Bridging a biogeographic 'gap': microfossil evidence for the quillwort *Isoetes* on the Cumberland Plain west of Sydney during the early Colonial period

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Abstract: Fossil spores preserved on historical archaeological sites at Parramatta and Richmond indicate that two or more species of the quillwort genus *Isoetes* (family Isoetaceae) were growing along rivers on the Cumberland Plain, west of Sydney, during the late 18th and early 19th centuries. Perispore ornamentation indicates the parent plants were related to *Isoetes drummondii* A.Braun and *Isoetes muelleri* A.Braun: A possible third species produced microspores that are similar to, but much larger than, the spores produced by modern *Isoetes muelleri*. Apart from one dubious record, *Isoetes* has not been found in the Sydney flora or on the New South Wales Central Coast and Central Tablelands botanical subdivisions, but does occur in the Central Western Slopes, and botanical subdivisions to the north of Sydney (North Coast, Northern Tablelands) and south (Southern Tablelands, South-Western Slopes, South-Western Plains), as well as in other States. Our data indicate the present day disjunct distribution of *Isoetes* in New South Wales is most likely to be due to European settlement. The ability of quillworts to survive moderate levels of disturbance during the early Colonial period raises the possibility that remnant populations may still survive in protected areas on the Cumberland Plain.

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Introduction

Organic-rich sediments, including buried topsoil and analogous cultural deposits on archaeological sites in Sydney, usually preserve diverse assemblages of fossil pollen and spores. Some of these represent native plants that are not present in the modern Sydney flora (cf. Carolin & Tindale 1994). For example, in 1996, numerous fresh-looking spores closely resembling those produced by the semi-terrestrial to freshwater aquatic quillwort species *Isoetes drummondii* A.Braun subsp *anomala* C.R.Marsden & Chinnock (family Isoetaceae) were recovered from sediments infilling an 1840s or older waterhole at Richmond on the Cumberland Plain west of Sydney (Fig. 1). The spores came from an approximately 1 m thick unit of laminated clays buried under about 0.5 m of late 19th and 20th century sands (Macphail 1996, 1999). Allochthonous pebbles, bottles and sherds of Victorian era blue and white pottery were scattered through the clay infill and demonstrate that the parent plants were alive sometime during the first five decades of European settlement of the Hawkesbury River district i.e. 1790–1840, when such waterholes provided water for stock.

This finding was wholly unexpected for two reasons: — firstly, *Isoetes* has not been conclusively recorded in the Sydney flora, and secondly, the closest known population of *Isoetes drummondii* subsp. *anomala* recorded in New South Wales occurs on the Southern Highlands, approximately 200 km southwest of Sydney (Carolin & Tindale 1994, Wilson 2000). Archaeological evidence showed that the c. 14 m long artificial waterhole had been dug in an existing depression, probably an abandoned high level channel of the Hawkesbury River, using a horse-drawn drag board (E.H. Higginbotham pers. comm.). Accordingly, it was uncertain whether *Isoetes* was growing along the middle reaches of the Hawkesbury River before European settlement in the 1790s or had been subsequently introduced, e.g. by the movement of stock from southern New South Wales, during the 19th century. The *Isoetes* collection held in the National Herbarium of New South Wales (NSW) includes specimens of *Isoetes drummondii* subsp. *anomala* collected from a 'marshy area near a stock reserve tank' at Henty on the South Western Slopes (NSW 410774).

We report here a second discovery of fossil *Isoetes* microspores in western Sydney, in buried silty soils on an historical archaeological site at the corner of George and Charles Streets, Parramatta, about 30 km southeast of Richmond (Fig. 2). The Parramatta microflora includes spores comparable to those produced by the two *Isoetes* species recorded in New South Wales and the age and context of the deposits are strongly against the parent plants being introduced by Europeans.

Present distribution and ecology of *Isoetes* in New South Wales

Only two of the fifteen living *Isoetes* species and subspecies currently recognised in Australia (Chinnock 1998) have been recorded in New South Wales: *Isoetes drummondii* A.Braun subsp *anomala* C.R.Marsden & Chinnock and *Isoetes muelleri* A.Braun (Wilson 2000). Both species are semi-terrestrial to freshwater aquatic herbs with leaves up to 30 cm long. Apart from one dubious specimen of *Isoetes muelleri* labelled 'ex Sydney' (NSW 234976), there are no herbarium records of either species from the Central Coast botanical subdivision, including Sydney, or the Central Tablelands botanical subdivision to the west. The closest known populations of *Isoetes drummondii* subsp. *anomala* occur on the Southern Tablelands and South-Western Slopes botanical subdivisions, whilst *Isoetes muelleri* is also found on the Central Western Slopes at Lake Cowal (NSW426409), and in the South-Western Plains, North Coast and Northern Tablelands botanical subdivisions (http://plantnet.rgbsyd.nsw.gov.au).

Isoetes drummondii also occurs in southwestern Western Australia, southeastern South Australia, Victoria and Tasmania (Fig. 3): *Isoetes muelleri* is even more widely distributed, with populations extending into the arid interior of Western Australia as well as the Northern Territory, northern South Australia and southwestern Queensland (Fig. 4).

Chinnock (1998) cites *Isoetes drummondii* as being widespread in swamps and seepages, where it may be fully submerged or emergent in very open situations. The species frequently occurs on disturbed sites and can be found growing in wet patches along fire breaks in pine plantations in South Australia and Victoria. Analogous populations in New South Wales and Tasmania occur in wet ditches along railway lines, and along roadsides and in drains respectively. *Isoetes muelleri* occupies a much broader range of habitats, from permanent subalpine tarns in Tasmania, to ephemeral swamps and rock pools in Central Australia.

Archaeological setting

Early Colonial Parramatta was largely built on a flight of Late Quaternary river terraces near to the tidal (and initially navigable) limits of the Parramatta River. Triassic shales (Ashfield Shale), which form the underlying bedrock, outcrop along the riverbanks. Remnants of the Holocene floodplain, formed after postglacial sea levels stabilised about the present day position about 6000 years ago level, occur up to 2 m elevation on both sides of the river (Mitchell 2003).

Archival and borelog evidence indicate that the pre-settlement topography of the Holocene floodplain was highly irregular due to the prevalence of levee-bank remnants (reduced to mounds) and back-swamp hollows (Lawrie 1982): Some of the more permanent freshwater ponds were used as a domestic water supply by the early Colonial period residents. Higher terraces above 5–6 m above sea level, including the terrace occupied by the George and Charles Streets archaeological site, are more likely to have formed during the Last Interglacial period some 120 000 years ago and any remnant fluvial landforms are highly subdued. Soils on these higher level terraces are predominantly highly leached, brownish grey to yellow-brown fine quartz sands or gradational red earths (Mitchell 2003). Both the A_1 and A_2 horizons have been strongly bioturbated by cicada larvae, with infilled burrows reaching to an average depth of about 35 cm and occasionally to 50–60 cm depth below ground level (Mitchell 2003).

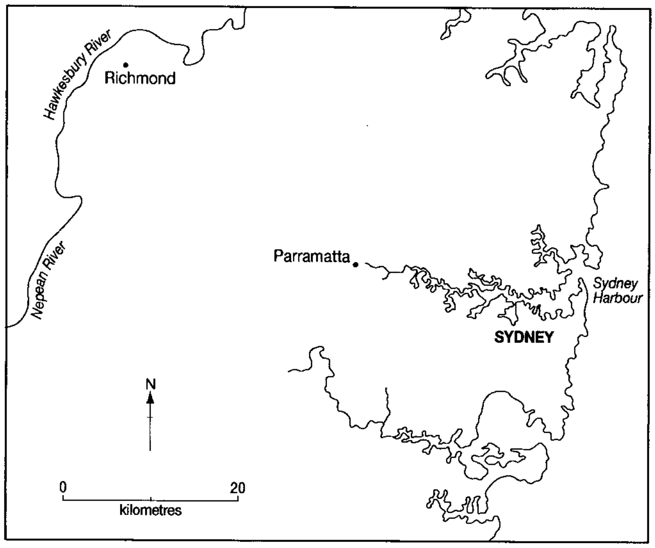

Fig. 1. The location of Parramatta on the Parramatta River and Richmond on the Hawkeasbury River west of Sydney.

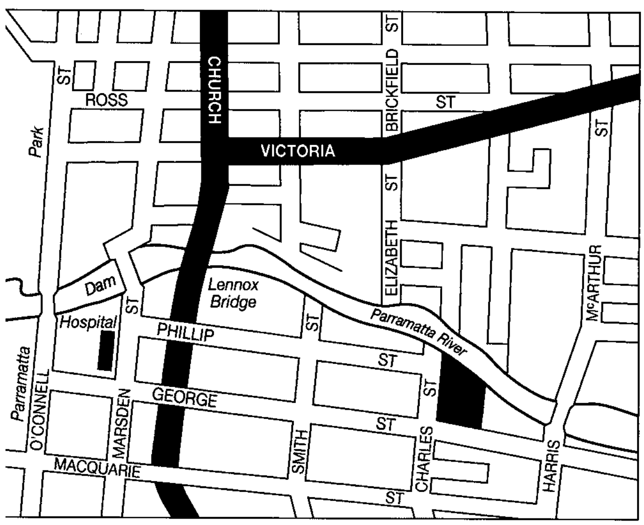

Fig. 2. The location of the George and Charles Street Parramatta archaeological site (shaded black) in relation to the upper Parramatta River.

Table 1. Relative pollen abundance, George and Charles Streets Parramatta archaeological site

Relative abundance calculated as a percentage of the total pollen and spore excluding algae.
+ equals values < 1%. Values based on pollen sums of less than 200 are statistically unreliable

TAXON		**Allotment 69**		**70**	**72**
	ACN 2425	**ACN 2430**	**ACN 2484**	**ACN 2202**	**ACN 2791**
Reworked Triassic pollen & spores	+		4%	1%	
Concentration (10^3 grains per gram)	0.3	0.3	1.3	1.8	0.15
POLLEN SUM (excluding Triassic spp.)	172	140	190	268	104
Definite exotics					
Malvaceae (cf *Hibiscus*)				+	
Pinaceae				9%	
Plantago lanceolata-type	+			1%	
Polygonum aviculare			+	+	
Poaceae (> 60 µm)	+			3%	
Probable exotics					
Apiaceae				+	
Arecaceae				+	
Asteraceae: high spine-types)				+	
Bidens-type				+	
Brassicaceae (*Rapa*-type)			+	+	
Chenopodiaceae			2%	16%	
Liguliflorae (*Taraxacum*-type)	4%	2%	2%	5%	6%
Rosaceae (*Fragaria*-type)			+		
Rosaceae (*Malus*-type)			3%		
Rosaceae			+		
Stellaria				+	
Non-local native taxa					
Cyathea		+		5%	2%
Dicksonia			+	2%	
Podocarpus				+	
Native trees & shrubs					
Acacia (granular)					11%
Acacia (non-granular)	+	1%			
Allocasuarina/*Casuarina*	11%	15%	21%	4%	11%
Banksia					1%
Dodonaea viscosa-type			+		
Eucalyptus	62%	49%	42%	6%	65%
Leptospermum spp.				+	
Monotoca			+		
unidentified Myrtaceae				2%	
unidentified tricolpates			+	+	
unidentified tricolporates			3%	+	
Native Herbs					
Asteraceae: low spine types		+		+	1%
Brassicaceae	+			+	
Cyperaceae	+		+	15%	
Lemna	1%				
Poaceae (< 50 µm)	10%	6%	13%	7%	1%
Ranunculus		+			
Restionaceae			+	+	
Native ferns & fern allies					
Calochlaena	+	3%	+	+	
Isoetes drummondii-type	2%	4%	+		
Isoetes muelleri-type				+	
Isoetes cf. *muelleri*					1%
Microsorium				+	
Monolete ferns			+	7%	
Pteris		+		+	
Pyrrosia-type	+			+	
Trilete ferns	2%	3%	2%	3%	1%
Liverworts & mosses					
Cingulatisporites spp. (Anthocerotae)	3%	9%	2%	3%	
Rudolphisporis rudolphi (Ricciaceae)	+	3%	+	3%	

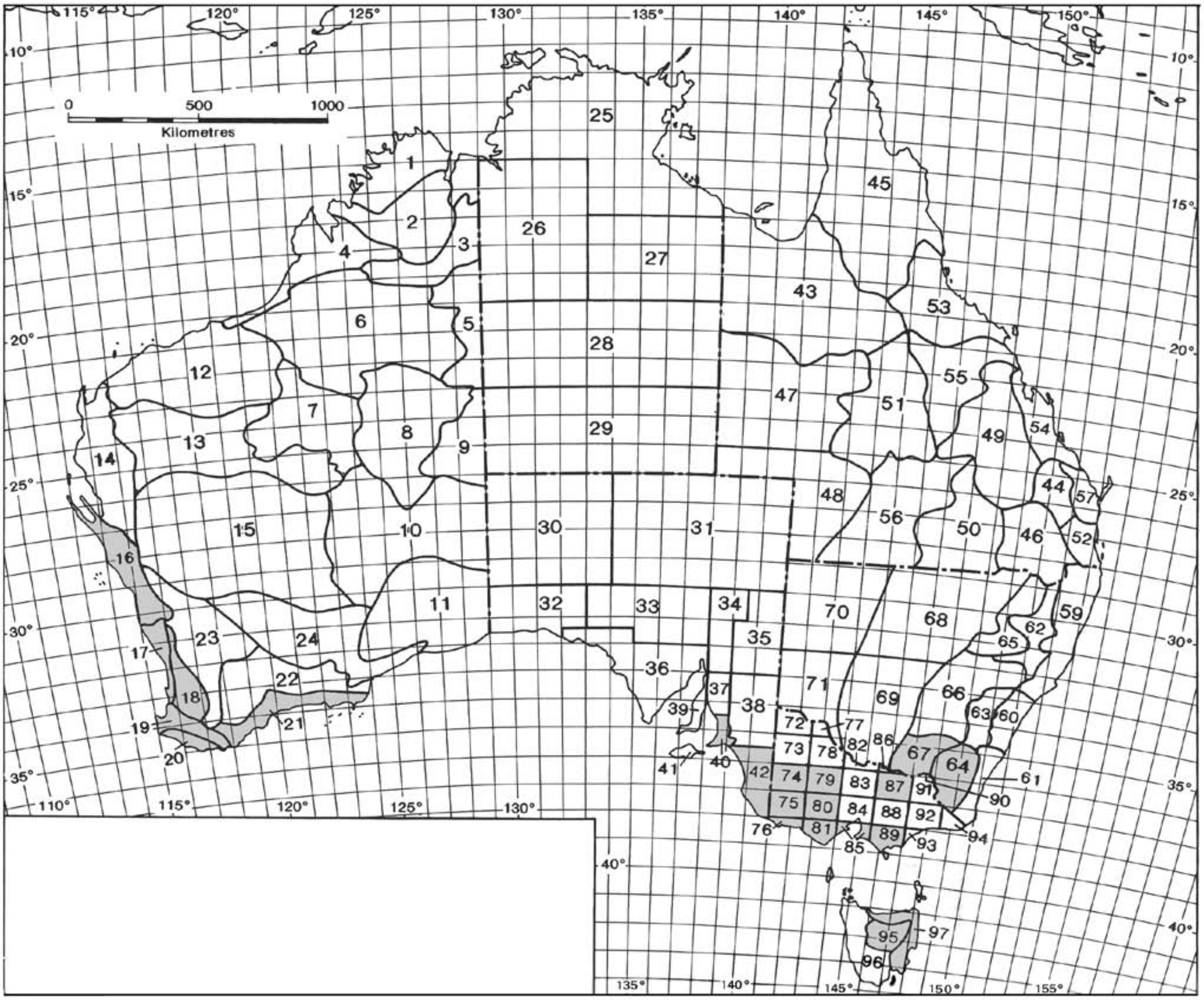

Fig. 3. The Australian botanical subdivisions (shaded) in which *Isoetes drummondii* A.Braun has been recorded (boundaries after Hnatiuk 1990).

Benson & Howell (1990) propose that at the time of European settlement, the higher terraces were covered by woodlands dominated by *Eucalyptus moluccana* (Grey Box) and *Eucalyptus tereticormis* (Forest Red Gum) with an open grassy understorey. Mangroves, *(Avicennia marina*) and samphires (Chenopodiaceae) are likely to have colonised the river margins below the tidal limit (approximately below Charles Street) while *Phragmites australis* (Common Reed) and *Melaleuca linariifolia* (paperbark), and *Angophora floribunda* (Rough-barked Apple) occupied wetter and drier areas on the river terraces respectively. Clearing and cultivation of the higher river terraces at Parramatta was carried out by convict gangs between 1789 and 1791, and the first crops including wheat, barley, oats and maize, were planted on ground broken up by hoe and fertilised by the ashes of burnt native vegetation.

Excavation results (Casey & Lowe 2004) confirm that the George and Charles Streets archaeological site, which is about 5 m above present day river level, was part of town leases occupied by five wattle-and-daub 'convict huts' by c. 1790. By c. 1809 the five properties were leased by emancipated convict and free settlers. In 1823, all Parramatta residents 'who could show no better claim to the portions they now occupy than mere sufferance [were invited to] apply for [21 year] leases' (Jervis 1961, p26) and a contemporary plan (Fig. 5) shows the archaeological site had been formally subdivided and occupied by diverse tenants although none of the six allotments are known to have been used for the agistment of stock from southern New South Wales. Subsequent residents appear to have occupied the early dwellings until at least the 1830s. By the mid 1850s, Lots 69, 70 and 72 were owned by William Brynes, a successful entrepreneur who built and occupied a large house and other commercial premises on the corner of George and Charles Streets. The Byrnes family controlled these three properties into the early 20th century and presumably used the area at the rear (river-side) for accommodating the various pets whose remains were uncovered during the excavation:

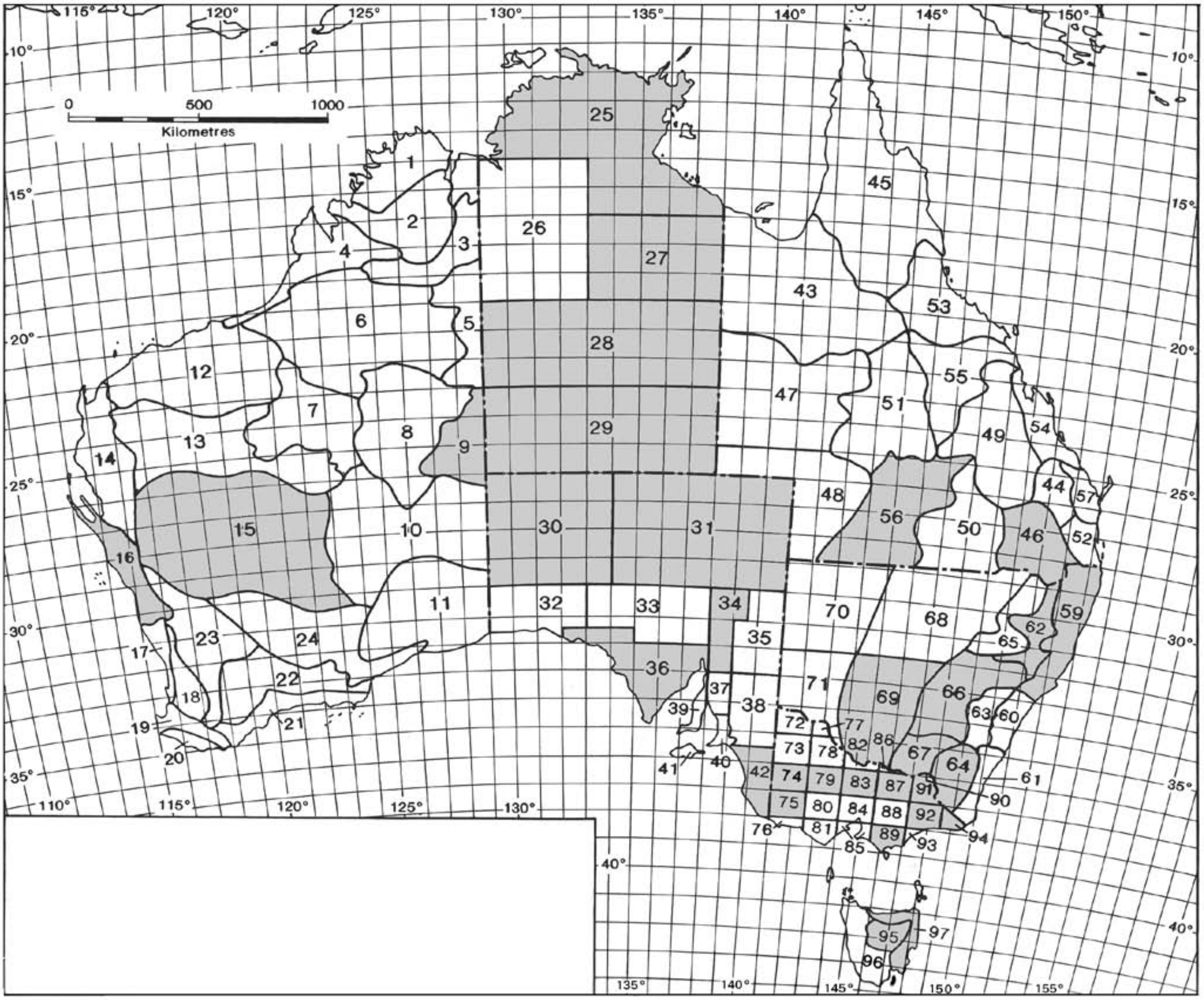

Fig. 4. The Australian botanical subdivisions (shaded) in which *Isoetes muelleri* A. Braun has been recorded (boundaries after Hnatiuk 1990).

a pony, a horse, a dog, two calves and possibly other animals. Lot 69 and part of Lot 70 were subsequent leased to a Chinese market gardener, Ah Chee, between 1905 and the 1930s. Two warehouses occupied the same property by the 1960s.

Fossil *Isoetes* microspores

Fossil *Isoetes*-type spores were recovered from buried deposits on Lots 69 and 70, which backed onto the c. 2 m high escarpment leading down to the present-day floodplain of the Parramatta River, and Lot 72, which fronted onto George Street (Fig. 5, Appendix 1). In all instances the sediments appear to be redeposited alluvium (R. Lawrie pers. comm.) that had undergone varying degrees of modification since 1788. For example, one of the two deposits preserving *Isoetes drummondii*-type spores on Lot 69 (ACN 2425) included whole and fragmented bricks, oyster shells, and fishbones and scales; the sample preserving *Isoetes muelleri*-type spores from Lot 70 (ACN 2202) comes from a section that had been heavily modified by market gardening and other 20th century activities. In contrast, *Isoetes* cf. *muelleri* spores found on Lot 72 (ACN 2791) were preserved in an essentially unmodified silty sand used as packing around a post that may have been part of a 1790s convict hut.

Many of the microspores are partially disrupted or unfavourably orientated, but sufficiently well-preserved/orientated specimens were found to determine their affinity using reference microspores recovered from herbarium specimens of commonly occurring *Isoetes* species in southeastern Australia (Plate 1, Figs A–K).

Age

The presence of pollen from introduced taxa, in particular pine (Pinaceae), and widely naturalised weeds such as cereals (Poaceae pollen > 60 µm in minimum diameter), dandelions (Asteraceae: Liguliflorae) and plantain

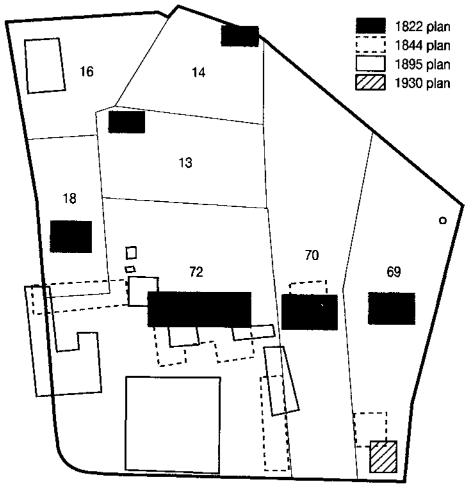

Fig. 5. The George and Charles St Parramatta site showing subdivision of into allotments in 1822 and location of buildings on the site up to 1890.

(*Plantago lanceolata*-type) are routinely used to distinguish sediments accumulating before and since European settlement (Macphail 1999). In some instances, a more precise age can be inferred if planting times have been recorded. The minimum age of the samples is less easily inferred because of the longevity (and replanting) of exotic trees such as pines (*Pinus* spp.) and oaks (*Quercus* spp.), and also because short-lived exotic herbs such as cereals and dandelions became widely naturalised during the late 18th and early 19th centuries.

A necessary condition is that the exotic pollen accumulated at the same time as the deposit in which they are preserved (in situ occurrences). Although this can be demonstrated for some soils buried to depths of 30 cm or less on some historical archaeological sites (Macphail 1999), several factors at the George and Charles Streets archaeological site make it likely that some pollen and spores have infiltrated the soil profile in rainwater or down cicada burrows. These factors include the high porosity/permeability of the A_1 and A_2 horizons, the high degree of bioturbation and the presence of illuvial clay laminae in the B horizon. Tillage and trampling by stock can also lead to the incorporation of younger material into older sediments. For example, all assemblages (Table 1) include low to frequent numbers of Liguliflorae pollen that are identical to those produced by the European dandelion, *Taraxacum officinale* and other introduced species such as the Common Sowthistle, *Sonchus oleraceus* L. A native source is considered improbable since the nearest species producing a similar pollen morphotype, *Microseris scapigera* (Walp.) Schultz-Bip and *Sonchus hydrophilus* Boulos, are mostly restricted to high elevations on the Blue Mountains west of the Cumberland Plain.

Liguliflorae, and other definite exotic pollen types such as Pinaceae (Table 1), support the archaeological data that the alluvium preserving fossil *Isoetes* microspores on Lots 69 and 72 have accumulated sometime between 1790 and the 1830s. The modified soil represented by ACN 2202 on Lot 70 is likely to be younger than c. 1830, or may be contaminated with younger material, based on (a) the low relative abundance of *Eucalyptus* and *Allocasuarina*/*Casuarina* pollen relative to other samples and (b) the significant representation of exotic pine and fruit tree (*Malus*-type) pollen.

Discussion & conclusions

Isoetes is the only widespread surviving genus of a geologically ancient order of heterosporous fern allies (Isoetales) whose origins lie in the shrub- and tree-sized lycopods forming the first terrestrial forests in the Devonian. A review of the palynological literature indicates fossil *Isoetes* microspores have not been recovered from any Australian Neogene sediment and are extremely rare in Holocene or earlier Quaternary deposits outside of southern Tasmania (see Macphail 1979). Although many mainland Quaternary sequences are situated within the modern range of *Isoetes*, the only known records of its microspores comes from earliest Pleistocene deposits near Daylesford, central Victoria (K. Sneiderman pers comm.), and Holocene estuarine sediments in Wilson Inlet, Denmark in southwest Western Australia (Macphail 1998). A not unlikely explanation is that *Isoetes* microspores have been overlooked or misidentified.

All living *Isoetes* possess leaves that superficially resemble low sedges or grasses, and are easily overlooked in botanical surveys (cf. Duncan & Isaac 1986). Nevertheless the absence of *Isoetes* on the Central Coast and Central Tablelands of New South Wales is difficult to explain, given the wide distribution and broad climatic tolerance of the genus within Australia. For example, *Isoetes muelleri* ranges from subalpine and alpine lakes in Tasmania to semi-permanent soaks and ephemeral pools in arid Central Australia, including on the top of Uluru/Ayres Rock, and in dune swales in the Simpson Desert (Jessup 1981, Hnatiuk 1990, Chinnock 1998).

The absence of archaeological and documentary evidence for natural or artificial ponds makes it highly unlikely that *Isoetes* had been deliberately introduced onto any of the three Parramatta allotments by stock. Conversely the documentary and fossil pollen evidence provides strong circumstantial evidence that *Isoetes* microspores could have been carried up in domestic water from ponds on the lower floodplain of the Parramatta River, between 1790 and 1840. The same deposits preserve spores of liverworts (form genera *Cingulatisporites*, *Rudolphisporis*) and mesophytic ferns (*Calochlaena*, *Pteris*, unidentified monolete and trilete species) as well as pollen of semi-aquatic (Cyperaceae, *Lemna*), and saltwater-tolerant (Chenopodiaceae) herbs.

If correctly interpreted, the microfossil data from the Parramatta and Richmond archaeological sites demonstrate that two or possibly more species of *Isoetes* were growing in wet habitats on the Cumberland Plain in the early Colonial period. If so occurrences were probably relatively rare.

The botanist Robert Brown collected extensively on the Hawkesbury and Grose Rivers in 1802–5, but did not record *Isoetes*, although he recorded the aquatic fern *Azolla*, which might be expected to occupy similar habitats to *Isoetes*. Nor does Bentham indicate any records of *Isoetes* in New South Wales in his *Flora Australiensis* in 1878 (D. Benson pers. com).

The corollary that European activities were responsible for their subsequent local extinction seems unavoidable. Intensive grazing may have been a factor since *Isoetes drummondii* subsp. *drummondii* is recorded as being palatable to introduced stock and native animals in Tasmania (see Chinnock 1998). Against this, the abundance of domestic waste in the Richmond waterhole shows that the *Isoetes* population was clearly tolerant of moderate levels of disturbance and pollution. Hence we speculate that that *Isoetes* may still survive in long-protected remnant wetlands on the Cumberland Plain. On the wider scale, the presence of *Isoetes* in the Central Coast botanical subdivision 'bridges' the biogeographic gap between populations on the Southern Tablelands and Central-Western and South-Western Slopes, and those on the North Coast and Northern Tablelands botanical subdivisions. We conclude therefore that the disjunct distribution of *Isoetes* in New South Wales also is likely to reflect European activities.

Note Added In Proof

Since this paper was prepared, *Isoetes drummondii*-type microspores have been found at a site at 95–101 George St., Parramatta in contexts that can be securely dated by the associated archaeological evidence (W. Thorpe pers. comm.). These are (1) a well-preserved specimen in soil infilling a hoe mark in a c. 1790–1800s orchard [ACN 791] and (b) a poorly-preserved specimen in organic-rich silts infilling an 1830s waterhole [ACN 1037].

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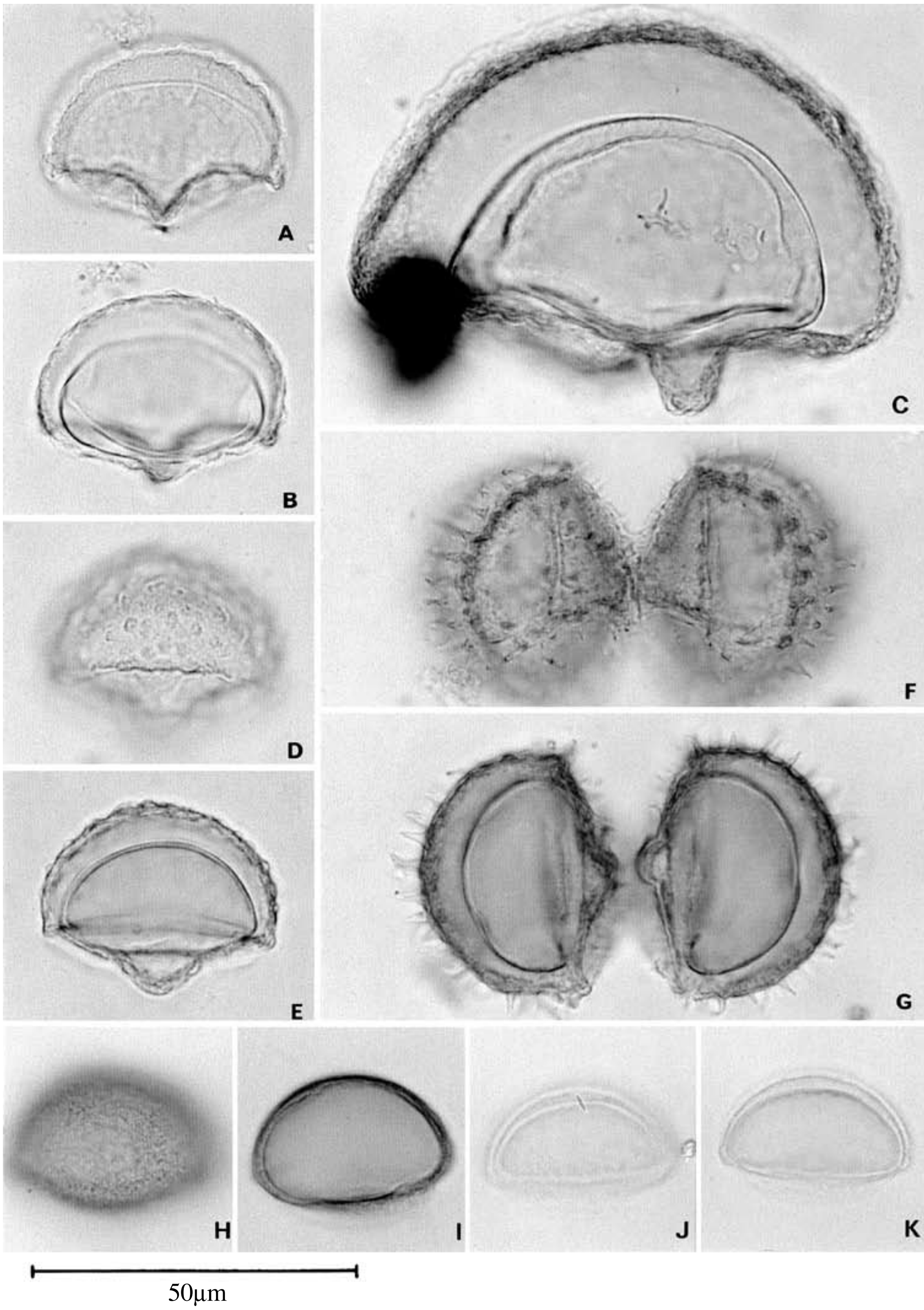

Plate 1: Microspores of living *Isoetes* species

All photomicrographs taken at x788 magnification (50 µm scale bar). Specimens are mounted in glycerol jelly unless otherwise noted. **Figs A–B.** *Isoetes drummondii* A.Braun subsp. *anomala* C.R.Marsden & Chinnock. Microspores in surface (Fig. A) and median (Fig. B) optical section showing laminated perine and weakly-developed 'keel'. Cultivated plant, Royal Botanic Gardens, Sydney. NSW629437. **Fig. C.** *Isoetes elatior* F.Muell. Microspore in median optical section showing laminated perine and well-developed 'keel'. Specimen collected by W.H. Archer. Locality and date not recorded on herbarium sheet but probably from Lake River, Longford, Tasmania, circa 1910). **Figs D–E.** *Isoetes pusilla* C.R.Marsden & Chinnock. Microspores in surface (Fig. D) and median (Fig. E) optical section showing shallow verrucate perine and well-developed 'keel'. Specimen collected from near Chiltern, Victoria, by H.B. Williamson, November 1910. NSW629447. **Figs F–G.** *Isoetes muelleri* A.Braun. Pair of attached microspores showing echinate perine and well-developed 'keel'. Cultivated plant, Royal Botanic Gardens, Sydney. NSW492905. **Figs H–I.** *Isoetes gunnii* R.Br. Microspores in surface (Fig. H) and median (Fig. I) optical section showing finely scabrate perine and weakly-developed 'keel'. Specimen (mounted in silicon oil) collected from Pine Lagoon, central Tasmania by D.J. Morris, 25 April 1974. HO 444280. **Figs J–K.** *Isoetes humilior* F.Muell. Microspores in surface (Fig. H) and median (Fig. I) optical section showing psilate perine and weakly developed, ± hyaline 'keel'. Specimen (mounted in silicon oil) collected from the entrance to Little Pine Lagoon, central Tasmania 17 January 1991 (collector not recorded on herbarium sheet). HO 142945.

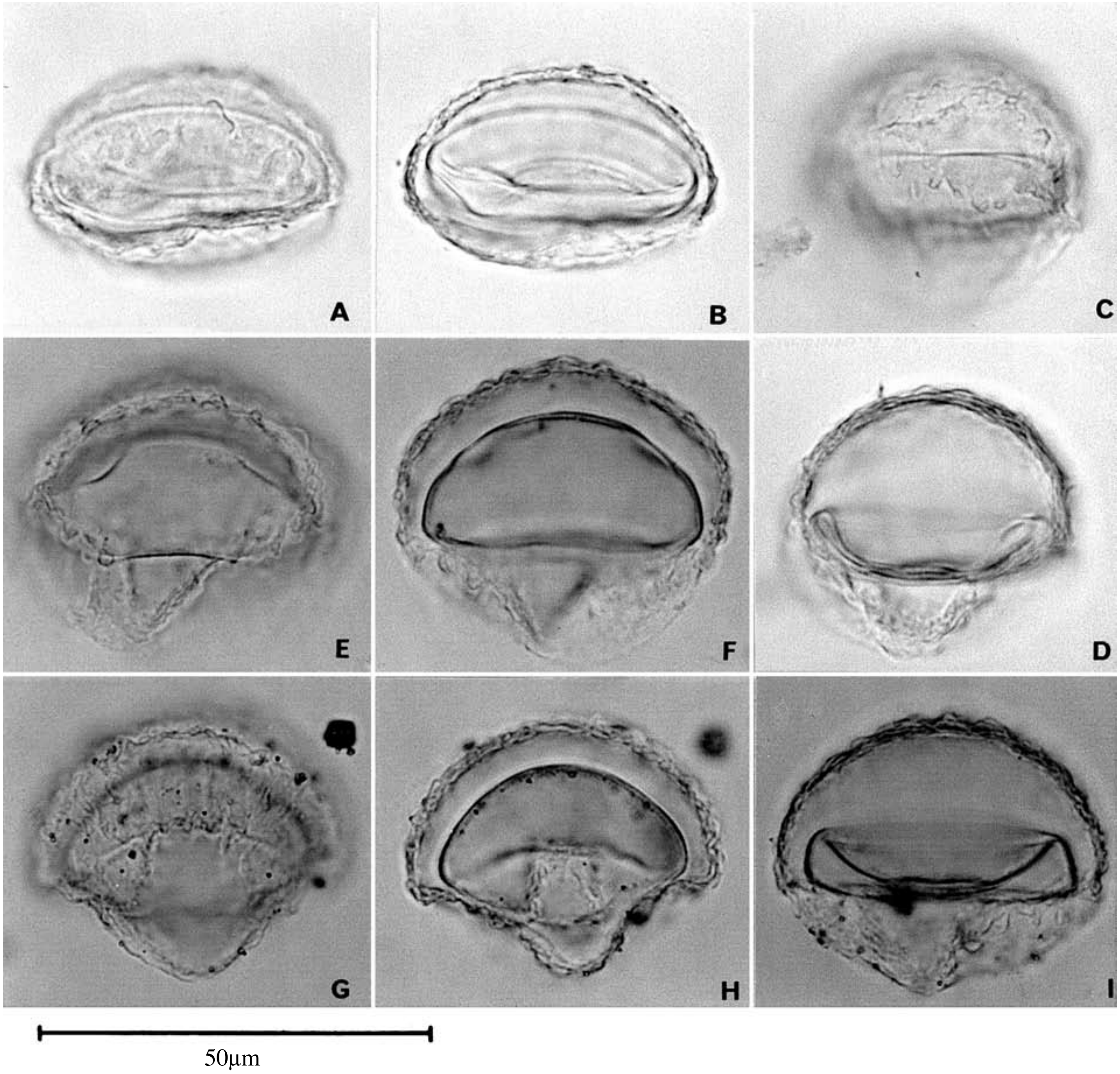

Plate 2: Fossil microspores assigned to *Isoetes drummondii* subsp. *anomala*-type

All photomicrographs taken at x788 magnification (50 µm scale bar) **Figs A–B.** Microspore in oblique surface (Fig. A) and median (Fig. B) optical sections section showing laminated/verrucate perine and well-developed 'keel'. George and Charles Streets Parramatta archaeological site: Lot 69 Area 15 ACN 2430. **Figs C–D.** Microspore in surface (Fig. C) and median (Fig. D) optical sections section showing laminated/verrucate perine and well-developed 'keel'. George and Charles Streets Parramatta archaeological site: Lot 69 Area 15 ACN 2425. **Figs E–F.** Microspore in surface (Figs E) and median (Fig. F) optical sections section showing laminated/verrucate perine and well-developed 'keel'. 1.20 m depth below ground surface. Richmond archaeological site. **Figs G–I.** Microspores in median optical sections section showing laminated/verrucate perine and well-developed 'keel'. 1.00 m depth below ground surface. Richmond archaeological site.

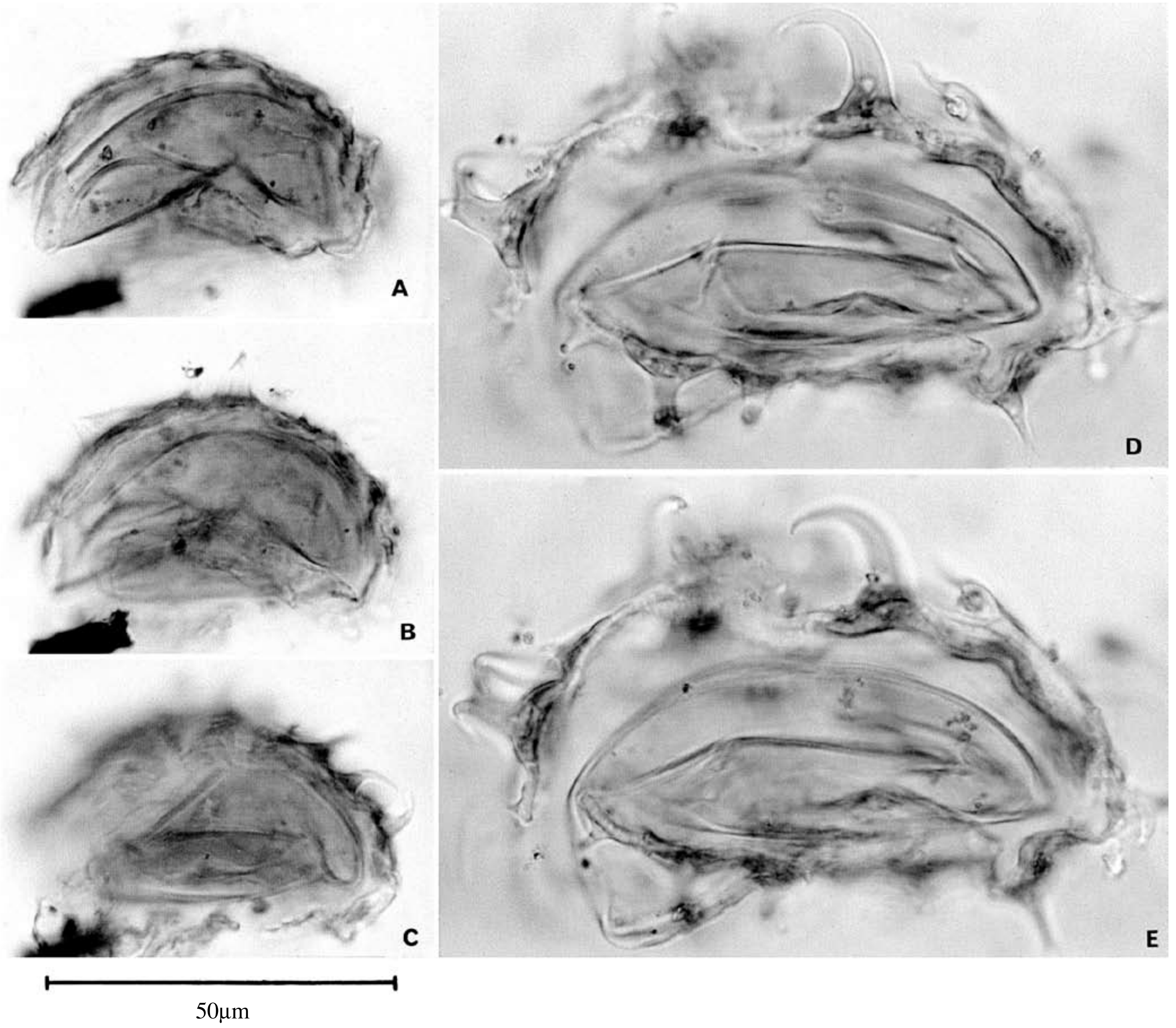

Plate 3: Fossil microspores assigned to *Isoetes muelleri*-type

All photomicrographs taken at x788 magnification (50 µm scale bar) **Figs A–C.** Relatively small microspore in oblique surface (Fig. A) and median (Figs B, C) optical sections showing echinate perine. George and Charles Streets Parramatta archaeological site: Lot 70 Area 15 ACN 2202. **Figs D–E.** Large microspore in median optical section showing robustly echinate perine. George and Charles Streets Parramatta archaeological site: Lot 72 Area 13 ACN 2791.

Appendix 1

Description of fossil *Isoetes* microspores from Parramatta

Isoetes drummondii-type (Plate 2, Figs A–I).

Description — Microspores are monads, heteropolar bilateral, monolete; laesura obscure but probably long and straight on the protruding (proximal) face; amb elliptical in polar view, biconvex in equatorial view; cell wall consisting of inner (exine) and outer (perine) layers which may become separated during the fossilisation process; exine thin, < 0.8 µm, ±hyaline; perine relatively thick ~1.6 µm, optically dense (laminated?), sinuous with scabrate-verrucate sculptural elements; Maximum measurement 33–36 x 36–42 µm (4 specimens).

Fossil distribution — George and Charles Streets Parramatta archaeological site: Lot 69 Area 15 ACN 2425 (2%) & ACN 2430 (4%), Area 16 ACN 2484 (trace). Richmond archaeological site: Samples 4 to 11 (2–45%).

Comment — Perine ornamentation in microspores of *Isoetes drummondii* A.Braun subsp. *anomala* C.R.Marsden & Chinnock varies from shallow indistinctly formed rugulae (Plate 1, Figs A–B) to well-developed verrucae which occasionally expand into longer protrusions. The fossil microspores recovered from the Parramatta and Richmond archaeological sites closely resemble the latter morphotype in that (i) the 'laminated' perispore is distinctly ornamented with irregularly distributed, low verrucae that occasionally expand into longer protrusions and (ii) the perispore 'keel' is well developed. The Victorian endemic species *Isoetes pusilla* C.R.Marsden & Chinnock produces ± identical microspores (Plate 1, Figs D–E) and this also is likely to case with microspores produced by *I. drummondii* subsp. *drummondii* C.R.Marsden & Chinnock. The perispore in the other *Isoetes* species found in Victoria and/or Tasmania, viz. *I. elatior* F.Meull. ex A.Braun (Plate 1, Fig. C), *I. gunnii* A.Braun (Plate 1 Fig. H–I) and *I. humilior* F.Muell. ex A.Braun (Plate 1, Fig. J–K) lack well-defined sculptural projections as do the Western Australian endemics *I. inflata* E.R.L.Johson, *I. mongerensis* E.R.L. Johnson and *I. tripus* A.Braun (see Chinnock 1998): Whether the perine of microspores produced by *Isoetes coromandelina* L. f. subsp. *macrotuberculata* C.R.Marsden, and *I. cristata* C.R.Marsden & Chinnock is ornamented is unknown (see Johnson 1984, Chinnock 1998).

Isoetes muelleri-type (Plate 3, Figs A–C).

Description — Microspores are monads, heteropolar, bilateral, monolete; laesura obscure but assumed to be long and straight on the protruding (proximal) face; amb elliptical in polar view, biconvex in equatorial view; cell wall consisting of inner (exine) and outer (perine) layers which may become separated during the fossilisation process; exine thin, < 0.8 µm, ± hyaline; perine thick ~2.5 µm, optically dense, surmounted by scattered, recurved (thorn-like) echini to 12 µm long with bases ~4 µm wide. Maximum measurements 38 x 56 µm (1 specimen).

Fossil d*istribution* — George and Charles Streets Parramatta archaeological site: Lot 70 Area 15 ACN 2202 (trace).

Comment — The species is distinguished from *Isoetes drummondii* subsp. *anomala* and other Australian species for which reference material is available, by short to long thorn-like protrusions (echini) on the perine. Some of the taller sculptural elements appear to be solid whilst others appear to be vacuolate and more strap-like in bright field optical section. Other *Isoetes* species described by Chinnock (1998) as producing spinulose to spinose or baculate/digitate microspores are endemic to Western Australia (*I. australis* R.S.Williams, *I. caroli* E.R.L.Johnson) and southeastern South Australia (*I. attenuata* C.R.Marsden & Chinnock)

Isoetes sp. cf. *I. muelleri* A. Braun (Plate 3, Figs D–E).

Description — Microspores are monads, heteropolar, bilateral, monolete; laesura obscure but assumed to be long and straight on the protruding (proximal) face; amb elliptical in polar view, biconvex in equatorial view; cell wall cell consisting of inner (exine) and outer (perine) layers which may become separated during the fossilisation process; exine thin, < 0.8 µm, ± hyaline; perine thick ~3.5 µm, surmounted by scattered recurved (thorn-like) echini to 16 µm long on bases to 8 µm wide; Maximum measurements 64x105 µm (1 specimen).

Fossil d*istribution* —George and Charles Streets Parramatta archaeological site: Lot 72 Area 13 ACN 2791 (1%).

Comment — The species is distinguished from reference specimens of *Isoetes muelleri* A.Braun by its much larger size (106 µm vs 56 µm) and the robust ornamentation. Vacuoles occur within the bases of the larger echini. Whether the morphotype represents a different species or is a large (polyploid?) variant of *Isoetes muelleri* is unknown.