Present and proposed research

The fundamental questions addressed by my PhD research are: how do gravel braided rivers respond to changes in climate? How are these changes recorded in the stratigraphic record? These will be addressed through the investigation of braided river deposits through a large-scale (last glacial-interglacial) climatic transition, incorporating smaller climatic scales.

Braided river processes and their deposits respond to changes in water discharge and sediment. These factors control whether the floodplain is aggradational, incisional, or at steady state, and the frequency of channel avulsion. Sediment load and discharge are controlled by factors including climate. If climate, and so sediment supply and discharge, can be linked to subsurface stratigraphy, it should be possible to interpret how climate change has affected fluvial behaviour. Glacial and fluvial erosion produce sediment with different characteristics; glaciers are considered to produce greater volumes of sediment with a finer average grain size than fluvially-dominated erosion processes. However, there is some debate over the influence of climate on the volume and characteristics of sediment produced by these erosive systems (Dühnforth et al., 2008). The change from a glacial to interglacial climatic regime causes a release of glacially-produced sediment that has filled valleys during glacial occupancy and needs to be removed before fluvial erosion can be effective. Depositional geometries within braided river stratigraphy can be used to infer changes in process and hence the effect of autogenic controls, and so test existing models of braided river stratigraphy. As erosion is an important factor in fluvial behaviour, the stratigraphy is not likely to be a complete record of fluvial process, and the preservation potential of these sediments needs to be taken into account (Sheets et al., 2002).

The Canterbury Plains on the east coast of central South Island, New Zealand have been chosen as the study area for this research due to the unique examples of large gravel-braided rivers that occur here. The southern Canterbury Plains cover an area of ~7000 km^2 and are made up of three large braided river basins, the Rakaia, Ashburton and Rangitata. Paleo- and modern flow regimes of these rivers are perpendicular to the Canterbury coastline, so that the cliff section bounding the Plains provides excellent cross-sectional exposure of braided river gravels over at least 70 km. These sediments are considered to represent a period from 30-7 ka (Ashworth et al., 1999), and so include the New Zealand Last Glacial Maximum (LGM) that occurred 22-18 ka (Suggate, 1990). As such, the cliffs record the braided river response to changing discharge and sediment flux (volume and grain size characteristics) associated with glacier advance and retreat in the headwaters.

Despite being adjacent to each other, these three basins have very different glacial histories, as during glaciations the smaller modern Ashburton catchment increased its drainage area at the expense of the Rakaia and Rangitata basins. This can be seen in the coastal stratigraphy, where the Ashburton has contributed equally to the construction of the Canterbury Plains, despite its current comparatively diminutive size. Changes in drainage area are driven by glacial processes, in that glacial ice is able to flow upslope and cross drainage divides. Hence, the Canterbury braided rivers record not only changes in sediment and water discharge due to the change from a fully glaciated to an interglacial climatic regime, but are simultaneously experiencing drainage capture that is amplifying the effects of the change in erosional regime, as capture is also driven by climate. It is important to distinguish this control from tectonic uplift, which is close to uniform in this area for the period under investigation (Tippett and Kamp, 1995). Existing field evidence for drainage capture will be supplemented by comparing the modern interglacial fluvial network with reconstructions of ice extent in these basins during full glacial (LGM) conditions, and the intermediary climate stages. This presents a unique opportunity to quantify the changes in discharge associated with changing climate. This can be done using Mitchell Plummer's 'Growing Glacier' mass balance model (Plummer and Phillips, 2003) at the Idaho National Laboratory. This model accurately reconstructs ice conditions for defined climate parameters (temperature, precipitation) which are known for the time period considered in this study (Alloway et al., 2007), using a 50 m Digital Elevation Model of the study basins. This will prove extremely useful in order to determine the detailed, quantitative history of changes in flow direction of key tributaries between the different river catchments, and so changes in drainage area of each basin, which will result in changes in sediment and discharge flux to the braided river systems, and so the stratigraphic response.

Stratigraphic panels that have been created for the Canterbury cliff sections to show braided river architecture on the scale of individual depositional units (i.e. bar surfaces, channel fills) will be used to interpret change from the smallest scale to that of the floodplain, through time. Geometries of depositional niches and high-resolution logging of gravel stratigraphy will be quantified in order to evaluate changes in braided river behaviour. Comparisons between the four panel sections allow interpretation of changes laterally across the fan and so between the catchments of the three major rivers. A chronology from optically-stimulated luminescence dating (OSL) and palynological environmental reconstruction will allow comparisons of similarly timed events in different basins.

Summary of research aims

- To identify changes in 3D depositional architecture of braided river systems and link these to climatic fluctuations.
- To investigate the effect of climate change on sediment production and discharge, and so braided river processes.
- To infer the preservation potential of braided river deposits by comparisons of the expected and occurring stratigraphy.

Summary of research objectives

- Creating a high-resolution regional stratigraphy for braided river deposits across a major (glacial-interglacial) climatic transition, with depositional units identified from the smallest scale (individual bar fronts, channel fills). Undertake comparisons of this stratigraphy over several 10s km laterally in order to identify changes in process across a fluvial fan and between adjacent catchments with differing glacial histories.
- To accurately date this stratigraphy in order to pinpoint climate changes by linking the depositional record to a known climate chronology, and to calculate rates of sedimentation.
- Numerical modelling and geomorphological mapping of catchment headwaters to identify and quantify climate-driven changes in drainage area and sediment production.

How the award would be used

This application to the Gill Harwood memorial fund is made to allow the use of Mitchell Plummer’s ‘Growing Glacier’ mass balance model in estimating the changes in drainage area due to tributary capture that have occurred between the Rangitata, Ashburton and Rakaia catchments due to climate change. This represents a novel application of a glacier mass balance model to gain a unique, quantitative insight into the discharge history of the rivers feeding the Canterbury Plains, which will then allow me to develop an enhanced understanding of the response of braided rivers to climate change, as recorded in the stratigraphy of the cliffs bordering the Plains. A one week visit to his laboratory in Idaho Falls is necessary in order to learn how to use this computer model, so the costs of a return flight Manchester, UK-Salt Lake City, Utah (£414), plus ground transportation within USA for one week (£105), are requested, in total £519. Other costs will be covered by NERC bench fees.

ALLOWAY, B. V., LOWE, D. J., BARRELL, D. J. A., NEWNHAM, R. M., ALMOND, P. C., AUGUSTINUS, P. C., BERTLER, N. A. N., CARTER, L., LICHFIELD, N. J., MCGLONE, M. S., SHULMEISTER, J., VANDERGOES, M. J. & WILLIAMS, P. W. (2007) Towards a climate event stratigraphy for New Zealand over the past 30 000 years (NZ-INTIMATE project). *Journal of Quaternary Science*, 22**,** 9-35.

ASHWORTH, P. J., BEST, J. L., PEAKALL, J. & LORSONG, J. A. (1999) The influence of aggradation rate on braided alluvial architecture: field study and physical scale-modelling of the Ashburton River gravels, Canterbury Plains, New Zealand. IN SMITH, N. D. & ROGERS, J. (Eds.) *Fluvial Sedimentology IV, Special Publication of the International Association of Sedimentologists* Blackwell, Oxford.

DÜHNFORTH, M., DENSMORE, A. L., IVY-OCHS, S. & ALLEN, P. A. (2008) Controls on sediment evacuation from glacially modified and unmodified catchments in the eastern Sierra Nevada, California. *Earth Surface Processes and Landforms,* 33**,** 1602-1613.

PLUMMER, M. A. & PHILLIPS, F. M. (2003) A 2-D numerical model of snow/ice energy balance and ice flow for paleoclimatic interpretation of glacial geomorphic features. *Quaternary Science Reviews*, 22**,** 1389-1406.

SHEETS, B. A., HICKSON, T. A. & PAOLA, C. (2002) Assembling the stratigraphic record: depositional patterns and time-scales in an experimental alluvial basin. *Basin Research,* 14**,** 287-301.

SUGGATE, R. P. (1990) Late Pliocene and Quaternary glaciations of New Zealand. *Quaternary Science Reviews,* 9**,** 175-197.

TIPPETT, J. M. & KAMP, J. J. (1995) Geomorphic evolution of the Southern Alps, New Zealand. *Earth Surface Processes and Landforms,* 20**,** 177-192.