GEOPHYSICAL INTERPRETATION OF PART OF THE TUZ GÖLÜ BASIN

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SUMMARY. — N.V. Turkse Shell carried out extensive exploration in the Tuz Gölü basin during 1970-1972. The area of geophysical activity extended east-west across the basin.

The interpretation of 422 km of six-fold coverage reflection data is presented here as unmigrated time contour maps, and as a suite of interpreted VAR time-sections.

In 1970, an experimental reconnaissance reflection survey was run over selected parts of the area. In 1971, this was followed by a reconnaissance reflection survey which was based on uphole surveys made at 5 km intervals along each line before production shooting started. In the western part of Tuz Gölü, where piercement structures had been observed on the early seismic lines, detail seismic lines were shot in 1972.

The gravity method was also used to delineate probable salt diapir trends. This gravity data have been compiled with the previous Esso and M.T.A. data. The gravity data of the western Tuz Gölü were processed by Shell in The Hague, using the polynomial method of residual-regional separation.

The relationship between some negative gravity anomalies, the indications of piercement structures and areas of topographic depression was investigated.

The results of two aeromagnetic surveys carried out by Gulf and M.T.A. (Mineral Research and Exploration Institute) are also discussed in this paper.

I. OUTLINES OF GEOLOGY

The Tuz Gölü basin is a NW-SE trending intramontane basin situated in a transverse structural depression. The basement is in general composed of Cretaceous ophiolites, or, where these are eroded, by Mesozoic limestones or Paleozoic metamorphics. The Tuz Gölü basin developed during the Upper Senonian-Oligocene. Over 10,000 meters of sediments accumulated in the deepest part of the basin, representing a complete sedimentary cycle. Subsidence occurred during the Upper Senonian-Lower part of Middle Eocene, followed by regression, which started in the upper part of Middle Eocene and lasted until the end of the Oligocene. After the main deformation, in late Oligocene or Miocene times, local basins, which formed during the Neogene, accumulated varying thickness of volcanics, and continental sediments, including lacustrine limestones. Tensional movements took place during the Neogene and continued into the Pleistocene, leading to volcanic activity which extended into historical times.

II. SEISMIC HORIZONS

No exploration well has ever been drilled in that part of the Tuz Gölü area, discussed in this paper (Fig. 1). Direct correlations between the seismic reflection horizons and geological strata are therefore not possible. However, the following horizons have been picked and tentatively identified.

a. Neogene unconformity 2

The shallow angular unconformity which is best seen on line TG-15 (Fig. 2) can be picked with confidence in a large part of the western Tuz Gölü area. However, this unconformity, which for simplicity's sake is called «Neogene unconformity 2», cannot confidently be correlated to the northern and eastern Tuz Gölü lines where it is less and less angular.

b. Neogene unconformity 1

In the eastern Tuz Gölü area only, a second angular unconformity below Neogene unconformity 2 can be recognized (Line TG-7, Fig. 3). This is «Neogene unconformity 1», which can be jump-correlated from line to line.

c. Oligocene reflections

The outstanding problem of the basin is the interval between the young unconformities and the basement. In the central part of the Tertiary basin, there is no pickable reflection in this interval (Fig. 3). In addition, the reflection packages in this interval in the western and eastern parts are different in character from one another and cannot be correlated across the central part. In the western Tuz Gölü area, this reflection interval, probably Oligocene in age, can be correlated and mapped with the help of tie lines. However, it should be borne in mind that correlations across the probable salt diapirs and the main fault zone running NW-SE along the western margin of the Tuz Gölü basin, may be out by a loop or so. On the other hand, in the eastern Tuz Gölü area, the same ret lection interval cannot be jump-correlated from line to line.

d. Probable salt reflections

In the western Tuz Gölü area, there are reflections in the lower half of the basement-Neogene unconformity 2 interval which are discordant to both the basement and the overlying reflection package of probable Oligocene age. These reflections which show undulations and steep dips, may be associated with salt pillows. The top of these reflections can be seen best on line TG-16 (Fig. 4). However, these probable top salt reflections cannot be correlated and mapped, because the seismic grid is not adequate for this purpose.

e. Basement reflections

In the eastern Tuz Gölü area, the top of a deep reflection package is taken as the seismic basement (e.g. Line TG-7, Fig. 3). This acoustic basement is probably correlatable with the top of the pre-Maestrichtian oil basement. Although there is no tie line in this part, jump correlation of the basement reflection across five lines is considered to be reliable. In western Tuz Gölü, the basement cannot be picked with confidence, except on lines TG-15 and possibly TG 16 (Fig. 2 and 4).

III. STRUCTURAL INTERPRETATION

The survey area extended from flank to flank across the basin in the south and along the southwest flank of the Tuz Gölü basin.

The structural styles observed in the Tuz Gölü basin vary considerably from west to east. As was pointed out earlier, the reflection mterval of interest cannot be correlated across the center of the basin. The western and the eastern Tuz Gölü areas are therefore discussed separately, although the basement reflections can be correlated over the whole area.

a. Basement (Fig. 5)

The basement outcrops along the Ankara-Adana road in the east, and at the northwest end of test line TG 2 in the west (Fig. 1).

In the eastern Tuz Gölü area seismic lines, rather steep basement dips towards the southwest can be seen, while in the west, dips are towards the northeast. The center of the basin, which is deeper than 10 km, has an axis running NW-SE. In eastern Tuz Gölü the basement and to a lesser extent the overlying sediments are normally down-faulted to the west close to the outcrop. A number of these faults can be correlated between the closely spaced lines TG 2 and 7, but with the present coverage, the basement faults towards the basin center cannot be correlated (Fig. 3 and 5). Beneath the diapiric structures (to be discussed later) the basement reflections are deformed by what is interpreted to be velocity uplift by the high velocity material of the diapirs.

b. Western Tuz Gölü

The most interesting prospects in the Tuz Gölü area are the probable halokinetic structures found only in the western part. There are two kinds of structure: diapirs and pillows. A reflection horizon affected by the probable halokinetic structures, has been mapped in western Tuz Gölü (Fig. 6). This horizon (T8) has probably an Oligocene age. The Neogene unconformity 2 is also mapped in this part of the basin. This reflection horizon is also affected by the halokinetic structures (Fig- 7).

1. *Diapirs.* — The best example of the diapirs can be seen on seismic line TG 7 (Fig. 3). The deepest reflections immediately ajdacent to the diapirs occur between 1.5 and 2.0 sec. which would correspond to a depth of 2 to 4 km (using processing velocities). These reflections are interpreted to come from a horizon not far above the top of the salt mother layer. The minimum thickness of overburden required for diapir growth to be initiated is postulated by various authors to fall in the range 2.1 to 7.6 km (Gussov, 1968). Tuz Gölü diapirs do not satisfy the higher limit of overburden thickness. However, it is worth pointing out that relatively high processing velocities resulted from routine velocity analysis and these may be indicative of a denser than average overburden.

The piercement structures seem to line up on two main trends which are parallel to the main northwest-southeast trend of the basin. It is believed that these piercement structures probably developed along zones of weakness in the overlying sediments and that they form irregular dike-like structures with different piercement levels and diapiric shapes along their crests. The western salt wall pierces through horizon T8 (Oligocene), whereas the eastern wall does not; Line TG 23, Fig. 8, Line TG 7, Fig. 3. By analogy with the salt stock families in northwestern Germany (Sannemann, 1968) it can be suggested that the eastern salt wall of Tuz Gölü is older than the western one. Based on the piercement indication on line TG 7 western extension (Fig. 3 and 6) there may be a third salt structure still farther to the west. Branching from the salt walls there may be short offshoots like the one picked on line TG 15, Fig. 2 and 6. This particular off-shoot is believed to be associated with an east-west fault. The piercement structures seem to have caused tangential and radial faults, Fig. 3 and 6. However, with the present seismic coverage and quality, the directions of some of these faults cannot be delineated with confidence.

2. *Pillow.* — A typical example of the non-piercing pillows can be seen on line TG 16 (Fig. 4). However, because of inadequate coverage, these top pillow reflections cannot be correlated and mapped. Moreover, three dimensional ray path geometry has to be taken into account when considering the reflections from a complex of undulating surfaces such as the tops of salt pillows.

3. *Fault zone* (Fig. 6). — The fault zone along the western margin of the Tuz Gölü basin coincides rather closely with a topographical depression. Line TG 19 (Fig. 9) clearly shows down-warping of the Neogene unconformity 2 and the presence of a considerable pre-Neogene fill to the west of the fault zone. It should be noted that correlation of horizon T8 across the salt walls and the main fault zone may be in error by one or two loops.

4. *The Neogene unconformity 2* (Fig. 7). — This map, which covers only the western Tuz Gölü area, shows that the western salt wall disturbs the unconformity, whereas the eastern one does not (Fig. 7). This is another point suggesting that the western salt wall is younger than the eastern one. The fault which runs along the eastern edge of the western salt wall is probably a tangential fault caused by the diapirism.

c. Eastern Tuz Gölü

Excluding the basement reflections, none of the reflections in the eastern Tuz Gölü area can be correlated and mapped. However, the reflection package between the Neogene unconformity 2 and the basement can be divided into four units, from top to bottom:

Unit 1 - This is a reflection package between the Neogene unconformity 1 and 2. This unit, which shows depositional features such as foresets is truncated by the Neogene unconformity 2 and wedges out towards the center of the basin (Fig. 3). The unit is gently folded and faulted. This package, which is about 700 m. sec. thick or line TG 8 (Fig. 10), is thinning to the north and is probably absent to the north of line TG 4 (Fig. 1).

Unit 2 - This unit, which is truncated by Unit 1, is probably the equivalent of the Oligocene package in the west. There are pronounced west-dipping reflections on a number of lines (e.g. line TG 7, Fig. 3).

Unit 3 - This unit can only be picked on two lines TG 2 and TG 7 (Fig. 3). The reflections within this unit wedge out to the east against Unit 4. Therefore, Unit 3 may be considered as the lateral equivalent of Unit 4.

Unit 4 - This unit, which is composed of a series of reflections sub-parallel to the basement, may represent the Cretaceous conglomerates, according to Y. Arıkan *(M.T.A. Bull.,* no. 85). These reflections can also be identified in the center of the basin (e.g. line TG 7, Fig. 3).

V. GRAVITY SURVEY

Gravity was used as an additional method to reflection seismic to delineate the diapiric salt trends in the western part of the Tuz Gölü area.

Turkse Shell and M.T.A. Institute gravity parties carried out surveys in the western part of the Tuz Gölü area in 1971 and 1972. Stations were measured along the profiles and then the data have been compiled with the existing Esso gravity survey to form a regional Bouguer gravity map, covering the whole Tuz Gölü area (Fig. 11).

a. Bouguer gravity map

In the western Tuz Gölü area, the map reveals two main negative anomaly trends which run NW-SE and merge in the north. Along both trends, diapiric structural indications are shown on the seismic sections (Fig. 3 and 8). On the western trend, break in the continuity occurs between the seismic lines TG 7 and 13. Further north, the anomalies are more isolated and the trend may be more discontinuous. To the west of these two well defined trends, a third negative anomaly also trending NW-SE is indicated by bends and wider contour spacing. In some cases the Bouguer anomaly appears to be shifted laterally with respect to the diapiric structure indications on the seismic sections. This was first thought to be the combination of the regional-plus-residual effect (see the following section b).

The most interesting phenomenon on the Bouguer map is the positive anomaly which coincides with the deepest part of the basin. However, the maximum Bouguer value at this positive anomaly is considerably smaller than the Bouguer values in the west and east. Therefore, this positive anomaly is considered to be a relative anomaly caused by the presence of diapiric negative anomalies.

b. Residual-regional separation

The Bouguer gravity data were processed by Shell in The Hague using the polynomial method of residual regional separation.

The residual gravity map (Fig. 12) shows, as expected, all the anomalies discussed in the previous chapter. The eastern of the two NW-SE negative anomaly trends is continuous from SE to NW, while on the western one the discontinuity located between seismic lines TG 7 and 13 is clearly seen. The two trends merge in the NW corner of the map.

To the west of these two trends a third negative, anomaly appears also trending NW-SE. However, this residual gravity map was derived from the early gravity data which at that time did not have adequate coverage in the eastern and southern part of the basin. Therefore, the shape and the trend of this westernmost negative anomaly is better expressed in the Bouguer map. The salt piercement indication on the western extension of line TG 7 is probably associated with this anomaly.

In some cases (e.g. the western of the two main negative trends) the negative anomalies still seem to be shifted laterally with respect to the salt piercement indications on the seismic sections, so that this is not due to a regional-plus-residual effect as was first suspected. This may be due to the superimposed gravity effects of the steeply-dipping pierced beds, low density sediments in the rim syncline below the unconformity, and/or the deep-seated, non-piercing, salt pillows.

One of the negative trends of the residual gravity map was selected for a model study. The aim of the study was to find out whether this negative residual gravity anomaly is caused by three isolated salt diapirs or by a salt wall. The gravity attraction of the models was calculated using a one-kilometer grid spacing (Fig. 13).

The gravity attraction of Model I, which consists of three isolated vertical elliptical cylinders, was computed for a density contrast of 0.25 gr/cm^3. The comparison of the theoretical gravity contour map with the residual gravity map is not very satisfactory.

Model II is a geometrical representation of a wall with varying width and piercement level. The theoretical gravity map of this model was also calculated using a density contrast of 0.25 gr/cm^3. The comparison of this contour map with the residual gravity map can be considered as reasonable.

However, a number of aspects have to be considered:

1. The absolute magnitudes of the theoretical anomalies are higher than the residual gravity anomalies. This may be partly due to the grid spacings of 2 km used for the residual map and only 1 km used for the theoretical map.

2. The negative residual anomalies are influenced by the presence of high positive anomalies in the northwest and southeast. This yields higher apparent gradients on the anomaly flanks.

3. The density contrast of 0.25 gr/cm^3 was taken as a suitable value in order to derive comparable magnitudes. Theoretically the density contrast should be less in the shallow part and higher in the deeper part.

None of the above points were taken into account in the calculations. Variations in the geometrical form of Model II would enable an even better fit to be produced.

VI. TOPOGRAPHY

The westerly of the two main gravity negative trends coincides rather well with the easternmost topographic depression. The eastern gravity anomaly trend does not show any surface expression because the salt movement associated with this anomaly does not affect even the Neogene unconformity (Fig. 6, 7, 14).

The westermost negative gravity anomaly, which is expressed by bends and wider spacings of the Bouguer contours along the well defined trend, coincides rather clearly with a marked topographic depression (Fig. 11, 14).

The coincidence of negative gravity anomalies with topographic depressions may be explained by the fact that graben features commonly develop in formations overlying the crests of upward-moving salt masses.

VII. AERO-MAGNETIC SURVEYS

In 1960, Canadian Aero Service Limited carried out aero-magnetic surveys for oil prospects (on behalf of Gulf Research and Development Company) and for mineral prospects (on behalf of Mineral Research and Exploration Institue of Turkey (M.T.A.)). Although the flight altitudes and base intensities of these two surveys are different, they have been compiled together in order to give a wider view of the southern Tuz Gölü area (Fig. 15).

The main feature on the total magnetic intensity contour map is the pronounced NW-SE trending positive anomaly. It is parallel to the structural trend of the basin and has a magnitude of about 400 gamma. The large dimensions of the anomaly indicate a deep-seated origin. Since the oil geological basement outcrops as marble, near the village of Obruk (i.e. on the SW flank of the positive anomaly), and since marble has a negligible magnetic susceptibility, the source material for the anomaly must be sought elsewhere.

It is interesting to note that the anomaly coincides with a positive residual gravity anomaly (Fig. 12). The gravity anomaly, however, is broken in two whereas the magnetic anomaly is continuous. This may be due to the effect of flight altitude on the resolution of aeromagnetic anomalies and/or the gravitational effects of shallow salt masses superimposed on deeper basement anomalies.

In the northeast, two positive aeromagnetic anomalies also lie on a NW-SE trend. The character and dimensions of these anomalies may be indicative of basement material whose magnetic susceptibility is different from that which causes the regional magnetic anomaly mentioned above.

The local high-magnitude anomalies farther to the north-east are clearly related to known ophiolite outcrops. The strong local anomalies in the southeast part of the Gulf survey and the southern part of the M.T.A. survey are caused by surface volcanics.

VIII. CONCLUSIONS

The reflection seismic, gravity and surface topographic data in the Tuz Gölü area indicate the presence of possible salt structures. The interpretation of geophysical data is in excellent agreement. The aeromagnetic data indicate different basement materials in the west and east of the basin.

The Tuz Gölü area has proved very interesting but structurally complex so that more geophysical surveying should result in a better understanding of the whole area. The source of the salt in the lake and in the subsurface should be investigated.

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REFERENCES

ARIKAN, Y. (1975): The geology and petroleum prospects of the Tuz Gölü Basin. *M.T.A. Bull.,* no. 85, Ankara.

GUSSOW, W.C. (1968): Salt Diapirism: Importance of temperature, and energy source of emplacement, Diapirism and Diapirs.

O'BRIEN, G.D. (1968): Survey of diapirs and diapirism, Diapirism and Diapirs.

SANNEMANN, D. (1968): Salt-stock families in Northwestern Germany. Diapirism and Diapirs.

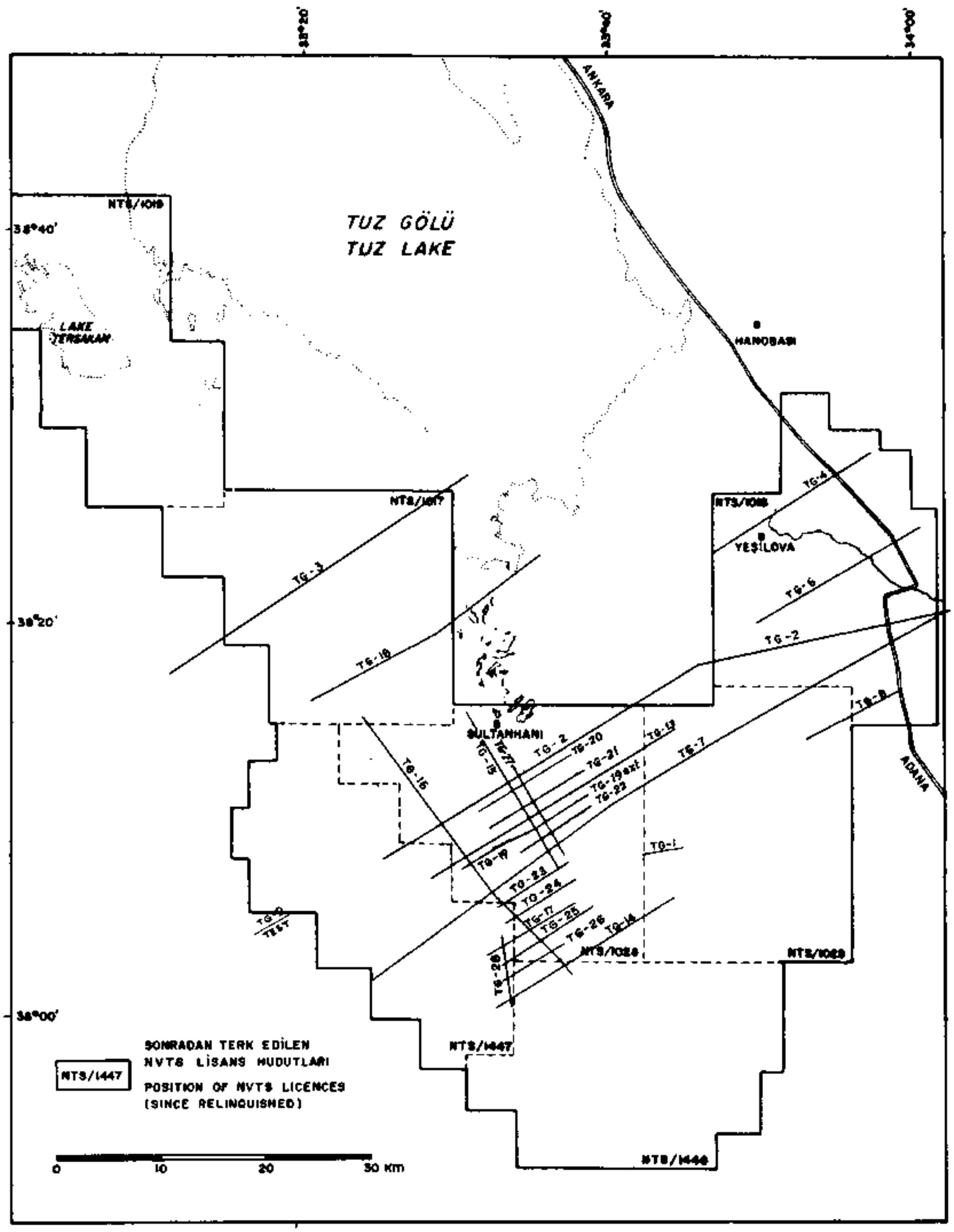


Fig. 1 — Seismic location map.

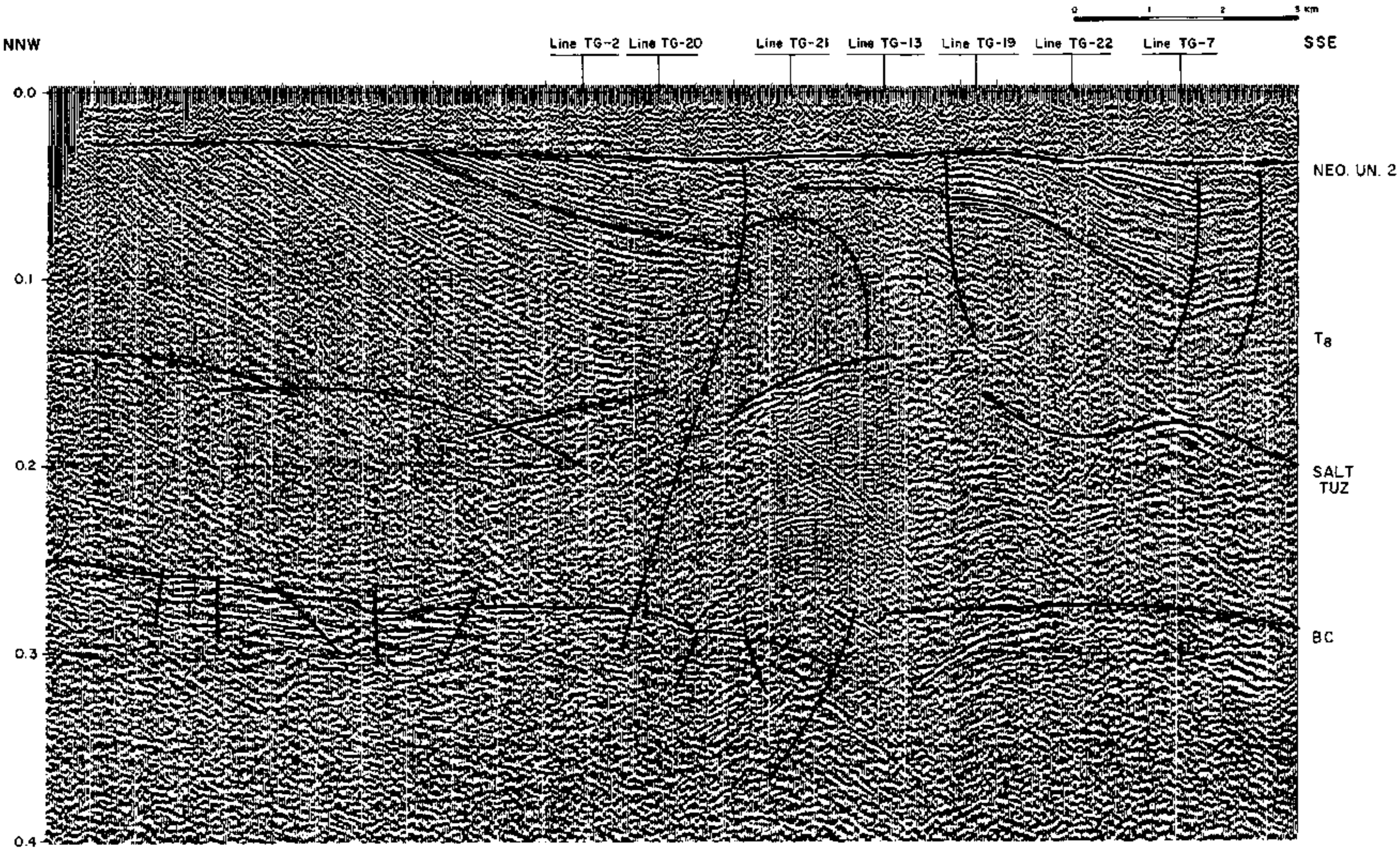


Fig. 2 — Seismic line TG-15.

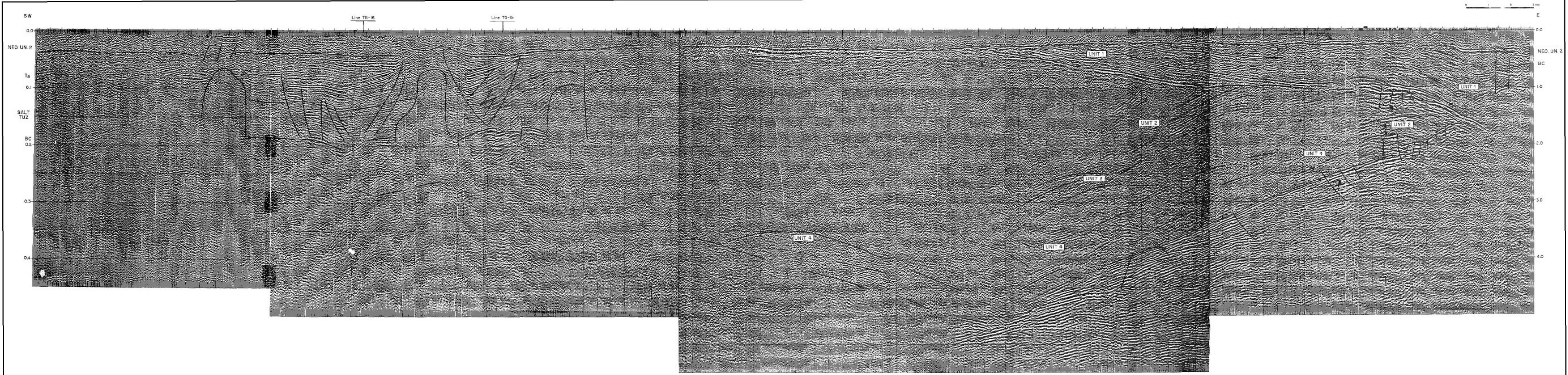


Fig. 3 — Seismic line TG-7.

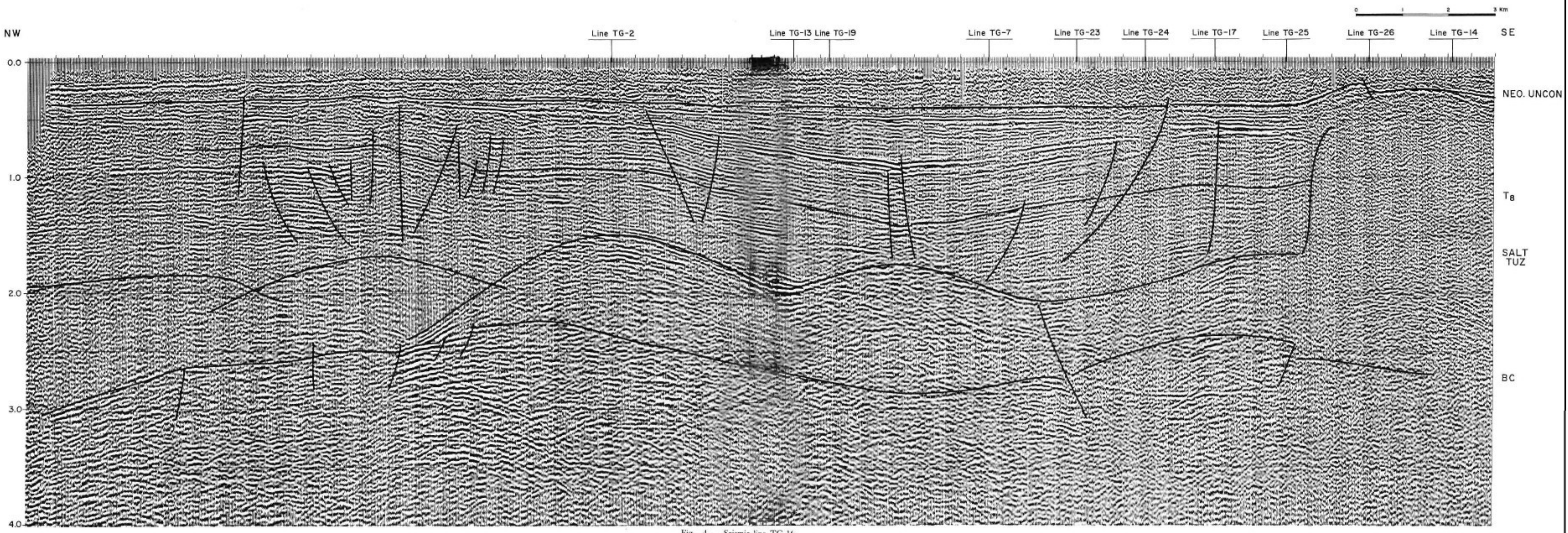


Fig. 4 — Seismic line TG-16.

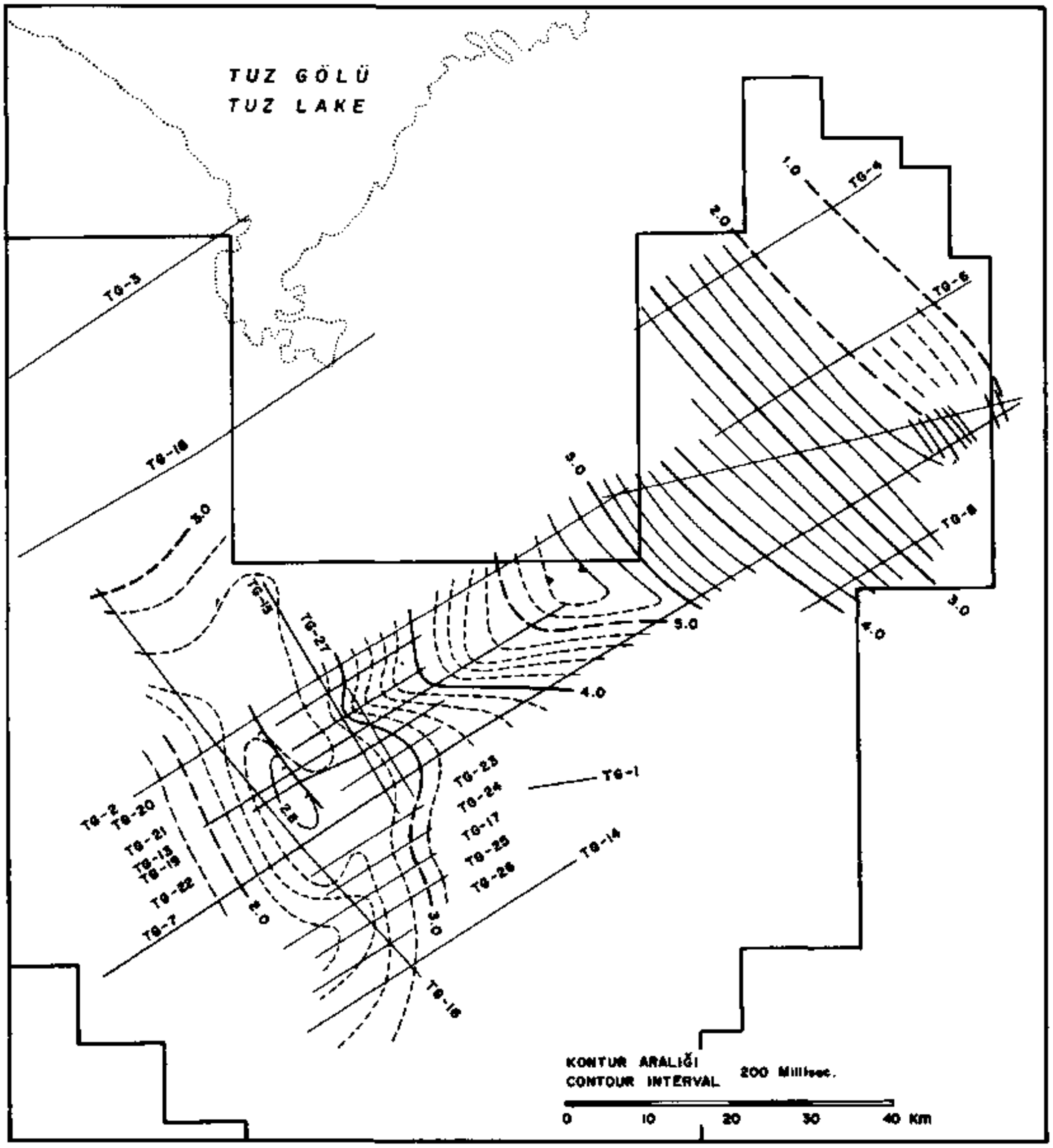


Fig. 5 — Unmigrated time contour map of seismic basement.

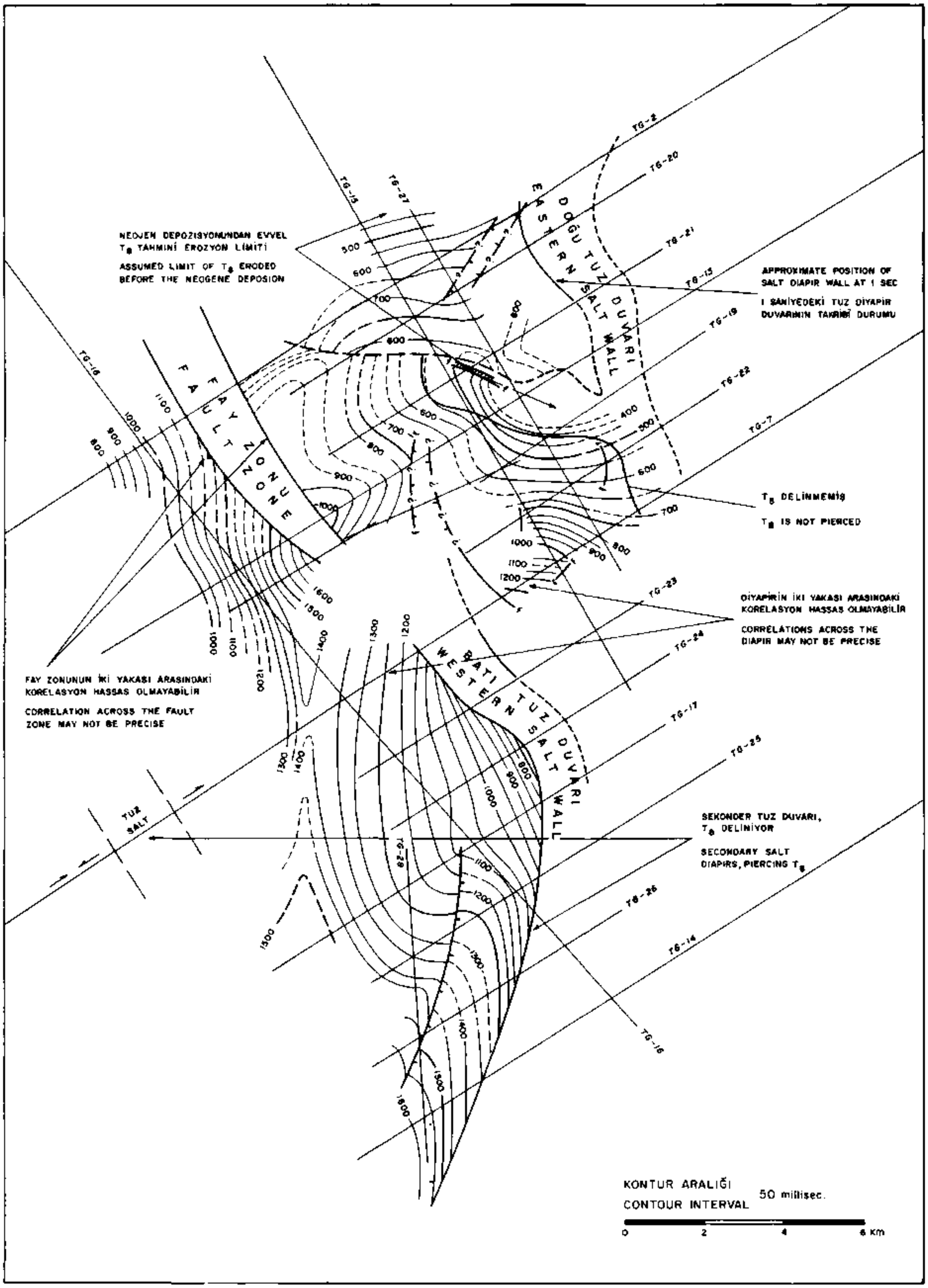


Fig. 6 — Unmigrated time contour map of seismic horizon T_8.

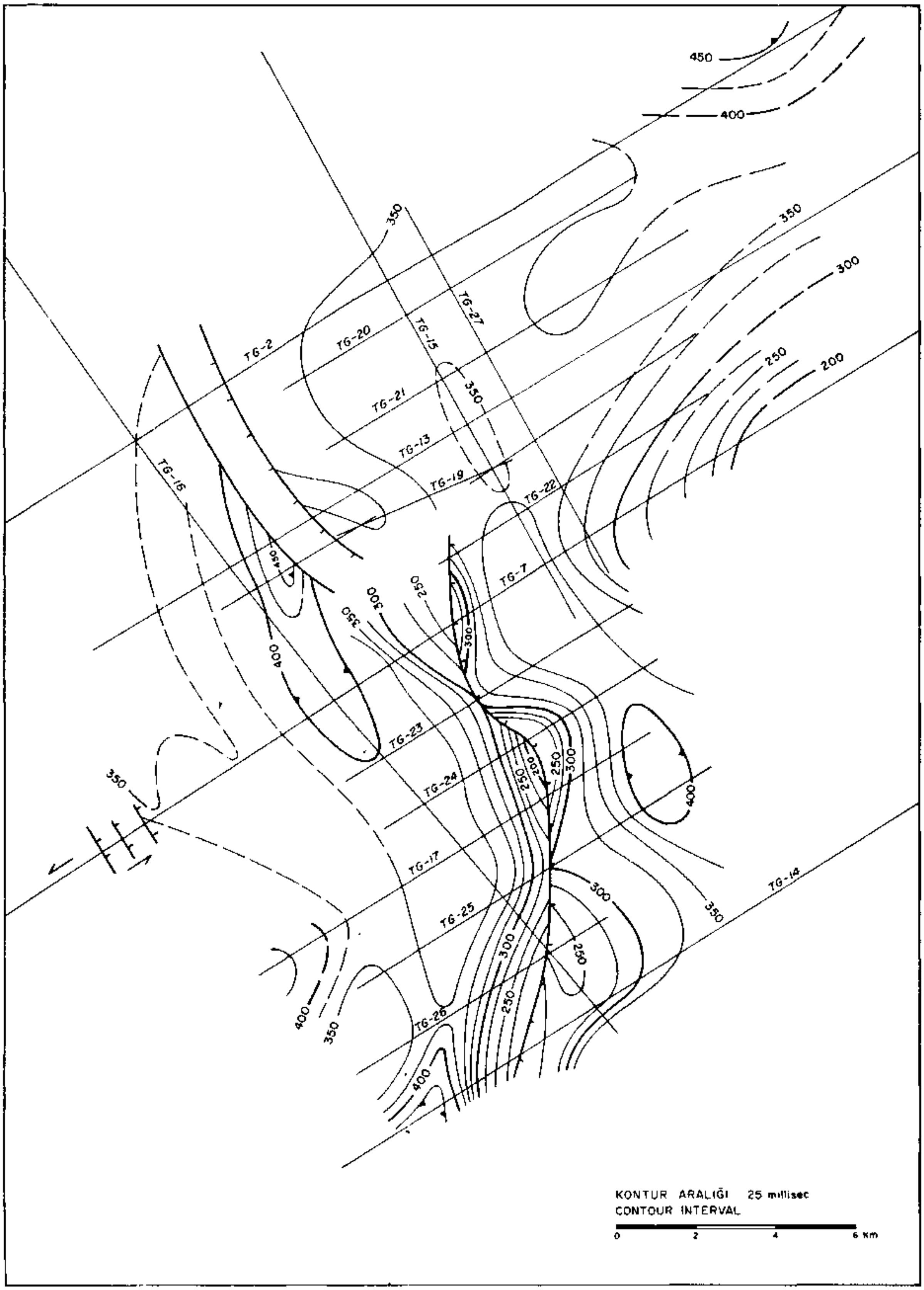


Fig. 7 — Unmigrated time contour map of Neogene unconformity.

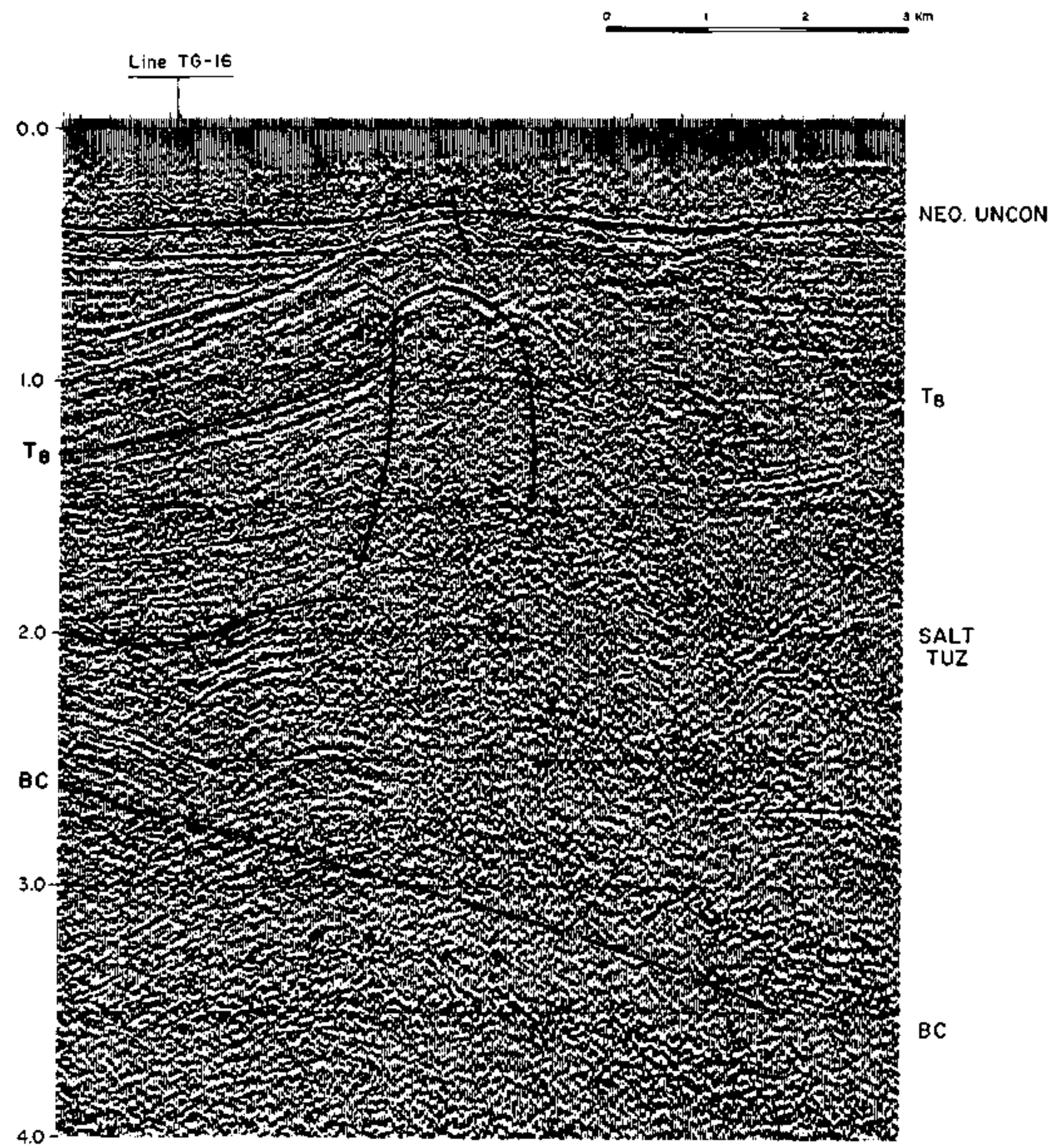


Fig. 8 — Seismic line TG-23.

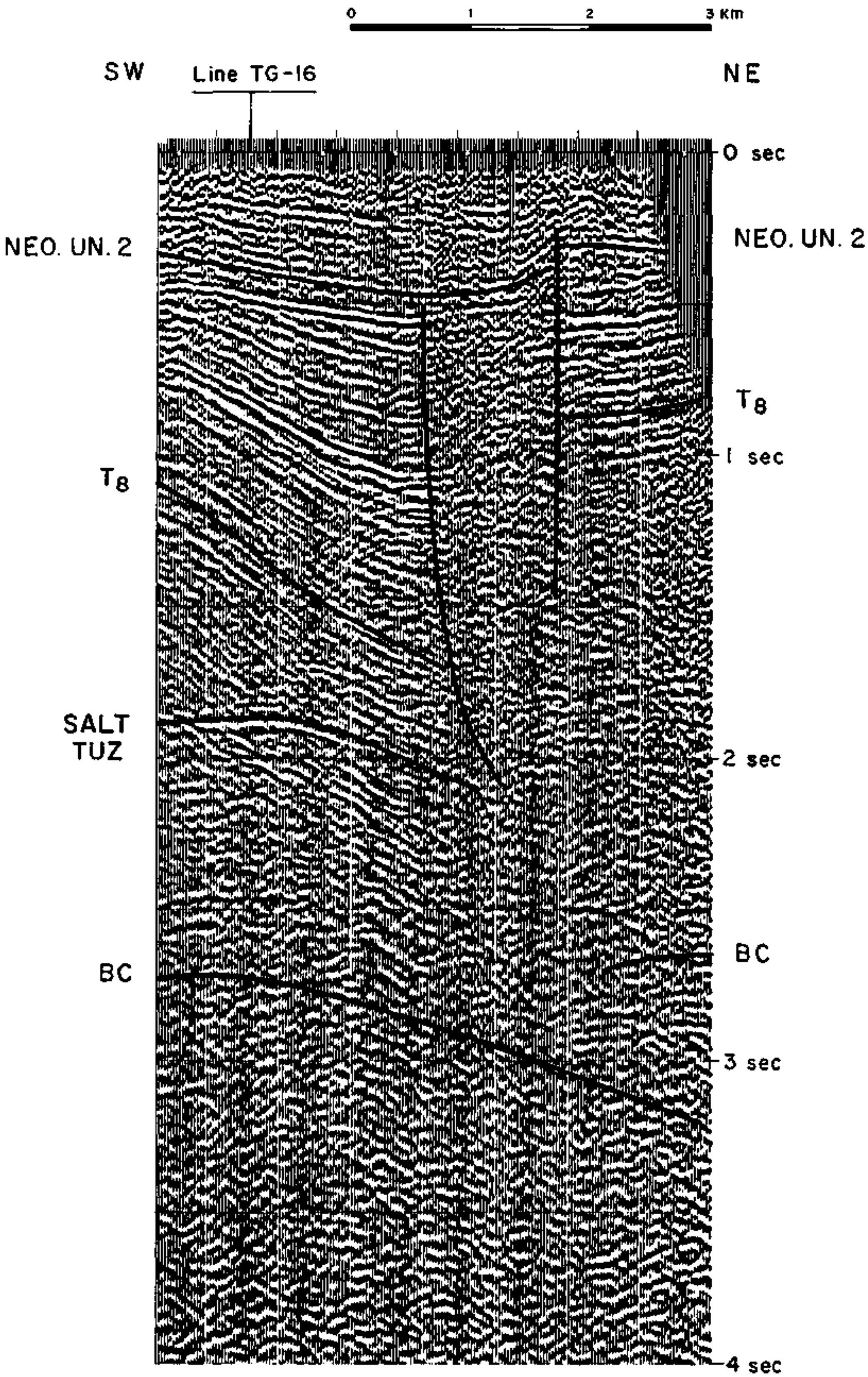


Fig. 9 — Seismic line TG-19.

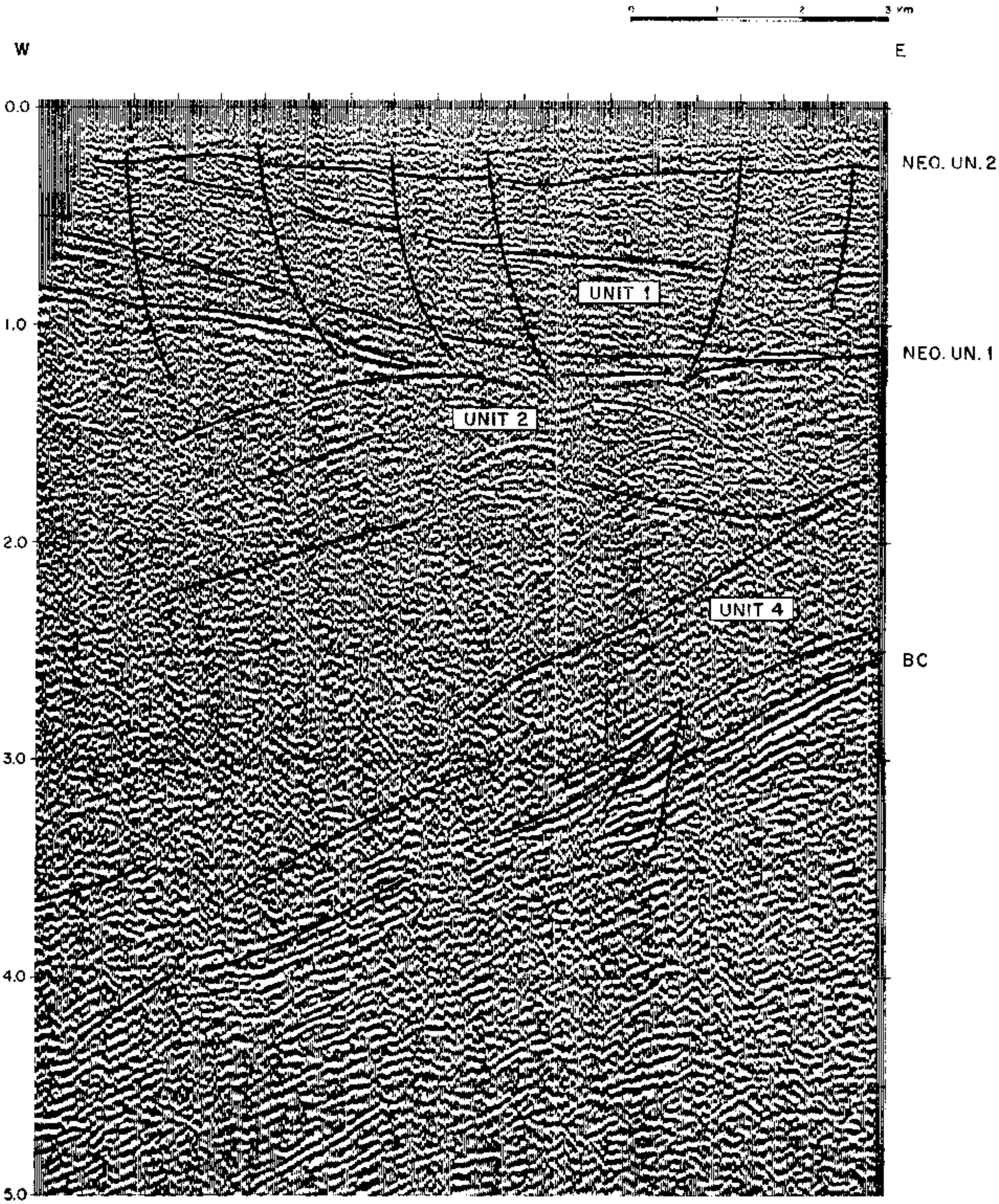
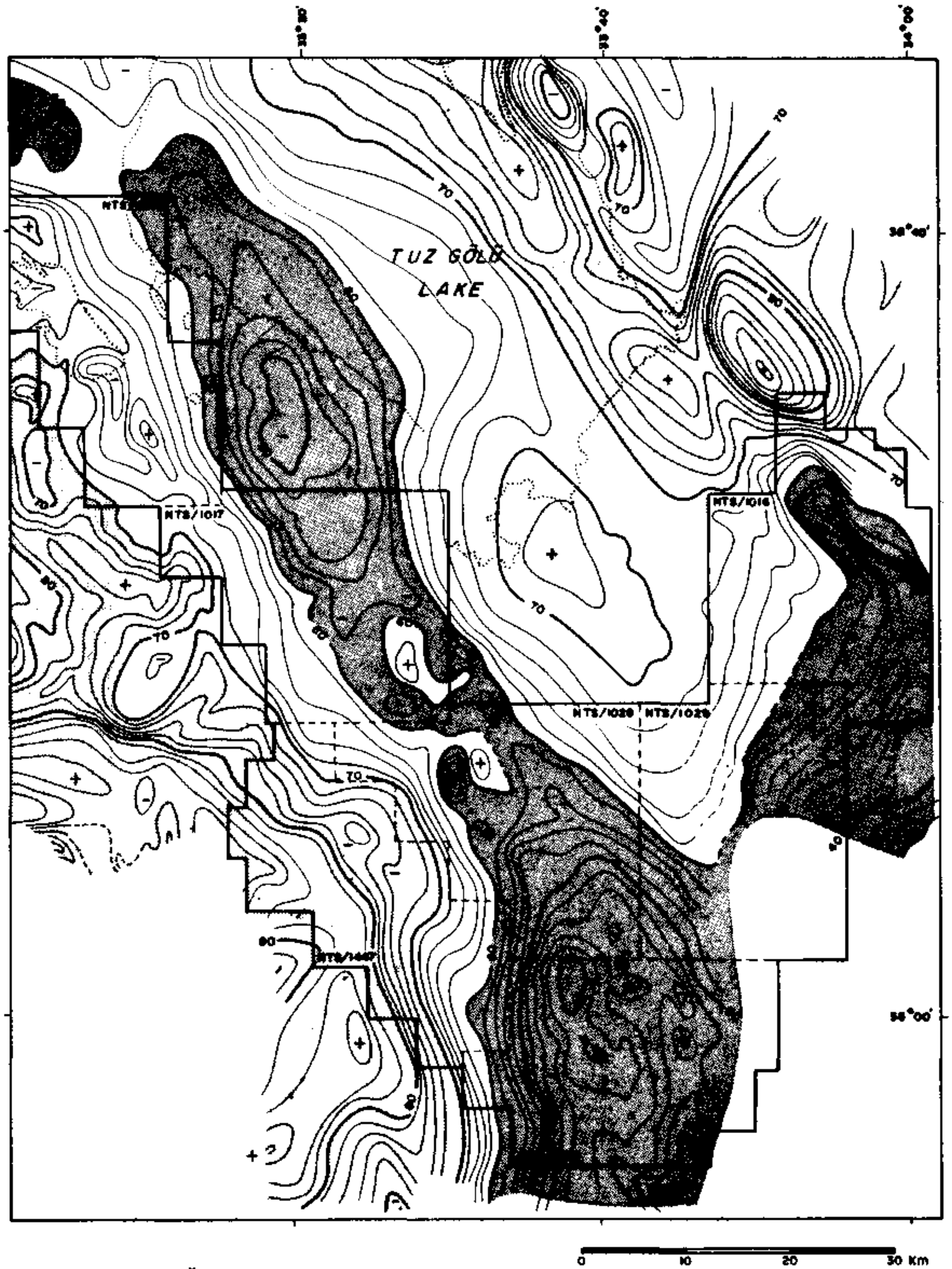


Fig. 10 — Seismic line TG-8.



KONTUR ARALIĞI 2 milligal CONTOUR INTERVAL

BOUGUER DEĞERLERİ
BOUGUER VALUES > 60 milligal

BOUGUER DEĞERLERİ
BOUGUER VALUES > 70 milligal

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POSITION OF NVTS LICENCES (SINCE RELINQUISHED)

Fig. 11 — Bouguer contour map.

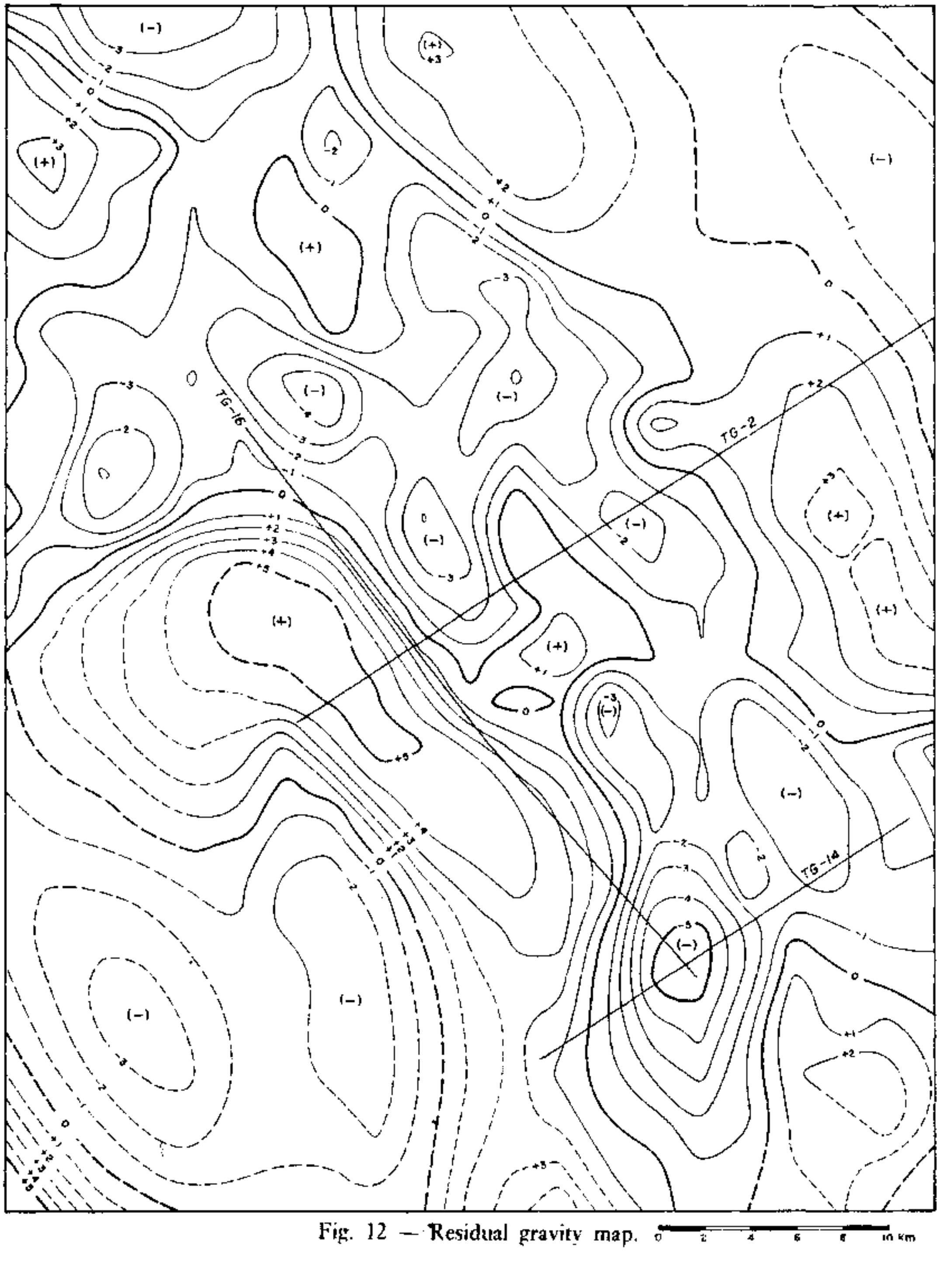


Fig. 12 — Residual gravity map.

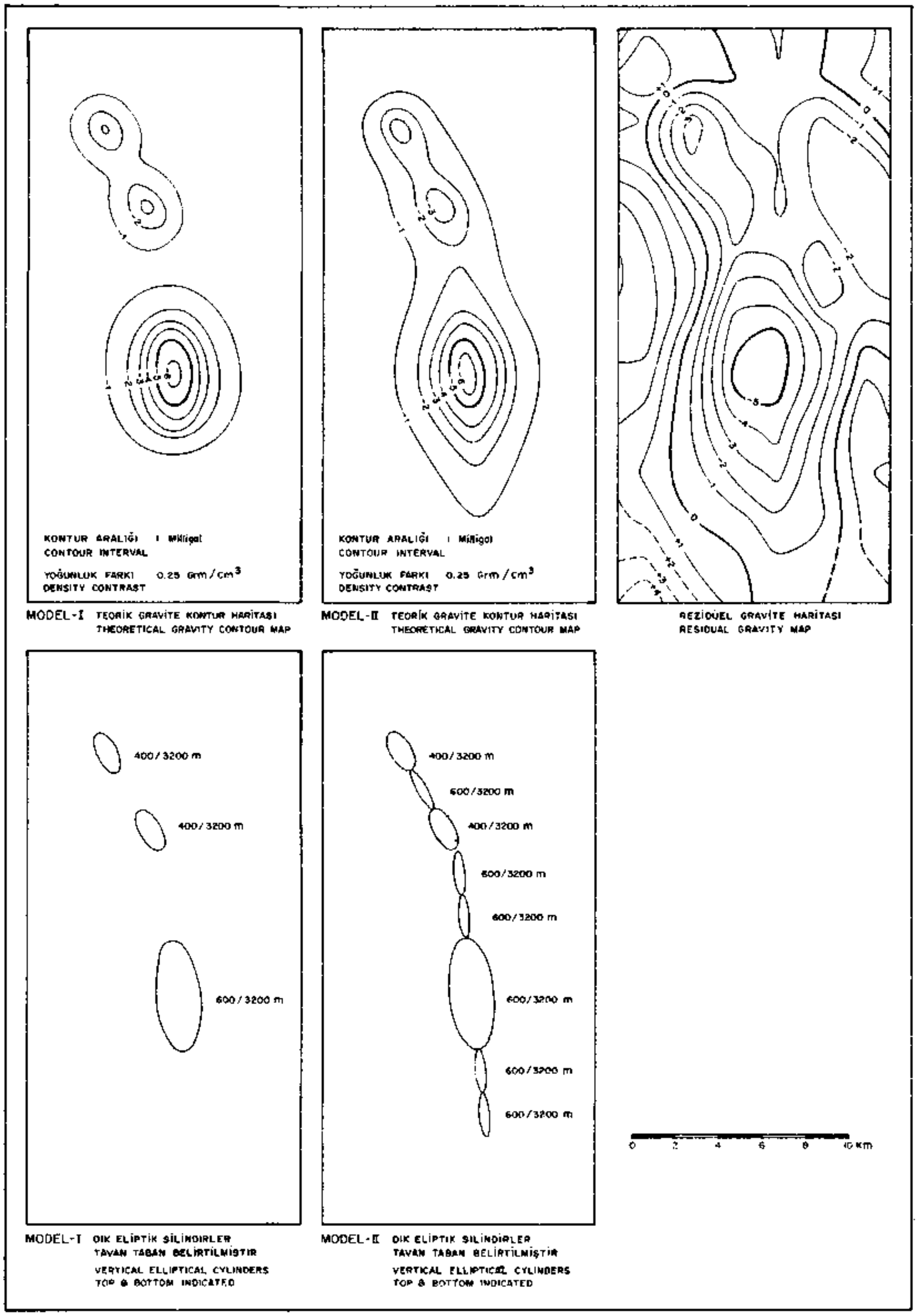


Fig. 13 — Model studies of residual anomalies.

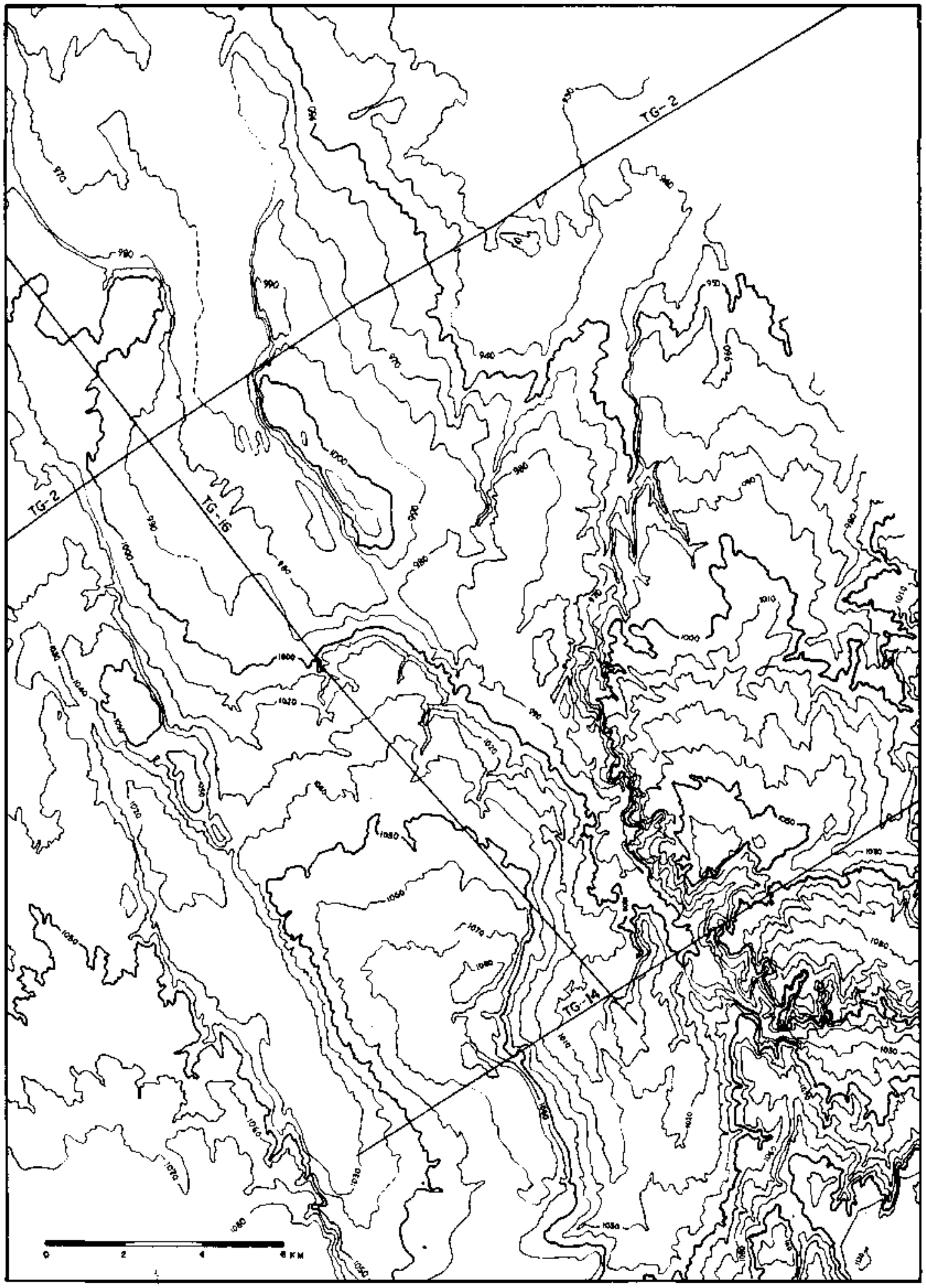
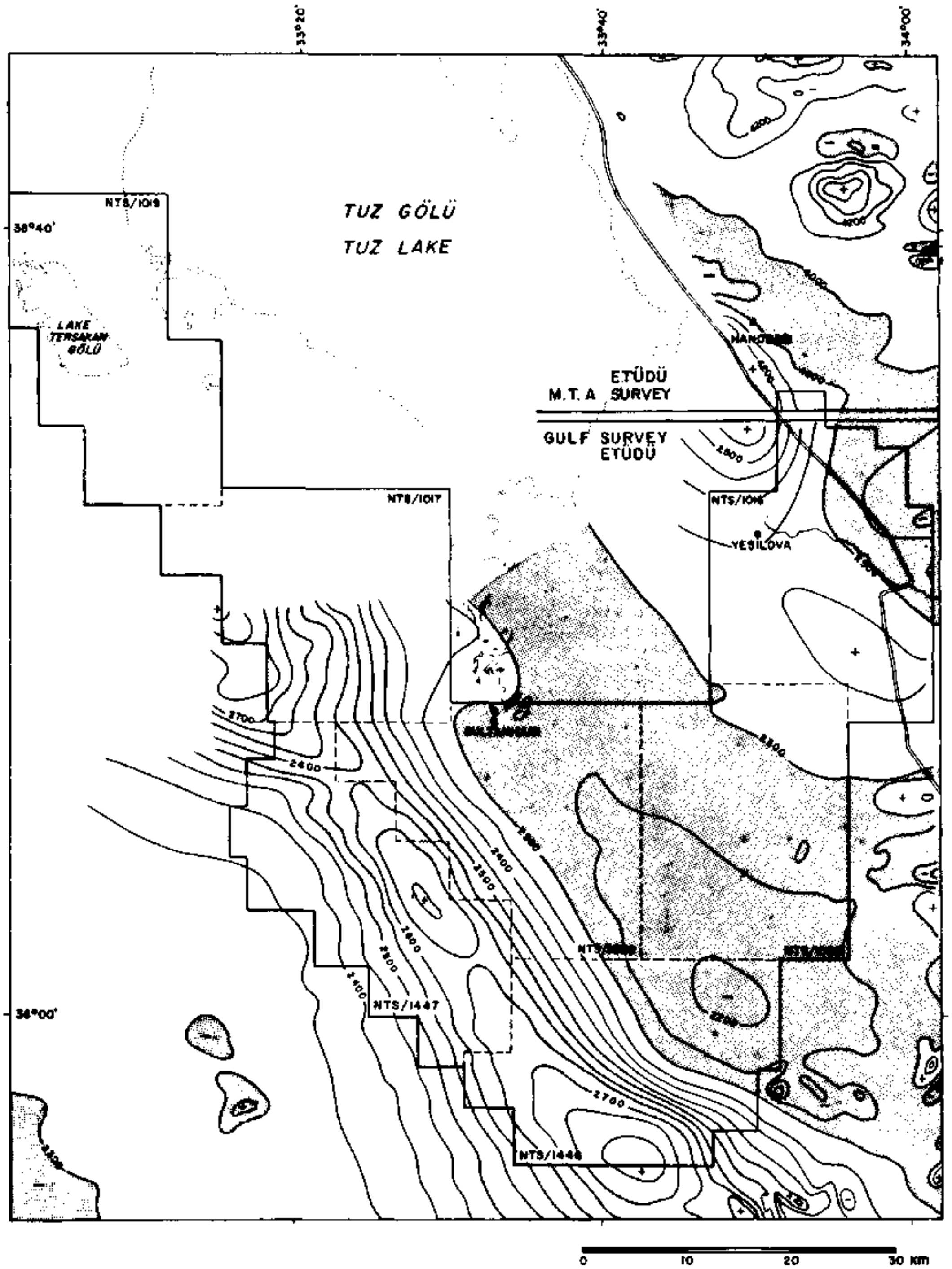


Fig. 14 — Surface topography contour map.



	GULF	M.T.A.	
CONTOUR INTERVAL	50 GAMMA	100 GAMMA	KONTUR ARALIĞI
FLIGHT ALTITUDE	6500 FEET	150 METRES	UÇUŞ YÜKSEKLİĞİ
TRAVERSE INTERVAL	1 KM	2 KM	TRAVERS ARALIĞI
BASE INTENSITY	ARBITRARY	ARBITRARY	BAZ DEĞERİ
DEĞERLER VALUES	> 2500	> 4200	
DEĞERLER VALUES	< 2300	< 4000	

NTS/1447 — SONRADAN TERK EDİLEN NVTS LİSANS HUDUTLARI
POSITION OF N.V.T.S. LICENCES (SINCE RELINQUISHED)

Fig. 15 — Airborne magnetometer survey total magnetic intensity map.