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Late Quaternary changes in flow-regime on the Gwydir distributive fluvial system, southeastern Australia

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ABSTRACT

Ages for large palaeochannels of the Gwydir distributive fluvial system (DFS) in northern New South Wales, Australia have been determined using single grain optically stimulated luminescence. Two palaeochannel systems have been found to dominate; the here named Coocalla (43–34 ka) and Kamilaroi (19–16 ka) which have inferred palaeodischarges 25–100 times the bankfull discharges of nearby channels of the contemporary Gwydir system, which appears to have been established during the Mid-Holocene. This scale differential is very much larger than that reported for other catchments in southeastern Australia, and reflects both a decline in catchment runoff through the Last Glacial cycle and the adoption of a distributary pattern sometime after 16 ka. Actual decline in catchment runoff, determined by comparing estimated palaeodischarge with contemporary flows upstream of the DFS where flow is confined to a single channel, indicate contemporary discharge to be 0.1 times and 0.25 times that of the Coocalla and Kamilaroi, respectively.

The chronology presented here shows periods of increased discharge in the Gwydir to be more or less coincident with those observed elsewhere in the Murray Darling Basin. Although no evidence of a 'Gum Creek' fluvial phase (from 35 to 25 ka) was found, the Coocalla and Kamilaroi palaeochannel systems broadly conform in age to 'Kerarbury' and 'Yanco' fluvial phases on the Murrumbidgee and Murray systems. This synchronicity with more southern catchments supports the hypothesis that La Nina – like conditions were semi-permanent for much of the Last Glacial cycle with moisture derived largely from the western Pacific Ocean.

1. Introduction

The plains of the Murray–Darling basin (MDB) provide abundant evidence of late Quaternary hydrological change in the form of well-preserved palaeochannels and their associated planform elements (e.g. Page et al., 1996; Watkins and Meakin, 1996; Young et al., 2002; Yonge and Hesse, 2009; Kemp and Rhodes, 2010). The floodplain of the Gwydir forms part of the Darling Riverine Plains (Watkins and Meakin, 1996); an extensive system of coalescing floodplains in the north of the MDB characterised by black cracking clay soils interspersed with sandy palaeochannels. We provide the first chronology for mapped fluvial systems (*sensu* Page et al., 1996) of the Gwydir floodplain based on single grain optically stimulated luminescence (OSL) dating, along with a brief description of their surficial expression and stratigraphy. As well as documenting the late Quaternary palaeohydrology of the Gwydir, we also, through consideration of possible mechanisms responsible for greatly increased discharges in Australia during the Last Glacial cycle, seek to add to the emerging discussion of palaeo-climatic drivers of fluvial activity across the continent (e.g. Nanson et al., 2008; Croke et al., 2011).

The majority of investigations into palaeohydrology of the MDB have been conducted in the southern part of the basin. Climate processes operating in the northern half of the MDB are commonly different from those controlling the hydrology of the southern half (see Sturman and Tapper, 2005; review by Gallant et al., 2011). Flooding in the southern catchments is primarily associated with cold fronts and cut-off lows, which have their greatest frequency in the months May to October (Qi et al., 1999). The catchments of the north are exposed to a larger variety of flood-producing weather patterns (Grootemaat, 2008) including advection of tropical moisture along meridional troughs ('easterly dips') between April and October; occasional cyclones moving inland from the east coast during summer (December–April); and localised thunderstorm

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activity associated with the penetration of strong cold fronts, particularly during the onset (November) and breakdown (March) of northern Australia's wet season.

The upper contributory catchment of the Gwydir is located at 29°–30° S and as a consequence is effected by both the northern and southern weather patterns. While most flood events are caused by southerly advection of precipitation of tropical origin, the Gwydir is still within reach of winter cold fronts, when the equatorward migration of the subtropical high pressure ridge allows them to extend further north. The latitudinal position of the Gwydir makes it sensitive to changes in the relative importance of the northern monsoonal versus southern frontal activity. Investigation of the palaeo-hydrology of the Gwydir thus promises to shed light on the wider story of late Quaternary climate change in Australia.

2. Regional setting

The Gwydir floodplain is a megafan or large 'distributive fluvial system' (DFS – Weissmann et al., 2010; Hartley et al., 2010) covering an area totalling ~ 6000 km^2. The Gwydir DFS emerges from the foothills of the Great Dividing Range in northern New South Wales (NSW), Australia. It is similar in form to many low fan-shaped floodplains that flank the western slopes of the Great Dividing Range in NSW and Victoria, recording at its surface dramatic changes in regional water balance in the form of numerous apparently distinct palaeochannel complexes (Fig. 1).

The contemporary flow regime is characterised by downstream declining discharges and greatly diminished channel capacities with numerous distributaries of unusual hydraulic geometry (Riley, 1977; Pietsch and Nanson, 2011) and poorly defined floodways known locally as 'watercourses'. Average annual flow in the Gwydir River immediately upstream of the fan at Pallamallawa (Fig. 1) is approximately 800 × 10^6 m^3, however variation is high with annual discharges ranging from near zero to four times the average annual discharge. Only in exceptionally large flows does the Gwydir River maintain a course to the Barwon River, the regional trunk stream. Only minor amounts of flow, representing about 10% of the average annual discharge passing Pallamallawa, are carried across the DFS by the two largest distributaries (the Mehi River and Carole – Gil Gil Creek). Pietsch and Nanson (2011) recount a complex history of off-take modification since settlement that now enables controlled distribution of non-flood flows amongst the channels of the Gwydir DFS. A palimpsest of disjointed palaeochannel and meander plain remnants interacts significantly with the contemporary flow regime, providing barriers to, and sometimes conduits of, surface floodwater, while widespread shallow sand and gravel aquifers, especially in the vicinity of Moree, contribute to high transmission losses in the contemporary system (A. Robertson [Moree Water Superintendent] pers. comm. 2001; Bureau of Rural Sciences, 2010). Where palaeochannel preservation permits assessment of channel wavelength, these complexes are found to be 6–12 times the size of channels of the contemporary system at equivalent locations in the DFS (Fig. 2). Furthermore, sand and gravel quarries across the DFS indicate previous sediment regimes to be much coarser than the characteristically muddy contemporary channels (see Fig. 5 in Pietsch and Nanson, 2011).

Within the modified Köppen classification scheme of Stern et al. (2000), the Gwydir Catchment spans two climate groups, with the climate of the upper part of the catchment (which supplies the majority of the runoff and has catchment area of ~12 300 km^2) described as temperate with no dry season and warm to hot summers, while the climate of the Gwydir DFS is classified as being subtropical with a moderately dry winter. Presently, snowfall makes an insignificant contribution to runoff, being a rare occurrence restricted to the highest parts of the catchment. Even during the coldest phases of the Last Glacial cycle, runoff and sediment discharge could not have been influenced by a large snowpack, nor periglacial activity, as 99.96% of the catchment above Pallamallawa is below 1400 masl – considered by Galloway (1965) to be the lower limit of periglaciation in the region. Modelling of snow cover (Galloway, 1986) under conditions of depressed temperatures (~5 °C lower than present) also shows that the Gwydir could not have had a significant snowpack. The palaeohydrology of the Gwydir catchment is thus distinguished from the well-studied catchments to the south e.g. the Goulburn–Murray (Bowler, 1978); Murrumbidgee (Page et al., 1996, 2009) and Lachlan (Kemp and Spooner, 2007; Kemp and Rhodes, 2010), which have all been argued to have experienced increased flow from melting snowpacks and high sediment discharge from denuded slopes during the coldest phases of the Last Glacial cycle.

3. Previous research

The 1968 Moree 1:250 000 geological map (covering an area almost coincident with the Gwydir DFS) is striking in its uniformity, with over 93% of its area assigned '*Riverine plain deposits of black and red clayey silt*, *sand and coarse gravel*' (Geological Survey of NSW, 1968). Riley and Taylor (1978) using Landsat imagery (band 5) differentiated on the Gwydir megafan '*most recent fan deposits*' from '*areas of older (?) fan deposits (displaying) numerous palaeochannels*, *lakes and dunes(?)*'. The 'most recent fan deposits' appear to coincide with the contemporary system of predominantly fine grain floodplain deposits that have formed around, between and on palaeochannels. The availability of detailed airborne radiometrics and higher resolution imagery and topographic data (see Fig. 3) allowed the NSW Department of Mineral Resources to further refine the mapping of previous decades to include mapping of individual palaeochannels and their associated meander- and backplains (Barnes et al., 2002; Dawson et al., 2003; Dawson and Spiller, 2005). No chronological data for the Gwydir catchment was collected as part of this work, however the mapped palaeochannels were considered by them to be correlates of the Bugwah Formation within the Macquarie catchment (see Watkins and Meakin, 1996).

The fluvial history of the Macquarie catchment, developed by Watkins and Meakin (1996), was found by Young et al. (2002) to be broadly comparable with that of the Namoi catchment, directly to the south of the Gwydir, with surface palaeochannels distinguishable into two units, an earlier larger unit termed the Carrabear (27–12 ka) and a later, smaller unit, the aforementioned Bugwah (13–6 ka). The contemporary system (the Marra Ck Formation) in both the Macquarie and the Namoi was found to be no older than 6ka, and as with the Gwydir, considerably smaller than either of the two surficial palaeo-channel units. This somewhat sparse data from the northern MDB is broadly consistent with the now well-established late Quaternary hydrological story developed for the southern MDB (Bowler, 1978; Page and Nanson, 1996; Page et al., 1996; Kemp and Rhodes, 2010) which has been divided into four 'phases'; the Coleambally phase, occurring from about 105 to 80 ka (the mid- to latter-part of Marine Isotope Stage 5),the Kerarbury phase from about 55 to 35 ka (Stage 3), the Gum Creek phase from about 35 to 25 ka (late Stage 3 to early Stage 2) and the Yanco phase from about 20 to 13 ka (late Stage 2), with flows broadly similar to the present flow regime establishing sometime within Stage 1.

Recent work in the Fitzroy River Basin (FRB) (Croke et al., 2011), central Queensland, may be more instructive given its relative proximity, being closer to the Gwydir than the Murrumbidgee and much of the Lachlan, albeit that the FRB is influenced by Southeast Trade Winds (Sturman and Tapper, 2005) in winter. A preliminary chronology assembled by Croke et al. (2011) for the FRB based predominantly on large aliquot OSL dating of disparate