Summary of Ph.D. Thesis

"Stratigraphical and Sedimentological Studies on the Cenomanian Rocks (Galala Formation), North Eastern Desert, Egypt"

This work concerns in detail with the stratigraphical and sedimentological characteristics of the Cenomanian Galala Formation outcropped in the area lies at the northern part of the Eastern Desert (western side of the Gulf of Suez). Such area includes (from south to north); Gebel El-Zeit, the Southern Galala, the Northern Galala, Gebel Ataqa and Gebel Shabraweet. This study throws more light on the lithostratigraphic attributes, petrography, sequence stratigraphic framework, the main diagenetic changes and the depositional environments of the Galala Formation.

Lithostratigraphy

The Galala Formation unconformably overlies the fluvial to fluvio-marine sediments of the Early Cretaceous Malha Formation. The unconformity is represented by paleosol horizons at Gebel El-Zeit and the Southern Galala and by intraformational conglomerates at Gebel Shabraweet. It is unconformably overlain by El-Khashm Formation at Gebel El-Zeit, the Northern Galala and Gebel Ataqa. The unconformable contact is delineated by the presence of undulated caliche zone. The Wata Formation is paraconformably overlying the Galala Formation at the Southern Galala. At Gebel Shabraweet, the Galala Formation unconformably underlies Maghra El-Hadida Formation. The contact is taken at the top of the cherty dolostone of the uppermost part of the Galala Formation.

The Galala Formation is composed of well-bedded mixed clastic-carbonate sequence. The percentage of the carbonate rocks increases northward at the expense of siliciclastics. The maximum thickness of the Galala Formation is recognized from Gebel Shabraweet (201.25 m) at the extreme northern part of the study area. This thickness diminishes out southward to reach its minimum at Gebel El-Zeit (71.5 m) at the extreme southern part of the considered area.

The bivalves (particularly oysters) are the most common macrofossils of the Galala Formation. The following macro-taxa were identified from the studied sequence; *Costagyra olisiponensis* Sharpe, *Ilmatogyra africana* Lamarck, *Amphidonte flabellatum* (Goldfuss), *Rhynchostreon suborbiculatum* (Lamarck), *Inocermas (Birostrina) tennuiradialis* Zakhera, *Rastellum carinatum* (Lamarck), *Parasea faba*

Sowerby, *Tenea delettrei* (Coquand), *Dosinia delettrei* (Coquand), *Plicatula auressensis* Coquand, *Glossus solimani* (Abbas), *Venericardia forgemoli* (Coquand), *Meretrix faba* (Sowerby), *Eoradiolites liratus* (Conrad), *Gyrostrea delettrei* (Coquand), *Neithea (Neithea) quinquecocostata* (Sowerby), *Nayadina (Nayadina) gaudryi* Thomas & Peron, *Protocardia hillana* (Sowerby), *Granocardium* sp., *Protocardia* sp., *Pholadomya* sp., *Barbatia* sp., *Trigonia* sp., *Anisocardium* sp., *Trigonarca* sp., *Tylostoma pallayi* (Fortau), *Tylostoma cosoni* Thomas & Peron, *Cerithium tenoklene*se (Coquand), *Pterocera incerta* d'Orbigny = *Strombus inceratus* d'Orbigny, *Pterodonta deffisi* Thomas & Peron, *Aporrhais dutrugei* Coquand, *Turritella dakhlensis* Abbass, *Columbellina fusiformis* Douvillé, *Turritella* sp., *Tylostoma* sp., *Angulithes mermeti* (Coquand), *Neolobites vibrayeanus* (d'Orbigny), *Nigericeras jacqueti* Schneegans, *Metoicoceras geslinianum* (d'Orbigny), *Rubroceras alatum* Cobban, *Hemiaster (Hemiaster) cubicus* Desor, *Hemiaster (Mecaster) pseudofourneli* Peron & Gauthier, *Mecaster batnensis* Coquand, *Heterodiadema libycum* (Desor), *Pedinopsis sinaea* Desor, *Micropedina olisiponensis* Forbes, *Coenholectypus larteti* Cotteau, *Tiaradia weldoni* Fourtau and *Trochodiadema libanoticum* De Lorial. From the above fossil association, the Galala Formation is dated back to the Late Cenomanian age.

Petrography

On the basis of the depositional texture, abundance and type of skeletal and non-skeletal particles and the binding material, the Galala Formation is subdivided into two petrographic assemblages; the carbonate lithofacies and the clastic lithofacies. Twenty-six lithofacies associations are recognized belonging to the carbonate assemblage. These are the dolomicrite, sandy dolomicrite, sandy glauconitic dolomicrite, birdseye dolomicrite, ferroan dolomicrite, cherty ferroan dolomicrite, dolosparite, caliche, fossiliferous marl, dolomitic marl, lime mudstone, dolomitic lime mudstone, dolomitic lithoclastic lime mudstone, algal bioclastic wackestone, molluscan-echinoidal wackestone, bioclastic foraminiferal wackestone, dolomitic molluscan wackestone, dolomitic echinoidal wackestone, foraminferal molluscan packstone, oncolitic packstone, ostracoda molluscan packstone, molluscan peloidal packstone, dolomitic peloidal packstone, dolomitic algal bioclastic packstone, oolitic peloidal grainstone and peloidal echinoidal grainstone. The clastic assemblage includes sandy dolomitic glauco-arenite, claystone, sandy claystone, glauconitic claystone, oyster claystone, glauconitic sandy oyster claystone, dolomitized claystone, sandy glauconitic siltstone, ferruginous quartz arenite, dolomitic quartz arenite, siliceous quartz arenite, evaporitic quartz arenite, rooted ferruginous sub litharenite and glauconitic dolomitic litharenite.

Diagenesis

The most striking diagenetic processes and their diagenetic environments are discussed and interpreted in detail. The carbonate diagenetic processes comprise the micritization, cementation, aggrading neomorphism, dolomitization and dedolomitization.

Skeletal particles (e.g. algae, echinoderms, molluscs and foraminifera) are influenced by the micritization process with variable degrees (partial to complete) in the marine-phreatic water. It was found that such micritization process is achieved by the effect of boring algae. Six types of carbonate cements are recorded. Three of shallow marine types (micrite, fibrous calcite and isopachous calcite cements) and three of meteoric water types (granular calcite, blocky calcite and syntaxial rim cements).

The aggrading neomorphism affects both the micrite and the skeletal allochems. This process is controlled by the presence of clay minerals, meteoric water and Mg-ions. The mechanism of this process depends upon the removal of Mg-ions which minimize the size of the calcite crystals due to forming a cage around them. The Mg- ions can be leached by the fresh meteoric water and picked up on the clay surface. The absorption of Mg ions on the clay surface leads gradually to removing the cage around the calcite crystals and causing the conversion of the high Mg-calcite and/or aragonite crystals into coarser low Mg-calcite crystals.

The dolomitization process is the most prominent diagenetic process of the Galala Formation. Two phases of dolomitization are comprehended on the basis of the field criteria, petrographic analysis, primary sedimentary structures, geochemical data and stable isotope study. These are the syngenetic and late diagenetic dolostones. The syngenetic dolostone is represented by the finely-crystalline dolostones (dolomicrites), which are possibly formed by the penecontemporaneous, early dolomitization of the precursor lime mudstones in seawater with normal salinity. The late diagenetic dolostone is portrayed by the coarsely-crystalline dolostones (dolosparite), which are most probably formed by the aggrading neomorphism of the dolomicrite in the mixing marine phreatic-meteoric zone during a later phase of dolomitization. The dedolomitization process is of limited distribution in the studied rocks. The meteoric water is responsible for the dedolomitization process of the precursor dolomites, whereas it results in the removal of the Mg from the dolostone and producing of calcite.

The compaction and cementation are the most important diagenetic processes striking the sandstones of the Galala Formation. The compaction is developed during the mesodigenetic regime. It includes the mechanical compaction and the pressure dissolution. Six types of cement are recognized as binding materials between the quartz grains in sandstones. These are from older to younger; the eodiagenetic grain-coating ferruginous cement, the mesodiagenetic quartz overgrowth, carbonate, evaporite, recrystallized silica and the telodigenetic intergranular ferruginous cements.

Sequence stratigraphy

The sequence stratigraphic framework of the Galala Formation is estimated on the basis of the sedimentological and obtainable biostratigraphic data, in addition to the regional correlation of the studied sections. Five sequence boundaries are identified The first sequence boundary separates between the

Galala and Malha formations. The second, third and fourth sequence boundary exhibit a differentiated nature. It is noticed that such sequence boundaries in Gebel El-Zeit are mainly represented by paleosols and caliche, while those of the Northern Galala, Gebel Ataqa and Gebel Shabraweet are mostly typified by emergence horizons of dolomites and dedolomites. The fifth (last) sequence boundary separates the Galala Formation from the overlying El-Khashm Formation at Gebel El-Zeit, the Northern Galala and Gebel Ataqa and Maghra El-Hadida Formation at Gebel Shabraweet.

The Galala Formation in the study area is subdivided into four depositional sequences, which are built up of three systems tracts; the lowstand (LST), transgressive (TST) and highstand (HST) systems tracts. The LST is realized only from Gebel El-Zeit, where it is made up of siliciclastics (mostly claystone and sandstone) organized in coarsening- and fining-upward parasequences. The TST is identified from Gebel El-Zeit, the Northern Galala, Gebel Ataqa and Gebel Shabraweet. It forms a series of aggradational-retrogradational, shallowing-upward parasequences which transgress across the ramp till the point of maximum flooding is reached. The HST is recognized from Gebel El-Zeit, the Northern Galala, Gebel Ataqa and Gebel Shabraweet. It is built up of aggradational-progradational, shallowing-upward parasequences of shallow subtidal to peritidal facies.

Environmental interpretation

The inference of the paleoenvironmental conditions during which the Galala Formation was deposited is depending upon the lithologic characters, sedimentary structures, faunal content, petrographic analysis, cyclicity and sequence stratigraphy. The Galala Formation reflects a shallow ramp depositional environment, whereas the proximal inner ramp facies is represented by the siliciclastic-dominated sediments of Gebel El-Zeit and by the mixed siliciclastic-carbonate, distal mid ramp facies of the rest of the study area with intra-ramp basin at the Southern Galala and a carbonate buildup at Gebel Ataqa.