**Catastrophic Freshwater Flooding on Earth: A Global Perspective**

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**Introduction to Special Issue**

As of 1990, the term ‘megaflood’ had only been used in about a dozen scientific publications but by 2009 there were around 1000 citations, which trend promoted the publication of a state-of-the-art volume on the subject (Burr et al., 2009). In the decade that followed there were 3000 citation of the term (Google Scholar search). If this trend continues the number of publications dedicated to megafloods (defined as > 1 million cumecs peak discharge) and other large floods is likely to double in the next ten years. The approach of the tenth anniversary of the Burr et al. (2009) volume was a spur to producing this Special Issue. In this volume we consider large-scale catastrophic freshwater flooding generally. The issue consists of 17 commission papers that roughly can be divided into specific case studies that progress knowledge of large-scale flooding, including processes and modelling, as well as more generic position papers that review the state of knowledge in different regions around the globe. The year 2019 has seen the passing of two leading megaflood scientists: John Shaw and Alexey Rudoy, as well of the passing of Robert Gilbert who is a co-author with Shaw et al. (2019; this volume), so this publication can stand as a testimonial to their achievements. John Shaw will be remembered for his insightful analyses of many aspects of fluvioglacial sediments and landforms and, in particular, his often provocative and controversial views on the role of subglacial meltwater processes in proglacial and subglacial landscape evolution. Although these ideas are not accepted by all, there can be no doubt that John’s hypotheses have stimulated the thought processes of many of the readers of this Special Issue. Alexey Rudoy was a distinguished Russian scientist who became fascinated with field evidence he believed showed that megafloods emanated from the Altai Mountains in Siberia and he visited the Altai nearly every year of his adult life. At a time when many of his contemporaries did not except the thesis of megafloods, Alexei developed his ideas, at first under the supervision of M.G. Groswald, also of megaflood fame. He rigorously promoted the Altai megaflood concept which he later consolidated as his ‘theory of diluvial morpholithogenesis’. It was Alexei who introduced Vic Baker and Paul Carling to the Altai, for which we are especially grateful.

Papers group roughly as indicating advances in techniques and interpretation and comprehensive reviews of the understanding of catastrophic flooding in different environments ranging from the continental scale to the more regional. A notable aspect of the last ten years has been the significant developments in numerical modelling of megaflood hydraulics. In particular we are now witnessing the emergence of ‘whole system’ models, whereby, for example, the draining of the reservoir of water is coupled to the dynamics of floodwaters in the downstream floodway, within even wider modelling possibilities now contemplated, such as the inclusion of ice-sheet dynamics or tectonics. Bohorquez et al., (2019a; this volume) couple a model for the Kuray-Chuja lake drainage to the downstream flood propagation, mediated by the behaviour of the intervening ice-dam. This procedure sheds light on the unknown failure mechanism and failure rate of the ice-dam. Future considerations of such ‘whole system’ models could include the dynamics of associated ice-masses, which cause impoundment, that set the timing and frequency and hence the number of floods associated with down-wasting of Quaternary ice-sheets and glaciers (Margold *et al*., 2018; Harrison *et al*., 2019) as well as the interaction of floods with the broader landscape and oceans (Benito and Thorndycraft, 2019; this volume). Thus, catastrophic flood modelling stands at a threshold. Modelling should lead to adaptive reasoning (Blair *et al*., 2019) as to how each flood behaved, how it should be modelled, and how it interacted with the regional landscape. Such thinking can lead to improvements in site-specific modelling generally (Agatova et al., 2019; this volume), and in modelling specific landform development such as large gravel dunes (Bohorquez et al., 2019b; this volume) but also guide the field scientist to specific locations that require closer attention. Moreover, advances in generic modelling of process and product, such as the synthetic stratigraphy of giant bars, should draw nearer.

Herget et al. (2019; this volume) review the burgeoning compendium of dates associated with Quaternary flood–related landforms in the Altai Mountains, Siberia. In particular, distinct problems are associated with deriving reliable cosmogenic, luminescence and radio-carbon dates in the region. A more nuanced and robust approach to the selection of sites and applied techniques will be required in the future, if reliable dates are to be obtained. Shaw et al. (2019; this volume) consider the origins of ‘s-forms’, a specific class of erosional bedforms in rock, of which some of the larger examples may be found along the course of exceptional floods. Although erosion of bedrock through ballistic impacts of mobile gravel has been associated with catastrophic floods commonly, the processes, associated landforms and their hydraulic interpretation have not received the same attention as depositional landforms. With regard to process, Carling and Fan (2019; this volume) considers the role of particle comminution and the associated energy expenditure in forming giant bar sedimentary associations and the definition of megafloods and superfloods more specifically.

The Columbia River basin has always been a special place for catastrophic flood research; most notable with respect to Missoula floods, emanating from the Cordilleran Ice Sheet and associated ice-dammed lakes and the Bonneville floods, emanating from pluvial lake Bonneville. It is nearly 100 years since J Harlen Bretz produced his first paper outlining the concept of a flood-related channelled scabland and O’Connor et al. (2019; this volume) comprehensively review the current state of knowledge. In similar vein Fisher (2020) reviews the evidence for megaflooding from glacial Lake Agassiz.

The Fennoscandian Ice Sheet, at maximum extent, covered all of Scandinavia, extending across the Baltic to Estonia, Latvia, Lithuania, most of Poland, and northern Germany. On occasion, it covered what is now the northern part of the North Sea to coalesce with the British ice sheet. It is now clear that proglacial drainage from the southern margins of the Fennoscandian Ice Sheet was conveyed via the Urstromtal valleys (east–west late Pleistocene ice-marginal channels of northern Germany) to what is now the southern North Sea basin (Winsemann *et al*., 2020). Weckwerth *et al*., (2020; this volume) provides an important contribution with respect to the knowledge base on large-scale Quaternary flooding in Poland, whereas Panin *et al*. (2020; this volume) provide a broader overview of catastrophic flood evidence across Europe, Fennoscandianavia and Russia, chiefly west of the Ural mountains.

The Patagonian ice-sheet of southern Argentina and Chile most probably was associated with widespread catastrophic outbreak floods, but until recently, there had been little attention to this subject in the region (Pacifici, 2009; Dussaillant et al., 2010) although the current risk of glacial-lake outburst floods in the Andes has been addressed more comprehensively (*e.g.* Frey *et al*., 2018). Benito and Thorndycraft (this volume) provide a detailed synthesis of Quaternary megaflooding within the Baker River region of Chile set into a broader landscape context. The largest historic jÖkulhlaups (glacial outburst floods) in Iceland were related to the Katla volcanic system and the Myrdalsjokull ice cap near the south-central coastline of the island. The peak discharge of the 1918 Katla jÖkulhlaup may have achieved megaflood status, with a flow of about 1 Sv (Tomasson, 1996). Prehistoric megafloods have also shaped the landscape of Iceland as documented by numerous studies. Carrivick & Tweed (2019; this volume) provide a comprehensive review of catastrophic flooding in Iceland and, importantly, also provide the first holistic consideration of evidence for such flooding in Greenland.

Within China there has been an explosion of interest in palaeofloods, so-far mainly related to the evidence provided by slackwater deposits for large, rather than catastrophic floods. Nevertheless, there is good evidence for major catastrophic flood events in the headwater regions of the Yellow and Yangtse rivers, as well as rivers in Szechuan province and in Tibet. However, little of this evidence is published. Liu *et al.* (2020; this volume) provide a comprehensive review of the scientific record of catastrophic flooding in China which provides a benchmark study for future research efforts. Yanchilina et al. (2019; this volume) present new evidence and review the likelihood that deglaciation of the Fennoscandinavian, Eurasian and Alpine Ice Sheets dispensed a vast amount of meltwater into Black, Marmara and Caspian Sea freshwater lakes During Heinrich Event 1. Evidence for the salt-water Zanclean megaflood of the Mediterranean remains tantalizingly evident and at the same time elusive. The current knowledge base is reviewed by Garcia-Castellanos et al. (2019; this volume) which should provide a spur to further investigations. Caruso et al. (2019) investigate sections in SE Spain and reaffirm that the onset of the Zanclean relates to abrupt reflooding from the Atlantic Ocean.

Greenbaum et al. (2020; this volume) provide flood-reconstructions and dates for exceptional floods in an hyperarid catchment within the Negev Desert of Israel. Although compared with some floods reported within this volume the peak discharges are not great, the floods likely are exceptional within the context of flood magnitude-frequency within hyper-arid environments of the eastern Mediterreanean; a topic worthy of further investigation especially in relation to climate change and the requirement to quantify water-resources in the Levant more widely (Abbas et al. 2020).

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