PRJ, Vol. 2. (January 1990); P. 25–41, 19 FIGS.

ON THE HYDROCARBON PROSPECTIVITY OF NORTH CYRENAICA REGION, LIBYA.

M. Sola* and B. Ozcicek**

الإحتمالات البترولية لمنطقة برقة — ليبيا

د. مصطفى صوله وبرهان اوزشيشك

تشكل منطقة برقة الجزء الشمالي الشرقي من ليبيا ، بينما تتركب المعالم التكتونية للمنطقة من مسطح برقة والأحواض والمرتفعات المحيطة به ، حيث يحتوي هذا المسطح على صخور رسوبية سميكة ترجع إلى الحين القديم ، والتي ربما لم تتأثر بعوامل التعرية حتى الحركة الهيرسينية .

خريطة الخاصية البوجيرية للمنطقة يتركز بوسطها مجال سالب يصل إلى – 20 ميلليجال ويعزى هذا إلى تواجد قطاع سميك من الصخور الرسوبية مقارنة بالمناطق المحيطة بها كما أكدته معلومات الآبار العميقة بالمنطقة . وتوجد تدرجات بمجال الخاصية البوجيرية وهي تطابق الفوالق الرئيسية التي تحدد معالم المسطح ، ويعكس المجال الموجب في إتجاه الشمال وجود صخور القاع على أعماق ضحلة بمرتفع الجبل الأخضر.

التباين في مجال الخاصية المغناطيسية المسجل بالمنطقة قد يكون ناتجاً عن صخور القاع نفسها ، أو عن مصادر بصخور القاع على أعماق تتراوح ما بين 1–8 كلم ، بينما التدرج في التباين الضعيف نسبياً قد يكون ناتجاً عن مصادر بالصخور الرسوبية .

وتغطي المسوحات السيزمية الإنعكاسية حوالي 30,000 كلم طولي بالمنطقة ، وقد ساعدت نتائج هذه المسوحات ، خاصة بعد ظهور وسائل التقنية الحديثة ، على تحديد أدق للمعالم التركيبية والتطابقية المعقدة في المنطقة .

وتؤكد المعلومات الجيولوجية والجيوفيزيائية ، ومعلومات تسجيلات الآبار بالمنطقة على وجود صخور رسوبية سميكة تحوي صخور المصدر وصخور المكمن .

وعليه فإن الإمكانيات البترولية للمنطقة تبدو مشجعة .

ABSTRACT

The north Cyrenaica region forms part of the north-eastern area of Libya. The Cyrenaica Platform and the uplifts, basins and sub-basins surrounding it constitute the main tectonic elements of the region. The Cyrenaica Platform accomodates considerably thick paleozoic sediments which appear to have escaped erosion until the Hercynian Orogeny.

A negative Bouguer anomaly (closure) of the order of twenty milligals is recorded over the Cyrenaica Platform. This anomaly is attributed to the thick sedimentary cover in this Platform compared to the parts around it. The deep well drilling data also support this view. Relatively high gravity gradients are present in the Bouguer gravity map bordering the Platform. These gradients are interpreted in terms of the major fault patterns. A large positive Bouguer gravity anomaly is located in the northern most extension of the region, outside the Cyrenaica Platform. It is apparently associated with the basement high in Al Jabal Al Akhdar Uplift.

The magnetic anomalies recorded in the region are believed to have been caused by basement or intrabasement sources at depth varying from 1 to 8 kilometers. The narrow and relatively weak magnetic trends are attributed to sources within the sediments.

The seismic reflection data in the region totals about 30,000 line-kilometres. The data of early seismic surveys (1960's) are invariably of poor quality compared to the recent improved coverages.

The results of seismic coverages, by modern techniques, have helped to sharpen the insights into the complicated structural and stratigraphic features occuring in the region. The available geological, geophysical and drilling data indicate the presence of thick sedimentary sequence containing source and reservoir rocks. The potential of the region for hydrocarbon accumulations, therefore, appear encouraging.

*Petroleum Research Centre, Tripoli, G.S.P.L.A.J.
**National Oil Corporation, Exploration Dept., Tripoli, G.S.P.L.A.J.

INTRODUCTION

The north Cyrenaica region occupies the northeastern corner of Libya. The region covers an area of around 200,000 square kilometers. It is bounded by the longitudes 20° E and 25° E and the latitudes from 29° N to 32° N. The surface elevations range from the sea level in most parts to a maximum of 250 m in Al Jabal Al Akhdar Uplift in the north. The region is surrounded by the Mediterranean sea to the north, the Egyptian Plains to the east, the Kufra Basin to the south and the Gulf of Sirte to the west (Fig. 1). Barr (1968) and Rahlich (1978) worked extensively on the geology of the Cyrenaica region. These and other studies reveal that the subsurface geology in this region is extremely complicated. Since the present work seeks to assess the hydrocarbon prospectiviy of the region, only an overview of the complicated structural environment is presented without detailed accounts of these studies.

Geophysical surveys commenced in the Cyrenaica region from the early 1950's. A large amount of gravity, magnetic and seismic data have so far been obtained. Also, over a hundred wells have been drilled. The results of these concerted efforts provide the basis for interpreting the geologic framework of the region. Vis-a-vis the old reflection seismic data, the recent results from modern seismic practice show that most of the wells in the Cyrenaica Platform and Al Jabal Al Akhdar Uplift happen to be off-located. The poor quality data of the earlier years thus appear to have caused the drilling of unproductive wells. Seismic sections from improved data acquisition and processing techniques compared with those of the same lines shot earlier clearly demonstrate the point. The situation therefore calls for a reassessment of the hydrocarbon prospectivity of the region. The new data in integration with the earlier ones is useful in two ways. First, it helps to find the causes for the failed wells.

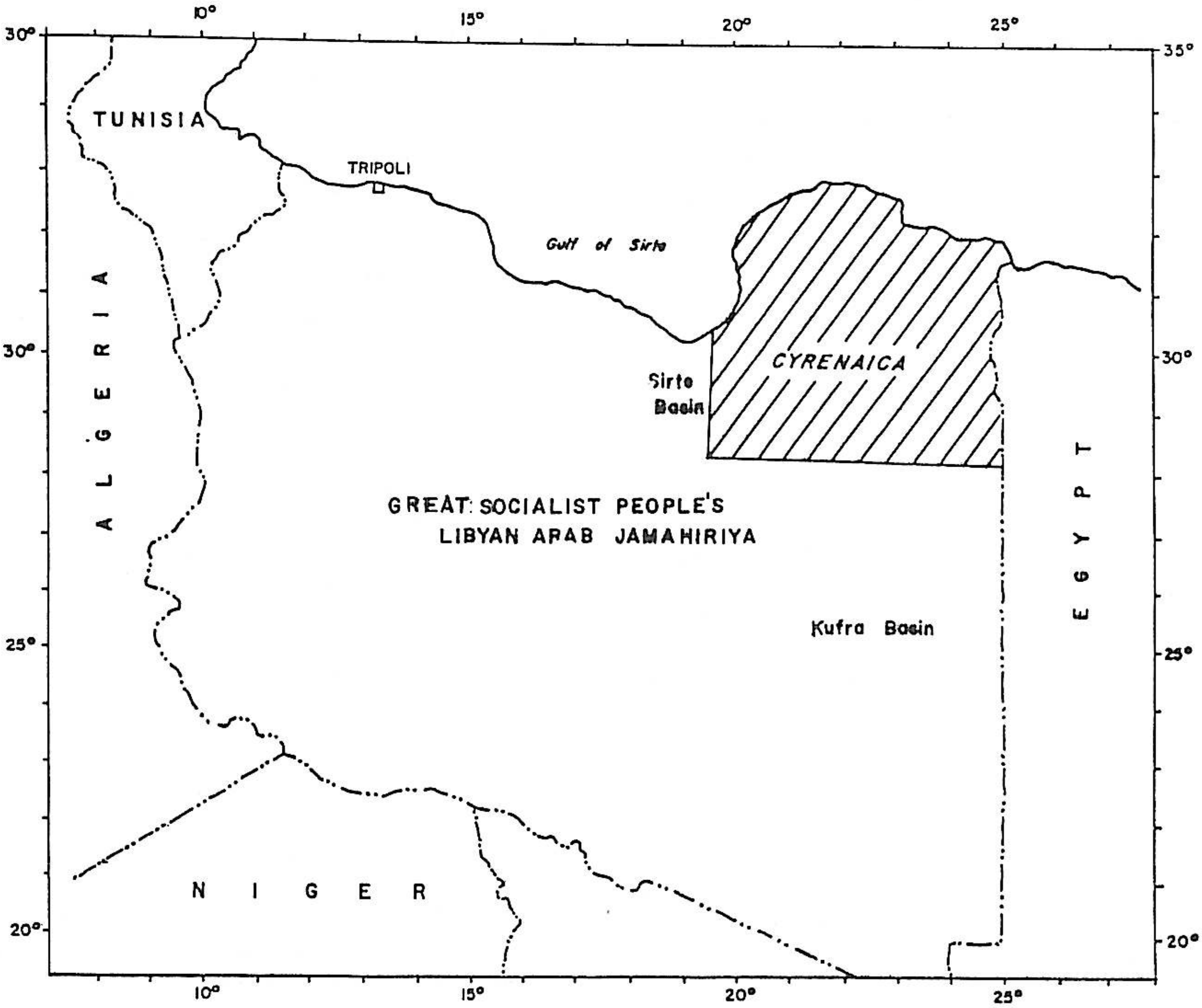

FIG. 1. Geographic location of Cyrenaica region

Second, it facilitates to improve the understanding of the complicated structural setting through more precise subsurface information than was available. An appraisal of the hydrocarbon prospectivity of the north Cyrenaica region is attempted here against this background. The work emphasises the promising prospectivity as indicated from the available subsurface data particularly from seismics.

GEOLOGY AND STRUCTURE

The north Cyrenaica region is covered by upper Cretaceous Tertiary and Recent sedimentary formations. The last includes marine sediments as well. Outcrops of all formations are rich in fossils Francis *et. al.* (1977), Zert (1974), Swedan *et al.* (1977), Klen (1974) and Rohlich (1974). Al Jabal Al Akhdar Uplift and the Great Sand Sea are the major geologic features of the region (Fig. 2).

The former occuring at the northern fringes of the Cyrenaica region contains sedimentary sequences dipping steeply towards the north. Elongated cliffs is therefore the prominent features of the terrain here. They are cut across by deep and broad wadis originating at the highs. Consequently, these parts contain thick and broad valley fills. Upper cretaceous rocks are exposed at the western margin of the Uplift. The Great Sand Sea located at the south of the platform passes eastwards into the Egyptian plains.

The rest of the Cyrenaica region has Tertiary and Quarternary deposits at the surface. Large escarpments and undulating gravel plains are present in the central and eastern parts of the region. Patches of Sabkha and sand dunes occur in the west and northwestern parts. These varied surface lithologies and topographic peculiarities affect the quality of the geophysical data, particularly, the gravity and seismic surveys in the region.

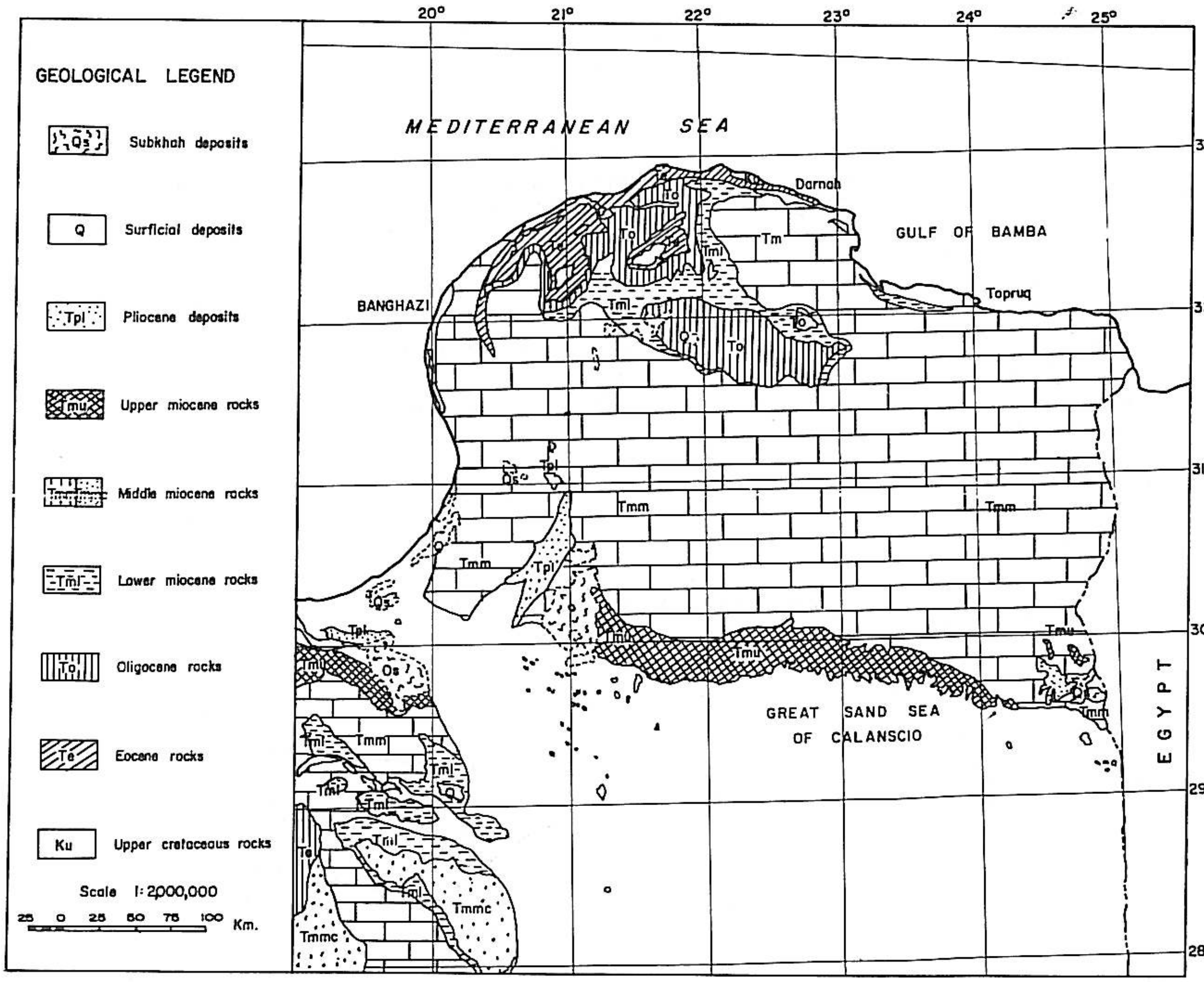

FIG. 2. Geological map of North Cyrenaica

The tectonic activity in the north Cyrenaica region, Rohlich, (1980), dates from the Caledonian to Middle Tertiary times. The repeated tectonic disturbances of this period have subjected the region to uplift, subsidence, tilting, faulting, folding and erosion. The major structural elements infered from geological, geophysical and drilling data are synthetised in Fig. 3.

They include the stable Cyrenaica platform in the centre. It abutts against the relatively unstable Al Jabal Al Akhdar Uplift in the north. The nearly east-west oriented Marmarica Hinge separates these two. In the northwest, however, the platform is limited by the Hamama graben and Antelat trough. The platform is bounded in the east by the Marmarica basin. These two are isolated by a Mesozoic (Marmarica) fault. The stable platform is limited in the south by the Jaghbub uplift. In the southwest, it is margined by the Sirte embayment. Goudarzi (1980) proposed a Tertiary fault line between the two at the southwestern limits of the platform. The Antelat trough occurs immediately east of this fault. It forms the unstable element at the northwestern part of the stable platform region. The geologic features of these major elements are reviewed below:

Cyrenaica Platform

The Cyrenaica (stable) platform is expected to have a total sedimentary thickness of about 5000 meters. The major part (4000 meters) of this sedimentary sequence is believed to be Paleozoics, ranging in age from Cambro-Ordovician to late Carboniferous, (Fig. 4). The rest is the combined Mesozoic and Tertiary thickness.

These sequences are unconfortably overlain by members of the Upper Cretaceous, (Fig. 5). The

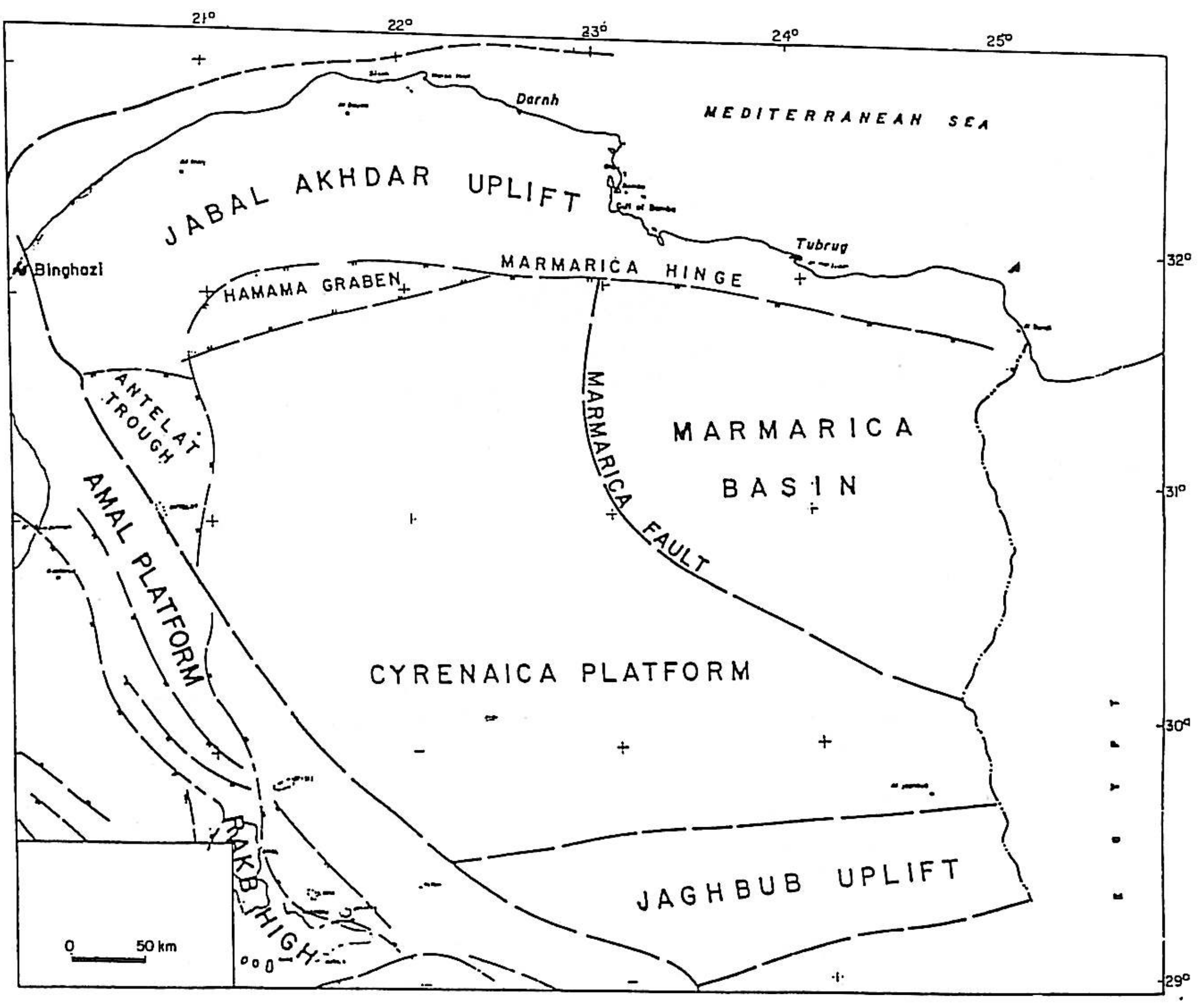

FIG. 3. Tectonic elements of North Cyrenaica

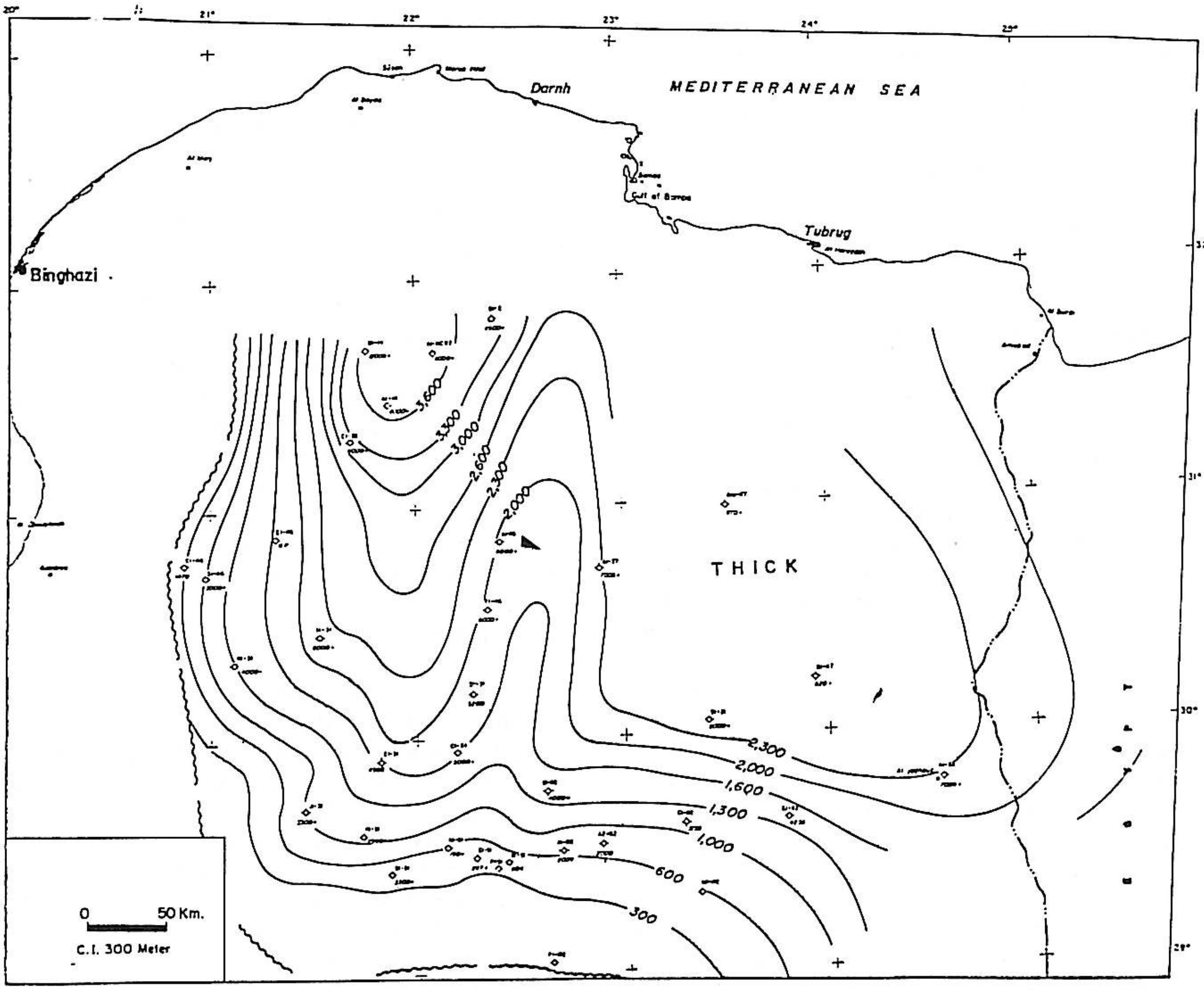

FIG. 4. Isopach map of total Paleozoic North Cyrenaica

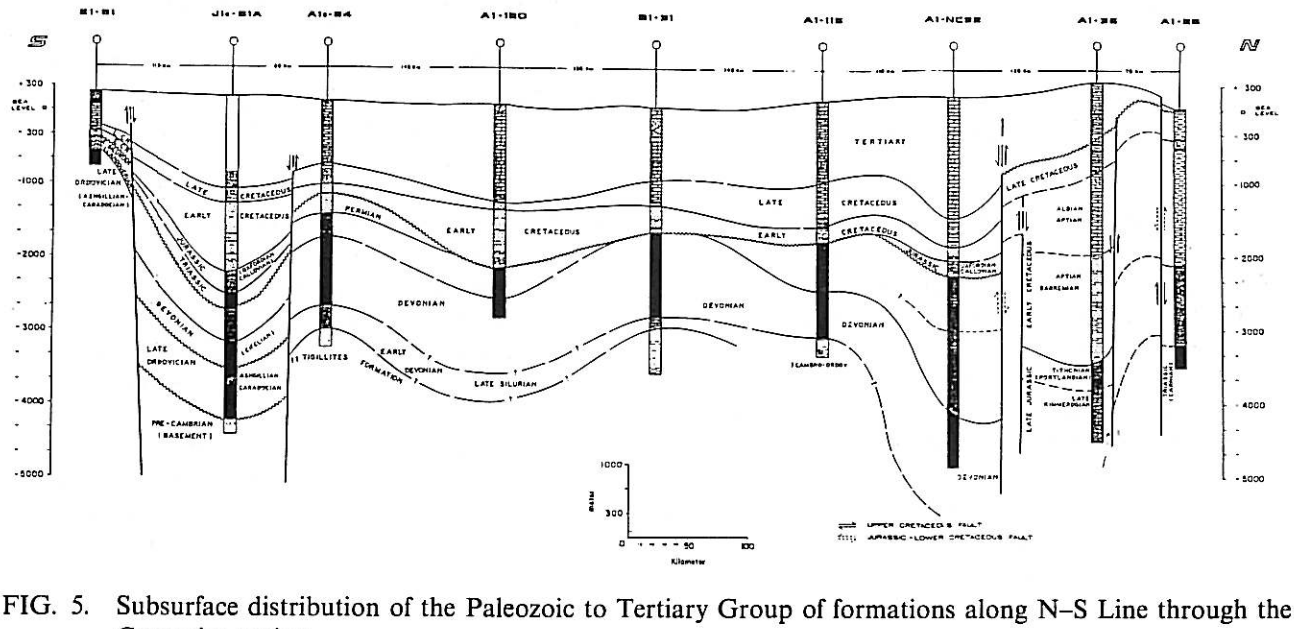

FIG. 5. Subsurface distribution of the Paleozoic to Tertiary Group of formations along N–S Line through the Cyrenaica region

maximum thickness of the Paleozoics in the stable platform part of the Cyrenaica region is brought out by this cross section. The thick Paleozoic sequence thins down to 300–400 meters towards the south and southeast extremities of the platform. Note the section also brings out the faulted contacts limiting the Cyrenaica platform in the northern as well as in the southern extremities.

Unstable platform constituents

The geoelements constituting the unstable platform portions are characterized by rapid subsidence throughout the Mesozoic era compared to that in the stable platform. The geoelements include Al Jabal Al Akhdar Uplift, the Antelat Trough, Hamama Graben and the offshore Basement Ridge.

The Cyrenaica platform abutts against the uplifted and exposed block of Al Jabal Al Akhdar. It comprises of a gentle domal complex exhibiting a rough northeast-southwest trend. The oldest formation reached by drilling in these parts lies within the Jurassic. The late Jurassic-early cretaceous thickness in the uplifted block is of the order of 4000 meters. This contrasts with their thickness of about 1000 meters in the Cyrenaica platform. The abrupt thickening of the formations of particularly the early cretaceous times is indicative of their deposition in a rapidly sinking trough during this period.

The Hamama Graben and Antelat Trough at the north and northwest margins of the platform are down-faulted blocks. They contain large thicknesses of the Jurassic/Cretaceous formations. These fault blocks are terminated in the north by a nearly northeast-southwest running late Cretaceous fault.

The offshore Basement Ridge is the one inferred from the magnetic data by Shell (1974). The Marmarica Basin at the eastern fringes of the platform is a fault basin. An arcuate Mesozoic fault separates this basin from the platform. The northern limit of the Basin is formed by the east-west oriented upper Cretaceous fault. Al Jabal al Akhdar was uplifted to the north of this fault. Thick marine sediments of Jurassic age are present in this Basin (El-Arnauti 1985).

The Jaghbub uplift bordering the southern limit of the Cyrenaica Platform appears to be a basement high as based on the available drilling data. Marine upper Cretaceous formations are present here on an undifferentiated basement. The uplift is believed to have taken place during the Caledonian orogeny with possible rejuvination in the Hercynian cycle. The Sirte Embayment is the last geoelement bordering the platform at the southwest margin. The two are inferred to be separated by an arcuate fault of probable Tertiary age. The major structural features of the Embayment trend nearly in the northwest-southwest direction.

GEOPHYSICAL STUDIES

Numerous geophysical surveys have been carried out in connection with oil exploration in the north Cyrenaica region. The early geophysical surveys date back to 1950's where a considerable amount of gravity and magnetics along with seismic reflection survey data have been acquired.

The geophysical activity slowed down during the seventies owing to poor siting of wells. It is now found to be the result of poor quality data of the early surveys used in siting them. However, geophysical operations at increased pace commenced by the early eighties. It is now continuing with data of greatly increased quality due to the improved data acquisition and processing technology employed in the recent years.

Data quality

The reflection seismic data so far acquired in the region totals to about 30,000 line-kilometers. They consist of the early single fold, and the later, multifold coverages. The sources employed include the conventional dynamite to modern vibroseis with Geoflex, Thumper and Dynoseis operational phases used at different time intervals. The basic data and that of the test lines run are maintained in the Data Center of the National Oil Corporation (NOC).

The quality of the seismic data acquired until the late sixties is generally poor. With the introduction of sophisticated instruments and advanced field techniques, the later seismic coverages yielded comparatively better quality data. The surface conditions in the different parts of the north Cyrenaica region vary considerably. Consequently, special needed to select the optimum data acquisiton parameters. Also the source comparison test is required in each part of the region to select the most effective one. Presently the choice is between the dynamite and vibroseis sources. The best of the two must be used as per the results of test runs in each area of different surface geology. A case in point is presented in Fig. 6.

The reflection seismic section obtained with the dynamite source is presented in Fig. 6a. The same line covered by vibroseis survey yielded the section in Fig. 6b. Note the significant energy level and horizontal resolution achieved with the dynamite source. The poor ground coupling in the area apparently resulted in the relatively poor tracing of the same reflectors in the section with the vibroseis source. Better quality seismic sections facilitated by vibroseis source compared to that from dynamite have also been reported. The example above emphasises the extent to

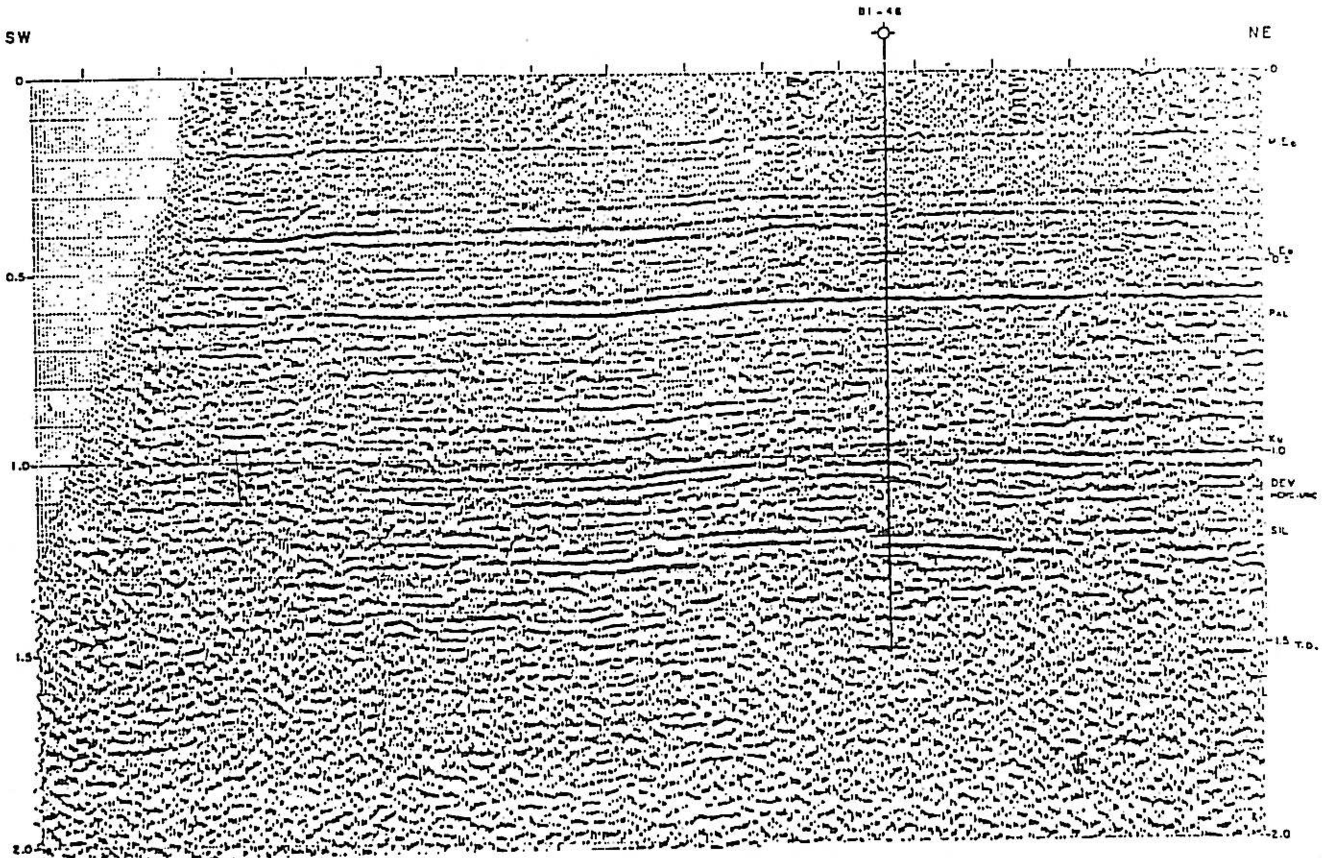

FIG. 6a. Source Comparison test [source: Dynamite, STN. INT: 55 m, VP. INT: 110 m, CDP. Cov: 4800%, DATUM: MSL.]

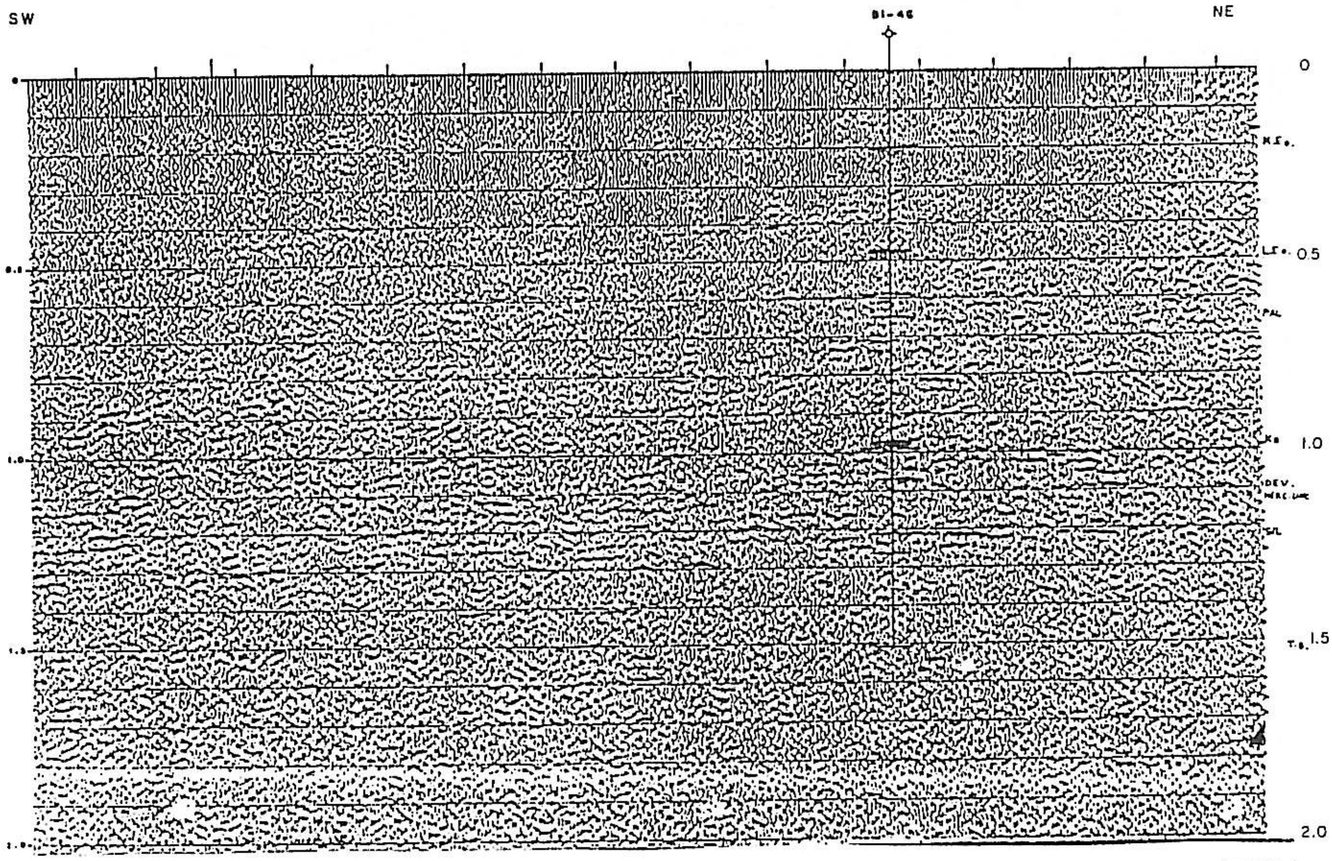

FIG. 6b. Source Comparison Test [Source: Vibroseis, STN. INT: 55 m, VP. Int.: 55 m, CDP. cov: 4800% DATUM: M.S.L.]

which the surface conditions control the eventual seismic results and the need for test surveys to improve the data quality in the different parts of this region.

The rugged topography and lateral density changes near the surface are considered to have caused correction errors in the gravity data of the region. It is therefore desirable to closely study the surface rock densities and evolve appropriate terrain correction strategy for improving the reliability and geologic effectiveness of the Bouguer gravity data in the Cyrenaica region.

INTERPRETATION

Gravity and magnetic studies have greatly helped to infer the structural framework and estimate the basement depth in the region. The Bouguer gravity map of the north Cyrenaica region is shown in Fig. 7. A large negative closure of about twenty milligals is present with northeast-southwest orientation over the platform part of the region. This anomaly occurs over the same part with the expected maximum thickness of the sediments as based on the drilling results. This closure is surrounded by a radial zone of relatively large gravity gradients. These zones correspond with the major fault occurences at the margins around the Cyrenaica Platform. In Al Jabal Al Akhdar Uplift, the Bouguer gravity map shows the presence of strong positive gravity anomaly which is presumably due to shallow basement.

A test study was made with the Bouguer gravity data of the region to map the Mesozoic-Tertiary unconformity. Fig. 8 consolidates the data and the results of the modeling along a north-south line. The gravity residual was computed assuming a linear regional gravity gradient. A density contrast of 0.25 gm/cc was assumed to determine the depth to the Mesozoic-Tertiary (density) surface. Note this depth to be about 500 m in the central portion of the gravity profile

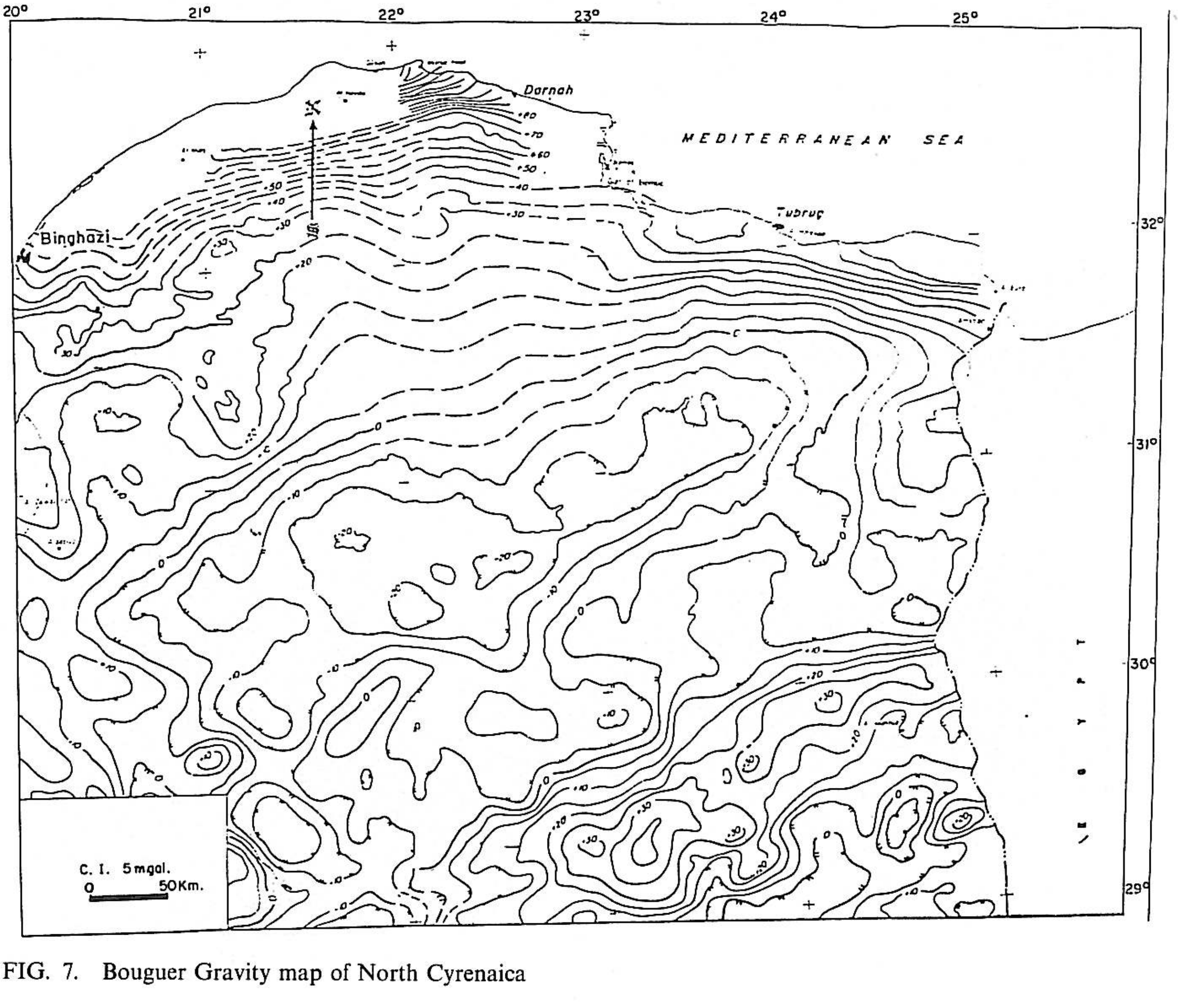

FIG. 7. Bouguer Gravity map of North Cyrenaica

(Fig. 8). The attempt opens up possibilities for the extention of the approach to map the Mesozoic-Tertiary interface in such areas as the Antelat Trough.

The magnetic field map of the north Cyrenaica region is shown in Fig. 9. The presence of relatively high frequency anomaly components in the south-eastern half, vis-a-vis the low frequency ones in the northwestern half of the region, apparently evidence the relatively shallow nature of the basement in the former compared to the depth in the northwestern parts. Inversion of the magnetic data in terms of the depth to the basement shows its variation from 1 to 8 km. The distribution of depths to the magnetic basement is roughly in agreement with the structural categorisation of the region, (Fig. 10). The stable deep basement beneath the central platform is seen to rise towards the northern offshore as well as in the southern inland parts of the region.

The seismic reflection survey has enormously contributed to the examination of the hydrocarbon potential of the region. The seismic results have enabled the marking of about forty favourable structural and stratigraphic features in the region. Some of the earlier seismic lines were subsequently re-shot by modern means to reckon the discrepancies, if any. The appraisal below highlights the outcome from the seismic surveys over the region.

REFLECTION SEISMIC SIGNATURES OF STRUCTURAL AND STRATIGRAPHIC TRAPS

Seismic signatures of some stratigraphic and structural traps are described here presenting some typical examples. Fig. 11 shows a distinct stratigraphic trap signature between 1.4 and 1.5 seconds on the line shot in the Amal Platform. The build up is possibly of Paleocene age. A prominent structural rise is indicated in the parallel seismic section (Fig. 12) between the two-way times 1.3 and 1.5 sec. The structural feature is reported to be of upper Cretaceous to Paleocene age.

The seismic signature of a deposit of lower Eocene age can be noted below the markedup segment in Fig. 13, at the two-way time of 1.55 seconds. The example is from the Antelat Trough. It is known to be located on a Paleocene platform of this region. A strati-structural feature is indicated in the seismic section of Fig. 14. It also pertains to the Antelat Trough. The feature at about 1.08 seconds right below the arrowed segment, is located in Lower Eocene dolomite. The well B1-41 is to the left of this feature and penetrates the horizon by over 40 milliseconds at its apex. It is classified as a marginally economic resource. The amplitude anomaly found on the feature is indicative of possible enhanced fracture porosity in the structure.

An example of a typical stratigraphic trap in the seismic sections of the Cyrenaica Platform part of the region is shown in Fig. 15. The feature below the arrowed segment at two-way time 1.1 to 1.2 seconds, is located in a Paleozoic horizon. The amplitude anomaly over the top of the structure and the observed polarity reversal there implies a probable reef development in a carbonate environment. Fig. 16 shows an example of a paleogeomorophological feature subcrop high. It is reported to be of carboniferous age on an Hercynian unconformity. As earlier, this feature lies below the segment of the line marked at 1.06 seconds. The truncated beds of the Devonian sequence can also

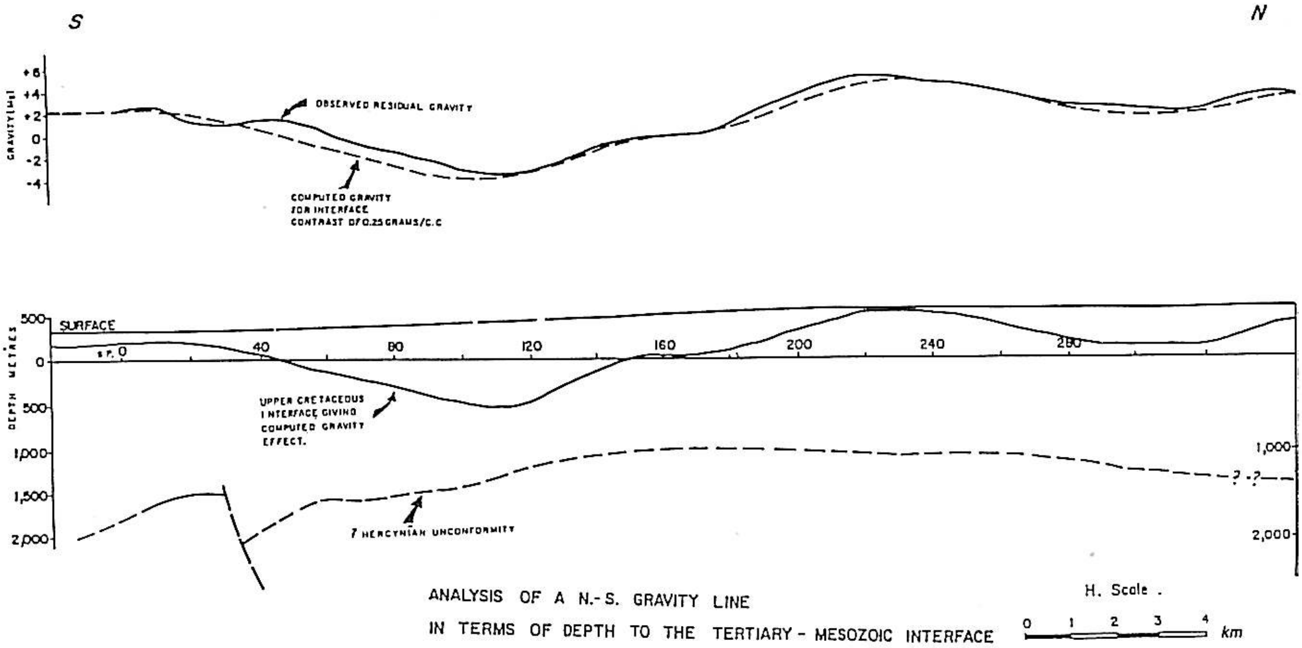

FIG. 8. Interpretation of Gravity profile.

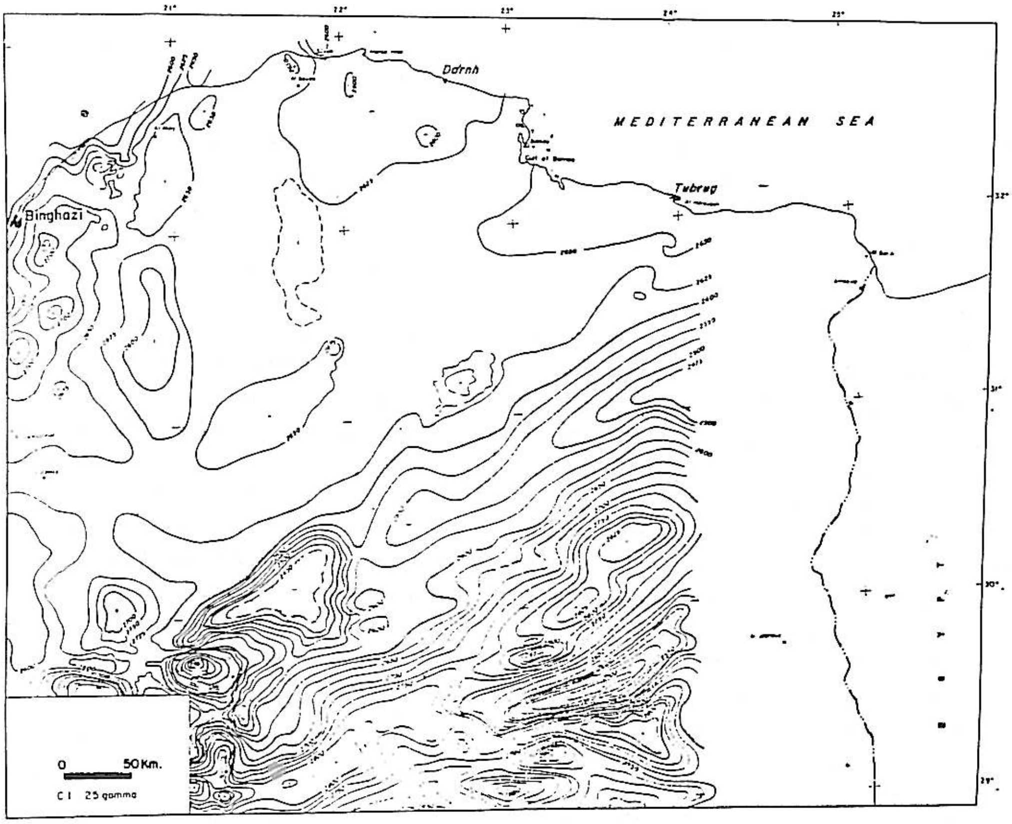

FIG. 9. Regional Magnetic Map of North Cyrenaica

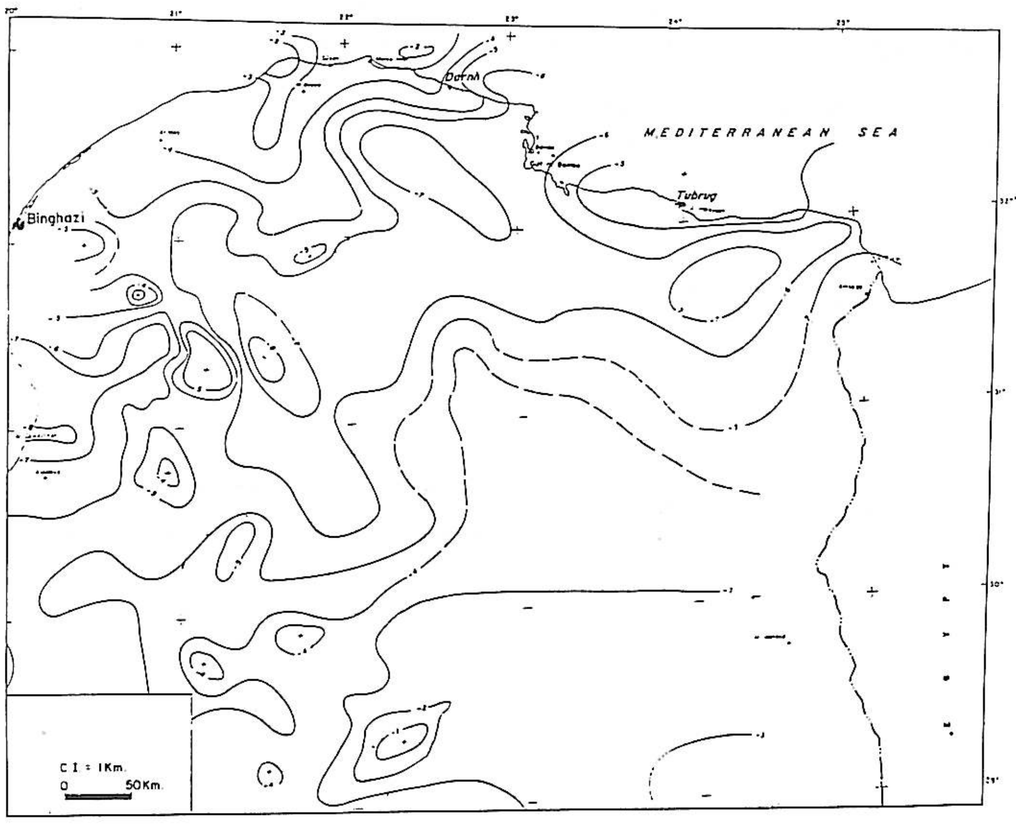

FIG. 10. Magnetic Basement Map of North Cyrenaica

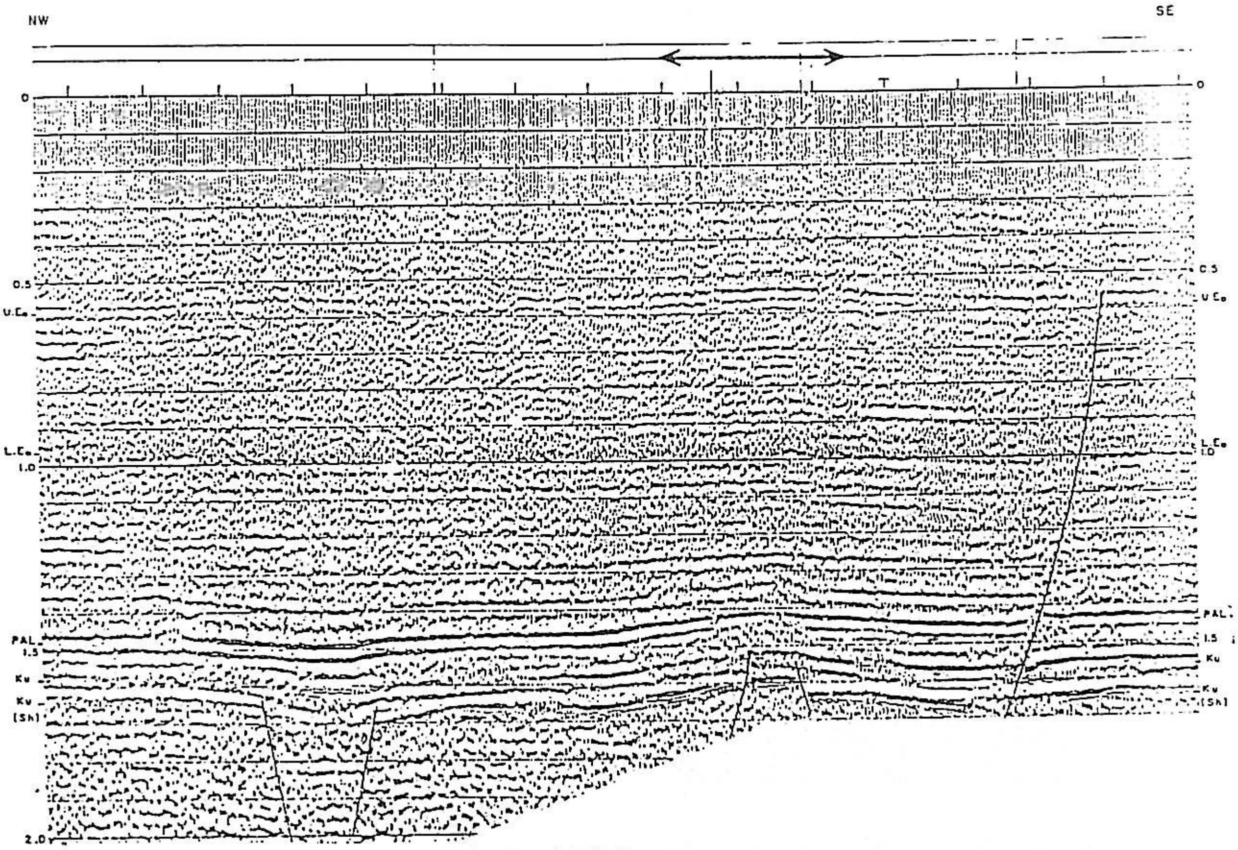

FIG. 11. Paleocene Build-up Features in Amal Platform

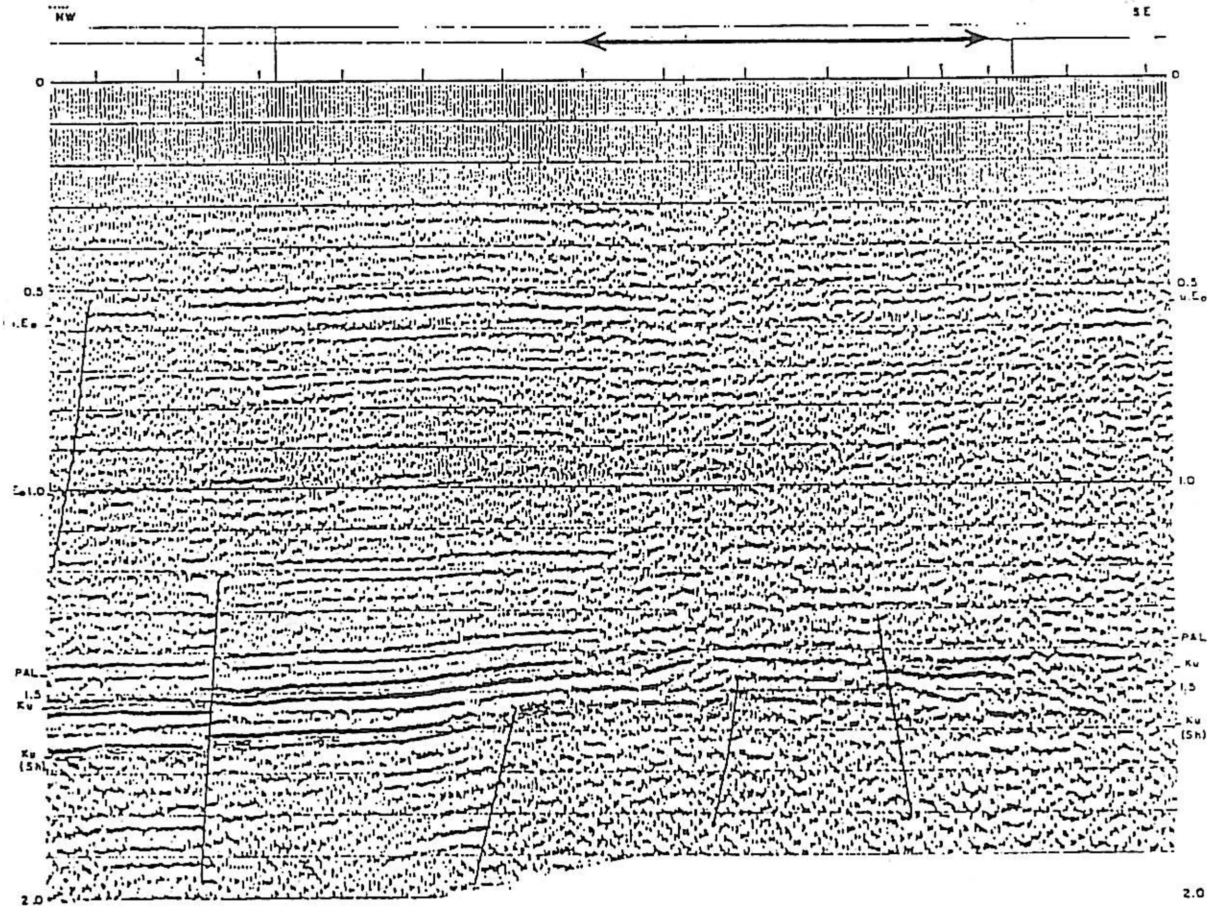

FIG. 12. Paleocene Structure in Amal Platform

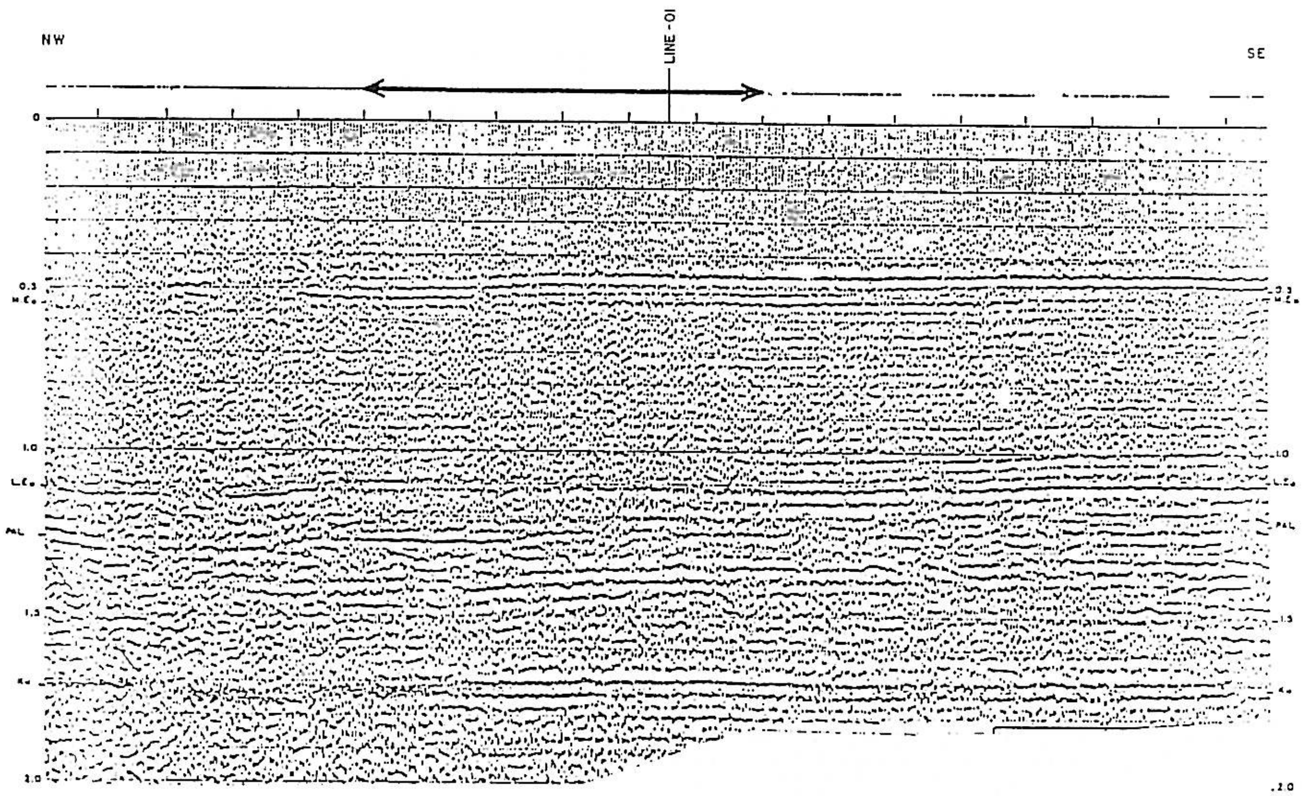

FIG. 13. A Lower Eocene Shoal Deposits in Antelat Trough

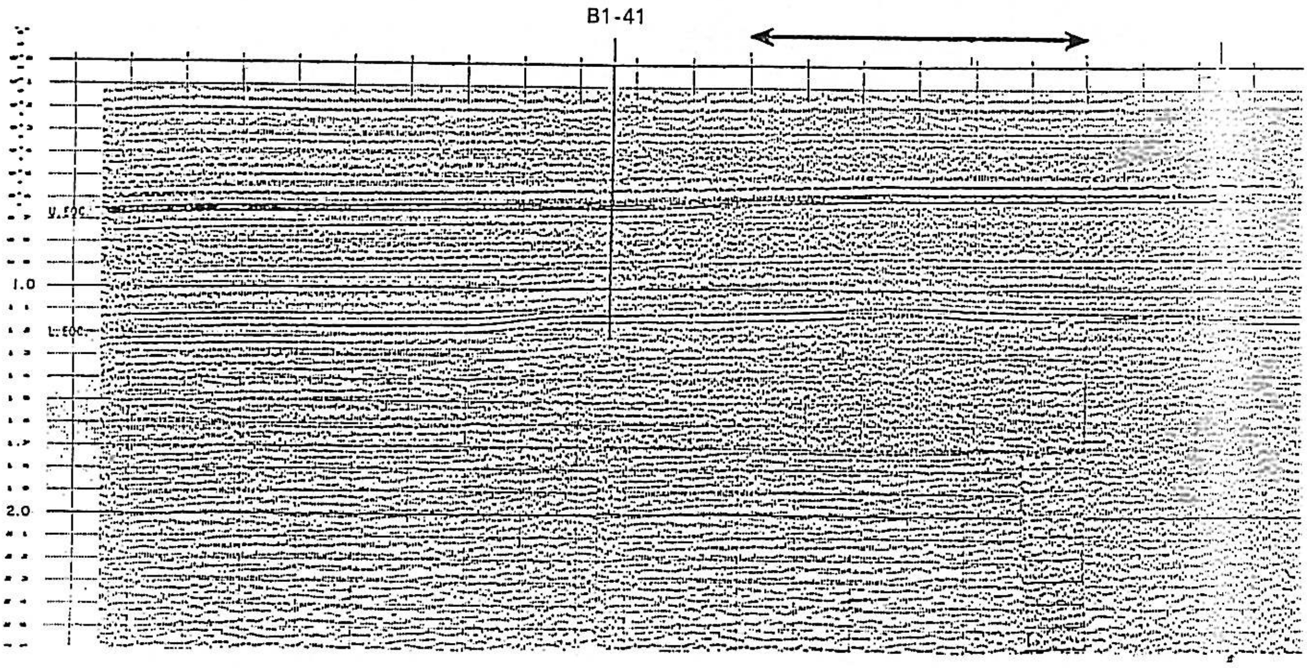

FIG. 14. Strati-Structural features in Antelat Trough

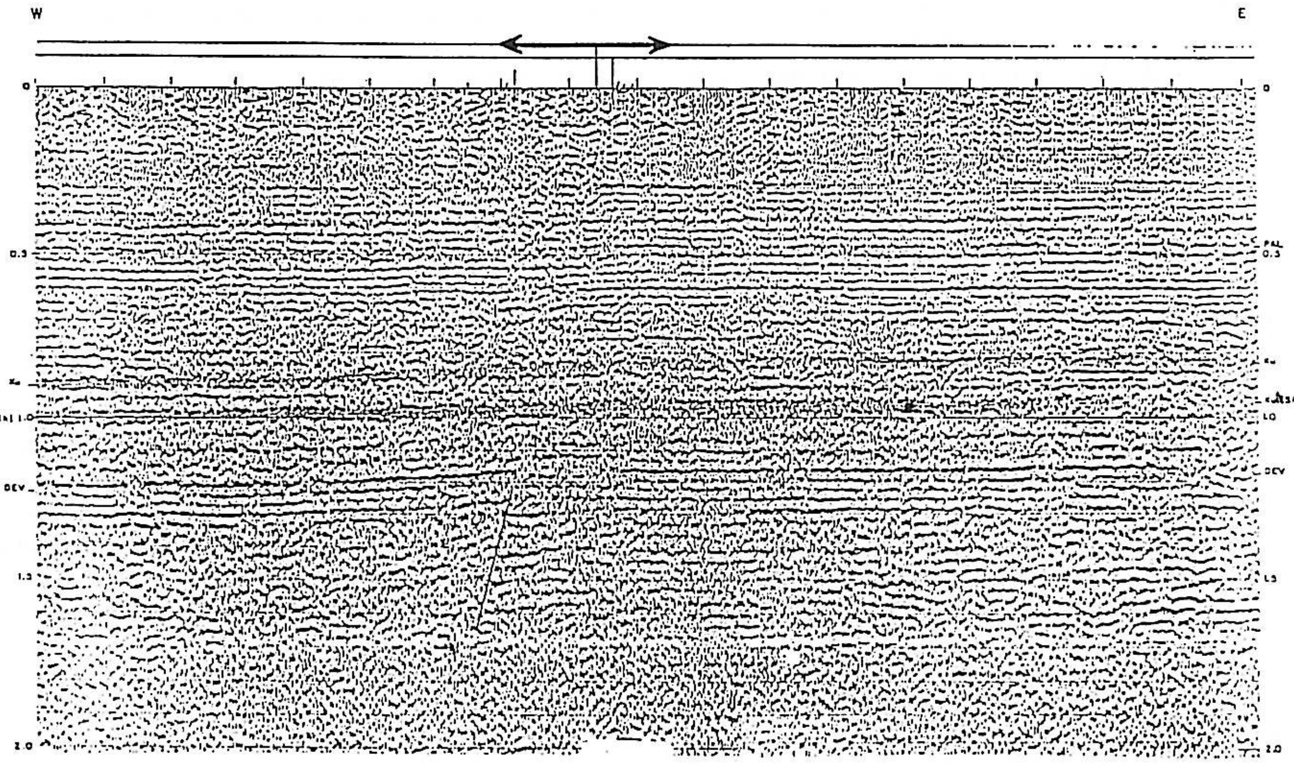

FIG. 15. A Stratigraphic feature on A Devonian Structure in Cyrenaica Platform

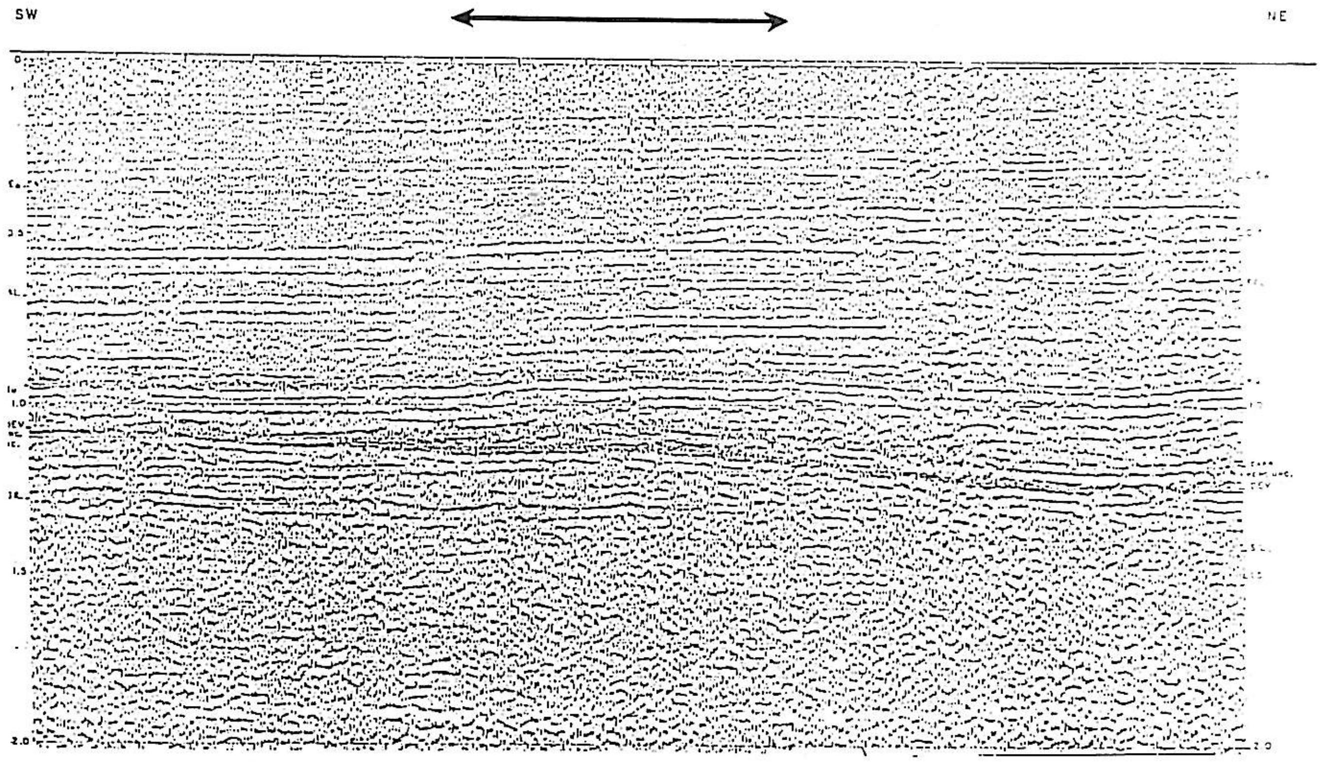

FIG. 16. A Carboniferous structure in Cyrenaica platform

be recognised a little left of the segment towards the southwest end. Such erosional hills and truncated beds are believed to be very prospective within the subcrop area of the Paleozoic formations of the region.

LOCATION OF OLD WELLS

The new seismic data was interpreted and the results were considered together with those of the old seismic data. The attempt shows that a number of wells drilled in the Cyrenaica region happen to be off-located, or were sited on the eroded crests of anticlines. Further, it is found that some wells did not go deep enough due to technical constraints. The examples here illustrate the inadequacy of the early seismic data. The failure of a majority of the wells drilled over the region is now found to be due to their improper locations based on the poor quality seismic sections of those times.

The seismic reflection section of an old line containing the well C1-46 later covered by modern means is presented in Fig. 17. It closely evidences the improper locaton of this well. The more encouraging structure is away from it towards the northeast part of the section. The well reportedly has strong oil-shows from the Tertiary, Mesozoic and Paleozoic formations. Another equally interesting case is presented in Fig. 18. The seismic section here pertains to a line reshot using modern techniques along an old line. The well B1-14 was located on the basis of the earlier seismic data. Note that the well penetrates actually the flank of the structure.

The location was deemed optimal based on seismic data. The re-assessment of seismic data thus consistently evidence the manner in which the wells have been off-located. The example also illustrate the greater efficiency that can be achieved with the modern seismic data acquisition and processing techniques.

HYDROCARBON PROSPECTIVITY

The hydrocarbon prospectivity of the north Cyrenaica region can be assessed based on the geological and drilling data integrated into the reflection seismic signatures of the subsurface structural setting. The results of the assessment so made are consolidated in Fig. 19.

Cyrenaica Platform

Mainly folded and faulted structural traps of Paleozoic age appear to be the promising hydrocarbon prospects of the province. Stratigraphic traps of the same age may exist along the Plaform margin including the Amal Platform. The Silurian and Devonian

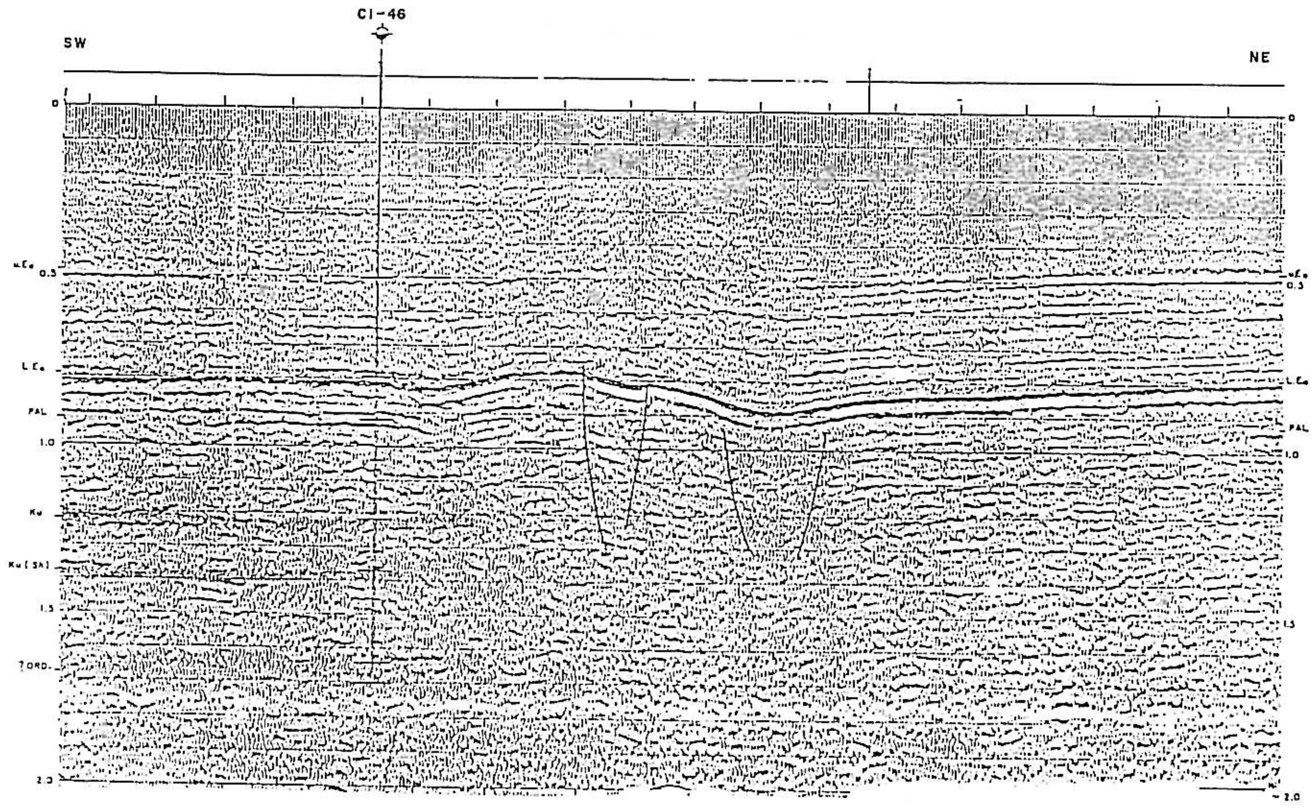

FIG. 17. A Lower Eocene structure in western margin of Cyrenaica Platform.

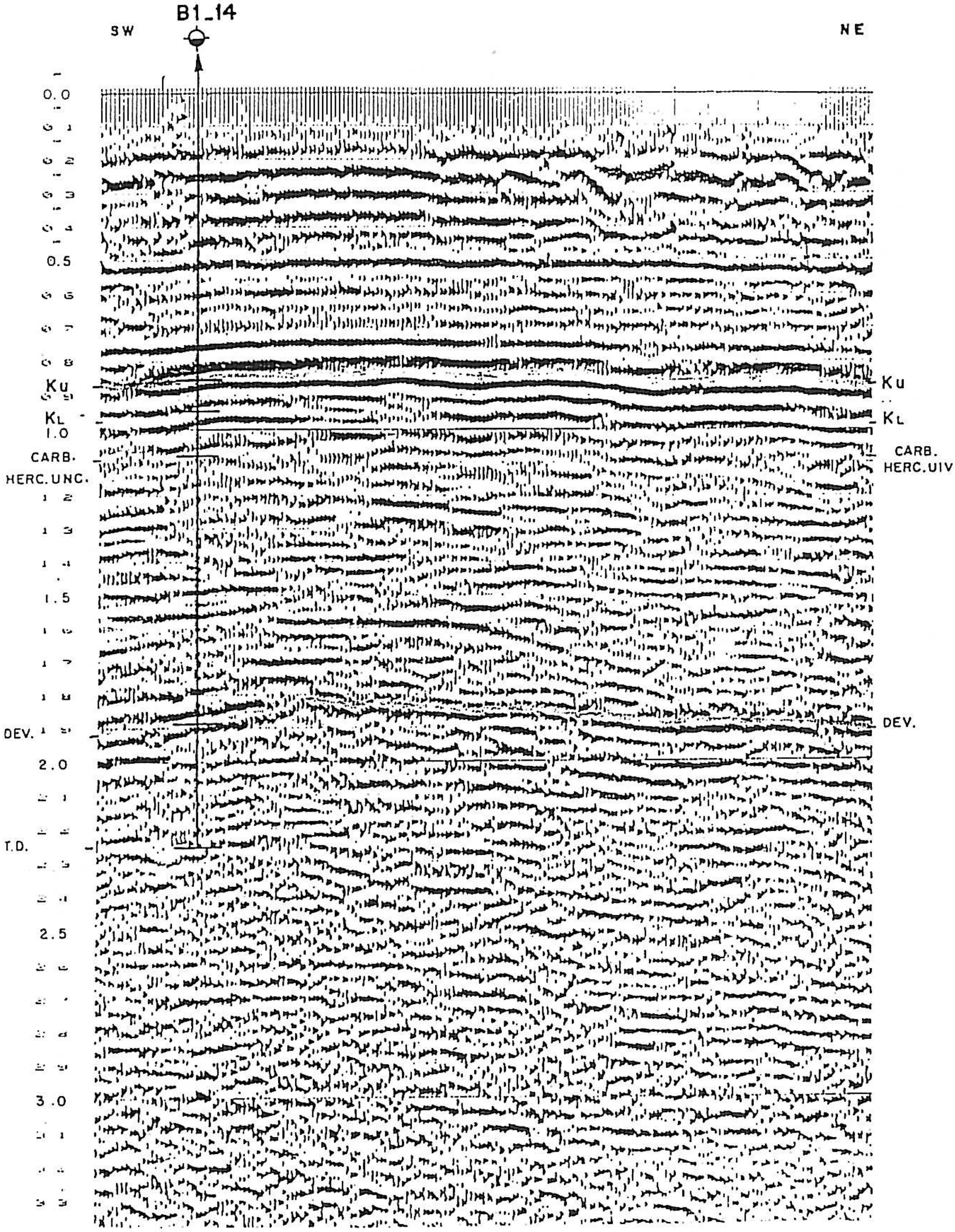

FIG. 18. Location of Well B1-14 on the Recently shot line Cyrenaica Platform.

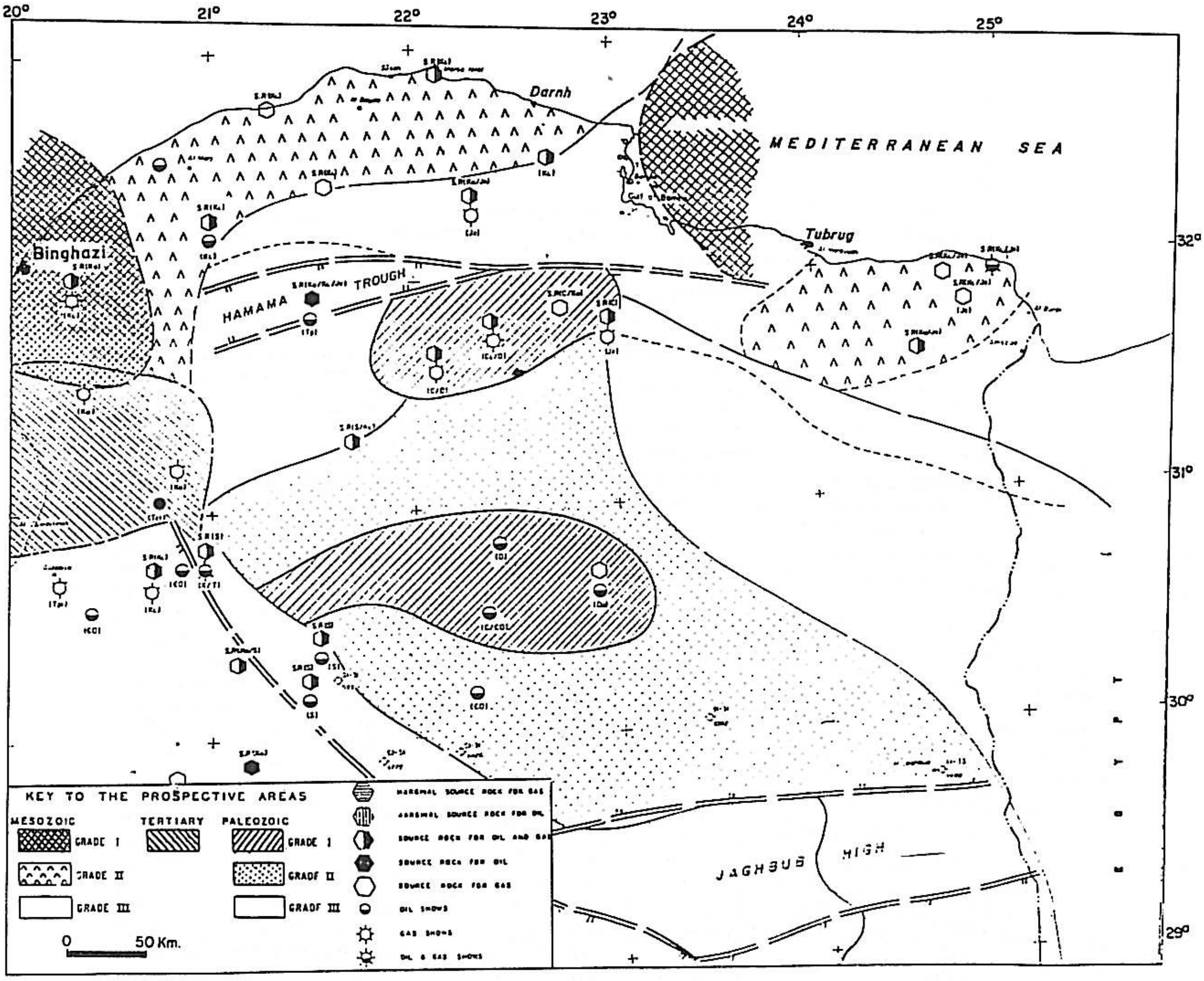

FIG. 19. Summary prospect map North Cyrenaica.

carboniferous shales are the source rocks of this tract. The sandstones ranging in age from Cambro-Ordovician to late Carboniferous have the potential to be the reservoir rocks. Some Mesozoic prospects are likely to be encountered along the eastern margin of the platform.

Al Jabal Al Akhdar Uplift and Marmarica Basin

The preserved, deep-seated, faulted and folded structures of Mesozoic age are the most promising traps of this geoelement. Less prospective are apparently the relatively highly uplifted structures since they are likely to be subjected to long periods of erosion, flushing or destruction of the hydrocarbon accumulations in such traps. Also the structures of Paleozoic age, not penetrated by drilling up to now, can be considered to be prospective. Jurassic, lower and upper Cretaceous shales constitute the main source rocks of this area. The Triassic shales reached in two wells have favourable source rock characteristics, Omer *et al.*, (1982). The thick shales of the Lower Cretaceous and compact evaporites as well as carbonates of the Upper Cretaceous are likely to be the main cap and seal rocks of the area.

Antelat and Hamama Trough

Structural and stratigraphic traps of Cretaceous and Tertiary age appear to be the main targets of this area. The Jurassic and Tertiary shales are the likely source rocks here Geochem (1982). The lower Cretaceous and Tertiary carbonates have the potential to be good reservoir rocks in this area.

Offshore

The upper Cretaceous structures situated to the north of Benghazi and Gulf of Bomba are very promising features in the offshore areas.

CONCLUSIONS

The above overview of the geologic and structural setting from the surface geologic and geophysical studies indicate that the hydrocarbon prospectivity of the north Cyrenaica region is quite promising. Significant level of oil and gas shows have been recorded in several wells of the region. The prospects include:

(a) the Paleozoic structural and stratigraphic features in the Cyrenaica Platform.
(b) the deep-seated faulted and folded structures of Mesozoic age in Al Jabal Al Akhdar Uplift and Marmarica Basin, and
(c) the Mesozoic and Tertiary traps in the Antelat and Hamama troughs.

Gravity and magnetic data have greatly helped in defining the major tectonic elements of the North Cyrenaica region. The former can be of additional use in inferring the Mesozoic structures.

ACKNOWLEDGEMENT

We would like to thank Dr. A. Mouzoghi J.V.D. General Manager and Mr. I. Baggar, the Exploration Manager of the National Oil Corporation for their encouragement and permission to present this paper at the Ninth Geophysical Convention, Turkey.

We also thank Mr. J. Molanazadeh, Dr. M. Salem, Dr. Bakbak and Dr. Busrewil for reading the manuscript and helpful comments on many aspects.

REFERENCES

BARR, F.T., 1968, Upper Cretaceous Stratigraphy of the Jabal Al Akhdar, Northern Cyrenaica. In; *Geology and Archaeology of Northern Cyrenaica, Libya.* F.T. Barr, ed., Petrol. Explor. Soc. Libya, p. 131–147, pls. 1–3, Tripoli.

CAVAGGION, M. and EL-ASHURI, O., 1986, *Revision of the Geology of Northern Cyrenaica,* (NOC. unpublished report)

CONANT, L.C. and GOUDARZI, G.H., 1967, Stratigraphic and tectonic framework of Libya. *Bull. Amer. Assoc. Petrol Geol.,* v. 51, no. 5, p. 719–730. Tulsa.

EL-ARNAUTI, A. and SHELMANI, M., 1985, Stratigraphic and Structural setting, N. Cyrenaica region (*Jour. Micropal. vol. 4, part 1, p. 1–10. eds.*) Thusu, B and Owens, B.

FRANCIS, M. and ISSAWI, B., 1977, Geological map of Libya 1:250.000, Sheet NH 34–2, SoluQ, Explanatory Booklet, Tripoli, I.R.C.

GOUDARZI, G.H., 1980, Structural Geology of Libya. In; *Third symposium on the Geology of Libya,* eds. M.J. Salem and M.T. Busrewil, vol. 3, p. 879–89.

KLEN, L., 1974, Geological map of Libya, 1:250.000, sheet: NI 34–14, Benghazi, Explanatory Booklet, Tripoli, I.R.C

OMAR, K.Z., FERJANI, K., KARKI, M.T., 1982, Geology and Hydrocarbon prospects of Cyrenaica, Jabal Al-Akhdar and related areas. (NOC unpublished report).

OZCICEK, B., 1986, A review of the seismic data quality in North Cyrenaica region, N.E. Libya (NOC unpublished report).

ROHLICH, P., 1974, Geological map of Libya, 1:250.000, sheet NI 34–15, Al Bayda. Explanatory Booklet Tripoli, I.R.C.

ROHLICH, P., 1978, Geological development of Jabal Al Akhdar, *Libya, Geol. Rundsch.* 67, 401–412.

ROHLICH, P., 1980, Tectonic development of Al Jabal Al Akhdar In; *Third Symposium on the Geology of Libya,* eds. M.J. Salem and M.T. Busrewil vol. 3, p. 923–931.

SWEDAN, A. and ISSAWI, B., 1977, Geological map of Libya, 1:250.000. sheet NH 34–4, Birhacheim. Explanatory Booklet, Tripoli, I.R.C.

ZERT, B., 1974, Geological map of Libya, 1:250.000, sheet NI 34–16, Darnah. Explanatory Booklet, Tripoli, I.R.C.