7 The Chobe-Zambezi Channel-Floodplain System: Anatomy of a Wetland in a Dryland

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Abstract

In this chapter, the Chobe-Zambezi channel-floodplain system is defined as the fluvially influenced area that is located around and between the Chobe and Zambezi rivers approaching their confluence. This area is located in the 'Four Corners' region, the informal term given to the region where the Botswana, Namibia, Zambia and Zimbabwe borders meet. The large-scale structure and medium-term (10^2–10^5 years) development of the channel-floodplain system is related to a combination of tectonic activity and climatically-driven changes to flow and sediment supply. The system has developed in a region of subsidence that is related to the East African Rift System. Upstream of the Mambova Rapids, the modern sinuous, alluvial channels are flanked by extensive floodplain wetlands, with crevasse splays, gullies, oxbows, scroll plains, abandoned channels and backwaters (stagnant or slow-flowing, channel-like depressions) all widespread. Collectively, these fluvial landforms create the physical template for shorter-term water, sediment and ecosystem dynamics. A strong flood and drying season dynamic is evident; river stages typically rise from January and peak around April, before subsequently falling again. The Zambezi provides the largest flow volumes, with flow spreading gradually from north to south through a complex system of active and partially active channels and floodplain wetlands towards the Chobe. Along the two rivers, lateral channel migration and extension of splays, gullies and backwaters has been negligible over at least the last 40–50 years, with few new oxbows forming. To the east, both rivers cross the uplifting Chobe fault, with each river forming complexes of steeper, bedrock anabranching channels in the region of the Mambova Rapids. The two rivers ultimately coalesce ~10 km farther downvalley, and continue as the Zambezi River. A longer term (>10^6 years) developmental model is outlined, which posits that headward retreat of the Victoria Falls, at present located ~80 km downstream of the Chobe fault, will initiate a phase of erosion that will cross the fault in ~1–2 million years' time. This phase of erosion will initiate deep channel incision, river network reorganisation and wider landscape denudation.

Keywords

Alluvial channel • Bedrock channel • Chobe River • Drylands • Floodplain wetlands • Zambezi River

7.1 Introduction

The Chobe River is located in northeastern Botswana, and flows from Lake Liambezi in the west to Kazungulu in the east, whereupon it forms a confluence with the larger Zambezi River (Fig. 7.1). The Chobe and Zambezi rivers are key landscape elements of the so-called 'Four Corners' region (Moore et al. 2007), with their typically sinuous, locally dividing, courses forming parts of the borders between Botswana, Namibia, Zambia and Zimbabwe (Figs. 7.1 and 7.2a). This complex river geomorphology has led to past conflict, with the ~3–4 km^2 Sedudu (Kasikili) Island, located between a northern and southern channel of the Chobe (Fig. 7.2a, b), being the subject of a past border

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dispute between Namibia and Botswana (see Information Box).

Beyond its role as an international border, the hydrology and geomorphology of the Chobe River have wider significance. Along with the Limpopo River (Chap. 16), and the Okavango (Chap. 2) and Kwando (Cuando) rivers (Chap. 2), the Chobe River represents one of the few permanently flowing (‘perennial’) rivers in Botswana territory. The spectacular fluvial landscape approaching the confluence of the Chobe and Zambezi rivers (Fig. 7.2a) is characterised by a complex of alluvial channels and extensive floodplain wetlands, with bedrock-influenced channels more prominent in the vicinity of the features known as the Mambova Rapids (Clark 1950; Moore and Cotterill 2010) or the Mambova Falls (Shaw and Thomas 1988; Thomas and Shaw 1991). In previous publications, the extensive area (~3000–4000 km^2) of alluvial channels and floodplain wetlands upstream of the Mambova Rapids (the preferred name herein) has been referred to by various names, including the Chobe swamps (Nugent 1990; Moore and Cotterill 2010; McCarthy 2013), the Chobe-Zambezi or Chobe floodplain (Shaw and Thomas 1988; Moore et al. 2007), and the Zambezi wetlands (Pricope 2013; Burke et al. 2016). Hereafter, the broader term Chobe-Zambezi channel-floodplain system is adopted to also encompass the more bedrock-influenced river reaches downvalley of the main area of alluvium and wetlands (Fig. 7.2a).

With the exception of the studies of Sedudu (Kasikili) Island that formed part of the aforementioned border dispute (see Information Box), until now there have been no detailed investigations of the fluvial landscape approaching the Chobe-Zambezi confluence, with the channel-floodplain system having received only passing mention in studies of long-term river development (e.g. Nugent 1990; Moore et al. 2007; McCarthy 2013) or reconstructions of Quaternary hydrological and lacustrine fluctuations (e.g. Shaw and Thomas 1988; Thomas and Shaw 1991). Furthermore, although part of the Chobe River lies within the Chobe National Park (located on the Botswana side of the Botswana-Namibia border—Fig. 7.2b) and is a focal point for wildlife populations and associated tourism activities (Fig. 7.2c), there is little specific visitor information regarding the channel-floodplain system and its importance for ecosystem service delivery. By comparison with the considerable research attention that has been devoted to the fluvial and fluvio-lacustrine landscapes elsewhere in

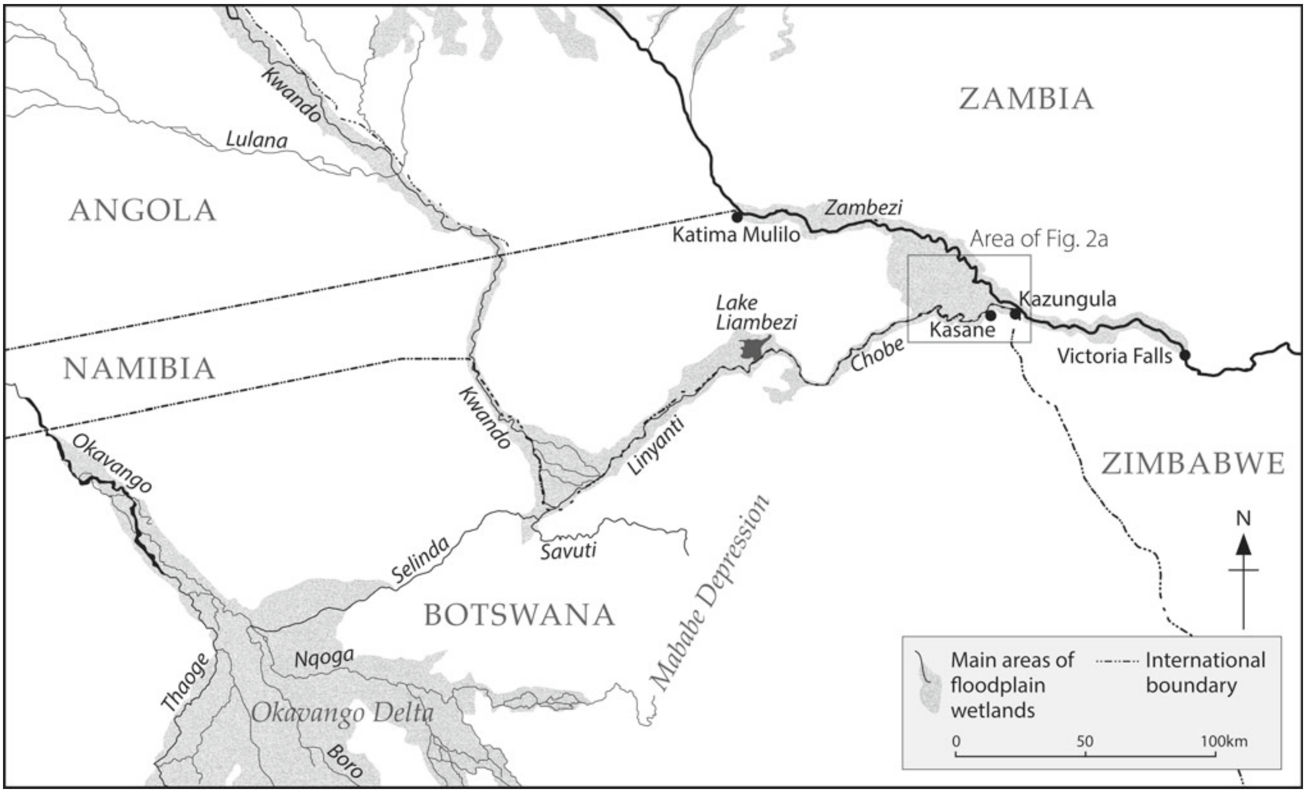

Fig. 7.1 Map encompassing the Four Corners region, showing the main landscape features referred to in this chapter, key locations, and the area covered by Fig. 7.2a. Note the northwest-southeast orientation of the three main rivers (Okavango, Kwando (Cuando), Zambezi) and the dog-legged but overall southwest-northeast orientation of shorter rivers that link these three main rivers, including the Linyanti and Chobe rivers

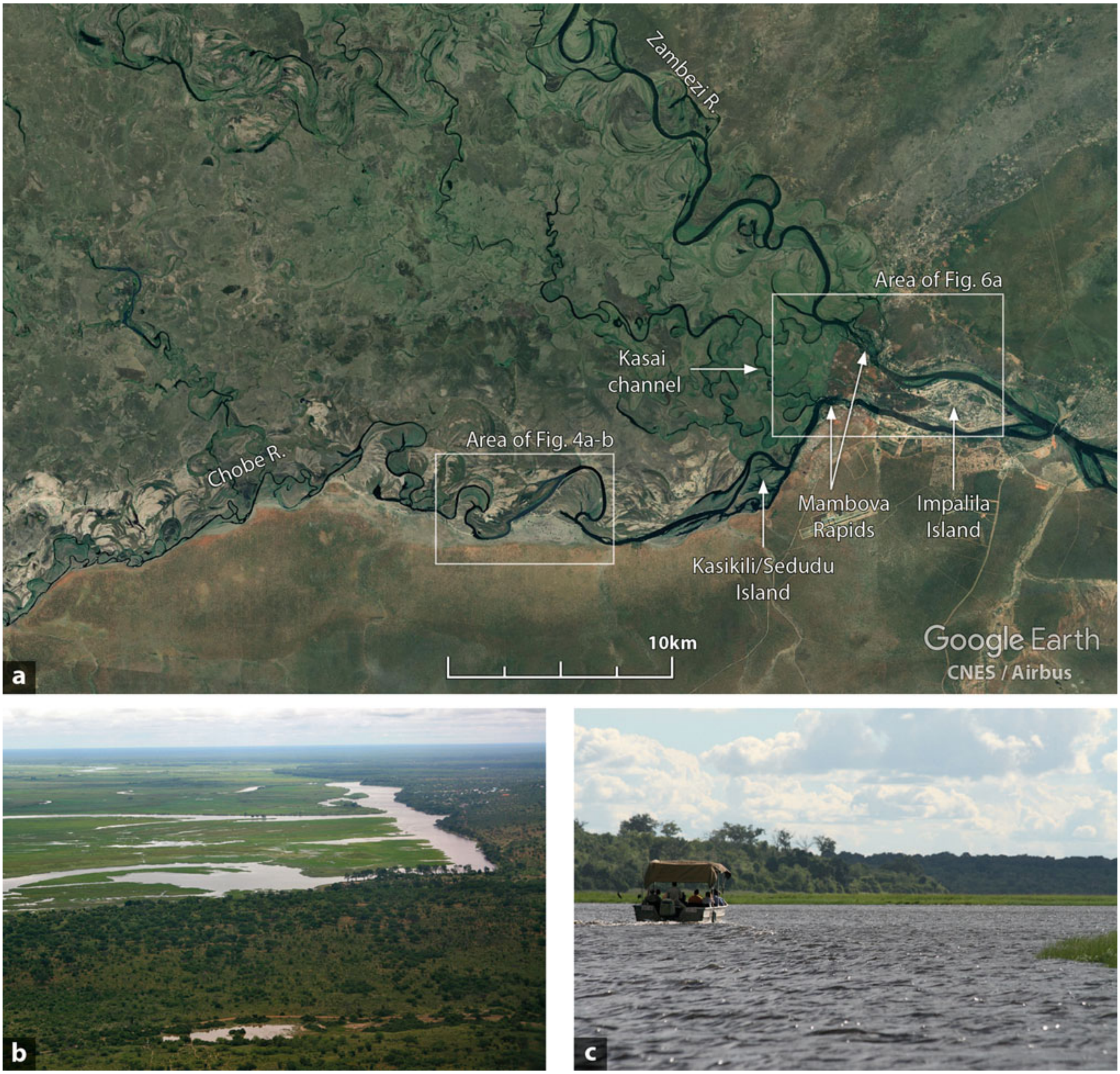

Fig. 7.2 **a** Satellite image (from Google Earth) of the area approaching the Chobe-Zambezi confluence, illustrating the complex of alluvial and bedrock fluvial landforms, other landscape features referred to in this chapter, and the areas covered by some other figures. **b** Oblique aerial view (looking downstream towards Kasane) of the Chobe River and escarpment taken during a time of rising stage (February 2016). The area in view forms part of the Chobe National Park and includes the downstream end of the disputed Sedudu (Kasikili) Island (see Information Box). **c** Ground level view of the Chobe River and escarpment in the Chobe National Park (view looking upstream)

northern and central Botswana, particularly the Okavango delta (Chap. 2) and Makgadikgadi (palaeo) lakes complex (Chap. 5), the Chobe-Zambezi channel-floodplain system appears to be a neglected cousin. This chapter describes the main fluvial landforms in the region, and outlines how they owe their origin and ongoing development to a complex interplay of tectonic activity and climate changes. We hope that this chapter and other ongoing studies will provide the basis for enhanced appreciation of this aspect of Botswana's geoheritage.

7.2 Geographical and Environmental Setting

The large-scale physiography of the Chobe-Zambezi region is related to a series of major southwest-northeast trending faults and subsidiary northwest-southeast trending faults that have resulted in regions of relative uplift (horsts) and subsidence (grabens). The more alluvial part of the Chobe-Zambezi channel-floodplain system has developed upstream of the Mambova Rapids in a low-gradient region of subsidence (Figs. 7.2a and 7.3a), essentially forming the northeastern part of what has been variably and loosely termed the Caprivi or Ngami Depression (e.g. du Toit 1927; Wellington 1955), Chobe graben (Nugent 1990), upper Zambezi Trough (Shaw and Thomas 1988), Kalahari Rift (Shaw and Thomas 1992), the Okavango-Linyanti Trough, Graben or Depression (McCarthy 2013) and the Okavango Graben (Pastier et al. 2017). These faults are related to the southwest propagation of the southwestern branch of the East African Rift System (EARS) but the limited geodetic and geophysical data mean that local crustal and lithospheric structures, mantle activity, and fault displacement patterns and rates are poorly known. Consequently, various deformation models for the region have been proposed, including an incipient rifting zone (e.g. Scholz et al. 1976; Modisi et al. 2000; Bufford et al. 2012), a composite graben (graben-within-graben) structure (e.g. McCarthy 2013) and a transtensional basin (Pastier et al. 2017).

The present-day hydrology of the Chobe-Zambezi channel-floodplain system is dominated by a strong flood and drying season dynamic. Whilst this marked seasonal regime is common to this part of central southern Africa, the location of the Chobe-Zambezi channel-floodplain within a depression amplifies the significance of floods. Seasonal movement of the Intertropical Convergence Zone and Congo Air Boundary are associated with austral summer rains. A strong north-south rainfall gradient means that the highest totals occur in the catchment headwaters in Angola and Zambia, so in the study region the Zambezi and Chobe river stages typically rise from January and peak around April, before subsequently falling again during the austral winter (Fig. 7.3b). Overbank flooding occurs with rising stage (Fig. 7.2b) but annual floodplain inundation patterns and extents are highly variable, and depend on the relative volumes and timing of peak flows along the two rivers, as well as the contributions from local rainfall and groundwater (Pricope 2013; Burke et al. 2016). The larger Zambezi provides the largest flow volumes, with overbank flow typically spreading gradually from north to south through a complex system of channels and floodplain wetlands (Fig. 7.2a) towards the Chobe River (Pricope 2013; Burke et al. 2016). Decadal-scale flow variations are also associated with El Niño-Southern Oscillation (ENSO) dynamics, with La Niña conditions tending to be associated with higher rainfall and higher flooding (Pricope 2013; Alexander et al. 2018; Heaney et al. 2019). In particularly wet years, such as occurred around the end of the first decade of the new millennium, some flow may also come from the Okavango Delta via the Selinda River (also termed the Selinda Spillway or Makgwekwana), to the Linyanti River and Lake Liambezi (Fig. 7.1; see also 'Fluvial Landforms' below), and thence to the Chobe River, with this smaller flood pulse typically peaking around June, July or August (Pricope 2013; Burke et al. 2016). Upstream of the Mambova Rapids, the characteristically low channel gradients (typically < 0.0001 m/m) mean that the Chobe has been reported to occasionally reverse its flow (i.e. flow east–west) over short distances (see Shaw and Thomas 1988; Pricope 2013; Burke et al. 2016). Near to Kasane, unambiguous measurements of this phenomenon are lacking, but 30–40 km farther west the phenomenon has been observed, and is driven by local rainfall patterns, the relative timing of flow from the Zambezi and Linyanti, and the associated relative flood levels in different parts of the system.

Importantly, the rivers in the study region are still largely unaffected by large dams, large-scale flow abstraction or significant channel engineering and so the flood dynamics and channel-floodplain morphologies remain close to their natural state. Although beyond the scope of this chapter, it is nevertheless worth noting that there is growing concern over declining river and groundwater quality, with widespread antibiotic resistance reported in river and sediment microbial populations as well as faecal isolates from many water-associated wildlife populations (Sanderson et al. 2018). In addition, flood dynamics and ENSO phenomena have been shown to be strongly correlated with increased under-5 diarrheal case reports (e.g. Fox and Alexander 2015; Alexander et al. 2018; Heaney et al. 2019).

7.3 Fluvial Landforms

Despite the ongoing debates over the most appropriate deformation model for the Chobe-Zambezi region, it is clear that fault activity has been a key factor in the development of many large-scale landscape elements, and also a profound influence on river drainage organisation and flood flow patterns (Fig. 7.1). To the west, the Okavango and Kwando (Cuando) rivers (Chap. 2) essentially terminate as large fan-shaped features (the 'inland deltas' of McCarthy 1993), with only relatively minor channels crossing the southwest-northeast oriented bounding faults at the toe of these features (Fig. 7.1). At the toe of the Okavango Delta, the Boteti River has breached the Kunyere and Thamalakane faults and follows a southeasterly course towards the

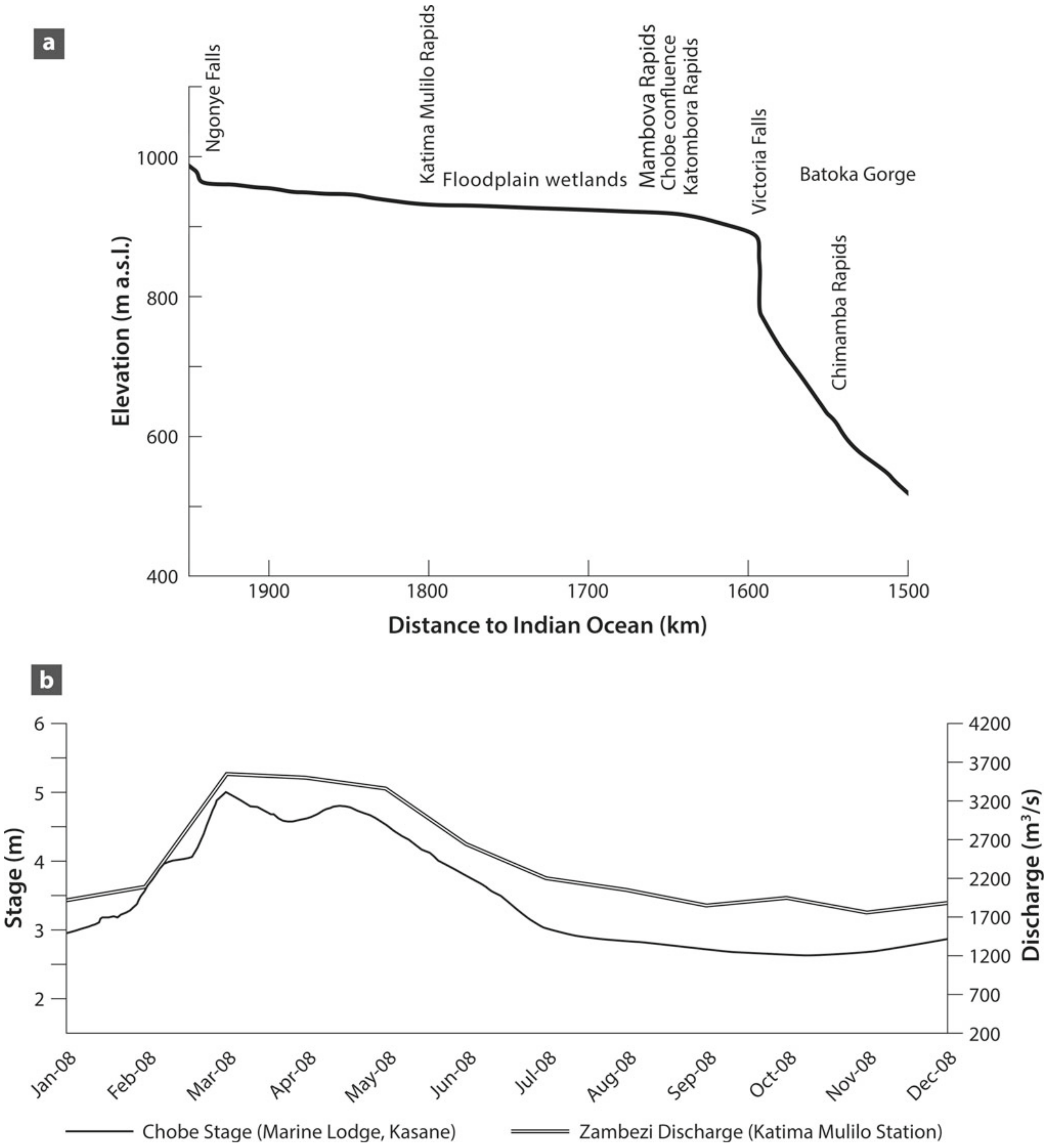

Fig. 7.3 **a** Long profile of part of the upper and middle sections of the Zambezi River, showing the location of the Chobe-Zambezi channel-floodplain system on a low-gradient reach upstream of the Mambova Rapids (modified after Nugent 1990 and Moore et al. 2007). **b** Pattern of mean monthly discharge (Zambezi River) and stage height (Chobe River) in an average year (2008) (after Pricope 2013 and Burke et al. 2016). The Zambezi data are from Katima Mulilo station (Department of Water Affairs, Namibia) and the Chobe stage data are from upstream of Kasane (derived from the ENVISAT Altimeter)

Makgadikgadi Pans complex (Chap. 5). At the foot of the Kwando Delta (also sometimes termed the 'Linyanti Swamps' or 'Mamili wetland'), the Linyanti fault has disrupted the flow, but the Savuti channel breaches the fault in the southwest and is joined by the Selinda from the west, and thereupon follows an easterly course towards the

Mababe Depression (Fig. 7.1). The Linyanti River is deflected by the fault to the northeast, whereupon it essentially terminates in a shallow depression adjacent to the fault to form the periodically inundated Lake Liambezi. A small channel has breached the bounding fault on the eastern margin of Lake Liambezi and commonly conveys flows towards the Chobe fault, essentially marking the start of the Chobe River (Fig. 7.1).

The course of the Chobe River is influenced by the southwest-northeast orientation of the Chobe fault. The river gradually increases in size downstream, becoming better defined as it approaches the main area of floodplain wetlands in the Chobe National Park (Fig. 7.2a). Although displacement rates along the Chobe fault are poorly known, uplift of some tens of metres is suggested by the fact that the prominent (up to ~30 m high) Chobe escarpment bounds the river (Fig. 7.2b, c), providing rare local exposure of sandstone and basalt. The escarpment rim is dissected by numerous small tributaries that deliver clastic sediment (dominantly clay, silt and fine-medium sand) to the Chobe (e.g. Sedudu River). There are few data on river sediment loads, but over time, the sinuous Chobe River has laterally migrated and reworked much of this sediment, forming well-defined scroll plains (Fig. 7.4a, b), commonly with 2–3 m of relief between the sandier ridges and the adjacent muddier, organic-rich swales (Fig. 7.4c). Banklines are formed mainly in fine-grained sediment (clay through fine-medium sand), with grasses and sedges widespread and shrubs and trees only present locally. Levees up to ~1.5 m high and some tens of metres wide are prominent features along some sections of bankline, and have been breached locally by crevasse splays that range up to ~0.1 km^2 in area (Fig. 7.4d). Numerous oxbows with various degrees of infilling provide evidence for past meander bend abandonment (Fig. 7.4a, b). The relatively open nature of oxbows, coupled with the patterns of erosion across the neck of some modern meander bends, indicates that many bend abandonment events result from chute cutoffs; across the upstream part of the neck, overbank flow leads to splay channels that extend downvalley and redistribute sediment, whilst on the downstream part, flow returning to the channel initiates headward-eroding gullies (Fig. 7.4a, b). If the upstream splays and downstream gullies ultimately connect, then increasing volumes of flow and sediment may be diverted from the main channel, ultimately leading to bend abandonment. Some of the stagnant or slow-flowing backwaters that parallel the main channel (Fig. 7.4a, b), including those in the vicinity of the disputed Sedudu (Kasikili) Island (Fig. 7.2a, b), may have formed as a consequence of gullies that have deepened rapidly relative to their rate of headward extension, and have since been inundated by river water.

The course of the upper Zambezi is also fault controlled. Initially, the river follows a south-southeasterly course, but then crosses rock outcrop at Katima Mulilo, whereupon the river steepens slightly across rapids (Fig. 7.3a), and is deflected more to the east-southeast, essentially skirting the northern margin of the main region of subsidence (Fig. 7.2a). Like the Chobe River, the Zambezi follows a sinuous course with alluvial, partly vegetated banklines (Fig. 7.2a). Evidence for past lateral channel migration and local chute cutoff-driven bend abandonment is provided by scroll plains and oxbows that are preserved adjacent to the modern channel (Fig. 7.2a), but in comparison to the Chobe, the limited number of tributaries in this river reach indicates a more limited sediment supply.

The low gradient region between the Chobe and Zambezi rivers is also marked by numerous fluvial landforms (Fig. 7.2a), including many scroll plains, oxbows and partially active and abandoned channels. As the courses of the two rivers start to converge towards the southeast, several secondary channels diverge from the right-bank of the Zambezi and follow sinuous courses southward and southeastward towards the Chobe (e.g. the Kasai channel—Figs. 7.2a and 7.5). By contrast with the main Chobe and Zambezi channels, but similar to many channels in the Okavango Delta (Tooth and McCarthy 2004a), the banklines of these secondary channels have relatively little clastic sediment and are largely formed by sedges and grasses (principally papyrus and phragmites) that are rooted in peat (Fig. 7.5). As such, the main function of these channels appears to be for flow rather than sediment conveyance, although observations of subaqueous bedforms (ripples, 2D and 3D dunes) nonetheless indicate some active transport of bedload sand.

Towards their confluence, both the Chobe and Zambezi rivers cross an uplifting horst block formed along a more northerly oriented part of the Chobe fault (in this area, also sometimes termed the Mambova fault–see Shaw and Thomas 1988; Fox and Alexander 2015) (Fig. 7.6a). Here, the rivers encounter basalt outcrop and initially follow separate courses separated by Impalila Island (Fig. 7.2a). Both rivers are characterised by interlacing networks of steeper, sediment-deficient channels that typically have incised ~5 m (Shaw and Thomas 1988) into the m-scale jointed but otherwise resistant bedrock (Fig. 7.6a–c). These river reaches closely correspond to the bedrock anabranching river style that is characteristic of some other southern African river reaches, such as along the Orange River approaching Augrabies Falls in western South Africa, and the Sabie and Olifants rivers in eastern South Africa (e.g. Heritage et al. 1999; Tooth and McCarthy 2004b; Tooth 2015; Milan et al. 2018, 2020). River gradients steepen across the Mambova Rapids (Figs. 7.3a and 7.6b), with areas of hydraulically abraded and plucked (quarried) bedrock and local boulder bars indicating active rock erosion and deposition during floods (Fig. 7.6c). On the lower

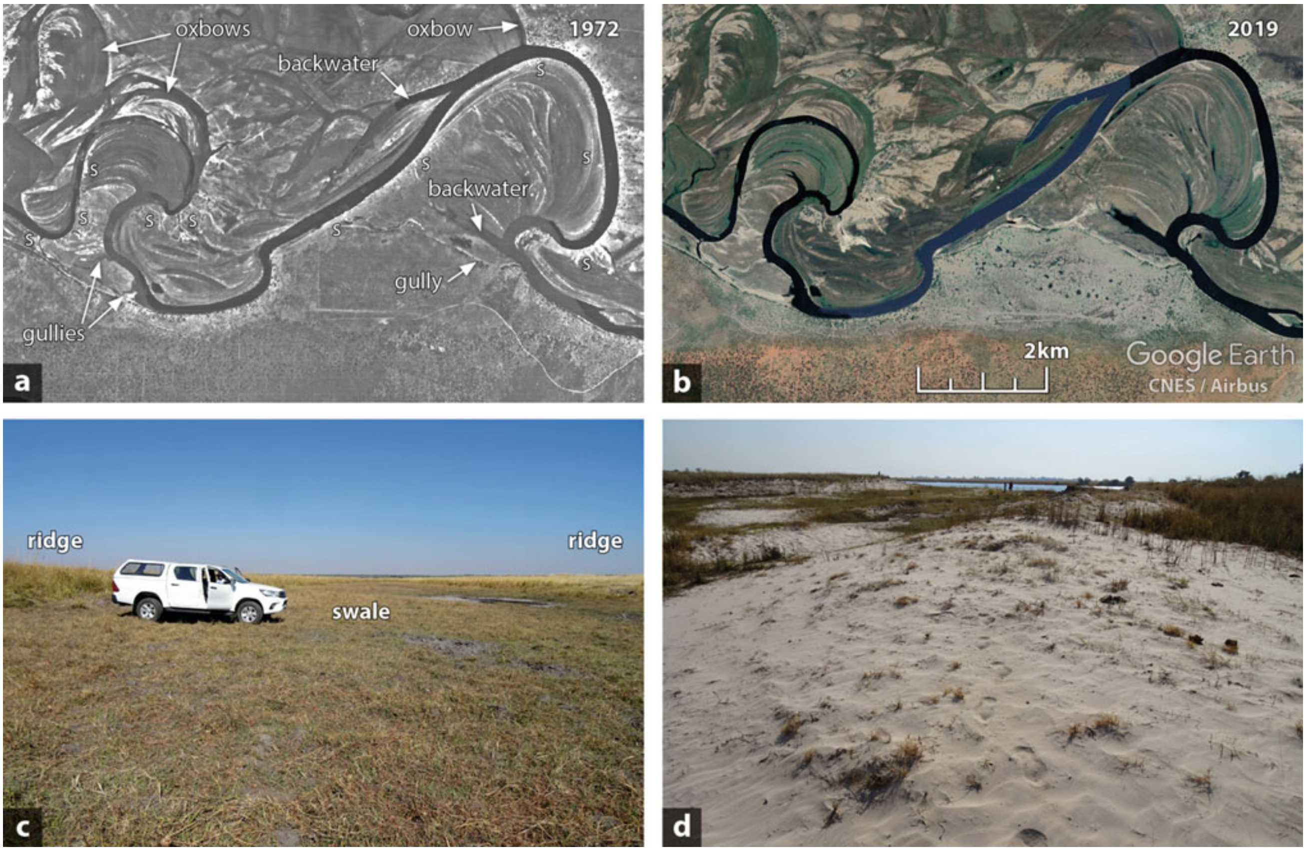

Fig. 7.4 The Chobe River and floodplain in the Chobe National Park illustrating alluvial landforms: **a** aerial image from 1972; **b** aerial image (from Google Earth) from 2019 (S indicates crevasse splay locations); **c** scroll plain on the inside of a meander bend, showing the topographic relief typically developed across the series of ridges and swales; **d** crevasse splay on the inside of a meander bend, showing sandy sediment emanating from a well-defined breach in the channel bank (view looking up the splay towards the main channel, located in the centre far distance)

Fig. 7.5 The Kasai channel, a secondary channel linking the Zambezi and Chobe rivers upstream of the Mambova Rapids (view looking downstream)

gradient reaches downstream of the falls, bedrock crops out locally and confines the channels and floodplains, but scroll plains provide evidence of some lateral channel migration and sediment reworking (Fig. 7.2a). The confluence of the two rivers occurs ~10 km downstream of the rapids near the town of Kazungula, whereupon the river continues westward as the Zambezi towards Victoria Falls, located on the Zimbabwe-Zambia border (Fig. 7.1).

7.4 Development of the Fluvial Landscape

The large-scale structure and medium-term (10^3–10^5 years) development of the Chobe-Zambezi channel-floodplain system is related to a combination of tectonic activity and climatically-driven changes to flow and sediment supply. The floodplain wetlands have developed in a region of long-term subsidence but a key control on fluvial landform

Fig. 7.6 **a** Satellite image (from Google Earth) of the Chobe and Zambezi rivers in the region of the Chobe fault and Mambova Rapids, illustrating the juxtaposition of alluvial fluvial landforms (left of image) and more bedrock-influenced fluvial landforms (middle and right of image). **b** Ground view of one of the shorter, steeper, permanently inundated, bedrock reaches at the Mambova Rapids (view looking upstream). **c** Ground view of one of bedrock reaches at the Mambova Rapids that is inundated during higher stages (view looking downstream towards the main channel, located in the far distance)

development is movement on the Chobe fault where it crosses the two rivers. The uplifting fault block provides the local base level for the rivers upstream, and so the critical factor is the relative uplift rate compared to the upstream channel-floodplain aggradation rate and/or the bedrock channel incision rates across the uplifting block. No data exist to constrain these rates, but four basic (end member) scenarios can be envisioned (Fig. 7.7):

(1) the fault uplift rate is greater than both the upstream channel-floodplain aggradation rate and the bedrock channel incision rates. This scenario results in partial or complete blockage (ponding) of channel flow and sediment transport in some upstream reaches, and abandonment of some bedrock channel reaches;
(2) the fault uplift rate is less than the channel-floodplain aggradation rates in reaches upstream. This scenario results in greater longitudinal sediment transfer, with downstream channels becoming more mixed bedrock-alluvial and parts of the outcrop becoming covered by sediment;
(3) the fault uplift rate is roughly in balance with the channel-floodplain aggradation rate and/or bedrock channel incision rates. This scenario results in equilibrium conditions, with rivers maintaining well-defined bedrock channels across the fault;
(4) the fault uplift rate is significantly less than the bedrock channel incision rates. This scenario results in the upstream passage of knickpoints, channel incision, gully formation and progressive evacuation of sediment from upstream reaches.

Aerial imagery (Fig. 7.6a) shows that whilst a few minor alluvial channels appear to be partially blocked by the uplifting fault block and some minor bedrock channels appear to be active only during the highest flows, the main channels of the two rivers are maintaining well-defined, dominantly bedrock courses. These observations suggest that the present-day channel-floodplain aggradation rate and/or bedrock channel incision rates are generally able to keep pace with uplift (scenario 3). In the past, however, scenario 1 may have applied for periods of time. A previous period (or periods) of more widespread blockage is suggested by evidence for the existence of an extensive former lake in the region upstream of the Mambova Rapids (Shaw and Thomas 1988; Thomas and Shaw 1991). Based on aerial image interpretation and fieldwork in the area south of Lake Liambezi, Shaw and Thomas (1988) described parallel series of curvilinear sandy ridges, which were interpreted as offshore bars formed during high lake phases, and adjacent diatomaceous, silty sediments, which were interpreted as lagoonal sediments. At several locations along the Chobe escarpment upstream of Kasane, Shaw and Thomas (1988) also described 'alluvial terraces' (or 'lacustrine terraces') of grey silty sand overlying calcrete hardpans. The calcrete contains localised concentrations of freshwater gastropod shells, some species of which were interpreted as indicating shallow, low-energy lacustrine conditions at the time of deposition. Based on these landforms and sediments, Shaw and Thomas (1988) posited the former existence of a 2000 km^2 palaeolake at ~936 m elevation that they named Lake Caprivi. Two radiocarbon ages from the shells indicated deposition of the shells at ~15 000 years BP, followed by subsequent formation of calcrete with falling water levels, with one other radiocarbon age from a shell indicating a return to high water levels between 2000 and 3000 years BP. The sites, sample materials and radiocarbon ages led Shaw and Thomas (1988) to conclude that Lake Caprivi was coeval with, and linked to, the 936 m Lake Thamalakane stage identified farther to the west. The relative importance of tectonic activity and climatic changes in promoting these and other, older high lake level phases in northern Botswana is unclear but Shaw and Thomas (1988) suggested that that the rock outcrop at the Mambova Rapids would have been a factor, as it would have formed a major impedance to the overflow of the 936 m lake.

By comparison with these lacustrine features, as yet there are no geochronological data for the channel-floodplain landforms and sediments in the Chobe-Zambezi channel-floodplain system. Nevertheless, the channel-floodplain landforms of the Chobe River that have been described in this chapter (e.g. scroll plains, oxbows, splays—Fig. 7.4) have all developed at elevations ~5–10 m lower than the surfaces of the terraces described by Shaw and Thomas (1988). This suggests that the disappearance of Lake Caprivi was followed by 5–10 m of channel incision, and then renewed lateral migration and floodplain formation. If this interpretation is correct, then the channel-floodplain landforms of the Chobe River—and by implication, many of the similar landforms along the Zambezi River—are probably of Holocene age. Based on comparison with ongoing optically stimulated luminescence (OSL) dating of similar fluvial landforms (e.g. scroll plains) in the Okavango delta (Larkin 2019; Tooth et al. 2022 submitted), a mid to late Holocene age for much of the Chobe River scroll plains is most likely, but this remains to be confirmed by ongoing studies.

Regardless of the channel and floodplain landform ages, analyses of aerial photographs and satellite images show that modern rates of change are very slow; along both the Chobe and Zambezi rivers, channel lateral migration, extension of crevasse splays and headward retreat of gullies and backwaters has been negligible over at least the last 40–50 years,

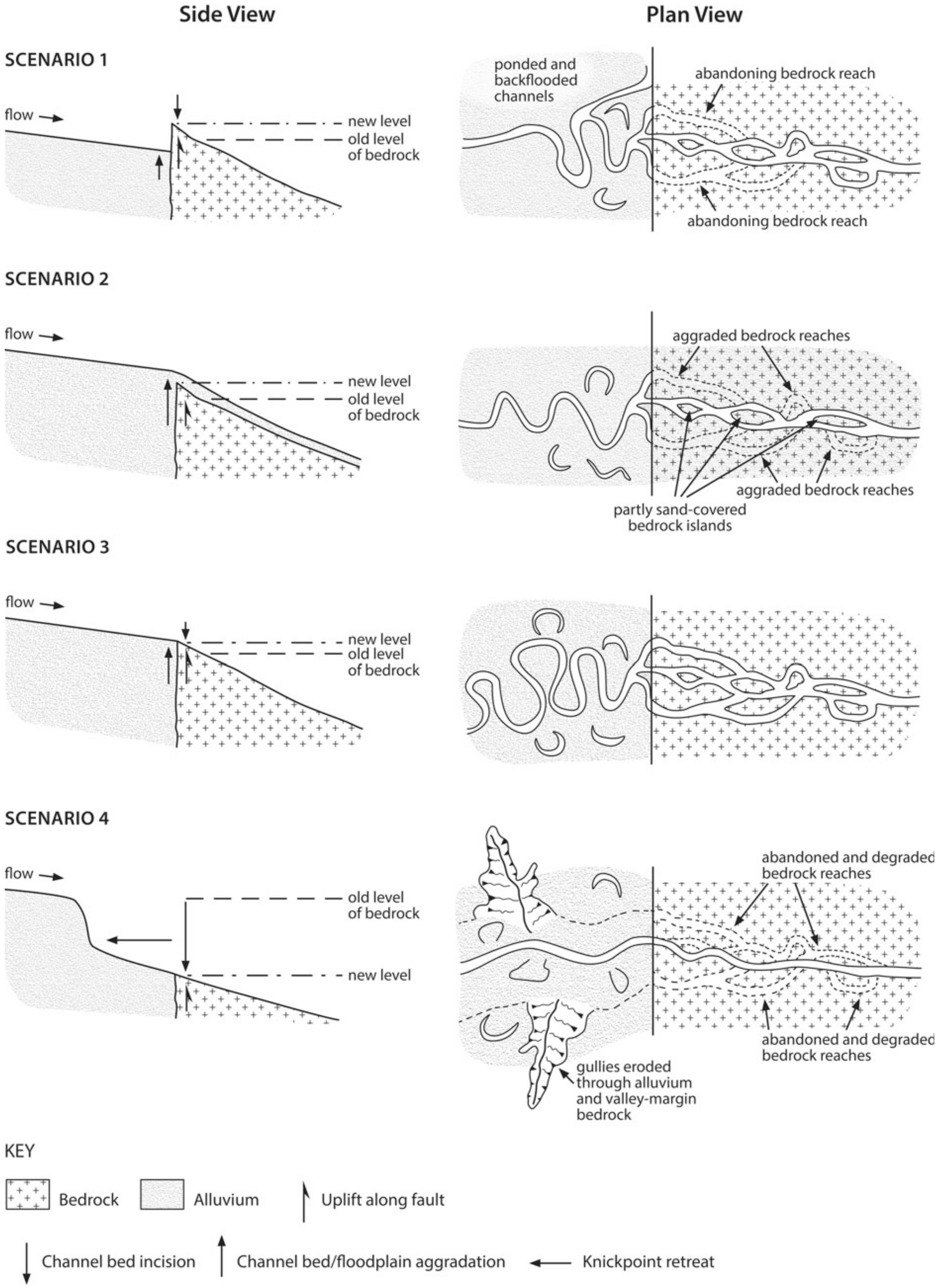

Fig. 7.7 Schematic illustrations of different scenarios of channel and floodplain change in the area around the Chobe fault

with few oxbows forming (e.g. Fig. 7.4a, b). Hence, although the observable evidence for former meandering channels, oxbows, scroll plains and splays might give the impression of a highly dynamic channel-floodplain system, on a timescale of a typical individual human lifetime (10^1–10^2 years), this is not the case. In essence, the modern Chobe-Zambezi channel-floodplain system provides a largely static—at best, very slowly changing—physical template that is nested within a complex of older, relic fluvial and lacustrine landforms.

7.5 Possible Future Developmental Trajectories

Along with the Okavango and Kwando rivers, the long-term behaviour of the Chobe-Zambezi channel-floodplain system is a key driver in the geomorphological development of northern Botswana and the surrounding areas of central southern Africa (Fig. 7.1). As this chapter has outlined, geological factors (e.g. tectonic activity, lithological outcrop) and long-term climate change have combined to drive various river responses, leading to a range of alluvial and bedrock fluvial landforms. Subsequent to the disappearance of Lake Caprivi, the modern bipartite character of the system was (re-)established, with alluvial channels and extensive floodplain wetlands developing upstream of the uplifting Chobe fault block, and more bedrock-influenced channels developing across and downstream of the fault block (Fig. 7.2a). Although small changes in the relative rates of fault uplift, channel-floodplain aggradation and bedrock channel incision are likely to control the details of reach-scale dynamics (Fig. 7.7–scenarios 1–3), this bipartite character is likely to persist on timescales of 10^4–10^5 years.

On longer timescales (>10^6) years, however, profound changes are likely to occur. Victoria Falls is located on the Zambezi River ~80 km downriver of the Mambova Rapids (Fig. 7.1), and represents a major knickpoint in the river long profile (Fig. 7.3a). In full flood, the falls have a maximum vertical drop of 108 m and width of 1700 m (Moore and Cotterill 2010). Like other great African waterfalls (e.g. Tooth 2015), the inevitable upstream retreat of Victoria Falls and the associated deep bedrock incision is progressively delivering significant base level change into the continental interior, and ultimately will influence the pattern and tempo of wider landscape denudation in the Chobe-Zambezi region. Based on the archaeological record, Moore and Cotterill (2010) have estimated that Victoria Falls is retreating at rates between ~0.040–0.080 m/yr. Assuming that these rates are maintained far into the future, then the falls will reach the Chobe-Zambezi confluence area in ~1 million years (with retreat rate at upper end of the range) to ~2 million years (with retreat rates at lower end of the range), and ultimately cross the Chobe fault. On the same timescale, the upstream retreat of the Mambova Rapids will likely already have delivered many metres of base level fall into the main region of alluvial channel and floodplain wetlands, but the arrival of the significantly larger falls will initiate a renewed phase of deep channel incision and wider landscape denudation (Fig. 7.7—scenario 4) that will pass northwest along the Zambezi River to its upper reaches and west-southwest along the Chobe and the Linyanti towards the Okavango Delta. Irrespective of future climate change scenarios and possible patterns and rates of EARS development, a likely outcome of this phase of deep incision is significant loss of alluvial river reaches and associated floodplain wetlands, with wider development of steeper, more confined, bedrock or mixed bedrock-alluvial reaches. Along the main region of subsidence, the present configuration of only partly connected alluvial river segments—each with different names, such as the Selinda, Linyanti, and Chobe (Fig. 7.1)—will progressively link more strongly. These linkages will give rise to a major river that erodes deep into the heart of central southern Africa as an increasingly integrated part of an enlarging Zambezi drainage network (cf. Wellington 1955; Moore and Larkin 2001; Moore et al. 2007, 2012; McCarthy 2013).

7.6 Conclusion

This chapter has provided the first comprehensive overview of the fluvial landforms of the Chobe-Zambezi channel-floodplain system, a neglected cousin of the better studied Okavango and Kwando systems. The descriptions of the different alluvial and bedrock fluvial landforms, and the outline of the key tectonic and climatic drivers involved in their development, hopefully will provide the basis for more detailed work that can improve understanding of the timing and rates of channel-floodplain changes. Collectively, the fluvial landforms in the region create the physical template within which occur shorter-term water, sediment and ecosystem dynamics, all of which have strong links to a range of contemporary environmental management concerns such as water quality and human and wildlife health (Fox and Alexander 2015; Alexander et al. 2018; Heaney et al. 2019). In addition, improved knowledge of past, present and possible future channel-floodplain dynamics provides opportunities for enhancing awareness of Botswana's rich geoheritage, with potential knock-on benefits for geoscience education, geotourism promotion and geoconservation efforts. These opportunities and benefits have yet to be exploited. In the Chobe National Park in particular, knowledge and insights regarding the past, present and possible future changes to the channel-floodplain system and associated ecosystem services need to be conveyed to visitors in simplified, widely accessible forms. Targeted use of improved signboarding, educational dioramas or computer animations could be used to help enhance the visitor experience provided by other aspects of the landscape and biota.

Information Box: The Role of Geomorphology in the Sedudu (Kasikili) Island Dispute Sedudu Island (known as Kasikili Island in Namibia) is a 3–4 km^2 island in the middle of the Chobe River, and is located ~5–10 km upstream of Kasane (Fig. 7.2a, b). The island is surrounded by two channels of the river, namely a 'northern channel' and a 'southern channel', and is frequently inundated during the seasonal floods. The island has no permanent residents but assumes significance because it was the subject of a long-running territorial dispute between Botswana and Namibia that culminated towards the end of the twentieth century. The dispute arose because of the imprecise wording of the agreement regarding the northern border in the 1890 Heligoland-Zanzibar Treaty. At that time, Southwest Africa (now Namibia) was under German control and Bechuanaland Protectorate (now Botswana) was under British control. Following their gaining of independence, the imprecise wording enabled both Namibia and Botswana to claim ownership of the island. The key issue was over which channel was the "main channel", as this would determine where the border between the two countries should be placed. Neither the German nor English versions of the 1890 Treaty: (i) clearly or consistently defined the notion of "main channel"; (ii) provided any criteria or guidance for identifying such a channel; or (iii) provided an unambiguous description or map of such a channel in the vicinity of the island. Consequently, the dispute centred on whether the border should run down the northern channel, thus ceding the island to Botswana, or whether it should run down the southern channel and so cede the island to Namibia.

In 1996, the two countries reached a Special Agreement to resolve the dispute in the International Court of Justice (ICJ) in The Hague. As reported by various commentators (Alexander 1999; Salman 2000; Johnson 2000), documentation associated with both the Botswana and Namibian cases included data and information regarding the hydrology, topography, sedimentology, and dynamics of the Chobe River channels and Sedudu (Kasikili) Island. Sequential aerial photographs from 1925 onwards show that the island has essentially been stable for many decades and has undergone no detectable changes in size and shape, so the northern and southern channels are effectively fixed in position. Hence, in its deliberations, and alongside other arguments concerning historical use, jurisdiction and navigability, the ICJ took into consideration the channel depths and widths, flow volumes, bed profile configurations, and bed and bank sediment characteristics (see https://www.icj-cij.org/en/case/98).

The 1999 ruling of the ICJ was that the border should run down the thalweg of the river (the line of deepest soundings) in the northern channel. This established the entirety of Sedudu (Kasikili) Island within Botswana's territory. The court recalled, however, that under the terms of a 1992 agreement (the Kasane Communiqué), the two countries had accepted that there should be unimpeded navigation for craft of their nationals and flags in the channels around the island, including free movement of tourists. Both countries were commended for their commitment to the peaceful resolution of the dispute, for respecting freedom of navigation, and for injecting environmental considerations into the navigable uses of the river (Salman 2000).

Sedudu Island hosts a significant wildlife population and remains one of the major tourist attractions in the Chobe National Park but in addition is a significant part of Botswana's geoheritage. In particular, the history outlined above illustrates the value of colonial-era historical aerial photographs in determining channel/island dynamics on decadal-centennial timescales, and also provides a rare example of where geomorphology has featured prominently in an international court of law to settle a border dispute.

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