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Palaeohydrology of lowland rivers in the Murray-Darling Basin, Australia

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A B S T R A C T

This study derives a new function describing the relationship of channel bankfull discharge (Q_{bf}) to channel width in modern rivers of the Murray-Darling Basin (MDB) of southeastern Australia and applies this to dated palaeochannels of seven rivers to quantify late Quaternary discharge history in this important basin. All rivers show high MIS3 and MIS2 Q_{bf}, declining in the Holocene. The Q_{bf} of modern MDB rivers is correlated with total catchment precipitation but comparison with palaeochannel Q_{bf} estimates shows that while enhanced runoff efficiency is necessary to account for much larger late Pleistocene palaeochannels, either lower or higher precipitation rates could have prevailed. A strong association between relative palaeo- Q_{bf} enhancement and temperature suggests a temperature-mediated mechanism controlling river discharge, such as the fraction of precipitation stored as snow and thawing in spring, the enhancement of orographic rainfall, or CO_2 feedbacks with vegetation cover. Significantly enhanced MIS3 Q_{bf} requires an additional mechanism, such as increased rainfall. These findings are consistent with others that increased moisture availability was associated with past colder climates, although this was not necessarily the result of enhanced precipitation.

1. Introduction

Understanding the hydrological response to climate change is of fundamental concern to both future and palaeoclimate studies. Yet there is a tension between modern data and modelling analyses linking colder temperatures with lower values of aridity or drought indices, and a widespread view in the palaeoclimate community that colder climates, such as during the last glacial maximum (LGM), were more arid (Scheff et al., 2017). Recent studies have explored both what is meant by terms such as aridity, drier and wetter in relation to palaeoclimate proxies and our interpretation of those proxies (Prentice et al., 2017; Scheff et al., 2017). One such proxy, with a history of conflicting climatic interpretation, is palaeochannels. In many lowlands they appear to offer one of the few, and most promising, insights into past hydrology and climate.

The palaeochannels of the Murray-Darling Basin (MDB) have long been used as a proxy for late Quaternary climate change in southeastern Australia (e.g.Bowler, 1978a; Nanson et al., 1992; Page et al., 2009). Much effort has gone into examining the geomorphology and chronology of the palaeochannels of these river systems, with early work concentrating on the southern Riverine Plains of the Murray and Goulburn Rivers (Pels, 1964; Bowler, 1967) and Murrumbidgee River (Butler, 1950, 1958; Langford-Smith, 1960; Schumm, 1968). The first generation of luminescence dating (using thermoluminescence – TL) was also conducted on these rivers (Page et al., 1991, 1996) replacing an earlier scant radiocarbon chronology plagued by contaminated ages. The Murrumbidgee TL chronology (Page et al., 1996) has provided the template for interpretation of the hydrology and chronology of subsequent investigations. More recent studies have examined the Darling (Bowler et al., 1978; Lawrie et al., 2012), Macquarie (Watkins and Meakin, 1996; Hesse et al., 2018), Lachlan (Kemp and Rhodes, 2010, 2017), Namoi (Young et al., 2002; Wray, 2009) and Gwydir (Pietsch et al., 2013) rivers (Fig. 1), and revised the Murrumbidgee chronology (Mueller et al., 2018), extending the geographic and climatic range of investigations into the northern MDB and applying optically stimulated luminescence (OSL) dating.

Despite some general agreement that palaeochannels in marine

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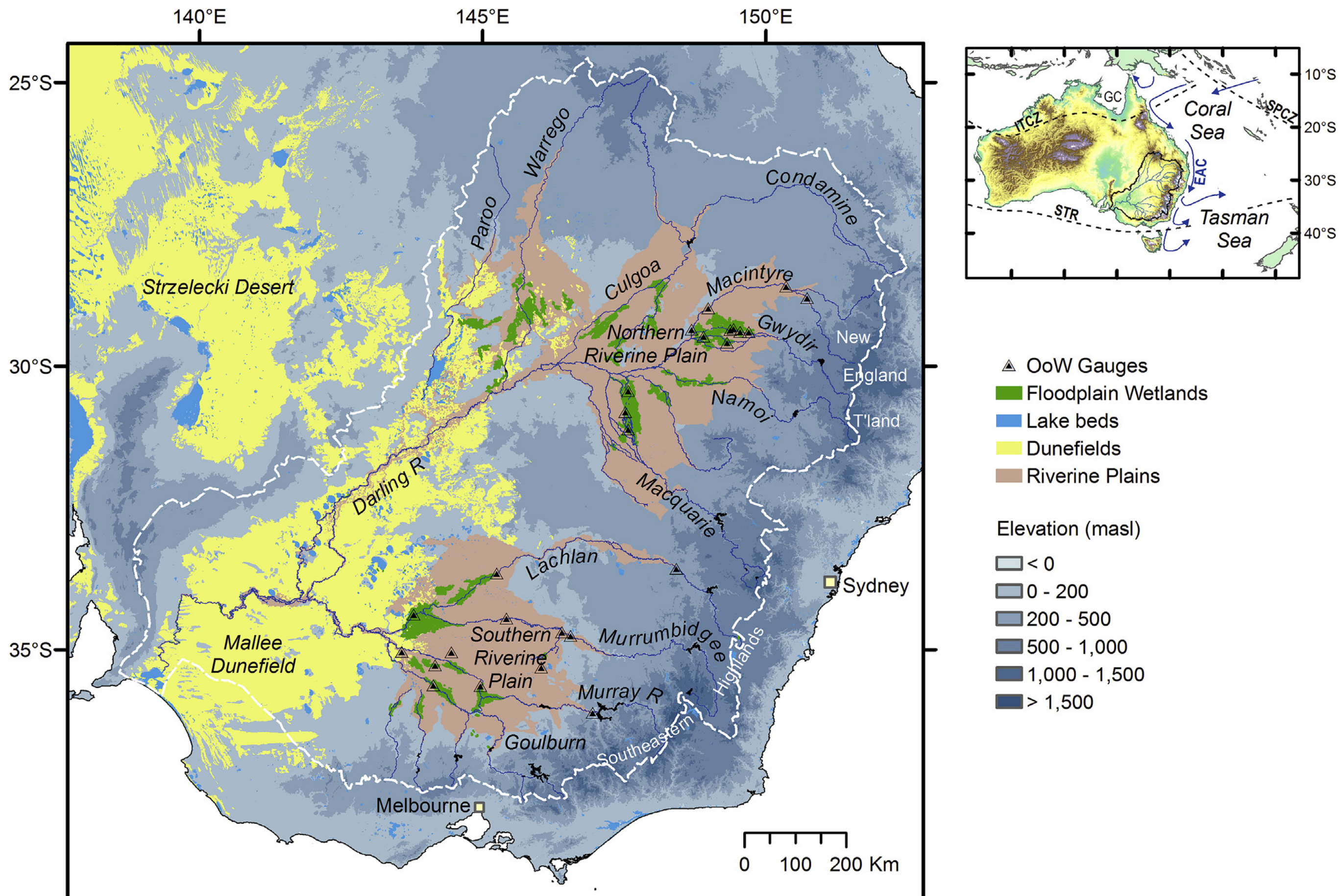

Fig. 1. Murray-Darling Basin (dashed white line) topography and drainage. Topography from Geoscience Australia Globalmap (2001). Areas of riverine plains (pink), floodplain wetlands (green) and dunefields (yellow) interpreted from ESRI background satellite imagery and Australian airborne radiometric mosaic (Geoscience Australia). NSW Office of Water gauge sites used to derive discharge equations shown by triangles. The index map shows the East Australian Current (EAC) and average January positions of the inter-tropical convergence zone (ITCZ), South Pacific Convergence Zone (SPCZ) and sub-tropical ridge (STR). GC – Gulf of Carpentaria. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

oxygen isotope stage (MIS) 5, 3 and 2 were larger than the modern MDB rivers, there are still areas of uncertainty. For example, it is not clear what conditions contributed to the elevated bankfull discharges of the last glacial cycle. Proxy evidence suggests the last glacial maximum (LGM) climate of southeastern Australia was up to 9 °C colder than the pre-industrial modern era (Galloway, 1965; Miller et al., 1997; Barrows et al., 2002). Consequently, the alpine tree line was much lower (Sweller and Martin, 2001; Kershaw et al., 2007) and fluctuated with hemispheric temperature change. However, treelessness at lower altitudes has also been attributed to lower precipitation (Dodson and Wright, 1989) and the effects of lower atmospheric carbon dioxide (Hesse et al., 2003). Some lakes were full or enlarged at the LGM and this has been attributed to either lower catchment evapotranspiration (Page et al., 1994) or high precipitation (Shulmeister et al., 2016) resulting in a positive moisture balance. However, the LGM was also a time of dry lakes in central Australia (Magee and Miller, 1998) and 'mega-lakes' existed at times during MIS5 and 3. Enhanced dust fluxes were experienced during the LGM (Hesse, 1994; Petherick et al., 2008; Fitzsimmons et al., 2013) and dune building has been found to have been greater at the LGM (Fitzsimmons et al., 2007, 2013; Hesse, 2016) in the Strzelecki Desert of central Australia and the Mallee Dunefield of the western MDB. There is thus a mixed picture of the nature of southeastern Australian environmental conditions at the LGM and earlier: some indicators of wetness, relating to runoff, strong evidence for much colder conditions, and some evidence indicative of aridity.

1.1. Palaeochannels and palaeohydrology of Murray-Darling Basin rivers

Previous studies have contributed to development of a regional framework of palaeochannel formation, palaeodischarge and associated fluvial activity over the last glacial cycle (Page et al., 2009). Following Bowler (1978b), this framework identified 'phases' of fluvial activity, each with multiple channels of characteristic planform and size ('complexes' in the terminology of Bowler, 1978; 'systems' in the terminology of Page et al., 1996). In each study, palaeochannel systems were identified and dated with a range of techniques and sampling densities.

Vast differences in the size of the palaeochannels relative to their modern fluvial counterparts have been interpreted as recording past episodes of greater bankfull discharge (Langford-Smith, 1959; Schumm, 1968). Schumm (1968) was the first to attempt a quantification of the palaeo bankfull discharges, applying Manning's equation to reconstructed channel dimensions and slope, and assumed roughness. For the 'ancestral' Gum Creek phase cutoff at Tombullen on the Murrumbidgee he derived a bankfull discharge around five times greater than the modern river. Bowler (1978) applied Dury's (1976) empirical equations relating bankfull