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Second symposium on the geology of Libya

University of Al-Fateh
Faculty of Science
Geology Department

UNIVERSITY OF AL-FATEH
FACULTY OF SCIENCE
DEPARTMENT OF GEOLOGY
TRIPOLI - LIBYA

September 16-21, 1978
Tripoli
Socialist People's Libyan Arab Jam

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WELCOME TO THE UNIVERSITY OF AL-FATEH TRIPOLI

The University of Al-Fateh welcomes you to the Second Symposium on the Geology of Libya. With such an international gathering, it is our hope that you will enjoy your stay here in the Jamahiriya both technically and socially. The Geology Department, having the honour of organizing this meeting, will endeavour to make it memorable for all.

Dr. Khairi Sgaier
President of the Higher Popular Committee
University of Al-Fateh
and Chairman of the Symposium

SYMPOSIUM COMMITTEE

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SYMPOSIA ON THE GEOLOGY OF LIBYA

In 1969, the Department of Geology, Faculty of Science, Al-Fateh University (then the University of Libya) organized the first international symposium on the geology of Libya. This first symposium was under the Chairmanship of Dr. Khairi Sgaier who was then the Dean of the Faculty of Science. The organizing committee included all members of the staff in the Geology Department and the committee was chaired by Dr. Carlyle Gray who was also the Chairman of the Department at the time.

The response to this first symposium was gratifying. Thirty three papers were presented at the meetings, 29 of which were subsequently published in a book entitled "The Geology of Libya". This book received a wide national and international distribution.

Since 1969, a vast amount of new data has accumulated, adding to and enabling revision of the existing knowledge on the geology of the country. At the same time, there has been a rapid advance in geologic concepts and methodology. As such, it was therefore decided to hold this second international symposium to provide an opportunity for the discussion and publication of the new data.

The response to this second symposium was even more gratifying. Over 300 geologists from different universities and geological institutions representing 23 countries will be attending the Symposium. About 110 of these will present papers at the meetings of the symposium.

We are very grateful to the University of Al-Fateh for sponsoring this Symposium. Without such help from the University, its various departments and personnel, the Symposium would never have materialized. We are also grateful for the help offered by the following:

- The Geology Department, Faculty of Science, Garyounis University, Benghazi for co-organizing and co-leading the Jabal Al Akhdar excursion.

- The Arabian Gulf Exploration Co. for their part in the organization and help in the Jabal Al Akhdar excursion.
- The Industrial Research Centre for their help and for supplying maps and other publications.
- The Earth Science Society of Libya.
- The Secretariat of Foreign Affairs for their help in facilitating visa procedures.
- The Secretariat of Internal Affairs for their help in customs and immigration procedures.
- The Secretariat of Information for providing information on tourist facilities.
- The Secretary of Dams and Water Resources for co-leading the Jabal Al Akhdar excursion.
- The Oasis Oil Co.
- The Arab Development Centre for printing the field guide book of the Jabal Nefusa and Ghadames areas.
- The National Oil Corporation for their help in organizing the Jabal Gargaf and Wadi Al-Shatti field excursion.

The Geology Dept.
Faculty of Science
University of Al-Fateh

THE UNIVERSITY OF AL-FATEH

Historical Background

The first university in Libya was established in 1955. It was called “The University of Libya” and started with the Faculty of Arts. Other faculties were later established in the three towns of Tripoli, Benghazi and Al Baida (East of Benghazi).

- In 1957, the Faculty of Science was established in Tripoli (this faculty later formed the nucleus of the University of Al Fateh). In the same year the Faculty of Economics and Commerce was established in Benghazi.
- In 1962, the Faculty of Law was established in Benghazi.
- In 1966, the Faculty of Agriculture was established in Tripoli.
- In 1967, the two Colleges of Higher Technology and Higher Education which were previously established in Tripoli with the help of UNESCO, were amalgamated with the University of Libya as the Faculty of Engineering and Faculty of Education.
- The year 1969 was a corner stone in the evolution and development of the University.

With the First ('Al-Fateh' in Arabic) of the September Revolution and emphasis on education and social development, a closer look at the University and its role in the new society was needed. As a result, the different facilities expanded and the curricula were examined and revised accordingly. The emphasis was on the University as a scientific and cultural centre reacting with society and not detached from it, geared to the real needs of the country rather than staying aloof within the confines of its walls, producing a new and competent graduate who believes in his heritage and culture. With this social awareness in mind, new faculties were planned to fulfill the needs of the country.

- In 1970, the Faculty of Medicine was established in Benghazi. In the same year, the existing colleges of Islamic Studies at Al Baida were grouped into one faculty — Faculty of Arabic Language and Islamic Studies.
- In 1972, the Faculty of Mining and Petroleum Engineering was established in Tripoli.
- By 1973, the University of Libya included ten faculties. However, during the four years following the Al-Fateh Revolution, social and industrial developments were rapidly achieved with concomitant increase in the numbers of those seeking higher education. To cope with this new situation, the University of Libya was split into two independent Universities in August 1973. viz. the University of Tripoli to include all the faculties in Tripoli and the University of Benghazi (presently re-named Garyounis) to include all the faculties in Benghazi and Al Baida. New faculties were added to the University of Tripoli e.g. Faculty of Medicine (1973), Faculty of Pharmacy (1975), Faculty of Veterinary Science (1976), Faculty of Education in Sebha (1976), Faculty of Nuclear Engineering (1978), thus making a total of ten new faculties.
- In April 1976 and following the cultural revolution in the University, the University of Tripoli was renamed the University of Al-Fateh.

Facts and Figures about the University of Al-Fateh:

Administration:

The University is run by the Higher Popular Committee and the Chairman of the Higher Popular Committee (who is equivalent to the President or the Chancellor of other Universities).

The Higher Popular Committee consists of:

- the Chairman of the Higher Popular Committee
- the two Vice Chairmen
- the Chairmen of the Popular Committees of the various faculties
- the General Secretary of the University
- A member of staff from each faculty (by election among students)
- the President of the Students' Union
- A student from each faculty (by election among students)
- An elected member of the University non-academic employees and workers.

Degrees Awarded

The following degrees are awarded by the University

- Bachelor Degree (All Faculties)
- Diploma (Engineering, Science, Education)
- Master (Engineering, Science, Agriculture and Humanities)

Language of Teaching:

Arabic for all Humanities, and mostly English for all other subjects. Feasibility studies are being carried out to evaluate the use of Arabic for the Applied Sciences.

Admission of students and the Yearly Academic System:

Full-time students are accepted on the basis of their marks in G.C.E. examination and the number of available places in each faculty. Since education is free, this method of selection provides an equal opportunity for each student.

Faculties of Science, Agriculture, Pharmacy and Medicine follow a two-term system with an examination period at the end of each term (February and June). Faculties of Education, Engineering, Mining and Petroleum Engineering and Veterinary Science follow a full year system with one examination period at the end of the Academic Year (June).

Budget:

Since the division of the University of Libya in 1974, the budget of the University of Al-Fateh alone is as follows:

Year	Current Expenditure (millions L.D.)	Development (millions L.D.)
1974	6.6	10.1
1975	7.5	36.6
1976	9.6	29.9
1977	11.0	29.0
1978	14.5	30.0

Library

The University Central Library houses approximately 19,500 books in Arabic and 10,400 books in English. It also subscribes to approximately 400 international journals.

Staffing

Non-academic Staff: A total of 935 out of which 117 are non-Libyan of 10 different nationalities.

Academic Staff: A total of 762 staff members out of which 410 are non-Libyan of 12 different nationalities. This is apart from the distinguished Visiting Professors who are frequently invited on a short term basis.

Students

- (A) Post graduates: A total of 724 distributed as follows: 533 studying abroad for M. Sc. and/or Ph. D. degree and 119 demonstrators studying at the Al Fateh University.
- (B) *Undergraduate Students*: A total of 5488 students (4152 males, 1336 females) compared to a total of 1374 students (1213 males, 161 females) in 1969/1970.

Data on the Faculty of Science

Departments: Mathematics, Physics, Chemistry, Zoology, Botany, Statistics, Geology and Computer Science.

Members of Staff: 251 members (154 non-Libyans)

Students: 763 students (Libyans: 454 males, 161 females - Non-Libyans: 90 males, 58 females).

The Faculty of Science is also responsible for teaching the science subjects relevant to various other faculties in the University.

The Geology Department

The Geology Department started in 1960 with Dr. Chapman as the Chairman and only staff member. The number of the students then was 13. Presently, the Department comprises 15 Staff members, 5 demonstrators and research assistants and 80 students (excluding the first year students).

The present Chairman is Dr. M. Busrewil.

Since its establishment, about 285 geology students graduated and took employment in different secretariats and institutions (e.g.) 30% in Secretariat of Petroleum, 16% in the Secretariat of Dams and Water Resources, 15% in the University of Al-Fateh, 8% in the Secretariat of Industry.

ABSTRACTS

Second symposium on the geology of Libya

**University of Al-Fateh
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Geology Department**

**September 16-21, 1978
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The Abstracts have not been edited by the Symposium Committee and are presented here in the form in which they were received from the authors.

Geophysical Analyses of Gravity data in the Northern Borderland Between Egypt and Libya

Y. E. Abdelhady

Recent work by Agarwal and Lal (1972), Mufti (1972) and others made available some information concerning subsurface shallow and deep seated structures from gravity analyses. Second vertical derivative, residual, regional and downward continuation maps were constructed on mathematical basis for the area under investigation. The computation operations were carried out using I.B.M. 1620 Computer. All maps were constructed using different grid spacing and various coefficients just to select the maps which bring up better understanding of the subsurface structural pattern of the area under study.

Geldart et al (1966) method was followed to evaluate faults parameters within the area under study along representative profiles.

After making comparative study between the oldest methods of gravity analyses such as Griffin (1949), Rosenbach (1953 a), Constantinescu (1961) and the up to date methods as Agarwal and Lal (1972) and Mufti (1972), the author found that the up to date methods are more reliable and have high resolution power in sedimentary basins having the same conditions as the area under investigation.

From this study the author constructed a map of the major tectonic trends in the area which is of importance as potential sector for oil exploration.

Mineralogical Properties of the Clay Fraction of Sarir Shara Soils and Sediments

Gilani Abdelgawad, Ezzedein Rahoma and W. Busch

A study of the clay fraction of major soil series and sediments in the Sarir area, southeast of Libya, disclosed a number of (a) morphological features reflecting a minimum of pedogenic processes (acolian as well as alluviation activities), and (b) mineralogical structures exhibiting domination of the clay fraction by expansible 2: 1 - layer silicates.

Fibrous clays of the attapulgite (palygorskite) form appear to be present in these soils, but the evidence obtained is to be confirmed.

Water Resources of South-eastern Libyan Sahara

Moid U. Ahmad

The Kufra and Sarir basins have huge ground water resources. Kufra basin alone contains about 25,000 Km³ of good quality water.

In the middle of the Sahara desert, a water well field (KPP) consisting of 102 wells was constructed by the end of 1972. Each well is 300 meters deep, designed to produce 76 L/S, and fitted with a self-propelled sprinkler which rotates over 100 ha in 60 hours. The distance between each well is 1120 meters. By using fertilizers and continuous irrigation over the coarse sand, a very high yield of alfalfa has been obtained.

In 1974-75, another well field consisting of 35 wells, Kufra Settlement Project (KSP) was constructed adjacent to KPP. At the recommendation of Ahmad, the wells were drilled up to a depth of 475 meters. The specific capacity of these wells doubled and tripled those of KPP wells.

Analytical and digital models indicate that the aquifer is behaving as leaky aquifer and most of the water is obtained from the shallow aquifer. The effect of partial penetration is greater than has been previously acknowledged. Transmissivities appear to be increasing as the cone of depression affects greater depths of saturated thickness. The transmissivity may be of the order 3700 M²/D in contrast to 1000 M²/D determined by pump tests.

In 1974, Ahmad designed the South Sarir well field consisting of 159 wells about 400 km north of Kufra well field. Thirty wells in two rows, 2 1/2 kms apart, are about 300 meters deep and screened from 150 to 300 meters. Six lines of 30 wells are spaced 10 kms apart perpendicular to the piezometric gradient. Long term pumping levels were predicted using Hantush leaky equation. 40 to 55 wells were pumped till April 1977. The drawdown data indicated an apparent storage coefficient of 0.2 after 600 days of pumping.

Ahmad designed the North Sarir Well Field which is situated near 28° N. latitude and 22° E. longitude, about 30 kms west of Sarir Oil Field. 80 wells have been drilled since 1977. The wells, 300 meters deep and screened between 150 and 300 meters, are designed to pump 76 L/S.

Wells of exceptionally high capacity (30-60 M³/HrM and transmissivity ranging from 3600 to 9800 M²/D) are found in sandy gravel which are overlain by thick beds of plastic shale containing lamellibranchiata. The shale beds disappear to the east and west in the adjacent wells but persist in a north-south direction. The variable content of feldspars & three types of quartz grain indicate that the source is an ancient terrane, perhaps the Pre-Cambrian rocks of the Tibesti Range. The hydrological study indicates the existence of an ancient river channel which has been named Sarir channel.

The existence of this and other undiscovered channels near Kufra, Sarir, Tazerbo and Jalo well fields may alter the present mining concept because these channels may be recharged from rains in Tibesti and Sudan.

A study of Landsat data since 1972, indicated that the cloud cover concentrates to the northwest and northeast of Tibesti Mountains between 23° N. and 20° N. latitude. The color composites of Landsat 1 on 25, 26 Sept. and 30 Oct., 1972 show the presence of near surface ground water in several streams coming from the mountain and then infiltrates into the sands.

Salama has determined the magnitude of recharge in the Sudanese Sahara Nubian basin which is in the southeast of Kufra basin. The amount of water recharged is estimated to be 20.6 million cubic meters per year, the abstraction rates are 1.2 million cubic meters per year and the amount of water permanent storage is 9740 million cubic meters.

A new well field to irrigate 10,000 has is being planned at Tazerbo and a well field consisting of 33 wells is under construction at Jalo.

On the basis of the behavior of Sarir and Kufra well fields, it would be possible to construct several more highly productive well fields in the Kufra and Sarir basins.

Palynology and biostratigraphy of the Tanezzuft and Acacus formations from the Ghadames basin, Tripolitania, Libya

T. K. Al-Ameri and J. B. Richardson

Palynological studies on more than 500 samples from 13 boreholes of marine deposits of upper Ordovician and Silurian (Llandovery, Wenlock, Ludlovian and

“Downtonian”) and possibly Lower Devonian age from the Ghadames basin in Tripolitania — Libya have revealed acritarchs, tasmanites, miospores, chitinozoa, scolecodonts, plant tissues, curypterid cuticle and graptolite siculae. 18 palynological zones based on miospores, acritarchs, and chitinozoa from the upper Ordovician to possibly Lower Devonian have been established. Six distinct types of palynofacies are fitted into a hypothetical model related to distance from shore line and it is tentatively suggested that they may relate to lagoonal, intermediate and open marine environments.

Lower Tertiary Stratigraphy and Tectonics of Northeastern Libya

F. T. Barr

The importance of early Senonian tectonics has been demonstrated in the core of Jabal al Akhdar. However, it appears that orogenic movements culminating in the Early Tertiary (late Landenian) may be responsible for some of the most widespread deformation recognized over much of northern Cyrenaica.

Paleocene outcrops in Jabal al Akhdar are rare; however, the presence of Paleocene fossils in distant parts of this region suggests that outer neritic seas covered the northern jabal perhaps even depositing a uniform chalk sequence, similar to the Al Uwayliah Formation, over much of this area. The scarcity of Paleocene sediments is the result of erosion following a major orogeny which folded and uplifted the entire Jabal al Akhdar. This strong tectonic event, here referred to as the *Cyrenaican Orogeny*, probably produced its first labor pains during the Late Cretaceous (possibly Campanian), and reached its maximum intensity in the Early Tertiary bringing the Paleocene to a conclusion. The result being that most if not the entire region was subjected to severe subaerial erosion at the end of Paleocene time. Final movements, albeit weak, may have persisted into the Early Eocene. The orogeny has not been recognized in the Sirt Basin where, in its deeper parts, sedimentation appears to be continuous throughout the Maestrichtian, Paleocene and Early Eocene.

Following the *Cyrenaican Orogeny*, a Lower Eocene (Ypresian) transgression

commenced, with seas slowly onlapping the steep flanks of the folded-uplifted highlands. This transgression continued its advance into the Middle Eocene (Lutetian) when most of northern Cyrenaica was again inundated by warm neritic Tethyan water. This transgression is evidenced by the deposition of the Apollonia Limestone. Stratigraphic sections have been measured along the coast between Derna and Susa which demonstrate this transgression. In the area of Marsa al Hilal, one of the few areas where the Upper Cretaceous Atrun Limestone — Eocene Apollonia Limestone unconformable contact is exposed, considerable evidence is available indicating the duration of this transgression. In Wadi al Atrun, a Lower Eocene (Ypresian) section of bathyal Apollonia Limestone unconformably overlies lower Maestrichtian Atrun Limestone. Nine kms to the west, in Wadi al Qalah, Middle Eocene (Lutetian) Apollonia Limestone unconformably overlies the Atrun Limestone. These sections indicate that during the Ypresian, on the flanks of a major Cyrenaican orogenic fold, bathyal conditions occurred, while only a few miles to the west, the structural axis was emergent. This was followed by Lutetian Limestones of the same formation, representing outer neritic deposition, which covered the entire area. These observations are in part corroborated by subsurface information.

Mineralogical composition of Jabal Nefusa phonolites

W. M. Bausch

The Jabal Nefusa phonolites are characterised by dominance of felsic components, or a very low color ratio. As mentioned by Almond et al. (1974), there may occur phenocrysts (mostly of alkali feldspar), but generally the phonolites are fine grained, poorly crystallised or even aphyric.

Besides microscopical analysis, the mineralogical composition has to be investigated essentially by means of X-ray diffraction. As main (felsic) components were found: sanidine, analcite, nepheline, sodalite and albite (given in order of approximately decreasing frequency).

The frequency of analcite is astonishing, and was not described before. There are given the relations of changing proportions of mineralogical compositions and detailed X-ray data.

Gravity Anomalies in Coordination with Fault Parameters and Geotectonic set up in the Northern Western Desert of Egypt

A. I. Bayoumi and M. B. Awad

The critical analysis of the observed gravity anomalies in the central portion of the Northern Western Desert of Egypt, particularly along an E-W trending profile stretching over 500 kms. across the desert and including the Qattara Depression reveals that the area is generally characterized by several structural features in the form of normal faulting of different ages and depth extents, with a maximum throw of 3000 meters.

Truncations and wedging ups of particular interest seem to be also complicating the relatively thick sedimentary section overlying the basement complex which lies in this particular area at depths greater than 5 kms.

Fault parameters including the density contrasts between the faulted "slabs" and the country rocks either sedimentary or crystalline, have been also evaluated, using a simple, rapid and consistent technique, illustrated mainly in the form of a new set of nomographs that have been theoretically computed by making use of fault slab formulae.

To narrow the wide range of possible solutions arising from ambiguities in gravity interpretations, seismic reflection control has been taken into consideration.

The present study, which also includes statistical analysis of gravity anomalies; namely, in the form of residuals, indicates that the geotectonic lateral compressional forces acting on the Northern portion of the African Shield seem to develop three major sets of Stress/Strain trend patterns of different tectonic phases. The oldest one, which runs almost along a N 35°W, seems to have been rotated anticlockwise (westwards) through a maximum angle of about 30°, initiating the second phase of tectonism which is responsible for developing the second Stress/Strain trend pattern. This anticlockwise rotation in the original direction of the geotectonic forces is probably due to the anticlockwise rotation of Africa relative to Arabia.

As a result of the clockwise rotation of

Africa relative of Arabia the direction of the geotectonic forces changed again eastwards from its old direction to reach a new position having a N 5°W direction.

Accordingly, it is stated here that:

1) The Gulf of Suez is not a conjugate shear of the Gulf of Aqaba as has been always assumed by many authors.

2) The three phases of deformations were actually responsible for the development of the Gulf of Suez, Gulf of Aqaba, and the Mediterranean trends, respectively.

Implications of geotectonic setting of EL Hamada El Hamra, Western Libya in view of potential field data

A. Bayoumi and A. Missalati

The present study is mainly concerned with the analysis of the anomalous features complicating the normal distribution of the earth's gravitational field in an area lying within EL Hamada EL Hamra Basin, Western Libya between Latitudes 28°30' N - 30°00' N and longitudes 10°00' E - 13°00' E.

The study emphasizes that such an area — being bounded from the south by the Gargaf Uplift and from the north by the southern flank of the Ghadamis Trough — is characterized by several local structural features, mainly in the form of horsts, grabens, and step faulting. Such structural features, which seem to have been originally initiated and developed by crustal movements at depth, are of different intensities, and trend patterns.

The present work also indicates that several of the observed anomalies signify either local structures complicating the basement complex or being associated with lithologic variations within the basement itself from metasediments and metavolcanics to granites.

On the other hand, the statistical analysis, which has been carried out on the "key variables" of the different local gravity anomalies, particularly those which have been analytically continued downwards to five different levels below the Bouguer one, readily reveals the following;

1) The area seems to have been subject to several tectonic cycles during the different tectonic phases which prevailed the area through its geologic history. Such tectonic cycles are considered to be generally

responsible for the development of major deformation trends corresponding fairly well with those of the Gulf of Suez, Gulf Aqaba, Mediterranean and with intensities exponentially decreasing with increasing depth as well as the formation of a number of stratigraphic and structural traps of economic interest.

2) The depth to the top of the basement complex, which corresponds to the level along which maximum variations in the tectonic parameters occur ranges between a few hundred feet in the southern portion of the area to more than 4 kms, in the north, with an average of about 2.5 kms.

3) The level along which the strain vanishes lies at about 10 kms, whereas the level along which the applied geotectonic forces reaches a minimum occurs at about 30 kms, which is more or less comparable to that of the lower limit of the base of the crust in Northern Africa.

Ground Water Nitrate Pollution in the Quaternary Aquifer, Eastern and Central Gefara Plain, S.P.L.A.J.

Dr. Mohamed N. Belaid

Concentrations of nitrate in the ground water of the Quaternary aquifer of the Gefara Plain are relatively high. Water from 6.94 percent of the sampled wells had nitrate concentrations less than 10 ppm, 93.06 percent had greater than 10 ppm and 48.55 percent had greater than 45 ppm. Ground water with nitrate concentrations exceeding 45 ppm can cause nitrate poisoning (cyanosis) to infants. Progressive increase of nitrate concentrations has occurred in some wells. Concentrations decrease with increasing well depth and well penetration below the water table. Quaternary deposits, composed mainly of sand and gravel contain abnormal nitrate concentrations. Potential sources of nitrate are fertilizers, feed lots, several types of legumes and the evaporite deposits in the south-western part of the study area.

Stratigraphic contribution to the Paleozoic of Southern Basins of Libya

E. Bellini - D. Massa

Part I - General Framework of the Murzuk and Ghadamis Basins (D. Massa).

The geology of the southern basins of Libya is particularly important in the general context of Africa. In our work the Paleozoic of these basins will be studied, from the Cambrian to Upper Carboniferous. The most recent publications concerning Libya and its neighbouring countries will be taken into account.

The Murzuk and Kufra basins represent in fact the two easternmost intracratonic basins of North Africa. They are sedimentary basins of prevalingly marine facies, affected by recurrent continental influences more frequent in the Kufra basin.

The paleogeographic and faciologic evolution of these basins are directly connected with Caledonian and Hercynian orogenic events which are clearly recorded and dated.

The knowledge about the geology of southern Libya has evolved in a progressive way. From 1930 to 1940, reconnaissance trips and first systematic observations were made mainly by Italian geologists under the direction of A. Desio.

From 1944 to 1955, due to the efforts of French geologists, mainly M. Lelubre and J.M. Freulon, the geological knowledge of Libya advanced considerably, especially in the western part.

Since 1956, a very important work has been realized by petroleum geologists (Fezzan and Ghadames basin); a great number of boreholes have been drilled in Libya, mostly in the Sirte and Ghadames basins.

From 1961 to 1976, AGIP improved the stratigraphic data about the Paleozoic outcrops of the Kufra basin and the subsurface Paleozoic sequences of central-eastern Cyrenaica.

Finally, the efforts of the Libyan geologists largely contributed to the knowledge of the geologic framework of this huge country. Some of their views have been published.

Now, 20 years after the beginning of petroleum exploration, a synthesis might be attempted. The work, however, is still in progress and certainly will further specify the contents of the present study. Unfortunately, a detailed geological map of these two basins does not yet exist.

Part II - The Murzuk Basin (D. Massa).

This huge intracratonic basin is situated East of the Hoggar Massif and West of the

Tibesti. It presents a complete Paleozoic series, from Cambrian to Carboniferous, of which the geological age has been established by means of correlations with the well studied Ghadames basin.

Sediments of the Infracambrian/Cambrian cycle are overlain by a reduced thickness of Lower and Middle Ordovician. The great glacio-marine episode of Upper Ordovician age, known all over North Africa, exists in Libya, where it has been dated Caradocian and Ashgillian. The wide Silurian transgression throughout North Africa, has reached the Murzuk basin during the Llandoveryan.

After the long Middle and Upper Silurian emersion, the region was submitted to the effects of the Caledonian orogenesis. The post-Caledonian sedimentary mega-cycle is of Early Devonian age (Tadrart and Ouan Kasa Fms: Pragian and Emsian). The Middle and Upper Devonian (Aouinet Ouenine Fm) with marine influences is related with the Devonian of Europe (Couvinian, Givetian, Frasnian and Famennian).

The Devonian mega-cycle ended with regressive sequences (Tahara Fm) of Strunian age.

The marine Carboniferous was the last episode of the Paleozoic. The transgression has been dated Upper Tournaisian: the Carboniferous sediments show mixed marine and lagoonal facies.

Locally sediments of Visean, Namurian, Bashkirian and Moscovian age have been identified.

During the Upper Carboniferous, red continental sediments were deposited (Tigentourine Fm).

The Hercynian orogenic phase is apparent through the folding of the Paleozoic series and through magmatism phenomena.

Part III - The Kufra Basin (E. Bellini).

The Kufra basin lies South-East of the Sirte basin, between the Tibesti Massif to the West and the high plutonic ring complexes of Jebels Archenu and Uweinat to the East.

The stratigraphic data available about this basin are mostly due to geological and photogeological surveys. Petroleum exploration is just beginning and no deep well has been drilled so far.

Stratigraphic boundaries in the geological maps are mainly based on mapped lithostratigraphic units but most of them lack

of sound biostratigraphic evidence and fossils records which might allow a confident and detailed dating of the sediments.

In their broad lines the Kufra and the Murzuk basins show a parallel geologic evolution. A wholly clastic sedimentary sequence is present in the Paleozoic (and Post-Paleozoic) of the subject basin.

The metamorphic Pre-Cambrian Basement is overlain by a very thick sequence of Cambrian and Ordovician age; locally an erosional surface, formed at the time of the great north african ice sheet, separates Cambrian (Hassaouna Fm) and Upper Ordovician sediments (Memouniat Fm).

In the Kufra basin, the Silurian marine ingression reached the south-eastern area and, probably, the northern area during the Uppermost Ordovician (Ashgillian). Lower to middle Silurian sediments constitute a complete sedimentary cycle; a very shallow marine environment is dominant (Acacus Fm).

Again the post-Caledonian sequence represents a sedimentary cycle of dominantly continental environment at the base (Tadrart - Ouan Kasa Fms) passing to open shallow marine during Middle-Upper Devonian (Binem Fm) and, locally, to marine-lagoonal in the uppermost part.

The Carboniferous sequence is mostly of continental environment and with pronounced thickness (Dalma Fm); a short marine episode, of probable Visean age, has been found both in the south-western and north-eastern outcrops of the basin.

Hercynian orogenic events caused the uplifting of the basin during Carboniferous times; as far as we know the presence of Upper Paleozoic or Lower Mesozoic (continental) sediments in the most sinking areas of the basin, is only hypothetical.

Post-Eocene Sedimentation in the Eastern Sirte Basin, Libya

A. C. Benfield and E. P. Wright

Reinterpretation and synthesis of oil company well logs supplemented by sample and geophysical log data from hydrogeological exploration boreholes has provided new information on the Post-Eocene succession in a 76,000 square kilometre area of Central Cyrenaica situated in the east of the Sirte Basin. In the south west of this area Oligocene sediments,

commonly between 700 ft and 1000 ft thick, comprise glauconitic sands and sandstones with interbedded shales, deposited in transitional and marine environments, overlain by fine to coarse sands with occasional clays, of fluvio-continental origin. Northwards the fluvial sands thin out within a dominantly marine sequence of shales, sands and carbonates which exceed 2300 feet in thickness in a northerly plunging trough midway between Jebel and Amal oil fields.

The full thickness of the succeeding Lower and Middle Miocene Marada Formation reaches over 3000 ft in the same trough, but elsewhere is around 1200 ft. Fine to coarse sands dominate the formation in the west and south shales, evaporites, sandy shales and sandy carbonates and ultimately die out north eastwards within interbedded clays and carbonates. Facies relationships indicate that the shoreline complex recognised at outcrop further west extends into the sub-surface with a south easterly trend.

Over the north eastern half of the area the Marada Formation is overlain with sharp disconformity by the newly recognised Post-Middle Miocene Calanscio Formation comprising up to 600 ft of unfossiliferous, fine to coarse sands, pebbly in part, with impersistent thin clays, which was deposited under fluvial conditions.

The Quaternary is chiefly represented by the aeolian sands of the Calanscio and Rebiana Sand Seas, together with thin gravels, surface calcretes, residual soils and Lacustrine deposits.

The paper concludes with a resume of the Post-Eocene sedimentation in the area in relation to its regional stratigraphic context.

Foraminiferal Biostratigraphy and Paleocology of the Apollonia Limestone (Eocene) of Cyrenaica (Ne Libya)

W. A. Berggren

Foraminiferal biostratigraphy and ecology of the Apollonia Limestone (Eocene) at three sections in NE Libya (Cyrenaica) is described.

The lower 110' (33.5 m) of the 220' (67 m) thick section of Apollonia Limestone exposed at Wadi al Atrun essentially spans the Early Eocene (Zones P6-basal P10) and lies unconformably upon the early Maestrichtian (*Globotruncana tricarinata*

Zone) Atrun Limestone. At Wadi al Qualah (~ 8-9 km west of Wadi at Atrun) the Apollonia Limestone is of Middle Eocene (upper part of Zone P11) age and lies unconformably upon the late Maestrichtian (*Abathomphalus mayaroensis* Zone) Atrun Limestone. The lower 365' (11 m) of the 425' (130 m) "Pyramid Peak" section of Apollonia Limestone (~ 6 km east of Wadi al Atrun) essentially spans the Middle Eocene (upper part of Zone P10-P14). A basal contact has not been observed in this section.

Morozovellids (*subbotinae*, *gracilis*, *aragonensis*) and acarininids (*soldadoensis*, *coalingensis*, *pentacamerata*) characterize the lower part of the lower Eocene section at Wadi al Atrun. The appearance of *Subbotina senni* and *Acarinina densa* and the relatively common occurrence of the *Acarinina pentacamerata-aspensis* group is used to denote the P9-10 interval in the upper part. Reworked Maestrichtian (globotruncanids) and (? reworked) Paleocene (*Morozovella velascoensis*, *Planorotalites pseudomenardii*, *Subbotina velascoensis*) elements are present in the basal sediments immediately above the unconformity. This is the first record of Paleocene in north central Cyrenaica.

A nearly complete Middle Eocene planktonic foraminiferal succession is present in the Pyramid Peak section. Common planktonic elements include *Truncorotaloides (rohri, collactea)*, *Globigerapsis (kugleri, barri-mexicana)* group, *subconglobatus*), *Subbotina senni* and the "Turborotalia" *pomeroli* group.

The single sample examined from immediately above the unconformity at Wadi al Qualah contains a rich planktonic fauna including, *i.al.*, *Morozovella (Lehneri, broedermanni)*, *Acarinina densa*, *Truncorotaloides (rohri and topilensis)*, *Globigerapsis kugleri*, "Turborotalia" *possagnoensis* and *Subbotina linaperta* which indicates a position within the upper part of Zone P11.

The lower Eocene section at Wadi al Atrun exhibits a pronounced shallowing in the Zone P9-10 interval from (probably) upper bathyal (200-600 m) to mid-neritic (< 100 m) depths. The bathyal fauna (Zones P6-P9) is characterized by *Nuttallides truempyi*, *Vulvulina spinosa*, *Alabamina dissonata*, *Globocassidulina subglobosa* and "Planulina" *cushmani*. This fauna is replaced

rapidly within Zone P9 by one characterized by hispidocostate (*gardnerae-rippensis* group) uvigerinids, costate (*jacksonensis*, *instabilis*, *macilenta*) buliminids, Cibicidoides (*alleni*, spp.), *Operculina* and *Nummulites*. Planktonic foraminifera, common in the lower part of this section, exhibit a marked diminution towards the upper part, and disappear in the uppermost part, above the level of the appearance of *Nummulites*. The (local) termination of several bathyal taxa in the later part of the early Eocene mirrors that seen at equivalent horizons in California (Lodo Formation) and coincides closely with recent interpretations made by seismic stratigraphy of a major eustatic sea-level change near the early/middle Eocene boundary. However, the presence of contorted slump masses in the Wadi al Atrun section within this interval suggests that local tectonism may also have been a factor in the change in bathymetry seen in this section.

The Middle Eocene "Pyramid Peak" section contains a rich and well preserved benthonic foraminiferal fauna which remains essentially uniform throughout and exhibits a marked affinity with the upper Eocene (Jackson) faunas of the Gulf Coastal region of the United States. The diachroneity in benthonic foraminiferal assemblages is attributed to the fact that Middle Eocene facies in the Gulf Coastal region contain a strong terrigenous component, whereas carbonate sequences, similar to that in Cyrenaica, are characteristic of the Late Eocene (Jacksonian).

Characteristic elements include hispidocostate (*gardnerae*) and striate (*dumblei*) uvigerinids, costate (*jacksonensis*) buliminids, *Cibicidoides (cocoaensis, pippeni)*, *Anomalinoidea bilateralis*, *Planulina* sp. cf. *P. cocoaensis* and compressed and inflated lenticulinids and costate marginulinids. The appearance of *Baggina* sp. and *Florilus spissa* in the P12-P14 interval suggest moderate shallowing in the younger part of the Middle Eocene. The total absence of nummulitids and operculinids is noted and, together with the relatively abundant planktonic fauna and absence of typically bathyal elements, suggests that deposition occurred on the outer part of a carbonate shelf (outer neritic: ~ 100-200 m).

The single sample examined from the Wadi al Qualah section (Zone P11) contains

a benthonic fauna essentially identical to that found at comparable levels in the Pyramid Peak section with the notable addition of *Nummulites* and *Operculina*. This suggests deposition at somewhat shallower depths (middle neritic: ~ 50-100 m) than the Pyramid Peak section.

Infiltration Conditions of Major Sandstone Aquifer Around Ghat, Libya

David J. Burdon

Ghat and Wadi Tanezzuft are situated on the outcrop of Cambro-Ordovician sandstones on the south-western flank of the Fezzan Groundwater Basin. These sandstones are major aquifers extending beneath most of the Basin, which has an area of the order of 450,000 km². Hydrogeological investigations over the past 25 years have generally led to the acceptance of the Ghat region as one of groundwater infiltration and aquifer recharge, so that groundwater flow is assumed from the south and south-west to the north and north-east. These concepts are based on limited data at points which are far apart, and with a tendency to assign to unexamined or inaccessible areas, characteristics which fit the general accepted concept for the Basin.

Field investigations in the Ghat area early in 1977 showed that many of the phenomena observed were incompatible with the concept of the area being one of infiltration and aquifer recharge. It appeared that infiltration does not occur as there are perennial pools on the sandstone in some wadis; that the groundwater is generally confined even with no definite impermeable cover; that in places the sandstones have been cemented to quartzites; that groundwater temperatures are high, but not abnormally so; and that groundwater mineralisation is low.

A working hypothesis is presented which seems to reconcile these contradictory facts and fit them into a coherent picture of what may have occurred following decreased or nil infiltration after the end of the last fluvial, say 10,000 years ago. Then decreased groundwater put-through allowed the geothermal heat flux to warm up the groundwater; in turn geothermally induced convection flow reversed groundwater flow on the recharge limb and boosted flow on the discharge limb; this was reinforced by aqua-thermal effects in the sandstones and

the shales. Meanwhile, initial falls in groundwater levels in the recharge area had produced a vadose zone at the base of which silica was precipitated, sealed the aquifer and provided an impermeable carapace with the sandstone when the groundwater again rose under geothermal heat and pressure effects. In this way, confined groundwater is now found in what appears to be an open sandstone aquifer. The hydrochemical data neither favours nor disproves this working hypothesis, which may be referred to as a "hydrothermal" working hypothesis.

The paper does not present this working hypothesis as if it were a proven explanation of the hydrostatics and hydrodynamics of a major groundwater basin. It draws attention to the danger of accepting one conventional hypothesis as proven, and emphasises the need for the multiple hypotheses approach when data is scarce and spread over vast areas, some almost totally inaccessible.

On the origin of the Messak Mellet and Plateau du Mangueni escarpment

Detlef Busche

The Messak Mellet/Plateau du Mangueni-escarpment, which is up to 300 m high, separates the Nubian sandstone surface (up to 1.100 m high) of the south and southwest margin of the Murzuk basin from the foreland surface (600 - 700 m high), which is largely developed in upper carboniferous limestone.

Strata generally dip towards the center of the Murzuk basin at a very low angle, but still somewhat steeper than the slope of the plateau surface toward the Murzuk sand sea. Geological profiles taken along the escarpment show that the border between the limestones and the Nubian sandstone, or between triassic red clays and the sandstone varies in altitude as the result of more pronounced uplift in the region south of Anai and in the Enneri Achelouma region on one side and relative depressions in the Salvador area and north of Anai. E.g. south of Col d'Anai less than the upper third of the escarpment face is in Nubian sandstone, as is the case in the El Oumr area. These observations, together with aerial photograph interpretation, lead to the conclusion that the upper plateau surface is fully denudational, lowered beneath the inferred structural surface of the Nubian

sandstone by at least 100 to 150 m.

Morphological features older than the escarpment are two surfaces linked by gentle slopes, inselbergs of various heights with bevelled tops, steep-sided valleys with rock terraces converging toward the basin center, and numerous endorheic non-structural depressions ranging from a few meters to several kilometers in diameter. The large valleys are best preserved north of Salvador, where all of them strike out into the air at the plateau rim at full width and depth, indicating that they are much truncated remnants of much longer valleys once coming from the west. It is through these old valleys that much of the sand seems to have been transported into the center of the basin to be transformed into the Murzuk sand sea. The present-day watersheds are much too small to have served as principal supply areas. The sand sea lies on the lowest and dissected erosion surface of the plateau.

In the course of surface lowering in pre-escarpment times the less resistant strata of triassic clays must have appeared at the surface first in the above-mentioned areas of gentle uplift. Facilitated erosion in the soft clays appears to have resulted in differential lowering of those surface areas as compared to those parts of the surface still being in sandstone. Thereby was initiated the growth of the escarpment, and the old drainage system was gradually dismembered. In the Plateau du Mangueni traces of W-E-trending pre-escarpment drainage are cut at right angles by valleys tributary to the Enneri Achelouma plain.

Lowering of the foreland seems to have progressed step-wise, so that the escarpment gradually grew from a gentle rise to a height of sometimes more than 300 m. This process can be traced in numerous slope profiles and surface remnants preserved on the tops of inselbergs along the whole escarpment. Two periods of development have to be distinguished: the more important older one of step-wise vertical lowering almost down to the lowermost rock surface, for which gentle sigmoidal slopes between the upper and respective lower surfaces were characteristic, and a younger phase of progressive steepening of the escarpment slopes up to the point of slope failure along all those sections it is where clays were present. During the latter phase the lower most rock surface was not remarkably lowered, but

toward the end of this phase considerable dissection seems to have set in. This oversteepening, which seems to have been a reflection of changing climatic conditions toward more aridity, has led to large-scale landsliding (cf. abstract and paper by Grunert in this volume).

Parallel to the growth of the escarpment and the dismembering of the old river systems a new dendritic runoff pattern established itself on the (upper) plateau surface, developed best north of Anai. With the exception of one area in the south of the study region the regional divide closely follows the plateau rim, often less than 100 m from it. Water-courses whose head reaches have been truncated by slope retreat are virtually absent, even where landsliding has taken place. This indicates that the escarpment has practically not changed its position since the initial stages of its development, with the exception of tahta slope retreat that occurred with the landsliding. The dendritic drainage system in its present form has originated after the landslide phase.

No evidence could be found for the support of the commonly held opinion of subparallel slope retreat over many kilometers. The reconstructed model of differential surface lowering is in agreement with results obtained in the Tibesti and Hoggar Mts.

The Basanitic Volcanoes of the Charian area, N. W. Libya

M. T. Busrewil and W. J. Wadsworth

The most recent phase of Tertiary — Quaternary volcanic activity in the Gharian area of N. W. Libya gave rise to a series of small volcanic vents and associated minor intrusions, less than 12 m.y. old. These are mainly of basanitic composition, although small quantities of undersaturated trachybasaltic differentiates have developed locally. Lherzolite fragments have been recorded from a number of localities. Brief field and petrographic descriptions are presented, together with 21 new chemical analyses.

A two-stage petrogenetic scheme is proposed. It is suggested that the basanitic magma was generated by partial melting of upper mantle lherzolites, possibly accompanied by eclogite or olivine opx

fractionation. Subsequently, limited low-pressure fractionation involving olivine cpx is believed to have occurred in sub-volcanic chambers or within the volcanic edifices, to produce small volumes of residual trachybasaltic material.

The Cainozoic Igneous rocks of Jabal al Haruj al Aswad, Libya

M. T. Busrewil and W. J. Wadsworth

The Haruj volcanics comprise one of North Africa's most voluminous alkaline igneous provinces. The volcanics ranging from olivine basalt to hawaiite are mostly porphyritic with combination of olivine and to a lesser extent clinopyroxene phenocrysts. Major element concentration and trace element abundances were determined for selected rocks from the Haruj area. The available chemical data suggest that the rocks belong to the alkali olivine basalt association and are slightly less alkalic than modern alkali suites. There is considerable variation in concentration of the minor and trace elements. The differentiated rocks are likely to have evolved by fractionation of the undersaturated alkalic basalts at a high level in the crust, the process being controlled largely by precipitation of olivine and clinopyroxene, perhaps aided by different degrees of partial melting mantle materials or possibly high pressure fractionation..

To the Sedimentology and facies development of Hasáwnah formation in Libya

Petr Čepek

The whole sequence of sandstones of Hasáwnah Formation in the area of Jabal al Hasáwnah/Jabal Fezzan, middle part of western Libya/appears to be dominantly marine in its origin.

Following sedimentary structures, significant for environmental interpretation have been observed: the cross-bedding, most frequent structure at all, is developed in several types; high angle cross stratification is a dominant type, having both unimodal as bimodal orientation. Occurrences of bimodal-bipolar herringbone cross stratification are rare. The sharp based cross-bedding associated with the cross-bedding with truncated top of sets are

most frequent modifications. The convoluted bedding, specific type of graded bedding and parallel lamination are also present. Typical sand bars could be distinguished on many places. The desiccation cracks have been observed too. They are very often accompanied by mechanoglyphs and deep cutted bioglyphic trace fossils.

Facies analysis of all observed sedimentary characteristics, particularly of the structures mentioned above, suggests tide dominant environment. The depositional environment on the transition of subtidal to intertidal zone, combined with fluvio-deltaic depositional influence/supply of terrigenous clastic material/appears to be most probable facies model.

The Cretaceous/Tertiary boundary in the northwestern part of the Hamada al Hamra basin in northwestern Libya

J. Chaloupsky, E. Hanzlíková, B. Záruba

During the geological mapping organized at the present time by the I.R.C., Tripoli, in the northwestern part of the Hamada al Hamra basin new geological and paleontological data have been obtained which make possible to precise the stratigraphic position of the Senonian and Lower Paleocene lithostratigraphic units the Lower Tár, Upper Tár and Hád Members of the Zimém Formation/. The Cretaceous/Tertiary boundary, often discussed in the previous papers, is traced close to the boundary of the Lower Tár and Upper Tár Members. It is evidenced by a great amount of well determinable macro and microfossils.

The paleogeographic changes near the Cretaceous/Tertiary Boundary, the lithofacial development of marine sediments, mostly carbonatic as well as rich macro and micropaleontological assemblages occurring in the delimited lithostratigraphic units are described in the submitted article. The stratigraphic correlation of the studied sequence with that of the Sirte basin in Central Libya is also presented.

Depositional Environment of the Lower and Middle Devonian Tadrart and Uan Caza Formations of the South West Fezzan and their relationship to the underlying Silurian Deposits

D. D. Clark-Lowes

The Tadrart Formation outcrops in a 180

km north south trending belt to the east of Ghat and through Aouinat to the north while the younger Uan Caza Formation is exposed in an area to the east of the Tadrart Formation east and south east of Ghat. The most comprehensive previous work on these formations is that of E. Klitzsch who has published type sections (1965, and 1970 in English Translation). Displaying a low angle (1° -- 6°) eastward dip the Tadrart and Uan Caza Formations comprise part of the Palaeozoic succession exposed at the western margin of the Murzuk basin. Measured vertical sections systematically recording rock type (mineralogy and texture), primary sedimentary structures, and biological features (trace fossils) have been used in conjunction with photomosaics of continuous lateral exposure in the field to define facies and to study their geometry. The Tadrart Formation with a maximum measured thickness of 320 m and the conformably overlying Uan Caza Formation (maximum measured thickness of 45 m) represent the broadly transgressive phase of a regressive/transgressive cycle in the Murzuk Basin from the Silurian (Llandovery) to the Middle Devonian (Eifelian). Llandoveryan marine graptolitic shales and siltstones of the Taneszuft Formation are overlain by the coarsening upwards Acacus Formation, representing a prograding deltaic succession, which is in turn overlain by the Devonian Tadrart Formation, which in its lower part comprises a braided stream delta top set sequence which passes up in the upper part of the formation to a coastal foreshore, shoreface, and proximal offshore sequence cut by tidal channels and offshore shoal sandstones. Lastly the marine spirifer and pelecypod fauna of the Uan Caza Formation claystones indicate the culmination of the cycle in marine continental shelf conditions.

The lower part of the Tadrart Formation consist mainly of fine and medium sandstones though very fine to coarse sandstones are present, the sorting is very variable but frequently poorly sorted, and claystone intraclasts are often present. The high percentage of quartz in the sandstones (quartz arenites), the absence of any detrital extraclasts of larger than very coarse sand grade, the presence of sandstone intraclasts and the remarkable paucity of argillaceous sediments is evidence for a polycyclic source

of the sand grains and a source area which was actively shedding detritus from weathered sandstone formations throughout much of the period of deposition of the Tadrart Formation. Planar tabular cross bedding with sets up to 2.8 m thick but usually less than 1 m thick and frequent intraformational recumbent folded cross beds is the dominant bedding type in the lower part of the Tadrart Formation and the subsidiary horizontal, homogeneous, rippled and trough cross bedding together with channel scour and fill features indicate an environment of great fluctuation of flow strength. The recumbent folded cross beds and other deformed beds (slumping and convolute bedding are present) suggest rapid deposition and the entrapment of interstitial water the presence of which allows the beds to undergo plastic deformation by the semihorizontal shear of sediment laden currents on their upper surfaces, and the expulsion of which on subsequent burial results in fluidized beds. The bedding types are grouped into those interpreted as being formed by high water stage braided stream bedform migration, i.e. transverse bar and linguoid bar downstream migration, by accretion on bar avalanche slopes, and those formed by low water stage accretion and modification processes and channel scour and fill. Channels of up to 25 m in width basal scour deposits lying with cross cutting relationship to lower beds and containing angular intraformational claystone and sandstone clasts are abundant in the upper part of the lower 150 m of the formation. They are interpreted as lateral accretion deposits in low sinuosity laterally shifting braided delta distributory channels. The upward transition to this facies represents a shift from proximal to distal fluvialite sedimentation and the initiation of some minor meandering. Palaeocurrent directions from cross bedding dip azimuths within the fluvialite facies indicate unidirectional flow to the west and north west with a range of 135° . Finer grained sediments (very fine sandstones and siltstones) containing marine trace fossils (*Arthropycus*, *Skolithos* and others) are present in 2.5 m to 20 m units within the succession of fluvialite deposits. An interpretation of these incursions into the continental sequence based upon a high constructive elongate braided delta complex model (interdistributory bays open to the sea

generate thin lenticular marine facies within continental fluvialite deposits) is compared with a model which requires (unlike the former model) an alternation in detrital input to the delta complex to explain the marine incursions, which are interpreted as marine transgressions consequent upon reduced or absent detrital input. The upper 170 m of the Tadrart Formation consists of mainly fine and silty fine sandstones with horizontal bioturbated bedding. Sublittoral and littoral offshore, shoreface and foreshore deposits are recognized with horizontal burrows sand trails (*Cruziana* Ichnofacies) in the deeper water deposits through to vertical burrows (*Skolithos* Ichnofacies) in the shallower more turbid water deposits. Cross cutting these are trough cross-bedded intertidal to subtidal channel bodies composed of slightly coarser grade sand. A laterally persistent 5 m thick massive horizontally bedded and crossbedded fine sandstone unit, with abundant indistinct pelecypod shell moulds, within the thin bedded bioturbated coastal sandstones and siltstones is interpreted as a lenticular offshore shoal sandstone. The evidence of transported and reworked pelecypod shells, the polydirectional current indicators, and the absence of channeling distinguish it from other massive sandstone bodies in the section. The dominant palaeocurrent direction in this upper part of the Tadrart Formation is to the south with a strongly bipolar subsidiary east-west component. This probably represents an onshore-offshore bipolarity a strong current longshore drift to the south. The Uan Caza Formation is an offshore clean, siltfree claystone deposit. It contains siltstone horizons displaying current ripples and in-drift climbing ripple lamination indicative of subtidal sheet deposits which may result from exceptional tides and consequent sediment-laden subtidal currents.

Finally a palaeogeography is proposed whereby the sediments studied are those laid down on the east and south east margin of an epicontinental sea (opening out to the north off the African Craton) where major detrital influx and rapid sedimentation has built prograding delta complexes during the Silurian and Lower Devonian periods (Acacus Formation and lower part of Tadrart Formation) the upper parts of which are reworked later in the Lower Devonian to generate the coastal sandstones of the upper

part of the Tadrart Formation. Reduction of relief and peneplanation in the source area to the south east caused decreased sediment supply and the transgressive shales of the Uan Caza Formation were laid down. A depocentre to the west or north west of Ghat is indicated rather than at the centre of the present Murzuk Basin.

Isopachs of the Silurian Taneszuft Formation also suggest a depocentre well to the west of the west of the Murzuk Basin axis. As palaeocurrent directions from Palaeozoic fluvialite sequences in the Kufra Basin to the north west of the Tibesti Massif also indicate a source to the south east the influence of this massif upon the Palaeozoic sedimentation is questionable. Uplift of the source region and the sediment generated from its erosion may be the major controlling factor in the Silurian and Devonian deposits of the study area.

Geology of a stratigraphic giant - The Messla oil field

H. J. Clifford

The Messla Oil Field is the most recent addition to the imposing list of some twenty giant fields discovered within the prolific Sirte Basin of Libya. The field, discovered in 1971, is located in the southeastern portion of the Sirte Basin, approximately 40 kilometers north of the supergiant Sarir Oil Field. Although in an early stage of development the field is estimated to contain approximately three billion barrels of original oil-in-place. The essential trapping mechanism is the updip truncation of the Lower Cretaceous Sarir Sandstone on a broad plunging nose.

The maximum oil column is 250 feet productive from an average depth of 8800 feet over a 200 square kilometer area.

The Messla Field is a seismically defined stratigraphic accumulation located on the easterly plunging nose of an ancestral basement ridge. The productive unit is the Lower Cretaceous fluvialite Sarir Sandstone which wedges out westward on the Precambrian Basement and is truncated by a profound unconformity at the base of the capping Upper Cretaceous marine shales.

The reservoirs consist of two Sarir sands separated by a continuous shale bed. Porosity values average 16 percent and the permeability, four hundred and fifty

millidarcies. Production as of early 1978 is in excess of 100,000 barrels per day of 40° API gravity oil with a cumulative production of 45 million barrels.

Synthesis of the Lower Paleozoic Palynostratigraphy of northern Africa

F. H. Cramer & M.D.C.R. Diez

The interval beginning at the Cambrian through the Devonian transition in Northern Africa (Morocco, Algeria, Tunisia, and Libya) and areas in its immediate paleoviciinity (Brazil, Iberia, SE Turkey, and Arabia) generally yield very well preserved palynomorph assemblages in rocks with thermal alteration indexes that place them at levels better than the upper limit of the oil and gas window.

Based in points of arrival, acmes, horizons of co-extinction, and homotactic sequences, a palynostratigraphic succession with fair to excellent chronologic precision has been constructed which is valid for this entire region. Acritarchs s.l., chitinozoans, and miospores (for the Silurian and Devonian), have been used. The region is now known to belong to the same series of succeeding paleophytoplankton provinces throughout up to the early Devonian so that correlations even over very long distances present homotaxis even in very detailed aspects; from the middle Devonian onward the increasing palynologic endemism precludes such long distance correlations.

Hydrogeological Conditions of the Northern part of the Western Desert, Egypt

M. S. Diab - F. A. Hammad - S. M. Atwa

The main objectives of this study are to asses in general aspects the quantity, quality and most promising aquifers for further land reclamation projects. Needless to say that these objectives necessitate the thorough examination of the relevant hydrological, geological, geophysical observations.

The primary reconnaissance hydrogeological studies done on the northern Part of the Western desert of Egypt reveals many new foundations. The area was found to comprise the following aquifers:

- (1) The dune water table aquifers.
- (2) The elevated water table aquifers.
- (3) The fissured limestone water table aquifers.
- (4) The Artesian aquifers.

Syenite and Carbonatite Plugs West of Jabal Awaynat, Southeastern Libya

A. K. Doughri - D. S. Sinha & R. S. Yeats

Two syenite plugs, each nearly 4 km in diameter, intrude nearly flat-lying Cretaceous sandstone in southeastren Kufra basin 100 km west of Jabal Awaynat near the Libyan-Egyptian-Sudanese common border. Forceful intrusion was accompanied by tilting outward of the sandstone to dips as high as 70° and by conjugate shear fracturing of the sandstone, indicating maximum principal compressive stress radial to the centre of each plug. Magnetic anomalies recorded at the intrusive borders suggest the intrusive contacts are near-vertical, discordant to sandstone bedding at depth. The syenite is leucocratic and fine to medium grained with local vertical foliation. Pods of biotite-apatite rock, sanidinite and magnetite rock are most abundant in the eastern body; locally the apatite rock contains nepheline. The central part of the eastern body consists of carbonatite agglomerate 500 metre in diameter, the first carbonatite rock discovered in Libya. The agglomerate contains rounded to sub-rounded fragments with clinopyroxene, green hornblende, plagioclase, brown biotite, magnetite, calcite and potassium feldspar in an altered glass matrix. Sovite occurs as fragments of equigranular calcite rock in agglomerate and a small dike intruding agglomerate; calcite occurs with potassium feldspar and brown biotite. The plugs contain up to 730 ppm Ce, 700 ppm Ba, 7200 ppm Ba, 1330 Zr, 2100 Nb, 900 ppm Y, 1600 ppm Sr, 340 ppm Rb, 100 ppm U and 950 ppm Th; these concentrations vary widely. The plugs, characterized by local zones of high magnetic susceptibility and moderate to strong radioactivity, are in contrast to the large syenitic and granitic ring complexes of Jabal al Awaynat and Jabal Arknu, which lack carbonatite and concentrations of rare earths.

Groundwater in Wadi Shati, Fezzan; a Case History of Resource Development

Laszlo Dubay

By late 1973 the Council for Land Reclamation and Development entrusted Italconsult SpA with the execution of a 3000 ha, land reclamation project in the Wadi Shati Brak- Eshkeda area, Fezzan,.

The agricultural development was based on the groundwater resources. Early hydrogeological investigations indicated the Cambro-Ordovician sandstone formations as the most likely source of groundwater, suitable for large scale development. The water wells drilled subsequently to provide irrigation water and aquifer performance monitoring facilities confirmed the expectations and identified in the Cambro-Ordovician sandstone one of the most important regional aquifer systems of Libya.

In the course of the subsequent hydrogeological studies and after the first appraisal of the hydraulic characteristics of the aquifer system, a groundwater model was built and operated with different hypotheses of additional groundwater extraction from 61×10^6 to 200×10^6 m³/year, to verify the soundness of the design of irrigation wells which were to be completed subsequently. According to the forecast drawdowns resulting from model operations the exploitation of irrigation wells appeared possible for a period by far in excess of the 35 years period considered.

The regional groundwater model, embracing nearly 125,000 km² was of the R/C digital-analog type, using the Advanced Statistical Analysis Program (ASTAP), an Installed User Program of IBM.

The first part of the agricultural development project became operational in late 1975, and by mid 1977 the whole area was under irrigation. The effects of the known amount of new groundwater extractions were closely followed for a period of more than two years and are still under scrutiny; they enabled a comparison to be made between effective and forecast drawdowns. The exploitation period revealed in general a good correspondence between forecasts and effective situation, the

measured drawdowns being slightly less than those envisaged. Of particular importance is, however, the fact that a new dynamic equilibrium occurred in a period of less than two years after exploitation started, in contrast with the model results which showed a new quasi equilibrium only after 20-25 years of operation. This very favorable situation points to the paramount importance of the unconfined portion of the prevailingly artesian aquifer system, which acts as a compensating reservoir on the groundwater extractions practiced in nearby areas.

The new groundwater development in the Brak-Eshkeda area has proved to be an excellent testing ground for the quantitative assessment of further development potential of the Cambro-Ordovician aquifer system and, at the same time, it allows to draw important conclusions on the most advantageous locations for further groundwater exploitations. The latter should be preferably located in the vicinity of the Jebel Fezzan, near to the outcrop area of Cambro - Ordovician sandstones, where water-table conditions prevail.

The hydrogeochemical characterisation of groundwaters in the Sirte basin, using Strontium and other elements

W. M. Edmunds

Strontium has been used as an exploration tool, along with other minor elements during evaluation of the groundwater resources of the Miocene and younger aquifers of the Sirte Basin. A wide variation in Sr²⁺ from < 0.1 to 29 mg/l is found and this variation can be related to lithofacies, reactions of carbonate and other minerals and to overall salinity changes. Strontium is therefore a very useful indicator element which has been successfully used, in conjunction with hydrogeological information and the geochemistry of major elements to define flow paths and groundwater evolution and origin.

The Sr²⁺ has been used to distinguish marine-derived from non-marine derived Miocene groundwaters and thence to trace the extent of leakage from one aquifer to another and to define hydrogeochemical facies within the main aquifers. In this paper the relevant hydrogeochemistry of strontium is examined and the extent of attainment of equilibrium with carbonate and sulphate

minerals and discussed. Lithium, boron and fluorine have also been used in a similar manner as potential trace elements to determine groundwater origin. The likely controls on the distribution and mobility of these elements in the Sirte basin aquifers are discussed in terms of mineral equilibria (fluorite) and other reactions.

The significance of these and other minor elements in relation to water supply and water use in Libya is briefly reviewed.

Investigation of radioactivity in the water Wells of Tripoli Area

E. A. Eissa - A. A. Missallati and K. M. El-Sherief

This paper represents the preliminary results of the initial stage of a research project concerning a large scale radiation survey of Libya. In this study samples of water from 68 (recorded) wells and springs in the metropolitan area of Tripoli were investigated by means of an automatic spectrometer. In this spectrometer beta radiations are detected by the liquid scintillation technique and the gamma-rays are detected by a well type 3" x 3" NaI (TI) crystal technique. Results of the analysis indicated that 34 wells are of high tritium contents. This will stand as a record of interest for the geologists and hydrogeologists in studying the local variations of the isotope composition of the subsurface water and the nature of recharge from one season to another. Health physicists will be interested in the hazards caused by these radioisotopes.

The geological interpretation of a gravity map of northern part of Marada graben (Sirte basin, Libya)

Salah I. El-Batroukh & Ahmed S. Zentani

A Bouguer anomaly map of the northern part of Marada graben is presented and interpreted. The main features of the map are: (1) A negative anomaly trending NW — SE approaching — 16 mgal in the SE then decreasing gradually up to — 2 mgal in the NW. (2) Steep anomaly gradient on both sides of the negative anomaly indicating fault lines.

(3) A narrow flanking areas of strong positive anomalies ranging from + 7 to + 17 mgal on both sides of the negative anomaly.

These anomalies are all superimposed on a strong regional gradient of 0.3 mgal/km to the south-west.

The negative anomaly is due to density contrast between the low density of the sediments and the high density of the basement. The positive belts on both sides of the negative anomaly are interpreted as horsts structures characterized by basement rocks at shallow depths.

The diminishing of the negative anomaly towards north-west is attributed to interruption of a very strong positive anomaly (35 mgal) in the north.

Structural sections across the graben are presented and compared with gravity models calculated by computer. Both show a very good agreement.

Monitoring the Deserts from Space

Farouk El-Baz

Although deserts occupy approximately 20% of the landmasses of the Earth, they remain one of the least understood of all its features. Among the reasons for this is the fact that deserts cover immense areas where harsh conditions prevail. Their remoteness and inaccessibility preclude their study by conventional means. However, remote sensing from space provides a unique opportunity to study monitor the desert environment. This is particularly true because deserts must be studied on a regional basis and because climatic conditions are nearly always favorable to monitoring from space.

Available data from manned space missions and Landsat satellites show that the reflectance properties of desert surfaces are indicative of the composition of the exposed rock rubble. Examples are given of distinct color zones in desert photographs that correlate with the amount of sand, desert-varnished pebbles, and clay minerals in the exposed soil.

Similarly, it has been shown that desert sands become redder as their distance from the source increases. This is due to the fact that individual sand grains become coated with an increased amount of iron oxides with the passage of time. This property is clearly demonstrated in the Sturt and Simpson deserts of south central Australia, the Namib Desert of southwest Africa, and the Empty Quarter of Saudi Arabia. Color zones in

space photographs of these areas can be used to delineate relative age zones within the sand fields.

Space photographs also provide an efficient way to monitor the extent of vegetation in arid regions. Photographs taken of the same area west of the Nile Delta by Gemini (1965) and Apollo-Soyuz (1975) astronauts clearly delineate the success of one desert reclamation project and the lack of progress in another. Landsat images of an area in southeastern Libya, which were taken at various times, show the stages of progress of a reclamation project based on the utilization of underground water.

These and other examples confirm the utility of space photographs and Landsat images in the investigation of desert landforms and of reclamation projects. However, the need exists for a complete survey of all parameters of the arid environments that can be successfully monitored from space; for example, the parameters that can be indicative of desertification, particularly in large regions such as the African Sahel. Similarly, the need exists to categorize the photocharacteristics of areas that exhibit good soil and hence can be reclaimed from the desert.

Today, the lack of meteorological data prohibits a full understanding of the desert environment. Space age technology can remedy the situation. Meteorological stations can be placed in remote areas to collect data and beam them to orbiting communications satellites. The latter can transmit the data to ground stations for analysis and synthesis. Monitoring the deserts from space in this way will help us utilize more of the land area of the Earth for the benefit of mankind.

Utilization of Orbital Imagery and Conventional Aerial Photography in the Delineation of the Regional Lineation Pattern of the Central Western desert of Egypt with a particular Emphasis on the Bahariya Region

H. A. El-Etr and A. R. Moustafa

Multi-band landsat images (scale 1:1,000,000 and 1:500,000) were used to delineate the photo lineations of an area approximating 281,280 sq km in the central Western Desert. A total of 481 lineaments and linears were detected of which 197 linear features are in the Bahariya Region

(approximately 41,150 sq km). For comparison purposes, aerial photographs (scale 1:60,000) and mosaics (scale 1:100,000) were used to delineate the detailed lineation pattern of the Central part of the Bahariya Region (approximately 18,530 sq km). In this case, a total of 81326 linears were identified.

A multi-stage procedure was adopted for the recognition of lineations on both orbital images and aerial photographs. All such lineations were later sorted out, on reliability basis, into three orders and were annotated, recorder for convenient equal unit areas then expressed in frequency diagrams and, in cases, isopleth maps.

The central Western Desert in the present study represents the central (mainly Eocene) limestone plateau of this Desert and includes the important Oases of Siwa, Bahariya, and Farafra. Miocene carbonate rocks are exposed, however, in Siwa Depression and Cretaceous clastic and carbonate rocks are present in the Bahariya and Farafra Depressions respectively. Besides, Oligocene clastic units are also reported in the Bahariya Depression.

The present study proved that the central Western Desert regional photo lineation patterns characterized by a strong degree of preferred orientation in the trends NW and ENE. Local deviations, however, are also reported in the Bahariya Region. These are attributed mainly to lithostratigraphic control.

Space images proved their value in deciphering regional lineations that may be obscured and (or) mutilated in the larger scale aerial photographs and mosaics. Such lineations proved to control, to a substantial degree, the shapes of the Siwa, Bahariya, and Farafra Depressions. Aerial photography, however, is still, and believed will continue to be, an indispensable medium of data acquisition that provides significant details of direct bearing on the local and semi-regional scales and provides a high resolution medium for checking the details and "ground meaning" of regional features on space imagery.

Inter-tidal and Storm Sedimentation from Wadi al Qattarah Member, Ar-Rajmah Formation (Middle Miocene), Jebel al Akhdar

A. S. El-Hawat

The occurrence of tidal flat and saline pond deposits within the dominantly carbonate middle Miocene Qattarah member (Ar-Rajmah Fm.), in Jebel al Akhdar area, is in response to the influence of a storm-formed barrier beach. Tidal flats developed behind the barrier and on the marginal areas between saline Ponds, that were spasmodically fed by sea water during storms.

Carbonate - Terrigenous Cyclic Sedimentation and Palaeogeography of the Marada Formation (Middle Miocene), Sirte Basin.

A. S. El-Hawat

The Marada Formation is a transgressive sequence that consists of carbonate-terrigenous cyclic succession. Seven sedimentary facies are distinguished: 1) Calcareous sandstone (estuarine channel), 2) Calcareous shale (lagoon), 3) Cross-bedded sandy grainstone (tidal inlet, channel, and delta); 4) Cross-bedded grainstone (barrier bars and beaches); 5) Dolomitic limestone (tidal flat); 6) Wackestone (marine bank); 7) Marl (marine deltaic fan). In cross-section, these facies are arranged in three successive informal depositional members: a) basal estuarine; b) lagoonal-barrier complex and c) open marine.

The palaeogeography of the period was dominated by inherited NNW-SSE trending Zelten Swell; which separates two parallel areas of subsidence, the Marada and East Zelten Basins. Over the swell, high energy carbonates accumulated; and in the basins, lower energy shale, marl and wackestone attain maximum thickness. Palaeogeography was maintained by syn-depositional differential subsidence; which was attributed to differential compaction of shales and marls, that was possibly, enhanced by spasmodic tectonic movement of pre-existing buried structures.

Cyclic carbonate-terrigenous sedimentation evolved through interplay of the rate of sea level rise, differential subsidence, and palaeogeography. These factors influenced trapping and releasing of terrigenous sediments in the nearshore area; that caused corresponding re-starting and shutting off carbonate productivity and transgression in the offshore area.

Biostratigraphy and Palaeoenvironment of Maastrichtian (upper Cretaceous) Foraminifera from Northcentral and Northwestern Libya

B. A. Eliagoubi and J. Dan Powell

The youngest Cretaceous foraminiferal faunas in Libya occur in the Sirte Basin and environs. These faunas consist of twenty-six cosmopolitan planktonic and benthonic genera and three, more restricted genera (*Omphalocyclus*, *Siderolites*, *Siphogenerinoids*) belonging exclusively to the Tethyan Realm. Forty-six species and varieties of foraminifera have been recorded and described by Eliagoubi (1978).

Two assemblage zones, The Zone of *Globotruncana fornicata* and the younger Zone of *Globotruncana conica* are proposed. Two subdivisions of the latter are that *Globotruncana gansseri* Subzone and the *Globotruncana contusa* Subzone, which are traceable across most of northern Libya. These zones provide precise correlations with the type Maastrichtian in Holland, with North America and with other parts of the world.

Three rock units, Waha Limestone, Kalash Limestone, and Lower Tar Marl, contain the Maastrichtian faunas. These formations have been studied in the subsurface of the Sirte Basin and at the Wadi Tar and Dor Talah surface localities west of Sirte Basin.

Suggested palaeoenvironments for the lower Maastrichtian limy sequence (Waha and Kalash limestones) are shallow shelf and possible offshore carbonate banks. The upper argillaceous beds (lower Tar Marl) reflect a general deepening of the water and a shift to an outer shelf-middle slope environment. The impoverishment of miliolids in the shallow-depth limestones is enigmatic, and may indicate special restrictive conditions, perhaps related to offshore shoaling over faulted bottom topography.

Kufra Pleistocene Lake Its Evolution & Role in the present Day Land Reclamation

I. M. Elramly

The present paper forms a part of a large scale systematic investigations on Water Resources Development in Kufra Basin, presently undertaken by the Secretariat of

Dams and Water Resources, Tripoli.

By the application of Landsat imago interpretations for Kufra Basin, and as well the ground observations by the author during his trip to the region in November 1977, some scientific evidences were brought to our knowledge and helped in the preparation of this paper.

Actually, the study involved the expected paleoclimatic conditions which were prevailing within this part of the Great Sahara during the Quaternary time. Reconstruction of the Pleistocene lake shoreline is presented in this work. The present day lakes of Buhayret Buwaymah and Bahr Ilet Geith located NE & West of Kufra Town respectively, are remnants of the previous large lake.

Evolutionary stages of the lake based on the presence of fresh water limostene layers, the finding of the *Melania tuberculata* Pleistocene fossil, and the morphological features of the Kufra depression added much light to the present study.

From shallow borings in the reclaimed areas of the Kufra Production Project, it is obvious that cyclic fluctuations in the climate resulted in the deposition of intercalated calcareous and loose sand layers with variable thicknesses within the examined profiles. This phenomena may result after some time in the building up of a shallow water table, from return irrigation water in the irrigated fields, in both Kufra Production and Settlement Projects. The present study includes some guidelines for future monitoring of shallow water tables. This will bring early attention to both projects personnel, before any drainage problem could occur.

Similarities between other inland Quaternary Lakes in Africa and Southwest Asia and the Kufra Lake are outlined in this work.

Stratigraphy and Lithofacies of the Continental Clastics (upper Jurassic and Lower Cretaceous of Jebel Nefusa, N. W. Libya

A. Y. - El-Zouki

The stratigraphical relationship and the various lithofacies of the Chicla, Cabao, and Chameau Mort Formations was undertaken in the present study. The Chicla Formation (Albian) shows lithofacies variation from one region to another. It mainly comprises of

supermature quartzarenite Sandstone and conglomeratio units which were deposited under differing alluvial conditions. In the eastern region the Sediments of the Chicla Formation were laid down by turbulent current actively in a braided channel, whereas in the western region the Sediments were deposited by a large meandering river.

The Cabao Formation (Wealen) comprises of essentially Sublitharenite Sandstones locally containing thin horizons rich in vertebrate fossils. In this study the vertebrate fauna provides new stratigraphical evidence. They strongly support a wealden (L. Cretaceous) age for the cabao Formation. The Chameau Mort Formation (U. Jurassic) displays two main lithofacies, a lower subarkosic sandstone facies and an upper gypsiferous mudstone sequence. Although the plant fauna described from the Chameau Mort Formation yielded no index fossils, it is separated from the Cabao Formation by the Shakshuk Limestone of Oxfordian — Kimmeridgian (U. Jurassic) age, and it succeeds the Middle Jurassic Tachal Limestone. This means that the Chameau Mort Formation must be Callovian — Kimmoridgian (U. Jurassic) in age. Several previous workers considered these clastic sequences as one formation. The main conclusion drawn here is that the Chicla, Cabao, and Chameau Mort Sandstones are three separate stratigraphic units.

Depositional Environments of the Chicla, Cabao, and Chameau mort formation as Revealed by scanning Electron Microscopy

A. Y. El-Zouki

The Chicla, Cabao, and Chameau Mort Formations are Mesozoic continental clastic sequences exposed in Jebel Nefusa, North-Western Libya. The Scanning Electron Microscope analysis of sand grains provided useful criteria which can serve in the distinction between these clastic deposits and also for recognition of depositional environments.

The sand grains of the Chicla Formation are dominated by v-shapes, impact pitting, and conchoidal breakage patterns. These features are diagnostic of a fluvialite environment.

The sand grains of the Chameau Mort Formation are distinguished by several

aeolian grain surface features such as dish-shape concavities, rounded grains and smooth surfaces.

The sand grains of the Cabao Formation show several mechanical patterns similar to those observed on sand grains from the Chicla and the Chameau Mort Formations. This may indicate a mixed continental environment where alluvial and aeolian conditions alternated.

Structure and Strain Determinations between Azizia and Garian/Tripolitania (Libya)

J. Erdmann

Investigations of the structural patterns and in-situ rock strains in the area between Azizia and Garian (longitudes $32^{\circ}10'$ /latitudes $13^{\circ}00' - 13^{\circ}15'$) have been carried out in 1976 and 1977. The main objectives were to determine

a) the present tectonic stress field by means of the new overcoring method

b) the paleo-stress regimes from Lower Triassic to Upper Cretaceous by means of many small-scale tectonic features (such as of joints, stylolites, slickensides, faults, dikes and strike/dip).

The dominant structural features of the investigated area are orientated in a northwest — southeast direction (140°). The Ras Hamia, Azizia and Bu Scebba formations reveal tectonic features that result from a maximum horizontal compressive stress of northwest — southeast direction. The structure of the Jurassic Bu Gheilan dolomites imply an east — west (90°) orientated compressive stress. The Cretaceous Ain Tobi Formation has been deposited during a period of tectonic quiet. From Oligocene up to Early Pleistocene the 140° orientations of Triassic age have been rejuvenated, accompanied by intrusive and extrusive volcanism. This stress-field preceded the Recent active maximum stress that is Northeast — southwest (50° to 70°) orientated.

At a few sites of in-situ strain measurements maximum horizontal compressive stress is still orientated in the northwest — southeast direction. From Recent rock strain investigations a boundary between two different Recent tectonic regimes is supposed running from Azizia to Garian.

Determinations of residual stress are in accordance with the Tertiary northwest — southeast orientated stress — field (140°). The residual maximum horizontal compressive stress has been revealed by second overcoring.

Stratigraphic Nomenclature of the pre upper Cretaceous Mesozoic Rocks of Jabal Nefusa, Libya

A. N. Fatmi, B. A. Eliagoubi & O. S. Hammuda

The nomenclature, unit boundaries and age limits of the Upper Cretaceous Mesozoic of Jabal Nefusa are discussed.

A new group namely Jado Group to include Cabao and Kikla Formations, and two new members namely Al Qabil Member (Upper) and Sart Buon Member (Lower) of Al Azizyah Formation are proposed.

The Tiji Group proposed by Hammuda (1969) and formally introduced by El Zouki (1976) for the Tiji Formation of Burolet (1963) is retained to include Shakshuk Formation, Chameau Mort Formation with Giosh shale members and Taqbal Formation. The Tiji Group is overlain by Jado Group and underlain by Bir el Ghenam Group.

The Bir al Ghanam Group of Christie (1955) is considered a valid name consisting of two formations — an upper Aberghe Formation with one Bu en Niran Member in the lower part and a lower Mahmel Formation of Burolet (1977). The Bu Ghaylan Formation is considered a facies equivalent of lower part of Mahmel Formation.

The Kurrush Formation is divisible into two members (not named), the upper member (mixed clastic and carbonate) corresponds to the lower division of Al Azizyah Formation of Burolet (1963) and Fatmi (1977). The lower member is dominantly a clastic unit.

Volcanics of Jabal Assawdá, Libya

František Fediuk - František Woller

During the geological mapping, organized by IRC, the volcanic complex of Jabal Assawdá was studied. This complex, which covers area of approximately 6,000 square kilometers is situated in the central part of Libya, south of Al Jufrah.

The bedrock of volcanites comprises a

complex of sedimentary rocks dated back from Maastrichtian to probably Oligocene age. At the northwestern margin of the volcanics enolites of cristaline schists were found. These represent fragments of the northern promotorics of the African Shield.

Morphologically the Jabal Assawdá virtually forms a plateau composed of multiple, criss-crossing lava flows, out of which younger volcanic cones, shield volcanoes and intrusions emerge. The observed thickness of the basalt flows complex totals up to 100 meters. The largest shield volcano has 10 kilometers in diameter and the highest peaks reach up to 800 meters a.s.l. Basalt cones are very frequently, and their diameter is from 100 meters to 1 kilometers mostly.

Intrusive types consists either of basaltic rocks similar to the subcrustal volcanics, or of subvolcanic intrusions of a plutonic appearance. The former category occurring mainly in the form of plugs, dikes and sills, the subvolcanic intrusions can be divided into two subtypes: intrusions penetrating into the flood basalts and intrusions into the shield volcanoes and volcanic cones.

Pyroclastics were found only sporadically. The effusives as well as fine grained rocks of intrusions are basalt rocks, but purely aphyric types were not found. In the most cases, phenocrysts are represented by olivine and by less conspicuous augite. The ground mass is usually a mixture of plagioclase/anorthite 60% and clinopyroxene. Less often olivine, ore mineral and vitreous mesostase occurs.

The mineral composition of the subvolcanic intrusions is basically identical with that of effusives. Some types contain a small amount of low sanidine. The porphyric texture is developed in this bodies in a margin part only, central parts are coarse grained, with gabboic texture.

According to the classification diagram total alcais: SiO₂ which is recommended by the IUGS Commission for Igneous Rocks Classification in 1977, most of the chemically analysed samples falls into olivine basalt goup and occasional can be classified as basanite, tholeiitic basalts, alkaline picrites and theralites. In the AFM diagram plots of basalts from the flows, cones, shield volcanoes and intrusions suggests a low degree of fractionation of this rocks. On the contrary, a more advanced differentiation can

be assumed for the subvolcanic intrusions.

The survey of trace elements content shows a global similarity with the corresponding results of the Gharyan area Almond et al. 1974/ with exceptions of the higher Rb content in the rocks from Jabal Assawdá.

The Jabal Assawdá is similar to other Libyan volcanic complexes, spatially related to crossing of the old Paleozoic structural elements/direction NNW-SSE/ and the young Paleozoic to Mesozoic structural elements/direction ENE-WSW/. The distribution of central eruptions and intrusions follows the above mentioned structures. The age of volcanics of Jabal Assawdá range between 10.5 and 12.3 m.y., according to previous authors.

Lherzolite nodules in the Jabal Assawdá

František Fediuk

Detail studies of basalt volcanics were carried out during the geological mapping on behalf of the Industrial Research Centre, Tripoli.

Ultramafic nodules of lherzolitc composition, occurring worldwide in alkali basalts and related rocks, are also known from Libyan Tertiary/Quaternary volcanic provinces. They have been mentioned from the Ghirian volcanica by Almond et al. 1974 and schematically presented /not very correctly/ on a sketch map by Forbes and Kuno 1967. It is highly reasonable to suppose that the other volcanic areas, Jabal Assawdá; Haruj, Jabal Eghei and Tibesti, should them contain as well. For the Jabal Assawdá' area, this presumption has been proved as a matter of fact.

The localities of nodules are numerous here. In some of them, the nodules are present scarcely, but in others they are abundant. The most remarkable locality, extremely rich in nodules, is situated 1,5 km N of Qualait Ferjan hill, 11 km SW of Socna. It is a slowly wedging basaltic sill 5 up to 20 m thick which consist of three parts, the upper and lower being almost nodule-free, but the middle one containing more nodules than the host basaltic rock. This nodule-rich part seems to enable a look inside the relations between nodules and the basalt: the brecciated peridotite is cemented by the basalt apparently formed by partial melting

of the former rock. During the intrusion, the nodules lacking marginal parts acted as lubricant.

In all Jabal Assawda' localities, the nodules occur exclusively in basaltic dikes, sills, necks and lavas of volcanoes of central type, they have not been ascertained in lava flows of fissure eruptions. Their mineralogy is very uniform. The predominant mineral is olivine with the range of Fo content between 88.4 and 91.2%. It amounts mostly not exceeding 30% there occur pyroxenes, from which the orthopyroxene contains En 90.1 - 91.1%. Comparatively high Al₂O₃ content in clinopyroxene (up to 6.29%), as well as other criterias, indicate a very deep level of equilibration. Clinopyroxene is also the main carrier of Cr₂O₃. Following Iherzolite vs. basalt trace elements ratios have been found Cr= 4.9, Yb= 2.0, Co= 1.8, Rb= 0.5, Th= 0.3, V= 0.3, Y= 0.2, Ba= 0.02 etc.

Evidence for a passage between northern and southern proto-Atlantic in Albian times

Reinhard Forster

Since Wegener presented his concept of continental drift much efforts have been undertaken to date the first open seaway between northern and southern proto-Atlantic. Recently collected faunas from SE-Nigeria reveal a first passage in Late Albian times. This is supported by the high degree of similarities between ammonite faunas from Nigeria and northern Africa, and a minimum of endemic species not only in faunas from the the Late Albian, but from the Lower and Middle Cenomanian.

Particularly convincing is the occurrence of a new species of the genus *Salaziceras* and the distribution of this genus and of representatives of the *Stoliczkaia africana* (*Pervinquiere*) group. The genus *Salaziceras* is known only by a small number of specimens from the Lower Vraconian of SE-France, Hungary, Tunisia and southern Morocco. Specimens of the *Stoliczkaia africana* group have been recorded from western Europe, northern Africa, Texas, Brazil, Angola and Zululand. This western Tethyan distribution and the absence of records from the Middle East, Madagascar, India and East Africa suggest a western short cut. This is more probable than a long migration along the East African coast and

via the Cape Seaway. There are no significant arguments for a direct "trans-Saharan" passage at this time.

The record of the endemic south Atlantic genus *Elobiceras* in a drilling core from the Ivory Coast Basin, and the close affinities of Early Upper Albian faunas from Angola with those of northern Africa, Texas and Mexico even suggest an earlier open seaway in Early Upper Albian times. One of the reasons why Tethyan ammonites occurred earlier in time in greater quantity and variety farther to the south than southern Atlantic species did migrate to the north might be the existence of unfavourable current systems in the early Atlantic.

Pan-African Age Granites of Northeastern Africa: New or Reworked Sialic Materials?

Paul D. Fullagar

Pan African ages for granitic rocks of northeastern Africa often have been attributed to remobilization of Archean sialic crust. However, an ensialic origin for these rocks is incompatible with the limited Sr isotopic data available for this region.

Six plutons representing several different types of post-tectonic alkali granite from the Red Sea Hills region of eastern Egypt yield Rb-Sr whole-rock isochron ages of 595 to 568 m.y. (These crystallization ages are based on a Rb₈₇ decay constant of 1.419×10^{11} yr⁻¹.) Five of these Egyptian Younger Granites have initial Sr₈₇/Sr₈₆ ratios of 0.7016 to 0.7025; one pluton has an initial ratio of 0.7061. These low ratios (~0.702) could not be produced by mobilizing Archean sialic crust ~600 to 550 m.y. ago, but could be produced by derivation of these granites from a lower crust or upper mantle with a low Rb/Sr ratio.

Rb-Sr isochron data for portions of the calcalkaline Ben Ghnema batholith within the Tibesti Massif in southern Libya indicate an age of approximately 550 m.y. with an initial Sr₈₇/Sr₈₆ ratio of 0.706. Absence of metamorphic textures and structures make it unlikely that these rocks were remobilized during a Pan-African event. Even if remobilization had occurred, it is unlikely that the original rocks were older than 650 m.y.

The only known ages of >2000 m.y. in northeastern Africa are for samples from

Jebel Oweynat. Published (Schürmann, 1974) Rb-Sr model ages on whole-rock samples generally are 600 to 500 m.y. -old. Since the Sr isotopic composition of whole-rock samples would not be expected to change as a result of metamorphism, these dates probably are fairly close to the time of igneous crystallization.

The isotopic data available indicate that the granitic rocks of northeastern Africa were produced 600 to 550 m.y. ago from a low Rb/Sr (probably non-sialic) source. The Jebel Oweynat area may simply represent a cratonic fragment.

Comparative study of quaternary and actual lagoons populations of *Cardium glaucum* (Mollusca, Bivalvia) around Mediterranean Basin

Gaillard Jean M.

Cardium glaucum (Mollusca, Bivalvia) appears in Mediterranean localities as an extremely variable species. In fact some morphological characters are dependent to a marked extent on the environment. Such characters are, to a high level, interesting in comparative paleoecological studies. The large populations of quaternary *Cardium glaucum* of paleosediments of lakes in Fezzan can be comparatively studied with populations of the same species living in actual lagoons along french mediterranean seashores.

Hydrogeology and water resources of the Benghazi plain. Part II: Groundwater hydraulics

A. K. Ghosh

The flow conditions in the Benghazi plain aquifer are extremely complex. Not only the medium is highly anisotropic and heterogenous but also, the nature of flow varies from laminar to turbulent. These conditions pose serious limitation on the use of standard techniques of estimating the hydraulic parameters like transmissibility, storage coefficient etc. In the present paper aquifer characteristics have been evaluated both by standard methods and also, by using data on water level fluctuation due to barometric pressure and ocean tides.

In the Benghazi Plain transmissibility varies from very low (i.e. areas with no yield) to very high (i.e. karstic channels). The

present study reveals that the aquifer in the Benghazi plain area is neither completely intergranular type it is completely dominated by the presence of karstic channels. Both these phenomena (i.e. intergranular nature and preferential channels) have their roles to play in shaping the flow regime of the aquifer. The flow condition is essentially laminar in the intergranular part and it becomes turbulent in the karstic channels. Further studies have been suggested in the present paper to examine the relative importance of the intergranular part and the channels and their interrelationship.

These studies should include establishment of separate piezometric network in the intergranular part and in the channels. Also, dye tracing should be performed to establish the nature and extent of karstic channels present in the area.

Potassium argon, Rubidium Strontium ages from the Tibesti Massif, S.P.L.A.J.

M. A. Ghuma

Potassium Argon and Rubidium Strontium ages (pairs) were done on biotites separates and whole rock samples in the Ben Ghnema batholith. The age pairs indicate an emplacement age of 550 M.y. The K/Ar ages done on biotite separates; and whole rock conform to an early Cambrian/late Proterozoic age. The Ages range from 586 ± 23 M.y. to a low of $485 + 20$ M.y. for the grandiorite, adamellite, granite and pegmatite, granophyr, aplitic dikes. The granitic rocks yielded 500 ± 514 M.y. The adamellite yielded a slightly higher K/Ar age at center of batholith. The oldest K/Ar age were found in the grandioritic rock to the east and extended to the southeast. of the batholith. The gabbroic rocks yielded extremely low K/Ar age.

The Rb/Sr age pairs for the granite and adamellites yielded the age 550 ± 11 M.y. The grandiorites and gabbro yield an isochron age of 556 ± 7 . The adamellites and grandiorite on the eastern part of the batholith yielded an isochron age of 586 ± 27 . The initial ratio Sr_{87}/Sr_{86} for these suites of the Ben Chnema batholith are low confirming the mineralogical finding that the Ben Ghnema granitic batholith has evolved from the lower crust-upper mantle source during the Pan African event.

The K/Ar and Rb/Sr age in the Ben

Ghnema batholith cover an age span of 90-150 M.y. with an emplacement age 550 M.y. (early Cambrian/late Proterozoic). The Concordance of K/Ar and Rb/Sr age within limits of experimental error further suggest that the granitic rock of the Ben Ghnema batholith and plutons further east in the Tibesti massif are of primary magma implaced during the Pan African event in Miogeosynclinal environment to the west and euogeosynclinal environment to east. The ages from the Tibesti massif conform with other ages further south done by Vachette (1964) in Chad and in the Sirte basin done by Williams (1968). The age pairs also conform with other ages in North Africa as a whole, in the eastern Hoggar of Algeria (Ferra and Gravelle, 1966) and southern Morocco (Hurley et Al., 1974).

The age relation in space and time indicate that a whole region east of Hoggar (including the Tibesti massif, the covered basement to north and east and regions west of Jabal Awenat was formed during the early Paleozoic. The event 500-600 M.y. had shaped the present configuration of North African shield in the Jamahiriya, and most of North Africa.

Pan African evolution in Jamahiriya and North Africa

Mohamed Ali Ghuma & John J. W. Rogers

In the Southern Jamahiriya and general area of North Africa a number of Plutonic igneous suites may be recognized as calcalkaline on the basis of published chemical information. These suites are: the 550 M.y. old Ben Ghnema batholith of the Tibestis, Jamahirga (Ghuma & Rogers in press); the 700 M.y. old batholithoc granite of Sudan (Neary et al., 1976) Some Pan African intrusive rocks near At Taif, Saudi Arabia (Marzouki & Fyfe, 1977) and 600-900 M.y. old plutonic rock associated with volcanic assemblages in South Western Saudi Arabia (Greenwood, et al., 1976). Petrographic descriptions of other assemblages indicate that calcalkaline plutonism was probably common throughout Archean to Pan-African time in Nigeria; in Archean to Kibaren time in the West African craton; in the 750 M.y. older granites of Egypt; and in late Proterozoic time in Morocco, northwest of the West African craton. Adequate chemical

information on these petrographically described suites, however, is not available. Polarity has been demonstrated in the Ben Ghnema batholith and in the southwestern Arabian shield Saudi Arabia.

The tentative impression obtained from the information summarized in the preceding paragraph is that the amount of calcalkaline magnetism in North Africa decreased from Early Precambrian time. Much of the magmatic activity of the Late Proterozoic (to Early Paleozoic) consisted of alkali-rich, silica-saturated granites that now extend from the western Ahoggar to the western Arabian shield. The full distribution and age of these granites is not known, but it seems apparent that the ratio of alkali-granite/calcalkaline rocks has shown a progressive increase from earlier to later Precambrian time in North Africa. It is not known whether this increase has been gradual or episodic.

Increase in the ratio of alkali granites to calcalkaline rocks is probably related to progressive increase in crustal stability in North Africa. At the present time there is no evidence that this crustal stabilization was caused by, or even occurred at the same time as, conventional plate-tectonics-style orogenic activity. The segregation process may, in fact, merely represent continued segregation of lithophilic elements upward out of the mantle.

Structure-Libya

Gus H. Goudarzi

Libya situated on the Mediterranean foreland of the African Shield, extends over a platform of cratonic basins. Several orogenies affected the tableland and formed the present major structural and tectonic features. The recognized major diastrophic disturbances include the Caledonian and Hercynian orogenies in Paleozoic time, and disturbances during Cretaceous, middle Tertiary (Oligocene through Miocene), and Holocene time. These events caused uplifts, subsidence, tilting, faulting, and intrusions. However, the effects of these diastrophic events were generally broad, and compressional folds are very few. East-west and north-south trending faults are present, but the major fault systems trend parallel to the Red Sea and other African rifts.

Precambrian basement rocks are exposed

in south-central Libya, west of Jabal Eghei, Tibesti area, in the southeastern part near the borders with Sudan and Egypt, at Jabal Fezzan north of Brach, and north of Waw an Namus.

Structure contours drawn on top of the Precambrian basement in north-western Libya trend generally east-west. From the center of the Hamada basin, the contours show a rise southeastward from 500 m below mean sea level to 500 m above sea level. From this structural high, the basement plunges westward into Tunisia and eastward into the Sirte embayment in the eastern half of Libya.

The major northwest-trending faults in the Sirte embayment have large displacements and suggest tension during formation. In the southern part of the embayment, the faults trend nearly north. Structure contours show that the top of the basement is at depths of 1500 m to more than 7000 m below sea level. Contours of individual blocks suggest tilting to the north.

Structure contours drawn on top of the basement on the Cyrenaica platform in northeast Libya show that the basement rises from more than 5000 m below sea level on the Egyptian border to the east and on the Gulf of Sirte to the west to 3000 m below sea level along a north-northwest trending arch that has several structurally high areas. An arcuate fault of probable Tertiary age separates the Cyrenaica platform from the generally depressed Sirte embayment to the west and southwest and from the Mediterranean basin to the north. The structurally elevated area of the Cyrenaica platform and the north end of the Hamada basin in western Libya may have been connected by the now tectonically depressed Gulf of Sirte.

In the southern part of Libya, the basement rocks probably are as much as 1700 m below sea level in the Kufra basin (southeastern Libya) and as much as 3000 m below sea level in the Murzuk (Morzuq-Marzuk) basin (southwestern Libya).

Study of the Karstic Spring of Ayn Zayanah

A. Guerre

Ayn Zayanah, the largest spring in the Jamahiriya, is located in the northern part of

Benghazi Plain at 1.5 km inland from the shore line. It flows into a natural basin open to the sea. The Blue Lagoon. The spring represents the outlet of an aquifer complex made of tertiary limestones and draining a groundwater basin of nearly 4200 km², extending over the northwestern slope of the Jabal Akhdar range. Its well regulated discharge was 5.5 m³/sec in 1977 of brackish water T.D.S. averaging 16.5 g/l.

Important karstic features occur mainly in the downstream sector of the basin and particularly in Benghazi Plain where essentially fossil karstic features and active galleries are well developed. The remaining part of the basin is constituted of a microfissured-microporous limestone aquifer of rather low permeability.

The karstic system immediately upstream the spring, in Coeffiah area, is characterized by two superimposed gallery networks at depths -10/-20 and -90 m. b.s.l. connected with a few large diameter vertical pipes. Detailed investigations of this active karst and of the surrounding limestone media have been carried out by various means: diving exploration, geophysical surveys (electromagnetic, electrical soundings, microgravimetry, shallow seismic refraction) and core wells with permeability tests.

Regular measurements of discharge, water level, salinity and water temperature have been performed on an observation network completed by 7 access wells drilled on the main flowing galleries.

The analysis of the data has permitted to study the hydraulic behaviour of the karstic system under different natural water level conditions and to define an optimal water level elevation which is expected to prevent the sea water intrusion in the karstic network. Technical alternatives to establish artificially this water level have been envisaged.

Large-scale fossil land-slides at the Messak Mellet/Plateau du Mangueni escarpment

Jörg Grunert

Geological profiles along the Messak Mellet/Mangueni escarpment are difficult to obtain, because the in-situ parts of the front slopes are largely obscured by large landslides. In the north of the study area the rotated slide segments are often more than 1

km long and more than 100 m wide. They are easily mistaken for tectonic features. The landslides cover as much as 3 km of terrain in the foreland, as measured from the plateau rim.

Landslides in the south of the study area are somewhat different in aspect, more of a giant mudflow type with more pronounced antithetic dislocations along the plateau rim. Landslides also form the slopes of the north-south trending tributary valleys entering Enneri Achelouma from both sides.

Landslides are the outcome of a fortuitous combination of lithology, erosional history, and climatic history. They occur wherever red triassic clays and/or carboniferous marls underlie the Nubian sandstones. Landsliding began after erosion had changed the escarpment's front slope profile from a relatively gentle, stable, and sigmoidal shape to an oversteepened profile likely to be similar to those sections of the escarpment today which are not underlain by clays. The lowermost piedmont plain (or "pediment") was already dissected down below the present wadi bed level when sliding began. The landslides cover remnants of the lowest and of more elevated former surfaces.

Evidently climate was less moist than during the time of piedmont plain formation under humid subtropical conditions, but still much more humid than today, as the clays must have been thoroughly wetted by groundwater in order to permit landsliding to take place. The clays are completely dry today.

All of the landslides are fossil and inactive today, as is evidenced by more than one generation of dune-sand covering in the central section of the research area, by several cycles of alluvial fan formation, glacial formation on soft materials, and subsequent dissection, all post-dating the landslides; and by the present-day erosional features of the landslide areas. Small final dislocations among the landslide segments appear to have taken place during the youngest major pluvial.

Geological and geomorphological observations on the north slope of the Tibesti Mountains

Horst Hagedorn

The geology and geomorphology of the north slope of the Tibesti Mts. have been the

subject of only a few studies. In the present paper some results of stratigraphic and geomorphic field work in the lower Yebigué Valley and the Tibesti foreland are put forward, based on field work during repeated stays at the German Research Station at Bardai and on aerial photograph interpretation.

Emphasis is given to the structure and aspects of the sandstone cover, the metamorphic basement (Tibestién) and to the younger volcanic features. Granite intrusion NE of Aozou, which are of importance for both the stratigraphic subdivision of the basement and for the geomorphic development of the region, are analyzed and classified by their highly varying appearance in the field.

Drainage and tectonic patterns are analyzed for selected areas and parameters derived for an overview classification.

Studies on present-day geomorphic processes in the arid northern margin of the Tibesti Mts. show that eolian deflation, corrosion, and accumulation are dominant today. For the Holocene and Pleistocene periods there appears a sequence of periods of dominant fluvial and eolian activity, expressed in a repeated pattern of changing altitudinal zones of landform development within the mountains and their foreland. Radiocarbon dates indicate the final two humid periods of the Holocene around 10 - 7,000 y.b.p. and 5,000 y.b.p.

Finally an attempt is made to apply the results of morphodynamic studies to the solution of geodynamic processes.

The Tertiary Volcanic rocks of Libya and Chad - Their plate tectonic significance from Paleomagnetic and Potassium-Argon age information

J. M. Hall, P. H. Reynolds and I. L. Gibson

We present extensive basic data with which to test conflicting models for the absolute motion of the African Plate. The test proposed is to examine the absolute age sequence and paleomagnetic poles for the approximately north-south line of Tertiary volcanic areas extending from Tibesti in Chad through Jebel Eghei, Haruj Assuad and Jebel Soda to Garian in Libya. Common pole positions, corresponding to the geographical location of one end of the line, or a regular

progression of ages along the line, would be evidence for a Hawaiian type motion of a lithospheric plate over a fixed mantle thermal anomaly (a "plume" or "hotspot"). Detailed paleomagnetic evidence is available for the three northern areas while 27 generally well defined potassium-argon whole rock ages are distributed between all five volcanic areas. With one exception the ages are Neogene. A significant and almost certainly real overlapping spread of ages of from 6 to 14 my characterize all areas except for Jebel Soda. This fact, together with the spread of paleomagnetic pole positions, mitigates against a simple Hawaiian type of plate-mantle relative motion. Possible complicating factors such as the presence of continental crust and the sampling bias in favour of late, capping volcanic products are considered. However, in the absence of further information, it seems necessary to regard the Tibesti-Garian volcanic line as being the product of several discrete mantle thermal sources. As such, the centers do not provide clear information on the recent absolute motion of the African Plate.

**Early Cenozoic Calcareous
nannoplankton Biostratigraph and
Paleobiogeography of North Africa and
the Middle East and Trans-Tethyan
Correlations**

Bilal U. Haq and Marie-Pierre Aubry

In the Early Cenozoic, North Africa and the Middle East formed important parts of the Tethyan link between the Atlantic Ocean on one side and the western Pacific Ocean on the other. The epicontinental marine Paleocene-Eocene sections of this region are indispensable in the understanding of calcareous plankton biogeographic patterns on both regional (Tethyan) and world-wide basis. In this paper we present calcareous nannoplankton biostratigraphy of the Paleocene-Eocene from Wadi al Atrun and Pyramid Peak sections in northern Cyrenaica, N.E. Libya; Djebel Cherahil, Djebel Bou Dabbous and El-Kef sections in Tunisia; Jebel-um-Rejam section in Jordan; Cherkessk and Essentuki sections in the Caucasus Mountains, U.S.S.R., and the Jebel Jenine sections in Lebanon. Correlations of Paleocene Eocene strata in the trans-Tethyan region (North Africa, including Egypt, and the Middle East, including Iran and Pakistan) based on

nannofossil and planktonic foraminiferal biostratigraphy, are suggested.

A comparison of the Paleocene-Early Eocene biogeographic patterns of the Atlantic Ocean with well preserved assemblages of the trans-Tethyan region show that the constituents of the open-ocean were essentially similar to those found in the Tethys seaway, with temporal differences in the relative dominance of some taxa in the late Paleocene. One relatively cold assemblage (*Prinsius martinii*) persists for a longer time in the Central Tethys, than it does in similar latitudes of the Atlantic. The DSDP sites in the Bay of Biscay show a nannoflora that is essentially Tethyan in character.

Light micrographs of some less well known taxa and scanning electron micrographs of well preserved assemblages are illustrated. Three new species are described: *Fasciculithus aubertae*, *F. stonehengeni* and *Heliolithus floris*.

**Tectonics and rock stress in the
Jefren-Azizia area/Tripolitania/Libya**

Helmut Häusler

Investigations of the tectonic inventory and the Recent rock stress have been carried out in the area between Azizia and Jefren during 1976 and 1977. It was intended to delineate the tectonic behavior of rocks through time (Lower Triassic to Recent).

The field work included measurements of faults, folds, dikes, joints, stylolites, horizontal slickensides and a new technique of receiving in situ stress data by overcoring.

The data reveal that different tectonic regimes were operative from the Triassic to present times. During the Triassic there is evidence of a stress field with a NW - SE - oriented main compressive stress, changing to a E - W - direction in the Jurassic. The NW - SE - direction was rejuvenated during end of Paleogene and Neogene as revealed by basaltic dikes, normal faults, joints and horizontal stylolites.

In situ strain determinations have been carried out at 12 sites. The horizontal stresses are predominantly compressive and depict two orientations of horizontal main compressive stress, NW - SE and NE - SW, the latter direction of which dominates in the eastern part of the investigated area.

A preliminary Revision of the Sahabi formation

Jean de Heinzelin

The definition of the Sahabi Formation which is proposed here relies on twenty measured sections located between 6 km south of the old fort and 25 km to the N-N-E along the Sebket El Janain; accessible outcrops extend further north and east, not measured yet.

A total thickness of 79 to 81 m is recorded at P12 - P13, resting on the eroded and decalcified surface of a bioclastic limestone, likely of Middle Miocene age.

The Sahabi Formation can be divided into 10 recognisable Members and Submembers qualified P,Q,R,S,T,U₁,U₂,V₁,V₂ and Z.

Members P and Q are shallow marine to littoral deposits. Members R to Y are complex estuarine deposits (mudflats, lagoons, diatomite pools, fluvial and tidal channels) interrupted by two minor marine incursions; Member Z is a complex of palcosol horizons.

Both marine incursions of Members R and T are characterized by peculiar assemblages of molluscs and ostracods.

Vertebrate fossils are distributed at various levels from Member Q to Submember V₁; the richest concentrations in mammal bones are found in the top of Member Q, in Member T and in Member U.

Profiles situated north of P12 - P13 show increasing thicknesses of Members T and U, likely due to a monoclinical flexure.

Contributions to the Stratigraphy and Micropaleontology of Jabal al Akhdar, North Eastern Libyan Jamahiriya: 3. Ostracoda and Planktonic foraminifera from the upper eocene of Jabal al Akhdar

F. Helmdach and R. El Khoudary

This paper presents the results of microbiostratigraphic studies on the Upper Eocene Apollonia formation exposed in the area of Wadi Bákúr, N.W. Jabal al Akhdar. 19 species (subspecies) of Ostracoda and 21 species (subspecies) of planktonic Foraminifera are discussed and illustrated and comments to their stratigraphic value and geographic distribution are given.

Based on the recorded planktonic Foraminifera the studied Upper Eocene

sequence is subdivided into a lower *Globigerinatheka semiinvoluta* Zone and an upper *Globorotalia cerroazulensis* s.l. Zone (Bolli, 1972).

Regional Hydrogeological aspects of the main artesian basins in North Africa

Himida, I. H. and Diab, M. S.

Regional geological structure of the North African Desert Platform with consideration of the hydrogeological, hydrological and hydrogeochemical data in different regions proved the existence of a number of extensive complex multi-layered artesian basins in which the Nubian Series formations and Intercalary Continental formations include the main ground water aquifers. The present study reveals great similarities in the hydrogeological conditions and groundwater chemical and genetic types for these artesian basins. The hydrogeological conditions are controlled by the geologic structure and the palaeohydrogeological history of the artesian basins in addition to the present arid climatic condition.

The Quaternary Gargarech Limestone, Tripolitania: Geology, Sedimentology and possible industrial utilization

Miloje Ilich and Werner Smykatz-Kloss

The Quaternary Gargarech limestone of Tripolitania makes an outstanding ridge along the Mediterranean coast extending from Zuara to Garabulli. The limestone is predominantly built up of shell fragments and quartz sand. The present paper deals with detailed micropaleontological, sedimentological, mineralogical and geochemical analysis, including the determination of some characteristic trace elements. On the base of these investigations and of some rock mechanical analyses the industrial utilization of the Gargarech limestone is discussed, e.g. its utilization for the production of cement, as building stone and for the production of hydraulic lime.

Current fluvio-geomorphological processes in the area of Djebel es Soda

Dieter Jäkel

The Djebel es Soda area lies 29°N on the southwestern edge of the Hon trench. In its highest parts it reaches an altitude of 800 to

900 m above sea level and is about 350 km air distance from the Mediterranean (Syrté). Rainfall occurs mainly in the winter months and is therefore caused by Mediterranean cyclones. There are not enough meteorological measuring stations distribution over the area. For the most part we must therefore rely on indirect climatic evidence such as fluvial formation processes. Studies carried out in the autumn of 1977 showed that the northern parts of the mountains receive higher rainfall than the southern edges. Fluvial forms thus show pronounced divergence characteristics. Observations and measurements revealed that current precipitation very quickly turns into surface run-off. Seepage hardly occurs on the slopes and on the basalt plateaus; it is mostly found in the wadis, where, as a result, groundwater renewal is possible. Because of the weathering process on the slopes the wadis contain a large amount of gravel. The size of the accumulated material and its distribution indicate that the intensity of current fluvial processes is at times equal to that of older, pluvial, periods. Only the extent of fluvial influence was greater in pluvial periods than today, as fossil pediments, alluvial fans and terraces show. Karst phenomena are at present hardly relevant. Compared with other desert areas, fluvial forms in the Djebel es Soda show no important differences and may thus be regarded as exemplary.

Groundwater Evaluation in Wadi Zam-Zam

Omar A. Jarroud

Agricultural development through irrigation is a major effort in Libya. One of the areas being developed is the Wadi Zam-Zam. The Wadi Zam-Zam Water Supply is entirely groundwater with essentially no local recharge. The main supply aquifer is artesian with pressure head of 65 m., above land surface.

In order to maintain sufficient pressure to keep a constant supply, the number of wells and discharge must be limited. Other groundwater aquifers may be developed to supply an additional resource to fulfil agriculture needs.

Water quality analysis indicates that corrosion should not be a problem other than perhaps steady corrosion when the wells are

closed. Consider the total dissolving solids and other criteria, water quality can be classified as good for irrigation.

Groundwater cooling in Wadi Zam Zam Artisan Aquifer

Omar A. Jarroud

The artesian groundwater aquifer in Wadi Zam Zam has average temperature of 56°C. The water must be cooled before application to agriculture.

Water temperature can be lowered by cooling pond or cooling tower or combination of both in what so called spray pond. Unlined cooling pond is less expensive than cooling tower but; requires higher water consumption. Therefore based on design assumption a mechanical drought tower may considered more efficient than cooling pond.

Igneous rocks of the Jabal al Hassawnah

L. Jurák, F. Fediuk and J. Šindelář

This paper is review of new data obtained during the geological mapping organized by IRC in the area Southwest of Al Jufrah.

Igneous rocks of three types and ages outcrop in the Jabal al Hassawnah Mts. which in the central part of Libya and centered 140 km NW of Sebha. The oldest are represented by granites and accompanying aplites and pegmatites which outcrop mainly in two inliers of the total area of 15 km². On means of radiometry we have obtained the values of 542 m.y. and 521 m.y. so that their intrusions can be attributed to the Panafrican Orogeny. The second group which is present only very rarely is composed of rhyolite tuffes and tuffites in clastic sediments of the Upper Cambrian Hassawnah Formation.

The most interesting of all is the third group represented by young, phonolitic rocks. The alkali basalt-phonolite association is very typical for the Tertiary to Quaternary complexes of Libja. It has been examined in detail namely in the Gharian area (Piccoli 1970, Almond et al. 1974). It is present, in none the less typical development and on even a greater area, in the central part of Libya where abundant phonolitic rocks of the Jabal al Hassawnah Mts. are accompanied by a small amount of basaltic rocks.

The phonolites are represented by

individual, isolated bodies whose number (regardless to a great amount of small dikes) totals 400 approximately. The bodies are not disseminated randomly but follow the main tectonical plan of the underlying rock units. Outcropping in anticlinal elevations, they usually occur in the form of two concentric rings out of which the inner one is composed of a number of smaller bodies while not very frequent but dimensionally big bodies comprise the outer one. The structure is emphasized by a vein rocks whose quantity increases toward the centre. The inner structure of the bodies is concentric as well, being made more significant by weathering and selective erosion processes which afflict central parts of the bodies in a more intensive manner, resulting in crater-like morphology.

From the composition viewpoint, the average representative of local phonolites is a strongly alkali, unsaturated rock, corresponding to nepheline phonolite of 20% normative nepheline and of 10% colour index. The alkali sum reaches up to 15,7% while the most frequent value of the $\text{Na}_2\text{O}:\text{K}_2\text{O}$ ratio is about 5:3. Possessing the apaitic coefficient of $0,99 \pm 0,5$, the rocks into a boundary zone between apaitic and miassic phonolites. Out of 29 samples which were analyzed, only one is slightly quartz-normative. The types containing eudialyte are very remarkable, their existence was proven no later than in 1955 by P. Bordet et al. on the basis of people occurrences but there have been found primary outcrops recently. The amount of eudialyte reaches occasionally up to 10% resulting in the increase of both the rocks natural radioactivity and the rare earth's content.

The phonolite bodies are seldom accompanied by subvolcanic forms of plutonic appearance. The most remarkable of them, penetrating the Wádí Darman Granite, has been differentiated from essexite to nepheline syenite and its basic types possess a distinguished affinity to alkali basalts. The basaltic rocks of the investigated area are composed either of veins or of lava flows and volcanic cones. Two phonolite samples were tested radiometrically, with the results of 15,7 and 29,9 m.y. respectively. This value is considerably lower than that for the Gharian phonolites (Piccoli 1970). The relation to

flood basalts, bordering in the northwest, has not been determined by field morphology; however, radiometric data suggest a very close interval. There where phonolites and basalt dikes are in contact the latter are younger doubtlessly; phonolitic xenolites of the basalt dikes are easily susceptible to vitrification, due to the high alkali content.

Seismicity and Seismotectonics of Libya

R.M. Kebeasy & Y.H. Ibrahim

Data of earthquakes which occurred in and around Libya during the period from year 262 to 1977 were collected from local sources, National Earthquake Information service center and Bureau Central International de Seismologie. Earthquake parameters are listed up in chronological order with description of earthquake effects whenever it is available. The distribution of epicenter indicated that most of earthquakes take place along the coastal region with the exception of few earthquakes which occur inland. Close coincidence between epicenter distribution and surface structure could be seen. Time distribution shows rapid increase of earthquake occurrence. Depth distribution of earthquake foci indicate that the seismic plane is dipping toward north. The relationship between the frequency of earthquake occurrences and magnitude is studied and accordingly parameters of reoccurrence are devised. Depending on the energy released during earthquakes the region was divided into different seismic zones.

Hydrogeology and Water Resources of the Benghazi Plain Part 1: Hydrogeological Set Up

Mohammed Yar Khan

The study area lies between $32^{\circ} 15'$ and $31^{\circ} 58'$ N latitudes and is bounded on the west by the Mediterranean sea and on the east by the First Escarpment of the Jabal Al Akhdar.

Surface rocks of the plain are of Middle Miocene age and are represented by the Benghazi Member of the Ar Rajmah Formation; scattered Quaternary sediments overlie the Miocene rocks and are mostly present along the sea coast. The Miocene rocks are free of plications in the study area and generally lie flat. Fractures and faults occur with significant north-south or

northwest-southeast trends. A north-south trending prominent fracture system lies along Ar Rajmah Project-Beninah-Sidi Mansur line.

The limestones of the Benghazi Member constitute the main aquifer and are underlain by grayish green marls and clays of Lower Miocene to Oligocene age. The Eocene aquifer is mainly constituted of fossiliferous and dolomitic limestones. The lithologic characteristics of the aquifers frequently change due to facies changes and therefore at places only one aquifer occurs irrespective of the age of the sediments or there are more than two aquifers.

The permeability of the aquifers varies from place to place and is mainly from solution along fracture and fault zones, although, there is also some primary permeability in the calcarenitic and chalky types of limestones.

The groundwater quality deteriorates with depth as well as from the east to the west. The phenomenon of salt water encroachment which is a major adverse factor in the development of the water resources of the plain is also described and discussed.

Contributions to the Stratigraphy and Micropaleontology of Jabal al Akhdar, North Eastern Libyan Jamahiriya:

4. Planktonic Foraminifera from the middle Eocene of the Northern Escarpment of Jabal al Akhdar

Riyad Hassan el Khoudary

The micropaleontological analysis of samples collected from the limestones of the Apollonia formation exposed on the northern escarpment of Jabal al Akhdar, to the south of Al-Hilal village, yielded beside an abundant benthonic foraminiferal assemblage, the following planktonic species:

Hantkenina cf. aragonensis, *H. dumblei*, *H. mexicana*, *H. longispina*; *Globigerinatheka subconglobata subconglobata*, *Ga. subconglobata curryi*, *Ga. subconglobata euganea*, *Ga. mexicana mexicana*, *Ga. mexicana barri*, *Ga. mexicana kugleri*, *Ga. index tropicalis*; *Orbulinoides beckmanni*; *Globigerinita pera*, *Gt. unicava unicava*, *Gt. unicava primitiva*, *Gt. africana*, *Gt. dissimilis dissimilis*; *Globigerina turgida*, *G. senni*, *G. yeguaensis*, *G. linaperta*, *G. trilobata*, *G. eoacaena*, *G. cryptophala*, *G. hagni*, *G. pseudoeoacaena pseudoeoacaena*, *G. tripartita*

tripartita, *G. tripartita tapuriensis*, *G. baconica*, *G. venezuelana*, *G. gortanii praeturritillina*, *G. pseudoampliapertura*; *Globorotalia broedermanni*, *Gr. spinulosa*, *Gr. spinuloinflata*, *Gr. bulbrooki*, *Gr. lehneri*, *Gr. bolivariana*, *Gr. cerroazulensis frontosa*, *Gr. cer. possagnoensis*, *Gr. cer. pomeroli*, *Gr. cer. cerroazulensis*; *Truncorotaloides collactea*, *Tr. topilensis*, *Tr. libyaensis*, *Tr. rohri*, *Tr. haynesi*; *Globigerinoides higginsi*, and *Globigerinoides sp. 1*.

The above mentioned planktonic faunas, which indicative for the Middle Eocene are discussed and illustrated, and their world wide stratigraphic value and distribution are indicated. A preliminary zonal subdivision of the Middle Eocene of Al-Hilal area is also discussed.

Age and metamorphic evolution of the basement complex around Jebel Uweinat

Jean Klerkx

The crystalline basement, outcropping around the alkaline intrusions of Jebel Uweinat, is composed at least by two major lithological units. The distinction is based on both lithological and metamorphic characters. The series of Karkur Murr, outcropping at the south of Jebel, consist of charnockitic gneisses, metamorphosed in the granulite facies. Rb/Sr age determinations on whole rock samples provide an age of 2670 Ma.

To the North, and separated from the series of Karkur Murr by a large zone of mylonites, occur the series of Ain Dua: they are composed granitic gneisses, with a mineral assemblage characteristic of the amphibolite facies; these gneisses often are injected by migmatites and locally they are affected by granitization. The age of the anatectic granites is 1840 Ma. It is assumed that the migmatitization is contemporaneous with the anatexis, while the age of the main metamorphic event affecting the gneisses of the series of Ain Dua is uncertain; a preliminary interpretation suggests that their age is close to 2700 Ma.

The major folds strike NNE and are overturned to the North-West. In both series remnants of recumbent folds striking NS are observed.

The relations between metamorphism and deformation are discussed.

The Transaharan Seaway during the Uppermost Cretaceous

Cornelius A. Kogbe

There is obviously no controversy over the existence of inland seas across the Sahara during the Cretaceous. The Saharan seas were extensions of the Tethys (Mediterranean) sea and the South Atlantic Ocean (Gulf of Guinea) into the African Continent.

Geologists have, however, disagreed on paleogeographic reconstructions of the seaway. Most workers agree in principle that there was an inland connection between the Atlantic and the Tethys through Libya, Algeria, Mali, Niger and Nigeria. Quite lately, one author stated categorically that no connection existed between the Saharan Seaway and the Gulf of Guinea during the Maastrichtian and Paleocene. He reaffirmed that there is no doubt that the Tethys sea had a connection with the Gulf of Guinea, but that the connection was through the Atlantic. This conclusion was based on the distinctive foraminifera assemblages in the coastal Nigerian Basin and the Sokoto Basin.

Very recent discovery of the Maastrichtian ammonite species *Libycoceras afikpoensis* (Reyment) in the Gilbedi area of northwestern Nigeria definitely favours the existence of a trans-Saharan seaway connecting the Tethys and the Gulf of Guinea. It can be erroneous to carry out paleogeographic reconstructions simply on the basis of foraminifera assemblage and depth of sea water. Changes in sea water depths are meaningless to eurybathic, nectonic ammonites which can swim actively in waters of different depths. The discovery of *Libycoceras afikpoensis* in the Sokoto Basin of north-western Nigeria reveals the paleogeographic distribution of this ammonite in north and western Africa. The genus has been described from the Maastrichtian of Libya, Algeria, Mali, Niger, Southern Nigeria and Angola. The recent discovery in northwestern Nigeria confirms the connection between the areas listed above and the Sokoto Basin during the Uppermost Cretaceous.

It is significant to note that the genus *Libycoceras* (Hyatt) has also been described from the Maastrichtian of Egypt, Palestine and Arabia. It is absent (or at least has never been described) in the Atlantic coastal basins

of north-western Africa, including Morocco, Mauritania, Senegal and Ivory Coast. The Maastrichtian connection between the Gulf of Guinea and the Mediterranean could only have been across the Sahara.

Strain Measurements and the Structural Pattern of the Mesozoic and Cenozoic West of Homs, Tripolitania, NW-Libya

Karl-Heinrich Kraft

At 14 sites west of Homs in-situ strain measurements have been carried out, the most which are located in the Upper Cretaceous Sidi as Sid Formation. Some recent rock strain data are achieved of the Middle Miocene Al Khums Formation and the Quaternary Gargaresh Formation. The results obtained from the latter formation show data that are more consistent than those achieved from the older rocks.

75 per cent of all strain data show a NE-SW direction of maximum horizontal compressive stress (H_{max}). The horizontal stress recorded normal to H_{max} is either slightly compressive or tensile.

Observations of small-scale tectonical features, such as joints, calcite filled veins, horizontal stylolites, slickensides, and minor faults have been made to reconstruct the palaeostress fields from Upper Triassic (Abu Shaybah Formation) through recent times.

Considering all investigated structural elements, it can be stated that the stress regime was not subjected to remarkable changes between Upper Triassic and Miocene. The orientation of the main horizontal stress was NW-SE throughout this period. A NE-SW-oriented extension existed temporarily during the Upper Cretaceous.

In contrast to the areas in the west (Aziziah Fault) and in the southeast (Hon Graben) there are no faults of major displacements in the investigated area of the Eastern Jebel Nefusa. An influence by the main tectonic trends can be observed only by means of small-scale structural elements.

Sabkha sedimentary Environments and their relationship to mineral and Hydrocarbon deposits

Jan Krason and J. Slade Dingman

Although the term, *sabkha* (literal transcription in Latin letters) means in Arabic the same as *dry lake* or *salt flat* in the

English language, recently, in the geological literature, the Arabic word is more commonly used. Therefore, authors of this paper also use the term, *sabkha*, simply for communicative reasons.

The main purpose and emphasis of this paper is for a better understanding of those geologic and geographic or paleogeographic environments which are characteristic for *sabkha* sedimentary basins and associated mineral deposits.

In view of previous detailed field investigations of modern *sabkha* environments by the senior author, supplemented by a thorough study of up-to-date literature relevant to the subject discussed, it appears that *sabkha* sedimentary environments are controlled primarily by two specific factors:

1. Arid and/or semi-arid climatic conditions characterized by net evaporation; and

2. The presence of a sedimentary basin which is periodically flooded with water.

Besides these two factors, there are at least several others which also control *sabkha* sedimentary environments, namely: sedimentological features, hydrogeological conditions, mineral composition and their associations, diagenesis and post-diagenetic alterations, and sources of mineral and rock forming components. However, perhaps because of an improper understanding of all of these factors and/or a lack of appreciation of their complex interrelationship in mineral formation processes, some authors have improperly applied the *sabkha* sedimentary environment as a metallogenic model to sedimentary environments with seemingly paleogeographic and lithofacies conditions, which in fact have been found not to be characteristic of *sabkha* environments at all.

Nevertheless, upon consideration of all of the above mentioned factors, critical and required for metallic and non metallic formation processes, it is concluded that *sabkha* environments can be favorable for various types of mineral and hydrocarbon deposits. In order to support this conclusion, examples of deposits which are known or thought to be associated with *sabkha* environments are given. *Mallahat al Bariqah*, located in the northwestern part of Libya, is cited as a classical coastal *sabkha*-type salt deposit. As a result of a thorough examination (Krason and Wala, 1967), large reserves of sodium chloride and potassium

salts were determined.

Special attention is also made to inland *sabkhas* known as *salars* of the Central Andes (northern Chile, western Bolivia, and northwestern Argentina) which are rich with commercially valuable potassium and nitrate salts. One of the largest *salars* in the region, *Salar de Atacama*, contains as much as 2000 to 4000 mg/l of lithium in the brine (Ericksen, 1976).

In view of discussion and criticism of those papers referring to copper and uranium deposits considered to be associated with *sabkha* environments, the authors of this paper conclude that *sabkha* sediments and/or environments should not be disregarded or underestimated as favorable locations for the formation of valuable ore deposits. As an example, the *Yeelirrie* uranium deposit of Western Australia is recognized as having formed in an environment in which the climatic, sedimentological, paleogeographic, hydrogeological and structural conditions are considered by the authors to be characteristic of an inland *sabkha*.

With regard to hydrocarbon deposits and their association with *sabkha* environments, references are made to Glennie's (1972) and Leeder and Zeidan's (1977) publications. In the first case, the presence of paleo*sabkha* environments of the Lower Permian or *Rotliegendes* time in the southern part of the North Sea and probably some other parts of the Western European Permian basin is well supported (real also Richter-Bernburg, 1972). However, the authors of this paper have considerable doubts in the application of "Giant late Jurassic *sabkhas* of Arabian Tethys" as proposed by Leeder and Zeidan (1977). However, the presence of evaporites of *sabkha* origin as caprocks to oil and/or gas reservoirs might be very meaningful, perhaps not only in the Persian Gulf region, but in other regions of the world as well.

In conclusion, the authors once again strongly emphasize the importance of studying Recent *Sabkha* environments. The results of these studies along with a good understanding of the role and interaction of all critical factors required for mineral and hydrocarbon formation processes and preservation conditions will ultimately lead to a better, more comprehensive approach to exploration for mineral and hydrocarbon deposits in the future.

Pan African Plate Tectonics and its Repercussions on the crust of Northeast Africa

A. Kröner

Pan African belts of the African mainland and the Arabian-Nubian Shield exhibit evolutionary features which are either compatible with intracontinental ensialic development or with plate margin and Wilson cycle tectonics during the time period -1100-500 Ma ago.

It is suggested that both the ensialic and plate margin developments were caused by the same fundamental subcrustal forces that are responsible for present-day lithospheric motion, and the Pan African event is therefore representative of a transition from Precambrian ensialic plate tectonics to Phanerozoic Wilson cycle tectonics.

The North African craton between the central Hoggar and eastern Egypt/Sudan is characterized by widespread late Pan African thermal activity, documented by voluminous calc-alkaline granitoid intrusions including alkaline and peralkaline ring complexes, as well as a general resetting of mineral isotopic systems in older basement rocks. Nagy et al. (1976) interpreted these features as evidence for progressive eastward growth of the West African craton but I suggest that pre-Pan African continental crust including Archaean elements (Ouweinat) was already in existence in northeast Africa. This crust was strongly affected by intraplate stresses resulting from closing of the Pharusian ocean in the western Hoggar and collisional tectonics in the Arabian shield.

Much of the late Pan African deformation in northeast Africa appears to have occurred by strike slip motion and there is a striking analogy with the Cenozoic deformation pattern behind the Himalayan belt in northeast Asia.

Following the model of Molnar and Tapponier (1975) the deformation patterns of Asia and northeast Africa are compared, and it is possible to relate the Pan African structures and magmatism between the Hoggar and Egypt/Sudan to continental collision and indentation of a semi-infinite hot crustal segment by a cold rigid plate (the West African craton).

Hydrogeology of the Gefara, N. W. Libya

G. P. Kruseman

This paper synthesizes the results of water resources research in the Gefara plain, conducted or supervised since 1969 by the Secretariat of Dams and Water Resources and by the Council of Agricultural Development.

An outline of the different aquifers is presented: the Ras Hamia sandstone aquifer, Abu Shaybah sandstone aquifer, Aziziya limestone aquifer, Kiklah sandstone aquifer, the lower Miocene sandy limestone aquifer, the middle Miocene aquifer, and the aquifer of the upper Miocene — Pliocene — Quaternary complex.

The Gefara is divided into several compartments by NW-SE zones of disturbance. Each compartment has its own typical aquifer configuration. They all have in common that along two East-West zones of disturbance the older formations have been down faulted to deeper and deeper levels. Several maps and cross-sections illustrate the depths, extension, and interrelationships, between the aquifers. The paper concludes with remarks on the available water resources and their exploitation.

The Sedimentation and Tectonics of the Murzuk Basin During the Early Cretaceous

J. Lorenz

The late Jurassic to early Cretaceous Messak Sandstone, cropping out in the northern part of the Murzuk Basin in southwestern Libya, is one of the several lithologically similar formations, all formerly categorized as "Nubian Sandstone", that have recently been described and subdivided within the basin. These formations are part of a depositional system which derived sediment from the uplifted Tibesti massif and the Tibesti-Harouj anticline. This coarse sediment was transported north into and across the slowly subsiding Murzuk Basin by a limited number of migrating braided river systems in a humid climate. Principal deposition occurred during flooding, producing broadly lenticular, tabular cross-bedded, coarse-grained sandstones. At the northern edge of the basin, the Gargaf Arch created an elevated base level, which

ponded drainage in those parts of the basin that were not areas of active stream deposition, and were not being aggraded up to local base level. In these subsiding but temporarily sediment-starved areas, large lakes and swamps collected massive clay deposits up to 20 meters thick. Nearer the source, in the southeast, alluvial fan type deposits compose most of the section.

Preserved thicknesses of this braided stream and lake/swamp system do not exceed 500 meters in exposed sections, though they may be thicker in the middle of the basin. The deposits are unconformably overlain by late Cretaceous to Tertiary carbonates and/or recent sand dunes. In the south and east of the basin, they unconformably overlie Pre-Cambrian to Paleozoic strata, while in the west and probably north, they grade up out of the Tilemsin Formation, an undated, probably non-marine redbed sequence which unconformably overlies Carboniferous marine beds.

The Kaolin deposit of El-Uweinat, Fezzan

Werner Smykatz-Kloss, Khaled R. Mahmoud and Gilani Abdelgawad

During soil surveying in SW Fezzan a layer of light greyishblue, compact and some meters thick claystone was detected around El-Uweinat (Serdeles, 120 km N of Ghat). Mineralogically, the claystone consists mainly of a well-ordered kaolinite- 1 T and of quartz, with minor amounts of muscovite and goethite. The latter forms small concretions in the upper part of the claystone layer. From grain size analysis it is evident that both, the goethite (the concretions of which are generally larger than 2 mm in diameter) and the quartz (which occurs mainly in the silt + sand fraction), can be removed from the kaolinite material, thus enriching the kaolinite to a valuable raw material for several technological uses. The horizontal extension of this kaolin deposit is not yet exactly known, but below some soil profiles in Wad Tanezuft, W of the probable source rock, the claystone layer had been found, too. From mineralogical and geochemical arguments it is evident that the kaolinite was formed by weathering of the Silurian Acacus sandstone and by transport to the northern playa around El-Uweinat.

The Influence of local Geology and soil Conditions on the Building response during earthquakes

D. V. Mallick & F. T. Morghem

Studies of damage to buildings during earthquakes in seismically active areas have revealed that the intensity of ground shaking during earthquakes and the associated damage to structures are greatly influenced by local geologic and soil conditions. With the result that it has become necessary to take into consideration the potential effects of geologic and soil conditions in building design and in the zoning of local areas. This paper reviews the design provisions for estimating the effects of these parameters, and suggests a correlation between the intensity of damage to buildings during earthquakes and local soil conditions.

Geological Problems related to Embankment dams in Libya

D. V. Malliok, Amin Awad, Siddik El Naas and Saad Khawalqa

This paper highlights the importance of geological and topographic characteristics of the site that have been considered as one of the governing factor in the planning, design and construction of various embankment dams in Libya. The knowledge of faults, shear zones, the width and module of cracks, the depth of the weathered zones in the abutment and the corresponding type of soils, the dip and the strikes of the bedding planes influences the alignment of the dam axis, the distribution of materials in the dam and the inclination of the core. Methods of treatment of certain defects such as weathering, faults, fracture, leakage, seepage and the control of ground water require specific engineering measures like grouting under pressure which will ensure satisfactory foundations.

In addition, the engineering properties like deformation moduls, compressive strength, creep, dynamic characteristics, damping, degree and the extent of rock weathering and the influence of water on the rock behaviour are of primary importance in the dam design.

The foundation and the abutment treatment of Wadi Caam Dam project is cited as an example.

The Upper Cretaceous-Tertiary Formations of Northern Libya A Synthesis

Mohamed Megerisi & V. D. Mamgain

Voluminous information has been gathered for the past two decades on the Upper Cretaceous-Tertiary Formations of Northern Libya. Most of the information has remained unpublished; Nevertheless, the few published papers and 1:2,000,000 scale geological map of Libya has served as a nucleus for the regional geological mapping on 1:250,000 scale initiated by the Industrial Research Centre in 1971. An area of nearly 300,000 Sq. km has since been mapped in Northern Libya and geological maps for 1.69,000 Sq. km area have already been released.

New data collected since the inception of regional geological mapping has led to the establishment of 22 mappable units for the Upper Cretaceous-Tertiary Formations of the Al Hammadah Al Hamrah-Al Jufrah region and 19 mappable units for the Al Jabal Al Akhdar region. The stratigraphic nomenclature of these Formations has been rationalised and some of them have been redefined in the light of new observations.

An attempt has been made here to present a synthesised account of the stratigraphic status, ecological, Palaeogeographical, litho and biostratigraphical nature of the Formations.

It has been observed that the Upper Cretaceous Tertiary Formations of the Al Hammadah Al Hamrah region exhibit a remarkable uniformity of characters and seem to continue below the Neogene-Quaternary cover to the east of Sirte basin and can be favourably compared and correlated with the Upper Cretaceous-Tertiary deposits of the western desert of Egypt and the Ghadames basin of Tunisia. The Upper Cretaceous-Tertiary Formations of Al Jabal Al Akhdar region, however, exhibit a facies distinct from the Al Hamadah Al Hamrah region, reflecting, their independent tectonic histories.

A broad outline of the tectonic history of the area since the Upper Cretaceous times has also been presented.

The "Al Khowayamat Formation" an enigma in the stratigraphy of Libya

Mohamed Megerisi & V. D. Mamgain

Some of the recently published geological maps of Libya on 1:250,000 scale show large areas of the southern parts of Al Jabal Al Akhdar (Sheets NH 34-3,4 & 35-1) exposing the Al Khowayamat Formation; defined as a 20 m thick sequence of dolomitic limestone to dolostone forming the lower Member capped by 6 m thick calcilutites and calcarenites with reticulate Nummulites constituting the Upper Member (Mazahar and Issawi 1976).

The northern continuation of these rocks north of latitude 32°N had formerly been mapped (Rohlich 1974) as Al Majahir Formation (Campanian) and Al Faidiyah Formation (Up. Oligocene-Lower Miocene) being the northern continuation of the Lower and Upper Members of Al Khowayamat Formation. The Al Majahir Formation was dated on the basis of unoriented thin sections of planktonic foraminifera, and the Al Khowayamat Formation was largely considered as of Upper Eocene-Oligocene in age on the controversial evidence of the presence of a Nummulitic horizon at the base of the Lower Member.

The controversy on the age was accentuated by the contrary claims and continued disagreement of the two teams supported by their Micropalaeontologists. The difficulties of isolating the microfossils from the hard dolostones and their poor state of preservation coupled with the scanty and incomplete outcrop exposures in the field added new dimensions to this problem; as a result the objective facts as presented by the two teams were published in the geological maps resulting in the disjunct borders of two sheets.

Recently the Industrial Research Centre has undertaken new investigations to solve this problem and the results of these studies are presented here.

Satellite Remote Sensing: The Other Alternative for Reconnaissance Geologic Mapping in the Remote Parts of Southern Libya

Amin A. Missallati

Combination of Dotprints and colored images generation for single channels, multiple channels and ratios by digital computer processing of LandSat MultiSpectral Scanner (MSS) tapes have

been used in this study to locate terrain features and discriminate different rock types in a test site area of approximately 900 square kilometers.

This test site is a small part of a large area located in the northern parts of the Tibesti region in southern Libya which was previously mapped by traditional field methods.

The resulting Dotprints and colored images covering the test site area, depict geologic patterns, closely resembling those mapped by traditional field methods. They also delineate more precisely some of the geologic boundaries as well as new structural patterns.

High-Pressure Megacrysts in Basaltic lavas from Djanet Oasis, Eastern Hoggar, Algerian Sahara

L. Morten - P. L. Rossi - M. Bondi and A. O. Brunfelt

Megacrysts of aluminous clinopyroxene and olivine are present in undersaturated (11.1 Ne-normative) basaltic lava flows from Djanet, Algerian Sahara. Megacrysts of spinel and orthopyroxene are found in the gravels on the surface of the lava flows. The clinopyroxenes are rich in Ca-Tschermak's and jadeite components and the olivines are Fo-rich.

Mineral chemistry, compared with experimental petrology data suggests that these megacrysts are near liquidus phases at about 22.5 Kbars and 1400°C of a picritic nephelinite magma. Fractionation at high pressure of such a megacryst suite is inferred to be responsible for the genesis of the undersaturated basanite host rock.

Is plate tectonics an Universal Theory?

Stanislaw Ostaficzuk

Some doubts to the plate tectonics have arisen in the domain of the Basement Tectonics. Straight lineaments, crossing different structures and/or regions are common on space imageries.

Author discusses some geological implications of different kinds of lineaments known to him from Libya and Europe. The course of these lineaments, supposedly running under the mediterranean denies recent plate tectonics concepts about the tectonic history of this basin.

Late Quaternary of southern Libya, climatic history

Pachur, Hans-Joachim Paul

For the reconstruction of humid phases of climate evidence from flat areas is more conclusive than evidence from mountainous areas, which have a more favourable climate owing to their orographic situation. For this reason our investigations are concentrated on the northern Tibesti foreland, the Serir Tibesti and the Serir Calanscio, and the Gilf Kebir region. High-carbonate freshwater sediments and low-energy fluvial forms were proved to exist in the Serir Tibesti. Stratigraphical investigations showed a triple structure of the fluvial accumulation. Lake formation took place in two humid phases around 13000 - 7000 B.P. and around 5000 B.P. Interpretation of large mammal bones, chronological classification by means of 14C dates and consideration of prehistoric evidence permit the reconstruction of geocological conditions: a precipitation of approx. 200 mm per annum is inferred. Rock from the Tibesti was transported fluvially in a probably periodically water-bearing river system with a length of over 1000 km. It is assumed that the Tibesti Mountains drained into the Mediterranean Sea. Owing to this river system, the elephant was still able to exist in the Serir Calanscio around 3000 B.P. The lakes finally dried out around 1900 B.P. with the growth of tamarisks on the lake floor. Prior to this, sebkhas were formed, and, about 5000 B.P., a change in accumulation occurred, shown by silt content in the calcareous muds. A fundamentally similar climatic development also took place in the Tibesti Mountains. Silty-sandy playa sediments were found in the Gilf Kebir region at the foot of cuestas. Their accumulation was preceded by heavy deflation of the bedrock. Stratigraphic evidence suggests that these sediments belong to the low-carbonate, silty-sandy stillwater deposits in the Gilf Kebir. The age of the sediment base is about 8400 years. The top of the over 6 m thick outcrops contains temporary places of settlement dated at 3800 B.P.

There fluvial terrace systems exist in the valleys of the Gilf Kebir. A characteristic feature is the damming up of the wadis by dunes, causing the formation of backwater basins. In recent times these basins were

hollowed out by the wind. In the Gilf Kebir foreland — as in the Serir Tibesti — the wind is the primary agent of morphological change, dominating in the Gilf Kebir region since approx. 2800 B.P. and in the Serir Tibesti since about 1900. The oldest dates from Libyan deserts are from high-carbonate lake sediments, dated at about 26000 B.P., and from calcareous tufa, about 28800 B.P. The more recent humid phases in the Serir Tibesti and Serir Calanscio are only documented in the period around 8500 B.P. Both areas contain neolithic temporary settlement places. These occur more frequently, however, in the Serir Tibesti. Older settlement phases were determined at higher altitudes in both areas. Investigations to date show the Libyan Desert to be extremely arid, both during the humid phases of the Holocene and at the present time. Further investigations are being carried out in the Gilf Kebir.

Water resources of the Socialist People's Libyan Arab Jamahiriya

P. Pallas

Although Libya has to be considered as an arid country with an average yearly rainfall of less than 100 mm over 93% of the country's land surface there are important potentialities for groundwater development; but, while most of the population, and consequently the water demand, is concentrated within a narrow strip along the Mediterranean coast, most of the groundwater potential is located to the south in the desert areas.

In this paper, five groundwater systems are considered as relatively independent from each other, so that even important abstraction from one groundwater system area will not have any predictable effect on the other nearby systems: the Gefara Plain system — the Hamada el Hamra, Sawf el Jin basin, Misratah area system — the Marzuq basin system — the Sarir - Kufra system — the Jabal Akhdar system.

Because of the rapid development of the irrigated agriculture mostly after 1969, the groundwater extraction passed from approximately 600 - 700 million cubic meters (Mm^3) per year in 1969, to 1600 Mm^3 /year today. Within the next 10 years this figure will reach 3700 Mm^3 /year. While in 1969, most of the groundwater extracted

could be considered as a renewable resource (the water extracted was approximately compensated by the annual recharge of the aquifers), in 1977, 60% of the groundwater is taken from the storage and in future 80% of the groundwater will come from reserves.

Quaternary lacustrine deposits in the Wadi Shati area, Libya

N. Petit-Maire, E. Bonifay and G. Delibrias with the collaboration of S. Ghellali and A. Sbata

Along 23° 30' N, between Al Mahrugah and Ashkida, extensive outcrops with lacustrine shells deposits (*Cardium glaucum*, *Melania tuberculata*) were found. A number of lake stages probably covering the whole Pleistocene period may be inferred from the type (shelly limestones or shelly sands) and situation of fossiliferous beds and other exposed sediments.

The Umm el Gadawal exposure, between the highest coquinas and the present sebka level, is dated 22500 years B.P. This date fits one of the high lake levels observed by Servant in Tchad and Gasse in Ethiopia.

Recent quaternary lacustrine/palustrine deposits in western Libya

N. Petit-Maire and G. Delibrias

In the Derj (30° N) south of Ghadames (29° N) and Edri (27° 30' N) regions, thick beds with concretions after vegetation and lacustrine gypsum deposits mark the past extent of fresh lacustrine/palustrine shallow water areas.

Associated prehistoric sites indicate human settlements around these water-places during the Upper Pleistocene (Aterian) and the Holocene (Neolithic). Charcoal from fire-places are being isotopically studied and will precise these dates when occidental Libya was less arid than nowadays.

Libyan and Indo-Pacific faunas of Molluscs: Tertiary to Recent

Giuliano Piccoli

The Tertiary mollusc faunas of Libya, known so far, are represented by pelecypods and gastropods of the neritic environment; the sea extended far inside the country during the Paleocene, forming later the long gulf of Jofra. The faunal assemblages of

molluscs are similar to the Indo-Pacific ones in the Paleogene and the Miocene; in the uppermost Miocene the faunas change in composition and since then the new inhabitants of the Mediterranean are of Northern Atlantic origin. The facts above listed depend on the tectonic history of the Mediterranean region as well as on the climatic changes within the area during the late Tertiary.

Hydrogeology and Water Resources of the Benghazi Plain Part III: Hydrology and Water Balance

T. S. Raju

The hydrological conditions of the Benghazi Plain and its adjacent areas and water balance of the Benghazi Plain, are presented.

The climate of the area is semi arid. The average rainfall for the past 20 years varies from 141 mm at Saluq, south of the Benghazi city to 393 mm at Qasr Libya near the top of the Jabal Al Akhdar. During the period from 1930 to 1940 the rainfall was somewhat higher. Potential evaporation for grass covered areas varies from 1530 mm at Shahat on the Jabal Al Akhdar to 1715 mm at Beninah. Average annual rainfall surplus estimates based on daily water balance of climatic parameters vary from 18 mm at Benghazi to 85 mm at Al Marj. Average runoff coefficient for the Wadi Al Qattarah drainage basin, which flows onto the plain is about 3%.

Water balance of the Benghazi Plain indicates an average annual net recharge of 141.2 million m³ from rainfall, surface water and ground water inflows, production of 81.6 m³ and outflow from the Ayn Zayanah of 74.0 million m³ and that 14.4 million m³ is coming from storage, indicating the overdraft condition of the groundwater reservoir.

Estimates show that the major groundwater inflow to the study area takes place through karstic channels and the flow through fractured and porous limestone outside the karstic channels is relatively small. However, the total groundwater inflow estimated based on transmissibility, hydraulic gradient etc (42.1 million m³ per year) is quite low when compared to the groundwater inflow estimated through water balance which comes to 115.5 million m³ per year. This indicates the probability of

additional karstic channels entering the plain from the 1st Escarpment and more flow through them than indicated.

The Paleocene Trans-Saharan Transgression and its Ostracod Fauna

R. A. Reyment & E. R. Reyment

During the Early Paleocene (Danian), or latest Maastrichtian, the last of the extensive trans-Saharan epicontinental transgressions began. At its acme, in Late Paleocene time, the sea stretched from Nigeria in the Gulf of Guinea, through present-day Niger Republic, Mali, Algeria and Libya. Faunistically, the most striking feature of this transgression is the wide distribution of many species of ostracods; there are at least 24 West African species in the Paleocene of Libya. An attempt is made to trace the course taken by this long, narrow inland ocean and to reconstruct some of the ecological conditions that prevailed during the relatively brief period of its maximum extent. World-wide considered, this transgression is anomalous and it is suggested that it could have resulted from the effects of geoidal eustasy.

The Paleocene transgression is compared and contrasted with the earlier analogues, to wit, that of the Cenomanian-Turonian passage and that of the Late Campanian to Early Maastrichtian. Statistically based palaeobiogeographical comparisons between the Libyan and Nigerian associations are presented. It is demonstrated that multivariate clines seem to have existed for all species analyzed quantitatively, such that the more northerly associations of Libya have tended to develop a greater carapace volume than the equatorially centered associations.

Gravity-Tectonic trend analysis of Siwa-Giaraboub Oases Area

S. Riad, Hassan A. El-Etr and Magdy A. Mohammed

The area studied lies between latitudes 29° N and 30° 30' N, and longitudes 24° E and 26° 30' E. It includes Siwa area in the Western Desert of Egypt and Giaraboub area in the Eastern Desert of Libya. The Bouguer anomalies in these areas were investigated and used for determining fault systems, probably present in the basement. Statistical studies of these faults show the

presence of three main tectonic trends: E-W, N 25° E and N 60+ W.

In Siwa area these trends are all present, with almost the same importance. In Giaraboub area the E - W trend is prominent.

Shear zones of NE (L.L.) and NW (R.L.) directions were detected in Siwa area.

The subsurface structure in both areas is complicated, but it is believed that the two oases are lying over uplifted blocks of the basement. They are being complicated by the presence of local positive and negative structures and by the action of shearing too.

Uranium in Pan-African Belts

John J. W. Rogers

The Pan-African event of 500-600 m.y. age is characterized, in different parts of Africa, by a variety of processes. These processes include crustal reactivation, anatexis, subduction, production of alkalirich granites, and extensive displacement of crustal blocks. Most of the exposed crystalline terrane, and probably the basement, of Libya has been affected by one or more of these processes. Regardless of the specific process occurring in a particular belt, areas of Pan-African activity must be regarded as zones of extensive release of energy. The extent of global energy release at this time is shown by the widespread development of Pan-African belts in Africa and the abundance of their correlatives in other parts of the world.

Major uranium deposits are associated with igneous activity in at least two Pan-African belts. The Rossing deposit of Namibia occurs in pegmatite-alaskite--migmatite bodies in the Damaran belt, and broad areas of uranium mineralization are associated with emplacement of the Younger Granites of Egypt. Furthermore, much of the hydrothermal mineralization in the Katangan belt of southern Zaire is also of Pan-African age. Deposits of correlative age and occurrence elsewhere include mineralized gneisses and granites of the Southern Appalachians of the United States and the Currais Novos area of Brazil. It seems likely that the thermal energy release that occurred in Pan-African belts was associated with upward migration of uranium at that time, but exact relationships and mechanisms are

unclear. Pan-African belts, therefore, should be considered likely areas for uranium exploration, both in the crystalline rocks of the belts and in sediments derived by erosion of the belts.

Comparison between the late Quaternary Terraces around the Atakor and Tibesti

P Rognon

The alluvial terraces of the large Atakor (central Hoggaar) and Tibesti wadi are compared. They directly depend upon the climatic variations of the Central Sahara in the recent Quaternary.

In spite of a distinct lithology, their characters are alike. The Tibesti "Oberterrasse" was formed during an arid phase close to the present period; its origin is rhexistasic; it is well represented in NW Tibesti. It can be found widely around the Atakor where it developed down from the granitic regions and is made of sand and reddish gravels.

In both regions, this terrace was then cut through. Then, grey or brown clayey silts, often rich in organic matter, constitute a new interfingered terrace. They deposited, during a biostasy phase, during a climatic period with rain all around the year and a quite dense vegetation.

This is the Tibesti "Mittelterrasse", dated 15000 to 8000 B.P. Its relations with a wet mediterranean type climate have been shown through pollen palaeosoils and diatoms analysis, as well in the Tibesti as in the Atakor. The Tibesti "Niederterrasse" developed during a drying up period (rhexistasy phase). It is mainly formed with sands, with flowing conditions close to the present ones. It is less developed in the Atakor where the granulometry is finer (silts) and where it is often confounded with the "Mittelterrasse". It could be distinguished from it and dated less than 6000 BP, in some places.

It seems that the process from the Pluvial period to the extant arid one was more progressive in the Atakor than in the Tibesti.

Tectonic Development of Jabal al Akhdar

P. Röhlich

Jabal al Akhdar and adjoining territories

north of 32 degrees latitude have been surveyed in the first phase of the contemporary geological mapping of Libya organized by the I.R.C. Tripoli (Klen, 1974; Röhlich, 1974; Žert, 1974). The present paper, being largely based on the results of that survey, deals with the questions of the tectonic development of Jabal al Akhdar. The essential conclusions may be summarized as follows.

1. Tectonic history: The sedimentary rocks exposed in Jabal al Akhdar (marine Upper Cretaceous and Tertiary) were moderately folded and faulted during the Santonian and early Ypresian intervals. From Middle Eocene to Middle Miocene, the area was subject to a slight warping followed by oscillating transgressions of a shallow sea. The youngest tectonic movements resulted in a gentle doming of the area associated with downfaulting of certain zones. The present gross geomorphology of Jabal al Akhdar roughly corresponds to its final uparching after the Middle Miocene.

2. Structural systems: The principal structural alignment of Jabal al Akhdar is NE-SW (late Cretaceous folding axes, major faults in the northwestern flank). This system is crossed by NW-SE and E-W trending faults. More easterly, the E-W trending slight faulting is dominant. Some prominent faults were reactivated during the tectonic development, partly with movement inversion.

3. Geotectonic position: Jabal al Akhdar developed in a tectonically exposed marginal part of the North African shelf. The Upper Cretaceous and Eocene sediments of the present coastal area partly may have been deposited on the continental slope. Jabal al Akhdar is the most prominent part of an extensive tectonic paleobarrier between the Tertiary epicontinental basin of northeast Libya and the Tethys deep-sea basin.

Oligocene Echinoid Faunas from Darnah, Libya, and Their Palaeoenvironmental significance

E. P. F. Rose

Irregular echinoids are an important element of the macrofauna in Tertiary carbonates which form the Jabal al Akhdar region of northeast Libya. The echinoid faunas are diverse. Specimens are locally abundant and generally well preserved. At

least thirty species occur within the Oligocene (Al Abraq Formation) near Darnah. Six different lithofacies may be distinguished in wadi exposures from Darnah to al Khalij twenty kilometres further east, each characterized by a distinctive echinoid biofacies. From analogy with living clypeasteroid, cassiduloid, and spatangoid echinoids, and functional interpretation of test morphology, this echinoid distribution can be related to the animals' original mode and place of life. Additional palaeoecological data are contributed by associated fish, molluscs and foraminifera. The different shallow-water, marine environments thus characterized can be recognised more widely in the Mediterranean Tertiary.

The type sections of the Cretaceous and Paleocene of Tunisia proposed for the Hypostratotypes and their application for correlation with planktonic zones of Libya

Joseph Salaj

Correlation of Tunisian type sections of the Upper Cretaceous and Paleocene, proposed for the Hypostratotypes, with standard Upper Cretaceous and Paleocene planktonic zonation, applied in Libya.

The vertical distribution of planktonic index species in the Upper Cretaceous of Tunisia on the one hand and phylogenetic relationships of some species and genera of the families Globotruncanidae and Heterohelicidae on the other hand point to the possibility of solution of some stratigraphic problems as well as to a more detailed subdivision of the Upper Cretaceous and Paleocene in Libya.

A feature specific of the North African, mainly Atlas region, is the presence of the Totundina cretacea — Praeglobotruncana imbricata Zone, also known from the stratotype of the Turonian in the overlier of the Rotalipora turonica Zone and in the underlier of the Helvetoglobotruncana helvetica Zone.

The one-keeled species Globotruncana turona sigali /Reichel/ is always found in the upper part of the Helvetoglobotruncana helvetica Zone and in the basal part of the Marginotruncana schneegansi Zone it already becomes extinct.

Appearance of the subspecies of the species Globotruncana concavata /Brotzen/

unambiguously determines the lower boundary of the Coniacian, however, they are unsuitable for a detailed subdivision of the Coniacian-Santonian.

The Upper Coniacian-Santonian is very well defined by the lineage of species of the genera *Sigalia* and *Ventilabrella*: *Sigalia deflaensis* /Upper Coniacian/, *Sigalia carpatica* /Lower Santonian/, *Ventilabrella decoratissima* /Middle Santonian/, *Ventilabrella alpina* /Upper Santonian/, *Ventilabrella glabrata* /Lower Campanian/.

From the base of the Upper Santonian *Globotruncana fornicata manauensis* Zone and proved also by ammonites in Tunisia, the species *Globotruncana elevata elevata* /Brotzen/ occurs first.

The Campanian as well as the Campanian-Maastrichtian boundary are very well defined not only in Tunisia /A.-L. Maamouri and J. Salaj 1971/, in the West Carpathians /J. Salaj and O. Samuel 1966/, mainly on the basis of the lineage: *Globotruncana arca arca* *Globotruncana arca rugosa* *Globotruncana falsostuarti*.

The species *Globotruncana falsostuarti* unambiguously determines the Maastrichtian base not only in the mentioned regions but also at the stratotype of the Maastrichtian regions but also at the stratotype of the Maastrichtian /J.-P. Belier and J.-M. Villain 1975/. The Maastrichtian base in Libya has so far been determined by appearance of the species *Globotruncana conica*, the index species of the same zones /B.A.H. Eliagloubi 1976/. The Upper Maastrichtian is characterized by the Zone *Racemiguembelina varians varians* s.l.

To the Danian s.l., on the contrary to the Danian s.s., are assigned the zones *Globigerina taurica* — *Globoconusa daubjergensis* and the *Turborotalia /Acarinina/ inconstans* Subzone, absent at the stratotype of the Danian.

For the reason that the T. /*Acarinina/ inconstans* Subzone still belongs to the nannoplankton zone with *Chiasmolithus danicus*, it is not considered as equivalent in age with the *Globorotalia uncinata* s.l. Zone. On the contrary, the latter together with the *Globoconusa kozlowskii* Zone already belongs to the nannoplankton zone *Ellipsolithus macellus*. Both zones together with the *Globorotalia angulata* Zone are assigned to the Montian s.l.

The zones *Globorotalia pusilla*,

Planorotalia pseudomenardii and *Globorotalia velascoensis* are assigned to the Upper Paleocene. It seems more correct to us to use the term Landenian s.l. /principle of priority/ instead of the term Thanetian. The qualities of both stratotypes are essentially the same and not very suitable. In Africa the term Landenian is rather used, also the supporting profile for the Upper Paleocene is proposed to be called Landenian s.l.

Stratigraphy of Al-Khums Formation Northwestern Libya

Mostafa J. Salem, A. C. Spreng

Stratigraphy of Al-Khums Formation (Miocene) in the vicinity of Al-Khums, northwestern Libya is presented. Twenty three stratigraphic sections were prepared and studied in detail. Two members namely Ras Al-Mannubia Member (upper), and An-Naggaza Member (lower) of Al-Khums Formation are proposed.

This formation transgressively overlies the various Cretaceous beds with a prominent unconformity. A structure contour map drawn on the unconformity illustrates the pronounced relief developed prior to the encroachment of the Miocene sea. The deposition of Al-Khums Formation was under shallow water conditions with reef patches development near the former shoreline. Lithologic and paleontological criteria indicate the formation represents two major transgressions separated by a regressive cycle.

In situ rock strain Measurements in Libya

Karlheinz Schäfer

For the first time in situ rock strain measurements have been carried out in Libya. Except in Liberia there are no previous in situ stress results of the African continent north of the equator. In this paper I report the results of stress determinations at 26 sites that extend from the Tunisian-Libyan border to Derna/Cyrenaica in the north and to Ghadames and the Jufrah oasis in the south. The present rock strain has been determined by overcoring of strain gages that were bonded to the rock surfaces. The range of rock ages selected for measurements was wide (Middle Triassic to Quaternary) but their lithologic character

was similar (solid homogeneous micrites). The orientations of maximum and minimum horizontal stress revealed a consistency across large areas.

Most stress values vary from 0-50 bars, many range between 50 and 150 bars and to one site the stress was tensile in all horizontal directions. At least three crustal domains in northern and central Libya can be defined by means of different in situ stress fields. The western Libyan stress domain extends from Tunisia into Libya and is terminated along a line that runs from Sabratah to Azizia, Bu Ngem and the Jebel Waddan east to the Hon graben.

This western Libyan stress field has a NW-SE-oriented maximum stress that is horizontal and compressive. To the east follows the central Libyan stress domain with a NE-SW-directed horizontal maximum compressive stress component that incorporates the entire Sirte basin and major parts of the Cyrenaica. A third in situ stress domain occurs along the Cyrenaican coastal area from Al Beda to the east. There, the stress field has a maximum compressive component of NW-SE-direction. It is suggested that Tripolitania and the eastern Cyrenaica and their lithospheric northern extensions are indenting the European plate in a northwestern direction corresponding to the drift direction of the African plate since about 9 m.y. The Sirte basin is located between those framing indenters and was subjected to extensional tectonics during the late Mesozoic and most of the Tertiary, but may have been under NE-SW-directed horizontal compression since the late Neogene.

Paleo- and Recent Stress Fields in Northern and Central Libya from the Cenozoic Structural Bearing

Karlheinz Schäfer

A selection of small-scale structural features have been applied as evidence for the existence of horizontal paleo-stresses within Mesozoic and Cenozoic platform carbonates of northern and central Libya. Major tectonic elements such as the late Mesozoic evolution of the Sirte graben and horst structures and the Cenozoic Tibesti-Garian volcanic chain have been considered additionally. It is shown that northwestern Libya was subjected to

horizontal crustal shortening in the NE-SW-direction from end-Cretaceous to Upper Oligocene with a climax during Middle to Upper Eocene. A different tectonic regime with mainly extensional movements to the NE and volcanic activity was contemporaneously effective from the volcanic chain to the east. Northwestern Libya is presently influenced by a NW-SE-directed horizontal principal stress of a stress field that was created already during the Middle Miocene. This stress field had a climax during the Upper Pliocene inducing a new volcanic episode but no major rifting in the Sirte basin.

It is concluded that the African plate while drifting NE-ward from Upper Cretaceous through end-Paleogene and moving NW-ward relative to stable Europe since 10 m.y. ago has induced the two tectonic regimes in northern Libya. The different crustal stress history in the Sirte basin may be due to a continuous NE-ward motion to the African plate after the indentation of Europe during the Upper Cretaceous by the Adriatic promontory as the continuation of Africa from NW-Libya and Tunisia to the north.

Actuogeological investigations and the interpretation of palaeo-environments in the Sahara

Erhard Schulz

In recent years there was quite some agreement among palaeoecologists that the Sahara of Pleistocene and Holocene times had a vegetation cover of forest in the mountain areas and lush steppe vegetation in the surrounding lowlands. Based on this concept optimistic speculations on the amount of groundwater stored in Pleistocene and Holocene sediments were made. The concept was based on the interpretation of fossil pollen spectra, but on very few botanical macro-remains. Further evidence was taken from pre- and protohistorical remains as well as from the type and distribution of fossil lacustrine and fluvial sediments.

Detailed studies on the problem of present-day pollen sedimentation conducted in 1969 in the Western Sahara and in 1977 in Central and Southern Libya and Northern Niger show that the concept has to be revised. A large number of those botanical

elements that were found in sediments in the Sahara, are nowadays transported into the desert from outside regions. Among the temperate elements *Pinus*, *Alnus*, *Quercus* and others are deposited as far south as northern Tibesti or the Plateau du Mangueni. Pollen of mediterranean flora are equally wide-spread and also indicate long-distance pollen transport over several thousand kilometers.

Based on these observations it can no longer be deducted from the fossil pollen spectra that the Pleistocene and Holocene vegetation cover was completely different both qualitatively and quantitatively.

Taking the few macro-remains and carefully interpreting the pollen records, one can only assume that the vegetation cover was somewhat more dense than today, but that the vegetation was of a similar type as today. For the mountain areas we have to expect a dry mediterranean shrub vegetation, but no forests.

In regard to groundwater resources one should therefore not overestimate the amount of recharge that may have taken place during Pleistocene and Holocene pluvials.

A contribution to the Hydrogeology of Siwa-Giarabub area (Egypto - Libyan Border)

Abdu A. Shata & Mohammad A. Tamer

In this area, the strata of hydrogeological interest are composed of a fissured limestone complex at top and a clastic complex at base. The upper complex, having a thickness of about 700 m, belongs to the Tertiary (Miocene and Eocene) and to the Upper Secondary (Upper Cretaceous Turonian). The lower complex, has a thickness of about 2600 m and its ages ranges from the Middle Secondary (Lower Cretaceous) to the Lower Primary (Cambrian). Facts from the wider region indicate that the two complexes are hydraulically connected, at least in part. The ground water of the upper complex is tapped from natural springs as well as from drilled boreholes and the piezometric level drops from about 24 m above sea level in the northwestern portion of the morphotectonical depression, to about 15 m below sea level in the opposite direction (southeast). The salinity increases in that direction i.e. from northwest to southeast.

and the range is rather wide, i.e. from about 1500 ppm to about 8000 ppm.

With regard to the lower clastic complex, it has a wide geographical distribution in the subsurface and outcrops in a narrow locality in the northwest direction (Gabal El Akhdar) and also in several places in the rainy areas to the south (Chad, Sudan, Nigeria... etc).

In some wells drilled in Siwa Oasis, the piezometric level of the ground water of this complex is about 100 m above sea level and the salinity is subject to wide variation (the lower horizons contain highly saline water of the order of 25,000 ppm, whereas in the upper horizons the salinity is less than 1000 ppm; occasionally, however, a fresh water horizon is wedged in brackish water horizons). The hydrology of the clastic complex in Siwa-Giarabub area is essentially influenced by the regional situation of the great arteries basin in NE Africa and is locally modified by the relatively high rain fall on Gabal El Akhdar. Dating of the water from the carbonate complex has been attempted, using the C 14 — method, and the results point to the fact that the ground water is, in part, Fossil water (25,000 to 40,000 years). This leaves the door open for discussion that the ground water in Giarabub — Siwa area has been accumulated during one or more period of the pluvial interval (Pleistocene).

Quaternary sedimentation of the western coastal plain of the Gulf of Sirte

N. S. Sherif

The Western coastal plain of the Gulf of Sirte covers an area of about 1,000 sq. km. and consists of several well defined physiographic features: an inner barrier with a sabkha depression to landward succeeded seawards by an outer barrier enclosing another sabkha depression.

The barriers consist of beach-dune ridge complexes, which reach heights of up to 15m. above sea level. They are composed of quartzose-carbonate sand and show different degrees of lithification. The sabkha depressions are enclosed basins, remains of infilled lagoons, with surface levels below that of the present sea level, and are sites of deposition of modern evaporites.

Two major transgressive events formed the physiography and the sedimentary pattern of

this coastal plain. The earlier transgression of late Pleistocene age reached a level close to that of the present sea and formed a barred island and lagoon, today preserved as the inner barrier and sabkha. The Flandrian transgression led to the sea reaching its present level just prior to 3,650 years B.P., and it appears to have spilled into the older lagoon behind the inner barrier. Subsequently, the outer barrier developed to enclose a lagoon to landward. The inlets which allowed this penetration of marine water into the inner and outer lagoons ultimately became closed and consequently the lagoons developed into the present day inner and outer sabkha depressions.

Clays and claystones in Libya

Jiří Šindelář and Pavel Jadrniček

Regional geological mapping at a scale of 1:250,000 in northern and central Libya, surveyed on behalf of the Industrial Research Centre, Tripoli, as well as exploration for iron ores, clays and claystones in central Libya yielded several new occurrences of clayey sediments and also checked some of those that had been known before. Qualities of some of these occurrences correspond to the first-class ceramic raw materials while others appear as promising for possible industrial exploitation in the future.

Probably the best ceramic raw materials in Libya occur in the Upper Devonian strata in the Wádí Shatti, accompanying the iron-ore deposits. The lower deposit (in the Basal Sandstone Formation) is represented by white, thin-bedded, exceptionally compact, illite-kaolinite claystone with varying admixture of silty-sized quartz. In the upper deposit (The Roof Beds Formation), the prevailing types are either black or grey clay shales or their altered equivalents. Apart from T-kaolinite, the most significant mineral present is mica, 14 A-mineral while iron oxides, carbonates and sometimes sulphates are subordinate. Petrologically even technologically, the raw material resembles the English "ball clays". In the northeastern vicinity of Sebha exposed kaolinite claystones are younger in geological position (they probably belong to Mesozoic Era). They are almost grey-white to white, their conchoidal varieties are flint-looking. These claystones will be used

ground as a binding agent in the production of fireclay bricks.

Corresponding kaolinite claystones crop out also in basal horizons along the whole length of the Jabal Nefusa escarpments (northern Libya). The most promising are the Triassic to Cretaceous kaolinite claystones belonging to the Abú Shayba and Kiklah Formation. Light grey claystones occurring on the western margin of the Al Khums map sheet contain, besides T-kaolinite, also quartz and small amount of mica and calcite. Mineral composition suggest the possibility of production of refractory ware whereas the coloured types (red and occasionally greenish) are suited for common types of stoneware. Nowadays known clayey sediments on the map sheet Tarabulus are of somewhat lower qualities. The Abú Ghaylan deposit and clays and claystones in the Kiklah and Sidi as Sid Formations contain, apart from kaolinite, mica and quartz, even 14 minerals, I-M structures and Fe and Ti components which give the rock its yellowish, grey or greenish grey colouring. Frequent are also the hematite types of claystones. Hand specimens studied from the Yafrin and Guassem deposit suggest that a production of stoneware and bricks is possible.

In Turonian and younger sediments green clays and claystones have been frequently found. The rocks for detail examination were collected near Mizdah (the Qasr Tigrinnah Formation), along the main road on the northern part of the map sheet Al Washkah (Maastrichtian Zimám Formation) and on the north of the map sheet Darnah near Umm or Razam (Miocene Al Faidiyah Formation). Besides illite and pM-kaolinite, the essential mineral present in green clays is montmorillonite. Alkaline chlorides sulphates and nitrates are significant accessories. The clays were tested and proved as satisfactory expanding material. After beneficiation the clays could be used even for other industrial purpose.

Attention was also paid to varicoloured (usually red-brown) calcareous clays of Quaternary in age that occur on the Darnah map sheet. These clays are mostly composed of kaolinite, calcite, Fe- and Al- oxides and hydroxides.

Structural control of Ground-water flow in the Mesozoic sandstone aquifers of

the Eastern part of Jebel, Nefusa, Libya

G. D. S. Singh

Sub-surface occurrence of the Mesozoic sandstone aquifers in the eastern part of Jebel Nefusa has more or less been established. The reservoir so developed constitutes perhaps one of the most powerful ground-water bodies in the whole of the Jamahiriya. The reservoir thickness, constituted of undifferentiated Kiklah, Kabao and Abu Shaybah formations has been estimated around 100 metres.

Ground-water flow is governed more by structural elements of subterranean and regional origin, than any thing else. This phenomenon is clearly reflected on the piezometric head differential analysis with respect to Beni Walid and Tarhuna. The differential works out to be 120 metres. Piezometric elevations at Beni Walid and Tarhuna are 200 and 80 metres above the mean sea level respectively. This obviously indicates that the ground-water flow occurs from south to north and north-east with an average gradient of 1 in 750 approximately.

The postulate that the reservoir slopes generally in a southern direction as against the northern slope of ground water surface is difficult to reconcile, but this is what field analysis proves to be. Elevations of the upper surface of the reservoir calculated again in terms of these two focii, reveal that they are 500 metres below the mean sea level at Beni Walid, and about 50 metres above the same datum at Tarhuna. Thus, an approximate gradient of the reservoir works out at 1 in 163. These fundamental hydrogeological parameters, in addition to several others, are strong evidence in support of the hypothesis that the ground-water flow is structurally controlled. The resultant effect of all these controls motivates sub-surface delivery of water into the Gefara Plain between the meridians 13°10' and 14°15' at an approximate rate of 1170 litres per second.

Total intensity aeromagnetic map of the Jabal al Awaunat area, southeastern Libya

Deb Shankar Sinha

Airborne geophysical survey employing magnetic and gamma-ray spectrometric methods was carried out in an area of about 29,300 square kilometres during 1973 in the

Jabal al Awaynat region of southeastern Libya. The survey was restricted to the Precambrian and the surrounding formations. In general, the Precambrian basement is magnetic compared to the surrounding formations. The northeast-southwest trending linear alignment of magnetic gradients at the central part of the Precambrian area separates it in two blocks and could indicate a deep fault characterising a sort of graben or a petrographic change in the Precambrian rocks. The presence of widespread magnetic materials ironstones, dolerites and basic granulites rawher than the gneisses themselves may contribute to the high magnetic level in the basement. There is good correlation between the major north-south, northeast, east-northeast and east-west trends of linear magnetic features and observed tectonic trends in basement. The syenites and granites of Jabal Arknu and Jabal al Awaynat are magnetically similar to the basement rocks which they intrude but the granites of Jabal Babuar and to lesser extent, Jabal al Bahri appears as magnetic lows in relation to basement. The widespread Tertiary trachytic plugs and ring structure in the west of the area are clearly depicted on the magnetic map. A number of small but strong magnetic anomalies located in a northeast trending zone between Jabal Arknu and Jabal al Awaynat is associated with lenses of quartz-magnetite-hematite rock in the basement.

On the application of Geophysical logging in the Assessment of Groundwater Potentialities of Gaddames - Hamada Basins

S. C. Sinha

This paper serves to illustrate the uses of geophysical logs in the assessment of groundwater potentialities in the Gaddames - Hamada basins. An area of about 170,000 Sq. Kms, bounded by Jebel Nefusa to the north, Gargaf Arch to the south, Tunisia - Algeria border to the west and the adjoining Sirte basin to the east, has been investigated by interpreting borehole geophysical and geological data from 105 Oil wells and 40 Water wells.

The oil well data consisted of lithology, stratigraphy and geophysical logs recorded using conventional resistivities, radiometric,

micro-devices, porosity logging, thermal and mechanical logging techniques. All these logs have been interpreted in the Office of the Secretariat of Dams and Water Resources in locating aquifers and computing their salinity and porosity. The interpreted data has been plotted as 14 no. geological cum hydrogeological cross-sections. The paper is illustrated with 5 such cross-sections and 2 regional maps showing details on two of the most promising and extensive aquifers in the area - Chicla (Lower Cretaceous) and Ras Hamia (Triassic).

Hydrogeological studies using Geophysical logs in Murzuk basin

S. C. Sinha and S. M. Pandey

This paper deals with a preliminary study of the groundwater possibilities in a 30,000 Sq. Kms area of Murzuk Basin bounded by Latitudes 25° - 27° N and Longitudes 13° 30' - 15° O' E. The paper is illustrated with one hydrogeological section.

Geophysical data from 3 oil wells and 2 deep water wells have been analysed for this study. Geology of the area could be understood mainly from the Oil well and water well files and partly from the maps published by Conant & Goudrazi and American Overseas Petroleum Limited.

The area under investigation is a part of a synclinal basin where the rock formations are sloping gently from north to south. Rock outcrops show older formations (Devonian) to the north and the younger (Tertiary) to the south. The present investigation reveals an increase in thickness of sediments from north to south. These rocks range in age from wind blown sands to Cambro-Ordovician. Some of the intermediate members in these sediments, Jurassics to Permian, either tend to pinch out in their northern extension or progressively thin down.

Aquifer features have been indicated in the granular sediments of Lower Cretaceous (Nubian), Jurassics, Carboniferous and Cambro-Ordovician rocks. Most extensive and good quality aquifers exist in Nubian sandstones in almost the whole area except to the north where older rocks are exposed. Next best are the Jurassics in the south and

Cambro-Ordovician to the north. The topographical and structural features suggest artesian to sub-artesian conditions in these aquifers. As Nubian aquifers are exploited appreciably through shallow tubewells in the populated parts of the investigated area, the Cambro-Ordovician and Jurassic aquifers may act as stand by sources of potable subsurface water and also to minimise over-exploitation of the Nubians. Aquifers in Carboniferous rocks are saline and have little practical use.

The investigation has revealed that major part of the Gaddames - Hamada basin is a potential source of potable subsurface water. The main aquifers are, — Garian, Chicla and Ras Hamia.

Irregular lateral extension and erratic quality distribution (both vertically and laterally) in the Garian aquifer suggest that this aquifer may not follow a well defined pattern. Chicla is by far the best aquifer in the region, — extensive, permeable, potable, and has considerable effective thickness. This aquifer is often under artesian to sub-artesian conditions due to favourable subsurface structure and topography. Ras Hamia, though deep seated, is the second best aquifer in the area. This aquifer is also fresh-water bearing in major part of the area and is also under pressure. In some parts where Garian and Chicla are absent or poor or uneconomic, Ras Hamia is there to compensate and meet the water requirements. Toward the southern limit of the investigated area, the Chicla and Ras Hamia aquifers tend to combine into a single aquifer unit.

The results of the present investigation may be used in formulating detailed hydrogeological programmes in some parts of the Gaddames - Hamada basins, with the ultimate objective of developments in a few favourable areas of these basins.

Meta - Halloysite from the Wadi Rumiya, Djebel Nefusa, - Its Occurrence and origin

Werner Smykatz-Kloss

Abstract. The walls of the Wadi Rumiya near Yefren, part of the Djebel Nefusa escarpment, show the rocks of the whole Kikla and Sidi Said formations. The crossbedded, yellowish-brown Kikla sandstone includes lenses and layers of

greenish-grey and reddish calystones which were studied by X-ray diffraction and differential thermal analysis. These clays, varying in thickness from few cm to 2-3 m, are synsedimentary in origin. They consist mainly of the kaolin group mineral *meta-halloysite*, $Al_2[(OH)_4Si_2O_5] \cdot x H_2O$; x being between 0.1 and 0.5. The *meta-halloysite* shows all states of structural order, from strongly disordered to wellordered, but most samples exhibit structures being clearly disordered after the crystallographic b-axis. Discussion of the genesis and diagenesis of the clay: synsedimentary formation of *halloysite*, $Al_2[(OH)_4Si_2O_5 \cdot 2H_2O]$, during the Cretaceous Kikla period and in a near-shore (probably lagoonal) marine environment, and alteration of this *halloysite* to *meta-halloysite* by diagenetic processes. The possible technical application of the clay is discussed, too.

**Mg-deficient dolomite
from the Ain Tobi
Member of the Jabal Nefusa,
Tripolitania**

Werner Smykatz-Kloss

The chief mineral of the Ain Tobi Member (lower part of the Sidi As Sid Formation) of the Jabal Nefusa, Tripolitania, is a *Mg-deficient dolomite*, which is associated by quartz and small amounts of calcite, halite and Mg-sulphates. This dolomite, showing a "normal" X-ray pattern, exhibits a strange decomposition behavior: in DTA curves the first endothermic deflection (which is due to the decomposition of the $MgCO_3$ component of the dolomite structure) is lowered more than $150^\circ C$ compared with "normal" dolomite. The reason for this decreased structural stability is the lack of 5-10% of the Mg of the structure. This deficiency of Mg is most probably reasoned by slightly acidic weathering solutions which leached the Mg from the structure. In the lower part of the Ain Tobi layers the dissolved Mg is precipitated as epsomite, $MgSO_4 \cdot 7 H_2O$, which quickly alters to hexahydrate, $MgSO_4 \cdot 6 H_2O$. Both Mg-sulphates occur as secondary fillings of clefts and cavities, together with small amounts of halite.

**Oolitic Magnetite from Wadi Al-Shati,
Fezzan, Sedimentary or Metamorphic in
Origin**

Nakhla, F. M. and W. Swykatz-Kloss

The Libyan iron ore deposit occurring in Wadi Al-Shati area, Fezzan, is dominantly composed of *magnetite* $Fe + ^2Fe_2 + ^3O_4$ which reveals well developed oolitic texture, indicating that it was most probably formed under shallow marine environment of deposition. According to Goudarzi and other workers, Wadi Al-Shati iron mineralization is believed to be of syngenetic sedimentary origin. However, the genesis of magnetite remains a questionable problem since it can hardly be explained from the sedimentological point of view. It is well known that magnetite could be formed in appreciable amounts under a relatively high temperature and low negative Eh values. Such favourable physico-chemical environment might be fulfilled by contact or regional metamorphism.

Mineralogical and geochemical investigations, by microscopic, DTA and X-ray methods, of more than 60 magnetite-rich ore samples from South Tarut in Wadi Al-Shati has shed some light on the genesis of magnetite revealing whether it has been formed by sedimentary or metamorphic process or it is of polygenic origin. The present study has discerned that Wadi Al-Shati iron ore deposit was initially deposited, under marine conditions, as synsedimentary goethite and berthierine (chamosite) during Upper Devonian time. The post mineralization processes, including diagenesis and low-grade metamorphism, resulted in the partial transformation of goethite and berthierine to magnetite while retaining the original oolitic texture of the ore. Heat was the main agent of metamorphism and was most probably related to Tertiary volcanic activity which is manifested by the extensive basaltic flows outcropping in the northern and eastern parts of Wadi Al-Shati area.

**Mineralogy and Geochemistry of
Synsedimentary iron Hydroxides and of
Concretionary Goethite from the Wadi
Rumiya, Djebel Nefusa**

Smykatz-Kloss, W and S. H. A. Shah

In the Wadi Rumiya near Yefren, the

sandstone of the Kikla formation contains several lenses and layers of claystones which are commonly bordered by small bands of fine-grained iron hydroxides. Besides this type of *syndimentary* goethite a second type of iron hydroxides occurs, forming brown concretions of goethite mainly in the lower part of the Kikla formation. These concretions vary in size between 2 and 80 cm in diameter and include a greenish claystone consisting of a true, well-ordered kaolinite. Both iron hydroxides, the syndimentary layer-type I and the diagenetic concretion-type II contain the same iron mineral (goethite) but differ in the structural state (in the degree of structural disorder), of this goethite, in their accessories and in their trace element patterns.

New Findings of Tertiary fauna in Jabal Hasawnah /Central Libya/

Zdeněk V. Špinar, Zbyněk Roček

In the course of geological survey of central Libya, organised and supported by Industrial Research Centre, Tripoli, a new freshwater series of Tertiray age was discovered and named Taráb Formation. The profile of the type locality of this series /western foot of Jabal Hasawnah; on the geological map of Libya 1:50,000 sheet 2081-II, point No 20) demonstrated that the series is formed by clay sediments with several thin carbonatic beds. These sediments, arisen by filling the small basin, are of the oligocene age, according to recent study. In open parts of the profile 5 carbonatic beds were found. The uppermost one is sterile, the remaining 4 are fossiliferous, containing gastropod shells, numerous skeletons and imprints of fishes (Pisces), frogs (Anura) and scarce remains of mammals (Mammalia: Hyracoidea).

Gastropod shells were found both in carbonatic beds (layer II-V) and in silicified fragments of rock found on the surface in the surroundings of the profile. In carbonatic beds, 2 specimens belonging probably to the family Cochlicopidae or to the family Vertinidae were found. Owing to the fact that shell apertures with decisive diagnostic characters are destroyed, exact determination will not be possible. In silicified fragments found outside the profile 2 species of gastropods were ascertained. The majority of relatively well preserved

shells probably belongs to the family Melanidae. Another specimen which is strongly damaged probably belongs to the family Succineidae.

In the locality under study, the fossil remains and imprints of fishes are predominant among other vertebrates. They are relatively well preserved and abundant. The material for study consists of more than 100 specimens, which are almost complete and many fragments. According to our study they belong to the species *Palaeochromis rousseti* Sauvage, 1907 (family Cichlidae Bleeker, 1859). In the material we had at our disposal there were fishes of medium size attaining the body length 53-120 mm (without tail fin). They possessed a conspicuously large head (about one third of the body length). The dorsal fin was long and continuous, with 12-13 firm spines and about 12 soft rays. The anal fin consisted of 3 hard spines and 8-9 soft rays, the abdominal fin of 3 hard and 5 soft rays. The pectoral fin was not supported by any hard spines and consisted only of 12 soft rays. The distal margin of the caudal fin was almost straight and the fin was supported by 22 rays. The scales were of the ktenoid type, usually with 7-12 radial lines. Intermaxillare and dentale bore several rows of long and conical teeth.

In laminated limestone the remains of frogs were also found: 15 incomplete skeletons and 7 imprints without preserved bones. They are small pipid frogs attaining body length of 42 mm. The frontoparietals of adult specimens are fused. These bones are narrow on the rostral end, while on the caudal end they are robust and vaulted. They fuse with occipitalia lateralia, and in some specimens also with ossa prootica. Otic capsules are conspicuously large, and in some specimens separated by the groove from frontoparietals. The vertebral column and pelvis are similar to those of *Xenopus leavis* and consists of 9 opisthococleous vertebrae. Sacral wings are slightly narrower than in above mentioned recent species. Femur is shorter than crus. Astragalus and calcaneus are separated. Metacarpals and metatarsals are long which demonstrates the permanently water-dwelling habitat of the frogs. Preliminarily we can state that these frogs belong to a new genus, considerably different from the genus *Xenopus*.

Among other findings there are also 2 incompletely preserved skulls, 1 almost

complete postcranial skeleton and 3 fragments of various body parts of a mammal *Titanohyrax palaeotherioides* (Schlosser, 1910) (Hyracoidea: Geniohyidae). Dorsal side of the skull No L-RŠ-77 is quite smooth. Teeth can be studied only in lateral view; only PM₂₋₄, M₁₋₂, PM₁₋₄ and M₁₋₂ are distinct. M₂ dex. is solenodont. The other preserved teeth are brachiodont, with conspicuous cingulum. As the specimens are young and immature, the teeth are rather small and the hindmost molars are still hidden inside the jaw. However, the description of teeth form agrees with data from the literature. The best preserved postcranial skeleton No 4-L-RŠ-77 demonstrates that the specimen is as large as a big rabbit or a cat. The adult animal certainly was much larger. The outline of the frontal part of the skull No 15-L-RŠ-77, together with the nasal bone and small lower incisor, are evidence of a form with a long rostrum.

Groundwater studies in the Triangle ben Ghashir-Tajoura-el Zawia (Tripoli, Libya), using radioisotope Techniques

F. M. Swailem, A. M. Eskangi, R. E. Shoheib and B. M. Mabrook

The problem of continuous lowering of underground water level due to exhaustive pumping, in the triangle Ben Ghashir-Tajoura-El Zawia makes it essential to study recharge processes in this area. Periodical field and laboratory works have been executed twice per year for a period of about five years. The work were undertaken in six representing localities in the area during the recharge time (winter time) and the discharge time (summer time).

The work includes complete chemical analyses of water, tritium measurement, determination of aquifer parameters as productivity, transmissibility and storage coefficient; and identification of direction and velocity of groundwater flow using radioisotope tracer techniques. The results are interpreted considering the geological and hydrogeological conditions of the region.

Geochemical and Mineralogical Investigations on evaporites of the Zouila Sabka Fezzan

Heinz J. Tobschall and Werner Smykatz-Kloss

The sabkha of Zouila is located about 120 km S of Sebha in central Fezzan. It is nearly 12 km long (E-W) and 2 km broad in S-N direction. Because of being dry during 11 months of the year, there are only few spots at the deepest depression of the salt lake which are filled with water. For the present study 20 samples have been collected from the rim of these "water holes", from two cross sections and from the hills of the northern surrounding area. Geochemical analyses for alkali and earth alkaline metals, for Fe, Si, Al and Mn, and mineralogical analyses by means of X-ray diffraction have been carried out. The variation in the amounts of occurring minerals halite, sylvite, carnallite, glauberite, gypsum, anhydrite, mirabilite, thenardite, quartz, goethite, kaolinite, calcite, and dolomite and the genesis of these minerals have been discussed.

A Review of the Investigations on the Wadi al Shatti Iron Ore Deposits, Northern Fezzan, Libya

T. M. Turk - A. K. Doughri and Syamadus Banerjee

This paper reviews the results of investigations carried out by the French Group between 1971 and 1976 in two stages, on the iron ore deposits of the Wadi al Shatti in northern Fezzan.

An area of about 3,000 sq.km. was geologically mapped on 1:40,000 scale, from east of Ash Sheb to west of Gottah, a distance of about 160 km. Further detailed mapping of about 255 sq.km. was done on 1:10,000 scale in the Ashkeda and South Taroot areas.

The iron ores occur in the Devonian Aouinet Ouenine Formation of Jabal Fezzan, in a 140 m thick sedimentary sequence ranging in age from Upper Frasnian to Strunian (Upper Devonian). There are three important iron ore horizons.

The best type of the ore is the magnetic reduced ore having a proved reserve of 420 m. tons with about 55% Fe content, along with a proved reserve of 375 m. tons of non-magnetic reduced ore and 100 m. tons of oxidised outcropping ore in the South Taroot area, about 40 km west of Brak. The total inferred reserve of all types of ores is about 3.5 billion tons, Fe content varying between 35% and 55%.

The studies also covered the mining, beneficiation, agglomeration, reduction, marketing, transport etc. for the possible exploitation of these ores for an Iron and Steel Industry. The limestone and dolomite resources of the area were also investigated for the purpose.

Palaeozoic Sedimentology of the Southeastern part of the Kufra Basin, Libya: a model for oil Exploration

Brian R. Turner

The Palaeozoic succession in the southeastern part of the Kufra Basin, Libya, has been divided into 10 sedimentary facies representing fluvial, tidal, subtidal, shoreface and marine shelf depositional environments. Repetition of facies is attributed to coastline interaction with a braided alluvial plain. During active fluvial input the depositional system prograded seaward due to a switch in the depositional loci or increase in regional tectonism. The abundance of deformed cross-beds in the fluvial deposits, inferred to have resulted from the action of current drag on a sand bed liquefied by earthquake shocks favours the latter interpretation. Inactivity of the fluvial system due to decrease in regional tectonism resulted in marine transgression and drowning of the coastline. The lack of preserved barrier complexes and presence of subtidal sand shoals and tidal flat sequences indicates a high tidal range (macrotidal > 4m), possibly analogous to contemporary macrotidal coastlines such as the North Sea coast of Germany.

Continental reconstructions indicate that throughout most of Palaeozoic time the Kufra Basin lay in the belt of prevailing westerly winds (between latitudes 35° and 60°S). However, since protection from these winds was afforded by two areas of positive relief centred on Tibesti and Jebel Uwaynat, and since wave power depends on wind fetch, it is unlikely that the Kufra coastline was buffeted by high winds and waves under normal conditions.

The presence of strong tidal currents implies that the Kufra Basin was connected with an open (Tethys), probably through the Qattara embayment in the northeast. The general lack of silts and muds is attributed to the nature of the fluvial input, wave and tidal processes in nearshore areas and the hydrographic setting of the basin.

The only suitable hydrocarbon source rocks in the basin are the offshore shelf facies of the Silurian Tannezouft Formation; although this is thin, has an immature carbon content, and coincides with few suitable structures.

One exception occurs in the northwest where structure, local increase in thickness at depth (2000 m±) and presence of reservoir rocks provide one of the few petroleum prospects in the basin; elsewhere conditions are generally unsuitable. Stratigraphic relations indicate that the Palaeozoic succession in the southeast part of the basin forms the exposed limb of a broad synclinal structure trending northeast-southwest. Faulting along this limb has exposed hitherto unrecognised Cambro-Ordovician sediments but hydrocarbon entrapment along the faulted limb of the fold is unlikely due to inadequate impermeable seal rocks and the generally small amount of displacement along faults compared to thickness of reservoir sands.

Because few structures coincide with depositional facies containing optimum reservoirs, stratigraphic traps become important as sites of oil and gas accumulation. However, the facies sequence lacks any major progradational deltaic succession or significant transgressive wedges, and since little mud was deposited in the basin there are few effective seals for sand reservoirs and no interfingering of sands and muds typical of multipay reservoirs.

Facies changes and depositional pinch-out of sands amenable to stratigraphic entrapment are infrequent and generally small and localised with little potential production for exploration incentive, especially in view of the distance from Kufra to the nearest sea terminal, some 1000 km to the northwest. Depositional pinch-outs may exist in the Cambro-Ordovician succession of Jebel Archenu when traced northwards into the subsurface, although they would require extensive drilling to prove.

Meteorite Impact Structures, Southeast Libya

James R. Underwood & Edward P. Fisk

In southeast Libya two circular structures 80 km apart have been identified as meteorite impact structures because of: (1) structural geometry, (2) style of deformation,

and (3) microscopic evidence of high-pressure shock metamorphism of quartz grains. The structures are designated, informally, the BP structure (2.8 km diameter; lat 25°19'N and long 24°20'E) and the Oasis structure (11.5 km diameter; lat 24°35'N and long 24°24'E).

Although no meteorite fragments, shatter cones, impact glass, Ni-Fe spherules, or megascopic breccias were found at either site, samples of sandstone from both structures show widespread shock metamorphic effects in quartz, e.g. cleavage and planar features (shock lamellae) with prominent orientations in the (0001), (1122), and (1011) planes and less prominent orientations in the (1013) and (1012) planes. The Libyan samples show orientations of shock lamellae that are similar to those in quartz from shocked Coconino Sandstone from Meteor Crater, Arizona. Dislocated quartz grains are common, and interstitial brown glass, similar to Fladen from other impact structures, occurs in some samples (French and others, 1972, 1974).

These structures were detected originally on orbital images (Kohman and others, 1976), and the smaller one was described by Martin (1969) who suggested it might be of meteoritic origin. The structures lie 125-165 km northeast of Kufra oasis where surface rock is quartz conglomerate, sandstone, and siltstone of the continental Nubian Sandstone (Lower Cretaceous). Subsurface geology of the Kufra basin is virtually unknown, but lithology of outcrops at the margins do not suggest the presence in the basin of rock that could produce the structures by diapiric deformation. The nearest surface occurrence of igneous rocks is 200 km to the south in the area of Jebel Arkenu and Jebel Awenat (Goudarzi, 1970).

Concentric circular ridges of deformed rock that compose the structures rise as much as 100 m above the surrounding desert plain and contrast in form with the buttes, mesas, and northwest trending ridges typical of the region. Although in lithology and intensity of deformation the structures are similar, the smaller one has a rim syncline and a distinct central block or peak, whereas the larger one does not. In both structures, dips range from zero to vertical; some beds are overturned. Faults are not conspicuous; most have displacements less than 20 m and

are related to folds which characteristically have gently plunging axes tangential to the structures. Lack of marker beds and obliteration of texture and bedding by extensive iron-oxide impregnation limit stratigraphic correlation and structural interpretation. The structures are dated only as post-Nubian; their close spacing and their similar weathering and erosional state suggest that they were formed simultaneously or nearly so, by double impact.

The occurrence of the unique and distinctive Libyan Desert glass, discovered in 1932, lies only 150 km east of the Libyan structures. The proximity of the structures to the glass site and the lack of disturbed strata of Nubian Sandstone in the area of the glass occurrence, suggest that the glass may have been produced by the impact events that produced the structures. The fission track method has been used to date the Libyan Desert glass at 28 m.y. (Storzer and Wagner, 1971).

Micropaleontologic record of the Messinian event at Esso Libya Inc. Well B1-NC35A on the Pelagian Platform

J. E. van Hinte, J. P. Colin and R. Lehmann

Esso Libya Inc. drilled well B1-NC35A in 1977 about 140 km N.E. of Tripoli offshore in 460 meters waterdepth. Sidewall cores were shot from the upper 500 meters below mudline because no cuttings had been recovered from that interval. The cores show the presence of evaporite between marls.

The marl above the evaporite is of Early Pliocene age with *Globorotalia margaritae* Bolli & Bermudez and a middle to upper bathyal origin is suggested by a high plankton/henthos ratio and the presence of such forms as *Uvigerina spinicostata* Cushman & Jarvis *Bulimina aculeata* d'Orbigny. The marl below the evaporite has primitive *Rectuvigerina cretensis* (Meulenkamp) and leftcoiling *Globorotalia acostaensis* Blow which suggest a middle Torton age, it probably originated is somewhat shallower depths (upper bathyal to outer peritic) as plankton is less dominant than above and *U. peregrina* Cushman and *B. striata* d'Orbigny represent the genera *Uvigerina* and *Bulimina*.

A similar situation was found in cuttings of a nearby well where the interval with

evaporites yielded the characteristic "Lago Mare" fauna of the mediterranean Messinian. The reasonable assumption that the evaporite at the B1 well also is of Messinian age implies the presence of an unconformity at its base.

This paper describes some key Foraminifera and Ostracoda recovered from the sidewall cores, speculates on the importance and the nature of the unconformity and concludes that approximately 500 meters of sediment were eroded as a result of a significant drop in sea-level.

Paleogene Vertebrate Fauna and Regressive Sediments of Dor el Talha, Southern Sirte Basin, Libya

A. Wight

As the result of two expeditions led by Dr. R.J.G. Savage to Dor el Talha escarpment, in 1968 and 1969, a fauna comprising twenty-one different vertebrate genera has been collected, representing mammals, reptiles and fish. The vertebrates were found all along the 150 km length of the escarpment, and this paper describes fossils found at thirty four localities. The escarpment extends in an east-west direction from the southeastern corner of the Haroudj basalt massif, and forms the northern limit of the Serir Tibesti. The sedimentary sequence exposed in the escarpment consists of a basal marine unit with a coquina of oyster shells, followed, upwards by approximately 40 metres of marine grey-green siltstones and calcilitites of near-shore marine origin. These beds are overlain by 35 metres of rhythmically-alternating white sandstones, green siltstones and claystones representing fluvial channel, point bar and overbank deposition. Capping this is up to 20 metres of mature, yellow-brown sandstone, possibly of fluvial or lacustrine origin.

The age of the 75-100 metre thick exposures is thought to range from Upper Eocene at the base, to Lower Oligocene at the top, by analogy with the Fayum deposits of Egypt and also by their stratigraphical relationship with the Paleocene to Middle Eocene sections described by Furst from the other three margins of the Serir Tibesti.

Stratigraphic and Micropaleontologic expression of the mediterranean late Miocene (Messinian) regression and early Pliocene (Zanclean) transgression in Northeastern Tunisia

Stephen K. Wiman

Evaporitic sediments deposited during the Late Miocene (Messinian) salinity crisis are exposed in northeastern Tunisia near the village of Raf-Raf and at Diebel Kechabta, south of Bizerte. The Upper Miocene Oued bel Khedim Formation exposed there consists of bedded and nodular anhydrite, fresh-water limestone and diatomites, with intercalations of silty marls which have yielded rare shallow-water benthic foraminifera, ostracodes and reworked planktic foraminifera. The Oued bel Khedim Formation is underlain by shallow-water marls assigned to the Tortonian Kechabta Formation.

The Messinian sequence is unconformably overlain at these localities by microfossiliferous marls of the Lower Pliocene (Zanclean) Raf-Raf Formation. Benthic foraminiferal assemblages indicate the Raf-Raf Formation marls exposed north of the Dorsale (Tunisian Atlas) were deposited at inner to middle shelf depths.

South of the Tunisian Dorsale the stratigraphic expression of the Messinian regression is predictably dissimilar. The youngest Miocene sediments from south of the Dorsale are Saouaf Formation marls of early Tortonian age exposed at the extremity of the Cap Bon peninsula. The Messinian on Cap Bon is represented by continental deposits of the Segui Formation. Highly microfossiliferous Raf-Raf Formation marls are well exposed in quarries, streams and road-cuts in the Nabeul-Hammamet area and provide information concerning the nature of the Early Pliocene transgression on Cap Bon. The oldest Raf-Raf Formation deposits on Cap Bon are assigned to the *Globorotalia margaritae margaritae* interval-zone (M P1 2 of Cita, 1975). Well preserved and diverse benthic foraminiferal assemblages have been used to estimate that Lower Pliocene Raf-Raf Formation marls accumulated at outer shelf to upper slope paleodepths on Cap Bon, and planktic foraminifera confirm that the Nabeul-Hammamet basin persisted through at least early Piacenzian time.

Stratigraphic expression of evaporitic and continental sediments of Late Miocene age is found on opposing flanks of the Tunisian Dorsale. The contrasts in the character of the Mio-Pliocene boundary interval in these two paleobasins (about 100 km apart) are due to their disparate basin margin positions at the beginning of the Messinian. The paleogeographic picture is further complicated by tectonic activity which has persisted from at least Middle Miocene to Pleistocene time along the Dorsale. Creation of the relatively deep Pliocene Nabeul-Hammamet basin is a tectonic event which is probably Messinian in age, for no basin of such depths is known to have existed there earlier in the Miocene.

Zirconium contents in Jabal Nefusa phonolites and distribution of zirconium in the rock forming silicate phases

L. Wirth

Zirconium contents were determined on 17 phonolites of the northeast Jabal Nefusa volcano, with help of X-ray fluorescence.

The remarkable high values (600 to 2400 ppm) correspond very well with the data given by Almond et al (1974), completing them to the more eastern part of the phonolite occurrences.

Furthermore, the distribution of zirconium within the different rock forming silicate phases was investigated by means of electron microprobe.

The contents and the location of zirconium seem to have significance for discussions of the development of the Jabal Nefusa magmas.

Hydrogeology of Mesozoic Aquifers in Western part of wadi al ajal

Marek Zaluski & Kamal E. Sadek

The Government Agricultural Development Project has been executed in Wadi Al Ajal areas since 1975.

Nearly two hundred water wells of the depth ranged from 200 m to 500 m have been located in the narrow strip of 100 km long, in the western part of the valley and drilled for that project.

The Libyan Office named Consulting Office for Drilling and Water Investigations was requested to carry on the reporting job for that project, including subsequent

comprehensive hydrogeological elaboration. Basing on the data collected during execution of above mentioned project, the hydrogeological conditions of the area in subject have been described in that article and presented on the background of general knowledge of region. There is a great deal of emphasis on the chemical composition of water. The rough model of ground water circulation in that region is also presented in the article.

The paper consists of 14 normal typed pages with two figures and two tables.

Hydrogeology and Hydrology of the Joufrah Area

Husni Zeino-Mahmalat

Hydrogeological studies, hydrological research based on flow and pump tests and observations of the wells in the Joufrah-socna area show that *adequate quantities of ground-water* can be extracted from the upper Cretaceous artesian dolomite aquifer for the Joufrah agricultural project. The long term drawdown in the project water wells is acceptable and the figures calculated after completion of drilling and research at the Joufrah construction site correspond approximately to the values reported earlier as well as to the figures used for the design of production wells, pumps and power supply. An analysis of research results shows that the values used in the design have been derived from realistic calculations.

The Joufrah project area is located in a *hydrogeologically very complex area* on the intersection of several structural and stratigraphic trends: the Sirte, Homra and Morzog Basins, the Hun Graben, and the Djebel Es Sawda volcanic massif. The geologic sections show wide distribution of a basin rim facies with predominant sandstones and carbonates comprising important aquifers. The widely distributed Paleozoic sandstone aquifers of the Morzog and Homra basins extend to Joufrah and connect this area with these basins. The Joufrah area is probably part of a very large, pressure connected hydraulic system comprising most of the Fezzan Region of Libya. Tectonically controlled permeability channels as well as aquifer contacts are believed to connect the Morzog Basin east of the Gargaf High with the Joufrah area along a pressure gradient.

An inflow compensating ground-water extraction in the Joufrah - Socna area is therefore expected. Hydrological evidence for a hydraulic system extending beyond the distribution of the Joufrah dolomite aquifer has also been presented.

The section at Joufrah commences at the top with Quaternary unconsolidated rocks comprising an unconfined, shallow aquifer of limited capacity and poor water quality.

The *upper Cretaceous dolomite and limestone artesian aquifer*, which is used for the Joufrah and Socna projects, is encountered below a 100 to 150 m thick cover of partly calcareous shales with a transition zone of minor carbonate aquifer beds at the base of shales.

The main aquifer interval of about 45 m thickness consists of fractured carbonates with porosity and permeability strongly enhanced by solution (Karst conditions) especially in the Socna area. The aquifer shows good permeabilities throughout with local zones of extremely high permeability. The pressure level had been influenced already at the beginning of the Joufrah project by the Socna production and was encountered at about 338 m above sea level. With ground elevations ground 300 to 330 m, free artesian flow was obtained in the Joufrah and Socna wells. Flow rates varied, some flows exceeding 500 m³/h were reported.

To explore the section below the main artesian aquifer the deep research well J -18 (total depth 702 m) and a deep piezometer J - 18Z were drilled. Below the main artesian aquifer, a thin, undifferentiated Cretaceous section was encountered. It represents probably the onlap of the Cretaceous on the Gargaf High. From 226 to 273 m a non-permeable shale-siltstone section yielded an upper Paleozoic, probably Devonian, microfauna. This section is underlain until the total depth of 702 m by a *sandstone aquifer* correlating with the *Cambro-Ordovician* and probably exceeding 500 m in thickness. The basement was not reached in any well of the Joufrah-Socna area.

A vertical connection of the deep (Paleozoic sandstone) and the shallow (upper Cretaceous dolomite) artesian aquifers is expected along fracture zones, such as faults connected with the Hun Graben. These vertical fracture conduits are proved by

surface artesian springs, such as Ain Hammam north-west of Socna (see chapter 10.5). Furthermore, hydrological evidence supports the presence of a zone of low permeability underlying the dolomite aquifer and connecting it with the deep sandstone aquifer.

A *hydrological research program* was initiated by the CAD on the Joufrah construction site, consisting of test well drilling including the deep well J-18 long term flow tests, pressure and well yield monitoring of all Joufrah and Socna wells, and installation of a meteorological station in the Djebl Es Sawda.

The results of the observations and tests were used for calculations of the hydrological aquifer parameters especially the coefficients of transmissibility T and of storage S. The tests had shown a break in drawdown development after about 7 to 10 days of flow in J-10, indicating groundwater sources from different aquifers.

Values of T (in m³/ sec.m) and S have been calculated from numerous tests and also by various methods (Theis, Thieme, Jacob, Chow) from non-steady and steady state flows and recovery during various time intervals. Median values obtained for the main aquifer were $T=2.7 \times 10^2$ and $S=1.1 \times 10^3$ from long term tests, $T=1.4 \times 10^2$ and $S=2.3 \times 10^4$ from short tests. The Paleozoic artesian aquifer showed an average of $T=1.1 \times 10^1$ m³/sec. m. reflecting the thickness of the section, and $S=1.9 \times 10^3$.

For determination of the *long term drawdown* in Joufrah an analog computer model was calculated using the T and S coefficients computed from long term tests. No rainfall recharge was used. The calculated regional drawdowns ranged from 36.4 m and 41.8 m below the present static water table after 50 years.

BIOGRAPHIES

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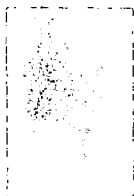
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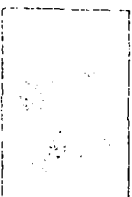
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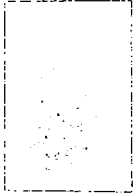
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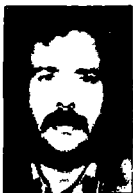
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(قسم الجيولوجيا)



لقد تأسس قسم الجيولوجيا بكلية العلوم سنة ١٩٦٠ م . برئاسة
الدكتور شامبان وكان عضو هيئة التدريس الوحيد وبلغ عدد الطلبة
١٣ طالبا . و يبلغ الآن أعضاء هيئة التدريس بالقسم ١٥ عضواً
وخمسة معيدين ومساعدى بحاث و يبلغ عدد الطلبة ٨٠ طالبا
(باستثناء طلبه السنة الاولى) .

والرئيس الحالى للقسم هو الدكتور المبروك الطاهر ابو سريويل
ومنذ أن تأسس القسم تخرج ٢٨٥ طالبا يشتغلون فى مختلف
الامانات والمؤسسات منهم ٣٠% فى أمانة النفط ، ١٦% فى
امانة السدود والموارد المائية ، ١٥% فى جامعة القانح ، ٨% فى
أمانة الصنعة .

(٨)

(معلومات عن كلية العلوم)

تشمل كلية العلوم الاقسام التالية :

(الرياضيات - الطبيعه - الكيمياء - الحيوان - النبات - الاحياء
الجيولوجيا - الحاسب الالى) .

(أعضاء هيئة التدريس)

بلغ اجمالي أعضاء هيئة التدريس ٢٥٩ عضواً بالكلية منهم ١٥٤ غير

ليبيين .

(الطلبة)

بلغ اجمالي الطلبة بالكلية ٧٦٣ طالبا وطالبة الليبيين ٤٥٤ و

١٦١ طالبة وغير الليبيين ٩٠ طالبا و ٥٨ طالبة .

وكلية العلوم كذلك مسئولة على تدريس المواضيع العلمية التي

لها علاقة بالكليات الاخرى بالجامعة

(المكتبة) :

تحتوي مكتبة الجامعة المركزية حوالى ١٩٥٠٠ مرجع باللغة العربية
وحوالى ١٠٤٠٠ مرجعا باللغة الانجليزية كما أن المكتبة مشتركة
فى حوالى أربعمائه مجلة علمية دوريه .
(الجهاز الادارى وأعضاء هيئة التدريس)

يلغ عدد أعضاء الجهاز الادارى ٩٣٥ عضوا منهم ١١٧ عضوا غير
ليين ينتمون الى ١٠ جنسيات مختلفه ويبلغ أعضاء هيئة التدريس
٧٦٢ عضوا منهم ٤١٠ غير ليين ينتمون الى ١٢ جنسيه مختلفه ه هذا
بالاضافه الى الاساتذه الزائرين البارزين والذين يدعون الى الجامعة
مرارا ولمدد قصيره .
(الطلبه) :

أ- دراسات عليا : ٧٢٤ طالبا موزعين كما يلى :
٥٣٣ يدرسون خارج الجماهيرية وذلك للحصول على شهادات -
الماجستير والدكتوراه .
و ١١٩ معيدا يدرسون فى جامعة الفاتح .
ب- طلبه الكليات : بلغ اجمالى طلبه كليات جامعة الفاتح ٥٤٨٨ و
٤١٥٢ طالبا و ١٣٣٦ طالبه) .
مقارنه ب ١٣٧٤ (١٢١٣ طالبا و ١٦١ طالبه فى السنه -
الدراسيه ١٩٦٩ - ١٩٧٠ م .

(لغة الدراسة)

تدرس جميع العلوم الانسانية باللغة العربية ومعظم باقى العلوم
باللغة الانجليزية كما تدرس الجامعة الآن امكانية تدريس جميع
العلوم باللغة العربية .
(قبول الطلبة ونظام الدراسة)

يتم توجيه الطلبة على كليات الجامعة المختلفه حسب درجاتهم
فى الثانويه العامه وحاجه البلد وامكانية كل كلية وبهذا فان الفرصه
للالتحاق متاحه للجميع .

تتبع كليات العلوم والزراعه والصيدله والطب نظام الفصلين -
الدراسيين فى السنه الواحده (ينتهى الاول فى شهر فبراير والثانى
فى شهر يونيو) بينما تتبع باقى الكليات نظام السنه الدراسيه
الواحده .

(الميزانيه)

منذ أنقسام الجامعة للييه الى جامعتين فان ميزانية جامعة
الفتاح موزعه كما يلى :

السنة	الميزانية السنويه (ملايين الدينارات)	ميزانية التنميه (ملايين الدينارات)
١٩٧٤	٦٦	١٠٠
١٩٧٥	٧٥	٣٦٦
١٩٧٦	٩٦	٢٩٩
١٩٧٧	١١٠	٢٩٠
١٩٧٨	١٤٥	٣٠٠

” حقائق وأرقام حول جامعة الفاتح ”

(الاداره) :

- تدار أمور الجامعة الاداريه شعبيا من خلال اللجنه الشعبيه العليا ويؤسر اللجنه أحد أعضائها يعرف برئيس اللجنه الشعبيه العليا . وتتكون اللجنه الشعبيه كالآتي : —
- رئيس اللجنه الشعبيه العليا .
- وكيلى اللجنه الشعبيه العليا .
- رؤساء اللجان الشعبيه بالكليات المختلفه .
- أمين عام الجامعه .
- ممثل عن أعضاء هيئة التدريس عن كل كلية يختاره أعضاء هيئة التدريس .
- رئيس اتحاد الطلبة .
- طالب عن كل كلية يختاره الطلبة .
- ممثل عن الموظفين والعمال بالجامعة .

(الشهادات) :

- تمنح جامعة الفاتح الشهادات التاليه :
- شهادة البكالوريوس .
- دبلوم على (كليات الهندسه والعلوم والتربيه)
- شهادة الماجستير (الهندسه والعلوم والزراعه والتربيه) .

أطلاقاً من كل هذا تم انشاء الكليات الجديدة التالية لتخدم احتياجات البلاد الانمائية وهي :

- أنشاء كلية الطب فى بنغازى سنة ١٣٩٠هـ / ١٩٧٠م وفى نفس السنة تم ضم كليات الدراسات الاسلامية بالبيضاء فى كلية واحدة تحت أسم كلية اللغة العربية والدراسات الاسلامية .
- أنشئت بطرابلس كلية هندسة النفط والتعدين سنة ١٣٩٢ هـ /

١٩٧٢م .

- فى سنة ١٣٩٣ هـ / ١٩٧٣م . كانت الجامعة الليبية تضم عشرة كليات ولكن التطور الهائل الذى عاشته البلاد خلال الاربع سنوات الاولى من عمر الثورة فى جميع المجالات أدى الى الزيادة الكبيرة فى طالبى العلم على جميع المستويات بما فيها الجامعى مما تطلب تحويل فرعى الجامعة بطرابلس وبنغازى الى جامعتين قائمتين بذاتهما فى شهر أغسطس ١٩٧٣م ضمت جامعة طرابلس آنذاك الكليات المتواجده بطرابلس وجامعة بنغازى التى تعرف الآن بجامعة قاريونس) والتى تضم الكليات الموجودة فى بنغازى والبيضاء - أضيفت بعد ذلك كليات جديدة الى الجامعة - بطرابلس كانت اولها كلية الطب سنة ١٣٩٣ هـ / ١٩٧٣م ثم كلية الصيدله سنة ١٣٩٥هـ / ١٩٧٥م وكلية البيطريه سنة ١٣٩٦ وكلية التربيه (مقرها مدينه سبها) ثم حديثا كلية الهندسة النوويه .

وبهذا اصبحت جامعة الفاتح تضم عشرة كليات .

- فى السابع من ابريل ١٩٧٦ تم تطهير الجامعة شعبيا وأصبحت تعرف بجامعة الفاتح .

" جامعة الفاتح "

(نبذة تاريخية)

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— أنشئت أول جامعة بليبيا سنة ١٣٧٥هـ / ١٩٥٥م تحت اسم  
الجامعة الليبية وكانت نواتها الأولى كلية الآداب أفتتحت  
بعدها كليات عدة في مدن ثلاث وهي ( طرابلس — بنغازى —  
والبيضاء ) .

— وفى سنة ١٣٧٧هـ / ١٩٥٧م . أنشئت كلية العلوم بطرابلس  
( أصبحت هذه الكلية فيها بعد نواة لجامعة الفاتح ) وفى  
نفس السنة أفتتحت كلية التجارة والاقتصاد بينغازى .

— وفى سنة ١٣٨٢هـ / ١٩٦٢م . أنشئت كلية الحقوق بينغازى .

— فى سنة ١٣٨٦هـ / ١٩٦٦م . أنشئت كلية الزراعة بطرابلس .

— فى سنة ١٣٨٧هـ / ١٩٦٧م أنضمت الى الجامعة الليبية  
بطرابلس كلتي الدراسات العليا وكلية المعلمين العليا تحت  
اسم كلية الهندسة وكلية التربية واللغات سبق وأن أنشئت لمساعدة  
منظمه اليونسيكو .

— سنة ١٣٨٩هـ / ١٩٦٩م . كانت سنة التحول الثورى فى تطوير  
الجامعة . . . فباندلاع ثوره الفاتح من سبتمبر واهتمامها بل لتعليم  
كان لواما أن تحظى الجامعة بالرعاية اللازمه حيث تم التوسع  
فى توفير مستلزماتها المختلفه وتمت مراجعة المناهج التعليميه  
لتخدم الجانبين العلمى والثقافى لتتفاعل الجامعة مع المجتمع  
غير بعيد عن تخدم مصالحه متخلصه من العزله داخل اسوارها  
مقدمة الى المجتمع جيل مؤمن بعروته واصالته ومجتمعهم .



هذا الذى لولا تكاتف جهود أقسام وموظفى هذه المؤسسة  
لما ظهر للموجود .

كما نتقدم بشكرنا الى كل الذين ساهموا فى انجاح هذه -  
الحلقة وهم :-

- قسم الجيولوجيا بكلية العلوم بجامعة قاريونس ببنغازى لمساهمته  
فى تنظيم وقيادة رحلة الجبل الاخضر .
- شركة الخليج للاستكشاف لدورهم فى تنظيم وانجاح رحلة الجبل  
الاخضر .
- مركز البحوث الصناعية لمساعدتهم وتقديمهم الخرائط والمطبوعات  
الاخرى لمساعدتهم فى تنظيم رحلة جبل قرقاف .
- الجمعية الليبية لعلوم الارض .
- أمانة الخارجية لمساعدتها فى استصدار تأشيرات الدخول  
للمشاركين فى هذه الحلقة عن طريق سفارتنا بالخارج .
- أمانة الداخلية لمساعدتها فى تسهيل اجراءات الدخول .
- أمانة الاعلام والثقافة لتقديم المطبوعات اللازمة .
- أمانة السدود والموارد المائيه لمشاركتها فى تنظيم وقيادة رحلة  
الجبل الاخضر .
- شركة الواحه للنفط .
- معهد الانماء العربى لطبعه كتيب رحلة جبل نفوسه .
- مؤسسة الطاقة الذريه .

## • الحلقات الدراسية عن جيولوجية ليبيا •

في سنة ١٩٦٩ م • نظم قسم الجيولوجيا بكلية العلوم بجامعة الفاتح ( الجامعة الليبية آنذاك ) الحلقة الدراسية الاولى عن جيولوجية ليبيا • وقد ترأس هذا اللقاء الدكتور خيرى الصغير الذى كان عميدا لكلية العلوم وقد شملت اللجنة التحضيرية لتلك الحلقة أعضاء هيئة التدريس بقسم الجيولوجيا الذى كان يرأسه الدكتور كارلايل جزاى •

وقد كانت الاستجابة مرضية للحلقة الدراسية الاولى حيث القى بها ثلاثة وثلاثون بحثا تم نشر تسعة وعشرون منها فى كتاب بعنوان جيولوجية ليبيا لقى توزيعه اقبالا كبيرا على الصعدين المحلى والعالمى •

ومنذ سنة ١٩٦٩ م • تم تجميع كمية هائلة من المعلومات التى أضافت الكثير الى معرفتنا بجيولوجية البلاد ••••• كما حدث تقدم ملحوظ فى النظريات وطرق البحث الجيولوجية ومن ثم كان قرار انعقاد هذه الحلقة الدراسية العالمية لاتاحة الفرص للمناقشه الهادفه ونشر ما جد فى هذا المضمار •

وقد كانت الاستجابة لهذه الحلقة أكثر تشجيعا حيث سيحضر هذا اللقاء أكثر من ثلاثمائه جيولوجى يمثلون جامعات ومؤسسات جيولوجية عدة ينتمون الى ثلاثة وعشرون بلدا •

وسيلقى مائه وعشرة من هؤلاء بحوثا تناول جيولوجية الجماهيرية وبهذه المناسبة نتقدم بجزيل شكرنا لجامعة الفاتح لرعايتها لقائنا

• بسم الله الرحمن الرحيم •  
مرحبا بكم في جامعة الفاتح بطرابلس

ترحب بكم جامعة الفاتح في حلقتها الدراسية الثانية  
عن جيولوجية ليبيا متمنين لكم إقامة طيبة ومثمرة علمية  
الصعيدين العلمي والاجتماعي في تجمعكم العالمي هذا  
بأرض الجماهيرية •

وقسم الجيولوجيا بكلية العلوم الذي يتشرف بتنظيم هذا  
• للقاء ليأمل أن يجعله ذكرى طيبة للجميع •



الجامعة المصرية

كلية العلوم

جامعة أسيوط

الكلية العلمية

طرابلس ١٩٧٨

طرابلس ١٩٧٨

كلية العلوم، الجامعة المصرية، الليبية الشعبية الاشتراكية



الجامعة المصرية

جامعة أسيوط

كلية العلوم

قسم الجيولوجيا

سنة ١٩٧٨ م

طرابلس، الجمهورية العربية السورية الاشتراكية