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Ground Magnetic Prospecting in Parts of the Calabar Flank Sedimentary Basin and Environs, South-South Nigeria

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Authors' contributions

This research was carried out in collaboration between all authors. Author DAO provided the softwares and analysed the data using the softwares. Author MJA collected the field data and proof read the work. Author CE collected a part of the field data and processed the manual data. All the authors read and approved the final manuscript.

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ABSTRACT

The Calabar Flank sedimentary basin has remained relatively unexplored using potential fields. In this study ground, magnetic data was acquired covering about three-quarters of the Calabar Flank sedimentary basin. Twenty-five traverses were acquired along major communities, each line covering about 4.5 km-5.0 km with station interval data collected at 0.2 km. The acquired field data was processed using both manual and computer software programs which include reduction to pole, polynomial filtering and horizontal gradient magnitude techniques. The results of the analysis indicate both deep and shallow seated anomalies with structures from depth computation which represented Horst and grabens structures in areas of shallow and deep sediments thickness accumulations. The manual depths computation from Stanley's 77, Petters half-width, and maximum slope methods indicate shallow depth ranging between 0.4 km–1.5 km between Ekprikang and Calabar, while the Creek town areas vary in depths between 1.6 km – 2.0 km these results collaborated with the horizontal gradient magnitude depths estimates which are

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more reliable indicating the horst structures with depths between 0.5 km–1.5 km around Calabar toward Ikang and the grabens with depths ranging between 2.0 km – 5.0 km between Creek Town and Okoyong. The study reveals that the Calabar flank sedimentary basin has sediment thickness good enough for further investigation of hydrocarbon deposits.

Keywords: Graben; polynomial filtering; horizontal gradient magnitude; hydrocarbons; reduction – to – pole.

1. INTRODUCTION

The Calabar Flank sedimentary basin was formerly a part of the Lower Benue Trough, but it was later renamed by its structural orientation [1,2,3] the basin is bounded by the Oban Massif to the north and the Calabar hinge line delineating the Niger Delta basin in the south and is separated from the Ikpe platform to the west by NW – SE trending faults [4,5].

The present study area covers latitude 4^{o}.55’00” – 5^{o}.02” 00” N and Longitude 8^{o}.11’00” – 8^{o}.35’00”E The magnetic prospecting method searches for variations in the magnetic field that causes changes in the subsurface geologic structures, this method has been previously well documented as a reconnaissance tool for hydrocarbon exploration in relatively unexplored basins [6,7,8,9]. Geophysical exploration works within this basin are few and mostly on aeromagnetic data. Land gravity data reported the presence of host and graben structure, within this basin [10]. This study of land magnetic survey is a pioneer work at producing a ground magnetic total field intensity map of the basin and computing the possible depth to magnetic basement vis-à-vis sediments thickness of the basin.

1.1 Geology

The Calabar Flank sedimentary basin is sitting directly on the Precambrian Oban massif (Fig. 1). This study took traverses passing along major communities, from Ikot-Nakanda to Ikang, also from Okoyong-abasi towards Creektown and along Calabar municipality. The sedimentary deposits within these townshas the youngest deposits of Benin Formation (Paleocene – Eocene) as the topmost unit, below this unit, is the clay sandy unit (lower Eocene). These two units cover about 90% of the entire mapped area. The above unit is underlain by a shale mudstone unit (Maastrichtian) which is further underlain by the Mfamosing limestone (Albian – Cenomanian). Then, this unit is also underlain by the Awi Formation Sanstone (Albian), this sanstone unit is sitting directly on the biotite and Migmatite gneisses of the Precambrian Oban massif (Fig. 1).

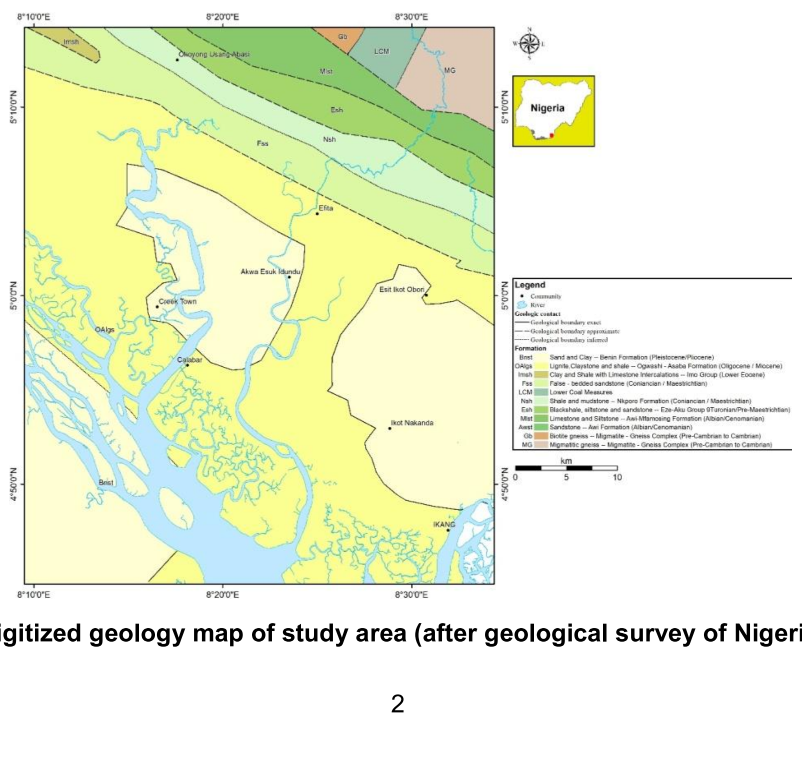

Fig. 1. Digitized geology map of study area (after geological survey of Nigeria, 1994)

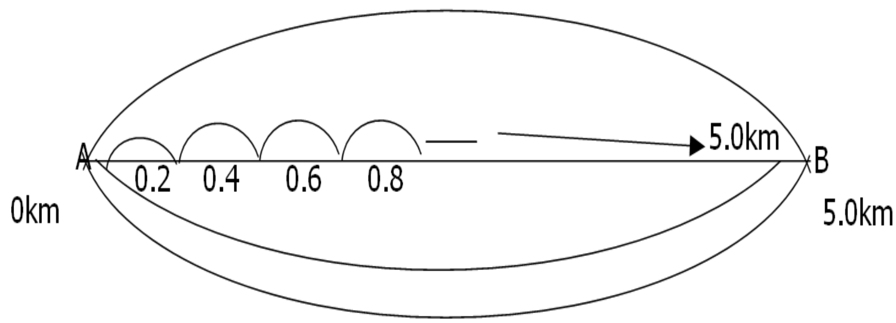

Fig. 2. Looping pattern in ground magnetic survey

2. METHOD OF STUDY

The proton precision magnetometer GSM – 19T was used in collecting ground magnetic data along twenty five traverses which runs across five major communities within the Calabar Flank area. During field data collection, base stations were created and field data collected in a loop pattern and tied to the base stations. The sampling intervals along traverses was 200 meters and the total distance of each traverse covered 5.0km. Each traverse had data sampled along and later tied to the initial base station by looping, a process which helps in diurnal variation correction [11,12].

Since the field traverses were very long and looping patterns needs to be closed within one hour a car was used for collecting the station intervals data, other field challenges such as creating traverses within busy terrains was accomplished with the aid of villagers.

2.1 Data analysis and Results

The acquired field data was processed both manually and with the aid of computer techniques which include the following map contouring, reduction to pole, polynomial filtering, and horizontal gradient magnitude. The manual processing involved correcting for diurnal variations on the acquired field data (Table 1). All the twenty-five lines were corrected and plotted as profile lines of total magnetic intensity field against distances. Also, anomaly residuals were plotted against distances and using depth computation techniques of Petters half width maximum slope, and Stanley's 1977 methods, the depth to magnetic basements were computed along flexure points. These depths along the major profiles indicated that areas around Ekprikang had a depth ranging between 0.4 km – 0.9 km, Calabar 1.5 km, Okoyoyong 1.6 km, IkotNakanda 1.8 km and Creek Town 2 km. Only three profiles were chosen for illustration (Figs. 3, 4, 5). The computer technique involved using all the twenty-five lines that were corrected for diurnal variations. The acquired field data and their corresponding coordinates were keyed into the computer using (U.S.G.S) United States geological services software format (XYZ), where X and Y are the longitude and latitude coordinates and Z the total magnetic field [6,4]. Different suites of this software was used to perform a separate function, the programs include the following A2XYZ, P2GRD GEOCON, and PC-contour which were used before producing the contoured total magnetic field intensity map of the study area Fig. 6).

The reduction to pole filtering which centers the magnetic anomalies was performed with the following softwareCk dims, PREP5, FFTFIL, FR-TP and DE-PREP5 to obtain the reduction to pole map (Fig. 7).

Also another filtering technique using the least square regression polynomial method with the software (SUFIT, GEOCON and PC-contour) was done and the residual magnetic map produced. The horizontal gradient magnitude technique has been well documented to obtain depths to magnetic basements using the following software Gradient, Hdep, and suffer 11.0. [13,14,15].

Table 1. Illustration of manually Diurnal variation correction chart for IkotNakanda profile

Station (♈)	Dist (km)	Avrg Rdg	Time (mins)	∆t (mins)	Diurnal drift rate	Diurnal drift correct	Diurnal drift correctdrdg	Diff in diurnal drift corretdrdg	Observed total field (T)	Anomaly T-T´	$T\text{-}T_B$
Base A		33130	1.41	-	24	-	33130	-38	33092	-19	
Base B		33398	1.49	8		19.2	33149	-19	33111	0	
Loop base A		33091	1.57	16		38.4	33168	0	33130	19	
A	C	T	U	A	L	S	U	R	V	E	Y
1	0	33092	2:01	-	0.34	-	33092	0	33130	-16	19
2	0.25	33126	2:03	2		0.68	33127	35	33165	-19	54
3	0.50	33076	2:05	4		1.36	33077	-15	33115	-31	4
4	0.75	33083	2:07	6		2.04	33085	-7	33123	-23	12
5	1.00	33094	2:08	8		2.72	33097	5	33135	-11	24
6	1.25	33144	2:10	10		3.4	33147	55	33185	39	74
7	1.50	33084	2:11	11		3.74	33088	-4	33126	-20	15
8	1.75	33104	2:13	13		4.42	33108	16	33146	0	35
9	2.00	33117	2:14	14		4.76	33122	30	33160	14	49
10	2.25	33116	2:15	15		5.1	33121	29	33159	13	48
11	2.50	33100	2:17	17		5.78	33106	14	33144	-2	33
12	2.75	33127	2:19	19		6.46	33134	42	33172	26	61
13	3.00	33126	2:22	22		7.48	33134	42	33172	26	61
14	3.25	33096	2:24	24		8.16	33104	12	33142	-4	31
15	3.75	33138	2:26	26		8.84	33147	55	33185	39	74
16	4.00	33095	2:27	27		9.18	33104	12	33142	-4	31
17	4.25	33098	2:29	29		9.86	33108	16	33146	0	35
18	4.50	33085	2:31	31		10.54	33109	17	33147	1	36
19	4.75	33102	2:33	33		11.22	33113	21	33151	5	40
20	5.00	33088	2:35	35		11.9	33100	8	33138	-8	27
21		33056	2:37	37		12.58	33069	-23	33107	-39	-4
Loop		33078	2:41	41		13.94	33092	0	33130	-16	19

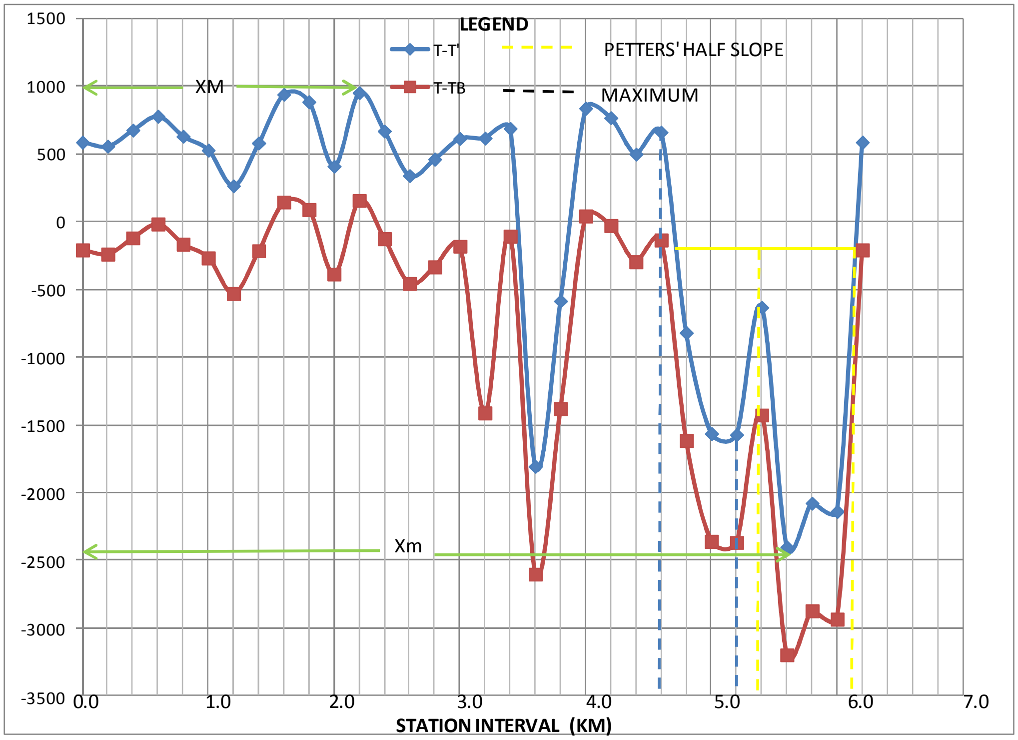

Fig. 3. Anomaly plot of profile along stadium – Edimotop calabar

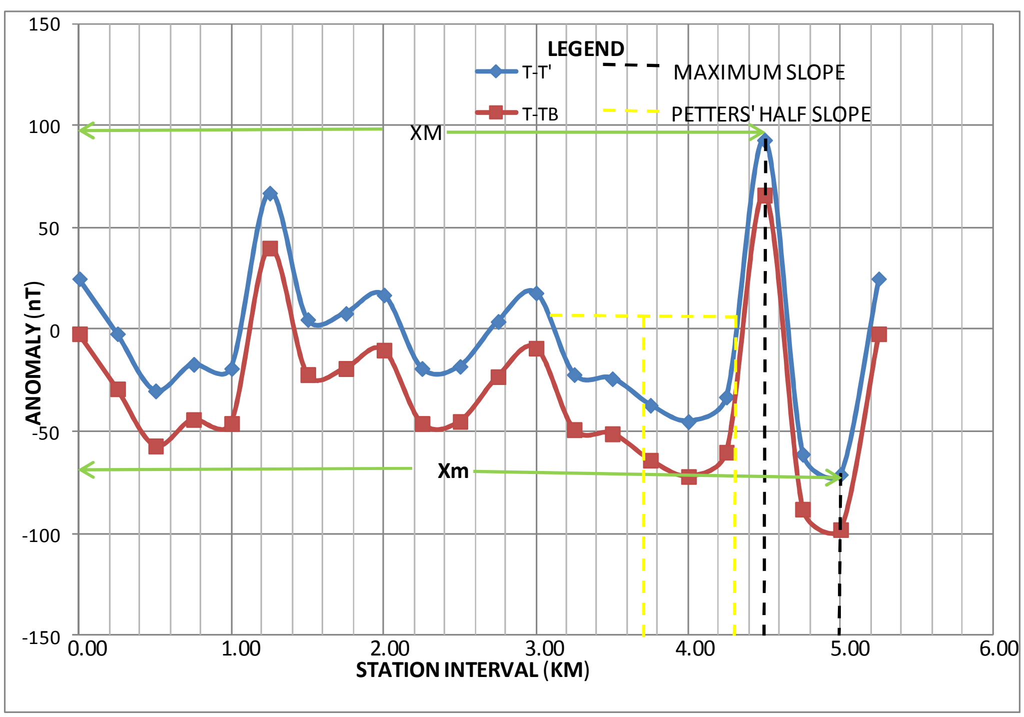

Fig. 4. Anomaly plot of profile along Ekprikang-Ikang

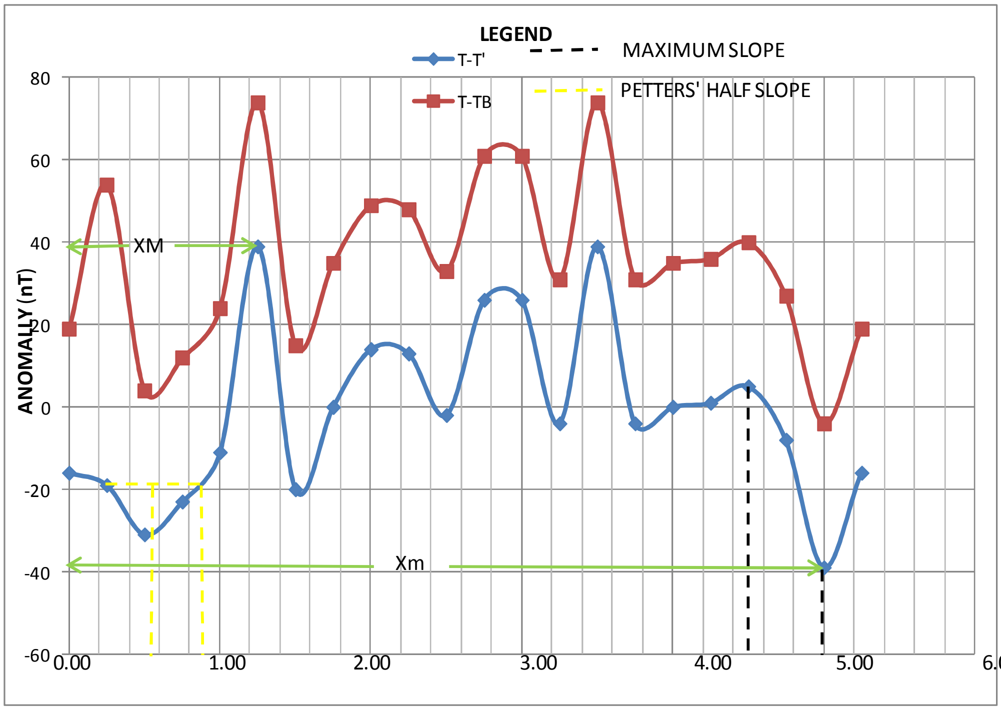

Fig. 5. Anomaly plot of profile along Ikot Nakanda

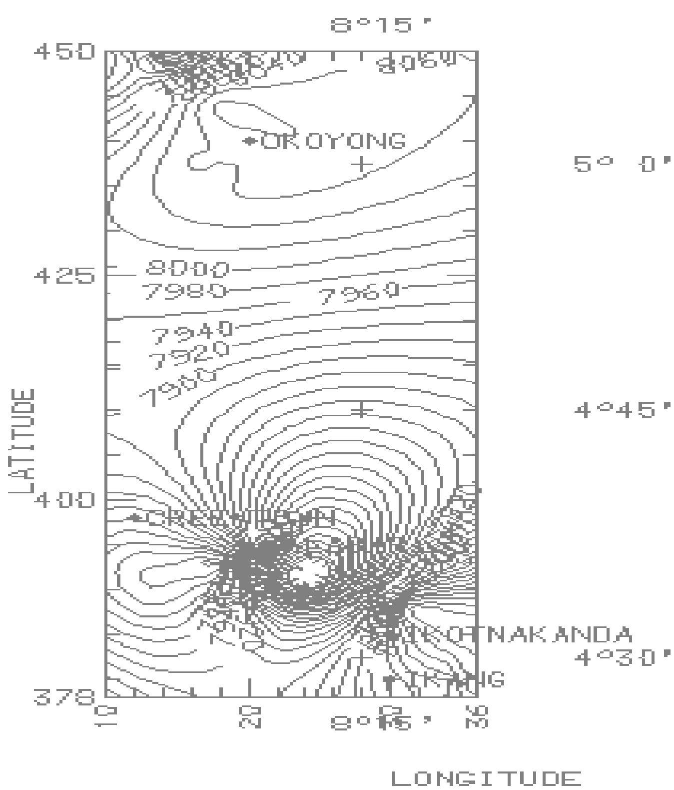

Fig. 6. Total magnetic field intensity map of the study area

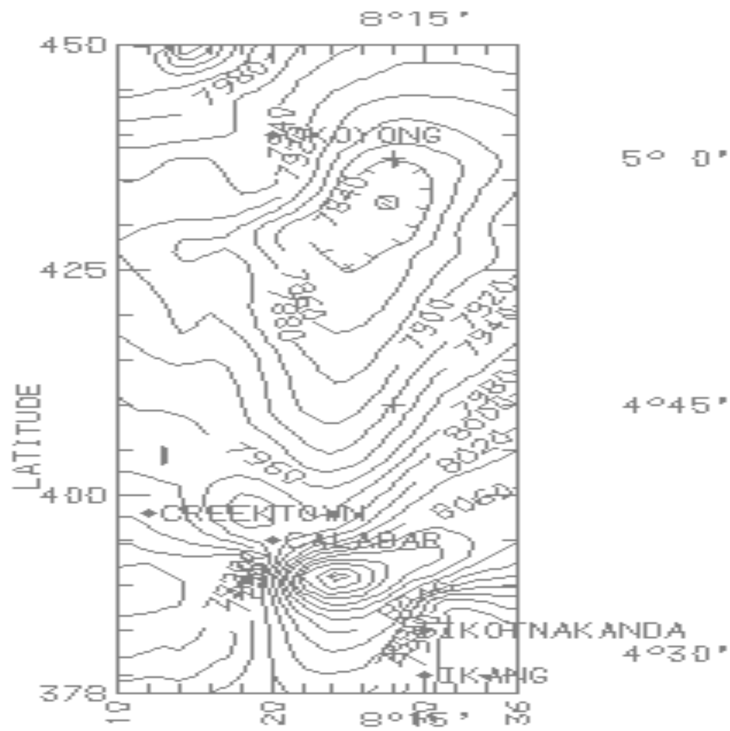

Fig. 7. Reduced - to – pole map of the study area

3. RESULTS AND DISCUSSION

Interpretation of the processed data started from the manual plot was anomaly profiles (Figs. 3, 4 5) indicated areas were depth to the magnetic basement were computed and depth to magnetic sources was 1.5 km at Calabar, 1.8 km at IkotNakanda, and Ekpri-Ikang 0.4 km. Also, other areas where such depths computations were made include Okoyong Abasi 1.6 km, Creek Town 2.0km these results indicate that the basin deepened towards Creek Town area and shallows towards Ekpri Ikang. These results were collaborated with those obtained from the computer processed techniques which utilized the contoured total magnitude intensity map which was reduced to pole, filtered as a residual file and further processed as horizontal gradient magnitude depth displaying the depth to magnetic basement of the studied area (Figs. 6,7,8,9). The reduction to pole map (Fig. 7). Has six centered anomalies, three occurred between Calabar and Ikang and another three between Creek Town and Okoyong. After polynomial fillering the residual map (Fig. 8) had five anomalies with spaced ecliptical contours forming a large deep-seated intrusive (10–100 nT) between Creek Town and Okoyong. Also Ikang towards Calabar has tight contours + 20 nT indicating shallow seated intrusives, this contour -50 seems to loosen between Calabar and Creek Town indicating sediments thickness. The horizontal gradient depth map (Fig. 9). Indicate that the areas around Calabar toward Ekprikang has depths ranges between 0.9 – 2.5 km and those areas around Okoyong towards Creek Town (1.7 km–3.5 km) these depths are in agreement with earlier geophysical research [6,7,9]. The other areas with greater sediment thickness has higher hydrocarbon exploration potentials. The numerous horst structures around Okoyong, Calabar, Creek Town and Ikang makes them prone to overheating from the adjacent Oban massif basement.

However, the basin area has sediments thickness between 0.9–5-9 km which is favourable for hydrocarbon exploration.

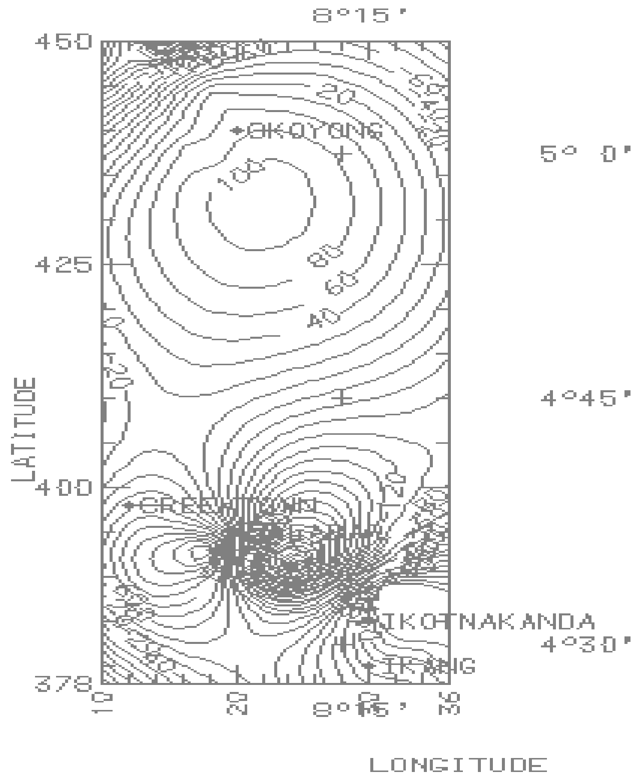

Fig. 8. Polynomial residual magnetic data of the study area

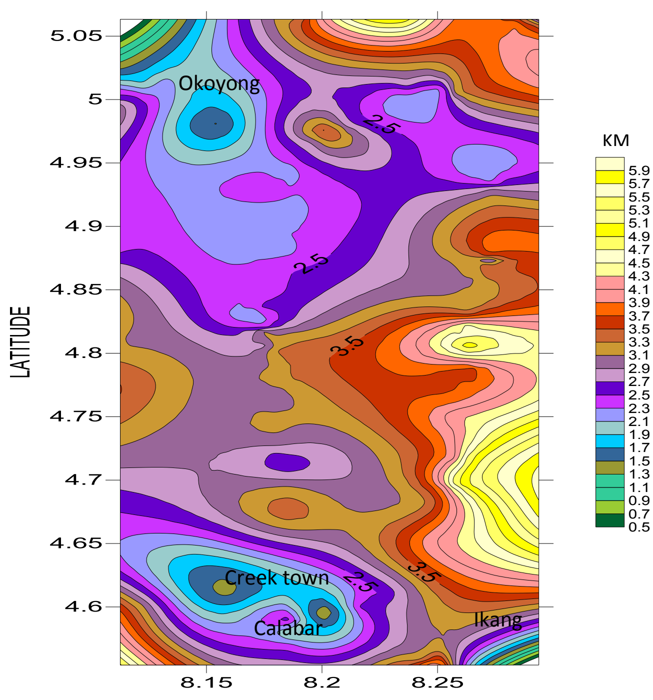

Fig. 9. Horizontal gradient magnitude depth map of the study area

4. CONCLUSION

Conclusively, the Calabar flank sedimentary basin and it's adjourning areas was studied using data collected from ground magnetic studies to produce the total magnetic field intensity map and a magnetic depth map for the area which has not been done. Areas of increased sedimentary thickness around Creek town, .5 km, Okoyong 2.5 km, and Ekpriikang 2.5 km, have been identified for further hydrocarbon exploration activities.

It's recommended that further geophysical exploration using seismic exploration methods be used within these areas for further hydrocarbon exploration activities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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