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Regional Variations in the Permeable Rocks and Porosity of the Water Bearing Formations in Central North Kordofan and West White Nile Areas

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ABSTRACT

The present study aimed to delineate the regional variations in the permeable rocks and porosity of the water bearing formations in Bara and Kosti basins. The study depended on the determination of the permeable rock ratios and porosity calculation for the lithological samples obtained from borehole pertaining to the study area. Freehand 9.02 software application was used in this study for drawing maps and sections .The lithology indicates vertical and lateral changes in the rocks (sediments) facies forming the subsurface formations. The permeable rocks form the water bearing formations (aquifers) while the impermeable rocks such as clays represent aquiclude layers. The permeable sediments compose of coarse sands and gravels in the western part whereas they consist of medium sands in the eastern part of the study area. The facies description indicates that the ratio (percent) of the permeable rocks decrease from more than 60 % in Bara Basin (Umm Rawaba and El Basheri Sub-basins) in the West to less than 20 % as in Kosti Basin in the East. The porosity values of these rocks range from 17 - 23 % in the western part (Bara Basin) to 28 % in the eastern part. The variation in the rock facies indicates that the sediments composing the water bearing formations were transported from the northwest and southwest directions.

INTRODUCTION

The study area lies in central North Kordofan and west White Nile areas (Fig. 1). It was known that the study area involves three water bearing formations (aquifers): upper, lower and deep. The upper and lower aquifers are located in Bara Basin and west of Kosti Basin whereas the deep aquifer is located in Kosti Basin (Fig. 2). The present study aims to show the regional variations in the rocks facies and porosity of the rocks forming the aquifers in the study area. This is due to the area is characterized by highly densely populated and important location in Central Sudan and the demand for water in increase currently and in the future. This is because the study area is far from the Niles water and the groundwater represents the main source of water. Therefore, the evaluation of the water bearing formations depends on the presence of the permeable rocks and effective porosity of these rocks.

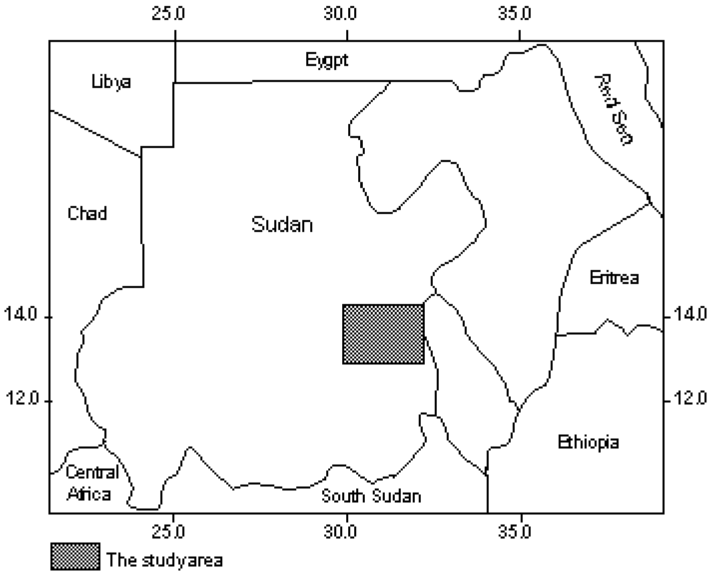

Fig. 1: Location map of the study area

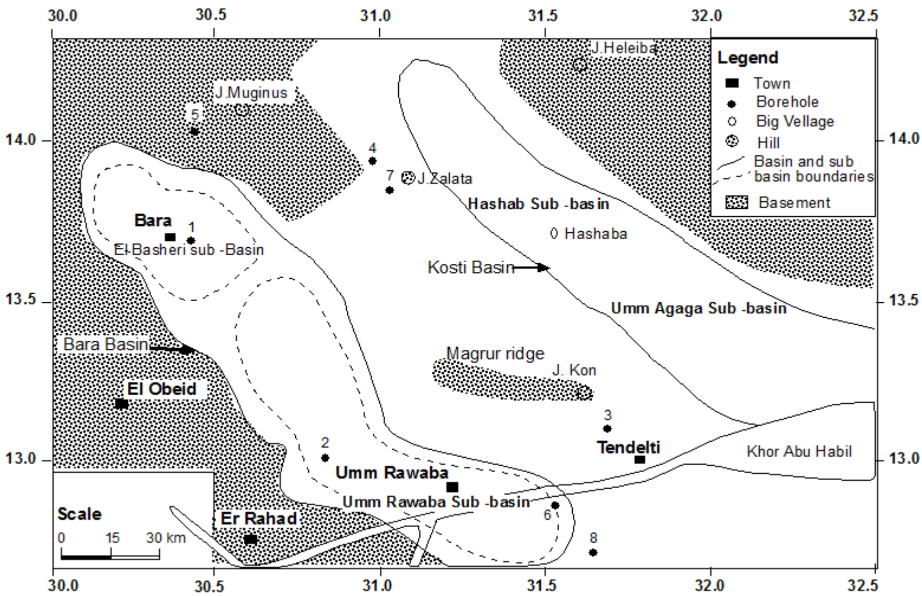

Fig. 2: Sedimentary basins and sub- basins in the study area. Modified from El Tayeb (2000)

Regional Geology:

The study area lies in the White Nile Rift Basin as a part of the Sudanese Rift Basins which are developed as a part of Central Africa Rift System (CARS). These basins extend from the western boundaries of Sudan to the eastern boundaries with Ethiopia (Salama 1985a). The Basement Complex rocks in Sudan represent the oldest geological unit which is assumed to be mainly of Pre- Cambrian age (Whiteman 1971). They crop out in the study area in form of Jebels (Hills) such as J. Mugunis, J Zalata, J. Heleiba and J. Kon. The Basement rocks are overlain by Nawa Series in areas around Er Rahad, or by Mesozoic sediments of Nubian Sandstone Formation at the base of the basins. The Mesozoic sediments of Nubian Sandstone Formation are overlain by the Umm Rawaba Formation. The thickness of the Nubian sediments reaches 700 m in Kordofan (Geotehnica 1985). Umm Rawaba Formation represents the main sedimentary unit in the area. It is mainly composed of unconsolidated sediments of sands, granules and clays. The geophysical investigation indicated that the thickness of the formation exceeds 500 m at Bara (El Mansour 2005). It is overlain by the superficial deposits of sand dunes (Qoz sands). The thickness of the all unconsolidated sedimentary column in the central part of Bara Basin reaches 1.4 km (Ali 1983).

MATERIALS AND METHODS

In this study, information of boreholes pertaining to the area was used (Tables 1 and Fig. 3). The information include: borehole locations, lithology, normal- long logs, aquifers thickness, formation resistivity, and electrical conductivity of the aquifer water. The thicknesses of permeable rocks for each borehole were measured directly and the ratio of these rocks calculated mathematically as a percentage to the total depth of the borehole. This is because the vertical extension of the permeable rocks through the borehole depth represents the aquifer thickness. Also the calculation of the porosity values for the rock forming the aquifers depended on the formation resistivity, water resistivity and formation factor values in the study area.

RESULTS AND DISCUSSION

1- Variation in the permeable rock ratios:

The thickness of the permeable rocks below the water table was measured from the boreholes lithology to delineate the ratios of these rocks throughout the study area. By dividing the thickness of the permeable rocks to the total depth for each borehole, the ratio will be obtained. Thus, the ratios were plotted as percent to show the variations in the permeable rocks in the area. The variations in the ratios are shown in figure. 4. The higher percent (ratios) which exceed 60% are recorded in the western part of the study area as in Bara Basin (Umm Rawaba and El Basheri Sub-basins) while the lower ratios are less than 20 % recorded in Kosti Basin in the eastern part of the study area. It is clear that the ratios of the permeable rocks increase westwards and that means the source of the permeable rocks lies in the west of the study area (Fig. 4).

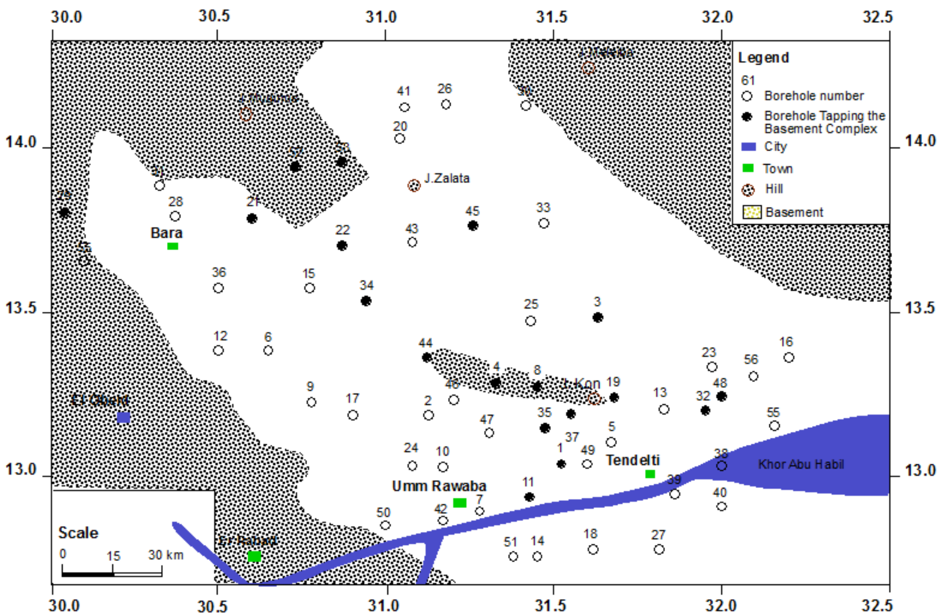

Figure 3: Borehole locations in the study area.

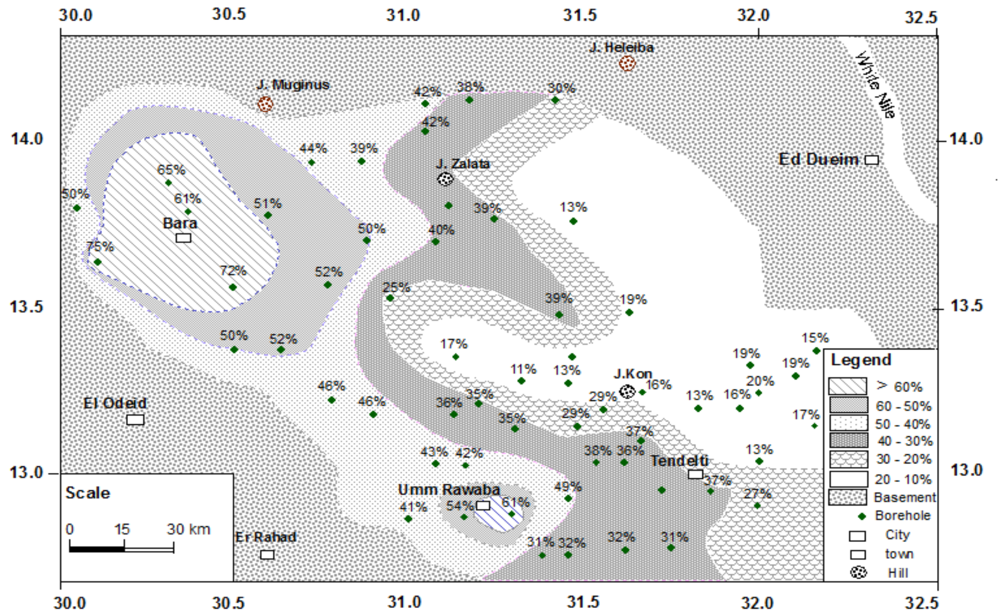

Fig. 4: A map showing the variation in the permeable rocks ratio (pecent) in the study area.

2- Variation in the Porosity:

In this study, the calculation and estimation of the porosity values depended on Archie Formulae (1942) as follow:

$$F = R_o / R_w \quad \ldots\ldots\ldots\ldots \quad 1$$

$$= a / \varphi^m \quad \ldots\ldots\ldots \quad 2$$

where F is the formation factor, R_o and R_w are the resistivities of the formation and formation water respectively, φ is the porosity, a and m are constants their values lie between 0.5 – 2.5 and 1.3 – 2.5 respectively (Telford et al. 1990).

R_o was obtained directly from the long normal logs and R_w was calculated from the electrical conductivity (EC) of the formation water based on (IFAD 2001) as follow:

$$R_w = 10000/ EC \ \text{Ohm- m} \quad \ldots\ldots\ldots \quad 3$$

Based on equation 1, the formation factor (F) was calculated for scattered localities and it ranges between 3 and 7 (Table 2). Based on Kirsch (2006) the porosity exponent (m) was determined to be 1.33 for the loose sands composing the aquifers in the study area. To find the constant (a), the porosity of the rocks forming the aquifers was measured to be 22 % based on laboratory tests for rock samples from chosen sites through the area and according to El Mansour (2005). Using equation 2, the constant will be about 0.6 in the study area. The formation factor (F), porosity exponent (m) and the constant (a) were used in the porosity calculation in these localities. The porosity ranges from 17 – 28 % (Table 1). The regional variation in the porosity in the study area is shown by Figure 5. The porosity ranges between 17 – 23% in Bara Basin but a high value of porosity recorded east of Bara Basin which reached 28%. The former values can be described as an effective porosity related to the presence of the permeable rocks while the later may be due to a decrease of the grain size of the sediments eastwards.

It is clear that the facies analysis of the borehole lithology and porosity calculation indicates vertical and lateral changes in the rocks forming the subsurface formations. The permeable rocks form the water bearing formations. They compose of coarse sands and gravels in the western part and consist of medium sands in the eastern part of the study area. These rocks decrease eastwards. The porosity of these rocks estimated to be between 17 and 28%. Impermeable sediments such as clays represent aquiclude layers separate the permeable rock. The variation in the rock facies and porosity values indicates the sediments composing the water bearing formations were transported from the northwest and southwest directions of the study area.

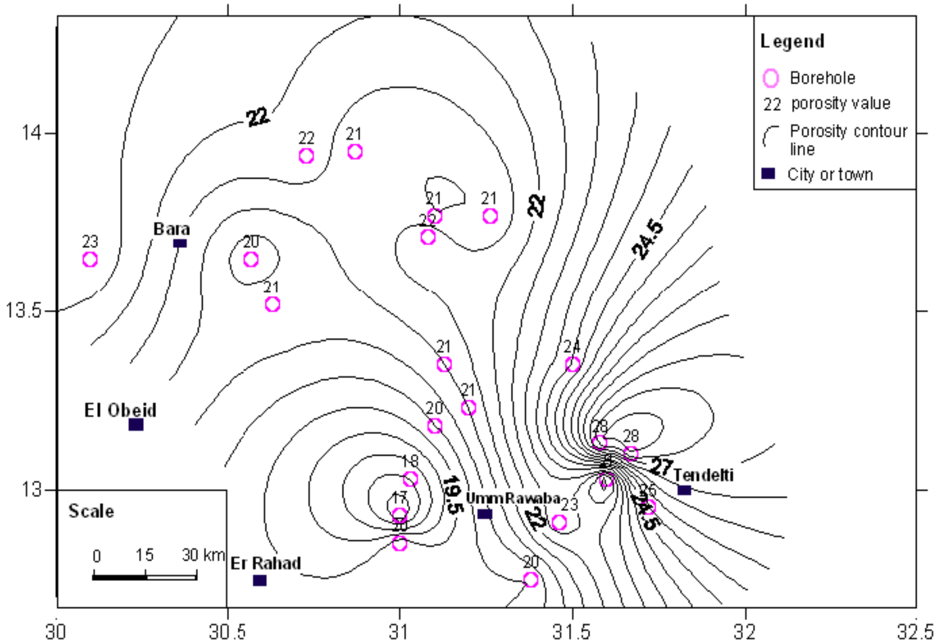

Fig. 4: Regional variation in the porosity in the study area.

Table 1: Showing borehole locations

No	Location	Lat.	Long.	W.D	T. D	TH	%
1	Abu Shitair	13.03	31.52	86	189	72	38
2	Abiya	13.18	31.10	95	158	57	36
3	Umm Saieda	13.48	31.63	73	158	30	19
4	Bit Goda	13.27	31.32	61	96	11	11
5	El Ribeitat	13.10	31.67	78	168	62	37
6	Umm Galabig	13.38	30.65	37	209	108	52
7	Al Goghan	12.88	31.28		200	122	61
8	El kebour	13.27	31.45		83	11	13
9	Et Tayara	13.22	30.78	73	300	138	46
10	Umm Reswa	13.02	31.17	90	189	79	42
11	El Ghabsha	12.91	31.46	81	192	94	49

12	Umm Tagor	13.38	30.50	31	218	109	50
13	Abu Gelba	13.83	31.28	75	80	10	13
14	Idd El Haloof	12.75	31.45		218	70	32
15	Antatya	13.58	30.77	42	235	122	52
16	Abu Lamiss	13.15	31.47	55	158	96	61
17	Umm Nageaha	13.18	30.90	90	224	105	47
18	Boli	12.77	31.62		238	76	32
19	Jaghora	13.24	31.67	76	120	19	16
20	El Shatieb	14.01	31.03		131	55	42
21	Umm Balgie	13.78	30.60	Flow	188	96	51
22	Umm Shaiba	13.70	30.87	35	100	5o	50
23	Ad Difase Goda	13.33	31.97	65	220	44	20
24	Umm Damier	13.24	32.00	60	252	108	43
25	El Kero	13.47	31.43	65	171	67	39
26	Sakara	14.13	31.18	51	182	69	38
27	Kermal	12.77	31.75	82	201	62	31
28	El Kalasa	13.78	30.37	26	135	82	61
29	El Shawag	13.80	30.05	40	79	40	50

30	Idd An Nabag	14.13	31.42	64	98	29	30
31	Al Hadied	13.88	30.32	25	152	99	65
32	Shaa El deen	13.20	31.95		221	42	19
33	El Hashaba	13.77	31.47	69	240	31	13
34	Majroor	13.54	30.93	39	115	29	25
35	Nagous	13.36	32.20	49	155	45	29
36	Ar Rawda	13.57	30.50	30	229	164	72
37	Totah	13.20	31.55		120	34	29
38	Kaboos	13.02	32.00	85	156	20	13
39	Umm Keterat	12.95	31.82	73	186	69	37
40	Wad Abu	12.90	32.00	65	244	66	27
41	El Benniya	14.12	31.05		170	71	42
42	Gidaideem	12.86	31.17		248	134	54
43	El Kilwat	13.71	31.08		125	50	40
44	Madlool	13.35	31.13	80	109	16	15
45	At Ticale	13.77	31.26	60	205	72	39
46	Halgaama	13.23	31.20		202	71	35
47	Shogar	13.13	31.30		155	56	36
48	Mangoor	13.03	31.03		218	65	30
49	Umm Ushara	13.03	31.60	76	215	77	36
50	Aman Allah	12.85	31.00		136	76	41
51	Umm	12.75	31.38		153	47	31
52	El Meraihbieba	13.94	30.73	50	91	40	44
53	Shigaila	13.95	30.87		127	50	39
54	Hamad El Seed	13.65	30.10		152	114	75
55	Rad El Sheakh	13.15	32.11	56			17
56	El Dinglawiya	13.30	32.1	59	240	46	19

W. D : Water Depth **T. D** : Total Depth

TH : Aquifer Thickness **%** : Permeable Rock Ratio (percent)

Table 2: The variation in the porosity values.

Location	Longitude	Latitude	EC	R_w	R_o	F	φ %
Abeya	30.65	13.58	1428	7	35	5	20 %
Bani Mohammed	31.58	13.13	1580	6.3	21	3.3	28 %
Umm Jub	31.50	13.35	3300	3	12	4	24 %
El Rebeitat	31.67	13.10	1200	5.8	18	3.2	28 %
Umm Gerif	30.63	13.52	1021	9.8	48	4.9	21 %
El Gubsha	31.46	12.91	690	14.5	63	4.3	23 %
Kendowa	31.00	12.93	1442	6.9	52	7	17 %
Taventara	31.00	13.07	1154	8.6	36	4.1	24 %
Jaghoa	31.67	13.24	3010	3.3	10	3	28 %
El Kero	31.43	13.47	3450	2.9	14	4.8	21 %
Umm Dam	31.10	13.77	1371	7.3	36	4.9	20 %
El Kilwat	31.08	13.71	1200	8.3	36	4.4	22 %
Madlol	31.13	13.35	2261	4.4	21	4.7	21 %
At Ticale	31.26	13.77	4000	2.5	12	4.8	21 %
Halgama	31.20	13.23	2057	4.9	22	4.9	21 %
Mangoor	31.03	13.03	1300	7.7	45	5.8	18 %
Uum Ushara	31.60	13.03	1357	7.4	35	4.7	21 %
Aman Allah	31.00	12.85	1457	8.6	44	5.1	20 %
Wad Burr	31.72	12.95	1535	6.5	25	3.8	25 %
Umm Daldamaya	31.38	12.75	943	10.6	55	5.2	20 %
Merehbeeba	30.73	13.94	1142	8.6	37	4.3	22 %
Shigaila	30.87	13.95	1286	7.8	37	4.7	21 %
Hamad El said	30.10	13.65	786	12.7	54	4.3	23 %
El Sarha	13.65	13.65	929	10.7	57	5.3	20 %

EC : Electrical conductivity
R_w : water Resistivity
R_o : formation resistivity
F : formation factor
φ % : porosity ratio (percent)

REFERENCES

Archie, G.F., (1942): The electrical resistivity log as an aid in determining some reservoir characteristics. Trans. A. I. M. E.In:

Ali, H. O. (1983): Numerical Analysis of Groundwater Resources in the Bara Basin, Sudan. International Conference on groundwater and Man, Sydney Australia.

El Mansour, A. A., (2005): Hydrogeological study of western Basin Northern Kordofan State. M. Sc. Thesis University of Kordofan, Sudan.

Geotehnika, (1985): El Obeid water supply project, Feasibility study of groundwater resources. Master report, National Water Administration, Ministry of Energy and Mining, Khartoum, Sudan.

IFAD, 1993: Northern Kordofan Rural Water Development Project, Special Identification Mission Reports, Ministry of Irrigation and Water Resources, Khartoum, Sudan.

Jacob, C. E. (1946): Drawdown Test to Determine Effective Radius of Artesian Well. In:

Kirsch, R., (2006): Groundwater Geophysics, A tool For Hydro Geology, published by Springer Verlay, Berlin, Germany.

Salama, R. B., (1985a): Buried troughs grabens and rifts in Sudan. Journal of Africa, Earth Sciences, 3 (3): 381 – 399.

Telford, W. M., Geldart, L. P., and Sheriff, R. E., 1990: Applied Geophysics, Second Edition, Cambridge University Press.

Thiess, C. V. (1935): The Relation Between the lowering of the Piezometric Surface and Rate and Duration of Discharge of a Well Using Groundwater Storage. In:

Toad, D. K. (1959): Groundwater Hydrogeology, 1 st. ed., John Wiley and Sons, New York.

Whiteman, A. J., (1971): The Geology of the Sudan Republic.