The Geology of the Okavango Delta

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Introduction

By its classical shape and the fact that it is amongst the largest of inland deltas in the world, the Okavango has attracted the attention of geologists for many years. Surprisingly, however, until very recently, little detailed work was undertaken in the region, with the result that geologically, the Okavango still remains poorly known.

Interest was first focused on the geology of the Okavango by the two scientific expeditions of Du Toit (1926) and MacKenzie (1946); and Du Toit (1926, 1927 and 1933) was the first investigator to suggest that the Delta had a tectonic connection with the East African Rift Systems. Following the establishment of a Geological Survey Department in the then Bechuanaland Protectorate in 1948, reconnaissance visits were made to Ngamiland, but the scarcity of bedrock exposures did not invite detailed mapping. However, the tectonically-active nature of the Okavango was realised by McConnell (1959) from the high incidence of earthquakes in the region and interpretation of aerial photographs by Jones (1962) led to the recognition of two north-easterly trending faults which impound the waters at the distal end of the Delta. More recently, a number of prospecting companies have undertaken geophysical and drilling operations in the areas surrounding the Delta, and the Geological Survey has mapped the region around Lake Ngami and conducted gravity and seismic investigations in the swamps. As a result, bedrock lithologies have been inferred with a fair degree of reliability and major structural elements have been determined. Satellite imagery (LANDSAT 1) studies have also contributed to an appreciation of the tectonic history of the region.

Geological succession

The key to the solid geology of the Okavango lies in the surface outcrops in the areas surrounding the swamps and in several boreholes which have penetrated the sub-Kalahari basement. This information is shown on the map at Fig. 1. The map also provides an interpretation of bedrock geology based on geophysical evidence over the concealed areas.

The oldest rocks are granitoid gneisses of the Archaean Basement Complex. Outcrops occur in the Qangwa Valley and near the Chobe River. Geophysical evidence suggests that the rocks extend in a wide belt north-eastwards from near the Aha Hills through the swamps on the north side of Gomare fault.

The variably metamorphosed strata of the overlying Damara supergroup form the Aha, Koanaka and Tsodilo Hills. They comprise quartz schists, quartzites and dolomitic marbles of late Pre-Cambrian age. In the country lying between the Ngamiland fence at the Kuke Gate and Lake Ngami, bedrock is reasonably well exposed and quartzites, shales and limestones of the relatively unmetamorphosed late Pre-Cambrian Ghanzi Formation occur, overlying the Kgwebe Formation. The latter unit comprises two members: a quart-feldspar porphyry which gives way laterally northwards to the Toteng diabase. Seismic and borehole evidence indicates that the diabase is thick and widespread in the Maun area, but the porphyry reappears in the Goha and Gubatsha Hills north-east of Maun. Radiometric dating of the porphyry has given an average of a little over 900 million years (Boocock, 1968).

Faulted outliers of Karroo supergroup strata of Late Palaeozoic to Mesozoic age occur in the region south of Lake Ngami, and geophysical evidence suggests that they spread extensively under the central parts of the Okavango. The succession consists of sandstones, shales and coal seams underlying basalts. The basalts are exposed near the Chobe and Ngwezumba Rivers to the north-east of the swamps and have been encountered in boreholes near Maun and to the south of Lake Ngami.

Overlying the bedrock in thicknesses of up to 300 m, but probably averaging considerably less, are vast expanses of brown and white, deltaic and windborne, medium to fine-grained sands and silts of Cenozoic age, which are collectively grouped with the Kalahari beds. Associated with these semi-consolidated layers of detritus, are hard, concretionary lenses of calcrete and silcrete. Little is known of the structure and succession of these superficial formations.

Structure

Photogeological and satellite imagery interpretations have confirmed that the distal end of the Okavango Delta is confined by two extensive north-east trending faults. Photogeological studies by Jones (1962) and Vermaak (1962) surmised that the Gomare ridge, which runs south-west from the central part of the Delta, is also a fault. Satellite imagery shows marked tonal contrasts across this ridge and also that the seif dunes to the west are abruptly terminated by this line. The line itself is visible only intermittently and disappears to the south-west. The disposition of major fault lines suggests that the Okavango might lie across a rifted graben.

Fig. 2 shows the disposition of the main structural elements adduced from photogeological and geophysical evidence. The trend that controls impounding of the swamps is north-easterly. Satellite imagery shows that this trend can be divided into two directions: the faults associated with the Ghanzi ridge which trend at 58° and the Thamalakane and Kunyere faults, which trend at 38°. The Gomare fault and its probable extension along the south-eastern side of the Linyanti swamps (Chobe fault), has a trend midway between these values. There is a possibility that the 38° trend on the Kunyere fault crosses the 58° trend in the neighbourhood of Toteng. Geophysical investigations described below have confirmed the bi-directional trend of the faults and that downthrow occurs on the side of the Delta.

Originally described as a secondary trend (Akehurst, 1973), many linear features have an orientation on an axis varying from directions at 133° to 155°. Reeves (1974) confirmed that magnetic and gravitational anomalies with north-easterly trends were truncated along well-defined lines more or less at right angles. He ascribed this pattern to underlying control by the Damaran rocks on which has been superimposed relatively minor tectonic activity of the present day.

A prominent trend also lies on an axis at 78°. A subsidiary trend crosses it at right angles at about 170°. Post-Karroo dykes, stated by Reeves *(op. cit.)* to trend at 110°, have not been identified on satellite imagery.

In an effort to elucidate the structural build of the Okavango depression, several geophysical surveys have been undertaken by the Geological Survey Department. A gravity survey was conducted by Reeves (1973), during which over 1 000 stations were set up throughout Ngamiland. The gravity contours which indicate variations in the density of the bedrock are shown in Fig. 1.

The two distal boundary faults, the Thamalakane and Kunyere faults, are substantiated by the results of the gravity survey, though the anomalies they produce are confused by the proximity of a series of two-dimensional gravity highs paralleling these faults. This anomaly was drilled at Gautsha Rapids (CR2), and after passing through 43 m of Kalahari beds and 27 m of Karroo basalt, the hole intersected

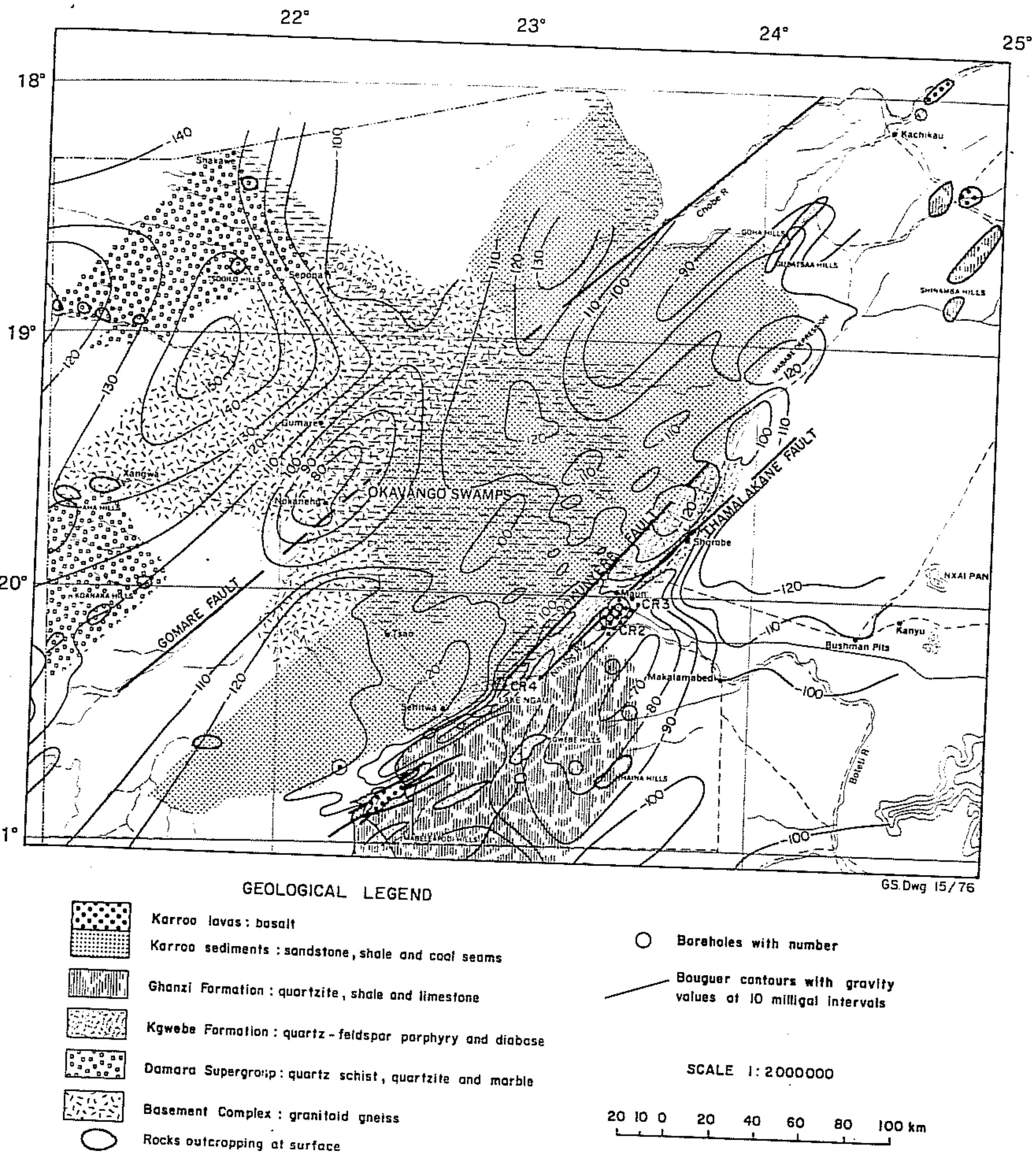

Fig. 1. Solid geology showing surface outcrops, boreholes to bedrock, interpreted bedrock geology in concealed areas and gravity contours

diabase. The diabase has been correlated with the Toteng diabase, which outcrops at Toteng and is associated with the largest of the families of anomalies. Thomas (1969) placed the Toteng diabase in the Kgwebe formation and the anomalies parallel the observed occurrence of Kgwebe porphyry. Similar two-dimensional gravity highs occur near porphyry exposed at the Goha and Gubutsha Hills (Reeves, 1974).

The lack of geological control has restricted quantitive evaluation, but preliminary interpretation of the gravitational data in the vicinity of the distal faults suggests that the throw to the north-west could be as much as 1 000 m. Evidence for an increasing thickness of sedimentary cover within the swamps, away from the boundary faults, is provided by the series of gravity lows which extend from the Lake Ngami-Tsau region, through Lion Island to the Selinda Spillway gravity low in the north-east.

North-west of the swamps and south of the Tsodilo Hills there is a large, triangular gravity low. This occurs in an area where the sandcover is known to be thin, and isolated outcrops of granitic basement occur further south-west in the Qangwa Valley. Reeves (1974) attributed the anomaly to either an upwarp of granitic basement or a large intrusive granite.

To provide additional control, particularly in the vicinity of the distal faults, a seismic refraction survey was conducted by Greenwood and Carruthers (1973). The results showed that the throw of the Thamalakane fault was 115 m at Shokwamokwa, and 120 m at Sakapane, and that north-west of the Kunyere fault the thickness of the superficial cover had increased to over 300 m. The seismic velocities indicated that through the middle part of the Delta, between the boundary faults and the Gomare fault, there were thick and extensive spreads of Karroo strata overlying an interpreted intrusive basement with similar velocities to the Toteng diabase.

The presence of a thick Karroo succession in the middle of the Delta, lying between Pre-Cambrian formations to the south-east and north-west, supports the contention that through faulting or rifting extends through the central part of the Okavango. The theory of rifting is further corroborated by earthquake studies which are described in the following section.

Seismicity and rifting

Reeves (1972) has established that the Okavango Delta lies within an area of continuing earthquake activity. In the nine-year period September 1965 to August 1974, a total of 38 events in the vicinity of the Delta were detected by the Rhodesian Meteorological Service. All Okavango events of magnitude 3,0 or greater on the Richter Scale, should have been detected by the Rhodesian seismograph network during this period and located to an accuracy better than 50 km. The epicentres are plotted in Fig. 2. The magnitude of the 38 events are distributed as follows:

5,0-5-9	1
4,0-4,9	4
3,0-3,9	26
less than 3,0	7

Larger events have been recorded in the past. During the period May 1952-May 1953 inclusive, South African seismographs recorded one magnitude 6 and 21 magnitude 5 events. The magnitude 6,7 earthquake of 11th October 1952, reportedly caused damage to buildings at Maun. It has also been suggested that the earthquakes of 1952 caused a change in the drainage pattern of the Delta (Pike, 1970).

In an attempt to delineate the seismicity of the Okavango Delta and environs, a micro-earthquake investigation was conducted by Scholz (1975). The Maun-Toteng area was found to be the most active area, with most tremors related to the

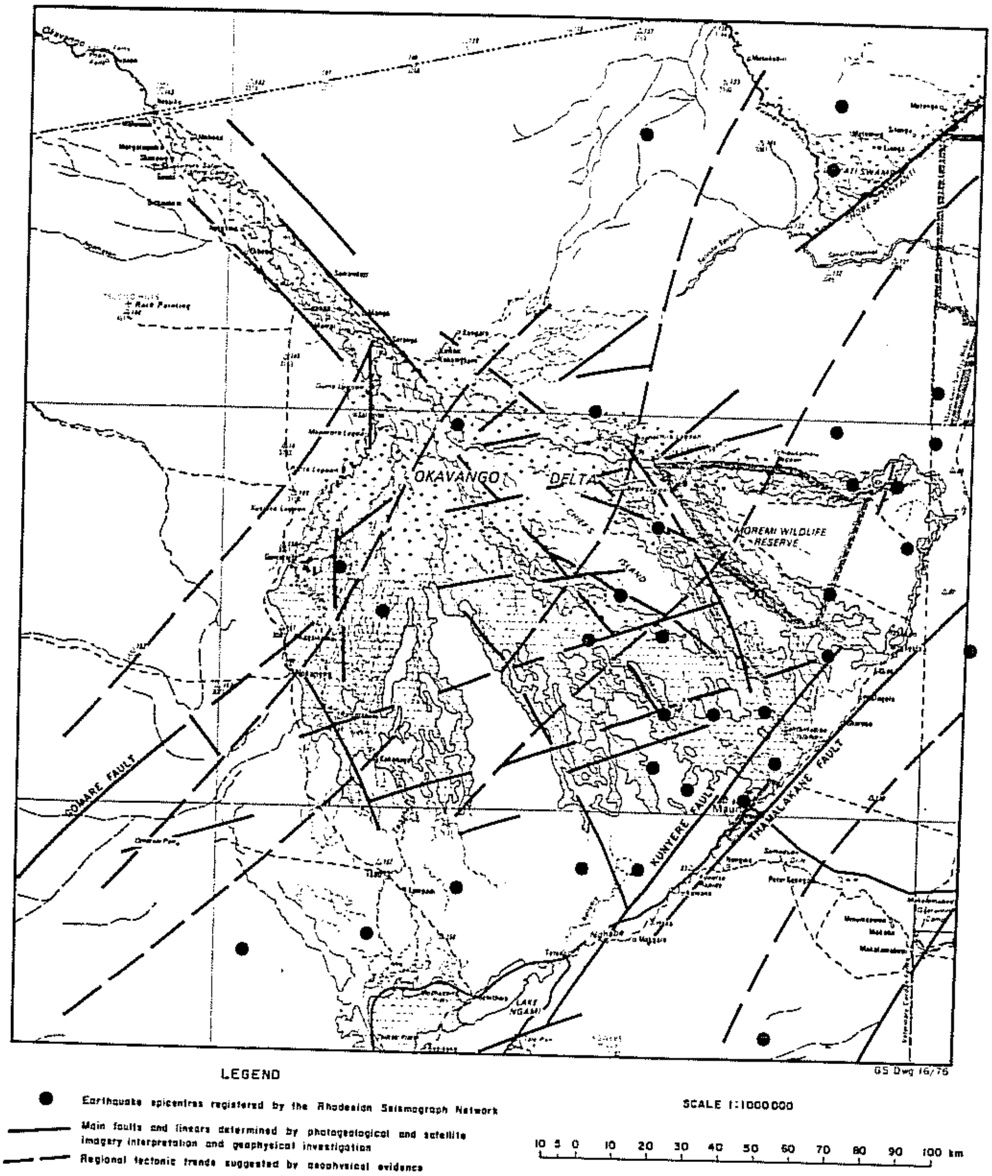

Fig. 2. Main structural elements and earthquake epicentres in the Okavango

north-easterly-striking Thamalakane and Kunyere faults. A composite focal mechanism for the well-located events in this area indicates normal faulting along planes dipping 60° to the north-west. Considerable activity was observed in the region of the Mababe Depression, and several events occurred in the region of the Chobe River. Activity decreased in the central part of the Delta and south-west of Lake Ngami, and was virtually non-existent in the upper Delta.

There is, therefore, strong seismic evidence for rifting in the Okavango. The focal mechanism for Okavango events is similar to that of the largest Kariba event (Gupta et al, 1972), and the persistent north-east trends of seismicity and faulting suggest that the activity is the southern end of the Luangwa Valley-Kariba gorge zone of seismicity, and may mark an incipient arm of the East African Rift System (Scholz, *op. cit.*).

Economic geology

Sulphide mineralisation is associated with the Ghanzi Formation to the south and east of the swamps. Coal is known to occur in downfaulted blocks of Karroo strata near Lake Ngami. As all these strata probably extend under the swamps, it is logical to assume that the mineral deposits also occur beneath the Okavango. The Delta also forms the repository for vast quantities of waterborne detritus, which contains a minor fraction of heavy ore minerals. Such minerals include rutile and ilmenite, which have been derived by weathering of the granites in the Angolan Highlands. Other minerals, including diamonds, could occur, but, as yet, no concentrations of placers of economic significance have been encountered.

The reports of early travellers to Ngamiland include references to gold, copper and other base metals, but it was not until 1962 that serious prospecting was started by the Johannesburg Consolidated Investment Co. The company's geological mapping programme did not reveal any mineralised zone and the concession lapsed. At this time, the idea that the Ghanzi beds represented a continuation of the copper-bearing Tsumis Formation of South West Africa and marked a link with the Katangan rocks of the Zambian copper belt, was actively considered. Anglo Vaal South West Africa (Pty) and, from 1971, a consortium headed by United States Steel Corporation, has held concessions over the entire strike belt of the Ghanzi Formation between the Namibian border and the Shinamba hills. Regional geochemical surveys have revealed copper anomalies, which drilling has shown to be related to narrow stratal zones of sulphide mineralisation lying at the top of the main arenaceous facies and below dark shales. The mineralisation has proved to be remarkably persistent along strikes for some 300 km, and appears to be genetically related to shallow palaeobasins. It comprises disseminated cupriferous sulphides, mainly chalcocite and bornite, with subordinate chalcopyrite and pyrite associated with sphalerite and argentiferous galena. Diagensis has led to the development of economically-significant zones of concentration along the axes of folds, and at present, these mark the target areas for evaluation by the prospecting companies. The ultimate origin of the copper probably lies with the intrusiveness of the Kgwebe Formation and the presence of native copper in Toteng diabase from a diamond drill core (CR2) tends to support this contention.

ACKNOWLEDGEMENTS

This paper is published with the authority of the Minister for Mineral Resources and Water Affairs, Botswana.

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