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THE SYDNEY BASIN - ENVIRONMENTAL CONTEXT

The Sydney region is located on the south-east coast of Australia between the coastline and the Great Dividing Range (Figure 1.1). The Sydney Basin is defined geologically and the study area for this research is restricted to the Hawkesbury sandstone formation which is the surface bedrock in the centre of the Greater Sydney Basin. Sydney is located towards the centre of the study area, and the cities of Newcastle and Wollongong roughly define its northern and southern extents. The Hawkesbury sandstone covers an area of approximately 190km x 90km - 17,100 square kilometres.

Throughout this work the study area will be called the Sydney region or the Sydney Basin interchangeably, this meaning the geographic extent of the Hawkesbury sandstone within the Greater Sydney Basin.

Geology of the Sydney Basin

The Greater Sydney Basin resulted from a marine transgression at the end of the Late Palaeozoic glaciation, followed by a marine regression during Late Permian and Triassic times. Three stratigraphic divisions have been defined within this region. The lowest division is the Narrabeen group, followed by the overlying Hawkesbury sandstone. The Wianamatta group is uppermost (Branagan *et al.* 1976: 28). The Wianamatta shale predominates in the centre of the region, forming the Cumberland Plain.

The Hawkesbury sandstone is a fairly friable medium with relatively homogenous grain size. It weathers cavernously to form overhangs (shelters) which occur in a range of topographic locations (see Figure 2.1-2.8). It also occurs as flat topped outcrops (platforms of varying sizes) and boulders, mainly on ridge tops but also along the sides of gullies and in valley bottoms.

For the purposes of this work, geological homogeneity was significant because the sandstone provides a homogeneous medium of a relatively restricted extent. In other parts of the Greater Sydney Basin, there are different surface sandstones (e.g. the Nowra sandstone, Narrabeen sandstone etc.), some of which also contain different styles of rock art (e.g. Officer 1992, 1993). The boundaries of this study area were selected on the basis of geology rather than on a presumed extent of the Sydney Basin style. Thus it was possible to impose a natural (and neutral) boundary and not pre-empt any conclusions about the region's outer limits.

Geomorphology: structure and terrain

Much of the earlier archaeological literature for the Region describes the area between the coast and the Great Dividing Range as the coastal strip (Lawrence 1968, Lampert 1971a, 1971b; Poiner 1976, Ross 1976, Attenbrow 1987). In the Sydney Region the 'coastal strip' is almost 90km wide and this descriptor conceals important geographic/environmental divisions. There is a maritime zone (which includes estuarine influences) on the eastern side of the coastal strip, while the coastal hinterland (or 'inland': Lampert and Hughes 1974, Poiner 1976) forms the western portion of the study area. Further subdivisions based on specific ecosystems can also be identified. These are relevant to our understanding and interpretation of prehistoric Aboriginal land use patterns in the Region.

Figure 2.1: A typical upper tributary gully with a ridgeline in background. Six engraving sites were located in this gully on various sandstone shelves and platforms visible.

Figure 2.2: The Georges River to the south of the region. View to the west from Alford's Point.

Figure 2.3: Engraving site on the ridge top overlooking Berowra Creek. This vast expanse of sandstone only had a single engraved motif on it.

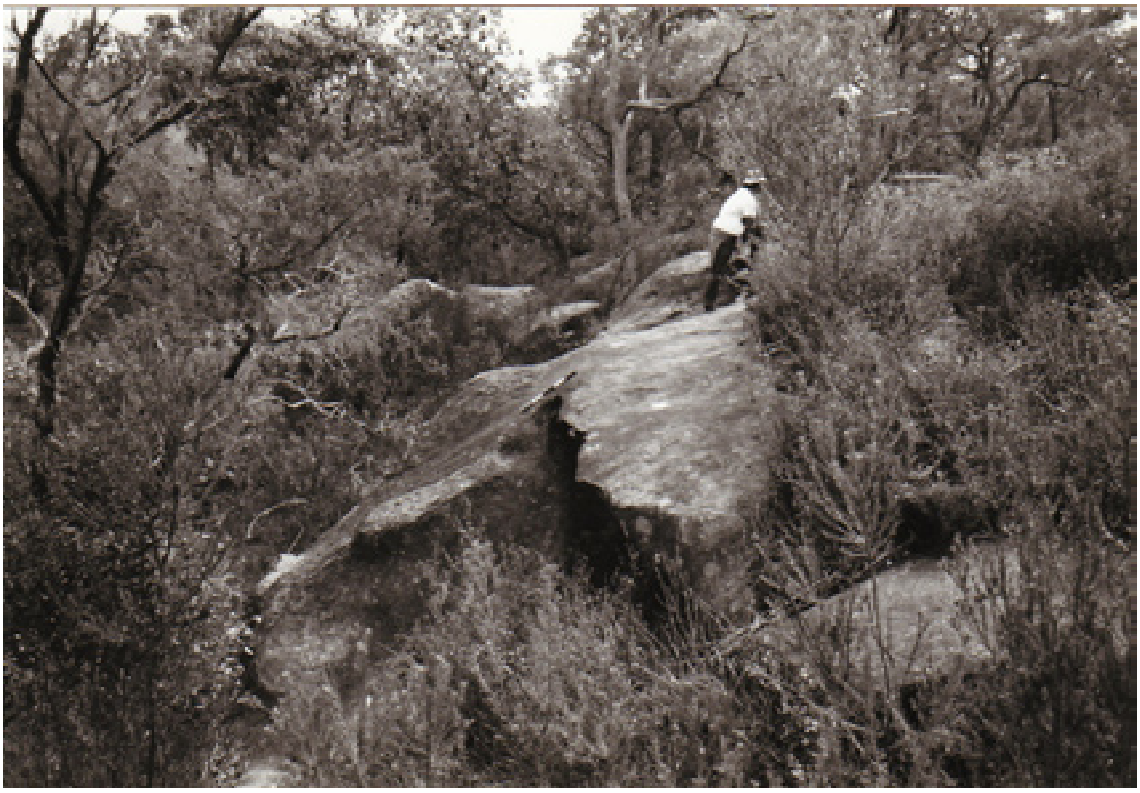

Figure 2.4: A relatively small boulder with engravings near Maroota, south of the Hawkesbury River. Engraved mundoes and anthropomorphs are located on this sloping top surface.

Figure 2.5: Large shelter with honeycomb weathering near Warre Warren Creek. Pigment art is located on a smooth surface at one side of this shelter.

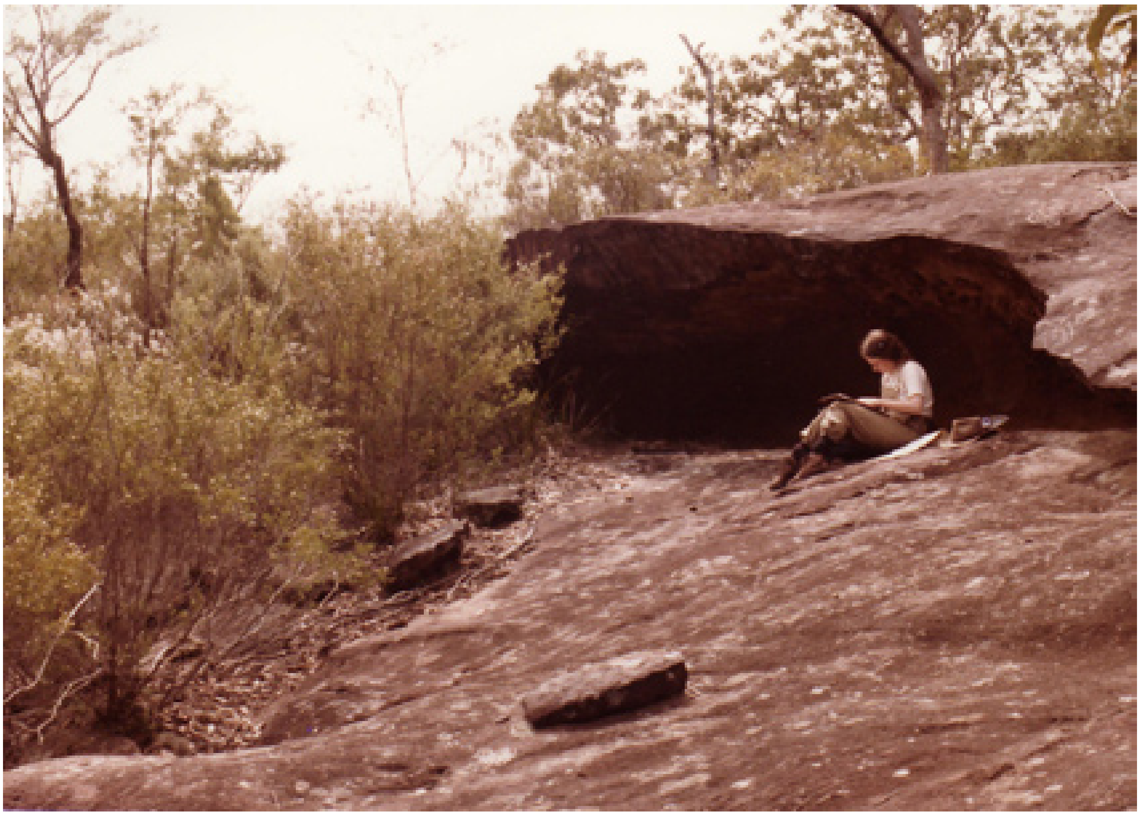

Figure 2.6: This small overhang near Wheelbarrow Ridge forms a lip in an extensive sandstone platform. Despite its small size, this shelter has a moderately large pigment art assemblage on its ceiling.

Figure 2.7: Large free-standing boulders such as this one near Howes Valley provide ideal shelters for a range of assemblage sizes.

Figure 2.8: This is the smallest recorded shelter in the region, near Warre Warren Creek. To enter this shelter you have to crawl in behind the tree. Three pigment motifs were found in this overhang.

The maritime zone includes the open coastal margin, coastal heath and estuaries. This zone extends roughly 15km inland from the coastline, with estuarine conditions along major waterways (e.g. the Hawkesbury, Parramatta and Georges Rivers). The hinterland zone includes riverine, forest and woodland environments. It is the strip of country between the maritime zone and the Blue Mountains. Throughout this work 'maritime' and 'coastal' will be used interchangeably to describe that zone, while 'hinterland' and 'inland' will be used to describe the westerly portion of the region. In both zones and all localised environments, the characteristics of the underlying sandstone geology dominate: with the landscape being unrelentingly dissected and fairly rugged.

In the centre of the Sydney Basin is the Cumberland Plain. This consists of open plain woodland on shale geology. Relief here is low and gently undulating. Surrounding the Cumberland Plain are the Hornsby, Woronora and Blue Mountains Plateaux. The boundaries between the Cumberland Plain and the adjacent north (Hornsby) and south (Woronora) sandstone plateaux are poorly defined. To the west of the Plain, however, is the distinctive Lapstone Monocline and Nepean Fault system (Branagan *et al.* 1976: 45). This research was confined mostly to the Hornsby and Woronora Plateaux, although some sites (on Hawkesbury sandstone) were known on the Blue Mountains Plateau.

Altitude varies across the region. The Hornsby Plateau has a maximum altitude of 250m AHD (Australian Height Datum) between Hornsby and the Hawkesbury River. Between the Hawkesbury River and the Hunter Range, elevation is consistently between 250-350m AHD. Mt Yengo, in the north-west of the region, has the highest elevation at 386m. Closer to the coast, the elevation is between 100-150m AHD.

The Blue Mountains Plateau, which is part of the Great Dividing Range, rises steeply from the Nepean to 250m AHD in the first line of ridges around Blaxland. The maximum elevation in the region is recorded at Blackheath in the Blue Mountains (1,087m AHD).

The Nepean-Hawkesbury River is a significant drainage catchment in this region. This system drains the three major plateaux, as well as part of the southern Tablelands. The Nepean River rises in the south-west of the Sydney Basin, and drains the Avon, Cordeaux, Cataract Rivers to its east, and the Nattai, Wollondilly and Cox's River from the west. It becomes the Hawkesbury River downstream of Richmond. The major river systems of the Colo and the Macdonald are also drained by the Hawkesbury River. Downstream of Wiseman's Ferry, the point at which the river becomes estuarine, there are several important creeks. Major catchments include Mangrove, Berowra, Cowan and Mooney Mooney Creeks. Pittwater and Brisbane Water are major embayments north and south of Broken Bay, wherein the Hawkesbury River meets the Tasman Sea.

Other major river systems occur within the central and south-eastern parts of the region. These include Port Jackson (Middle Harbour and the Lane Cove and Parramatta Rivers), Botany Bay (the Cook's and Georges Rivers) and Bates Bay (Port Hacking).

The regional or 'culture-area' population (Peterson 1976: 51) is described well by this set of catchments. The geographic extent of Hawkesbury sandstone is smaller than the outer Hawkesbury-Nepean watershed boundaries, particularly in the south and west. The northern boundary of the catchment is at the Hunter Range, which also delimits the northern extent of the Hawkesbury sandstone.

Climatic and eustatic change

The Sydney region presently possesses a generally warm climate with uniform annual rainfall. In the Blue Mountains there is a long, mild summer, while elsewhere there is a hot summer. Temperatures are generally dependent upon season, aspect, distance from sea and elevation. Proximity to the sea is the major factor in maintaining temperate conditions, namely mild winter minimum temperatures and summer maximum temperatures. On the coast the summer temperature is commonly less than 26°C, while that on the Cumberland Plain is greater than 29°C. Winter

minimums, on the other hand are commonly between 8-9°C on the coast and 5-6°C inland (http://www.bom.gov.au/climate/averages/tables).

The average annual rainfall also varies with distance from the coast. The coastal annual fall is in the order of 1,210mm, with the heaviest falls in autumn. In the hinterland, the rainfall is lower (around 670 mm/year) and the heaviest falls are in summer (Bureau of Meteorology: http://www.bom.gov.au/climate/averages/tables).

At the height of the Last Interglacial period, between 120,000 to 130,000 years ago, sea levels were up to 5 metres higher than today. Throughout the Late Pleistocene temperatures in south-eastern Australia are known to have fluctuated as the region experienced glacial and periglacial conditions. Glaciation commenced around 31-34,000 years ago, and at this time the mean temperature was probably only 3ºC below present. During the period between 25-15,000 years ago, however, mean annual temperatures would have been between 6ºC to 10ºC below present (Kershaw *et al*. 2000: 490). Throughout the late Pleistocene, conditions were generally drier than they are today (Dodson and Thom 1992: 121, 132) – with rainfall possibly at 50% of today's values (Kershaw *et al*. 2000: 491). By 15,000 BP, temperatures were rising and deglaciation was in progress. The colder conditions lasted until c.10,000 BP. Lands to the east of the coastal Ranges would have experience a gradual increase in rainfall and vegetation growth between 15 –10,000 BP (Dodson and Hope 1983: 75).

By 10,000 years ago (at the beginning of the Holocene), conditions in many coastal areas would have been similar to what they are today. Between 8-4,000 BP, it was warmer and wetter with both temperature and rainfall higher than at present. Around 5,000 years ago, a return to a slightly cooler climate is thought to have occurred, while after 3,000BP the El Niño-Southern Oscillation (ENSO) began to operate as it does now – with an increase in seasonality for rainfall, and more marked winter-summer patterns in some areas (Markgraf and Diaz 2000: 475). Temperatures continued to drop so that in the period from between 3,500 and 2,000 BP the temperatures were 2-3ºC lower than today and it was drier (Harrison and Dodson 1993: 279-80). In the last 1,000 years the temperature and rainfall have been relatively stable.

The main effect of these temperature and rainfall variations would have been in terms of the vegetation regimes likely to be available to Aboriginal people. With moister conditions, rainforests and wet sclerophyll would have increased (at the expense of grasslands and dry sclerophyll) and swamps would have increased in size. Species diversity and abundance within communities may also have changed. With drier conditions, the reverse of these characteristics would be expected – and more open conditions would have prevailed. Changes in water availability and vegetation patterns would have affected available animal species distributions – and potentially fire regimes as well (Attenbrow 2004, Dodson and Mooney 2002, Markgraf and Diaz 2000).

During the last Glacial Maximum (LGM) between 30,000-15,000BP (Chappell, in prep.) the sea level was between 110-130m below its present level (Roy 1998). The Sydney coastline, now at Sydney Heads, would have been 25-35 kilometres further east. The major river systems – which are now estuarine - would have been fresh water. As the sea level rose (between ca 18,000 – 6,500 BP), the catchments of these rivers would have slowly become inundated with estuarine conditions eventually being established. The current coastline has only existed for the last 6,500 years (Chappell 1982:71, 1983b: 121; Chappell and Thom 1977:278-80). Sydney has a drowned embayed coast, with prior bedrock valleys partially infilled by sandy barriers, tidal flats, and deltaic plains (Roy and Thom 1981:471). Rocky headlands alternate with bays which incorporate bay head beaches, barrier beaches and lagoons. There is no broad coastal lowland (Branagan *et al*. 1976: 50). The coastal zone morphology is due primarily to the Holocene eustatic sea level rise. Many of the present coastal forms, however, were initiated during Pleistocene stages of higher sea level. Following the Holocene transgression, these have been reworked and extended.

While generally stable from c.6,500 years ago, there was another sea level rise (between 1-2m in height) sometime between 4-3,000 BP (Baker and Haworth 2000). It has been argued that the marine coastal ecology probably did not stabilise until c.4,000 BP, meaning that shellfish and

estuarine resources probably did not become important to coastal/estuarine inhabitants until this time (Callaghan 1980, White and O'Connell 1982).

The drowning of the coast affected the region in several ways. It reduced the available land area for habitation, altered the configuration of the coastline and (eventually) substantially increased the estuarine conditions along the present shorelines. While the sea was encroaching on the land mass, it has been argued that there would have been an immature coastal morphology with no, or fewer, lagoons, less established tidal rock platforms and generally less shallow water, compared with periods of stable sea level. An immature coast is less diverse and also poorer in resources. Coastal productivity would not have been as great during the period of rising sea levels in the late Pleistocene/early Holocene, as in the mid- to late Holocene (Callaghan 1980; Lampert and Hughes 1974; Walters 1992b; White and O'Connell 1982). The implications of these changing climatic conditions and resource opportunities for human populations living in the region are obvious.

Vegetation

The vegetation in the Sydney Region is diverse and dependant primarily on geology, aspect and topography. Proximity to the coast and water (sea, rivers, creeks etc.), rainfall and elevation are also determining factors. Vegetation surveys have been undertaken in various ecological zones within the region. The following three are summarised here to demonstrate the regional variation, because these locales contain large numbers of art sites, including those excavated for this research.

Ku-ring-gai Chase National Park

Maritime conditions prevail here with estuarine and major tidal creek system, coastal heath, open woodland. Ku-ring-gai Chase National Park is bounded on the north by the Hawkesbury River and to the east by Pittwater. The ridge along the Cowan-Berowra peninsula marks its western boundary, and Cowan Creek flows south-north through its centre.

A vegetation analysis for the park (NPWS 1988:7-9), covering more than 15,000ha, identified 24 plant communities, several of which are of limited size and associated with unusual geological and topographic features (e.g. remnant rainforest communities along western Pittwater, diatreme vegetation communities at Campbell's and Smith's Craters and dyke vegetation communities on West Head).

Predominant vegetation communities include coastal heath, swamp sedge, littoral vegetation, low woodland and open forest (Beadle *et al*. 1986).

Mangrove Creek

Mangrove Creek drains north-to-south into the Hawkesbury River and is c.36 kilometres long. It is the second major northern tributary valley along the Hawkesbury River west of the coastline, and has a catchment area of 420 sq km (Vinnicombe 1980). It is at the hinterland/maritime transition with estuarine conditions present at its confluence with the Hawkesbury.

The Judge Dowling Range forms its western watershed boundary while Peat's Ridge forms its eastern boundary. This catchment's northernmost tributaries start in the Hunter Range.

The climate of this area can be generally categorised as fringe temperate maritime. While the summers are hot and warm and the winters cool to mild, these are more extreme than on the truly temperate maritime coastal strip. Rainfall on the coast and on the Somersby Plateau averages 1,200–1,600mm per year (Bureau of Meteorology 2007: http://www.bom.gov.au/climate/averages/).

A vegetation survey of Upper Mangrove Creek (Benson 1979) identified four communities in this area: Woodland, Open Forest (associated with Hawkesbury sandstone), Open Forest/Tall Open Forest (associated with the Narrabeen Group on the lower drier aspect of the hillslopes) and Tall Open Forest.

The various topographic locations defined in this catchment by Attenbrow (2004) were used in this research. These are broadly ridge tops, hill sides and valley bottoms. The cut-off for distinguishing these topographic locations was 5m in elevation below ridge tops and above valley bottoms (respectively).

Yengo National Park

This area is true hinterland at the north-west edge of Hornsby Plateau at the most northern extent of the Hawkesbury sandstone. In the upper reaches of the Macdonald River this area has higher average elevation and relief. Most deeply incised creek lines and rivers in this area have Narrabeen sandstone exposed in the lowest valley levels. Extensive areas of Quaternary alluvium occur here along the valley bottoms of major creek and river systems, and along the western ridgeline boundary, e.g. Mellong Swamp.

The annual average rainfall varies considerably here. This results from the area's distance from the coast, and the counteracting orographic effects of the elevated landscape. At Howes Valley the annual rainfall is 737mm (Bureau of Meteorology 1975). Most of this area has little standing water and there is rapid runoff of rainwater. Numerous springs, however, are known to exist across the area (Sanders *et al*. 1988: 15) these being of variable reliability (John Bowen, *Big Yango*, pers. comm. 1988).

While thirteen vegetation communities were identified here, more than 75% of the vegetation can be characterised by four communities. The most common vegetation community across the area is the Hawkesbury sandstone woodland, followed by the Narrabeen-Hawkesbury ironbark forest, the Sheltered Hawkesbury Sandstone forest and the Complex Hawkesbury sandstone sheltered forest. On richer and moister soils are pockets of rainforest and sheltered forest. Paperbark swamps are also recorded in poorly drained, alluvial areas (Sanders *et al*. 1988: 64-81).

The vegetation regimes across the hinterland area are extremely complex and variable. Geology and landform are major determining factors in the distribution of vegetation communities. The ridges capped by Hawkesbury sandstone are much less varied geologically than the gullies. The gullies cut through a range of geological strata as well as colluvium and alluvium (Sanders *et al.* 1988: 82-6), providing a complex mosaic of soil types and vegetation communities in these locations.

While the economic resources of this true hinterland are significantly reduced in comparison with the maritime or estuarine environments, it can be expected that the resources of this area were not marginal since the complex distribution of the vegetable resources would have ensured ecological variability and localised resource rich high-value patches (cf. Fletcher-Jones 1985).

Conclusions

The Sydney region is within the fertile coastal zone. Environmental conditions across the region vary in terms of localised biomass. The two main economic zones defined for this work are the coastal and hinterland zones.

Localised resources could be expected within these broadly defined environmental zones. Geological variation is known to delimit the extent of particular lithic resources (e.g. silcrete is found in cobbles of the St Mary's formation on the Cumberland Plain; the gravel beds of the Nepean are a localised source of cherts and silicified tuff[2]; quartz is ubiquitous across the Hawkesbury sandstone formation (although good quality sources are not common); axe quality

[2]Previously known as 'indurated mudstone'

basalt occurs across the region in localised areas (e.g. Kulnura, Mount Yengo, Prospect, Barranjoey headland).

Food resources would not have been dispersed evenly across the region. The maritime/ estuarine influence extends approximately 10km inland along major river systems. Fish, water birds and eels would have contributed significantly to the diets of those living further inland. However, even in close proximity to major waterways, there could not have been the same degree of aquatic specialisation afforded by the coastal zone. These variations in resources are likely to have affected the social organisation of groups across the region.