Victoria Falls: Mosi-oa-Tunya – The Smoke That Thunders

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Chapter 15
Victoria Falls: Mosi-oa-Tunya – The Smoke That Thunders

Andy Moore and Fenton (Woody) Cotterill

Abstract Victoria Falls are located on the Zambezi, southern Africa's largest river. In full flood with a maximum vertical drop of 108 m, and length of 1,700 m, they form the world's largest sheet of falling water. The Falls demarcate two sections of the Zambezi of contrasting geomorphology: the low gradient, broad channel of the Upper Zambezi and the steep gradient, narrowly incised downstream Batoka gorges, ~100 km in length. The Victoria Falls represent the modern position of a west-migrating knickpoint that incised the lower gorges into Jurassic (Karoo-age) basalts that form the bedrock. Evolution of the Falls and lower Gorges was accompanied by deposition of Late Cenozoic sediments of the Victoria Falls Formation (VFF), which preserve a remarkable assemblage of hominin artefacts. This archaeological record provides a unique context to decipher how the Batoka gorges evolved through the Pleistocene; two contrasting estimates, obtained from these hominin artefacts, constrain estimates of headward erosion rates, westward, to between 0.042–0.052 m/year and 0.067–0.080 m/year. This faster rate means that headward erosion has incised 20 km of gorges below the Falls in 300–250 ka. The present position of the Victoria Falls reflects the culmination of evolutionary events initiated by diversion of drainage off the Kalahari plateau into the mid-Zambezi river that occupies a deep graben.

Keywords Basalt • Batoka gorges • drainage evolution • hominin evolution • Kalahari Plateau • knickpoint retreat • Zambezi River

15.1 Introduction

The Victoria Falls, or Mosi-oa-Tunya (The Smoke That Thunders), as they are known by their more descriptive vernacular name (Fig. 15.1) are located on the Zambezi, southern Africa's largest river (Fig. 15.2). With a length of 1,700 m and maximum vertical drop of 108 m, they form the world's largest sheet of falling water when in full flood. Their breathtaking beauty moved David Livingstone to write that "scenes so lovely must have been gazed upon by angels in their flight," and earned their designation as a UNESCO World Heritage Site in 1989.

The Victoria Falls demarcate two sections of the Zambezi with markedly contrasting geomorphologic characteristics, designated the upper- and mid-Zambezi, respectively (Wellington 1955). Upstream, the river flows in a low gradient, broad channel, which exceeds 2 km width in places. Below the Falls, the gradient is markedly steeper (Fig. 15.3), and the river is constrained by a series of narrow gorges, some 100 km in total length (Fig. 15.4). Downstream of these gorges, the Zambezi widens into the broad valley known as the Gwembe Trough, in which Lake Kariba is impounded.

Stone artefacts in river terrace gravels, along the Zambezi valley, testify to a lengthy and near continuous period of occupation by a succession of hominin cultures, extending back to the Early Pleistocene and possibly late Pliocene (Clark 1950). These stone implements present earth scientists with a remarkable geochronological resource, because they constrain ages of sediments, and so provide a time frame for elucidating

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Fig. 15.1 Aerial view of the Victoria Falls and upper gorges, looking west. The former river banks prior to incision of the gorges is marked by the low scarp above the pale-hued, gently sloping surface that bounds the gorges (Photo R. Watts)

the evolution of the Falls and the downstream gorges. The story they tell us is, in turn, intrinsically linked with geomorphological events that changed surrounding landscapes across Africa through the Plio-Pleistocene.

15.2 Geographic Setting

The Victoria Falls are located on the section of the Zambezi that forms the international boundary separating Zambia and Zimbabwe (Fig. 15.2). Access is by good road, rail and air links to the town of Victoria Falls on the Zimbabwe side of the Zambezi, and Livingstone on the Zambian side. The area experiences summer rainfall (mainly during the months of November to March), with an average annual precipitation of 600 mm, which supports a broad-leaved savannah tree and shrub plant community. Nonetheless, peak river flow across the Falls occurs in April, controlled primarily by the input from the higher rainfall area (~1,600 mm per annum) in the Zambezi's headwaters in Angola and northern Zambia on the Southern Equatorial Divide – the watershed with the Congo River basin.

15.3 Landforms and Geology

15.3.1 The Zambezi River Above Victoria Falls

Figure 15.4 illustrates the stretch of the River immediately above and below the Victoria Falls where Jurassic (Karoo-age) basalts form the bedrock. The broad channel of the Upper Zambezi is broken by numerous islands, which increase in number with proximity to the Falls. The sedimentary sequence which overlies the basalts along the margins of the Zambezi is collectively referred to as the Victoria Falls Formation (VFF) and is summarized in Table 15.1 and Fig. 15.5. The detailed knowledge of

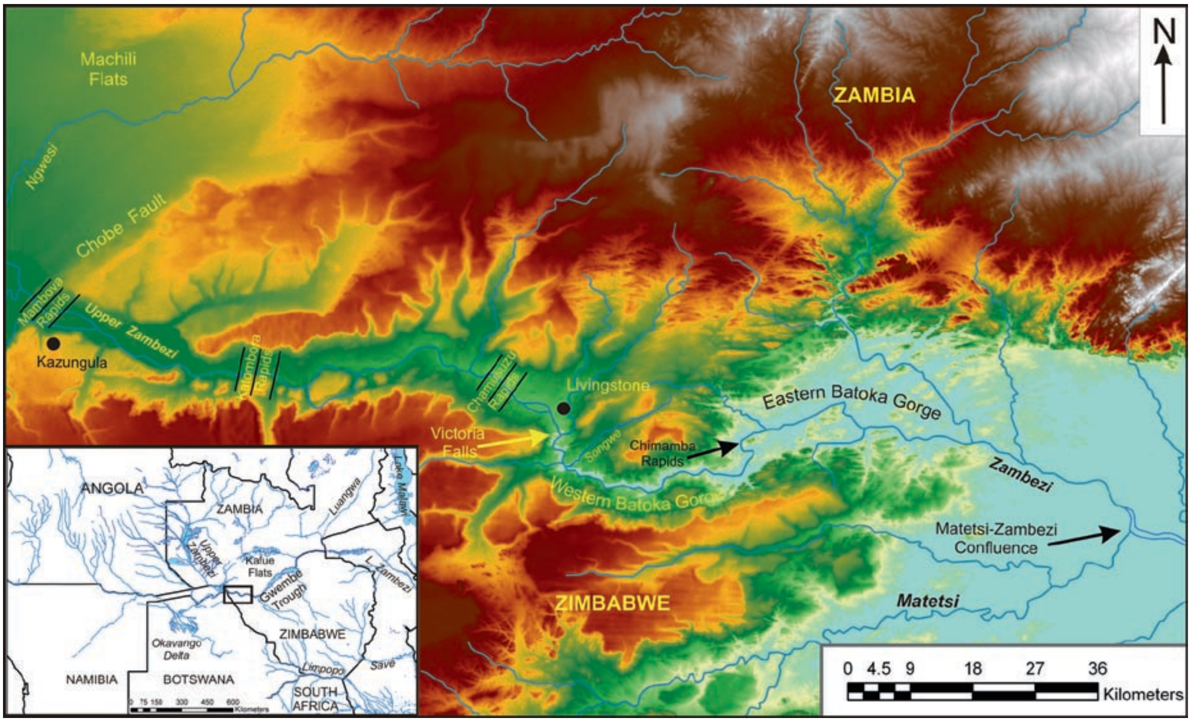

Fig. 15.2 The situation, in south-central Africa, of the Batoka gorge incised by the Zambezi River, in which the Victoria Falls represents the extant position of westward knickpoint migration of the Zambezi River. The ~100 km Batoka Gorge is situated between the Victoria Falls and the Matetsi-Zambezi confluence. Principal rapids upstream of Victoria Falls are labelled. In a continental context, the Batoka Gorge represents a site of significant incision into the eastern margin of the Kalahari plateau. It testifies to the evolution of a widening exorheic drainage net through sequential piracies of endorheic rivers draining the Kalahari plateau

the geology and geomorphology of country surrounding the Victoria Falls is a testament to the thorough research by geologist F. Dixey and archaeologist, J. D. Clark. They elucidated the stratigraphy of Zambezi sediments formed through the late Cenozoic in relation to ongoing occupancy of the valley by hominins. Their research entailed extensive field mapping in tandem with detailed excavations of representative sediments (Clark 1950; Dixey 1950). These descriptions remain an invaluable legacy to current researchers which can be judged by the fact that Clark's (1950) detailed study underwrites the present work in significant respects.

The river is bounded by a low (15–45 m) scarp, at a distance of about 5–6 km from the main channel, which marks the junction with the surrounding low-relief basalt plain, which is ascribed to the African Erosion Surface (Lister 1987; Moore et al. 2009). The basalt bedrock at the crest of this scarp is capped by a silicified limestone, designated The Chalcedony Beds (Dixey 1950; Fig. 15.5). The age of this unit is not well-constrained, but its origin may be linked to the development of the widespread African Surface (Lister 1987; Moore et al. 2009). The Chalcedony is overlain by a coarse sandstone, often silicified, that is known as the Pipe Sandstone. The Pipe Sandstone is in turn overlain by beds of red Kalahari sand, of variable thickness, interpreted to be of aeolian origin, and termed Kalahari Sand I (KS I) (Dixey 1950).

A series of abandoned river terraces have been recognized between the valley scarps and the modern channel of the Zambezi. The Upper Terrace is capped by two gravel benches separated in height by about 6 m altitude. Their modern association with the Zambezi varies, depending on local bedrock; so they extend up to 15 m vertically above the river, but some deposits are preserved at the present river level on ledges of the basalt bedrock. These upper terraces are referred to as Older Gravels I (OG I) (at the higher elevation) and Old Gravels II (at the lower level) respectively. Relict patches of KS I overlie these two gravel units.

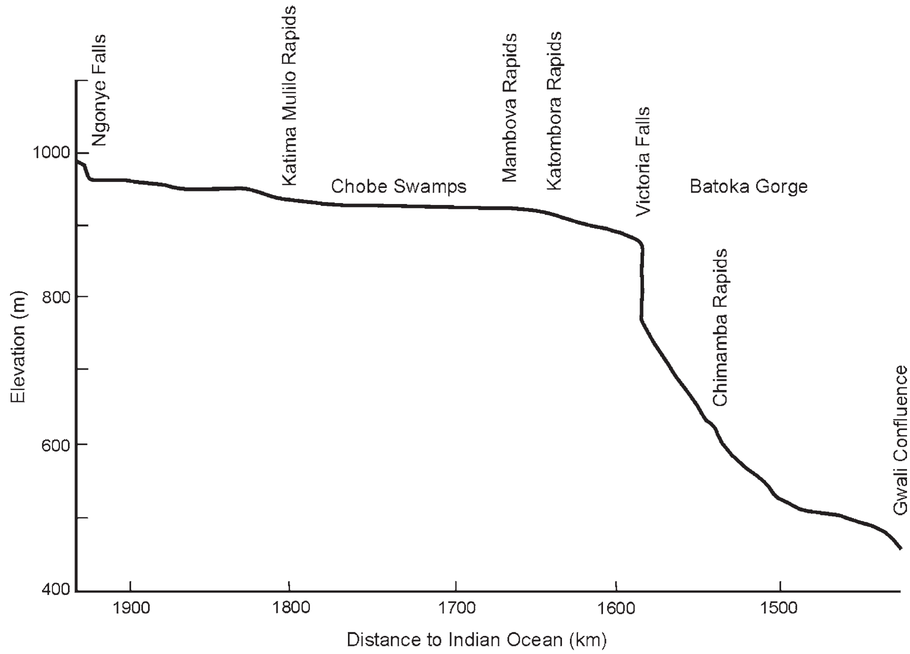

Fig. 15.3 Profile of the Upper Zambezi River, between N'gonye Falls and the Gwayi confluence, to show the radical changes in gradient along the Batoka Gorge, compared to the senile profile of the river where it crosses the Okavango Graben (Modified from Moore et al. 2007)

Their upper surfaces are cemented by a pedogenic ferricrete (termed Ferricrete I), inferred to have formed at the base of the KS I (Fig. 15.5). The higher gravels (OG I) contain Early Stone Age (ESA) Acheulian stone artefacts, and more rarely, rolled older Oldowan tools. The oldest stone artefacts preserved in the lower gravel unit (OG II) are attributed to the middle to late ESA, and also include Sangoan tools of the early, or pre-Middle Stone Age (MSA). The ferricrete cementing the upper surface of the Older Gravels entombs early MSA Sangoan picks and flakes, which are interpreted to have accumulated on the surface of the gravels prior to deposition of the KS I and induration by Ferricrete I (Clark 1950).

Younger Gravels and alluvial sands have accumulated on a Middle Terrace, at an elevation less than 10 m above the modern river. In parts, these are overlain by reworked Kalahari Sand (KS II). Lupemban (MSA) artefacts are preserved in these Younger Gravels and also the upper levels of KS 1, while KS 2 contains only later MSA artefacts, provisionally assigned to the Tshangulan culture. Below the Middle Terrace, the river is bounded by reworked aeolian sands and calcareous sandy alluvium (Dixey 1950). The most recent hominin living sites were attributed to the LSA, and these were on the calcareous sandy alluvium (Clark 1950).

The two deposits of Kalahari sands (KS I and KS II) testify to distinct episodes of regional aridity centred on the Mega-Kalahari sand sea. KS I and the basal pedogenetic ferricrete reflect a break in river flow of at least 140,000 years, which is designated the VFF unconformity (Cotterill 2006; Cotterill and Moore in review). Archaeological artefacts associated with these two sand beds allow us to constrain deposition of these Kalahari sands to within respective Marine Oxygen Isotope Stages (Cotterill and Moore in review), reliably documented in palaeo-climate archives (EPICA 2004; Lisiecki and Raymo 2006). The association of Tshangulan artefacts with KS II delimits its deposition within MIS 4 (71–57 ka[1]), in agreement with reliable U-series dates (Deacon 2001) that constrain the contemporaneous Howieson's Poort industry in South Africa. The age of KS I is more difficult to establish precisely, because the tenure of the early MSA Sangoan industry is not well-constrained. Nevertheless, available evidence allows us to constrain KS I to within MIS 12 or, less likely, MIS 14: between 474–427 ka or 568–528 ka, respectively (Cotterill and Moore in review).

[1]ka stands for 1,000 years

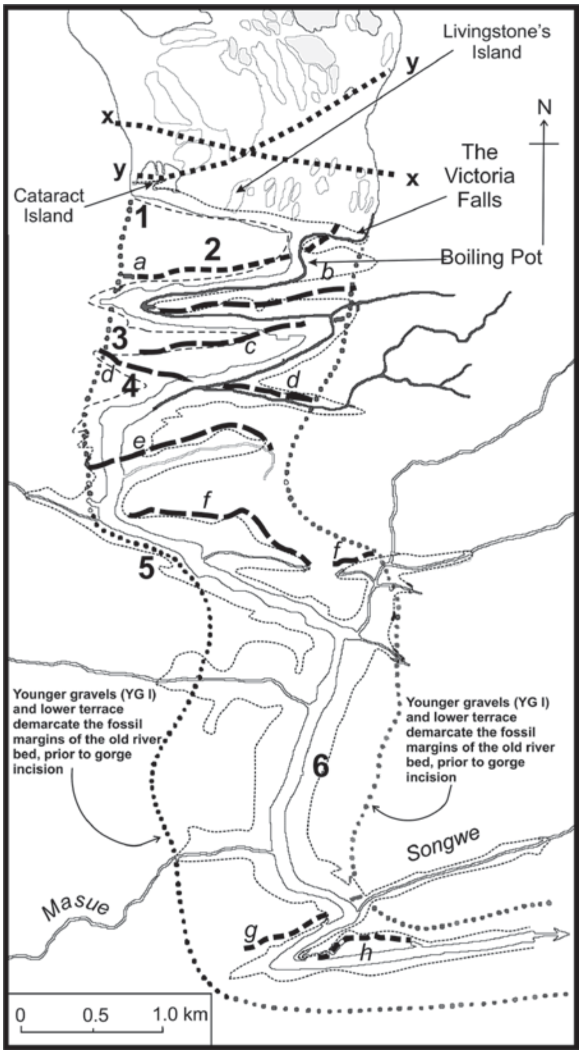

Fig. 15.4 The Victoria Falls and Gorges, modified from Wellington (1955: Fig. 86, 393), with numbers of gorges labelled one to six and past positions of the waterfalls labelled *a–h* (dashed lines). The edges of the Batoka Gorge approximated by fine dashed lines. The bold dotted lines *x–x* and *y–y* denotes where the next lines of future falls could develop (Bond 1976)

15.3.2 Zambezi Below Victoria Falls

At the Victoria Falls, the Zambezi plunges in a single drop into a narrow cleft, some 60–120 m wide, known as First Gorge, which varies from 80 m in depth at the western end, to 108 m in the centre. During peak flood, the wall of water forming the Falls is divided by two islands (Cataract Island near the western end, and Livingstone Island near the centre), but more islands emerge during periods of low flood (Clark 1950; Bond 1976). The walls of the gorge are built up of six thick, dark, fine-grained basalt lava units exhibiting a strong vertical jointing. These are separated by amygdaloidal basalts that weather to a purple-red colour, which represent the contacts (tops and bottoms) of individual lava flows (Fig. 15.6). A fine example of the amygdaloidal basalt variety is seen on the path from Victoria Falls Hotel to the Falls (Bond 1976).

Table 15.1 Summary of the stratigraphy of the Victoria Falls Formation (VFF)

10. Aeolian sand and alluvium (LSA)
9. Redistributed Kalahari Sand (KS II) (Tshangulan)
8. Younger Gravels I (Lupemban)
7. Kalahari Sand I (KS I) (Lupemban)
6. Ferricrete I
-------------------------- (Sangoan accumulated on Old Gravels)
5. Old Gravels II (OG II) (Mid- to Late-ESA and Sangoan)
4. Old Gravels I (OG I) (Rolled Oldowan and Acheulian)
----
3. Pipe sandstone
----
2. Silicified limestone or "Chalcedony"
---------------------------- Marked Unconformity
1. Karoo Basalt

Dashed lines denote significant erosional gaps

The river exits the First Gorge near the eastern end via a narrow, north–south outlet known as the Boiling Pot. Thereafter, it follows a series of gorges, generally oriented just south of either east–west or west–east, some linked by south-flowing channels. These have been incised into a continuation of the broad valley in which the Zambezi flows above the Falls and are known, in a downstream direction to the confluence with the east bank Songwe tributary, as the Second to Sixth Gorges (Fig. 15.4). The amygdaloidal basalt is less resistant to erosion than the fine-grained massive variety, and in the lower gorges, can be recognized by breaks in the steepness of the walls, marked by lines of trees (Fig. 15.6).

Immediately downstream of the Songwe, the river swings sharply to the east into the Batoka Gorge, which maintains this general direction for some 90 km thereafter. It narrows some 30 km downstream at the Chimamba rapids, where there is a drop of some 6–7 m. It is here that when:

> one stands on the brink of the lower cataract and sees the whole volume of the great Zambezi converging into a single pass only 50 to 60 feet in width, shuddering, and

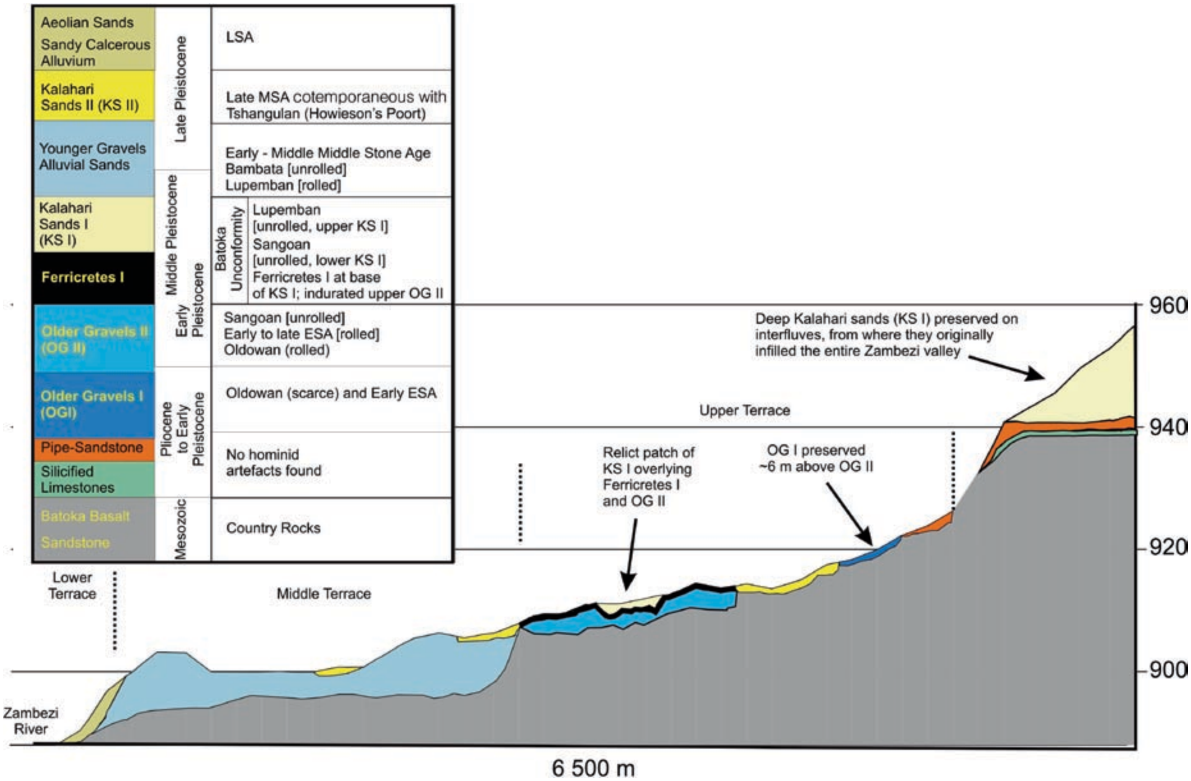

Fig. 15.5 Schematic transect of the three principal terraces within the wide valley of the Upper Zambezi River (only north bank depicted) above Victoria Falls, to illustrate stratigraphic relationships among alluvial and aeolian sediments. The Chalcedony beds interface with overlying Pipe Sandstone. Both sediments overlie the Batoka basalts, in parts, predating the river gravels. Stone Age artefacts preserved in their respective sediments are listed in the legend. In this region of the river, YG I is confined to the Middle Terrace, with Older Gravels II (OG II), capped by Ferricretes I and KS I, confined to the Upper Terrace. The Batoka Unconformity represents a break in alluvial deposition, when KS I covered the entire valley, but was subsequently eroded. Deposition of Kalahari Sands II (KS II) is inferred to have occurred between 71–57 ka in Marine Isotope Stage (MIS) 4. Vertical axis is exaggerated (not to scale) and distances and heights are approximate estimates (Compiled from illustrations and descriptions in Clark 1950 ; Dixey 1950)

> then plunging for 20 feet in a massive curve that seems in its impact visibly to tear the grim basaltic rocks asunder, one learns better than from the feathery spray-fans of the Victoria Falls what force there is in the river, and one wonders no longer at the profundity of the gorge! (Lamplugh 1907: 151).

The Chimamba Rapids demarcate a sharp break in the geomorphological unity of the Batoka Gorge, because downstream the Zambezi widens markedly, with decreasing gradient (Figs. 15.2 and 15.3). This break represented by the Chimamba Rapids is designated the Batoka Discordance (Cotterill 2006; Cotterill and Moore in review).

15.4 Evolution of the Victoria Falls and Lower Gorges

The northern banks of the gorges below the Falls, in particularly the upper ones, show evidence of water wear, and it was realized at an early stage that these mark former positions of the Falls (e.g., Wellington 1955). It is generally accepted that there are at least six abandoned former lines of falls (shown by dashed lines as *a–f*, Fig. 15.4). Wellington (1955) presented evidence for two further former fall lines (*g*, *h*) near the Songwe confluence.

Fig. 15.6 View of the Second and Third Gorges, looking east. Note the massive lava flows forming the walls of the gorges, separated by breaks in slope, which reflect amygdaloidal basalt, representing the upper and lower brecciated sections of successive lava flows. This brecciated basalt is frequently an aquifer, reflected by the vegetation that has colonized these sections of the basalt succession (Photo R. Watts)

The easterly oriented gorges are clearly structurally controlled, and aligned along either readily eroded faults with vertical throws of approximately 50 m (second and fifth Gorges), or prominent joints associated with shatter zones (Wellington 1955; Bond 1976). At each earlier position of the Falls, erosion would selectively incise the next line of weakness, upstream, and thus establish it as a new fall line; whereafter the earlier line was abandoned. A less prominent and probably more resistant set of north–south joints controls the south-flowing sections of the river below the Falls. The steep-sided Batoka Gorge would similarly have been incised by headward erosion, presumably also exploiting a line of structural weakness. If so, the advancing Batoka Gorge knickpoint may not have always presented a cascade as dramatic as the modern Falls, capped by their armour of massive basalt.

There are a number of pointers to the future evolution of the Falls. Immediately upstream of the Falls are two structural lines (*x–x* and *y–y*) that are readily identified from aerial photographs (Fig. 15.4). The lip of the modern Falls is lowest at the Devil's Cataract, between the western river bank and Cataract island, which carries the greatest concentration of water during flood. This may, therefore, mark the beginning of a north–south gorge, linking to structural line *x–x*, where the next fall line could develop. However, a deep, narrow cleft on Cataract Island is aligned with the second line of weakness (*y–y*). This cleft does not normally carry a great volume of water, but there is a strong flow in times of flood, when the river's erosive power is greatest. The alternative possibility is that over time, more rapid erosion along the line of weakness reflected by the Cataract Island cleft will progressively capture the flow from the

Devil's cataract, leading to development of a new fall line following *y–y* (Bond 1976; Fig. 15.4).

This discussion of the evolution of the Victoria Falls has still to answer the question as to what factors *initiated* the development of such a dramatic knickpoint in the interior of the African continent. Two contrasting models have been proposed. The first interprets the Falls in terms of a headward-migrating knickpoint, reflecting the youngest (Plio-Pleistocene) cycle of erosion, initiated by uplift of the coastal plain (King 1963). However, several lines of evidence point to an alternative explanation – that the Upper Zambezi was captured by a headwater tributary of the middle Zambezi relatively recently in the late Cenozoic (e.g., Du Toit 1933; Bond 1976; Moore and Larkin 2001). The rapid headward erosion of the Batoka and higher gorges would have been initiated by the marked lowering in base level of the Upper Zambezi following this capture. A system of major NE–SW faults traverses the bed of the Zambezi for over 160 km upstream of Victoria Falls. These represent the southwest extension of the East African Rift System (EARS) that initiated the development of the Okavango Graben, which includes the Machili Flats as part of the graben floor (Fig. 15.2). The gradient of the river shows distinct changes along this faulted section, especially where it crosses this shallow rift valley (Dixey 1950; Nugent 1990). Thereafter it steepens at the Mambova Rapids immediately downstream of the Graben (Figs. 15.2 and 15.3), plausibly reflecting uplift of the eastern rift shoulder. This uplift may have been responsible for triggering or accelerating aggressive headward erosion of a north bank tributary of the mid-Zambezi, which ultimately captured the modern upper sections of the river.

An important, additional, question pertains to what caused the break in geomorphological unity of the Batoka Gorge at the Chimamba rapids (the Batoka Discordance). This has been interpreted to reflect a period when the river ceased to flow, after the Zambezi had attained its modern topology (Derricourt 1976; Moore and Larkin 2001; Cotterill 2006; Moore et al. 2007), as a result of deflection of the upper Zambezi into a major inland lake in northern Botswana (Palaeolake Makgadikgadi) following uplift across the line of the river along the Chobe Fault – part of the Okavango Rift system (Fig. 15.2). A ferricrete on the bed of the Zambezi immediately above Victoria Falls may testify to the period when the flow from the upper reaches of the river was cut off. Flow was restored once the Zambezi again breached the barrier presented by the Chobe fault, whereafter the river incised the western Batoka and upper gorges.

15.5 Time Frame for Evolution of the Victoria Falls and Lower Gorges

It was realized by Lamplugh as early as 1907 that the sediments of the VFF, with their preserved hominin stone artefacts, offer a time frame for dating of the evolution of the gorges below Victoria Falls. More recently, available evidence was summarized by Derricourt (1976), but now we know that his reasoning and calculations were based on heavily underestimated ages of the different Stone Age cultures. The recent progress achieved in dating the MSA (McBrearty and Brooks 2000) has underpinned a reappraisal of the archaeological record, which in turn allows us to re-evaluate the antiquity of the Victoria Falls and its gorges.[2]

Scattered deposits of KS II cap gently sloping terraces above the western Batoka Gorge (upstream of the Chimamba Rapids), and extend upstream to the beginning of the fourth Gorge. At the time this unit was deposited, it would have been eroded by the broad river that occupied the higher sections of the valley. It follows that the Victoria Falls regressed 2.96 km from the end of third Gorge to the present position subsequent to the deposit of the KS II with its Tshangulan artefacts. Similarly, the Younger Gravels (YG I), with their Lupemban artefacts form a distinct terrace above the Gorges for a distance of 20 km below the modern Falls.

Limits of 71–57 ka for the Tshangulan culture (preserved in KS II) indicate headward erosion rates of 0.042–0.052 m/year for incision of the 2.96 km from the end of the third Gorge to the present position of the waterfall. In contrast, the age of 300–250 ka bracketing the Lupemban industry, associated with YG I, constrains rates of headward erosion to incise the 20 km below the falls at 0.067–0.080 m/year – almost double the estimated erosion rate based on the Tshangulan constraint (Table 15.2). The reason for the disparity

[2] Complete reference to archaeological work which allowed for this re-evaluation can be found in Cotterill (2006) and Cotterill and Moore (in review).

Table 15.2 Estimates of erosion rates of lower gorges and estimated time taken to erode the gorges

Estimates of erosion rates of Lower Gorges				
Section of gorge used for erosion rate estimate	*Distance eroded (km)*	*Stone Age culture constraining erosion rate*	*Age bracket of culture*	*Estimated erosion rate (m/year)*
Modern Falls to end of Third Gorge	2.96	Tshangulan	71–57 ka	0.042–0.052
20 km downstream of modern Falls	20	Lupemban	300–250 ka	0.067–0.080
Estimated time taken to erode the gorges				
Section of gorge	*Distance (km)*	*Stone Age culture constraining erosion rate*	*Estimated erosion rate (m/year)*	*Time required for erosion*
Victoria Falls to Chimamba Rapids	40.71	Tshangulan[1] Lupemban	0.042–0.052 0.067–0.080	970–783 ka 608–509 ka
Age limits for erosion of W Gorges assuming VFF Unconformity = 140 ka			0.042–0.080	1100–649 ka[a]
Age limits for erosion of Eastern Batoka Gorge (below Chimamba Rapids)	60	Tshangulan Lupemban	0.042–0.052 0.067–0.080	1.43–1.15 ma 0.90–0.75 ma
Time for erosion of entire Batoka Gorge excluding time gap represented by the Batoka Discordance	100.71	Tshangulan Lupemban	0.042–0.052 0.067–0.080	2.54–2.07 ma 1.65–1.40 ma
Time bracket for erosion of entire Batoka Gorge excluding time gap represented by the Batoka Discordance	100.71		0.042–0.080	2.54–1.40 ma[b]

[a](970 + 140) to (509 + 140) ka

[b](0.970 + 1.429 + 0.14) ma to (0.529 + 0.750 + 0.14) ma

[1]This Late MSA Industry is provisionally called Tshangulan subject to new research

between these estimates is not clear, and difficult to elucidate in light of current knowledge. It most likely reflects an underestimate age of the Lupemban, which points to a corresponding overestimate of erosion rate. It is nonetheless likely that flow rates, and thus the rate of gorge incision, decreased between Lupemban and Tshangulan times as a consequence of the severance of tributaries of the upper Zambezi by river capture. This can be attributed to severance of a former Kafue – Upper Zambezi link (Moore and Larkin 2001), resulting in the formation of Palaeo-Lake Patrick, which inundated an area of ~17 000 km^2 in the vicinity of the present day Kafue Flats (Fig. 15.2, Inset). The tenure of this lake has been dated from the mid-Pleistocene to approximately 300 ka, when the Upper Kafue was captured by a tributary of the mid-Zambezi (Simms 2000). The formation of Palaeo-Lake Patrick accounts for the loss of a significant east bank tributary of the Upper Zambezi (Cotterill 2006), with concomitant loss of erosive power.

The Chimamba rapids are considered to mark a significant break in the erosion of the Batoka Gorge, when the Zambezi was diverted into northern Botswana (Moore and Larkin 2001) – a hydrological input prerequisite to maintain the 945 m lake level of Palaeo-Lake Makgadikgadi (Grove 1969). Based on the two estimates of erosion rates, the time taken to erode the 41.71 km from the Chimamba Rapids to the modern Falls is bracketed between 970–783 ka (slower Tshangulan constraint) and 634–529 ka (faster Lupemban constraint) (Table 15.2). This excludes the minimum 140 ka break represented by the VFF unconformity. Thus, the minimum age constraint (529 + 140 = 669 ka), which brackets erosion of the western Batoka Gorge, reflects the most recent time that the Zambezi could have maintained the 945 m lake level of Palaeo-Lake Makgadikgadi in northern Botswana. This is consistent with the presence of an ESA factory site on the lake floor at an elevation of 936 m (McFarlane and Segadika 2001).

At present there are no reliable, independent constraints on the time frame for erosion of the eastern Batoka Gorge. While Older Gravels have been recorded in the lower reaches, it has not yet been firmly established whether these include OG I and OG II, or only the older unit. Based on the Lupemban and Tshangulan erosion rates, the time for incision of the 60 km of the eastern Batoka Gorge is bracketed between 900–750 ka and 1.43–1.15 ma[3] respectively. The total time indicated for erosion of the eastern and western sections of the gorge is therefore bracketed at 1.67–1.42 ma (faster rate of erosion) and 2.54–2.08 ma (slower erosion rate) (Table 15.2).

Nevertheless, the date for the commencement of the erosion of the Batoka Gorge (which equates to when the upper Zambezi was captured by the mid-Zambezi) is clouded by two uncertainties. Firstly, the timing of the break in erosion represented by the Chimamba Discordance is not yet well-constrained. Secondly, the Batoka Gorge widens markedly and decreases in gradient below the Chimamba rapids. Both these signatures preserved along the Zambezi's channel point to erosion of the Eastern Batoka gorge by a much larger flow than that which incised the western section upstream. This invokes the link to the upper Zambezi's catchment of a much larger river, which was plausibly the Palaeo-Chambeshi, with its headwaters in Katanga and northeast Zambia. It is interesting to speculate that erosion by such an enhanced flow would have been even faster than the estimates based on the Lupemban constraints (Cotterill 2006; Cotterill and Moore in review).

15.6 Summary

The modern physiographic context of the Victoria Falls reflects the culmination of events initiated by piracy of the Upper Zambezi by a mid-Zambezi headwater. In their context of conjoining the two segments of the Zambezi river of disparate origins, the Victoria Falls highlights the preservation of several, interlinked suites of evidence, which provide unprecedented insights into landscape evolution through the Plio-Pleistocene. These events have been driven by tectonic activity along the southwest extension of the African Rift System. The landforms created by eroding and aggrading agencies of the Zambezi River preserve a remarkable legacy of hominin artefacts. This archaeological record provides a unique framework to decipher how the Batoka gorges evolved through the Pleistocene. More detailed mapping and characterization of the stone artefact assemblages in the Old Gravels, which extend along the lower reaches of the Batoka Gorge, will undoubtedly refine our understanding of the evolution of the Victoria Falls. Nevertheless, the detailed knowledge we have been able to summarize for the origin of the Victoria Falls and the spectacular Batoka gorges is a testament to the careful mapping and attention to detail of a remarkable group of scientists. They blazed the trail in elucidating how geological events forged the Victoria Falls, through the period when our hominin ancestors populated the Zambezi valley.

[3] ma stands for 1,000,000 years

The Authors

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Fenton (Woody) Cotterill (Ph.D., University of Stellenbosch, South Africa) is a research fellow in the Africa Earth Observatory Network (AEON) at the University of Cape Town, where his interests centre on the evolution of Africa's biodiversity and landscapes, employing molecular genetic studies of indicator species to elucidate how landscapes have reacted to tectonism. From 1992 to 2003 he was Curator of Mammalogy, Natural History Museum of Zimbabwe, Bulawayo. His doctorate examined how the evolution of lechwe antelopes has interfaced with palaeo-drainage

dynamics across central Africa. Taxonomic research, focused primarily on Africa's Chiroptera and Bovidae, includes the description of three new species of mammals. He has published over 40 publications spanning a range of interests. These include the epistemology interlinking natural science collections, biodiversity science and environmental conservation; biogeography and systematics of vertebrates; and impacts of geomorphological evolution on biodiversity dynamics.

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