The Avon Heathcote Estuary – Ihutai

In the late 70s I completed a PhD at the University of Canterbury, New Zealand called The Environmental Geology of the Avon-Heathcote estuary.

I came to some surprising, counter-intuitive, conclusions, and published a couple of papers based on my research in the mainstream earth science peer-reviewed literature.

It was an innovative, richly ideated piece of work. Reviewing it, all these years later, I believe it still deserves to be taken seriously. It stands up well.

Check at www.macpherson.co.nz for the latest iteration of this paper – I'm taking a fresh look at my PhD work (the detail is excellent), and will re-interpret some of the core logs to focus on particular aspects and draw more focused conclusions.

This paper looks at the evidence for post-European mud – anthropogenic mud – caused by the major disruption to the estuary's catchment when the first settlers arrived. To quote from my thesis:

"The first European settlers arrived in the Christchurch area in 1850, and by 1875 the population had risen to more than 10 600 (Retter, personal communication). Early maps of the area (known as Black Maps and held by the Lands and Survey Department, Christchurch - see Scott (1963) for a redrafted version) indicate that in about 1850 the area which is now Christchurch City was predominantly wet marshy land, with shallow ponds and shaking bogs, vegetated with rushes, flax and ferns. To the east the older parts of the dune complex were covered with grasses and Manuka, while the youngest, easternmost dunes were unvegetated.

"Areas of open grassland were interspersed between the swamps and sandhills. In the earliest days of settlement surface water in the area was clear and pure in appearance, and quite suitable for drinking (Scott, 1963, p.68). However, as the population grew, the quality of the surface water declined, and after rain the area was often a " ... pestilential swamp" (Hercus, 1942). Although early drainage works were undertaken by the Canterbury Provincial Council, a lack of unanimity and purpose meant that it was 1878 before the newly formed Christchurch Drainage Board (CDB) could begin an underground sewage and stormwater network. By 1901, 54 km of pipes were laid, and 3.2 X 10 6 gallons of effluent flowed daily to a sewage farm near the present day oxidation ponds (immediately to the west of the estuary). As a result the quality of surface water in the area improved, and in 1890 the Colonial analyst reported that water entering the estuary after passing through the new sewage farm was " ... deprived of any harmfull constituents" (Hercus, 1942, p.57)."

"Although it was never intended to, the sewage system altered surface runoff characteristics. By 1930, a minimum of 600 gallons/acre/day of groundwater entered the sewers from the City area (Scott, 1963), reducing surface runoff from unpaved areas as a result.

The significance of this effect is illustrated by the observation that in 1930, 30% of the freshwater catchment of the [estuary] which covers 73[2] miles and contains 75 miles of natural watercourses was serviced by sewers, with a total length of 152 miles (Scott, 1963)."

Anthropogenic mud

One of the key themes in my narrative was[1] the discovery of a layer of unusual mud, sometimes visible on the intertidal flats, sometimes buried under younger sediment, that I identified as 'anthropogenic' – a result of the events described above.

First, some geology

The stratigraphy (the 'layering') of sediment underlying the surface of this estuary, as evident in 1978, was complex within some fairly narrow parameters, and highly variable across the basin.

From oldest to youngest, the usual sequence was:

- A 'basement' of pre-estuarine clean, mud-free, open-ocean sand that pre-dates the formation of the estuary (some time between 450 and 2,000 years ago). This was my unit A
- Above the ocean sand, there was a sequence of sandy and muddy sediment, commonly about 2 metres thick, but variable in thickness, that was deposited after the estuary was enclosed. This was unit B
- Within this estuary sequence was an upper, sometimes uppermost, layer of plastic, olive-coloured mud and sandy mud, interpreted by me to be immediately post-European, representing a biologically catastrophic response to the arrival of the settlers. This was unit C

- In my thesis I said that unit C overlay (was younger than) unit B. This may have misled Deely and others. Looking back at my core logs, it's more accurate to say that unit C was interlayered within unit B. Usually, when it was present, it was the uppermost layer, but not always. Deposition of unit C was an interlude. Sometimes, in some places, unit B 'business as usual' returned.

While the olive plastic mud of unit C in my stratigraphy was commonly massive (structure-less) in appearance, it was also sometimes laminated (for example, in core 13), and sometimes rich in coarse, leafy (probably *Zostera* leaves) and shelly organic debris. I used the term 'organic hash' in a number of my core logs.

The contact between unit C and Unit B beneath it was usually sharp, with a major textural break, but in a few cores the contact was gradational, with interbedded sand and mud grading up through sandy plastic mud to plastic mud (cores 37 and 41 for example).

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[1] I'm writing this paper in the past tense. Post earthquakes and extensive liquefaction, many of the subsurface features that I described in 1978 will have been destroyed. My 1978 estuary no longer exists.

What and where was unit C?
Cores with a layer of olive plastic mud occurred throughout the estuary, with the thickest recorded from the north-west corner. However not all cores contain unit C mud. By 1978 it had been eroded from some mid to low-tide locations.

There was no apparent relationship between occurrences of plastic mud and water depth at high tide, and the unit was apparently deposited throughout the estuary. Because of its cohesiveness it was (and if it still exists, will be) more resistant to erosion than other sediment, and was exposed at the surface in many locations in the estuary.[2] When exposed on the higher intertidal flats unit C tended to be rich in coarse organic debris (leafy material, twigs and shell fragments), and had a fibrous, crumbly texture.

Unit C had a mean mud content of 80% (s = 17%, N = 15), a sand fraction mean diameter of 3.08 psi (s = 0.16 psi, N = 10), and a mean sorting of 0.47 (s = 0.04, N 10). The mean thickness of the unit, from four apparently complete sections (with gradational or planar contacts - cores 17, 22, 39 and 46) was 25 cm, and the average height above datum of the top of the unit was 8.96 m.

While unit C sediment was different in appearance from both overlying (younger) and underlying (older) sediment, it had a markedly uniform appearance from core to core, and very similar physical properties. Figures 63 and 64 in my thesis show the granulometric properties of unit C sand, which was finer and poorer sorted than any of the subgroups of the underlying unit B, and there was no relationship between the sand properties of unit C and water depth.

Unit C sediment is different from any other sediment in the AHE, both ancient and modern; it was deposited as a thin blanket throughout the estuary – in many places where fine sediment had not previously been deposited, and where it has not been deposited since.

What does unit C tell us?
It was deposited during a period of very much higher than usual suspended sediment concentrations – in other words from exceptionally muddy water that flooded the whole estuary, and:

1. It was deposited relatively rapidly and at uniform rates
   - hence the absence of layering, indicating that mud supply was at a more or less uniform rate
   - hence the independence (lack of relationship between) of sand fraction properties, muddiness, and high tide water depth
2. It was deposited for some time – several decades.

[2] My Thesis Figure 62 is a photo-montage of surface 'outcrops' of unit C. The individual photos have been scanned and are available for inspection at www.macpherson.co.nz

To summarise, unit C's depositional environment – the conditions under which it formed – were characterised by exceptionally and consistently muddy water, for an extended period. There had been nothing like it, before or since.

The only event likely to have flooded the estuary with mud, for long enough to build up of tens of centimetres of sediment, was extensive earthworks – roading, drain-cutting, building – in its neighborhood during the third quarter of the 19th Century. If this Interpretation is correct, the unit B/unit C contact can be dated at about 1850, and the upper contact some time between 1875 and 1900.

If unit C was deposited at an average thickness of 50 cm throughout the estuary, this would represent an accumulation rate of 2 cm/year for the 25 year period 1850-1875 (or a slower rate if the event lasted until the turn of the century) a total of $3.0 \times 10^6\ m^3$ of sediment, which corresponds to the figure predicted in Part One (and in detail in Appendix 1) for the decrease in the tidal compartment during this period.

So what did it look like?
Go to Thesis Figure 62: Surface occurrences of post-European anthropogenic mud – subsurface stratigraphic unit C – in the Avon-Heathcote Estuary, for the original 1 page photo-montage, or to the web page linked from www.macpherson.co.nz for the individual scanned photos.

What do these photos, and my captions, tell us about unit C?

1. It is distinctively different from all other sediment in the estuary
2. There is only one layer of sediment with its defining characteristics
   Careful re-analysis of my core logs indicate that the depositional event represented by this layer was unique, exceptional, and contemporaneously widespread in the estuary

3. It was consolidated enough to break off in lumps at erosion edges
4. When exposed at or near the high water mark unit C was often rich in organic material – leaves, shells and organic hash, an assemblage similar to the accumulations along the modern high water mark.
5. It was commonly exposed at the surface at the edges of the estuary
6. Its upper surface was usually intensively bored by bottom-living animals
7. It dipped at a lower angle offshore than the contemporaneous surface.
   This last point is very important – it shows that unit C accumulated when the estuary was appreciably shallower than it was in 1978
8. Cores collected offshore from the eroding edge of unit C did not contain any of unit C – it had been eroded away.

At the time I made my observations (and took my photographs) the presence of unit C seemed unremarkable. I had identified the presence of an anthropogenic mud layer, evident in subsurface logs and on the surface.

Now, in 2014, in the light of an alternative interpretation by Deely, and with the benefit of the work of others, and after the impact of the 2011 earthquakes, these observations assume a greater significance. Could it have accumulated in the early to mid 20th century as JM Deely claimed? All of the physical evidence says no, and in the absence of a feasible process, or contemporary observations, it cannot have done so. Deely was wrong.

Does it represent an anthropogenic layer, with a mid to late 19th century age, deposited as a result of the early settlement of Christchurch? The voices of the time say it almost certainly did, and there is no credible contradictory evidence.

The process is explicable, the remnant unit C sediment has the appearance of an 'old', consolidated sedimentary unit, and its dip directions (the sedimentary surface at the time of deposition) show that it accumulated in an appreciably shallower estuary. The evidence is overwhelming. I was right.

Notes:

1. What's the relationship of the historical unit C with contemporary surface mud in the estuary – especially in the two long-term mud depositories in the Heathcote basin and on the northeast slopes?

   Good question. Some cored occurrences of unit C appear to be overlain by unit B-like material, suggesting that unit C deposition was an interlude, to be replaced by 'business as usual' layered sand.

   Could it be that in the mud depositories, mud has been continuously present since 1850 (and maybe before). Some of it may be equivalent to unit C, in other words, stratigraphically equivalent to unit C

2. What does the occurrence and provenance of unit C tell us about likely responses to the 2011 earthquakes, and to possible future engineering works?

3. What about the on-shore, estuary-adjacent work of the NIWA tsunami-hunters? Burning at the time of Maori arrival. Does this correspond to Deely's black layer?
4. And as a nice endnote, Deely's pollen analysis shows that Maori deforestation may have caused a smaller but analogous event – a precursor of the much more dramatic post-European environmental impact. Logs from adjacent salt marsh logs reinforce this possibility. A potent area for future research?

Version control
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