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New Geological and Hydrogeological Information on the Eastern Border of the Gondo Plain (Burkina Faso)

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Abstract: The Gondo plain lies between Mali and Burkina Faso and it is in interland basin into the West African Craton. Since 2003, this study has been carried out two research projects on the southwest part of the plain, where the piezometric levels are very low (50 m to 100 m). It has two main purposes: find water resources to provide drinking water supply to Ouahigouya town and assess the exploitation possibility of the deep aquifer for rural water supply. Combined methods were used to reach the objectives of this study—remote sensing, geology, geophysics (electromagnetism and resistivity methods), hydrochemistry and isotope chemistry. So, the methodology allows to specify the geology and the tectonic of the eastern border of the basin, identify and characterize the different aquifers and their relationships. Through the implementation of 250 m deep drilled boreholes, this study reveals that the water level of the lower Cambrian limestones can be under pressure below the continental terminal deposits. The study highlights paleo-karstic zones in the Gondo plain and shows that water chemistry and isotope chemistry can be used to differentiate water sheets and evaluate their recharge.

Key words: Gondo plain, aquifers, geophysics, trial water drilling, isotopic chemistry, piezometric.

1. Introduction

The big cities located in the crystalline zone of Burkina Faso which encounter some difficulties related to drinking water supply. It is the case of Ouahigouya. The city is exploiting 12 drilled boreholes and 11 wells with a combined outflow of 266 m³/h. In addition, it also exists there three light surface water treatment unities. Despite these resources, Ouahigouya is facing problems of water resources availability during the yearly hotter months which are March, April and May. The reason is the low unit rates of the catchments. Two solutions have been envisaged in order to definitely solve the drinking water supply of the city [1].

- To build a dam on the Nakanbé river at 40 km far from the city (eastward);
- To exploit the deep aquifers of the Gondo plain located at 40 km far from Ouahigouya city in the westward.

The implementation of the second solution needed a good knowledge of the hydrogeology and the groundwater reserves of the Gondo plain.

It was also known that the rural populations of that plain have encountered tremendous difficulties of water supply. This is due to the high depth of the static level of the near surface aquifer of the Continental Terminal deposits varying between 50 and 65 meters in Burkina Faso and reaching up to 100 meters in Mali [2-7]. In order to win water in the wells of the area, people have used animal traction. In this case, it would be interesting to know if the catchment of the deep aquifer underlying the Continental Terminal would allow a water level close to the surface in order to be easier to exploit. The main condition would be a confined deep aquifer.

In order to solve these two problems, a multidisciplinary approach including geology, tectonic,

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remote sensing, geophysics, test boreholes, water chemistry and isotopic chemistry has been applied in a study conducted by the Department of Earth Sciences of Ouagadougou. It is given in the present paper a synthesis of the results of the investigations.

2. Geology and Hydrogeology of the Study Area

The Gondo plain is located between Burkina Faso and Mali and has an area of 30,000 km² [2]. Only 6,000 km² of this area are situated in Burkina Faso (Fig. 1). The Gondo plain is extended south-west toward north-east with a slight curve. It is drained southward by the Sourou, a tributary of the Mouhoun [2, 8] which is the only permanent river in Burkina Faso. At its north side, the plain receives on its banks provisions of lesser importance river coming from the cliffs of Bandiagara and the crystalline basement of Burkina Faso with endorheic behaviour. They seem to flow and give up their water to a still active lake.

Geologically, the plain leans north-west on the sandstones of the cliffs of Bandiagara, southward and eastward on the crystalline basement of Burkina Faso. The formations of the continental terminal overlay in inconformability, the older sediments of the lower Cambrian (Fig. 1) [2, 7, 9, 10].

In this study, the investigations covered an area located on both sides of the road Ouahigouya-Bandiagara where the distribution of the piezometric levels and the cross section of the existing boreholes and wells allowed to give the tectonic pattern of Fig. 2 as research hypothesis. In the absence of outcrop rocks, the research hypothesis had been confirmed by other investigation methods such as remote sensing and geophysics [2].

3. Materials and Methods

Coupled methods—remote sensing, geology and hydrogeology on the field, geophysical methods and geochemisty were used.

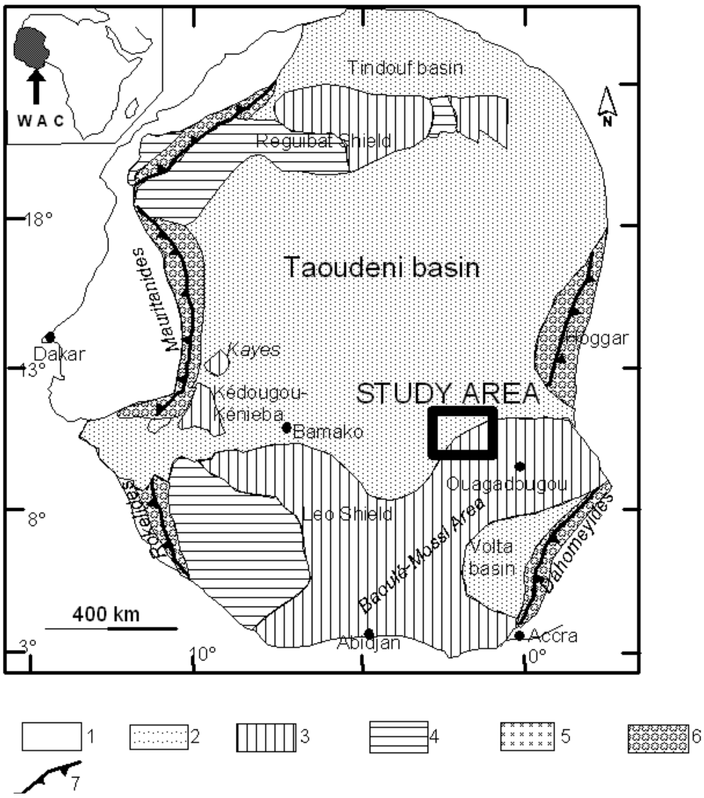

Fig. 1 Regional geological map context of the study are: (1) Mesozoic to Cenozoic cover, (2) Upper Proterozoic and Phanerozoic, (3) Lower Proterozoic, (4) Archean, (5) Panafrican orogenesis, (6) Caledonean and Hercynean orogenesis and (7) Thrust fault, WAC: West African Craton.

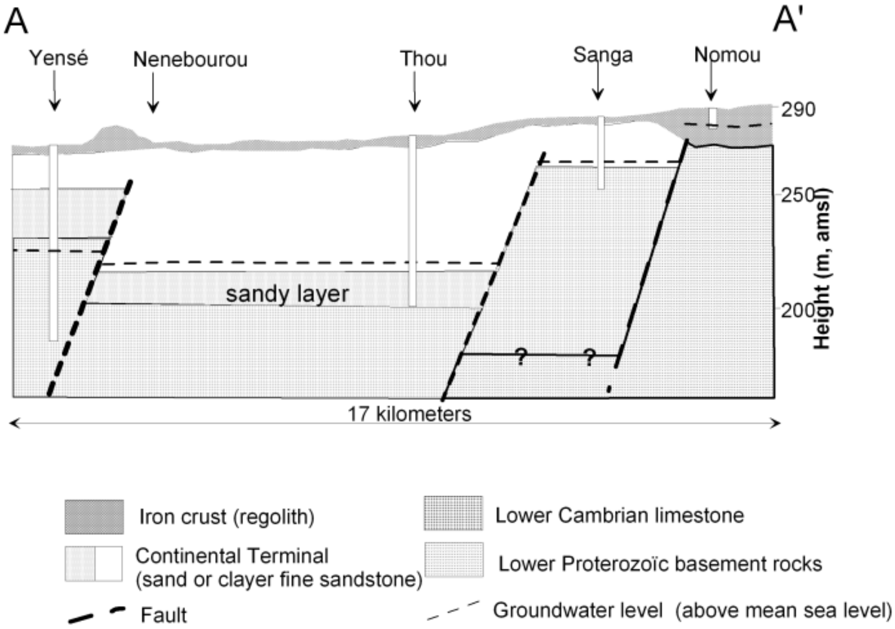

Fig. 2 Structural cross-section of the eastern border of the Gondo plain.

Because of the lack of outcrop rocks and the general surfacial cover of iron crust on the sedimentary rocks, remote sensing can give information on the geology and the structures like faulting. Borehole samples description gives indication on the type of rocks in the study area. Five deep boreholes in the study area were done for this program at Doubare, Sanga, Thou, Toeni and Koulerou. Three geophysical methods—magnetism, resistivity method (with Schlumberger systems) and electromagnetism (dipole method) with a Max Min device of Apex mark (Canada) were used on the study area. These methods used were in order to prove the geological contact between basement rocks and the covering material and detect the main faults. Eight electrical profiles coupled with electromagnetic profiles were realised. Electromagnetic, electrical (Schlumberger configuration in 1D profiles and electrical soundings), magnetic methods were used in order to prove the geological contact between basement rocks and the covering material and detect the main faults. Eight electrical profiles coupled with electromagnetic profiles were realised. One main magnetic profiles and 34 electrical soundings were done in the study area [1, 2].

4. Results and Discussion

4.1 Tectonic through Remote Sensing

The pre-existing maps show few faults in the Gondo plain. This is not the case of the exploited satellite image. Indeed the ETM+ image of LANDSAT 7 can allow to identify numerous lineaments which could be assimilated to fractures affecting the study area. The lineaments show essentially directions which are parallel to the extension of the Gondo plain (Fig. 3). Some fractures go from the basement and across the plain with a north-west south-east direction. These lineament directions are comparable to those of the rare major accidents of the structural patterns of previous authors [3, 9].

4.2 Confirmation and Precision of the Tectonic Hypotheses by Geophysical Methods

The diagram of the Fig. 2 constituted a research hypothesis to be confirmed or infirmed by the geophysics.

Only in the area of Thiou (around the road to Bandiagara), the following works were carried out—4 km of profile in magnetism, 29.5 km of electromagnetic profiles (with 150 m of reel intervals) and 4.325 km

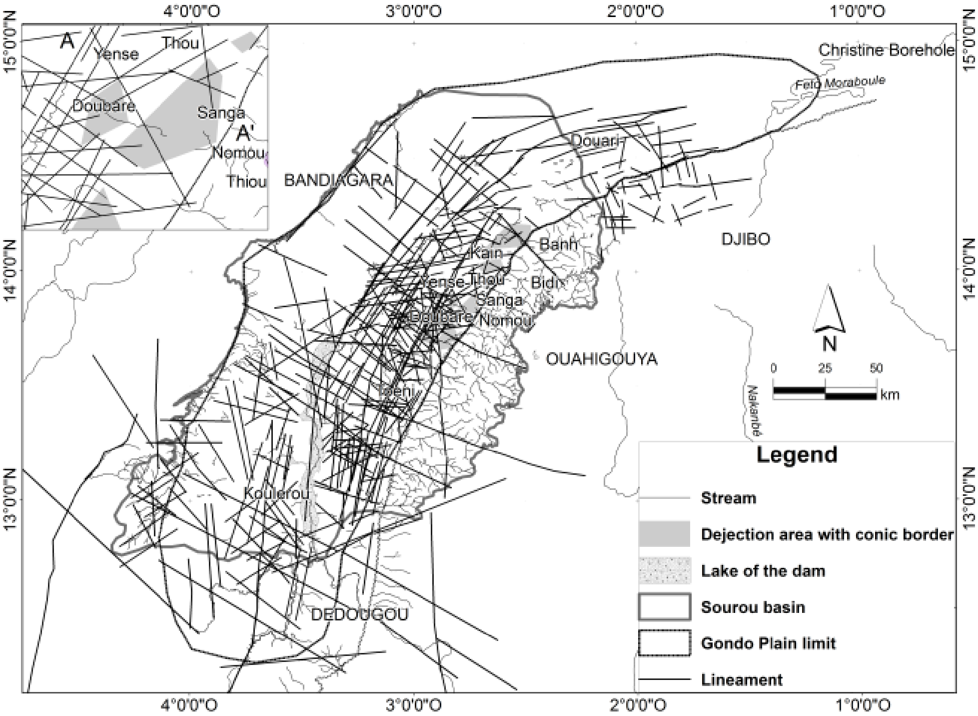

Fig. 3 Lineaments drawn from Landsat 7 image of Gondo plain (AA': location of the cross section in Fig. 2).

of electrical resistivity method profiles (AB = 400 m and MN = 40 m) for the anomaly areas revealed by the previous geophysical methods. Then, the anomalies were tested by 34 electrical soundings.

The profile P1, which has 17 km long, highlights the supposed faults and confirms perfectly the structural diagram given in Fig. 2 and used as research hypothesis. In the electromagnetism method, the major faults were highlighted by inversions in the evolution curves of the in phase and out phase components. This is the case when the interval between the reels is 150 m. When the interval between the reels is 100 m, the geological accidents are also observed but without inversion. These profiles show the extension of the lower Cambrian's strip not found on the previous maps. They also precisely locate the limit of the rift valley which has received the deposits of the Continental Terminal (Fig. 4). Each geological unit is characterized by electrical soundings having a specific aspect.

4.3 Test Boreholes Data

Within the framework of the present study, five tests boreholes were carried out in Doubaré, Thou, Nomou, Koulérou and Toéni:

- In the borehole of Doubaré (252 m deep), the level of the deep groundwater is 46 m, therefore, 19 m above the level of near surface aquifer of the Continental Terminal deposits met at a depth of 65 m. This borehole shows that the aquifer of the lower Cambrian is really confined under the deposits of the Continental Terminal. It was the hypothesis which should be verified by the present researches.
- The borehole of Thou was a non-productive borehole. It shows that the aquifer of the lower Cambrian is not a continuous aquifer which is productive everywhere in the basin.
- The boreholes of Koulérou and Toéni have met high productive karstified limestones. Unfortunately, the lack of adapted drilling equipments did not allow the right catchment of these karts. The borehole of Koulérou and some other dozens of boreholes in the region were abandoned for the same reason.

The main results won thanks these boreholes are listed below:

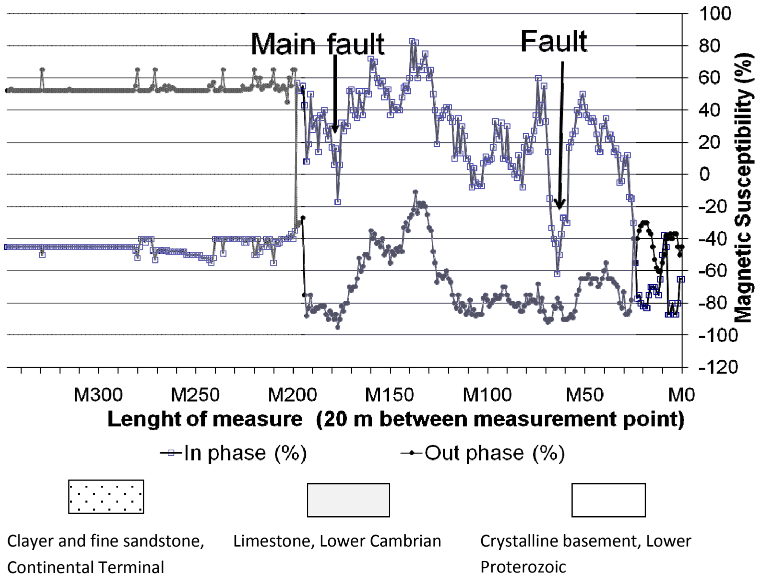

Fig. 4 Geophysical profiles across the crystalline basement and the overlying sediments.

(1) The proof is made that the aquifer of the lower Cambrian is confined under the upper aquifer of the Continental Terminal;

(2) The discovery of karstic zones in the lower Cambrian formations is overlaid by the continental terminal formations. It is the second karstic area highlighted in the country after this of the Christine borehole located in northern Burkina Faso and in the same lower Cambrian formations. This discovery should lead to a new vision of the water supply systems of the villages and the cities of the affected regions.

4.4 Piezometry, Chemistry and Water Isotopic Chemistry and Groundwater Recharge

The Gondo plain shows a piezometric depression where the distribution of the conductivities of the water resources follows closely this configuration of the levels of the continental terminal aquifer groundwater (Figs. 5 and 6). However, the initial aspect of this piezometry has been modified by some surface constructions such as the Dam of Sourou [5]. The fluctuations of the groundwater are high in the crystalline basement and in the lower Cambrian, but very low in the continental terminal (Fig. 7).

Above the latitude of 13°, the groundwaters are over-concentrated of salts. This high concentration is located in the central and deepest part of the depression. This suggests a significant contribution of the evaporation on a confine aquifer in the genesis of the piezometric depression.

The ion concentration in the groundwaters of the Sourou basin eastern border is low and indicates that these ones are potable. The analysis of the silica distribution allows a differentiation of the aquifers as shown by the Fig. 7. The concentrations in tritium (Fig. 8) show that the groundwater recharge is easier in the basement formations and the lower Cambrian than in the continental terminal.

5. Conclusions

The present study allowed, firstly, getting considerable new information on the tectonic of the eastern border of the Gondo plain and secondly, a differentiation and a characterization of the groundwaters. The piezometric data and the water chemistry (major elements) and water isotopic chemistry show that the groundwater fluctuations are high at the border of the basin and low inside. The water qualities are good and the recharge is easier in the basement area and the lower Cambrian than in the continental terminal formations.

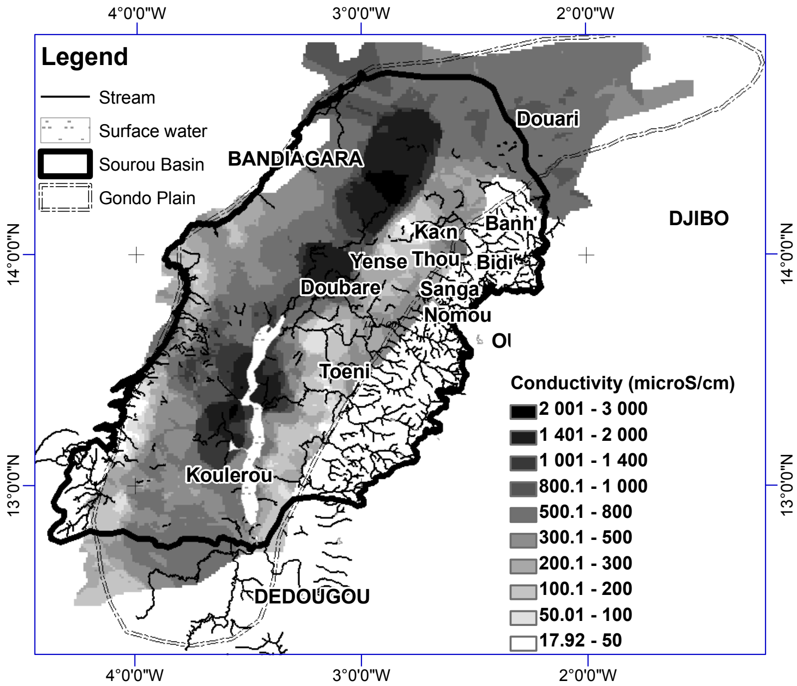

Fig. 5 Groundwater electrical conductivity distribution in the Gondo plain.

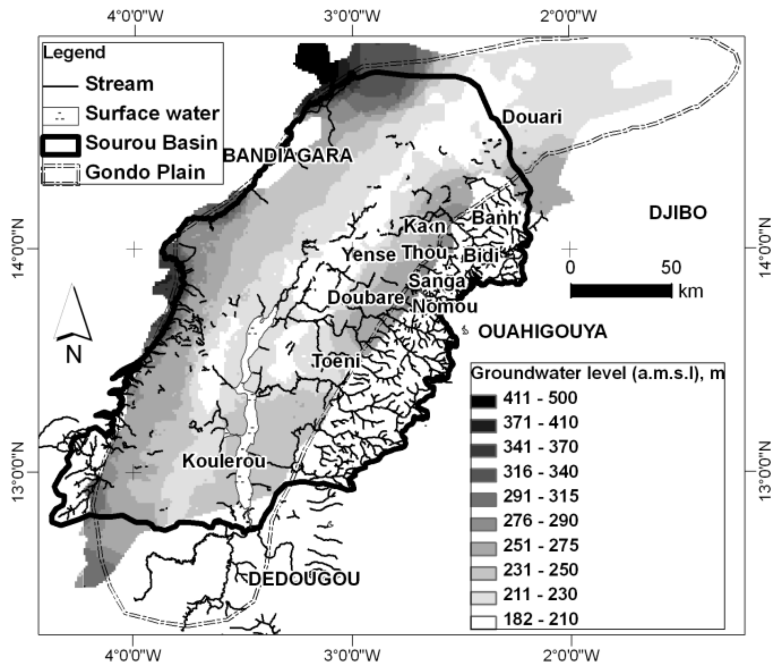

Fig. 6 Map of the piezometric depression of Gondo plain.

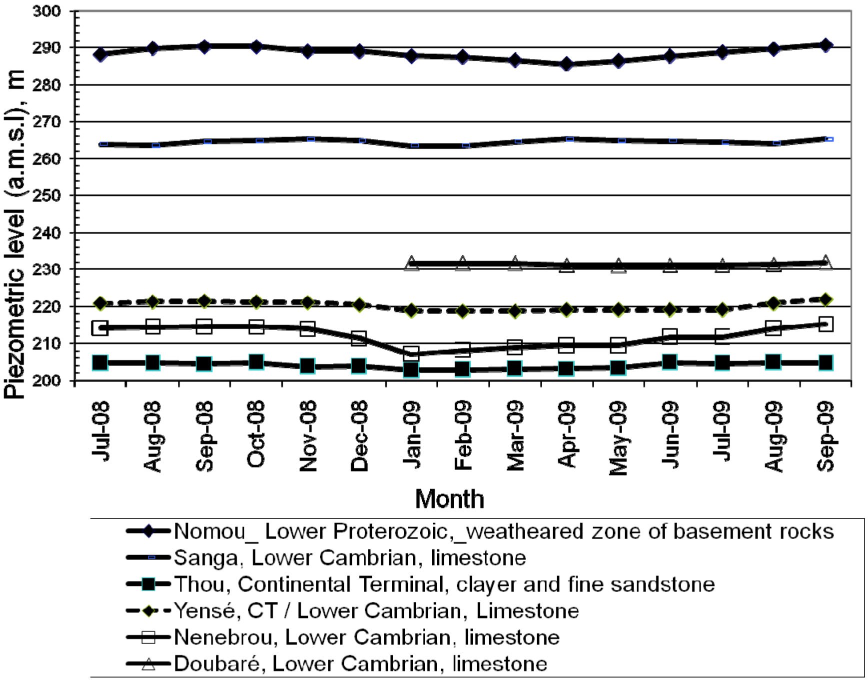

Fig. 7 Monthly variations of the piezometric levels (July 2008 to September 2009).

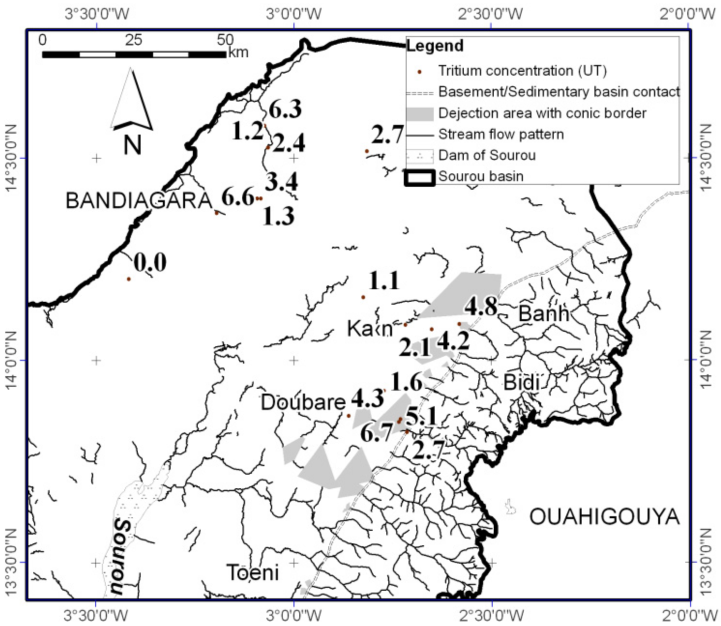

Fig. 8 Tritium concentration (UT) distribution in the eastern border of the Gondo plain.

Acknowledgments

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