WATERFALLS, SCIENCE AND AESTHETICS

Abstract: Waterfalls and rapids are a subject of study by scientists and scholars from a variety of academic and professional backgrounds. Unlike cave research, known as speleology, which also involves many different disciplines, the study of waterfalls is not generally regarded as a distinct branch of knowledge. Long neglected as subjects of research, waterfalls have received considerable attention since the 1980s. This paper traces the study of waterfalls from the late eighteenth century, a period when both a scientific and an aesthetic interest in landscape developed in Europe, to the present. The work of geographers, geologists and others who studied landforms and landscapes is examined, with particular attention to those who expressed a special interest in waterfalls, notably Alexander von Humboldt. The study argues that the scientific and aesthetic approaches to landscape research are not incompatible, and supports the view that both are necessary for a full understanding and appreciation of the environment in which we live.

Key words: waterfalls; landscape research; science and aesthetics; Humboldt.

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“... the interesting phenomenon of cataracts” Alexander von Humboldt (1821, p. 66).

Introduction

Despite the interest shown by Alexander von Humboldt, waterfalls, long appreciated by painters and poets, were largely neglected by scientists and scholars until relatively recently. In contrast, other landforms, such as mountains and caves, received considerable attention from researchers from a wide range of disciplines, including geography. The following discussion suggests that studies of waterfalls should be undertaken within a comprehensive
framework that includes a consideration of their aesthetic qualities as well as their
geographical significance and scientific aspects such as their geology and ecology. Humboldt
raised the question of terminology in relation to waterfalls, commenting on the vagueness of
words such as ‘cataract’, ‘cascade’, ‘falls’ and ‘rapids’ (Humboldt 1821, p.57). In this essay
the word ‘waterfall’ embraces all of these fluvial phenomena. While focusing on waterfalls,
this paper supports the view expressed by Laura Dassow Walls, that “We in the twenty-first
century need to reclaim Humboldt” (Walls 2009, p. x), which “means revisioning science as
an intrinsic constituent of the humanities, reading beyond the ‘two cultures’ to grasp a
worldview that knew how to distinguish the natural and social sciences, the arts and the
humanities, but knew also how fully each interpenetrated all the others” (Walls 2009, p. xi).

Arguing for synthesis in the study of waterfalls, this essay refers to the literature about
mountain and cave research, as well as on that relating specifically to falls and rapids.

Mountain geography and waterfall studies

Mountains have been studied intensively by geographers, geomorphologists and others
(Barsch and Caine 1984, Smethurst 2000). David Smethurst observed, “Scholars have studied
the mountain world for better than two centuries, yet no agreed-upon body of mountain
literature has emerged. Instead, there is a vast array of scattered publications dealing with
high places ...” (Smethurst 2000, p. 35). Smethurst’s words equally apply to the study of
waterfalls. The array of publications on waterfalls may not be as vast as that devoted to
mountain topics, but it is certainly scattered. As is demonstrated later in this essay, papers on
many aspects of waterfalls are found in scholarly journals of various kinds. Geographers are
amongst the writers who have contributed to this body of literature, but waterfalls have also
been the subject of study by scientists and scholars from fields as diverse as geology,
freshwater ecology and tourism. Indeed, much of the literature on waterfalls is in the form of
tourist guidebooks designed for the use of ‘waterfall lovers’ who engage in ‘waterfalling’, to
use a term in current use (Hudson 1998). Some of these guidebooks, though not intended as scholarly or scientific works, are written by geographers with specialized knowledge of waterfalls. The waterfall guides by Gregory Plumb (2005, 2008) in the USA, and Florian Spichtig and Christian Schwick (2007) in Switzerland are examples of these.

In view of arguments in support of a “need to develop a mountain geography literature that expands the study of mountains to include the political, economic, cultural and social dimensions of their environments and peoples” (Smethurst 2000, p.35), it might be suggested that a field known as waterfall geography should be similarly developed. Indeed, we could take the argument further and propose the recognition of a new branch of knowledge equivalent to speleology, the study of caves, a field of research and scholarship devoted to waterfalls instead of the underground world.

**Waterfalls, caves, and their study**

Both caves and waterfalls have long been popular with tourists and day trippers with a taste for the curiosities and beauties of nature (Erikstad 2008, Hose 2008, Hudson 1998). Since the nineteenth century, largely due to the work of Frenchman Edouard-Alfred Martel (1859-1938), the systematic exploration and study of caves has become widely recognized as a distinct branch of knowledge which became known as spéléologie, a word coined by archaeologist Emile Rivière. Today, speleology brings together diverse disciplines, including geography, geology, geomorphology, climatology, hydrology, botany, zoology, chemistry, palaeontology, archaeology, anthropology, tourism studies and the study of rock art. Cave exploration and surveying continue to be important aspects of speleology, while caving and potholing, or spelunking as it is called in the USA, remain popular recreational activities.

Like caves, waterfalls continue to attract visitors who are content to enjoy their natural beauty passively, and others who use waterfall sites to engage in pursuits ranging from moderate exploration, bathing and photography to extreme sports such as whitewater rafting,
canyoning, rock climbing, ice climbing and abseiling. Recently, however, waterfalls have received increased attention from scientists and other scholars from a wide variety of backgrounds. This paper explores the wide range of waterfalls research, a field probably as diverse as speleology. Seventy years ago these popular landscape features were largely neglected as subjects of serious study, something that was noted with disapproval by one eminent geomorphologist who wrote: “Waterfall sites more than any other geomorphic feature attract and hold the interest of the general public. Because they have such a popular approval waterfalls are not given serious attention by some students of systematic geomorphology. This attitude is not to be commended. Waterfalls are significant items for geomorphic investigation” (Engeln 1942, p. 179). They are also significant items for investigation by geographers, a fact appreciated by Alexander von Humboldt, the polymath considered by some to be “[t]he founder of modern geography” (Crone 1970, p. 14).

**Waterfalls and cultural geography**

Humboldt’s intellectual curiosity was unbounded, and it is not surprising that waterfalls were among the features of the landscape that interested him (Humboldt 1821, p.66). Indeed, Humboldt lived at a time when a taste for landscape beauty was fashionable, and waterfalls were widely admired for their sublime and picturesque qualities (Hudson 2000, 2012). Cascades and cataracts were commonly chosen as subjects by painters and poets of that Romantic period. In view of the interest shown by Humboldt, it is surprising that, until late in the twentieth century, waterfalls were relatively neglected by geographers, both those specializing in geomorphology and those whose interests were mainly in the cultural landscape (Engeln 1942, Hudson 2000, Young 1985). For cultural geographers, waterfalls and rapids are significant for a variety of reasons. As barriers to navigation, they have influenced patterns and modes of transport with consequences that have affected economic
development and the location and growth of human settlements. This was one of the great concerns of nineteenth century European explorers and others involved in the ‘opening up’ of the African interior where river transport was often hindered by falls and rapids. In the view of British geographer George Chisholm, for example, “The most signal example of the effect of waterfalls and rapids in retarding the development of civilisation is undoubtedly presented by the continent of Africa, the “darkness” of which is almost entirely due to this cause” (Chisholm 1885, p. 420).

Waterfalls can have important economic benefits, however. Their exploitation for power generation and tourism has stimulated local, regional, and national economies, with notable consequences for settlement patterns and urban development. Niagara Falls, Victoria Falls, Yosemite National Park, Fall Line cities, Switzerland and Norway are among the many different geographical examples of this. Several of the world’s great waterfalls are located on international boundaries, Niagara, Victoria and Iguassu Falls, for example, a fact that has serious implications for their exploitation and management. The influences of waterfalls on cultures around the world range from the economic to the religious and artistic. Some waterfalls are sites where opportunities for fishing are particularly favourable, as at salmon leaps on numerous European and North American rivers. A notable African example is the Wagenia fishery at Boyoma Falls on the Congo River near Kisangani. Celilo Falls on the Columbia River, USA, was an important tribal fishing site until it was flooded when the Dalles Dam was constructed in 1957. Similarly, the traditional Laotian fishery at the Khone Falls on the Mekong River is now under threat from a planned hydroelectric power scheme (Baird et al. 2001).

Around the world, waterfalls feature in myth and legend, many falls having important religious significance. Some, such as the falls at Nachi in Japan, Tirupati in India, and Villa Bonheur in Haiti, are places of pilgrimage. Waterfalls have inspired artists in cultures as far
apart in space and time as Song Dynasty China (960 – 1276 AD) and eighteenth and nineteenth century Europe, in both of which tumbling rivers and streams were popular subjects for poets and landscape painters. In the world of music, too, waterfalls have a role which is notably expressed in the songs of the Kaluli people of Papua New Guinea (Feld 1981). Perhaps nowhere is the cultural importance of waterfalls in some traditional societies better illustrated than in Harner’s study of an indigenous tribe in Ecuador: *The Jivaro; People of the Sacred Waterfalls* (Harner 1984). In today’s world, the importance of waterfalls is particularly well recognized in connection with their roles as providers of renewable energy and as resources for the development of ecotourism. The earliest studies of waterfalls, however, were mainly associated with the development of geology and geomorphology, and even among scientists working in those related fields, cascades and cataracts were, apparently, not regarded as very significant features of the landscape.

**Waterfalls and geomorphological research**

Among the few researchers who gave serious attention to waterfalls was Oscar von Engeln. In addition to the chapter entitled “Waterfall Sites” in his book *Geomorphology: Systematic and Regional*, he wrote two papers on waterfalls which were published in 1929 and 1940 (Engeln 1929, 1940, 1942). The earlier of these papers describes the erosive action of water and discusses various waterfalls, including Niagara, particularly the role of stream flow and other agencies in their formation. The later article considers the development of knickpoints and their relationship to cap-rock waterfalls. While decrying the neglect of waterfalls as subjects of research, Engeln acknowledged the contributions of previous scholars who had studied these landforms, referring to the work of Davis (1884), Gilbert (1895), and Noyes (1926). He made no mention of books on waterfalls by authors such as Holley (1883), Gibson (1887), and Rashleigh (1935), probably because these are mainly descriptive works for the general reader rather than scientific studies. Chisholm’s paper ‘Waterfalls and rapids’
published in the *Scottish Geographical Magazine* was a rare contribution to scholarly
discussion of waterfalls at this time, a broad study notable for its treatment of both the
physical and human geographical aspects of the subject (Chisholm 1885).

A century later, a writer observed that “waterfalls remain a very much neglected aspect of
river studies” (Young 1985, p. 82). Young mentioned a few other papers on waterfalls
published since Engeln’s time, two reporting field studies (Schwarzbach 1967, Mainguet
1972), and three mainly describing laboratory simulation exercises (Philbrick 1970, Holland
and Pickup 1976, Gardner 1983). Young’s 1985 paper is particularly important for
emphasizing that cap rock falls exemplified by Niagara, and commonly described in
textbooks, are but one of several types of waterfall, and that many falls are buttressed
outward at their base, instead of overhanging. His paper demonstrates that the formation and
retreat of waterfalls can be caused in a variety of ways, commonly related to stress
distribution in the rock face, and that even the well known processes of undercutting are not
fully understood. After the publication of Gilbert’s monograph on Niagara Falls (Gilbert
1895), the formation and retreat of waterfalls by undercutting was widely accepted as the
norm, versions of his diagram of the erosion process being reproduced in numerous
textbooks.

The process described by Gilbert was not a new idea. In 1830, Charles Lyell published the
first volume of his *Principles of Geology* in which he described in detail undercutting at cap-
rock waterfalls. (Lyell 1830, pp. 179-180). Another observation on waterfalls that Lyell noted
was the formation of travertine and tufa deposits as seen at ‘the cataract of Tivoli’ (Lyell
1830, p. 208), a phenomenon that had long been recognized.

Lyell was a proponent of uniformitarianism, first propounded by Hutton in 1785, and later
disseminated by Playfair (Hutton 1788, 1795, Playfair 1802). In contrast to proponents of
catastrophism, uniformitarianists saw waterfalls as ever-evolving landforms where natural
processes continue to act as they have always acted, operating on the land surface in way that
contributes to its disintegration and reduction. Thornton Force, a waterfall in Yorkshire,
provided Playfair with striking evidence that supports Hutton’s theory (Playfair 1822, p.225).
Here Playfair observed an unconformity which indicates that geological processes of the past
are the same as those operating today continued over vast periods of time. Later, W. M.
Davis, the ‘father of American geography’, contributed to the discussion of the origins of
waterfalls when he considered the role of stream displacement by deposits of glacial drift
(Davis 1884).

**Waterfalls, geography and aesthetics**

While the focus of waterfall research in the eighteenth and nineteenth centuries was on their
geology, the Scottish geographer, George Chisholm, extended his study of these landforms to
include their broader geographical significance. After describing the formation and global
distribution of waterfalls and rapids, Chisholm discusses “the effects of these obstructions on
human intercourse and civilisation” (Chisholm 1885, p. 417). Surprisingly, he focused his
attention only on the disadvantages of falls and rapids, ignoring entirely their important role
as sources of mechanical and hydroelectric power. He also failed to acknowledge their
growing importance as attractions in the then burgeoning tourism industry.

The tourism industry which developed in Europe during the eighteenth and nineteenth
centuries had its origin partly in the Grand Tour which, at first, involved travellers who went
mainly to see places of cultural significance, such as great cities, famous buildings, classical
ruins and important art collections. Later, however, as the taste for landscape beauty became
fashionable, more tourists travelled to wild, mountainous regions where waterfalls were
among the most popular scenic attractions. Landscape painters both reflected and stimulated
this interest. Cotman and Turner in Britain, and artists belonging to the Hudson River School
in America, are among those particularly notable for their waterfall paintings. Educated
travellers and writers of the period, such as Thomas Pennant (1726-1798) and Arthur Young (1741-1820) expressed an interest in both the aesthetic and the scientific aspects of the landscapes they saw. Typically, both men took great delight in waterfalls. Scientists, too, were attracted to these areas in order to study the natural landscapes on the spot. While making systematic observations for their scientific purposes, they were also aware of the scenic beauty of the places they visited. This was the Romantic era when the concepts of the Beautiful, the Sublime, and the Picturesque were important topics of discussion in intellectual circles (Hudson, 2000).

Although the word ‘Romanticism’ is usually associated with the arts, including literature, painting and music, scholars have recognized “the potential interconnections in the Romantic period between literature, aesthetic theory and the emergence of Earth sciences” (Furniss 2010, p.305). In his study of James Hutton’s *Theory of the Earth*, Furniss argues that the author, widely acknowledged as the founder of modern geology, developed ideas “that drew on and reconfigured what Heringman calls the ‘geological sublime’ – a geo-aesthetic category that was common to the aesthetic geology and geological aesthetics of the period” (Furniss 2010, p. 307, Herringman 2004). Charles Lyell, like Hutton and Playfair, had little to say about aesthetics when writing *Principles of Geology* (Lyell 1830, 1832, 1833), but, in his two volume account of his *Travels in North America*, written for “the general reader” (Lyell 1855, vol. 1, p.v), he remarks on the beauty of some of the landscapes he saw on the journey. Understandably, he spent much of his time at Niagara Falls, described and discussed at length in both volumes of his *Travels*. Apart from writing extensively on their geological formation and history, Lyell also describes the aesthetic qualities of the Falls which, “though continually in motion, have all the effect of a fixed and unvarying feature in the landscape” (Lyell 1855, vol.2, p.91).

**Darwin and Humboldt**
Later geologists who, like Lyell, built on the work of Hutton and Playfair, broadened their approach to landscape studies, introducing an aesthetic dimension to their analyses. Charles Darwin, too, was greatly influenced by Lyell, and took a copy of *Principles of Geology* with him on his voyage on the *Beagle*. Darwin was concerned with the relationship between science and aesthetics, and Livingstone observes that in the early years of the scientist’s career, “there are suggestions that Darwin was already working toward a scientific explanation of landscape appreciation” (Livingstone 2011, p.108). There is evidence that Darwin’s appreciation of landscape beauty began to emerge when he was a boy. In a letter written in 1838, he recalls a holiday in Wales when he was ten and a half years old: “I remember a certain shady green road (where I saw a snake) & a waterfall with a degree of pleasure, which must be connected with the pleasure from scenery, though not directly recognized as such” (Darwin 2012). Darwin’s record of his scientific travels in 1831-1836 is replete with detailed observations on scenic qualities of the landscapes he saw, but he had little to say about waterfalls (Darwin 1961). In this he differed from the man who probably had the greatest influence on him, Alexander von Humboldt. Darwin declared that Humboldt, “like another sun illumines everything I behold” (Keynes 2001, p.42). In his *Personal Narrative of Travels to the Equinoctial Regions of the New Continent*, Humboldt includes his reflections on “the interesting phenomenon of cataracts” (Humboldt 1821, p. 66) which he discusses in the comprehensive, holistic manner characteristic of the writer. Humboldt begins by noting the lack of precision in terminology used in describing waterfalls and rapids:

In hydrographic descriptions of countries, the vague names of *cataracts*, *cascades*, *falls* and *rapids* (*saltos*, *chorros*, *pongos*, *cachoeiras*, and *raudales*), which denote those tumultuous movements of water, which arise from very different circumstances of the ground, are generally confounded with one another (Humboldt 1821, p.57).
Humboldt follows this with his thoughts on a wide range of topics related to waterfalls and rapids, drawing on examples from various parts of the world. Variety in formation, processes of erosion, influence of geology, behaviour of currents, evaporation of droplets in the spray, and consequences of falls for navigation are among the aspects of waterfalls that Humboldt considers. It is interesting to note that, while Humboldt accepts that flowing water loaded with sand and pebbles is capable of eroding channels, he believes that large chasms at waterfall sites where the bedrock is very resistant cannot have been formed in this way, and must have been caused by past convulsions of the earth’s crust. Humboldt also comments on the visual and aural qualities of falls and rapids. He observes, “A solitary cataract, like Niagara or the cascade of Terni, affords an admirable but single picture that varies only as an observer changes his place. The rapids, on the contrary, above all when they are adorned with large trees, embellish a landscape during a length of several leagues” (Humboldt 1821 p. 59). The sound generated by rapids such as those on the Nile and the Orinoco, the latter “eminently picturesque from the varied appearance of the waters, the palm trees, and the rocks” (Humboldt 1821, p. 60), also receive the scientist’s attention. As Bunkse observes, “Humboldt demonstrated that art could be an integral part of the scientist’s world view” (Bunkse 1981, p. 146). This is well demonstrated by Humboldt in his illustrated accounts of the South American Cordilleras in which he describes some of the waterfalls he saw. Notable among these is Humboldt’s detailed description of Tequendama Falls on the Bogota River (Humboldt 1814, pp. 72-80), illustrated with a plate based on the author’s own sketch of the waterfall (Fig. 1). Humboldt’s interest in every aspect of the phenomena he observed is demonstrated by his account of the ‘Indian fable, which attributes the cataract of Tequendama to the founder of the empire of Zaque’ (Humboldt 1814 p. 75), as well as providing details about geology,
vegetation, microclimate, height and volume of the fall, and other matters. Humboldt attributes the origin of the chasm at the waterfall site to past earthquake activity. In his discussion of the magnificent scenery at Tequendama, Humboldt reflects on the aesthetics qualities of waterfalls in general: “The impression they leave on the mind of the observer depends on the concurrence of a variety of circumstances. The volume of the water must be proportioned to the height of the fall, and the scenery around must wear a wild and romantic aspect” (Humboldt 1814, p. 76). Humboldt then briefly considers these qualities in relation to some of the world’s most famous waterfalls -- Pissevache, Staubbach, Niagara and the Rhine Falls. When measured against Humboldt’s aesthetic standards, “Tequendama forms an assemblage of every thing that is sublimely picturesque in beautiful scenery” (Humboldt 1814, p. 77).

Quality as well as quantity

The scientific study of landscape continued to advance during the nineteenth century. In his book *The Scenery of Scotland*, first published in 1865, eminent geologist Archibald Geike offers a geological interpretation of the landscape, but says little about the beauty of the waterfalls he mentions. He does, however, make the significant observation that the Scottish landscape is of interest to students of both geology and aesthetics (Geike 1887 p.11). Moreover, Geike advocates landscape analysis which combines science with aesthetics:

To subject Scottish scenery to dissection and analysis may seem a sort of ruthless proceeding, like that of a pedant who insists on cutting a flower to pieces and showing you its structure in order that you may adequately enjoy its beauty. But, fortunately, let the formal geologist do and say what he likes, the beauty and grandeur of the landscape remain unimpaired. Nay, if only he can present his results in simple and intelligible guise, they will be
found in no degree to lessen the charm of scenery. He cannot diminish the romance that hangs like a golden mist over the country; on the contrary, he reveals another kind of romance, different indeed in kind but hardly less attractive, wherein firth and fell, mountain and glen, glow with all the fervour of a poet’s dream (Geike 1887, p.12).

Geike reveals his aesthetic sensitivity in analysing the influence of geology and vegetation on scenery when describing Scottish Highland landscapes: “The craggy Highland character of these hills is heightened by the softly undulating contour of the clay-slate hills that come in front of them, while in the Trossachs and along the shores of Loch Katrine and Loch Achray, their ruggedness and gloom are softened by the fairy-like garniture of mountain-ash, oak, birch, and willow which lend such charm to that district of the Highlands” (Geike 1887, p. 212). Elsewhere he emphasizes the role of geology in determining the aesthetic qualities of certain Highland lakes that are “more picturesque, for as they run across the strike they traverse a greater variety of rocks, and these present their truncated ends along both declivities” (Geike 1887, p.239). It is easy to see how a similar approach to landscape analysis can be applied to waterfalls. The following is an example in which Arthur Raistrick relates the occurrence and form of Pennine waterfalls to the rhythmic succession of limestone, sandstone and shale strata:

This ‘rhythm’ is responsible for the great abundance of waterfalls. Every side-stream leaps over each limestone in turn, and there is no part of England with anything to compare with the number of falls and with the beauty of these tributary streams. Some of the falls over the thicker limestones are high – like Hardraw Scar, 80 ft, Mill Gill Force and Parker Gill Force near Askrigg, and Ashgill Force near Garrigill – while others come down a series
of steps, bed by bed. Every fall has its own particular character and beauty  
(Raistrick 1968, p. 37).

A notable proponent of the aesthetic study of landscape was Lieutenant Colonel Sir Francis Younghusband. As President of Britain’s Royal Geographical Society, he expressed the view that “the characteristic of the face and features of the earth most worth learning about, knowing, and understanding is their beauty; and that knowledge of their beauty may be legitimately included within the scope of geographical science” (Younghusband 1920, p. 3).

He continued, “It may be argued, indeed, that science is concerned with quantity – with what can be measured – and that natural beauty is quality which is something that eludes measurement. But Geographical science, at least, should refuse to be confined within any such arbitrary limits and should take cognizance of quality as well as quantity” (Younghusband 1920, p. 3).

These words, spoken by Younghusband in his 1920 Presidential Address to the RGS, fell on the receptive ears of Vaughan Cornish who was in the audience. Two decades later, Cornish wrote, “I responded immediately to this appeal, and in works since published have recorded the advance in my investigations. This has now reached the stage when the subject can be formulated in a manual” (Cornish 1946, p. 15). That manual took the form of a little book entitled The Beauties of Scenery, first published in 1943. Up to the time of his decision to make a systematic study of landscape beauty, Cornish devoted much of his geographical research to waves of various kinds, those occurring in seas, sand deserts, snow fields and in earthquake activity, for example (Goudie 1972). Much of the chapter on ‘The Falls and Rapids of Niagara’ in his book The Travels of Ellen Cornish is devoted to the study of waves in the rapids below the Falls, but it also contains detailed observations of the sights and sounds that Vaughan Cornish and his wife experienced during their three week scientific visit to Niagara Falls. There they witnessed “the glory of cataracts and waterfalls, and added
something to the science of waves” (Cornish 1913, p.146)). In his accounts of Niagara Falls and of Minnehaha Falls near Minneapolis, Cornish demonstrates his interest in the aesthetic qualities of waterfalls, a subject that, perhaps surprisingly, receives comparatively little attention in *The Beauties of Scenery*.

**Among the waterfalls of the world: Rashleigh and after**

While Vaughan Cornish was pursuing his studies of landscape aesthetics, another global traveller, Edward C. Rashleigh, was gathering material for a major work on waterfalls, a book published in 1935 under the title *Among the Waterfalls of the World*. Rashleigh believed “that in this book, for the first time under one cover, there is presented to the reader, a fairly complete account of all the more notable waterfalls of the world accompanied for the first time again, as far as such are available, by accurate engineers’ figures as regards their respective volumes and dimensions” (Rashleigh 1935, p. 3). Rashleigh’s motivation for this work is revealed when he states, “It is, indeed, the rapidly increasing spoliation, amounting in some cases almost to entire destruction, of so many of the notable waterfalls that has prompted me to the task of compiling this book and to record some descriptions of the most famous of them while they still retain something of their pristine grandeur” (Rashleigh 1935, p. 15). The main cause of the spoliation of waterfalls was, as it continues to be, the abstraction of water from rivers for the generation of electricity and for irrigation purposes. Today, among those with a serious interest in waterfalls, Rashleigh’s book remains a highly regarded work.

Ten years after Rashleigh’s book, another global study of waterfalls was published, one that compares major falls around the world with those in Yosemite National Park (Brockman, 1945). Far more comprehensive was the broad based study of waterfalls by American geologist Richard Pearl. Pearl who, as editor of a popular geology journal entitled *Earth Science*, published a series of articles on the subject in 1973 -1975. Most of these appear
under the heading ‘Waterfalls: an explanation’, and are written mainly as a geomorphological study (Pearl 1974, 1975). In addition to a discussion of the various ways in which waterfalls originate and develop, the articles include a comprehensive and detailed classification of these landforms based on their origins. Pearl precedes his ‘explanation’ of waterfalls with a series of articles entitled ‘Waterfalls; an appreciation’ in which he considers briefly other aspects of the subject, including aesthetics, representation in art, ecology, hydropower and related urban development (Pearl 1973). Had these articles been published as a book, as the author appears to have intended (Pearl 1973, p.183), Pearl’s largely overlooked work on waterfalls might have received much greater attention.

The ten years following Richard Pearl’s death in 1980 saw some advance in the geomorphological study of waterfalls, notably the work of Young, mentioned earlier. Since Young’s remark about the neglect of the subject, geomorphologists around the world have done research on various aspects of waterfalls. The following examples illustrate the global distribution of waterfall sites investigated and the range of topic: geology and waterfall formation in Amazonas, Brazil (Nogueira and Sarges 2001) and the Polish Outer Carpathian (Alexandrowicz, 1994), postglacial recession of waterfalls in Switzerland (Hayakawa 2011), recession of fault-scarp waterfalls in Taiwan (Hayakawa et al. 2009), travertine deposition at Indarri Falls, Queensland (Drysdale and Gale 1997), morphology, processes and evolution of two waterfalls in New South Wales (Bishop and Goldrick 1992). Other aspects of waterfalls that have been studied include their ecology, and the impact of human activity on the flora and fauna associated with tumbling rivers and streams (Ikpi and Offem 2011, Patiño et al. 2010, Torrente-Vilara et al. 2011). The economic importance of waterfalls as sources of hydropower and as tourism attractions has also been examined (Hudson 1998, 2004, 2012, Ranasinghe 1997).
Problems of defining waterfalls and measuring their heights are discussed by Mabin in the context of Australia (Mabin 2000). Among those who study the subject, the debate continues on what constitutes a waterfall in terms of angle of descent, volume, height and permanence. Questions such as these have implications for waterfall databases such as those compiled by Bryan Swan, Dean Goss and Scott Ensminger (Northwest Waterfall Survey: Waterfalls of the Northeastern United States; Western New York Waterfall Survey; World Waterfall Database). Newly recorded waterfalls continue to be added to published lists, many of these falls being found in parts of the world that have long been intensively explored and surveyed. The authors of a book published in 2000 claim to have “discovered” or at least recorded for the first time, about two hundred waterfalls in Yellowstone National Park (Rubinstein et al. 2000). By September, 2011, Scott Ensminger had recorded 1,096 waterfalls in his Western New York Waterfall Survey. While explorations in various parts of the world continue to add ‘new’ waterfalls to the records, it is in the regions most intensely surveyed and studied that the greatest number of recorded falls are found. Of the 7827 waterfalls recorded in the World Waterfall Database 7112 are in North America, 245 are in Europe, 157 in Asia, 134 in Oceania (islands in the world’s oceans), 87 in South America, 47 in Africa, and 45 in Australia (World Waterfall Database). This database is, of course, a work in progress, and makes no claim to record all known waterfalls. An indicator of the incompleteness of the data recorded is the fact that one survey of Scottish waterfalls lists over 750 falls, more than four times the total number accorded to the whole of Europe (Stott 1987).

Since 1980 there has been a flood of waterfall guidebooks produced mainly for walkers and tourists. These books were usually written by authors who had visited many of the falls in the countries or regions they described, and some had specialist geographical and geological knowledge which give authority to their work. Notable among these is geographer Gregory Plumb who has written guides to the falls of the US Pacific Northwest and
Tennessee, and devised a scale for comparing the visual magnitude of waterfalls (Plumb 1993, 2005, 2008). Contemporaneous with the work of Plumb is that of another geographer, Brian Hudson, whose broad interest in waterfalls focuses mainly on their aesthetic qualities, their role in the world of art, and their importance as tourism attractions and as influences on the growth and distribution of human settlements (Hudson 1998, 1999, 2000, 2001a, 2001b, 2002, 2003, 2004, 2006). His recent book *Waterfall: Nature and Culture* “is comprehensive in its approach”, including accounts of the geomorphology and ecology of waterfalls, but focusing mainly on ‘the roles that they play in the human experience’ (Hudson 2012, p. 7). Among the various topics discussed in Hudson’s book is artificial waterfalls, a subject that has long received much attention from landscape architects, but which has also attracted interest in terms of their economic value as urban tourism attractions (New York City Economic Development Corporation 2008).

The proliferation of books on waterfalls in recent years reflects a growing public interest in these landscape features. People who regularly visit and enjoy the sights and sounds of tumbling streams are known variously as waterfall lovers, fans, buffs, or collectors. Like the poets Wordsworth and Coleridge, they “hunt waterfalls” (Wordsworth 1941, p. 183), often taking photographs of them, and sometimes compiling detailed records of the falls they observe. Today, this activity is commonly referred to as ‘waterfalling’, and the term ‘waterfallology’ has come into popular use to describe the active interest in waterfalls. A much earlier word for someone who took great interest in waterfalls was ‘cataractist’ (Ousby 1990, p. 183), but ‘cataractology’ is a term that today is applied to a branch of ophthalmology. In the world of science and scholarship applied to the subject of waterfalls no word comparable with speleology has come into general use, and probably none is needed. While it has been shown to be useful to include under the umbrella term speleology the many disciplines that are involved in the study of caves, there is probably no need for similarly
defined branches of knowledge focusing on all other types of landform such as cliffs, gorges, estuaries or, indeed, waterfalls. Waterfalls are features that should not be overlooked in the study of landscape, however. They deserve serious attention from geographers and other scholars and scientists. Geographers, with their characteristically synthetic approach to the study of the earth, are particularly well qualified to apply scientific and aesthetic analysis to this research.

**Conclusion**

While not an exhaustive survey of the study of waterfalls, the foregoing discussion demonstrates the breadth of this field of science and scholarship, and shows the greatly increased interest in the subject over the past thirty years. These interesting phenomena are important not only for their economic value as resources for energy supply and tourism development, but also because of their long-established cultural role in the scientific and artistic worlds. Unlike cave research, a special term for the study of waterfalls may not be justifiable, but today these landforms attract the attention of scientists and scholars from a wide range of disciplines. As features of the landscape under threat from a variety of human activities, waterfalls are especially worthy of our serious attention. Waterfalls research, a field in which some of the world’s greatest scientists have made important contributions, continues to attract the interest of scholars with diverse backgrounds and specializations. While recognizing the necessity for research to focus on specific aspects of the subject, we should remember the importance of locating these detailed studies within the broader global context. Humboldt’s synthetic approach remains the model to which geographers and others should aspire.
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Northwest Waterfall Survey. Available from:


List of figures

Figure 1.

Tequendama Falls, Colombia. This engraving, published in 1810, is based on a sketch made by Alexander von Humboldt who visited the waterfall in 1801.