The new gravimetric network of the north-eastern part of Algeria

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ABSTRACT

The north of Algeria is situated between the limit of the African and Eurasian plates. It considers as one of the best areas to study neotectonics structures and their geodynamical effects. On offshore, recent geophysical studies have allowed to imaging the deep structure of the Algerian basin. However, these images need to be improved and adjusted on onshore, especially in the easternmost part where, the process of geodynamic evolution is particular, with slow but hot accretion processes. This paper presents all stages of the gravimetric network of the north-eastern part of Algeria, including its development and data processing. The established gravimetric network is located between coordinates 07°00′–08°00′ east and 36°00′–36°45′ north. It consists of thirty-nine stations connected to the zero-order gravimetric network by means of relative gravimetric measurements. This gravimetric network contains 61 triangular geometry loops and 99 links. The description of the design, the gravity survey network and the gravimetric stations coordinates are given. The accuracy of the determination of gravity values at each station is about 11 μGal, using a terrestrial Scintrex CG3 gravimeter. The gravimetric network is compensated using ginning and the least squares methods. 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 north-eastern part of Algeria.

1. Introduction

A wide-angle seismic data constrained by multichannel seismic reflection, gravity and magnetic data have allowed imaging eastern Algerian basin deep structure and its southern margin (Bouyahiaoui et al., 2015; Arab et al., 2016). Based on the crustal structure and the magnetic anomaly pattern of the deep basin, a kinematic reconstruction model was proposed by Bouyahiaoui et al. (2015). On onshore, this model is poorly fit because the terrestrial part is not covered by the reverse shots, and thus precise modeling of the reflectors at this place was not possible. Therefore, to better fitting the kinematic reconstruction model, geophysical studies are planned in the north-eastern part of Algeria. This part is a large plain that is formed of African Mesozoic to Cenozoic sedimentary cover and characterized by intense Triassic salt diapirism (Dubourdieu, 1956; Rouvier, 1977; Chikhi Aouimeur, 1980; Perthusirot and Rouvier, 1992). It appears as a depression elongated E-W and bordered by reliefs made up of allochthonous lands belonging to the Tellian domain (Vila, 1980). Inside this plain, the most known and studied-one is the Guelma Neogenic intra-mountainous basin, “pull–apart” type, which is tectonically very active (Harbi et al., 1999; Yelles-Chaouche et al., 2006). It is delimited by faults’ borders (Boucheougouf and Hammam N’baïlis faults) which generated a seismic event such as 21/12/1980 Ms = 5.2, 19/01/1997 Ms = 4.0 and 26/09/2003 Ms = 4.8 (Harbi and Maouche, 2009; Bendjama et al., 2021). These faults might be related to the hydrothermal activity in the region (Maouche et al., 2013). As a part of the geological structure of north-eastern part of Algeria, a gravimetric survey was initiated recently in the region. In this work, the established gravimetric network is presented for the first time. The gravimetric network considers the first feasible step before any gravimetric study.

Several jobs on the gravimetric networks were carried out in Algeria. The first reference gravimetric station network of Algeria has been realized by Lagrula (1951, 1959) (Lagrula, 1951, 1959). This network was established in Algeria and Tunisia, using a gravimeter with 100 μGal drift. At the present, this network is of no use because of the absence of an attachment scheme, a vague description of their location and urban development. In 1983, a second gravimetric network was established by Idres, in the north of Algeria using Worden 774 gravimeter (Idres, 1983). This network is composed of seventy-four reference stations and five replacement stations. Actually, the few measures number of...
references stations, the very wide distance and the measurements quality do not allow using this network. In 2000, an absolute measurement network has been installed by Institut National de Cartographie et Teledetection (INCT) (Olivier, 2002). This network consists of 12 references stations distributed throughout the Algerian territory (Figure 1). For the first time, the absolute network of order zero was created in Algeria, with accuracy of the determination of gravity values at individual stations about 0.5 μGal to 1.5 μGal, using a FGS gravimeter (Olivier, 2002). Locally, Foudil-Bey in 2004 executed gravimetric network in the Mitidja basin (north of Algeria) using Scintrex CG3 gravimeter, with determination accuracy of about 12 μGal (Foudil-Bey, 2003). Recently, a new gravimetric network was executed in the upper Cheliff basin (north of Algeria) (Bendali et al., 2019, 2022). The accuracy of the determination of gravity values at individual stations is about 13 μGal, using LaCoste Romberg D220 gravimeter.

Several gravimetric surveys were acquired in the north-eastern part of Algeria (e.g. Zerdazi, 1990; Abbout et al., 2009; Boubaya et al., 2011; Maouche et al., 2013). In order to complete and homogenize the gravimetric database, we present the gravimetric network established in 2020. It is located at coordinates 07° 00’–08° 00’ east and 36° 00’–36° 45’ north. 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 north-eastern part of Algeria. The installed gravimetric network consists of thirty-nine stations connected to the zero-order gravimetric network by means of relative gravimetric measurements. All reference stations of this gravimetric network are carried out using a terrestrial Scintrex CG3 gravimeter.

2. Acquisition, data quality and processing

We have chosen accessible, secure and easily identifiable places to install the north-eastern part of Algeria network. In the first time, we built slabs. Then, in second phase we measure the gravity “G”. In order to attenuate the entropic noise and collapse of the gravimetric references, we construct concrete slabs measuring 40*40 cm², with a thickness of 12 cm. We have executed thirty-nine reference gravimetric stations, separated by a distance of about 15 km (Figure 2). The gravity measurements program is performed by Scintrex CG3 gravimeter and their topographic coordinates are determined by Garmin navigation GPS. The established gravimetric network at north-eastern part of Algeria forms a mono-block,
Figure 2. Location maps of the study area. (a) The red square represents the north-eastern part of Algeria location, (b) shows the gravimetric network geographical distribution and (c) used acquisition protocol.
as recommended in the literature (e.g., Basic et al., 2004). This gravimetric network contains 61 triangular geometry loops and 99 links (Figure 2). This trigonometric geometry allows reducing the error on difference of gravity calculation between two stations “delta G”. In addition, before starting the measurement, the gravimeter is allowed to stabilize for 5 min in order to reduce the instrumental error. The measurement time on each reference station is of 60 s by one value. We have registered 4 repeated values for each reference station. Overall, the difference between them did not exceed 5 μGal. Except for few isolated cases (very strong winds and rain), we have redone measurements.

The measurements between the absolute stations are carried out using the following diagram A-B-C-A-C-B-A (Figure 2c). For each loop, illustrated by a triangle, we determine three “delta G”. On the set of thirty-nine reference stations, we proceed by triangular method, except for one directly link between BordjSabat–Essebt. These triangles are connected to each other and form a single block. The link between each two successive loops is provided by a common reference station. The installed network is attached with the zero-order gravimetric Algeria network reference. The connection is assured by the absolute gravimetric reference of Constantine, located at Ain Smara inside the Centre de Recherche en Astronomie, Astrophysique et Géophysique (CRAAG) regional station.

The observed gravity is calculated using the relative difference of the corrected device reading. The lunar-solar correction is a direct computation of the tidal potential following the formula proposed by Longman (1959) and developed by Gemael (2002); Amarante and Trabanco (2016). The ocean tides exert a periodic overload on the ocean floor. This charge causes a gravimetric signal of same periodicity as the terrestrial

Figure 3. The gravimetric network of the north-eastern part of Algeria. The black values show the measured ‘delta G’ between two successive stations. The blue values inside the different triangles represent the closure gap values.
Table 1. Link values before and after compensation using the manual and the least square methods.

| Link                        | Measured Delta G (µGal) | Adjusted Delta G (µGal) |
|-----------------------------|-------------------------|-------------------------|
| Ain Charchar – Azzaba       | 15443                   | 15449                   |
| El Elmia – Ain Charchar     | 8396.6                  | 8396.6                  |
| Cheurfa – El Elmia          | -2996                   | -2999                   |
| Drear – Cheurfa             | -6119                   | -6115                   |
| Besbes – Drear              | -10345                  | -10350                  |
| Souk Ahras – Besbes         | -207831                 | -207837                 |
| Es Sebt – Azzaba            | 25038                   | 25045                   |
| Ain Charchar – Es Sebt      | -40487                  | -40494                  |
| Ain Charchar – Bekkouch Lakhdar | -9639                  | -9636                   |
| El Elmia – Bekkouch Lakhdar | -18032                  | -18034                  |
| Cheurfa – Bekkouch Lakhdar  | -15033                  | -15041                  |
| Nechmaya – Cheurfa          | 74140                   | 74133                   |
| Nechmaya – Ain Ben Beida    | 32770                   | 32768                   |
| Bekkouch Lakhdar – Nechmaya | -59089                  | -59092                  |
| Bekkouch Lakhdar – Es Sebt  | -30858                  | -30858                  |
| Bekkouch Lakhdar – Bouati Mahmoud | -42457                | -42459                  |
| Bouati Mahmoud – Nechmaya   | -16638                  | -16633                  |
| Bouati Mahmoud – Ain Ben Beida | 11605                  | 11603                   |
| Cheurfa – Ain Ben Beida     | -41360                  | -41365                  |
| Drear – Ain Ben Beida       | -35254                  | -35250                  |
| Chihan – Ain Ben Beida      | -13521                  | -13515                  |
| Drear – Chihan              | -21740                  | -21735                  |
| Besbes – Chihan             | -11380                  | -11385                  |
| Bordj Sahab – Es Sebt       | 127447                  | 127419                  |
| Es Sebt – Bouhamdane        | -90788                  | -90776                  |
| Bordj Sahab – Bouhamdane    | 36653                   | 36643                   |
| Bouhamdane – Rokia          | 44076                   | 44070                   |
| Es Sebt – Rokia             | -46715                  | -46706                  |
| Rokia – Bouati Mahmoud      | 35112                   | 35105                   |
| Bouati Mahmoud – Guelma     | -67851                  | -67844                  |
| Rokia – Guelma              | -32743                  | -32739                  |
| Guelma – Guelat Bou Shaa    | 21848                   | 21852                   |
| Guelat Bou Shaa – Bouati Mahmoud | 45995                  | 45992                   |
| Nechmaya – Guelat Bou Shaa  | -29342                  | -29359                  |
| Nechmaya – Bouchechouf      | -7441                   | -7426                   |
| Ain Ben Beida – Bouchechouf | -40206                  | -40194                  |
| Chihan – Bouchechouf        | -53720                  | -53709                  |
| Bouchechouf – Medjefzia     | -19981                  | -19991                  |
| Medjefzia – Chihan          | 73715                   | 73700                   |
| Medjefzia – Machroha        | -124182                 | -124200                 |
| Chihan – Machroha           | -197891                 | -197900                 |
| Machroha – Besbes           | 209277                  | 209285                  |
| Machroha – Souk Ahras       | 1433                    | 1447                    |
| SellaoouAnnouna – Bordj Sahab | 30135                   | 30132                   |
| SellaoouAnnouna – Bouhamdane | 66783                   | 66775                   |
| SellaoouAnnouna – Hammam Debagh | 84973                  | 84772                   |
| Bouhamdane – Hammam Debagh  | 18000                   | 17999                   |
| Hammam Debagh – Rokia       | 26076                   | 26071                   |
| Guelma – Hammam Debagh      | 66644                   | 6668                    |

Table 1 (continued)

| Link                        | Measured Delta G (µGal) | Adjusted Delta G (µGal) |
|-----------------------------|-------------------------|-------------------------|
| Guelma – SellaoouAnnouna    | 78105                   | 78106                   |
| Guelma – Boumahra Ahmed     | 22005                   | 21997                   |
| Boumahra Ahmed – Guelat Bou Shaa | -143                | -145                    |
| Boumahra Ahmed – Nechmaya   | 29214                   | 29214                   |
| Boumahra Ahmed – Bouchechouf | 21776                   | 21788                   |
| Ain Regada – Bordj Sahab    | 68156                   | 68168                   |
| Oued Zanati – Ain Regada    | -32965                  | -32971                  |
| Oued Zanati – Bordj Sahab   | 35194                   | 35197                   |
| SellaoouAnnouna – Oued Zanati | -5062                  | -5065                   |
| SellaoouAnnouna – Ain Mahklof | -58775                 | -58751                  |
| SellaoouAnnouna – Ain Larbi | -60218                  | -60229                  |
| SellaoouAnnouna – Ain Larbi | -138223                 | -138235                 |
| Guelma – Ain Larbi          | -29394                  | -29396                  |
| Guelma – Khezzara           | 108930                  | 108937                  |
| Khezzara – Boumahra Ahmed   | 51401                   | 51393                   |
| Khezzara – Hammam N’bail    | -13217                  | -13224                  |
| Hammam N’bail – Boumahra Ahmed | 64618                  | 64617                   |
| Hammam N’bail – Bouchechouf | 86413                   | 86405                   |
| Hammam N’bail – Medjefzia   | 66422                   | 66414                   |
| Hammam N’bail – Machroha    | -57777                  | -57786                  |
| Hammam N’bail – Ain Larbi   | -95709                  | -95715                  |
| Ain Larbi – Ain Mahklof     | 1461                    | 1458                    |
| Ain Mahklof – Oued Zanati   | 53708                   | 53706                   |
| Tamouka – Oued Zanati       | 46599                   | 46606                   |
| Tamouka – Ain Mahklof       | -7106                   | -7100                   |
| Tamouka – Ain Soltan        | -67297                  | -67303                  |
| Ain Soltan – Ain Mahklof    | 60200                   | 60203                   |
| Ain Soltan – Ain Larbi      | 58735                   | 58745                   |
| Ain Soltan – Sedrata        | 55087                   | 55096                   |
| Ain Larbi – Sedrata         | -3660                   | -3649                   |
| Ain Larbi – Khezzara        | -19192                  | -19187                  |
| Khezzara – Hammam N’bail    | 114905                  | 114902                  |
| Bir Bouhouche – Tamouka     | 33362                   | 33372                   |
| Bir Bouhouche – Ain Soltan  | -33923                  | -33931                  |
| Sedrata – Bir Bouhouche     | -21160                  | -21165                  |
| Sedrata – Oum El Adhaim     | -38538                  | -38525                  |
| Oum El Adhaim – Bir Bouhouche | 17362                  | 17360                   |
| Khezzara – Oum El Adhaim    | -29273                  | -29287                  |
| Md’adourouche – Oum El Adhaim | -13395                 | -13390                  |
| Sedrata – Khemissa          | -15549                  | -15538                  |
| Khemissa – Md’adourouche    | -9594                   | -9597                   |
| Md’adourouche – Tiffech     | 5107                    | 5100                    |
| Md’adourouche – Zaouroria   | 45543                   | 45537                   |
| Zaouroria – Tiffech         | -40435                  | -40437                  |
| Tiffech – Khemissa          | 4499                    | 4497                    |
| Tiffech – Hammam N’bail     | 119411                  | 119399                  |
| Tiffech – Souk Ahras        | 63066                   | 63060                   |
| Mechroha – Tiffech          | -61266                  | -61613                  |
tides. The amplitude depends on the distance between the oceans and the considered station. In our case, these overload effects have been calculated, they are less than 1 μGal. In addition, the operator must record the measurement time and geographical coordinates of study area. We apply the instrumental drift correction. In this case we consider the drift is linear and we distribute it proportionally on all the device readings according to the observation time. Practically, a reading is realized at station A at time t1, a second and a third measurements at stations B and C at time t2 and t3 respectively. 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). This instrumental drift is obtained by Eq. (1).

\[
D = \frac{(Rc_2 - Rc_1)}{(t_2 - t_1)}
\]

(1)

where, D: the instrumental drift (in μGal/h).

\(Rc_2\): the reading value at time = t_2 (in μGal),

\(Rc_1\): the reading value at time = t_1 (in μGal).

After applying the instrumental drift correction, we calculate the difference of gravity between two successive stations. In each triangle, we determine six difference gravity values “delta G”. The final gravity difference calculated represents an average of “delta G” between two successive stations. Once, the gravity difference values between the relative stations of the gravimetric network are calculated, we determine the closing gap for each triangle (Figure 3).

### 3. Compensation of the gravimetric reference network

Theoretically the closing gap should be equal to zero, however in practice this is not the case. Therefore, the determined closing gap for each triangle must be compensated. We divide the obtained value of closing on the three links of each triangle (Koler et al., 2012; Bendali et al., 2019). The challenge is to compensate all closing gap in order to make this value zero. Accordingly, we must choose the same direction of orientation for all the meshes (Idres and Aïfa, 1995). There are several theories to make the compensation; among these theories are the following methods:

- **The auxiliary coefficients method**: this method focuses on two steps; the first-one is for the determination of the auxiliary coefficient (L) for each mesh (Idres and Aïfa, 1995; Idres et al., 2013). This determination is performed using the formula (AX = B) and assumed to be linear.

The origin of this formula is the following Eq. (2):

\[
F_\mu = P_\mu L_\mu - \sum N_\mu L_\lambda
\]

(2)

\(F_\mu\), \(P_\mu\) and \(L_\mu\) represent the closing gap; the symbol on the side is the auxiliary coefficient of the mesh (μ).

\(N_\mu\) and \(L_\lambda\) represent the number of common sides of the meshes (λ) and (μ); and the auxiliary coefficient of the mesh (λ).

Then, with Eq. (3) we calculate the Correction (Ck) to be restored to each link (Idres and Aïfa, 1995; Idres et al., 2013):

\[
C_k = - \sum L_\lambda e_{k,\lambda}
\]

(3)

with:

- \(e_{k,\lambda} = -1\) if the k side is crossed in the negative sense,
- \(e_{k,\lambda} = 0\) if the k side does not belong to the mesh,
- \(e_{k,\lambda} = +1\) if the k side is crossed in the positive sense.

- **The Kirchhoff method**: this method relies on the existing likeness between the gravimetric reference network and the electrical circuit. In fact, that means each mesh that makes up the basic gravimetric reference network tie in the meshes crossed by an electrical current. In a simpler way we can assimilate to the reference gravimetric base network the same corrections as for the electrical circuit. Hence, the writing of the mesh equation is similar. In order to determine the correction in this method we have to solve the linear system AX = B, knowing that there will be a large multiplication of equations. Eqs. (4) and (5) allow the adjustment of gravity network.

**Figure 4. The difference between the measured and compensated gravity using the least squares method.**
Nodes equation: \( \sum E_i = 0 \)  

Meshes equation: \( \sum E_i = -F_\mu \) 

\( E_i \) and \(-F_\mu\) in Eqs. (4) and (5) represent the correction to be brought to the mesh and the mesh closure gaps, respectively.

- **The least squares method:** this method allows obtaining the most probable values of gravity using the least squares (Koler et al., 2012). The adjustment is illustrated by relationship between the measured and the requested values, given by following Eq. (6):

\[
R + R_c = G + N_0 + D
\]

where \( R \) is gravimetric reading, \( R_c \) is the correction of gravimetric reading, \( G \) is the value of gravity, \( N_0 \) is daily gravimeter zero, and \( D \) is gravimeter drift. Since the differences in gravity between two reference stations are used with relative gravimetric measurements, then the amount for the daily zero \( N_0 \) is cancelled (Basic et al., 2004). Eqs. (7) and (8) allow the adjustment of gravity network.

\[
I + V = A x
\]

where \( I \) is the vector of shortened measurements, \( A \) is the configuration matrix, \( x \) is the vector of unknowns;

\[
s_0 = \sqrt{\frac{\nu'Pv}{m - n - d}}
\]
with: $s_0$ is the reference error (mean error of unit weight). $P$ is the weight matrix; $m$ is the number of measurements; $n$ is the number of unknowns and $d$ is the network defect.

- **The weighted and datum-free constraints:** The adjustment model can be either weighted constraint or datum-free, depending on data and specific requirements (Hwang et al., 2002). This model is chosen when there is a reliable additional gravity data used to adjust the network. Indeed, when it is necessary to attach a gravity network to an existing gravity network of a higher order. The datum-free model requires no gravity datum and uniquely determines relative gravity values among all stations. The estimated gravity values are derived from the first gravity value (called starting gravity value).

The ginning method: is known as the manual method. It relies on the manual delivery of the closure gaps on each link. Besides, by adding that theoretically the sum must be equal to zero. Precisely, the closure gap must be distributed over the different loop mesh. Therefore, the operator must ensure that the added value to each link must be balanced. The operator must also affect the compensation corrections on the all-relative gravimetric network, until the latter is compensated (Yaghoub, 2010; Koler et al., 2012; Idres et al., 2013). As it is mentioned previously the closure deviation of each mesh must be distributed in a locally balanced manner at the level of the loops. Then, we add these values to the value obtained from the difference in gravity calculated between the various points of the mesh.

These methods are automatically relying on the squares means with a uniform division of the closures gaps. In addition, the ginning method takes into consideration the quality of measurement according to the observations of the operator in the field. In our case, in order to have an unerring correction of the closing gaps and to correct everything carefully step by step, we apply the manual and the least square methods. Firstly, the gravity network was adjusted using the least squares method to combine the relative-gravity observations to determine a single best-fit gravity value at each station. The network adjustment was carried out using the software GSAdjust from USGS (Hwang et al., 2002; Kennedy, 2020). Least-squares adjustment provides an estimate of statistical uncertainty. A datum-free model needs no gravity datum and uniquely determines relative gravity values at each station, and using the chi-square test, an estimate of the overall network uncertainty. After adjusting the gravity data, the difference between the compensated and measured values from this software are presented in the table below (Table 1). The difference between the measured and adjusted gravity differences (residuals) is represented as Gaussian (Figure 4). The average station adjusted-gravity standard deviation is about $15 \mu$Gal.

In the case of punctual studies carried out with the same operator and only one gravimeter, the ginning (manual) method is very reliable. It allows to take into consideration measure-by-measure and associate the compensation according to the measurement conditions (e.g., high drift, noise, etc.). The final gravity difference values at the relative stations of the gravimetric network of the north-eastern part of Algeria are given in Figure 5.

**4. Link to the zero order gravimetric Algeria network**

We proceed to perform the final values of gravity for all relative stations in our gravimetric network of north-eastern part of Algeria. It will be the final step to have real values of relative gravity. The fundamental step to begin the calculation is to connect the new gravimetric network at a known base. For this step we will use the station of Algerian absolute network. We use the absolute gravimetric reference of Constantine, located at Ain Smara inside the CRAAG regional station. We proceed by linear link $(G_0, G_1, G_2, G_3)$; where $G_0$ represents the zero-order gravity reference station (Constantine) and $G_i$ represents the established gravity reference station. After calculating the final gravity of the new reference station, we can determine the gravity value for others gravimetric reference of the north-eastern part of Algeria (Table 2).

**5. Error estimate**

The gravimetric measurement is meaningless if it is not accompanied by its accuracy. A first type of parasitic error is eliminated by repeating the measurements at each station. The second type of error depends on the performance of the instrument and its accuracy, these are the experimental errors. We consider the mean squared error as the most probable error for all accidental (experimental) errors. We mention that the instrumental accuracy is about $5 \mu$Gal, as described previously.

To estimate the accidental error on the determination of gravity values at each established gravimetric reference station in the north-eastern part of Algeria, we have determined the standard deviation of each measurement (N). The standard deviation for all measurements which is divided by square root of (N) is represented by the mean value for (N) measures (Schoeffler, 1975). It is illustrated by Eq. (9);

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

**Table 2. The final gravity values at the gravimetric stations of the north-eastern part of Algeria.**

| Reference station     | Longitude | Latitude | G (\(\mu\)Gal) |
|-----------------------|-----------|----------|-----------------|
| Ain Ben Beida         | 7,6958    | 36,6147  | 979857126       |
| Ain Charchar          | 7,2215    | 36,7325  | 979893086       |
| Ain Larbi             | 7,3968    | 36,2669  | 979634812       |
| Ain Makhlouf          | 7,2515    | 36,2451  | 979636270       |
| Ain Regada            | 7,0738    | 36,2602  | 97967005         |
| Ain Soltan            | 7,3532    | 36,1825  | 979576067        |
| Azzaba                | 7,1060    | 36,7423  | 97987763         |
| Bakkouch Lakhdar      | 7,3074    | 36,6984  | 979883450        |
| Bbeses                | 7,8464    | 36,7011  | 979882026        |
| BirKeboubache         | 7,4269    | 36,0151  | 979609998        |
| Bordj Sabath          | 7,0439    | 36,4050  | 979725173        |
| Bouariti Mahrous       | 7,3281    | 36,5910  | 979840991        |
| Bouchegouf            | 7,7292    | 36,4711  | 979816932        |
| Boughanane            | 7,1129    | 36,4633  | 979671816        |
| Boumahrah Ahmed       | 7,5131    | 36,4604  | 979795144        |
| Cherfka               | 7,5540    | 36,7204  | 979859491        |
| Chiliani              | 7,7765    | 36,6469  | 979870641        |
| Dérat                 | 7,7496    | 36,6883  | 979892376        |
| El Eulma              | 7,4629    | 36,7381  | 979901482        |
| Es Sebt               | 7,0783    | 36,6618  | 979852592        |
| Guelaa Bou Sbaa       | 7,4741    | 36,5483  | 979794999        |
| Guelma                | 7,4299    | 36,4614  | 979731747        |
| Hammam Debagh         | 7,2719    | 36,4581  | 979779815        |
| Hammam N’Bail         | 7,6411    | 36,3250  | 979730527        |
| Khemissa              | 7,6506    | 36,1966  | 979615625        |
| Khezzara              | 7,5306    | 36,3690  | 979473571        |
| M’douourouch          | 7,8199    | 36,0762  | 979606028        |
| Mechrouch             | 8,3874    | 36,3579  | 979762741        |
| Medjesfia             | 7,7840    | 36,4339  | 97996941         |
| Nechmaya              | 7,5123    | 36,6106  | 979824358        |
| Oued Zenati           | 7,1673    | 36,3177  | 979689976        |
| Oum El Adhaim         | 7,6049    | 36,0258  | 979592638        |
| Roknia                | 7,2894    | 36,4885  | 979805886        |
| Sédara                | 7,5322    | 36,1330  | 979631163        |
| Selloua Announa       | 7,2502    | 36,3866  | 97995041         |
| Souk-Ahras            | 7,9393    | 36,2701  | 979761488        |
| Tamlouka              | 7,1397    | 36,1583  | 979643370        |
| Tiffech               | 7,7852    | 36,1912  | 979611128        |
| Zaouraria             | 7,9577    | 36,2249  | 979651565        |
where, $\delta$ represents the accuracy, $\sigma$ is the standard deviation and $N$ is the number of measurements.

In the established gravimetric network at north-eastern part of Algeria, the closure gap of the gravity measurements is ranging from 0 µGal to 19 µGal (in absolute values). It is pointed out that each reference gravimetric station is measured between 3 to 6 times. The re-measurement allows ensuring a well connection between two successive meshes. This gives us, the determination accuracy of the measured gravity values at each individual station. We have taken $\sigma$ equal to the highest value (19 µGal) and $N$ equal to 3. So, we estimate the accuracy on the determination of the gravity is about of $\delta = 11$ µGal.

6. Conclusion

A new gravimetric network is achieved in the north-eastern part of Algeria. It consists of thirty-nine relative stations. The reference stations of this gravimetric network are carried out using a terrestrial Scentrex CG3 gravimeter. This gravimetric network contains 61 triangular geometry loops and 99 links. It is connected to Algerian absolute gravimetric station is measured between 3 to 6 times. The re-measurement allows ensuring a well connection between two successive meshes. This gives us, the determination accuracy of the measured gravity values at each individual station. We have taken $\sigma$ equal to the highest value (19 µGal) and $N$ equal to 3. So, we estimate the accuracy on the determination of the gravity is about of $\delta = 11$ µGal.

Declarations

**Author contribution statement**

Yasser Bayou & Boualem Bouyahiaou: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mohamed Cherif Berguig: Conceived and designed the experiments; Wrote the paper.

Abdelsam Abtout: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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**Data availability statement**

Data included in article/supp. material/referenced in article.

**Declaration of interests statement**

The authors declare no conflict of interest.

**Additional information**

No additional information is available for this paper.

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**References**

Abbout, A., Aila, T., Bouchèche, S., Bouyahiaou, B., 2009. Contributions géologique et géophysique préliminaires à l’étude des structures hydrothermales de Hammam Debbagh, bassin de Guelma, Algérie. 4ème Congrès Maghrébin de Géophysique Applique. (CMGAA4), Hammamet, Tunisia. (insu-00354334).

Amanarante, R.R., Trabanco, J.L.A., 2016. Calculation of the tide correction used in gravimetry. Rev. Bras. Geofís. 24, 193–206.

Arab, M., Rabaineu, M., Déverchère, J., Bracene, R., Belhai, D., Roiwe, F., Marok, A., Bouyahiaou, B., Granjeon, D., Andriessen, P., Sage, F., 2016. Tectonostratigraphic evolution of the eastern Algerian margin and basin from seismic data and onshore-offshore correlation. Mar. Petrol. Geol. 77, 1355–1375.

Basic, T., Markovinovic, D., Reza, M., 2004. Basic gravimetric network of the republic of Croatia. In: IAG International Symposium Gravity, Geoid and Space Missions. Porto, Portugal, pp. 1–6.

Bendali, M., Bouyahiaou, B., Belmecheri, A., Bentridi, S.E., About, A., 2019. The new gravimetric network of the upper Chefil basin. Mediterr. J. Model. Simul. 11, 58–68.

Bendali, M., About, A., Bouyahiaou, B., Boukerbort, H., Marok, A., Reolid, M., 2022. Interpretation of new gravity survey in the seismogenic Upper Chefil Basin (North of Algeria): deep structure and modeling. J. Mar. Geol. 48, 205–224.

Bendjama, H., Yelles-Chaouche, A., Boualia, O., Abacha, I., Mohammedy, V., Beldjoudi, H., Rahmani, S.E.T., Belhouaneu, O., 2021. The March 2017 earthquake sequence along the E-W trending Mida Aicha-Debbagh Fault, northeast Algeria. Geosci. J.

Boubaya, D., Allek, K., Hamoudi, M., 2011. Is there a hidden near surface salt diapir in the Guelma basin, north-east of Algeria? J. Appl. Geophys. 73, 345–356.

Bouyahiaou, B., Fabbri, S., About, A., Klingelhoeffer, F., Yelles-Chaouche, K., Schnürle, P., March, A., Déverchère, J., Arab, M., Galve, A., Gollet, J.Y., 2015. Crustal structure of the eastern Algerian continental margin and adjacent deep basin implications for late Cenozoic geodynamic evolution of the western Mediterranean. Geophys. J. Int. 201, 1912–1938.

Chikhi Anoumir, F., 1980. Les rudistes de l’Apitien supérieur de Djebel Ouenza (Algérie,Nord-Est), PhD thesis. USTHB University, Algiers, Algeria, p. 111.

Dubourdieu, G., 1956. Etude géologique de la région de l’Ouenza (confins Algero-tunisiens) publication du service de la carte géologique de l’Algérie. Bulletin 10, 659.

Foulds-Bey, N., 2003. Établissement d’un réseau de bases pour la plaine de la Mitidja.

Gemaël, C., 2002. Introducción a Geodésica Física, second ed. Editora da UFRP, Curitiba, Paraná, Brazil.

Harbi, A., Mauvois, S., Ayadi, A., 1999. Neotectonics and associate seismicity in the eastern Tellian Atlas of Algeria. J. Seismol. 3, 95–104.

Harbi, A., Mauvois, S., 2009. Les principaux séismes du Nord-Est de l’Algérie. Mém. Serv. Géol. Natl. 16, 106.

Hlawg, C., Wang, C.G., Lee, I.H., 2002. Adjustment of relative gravity measurements using weighted and datum-free constraints. Compt. Geosci. 28, 1005–1015.

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’Algérie. Thèse de Magister, Université des Sciences et de la Technologie Houari Boumedien, Alger (Algérie), p. 75p.

Idres, M., Aila, T., 1995. Some parameters to improve gravity network accuracy: application to new reference base station network of North Algeria. Bull. Serv. Géol. de l’Algérie 6, 79–94.

Idres, M., Bourmaute, A., Ouyed, M., Bougoucha, M.S., 2013. Quelques procédures pouvant améliorer la qualité d’un réseau gravimétrique. Bull. Sci. Geographiques 28, 45–50.

Kennedy, J., 2020. GSAdjjust v1.0: U.S. Geological Survey Software Release, 20 December 2020.

Koler, B., Medved, K., Kuhar, M., 2012. The new fundamental gravimetric net-work of Slovenia. Acta Geod. Geophys. Hung. 47, 271–286.

Lagrusse, J., 1951. Etude gravimétrique de l’Algérie-Tunisie. Bull. Serv. Carte Géol. de l’Algérie 4 (2), 114p.

Lagrusse, J., 1959. Nouvelles études gravimétriques, première partie, stations de référence de l’Algérie et du Sahara. In: Service de la carte géologique de l’Algérie. Nouvelle série, 25, Travaux collaborateurs.

Longman, I.M., 1959. Formulas for computing the tidal accelerations due to the Moon and the Sun. J. Geophys. Res. 64, 2351–2355.

Mauvois, S., Abtout, A., Merabet, N., Aila, T., Lamali, A., Bouyahiaou, B., Bouchèche, S., Ayache, M., 2013. Tectonic and hydrothermal activities in Debbagh, Guelma basin, north-east of Algeria. J. Seismol. 3, 95–104.

Ouennza (confinis Algero-tunisiens) publication du service de la carte géologique de l’Algérie. Bulletin 10, 659.

Ouennza (confinis Algero-tunisiens) publication du service de la carte géologique de l’Algérie. Bulletin 10, 659.

Perthuisot, V., Rouvier, H., 1992. Les diapirs du Maghreb central et oriental ; des diapirs variés, résultats d’une évolution structurale et pétro génétique complexe. Bull. Soc. Géol. Fr. 163 (6), 751–760.

Rouvier, H., 1977. Géologie de l’extrême Nord tunisien: tectoniques et paléogéographies superposées à l’extrême orientale de la chaîne nord maghrébine. Pierre et Marie Curie University, Paris, France, p. 898. Phd thesis.

Schoffler, J., 1975. Gravimétrie appliquée aux recherches structurales et à la prospection géologique et minières. Est. Technip, Paris.
Vila, J.M., 1980. La chaine alpine d’Algérie orientale et des confins Algéro-tunisiens. Thèse de Doctorat, Université de Pierre et Marie Curie, Paris, France, 1980.

Yaghoub, H., 2010. Établissement des nouveaux réseaux multi-observations géodésiques et gravimétriques et détermination du géoïde en Iran. Thèse de doctorat, université de Montpellier II, p. 193.

Zerdazi, A., 1990. Etude gravimétrique du mole d’Ain M’illa, et de l’Atlas Saharien septentrionale orientale (Nord-Est d’Algérie). Thèse doctorat Es Science université de Lausanne, Suisse, p. 227.

Yelles-Chauache, A.K., Boudiaf, A., Djellit, H., Bracène, R., 2006. Tectonique active de la région nord-algérienne. Geoscience 338, 126–139.