The Fluvial Archives Group: 20 years of research connecting fluvial geomorphology and palaeoenvironments

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1. Introduction: from rivers to fluvial archives

The Fluvial Archives Group (FLAG) was formed in 1996 under the auspices of the British Quaternary Research Association (QRA). The rationale for its creation was the desire to bring together those working across timescales encompassing the last few million years to the Holocene and even modern process studies. The principles of uniformitarianism are important in the validation of this grouping of interests, with the modern and recent providing analogues from which the older and longer-timescale sequences can be more readily interpreted. The creation of FLAG occurred in the context of improved understanding of terrestrially-based Quaternary sequences and at a time when knowledge of the environmental significance of river systems had also seen great advances, following several decades of engineering experience and research into the management of such systems. This field was subsequently transformed in the European Union by the Water Framework Directive (WFD, 2000), which promoted a strategy for the re-naturalization of rivers. Above all, the WFD implied the (re-)establishment of an initial, pre-anthropogenic, reference state, the recovery of which was a prime aim. This would be a demanding task, considering that rivers are characterized by constant change, even without anthropogenic intervention. The evidence for and understanding of such change, observable at various timescales, is very much the business of FLAG (see below, section 6).

Rivers are (or have been) present over the entirety of Earth's continental crust, from the Equator to the temperate and coldest areas. The deserts reveal evidence for erstwhile (palaeo)rivers (e.g., Busche, 1998; Glennie, 2001) and beneath the Antarctic ice are features that can be interpreted as former river valleys (Jamieson and Sugden, 2008).. Rivers are highly sensitive to environmental change: climate change, base-level change (in relation to tectonic activity or eustasy) and, as already mentioned, human influence. In addition, the complexity of external forcing from these influences is superimposed on intrinsic fluvial dynamics that are also complex, involving, for instance, factors such as thresholds and topographic properties (Vandenberghe, 2002; Vandenberghe and Woo, 2002). On this basis, rivers must be considered as excellent witnesses of the dynamics affecting Earth surface systems. This would, nonetheless, be valueless if rivers were not also reliable recorders of these changes, in various ways, such as the disposition of their sedimentary products, their composition and the high diversity of their sedimentary facies. Fluvial archives can thus be considered as palaeoenvironmental records of considerable value, in that they allow not only the reconstruction of past environmental changes but also the explanation of these changes.

2. FLAG history and activity

FLAG is an independent international research group that offers researchers involved in the study of past fluvial systems a forum within which to exchange and develop ideas. The main activity of the group is its organization of combined conference and field meetings, with a varied geographical coverage (Table 1). These invigorate discussion about approaches in different fluvial environments and assist in the training of early-career researchers. FLAG has also demonstrated its international involvement by the organization of sessions at EGU (European Geosciences Union), INQUA (International Union for Quatern ary Science) and IAG (International Association of Geomorphology) conferences. Many of these initiatives have led to journal special issues, e.g. in Geomorphology, Boreas, Quaternary International, Proceedings of the Geologists' Association, Netherlands Journal of Geosciences, Quaternaire, Géomorphologie, amongst others (Table 1). They have also facilitated the participation of researchers from different continents. FLAG's long-timescale focus coincided, between 2000 and 2007, with successive IGCP (International Geosciences Programme) projects (see below), which were further instigators of meetings and sources of special issues, adding Current Science (India), Global and Planetary Change and Quaternary Science Reviews to the above list. FLAG currently has a network of ~500 members in ~20 countries and with activities in many other locations globally (Figure 1).

Table 1: Special issues of journals based on FLAG initiatives

2015 (from Bonn INQUA Focus Area project meeting, 2014)	Zeitschrift für Geomorphologie Supplement 59–3	edited by J. Herget, K. Gregory and G. Benito: Hydrological extreme events - modelling and significance for understanding global change, demonstrating multidisciplinary context
2014 (from FLAG biennial meeting, Luxemburg, 2012)	Boreas, 143, issue 2	edited by S. Cordier, D.R. Bridgland, J. Vandenberghe and D. Harmand. Fluvial archives from past to present.
2012 (from FLAG session at INQUA 2011)	Geomorphologie: relief, processus, environnement, 4	edited by Cordier S. and D.R. Bridgland: From fluvial geomorphology to fluvial archives.
2012 (from FLAG biennial meeting, Vila Velha de Ródão, Portugal, 2010)	Geomorphology 165–166:	edited by Martin Stokes, Pedro P. Cunha and Antonio A. Martins: Techniques for analyzing Late Cenozoic river terrace sequences.
2010 (from FLAG biennial meeting, Budapest, Hungary, 2008)	Proceedings of the Geologists' Association, 121, Issue 2:	edited by J. Vandenberghe, S. Cordier and D.R. Bridgland: Fluvial records as archives of human activity and environmental change.
2009 (from IGCP 518)	Global and Planetary Change, 68	Edited by R. Westaway, D.R. Bridgland, R. Sinha and T. Demir: Fluvial sequences as evidence for landscape and climatic evolution in the Late Cenozoic: a synthesis of data from IGCP 518.
2008 (from FLAG biennial meeting,	Quaternary International, 189, Issue. 1	edited by M. Coltorti and P. Pieruccini: Fluvial architecture and dynamics in rising mountain chains and related

Siena, Italy, 2004)		basins - tectonic and climatic influences and human impacts papers from the FLAG biennial meeting in Siena, Italy.
2008 (from FLAG session at EGU, 2005) ,	Geomorphology, 98, Issue. 3–4	edited by J. Vandenberghe, V. Vanacker and D. Bridgland: Human and climatic impacts on fluvial and hillslope morphology papers in part arising from the FLAG session at EGU Symposium in Vienna.
2007 (from IGCP 449 meeting, Malaga Spain, 2004)	Quaternary Science Reviews, 26, Issue. 22–24	edited by D.R. Bridgland, D. Keen and R. Westaway: Global correlation of Late Cenozoic fluvial deposits: a synthesis of data from IGCP 449.
2007 (from joint conference in Bonn, Germany, 2005)	Geomorphology 92, Issue. 3–4	edited by J. Herget, R. Dikau, K.J. Gregory and J. Vandenberghe: The fluvial system past and present dynamics and controls.
2005	Geomorphology, 70, Issue. 3–4	edited by E.M. Latrubesse, J.C. Stevaux and R. Sinha: Tropical rivers.
2004 (from FLAG biennial meeting, Clermont-Ferrand, France, 2002)	Quaternaire, 15, No. 1/2	edited by J.-F. Pastre, P. Antoine, D. Bridgland and D. Maddy: Papers from the FLAG biennial meeting in Clermont-Ferrand.
2004 (from inaugural IGCP449 meeting in Prague, Czech Republic, 2001)	Proceedings of The Geologists' Association, 115, No. 2 and No. 4	edited by D. Bridgland, S. Tandon and R. Westaway: Global correlation of Late Cenozoic fluvial deposits (IGCP 449) .
2003 (from INQUA project meeting	Quaternary Science Reviews, 22, Issue 20	edited by R. van Balen, J. Vandenberghe and K. Kasse: Fluvial response to rapid environmental change.

Haarlem, 2001)		
2003 (from IGCP449 meeting Kanpur, India, 2001)	Current Science, 84, Issue 8 (Delhi):	edited by R. Sinha and S. Tandon: Papers from the IGCP449 meeting in Kanpur, India.
2002 (from FLAG biennial meeting, Mainz, Germany, 2000)	Netherlands Journal of Geoscience, 81, No. 3/4:	edited by K. Kasse: Papers from the FLAG biennial meeting in Mainz.
2001 (from FLAG session at INQUA 1999)	Quaternary International, 79:	edited by J. Vandenberghe and D. Maddy: The response of river systems to climate change.
2001 (from FLAG meeting, Cheltenham, UK, 1998)		Maddy, D., Macklin, M.G. and J. Woodward (eds.): River Basin Sediment Systems: Archives of Environmental Change. Balkema.
2000 (from FLAG meeting, Arcen, Netherlands, 1997)	Geomorphology, 33, Issue 3/4:	edited by J. Vandenberghe and D. Maddy: Quaternary Fluvial Archives.

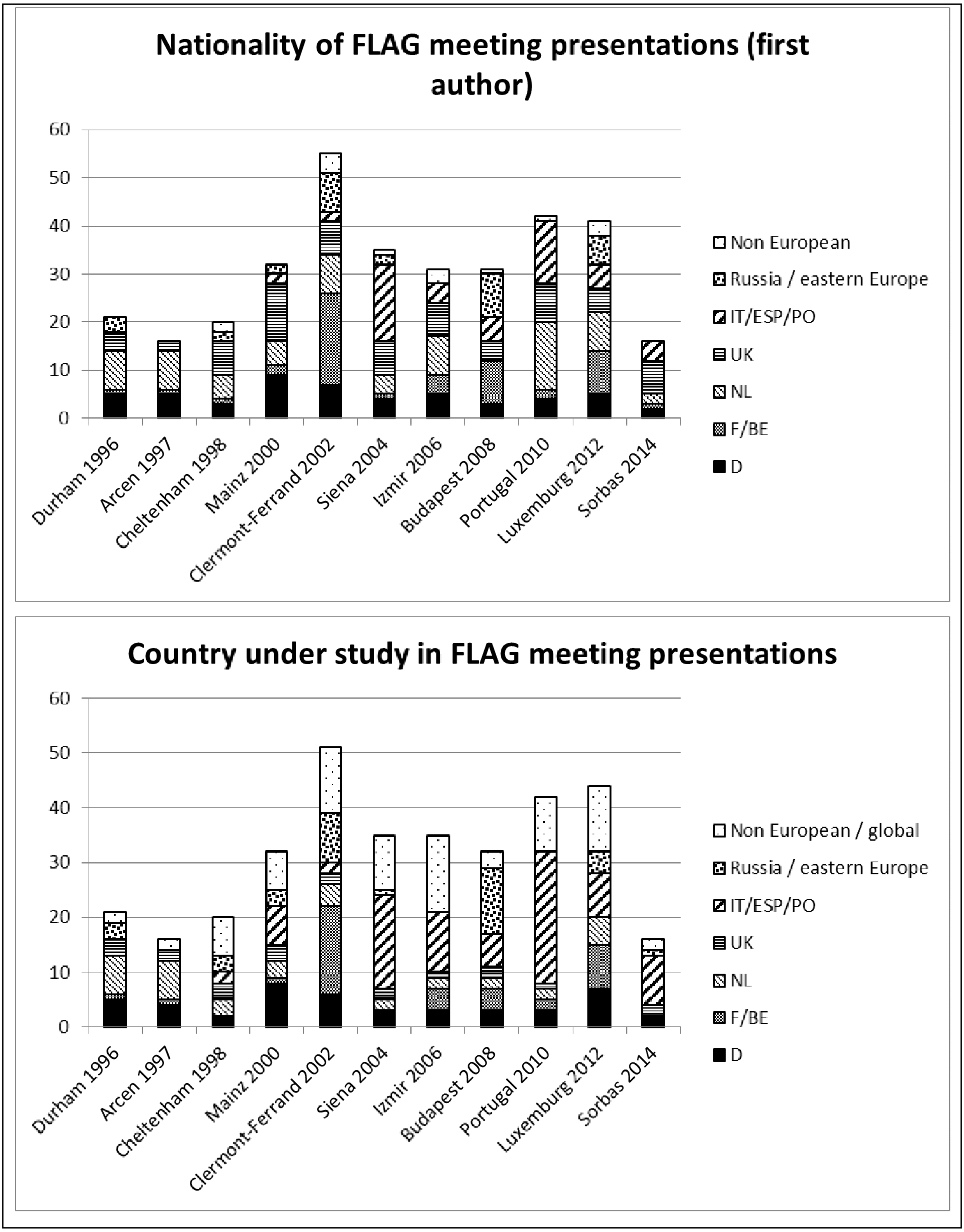

Figure 1 - Participants presenting and study areas presented during FLAG meetings

3. The evolution of FLAG research and objectives

Since its inception, FLAG has pursued objectives related to the facilitation, dissemination and exchange of research on fluvial archives, through a number of foci and themes. The initial objectives of the group, reaffirmed in the Foreword of the FLAG 2002 special issue (Pastre et al., 2004), were:

- to promote the value of investigating fluvial archives through the production of widely available and readily accessible published information;
- to establish a forum for the exchange of information and ideas;
- to identify foci for future research and, in particular, to identify the gaps in current knowledge;
- to facilitate joint 'focused' initiatives directed at addressing problems.

These objectives have remained central to FLAG during the past 20 years, although their formulation has been regularly modified. The most recent refinement promotes as main goals:

- provision of a community for discussion of key issues concerning fluvial archives, including organising biennial discussion / field meetings, sessions at relevant international conferences and special issues of journals;
- continued promotion of the value of fluvial archives by means of readily accessible published information;
- coordination of activity with other research groupings with overlapping interests, e.g. by co-convening sessions and collaborating on publications.

Early research by FLAG pursued two themes: (1) fluvial archives as templates for long terrestrial records (e.g., spanning the whole of the Pleistocene) and (2) fluvial environments and processes in relation to external and internal forcing. This changed in 2000, following the decision to extend FLAG beyond its initial 3-year status as a funded research group of the QRA. From that point onwards four foci were identified:

(1) Global Correlation of Late Cenozoic fluvial deposits,

(2) Fluvial response to crustal instability,

(3) Fluvial response to rapid environmental change during the last two glacial–interglacial cycles (200 ka), and

(4) Holocene fluvial system response to frequent and rapid periods of environmental change: identification and modelling of forcing factors.

Focus 1 coincided with a new project within the UNESCO International Geoscience Programme (IGCP, formerly International Geological Correlation Programme): IGCP 449, which had the same name as FLAG focus 1 and ran for five years, 2000–2004 (Bridgland et al., 2007). A follow-up project, IGCP 518 (Fluvial sequences as evidence for landscape and climatic evolution in the Late Cenozoic) continued work on this focus during 2005–2007 (Westaway et al., 2009a). Aspects of foci 2 – 4 were also included within the general themes of these successive IGCP projects, which extended FLAG activities worldwide.

The continuing evolution of research activity, not least the marked increase in studies based on geochronology and modelling, led in each of the four foci to increased attention for the creation of databases of fluvial events and archives, modelling and quantification of erosion and sediment accumulation rates, the derivation of palaeo-environmental information from fluvial archives and (in focus 4) the relation between anthropogenic activities and fluvial environments. In 2015, following discussion amongst the current executive and after presentation at a business meeting at the INQUA Congress in Nagoya, FLAG activities were reorganized into eight foci, grouped within three key themes:

Themes/Foci:

1. Natural and anthropogenic forcing at various timescales

1.1. Fluvial response to long-term (Pleistocene) climate and sea-level change, tectonic activity and other crustal movements

1.2. Fluvial response to Holocene climate, sea-level change and anthropogenic forcing

2. Approaches and methods for studying fluvial archives

2.1. Study of palaeoenvironmental, biostratigraphical and archaeological data contained within fluvial archives (fluvial deposits and landforms, alluvial fans, lakes, caves), including geoarchaeology of river corridors.

2.2. Modelling and otherwise quantifying long-term evolution of fluvial systems

2.3. Geochronological constraints on fluvial archives

2.4. Application of new field techniques to fluvial archives, e.g. geophysics

3. Fluvial activity in relation to present and future climate and environmental change

3.1. Applied elements of fluvial archives -.e.g. economic geology (aggregates & placer deposits) or archives as sources of baseline information for river restoration.

3.2. Using fluvial archives to inform future climate change planning

Within this increased number of defined activities are three overarching themes that define FLAG as a research group at the intersection of a number of disciplines (Figure 2). It is from this baseline that collaboration is possible. In particular, FLAG's interests encompass the full span of the Quaternary and sometimes extend into the pre-Quaternary, where the origins of modern-day systems have such deep-time origins. Over this longer timescale, fluvial systems have been both recorders of external forcing (climate, human/hominin societies) and key players in the formation and evolution of modern landscapes, (Bridgland and Westaway, 2008a, b, 2014; Westaway et al., 2009a; Bridgland and White, 2014. 2015).

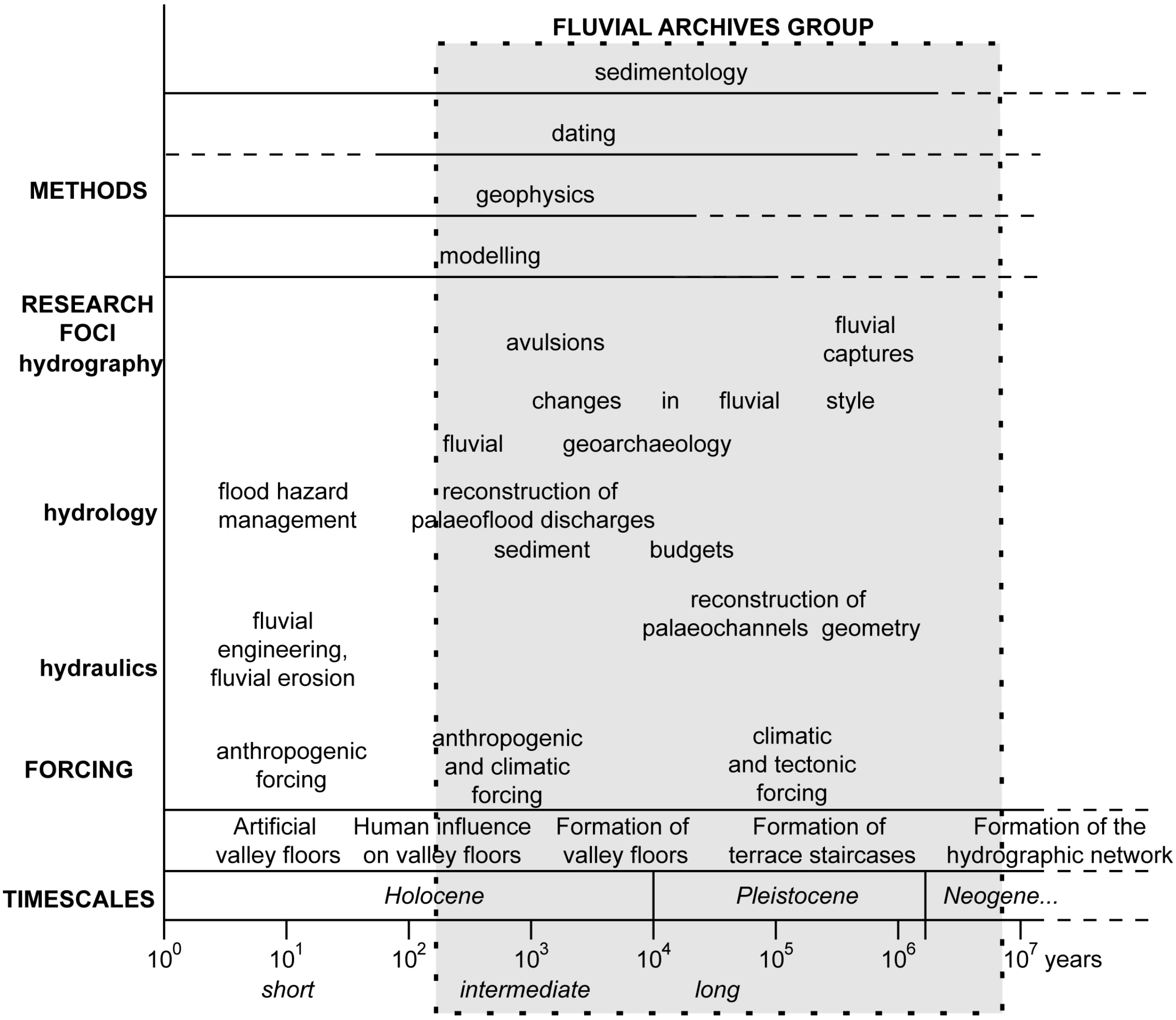

Figure 2 (after Cordier and Bridgland, 2012) : the framework of FLAG, research

At the same time, the Focus on the Holocene has also enabled fruitful collaboration over many years with other bodies, in particular with the 'GLObal Continental PalaeoHydrology' (GLOCOPH) group and the 'Past Global Changes' (PAGES) project-Focus 4, which includes the former working group 'Land-Use and Climate Impacts on Fluvial Systems' (LUCIFS). FLAG and these groups share a common focus on sedimentary archives and their reflection of environmental dynamics, but GLOCOPH and PAGES-Focus 4 are mainly concerned with the latest (Lateglacial) Pleistocene–Holocene timescale. FLAG, GLOCOPH and PAGES-

Focus 4 thus have in common the study of fluvial sediments (including a robust geochronological dataset) and the ways in which they relate to complex environmental changes.

4. FLAG at the intersection between scientific disciplines

FLAG is thus located at the crossroads between several disciplines: fluvial geomorphology, Quaternary terrestrial stratigraphy, palaeoenvironmental research, geochronology, geoarchaeology and even biostratigraphy. Each field has a voluminous and ever-growing literature devoted to it, but this often fails to refer to the parallel branches. It has been an express aim of FLAG for the last 20 years to include all these fields, and offer a forum for discussions between workers in these fields. However, this endeavour is not yet complete. The need for such linkage is exemplified by two recent papers in Geomorphology that review the discipline of fluvial geomorphology, by Wohl (2014) and Piégay et al. (2015). Neither paper recognized the role of historical / geological processes in shaping fluvial geomorphic systems, with no mention of FLAG, GLOCOPH or LUCIFS. This suggests a lack of multi-disciplinary thinking, since FLAG special issues have also appeared regularly in the same journal Geomorphology (Table 1: Vandenberghe and Maddy, 2001; Herget et al., 2007; Vandenberghe et al., 2008) and Stokes et al., 2012), in addition to papers related to FLAG activity published outside these special issues. Notwithstanding the focus of FLAG on archives, geomorphology plays a pivotal role in those archives. The Wohl paper is, as the author states, written especially from a US and UK perspective. It discusses in detail the development of thematic conceptual frameworks since the start of fluvial geomorphology. However, the emphasis is on intrinsic processes with scant reference to the abundant body of literature showing the significance of external effects on fluvial evolution, such as climate (Vandenberghe, 1995, 2002, 2003, 2008, 2015; Antoine, 1994; Bridgland, 1994, 2000; Maddy et al., 2000, 2001; Starkel, 2003; Cordier et al., 2006, 2012, 2014) and tectonic and/or crustal processes (Veldkamp and Van den Berg, 1993; Antoine, 1994; Van den Berg, 1994; Bridgland, 1994, 2000; Maddy, 1997; Antoine et al., 2000; Westaway et al., 2003, 2006, 2009b; Mather and Hartley, 2006; Stokes et al., 2008; Bridgland and Westaway, 2008a, b; see also Demoulin et al., this issue). Although anthropogenic impact on fluvial geomorphological processes is mentioned in those two papers, very little of the work cited includes pre-modern timescales (e.g. work by GLOCOPH and LUCIFS – Macklin et al., 2006, Houben et al., 2006, Herget, 2000, Hofmann et al., 2010, Thorndycraft and Benito, 2006). This omission seems to reflect a partial analysis of relevant journals, with key fluvial geomorphological papers in journals such as Quaternary International, Quaternary Science Reviews, Journal of Quaternary Science and Boreas (see Table 1) not included in the analyses by Wohl (2014) and Piégay et al. (2015). Indeed, Piegay et al. (2015) raise questions about the representativeness of the sampling that underpins their paper and recognize the variability in strategy of the diverse journals in a highly interdisciplinary field, suggesting that a broader inter-journal comparison would be highly desirable. The authors of this paper would argue that this is the case, but recognize that it is also a function of the practical difficulties of working at this disciplinary intersection. Such a selection strategy is also likely to reflect the approach developed by many researchers in the context of the Water Framework Directive, which (implicitly or explicitly) assumes that a reference state can be defined by focusing only on the recent (e.g., last few centuries) evolution, without realizing the need for this evolution to be placed in a longer timescale (Holocene and often beyond) to be fully understood.

As this present paper was being compiled another one was published, by Herman and Champagnac (2016), which seeks to use thermochronology (cf. Reiners and Brandon, 2006) in support of the evidence from accumulated sediment in offshore marine basins for increased erosion in the latest Pliocene, in association with global cooling. Although it is branded a 'debate article', and the principle debated by e.g. Nie et al. (2015), there seems once again to be a complete lack of awareness of the empirical evidence from fluvial archives, published in Quaternary journals, for just such an increase. This is regrettable, since these archives provide direct rather than indirect evidence, coming from the accelerated incision of river valleys recorded in terrace sequences. Indeed, the fluvial archives also point to a later and equally notable acceleration in erosion (incision) that could be related to increased climatic severity following the Mid-Pleistocene revolution, as charted in several FLAG outputs (e.g., Bridgland and Westaway, 2008a, b, 2012; Westaway et al., 2009a). This failure to take account of different literature groups is symptomatic of the over-specialism in some branches of science, pointing surely to the importance of the multidisciplinary, intersectional approach favoured by FLAG.

In relation to other collaborative applications, numerical-dating techniques have always been for FLAG an essential tool for fluvial-system reconstruction and have greatly improved in their reliability in the past 20 years. For example, Rixhon et al. (this issue) enumerate substantial advances, for example in understanding the stratigraphic significance of AMS radiocarbon dating of material contained within fluvial deposits, the progression and standardization of luminescence dating protocols, advances in understanding leading to more reliable ESR age estimates, advances in modelling erosion rates and surface dating using terrestrial cosmogenic nuclides and improved precision of uranium-series dating. Linkages between the fluvial and dating communities are usually good because specialists amongst the latter have constant need of sedimentary environments in which to test their theoretical advances.

The difficulty of communication across disciplinary boundaries requires FLAG to redouble its efforts to promote the usefulness of fluvial archives, which is part of the rationale behind the newly proposed third theme (foci 3.1 and 3.2). The editors argue that FLAG activities should continue to focus on the understanding of complex systems (cf. Vandenberghe and Vanacker, 2008) and their evolution at different timescales and under differing environmental conditions (cf. Vandenberghe and Maddy,2001), with emphasis on external forcing influences from people, climate and tectonic activity.

5. The FLAG approach: a guideline

The term 'sedimentary archive(s)', now in common usage (especially among geoarcheologists; cf. Arnaud-Fassetta, 2007; Carozza, 2012), is important for two reasons: first because it establishes a continuum between the past and the present and, second, because it highlights the importance of fieldwork in (palaeo)environmental studies. Whereas developments in technology (including remote sensing, LIDAR and modelling) can aid the understanding of fluvial landscapes, they cannot operate in isolation from field study. Such research should not be limited to a localized ground-truthing approach because this precludes the emergence of a comprehensive understanding of processes (cf. Piégay et al., 2015). An important contribution of FLAG has been its provision of the means for those developing new technologies related to fluvial activity to experience riverine environments of various types, from the more typical humid temperate regions of Europe to the extreme dryland context of southern Spain (e.g. Harvey et al., 2014).

A further key part of the FLAG approach to improved technology is the attention given to dating, as discussed above. Dating is essential for assembling an integrated framework incorporating all the (palaeo)environmental markers, such as climate or biostratigraphical evidence, which are useful both for the reconstruction of landscape dynamics (Occhietti et al., 2012) and for robust comparison of sequences from different regions. Dating is also crucial to an understanding of the complex issues related to the continuity (or otherwise) of morpho-dynamics, and the distinction between trends and events, slow changes and extreme events, although it must be admitted that the duration and significance of extreme events are not easily transposable between Pleistocene, Holocene and recent timescales (see, for example, Anton et al., 2015). The application of dating must be undertaken with caution, however. For example, it is important that sampling takes account of how representative a single date from a deposit might be; factors such as lateral (within terrace) variations, sedimentary architecture, errors inherent in the data and the type of date (e.g., exposure versus burial etc.) must all be considered. The interdisciplinary nature of FLAG activity is valuable here, since it can provide independent checks on dating results (from biostratigraphy, geoarchaeology, sedimentology and even modelling).

This scientific basis for the study of fluvial archives is critical because sedimentary sequences are a link between the past and the present. In addition to drawing on the findings of modern process-based studies, which can sometimes be too reductionist to scale up to larger landscape-scale explanations of change; continuous, high-resolution reconstructions (as for the evolution of Rhine–Meuse delta for more than 10 ka: Stouthamer et al., 2010) can provide valuable links between the past and present, and between medium and short timescales. This linkage is important, for example, to set the initial reference state for a river renaturalization strategy (Herget, 2000; Adam et al., 2007; Montgomery, 2008; Vandenberghe et al., 2012) or to emphasize natural heritage (see below). Quaternary fluvial archives can thus provide a valuable framework for future landscape management (e.g., Griffiths et al., 2002; Mather et al., 2002).

6. FLAG from the past to the future

It follows from the above that even if FLAG is characterized, through the study of fluvial archives, by an emphasis on the past, it has always been anchored in present-day research. This is exemplified by developments during the decade since the WFD concerning the renaturalization of rivers. In this a key requirement is to define a reference period for river restoration, keeping in mind that recent research underlines the fact that fluvial systems are characterized by change rather than by stability, entirely challenging the concept of a 'pre-anthropogenic reference state'. A wider perspective, especially including the understanding of the temporal evolution of processes within the entire fluvial system and under varying external and internal conditions, seems more useful rather than pinpointing a certain reference state that must inevitably be arbitrary. In a similar way, awareness of present-day research trends recognizes that anthropogenic forcing affecting fluvial systems during the last few thousand years, which were included within FLAG-focus 4 as initially defined, have tended in recent years to become the province of newly formulated research groups specifically devoted to these topics: e.g., the Working Group of Geoarchaeology (part of the

International Association of Geomorphology), LUCIFS-PAGES Focus 4, the European Geoarcheological Panel. Many publications (e.g. Wolf et al., 2014) underline, however, the porosity between the various research groups and the similarities between the approaches proposed by many researchers.

A further recognition of changing trends in present-day research is shown by the need for the specific inclusion of modelling approaches within the newly defined set of themes (focus 2.2). Landscape evolution modelling enables many of the key FLAG research questions regarding the relative importance of different external drivers to be addressed experimentally, as has been published in a number of the special issues listed in Table 1 (see also Veldkamp et al., this issue). A key potential role for FLAG is the evaluation of such numerical modelling approaches in relation to actual fluvial archives. This is not as simple as it might seem at first, both conceptually (e.g. due to issues of robustly defining initial conditions for model runs which start with ancient landscapes) and practically (e.g. due to differences in the data presented in each discipline). The desire to bridge these gaps and provide a vehicle for such interdisciplinary discussions led to the initiation of the FACSIMILE (Field and Computer SIMulation In Landscape Evolution) network by Darrel Maddy, Tom Veldkamp and John Wainwright. This group has met in 2013, 2014 and 2015 and a special issue of Earth Surface Processes and Landforms is currently in preparation, showcasing the outcomes of this initial work, which feeds directly into FLAG through common membership and shared interests.

7. Contents of the special issue

The special issue includes eighteen contributions. Eight correspond to thematic papers devoted to topics that represent key issues for the research performed within FLAG. Amongst these are papers devoted to tectonic forcing, and to the relationships between karst and fluvial systems, between glaciers and fluvial systems, and between alluvial fans and river terraces. Thematic review papers with a significant methodological component relate to numerical dating methods as applied to fluvial archives, to the relationship between palaeontology and fluvial archives, to the significance of biostratgraphical evidence from fluvial archives, and to advances in numerical modelling of fluvial archives. The remaining papers report on case studies that reflect the diversity of the research performed within the Fluvial Archives Group during its first 20 years, some in the form of reviews and others reporting new research. These papers focus on rivers located in Europe (the Tagus, Rhine, Dnieper), the Middle

East (Turkey and Syria), Asia (Yellow and Weihe Rivers) andAustralia. The timescales considered range from the pre-Quaternary to the historical period, with topics ranging from internal and external forcing on fluvial systems to post-prehistoric fluvial geoarchaeology.

The first paper, by Demoulin et al., is a review of recent developments that have enhanced understanding of vertical crustal motions. It includes coverage of fluvial responses to such motions in the form of knickpoint propagation upstream within drainage networks, a field of research that has seen little exposure in FLAG output previously. An attempt is made to reconcile inverse modelling of river longitudinal profile evolution (a means for reconstructing regional tectonic histories) with the empirical evidence from sedimentary archives in fluvial systems, although the authors conclude that more effort is required to bridge the gaps between the different research communities, at the opposite extremes of which are the mathematical modellers and the field geomorphologists.

The second paper, by Harmand et al., explores the relationships between fluvial archives at the surface and subsurface (karst) through existing research papers and presents a four-fold typology for the links between fluvial evolution and karstification, based upon different settings: (1) base- and cave-level lowering, (2) base and cave-level increases, (3) glaciation and (4) karst in evaporitic terrains. Examples are used from across different climate settings (humid to arid) and topics such as dating methods applicable to karstic environments are discussed.

Next, Cordier et al. focus on the relationship between glacial and fluvial dynamics throughout the Quaternary. They deal first with the disruptive role of glaciers located downstream from fluvial systems, then turn their focus onto the fluvial response to changes in glaciers located in the headwaters of fluvial systems, e.g. acting as major water and sediment sources (‘glacially-fed rivers’). Review of research performed in several areas, especially Europe, thus allows them to assess the complexity of the fluvial response and to propose a model for the behaviour of glacially-fed rivers.

Mather et al. then examine the dynamic role of alluvial fans within the fluvial landscape and their interaction with river systems, highlighting the potential value of such fans to the wider fluvial archive community. General relationships observed from the existing literature, together with new data from Morocco and SE Spain, are combined into a conceptual model. They found that alluvial fans act as potential 'buffers' between hillslopes and river terrace records under the influence of 'top down' climate-driven high sediment supply and alluvial fan aggradation, and 'couplers' during periods of less sediment (in relation to water) discharge and alluvial fan incision.

In the next paper, Rixhon et al. review the application of numerical dating methods to fluvial archives, underlining the considerable improvements over the last two decades and the significance of the obtained ages for the reconstruction of fluvial palaeoenvironments. The present-day limitations that represent perspectives for further investigations are also identified.

In the following paper Chauhan et al., review the advances during the past decade (updating the IGCP 449 review in this same journal by Mishra et al., 2007) in knowledge of hominin occupation across Europe, Asia and Africa, based on artefact occurrences in fluvial contexts. An overarching finding is confirmation of the well-established view that in Europe there is a demarcation between handaxe making in the west and flake–core industries in the east, although on a wider scale that pattern is undermined by the recognition of Lower Palaeolithic bifaces in the Far East. The paper also underlines that, although it seems to have appeared at different places and at different times in the later Lower Palaeolithic, the arrival of Levallois technology as a global phenomenon was similarly timed across the area occupied by Middle Pleistocene hominins, at around 0.3 Ma.

The biostratigraphical significance of fluvial archives is the core theme of the next paper, by White et al., who also assess the value of palaeontological evidence from fluvial archives to reconstruct palaeoenvironmental conditions. The review, organized geographically, underlines the advances in knowledge over recent decades, with the emergence of robust datasets from regions such as NW Europe. The contrast between these areas and other, poorly investigated regions, is discussed, as are associated research perspectives.

The last thematic review paper is by. Veldkamp et al. It summarizes developments in numerical modelling of fluvial landscape evolution over the last twenty years, showing how the importance of this approach has grown in the published literature. Models are helpfully divided into those that are most appropriate for different depositional domains, to provide direction for non specialist users in addition to tracing change. Key limitations are then discussed, and a plea made to readers to remember that numerical modelling has yielded the important insight that external driving forces may not leave a recognizable sedimentary signal, before setting the agenda for the next 20 years of such research.

Two case studies papers are then devoted to the rivers of the Iberian Peninsula. The first, by Silva et al.. analyses the chronology of fluvial terrace sequences of the two most important fluvial basins in Central Spain, the Tagus and Duero, using a statistical approach. Considering the 73 published geochronological data available, it is possible to reconstruct the overall trend of valley downcutting during the last 2.3 million years and to assign numerical ages to terraces levels at different relative elevation.

The second paper, by Cunha et al., reports on a re-analysis of the fluvial deposits containing the important Vale do Forno archaeological sites, in the Lower Tejo (Tagus) River, Portugal. New OSL dates are presented, alongside detailed stratigraphic compilation and description of multiple artefact assemblages. The research pushes back human occupation in this region into the Middle Pleistocene, prior to the Last Interglacial and older than previously thought.

Van Dinter et al. have integrated geological and archaeological datasets to demonstrate the concurrence of the gradual abandonment of a major Rhine channel at Utrecht in the Netherlands, the development of human habitation in the area, and the interactions between them. This case study highlights the stage-wise abandonment of a natural river channel, due to avulsion, coincident with intensifying human occupation in Roman and Early Medieval times. The analyses make maximum use of very rich data sets available for the study area and the tight age control that the geo-archaeological dataset facilitates, offering extra means of time control to document the pacing of the abandonment process. This allows quantification of the changes in river dimensions and meander style and provides discharge estimates for successive stages of the abandonment phase.

Panin et al. report on investigations in valleys of the River Seim and its tributaries in the middle Dnieper basin (west-central Russian Plain), where two low terraces and a floodplain with characteristic large and small palaeochannels exist. The two-phase deepening of the valley occurred in the last quarter of the last glacial epoch but cannot be attributed directly to the glacial-interglacial transition. Both the detected incision events correspond to relatively warm climate phases - late MIS 3, post-LGM warming including the Bølling-Allerød interstadial. An anomalously large size of the preserved river palaeochannels suggest that the post-LGM incision phase was induced by a climatically forced large increase of water runoff. Considerable increase of water discharges is considered the most probable cause for the late MIS 4 incision phase also. Therefore river incision seems to have been governed by changing water runoff that oscillated in phase shift with the thermal regime.

In the following paper, Maddy et al., review the research undertaken on the Gediz River (Western Turkey) during the life of FLAG, this being the location of the group's 2006 plenary meeting. The paper includes new geochronological data that allow a revised model to be proposed for the Early Pleistocene evolution of the Gedizsystem, underlining the respective role of climate and volcanism.

The following paper, by Bridgland et al., is a review of work over the past 15 years on fluvial archives in Syria and Turkey, where preservation spans several contrasting crustal types. Variation between patterns of archive preservation, essentially differences in sediment disposition, is in indeed the key theme of the paper, which reports on the well-known twin rivers of Mesopotamia (Tigris and Euphrates), as well as smaller systems in the two countries.

In the following paper, Hu et al. explore the evolution of an important reach of the Yellow River: the Sanmen gorge, by which the river flow through the Xiaoshan mountains and into its lower course to the Pacific Ocean. The formation of this gorge, linking the formerly internally-draining inner Fenwei graben with the lower valley in Eastern China, was a key event in the formation of Yellow River as exists today. A geochronological approach, based on the stratigraphical relations between fluvial and overlying aeolian deposits, is used to reconstruct landscape evolution during the last few million years, dating the formation of the Sanmen gorge to between 3.6 and 1.2 Ma.

The following paper, by Rits et al., also focuses on part of the Yellow River catchment, namely the Luo River located in the Weihe Basin (Central China). A multi-proxy approach has allowed the reconstruction of Luo River evolution since the Middle Pleistocene. The respective roles of climate and tectonic activity in the formation of the fans and terraces preserved in this area is deciphered. This paper also proposes a reconstruction of the palaeogeographical setting in which the Middle-Pleistocene Dali Man lived.

The penultimate paper, by Kemp et al., examines lacustrine–fluvial archive interaction using new fluvial and chronological evidence that provides insights into Quaternary environmental change from a key site archaeological site in southeastern Australia, the Willandra lakes. Combined with the 70 years of published studies in the region, the information is used to demonstrate that during the LGM surface water was seasonally abundant and that the subsequent drying of the system is best explained by river avulsion at circa 18.4 ka.

The final paper in the volume, by Stokes et al., focuses on fluvial archives in the High Atlas Mountains of Morocco. It is the first synthesis of strath river terrace records for this important geographic area along the mountainous margin of the NW Saharan desert region. These fluvial archives demonstrate that the key controls on Quaternary landscape development are bedrock geology configuration (which controls terrace location) and the western Mediterranean climate at 100 ka (the main driver of terrace aggradation and incision), with active tectonics playing a dominantly localized role.

The papers presented in this special issue encompass the range of topics and study areas covered by activities within the Fluvial Archives Group. This underlines the significant advances that have been realized since the inception of FLAG, both from a methodological point of view and in term of understanding the drivers that control the evolution of fluvial systems, in particular the role of external forcing.

Within this discipline, FLAG must be considered a significant actor amongst research groups devoted to the study of fluvial systems. Its role is also enhanced through partnerships that have been developed during recent decades, and which are regularly expressed by the organization of joint sessions in main conference and by the publication of more than fifteen special issues. The results exposed in this special issue also underline the range of issues that represent research perspectives for future years... and for the next two decades of FLAG activity.

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