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SUSTAINABLE DEVELOPMENT OF GROUNDWATER RESOURCES IN CHINA AND AFRICA

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Preface

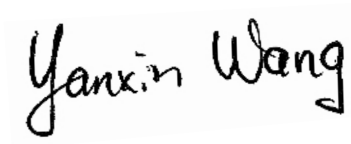
Sustainable exploitation of water resources is one of the global strategic issues closely related to the survival and development of human society. Water resources research should therefore become a major topic for scientific collaboration between China and other countries.

Botswana is a typical arid and semi-arid area, which has been faced with serious conflict between water supply and demand. In the context of global warming, water shortage may deteriorate further. Therefore, it is urgent to introduce advanced water resource management theories, methods and technologies to alleviate water crisis at Botswana. In order to promote the traditional friendship between China and Botswana and implement the relevant cooperation agreements signed after the Beijing China-Africa Forum, research work of the project on Groundwater Resource Exploitation and Protection in Botswana was carried out under the leadership of Prof. Teng Ma of China University of Geosciences (Wuhan), with financial support of Ministry of Science and Technology of P.R. China.

Since the implementation of the project, relevant information or data about Botswana groundwater resource have been collected. Through the cooperation with University of Botswana and Department of Geological Survey at Botswana, field investigation and seminar discussion were completed successfully. The major achievements includs: a. analysis of response of Okavango Delta to climate change in 20 years using multi-temporal remote sensing; b. understanding of the impact of fault system at the southeastern boundary of the Okavngo Delta on groundwater occurrence in Botswana; C. verification of geohemical evolution pattern and source of salinity in Makgadikgadi Pan using chlorine isotope; and d. understanding of the origin and fate of nitrate in groundwater of Ramotswa using nitrogen and oxygen isotopes.

In order to summarize the results of the research work in Botswana and maintain long term cooperation with African countries, the International Conferenc on Sustainable Use of Groundwater Resources in Africa was held on October 9th-10th, 2010 at China University of Geosciences. A total of 12 reports were presented at the conference, and 12 papers were included in the proceedings. The conference provided a platform for sharing experiences and advances in the field of groundwater resources studies both in China and in Africa.

In the 21st century, water resources and environmental studies will become increasingly important for China-Africa collaboration. I believe this volume will serve as a milestone for the collaboration in water resources research.



Yanxin Wang, Professor of Hydrogeology

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Hydrogeology and Groundwater Management in Botswana

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Abstract: This document outlines the hydrogeology and the broad groundwater management scenario in Botswana. Emphasis is given to the ever diminishing resource as well as the ever-increasing demand placed on this limited resource. This create an inevitable assortment of challenges which needs urgent attention ranging from limited recharge, over abstraction, policy issues as well as institutional framework.

Keywords: groundwater management; recharge; diminishing resources; challenges

1 Introduction

Botswana is a landlocked country located at the centre of Southern Africa Plateau (Fig. 1). It has a relatively low annual rainfall (less than 600mm, Fig. 2) and high rates of evapotranspiration. With a semi-arid climate and hence very limited surface water bodies dependency on groundwater is high. Botswana depends to a large extend on the exploitation of its groundwater reserves to meet its ever-growing water demand due to urbunisation, mining, agriculture, industrialization and domestic needs.

2 The Hydrogeology of Botswana

2.1 The Geology of Botswana

The geology of Botswana spans the entire geologic time from the Archean through to the Phanerosoic (Fig. 3).

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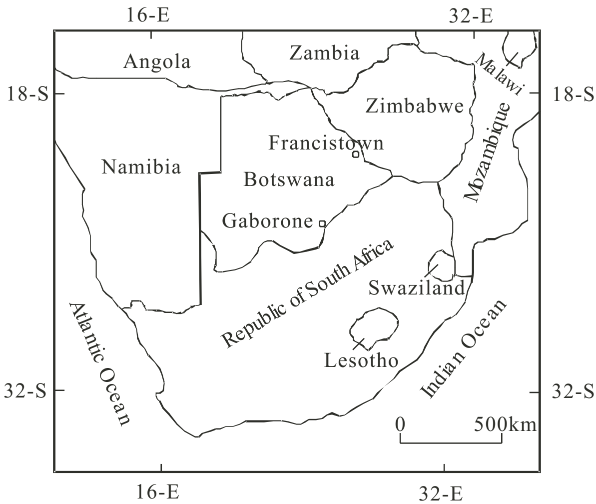

Fig. 1 Location of Botswana

Geotectonically Botswana is located on the boundary of Congo Craton and Kalahari Craton, which is mainly composed of Kaapvaal Craton, Zimbabwe Craton and Limpopo Belt (Fig. 4). To a large extent (about 80%) of the geology of Botswana is overlain by the younger (Tertiary to recent) Kalahari which is an assemblage of aeolian sands, calcrete/silcrete and clay horizon beds. The geological units of Botswana are described below in brief (Fig. 5).

2.1.1 Archean Rocks

The Archean units are the oldest in Botswana and include three distinct terrains namely the Kaapvaal Craton, the Zimbabwe Craton and the Limpopo Mobile Belt. The Limpopo mobile Belt is sandwiched between the cratons and they are all described below.

2.1.1.1 The Kaapvaal Craton

This covers most of Southern Africa as well as the south eastern and Eastern Botswana and the western and western boundaries are not yet defined due to the Mesozoic to recent cover (Carney *et al.*, 1994). It is made of a sequence of Granite-greenstone associations with gneisses, migmatites, meta-sedimentary and volcanic rocks. The subdivisions of the Kaapvaal Craton include the Lobatse Volcanic group and the Gaborone Granite complex. The granitoid and genissic comple-

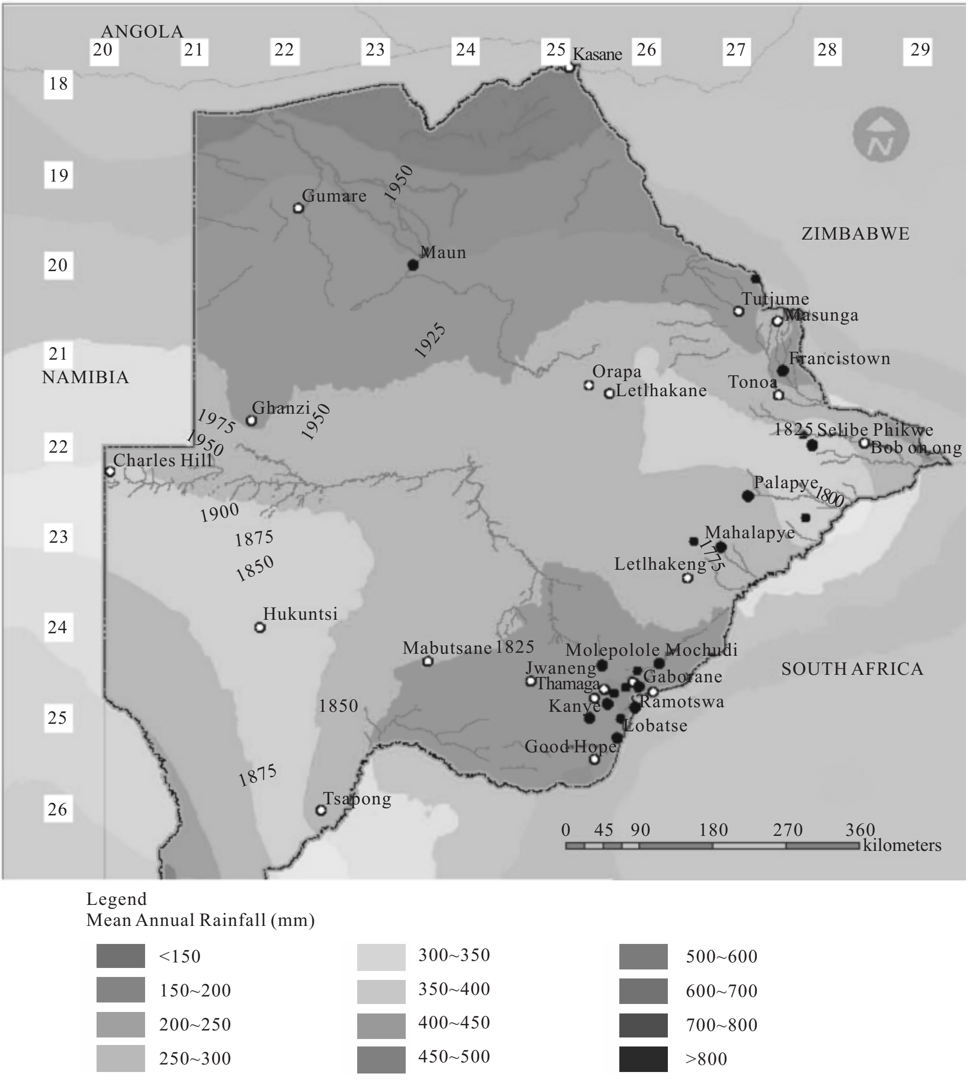

Fig. 2 Mean annual rainfall

(Source: Department of Water Affairs, 2006)

EON	ERA	PERIOD	MILLIONS OF YEARS AGO
Phanerozoic	Cenozoic	Quaternary	1.6
		Tertiary	66
	Mesozoic	Cretaceous	138
		Jurassic	205
		Triassic	240
	Paleozoic	Permian	290
		Pennsylvanian	330
		Mississippian	360
		Devonian	410
		Silurian	435
		Ordovician	500
		Cambrian	570
Proterozoic	Late Proterozoic Middle Proterozoic Early Proterozoic		2 500
Archean	Late Archean Middle Archean Early Archean		3 800?
Pre-Archean			

Fig. 3　Summarised geologic time scale

(Source：http：www. pubs. usgs. gov/gip/fossils/numeric. htm)

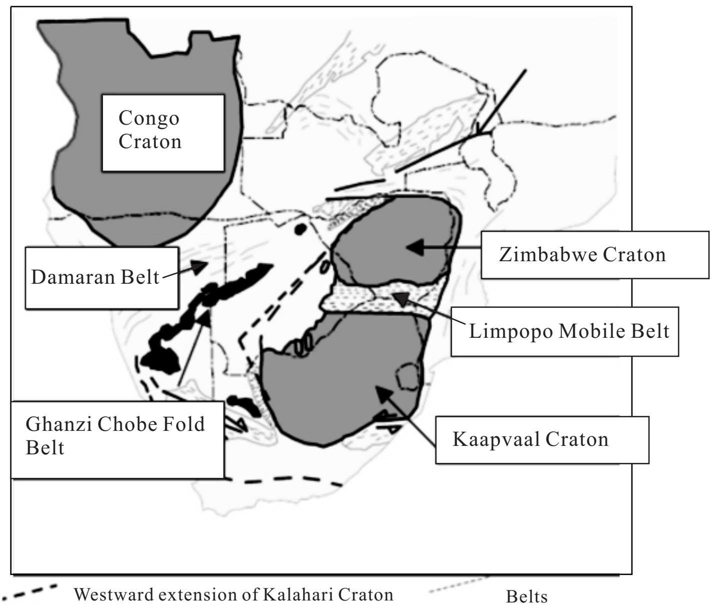

Fig. 4　Major structural features (Cratons，Fold and Mobilebelts)

(Source：PC Atlas Botswana)

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xes make up to 90% of the Kaapvaal Craton.

2.1.1.2 Zimbabwe Craton

This covers the north-eastern Botswana around Francistown. Its western boundary is the south-west trending Early Proterozoic Mogondi Orogenic Belt and in the east extends into Zimbabwe. The Zimbabwe Craton is comprised of Archean tonalitic gneisses which makes up to 75% of this Craton and a series of Greenstone Belts are important among which are the Matsuyama, the Vumba and the Tati greenstone belts.

2.1.1.3 Limpopo Belt

This is the ENE trending zone between the cratons which are characterized by highly complex deformation and metamorphism. Cox and others (1965) divided it into the northern and southern marginal zones (NMZ and SMZ respectively) and a Central Zone (CZ) using photogeological techniques. It made up of an assemblage of gneisses, granitoids and migmatites.

2.1.2 Proterozoic

Proterozoic rocks are nominally split into an upper and lower sequence. The lower (older) includes predominantly the Transvaal and the Waterberg Super groups. The upper sequence contains the Damaran and Ghanzi Chobe Fold Belt rocks (NWMP Vol. 4, 2006). Those rocks generally comprise of shales, siltstones and quartzites.

The Damaran and Ghanzi Chobe Fold Belt rocks are found in the north western area of Botswana. The Ghanzi Group sediments outcrop in a belt trending northeast from the Mamuno area on the Namibian border (Ghanzi Ridge) and also appear again to the east of the delta. The Damaran and Ghanzi Chobe Belt rocks includes a wide range of metamorphosed rocks (generally sandstones and quartzites) although the Damaran also includes a karstic dolomite series found in the northwest Ngamiland (Aha Hills).

2.1.3 The Phanerozoic Deposits

The Karoo Supergroup comprise a succession of sedimentary and volcanic rocks.

2.1.3.1 Karoo Deposits

The Karoo deposits adopt an age of 570Ma and cover several periods of geological time from the Permo-Carboniferous through the Permian, Triassic to the early Jurassic. Consequently they have a wide variety of rock types as well as an extensive representation covering approximately 80% of the country. The lithostratigraphy and nomenclature of the Karoo Supergroup was established by Smith (Smith, 1984), who divided it into 3 units: the Stormberg Basalt, the Upper Karoo-Lebung Group and the Lower Karoo-Dwyka and Ecca Series.

The Lower Karoo-Dwyka and Ecca Series: moraine and periglacial fluvio-lacustrine sediments, more moist clay rich sediments in the Lower Ecca group.

The Upper Karoo-Lebung Group: aeolian sandy sediments and dunes.

2.2 The Hydrogeology of Botswana

2.2.1 Previous Works

Several works relating to the study of groundwater resources in Botswana have been carried out. These include works carried out for the purposes of understanding the resource (research) as well as its development for village water supply, Such as the groundwater resources map of Botswana (Fig. 6, DGS, 1987) and the progressive development of all the 23 wellfields which are managed by DWA and 12 wellfields which are managed by DGS. There are around 25 000 officially registered boreholes in Botswana of which 10 000 are Government of Botswana (GOB) owned water supply boreholes (Department of Water Affairs, 2006) mainly in the above mentioned 35 wellfields. Besides government wellfields which are under DWA and DGS, there are several privately owned wellfields such as those owned by major abstractors(e. g. the mines). All these represent a significant amount of data which was generated during the projects undertaken to develop the resource.

2.2.2 Classification of Productive Units

All Botswana aquifers have been broadly classified into four categories according to the physical structure and nature of rocks or sediments which form the aquifer. These are Intergranular, Fractured, Intergranular/Fractured and Karst.

2.2.2.1 Intergranular (Porous) Aquifers

These occur mainly in unconsolidated sediments and river alluviums, and they store water by predominantly primary porosity. These include river sediments as well as the Kalahari beds especially around the Okavango Delta in the north west, the south west and along most rivers in Botswana.

2.2.2.2 Fractured Aquifers

Fractured aquifers are those where water is primarily stored in fractured within the rocks.

2.2.2.3 Intergranular/Fractured Aquifers

In these kind of aquifers, water is stored both in the primary intergranular pore spaces and fracture spaces. A classic case is the Ntane sandstone as well as the Ecca both of the Karoo system.

2.2.2.4 Karst Aquifers

These are aquifers where water is stored in secondary porosity created by the dissolution of carbonate minerals. They include the Ramotswa Dolomite aquifer, the Lobatse and the Kanye aquifers.

2.2.3 Productivity Classes and Colour Codes

The aquifers in Botswana have been classified into five productivity classes, each of which has been given a specific colour code (Fig. 6). On the map also the corresponding geological units are represented by symbols in the background on which the productivity has been overlain. The colour codes used are as follows from the worst to the best cases: Yellow(worst), Pale Green, Green, Pale Blue and Blue (best).

2.2.3.1 Recharge

Areas where there is no recharge are shown by white dots.

2.2.3.2 Prospects

The hydrogeological map also shows the prospects of getting water (aquifer potential) on each of the aquifers. The prospects range from poor (0～1L/s) through fair (1～4L/s) to good (>4L/s).

3 Groundwater Management in Botswana

Continued good management of groundwater resources in Botswana is essential as this resource provides the day to day supply for the majority of areas in the country.

3.1 Groundwater Management

3.1.1 The Government

In Botswana, water like any another resource is owned and managed by the state. This is done via three government bodies which are the Department of Water Affairs, the Department of Geological Survey (DGS) and Water Utilities Cooperation (a parastatal body).

3.1.1.1 Department of Water Affairs

This department is primarily responsible for development and supply of water to rural areas and major villages. It also has the following roles.

(1) Responsible for groundwater development for village water supply.

(2) Keeps BH certificates copies.

(3) Is the secretariat of the Water Apportionment Board (WAB).

(4) Manages and monitors BHs of operational wellfields.

3.1.1.2 Department of Geological Survey

The Department of Geological Survey on the other hand is responsible for the management of non-operational wellfields (i.e. where there is no abstraction/pumping). It also has the following specific roles.

It is responsible for: ①management of non-operational wellfields; ②registering all water BH and keeping copies of certificates; ③Monitoring all other abstractors including DWA and WUC.

3.1.1.3 Water Utilities Cooperation (WUC)

Water Utilities Corporation (WUC) is a parastatal organisation, wholly owned by the Botswana Government. It was established in 1970 by an Act of Parliament with a mandate to manage a single project for the supply and distribution of water in which was then called the Shashe Development Area. In 39 years since its inception, its mandate has expanded to supplying all the urban centers in the country. This involves planning, constructing, operating, treating, maintaining and distributing water resources in the country's urban centers and other areas mandated by the Botswana Government.

WUC also supplies bulk treated water to the Department of Water Affairs for onward distribution to some of the major villages. Currently plans are at an advanced stage to expand the Corporation's mandate to include the takeover of water supply and waste water management from the Department of Water Affairs and District Councils respectively.

3.1.2 Other Abstractors

All other major abstractors (mainly mines) monitor and manage their own wellfields and are accountable to the government. They register their BHs with the DGS. They also submit an annual report to the WAB for decision making. DGS/DWA conducts regular spot checks on them so as to ensure compliance to agreed standards.

3.2 The structures/Infrastructure in place

In order to manage the large amounts of data generated by the continuous development and management of the groundwater resources (and other resources) in Botswana, the governments has invested in the various equipments to enable easy handling of the data. These includes among others: NIGIS for the whole Ministry of Minerals Energy and Water Resources, Aqua-Base for chemistry data used by DWA, WellMon used by DWA and ArcGIS 9.3 packages used by both departments.

3.2.1 NIGIS

NIGISis an acronym for National Integrated Geoscience Information System. Ideally all information pertaining to Geoscience should be residing in this system including Hydrogeology information. The following picture (Fig. 7), is a map view showing the Hydro features managed by the system.

3.2.2 Aqua-Base

There were systems in place before the integration of geoscience information. Such systems include: ①acquabase which is a MS SQL database containing chemistry data; ②The data has not been migrated to NIGIS as yet which meant chemistry data was sourced from DWA.

3.2.3 WellMon

Wellmon is an acronym for Wellfield Monitoring. It is also a MS SQL database hosting wellfield monitoring information. This data was also sourced from DWA.

All this information was combined to give data sets requested for the project.

3.3 The Challenges Faced by Groundwater Managers in Botswana

3.3.1 Administrative

3.3.1.1 The Gap of Private Farmers

The available information concerning boreholes owned by private farmers is just a single point in time(i. e. at the time of drilling). No information is collect-

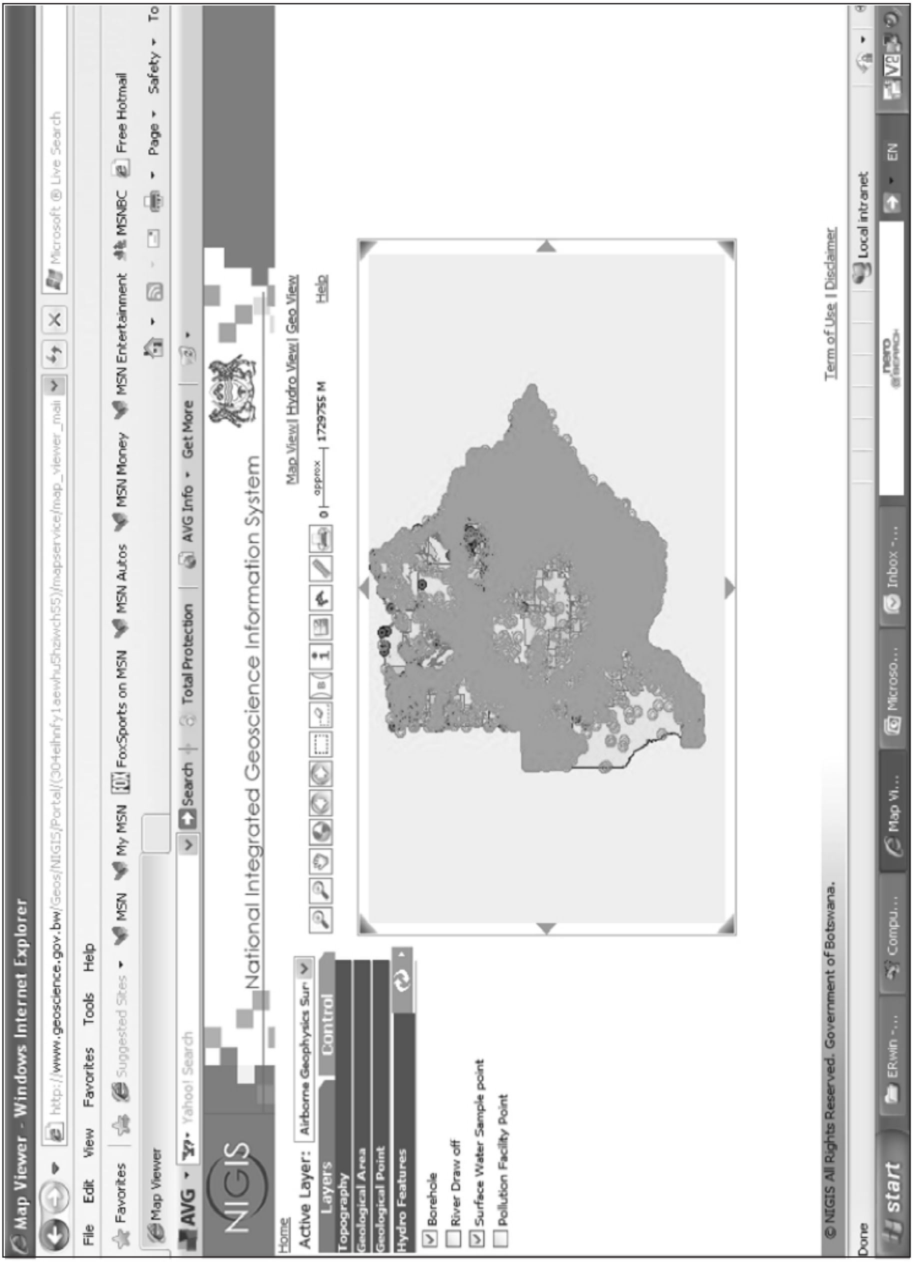

Fig. 7 A map view showing the Hydro features managed by NIGIS system

ed on what happens to the borehole after drilling including the monitoring of ap-

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