Chapter V

Summary and Conclusions

This study deals with the stratigraphy, paleontological studies of bivalves, gastropods, cephalopods, and echinoids, paleoecological investigations, the paleobiogeographic distribution of the studied fauna as well as determination of the paleoenvironment of the Upper Cretaceous succession of the three measured sections; Gebel Ekma (southern Sinai), East Themed area (east central Sinai), and Gebel Yelleg (northern Sinai).

The studied Upper Cretaceous sequence of these measured sections were subdivided lithostratigraphically into eight lithostratigraphic units as follows:

1. *Galala Formation* (Late Albian – Late Cenomanian)
2. *Raha Formation* (Early – Late Cenomanian)
3. *Abu Qada Formation* (Late Cenomanian – early Middle Turonian)
4. *Buttum Formation* (Early – early Middle Turonian)
5. *Wata Formation* (Early – Late Turonian)
6. *Matulla Formation* (?Late Turonian – Campanian)
7. *Themed Formation* (Coniacian – Santonian?)
8. *Sudr Chalk* (Campanian – Maastrichtian).

The paleontological investigations led to the recognition of 172 species and subspecies of macrofossils. Among them 89 bivalve species and subspecies belonging to 61 genera, 34 families, 13 orders and 3 subclasses. Thirty-six gastropod species belonging to 30 genera, 19 families, 4 orders and 2 subclasses. Fifteen cephalopod species belonging to 10 genera, 7 families and 2 orders. Thirty-two echinoids (16 regular and 16 irregular) belonging to 16 genera, 15 families, 10 orders and one subclass. Four bivalves are new; *Brachidontes blanckenhorni* from the Upper Cenomanian of the East Themed area, *Pseudoptera themedensis* from the Lower Turonian of the East Themed area, *Linearia aegyptiaca*, and *Pollex sinaiensis* from the Upper Cenomanian of

Gebel Ekma. Twenty-five species were recorded from Egypt for the first time, two of them are the first documentation of the ammonite *Rubroceras* from outside New Mexico and the first documentation, for North Africa and the Middle East, of the standard Lower Santonian *Cladoceramus undulatoplicatus* (Roemer). The generic name of *Siliqua humei* Fourtau, 1917 changed to *Plectomya* de Loriol, 1868 rather than to the genus *Siliqua* Megerle von Mühlfeld, 1811. As well as the generic name of *Venus delettrei* Coquand, 1862 changed to *Tenea* Conrad, 1870 and consequently, the family Veneridae changed to family Arcticidae Newton, 1891.

The studying of the aforementioned macrofossils led to the construction of five ammonite zones and thirteen zones based on other macrofossils at Gebel Ekma, six ammonite zones and fourteen zones based on other macrofossils at East Themed area, and four ammonite zones and twelve zones based on other macrofossils apart from two larger foraminiferal zones at Gebel Yelleg as follows:

I. Gebel Ekma

A. Ammonite zones; from base to top as follows:

Neolobites vibrayeanus Total Range Zone

Vascoceras cauvini – *Pseudaspidoceras pseudonodosoides* – *Rubroceras alatum* Assemblage Zone

Choffaticeras segne Total Range Zone

Choffaticeras sinaiticum Total Range zone

Coilopoceras requienianum Total Range Zone.

B. Biozones based on other macrofossils; from older to younger as follows:

Ceratostreon flabellatum – *Rhynchostreon suborbiculatum* Acme Zone

Tenea delettrei – *Ichthyosarcolites* sp. – corals Acme Zone

Ambigostrea pseudovillei – *Ilymatogyra africana* Acme Zone

Costagyra olisiponensis Acme Zone

Hemiaster (*Mecaster*) *heberti turonensis* – *Coenholectypus turonensis* Acme Zone

Phymosoma abbatei – *Tylostoma (T.) cossoni* Acme Zone

Rachiosoma irregulare Acme Zone

Pycnodonte (*Costeina*) *costei* Acme Zone

Hemiaster fourneli – *Petalobrissus waltheri* Acme Zone

Cladoceramus undulatoplicatus Total Range Zone

Nicaisolopha tissoti Total Range Zone

Nicaisolopha nicaisei – *Ambigostrea bretoni* Total Range Zone

Pycnodonte (*Phygraea*) *vesicularis vesicularis* Acme Zone.

II. East Themed Area

A. Ammonite zones; from base to top as follows:

Neolobites vibrayeanus Total Range Zone

Vascoceras cauvini Total Range Zone

Choffaticeras quaasi – *Choffaticeras securiforme* Total Range Zone

Choffaticeras segne – *Vascoceras harttii* Total Range Zone

Choffaticeras sinaiticum – *Thomasites rollandi* Total Range Zone

Coilopoceras requienianum Total Range Zone.

B. Biozones based on other macrofossils; from older to younger as follows:

Ceratostreon flabellatum Acme Zone

Nerinea gemmifera – *Praeradiolites biskraensis* – corals Acme Zone

Ilymatogyra africana Acme Zone

Costagyra olisiponensis Total Range Zone

Pycnodonte (*Phygraea*) *vesicularis vesiculosa* – *Inoceramus* ex gr. *pictus* Interval Zone

Hemiaster (*Mecaster*) *heberti turonensis* – *Coenholectypus turonensis* Acme Zone

Phymosoma abbatei – *Tylostoma* (*T.*) *globosum* Acme Zone

Durania gaensis – *Praeradiolites ponsianus aegyptiacus* – caprinidae Assemblage Zone

Trochacteon salamonis Total Range Zone

Cucullaea (*Idonearca*) *trigona* – *Rachiosoma geysi* Acme Zone

Nerinea requieniana – coralline sponge Total Range Zone

Hemiaster (*Mecaster*) *fourneli* – *Petalobrissus waltheri* Acme Zone

Oscillopha dichotoma – *Plicatula ferryi* Total Range Zone

Pycnodonte (*Costeina*) *costei* Total Range Zone.

III. Gebel Yelleg

A. Ammonite zones; from base to top as follows:

Neolobites vibrayeanus Total Range Zone

Chofaticeras segne – *Thomasites rollandi* Total Range Zone

Coilopoceras requienianum Total Range Zone

Metatissotia ewaldi Total Range Zone.

B. Biozone based on other macrofossils and larger microfossils; from older to younger as follows:

Ceratostreon flabellatum – *Pterocera incerta* Acme Zone

Orbitolina conica Total Range Zone

Eoradiolites liratus Total Range Zone

Gyrostrea delettrei – *Rhynchostreon suborbiculatum* – *Hemiaster* (*Hemiaster*) *gabrielis* Acme Zone

Praealveolina cretacea Total Range Zone

Nerinea gemmifera – *Praeradiolites biskraensis* – corals Acme Zone

Ambigostrea pseudovillei – *Ilymatogyra africana* Acme Zone

Costagyra olisiponensis Acme Zone

Pycnodonte (*Phygraea*) *vesicularis vesiculosa* – *Rastellum carinatum* Total Range Zone

Hemiaster (*Mecaster*) *heberti turonensis* – *Coenholectypus turonensis* Acme Zone

Phymosoma abbatei – *Tylostoma (T.) globosum* Acme Zone

Durania arnaudi – *Praeradiolites ponsianus aegyptiacus* – *Praeradiolites irregularis* Assemblage Zone

Cucullaea (*Idonearca*) *maresi* Total Range Zone

Pycnodonte (*Costeina*) *costei* – *Oscillopha dichotoma* – *Plicatula ferryi* Assemblage Zone.

Based on the correlation and the integration of these proposed zones a biostratigraphic framework was erected resulting in seven ammonite zones, twenty zones based on other macrofossils, and two larger foraminiferal zones.

The proposed zones were correlated with other zones proposed by other authors from different localities in Egypt. Based on the occurrence of some zonal species and the co-occurrence of some other key species belonging to different faunal realms and provinces the integration, chronostratigraphic position and correlation of the proposed zones are discussed with some related and neighbouring countries as well as with the standard zones. The standard Lower Santonian *Cladoceramus undulatoplicatus* Zone is recognized for the first time from the North Africa and the Middle East. This led to facilate the determination of the Coniacian/Santonian boundary, which is located within the Shaly Member of the Matulla Formation, coinciding with the base of the *Cladoceramus undulatoplicatus* Zone. The Albian/Cenomanian, Cenomanian/Turonian, Turonian/Coniacian, Santonian/Campanian and Campanian/Maastrichtian boundaries were also discussed.

The ecological composition of the studied bivalves, gastropods, cephalopods, and echinoids are discussed.

The paleoecological investigations revaled the following results:

1. The Galala Formation at the East Themed area especially its upper part indicates that it was deposited on the outer shelf in warm, shallow, clear water of normal salinity.

2. The Galala Formation at Gebel Yelleg represents a reef complex facies and was deposited in shallow, warm, clear water of normal salinity.

3. The Raha Formation at Gebel Ekma was deposited in shallow, fully marine waters of the inner sublittoral to near- shore zone, at depth of less than 30 m.

4. The lower member of Abu Qada Formation at Gebel Ekma was depopsited in a shallow marine environment less than 45 m deep, while the upper member represents a regressive cycle.

5. The Abu Qada Formation at the East Themed area was deposited in the shallow, low-energy inner sublittoral zone at a depth of around 20-45 m.

6. The Buttum Formation indicates very shallow lagoonal or sabkha deposits on tidal flats (Issawi *et al.* 1999).

7. The Wata Formation represents a carbonate platform facies and reflects depostion in the shallow sublittoral zone. The abundance of rudists in the Wata Formation at the East Themed area and Gebel Yelleg indicate tropical shoal conditions.

8. The sandy member of the Matulla Formation at Gebel Ekma reflects a regressive phase during the latest Turonian and Early Coniacian, paralleling the major global drop in sea level associated with the early pulses of the Laramide orogeny, and locally with the Syrian Arc Event. The shaly member and the phosphatic member were deposited under shallow marine conditions at depth of less than 30 m.

9. The Themed Formation at both Gebel Yelleg and the East Themed area was deposited at nearly the same conditions, which indicates a warm, offshore environment at a depth of 40-85 m.

10. The Sudr Chalk was deposited in open marine offshore environment.

The paleobiogeographic distribution of the studied fauna indicate that 20% are endemic, 1% cosmopolitan in distribution. The remaining fauna shows Tethyan affinity; a strong affinity to North Africa (62%), southern Europe (47%) and the Middle East (42%). They also show some relationship to West Africa (8%), South America (8%), India (7%), Madagascar (6%), North America (5%), but to a much lesser degree.