FAN DELTA GEOMETRY OF THE LOWER BURDEKIN RIVER SYSTEM, NORTH QUEENSLAND

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SIGNIFICANCE OF THE BURDEKIN DELTA

The Burdekin Delta is a major Australian irrigation area with more than 35,000 ha of irrigated sugarcane and other crops. Natural flows along the river have been extensively modified by dams and there has been extensive groundwater extraction, resulting in high risk of intrusion of marine waters. The system overlies major groundwater supplies, is close to environmentally sensitive wetlands, waterways, and estuaries, and discharges into the lagoon of the Great Barrier Reef (LBI 2004). Water management practices have evolved over the last few decades in response to local needs, including riverbed sand dams, extraction of river water to distribution channels, and artificial replenishment of the groundwater systems.

Because of the importance of hydrogeology in water management in the Burdekin Delta there has been a long history of subsurface investigations since the 1960s when such data began to be kept (Narayan *et al.* 2003, Bistrow *et al.* 2000, McMahon *et al.* 2000, Wiebenga *et al.* 1975, Arunakumaren *et al.* 2000). The Delta has also been long used as one of the type examples of deltaic sedimentation since the pioneering work of Coleman & Wright (1975). Major studies include those undertaken by Coleman (1976), Galloway (1975) Pringle (1984, 2000), and Fielding *et al.* (in press).

The economic significance and environmental sensitivity of the Burdekin Delta has made it the subject of ongoing research by many agencies. A recent CRC LEME investigation (Lawrie *et al.* 2004) carried out geophysical logging of 73 key bore holes and a literature review of the Cainozoic stratigraphy in the Burdekin Delta. The geophysical logging was of selected nested piezometer monitoring boreholes in the Lower Burdekin Delta study area. Techniques used were induction (conductivity) and gamma radiometric logging. Two recently drilled holes were geologically logged in detail to validate historical geological descriptions. Both the geophysical and geological logs were used to assess the suitability of the data for a more thorough sedimentary architecture study of the Lower Burdekin.

This paper uses the data evaluated in that study to place the sediments of the Burdekin Delta in an overall geomorphic context—an approach that has not been taken since the work of Hopley (1970).

CURRENT MODELS OF THE BURDEKIN DELTA

Previous sedimentological studies of the Burdekin Delta have concentrated on the Holocene system. The earliest of these focused on the seaward margin and recognised the dominance of wave (Galloway 1975) or mixed wave-tide (Coleman & Wright 1975) sedimentary processes. A more recent study (Ozestuaries undated) classified the estuarine funnel of the Burdekin delta as tide dominated. Other studies (Pringle 1984, 2000) described the extensive wave-dominated coastal tract. The most recent study (Fielding *et al.* in press) explains the Burdekin Delta within the context of a river flood dominated depositional system. As the elephant is to the blind sages, so the Burdekin Delta is many things to many researchers.

Can these differing interpretations be reconciled? Partly, as is the case of the parabolic elephant, researchers have been studying different aspects. Thus, while the bulk of the Burdekin Delta sediments were deposited during river floods, these have undergone extensive wave and some tide reworking, resulting in the prograding spit of Cape Bowling Green.

This then highlights another aspect, the fact that all of these studies have focussed on aspects of the Holocene succession, rather than the whole. Even the sediments of the Holocene Burdekin Delta are a small part of a much larger Late Neogene depositional system. Prior to the Holocene the Burdekin River flowed north, rather than east, following the course of what is now the Haughton River (Woolfe *et al.* 1998, Fielding *et al.* 2003). The presence of thick pre-Holocene sediments beneath the modern Delta (ca. 150 m beneath Cape Bowling Green) shows that this switching has occurred repeatedly throughout the Late Neogene. Any understanding of the modern Burdekin Delta must therefore occur within the framework of the larger Neogene delta complex of which it is the most recent component.

DEM AND GEOMORPHIC INFORMATION

The extreme flatness of the Burdekin landscape, laser levelling of fields for flood irrigation, and dense

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sugarcane cultivation has obscured many subtle geomorphic features. Apart from the Burdekin River, its major distributaries and some abandoned channels, only a few bedrock hills disrupt the flatness of the landscape away from the beach ridges and tidal channels of the coastal zone. The recent acquisition of laser altimeter data has resulted in a new, high resolution Digital Elevation Model (DEM, Figure 1) over the Burdekin Delta that reveals many subtleties in the landscape that were not available to earlier researchers. The DEM has a 10 metre lateral resolution and submetre vertical resolution. These data provide new insights into the geomorphology and formation of the Burdekin Delta complex.

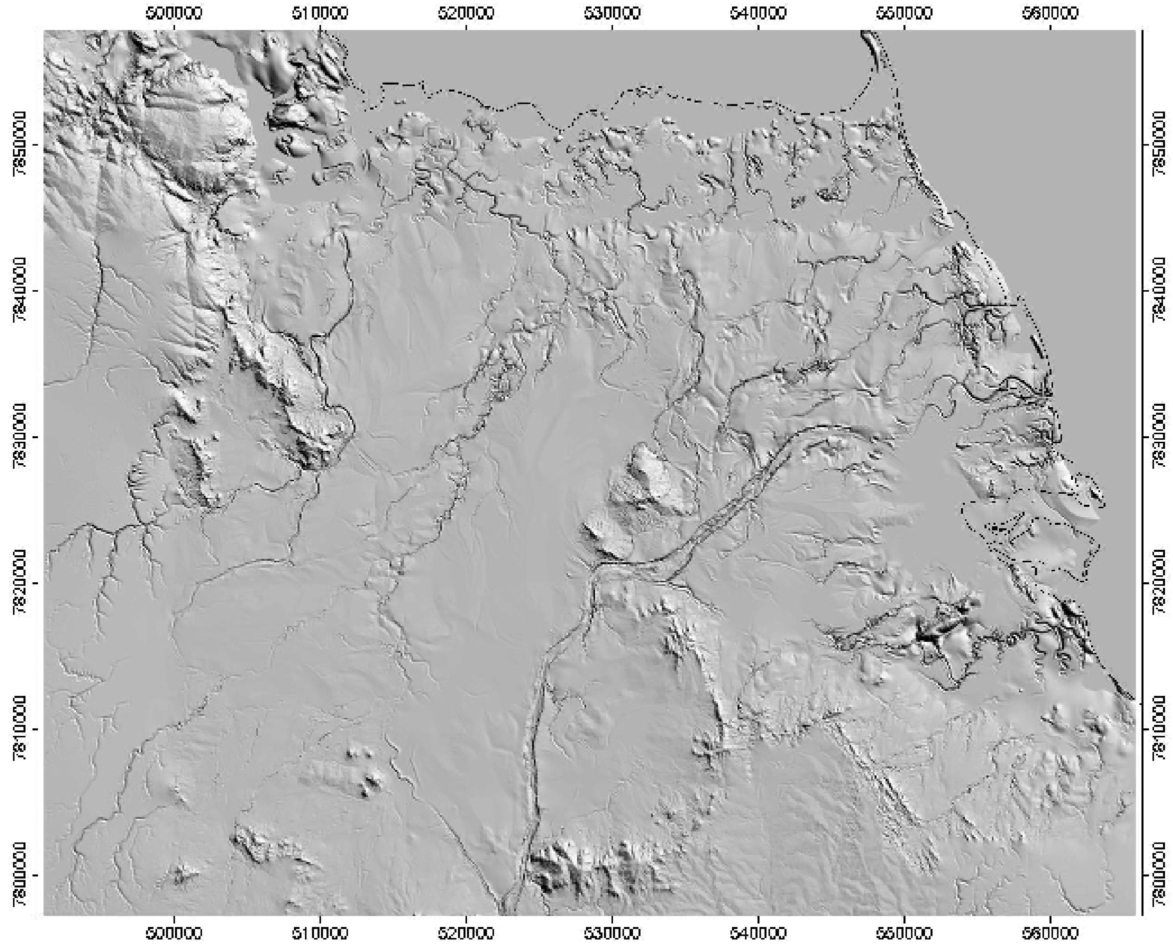

Figure 1: Grey-scale laser altimeter DEM of the Burdekin Delta with log stretch.

The Burdekin River descends the Great Escarpment from the Hervey Range approximately 130 km upstream of the river mouth. For approximately 30 km it flows through an incised valley before debouching onto the coastal plain. A major constriction in the present channel occurs where the river passes through two hills at a location known as *The Rocks* (elevation ca. 20 m). From this point to the mouth of the river is a further 30 km characterised by a sub-aerial gradient of 1:1,500, or 0.038 of one degree.

Twenty seven km upstream of *The Rocks* is a significant bifurcation. A major inactive channel flows north-west towards the Haughton River and probably represents the relict Late Pleistocene course of the Burdekin. This channel is incised into depositional lobe complexes with relict leveed channels that extend northward from the modern river immediately west of *The Rocks*. These lobes are earlier Pleistocene depositional features. The modern river flows east through *The Rocks* and forms another depositional lobe. The Pleistocene distributary lobe complexes consist of first order depositional lobes 3-8 km wide and 12-20 km long. Second order lobes are 3 km long and 1 km wide, while the third order lobes are 1 km long and < 1 km wide. The first order channels are ca. 500 m wide, second order channels 100 m wide and third order channels less than this. These lobes are mapped as levees by Hopley (1970), but it is my view that they are too wide to be classified as such. All are incised by runoff channels that are infilled by the modern sediments of the Burdekin Delta.

The only part of the Burdekin Delta complex that is currently active is the modern coastal fringe, where deposition is graded to present sea level. Deposition is fluvial-dominated, with most of this occurring during peak floods. The overall Holocene delta system is approximately 30 km across. The active delta is approximately 10 km wide, with individual delta lobes 2-3 km across. Channel avulsion occurs approximately every 1,000 years or less, with 10 major channels in addition to the one presently active (Fielding *et al.* in press). The internally braided trunk stream of the Burdekin River has a width of 500-100 m and the channel appears stable. Second, third, and fourth order distributaries have widths of 250-500 m. 100-20 m, and < 100 m, respectively. Levees of the main river are 100 m wide.

Extensive redistribution of fluvial sediment occurs along the seaward margin, resulting in lengthening of spits at rates of up to 375 m per annum (Pringle 2000). Belperio & Johnson (1985) observed that longshore drift transports 0.45 Mt of sand per year, equivalent to the average annual supply of the Burdekin River. During the 40 years from 1940-1980, the zone of sediment accretion also migrated seawards by up to 1 km (Pringle 1984).

SUBSURFACE INFORMATION

Detailed sedimentological studies of the Burdekin Delta complex have been confined to the Holocene (e.g., Fielding *et al.* in press), associated coastal deposits (Pringle 1984, 2000) or the immediate offshore environment (Fielding *et al.* 2003, Woolfe *et al.* 1998). No published study exists of the sedimentary architecture or depositional processes of sediments further inland or of Pleistocene age, although the fluvial sedimentology of the Burdekin River further inland has been well studied (e.g., Alexander *et al.* 1996, Fielding & Alexander 1996). A number of representative cross sections have been published (e.g., McMahon *et al.* 2000, Arunakumaren *et al.* 2000) but these have tended to be skewed towards hydrogeological modelling, not sedimentary interpretation. However, lithological logs for many of the water bores in the area provide an invaluable archive of data.

Those examined by Lawrie *et al.* (2004) were classified into facies and assemblages according to the methodology evolved by Miall (1996). These data show that the succession is dominated by non-marine (96.6%) coarse-grained (56.9% sand and gravel) sediments. Gravely muds are a minor facies, suggestive of sediment gravity flows. Marine sediments include organic rich (mangrove) muds, shelly muds, and shell and/or coral-bearing sand. The marine facies are found only in the coastal fringe.

Down-hole gamma logs (Lawrie *et al.* 2004) show a prominent inflection point at the base of the Holocene succession in the coastal fringe. The top of Pleistocene surface shallows landward and forms the modern land surface across much of the region. Other inflections in the gamma data suggest other sequence boundaries deeper in the succession but their presence is not yet confirmed from lithological data.

IS THE BURDEKIN DELTA A FAN DELTA COMPLEX?

The study has shown that sediments of the Burdekin Delta:

- Were deposited as a series of distributary depositional lobes;
- These differ from conventional deltaic depositional systems with leveed channels and crevasse splays;
- Are dominated by a bimodal grainsize with gravely sands forming channel facies and muds flood plains;
- Are almost entirely non-marine in origin.

These features suggest that the sediments of the Lower Burdekin River represent an alluvial fan-to-fan delta complex, rather than a more conventional delta. The braided morphology of main channels and the fanwise distributary system suggests that it is a Type J fan (or braid) delta (Nermec & Steel 1988). Non-geomorphological classifications based on grainsize alone (Corner *et al.* 1990, Nermec 1990) would class the Burdekin as a coarse-grained low-gradient delta. Despite the distance of the Delta from the Great Escarpment, the Burdekin is notable in having so many attributes of a fan-delta complex which would otherwise disqualify it from such a classification (McPherson *et al.* 1988).

IMPLICATIONS

Deposition of the sediments of the Lower Burdekin in a fan-delta complex has a number of implications for aquifer geometry. They are:

- The presence of mud in gravel-rich alluvial fan successions need not indicate low energy deposition as such sediments can be deposited by low density mudflows;
- Facies architecture consists of two strongly contrasting lithologies: gravely sands; and muds. Silty

and organic-rich facies typical of more conventional delta systems are absent;

- The three-dimension architecture of the sediments is likely to be very complex with numerous cross-cutting relationships that may not be well related to changes in sea level;
- Individual channels may, however, show relatively low sinuosity with a braided internal architecture, as are the present distributaries of the Burdekin River;
- Drill or geophysical line spacings of 500 m or less will be needed to pick up even first order channels in the subsurface unless lateral continuity can be demonstrated between the bodies, for example by closely-spaced AEM flight lines. Sand and gravel bodies encountered in drilling should be assumed to be laterally discrete although possibly connected upstream.

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