Chapter 2
Stratigraphy

Abstract The Lower Miocene Moghra Formation, northwestern Egypt was studied for its stratigraphy and geo-chronology. The Moghra Formation was divided into seventeen units according to lithology. The first unit is represented by marine fine-grained siliciclastic deposits with *Ophiomorpha* trace fossils (Unit I), and this is overlain by Unit II that consists of shallow marine coarse-grained siliciclastic deposits. This unit is rich in vertebrate fossil fragments. Unit III is composed of fine to coarse-grained siliciclastc deposits with *Ophiomorpha* trace fossils. Unit IV consists of a thick shale section with erosive base and variable thickness. The sediments of the overlying Unit V consist of three bioturbated sandstones beds. Unit VI is based by a major erosional surface and consists of fluvial-tidal sediments rich in vertebrates and silicified trunks. This unit is similar to Unit II in composition. Unit VI is overlain by unit VII, which is represented by sand-shale intercalation (sand dominated) and becomes more shaley upwards with *Ophiomorpha* and *Thalassinoid* trace fossils. Units VIII, Unit X, XII, XIV and XVI are similar to Unit VI in their composition. Unit IX is based by heterolithic strata with burrows and topped by marine shales towards the east. Units XI, XIII, XV are represented by calcareous beds and rich in *Ophiomorpha* and bioturbation ichnofacies. Unit XVII is represented by fossiliferous limestone and shale. Strontium isotope analysis of macrofossil fragments within Moghra Formation has provided a geochronology for the section and established a correlation with the global time-scale. Strontium isotope ratios of macrofossils are consistent and indicate an age for the Moghra Formation ranging from 20.5 Ma at the base to 17 Ma at the top, placing most of the study area within the Burdigalian.

2.1 Introduction

The Miocene stratigraphic work of previous authors in the Western Desert of Egypt has been discussed in Chap. 1. The present chapter deals with the detailed stratigraphy of the Lower Miocene Moghra Formation in the study area.

S. M. Hassan, *Sequence Stratigraphy of the Lower Miocene Moghra Formation in the Qattara Depression, North Western Desert, Egypt*, SpringerBriefs in Earth Sciences, DOI: 10.1007/978-3-319-00330-6_2,

The present study in the area of Moghra draws upon the principles of sequence stratigraphy to provide an integrative technique for forming and testing correlation based hypotheses.

Thirty seven GPS-based geological profiles, in the northeastern part of the Qattara depression, were measured for the lithological and sedimentological (both vertical and horizontal) characteristics of the exposed rocks as well as the vertebrate and invertebrate fossil content. From the thirty seven geological profiles around sixteen sections were made. Several locations between sections were described for the lateral correlation and variation in the lithology and tracing the depositional facies and bounding surfaces (Appendix). The sections from west to the east as follows: 22, 25, 24, 23, 21, 20, 9, 7, 8, 10, 1, 2, 3, 4, 6 & 5 (Fig. 2.1). The aim is to distinguish the main diagnostic characteristics through the succession with regard to sedimentary features and environments, diagenetic phenomena, thickness, boundaries and unit distribution. The objective also is to elucidate the environmental setting of the different sedimentary units within the measured profiles. This helps evaluate the sequences stratigraphic analysis, considered as one of the main goals in the present study. The description of the different lithologic units, thicknesses and sedimentary structures are presented here under. Symbols for lithology and sedimentary structures in these figures are supplied in the legend figure in appendix.

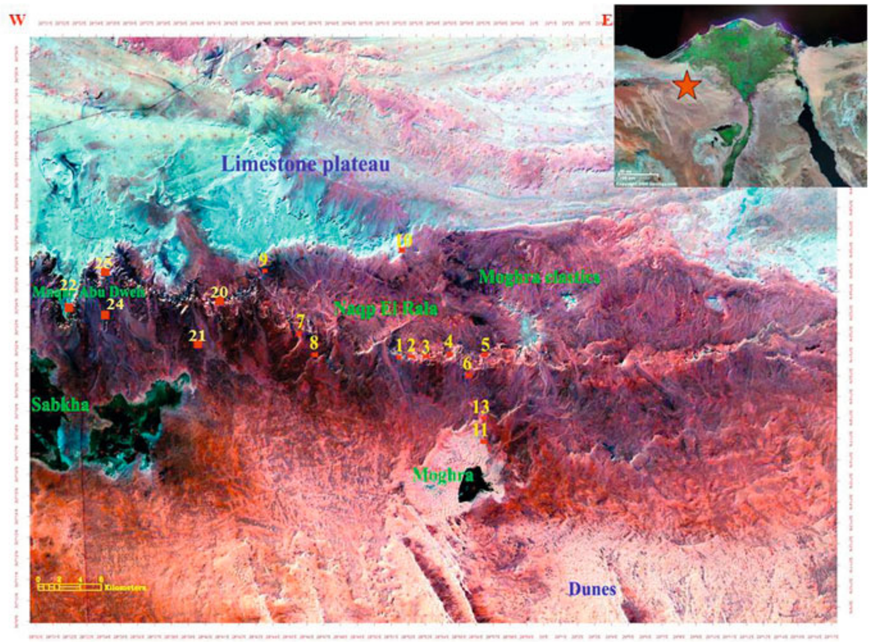

Fig. 2.1 Staellite image of the study area, showing the measured section from East to the West

2.2 Stratigraphy of the Area

The studied successions could be subdivided according to the dominant lithology into repeated cycles of intercalated sandstone and mudstone. Most cycles are erosionally-based by cross-bedded sandstone and terminated by *Ophiomorpha* sand and other marine strata. The studied succession was subdivided into sixteen units according to lithology. The first one is represented by marine fine siliciclastics deposits with *Ophiomorpha* trace fossils (unit I), which is overlain by unit II that consists of shallow marine coarse siliciclastic deposits (Unit II). This unit is rich in vertebrate fossil fragments. Unit III is composed of fine to coarse siliclclastc deposits with *Ophiomorpha* trace fossils. Unit IV is represented by thick shale section with erosive base and variable thickness. The sediments Unit V, is recorded overlying unit IV and consists of three bioturbated sandstones. Unit VI is based by erosional surface and consists of fluvial input sediments rich in vertebrates and silicified trunks. This unit is similar to unit II in composition. Unit VI is overlain by unit VII, which is represented by sand shale intercalation with the sand dominated and become more shaley upward with *Ophiomorpha* and *Thalassinoid* trace fossils. Units VIII, Unit X, XII, XIV and XVI are similar to unit VI in their composition. Unit IX is based by heterolithic bed with burrows and topped by marine shale bed towards east. Units XI, XIII, XV are represented by calcareous beds and rich in *Ophiomorpha* and bioturbation. However, these units have not been discussed in details because they have now been superseded by sequence stratigraphy subdivision (more details of sequence subdivision in Chap. 5). These lithostratigraphic units however, have been useful for the preliminary field correlation before constructing the sequence stratigraphic model.

The following table gives an extended summary for the main stratigraphic units of the northeastern part of Moghra Depression (Table 2.1).

2.3 Geochronology

There is a lack of suitable material for absolute dating of the critical mid Cenozoic Moghra Formation by conventional methods such as K/Ar or $^{40}Ar/^{39}Ar$. However, indirect dating using strontium isotope stratigraphy is possible. Precise and detailed data on the variability of strontium isotopes with time in the world's oceans is now known for much of Phanerozoic time (see Howarth and Mcarthur 1997) and local curves for specific stratigraphic sections are increasingly used to infer absolute ages (e.g., Hurst 1986; Mckenzie et al. 1988; Rundberg and Smalley 1989; Smalley et al. 1986; Whitford et al. 1996). For the mid Cenozoic in particular, the strontium isotope sea-water curve changes rapidly with time, and so is particularly suitable for geochronology. In this time interval, resolution of stage boundaries is better than 0.5 m.y. (Howarth and Mcarthur 1997; Oslick et al. 1994), making the method a powerful tool for improving correlation between biostratigraphic and chronostratigraphic timescales (Graham et al. 2000).

Table 2.1 The stratigraphic classification of the studied sections

Section	Thickness (m)	WP	Location	Units/Thick (m)		Field description
1	77	003		V	19.5	Bioturbated bed + shell (pelecpods).
				IV	8	Shale + plant remains
				III	10	Burrowed sandstone + *Ophiomorpha*
				II	29.5	Sand, vertebrates, wood.
				I	10.1	*Ophiomorpha* sandstone
Aux	38.5		30° 21.255'N 28° 52.195'E	V	10.5	Highly bioturbated sand with thick *Thalassinoides* rather than *Ophiomorpha* + sandstone with ripples & flasers + fossiliferous sandstone with pelecypods, shale layers
				IV	22	Black shale with slumping structure.
				II	5	Fluvial sand, vertbrates
2	41.8	6	30° 21.263'N 28° 52.321'E	II	32	Fluvial sand, vertbrates
				I	12.2	Burrowed sand shale intercalated.
3	14.7	020 Top 001 Base	30° 20.911'N 28° 53.625'E 30° 20.909'N 28° 53.625'E	II	7.7	Sandstone
				I	7	Sandstone, burrowed, gypsum
4	111.3	013	30° 21.039'N 28° 55.130'E	X	20	Sandstone, vertebrates and trunks
				IX	3.5	Sand- shale intercalations
				VIII	8.5	Sandstone, vertebrates and trunks
				VII	6	Wavy and ripple laminted heterolithic bed + siltstone with ferruginous hard crust.
				VI	10.3	Coarse sand grain with silicified wood fragments and bone fragments.
				V	16.5	Fine calcareous sand, highly bioturbated with *Thalassionoid*.
				IV	12.15	Fine sand + lag with vertebrates + cross bedded sand + ripple and flaser sand intercalated with shale.
				III	5.6	*Ophiomorha* and *Thalassinoid* medium sand + laminted shale + heterolithic bed.
				II	15	Sandstone, vertebrates and trunks
				I	13.6	Sandstone, shale with *Ophiomorpha*
5	92		30° 21.173'N 28° 57.893'E	XII	15	Fining up ward cross-bedded sandstone + roots and topped by Marmarica limestone.
				XI	10	Calcareous cross-bedded sandstone with large root cast.
				X	25	Slope forming, cross-bedded large scale fining upward sandstone.
				IX	13.7	Calcareous sandstone with *Ophiomorpha* + micaceous sandstone
				VIII	19	Sandstone with vertebrates + micaceous sandstone
				VII	3.3	Shale + flaser and laminted sandstone.
				VI	8.5	Fining upward sandstone, cross bedded + trunks

(continued)

Table 2.1 (continued)

Section	Thickness (m)	WP	Location	Units/Thick (m)		Field description
5’	15	63?	30° 21.541’N 28° 58.448’E	XVII	15	Cross-bedded fine sands with mangroves + thin laminted shale + hard dolomitic bioturbated.
6	163.5	42	30° 20.683’N	X	18	Trough filling cross-bedded sandstone + silicified trunks in the base and bioturbated and botridal sand in the top + dolomite
			28° 56.697’E	IX	2	Thin laminated, ripple silt with fine sand
				VIII	53	Slope forming, fine to medium cross-beded sans with 5 erosional surfaces marked by silicfied wood and vertebrates (coprolites) + mud shale intercalation in the top.
				VII	14	Highly bioturbated (honycamb) and homogenized sand + micaceous sand.
				VI	33	Slope forming cross-bedded coarse to medium sand with large trunks.
				V	12.1	Slope forming cross-bedded medium to fine grained sandstone with muddrapes and burrowed + hard mudstone + fractured mudstone and ferruginated
				IV	10	Cross-bedded sandstone mostly trough, with small scale tabular cross-bedding and silicified palm tree.
				III	16.8	Shale with gypsum and plantremains + *Ophiomorha* fine sand_channel fill cross-bedding sandstone + *Ophiomorha* sand.
				II	11	Tabular cross-bedded sand + trough cross bedding medium to fine sand + lag with vertebrates + trough cross-bedded sand.
				I	2	Highly bioturbated fine sand.
7	92.5	76	30° 22.389’N 28° 46.067’E	VI	12	Slope forming, medium to coarse cross-bedded sand with several erosional surfaces marked by silicfied wood and vertebrates.
				V	8	Slope forming, medium to coarse cross-bedded sand silicified wood and vertebrates.
				IV	4	Sand-shale intercalations, the sand rich in glauconite pellets and fissile shale.
				III	19.7	Fill structure, thin laminted heterolithic bed + burrowed sand + sand shale interclation + heterolithic bed.
				II	17.6	Slope forming, medium to coarse cross-bedded sand with three erosional surfaces marked by silicfied wood and vertebrates.
				I	6.6	Fine sand with mud drapes.
					15.3	Sand-shale intercalations, highly burrowed sand + shale with plant remains.
					8	Highly bioturbated heterolithic beds + micaceous sand with mud drapes.
8	28.5		30° 21.123’N	II	10	Sandstone, vertebrates, wood
			28° 47.562’E	I	18.2	Sand, shale intercalated, *Ophiomorpha*
9	86.5	69	30° 25.312’N	XVII	22	Fossiliferous limestone, shale
			28° 45.004’E	XVI	20	Sandstone, vertebrates, wood
				XV	21.5	Fossiliferous limestone
				XIII	24	Sand-shale intercalations
10	36	66	30° 26.294’N 28° 52.41’E	XVII	36	Sandstone, fossiliferous limestone

(continued)

Table 2.1 (continued)

Section	Thickness (m)	WP	Location	Units/Thick (m)		Field description
11&12	11.1	94	30° 17.527'N 28° 57.040'E	Zero?	11.1	Cross-bedded sand with small burrows + fractured claystone kaolinitic with small burrows + sandstone with vertical burrows + cross-bedded sand with erosive base + sand shale intercalcated + cross-bedd sand + mudstone with burrowed + sand shale interclation + shale with burrows
13	26.3	95	30° 18′101'N 28° 57.539'E	Zero?	26.3	Sand with silicified + siltstone + cross-bedded sand + shale non fissile + sand with clay intercalation + sandstone with bone fragment + crust + cross-bedded with vertebrates and bone fragments.
20	136.2	181 27	30° 24.224'N 28° 42.844'E	XVI	19	Sandstone, wood, vertebrates
				XV	29	Calcareous Sandstone, shell fragments
				XIV	9	Sandstone
				XIII	4.5	Sand-shale intercalation
				XII	8.5	Sandstone
				XI	1.5	Calcareous sandstone, shell fragments, *Ophiomorpha*
				X	8.5	Sandstone, wood, vertebrates
				IX	22	Calcareous Sandstone, *Ophiomorpha,* shell fragments
				VIII	11.5	Sandstone, wood, vertebrates
				VII	5.5	Sand-shale intercalation
21	230.15		30° 22.87'N 28° 41.135'E	XVI	50	Sandstone, wood, vertebrates
				XV	12.5	Sand-shale intercalation
				XIV	9	Sandstone
				XIII	15.5	Sand-shale intercalation, burrowed
				XII	10	Sandstone, wood, vertebrates
				XI	35	Homogenized cross-bedded sand.
				X	25	Sandstone, wood, vertebrates
				IX	9	Sand-shale intercalation, sand lenses
				VIII	34.5	Sandstone, vertebrates
				VII	3.5	Sandstone, *Ophiomorpha, Thalassinoid*
				VI	8	Sandstone, wood, vertebrates
				V	2.5	Sandstone, *Ophiomorpha*
				IV	3	Sand-shale intercalation
				III	3	Sandstone, *Ophiomorpha*
				II	7.5	Cross-bedded sandstone
				I	15.5	Sand-shale intercalation

(continued)

Table 2.1 (continued)

Section	Thickness (m)	WP	Location	Units/Thick (m)		Field description
22	171.5		30° 24.662'N 28° 33.836'E	XV	3	Calcareous sandstone
				XIV	26.5	Sandstone, wood, vertebrates
				XIII	30.5	Calcareous sandstone, sand-shale intercalated, *Ophiomorpha*
				XII	19.5	Sandstone, bones, *Ophiomorpha*
				XI	26.5	Calcareous sandstone, *Ophiomorpha, Limestone*
				X	20	Sandstone, wood, vertebrates
				IX	2	Sand-shale intercalation, burrowed
				VIII	8	Sandstone, gypsum at the base
				VII	20.5	Sand-shale intercalation, burrowed (*Ophiomorpha*)
				VI	7.5	Sandstone
23	13	197	30° 21.66316 28° 37.10199	?	13	Calcareous sandstone
24	61	204	30° 24.89'N 28° 35.114'E	XI	7	Calcareous sandstone
				IX	9.5	Sand-shale intercalation, *Ophiomorpha, Sandstone*
				VIII	22	Sandstone
				VII	22.5	Sand-shale intercalation, *Ophiomorpha*
25	88.5	205	30° 26.14962 28° 34.92005	XIII	41.3	Fossiliferous limestone_shale-sand intercalation + cross-bedded sandstone
				XII	30	Slope forming cross-bedded sandstone
				XI	18	Shale-sand intercalation + Fossiliferous limestone
26	30	213&214		Zero	30	Fine calcareous sandstone with largetrunks + shale + fine sandstone
30	87		30° 20.77512 28° 52.90753	VI	12.5	Sandstone, wood, vertebrates
				V	27	Sandstone, *Ophiomorpha*
				IV	4	Mudstone with plant remains
				III	4	Cross-bedded sandstone
				II	6	Sandstone, wood, vertebrates
				I	31.5	Shale, sandstone, wood, vertebrates
32	33		30° 26 51.421 28° 46 51.961	XVII	33	Sand-shale intercalation, fossiliferous limestone

*Zero is a unit candidate to be below unit I

2.3.1 Previous Work and Discussion

The major difficulty in assessing the age of Moghra is that the site is not associated with volcanic deposits, making it impossible to date the Moghra mammals radiometrically. Some of the previous works considered the only way to assess the age of the Moghra mammals is by faunal correlation with fossil sites that have absolute dates. In East Africa, a time successive sequence of radiometric dates has been developed for a number of localities ranging across the early and middle Miocene, and the age of the Moghra fossil mammals can be estimated by comparison of the Moghra fauna with that of East Africa as indicated by Miller and Simons (1996). They argued that the most conservative estimate for the age of Moghara is 18–17 Ma, approximately the same age as the Rusinga (Hiwegi) fauna. In addition, relatively rarer faunal elements shared between Moghara and Napak, but not with Zelten in Libya, suggest that Moghara is older than Zelten. The same authors stated, however, that the evidence that Moghara may be as old as Napak (ca. 19 Ma) is not compelling as almost all genera shared between Moghara and Napak are also found at Rusinga (ca. 18–17 Ma). These findings are in general agreement with those reached by Pickford (1991) concerned with the age of Zelten, and confirm the hypothesis of Geraads (1987) that Moghra is older than Zelten. They indicated that the Moghara mammals are probably about 18–17 Ma, and have their closest biogeographic affinities with certain East African sites. In fact, it appears that the Moghara fauna is more similar to the mammals from a number of East African sites than it is to the fauna from Gabal Zelten, Libya.

McCrossin (2008) concluded that the assessment of the Jabal Zaltan and Moghra faunas indicates that previous attempts at biochronologic correlation oversimplified the span of time represented by these deposits. Rather than being roughly equivalent to Maboko (ca. 15–16 Ma), the mammal faunas of Jabal Zaltan extend for long periods of time, from the terminal Oligocene or basal Miocene (ca. 22–26 Ma?) in the northern reaches of the Marada Formation to the middle-later part of the Middle Miocene (ca. 12–15 Ma) near Wadi Shatirat. He also mentioned that mammal fossils from Moghara date not only from the later part of the early Miocene (ca. 17 Ma) but also from the early part of the middle Miocene (ca. 15 Ma). Contrary to widely held opinion, the cercopithecoid from Gabal Zelten is more primitive (and probably, therefore, more ancient) than *Prohylobates tandyi* from Moghara. Reassessment of the mammal faunas of Gabal Zelten and Moghara demonstrates a substantial degree of North African zoogeographic provincialism, together with connections to sub-Saharan Africa and Eurasia.

Others works considered the geochronology of the Neogene is based, to a large extent, on paleontological as well as stratigraphical evidence. The large collection of macroinvertebrates recorded from the Miocene of Egypt (Blanckenhorn 1900; Blanckenhorn 1901; Fourtau 1920; Sadek 1968; Said and Yallouze 1955, etc.) has not been successfully used to zone the Miocene rocks. Mention has frequently been made of the cephalopod *Aturia aturi* as an index of the Langhian (Said 1990). However, the present study succeeded in using macroinvertbebrates to date the

Miocene of Moghra Formation within Burdigalian. Agree with Abdallah (1966) mentioned that the Moghra Formation is of Burdigalian age and the lowermost Lower Miocene (Aquitanian) is not found. Furthermore, Upper Miocene (post—Tortonian-Helvetian) is absent also.

For earlier studies involving the ages of Moghra and Zelten based on previous radiometric information or correlation of marine (foraminifera) or land animals see Arambourg (1963); Bernor (1984); Desio (1935); Hamilton (1973a), (b); Harris (1973); Hoojier (1978); Pickford (1981), (1983), (1991); Savage (1967), 1969, 1971, 1990); Savage and Hamilton (1973); Savage and White (1965); Savage in Selley (1966); Tchernov et al. (1987); Thomas (1979), (1984); Wilkinson (1976); Van Couvering (1972); Van Couvering and Berggren (1977); Van Couvering and Van Couvering (1975).

2.3.2 Absolute Ages from Strontium Isotopes

2.3.2.1 General Principles

Dating marine sediments using strontium isotopes is based on the following assumptions and observations: (1) at any point in time, the $^{87}Sr/^{86}Sr$ ratio of sea-water is homogeneous throughout the world's oceans (Elderfield 1986; Faure 1986) because the oceanic residence time of strontium (24 m.y.) is much longer than the mixing time of the oceans (c. 0.001 m.y.) (Broecker and Peng 1982); (2) over geologic time, sea-water $^{87}Sr/^{86}Sr$ varies because of changes in the relative fluxes of strontium to the oceans from different sources (e.g., continental runoff, hydrothermal outflow at mid-ocean ridges, diagenetic reflux from buried pore waters), each with its own characteristic $^{87}Sr/^{86}Sr$ ratio (Palmer and Edmond 1989; Richter et al. 1992). At steady state, these inputs are counteracted by removal of strontium via sedimentation, and exchange of radiogenic strontium in hydrothermal waters for that in basalts (Veizer 1989); and (3) strontium is removed from sea-water by co-precipitation in biogenic carbonate. The isotope composition of strontium in calcitic macrofossils is identical to that of the oceans in which they lived, provided that the macrofossils are well preserved and the effects of diagenesis are minimal (Richter and Depaolo 1987). Although planktic foraminifera are often used for calibration of sea-water curves, there is no convincing evidence that contemporaneous bottom-dwelling benthic foraminifera or macrofossils have significantly different $^{87}Sr/^{86}Sr$ values from their planktic cohabitors (Graham et al. 2000).

2.3.2.2 Methods

The sections of Moghra Formation have been well studied stratigraphically and have macrofossil faunas, providing excellent material for strontium isotope analysis and for biostratigraphic control.

2.3.2.3 Fossil Collections

About 10 samples of fresh macrofossil shell material, mainly pectinids, Echinodermata, and oysters, were collected from several previously well documented earliest Miocene sections within the Moghra Formation. In all cases the associated lithostratigraphic units (in this formation) bearing the fossils had previously been assigned to Lower Miocene. The fossils represent mainly isolated specimens from separate localities and different sections. Stratigraphic information for the analysed fossil collections is summarized in Table 2.2.

Table 2.2 Strontium isotope data and age calculations for macrofossils samples

Type of fossil	Sample No.	Unit	$Sr^{87/86}$	Precision	Age (Ma)
Mollusca (Pelecypoda)	(10-7)	XVII	0.708658	0.000018	17
Pecten (N)	(10-6-2)	XVII	0.708700	0.000010	16.5
Echinodermata	(10-3)	XVII	0.708637	0.000010	17.1
Echinodermata	(9-1-2)	XIII	0.708615	0.000010	17.4
Mollusca (Pelecypoda)	(20-9-1)	XV	0.708525	0.000018	18.2
Echinodermata	(22-12)	XI	0.708656	0.000011	18
Mollusca (Oyster)	(Ox2)	V	0.708534	0.000010	18.2
Mollusca (Oyster)	(1-2-5-1)	II	0.708170	0.000010	23
Mollusca (Oyster)	(3-2-2)	II	0.708445	0.000018	19.6
Mollusca (Pelecypoda)	(21-1-4)	I	0.708410	0.000018	21

Analyses undertaken at Lamont Doherty Earth Observatory Lab, Columbia University, New York.

2.3.2.4 Analytical Methods

Macrofossil material (mainly pectinid mollusks, Oyster and Echinodermata) were prepared. From the original suite of fossil samples, 10 were selected for Sr isotope analysis, from different localities. After careful cleaning to remove surficial impurities or rock matrix, the shells were powdered and small (30–50 mg) aliquots were leached in cold 1 *M* acetic acid (Bailey et al. 2000). Acetic acid was used for sample dissolution in order to minimize the extraction of strontium from dolomite, clays, and other terrigenous material (Depaolo 1986).

Sr was extracted from the leachates using a single pass over small (0.1 ml) beds of EICHROM™ Sr resin. Strontium isotope analysis of macrofossil material was carried out on a VG sector 54 multi-collector thermal ionization mass spectrometry (TIMS) at Lamont Doherty Earth Observatory Lab (Fig. 2.2), Columbia University, New York. General methods are described in Bailey et al. (2000).

Fig. 2.2 Mass spectrometer at Lamont Doherty earth observatory lab, Columbia university, New York

2.3.2.5 Results and Discussion

Macrofossil samples show a coherent pattern of slightly increasing strontium isotope ratios with stratigraphic height, indicating an upwards younging direction (Fig. 2.3) as seen in Hodell et al. 1990 (Fig. 2.4).

Macrofossil samples have significantly high strontium isotope ratios ranging from 0.708410 ± 0.000018 to 0. 708658 ± 0.000018 (Table 2.2). There is a smooth and consistent increase in $^{87}Sr/^{86}Sr$ up through the section, the basal two samples having a mean of 0.7084275 (20.05 ± ? Ma), the middle three samples

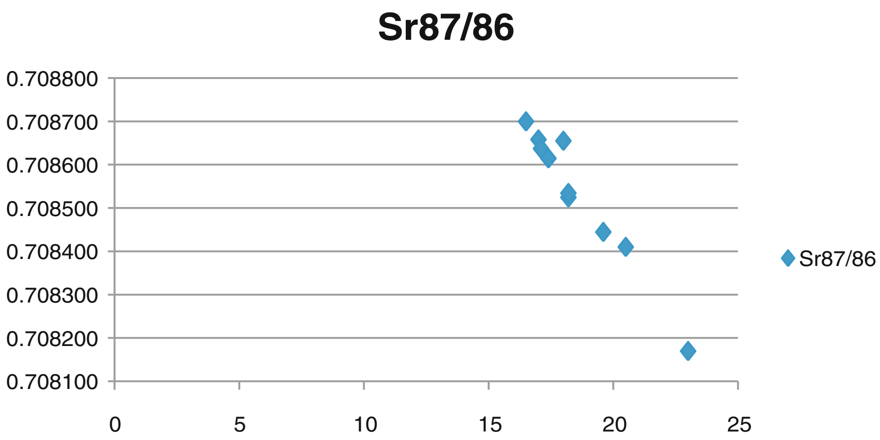

Fig. 2.3 $^{87}Sr/^{86}Sr$ seawater curve during early Miocene

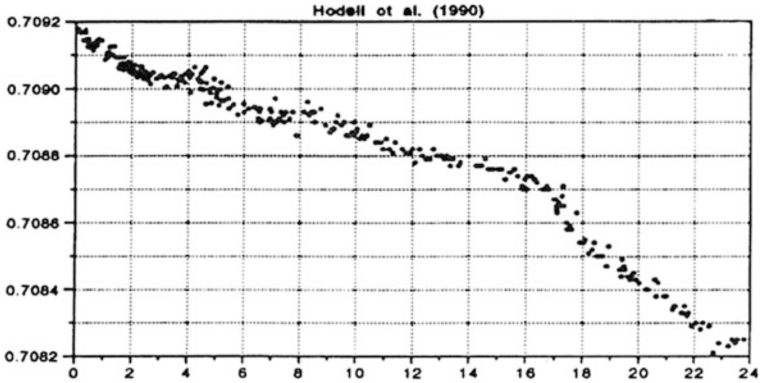

Fig. 2.4 Variation in the stronium isotopic composition of seawater on a progressively expanding timescale during Neogene (modified from Hodell et al. 1990)

having a mean of 0.7085716 (18.3 ± ? Ma) and the top three samples a mean of 0.708636 (17.16 ± 0.? Ma) Table 2.2.

The $^{87}Sr/^{86}Sr$ of two samples 1-2-5-1 and 10-6-2 are significantly different from adjacent samples, and have been excluded as an outlier. The sample 1-2-5-1 is oyster and sample 10-6-2 is pectin, thick-shelled pectin distinctly different from the thin-walled pectinids which comprise the other samples. Two excluded samples have lower $^{87}Sr/^{86}Sr$ suggesting they could be older, reworked from lower down in the succession, or they were originally aragonitic and their original $^{87}Sr/^{86}Sr$ have been altered by neomorphism and/or diagenesis.

2.3.2.6 Summary

Strontium isotope analysis of macrofossil fragments from Moghra Formation has provided a chronology for the section and established a correlation with the global time-scale. Strontium isotope ratios of macrofossil are identical and indicate an age for the section ranging from 20.5 Ma at the base to 17 Ma at the top, placing most of the section within the Burdigalian.

References

Abdallah A (1966) Stratigraphy and structure of a portion in the North Western desert of Egypt (El Alamein-Dabaa-Qattara-Moghra areas) with reference to its economic potentialities. Geol Serv Egypt, Paper, 45:1–19

Arambourg C (1963) Continental vertebrate faunas of the tertiary of North Africa. In: Howell FC, Bourliere F (ed) African ecology and human evolution. Aldine Press, Chicago, p 55–60

Bailey T, Mcarthur J, Prince H, Thirlwall M (2000) Dissolution methods for strontium isotope stratigraphy: whole rock analysis. Chem Geol 167:313–319

Bernor R (1984) A zoogeographic theater and biochronologic play: the time-biofacies phenomena of Eurasian and African Miocene mammal provinces. Paléobiologie continentale 14:121–142

Blanckenhorn M (1900) Neues zur Geologic and Palaontologie Aegyptens 11, Das Palaeogen (Eocan und Oligocan). Deut Geol (Jesell. Zeitschr) 52:403–479

Blanckenhorn M (1901) Neues zur Geologie und Palaeontologie Aegyptens: III: Das Miozän. Zeitschrift der Deutschen Geologischen Gesellschaft 53:52–132

Broecker W, Peng T (1982) Tracers in the sea, vol. 690. Lamont-Doherty Geological Observatory, Palisades, New York

Depaolo D (1986) Detailed record of the neogene Sr isotopic evolution of seawater from DSDP site 590B. Geology 14:103–106

Desio A (1935) Missione scientifica della Reale Accademia d'Italia a Cufra (1931-IX); vol. I, Studi geologici sulla Cirenaica, sul deserto Libico, sulla Tripolitania e sul Fezzan orientali

Elderfield H (1986) Strontium isotope stratigraphy. Palaeogeogr Palaeoclimatol Palaeoecol 57:71–90

Faure G (1986) Principles of isotope geology. Wiley, New York, p 589

Fourtau D (1920) Contribution a l'etude des vertébrés miocènes de l'Egypte. Government Press, Cairo, p 122

Geraads D (1987) Dating the northern African cercopithecid fossil record. Human Evolution 2:19–27

Graham I, Morgans H, Waghorn D, Trotter J, Whitford D (2000) Strontium isotope stratigraphy of the Oligocene-Miocene Otekaike Limestone (Trig Z section) in Southern New Zealand: age of the Duntroonian/Waitakian stage boundary. N Z J Geol Geophys 43:335–348

Hamilton W (1973a) The lower Miocene ruminants of Gebel Zelten, Libya. Br Mus (Nat Hist) 21:73–150

Hamilton W (1973b) North African lower Miocene rhinoceroses. Br Mus (Nat Hist) 24:351–395

Harris J (1973) Prodeinotherium from Gebel Zelten, Libya. Br Mus (Nat Hist) 23:285–348

Hodell DA, Mead GA, Mueller PA (1990) Variations in the strontium isotopic composition of seawater (8 Ma to present): Implications for chemical weathering rates and dissolved fluxes to the oceans. Chem Geol 80:291–307

Hooijer DA (1978) Rhinocerotidae. In: Maglio VJ, Cooke HBS (eds) Evolution of African mammals. Harvard University Press, Cambridge, p 371–378

Howarth R, Mcarthur J (1997) Statistics for strontium isotope stratigraphy: a robust LOWESS fit to the marine Sr-isotope curve for 0 to 206 Ma, with look-up table for derivation of numeric age. J Geol 105:441–456

Hurst R (1986) Strontium isotopic chronostratigraphy and correlation of the Miocene monterey formation in the Ventura and Santa Maria basins of California. Geology 14:459–462

Mccrossin ML (2008) Biochronologic and Zoogeographic relationships of early-middle Miocene mammals from Jabal Zaltan (Libya) and Moghara (Egypt). Geol East Libya 3:267–290

Mckenzie J, Hodell D, Mueller P, Mueller D (1988) Application of strontium isotopes to late Miocene-early Pliocene stratigraphy. Geology 16:1022–1025

Miller E, Simons E (1996) Relationships between the mammalian fauna from Wadi Moghara, Qattara depression, Egypt, and other early Miocene faunas. In: Proceedings of the Geological Survey of Egypt Centennial Conference, p 547–580

Oslick J, Miller K, Feigenson M, Wright J (1994) Oligocene–Miocene strontium isotopes: stratigraphic revisions and correlations to an inferred glacioeustatic record. Paleoceanography 9:427–443

Palmer M, Edmond J (1989) The strontium isotope budget of the modern ocean. Earth Planet Sci Lett 92:11–26

Pickford M (1981) Preliminary Miocene mammalian biostratigraphy for western Kenya. J Hum Evol 10:73–97

Pickford M (1983) Sequence and environments of the lower and middle Miocene hominoids of western Kenya. In: Ciochon R, Corruccini RS (eds) New interpretations of ape and human ancestry. Plenum Press, New York, p 421–439

Pickford M (1991) Biostratigraphic correlation of the middle Miocene mammal locality of Jabal Zaltan, Libya. In: Salem MJ, Busrewil MT (eds) The geology of Libya. Academic Press, New York, p 1483–1490

Richter F, Rowley D, Depaolo D (1992) Sr isotope evolution of seawater: the role of tectonics. Earth Planet Sci Lett 109:11–23

Richter FM, Depaolo DJ (1987) Diagenesis and Sr isotope evolution of sea-water using data from DSDP site 590B and 575. Earth Planet Sci Lett 90:382–394

Rundberg Y, Smalley P (1989) High-resolution dating of cenozoic sediments from northern North sea using 87Sr/86Sr stratigraphy. AAPG Bull 73:298–308

Sadek A (1968) Contribution to the Miocene stratigraphy of Egypt by means of miogypsinids. Proc 3rd Afr Micropaleontol Colloq Cairo 509−514

Said R (1990) The geology of Egypt. AA Balkema, Rotterdam

Said R, Yallouze M (1955) Miocene fauna from Gebel Oweibid, Egypt. Bull Fac Sci Cairo Univ 33:61–81

Savage R (1967) Early Miocene mammal faunas of the Tethyan region. Syst Assoc Pub1 Lond 7:247–282

Savage R (1969) Early tertiary mammal locality in southern Libya. Proc Geol Soc Lond 1657:167–171

Savage R, Hamilton W (1973) Introduction to the Miocene mammal faunas of Gebel Zelten, Libya. Br Mus (Nat Hist) 22:515–527

Savage R, White M (1965) Two mammal faunas from the early tertiary of central Libya. Proc Geol Soc Lond 1623:89–91

Savage RJG (1971) Review of the fossil mammals of Libya. In: Gray C (ed) Symposium on the Geology of Libya. Faculty of Science, University of Libya, Tripoli, Libya, p 215–225

Savage RJG (1990) The African dimension in early Miocene mammal fauna. In: Lindsay EH (ed) European neogene mammal chronolgy. Plenum Press, New York, pp 587–599

Selley R (1966) The Miocene rocks of the Marada and Jebel Zeltan. A study of shoreline sedimentation. Geol Soc Lond 1623:89–91

Smalley P, Nordaa A, Raheim A (1986) Geochronology and paleothermometry of neogene sediments from the Vøring plateau using Sr C and O isotopes. Earth Planet Sci Lett 78:368–378

Tchernov E, Ginsburg L, Tassy P, Goldsmith N (1987) Miocene mammals of the Negev (Israel). J Vertebr Paleontol 7:284–310

Thomas H (1979) Les bovide′nes Miocenes rifts est-africans: implications pale′obiographiques. Bull Soc Ge′ol Fr 21:295–299

Thomas H (1984) Les Bovidae (Artiodactyla:Mammalia) Mioce/ne du sous-continent indien de la pe/ninsule arabique et de 1'Afrique:biostratigraphie, bioge/ographie et e/cologie. Palaeogeogr Palaeoclimatol Palaeoecol 45:251–299

Van Couvering J (1972) Radiometric calibration of the European neogene. In: Bishop W, Miller J (eds) Calibrarion of hominoid evolution. Scottish Academic Press, Edinburgh, p 247–272

Van Couvering J, Berggren W (1977) Biostratigraphical basis of the Neogene time scale. In: Kauffman EG, Hazel JE (eds) Concepts and methods in biostratigraphy. Drowden, Hutchinson & Ross, Pennsylvania, p 283–306

Van Couvering J, Van Couvering J (1975) African isolation and the Tethys seaway. In: VI th b, Congress regional committee on mediterrraen neogene stratigraphy, p 363–367

Veizer J (1989) Strontium isotopes in seawater through time. Annu Rev Earth Planet Sci 17:141–167

Whitford D, Allan T, Andrew A, Craven S, Hamilton P, Korsch M, Trotter J, Valenti G (1996) Strontium isotope chronostratigraphy and geochemistry of the Darai limestone: Juha 1X Well, Papua New Guinea: Petroleum exploration and development in Papua New Guinea. In: Proceedings of the 3rd PNG petroleum convention, p 369–380

Wilkinson A (1976) The lower Miocene Suidae of Africa. Fossil Vertebr Afr 4:173–282

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