachne* and Cyperaceae stems although *Terminalia* spp., *Ampelocissus acetosa* and *Vitex glabrata* continue in low numbers. Phase 4, spit 9 to the surface; the lower limit is defined by the spit at which all taxa show a great increase in numbers, and, by a shift to more deciduous taxa. It can be characterised as dominated by broad-leaf deciduous tree and vine fruits: *Ampelocissus acetosa Terminalia* spp., *Vitex glabrata, Celtis philippensis.* In addition this phase shows significant presence of *Adansonia gregorii* (boab pods). Perennial grass, shrub and water weed seeds disappear from the record.

Plectrachne: Evidence of processing

The *Plechtrachne* sp. remains are interesting because they consist only of basal culms of grass stems. These have been preserved, with perhaps 1% burned (McConnell 1996).

Similarly, the Cyperaceae stems are short fragments of small diameter reed or sedge stems, such as might be used in basket-making (Roth 1984 [1901]). It is not possible to make a definite identification of the grass type, beyond the fact that they are the culms from a large hummock grass. Hillman's work on the process of threshing grains and the remains that may be expected at each stage of the process, has provided some insight into the interpretation of the *Plectrachne* remains (Hillman 1984:1-10). Hillman's study of the hand processing of wheat, as an ethnographic analogy for understanding archaeological finds, shows that a uniform activity done to a sample of the same taxon will result in a series of uniform residues that become part of the archaeological record that can then be interpreted. All remains of spinifex culms in the site represent the base of the stem above the roots: the uniform length of remains and the uniform plant part both indicate that processing has taken place.

This activity would very likely have been processing the grass for resin extraction. Cleland (1957) and Latz (1995) include detailed descriptions of the steps of processing. The stage represented by the culms may be threshing the resinous stems on a heated rock to extract the resin from the basal stems which contain the most resin. Gathering and singeing the upper stems generally occurs in the field, reducing the carryweight to the most economical portion.

Comparisons with regional climatic records

The Carpenter's Gap site botanical record is the first direct evidence of environmental conditions during the late Pleistocene in the southern Kimberley. This record can be correlated with available palynological records, and vegetation studies.

Studies of the Kimberley rainforest formation (Keneally et al. 1991; McKenzie 1991) suggest that rainforest taxa extended in much larger communities during the late Pleistocene. Pollen cores show that rainforest angiosperms formed a large part of the flora prior to 80,000 BP (Kershaw 1986:48; van der Kaars 1989, 1991).

The late Pleistocene, 40-24,000 BP, has been characterised as having constantly higher lake levels than present with higher levels of dune building than the Holocene, and temperatures averaging 4°C less than the present (Wasson and Donnelly 1991; Kershaw 1995). Bowler has proposed an increase of effective or absolute rainfall to 900-1200 mm/yr or 800/1000 mm/yr (Bowler 1983:5). The Lombok Ridge data shows Poaceae as the dominant taxon at this time with roughly equivalent peaks at 52,000 BP, 28,000 BP and the most recent peak at 17,000 BP (van der Kaars 1991). Kershaw proposes a sparse woodland cover and presumes the existence of grasslands (Kershaw 1983:15). This accords well with the extensive *Plectrachne* and Cyperaceae remains recovered at Carpenter's Gap. This perennial hummock grass grows in arid lands and not as an understorey to woodland (Beadle 1981:533, 534; AUSLIG 1990:44). *Plectrachne* spp. require 2-300 mm per year so it appears that Bowler's increase in rainfall is not supported (Beadle 1981:532). However, the large number of Cyperaceae stems suggest the presence of extensive stretches of wetlands around the site, which are not there at present. The large number of Cyperaceae stems and the slight increase in *Terminalia* seed that occurred between spits 33 and 25 may be taken as partial support for an increase in available moisture or a more even rainfall distribution at this time.

Circa 24-10,000 BP the Lombok Ridge record shows high amounts of Poaceae reaching a peak at 17,000 BP. Cyperaceae and Chenopodiaceae reach their highest numbers at 26,000 BP (van der Kaars 1991). Chenopodiaceae decline steadily, but Cyperaceae maintain steady numbers, at about half that of the preceding phase. The northeastern record indicates a sparse cover of sclerophyll vegetation and grassland with all rainforest gone. Rainfall was less than 1400 mm/yr and probably less than 1000 mm/yr with possible periodic drying of wetlands (Kershaw 1983:37). Lower temperatures are indicated by the increase in cool weather taxa (Singh 1983:41).

The Carpenter's Gap site record shows that rainforest taxa such as *Terminalia* and *Ampelocissus acetosa* continue in low numbers in the northwest and do not die out completely. At Carpenter's Gap Chenopodiaceae and Poaceae dominate the record during phase 3, 24-10,000 BP. Both these families currently grow in interior grasslands that are seasonally dry with very low moisture requirements ranging around 150-420 mm/yr (Beadle 1981:497). This may support Kershaw's claim for periodic drying c. 25-20,000 BP (Beadle 1981:500, 501, 503; Kershaw 1983:37). Chenopodiaceae alliances require an ambient temperature range of 18-30°C and are currently confined south of latitude 21° (Beadle 1981:496, 506; Perry and Lazarides 1962). This line runs roughly from Roeburne to Mackay and through the Great Sandy Desert (AUSLIG 1990:42, 43). As the site is at S17°25', it suggests that the range for Chenopodiaceae has shifted south by 350 km since approximately the height of the Last Glacial Maximum, or 18,000 BP. This does support the cooler temperatures proposed by Singh (1983).

The Holocene is characterised by a brief rise in lake levels around 8-5000 BP, increased temperature towards today's mean, and minor dune building activity, all signifying a less stable environment. The Lombok Ridge data shows that tree taxa and quantity increase during the Holocene, after 9000 BP with a steep rise at 7000 BP. At the same time there is a decline in Poaceae to around half their previous numbers after 6000 BP. Cyperaceae and Chenopodiaceae drop down to very low counts around 9000 BP and pick up numbers again in the past 5-4000 ka (van der Kaars 1991). The surge in tree growth between 9000 BP and 7000 BP indicates that this period was wetter than the present (Schulmeister and Lees 1995; Schulmeister 1992:113). Jennings' study of dunes and intertidal flats in the Fitzroy estuary indicates that coastal mangroves may have been more extensive from 7400-6000 BP which would suggest that the region experienced a significantly longer and heavier rainy season than now (Jennings 1975:252). The 1 m diameter stumps of the mangrove, *Avicennia marina*, suggest a well-established tall mangrove forest, contrasting with the scrub mangroves of today. Precipitation of 1500-2500 mm annual rainfall has been shown to result in such large tree trunks (Jennings 1975:251). Following this, the dating of cheniers along northern Australian coastlines has shown a decrease in fluvial activity from 2800-1600 BP (Lees and Clements 1987). These formation processes are not yet well understood; however,

they appear to be linked to decreased wet season precipitation (Lees and Clements 1987:316).

Pollen evidence from tropical Australia shows the onset of an ENSO dominated climate at ca 4000 BP (Schulmeister and Lees 1995). Stratigraphy from Geegully Creek, a tributary of the Fitzroy River, has been interpreted as indicating that the monsoon regime was less intense prior to 6500 BP (Wyrwoll et al. 1992). Stratigraphy of the alluvial deposits of Geegully Creek indicates that there appears to be no significant break in the depositional record over the last 6500 BP but there is a strong disconformity prior to this suggesting a major change in precipitation regime, although at present the deposits have not been reliably dated. Semeniuk (1995) demonstrates that the disconformity prior to 6500 BP in Wyrwoll et al.'s data may be interpreted several ways, either as a sign of increased precipitation, or as a sign of increased aridity or some variation on this. The current disagreement surrounding Holocene climate change points to a general lack of fieldwork in this part of Australia. It is important to note that nothing is known of the palaoehydrology, basin dynamics or rainfall/groundwater phase relationships in the northwest (Wyrwoll et al. 1992; Semeniuk 1995).

At the Carpenter's Gap site tree fruits dominate the record, particularly taxa associated with vine thicket/rainforest. This appears to support the increase in rainfall recorded for the Holocene. Chenopodiaceae and Cyperaceae drop out of the record completely. The Poaceae genera present change to *Aristida* which has a moisture requirement of 70 mm/growing season, and perennial grasses with higher moisture requirements such as *Panicum* and *Plectrachne* disappear entirely from the record (Beadle 1981:541). The brief, dry phase during the recent Holocene noted by Lees and Clements may be reflected in the upsurge in dry flora from spits 5 through 3. *Aristida* spp. are also associated with overgrazing by cattle (Petheram and Kok 1991:36-47). Cattle stations surround the site.

Today, the Fitzroy River estuary receives 600 mm per year and supports low scrub mangroves (Bureau of Meteorology 1995). In spite of an effective doubling of rainfall since the Last Glacial Maximum, the dominant vegetation formation in the southern Kimberley today is a savannah composed of ephemeral grasses and *Eucalyptus*. The continued shift of vegetation to reflect increasing aridity, in spite of an actual increase in rainfall, may be due more to the increased seasonality of precipitation. Thus seasonal stress and not lack of moisture may be the limiting factor at present in the southern Kimberley.

Environmental reconstructions

Environmental changes through the late Pleistocene and the Holocene can be inferred from the major taxa recovered from Carpenter's Gap.

The following vegetation reconstruction may, in fact, reflect a shift in areal focus with each phase. The remains in Phases 1 and 2 may reflect exploitation of the area immediately around the site. During glacial aridity (Phase 3) foraging ranges may have been generally more extensive. If ephemeral sources of surface water were less often available and were less predictable it could be expected that foraging would be focussed upon fewer locations at greater distance from the shelter, such as the few permanent water sources in the ranges. During this time the shelter might only have been used when passing from one permanent water source to another. This explanation is not inconsistent with either the small quantity of cultural material deposited during this phase or the combination of plant materials recovered. The most recent phase has very likely seen a return to foraging in close proximity to the site area.

Vegetation models for the Bungle Bungle Ranges derived from Scarlett (1985) also reflect this pattern of movement. Tree taxa are concentrated along the range slopes and the permanent water sources. The grass and shrub taxa are located in broad areas of intervening savannah. Thus, utilisation of wet season taxa would involve restricted movement, while utilisation of dry season grass and shrubland taxa would involve extensive movement.

The site botanical remains have been combined with the records of Jennings (1975), Beadle (1981), Kershaw and Nix (1988), Bowler (1983), Wasson and Donnelly (1991) and Chappell's (1993) sea level data to create a picture of the Kimberley region's changing environment during the past 40,000 years (Fig. 7). Figure 7 illustrates the relationship between available moisture, both precipitation and groundwater, and the site's distance from the ocean as sea level rose and fell. Both these factors, in addition to temperature, affected the vegetation formations which are suggested to have existed in the southern Kimberley from the late Pleistocene to the present.

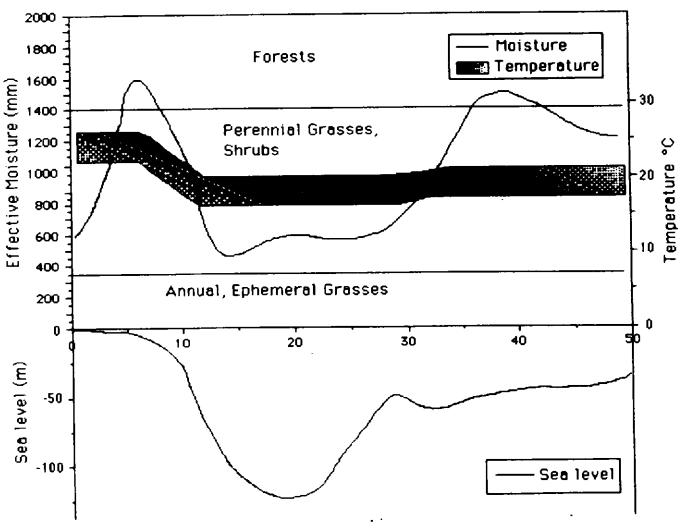

Figure 7 Model of effective moisture and vegetation for the southern Kimberley region. Compiled from Jennings (1975), Beadle (1981), Kershaw and Nix (1991), Chappell (1993), Bureau of Meteorology and the Carpenter's Gap data.

Phase 1

The record shows abundant *Plectrachne* sp. and Cyperaceae from the base of the excavation to spits 51 to 39, 45-30,000 BP, possibly indicating an arid environment with sand dunes, but with sufficient surface moisture to maintain sizeable stands of sedges. Tall tropical perennial hummock grassland may have covered a more extensive area around the Napier and Oscar ranges. The environment can be reconstructed

as a grassland of perennial tall tropical grasses and sedges growing around permanent streams and wetlands, with shifting dunes creating inroads in the wetlands. Latz has noted perhaps the remnants of a similar formation growing in the northwest of central Australia where *Plectrachne* sp. grow on the former lake bed, now covered in sand (Latz 1995:15).

Phase 2

Phase 2, 30-25,000 BP, spits 38 to 25, shows that perennial grassland vegetation continue to dominate the landscape with an increase in rainforest taxa. This indicates an increase in moisture sufficient to maintain deciduous trees which have higher water requirements than grasses. As proposed by Keneally, Keighery and Hyland (1991) the vine thicket/rainforest may have been more extensive at this time. Nutritionally speaking, this phase, with both rainforest taxa and perennial grassland taxa available may have provided the most abundant and greatest variety of food plants.

Phase 3

The presence of Chenopodiaceae and Amaranthaceae, Cyperaceae and perennial grasses in the site record, are the best current evidence for an arid phase in the southern Kimberley ca. 25,000-11,000 BP, spits 24 to 10. The Chenopodiaceae/Amaranthaceae and perennial grasses *Panicum* sp. are recorded at the site for only a relatively brief period, during which they dominate the record. The region may be reconstructed as a shrubland-grassland mosaic extending across a landscape with increasingly saline and calcareous soils, associated with Chenopodiaceae. Available moisture in the form of precipitation and streams had decreased, as noted by the decline of rainforest tree taxa; however, sufficient moisture was still available to support perennial grasses and shrubs.

There are several Chenopod/perennial grass shrubland formations present today that may provide a modern analogous formation to the arid maximum vegetation. Mitchell-Flinders grass extends across the northeast at present, from central Queensland up to the Northern Territory, where it becomes disjunct (Whyte 1968; Kershaw 1995). It is described as:

> open tussock grassland of perennial species with a lower but prominent annual component ... *Astrebla* spp., *Panicum* spp. [dominant] with *Chenopodium* spp. and *Cyperus* spp. growing along channels and depressions. (Whyte 1968:273-4)

The Mitchell grasses (*Astrebla* spp.) are four species which may be found growing together and are found growing in association with *Chenopodium* spp. and *Cyperus* spp. and other perennial grasses (Beadle 1981).

In addition, the *Atriplex vesicaria* and the *A. vesicaria* suballiances *Ixiolaena leptolepis* and *Bassia* spp. consist of various chenopods with *Panicum decompositum* and *Eragrostis setifolia*, all perennials (Beadle 1981:496-500). The moisture requirements range from 150-240 mm/yr for the *Ixiolaena leptolepis* alliance, to 250-410 mm/yr for the *Atriplex vesicaria* alliance.

Evidence of extreme environmental stress may be visible in the site record for the terminal Pleistocene. Over 95% of all the *Terminalia* sp. seeds from spits 22 to 9 are burned. This can be interpreted as indicating that cooking was necessary for processing due to high salinity, or that the surviving species needed cooking in order to be rendered palatable. Similarly, the *Ampelocissus acetosa* seed are burned from only this time period, in addition to the grass and chenopod seed (Fig. 6).

Phase 4

The most recent remains, phase 4, spits 9 to the surface, 10,000 BP to the present, consist primarily of deciduous tree and vine fruits with no evidence of perennial shrubs or grasses. The dominance of tree fruits associated with vine thicket/rainforest suggests an increase in available moisture, but surface water is insufficient to maintain notable populations of sedges and perennial grasses. This indicates a generally drier environment at present, than during the late Pleistocene possibly due to an inaccessible water table. Available records indicate that precipitation has increased, so the role of subsurface water and seasonality in the arid northwest remains to be studied further. The increase in cultural burning may also have caused the rainforest to retreat to fire-shadows affording protection, so that, in spite of an increase in precipitation that might promote the spread of rainforest as Keneally et al. (1991) and McKenzie (1991) propose, we actually see a decline in the rainforest cover. A brief dry phase during the recent Holocene may be reflected in the upsurge in dry flora from spits 5 through 3.

Conclusion

The Carpenter's Gap site provides botanical evidence for a continuous cultural presence in the southern Kimberley for the past 40,000 years. Some indications of long-term shifts in flora can be extrapolated from the archaeological record. The evidence in the rockshelter of shifts in environment suggest that alternate plant food procuring strategies occurred as a response to environmental changes. The record suggests that the Aboriginal inhabitants did not abandon this region during the Last Glacial Maximum, but adapted their survival strategies to cope with a changing environment.

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