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## Human impact on the natural environment in early colonial Australia

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### Abstract

Little Llangothlin Lagoon on the New England Tablelands of northeast New South Wales possesses the most detailed and best verified  $^{210}\text{Pb}$  chronology yet available in Australia. Recent criticisms of the length of the record are shown to be based on a faulty understanding of the principles of  $^{210}\text{Pb}$  dating. Attempts to revise the chronology of the lower part of the dated sequence by several decades must be rejected given that (a) fundamentally dissimilar chronological models yield ages that are statistically indistinguishable and (b) the most extreme manipulation of the modelling data fails to alter the basal dates in the profile by more than three years. The most telling criticism of the revisionist view, however, comes from the exact concordance between the dates from the basal part of the sequence, the historical date of official European contact and the massive changes in palynology, geochemistry and soil erosion resulting from that contact.

The thesis that environmental disturbance immediately prior to the time of official European contact in Australia was the result of human activity is supported by a wealth of documentary evidence revealing the illegal or unsanctioned presence of Europeans throughout much of southern and eastern Australia years before official records began. Likewise, it is clear that many elements of the pre-contact Australian environment, including certain of its soils, were fragile and susceptible to rapid and dramatic disturbance under the impact of European land use. Finally, there is convincing evidence of stable chemical and mineralogical conditions in several southeast Australian lakes throughout the last millennium or more, conditions that were altered catastrophically with the arrival of the first Europeans and their stock.

### Introduction

Gale and Haworth's (2002) paper on human environmental disturbance in Australia prior to official European contact used information derived from lake sediments to add an additional dimension to our understanding of the early colonial history of the continent. Well-dated sedimentary sequences from the New England Tablelands of northeast New South Wales (Figure 1) yielded evidence of enhanced rates of soil erosion and disturbance to lake sediment chemistry perhaps decades before the accepted date of European arrival in the 1830s. This disturbance is unlikely

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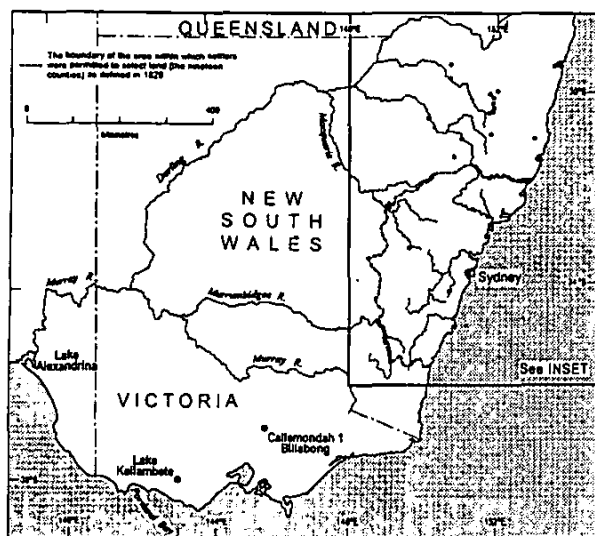
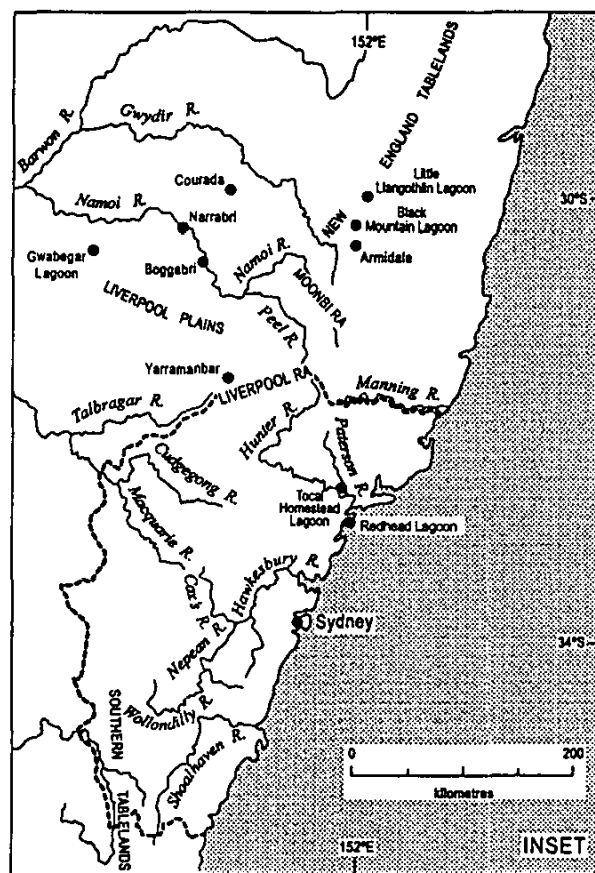


Figure 1. Southeast Australia showing the locations mentioned in the text.

to have been a consequence of natural processes. Instead, it is likely to indicate the presence of either Europeans or the ripples of their culture in New England well before the official date of settlement. These findings provide us with information that is not easily obtained through conventional documentary sources. They have implications for our comprehension of the timing and processes of European colonisation of the continent and for our understanding of the long-term response of the biophysical environment to human impacts. Tibby offers a number of comments on this work and on our broader research on the late Holocene environmental history of Australia. In the first part of this reply, we address his specific criticisms. In the second part, we tackle the more general issues arising from his discussion.

#### <sup>210</sup>Pb as a chronological tool

Tibby points out that the <sup>210</sup>Pb chronology at Little Llangothlin Lagoon in northeast New South Wales extends back to 1806±12, that this lies beyond the generally accepted range of 120–150 years of the technique and that this alone renders inappropriate any attempt to differentiate official and pre-official contact at the site. Although introductory reviews of the <sup>210</sup>Pb procedure not unreasonably provide a single value for the range over which the technique is applicable, <sup>210</sup>Pb analysis cannot be compared with more conventional isotopic dating techniques (indeed, strictly, it is not a dating technique at all). Thus, the activity of any sample down a sequence is dependent not only on time but also on the initial activity of the material. The greater the initial activity, therefore, the longer the time span over which it is possible to obtain reliable determinations. Thus, materials of high initial



activity should, all things being equal, provide both longer and higher resolution records than materials of low initial activity. A comparison of the calculated initial activity of the Little Llangothlin Lagoon sediments with those of other sites in New South Wales shows that the lake's sediments possess significantly higher activities than any other location for which we have records (Table 1). Little Llangothlin Lagoon would thus be expected to yield significantly longer <sup>210</sup>Pb chronologies than any of these other sites.

Site	Latitude and longitude	Initial excess <sup>210</sup> Pb activity (Bq kg <sup>-1</sup> )	Source of data
Black Mountain Lagoon	30°17' S, 151°40' E	71.3	Haworth <i>et al.</i> (1999)
Gwabegar Lagoon	30°36' S, 148°59' E	44.7	S.J. Gale, unpublished data
Little Llangothlin Lagoon	30°05' S, 151°46' E	155.1	Gale <i>et al.</i> (1995)
Tocal Homestead Lagoon	32°37' S, 151°35' E	53.6	Cook <i>et al.</i> (in submission)

Table 1: The initial excess <sup>210</sup>Pb activity of lake sediments in New South Wales.

Notwithstanding this, it is interesting to note that whilst Tibby feels obliged to cast doubt on the reliability of a ~183 year (calibrated) record from Little Llangothlin Lagoon, he has no compunction about accepting the reliability of and publishing a ~181 year (uncalibrated)  $^{210}\text{Pb}$  record from Lake Sonachi in Kenya (Verschuren *et al.* 1999a). Similarly, although Tibby stresses the importance of assessing competing models of  $^{210}\text{Pb}$  accumulation prior to determining chronologies (an approach that we scrupulously followed in our work at Little Llangothlin), he has chosen to ignore this advice in his own research (Verschuren *et al.* 1999a, 1999b, 2000; Reid *et al.* 2002).

### Calibration of the $^{210}\text{Pb}$ chronology

According to the historical record, the arrival of the first squatter and his sheep on the Llangothlin run took place in the late 1830s (Gale and Haworth 2002:127). This date in the  $^{210}\text{Pb}$  record coincides with the most dramatic alteration observed in the entire pollen sequence. Tibby, however, argues that it is probable that the  $^{210}\text{Pb}$  chronology underestimates ages in this part of the core and that the more minor changes in the pollen record lower down the sequence represent the point of official contact. He would thus like to alter the chronology of the lower part of the dated sequence by several decades to accommodate his proposals. We point out first of all that our modelling of the  $^{210}\text{Pb}$  chronology was based on two fundamentally dissimilar approaches representing the end members of a continuum of sedimentary processes: the Constant Initial Concentration (CIC) model and the Constant Rate of Supply (CRS) model. These very different methods yielded ages that were statistically indistinguishable, yet Tibby would like us to discard both sets of results in order to accommodate the dates that he would prefer fitted to the sequence.

Secondly, we have modelled the  $^{210}\text{Pb}_{\text{excess}}$  activity profile that would be required in order to generate the chronology that Tibby would favour. To do this, we employed the CRS model and used measurements of unsupported  $^{210}\text{Pb}$  activity per unit volume of mineral matter. The activity profile above 1.24 m in the sequence cannot be easily altered since all but one of the samples yielding positive excess  $^{210}\text{Pb}$  values in the core were measured during our initial analysis. We therefore used the activity–depth relationship derived for the lower part of the sequence (Gale *et al.* 1995:402) to estimate activities below the depth at which our measurements ended. We progressively extrapolated the excess  $^{210}\text{Pb}$  profile to totally unrealistic depths in the sediment column<sup>1</sup>, but found it impossible to increase the mean ages at the bottom of our

profile by more than two or three years (whilst the changes higher up the sequence were insignificant). Not only does this give us considerable confidence in the robustness of our chronology, but it makes it inconceivable that the  $^{210}\text{Pb}$  dates could ever approximate to the values required to support Tibby's hypothesis.

The concordance between the date of arrival of the first official squatter at the site, the corresponding date in the  $^{210}\text{Pb}$  chronology and the most dramatic shifts in the entire pollen record provides compelling evidence for the reality of the Little Llangothlin chronology. Part of Tibby's attempt to discredit this is based on his assertion that the response of vegetation to first contact throughout much of Australia was relatively muted. We address this issue in the following section.

### The impact of early European contact on vegetation

Tibby argues that, far from the dramatic changes in vegetation consequent upon European contact that are seen in the Little Llangothlin record, many Australian pollen sequences show only a minor reduction in arboreal taxa at this time. Indeed, he claims that high-resolution records show that the first changes wrought by contact were increases in grasses and herbs, with decreases in tree pollen occurring only later. He therefore argues that the more minor changes in palynology that we observed lower down the Little Llangothlin core must represent the official point of contact and that our chronology at this point must thus be in error by some 30 years or more.

We have demonstrated above the robustness of our chronology, the fact that dates modelled using fundamentally different approaches yield identical results and that the most extreme manipulation of the modelling data fails to alter the basal dates in the profile by more than three years. However, we should also like to query the evidence upon which Tibby's assertion of the nature of post-contact vegetation changes is based. First, we are told that high-resolution records tell a story different to that of the New England Tablelands. Yet, apart from the sequence from Little Llangothlin Lagoon itself (Gale and Pisanu 2001), we are not aware of any high-resolution record of the palynology of the early contact period from anywhere in Australia (Gale 2003:12–13); no other record has yet been published in which the point of European contact has been unequivocally established using geochronometric means.

Secondly, in the one published example cited by Tibby, that by Mooney and Dodson (2001) from Lake Keilambete in southwest Victoria, European contact is determined on the basis of the first appearance of exotic *Pinus* pollen in the sequence. Yet the *Pinus* must clearly post-date the point of contact, although it is impossible to state by how much. There is convincing evidence from several Australian sites, however, that the lag between European contact and the appearance of exotic pollen grains may be as long as a century (Gell *et al.* 1993; Gale and Pisanu 2001; Mooney *et al.* 2001). Further confusing the chronology at Lake

1. The activity–depth relationship was employed to extend the  $^{210}\text{Pb}_{\text{excess}}$  profile in a stepwise fashion to a depth of 2.00 m. Radiocarbon dating would suggest an approximate age of 4000 years for this part of the core (Gale and Haworth 2002:130), far beyond the date at which  $^{210}\text{Pb}_{\text{excess}}$  activity would remain detectable.

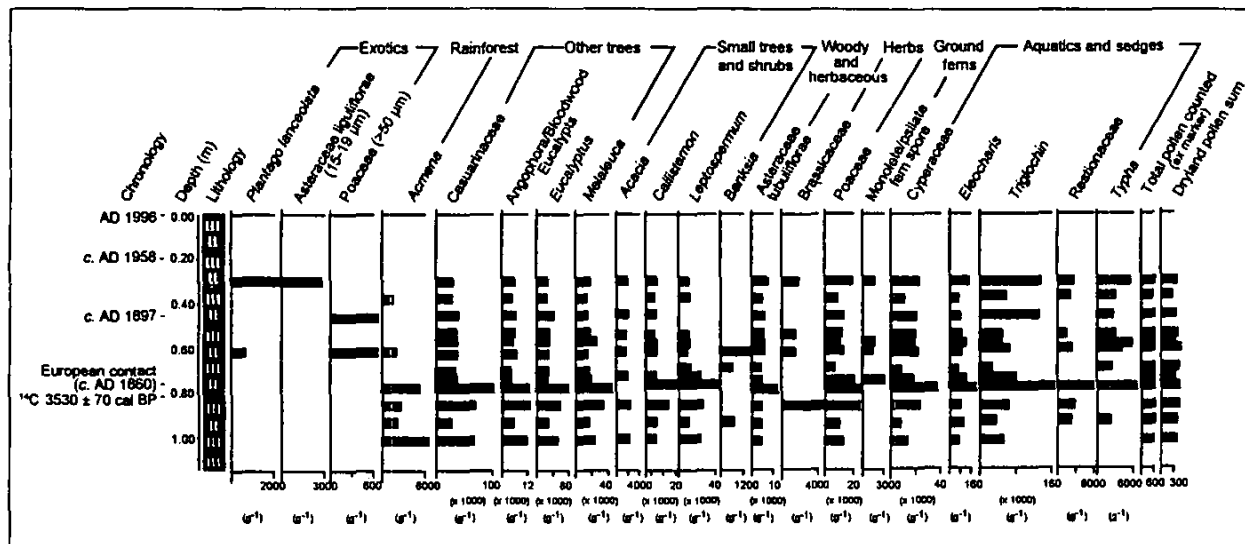


Figure 2: Pollen concentration, core F4c, Redhead Lagoon, Dudley, central eastern New South Wales. The chronology is based on accelerator mass spectrometric  $^{14}\text{C}$  analyses calibrated to calendar years and geochemical markers including heavy metal concentrations and  $^{137}\text{Cs}$  activities.

Keilambete is the appearance of *Plantago*, which is likely to be of exotic origin, some distance below the depth at which *Pinus* first appears.

Notwithstanding the difficulties associated with the chronology at Lake Keilambete (and we stress that this is not intended as a criticism of Mooney and Dodson, who are transparently honest about their data), we can see no evidence in the Keilambete record for a post-contact increase in grasses and herbs (if anything, there is a decrease in percentage values). Nor is the decline in tree taxa apparently delayed, though it is impossible to comment meaningfully on this given the absence of dates and the likely dramatic fluctuations in minerogenic deposition rates in the decades immediately after contact.

Thirdly, even if there were some truth in Tibby's assertion that pollen records from southwest Victoria yield little evidence of the effects of European contact (and every one of his published and unpublished examples comes from this limited area of the continent), there can be little justification for extrapolating this belief over one thousand kilometres northeast to the Tablelands of northeast New South Wales. Indeed, evidence from elsewhere in eastern New South Wales demonstrates that, as in New England, dramatic shifts in vegetation, and tree cover in particular, took place immediately upon contact (Figure 2).

Finally, Tibby seeks to discredit the concordance of the major changes in the pollen record and a  $^{210}\text{Pb}$  date that coincides with the official date of arrival of squatters at Little Llangothlin by suggesting that the vegetation around the lagoon was unlikely to have been disturbed until some time after official contact. Tibby does not indicate the length of this lag, but the more than halving of excess  $^{210}\text{Pb}$  activities over this part of the core suggests that a period of several decades is likely to have been involved.<sup>2</sup> For a pastoralist to have ignored one of the few major permanent

sources of water on his property for so long appears unlikely, to say the least. Tibby's explanation that the lake lay at some distance from the homestead (a matter of 6 km) is simply not credible. The shepherding system that was employed at the time meant that even the most distant parts of runs were grazed on a regular basis (Walker 1966:25; Blomfield 1978:17, 31–33). More importantly, since sheep cannot travel far to water, their browsing must be concentrated around creeks and waterholes (Barr and Cary 1992:13). This would have been particularly the case under the drought-dominated conditions that the Tablelands experienced throughout the first half of the nineteenth century (Gale and Pisanu 2001:488), when the lagoon would have provided essential drought relief for the stock on the run. Sheep are vigorous overgrazers. They graze selectively and aggressively, and when feed is short they grub at plant roots (Hamilton 1892:209; Barr and Cary 1992:13). Seedlings of *Casuarina cunninghamiana*,<sup>3</sup> in particular, are relished by stock and natural regeneration rarely occurs in areas to which sheep have access (Anderson 1968:67). The foliage of *C. cunninghamiana* may also be used as drought fodder (Maiden 1889:122; Anderson 1968:67). Under these conditions, the pure stands of

2. Excess  $^{210}\text{Pb}$  activity decreases by a factor of two every  $22.26 \pm 0.22$  a (the half-life of  $^{210}\text{Pb}$  [Höndorf 1969]). Consequently, so long as the  $^{210}\text{Pb}_{\text{excess}}$  in a sedimentary sequence is isolated by burial from further addition or from removal, its activity will decline with depth at a rate given by its half-life.

3. The species of *Casuarinaceae* that experienced dramatic decline at Little Llangothlin Lagoon at the time of European contact was almost certainly *C. cunninghamiana* (Gale and Pisanu 2001:489).

*C. cunninghamiana* that probably fringed the lake (Gale and Pisanu 2001:489) are likely to have experienced dramatic degradation immediately following the depasturing of sheep in the catchment.

### Pre-contact sedimentation rates

The rate of sedimentation in Little Llangothlin Lagoon in the decades prior to the accepted date of arrival of Europeans in the catchment is far higher than would be anticipated in an environment peopled by a limited number of hunter-gatherers. Gale and Haworth (2002) demonstrated this first by using evidence of sediment yields under immediate pre-settlement conditions on the Southern Tablelands of New South Wales, an area geomorphologically and climatically closely comparable with New England. The predicted lake sedimentation rate for a catchment and lake basin the size of Little Llangothlin Lagoon is 20 times lower than the early nineteenth century rate in New England. They followed this up by comparing Late Pleistocene–early Holocene lake sedimentation rates obtained from elsewhere in New England with those from the early nineteenth century at Little Llangothlin. In this case, rates at the study site are over six times higher. Finally, they compared vertical sedimentation rates during the Late Pleistocene–early Holocene within Little Llangothlin Lagoon itself with the early nineteenth century rates at the same site. In this case, the early nineteenth century rates are almost 30 times higher. In all cases, these figures were qualified by the assumptions that must be taken into account when making such calculations.

Tibby challenges the last of these calculations. First, he calibrates our Late Pleistocene–early Holocene rate to calendar ages, obtaining a vertical accumulation rate of  $0.070 \text{ mm a}^{-1}$ . Employing this figure, the early nineteenth century rates are 34 times higher than those of the Late Pleistocene–early Holocene. Secondly, in order to calculate sedimentation rates for the same core during the late Holocene, he chooses to employ  $^{14}\text{C}$  analyses from depths of 2.170–2.150 m and 1.729–1.707 m. These yielded ages of  $3860 \pm 110 \text{ BP}$  and  $3880 \pm 200 \text{ BP}$  respectively. We considered these ages to be equivocal and felt that it was impossible to assess the reliability of these assays. A better means of obtaining the sort of data sought by Tibby would be to calculate vertical sedimentation rates between the point of European contact and the highest reliable  $^{14}\text{C}$  age in the core ( $6740 \pm 340 \text{ cal BP}^4$  at 2.510–2.485 m). This approach yields a vertical sedimentation rate of  $0.23 \text{ mm a}^{-1}$ . This is an order of magnitude less than the early nineteenth century rate, despite the fact that the late Holocene rate includes the episode of higher sedimentation immediately prior to the time of official contact. Once again, we qualify these figures. Complications due to sediment compaction, variations in plant organic content and differences in bulk density, along with environmental shifts, alterations in

sedimentation rates, potential breaks in deposition and possible changes in the pattern of lake sedimentation make comparison of vertical sedimentation rates difficult. Nevertheless, the dramatic differences in these figures remain unchanged by Tibby's calculations and are suggestive of major disturbance to the natural system during the early years of the nineteenth century.

### Pre-contact lake sediment chemistry

Detailed studies of the chemistry of the Little Llangothlin Lagoon sediments reveal that the stable geochemical conditions that had prevailed for a long period prior to the start of the nineteenth century had been disrupted well before the official date of arrival of Europeans in the catchment. The start of this disruption predates the earliest  $^{210}\text{Pb}$  date obtained for the core and is likely to have occurred in the later part of the eighteenth century or the early years of the nineteenth century. Tibby argues, however, that the late Holocene variation of calcium, sodium and potassium is such that it is impossible to distinguish this phase of disruption from that of background trends of these elements. A different argument is employed by him to explain away the pre-official contact increase in phosphorus values. This is attributed to post-depositional mobility, unfortunately ignoring our point that such a mechanism would necessitate the translocation of elements in differing directions through the sequence (Gale and Haworth 2002:131).

We have tested Tibby's thesis that the pre-official contact phase of chemical disruption cannot be distinguished from the long-term variability of sediment chemistry by considering the behaviour of the oxides of calcium, sodium, potassium and phosphorus in the sequence. To avoid the problems inherent in the analysis of closed or compositional data sets (see, for example, Aitchison [1986]), we have expressed these data as ratios (Figure 3). Contrary to Tibby's assertion, the chemistry of the pre-European lake sediments (2.15–1.17 m) displays very little variation. More significantly, those samples from the pre-official contact phase of disturbance (1.17–1.11 m) lie well beyond the 95% confidence limits of the pre-European sediments, making it extremely difficult to explain away the chemical anomaly as a product of background variations in sediment chemistry. Notably too, the transitional samples plot in stratigraphic sequence between the pre-contact and the post-official contact clusters, as would be anticipated given progressive environmental disruption in the lead up to the arrival of official settlers.

Lest this demolition of Tibby's argument be interpreted as an artefact of the analytical procedure used, we have employed a second, contrasting approach to the interpretation of the data set. Principal components analysis (by covariance) was undertaken on those data from above 2.15 m in the 50 mm core. Analysis was again focussed on the four oxides specified by Tibby: calcium, sodium, potassium and phosphorus. To avoid the computational difficulties associated with closed data sets, each of these

4. The uncalibrated accelerator mass spectrometric  $^{14}\text{C}$  age is  $5880 \pm 300 \text{ BP}$  (OZA913U).

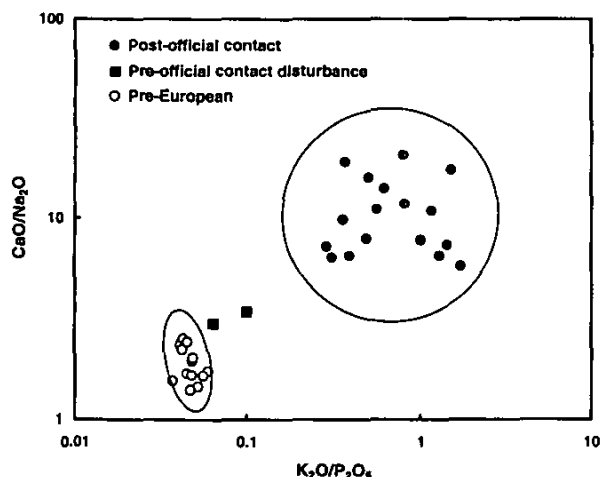


Figure 3:  $K_2O/P_2O_5$  versus  $CaO/Na_2O$  ratios of sediments from the upper 2.15 m of the 50 mm core, C2.0, Little Llangothlin Lagoon, Guyra, northeast New South Wales. The envelopes represent 95% confidence limits.

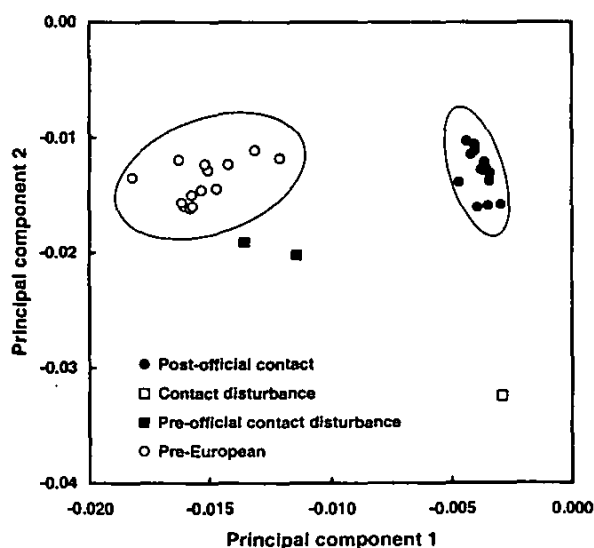


Figure 4: Principal components analysis (by covariance) of the oxides of calcium, sodium, potassium and phosphorus normalised against the summed contribution of the oxides of silicon, titanium, aluminium and iron from the upper 2.15 m of the 50 mm core, C2.0, Little Llangothlin Lagoon, Guyra, northeast New South Wales. The top sample from the sequence was excluded from the analysis. The four clusters represent the optimum determined by K-means clustering. The envelopes represent 95% confidence limits.

was normalised against the summed contribution of the oxides of silicon, titanium, aluminium and iron. The first two eigenvectors of the principal components analysis explain 92.5% of the total variance of the data set. Using the *F*-score, K-means clustering of the first two principal components revealed the optimum number of clusters to be four (Figure 4). The pre-European sediments (2.15–1.17 m) and the post-official contact sediments (1.00–0.12 m) are distinguished, along with those samples from the pre-official contact phase of disturbance (1.17–1.11 m) and the single sample from the point of official contact (1.04–1.00 m). The transitional samples lie well beyond the 95% confidence limits of the pre-European sediments, making it highly unlikely that their aberrant character is a by-product of background chemical variability.

#### Drying of the lake basin leading to deflation of lake sediments

Tibby suggests that Little Llangothlin Lagoon becomes dry during droughts and that under such conditions it is likely that sediment is deflated from the basin. He argues that this would reduce the overall apparent rate of sedimentation in the lake. In the immediate pre-contact era, by contrast, he proposes that the sediments would have been rapidly insulated from deflation by their burial by post-contact sediment. The rate of immediate pre-contact deposition would therefore appear to be much greater than that which preceded it.<sup>5</sup>

The evidence upon which Tibby bases this thesis is the report by Brock *et al.* (1999) that Little Llangothlin Lagoon became dry in the drought of 1980–81. Tibby therefore infers that such drying events (with their consequent loss of sediment) must have occurred at 'decadal-centennial' intervals. What he is clearly unaware of is that this drying was the result of the construction during the mid-twentieth century of an outlet through the lunette that dams the lake (Briggs 1976:33). The aim of this was to allow grazing on the lake bed. Yet even with an artificially-lowered outlet, the lake dried on only a single occasion and, even then, meadows covered the still-moist lake floor (M.A. Brock, personal communication, 10 June 2004). Under these conditions, sediment loss by deflation would have been impossible.

Interestingly, since the outlet was restored to its natural state by the New South Wales National Parks and Wildlife Service in 1989, the lake waters have remained high, despite

5. If the lake basin had experienced deflation, the integrity of the sedimentary record in the lagoon would have been destroyed. Yet detailed magnetostratigraphic logs from a network of 37 coring sites across the lagoon reveal a consistent stratigraphic picture, with individual stratigraphic features traceable across the entire lake basin (Gale and Haworth 2004). Such a pattern is most unlikely to have been preserved had deflation removed and reworked sediment across the lake floor under dry conditions.

the incidence of droughts comparable with that experienced in 1980–81.<sup>6</sup> It is clear that up until it was breached in the middle of the twentieth century, the natural dam was able to maintain lake levels at the site even under conditions of severe drought.

### Discussion

In addition to the specific comments dealt with above, Tibby makes several somewhat veiled criticisms of the broader implications of our work, although without marshalling any specific arguments against them. These include:

1. An attempt to discredit our thesis that environmental disturbance immediately prior to the time of official European contact in New England was the result of human activity.
2. A disparagement of our model of environmental fragility, rapidly and dramatically disturbed by European contact.
3. A denial of our suggestion that relatively stable conditions of lake chemistry prevailed in the millennia prior to contact.

We address these wider issues in the following sections.

#### *Human environmental disturbance prior to official European contact in early colonial Australia*

We have demonstrated above the reality of environmental disturbance prior to the official date of European contact at Little Llangothlin Lagoon. This produced both significant changes in vegetation and notable increases in rates of soil erosion. Gale and Haworth (2002) showed that these disturbances are likely to have been the direct or indirect result of European activity. The presence of Europeans so far north at this time was, with very few exceptions, illegal or unsanctioned. The documentary record is therefore unlikely to preserve information on their movements or activities. Nevertheless, there is growing evidence for the presence of either Europeans or the shadow of European culture on the Tablelands decades before the first wave of official squatters swept up the Moonbi Range into New England. Much of this evidence is reviewed by Gale and Haworth (2002:127, 133) and need not be repeated here, particularly as neither Tibby nor any other commentator has cast any doubt on the reliability of our information. Since that paper was written, however, further evidence has come to light confirming the unsanctioned presence of Europeans in northern New South Wales in the early years of the nineteenth century.

6. During the six-month period from April to September 2000, for example, only 139.2 mm of rain fell at Armidale, 47 km south of the lake, slightly less than the amount that fell during the driest six-month period of the 1980–81 drought. Similarly, only 141.2 mm fell in the period April to September 2002, less than a millimetre more than in the driest six months of the 1980–81 drought.

Thus, in 1826 or early 1827, 20 bushrangers established a village at Courada at the head of Terry Hie Hie Creek, northeast of Narrabri and 200 km beyond the Limits of Location (Rolls 1981:104). Soil was taken under the plough, wheat was grown and drainage was manipulated to water the cattle that they intended to duff. Of perhaps broader significance is the evidence that, in late 1830 or early 1831, Benjamin Singleton and Richard Yeomans organised a secret expedition from Yarramanbar, north of the Liverpool Range, up the Peel River in search of the mythical Kindur River and the well-watered territories adjoining it (Boyce 1970:29–30). The serendipitous preservation of this scrap of information begs the question of how many similar ventures beyond the Limits may have gone unrecorded. Finally, in 1831, Thomas Mitchell's official Kindur expedition stumbled across a large stockyard littered with numerous bullock bones on the floodplain of the Namoi, immediately west of the modern town of Boggabri and over 100 km beyond the official marchlands (Mitchell 1838a:44).

Nor was this secret colonisation restricted to New England. There is now considerable evidence that Europeans penetrated much of eastern and southern Australia years before official records began. Clandestine squatters, escaped convicts and anonymous stockmen left only a sparse paper trail. Nevertheless, we know that sealers had discovered Lake Alexandrina at the mouth of the Murray at least fifteen months before Charles Sturt's arrival in 1830 (Forbes to Sleeman 1829; Gill 1906). Similarly, it is widely recognised that the Hentys' squatting dynasty was established in Portland Bay in present-day southwest Victoria in 1834, more than two years before Thomas Mitchell led his party of discovery from Sydney to *Australia Felix* (Mitchell 1838b:238–241). What is less well-known, however, is that sealers and whalers had settled in the Bay more than six years before the arrival of the Hentys (Long 1917; Learmonth 1934:55). Even deep in the interior, surreptitious pastoralists were staking out land in the remote corners of northwest New South Wales and southwest Queensland as early as 1860, months before the lumbering carnival of Burke and Wills' Great Victorian Exploration Expedition had been guided through the region by stockmen already familiar with much of the country through which they were passing (Shaw 1987:17, 21).

#### *Environmental fragility and its disturbance by European contact*

The question of the fragility of the pre-contact Australian environment is clearly complex and multi-faceted. Tibby does not specify which aspect of the physical landscape he is referring to when he criticises our model of environmental frailty. Nevertheless, since much of our research has focussed on soil erosion, we imagine that the fragility (or otherwise) of pre-contact soils must represent an important target for his scepticism. Gale (2003) has reviewed a large body of descriptions of soils made by the first Europeans to penetrate various parts of the continent and has assessed

those few soils thought to have been preserved in their pre-contact states. It is apparent that certain pre-contact Australian soils are likely to have been very fragile and thus highly susceptible to disturbance. Moreover, it is clear that the impact of European land use may have been of such magnitude that the soils were transformed within only a few years of contact. Bulk densities were increased, pore space and permeability was reduced, soil crusts were broken down, soil aggregates were crushed and surfaces were compacted. The effect of these changes was to reduce infiltration capacity, to increase runoff and thus to denude the soils and enhance sediment yield.

Gale (2003) has also reviewed both the documentary evidence of early-contact soil erosion and the few well-dated records of sediment yield that extend back to before the time of European contact. Both sets of data suggest that dramatic increases in erosion occurred within a decade or two of contact.

#### *The stability of lacustrine chemistry in the millennia prior to European contact*

One of the most significant findings of our work at Little Llangothlin is the suggestion that stable geochemical conditions had existed in the catchment for several millennia before the arrival of Europeans. Tibby challenges this proposition, but, as we have shown above, the chemistry of the lake sediments prior to contact exhibits low

variability that differs significantly not only from that of the post-official contact sediments, but also from those sediments apparently disturbed by direct or indirect human activity in the late eighteenth or early nineteenth centuries.

A similar picture of stability comes from other lake sediment records of the same period. At Tocal Homestead Lagoon in the valley of the Paterson River in central eastern New South Wales, high-resolution histories covering the last two millennia tell a story of consistent magnetic mineralogical conditions (Figure 5). It is notable, too, that several of the composite records of late Holocene environmental change derived by Dodson and Mooney (2002) paint a picture of environmental stasis over the millennium or more prior to contact. Finally, the evocation of stable chemical and mineralogical conditions in the sediments of several southeast Australian lakes during the late Holocene is supported by Tibby's own reconstructions of lake water chemistry in Callemondah I Billabong in central Victoria (Tibby *et al.* 2003). These reveal a remarkable stability in reconstructed pH for over 3000 years prior to the end of the nineteenth century.

#### Acknowledgements

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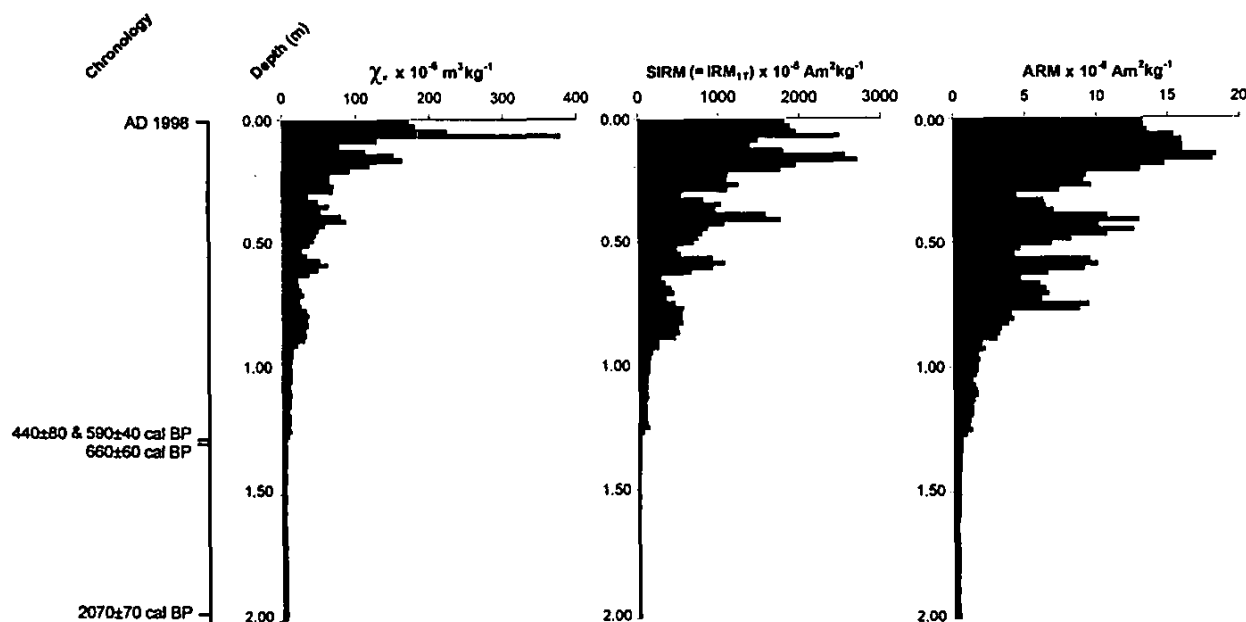


Figure 5: Low-frequency mass-specific magnetic susceptibility ( $\chi_f$ ), saturated isothermal remanent magnetisation (SIRM) and anhysteretic remanent magnetisation (ARM), core TCA9b, Tocal Homestead Lagoon, Paterson, central eastern New South Wales (Cook *et al.* in submission). The chronology is based on accelerator mass spectrometric  $^{14}\text{C}$  analyses calibrated to calendar years.



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