Mapping Of Tectonic Accidents And Their Relation With The Spring Waters Of The South Of Haut-Sassandra (Côte d'Ivoire)

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Abstract: This study is about the mapping of regional fractures and their relation with the spring waters of South Haut-Sassandra (Central-West of Côte d'Ivoire). Tectonic accidents map is made from regional fractures of the geological map, the hydrostructural interpretation of the main rivers and the aeromagnetic map of the study area. The relation between tectonic accidents and springs water in the region is made from superposition the map of regional fractures obtained to that of the spring waters location. The results show that the fractures are mainly oriented N110° to N140°. They represent 8 to 10% of the total. These fractures intercept source waters, except to fractures N10-20°, N30-40° and N50-60°. Source related fractures have variable lengths and the most important are 94 km long. These results will assist hydrogeological prospections, aimed at using spring waters for the drinking water supply of the populations of the study area.

Keywords: Aeromagnetic geophysics, Côte d'Ivoire, geology, hydrogeology, spring water

1. Introduction

The abundance of natural spring waters makes the specificity of South Haut-Sassandra (Central-West of Côte d'Ivoire). Springs water is defined as ground water of origin, respecting the emergence of the recommended values for the potability of water intended for human consumption [1]. This water is important role in providing drinking water to the population of this region. Spring water is a solution of the difficulties of drinking water supply for the population. In cities such as Daloa (capital of Haut-Sassandra region), the population prefers to drink spring water compared to that distributed in households by SODECI (Water Distribution Company of Côte d'Ivoire). Indeed, spring waters are much clearer and odourless compared to those arriving in households. The water treated and distributed by SODECI comes from the river "Lobo". This water has organoleptic characteristics not appreciated by the population. Like the work of authors of the references [2, 3], the geological structures related to these sources are poorly known. The structural characterization of the aquifer system of the spring would contribute to improve the hydrogeological understanding of these groundwater resurgences. It will also expand the knowledge of the groundwater resource of the localities concerned. The aim of this study is to characterize the geological accidents related to spring waters in the South of Haut-Sassandra. A priori, it is to establish a map of regional fractures, from the main watercourses, the geological map and the aeromagnetic map of the study area. The study area (South of Haut-Sassandra) is located north of the square degree of Daloa, in the central-west of Côte d'Ivoire. It is particularly characterized by an abundance of groundwater resurgence. It includes the departments of Daloa, Issia, Saïoua and Zoukougbeu. Its area is approximatively 8800 km² (Figure 1). The Haut-Sassandra region belongs to the Precambrian basement, which covers 97.5% of the Ivorian territory. The basement of the study area is mainly composed of magmatic and metamorphic rocks. These geological formations are lengthened in the NE-SW direction. The granitoids (granites and granodiorites) and the dioritoids (diorites) constitute essential of the magmatic rocks. The metamorphic rocks are usually migmatites and schists [4]. These rock formations contain two types of aquifers (alterites and fissures) functioning as a composite aquifer. Alterite aquifers are capacitive reservoirs [6]. Fractures aquifers are underlying aquifers to alterites. They result of tectonic events.

2. Material and methods

The methodology used is to elaborate the major fracture map of the study area and to characterize regional accidents related to spring water.

2.1. Elaboration of the major fractures map

The map of regional accidents is made from three cartographic supports. These are: geological, hydrographic maps of the main rivers and aeromagnetic of the study area.
Using the Surfer software, the regional fractures of the geological map and the main rivers in the study area are extracted. From the magnetic susceptibility contrasts of the rocks, the aeromagnetic geophysical method allows to identify the major tectonic accidents of the study area [7]. The data of the total magnetic field used, for the realization of the aeromagnetic map, are obtained in 1976.

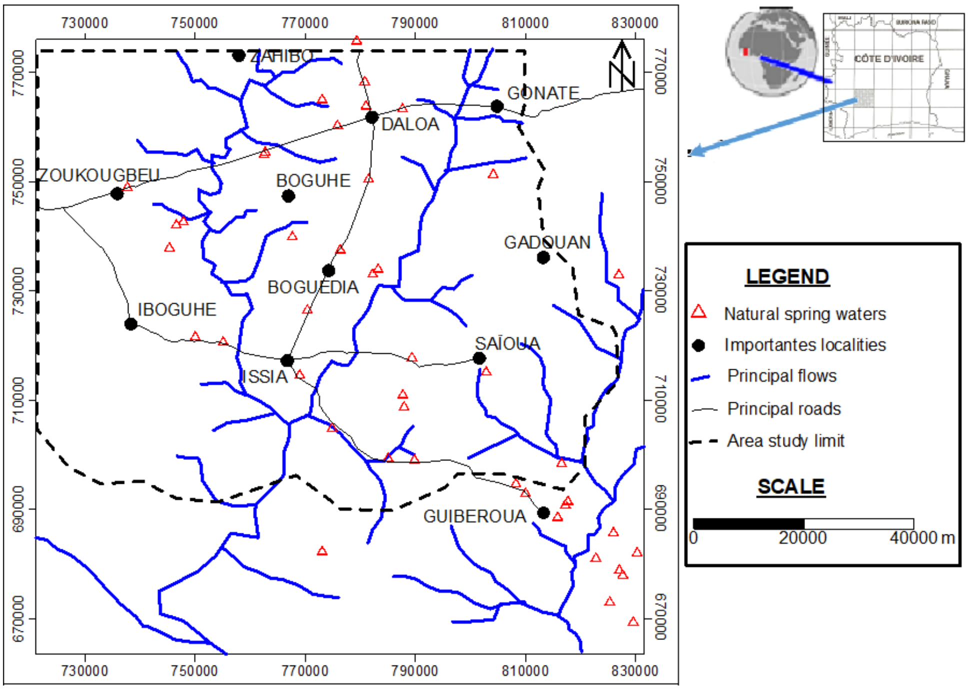

Figure 1: Location map of South Haut-Sassandra and the main spring waters

Surveys are conducted on North-South flight lines by Kenting Earth Sciences Ltd. These surveys are made, as part of, a program of cooperation between the Government of Canada and the Government of Côte d'Ivoire, under the auspices of the Canadian International Development Agency. Magnetic field data are corrected from altitude, latitudes and diurnal variations. The values of the geomagnetic field depend exclusively on the heterogeneity of the underlying geological formations [8]. The aeromagnetic map is reduced to the equator, to refine the geomagnetic contrast between the geological structures. The extraction of geomagnetic fractures is made from the aeromagnetic map reduced to the equator. It is the analysis of discontinuities at the contours of the geomagnetic field. All these operations performed using the Geosoft software. These fractures are validated, from fractures of the geological map and drilling having a non-zero water flow. The final regional accident map is a synthesis of the fracture maps, obtained from geological map, hydrographic map and the geomagnetic analysis.

2.2. Characterization of regional fractures related to spring waters

It is a geometric characterization (orientation, length) of fractures related to spring waters. This requires, a priori an identification of fractures in relation to these spring waters. For this, the final fracture map is superimposed on the source water distribution map. Fractures, which intercept the sources are characterized.

3. Results

3.1. Map of regional accidents

3.1.1. Fractures from the geological map

The fractures extracted from the geological map present three (03) groups of the most important directional classes. They are the orientation fractures (Figure 2):

- N120° to N140°, more numerous with frequencies in number and cumulated length which reach, respectively 18% and 21%;
- N100° to N120° and N140-150°, second, with frequencies in numbers between 10 and 12% and cumulative length frequencies that reach 13%;
- N30-40°, less important, with frequencies in number and cumulated length less than 8%.

The other directional classes (N0° to N20°, N40° to N100° and N150° to N180°) are weakly represented, with less than 5% of the total number.

3.1.2. Fractures from the hydrographic map

In crystalline basement area, the hydrographic network is mainly linked to fractures. The structural interpretation of the main watercourses in the study area has made it possible to map the fractures follow by the hydrographic network (Figure 3). Fractures with the directions N110° to N130° are the most important. They correspond to between 10 and 12% of total workforce. Secondly, these are the direction fractures N90° to N110° and N150° to N180 °, with 7 to 9% of the total. Directional classes N30-40°, N70-80° and N130-140° correspond to the third least important group. They have a frequency in number equal to 5%. Fractures N0° to N20°, N40° to N70°, N80-90° and N140-150° are the less represented, with less than 3%. In cumulated length, the N80° to N100° fractures are the most represented, with 12% of the total. Fractures N30-40° and N100° to N140° have cumulative length frequencies between 8 and 10%. The fractures N0° to N20°, N50° to N80° and N140° to N180° correspond to less than 5%.

3.1.3. Fractures from geomagnetic analysis

The major geomagnetic fractures have, a priori, required the realization of the geomagnetic field map reduced to the equator. This map highlights geomagnetic anomalies, whose values are between 30980 to 31300 nT. These anomalies reflect at a time the magnetic signatures of deep and surface structures. They have elongated forms in the NE-SW direction, like the geological formations of the study area.

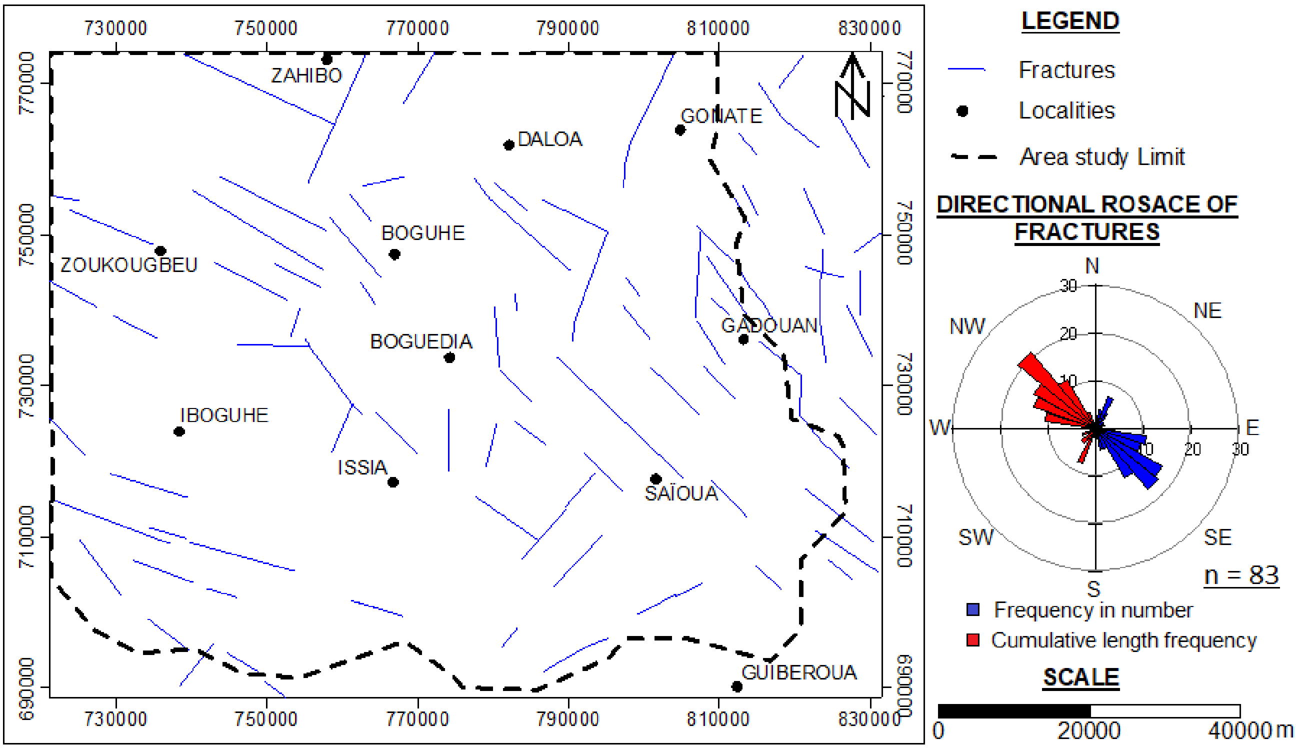

Figure 2: Fractures extracted from the geological map of the study area

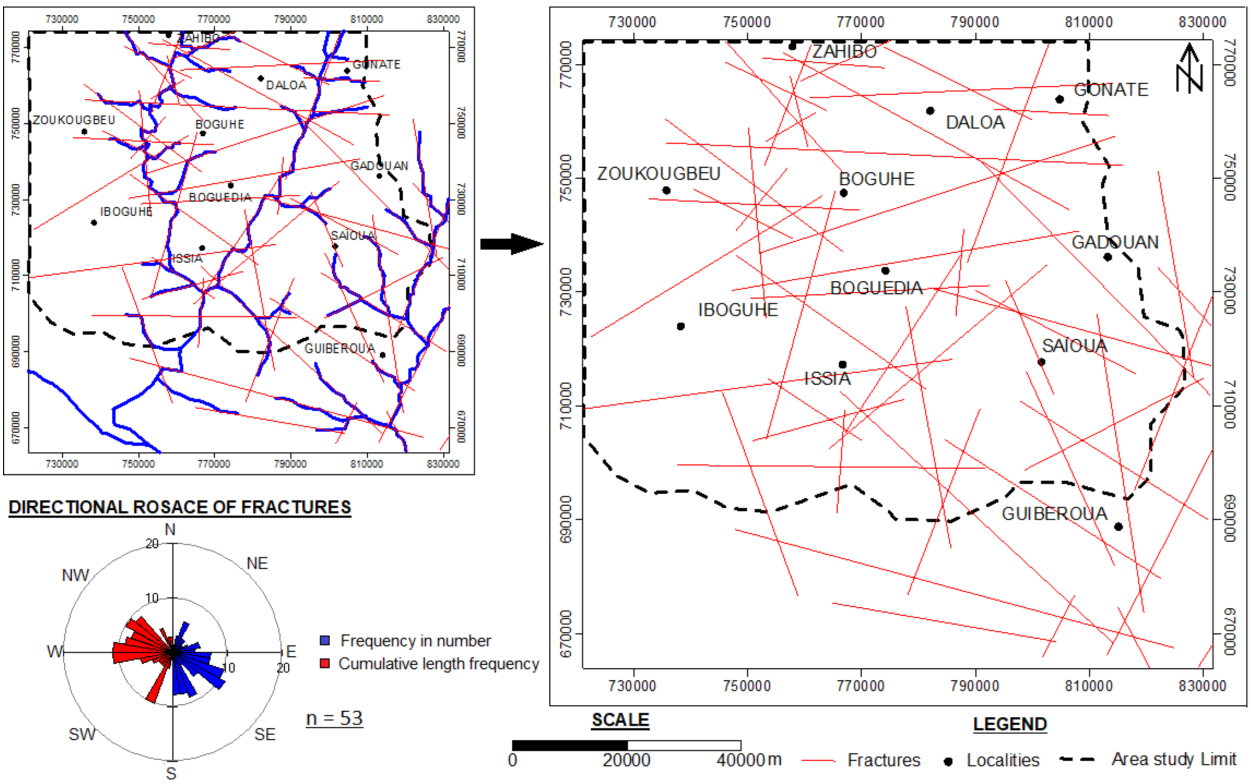

Figure 3: Fractures map obtained from the Hydrographic Network of the Study Area

The reduced field map at the equator is characterized by the fact that the rocks, which are the sources of the natural magnetizations, are placed exactly in a position of the geomagnetic anomalies observed. The analysis of the contours of the geomagnetic values on this map makes it possible to identify several geomagnetic discontinuities on the map. These discontinuities correspond to fractures in the subsoil (Figure 4).

Regional fractures highlighted, from the geomagnetic map are of various sizes and orientations (Figure 5). The directional study of these geomagnetic discontinuities shows that the fractures of directions N120 ° to N150 ° are the most important. Their frequencies in number are between 10 and 12%. The fractures N40-50°, N60-70°, N90° to N120° and N150° to N170° are second, with 6 to 8% of the total. Regional accidents N0° to N40°, N50-60°, N70° to N80° and N170-180° are third, with less than 4% of the total.

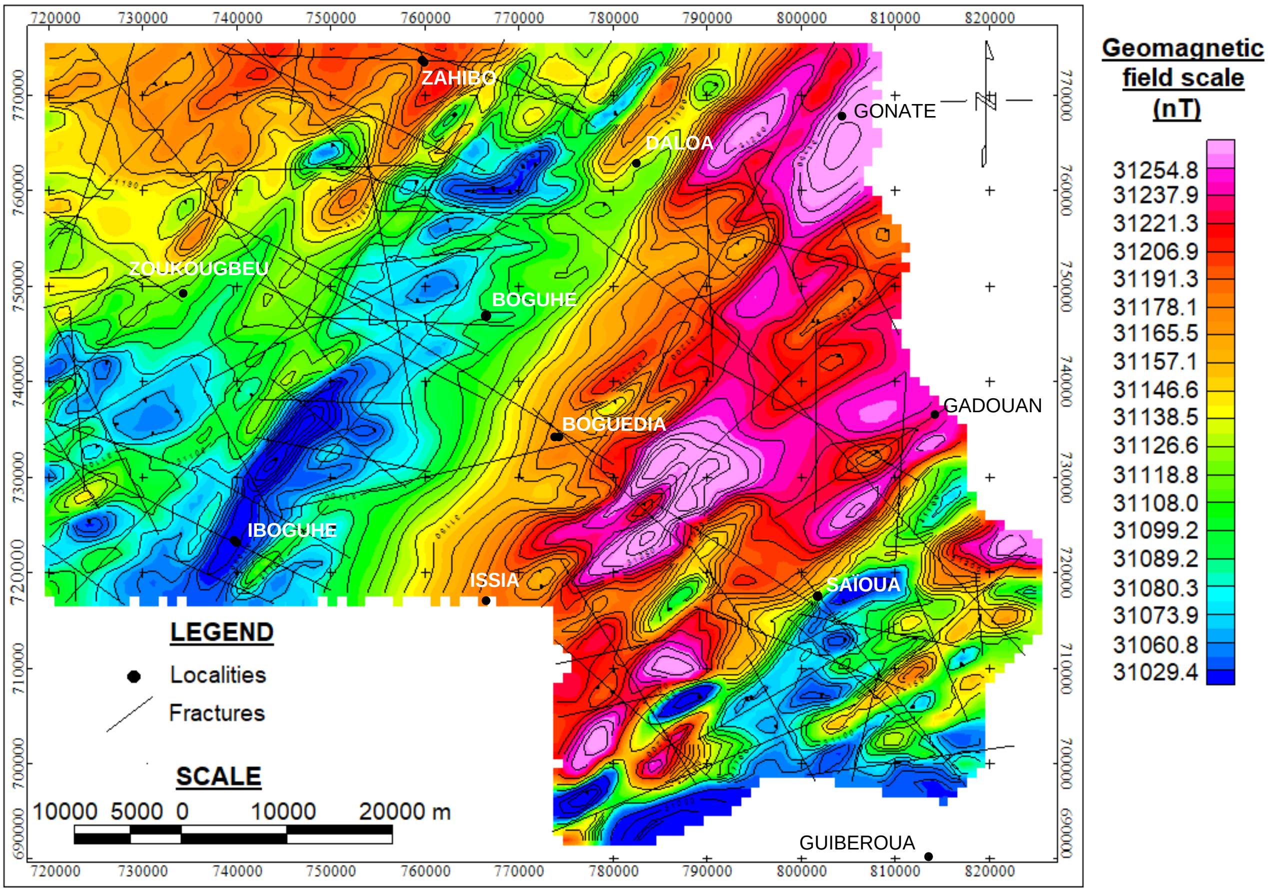

Figure 4: Fractures on the map of the geomagnetic field reduced to the equator.

In cumulative length, the fractures N40-50° correspond to 12% and the fractures N110° to N140° represent 8 to 10% of the total. The orientations N60-70°, N90° to N110° and N140° to N160° indicate 6% and discontinuities geomagnetic N20-30° and N60-70°, 4%. The direction fractures N0° to N20°, N30-40°, N50-60°, N80-90° and N160° to N180° have the lowest cumulative length frequencies. They represent less than 2% of the total.

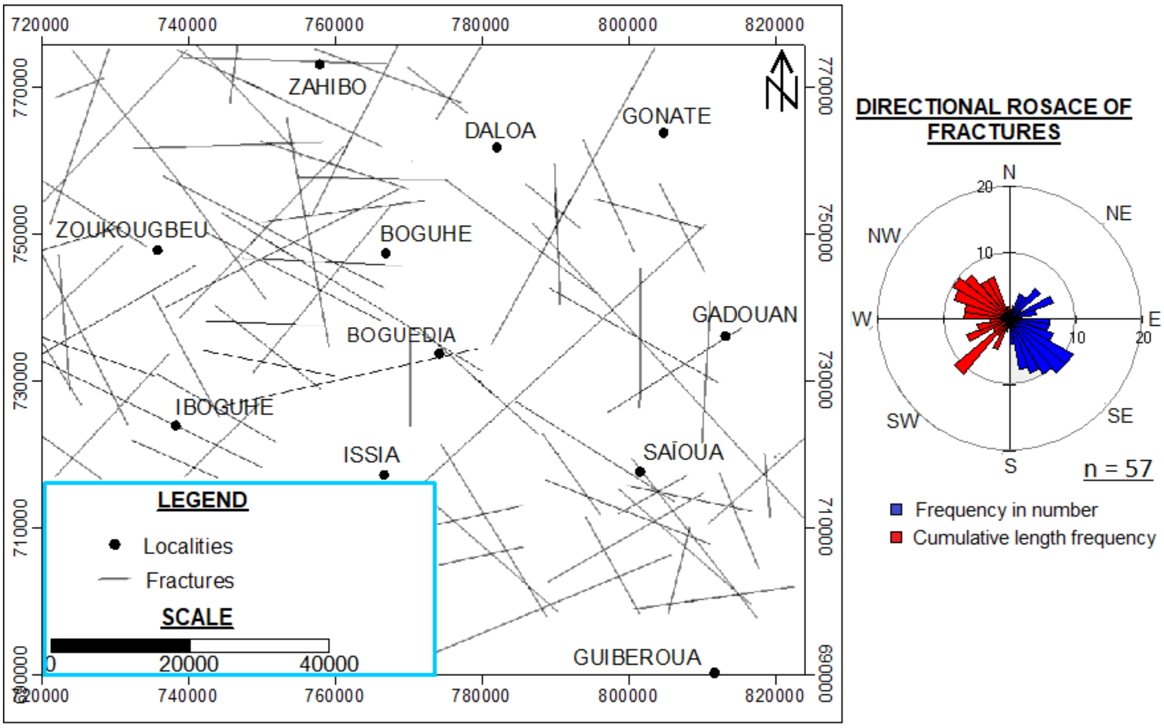

Figure 5: Fracture map extracted from the map of the reduced geomagnetic field at the equator

Validation of geomagnetic fractures

The superposition of the fractures extracted from the geological map to the geomagnetic fractures shows that certain fractures of the geological map coincide perfectly with those identified from the geomagnetic map (Figure 6). Their respective directional rosaces, in number and cumulative length, have similarities. The majority orientations correspond to directional N120° to N140° for fractures of the geological map and N120° to N150° for geomagnetic fractures. When we superimpose the geomagnetic map fractures than the distribution of drilling having rate of flow better than 2.5 m3/h of South Haut-Sassandra. We note that several geomagnetic fractures intersect drillings (Figure 7). All this allows us to say that the geomagnetic fractures correspond to regional accidents that affected the basement of the study area. They complete the fractures already confirmed on the geological map.

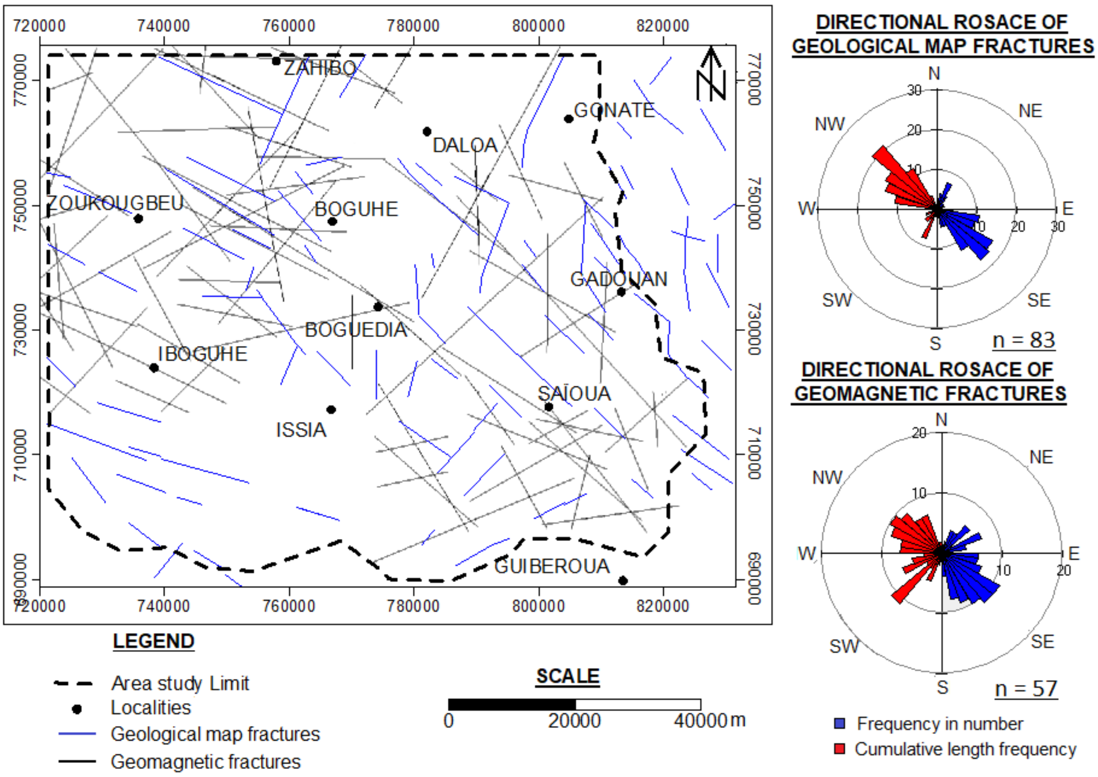

Figure 6: Superposition of Fractures from the Geological Map to Geomagnetic Fractures

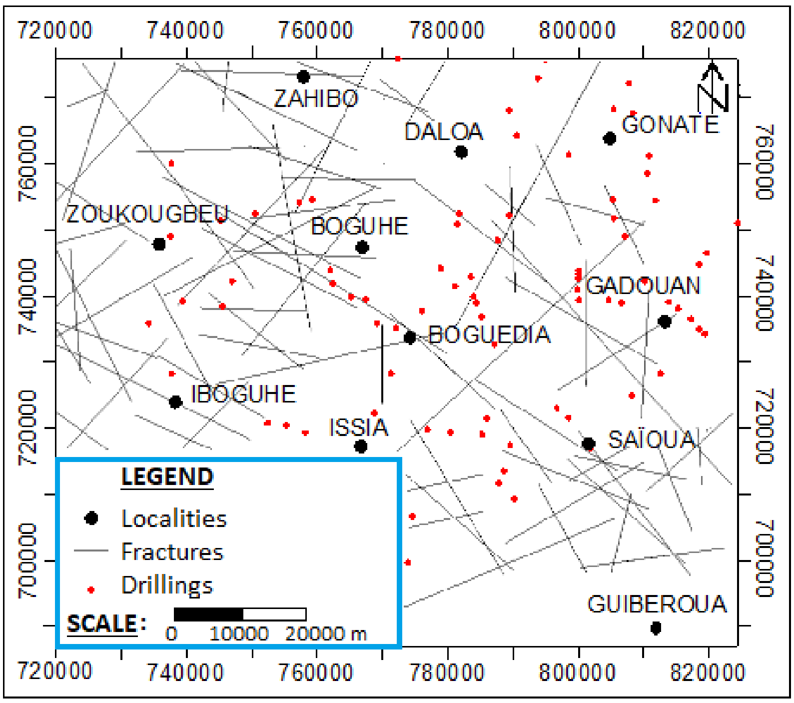

Figure 7: Superposition of fractures from the geological map to geomagnetic fractures

3.1.4. Fracture Map of South of Haut-Sassandra

The fracture map of the study area corresponds to the synthesis of fracture maps extracted from the geological map, the hydrographic network and the analysis of the geomagnetic map (Figure 8). Fractures N110° to N140° are the most important. They represent 8 to 10% of the frequency in number. Regional accidents N10° to N30°, N40°-50°, N60° to N80°, N90° to N110° and N140° to N160° are second. They represent 4 to 6% of the total. The least represented orientations are N0-10°, N30-40°, N60-70°, N80-90° and N160° to N180° fractures.

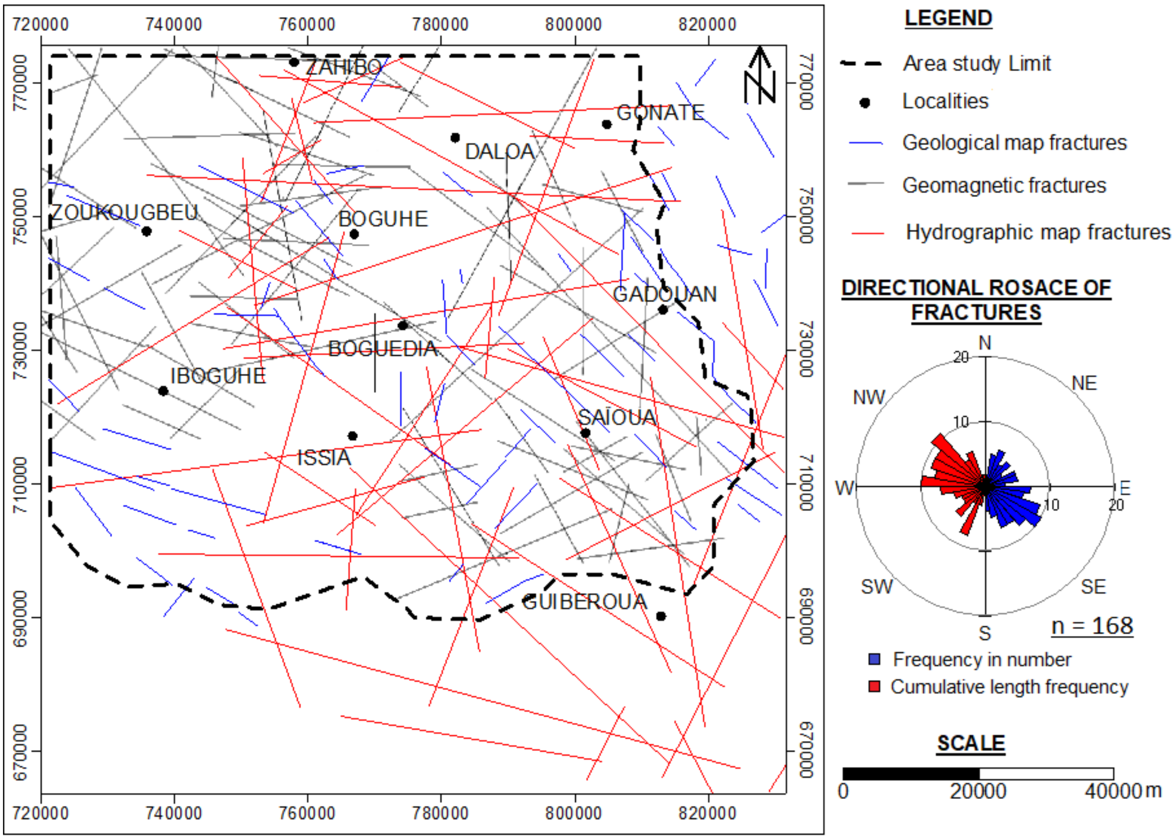

Figure 8: Fracturing map of the study area

3.2. Structural characterization of spring water associated with fracturing

The superposition of the spring waters map to the fractures map of the study area makes it possible to identify the relation that could exist between spring water and these regional accidents in the study area. Several fractures intercept the spring water points (Figure 9). Some springs are located at the intersection of several major fractures. This is the case in the localities near Saïoua and Boguhe. Of the 44 sources used in this study, 30 (68.2%) intercept fractures. This justifies the permanent regiment of these springs in the dry season. They are constantly feed by groundwater drained by regional accidents. Spring waters that do not intercept these fractures (31.8%) are also perennial. They are surely related to local unmapped fractures in this study. These local fractures are usually connected to regional accidents. This explains their permanence. Source waters in the study area belong to the family of sources of fault or fracture. These fractures serve as groundwater drainage channels to recharge the water sources in the study area. The orientations and lengths of geological accidents at the origin of these springs vary. The most important are the fractures of direction N110° to N140°. They represent 13 % of regional fractures that intercept spring waters. They are followed by the N60-70° and N80-90° orientation classes. They represent 10% of the total. Directional classes N0-10°, N20-30°, N40-50°, N100-110°, N150-160° and N160-170° correspond to 5%. The least represented fractures are the classes of directions N70-80°, N90-100° and N140-150°, with less than 2% of the total. Some fracture orientations do not intercept the spring waters studied. These are N10°-20°, N30°-40° and N50°-60° fractures. Fractures that intercept spring water have varying lengths. The longest ones reach 94 km. The relation between fractures and spring water is also studied locally. The case of the city of Daloa, capital of the region of Haut-Sassandra is examined. This city contains many permanent spring waters. The population drinks mainly the groundwater or spring waters. Figure 10a shows the city of Daloa, with some spring water points. These sources are located near the shallows or on slopes. These shallows have an elongated form (Figure 10b). The structural interpretation of these shallows highlights the geological structures to which they are linked (Figure 10c). It is noted that the identified fractures intersect most spring water points in Daloa (Figure 10d). These spring waters therefore closely related to geological accidents that affect the basement of Daloa.

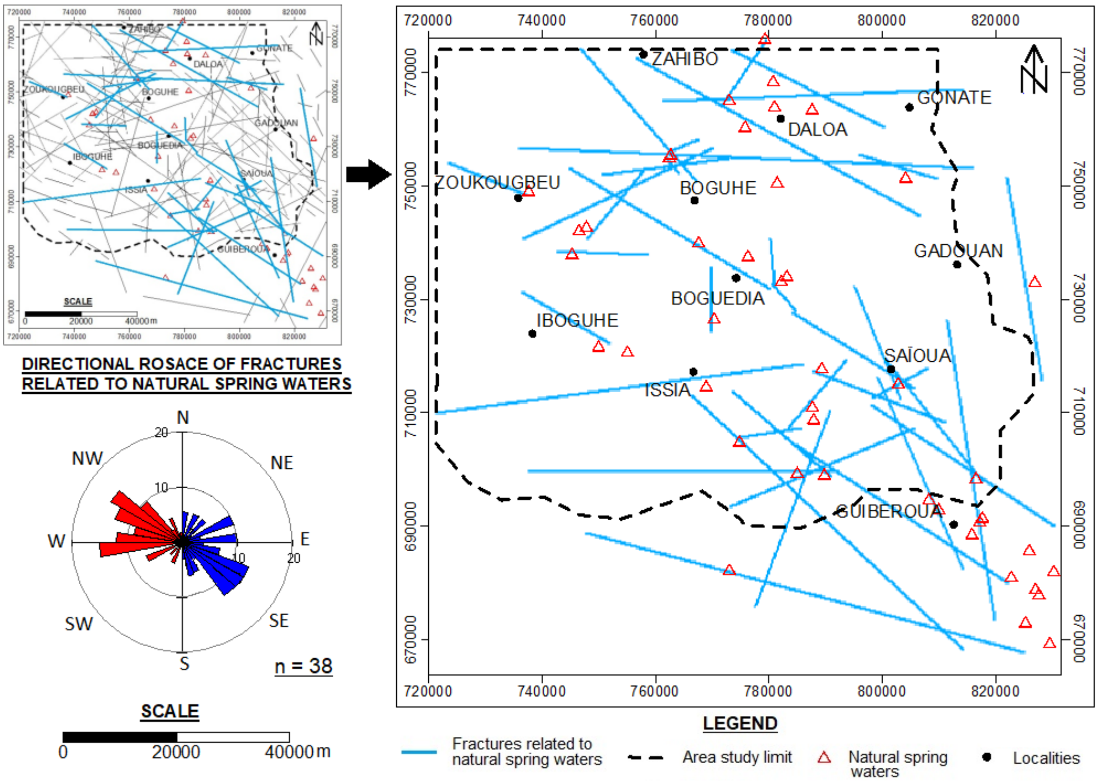

Figure 9: Fractures Map related to spring waters

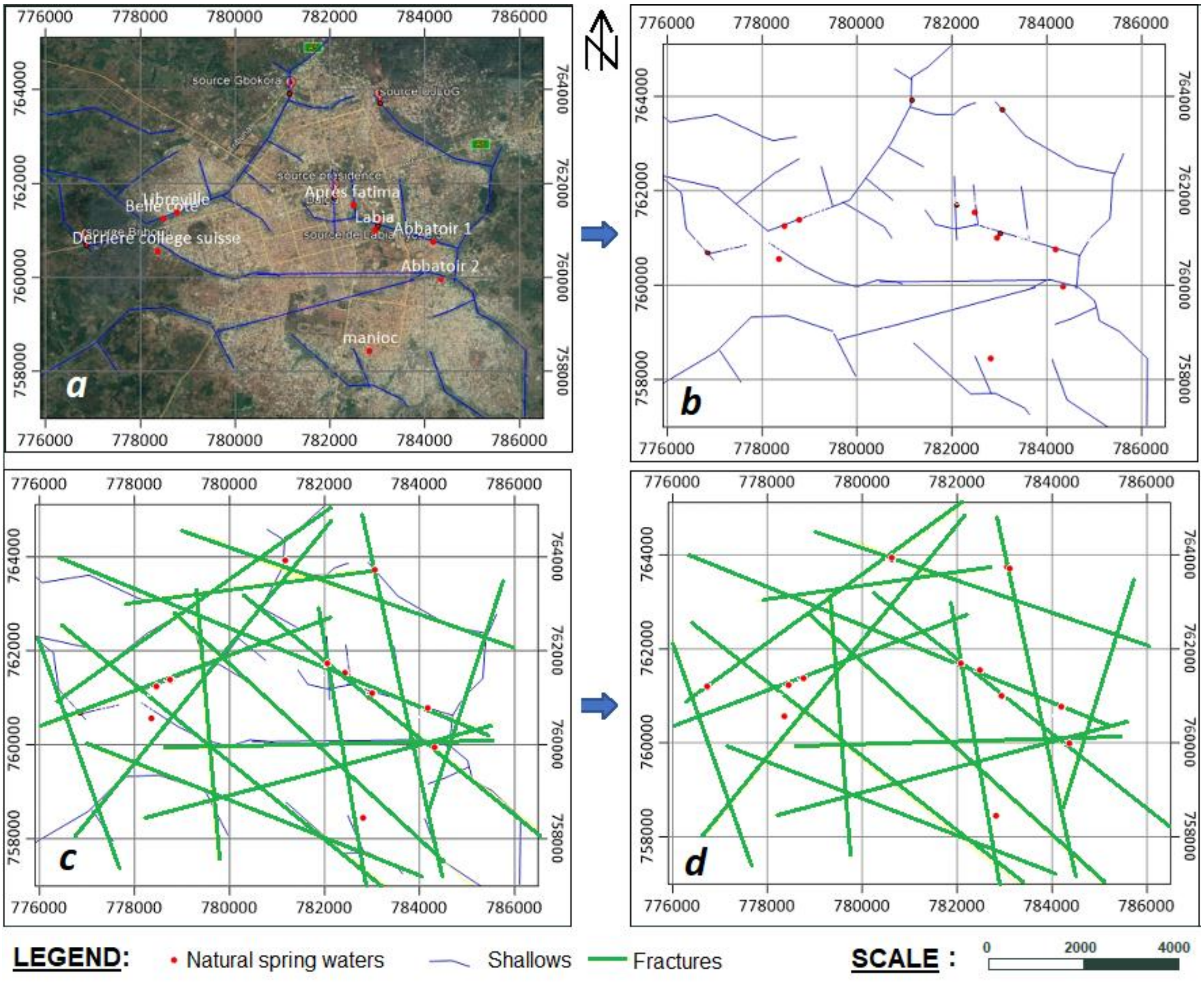

Figure 10: Spring Water relation and Geological Accidents in Daloa City.

4. Discussion

The use of different cartographic supports (geological, hydrographic and geomagnetic maps) makes it possible to determine the fractures that affect the crystalline basement. The fractures of the geological map and the hydrographic network are confirmed fractures. They participate in the flow and storage of groundwater [9]. The geomagnetic method has long been used for mapping geological formations and tectonic accidents that affect them. It is mainly used to discriminate structures that have controlled ore deposition [10]. The aeromagnetic method, in this study, makes it possible to obtain a geostructural diagram of the geological formations of the study area. In particular, it does not make it possible to determine the presence of groundwater, but it helps to highlight the fractures that drain the groundwater. The map of the geomagnetic field reduced to the equator allows to highlight geomagnetic formations oriented NE-SO. This result is according to that of Djroh in 2013, who worked on the quantification of a nickel deposit in Samapleu in the locality of Biankouma (West of Côte d'Ivoire). Indeed, it obtains NE-SW oriented magnetic anomalies and NW-SE majority oriented fractures, as it is our case. The different fractures are highlighted, from the map of the magnetic field reduced to the equator. These techniques are also used in Morocco, where the geostructural interpretation of the magnetic anomaly map revealed faults in the Figuig oasis [11]. In Nigeria, this technique is used to determine faults in the Lafiagi region of Nigeria [12]. Geomagnetic mapping of regional accidents are suitable for geostructural studies. The works of reference [3] show that the springs observed in the study area are located outside the fractures. He deduced that these springs represent outlets for aquifers of alterites. Our results show that spring waters studied are related to subsoil fracturing. Our results are a complement to those of reference [3]. In indeed, these springs are outlets of aquifers of alterites, but depend on subsurface fractures. The spring waters of south of Haut-Sassandra are perennial and are not influenced by seasonal fluctuations. In the dry season, these springs produce water for the population, which prefers them over faucet water. In the localities of Daloa, Zoukougbeu, etc. the population, for its needs in drinking water uses these springs, all the year. It also makes use of this water, all year round, for vegetable crops or rice. The objective of this study is to characterize the tectonic accidents related to spring waters in the South of Haut-Sassandra.

5. Conclusion

The objective of this study is to characterize the tectonic accidents related to spring waters in the South of Haut-Sassandra. The adopted methodology is based on the structural study of spring waters. The fractures used are extracted from the geological map, the hydrographic network and the geomagnetic map of study area. The results showed that fractures of direction N110° to N140° are most represented in the study area. They represent 8 to 10% of the total. The spring waters studied are related to the fracturing of the basement. Except of fractures of direction N10°-20°, N30°-40° and N50°-60 ° all fractures are in contact with at least source water. Some springs are located at the interception of several fractures. All this justifies their permanent regiment, which makes the happiness of the populations of the region. These fractures have variable lengths and the longest reach 94 Km. These results will assist hydrogeological prospection, aimed at using spring waters for the drinking water supply of the populations of the study area.

References

[1] J.C. Bligny and P. Hartemann, "Les eaux minerales naturelles et les eaux de sources : cadre reglementaire et technique, " Comptes Rendus Geosciences, 337, pp. 279–284, 2005.

[2] J.C. Maillary, Notice explicative de la carte hydrogeologique à 1/200000 de Daloa (Côte d'Ivoire). Contribution à la carte hydrogeologique de reconnaissance de la Côte, d'Ivoire. BRGM-SODEMI, 1964.

[3] R. Ligban, "Caracterisation hydrogeologique et origine des eaux de sources naturelles dans le degre carre de Daloa (Centre-Ouest ; Côte d'Ivoire), "Thèse de doctorat, Universite Nangui Abrogoua, (Abidjan, Côte d'Ivoire), 2013.

[4] O. A. Ahimon, Y. Kone, H. Bonnot, A. Okou, S. S. Tia et I. Diaby, "Carte geologique de Daloa 1/200000, feuille Daloa", Dir. Geol., Abidjan, Côte d'Ivoire, 1988.

[5] T. Lasm, F. Kouame, N. Soro, J. P. R. Jourda et J. Biemi, "Analyse geostatistique de la fracturation extraite de l'imagerie spatiale aeroportee et satellitaire. Application à la region de Man-Danane" Revue ivoirienne des sciences et Technologie, 5 pp. 135-154, 2004.

[6] J. Dubois, M. Diament et J.P. Cogne, Geophysique : cours et exercices corriges, 4e edition, Paris, Dunod, 2011.

[7] D.J. Isles and L.R. Rankin, Geological Interpretation of Aeromagnetic Data. Society of Exploration Geophysicists and Australian Society of Exploration Geophysicists, 2013.

[8] S.P. Djroh, Etudes geophysique et geologique du gisement cupronickelifere a platinoïde de Samapleu. Essai de modelisation 3d par interpretation des donnees magnetiques et electriques, Thèse de Doctorat 3ème cycle, Universite de Cocody, Abidjan (Côte d'Ivoire), 2014.

[9] A. P. Sombo, Application des methodes de resistivites electriques dans la determination et la caracterisation des aquifères de socle en Côte d'Ivoire. Cas des departements de Sikensi et de Tiassale (Sud de la Côte d'Ivoire), Thèse de Doctorat. Universite Felix Houphouët Boigny de Cocody, (Abidjan, Côte d'Ivoire), 2012.

[10] E. Thomas, B. Mougin, N. Debeglia, et J. Perrin, Apports des leves geophysiques aeroportees à la recherche et la protection des ressources en eau : Application à la region du Leon (Finistère). Etude realisee dans le cadre des operations de service public du BRGM 2002-PIR-222, 2002.

[11] M. Amar, A. Manar et M. Boualoul, "Apport de la cartographie aeromagnetique à l'identification structurale du système aquifère des sources de l'oasis de Figuig". Bulletin de l'Institut Scientifique, 34 pp. 29–40, 2012, 2012.

[12] K. A. Olawuyi, D. A. Bankole, G. O. Omosuyi, and O. A. Adelusi, "Integration of Magnetic, Gravity and Geologic Data in Mapping Geologic Structures: A Case Study of a part of Lafiagi (Sheet 203), Southwestern Nigeria". AAPG/SEG- International Conference &

Exhibition, Melbourne, 13-16 Septembre 2015, Melbourne, Australia, pp. 359-367, 2015.

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