Palaeoflood hydrology: an emerging science

Diane Saint-Laurent
Section Géographie, Université du Québec à Trois-Rivières, C.P. 500, Trois-Rivières, Québec G9A 5H7, Canada

Abstract: On examining the scientific literature of recent years, one notices an increase in the number of studies of global warming and its impact on the Earth’s various environments. Research has been undertaken in various fields such as geomorphology, hydrology and many others. In the context of climatic change, there is growing interest in the study of past floods, or palaeofloods. Researchers are attempting to reconstitute the chronology of past floods, especially with respect to past or subrecent climatic changes. The work involves using different methodological approaches borrowed from various disciplines including geology, geomorphology and ecology. The reconstruction of ancient hydrological events such as palaeofloods in fact requires that different methods and techniques be combined in order to trace the chronology of events as precisely as possible using different biophysical parameters. A wide variety of indicators are used in the chronological reconstruction of ancient fluvial environments, whether in humid, subhumid or desert regions. These indicators involve analysing stratigraphic sequences and sedimentary deposits, organic matter and macrorest deposits, as well as using radiocarbon dating ($^{14}$C), thermoluminescence (TL), and dendrochronology and lichenometry. In fact, most work on the reconstitution of the frequency and magnitude of ancient floods uses several methods and techniques to obtain the long-term chronology of flood events in relation to the specific conditions (e.g., climate, geomorphology) of a region or study area. With the publication of several studies in palaeohydrology, it was interesting to examine, through a literature review, the various approaches used in the study of palaeofloods. This kind of study has seen major advances, which can be explained partly by the interest generated by global climate change and its effect on river-system dynamics.

Key words: chronology, Holocene, palaeoflood, palaeostage indicators, slackwater deposits.

1 Introduction

Scientific research over the last two decades has been characterized by an increase in the number of studies of global warming and its impact on the Earth’s various environments (e.g., terrestrial and aquatic ecosystems, river systems). The research
concerns different fields such as geomorphology, ecology, hydrology and many others. Research in hydrology has attempted to establish links between climate change and variations in river systems. Some research, for instance, delves into the impact of global warming on flooding over the last few decades and on changes to hydrological systems as a result of climatic change (Wells, 1990; Newson and Lewin, 1991; Martin, 1992; Rind et al., 1992; Knox, 1993, 2000; Branson et al., 1996). However, it would appear that the chronological scales used are often too short to evaluate correctly the impacts of climate change on hydrological phenomena (Brakenridge, 1980; Chatters and Hoover, 1986; Stedinger and Cohn, 1986; Smith, 1991; Brown et al., 2001; Alila and Miraoui, 2002). Furthermore, it becomes difficult to establish which phenomena are a result of actual climate changes and which result from anthropogenic changes, especially over the past 100 years. These difficulties have led some researchers to consider using much longer chronological scales, i.e., the 1000-year scale, to better understand the impacts of climate changes and their effects on ancient and recent river systems.

In the context of climate change, there is growing interest in the study of past floods, or palaeofloods. Researchers are attempting to reconstitute the chronology of past floods, especially with respect to past or subrecent climatic changes. The reconstruction of ancient hydrological events such as palaeofloods in fact requires that different methods and techniques be combined in order to trace the chronology of events as precisely as possible using different biological and physical indicators. The earliest research in this field was conducted in the USA, more specifically in the southern and southeastern parts of the country, which are regions characterized by an arid and semi-arid climate. Over the last few years, however, there has been an increasing number of studies from other parts of the world. Much of this research is based on previous work but with new elements of interpretation that are mainly related to the many fluvial environments and climatic patterns associated with floods. The emergence of this new research on palaeofloods will not only help increase understanding of the dynamics of river systems in highly diverse environments, but will also shed new light on the interaction between river systems and climatic change.

II Palaeoflood studies

In reviewing the scientific literature over the last 20 years, there appears to be growing interest in palaeoflood studies. Such studies seek to reconstruct ancient or historical flood events. However, the earliest studies that sought to understand the context of ancient river environments date back to the nineteenth century and include the work of C.T. Jackson (1839) in Mount Katahdin (Maine) and J.D. Dana (1882) in the Connecticut River Valley (Massachusetts) and, more specifically, the work of J.H. Bretz (1923) in the Columbia Plateau region (Washington) (see Costa, 1987; Patton 1987). Researchers were attempting to understand the formation of stratigraphic sequences of the Pleistocene Age, some of which appeared to be associated with major floods that had been caused by such events as the collapse of glacial dams. Though this work has shed new light on palaeohydrological research, sustained research in the study of ancient floods is very recent and basically covers the last two decades. On this note, it is important to mention the pioneering work

Though palaeohydrological research was dominant in the early 1980s, there appears to be an increasing number of recent studies from different areas of the world, including Australia, Africa and Asia (Baker et al., 1983, 1985; Gale et al., 1990; Wohl et al., 1994; Zawada and Hattingh, 1994; Tooth and Nanson, 1995; Hattingh and Zawada, 1996; Kale et al., 1996; Dollar, 1998; Yang et al., 2000; Grossman, 2001; Jones et al., 2001; Oguchi et al., 2001; Heine and Heine, 2002). This research deals with the study of palaeofloods with respect to climate changes over the last few millennia (~10 000 years) as well as the chronological study of floods using different geomorphological and biological indicators. In many cases, the research is based on approaches that use highly varied methods and techniques, which are generally associated with palaeoenvironmental studies (e.g., palaeoecology, palaeoclimatology, palaeosoils, stratigraphy). This allows different biophysical indicators to be combined, which leads to a better understanding of the ancient environments where the hydrological events occurred.

Moreover, there have been a considerable number of studies carried out in regions characterized by arid or semi-arid climates, such as the southern and south-eastern parts of the USA (Costa, 1978; Tullis et al., 1983; Patton and Handsman, 1984; O’Connor et al., 1984; Patton and Boison, 1986; Partridge and Baker, 1987; Enzel, 1992; Ely et al., 1993; Enzel et al., 1993, 1994; McQueen et al., 1993; Grimm et al., 1995; House and Baker, 2001; Ostenaa et al., 2002). This wealth of research is largely due to the influence of the pioneering work of Baker (1973) and other researchers working in these parts of the USA. However, the last few years have seen a growing number of studies in other areas of the world, especially in regions characterized by humid and subhumid climates, such as Japan, India and China (Ely et al., 1996; Brown et al., 2000; Yang et al., 2000; Grossman, 2001; Jones et al., 2001; Oguchi et al., 2001) or cold and temperate climates such as Europe and Canada (Macklin et al., 1992; Passmore and Macklin, 1994, 2000; Hay et al., 1997; Benito et al., 1998; Moser et al., 2000; Wolfe and Thomas, 2001; Livingston et al., 2001; Saint-Laurent et al., 2001; Arnaud-Fasseta, 2002; Saint-Laurent and McNeil, 2002; Saint-Laurent and Saucet, 2003). Much of this work has the same aim, namely to reconstitute the Holocene chronologies of flood events and to understand the evolution of ancient or subrecent river environments. There are also a number of studies that attempt to establish much longer chronologies, i.e., those associated with the glacial eras of the Pleistocene, for instance (Baker and Bunker, 1985; Jarrett and Malde, 1987; Gordon, 1993; Rathburn, 1993; Smith and Fisher, 1993; Baker et al., 1993; Rea et al., 1994; Lewis et al., 2001). Some of these studies have specifically focused on the problems associated with identifying catastrophic floods induced by the collapse of glacial lakes (Smith and Fisher, 1993; Baker et al., 1993). Lastly, there are studies that were conducted in mountainous regions (Chatters and Hoover, 1986; Jarrett, 1990; Waythomas and Jarrett, 1994; Gottesfeld, 1996; Jarrett and Tomlinson, 2000; Johnson and Warburton, 2002). In these environments, watercourses are often characterized by a ‘torrential’ type of river system that, because of the force of the current, allows coarse deposits such as gravel, pebbles or even large pieces of rock to be transported. The presence of such materials and their
topographic location along river terraces has led to the identification of various present or more ancient flood events.

III Slackwater deposits and palaeostage indicators

Many studies have analysed slackwater deposits (SWD) to reconstruct the palaeoflood history of rivers (Costa, 1978; Patton et al., 1979; Patton and Baker, 1981; Kochel et al., 1982; Ely and Baker, 1985; Baker, 1987; McQueen et al., 1993; Waythomas and Jarrett, 1994; Zawada and Hattingh, 1994; Hattingh and Zawada, 1996; Ely et al., 1996; Ely, 1997; Meirovich et al., 1998; Brown et al., 2000; Greenbaum et al., 2000, 2001; Yang et al., 2000; Jones et al., 2001; Heine and Heine, 2002). These kinds of deposits are mainly composed of fine-grain sediments (silt and fine sand) from river banks that were deposited during ‘large floods in areas of reduced flow velocity caused by ponding, eddying, or back-flooding up tributaries’ (Ely and Baker, 1985: 104). In fact, such deposits are usually found at the mouths of rivers or in slow-flowing waters, thus enabling particle sedimentation. They were found in different fluvial environments and, for many researchers, serve as adequate physical and geomorphologic indicators in the reconstruction of ancient floods. Baker (1987) established different sedimentological criteria for characterizing slackwater deposits (see Table 1) as well as indications on the fluvial environments that most favour their formation.

In many studies researchers used both slackwater deposits and palaeostage indicators (PSI) for the reconstruction of ancient floods. In addition to slackwater sediments, flood debris and silt lines or scars left on tree trunks by ice or logs transported by the current are often well-preserved along river terraces and facilitate the reconstruction of ancient flood events (Harrison and Reid, 1967; Baker, 1987; Hupp, 1988; McCord, 1990; Wohl et al., 1994; Gottesfeld, 1996; Ostenaa et al., 2002). In fact, several researchers have used slackwater deposits and palaeostage indicators concomitantly to reconstruct former flood levels or to complete the flood chronology (Kochel and Baker, 1982, 1988; Ely and Baker, 1985; Hosking and Wallis, 1986; Stedinger and Baker, 1987; Enzel, 1992; Enzel et al., 1993; Waythomas and Jarrett, 1994; Wohl et al., 1994; Jarret and Tomlinson, 2000; Greenbaum et al., 2000; Yang et al., 2000; Ostenaa et al., 2002). As Knox (2000) notes, these various indicators constitute ‘archival data’ that enable the palaeoflood timeline to be more easily reconstructed.

In addition to slackwater deposits and palaeostage indicators, the morphological description of buried soil (palaeosol) along river terraces and its degree of maturity may also constitute morphosedimentological indicators that can be used to identify successive phases of flooding and/or dewatering (Chatters and Hoover, 1986;

Table 1 Sedimentological criteria for recognizing individual flow eventsa

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Abrupt vertical grain size change</td>
<td>Abrupt change in the size of grains deposited during flood events.</td>
</tr>
<tr>
<td>(2) Slope colluvium and tributary alluvium interfingering with SWD from main channel</td>
<td>Interfingering of slopes and tributary deposits with slackwater deposits.</td>
</tr>
<tr>
<td>(3) Fine silt, clay and organic layers that are deposited from the washload of the flood</td>
<td>Layers deposited from floodwash.</td>
</tr>
<tr>
<td>(4) Buried soils that offer some estimate as to the duration of exposure, indicating a hiatus in sedimentation by large floods for a period represented by the age and degree of the soil development</td>
<td>Indicator of flood duration and sedimentation hiatus.</td>
</tr>
</tbody>
</table>

Note: *See Baker (1987); Greenbaum et al. (2001: 162).
McQueen et al., 1993; Ely, 1997; Jarrett and Tomlinson, 2000; House and Baker, 2001; Jones et al., 2001; Heine and Heine, 2002). The granulometric variations of the sediments, the consistency and colour of the layers, the presence of organic beds and pedogenetic alterations are all parameters that shed light on how river terraces were formed over the years. Authors such as Heine and Heine (2002), for instance, have used different pedological parameters to establish the chronosequence of flood events along the Kuiseb River (central Namib Desert, Namibia). The presence of induration layers (thin salt and gypsum laminae) interbedded in flood silt suggests some phases of stability in the river terraces. The presence of these interbedded palaeosoils in the slackwater deposits is seen as an interruption in the phases of flooding. Chatters and Hoover (1986) and McQueen et al. (1993) also used pedological criteria (e.g., texture, colour, presence of organic beds) to reconstitute non-palaeoflood and palaeoflood phases. The presence and thickness of alluvial horizons (B horizons) and the concentration of iron oxides in the accumulation horizons are also pedogenetic parameters that are used to evaluate the rate of development of soils buried in river terraces (Jarrett and Tomlinson, 2000). These indicators, combined with stratigraphic sequences, for instance, can be used to estimate the relative age of the terraces and to also evaluate the dewatering phases (soil formation) of those associated with the floods (accumulation of slackwater deposits).

In general, the presence of buried soils in river terrace sediments points to periods of stability that account for the development of such soils. In sedimentary sequences, one can thus find several palaeosoils interbedded in layers of sediments deposited during successive phases of flooding. Knox (1985, 2000) and Ely (1997), for instance, sought to establish correlations between the various sedimentary sequences found in river terraces and the climatic changes of the Holocene. The palaeosoils found in sedimentary sequences thus appear to be more associated with rather dry climatic periods, whereas the successive accumulation of slackwater deposits appears to be related to more humid climatic periods. Finally, flood chronologies from several regions suggest that times of rapid climate change (during Holocene) ‘have a tendency to be associated with more frequent occurrences of floods’ (Knox, 2000: 439).

**IV Reconstruction of palaeoflood chronology**

A wide variety of indicators are used in the chronological reconstruction of ancient fluvial environments, whether in humid, subhumid or desert regions. These indicators involve analysing stratigraphic sequences and sedimentary deposits, organic matter and macrorest deposits, as well as using radiocarbon or isotope dating methods (Baker et al., 1985; Ely, 1997; Mahaney, 1998; House and Baker, 2001), thermoluminescence (TL) or optically stimulated of luminescence (OSL) (Murray et al., 1992; Duller, 1996; Greenbaum et al., 2000, 2001; Kale et al., 2001) and dendrochronology (Costa, 1978; Hupp, 1988; Jarrett, 1990; Grimm et al., 1995) or lichenometry (Innes, 1983; Harvey et al., 1984; Macklin et al., 1992; Macklin and Lewin 1993; Johnson and Warbuton, 2002). Radiocarbon dating ($^{14}$C) is by far the most commonly used dating method for establishing flood chronology (Baker et al., 1985; Chatters and Hoover, 1986; Ely et al., 1992; Waythomas and Jarrett, 1994; Wohl et al., 1994; Ely, 1997; Jones et al., 2001; Heine and Heine, 2002; Ostenaa et al., 2002). The method can be used to date events found on relatively recent chronological
scales (between ±20,000 and 100 years BP) (Mahaney, 1998). But the main problem in reconstructing palaeofloods essentially lies in finding layers of organic matter in the sedimentary sequences, which makes it difficult to date the flood events using radio-carbon (14C) methods (Kochel and Baker, 1988; Knox, 1993; Greenbaum et al., 2001). In arid or semi-arid environments, these organic layers are often rare because of the prevalent climatic conditions which do not favour the formation of a thick vegetation cover. However, this problem is not typical of these environments but also characterizes humid regions (Knox, 2000; Yang et al., 2000; Saint-Laurent and Lavoie, 2004). The frequent absence of such organic matter layers in sediments is either due to an overly short vegetation cover formation period between phases of flooding or the erosion of such layers through the action of different natural phenomena (e.g., streaming, gliding, bioturbation, fluvial erosion).

Other methods through which flood events can be dated include dendrochronology and lichenometry (Hupp, 1988; Jarrett, 1990; McCord, 1990; Macklin et al., 1992; Grimm et al., 1995; Gottesfeld, 1996; Johnson and Warburton, 2002). The thermoluminescence (TL) technique can be used to obtain relatively precise dating of archaeological samples (artefacts) (Duller 1996), but it requires that archaeological objects be found in situ in river terraces at the location of the sites being studied, which is rare. Moreover, certain dating techniques that use optical stimulation luminescence (OSL) based on crystal structures of quartz or feldspar grains are currently not very reliable for dating river deposits, unlike aeolian deposits, for instance (Duller, 1996; Mahaney, 1998). Researchers who have used this technique to date flood deposits have noted considerable margins of error compared with the dates obtained by radiocarbon dating (Porat et al., 1996; Greenbaum et al., 2000, 2001). The various problems involved in dating ancient floods make us aware of the importance of using as many physical and biological field indicators as possible in order to reconstitute the chronology of flood events as precisely as possible.

V Palaeofloods and past climate

Various authors have attempted to reconstitute the chronology of flood phases with climate changes of the Holocene (McDowell, 1983; Knox, 1985, 1993, 2000; Ely and Baker, 1985; Webb et al., 1988; Wells, 1990; Smith, 1992; Ely et al., 1993; Rumsby and Macklin, 1994; Ely, 1997; Yang et al., 2000; Grossman, 2001; Lewis et al., 2001). Researchers noted certain correlations between flood recurrences and variations in climate over the last 10,000 years. For instance, it was noted that periods of climatic deterioration, combined with more humid conditions, often led to an increase in the recurrence of flooding. On the other hand, periods of climatic warming combined with drier conditions are often characterized by a decrease in flooding (see Table 2). Ely (1997) noted ‘that the largest floods during the middle and late Holocene in Arizona and southern Utah cluster into distinct time periods that reflect regional and global climate fluctuations’ (see Knox, 2000: 451). More specifically, the period from 5000 to 3600 14C years BP (dendrocalibrated age, 3800–2200 BC) and the period after 2200 14C years BP (400 BC) are characterized by high-magnitude floods. Furthermore, warm intervals, such as the Medieval Warm Period, are characterized by a decrease in the number of large floods (Ely, 1997; see also Knox, 2000: 451). The different regional chronologies of flood recurrences are relatively comparable.
Table 2 Summary of palaeoflood studies concerning the relation with floods events and climatic variations of Holocene

<table>
<thead>
<tr>
<th>Site</th>
<th>Flood events</th>
<th>Chronology of Holocene</th>
<th>Characteristics of palaeoclimate</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ara River, Central Japan</td>
<td>Increase of large floods</td>
<td>9500–7500 yr BP</td>
<td>Cool climate</td>
<td>Grossman (2001)</td>
</tr>
<tr>
<td>Yellow River, China</td>
<td>Large floods</td>
<td>8000–6000 yr BP</td>
<td>Wet climate</td>
<td>Yang et al. (2000)</td>
</tr>
<tr>
<td>Upper Mississippi Valley, USA</td>
<td>Small floods</td>
<td>8000–6500 yr BP</td>
<td>Warming and drying climate</td>
<td>Knox (1985)</td>
</tr>
<tr>
<td></td>
<td>Large floods</td>
<td>From 6000–4500 yr BP</td>
<td>Climates conditions became cooler and/or more moist</td>
<td></td>
</tr>
<tr>
<td>Ara River, Central Japan</td>
<td>Increase of large floods magnitude</td>
<td>5500–4500 yr BP</td>
<td>Climate colder and increases in storm frequency</td>
<td>Grossman (2001)</td>
</tr>
<tr>
<td>Arizona and southern Utah, USA</td>
<td>High-magnitude floods</td>
<td>5000–3600 yr BP</td>
<td>Cool and wet climate and increases frequency of strong El Niño events</td>
<td>Ely (1997)</td>
</tr>
<tr>
<td></td>
<td>Increase of floods</td>
<td>4800–3600 yr BP</td>
<td>Wet climate</td>
<td>Ely et al. (1993)</td>
</tr>
<tr>
<td>Ara River, Central Japan</td>
<td>Decrease of floods</td>
<td>3600–2200 yr BP</td>
<td>Climate warmer</td>
<td>Grossman (2001)</td>
</tr>
<tr>
<td>Upper Mississippi Valley, USA</td>
<td>Decrease of large floods</td>
<td>3350–3000 yr BP</td>
<td>Intensity of precipitation (?) during this period</td>
<td>Knox (1985)</td>
</tr>
<tr>
<td></td>
<td>Large floods</td>
<td>3000–2000 yr BP</td>
<td>Intensity of precipitation (?) during this period</td>
<td></td>
</tr>
<tr>
<td>Ara River, Central Japan</td>
<td>High-magnitude floods</td>
<td>1100–900 yr BP</td>
<td>Medieval Warm Period (MWP)</td>
<td>Knox (2000)</td>
</tr>
<tr>
<td>Arizona and southern Utah, USA</td>
<td>Increase larger floods</td>
<td>Between 950 and 550 yr BP</td>
<td>Medieval Warm Period (MWP)</td>
<td>Grossman (2001)</td>
</tr>
<tr>
<td></td>
<td>Decrease of floods</td>
<td>800–600 yr BP</td>
<td>Warm climatic conditions</td>
<td>Ely et al. (1993)</td>
</tr>
<tr>
<td>Rio Casma, northern coastal Peru</td>
<td>Minimum frequency of floods</td>
<td>Between AD 1325 and 1240 BC</td>
<td>Medieval Warm Period (MWP)</td>
<td>Wells (1990)</td>
</tr>
</tbody>
</table>

Grossman states that ‘in general, the entire temperate zone of the Northern Hemisphere shows a similar sequence of climatic changes so that fluvial records should be comparable’ (Grossman, 2001: 32). Knox (1993, 2000), who compared the south-western regions of the USA (Arizona and Utah) with the Mississippi Valley, in fact found obvious correlations: ‘Palaeoflood records for the southwest against those for the east suggest that temporal patterns of variation for at least part of the flood series are causally linked’ (Knox, 2000: 452). Moreover, the increase in and frequency of floods identified during the Holocene often coincide with other events, such as the
increase in lake levels or changes to the vegetation cover that are reflected in the pollen assemblages (Knox, 1993, 2000; Ely et al., 1993).

Although regional and continental chronologies show a number of similarities, these appear to be less common on a world scale, according to Knox (2000), who notes that many regional studies were synchronous but not always worldwide. In fact, a number of chronological inconsistencies can be seen when comparing the various regions of the world, especially Europe, Japan, China and the USA (Knox, 1993, 2000). For instance, the periods identified as being characterized by a high rate of flood recurrence are not the same everywhere. For instance, substantial differences are noted among the flood events that occurred from 950 to 550 years BP for the southern USA and Central Japan (see Table 2). In the first case (Arizona and southern Utah), the chronological period of 800–600 years BP is associated with a decrease in flooding, whereas for the area along the Ara River (Central Japan), the period from 950 to 550 years BP saw an increase in flooding. For the beginning of the Holocene (Table 2), there also appears to be a low chronological correspondence between the Ara River region (Japan) and that of the Upper Mississippi Valley (USA): the first is characterized by a cold climate with increased flooding (9500–7500 yrs BP), and the second by a decrease in flooding (8000–6500 yrs BP) as well as a warmer climate (Table 2). In fact, there are also most likely several other examples of a lack of chronological correspondence in palaeoflood studies. This lack of synchronism between the chronologies of the different regions of the world in fact reveals considerable variability in climatic systems on a world scale as well as the difficulty in precisely reconstructing all the flood events associated with climatic variations, both minor and major.

This brings us to consider the true impact of climate change on the dynamics of river systems. If one takes into account the work of Knox (1993, 2000), Ely (1997) and Ely et al. (1993), for instance, it could be said that relatively minor climatic variations can cause relatively major changes in flood phenomena. For instance, research conducted by Knox (1993, 2000) in the Upper Mississippi Valley (USA) seems to show that the periods of heavy flooding identified during the Holocene could be caused by relatively modest changes in climate. For example, changes in mean annual temperatures of only approximately 1–2°C and mean annual precipitation of 1–20% would be required to bring about marked climate changes during this period of the Holocene, which would naturally have an effect on flood recurrence. The author concludes that ‘modest climate changes, generally smaller than climate changes predicted by global circulation models for greenhouse gas increases, caused large and sometimes abrupt adjustments in both magnitudes and frequencies of floods in the Upper Mississippi Valley’ (Knox, 1993: 432). In a context of global climate change, an increased risk of flooding appears to be likely in the near future, and such an increase could prove to be dramatic in many parts of the world. This is why it is important to continue with research in this area to better understand the relationships between climatic variations and the dynamics of river systems and flood phenomena.

VI Conclusion

Over the last few years, palaeohydrology and, more specifically, palaeoflood research have seen major advances, which can be partly explained by the interest
generated by global climate change and its effect on river-system dynamics. Several studies, in fact, deal with the chronology of ancient floods with respect to climate changes over the past millennia, thus allowing for a better understanding of flood phenomena while taking into account changing climatic environments. This recent work also leads to a better understanding of the dynamics of river systems with respect to highly varied environments, especially arid or semi-arid regions versus humid or subhumid climates.

The emergence of a wealth of palaeoflood research also led to the development of highly varied methodological approaches for reconstituting ancient fluvial environments. The need to borrow methods and techniques from various other fields (e.g., geomorphology, climatology, pedology, ecology) proves, in fact, to be virtually indispensable when attempting to reconstitute ancient or subrecent environments. The use of different biophysical indicators (sedimentology, palaeosoils, dendrochronology, lichonometry, dating methods, etc.) requires the use of a multidisciplinary approach, without which such palaeoenvironmental reconstitutions would be difficult. Furthermore, it is still relatively difficult to reconstitute past hydrological conditions since several morphological, sedimentological, stratigraphic and other types of indices may have been modified or degraded by the action of various natural or anthropogenic agents.

Lastly, the reconstitution of longer chronologies (i.e., on a millennium scale) allows us to better understand how hydrological events occurred in the past and undoubtedly to better predict the consequences of climatic variations on current fluvial environments. These studies will increase knowledge of flood phenomena and enable the planning of riverside developments that are better suited to the dynamics of the river systems.

Acknowledgements

Part of this work was funded by the Natural Sciences and Engineering Research Council of Canada and Université de Québec à Trois-Rivières’s FIR (research fund). The author acknowledges the contribution made by graduate student Luc Lavoie and the collaboration of Danielle Trudel.

References


Enzel, Y. 1992: Flood frequency of the Mojave River and the formation of late Holocene playa lakes, southern California, USA. The Holocene 2, 11–18.


