Chapter

Introductory Chapter: An Introduction to the Stratigraphic Setting of Paleozoic to Miocene Deposits Based on Paleoecology, Facies Analysis, Chemostratigraphy, and Chronostratigraphy - Concepts and Meanings

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1. Introduction

This is the introductory chapter of the book "New insights into the stratigraphic setting of Paleozoic to Miocene deposits: case studies from the Persian Gulf, Peninsular Malaysia and south-eastern Pyrenees." In this chapter, the research themes studied in this book have been introduced referring to the paleoecological and facies analysis techniques and methodologies, pertaining, in particular, an Oligo-Miocene carbonate succession of the Persian Gulf (Asmari Formation), the chemostratigraphy of Paleozoic carbonates of Peninsular Malaysia through the integration of stratigraphic, sedimentologic, and geochemical data, and the chronostratigraphy of a small ice-dammed paleolake in Andorra, applying the FFT (Fast Fourier Transform) analysis, resulting in sixth-order stratigraphic cycles, which have outlined the occurrence of glacially controlled system tracts and unconformities.

The topic of the Asmari Formation and its depositional environments has been deeply studied [1–12]. Referring to its biostratigraphy, it was earlier outlined in the 1960s based on unpublished reports [11]. The application of isotopic stratigraphy has later proved that the sediments ascribed to the Miocene "Aquitanian" are, in fact, Late Oligocene, Chattian in age. This was proved by the application of Sr-isotope stratigraphy to cored sections from 10 Iranian oil fields and 14 outcrop sections, within the framework of a high resolution sequence stratigraphy study down to fourth order cycles. The Chattian/Aquitanian boundary is marked by a major faunal turnover, with the general extinction of *Archaias species* and *Miogypsinoides complanatus*. The age interpretation of the early, unpublished zonations has needed a deep revision and the establishment of an updated biozonation. The new zonation and the stratigraphic ranges of selected key species have been presented by Laursen et al., 2009 [11].

The isotopic stratigraphy based on strontium has constrained the stratigraphic setting of the Asmari Formation [8]. This formation, consisting of approximately 400 m of cyclic platform limestones and dolostones, with subordinate intervals of sandstones and shales, has been studied in the subsurface at several oil fields and in an outcrop section. The methods of Sr-isotope stratigraphy is suitable for dating these strata because of the fast rate of marine strontium ratio during the depositional processes (roughly 32–18 My). The profiles of age against depth in the four areas have shown a decrease from higher accumulation rates in the lower Asmari to lower rates in the middle-upper part of the formation. These changes reflect the dynamics of platform progradation, from early deposition along relatively high accommodation margin to slope settings and then, to conditions of lower accommodation on the shelf top [8]. The ages of the sequence boundaries have been estimated from the age-depth profiles at each locality, providing a framework for stratigraphic correlation. The depositional sequences have an average duration of 1–3 My, whereas the component cycles represent average time intervals of 100–300 ky.

On the other side, the Kinta limestones have been matter of previous studies, mainly referring to the depositional environments [13–16]. In the Kinta valley, they are composed of medium-to-dark gray, fine-grained, thinly bedded limestones, with preserved bedding planes and slump depositional features. The faunal content is quite scarce, except that some conodont faunas, while a high organic content is suggested from the dark color of the deposits. The sedimentological and facies analysis has suggested the occurrence of low energy, slope environment hosting the deposition of the Kinta limestones. The high organic content coupled with the lacking of benthic fauna has indicated a low-oxygen setting. On the other side, the Kinta limestones were dominated by mudstones interlayered with bedded cherts and perhaps were deposited in a slope environment with a significant contribution of pelagic deposits [13]. The geological evolution of the Kinta Valley has been recently outlined as characterized by both deposition and structural deformation [14]. During the Devonian, the deposition started, composed of alternating sandstones and mudstones, followed in the Carboniferous by fine-grained shales, which are, in turn, overlain by Permian limestones. During the Triassic-Early Jurassic, the intrusion of granites cut previously deposited carbonate deposits. The whole deposits are overlain by Quaternary alluvial deposits. An early compressional event and a late extensional event have been distinguished [14]. Folding and thrusting occurred during the compression, also controlling the granitic intrusion, which was fractured due to compressional deformation. The extensional tectonic event resulted from the individuation of normal faults, controlling the present-day drainage network evident from DEM analysis [14].

A high resolution biostratigraphy of the Kinta limestones has been later proposed based on conodonts sampled in three boreholes, composed of carbonate mudstones with shales and siltstones [15]. Nine diagnostic conodont genera and 28 age diagnostic conodont species have been identified. In particular, *Pseudopolygnathus triangulus triangulus* and *Declinognathodus noduliferus noduliferus* have indicated that the successions, pertaining to the Kinta limestones, range in age from the Upper Devonian to the Upper Carboniferous. Moreover, these data have provided clues to the Paleo-Tethys paleogeographic reconstruction and paleo-depositional conditions [15]. Recently, the deformational styles and the structural history of the Paleozoic limestones of the Kinta Valley have been defined by using remote sensing mapping, outcrop samples, and hand specimens [16]. An early extensional event has been identified, as marked from normal faults, while a compressional event was indicated by a set of strike-slip faults. The geologic evolution has been interpreted as an intra-basinal extension during Permo-Triassic times, which was followed by a Late Miocene to Quaternary tectonic uplift [16].

The high resolution chronostratigraphy of the paleo-lakes is a main research topic, which has been deeply studied by several authors [17–27]. In particular, the Ibate paleolake has shown a distal lacustrine environment with low-oxygen conditions in its bottom waters [17].

The occurrence of *Anacolosidites eosenonicus* sp. nov., combined with the lacking of *Steevesipollenites nativensis*, indicates a late Santonian age for the paleolake (ca. 84 Ma). This age is constrained by the occurrence of carbonized sclereids that are associated with the "Great Santonian Wildfire" recorded in coeval marine offshore strata of the Campos and Santos basins [17]. The palynological content, coupled with the occurrence of rhythmic deposits have indicated a Late Santonian age of these deposits. The age assignment is based on palynostratigraphic relationships established from a reliable biostratigraphic framework, based on integration of palynological and biostratigraphic data [17]. On the other side, the Qaidam lake represents an excellent example in order to study the interplay of climatic and tectonic controls on continental saline lakes [19]. Two main events of increase of salinity have been controlled by the climate during the Late Eocene since the Oligocene, while tectonic events have controlled the migration of the saline centers [19]. The accumulation of halites and their preservation were the result of a coupled control by active tectonism, in order to provide accommodation space and trigger a rapid subsidence.

The Navamuno peatbog system, located in western Spain, has been deeply studied [21]. During the Late Pleistocene, it was dammed by the Cuerpo de Hombre glacier and was fed by lateral meltwaters. This depression was then filled by glaciolacustrine deposits. During the Holocene, its geologic evolution was controlled by a fluvial plain, controlling the episodes of shallow pond/peat bog sedimentation. An age model was constructed based on radiocarbon dating, allowing to interpret the environmental changes during the Late Glacial and the post-glacial [21]. Another representative paleolake is the Tangra Yumco, represented by a wide saline paleolake located on the Tibetan Plateau, which has been recently studied as a valuable example in order to reconstruct the climatic variations [23]. Micropaleontologic and sedimentologic data have been integrated with isotopic stratigraphy. Integrated stratigraphic information has allowed to reconstruct the geologic evolution of the paleolake during the last 17 ky [23]. The lake level was low at 17 ky BP, followed by a highstand phase at 8–9 ky BP. Since 2.5 ky, the paleolake remained stable regarding its level, with a short highstand-lowstand cycle around 2 ky [23]. These changes have been considered as good hints of paleo-climatic conditions in order to refine the paleo-climatic models in this area.

In this book, different case studies have been presented, respectively, located in the Persian Gulf, in the Peninsular Malaysia, and in the Andorra. To this aim, it should be useful to clarify their geological structure to put the studied cases in a proper geological setting [28–30]. The Persian Gulf is represented by an enclosed sea, limited from the western Arabian platform to the south and by the Zagros fold and thrust belt to the north-east. These mountains define the zone of convergence between the Arabian plate and the Eurasian plate and represent, perhaps, a tectonically active area. Since the last glacial maximum (18 ky BP), the sea level fluctuations in the Persian Gulf have been predicted in order to show their variability [28]. The paleo-shoreline reconstructions of the gulf have been compared with the general models of glacio-hydro-isostatic effects. Starting from the peak of the glaciations (14 ky), the Persian Gulf is free from the marine influence. The present shoreline of the Persian Gulf was reached about 6 ky ago, also controlling the evolution of the deltas of the rivers Euphrates, Tigris, and Kan [28]. In the Persian Gulf, the present-day water depths do not exceed 100 m, while the average water depths are of 35 m, suggesting that it was above the sea level during glacial times.

The geological setting of the Persian Gulf and the Oman Gulf has been studied by Ross et al. [29]. During Mesozoic times, the Arabian platform was formed by the Arabian Peninsula, by the Persian Gulf, by the south-western Iran, and by the eastern Iraq [29]. Significant geological processes outlined in this region include the deformation of the Musandam Peninsula during the Late Cretaceous and the

Middle Tertiary and the corresponding subduction processes, the collision of the Arabian platform and of the Eurasian plate, controlling the formation of the Zagros fold and thrust belt. This orogenesis has reduced the former platform to the Persian Gulf. This reduction was also controlled by the tectonic uplift of the Arabian Peninsula during the opening of the Red Sea and by saline tectonism [29]. During recent times, tectonics is still active in this complex region at the northern edge of the Gulf of Oman. Here, the Arabian plate has undergone subduction, while the Arabian and Eurasian plates lie in a collisional setting.

As a general rule, the Persian Gulf Basin represents a foreland basin, lying between the western Zagros fold and thrust belt, whose formation was controlled by the collision between the Arabian and the Eurasian plates [30]. An interesting topic is that the name "Persian Gulf" refers not only to the Persian Gulf but also to the Gulf of Oman, to the Straits of Hormuz, and to various outlets which are genetically related to the Arabian Sea. During the Early Triassic, the thermal subsidence and the stretching of the Arabian Plate started, resulting in extensional faulting and rifting of Zagros, opening the neo-Tethys sea. During the Late Cretaceous, a new tectonic phase controlled the beginning of the Alpine orogeny, resulting in major uplift and erosion, in addition to the closure of the Neo-Tethys sea [30]. During the Tertiary tectonic phase, the Late Alpine orogeny verified, resulting from the collision of the Arabian and Eurasian plates, resulting in the formation of the Zagros fold and thrust belt and then, the individuation of the foreland Persian Basin. Another main geodynamic event is represented by the opening of the Red Sea, about 25 My ago, resulting in the separation of the African and Arabian plates [30].

In this book, another important research topic is represented by the Peninsular Malaysia [31–36]. Three main tectonostratigraphic belts characterize these regions, respectively, the Western Peninsular Malaysia, the central Peninsular Malaysia, and the eastern Peninsular Malaysia. The oldest rocks can be found at the northwestern portion of the peninsula, while relatively younger rocks can be found toward the southeast. In the Peninsular Malaysia, the Upper Paleozoic and Mesozoic sequences have been studied in detail, regarding the structural and stratigraphic setting [32]. In particular, the Upper Paleozoic sequences have revealed several phases of folding coupled with the regional metamorphism, perhaps suggesting the occurrence of two main compressional events affecting the Peninsular Malaysia (Late Permian and Middle-Late Cretaceous) [32]. The Late Permian compressional event has controlled the intrusions of major plutons, cropping out in the eastern range. Harbury et al. [32] have suggested that the Permo-Triassic granites of the eastern belt have been separated from the granites cropping out in the main range due to crustal attenuation and subsidence during the Triassic and the Jurassic. I have found very clear on the geology of Peninsular Malaysia the study of Metcalfe [34]. This author has suggested that the aforementioned three belts occur based on different stratigraphic and structural settings, coupled with magmatism, geophysical signatures, and geologic evolution. The Western Belt is composed of the Sibumasu Terrane, derived from the margin of Gondwana during the Permian. The central and the eastern belts are composed of the Sukhothai Arc, formed during the Late Carboniferous-Early Permian on the Indochina continental margin [34]. During the Early Triassic, the collision between the Sibumasu and Sukhothai Arcs started, allowing for the formation of a foredeep basin and of an accretion complex. Granitic intrusions have cut the Western Belt and the Bentong-Raub suture zone. A back-arc basin (Sukhothai) opened during the Early Permian, collapsing and closing during the Middle-Late Triassic. In the Malay Peninsula, the marine deposition ended during the Late Triassic and red beds formed a cover sequence during the Cretaceous. A main tectonic and thermal event occurred during the Late Cretaceous, coupled with individuation of faults and granitic intrusion [34].

The third research topic of this book is represented by the geology of the Andorra (Spain), put in the regional context of the south-eastern Pyrenees [37–42]. The Andorra region is located in the central Pyrenees (Spain). This region has been strongly folded during the rotation of the Iberian Peninsula on the European plate. The stratigraphy of the Andorra region is characterized by the occurrence of rocks ranging in age from the Cambrian to the Ordovician, composed of conglomerates, limestones, phyllites, quarzites, and slates [40]. Moreover, gneiss and schist crop out in the cores of anticlines located in the north-eastern sector of the country. The occurrence of antiforms and anticlines is linked with shear zones including thrusts of metamorphosed sediments. In the south-eastern Andorra region, the Mt. S. Louis-Andorra Batholith crops out, controlling the metamorphism on its western edge.

A classical paper dealing with the Andorra's geology is that of Hartevelt [41]. The study region includes part of the Axial Zone, the Nogueras Zone, and the related marginal throughs. The outcropping formations, mapped with detail, range in age from the Cambro-Ordovician to the Pliocene. The detailed lithostratigraphy of this formation has allowed for the stratigraphic correlation with other regions of the Pyrenees. In this zone, the Hercynian orogenesis has controlled the formation of geological structures controlled by N-S trending stresses. A first tectonic phase has formed wide folds of kilometric extension, while the second one has controlled the formation of different compressional structures [41]. The thrust sequences in the eastern Pyrenees have been deeply investigated [42]. In this region, the Alpine thrusts involve both the basement and the sedimentary cover. Balanced cross sections have been constructed in order to restore the geometry of the thrusts and the propagation sequence, so resulting in a piggy-back sequence [42]. A duplex has been reconstructed, whose sole thrust is represented by the Vallfogona thrust, while the roof thrust owes its roots in the Axial Zone. Small antiforms have also been reconstructed, occurring as wide folds involving the higher sequences [42]. Casas et al. [43] have discussed the role of the Hercynian and Alpine thrusts in the Upper Paleozoic rocks of the Central and Eastern Pyrenees. The geological structure of the pre-Hercynian rocks of the Central and Eastern Pyrenees, forming the antiformal stack of the so-called Axial Zone, is characterized by coeval folds and thrusts, both Alpine and Hercynian. These thrusts separate sheets, ranging in age from the Upper Paleozoic to the Devonian, showing a different lithostratigraphy and geological structure [43]. Some examples have been shown in order to discuss the role of the Hercynian and Alpine thrusts in controlling the geological setting of the Pyrenees [43].

2. Facies analysis and paleoecology

In this book, the sedimentary environments and the paleoecology of the Oligo-Miocene deposits of the Asmari Formation have been reconstructed based on biostratigraphy, microfacies analysis, and facies analysis (see Chapter 1). Moreover, in Chapter 2, the facies analysis of Paleozoic carbonates drilled by three boreholes located in the Western Belt has been carried out. Perhaps, it should be useful to clarify some concepts and methods of facies analysis and paleoecology.

The stratigraphic analysis is mainly based on the field geological survey, on the measurement of stratigraphic sections and on the lithologic and paleontologic descriptions, with the aim to reconstruct the depositional environments and to correlate the stratigraphic sequences. A basic paper on facies analysis is that of Flugel [44], showing that every facies in a depositional setting is characterized by petrographic, geognostic, and paleontological characters, clearly different from the same characters of other facies occurring in the same geological period. The facies analysis needs interdisciplinary studies, as stated by Amanz Gressly in 1838 [45], showing that in the facies analysis, the sedimentologic, paleontologic, and geochemical data provide a basic information about the depositional environments, the lithogenesis, and the fossils.

In particular, the concept of facies needs to be recalled. It is a rocky body having distinct lithological, physical, and biological characteristics, allowing for its distinction from the adjacent rocky bodies. The concept of facies is usually referred to the whole characteristics of a sedimentary unit, including, the lithology, the grain-size, the sedimentary structures, the color, the composition, and the biogenic content [46]. A single facies does not indicate a single environment, but one or more geological processes through which the sediments have been deposited [47]. Perhaps, the environmental interpretation may be derived by the concept of facies association and by the integration of the physical characters of the deposits with the paleoecological ones. The facies associations are composed of several facies, occurring in combination and representing one or more depositional environments or facies groups, which are genetically related one to each other. Their shape is the cycle or the sequence, which is not a random vertical succession of facies. The facies associations are controlled by the Walther law, one of the most basic principles of stratigraphy. On the other side, a facies model is a general summary of depositional systems, including many single examples from recent sediments and old rocks.

Main criteria of facies analysis are briefly recalled [46, 47]. They include: (i) the mineralogic and petrographic composition, which gives information mainly on the provenance (relief, climate, and lithology of the source area), but also on the transport and on the diagenesis; (ii) the textural analysis, giving information on the provenance (shape), but mainly on the dynamics of transport and deposition; (iii) the fossil content, allowing for the dating and the correlation of deposits and giving paleoecological information and on the reworking; (iv) direction data, consisting of paleo-currents and paleo-slope models and dispersal of sediments, deduced from current lineations and depositional geometries; (v) geometry of the sedimentary bodies, derived through the synthesis of previous data and giving information on the depositional environments; and (vi) vertical sequential analysis, allowing for the determination of the relative depth fluctuations, the shoreline migrations, the growth and retreat of depositional systems, and the evolution of the sedimentary basins (basin analysis).

The paleoecology is represented by the study of the interactions between the organisms and the environments across the geological time scales and is linked with other disciplines, including the paleontology, the ecology, the climatology, and the biology [48]. It was born as a branch of the paleontology through the examination of the fossil and the ancient life environments. The main paleoecological approaches include: (i) the classic paleoecology, which is based on the fossils allowing for the reconstruction of the ancient ecosystems and uses the fossil remnants, such as the shells, the teeth, the pollens, and the seeds. A final result will be a paleo-environmental reconstruction. (ii) The evolutionary paleoecology, based on the holistic approach and using both the fossils and the physical and the chemical changes in the atmosphere, lithosphere, and hydrosphere in order to study the vulnerability and the resilience of species and environments. (iii) The community paleoecology, based on statistical methods and making use of physical models and computer analyses [48].

A main aim of the paleoecology is to construct a detailed model of the environments of life of the fossils, using the archives (represented by sedimentary sequences), the proxies (providing evidence of the biota and the related physical environments), and the chronology, allowing for the dating of events in the archive. Important proxies to carry out these reconstructions include the charcoal and pollens, particularly applied in paleolakes and peats. Some main paleoecological studies have been carried out in the Persian Gulf [49, 50]. Abdolmaleki and Tavakoli [49] have stated as the Permo-Triassic boundary represents one of the most important mass extinctions during the history of the earth, marking for a strong decrease of the living taxa. Important changes of depositional processes also occurred, forming anachronistic facies in whole earth. Anachronistic facies have been reported in the Early Triassic deposits of the Persian Gulf, consisting of microbial facies, composed of stromatolitic boundstones, oncoidal facies, and thrombolytic facies. The formation of these facies has also been controlled by the fluctuations in the $CaCO_3$ saturation level [49]. García-Ramos et al. [50] have evaluated the live-dead fidelity of the Mollusk assemblages in soft sediments of the carbonate tidal flats along the coasts of the Persian Gulf. Wide differences of this parameter have been controlled by the early cementation, lateral mixing, strong bioturbation, and low sedimentation rates. The obtained results have suggested that the average times in carbonate tidal flats are higher if compared with the times affecting the subtidal carbonate environments [50].

3. Chemostratigraphy

In this book, the chemostratigraphy of Paleozoic carbonates of the Western Belt (Peninsular Malaysia) has been studied (see Chapter 2). Perhaps, it should be useful to recall the chemostratigraphy as a branch of the integrated stratigraphy. Different stratigraphic methods are included in the integrated stratigraphy, including the chemostratigraphy, the isotopic stratigraphy, the oxygen isotopes, the carbon isotopes, the strontium isotopes, the orbital cyclostratigraphy, the response of the climate system to the orbital forcing, the orbital forcing and the sedimentary environments, the identification of cyclical features, and the spectral analysis of time series. Particular attention must be given to the methods of absolute dating and to the geological time scale. The chemostratigraphy (chemical stratigraphy) is based on the study of the chemical variations in the sedimentary successions with the aim to reconstruct the stratigraphic relationships [51–55]. It is based on the principle that the chemical signatures may be used as fossil groups or lithological groups in order to establish the stratigraphic relationships between the rocky layers. The types of chemical variations may be summarized [51]. Colorimetric variations among the strata may be detected in some stratigraphic sequences, triggered by the content of metals of transition incorporated during the deposition. Other colorimetric variations may be controlled by variations in the content of organic carbon in the deposits. The development of new techniques of analysis, including the electronic microprobe and the X-ray fluorescence, has facilitated the chemical analysis of the deposits, coupled with the geochemistry of the stable isotopes. In particular, the variability of the oxygen in the carbonate shells of foraminifera represents a proxy for the temperatures of the ocean during the geological past [56–57]. Recently, there were some attempts to formalize the chemostratigraphy as a standard method of stratigraphy [54–55], but this discipline is too young and many efforts need to be made again.

4. Chronostratigraphy

In this book, a chronostratigraphic reconstruction of lacustrine deposits located in Spain has been carried out (see Chapter 3). For this reason, it is useful to recall some chronostratigraphic concepts. Recently, the definitions of chronostratigraphy and geochronology have been deeply revised [58]. The realignment of the two terms has been proposed, contemporaneously solving the problem if the Geological Time Scale must have single or double time units. This discussion must be carried out based on the use of the Geological Time Scale (GTS) reported in the International

Stratigraphic Chart of the International Commission of Stratigraphy and its units. It must be taken into account that the last version of the International Stratigraphic Chart has been published in 2018 [59]. The most used units are represented by the geological periods of the geochronology (Triassic, Jurassic, for instance) and the chronostratigraphic systems on which they are based. These systems are composed of series and stages, while the periods, epochs, and stages are referred to time intervals during which the deposition of strata occurred. Therefore, there is a double hierarchy of chronostratigraphic units (time/rocks), which have been used to indicate rocky strata contemporaneously deposited and time intervals (geochronologic) used to indicate intervals during which geological processes occurred, including the evolution, the extinction, the deformation, and the transgression/regression, for instance [58]. In the meaning of this paper, the geochronology indicates the timing and the age of main geological events of the earth's history (such as a glaciations or a mass extinction). Moreover, it refers to the methods of numerical dating.

On the other side, the definition of chronostratigraphy is quite different. It includes the whole range of the stratigraphic disciplines, such as the magnetostratigraphy, the chemostratigraphy, the sequence stratigraphy, the cyclostratigraphy, and the radiometric dating [60–64]. The main aims of the chronostratigraphy include both the establishment of the time relations of regional successions and the definition of a GSSP (Global Boundary Stratotype Section and Point). In the realignment proposed by Zalasiewicz et al. [58], the chronostratigraphic (time/rock) and geochronologic (time) units have been, respectively, defined as it follows: (i) eonothem (Phanerozoic, for instance); (ii) erathem (Mesozoic, for instance); (iii) system (Cretaceous, for instance); (iv) series (Upper Cretaceous, for instance); (v) stage (Cenomanian, for instance); (vi) eon (Phanerozoic, for instance); (vii) era (Mesozoic, for instance); (viii) period (Cretaceous, for instance); (ix) epoch (Late Cretaceous, for instance); and (x) age (Cenomanian, for instance). The proposed method is to use the chronostratigraphic units in reference to layered rocks and to use the geochronologic units in reference to time and phenomena associated to the rocks [58].

5. Outline of this book

This book examines different stratigraphic studies regarding the fields of facies analysis and paleoecology, chemostratigraphy, and chronostratigraphy focusing on several applications, including the paleoecology and the sedimentary environments of the Asmari Formation (south-eastern Persian Gulf), allowing for the recognition of two assemblage zones based on foraminifera, indicating an age ranging between the Chattian and the Aquitanian, while facies analysis has indicated a depositional environment of carbonate ramp, the chemostratigraphy of Paleozoic carbonates in the Western Belt through the integration of stratigraphic, sedimentological, and geochemical data on three boreholes, indicating that the variations of major elements is directly related to the lithofacies types in the study samples and finally the application of the chronostratigraphic chart through a Fast Fourier Transform (FFT) analysis on lacustrine deposits of Andorra (Spain), indicating the occurrence of 6th order stratigraphic cycles, genetically related to high frequency sea level fluctuations during the Late Pleistocene.

This book contains four chapters, as follows:

Chapter 1 [Introductory Chapter: An Introduction to the stratigraphic setting of Paleozoic to Miocene deposits based on paleoecology, facies analysis, chemostratigraphy, and chronostratigraphy: Concepts and Meanings].

Chapter 2 [Paleoecology and Sedimentary Environment of the Oligocene-Miocene (Asmari Formation) deposits, in Qeshm Island, SE Persian Gulf].

Chapter 3 [Chemostratigraphy of Paleozoic carbonates in the Western Belt, Peninsular Malaysia; case study from the Kinta Valley].

Chapter 4 [High-resolution chronostratigraphy from an ice-dammed paleolake in Andorra: MIS 2 Atlantic and Mediterranean paleoclimate inferences over the SE Pyrenees].

Conflict of interest

I declare that there is no conflict of interest.

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