THE FREE-AIR AND BOUGUER GRAVITY MAPS OF SOMALIA

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ABSTRACT

The Bouguer gravity map (southern sheet and northern sheet) and the free-air map of Somalia are presented in this paper. These maps were obtained by using the data of the gravity survey made by the authors during 1984 and 1985 and the gravimetric data of previous surveys aimed to hydrocarbon research. Data were all refered to a single base station located in Mogadiscio.

RIASSUNTO

Viene presentata la carta gravimetrica del Bouguer (foglio sud e foglio nord) e quelle in aria libera della Somalia. Queste carte sono ottenute utilizzando i dati del rilievo gravimetrico effettuato dagli autori nell'84 e 85 e i dati gravimetrici di precedenti prospezioni a scopo di ricerca di idrocarburi. I dati sono stati tutti riferiti ad un'unica stazione di base situata in Mogadiscio.

INTRODUZIONE

Although the gravimetric method of geophysical surveying was sistematically used in oil exploration in Somalia since the late 1960's, its application was essentially qualitative and aimed only at the solution of local geological problems. The studied areas were scattered and inhomogeneusely distrubuted throughout the country. In order to unify the preexisting gravity data and compile a comprehensive Bouguer gravity map of Somalia, the geophysical section of the Somali Faculty of Geology in collaboration with the geophysical section of the Department of Geophysics and Volcanology of the University of Naples carried out during 1984 and 1985 an extensive gravity survey.

Such a survey has been considered essential to get information about the characteristics of the longer wavelenght spectral components of the gravity field of Somalia to study the tectonic-structural state of the deeper crust and in particular to determine the depth to the Moho and to the Precambrian basement; these are of importance to all regional geological studies and also for oil explorations.

Several papers about the deep structures of East Africa have been so far published (BROWN at al., 1985; GILDER, 1978, GOUIN, 1970; HERBERT & LANGSTON, 1985: MAKRIS et al., 1927, RABINOWITZ, 1971; SEARLE & GOUIN, 1972; SLETTENE et al., 1973). They were mainly concerned with seismic data and in some cases also with gravity measurements. However, these studies generally regard specific areas of main geodynamic interest. Therefore, there is a lack of a total coverage of the area and in particular a void exists as far as the Somalian region is concerned.

In this paper, the gravity results of the first phase of the research,mainly concerned with data acquisition, will be presented. Two short papers concerning the gravity base network were already published (RAPOLLA et al., 1984; DORRE & RAPOLLA, 1985).

GRAVITY OBSERVATIONS

During 1984 and 1985, 830 gravity measurements were madeon southern, central and northern Somalia. The measurements were taken along roads and tracks which were accessible and which were more or less perpendicular to the main regional structures.

The mean distance between adjacent stations was about 5 km. Such spacing seemed adequate given the aim of the survey.

The gravity readings were made by a thermally compensated Worden Master Gravimeter. The meter was calibrated on the Mogadiscio-Afgoy calibration trajectory, previously established by the Somali Gulf Oil Company (A.M. VAN DAMME. 1964). Base station were established as the work progressed. They were tied to the fondamental gravity station of Mogadiscio, having an absolute gravity value of g=978072.20 mgal. This station has been previously connected to another fondamental gravity base station in the former Mogadiscio Airport. The latter was linked to the International Woods Hole Gravity base network (MASON SMITH, ANDREWS, 1962).

The gravity value of each base station was determined from an average of at least three measurements. The gravity differences between grid and base station were determined by a single observation at the former and to the nearest base station, within a time interval of generally less than two hours. The drift rate between base readings was determined for all circuits and used to calculate the drift from the reading time at each intermediate grid station.

The station elevation was determined by means of an accurate microbarometric survey utilizing a precision Paulin System altimeter. The altimetric measurements were made in loops of generally less than two hours duration and were tied to numerous trigonometric points and bench marks. Considering the utilized methodology, the flatness of the terrain and the pratically constant barometric conditions of the area under study, the overall error of the heights is considered to be within ± 5m, which is acceptable given the aim of our gravity survey. The locations of the gravity stations were determined from the existing topographic maps of scale 1:100.000.

A density value of 2.2 g/cm^3 r 2.3 g/cm^3 was utilized to calculate the Bouguer corrections. The second value of density was only attributed to the crystalline basement of the Bur Region. Both values of density are lower than the values generally used for crustal studies. However, as these figures were used by various oil companies which worked in Somalia, whose data we utilized to complete our Bouguer map, and they are actually the most compatible with the geological features of Somalia, we preferred to use these density values even for our gravity data. Anyway, in low altitude and flat areas as central and southern Somalia, small differences in the Bouguer density values are not critical.

In order to calculate the free-air anomaly and the Bouguer anomaly of each station, we evaluated the theoretical gravity value at the point of observation at this topographic level, and then determined the difference between this corrected value and the value of the observed gravity at the point of observation (RAPOLLA 1982). The normal gravity values were calculated by the International gravity formula of 1930 and of 1967. The former was actually utilized as this was the formula the oil companies used.

Due to the lack of detailed topographic map, no terrain correction was applied to the data. Anyway, this was considered to be not critical given the extreme flatness of the area.

FREE-AIR ANOMALY MAP

Free-air anomaly map have been constructed over southern and central Somalia. The map was based on the gravimetric measurements obtained from the gravity survey of the Faculty of Geology of Somali National University as the measured data of the oil companies were not available. The map, attached to this paper, has been contoured at 20 mgal interval. A large linear positive anomaly trends towards the Indian Ocean running parallel to the coastal area of Somalia. This regular general trend is modified in the areas near Eyl, Kisimaio and, much more evidently, in the Brava region, where a positive anomaly extends inland as far as near Dinsor. The maximum relative anomaly of this features is 40 magal. The rest of the studied area is dominated by a negative free-air anomaly. The maximum negative values can be seen on central and south-western Somalia, where the values decrease down to -65 mgal.

Without attempting at this stage of the research any quantitative interpretation, we may already deduce from the free-air map that, at last in some regions, the crustal situation of Somalia is far from isostatic equilibrium.

BOUGUER ANOMALY MAP

The Bouguer anomaly field of Somalia is presented in two different attached maps: the southern sheet which comprises the area between latitudes 5°N and 11°N and the southern sheet between latitudes 1.5°S and 5°N. Both maps have been obtained by integrating the gravity data from our surveys with the Bouguer maps from several oil companies (AGIP, Hammar Oil Co., Roger Expl., Sciabelli Oil Co., Somali Gulf Oil Co.). In order to homogenize the data of the different companies, among themselves and with our data, several of our profiles have been chosen to cross the areas surveyed by these companies. In fact, Boguer data of some oil companies were referred to an arbitrary reference base station. By correlating our profiles with the corresponding oil companies profiles, we were able to reduce all the data to a common reference base, that is the Mogadishu base station. The oil companies Bouguer data were digitized on a 5 km x 5 km square grid.

These gathered data permitted us to get a sufficiently detailed picture of the gravity field of Somalia with the exception of the north-western and north-central Somalia. In these areas the topography is by far no more flat as in the other parts of Somalia and we felt a barometric levelling was not accurate enough to give a sufficient confidence in the results. Moreover no oil company Bouguer map is up to now available. For sake of completness, Bouguer data from different literature sources have been utilized to complete the gravity maps on areas outside the boundary of Somalia (MAKRIS et al., 1972; SEARLE, GOUIN,1972; GOUIN,1970).

The main feature of the Bouguer gravity map of Somalia is a negative anomaly which reduces going east towards the Indian Ocean. This negative feature is a characteristic of all East Africa (GILDER, 1978).

The Bouguer isoanomalies of north-eastern Somalia reveal a quite regular negative trend which form a sheaf of subparallel curve running roughly NE-SW. On the northern--most side, the curves, instead, arch westwards again trending parallel to the coast. A negative gravity low forms in the inner part centered west of Garowe. As a matter of fact, the western side of this anomaly is obtained by extrapolation and further measurements are required in order to secure the real trend of the isogal.

On central Somalia, the most prominent features are the large gravity through west of Obbio and the steep gravity gradient along the coastal area. There are other closures with smaller extensions on Dusamareb and on areas near the Somali-Ethiopian border.

Examination of the southern sheet reveals a more complex pattern in the Bouguer anomalies. The isogals are more irregular and the range in amplitude is greater, from -65 mgal to more than +40 mgal. A conspicuous relative high is found in correspondence to the Bur Region. East and west of Jilib and near Lugh there are smaller negative closures. As in the northern sheet, even here, the gravity gradient becomes steeper towards the coastal regions. Both sheets are characterized by positive gravity anomalies along the coastal area. Sharp prominent positive gravity nosing can be seen on the southern sheet and particularly in the nearby areas of Brava and Kisimaio. The former extends for nearly 200 km west of Brava and has an amplitude of nearly 40 mgal. Even in this case, as in the free-air map, the irregular shape of the contours of the Bouguer maps indicate an inhomogeneity of the crustal and subcrustal strucures of Somalia.

CONCLUSIONS

Up to now, the Somali plate has been considered as an homogeneous one, bordered by areas where intense geodynamic activity took place or is taking place. On the contrary, the gravity features of Somalia suggest that most probably subzones have to be distinguished within the Somali region. The second phase of this research will be addressed first to data analysis and then to a quantitative reconstruction of the morphology of the main crustal and subcrustal discontinuities. Filtering out the shorter wavelenght components of the gravity field should in fact give a picture of the regional trends much more suitable for a quantitative interpretation of the crustal and subcrustal features of geodynamic interest (RAPOLLA, 1982). On the other side, local anomalies which are of interest for local geological problems and oil exploration, can only be cleared out if a correct evaluation of the regional trend is made and the subtracted to the actual anomaly field. The study of these local anomalies will be also a future target of our research program.

ACKNOWLEDGMENTS

We thank the Somali Ministry of Minerals and Water Resources for the collaboration. We acknowledge also the Dept. of the Cooperation for Development of the Italian Ministry of Foreign Affairs and the Italian Ministry of Public Education for their financial support.

A complete output of the data may be available on request.

REFERENCES

AGIP (1965) - Rilievo gravimetrico della Somalia nord orientale. Unpubl. rep., Min. Miner. Water Res., Geoph Dept., Mogadishu.

BROWN S.E., FAIRHEAD J.D., MOHAMED I. (1985) - Gravity study of the White Nile Rift, Sudan and its regional tectonic setting. Tectonophysic, 113.

GILDER R.W. (1978) - Comparison of East African Rift system and the Permiam Oslo Rift. I.B. Bamberg and E.R. Neumann eds., Tectonics and geophysics of continental rifts.

GOUIN P. (1970) - Seismic and gravity data from Afar in relation to surrounding area. Philos. Trans. Roy. Soc. London Ser. A, 267.

HAMMAR OIL COMPANY (?) - Reports on gravity surveys. Unpubl. Rep., Geoph. Dept. Min. Miner. Water Res., Mogadishu.

HERBERT L., LANGSTON C.A. (1985) - Crustal thickness at AEE (Adis-Ababa, Ethiopia) and NAI (Nairoby,Kenya) using teleseismic p-wawe conversion. Tectonophysics 111.

MASSON SMITH D., ANDREWS E.M. (1962) - East Africa gravity base systems. Geophysical Journal of the Royal Astronomical Soc., Vol. 7, N. 1.

MAKRIS J., MENZEL H., ZIMMERMAN J. (1972) - A preliminary interpretation of the gravity field of Afar, north-east Ethiopia. Tectonophysics 15 (1/2).

MULLER S., BONJER (1973) - Average structure of the crust and upper mantle in E. Africa. Tectonophysics 20.

PHILIP D. RABINOWITZ (1971) - Gravity anomalies of East African continental Margin. Journal of Geophysical Research, Vol. 76, N. 29.

RAPOLLA A., DORRE A.S., CARRARA E., ROBERTI N., HASSAN M. (1985) - Studio gravimetrico e magnetico della Somalia: descrizione della rete gravimetrica base della Somalia centro-meridionale. Quad. di Geol. della Somalia, Vol. 8, Mogadiscio.

RAPOLLA A., DORRE A.S., HASSAN M. (1986) - Studio gravimetrico della Somalia: descrizione della rete gravimetrica di base della Somalia centrale e nord orientale. Quad. Geol. della Somalia, Vol. 9, Mogadiscio.

RAPOLLA A. (1982) - Some aspects of the interpretation of gravity data for the study of regional and local structures. In: The solution of the inverse problem in geophysical interpretation, Plenum Press. London.

ROGERS OIL COMPANY (?) - Reports on gravity survey. Unpubl. rep., Geoph. Dept. of Min. Miner. Water Res., Mogadishu.

SEARLE R., GOUIN P. (1972) - Gravity survey of the central part of the Ethiopian Rift Valley. Tectonophysics 15 (1/2).

SLETTENE R.L., WILCOX L.E., BLOUSE R.S., SANDERS J.R. (1973) Tech. Pap. 73-3 U.S. Defence Agency, Ref. in GILDER, 1978.

VAN DAMME A.M. (1962) - Gravimeter calibration bases Mogadiscio. Unpubl. Rep. Geoph. Dept. Min. Miner. Water Res., Mogadiscio.

VAN DAMME A.M. (1964) - Gravity base net of Somali Gulf Oil Company. Unpubl. Rep., Geoph. Dept. Min.Miner. Water Res., Mogadiscio.