Preliminary results of detailed inventory of transboundary aquifers in Benin (West Africa)

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ABSTRACT

Benin transboundary aquifers are inventoried in the framework of the UNESCO-ISARM project entitled "Inventory of transboundary aquifers in West Africa". Data and information collected through this project will enable to establish the database of UNESCO-IGRAC Centre of the transboundary aquifers in West Africa. They will also help to develop a GIS inventory of transboundary aquifers of the West Africa as a contribution to ISARM Africa. This inventory will lead up to elaboration of specific cooperative projects. Identification of transboundary hydrogeological layers was based on hydrogeological cross-sections used to verify the continuity of different aquifers across international borders. In addition, characteristics of each transboundary aquifer were investigated.
The results of this study show that Benin has transboundary continued aquifers in two sedimentary basins: the coastal sedimentary basin in the Southern and the sedimentary basin of Kandi in the North-East. In the first basin, there are four aquifers shared with the Togo in the West and Nigeria in the East. From the bottom to top, we are: the Turonian-Coniacian (Upper Cretaceous) aquifer (sands and sandstones), the Paleocene aquifer (limestones and sands), the Continental terminal aquifer (sands) and the Quaternary (the coastal and alluvial sands). In the second basin, there are two aquifers shared with Niger in the North and Nigeria in the East: The Paleozoic (Cambrian-Ordovician) aquifer (conglomerates and sandstones) at the base and the Silurian and Quaternary aquifer (sandstone and alluvial sands of Niger River) at the top. These inventoried aquifers are of varied hydrodynamic type (free, captive or semi-captive) and of varied quality (including facies and total mineralization).

Keywords: Inventory, transboundary Aquifer, coastal sedimentary basin, basin of Kandi, Benin

1. INTRODUCTION

This study results from recommendations of the different ISARM workshops on inventory of transboundary aquifers in West Africa. It concerns inventory of aquifers that Benin shares with others countries of the Guinea Gulf (Togo, Nigeria, Niger and Burkina Faso).

Guinea Gulf is one of the most populated regions in West Africa. This region experiences a rapid demographic growth worsened by the internal rural exodus and migration of people coming from the hinterland (Sahelian countries). Moreover, it records, a rapid urbanization and economic growth of which a substantial part escape the regional countries planning (informal sector). This causes an important pressure on water resources. The results are a tendency of groundwater over extraction, aquifers pollution and loss of wetland ecosystems. Water demand becomes more and more important and will be likely to create conflicts between various users as already observed between breeders and farmers during transhumance period.

As surface water catchments, aquifers stretch often over two or several countries. But contrary to the surface water, these aquifers are yet not well known in West Africa with regard to their nature and as their functioning. This is the interest of the paper.

In terms of geology, the figure 1 shows that Benin country extends essentially on a crystallophyllous and crystalline socle of Proterozoic age. This base which takes up the central part of the country is covered on its north-western, north-eastern and south peripheral areas with layers more or less recent. These are respectively transgressive layers from the ending Proterozoic of Atacora, Paleozoic basin of Kandi and Cenozoic to coastal Quaternary sedimentary basin.

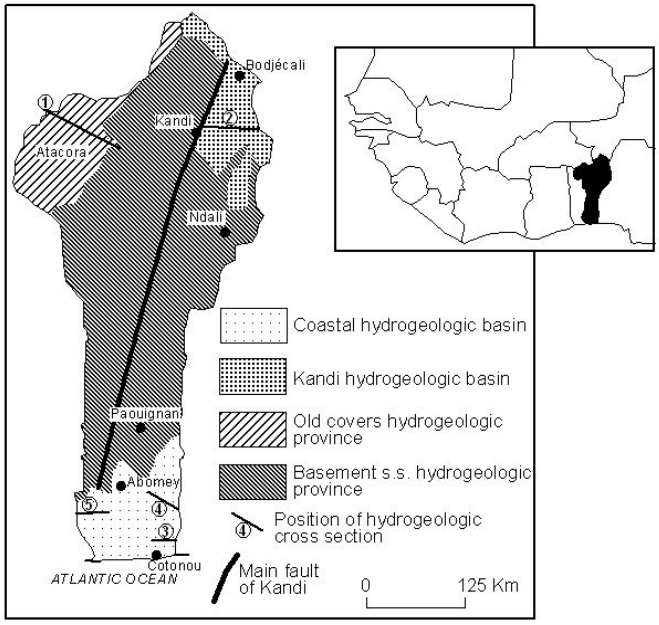

Figure 1: Location map of hydrogeological areas in Benin

This geological structure in Benin is divided into four distinct main hydrogeologic provinces (Boukari, 2007). There are: (i) a vast central province, with intermittent aquifers of fractures and crack (hydrogeologic province of the socle ss.), (ii) a north-western province, with intermittent aquifers, with on its western borders an sedimentary type aquifer more or less continuous (hydrogeologic province of the ancient atacora layers), (iii) a north-eastern province with continuous aquifer (hydrogeologic province of Kandi basin) and at last, (iv) a province in the south, with continuous aquifers (hydrogeologic province of the coastal basin).

2. OBJECTIVES AND METHOD

All the hydrogeologic provinces of Benin seem to be extended beyond its international borders to stretch more or less widely inside of either of the boundaries countries. So, it is to show the extension modalities of the hydrogeological zones that the structure even the geometry of their various aquifers is briefly described. Each aquifer description is completed by synthetic data on its chemical quality. Finally crossed results will enable to implement a mechanism of integrated and concerted transboundary water resources management in common countries.

The study is based on knowledge compilation on the different hydrogeologic provinces of the country, in order to identify and characterize the shared aquifers. This method allowed to collect or to realize hydrogeological section on the border areas of these provinces. So, the shared aquifers are briefly described according to the geological and structural context. It's the same for their geometry as well as their hydrodynamic and hydrochemical parameters. About 350 geological boreholes section of drillings, piezometers and nicked drillings distributed on the sedimentary coastal basin were exploited.

3. RESULTS

3.1. Hydrogeologic provinces with intermittent aquifers

The hydrogeologic provinces with intermittent aquifers take up about 83% of the beninese territory. They are often structured in many small hydrogeologic basins. Their typical hydrogeologic

section (Guiraud, 1987; Boukari, 1982) and their study should take a local character in the cross-border approach. Interconnections between basins are nevertheless possible by the means major faults. The hydrogeologic province of the socle s.s. is shared with Nigeria in the East and Togo in the West.

Water type of the intermittent aquifers is usually calcic or magnesium bicarbonate. If the mineralization of the province waters of the socle s.s. is average to strong (average conductivity on the order of 400 µS/cm), with a pH close to neutrality (Zimé Mora and Mondja Chabi, 2006), the one of old provincial layers is weak, with an acidic pH (TurkPak/SCET-Tunisie, 1991). This differentiation proves that the nature of the first reservoirs is meanly migmatito-gneissic and granitic and that of the second ones is quartzo-sandstone.

However, it is necessary to specify that on the old layers of the hydrogeologic province in the north-west part of Benin, shared with Burkina (north and west) and Togo (south), the aquifer of the old sedimentary basin of Pendjari, in the west part of this province (Fig. 2), could present more or less regional character, as of those of the recent basin of Kandi and the coastal basin. Present embryonic knowledge of the hydrogeology on this old basin doesn't yet allow us to conclude.

Therefore attention is focused on the two hydrogeologic provinces with continuous aquifers, i.e. the hydrogeologic coastal basin and the hydrogeologic basin of Kandi.

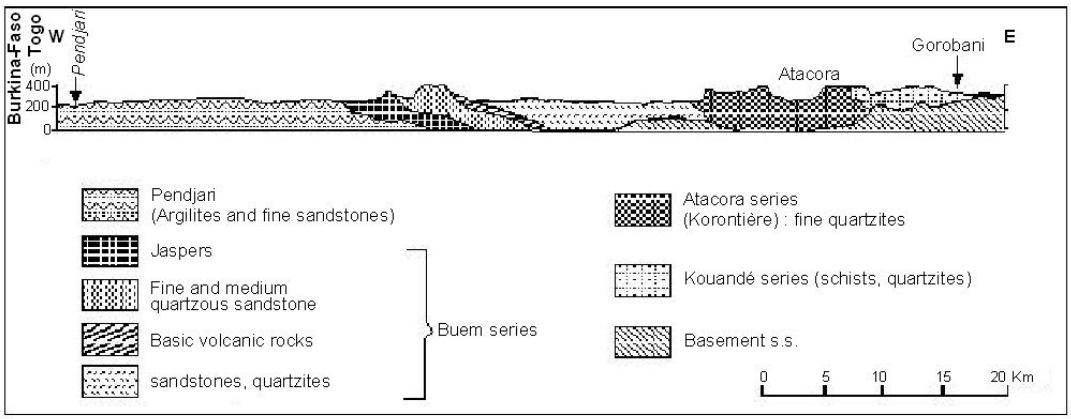

Figure 2- Geological section through Atacora series and its forward country (IRB, 1982)

3.2. Hydrogeologic provinces with continuous aquifers

They are the hydrogeological coastal basin of Benin and the hydrogeological basin of Kandi.

The **coastal sedimentary basin** of the Benin occupies roughly 10% of Benin territory, but contains about 35% of the whole country groundwater (Direction de l'Hydraulique, 2000). Its current population is approximately 65% of the whole in Benin. It estimated by 6 752 569 inhabitants (INSAE, 2003). These coastal sedimentary deposits of Benin are part of the vast sedimentary basin of the Guinea gulf which extends from Ghana (in the west) to Nigeria (in the east) (Slansky, 1968). These deposits have a monoclinal structure characterized by a growing differential subsidence towards the SSE (Dray *et al.*, 1988). Eight stratigraphical units were counted based on the lithological and sedimentary marks that indicate the successive variations of the sea level (Affaton *et al.*, 1985, IRB, 1987, Lang *et al.*, 1990, Oyédé, 1991).

On the whole, there are four aquifers in this basin (Upper Cretaceous aquifer, Paleocene aquifer, Continental terminal aquifer and Quaternary aquifer), separated one to the other by clayey and marls layers. Several authors described these aquifers which are ones of the relevant drinking water supply sources in Benin (Bouzid, 1971; GIGG, 1983; Pallas, 1988; Turkpak International/SCET-Tunisie, 1991; SOGREAH/SCET -Tunisia, 1997). The mean are those of the Upper Cretaceous and of the Continental terminal. Figure 3 to 5 show their respective structure and geometry at the international borders of Benin. Figure 3 describes the geometry of the Continental terminal aquifer of the plateau of Sakété while the figure 4 and 5 show the geometry of the Upper Cretaceous aquifer (Turonien-Coniacien) respectively at the east of the plateau of Ketou and at the west of the plateau of Aplahoué.

According to their lithological nature, aquifers reservoirs of the coastal sedimentary basin are sandstones and sand of quartz nature with, consequently water of weak mineralization (Continental terminal and Cretaceous). However a very long stay in the reservoir, frequent water table presence, clayey or marls layers or multi-layers, as well as the nearness of saline reservoirs, can sometimes raise this mineralization. On the other hand, waters of limestone Palaeocene reservoir usually have an average mineralization.

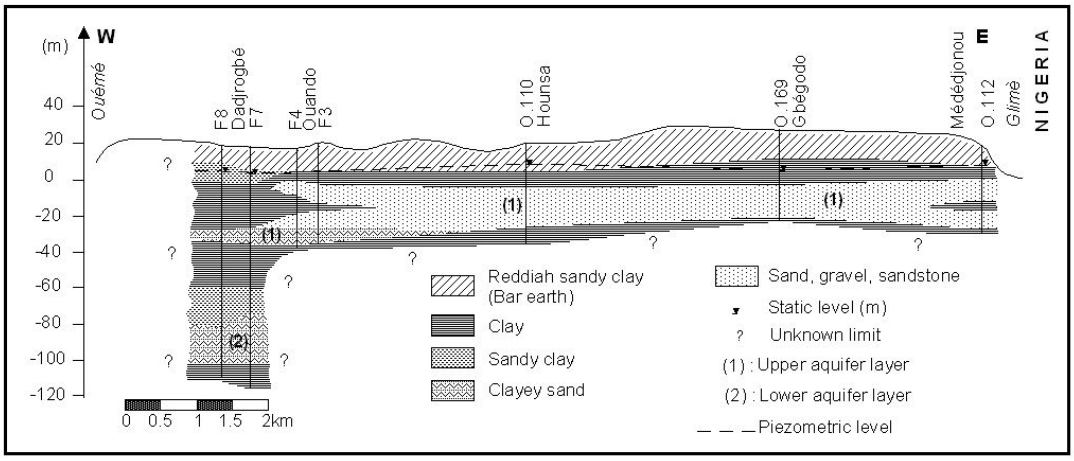

Figure 3: Hydrogeological section of the plateau of Sakété following the trace n°3 of the figure 1, showing the continuity of the Continental terminal aquifer towards Nigeria in the East (Alassane, 2004).

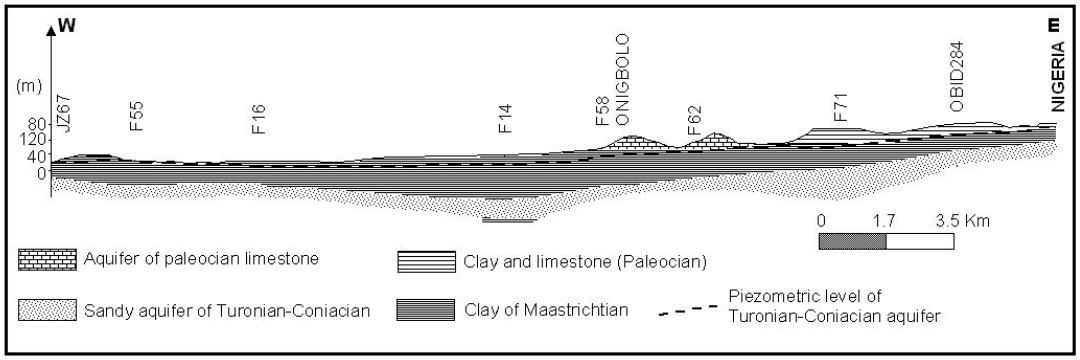

Figure 4: Hydrogeological section following the trace N°4 of the figure 1, showing the continuity of the Paleocene and Upper Cretaceous aquifers towards Nigeria in the East.

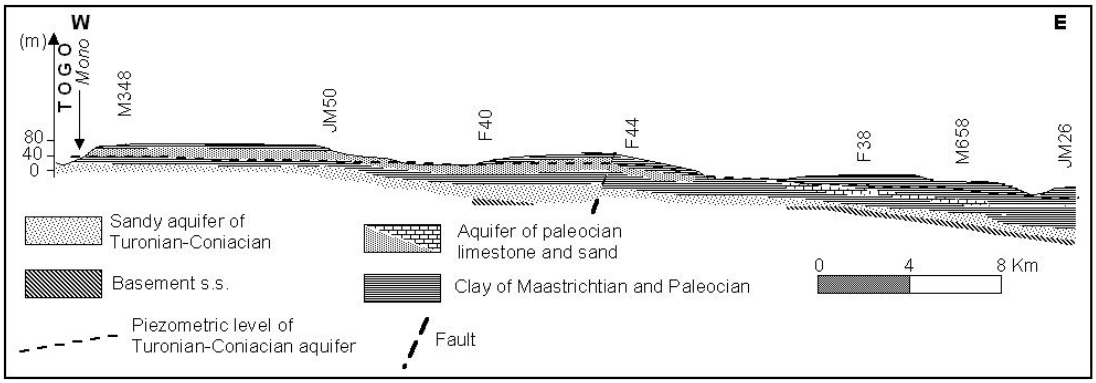

Figure 5: Hydrogeological section of the plateau of Aplahoué following the trace N°5 of the figure 1, showing the continuity of the Paleocene and Upper Cretaceous aquifers towards Togo in the West

The **sedimentary basin of Kandi** is the extension in Benin of the bigger basin named Sokoto basin in Nigeria and Illumenden in Niger. This is a continental basin, of Paleozoic to Secondary age, with Tertiary relics. It locates in the extreme northeast part of Benin (Fig. 1) and covers an area about 8 000 km² which represents 7% of the whole territory. It is subdivided in two compartments by an oriented SW-NE horst where the medium Proterozoic base (revived by the panafricain orogenesis) appears.

The north-western compartment appears more vast (more than 2/3 basin) than the south-eastern compartment. In the whole basin, the Paleozoic sediments usually have a slope of 10º in general towards the WNW (Konaté *et al.*, 1994). Six stratigraphical units were identified in since the Cambrian until the relics of Continental terminal, based on the lithological, sedimentary and paleontological indicators (IRB, 1982, Alidou, 1983, TECHNOEXPORT, 1984 and Konaté, 1996).

This is the more productive hydrogeologic zone after the coastal zone. But contrary to the latter, it still remains less populated and not very known. Although, it is from Paleozoic age, its aquifers layers are comparatively continuous and research of cracking using photo-interpretation by geophysics is not usually necessary (BURGEAP and BRGM, 1986) especially for current flows in rural hydraulic.

According to our current knowledge, two main aquifers can be distinguished (Fig.6). The first aquifer, unconfined is constituted by coarse sandstones of the Cretaceous (Unit IV). It is in continuous hydraulic with the Niger River deposits in its extreme northern. Its substratum is constituted by the fine sandstones and argillite of the Silurian (Unit III), which are considered as impervious or very little permeable.

Under the fine sandstones and Silurian argillite, the second aquifer reservoir is constituted by the layers with coarse granularity of the Cambro-Ordovician (Units I and II). Confined, it become unconfined in the west and south peripheral areas of the basin (transition zone between the basin and the layers of the Proterozoic panafrican basement) where these Cambro-Silurian layers raised to the surface. Its reservoir, relatively indurated, is usually not very productive (BURGEAP-BRGM, 1986; Turkpak International-SCET-Tunis, 1991), with flows rarely higher of $5m^3/h$. It can present a gushing artesian aspect in the north towards the River Niger deposits (boreholes of Bodjécali). It is shared with Nigeria to the northwest and Niger to the north. Total mineralization of the upper aquifer of Kandi

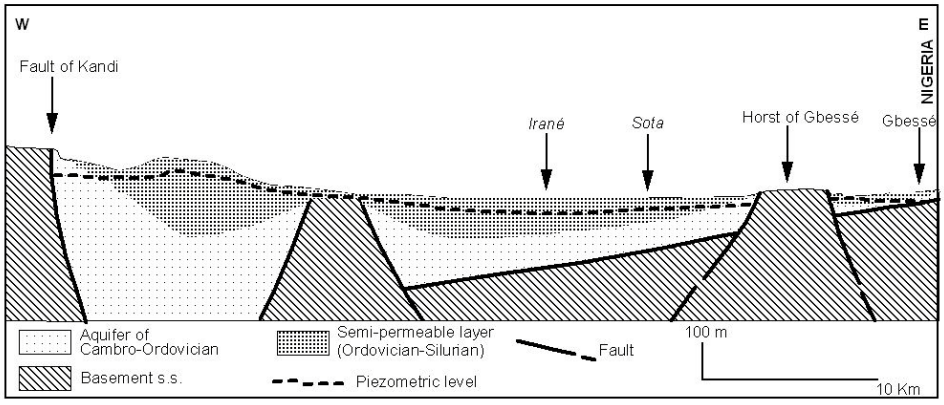

Fig. 6- Hydrogeological section of the sedimentary basin of Kandi following the trait N°2 of Figure 1, showing the continuity of the Cambro-Ordovician aquifer towards Nigeria in the North-West. (Boukari, 2007, according to interpretative section of Konaté, 1996).

basin is, as expected, very weak; the reservoir being particularly constituted of sandstone quartz. Electric conductivity of water frequently lies between 25 and 60 µS/cm. On the other hand, regarding the lower aquifer, this mineralization is average (conductivity lying between 131 and 425 µS/cm), because of the relatively long stay of water in the reservoir. The type of this water is bicarbonate calcium and magnesium; its quality is good for drinking (TurkPak/SCET-Tunisie, 1991).

4. DISCUSSION

According to the four hydrogeologic provinces of Benin, the basement s.s. province and that of the old layers have intermittent aquifers. Even, if they cover more than 80% of Benin territory and they cross the borders countries, they still present a special hydrogeology context that limits the use conflict risks on either side of these borders. Regarding the coastal province, the transboundary problems are more or less important according to the kind aquifer. The Continental terminal aquifer is the most exploited in the southern plateaus (Comè, Allada and Sakété), those of the Upper Cretaceous and Palaeocene being more or less deep. The concerned area is the plateau of Sakété which is itself shared with Nigeria in the east. The Cretaceous and Palaeocene aquifers become superficial or flushing to the North, where they are shared, not only with Nigeria in the East (plateau of Ketou), but, also, with Togo in the West (plateau of Aplahoué).

As for the hydrogeologic province of Kandi, it is shared with Nigeria in the east (basin of Sokoto) and with Niger in the north (basin of Iullemeden). Under all these conditions, concerted transboundary approach, is recommended for the Guinea gulf aquifer, specially the continuous aquifers management.

5. CONCLUSIONS

Benin have four hydrogeologic provinces, with two provinces of intermittent aquifers and two provinces of continuous aquifers. Regarding the structure and geometry of their aquifers, these provinces are all shared with the boundary countries.

The chemical quality of the aquifers is naturally good. However, the intermittent aquifers show a special hydrogeology that limits the use conflict risk in the boundary area. For the continuous aquifers, the shared countries must to implement the collective plan to exploit and manage groundwater of the sub-region of the Guinea gulf, in order to prevent the use conflict risks.

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