Dating and provenancing sediments of a palaeoflood record at the terminus of the Murray-Darling Basin

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Research aim

The objective of this project is to contribute to the development a Holocene palaeoflood record for the Murray-Darling Basin (MDB). This will be achieved through detailed chronological and geochemical analysis of a known palaeoflood sequence located at the terminus of the MDB in the River Murray in South Australia. Based on these (and other) analysis it will be possible to reconstruct the frequency of palaeofloods originating from the Murray and Darling sub-basins, increasing our understanding of the frequency of flood and drought dominated regimes affecting eastern Australia. Furthermore, by reconstructing the hydroclimatic variability in eastern Australia (precipitation), this record will shed light on the behaviour of Southern Hemisphere climate drivers during the Holocene.

Project description

The Murray-Darling Basin (MDB) drains 1.07 million km^2 of Australia's landmass and extends across climatically and geologically distinct regions of eastern Australia. Consequently, precipitation and streamflow in different parts of the Basin are driven by distinct synoptic-scale climate systems (Fig.1a). The synchronous/asynchronous behaviour of these climate systems, and their role in driving flood and drought extremes in eastern Australia is not well constrained, nor captured in the instrumental record (~120 years in total). Currently there are very few records capable of inferring discharge and hydroclimatic variability from the Basin, with existing reconstructions relying on indirect proxy records of precipitation from sites located outside of the Basin, and limited to the last millennium (Gallant et al., 2011; Gergis et al., 2012; McGowan et al., 2009; Vance et al., 2013). Despite this, existing records nevertheless imply that the instrumental record does not capture the full range of hydroclimatic variability for the Basin, suggesting that significantly longer and more frequent wet and dry periods have been experienced in eastern Australia in the pre-instrumental period (Tozer et al., 2016). As such, long-term palaeorecords of eastern Australia's hydroclimate are crucial for documenting MDB discharge variability to inform management of MDB resources, especially under projected climate change.

Recent geomorphic investigations of the lower River Murray in South Australia uncovered a laminated fine-grained mud unit extending to >10 metres depth preserved at the terminus of the MDB (De Carli et al., 2020). Preliminary radiocarbon ages revealed that the upper portion of the unit dates from the mid to late Holocene (ca. 3.3 to 7.6 ka). A pilot study was undertaken to characterise sedimentary signatures in sediment two cores and assess the potential for palaeoflood reconstruction (Fig. 1b) (De Carli et al., 2020). Physical (grainsize), geochemical (Itrax XRF) and mineralogical (XRD) analysis implied it is possible to isolate three distinct detrital signatures, diagnostic of sediments sourced and transported from either subtropical northern or temperate southern regions of the MDB (Gingele et al., 2005; Marx et al., 2010) (Figs. 2-3). Recent research has revealed that sediments in the downstream reaches of the MDB have experienced considerable lag times in excess of 1 Ma, with multiple episodes of burial, reexposure and alteration during sediment conveyance from source to sink (Fülöp et al., 2020). The implication of this is that sedimentary signatures, especially at the terminus of the MDB, require careful consideration of sediment conveyance processes and a multi-proxy approach to tease apart geochemical signatures and infer provenance.

A new suite of longer sediment cores were acquired during a field campaign undertaken in February 2020. This field campaign was funded through a successful small project GeoQuEST Grant awarded in 2019, with sediment cores acquired using vibracore and whacker techniques from billabongs and floodplains adjacent to the main channel between Mannum and Murray Bridge in South Australia (Fig. 1b). Multi-proxy analysis is being undertaken on these sediment cores to reconstruct palaeoflood frequency for the MDB.

To date three sediment cores located on a floodplain at Murray Bridge have been analysed using Itrax Xray Fluorescence (XRF) in order to characterise the depositional environment and investigate geochemical signatures (Figure 4, Table 1). This investigation has formed a SCIP310 Directed Studies student research project undertaken at the University of Wollongong in 2021. Preliminary results from this investigation have characterised a laminated stratigraphic sequence recording two distinct suspended sediment signatures reflective of the Murray and Darling catchments (Figure 5). Trace element analysis (ICP-MS) is now being undertaken on these sediment cores as part of the multi-proxy analysis to further tease apart geochemical signatures and infer/confirm provenance. Optically-Stimulated Luminescence (OSL) dating is being undertaken on the sequence to establish a robust high-resolution chronology for the palaeoflood record and constrain the timing of deposition.

Based on these (and other) analysis it will be possible to reconstruct the frequency of palaeofloods originating from the Murray and Darling sub-basins, increasing our understanding of the frequency of flood and drought dominated regimes affecting eastern Australia. Furthermore, by reconstructing the hydroclimatic variability in eastern Australia (precipitation), this record will shed light on the behaviour of Southern Hemisphere climate drivers during the Holocene.

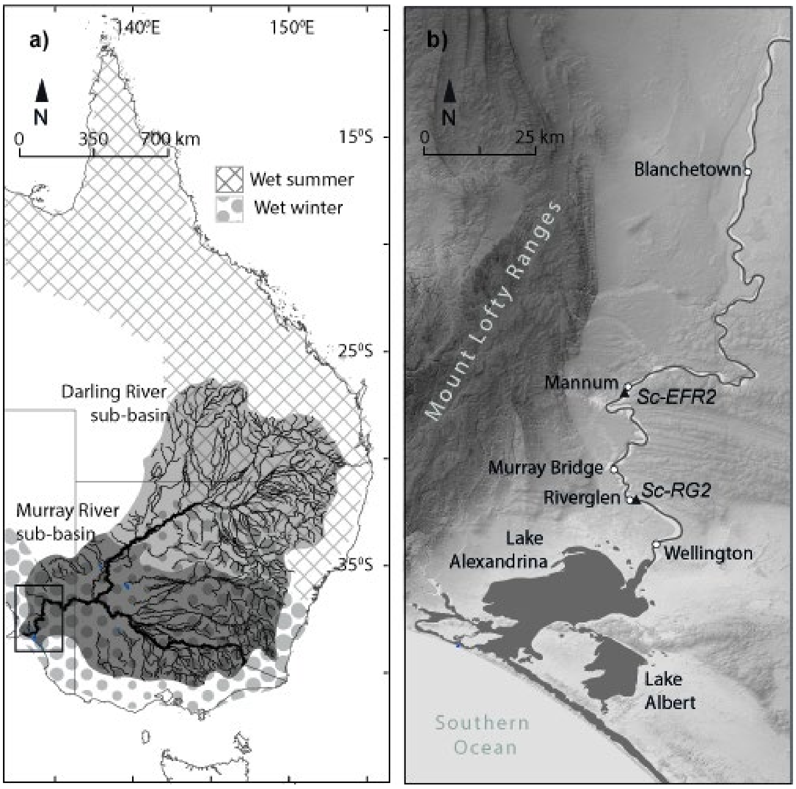

Figure 1. The Murray-Darling Basin (MDB) covering eastern Australia, and the lower Murray River (LMR) at its terminus in South Australia. **a.** Seasonal rainfall patterns; cross hatching in northeastern Australia (NEA) representing summer precipitation over the Darling River sub-basin (shaded light grey), and black dots in southeastern Australia (SEA) reflecting winter precipitation over the Murray River sub-basin (shaded dark grey). The Darling and Murray rivers are portrayed as bold within their respective sub-basins. **b.** Location of sediment cores acquired at Mannum (Sc-EFR2) and Riverglen (Sc-Rg2) on which the pilot study was previously undertaken to characterise sedimentary signatures.

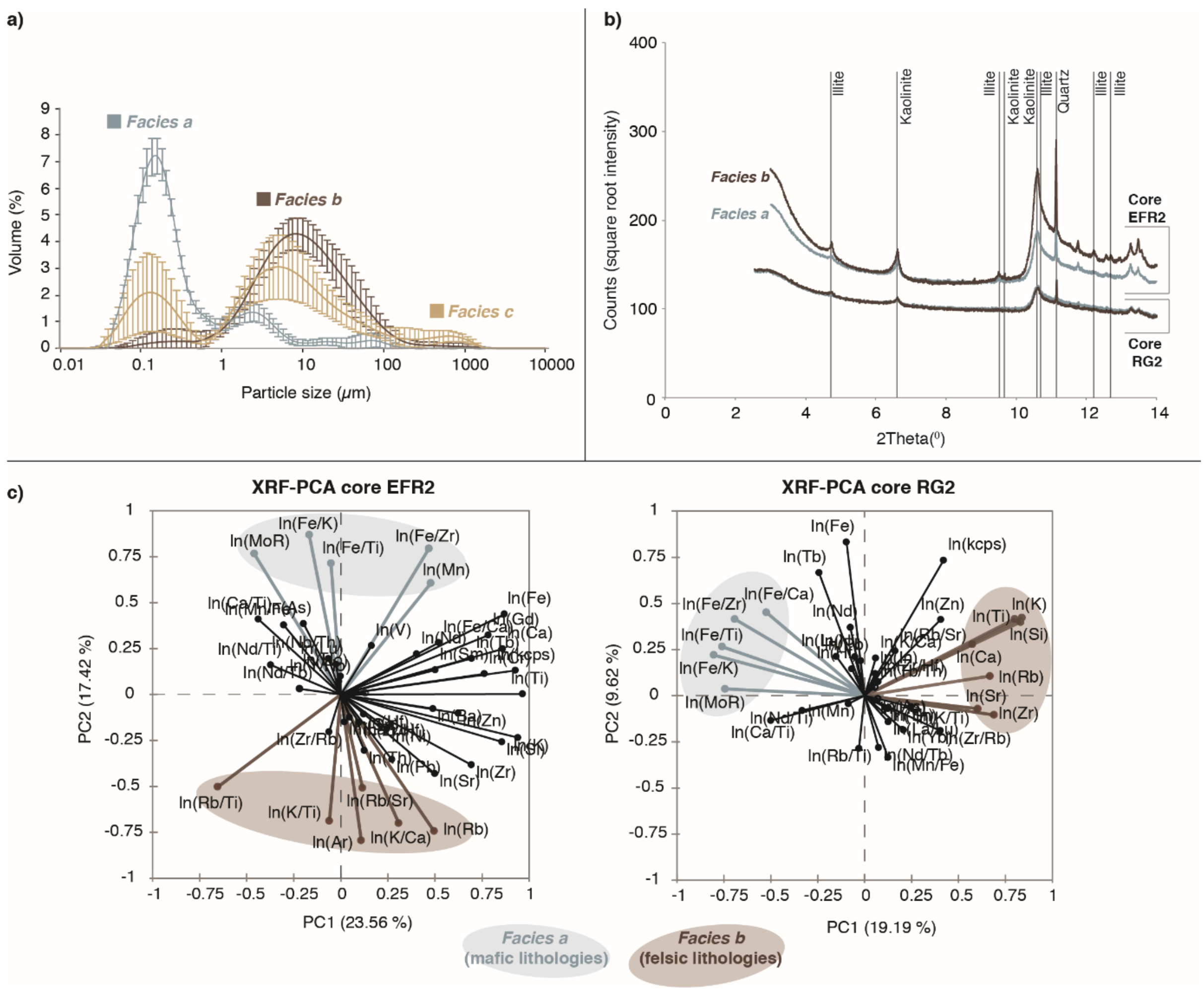

Figure 2. Physical and geochemical signatures delineated for facies a to c in pilot study. The laminated sequence is characterised by olive-black to grayish-olive silts (facies b) interbedded with hundreds of light-gray clay laminae (facies a). Occasional grayish-olive fine-grained sand layers interrupt the laminated sequence, and are often associated with unconformities, representing hiatus within the sequence (facies c). **a.** Distinct grainsize modal peaks of facies a to c diagnostic of different sources, sediment pathways and modes of transport through the MDB. **b.** Representative clay patterns for facies a and b in cores EFR2 and RG2 showing illite and kaolinite assemblages. **c.** Geochemical signature of facies a and b represented through principal components analysis (PCA). Multivariate analysis revealed that facies a is enriched predominantly in Fe and smectites characteristic of sediments originating from the Darling River sub-basin, and facies b is enriched in Rb, K, kaolinite and illite, characteristic of sediments originating from the Murray River sub-basin (Gingele et al., 2005; Marx et al., 2010).

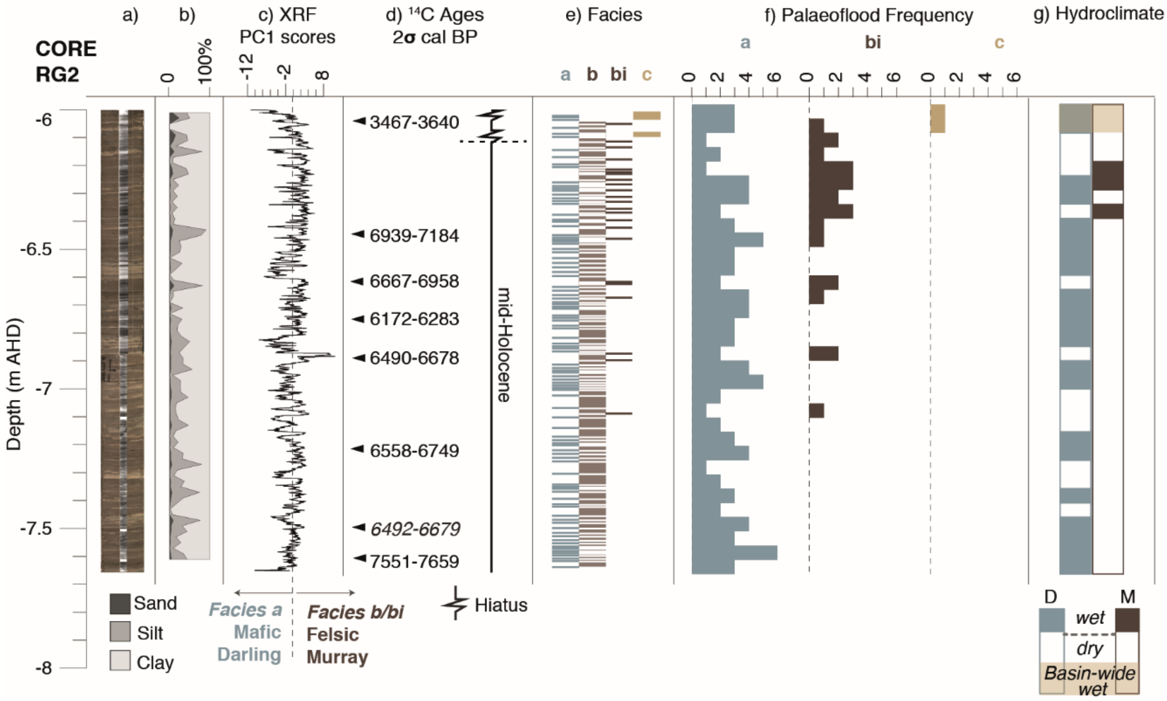

Figure 3. Palaeoflood sequence in core RG2 inferred from multi-proxy analysis undertaken in initial pilot study. **a.** Optical image and x-radiograph. **b.** Grainsize analysis. **c.** Principal component scores of Itrax XRF geochemical data. **d.** Radiocarbon ages reported as cal years BP with 2 sigma errors. **e.** Composite record of facies a to c delineated from grainsize and geochemical analysis. The facies architecture of the laminated sequence is thought to reflect well the hydrologic regime of the MDB rivers; peak summer dischargers from the Darling River sub-basin (facies a) episodically overwhelming the baseline discharge dominated by perennial winter flows and spring seasonal snowmelt from the Murray River sub-basin (facies b). Occasional high-energy events that punctuate the record (facies c) are interpreted as Basin-wide peak discharges whereby flood peaks for both the Murray and Darling sub-basins coincide, comparable to Basin-wide flood events that occurred in 1956 and 1974. **f.** Palaeoflood frequency highlighting periods of low versus high frequency. **g.** Hydroclimatic variability in the MDB inferred from the palaeoflood archive; reflecting alternating flood and drought-dominated regimes for the Darling (D) and Murray (M) sub-basins.

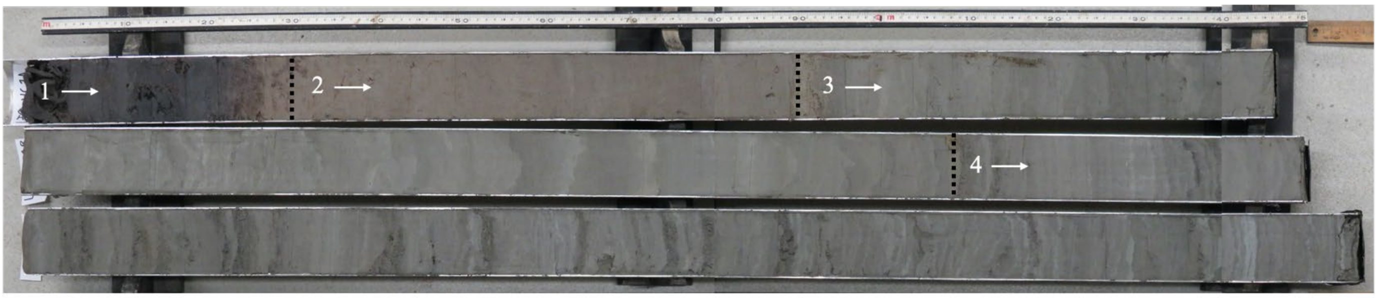

Figure 4. One of three sediment cores (LF20_VC1) acquired in 2020 from Murray Bridge showing the fine-grained laminated sequence separated into Units 1-4 (as described in Table 1).

Table 1. Sedimentary units and characteristics of sediment core LF20_VC1 acquired from Murray Bridge (described from the base to top of the core).

Name	*Description and Characteristics*	*Depth*
Unit 4	Predominantly dark grey (5Y 4/1) clays interspersed with olive grey (5Y 4/2) and very dark grey (7.5YR 3/1) centimetre to millimetre laminations. Very dark grey laminae associated with > organics, charcoal and sand. Interspersed fine grained micaceous sand pockets	256-452
Unit 3	Dark grey (5Y 4/1) and olive grey (5Y 4/2) clays, large sometimes poorly defined centimetre-scale laminations with limited levels of sand, organic matter and charcoal	90-256
Unit 2	Dark grey (5Y 4/1) fine silty clays. Massive, with no visible organics, shell deposits, charcoal or sand.	30-90
Unit 1	Black (7.5Y YR 2/0) fine-grained clay. High organic content. Contemporary environment.	0-30

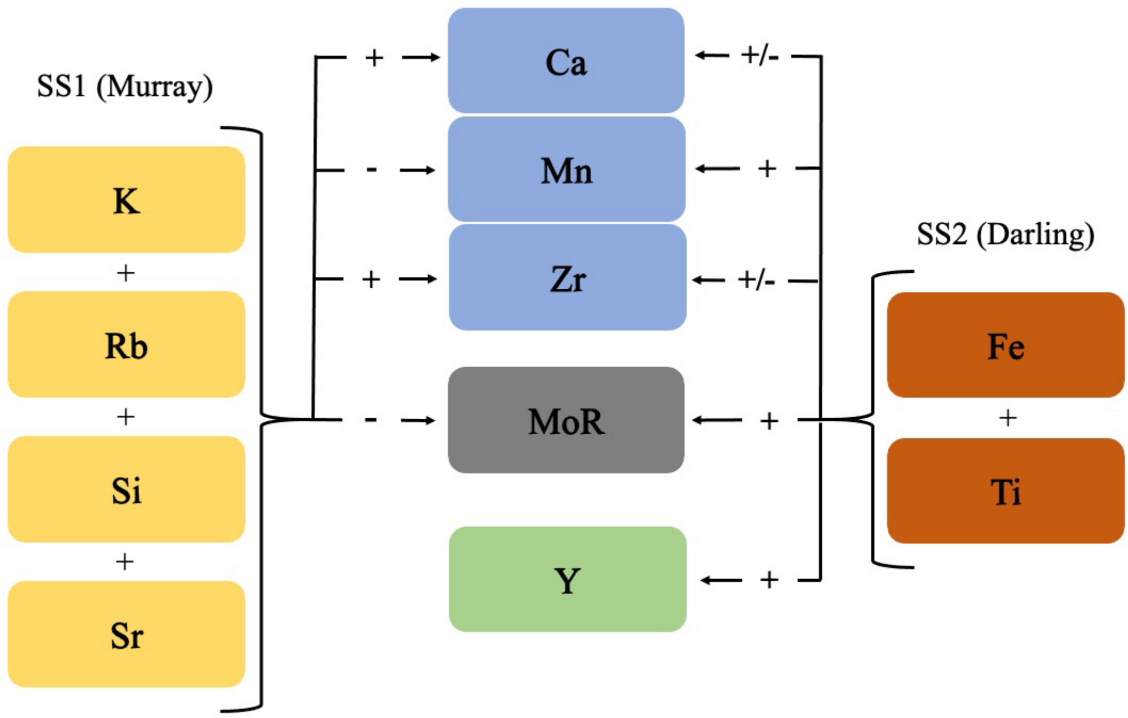

Figure 5. A diagrammatic representation of the broad inter-element dynamics between sedimentary signatures 1 and 2 identified from sediment core LF20_VC1. Suspended sediment signatures characterised for LF20_VC1 depicting Murray and Darling sources. Plus and minus signs denote positive and negative correlations. The elements at the centre of the diagram can be considered the axis of the geochemical record: as SS1 or SS2 switch 'on and off', the statistical connectivity between the detrital elements on one side of the axis strengthens and in doing so shifts the sediment signal to one side of the diagram. During this process the various relationships with intermediary elements are turned on and off as different environmental and depositional processes wax and wane over time.

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