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Geophysical Implications of North Hurghada Area, Northern Red Sea, As Revealed from Gravity and Aeromagnetic Data

TH. ABDEL FATTAH* and M.B. AWAD**
*Geology Department, Fac. of Science, Univ. of Alexandria, Egypt
**National Institute of Oceanography, Alexandria, Egypt

ABSTRACT. This study is mainly devoted to the existing gravity and aeromagnetic anomalies of the northern Red Sea and its junction with the Gulf of Suez. The tectonic elements as well as the subsurface structural features and their relations to the evolutionary stages of the Red Sea opening are considered here. This study has revealed that :

1) The continental crust in this area is tectonically affected by specific system of faulting as a result of tensional stresses acting nearly N45°E-S45°W.

2) The tectonic elements acting in this area are certainly different from those in the central and southern Red Sea. Deep-seated normal fault system trending NW-SE affects the basement of the continental crust as well as the sedimentary cover.

3) These tectonic elements probably take part in seismicity of the study area and its surrounding extension.

4) A distinct basement relief varies between highs and lows with an average depth below 6.7 km level as deduced from gravity downward continuation.

Introduction

Red Sea as a whole and specially its northern part in addition to the Gulfs of Suez and Aqaba have their complicated tectonic history and evolution. Moreover, some sorts of tectonic activities are still present. Much studies are carried out in this particular area. Lowell and Genik (1972) concluded that the Red Sea has been formed as a result of structural development which has been associated with the motion of the Arabian-African plates. Girdler and Styles (1974) and Roser (1975) have concluded that the evolution of the Red Sea can be divided into two distinct phases based on magnetic anomalies associated with the sea floor spreading. The younger phase has the age of 4 to 5 MY. (Late Clysmic event). The other phase which is older has 41 MY age. Webster and Riston (1982) studied the rifting system at the Gulf of Suez area and concluded that this rifting might be initiated during the Late Oligocene time. Tewfiq and Ayyad (1982) believed that the Red Sea graben was initiated as a result of arching, thinning and stretching of the continental crust of the Arabo-Nubian massif. This was associated with extensive block faulting. Jordi (1984) concluded that the Red Sea-Gulf of Suez graben system was developed as a result of early rifting between the African and Arabian plates in Late Mesozoic to Tertiary times. He added that during Eocene-Oligocene time Red Sea was still separating and the Gulf of Suez was stable. Miocene spreading of the Red Sea and Sinai block has been moving together with the Arabian plate and as a result, spreading of the Gulf of Suez was reactivated. In Post Miocene time a further opening of the Red Sea has been taken up by lateral movements along the Aqaba fault. Barakat and Miller (1984) concluded that the entire northern Red Sea is underlain by similar basement which is mainly of acidic type. This in turn shows that this area has been formed by extension rather than sea floor spreading. Khattab (1986) used different geophysical methods and concluded that a part of the basement at some localities of the northern Red Sea was involved in at least two faulting effects, namely, the Red Sea and Aqaba-Dead Sea trends. He added that the Aqaba-Dead Sea trend is mainly a left lateral shearing which may subsequent to the Gulf of Suez rifting. He interpreted the N-NE trending magnetic anomaly at the entrance of the Gulf of Aqaba as a rotated basement block due to the same shear movement. Meshrif (1990) concluded that the Red Sea rifting axis extends toward its northern part of the Gulf of Suez.

Data Analysis and Interpretation

Both Bouguer gravity and total intensity magnetic maps are used in an integrated manner in order to evaluate the subsurface tectonic elements in an important zone of the Red Sea. The area is located at the extreme NW part of the Red Sea at its junction with the Gulf of Suez (Fig. 1). Figure (2) represents the Bouguer gravity map used in this study. All tectonic and structural elements are included in this map. The preliminary analysis of this map shows the following features :

a) One major NW-SE anomalous trend is located nearly at the central part of the area.

b) Another important negative anomaly is located at the extreme SW part of the area and extending at the same direction as the positive anomaly.

c) Major faults dominate and extending at the same direction as the major anomalies.

d) High gradient contours occur at the extreme SW part of the area toward the Red Sea mountainous area.

effects. The regional map represented on Fig. (3) is still characterized by the presence of the major anomalies defined before on the Bouguer gravity map. The presence of the dominated high anomalous feature in both Bouguer and regional gravity maps may be attributed to plugging of a relative high density material beneath the granitic mass underlying the sedimentary cover. Some authors *e.g.* Meshrif (1990) has attributed this phenomenon to the presence of some sorts of rifting in this area. The presence of the huge extended granitic mass makes this assumption far from truth and instead other reasons must be given. The uplifting of the granitic mass in the form of a horst may cause such type of positive anomalies, where the density contrast between the sedimentary cover and the granitic basement is positive.

The analysis of the residual gravity map (Fig. 4) shows a positive anomalous trend with less wave length at the same position of the positive anomaly noticed on both the Bouguer and regional gravity maps. Some scattered local anomalies also occur. These local anomalies may be attributed to the presence of some local structures in the sedimentary cover.

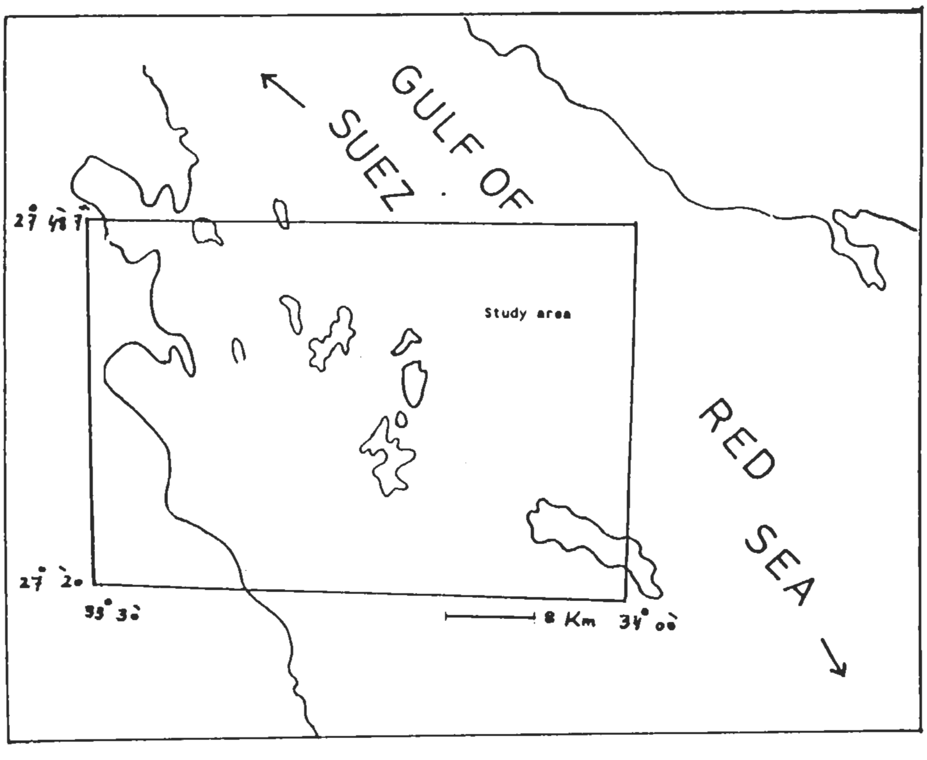

FIG. 1. Location map of the study area.

The Bouguer gravity map has been exposed to many processing techniques in order to separate both the shallower and deep features. Griffin's method (1949) is used to separate both the regional and local gravity

Using the method after Constantinscu and Botezatu (1961), the downward continuation effect is calculated. Different levels of continuation at depth levels of 2.66, 4, 5.33 and 6.67 km are calculated (Fig. 5, 6, 7

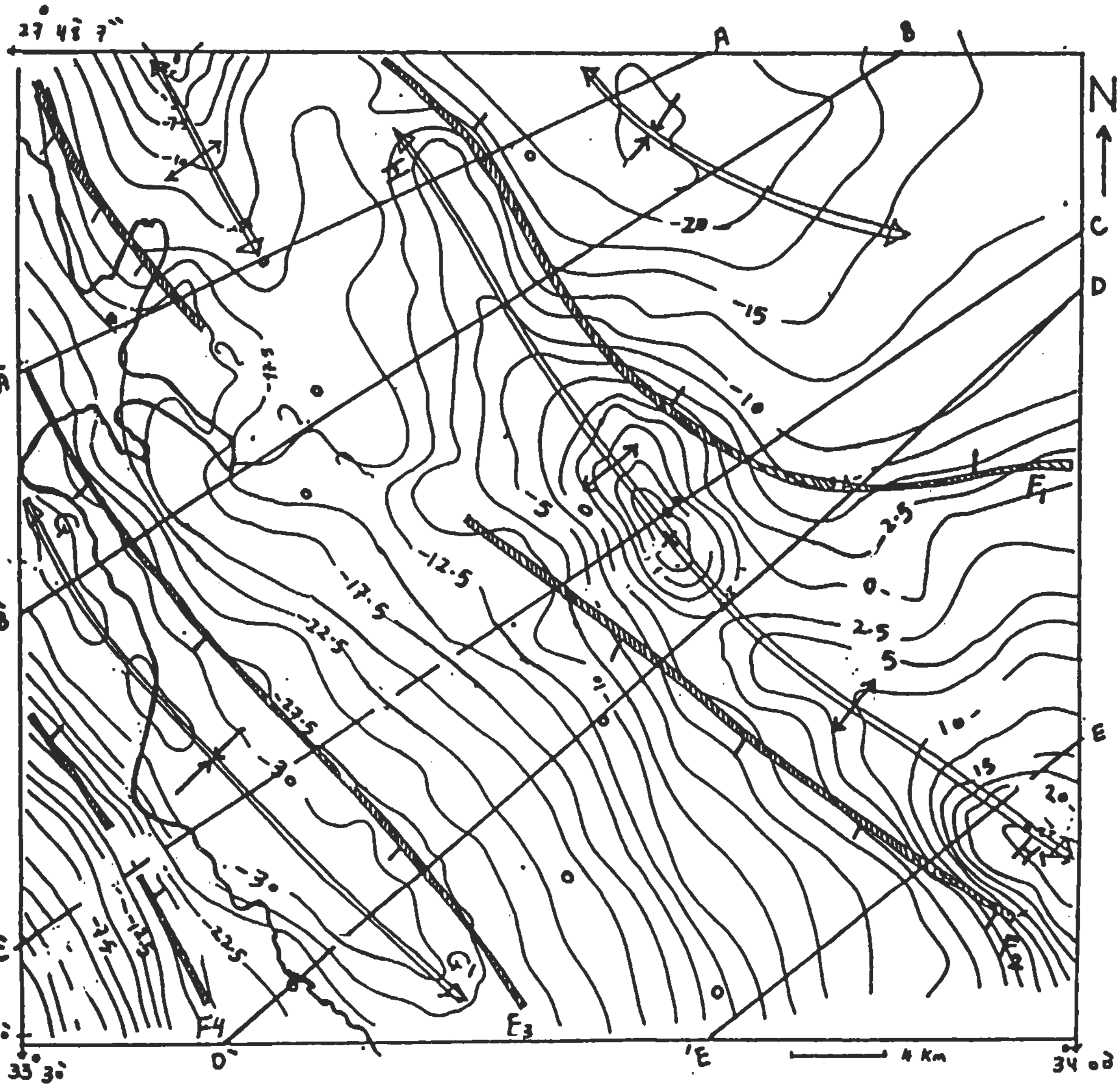

FIG. 2. Bouguer gravity map, C.I. 2.5 mgal.

Probable major deep seated fault zone

Probable high belt structure

Probable low belt structure

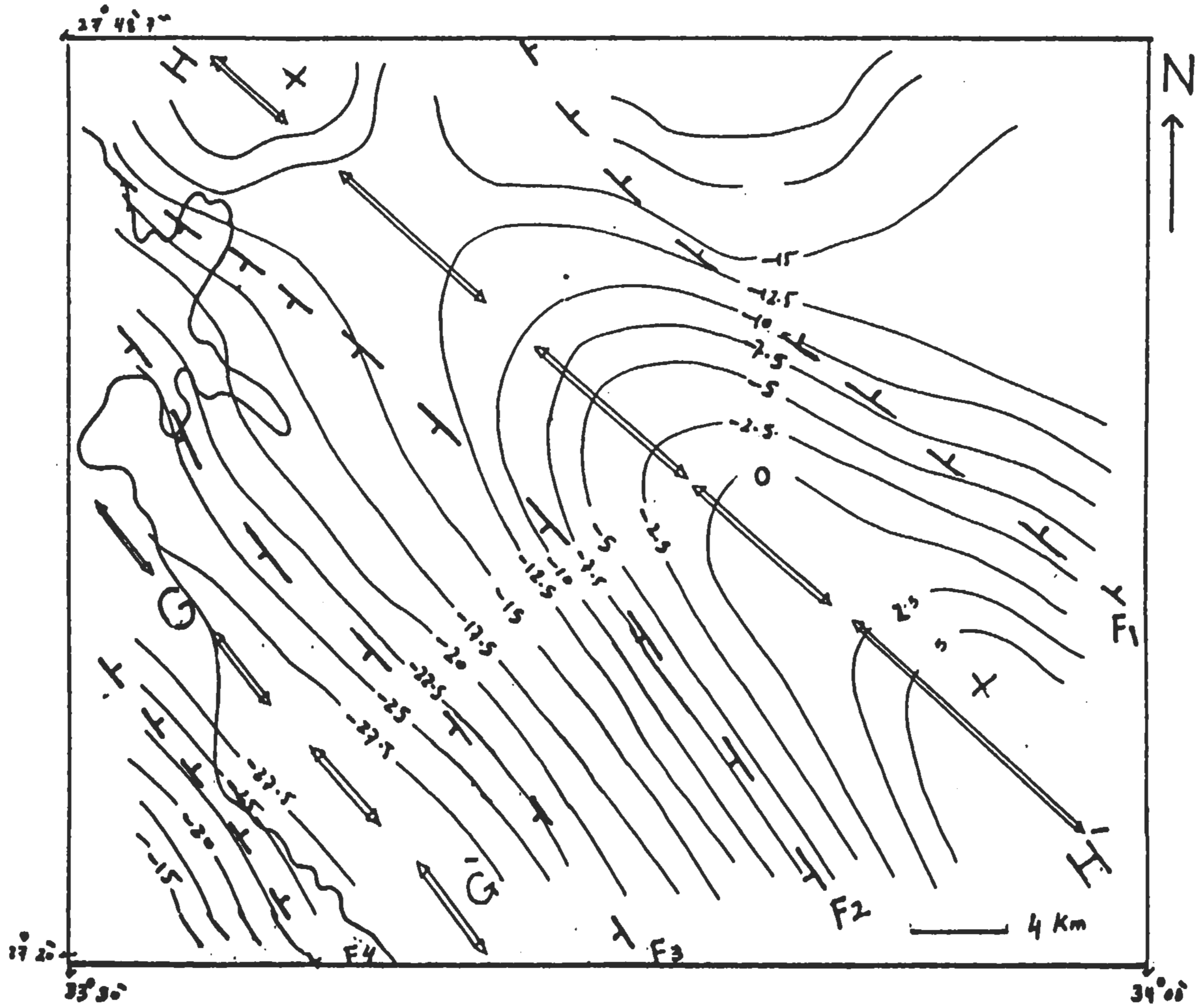

FIG. 3. Regional gravity map, (3 d spacing) C.I. 2.5 mgal.
Probable major deep seated fault
High belt axis H-H′
Low belt axis G-G′

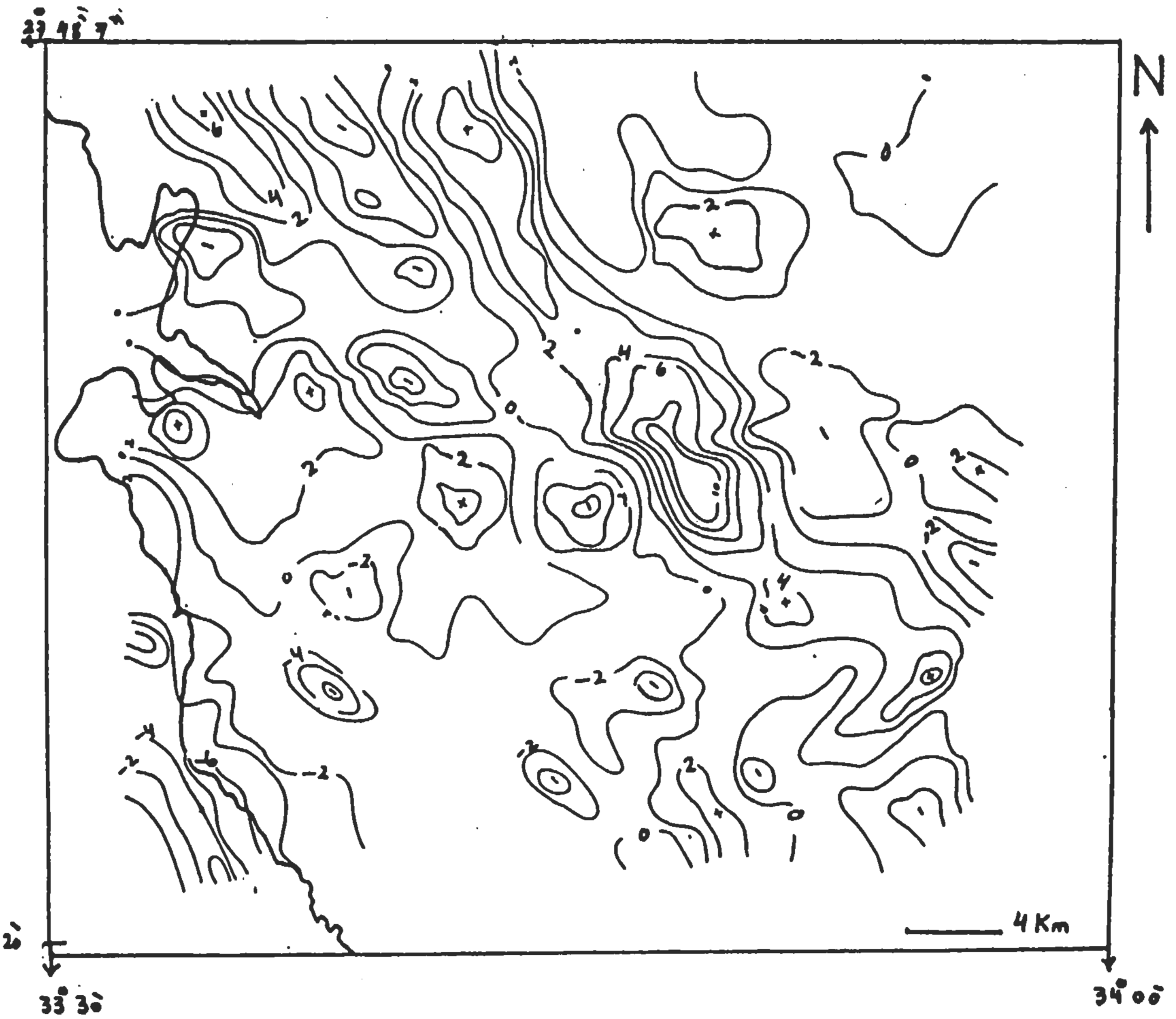

FIG. 4. Local gravity map (3rd spacing) C.I. 2 mgal.

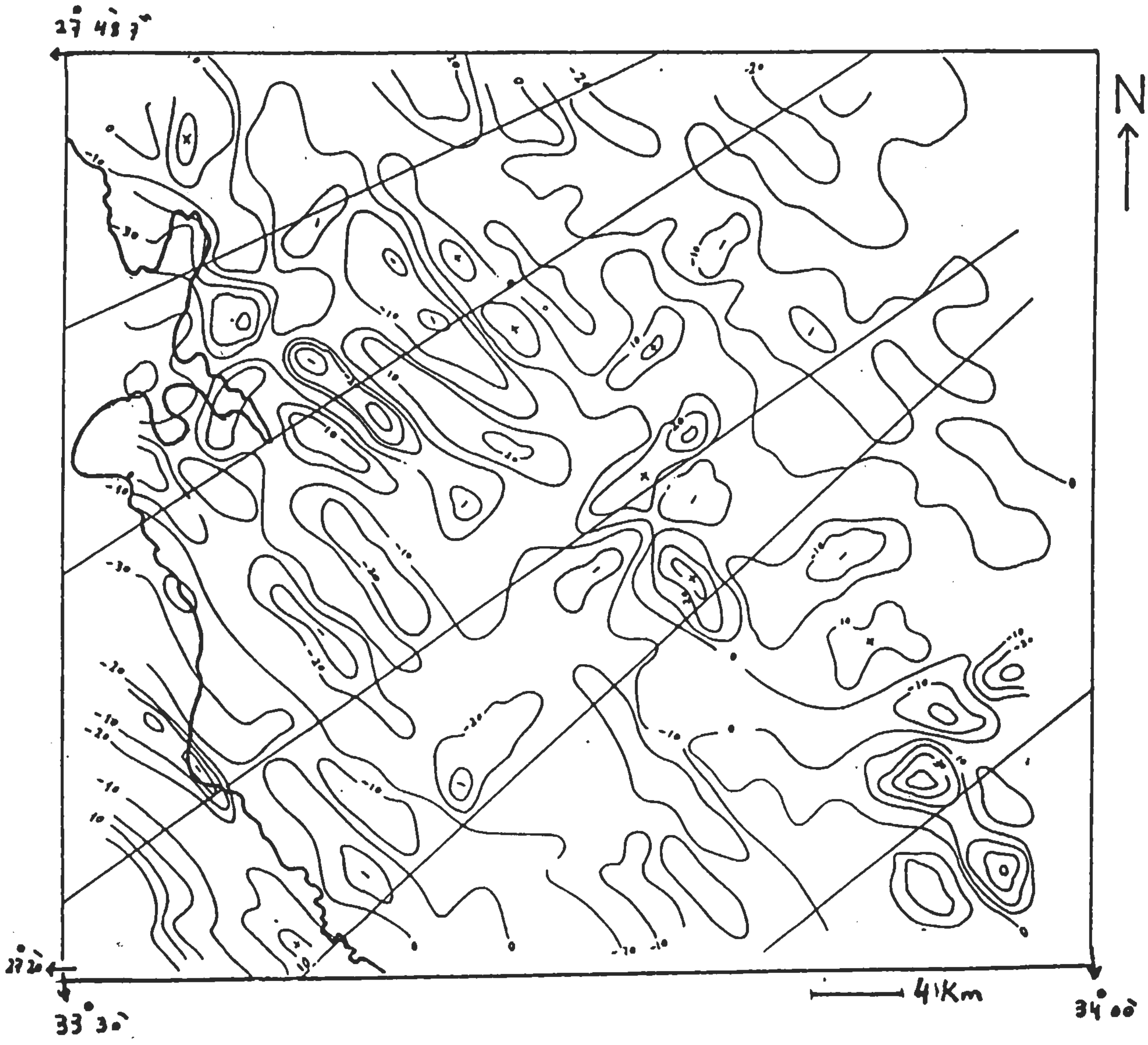

FIG. 5. Downward continuation map (2nd spacing) C.I. 10 mgal.

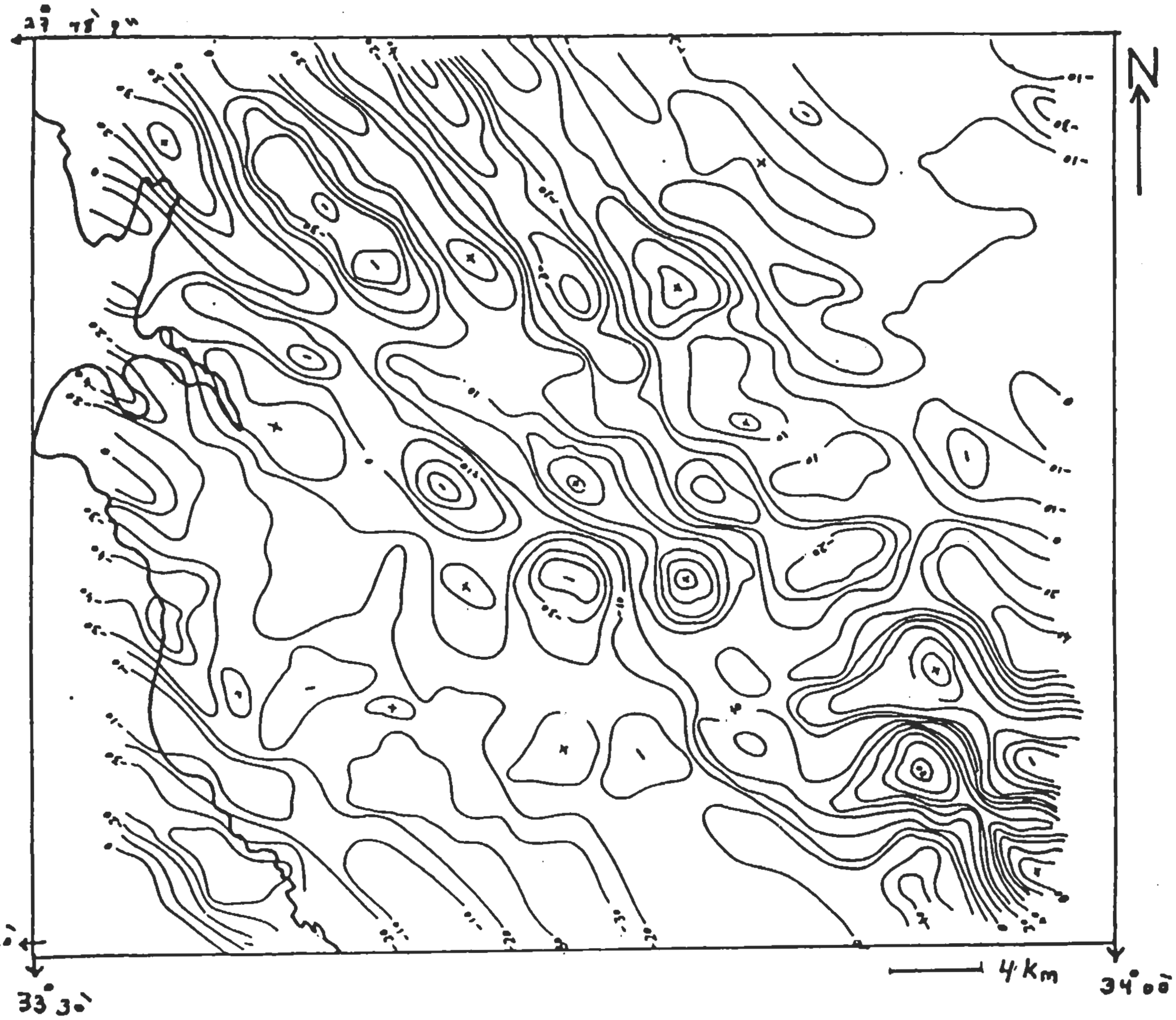

FIG. 6. Downward continuation map (3rd spacing) C.I. 20 mgal.

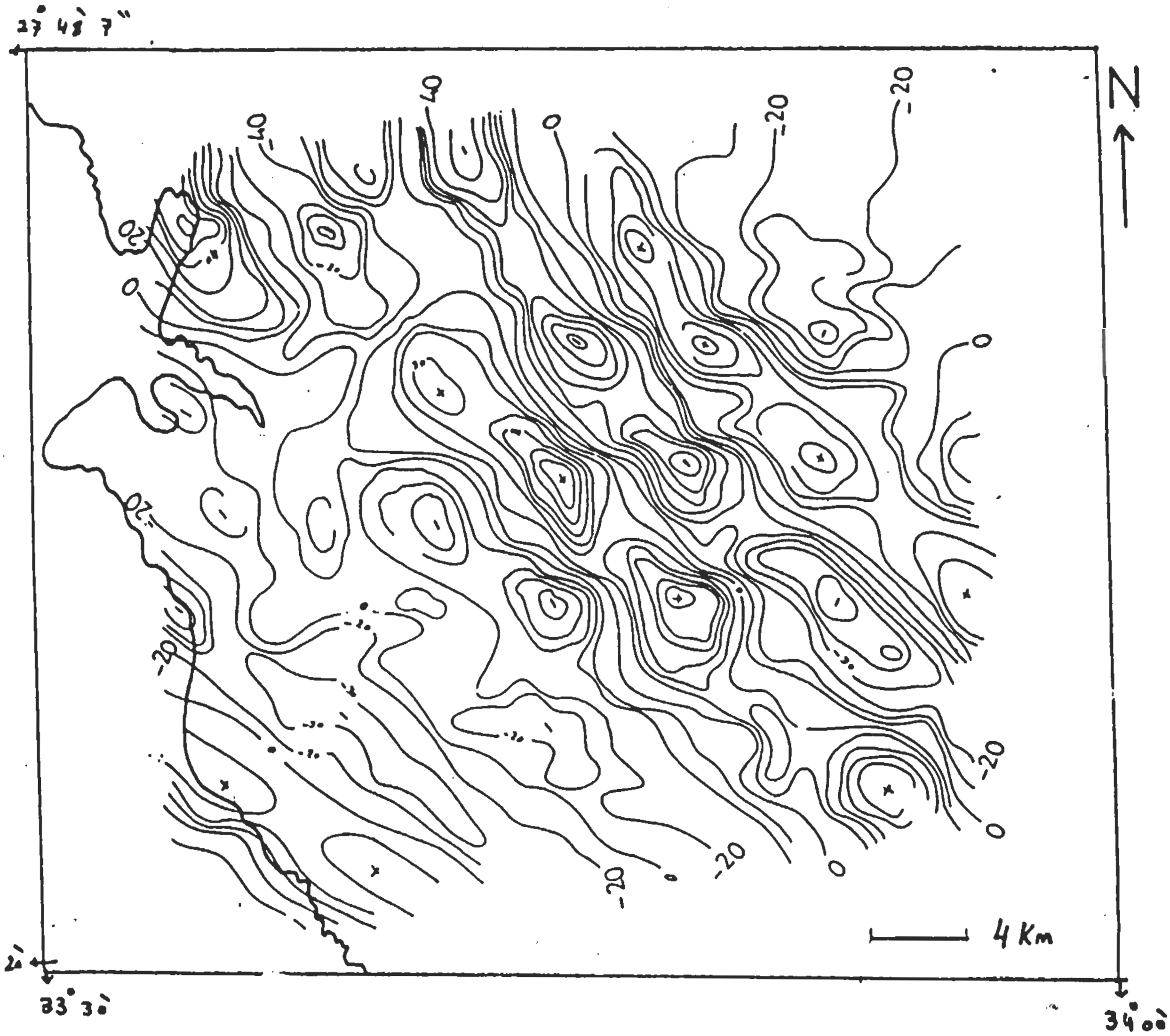

FIG. 7. Downward continuation map (4th spacing) C.I. 20 mgal.

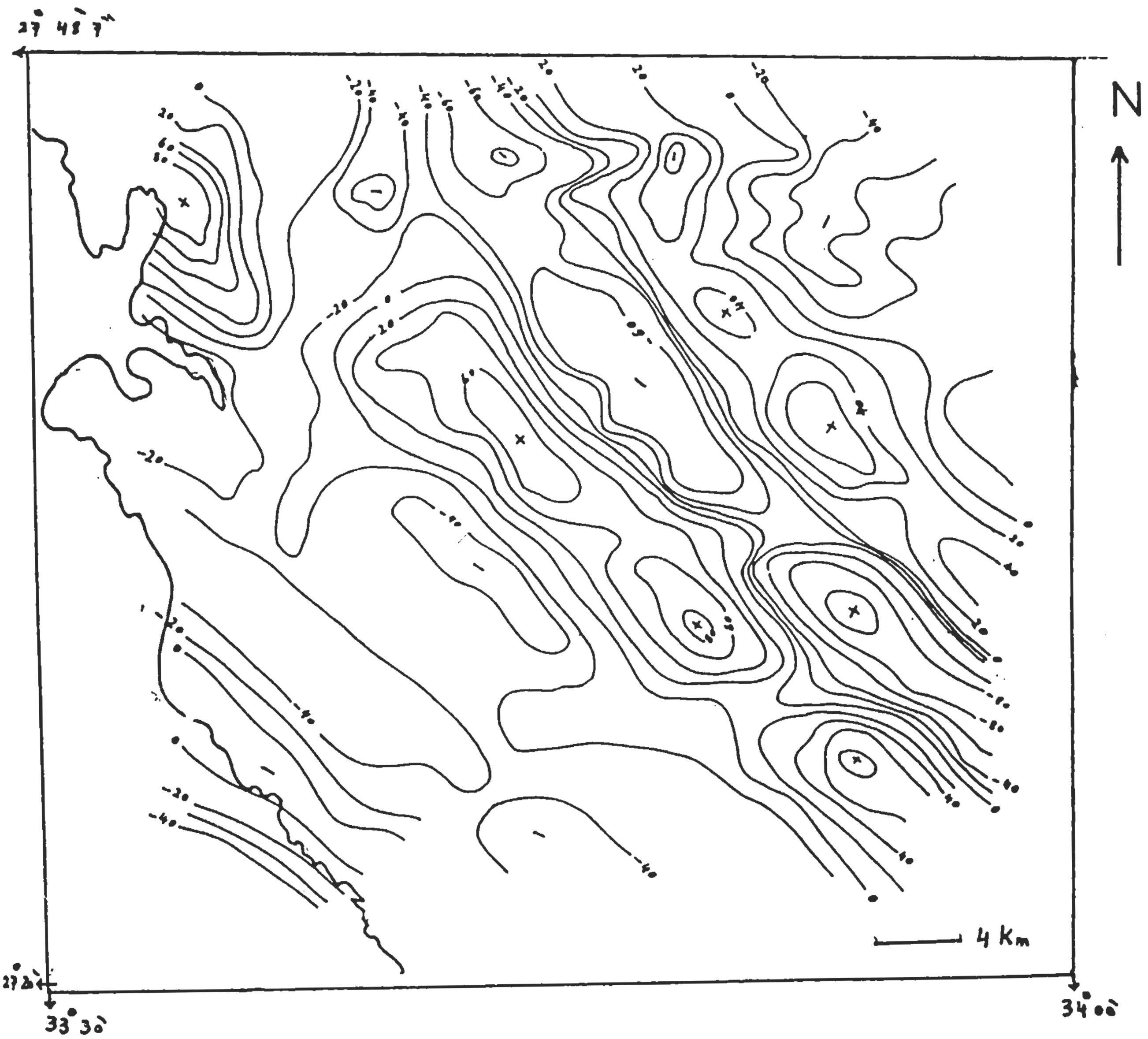

FIG. 8. Downward continuation map (5th spacing) C.I. 20 mgal.

and 8 respectively). All maps are compiled together in order to give the full structural features at different depths. Beginning with the 4 km level and deeper the structural pattern seems to be more or less identical and constant reflecting continuous structural behavior till the maximum depth interpreted. The analysis of these maps also revealed that the depth to the top of the basement complex in the study area lies possibly below the 4 km depth. It is also noticed that the deepest basement lies at the southwestern part of the area.

All gravity maps are compiled together in an integrated manner and a tectonic map is prepared (Fig. 9). The analysis of this map reflects all tectonic and structural elements of the area.

The total intensity magnetic map (Fig. 10) is characterized by the presence of a distinct positive magnetic anomaly nearly at the same position of the positive one on the Bouguer gravity map. Griffin's method (1949) is also used here to separate both regional and local effects (Fig. 11 and 12). Figure (11) represents the regional magnetic map which is identical with the total intensity in Fig. (10). The positive anomaly is more clear with an elongation toward the NE direction which is the Aqaba trend. Figure (12) represents the local magnetic map which is characterized by a complicated anomalous pattern reflecting the structural shape of the sedimentary cover. The downward continuation maps at the levels 2.66, 4 and 5.33 km (Fig. 13, 14 and 15) are calculated using the same method

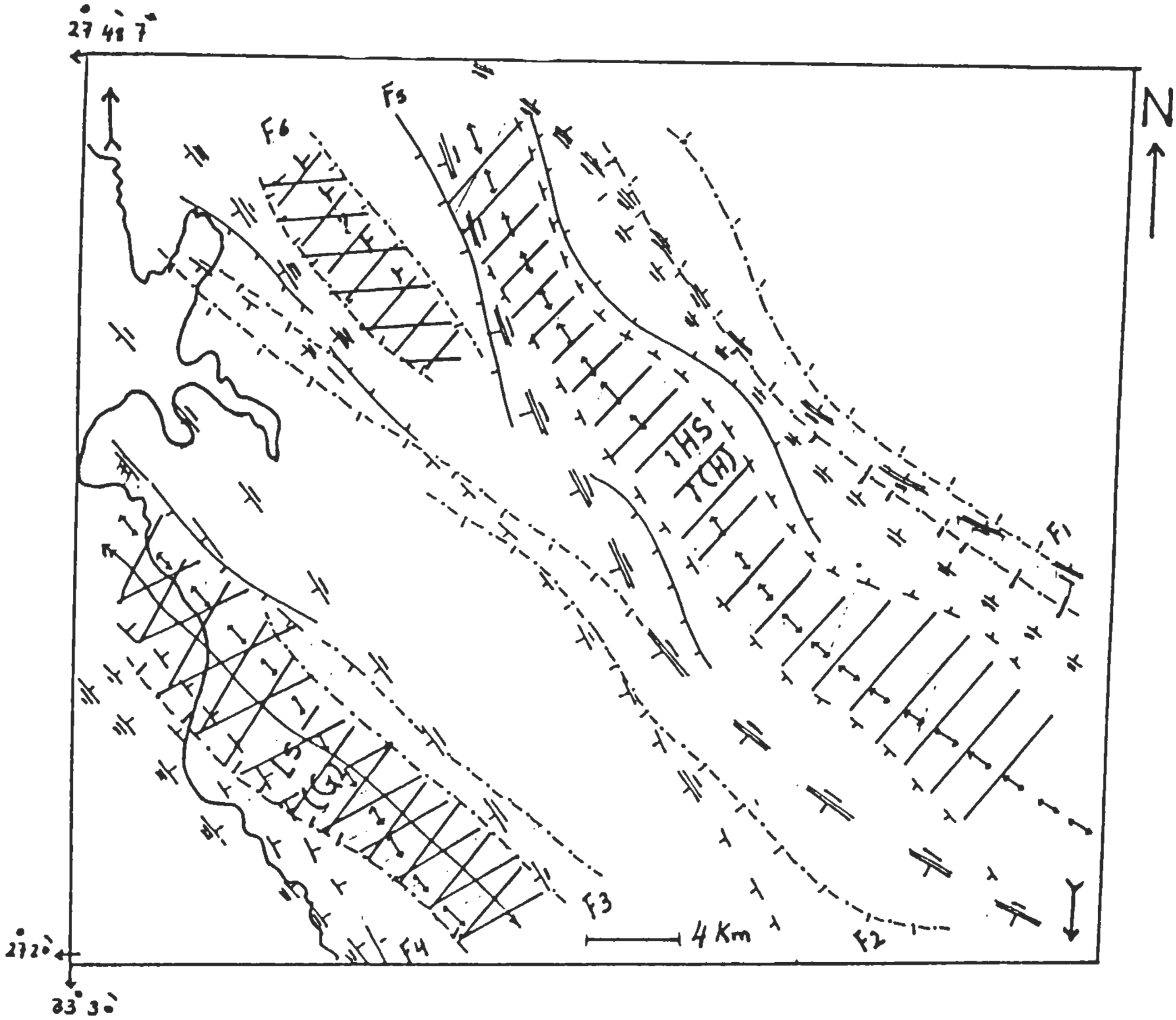

FIG. 9. Compiled subbottom structure map of the study area as revealed from gravity interpretation.

Shallow faults (revealed from residual gravity map).

Deep faults (revealed from regional gravity map).

Bouguer faults.

Horstal structural belt (H) (HS).

Grabenal structural belt (G) (LS).

Second vertical derivative fault.

Downward continuation fault.

Downward tectonic movement.

Upward tectonic movement.

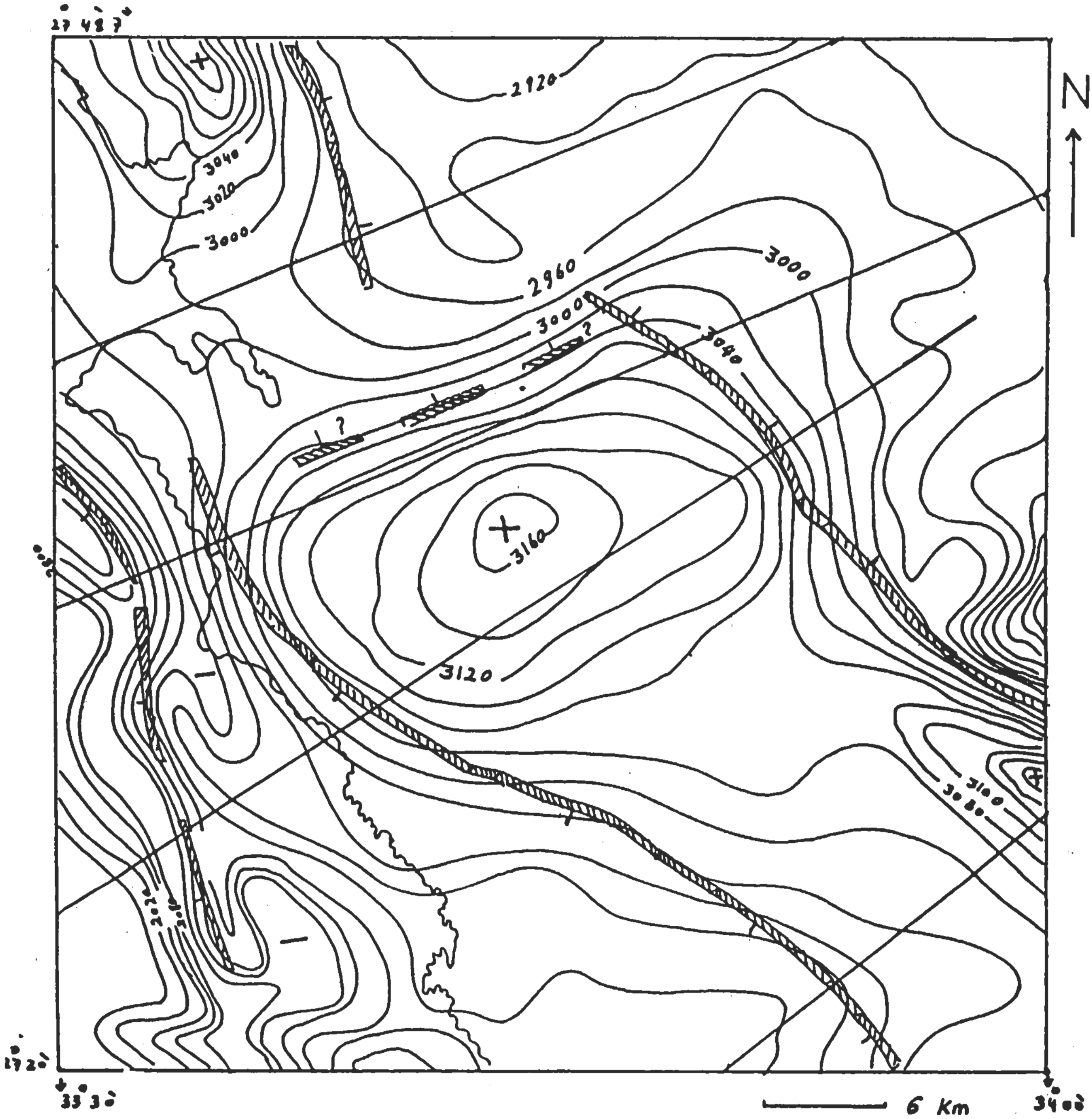

FIG. 10. Aeromagnetic map, C.I. 20 γ.

Inferred fault

Verified fault

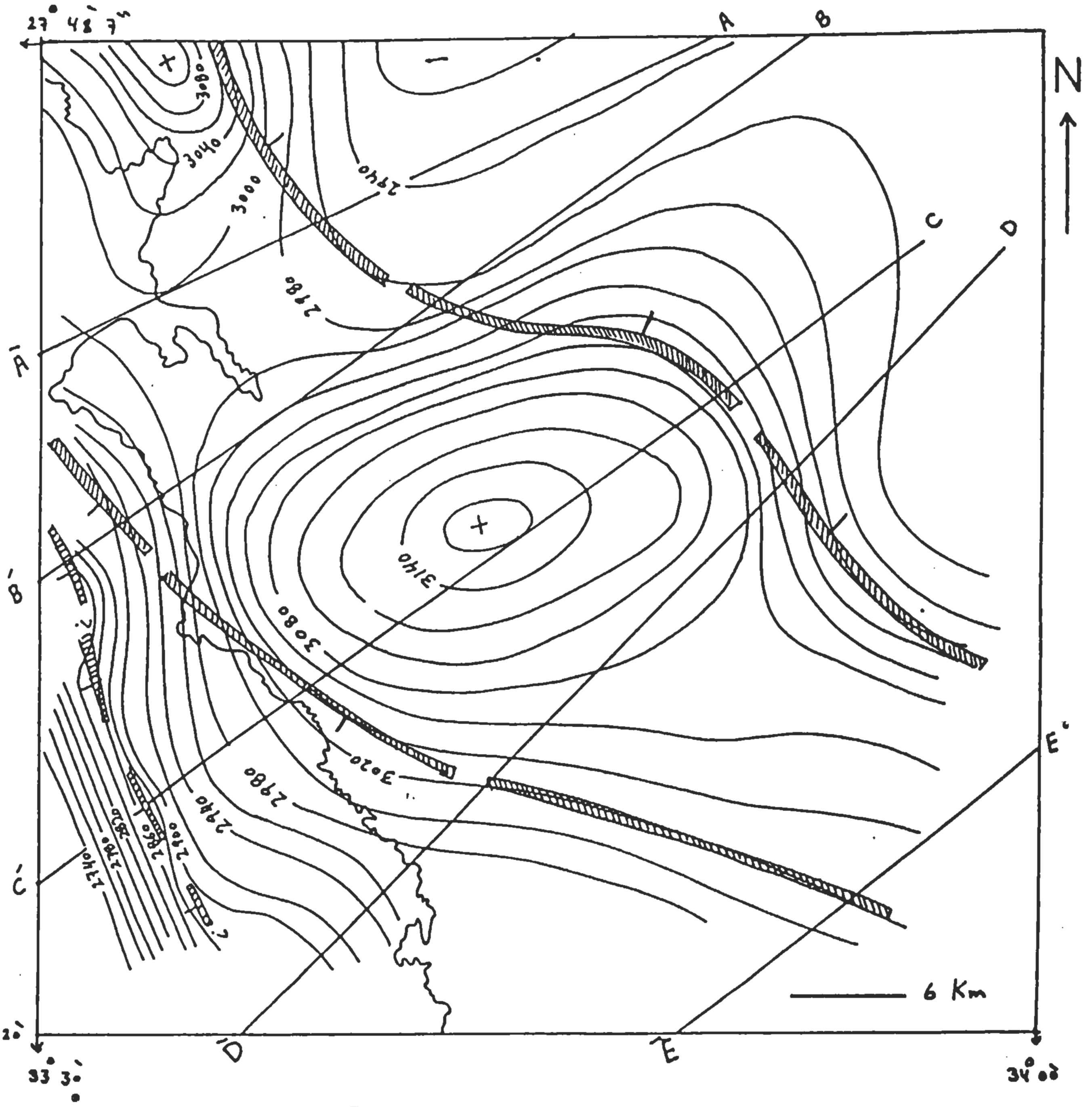

FIG. 11. Regional magnetic map C.I. 20 γ

Verified deep seated regional fault

Inferred regional fault zone

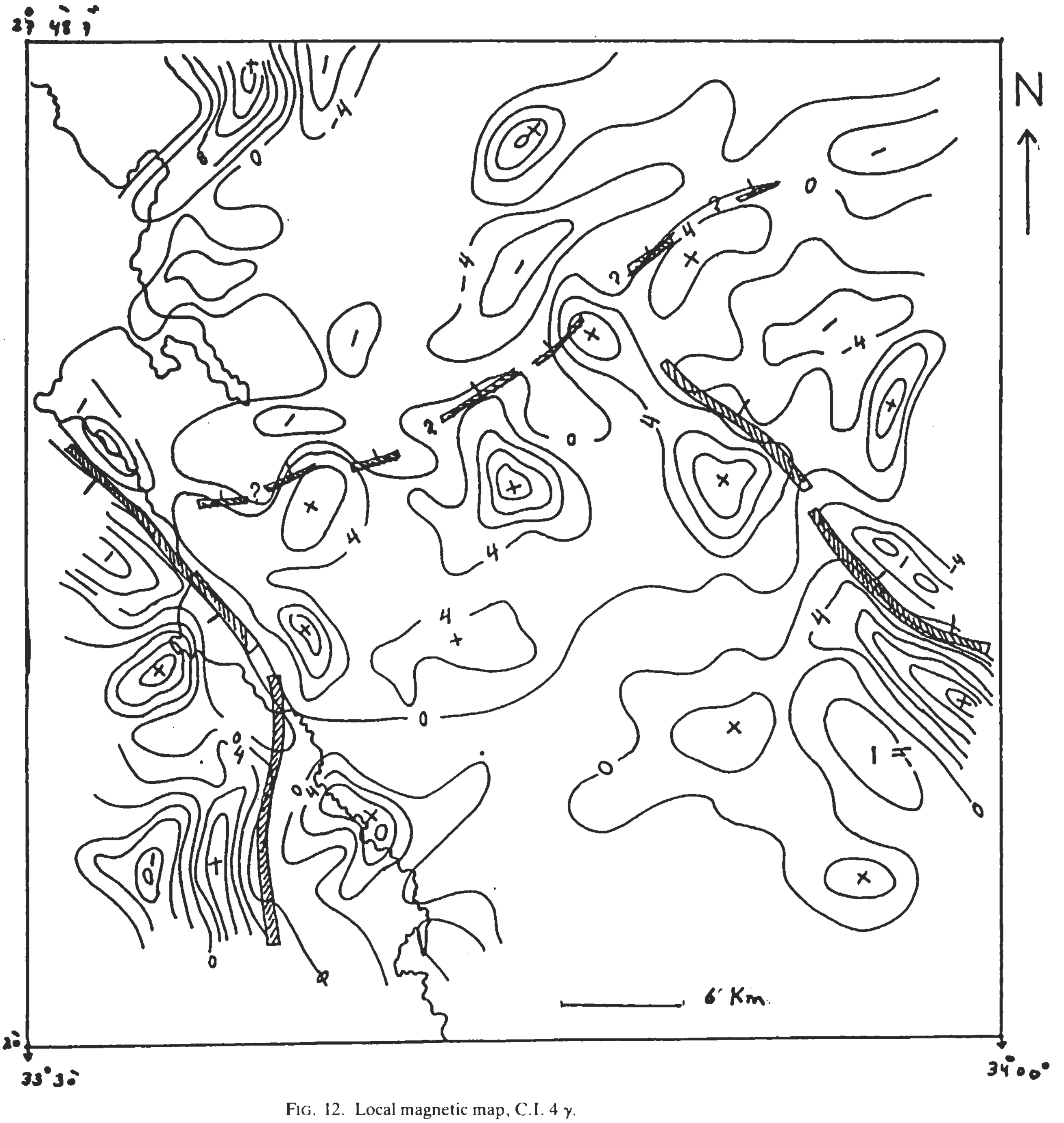

FIG. 12. Local magnetic map, C.I. 4 γ.

Shallow fault as revealed from residual magnetic map.

Inferred shallow contact (most likely due to low magnetic lithologic variation).

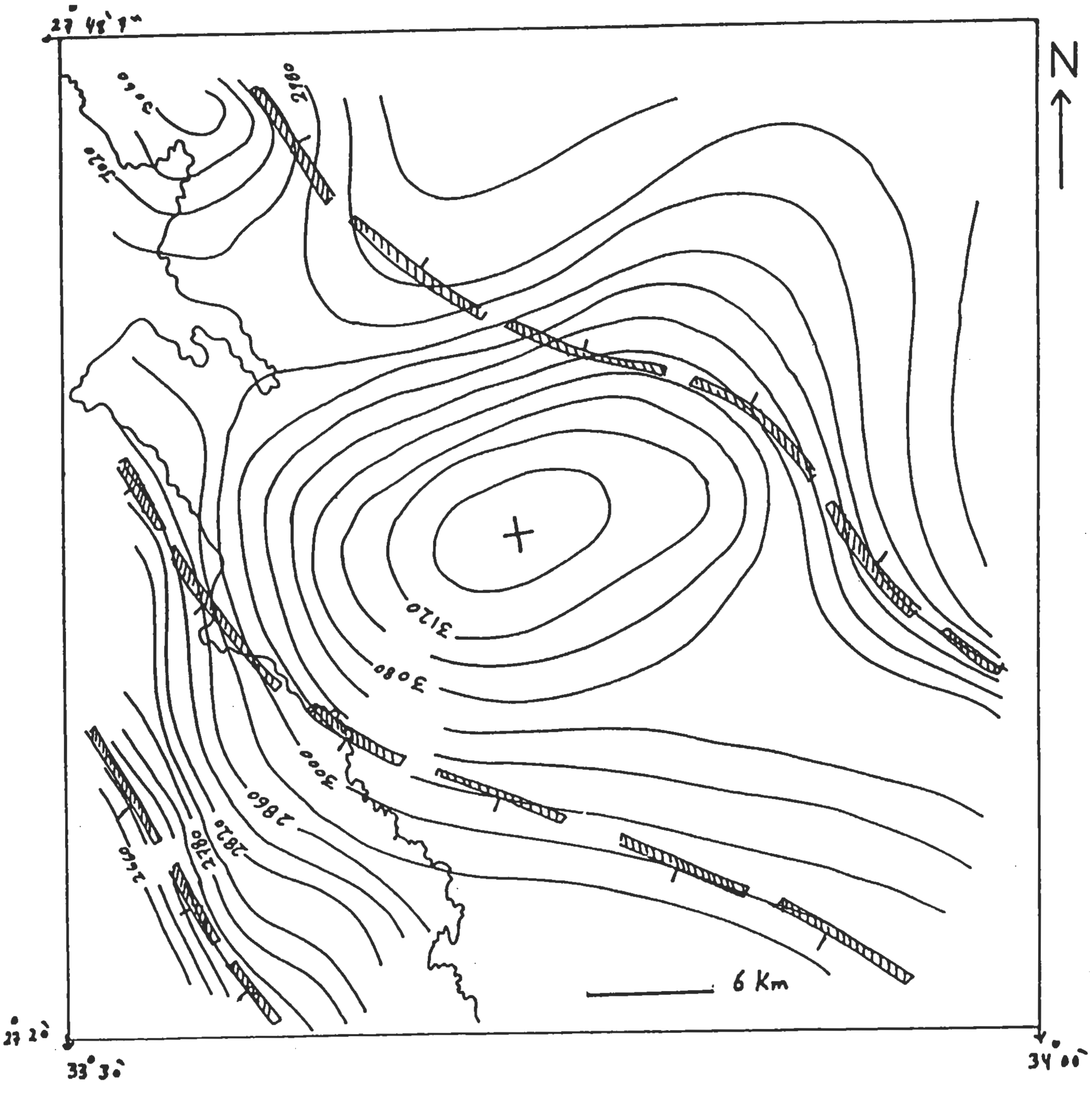

FIG. 13. Magnetic downward continuation map (1st spacing) C.I. 20 γ.
Verified fault

N.B. See upward continuation map of 2 km for study and comparison.

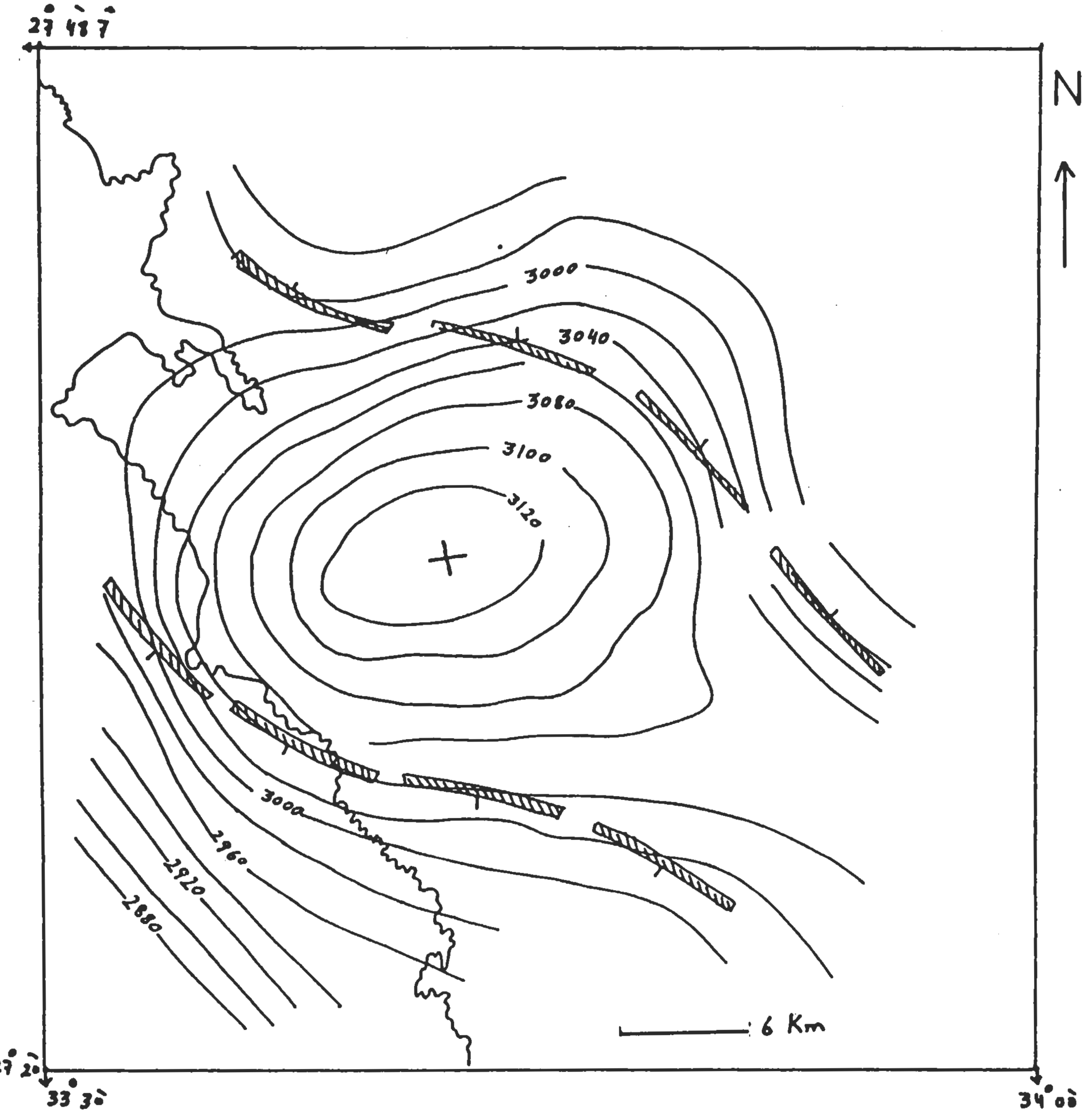

FIG. 14. Magnetic downward continuation map (2nd spacing) C.I. 20 γ.
Verified deep seated fault zone.

N.B. See upward continuation map of 4 km for study and comparison.

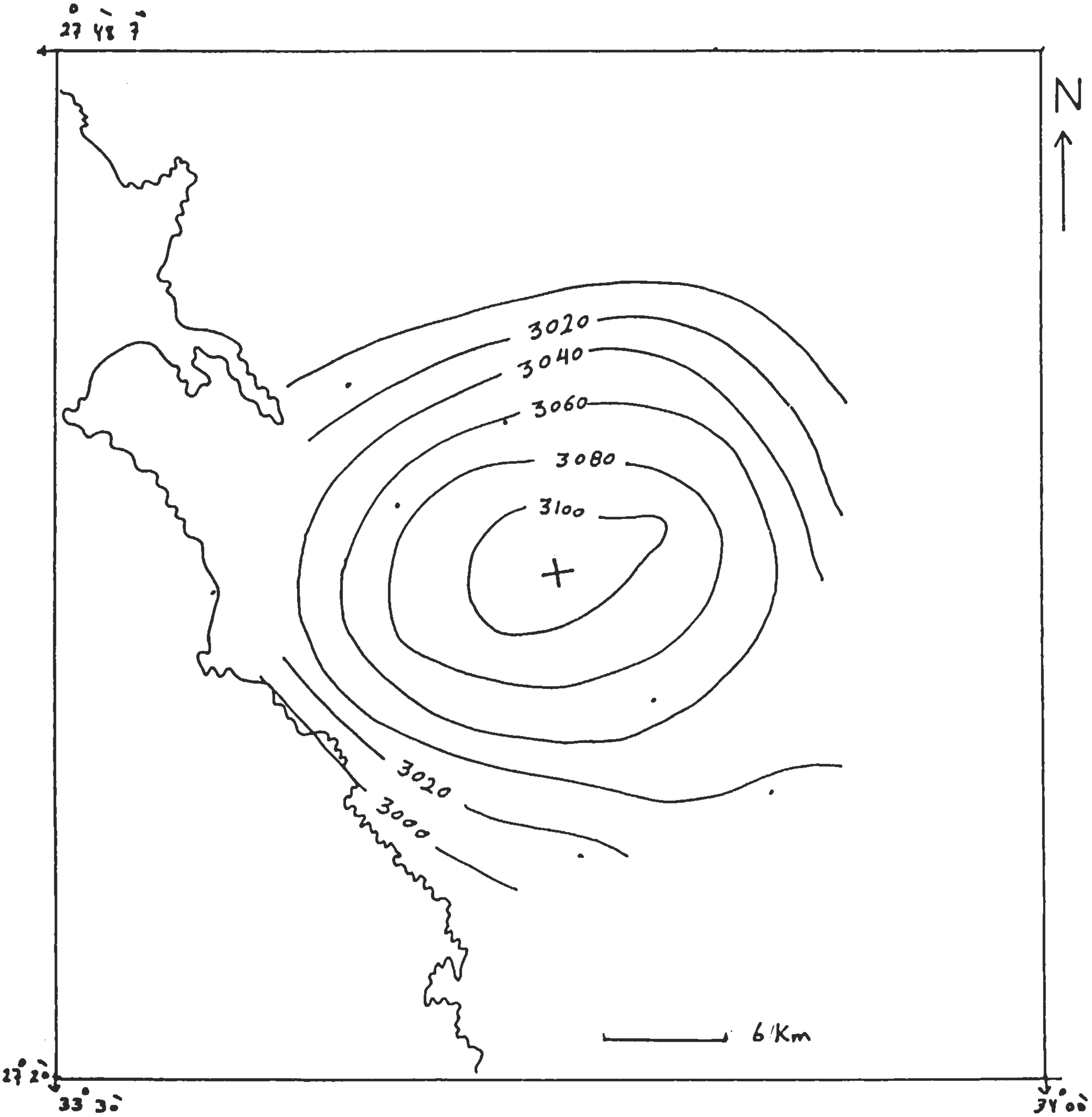

FIG. 15. Magnetic downward continuation map (3rd spacing) C.I. 20 γ.
+ Deep seated rooted intrusive igneous body (most likely basic intrusion in cylindrical ring shape)

N.B. See upward continuation map of 6 km for study and comparison.

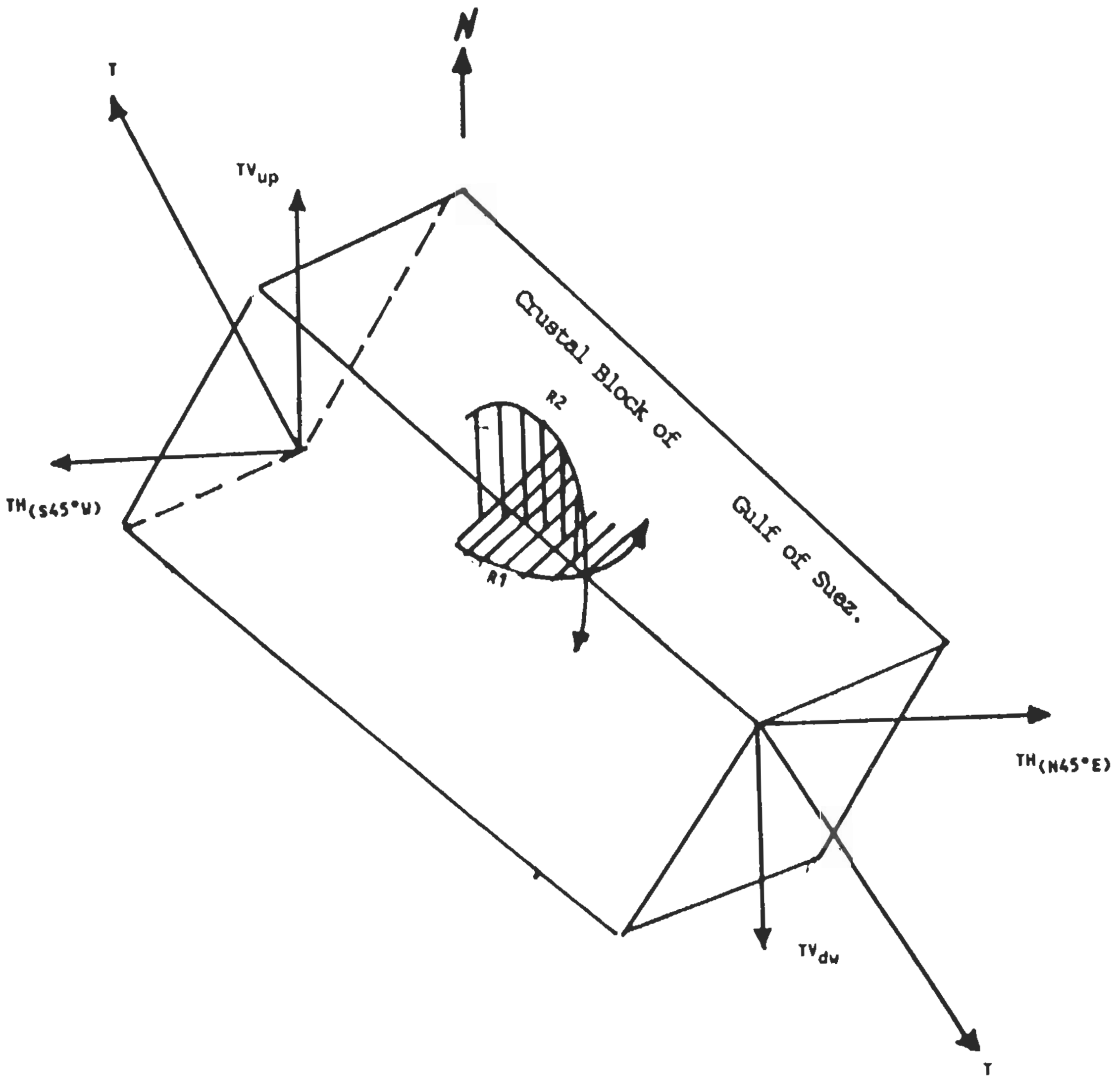

FIG. 16. 3 D-diagram showing the relative tectonic movement of the crustal blocks of the study area.

R_1 : Horizontal tectonic rotation strike slip fault due to:
TH: horizontal tectonic force component led to rifting of the crustal body.

R_2 : Vertical tectonic rotation led to relative vertical movement of the crustal body due to:
TV: Vertical tectonic force component

T. Major tectonic force

applied in gravity interpretation. Only one major central anomaly still dominate. The causative body of such an anomaly may be attributed to a deep-seated magnetic body.

Integration of all gravity and magnetic maps gave the following remarks :

1) The tectonic origin of the major uplifted NW-SE dominated structures has been initiated generally by structural uplifting of the basement complex which may be affected by crustal movement at deep-seated depths.

2) The vertical component of the tectonic movement is directed downward at the SE part and upward at the NW part of the study area.

3) Some sorts of deep-seated movements dominate. Such movements causing the following phenomena :

a) A fault system trending nearly N45°W is created as a result of tensional stresses. The eastward tensional component is slightly directed downward while the western component is directed upward (Fig. 16).

b) The rifting system pronounced in the study area is characterized by the presence of a relatively deep seated NW-SE graben structure. This most probably was followed by another tectonic phase of vertical uplifting forming the central horstal structure trending NW.

Using the residual gravity map (Fig. 4) a quantitative tentative depth map of the surface of the basement (Fig. 17) is prepared using Smith's method (1959).

Summary and Conclusions

Compiled gravity and magnetic studies at the northwestern part of the Red Sea revealed the following concluding remarks :

1) This part of the Red Sea is being considered as a continental crust affected indirectly with the rifting and spreading processes in the middle and southern Red Sea. This is accompanied by the rotational phenomena of the African and Arabian plates causing important tectonic effects and then high seismicity in the northern Red Sea.

2) The central positive anomalous pattern has its elongation axis toward the Aqaba trend. This feature may throw light on the relation between this area and

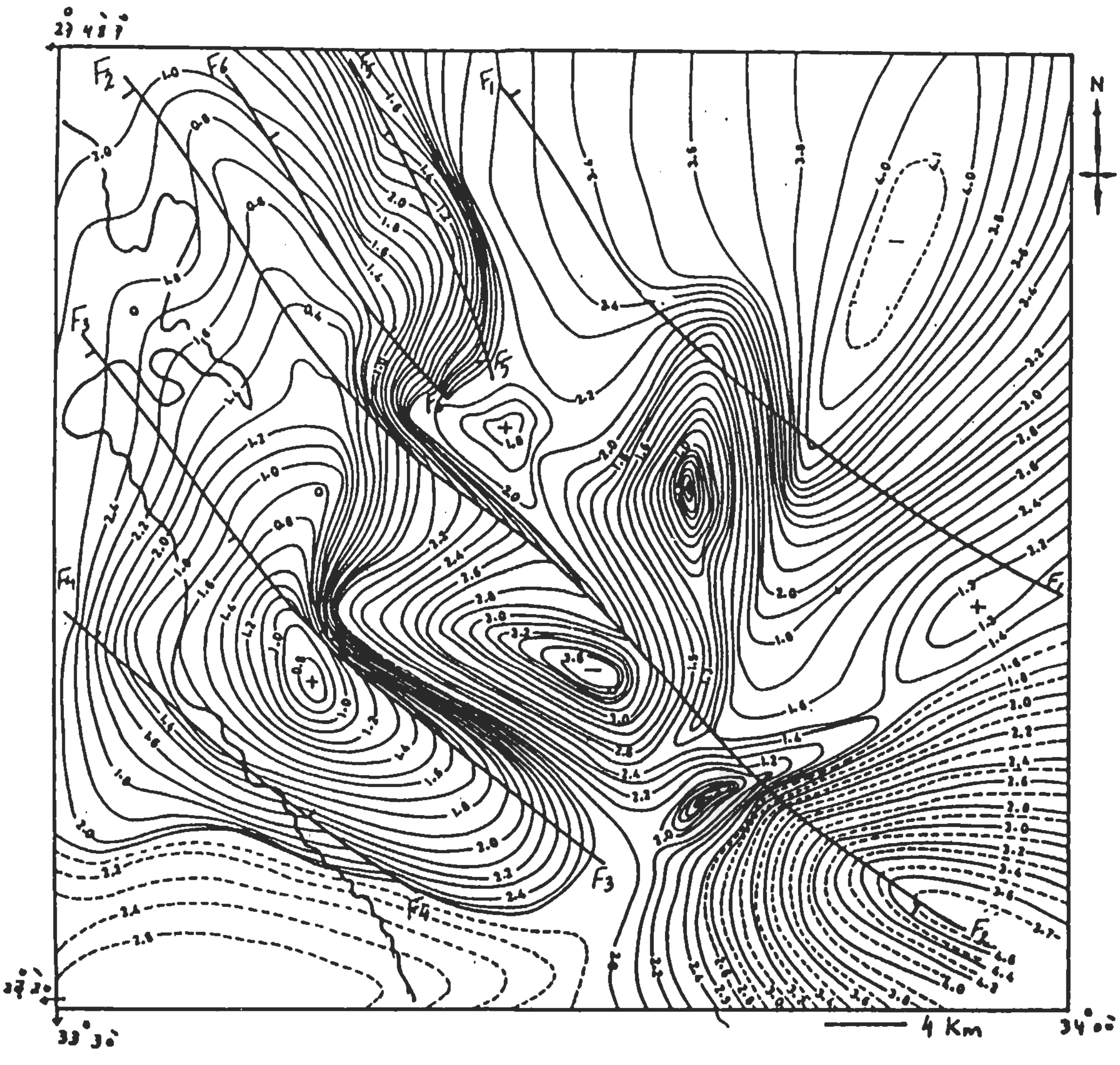

FIG. 17. Tentative basement relief map interpreted from gravity data (using Smith's method 1959) C.I. = 100 m.

the Aqaba-Dead Sea trend.

3) This area is of course not separated from what happened and still happen in the whole Red Sea.

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المفاهيم الجيوفيزيائية لمنطقة شمال الغردقة - شمال البحر الأحمر كما أوضحتها بيانات الجاذبية الأرضية والمغناطيسية الجوية

ثروت عبد الفتاح و مراد باسيلي عوض
قسم الجيولوجيا - كلية العلوم - جامعة الأسكندرية والمعهد القومي لعلوم البحار والمصائد - الأسكندرية - جمهورية مصر العربية

المستخلص: اختصت هذه الدراسة بشاذات الجاذبية الأرضية والمغناطيسية الجوية فى منطقة شمال البحر الأحمر مع اتصاله بخليج السويس، واهتمت الدراسة بالعناصر التكتونية إضافة إلى المظاهر التركيبية التحت سطحية وعلاقاتها بمراحل تطور انفتاح البحر الأحمر.

ولقد أوضحت هذه الدراسة ما يلى:

١ - لقد تأثرت القشرة القارية في هذه المنطقة تكتونياً بنظام خاص من الفوالق كنتيجة لإجهادات شديدة تعمل تقريباً في اتجاه شمال ٤٥° شرق - جنوب ٤٥° غرب.

٢ - العناصر التكتونية المؤثرة في هذه المنطقة تكون مختلفة بالتأكيد عن تلك المؤثرة على المنطقة الوسطى والجنوبية للبحر الأحمر ويوجد نظام من الفوالق العادية العميقة تتجه شمال غرب - جنوب شرق يؤثر على كل من صخور القاعدة للقشرة القارية والغطاء الرسوبي أعلاها.

٣- ربما يكون لهذه العناصر التكتونية دورًا في النشاط الزلزالي بمنطقة الدراسة وأجوارها.

٤ - لصخور القاعدة تضاريس واضحة تتنوع بين مرتفعات ومنخفضات بمتوسط عمق نحو ٦٫٧ كم حسبما اشتق من استمرارية الجاذبية لأسفل.