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A Special River System: Review of Okawango Delta

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Abstract

The Okavango Delta is one of the largest inland deltas in the world. It was formed by the Okavango River injected into the Kalahari Desert. During this period, most of the river's water was lost through evaporation due to drought. It is located in northern Botswana and covers an area of about 15,000 square kilometers. It was formed by the Okavango River injected into the Kalahari Desert. Most of the water is lost through evaporation and transpiration. Approximately 11 cubic kilometers of water irrigates 15,000 km2 of land each year, and the excess water will flow into Lake Engami. This delta can be divided into three parts: 1) permanent swamp; (2) seasonal swamp, when seasonal floods occur, the area will grow vegetation; (3) the remaining part is forest and grassland (Wilson, 1973). This delta is actually a very huge alluvial fan with an area of about 40,000 km2. Among them, 9,000km2 is a permanent wetland (perennial wetland), and 14,000km2 is a seasonal wetland (seasonal wetland). The radial length of its central axis exceeds 150km, and the area of rivers, lakes, sandbars, seasonal wetlands and permanent wetlands included is 22,000km2. The reason for the formation of the Okavango Delta is an unresolved problem. For decades, different scholars have discussed this from different aspects and angles, but it has been difficult to achieve a completely convincing effect. To a large extent, the reason for its formation is very complicated, and it is the final result of the interaction of many factors, and the reason for the formation of Okavango's river model is very different from the current traditional understanding of the river model. For example, in the traditional sense, it is generally believed that the formation of the channel pattern is mainly related to the way the river transports the sediments. The bottom transport generally forms a braided river, the mixed transport generally forms a meandering river, and the suspended transport generally forms a direct-flow river, but Okavango Breaking this model, different types of sediment transport methods can form meandering rivers, and the current research hotspots in academic circles are concentrated on the transition mode from meandering rivers to braided rivers, which is also common in nature. Type, but Okavango's river course changes from meandering river to direct-flow river, which is very different from our usual change of river course mode. Many scholars have conducted a lot of research work from different angles and put forward many different explanations, but they have not been able to achieve satisfactory results. The reasons for the formation of the Okavango Delta, the type of river channel, the mode of river transition, and the nature and characteristics of the delta are all different from our current views on deltas, fan deltas, and river channels. Studying the Okavango Delta can help us Breaking through the traditional understanding of these issues has brought us many new inspirations. This article mainly collects more than 20 foreign literatures on Okavango in the past 30 years. Based on the research results of domestic and foreign scholars and meandering rivers, Okavango Delta is a typical meandering river delta. Combining the idea of "combining the present and discussing the ancient", conducts research on the Okavango Delta, summarizes previous research results and progress, and systematically summarizes these

documents, briefly reviews the overall research status and existing problems, and points out that the current urgent need The issue of in-depth research is expected to arouse the interest and attention of domestic scholars in the study of Okavango.

Keywords

Okavango Delta; Meandering River; Channel Pattern; Alluvial Fan; Wetland.

1. Introduction

Botswana is a low-lying plateau landlocked republic in Southern Africa, 70% of which is covered by the Kalahari Desert, with a total area of 600,370 square kilometers and an average elevation of about 1,000 meters. It borders South Africa to the south, Namibia to the west, and Zimbabwe to the northeast. Between 20° to 28° east longitude and 17° to 28° south latitude. Most areas have a tropical arid grassland climate. The western part is desert, which is a tropical desert climate. The average annual temperature is 21°C and the average annual precipitation is 400 mm. Okavango Delta, also known as "Okavango Swamp", It is located in northwestern Botswana, between 18° to 21° south latitude and 23° to 27° east longitude. Covering an area of approximately 15,000 square kilometers, it is a lush tropical swamp, surrounded by Kalahari desert grasslands, and is the largest inland delta in the world. Rainwater from the highlands of Angola gathered to form a turbulent torrent. The Okavango River, known as the "River of Life in Botswana", passed through the dry Kalahari Desert, carving out a special meander shape of "nine bends and eighteen bends", and finally formed Unique fan-shaped delta. The Okavango River overflows south, wherever it goes, trees are luxuriant, and various life forms are springing up like bamboo shoots after rain. The environment of beautiful water and grass has become a paradise for birds and animals.

The Okavango Delta, located in northern Botswana, is one of the largest inland deltas in the world. The Okavango Delta is actually a huge alluvial fan. Its area has strong seasonal characteristics, and its area will vary greatly in different seasons. In the dry season, the smallest area is only 16,000km2, but in the rainy season, its maximum area can reach 40,000km2. Among them, 9,000km2 is permanent wetland, and 14,000km2 is seasonal wetland (seasonal wetland). wetland). The Okavango Delta is mainly composed of two parts: one is a long and narrow corridor zone, also called Panhandle, with a width of 12km, which mainly develops permanent swamps; the other is a wide fan-shaped part with a width of about 120km and mainly develops seasonal swamps. In this area, the rivers are intertwined to form a network of rivers and contain thousands of sandbanks.

According to the different geomorphological characteristics of the Okavango Delta, the Okavango Delta can be divided into four parts: 1. A narrow entry corridor, also known as a panhandle, 2. A permanent swamps (permanent swamps) , 3. Seasonal swamps (seasonal swamps), 4. Dry land (permanent dry distal areas).Okavango Delta is a very complex system, its formation is closely related to climate, topography, tectonic movement, sedimentation, and hydrological characteristics. The cause of it is very complicated, and this issue is still pending. Some scholars have put forward different explanations. For example, Alex du Toit was the first to think that the delta was formed by faults, and that the delta was related to the graben formed by the East African Rift. Okavango Delta is located in the northern part of Botswana, with strong tectonic activity and frequent earthquakes. According to research, the pattern of rivers has changed many times in history. Mccathy believes that tectonic movement is the cause of the changes in river patterns, but there is no direct evidence (Mccathy, 1970).

Okavango's river system broke the current people's traditional and mechanical understanding of rivers. Traditionally, people believed that the shape of rivers was mainly affected by the way sediments were transported in the river water. Like a river, mixed transportation generally forms a meandering river, and suspended transportation generally forms a direct-flow river. However, in the northwest of Botswana, whether it is a meandering river or a direct-flow river, all rivers are

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intertwined, and they all have the characteristics of sediment transport, which contradicts the current understanding of rivers. (I.G. Stanistreet, B. Cairncross * and T.S. McCarthy).

From upstream to downstream, the overall characteristics of the Okavango River Delta are that the curvature and width of the river change from large to small, and the depth from small to large. The change pattern of rivers is from meandering river to dc river, which is different from the change pattern of general rivers from meandering river to braided river. Parker's (1976) gave an accurate description of the transformation characteristics of the Okavango Delta based on the depth-width ratio and Froude coefficient. But why Parker's (1976) method is so successful in the Okavango Delta region, and explained differently in other places, the reason is not well understood at present, and further research is needed (eg Bridge, 1993; Chew and Ashmore, 2001 ; Tooth and Nanson, 2004). Therefore, more research is needed on the genetic model of rivers.

Due to the arid climate, about 95% of the river water flowing into the delta from the upstream will be lost through evaporation or plant transpiration, the other 3% will penetrate into the groundwater, and only 2% of the surface water will flow through the delta and eventually flow downstream Ngami Lake.

Okavango Delta is the largest wetland system in southern Africa and the largest wetland system in the world in its pristine state. When it reaches its maximum size, the area of the delta will increase to 22,000 km2. The earliest discovery of the Okavango Delta was Alex du Toit. He believed that the Okavango Delta was formed by faults and is located in a graben structure related to the formation of the Great Rift Valley in East Africa. The Okavango River originates in the highlands of Angola and ends in the open flat plains of northwest Botswana. It has many names, such as Okavango Delta and Okavango Marsh. In recent years, more and more publications The literature called it Okavango fan (Stanistreet and McCarthy, 1993a), but for convenience, people are still accustomed to calling it Okavango Delta. The Okavan Delta is one of the largest surface fans in the world, with a central radiating length of more than 150km, and an area of 22,000km2 of rivers, lakes, sandbars, seasonal and permanent wetlands. Due to the existence of malaria mosquitoes and tsetse flies, the area is rarely disturbed by human activities, and the whole area remains in a very primitive state.

2. Study Area

The formation of the Okavango Delta originated from the graben formed by the sinking of the southern African plate 1.8 million years ago. It is a depression in the Kalahari Desert. Due to the continuous injection of the Okavango River, 2 million Tons of sand and debris deposited on the Kalahari Desert, forming a unique fan-shaped delta. The Okavango River originates in the central highlands of Angola, 900 kilometers northwest of the Okavango Delta. The rainfall in this area reaches 1200mm-1800mm. The average annual rainfall in the Okavango Delta is 500 mm. Rainfall is distributed in the southern hemisphere during the summer. From October to May of the following year, the peaks appear in January and February. Okavango can be divided into three parts, one is the handle area, the permanent swamp and the seasonal swamp. (1) Narrow and long handle area: It is the area of the main river channel, which is essentially the dense paper of Okavango River.The area roaming in the sedge and the river is the area between two parallel faults that flow to the permanent swamp. (2) Permanent swampland: Irrigated by a long and narrow handle area, where the Okavango River is divided into three main channels: Nqogha, Jao-Boro and Thaoge. This part is composed of river channels at the edges of papyrus, small forest edges, circular islands and wild dense palm plants. (3) Seasonal swamps: Irrigated by permanent swamps, it is a wide variety of seasonal area, where water exists only when seasonal floods arrive between May and September. When the water weakens and evaporates, a large area of grass will appear and many herbivores will appear.The Okavango Delta is located in the Kalahari Desert and forms an inland river in the Kalahari Basin (pictured). This delta mainly exists in the depression zone extending with the East African Rift Structural Belt (Scholz et al., 1976; Modisi et al., 2000; Gumbricht et al., 2001; McCarthy et al., 2002). There are three north-east faults: Gomare fault, Kunyere fault and Thamalakane fault.

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The Okavango River comes from the highlands of Angola, and the upstream is called the Kubango River. When it rained heavily in March, the river flooded and crossed the border into the Kalahari Desert in Botswana. For a period of time, the river traverses a rather narrow corridor that is clamped by ridges on both sides, 15km wide. The delta is close to the edge of the Kalahari Desert, where papyrus and phoenix palm grow luxuriantly. The abundant waters also provide an ideal ecological environment for ospreys, kingfishers, hippos, crocodiles and gobys. The Okavango River system carries more than 2 million tons of sediment into the delta every year, while 3% of its river water flows into the Entu Lake at the other end or across the 482 km-long Kalahari area, and then injects sand. Wuhu Lake and Magadijiadi Basin. The area of the delta can expand to more than 20,000 square kilometers during the peak flood discharge period, and shrink to less than 9,000 km2 during the low tide period.

The wetlands of the Okavango Delta are irrigated by the Okavango River, and its two source-direction tributaries (the Cubango and the Quito) are located in the Angolan highlands. The Okavango River flows through Namibia and finally flows into Mohembo, Botswana. Down Mohembo, the Okavango River is limited to a long and narrow terrain, the Panhandle (pictured). Continuing down, Okavango flows through the Gomare fault and then divides into many branch channels, which are scattered over a large area to form fans (pictured). The width of these branch channels gradually decreases with the increase of the downstream distance. Eventually, the river water diffuses in the lower part, plants begin to grow, and sediments are deposited.

Wilson divided the delta terrain into three parts: (1) the corridor zone, the panhandle area, approximately 100km long and 10km wide; (2) the permanent swamp area located in the middle of the delta, where many branch rivers are distributed , And the banks of these branch rivers are covered with dense plants; (3) The rest are seasonal swamps, where there is very little peat, and the flow of the river is not restricted by the river, and it spreads out (Wilson, 1973).

3. Discussion

For a long time, the academic circles have conducted in-depth studies on the deposition system of alluvial fans (Allen, 1965; Blair and McPherson, 1994; Bull, 1972; Zhang Chunsheng et al., 1995; Wu et al., 2016). Early studies suggested that alluvial fans are cone-shaped sediments accumulated near the foot of the mountain. This sedimentary system generally develops in arid and semi-arid areas. The slope is steep, the fan radius is small, and the sediment particles are coarse. Braided rivers, debris flows, overflows and sieving deposits are mainly developed (Bull, 1978; Leedweand Mack, 2001; Balance, 1984; Baltzer and Puser, 1990; Eyles and Koosis) ,1988; Harvey, 1984,2012). Some scholars divide alluvial fans and river systems according to the size of fan radius and slope (Blairand McPherson, 1994). According to the degree of development of braided rivers, mud-rock flows, and overflows, alluvial fans are divided into rivers, mud-rock flows and mud-rock flows. Alluvial fans dominated by flooding (Gallway and Hobday, 1996). In order to distinguish the alluvial fans in arid areas, the alluvial fans with perennial river flow on the surface are called wet fans (Nemec and Steel, 1988), and the fans with undeveloped debris flow, overflow and sieve deposits on the fan are called river fans. River fans with a radius of tens or even more than 100 kilometers are called giant fans (Stanistreet and Mc Carthy, 1993; North and Panson, 2007; Fisher and Nichols, 2007; Fielding et al., 2012; Li Zengxue, 2018). The proposal of the branch river system (DFS) concept has further aroused the attention of river fans (Weissmann et al., 2010, 2011, 2015; Hartley et al.al., 2010, 2013, 2016; Quartero et al., 2015; Owen et al., 2015, 2016), Hartley et al. (2010) and Weissmann et al (2010) summarized the previous idioms, the radius is less than Fans with a radius of 20~30 km are called alluvial fans, fans with a radius of 30~100 km are called river fans, and fans with a radius of more than 100 km are called giant fans. At present, there are more and more researches on river fans (Fontana et al., 2014; Arzani, N., 2005), but more attention has been paid to the geometry of the fan body and the distribution and evolution of the water system on the fan. There are not many examples of science and sedimentology anatomy. At present, the understanding of the facies zone distribution of fluvial fans, the petrological characteristics of sediments, sedimentary structure and stratigraphic

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structure is still very limited, which affects the understanding of the sedimentary system of underground fluvial fans, it is necessary A detailed investigation of a single modern river fan is carried out to enrich the sedimentary pattern of the river fan.Fan deltas are alluvial fans that are pushed into stable water bodies (Holmes, 1965; Nemec and Steel, 1988; Nemec, 1990). This definition can be extended to river fans. The sedimentary system formed by pushing river fans into stable water bodies is called It is a river fan delta. However, the terminal systems of fluvial fans and alluvial fans are quite different. The terminal systems of alluvial fans mainly develop laminar sediments (Wells and Harvey, 1987; Rust and Gostlin, 1981), while the terminal systems of river fans may develop braided rivers and The deposition of meandering rivers may also form braided rivers or meandering river deltas (McPherson et al., 1988).

Although the delta and alluvial fans show similar characteristics on the plan view, there are obvious differences in structure and formation mode between them. Early studies believed that alluvial fans are cone-shaped sediments with a certain slope, while deltas have relatively flat surfaces with very small slopes; the formation of fan deltas is due to the fact that the sediments in the channels have lost the limits of the channels and are in a large area. The formation of upward accumulation, while the formation of deltas is due to the fact that after the river channel carrying sediments is injected into a stable water environment, the flow velocity decreases and accumulation is formed in the direction of the water body. From this definition, Okavango Delta belongs to a kind of alluvial fan (McCarthy and Cadle, 1995). , But because the word Okavango delta has been deeply rooted in people's minds, people still prefer to use Okavango delta instead of Okavango alluvial fan today. According to the genesis of alluvial fans, Stanistreet and McCarthy (1993) divide them into three main types: 1. Debris flow fans, which are mainly alluvial fans formed by the action of debris flows, commonly known as dry fans; 2. Braided river fans, There are mainly alluvial fans formed by the action of braided rivers, that is, wet fans; 3. Low-curvature meandering river fans, mainly alluvial fans formed by the action of meandering rivers (picture), so many alluvial fans of classical studies can be classified Into these 3 types. Through the investigation of different fan types, it is proposed to classify the Okavango Delta into a new type of alluvial fan, namely the low curvature meandering river fan (pictured).

4. Interpretations and Conclusion

Okavango Delta is a river fan with river sediments as the main operating force. The sedimentary landforms, channel morphology, sedimentary structure and sediment characteristics of each part of the fan are obviously different from those of the classic alluvial fan. The river channel spreads radioactively from the top of the fan, and the grain size of the sediment gradually decreases downstream, and the width of the channel downstream continues to decrease, the depth becomes shallower, and the number increases. The Okavango Delta lacks debris flow deposits. At least four different sedimentary environments are developed on the fan margin, one is lake, one is marsh, one is land, and the other is stagnant depression on land.

The river course pattern of the Okavango Delta is different from the traditional view that meandering rivers usually develop in areas with large slopes and high flow energy, and the curvature of the river course will change with the slope of the valley. (1) Traditionally, it is generally believed that meandering rivers usually develop in areas with higher valley slopes and greater river water energy (eg Lane, 1957; Leopold and Wolman, 1957; Ackers and Charlton, 1970; Schumm and Kahn, 1972; Ferguson, 1981). (2) In order to maintain the continuity of the river slope, as the slope of the river valley becomes larger, the curvature of the river channel also becomes larger (e.g. Schumm, 1963; Gomez and Marron, 1991). The meandering river in the Okavango Delta occurs in the Panhandle area where the river bed has a small slope, and the DC river occurs in the fan-shaped area with a large slope. Parker’s (1976) used the depth/width ratio and the slope/Froude coefficient to provide a reasonable explanation for the change in channel patterns.

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References

[1] Orman D. Smith a,* Terence S. McCarthy b W.N. Ellery c1996Avulsion and anastomosis in the panhandle region of the Okavango Fan, Botswana Geomorphology 20 (1997) 49 65.

[2] McCarthy, T.S. and Metcalfe, 1990. Chemical sedimentation in the semi-arid environment of the Okavango Delta, Botswana.Chem. Geol., 89:157 178.

[3] McCarthy, T.S., Stanistreet, I.G. and Cairncross, B., 1991. The sedimentary dynamics of active fluvial channels on the Okavango fan, Botswana. Sedimentology, 38:471 487.

[4] McCarthy, T.S., Ellery, W.N. and Stanistreet, I.G., 1992. Avulsion mechanisms on the Okavango fan, Botswana: the control of a fluvial system by vegetation. Sedimentology, 39:779 795.

[5] McCarthy, T.S., Ellery, W.N. and Ellery, K., 1993a. Vegetationinduced subsurface precipitation of carbonate as an aggradational process in the permanent swamps of the Okavango (delta) fan, Botswana. Chem. Geol., 107:111 131.

[6] McCarthy, T.S., Green, R.W. and Franey, N.G., 1993b. The influence of neo-tectonics on water dispersal in the northeastern regions of the Okavango swamps, Botswana. J. Aft. Earth Sci., 17:23 32.

[7] T . S McCarthy, W . N .Ellery and I . G . Stainystreet1992Avulsion mechanisms on the Okavango fan, Botswana: the control of a fluvial system by vegetationSedimentology (1992)39,119-195.

[8] McCarthy, T.S., Ellery, W.N., Rogers, K.H., Cairncross, . (1986) The roles of sedimentation and plant growth in changing Row patterns in the Okavango Delta, Botswana. S. Afr. J.Sci., 82,579-584.

[9] Mccarthy, T.S., Mciver, J.R., Cairncross, 1989. The inorganic chemistry ofpeat from the Maunachira channel-swamp system, Okavango Delta, Botswana. Geochim. Cosmochim. Acra, 53.

[10] McCarthy, T.S., Rogers,K.H., Stainystreet, I.G., Ellery,W.N. (1988a) Features of channel margins in the Okavango Delta. Palaeoecol. Afr., 19, 3-14.

[11] McCarthy, T.S., Stainystreet, (1991)The sedimentarydynamicsof active Ruvialchannels on the Okavango fan, Botswana. Sedimentology, 38,471-487.

[12] Mccarthy, T.S., Stanistreet, I.G., Cairncross,.1988. Incremental aggradation on the Okavango Delta-fan, Botswana. Geomorphology,I, 267-278.

[13] T. Gumbricht,1 J. Mccarthy1* And T. S. Mccarthy, 2003. Channels, wetlands and islands in the okavango delta, botswana, and their relation to hydrological and sedimentological processesEarth Surf. Process. Landforms 29, 15–29 (2004).

[14] Stainystreet,T. S.McCarthy, 2004. Controls on the transition from meandering to straight channels in the wetlands of the okavango delta, botswanaEarth Surf. Process. Landforms 29, 1627–1649 (2004).

[15] I.G. Stanistreet, B. Cairncross * and T.S. McCarthy, 1992. Low sinuosity and meandering bedload rivers of the Okavango Fan: channel confinement by vegetated lev6es without fine sedimentSedimentary Geology, 85 (1993) 135-156.