p-ISSN : 2335-1357 e-ISSN : 2437-1122

Mediterranean Journal of Modeling and Simulation

Med. J. Model. Simul. 11 (2019) 058-068

The New Gravimetric Network of The Upper Chelif Basin

Mohamed Bendali [a], [b] *, Boualem Bouyahiaoui [a], Adel Belmecheri [c], Salah-Eddine Bentridi [b], Abdeslam Abtouta [a]

[a] Centre de Recherche en Astronomie, Astrophysique et Géophysique. Bp 63, route de l'observatoire, Bouzaréah 16340, Alger, Algérie
[b] Laboratoire de l'énergie et des systèmes intelligents, Université de Khemis Miliana, Route de Théniet El-Had, 44225, Khemis Miliana, Algérie
[c] Baker Hughes, a GE company

ARTICLE INFO

Article history :
Received March 2019
Accepted July 2019

Keywords :
North Algeria ;
Upper Chelif basin ;
Gravimetric network ;
Gravity survey ;
Lacoste & Romber D220.

ABSTRACT

This paper presents all stages of the gravimetric network of the upper Chelif basin, including its development and data processing. This network consists of twenty six gravimetric stations. The descriptions of the design ; the gravity survey of the network and the gravimetric stations coordinates are given. These gravimetric stations are connected to the Algerian zero order gravimetric network by means of relative gravimetric values. The measurements were performed using a terrestrial LaCoste Romberg D220 gravimeter, with an instrumental accuracy of 1ţglas. The accuracy of the determination of gravity values at individual stations is about 13 ţgals. In order to ensure the uniformity of obtained results and thus avoid having several gravity values at the same station, the network has been compensated. This compensation was performed by the ginning method.

1. Introduction

Gravimetric networks provide the frame for gravimetric on regional or local scales. They consist of gravimetric stations where the gravity (G) has been determined by absolute or relative methods. A reference gravimetric station network is established primarily to tie relative measurements to absolute gravity value from the national gravity datum and on the other hand, for the investigation of gravity variations with time. This variation is the key to follow the evolution of the instrumental drift. For this and in order to control the quality of measurements, it is necessary to reoccupy a known gravity station each 4 to 5 hours [1, 2]. Therefore, it is necessary to have a reference gravimetric station, whose

*Email :bendalimohamed86@gmail.com ; mohamed.bendali@univ-dbkm.dz ; Tel. : +213 23 18 90 98 /99 (office 265) ; fax : +213 23 18 91 01

G value is known with good accuracy and with a good spatial distribution inside the all study area. So that, we can return in the shortest time to consider the variation of the gravimeter drift as linear [3].

The first reference gravimetric station network of Algeria has been realized by Lagrula (1951, 1959), from the Bouzaréah station as a part of the world network [4, 5]. At the present, this network is of no use because of the absence of an attachment scheme and a vague description of their location [6]. In 1983, Idres realized a gravimetric network for the north of Algeria. This network is composed of seventy-four reference stations and five replacement stations [7]. The low measures number and the measurements quality do not allow to use this network. Since, an absolute measurement network has been installed. This network is composed of twelve references distributed throughout the Algerian territory [8]. These absolute measurements serve as a reference stations for the development of local networks, such as the Mitidja gravimetric network [9]. Our study area does not have its proper gravimetric network, except for the reference station of gravimetric network established by Idres 1983 [7]. This reference station is located at the intersection of the Algiers-Oran and Chlef-Ténès national roads. This crossroads has since been refurbished and the gravimetric landmark destroyed. That why, it becomes necessary to install a new absolute gravimetric network in the concerned area.

In this work, we present the gravimetric network of the upper Chelif basin established recently. As a part of the geological structures of Khemis Miliana plain study, a gravimetric survey was initiated recently in the region [10]. To carry out this study we must start by the realization of gravimetric references network. It should be emphasized that the main objective of the establishment of this gravimetric network is to ensure a quality basis for all future works with respect to the gravimetric studies in the upper Chelif basin. The installed gravimetric network consists of twenty-six stations connected to the zero order gravimetric network by means of relative gravimetric measurements. All reference stations of this gravimetric network were carried out using a terrestrial LaCoste Romberg D220 gravimeter.

2. The zero order gravimetric Algeria network

The zero order gravimetric network of Algeria is represented by twelve absolute gravimetric stations, which are distributed over the whole territory of Algeria (Fig. 1). The measurements were realized during 2001 [8]. For an average occupancy time of more than 14 hours, the accuracy on the determination of the gravity is about of 1.5 μgals. During the absolute gravity measurement program, which was performed by INCT (Institut National de Cartographie et Télédetection), a set of 100 measurements is realized, each 17 minutes [8]. The average and the gap for each set are immediately calculated and displayed on the screen. The final value of gravity is calculated by taking the arithmetic mean of all the registered data. For each calculated gravity corrections sequence is applied. This sequence of processing is summarized by : movement equation, instrumental correction, geophysical corrections (earth tides, ocean overload, atmospheric pressure, Movement of the pole) [8].

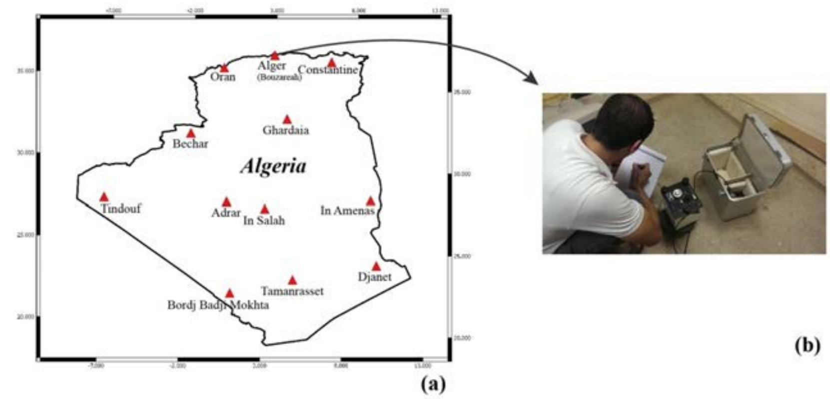

Fig. 1 – (a) Geographical distribution of the zero order gravimetric Algeria network [4]. (b) The zero order absolute station, located at Algiers (Bouzaréah) used in this work

3. Survey of the gravimetric network of the upper Chelif basin

The relative gravimetric survey of the gravimetric network ofthe upper Chelif basin included twenty six relative gravimetric stations (Fig. 2). All the stations were integrated into thirty-four geometric triangles and one polygon. In this way the gravimetric network of the upper Chelif basin was tied into the gravimetric network of the INCT. In the survey of the gravimetric network of the studied area, direct connections were created between single absolute gravimetric stations by means of relative gravimetric measurements. Four direct connections between the gravimetric reference station network of the upper Chelif basin and the zero order absolute station, located at Algiers (Bouzaréah, Fig. 1b) were measured. This connection is provided by the Hoceinia gravimetric reference station.

The absolute reference stations were measured using a terrestrial LaCoste Romberg D220 gravimeter. This special device in the gravimeters range is appropriate for such measurements type. This gravimeter is equipped with a thermostatic system and characterized by an instrumental accuracy of 1μgal ($1m/s^2 = 105mgals = 108\mu gals$). The topographic coordinates of gravimetric reference station were determined using a commercial navigation GPS device.

4. Choice of the site : reference gravimetric station

In order to install our absolute gravimetric network, we have chosen accessible, secure and easily identifiable places. We have realised twenty-six reference gravimetric stations, separated by a distance of about 15 to 20 km (Fig. 2). The majority of the reference gravimetric stations are built by a concrete slab measuring 40 cm x 40 cm, with a thickness of 15 cm.

Before choosing any site of gravimetric measurements, we should carefully consider that :

- The reference gravimetric station must be implanted on a hard outcrop, or on healthy ground. Thus, we cannot put a reference on a fragile soil or any places with possible underground cavity,
- The location must allow us to respect the time of closing and reserved the linear drift,
- The reference gravimetric station must be accessible, secure and easily identifiable, in our case we chose the seat of the municipality (APC).

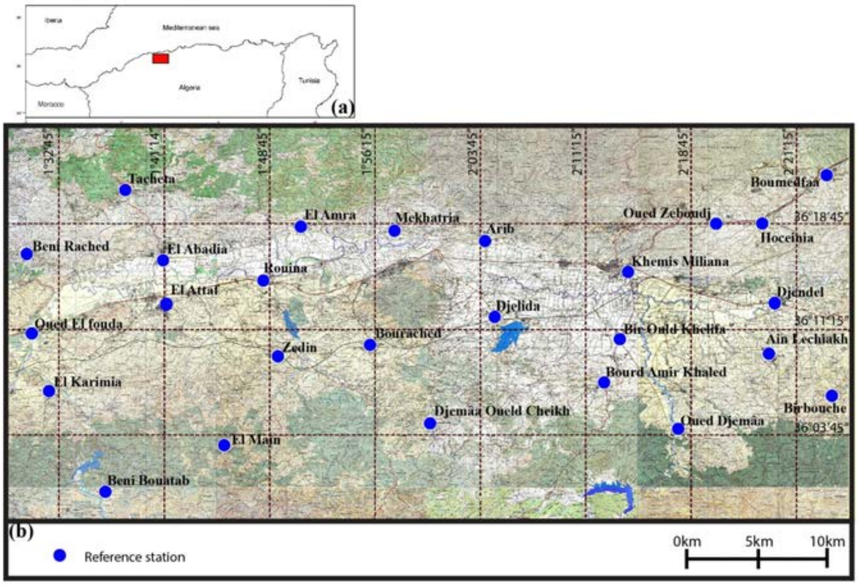

Fig. 2 – Location map of the study area.(a) The red rectangular represent de location of the upper chelif basin. (b) The geographical distribution of the gravimetric network of the upper Chelif basin

5. Data acquisition and processing

The measurements between the absolute stations were carried out using the scheme A-B-C-A-C-B-A (Fig. 3). This provided the opportunity to analyze the gravimetric datum, as well as it gives the possibility to control the absolute gravity values. Furthermore, these connections enabled comparisons between the adopted gravity values and the measured ones. For each loop, illustrated by a triangle (ABC, Fig. 3), we determined three "detla G". On the set of twenty-six reference stations, we proceeded generally by the triangular method, except for one polygon link between Arib – Khemis Miliana – Djendel and Djelida (Fig. 4). The connection between the gravimetric reference stations is performed by thirty-five meshes. This geometry is illustrated by thirty-four triangles and one polygon (Fig. 4). A total of sixty links between the twenty-six gravimetric reference stations has been realized during gravimetric cruise (Fig. 4).

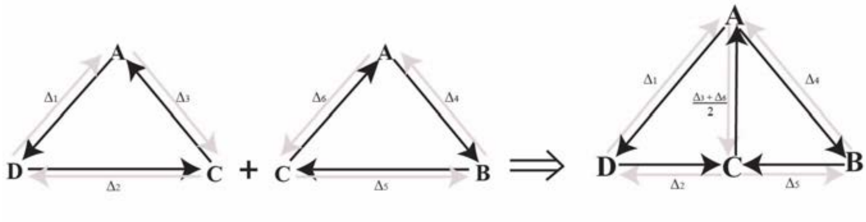

Fig. 3 – Acquisition protocol used for 'delta G' determination. A, B, C and D represent the gravimetric reference stations.

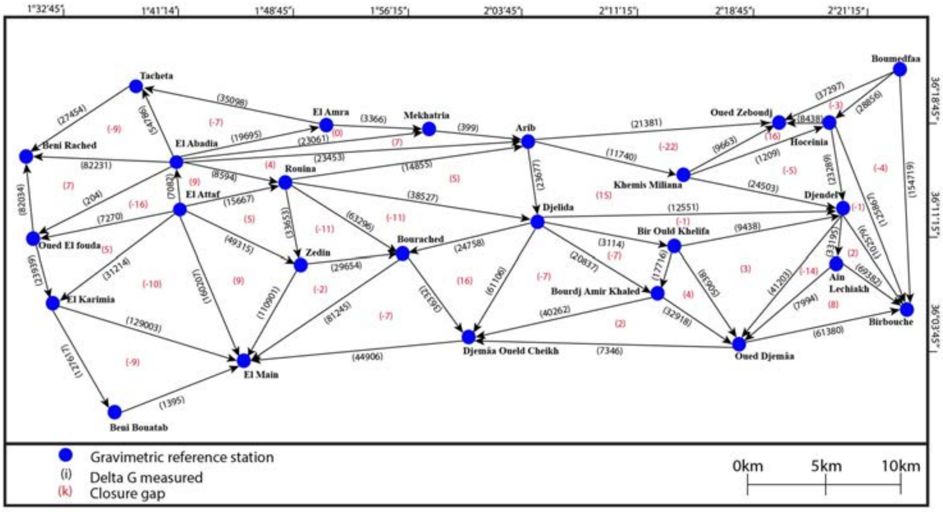

Fig. 4 – The gravimetric network of the upper Chelif basin. The black values show the measured gravity difference between two successive stations. The red values in the meshes represent the closure gap values

After the setting up and leveling of the instruments at any station, their heights were measured. Due to the vibrations which are present during the transport and carriage of the instrument, we waited for five minutes after the leveling of the instrument, in order to allow the measuring system to steady by itself. The observed gravity was calculated using the relative difference of the corrected device reading. Two gravimetric corrections were applied. Firstly, the moon-solar correction, which is calculated by introducing the measurement time and geographical coordinates of study area [11, 12]. This calculation is based on the Longman formula (1959), given by :

$$G_t = 3G_r/2[2M/(3d_{t1})^2(sin^2p\square 1)+M_r/(d_{t1})^4(5cos^3p\square 3cosp)+2S/(3D_{ts})^3(3cos^2q\square 1)] \quad (1)$$

G_t : the moon-solar correction,
p : the zenith angle of the moon,
q : the zenith angle of the solar,
M : the moon mass,
S : the solar mass,
d_{t1} : the distance between the earth and the moon,
D_{ts} : the distance between the earth and the solar.
Therefore, we apply the following correction :

$$R_t = R_c + G_t \quad (2)$$

R_t : the corrected measure of the moon-solar (in μgals),
R_c : the measure to correct (in μgals),
G_t : the moon-solar correction (in μgals).
Afterwards, we applied the instrumental drift correction ; we distributed it proportionally on all the device readings according to the observation time. The drift correction is

calculated by reoccupying a G of the known station several times. It's obtained by :

$$D = (R_c2 \square R_c1)/(t2 \square t1)$$

D : the instrumental drift (in $\mu gals/h$),
R_c2 : the corrected measure of the moon-solar at time $= t2$ (in $\mu gals$),
R_c1 : the corrected measure of the moon-solar at time $= t1$ (in $\mu gals$).

A reading is made at station A at time t1, then a reading at station B attime t2 and at C at time t3. Then, we must go back to station A to perform a reading at time t4, the difference between the two readings at station A corresponds to the drift of the gravimeter over the time interval (t4-t1). A check up on the closing gap of the mesh is performed to initiate an adjacent mesh. An average is then calculated and assigned to the common link to the other two meshes [2, 9]. This operation will continue until the completion of the network. The link between each two successive loops is provided by a common reference station (Fig. 4).

6. Reference network compensation :

After applying gravimetric corrections, six difference gravity values 'Delta G' are determined in each mesh showing in the figure 4 (ABC). The gravity values difference between two successive reference stations (ex. AB) is calculate for an average 'Delta G' value. Once, the difference gravity values between the relative stations of the gravimetric network were calculated, we determine the closing gap for each triangle. Theoretically the closure gap should be zero but in practice this is not the case. Then, the compensation is necessary to ensure that the results are uniform and thus avoid to have several gravity values to the same station [13]. In the literature, several compensation methods have been developed, we quote :

- The ginning method (called manual) : this method is based on the distribution of closure gaps on each link. The algebraic sum of these links must be zero. The operator shall ensure that the value added to each link does not exceed 10 μgals and a preferential distribution of closing differences must be adopted on each link [2, 14, and 15]. Then the operation is repeated until the network is compensated. For each mesh, we took an average of adjustment. This average represents the closure gap divided on three links. Then, we add this average value from the calculated difference gravity values.
- The auxiliary coefficients method : This method is carried out in two times. The first-one consists to determine the auxiliary coefficient (L) corresponding for each mesh [13, 15]. This determination is based on the resolution of the linear system (AX=B), as follows :

$$F_\mu = P_{\lambda\mu} L_\mu \square \sum N_{\mu\lambda} L_\lambda \qquad (3)$$

F_μ, $P_{\lambda\mu}$ and L_μ represent the closure gap, the side number and the auxiliary coefficient of the (μ) mesh.
$N_{\mu\lambda}$ and L_λ represent the common side number of the (λ) and (μ) meshes ; and the auxiliary coefficient of the (λ) mesh.

Then, we calculate the Correction (C_k) to be restored to each link [13, 15] :

$$C_k = \square \sum L_\lambda \varepsilon_{k\lambda} \tag{4}$$

With :
$\varepsilon_{k\lambda} = \square 1$ if the k side is crossed in the negative sense,
$\varepsilon_{k\lambda} = 0$ if the k side does not belong to the mesh,
$\varepsilon_{k\lambda} = +1$ if the k side is crossed in the positive sense.

– The Kirchhoff method : based on the similarity between a reference network and an electrical circuit [15]. Indeed, each mesh of gravimetric reference network station corresponds to a branch crossed by an electrical current, hence the writing of the nodes and meshes equations [7]. In order to determinate the correction, noted Ei, the system $AX = B$ must be resolved, as follows :

$$\sum E_i = 0 \text{ (nodes equation)} \tag{5}$$

$$\sum E_i = \square F_\mu \text{ (meshes equation)} \tag{6}$$

E_i and $\square F_\mu$ represent the correction to be brought to the mesh and the mesh closure gaps, respectively.

All these automatic methods based on the squares means, divided obtained gaps in a uniform way. This redistribution of the gaps ignores the field measurement quality. Only the ginning method takes into account the operator's field observations. In our case and in order to correct the closure gaps we adopted the ginning method (Fig. 5). The final difference gravity values between the relative stations of the gravimetric network of the upper Chelif basin are given in the figure 5.

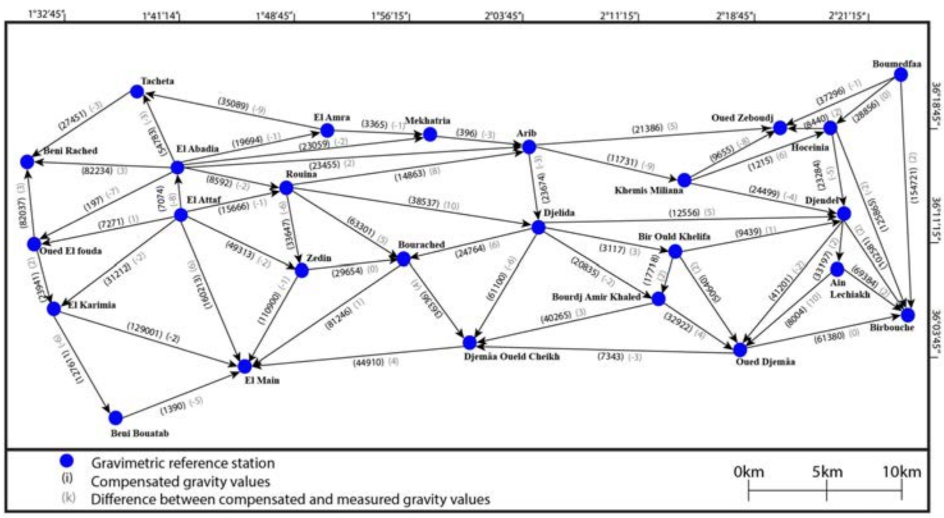

Fig. 5 – The gravimetric network of the upper Chelif basin. The black values represent the compensated gravity values. The grey values show the difference between the compensated and measured values

7. Attachment to the zero order gravimetric Algeria network

After calculating of the difference gravity values between the relative stations of the gravimetric network of the upper Chelif basin, we will perform the final gravity values 'G' calculation step. This calculation is based on the attachment of one of reference stations established with one of the zero order gravimetric Algeria network reference. For this, we used the absolute gravity reference of Algiers, located at Bouzaréah inside the CRAAG. We proceeded by linear link (G0-G1-G0-G1-G0) ; when G0 represent the zero order gravity reference station at the Bouzareah (CRAAG) and G1 represent the first order gravity reference station established at the Hoceinia (Fig. 2). After calculating the final gravity Hoceinia reference station, we will be able to know the value of the gravity at the others gravimetric reference stations of the upper Chelif basin (Tab. 1).

To estimate the error on the determination of gravity values for each gravimetric reference stations established in the upper Chelif basin, we have determined the standard deviation of each station for "N" carried out measurements. As the instrumental accuracy is about of 1μgal, the accuracy on the mean value for "N" measures will represent the standard deviation for all measurements divided by square root of N [16].

$$\delta = \frac{\sigma}{\sqrt{N}} \tag{7}$$

δ : The accuracy,
σ : the standard deviation,
N : the number of measurements.

In our case, the standard deviation of the gravity measurements is ranging from 0 to 22 μgals. Each gravimetric reference station is measured 3 times, or 6 times to ensure the connection between two successive meshes. This gave us, the determination accuracy of the measured gravity values at each individual station within a range of 1 $\mu gals$ to 13 $\mu gals$. Finally, to give a single accuracy for the determination of the gravity values of the whole gravimetric network of the upper Chelif basin, we consider the highest value of the standard deviation from all performed gravity measurements. So, we estimated the accuracy to be about 13 μgals.

Table 1 – The final gravity values of the gravimetric stations of the upper Chelif basin

Reference station	**Longitude**	**latitude**	**G** ($\mu gals$)
El Abadia	1,6860	36,2689	979806965
AinLechiakh	2,4048	36,1589	979714083
El Amra	1,8494	36,3089	979787271
Arib	2,0680	36,2919	979783510
Birbouche	2,4796	36,1090	979644699
BeniBouatab	1,6176	35,9950	979655216
BeniRached	1,5242	36,2764	979724731
BirOuldKhelifa	2,2280	36,1761	979756719
Bordj Amir Khaled	2,2093	36,1247	979739001
Boumedfaa	2,4734	36,3699	979799420
Bourached	1,9315	36,1693	979735072
Djelida	2,0794	36,2025	979759836
DjemâaOueldCheikh	2,0029	36,0762	979698736
Djendel	2,4118	36,2185	979747280
El Attaf	1,6822	36,2233	979814039
EL Karimia	1,5506	36,1145	979782827
Hoceinia	2,3970	36,3126	979770564
KhemisMiliana	2,2378	36,2551	979771779
El Main	1,7585	36,0503	979653826
Mekhatria	1,9606	36,3040	979783906
Oued El Fodda	1,5302	36,1830	979806768
OuedDjemâa	2,2972	36,0697	979706079
OuedZeboudj	2,3422	36,3124	979762124
Rouina	1,8050	36,2449	979798373
Tacheta	1,6412	36,3523	979752182
Zedin	1,8223	36,1558	979764726

8. Conclusion

The fundamental gravimetric network of the upper Chelif basin consists of twenty-six relative stations. The measurements were performed using a terrestrial LaCoste Romberg D220 gravimeter. Data post-processing was performed by taking into account all the necessary reductions for the measured gravity values (moon-solar and drift corrections). Such corrected gravity values at each single gravimetric station provided needed data to estimate the differences between considered gravity stations. The final gravity values for the relative gravimetric stations of the upper Chelif basin were obtained by adjusting all the observations over the entire network. The accuracy of determination of the gravity values at each individual station is about of 13 μgals. It could be concluded that the measurements in the fundamental gravimetric network of the upper Chelif basin were well performed. Hence, the obtained gravity values show an appropriate accuracy. It would be advisable to repeat the gravimetric observations over the network within the next few years, in order to obtain an insight into the possible changes in gravity over time.

Acknowledgements

This paper is the result of a scientific research project funded by the CRAAG (Centre de Recherche enAstronomie, AstrophysiqueetGéophysique), which was carried out by the gravimetric and geodesic team. The authors are grateful for this financial support. We also thank the editor and the anonymous reviewers for their constructive remarks and comments that allowed significant improvements to be made.

REFERENCES

[1] Abtout, A., Boukerbout, H., Bouyahiaoui, B., &Gibert, D., 2014. Gravimetric evidences of active faults and underground structureof the Cheliff-seismogenic basin (Algeria). Journal of AfricanEarth Sciences, 99, 363–373. doi :10.1016/j.jafrearsci.2014.02.011.

[2] Koler, B., Medved, K &Kuhar, M., 2012.The new fundamental gravimetric network of Slovenia.ActaGeod. Geoph. Hung., Vol. 47(3), pp. 271–286. DOI : 10.1556/AGeod.47.2012.3.1.

[3] Bouyahiaoui, B., Djeddi, M., Abtout, A., Boukerbout, H. &Akacem, N., 2011. Etude de la croûte archéenne du môle In Ouzzal (Hoggar Occidentale) par la méthode gravimétrique : identification des sources par latransformée en ondelettes continues, Bull. Serv. Geol. Nat., 22, 259–274.

[4] Lagrula, J., 1951. Etude gravimétrique de l'Algérie-Tunisie. Bull. Serv. Carte Géol., Algérie, 4, 2, 114p.

[5] Lagrula, J., 1959. Nouvelles études gravimétriques, première partie, stations de référence de l'Algérie et du Sahara. Publ. Serv. Carte Géol., Algérie, Nouvelle série, 25, travaux collaborateurs.

[6] Bureau Gravimétrique International B.G.I., 1977; 1978. Transformation du système ORSTOM en IGSN1971 à partir des résultats publiés dans le catalogue : « Etablissement de l'IGN71 ». Cf (4), Univ. P. et M. Curie, Paris (France).

[7] Idres, M., 1983. Réseau de bases de référence et cartes des anomalies de Bouguer et isostatique de l'Algérie du Nord; Etude gravimétrique du massif d'Alger. Thèse de Magister, USTHB, Alger (Algérie), 75p.

[8] Olivier, F., 2002. Réseau de gravimétrie absolue algérien. Bulletin des Sciences Géographiques,N°09, INCT.

[9] Foudil-Bey, N., 2003. Etablissement d'un réseau de bases pour la plaine de la Mitijda, Etudegravimétrique de la région d'AinTaya.Mémoire d'ingéniorat USTHB. 66 pages.

[10] Bendali, M., Bouyahiaoui, B., Boukerbout, H., Neche, B., Bentridi, S-E., Abtout, A., 2019. Gravimetric study of the KhemisMiliana plain (upper Cheliff basin) : Structure of the transition zone between the Cheliff and Mitidja basin (North of Algeria). The Structural Geology Contribution to the Africa-Eurasia Geology : Basement and Reservoir Structure, Ore Mineralisation and Tectonic Modelling. DOI : 10.1007/978-3-030-01455-1_60.

[11] Chouteau, M., 2002. Géophysique appliquée I. Ecole Polytechnique de Montréal. 103 pages.

[12] Dubois, J., Diament, M., & Cogne, J-P., 2010. Géophysique, Cours et exercices corrigés, 4eme édition, Dunod.

[13] Idres, M &Aifa, T., 1995. Some parameters to improve gravity network accuracy : application to new reference base station network of North Algeria. Bull. Serv. Geol. Algérie. Volume 6, Numéro 1, Pages 79-94.

[14] Yaghoub, H., 2010. Etablissement des nouveaux réseaux multi-observations géodésiques et gravimétriques et détermination du géoïde en Iran. Thèse de doctorat, université de Montpellier II, pages 193.

[15] Idres, M., Bourmatte, A., Ouyed, M., &Boughacha, M-S. 2013. Quelques procédures pouvant améliorer la qualité d'un réseau gravimétrique, Bulletin des Sciences Géographiques, N°28, 45-50.

[16] Schoeffler, J. 1975. Gravimétrie appliquée aux recherches structurales et à la prospection pétrolière et minière. Paris, Edi Technip.