# STRATIGRAPHY OF THE PALEOGENE SUCCESSION OF JABAL HAFIT, AL-AIN, U.A.E.

**A THESIS**

**Presented By**

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**For**

**The Degree of Doctor of Philosophy of Science (GEOLOGY)**



**To**

**Geology Department**
**Faculty of Science**
**Ain Shams University**

**1991**

بسم الله الرحمن الرحيم

TO MY DEAR FATHER
FOR EVERY THING

بسم الله الرحمن الرحيم

## ACKNOWLEDGEMENTS

I would like to thank Prof. M.A. BASSIOUNI, the Dean of the Faculty of Science Ain Shams University for his supervision, stimulating guidance and reading the manuscript.

No words can adequately express my deep gratitude to Prof. A.R.A. HAMDAN, Head of the Geology Department, U.A.E University for suggesting the subject of study, help in collecting the samples, supervision, fruitful discussions, and reading the manuscript.

I am greatly indebted to Prof. M.A. BOUKHARY, Department of Geology, Ain Shams University, for supervision, help in identifying the nummulitids, instructive discussions, reading the manuscript and for his overall generous attitude.

Sincere gratitude is due to Dr. H.S. ANAN, for his help in collecting the samples, in identifying the planktonic foraminifera, in the subjective discussions and for reading the manuscript.

I am grateful to Mr. HASSAN ABD EL-FATTAH, the photographer in the Audio visual department, U.A.E. university, for his good help in photographing the nummulitids and for his great cooperation.

My deep thanks go to Dr. FAESAL ABUL KADER, the director of the veterinary clinic, al-Ain, U.A.E., for his generous help in photographing the planktonic foraminifera by using the scanning electron microscope (SEM).

Finally I would like to thank my colleagues in the Department of Geology both in Ain Shams University, Particularly Prof. Dr. A. STROUGO and Dr. MONA HAGGAG, and U.A.E. University for their help and encouragement.

## CONTENTS

# CHAPTER (I)

## INTRODUCTION TO THE STUDY AREA

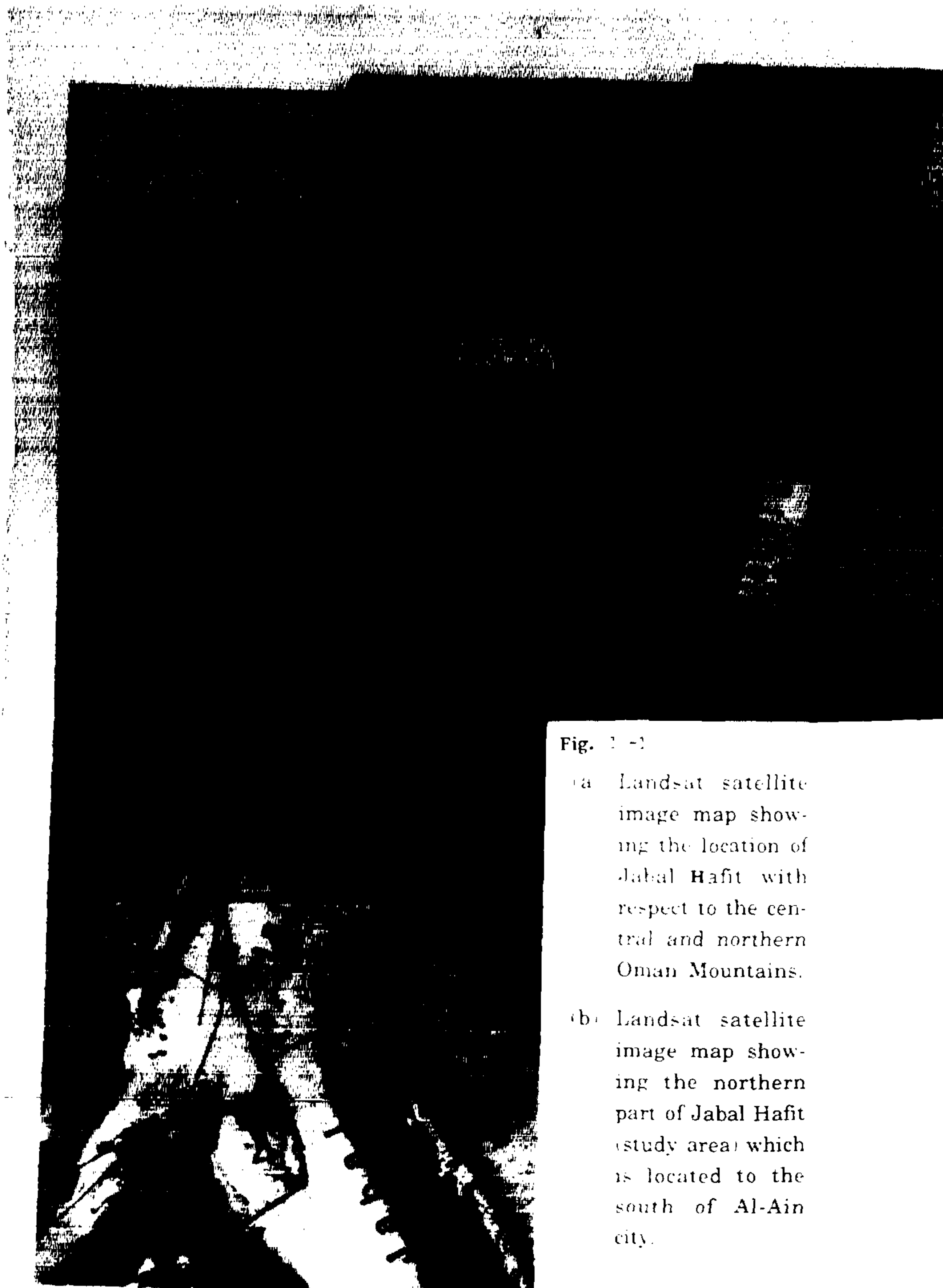
### 1. Location:

Al-Ain city is situated in the east of Abu Dhabi Emirate (United Arab Emirates) near the border with the Sultanate of Oman. It is the administrative center of the Eastern province and one of the largest and most ancient oasis of the Arabian Peninsula due to a plentiful supply of fresh underground water from the Oman Mountains to the east. It is characterised also by the establishment of the U.A.E. University. Jabal Hafit is considered as one of the most prominent monuments of the city (Fig. 1-1). Geologically, Al-Ain is believed to be located at the margin of the Oman Mountains and has been involved in the later stages of the mountain building processes.

Jabal Hafit (study area) is located to the south-east of Al-Ain city (lat. 24° 02' to 24° 13' N and long. 55° 44' to 55° 49' E). It is bounded to the north by Al-Ain city, to the east by Al-Jaww Plain, to the southeast by Mazyad, to the south by Oman and to the west by Ain Al-Faydah and Zakher. Ain Al-Faydah is a monumental area nearby Jabal Hafit and located to the west of it. It is believed that the source of its famous hot spring is situated under Jabal Hafit.

### 2. Geomorphology:

The geomorphology of Jabal Hafit is determined by its anticlinal structure. Its length is about 29 km, the width is about 5 km and it reaches an elevation of 1160 m above sea level. In the core of the mountain to the south, where the succession is composed almost of Rus Formation limestones and dolomites resistant to wadi erosion, the mountain is a whaleback with beds dipping down to the east and to the west in both limbs. The drainage is consequent on these dips and runs in deeply incised steep gullies. Marl forms an important part of the overlying Dammam Formation, it is less resistant to erosion leading to the development of two subsequent wadis parallel to the axis of the mountain: Wadi Tarabat to the east and Wadi Al-Nahayan to the west. North of the core of the anticline, the lower and middle intervals of the Dammam Formation are eroded forming a low-lying area with small hills enclosed between the



**(b)**

**Fig. 1 -1**

(a) Landsat satellite image map showing the location of Jabal Hafit with respect to the central and northern Oman Mountains.

(b) Landsat satellite image map showing the northern part of Jabal Hafit (study area) which is located to the south of Al-Ain city.

strike ridges of more resistant Asmari Formation limestone. These two strike ridges are called in the present study the "east cuesta" which reaches in some parts an elevation of 320 m. and the "west cuesta", with a maximum elevation of 460 m (Fig. 1-2).

## 3. Structure:

Jabal Hafit is a long (29 km), narrow (about 8 km exposed width), asymmetric, composite anticline. The east cuesta (dipping about 70°) is steeper than the west cuesta (dipping about 29°).

HUNTING (1979) described Jabal Hafit as a periclinal fold plunging south in Oman and north in the U.A.E. It is overturned and partly overthrust to the east. North-east of the Cement Factory, the axis of the fold is offset towards the east by a zone of complex structure. WARRAK (1986) reported that the structure consists of three en echelon anticlines; a main Jabal Hafit anticline in the south and two subsidiary ones to the north between the east cuesta and the west cuesta. These anticlines are linked in a simple zigzag pattern, with the anticlines of opposed plunges separated by a doubly plunging composite syncline.

Another important feature of Jabal Hafit structure recorded by WARRAK (1986) is the occurrence of major gentle folds superimposed on the east limb. These folds are responsible for the changes in the direction of dip from east to west through vertical, which are observed nearly along the whole length of the limb.

HUNTING (1979) reported that the rocks are cut by numerous normal and near vertical faults and other fractures as well as by reverse faults. Normal faults are either perpendicular to the axis of the fold or form north-east and north-west-trending sets with displacements which tend to elongate the rocks along the fold axis. In the north, the faults have formed zones of enhanced cementation and are marked by the rocky ridges perpendicular or oblique to the fold axis, particularily noticeable in the area of low hills south of the industrial area. In the south, fractures are marked by calcite veining. The calcite forms coarse prismatic crystals at right angles to the fractures walls and is locally colour-banded parallel to these walls. A prominent group of north-trending fractures on the crest and west limb of the fold in the extreme

Fig. 1-2:

A – [illegible] from the north. Note the western dip of the beds on the right side of the photo and the easterly dip of the beds on the left side of the photo.

B – Photograph showing the [illegible]

south is related to a monoclinic developed within this limb in the Oman. Nearly all faults observed either die out away from the core of the Jabal Hafit anticline or show reduced displacements. It appears that the strains have been taken up by internal flowage within the incompetent marl layers and that nearly all observed faulting and fracturing is related to the growth of the fold and is not due to later earth movements.

## 4. MATERIALS AND METHODS

In this study 289 rock samples are collected from 8 outcrop measured sections representing the Paleogene succession of Jabal Hafit: sections 1 (Wadi Tarabat) and 2 (core of Jabal Hafit) represent the core of the anticline, sections 3 (Wadi Al-Nahayan and Ain Al-Faydah), 5 (Cement Factory round about), 6 (Cement Factory marl open pit mine), 7 (Al-Ain Zoological Garden) and 8 (Cement Factory chalk open pit mine) represent the western limb, while section 4 (Mazyad Road) represents the eastern limb (Fig.1-3). Figure 1-4 is a geological map of the study area, modified from HUNTING (1979).

Standard stratigraphical and micropaleontological techniques and methods are used to analyse the collected samples. The following is a brief description of the micropaleontological methods:

1. The samples were crushed, washed and finally dried. The foraminiferal species of the planktonics and smaller nummulitids were separated under the binocular microscope, whereas the large nummulitids were separated by the naked eye according to their morphology and biometry.

2. The planktonic foraminifera were identified, photographed by using the scanning electron microscope, classified phylogenetically and subdivided into stratigraphic zones and finally the distribution charts were drawn for the planktonic species in the different measured sections (except section 8, due to the scarcity of the fauna).

3. The nummulitids were biometrically analysed, thin-sectioned axially and equatorially, photographed (using the scanning electron microscope in case of smaller nummulitids) both A and B-forms axially, equatorially and externally. Spiral diagrams were drawn for each species. The nummulitids were identified phyletically and classified into biostratigraphic zones and finally distribution

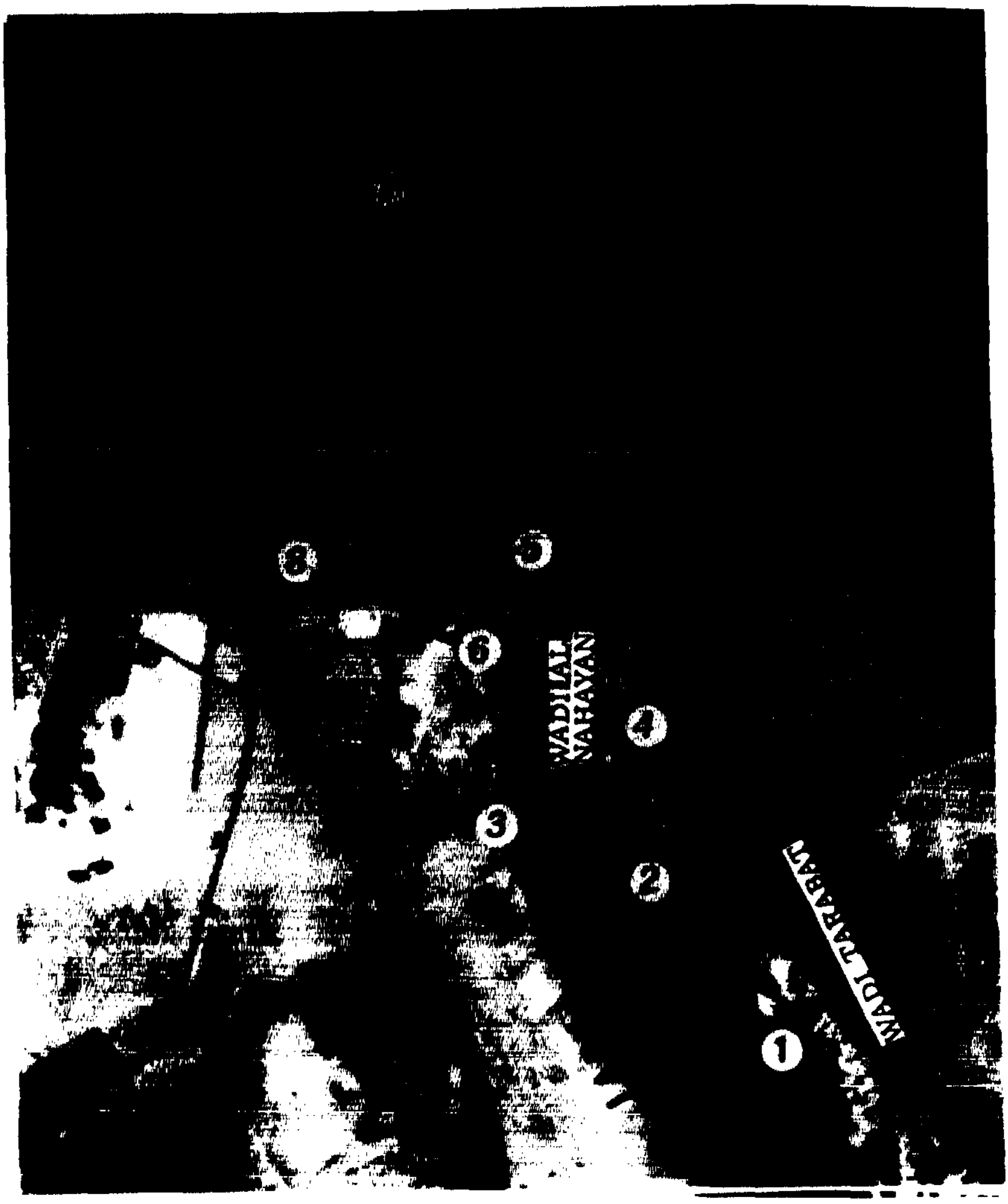
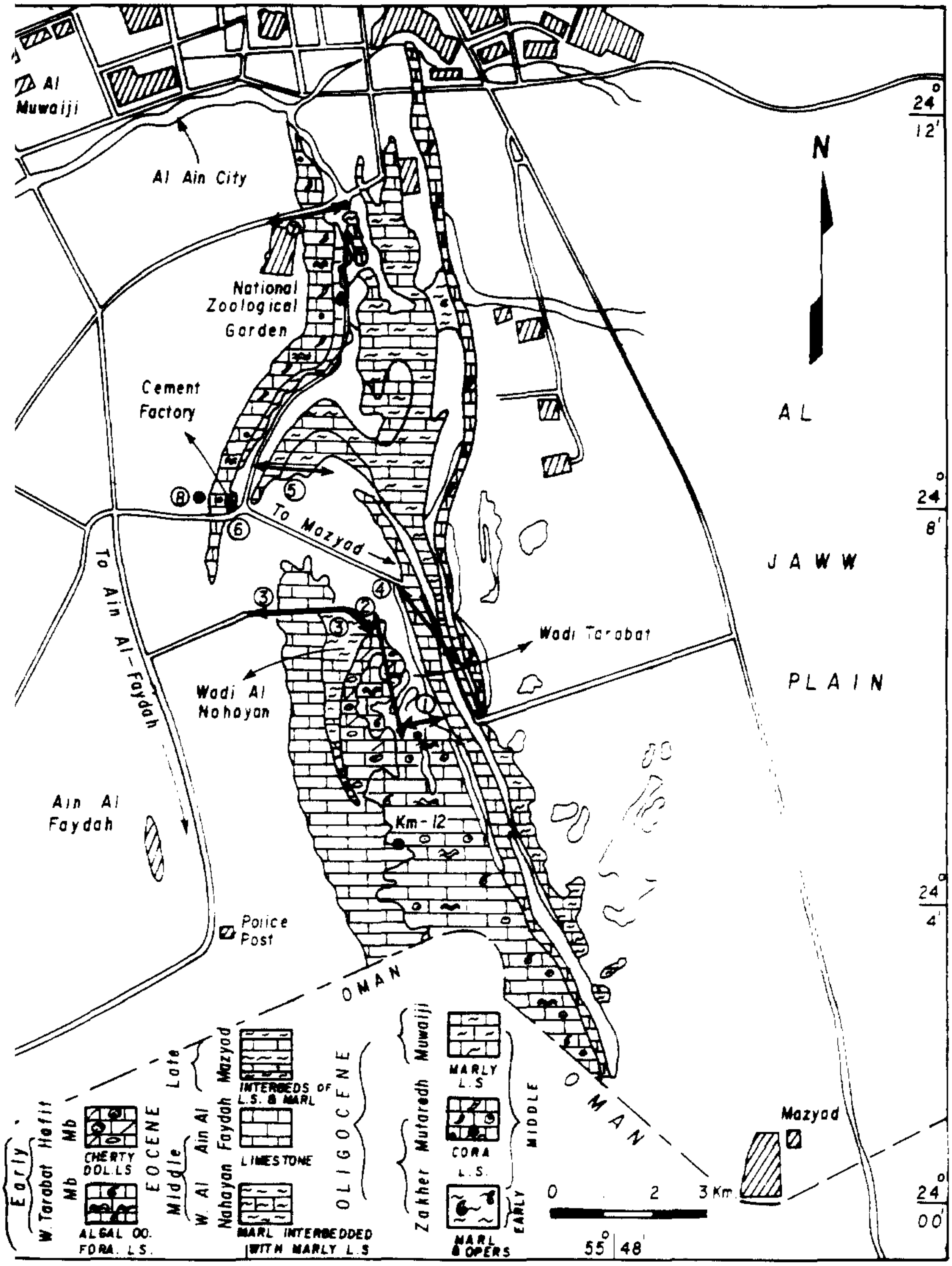



**Fig. (1-3)**

Landsat satellite image map showing the [illegible] of Jabal al Hafit and the location of the eight measured sect[illegible]

1 Wadi Tarabat
2 [illegible] Jabal Hafit
3 Wadi al Nahayan & Ain Al Faydah
4 Mazyad Road
5 Cement Factory [illegible] about
6 Cement Factory [illegible]
7 Al Ain Zoological Gardens
8 [illegible]




ig.( 1.4 ) Geological map of Jabal Hafit ( after Hunting. 1979 - with modification ) charts were drawn for the Nummulites species in the different measured sections.

4. On the basis of micropaleontological analysis of the planktonic and large benthonic (nummulitids) foraminifera, it has been possible to classify the fauna and to study the phylogenetic relationships between species and to discuss the lineages which are known internationally besides those that have been erected herein.

5. Biostratigraphic zonations for the planktonics and nummulitids of the Paleogene successions have been erected.

# CHAPTER (II)
# PREVIOUS WORK

The stratigraphy of the Paleogene successions in Al Ain region has been attempted by several workers. GIBB (1970), TERRATEST (1973) and HOLDERBANK (1975) carried out surveys as part of a feasibility study for establishing Al Ain Cement Factory. Their works were submitted as internal reports to the concerned departments of the U.A.E. TERRATEST (1973) described a Paleocene succession exposed in Jabal Malaqet, east of Al Ain, consisting of marl layers, glauconitic limestone and marly limestone interbedded by fine-grained breccia with some chert. The strata exposed in the Jabal Hafit range were considered of Lower, Middle and Upper Eocene age on the basis of their foraminiferal content. Middle Eocene rocks were assigned to the conglomeratic unit and form the main part of the Jabal Hafit, whereas an Upper Eocene age was assigned to the overlying foraminiferal limestones interbedded with thin marl layers, exposed west of the core of Jabal Hafit and south of Al Ain.

HUNTING (1979), studied the geology of Al Ain region and established a geologic map of Jabal Hafit. This investigation has resulted in the first lithostratigraphic and chronostratigraphic subdivision of the Paleogene strata (Table 2.1). The ages of lithostratigraphic units are mainly based on the micropaleontologic dates of TERRATEST (1973). The HUNTING report recognised eleven mappable and coded rock units (where: T = Tertiary, l = Lower, e = Eocene, o = Oligocene, and m = Miocene) arranged, from base to top, as follows:

**1. Cream Limestone ($Tle_1$), Paleocene to Middle Eocene:**

It is composed of cream medium and coarse-grained porous limestone partly dolomitised. The base of this unit is not exposed and is only recorded in a borehole drilled south of the Al Ain industrial area (Senaiyah). It overlies unconformably the shallow-water Simsima Limestone of Maestrichtian age (GLENNIE et al., 1974).

**2. Grey Nodular Limestone ($Tle_2$), Middle Eocene:**

It is unconformable with the underlying rock unit ($Tle_1$). It consists of grey fine and medium-grained well bedded nodular limestone with chert segregation. Pebble and boulder limestone conglomerates are also recorded in this unit.

**3. Lower yellow Marl ($Tle_3$), Middle Eocene:**

It is composed of yellow, locally crimson claystone and marl in the north and changes towards the south to thin, nodular limestone.

**4. Buff Nodular Limestone ($Tle_4$) , Middle Eocene:**

This rock unit consists of buff, grey-weathered medium grained limestone interbedded with yellow marl.

**5. Middle Yellow Marl ($Tle_5$), Middle Eocene:**

It is a succession of yellow, locally crimson marl and claystone with thin marly limestone bands.

**6. Brown Nummulitic Limestone ($Tle_6$), Upper Eocene:**

This rock unit consists of brown, medium-grained foraminiferal limestones with rough weathered surfaces. In the north, it is underlain by buff, thinly bedded limestones and marls interbeds:

**7. Upper Yellow Marl ($Tle_7$), Upper Eocene:**

It is similar in composition to the Lower Yellow Marl ($Tle_5$) unit. It consists of yellow, buff and brown marl and claystone with thin muddy limestone bands.

**8. Biostromal Limestone ($Tlo_1$), Lower Oligocene:**

It is a succession of grey weathered, medium-grained, thickly bedded nodular limestone with abundant fossil debris

**9. Muddy Calcarenite and Marl ($Tlo_2$), Oligocene to Miocene:**

It is conformable with the underlying biostromal limestone and is only exposed at the base of the eastern flank of Jabal Hafit. It consists of interbedded, muddy calcarenites and fossiliferous limestones and clays. The upper part consists of a thinly bedded sequence of muddy calcarenites, oolitic and bioclastic limestones and gypsiferous marls and clays with abundant fossils. This top part of the unit is considered of Miocene age.

**10. Clay with Gypsum ($Tm_1$), Miocene:**