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Paleozoic Geodynamic Evolution of the Northeastern African Epicratonic Basins: An Outline

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8 Text-Figures and 1 Table

Africa
Epicratonic Basin
Evolution
Transgression
Regression
Tectonics

Contents

Die geodynamische Entwicklung des nordostafrikanischen epikratonischen Beckens: Ein Überblick

Zusammenfassung

Die geodynamische Geschichte des Paläozoikums des nordöstlichen Randes Afrikas wird zusammengefasst. Die wesentlichen Etappen der paläogeographischen, tektonischen und magmatischen Entwicklung des Randes werden beschrieben. Das Vorhandensein von Lücken in den Sedimentabfolgen wird hervorgehoben wie auch ihre tektonische Bedeutung. Ein tektonostratigraphisches Schema wird vorgeschlagen.

Abstract

The geodynamic history of the Paleozoic northeastern African margin is summarized. The main stages of the paleogeographic, tectonic and magmatic evolution of the margin are described. The presence of hiatuses in the sedimentary sequences and their tectonic significance are stressed. A tectonostratigraphic chart is presented.

1. Introduction

This paper summarizes the Cambrian to Permian geodynamic history of the large basins developed along the northeastern African epicratonic margin after the Pan-African orogeny (Text-Fig. 1). These basins display sedimentary intervals interrupted by hiatuses reflecting tectonic instability. A set of paleogeographic/paleotectonic maps is presented (Text-Figs. 2–8) illustrating the main stages of the evolution of the margin. Each map shows

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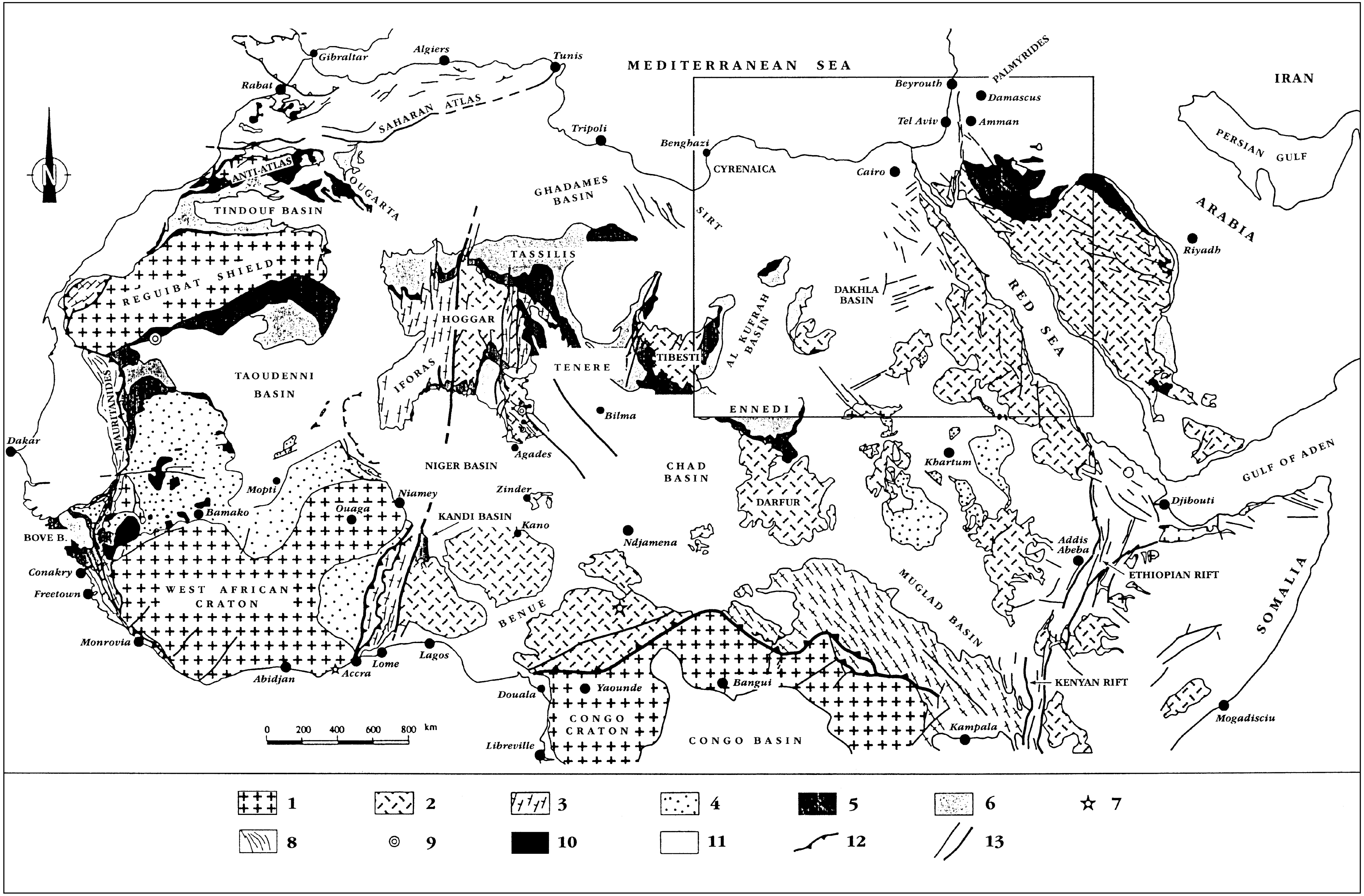


Text-Fig. 1.
Geological location map (modified from M. KONATE [1996]).
1 = Early Proterozoic craton; 2 = PanAfrican rejuvenated basement; 3 = PanAfrican belt; 4 = Late Precambrian sediments; 5 = Early Paleozoic; 6 = Late Paleozoic; 7 = Accra and northern Cameroon Paleozoic basins; 8 = Mauritanides/Variscan belt; 9 = post-orogenic intrusion; 10 = Liassic dolerites; 11 = Mesozoic/Cenozoic; 12 = PanAfrican thrust; 13 = Faults. Insert frame shows location of Text-Figs. 2 to 8.

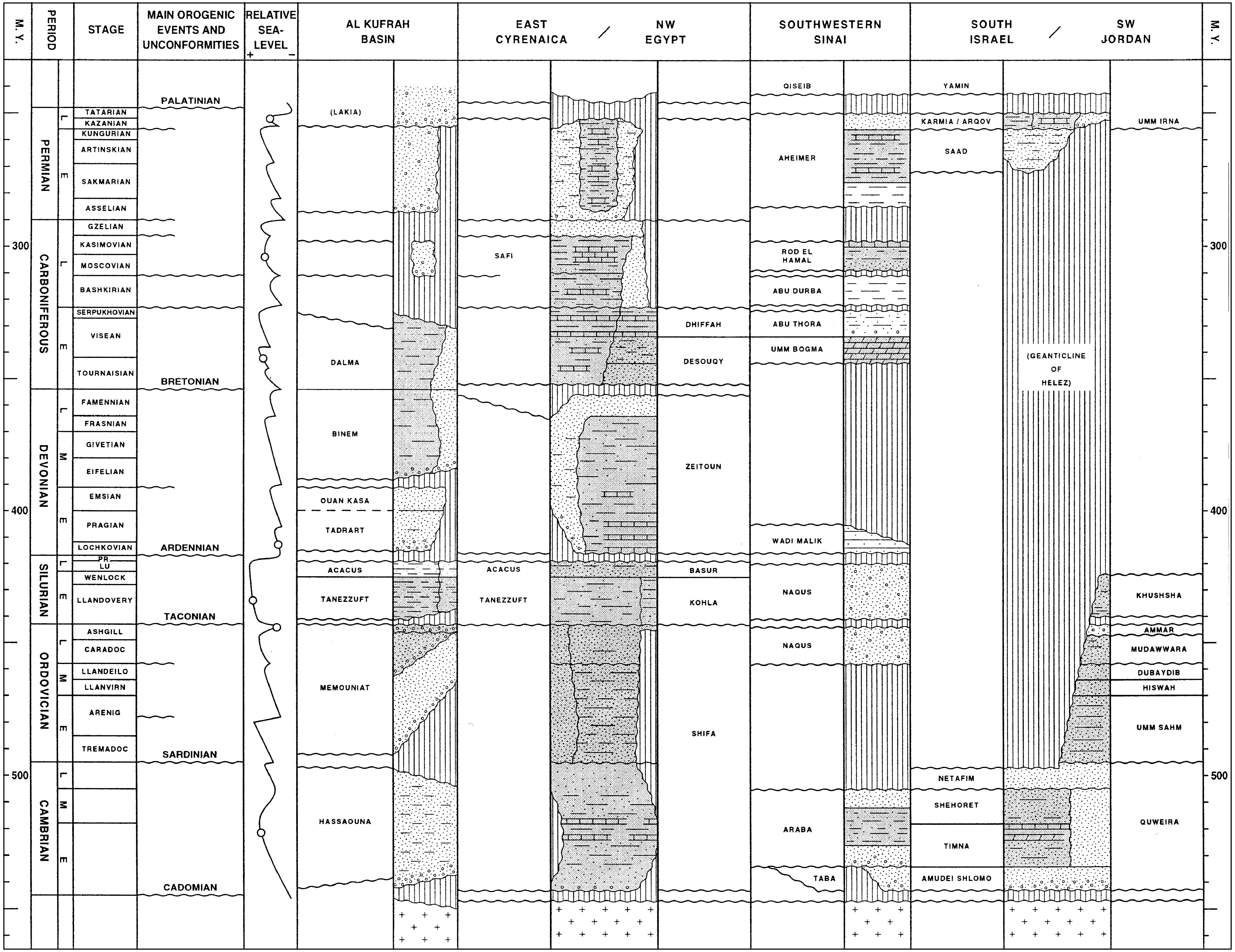
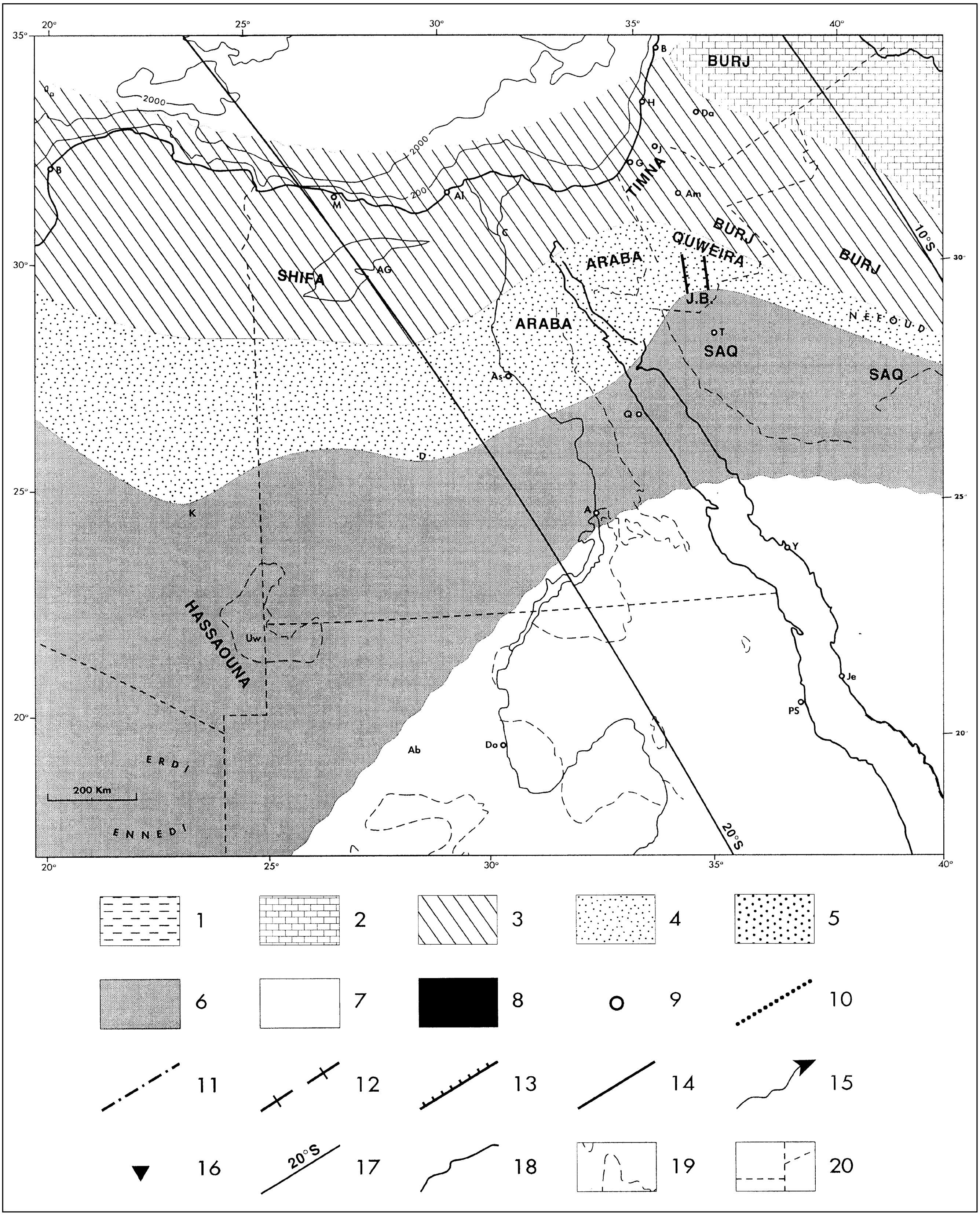


Table 1.
Lithostratigraphic and tectonic correlation chart of Paleozoic sediments of some northeastern African and northwestern Arabian basins.
Time scale is from GRADSTEIN & OGG (1996).
Grey shading indicates marine formation. Hatching indicates stratigraphic hiatuses (gap or erosion).



Text-Fig. 2.
Late Early Cambrian (523–519 Ma) paleogeographic and paleotectonic map.
Names of the main lithostratigraphic units are given (capital letters).
1 = deep basin; 2 = carbonate platform; 3 = mixed platform; 4 = terrigenous platform; 5 = fluviatile-deltaic environment; 6 = fluviatile-lacustrine environment; 7 = exposed land; 8 = volcanics; 9 = alkaline anorogenic complex; 10 = dyke; 11 = depocenter; 12 = uplifted arch; 13 = active normal fault; 14 = fault; 15 = direction of sediment supply from paleoriver; 16 = tillite; 17 = paleo-meridian; 18 = present day shoreline; 19 = present day Precambrian basement/sedimentary cover limit; 20 = state boundary.
A = Asswan; Ab = Djebel Abiod; Al = Alexandria; Am = Amman; As = Assyut; AG = Abu Gharadig; B = Beirut; Be = Benghazi; C = Cairo; D = Dakhla; Da = Damascus; Do = Dongola; G = Gaza; H = Haifa; J = Jerusalem; Je = Jeddah; JB = Jafr Basin; K = Al Kufrah; Kh = Khartoum; M = Matruh; Q = Quseir; PS = Port Sudan; T = Tabuk; Uw = Uweinat; Y = Yambu.

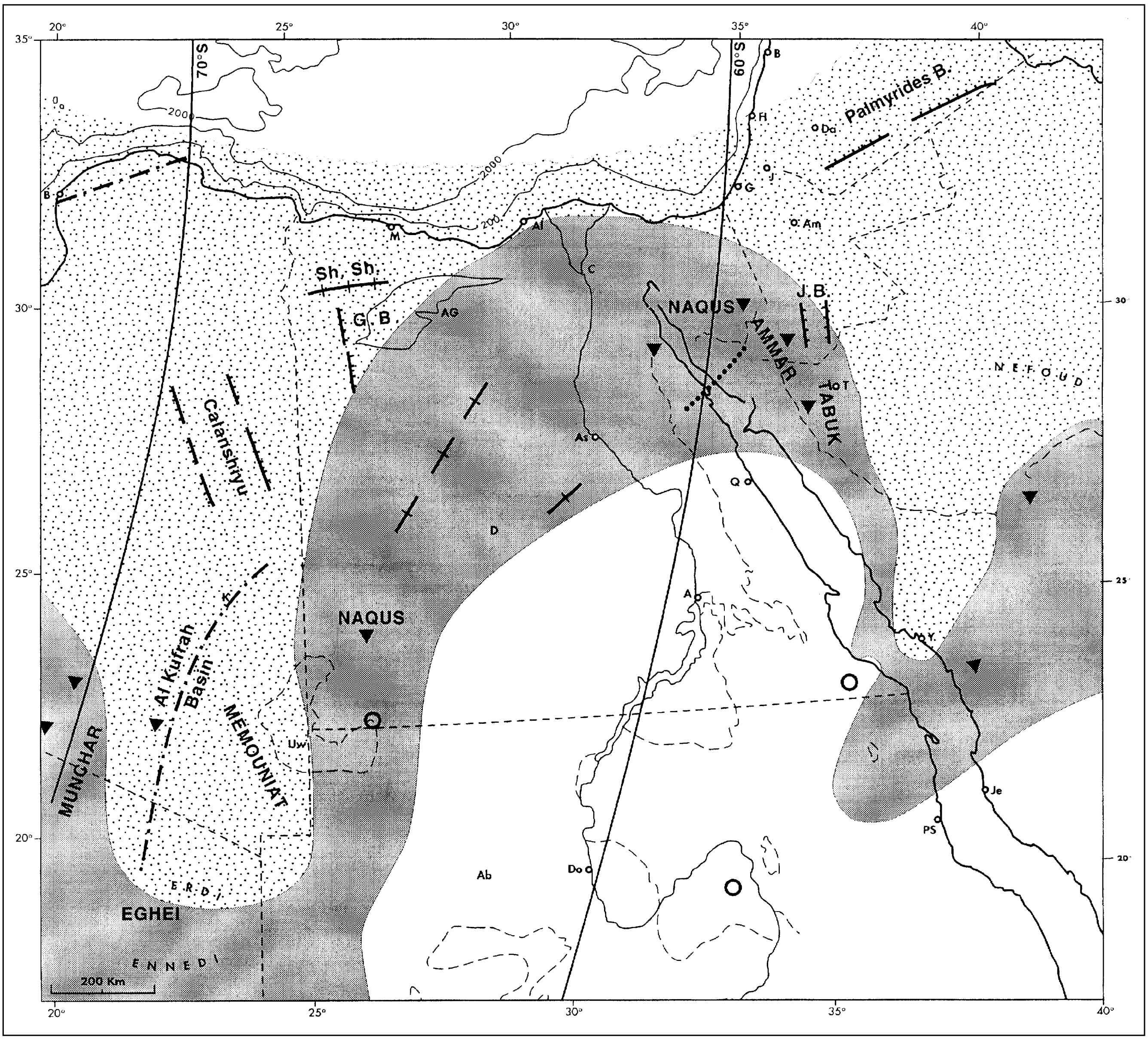
supposed paleolatitudes, paleoenvironmental domains distribution, the location and name of the main preserved lithological formations, active tectonic trends, and magmatic occurrences. Comments on these maps, and on transitions between them are given. Table 1 summarizes some of the main, presently preserved sequences, highlighting the hiatuses. The time scale used is that of GRADSTEIN & OGG (1996).

2. Late Early Cambrian (523–519 Ma)

(Text-Fig. 2)

The oldest dated sediments are thin, dominantly terrigenous formations outcroping in northeastern Egypt and eastwards. These formations locally conformably overlie coarse, probably earliest Cambrian clastics, e.g. the Taba Fm. of central eastern Sinai. They correspond to the oldest marine transgression across the eroded post-PanAfrican topographies along the northern African-Arabian margin. A mixed platform developed along the margin, as exemplified by the Timna Fm. of southern Israel; it consists of sandstones, dolomites, dolomitic limestones and shales, with early Cambrian trilobites (HIRSCH, 1990). Similar facies, including rare carbonates, are reported in wells drilled in the northern Western Desert (Shifa Fm.). Southwards, the shallow marine sandstones of the Araba Fm., containing abundant tribolite tracks (Cruziana), were deposited. A flat continental domain with large fluviatile basins, extended from southern Libya to northern Saudi Arabia. Continental sandstones are preserved in some basins, e.g. the Kufrah and Dakhla basins. The non-marine sandstones of the Saq Fm., palynologically dated as early Cambrian to early Ordovician (KEEGAN et al., 1990), are present from Jordan to north-central Arabia (STUMP et al., 1995).

During the Mid-Late Cambrian, terrigenous facies developed along the platform, probably connected with a marine regression increasing by the end of the Cambrian. The brief drop in sea-level often registered along the African margin probably reflects, in part, regional topographic elevations caused by gentle tectonic deformation



Text-Fig. 3.
Late Ashgill (latest Ordovician, ca. 444 Ma) paleogeographic and paleotectonic map.
Same legend as Text-Fig. 2. GB = Ghazalat Basin; Sh Sh = Sharib Sheiba.

(FABRE, 1988). This Cambrian/Ordovician transition ("Sardinian") tectonic event was responsible for systematic hiatuses or slight unconformities in the sedimentary sequences.

A marine transgression during the Tremadoc is indicated in southwestern Jordan (BEYDOUN et al., 1994). However, terrigenous facies, palynologically dated (e.g. by MOLYNEUX & PARIS, 1985), were predominant during the Early and Mid Ordovician. A pre-Caradoc tectonic event (FABRE, 1988) was ubiquitous though gentle.

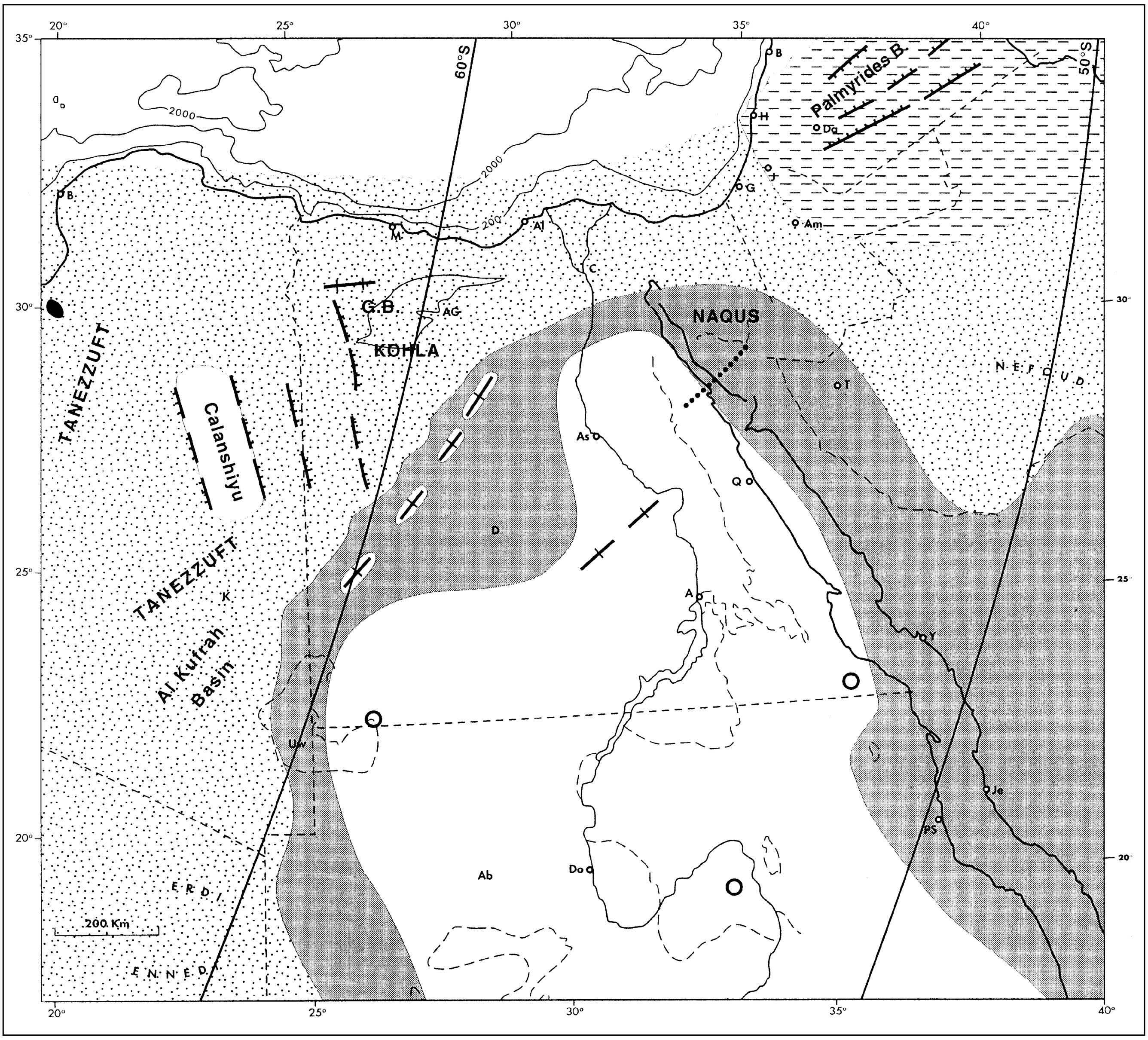
3. Late Ashgill (latest Ordovician, ~444 Ma)

(Text-Fig. 3)

The latest Ordovician was a period of major glaciation in northern Africa, leading to low sea-level. The 100–200 m thick, white fluvio-glacial sandstones of the Naqus Fm., including quartz pebbles as dropstones and locally coarse tillites, was deposited from Uweinat area to Sinai and southwestern Jordan. Similar facies extend westward into the Chad-Libya confines and, eastward fringe the Nefoud Basin to the South. Northern Sudan and southern Egypt were exposed lands. Shallow marine terrigenous gulfs extended into eastern Libya and northern Saudi Arabia.

Some magmatic bodies were intruded. These include a stratigraphically dated NE-SW trending granitic dyke in southern Sinai, anorogenic complexes in Uweinat (SCHANDELMEIER et al., 1983) and Nubia (SCHANDELMEIER & REYNOLDS, 1997), and volcanic and magmatic rocks in western, central and eastern Sirt Basin (WENNEKERS et al., 1996). The very frequent presence of unconformities on both top and bottom of the latest Ordovician formations has been taken to reflect "Taconian" events (ABED et al., 1983; STUMP et al., 1995; WENNEKERS et al., 1996). The Ordovician tectonic instability is also evidenced by the initiation of large structures such as

a) the subsident basins of Al Kufrah (>1200 m), Ghazalat and the northeastern Libyan margin (WENNEKERS et al., 1996), and



Text-Fig. 4.
Llandovery (Early Silurian, ca. 413 Ma) paleogeographic and paleotectonic map.
Same legend as Text-Fig. 2. GB = Ghazalat Basin.

b) the uplifted arches of Calanshiyu, Bahariya and Sharib Sheiba (KEELEY, 1989; GUIRAUD et al., in press).

4. Llandovery (Early Silurian, ~434 Ma)

(Text-Fig. 4)

The Llandovery was characterised by global high sea-level, accompanied by a major transgression on the northern African and Arabian platforms. Shallow marine domains developed west and east from Egypt; it was largely exposed by this time. Graptolite shales were deposited in Libya (Tanezzuft Fm.), in northwestern Egypt (Kohla Fm.) and in northern and eastern Arabia (Qusaiba Fm.). A sandstone belt fringed the shorelines; fluviatile basins occurred in the continental domain. The magmatic activity was very similar to that experienced during the latest Ordovician. Subsidence seems to have decreased.

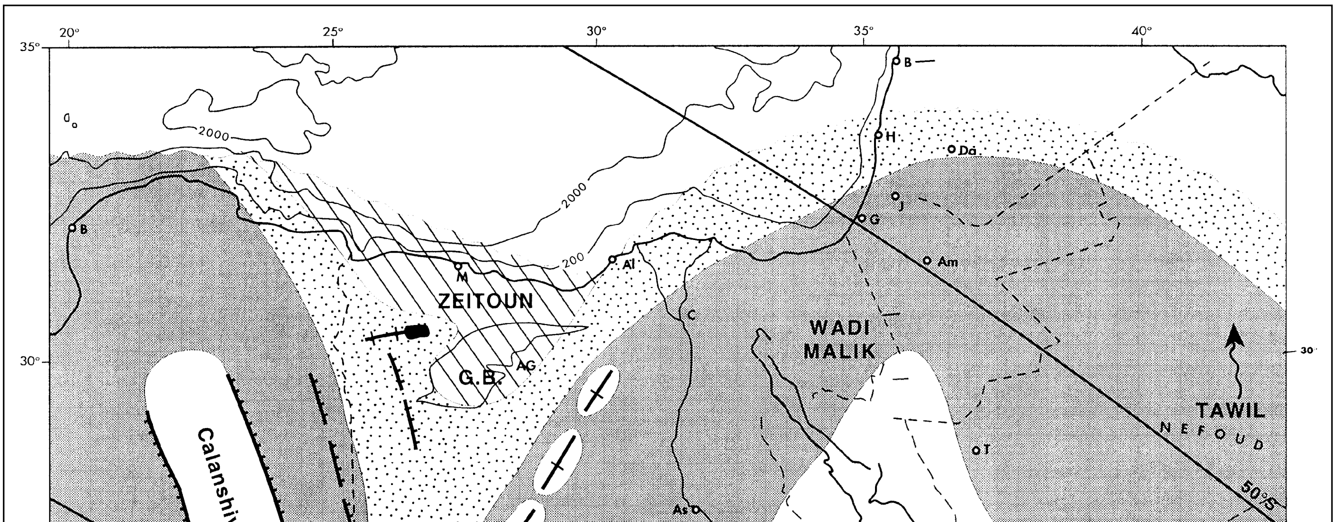
During the late Silurian sandstone deposition dominated prior to gentle tectonic activity ("Acadian" or "Ardennian" event), expressed by frequent latest Silurian–earliest Devonian hiatuses and unconformities (STUMP et al., 1995; WENNEKERS et al., 1996; SEMTER et al., 1997).

5. Late Lochkovian (Early Devonian, ~413 Ma)

(Text-Fig. 5)

Low sea-levels characterise the Early Devonian. The marine domain was restricted to northwestern Egypt where a shallow terrigenous to mixed platform, palynologically dated (GUEINN & RASUL, 1986) persisted (Zeitoun Fm. of the Ghazalat Basin). In the continental domain, the Kufrah Basin was active (Tadrart Fm.) with rivers flooding toward the north and feeding a huge delta in the Kufrah area (GRIGNANI et al., 1991). The Dakhla Basin persisted in Southern Egypt. Fluviatile environments prevailed in northwestern Arabia (Nefoud Basin).

Some magmatic activity is reported from Nubia (alkaline complexes) and along the Sheiba High of northwestern Egypt (flow basalts) (MENEISY, 1990). Gentle tectonic activity occurred; it was responsible for the uplift of the Calan-



Text-Fig. 5.
Late Lochkovian (Early Devonian, ca. 413 Ma) paleogeographic and paleotectonic map.
Same legend as Text-Fig. 2. GB = Ghazalat Basin; Ga B = Garara Basin; SNB = South Nile Basin.

shiyu and Bahariya-Uweinat arches and slight subsidence of the Ghazalat Basin.

During the Middle and Late Devonian a limited transgression accompanied by deposition of limestones and shales, occurred in the Ghazalat Basin; it was followed by a regression apparently briefly amplified around the Devonian-Carboniferous boundary. Block tilting or domal uplifts occurred in many areas. The "Geanticline of Helez", extending from Sinai to the western Palmyrides, formed at that time (GVIRTZMAN & WEISSBROD, 1985) and underwent strong erosion (KOHN et al., 1997). The Ghazalat Basin was inverted (KEELEY, 1989). These deformations underline the "Bretonian" event (WENNEKERS et al., 1996).

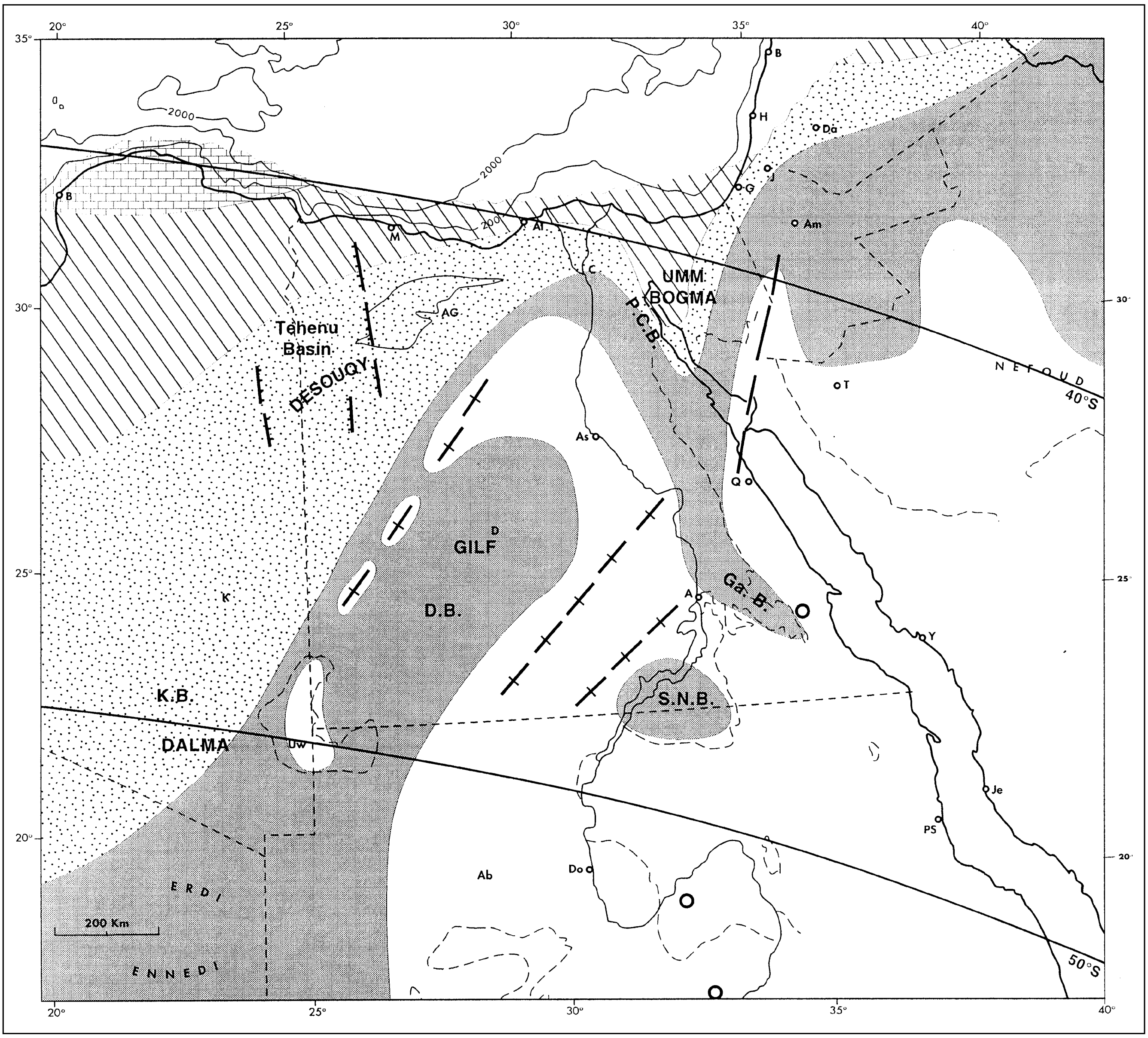
6. Early Carboniferous (~342 Ma)

(Text-Fig. 6)

The Early Carboniferous witnessed a global high sealevel and warm temperatures, with the sea invading eastern Libya, up to the Al Kufrah Basin. A shallow marine terrigenous platform developed (i.e. Desouqy Fm.), passing northwards to mixed platforms (Cyrenaica and the Palmyrides) or carbonate platform (Umm Bogma Fm. in Sinai). Subsidence initiated in the Tehenu and northern Cyrenaica basins (KEELEY, 1989, 1994; WENNEKERS et al., 1996).

In the continental domain, the Dakhla, Garara and South Nile basins were active; exposed lands probably prevailed in western Saudi Arabia. Both marine and continental Carboniferous formations provide good stratigraphic controls. The Bahariya-Uweinat and, probably, the Tarfawi-Qena and Chephren-Kom Ombo NE-SW trending arches were still active.

The latest Early Carboniferous registered some tectonic instability, evidenced by unconformities in Libya ("Sudetian" event of WENNEKERS et al., 1996) and in Sinai (ISSAWI, 1996). This event was probably responsible for regional uplifts resulting in both important marine regression in eastern Libya and narrowing of continental fluviatile basins (e.g. Al Kufrah B.). The deformations increased westwards; this event was a major one in northwestern Africa (FABRE, 1988).



Text-Fig. 6.
Latest Tournaisian – earliest Visean (Early Carboniferous, ca. 342 Ma) paleogeographic and paleotectonic map.
Same legend as Text-Fig. 2. DB = Dakhla Basin; Ga B = Garara Basin; KB = Al Kufrah Basin; PCB = Proto-Clysmic Basin; SNB = South Nile Basin.

7. Late Moscovian (Late Carboniferous, ~304–306 Ma)

(Text-Fig. 7)

During the early Late Carboniferous (Bashkirian) low sea-levels prevailed; the marine domain was limited to Cyrenaica and northeastern Egypt. Gentle deformation occurred before the Moscovian, as evidenced in Sinai by the presence of an unconformity between the Abu Durba and the overlying Rod El Hamal formations (ISSAWI, 1996).

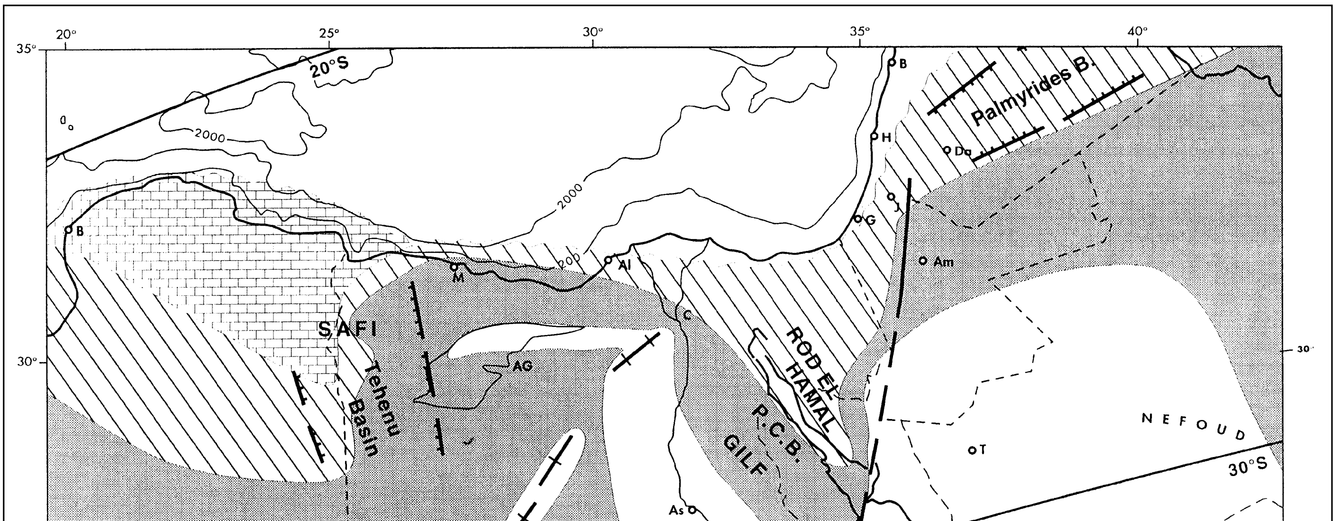
Higher sea-level occurred during the Moscovian. A mixed platform fringed the margin, characterized by some fossiliferous carbonate sequences developed both in the upper part of the series and northwards. The presence of brachiopod and crinoid faunas implies warm waters. In the continental domain, due to the uplift of some arches (e.g. South Sirt or Uweinat), fluviatile basins may have been smaller than previously.

A major unconformity underlines the Carboniferous/Permian transition over large areas. In the Levant, the "Geanticline of Helez" then developed (GVIRTZMAN & WEISSBROD, 1985). The Sirt Basin s.l. was uplifted in northeastern Libya (WENNEKERS et al., 1996). These deformations may be regional echoes of the "Asturian" event; they could be approximately synchronous with (or post-date) a sharp cooling in the global climate associated with a drop of the sea-level (ROSS & ROSS, 1988).

8. Late Kazanian (Late Permian, ~253–254 Ma)

(Text-Fig. 8)

The formations attributed to the Permian are often poorly dated in the studied area. Contacts with underlying and overlying units generally show unconformities related to gentle tectonic events followed by erosion. The pre-Late Permian ("Saalian") unconformity is well documented in the Levant area (GARFUNKEL & DERIN, 1985), in northwestern Egypt (KEELEY, 1994), and more widely over the Arabian sub-plate (pre-Khuff event) and in northwestern Africa (FABRE, 1988).



Text-Fig. 7.
Late Moscovian (mid Carboniferous, ca. 305 Ma) paleogeographic and paleotectonic map.
Same legend as Text-Fig. 2. DB = Dakhla Basin; Ga B = Garara Basin; Mi = Missawag Basin; PCB = Proto-Clysmic Basin; SNB = South Nile Basin.

A tentative map (Text-Fig. 8) is given here for the early Late Permian. A narrow, shallow marine platform fringed the margin, characterized by mixed and carbonate facies, the latter well dated by fusulines in southern Israel (Arqov Fm.; HIRSCH, 1990). In the continental domain fluviatile sandstones accumulated in several basins, sometimes subsiding as Missawag (south of Siwa Oasis), Lakia initiating in northwestern Sudan, or minor grabens located along the Dead Sea fault zone (POWEL & KHALID MOHAMED, 1993). Subsidence probably also affected large domains along the continental margin; there is evidence for this in the Tunisian-Libyan confines (STAMPFLI et al., 1991). Tensional tectonic activity prevailed during Permian times. This character is underlined by rejuvenation of magmatism: mid–late Permian basalts emplaced in the Gulf of Sirt (ALMOND, 1991) and in central Sinai (STEINITZ et al., 1992); anorogenic complexes were intruded in the Nubia province of northern Sudan.

The Permian/Triassic transition is often underlined by hiatuses thought to correspond to a "Palatinian" tectonic event (FABRE, 1988), and along the shallow marine platform, to the influence of a brief global drop in sea-level associated whith severe glaciation (ROSS & ROSS, 1988).

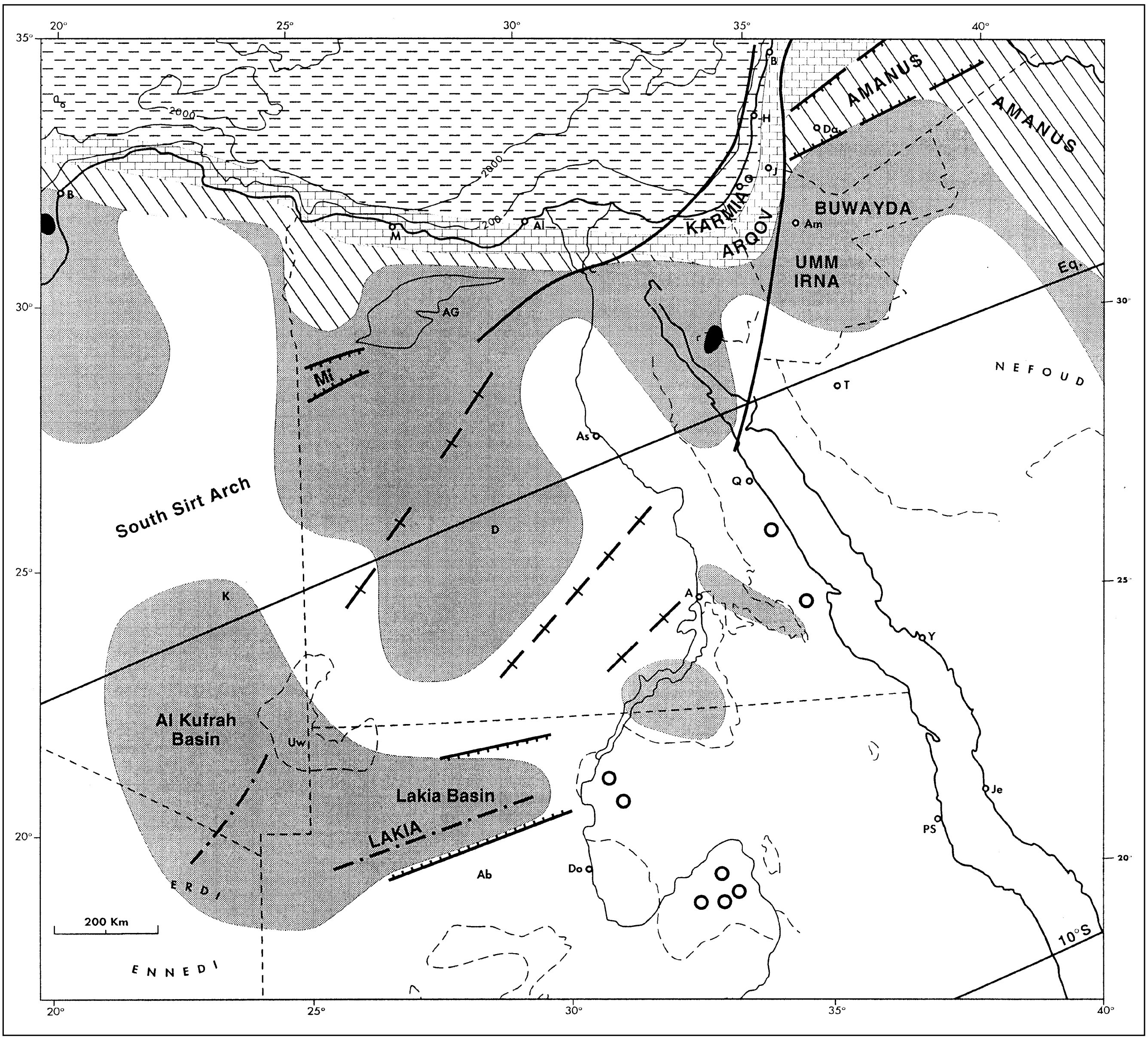
9. Discussion and Conclusions

9.1. Basins and Arches Individualization

Most of the basins underwent post-sedimentary erosion related to the numerous tectonic events affecting the African-Arabian plate during the Paleozoic and subsequently. This character must be taken into account when studying the northern Unstable Shelf, corresponding to the Syrian arc s.l.; it was inverted and folded from Late Cretaceous times (GUIRAUD & BOSWORTH, 1997). Several Paleozoic basins nevertheless formed and have been more or less preserved e.g. (Text-Fig. 1):

- the Al Kufrah-Lakia, Dakhla, Jafr and Nefoud basins in the intracratonic domain;
- the Tehenu Basin and the north Cyrenaica Basin in the Unstable Shelf.

The north–south trending Early Paleozoic Ghazalet Basin of northwestern Egypt was strongly disrupted. Some



Text-Fig. 8.
Late Kazanian (Late Permian, ca. 253–254 Ma) paleogeographic and paleotectonic map.
Same legend as Text-Fig. 2. Mi = Missawag Basin.

uplifted arches trending NNW–SSE to NE–SW appeared, e.g. the south Sirt, the Calanshiu, the Bahariya-Uweinat and the Middle Egypt arches. The Nubia province, intruded by numerous alkaline anorogenic complexes from Ordovician times and subsequently, was also active as a large swell.

Finally, the lack during most of the Paleozoic of indications of activity along the present day E–W Mediterranean margin and the N–S Dead Sea fault zone are stressed. These trends were initiated by the Late Carboniferous (Text-Fig. 7), becoming more distinct by Permian times (Text-Fig. 8) in connection with the opening of Neotethys. The ENE–WSW trending Palmyrides trough, active already in the Ordovician (Text-Fig. 3), is a noticeable exception.

9.2. Transgressions, Regressions and Tectonic Events

The Paleozoic sequences of the northeastern African margin provide clues to substantial episodic changes in sea-level. The main transgressions took place in the Early Cambrian, the Tremadocian, the Llandovery, the Mid/Late Devonian, the Early Carboniferous, the Moscovian, the Early Permian. Regressions occurred in the Late Cambrian, latest Ordovician (in conjunction with a severe glaciation), latest Devonian, latest Early Carboniferous, latest Carboniferous and Late Permian.

The tectonic history shows an alternation of long periods of predominantly gentle basin subsidence and normal faulting, and short periods of gentle folding and, sometimes, basin inversion. These brief tectonic events were possibly associated with strike-slip rejuvenation of some major fault zones, accompanied by drag-folding like that discriminated in northwestern Africa (MASSA et al., 1972). That such fault rejuvenation has not been noted in NE Africa may be due to insufficient outcrop or inadequate seismic studies. They denote changes in the paleostress fields. Moreover they generally follow the previous mentioned regressions which they increase, specially along the uplifted arches which then develop. In the basins they contribute to the development of hiatuses and unconformities.

Table 1 lists these tectonic events and shows their stratigraphic position. The main events separate the different Paleozoic periods or sometimes, some epochs or – seldom – stages. Such events have been individualized by several authors working in neighbouring regions of the northern African-Arabian plate margin, among them WENNEKERS et al. (1996) for the Sirt basins, FABRE (1988) for northwestern Africa and STUMP et al. (1995) for Saudi Arabia. Most of these authors tried to correlate these events with the major episodes discriminated in the Caledonian/Variscan belts of Western Europe. Such a tectonic chart is proposed on Table 1. The northeastern African plate margin was nevertheless a passive margin during the Paleozoic, registering echoes of the major tectonic events which affected the northwestern African margin resulting in thrust belts such as the Mauritanides and the Moroccan Meseta.

Recent works dealing with intracontinental tectonics showed the close linkage between active belts and the intraplate domains, both for stress fields and timing of deformation (ZIEGLER et al., 1995; GUIRAUD & BOSWORTH, 1997). That is why the here proposed tectonostratigraphic chart, which is tentative and could be improved, ought to be considered and could give a frame for future works.

Acknowledgements

Improvements to the paleogeographic-paleotectonic maps by Dr. BAHAY ISSAWI were greatly appreciated. Fruitful reviews were given by Dr. J. TALENT and Dr. J. FABRE. A. DELPLANQUE is thanked for drawing the illustrations, and C. BARRE for typing the manuscript.

References

ABED, A.M., MAKHLOUF, I.M. & AMIREH, B.S.: Upper Ordovician glacial deposits in southern Jordan. – Episodes, **16**, 316–328, 1993.

ALMOND, D.C.: Anorogenic magmatism in Northern Africa. – In: The Geology of Libya (SALEM, M.J. et al., eds.), Elsevier, Amsterdam, 5, 2495–2510, 1991.

BEYDOUN, Z.R., FUTYAN, A.R.I. & JAWZI, A.H.: Jordan revisited: hydrocarbons habitat and potential. – Journal of Petroleum Geology, **17**, 177–194, 1994.

FABRE, J.: Les séries Paléozoïques d'Afrique: une approche. – Journal of African Earth Sciences, **7**, 1–40, Oxford 1988.

GARFUNKEL, Z. & DERIN, B.: Permian–Early Mesozoic tectonism and continental margin formation in Israel and its implications for the history of the Eastern Mediterranean. – Geological Society of London, spec. Publ., **17**, 187–201, 1985.

GRADSTEIN, F.M. & OGG, J.: A Phanerozoic time scale. – Episodes, **19**, 3–4 and table, 1996.

GRIGNANI, D., LANZONI, E. & ELATRASH, H.: Palaeozoic and Mesozoic subsurface palynostratigraphy in the Al Kufrah Basin, Libya. – In: The Geology of Libya (SALEM, M.J. et al., eds), Elsevier, Amsterdam, 4, 1159–1228, 1991.

GUEINN, K.J. & RASUL, S.M.: A contribution to the biostratigraphy of the Palaeozoic of the Western Desert, utilising new palynological data from the subsurface. – EGPC VIII Exploration Conference, Cairo, 1986.

GUIRAUD, R., ISSAWI, B. & BOSWORTH, W.: Phanerozoic history of Egypt and surrounding areas. – In: ZIEGLER, P.A., CAVAZZA, W. & ROBERTSON, A.H.F. (eds.): PeriTethys Memoir, PeriTethyan Rift/Wrench Basins and Passive Margins. – Mémoires du Muséum National d'Histoire Naturelle de Paris, 1999 (in press).

GUIRAUD, R. & BOSWORTH, W.: Senonian basin inversion and rejuvenation of rifting in Africa and Arabia: synthesis and implications to plate-scale tectonics. – Tectonophysics, **282**, 39–82, Amsterdam 1997.

GVIRTZMAN, G. & WEISSBROD, T.: The Hercynian Geanticline of Helez and the Late Paleozoic history of the Levant. – Geological Society of London, Spec. Publ., **17**, 117–186, 1985.

HIRSCH, F.: Aperçu de l'histoire phanérozoïque d'Israèl. – Journal of African Earth Sciences, **11**, 177 -196, Oxford 1990.

ISSAWI, B: Tectono-sedimentary synthesis of the Paleozoic basins in Egypt. – EGPC 13th Petroleum Conference, Cairo, Exploration Vol. **1**, 1–23, 1996.

KEEGAN, J.B., RASUL, S.M. & SHAHEEN, Y.: Palynostratigraphy of the lower Paleozoic, Cambrian to Silurian of the Hashemite Kingdom of Jordan. – Review of Palaeobotany and Palynology, **66**, 167 -180, Amsterdam 1990.

KEELEY, M.L.: The Palaeozoic history of the Western Desert of Egypt. – Basin Research, **2**, 35–48, Danvers 1989.

KEELEY, M. L.: Phanaerozoic evolution of the basins of Northern Egypt and adjacent areas. – Geologische Rundschau, **83**, 728–742, Stuttgart 1994.

KOHN, B.P., FEINSTEIN, S., FOSTER, D.A., STECKLER, M.S. & EYAL, M.: Thermal history of the eastern Gulf of Suez, II. Reconstruction from apatite fission track and 40Ar/39Ar-K-feldspar measurements. – Tectonophysics, **283**, 219–239, Amsterdam 1997.

KONATE, M.: Evolution tectono-sédimentaire du bassin paléozoïque de Kandi (Nord Bénin, Sud Niger) – Un témoin de l'extension post-orogénique de la chaîne panafricaine. – Thèse Géologie, Univ. Bourgogne, 2 vol., 301 & 188 p., 1996.

MASSA, D., RUHLAND, M. & THOUVENIN, J.: Structure et fracturation du champ d'Hassi-Messaoud (Algérie). Deuxième partie: application au réservoir cambrien d'Hassi-Messaoud Nord. Nouvelle interprétation tectonique. – Revue de l'Institut Français du Pétrole, **27**, 665–713, 1972.

MENEISY, M.Y.: Vulcanicity. – In: The Geology of Egypt (SAID, R., ed.), Balkema, Rotterdam, 157–172, 1990.

MOLYNEUX, S.G. & PARIS, F.: Late Ordovician Palynomorphs. – In: The Palynostratigraphy of North-East Libya (THUSU, B. & OWENS, B., eds.), Journal of Micropalaeontology, **4**, 11–26, 1985.

POWEL, J.H. & KHALIL MOHAMED, B.: Structure and sedimentation of Permo-Triassic and Triassic rocks exposed in small-scale horts and grabens of pre-Cretaceous age: Dead Sea margin, Jordan. – Journal of African Earth Sciences, **17**, 131–143, Oxford, 1993.

ROSS, C.A. & ROSS, J.R.P.: Late Palaeozoic transgressive-regressive deposition, in sea-level changes: an integrated approach. – Society of Economic Paleontologists and Mineralogists, Spec. Publ., **42**, 227–247, 1988.

SCHANDELMEIER, H. & REYNOLDS, P.O. (eds): Palaeogeographic-Palaeotectonic Atlas of North–Eastern Africa, Arabia and Adjacent Areas. – Balkema, Rotterdam 1997.

SCHANDELMEIER, H., RICHTER, A. & FRANZ, G.: Outline of the geology of magmatic and metamorphic units from Gebel Uweinat to Bir Safsaf (SW-Egypt/NW-Sudan). – Journal of African Earth Sciences, **1**, 275–283, 1983.

SEMTNER, A.K., REYNOLDS, P.O., SCHANDELMEIER, H. & KLITZSCH, E.: The early Silurian (Llandovery, ca. 435 Ma). – In: Palaeogeographic-palaeotectonic atlas of north-eastern Africa, Arabia and adjacent areas (SCHANDELMEIER, H. & REYNOLDS, P.-O., eds.), Rotterdam, Balkema, 21–23, 1997.

STAMPFLI, G., MARCOUX, J. & BAUD, A.: Tethyan margin in space and time. – Palaeogeography, Palaeoclimatology, Palaeoecology, **87**, 373–409, Amsterdam 1991.

STEINITZ, G., BARTOV, Y. & EYAL, M.: K-Ar and Ar-Ar dating of Permo-Triassic magmatism in Sinai and Israel – initial results. – In: Israel Geological Society, Annual Meeting, **147**, 1992.

STUMP, T.E., AL-HAJRI, S. & VAN DER EEM, J.G.L.A.: Geology and biostratigraphy of the Late Precambian through Palaeozoic sediments of Saudi Arabia. – Review of Palaeobotany and Palynology, **89**, 5–17, Amsterdam 1995.

WENNEKERS, J.H.N., WALLACE, F.K. & ABUGARES, Y.I.: The Geology and Hydrocarbons of the Sirt Basin: A Synopsis.–In: The Geology of Sirt Basin (SALEM, M.J. et al., eds.), Elsevier, Amsterdam, **1**, 3–58, 1996.

ZIEGLER, P.A., CLOETINGH, S. & VAN VEES, J.D.: Dynamics of intraplate compressional deformation: the Alpine foreland and other examples. – Tectonophysics, **252**, 7–59, Amsterdam 1995.

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