Lower Cretaceous (Upper Barremian-Lower Albian) Ammonite faunas of the Kopet Dagh Basin, NE Iran

Submitted for degree of Doctor of Philosophy

Seyed Naser Raisossadat

University College London
Department of Geological Sciences

June 2002

ProQuest Number: 10010098

All rights reserved

INFORMATION TO ALL USERS
The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript
and there are missing pages, these will be noted. Also, if material had to be removed,
a note will indicate the deletion.

ProQuest 10010098

Published by ProQuest LLC(2016). Copyright of the Dissertation is held by the Author.

All rights reserved.
This work is protected against unauthorized copying under Title 17, United States Code.
Microform Edition © ProQuest LLC.

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

Abstract

The Kopet Dagh basin is situated in the north-east of Iran. The ammonite faunas of the Sarcheshmeh and Sanganeh Formations have been studied. Ten stratigraphic sections have been measured and sampled.

Species of Heteroceratidae, Ancyloceratidae, Deshayesitidae, Parahoplitidae, Douvilleiceratidae, Desmoceratidae and Oppeliidae are described, some new to the basin. The faunas are of Late Barremian to Late Aptian age. Previous records of Early Albian forms are reviewed.

A Lower Cretaceous ammonite biozonation for the Kopet Dagh Basin is proposed and can be correlated to the standard Mediterranean biozonation in most sub-stages.

The ammonite faunas are grouped into four morphogroups. Study of the distribution of the shell morphogroups in relation to lithofacies indicates that facies and associated sea-level changes played a significant role in the distribution of ammonites in the basin. The Parahoplitidae and Deshayesitidae, both with ornamented shells, lived in medium to high energy environments, while the smooth-shelled Desmoceratidae and Oppeliidae preferred quieter conditions.

The effects of two significance sea-level rises and many minor ones can be traced in the Sarcheshmeh and Sanganeh Formations. In most cases, genera or species first appear in the basin in transgressive and highstand systems tracts.

The palaeobiogeographical relationships of the ammonites indicate that during the Late Barremian to Upper Aptian the basin formed part of the Mediterranean-Himalayan Province, but in the latest Aptian and Albian was open to Mediterranean-Caucasian faunas. The ammonite faunas coupled with the palaeogeographical position of the basin at the northern margin of Tethys indicate a close relationship with the Caspian and Caucasian regions.

Acknowledgements

First of all I would like to thank my supervisor at UCL, Professor Peter Rawson, for his guidance, help and support. I have learned an immerse amount from working with him. Financial support from the Ministry of Science, Research and Technology of Iran is greatly acknowledged.

Further I am grateful to the academic staff of the Geological departments at UCL and Birkbeck College, especially Professor A. Lord, Dr. J. Thurow, Dr. C. Bristow and Dr. N. Morton for their time and for contributing ideas for my research. Technical staff in the Department of Geological Sciences (UCL), Toby Stiles and Jim Davey, helped with photography. Thanks are extended to all my friends who helped me with computer programmes and translations, especially Dr. Artem Oganov, Dr. Ben Walsworth-Bell, Dr. Matthew Phillips and Dr. Peter Sushko (Physics Dept.).

I thank staff of the Natural History Museum, London, especially Dr. H. G. Owen, Dr. R. Casey, Dr. E. F. Owen and Mr. S. Baker for their help and valuable discussion. I am also thankful to Professor K. Seyed-Emami (Tehran University) who encouraged me to choose this topic, Dr. T. Bogdanova (St Petersburg), Professor M. Kakabadze (Tblisi) and other palaeontologists for their helpful discussion over the specimens and Dr. A. Afshar-Harb (Tehran, National Iranian Oil Company) and Professor R. Moussavi-Harami (Mashhad University) for discussing the lithostratigraphy of the study area. Thanks go to my Iranian friends Messrs Amini, Etminani, Khanehbad, Baghcheghi, Hatami and Mirkhodadadi for their help in field work. Logistical support for field work was partly financed by Birjand University and the Department of Geological Sciences at UCL.

My deepest thanks are due to my dear wife, Maryam, for her understanding and patience during my PhD, and numerous sacrifices, which enable me to concentrate on my work. Finally I would like to give my best thanks to my mother and my family for their unconditional love and support extended to me over the years.

Contents

Abstract 1

Acknowledgements 2

Contents 3

List of Figures 7

List of Tables 12

Chapter 1. Introduction 13

1.1. The geographical setting 13

1.2. General Geology 17

1.3. Previous work on the Kopet Dagh Basin 18

1.4. Aims and Methods 19

Chapter 2. Stratigraphy 21

2.1. Lower Cretaceous formations 21

2.1.1. Shurijeh Formation 21

2.1.2. Tirgan Formation 23

2.1.3. Sarcheshmeh Formation 23

2.1.4. Sanganeh Formation 25

2.1.5. Aitamir Formation 28

2.2. Measured sections 28

2.2.1. Takal Kuh sections 28

2.2.2. Amand section 43

2.2.3. Raz section 45

2.2.4. Sheykh section 50

2.2.5. Bibahreh section 51

2.2.6. Tirgan Section 56

2.2.7. Kalat road section 62

2.2.8. Sanganeh section 62

2.2.9. Ghorghoreh section 70

2.3. Correlation and discussion 73

Chapter 3. Systematic Description 78
Family Phylloceratidae Zittel 1884 79
Subfamily Phylloceratinae Zittel 1884 79
Family Gaudryceratidae Spath 1927 81
Family Oppeliidae H. Douville 1890 83
Subfamily Aconeceratinae Spath 1923 83
Family Desmoceratidae Zittel 1895 89
Subfamily Barremitinae Breskovski 1977 89
Subfamily Pseudosaynellinae Casey 1961 91
Subfamily Puzosiinae Spath 1922 93
Family Ancyloceratidae Gill 1871 95
Subfamily Crioceratitinae Gill 1871 95
Subfamily Ancyloceratinae Gill 1871 98
Subfamily Helicancylinae Hyatt 1894 102
Family Heteroceratidae Hyatt 1900 105
Family Douvilleiceratidae Parona & Bonarelli 1897 118
Subfamily Cheloniceratinae Spath 1923 119
Family Deshayesitidae Stoyanow 1949 122
Subfamily Deshayesitinae Stoyanow 1949 125
Family Parahoplitidae Spath 1922 157
Subfamily Acanthoplitinae Stoyanow 1949 162
Subfamily Parahoplitinae Spath 1922 177
Family Cymatoceratidae Spath 1927 181

Chapter 4. Biostratigraphy 182
4.1. Introduction 182
4.2. Current definition and biozonation of the Barremian to Albian Stages 184
4.2.1. The Barremian Stage 184
4.2.2. The Aptian Stage 185
4.2.3. The Albian Stage 190
4.3. Biozonation of the Kopet Dagh 191
4.3.1. Introduction 191
4.3.2. The proposed zonal scheme 192

4.4. Conclusions 206

Chapter 5. Ammonites and Lithofacies 209
5.1. Introduction 209
5.1.1. Mode of life of ammonites 209
5.1.2. Post mortem drift 210
5.1.3. Previous research 211
5.2. Ammonite and lithofacies distributions in the studied sections 212
5.2.1. Takal Kuh sections 212
5.2.2. Amand section 216
5.2.3. Raz section 217
5.2.4. Sheykh section 218
5.2.5. Other sections 218
5.3. Discussion 220
5.3.1. Families and lithofacies 220
5.3.2. Morphogroups and lithofacies 222
5.4. Comparison with previous morphogroup studies 225
5.5. Conclusions 230

Chapter 6. Ammonites and Sea Level Changes 233
6.1. Sequences and sea-level fluctuations 233
6.2. The faunal response to sea-level change 234
6.3. Relationship between ammonites and sea-level changes in the Kopet Dagh Basin 235
6.3.1. Takal Kuh area 236
6.3.2. Sanganeh and Tirgan sections 248
6.3.4. Other sections 254
6.4. Discussion 254
6.5. Conclusions 257

Chapter 7. Palaeobiogeographical relationships of the Kopet Dagh ammonite faunas 261
7.1. Introduction 261

7.1.1. Early Cretaceous global palaeobiogeography 261
7.1.2. Early Cretaceous Palaeocurrents 265
7.2. The Kopet Dagh faunas 267
7.2.1. Palaeogeography 267
7.2.2. Palaeobiogeographical relationships of the faunas 270
7.3. Conclusions 282

Chapter 8. Conclusions 285
References 287
Plates 317

List of Figures

Figure 1.1. Iranian major tectono-sedimentary units. 14
Figure 1.2. Geographical names and their positions. 15
Figure 1.3. General stratigraphical column of the Cretaceous at the Kopet Dagh Basin. 16
Figure 2.1. Type section of the Sarcheshmeh Formation in the Khur valley, Mashhad-Kalat road. 24
Figure 2.2. Type section of the Sanganeh Formation to the west of Sanganeh village. 27
Figure 2.3. General view of the Sarcheshmeh (A), Sanganeh (B) and Kalat (C) Formations at the Takal Kuh section (1). 30
Figure 2.4. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Takal Kuh section (1). 31
Figure 2.5. Shaly limestone of the lower part of the Sarcheshmeh Formation in the Takal Kuh section (1). 30
Figure 2.6. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Takal Kuh section (2). 38
Figure 2.7. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Amand section. 46
Figure 2.8. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Raz section. 52
Figure 2.9. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Sheykh section. 54
Figure 2.10. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Bibahreh section. 57
Figure 2.11. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Tirgan section. 60
Figure 2.12. Upper part of the Sarcheshmeh and lower part of the Sanganeh Formations in the Tirgan section. 60
Figure 2.13. Cone-in cone structure in shaly beds of the Sanganeh Formation, Tirgan section. 60
Figure 2.14. Concretion in the Sanganeh Formation, Tirgan section. 61

Figure 2.15. Thick-bedded limestones of the Uppermost part of the Tirgan Formation on the Mashhad-Kalat road. 61
Figure 2.16. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Kalat section. 63
Figure 2.17. Marl and marly limestone sequences of the lower part of the Sarcheshmeh Formation in the Sanganeh section. 66
Figure 2.18. Weathered pencil marls of the lower part of the Sarcheshmeh Formation, Sanganeh section. 66
Figure 2.19. Fossiliferous limestone bed between marls in the Sarcheshmeh Formation in the Sanganeh section. 67
Figure 2.20. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Sanganeh section. 68
Figure 2.21. Sarcheshmeh-Sanganeh Formations boundary at Sanganeh section, dark to black shales of the Sanganeh Formation above light grey shales and fossiliferous limestone of the Sarcheshmeh Formation. 67
Figure 2.22. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Ghorghoreh section. 71
Figure 2.23. A fossiliferous limestone marks the Sarcheshmeh-Sanganeh boundary, Mashhad-Sarakhs road near Ghorghoreh section. 67
Figure 2.24. Lithological and biostratigraphical correlation chart in the Sarcheshmeh and Sanganeh Formations in the Kopet Dagh Basin. 76
Figure 2.25. Correlation chart of the Lower Cretaceous formations in the Kopet Dagh Basin 77
Figure 2.26. Preliminary scheme of facies at the Kopet Dagh Basin based on ammonites distribution, benthic fossils and lithology of measured sections. 77

Figure 3.1. Ratio of U/D in *Aconeceras haugi* in sample TK 76. 88
Figure 3.2. Relationship between diameter and ratio of U/D in *Aconeceras haugi* at Takal Kuh section (2). 88
Figure 3.3. Phylogenetic trend in Ancyloceratidae. 99
Figure 3.4. Coiling type of heteromorphs. 101

Figure 3.5. Change of shell shape in the Heteroceratidae and Deshayesitidae. 107
Figure 3.6. Comparison in suture lines of Hemihoplitidae, Heteroceratidae and Deshayesitidae. 108
Figure 3.7. Secondary ribs numbers in some species of the family Deshayesitidae. 124
Figure 3.8. Secondary rib numbers in some species of the Deshayesitidae collected from the Kopet Dagh Basin. 125
Figure 3.9. Relationship between diameter and ratio of SR/PR in *Turkmeniceras multicostatum.* 127
Figure 3.10. Comparison of ratio SR/ PR in *Deshayesites weissi.* 142
Figure 3.11. Changes in suture elements in the Families Deshayesitidae, Parahoplitidae and Douvilleiceratidae. 159
Figure 3.12. Changes in rib pattern and shape of venter in the family Parahoplitidae in some specimens of the Kopet Dagh Basin. 160
Figure 3.13. Hypothesised relationship between Parahoplitidae genera. 161

Figure 4.1. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Takal Kuh section (1). 195
Figure 4.2. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Takal Kuh section (2). 196
Figure 4.3. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Amand section. 197
Figure 4.4. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Raz section. 200
Figure 4.5. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Bibahreh section. 202
Figure 4.6. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Tirgan section. 203
Figure 4.7. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Sanganeh section. 204
Figure 4.8. Distribution of ammonite genera in the Upper Barremian-Lower Albian at sequences in the Kopet Dagh basin. 208

Figure 5.1. Relationship between lithology and ammonite genera in the Takal Kuh section (1). 214
Figure 5.2. Distribution of ammonite genera in each lithofacies in the Takal-Kuh section (1). 214
Figure 5.3. Relationship between ammonite genera and lithology in the Takal Kuh section (2). 215
Figure 5.4. Distribution of ammonite in each lithofacies in the Takal Kuh section (2). 216
Figure 5.5. Distribution of ammonite genera in each lithofacies in the Amand section. 217
Figure 5.6. Relationship between genera and lithology in the Amand section. 219
Figure 5.7. Relationship between of ammonite genera in the central and eastern part of the Kopet Dagh Basin. 219
Figure 5.8. Distribution of *Acanthohoplites* and *Hypacanthoplites* in each lithofacies in the central and eastern part of the Kopet Dagh Basin. 221
Figure 5.9. Distribution of ammonite families in each lithofacies in the Kopet Dagh Basin. 237

Figure 6. 1. Relationship between ammonite fauna and sea-level changes in the Takal Kuh section (1). 243
Figure 6. 2. Relationship between ammonite fauna and sea-level changes in the Takal Kuh section (2). 249
Figure 6. 3. Relationship between ammonite fauna and sea-level changes in the Amand section. 252
Figure 6. 4. Relationship between ammonite fauna and sea-level changes in the Tirgan section. 255
Figure 6. 5. Relationship between ammonite fauna and sea-level changes in the Sanganeh section. 258
Figure 6.6. Calibration of proposed biozones, and number of genera and species in every biozone, with third order relative sea-level changes in the Kopet Dagh Basin and with Haq *et al.*'s 1988 curve. 263

Figure 7.1. The main biochores plotted on the land and marine reconstruction for 120 Ma. 266
Figure 7.2. Hypothetical palaeocurrent pattern for mid-Cretaceous times.
Figure 7.3. Main tectonic subdivisions of Iran. 267
Figure 7.4. Early Cretaceous (Aptian) preliminary palaeogeographical and paleofacies pattern for north and central of Iran. 269
Figure 7.5. Distribution of *Martelites*, *Heteroceras* and *Barremites* during Late Barremian times. 271
Figure 7.6. Distribution of *Australiceras*, *Deshayesites*, and *Dufrenoyia* during Early Aptian times. 277
Figure 7.7. Distribution of Parahoplitidae during Late Aptian times. 281
Figure 7.7. The Lower Cretaceous outcrops in Iran. 283

List of Tables

Table 4.1. Correlation chart of Upper Barremian- Lower Albian of ammonites biozones in the Tethyan and Boreal Realms. 183

Table 4.2. Upper Barremian-Lower Albian correlation chart of ammonite biozones in the Kopet Dagh sedimentary basin and adjacent parts of the Tethyan Realm. 188

Table 4.3. The standard biozonation and the proposed biozonation for the Upper Barremian of the Kopet Dagh basin. 193

Table 4.4. The standard biozonation and the proposed biozonation for the Aptian of the Kopet Dagh basin. 198

Table 4.5. The standard biozonation and proposed biozonation for the Lower Albian of the Kopet Dagh basin. 206

Table 5.1. Distribution of ammonite families in different lithology at the Kopet Dagh Basin. 220

Table 5.2. Proposed ammonite morphogroups for the Sarcheshmeh and Sanganeh Formations in the Kopet Dagh Basin. 223

Table 5.3. Diversity and abundance of ammonites in the Sarcheshmeh, Sanganeh and Aitamir Formations when classified according to Tanabe *et al.*'s (1978) and Marcinowski and Wiedmann's (1985, 1988) morphogroups. 226

Table 5.4. Probable facies and habitat of the Aptian-Cenomanian ammonites of the Kopet Dagh basin based on Batt's (1989) morphotype classification. 227

Table 6.1. Principal terms in sequence stratigraphy. 233

Table 7.1. Geographical distribution of selected Late Barremian-Aptian ammonites of the Kopet Dagh Basin. 272

Table 7.2. Comparison of *Deshayesites* species of the Kopet Dagh Basin and other areas. 278

Chapter 1. Introduction

1.1. The geographical setting

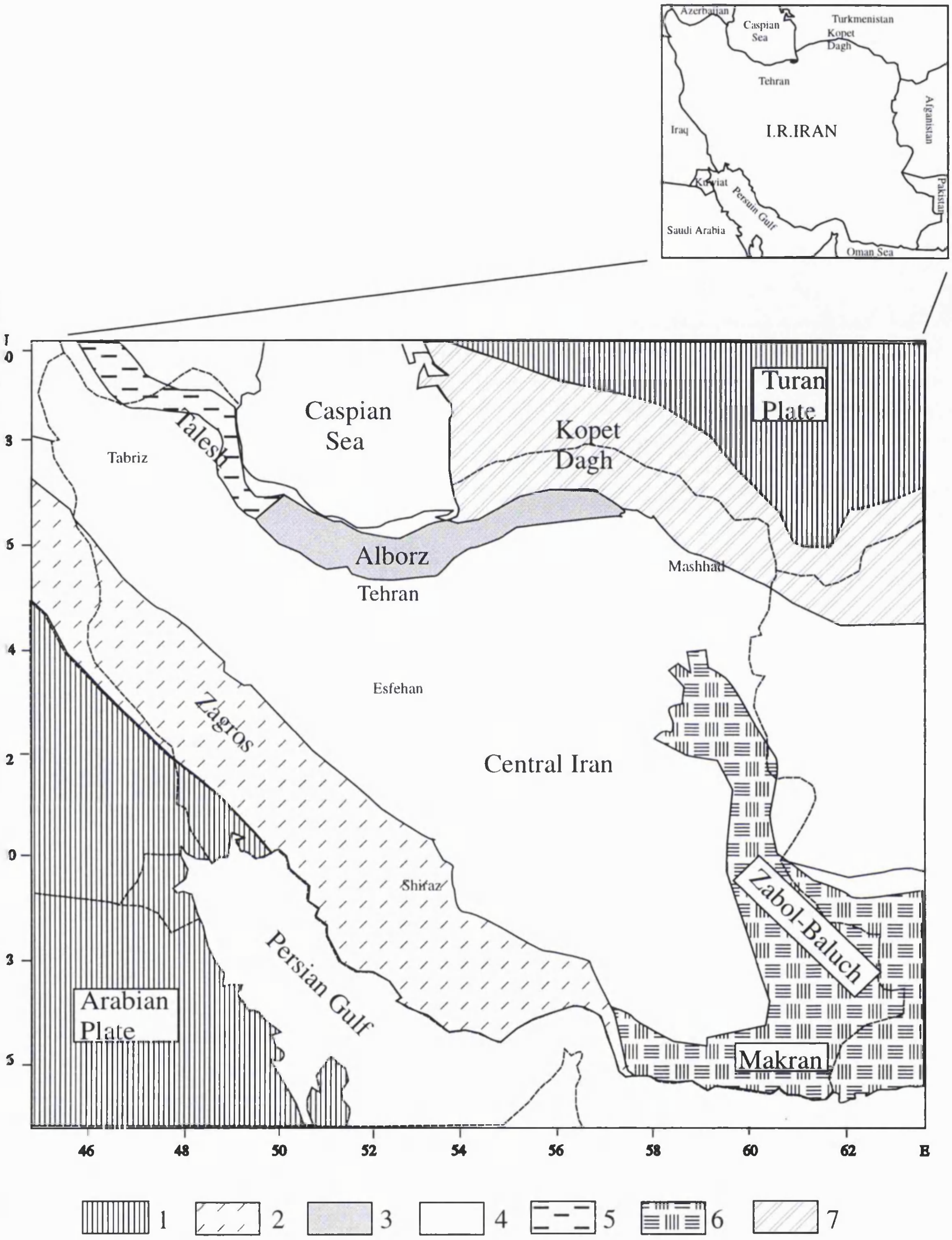
The Kopet Dagh sedimentary basin is situated in the north-east of Iran and the south of Turkmenistan. The name of Kopet Dagh (Koppeh Dagh) originated from Russian writers. It is geographically named the Hezarmasjed ridges. The Iranian part of the Kopet Dagh basin is geographically located between 54° 00′ and 61° 14′ east longitude and 36° 00′ and 38° 16′ north latitude (Figures 1.1 & 1.2). For convenience of description and discussion the region is divided here into three parts, eastern, central and western (Figure 1.2).

The region is mainly mountainous and the topography has a first order relation with geological features. The anticlines mainly stand as high lands, while synclines form low lands, valleys and intramontain plains. In addition the morphology of the region is much controlled by the ridge-forming Mozduran (Jurassic), Tirgan (Lower Cretaceous), Kalat (Upper Cretaceous) and Chehel Kaman (Paleocene) Formations.

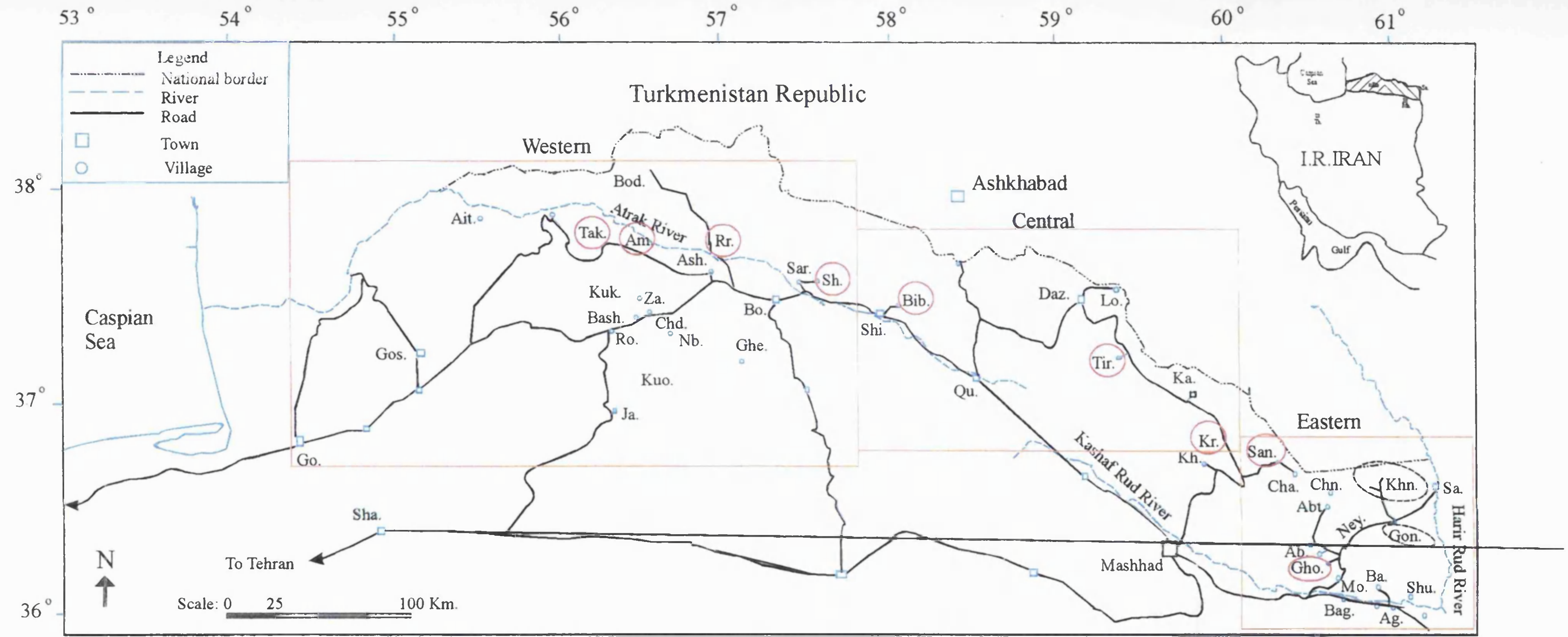
The Cretaceous Sanganeh, Abderaz, and Abtalkh Formations and Tertiary Khangiran Formation are highly weathered, valley-forming rock units that give rise to badlands topography. The Cretaceous Shurijeh, Sarcheshmeh and Aitamir Formations and Tertiary Pesteligh Formation (Figure 1.3), being moderately resistant to weathering, form small ridges and hills. The highest peak of the region is the Khorkhud Mountain, 2929 metres above sea level.

Two plains, Gorgan and Sarakhs are in the eastern and western parts of the region respectively. The Gorgan plain is a continuation of the Caspian Sea depression. The Sarakhs plain, with an average elevation of about 330 -400 metres above sea level, is the south-west continuation of the Turkmenistan plain and Gharaghum desert. The Mashhad-Quchan-Shirvan, Bojnord, Ashkhaneh and Darehgaz plains are the biggest intramontain plains and parallel the structural trend.

Climate is variable in the Kopet Dagh and Hezarmasjed region. In summer it is dry and hot and in winter cold and semi humid. The lowest average annual precipitation



Fgure 1.1. Iranian major tectono-sedimentary units (modified from Berberian and King, 1981). **1**-Stable areas, Arabian Precambrian platform in south west and Turanian Hercynian Plate in north east, **2**- Zagros, including Zagros foredeep, main sector of the marginal active fold belt peripheral to stable areas and High Zagros, **3**- Alborz Mountains, **4**- Central Iran lying between the two marginal active fold belt, **5**- Talesh, Armenian late Hercynian belt with a possible continuation to Iranian Talesh Mountain, **6**- Zabol-Baluch and Makran post-ophiolite flysch troughs, **7**- Kopet Dagh folded belt and foredeep.



Ab.= Abderaz
Abt.= Abtalkh
Ag.= Aghdarband
At.= Aitamir
Am.= Amand
Ash.= Askhaneh
Bag.= Baghbagho
Ba.= Baghak
Bash.= Bashkalateh
Bib.= Bibahreh
Bo.= Bojnord
Bod.= Bozdagh
Chd.= Chaman Bid
Chn.= Chehelkaman
Daz.= Darreh Gaz
Gha.= Gharagitan
Ghe.= Ghelli
Gho.= Ghorghoreh
Go.= Gorgan
Gon.= Gonbadli
Gos.= Gonbad Kabus
Ja.= Jajarm
Ka.= Kalat
Kr.= Kalat road
Khn.= Khangiran
Kho.= Khoshyelag
Kh.= Khur
Kuk.= Kuh Khorkhod
Kuo.= Kuh Ozum
Lo.= Lotafabad
Mo.= Mozduran
Nb.= Nabia
Qu.= Quchan
Ro.= Robate Gharabil
Rr.= Raz road
Sa.= Sarakhs
Sar.= Sarcheshmeh
San.= Sanganeh
Sh.= Sheykh
Sha.= Shahrud
Shi.= Shirvan
Shu.= Shurijeh
Tak.= Takal Kuh
Ney.= Neyzar Gorge
Tir.= Tirgan
Za.= Zard

Figure 1.2. Geographical names and their positions, location of measured sections ◯, gas reservoirs are shown by ⬭.

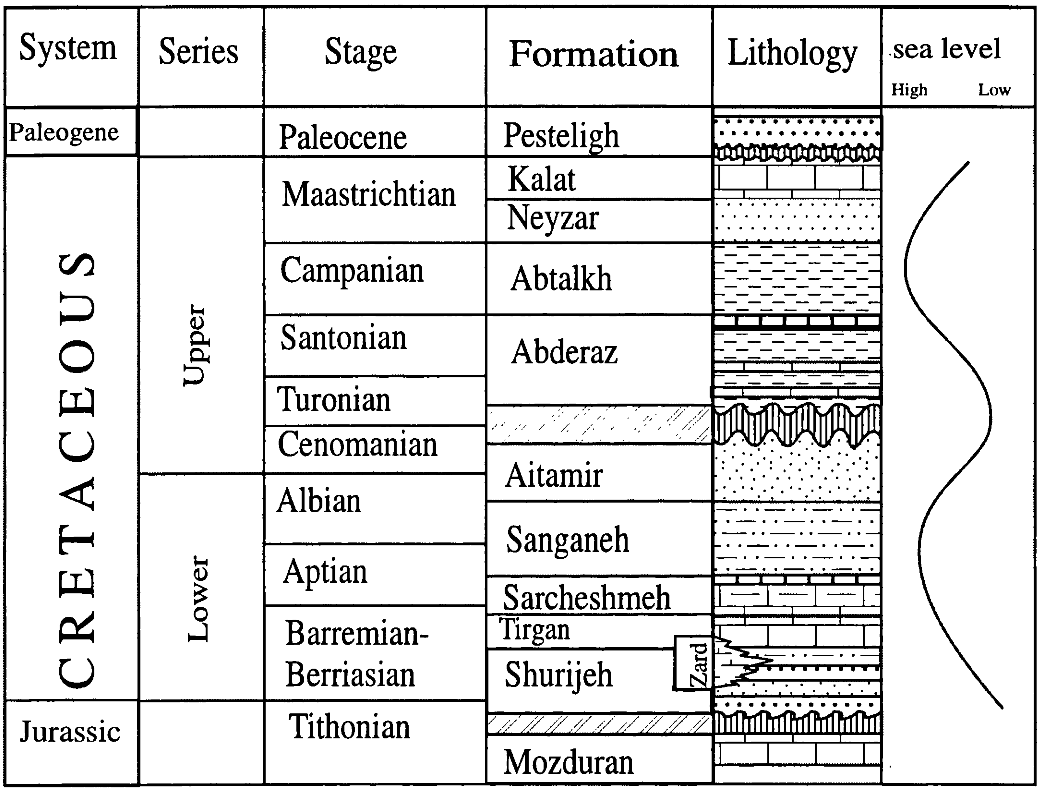
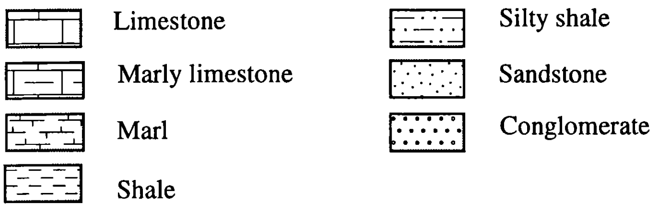


Figure 1.3. General stratigraphical column of the Cretaceous at the Kopet Dagh Basin (modified from Kalantari, 1987 and Immel *et al.* 1997).

Key



is reported as 160 mm from Sarakhs in the south-east, and the highest is 700 mm from Maraveh Tappeh in the north-west. The temperature varies by more than 60° Celsius between summer and winter and fluctuates between –20° C and 43° C.

The biggest city is Mashhad, the centre of Khorasan Province, with more than 2 million population. The other major cities are Bojnord, Quchan, Shirvan, Darehgaz and Sarakhs respectively. Gas reservoirs occur in the eastern part of the Kopet Dagh, 30 kilometres north-west of Sarakhs.

1.2. General Geology

A simplified tectono-sedimentary map of Iran is shown in Figure 1.1. The Kopet Dagh basin formed as an intracontinental basin in north-east Iran, after the closure of the Hercynian Ocean following the Early Kimmerian orogeny (Berberian & King, 1981). From the Jurassic through to the Eocene, relatively continuous sedimentation is recorded by five major transgressive- regressive sequences in the eastern Kopet Dagh (Afshar-Harb, 1979,1983). Subsidence started in the Kopet Dagh basin in the late Middle Jurassic (Afshar-Harb, 1979; Seyed-Emami and Alavi-Naini, 1990; Seyed-Emami *et al.*, 1994,1996). Fault-controlled subsidence of the basin from Jurassic to Oligocene times has resulted in up to 10 kilometres of sediment being deposited (Berberian and King, 1981).

From near the end of the Jurassic through to the Early Cretaceous (Neocomian), the sea withdrew from the eastern Kopet Dagh basin towards the west, and a sequence of fluvial siliciclastic sediments was deposited across the eastern part of the basin (Figure 1.2) (Moussavi-Harami and Brenner, 1993). The marine limestones west of the study area recorded the establishment of marine environments sometime during the Early Cretaceous in the central and western parts of the Kopet Dagh basin (Afshar-Harb, 1979, 1994). During the Barremian, southeastward transgressions across the Sarakhs area re-established marine environments (Figure 1.2) that persisted through the Late Cretaceous, except for a short period during the Late Cenomanian or Early Turonian (Afshar-Harb, 1979; Mahboubi *et al.*, 1995; Khazaee, 1995). Red beds of the Pesteligh Formation were deposited during the early Paleocene regression and were followed by deposition of marine Eocene-Oligocene sediments and Mio-Pliocene-Pleistocene nonmarine sediments.

Repeated transgressions and regressions continued through the Miocene, when the basin was folded during the late Alpine compression, creating the anticlinal traps of the Khangiran and Gonbadli gas fields (Afshar-Harb, 1979; Moussavi-Harami and Brenner, 1993).

The trend of the Kopet Dagh structure forms a north-facing curve with the centre of the curvature in the south of the region. The curvature in the Kopet Dagh is due to the north-eastward movement of Central Iran.

The trend of anticline and synclines is north-west- south-east on the whole. In the eastern part of the region anticlines are more symmetrical than in the western part. In the west of the Kopet Dagh most anticlines similar to the Kuh-e Khorkhud, Takal Kuh, Kuh-e Ozum, Nabia and Boz Dagh have mainly a gentle north flank, and a steep faulted south flank.

There are two types of faults. The first are nearly parallel to folds and the second ones are transcurrent and usually make a right angle with the previous ones.

No volcanic activity has been reported from the basin, except post-orogenic activity in the south-western part of the basin between Central Iran and the Kopet Dagh boundary, dated to the end of Tertiary.

1.3. Previous work on the Kopet Dagh Basin

The basin has been noticed and investigated by geologists for many years, mainly because of the presence of hydrocarbons.

The first geological work in the region was carried out by Grisbach for the Geological Survey of India. Some part of his investigation is included in Clap (1940).

The eastern part of the Kopet Dagh basin was first explored by F. Reeves, B.F. Buie and W.P. Wilson in 1937 on behalf of the Anglo-Persian Oil Company, but their work was not published (Afshar-Harb, 1979). A reconnaissance trip to the eastern part of the Kopet Dagh was made by Goldschmid and Fakhraee in 1952 on behalf of the Amiranian Oil Company. Detailed geological studies have been done by geologists of the National Iranian Oil Company (NIOC) during the 60's and 70's. The most important publications are by Afshar-Harb (1969, 1979) on general geology and petroleum geology, Kalantari (1969) on Jurassic and Cretaceous foraminifera, Hubber (1976) on geological maps and Madani (1977) on the Jurassic sequence.

As mentioned before, the hydrocarbon reservoirs are an important factor that has led to a large number of investigations during the last 25 years. A lot of research has focused on the Mozduran (Jurassic) and Shurijeh (Cretaceous) Formations, which are known as reservoirs: for example by Lasemi (1995), Moussavi-Harami and Brenner (1990, 1992, 1993), and Adabi and Rao (1991). There are some works on the palaeontology of the Kopet Dagh basin. Jurassic-Cretaceous ammonites have been studied by Seyed-Emami (1980); Seyed-Emami and Aryai (1981); Seyed-Emami *et al.* (1984; 1994; 1996) and Immel *et al.* (1997). Raisossadat and Moussavi-Harami (1993, 2000) studied the Sarcheshmeh and Sanganeh foraminifera and sea level changes at the eastern part of the basin and Khazaee (1995) the Maastrichtian rudists of the Kopet Dagh.

Geological maps of the whole of the Iranian part of the Kopet Dagh basin have been published at 1:250000 scale and for some parts at 1:100000 scale by the NIOC and the GSI (Geological Survey of Iran). Among the regional and local geological research reference can be made to Ruttner (1984,1991,1993), Eftkharnezhad and Behroozi (1991), Khodaee and Feiznia (1993).

1.4. Aims and Methods

Despite the studies on the Kopet Dagh basin quoted above, in many fields research has yet to be undertaken. For instance the foraminifera have been studied more than the other fauna. But most of the foraminifera in the Jurassic and Cretaceous are long ranging species and are not good fossils for biostratigraphy, so it is necessary to place more emphasis on ammonites in order to make a better correlation with standard biozonations and stages.

In this study the ammonite fauna and biostratigraphy of the Lower Cretaceous Sarcheshmeh and Sanganeh Formations in the Kopet Dagh Basin are investigated.

A single specimen of *Paraspiticeras* is recorded from the Tirgan Formation (Immel *et al.*, 1997), but the Sarcheshmeh Formation is the first deposit that contains numerous beds with ammonites in the Kopet Dagh, especially in the western part. The Sarcheshmeh and Sanganeh Formations ammonite fauna has been mentioned by Immel *et al.* (1997), but that study was based only on spot samples. This indicated that the ammonite fauna deserves closer examination based on accurate bed-by-bed collecting. On the other hand there is variance between the age of the formations as deduced from foraminifera and that indicated by ammonites. This conflict also required further investigation.

Ten stratigraphical sections have been measured and sampled during fieldwork in summer 1998 and 1999 (Figure 1.2). About seven hundred specimens were collected. Most of the sections include the whole of the Sarcheshmeh and Sanganeh Formations. For some sections only parts of the sequence could be measured, because of weathering, faulting and poor exposure.

The real thickness has been calculated and stratigraphical sections were drawn by using computer software packages. Excel software has also been used for drawing charts and graphs.

The ammonite taxa are described, and based on the identified species a biozonation has been introduced for the Sarcheshmeh and Sanganeh Formations. The biozonation makes possible correlation with other parts of the Tethyan Realms. The relationship between ammonite distributions and facies, and ammonite distributions and sea level changes is examined. The palaeobiogeographical relationships of the faunas are discussed. Global dispersion of ammonite genera has been illustrated in some maps for better understanding of palaeobiogeographical and palaeogeographical aspects.

Chapter 2. Stratigraphy

2.1. Lower Cretaceous formations

A single megasequence in the Kopet Dagh basin embraces the bulk of the Lower Cretaceous sedimentary rocks. It starts with the Shurijeh Formation conglomerate and sandstone, and finishes with the Sanganeh Formation dark grey shales and siltstones. Therefore, although this thesis is concerned only with the faunas of the Sarcheshmeh and Sanganeh Formations, the other formations are also described briefly to give a better view of the megasequence and the position of the studied formations (Figure 1.3).

2.1.1. Shurijeh Formation

The name of this formation is derived from the village of Shurijeh in the eastern Kopet Dagh, but the type section is in the Khur valley in the Mashhad-Kalat road, as introduced by Afshar-Harb (1979) (Figure 1.2). This was chosen as the type section, because the Khur section represents the best development of the Shurijeh Formation. However, Afshar preferred to keep the name Shurijeh Formation as it has been used for a long time in NIOC reports and other publications.

The Shurijeh Formation mainly consists of reddish brown shale, claystone, sandstone, quartzitic sandstone, gypsum, and conglomerate with subordinate carbonate beds. A carbonate unit is developed in the middle part of the Formation, which pinches out east of 60° 20′ longitude (Afshar-Harb, 1994). A sandstone bed in the lower part of the formation forms a gas reservoir in the Khangiran and Gonbadli regions.

Although the Shurijeh Formation consists mainly of non-marine deposits, some marine beds occur in the western part of the outcrop. The most common faunal assemblage reported by Kalantari (1969) is as follows; *Calpionella alpina* (calpionellid), *Nautiloculina oolithica* and *Pseudocyclammina lituus* (foraminifera). This limits the age of this formation to the Berriasian to Barremian.

Rahghi (in Afshar-Harb, 1979) reported the following fauna from the west of the

Kopet Dagh: *Ammobaculites* sp., *Nautiloculina oolithica*, *Pseudocyclammina lituus*, *Torinosuella peneropliformis* (foraminifera), and *Clypenia* sp. (alga). This fauna indicates an Upper Tithonian to Neocomian age for the Shurijeh Formation in the west of the Kopet Dagh.

Moussavi-Harami and Brenner (1992) reported that the Shurijeh Formation consists mostly of sublithic arenite red beds deposited during a regressive phase of sedimentation dominated by rapid siliciclastic sediment supply. The lower and middle parts of the formation were deposited in low sinuosity braided fluvial systems and the upper part was deposited in high sinuosity meandering systems. They concluded that geohistory diagrams for the eastern part of the Kopet Dagh basin indicate that since the mid Early Cretaceous, the major factor that contributed to basin subsidence was sediment loading rather than tectonic subsidence. Their observation also shows that a relatively thick package of shallow marine to terrestrial sediments could have accumulated in a basin that has undergone minimal tectonic subsidence.

The Shurijeh Formation changes laterally to marine bluish grey and olive green marl, calcareous shale, greenish grey and buff grey sandstone and subordinate sandy limestone beds in the western part of the Kopet Dagh. This sequence is named the Zard Formation. According to Kalantari (1969), the Hauterivian substage is indicate by the presence of foraminifera such as *Brotzenia tenuicostata*, *Haplophragmium aequale*, *Haplophragmoides globosa*, *Lenticulina bettenstaedti*, *L. crepidularis*, *L. saxonica*, *L. nodosa*, *Saracenella vestita* and *Triplasia emslandensis*. The following foraminifera indicated the Barremian stage and are reported by Kalantari and Kavari (in Afshar-Harb 1979), *Dictyoconus arabicus*, *Gavelinella barremiana*, *Globigerina infracretacea*, *Globorotalites intercedens*, *Lenticulina ouachensis*, *Marssonella oxycona*, *Tritaxia tricarinata* and *T. pyramidata*. Some ostracods were also identified by Kavari, such as *Cytherelloidea ovata*, *Protocythere auriculata* and *Protocythere triplicata*. The upper part of the Zard Formation may equate with the lower part of the Tirgan Formation.

2.1.2. Tirgan Formation

The name of this Formation comes from the village of Tirgan, 40 kilometres south of the town of Darrehgaz in the north of the Kopet Dagh (Figure 1.2). The Tirgan Formation consists of organodetrital and oolitic limestone with intercalations of marl and calcareous shale (Afshar-Harb, 1969).

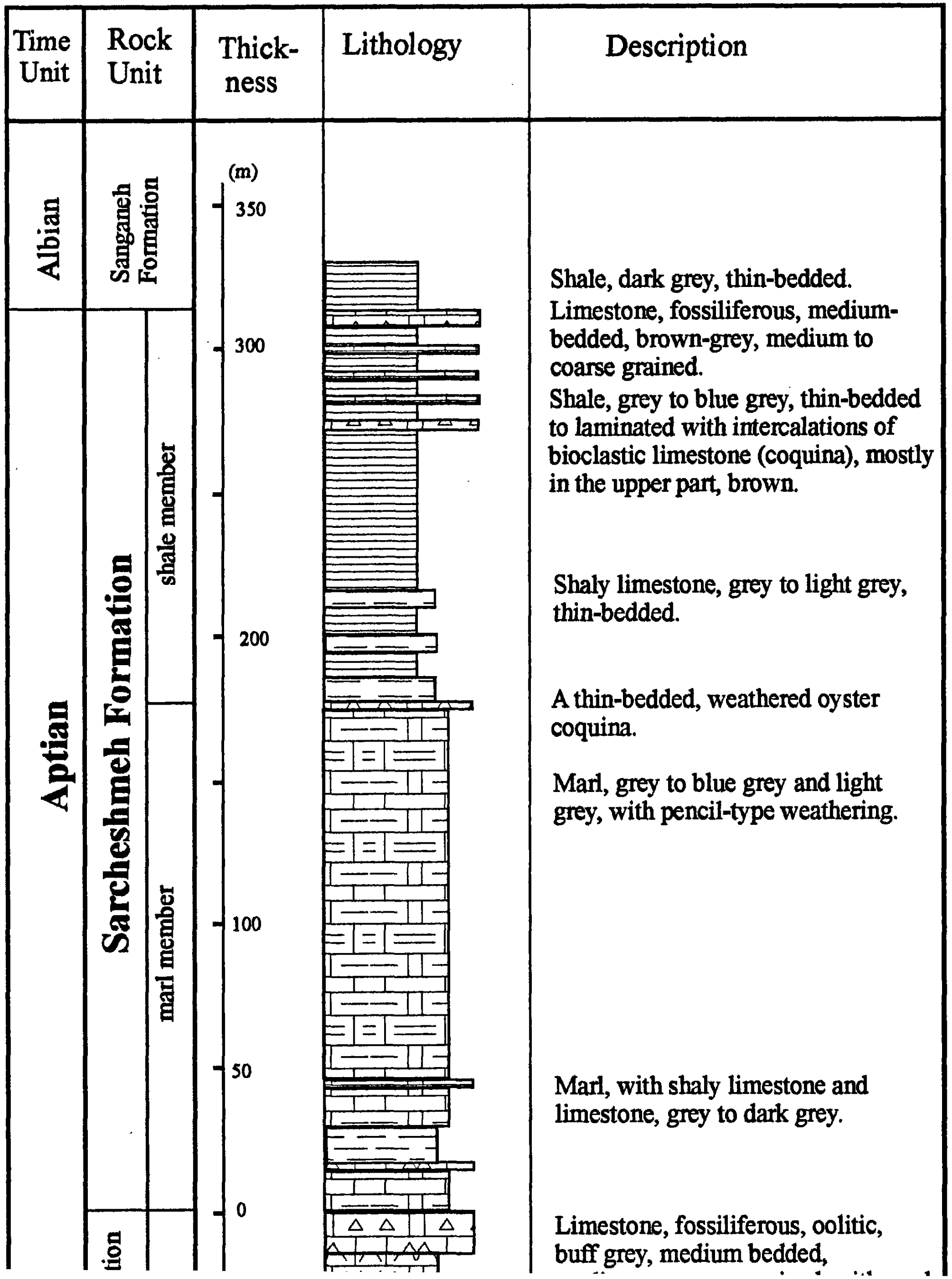
In the type section, the Tirgan Formation is 780 metres thick. The thickness of the formation reduces eastward and westward so that in the Khangiran gas wells the formation is only about 40 metres thick. The western-most Takal Kuh section, the most northerly exposure of the Tirgan Formation in the western part of the Kopet Dagh, is only 250 metres thick (Afshar-Harb, 1994). Three successive foraminifera faunas have been recognized (Kalantari, 1969; Afshar-Harb, 1994). The lowest has a Hauterivian age, indicated by: *Brotzenia tenuicostata*, *Haplophragmoides aequale*, *Lenticulina bettenstaedti*, *L. saxonica* and *L. nodosa*. A Barremian fauna is indicated by the following foraminifera: *Dictyoconus arabicus*, *Goloborotalia bartensteini*, *Globigerina infracretacea*, *Marssonella oxycona*, *Tritaxia pyramidata* and *T. tricarinata*. A third assemblage includes *Nautiloculina circularis* and *Dictyoconus* sp., *Lithonella* sp. and *Orbitolina discoidea-conoidea*, indicating an Aptian age (Kalantari, 1969). Immel *et al.* (1997) reported the ammonite *Paraspiticeras percevali*, which is of Barremian age.

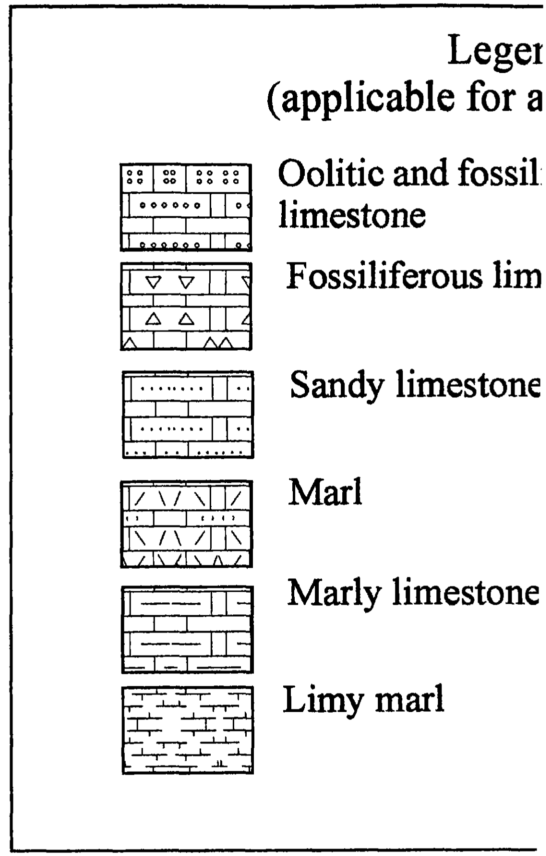
2.1.3. Sarcheshmeh Formation

Sarcheshmeh is a village in the central Kopet Dagh, 14 kilometres east of the town of Bojnord. However, Afshar-Harb (1979) chose a succession in the Khur valley on the Mashhad-Kalat road as type section because it shows the characters of the formation better (Figure 1.2).

This formation normally consists of two informal members, a lower marl and an upper shale member. At the type section the lower is formed by 178 metres of uniform light green grey to blue grey marl, with pencil weathering (see page 66). A 20 centimetres thick oyster coquina occurs at the top of this member in the type locality.

Figure 2.1. Type section of the Sarcheshmeh Formation in the Khur valley, Mashhad-Kalat road (Ages based on Afshar Harb, 1994, which are modified in this thesis, see page 77).





The upper member includes 98 metres of dark bluish grey calcareous shale weathered to light grey green in the lower part overlain by 34 metres of alternating bluish-grey shale and thinly layered limestones (Afshar-Harb, 1979; Raisossadat and Moussavi-Harami, 1993) (Figure 2.1).
Eastward the formation thickness decreases to about 200 metres in the Mozduran Pass and 100 metres in the Shurijeh Gorge. From the Khur valley to the west, the thickness of the lower member increases and in central and east-central Kopet Dagh varies between 200 and 350 metres. To the south of the Takal Kuh- Donghuz Dagh fault the marl member was not deposited and only shale layers of the upper member are represented. On the north flank of the Takal Kuh anticline the formation is over 970 metres thick and consists of marls and shales (Afshar-Harb, 1979) in which the two members can not be separated. In the Jozak succession there are only a few metres of the Sarcheshmeh shales overlain by thin beds of sandstones and shales of the Aitamir Formation (Afshar-Harb, 1994).

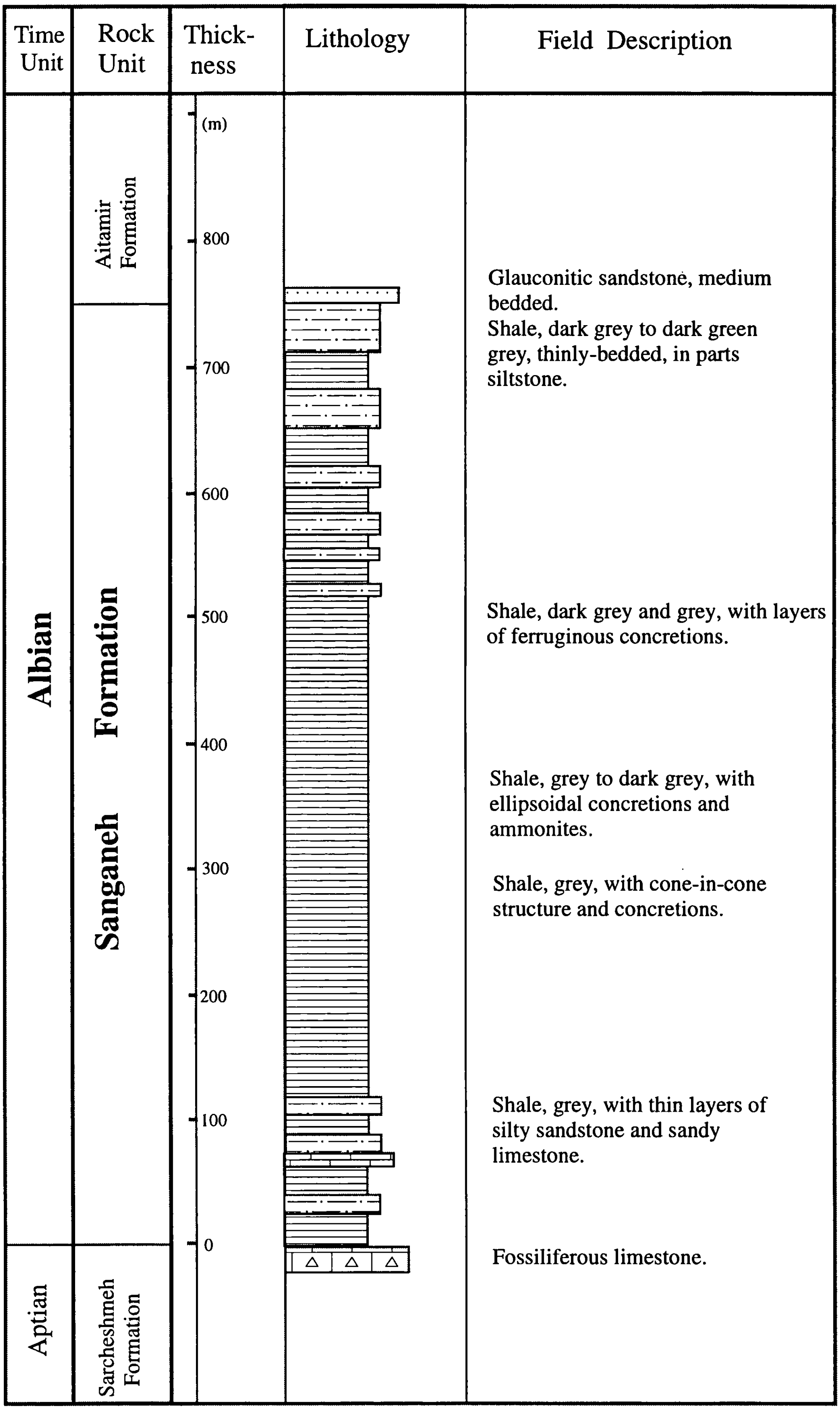
The formation is moderately weathered and forms a distinct grey rock unit between the ridge-forming, brown-weathering Tirgan Formation and the low lying dark grey to black Sanganeh Formation.

Kalantari (1969) reported the following foraminifera: *Ammobaculites reophacoides*, *Astacolus* cf. *schloenbachi*, *Brotzenia cretosa*, *Citharina aptiensis*, *Dentalina distincta*, *D.* sp., *Gaudryina dividens*, *Globorotalites aptiensis*, *Marginulina robusta*, *Marssonella trochus*, *Meandrospira djaffaensis*, *Orbitolina kurdica*, *O. discoidea*, *O. conica*, and *Verneuilinoides subfiliformis*, which suggest an Aptian age for the Sarcheshmeh Formation. On the other hand the following ammonites are noted by Immel *et al.* (1997); *Anahamulina nicortsmindensis*, *Colchidites securiformis*, *C. ratshensis*, *C. tenuicostatus*, *C. tinae*, *C.* sp. ex. gr. *colchicus*, *Deshayesites latilobatus*, *Imerites favrei*, *Hemihoplites* sp. and *Prodeshayesites tenuicostatus*, which indicate a Late Barremian- Early Aptian age.

2.1.4. Sanganeh Formation

The name derives from the village of Sanganeh, 70 kilometres north-east of the town of Mashhad (Figure 1.2). The Sanganeh Formation includes dark grey to black-weathering shale with greenish shale and a few thin siltstone beds in some areas.

Figure 2.2. Type section of the Sanganeh Formation to the west of Sanganeh village (Ages based on Afshar Harb, 1994, which are modified in this thesis, see page 77).



2.1.5. Aitamir Formation

The Aitamir Formation is described here because the lower part of the formation is supposed to be the same age as the upper part of the Sanganeh Formation. Moreover the Aitamir Formation contains a good variety of ammonite genera.

The name comes from the village of Aitamir in the west of the Kopet Dagh, 70 kilometres north-east of the town of Gonbad-e-Kabus (Figure 1.2). This formation includes two informal members: the lower member consists of thick sandstone beds and some glauconitic shale, and the upper member is a glauconitic shale with glauconitic sandstone. A few coquina beds are developed in this formation in the Sarakhs area. The lower contact with the underlying Sanganeh Formation is conformable and the upper contact with the overlying Abderaz Formation is disconformable (Afshar-Harb, 1979). Kalantari (1969) reported some foraminifera, such as *Anomalina aumalinsis*, *Gavelinopsis cenomanica*, *Gavelinella baltica*, *Hedbergella brittonensis*, and *H. delrioensis*. Rahghi (in Afshar-Harb, 1994) added some further species: *Dorothia bulletta*, *Globigerina infracretacea*, *Rotalipora apenninica*, and *Globorotalites* aff. *micheliniana*. These may indicate a Late Albian-Cenomanian age.

According to Immel *et al.* (1997) the following ammonites confirm a a Mid Albian-Cenomanian age; *Acanthoceras tapara*, *Anahoplites daviesi*, *A. sinzowi*, *A.* cf. *pleurophorus*, *A.* cf. *planus*, *Anisoceras* sp. ex. gr. *armatum*, *Callihoplites* sp., *Cheloniceras* (*Epicheloniceras*) cf. *aphanasievi*, *Cunningtoniceras cunningtoni*, *C. inerme*, *Epihoplites* (*E.*) aff. *denarius*, *Hoplites* (*Isohoplites*) aff. *eodentatus*, *H.* (*H.*) cf. *baylei*, *Hyphoplites arausionensis*, *H. crassofalcatus*, *Hypoturrilites mantelli*, *H. gravesianus*, *H.* cf. *tuberculatus*, *Mantelliceras saxbii*, *M. mantelli*, *M. cantianum*, *Mariella* (*M.*), *dorsetensis*, *Mortoniceras* (*M.*) sp. ex. gr. *inflatum*, *Placenticeras guardakense*, *P.* cf. *kysylkurganense*, *Schloenbachia* spp. ex. gr. *varians*, *Semenoviceras* cf. *tamalakensis* and *S.* aff. *gracilis*.

2.2. Measured sections

2.2.1. Takal Kuh sections

Two sections have been measured in this area. They are the thickest sections measured (Figure 2.3). Here, the Sarcheshmeh and Sanganeh Formations have numerous beds, with ammonites. Takal Kuh is situated north-west of Ashkhaneh, 55 kilometres from Ashkhaneh along the road to Shahrabad (Figure 1.2). For access to the measured sections a track, passable by car, is used for roughly 15 kilometres. Takal Kuh section (1) and Takal Kuh section (2) are located at 37° 43′ north latitude and 56° 10′ east longitude, and 37° 43′ north latitude and 56° 7′ east longitude respectively.

2.2.1.1. Takal Kuh section 1

Sarcheshmeh Formation (1210 m.): The first marly limestone beds of the Sarcheshmeh Formation have a conformable relationship with the last fossiliferous limestone of the Tirgan Formation. At this locality the formation cannot be divided into two members. The lowermost part of the Sarcheshmeh Formation is mostly formed by grey marly limestone with a few shaly limestones (Figure 2.4). *Argvethites* sp., *Barremites* cf. *difficilis*, *Martelites securiformis*, *M.* sp. 1, *Heteroceras* sp. 1, *Imerites sparsicostatus*, *Paraimerites* sp., *Toxoceratoides* sp., *Turkmeniceras* cf. *tumidum* and *Turkmeniceras multicostatum* have been identified from these layers.

Shaly limestones are predominant from 320 to 550 metres from the base of the formation (Figure 2.5). Their colour is darker than in previous layers. A few sandy limestone beds appear at the top of this part. Ammonites are rare in these layers. However, a few specimens were collected and identified as *Deshayesites* cf. *weissiformis, D.* sp. 1 and *Ancyloceras* cf. *manteli.* Based on these ammonites and those described previously, the Barremian-Aptian boundary should be placed between sample 22 and sample 24 where the last *Turkmeniceras* and first *Deshayesites* have been found respectively. Here, the first appearance of *Deshayesites* (Sample 24) is taken as the base of the Aptian.

Thin-bedded grey shaly beds with thin limy marl and marl beds were deposited above the shaly limestone extending from 550-650 metres. Two collected samples contain the ammonites *Deshayesites oglanlensis* and *D.* cf. *tuarkyricus.*

Figure 2.3. General view of the Sarcheshmeh (A), Sanganeh (B) and Kalat (C) Formations at the Takal Kuh section (1), looking north.

Figure 2.5. Shaly limestone of the lower part of the Sarcheshmeh Formation at the Takal Kuh section (1).

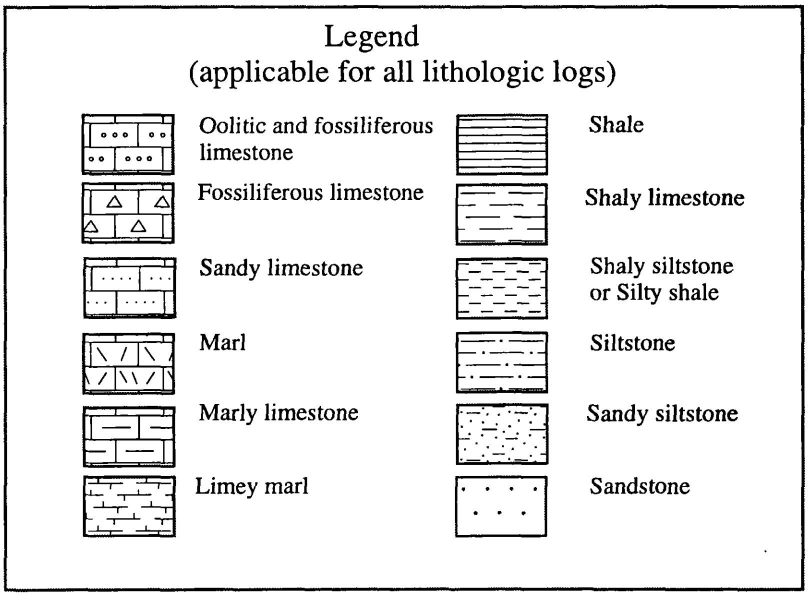
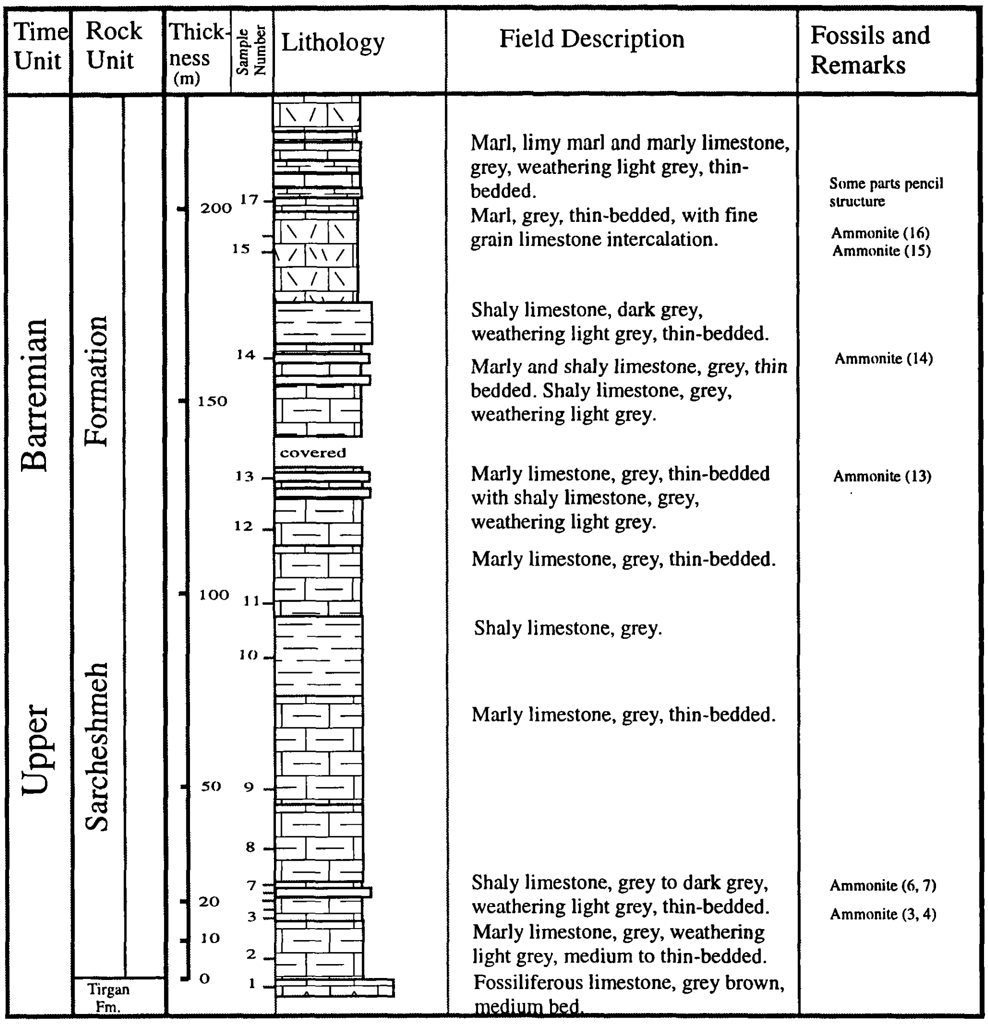


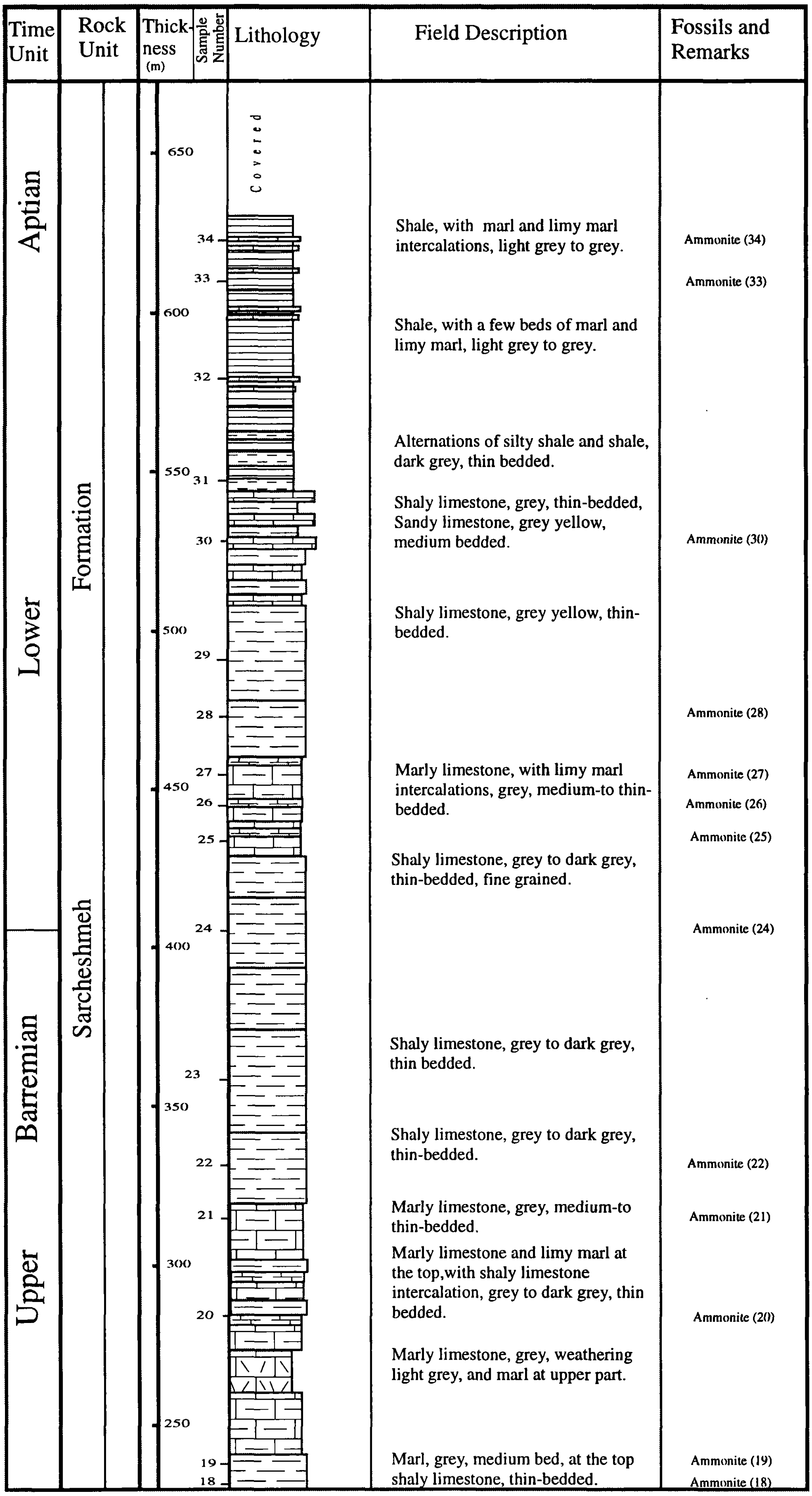
Figure 2.4. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Takal Kuh section (1).

Latitude: 37° 43' N　　Longitude: 56°10' E



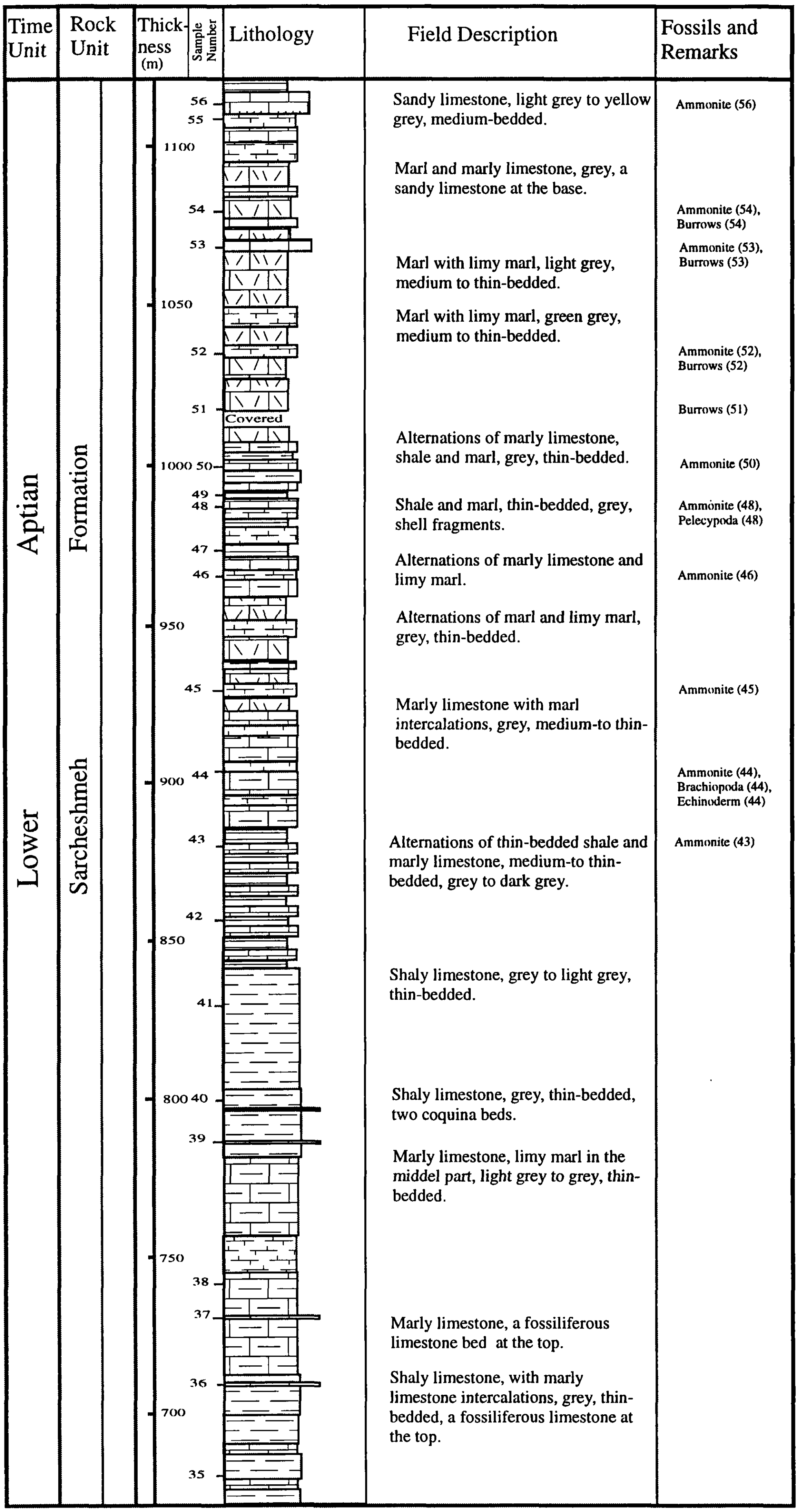
Takal Kuh section (1)

Continued



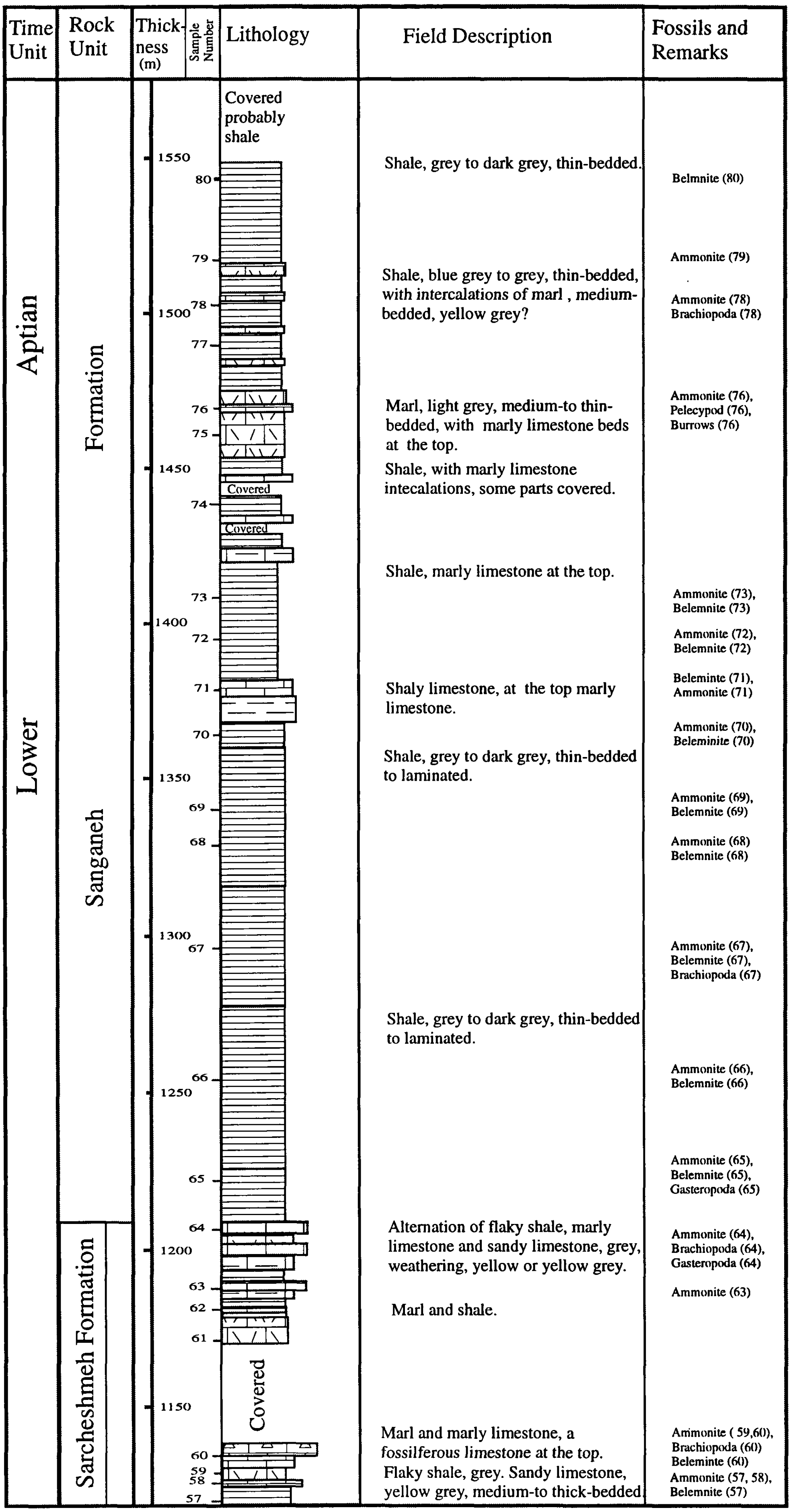
Takal Kuh section (1)

Continued



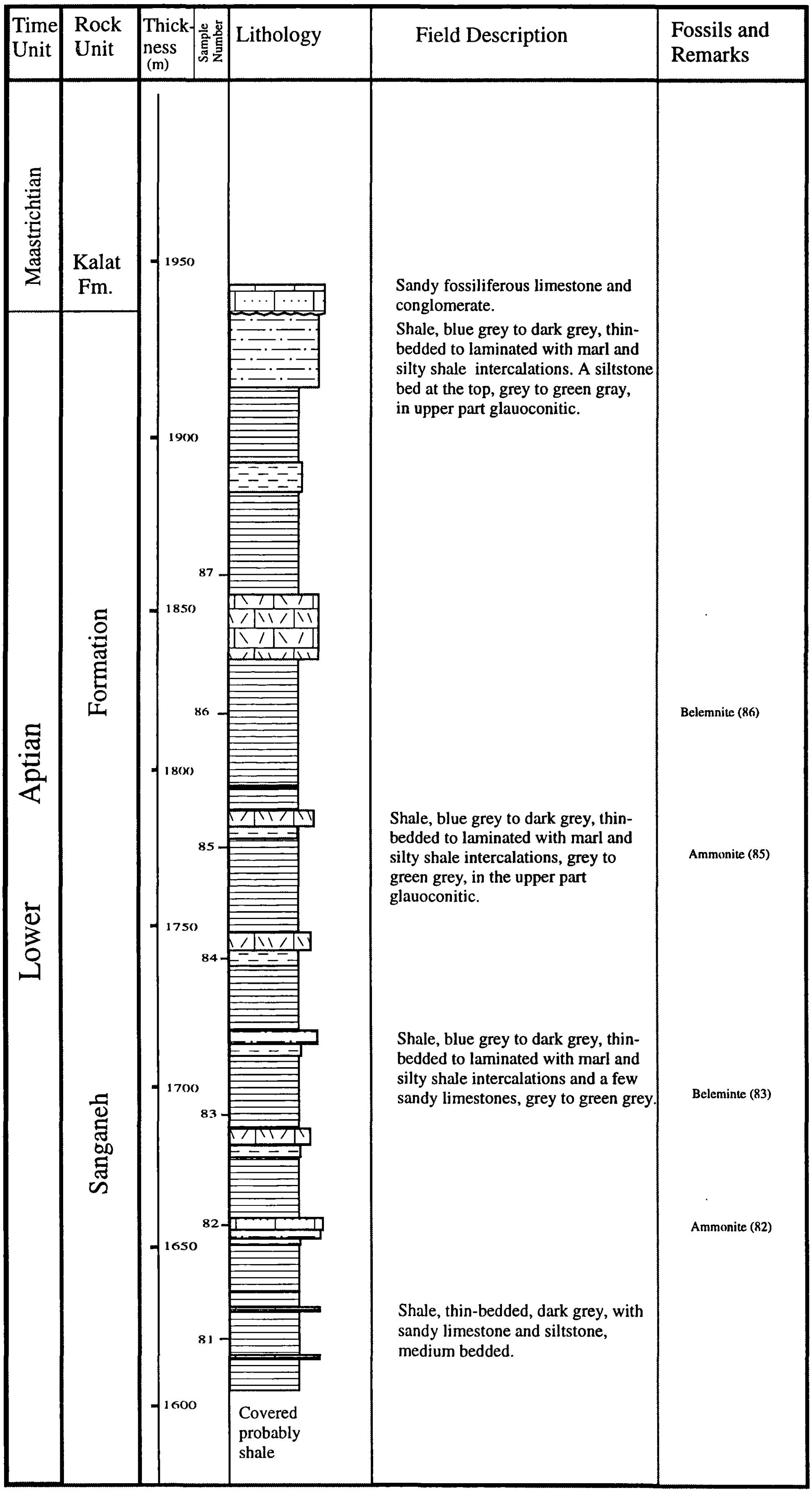
Takal Kuh section (1)

Continued



Takal Kuh section (1)

Continued



Takal kuh section (1)

Between 650 and 900 metres the section consists of an alternation of light grey to grey marly limestone and shaly limestone with fossiliferous limestones in the middle and shale beds at the top. This interval lacks ammonites, except one sample at the top of this part, which yielded *Deshayesites oglanlensis.*

The next two hundred metres (900-1100 m.) consists of thin-to medium-bedded grey marly limestone, marl and limy marl. These layers are rich in ammonites, with the following species; *Deshayesites dechyi*, *D.* cf. *euglyphus*, *D.* cf. *involutus*, *D. luppovi*, *D. oglanlensis*, *D.* cf. *planus*, *D. weissi*, *D.* sp. 2, *D.* sp. 3, *Phylloceras* sp. and *Phyllopachyceras* sp. Other macrofauna such as echinoderms, brachiopods and pelecypods are present in some layers. Burrowing, which probably reflects echinoderm and pelecypod activity, is seen in the marls and marly limestones.

The final hundred metres of the Sarcheshmeh Formation contain grey laminated shale beds with light grey to yellow grey, medium-bedded, sandy fossiliferous limestone intercalations. Collected samples include *Aconeceras haugi*, *Cheloniceras* sp., *Deshayesites deshayesi*, *D.* cf. *involutus*, *D. luppovi* and *Melchiorites* aff. *melchioris*. The ammonite assemblage fauna in the Sarcheshmeh Formation suggests a latest Barremian-Early Aptian age for this formation.

<u>Sanganeh Formation</u> (730 m.): Dark grey, thin-bedded, strongly weathered shales of the Sanganeh Formation were deposited over the Sarcheshmeh Formation; the contact is conformable. A sequence of shales about 200 metres thick forms the lowermost part of the Sanganeh Formation (Figure 2.4). It yields *Aconeceras haugi*, *Cheloniceras* sp., *Deshayesites deshayesi*, *Melchiorites* aff. *melchioris*, *Pseudosaynella* sp. and *Tonohamites* sp.

Above these layers a shale sequence with an alternation of marly limestone, shaly limestone and marl was deposited. Differentional weathering of these lithologies forms small ridges among the high weathered badland topography of the Sanganeh shales. A few silty shale and sandy fossiliferous limestones beds can be seen in the upper part of the formation. These layers contain *Aconeceras haugi*, *Deshayesites* cf. *planus*, *D.* cf. *consobrinoides*, *D.* cf. *multicostatus*, *Melchiorites* aff. *melchioris*, *Australiceras* sp. and *Tonohamites* sp.

Belemnites have also been collected, including *Neohibolites* spp., *Duvalia* sp. and *Oxyteuthis* sp.

In the shale beds of the Sanganeh Formation ammonites are small. This may be due to post depositional compaction of the shales, when mid to outer whorls fragmented and just the pyritised inner whorls remained. In the marly limestone and limestone beds big ammonite shells are found.

The basal conglomerate and sandy limestone of the Kalat Formation, of Maastrichtian age, rests with angular unconformity on the Sanganeh Formation. The ammonite assemblage fauna in the Sanganeh Formation suggests a mid Early Aptian age for this formation.

2.2.1.2. Takal Kuh section 2

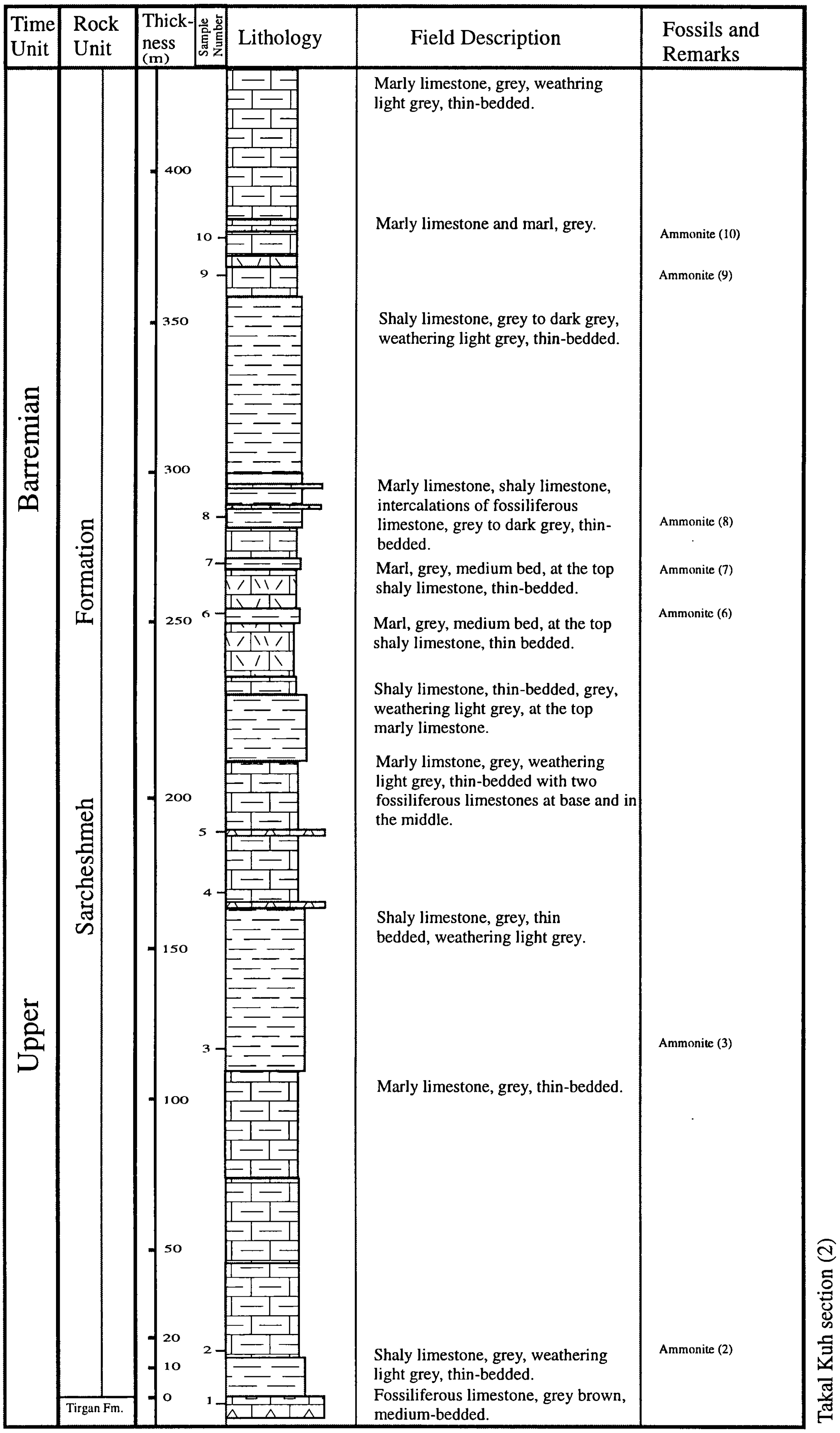
This section is about 4 kilometres west of section (1). The lithology is very similar to that of section (1), with minor lateral changes in some beds. Some of the difference may be due to weathering and the state of the exposure.

<u>Sarcheshmeh Formation</u> (1220 m.): The first 700 metres of the section are formed by marly limestone and shaly limestone beds with a few fossiliferous limestone and marl intercalations (Figure 2.6). The following ammonites are found: *Argvethites* sp., *Martelites securiformis*, *M.* cf. *tinae*, *M.* cf. *tenuicostatus*, *M.* sp. 1, *M.* sp. 2, *Deshayesites luppovi, D. oglanlensis*, *D.* cf. *tuarkyricus*, *D.* cf. *weissiformis*, *Heteroceras* cf. *colchicus*, *Turkmeniceras multicostatum* and *T.* cf. *tumidum*, which indicate a Late Barremian-Early Aptian age. The base of the Aptian is taken at the first appearance of *Deshayesites* in sample number 17.

Above are 300 metres of grey and dark grey marl and marly limestone alternations with fossiliferous limestone intercalations. These layers contain the following ammonites; *Deshayesites* cf. *euglyphus*, *D. luppovi*, *D. oglanlensis*, *D.* cf. *planus*, *D. weissi*, *D.* cf. *weissiformis* and *Pedioceras* sp.

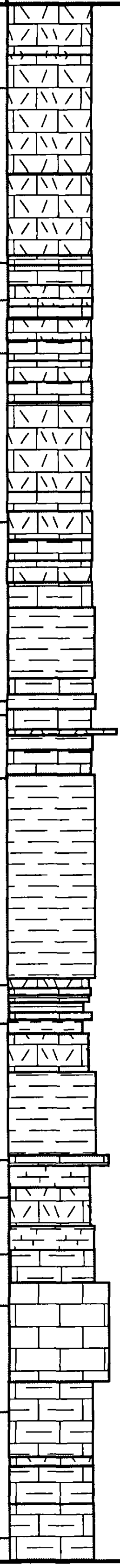
Figure 2.6. Stratigraphic column of the Sarcheshmeh and Sanganeh Formations in the Kopet Dagh Basin, NE Iran, Takal Kuh section (2).

Latitude 37° 43' N Longitude: 56 °7' E



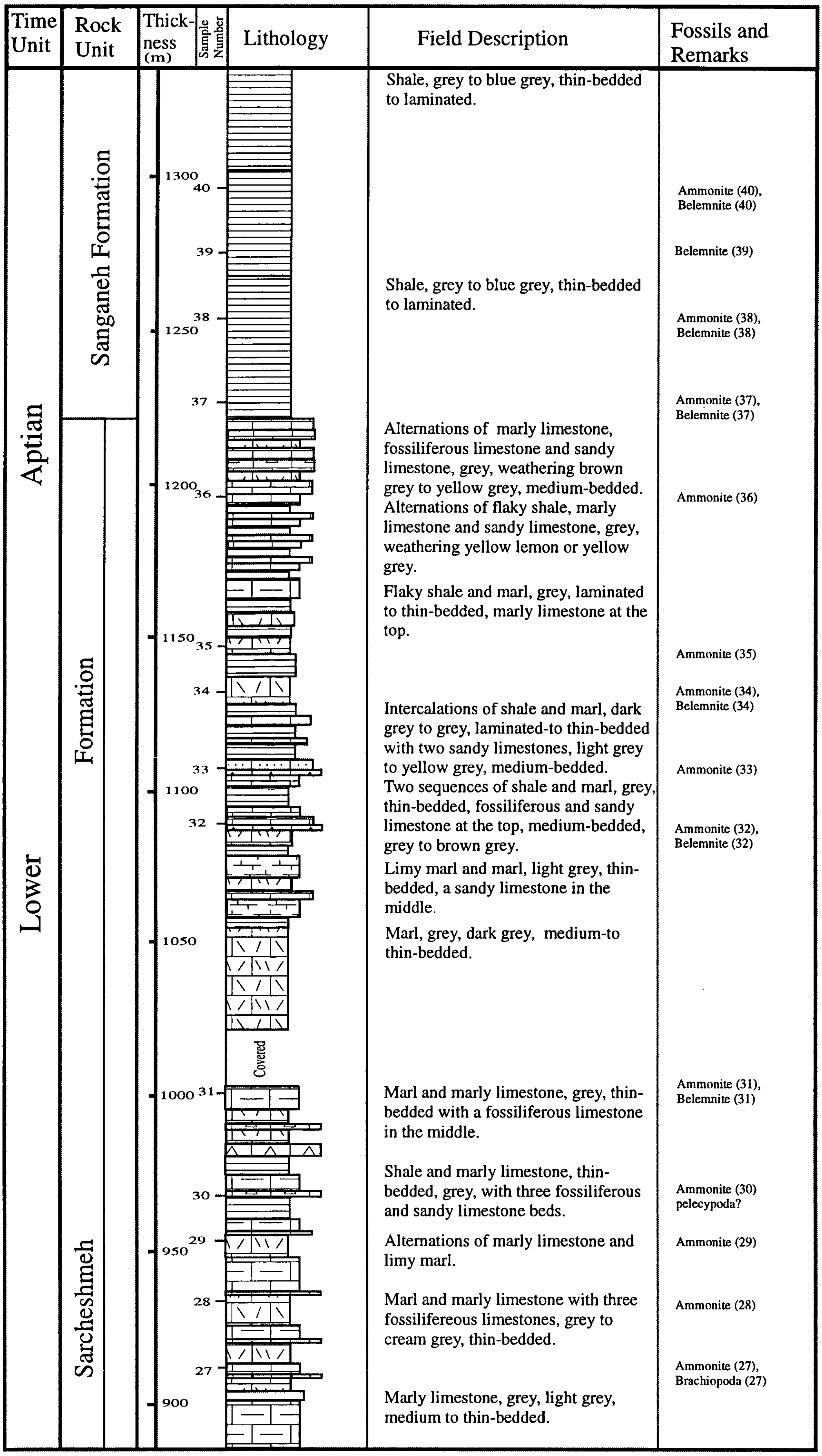
continued

Takal Kuh section (2)



Time Unit	Rock Unit	Thickness (m)	Sample Number	Lithology	Field Description	Fossils and Remarks
Lower Aptian	Sarcheshmeh Formation	850	26		Marl, dark grey to grey, weathering light grey, medium to thin-bedded, nodular structure.	
					Marl, grey to light grey, thin-bedded, pencil structure.	
		800	25, 24, 23		Marl and marly limestone, black grey, weathering light grey to grey, thin-bedded, pencil structure.	Ammonite (25), Ammonite (24), Ammonite (23)
		750	22		Alternation of marly limestone and marl light grey, thin-bedded to medium-bedded.	Ammonite (22)
		700	21, 20		Shaly limestone and marly limestone, grey, weathering light grey to yellow grey, thin-bedded, a fossiliferous limestone in the middle.	Ammonite (20, 21)
		650	19		Shaly limestone, grey, thin-bedded.	Ammonite (19)
		600	18, 17		Alternations of shaly limestone, marl and limy marl, grey, light grey to yellow grey.	Ammonite (18), Ammonite (17)
Upper Barremian					Shaly limestone, grey, thin-bedded.	
		550	16, 15, 14		Alternations of marly limestone, marl and limy marl, grey, weathering yellow grey to light grey, medium-to thin-bedded, a limestone bed at the top.	Ammonite (16), Ammonite (15), Belemnite (15), Ammonite (14)
		500	13		Limestone, grey yellow, medium-bedded.	Ammonite (13)
		450	12, 11		Marly limestone, with marl intercalation, grey, medium-to thin-bedded.	Ammonite (13), Ammonite (11)

Continued



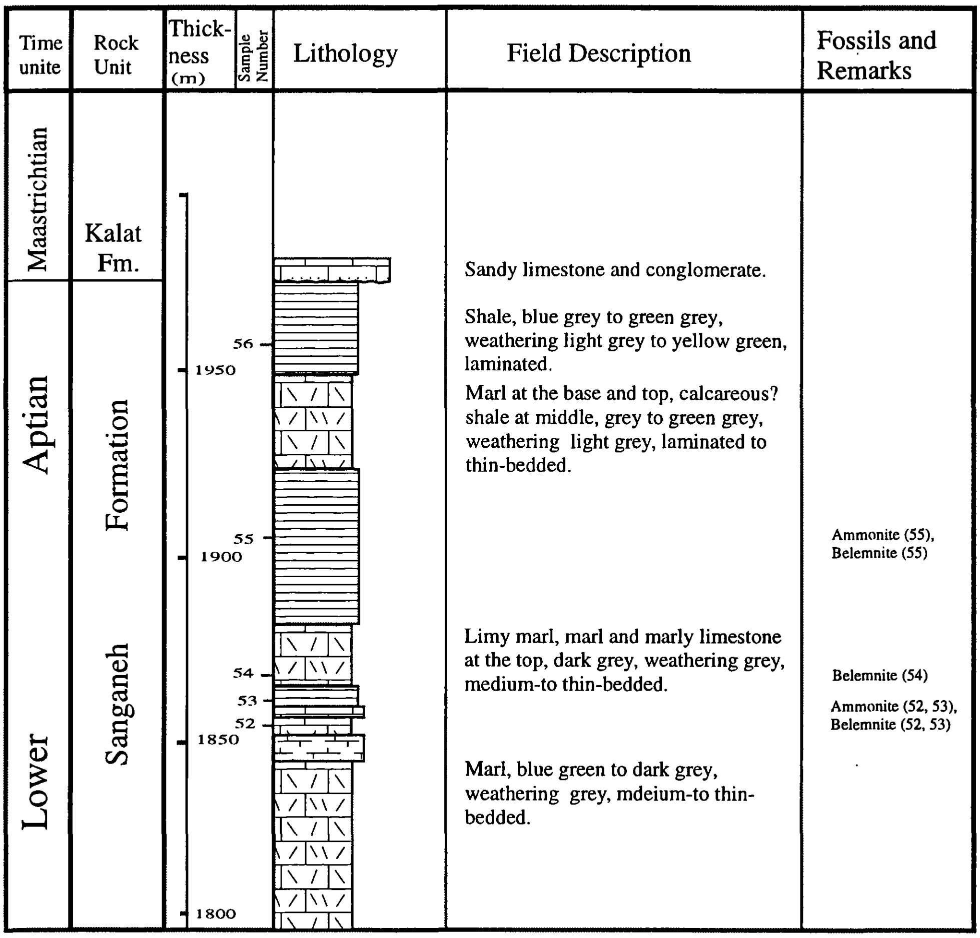
Takal Kuh section (2)

Continued

Time Unit	Rock Unit	Thickness (m)	Sample Number	Lithology	Field Description	Fossils and Remarks
Lower Aptian	Sanganeh Formation		51/1	122	Shale, grey to dark grey with fossiliferous and sandy limestone intercalations, grey to cream grey, medium-bedded.	Ammonite (51/1) Belemnite (51/1)
			51, 50			Ammonite (50, 51), Beleminte (50)
				121	Shale blue grey to green grey, thin-bedded to laminated with marl, thin- to medium-bedded.	
		1750				
		1700				
			49			Ammonite (49), Beleminte (49)
		1650				
			48		Marl, grey to dark grey, medium-and thin-bedded.	Ammonite (48), Belemnite (48), Brachiopoda (48)
		1600				
			47		Marl, grey to light grey, thin-bedded.	Ammonite (47), Belemnite (47), Brachiopoda (47)
		1550				
			46		Shale, dark grey to grey, laminated with intercalations of marl, thin-bedded.	Ammonite (46)
			45			
		1500				
			44		Shale, light grey, thin bedded, with limy marl beds at the top.	Ammonite (44), Belemnite (44)
		1450			Shale and marl, grey, light grey.	
			43			Ammonite (43), Belemnite (43)
					Limy marl and shale, dark grey to grey, weathering light grey.	
			42			Ammonite (42), Belemnite (42)
		1400				
					Marl, grey to blue grey, thin-bedded.	
			41			Beleminite (41)
		1350				

Takal Kuh section (2)

Continued



Takal Kuh section (2)

Shale beds appear in the last 200 metres. They are accompanied by marly limestones, marls, and sandy and fossiliferous limestones. The number of sandy and fossiliferous limestones increases in this part compared with in the beds below. *Australiceras* sp., *Deshayesites* cf. *consobrinoides*, *D.* cf. *dechyi*, *D. deshayesi*, *D.* cf. *multicostatus*, *D. weissi*, *E.* (*Eogaudryceras*) sp., *Cheloniceras* sp. and Cymatoceratidae (Nautiloidea) occur here. The ammonites indicate a Late Barremian-Early Aptian age for this formation.

Sanganeh Formation: (720 m.) The formation starts with grey to blue grey thin-bedded to laminated shales. Then marl beds appear among the shales (Figure 2.6). The marl intervals are up to 50 metres thick. The fauna includes *Aconeceras haugi*, *Deshayesites consobrinoides*, *D. deshayesi*, *D.* cf. *multicostatus*, *D.* sp. nov., *Dufrenoyia* sp., *Melchiorites* aff. *melchioris*, *Cheloniceras* sp., *Pedioceras* cf. *anthulai*, *Pseudosaynella* sp., *Tonohamites* sp. (Ammonoidea) and Cymatoceratidae (Nautiloidea).

Belemnites occur in the Sanganeh Formation and include *Neohibolites* spp. and *Oxyteuthis* sp.

This assemblage indicates an Early Aptian age for the Sanganeh Formation in this section. The upper boundary of the Sanganeh Formation with the Kalat Formation (Maastrichtian) is marked by an angular unconformity.

2.2.2. Amand section

The section is only about 18 kilometres east of the Takal Kuh section (1) (Figure 1.2), near to the Amand road and extends to Amand village. The base of the section is located at 37° 47′ north latitude and 56° 20′ east longitude. This section shows similarity to the Takal Kuh sections. In later sections of this thesis the Takakl Kuh and Amand sections are sometimes referred to jointly as the 'Takal Kuh area'.

Sarcheshmeh Formation (1110 m.): The lower contact of the formation with the Tirgan Formation is a faulted contact. The first 200 metres of the section include alternations of marly limestones and shaly limestones, and are barren of ammonites. The next 150 metres are similar to the first part but a few thin-bedded limestones appear (Figure 2.7). Ammonites are mostly found in the marly limestones and include *Martelites* cf. *tenuicostatus, M.* cf. *tinae, M.* sp. 1, *M.* sp. 2 and *Heteroceras* cf. *colchicus.*

Then an alternation of shale and shaly limestones with a few marly beds is seen for almost the next 300 metres. These layers contain *Barremites* cf. *difficilis, Deshayesites* cf. *euglyphus, D. oglanlensis, Martelites securiformis, M.* cf. *tenuicostatus, M.* cf. *tinae, Turkmeniceras multicostatum* and *T.* cf. *tumidum.* The first appearance of *Deshayesites* is taken as the base of the Aptian in sample number 13.

The sediments are followed by a few sequences of shaly limestone, marly limestone, shale and limy marl, with occasional thin-bedded limestones. Ammonites are rare but a few *Deshayesites* cf. *weissiformis* were collected.

Shale beds decrease and marly beds increase in the uppermost part of the Sarcheshmeh Formation. These sediments are accompanied by sandy and fossiliferous limestone intercalations. The last fossiliferous limestone marks the top of the Sarcheshmeh Formation. *Deshayesites* cf. *consobrinoides, D. dechyi, D. deshayesi, D.* cf. *involutus, D. luppovi, D.* cf. *planus, D. weissi,* and Cymatoceratidae are seen here.

Based on these ammonites a Late Barremian-Early Aptian age is suggested for the Sarcheshmeh Formation.

<u>Sanganeh Formation</u>: A few tens of metres of the Sanganeh Formation were measured, but parts of the formation are covered by weathered material. There seems no important change in ammonite content and age from the Takal Kuh section.

Black to dark grey thin-bedded to laminated shales were deposited in the lower part of the formation. *Aconeceras haugi, Deshayesites deshayesi, D.* sp. nov. and *Pedioceras* cf. *anthulai* are identified from collected samples. This assemblage indicate an Early Aptian age for the base of the Sanganeh Formation in this section.

2.2.3. Raz section

This section is situated 45 kilometres north-west of Bojnord along the Bojnord-Raz road (Figure 1.2). The geographical position of the section is 37° 46′ north latitude and 56° 56′ east longitude. This section is about 60 kilometres east of the Amand section. The formations are thinner here and show some lithofacies differences. The thickness of the formations here suggests that the area has not been affected by syndepositional Takal Kuh fault activity and that it may lie at the margin of the subsiding area.

Ammonites are not common here, but an interesting aspect is the difference in ammonite levels. At the Takal Kuh section *Dufrenoyia* was found in the uppermost part of the Sanganeh Formation, whilst in the Raz section it was collected from the uppermost part of the Sarcheshmeh Formation (see p.74).

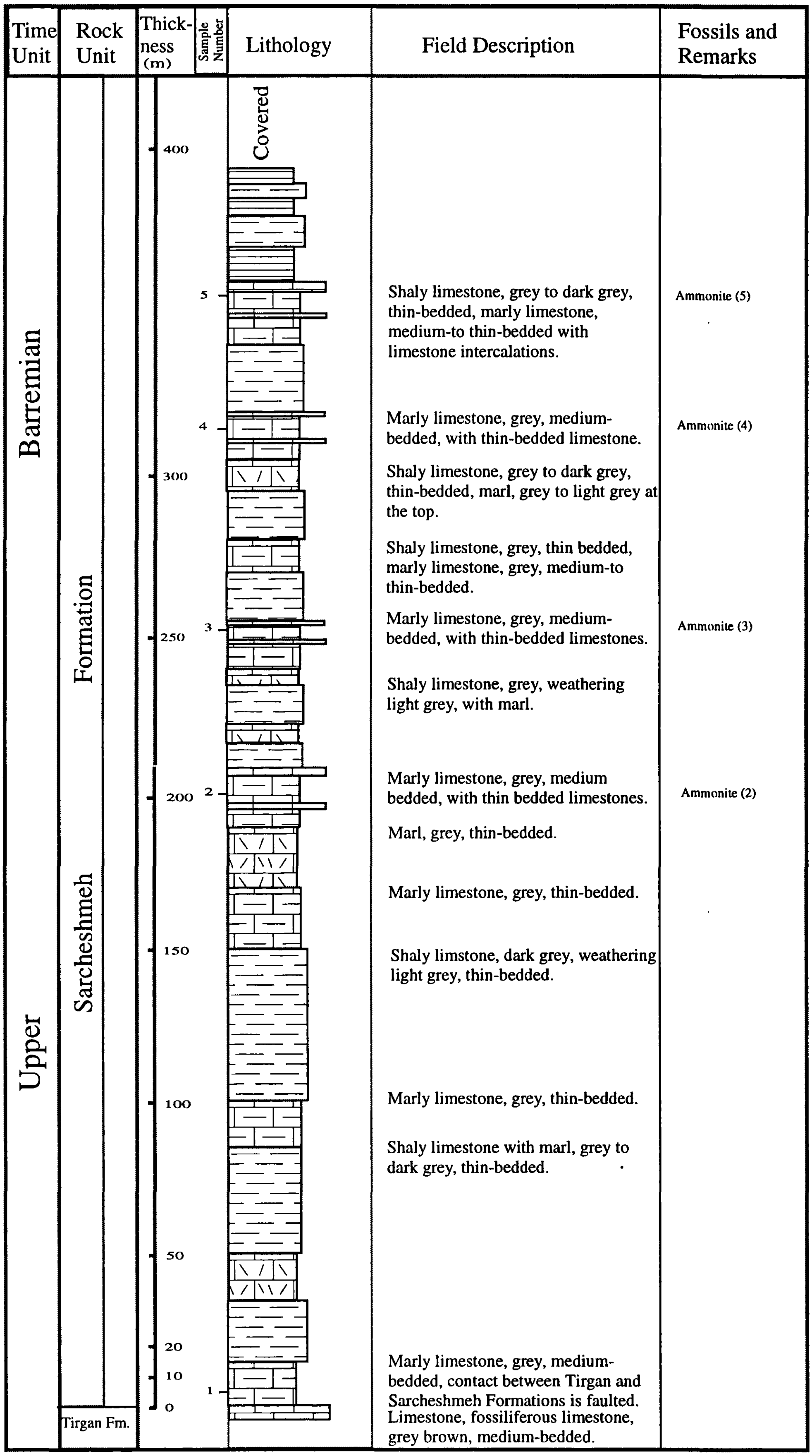
Sarcheshmeh Formation: The lower member of the formation is formed by thin to medium-bedded grey marl and marly limestones. This part of the formation is barren of ammonites, therefore it has not been measured and sampled. Only the shale member has been measured and its thickness is 270 metres (Figure 2.8).

The first 100 metres of the shale member consists of homogenous dark grey to green-grey shales with a few marl beds. The following ammonites occur: *Pedioceras* cf. *anthulai*, *Pseudosaynella* sp. and *Deshayesites* spp. In the next following 100 metres fossiliferous limestone beds occur in the shales. The thickness of individual limestones is less than half a metre and is mostly about 20 centimetres. One layer is completely composed of pelecypod shells and debris. A few *Deshayesites* spp. were collected from this part.

In the final 70 metres the number of fossiliferous limestone beds increases, and some are as thick as 2 metres. These limestones contain brachiopods and orbitolinids in large numbers and fewer pelecypods and echinoderms. The following brachiopods occur here: *Sellithyris sellalindensis*, *S. carteroniana* and *Praelongithyris credneri* (Personal communication, Dr. E.F. Owen, Natural History Museum London). A few fragmentary ammonites occur: *C.* (*Cheloniceras*) sp., *Dufrenoyia* sp. and *E.* (*Eotetragonites*) sp.

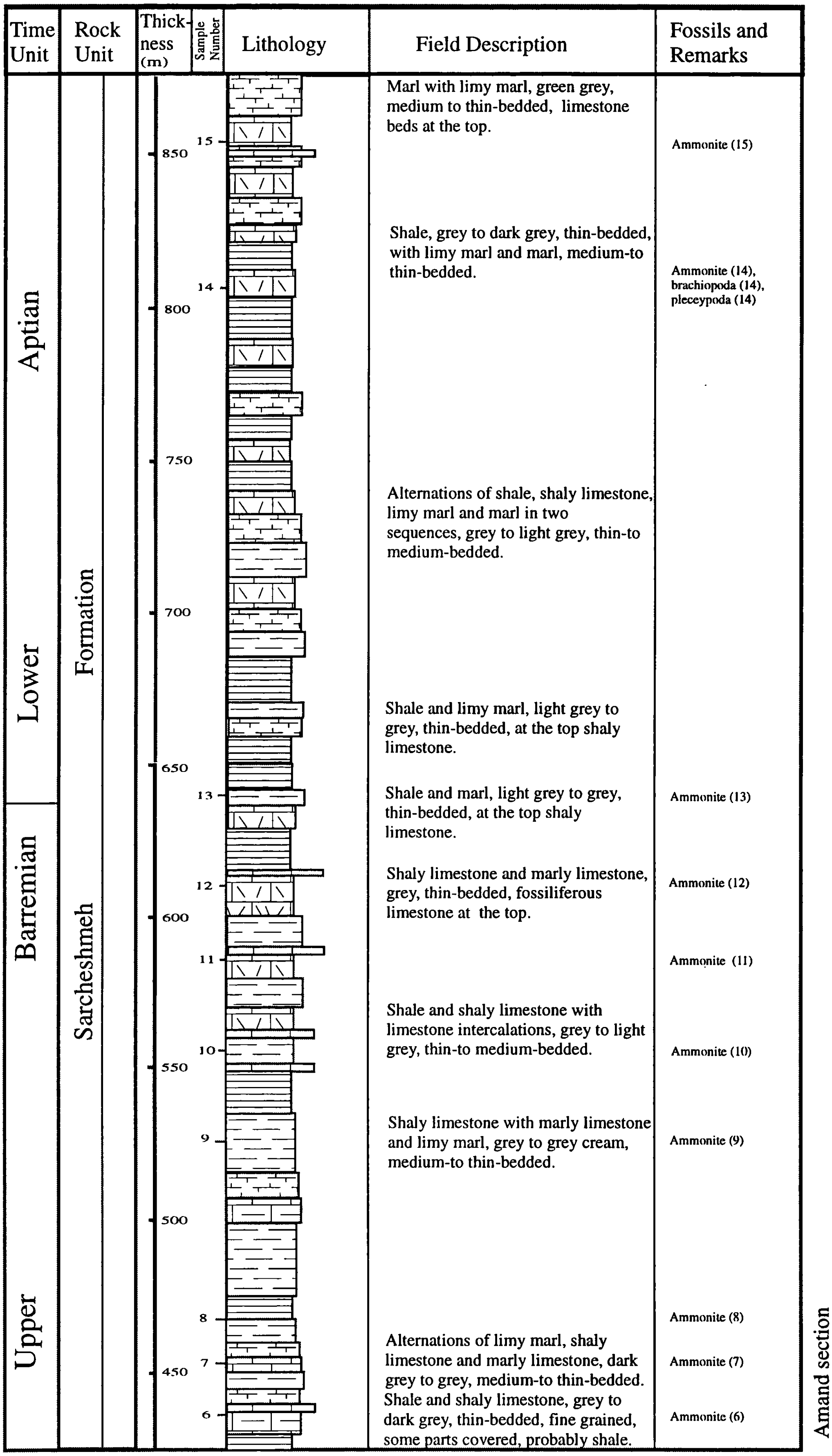
Figure 2.7. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Amand section.

Latitude: 37 °47' N Longitude: 56°20' E

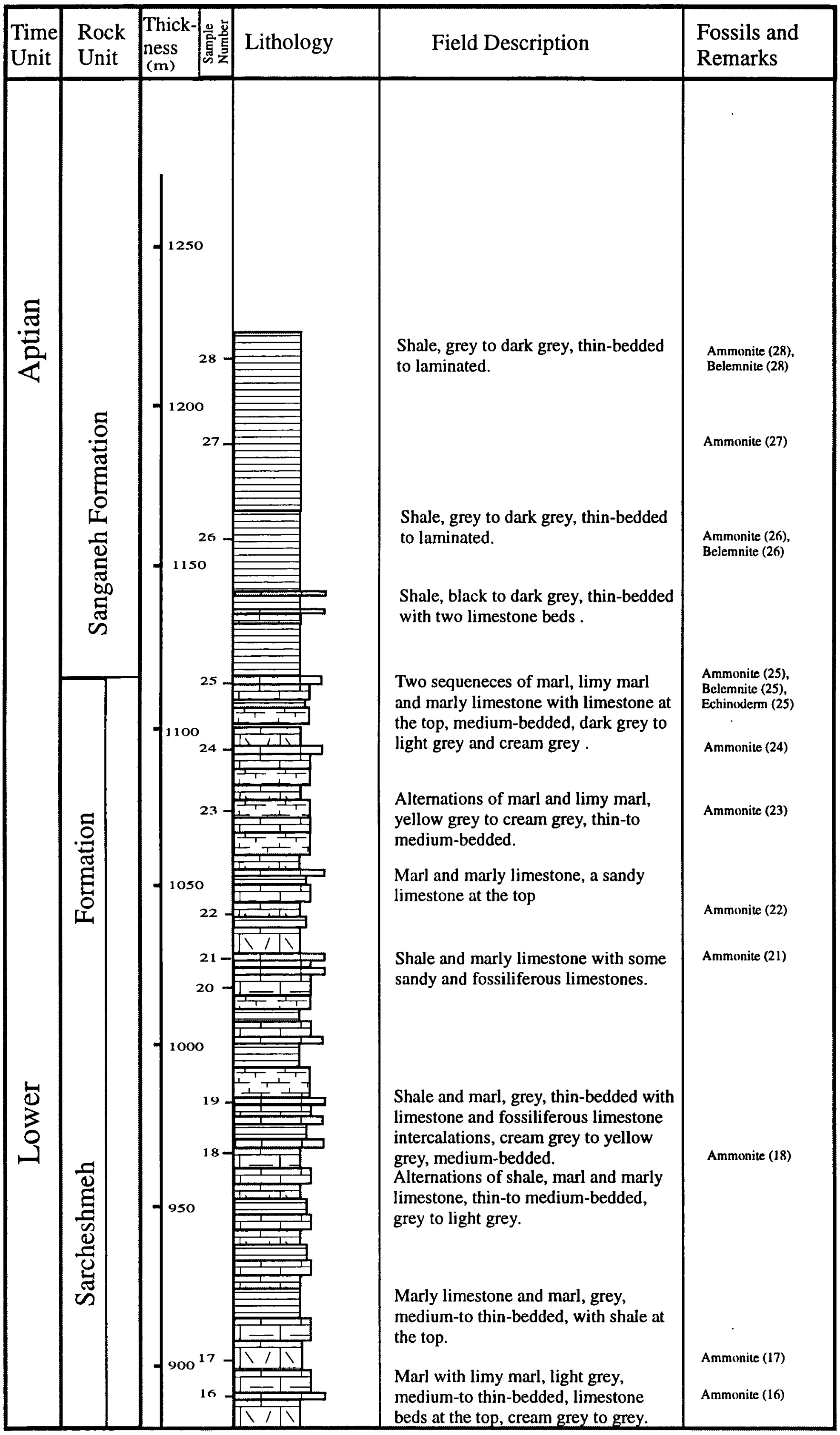


Amand section

continued

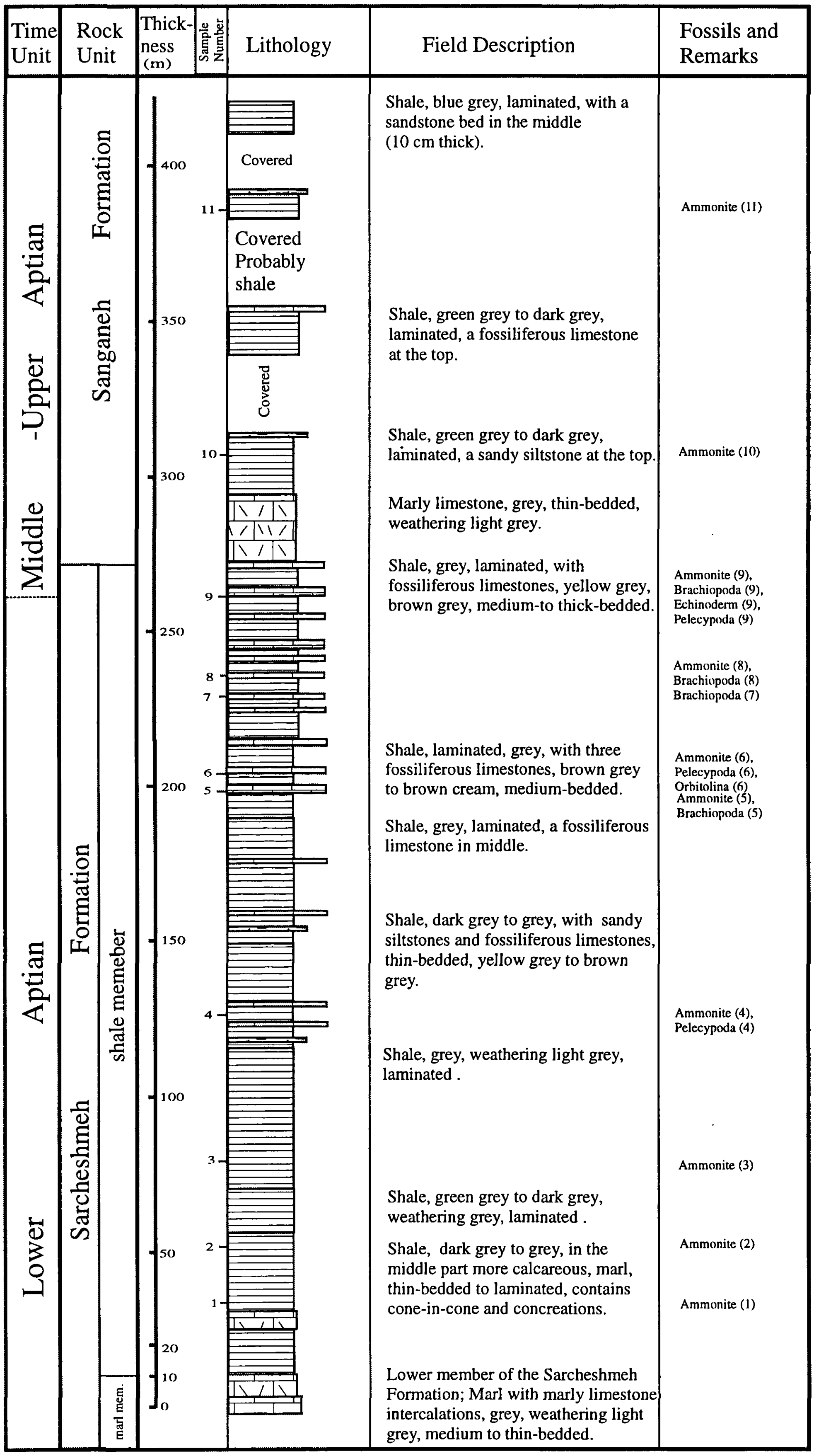

Time Unit
Rock Unit
Thickness (m)
Sample Number
Lithology
Field Description
Fossils and Remarks
Upper Barremian
Lower Aptian
Sarcheshmeh Formation
850
800
750
700
650
600
550
500
450
15
14
13
12
11
10
9
8
7
6
Marl with limy marl, green grey, medium to thin-bedded, limestone beds at the top.
Ammonite (15)
Shale, grey to dark grey, thin-bedded, with limy marl and marl, medium-to thin-bedded.
Ammonite (14), brachiopoda (14), pleceypoda (14)
Alternations of shale, shaly limestone, limy marl and marl in two sequences, grey to light grey, thin-to medium-bedded.
Shale and limy marl, light grey to grey, thin-bedded, at the top shaly limestone.
Shale and marl, light grey to grey, thin-bedded, at the top shaly limestone.
Ammonite (13)
Shaly limestone and marly limestone, grey, thin-bedded, fossiliferous limestone at the top.
Ammonite (12)
Ammonite (11)
Shale and shaly limestone with limestone intercalations, grey to light grey, thin-to medium-bedded.
Ammonite (10)
Shaly limestone with marly limestone and limy marl, grey to grey cream, medium-to thin-bedded.
Ammonite (9)
Ammonite (8)
Alternations of limy marl, shaly limestone and marly limestone, dark grey to grey, medium-to thin-bedded.
Ammonite (7)
Shale and shaly limestone, grey to dark grey, thin-bedded, fine grained, some parts covered, probably shale.
Ammonite (6)
Amand section

continued



Amand section

Figure 2.8. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Kopet Dagh Basin, NE-Iran, Raz section. Latitude: 37°46' N Longitude: 56°56' E



Raz Section

The ammonite assemblages indicate an Early Aptian age for this shale member of the Sarcheshmeh Formation.

Sanganeh Formation (150 m.): The Sanganeh Formation commences above the last fossiliferous limestone of the Sarcheshmeh Formation. Its synclinal outcrop forms a valley, and some parts of the formation are covered by weathered material. At the base there are 20 metres of grey, thin-bedded marly limestones without ammonites. These are overlain by green-grey to dark grey laminated shales with thin (not more than 20 cm) sandy limestones and a limestone band (Figure 2.8). *Acanthohoplites* sp. 2 occurs in the middle to upper part of theses beds. It indicates a Late Aptian age. Nothing overlies the Sanganeh Formation and it seems that the upper part of the formation was eroded.

2.2.4. Sheykh section

This section is situated near to Sheykh village at 37° 33′ north latitude and 57° 32′ east longitude. For access to the section a second class road branches 10 kilometres along the Bojnord-Mashhad road from Bojnord and goes to Sarcheshmeh village, which the name of the Sarcheshmeh Formation is taken from. Sheykh is located about 5 kilometres north of Sarcheshmeh (Figure 1.2).

Sarcheshmeh Formation (540 m.): The lower member of the formation is similar to that at the type section and is formed by grey, thin-bedded marl and marly limestones. The number of fossiliferous limestone beds in this member is noticeable. These limestones contain echinoderms, brachiopods (*Praelongithyris credneri*, *Lamellaerhynchia* sp.) and pelecypods. The thickness of the lower member is about 290 metres (Figure 2.9).

The shale member is mostly composed of shaly limestones and is 250 metres thick. The upper part of this member is mainly covered, but the uppermost is exposed and includes marl and fossiliferous limestones. *Pedioceras* cf. *anthulai* from the lower part of the member indicates an Early Aptian age.

Sanganeh Formation (320 m.): The lower part of the formation is covered by weathered material. In the upper part blue-grey laminated shales occurs. Some beds are black and dark coloured, suggesting they contain organic carbon. A few thin-bedded fossiliferous limestones are seen among the shales (Figure 2.9). In the uppermost part of the formation silty shale and siltstones appear and finally pass up into the first glauconitic sandstone, which is taken to mark base of the Aitamir Formation.

2.2.5. Bibahreh section

This section has been measured near to Bibahreh village, which is situated 20 kilometres north of Shirvan (Figure 1.2). The exact location of the section is 37° 31′ latitude and 58° 7′ longitude. The Tirgan Formation is the oldest exposure formation in this area and mostly forms ridges and mountains. The Sarcheshmeh and Sanganeh Formations commonly outcrop on the slopes and in valleys respectively.

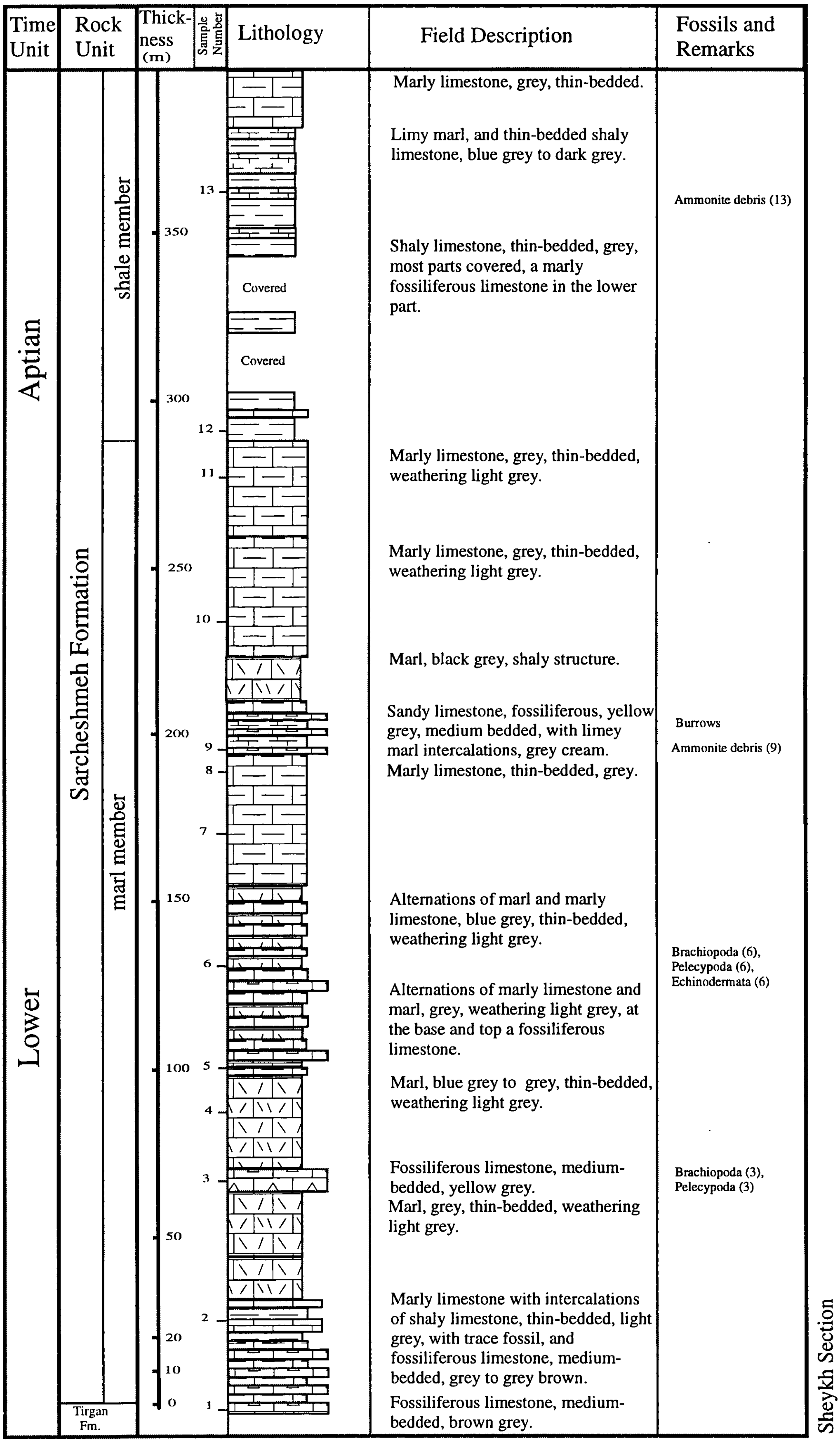
Sarcheshmeh Formation (435 m.): Tirgan Formation is overlain conformably by the Sarcheshmeh Formation. This starts with alternations of marly limestones and fossiliferous limestones. The fossiliferous limestones contain orbitolinids and shell fragments such as echinoderms, pelecypods and brachiopods. Above are marls, forming the bulk of the lower member. But a few fossiliferous limestones are also seen in the middle and upper part of the member. The marl member is less than 300 metres thick. Fragments of deshayesitids occur in the upper part of this member, but are too highly weathered to collect.

The shale member is about 150 metres thick and is formed by green-grey to blue-grey thin-bedded to laminated shales (Figure 2.10). Fossiliferous limestones appear in the upper part of the member and the last one is taken as the top of the Sarcheshmeh Formation. A fragment of *Parahoplites* cf. *maximus* from the upper part of the shale member indicates a Mid Aptian age, while the formation as whole is probably of Early to Mid Aptian age.

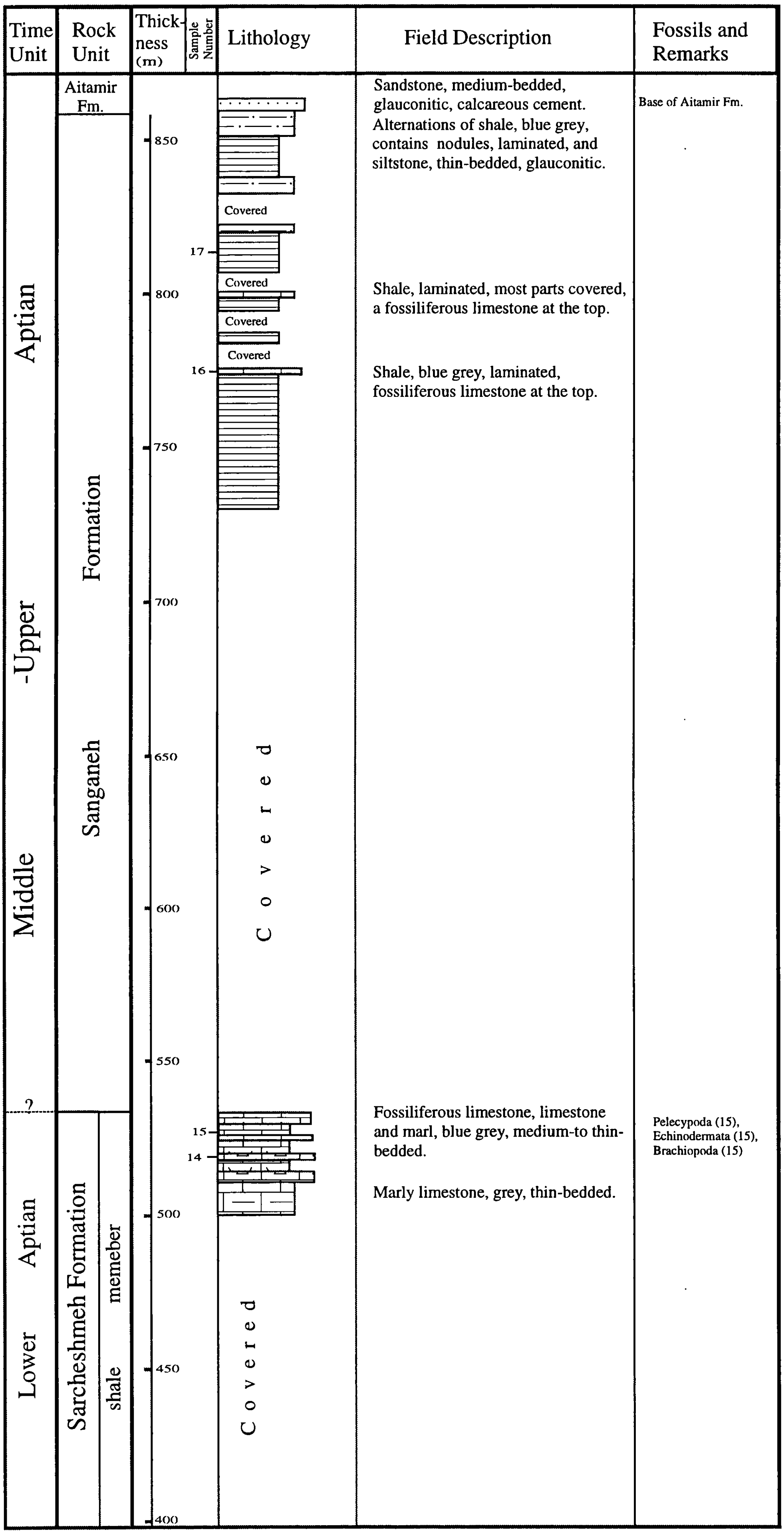
Sanganeh Formation (210 m.): The formation starts with 10 metres of marly limestone and is followed by grey to green grey thin-bedded to laminated shales. Then it gradually changes to silty shale and sometimes siltstone, containing concretions and septarian nodules (Figure 2.10). In the uppermost part of the formation *Acanthohoplites* spp., *Hypacanthoplites* cf. *clavatus* and *H. uhligi*

Figure 2.9. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Sheykh section.

Latitude: 37°33' N Longitude: 57°32' E



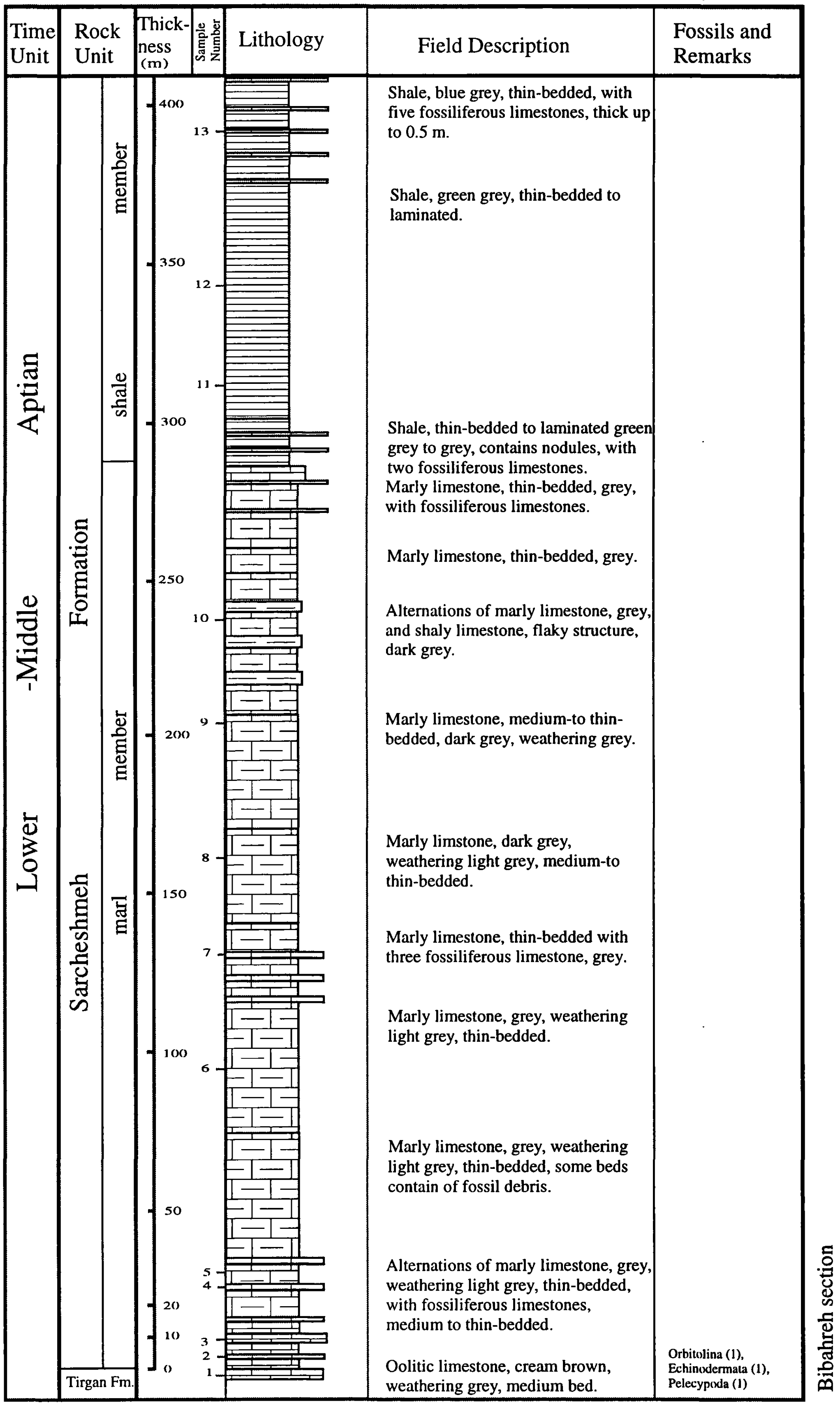
Continued



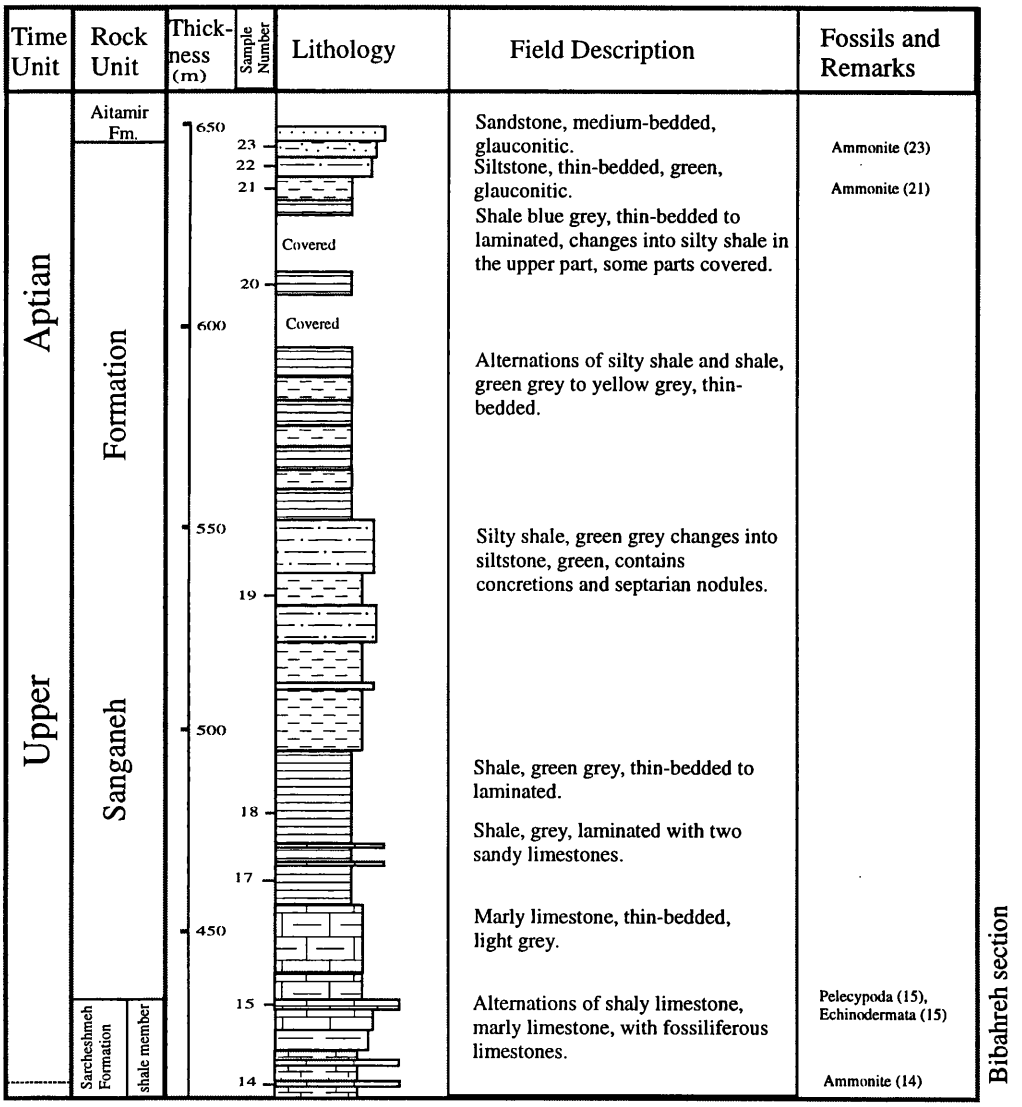
Sheykh Section

Figure 2.10. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Bibahreh section.

Latitude: 37°31' N Longitude: 58°7' E



continued


Time Unit
Rock Unit
Thick-ness (m)
Sample Number
Lithology
Field Description
Fossils and Remarks
Upper Aptian
Aitamir Fm.
Sanganeh Formation
Sarcheshmeh Formation
shale member
650
600
550
500
450
23
22
21
20
19
18
17
15
14
Covered
Covered
Sandstone, medium-bedded, glauconitic.
Siltstone, thin-bedded, green, glauconitic.
Shale blue grey, thin-bedded to laminated, changes into silty shale in the upper part, some parts covered.
Alternations of silty shale and shale, green grey to yellow grey, thin-bedded.
Silty shale, green grey changes into siltstone, green, contains concretions and septarian nodules.
Shale, green grey, thin-bedded to laminated.
Shale, grey, laminated with two sandy limestones.
Marly limestone, thin-bedded, light grey.
Alternations of shaly limestone, marly limestone, with fossiliferous limestones.
Ammonite (23)
Ammonite (21)
Pelecypoda (15), Echinodermata (15)
Ammonite (14)
Bibahreh section

were collected. The Sanganeh Formation is overlain conformably by the Aitamir Formation. A few tens metres above the base of the latter an indeterminate hoplitinid was found. From the ammonite and stratigraphical position, a Late Aptian-earliest Albian age is suggested for the formation.

2.2.6. Tirgan Section

This section is situated to the north of Tirgan village, at 37° 10′ north latitude and 59° 16′ east longitude. Tirgan village is 60 kilometres east of Darehgaz along the Darehgaz-Kalat road. For access to the village and section a 5 kilometres track should be followed (Figure 1.2).

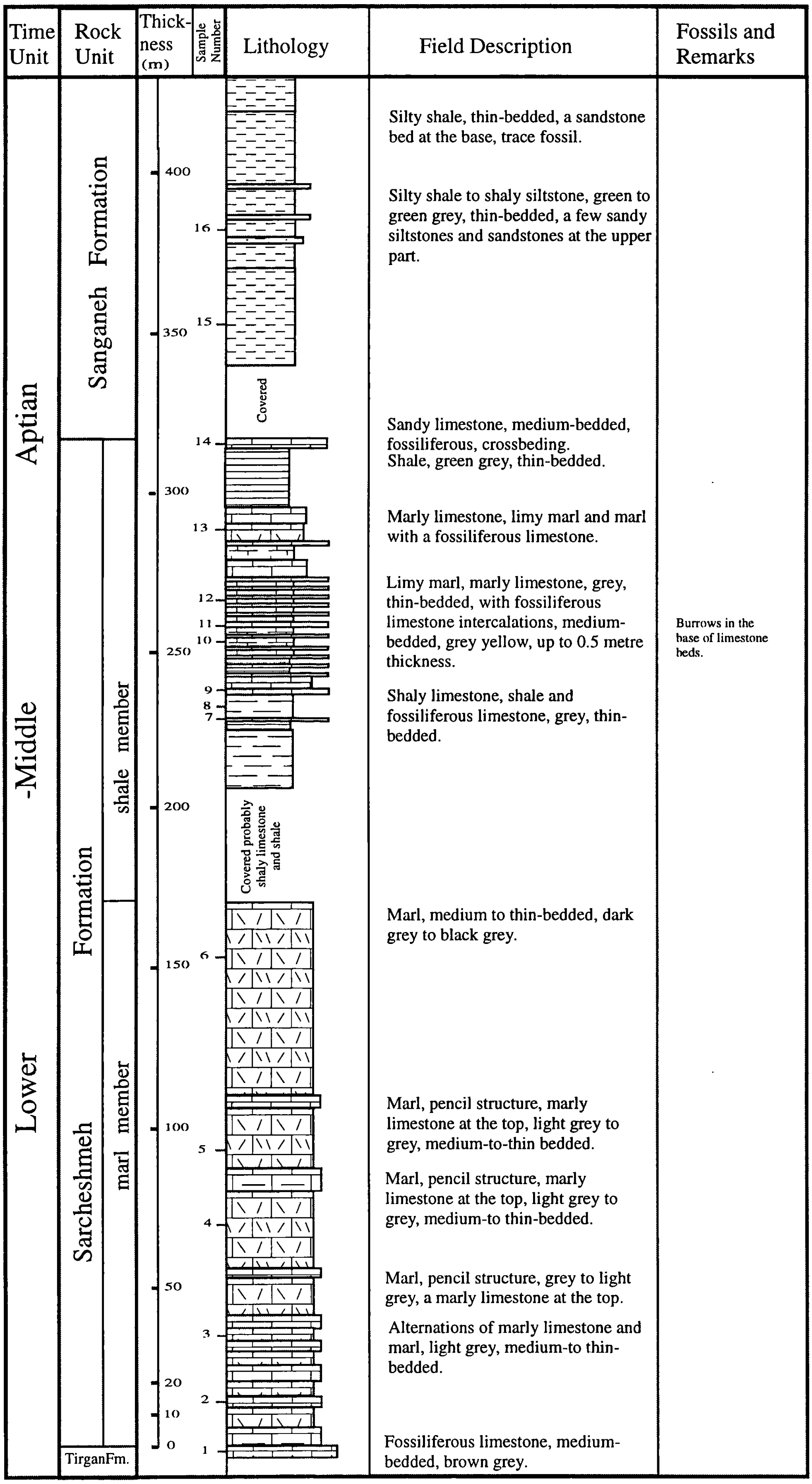
Sarcheshmeh Formation (315 m.): The first marly limestone beds of the Sarcheshmeh Formation rest conformably on the last fossiliferous and crystalline thick-bedded limestone of the Tirgan Formation. The lower part of the formation is formed mainly by marls (Figure 2.11). A few marly limestone intercalations occur and form small ridges because of their resistance. These marls weather and break into pencil-shaped pieces, so they are known as pencil marl in this region (see Figure 2.18). The lower member is barren of ammonites and other macrofossils.

Part of the shale member is covered and probably is formed by shale or shaly limestone. In the middle part of this member an alternation of limy marl, marly limestone and fossiliferous limestone can be seen. Macrofossils, such as echinoderms, brachiopods and pelecypods, occur in the limestone beds and burrows are present at the base of some limestones. In the uppermost part of the shale member the fossiliferous limestone beds decrease. A cross-bedded sandy limestone bed (Figure 2.12), with shell fragments is taken as the top of Sarcheshmeh Formation. No ammonites occur in this member. An Early to Mid Aptian age is suggested based on its stratigraphical position.

Sanganeh Formation (865 m.): The formation is mostly formed by shale, silty shale and siltstone. But fine sandstone beds and a fossiliferous limestone bed are also found in the lower part. Above is a thick sequence of blue-grey shales with a few silty shales or siltstones (Figure 2.11).

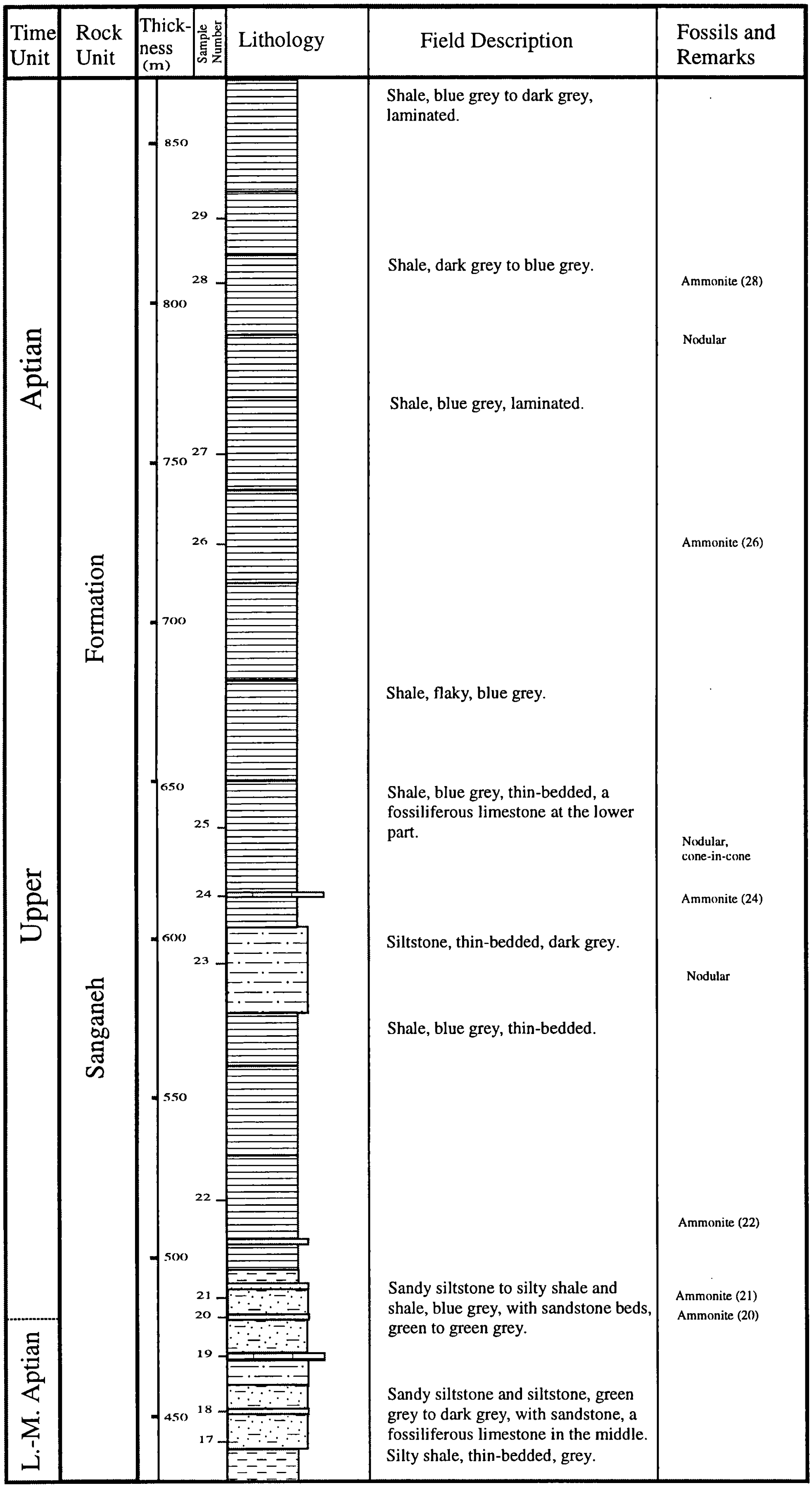
Figure 2.11. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Tirgan section.

Latitude: 37°33' N Longitude: 59°16' E



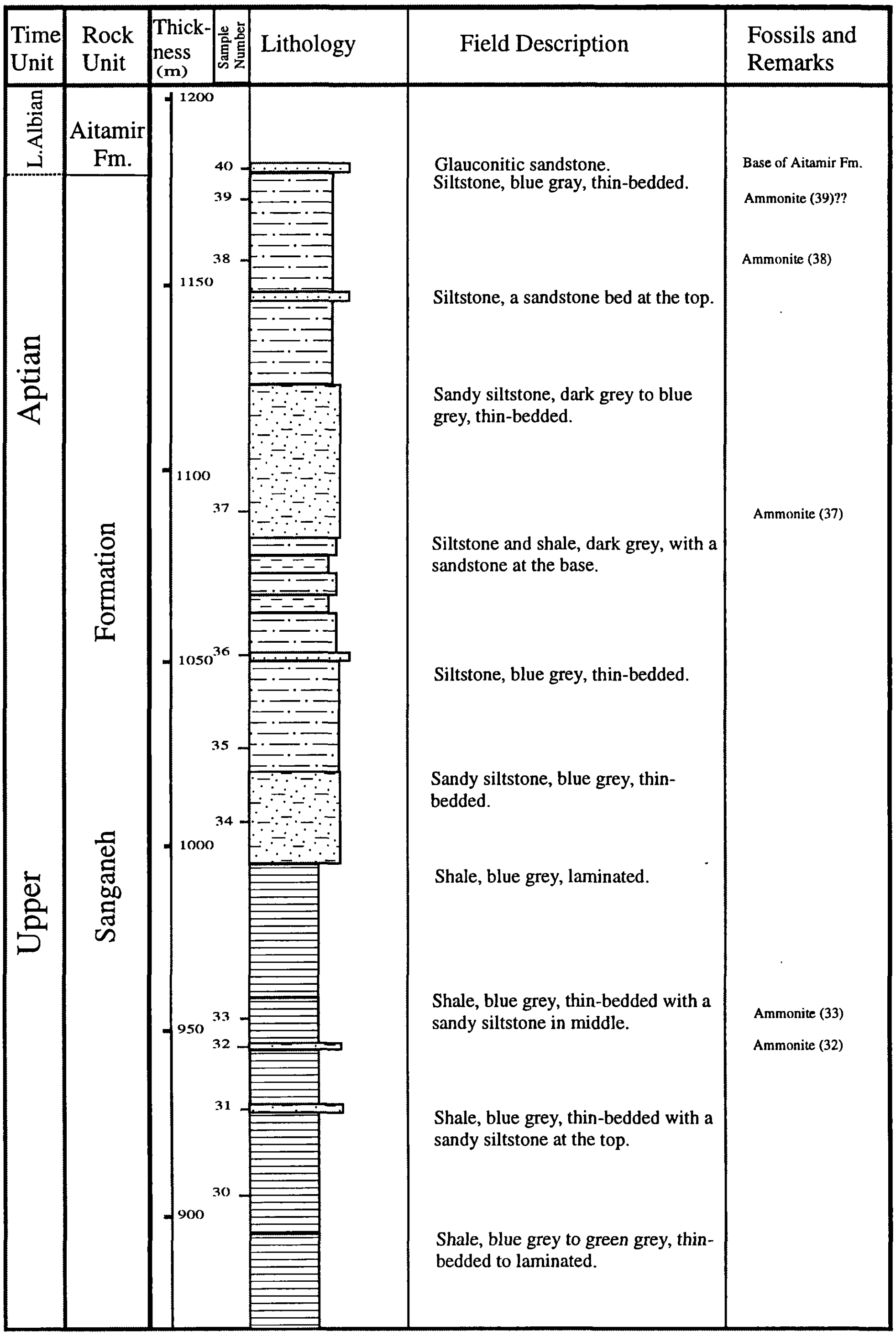
Tirgan section

continued



Tirgan section

Continued



Tirgan section

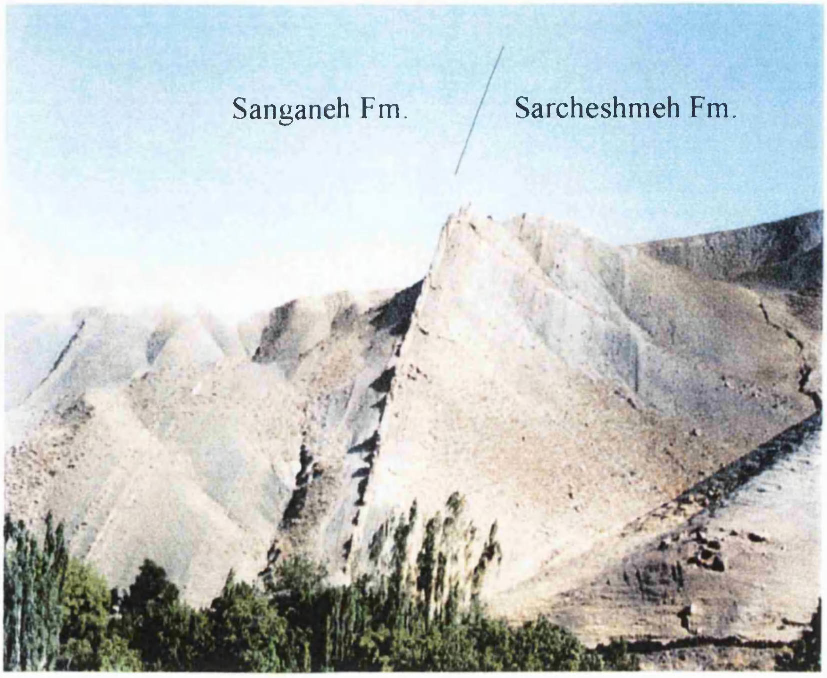


Figure 2.12. Upper part of the Sarcheshmeh and lower part of the Sanganeh Formations at the Tirgan section. The uppermost fossiliferous limestone of the Sarcheshmeh Formation can be followed for a long distance. Looking south.

Figure 2.13. Cone-in-cone structure in shaly beds of the Sanganeh Formation, Tirgan section; yellow colour is due to weathering.

Figure 2.14. Concretion nodule in the Sanganeh Formation, Tirgan section; yellow colour is due to weathering.

Figure 2.15. Thick bedded limestones of the uppermost part of the Tirgan Formation on the Mashhad-Kalat road, near Taherabad village. Looking north.

Cone-in-cone structures and concretions found in this part (Figures 2.13, 2.14). These layers contain ammonites such as *Acanthohoplites* spp., *Hypacanthoplites* cf. *anglicus*, *H.* cf. *elegans*, and *H.* cf. *subrectangulatus.*

In the upper part of the formation facies change again, and siltstones and sandy limestones with a few sandstone beds appear. One specimen each of *Acanthohoplites* spp., *Hypacanthoplites* cf. *anglicus* and *H. uhligi* were collected. A Late Aptian-Lowermost Early Albian age is proposed for the Sanganeh Formation. The first glauconitic sandstone marks the base of the Aitamir Formation. A leyemeriellid was collected from the lowermost part of this Formation.

2.2.7. Kalat road section

This section was measured along the Mashhad-Kalat road and is near to the Sanganeh section. The Sarcheshmeh and Sanganeh Formations are similar to the same formations in Sanganeh section.

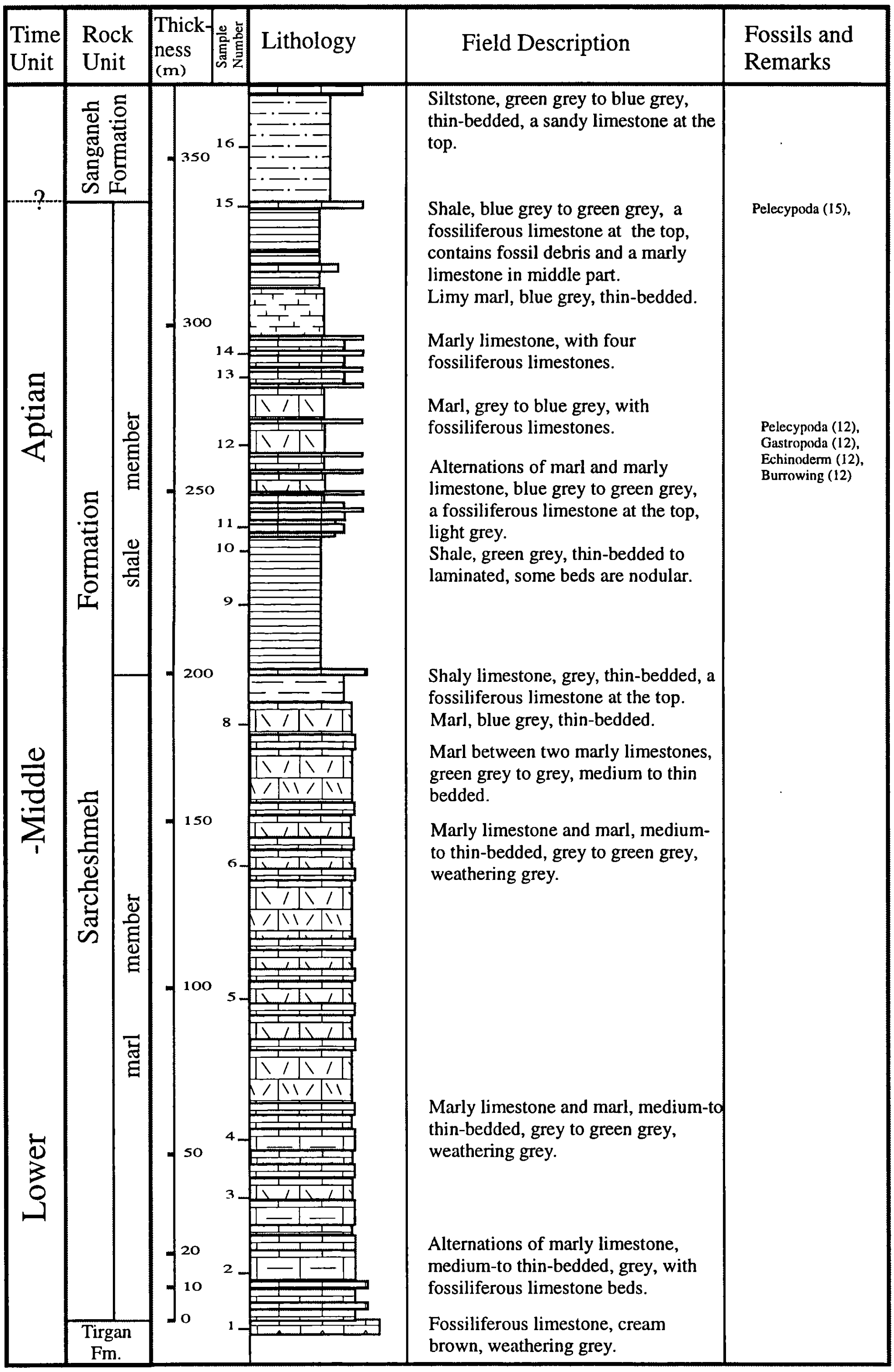
<u>Sarcheshmeh Formation</u> (335 m.): The thick-bedded limestone of the uppermost part of the Tirgan Formation (Figure 2.15) is covered by grey, thin, mostly bedded marl and marly limestones intercalations of the lower member of the Sarcheshmeh Formation. Shale, silty shale and siltstones with fossiliferous limestone intercalations form the upper member (Figure 2.16). The formation is barren of ammonites.

<u>Sanganeh Formation</u> (265 m.): This formation is often formed by grey to blue green and green grey shale and silty shale, with some silty sandstone and sandstone beds. The whole of formation was not measured, because some parts are covered by weathered material and also ammonites are rare. *Hypacanthoplites uhligi* occurs 260 metres above the base of the formation. A Late Aptian age is suggested for the Sanganeh Formation.

2.2.8. Sanganeh section

This section has been measured 5 kilometres west of Sanganeh village and on the west side of the Sanganeh village road. The section is situated at 36° 36′ north latitude and 60° 14′ eastern longitude and is located about 80 kilometres north-east of Mashhad and 20 kilometres east of the Mashhad-Kalat road.

Figure 2.16. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Kalat Road section.
Latitude: 36° 55' N Longitude: 59° 54' E



Kalat Road section

Continued

Time Unit	Rock Unit	Thickness (m)	Sample Number	Lithology	Field Description	Fossils and Remarks
Upper Aptian	Sanganeh Formation	600	20		Silty shale, blue grey to dark blue, thin-bedded, with siltstone intercalations.	Ammonite (20)
				Covered probably shale		
		550			Silty shale, blue grey to dark blue, thin-bedded.	
					Silty shale, green grey to blue grey, thin-bedded, with siltstone intercalations and a sandy limestone at the top.	
		500		Covered Probably shale		
					Silty shale, green grey, thin-bedded.	
		450	19		Silty shale, green grey to blue grey, a fossiliferous limestone at the top, pelecypoda debris.	
			18		Silty shale, green grey to dark blue grey, thin-bedded, at the top a sandstone bed with calcareous cement.	
		400	17		Silty shale, green grey to blue grey, a green sandstone at the top.	

Kalat Road section

This section is about 10 kilometres from the type section of the Sanganeh Formation.

Sarcheshmeh Formation (350 m.): The formation lies on the Tirgan Formation and their contact is conformable. Marly limestone and marl beds were deposited above the last limestone bed of the Tirgan Formation, to form the lower member. The beds are mostly grey to dark grey but weather lighter (Figure 2.17). The marl beds to pencils marls (Figure 2.18). Thin-bedded fossiliferous limestones occur (Figure 2.19). A few trace fossils (*Paleodiyctyon*) are preserved.

The upper member of the formation is mostly formed by shale and silty shale. The colour of the upper member changes to green grey and dark grey. Fossiliferous limestones are present in this member more than in the lower member (Figure 2.20). The uppermost limestone bed forms the top of the Sarcheshmeh Formation.

The Sarcheshmeh Formation is barren of ammonites here. The marls and shale beds do not have any macrofossils, but in the fossiliferous limestones brachiopods, pelecypods, echinoderms and orbitolinids are found. Some fossiliferous limestones are completely formed by thick-shelled pelecypods (*Ostrea* and *Exogyra*) and brachiopods. Their thickness is not more than 20 centimetres. These layers may suggest crises in environmental conditions.

Sanganeh Formation (500 m.): Above the last limestone bed of the Sarcheshmeh Formation are about 10 metres of limy marl which is taken as the base of the Sanganeh Formation. Above these limy marls occur 20 metres of blue grey shale, which then pass gradually upward to silty shale with silty sandstone intercalations (Figure 2.20). These shales and siltstones are darker than the upper member of the Sarcheshmeh Formation and are green grey to dark blue grey (Figure 2.21). The number of silty shales decreases in the middle part of the formation but increases in the upper part of the formation where there is a passage up into the Aitamir sandstones. Cone-in-cone structures are seen in the shales and concretions are also common, sometimes with ammonites in their cores. The Sanganeh Formation contains ammonite mostly in the middle to upper part of the formation. The following occur: *Acanthohoplites* cf. *aschiltaensis*, *A.* cf. *bigoureti*, *A.* sp., *Colombiceras* sp., *Cheloniceras* (*Epicheloniceras*) sp., *Hypacanthoplites uhligi*,

Figure 2.17. Marl and marly limestone sequences of the lower part of the Sarcheshmeh Formation at the Sanganeh section, colour changes from light grey to dark grey. Looking north.

Figure 2.18. Weathered pencil marls of the lower part of the Sarcheshmeh Formation, Sanganeh section.

Figure 2.19. Fossiliferous limestone bed between marls in the Sarcheshmeh Formation at the Sanganeh section.

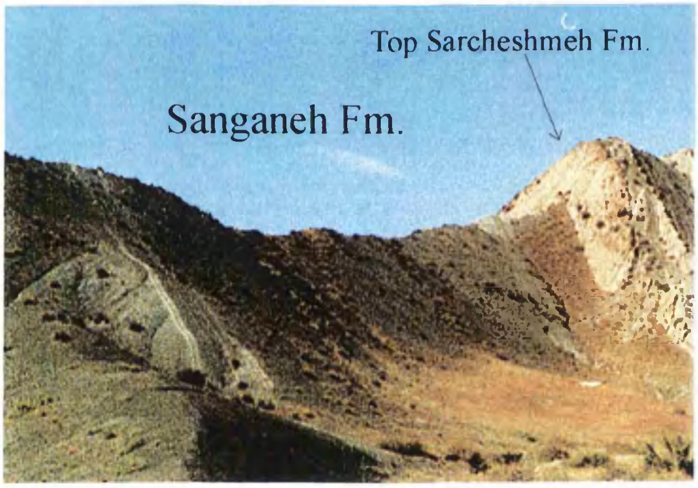


Figure 2.21. Sarcheshmeh-Sanganeh Formations boundary at Sanganeh section, dark to black shales of the Sanganeh Formation above light grey shales and fossiliferous limestones of the Sarcheshmeh Formation, looking north.

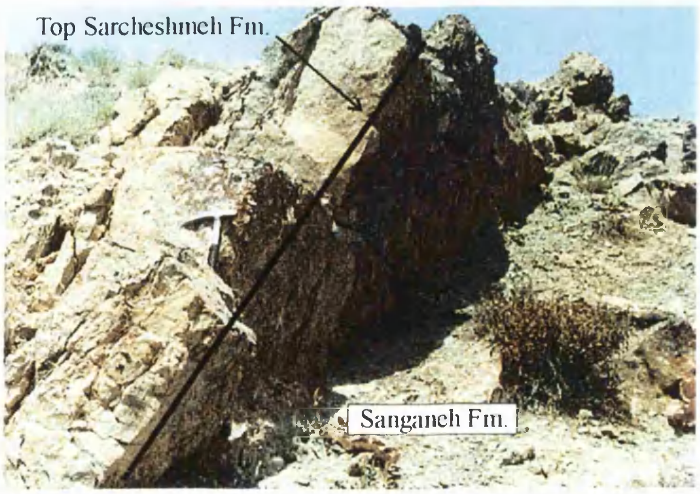
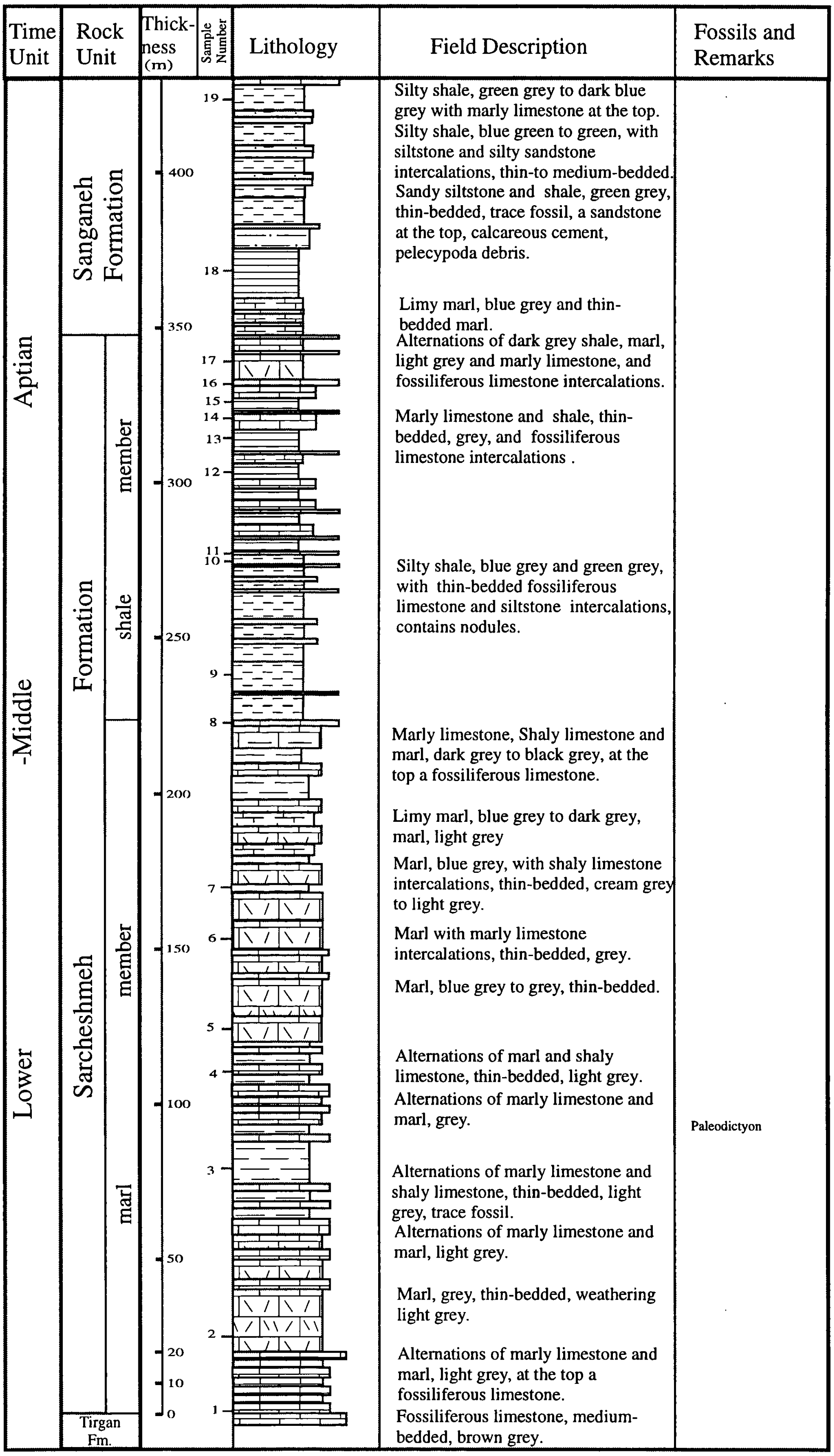


Figure 2.23. A fossiliferous limestone (overturned here by a local fault) marks the Sarcheshmeh-Sanganeh boundary, Mashhad-Sarakhs road near the Ghorghoreh section.

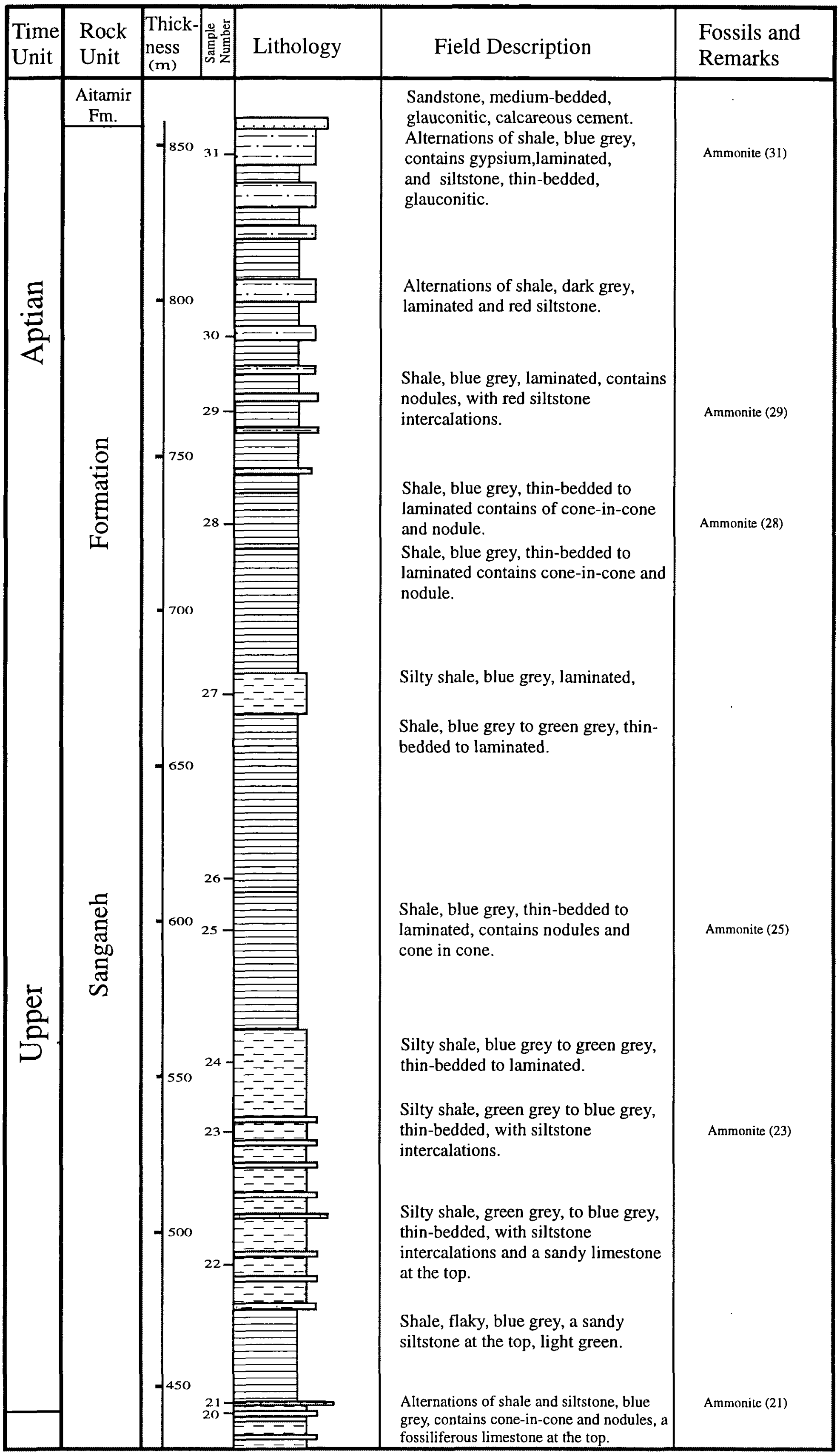
Figure 2.20. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Sanganeh section.

Latitude: 37° 43' N Longitude: 56° 10' E



Sanganeh section

continued



Sanganeh section

Hypacanthoplites clavatus, Hypacanthoplites sp. and *Parahoplites* cf. *campichii.*

The ammonite assemblage suggests a Late Aptian-earliest Albian age for this formation.

2.2.9. Ghorghoreh section

This is the last section, measured in the eastern part of the basin.

Sarcheshmeh Formation (195 m.): The marl member is formed by marl, limy marl and marly limestone with a few fossiliferous limestones. Brachiopods are abundant in the fossiliferous limestones. *Sulcirhychina* spp. and *Sellithyris carteronina* are identified (personal communication, Dr. E.F. Owen, NHM London).

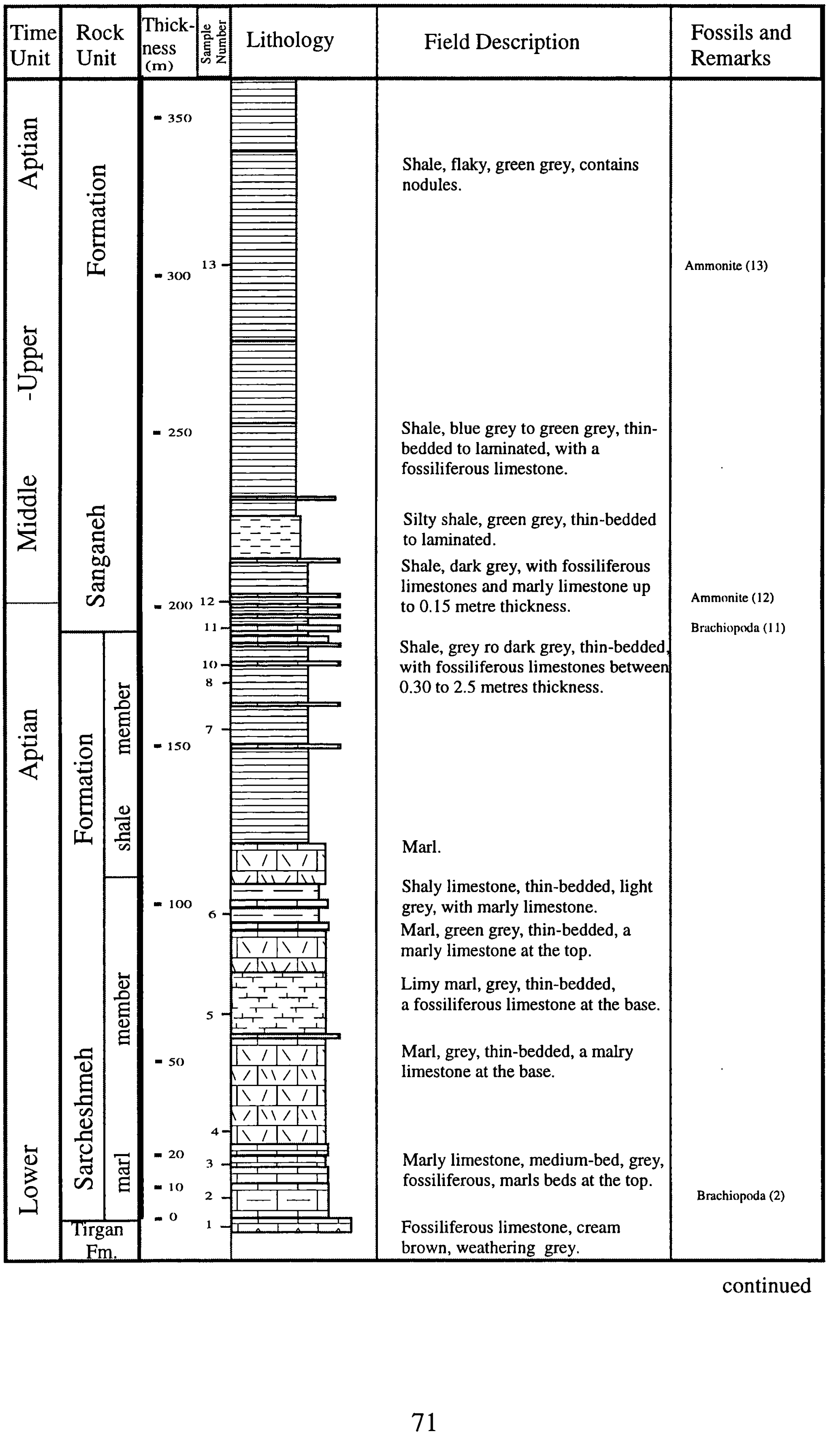
The shale member is sharply distinguished by grey to dark grey thin-bedded to laminated shales. The number of fossiliferous limestones increases in the upper part of the member (Figure 2.22). Brachiopods were collected from some fossiliferous limestones, but no ammonite faunas are found in the Sarcheshmeh Formation. It appears that the sediments were deposited in a shallow marine environment. The last fossiliferous limestone bed is known as the top of the Sarcheshmeh Formation (Figure 2.23). According to its stratigraphical position an Early Aptian age is suggested for the Sarcheshmeh Formation.

Sanganeh Formation (525 m.): Some parts of the formation are covered by weathered material. It starts with a few thin-bedded fossiliferous limestone beds up to 0.15 metres thick and silty shale intercalations. Then appear homogenous blue grey to green grey thin-bedded to laminated shales representing almost the formation (Figure 2.22). The lithology changes to silty shale and siltstone in the uppermost part of the formation. The first glauconitic sandstone is taken as the base of the overlying Aitamir Formation.

Two ammonites were collected from the Sanganeh Formation, *Dufrenoyia* sp. from sample 12 and *Parahoplites* cf. *maximus* from sample 13. The base of the Sanganeh Formation is probably late Lower Aptian. However, the Aptian-Albian boundary is not clear in this section.

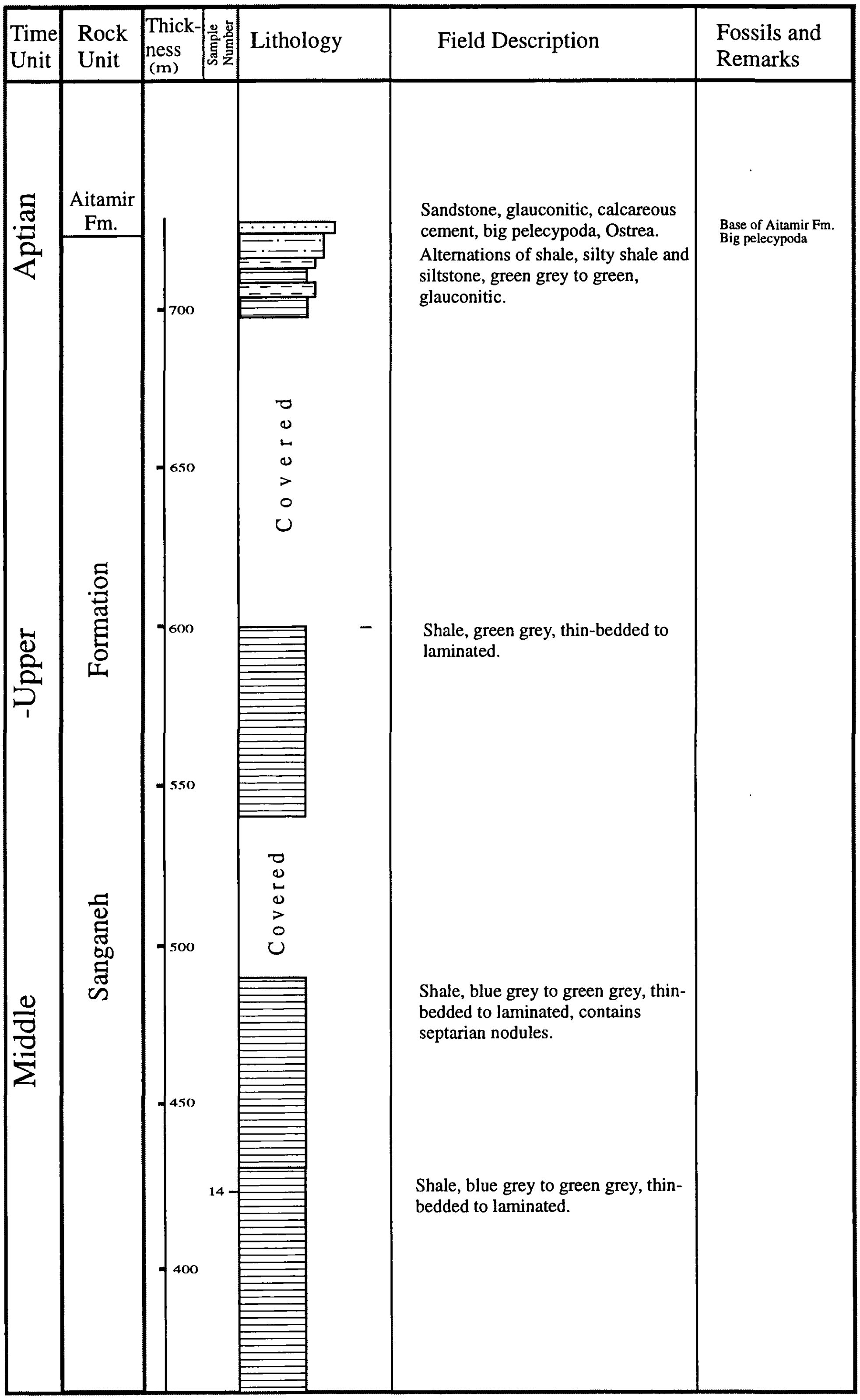
Figure 2.22. Stratigraphical column of the Sarcheshmeh and Sanganeh Formations in the Ghorghoreh section.

Latitude: 36° 14' N Longitude: 60°29' E



Ghorghoreh section

continued



Ghorghoreh section

2.3. Correlation and discussion

Similarities in lithology and the presence of some distinctive beds makes possible a lithological correlation from section to section. The thickness of the Sarcheshmeh Formation decreases from west to east (Figure 2.24). Except in the Takal Kuh area sections, which are about 1200 metres thick, the thickness is not more than 600 metres. This suggests that subsidence in the Takal Kuh area was twice that in other parts of the basin. In the Takal Kuh area the formation does not show the divisions seen in the type section, although there is similarity in lithologies. The limestone beds in the upper part of the upper member of the Sarcheshmeh Formation can be followed in all sections. The top of the last limestone bed is taken as the top of the Sarcheshmeh Formation and it can be used as a marker bed. As the thickness of the Sarcheshmeh Formation at the Takal Kuh is thicker than in other sections, so the limestone beds are also thicker.

The Sanganeh Formation's thickness fluctuates from west to east (Figure 2.24). In the Takal Kuh area it is about 750 metres thick. Here the formation contains some fossiliferous and sandy limestones, which are pinched out to the east and cannot be seen in the Raz section. Furthermore, the Sanganeh Formation is more calcareous in the Takal Kuh area than in the central and eastern parts of the Kopet Dagh. As the formation at Takal Kuh is overlain by the Kalat Formation unconformably, of Maastrichtian age, it is assumed that part of the formation was eroded by pre-Maastrichtian movements.

At the Sheykh section the formation is less than 400 metres thick, but its thickness reaches to 850 metres in the Tirgan section to the east. Farther east its thickness decreases again and in the Sanganeh section it is 500 metres thick (Figure 2.24).

Where the Sanganeh Formation is complete and overlain by the Aitamir Formation, the uppermost part of the formation is grey-green to green and contains glauconite. The central part of the basin received most detrital material as is seen in the Tirgan, Kalat and Sanganeh sections. Here, a few fine-grained sandstones and limestones are present among the shale beds of the Sanganeh Formation but their correlation needs closer investigation.

The Sarcheshmeh and Sanganeh Formations are not exactly the same age along the basin.

In the Takal Kuh and Amand sections the presence of *Turkmeniceras*, *Heteroceras* and *Martelites* proves a Late Barremian age for the base of the Sarcheshmeh Formation, while ammonites in the upper part of the formation are of mid Early Aptian age (Figure 2.25). The top of the Sarcheshmeh Formation is younger in the Raz section where *Dufrenoyia* is found in the uppermost part of the formation, indicating a late Early Aptian age.

From Sheykh towards the south, ammonites are rare or fragmentary in the Sarcheshmeh Formation and do not allow a confident biostratigraphical correlation. Overall, a Late Barremian-Early Aptian age is attributed to the Sarcheshmeh Formation based on ammonite contents and stratigraphical position.

The Sanganeh Formation preserves the best ammonite assemblages in the Takal Kuh, Amand, Bibahreh, Tirgan and Sanganeh sections. *Deshayesites* and *Dufrenoyia* indicate an Early Aptian age for the formation. The presence of *Dufrenoyia* in the Takal Kuh section (2) makes possible a biostratigraphical correlation of the top of the Sanganeh Formation there with the top of the Sarcheshmeh Formation in the Raz section. The presence of *Acanthohoplites*, *Parahoplites* and *Hypacanthoplites* in the central and eastern sections suggested a Mid to Late Aptian age for the Sanganeh Formation in these area. Based on this research and Immel *et al.* (1997) an Early Aptian-Early Albian age is suggested for the Sanganeh Formation (Figures 2.25), with the base becoming younger eastward.

Based on measured sections, macro- and microfaunal contents and from previous published work, it is possible to introduce a simplified facies scheme along the basin (Figure 2.26). In the Late Barremian when the Tirgan Formation was being deposited in the eastern part of the basin, shaly and marly beds of the lower part of the Sarcheshmeh Formation in the western part of the basin were favourable for ammonites. Moreover, changes in lithology confirm deeper environments in the northern and western part of the basin. The Early Aptian transgression continued to the east and ammonites migrated with it to the Raz, Sheykh and Bibahreh sections.

In Mid to Late Aptian times, facies changed to less calcareous shales and silty shales, siltstones or even fine sandstone beds (Sanganeh Formation). In these lithologies benthic macrofossils and benthic microfossils are rare or absent and this suggests a deeper environment.

In the Raz section Parahoplitidae are found in the Sanganeh Formation, but to the east in the Sheykh section there is no sign of ammonites in the Middle to Upper Aptian sequences. Nevertheless ammonites were distributed further to the east, as they are found in the Middle to Upper Aptian sequences in the Bibahreh, Tirgan, Kalat road, Sanganeh and even Ghorghoreh sections.

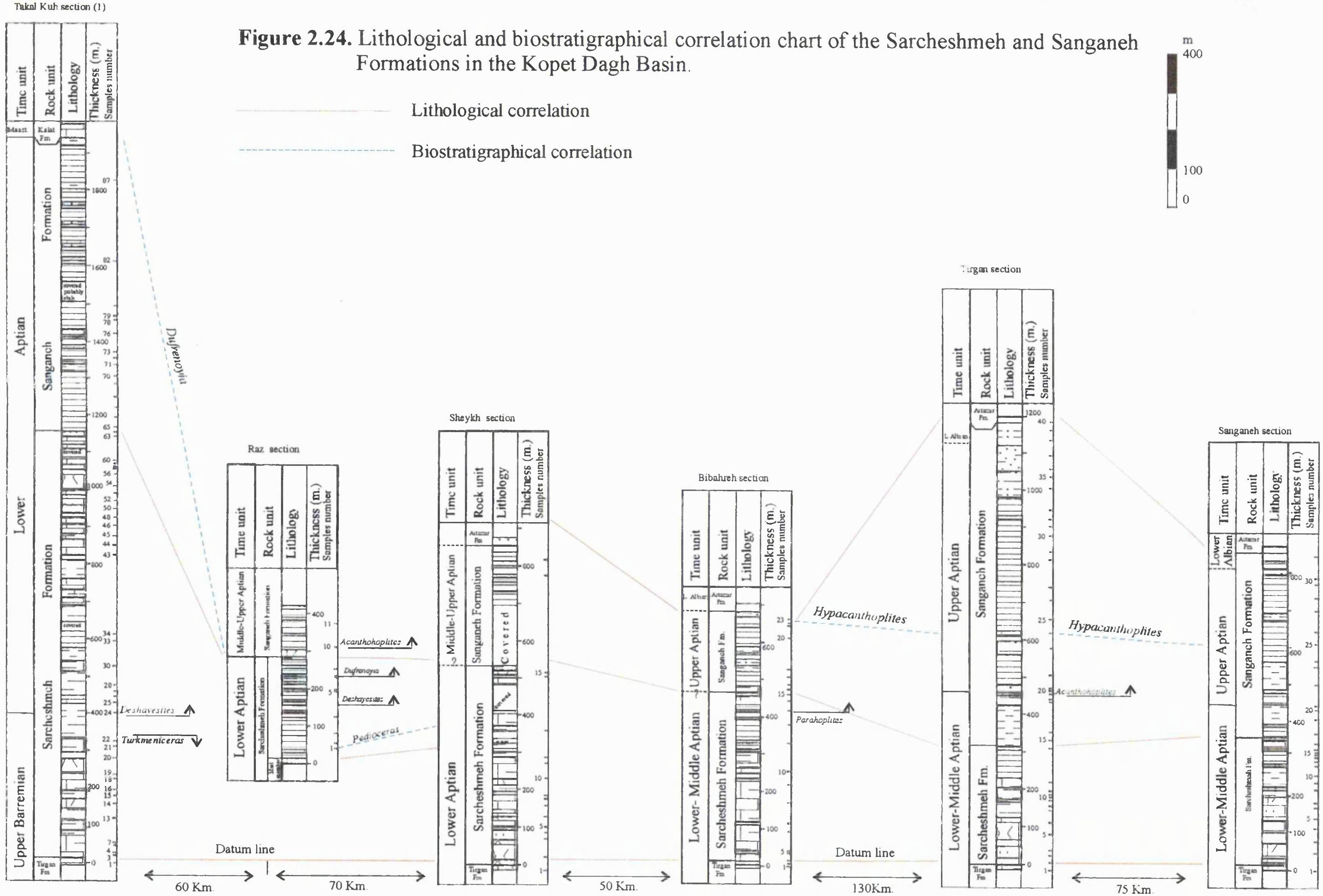


Figure 2.24. Lithological and biostratigraphical correlation chart of the Sarcheshmeh and Sanganeh Formations in the Kopet Dagh Basin.

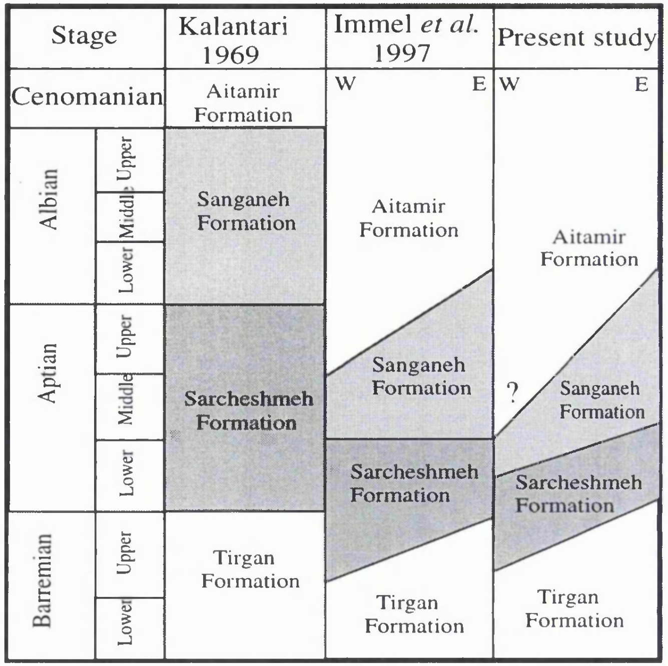
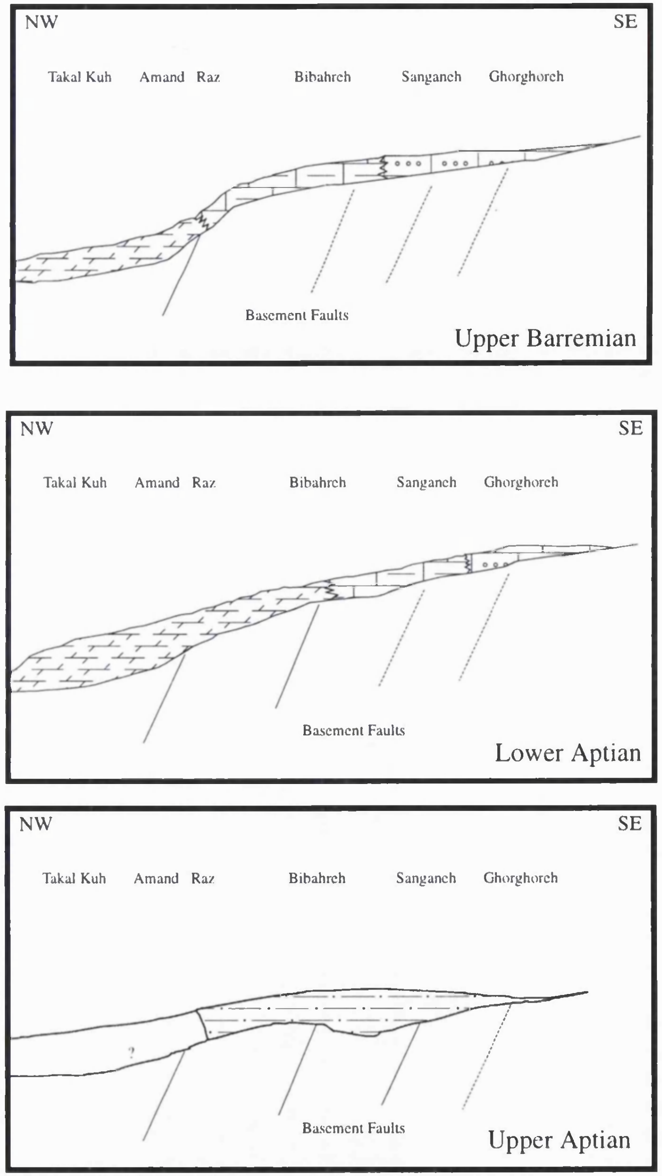


Figure 2.25. Correlation chart of the Lower Cretaceous formations in the Kopet Dagh Basin.



Fossiliferous limestone, oolitic limestone facies (Tirgan Fm.)
(Intertidal, shallow water and high energy environment)

Marly limestone and marl facies (Sarcheshmeh Fm.)
(Subtidal environments)

Shaly and marly limestone, fine grain limestone facies (Sarcheshmeh Fm.)
(Facies dominated by ammonite fauna, off-shore and quiet water environment)

Shale, silty shale and shaly siltstone facies (Sanganeh Formation)
(basin received material from land, off-shore and agitated environment)

Figure 2.26. Preliminary scheme of facies in the Kopet Dagh Basin based on ammonites distribution, benthic fossils and lithology of measured sections.

Chapter 3. Systematic Descriptions

Ammonite classification is based on phylogeny as far as possible. Elements such as suture line, ornamentation and coiling are important in interpreting ammonite phylogeny. However, study of ontogeny and dimorphism provide an additional key for better understanding of ammonite classification and evolution. German and Russian authors have generally placed more stress on the suture line in phylogeny and classification, whilst English and French palaeontologists lay great emphasis on ornamentation and type of coiling.

Schindewolf (1968) and Wiedmann (1966, 1969) developed essentially different phylogenies for the Jurassic and Cretaceous ammonoids. Their arguments were based mainly on the number of lobes in the primary suture and on the early ontogenetic pattern of the suture line. Wiedmann (1966, 1969) proposed placing all ammonoids with quadrilobate primary suture in the suborder Ancyloceratina. During the transition from normal coiled ammonoids to heteromorphs the septum and consequently the suture line underwent transformation. The first umbilical lobe (U^1) disappeared and the dorsal lobe, which is one of the most stable features, changed considerably.

Unlike all Jurassic and most Cretaceous ammonoids, which are characterised by a quinquelobate primary suture, Cretaceous heteromorphs have a simplified primary suture which is divided into quinquelobate (Ancylocerataceae) or quadrilobate (Turrilitaceae, Scaphitaceae). The unstable quinquelobate primary suture is characterised by rapid disappearance of the first umbilical lobe (U^1) and subsequent formation of new elements based on the suture consisting of four lobes. This peculiar type of primary suture is combined with a bilobate prosuture. A primary suture of this type was established for the superfamily Ancylocerataceae (Doguzhaeva and Mikhailova, 1982).

In this chapter the classification and phylogeny of those families and genera, which are found in the Sarcheshmeh and Sanganeh Formations will be discussed.

Classification follows that given in the Treatise on Invertebrate Palaeontology, part L (Wright *et al.*, 1996).

The present study represents the first systematic sampling in the Kopet Dagh basin. It is based on material which was collected in summer 1998 and 1999. Every genus and species is described briefly, and their occurrence and distribution in the stratigraphical column of the study area are discussed when appropriate. But not all taxa are discussed in detail. The systematic palaeontology concentrates on those that are either well enough preserved for firm identification, or that are new to the basin. The remaining taxa are described briefly.

Shell measurements (in mm) are given in the following order; Diameter (D), whorl height (WH), ratio of whorl height to diameter (WH/D), whorl thickness (WT), ratio of whorl thickness to diameter (WT/D), umbilical width (U), ratio of umbilical width to diameter (U/D), primary ribs in the umbilical area (PR) and all ribs (primary and secondary) on the ventral margin (SR). Because some specimens are incomplete and not all dimensions can be measured, the ratio of whorl thickness to whorl height (WT/WH) is also given.

Abbreviations for localities of listed material are as follows; TK= Takal Kuh section (1); TAK= Takal Kuh section (2); Am= Amand; Raz= Raz road section; SH= Sheykh section; Bib= Bibahreh section; Tr= Tirgan section; Kt= Kalat road section; Sn= Sanganeh section; Gho= Ghorghoreh section.

Suborder Phylloceratina Arkell 1950

Superfamily Phyllocerataceae Zittel 1884

Family Phylloceratidae Zittel 1884

Subfamily Phylloceratinae Zittel 1884

Genus *Phylloceras* Suess 1865

Type species: *Ammonites heterophyllus* Sowerby 1820, by original designation.

Phylloceras sp.

Plate 1, Figure 1

Material: One specimen [TK 50/ 5].

Description: The only characteristic feature is fine and dense ribs.

Discussion: Among the Early Cretaceous phylloceratids, *Phylloceras* is distinguished by its fine and dense ribs, so this fragment is assigned to that genus. This is thus the first record of *Phylloceras* from the Kopet Dagh. The nearest match in the literature appears to be with some specimens from South Africa figured by Kennedy and Klinger (1977) as *P.* (*Phylloceras*) *serum* Oppel.

Occurrence: Upper part of the Sarcheshmeh Formation in the Takal Kuh section (1).

Genus *Phyllopachyceras* Spath 1925

Type species: *Ammonites infundibulum* d'Orbigny 1841, by original designation.

Phyllopachyceras sp.

Plate 1, Figure 2

Material: One specimen [TK 53/ 2].

Description: Involute, whorl section compressed oval with sub-parallel flanks, rounded and broad venter. The surface of the shell is ornamented by widely spaced and flexuous ribs, which are stronger on the outer part of the flank. They flex backward on the upper mid-flanks and across the venter.

Discussion: This is the first record of *Phyllopachyceras* from the Kopet Dagh. The specimen is poorly preserved and is difficult to identify to species level as it is incomplete. The moderately coarse ribbing on the outer part of the whorl suggests it is a *Phyllopachyceras*; *Phylloceras* has fine ribs or radial lirae throughout growth.

Occurrence: Upper part of the Sarcheshmeh Formation in Takal Kuh section (1).

Suborder Lytoceratina Hyatt 1899

Superfamily Tetragonitaceae Hyatt 1900

Family Gaudryceratidae Spath 1927

Genus *Eogaudryceras* Spath 1927

Type species: *Ammonites numidus* Coquand 1880, by original designation.

Discussion: According to Kennedy and Klinger (1979, p. 124), although *Eotetragonites* was originally separated from *Eogaudryceras* 'on the basis of the presence of strong constrictions throughout development and a suture with irregularly bifid saddles' in the former subgenus, these differences simply separate the type species. Kennedy and Klinger (1979) noted that Wiedmann (1962) had already pointed to the occurrence of *Eogaudryceras* without constrictions and *Eotetragonites* with constrictions and that the two subgenera are better separated on the basis of whorl section. The *Eogaudryceras* whorl section is more rounded whereas in *Eotetragonites* it is rather depressed and more angular or rectangular. The absence of curved striae in *Eotetragonites* is another difference. *Gaudryceras* may be distinguished from *Eogaudryceras* by its weaker and less flexuous ribs, more rapidly growing whorls and suture line pattern (Casey, 1960). *Eogaudryceras* is similar to *Anagaudryceras* and the later genus is believed to have evolved from *Eogaudryceras* during the Early Albian. *Eogaudryceras* is characterized by having constrictions only on the early whorls and lacks the fold-like ribs of *Anagaudryceras* (Kennedy and Klinger, 1979).

Distribution: The subgenus is recorded from Europe, the Caucasus, Algeria, South Africa, Madagascar, Egypt, California and Antarctica (Wright *et al.*, 1996), and Iran.

Age: Barremian- Late Albian (Wright *et al.*, 1996, p. 3).

Subgenus *Eogaudryceras s.s.* Spath 1927

Distribution: As for the genus.

E. (*Eogaudryceras*) sp.

Plate 1, Figure 3

Material: One specimen [TAK 36/ 29].

Description: The specimen is a corroded whorl fragment. Moderately evolute, whorl section circular to sub-circular. Shell smooth but traces of constrictions can be seen on the flanks.

Discussion: This is the first record of *E.* (*Eogaudryceras*) from the Kopet Dagh. The specimen is too incomplete and worn for species identification. The shell may have been covered with fine lirae before being weathered.

Occurrence: Uppermost part of the Sarcheshmeh Formation in the Takal Kuh section (2).

Subgenus *Eotetragonites s.s.* Breistroffer 1947

Type species: *Eotetragonites raspaili* Breistroffer 1947.

Discussion: There are difficulties in separating some *Eotetragonites* from *Tetragonites* species, which probably reflects their phylogenetic relationship. However, *Eotetragonites* has deeper constrictions and straight or convex ribs on the flanks.

Distribution: As for the genus.

E. (*Eotetragonites*) sp.

Plate 1, Figure 4

Material: One fragment [Raz 9/ 1].

Description: The whorl fragment is moderately evolute; whorl section sub-rectangular to elliptical, shell surface smooth with strong constrictions or collar-like radial ribs.

Discussion: This is the first record of *E.* (*Eotetragonites*) from the Kopet Dagh. The specimen is incomplete and cannot be identified to species level, but the deep constrictions characterised the subgenus. The specimen compares closely with *Eotetragonites aketoensis* figured by Obata and Futakami (1992, pl. 6, figs. 1a-c, text-fig. 8).

Occurrence: Uppermost part of the Sarcheshmeh Formation in the Raz section.

Suborder Ammonitina Hyatt 1899

Superfamily Haplocerataceae Zittel 1884

Family Oppeliidae H. Douville 1890

Subfamily Aconeceratinae Spath 1923

The subfamily is characterised by having an involute, compressed or oxycone shell, smooth surface or falcoid ribs and a keel. There are several taxa in the Aconeceratinae that often regarded as separate genera but which have been grouped by Wright *et al.* (1996) as subgenera of *Aconeceras* and here this classification will be followed. The genus *Aconeceras* was placed in the Desmoceratidae by Spath (1929) and Wright (1953). Casey (1954) returned it to the Oppeliidae, and that has been followed subsequently (eg. Arkell *et al.*, 1957; Wright *et al.*, 1996).

According to Casey (1961c) and Wright *et al.* (1996) the Aconeceratinae were probably derived from the Streblitinae, which lived at least to the Hauterivian. Conversely, Wiedmann (1966) proposed that the bluntly keeled *Neolissoceras aberrans* is the ancestor of the subfamily.

Genus *Aconeceras* Hyatt 1903

Type species: *Ammonites nisus* d'Orbigny 1841, by monotypy.

Generic characters: Involute oxycone with flattened or gently convex sides that narrow above to a hollow microscopically serrated carina or keel. Ventro-lateral shoulders are distinct or absent. Umbilicus with angular rim and low steep wall, flanks almost smooth or bearing sickle-shaped, forwardly inclined striae or faint flattened ribs. Suture line with narrow trifid lateral lobes and tall lateral saddle and many secondary elements declining in regular series to the umbilicus.

Discussion: The separation of some genera of the Aconeceratinae was based on presence of ribs and denticulation of keel and it seems this division is not useful in practice (Wright *et al.*, 1996). Thus *Aconeceras*, *Sanmartinoceras*, *Sinzovia*, *Theganoceras* and *Gyaloceras* are grouped as subgenera of *Aconeceras.* The subgenus *Aconeceras s.s.* is known principally by immature (incomplete) shells or nuclei that lack the mouth-borders. Therefore it is not clear whether lappets and rostrum comparable to those of the subgenus *Sanmartinoceras* occur, or if the edge of its peristome follows the growth- lines as in *Falciferella.*

Distribution: The genus is recorded from Europe, north-east Greenland, Algeria, South Africa, Madagascar, Australia, Argentina, Nepal and Antarctica (subgenus *Theganoceras*) (Wright *et al.*, 1996), and Iran.

Age: Late Barremian- Early Albian (Wright *et al.*, 1996, p. 14).

Subgenus *Aconeceras* (*Aconeceras*) Hyatt 1903

A. (*Aconeceras*) *haugi* (Sarasin 1893)

Plate 1, Figure 5

1893 *Oppelia haugi* Sarasin, p. 156, pls. 4-6, figs. 11a-c.
1961c *Aconeceras* cf. *haugi* (Sarasin); Casey, p. 128, text-fig. 40g-h.
1973a *Aconeceras haugi* (Sarasin); Kemper, p. 42, pl. 2, fig. 4.
1982 *Aconeceras haugi* (Sarasin); Renz, p. 21-22, pl. 1, fig. 14a-b.
1995 *Aconeceras haugi* (Sarasin); Kemper, pl. 2, fig. 4.

Holotype: School of Mines, Paris. The specimen described and figured by Sarasin.

Material: 159 specimens [TK 56/ 5; TK 59/ 1-6; TK 60; TK 65/ 1-7; TK 66/ 1-4; TK 67; TK 69/ 1-3; TK 70; TK 72/ 1-19; TK 73/ 1-4; TK 76/ 1-21; TK 78/ 1-3; TK 79/ 1-7; TAK 37; TAK 38; TAK 39/ 1; TAK 40/ 1-3; TAK 43/ 1-3; TAK 44/ 1-3; TAK 45/ 1-40; TAK 46/ 1-5; TAK 47/ 1-8; TAK 48/ 1-5; TAK 49/ 1-4; TAK 50; TAK 52/ 1-2; Am 26/ 12-17; Am 27/ 28-29; Am 28/ 1-2].

Description: Involute, oxycone, high whorled, whorl section sub-fastigiate, ventro-lateral shoulder rounded but distinct, sides parallel, flattened, keel distinct.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH
TAK 37	21	12	0.57	2	0.1	2	0.1	0.17
TK 76/1	17.3	10	0.58	2.5	0.14	1	0.06	0.25
TK 72/ 1	17	10	0.59	4	0.24	1	0.06	0.4
TK 79/ 1	17	10.7	0.63			2.5	0.15	
TAK 39	16.5	10	0.61	4	0.24	1.5	0.09	0.4
TK 76/ 5	16	10	0.63	3.3	0.21	1	0.06	0.33
TK 76/ 2	15.5	9	0.58	3	0.19	1	0.06	0.33
TAK 45/ 1	15.5	8	0.52	4	0.26			0.5
TK 76/3	15.2	9.2	0.61	2	0.13	1	0.07	0.22
TK 76/ 4	15.2	9	0.59	2	0.13	1	0.07	0.22
TK 65/ 1	15	9	0.6	5	0.33	2.5	0.17	0.56
TK 65/ 2	15	8	0.53	5	0.33	2	0.13	0.63
TK 72/ 3	15	9	0.6	3.5	0.23	1.5	0.1	0.39
TK 72/ 2	14.5	9	0.62	3.5	0.24	1.5	0.1	0.39
TK 76/ 6	14.5	7	0.48	2.2	0.15	1	0.07	0.31
Am 26/ 1	14	7	0.5	3	0.21	2	0.14	0.43
TAk 45/ 2	14	9.5	0.68	4	0.29			0.42
TAK 45/ 3	14	8.5	0.61	3.5	0.25	1	0.07	0.41
TK 76/ 7	13.3	7.4	0.56	1.7	0.13	1	0.08	0.23
TK 59/ 1	13	7.5	0.58	3.5	0.27	1.5	0.12	0.47
TK 65/ 3	13	7	0.54	4	0.31	2	0.15	0.57
TAK 45/ 4	13	8	0.62	3	0.23	2	0.15	0.38
TAK 45/ 5	13	7	0.54	3.5	0.27	2	0.15	0.5
TK 67	12.5	7.5	0.6	3	0.24	1	0.08	0.4
TAK 46/ 7	12.5	7	0.56	3	0.24	1	0.08	0.43
TAK 45/ 8	12.5	7	0.56	3	0.24	1	0.08	0.43
TK 65/ 4	12	6.5	0.54			2.5	0.21	
TK 67	12	7.5	0.63	3	0.25	1	0.08	0.4
TK 72/ 4	12	7	0.58	2.5	0.21	1	0.08	0.36
TK 73/ 1	12	7.6	0.63	3	0.25	1	0.08	0.39
TK 76/ 8	12	7.3	0.61	2	0.17	1	0.08	0.27
TAK 38	12	6	0.5	2	0.17	2.5	0.21	0.33

TAK 45/ 6	12	6.5	0.54	3	0.25	1	0.08	0.46
TK 76/ 9	11.8	7.2	0.61	1.7	0.14	1	0.08	0.24
TK 76/ 10	11.8	6.4	0.54	2.4	0.2	1	0.08	0.38
TAK 40	11.5	6	0.52	2.5	0.22	1	0.09	0.42
TAK 46/ 1	11.5	6.8	0.59	3	0.26	1	0.09	0.44
TAK 48/ 1	11.5	7	0.61	2.7	0.23	1	0.09	0.39
TAK 45/ 9	11.3	6.5	0.58	3	0.27	1	0.09	0.46
TAK 43/ 1	11	6.5	0.59	3	0.27	1	0.09	0.46
TAK 43/ 2	11	6	0.55			1	0.09	
TAK 45/ 12	11	6	0.55	3	0.27	1	0.09	0.5
TAK 45/ 14	11	6.7	0.61	3	0.27	1	0.09	0.45
TAK 52/ 1	11	6.5	0.59	2.8	0.25	1	0.09	0.43
TAK 45/ 13	10.7	5.5	0.51	2.5	0.23	1	0.09	0.45
TK 65/ 7	10.5	5.5	0.52	2.8	0.27			0.51
TK 76/ 15	10.5	6.5	0.62	2.4	0.23	1	0.1	0.37
TAK 45/ 10	10.5	5.5	0.52	3	0.29	1	0.1	0.55
TAK 45/ 11	10.5	5	0.48	3	0.29	1	0.1	0.6
TAK 45/ 16	10.5	6	0.57	2.7	0.26			0.45
TAK 45/ 17	10.5	5.7	0.54	2.4	0.23	1	0.1	0.42
TK 65/ 5	10	5.5	0.55	2.5	0.25	1	0.1	0.45
TK 65/ 6	10	6	0.6	2.5	0.25	1	0.1	0.42
TK 66/ 1	10	6	0.6	2.6	0.26	1.5	0.15	0.43
TK 72/ 5	10	5.5	0.55	2	0.2	1	0.1	0.36
TK 76/ 16	10	5.7	0.57	2.8	0.28	1	0.1	0.49
TK 76/ 17	10	5.4	0.54	2.6	0.26	1	0.1	0.48
TK 78/ 1	10	5.4	0.54	2.2	0.22	1	0.1	0.41
TAK 45/ 15	10	6	0.6	2.2	0.22			0.37
TAK 46/ 2	10	6	0.6	1	0.1	1	0.1	0.17
TK 76/ 11	9.5	5.5	0.58	1.5	0.16	1	0.11	0.27
TK 76/ 12	9.5	5.7	0.6	2	0.21	1	0.11	0.35
TK 59/ 2	9	5	0.56	2.5	0.28	1.3	0.14	0.5
TK 72/ 7	9	4.5	0.5	2.5	0.28	1.5	0.17	0.56
TK 72/ 8	9	5	0.56	2.2	0.24	1.5	0.17	0.44
TK 72/ 11	9	4	0.44	2	0.22	2	0.22	0.5
TK 73/ 2	9	5	0.56	2.5	0.28	1	0.11	0.5
TK 76/ 21	9	5	0.56	2.4	0.27	1	0.11	0.48
TK 78/ 2	9	5.3	0.59	2.5	0.28	1	0.11	0.47
TK 78/ 3	9	5	0.56	2.5	0.28			0.5
TAK 43/ 3	9	5	0.56	2.5	0.28	2	0.22	0.5
TAK 44/ 1	9	4	0.44	2.5	0.28	2	0.22	0.63
TAK 44/ 2	9	5	0.56	2	0.22	1.5	0.17	0.4
TAK 46/ 4	9	5	0.56	2.5	0.28	1	0.11	0.5
TAK 47/ 1	9	5	0.56	2.5	0.28	1.5	0.17	0.5
TAK 45/ 20	8.6	5.5	0.64	2.7	0.31	1	0.12	0.49
TK 72/ 9	8.5	5	0.59	2	0.24	1.5	0.18	0.4
TAK 43/ 4	8.5	4.5	0.53	2.5	0.29	2	0.24	0.56
TAK 47/ 3	8.5	5.5	0.65	2.3	0.27	1.5	0.18	0.42

TK 76/ 13	8.3	4.4	0.53	1.4	0.17	1	0.12	0.32
TK 59/ 3	8	5	0.63	2.5	0.31	1.2	0.15	0.5
TK 59/ 4	8	5	0.63	2.4	0.3	1.2	0.15	0.48
TK 66/ 2	8	3	0.38	2	0.25	1	0.13	0.67
TK 72/ 6	8	5	0.63	2.5	0.31	1	0.13	0.5
TK 79/ 3	8	4.2	0.53	2	0.25	1	0.13	0.48
TK 79/ 5	8	4.5	0.56	2	0.25	1	0.13	0.44
TK 79/ 7	8	4	0.5	1.3	0.16	1	0.13	0.33
TAK 43/ 5	8	4	0.5	2	0.25	1	0.13	0.5
TAK 43/ 6	8	3.5	0.44	2	0.25	1	0.13	0.57
TAK 45/ 18	8	4.6	0.58	2.3	0.29	1	0.13	0.5
TAK 46/ 3	8	5	0.63	2.3	0.29	1	0.13	0.46
TAK 46/ 5	8	4.5	0.56	2	0.25	1	0.13	0.44
TAK 47/ 5	8	4.3	0.54	2.4	0.3	1.2	0.15	0.56
TAK 48/ 3	8	4	0.5			1	0.13	
TAK 45 / 19	7.8	4.5	0.58	2	0.26	2	0.26	0.44
TAK 47/ 4	7.8	4.5	0.58	3.4	0.44	2	0.26	0.76
TK 72/ 19	7.7	4.2	0.55			1	0.13	
TK 59/ 5	7.5	3.5	0.47	2	0.27	1	0.13	0.57
TK 59/ 6	7.5	4	0.53	2.5	0.33	1.1	0.15	0.63
TK 72/ 12	7.5	4.1	0.55	2	0.27	1	0.13	0.49
TK 79/ 2	7.5	4	0.53	2.5	0.33	1	0.13	0.63
TAK 44/ 3	7.5	4	0.53	1	0.13	1	0.13	0.25
TAK 46/ 6	7.5	4.5	0.6	2.4	0.32	1	0.13	0.53
TAK 46/ 7	7.5	3.5	0.47	2	0.27	1	0.13	0.57
TAK 47/ 2	7.5	5	0.67	2	0.27	1	0.13	0.4
TK 72/ 14	7.4	4	0.54	2	0.27	1.5	0.2	0.5
TK 59/ 7	7	4	0.57	2.3	0.33	1	0.14	0.58
TK 69/ 1	7	4	0.57	2	0.29	1	0.14	0.5
TK 72/ 10	7	3.5	0.5	2	0.29	1.5	0.21	0.57
TK 72/ 13	7	3	0.43	2	0.29	1	0.14	0.67
TK 76/ 14	7	4.2	0.6	1.5	0.21	1	0.14	0.36
TAK 52/ 2	7	3.7	0.53	2	0.29	1	0.14	0.54
TK 76/ 18	6.6	3.6	0.55	2	0.3	1	0.15	0.56
TK 72/ 15	6.5	3.4	0.52	1.8	0.28	1	0.15	0.53
TK 76/ 19	6.5	3.7	0.57	2.1	0.32	1	0.15	0.57
TAK 48/ 2	6.5	3.5	0.54			1	0.15	
TK 72/ 17	6.3	3.5	0.56	2	0.32	1	0.16	0.57
TK 72/ 16	6.2	3.5	0.56	1.8	0.29	1	0.16	0.51
TK 76/ 20	6	3.4	0.57	1.8	0.3	1	0.17	0.53
TK 79/ 6	6	3.3	0.55	1.8	0.3	1	0.17	0.55
TK 73/ 3	5.8	3	0.52	2	0.34	1	0.17	0.67
TK 70	5.5	3	0.55	1.6	0.29	1	0.18	0.53
TK 79/ 4	5.3	2.2	0.42	2	0.38	1	0.19	0.91
TK 66/ 3	5	3	0.6	2	0.4	1	0.2	0.67
TK 66/ 4	5	2.5	0.5	2	0.4	1	0.2	0.8
TK 69/ 2	5	3	0.6	1.5	0.3	1	0.2	0.5

TK 73/ 4	5	2.5	0.5	1.7	0.34	1	0.2	0.68
TK 72/ 18	4.2	2.7	0.64	1.5	0.36	1	0.24	0.56

Discussion: *Aconeceras haugi* occurs in a few beds at the Takal Kuh and Amand sections. Based on dimension data, the ontogeny has been examined. The analysis shows a close relationship between diameter and ratio of U/D. With increase in diameter the ratio of U/D decreases, i.e. the shell became a little less involute. This was tested for Sample TK 76 and the regression coefficient is convincing (Figure 3.1), but the analysis for the whole of the section is less convincing (Figure 3.2).

Figure 3.1. Relationship between diameter and ratio of U/D in *Aconeceras haugi* in sample Tk 76

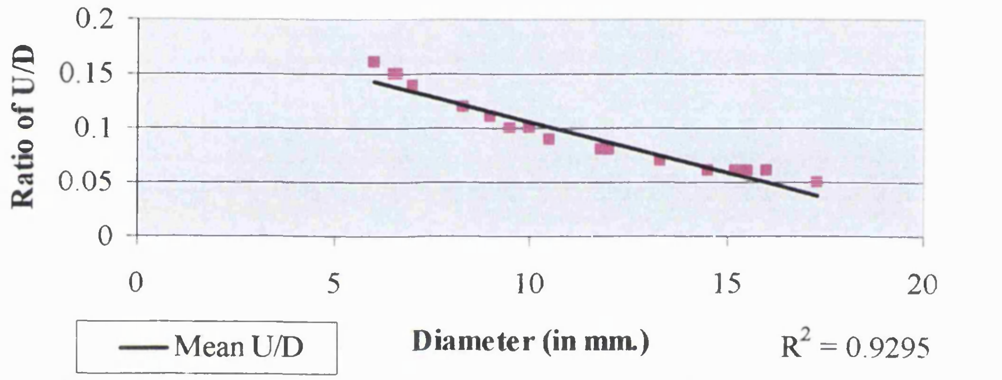
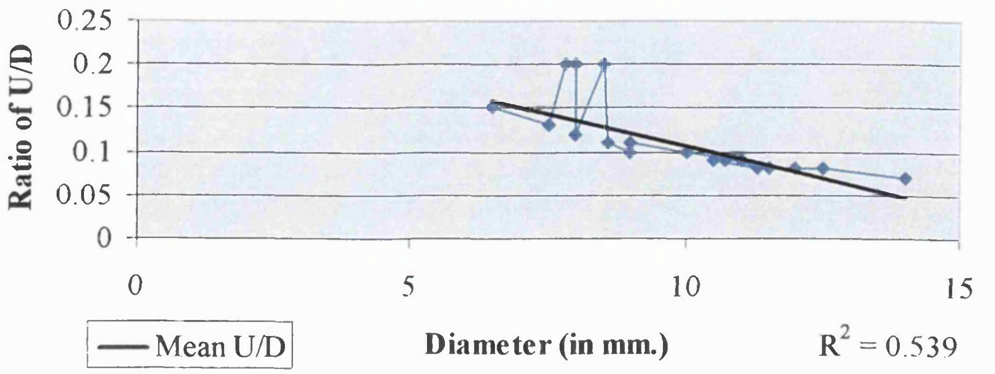


Figure 3.2. Relationship between diameter and ratio of U/D in *Aconeceras haugi* at Takal Kuh section (2)



A. haugi differs from *A. nisus* by possessing a ventro-lateral shoulder. According to Renz (1982), *Sanmartinoceras groenlandicum* (see Casey 1961c, p.131, text-fig. 42) is distinguished from *Aconeceras haugi* by more pronounced costae, a high-serrated keel and a spiral depression.

Distribution: France, Venezuela (Renz, 1982), Germany (Kemper, 1973a, 1995), and Iran.

Occurrence: Uppermost part of the Sarcheshmeh and the whole of the Sanganeh Formations in the Takal Kuh and Amand sections.

Superfamily Desmocerataceae Zittel 1895
Family Desmoceratidae Zittel 1895
Subfamily Barremitinae Breskovski 1977

Discussion: The Barremitinae have been split into several different genera or subgenera, including *Barremites* Kilian 1913; *Raspailiceras* Wright 1956; *Reboulites* Dimitrova 1967; *Cassidoiceras* Dimitrova 1967; *Montanesiceras* Breskovski 1977; *Trimontioniceras* Breskovski 1977; *Kostovites* Breskovski 1977 and *Nikolovites* Breskovski 1977. Cecca *et al.* (1998) considered that the genera suggested by Dimitrova and Breskovski are synonymous with previously published genera, and some may be dimorphic pairs.

As already noted by Hoedemaeker (1994), the common location of ribs and or collars and related constriction are useful characters for distinguishing Barremitinae from barremitid-like holocodisids.

Genus *Barremites* Kilian 1913

Type species: *Ammonites difficilis* d'Orbigny 1841, by monotypy.

Generic characters: *Barremites* is characterised by an involute shell, rounded to very sharp umbilical margin and venter, fine ribs and fairly distinct constrictions.

Distribution: Europe, northern Africa, Japan, Mexico and Colombia (Wright *et al.*, 1996), and Iran.

Age: Late Hauterivian- Late Barremian (Wright *et al.*, 1996, p. 69).

Barremites cf. *difficilis* (d'Orbigny 1841)
Plate 1, Figure 8

cf. 1840 *Ammonites difficilis* d'Orbigny, p.135, pl. 41, figs. 1, 2.
cf. 1960 *Barremites difficilis* (d'Orbigny); Druschitz & Kudryutzeva, p. 299, pl. 42, figs. 1a, b.
cf. 1976 *Barremites difficilis* (d'Orbigny); Avram, p. 44, pl. 4, fig. 4.
cf. 1982 *Barremites difficilis* (d'Orbigny); Obata, Maiya, Inoue, and Matsukawa, pl. 1, figs. 7a-d.
cf. 1984 *Barremites difficilis* (d'Orbigny); Obata, Matsukawa, Tanaka, Kanai and Watanabe, p. 21-22, pl. 1, figs. 5, 6, 7.
cf. 1987 *Barremites difficilis* (d'Orbigny); Immel, p. 83, pl. 8, fig. 1.
cf. 1997 *Barremites difficilis* (d'Orbigny); Delanoy, pl. 59, fig. 1.

Syntypes: d'Orbigny described and figured one specimen but mentioned that there were other specimens in various collections. Therefore they are treated as syntypes.

Material: 12 specimens [TK 3/ 1-3; TK 6; TK 7; Am 9/ 1-7].

Description: (Based on nine fragments and three external moulds). Shell involute. Due to compaction it is uncertain whether the venter is acute or has a keel. The thickest part of the whorl is in the lower part of the flanks, near the umbilical area. The umbilicus is rather deep. One specimen has fine ribs and one has a constriction, the others are weathered and without ornamentation. Suture lines are present in three specimens but incompletely visible.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH
TK 3/1	34.5	13	0.38			4.5	0.13	
TK 7	34.5	18	0.52	3.5	0.1	5	0.14	0.19
TK 6	26	13.5	0.52			3.5	0.13	
TK 3/3	24.5	11	0.45			2.5	0.1	
Am 9/ 1	23.5	12	0.51	4	0.17	3	0.13	0.33

Am 9/ 2	16	10	0.63	5	0.31	3	0.19	0.5
TK 3/2	15	7.7	0.51			2	0.13	
Am 9/ 3	15	8.5	0.57	4	0.27	2.5	0.17	0.47
Am 9/ 4	15	8.5	0.57			2	0.13	
Am 9/ 5	12.5	7	0.56	3	0.24			0.43
Am 9/ 6	12	9	0.75	2.5	0.21	1	0.08	0.28
Am 9/ 7	9	5	0.56	3	0.33			0.6
Holotype	82	42	0.51	15	0.18	13.2	0.16	0.36

Discussion: This is the first record of *Barremites* from the Kopet Dagh. The combination of constrictions, fine ribs and a rather deep umbilicus suggests that these poorly preserved specimens can be compared with *Barremites difficilis*. The largest specimen is only 34.5 mm diameter. Several have similar proportions to the holotype.

Specimens of this species figured by Druschitz & Kudryutzeva (1960) do not show constrictions, but those illustrated by Immel (1987), Obata *et al.* (1982) and Obata *et al.* (1984) do. The specimens can be attributed to *Barremites* cf. *subdifficilis* because of their fine ribs. *Barremites difficilis* extends through the whole of the Barremian and is therefore not a good index fossil but it can be used in assemblage zones.

Distribution: France (d'Orbigny, 1840), Germany (Immel, 1987), Carpathian (Avram, 1976), Russia (Druschitz & Kudryutzeva, 1960), Japan (Obata *et al.*, 1984) and Iran.

Occurrence: Lowermost part of the Sarcheshmeh Formation in Takal Kuh (1) and Amand sections.

Subfamily Pseudosaynellinae Casey 1961

This subfamily is interpreted as probable derivatives of *Barremites* that combined a ribbed stage with a tendency to oxyconic form. Casey (1961c, p.169) assigned the Pseudosaynellinae to the Desmocerataceae rather than the Hoplitaceae, mainly because of the presence of constrictions and the absence of tubercles.

Genus *Pseudosaynella* Spath 1923

Type species: *Ammonites bicurvatus* Michelin 1838, by original designation.

Generic characters: Shell involute, compressed and discoidal. Ribs sigmoidal. Primary ribs start from the umbilical margin and secondaries are intercalated between the primaries or branch from them. Ribs do not extend over the ventral area. The suture line is asymmetrical with trifid first lateral lobe, bifid saddles and numerous auxiliaries (Casey, 1961c).

Discussion: *Pseudosaynella* is derived from Aconeceratinae on account of its constriction and sutures line (Casey, 1954a). Like *Neosaynella*, 'it has the sutural character of a compressed desmoceratid with asymmetrical principal lobe and dominant external saddle' (Casey, 1961c, p. 121).

Distribution: Europe and Russia (Druschitz & Kudryutzeva, 1960; Wright *et al.*, 1996), and Iran.

Age: Early Aptian-Late Aptian (Wright *et al.*, 1996, p. 71).

Pseudosaynella sp.

Plate 1, Figures 6 & 7

Material: 8 specimens [TK 65/ 1-3; TAK 45/ 1-3; Raz 1/ 5; Raz 2/ 17].

Description: All the specimens are small (maximum diameter 15.5 mm) but one shows the body chamber. Discoidal, involute, with flattened sides and sharpened venter. Umbilicus narrow with distinct rim, shell smooth or with sigmoidal ribs, occasionally branching, stronger at the upper part of the flank. Suture line is clear in some specimens, showing a bifid saddle and trifid lateral lobe; the lobes are deeper than the saddles.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH
TAK 45/ 1	**15.5**	**8**	**0.51**	**4**	**0.25**			**0.5**
TK 65/ 1	**15**	**9**	**0.6**	**5**	**0.33**	**2.5**	**0.16**	**0.55**
TK 65/ 2	**15**	**8**	**0.53**	**5**	**0.33**	**2**	**0.13**	**0.62**
TAK 45/ 2	**14**	**9.5**	**0.67**	**4**	**0.28**			**0.42**
TK 65/ 3	**13**	**7**	**0.53**	**4**	**0.30**	**2**	**0.15**	**0.57**
TAK 45/ 3	**13**	**8**	**0.61**	**3**	**0.23**	**2**	**0.15**	**0.37**

Discussion: Because of compression the specimens in sample TAK 45 look like *Aconeceras*, but their flanks are more convex than in *Aconeceras*. Close examination shows they differ from *Aconeceras* in the suture line and rib pattern, which are seen in some specimens. They may compare with *P. bicurvata* Michelin as figured by Casey (1961c, p. 171).

Occurrence: Lower part of the Sanganeh Formation in the Takal Kuh and Amand sections.

Subfamily Puzosiinae Spath 1922

Genus *Melchiorites* Spath 1923

Type species: *Ammonites melchioris* Tietze 1872, by monotypy.

Generic characters: *Melchiorites* is characterised by a moderately evolute shell, subquadrate whorl section and presence of constrictions, with ribs between.

Discussion: *Melchiorites* is similar to *Valdedorsella* but the latter genus is distinguished by the absence of ribs between constrictions.

Distribution: Europe, northern Africa, Madagascar and California (Wright *et al.*, 1996), and Iran.

Age: Late Barremian- Early Albian (Wright *et al.*, 1996, p. 75).

Melchiorites aff. *melchioris* (Tietze 1872)

Plate 1, Figure 9

aff. 1872 *Ammonites melchioris* Tietze, p.135, pl. 9, figs. 9-10.

aff. 1962 *Melchiorites melchioris* (Tietze); Collignon, p. 36, pl. 230, fig. 980.

aff. 1968 *Melchiorites melchioris* (Tietze); Wiedmann and Dieni, p. 109, pl. 10, fig. 4.

aff. 1982 *Melchiorites melchioris* (Tietze); Renz, p. 23, pl. 2, fig. 20.

aff. 1997 *Melchiorites melchioris* (Tietze); Delanoy, pl. 59, fig. 2.

Material: 20 specimens, [TK 59/ 1, 2; TK 64; TK 66/ 1, 2; TK 72/ 1-5; TK 73/ 1, 2; TK 76; TAK 38; TAK 43?; TAK 44; TAK 51/ 1/ 28-30].

Description: The specimens are small (maximum diameter 15 mm) and semi-involute. Umbilicus one fourth to one fifth of the diameter. Whorl section rounded, slightly wider than high, thickest part below mid flank, sides slightly convex to flat. Slightly prorsiradiate constrictions curve forward over the broad venter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH
TAK 44	15	7	0.47	6.5	0.43	5.5	0.37	0.93
TAK 51. 1/29	14	7	0.5	5.3	0.38			0.76
TAK 51/ 28	11.6	5	0.43	4.5	0.39	2	0.17	0.9
TK 66	11	6.5	0.59	5	0.45	2	0.18	0.77
TK 72/ 1	9.5	5.2	0.55	3.2	0.34	2	0.21	0.62
TAK 43	9.5	5	0.53	4	0.42	1	0.11	0.8
TK 72/ 2	9	3.7	0.41	3.5	0.39	2.5	0.28	0.95
TK 64	9	4.5	0.5	2.2	0.24			0.49
TAK 51/ 30	7.7	4	0.52	3.7	0.48	1	0.13	0.93
TK 76	7	3	0.43	2.7	0.39	2	0.29	0.9
TK 73/ 1	6.3	3	0.48			1.5	0.24	0
TK 73/ 1	6.3	3	0.48			1.5	0.24	0
TK 66/ 2	5.5	2.5	0.45	1.7	0.31	1.5	0.27	0.68
TK 72/ 4	5.3	2.5	0.47	1.3	0.25	1	0.19	0.52
TK 59/ 1	5	2.5	0.5	2	0.4	1	0.2	0.8
TK 59/ 2	4.5	2.5	0.56	1.5	0.33	1	0.22	0.6
TK 72/ 3	4	2	0.5	1.5	0.38	1	0.25	0.75
TK 72/ 5	4	2	0.5	1.7	0.43	1	0.25	0.85
TK 73/ 2	4	2.2	0.55	1.5	0.38			0.68
TK 73/ 2	4	2.2	0.55	1.5	0.38			0.68

Discussion: Because of their small size, the specimens cannot be identified firmly, but show affinities with *Melchiorites melchioris*.

Occurrence: Lower and middle part of the Sanganeh Formation in the Takal Kuh sections.

Suborder Ancyloceratina Wiedmann 1966
Superfamily Ancylocerataceae Gill 1871

Ancestors of the Ancylocerataceae should be probably among the members of Jurassic Superfamily Spirocerataceae because heteromorphs existed among this superfamily (Doguzhaeva and Mikhailova, 1982; Wright *et al.*, 1996).

It is now well established that the Cretaceous heteromorphic Ancylocerataceae lead to normally coiled Deshayesitidae, Parahoplitidae and Douvilleiceratidae (e.g. Casey, 1960; Wiedmann, 1969; Doguzhaeva and Mikhailova, 1982; Wright *et al.*, 1996). All these families have the same type of unstable five lobed second suture with subsequent reduction of the first umbilical lobe. Their variety and short time range make them useful as index fossils.

Family Ancyloceratidae Gill 1871

The ancyloceratid genera *Pedioceras, Australiceras, Ancyloceras, Toxoceratoides* and *Tonohamites* are recorded from the Kopet Dagh Basin for the first time. Most specimens are not complete and do not allow detailed examination of their phylogeny. However they are new records for the basin and more sampling may lead to better understand of the phylogeny of the family.

Subfamily Crioceratitinae Gill 1871

Genus *Pedioceras* Gerhardt 1897

Type species: *Pedioceras cundinamarcae* Gerhardt 1897, by subsequent designation (Hyatt, 1903, p. 108).

Generic characters: Early whorls in contact, then coils opening, whorl section sub-quadrate. Ribs fine, straight or sinusoidal, with two rows of ventro-lateral tubercles, secondary ribs rare.

Discussion: Wright *et al.*, (1996) regarded *Pseudocrioceras* as a possible synonym of *Pedioceras*. However, Kakabadze (1978, 1981) believed that the genera *Pedioceras* and *Pseudocrioceras* clearly differ in ornamentation and type of coiling in the early ontogenetic stages. The early ontogenetic stage of *Pedioceras* is supposedly characterized by having only ventral and lateral tubercles whereas the early stage of *Pseudocrioceras* is characterized by the presence of ventral and umbilical tubercles. Moreover their mature stages differ in the mode of uncoiling and suture line. I do not find these differential characters in some of the figures published by Kakabadze and Thieuloy, (1991) and Kakabadze and Hoedemaeker, (1997); for example text figure 4 of Kakabadze and Hoedemaeker (1997) shows a *Pedioceras* with umbilical tubercles. Hence I regard the two genera as synonyms.

Distribution: France, Caucasus, California, Mexico and Colombia (Wright *et al.*, 1996), and Iran.

Age: Barremian- Early Albian (Wright *et al.*, 1996, p. 214).

Pedioceras cf. *anthulai* (Eristavi 1955)
Plate 1, Figures 10 & 11

cf. 1899 *Crioceras orbignyi* (Matheron); Anthula, p. 125, pl. 12, figs. 2a-c.
cf. 1955 *Ancyloceras anthulai* Eristavi, p. 113.
non 1981 *Pseudocrioceras anthulai* (Eristavi); Kakabadze, pl. 18, fig. 1.
cf. 1991 *Pseudocrioceras anthulai* (Eristavi); Kakabadze & Thieuloy, p. 89-90, pl. 3, figs. 2-4, text fig. 9.
cf. 1997 *Pseudocrioceras anthulai* (Eristavi); Kakabadze & Hoedemaeker, p. 68, pl. 2, fig. 2.

Holotype: Institute of Palaeontology, University of Vienna (Anthula Colln), from Daghestan.

Material: 60 specimens [TAK 37; TAK 51/ 1/ 1-27; SH 13/ 1-9; Raz 1/ 1-3; Raz 2/ 1-14; Raz 3/ 1-5; Am 26/11].

Description: The specimens are mainly fragmentary, and the early whorls usually missing. Planispiral shell. Whorls in contact or a little loosely coiled, initial part unclear or crushed. Whorl section is sub-rectangular to rectangular, whorl height and width nearly equal. Ribs alternatively single and bifurcating, straight with a row of tubercles on the ventral margin and a row of smaller ones on the flank. Secondaries start from the lower third of the flanks in young forms to the upper part in adult forms; some of them are attached to the primaries and some are intercalated.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH
SH 13/ 2	**18**	**7**	**0.46**	**7**	**0.22**	**7**	**0.22**	**1**
Raz 2/ 7		**16.5**		**18**				**1.09**
Raz 3/ 5		**14.5**		**14**				**0.97**
SH 13/ 1		**14**		**14**				**1**
Raz 2/ 6		**14**		**12.5**				**0.89**
Raz 2/ 2		**13**		**13**				**1**
Raz 2/ 12		**13**		**10**				**0.77**
Raz 1/ 2		**13**		**11**				**0.85**
Raz 3/ 1		**13**		**14**				**1.08**
SH 13/ 9		**11**		**11**				**1**
Raz 2/ 1		**11**		**8**				**0.73**
Raz 3/ 4		**11**		**11**				**1**
SH 13/ 8		**10**		**9**				**0.9**
SH 13/ 4		**9**		**8**		**7**		**0.89**
SH 13/ 5		**9**		**10**				**1.11**
Raz 1/ 1		**8.5**		**8.5**				**1**
SH 13/ 6		**8**		**7**				**0.88**
Holotype	**77**	**34**	**0.44**	**25**	**0.32**			

Discussion: Because of deformation of some specimens, the whorl section does not match those illustrated by Kakabadze & Thieuloy (1991, pl. 6, figs. 2-4) and Kakabadze & Hoedemaeker (1997, pl. 12, fig. 2), but there is a similarity as whole. According to Kakabadze & Thieuloy (1991), *Pseudocrioceras anthulai* is characterised by having lateral tubercles and in most of their specimens this character is fairly clear. They also illustrated in text-fig. 9 two rows of ventro-lateral tubercles on each flank in big shells.

Distribution: Upper Barremian-Lower Aptian of Daghestan, Georgia (Kakabadze, 1978, 1981), Colombia (Kakabadze & Thieuloy, 1991; Kakabadze & Hoedemaeker, 1997) and Iran.

Occurrence: Lower to middle part of the Sanganeh Formation in the Takal Kuh (2) and upper part of the Sarcheshmeh Formation in the Sheykh and Raz sections.

Pedioceras sp.

Plate 2, Figure 4

Material: 2 whorl fragments [TAK 25/ 2, 3].

Description: Whorls open, whorl section subrectangular, ribs extend straight from central part of the dorsal surface to the venter; two rows of tubercles, one on the flank and the other on the venter. Ribs disrupted on venter by a groove.

Discussion: The specimens are incomplete and cannot be identified to species level. But they show some similarity to *Pedioceras provinciale* Matheron (see Ropolo *et al.*, 1999).

Occurrence: Lower part of the Sarcheshmeh Formation at Takal Kuh section (2).

Subfamily Ancyloceratinae Gill 1871

The subfamily embraces a group of generally large heteromorphs with ancyloceratid coiling including such well-known genera as *Ancyloceras*, *Australiceras* and *Tropaeum* (Wright *et al.*, 1996).

Wright *et al.* (1996, p. 215) noted two phylogenetic trends; one includes 'increasingly close coiling, differentiation of ornament on the hook, and loss of trituberculation, at least in middle growth'. This trend was well-documented by Casey (1960, p. 19 and text-figure 5) who suggested that *Tropaeum*, *Australiceras* and *Ammoniticeras* evoluted as parallel radiations from *Ancyloceras*; that *Ancyloceras* and *Ammoniticeras* are linked by *Epancyloceras*; and that *Tropaeum* and typical *Australiceras* branched from the group of *Australiceras gigas*. His suggested evolutionary pattern is shown in Figure 3.3. A second trend is for ptychoceratid coiling to develop through straightening and lengthening of the shaft.

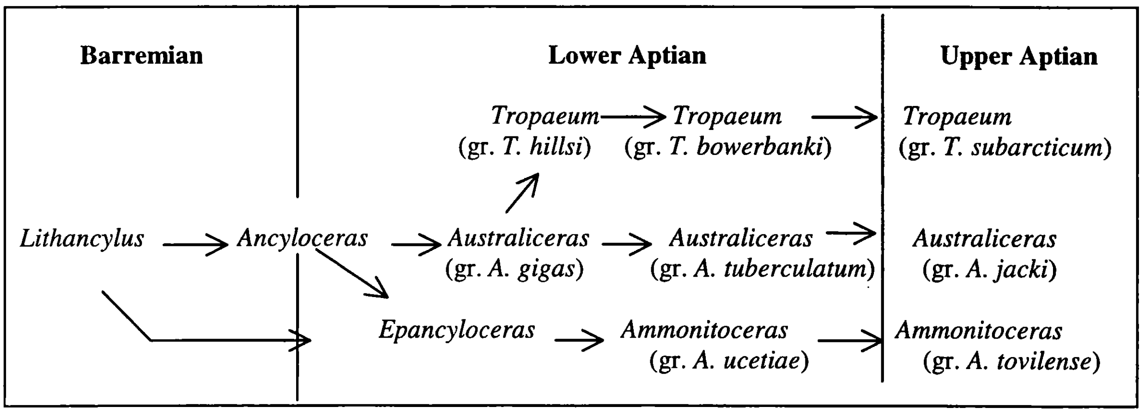


Figure 3.3. Phylogenetic trend in Ancyloceratidae (From Casey, 1960).

In the Kopet Dagh, the Ancyloceratinae are represented by a few fragments of *Australiceras* and *Ancyloceras*.

Genus *Ancyloceras* d'Orbigny 1842

Type species: *Ancyloceras matheronianum* d'Orbigny 1842, by subsequent designation (Haug, 1889, p.212).

Generic characters: *Ancyloceras* is characterised by an open planispiral whorl, and long shaft and short hook with big tubercles.

Distribution: Europe, south-eastern Africa, Madagascar, Japan, California and Colombia (Wright *et al.*, 1996), and Iran.

Age: Early Barremian-Early Aptian (Wright *et al.*, 1996, p. 216)

Ancyloceras cf. *mantelli* Casey 1960

Plate 2, Figure 2

cf. 1930 *Ancyloceras matheronianum* d'Orbigny; Spath, p. 421, 454.

cf. 1960 *Ancyloceras mantelli* Casey, p. 21, pl. 1, fig. 3, pl. 2, fig. 1, pl. 3 figs. 1-2.

Material: One fragment [TK 28].

Holotype: Natural History Museum, London, C3748 (S.H. Beckles Colln), from the Atherfield Clay Series, Crackers, Atherfield, Isle of Wight.

Description: An incomplete spiral whorl fragment; sculpture includes trituberculated main ribs and fine intermediary ribs without tubercles: lateral tubercles occur but are broken.

Discussion: Despite the fragmentary nature of the specimen it appears to belong to *Ancyloceras* and compares closely with similar growth stages of *A. mantelli* Casey.

Distribution: Lower Aptian in England (Casey, 1960) and Iran.

Occurrence: Lower part of the Sarcheshmeh Formation in Takal Kuh section (1).

Genus *Australiceras* Whitehouse 1926

Type species: *Crioceras jacki* R. Etheridge Jr. 1880, by original designation.

Generic Characters: The coiling is typically crioceratitid, but may be aspinoceratid or ancyloceratid in early species (Figure 3.4). Trituberculate costae occur in early whorls and body-chamber.

Discussion: Casey (1960, p. 44, 1961b, p. 45) discussed at length previous interpretation of *Australiceras* and the problem of differentiating it from *Tropaeum*. He regarded the two genera as distinct, and that view was followed by Wright *et al.* (1996).

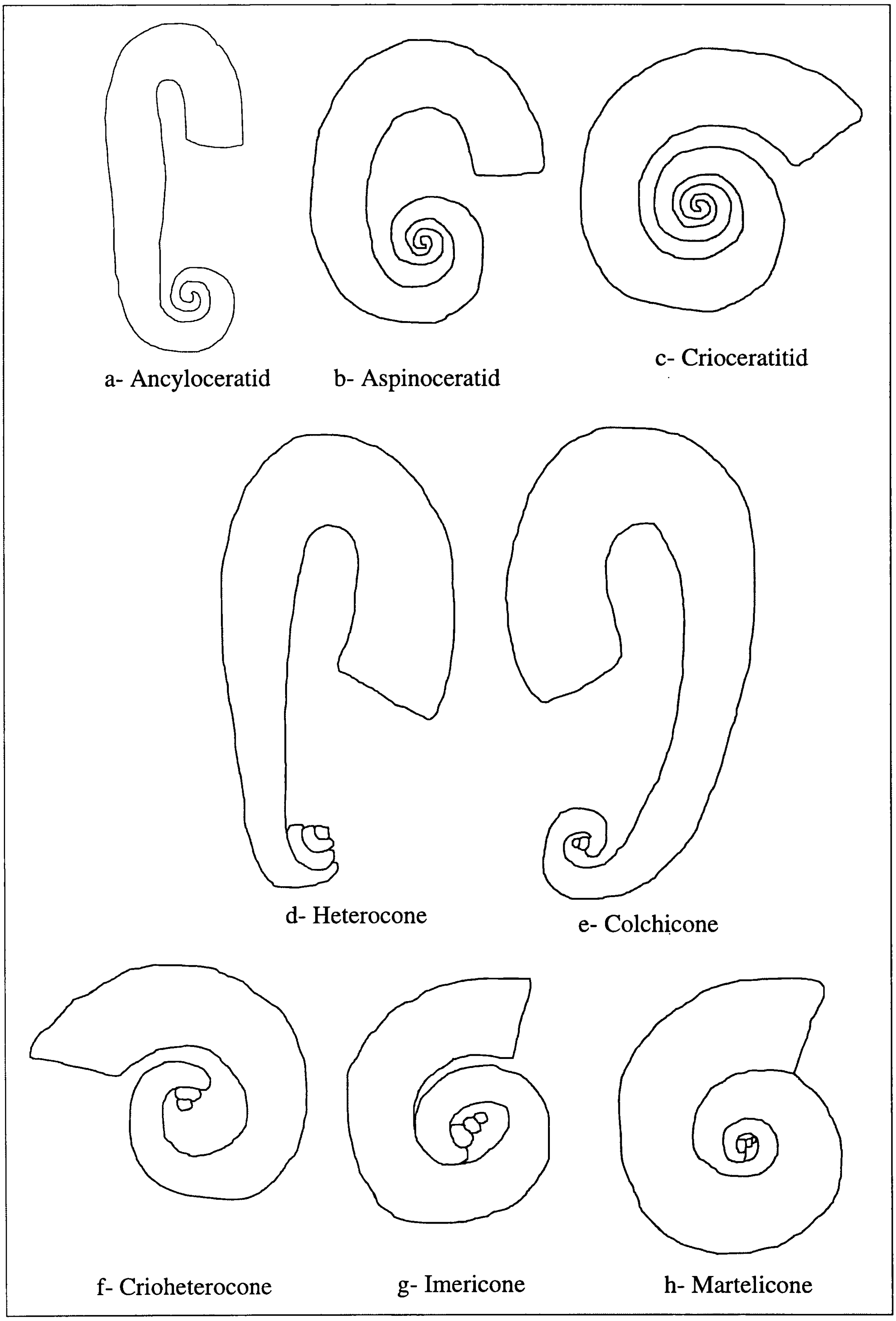


Figure 3.4. Coiling type of heteromorphs (redrawn from Casey, 1960 and Delanoy, 1997).

It appears that the final hook in species of *Tropaeum*, with the exception of the *Tropaeum hilisi* group, does not extended as much as in *Australiceras*; it is only in the last whorl that the coiling begins to open to form a weak hook.

Distribution: England, France, Germany, Bulgaria, Caucasus, South Africa, Madagascar, Pakistan, Australia, Japan, California and Colombia (Dimitrova, 1967; Wright *et al.*, 1996), and Iran.

Age: Aptian (Wright *et al.*, 1996, p. 216).

Australiceras sp.
Plate 2, Figure 1

Material: 2 specimens [TK 82, TAK 36/ 24].

Description: Initial parts crushed or broken, but coiling aspinoceratid. On the shaft and hook the whorl section is subrectangular, the sides flattened to concave, and the venter broadly arched. Ribs are dense and narrow at first, then more or less suddenly change to distantly-spaced. Three big ribs on the hooked body-chamber have two rows tubercles on the sides and two rows on the venter.

Discussion: Because of the incomplete shell it is not possible to name the species.
Occurrence: Upper part of the Sarcheshmeh and Sanganeh Formations in Takal-Kuh sections.

Subfamily Helicancylinae Hyatt 1894

The genera of the subfamily are problematic in the literature because most times only fragments are described. Lack of information hinders discussion about phylogeny. Two genera, *Tonohamites* and *Toxoceratoides*, are recorded from the Kopet Dagh for the first time. *Tonohamites* is very similar to *Toxoceratoides*, which it appears to replace in the top of the Lower Aptian. However *Tonohamites* is characterised by its thicker costation, and untuberculated ribs on the final hook (Casey, 1961).

Genus *Toxoceratoides* Spath 1924

Type species: *Toxoceras royerianum* d'Orbigny 1842, by original designation.

Generic characters: The coiling is ancyloceratid or toxoceratid. Early whorls and shaft with trituberculate ribs. Final hook bears simple ribs, with bifurcate or trifurcate secondary ribs intercalated in between. Suture line is ancyloceratid with bifid saddle and trifid lobes.

Discussion: Spath (1924) introduced the genus in his list of ammonite species from the Speeton Clay, but gave no diagnosis. Arkell *et al.* (1957) suggested that it is a synonym of *Hamiticeras*. The latter genus has a *Toxoceratoides*-like shaft, but it differs from *Toxoceratoides* by having a final hook parallel to the shaft, and sharp and strong ribs, single and widely spaced (Aguirre-Urreta 1986).

Because of the small size and nature of the coiling, finding complete specimens is not easy. Therefore a large number of species have been identified and different authors use different characteristics to separate species. The only distinct characters for specific separation are the coiling, whorl section and ornament of the body chamber and shaft (Aguirre-Urreta, 1986).

Aguirre-Urreta (1986, p. 295) noted that, with the exception of a doubtful record in Australia Day (1974), there is no evidence that *Toxoceratoides* had an initial helix. If it did, it would be necessary to analyse the taxonomic position of this genus again, as the presence of an initial helix is a typical feature of the contemporaneous Heteroceratidae.

Distribution: *Toxoceratoides* is recorded from western Europe, eastern Europe, western Asia, eastern Africa, South Africa, California, Argentina, Antarctica and Mozambique (Förster, 1975; Wright *et al.*, 1996), and Iran.

Age: Early Barremian- Late Aptian (Wright *et al.*, 1996, p. 223).

Toxoceratoides sp.

Plate 2, Figures 5 & 6

Material: One fragments [TK 16].

Description: More or less curved shaft, with spherical to sub-rectangular whorl section; Ribs straight, single ones intercalated with bifurcate ribs, two rows of tubercles on the venter.

Discussion: The specimen is not complete, but it shows some of the generic characters. Another specimen, which was collected in sample TK 76, is questionably attributed to this genus. The specimens show some similarity to *Toxoceratoides subproteus* Casey (1980, p. 651, pl. 103, fig. 3). *Toxoceratoides subproteus* may provide a link between *Toxoceratoides* and *Tonohamites*.

Occurrence: Lower part of the Sarcheshmeh formation in the Takal Kuh section.

Genus *Tonohamites* Spath 1924

Type species: *Tonohamites decurrens* Spath 1924, by original designation.

Generic characters: Coiling like *Toxoceratoides*. Ribs more rounded and tuberculation weaker than in *Toxoceratoides*. On the final hook all ribs are single, strong and rounded. Suture line as in *Toxoceratoides*.

Discussion: Klinger & Kennedy (1977) pointed out the close relationship between *Toxoceratoides* and *Tonohamites*. *Tonohamites* differs from *Toxoceratoides* mainly in the ornament of the final hook. In *Tonohamites* tuberculation on the shaft is usually reduced, but species like *Tonohamites decurrens* Spath with a strong trituberculate phragmocone show the close relationship between these two genera (Aguirre-Urreta, 1986).

Distribution: Europe, the Caucasus, South Africa, Madagascar, Argentina and Colombia (Wright *et al.*, 1996; Kotetishvili, 1988), and Iran.

Age: Aptian (Wright *et al.*, 1996, p. 223).

Tonohamites sp.
Plate 2, Figure 3

Material: Two specimens [TK 65, TAK 37].

Description: Two incomplete shafts have a circular or sub-circular whorl section and slightly flattened dorsum; ribs unbranched, bending a little backward on the dorsal margin, disrupted on the venter by a groove with two rows fine costae.

Discussion: The specimens are incomplete and small, belonging to an early stage of growth. They appear similar to *T. limbatus* Casey (1961b, p.89, pl. 20, figs. 3,4, pl. 21, fig. 3).

Occurrence: Lower to middle part of Sanganeh Formation in Takal Kuh sections.

Family Heteroceratidae Hyatt 1900

Discussion: Delanoy (1997) has studied the Heteroceratidae of south-east France in detail. His division into genera shows some differences with Wrights's (1996) classification. Here I follow Delanoy's classification, in which differentiation at generic and sub-generic level is based on the presence or absence of tubercles (a major character in classification of some other heteromorph groups, too) and the nature of the coiling.

Delanoy (1997) put the type species of *Colchidites* (*C. colchicus*) in *Heteroceras*. Therefore he treated *Colchidites* as an invalid genus and distributed its species between *Heteroceras* and *Martelites*. He noted that the transition from *Heteroceras* to *Martelites* is marked by the development of a planispiral stage between helix and shaft/ hook. Hence forms in which the helical initial stage passes immediately into a straight or slightly curved shaft, followed by a terminal hook, belong to *Heteroceras*, while those in which the helical stage is followed by one or more planispiral whorls and then a terminal hook belong to *Martelites*. *Paraimerites* differs from *Martelites* (= *Colchidites* pars) by having a pair of tubercles on the venter. Delanoy also suggested that *Eristavia* is a synonym of *Imerites* and should no longer be used.

The transition from heteromorph to normally coiled ammonoids has been convincingly traced in a phylogenetic series linking the Barremian Heteroceratidae with Aptian Deshayesitidae (Figure 3.5). The similarity of ornament, cross section of the whorls and most importantly the development of the suture line during ontogeny of the shell in the last *Martelites* and the first *Turkmeniceras* (Deshayesitidae) confirms that they are related (Wiedmann, 1969; Bogdanova, 1971a; Mikhailova, 1979, 1982) (Figure 3.6).

Sampling bed by bed in the Kopet Dagh Basin permits the examination of the morphological changes and phylogentic aspects in the Heteroceratidae that have been suggested by Kakabadze (1975), Mikhailova (1979) and Aguirre-Urreta and Klinger (1986).

Genus *Heteroceras* d'Orbigny 1849

Type species: *Turrilites emericianus* d'Orbigny 1842, by subsequent designation (Meek, 1876, p. 477).

Generic characters: Small to large heteromorph in which the initial whorls are helically coiled with the whorls closely spaced or touching. The remainder of the shell is gently curved (heterocone) to loosely coiled (colchicone) in a more or less plane spiral and has a final hook (Figure 3.4). Ribs strong on the umbilical area, and narrow over the ventral region. They are asymmetrical or sinusoidal on the helical whorls, becoming radial and straight on the planispiral whorls. Most are single, but some bifurcate on the ventral area. Peristome sinusoidal. Suture ancyloceratid, with four lobes including an asymmetric, trifid lateral lobe.

Discussion: The lack of tubercles distinguishes *Heteroceras* from *Argvethites*, *Acrioceras* and *Lytocrioceras*, when initial whorls are missing.

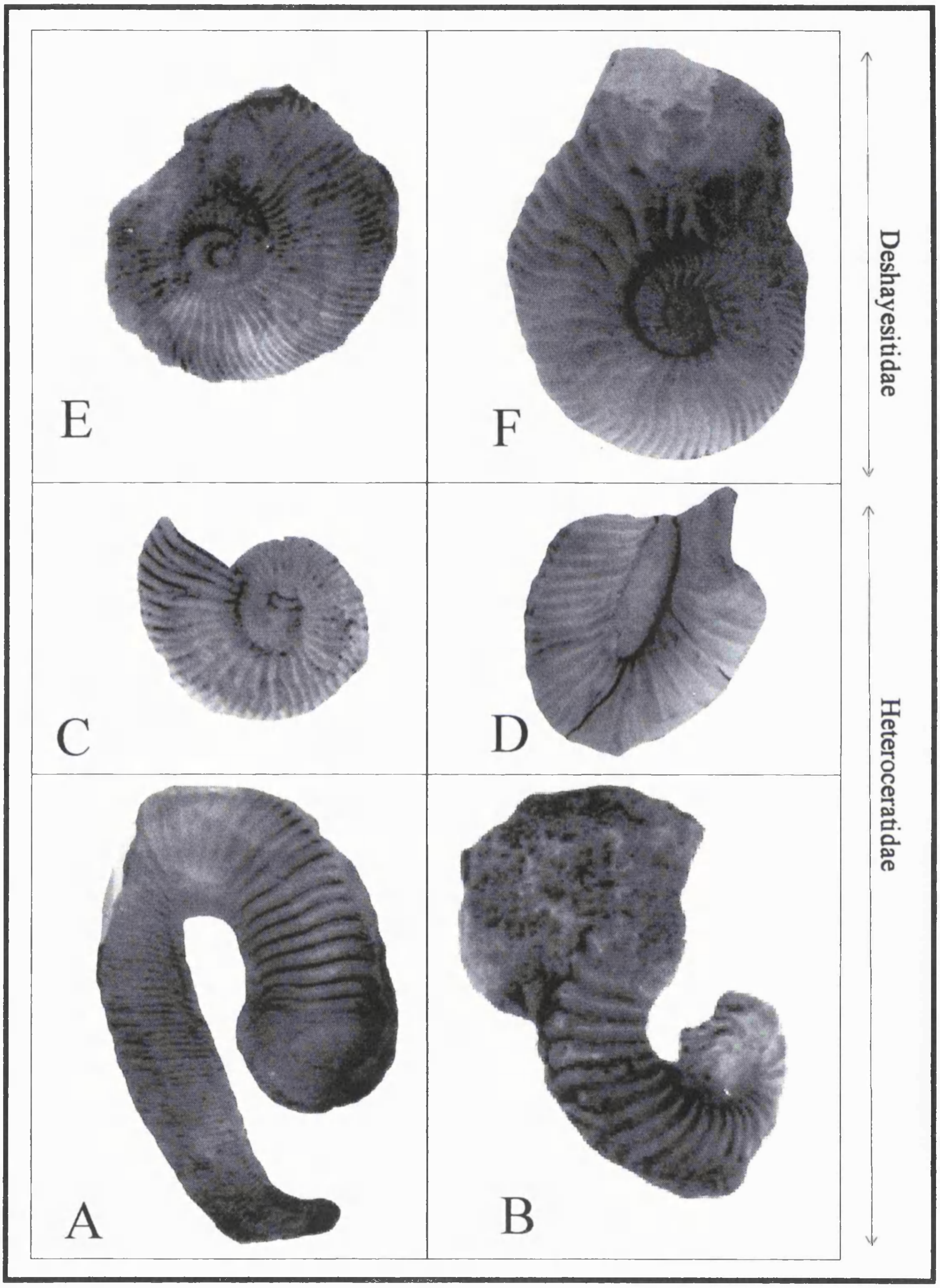


Figure 3.5. Changes of Shell shape in the Heteroceratidae and Deshayesitidae, A) *Heteroceras* cf. *colchicus*, TAK 7/1; B) *Paraimerites* sp., TK 14-15/3; C) *Martelites* cf. *tinae*, TK 18-20; D) *Argvethites* sp., TK 14-15/ 15; E) *Turkmeniceras multicostatum*, Am 10/1; F) *Deshayesites luppovi*, TK 46/21. All figures in natural size, B-x2.

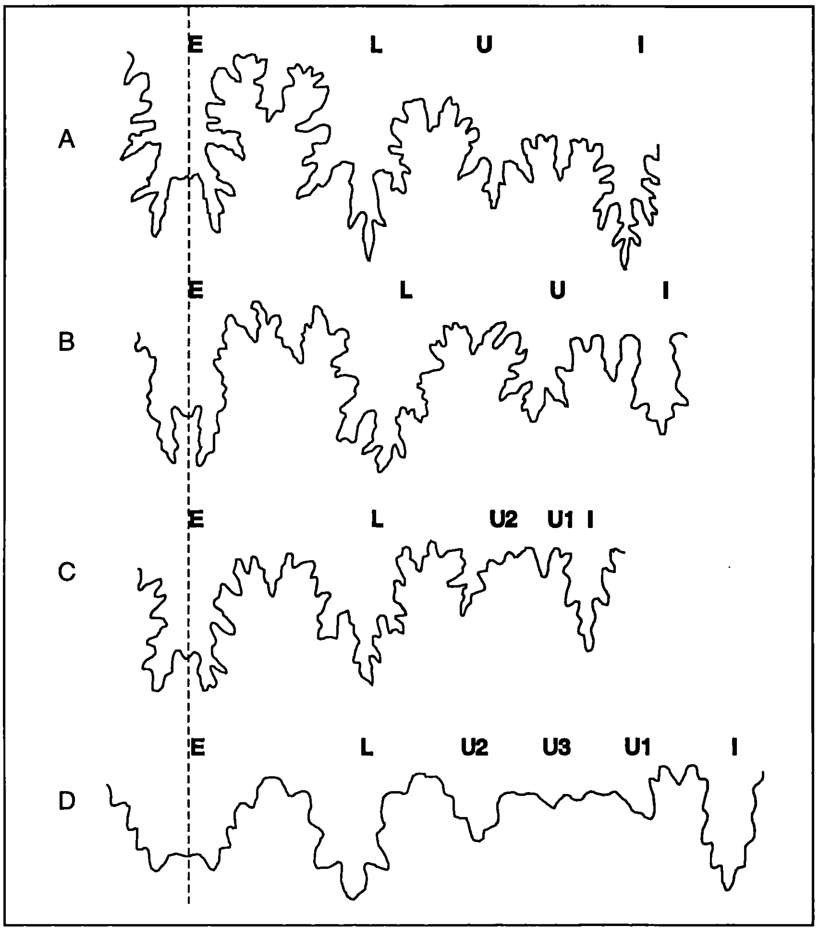


Figure 3.6. Comparison in suture lines of Hemihoplitidae, Heteroceratidae and Deshayesitidae; A) *Hemihoplites* cf. *astarte,* B) *Martelites shaoriensis,* C) *Turkmeniceras multicostatum,* D) *Deshayesites deshyesi* (After Tovbina, 1965; Wiedmann, 1966; Schindewolf, 1966; Kakabadze, 1975)

Distribution: Southern and Central Europe, eastern England, the Caucasus, Iran, Japan, Canada, California, Columbia, Peru, Argentina and South Africa (Jeletzky, 1970; Kakabadze and Thieuloy, 1991; Rawson, 1995; Wright *et al.*, 1996).

Age: Late Barremian (Delanoy, 1997, p. 41; Klinger *et al.*, 1984).

Heteroceras cf. *colchicus* (Djanelidze 1926)
Plate 3, Figures 1, 2 & 3

cf. 1926 *Colchidites colchicus* Djanelidze, p. 265, pl. 1, fig. 1.
cf. 1971 *Colchidites colchicus* Djanelidze; Kakabadze, p. 54, pl. 6, figs. 1, 2.
cf. 1997 *Colchidites* sp. ex gr. *C. colchicus* Djanelidze; Immel *et al.*, p. 174, pl. 8, fig. 5.

Holotype: Georgian Institute of Academy of Science, No 1/ 10482, figured by Djanelidze, collected from Nikotsminda, western Georgia.

Material: 31 specimens [TK 14/ 1-3; TK 14-15/ 2-6, 9, 10; TK 15/ 1-3; TK 16; TAK 4/ 1-4; TAK 5/ 1; TAK 6/ 1, 3-9; TAK 7/ 1-2; Am 1/ 3; Am 2/ 3].

Description: Most specimens are broken pieces or external moulds, mainly of shafts and hooks, of small to medium size. The most complete is 76 mm long, while the type specimen is 155 mm long (Kakabadze, 1971). The helical stage probably **embraces at least 3 whorls**. Whorl section sub-rounded to sub-rectangular. Ribs are fine, curved and rather dense on the helical part, then become straight or a little bent and rounded, but still fine and dense, on the shaft. On the hook they become stronger and bifurcate; the secondaries branch or are intercalated on the upper third of the flank. One specimen shows a final stage in which the ribs become single again.

Discussion: Specimens TK 15 compare with material from the Kopet Dagh described by Immel *et al.* (1997) as *Colchidites* cf. *colchicus*; Immel's specimens were examined in the Munich collection.

Distribution: Caucasus (Kakabadze, 1971) and Iran.

Occurrence: Lower part of the Sarcheshmeh Formation in the Takal Kuh and Amand sections.

Heteroceras spp.

Plate 3, Figure 4

Material: 3 specimens [TK 3/ 4; TK 13; TK 14-15/ 1].

Description: The specimens are impressions of shafts and a fragment of a hook. Shafts straight, with fine and dense ribs, more or less straight. TK 14-15/ 1 is an incomplete hook; ribs straight or slightly bent, primary ribs start from umbilical area, some pass into secondary ribs on the other side of the flank, a few secondary ribs intercalated between primaries.

Discussion: Lack of well preserved shells makes accurate identification impossible, but these specimens differ from other *Heteroceras* in having thicker, less dense ribs and fewer bifurcating ribs. Specimen TK 14-15/ 1 (Pl. 2, Fig. 4) is similar to a specimen figured by Delanoy (1997, p. 51-53, pl. 12, fig. 2, pl. 17, fig. 5, pl. 27, fig. 1) as *Heteroceras* cf. *emerici*, but specimens TK 3 and TK 13 can only be questionably attributed to *Heteroceras*.

Occurrence: Lower part of the Sarcheshmeh Formation in the Takal Kuh sections.

Genus *Argvethites* Rouchadze 1933

Type Species: *Heteroceras* (*Argvethites*) *minor* Rouchadze 1933, by original designation.

Generic characters: A small form in which the turricone is attached to a straight shaft, which terminates in a hook. Ventro-lateral tubercles appear on the penultimate or last whorl of the turricone or the base of the shaft and become gradually stronger until the final part of the hook, where they usually disappear. In some cases, they continue to the final part of the hook. The ribs are sinusoidal on the turricone becoming weakly curved on the first part of the hook. Trifurcate ribs exist between bifurcate ribs. Two types of bifurcate ribs are recognised; either the bifurcation point is located at mid-flank and the two secondary ribs cross the venter or bifurcation starts at the level of the ventral tubercles (Delanoy, 1997).

Discussion: *Argvethites* differs from *Heteroceras* by having paired ventral tubercles. According to Kakabadze (1975) a siphonal furrow on the shaft occurs mainly in *Argvethites*. However this character is known from other unrelated heteromorph groups such as *Toxoceratoides* (Aguirre-Urreta, 1986).

Distribution: The genus is recorded from south-east France, Spain, the Czech Republic and Caucasus (Braga *et al.*, 1982; Delanoy, 1997; Wright *et al.*, 1996), and Iran.

Age: Late Barremian (Delanoy, 1997, p. 167).

Argvethites sp.

Plate 3, Figures 5, 6 & 7

Material: 6 specimens [TK 14-15/ 14, 15; TK 15/ pocket 2; TAK 2/ 1; TAK 6/ 2, 10].

Description: The specimens are broken and fairly compacted shafts, a piece of hook and a piece of the early coils. Primary ribs bifurcate on the outer part of the shaft, and there is a row of tubercles in the ventro-lateral area.

Discussion: The specimens are too incomplete for identification to species level.

Occurrence: Lower part of the Sarcheshmeh Formation in the Takal Kuh sections.

Genus *Imerites* Rouchadze 1933

Type Species: *Imerites giraudi* Kilian 1898, by original designation.

Generic characters: Small to medium size, imericone or crioheterocone shell (Figure 3.4). The initial part of the shell coiled in a dextral helical spiral; ornamented with simple or bifurcate ribs, starting from the umbilical area. Their relief is more or less reduced over the ventral area, and strong on the flanks, generally straight and bituberculate. The remainder of the shell bears simple or fibulate ribs with lateral and ventro-lateral tubercles. Suture lines ancyloceratid (Delanoy, 1997).

Discussion: *Imerites* differs from *Paraimerites* by having lateral tubercles, but this character is not clear in some stages of growth. *Imerites* and *Eristavia* are similar in type of coiling and ventral tubercles but *Eristavia* has some ribs that are limited to the dorsal margin (Kakabadze, 1971). Wright *et al.* (1996) put *Paraimerites* and *Eristavia* as synonyms of *Imerites*. In this thesis *Eristavia* is regarded as synonym of *Imerites*, but *Paraimerites* is retained as a distinct genus because it lacks the lateral tubercles found in *Imerites*.

Distribution: The genus is recorded from south-east France, eastern Europe, the Caucasus, Turkmenistan and Iran (Delanoy, 1997; Immel *et al.*, 1997; Tovbina, 1963; Wright *et al.*, 1996).

Age: Late Barremian (Delanoy, 1997, p. 153; Kakabadze, 1971, p. 60).

Imerites sparcicostatus Rouchadze 1933

Plate 3, Figure 8

1933 *Imerites sparcicostatus* Rouchadze, p. 253, pl. 21, fig. 1.
1970 *Imerites sparcicostatus* Rouchadze; Kotetishvili, p. 84, pl. 13, fig. 2.
1971 *Imerites sparcicostatus* Rouchadze; Kakabadze, p. 42-43, pl. 2, figs. 3-4.

Material: 10 specimens [TK 4/ 1-8; TK 18-20/ 6; TK 20/ 4].

Holotype: Georgian Institute of Academy of Science, No 447/ 1113, figured by Rouchadze, collected from Golsheva, western Georgia.

Description: Most specimens are broken and missing the early or last whorls. Whorl section sub-rectangular, the thickest part of the whorl near the venter. Ribs are straight and widely spaced in last whorls, sharp and radial, becoming thicker towards the body chamber. One rows of tubercles on the ventral margin, lateral tubercles are not clear and eroded.

Discussion: The specimens closely match previously figured examples. According to Kakabadze (1971), *I. sparcicostatus* differs from *I. favrei* in having a higher helix and less compact, straighter ribs. The collected samples are attributed to *I. sparcicostatus*, because of their rib pattern and the ribbing density, which is less than in *I. favrei*.

Distribution: Georgia (Kakabadze, 1971) and Iran.

Occurrence: Lowermost part of the Sarcheshmeh Formation in the Takal Kuh section (1).

Genus *Paraimerites* Kakabadze 1967

Type species: *Heteroceras densecostatus* Renngarten 1926, by original designation.

Generic characters: Helically coiled at first, then open planispiral whorls. Helical whorls with simple ribs, planispiral whorls with bifurcate ribs and a ventro-lateral tubercle.

Discussion: The genus is separated from *Martelites* by the presence of ventro-lateral tubercles and from *Eristavia* and *Imerites* by the lack of lateral tubercles (Klinger, 1976). Delanoy (1997) considered that it is difficult to decide about validity of the genus *Paraimerites*. But he used this genus without discussion.

Distribution: The genus is recorded from France, the Caucasus and South Africa (Aguirre-Urreta and Klinger, 1986; Delanoy, 1997; Kakabadze, 1971) and Iran.

Age: Late Barremian (Delanoy, 1997, p. 160).

Paraimerites sp.

Plate 3, Figure 9

Material: 2 specimens [TK 14-15/ 13, SH 9].

Description: An initial helix is following by a small open planispiral whorl. On the latter each primary rib bears a ventro-lateral tubercle, and secondary ribs are very rare.

Discussion: The material is too poor for firm identification but may be close to *P. planus* Kakabadze (1971, p. 86, pl. 20, fig. 3).

Occurrence: Lower part of the Sarcheshmeh Formation in the Takal Kuh and Sheykh sections (1).

Genus *Martelites* Conte 1989

Type species: *Martelites marteli* Conte, 1989, by original designation.

Generic characters: Martelicone (Figure 3.4). Initial part is turricone, with the whorls in contact and coiled dextrally or sinistrally. Whorl section sub-quadratee to sub-circular, oval or elliptical. Ribs regularly spaced, radial, sinusoidal, convex or concave, alternately simple and bifurcate, thickest across the venter. On the body chamber the ribs are initially similar to those on the phragmocone then become simple. Peristome is sinusoidal. Suture line ancyloceratid (Delanoy, 1997).

Discussion: The genus differs from *Heteroceras* by having one or more planispiral whorls. There is a trend for the number of whorls in the planispiral stage to increase as the helix gradually reduces (Mikhailova, 1979).

Distribution: *Martelites* is recorded from south-east France, Georgia, South Africa, Argentina (Aguirre-Urreta and Klinger, 1986; Conte, 1989; Delanoy, 1997, Wright *et al.*, 1996), and Iran.

Age: Late Barremian (Conte, 1989, p. 43; Delanoy, 1997, p. 126).

Martelites cf. *tenuicostatus* (Kakabadze 1971)

Plate 3, Figures 10 & 11

cf. 1971 *Colchidites tenuicostatus* Kakabadze, p. 82, pl. 17, fig. 2; pl. 19, fig. 4.

cf. 1997 *Colchidites tenuicostatus* Kakabadze; Immel *et al.*, p. 174, pl. 8, fig. 8.

Material: 67 specimens [TK 15/ 4; TK 16/ 1; TK 18/ 1-8, 11; TK 18-20/ 4-5; TK 19/ 2, 4; TAK 9/ 3, 6, 7, 9; TAK 10/ 3, 8, 10, 13; TAK 12/ 2, 3, 9, 16-18; Am 1/ 1, 5; Am 2/ 2; Am 3/ 1, 3, 11, 12, 14; Am 4/ 1, 3-6, 8, 10; Am 5/ 1, 2, 5, 7-15; Am 6/ 1, 3; Am 7/ 1-4, 6, 7; Am 8/ 1, 5; Am 9/ 15, 19, 21].

Holotype: Georgian Institute of Academy of Science, No 255/ 76, figured by Rouchadze, collected from Betlevi, western Georgia.

Description: Some specimens are a little crushed. The initial helix is very small, whorls in contact in the planispiral stage. Ribs divisible into primaries which begin at the umbilical margin and secondaries which alternate more or less regularly with primaries; secondaries originate from the middle to one third of the way up the outer flank. TK 18/ 4 has 34 primary ribs at the umbilical margin at 40 mm diameter.

Discussion: The ribs of *M. tenuicostatus* are more curved and more dense than those of *M. securiformis.*

Distribution: Caucasus (Kakabadze, 1971), Kopet Dagh (Immel *et al.*, 1997).

Occurrence: Lower part of the Sarcheshmeh Formation in the Takal Kuh and Amand sections.

Martelites securiformis (Simonovich, Bastevich and Sorokin 1875)

Plate 3, Figures 12 & 13

1875 *Colchidites securiformis* Simonovich, Bastevich and Sorokin, p. 166, pl. 4, fig. 3a-b.

1971 *Colchidites securiformis* Simonovich, Bastevich and Sorokin; Kakabadze, p. 81, pl. 17, fig. 4.

1997 *Colchidites securiformis* Simonovich, Bastevich and Sorokin; Immel *et al.*, p. 172, pl. 8, fig. 9.

Holotype: Georgian Institute of Academy of Science, No 36/ 1236, figured by Rouchadze, collected from Kutaisy, western Georgia.

Material: 65 specimens [TK 14-15/ 7, 8; TK 16-18/ 1, 2, 4-6, 8, 10, 14, 16; TK 18-20/ 1-3, 7-10; TK 20/ 2, 3, 5,15, 16; TAK 10/ 1, 2, 4-6, 9, 12, 15, 16, 17; TAK 11/ 1-10, 13-15; TAK 12/ 4, 6-10, 12, 15; TAK 14/ 3?, 5?, 8?; Am 5/ 6, 16, 17; Am 8/ 2, 3; Am 12/ 2, 4].

Description: Whorls are in contact: preserved whorls start at about 10 mm diameter and adjacent early whorls are helical, but poorly preserved. Planispiral whorl section rounded to sub-rectangular, venter seems flattened, but does not have a distinct margin. Primaries are straight or a little sinusoidal. They start from the umbilical area, then bifurcate in mid to upper third of the flank; some secondaries not attached to a primary. 40 secondary ribs at 17 mm diameter on the venter.

Discussion: Kakabadze (1971) reported that the first helical whorl in *M. securiformis* is loose and not in contact but this character cannot be examined easily in the Kopet Dagh examples. The ribs bend forward less in *M. securiformis* than in *M. tenuicostatus*.

Distribution: Georgia (Kakabadze, 1971) and Iran (Immel *et al.*, 1997).

Occurrence: Lower part of the Sarcheshmeh Formation in the Takal Kuh and Amand sections.

Martelites cf. *tinae* (Eristavi) 1955

Plate 3, Figures 14 & 15

cf. 1955 *Colchidites tinae* Eristavi, p. 121, pl. 4, fig. 11.

cf. 1971 *Colchidites tinae* Eristavi; Kakabadze, p. 52, pl. 4, fig. 2.

cf. 1997 *Colchidites tinae* Eristavi; Immel *et al.*, p. 174, pl. 8, fig. 7, 10.

Material: 26 specimens [TK 16-18/ 17, 19; TK 18-20/ pocket 2; TK 20/ 12, 13, pocket 2; TAK 9/ 5; TAK 10/ 7, 14; TAK 11/ 11,12; TAK 12/ 11; Am 1/ 6; Am 6/ 2, 4; Am 7/ 5; Am 9/ 14-16].

Holotype: Georgian Institute of Academy of Science, No 370/ 45, figured by Eristavi, collected from Niktosminda, western Georgia.

Description: Helical part is relatively clear. Whorl section round to sub-rectangular, venter seems flattened, but does not have a distinct margin. Primaries are slightly curved; they start from the umbilical area, then bifurcate in mid to upper third of the flank; some secondaries are not attached to the primary.

Discussion: *M. tinae* has a well-developed helix relative to other described species. The Iranian specimens show this character and are therefore compared with *M. tinae*.

Distribution: Georgia (Kakabadze, 1971) and Iran (Immel *et al.*, 1997).

Occurrence: Lower part of the Sarcheshmeh Formation in the Takal Kuh and Amand sections.

Martelites sp. 1

Plate 3, Figure 17

Material: 17 specimens [TK 16-18/ 7, 9, 11-13; TK 18/ 9, 10; TK 19/ 1, 3, 5; TAK 9/ 1, 2; TAK 10/11; TAK 12/ 1, 5; Am 2/ 1, 4; Am 3/ 2, 4, 7, 8; Am 4/ 2; Am 5/ 2, 4].

Description: Early whorls are not too clear but planispiral coiling more or less developed. Whorls section sub-quadrate. Primary ribs start from upper part of the umbilical border at a feeble tubercle. Secondaries alternate with primaries; most secondaries are free, commencing on the upper third to quarter of the flank.

Discussion: This species is separated from other *Martelites* described here by having straight ribs and more secondary ribs are intercalated than in other Kopet Dagh forms. The nearest described form is *Martelites ratshensis* Rouchadze (Kakabadze, 1971, pl. 12, fig. 5, pl. 14, figs. 2, 4, 5).

Occurrence: Lower part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Martelites sp. 2

Plate 3, Figure 16

Material: 11 specimens [TAK 9/ 4, 8, 10, 11; Am 1/ 2, 4; Am 3/ 5, 9,10; Am 4/ 7, 9].

Description: Early whorls are not clear but planispiral coils well developed. Ribs a little sinusoidal over the flanks and curve on the venter; secondaries either bifurcate or are intercalated or the upper third of the flanks.

Discussion: The nearest described form is *Martelites ellissoae* Kakabadze (1971, pl. 5, fig. 3) which, like the Kopet Dagh forms, has more strongly curve ribs than other *Martelites.*

Occurrence: Lower part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Superfamily Hoplitaceae H'Douville 1890

Family Douvilleiceratidae Parona & Bonarelli 1897

The Douvilleiceratidae embrace a group of strongly-ribbed, tuberculate, evolute ammonites in which the suture is characterised by a massive external saddle and broad, open first lateral lobe. They have a continuous record from the base of the

Barremian to the Mid Aptian times. They were probably derived from Ancylocerataceae (Wiedmann, 1966; Wright *et al.*, 1966).

Ornament appeared very early in the Douvilleiceratidae. Infrequent umbilical tubercles appear in the middle of the second whorl, but ribs develop later (Mikhailova, 1979).

Subfamily Cheloniceratinae Spath 1923

Phylogeny

Members of the subfamily Cheloniceratinae lived alongside Deshayesitidae and Parahoplitidae. They differ from the Roboloceratinae in the occurrence of two rows of spines on the flanks. Casey (1961c, p. 193) has shown that the evolution of the Cheloniceratinae starts with coarsely ribbed and fairly large *Procheloniceras*, passes through smaller, monotuberculate *Cheloniceras*, with frequent costation, and leads to the trituberculate *Epicheloniceras*. *Procheloniceras* appears in the *forbesi* Zone. *Cheloniceras* has an almost world-wide distribution, appearing in the *deshayesi* Zone and continuing to the base of the Upper Aptian. Its species coexisted with *Deshayesites* and *Dufrenoyia*. The trituberculate *Epicheloniceras* are practically confined to the base of the Upper Aptian but extended up to the top of the Aptian. Their association with this level has also been reflected in the zonal scale (Casey, 1961c).

Genus *Cheloniceras* Hyatt 1903

Type species: *Ammonites cornuelianus* d'Orbigny 1841, by designation of International commission on Zoological Nomenclature opinion 1956, p. 428.

Description: Moderately evolute, umbilicus fairly deep. Whorl section subrectangular to oval. Primary ribs originate at umbilical margin, secondary ribs start from lateral tubercles, tertiary ribs in some species intercalated between every two main ribs. Suture-line with very broad lateral lobe, deep and narrow ventral lobe and bifid external saddle.

Distribution: Europe, Russia, Iran, eastern Africa, South Africa, Madagascar, Japan, California, Texas, Mexico and southern America (Druschitz & Kudryutzeva, 1960; Szives, 1999; Wright *et al.*, 1996).

Age: Late Aptian (Wright *et al.*, 1996, p. 269).

Subgenus *Cheloniceras s.s.* Hyatt 1903

Discussion: *Cheloniceras s.s.* has umbilical and lateral tubercles only.

C. (*Cheloniceras*) spp.

Plate 3, Figures 18, 19 & 20

Material: 11 specimens [TK 58/ 11; TK 67; TK 68; TK 69; TAK 32/ 6; TAK 36/ 1, 2; TAK 38; TAK 45; TAK 48; TAK 49].

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR
TAK 36/ 2	66	25	0.37	23	0.34	16	0.24	0.92	36	
TAK 32/ 6	62	22	0.35	31	0.5	20	0.32	1.40	32	
TK 58/ 11	45	16	0.35						30	

Discussion: Samples TK 67, 68, 69 and TAK 38, 45, 48 49 were found in shales and only the early whorls remained, so they do not show good characters for species identification, but more than one species is represented. TK 58/ 11 is a distorted specimen. It is moderately involute, with a relatively deep umbilicus. Some ribs branch into two, with clear tubercles at the bifurcation point near to the umbilical margin. TAK 36/ 2 is a compacted specimen and shows similarity in rib pattern to TK 58/ 11, but the ribs are more densely spaced. TAK 32/ 6 and TAK 36/ 2 are not affected by compaction. Sample TAK 32/ 6 is moderately evolute, with a relatively wide umbilicus (one third of the diameter), steep umbilical wall, ovate to sub-rectangular whorl section, and flattened venter. The ribs are straight, and bifurcate, from the tuberculate umbilical margin. These specimens appear similar to *C.* (*Cheloniceras*) *meyendorfi* d'Orbigny (Casey, 1962, p. 222, pl. 36, fig. 4, text-fig. 74). Specimen TAK 36/ 2 is very evolute, but the rib pattern and whorl section match those of TAK 32/ 6. The specimens are accompanied by a *deshayesi* Zone assemblage.

Occurrence: Lower part of the Sanganeh Formation in Takal Kuh sections.

Subgenus *Epicheloniceras* Casey 1954

Type species: *Douvilleiceras tschernyschewi* Sinzow 1906.

Discussion: *Epicheloniceras* has ventro-lateral tubercles in the earlier whorls.

C. (*Epicheloniceras*) sp.

Plate 3, Figure 21

Material: 4 specimens [Sn 21/ 3, 5, 7].

Description: Moderately evolute, whorl section subrectangular, ventral margin flattened. Primary ribs start from upper part of the umbilical wall and bear lateral and ventral tubercles. Secondary ribs are intercalated between primaries; they are thinner than primaries, most of them are free and commence from upper part of the umbilical wall. All ribs are thicker over venter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR
Sn 21/ 3		27	0.42	25				0.92		
Sn 21/ 7		14		15				1.07		

Discussion: The ventro-lateral tubercles show that these specimens belong to *Epicheloniceras*. The specimens in sample Sn 21 are accompanied by *Acanthohoplites* and *Colombiceras* in the Sanganeh section. Bib 23 from the Bibahreh section is an external mould and appears with *Hypacanthoplites*.

Occurrence: Middle to upper part of the Sanganeh Formation in the Sanganeh and Bibahreh sections.

Superfamily Deshayesitaceae Stoyanow 1949

Family Deshayesitidae Stoyanow 1949

Phylogeny of the Deshayesitidae

The Deshayesitidae is the best ammonite family in the uppermost Barremian-Lower Aptian for biostratigraphy and correlation of stratigraphic sections in the Mediterranean-Himalayan Province. The family became extinct in mid Aptian times. The distinct and obvious characters of the genera and species of this family, which existed for a short time only, allowed a detailed biozonation for the Lower Aptian to be established in the last century (Casey, 1964; Bogdanova and Tovbina, 1994; Bogdanova and Mikhailova, 1999). For this reason the Early Aptian is considered the time of the Deshayesitidae.

Phylogenetic relationships among genera of the family Deshayesitidae and its descendants are still under question. Here phylogenetic trends of the family and evolution among the genera and species, with particular emphasis on the studied area, will be discussed.

The systematic position of the Deshayesitidae has changed dramatically during the past 40 years. Casey (1961c, pp. 173-174; 1964, pp. 289-291) reviewed earlier classifications where placing it in the Douvilleicerataceae (Ammonitina).

Wiedmann (1966) radically changed this classification by placing the family in a Superfamily Deshayesitaceae within the Suborder Ancyloceratina. In the revised Treatise (Wright *et al.,* 1996) this position is followed. Here, the genera, *Turkmeniceras, Prodeshayesites, Neodeshayesites, Burkhardtites* and *Kuntziella* are assigned to the subfamily Deshayesitinae. Bogdanova and Mikhailova (1999) subsequently placed the genera *Turkmeniceras*, *Deshayesites*, *Paradeshayesites*, *Dufrenoyia* and *Obsoleticeras* (gen. nov.) in the family Deshayesitidae. It seems that three genera, *Turkmeniceras*, *Deshayesites* and *Dufrenoyia* are common to all classifications.

The route by which the normally coiled Deshayesitidae evolved from heteromorph ammonites is still under discussion. It is uncertain whether *Deshayesites* originated from the Heteroceratidae (Wiedmann, 1966; Wright, 1981) through the evolutionary series *Heteroceras-'Colchidites'* (=*Martelites*)-*Turkmeniceras,* with a helicoid initial coil, or from the Hemihoplitidae via *Crioceratites-Hemihoplites,* with a spiral coil (Wiedmann, 1969) (Figure 3.5).

The similarity in whorl section, ornament, and close changes of the suture in the last *Martelites* and the first *Turkmeniceras,* confirms their relationship (Schindewolf, 1966; Kemper, 1967; Mikhailova, 1979) (Figure 3.4 & 3.5). *Turkmeniceras, Deshayesites* and *Dufrenoyia* may be similar in shell shape and ornament, but Bogdanova (1971a) who made a detailed study of them, believed some differences might be found between *Turkmeniceras* and the early *Deshayesites.*

The suture line has five lobes in the Deshayesitidae but their ancestors, Heteroceratidae, had four lobes. However, the fifth lobe is absent in the first whorl of the Deshayesitidae (Bogdanova and Mikhailova, 1999).

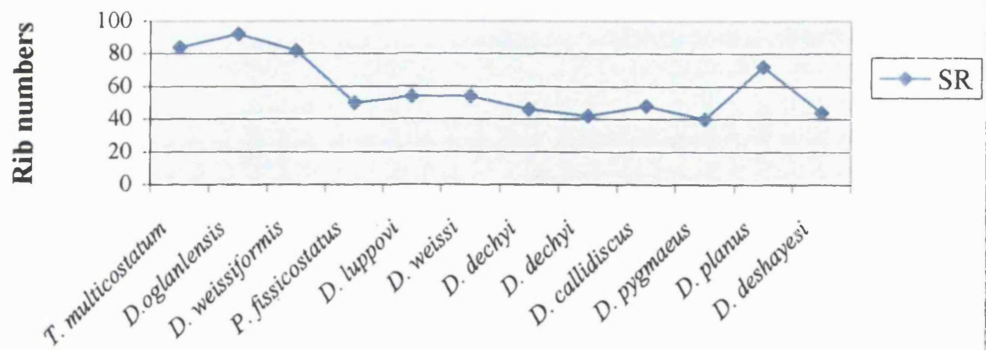
There is a series of developments in the genera of the family Deshayesitidae. *Turkmeniceras* has a moderately involute shell, with the first and second whorls just in contact, weakly sigmoidal ribs, flattened venter and only two inner lobes in the suture, instead of three or even four. An increase in the involution of the whorls and reduction in rib numbers are characteristic for *Deshayesites* (Bogdanova, 1971a; Mikhailova, 1979). *Dufrenoyia* is typified by a flattening of the venter, and development of a sharp inflection of the ribs along its margins (Casey, 1964). But the early growth stage of *Deshayesites* may also have a flattened venter. Thus small species of the two genera may be difficult to distinguish.

Here, the rib numbers of some typical species of the family Deshayesitidae have been examined as a phylogenetic feature. Specimens of nearly equal diameter were selected (Table 3.1). The table and graph show that overall the number of secondary ribs reduces with age (Figure 3.7). i.e. the younger species have less ribs than older ones. However, the secondary rib numbers in *D. planus* increase relative to previous ones.

Table 3.1. Primary and secondary rib numbers for some typical species of the family Deshayesitidae.

	Quoted Biozone	Diameter	PR	SR
Turkmeniceras multicostatum (Tovbina 1963)	*turkmenicum*	37.5	52	84
Deshayesites oglanlensis (Bogdanova 1983)	*tuarkyricus*	37.5	22	92
Deshayesites weissiformis (Bogdanova 1983)	*tuarkyricus*	39.5	20	82
Prodeshayesites fissicostatus (Casey, 1964)	*fissicostatus*	40	23	50
Deshayesites luppovi (Bogdanova 1983)	*weissi*	58	22	54
Deshayesites weissi (Bogdanova 1977)	*weissi*	37.2	20	54
Deshayesites dechyi (Bogdanova, Kvantaliani & Schrikadze, 1979)	*weissi*	34	28	46
Deshayesites dechyi (Bogdanova, 1977)	*weissi*	41.1	20	42
Deshayesites callidiscus (Casey, 1964)	*callidiscus*	35	18	48
Deshayesites pygmaeus (Casey, 1964)	*callidiscus*	36		40
Deshayesites planus (Casey, 1964)	*deshayesi*	35	24	72
Deshayesites deshayesi (Bogdanova, 1977)	*deshayesi*	38.8	22	44

Firgure 3.7. Secondary ribs numbers in some species of the family Deshayesitidae



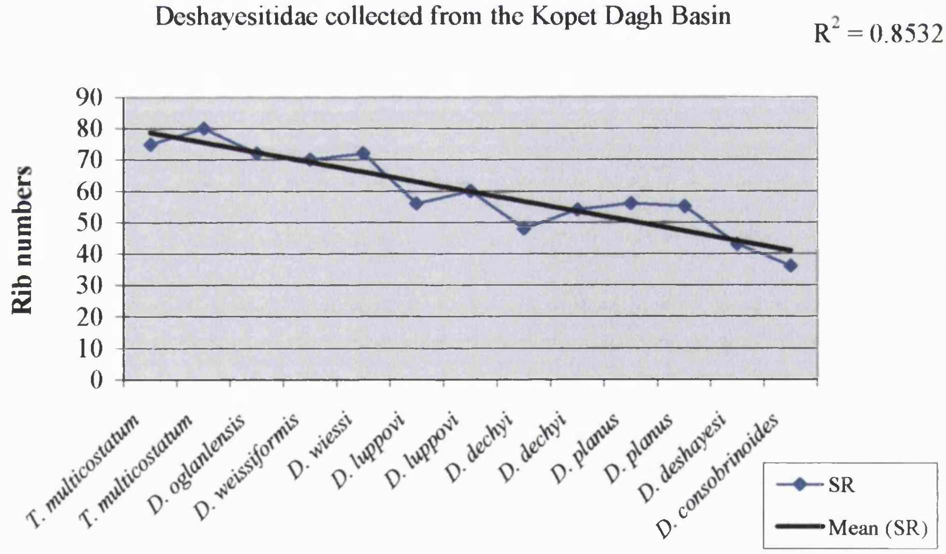
Analysis of samples from the Kopet Dagh confirmed that here too the ribs numbers reduce through the sequence in general (Table 3.2, Figure 3.8).

Table 3.2. Primary and secondary rib numbers for some species of Deshayesitidae in the Kopet Dagh Basin.

Table 3.2. Primary and secondary rib numbers for some species of Deshayesitidae in the Kopet Dagh Basin.

	Sample	Diameter	Primary rib	Secondary rib
Turkmeniceras multicostatum	TK 20/ 7	41.5	36	75
Turkmeniceras multicostatum	TK 21-22/ 4	32	42	80
Deshayesites oglanlensis	TAK 23/ 12	33.8	22	72
Deshayesites weissiformis	TAK 18/ 2	35	26	70
Deshayesites weissi	TK 52/ 3	29	24	72
Deshayesites luppovi	TK 46/ 21	40	22	56
Deshayesites luppovi	TAK 29/ 1	45	30	60
Deshayesites dechyi	TAK 32/ 1	32	26	48
Deshayesites dechyi	TK 46/ 6	40	24	54
Deshayesites planus	TAK 29/ 4	40	25	56
Deshayesites planus	Am 25/ 7	32	20	55
Deshayesites deshayesi	TAK 36/ 3	41.5	21	43
Deshayesites consobrinoides	TK 82/ 2	30	20	36

Figure 3.8. Secondary rib numbers in some species of the Deshayesitidae collected from the Kopet Dagh Basin



Subfamily Deshayesitinae Stoyanow 1949

Genus *Turkmeniceras* Tovbina 1963

Type species: *Turkmeniceras turkmenicum* Tovbina 1963, by original designation.

Suture has broad, shallow lobes; umbilical lobe slightly asymmetrical, umbilical lobe (U) located on umbilical shoulder or just on lateral side.

Discussion: This genus is distinguished from *Deshayesites*, *Prodeshayesites* and *Paradeshayesites* by the initial loose coiling and the presence of two inner lateral lobes instead of three or even four. In *Turkmeniceras* species the umbilical lobe (U) lies either on the umbilical wall or on the flank, near the umbilical shoulder, and it gradually shifts to the flank in almost all species of the genus.

In Bogdanova's (1971a) study of *T. geokdrense* Tovbina, she noted that the the initial whorl is in contact and there is no uncoiled-whorl stage, while in *T. turkmenicum* and its variants the initial whorls uncoil.

Distribution: Turkmenistan (Wright *et al.*, 1996) and Iran.

Age: Late Barremian (Wright *et al.*, 1996, p. 271).

Turkmeniceras multicostatum Tovbina 1963

Plate 4, Figures 1, 2, 3, 4, 5 & 14 a-c

1963 *Turkmeniceras multicostatum* Tovbina, p. 104, pl. 1, figs. 4a-b, 5.
1971a *Turkmeniceras multicostatum* Tovbina; Bogdanova, p. 22.

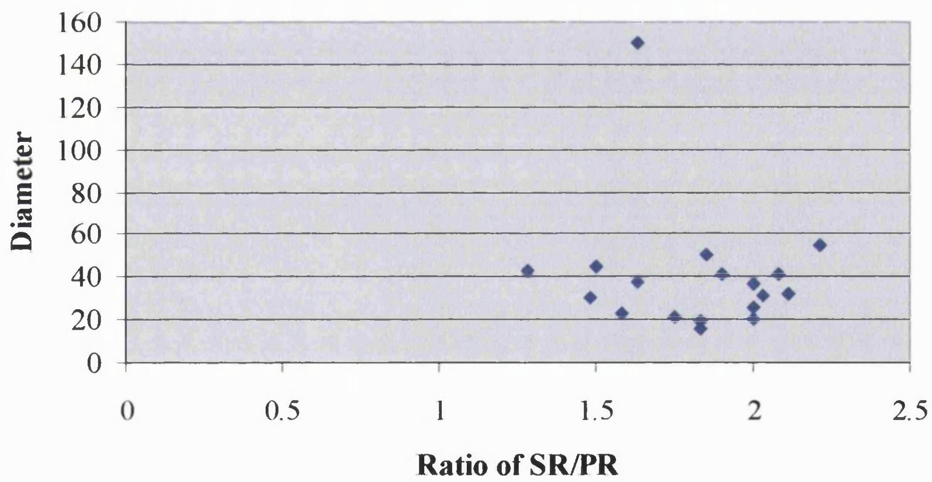
Holotype: Institute of Geology, St. Petersburg University, No. 5/ 8293, collected from Balkhan, Turkmenistan.

Material: 69 specimens [TK 14-15/ 11?, 12; TK 16-18/ 15, 18, 20?; TK 20/ 6,7, 8?, 9?, 10, 11; TK 21/ 1-3; TK 22/ 1-7; TK 21-22/ 1-4; TAK 13/ 1, 2, 4, 7, 11; TAK 14/ 2, 7, 9; TAK 15/ 1-7; TAK 16/ 1-3, 5-7, 9-13; Am 9/1-13; Am 10/ 1-4, 6, 10, 11; Am 11/ 5-11; Am 12/ 1, 3].

Description (Specimens up to 55 mm diameter except one of 150 mm): Shell slightly involute, umbilicus between about one third and a quarter of the diameter (U/D= 0.25-0.39). Whorls flanks nearly flat, whorl section sub-rectangular, slightly

Description (Specimens up to 55 mm diameter except one of 150 mm): Shell slightly involute, umbilicus between about one third and a quarter of the diameter (U/D= 0.25-0.39). Whorls flanks nearly flat, whorl section sub-rectangular, slightly compressed (WT/WH= 0.29-0.88), widest in the lower third of the flanks; venter broad and flat. Ribs dense, quite fine, and weakly sigmoidal, straight or curving forward slightly over the venter. Primaries start from the umbilical wall, secondaries originate two-thirds to three quarters of the way over the flank; some are attached to primaries, others are intercalated. There are 24-41 primary ribs and 44-72 secondary ribs at 15-30 mm diameter, rising to 33-70 and 67-104 at 30-50 mm. The secondary/primary ribs ratio varies from 1.28 to 2.21 (Figure 3.9). This figure that the ratio of SR/ PR is not related to diameter.

Figure 3.9. Relationship between diameter and ratio of SR/PR in *Turkmeniceras multicostatum*



Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Am 10/ 13	**150**	**55**	**0.36**	**21.4**	**0.14**	**53.3**	**0.35**	**0.38**	**41**	**67**	**1.63**
TK 21/ 2	**55**	**21**	**0.38**	17	**0.30**	7	**0.12**	**0.80**	**38**	**84**	**2.21**
TAK 14/ 7	**50**	**19**	**0.38**	7	**0.14**	**18**	**0.36**	**0.36**	**40**	**74**	**1.85**
TAK 13/ 4	**45**	**20**	**0.44**	9	**0.2**	**13**	**0.3**	**0.45**	**54**	**82**	**1.51**
TK14-15/11	**43**	**16**	**0.37**	6	**0.13**			**0.37**	**70**	**104**	**1.48**
TK 20/ 7	**41.5**	17	**0.40**	5	**0.12**			**0.29**	**36**	75	**2.08**

TAK 14/ 2	32	11	0.34			12	0.37		44	93	2.11
TAK 16/ 11	32	13	0.40			10	0.31		37		
Am 10/ 2	31.5	15	0.47	5.5	0.17	8	0.25	0.36	33	67	2.03
TAK 16/ 3	31	11	0.35	5	0.16	10	0.32	0.45			
TAK 16/ 9	30	12	0.4	10	0.33			0.83	54	80	1.48
TK 18-20/ 7	29	11	0.37			9	0.31		41		
TK 21-22/ 1	29	13	0.44			7	0.24		33		
TAK 16/ 13	26	10	0.38	4	0.15	9	0.34	0.4	36	72	2
TK 16-18/ 18	23	7	0.30	4	0.17	9	0.39	0.57	34	54	1.58
TAK 11/ 6	22	10.5	0.47	6	0.27	8	0.36	0.57	28		
TAK 11/ 6	22	10.5	0.47	6	0.27	8	0.36	0.57	28		
TAK 13/ 2	21	10	0.47	5	0.23	7	0.33	0.5	32	56	1.75
TK 22/ 2	20	9	0.45			6	0.3		35		
TAK 13/ 11	20	8	0.4			7	0.3		36	72	2
TK 21/ 3	19	8	0.42			5	0.26		36	66	1.83
Am 9/ 2	19	7.5	0.39	5.5	0.28	5.5	0.28	0.73			
TAK 16/ 14	19	7	0.36	5	0.26	6	0.31	0.71			
TAK 13/ 7	18	9	0.5			6	0.33		36		
Am 9/ 1	17	10	0.58	6	0.35	5	0.29	0.6	26		
Am 9/ 3	16	6	0.37	5	0.31	5.5	0.34	0.83	24	44	1.83
Am 9/ 10	15	6	0.4			4.5	0.3				
Am 9/ 4	14	6	0.42	4.5	0.32	4	0.28	0.75	24		
Am 9/ 5	13.5	6	0.44	4.5	0.33	4.5	0.33	0.75			
Am 9/ 12	13	7	0.53	5	0.38	3.5	0.26	0.71			
Am 9/ 13	12	4.5	0.37	4	0.33	4	0.33	0.88			
TK 20/ 8		15.5		8.5				0.54			
TK 20/ 9		26		10.5				0.40			
TK 21/1		18		7.5				0.41			
TK 22/ 3		21		9				0.42			
TK 22/ 4		11		7				0.63			
TK 22/ 5		14		7				0.5			
TK 22/ 7		20		9				0.45			
Am 9/ 6		6		5				0.83			
Am 9/ 7		9		6				0.66			
Am 9/ 8		6		5				0.83			
Am 9/ 9		6.5		5				0.76			
Am 9/ 11		10		5				0.5			
TAK 15/ 3		12		10				0.83	~40		
TAK 15/ 5		15		7				0.46	39	93	2.38
Holotype	37.5	15.3	0.40	10.5	0.28	13.4	0.35	0.68	52	84	1.61

Discussion: most of the material is under 40 mm diameter, as is the holotype. A much larger specimen of 150 mm diameter shows half a whorl of body chamber, and here the number of secondary ribs diminishes until eventually most primaries remain single and they are much coarser (Pl. 4, Fig. 5). The earlier whorls of this specimen closely match the other specimens in rib pattern and density. The number of ribs in most specimens is close to that in the holotype. However, one specimen (TK 14-15/ 11) is much more finely ribbed and is only provisionally included in the species.

Incomplete specimens, especially if the early stages and suture lines are unclear, can be confused with *T. rarecostatum*, except that *T. multicostatum* is more finely ribbed.

Distribution: Kopet Dagh (Turkmenistan (Tovbina, 1963; Bogdanova, 1971a) and Iran).

Occurrence: In the lower part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Turkmeniceras cf. *tumidum* Bogdanova 1971
Plate 4, Figures 6, 7, & 8

cf. 1971a *Turkmeniceras tumidum* Bogdanova, p. 342, pl. 6, fig. 5.
cf. 1999 *Turkmeniceras tumidum* Bogdanova; Bogdanova and Prozorovsky, pl. 2, figs. a-b.

Holotype: F. N. Chernyshev Central Geological Museum, TsGM 5/ 10096, from Tuarkyr in the area of the Gobekadzhi wells, Turkmenistan.

Material: 21 specimens [TK 20/ 1; TAK 13/ 3, 5, 6, 8, 10, 12, 13, 14; TAK 14/ 1, 4; TAK 16/ 4, 8; Am 10/ 5, 7, 9, 12; Am 11/ 1-4].

Description: Most specimens are at least partially crushed so that exact whorl proportions are often indeterminate. Shell slightly involute, umbilical area is more than one third of the diameter. Whorl section sub-rectangular, flanks parallel and flat, venter curved. Ribs straight or weakly sigmoidal; primaries start on the umbilical wall, secondaries branch or are intercalated at about mid flank, though sometimes migrating from the lower third of the flanks to the upper third of the flanks during growth. On the venter all ribs are directed slightly forward. Between 24-40 primary ribs and 60-90 secondary ribs occur at 21-90 mm diameter. The suture line is not visible.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 14/ 1	90	40.5	0.45	12	0.13	32.5	0.36	0.29	33	60	1.81
TK 20/ 1	74.7	24	0.32	12	0.16	28	0.37	0.5	24	66	2.75
Am 11/ 1	69	26	0.37	10	0.14	25	0.36	0.38	40	90	2.25
Am 10/ 12	57.5	29	0.5			21	0.36		38		
TAK 16/ 4	43	27	0.62	9	0.20	16	0.37	0.33	39	78	2
TAK 13/ 8	31	11	0.35	5	0.16	8	0.25	0.45	30	45	1.5
TAK 13/ 6	24	10	0.41		0	9	0.37	0	30		
Am 10/ 5	22.3	10.5	0.47			8.5	0.38				
TAK 14/ 4	21.7	8	0.36			8	0.36				
TAK 16/ 8		22		7				0.31			
Am 11/ 3		21		10				0.47			
Am 11/ 2		19		5.5				0.28			
Am 10/ 9		21		14				0.66			
Holotype	80.7	32.6	0.4	28	0.34	25.2	0.31	0.85	22	58	2.64

Discussion: *T. tumidum* differs from other species by its coarser more widely spaced primary ribs. Sometimes the venter is flat and broad and looks like that of *T. rarecostatum.*

Distribution: Kopet Dagh (Turkmenistan (Bogdanova, 1971a; Bogdanova and Prozorovsky, 1999) and Iran).

Occurrence: In the lower part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Genus *Deshayesites* Kazansky 1914

Type species: *Ammonites deshayesi* Leymerie in d'Orbigny 1841, by original designation.

Generic characters: Shell discoidal, semi-involute, flanks and venter flattened or a little convex. Body chamber about half a whorl in length. Umbilical width from one-fifth to more than one-third the diameter. Ribs sigmoidal, curving forward on venter. Primaries start at umbilicus and secondaries are intercalated or branch from the primaries. Peristome sinusoidal. Suture line with trifid lobes, the first one moderately deep, and simplified auxiliary elements.

Discussion: Casey (1964, p. 292) noted that Kazansky (1914) introduced *Deshayesites* as a subgenus of *Hoplites*, for species now distributed among *Deshayesites*, *Prodeshayesites* and *Dufrenoyia*. He also pointed out that *Prahoplitoides* Spath (1922, p. 111) is an objective synonym of *Deshayesites*, while references in Canadian literature to species of *Deshayesites* (Mclearn, 1932; Warren, 1937) are based on the occurrence of the Albian genus *Subarcthoplites* Casey. The Colombian species described by Riedel (1937) as *Deshayesites stutzeri*, *D. nodosus*, *D. rotundus* and *D. colombianus* are more closely related to *Dufrenoyia* than to *Deshayesites* (Casey, 1965).

Distribution: The genus is characteristic of the Lower Aptian and recorded from Europe, Greenland, Russia and the Arctic (Druschitz and Kudryutzeva, 1960; Wright *et al.*, 1996), and Iran.

Age: Early Aptian (Wright *et al.*, 1996, p. 271).

Deshayesites cf. *tuarkyricus* Bogdanova 1983

Plate 4, Figure 9

nom. nud. cf. 1979 *Deshayesites tuarkyricus* Bogdanova, pl. 2, fig. 2.

cf. 1983 *Deshayesites tuarkyricus* Bogdanova, p. 132, pl. 1, figs. 1-4, pl. 2, fig. 4.

cf. 1999a *Deshayesites tuarkyricus* Bogdanova; Cecca, Dhondt & Bogdanova, figs. 6c-d.

cf. 1999 *Deshayesites tuarkyricus* Bogdanova; Bogdanova and Prozorovsky, pl. 3, figs. a-c.

Material: 3 specimens [TK 34/ 2; TAK 17/ 4; TAK 18/ 1].

Holotype: St. Petersburg Museum, No. 1/ 9442, from Taurkyr and Lausan, Turkmenistan.

Description: The specimens are incomplete and partially crushed. Shell moderately evolute, coiling being open in the last whorl. Whorl section sub-rectangular, venter flat and broad. Ribs dense and fine; primary ribs originate from the umbilical edge and are coarser and stronger on the upper third of flanks; every primary rib has two secondary ribs, which start from mid flank.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 18/ 1	32	16	0.49			8.5	0.27				
TAK 17/4	20	9	0.45	6	0.3		0	0.67			
TK 34/ 2		12		10.5				0.88			
Holotype	91	46	0.51	24.3	0.268	17	0.19	0.53	28	122	4.36

Discussion: Identification is not easy and the specimens are similar to *Turkmeniceras* and to *D. oglanlensis.* However they differ in their rib pattern. The ribs are more sigmoidal in *D. tuarkyricus* than in *Turkmeniceras.* They are stronger in *D. oglanlensis* in mid flank and have umbilical bullae. *D. tuarkyricus* has previously been reported only from Turkmenistan. It appears to be endemic to the Kopet Dagh basin.

Distribution: Kopet Dagh (Turkmenistan (Bogdanova, 1983), Iran).

Occurrence: In the lower part of the Sarcheshmeh Formation in Takal Kuh sections.

Deshayesites oglanlensis Bogdanova 1983

Plate 4, Figures 10 & 11

nom. nud. cf. 1979 *Deshayesites oglanlensis* Bogdanova, pl. 2, fig. 5.

1983 *Deshayesites oglanlensis* Bogdanova, p. 136, pl. 2, figs. 5-9, text-figs. 5-6.

1995 *Deshayesites oglanlensis* Bogdanova; Delanoy, p. 74, pl. 9, fig. 1.

1999 *Deshayesites oglanlensis* Bogdanova; Avram, p. 441, fig. 4a-b.

1999 *Deshayesites oglanlensis* Bogdanova; Bogdanova & Prozorovsky, pl. 3, figs. d-e.

1999 *Deshayesites oglanlensis* Bogdanova; Ropolo, Gonnet & Conte., p. 177-178, pl. 17, figs. 1-2.

Material: 50 specimens [TK 33/ 1-6; TK 34/1; TK 43/ 1, 3-6, 8-10; TK 44/ 1; TK 46/ 9, 20; TK 48/ 5, 17, 18, 21; TAK 17/ 6, 10, 13; TAK 18/ 6, 9; TAK 19?; TAK 21/ 1; TAK 22/ 1; TAK 23/ 1-3, 5-10; .TAK 24/ 1-8; TAK 25/ 1; Am 13/ 3].

Holotype: St. Petersburg Museum, No. 12/ 9442. Figured by Bogdanova, from Balkhan, Turkmenistan.

Description: Moderately involute, umbilicus about a quarter to one third of diameter (U/D= 0.21-0.35), whorl section sub-rectangular, venter rounded and narrow, flanks a little flattened. Ribs fine and dense, fasciculate, their relief is weaker in the middle part of the sides; primary ribs arise in pairs from well-marked peri-umbilical bullae, and bifurcate or trifurcate at mid flank. There are between 19-28 primary ribs and 56-102 secondary ribs per whorl in 12-53 mm diameter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 17/ 10	53.3	24.2	0.45			13	0.24				
TK 44/ 1	41	19.2	0.46			9	0.22				
TAK 23/ 2	37	17.7	0.47			8.5	0.23		24	102	4.25
TAK 23/ 3	34	14.7	0.43	4		7	0.21	0.27			
TAK 23/ 12	33.8	15	0.44	5		9.2	0.27	0.33	22	72	3.27
TK 43/ 6	31	14	0.45			8	0.26				
TAK 23/ 6	30.7	13	0.42			10	0.33				
TK 34/ 1	30.5	12.4	0.40			9	0.3		22	70	3.18
TAK 23/ 9	30.5	14.5	0.47	5		8	0.26	0.34	24		
TK 43/ 1	29	15	0.51			9	0.31		20		
TAK 23/ 10	29	12.7	0.43			7	0.24				
TAK 17/ 13	28.6	32	1.11	8.6		8.7	0.3	0.27	22	80	3.64
TK 48/ 17	26.2	12	0.45	4	0.15		0	0.33			
Am 16/ 2	26	11.8	0.45			5.7	0.22		28	75	2.68
TK 43/ 10	25.5	11.5	0.45	4	0.16	5	0.2	0.35	19	60	3.16
TK 46/ 9	25	12.8	0.51			6	0.24				
TAK 24/ 5	25	12.3	0.49	4		6	0.24	0.33	21	60	2.86

TK 43/ 5	23	14	0.60			5	0.22				
TAK 23/1	23	9.7	0.42			6	0.26				
TK 43/ 9	22	11.5	0.52			5.3	0.24				
TAK 17/ 6	22	10	0.45	4.5	0.2	7	0.32	0.45	27	73	2.7
TK 48/ 18	21	10.5	0.5	4.5	0.21	7.5	0.36	0.43	19		
TAK 24/ 1	20	7.3	0.36			6.3	0.32		20	60	3
TK 33/ 1	19.5	10	0.51			5.5	0.28				
TAK 24/ 8	19	9.5	0.5	3		5	0.26	0.32	21	60	2.86
TK 33/2	17	8	0.47			4.5	0.26				
TK 43/ 3	16	7	0.43			5.5	0.34		20	56	2.8
TK 33/ 5		17.5		5.2				0.3			
TK 43/ 8		24				13					
TK 46/20		11		7.3				0.66			
TK 48/ 5		17		7				0.41			
Holotype	37.5	17	0.46	8.4	0.22	10.6	0.28	0.49	22	92	4.18

Discussion: *Deshayesites oglanlensis* is a characteristic form of the *D. tuarkyricus* Zone (Bogdanova, 1979, 1983). Delanoy (1995) reported the density of ribs in *Deshayesites oglanlensis* as being greater than in *Deshayesites tuarkyricus*. Avram (1999) believed that Delanoy's specimens are more closely related to *Deshayesites planicostatus* but they are retained here in *Deshayesites oglanlensis*. *D. oglanlensis* is similar to *D. callidiscus* but has finer ribs in the inner whorls.

Distribution: Lowermost Aptian in France (Delanoy, 1995), Turkmenistan (Bogdanova, 1979, 1983) and Iran. Avram (1999) recorded *D.* aff. *oglanlensis* in an assemblage ammonite fauna from the *forbesi* or *weissi* Zone in Romania.

Occurrence: Middle part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Deshayesites cf. *weissiformis* Bogdanova 1983

Plate 4, Figure 12, 15

cf. 1983 *Deshayesites weissiformis* Bogdanova, p. 134, pl. 2, figs. 1-3, pl. 3, fig. 7, text figs. 3, 4.

cf. 1995 *Deshayesites weissiformis* Bogdanova; Delanoy, p. 74, pl. 5, fig. 2.

cf. 1999 *Deshayesites weissiformis* Bogdanova; Avram, p. 440-441, figs. 3a-c.

cf. 1999a *Deshayesites weissiformis* Bogdanova; Cecca, Dhondt & Bogdanova, p. 278, pl. 6, figs. 2, 3.

cf. 1999 *Deshayesites weissiformis* Bogdanova; Ropolo, Gonnet & Conte, p. 179, pl. 18, fig. 3.

Material: 38 specimens [TK 25/ 1-6; TK 26/ 1-2?; TK 27/ 1-2?;TK 28?; TK 30?; TK 43/ 2, 7; TAK 17/ 1-3, 7, 9; TAK 18/ 2-5, 7, 8; TAK 20?; TAK 24/ 9, 10; Am 14/ 1-4; Am 15/ 1-6; Am 16/ 2, 11].

Holotype: St. Petersburg Museum, No. 7/ 9442, from Taurkyr, Turkmenistan.

Description: Some specimens are compressed and broken. Moderately involute, umbilical area between one third and one quarter of diameter. Whorl section sub-rectangular, flanks parallel, venter flat and broad. Primary ribs start from the upper part of the umbilical wall, bear tubercles around the umbilical margin, and bifurcate about a quarter of the way over the flank; secondaries are the same thickness as the primaries. Some secondary ribs are intercalated between branches, starting nearly half-way over the flanks. All ribs curve forward on the upper part of the flank, but run straight over the venter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 17/ 3	60.5	19	0.31	10.8	0.18			0.57			
Am 22/ 2	55.5	23	0.41	17.7	0.32			0.77			
Am 22/ 3	52	21.5	0.41	15	0.29			0.7			
TAK 18/ 4	47.5	18.5	0.39		0	14	0.29				
Am 18/ 1	40	17.5	0.44	11	0.28			0.63			
Am 18/ 5	39	19.5	0.5	10.5	0.27			0.54			
Am 15/ 1	38	16	0.42	11	0.29			0.69			
TAK 18/ 2	35	15	0.43	5.6	0.16	9.4	0.27	0.37	26	70	2.69
Am 16/ 11	32.5	51.6	0.44	5		8.2	0.25	0.34			
Am 15/ 3	32	15	0.47	8	0.25			0.53			
TAK 18/5	31.6	14.5	0.46	5	0.16	10.5	0.33	0.34			
TAK 18/ 3	31.5	12	0.38	4	0.13	10	0.32	0.33	~30	~82	2.73
TK 25/ 5	19	7	0.37	3	0.16	5	0.26	0.43			
TK 25/ 2		14		7.5				0.54			
TK 25/ 3		9		3.5				0.39			
TK 25/ 4		9		3				0.33			

TK 28		23		6				0.26			
TK 25/ 1		26		10				0.39			
TAK 17/ 1		26.4		14.6				0.55	~39	~70	1.79
TAK 17/ 2		15				12					
TAK 24/ 9		18.5		11.5				0.62			
TAK 24/ 10		18		8.8				0.49			
Holotype	111	51.6	0.47	32.7	0.3	26.9	0.24	0.63	24	94	3.92

Discussion: The species is similar to *D. oglanlensis* and sometimes cannot be easily separated. The width of umbilicus in *D. weissiformis* is a little greater than in *D. oglanlensis*. Moreover the number of ribs in *D. weissiformis* is a little less than in *D. oglanlensis* at the same diameter.

Distribution: France (Delanoy, 1995), Romania (Avram, 1999) Turkmenistan (Bogdanova, 1983), and Iran.

Occurrence: Middle part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Deshayesites cf. *euglyphus* Casey 1964

Plate 4, Figure 13

cf. 1964 *Deshayesites euglyphus* Casey, p. 336-337, pl. 52, figs. 1-4, pl. 56, fig. 1a-b.
cf. 1999 *Deshayesites euglyphus* Casey; Bogdanova, pl. 2, fig. 7.
cf. 1999 *Deshayesites euglyphus* Casey; Bogdanova & Prozorovsky, pl. 4, fig. a, d-f.

Material: 7 specimens [TK 34/ 3, TK 48/ 22, TAK 22/ 2, TAK 23/ 4, Am 13/ 1, 2, 4].

Holotype: Reading University, Geology Dept., No. 6958, from Atherfield Clay Series, Atherfield, Isle of Wight, UK.

Description: The specimens are fragmentary. The early whorls are not preserved. Moderately evolute. Whorl section subrectangular, flanks parallel. Primary ribs start from the upper part of the umbilical wall, secondary ribs branch from the primaries or are intercalated in the lower third of the flank to mid flank; ribs flatter and bend forward more on the venter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TK 48/ 22		30		9				0.3	21	45	2.14
TAK 22/ 2		28.5		9				0.32	18	36	2
TK 34/ 3		27.4		10.5				0.38			
TAK 23/ 4		20		7				0.35			
Am 13/ 2		20		6				0.3			
Holotype	66	29	0.44	19.8	0.3	18.4	0.28	0.68			

Discussion: According to Casey (1964) there are some similarities between *D. euglyphus* and *D. kiliani*, but the latter has a narrower umbilicus and more frequent ribs. The Kopet Dagh specimens compare with *D. euglyphus*, but the ribs are a little more flattened in the ventral area.

Distribution: England (Casey, 1964), Turkmenistan (Bogdanova, 1999) and Iran.

Occurrence: Middle part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Deshayesites luppovi Bogdanova 1983

Plate 5, Figures 1, 2 & 3; Plate 6, Figure 14

1952 *Deshayesites* aff. *dechyi* Papp; Luppov, p. 203, pl. 8, fig. 1.

nom. nud. 1971b *Deshayesites luppovi* Bogdanova, p. 22.

1983 *Deshayesites luppovi* Bogdanova, p. 139, pl. 3, figs. 1-6.

1999 *Deshayesites luppovi* Bogdanova; Avram, p. 447, figs. 5f-g.

1999 *Deshayesites luppovi* Bogdanova; Bogdanova, pl. 1, fig. 10.

1999 *Deshayesites luppovi* Bogdanova; Bogdanova & Prozorovsky, pl. 3, fig. f.

1999 *Deshayesites luppovi* Bogdanova; Ropolo, Gonnet & Conte, p.178-179, pl. 16, figs. 4-5.

Holotype: St. Petersburg Museum, No. 23/ 9442, from Kobadag, Turkmenistan.

Material: 62 specimens [TK 45/ 1-2; TK 45-48/ 1-7; TK 46/ 1, 4, 10, 11, 15, 16, 18, 21-27; TK 48/ 1-4, 10, 12, 16; TK 58/ 3, 6; TAK 17/ 5, 6, 8; 11; TAK 29/ 1-3; TAK 30/1, 3, 4; TAK 31/3; TAK 33/1; Am 16/ 3-5, 6-9, 10?, 11-13; Am 17/ 1, Am 25/ 1, 2, 5].

Description: Moderately involute, umbilicus about one third of diameter. Whorl section rounded to sub-rectangular, the thickest part in the lower part of the flank, a little compressed, venter flat and broad, umbilical wall steeply rounded. Ribs sigmoidal; primaries start from upper part of the umbilical wall, then curve strongly backwards on the lower third of the flanks, where they are thicker and stronger. Secondaries at first are irregularly intercalated between primaries, either in ones or twos, on the lower third of the flank, some fusing with adjacent primaries. With further growth ribbing became more regular, single secondaries branching at a low angle from primaries just above mid flank. Near the ventral margin all ribs widen suddenly and cross the venter as a broad and flat ridge. There are 16-30 primary ribs and 46-63 secondary ribs at 40-105 mm diameter, The secondary/primary ribs ratio varies from 2 to 2.86.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TK 45/ 1	**105**	**50**	**0.48**	**28.5**	**0.27**	**29**	**0.28**	**0.57**	**23**	**47**	**2.04**
TK 48/ 3	**82**	**34**	**0.41**	**12**	**0.15**	**24**	**0.29**	**0.35**	**22**	**63**	**2.86**
TAK 30/ 1	**62**	**28**	**0.45**	**9**	**0.15**	**19**	**0.31**	**0.32**	**22**	**54**	**2.45**
TK 48/ 2	**60**	**21**	**0.35**	**12.5**	**0.21**	**20**	**0.33**	**0.6**	**24**	**60**	**2.5**
TK 46/ 19	**60**	**25**	**0.42**	**9**	**0.15**	**17**	**0.28**	**0.36**			
TK 45/ 2	**51**	**21**	**0.41**	**16**	**0.31**	**10**	**0.2**	**0.76**	**23**	**46**	**2**
TAK 29/ 1	**45**	**18**	**0.4**		**0**	**14**	**0.31**	**0**	**30**	**54**	**1.8**
TK 46/ 11	**42**	**18**	**0.43**	**6**	**0.14**	**12**	**0.29**	**0.33**	**22**	**54**	**2.45**
TK 46/ 10	**40**	**18**	**0.45**		**0**	**12**	**0.3**	**0**	**16**		
TK 46/ 21	**40**	**18**	**0.45**	**8.5**	**0.21**	**12**	**0.3**	**0.47**	**22**	**56**	**2.55**
TK 53/ 1	**39**	**18**	**0.46**		**0**	**13**	**0.33**	**0**			
Am 17/ 1	**37**	**14**	**0.38**		**0**	**12**	**0.32**				
TK 46/ 24	**28**	**13**	**0.46**	**7**	**0.25**	**10**	**0.36**	**0.54**			
TK 48/ 16	**26**	**11**	**0.43**		**0**	**7**	**0.27**	**0**			
TK 46/ 22		**18**		**7**				**0.39**			
TK46/ 23		**18**		**6**				**0.34**			
TK 48/ 1		**18**		**8.5**				**0.47**	**24**		

TK 48/ 4		**26**		**11**				**0.43**				
TK 48/ 12		**19**		**6**				**0.32**				
TK 48/ 15		**13**		**6**				**0.45**				
TK 46/ 15		**22**		**14.5**				**0.66**				
TK 46/ 16		**22**		**10.5**				**0.48**				
TK 46/ 17		**24**		**10**				**0.42**				
TK 46/ 18		**22**		**10**				**0.45**				
TK 46/ 26		**18**		**7**		**15**		**0.39**	**22**	**40**	**1.82**	
TK 46/ 27		**28**		**11.5**				**0.41**				
TAK 30/ 3		**22**		**9**		**15**		**0.41**				
Am 16/ 3		**54**		**25**				**0.47**				
Holotype	**58**	**21**	**0.36**	**15**	**0.26**	**18**	**0.31**	**0.7**	**22**	**54**	**2.45**	

Discussion: The specimens are comparable in rib pattern and width of umbilicus with the holotype. In other dimensions, some specimens resemble *Deshayesites forbesi*. The two species appear very similar though the rib pattern of *Deshayesites forbesi* seems more regular than that of *Deshayesites luppovi*. Some incomplete specimens are similar to *Deshayesites pappi*, but in the latter species the secondary ribs appear in the upper part of flanks.

Distribution: Lower Aptian France (Ropolo *et al.*, 1999), (*weissi* Zone) in Romania (Avram, 1999), the northern Caucasus and Turkmenistan (Bogdanova, 1971, 1983, 1991), and Iran.

Occurrence: Middle part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Deshayesites weissi (Neumayr & Uhlig 1881)

Plate 4, Figure 16

1881 *Hoplites weissi* Neumayr & Uhlig, p.179, pl. 46 fig. 1, pl. 47, fig. 1.

1902 *Hoplites (Deshayesites) weissi* Neumayr & Uhlig; von Koenen, p. 207, pl. 45, fig. 1.

1960 *Deshayesites weissi* (Neumayr & Uhlig); Druschitz and Kudryutzeva, p. 310, pl. 1, fig. 1.

1971b *Deshayesites weissi* (Neumayr & Uhlig); Bogdanova, p. 22.

1977 *Deshayesites weissi* (Neumayr & Uhlig); Bogdanova, p. 47, pl. 1, figs. 1-4; pl. 4, fig. 6.

?1999 *Deshayesites weissi* (Neumayr & Uhlig); Avram, p. 439, figs. 2a-c.

1999 *Deshayesites weissi* (Neumayr & Uhlig); Bogdanova & Prozorovsky, pl. 4, figs. b-c.

Syntypes: Both the specimens figured by Neumayr and Uhlig (1881) are lost; one was in the Schloenbach collection in the Königlichen Geologischen Landesanstalt, Berlin, and the other was in the Geologischen Reichsanstalt, Vienna. A Neotype should be designated from appropriate German material.

Material: 39 specimens [TK 48/ 6-9, 11-13?; TK 50/ 2-4; TK 52/ 2-10; TAK 27/ 1-3; TAK 28/ 1-3; TAK 30/ 2; TAK 31/ 1-2; TAK 32/ 1, 3, 4; TAK 33/ 1; TAK 36/ 22; Am 18/ 1-6; Am 22/ 1-3].

Description: Some specimens are compressed and broken. Moderately involute, umbilicus between one third and one quarter of the diameter (U/D= 0.25-0.35). Whorl height more than whorl thickness, venter broad and convex, flanks sub-parallel, umbilical wall steep. Sigmoidal ribs start from the umbilical wall, bifurcate one third to half way over the flanks, while other secondary ribs are intercalated at the some level. Ribs curve forward over the venter. In small specimens ribs are more dense than in larger ones. There are between 22-36 primary ribs and 40-98 secondary ribs per whorl at 24-145 mm diameter. The secondary/primary ribs ratio varies from 1.82 to 4.08.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 32/ 4	145	53.5	0.37	18.5	0.13	51	0.35		30	68	2.27
Am 22/ 2	56	25	0.45	10	0.18	18	0.32	0.4	28		
Am 22/ 3	54	23	0.43			18	0.33				
TK 48/ 8	49	22.5	0.46	8	0.16	12.5	0.26	0.35	22	59	2.68
Am 15/ 1	45	20	0.44			11	0.24				
Am 18/ 1	40	18	0.45			13	0.33				
Am 18/ 5	38	19	0.5			10	0.26		22	40	1.82
TK 50/ 2	35	15	0.42			8.2	0.23				

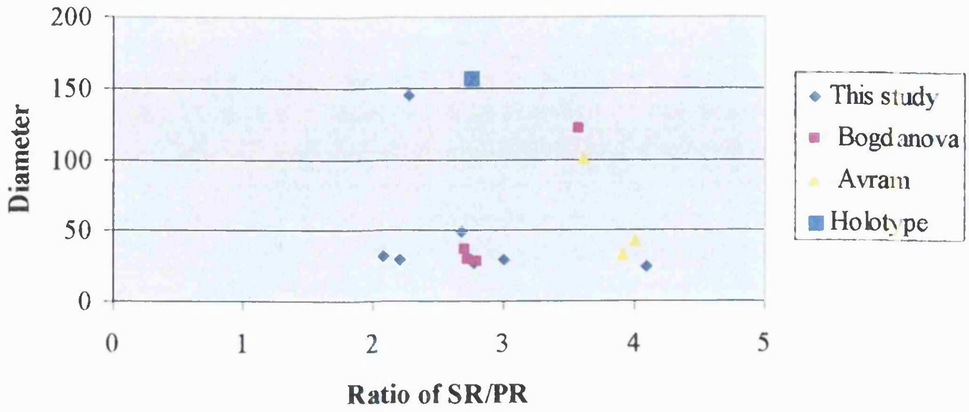
TK 52/ 5	32.5	15	0.46	8	0.25	8	0.25	0.53		70	
TAK 32/ 1	32	14.7	0.46			9.5	0.3		26	54	2.08
TK 52/ 7	30	13	0.43	6	0.2	8.5	0.28	0.46	30	66	2.2
TK 52/ 3	29	11	0.38	9	0.31			0.81	24	72	3
TK 48/ 9	27.5	14.5	0.53	5	0.18	7	0.25	0.34	26	72	2.77
TAK 31/ 1	24.3	11.6	0.48			6.3	0.26		24	98	4.08
Am 18/ 3	19	8	0.42			5	0.26				
TK 50/ 3	12.2	6	0.49			3	0.25				
TK 48/ 6		14		6				0.42			
TK 48/ 11		19		5				0.26			
TK 48/ 13		11.5		4.7				0.40			
TK 28/ 1		24		10.2				0.42	27	45	1.67
TAK 28/ 2		23		11				0.47	36	58	1.61
TAK 27/ 1		26				17					
TAK 27/ 3		22		9				0.40			
Syntype	157	71	0.45	40	0.25	38	0.24	0.56	34	93	2.74

Discussion: The material shows most characters of the species. The ratio of SR/PR in *D. weissi* has been analysed (Table 3.3, Figure 3.10). The data shows that the ratio of SR/PR in the study area samples and in Bogdanova's samples are similar and their averages are near to the holotype, but Avram's samples from Romania differ.

Table 3.3. Comparison of ratio of SR/ PR in *D. weissi* in this study and two published papers.

SR/PR (this study)	**D (this study)**	**SR/PR (Bogdanova)**	**D (Bogdanova)**	**SR/PR (Avram)**	**D (Avram)**	**SR/PR (Holotype)**	**D (Holotype)**
4.08	24.3	2.8	28.6	3.9	33.4	2.74	157
2.77	27.5	2.73	30	4	43		
3	29	2.7	37	3.61	101		
2.2	30	3.57	121.6				
2.08	32						
2.68	49						
2.27	145						

Figure 3.10. Relationship between diameter and ratio of SR/PR in *Deshayesites weissi*



Distribution: Germany (von Koenen, 1902), Romania (Avram, 1999), Russia (Druschitz and Kudryutzeva, 1960), Turkmenistan (Bogdanova, 1977) and Iran.

Occurrence: Middle part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Deshayesites dechyi Papp 1907

Plate 4, Figures 4, 5 & 6

1907 *Parahoplites dechyi*; Papp, p.171, pl. 9, figs. 1-5.

1952 *Deshayesites dechyi* Papp; Luppov, p. 204, pl. 7, figs. 2-4.

1960 *Deshayesites dechyi* Papp; Druschitz & Kudryutzeva, p. 310, pl. 1, fig. 6.

1977 *Deshayesites dechyi* Papp; Bogdanova, p. 50, pl. 2, figs. 1-5.

1979 *Deshayesites dechyi* Papp; Bogdanova, Kvantaliani & Schrikadze, p. 5, pl. 1, figs. 1-5, pl. 2, figs. 1-3, text-fig. 2.

1999 *Deshayesites dechyi* Papp; Bogdanova, pl. 2, figs. 3 & 4.

1999 *Deshayesites dechyi* Papp; Bogdanova & Prozorovsky, pl. 4, fig. h.

Syntypes: There are six syntypes in this collection. As far as I am aware subsequent authors have not designated a Lectotype. Specimens are in Hungarian Geology State Museum (Dechy Colln), Budapest, from Daghestan, Caucasus.

Material: 15 specimens [TK 46/ 6, 12, 13; TK 53/1; TK 60/ 1-6; TAK 32/ 2; Am 16/ 1; Am 17/ 2; Am 24/ 4; Am 25/ 3].

Description: Moderately involute, umbilical area about one third of diameter. Whorl section sub-rectangular, thickest part above the umbilical area. Ribs sigmoidal, maximum elevation and strength on lower third of sides, one or two secondary ribs are intercalated between the lower third and mid flank, between each primary; ribs are a little flattened and weak on the venter. In last half whorl one secondary rib is associated with each primary. There are between 20-32 primary ribs and 54-64 secondary ribs per whorl at 40-141 mm diameter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 32/ 2	**141**	**54**	**0.38**	**20**	**0.14**	**52**	**0.37**	**0.37**	**32**	**64**	**2**
Am 16/ 1	**48**	**17**	**0.35**			**15.5**	**0.32**		**24**	**60**	**2.5**
Am 25/ 3	**48**	**22**	**0.46**	**13**	**0.27**	**16**	**0.33**	**0.59**	**24**	**54**	**2.25**
Am 17/ 2	**41**	**17**	**0.41**	**7.7**	**0.19**	**17**	**0.41**	**0.45**			
TK 46/ 6	**40**	**18**	**0.45**			**13**	**0.33**		**24**	**54**	**2.25**
TK 46/ 12	**39.5**	**20**	**0.51**			**13**	**0.33**		**20**		
TK 46/ 13	**39**	**19**	**0.49**			**11.5**	**0.29**		**24**		
TK 53/ 1	**39**	**18**	**0.46**			**13**	**0.33**				
TK 60/ 3		**23**		**7**				**0.30**			
TK 60/ 4		**22**		**10**				**0.45**			
TK 60/ 5		**22**		**10**				**0.45**			
Syntype	**40**	**23**	**0.5**	**14**	**0.28**				**22**	**44**	**2**
Bogdanova *et al.*,1979	**40.7**	**15.8**	**0.39**	**10.2**	**0.25**	**13.1**	**0.32**	**0.64**	**32**	**54**	**1.69**

Discussion: *Deshayesites dechyi* is similar to *D. forbesi* in rib pattern, but the latter is more evolute and has less strong ribs. *D. dechyi* differs from *D. consobrinoides* by a less convex venter and from *Deshayesites consobrinus* by having irregularly branching ribs (Bogdanova *et al.*, 1979). In whorl section *D. dechyi* is similar to

Prodeshayesites bodei. The main difference between the two species lies in the suture line. The suture of *D. dechyi* is characterized by narrow and high elements.

Distribution: Lower Aptian of the north-west and north Caucasus (*dechyi-deshayesi* Zone) (Druschitz and Kudryutzeva, 1960; Bogdanova *et al.*, 1979), Caspian region (*weissi-deshayesi* Zone) (Bogdanova, 1977) and Iran.

Occurrence: Middle part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Deshayesites cf. *involutus* Spath 1930

Plate 6, Figures 1, 2, 3 & 4; Plate 7, Figures 1, 2

cf. 1930b *Deshayesites involutus* Spath, p. 432.

cf. 1961a *Deshayesites involutus* Spath; Casey, p. 609.

cf. 1964 *Deshayesites involutus* Spath; Casey, p. 310, pl. 45, figs. 1a-c, 4a-b, text fig. 107.

cf. 1999 *Deshayesites* cf. *involutus* Spath; Avram, p. 454, fig. 8d.

Holotype: British Geological Survey, No. 30919, from Hythe beds, Hythe, Kent, UK.

Material: 15 specimens [TK 46/ 2?; TK 53/ 3?; TK 58/ 1, 5, 7-10; TK 60/ 7-9; TK 63; Am 21/ 3-5; Am 24/ 1].

Description: Moderately evolute, umbilical area is around one third of diameter. Whorl section sub-rectangular, thickest in the lower one third part of the flank, umbilical wall vertical with rounded shoulder. Ribs weakly sigmoidal, primaries smooth in the middle flank and strong near the umbilical margin and venter, bifurcate or trifurcate, secondary ribs irregular, start in the mid flank. There are between 26-30 primary ribs and 40-54 secondary ribs per whorl at 153-185 mm diameter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TK 58/ 10	185	71	0.38	32	0.17	58	0.31	0.45	28	54	1.93
TK 58/ 9	181	62	0.34	33	0.18			0.53	30	48	1.6
TK 58/ 7	178	60	0.34	39	0.22	61	0.34	0.65			
Am 21/ 5	170	59	0.35	26	0.15	63	0.37	0.44	26	54	2.08
TK 58/ 8	161	50	0.31	32	0.2	57	0.35	0.64	28	50	1.79
TK 63/ 1	153	53	0.35	33	0.22	59	0.39	0.62	27	47	1.74
TK 53/ 3		33		12				0.36			
TK 58/5		45		24				0.53			
TK 60/ 7		68		18.5				0.27	26	40	1.54
TK 60/ 8		63.5		28.5				0.44			
TK 60/ 9		70		26				0.37			
Am 24/ 1		22		11				0.			
Holotype	122	48.5	0.4	30.5	0.25	34	0.28	0.62			

Discussion: The specimens are not complete enough for definite identification. *Deshayesites involutus* differs from *Deshayesites grandis* in its finer ribbing.

Distribution: England (Spath, 1930; Casey, 1961a, 1964), Romania (Avram, 1999) and Iran.

Occurrence: Middle part of the Sarcheshmeh Formation in Takal Kuh and Amand sections.

Deshayesites cf. *planus* Casey 1961

Plate 6, Figure 5, 6

cf. 1961a *Deshayesites planus* Casey, p. 609.

cf. 1964 *Deshayesites planus* Casey; Casey, p. 323, pl. 57, fig. 5, text-figs. 112a, b, e.

cf. 1971b *Deshayesites planus* Casey; Bogdanova, p. 22.

cf. 1977 *Deshayesites planus* Casey; Bogdanova, p. 52, pl. 3, figs. 1-5, pl. 4, figs. 7-8, text-figs. 4a-b.

cf. 1999 *Deshayesites planus* Casey; Avram, p. 445, figs. 5c, d-e.

cf. 1999 *Deshayesites planus* Casey; Bogdanova & Prozorovsky, pl. 4, figs. g & i.

Holotype: British Geological Survey, ZM 1667 (Casey Colln), from Atherfield Clay Series, Atherfield, Isle of Wight, UK.

Material: 18 specimens [TK 46/ 14; TK 52/ 1; TK 54/ 1-8; TK 71/ 8-12; TAK 29/ 4; Am 25/ 4, 7, 8].

Description: Shell moderately involute, umbilical area is about one third of diameter and bears tubercles at the umbilical margin. Whorl section sub-rectangular, thickest in the lower one third of flanks, venter curved and flanks slightly flattened. Primary ribs start from upper part of umbilical wall, and form a sigmoidal curve on the flank. They are thicker on the lower third of flank, thinner at the middle of flank; one or two secondary ribs are intercalated between each primary at mid flank. There are 22-25 primary ribs and 50-77 secondary ribs at 25-62 mm diameter. The secondary/primary ribs ratio varies from 2.27 to 3.5.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TK 54/ 2	62	27	0.44	9.8	0.16	21	0.34	0.36	22	58	2.64
TK 54/ 6	55	21.4	0.39	8	0.15			0.37	22	50	2.27
TAK 29/ 4	40	18		10		12		0.55	25	56	2.24
Am 25/ 7	33	16	0.48	7	0.21	8		0.43	22	77	3.5
TK 71/ 8	26	14	0.54			7	0.27		20	51	2.55
TK 45/ 7	25	12	0.48	6.5	0.26	9	0.36	0.54			
TK 54/ 1		19		9.5				0.5			
TK 54/ 3		19		6				0.31			
TK 54/ 8		19.3		9.4				0.48			
TK 71/ 9		24		6.5				0.27			
TK 71/ 10		13.5		5				0.37			
TK 71/ 11		20		7				0.35			
Holotype	33	13	0.4	8	0.24	10.9	0.33	0.61	24	72	3

Discussion: Most specimens are crushed (WT/WH= 0.27-0.55), but other measured proportions are similar to those of the holotype. The species is mostly distributed in the Sarcheshmeh Formation, but sample 71 is from one of two limestone beds in the overlying Sanganeh Formation.

Distribution: England (Casey, 1961a, 1964), Romania (Avram, 1999), Turkmenistan (Bogdanova, 1971b, 1977) and Iran.

Occurrence: Upper part of the Sarcheshmeh and middle part of the Sanganeh Formation in Takal Kuh and Amand sections.

Deshayesites deshayesi (d'Orbigny 1841)
Plate 6, Figures 10, 11, 12 & 13

1841 *Ammonites deshayesi* Leymerie; d'Orbigny, p. 288, pl. 85, figs. 3, 4.
1899 *Hoplites deshayesi* Leymerie; Anthula, p. 108.
1914 Hoplites *(Deshayesites) deshayesi* Kazansky, pp. 100-103, pl. 6, figs. 81-83, pl. 7, figs. 100-101.
1960 *Deshayesites deshayesi* (d'Orbigny); Druschitz & Kudryutzeva, p. 309, pl. 1, fig. 2, 5
1961a *Deshayesites deshayesi* (d'Orbigny); Casey, p. 508, 523, 538, 593, 609.
1964 *Deshayesites deshayesi* (d'Orbigny); Casey, p. 295, pl. 43, fig. 3, pl. 47, fig. 9, pl. 51, fig. 6 (see for extensive synonymy).
1971b *Deshayesites deshayesi* (d'Orbigny); Bogdanova, pl. 3, fig. 6, pl. 4, fig. 1-2.
1971 *Deshayesites deshayesi* (d'Orbigny); Kemper, pl. 29, fig. 7.
1973 *Deshayesites deshayesi* (d'Orbigny); Glazunova, p. 120, pl. 76. fig. 1
1977 *Deshayesites deshayesi* (d'Orbigny); Bogdanova, p. 55, pl. 3, fig. 6, pl. 4, fig. 1-2.
1979 *Deshayesites deshayesi* (d'Orbigny); Bogdanova, pl. 2, fig. 6.

Lectotype: National Museum of Natural History, Paris, No. 5579c. Selected by Casey (1961a) from d'Orbigny's surviving syntypes. Argiles à Plicatules of Bailly-aux-Forges, Paris Basin, France.

Material: 104 specimens [TK 56/ 1-5; TK 57/ 1-5; TK 59/ 1-7; TK 65/ 1-2; TK 86; TAK 34/ 1-3; TAK 36/ 3-16; TAK 37; TAK 42/ 1-3; TAK 43/ 1-2; TAK 44/ 1; TAK 49/ 1-16; TAK 50?; Am 23/ 1-9; Am 26/ 1-9; Am 27/ 1-26].

Description: Most specimens are not larger than 20 mm diameter (except sample TAK 36) but well preserved. Moderately involute, umbilical width is between one fifth and one quarter of the diameter (U/D= 0.2-0.37), the umbilicus is relatively deep with nearly vertical wall. Whorls sub-rectangular, thickest part at the lower part of the flank. Ribs narrow, sigmoidal, primary ribs start from above the umbilical wall, secondary ribs branch from the primaries at the mid flank and bend forward over venter; more than one secondary rib sometimes can be seen between two primaries. There are 17-31 primary ribs and 25-62 secondary ribs at 11-72 mm diameter. The secondary/primary ribs ratio varies from 1.67 to 2.58. Some specimens are weathered and rib numbers cannot be counted.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 36/ 13	70	28	0.4	15	0.21	23	0.33	0.53	22	40	1.82
TAK 36/ 12	69.5	27	0.39	11	0.16	20	0.29	0.40	24	62	2.58
TAK 36/ 16	66	28	0.42	16.3	0.25	23.3	0.35	0.58	21	44	2.1
TAK 36/ 14	64	25	0.39	15	0.23	20	0.31	0.6	22	46	2.09
TAK 36/ 10	59.8	25	0.42	12.5	0.21	19.5	0.33	0.5	21	45	2.14
TAK 36/ 9	53.4	20.5	0.38	11.3	0.21	17.2	0.32	0.55	29	50	1.72
TAK 36/ 15	53	20	0.38	9.5	0.18	12	0.23	0.47	21	45	2.14
TAK 36/ 11	49	20	0.41	10	0.2	18	0.37	0.5	24	60	2.5
TAK 36/ 6	44	18	0.41	8.6	0.2	10.3	0.23	0.47	24	54	2.25
TAK 36/ 3	41.5	17	0.41	10	0.24	11.5	0.28	0.58	21	43	2.05
TAK 36/ 8	35	15.2	0.43	9.7	0.28	12.2	0.35	0.63	20	30	1.5
TAK 36/ 4	32.3	14	0.43	6.5	0.2	11.5	0.36	0.46	20	51	2.55
TAK 36/ 5	31.7	14	0.44	7	0.22	9	0.28	0.5	20	43	2.15
TAK 36/ 7	30.5	15	0.49	7.7	0.25	9.5	0.31	0.51			
TK 65/ 2	19.5	8.5	0.44	6	0.31	6	0.31	0.70			
TK 65/ 1	19	9	0.47	6	0.32	6.5	0.34	0.66			
TK 56/ 1	16	7.5	0.47	4	0.25	4	0.25	0.53			
Am 23/ 1	16	7.5	0.47	4	0.25	4.5	0.28	0.53			
Am 27/ 3	15.4	8	0.52	4.7	0.31	4	0.26	0.58	30	50	1.67
TK 59/ 3	15	6.3	0.42	3.5	0.23	3.5	0.23	0.55			
Am 27/ 5	13.8	8	0.58	4.5	0.33	3.2	0.23	0.56			
TK 59/ 4	13.5	7	0.52	3	0.22	3	0.22	0.42	17	38	
TK 56/ 2	13	6	0.46	3.5	0.27	3.5	0.27	0.58			
Am 27/ 4	13	6.5	0.5	4.4	0.34	4.2	0.32	0.67	31	64	2.06
Am 27/ 6	13	6	0.46	3.7	0.28	3.7	0.28	0.61			
TK 56/ 5	12.9	6	0.47	3.7	0.29	3	0.23	0.61			

TK 56/ 3	12.5	6	0.48	3.7	0.3	3	0.24	0.61			
TK 59/ 1	12.5	6	0.48	4.5	0.36	3.5	0.28	0.75			
Am 27 /9	12.5	6.8	0.54	5.5	0.44	3.5	0.28	0.80			
TK 57/ 5	12	5	0.42	3.2	0.27			0.64			
Am 27/ 7	11.8	5.4	0.46	4	0.34	3.2	0.27	0.74			
TK 56/ 4	11.5	5	0.43	3.8	0.33	3	0.26	0.76			
Am 27/ 8	11.5	6.5	0.57	4	0.35	3	0.26	0.61			
Am 23/ 3	11.3	5	0.44	3	0.27	3	0.27	0.6			
TK 59/ 5	11	5.5	0.5	4	0.36	3	0.27	0.72	17	25	
Am 27/ 10	11	4.5	0.41	3.5	0.32	3	0.27	0.77			
TK 57/ 3	10.9	5.5	0.5	3	0.28	2.2	0.2	0.54			
TK 59/ 2	10.5	5	0.48	4	0.38	3	0.29	0.8			
Am 23/ 2	10.5	5.8	0.55	3.5	0.33	2.5	0.24	0.60			
Am 23/ 4	10.5	4	0.38	3.8	0.36	3	0.29	0.95			
Am 27/ 11	10	5	0.5	4	0.4	2.5	0.25	0.8			
TK 59/ 7	9.5	5	0.53	3.2	0.34	3	0.32	0.64			
TK 57/ 4	9	4.5	0.5	3.7	0.41	2.3	0.26	0.82			
TK 57/ 1	8.6	3.6	0.42	3	0.35	2.7	0.31	0.83			
TK 59/ 6	8.5	4.5	0.53	3	0.35	3	0.35	0.66			
TK 57/ 2		5.5		3.8				0.69			
Lectotype	32	14.7	0.46	11	0.33	9.3	0.29	0.74		44	

Discussion: Most small specimens are preserved in shales, where the outer whorls have been crushed. However, both these and the larger specimens from TAK 36 are close in whorl proportion and rib pattern to the lectotype and other figured specimens of *D. deshayesi.*

Distribution: England (Casey, 1961a, 1964), Germany (Kemper, 1971), Russia (Glazunova, 1973; Druschitz and Kudryutzeva, 1960), Turkmenistan (Bogdanova, 1977) and Iran.

Occurrence: Upper part of the Sarcheshmeh Formation and lower to middle part of the Sanganeh Formation in Takal Kuh and Amand sections.

Deshayesites cf. *consobrinoides* Sinzow 1909

Plate 5, Figures 7, 8; Plate 6, Figures 7, 8 & 9

cf. 1909 *Parahoplites consobrinoides* Sinzow, pp. 3-4.

cf. 1947 *Deshayesites consobrinoides* d'Orbigny; Arkell, p. 170, fig. 18, 14b.

cf. 1961a *Deshayesites consobrinoides* d'Orbigny; Casey, p. 508, 523,609.

cf. 1964 *Deshayesites consobrinoides* Sinzow; Casey, p. 302, pl. 44, figs. 5, 6, pl. 52, fig. 2, Text-fig. 106j-n (see for extensive synonyms).

cf. 1971b *Deshayesites consobrinoides* Sinzow; Bogdanova, pl. 3, fig. 3.

cf. 1973 *Deshayesites consobrinoides* Sinzow; Glazunova, pl. 123, pl. 77. figs. 1-5.

cf. 1979 *Deshayesites consobrinoides* Sinzow; Bogdanova, Kvantaliani & Schrikadze, pl. 3, fig. 3.

cf. 1999 *Deshayesites consobrinoides* Sinzow; Bogdanova, pl. 2, fig. 1.

cf. 1999 *Deshayesites consobrinoides* Sinzow; Bogdanova & Prozorovsky, pl. 6, figs. c-d.

Lectotype: Karpinsky Museum, St. Petersburg (one of specimens that collected by Sinzow, 1898), No. 17727, from the Lower Aptian of Saratow, Russia.

Material: 11 specimens [TK 82/ 1-3; TAK 36/ 18, 20, 21; TAK 51/ 1, 2, 4; Am 24/ 2, 3].

Description: Moderately involute, umbilical width about one third of diameter. Whorl sections sub-rectangular, sides nearly parallel, venter a little flattened. Ribs sharp and strong, sigmoidal; primary ribs start from upper part of umbilical wall, secondary ribs are intercalated between primaries between the mid flank and outer third. There are 20-24 primary ribs and 36-50 secondary ribs at 11-72 mm diameter. The secondary/primary ribs ratio varies from 1.73 to 2.18.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 36/ 21	138	55	0.4	31	0.22	44	0.32	0.56	24	50	2.08
TAK 36/ 18	130	50	0.38	28	0.22	41	0.32	0.56	21		
TAK 51/ 4	55	24	0.44			20	0.36		22	48	2.18
TK 82/ 3	43	19	0.45	12	0.28	14	0.32	0.63	22	40	1.82
TK 82/ 2	30	12	0.41	6.4	0.21	10	0.33	0.52	20	36	1.8
TK 82/ 1	27	14	0.5	6	0.22	6.8	0.25	0.44	22	38	1.73
Sorbonne Coll.	31	13	0.42	9.9	0.32	9.6	0.31	0.76			

Discussion: *Deshayesites consobrinoides* is very similar to *Deshayesites deshayesi*, but is more coarsely ribbed and is stouter with a wider umbilicus than average *Deshayesites deshayesi* (Casey, 1964, p. 303).

Distribution: Europe (Casey, 1964), Russia (Glazunova, 1973), the Caucasus (Bogdanova, Kvantaliani & Schrikadze, 1979), Turkmenistan (Bogdanova, 1971, 1999) and Iran.

Occurrence: Middle part of the Sanganeh Formation in Takal Kuh section.

Deshayesites cf. *multicostatus* Swinnerton 1935

Plate 7, Figure 3

cf. 1935 *Deshayesites multicostatus* Swinnerton, p.31, pl. 1, fig. 1a-c.
cf. 1961a *Deshayesites multicostatus* Swinnerton; Casey, p. 508, 523, 569, 570, 609.
cf. 1964 *Deshayesites multicostatus* Swinnerton; Casey, p. 304-305, pl. 43, figs. 5a-b, 6.
cf. 1973 *Deshayesites multicostatus* Swinnerton; Glazunova, p. 130, pl. 84, fig. 1.
cf. 1999 *Deshayesites multicostatus* Swinnerton; Avram, p. 441, fig. 3b-d.

Holotype: Natural History Museum, London, C36366, (Swinnerton Colln), from the Sutterby, Marl of Sutterby Lincolnshire, UK.

Material: 7 specimens, [TK 82/ 4; TAK 51/ 5-9; TAK 36/ 17].

Description: Moderately involute, umbilical width is around one fifth to one quarter of diameter. Whorl section sub-rectangular, flanks nearly parallel, venter a little curved. Primary ribs originate from umbilical wall, sigmoidal at first and more straighter in last whorl of adult specimens. One or two secondary ribs intercalated between primaries in the middle third of the flank in early whorls, and branching from them on last half whorl, ribs cross venter forwardly convex. Twenty eight primary ribs and sixty secondary ribs at 125 mm diameter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 51/ 6	125	56	0.45	26	0.21	27	0.22	0.46	28	60	2.14
TAK 36/ 17	79	37	0.47	20.5	0.26	19	0.24	0.55	24	62	2.58
TAK 51/ 5		35		16				0.46			
Holotype	50	24	0.48			13	0.25		16	34	2.13

Discussion: The specimens show similarity with Casey's figure (pl. 43. fig. 5). They are accompanied by *D. consobrinoides* and *D. deshayesi.*

Distribution: England (Casey, 1961a, 1964), Russia (Glazunova, 1973), Romania (Avram, 1999) and Iran.

Occurrence: Uppermost part of the Sarcheshmeh Formation and in the Sanganeh Formation at Takal Kuh section (2).

Deshayesites sp. nov.

Plate 7, Figure 5

Material: 17 specimens [TAK 39/ 1-2; TAK 40/ 1-3; TAK 49/ 17-21; TAK 52/ 3-5; Am 27/ 28, 29; Am 28/ 1, 2].

Description: Small size, some weathered. Shell semi-involute, with small umbilical area, whorl height greater than width. Whorl section rounded to sub-rectangular, flanks parallel. Ribs sigmoidal, fine, sharp and dense, bending forward and weak on the venter, secondary ribs branch nearly at the umbilical margin.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Am 27/ 1	27	14	0.53	4.5	0.17	6	0.22	0.31			
TAK 49/ 1	24	11	0.46			5.2	0.22				
TAK 52/ 1	21	11	0.54	5.2	0.25	4.5	0.22	0.47			
TAK 49/ 2	20	10	0.51			4.5	0.23				
TAK 40	17	9	0.53	5	0.29	4	0.24	0.56			
TAK 49/ 3	17	8	0.48			4.5	0.27				
Am 27/ 2	16	8.4	0.53	6	0.38	4	0.25	0.71	26	55	2.12

TAK 49/ 4	**14**	**6**	**0.44**			**4**	**0.29**				
TAK 49/ 5	**13**	**6**	**0.46**			**4**	**0.31**				
TAK 49/ 6	**13**	**7.5**	**0.58**								
TAK 43	**12**	**6**	**0.5**	**4.7**	**0.39**	**2.8**	**0.23**	**0.78**			

Discussion: A few small inner whorl specimens have been collected from shales in the middle part of the Sanganeh Formation at Takal Kuh (2) and Amand sections. Their rib pattern and density are similar to that of early deshayesitids, and the specimens are accompanied by a *deshayesi* Zone assemblage fauna. They appear to be a new species and Bogdanova (personal communication) confirmed that she has not seen such specimens in the *deshayesi* Zone.

Distribution: Middle to upper part of the Sanganeh Formation at Takal Kuh (2) section.

Deshayesites sp. 1

Plate 7, Figure 4

Material: 5 specimens [TK 24/1-5].

Description: The specimens are fragmentary. Shell compressed, whorl section sub-rectangular. Fine ribs cross the almost smooth lower part of the flank; secondary ribs appear in the upper quarter of the flank.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	SR	PR	SR/ PR
TK 24/ 2		**23**		**3.5**				**0.15**			

Discussion: This form was collected from beds between the last *Turkmeniceras* and the first *Deshayesites*. The fragmentary nature of the material makes positive identification impossible, but their rib pattern suggests they are more similar to *Deshayesites* than to *Turkmeniceras*.

Occurrence: Lower part of the Sarcheshmeh Formation in Takal Kuh section (1).

Deshayesites sp. 2

Plate 7, Figure 9

Material: One fragments [TK 46/ 7].

Description: Whorl section rounded to sub-rectangular, flattened and broad venter; Primary ribs sharp in the lower part and thick and strong in the upper part of the flank. One or two secondary ribs are intercalated between primaries and commence on the upper part of the flank; bullae occur at the branching point.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	SR	PR	SR/ PR
TK 46/ 7		22		20				0.91			

Discussion: The rib pattern of this specimen is unique.

Occurrence: Middle part of the Sarcheshmeh Formation in Takal Kuh section.

Deshayesites sp. 3

Plate 7, Figures 6, 7

Material: 5 fragments [TK 56/ 7, 8; TK 64/ 1, 2; TK 50/1; TK 71/ 7].

Description: Shell moderately evolute, umbilical width is around one quarter to one fifth of diameter. Whorl section sub-rectangular, sides nearly parallel. Primary ribs start from lower part of the umbilical wall, secondaries bifurcate from the primaries at low to mid flank; ventrally the ribs form very low clavate margins to the smooth venter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TK 50/ 1	60	23	0.39	23				1			
TK 64/2	26	11	0.42			8	0.31		21	45	2.14
TK 64/1	19	10	0.53	5	0.26	5	0.26	0.5	20		
TK 56/ 7		12		12				1			

Discussion: The specimens have a hook shape; this may be distortion or may suggest that the last whorls are becoming more open.

Occurrence: Middle and upper part of the Sanganeh Formation in Takal Kuh section (1).

Deshayesites spp.

Plate 7, Figure 8

Material: 14 specimens [TK 53/ 4-6; TK 60/ 1, 2; TAK 51/3; Raz 2/ 15-16; Raz 4/ 1-4; Raz 6/ 1- 3].

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
TAK 51/ 3	99	35	0.35	18	0.18	35	0.35	0.51	26	35	1.35
TK 50/ 5		20		15				0.75			
TK 53/ 4		11		8				0.73			
TK 53/ 6		14		11				0.79			
TK 60/ 1		21		11				0.52			
RAZ 4/ 1		18		13				0.72			
RAZ 4/ 2		19		14				0.74			
RAZ 6/ 2		16		10				0.63			

Discussion: These small and incomplete specimens belong to more than one species, with differing rib patterns. In the Takal Kuh (1) specimens the ribs spring from near the umbilical margin. They resemble *Deshayesites pappi* Bogdanova. The Takal Kuh (2) sample has straight and less sigmoidal ribs than other specimens and shows similarity to *Deshayesites vectensis* Casey.

The Raz specimens are important and useful for correlation. *Dufrenoyia* occurs above them. One of them (Raz 4/ 2) is more complete and looks close to *D. dechyi* Papp.

Occurrence: Middle to upper part of the Sarcheshmeh Formation in Takal Kuh and Raz sections.

Genus *Dufrenoyia* Kilian and Reboul 1915

Type species: *Ammonites furcatus* J. de C. Sowerby in Fitton 1836, by original designation.

Generic characters: Characterised by medium sized shell, having flat and angular venter bearing ventro-lateral clavi to varying growth stage. Umbilicus relatively wide, ribs flattened on the upper part of the flank and ventral area.

Discussion: *Dufrenoyia* differs from *Deshayesites* by developing a flat venter with ventro-lateral clavi in at least the earlier growth stage and sometimes with ventral interruption of ribbing.

Distribution: Europe, Russia, Turkmenistan, Japan, USA, Venezuela, Mexico and Colombia (Bogdanova, 1979; Druschitz & Kudryutzeva, 1960; Wright *et al.*, 1996), and Iran.

Age: Aptian-?Early Albian (Wright *et al.*, 1996, p. 273).

Dufrenoyia sp.

Plate 8, Figures 1, 2, 3 & 4

Material: Eleven specimens [TK L/ 2-6; TAK 53; TAK 55/ 1-2; Raz 6/ 4; Raz 8/ 1; Raz 9/ 2; Gho 12].

Description: Shell discoidal, slightly evolute, whorl section sub-rectangular to oval, venter truncated, forming well-marked angle with flanks. Primary ribs rise at the umbilicus margin, and bear feeble tubercles there. Secondary ribs are intercalated or occasionally branch from mid-flank and they broader and flatten on the upper part of the flank and venter. They cross the venter in a straight line. Feeble denticulation occurs on the ventro-lateral shoulder. There are 18-21 primary ribs and 33-42 secondary ribs at 13-99 mm diameter. The secondary/primary ribs ratio varies from 1.83 to 2.1.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Gho 12	99	41	0.41	34	0.34	28	0.28	0.83	18	33	1.83
TK 71/5	65	28	0.43	14	0.22	16	0.25	0.5	20	42	2.1
TAK 55/ 1	21	7.5	0.37	4.5	0.22	3	0.15	0.6	21	42	2
TK 71/ 2	29	13	0.45	5	0.17	7	0.24	0.38	20	42	2.1
TAK 53	13	7	0.54	4	0.31	3.2	0.25	0.57	20	38	1.9
Raz 8/ 1		54		37				0.69			
Raz 6/ 4		29		18				0.62	21	45	2.14
TK 71/ 4		25		13				0.52			
TK 71/6		15		9.5				0.63			

Discussion: Most of the specimens clearly belong to a single species, characterised by a flat venter and flattened ribs on the upper part of the flanks and ventral side. But two specimens may be different. Specimen Gho 12 is unique in rib pattern. Primary ribs are strong especially in lower part of the flanks and a little compressed. Secondary ribs commence from the upper third of the flanks. Venter flattened but there is not a sharp margin or tubercles.

Specimen TK L/ 4 shows some similarities to *Burkhardites* (Personal communication with T. N. Bogdanova). *Burkhardites* is distinguished from *Dufrenoyia* by more sharp, dense, and less flattened ribs on the flanks. *Burkhardites* has been mostly reported from South and Central America and Spain (Humphrey, 1949) and is of Late Aptian age.

Occurrence: Upper part of the Sanganeh Formation in Takal Kuh, the Sarcheshmeh-Sanganeh Formations boundary in Raz and lowermost part of the Ghorghoreh sections.

Family Parahoplitidae Spath 1922

Phylogeny

Middle and Upper Aptian sequences are characterised by the Parahoplitidae. Study of the phylogeny of the Deshayesitidae, Parahoplitidae and Douvilleiceratidae shows similarity in the main characters of these families. During the development of the suture all three families show a similar second suture, and all have a reduced first umbilical lobe. However, new sutural elements then appear in different ways: as a result of division of the saddle U/I in Deshayesitidae, of the saddle L/U in Parahoplitidae or lobes L/U in Douvilleiceratidae (Mikhailova, 1979) (Figure 3.11 & 3.12a).

Acanthohoplites is the main genus of the family. The genus branched in two main directions in Mid to Late Aptian times. The first branch has a few lateral tubercles on the last whorls and fine ribs (*A. nolani*, *A. uhligi*). The second branch is marked by coarse ribs, most of which have lateral tubercles (*A. bigoureti*, *A. abichi*) (Mikhailova, 1979).

Druschitz and Mikhailova (1963) considered that *Acanthohoplites, Colombiceras* and *Gargasiceras* probably originated from *Deshayesites.* Casey (1965) noted that a link between *Colombiceras* and *Dufrenoyia* is more acceptable than between *Colombiceras* and *Deshayesites* for biostratigraphical reasons. However, (Mikhailova, 1979) suggested that *Colombiceras* evolved from *Acanthohoplites*, as a result of transformation in the ornament (Figure 3.12). *Colombiceras* is characterised by infrequent tubercles, which appear on the flank approximately in the middle of the second whorl. Ribs start to rise on the third whorl and are flattened, especially on the venter.

Mikhailova (1979) also considered that *Parahoplites* originated from *Acanthohoplites*, which kept its ancestor's shell shape but in adult stages lost the tubercles. This idea is supported by a study of the ornament on the early whorls. In *P. melchioris* eight to ten tubercles are seen in the second whorl. Then the shell becomes smooth for some distance and tubercles disappear until the middle of the fourth whorl. Ribs appear at the end of the fourth whorl, therefore Mikhailova (1979) suggested that the tubercles originated from ancestral forms.

Hypacanthoplites is believed to have originate from *Acanthohoplites. Hypacanthoplites* is characterised by a flattened venter, fine ventro-lateral tubercles, straight ribs and weakened ribbing on

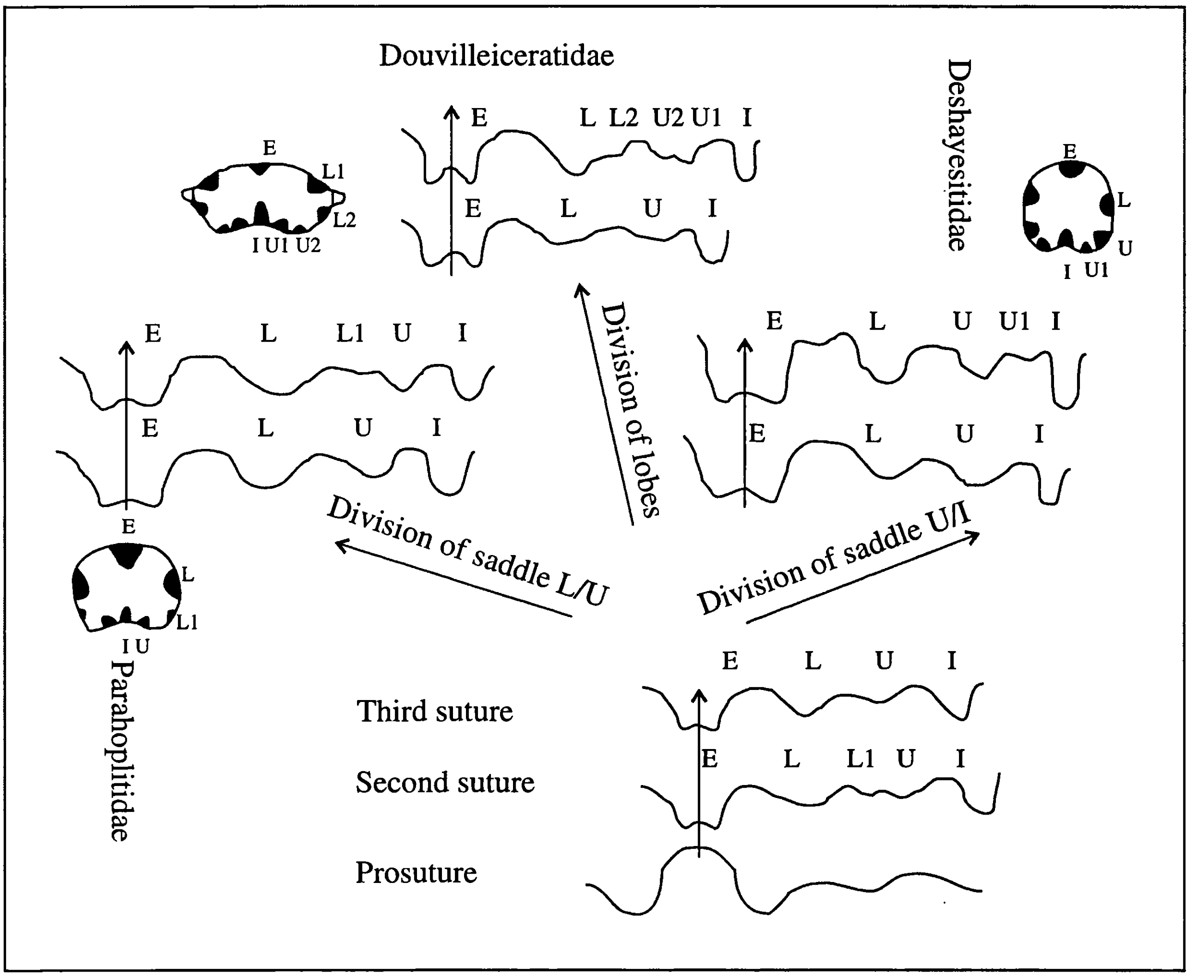
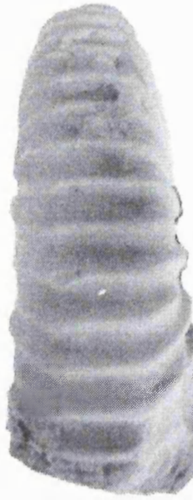


Figure 3.11. Changes in suture elements in the Families Deshayesitidae, Parahoplitidae and Douvilleiceratidae (Modified from Mikhailova, 1979).

E-*Parahoplites* cf. *campichii;* Sn 21/10

F- *Acanthohoplites* sp. 1; Sn 21/12



G-*Hypacanthohoplites uhligi;* Bib 23/6

C- *Colombiceras* sp.; Sn 21/1

D- *Acanthohoplites* cf. *bigoureti; Sn 24/ 1*

A- *Acanthohoplites* sp. 2; Raz 10/3

B- *Hypacanthohoplites uhligi;* Bib 23/8

Figure 3.12. Changes in rib pattern and shape of venter in the family Parahoplitidae in some specimens of the Kopet Dagh Basin. For further explanation see the text. All figures in natural size, A- X1.5.

the siphonal line (Figure 3.12a). However if growth continued enough, the venter returned to the rounded stage similar to that in *Acanthohoplites* (Casey, 1965).

H. rubricosus Casey is the earliest member and a typical species of the genus, marked by curved ribs and lack of ventro-lateral tubercles at an early stage of growth. Through the sequence, the genus develops a more angular venter, ventro-lateral tuberculation, and less curved ribs. At the same time the umbilical tubercles decrease (Casey, 1965).

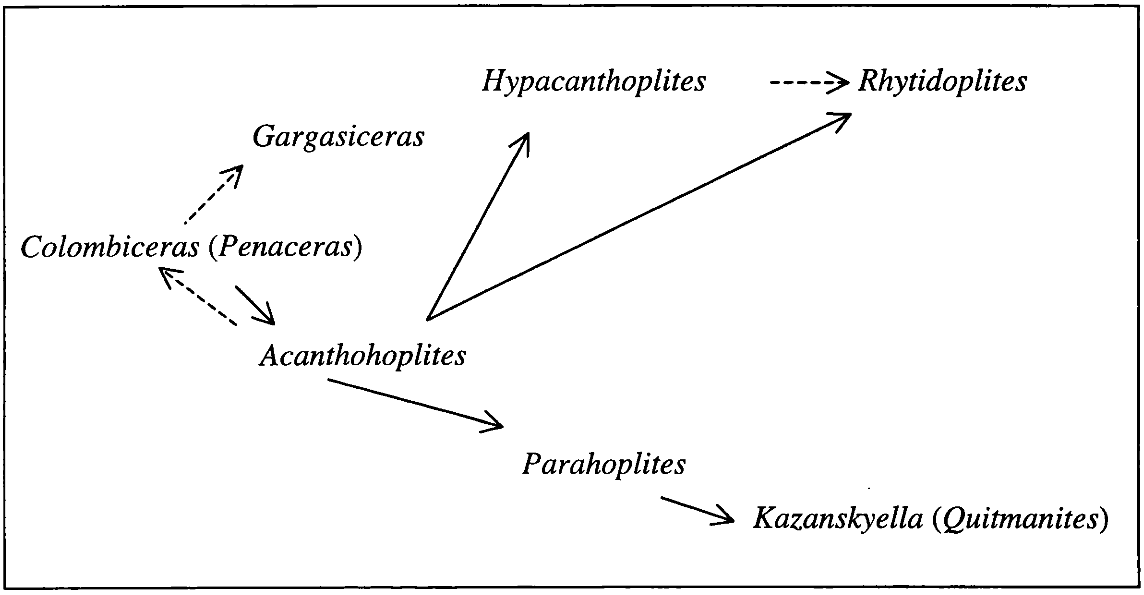


Figure 3.13. Suggested relationship between Parahoplitidae genera.

It can be concluded that through the Mid Aptian to Early Albian rib numbers increased in Parahoplitidae as whole, but ventral flattening fluctuated over the same period. In *Parahoplites* and *Nolaniceras* the venter became rounded whilst *Hypacanthoplites* followed the *Colombiceras* pattern with flattened venter. Morphologic changes such as rib pattern on flank and venter, and shape of venter have been compared in selected specimens from the Kopet Dagh Basin (Figure 3.12).

Other genera such as *Gargasiceras*, *Rhytidoplites*, *Penaceras* and *Kazanskyella* are not common in eastern Tethys and not recorded from the Kopet Dagh Basin, so they are not discussed here: the reader refer for more details about these genera to Casey (1954b), Cantu-Chapa (1963), Scott (1940a), Stoyanow (1949) and Wright *et al.*

(1996). The phylogenetic interrelation of the various genera is summarised in Figure 3.13. This is the author's interpretation, based partly on the Kopet Dagh faunal successions and partly on previous published suggestions.

Subfamily Acanthoplitinae Stoyanow 1949

Genus *Hypacanthoplites* Spath 1923

Type species: *Acanthohoplites milletianum* d'Orbigny var. *plesiotypica* Fritel 1906, by original designation.

Generic Characters: Moderately evolute, whorl section varies from hexagonal and rectangular in early whorls to subrectangular in adult. Ribs straight or flexuous, rising at umbilical tubercles, secondary ribs intercalated or branch from primaries at lateral tubercles, all ribs cross straight over the venter and bear a ventro-lateral tubercle. In the adult stage, the venter becomes rounded and the umbilical, lateral and ventro-lateral tubercles gradually disappear. Suture line has a trifid lateral lobe and auxiliary elements.

Discussion: Casey (1965, p. 423) has clarified the confusion surrounding the interpretation of the type species of *Hypacanthoplites*, and hence of the genus.

Distribution: Europe, Russia, Iran, northern Africa, Madagascar, California and Texas (Druschitz & Kudryutzeva, 1960; Wright *et al.*, 1996).

Age: Late Aptian- Early Albian (Wright *et al.*, 1996, p. 275).

Hypacanthoplites uhligi (Anthula) 1899

Plate 8, Figures 5, 6, 7 & 8

1899 *Parahoplites uhligi* Anthula, p. 114, pl. 10, fig. 1.

1907 *Parahoplites uhligi* Anthula; Sinzow, p. 498, pl. 7, fig. 9.

1914 *Acanthohoplites uhligi* (Anthula); Kazansky, p. 86, pl. 5, figs. 71-72.

1960 *Acanthohoplites uhligi* (Anthula); Druschitz & Kudryutzeva, p. 324, pl. 11, figs. 1a-b.

1975 *Acanthohoplites (Nolaniceras) uhligi* (Anthula); Förster, p. 206, pl. 9, figs. 6-7.

1980 *Hypacanthoplites uhligi* (Anthula); Seyed-Emami, p. 772, pl. 4, figs. 1-7; pl. 5, figs. 2-4; pl. 6, figs. 1a-c.

1982 *Hypacanthoplites uhligi* (Anthula); Kemper, pl. 8.4-3, fig. 5.

Holotype: Institute of Palaeontology, University of Vienna (Anthula Colln), from Daghestan, Caucasus.

Material: 58 specimens [Sn 23/ 1, 3-10; Sn 25/ 1-15; Sn 28/ 1-12; Sn 29/ 1; KR 20/ 1-3; Bib 23/ 1-3, 5-9, 11-17, 20, 22; Tr 33].

Description: Moderately evolute, umbilical width between one fourth to one fifth of the diameter. Whorl section rectangular, whorl height and whorl width nearly equal (WT/WH= 0.7-0.95). Thickest part of the flank near umbilical margin. Venter flattened at first gradually becoming arched in adults. Primary ribs are straight or feebly flexuous, and start from upper part of the umbilical wall. Secondary ribs mainly branch from or intercalated between primaries at about mid-flank. There are 21-31 primary ribs and 38-49 secondary ribs at 18-48 mm diameter. The secondary/primary ribs ratio varies from 1.29 to 2.14.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Sn 28/ 1	51.5	28.4	0.55			14	0.27	0			
Bib 23/ 12	48	17	0.35	16	0.33	15	0.31	0.94	25		
Bib 23/ 8	47	20.5	0.44	15.5	0.33	15.5	0.33	0.76	22	47	2.13
Sn 23/ 3	43.5	20	0.46	14	0.32	14	0.32	0.7	22		
Sn 25/ 6	41	18	0.44	15	0.37	13	0.32	0.83	24	40	1.66
Sn 25/ 1	39.5	20	0.51			10.5	0.27	0		45	
Sn 25/ 2	39.5	17.5	0.44	12	0.3	11	0.28	0.69	22	49	2.22
Bib 23/ 14	37	16	0.43			9	0.24		21	44	2.09
Sn 28/ 7	35	15	0.43	13	0.37	12	0.34	0.87	24	46	1.91
Sn 25/ 5	34.5	17	0.49	11.5	0.33	9.5	0.28	0.68	31	40	1.29
Sn 25/ 3	34	15	0.44	11	0.32	8.5	0.25	0.73	24	47	1.95
Sn 28/ 4	34	15	0.44	12	0.35	11	0.32	0.8	23	42	1.82
Sn 23/ 6	33	12	0.36		0	10.5	0.32				
Sn 23/ 1	31	14.5	0.47	11	0.35	9.5	0.31	0.76	23	47	2.04
Sn 29	29	13.5	0.47	10.5	0.36	7	0.24	0.78			
Bib 23/ 11	27.5	12	0.44	10.5	0.38	8.5	0.31	0.88	26	38	1.46
Sn 25/ 11	26	11	0.42	9	0.35	8	0.31	0.82			

Sn 28/ 6	26	11	0.42	10.5	0.4	7.5	0.29	0.95	21	42	2
Sn 23/ 4	25	12	0.48	8	0.32	7	0.28	0.67	22		
Sn 25/ 4	22	10	0.45	7	0.32	6	0.27	0.7	24	45	1.87
Sn 25/ 12	18	8	0.44	6	0.33	6	0.33	0.75			
Sn 25/ 15	18	8	0.44	6.5	0.36	5	0.28	0.81	26	48	1.84
Sn 23/ 5		14.5		12							
Sn 28/ 2		21.5		19				0.88			
Sn 28/ 3		17		14		15		0.82			
Sn 28/ 5		17		14				0.82			
Bib 23/ 6		17		14				0.82			
Bib 23/ 19		24.5		18.5				0.76			
Tr 33		56		26				0.46	27	54	2
Holotype	120	50	0.42	37	0.31	36	0.3	0.74			

Discussion: In adult forms ribs are sometimes slightly swollen in mid flank and where secondary ribs branch from primaries. There are similarities between some specimens of this species and specimens of *H. subrectangulatus*. But they differ in rib pattern; secondary ribs in *H. uhligi* are mainly attached to the primaries and also locally start below the mid flank.

Distribution: Germany (Kemper, 1982), Caucasus (Druschitz and Kudryutzeva, 1960; Glazunova, 1953; Kazansky, 1914), Kopet Dagh (Bogdanova *et al.*, 1963; Luppov *et al.* 1960; Sinzow, 1907; Seyed-Emami, 1980 (Iran)) and Mozambique (Förster, 1975).

Occurrence: Upper part of the Sanganeh Formation in the Sanganeh, Kalat Road, Bibahreh and Tirgan sections.

Hypacanthoplites cf. *elegans* (Fritel) 1906

Plate 8, Figures 11, 12

cf. 1906 *Acanthoceras milletianum* (d'Orbigny) var. *elegans* Fritel, p. 146, fig. 3.

cf. 1907 *Parahoplites uhligi* Anthula; Collet, pl. 8, figs. 6-7 only.

cf. 1935 *Acanthohoplites* (*Hypacanthoplites*) *elegans* (Fritel); Breistroffer, p. 209.

cf. 1947 *Acanthohoplites elegans* (Fritel); Breistroffer, p. 28.

cf. 1950 *Hypacanthoplites elegans* (Fritel); Casey, p. 277, pl. 14, fig. 12.

cf. 1961a *Hypacanthoplites elegans* (Fritel); Casey: p. 529, 560, 609.

cf. 1965 *Hypacanthoplites elegans* (Fritel); Casey, p. 439-440, pl. 71, figs. 1a-b, pl. 72, fig. 3, pl. 74, figs. 10a, b, text-fig. 163a-c.
cf. 1971 *Hypacanthoplites elegans* (Fritel); Kemper, pl. 28, fig. 2, pl. 29, fig. 5.
cf. 1982 *Hypacanthoplites elegans* (Fritel); Kemper, pl. 8.4-4, figs. 3, 4, 6.

Neotype: Natural History Museum, London, C11763, designated by Casey 1965, (Collet Colln), from the *jacobi* Zone of Vöhrum, Hanover, Germany.

Material: 5 specimens [Tr 24-26/ 9, 11, 14, 15; Tr 26-28/ 1].

Description: The material consists of crushed fragments. Shell moderately evolute. Whorl section sub-rectangular, wider at the lower part. Venter flat, ventral shoulders a little rounded. Ribs dense, and bear tubercles on the umbilical margin. Primary ribs commence from middle part of the umbilical wall, are straight up to mid-flank, then bend forward. All ribs equal and a little thicker in the ventral area.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Tr 24-26/ 15		**43**		**35.5**				**0.83**	**27**	**51**	**1.88**
Tr 24-26/ 11		**27**		**21**				**0.78**	**27**	**66**	**2.44**
Tr 24-26/ 9		**24**		**20.5**				**0.85**			
Tr 26-28/ 1		**13**		**10**		**10**		**0.77**	**28**	**50**	**1.79**
Neotype	**50**	**22**	**0.44**	**18**	**0.36**	**14**	**0.28**	**0.82**		**70**	

Discussion: This is the first record of the *H.* cf. *elegans* from the Kopet Dagh. *H. elegans* differs from *H. clavatus* by having denser ribs and a rounded ventral margin. The specimens show similarity with Casey's (1961a, 1965) figures.

Distribution: England (Casey, 1965), Germany (Collet, 1907; Kemper, 1971), France (Breistroffer, 1947) and Iran.

Occurrence: Middle part of the Sanganeh Formation in the Tirgan section.

Hypacanthoplites cf. *clavatus* (Fritel) 1906

Plate 8, Figures 9, 10

cf. 1906 *Acanthoceras milletianum* (d'Orbigny) var. *clavata* Fritel, p. 246, fig. 4.

cf. 1907 *Parahoplites sarasini* Collet; p. 522, pl. 8, fig. 9 only.

cf. 1939a *Acanthohoplites clavatus* (Fritel); Spath, p. 238.

cf. 1947 *Hypacanthoplites clavatus* (Fritel) Spath; Breistroffer, p. 83.

cf. 1950 *Hypacanthoplites clavatus* (Fritel); Casey, p. 277.

cf. 1961a *Hypacanthoplites clavatus* (Fritel); Casey, p. 529, 542, 560, 609.

cf. 1965 *Hypacanthoplites clavatus* (Fritel); Casey, p. 448, pl. 73, figs. 9a-c, text-fig. 167a-e.

cf. 1980 *Hypacanthoplites clavatus* (Fritel); Seyed-Emami, p. 725, pl. 3, fig. 3.

cf. 1982 *Hypacanthoplites clavatus* (Fritel); Kemper, pl. 8.4-4, figs. 1-2.

Neotype: Natural History Museum, London, C11759, designated by Casey 1965, (Collet Colln), from the *jacobi* Zone of Vöhrum, Hanover, Germany.

Material: 3 specimens [Sn 23/ 2; Bib 23/ 10, 18, 21].

Description: The specimens are crushed. Moderately evolute, whorl section sub-rectangular, widest part near umbilical area. Venter flat. Primary ribs start from umbilical wall, almost straight, bend slightly forward on the flanks, straight on the venter. Secondary ribs branched from or intercalated between primaries, starting near to umbilical margin or on the lower third of the flanks.

Measurements:

	D	WH	WH/ D	WT	WT/ D	U	U/D	WT/ WH	PR	SR	SR/ PR
Bib 23/ 21	22	19	0.86			8	0.36		22		
Bib 23/ 18		24.5		17				0.69	24	51	2.13
Sn 23/ 2	30.5	14	0.46	10.5	0.34	9	0.3	0.75	23		
Neotype	28	13	0.46	12	0.43	9.5	0.35	0.92			

Discussion: The specimens show no trace of lateral tubercles, but show a weak trace of umbilical and ventro-lateral tubercles. *H. clavatus* differs from *H.*

subrectangulatus in rib pattern, secondary ribs start from the lower third of the flank in *H. clavatus* whereas they start on the mid to upper third of the flank in later species. It should be noted that despite the specific name, most known examples of *H. clavatus* bear ventro-lateral tubercles rather than clavi.

Distribution: England (Casey, 1965), France (Breistroffer, 1947), Germany (Collet, 1097; Kemper, 1982) and Iran (Seyed-Emami, 1980).

Occurrence: Uppermost part of the Sanganeh Formation in the Bibahreh section.

Hypacanthoplites cf. *subrectangulatus* (Sinzow) 1907

Plate 8, Figures 13, 14 & 15

cf. 1907 *Acanthohoplites nolani* Seunes var. *subrectangulata* Sinzow, p. 505-506, pl. 8, figs. 6-10.
cf. 1960 *Hypacanthoplites subrectangulatus* (Sinzow); Druschitz and Kudryutzeva, p. 333, pl. 15, figs. 6a-b.
cf. 1965 *Hypacanthoplites subrectangulatus* (Sinzow); Casey, p. 438, text-fig. 163 d-e, f-g.
cf. 1989 *Hypacanthoplites subrectangulatus* (Sinzow); Follmi, p.132, pl. 6, fig. 10.

Syntypes: There are two specimens in the Sinzow collection, from Mangyshlak, Kazakhstan. No lectotype has been designated.

Material: 19 specimens [Tr/ 24-26/ 1-8, 10, 12, 13; Tr 26-28/ 2-9].

Description: Most specimens are fragments or incomplete. Quite evolute, cross section sub-rectangular with flattened venter, flanks parallel, whorl height and whorl width nearly equal (WT/ WH= 0.76-0.95). Primary ribs start from umbilical margin, weakly S shaped on flanks, thicker on the lower half, secondary ribs start at the middle to the upper third of the flank, majority intercalated but some branch from primaries. Umbilical and lateral tubercles present on some primary ribs and in some specimens seem eroded or weak, but ventro-lateral tubercles present on all ribs.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Tr 26-28/ 6	34	15.5		12				0.77	18	42	2.33
Tr 24-26/ 8	28	13	0.46	12	0.43	9	0.32	0.92	27	48	1.78
Tr 24-26/ 7		30		28.5				0.95	21	36	1.71
Tr 26-28/ 9		24		22				0.91			
Tr 26-28/ 2		21		19				0.90			
Tr 24-26/ 1		20		16				0.8			
Tr 24-26/ 4		19		15				0.78			
Tr 24-26/ 10		19		15				0.78			
Tr 2426/ 2		16		11				0.68	24	42	1.75
Tr 24-26/ 3		16		14				0.87			
Tr 26-28/ 3		15		12				0.8			
Tr 26-28/ 4		15		13				0.86			
Tr 24-26/ 13		13		10				0.76			
Tr 24-26/ 6		11		10				0.90	18	42	2.33
Tr 26-28/ 7		10		9				0.9			
Syntype	34	11	0.32	10	0.29			0.91	23		

Discussion: This is the first record of the *H.* cf. *subrectangulatus* from the Kopet Dagh. Casey (1965, p. 438) put *H. subrectangulatus* in a species group including *H. rubricosus* Casey, *H. pygmaeus* (Sinzow), *H. nolanisimilis* Breistroffer, *H. mangyschlakensis* Glazunova and *H. tscharlokensis* Glazunova. *H. rubricosus* differs from *H. subrectangulatus* by having more attached secondary ribs, which start at the lower third of the flank. Moreover the ventro-lateral tubercles seem stronger in *H. subrectangulatus*.

Distribution: Austria (Follmi, 1989), Russia (Druschitz and Kudryutzeva, 1960), Mangyshlak (Sinzow, 1907) and Iran.

Occurrence: Middle part of the Sanganeh Formation in the Tirgan section.

Hypacanthoplites cf. *anglicus* Casey 1950

Plate 9, Figure 3

cf. 1950 *Hypacanthoplites anglicus* Casey, p. 291, pl. 14, fig. 1.

cf. 1953 *Hypacanthoplites kopetdaghensis* Glazunova; p. 49, pl. 10, figs. 1-3.

cf. 1958 *Hypacanthoplites anglicus* Casey; Destombes, p. 308.

cf. 1961a *Hypacanthoplites anglicus* Casey; Casey, p. 529, 534, 609.

cf. 1965 *Hypacanthoplites anglicus* Casey; Casey, p. 427, pl. 71, figs. 4-7, pl. 74, fig. 2, text-fig. 162 b, d, g.

cf. 1971 *Hypacanthoplites anglicus* Casey; Kemper, pl. 28, fig. 4, pl. 30, fig. 4.

cf. 1989 *Hypacanthoplites anglicus* Casey; Follmi, p. 132, pl. 6, fig. 11.

Holotype: British Geological Survey, No. 74097, (Casey Colln), from Folkestone, Kent, UK.

Material: One specimen [Tr 38].

Description: The specimen is a corroded whorl fragment. Whorl section sub-rectangular, flanks parallel, shoulder in ventral area distinct. Ribs straight and strong on the flanks and venter, slightly flattened on ventral area, secondary ribs intercalated between primaries, elevated on the middle part of the flank.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Tr 38		31		26							
Holotype	39	14.5	0.38	13.2	0.34	12.8	0.33	0.91		25	

Discussion: The Transcaspian species *H. kopetdaghensis* Glazunova (1953) is regarded as a synonym of *H. anglicus* (Casey, 1965). *H. anglicus* differs from other identified species in the study area by having coarse, sharp and straight ribs, and all secondary ribs are intercalated.

Distribution: South-east England (Casey, 1950, 1961a, 1965), France (Destombes, 1958), Turkmenistan (Glazunova, 1953) and Iran.

Occurrence: Uppermost part of the Sanganeh Formation in the Tirgan section.

Hypacanthoplites sp.

Plate 8, Figure 16

Material: One specimen [Sn 31].

Description: Moderately evolute. Cross section in last half whorl rounded with flattened venter but more angular in early whorls, whorl height and whorl width nearly equal. Primary ribs start from umbilical margin, straight, thicker in the lower half of the flank, secondary ribs start in the lower third to middle of the flank, majority free but some secondary ribs attached to primaries.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Sn 31	120	51	0.42	49	0.41	35	0.29	0.96	27	41	1.51

Discussion: This specimen was collected from highest beds of the Sanganeh Formation in the Sanganeh section. The flattened venter suggests this specimen is a *Hypacanthoplites,* but there are no umbilical, lateral or ventral tubercles in this large specimen.

Occurrence: Uppermost part of the Sanganeh Formation in the Sanganeh section.

Genus *Acanthohoplites* Sinzow 1907

Type Species: *Parahoplites aschiltaensis* Anthula 1899, by subsequent designation (Roman 1938, p. 348).

Generic characters: Moderately evolute, whorl section oval or sometimes subrectangular. Ribs weak in early whorls; single or branched, bifurcated or trifurcate, thickened around umbilical margin to form umbilical bullae and bearing small tubercles on the sides; all ribs equal in ventral area. Suture line is more symmetric than in *Parahoplites* and consists of four lobes and four saddles. The umbilical lobe can be either shorter or longer than the first lateral lobe. The first lateral lobe is almost symmetrical and often wider than the umbilical lobe. Saddles bifid and first lateral saddle is almost twice as narrow as the external one.

Discussion: *Acanthohoplites* lies morphologically between *Parahoplites* and *Hypacanthoplites*. Therefore sometimes it is difficult to assign specimens to the correct genus.

Some authors use *Nolaniceras* (Casey, 1965) as a subgenus of *Acanthohoplites* (Förster, 1975), while others regarded it as a junior subjective synonym of *Acanthohoplites* (Bogdanova and Tovbina, 1994; Druschitz and Kudryutzeva, 1960; Kopaevich *et al.*, 1999), that view is followed here. Wright *et al.* (1996, p. 275) have confused the situation by retaining *Nolaniceras* as a separate genus but erroneously recording it as a Lower Albian form, while in a zonal table (p. 279) placing the *nolani* Zone in the Late Aptian and including the index species in *Acanthohoplites*

Distribution: Europe, Georgia, Transcaspia, eastern Africa, Madagascar, Japan, California, Arizona and Mexico (Wright *et al.*, 1996), and Iran.

Age: Late Aptian (Wright *et al.*, 1996, p. 275).

Acanthohoplites cf. *bigoureti* (Seunes) 1887

Plate 9, Figures 1, 2

cf. 1887 *Acanthoceras bigoureti* Seunes, p. 566, pl. 14, figs. 3-4.

cf. 1899 *Parahoplites bigoureti* (Seunes); Anthula, p. 117, pl. 13, figs. 2a-c.

cf. 1907 *Acanthohoplites bigoureti* (Seunes); Sinzow, p. 488, pl. 6, figs. 4-6.

cf. 1960 *Acanthohoplites bigoureti* (Seunes); Druschitz and Kudryutzeva, p. 321, pl. 8, figs. 1-2.

cf. 1971 *Acanthohoplites bigoureti* (Seunes); Kemper, pl. 25, fig. 4.

cf. 1975 *Acanthohoplites bigoureti* (Seunes); Förster, p. 205. pl. 9, fig. 4.

cf. 1980 *Hypacanthoplites bigoureti* (Seunes); Seyed-Emami, p. 726, pl. 3, figs. 7, 11.

Syntypes: Sorbonne University Museum, collected by Seunes, from Clansayes, France. There are two syntypes in this collection; no lectotype has been designated by subsequent authors.

Material: 5 specimens [Sn 23/ 11, 13-16].

Description: Moderately evolute, umbilical width about one third of diameter. Whorl section sub-rectangular to rounded, venter broad, flattened with distinct shoulder up to 50 mm diameter, then more rounded. Umbilicus is one third of the diameter. Primary ribs start at the upper part of the umbilical wall, some remain single, in others secondary ribs branch from a tubercle in mid flank, or, more often, are intercalated between primaries, all ribs cross straight over the venter. Two lateral lobes are seen on some specimens, the larger one is trifid and deeper than the second and smaller one.

There are 24-28 primary ribs and 36-59 secondary ribs at 41-116 mm diameter. The secondary/primary ribs ratio varies from 1.48 to 2.11.

Measurements:

	D	**WH**	**WH/D**	**WT**	**WT/D**	**U**	**U/D**	**WT/WH**	**PR**	**SR**	**SR/ PR**
Sn 23/ 4	**116**	**45.5**	**0.39**	**36**	**0.31**	**31**	**0.27**	**0.79**	**28**	**59**	**2.11**
Sn 23/ 3	**85**	**33**	**0.39**	**31**	**0.36**	**25**	**0.29**	**0.93**	**26**	**50**	**1.92**
Sn 23/ 1	**54**	**23**	**0.43**	**22**	**0.41**	**20.5**	**0.38**	**0.95**	**25**	**37**	**1.48**
Sn 23/ 6	**41**	**17**	**0.41**	**13**	**0.32**	**14**	**0.34**	**0.76**	**24**	**36**	**1.5**
Sn 23/ 5		**22**		**18**		**19**					
Syntype	**53**	**23**	**0.43**	**22**	**0.42**	**18**	**0.34**	**0.96**			

Discussion: The specimens closely match with figures by Sinzow (1907) and Druschitz and Kudryutzeva (1960). They also show similarity with *Acanthohoplites abichi* Anthula (Sinzow, 1907, pl. 6, figs. 1-3), but the ribs in the latter species are denser.

Distribution: Germany (Kemper, 1971), Russia (Druschitz and Kudryutzeva, 1960), the Caucasus (Anthula, 1899), Mangyshlak (Sinzow, 1907), Iran (Seyed-Emami, 1980) and Mozambique (Förster, 1975).

Occurrence: Upper part of the Sanganeh Formation in the Sanganeh section.

Acanthohoplites cf. *aschiltaensis* (Anthula) 1899

Plate 9, Figure 4

cf. 1899 *Parahoplites aschiltaensis* Anthula, p.117, pl. 10, figs. 2, 3, pl. 11, fig. 1.
cf. 1907 *Acanthohoplites aschiltaensis* (Anthula); Sinzow, p. 479, pl. 5, figs. 1-8.
cf. 1914 *Acanthohoplites aschiltaensis* (Anthula); Kazansky, p. 67, pl. 3, fig. 47.
cf. 1953 *Acanthohoplites aschiltaensis* (Anthula); Glazunova, p. 42, pl. 8, figs. 1-3.
cf. 1960 *Acanthohoplites aschiltaensis* (Anthula); Druschitz and Kudryutzeva, p. 319, pl. 7, fig. 2, 3.
cf. 1971 *Acanthohoplites aschiltaensis* (Anthula); Kemper, pl. 25, fig. 4.
cf. 1975 *Acanthohoplites aschiltaensis* (Anthula); Förster, p. 203-205, pl. 9, fig. 3.

Syntypes: Institute of Palaeontology, University of Vienna (Anthula Colln) and Upsala Museum (Sjogren Colln), from Daghestan.

Material: One specimen [Sn 23/ 12].

Description: Moderately evolute, umbilical width about one third of the diameter. Whorl section sub-rectangular to rounded in final whorl, venter at first flattened then more rounded. Ribs slightly sinuous on flanks but straight over venter, primary ribs start from umbilical margin, are stronger on the lower third of the flank and venter and smoother on mid-flank, secondary ribs mainly intercalated between primaries.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Sn 23/ 12	102	44	0.43	37	0.36	34	0.33	0.84	29	60	2.07
Syntype	70	30	0.43	25	0.36	23	0.32	0.83	20	45	2.25

Discussion: This is the first record of the *A.* cf. *aschiltaensis* from the Kopet Dagh. *A. aschiltaensis* differs from *A. bigoureti* in rib pattern; in the latter species the ribs are wider and some single primary ribs are seen.

Distribution: Germany (Kemper, 1971), Russia (Druschitz and Kudryutzeva, 1960; Glazunova, 1953), the Caucasus (Anthula, 1899; Kazansky, 1914) Mangyshlak (Sinzow, 1907), Mozambique (Förster, 1975) and Iran.

Occurrence: Middle part of the Sanganeh Formation at Tirgan and Sanganeh sections.

Acanthohoplites sp. 1

Plate 9, Figure 5

Material: One broken specimen [Sn 21/ 12].

Description: Shell fairly evolute, whorl section rounded to sub-rectangular; ribs start from upper part of the umbilical wall, sharp on lower part of the flanks but flattened on the upper part of the flanks and ventral area. They also bend forward over the ventral area; bifurcation starts at mid-flank.

Discussion: The specimen may compare with *Acanthohoplites trautscholdi* Simonovich, Bastevich and Sorokin (Sinzow, 1907, pl. 4, figs. 9-17).

Occurrence: Upper part of the Sanganeh Formation in the Sanganeh section.

Acanthohoplites sp. 2

Plate 9, Figures 6a-b, 7

Material: 19 specimens [Raz 10/ 1-3; Raz 11/ 1-16].

Description: All specimens are fragments. Moderately evolute, whorl section sub-rectangular, flanks parallel, venter slightly flattened but does not have a distinct shoulder. Primary ribs start from middle part of umbilical wall, slightly flexuous on the flanks and straight over the venter, secondary ribs branch from primaries or intercalated between them, thicker at the ventral area, no tubercles on the flanks or venter.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Raz 11/ 3		**17**		**17**				**1**			
Raz 11/ 6		**18**		**14**				**0.78**			
Raz 11/ 1		**17**		**16**				**0.94**			
Raz 11/ 12		**17**		**13**				**0.76**			
Raz 10/ 1		**16**		**17**				**1.06**			
Raz 11/ 2		**16**		**13**				**0.81**			
Raz 11/ 4		**15**		**10**				**0.67**			
Raz 11/ 11		**15**		**13**				**0.87**			
Raz 11/ 13		**15**		**10**				**0.67**			
Raz 11/ 5		**13**		**10**				**0.77**			
Raz 11/ 14		**13**		**10**				**0.77**			
Raz 11/ 9		**11**		**10**				**0.91**			
Raz 10/ 2		**11**		**11**				**1**			

Discussion: The specimens are incomplete and cannot be identified to species level. *A*. sp. 2 differs from *A*. sp. 1 by its more compact ribs and a slightly flattened venter. Moreover all specimens of *A*. sp.2 are small.

Occurrence: Lower part of the Sanganeh Formation in the Raz section.

Acanthohoplites spp.

Plate 9, Figures 10, 11

Material: 11 specimens [Sn 21/6; Tr 20-21/ 1-6; Tr 22/ 1; Tr 32; Tr/ 37; Bib 21].

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Tr 22/ 1		**25.5**		**20**				**0.78**			
Tr 20-21/6		**24**		**18**				**0.75**			
Tr 20-21/ 3		**22**		**18**				**0.82**			
Bib 21		**22**		**20**				**0.91**			
Tr 20-21/ 5		**20.5**		**15.5**				**0.76**			
Tr 20-21/2		**19**		**15**				**0.79**			

Discussion: All the specimens are crushed. Samples with catalogue number Tr 20-21 and Tr 22 are all similar. Whorl section subrectangular, flanks parallel, venter flattened in early whorls and rounded in later whorls; primary ribs start from middle part of umbilical wall, a little flexuous on the flanks and straight over the venter, secondary ribs intercalated between primaries or attached them. They may compare with *A. lorioli* Sinzow.

In Tr 37, the whorl section is subrectangular, venter rounded, primary ribs start from upper part of the umbilical wall, secondaries intercalated from middle part of the flank. It shows similarity to *A. subangulatus* Sinzow. Sn 21/ 6 is semi-evolute, whorl section subrectangular, primary ribs straight and sharp, venter flattened. The specimen may compare with *A. multispinatus* Anthula. However it also shows similarity to *Colombiceras*. In Bib 21, the venter is rounded, primary ribs start from umbilical margin, secondary ribs intercalated, all ribs bend fairly forward on the venter. This may be *A. bigoti* Seunes.

Occurrence: Middle part of the Sanganeh Formation in the Sanganeh, Tirgan and Bibahreh sections.

Genus *Colombiceras* Spath 1923

Type Species: *Ammonites crassicostatus* d'Orbigny 1840, by original designation.

General characters: Moderately evolute, whorl section rectangular to sub-rectangular, sides parallel and venter flattened. Ribs straight or sometimes slightly curved on the flanks, and cross forwards over the venter, flattened on the upper part of the flanks and venter. Primary ribs commence from upper part of the umbilical wall. In young forms, secondary ribs either branch from a primary rib at a mid-lateral tubercle or are intercalated between adjacent primaries at mid flank. In the adult bifurcation can start below mid-flank. Suture line consists of a sub-rectangular and long ventral lobe, trifid lateral lobe, bifid saddles and simplified auxiliaries.

Discussion: Flattened ribs on the upper part of the flanks and venter are a good character for this genus. However it shows some similarities with *Gargasiceras,* but the latter has a slight groove on the venter and in young forms the primary ribs start on the lower third of the flank.

Distribution: The genus is recorded from England, France, Austria, Sardinia, Romania, Georgia, Turkmenistan, Mozambique, Madagascar, Texas, Mexico and Colombia (Follmi, 1989; Förster, 1975; Sinzow, 1907; Wright *et al.*, 1996), and Iran.

Age: Late Aptian (Wright *et al.*, 1996).

Colombiceras sp.

Plate 8, Figures 8, 9

Material: 6 specimens [Sn 21/ 1, 2, 4, 8, 9].

Description: Shell moderately evolute, whorl section sub-quadrate to sub-rounded, venter broad, apparently flattened, though this is not obvious. Ribs thick, straight, flat-topped, primary ribs start at umbilical wall, bifurcating at mid-flank, mostly from a bulla.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Sn 21/ 2	46	18	0.39	22	0.47			1.22			
Sn 21/ 4	38	18	0.47	19	0.5			1.06	21	30	1.42
Sn 21/ 1		25		26		29		1.04	20	26	1.3

Discussion: This is the first record of the genus from the Kopet Dagh. The specimens may be close to *Colombiceras caucasicum* Luppov (Druschitz & Kudryutzeva, 1960, p. 330, pl. 5, figs. 3a-b; pl. 6 figs. 3a-b; Follmi, 1989, p. 131, pl. 6, fig. 6). According to Casey (1965, p. 421) *Colombiceras caucasicum* is similar to *C. tobleri* (Sinzow), but differs from later species by lack of lateral tubercles/ bullae in early whorls.

Occurrence: The upper part of the Sanganeh Formation in the Sanganeh section.

Subfamily Parahoplitinae Spath 1922

Genus *Parahoplites* Anthula 1899

Type species: *Parahoplites melchioris* Anthula 1899, by original designation.

General characters: Moderately involute. Whorl section sub-rectangular, sides flattened and venter broadly curved. Primary ribs start from umbilical wall, slightly sigmoidal on flanks; a primary rib on one flank normally passes into a secondary rib on the other flank. Two or sometimes three secondary ribs between primaries, normally free but some attached, starting in middle third of the flank. Suture line includes a large external saddle, simplified lateral saddle and trifid lateral lobe.

Discussion: Anthula (1899) suggested the name of *Parahoplites* for ammonites that he believed to be between *Hoplites* and *Acanthoceras* in character. He classified species of *Parahoplites* into two main groups, *P. melchioris* and *P. aschiltaensis*. He mentioned that all forms of the *P. aschiltaensis* group and *P. treffryanus* from the *P. melchioris* group differ from his general description by having lateral tubercles on the main ribs. More study was carried out by Sinzow (1907) in his description of the Aptian ammonites of the Mangyshlak Peninsula. He retained *Parahoplites* for the *melchioris* group, and proposed *Acanthohoplites* for the *P. aschiltaensis* group.

Distribution: Europe, Russia, Georgia, Transcaspia, Iran, Arizona, Texas, Colombia, Peru (Asitove *et al.*, 1984; Druschitz and Kudryutzeva, 1960; Kotetishvili, 1988; Wright *et al.*, 1996; Zahedi, 1973).

Age: Late Aptian (Wright *et al.*, 1996).

Parahoplites cf. *campichii* (Pictet and Renevier) 1858

Plate 10, Figures 1, 2

cf. 1858 *Ammonites campichii* Pictet and Renevier, p. 25, pl. 2, fig. 2.
cf. 1907 *Parahoplites campichii* (Pictet and Renevier); Sinzow, p. 460, pl. 1, figs. 4-7.
cf. 1960 *Parahoplites campichii* (Pictet and Renevier); Druschitz and Kudryutzeva, p. 315-316, pl. 4, figs. 3a-b.

Holotype: Geological Museum of Academy of Science, Switzerland, From du Pont (de Joux Lake) area, Switzerland.

Material: 2 specimens [Sn 21/ 10, 11].

Description: The specimens are crushed. Whorl section sub-quadrate with flattened sides, convex venter, rather deep umbilicus. Ornamentation consists of dense primary ribs, arising at umbilical margin. Secondary ribs generally start in mid flank, occasionally branching from a primary but normally intercalated singly or in pairs between primary ribs. On the upper third of the flank and venter all ribs bend forward, and uniformly flattened.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Sn 21/ 10		65		48				0.73			
Sn 21/ 11		48		41.5		30		0.86	24	54	2.25
Holotype	145	71	0.49	55	0.38	34.5	0.24	0.77			

Discussion: The specimens show some similarity to the *Parahoplites sjogreni* Anthula figured by Druschitz and Kudryutzeva (1960, pl. 8, figs. 1a-b, pl. 6, fig. 1).

Distribution: Switzerland (Pictet and Renevier, 1858), Russia (Druschitz and Kudryutzeva, 1960), Mangyshlak (Sinzow, 1907) and Iran.

Occurrence: Middle part of the Sanganeh Formation in Sanganeh section.

Parahoplites cf. *maximus* Sinzow 1907

Plate 10, Figure 4

cf. 1907 *Parahoplites maximus* Sinzow, p. 464, pl. 1, figs. 1-3.

cf. 1913 *Parahoplites maximus* Sinzow; Kilian, p. 345.

cf. 1938 *Parahoplites maximus* Sinzow; Rouchadze, p. 201.

cf. 1960 *Parahoplites maximus* Sinzow; Druschitz and Kudryutzeva, p. 315, pl. 5, figs. 4a-b.

cf. 1965 *Parahoplites maximus* Sinzow; Casey, p. 408-410, pl. 68, figs. 5a-b, pl. 69, figs. 1, 2a-b, text-fig. 148.

cf. 1982 *Parahoplites maximus* Sinzow; Kemper, pl. 8.4-1, fig. 1.

Lectotype: Selected by Casey (1965) from Sinzow (1907), pl. 1, fig. 1, from the Aptian of Mangyshlak, Kazakhstan.

Material: 2 specimens [Gho 13; Bib14?].

Description: Moderately involute, umbilical width is between one fourth and one-fifth of the diameter, umbilical wall high. Whorls section is sub-quadrate, venter arched. Primary ribs originate on upper part of the umbilical wall, nearly straight but feebly bent or curved forward on the uppermost part of the flank, thicker near the umbilical margin; generally a primary rib on one side became a secondary on the other side; secondary ribs attached to primaries or intercalated, commencing at middle third of the flank.

Measurements:

	D	WH	WH/D	WT	WT/D	U	U/D	WT/WH	PR	SR	SR/ PR
Gho 13	**114**	**54**	**0.47**	**49**	**0.43**	**26**	**0.23**	**0.90**	**23**		
Lectotype	**183**	**86**	**0.47**			**43**	**0.24**				

Discussion: This is the first record of the *P.* cf. *maximus* from the Kopet Dagh. This species is a well-known form in the *punfieldensis* Zone in England and Germany. Specimen Bib 14 is incomplete, therefore is only questionably attributed to this species.

Distribution: England (Casey, 1965), Germany (Kemper, 1982), Russia and Mangyshlak (Druschitz and Kudryutzeva, 1960; Sinzow, 1907) and Iran.

Occurrence: Middle part of the Sanganeh Formation in Bibahreh and Ghorghoreh sections.

Subclass Nautiloidea Agassiz 1847

Order Nautilida Agassiz 1847

Superfamily Nautilaceae de Blainville 1825

Family Cymatoceratidae Spath 1927

Genus indet.

Plate 10, Figure 3

Material: 5 specimens [TAK 36/ 25-28; TAK 51/ 10; Am 21/6].

Description: Involute, sub-globular to sub-spherical, whorl section rounded. Ribs dense, straight or curved on the flank and bending forward on the venter.

Discussion: This is the first record of Cymatoceratidae from the Kopet Dagh. Kummel (1956) reported 64 species of with only 6 species is the next largest genus. Thus *Cymatoceras* is the most common genus of the Family Cymatoceratidae. On the other hand most species are recorded from the Cretaceous and only two species, one from the Late Jurassic of Argentina and one from the Oligocene of Japan are known as non-Cretaceous species of this genus.

Cymatoceras differs from other genera of the family in rib pattern, shape of shell or suture line. Ribs are V shaped on the flank and venter in *Eucymatoceras*. *Epicymatoceras* is distinguished from *Cymatoceras* by its sub-quadrate whorl section.

Cymatoceras differs from *Paracymatoceras* in the suture; in the latter genus a lateral lobe and umbilical saddle are developed. Because the suture on the Iranian specimens cannot be seen, it is impossible to decide whether they belong to *Cymatoceras* or *Paracymatoceras*.

Distribution: Uppermost part of the Sarcheshmeh Formation in Takal Kuh (2) section and in a limestone bed at the upper part of the Sanganeh Formation in Takal Kuh (2) and Amand sections.

Chapter 4. Biostratigraphy

4.1. Introduction

Ammonites provide one of the most precise biostratigraphical tools for correlating Lower Cretaceous sediments. But for much of Early Cretaceous time there was a separation into Tethyan and Boreal Realms (Chapter 7), and this sometimes makes long-distance correlation difficult. However, some ammonite genera were distributed world-wide and this helps to resolve some of the correlation problems.

Because the early Cretaceous ammonite sequences of Western Europe have been studied more than those in other areas of the world and the stage stratotypes are in this region, the ammonite zones proposed there are normally accepted as the standard biozonation.

Cretaceous stages, their boundaries and index faunas in Europe have been discussed by Birkelund *et al.* (1984). Hancock (1991), in a paper entitled 'Ammonite scales for the Cretaceous System' compiled information up to that date. More recently the Barremian, Aptian and Albian stages were discussed by Rawson (1996), Erba (1996) and Hart *et al.* (1996) respectively.

During the last decade the Lower Cretaceous Cephalopod Team (now a working group of the Subcommission on Cretaceous Stratigraphy (SCS) of IUGS) has held five International Workshops, concerned primarily with improving the standard biozonation for the Mediterranean area of the Tethyan Realm (Hoedemaeker and Bulot, 1990; Hoedemaeker *et al.* 1993, 1995; Rawson *et al.*, 1999; Hoedemaeker and Rawson, 2000) (Table 4.1).

In this chapter, firstly the current division and biozonation of the Upper Barremian to Lower Albian Sub-Stages will be discussed. Secondly, an attempt is made to construct a zonal scheme for the Kopet Dagh ammonite fauna, to correlate it with the standard biozonation and to explain its limitations and applications.

Stage	Substage	Casey, 1961; Hancock, 1991 (S. E. England)	Kemper, 1973; Rawson, 1983 (North Germany/ England)		Busnardo, 1984; Delanoy, 1997; Ropolo *et al.*,1998, 1999 (France)	Hoedemaeker and Rawson, 2000 (Mediterranean Region)	Kotetshivili *et al.*, 2000 (Caucasus)
Albian	M.	*Hoplites dentatus*				*Hoplites dentatus*	*Hoplites dentatus*
Albian	Lower	*Douvilleiceras mammillatum*	*Douvilleiceras mammillatum*		*Douvilleiceras mammillatum*	*Douvilleiceras mammillatum*	*Douvilleiceras mammillatum*
Albian	Lower	*Leymeriella tardefurcata*	*Leymeriella regularis* *Proleymeriella schrammeni*		*Leymeriella tardefurcata*	*Leymeriella tardefurcata*	*Leymeriella tardefurcata*
Aptian	Upper	*Hypacanthoplites jacobi*	*Hypacanthoplites jacobi*	Upper	*Hypacanthoplites jacobi*	*Hypacanthoplites jacobi*	*Hypacanthoplites jacobi*
Aptian	Upper		*Acanthohoplites nolani*	Upper	*Diadochoceras nodosocostatum*	*Acanthohoplites nolani*	*Acanthohoplites nolani*
Aptian	Upper	*Parahoplites nutfieldensis*	*Parahoplites nutfieldensis*	Middle		*Parahoplites melchioris*	*Colombiceras tobleri*
Aptian	Upper	*Cheloniceras (Epicheloni-ceras) martinioides*	*Epicheloniceras tschernyschewi* *Tropaeum drewi*	Middle	*C. (Epicheloniceras) martinioides*	*C. (Epicheloniceras) subnodosocostatum*	*C. (Epicheloniceras) subnodosocostatum*
Aptian	Lower	*Tropaeum bowerbanki*	*Tropaeum bowerbanki*	Lower	*T. bowerbanki/ D. furcata*	*Dufrenoyia furcata*	*Dufrenoyia furcata*
Aptian	Lower	*Deshayesites deshayesi* *Deshayesites forbesi*	*Deshayesites deshayesi*	Lower	*Deshayesites deshayesi*	*Deshayesites deshayesi*	*Deshayesites deshayesi*
Aptian	Lower	*Prodeshayesites fissicostatus*	*Prodeshayesites fissicostatus*	Lower	*Deshayesites weissi* *Deshayesites tuarkyricus*	*Deshayesites weissi* *Deshayesites tuarkyricus*	*D. weissi- Procheloniceras albrechti-austriae*
Barremian	Upper		*Parancyloceras bidentatum & Parancyloceras scalare*		*Pseudocrioceras waagenoides*	*Pseudocrioceras waagenoides*	*Colchidites securiformis*
Barremian	Upper				*Martelites sarasini*	*Martelites sarasini*	
Barremian	Upper				*Imerites giraudi*	*Imerites giraudi*	*Imerites giraudi*
Barremian	Upper		*Simancyloceras stolleyi*		*Hemihoplites feraudianus*	*Hemihoplites feraudianus*	*Hemihoplites soulieri*
Barremian	Upper		*Ancyloceras innexum & Simancyloceras pingue*		*Gerhardtia sartousiana*	*Heinzia sartousiana*	*Heinzia sartousiana*
Barremian	Upper		*Paracrioceras denckmanni*		*Ancyloceras vandenheckii*	*Ancyloceras vandenheckii*	*Ancyloceras vandenheckii*

Table 4.1. Correlation chart of Upper Barremian- Lower Albian ammonite biozones in north-west European and Mediterranean areas.

4.2. Current definition and biozonation of the Barremian to Albian Stages

As the ammonite faunas of the studied formations are of Late Barremian-Early Albian age, the biostratigraphy and biozonation of this interval will be briefly explained.

4.2.1. The Barremian Stage

The Barremian stage was first defined by Coquand (1861), based on successions in the south-east of France. One of his cited localities, Angles (Basses-Alpes), was designated by Busnardo (1965) as 'stratotype', though the Barremian Working Group of the Subcommission on Cretaceous Stratigraphy have since suggested that the base of the Barremian should be defined in the Río Argos section of south-east Spain (Rawson, 1996). The typical Barremian ammonite faunas belong to the Mediterranean Province. They have been studied extensively in recent years, especially in France (Delanoy, 1992, 1994, 1995, 1997; Vermeulen, 1996), Georgia and adjacent areas (Kakabadze, 1971, 1975, 1983; Kotetishvili, 1988; Kotetishvili *et al.*, 2000), Romania (Avram, 1983) and the Czech Republic (Vasicek *et al.*, 1983). Klein and Hoedemaeker (1999) and Hoedemaeker and Rawson (2000) have reviewed the biostratigraphy and highlighted some of the remaining problems. The Upper Barremian zonation is discussed in more detail below.

4.2.1.1. Upper Barremian biozonation

Several markers have been proposed for the base of the Upper Barremian Sub-Stage. In particular, Busnardo (1984) used the first appearance of *Emericiceras* in south-east France. Later, *Ancyloceras vandenheckii* was suggested for the basal marker in the Mediterranean region (Hoedemaeker and Bulot, 1990; Rawson, 1996).

Representative species of heteroceratid genera are used as index fossils in the Upper Barremian ammonite biozonation (Hoedemaeker *et al.*, 1993, 1995; Kakabadze, 1971, 1983; Tovbina, 1963). Their almost world-wide dispersion and limitation to the Upper Barremian makes it possible to correlate deposits in widely scattered areas (Table 4.1). Although their major centre of occurrence is in the Caucasus and Turkmenistan (Kakabadze, 1971, 1975; Kotetishvili, 1988, Kotetishvili *et al.*, 2000), they are also recorded from France (Busnardo 1984; Delanoy, 1997; Hancock, 1991), from more northerly latitudes in England (Rawson, 1995), Canada (Jeletzky, 1976) and Japan (Obata *et al.*, 1976) as well from the southern hemisphere in Zululand (Klinger *et al.*, 1984) and Argentina (Blasco *et al.*, 1980; Aguirre-Urreta and Klinger, 1986).

Turkmeniceras turkmenicum was suggested as a marker for the uppermost Barremian by Russian palaeontologists (Bogdanova, 1971a; Bogdanova and Tovbina, 1994; Tovbina, 1963). As *Turkmeniceras* is only recorded from the Kopet Dagh, *Hemihoplites ridzewskyi* was suggested as an alternative by Hoedemaeker *et al.* (1993). However, Hoedemaeker and Rawson (2000) have now adopted the *Pseudocrioceras waagenoides* Zone, first proposed for Georgian sequences (Kakabadze and Kotetishvili, 1995) for the West Mediterranean zonation. It replaces the upper part of their *Martelites securiformis* Zone (Table 4.1).

4.2.2. The Aptian Stage

The name of stage was taken from Apt in south-east France by d'Orbigny (1840). Aptian ammonite faunas have been studied in England by Casey (1961a, 1960-1980), in Germany by Brinkmann (1937) and Kemper (1967, 1971, 1973b, 1982, 1995), in France by Breistroffer (1947), in Romania by Avram (1999) and in Russia by Bogdanova (1971b, 1983, 1991). Casey (1961a) introduced a biozonation for the Aptian Stage that has been quoted in many papers in the last few decades (Table 4.1). It was based on the sequences in south-east England, but is applicable much more widely with some local modifications (e.g. Kemper, 1976). Faunal differentiation between the English and German faunas on the one hand and those of the south-east of France on the other is much less marked than earlier in the Cretaceous (Rawson, 1981; Hoedemaeker, 1990). Hence the current zonation for the Mediterranean region (Hoedemaeker and Rawson, 2000) uses many of the same genera, and even some of the same species.

An important series of papers has documented the Aptian faunas of the Russian Platform, the Caucasus and Mangyshlak (e.g. Bogdanova, 1977, 1979, 1983; Glazunova, 1973; Druschitz and Kudryutzeva, 1960; Tovbina, 1979). The Mediterranean Region zonation embraces some of the Lower Aptian deshayesitid zones first established in Mangyshlak (Bogdanova, 1971; Bogdanova and Tovbina, 1994; Tovbina, 1968, 1980).

The Barremian-Aptian boundary is problematic. The first appearance of *Prodeshayesites* has been taken to mark the base of the Aptian in England, Germany and south-east France (e.g. Casey, 1961a; Birkelund *et al.*, 1984; Kemper, 1973b). Busnardo (1965) fixed the boundary in the type area of the Aptian by the appearance of *Pseudohaploceras matheroni*. However, according to Delanoy (1992), *Pseudohaploceras matheroni* occurs in the *Martelites sarasini* Zone (Barremian). Busnardo (1984) later recorded *Prodeshayesites* from beds below his *Pseudocrioceras coquandi* Zone, and placed them at the base of the Aptian.

Delanoy (1991) also recorded *Prodeshayesites* and *Paradeshayesites* from south-east France. However, he later (Delanoy, 1995) revised his identifications and attributed the '*Prodeshayesites*' to *Deshayesites*. This means that *Prodeshayesites* is limited to east Greenland, England and North Germany. In both East Greenland and eastern England it apparently precedes true *Deshayesites* (Casey, 1961a, 1964; Kelly and Whitham, 1999). However, the taxonomic status of *Prodeshayesites* is now questioned; Kemper (1995) considered it to be a synonym of *Deshayesites* and stressed the affinity of '*Prodeshayesites*' with some Turkmenian species of *Deshayesites*. Furthermore, Bogdanova and Tovbina (1994) correlated the English *Prodeshayesites fissicostatus* Zone with the *Deshayesites tuarkyricus* Zone of Turkmenistan.

The Aptian Stage is divided into two parts, Lower and Upper Aptian, in north-west Europe (e.g. Casey, 1961a; Rawson, 1983; Erba, 1996), whilst recent revisions of the Lower Cretaceous ammonite biozonation of the Mediterranean Region retain the three-fold subdivision of French authors (Erba, 1996; Hoedemaeker *et al.*, 1993, 1995; Hoedemaeker and Rawson, 2000).

4.2.2.1. Aptian biozonation

Russian palaeontologists introduced a biozonation based on Deshayesitidae for the Lower Aptian, which could be traced in Turkmenistan and Georgia (Bogdanova, 1971b; Bogdanova and Tovbina, 1994; Kotetishvili *et al.*, 2000; Tovbina, 1963). The Lower Cretaceous Cephalopod Team accepted this biozonation as a standard for the Mediterranean area (Hoedemaeker *et al.*, 1993, 1995).

Deshayesites is Mediterranean-Himalayan Province genus. It is recorded from east Greenland, across Europe to the Caucasus and Russia (Rawson, 1981; Kotetishvili, 1988), and from north Africa (Memmi, 1995, 1999). Seyed-Emami *et al.* (1971) also recorded this genus from central Iran for the first time. The genus has not been reported from the southern hemisphere and the Far East. There is confusion on over whether the Venezuelan records of *Deshayesites* really belong to this genus (Birkelund *et al.*, 1984; Erba, 1996).

The *Deshayesites tuarkyricus* Zone was suggested by Bogdanova (1971b, 1983) for sequences in Turkmenistan. Then it was chosen for the whole of the Mediterranean region (Hoedemaeker and Bulot, 1990). Delanoy (1995), Ropolo *et al.* (1998, 1999) and Cecca *et al.* (1999b) recorded the assemblage faunas of the *tuarkyricus* Zone in France, although *D. tuarkyricus* itself is limited to the Mangyshlak (Turkmenistan) and Transcaspia. Kotetishvili *et al.* (2000) could not distinguish the *tuarkyricus* Zone in the Caucasus and suggested a broader *D. weissi-Procheloniceras albrechti-austriae* Zone as the basal Aptian biozone (Table 4.1).

The second Lower Aptian ammonite zone is the *D. weissi* Zone (Table 4.1 & 4.2). Bogdanova and Tovbina (1994) noted that the range of the *weissi* Zone is established from the stratigraphical range of two species, *Deshayesites weissi* and *Deshayesites planus*. While *D. weissi* is known only from North Germany, Romania, the Greater Balkans, Taurkyr and Kubadag (Kopet Dagh), the latter species is more widespread. Bogdanova and Tovbina (1994) believed that the *weissi* Zone in Transcaspia could be correlated with the *forbesi* Zone (Casey, 1961a) in England and the *weissi* Zone (Kemper, 1976) in Germany. However, Avram (1999) believed that the *D. forbesi* and *D. weissi* Zones are not the same. He provisionally correlated the base of the *weissi* Zone with the base of the *callidiscus* Subzone (upper subzone of the *forbesi* Zone) and it ranges up to the base of the *grandis* Subzone (upper subzone of the *deshayesi* Zone).

Deshayesites deshayesi is the most common species of *Deshayesites* and spread through most of the areas from which the genus is recorded (Bogdanova, 1971, 1979; Bogdanova and Tovbina, 1994; Druschitz and Kudryutzeva, 1960; Druschitz and

Stage	Substage	Hoedemaeker and Rawson, 2000 (Mediterranean region)	Kotetshivili *et al.*, 2000 (Caucasus)	Tovbina, 1963; Bogdanova and Tovbina, 1994 (Turkmenistan-Kopet dag)	**This Study** (Iran- Kopet Dagh)
Albian	Lower	*Douvilleiceras mammillatum*	*Douvilleiceras mammillatum*		*Douvilleiceras* spp.
		Leymeriella tardefurcata	*Leymeriella tardefurcata*		*Leymeriella tardefurcata*
Aptian	Upper	*Hypacanthoplites jacobi*	*Hypacanthoplites jacobi*	*Hypacanthoplites jacobi*	*Hypacanthoplites uhligi*
		Acanthohoplites nolani	*Acanthohoplites nolani*	*Acanthohoplites nolani* *Acanthohoplites prodromus*	*Acanthohoplites* spp.
	Middle	*Parahoplites melchioris*	*Colombiceras tobleri*	*Parahoplites melchioris*	*Parahoplites* spp.
		Cheloniceras (Epicheloniceras) subnodosocostatum	*C. (Epicheloniceras) subnodosocostatum*	*C. (Epicheloniceras) subnodosocostatum*	*C. (Epicheloniceras) subnodosocostatum*
	Lower	*Dufrenoyia furcata*	*Dufrenoyia furcata*	*Dufrenoyia furcata*	*Dufrenoyia* sp.
		Deshayesites deshayesi	*Deshayesites deshayesi*	*Deshayesites deshayesi*	*Deshayesites deshayesi*
		Deshayesites weissi	*D. weissi- Procheloniceras albrechti-austriae*	*Deshayesites weissi*	*Deshayesites weissi*
		Deshayesites tuarkyricus		*Deshayesites tuarkyricus*	*Deshayesites oglanlensis*
Barremian	Upper	*Pseudocrioceras waagenoides*	*Colchidites (=Martelites) securiformis*	*Colchidites (=Martelites) ratshensis* / *Turkmeniceras turkmenicum*	*Martelites securiformis* / *Turkmeniceras multicostatum*
		Martelites sarasini			*Martelites securiformis*
		Imerites giraudi	*Imerites giraudi*	*Imerites giraudi*	*Heteroceras* spp.
		Hemihoplites feraudianus	*Hemihoplites feraudianus*		
		Heinzia sartousiana	*Heinzia sartousiana*		
		Ancyloceras vandenheckeii	*Ancyloceras vandenheckeii*		

Table 4.2. Upper Barremian-Lower Albian correlation chart of ammonite biozones in the Kopet Dagh basin and adjacent parts of the Tethyan Realm.

Gorbatschik, 1979; Casey, 1964; Hancock, 1991; Memmi, 1995, 1999; Rawson, 1983; Shulgina, 1996). It is thus used widely as the index fossil of the penultimate Lower Aptian zone (Table 4.1).

Dufrenoyia is a widely distributed genus and *D. furcata* is the index fossil for the uppermost part of the Lower Aptian in the Mediterranean region. Casey (1961a) suggested *Tropaeum bowerbanki* as index species for the uppermost zone of the Lower Aptian in southern England, but *Dufrenoyia furcata* also occurs in that zone.

The *Cheloniceras (Epicheloniceras) subnodosocostatum* Zone is the lowest biozone of the Middle Aptian of the Mediterranean region, and the index species is recorded also from the Caucasus (Kotetishvili *et al.*, 2000), Mangyshlak (Kopaevich *et al.*, 1999) and north Africa (Memmi, 1999). This zone possibly correlates with the *C. (E.) martinioides* Zone (Casey, 1961a) of southern England, the *Tropaeum drewi* and *C. (E.) tschernyschewi* zones in North Germany (Rawson, 1983) and the *C. (E.) tschernyschewi* Zone in Russia (Glazunova, 1973; Baraboshkin, 1998).

The *Parahoplites melchioris* Zone (Stoyanow, 1949) was used initially by Georgian authors (e.g. Eristavi, 1960), then recommended for the whole of the Mediterranean region (Hoedemaeker *et al.*, 1993; Hoedemaeker and Rawson, 2000). This zone is equivalent to the *Colombiceras tobleri* Zone of Georgia (Kotetishvili *et al.*, 2000) and may correlate with the *P. nutfieldensis* Zone of southern England (Casey, 1961a; Kemper, 1973a).

The Upper Aptian is divided into the *Acanthohoplites nolani* and *Hypacanthoplites jacobi* zones. *Acanthohoplites nolani* is well known from Germany, the former Soviet Union and Madagascar (Collignon, 1978; Kemper, 1971; Owen, 1996). It is also recorded from central Iran (Seyed-Emami, 1980). Kopaevich *et al.* (1999) suggested that the *A. aschiltaensis* and *A. nolani* zones of Mangyshlak are equivalent to the *A. nolani* Zone of Hoedemaeker and his co-workers.

The *Hypacanthoplites jacobi* Zone is the highest Aptian zone, and is recognised from southern England, through Europe to the Caucasus (Table 4.1).

4.2.3. The Albian Stage

The Albian stage was introduced by d'Orbigny (1840-1843). Ammonite faunas of this stage were studied in France by Breistroffer (1947) and Latil (1994), in Germany by Brinkmann (1937) and Kemper (1982), and in England by Spath (1923-1943) and Casey (1965). Owen (1971, 1973, 1988, 1996, 1999) focused on Albian biostratigraphy and palaeobiogeography, mostly of the European area. Albian ammonite faunas and their biostratigraphy were described from the Carpathians by Vasicek (1995), from the Crimea by Marcinowski and Naidin (1976), Marcinowski and Wiedmann (1985) and from the former Soviet Union by Druschitz and Kudryutzeva (1960), Saveliev (1973, 1992), Mikhailova and Saveliev (1989) and Baraboshkin (1996).

In a discussion of the Aptian-Albian boundary, Casey (1999) suggested that the current use of the first appearance of *Leymeriella* to mark the base of the Albian is unsatisfactory because of its limited geographical distribution. He proposed that the first appearance of *Hypacanthoplites* should be used instead, because of the world-wide distribution of the *Acanthohoplites-Hypacanthoplites* lineage. This would lower the base of the Albian. However, he mentioned that early *Hypacanthoplites* can only be distinguished easily from *Acanthohoplites* in microconchs and juvenile macroconchs. Moreover, some *Acanthohoplites* and *Hypacanthoplites* species are recorded together by some authors (e.g. Druschitz and Kudryutzeva, 1960; Collignon, 1962; Casey, 1965; Mandov and Nikolov, 1992; and this study). Hence Casey's proposal raises new difficulties in recognising the boundary.

Recently Kennedy *et al.* (2000) also discussed the Aptian-Albian boundary and suggested two sections in France as potential global boundary stratotype sections. They put the *Hypacanthoplites jacobi*, *Proleymeriella schrammeni* and *Leymeriella germanica* zones in the uppermost part of the Upper Aptian and took the first appearance of *Leymeriella tardefurcata* as the base of the Albian.

The Lower Cretaceous Cephalopod Team still uses the first appearance of *Leymeriella* to mark the base of the Albian (Hoedemaeker and Rawson, 2000) and I follow their biozonation, pending a decision by the Albian Working Group of the Subcommission on Cretaceous Stratigraphy.

4.2.3.1. Lower Albian biozonation

Leymeriella tardefurcata has long been used as index for the lowest Albian biozone (e.g. Spath, 1923a; Brinkmann, 1937; Breistroffer, 1947; Casey, 1961a; Hoedemaeker *et al.*, 1993). It has a widespread distribution in Europe, the Caucasus and Transcaspia, being recorded in England (Casey, 1961a), France (Breistroffer, 1947; Latil, 1994), Germany (Kemper, 1973b, 1975), Austria (Kennedy and Kollmann, 1979), Bulgaria (Ivanov, 1991), Russia (Baraboshkin, 1996) and Mangyshlak (Saveliev, 1973, 1992). It is used as a zone fossil across the whole of this area. However, it has not been recorded further afield, hence Casey's (1999) suggestion discussed above.

The second biozone of the Lower Albian is that of *Douvilleiceras mammillatum*. *Douvilleiceras* is a widespread genus known from Britain, Germany, France, Switzerland, Poland, Georgia, Iran, Kazakhstan, Madagascar, northern India, central Canada, California, Colombia, Peru, Texas and Venezuela (Collignon, 1963; Follmi, 1989; Hancock, 1991; Immel, 1987; Jeletzky, 1980; Kotetishvili, 1988; Marcinowski and Wiedmann, 1988; Owen, 1988 and Seyed-Emami and Immel, 1996). The *mammillatum* Zone is recognised in south-east England, France, the Caucasus, Russia, and even north Africa and Madagascar (Baraboshkin, 1996; Busnardo, 1984; Casey, 1961a; Collignon, 1978; Kotetishvili *et al.*, 2000 and Memmi, 1999). However, Saveliev (1992) and Kopaevich *et al.* (1999) used *Sonneratia* and *Otohoplites* species as biozonal indices for the Mangyshlak area.

4.3. Biozonation of the Kopet Dagh

4.3.1. Introduction

Bed-by-bed sampling and measurement of the 10 stratigraphical sections studied here provides a firm basis for a biozonation for the Upper Barremian-Lower Albian of the Kopet Dagh Basin. The faunas show very close affinities with those from Mangyshlak and Georgia, and have much in common with those of the west Mediterranean Region and southern England. Thus I have attempted to apply the 'standard' biozonation of the West Mediterranean Province discussed above and tabulated by Hoedemaeker and Rawson (2000). However, the index fossils of some of the standard biozones have not been found in Iran. In these cases I have suggested a local taxon instead, in agreement with Casey's (1996, p. 73) philosophy, that 'a zonal scheme based on fossils present in the strata is preferable to one based on fossil that are not'. The proposed zonation is summarised in Table 4.2.

4.3.2. The proposed zonal scheme

4.3.2.1. Barremian

4.3.2.1.1. Lower Barremian

The oldest ammonite recorded from the Cretaceous of the Iranian Kopet Dagh is a single specimen from the uppermost part of the Tirgan Formation. It was recorded by Immel *et al.* (1997) and identified as *Paraspiticeras percevali*, belonging to the Douvilleiceratidae. It was found in the north-west part of the basin. This genus is also recorded from Europe and the Caucasus (Avram, 1983; Kotetishvili, 1988).

4.3.2.1.2. Upper Barremian

The Upper Barremian ammonites of the Kopet Dagh Basin are *Barremites, Toxoceratoides, Heteroceras, Argvethites, Imerites, Paraimerites, Martelites, Hemihoplites* and *Turkmeniceras*. *Hemihoplites* has not been collected by the author but is recorded by Immel *et al.*, (1997).

Although the index species of the standard biozonation have not been found in the basin, two biozones are suggested for the Upper Barremian based on taxon ranges in the Takal Kuh and Amand sections (Tables 4.2 & 4.3).

Heteroceras spp. Zone- This zone is an assemblage zone. The base of zone is defined by the appearance of *Heteroceras*. Other characteristic taxa include *Barremites* cf. *difficilis*, *Argvethites* sp., *Imerites favrei, Imerites sparcicostatus* and *Hemihoplites* sp. (Table 4.3). This zone appears in the lowermost part of the Sarcheshmeh Formation in the Takal Kuh sections (Figures 4.1& 4.2). It can be compared with the lower part of the *Imerites favrei-Heteroceras astieri* Zone, which reprresents the whole of the Upper Barremian, in the Caucasus (Kakabadze, 1983, 1989), and the *Hemihoplites feraudianus* and *Imerites giraudi* zones of the West Mediterranean Province (Hoedemaeker *et al.*, 1995; Hoedemaeker and Rawson, 2000).

Table 4.3. The standard biozonation and the proposed biozonation for the Upper Barremian of the Kopet Dagh basin.

<table>
<tr><th>Stage</th><th>Substage</th><th>Standard biozonation
(Hoedemaeker and Rawson, 2000)</th><th colspan="2">Proposed biozonation</th><th>Assemblage fauna
Recorded in this study
Recorded by Immel et al., 1997
<u>Recorded in both studies</u></th></tr>
<tr><td rowspan="7">BARREMIAN</td><td rowspan="6">Upper Barremian</td><td>Pseudocrioceras waagenoides</td><td rowspan="2">Martelites securiformis</td><td>Turkmeniceras multicostatum</td><td>Turkmeniceras multicostatum, T. cf. tumidum, <u>Martelites securiformis</u>, M. cf. tinae, M. cf. tenuicostatus, M. sp. 1, Barremites cf. difficilis, and Imerites sparcicostatus</td></tr>
<tr><td>Martelites sarasini</td><td>Martelites securiformis</td><td><u>Martelites securiformis</u>, M. ratshensis, M. tinae, M. tenuicostatus, M. cf. tinae, M. cf. tenuicostatus, M. sp. 1, M. sp. 2, Paraimerites sp., <u>Heteroceras cf. colchicus</u>, Argvethites sp., Toxoceratoides sp. and Barremites cf. <u>difficilis</u></td></tr>
<tr><td>Imerites giraudi</td><td colspan="2" rowspan="2">Heteroceras spp.</td><td rowspan="2"><u>Heteroceras cf. colchicus</u>, H. sp., Argvethites sp., Imerites favrei, I. sparcicostatus and Hemihoplites sp.</td></tr>
<tr><td>Hemihoplites feraudianus</td></tr>
<tr><td>Hemihoplites sartousiana</td><td colspan="2" rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Ancyloceras vandenheckii</td></tr>
<tr><td>L.Barremian</td><td></td><td colspan="2"></td><td>Paraspiticeras percevali</td></tr>
</table>

Martelites securiformis Zone- This zone is an assemblage zone. The base of the zone is defined by the first appearance of *Martelites securiformis*. The zone is known in the Takal Kuh and Amand sections (Figures 4.1-4.3). It correlates with the *securiformis* Zone of Georgia (Druschitz and Gorbatschik, 1979; Kakabadze, 1975; Kotetishvili *et al.*, 2000) and the *M. sarasini* and *Pseudocrioceras waagenoides* zones of the West Mediterranean Province. The zone is divided into two subzones, *Martelites securiformis* and *Turkmeniceras multicostatum*.

Martelites securiformis Subzone- The subzone is characterised by the appearance of *Martelites*, but without *Turkmeniceras*. Other taxa include *Toxoceratoides* sp. (which also occurs below), *Heteroceras* cf. *colchicus*, *Argvethites* sp. and *Paraimerites* sp.

Turkmeniceras multicostatum Subzone- *Martelites* still occurs, but is joined by *Turkmeniceras*. The base of the zone is defined by the first appearance of *Turkmeniceras multicostatum*, and *T.* cf. *tumidum* also occurs. Longer ranging taxa include the last *Barremites* cf. *difficilis*. The subzone can be correlated with the *T. turkmenicum* Subzone of Mangyshlak (Bogdanova and Tovbina, 1994) and the *Pseudocrioceras waagenoides* Zone of the west Mediterranean region.

4.3.2.2. Aptian

4.3.2.2.1. Lower Aptian

Lower Aptian ammonites occur in the middle and upper parts of the Sarcheshmeh Formation. The following genera are recorded: *Phylloceras*, *Phyllopachyceras*, *Eogaudryceras*, *Eotetragonites*, *Aconeceras*, *Pseudosaynella*, *Melchiorites*, *Pedioceras*, *Ancyloceras*, *Australiceras*, *Cheloniceras*, *Deshayesites*, *Dufrenoyia* and Cymatoceratidae (Nautiloidea). *Deshayesites* with 50% and *Aconeceras* with 30% of the Lower Aptian specimens are the most abundant. The following biozones are suggested for the Lower Aptian of the Kopet Dagh Basin:

Deshayesites oglanlensis Zone- This zone is an assemblage zone. The base of the zone is marked by the appearance of *Deshayesites oglanlensis* in the Takal Kuh and Amand sections (Figures 4.1-4.3). Other species include *Deshayesites dechyi, D.* cf. *euglyphus*, *D. luppovi, D.* cf. *weissiformis*, *D. tenuicostatus*, *D.* cf. *tuarkyricus*, *D.* sp. 1 *Pedioceras* sp. and *Ancyloceras* cf. *mantelli* (Table 4.4). As *D. oglanlensis* is more abundant than *D.* cf. *tuarkyricus* and other species it is proposed as the zonal index. The assemblage shows more similarity to Turkmenian and Caucasian faunas than to those from north-west Europe. However, some more widespread species also occur.

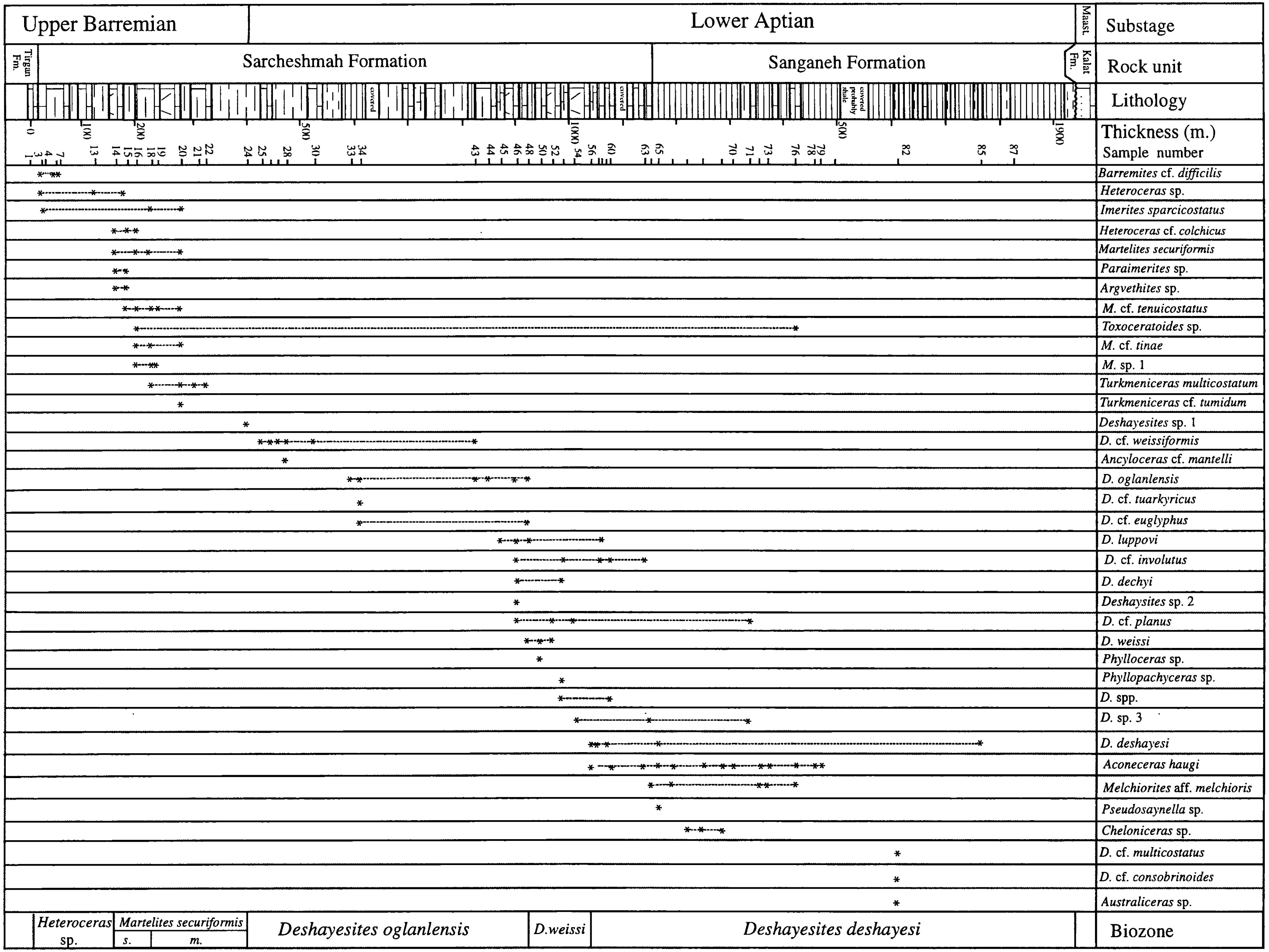


Figure 4.1. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Takal Kuh section (1), *s.= securiformis* Subzone, *m.= multicostatum* Subzone.

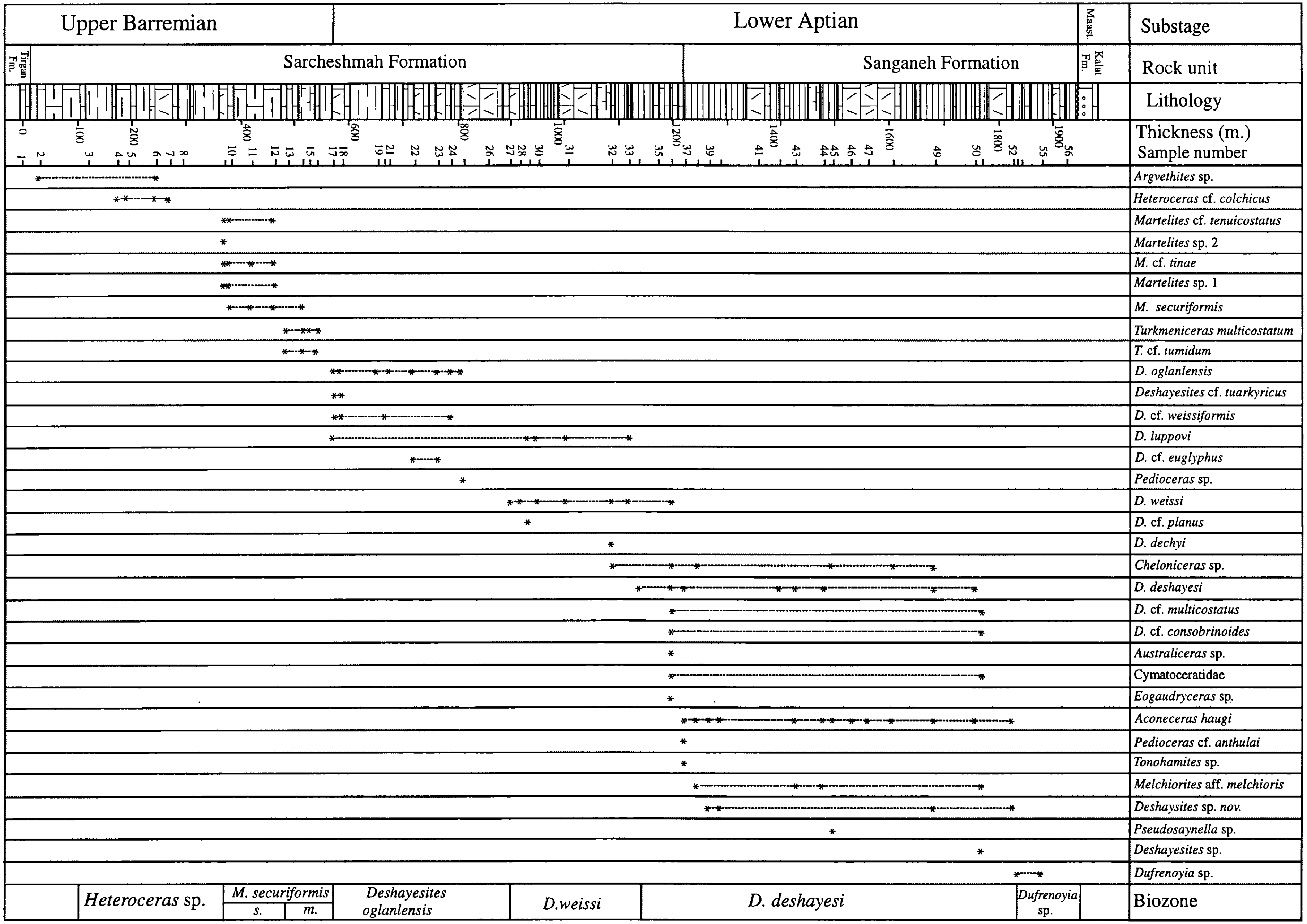


Figure 4.2. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Takal Kuh section (2), *s.= securiformis* SubZone, *m.= multicostatus* Subzone.

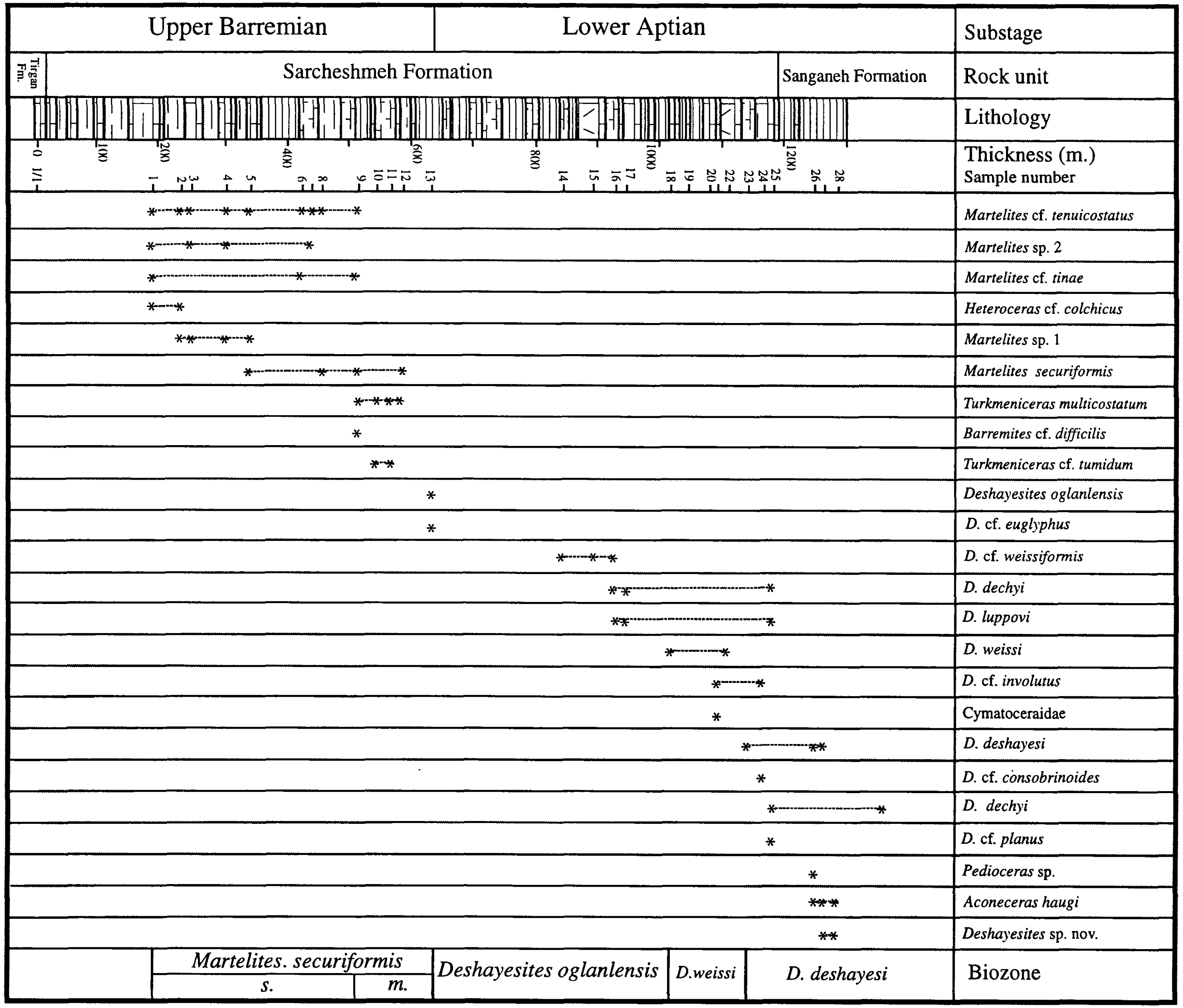


Figure 4.3. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Amand section, *s.= securiformis* Subzone, *m.= multicostatus* Subzone.

Table 4.4. The standard biozonation and the proposed biozonation for the Aptian of the Kopet Dagh basin.

Stage	Substage	**Standard biozonation** (Hoedemaeker and Rawson, 2000)	**Proposed biozonation**	**Assemblage fauna** ***Recorded in this study*** *Recorded by Immel et al., 1997* *Recorded in both studies*
APTIAN	Upper Aptian	*Hypacanthoplites jacobi*	*Hypacanthoplites uhligi*	*Hypacanthoplites uhligi*, ***H.* cf. *anglicus*, *H.* cf. *clavatus*, *H.* cf. *elegans***, *H. shepherdi*, ***H.* cf. *subrectangulatus***, ***H.* sp.** and ***Acanthohoplites* spp.**
		Acanthohoplites nolani	*Acanthohoplites* spp.	***Acanthohoplites* cf. *aschiltaensis*, *A.* cf. *bigoureti*, *A.* spp., *A.* sp. 1** and ***A.* sp. 2**
	Middle Aptian	*Parahoplites melchioris*	*Parahoplites* spp.	*Parahoplites* sp. ex gr. P. *melchioris*, ***P.* cf. *maximus*, *P.* cf. *campichii*, *Colombiceras* sp.** and ***C.* (*Epicheloniceras*) sp.**
		Cheloniceras (*Epicheloniceras*) *subnodosocostatum*	*Cheloniceras* (*Epicheloniceras*) *subnodosocostatum*	***C.* (*Epicheloniceras*) sp.**, *C.* (*E.*) cf. *aphanasievi*, *C.* (*E.*) *subnodosocostatum*, *C.* (*E.*) *waageni* and *C.* (*E.*) *tzankovi*,
	Lower Aptian	*Dufrenoyia furcata*	*Dufrenoyia* sp.	***Dufrenoyia* sp.**, and ***Eogaudryceras* (*Eotetragonites*) sp.**
		Deshayesites deshayesi	*Deshayesites deshayesi*	***Deshayesites* cf. *consobrinoides*, *D. deshayesi*, *D.* cf. *involutus*, *D. luppovi*, *D.* cf. *multicostatus*, *D.* cf. *planus*, *D.* sp. nov., *D.* spp., *D.* sp. 3, *Aconeceras haugi*, *Australiceras* sp., *Cheloniceras* spp., *Eogaudryceras* (*Eogaudryceras*) sp., *Melchiorites* aff. *melchioris*, *Pedioceras* cf. *anthulai*, *Pseudosaynella* sp., *Tonohamites* sp., *Toxoceratoides* sp.** and **Cymatoceratidae.**
		Deshayesites weissi	*Deshayesites weissi*	***Deshayesites dechyi*, *D.* cf. *euglyphus*, *D.* cf. *involutus*, *D. luppovi***, *D. latilobatus*, ***D.* cf. *planus*, *D. weissi***, and ***D.* sp. 3, *Phylloceras* sp., *Phyllopachyceras* sp.** and *Anahamulina nicortsmindensis*
		Deshayesites tuarkyricus	*Deshayesites oglanlensis*	***Deshayesites dechyi*, *D.* cf. *euglyphus*, *D. luppovi*, *D. oglanlensis*, *D.* cf. *planus*, *D.* cf. *weissiformis*, *D.* cf. *tuarkyricus*, *D.* sp. 1, *D.* sp. 2, *Ancyloceras* cf. *mantelli*, *Pedioceras* sp.** and *Prodeshayesites* (=*Deshayesites*) *tenuicostatus*

By its position, this zone is correlated with the *D. tuarkyricus* Zone of the west Mediterranean region and can possibly be correlated with the *Prodeshayesites fissicostatus* Zone in England and the *P. tenuicostatus* Zone in Germany. Immel *et al.* (1997) recorded *Prodeshayesites tenuicostatus* from the lower part of the Sarcheshmeh Formation, but as mentioned earlier in this chapter, this record should be examined again.

Deshayesites weissi Zone- This zone is an assemblage zone. The base of the zone is marked by the appearance of *Deshayesites weissi.* Other taxa include *Deshayesites dechyi, D.* cf. *involutus, D.* cf. *planus, D.* sp. 2, *D.* spp., *Phylloceras* sp., *Phyllopachyceras* sp. and Cymatoceratidae. This zone occurs in the upper part of the Sarcheshmeh Formation in the Takal Kuh and Amand sections (Figures 4.1-4.3). Immel *et al.* (1997) recorded *Anahamulina nicortsmindensis* from the Sarcheshmeh Formation and *Deshayesites latilobatus* from the upper part of the Sarcheshmeh Formation, and these probably came from the *weissi* Zone.

Deshayesites deshayesi Zone- This zone is an assemblage zone. The base of the zone is marked by the appearance of *Deshayesites deshayesi.* Other taxa include *Deshayesites* cf. *involutus, D.* cf. *consobrinoides, D.* cf. *multicostatus, D.* sp. nov., *D.* spp., *Eogaudryceras (E.)* sp., *Aconeceras haugi, Pseudosaynella* sp., *Pedioceras* cf. *anthulai, Melchiorites* aff. *melchioris, Australiceras* sp., *C.* (*Cheloniceras*) spp. and Cymatoceratidae (Nautiloidea) (Table 4.4). This zone occurs in the uppermost part of the Sarcheshmeh Formation and the Sanganeh Formation in the Takal Kuh and Amand sections (Figures 4.1-4.3).

In the Raz section the lower part of the Sarcheshmeh Formation is mostly formed by marl and marly limestone and is barren. The shaly beds with limestone intercalations of the upper part of the Sarcheshmeh Formation include *Pedioceras* and *Deshayesites* fragments (Figure 4.4). This interval is attributed to the *weissi* to *deshayesi* zones.

Dufrenoyia sp. Zone- This zone is a total range zone. The base of the zone is defined by the appearance of *Dufrenoyia* sp. It occurs in the uppermost part of the Sanganeh Formation in the Takal Kuh section (2). The Sanganeh Formation in the Takal Kuh is

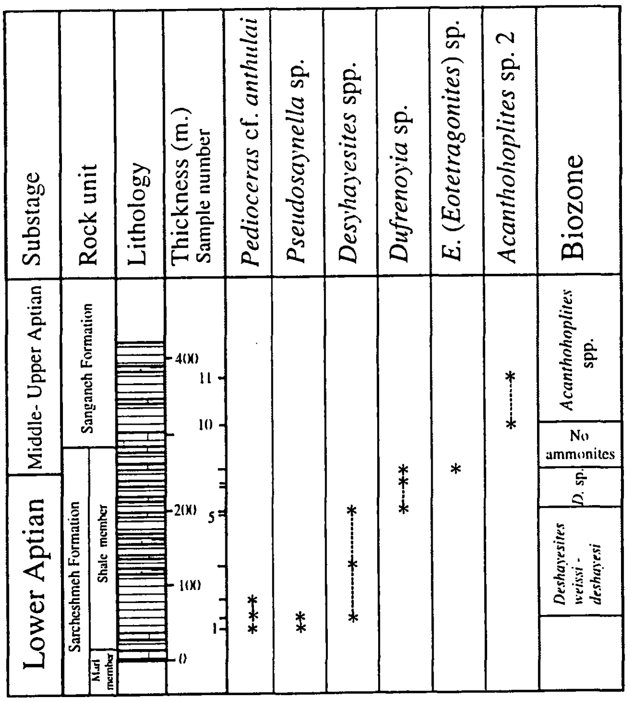


Figure 4.4. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Raz section, *D.* sp.= *Dufrenoyia* sp.

overlain unconformably by the Kalat Formation (Maastrichtian) and has probably been eroded, so this zone is not well developed (Figure 4.2). Three fragments of *Dufrenoyia* sp. and one *Eogaudryceras* (*Eotetragonites*) sp. were also found in the uppermost part of the Sarcheshmeh Formation in the Raz section (Figure 4.4).

4.3.2.2.2. Middle Aptian

Sparse Middle and Upper Aptian ammonite faunas occur in the Sanganeh Formation. The *Cheloniceras* (*Epicheloniceras*) *subnodosocostatum* and *Parahoplites* spp. Zones of the Middle Aptian have been identified in the uppermost part of the Sarcheshmeh Formation and the lower part of the Sanganeh Formation in the central and eastern parts of the basin. In some sections, such as at Raz, the corresponding levels are unfossiliferous.

Cheloniceras (*Epicheloniceras*) *subnodosocostatum* Zone- This zone is an assemblage zone. The base of the zone is marked by the appearance of *Cheloniceras* (*Epicheloniceras*) *subnodosocostatum*. Other taxa include *C.* (*E.*) sp. (this study), and *C.* (*E.*) *waageni*, *C.* (*E.*) *tzankovi*, *C.* (*E.*) *subnodosocostatum* and *C.* (*E.*) cf. *aphanasievi* (Immel *et al.*, 1997) (Table 4.4). This zone occurs in the Sanganeh Formation at the Sanganeh and Kalat Road sections.

Parahoplites spp. Zone- This is an assemblage zone. This zone is defined by the appearance of *Parahoplites*, including: *Parahoplites* cf. *maximus, Parahoplites* cf. *campichii*, *Parahoplites* sp. (Baghak Villages), and *Parahoplites* sp. ex gr. *melchioris,* which is recorded from the Sanganeh section by Immel *et al.* (1997). Another characteristic species is *Colombiceras* sp. (Figures 4.5 & 4.7). The zone occurs in the uppermost part of the Sarcheshmeh and lower part of the Sanganeh Formation in the Bibahreh, Sanganeh and Ghorghoreh sections. (Figures 4.5, 4.7; Table 4.4). In the Sanganeh section *Colombiceras sp.*, *Epicheloniceras sp.* and *Parahoplites* cf. *campichii* co-occur with *Acanthohoplites* sp. 1 in sample number 21. It is assumed this is the last occurrence for the three first species and the upper boundary of the *Parahoplites* spp. Zone is taken here. However, it needs more investigation.

4.3.2.2.3. Upper Aptian

The Upper Aptian is marked in the Sanganeh Formation by the presence of *Acanthohoplites* in the Raz section, and of *Acanthohoplites* and *Hypacanthoplites* in the Tirgan, Bibahreh, Kalat road and Sanganeh sections. The *Acanthohoplites* spp. and *Hypacanthoplites uhligi* zones are suggested for the Upper Aptian of the Kopet Dagh Basin.

Acanthohoplites spp. Zone- The base of zone is defined by the appearance of *Acanthohoplites*, which characterises the zone. The material is neither well preserved nor common, but includes *Acanthohoplites* cf. *aschiltaensis*, *Acanthohoplites* cf. *bigoureti*, *Acanthohoplites* spp., *Acanthohoplites* sp. 1 and *Acanthohoplites* sp. 2.

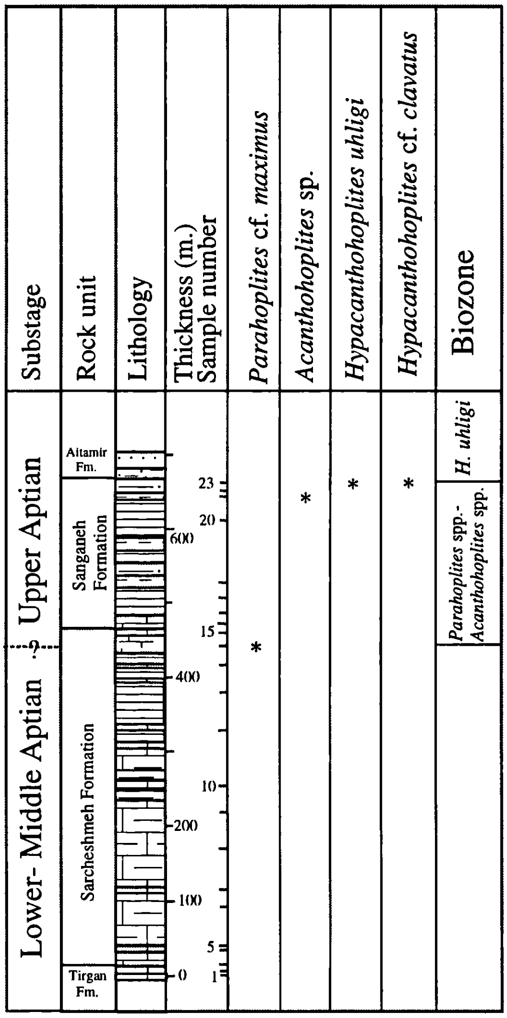


Figure 4.5. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Bibahreh section, *H. uhligi*= *Hypacanthoplites uhligi.*

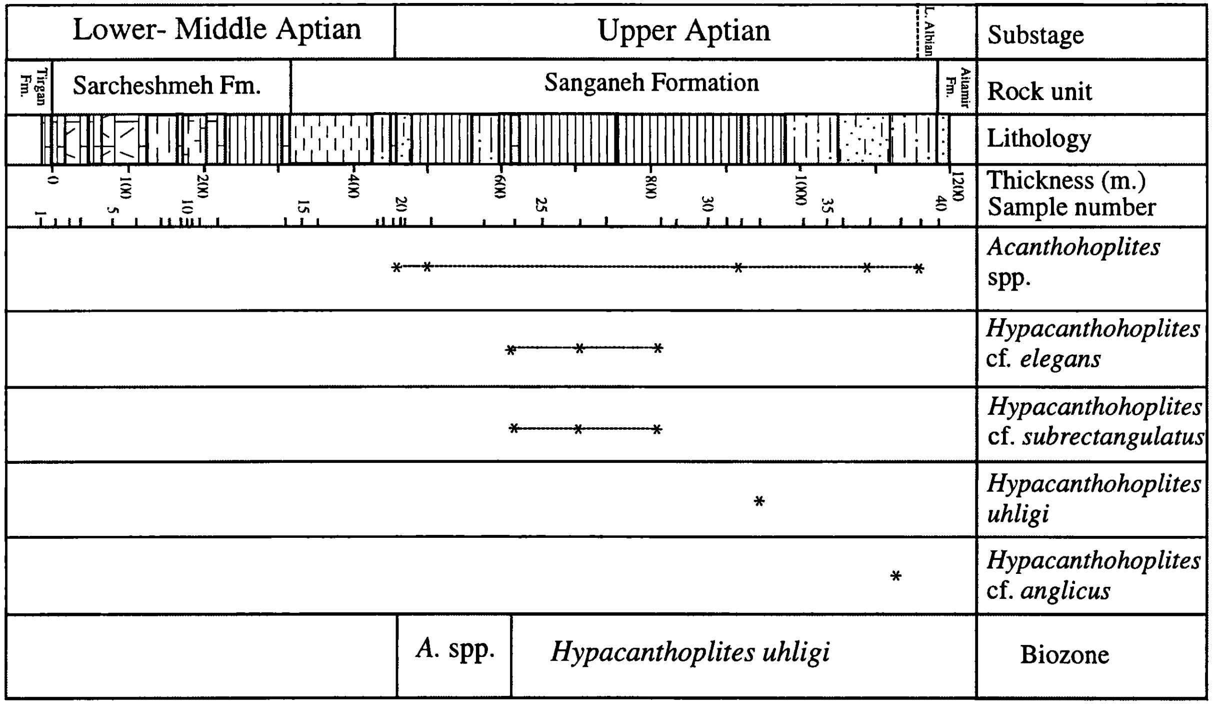


Figure 4.6. Ammonite range chart of the Sanganeh Formation in the Tirgan section, A. spp.= *Acanthohoplites* spp.

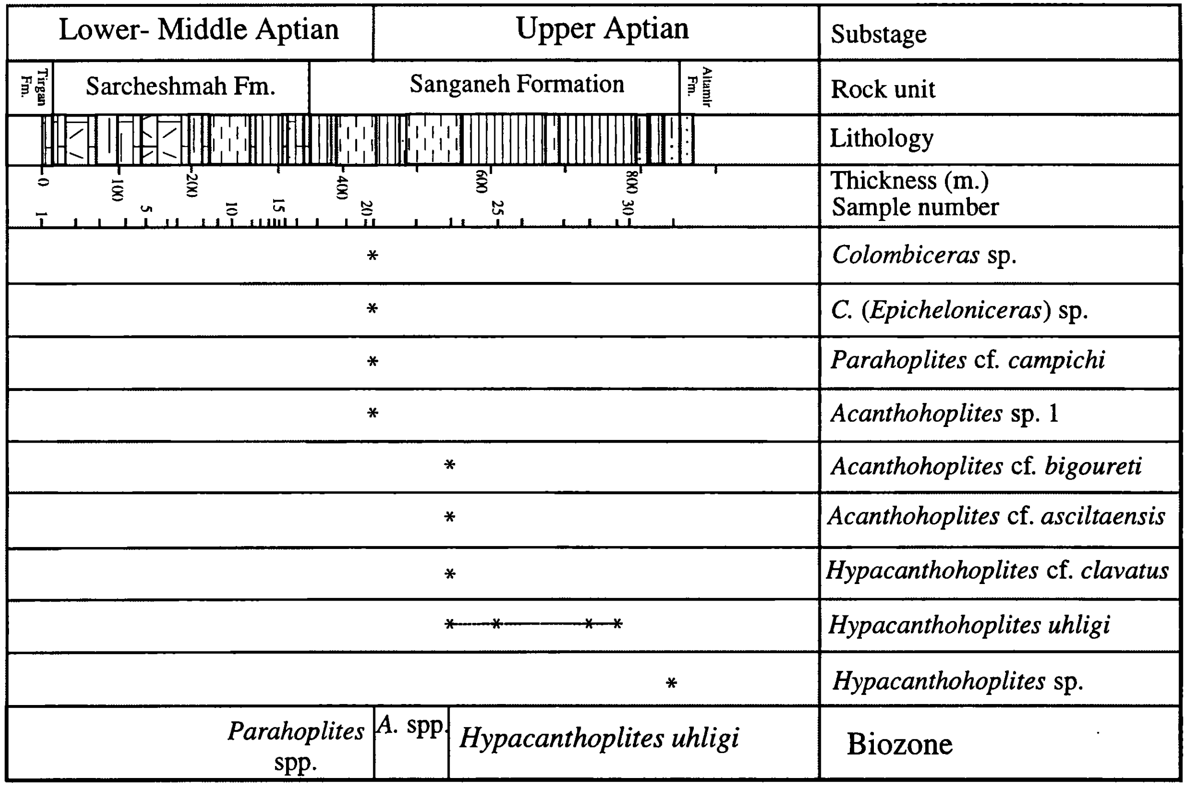


Figure 4.7. Ammonite range chart of the Sarcheshmeh and Sanganeh Formations in the Sanganeh section, *A.* spp.= *Acanthohoplites* spp.

This zone occurs in the lower to middle part of the Sanganeh Formation in the Raz, Bibahreh, Tirgan, and Sanganeh sections (Figures 4.4-4.7). In the Bibahreh section *Acanthohoplites sp.* occurs in sample number 21. *Hypacanthoplites uhligi* occurs ten metres above the former species in sample number 23. Therefore the presence of *Acanthohoplites* here is taken as last the occurrence of the taxon. In the Sanganeh section, the occurrence of *A. aschiltaensis* and *A. bigoureti* with *H. uhligi* is taken as the upper boundary of the *A.* spp. Zone. This zone is taken to equate with the *A. nolani* Zone (Table 4.2).

Hypacanthoplites uhligi Zone- This is an assemblage zone. The base of the zone is marked by the appearance of *Hypacanthoplites uhligi.* Other characteristic species include *H.* cf. *anglicus, H.* cf. *clavatus, H.* cf. *elegans, H.* cf. *subrectangulatus* and *Acanthohoplites* spp. Moreover *H. shepherdi* and *H. uhligi* are recorded by Immel *et al.* (1997) (Table 4.4). This zone occurs in the upper part of the Sanganeh Formation at the Bibahreh, Tirgan, Kalat road and Sanganeh sections (Figure 4.5-4.7). This zone is taken to equate with the *H. jacobi* Zone (Table 4.2).

4.3.2.3. Albian

4.3.2.3.1 Lower Albian

Lower Albian ammonites are well represented in the upper part of the Sanganeh Formation by *Leymeriella (L.) tardefurcata, L. (N.) regularis, Douvilleiceras* aff. *mammillatum, D.* sp. ex gr. *monile, Beudanticeras newtoni* and *Uhligella* sp. in the Sheykh, Amirabad (10 km. south-east of Sanganeh), and Taherabad (off the Kalat road) sections (Immel *et al.*, 1997). The collected ammonites are spot samples and more sampling is needed for better understanding of their position. The author has not found them yet. But a leymeriellid fragment was found a few metres above the Sanganeh Formation in the Aitamir Formation at the Tirgan section.

Table 4.5. The standard biozonation and proposed biozonation for the Lower Albian of the Kopet Dagh basin.

Stage	Substage	**Standard biozonation** (Hoedemaeker and Rawson, 2000)	**Proposed biozonation**	**Assemblage fauna** ***Recorded in this study*** *Recorded by Immel et al., 1997* <u>*Recorded in both studies*</u>
ALBIAN	Lower Albian	*Douvilleiceras mammillatum*	*Douvilleiceras sp.*	*Beudanticeras* sp. ex gr. *B. newtoni, Uhligella* sp., *Douvilleiceras* aff. *mammillatum* and *D.* sp. ex gr. *D. monile.*
		Leymeriella tardefurcata	*Leymeriella tardefurcata*	*Leymeriella (L.) tardefurcata, L. (Neoleymeriella) regularis.*

Based on Immel *et al.*'s (1997) records, the *Leymeriella tardefurcata* and *Douvilleiceras* spp. zones are suggested for the Lower Albian of the Kopet Dagh Basin. The first one is known by the occurrence of *Leymeriella (L.) tardefurcata* and *L. (N.) regularis* and the second one is defined by the presence of *Beudanticeras newtoni*, *Uhligella* sp., *Douvilleiceras* aff. *mammillatum* and *D.* sp. ex gr. *monile* (Table 4.5).

4.4. Conclusions

Thirty ammonite genera occur in the Upper Barremian to Lower Albian sequences of the Kopet Dagh (Figure 4. 8). Based on the ammonite assemblages a Late Barremian-Early Aptian age is confirmed for the Sarcheshmeh Formation and an Early Aptian-Early Albian age is accepted for the Sanganeh Formation. The lower and upper boundaries of the formations are diachronous and become younger towards the south-east, suggesting a transgression may have come from the north-west.

Based on assemblage faunas 12 biozones are suggested for the Upper Barremian to Lower Albian sequences. The *Heteroceras* spp. and *Martelites securiformis* zones (the latter including the *Martelites securiformis* and *Turkmeniceras multicostatum* subzones) are suggested for the Upper Barremian Sub-Stage. The *Deshayesites oglanlensis*, *Deshayesites weissi*, *Deshayesites deshayesi* and *Dufrenoyia* sp. zones are proposed for the Lower Aptian Sub-Stage. The *Parahoplites* spp. and *Epicheloniceras subnodosocostatum* zones are suggested for the Middle Aptian and the *Acanthohoplites* spp. and *Hypacanthoplites uhligi* zones for the Upper Aptian Sub-Stage. The Lower Albian biozones are *Leymeriella tardefurcata* and *Douvilleiceras* sp. All the suggested biozones appear to correlate with the standard biozones. However, some of the suggested biozones need more study to establish them more firmly.

Conversely, this study indicates that *Deshayesites oglanlensis* would be a better index for the basal Aptian zone of the west Mediterranean region than *D. tuarkyricus*. The latter species is known only from Turkmenistan, while *D. oglanlensis* is also recorded from France, Romania and Iran. In Turkmenistan, both species first appear together in the same beds (Bogdanova and Prozorovsky, 1999)

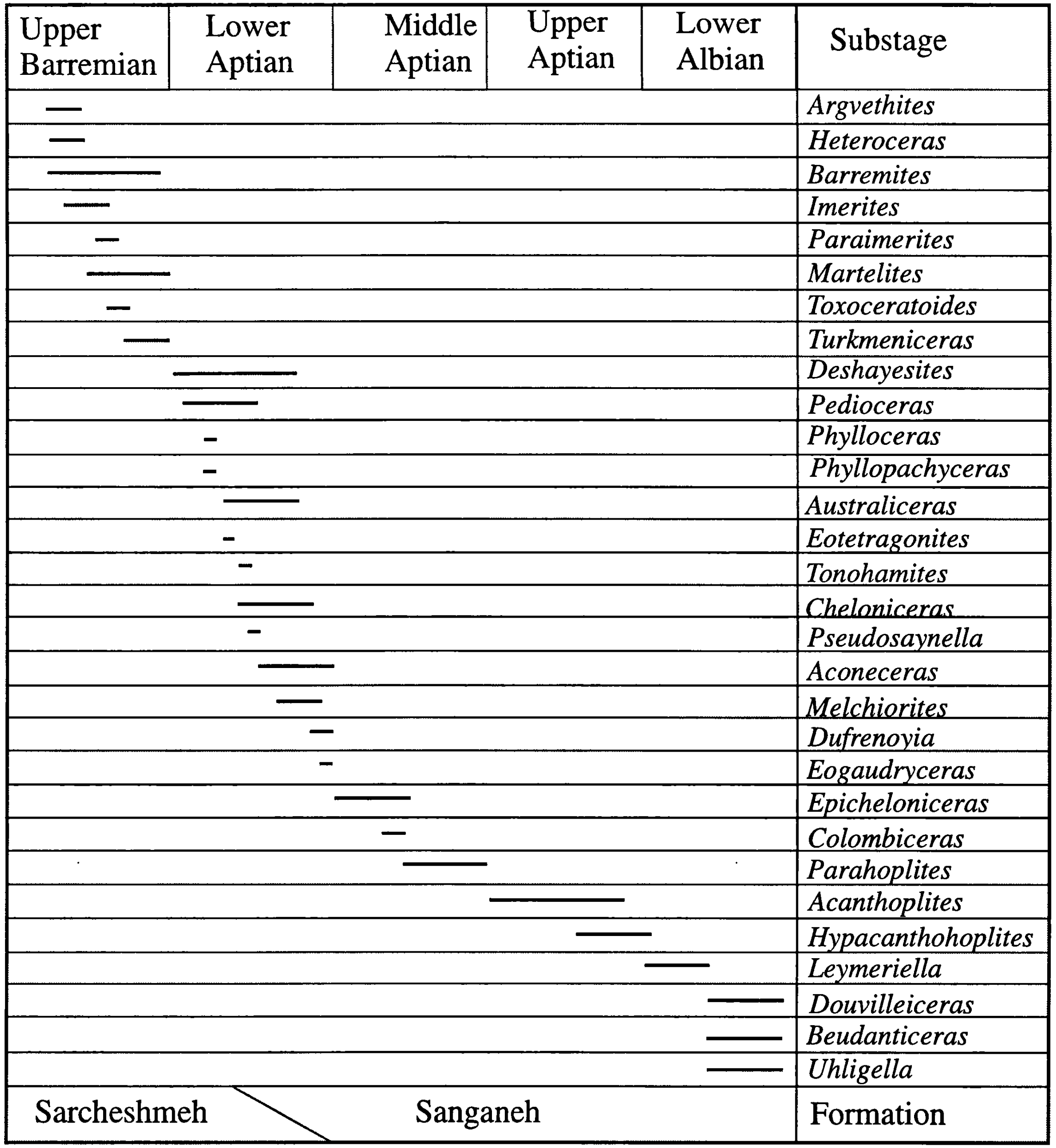


Figure 4.8. Distribution of ammonite genera in the Upper Barremian-Lower Albian at sequences in the Kopet Dagh Basin.

Chapter 5. Ammonites and Lithofacies

5.1. Introduction

Historically, ammonites have been visualised as essentially free-swimming organisms that lived independently of the substrate. However, an increasing number of studies have demonstrated that the distribution of many ammonite morphotypes shows a relationship with lithofacies. The study of this relationship can provide evidence for mode of life, especially in terms of water depth. In this introduction current views on the mode of life and post-mortem dispersal of ammonites are summarised and some of the more important studies on morphotype/lithofacies relationships highlighted. The reminder of the chapter examines the distribution of ammonite taxa in relation to lithofacies in the Kopet Dagh Basin, discusses the morphogroups recognised there, and then compares the results with those of previous studies to draw some general palaeoecological conclusions.

5.1.1. Mode of life of ammonites

Laboratory studies on shell form and function, coupled with field studies on ammonoid distributions and ecology, have provided much information of the mode of life of ammonites, Westermann (1996) has drawn much of this together in a major review. Generally, the epipelagic-mesopelagic boundary for ammonites is considered to have been at a depth of about 240 m. This limitation is because of the physiology of the phragmocone of cephalopods. Lower than 240 m hydrostatic and osmotic pressures are high for ammonites, which could not live and stay below this depth (Hewitt, 1993; Westermann, 1990, 1996).

It appears that although some ammonites were planktonic, the majority were demersal, living close to the epicontinental sea floor, where they obtained their prey (Westermann, 1990, 1996). Planktonic ammonites include drifters such as serpenticones, and vertical migrants such as spherocones and cadicones. Nektonic forms are represented by oxycones as well as some platycones.

The life orientation of many diverse heteromorphs has been investigated and many are regarded as planktonic (Ward, 1976; Ward and Westermann, 1977; Okamoto 1984, 1988 a b; Westermann, 1996). High spired torticones were more stable than low spired and helical forms. Cyrtoconic forms with compressed shell, weak and densely spaced septa indicate a shallower and more sluggish habitat than orthoconic forms (Westermann, 1977).

Orthoconic and gyroconic shells were also stable; their apertures pointed more or less horizontally without the need for an apical ballast. They could have swum vertically but ovate compressed forms could have moved slowly horizontally (Westermann, 1996).

These heteromorphs with straight shafts and U-shaped connections have alternating stable and unstable growth stages separated by a complete 'flip over' in orientation. They must have been planktonic (Ward, 1976).

According to Westermann (1996), increased acceleration speed and steerage in ammonites could be achieved by reducing drag through 1) narrowing the umbilical area which meant more involute coiling 2) Compacting the disk shape which led to narrowing the whorl section or developing a sharp or narrowly rounded venter and 3) reducing the ornamentation.

5.1.2. Post mortem drift

Although the present work is not concerned with interpretation of the hydrodynamic characteristic of the ammonite-shells, it is important to know if post-mortem dispersion affected and changed the studied assemblage. Post-mortem long-distance drift is suggested by comparison with the present-day example of *Nautilus*, which can drift for several hundred kilometres (Reyment, 1970, 1980). However, Ward (1980), taking into account the shell shapes, considers that 'ammonites and nautilids were dissimilar ecologically'. The lack of damage or puncture in most ammonites suggests that they either rapidly sank to the bottom or did not float very far (Kennedy and Cobban, 1976). A small-scale post-mortal transport of a maximum of a few kilometres is sometimes recorded for some groups of Ammonitina (Cecca, 1988, 1992). Wider post-mortal drift has been demonstrated for lytoceratid and phylloceratid shells (Tanabe, 1979; Westermann 1990).

5.1.3. Previous research

Scott (1940b) was one of the first authors to link the distribution of ammonites with lithofacies and then to make deductions about depth of water. Other important studies include those on European Jurassic faunas by Ziegler (1963, 1967) and Donovan (1985). Tanabe *et al.* (1978) analysed ammonoid assemblages from the Upper Turonian of Central Hokaido, Japan. Kakabadze (1979) studied the occurrence of representative Ancyloceratidae genera within different sediment types in the Caucasian Lower Cretaceous.

Bulot (1993) analysed ammonite/facies relationships in the Valanginian to Hauterivian of south-east France, demonstrating differences between basinal and shelf faunas. In the same area, Reboult and Atrops (1997) quantified variation in the Valanginian ammonite faunas of the Vocontian Basin both within limestone-marl cycles and within parasquences sets. Tsujita and Westermann (1998) studied the hydrodynamic and hydrostatic aspects of ammonoids and their relation to lithofacies.

One of the most detailed studies was by Batt (1989, 1991, 1993), who investigated ammonite distribution and ecology in the Western Interior Cretaceous Seaway and related morphotype occurrence to lithofacies and probable environments. He divided the ammonite fauna of the Greenhorn Cyclothem into eighteen morphogroups and concluded that the distribution of certain morphotypes suggests depth-restriction. For example, compressed, disc-shaped, and heavily nodose forms generally indicate bottoms shallower than about 50 metres. Those with heavy ornamentation were apparently poor swimmers that may have spent much of the time on the bottom. Heteromorph ammonites with helically coiled shell appear to have been sluggish demersal. Some heteromorphs, including U-shaped adult forms, adaptated to pelagic life and were sluggish.

Batt (1989) also suggested that ammonites appear to have been sensitive to oxygenation. Absence of certain morphotypes may indicate poorly oxygenated conditions. For example, the presence of pelagic forms while all benthic and demersal are absent might indicate that oxygen was restricted to the upper part of the water column. Some ammonites apparently have not been restricted by facies or depth, but distributions of some morphotypes suggest they are useful in palaeobathymetric studies. A summary of Batt's morphotype groups will be tabulated and compared with ammonite groups in the Kopet Dagh Basin later in this chapter.

5.2. Ammonite and lithofacies distributions in the studied sections

In this section, the distribution of ammonite genera in relation to lithology will be analysed. The study is based on 10 stratigraphical sections, which cover most of the basin from west to east. The studied sections documented a decrease in abundance and diversity of ammonite fauna in that direction. More than forty beds in the Sarcheshmeh and Sanganeh Formations contain ammonites in the Takal Kuh sections, whereas the number decreases to two beds in the Ghorghoreh section. In addition, belemnites only occur in the north-west sections, while other macrofauna, such as brachiopods and echinoderms are mostly found in the south-east section and may be used for environmental interpretation and correlation, where there are no ammonites.

Although numerous ammonite genera have been identified, only those in which at least ten specimens have been collected from a locality are used in the analyses. In the field numerous different lithologies have been identified but here they are all classified into six broad lithologies: siltstone, silty shale, shale, marl, shaly/marly limestone and limestone. This generalisation means, for example, that 'limestone' embraces coarse grained limestone, fossiliferous limestone and sandy limestone, all normally indicating a shallow water environment.

5.2.1. Takal Kuh sections

In the Takal Kuh section (1) seven ammonite genera are represented by more than 10 specimens: *Aconeceras*, *Barremites*, *Deshayesites*, *Heteroceras*, *Martelites*, *Melchiorites* and *Turkmeniceras*.

Martelites and *Heteroceras* are distributed mostly in marl and shaly/marly limestones (Figures 5.1, 5.2). These two genera were collected from the lower part of the Sarcheshmeh Formation. Field observation and study on foraminifera (in progress) show that other macrofauna and microfauna are rare or absent. Moreover, benthic faunas are absent in this western part of the basin. From this point of view, the lower part of the Sarcheshmeh Formation was probably deposited in a hypoxic to anoxic environment. It must be mentioned that the middle and upper part of the Sarcheshmeh Formation in the Takal Kuh area has more fossiliferous limestone beds and the sediments are lighter in colour than in the lower part.

Turkmeniceras is found mostly in shaly/marly limestone and marls. The genus occurs in similar facies to the Heteroceratidae, which descended from *Turkmeniceras*.

Deshayesites is distributed in all mentioned lithologies. Small, pyritised inner whorls (less than 20 mm diameter) can be found in shale and marl beds, medium sized specimens in marl and shaly/marly limestone and large size and adult forms (more than 50 mm in diameter) in limestones and sandy limestones. A few small *Dufrenoyia* and *Cheloniceras* are also found in shale beds of the upper part of the Sanganeh Formation in the Takal Kuh sections.

Barremites was collected from shaly/marly limestone beds of the lower part of the Sarcheshmeh Formation (Figure 5.1). *Aconeceras* and *Melchiorites* are found in shale beds of the Sanganeh Formation (Figure 5.2). The shale beds of the Sanganeh Formation are more argillaceous and less calcareous than the shale of the Sarcheshmeh Formation.

The distribution of ammonite genera in the Takal Kuh section (2) shows a similarity with the Takal Kuh section (1) (Figure 5.3).

Aconeceras and small sized *Deshayesites* are found in the marl beds of the Sanganeh Formation, whereas *Turkmeniceras* is found in the marls beds of the lower part of the Sarcheshmeh Formation. Marl beds in the Sarcheshmeh Formation are more calcareous than marl beds in the Sanganeh Formation.

Figure 5.1. Relationship between lithology and ammonite genera in the Takal Kuh section (1)

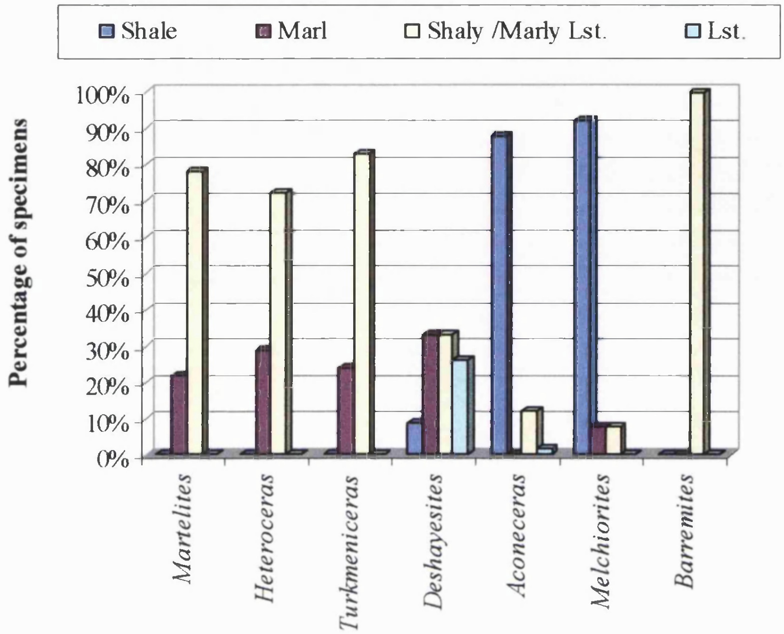
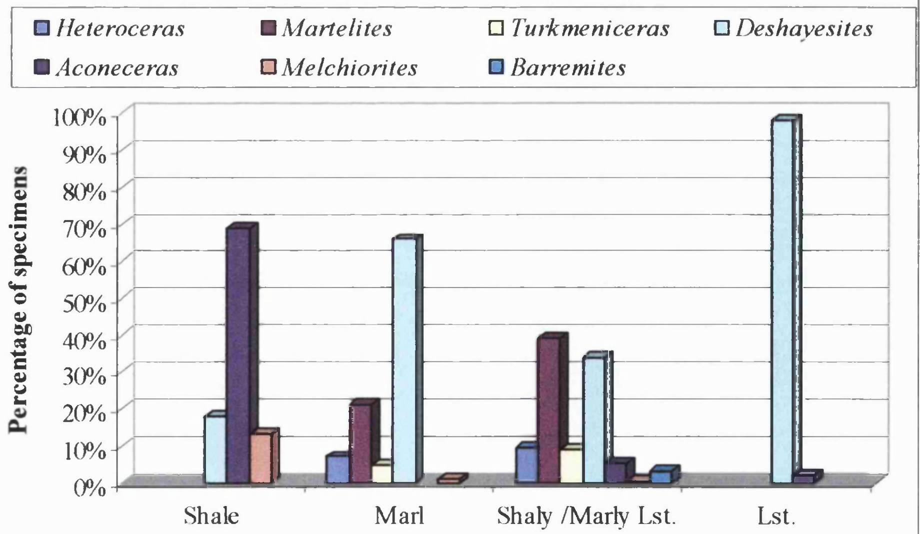


Figure 5.2. Distribution of ammonite genera in each lithofacies in the Takal Kuh section (1)



In shale beds the predominant genus is *Aconeceras*, but *Melchiorites* and small *Deshayesites* are seen also (Figure 5.4). The number of collected specimens of *Melchiorites* is low (about 6%), but all were found in shale beds (Figure 5.4). Planispiral and ornamented forms such as *Deshayesites* and *Turkmeniceras* are found in limestone beds (Figure 5.4). In marl beds, the three major genera are *Deshayesites*, *Aconeceras* and *Turkmeniceras* (66%, 23% and 11% respectively) (Figure 5.4).

In the shale beds of the Sanganeh Formation, numerous specimens of belemnites have also been collected. Foraminifera also show an increase in diversity compared to in shale beds of the Sarcheshmeh Formation. This may suggest environmental condition improved in shale beds of the Sanganeh Formation.

Figure 5.3. Relationship between ammonite genera and lithology in the Takal Kuh section (2)

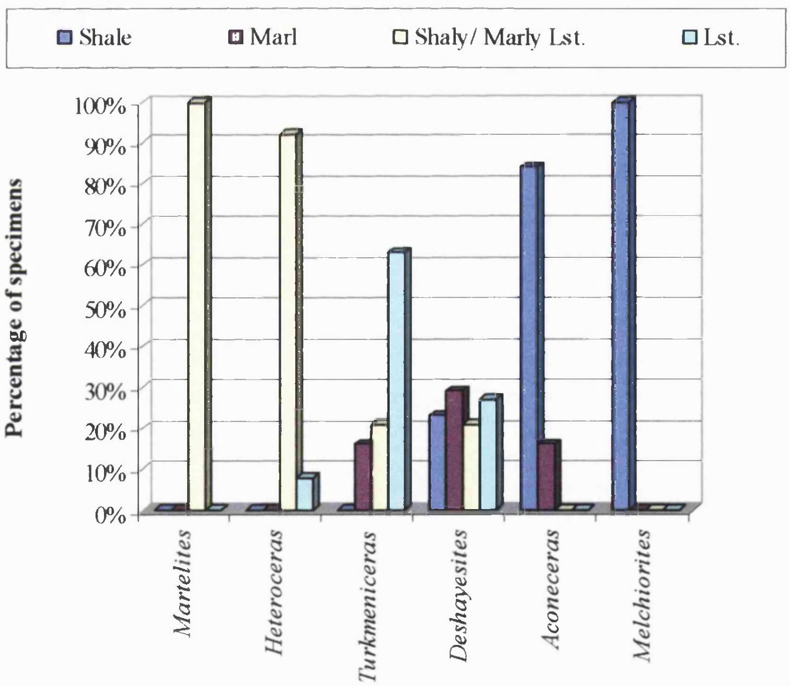
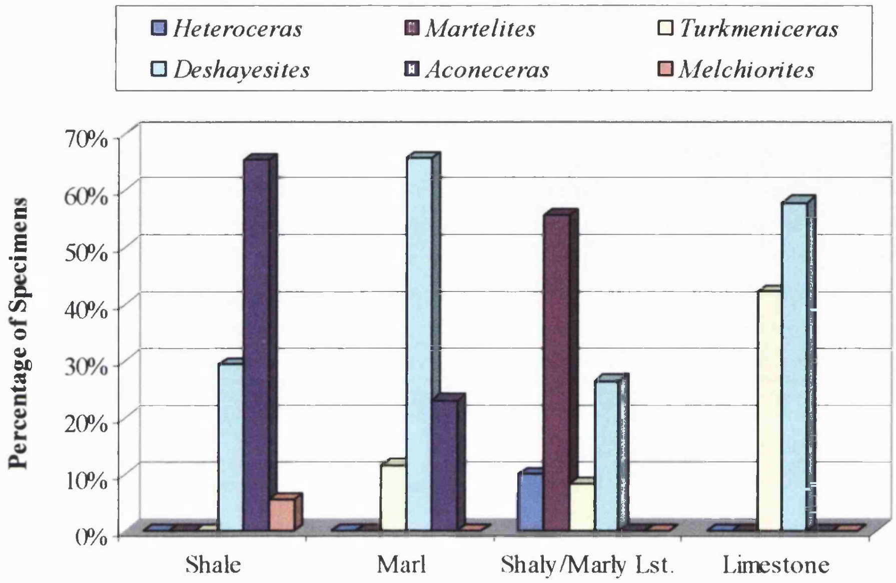


Figure 5.4. Distribution of ammonite in each lithofacies in the Takal Kuh section (2)



5.2.2. Amand section

The Amand section is the third section that has been measured in the Takal Kuh area. In this section the lowermost part of the Sarcheshmeh Formation has been cut by a fault(s), but there are still some layers with heteroceratids. *Barremites* and *Aconeceras* are mostly distributed in shale beds and *Martelites* and *Turkmeniceras* are found in shaly/marly limestone beds (Figures 5.5, 5.6).

As in the Takal Kuh section (2) more than 80% percent of ammonite genera in the marl beds belong to the Deshayesitidae (*Deshayesites*, *Turkmeniceras*) (Figure 5.5). In limestone beds only *Deshayesites* species are abundant. Although shaly/marly limestone beds contain over 50% of heteromorphs, their descendants, the Deshayesitidae, are also found in this lithology (Figure 5.5).

Figure 5.5. Distribution of ammonite genera in each litohfacies in the Amand section

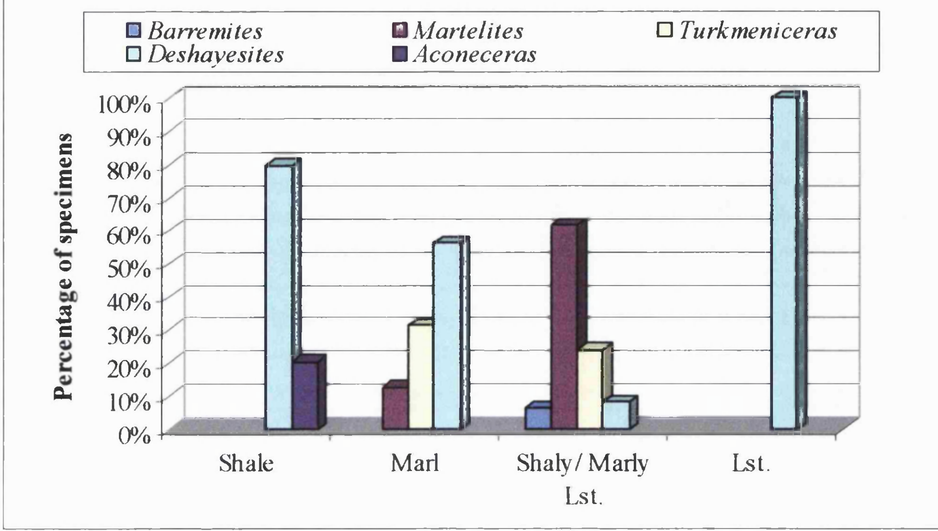
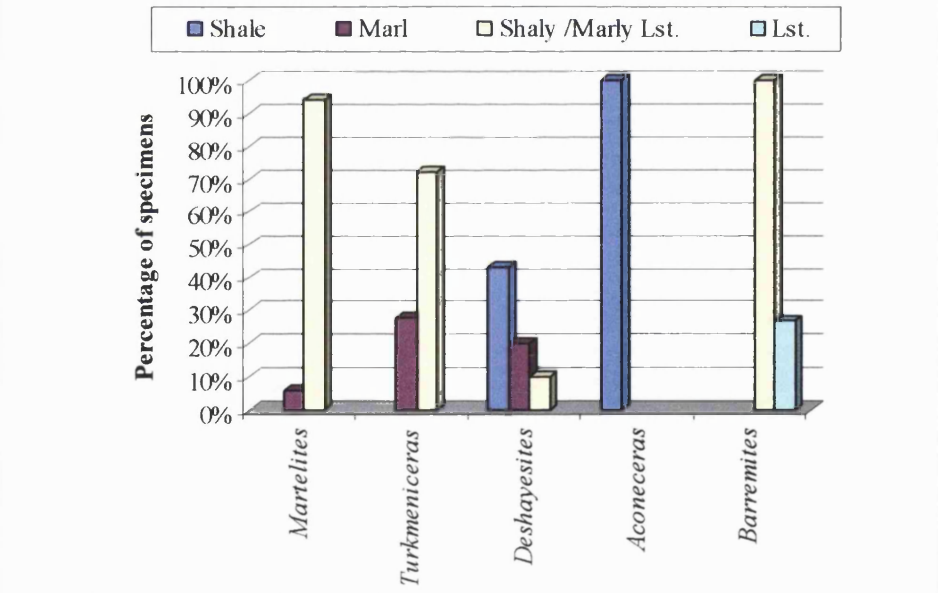


Figure 5.6. Relationship between genera and lithology in the Amand section



5.2.3. Raz section

The Raz section, which is about 45 km south-east of the Amand section, is the nearest section to the Takal Kuh area. The lower part of the Sarcheshmeh Formation includes grey to light grey marl to marly limestone beds and there is no sign of ammonites in this part of the formation. Its thickness has not been measured but it is much less than much less than in the Amand and Takal Kuh sections. The upper member of the formation consists of shale beds with fossiliferous limestone intercalations, which were mostly deposited in the uppermost part of this member. A small sized heteromorph ammonite, *Pedioceras*, and small *Deshayesites* are both found in some shale layers, but not together in the same bed.

In the fossiliferous limestones in the upper part of the Sarcheshmeh Formation, assemblage faunas include brachiopods, echinoderms and foraminifers (*Orbitolina*). A few broken ammonites such as *Dufrenoyia* and *Eotetragonites* have been collected from these limestone beds. In the Sanganeh Formation of the Raz section, *Acanthohoplites* is found in silty shale and clay shale beds. This is discussed below (section 5.2.5).

5.2.4. Sheykh section

In the Sheykh section the number of limestone intercalations increases through the Sarcheshmeh Formation. A few specimens of *Pedioceras* have been collected from shale beds. This genus is also found in one shaly layer just above a sandy fossiliferous limestone bed in the Takal Kuh section (2). As these shale beds are intercalated by fossiliferous limestone, it suggests the shale beds were deposited in a shallow water environment. The Sanganeh Formation is barren of ammonites at this section.

5.2.5. Other sections

In the Bibahreh, Tirgan, Kalat Road, Sanganeh and Ghorghoreh sections the thickness of the Sarcheshmeh Formation decreases from north-west to south-east and there is no sign of ammonites. Based on field observations, the faunal assemblages in the limestone beds consist of brachiopods, pelecypods, echinoderms and orbitolinids. Some oolitic limestone is reported from the eastern part of the basin (Raisossadat and Moussavi-Harami, 2000). Shallowing water environments and paleoecologic conditions have probably affected ammonite distribution. Based on geologic maps and Afshar Harb (1979), the east and south-eastern part of the basin was surrounded by low lands. It can be assumed this area was like a gulf, which connected with open sea to the north during Late Barremian to Early Aptian times.

In the Raz, Bibahreh, Tirgan, Kalat Road, Sanganeh and Ghorghoreh sections various genera of Parahoplitidae (*Acanthohoplites*, *Colombiceras*, *Hypacanthoplites* and *Parahoplites*) are found in the Sanganeh Formation. Among these, *Acanthohoplites* and *Hypacanthoplites* are the most common. They occur in shale, silty shale and siltstone or even silty sandstone beds (Figures 5.7, 5.8). In some cases concretions accompany ammonites or ammonites form the core of concretions. There is no sign of other macrofauna in the ammonite beds.

Figure 5.7. Relationship between facies and ammonite genera in the central and eastern part of the Kopet Dagh

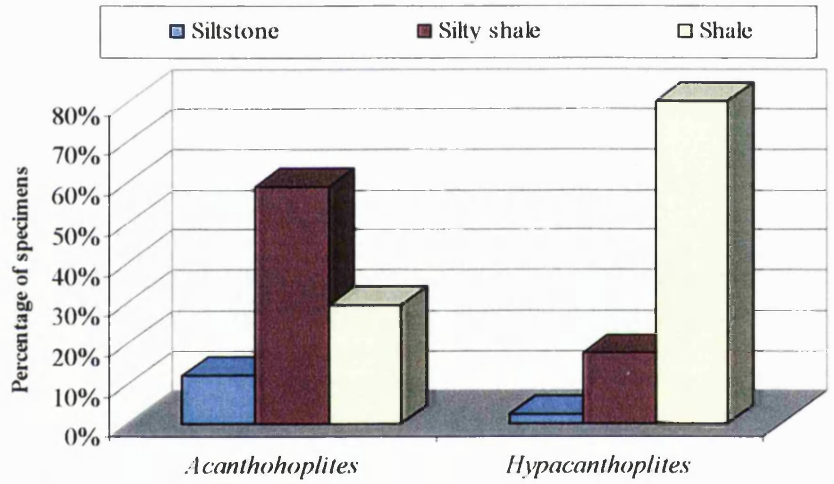
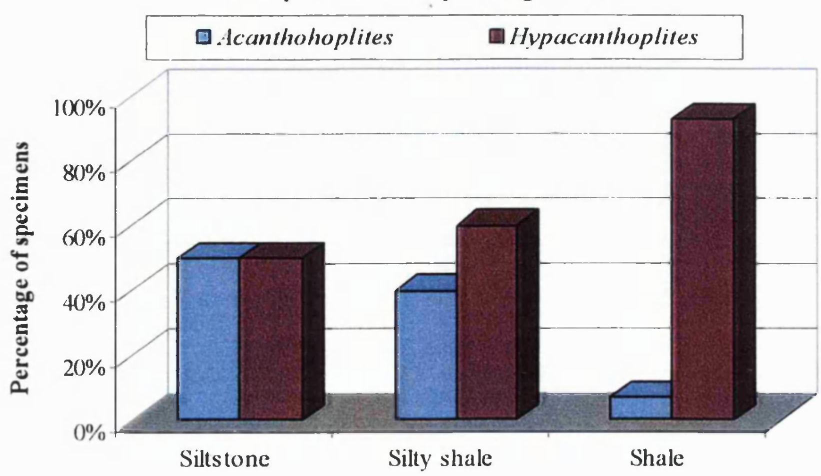


Figure 5.8. Distribution of *Acanthohoplites* and *Hypacanthoplites* in each lithofacies in the central and eastern part of the Kopet Dagh Basin



5.3. Discussion

The distribution of many, though not all, of the genera discussed above shows a relationship with lithofacies. In this section the genera are grouped into (a) families and (b) morphogroups, and their relationship with lithofacies summarised.

5.3.1. Families and lithofacies

Table 5.1 and Figure 5.9 show the distribution of families in relation to lithofacies. They demonstrate a clear causal link between the two. The Parahoplitidae are limited to silty shales and siltstones, where they form 100% of the ammonite fauna. The Heteroceratidae are limited to marls and shaly-marly limestones. The Ancyloceratidae are a minor element of the fauna but are most common in shales, as are the smooth-shelled Desmoceratidae and Oppeliidae. Conversely, the Deshayesitidae are common across a broad range of facies, from shales to limestones.

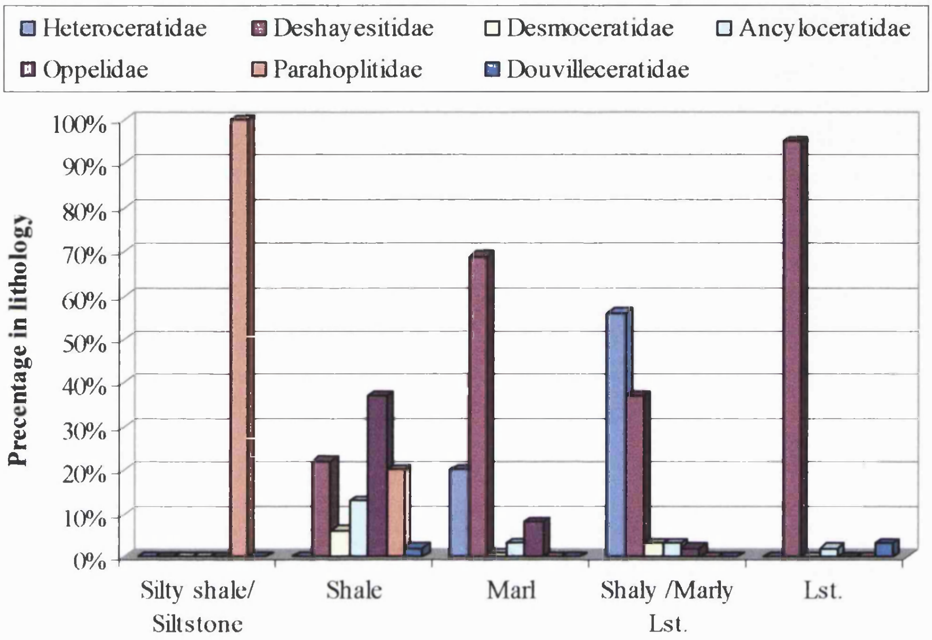
These observations confirm results of some previous studies. For example Cecca (1998) reported the highest frequency of the family Desmoceratidae in marly deep successions, in the northern part of the Trento Plateau. Roch (1930) also recorded a high abundance of this family in marly Cephalopod facies from western Morocco. Westermann (1996) suggests an outer-shelf to upper slope habitat for *Barremites*. This suggestion may apply for *Aconeceras* as well.

Table 5.1. Distribution of ammonite families in different lithologies in the Kopet Dagh Basin.

Lithology	**Silty Shale/ Siltstone**	**Shale**	**Marl**	**Shaly/ marly Limestone**	**Limestone**
Heteroceratidae	0%	0%	20%	56%	0%
Deshayesitidae	0%	22%	69%	37%	95%
Desmoceratidae	0%	6%	1%	3%	0%
Ancyloceratidae	0%	13%	3%	3%	2%
Oppeliidae	0%	37%	8%	2%	0%

Douvilleiceratidae	0%	2%	0%	0%	3%
Total	100%	100%	100%	100%	100%

Figure 5.9. Distribution of ammonite families in each lithofacies in the Kopet Dagh Basin



Reboult and Atrops (1997) concluded that Valanginian calcareous beds in the south-east of France are characterised by a high proportion of ornamented forms (Neocomitidae and Olcostephanitidae), whereas argillaceous beds are marked by high frequencies of smooth form (Phylloceratid). The parallelism between the faunal and lithology variations suggests that the factors controlling the lithology also have an influence on ammonite association. The modification of bathymetry could have changed the environmental conditions and so controlled the ammonite assemblage.

A similar picture applies in the Kopet Dagh Basin, where smooth genera such as *Aconeceras*, *Melchiorites* and *Barremites* are mostly found in shale and shaly marly beds and ornamented ammonites genera such as *Deshayesites* and *Turkmeniceras* are found in marl and limestone beds.

In the Kopet Dagh Basin, the Ancyloceratidae are particularly common in marls and marly limestones. Both Batt (1993) and Westermann (1966) believed U-shape heteromorph and those that have first trochospiral and then planispiral coiling or planispiral and hooked adult body chamber, were mostly pelagic or demersal.

In a study on the relationship between facies and the distribution of Ancyloceratidae in Georgia, it was confirmed that the Ancyloceratidae are abundant in marl, marly limestone and sandy glauconitic limestone. It may indicate that the distribution of heteromorph ammonites was limited by marly limestone and marl facies (Kakabadze, 1979). Many of large ancyloceratids that Casey (1960) described from southern England are also occur in shallow-water sediments. Few big (or adult) specimens were found in sandy limestones in the Sarcheshmeh and Sanganeh Formations. The presence of the heteromorphs Ancyloceratidae in marly limestone facies of the Sarcheshmeh Formation might be compared with the Georgian Ancyloceratidae.

Two hypotheses can be suggested for presence of Ancyloceratidae in shallow-water limestones of the Lower Aptian of the Kopet Dagh. Either, big and adult specimens were more sluggish than young ammonoids and preferred living in shallow water environments, or they have been drifted after their death by currents towards to shallow water environments.

Parahoplitidae are found in the Sanganeh Formation in the central and eastern parts of the basin, where the section consists of shales, silty shales and siltstones. There is no sign of other macrofaunas or even benthic foraminifera, even though concretions are found in these layers. These features suggest the sea floor was agitated. It is probable that the Parahoplitidae lived in the upper and middle parts of the water column.

5.3.2. Morphogroups and lithofacies

Rather than adopting Batt's (1989) complex division into 18 morphogroups, the writer has adopted a simpler scheme in which only four morphogroups are distinguished (Table 5.2). This is because of the more limited amount of material available in the present study compared with in Batt's. Some genera are quite scarce, and to consider a morphogroup represented by only a few specimens is not reliable. For example, the only *Phylloceras* and *Phyllopachyceras* collected were a few large forms from shallow-water limestone beds, but it is unlikely that these genera were limited to a shallow-water environments. Further studies on the basin may lead to more morphogroups being considered.

Table 5.2. Proposed ammonite morphogroups for the Sarcheshmeh and Sanganeh Formations in the Kopet Dagh Basin.

Morphogroup	Genera	Dominate Facies
1- Heteromorphs	*Ancyloceras, Argvethites, Australiceras, Heteroceras, Martelites, Imerites, Paraimerites, Pedioceras,* and *Toxoceratoides*	Shaly/marly limestone
2- Smooth surface, compressed and disc shaped	*Aconeceras, Barremites, Melchiorites* and *Pseudosaynella*	Shale and Marl
3- Semi-evolute, ribbed and planispiral shells	*Turkmeniceras*	Shaly/marly limestone, Marl
	Cheloniceras, Deshayesites, Dufrenoyia, Eotetragonites and *Eogaudryceras*	Not really related to facies, moderate and big ones in limestone
4- Coarsely ribbed, well ornamented and with quadrate whorls	*Acanthohoplites, Colombiceras, Hypacanthoplites*, and *Parahoplites.*	Silty shale and siltstone

Three of the four morphogroups show a close relationship with lithofacies (Table 5.2). However, other factors may also be linked with the morphogroup distributions. For instance, most heteromorphs are found in Upper Barremian shaly or marly limestones. There are shaly and marly limestones in the Lower Aptian but heteromorphs are not abundant. This may reflect differences between the shaly and marly limestones of the Upper Barremian and the Lower Aptian or it may relate to sea level changes. This aspect is discussed in chapter 6.

Morphogroup 1 is a heteromorph group, characterised by U-shaped shells such as *Heteroceras* and *Argvethites*, cyrtoconic forms such as *Toxoceratoides*, and a combination of helical and planispiral forms such as *Martelites*, *Imerites* and *Paraimerites*. This group is mainly distributed in thin-bedded marly and shaly limestones in the lowermost part of the Sarcheshmeh Formation.

Morphogroup 2 includes compressed, disc-shaped and smooth ammonites (Leiostraceous), which are represented by *Aconeceras* and *Barremites*. *Barremites* is associated with a transgression low in the Sarcheshmeh Formation, which lies on the Urogonian facies of the Tirgan Formation. *Aconeceras* can be found in the thin-bedded to laminated, grey to dark grey marls and shales of the uppermost part of the Sarcheshmeh Formation and lower to middle part of the Sanganeh Formation. This morphogroup includes other smooth ammonites such as *Melchiorites* and *Pseudosaynella*.

Morphogroup 3 ammonites possess semi-evolute, ribbed planispiral shells. Representative genera include *Deshayesites*, *Dufrenoyia* and *Turkmeniceras*. Most genera in this group do not show a good relationship to facies, but *Turkmeniceras* is found mostly in shaly/marly limestone and marl beds.

Deshayesites is present in most parts of the Sarcheshmeh and Sanganeh Formations. This genus can be divided into three groups based on size. The first consists of strongly ribbed forms that are at least 50 mm diameter, mostly found in sandy marly limestones and sandy limestones. They are accompanied by other macrofauna such as brachiopods and a few echinoderms. The second group is finely ribbed with representative specimens mostly around 20-50 mm diameter. They are found in shaly/ marly limestones, which also contain belemnites. The third group is less than 20 mm in diameter and is found in shales.

The three groups probably reflect preservational differences in different lithofacies. In the shales, the earliest whorls are pyritised and remained solid during compaction, while later whorls remained empty and were flattened and destroyed. In the more calcareous beds either drusy calcite or sediment infilled many of the chambers and specimens were more completely preserved.

Morphogroup 4 is characterised by an evolute shell, ornamented with and dominated by coarse ribs, with quadrate whorls. *Acanthohoplites*, *Colombiceras*, *Hypacanthoplites* and *Parahoplites* are classified in this morphogroup. These ammonites are found in shale, silty shale and siltstone or even silty sandstone beds in the Sanganeh Formation. In the Tirgan and Sanganeh sections the Sanganeh Formation is thicker than in the other sections, the shales are less calcareous and there are more silty beds. Hence these sections have yielded more examples of morphogroup 4.

5.4. Comparison with previous morphogroup studies

Tanabe *et al.* (1978) divided the Turonian ammonites of Hokkaido into three major morphotypes; A) strongly ornamented B) heteromorphs and C) smooth or weakly ornate. Marcinowski and Wiedmann (1985, 1988) followed Tanabe's scheme and used it to classify Albian ammonites of the Carpathian area. They used three terms, trachyostraceous (for ornamented forms), heteromorph and leiostraceous (for smooth or weakly ornamented forms). They mentioned that the distribution pattern of the ammonites was probably controlled by their mode of life. They assumed that group A and B of Tanabe's scheme had a demersal or mobile benthic habitat and lived in nearshore and shallow environments. But group C had a planktonic or demersal habitat and lived mostly in offshore environments of shallow to moderate depth.

Table 5.3 is an attempt to classify the ammonite fauna of the Kopet Dagh Basin based on the works of Tanabe *et al.* (1978) and Wiedmann and Marcinowski (1985, 1988).

Table 5.3. Diversity and abundance of ammonites in the Sarcheshmeh, Sanganeh and Aitamir Formations when classified according to Tanabe *et al.*'s (1978) and Marcinowski and Wiedmann's (1985, 1988) morphogroups (N= number of genera).

Fm.	Trachyostraceous	N.	%	Heteromorphs	N.	%	Leiostraceous	N.	%
Aitamir	*Acanthoceras* *Cunningtoniceras* *Placenticeras* *Mantelliceras* *Hyphoplites* *Schloenbachia* *Mortoniceras (M.)* *Callihoplites* *Epihoplites (E.)* *Semenoviceras* *Anahoplites* *Hoplites* *(Isohoplites)*	14	83	*Hypoturrilites* *Mariella (M.)* *Anisoceras*	3	17			
Sanganeh	*Douvilleiceras* *Leymeriella (L.)* *Hypacanthoplites* *Parahoplites* *Cheloniceras (E.)* *Acanthohoplites* *Colombiceras* *Dufrenoyia*	8	53	*Australiceras* *Pedioceras*	2	13	*Uhligella* *Beudanticeras* *Aconeceras* *Pseudosaynella* *Melchiorites*	5	33
Sarcheshmeh	*Eogaudryceras* *Cheloniceras* *Deshayesites* *Prodeshayesites* *Hemihoplites* *Turkmeniceras*	6	35	*Ancyloceras* *Pedioceras* *Toxoceratoides* *Anahamulina* *Imerites* *Martelites* *Argvethites* *Heteroceras* *Paraimerites*	9	53	*Phylloceras* *Phyllopachyceras* *Barremites*	2	12
Total	As above	28	57	As above	14	28	As above	7	14

Batt (1989) classified the ammonite fauna of the Upper Albian- Middle Turonian of the Greenhorn Cyclothem of the Western Interior of USA into eighteen groups. He examined facies and habitat for every morphotype group.

In Table 5.4, the Kopet Dagh genera are reclassified into Batt's morphogroups. Fourteen groups can be matched among his eighteen groups, but for four groups of Batt's division the writer could not find suitable genera. Note the table includes Albian and Cenomanian genera recorded by Immel *et al.* (1997) and Seyed-Emami (1980) and there is no detailed information about the number of specimens.

Table 5.4. Probable facies and habitat of the Aptian-Cenomanian ammonites of the Kopet Dagh basin based on Batt's (1989) morphotype classification (Genera recorded by the author are in bold).

	Morphotype	Facies	Habitat	Genera in Kopet Dagh
G.1	Heavily ornamented, planulate, generally quadrate whorl (Acanthoceratida).	Shoreface sandstones and proximal offshore shales.	Low hydrodynamic stability and poor streamlining suggest that ammonites with these shells were poor swimmers and may have been benthic.	*Cunningtoniceras*, *Acanthoceras* (Aitamir Fm.); *Leymeriella*, *Douvilleiceras* (Sanganeh Fm.)
G.2	planulate evolute shell, quadrate whorl, ornamented, dominated by coarse rib, shell flanks and venter tend to be more rounded than group 1.	Shore face to distal offshore.	Vagrant benthic or Nektobenthic (=demersal)	*Mortoniceras*, *Schloenbachia* (Aitamir Fm.); ***Parahoplites***, ***Hypacanthoplites***, ***Acanthohoplites***, ***Colombiceras*** (Sanganeh Fm.)
G.3	Highly spinose, planulate and cadicone.	Proximal offshore to mid basinal areas.	A wide depth tolerance.	***Cheloniceras*** (Sanganeh Fm.)
G.4	Involute nodose ammonites with generally quadrate whorl section, sphaerocone to platycone.	Typically associated with proximal to medial offshore.	Demersal to vagrant benthic forms.	*Mantelliceras* (Aitamir Fm.)
G.5	Depressed, generally ribbed as juveniles and smooth as adults (cadicone).	Shoreface sands to medial offshore muds.	Juveniles pelagic, adults demersal.	
G.6	Depressed, quadrate whorl sections, ribbed as juveniles and smooth as adults.	Shoreface to proximal offshore.	Shell shape and adult streamlining suggest that these ammonites were mobile and demersal.	*Uhligella*, ***Melchiorites*** (Sanganeh Fm.)
G.7	Whorl sections are typically well rounded or oval and shell surfaces bear very fine ribs and collared	Proximal to medial offshore mud facies, may be post-mortem	Complex suture with high lobes and saddles indicate demersal ammonite habitat in deep water.	***Phylloceras*** ***Phyllopachyceras*** (Sarcheshmeh Fm.)

	constructions (Desmoceratid).	drift.		
G.8	Relatively small, compressed, evolute shells with ribbed surface (serpenticones and some planulates).	Shallow areas	Pelagic drifters in middle part of the water column in shallow areas.	***Dufrenoyia, Deshayesites, Eogaudryceras, Eotetragonites,*** *Prodeshayesites,* ***Turkmeniceras*** (Sarcheshmeh Fm.)
G.9	Compressed, ribbed, planulate shells that in some cases become smooth during ontogeny.	Shoreface sand to medial offshore mud facies.	First relatively shallow pelagic carbonate facies, then migrate into basinal areas	*Hyphoplites, Callihoplites, Epihoplites* (Aitamir Fm.); *Hoplites* (Sanganeh Fm.); *Hemihoplites* (Sarcheshmeh Fm.)
G10	Small, compressed, very finely ribbed to smooth planulate ammonite.	Not restricted by latitude or distance from shore.	Pelagic.	*Semenoviceras, Anahoplites* (Aitamir); *Beudanticeras* (Sanganeh Fm.);
G.11	Compressed, disc shaped ammonites (oxycone).	Shorfaces sand proximal offshore mudfacies.	mobile demersal.	*Placenticeras*, (Aitamir Fm.); ***Aconeceras, Pseudosaynella*** (Sanganeh Fm.); ***Barremites*** (Sarcheshmeh Fm.)
G.12	Tightly coiled helical ammonite shells (torticone).	Shoreface sand and proxima; offshore mud	Shell shape and phragmocone buoyancy producing a stable vertical floating position would have limited horizontal motility but facilitated vertical movement, nektobenthic (=demersal) feeding off the bottom.	*Hypoturrilites, Mariella* (Aitamir Fm.)
G.13	Loosely coiled helical ammonites.	Central to distal offshore	Sluggish demersal.	
G.14	Delicate shells with a U-shaped adult living chamber	Apparent lack of facies control	Life as a drifter with limited motility and post-mortem drift of empty shells with a stable floating orientation, deeper dwelling forms, related to subtropical or temperate watermasses	*Anisoceras* (Aitamir Fm.); ***Australiceras*** (Sanganeh Fm.); *Anahamulina,* ***Ancyloceras, Heteroceras, Toxoceratoides*** (Sarcheshmeh Fm.)

G.15	Sphaeroconic phragmacone and hooked adult bodychamber	Distal offshore part to proximal offshore areas	Possibly restricted by oxygenation in the lower part of the water column	***Pedioceras*** (Sarcheshmeh and Sanganeh Fms)
G.16	Hooked body chamber but compressed evolute phragmocone	Apparently not restricted to facies	Shell shape, restricting locomotion suggest a planktonic habitat widespread distribution during anoxic interval indicates that these ammonites may have inhabited upper part of the water column	***Argvethites*, *Imerites*, *Martelites*, *Paraimerites*** (Sarcheshmeh Fm.)
G.17	Orthocone, circular whorl section.	Complete lack of facies control, may in part be a factor of post-mortem drift.	Lived in upper part of the water column and planktonic.	
G.18	Orthicon, compressed whorl.		Sluggish horizontal and rapid vertical movements.	

On the other hand, there are not many specimens of some genera collected by the author, such as *Phyllopachyceras*, and their presence cannot provide a reliable interpretation of facies and habitat. The facies that have been suggested by Batt are similar to those in the Kopet Dagh Basin for most groups.

5.5. Conclusions

This study has shown that in the Kopet Dagh basin, the marls and shaly/marly limestones of the Sarcheshmeh Formation are dominated by heteromorph ammonites (morphogroup 1). But well-ribbed and planispiral shells (morphogroup 3) occur in marly limestone and limestone intercalations. In the Sanganeh Formation argillaceous shales, silty shales and siltstones are dominant. In the quieter areas and off-shore environments leiostraceous ammonites (morphogroup 2) thrived, whilst in the more agitated and higher energy environments trachyostraceous ammonites (morphogroup 4) were in a majority. It should be noted that all recorded genera do not have the same abundance. For example in the lower part of the Sarcheshmeh Formation heteromorphs are abundant, in the upper part of the Sarcheshmeh Formation, deshayesitids are abundant, whilst in the Sanganeh Formation Parahoplitidae are in the majority.

The author's observations, coupled with evidence from previous studies, suggest that the relationship between ammonites and depth of water can be interpreted with reasonable confidence.

In comparison with the works of Batt (1993) and Westermann (1996) suggests that members of morphogroup 1 were planktonic and vertical migrants in deeper mid water, about 80-120 m. The lack of a benthic fauna such as brachiopods and echinoderms, and the presence of belemnites (sample 19) may indicate an offshore mud carbonate. Marcinowski and Naidin (1976) stated that heteromorphs usually occur in shaly and marly facies rather than in the sandy facies.

Morphogroup 2 embraces smooth, often compressed or discoidal ammonites for which a pelagic, swimming habitat is suggested. Scott (1940b) suggested a maximum depth of about 40 metres for such ammonites, based on facies and associated fauna.

Batt (1989) believed that small compressed fine ribbed to smooth planulate ammonites (his group 10) were not restricted by latitude or distance from shore and may have been pelagic drifters. The above interpretation may apply for morphogroup 2 ammonite genera like *Barremites* and *Aconeceras* in the study. A pelagic and swimming habitat is suggested for this group.

Morphogroup 3 can be compared with morphogroup A of Tanabe *et al.* (1978) and group 9 of Batt (1989). In the Kopet Dagh, the dominant member of the group is *Deshayesites*, whose wide dispersion suggests that it was not dependent on facies. It was probably demersal or sluggish nektic and lived in the middle of the water column.

Scott (1940b) mentioned that ammonites are not found in reef limestone and *Orbitolina* beds, and are rare in shell beds or coquinal limestone. But he recorded *Dufrenoyia* in great abundance in an arenaceous coquinal limestone. In the Raz section, in the fossiliferous limestone of upper part of the Sarcheshmeh Formation, a few *Dufrenoyia* and *Eotetragonites* are found and may compare with Scott's record. It might be also suggested that these specimens are post-mortem and were transported by currents to shallow water environments.

Morphogroup 4 may coincide with Scott (1940b) and Batt (1989) interpretation. Scott (1940b) believed that, sculptured type with quadrate to ovate whorl section (group 5 & 7 of his classification) such as *Hoplites*, *Parahoplites*, *Douvilleiceras* and *Hypacanthoplites* (p. 20) inhabit the infraneritic zone (20-100 meters depth). These genera mostly occur in arenaceous limestone and shales in which rudists, corals, orbitolinids and oyster beds are not found. Batt (1989) suggested shoreface to distal offshore areas for evolute shell with quadrate whorl section and ornamented by coarse ribs (his group 2). Members of this morphogroup were vagrant benthic or nektobenthic. This position is very similar to the Sanganeh Formation in the central and eastern part of the Kopet Dagh Basin.

Marcinowski and Wiedmann (1988) believed the dominance of trachyostraceous specimens and the virtual absence of heteromorphs supports the idea that hoplitid faunas favoured the agitated waters of nearshore environments. Marcinowski and Wiedmann (1985) compared ornamented hoplitinid ammonites with group A of Tanabe, Obata and Futakami (1978). The fourth morphotype group in the Kopet Dagh Basin was mostly deposited in silty shale and siltstones and can be compared with assemblage faunas in the Carpathians and Japan.

In conclusion, the comparison between ammonite morphotype groups in the Kopet Dagh Basin and those recognised in the Western Interior Cretaceous Seaway and elsewhere suggests that the relationship between ammonite morphotypes and facies does not depend on age and geographical position. In other words although ammonite genera evolved through geological time they can still be arranged into recurring morphogroups, some of which are adapted to particular facies and environments. However, it should be stressed that not all ammonite morphotypes are dependent on facies.

Chapter 6. Ammonites and Sea-level changes

This chapter discusses the relationship between ammonite distributions in the Kopet Dagh Basin and the sea-level changes that are indicated by sequence stratigraphical analysis. The analysis is a preliminary one and further field research is required to test the provisional conclusions.

6.1. Sequences and sea-level fluctuations

Transgressions and regressions have long been recognised from analysis of the stratigraphical record. Suess (1906) was the first to propose that transgression and regression were caused by eustatic changes of sea-level. The application of the technique of sequence stratigraphy by Vail *et al.* (1977) and Haq *et al.* (1987, 1988) has been a major development in this subject.

The documentation and age dating of stratigraphical sequences in marine outcrops in different parts of the world have led to a new generation of Mesozoic and Cenozoic sea-level cycle charts based on sequence stratigraphical principles. A complex terminology has developed, the main elements of which are summarised in Table 6.1.

Table 6.1. Principal terms in sequence stratigraphy (after van Wagoner, 1988).

Term	Definition
Sequence stratigraphy	The study of rock relations within a chronostratigraphic framework of repetitive genetically related strata bounded by surfaces of erosion or non depositional or their correlative conformities.
Depositional sequence	A set of strata bounded at least in part by unconformities and correlative conformities (the 'sequence boundary'). A sequence can be subdivided into systems tracts, parasequences and parasequence sets
Parasequences	Small-scale sedimentary cycles that are the fundamental building block of sequences
Systems tract	Divisions of a depositional system or parasequence, consisting of Lowstand, Transgressive and Highstand systems tracts.
Marine-flooding surface	A surface that separates younger from older strata, across which there is evidence of an abrupt increase in water depth.

The sequence stratigraphical charts document cycles of sea-level change on very varying scales, from many millions of years duration to Milankovitch scale changes of as little as 20000 years. What caused some of these changes remains problematic, especially for those of durations longer than the Milankovitch scale. Glaciation and deglaciation is accepted as a major cause of some global falls and rises in sea-level from the late Paleogene onward. But for the Mesozoic and early Cenozoic there is no evidence of widespread glaciation, and tectonic, tectono-climatic or climatic events may have been responsible. In his review of the problem, Kakabadze (1996) considered that global sea-level changes may be caused either by changes in the amount of water in oceans or by changes in the volume of the ocean basins. It is likely that these two phenomena may periodically coincide in time. He concluded that it is questionable if all the second and third order curves of Haq's chart really have a global eustatic origin.

6.2. The faunal response to sea-level change

The relationship between marine faunas, and regressions and transgressions has been discussed extensively. On the broadest scale, Newell (1967) recognized six episodes of Phanerozoic mass extinction, end-Cambrian, end-Ordovician, Late Devonian, end-Permian, end-Triassic and end-Cretaceous. Hallam (1989, fig. 1) showed that such mass extinctions are related to global falls in sea-level.

House (1993) has analysed the relationship between sea-level changes and ammonite family diversity through the Phanerozoic. The figures provided by him show that in transgression events ammonite diversity is high and during regressions ammonite diversity falls. Wiedmann (1988) came to a similar conclusion in his study of Late Cretaceous events, while suggesting that at peak transgression provincialism also increased.

Several authors have studied Early Cretaceous faunas. In particular, Rawson (1993) examined the influence of sea-level changes on the migration and evolution of Early Cretaceous taxa. Based on palaeobiogeographical evidence he showed that migration of families to a new realm was related to sea-level rise, while sea-level fall led to provincialism and speciation, even when seaway connections remained open.

Reboult and Atrops (1997) studied quantitative variations in the Valanginian ammonites faunas within limestone-marl cycles and within parasequence sets in the Vocontian Basin, Southern France. They concluded that the abundance of ammonite taxa from the base to the top in some parasequences is different and shows a rhythmic variation. The distribution of some families is related to lithofacies, and the facies changes reflect changes in water depth. But such bathymetric changes did not affect the abundance of some ammonite families that were living in the upper water column.

Hoedemaeker (1995) also discussed the relationship between ammonites and 2nd and 3rd order sea-level fluctuation in the lowest Cretaceous of south-east Spain. He found that ammonite fauna diversity reached its minimum in sea-level falls through the Berriasian to Barremian. The rapid and high magnitude sea-level falls, which are recognised world wide, produced long term fluctuations and caused ammonite extinctions. Conversely, high diversity was attributed to high eustatic sea-level stands.

6.3. Relationship between ammonites and sea-level changes in the Kopet Dagh Basin

The relationship between the regional sea-level changes recognised on lithological/ sequence stratigraphical evidence and ammonite faunas is summarised in Figures 6.1 to 6.5. Each figure shows a lithological log, the first appearance of ammonite genera or species, parasequence boundaries (PSB), relative sea-level changes and ammonite taxa numbers. It should be noted that the first appearance and taxa numbers are based on sampling and field description, and that further sampling may modify these results. The type of preservation may also influence the aparent first appearance of taxa and the number of specimens collected (see p. 224). The lower boundaries of fossiliferous limestones, sandy limestones, marly limestones and siltstones are taken to indicate parasequence boundaries and lowstand systems tracts. Marls, limy marls and marly limestones mark transgressive systems tracts. Shaly limestone and shales mark highstand systems tracts. This classification depend on parasequence composition, for example if a parasequence starts with a sandy limestone, marly limestones will form transgressive systems tracts, but if there are no fossiliferous or sandy limestones in a parasequence, marly limestone may indicate the sequence boundary and lowstand systems tract.

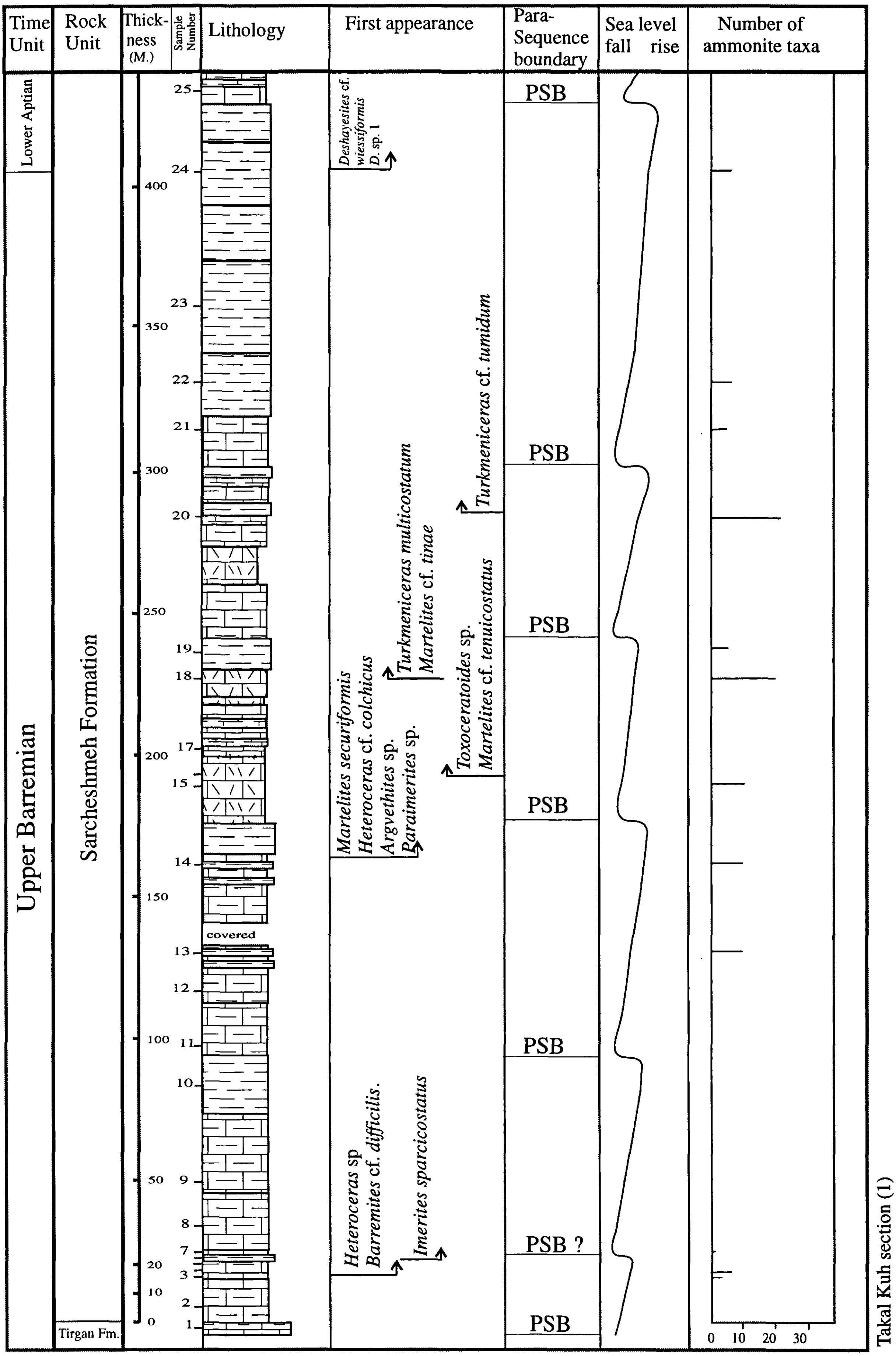
Some of the genera discussed below, such as *Aconeceras* and *Deshayesites*, occur in considerable numbers at several levels. Others are less common, and in rare cases a genus or species may be represented by a single specimen. Nevertheless, all specimens are used in the assessment of first appearances.

6.3.1. Takal Kuh area

Three stratigraphical sections were measured in the Takal Kuh area. In the Takal Kuh section 1 (Figure 6.1), heteromorph genera, including *Argvethites*, *Heteroceras*, *Imerites*, *Martelites* and *Paraimerites*, and the planispiral form *Barremites* appear in the lower part of the Sarcheshmeh Formation (Upper Barremian). Here the first appearance of every genus or species is in the shaly limestone, marl or marly limestone of the transgressive and highstand systems tracts, during an inferred sea-level rise (Figure 6.1).

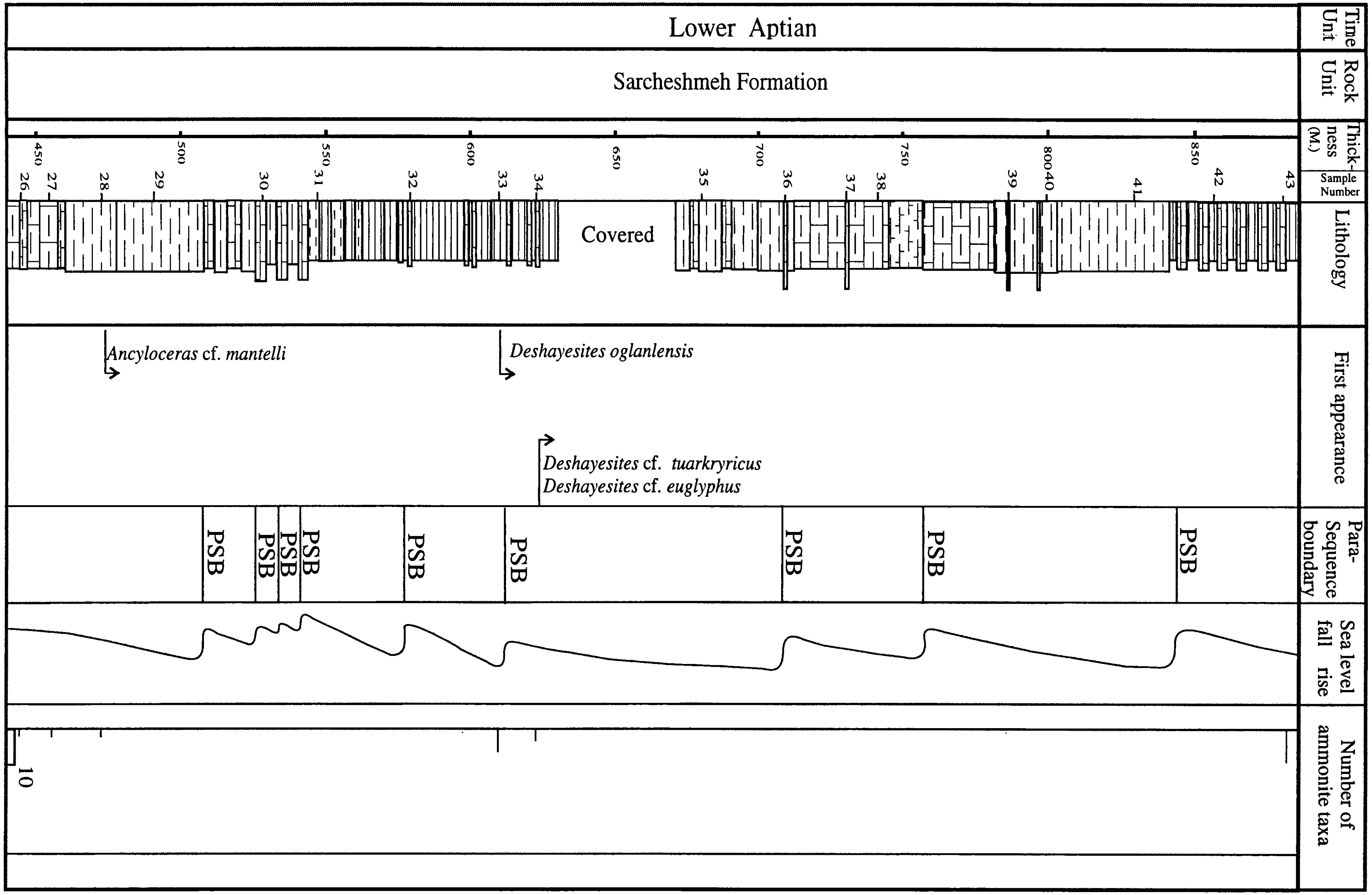
In the middle part of the Sarcheshmeh Formation (uppermost Upper Barremian-Lower Aptian) the planispiral ammonites *Turkmeniceras* and *Deshayesites* and the heteromorph form *Ancyloceras* occur. *Turkmeniceras* and *Ancyloceras* first appear in the shaly limestones and marls, which mark transgressive and highstand systems tracts. *Deshayesites* species also often appear first in shaly limestone, shales, limy marls and marls. But in some cases, like samples 48 and 82, their first appearance is in limestones, which means they also occur in lowstand systems tracts.

With the beginning of the Aptian, the number and diversity of heteromorphs falls. It is not clear if this is because of ecologic conditions or sea-level changes. However there is no gap or pause in deposition at the Barremian-Aptian boundary. In the middle part of the section the number of ammonite taxa falls for about the next 150 metres. Afterward in the middle and upper part of the formation new genera including *Phylloceras*, *Phyllopachyceras*, *Aconeceras*, *Cheloniceras* and *Melchiorites* appear, and the diversity of ammonite taxa increases upwards. The parasequences are thinner in this part of the formation (Figure 6.1, page 239). If we assume an equal time interval for each parasequence, the depositional rate was slower and relative sea-level changes were more frequent in the upper part of the Sarcheshmeh Formation.



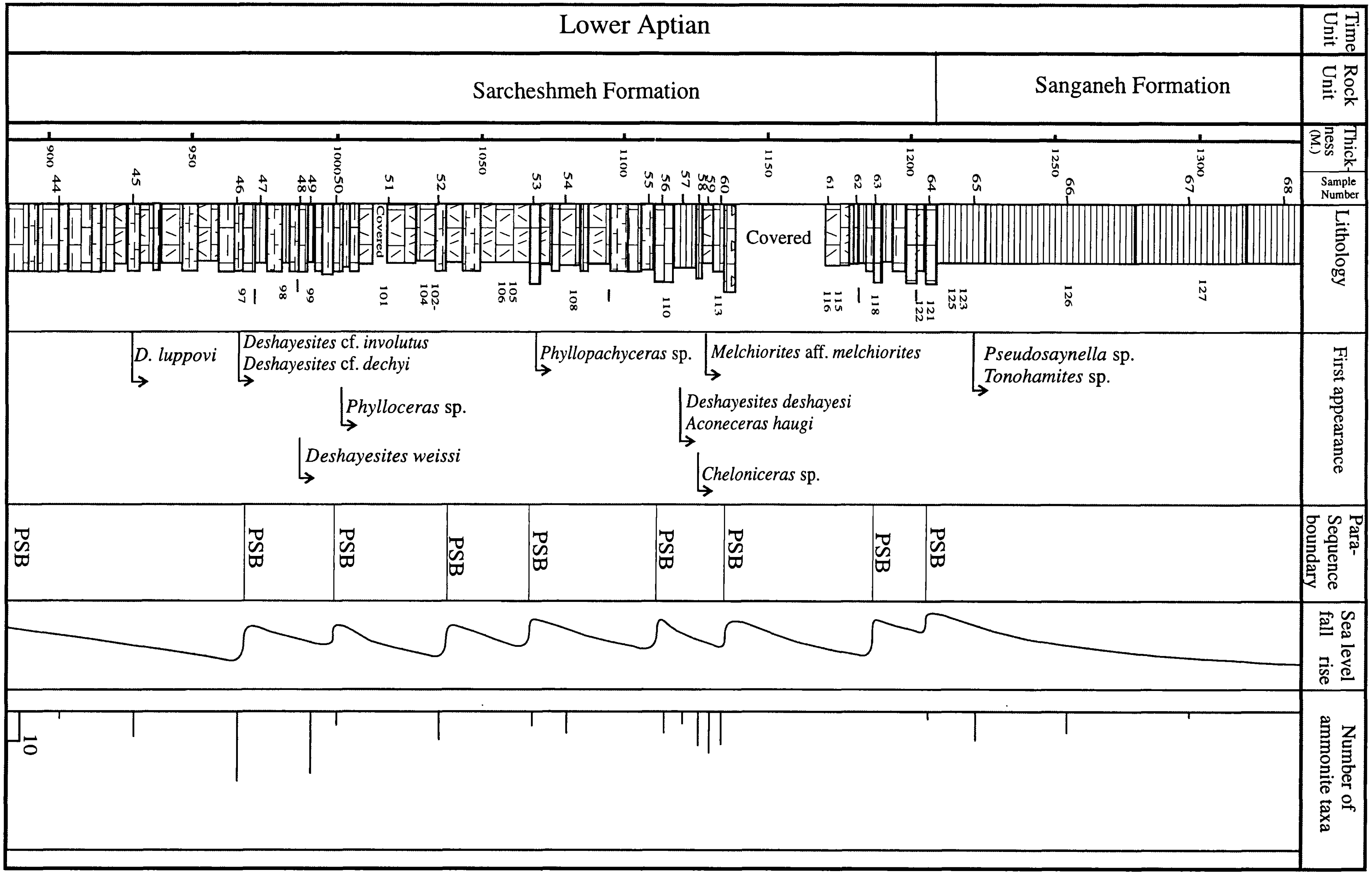
continued

Figure 6.1. Relationship between ammonite fauna and sea level changes in the Takal Kuh section (1).



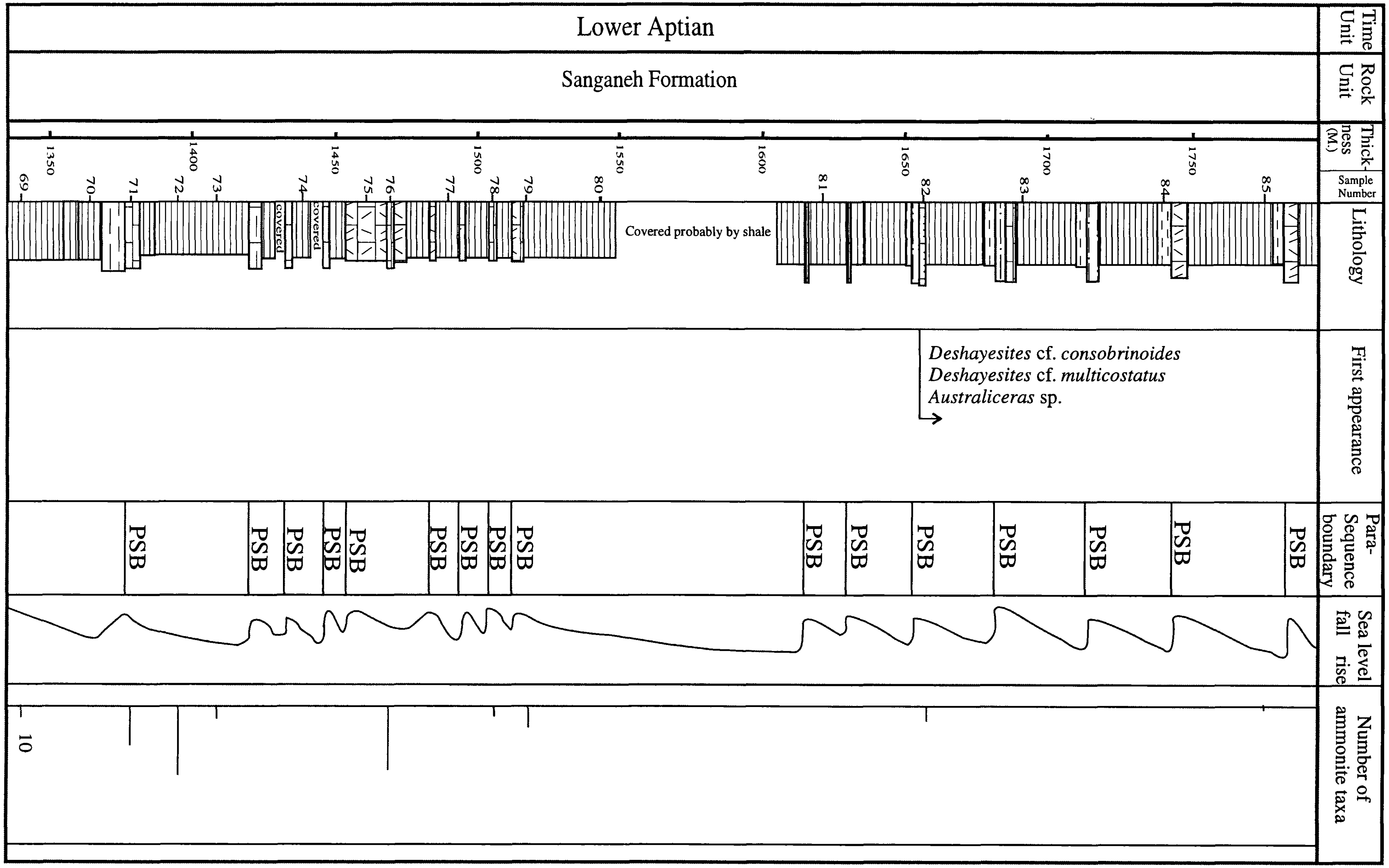
Takal Kuh section (1)

continued



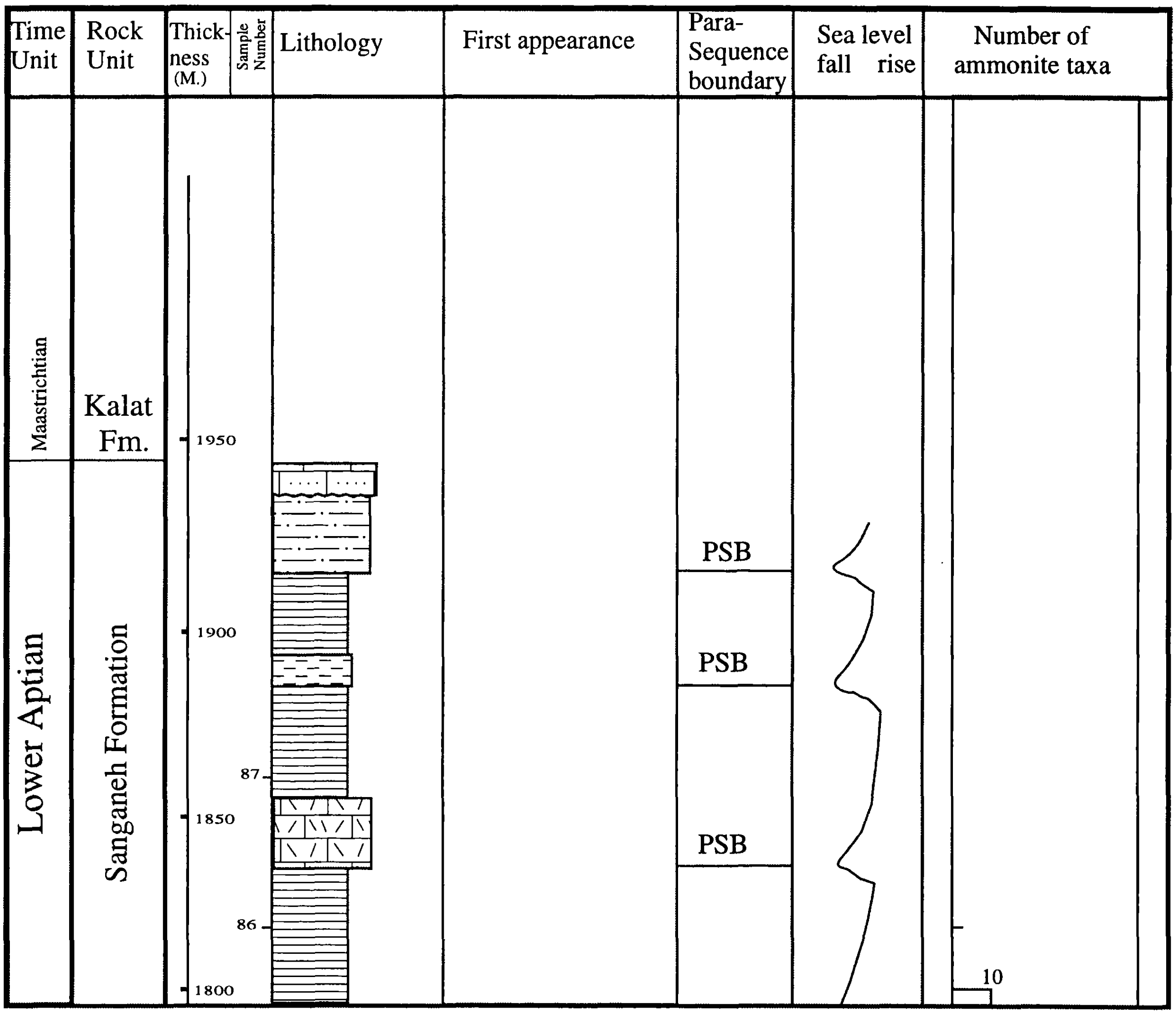
continued

Takal Kuh section (1)



continued

Takal Kuh section (1)



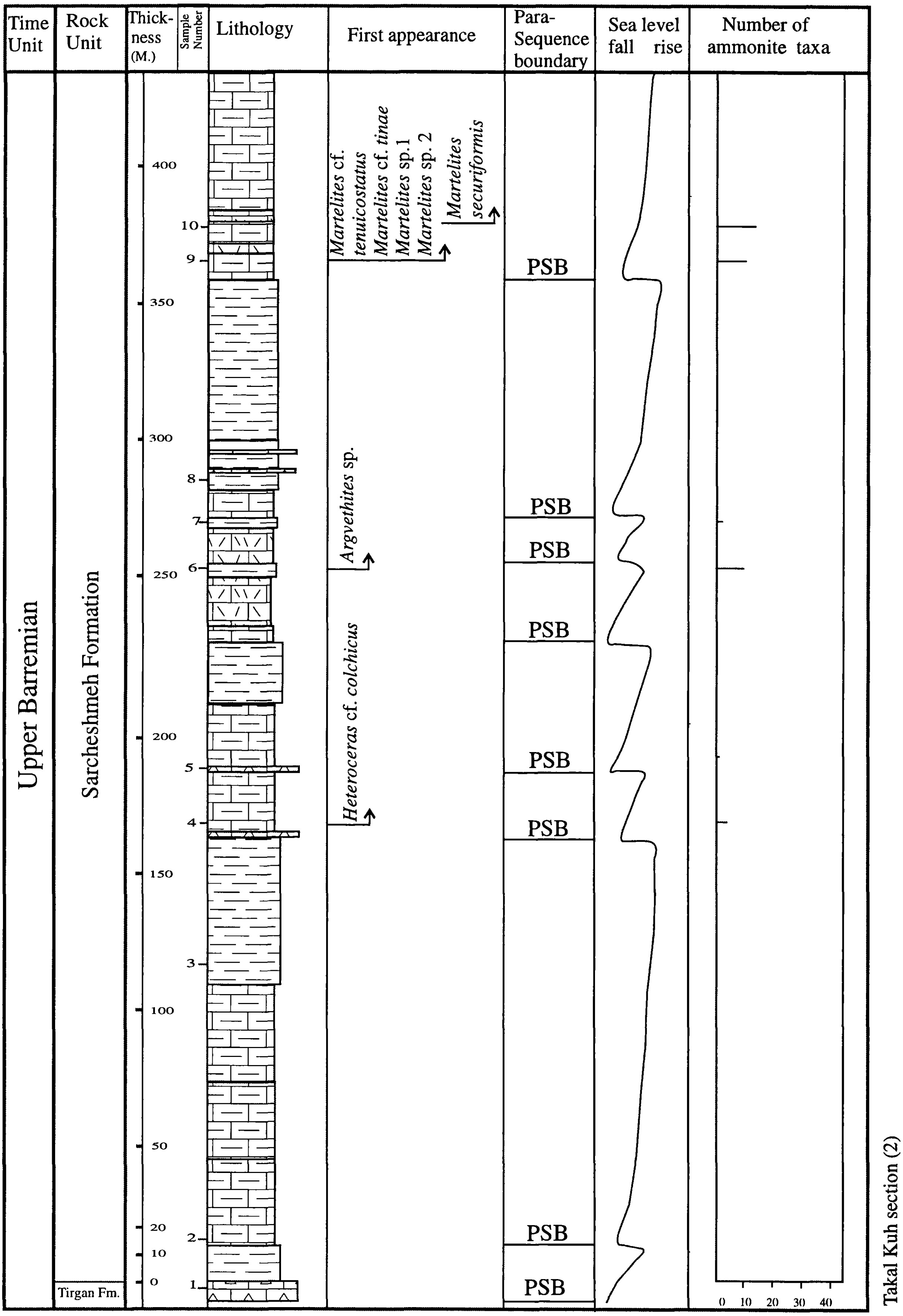
Takal Kuh section (1)

In the Sanganeh Formation the lithology changes mainly to shales and they are less calcareous than the Sarcheshmeh Formation shales. In contrast the number of sandy and fossiliferous limestones decreases. The Sanganeh Formation was probably deposited in deeper and quieter environments compared with the underlying and overlying Sarcheshmeh and Aitamir Formations. It is in this formation that *Pseudosaynella*, *Tonohamite*s and *Australiceras* first appear. The first two genera occur in shale beds, which are taken as highstand systems tracts, but the third one occurs with two *Deshayesites* species in a sandy fossiliferous limestone bed (lowstand systems tract). The numbers of collected specimens also increase in transgressive and highstand systems tracts as whole.

In the Takal Kuh section 2 the relationship between ammonites and sea-level changes in the Sarcheshmeh and Sanganeh Formations is similar to that in the Takal Kuh section 1. In the lower part of the Sarcheshmeh Formation *Argvethites*, *Heteroceras* and *Martelites* first appear in shaly limestones, marly limestones and marls, while *Turkmeniceras* first appears in a limestone (Figure 6.2). In the middle part of the formation *Deshayesites* and *Pedioceras* appear. Their first occurrence is in marls and marly limestones, that is in transgressive systems tracts. In the upper part of the Sarcheshmeh Formation *Cheloniceras*, *Australiceras*, *Eogaudryceras* and cymatoceratid nautiloids appear together, in a marly limestone that may represent a slight rise in sea-level.

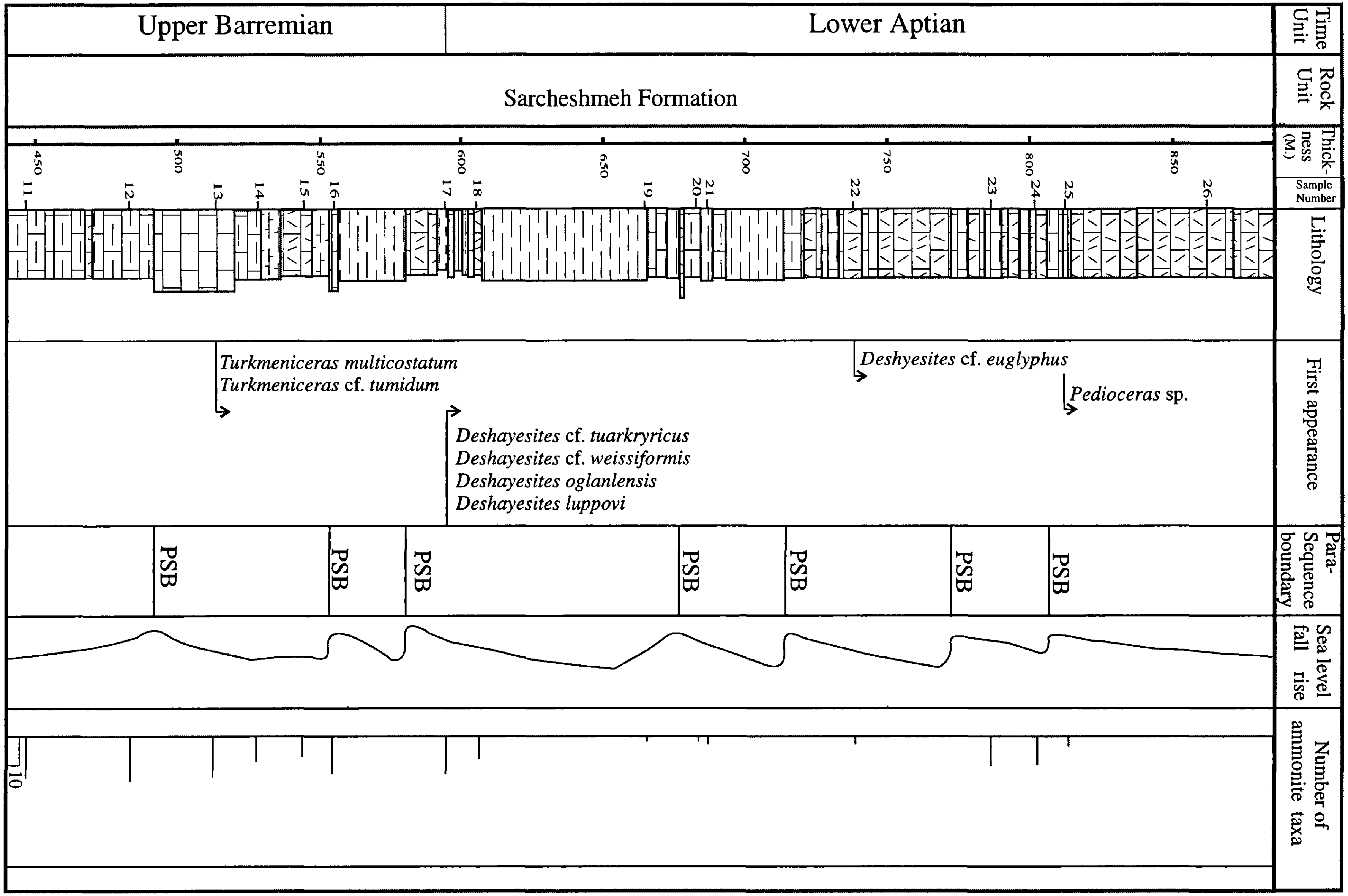
In the Sanganeh Formation marls, marly limestones and limestones are intercalated with shales in the lower part of the formation, but their thickness and numbers decrease in comparison to similar beds in the Sarcheshmeh Formation.

Aconeceras, *Pedioceras*, *Tonohamites*, *Melchiorites*, *Pseudosaynella* and *Dufrenoyia* appear in the Sanganeh Formation in this section (Figure 6.2). Most of these genera first appear in shale. In the lower part of the formation the number of collected taxa is low but it reaches its peak in the middle part. In the upper part of the formation again taxa numbers decrease. The diversity of ammonite genera in the Sanganeh Formation is less than in the Sarcheshmeh Formation.



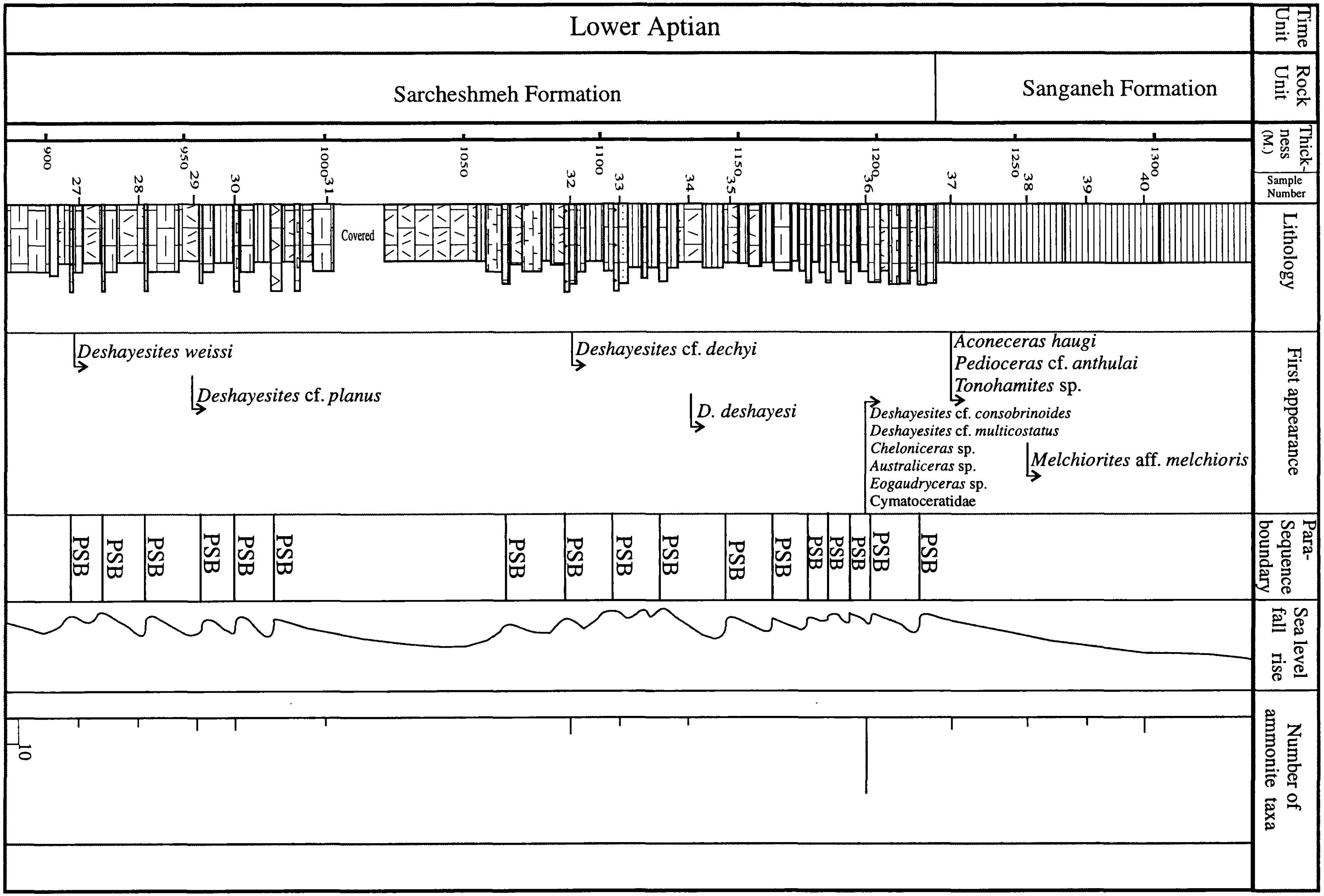
continued

Figure 6.2. Relationship between ammonite fauna and sea level changes in the Takal Kuh section (2).



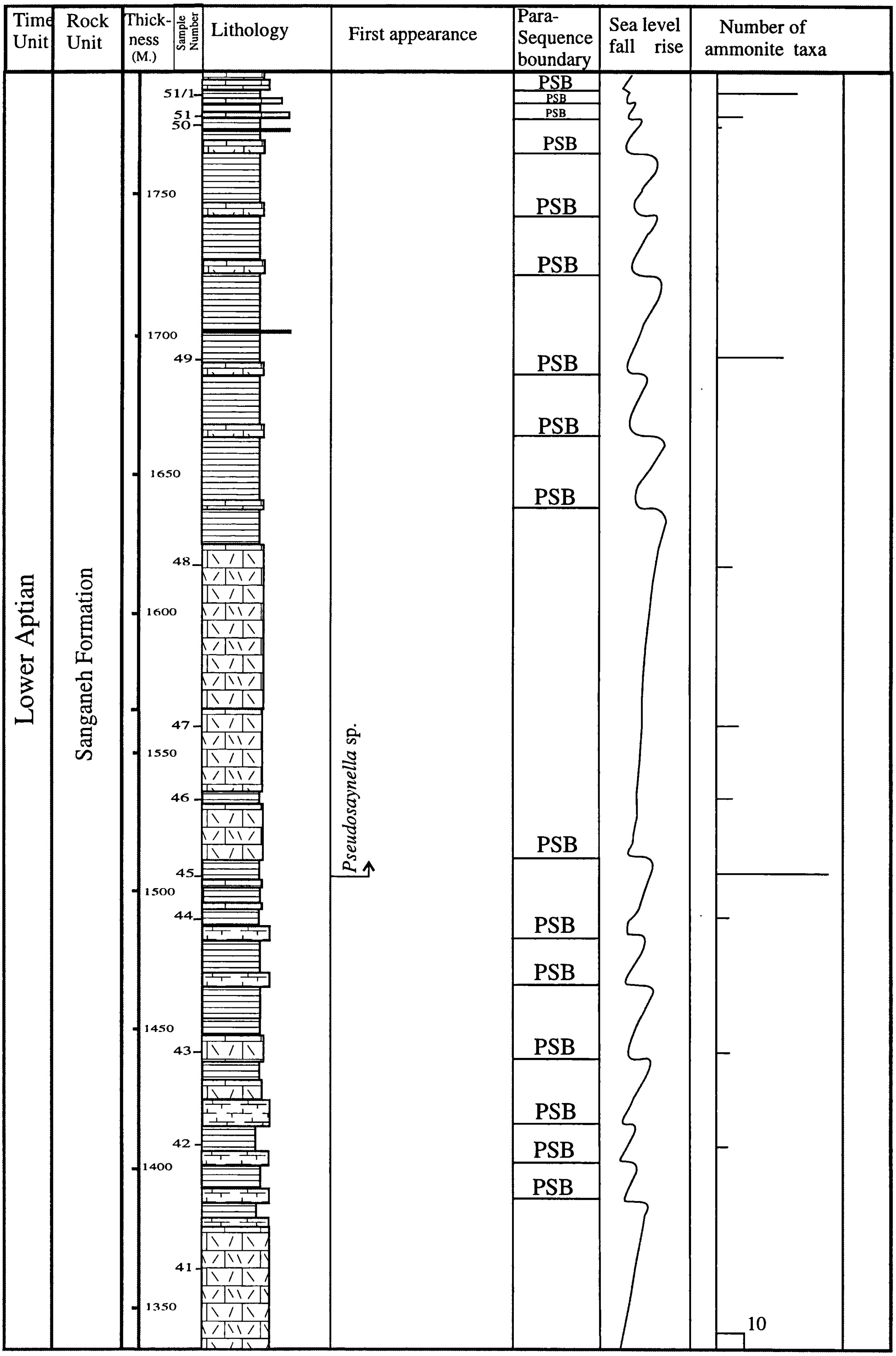
Takal Kuh section (2)

continued



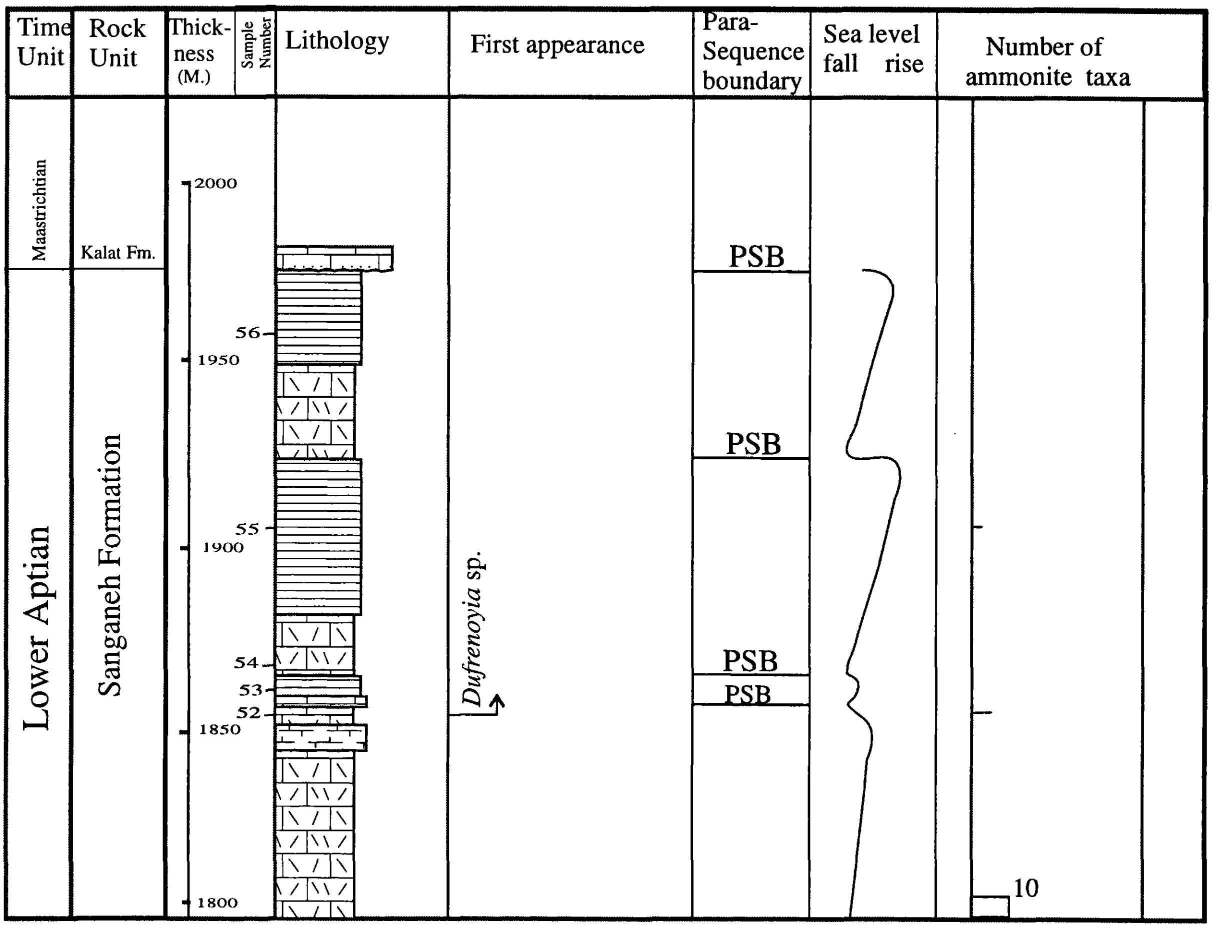
continued

Takal Kuh section (2)



Takal Kuh section (2)

continued



Takal Kuh section (2)

A thick sandy and fossiliferous limestone occurs in the upper part of the Sanganeh Formation at the Takal Kuh sections (sample number 82 in Takal Kuh section 1 and sample number 51 in Takal Kuh section 2), containing big *Deshayesites* and *Australiceras*. It may represent a fall in sea-level at the Takal Kuh area. This layer cannot be traced in other parts of the basin.

The occurrence of ammonites in relation to sequences in the Amand section is similar to that in the Takal Kuh sections, but the diversity of ammonite genera in this section is less than in the Takal Kuh sections. In the lowest part of the Sarcheshmeh Formation no ammonites were found. In the lower to upper part of the formation the first appearance of *Martelites*, *Turkmeniceras*, *Deshayesites* and Cymatoceratidae is in marly limestones, marls and shaly limestones (Figure 6.3). In the lower to middle part of the formation the number of ammonite taxa peaks, then decreases in the upper part.

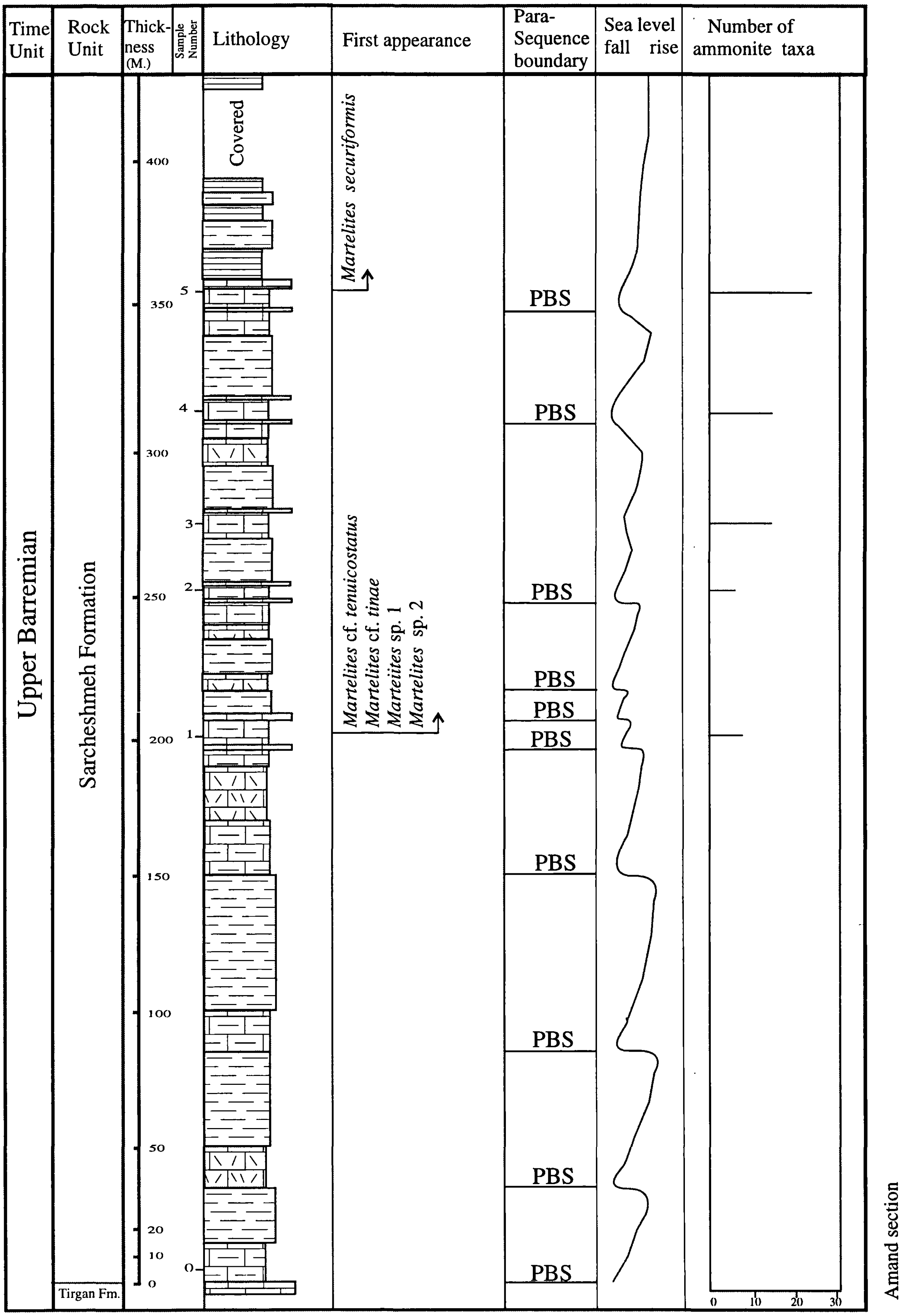
Only the lowest part of the Sanganeh Formation was measured in the Amand section. In this part two genera, *Pedioceras* and *Aconeceras*, appear in shale beds.

6.3.2. Sanganeh and Tirgan sections

In the Sanganeh and Tirgan sections, there is no sign of ammonites in the Sarcheshmeh Formation but in the Sanganeh Formation ammonites occur, including *Parahoplites*, *Acanthohoplites*, *Hypacanthoplites* and *Colombiceras*.

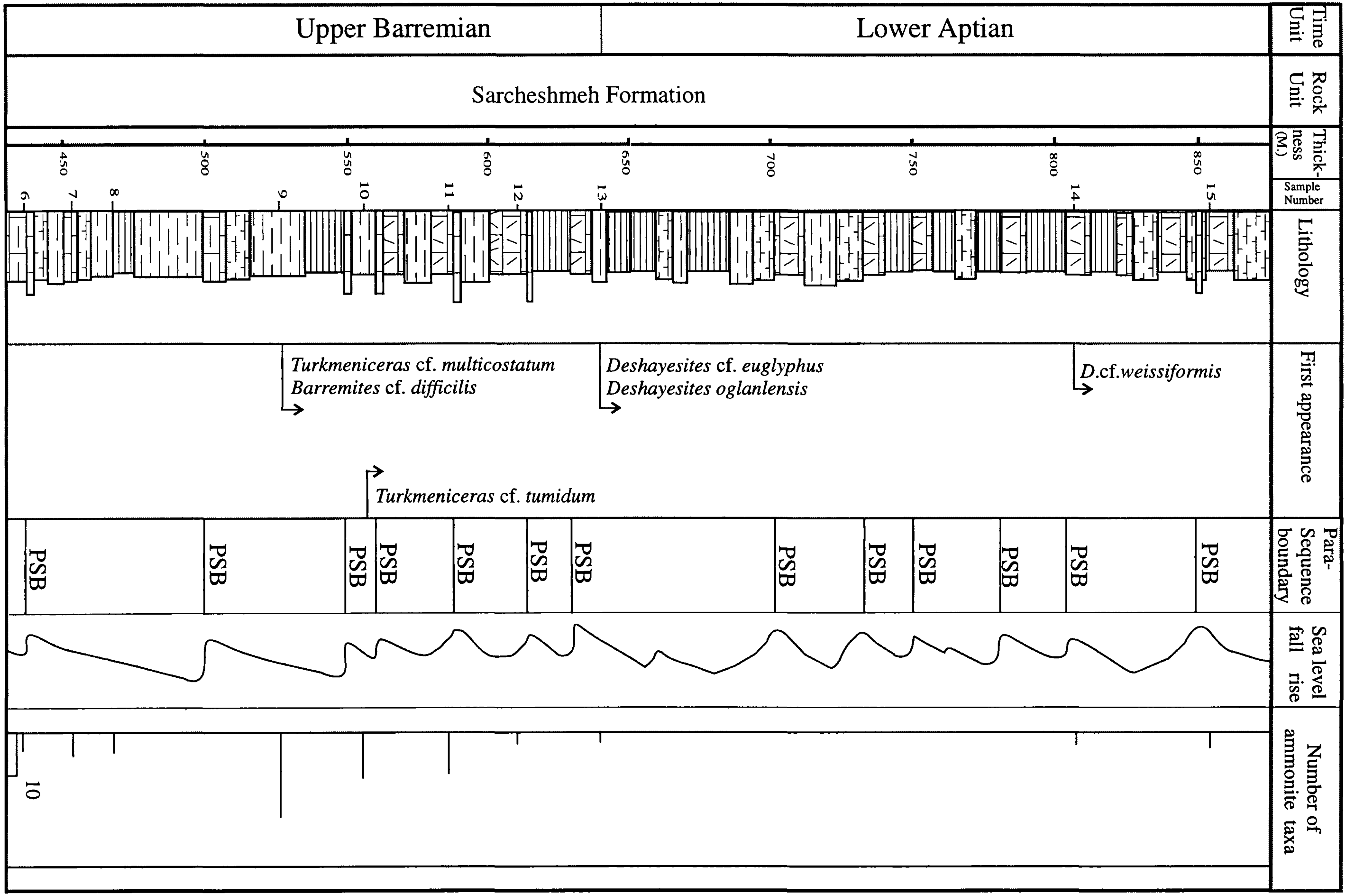
The base of the Sanganeh formation in the Tirgan section marks a significance Late Aptian sea-level rise. The first appearance of genera or species is often in silty shales which are taken to represent lowstand system tracts (Figure 6.4).

In the lower and middle part of the formation sea-level fluctuations led to the occurrence of new genera and species and taxa numbers are also higher than in the upper part of the formation (Figure 6.4). The numbers of ammonite taxa reaches its peak in transgressive and highstand systems tracts in some parasequences.



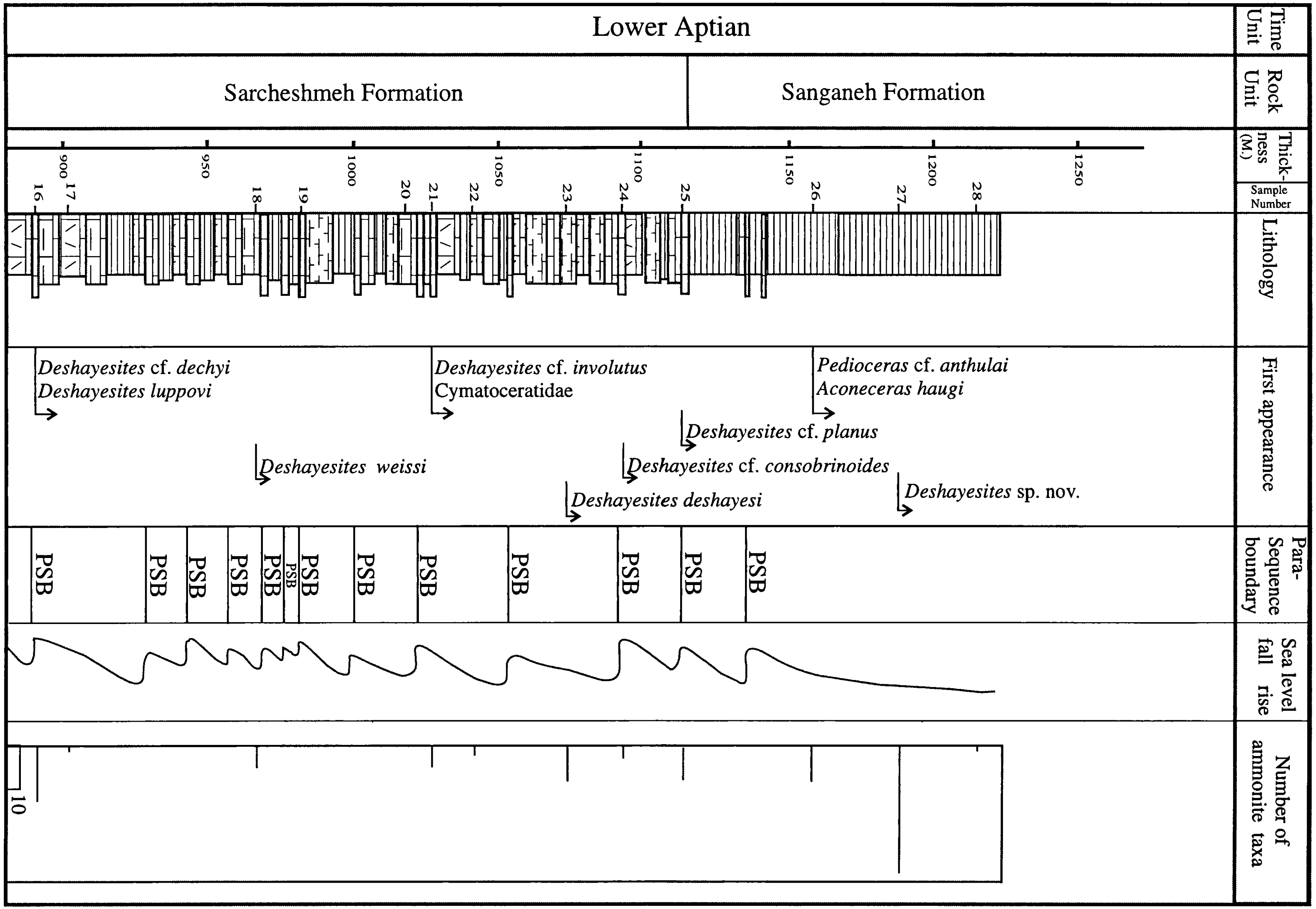
continued

Figure 6.3. Relationship between ammonites and sea level changes in the Amand section.

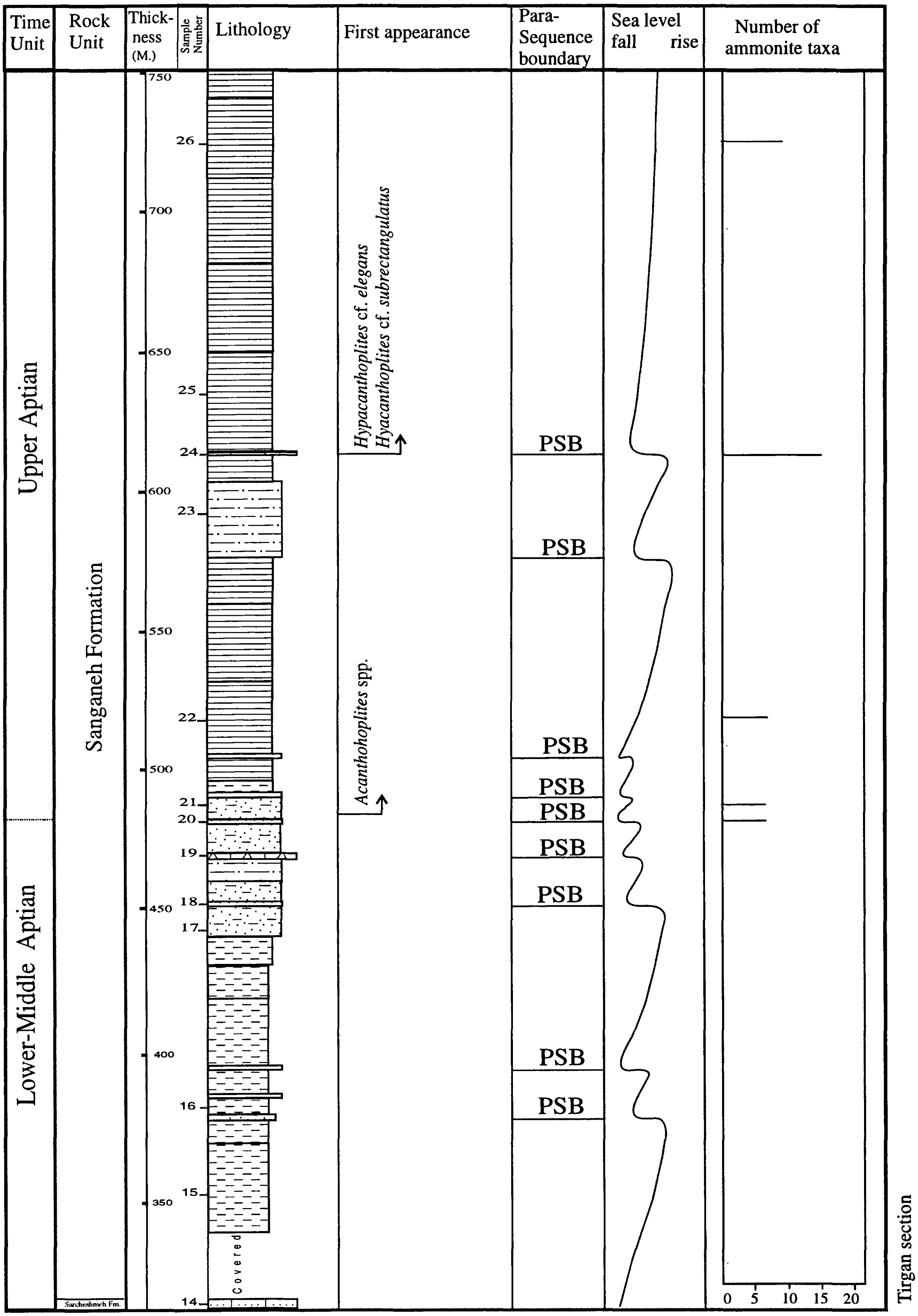


continued

Amand section

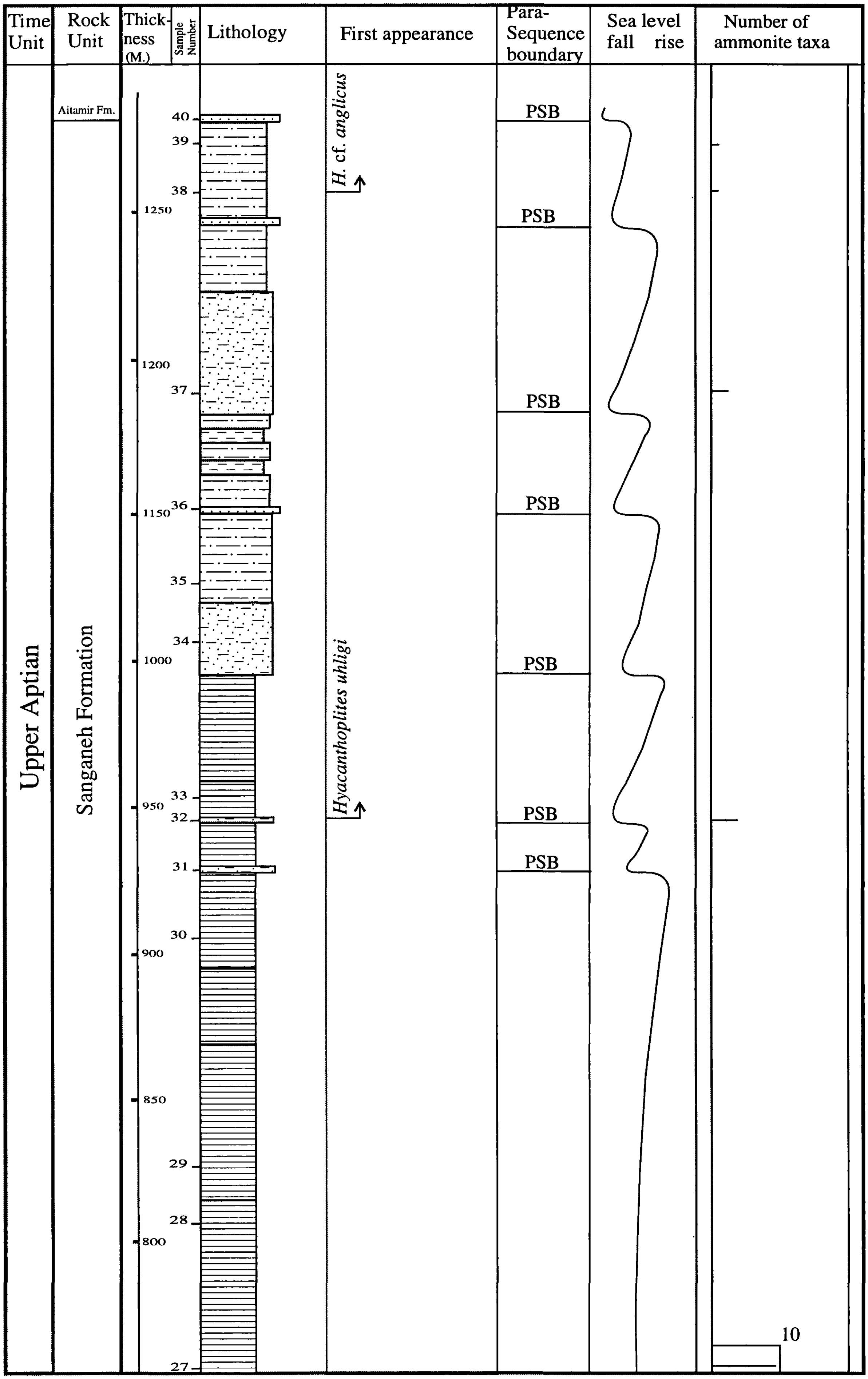


Amand section



Continued

Figure 6.4. Relationship between ammonite fauna and sea level changes in the Tirgan section.



Tirgan section

In the Sanganeh section, except for sample 21, new genera appear during the transgressions and water influx to the basin and at the same time an increase in taxa numbers is seen. In the lower and upper part of the Sanganeh Formation parasequences are frequent and thin while in the middle part they are not developed (Figure 6.5). This trend can be also seen in the Tirgan section. It seems that during deposition of the middle part of the formation more uniform conditions prevailed.

6.3.4. Other sections

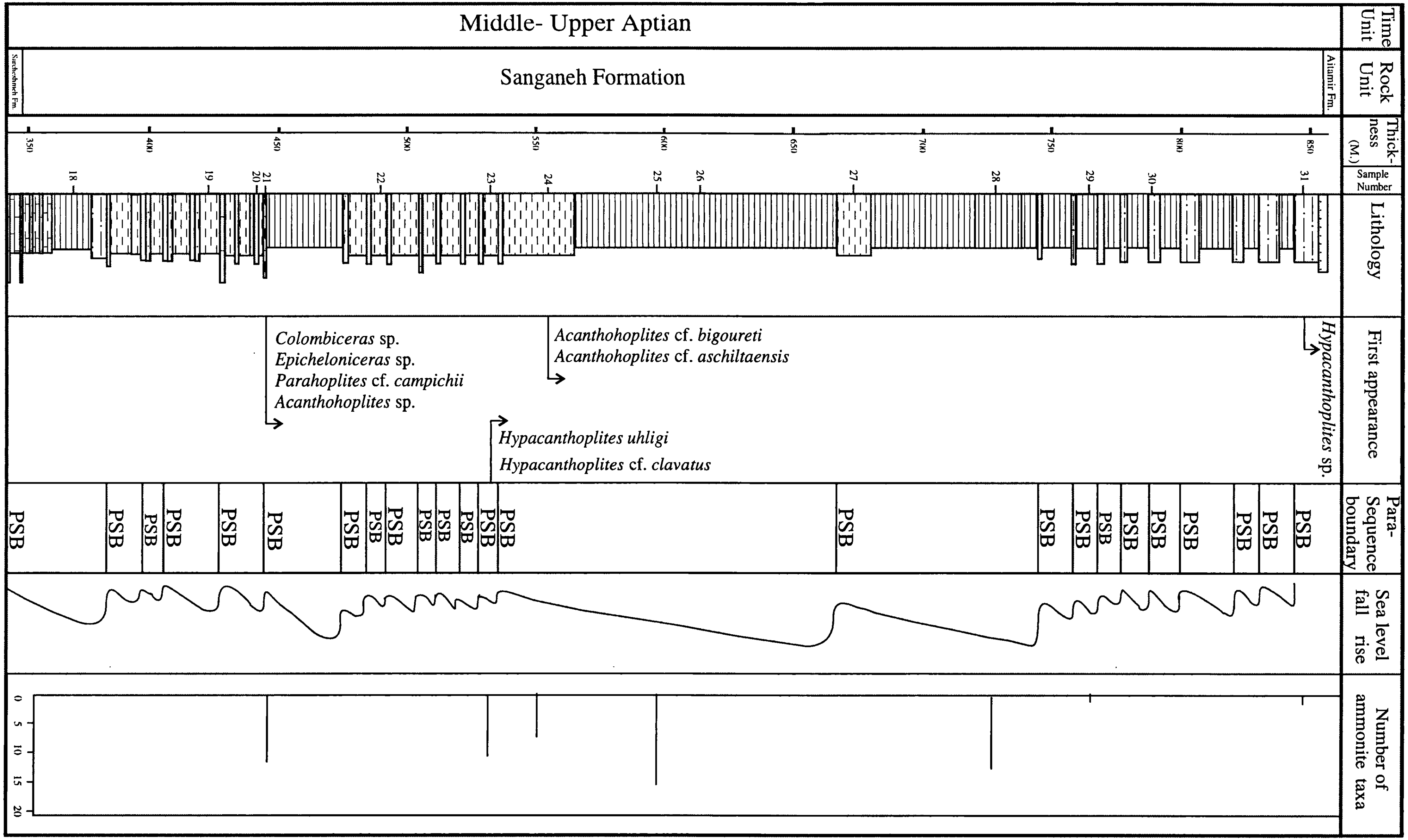
The other measured sections contain ammonite faunas in some layers but the number of layers and ammonite specimens are not enough to permit testing the relationship between ammonites and sea-level changes. However, parasequences can be identified and the appearance and presence of ammonite genera or species more or less reflect that seen in other sections.

6.4. Discussion

As the thickness of the formations changes from one measured section to another, the thickness and numbers of parasequences also changes. In particular, in the Takal Kuh area the Sarcheshmeh Formation is thicker than in other areas and there are more parasequences. Based on regional geology the Takal Kuh fault was active during the Cretaceous. It appears that the number of parasequences and sea level fluctuations in this area is partially related to the activity of this fault. If the Takal Kuh sections are correlated with sections to the east and south-east of this area, some beds pinch out and it may be assumed these layers and their respective parasequences had a regional tectonic origin.

In the Sarcheshmeh and Sanganeh Formations about 45 parasequences have been recorded in the Takal Kuh area. These parasequences were deposited during the Late Barremian to Early Aptian. If we assume 5.5 million years for this interval (Gradstein *et al.*, 1999) and complete preservation and recognition of all parasequences, then the average duration of a parasequence was 80000 years.

Figure 6.5. Relationship between ammonite faunas and sea-level changes in the Sanganeh section.



Sanganeh section

0 10 40 m.

Over the basin as a whole parasequences are thicker in the lower part of the Sarcheshmeh Formation than in the upper part. The sandy and fossiliferous limestone beds of the uppermost part of the Sarcheshmeh Formation may represent an important fall in relative sea-level before significant transgression occurred over the basin to deposit the Sanganeh Formation.

The trend of relative sea level rise from the Sarcheshmeh Formation to the Sanganeh Formation can be traced in all measured sections. It is indicated by the predominance of shales in the latter formation. The shales are dark grey to black or green-grey, and were probably deposited on an intermittently anoxic sea floor. Marly limestone, marl, and limestone beds still occur but they are thinner in comparison with similar layers in the Sarcheshmeh Formation. The lithology of these harder beds gradually changes toward the eastern part of the basin, passing into silty shales and siltstones. This may relate to epirogenic activity in the lands surrounded the basin or reflect the influx of cool water due to sea level rise and a greater connection to the northerly basins.

Although some key beds can be followed along the whole of the basin or at least most parts of the basin, they are not necessarily of the same age throughout the area. The uppermost limestone bed of the Sarcheshmeh Formation, which is accepted as the Sarcheshmeh and Sanganeh Formation boundary, can be traced along the basin. It is a key marker bed that may represent a significant sea level fall.

The number of ammonite specimens in the Sarcheshmeh Formation shows rhythmic changes in the Takal Kuh area in the western part of the basin. Here, three main peaks and few minor peaks in the ammonite fauna can be seen (Figures 6.2, 6.3). The number of ammonite genera or species, and of specimens, in the Sarcheshmeh Formation decreases notably from here eastwards.

Whilst the number of ammonites collected from the Sanganeh Formation decreases eastward from the Takal Kuh sections to Sheykh and Bibahreh, it increases again in the Tirgan and Sanganeh sections further to the east. This may reflect the physiography of the basin, lithology, type of preservation and environmental conditions. Subsidence may relate to fault activity in the Tirgan and Sanganeh sections. However, this needs more investigation.

Overall, sea level rose during the Late Barremian to Albian across the Kopet Dagh Basin. It appeared to reach a local peak in the Late Aptian to Early Albian, during deposition of the Sanganeh Formation. A preliminary correlation between biozones, numbers of genera and species, and third order relative sea-level changes in the basin is presented in Figure 6.6. The number and diversity of ammonite genera and species reached its highest in the Late Barremian and Early Aptian, and decreased in Mid and Late Aptian times. Parasequences (and sequences) show that in the Late Barremian and Early Aptian sea-level fluctuated more than in Mid and Late Aptian times. Correlation of third order sea-level changes in the Kopet Dagh Basin with Haq *et al.*'s (1988) curve suggests both differences and similarities. If the Haq *et al.* chart is accepted as a world wide trend in sea-level changes, then similar trends in the Kopet Dagh curve could reflect global effects and differences could reflect local effects.

6.5. Conclusions

The effect of relative sea-level changes can be recognised in the Sarcheshmeh and Sanganeh Formations throughout the Kopet Dagh Basin. A significant sea-level rise is marked by the change from the thick-bedded limestones of the Tirgan Formation to the marly and shaly limestone beds of the Sarcheshmeh Formation. With this event the Late Barremian heteromorphs such as *Martelites* and *Heteroceras* and planispiral forms such as *Turkmeniceras* invaded the basin. During the Early Aptian sea-level fluctuated and with some water influxes new genera or species entered the basin. The most important genus is *Deshayesites* with its numerous species.

When deposition of the Sanganeh Formation commenced in the western part of the basin (Takal Kuh area) during Early Aptian times, smooth-shelled genera such as *Aconeceras*, *Melchiorites* and *Pseudosaynella* entered the area. But the number of new genera and species is less than in the Sarcheshmeh Formation. These forms failed to penetrate further east, where the Sarcheshmeh Formation was still being deposited in the Tirgan and Sanganeh sections and no ammonites are known.

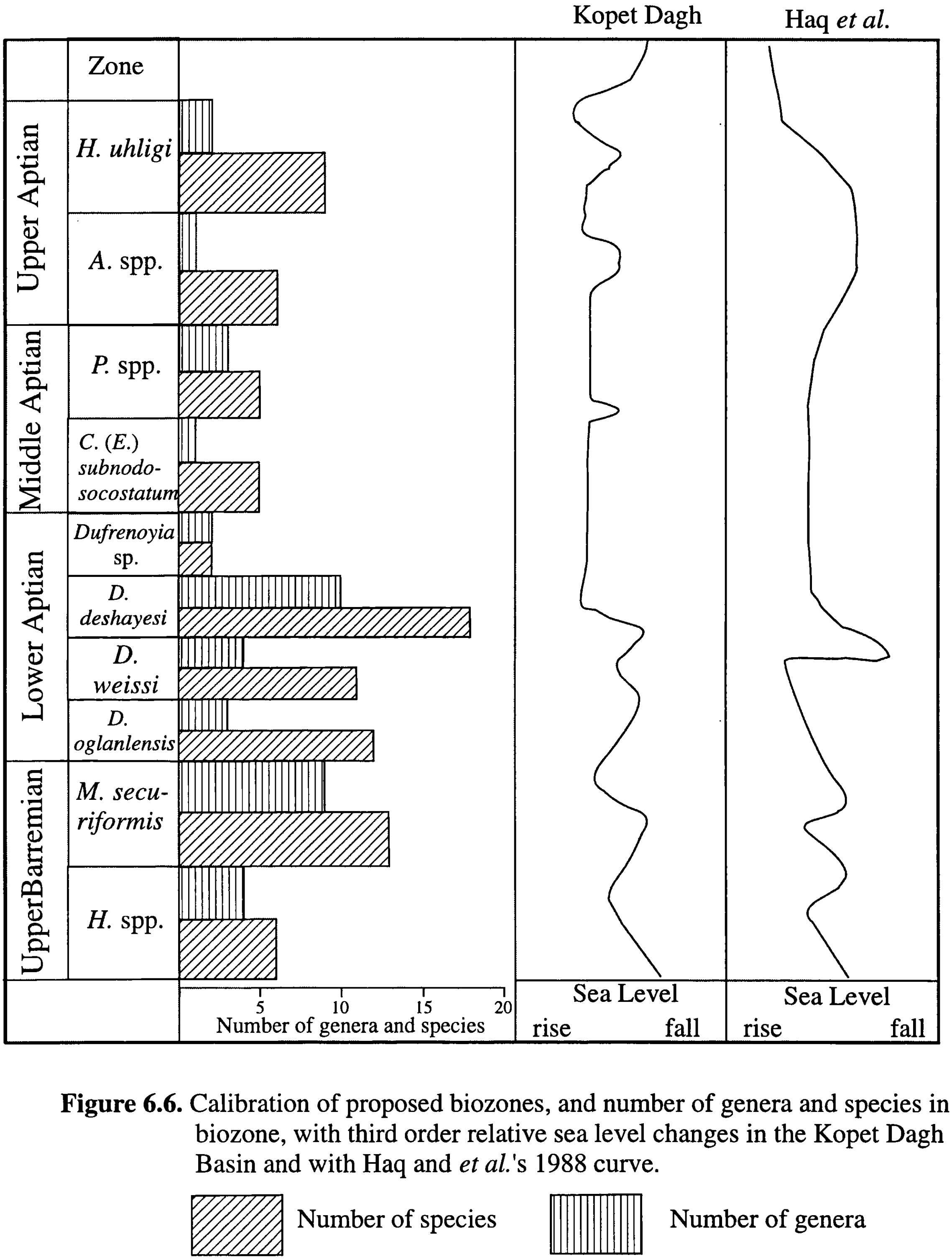


Figure 6.6. Calibration of proposed biozones, and number of genera and species in every biozone, with third order relative sea level changes in the Kopet Dagh Basin and with Haq and *et al.*'s 1988 curve.

Here the change to the more shaly, deep-water facies of the Sanganeh Formation took place later, in the Late Aptian. Again some new genera and species appeared with the sea-level rise, this time ribbed forms such as *Hypacanthoplites* and *Parahoplites.* Hence different genera and species are seen in the Sanganeh Formation as it transgresses from west to east.

In most cases the first appearance of new genera or species in the basin happens in transgressive and highstand systems tracts. The most abundant ammonite faunas also often coincide with transgressive and highstand systems tracts. This is similar to the pattern suggested by Hoedemaeker (1995) and Rawson (1993). In a few cases the first appearance of a genus or species occurs in limestones or in other words in lowstand systems tracts. This could support Reboulet's (1995) conclusion that the appearance of new genera is related to lowstands and extinction with transgressions in third order sequences. But it may be that in the Kopet Dagh the taxa concerned first appeared in transgressive or highstand systems tracts such as shaly limestone or shales, but have been crushed or destroyed in these more easily weathered sediments.

Delanoy and Magnin (1994) suggested that both evolutionary trends and ammonite morphotypes may relate to sea-level changes. From a morphologic point of view the present study support this. In the lower part of the Sarcheshmeh Formation, when the sea-level commenced to rise, the heteromorphs appeared. In the middle and upper part of the formation planispiral forms such as *Deshayesites* occurred. Sea level rise in the Sanganeh Formation, which probably reached a higher level than in the Sarcheshmeh Formation, was accompanied by oxyconic and smooth shelled ammonites such as *Aconeceras, Pseudosaynella* and *Melchiorites.*

In Chapter 5 it was shown that the Heteroceratidae, Ancyloceratidae and Deshayesitidae were limited to platform and nearshore areas whereas Desmoceratidae, Oppeliidae and Parahoplitidae were the main components of offshore and basinal areas. It seems the factors that controlled lithology could have also an influence on the ammonite associations as is seen in the Parahoplitidae and Oppeliidae. But it is not clear why the abundance and diversity of ammonites in the

Sarcheshmeh Formation falls from the west to the east of the basin. The occurrence of the thickest sequences in the western sections (Takal Kuh area) could indicate that bathymetery is a factor that should be considered.

In conclusion, although sea-level changes appeared to influence the first appearance of a genus or species in the basin, ecological and local bathymetric conditions also influenced the distribution of ammonites within the basin.

Chapter 7. Palaeobiogeographical relationships of the Kopet Dagh ammonite faunas

7.1. Introduction

7.1.1. Early Cretaceous global palaeobiogeography

Latitudinal and provincial control of ammonite faunas was common throughout the Mesozoic. Hence numerous biogeographical units (biochores) have been recognised and ranked. Because both the ranks (Realm, Province, etc.) and names have varied from author to author, Westermann (2000a, b, on behalf of the " Friends of Palaeobiogeography") has discussed the classification and nomenclature of marine palaeobiogeographical units and reviewed the Mesozoic marine faunal realms. He suggested a guideline for synonyms, homonyms and useful names, and stressed that the ranking of a particular biochore could change through time. Thus, for example, 'Boreal' would normally be used for a realm but could be super-realm at times. In this chapter I regard the Early Cretaceous Boreal and Tethyan biochores as realms, following widespread practice (e.g. Rawson, 1981; Page, 1996).

Tectonic movements and sea-level changes (regressions and transgressions) caused seaways connecting basins to open or close and led to several distinct biochores developing within each realm. Thus numerous subrealms and provinces have been named (e.g. Saks *et al.*, 1975; Rawson, 1981; Wiedmann, 1988; Hoedemaeker, 1990; Page, 1996; Westermann, 2000b), some of which are discussed below.

During the earlier part of the Cretaceous (Berriasian to Barremian) the Boreal Realm embraced the Arctic basins and the seas extending southward from there over parts of North America, northern Europe and Siberia. The Boreal seas were largely land locked but linked by narrow seaways to the Tethyan Realm. It is this geographical isolation that helped to maintain a distinct Boreal fauna.

The Tethyan Realm includes low latitude areas such as Africa, the Pacific, the Middle East and America, and centred on the former Tethys Ocean. An Austral Realm has also been proposed for high southerly latitudes (Stevens, 1973), based primarily on belemnites. Although a few endemic ammonite genera are known from this area, most ammonite faunas are of Tethyan type, so the Austral biochore is better regarded as a province (see below).

Tethyan faunas were much more diverse than Boreal ones. Along the boundaries of the two realms mixing of ammonite faunas is documented.

Although the Boreal and Tethyan Realms were clearly distinguished during Berriasian to Barremian times, the pattern had changed by the beginning of the Aptian. During latest Barremian to Early Albian times more extensive marine connections developed between the various areas, therefore provincialism decreased (Rawson, 1981). Ammonite genera migrated from Tethyan to more northerly areas and caused the Boreal Realm to shrink or disappear. For instance in the Early Aptian Deshayesitidae and Ancyloceratidae migrated from the Tethyan Realm to areas such as north Germany, the Russia Platform and even Greenland, all of which belonged previously to the Boreal Realm. Thus Rawson (1981), Owen (e.g., 1996) and Page (1996) claimed that the Boreal Realm can not be distinguished from the Tethyan Realm during the Aptian. However, within the Tethyan Realm, Page (1996) recognised seventeen provinces during the Early Cretaceous, some of them applicable to the Aptian.

Based on previous works (mainly Rawson, 1981; Page, 1996; Owen, 1973, 1988, 1996; Westermann, 2000b) the following subdivisions of the Tethyan Realm are recognised for latest Barremian and Aptian times (Figure 7.1).

A- Mediterranean-Himalayan Province: includes England, Germany, the Russian Platform, France, Spain, Italy, Eastern Europe, Crimea, the Caucasus, Mangyshlak, Himalayas, India, south-east Asia, Madagascar, east Africa, the Middle East, north and central Africa.

B- Pacific-Atlantic Province: includes northern part of South America (Venezuela, Brazil and Colombia), North America, Canada, Greenland and Siberia.

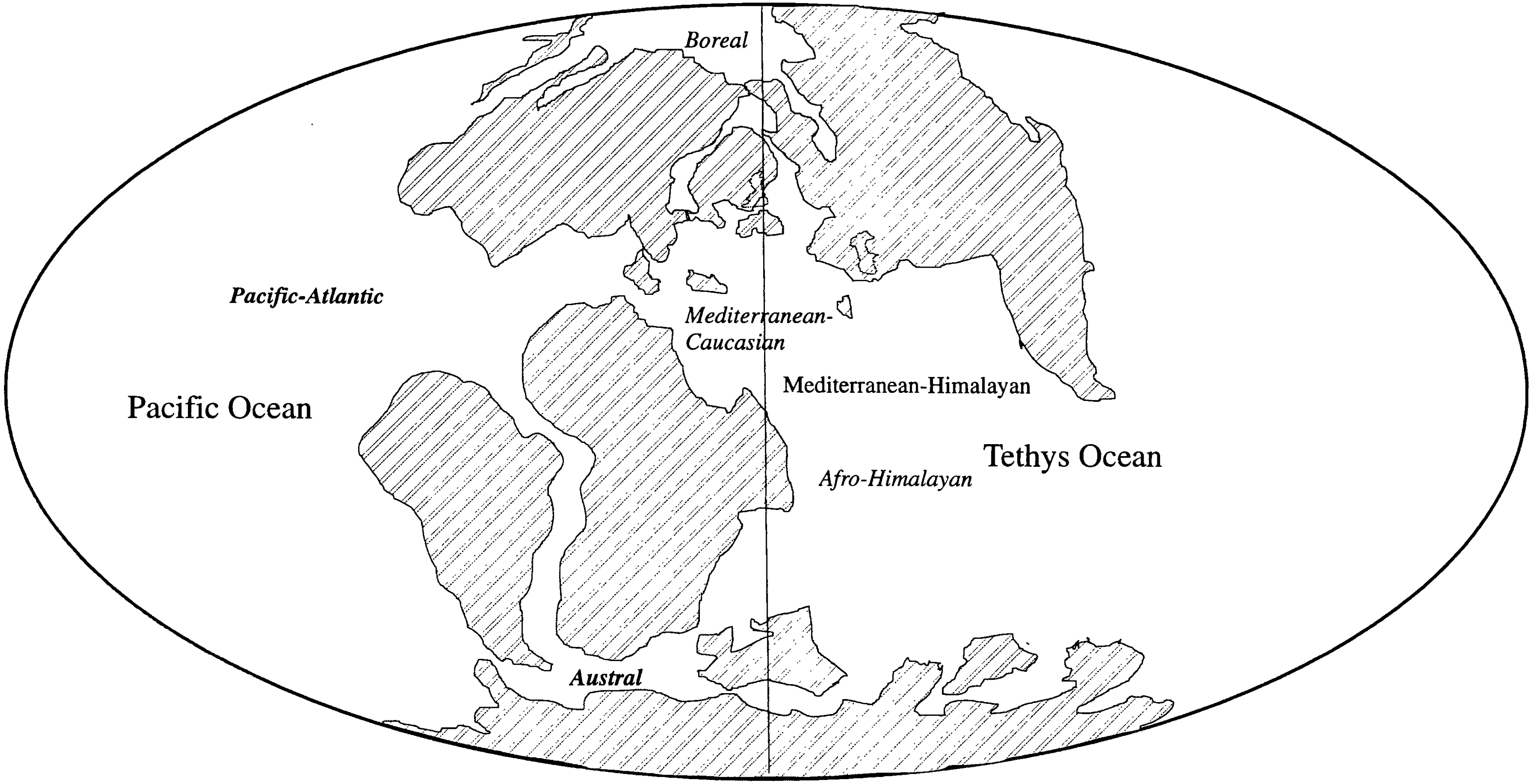


Figure 7.1. The main biochores plotted on the land and marine reconstruction for 120 Ma. Roman, proposed for Aptian; *Italic*, proposed for Albian; ***Bold-Italic***, for both. (Palaeogeography modified from Hay *et al.*, 1999).

C- Austral Province: includes South Africa, Argentina, Patagonia, Antarctica, Australia and New Zealand.

This general pattern continued into the earliest Albian, but from late Early Albian times a distinct provincialism occurred between the northern part of the northern hemisphere, traditionally known as the Boreal Realm, and other parts of the world. The characteristic fauna of the Boreal Realm is the Gastroplitinae.

The following are the principal biochores:

Tethyan Realm;

A- Mediterranean-Caucasian Province: includes Europe, the Russian Platform, Crimea, the Caucasus and Mangyshlak. This province corresponds approximately with the European (Hoplitinid) Province of Owen (1973, 1988) and Page (1996).

B- Afro-Himalayan Province: includes east Africa, the Middle East, north and central Africa, Madagascar, the Himalayas, India and south-east Asia.

C- Pacific-Atlantic Province: includes northern South America (Venezuela, Brazil and Colombia) and Western Interior of United States.

D- Austral Province: includes Argentina, Patagonia, Antarctica, Australia, New Zealand and South Africa.

Boreal Realm: includes Canada, Siberia and Greenland.

The Mediterranean-Caucasian and Afro-Himalayan Provinces together represent the Aptian Mediterranean-Himalayan Province.

According to Page (1996) the Phylloceratina and Lytoceratina are widely distributed globally but many genera occur primarily in the Mediterranean-Himalayan Province, where the group was often abundant. They were often abundant in deeper water areas subject to oceanic influences and less abundant or absent in neighbouring shelf sea deposits.

The distribution of Lytoceratina may have been controlled by latitude. An ecological rather than latitudinal control on the distribution of Phylloceratina is supported by their occurrence at relatively high latitudes in areas adjacent to open seas throughout the Jurassic and Cretaceous. The Haplocerataceae are also known as Tethyan forms. The Ancyloceratina and many Ammonitina were globally distributed, although some endemic forms also existed (Page, 1996). The most effective stage for dispersal would have been in the immediate post hatching juvenile stage or in the nektonic or planktonic stage.

7.1.2. Early Cretaceous Palaeocurrents

The distribution patterns of Cretaceous foraminifera, ammonites and rudists show that their dispersion was controlled by climate and sea currents (Addicott, 1970; Neaverson, 1955; Cox *et al.* 1969; Gordon, 1973). Luyendyk *et al.* (1972) and Gordon (1973) suggested a 'westward flowing circumglobal' current system in the Tethys Ocean based on;

1- The homogenous nature of Tethyan faunas in the ocean. The marine fauna of the temperate seaways was sharply differentiated from that of the cool Arctic Ocean, whilst southern hemisphere seas had closer faunal resemblance to the Tethyan zone.

2- A Caribbean source of Tethyan faunas on mid-Pacific guyots.

3- Evidence of a warm climate in Europe that may have been related to the poleward deflection of Tethyan waters associated with the bulge of Africa.

Barron and Peterson (1989) criticised Gordon's pattern of westward flowing circumglobal currents. They noted that a westward current occurred in the central Pacific, but in Tethys the flow pattern was complicated and westward flow occurred only in part of Tethys. There was also clockwise flow, which produced general easterly flows along the northern and southern margins of the ocean (Figure 7.2).

A new palaeogeographical pattern for the Cretaceous was proposed by Hay *et al.* (1999). The majority of plate tectonic reconstructions for the Cretaceous are based on six continents, North America-Greenland, South America, Africa, Antarctica-Australia, India-Madagascar and Eurasia, separated by ocean passages. But Hay *et al.* recognised three large continental blocks, each with some shallow seas, North America-Eurasia, South America-Antarctica-India-Madagascar-Australia and Africa (Figure 7.1).

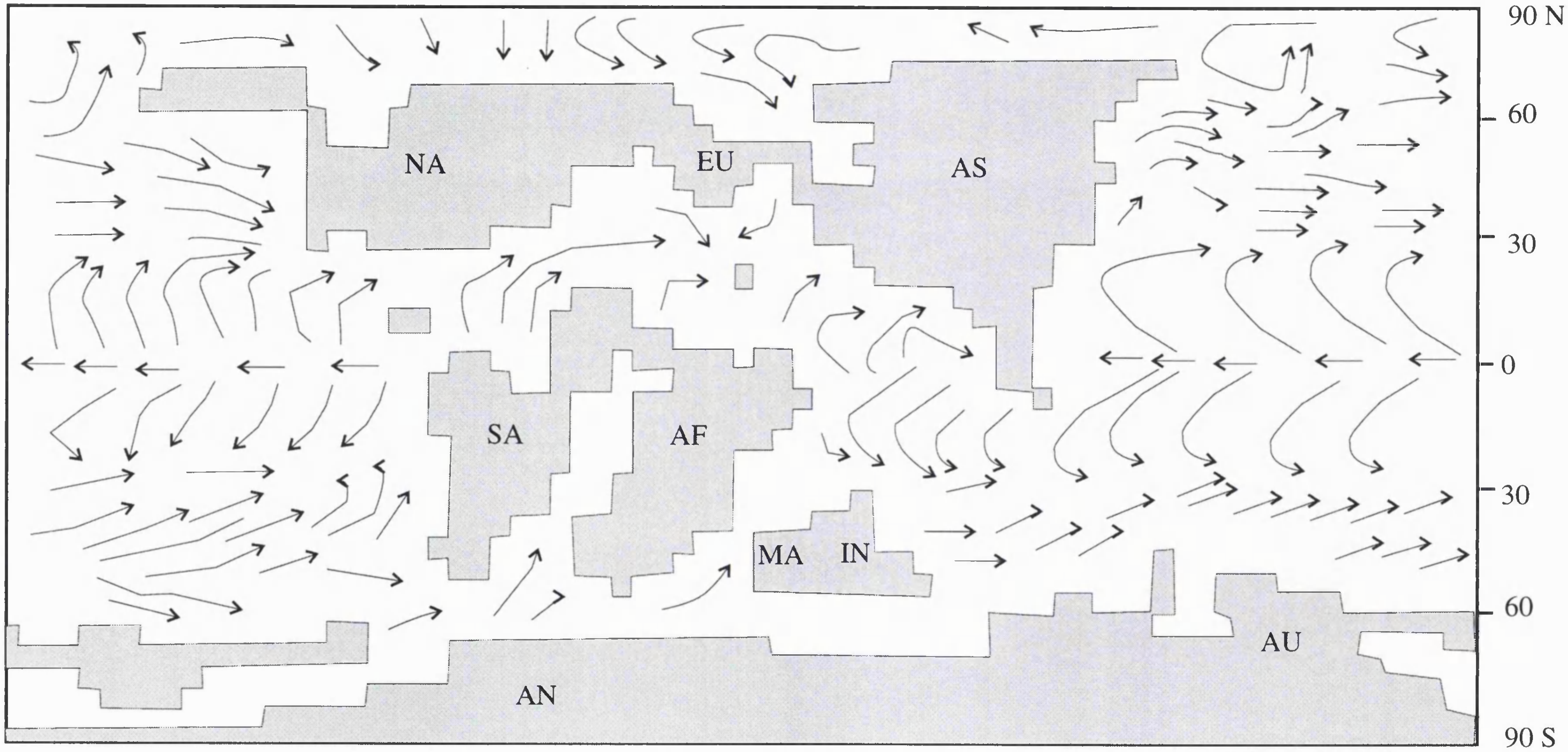


Figure 7.2. Hypothetical palaeocurrent pattern for mid-Cretaceous times (Redrawn and simplified from Barron and Peterson, 1989). AF= Africa, AN= Antarctica, AS= Asia, AU= Australia, EU= Europe, IN= India, MA= Madagascar, NA= North America, SA= South America.

There was a large Pacific in the western hemisphere, with Tethys extending to the east and narrow seaways around Africa, connecting western Tethys (Mediterranean area) to the North and South Atlantic. They believed there were no deep passages between the central Atlantic and Pacific in the west and between the Atlantic and the Canadian Basin (Arctic) in the north. This pattern gives a new view of palaeogeography and palaeocurrents and consequently of palaeobiogeography. For example it may explain better the distribution of some Late Cretaceous vertebrates (dinosaurs) in southern continents (Hay *et al.*, 1999). However, it needs more testing by lithological and fossil records.

7.2. The Kopet Dagh faunas

7.2.1. Palaeogeography

The tectonic and palaeogeographical positions of the Kopet Dagh remain uncertain. Tectonically, the area formed part of the Northern Domain (Stocklin, 1977) (Figure 7.3). It may have lain between the Central Iranian microcontinent and Laurasia, or possibly between the Cimmerian continent and Laurasia (Sengor, 1990). According to Adamia (1988) the Great Caucasus, Transcaspia (Kopet Dagh), Alborz and Central Iran lay at the north Tethyan margin. The Early Cretaceous palaeolatitude has not been determined but is somewhere between 27° N (the Triassic position) and 32° N, which is the Cretaceous position of the Turan plate to the north (Soffel and Forster, 1984).

It is not clear if the basin was connected to other basins to the west, south and east during the Late Barremian to Early Aptian. Probably the basin was like a gulf, and was connected to the open sea from the north and north-west. However the sea transgressed from west to east across the basin.

There is no evidence so far of ammonites in sequences in the eastern part of Iran. More study is necessary to find the exact ages of these areas, and their palaeobiogeographical relationship with the Kopet Dagh. There are some similarities in ammonite faunas of the Kopet Dagh and Central Iran, but it is not clear whether these basins were connected because of the lack of geological evidence (Figure 7.4).

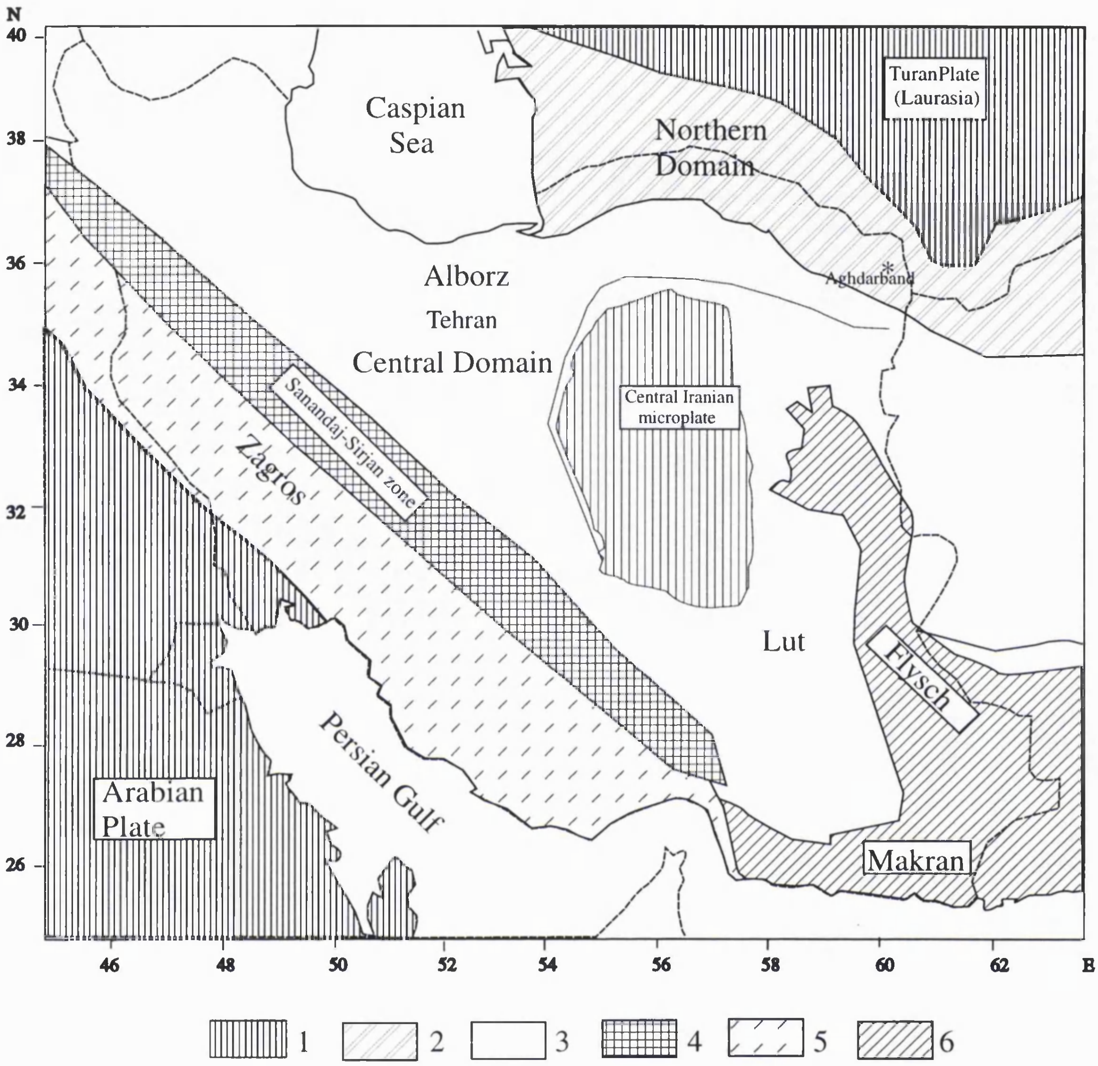


Figure 7.3. Main tectonic subdivisions of Iran (modified and simplified from Stocklin, 1977 and Davoudzadeh *et al.*, 1981).
1-Stable areas, Arabian Precambrian platform in south west and Turanian Hercynian Plate in north east, **2**- Northern Domain including Neogene-Quaternary foredeeps transitional from unfolded foreland to marginal fold zone and Jurassic-Paleogene folded and faulted zone, **3**- Central Domain including Continental crust, Precambrian basement (Central Iranian microplate), Kimmerian and Alpine folding, partly covered by Neogene-Quaternary sediments, **4**- Sanandaj- Sirjan Metamorphic belt (Mainly Mesozoic oceanic sediments), **5**- Southern Domain including Neogene foredeep transitional from unfolded foreland to marginal fold zone and Mesozoic-Paleogene pericratonic shelf deposits, **6**- Paleogene Flysch, partly Upper Cretaceous with Ophiolitic melanges and melange-like volcanic-sedimentary association.

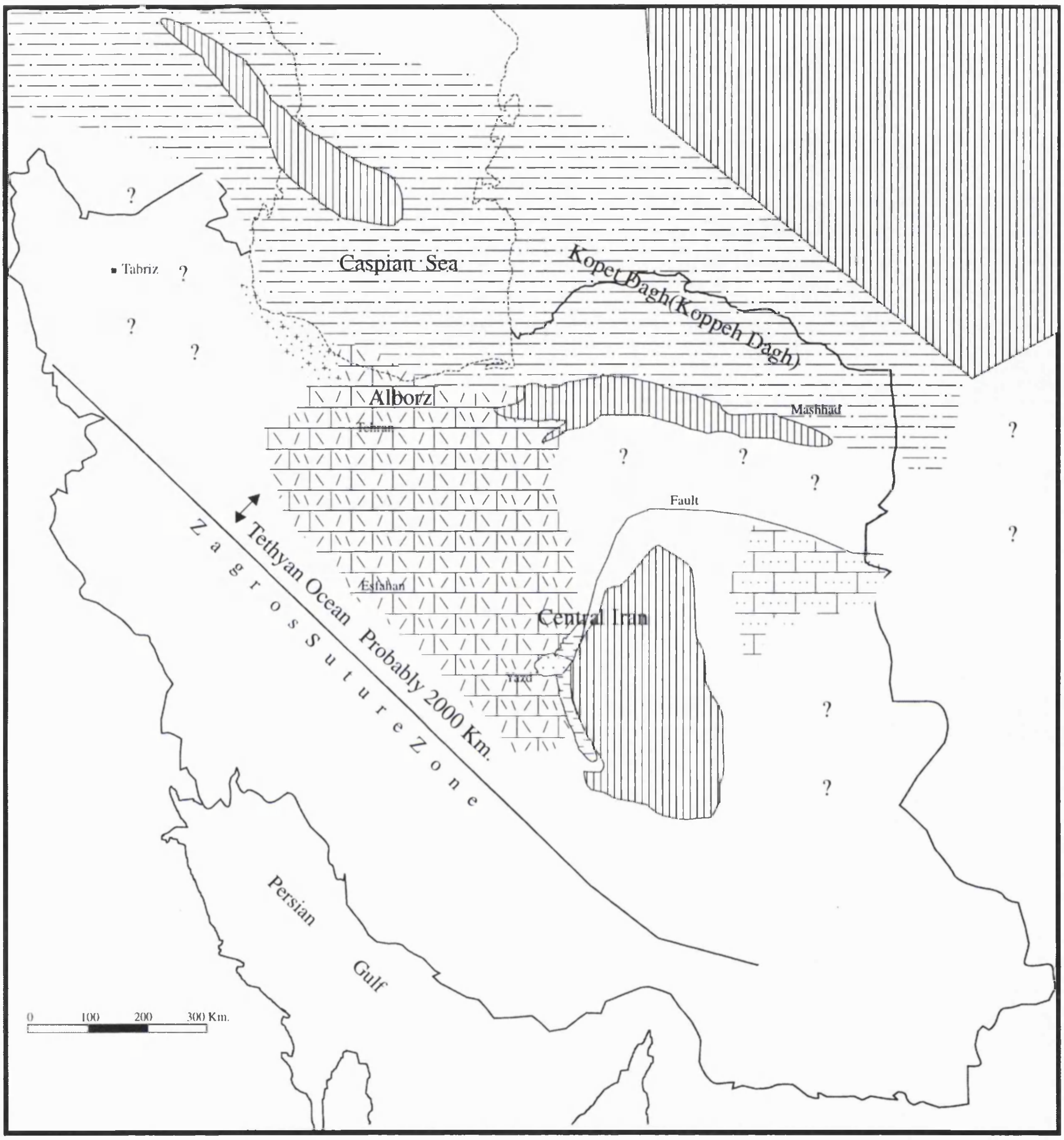


Figure 7.4. Early Cretaceous (Aptian) preliminary palaeogeographic and palaeofacies pattern for north and Central Iran (based on numerous references).

Sandstone, limestone, marl,shale

Orbitolina limestone (mostly north), limestone, marl, shale

Sandy limestone and *Orbitolina* limestone

Marl and shale (Biabanak Fm.)

Clastic sediments and volcanics

Thick conglomerate and sandstone

Land or nondepositional areas

7.2.2. Palaeobiogeographical relationships of the faunas

In this section the global distribution of those families and genera that occur in the Kopet Dagh Basin is summarised to provide the basis for the palaeobiogeographical conclusions in section 7.3.

7.2.2.1. Earliest Cretaceous (Berriasian- Early Barremian)

During the Berriasian to Hauterivian the sea withdrew from the Kopet Dagh and non-marine (Shurijeh Formation) or very shallow marine (Zard Formation) sediments were deposited. After the Neocomian regression the appearance of Urgonian facies (*Orbitolina* limestones) in the Barremian sequences in Iran correlates with a world wide sea level rise which was proposed by Haq *et al.* (1987).

The deposition of *Orbitolina* limestones finished in most parts of the Kopet Dagh before the end of the Barremian. *Paraspiticeras percevali* is the only Early Barremian ammonite recorded from the basin. This is the earliest ammonite of Cretaceous age known from the Kopet Dagh.

7.2.2.2. Late Barremian

Heteromorph Heteroceratidae have an almost cosmopolitan distribution (Table 7.1). They are well-known in many parts of the Tethyan Realm and have recently been recorded from the Boreal Realm (Rawson, 1995) (Figure 7.5). However, the presence of *Imerites* and *Paraimerites* in the Kopet Dagh may suggest a connection with the Caucasus (Kotetishvili, 1988) and France (Delanoy, 1997).

Barremites is recorded from the Upper Barremian sequences of eastern England, north-west Germany, France, Caucasus, Russia and Japan (Table 7.1), and north Africa and Mexico (Wright *et al.*, 1996) (Figure 7.5).

In the uppermost part of the Barremian *Turkmeniceras* appears. This earliest deshayesitid is known only from Turkmenistan and the Kopet Dagh.

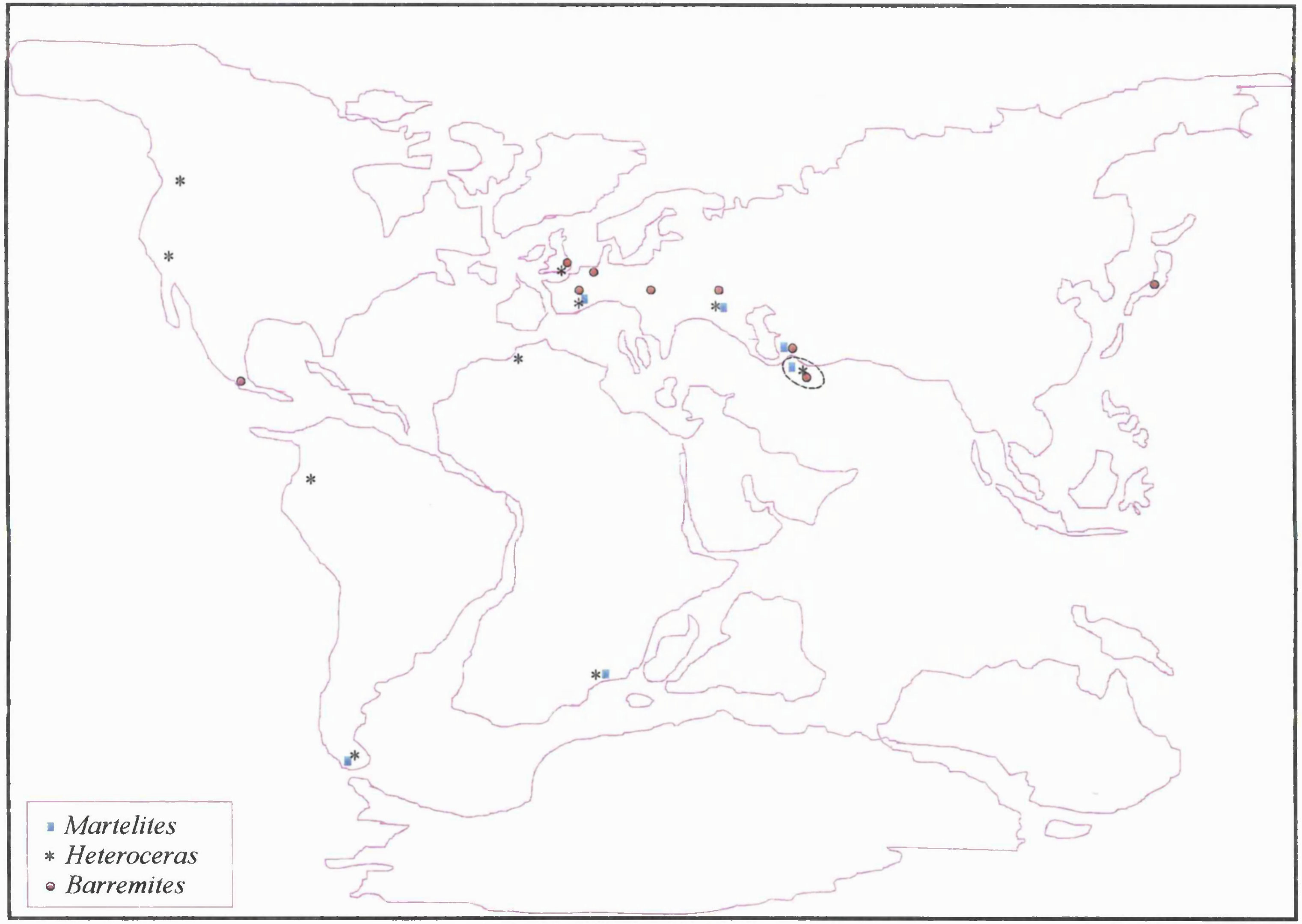


Figure 7.5. Distribution of *Martelites*, *Heteroceras* and *Barremites* during Late Barremian times. ⬭ study area.

Table 7.1. Geographical distribution of selected Late Barremian-Aptian ammonites of the Kopet Dagh Basin.

	Kopet Dagh-Iran (X= Present study)	**Central Iran**	**Turkmenistan**	**Caucasus & Russia C.= Caucasus; R.= Russia**	**Eastern Europe (Carpathians, Romania, Poland)**
Martelites	X- Immel *et al.*, 1997	----	Tovbina, 1963; Bogdanova and Prozorovsky, 1999	C. (Kakabadze, 1971, 1989; Kotetishvili, 1988)	Bulgaria (Mandov and Nikolov, 1992)
Heteroceras	X	----	Tovbina, 1963; Bogdanova and Prozorovsky, 1999	C. (Rouchadze, 1933, 1938; Kotetishvili, 1970; Egoian, 1965; Kakabadze, 1971, 1975, 1989; Kotetishvili, 1988	Bulgaria (Nikolov, 1964; Dimitrova, 1967), Romania (Simoniescu, 1898), Hungary (Fülop, 1964) Czechoslovakia (Uhlige, 1883)
Barremites	X	----	?	R. (Druschitz & Kudryutzeva, 1960)	Carpathian (Duraj *et al.*, 1990), Bulgaria (Mandov and Nikolov, 1992)
Toxoceratoides	X	----	Bogdanova and Prozorovsky, 1999	C. (Kakabadze, 1981)	Romania (Avram, 1976)
Turkmeniceras	X	----	Tovbina, 1963; Bogdanova, 1971a; Bogdanova and Prozorovsky, 1999	-----	-----
Deshayesites	X- Immel *et al.*, 1997	Seyed-Emami *et al.*, 1971	Bogdanova, 1977, 1983, 1991; Cecca *et al.*, 1999a; Bogdanova and Prozorovsky, 1999	C. (Bogdanova *et al.*, 1979; Kotetishvili, 1988), R. (Glazunova, 1973)	Romania (Avram, 1999), Slovakia (Vasicek & Rakus, 1995; Vasicek, 1995); Bulgaria (Mandov and Nikolov, 1992)
Dufrenoyia	X	----	Bogdanova, 1979	C. (Kotetishvili, 1988), R. (Durschitz & Kudryutzeva, 1960)	Bulgaria (Mandov and Nikolov, 1992)

Australiceras	X	----	Sinzow, 1905	C. (Kakabadze 1977; Kotetishvili, 1988), R.(Glazunova, 1973)	Bulgaria (Dimtrova, 1967)
Aconeceras	X	----	Bogdanova and Tovbina, 1994	C. (Kotetishvili, 1988), R. (Druschitz & Kudryutzeva, 1960)	
Cheloniceras	X	Seyed-Emami *et al.*, 1971	Bogdanova and Tovbina, 1994; Bogdanova and Prozorovsky, 1999	C (Kotetishvili, 1988), R. (Glazunova, 1973; Druschitz & Kudryutzeva, 1960),	Hungary (Szives, 1999)
Parahoplites	X	Zahedi, 1973; Asitove *et al.*, 1984	Sinzow, 1907; Tovbina, 1982	C. (Sinzow, 1909; Kotetishvili, 1988), R. (Glazunova, 1973; Druschitz and Kudryutzeva, 1960),	Bulgaria (Mandov and Nikolov, 1992)
Acanthohoplites	X	Zahedi, 1973; Asitove *et al.*, 1984	Sinsow, 1907	C. (Anthula, 1899; Kotetishvili, 1988), R. (Druschitz and Kudryutzeva, 1960)	Hungary (Szives, 1999), Slovakia (Vasicek, 1995; Bulgaria (Mandov and Nikolov, 1992)
Hypacanthoplites	X- (Seyed-Emami, 1980), (Immel *et al.*, 1997)	Seyed-Emami *et al.*, 1971; Asitove *et al.*, 1984	Sinsow, 1907; Luppov *et al.* 1960; Bogdanova *et al.*, 1963)	C. (Kazansky, 1914; Glazunova, 1953; Druschitz and Kudryutzeva, 1960; Kotetishvili, 1988), R. (Druschitz and Kudryutzeva, 1960)	Hungary (Szives, 1999); Bulgaria (Mandov and Nikolov, 1992)
Colombiceras	X	Zahedi, 1973; Asitove *et al.*, 1984	Turkmenistan (Sinsow, 1907)	R. (Druschitz and Kudryutzeva, 1960), C. (Kotetishvili, 1988)	Bulgaria (Mandov and Nikolov, 1992)
Melchiorites	X	?	?	C. (Kotetishvili, 1988)	Slovakia (Vasicek and Rakus, 1995)

Continued

	Germany & SE England	France	South Africa	Far East (Japan)	South America	North America
Martelites	----	Delanoy, 1997	Kennedy and Klinger, 1975; Klinger, 1976; Klinger *et al.*, 1984	?	Argentina (Aguirre-Urreta & Klinger 1986), Colombia (Kakabadze & Hoedemaeker, 1997)	
Heteroceras	E. (Rawson, 1995)	d'Orbigny, 1851; Kilian, 1889; Delanoy, 1992, 1997	Kennedy and Klinger, 1975; Klinger, 1976; Klinger *et al.*, 1984; Aguirre-Urreta and Klinger, 1986	Obata *et al.*, 1976; Obata *et al.*, 1984	Colombia (Royo Y Gomez, 1945; Etayo-Serna, 1968; Kakabadze and Thieuloy, 1991), Argentina (Aguirre Urreta and Klinger, 1986)	California (Murphy, 1975), Canada (Jeletzky, 1970)
Barremites	E. (Rawson, 1995)	Autran and Delanoy, 1987; Delanoy, 1997; Italy (Cecca *et al.*, 1998b)	?	Obata *et al.*, 1982, 1984	?	?
Toxoceratoides	E. (Spath, 1924, 1930b; Casey, 1961b, 1980; Howarth, 1962), G. (von Koenen, 1902)	France (d'Orbigny, 1842; Roch, 1927);	Mozambique (Förster, 1975), Zululand (Klinger & Kennedy, 1977)	?	Colombia (Etayo-Serna, 1979; Martinz, 1982), Patagonia (Leanza, 1970; Aguirre-Urrata, 1986).	Canada (Jeletzky, 1964); California (Murphy, 1975);
Turkmeniceras	----	----	----	----	----	----
Deshayesites	E. (Spath, 1930b; Casey, 1961a, 1964), G. (Kemper, 1967, 1982, 1995); Austria (Follmi, 1989	Delanoy, 1995; Ropolo *et al.*, 1999	?	?	Venezuela ? (Renz, 1982)	?
Dufrenoyia	E. (Casey, 1964), G. (Kemper, 1995)	Breistroffer, 1947	Collignon, 1962	Obata *et al.*, 1984	Colombia (Etayo-Serna, 1979), Venezuela (Renz, 1982)	Scott, 1940;Young, 1974
Australiceras	E. (Casey, 1961b, 1980), G. (Kemper, 1995)	?	Klinger and Kennedy, 1977, Madagascar (Collignon, 1962)	Obata *et al.*, 1975; Obata and Matsukwa, 1988	Colombia (Royo y Gomez, 1945), Patagonia (Favre, 1908)	Anderson, 1938

Aconeceras	E. (Casey, 1961b, 1962; Rawson, 1995), G. (Kemper, 1995)	Busnardo, 1984	Klinger, 1976, Madagascar (Förster, 1975), Madagascar (Collignon, 1962)	?	Venezuela (Renz, 1982), Colombia (Etayo-Serna, 1979)	?
Cheloniceras	E. (Casey 1961a, 1966), G. (Kemper, 1982, 1995)	Kilian, 1915; Autran and Delanoy, 1987	Kennedy & Klinger, 1975	?	Renz, 1982?	Young, 1974
Parahoplites	E. (Casey, 1965), G. (Kemper, 1982, 1995), Austria (Follmi, 1989)	Breistroffer, 1947	?	?	?	Stoyanow, 1949
Acanthohoplites	G. (Kemper, 1982; Immel, 1987)	Autran and Delanoy, 1987	Kennedy and Klinger, 1975; Mozambique (Förster, 1975), Madagascar (Collignon, 1962)	?	Colombia (Etayo-Serna, 1979)	?
Hypacanthoplites	E. (Spath, 1939b; Casey, 1960, 1961a, 1965), G. (Bristroffer, 1933; Kemper, 1982), Austria (Follmi, 1989	Breistroffer, 1947	Mozambique (Förster, 1975), Madagascar (Collignon, 1962)	Obata and Futakami, 1992	?	Young, 1974
Colombiceras	E. (Casey, 1965), Austria (Follmi, 1989).	?	Mozambique (Förster, 1975), Madagascar (Collignon, 1962)		Venezuela (Renz, 1982), Colombia (Etayo-Serna, 1979)	Stoyanow, 1949
Melchiorites	?	Italy (Cecca, 1999)	?	?	Colombia (Etayo-Serna, 1979)	?

7.2.2.3. Early Aptian

In Early Aptian times *Deshayesites* was dominant in the Kopet Dagh Basin. It is widely distributed in the northern hemisphere (Table 7.1), as far south as Tunisia (Memmi, 1995, 1999) and as far north as Greenland (Kelly and Whitham, 1999) (Figure 7.6).

Casey (1961a, 1964) has studied the English Deshayesitidae in detail. Russian palaeontologists have introduced numerous new species (Bogdanova, 1977, 1979, 1983, 1991; Bogdanova *et al.*, 1979; Druschitz & Kudryutzeva, 1960; Glazunova, 1973), some of which may be synonyms of Casey's species.

Deshayesites species in the Kopet Dagh Basin show closest similarity to the species recorded from Turkmenistan, Mangyshlak and Caucasus. Moreover, some of Casey's species are identified from the basin. Table 7.2 shows the identified *Deshayesites* species from the Kopet Dagh Basin. Among twelve identified species, nine species are common with Turkmenistan, whilst six species are shared with south-east England. This table confirms a good connection between these areas.

The distribution of *Dufrenoyia* is shown on Figure 7.6. The genus is more widely distributed than *Deshayesites*, especially to the west. It is interesting that the first Deshayesitidae (*Turkmeniceras*) appeared in the Kopet Dagh and Turkmenistan, while the descendant *Deshayesites* spread to the Caucasus, Europe and even Greenland. Moreover *Dufrenoyia* occurs in North America and the northern part of South America, where *Deshayesites* is absent or recorded only questionably.

Melchiorites and *Pseudosaynella* from the Desmoceratidae, *Eogaudryceras* from Tetragonitidae and *Phylloceras* and *Phyllopachyceras* from the Phylloceratidae are recorded from the study area, and Cecca (1998) believed these families are fully Tethyan (Mediterranean-Himalayan).

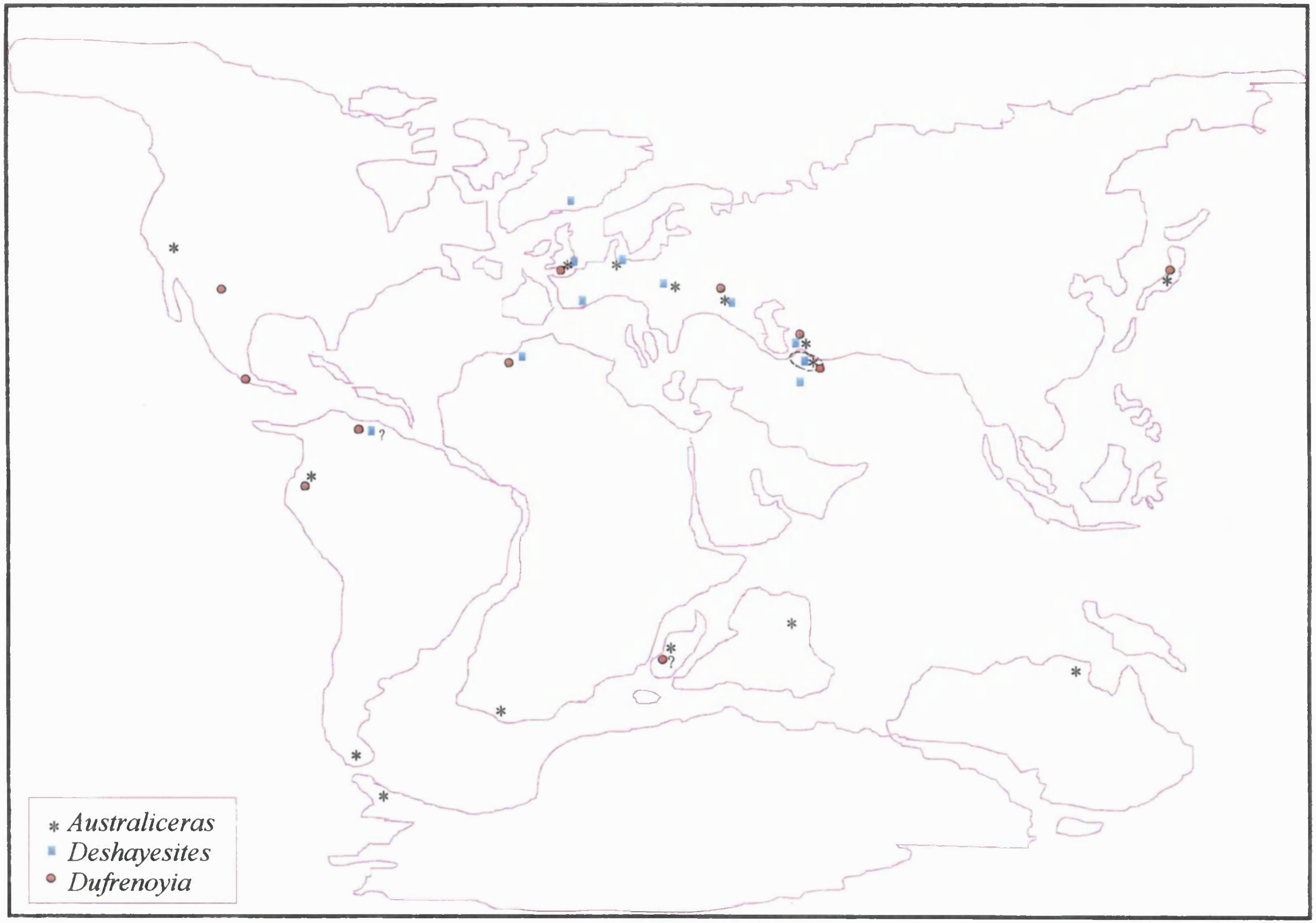


Figure 7.6. Distribution of *Australiceras*, *Deshayesites* and *Dufrenoyia* during Early Aptian times. ⬭study area.

Table 7.2. Comparison of *Deshayesites* species of the Kopet Dagh Basin and other areas.

Deshayesites Species	**Study area**	**Turkmenistan**	**Caucasus**	**Romania**	**France**	**England**
D. tuarkyricus Bogdanova	X (cf.)	X	---	---	---	---
D. oglanlensis Bogdanova	X	X	?	X	X	---
D. weissiformis Bogdanova	X (cf.)	X	?	X	X	---
D. euglyphus Casey	X (cf.)	---	?	---	X	X
D. luppovi Bogdanova	X	X	?	X	X	---
D. weissi Neumayr & Uhlig	X	X	X	X	X	?
D. dechyi Papp	X (cf.)	X	X	---	?	---
D. involutus Spath	X (cf.)	---	---	X	?	X
D. planus Casey	X (cf.)	X	---	X	?	X
D. deshayesi d'Orbigny	X	X	X		X	X
D. consobrinoides Sinzow	X (cf.)	X			X	X
D. multicostatus Swinnerton	X (cf.)	---	X	X	X?	X

Pseudocrioceras, *Tonohamites*, *Australiceras* and *Ancyloceras* from the Ancyloceratidae are recorded from the Kopet Dagh. This family has a cosmopolitan distribution. Generally heteromorphs are regarded as more sluggish in movement than planispiral ammonites but their global distribution contradicts this assumption. *Australiceras* is a good example. The genus was first found in Australia (Whithouse, 1926). More than seven decades onward it is recorded from many parts of the world (Table 7.1; Figure 7.6).

Aconeceras (Oppeliidae) is found with small deshayesitids in the Lower Aptian of the Kopet Dagh Basin. *Aconeceras* is recorded from England, Germany, the Caucasus, Turkmenistan, Australia, Argentina and Colombia (Table 7.1) and even farther to the north and south in the Arctic and Antarctic (Casey, 1961c; Thomson, 1974). In France the appearance of *Aconeceras* is marked by a sudden influx of *Aconeceras nisus* at the base of the Upper Aptian (Casey, 1961c; Busnardo, 1984). The thin and fragile test of the Aconeceratinae suggests that they were pelagic forms and during the Early Cretaceous entered the neritic zone only when conditions were favourable for their growth (Casey, 1961c)

The Family Cymatoceratidae is the only nautiloid group known from the Kopet Dagh Basin. The family has been recorded mostly from the Tethyan Realm; Italy (Wiedmann and Dieni, 1968), England, France, Crimea, India, Ethiopia (Teichert *et al.*, 1964), the Caucasus and Russia (Druschitz and Kudryutzeva, 1960).

7.2.2.4. Mid- Late Aptian

Cheloniceras (Douvilleiceratidae), *Colombiceras*, *Parahoplites*, *Acanthohoplites* and *Hypacanthoplites* (Parahoplitidae) are widely distributed in the shelf seas of Europe, the Caucasus, west-Central Iran, Kopet Dagh, southern Africa, Madagascar and even Japan and America (Owen, 1996) (Figure 7.7). The Douvilleiceratidae originated in Europe (Owen, 1973, 1988), then dispersed to the other parts of the Tethyan Realm. The Parahoplitidae are of uncertain origin (Wright *et al.*, 1996) but the Kopet Dagh and west-central Iranian faunas are similar to those of the Caucasus and Caspian areas (Seyed-Emami, 1971; Zahedi, 1973; Asitove *et al.*, 1984; Seyed-Emami and Immel, 1995, 1996). But there is no evidence to indicate how the Kopet Dagh and Central Iran were connected. The widespread distribution of *Parahoplites* (Table 7.2) might be related to world wide sea-level rise in the Late Aptian. However, it is not recorded from Greenland and Spitsbergen (Owen, 1996).

7.2.2.5. Early Albian

The presence of Leymeriellidae, Douvilleiceratidae and Desmoceratidae in the Kopet Dagh provides links with several areas. The genus *Leymeriella*, which is recorded in the study area and Central Iran (Seyed-Emami and Immel, 1993; Immel *et al.*, 1997), is also recorded from Europe (Casey, 1960; Owen, 1973; Latil, 1994; Mandov and Nikolov, 1992), the Transcaspian (Saveliev, 1973, 1992; Baraboshkin, 1996) and even Greenland (Birkelund and Hakansson, 1983) and Spitsbergen (Nagy, 1970). The genus is believed to be Tethyan in origin (Owen, 1996).

Douvilleiceras has a widespread distribution. The genus is recorded from Europe (Casey, 1962; Latil, 1994; Mandov and Nikolov, 1992), the Transcaspian and Mangyshlak (Saveliev, 1973; Baraboshkin, 1992, 1996), Madagascar (Collignon, 1963), South Africa (Kennedy and Klinger, 1975), Colombia (Etayo-Serna, 1979), and even Canada (Jeletzky, 1964, 1970). The genus is found in the study area and also in Central Iran (Seyed-Emami, 1980; Immel *et al.*, 1997).

Two desmoceratid genera, *Uhligella* and *Beudanticeras*, are also recorded from the Kopet Dagh Basin. *Uhligella* is known from the Caucasus (Kotetishvili *et al.*, 2000), Europe, northern Africa and Venezuela (Wright *et al.*, 1996), and Madagascar (Collignon, 1963). *Beudanticeras* is recorded from Central Iran (Seyed-Emami and Immel, 1996), the Caucasus (Kotetishvili, 1988), Europe, the Sinai Desert, eastern Australia, Japan, Alaska, Canada (British Colombia), Texas and Argentina (Patagonia) (Wright *et al.*, 1996), Madagascar (Collignon, 1963), and northern Africa (Memmi, 1995)

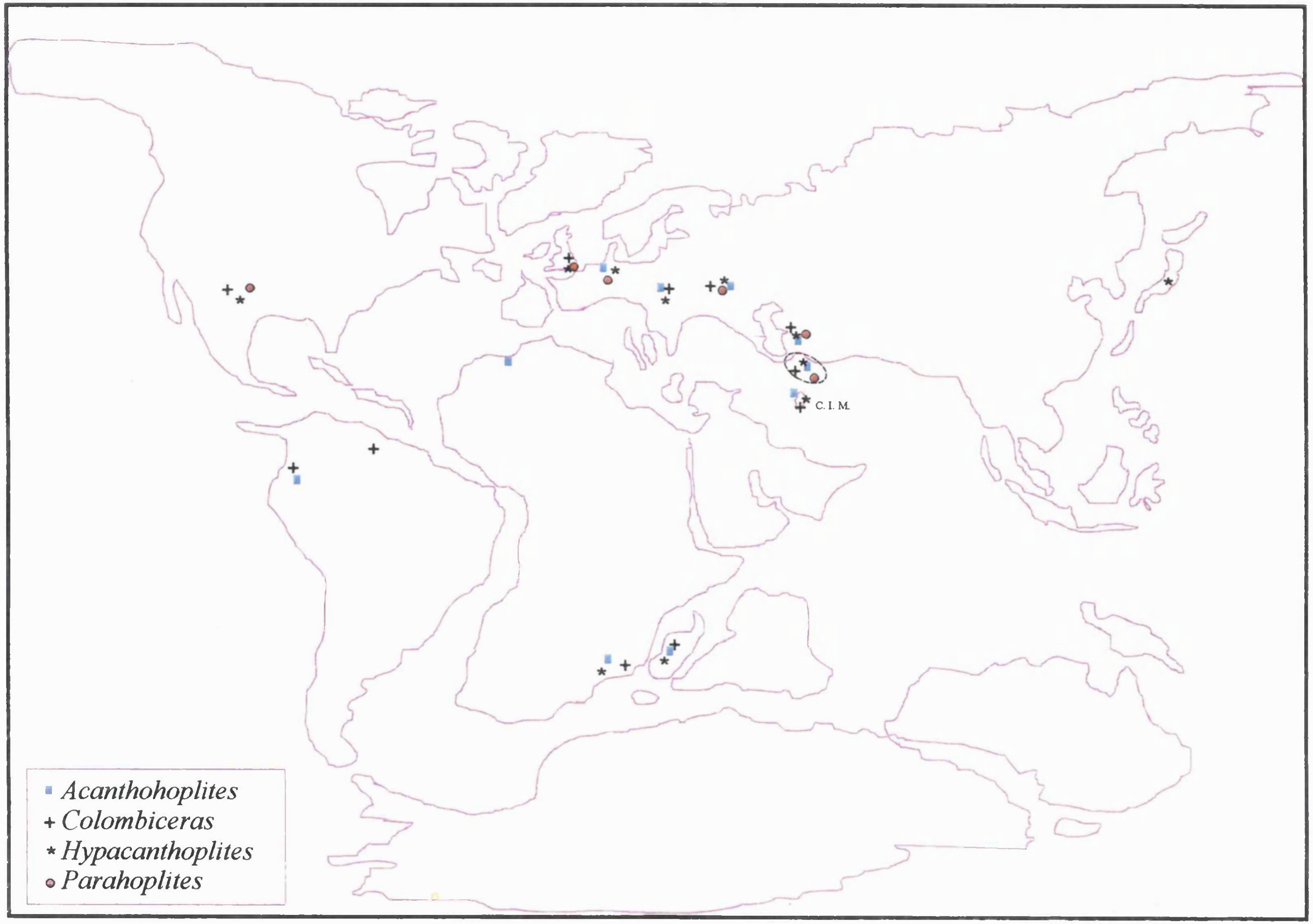


Figure 7.7. Distribution of Parahoplitidae during Late Aptian times. ⊂⊃ study area. C. I. M.= Central Iranian Microplate.

7.3. Conclusions

Many of the latest Barremian and Aptian genera recorded here have a global or very widespread distribution, while others occur over a more limited area. Among the latter, the latest Barremian genera *Argvethites*, *Martelites*, *Imerites* and *Paraimerites* indicate a connection with the Mediterranean area via the Caucasus. On the other hand *Turkmeniceras* (Deshayesitidae) is only known from Turkmenistan and the Kopet Dagh Basin. In the earliest Aptian its descendant, *Deshayesites*, spread over much of Europe. But again there is a particularly close relationship between the Kopet Dagh *Deshayesites* and those of Turkmenistan.

The Parahoplitidae were an important family in the Kopet Dagh Basin in Late Aptian times. Although this family has a cosmopolitan dispersion, the Kopet Dagh assemblage is closer to those from Mangyshlak, the Caucasus and Germany than from other part of the world. Thus the latest Barremian and Aptian faunas belong to the Mediterranean-Himalayan Province.

The Ammonite genera recorded from the Lower Albian sequences of the Kopet Dagh Basin support the placing of the fauna in the Mediterranean-Caucasian Province.

Late Aptian-Early Albian ammonite genera recorded from west Central Iran (Seyed-Emami, 1997) are similar to those from the Kopet Dagh. The region from which they are recorded is at least 400 kilometres away from the Kopet Dagh. No ammonites occur between these areas (Figure 7.8). In Central Iran, the appearance of the Early Albian genus *Arcthoplites* shows a boreal influence, but it seems unlikely that this migration occurred via the Kopet Dagh.

The distribution and biogeographical relationships of some elements of the Kopet Dagh faunas provide some clues for directions of dispersal and therefore of palaeocurrents. The earliest deshayesitid, *Turkmeniceras*, may have originated in the Turkmenistan/Kopet Dagh area. In the earliest Aptian its descendant, *Deshayesites*, spread over much of Europe while the slightly younger *Dufrenoyia* migrated further, to regions around the Caribbean and Gulf of Mexico. This would suggest a generally

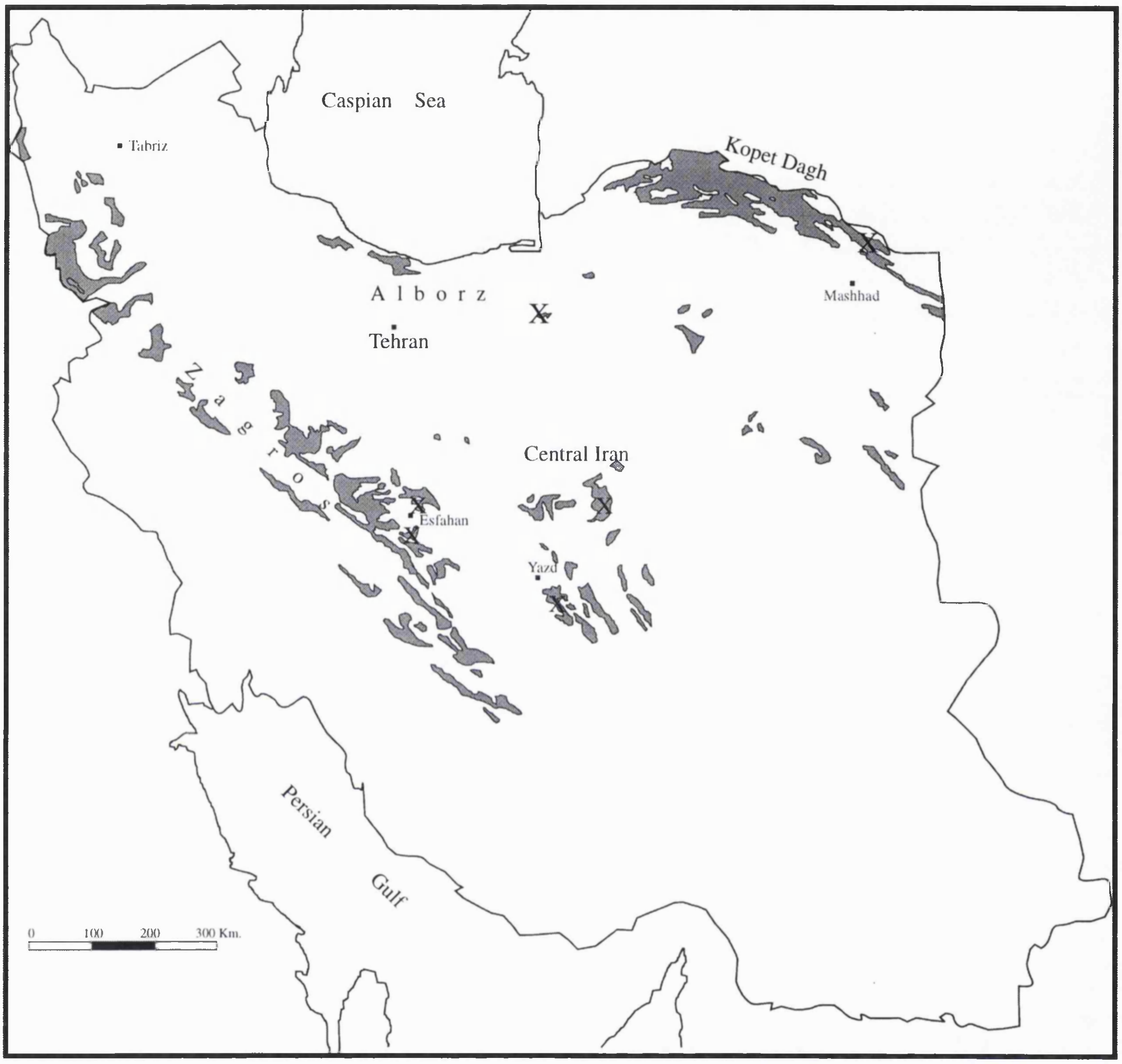


Figure 7.8. The Lower Cretaceous outcrops in Iran. Areas with Upper Aptian-Lower Albian ammonites indicated by X.
(Redrawn and simplified after Aghnabati, 1986).

westward spread. Such a pattern could tie with Klinger *et al.*'s (1984) suggestion that the Heteroceratidae may have originated in Eastern Europe early in the Barremian. They could then have migrated westward to account for the circum-Mediterranean occurrences as well as those near the Cretaceous equator in other parts if the world. On the other hand, the presence of *Heteroceras* in the Kopet Dagh Basin could be explained by clockwise migration by a mid-latitude current flowing to the north as proposed by Baron and Peterson (1989).

Klinger and Kennedy (1977) believed that the origin of *Australiceras* was somewhere between England and east of the Caspian Sea. They pointed out the similarity between the faunas of the Mediterranean area and those of Zululand, Mozambique, India and Australia on the one hand, and those of south America and the Antarctic region on the other, but noted differences with faunas of western North America. Such a dispersal would again fit with Barron and Peterson's (1989) palaeocurrent patterns.

In summary, the faunas of the Kopet Dagh show close relationships with faunas to the north and west, and there is some limited evidence from the dispersal of some forms to support with palaeocurrent patterns suggested by Barron and Peterson (1989).

Chapter 8. Conclusions

1: The thickness of the Sarcheshmeh and Sanganeh Formations changes along the basin. The thickness of the Sarcheshmeh Formation reduces from west to east, while the thickness of the Sanganeh Formation fluctuates along the basin.

2: 25 ammonite genera and 61 species have been identified and described, most of them new to the basin. The genera recorded are *Phylloceras*, *Phyllopachyceras*, *Eogaudryceras*, *Aconeceras*, *Barremites*, *Pseudosaynella*, *Melchiorites*, *Pedioceras*, *Ancyloceras*, *Australiceras*, *Toxoceratoides*, *Tonohamites*, *Heteroceras*, *Argvethites*, *Imerites*, *Paraimerites*, *Martelites*, *Cheloniceras*, *Turkmeniceras*, *Deshayesites*, *Dufrenoyia*, *Hypacanthoplites*, *Acanthohoplites*, *Colombiceras* and *Parahoplites*. Nautiloids (Cymatoceratidae) are also recorded. The faunas indicate a Late Barremian to Early Aptian age for the Sarcheshmeh Formation and an Early Aptian to Early Albian for the Sanganeh Formation. However, the lower and upper boundaries of the formations are diachronous along the basin.

3: Based on the ammonite assemblages, 12 biozones are suggested for the Upper Barremian to Lower Albian sequences. The *Heteroceras sp.* and *Martelites securiformis* zones are suggested for the Upper Barremian Sub-Stage. The *Deshayesites oglanlensis*, *Deshayesites weissi*, *Deshayesites deshayesi* and *Dufrenoyia* sp. zones are proposed for the Lower Aptian Sub-Stage. The *Parahoplites* spp. and *Epicheloniceras subnodosocostatum* zones are suggested for the Middle Aptian and the *Acanthohoplites* spp. and *Hypacanthoplites uhligi* zones for the Upper Aptian Sub-Stage. The Lower Albian biozones are *Leymeriella tardefurcata* and *Douvilleiceras* sp. All the suggested biozones appear to correlate with the standard biozones of the Mediterranean area. However, some of the suggested biozones need more field study to establish them more firmly.

4: There is a relationship between the distribution of some families and genera and lithofacies. The Parahoplitidae are limited to silty shales and siltstones, whereas the Heteroceratidae are limited to marls and shaly/marly limestones. The Ancyloceratidae are a minor element of the fauna but are most common in shales, as are the smooth-shelled Desmoceratidae and Oppeliidae. Conversely, the Deshayesitidae are common across a broad range of facies, from shales to limestones.

The ammonite faunas are grouped into four morphogroups. Heteromorphs such as *Martelites* and *Heteroceras* are distributed mostly in shaly/marly limestones; smooth surfaced, compressed and disc shaped forms such as *Aconeceras* and *Barremites* are found in shale and marl beds; coarsely ribbed, well ornamented forms with quadrate whorls, such as *Hypacanthoplites* and *Parahoplites*, are distributed in silty shales and siltstones. But semi-evolute, ribbed, planispiral shells such as *Deshayesites* do not show a clear relationship to lithofacies.

5: The effect of relative sea-level changes can be recognised in the Sarcheshmeh and Sanganeh Formations throughout the Kopet Dagh Basin. In most cases the first appearance of new genera or species in the basin happens in transgressive and highstand systems tracts. The most abundant ammonite faunas also often coincide with transgressive and highstand systems tracts.

6: From a palaeobiogeographical point of view, the ammonite faunas show affinity with the Mediterranean and Caucasus areas, although there are some genera with a global distribution. The Kopet Dagh Basin was a part of the Mediterranean-Himalayan Province of the Tethyan Realm during latest Barremian to Aptian times and was a part of the Mediterranean-Caucasian Province during Late Aptian to Early Albian times.

The earliest deshayesitid, *Turkmeniceras*, has been recorded only in the Turkmenistan/Kopet Dagh area. It may suggest that the family originated from this area.

References

Adabi, M. H. and Rao, C. P. 1991. Petrographic and geochemical evidence for original aragonite mineralogy of Upper Jurassic carbonates (Mozduran Formation), Sarakhs area, Iran. *Sedimentary Geology* **72**, 253-267.

Adamia, Sh. 1988. Geophysics in the Carpathians-Caucasus region. In *Evolution of the northern margin of Tethys* (eds Pauks, J., Dercourt, M. & Nairn A. E. M.), *Mémoires de la Societé Geologique de France*, Nouvelle serie **154**, 210-222.

Addicott, W. O. 1970. Latitudinal gradients in Tertiary molluscan faunas of the Pacific coast. *Palaeogeography, Palaeoclimatology, Palaeoecology* **8**, 287-312.

Afshar-Harb, A. 1969. A brief history of geological exploration and geology of the Sarakhs area and the Khangiran field. *The Bulletin of the Iranian Petroleum Institute* **37**, 86-93. [In Persian]

Afshar-Harb, A. 1979. *The stratigraphy, tectonics and petroleum geology of the Kopet Dagh region, Northern Iran*, Unpublished PhD thesis, Imperial College of Science and Technology, London, 316 pp.

Afshar-Harb, A. 1982. *Geological quadrangle map of Darreh Gaz*, 1:250,000 scale (one sheet). Exploration and Production, National Iranian Oil Company (N.I.O.C.), Tehran.

Afshar-Harb, A. 1994. Geology of Kopet Dagh. In *Treatise on the geology of Iran.* (Chief ed. Hushmandzadeh, A.), 275 pp., Geological Survey of Iran, Tehran. [In Persian]

Aghanabati, A. 1986. *Geological Map of Iran*, 1:10,000,000 scale. Geological Survey of Iran, Tehran.

Aguirre-Urreta, M. B. 1986. Aptian ammonites from the Argentinian Austral Basin, the Subfamily Helicancylinae Hyatt 1894. *Annals of the South African Museum* **96**, 271-313.

Aguirre-Urreta, M. B. and Klinger, H. C. 1986. Upper Barremian Heteroceratinae (Cephalopoda, Ammonoidea) from Patagonia and Zululand, with comments on the systematics of the subfamily. *Annals of the South African Museum* **96**, 315-358.

Anderson, F. M. 1938. Lower Cretaceous deposits in California and Oregon. *Geological Society of America, Special Paper* **16**, 1-339.

Anthula, D. J. 1899. Über die Kreidefossilien des Kaukasus mit einem allgemeinen Uberblick über die Entwicklung der Sedimentärbildungen des Kaukasus. *Beiträge zur Paläontolgie und Geologie Österreich-Ungarns und des Orients* **12**, 53-159.

Arkell, W. J. 1947. The geology of the country around Weymouth, Swanage, Coirfe and Lulworth. *Memoirs of Geological Survey of the Great Britain* **12**, 386 pp.

Arkell, W. J., Kummel, B. and Wright, W. C. 1957. Mesozoic Ammonoidea. In *Treatise on invertebrate paleontology* (ed. Moore, R. C.) *Part L, Mollusca 4, Cephalopoda, Ammonoidea*, pp. L80-L490. The Geological Society of America and University Kansas Press, New York and Lawrence.

Asitove, L., Melnikov, B., Krivyakin, B. and Morozov, L. 1984. *Geology of the Khur area* (*Central Iran*). Geological Survey of Iran, Report **23**, 288 pp., Tehran.

Autran, G. and Delanoy G. 1987. Mise en évidence d'un niveau à ammonites aptiennes dans la basse vallée Var (Alpes-Maritimes, Frances). Conséquences paléogéographiques. *Geobios* **20**, 415-422.

Avram, E. 1976. Les fossiles du flysch eocrétacé et des calcaires titoniques des hautes vallées de la Doftana et du Tirlung (Carpates Orientales). *Mémoires. Institute de Geologie et de Géophysique* **24**, 5-74, Bucharest.

Avram, E. 1983. Barremian ammonite zonation in the Carpathian area. *Zitteliana* **10** 509-514.

Avram, E. 1999. The *Deshayesites* Kazansky, 1914 (Ammonoidea) Representatives in Romania, a Link between the West-European and Caspian Assemblages of this Genus. In *Advancing Research on living and fossil cephalopods* (eds Oloriz F. & Rodriguez-Tovar F. J.), pp. 437-462, Kluwer Academic/ Plenum Publishers, New York.

Baraboshkin E. J. 1996. The Russian Platform as controller of the Albian tethyan/Boreal ammonite migration. *Geologica Carpathica* **47**, 274-284.

Baraboshkin E. J. 1998. The new data on the Aptian zonation in the Ulyanovsk (Simbirsk) region, Russian Platform. (Fifth International Cretaceous Symposium- Eds. Horna H von F., Tröger, K.A. and Voigt, S.) *Zentalblatt für Geologie und Paläontologie Teil I*, H. **11/12**, 1131-1147.

Baraboshkin, E. J. 1992. The Lower albian of Centralparts of the Russian Paltform. In *The Phanerozoic stratigraphy of the central part of the East-European Platform*, pp.2-36, Publication of Centrgeologia, Moscow. [In Russian]

Barron, E. J. 1989. Studies of Cretaceous climate. In *Understanding climate change* (eds Berger, A., Dickinson, R. E. & Kidson, J. W.), Geophysical Monograph 52, pp. 149-158, American Geophysical Union and International Union of Geodsy and Geophysics, Washington, DC, United States.

Barron, E. J. and Peterson W. H. 1989. Model simulation of the Cretaceous ocean circulation. *Science* **244**, 684-686.

Batt, R. J. 1989. Ammonite shell morphotype distributions in the Western Interior Greenhorn Sea and some paleoecological implications. *Palaios* **4**, 32-42.

Batt, R. J. 1991. Sutural amplitude of ammonite shells as a paleoenvironmental indicator. *Lethaia* **24**, 219-225.

Batt, R. J. 1993. Ammonite morphotypes as indicators of oxygenation in epicontinental seas. *Lethaia* **26**, 49-64.

Berberian, M. and King, G. C. P. 1981. Toward a palaeogeography and tectonic evolution of Iran. *Canadian Journal of Earth Science* **18**, 210-265.

Birkelund, T. and Hakansson, E. 1983. The Cretaceous of North Greenland - a stratigraphic and biogeographical analysis. *Zitteliana* **10**, 7-25.

Birkelund, T., Hancock, J. M., Hart, M. B., Rawson, P. F., Remane J., Robaszynski, F., Schmid, F. and Surlyk, F. 1984. Cretaceous stage boundaries - proposals. *Bulletin of the Geological Society of Denmark* **33**, 3-20.

Blasco, G., Nullo, F. F. and Ploczkiewicz, J. 1980. Ele genero *Colchidites* Djanelidzé, 1926 y la posicion estratigrafica del genero *Hatchericeras* Stanton, 1901 en la Estancia Tucu-Tucu, Provincia de Santa Cruz. *Revista de la Asociación Geológica Argentina* **35**, 51-58.

Bogdanova, T. N. 1971a. New Barremian ammonites from western Turkmenia. *Paleontological Journal* **5**, 334-344.

Bogdanova, T. N. 1971b. *Lower Aptian and bordering strata of western and southern Turkmenia.* Avtoreferat dissertatsii na soiskonie unchenoi stepenni Kanditata geologo-mineralogicheskogo nauk., 30 pp. [In Russian]

Bogdanova, T. N. 1977. On some *Deshayesites* of western Turkmenia. *Ezhegondik Vsesoyuznogo Paleontologiche skogo obshchestva* **19**, 46-70. [In Russian]

Bogdanova, T. N. 1979. Ammonites of the family Deshayesitidae of Turkmenia. In *Plankton I organicheskii mir pelagiali v istorii Zemli* (ed. Bogdanova, T. N.), Trudy XIX sessii Vsesoyuznogo Paleontologicheskogo Obshchestva, pp. 152-170, Leningrad. [In Russian]

Bogdanova, T. N. 1983. *Deshayesites tuarkyricus* Zone; the lowermost zone of the Aptian in Turkmenistan. *Ezhegodnik Vsesoyuznogo Paleontologicheskogo Obshchestva* **26**, 128-147. [In Russian]

Bogdanova, T. N. 1991. New ammonite species from the Lower Aptian of Turkmenia. *Ezhendnik Vesesoyuznogo Palaeontologicheskogo Obschestva* **34**, 77-98. [In Russian]

Bogdanova, T. N. 1999. The Lower Aptian of the Mangyshlak Mountains. *Stratigraphy and Geological Correlation* **7**, 343-355.

Bogdanova, T. N., Kavantaliani, I. V. and Scharikadze, M. Z. 1979. Some Early Aptian Deshayesitidae from Central Dagestan. *Geologica Balcanica* **9** (3), 3-12, Sofia. [In Russian, English abstract]

Bogdanova, T. N. Luppov, N. P. and Yahnin, E. Y. 1963. On stratigraphy of the Aptian and Albian deposits of Tuarkyr. *Trudy Vsesoyuznogo Nauchno-Issledovatelskogo Geologicheskogo Inistuta* nove serie **109**, 75-97. [In Russian].

Bogdanova, T. N. and Mikhailova, I. A. 1999. Origin and Evolution of the family Deshayesitidae (Ammonoidea). *Paleontological Journal* **33**, 522-529.

Bogdanova, T. N. and Prozorovsky, V. 1999. Substantiation of the Barremian/ Aptian boundary. *Scripta geologica, Special Issue* **3**, 45-81.

Bogdanova, T. and Tovbina, S. Z. 1994. On development of the Aptian ammonite zonal standard for the Mediterranean region. *Géologie Alpine* Mémoire H. S. n^{0} **20**, 51-59.

Braga, J. C., Company, M., Linares, A., Rivas, P., and Sandoval, J. 1982. Contribución a la bioestratigraphia del Aptense de las Cordilleras Béticas. *Cuadernos de Geología Ibérica* **8**, 691-701.

Breistroffer, M. 1933. Étude de l'étage Albien dans le Assif de la Chartreuse (Isére st Savoie). *Annales de l' Universite de Grenoble* **8**, (2, 3), 187-236.

Breistroffer, M. 1935. Sur le presence d'une faune á Aucellines dans l'Albien de la Chartreuse. *Comptes Rendus de la Societé Géologique de France*, Séance Fevrier **4**, 28-30.

Breistroffer, M. 1947. Sur les zones d'ammonites dans l'Albien de France et d'Angleterre. *Travaux du Laboratoire de Géologie de la Faculté des sciences de l'Universite Grenoble* **26**, 1-88.

Brinkmann, R. 1937. Biostratigraphie des Leymeriellenstammes nebst Bemerkungen zür Paläogeographie des Nordwestdeutschen Alb. *Mitteilungen aus dem Geologischen Staatsinstitut in Hamburg* **16**, 1-18.

Breskovski, S. V. 1977. Genres nouveaux du crétacé inférieur de la famille Desmoceratidae Zittel, 1985 (Ammonoidea). *Comptes rendus de l'Académie bulgare des Sciences* **30**, 1463-1465.

Bulot, L. G. 1993. Stratigraphical implications of the relationships between ammonites and facies: examples taken from the Lower Cretaceous (Valanginian-Hauterivian) of the western Tethys. In *The Ammonoidea: Environment, ecology and evolutionary change* (ed. House, M. R.), Systematics Association, Special Volume 47, pp. 243-266. Clarendon Press, Oxford.

Busnardo, R. 1965. Le stratotype du Barrémien, 1. Lithologie et macrofaune. In *Colloque sur le Crétacé inférieur* (Lyon, September 1963). *Mémoires Bureau de Recherches Géologiques et Minières* **34**, 101-116.

Busnardo, R. 1984. Crétacé inférieur, Ammonites. In *Synthése Geologique du Sud-Est de La France. Mémoires Bureau de Recherches Géologiques et Minières* **125**, 292-294.

Cantu-Chapa, A. 1963. Étode biostratigrphique des ammonites du centre et de l'est du Mexique. *Mémoires de la Societé Géologique de France* (series 5) **42**, 1-103.

Casey, R. 1950. The junction of the Gault and Lower Greensand in East Sussex and at Folkestone, Kent. *Proceedings of the Geologists' Association* **51**, 268-298.

Casey, R. 1954a. *Falciferella*, a new genus of Gault ammonites, with a review of the family Aconeceratidae in the British Cretaceous. *Proceedings of the Geologists' Association* **65**, 262-277.

Casey, R. 1954b. New genera and sungenera of Lower Cretaceous ammonites. *Journal of Washington Academy of Sciences* **44**, 106-115.

Casey, R. 1960. *A Monograph of the Ammonoidea of the Lower Greensand.* Part 1, pp. 1-44 (Palaeontographical Society Monograph).

Casey, R. 1961a. The stratigraphical palaeontology of the Lower Greensand. *Palaeontology* **3**, 487-621.

Casey, R. 1961b. *A Monograph of the Ammonoidea of the Lower Greensand.* Part 2, pp. 45-118 (Palaeontographical Society Monograph).

Casey, R., 1961c. *A Monograph of the Ammonoidea of the Lower Greensand.* Part 3, pp. 119-216 (Palaeontographical Society Monograph).

Casey, R. 1962. *A Monograph of the Ammonoidea of the Lower Greensand.* Part 4, pp. 217-288 (Palaeontographical Society Monograph).

Casey, R. 1964. *A Monograph of the Ammonoidea of the Lower Greensand.* Part 5, pp. 289-398 (Palaeontographical Society Monograph).

Casey, R. 1965. *A Monograph of the Ammonoidea of the Lower Greensand.* Part 6, pp. 399-546 (Palaeontographical Society Monograph).

Casey, R. 1980. *A Monograph of the Ammonoidea of the Lower Greensand.* Part 9, pp. 633-660 (Palaeontographical Society Monograph).

Casey, R. 1996. Lower Greensand ammonites and ammonite zonation. *Proceedings of the Geologists' Association* **107**, 69-76.

Casey, R. 1999. The age of the Argiles à *Bucaillella* of Normandy, the systematic position of the Cretaceous ammonite genera *Bucaillella* and *Arcthoplites*, and the delimitation of the Aptian/Albian boundary. *Cretaceous Research* **20**, 609-628.

Cecca, F. 1988. Ammonites méditerranénnes du Tithonique inférior de l'Ardèche: analyse des afflux téthysiens. *Geobios* **21**, 169-186.

Cecca, F. 1992. Ammonite habitats in the Early Tithonian of Western Tethys. *Lethaia*, **25**, 257-267.

Cecca, F. 1998. Early Cretaceous (pre-Aptian) ammonites of the Mediterranean Tethys: palaeoecology and palaeobiogeography. *Palaeogeography, Palaeoclimatology, Palaeoecology* **138**, 305-323.

Cecca, F., Faraoni, P. and Marini, A. 1998. Latest Hauterivian (Early Cretaceous) ammonites from Umbria-Marche Apennines (Central Italy). *Palaeontographia Italica* **85**, 61-110.

Cecca, F., Dhondt, A. V. and Bogdanova, T. N. 1999a. The Aptian stratigraphy of southern Tuarkyr (NW Turkmenistan, central Asia). *Rivista Italiana di Paleontologia e Stratigrafia* **105**, 377-396.

Cecca, F., Ropolo, P. and Gonnet, R. 1999b. The appearance of the genus *Deshayesites* (Kazansky, 1914 Ammonoidea) in the lowermost Aptian (Lower Cretaceous) of la Bédoule (SE France). *Rivista Italiana di Paleontologia e Stratigrafia* **105**, 267-276.

Clap, F. G. 1940. Geology of Eastern Iran. *Bulletin of the Geological Society of America* **51**, 1-102.

Collet, L. W. 1907. Sur quelques espèces de l'Albien inférieur de Vöhrum (Honovre). *Mémoires de la Sociéte de Physique et d'Histoire Naturelle de Geneve* **35**, 519-529.

Collignon, M. 1962. *Atlas des fossiles caracteristiques de Madagascar* (*Ammonites*), 9, (Aptien), 64 pp., Service Géologique, Tananarive.

Collignon, M. 1963. *Atlas des fossils caracteristiques de Madagascar (Ammonites)*, 10, (Albien), 184 pp., Service Géologique, Tananarive.

Collignon, M. 1978. La partie moyenne du Crétacé à Madagascar entre l'Aptien et le Coniacien. In *Evénemènts de la partie moyenne du Crétacé* (eds Reyment, R. A. and Thomel, G.), *Annales du Museum d'Histoire Naturelle de Nice* **4** (1976), xv1-xv15.

Conte, G. 1989. Fossiles du Plateau d'Albion. *Les Alpes de Lumières* **99**, 1-72.

Coquand, H. 1861. Sur la convenance d'établir dans le groupe inférieur de la formation crétacée un nouvel étage entre le Néocomien proprement dit (couches à *Toxaster complanatus* et à *Ostrea couloni*) et le Néocomien Supérieur (étage Urgonien d'Orbigny). *Mémoires de la Societé d'Emulation Provence* **2**, 1-127.

Coquand, H. 1880. Études supplémentaires sur la paléontologie algérienne. *Bulletin de la'Academie Hippone* **15**, 1-449.

Cox, L. R., Newell, N. D., Boyd, D. W., Branson, C. C., Casey, R., Chavan, A., Coogan, A. H., Dechaseaux, C., Fleming, C. A., Hass, F., Hertlein, E. G., Kauffmann, E. G., Keen, A. M., LaRocque, A., McAlester, A. L., Moore, R. C., Nuttall, C. P., Perking, B. F., Puri, H. S., Smith, L. A., Soot-Ryen, T., Stenzel, H. B., Trueman, E. R., Turner, R. D., and Weir, J. 1969. *Treatise on Invertebrate Paleontology* (ed. Moore, R. C.) *Part N, Mollusca 6, Bivalva 2.* pp. N491-N952, The Geological Society of America and University Kansas Press, New York and Lawrence.

Davoudzadeh, M., Soffel, H. and Schmidt, K. 1981. On the rotation of the Central-East Iran microplate. *Neues Jahrbuch für Geologie und Paläontologie Monatsheftte* **1981** (3), 180-192.

Day, R. W. 1974. Aptian ammonites from the Eromanga and Surat Basins, Queensland. *Publication of the Geological Survey of Queensland* (360), *Palaeontological Papers* **34**, 1-19.

Delanoy, G. 1991. Sur la prsénce du genre *Prodeshayesites* Casey, 1961 (Ammonoidea) dans l'Aptien inférieur du Bassin Vocontien. *Cretaceous Research* **12** (4), 437-441.

Delanoy, G. 1992. Les ammonites du Barrémien supérieur de Saint-Laurent de l'Escaréne (Alpes- Maritimes, Sud-Est de la France). *Annales du Muséum d'Histoire Naturelle de Nice* **9**, 1-148.

Delanoy, G. 1994. Rapport sur l'étage Barrémien. *Géologie Alpine*, Mémoire H.S. n° **20**, 43-50.

Delanoy, G. 1995. About some significant ammonites from the Lower Aptian (Bedoulian) of the Angles- Barrême area (South-East France). *Memorie Descrittive della Carta Geologica D'Italia* **51**, 65-101.

Delanoy, G. 1997. Biostratigraphie des faunes d'Ammonites à la limite Barrémien-Aptien dans la region d'Angles- Barrême-Castellane. *Annales du Muséum d'Histoire Naturelle de Nice* **12**, 1-270, 62 tables.

Delanoy, G. and Magnin, A. 1994. Evolution of the coiling of heteromorphic ammonites due to sea events. *Comptes Rendus de l' Academie des Sciences Paris*, Serie 2, **318**, 843-848

Destombes, P. 1958. Révision de l'Albien de la région du Havre. Deductions paléogeographiques sur le N. W. du Bassin Parisien au Crétacé moyen. *Bulletin de la Societé Géologique de France* **6**, 305-313.

Djanelidze, A. 1926. Mélanges géologiques et paléontologiques. *Bulletin de l'Université de Tiflis* **6**, 232-266. [French abstract]

Dimitrova, N. 1967. *Les fossiles de Bulgarie. IV, Crétacé inférieur: Cephalopoda (Nautiloidea et Ammonoidea)*. 244 pp., Publication Bulgarian Academy of Science, Sofia.

Doguzhaeva, L. and Mikhailova, I. 1982. The genus *Luppovia* and the phylogeny of Cretaceous heteromorphic ammonoids. *Lethaia* **15**, 55-65.

Donovan, D. T. 1985. Ammonite shell form and transgression in the British Lower Jurassic. In *Lecture Notes in Earth Sciences 1, Sedimentary and Evolutionary Cycles* (ed. Friedman, G. M.), pp. 48-57, Springer-Verlag.

Druschitz, V. V. and Kudryutzeva, M. P. 1960. *Atlas of Lower Cretaceous fauna of the northern Caucasus and Crimea*. 396 pp., Trudy Vsesoyuznogo Nauchno-Issledovatelskogo Geologicheskogo Instituta, Moscow.

Druschitz, V. V. and Gorbatschik, T. N. 1979. The zonal concept of the Lower Cretaceous of Southern USSR, based on ammonites and foraminifera. *Aspekte der Keride Europas, International Union of Geological Sciences* **6**, 107-116.

Druschitz, V. V. and Mikhailova, I. A. 1963. The boundary between the Aptian and Albian. *Byulleten Moskovskogo Obschestva Ispytateley Prirody, Otdelenie Geologiya* **38** (6), 84-93.

Duraj, M., Filak, P. and Vasicek, Z. 1990. Desmoceratids from the Hauterivian-Barremian boundary (Lower Cretaceous) on the locality Lietavska Lucka near Zilina (west Carpathians, the Krizna nappe). *Khihovnicka Zemhino Plynu a Nafty* **9**, 55-68.

Eftekharnezhad, J. and Behroozi, A. 1991. Geodynamic significance of recent discoveries of ophiolite and late Palaeozoic rocks in NE-Iran (Including Kopet Dagh). *Abhandlungen der Geologischen Bundesanstalt A* **38**, 89-100.

Egoian, V. L. 1965. On the first find of colchiditids in north-western Caucasus. *Trudy Vesesoyuznogo Neftyanogo Nauchno-Issledovatelskogo Geologoravedochnogo Instituta Moscow* **44**, 116-127 [In Russian].

Erba, E. (compiler), 1996. The Aptian stage. *Bulletin de L'institut Royal des Sciences Naturelles de Belgique, Science de La Terre* **66**, 31-43.

Eristavi, M. S. 1955. Lower Cretaceous fauna of Georgia. *Akademya Nauk Gruzinskoi S S R, Instituta Geologichskago i Mineralogicheskago Monographia* **6**, 1-224 [In Russian].

Eristavi, M. S. 1960. The Lower Cretaceous of the Caucasus and Crimea. *Akademya Nauk Gruzinskoi S S R, Instituta Geologichskago i Mineralogicheskago Monographia* **10**, 1-149. [In Russian]

Etayo Serna, F. 1968. Apuntaciones acerca de alcunas Amonitas interesantes del Hauteriviano y del Barremiano de la region de Villa de Leiva (Boyaca, Colombia, S. A.) *Boletín de Geología Universidad Industrial de Santander* **24**, 51-71.

Etayo Serna, F. 1979. Zonation of the Cretaceous of central Colombia by Ammonites. *Publicaciones Geologícas Especiales del Ingeominas* **2**, 1-186.

Etheridge, R. 1880. On a collection of fossils from Bowen River Coalfield and the limestone of the Fanning River, North Queensland. *Proceedings of the Royal Physical Society of Edinburgh* **5**, 263-328.

Favre, F. 1908. Die Ammoniten der unteren Kreide Patagoniens. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beilage-Band* **25**, 601-647.

Fitton, W. H. 1836. Observations on some of the strata between the Chalk and Oxford Oolite in the south-east of England. *Transactions of the Geological Society of London*, series 2, **4**, 103-390.

Follmi, V. K. 1989. Beschreibung neugefundener Ammonoidea aus der Vorarlberger Garschella-Formation (Aptian-Albian), *Jahrbuch der Geologischen Bundesanstalt* **A 132**, 105-189.

Förster, R. 1975. Die geologische Entwicklung von Süd-Mozabique seit der Unterkreide und die Ammoniten-Fauna von Unterkreide und Cenoman. *Geologisches Jahrbuch* **B12**, 3-324. [English abstract]

Fritel, P. 1906. Sur les variations morphologiques d'*Acanthoceras milletianum*, d'Orbigny sp. *Le Naturaliste*, 28th year, series 2, **472**, 245-257.

Fülop, J. 1964. Unterkreide-Bildungen (Berrias-Apt) des Bakonggebriges. *Geologica Hungeria* **13**, 1-194.

Gerhardt, K. 1897. Beiträg Zur Kenntniss der Kreideformation in Columbien. In Gustav Steinmann, Beiträge zur Geologie und Paläeontologie von Südamerika. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beilage-Band* **11**, 118-208.

Glazunova, A. E. 1953. *Aptian and Albian ammonites from Kopet Dag, Lesser and Greater Balkhans and Mangyshlak.* 97 pp., Trudy Vsesoyuznogo Nauchno-Issledovatelskogo Geologicheskogo Instituta Moscow. [In Russian]

Glazunova, A. E. 1973. *Palaeontological evidence for stratigraphic subdivision of the Cretaceous in Povolzhye, Lower Cretaceous.* 324 pp., Nedra Publication, Moscow. [In Russian]

Gordon, W.A. 1973. Marine life and ocean surface currents in the Cretaceous. *Journal of Geology* **81**, 269-284.

Gradstein, F. M., Agterberg F. P., Ogg J. G., Hardenbol J. and Backstrom, S. 1999. On the Cretaceous time scale. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* **212**, 3-14.

Hallam, A. 1989. The case for sea-level change as a dominant causal factor in mass extinction of marine invertebrates. *Philosophical Transactions of the Royal Society of London* **B 325**, 437-455

Hancock, J. M. 1991. Ammonite scales for the Cretaceous System. *Cretaceous Research* **12**, 259-291.

Haq. B. V., Hardenbol, J. and Vail, P. R. 1987. The chronology of fluctuating sea levels since the Triassic. *Science* **235**, 1156-1161.

Haq. B. U., Hardenbol, J. and Vial, P. R. 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In *Sea-Level changes - An Integrated Approach* (eds Wilgus, C. K., Hastings, B. S., Kendall, C. G. St., Posamentier, H. W., Ross C. A. & Van Wagoner, J. C.), Society of Economic Paleontologists and Mineralogists, Special Publication 42, pp. 71-1-5, Tolsa, USA.

Haug, E. 1889. Beiträg zur Kenntniss der oberneocom Ammonitenfauna der Puezalpe bei Corvara (Südtirol). *Beiträge zur Paläontologie Österrich-Ungarns und des Orients* **7**, 193-231.

Hart, M. (Compiler) Amedro, F. and Owen, H. 1996. The Albian stage and substage boundaries. *Bulletin de L'institut Royal des Sciences Naturelles de Belgique, Science de La Terre* **66**, 45-56.

Hay, W. W., DeConto, R. M., Wold, C. N., Wilson, K. M., Voigt, S., Schulz, M., Wold-Rossby, A., Dullo, W.C., Rono, A. B., Balukhovsky, A. N., and Söding, E., 1999. Alternative global Cretaceous paleogeography. In *Evolution of the Cretaceous Ocean-Climate System* (eds Barrera, E. & Johnson, C. C.), pp. 1-47, Geological Society of America, Special Paper 32, Boulder, Colorado.

Hewitt, R. A. 1993. Relation of shell strength to evolution. In *The Ammonoidea: Environment, Ecology and Evolutionary Changes* (ed. House, M. R.), Systematics Association, Special Volume 47, pp. 35-56, Clarendon Press, Oxford.

Hoedemaeker, Ph. J. 1990. The Neocomian boundaries of the Tethyan Realm based on the distribution of ammonites. *Cretaceous Research* **11**, 331-42.

Hoedemaeker, Ph. J. 1994. Ammonite distribution around the Hauterivian-Barremian boundary along the Río Argos (Caravaca, SE Spain). *Géologie Alpine*, Mémoire H.S.n° **20**, p. 219-277.

Hoedemaeker, Ph. J., 1995. Ammonite evidence for long-term sea-level fluctuations between the 2nd and 3rd order in the lowest Cretaceous. *Cretaceous Research* **15**, 231-241.

Hoedemaeker, Ph. J. and Bulot, L. 1990. Preliminary ammonite zonation for the Lower Cretaceous of the Mediterranean region. *Géologie Alpine* **66**, 123-127.

Hoedemaeker, Ph. J., Cecca, F., Avram, E., Company, M., Delanoy, G., Erba, E., Ettachfini, M., Faraoni, P., Kakabadze, M., Landra, G., Marini, A., Memmi, L., Pallini, G., Rawson, P. F., Ropolo, P., Sandoval, J., Tavera, J. and Vasicek, Z. 1995. Report on the 3rd workshop on the standard Lower Cretaceous ammonite Zonation of the Mediterranean region. *Memorie Descrittive della Carta Geologica D'Italia* **51**, 213-215.

Hoedemaeker, Ph. J., Company, M., Aguirre-Urreta, B., Avram, E., Bogdanova, T. N., Bujtor, L., Bulot, L., Cecca, F., Delanoy, G., Erba, E., Ettachfini, M., Memmi, L., Owen, H. G., Rawson, P. F., Sandoval, J., Tavera, J., Thieuloy, P., Tovbina, S. Z., and Vasicek, Z. 1993. Ammonite zonation for the Lower Cretaceous of the Mediterranean region; basis for stratigraphic correlations within IGCP-project 262. *Revista Española de Paleontologica* **8**, 117-120.

Hoedemaeker, Ph. J. and Rawson, P. 2000. Report on the 5th International Workshop of the Lower Cretaceous Cephalopod Team (Vienna, 5 September 2000). *Cretaceous Research* **21**, 857-860.

House, M. R. 1993. Fluctuations in ammonoid evolution and possible environmental controls. In *The Ammononidea: Environment, ecology and evolutionary change* (ed. House M. R.), Systematics Association, Special Volume 47, pp. 13-34. Clarendon Press, Oxford.

Howarth, M. K. 1962. The Yorkshire type ammonites and Nautiloids of Young and Bird, Phillips and Martin Simpson. *Palaeontology* **5**, 93-136.

Hubber, H. (Compiler) 1976. *Geological map of Iran*, 1: 1000,000 scale, (Sheet No. 3). Geological map of North-East Iran. Exploration and Production, N.I.O.C., Tehran.

Humphery, W. E. 1949. Geology of the Sierra de los Muertos area, Mexico. *Bulletin of the Geological Society of America* **60**, 89-176.

Hyatt, A. 1903. *Pseudoceratites* of the Cretaceous. Monographs of the United States Geological Survey, 44, pp. 1-352.

Immel, H. 1987. Die Kreideammoniten der Nördlichen Kalkalpen. *Zitteliana* **15**, 3-163.

Immel, H., Seyed-Emami, K. and Afshar-Harb, A. 1997. Kreide-Ammoniten aus dem iranischen teil des Koppeh-Dagh (NE-Iran). *Zitteliana* **21**, 159-190.

Ivanov, M. 1991. Albian ammonites biostratigraphy in Northwest Bulgaria. *Geologica Balcanica* **21**, 17-53.

Jeletzky, J. A. 1964. Illustrations of Canadian fossils. Lower Cretaceous marine index fossils of the sedimentary basins of western and arctic Canada. *Geological Survey of Canada, Paper* **64**, 11, 1-100.

Jeletzky, J. A., 1970. Cretaceous macrofauna. In *Geology and economic minerals of Canada*. Economic Geology reports of Geological Survey of Canada **1**, 649-658.

Jeletzky, J. A. 1976. Mesozoic and ?Tertiary rocks of Quatsino Sound, Vancouver Island, British Columbia. *Geological Survey of Canada Bulletin* **242**, 1-243.

Jeletzky, J. A. 1980. New or formerly poorly known biochronologically and paleobiogeographically important gastroplitiid and cleoniceratinid (Ammonitida) taxa from Middle Albian rocks of mid-western and Arctic Canada. *Geological Survey of Canada, Paper* **79-22**, 1-63.

Kakabadze, M. V. 1971. The colchidititids and their stratigraphical significance. *Trudy Geologichskago Akademya Nauk Gruzinskoi S S R* **26**, 1-115. [In Russian]

Kakabadze, M. V. 1975. Lower Cretaceous heteoceratides of Georgia and adjacent regions. Issues of Palaeontology and Stratigraphy of Mesozoic of Georgia. *Trudy Geologichskago Akademya Nauk Gruzinskoi SSR* **47**, 63-131. [In Russian]

Kakabadze, M. V. 1977. New and little known Ancyloceratidae from the Caucasus. *Trudy Geologichskago Akademya Nauk Gruzinskoi SSR* **58**, 128-151.

Kakabadze, M. V. 1978. On the systematic and stratigraphical significance of the genera *Pseudocrioceras* Spath, *Audouliceras* Thomel and *Kutatissites* Kakabadze. *Annales du Muséum d'Histoire Naturelle de Nice* **4**, 1-9.

Kakabadze, M. V. 1979. Facies and environments of Georgian Ancyloceratids (Lower Cretaceous, USSR), *Aspekte der Kreide Europas, International Union of Geological Sciences series A* **6**, 141-149.

Kakabadze, M. V. 1981. The ancyloceratids of the south of the USSR and their stratigraphical significance. *Trudy Geologicheskogo Akademya Nauk Gruzinskoi S S R* **71**, 1-196. [In Russian, English abstract]

Kakabadze, M. V. 1983. On the Hauterivian-Barremian correlation between the south of the USSR and certain Southern and Northern regions of Europe. *Zitteliana* **10**, 501-508.

Kakabadze, M. V. 1989. The Barremian biostratigraphical subdivisions of Georgia (USSR) and comparison with some Western Mediterranean regions. In *Cretaceous of the Western Tethys* (ed. Wiedmann, J.), Proceedings 3rd International Cretaceous Symposium Tubingen 1987, pp. 551-560, E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Kakabadze, M. V. 1996. Palaeobiogeography and the problem of estimation of the nature of global eustatic events. *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg* **77**, 395-401.

Kakabadze, M. V. and Hoedemaeker, Ph. J. 1997. New and less known Barremian-Albian ammonites from Colombia. *Scripta Geologica* **114**, 57-117.

Kakabadze, M. V. and Kotetishvili, E. 1995. New data on the Upper Barremian biostratigraphy of Georgian region (Caucasus). *Memorie Descrittive della Carta Geologica D'Italia* **51**, 103-108.

Kakabadze, M. V. and Thieuloy J. P. 1991. Ammonites Hétéromorphes du Barrémien et de L'Aptien de Colombie. *Géologie Alpine* **67**, pp. 81-113.

Kalantari, A. 1969. *Foraminifera from the middle Jurassic-Cretaceous successions of Kopet Dagh region (NE-Iran)*, 298 pp. Exploration and Production, N. I. O. C., Geological Laboratory publication 3, Tehran (Ph.D. thesis, London University).

Kalantari, A. 1987. *Biofacies map of Kopet Dagh region.* Exploration and Production, N. I. O. C., Tehran.

Kazansky, P. A. 1914. Description d'une collection des cephalopods des terrains Crétaces du Daghestan. *Izvestiya Tomskogo ekhnicheskogo Instituta* **32** (4), 1-127.

Kelly, S. R. A. and Whitham, A. G. 1999. Deshayesitid ammonites from the Lower Aptian (Lower Cretaceous) of North-East Greenland. *Scripta Geologica, Special Issue* **3**, 89-95.

Kemper, E. 1967. Die älteste ammoniten fauna im Aptium nordwest-Deutschlands. *Paläontologische Zeitschrift* **41**, 119-131.

Kemper, E. 1971. Zur Gliederung und Abgrenzung des norddeutschen Aptium mit Ammoniten. *Geologisches Jahrbuch* **89**, p. 359-390.

Kemper, E. 1973a. Die Unterkreide im Untergrund der Gehrdener Berge und in der Deister-Mulde. *Bericht der Naturhistorischer Gesellschaft zu Hannover* **117**, 29-54.

Kemper, E. 1973b. The Aptian and Albian stages in north west Germany. In *The Boreal Lower Cretaceous* (eds Casey, R. & Rawson, P. F.), pp. 327-344, Seel House Press, Liverpool.

Kemper, E. 1976. Geologischer Führer durch die Grafschaft Bentheim und die angrenzenden Gebiete, mit einem Abriss der emsländischen unterkreide. 206 pp. Bentheim-Nordhorn.

Kemper, E. 1982. Die Ammoniten des späten Apt und frühen Alb Nordwestdeutschlands. *Geologisches Jahrbuch* **A 65**, 553-557.

Kemper, E. 1995. Die Entfaltung der Ammoniten und die Meeresverbindungen im borealen unter-und Mittel- Apt. *Geologisches Jahrbuch* **A141**, 171-199.

Kennedy, W. J. and Cobban, W. A. 1976. Aspects of ammonite biology, biogeography and biostratigraphy, *Special Paper in Palaeontology* **17**, 1-94.

Kennedy, W. J., Gale, A. S., Bown, P. R., Caron, M., Davey, J. R., Gröcke, D. and Wray, D. S. 2000. Integrated stratigraphy across the Aptian-Albian boundary in the Marnes Bleues, at the Col de pré-Guittard, Arnayon (Drôme), and at Tarttonne (Alpes-de-Haute-Provence), France: a candidate Global Boundary Stratotype Section and Boundary Point for the base of the Albian Stage. *Cretaceous Research* **21**, 591-720.

Kennedy, W. J. and Klinger H. C. 1975. Cretaceous faunas from Zululand and Natal, South Africa. Introduction, stratigraphy. *Bulletin of the British Museum* (Natural History) Geology series **25**, 263-315.

Kennedy, W. J. and Klinger H. C. 1977. Cretaceous faunas from Zululand and Natal, South Africa. The ammonite family Phylloceratidae. *Bulletin of the British Museum* (Natural History) Geology series **27**, 349-380.

Kennedy, W. J. and Klinger, H. C. 1979. Cretaceous faunas from Zululand and Natal, South Africa. The ammonite family Gaudryceratidae. *Bulletin of the British Museum* (Natural History) Geology series **31**, 121-174.

Kennedy, W. J. and Kollmann, H. A. 1979. Lower Albian ammonites from the Tannheim Formation near Losenstein, Upper Austria. *Beiträge zur Paläontologie und Geologie Österreich* **6,** 1-25.

Khazaee, A. R. 1995. *Systematic study of Rudist limestone fauna of the Kalat Formation (Upper Cretaceous) in the type section at the Kopet Dagh Basin.* Unpublished MSc. Thesis, 120 pp., Mashhad University, Iran. [In Persian]

Khodaee, M., and Feiznia, S. 1993. Sedimentary environment and diagenetic phenomena of Tirgan Formation (Hauterivian, Lower Aptian) in Kopet Dagh Basin - Northeast Iran, proposing the facies model. *Annual meeting abstracts, American Association of Petroleum Geologists and Society of Economic Palaeontologists and Mineralogists*, pp. 128-129.

Kilian, W. 1889. *Description Géologique de la Montagne de Lure* (*Basses-Alpes*). Masson, 458 pp., Paris.

Kilian, W. 1907-1913. Unterkreide (Palaeocretacicum). In *Lethaea Geognostica* (ed. Frech, F.), Handbuch der Erdgeschichte, 2, Das Mesozoicum, 3, Kreide **Lief 1**, 1907, 1-168, **Lief 2**, 1910, 169-287, **Lief 3**, 1913, 289-398.

Kilian, W. 1915. Contribution à l'étude des faunes Paléocrétacées du Sud-est de la France, 1, La faune de l'Aptien inférieur des environs de Montélimar (Drôme). *Mémoires pour Servir a l'Explication des Cartes Geologiques Detaillee de la France*, pp. 1-122.

Klein, J. and Hoedemaeker Ph. J. 1999. Ammonite stratigraphy of the Valanginian to Barremian for the Mediterranean region. *Scripta Geologica, Special Issue* **3**, 97-127.

Klinger, H. C. 1976. Cretaceous heteromorph ammonites from Zululand. *Geological Survey of South Africa, Memoir* **69**, 1-142

Klinger, H. C., Kakabadze M. V. and Kennedy, W. J. 1984. Upper Barremian (Cretaceous) heteroceratid ammonites from South Africa and the Caucasus and their palaeobiogeographic significance. *Journal of Mollscan Studies* **50**, 43-60.

Klinger, H. C. and Kennedy, W. J. 1977. Cretaceous faunas from Zululand, South Africa and southern Mozambique. The Aptian Ancyloceratidae (Ammonoidea). *Annals of the South African Museum* **73**, 215-359.

Koenen, A. von. 1902. Die Ammonitiden des Norddeutschen Neocom (Valanginien, Hauterivien, Barremien und Aptien). *Königlich Preussischen Geologischen Landesantalt und Bergakademie* (N.F.) **24**, 1-451.

Kopaevich L. F. Alkeseev, A. S., Baraboshkin E. Yu. and Beniamovskii, V. N. 1999. Cretaceous sedimentary units of Mangyshlak Peninsula (western Kazakhestan). In *Peri-Tethys: stratigraphic correlation 3* (eds Crasquin-Soleau, S. and De Wever, P.), *Geodiversita* **21**, 407-419.

Kotetishvili, E. V. 1970. Stratigraphy and fauna of the *Colchidites* horizon and adjacent horizons of Western Georgia. *Trudy Geologicheskogo Akademya Nauk Gruzinskoi SSR* **25**, 1-116. [In Russian]

Kotetishvili, E. V. 1988. Distribution globale des ammonites éocrétacées du Caucase. In *Cephalopods-Present and Past, Second International Cephalopod Symposium* (eds Wiedmann, J. & Kullmann, J.), pp. 453-468, Schweizerburt'sche verlagbuchhandlung, Stuttgart.

Kotetishvili, E., Kakabadze, M. and Kakabadze, I. 2000. Steps in Evolution of the Early Cretaceous ammonites of Georgia. *Trudy Akademya Nauk Gruzinskoi SSR, A. Djanelidze Geologiskii Institut, Novya Serie* **115**, 76-85. [In Russian, English abstract]

Kummel, B. 1956. Post-Triassic Nautiloid Genera. *Bulletin of the Museum of Comparative Zoology* **114**, 325-494.

Lasemi, Y. 1995. Platform carbonates of the Upper Jurassic Mozduran Formation in the Kopet Dagh Basin, NE-Iran, facies, paleoenvironmental and sequences. *Sedimentary Geology* **99**, 151-164.

Latil, J-L. 1994. Les Lyelliceratinae Spath, 1921 (Ammonitina, Ammonoidea) de l'Albien inférieur et moyen dans le basin de Paris et sur les bordures du bassin vocontien: Stratigraphie, Paléobiogéographie et Taxonomie. *Géologie Alpine*, Mémoire H.S. n° **20**, p. 327-381.

Luppov, I. P. 1952. Lower Cretaceous deposits of NW Caucasus and their fauna. *Trudy Veseoyuznogo Neftyanogo Nauchno-Issledovatelskogo Geologoravedochnogo Instituta Moscow* **65**, 1-238. [In Russian]

Luppov, N. P., Sirotina, E. A. and Tovbina, S. Z. 1960. About stratigraphy of Aptian and Albian deposits of the Kopet Dag. *Trudy Vsesoyuznogo Nauchno-Issledovatelskogo Geologicheskogo Inistuta* nove serie **42**, 156-173. [In Russian]

Luyendyk, B. P., Forsyth, D. and Philip, J. D. 1972. Experimental approach to the oceanic surfaces waters. *Geological Society of America Bulletin* **83**, 2649-2664.

Mahboubi, A., Lasemi, Y. and Moussavi-Harami, R. 1995. Facies analysis and sedimentary environments of the Kalat Formation (Upper Cretaceous) in eastern Kopet Dagh, NE-Iran. *Journal of Science Tehran University* **21**, 24-37. [In Persian, English abstract]

Madani, M. 1977. *A study of the sedimentology, stratigraphy and regional geology of the Jurassic rocks of Eastern Kopet Dagh, NE-Iran*. Unpublished PhD. thesis, London University, 264 pp.

Mandov, P. G. and Nikolov, T. 1992. Les successions d'ammonites et la subdivision des étages du Crétacé inférieur téthysien. In *New aspect on Tethyan Cretaceous Fossil Assemblages* (eds Kollmann H. & Zapfe H.), pp. 223-230, Schriftenreihe der Erdwissenschaftlichen Kommissionen der Österreichischen Akademie der Wissenschaften, Band 9, Vienna.

Marcinowski, R. and Naidin, D. P. 1976. An Upper Albian ammonite fauna from Crimea. *Acta Geologica Polonica* **26**, 83-118.

Marcinowski, R. and Wiedmann, J. 1985. The Albian ammonite fauna of Poland and its paleogeographical significance. *Acta Geologica Polonica* **35**, 199-218.

Marcinowski, R. and Wiedmann, J. 1988. Palaeogeographic implications of the Albian ammonite faunas of Poland. In *Cephalopods-Present and Past, Second International Cephalopod Symposium*, (eds Wiedmann, J. & Kullmann, J.), pp. 491-504, Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Martinez, R. 1982. Ammonoideos Cretacicos del Prepirineo de la provincia Lieida. *Publicaciones de; Instituto Geologico Universidad de Barcelona* **17**, 1-197.

Mclearn, F. H. 1932. Problem of the Lower Cretaceous of the Canadian interior. *Transactions of the Royal Society of Canada* **25**, 157-175.

Meek, F. B. 1876. A report on the invertebrate Cretaceous and Tertiary fossils of the Upper Missouri Country. *F. V. Hayden, Report of the United States Geological and Geographical Surveys of the Territories* **9**, 629 pp.

Memmi, L. 1995. Aptian biostratigraphy of northeastern Tunisia. A stratigraphical approach of Aptian and Albian of Tunisia. *Memorie Descrittive della Carta Geologica D'Italia* **51**, 109-120.

Memmi, L. 1999. L'Aptien et L'Albien de Tunisie. Biostratigraphie à partir des ammonites. *Bulletin de la Societé Géologique de France* **170**, 3, 303-309.

Michelin, H. 1838. Note sur une argile dépendant du Gault. *Mémoires de la Societé Géologique de France* (Series 1) **3**, 97-103.

Mikhailova, I. A. 1979. The evolution of Aptian ammonites. *Paleontological Journal* **13**, 267-274.

Mikhailova, I. A. 1982. The system and phylogeny of the higher taxa of Cretaceous ammonoids. *Paleontological Journal* **16** (2), 12-28.

Mikhailova, I. A. and Saveliev, A. A. 1989. The Albian Stage. In *Zones of Cretaceous system in USSR, Lower series* (ed. Prozorovsky, V. A.), pp.141-217, Trudy Mezhfakultetskogo Stratigarficheskogo Komiteta SSSR 20, St. Petersburg. [In Russian]

Mohajer, G. 1976. The role of hydrocarbon migration in the formation of Khangiran gas field and its significance in the exploration of the Kopet Dagh region. In *The Second Iranian Geological Symposium*, pp. 243-262. (Iranian Petroleum Institute, Tehran). [In Persian]

Moullade, M. 1966. Etude stratigraphique et micropaléontologique du crétacé inférieur de la 'fosse vocontienne'. *Documents des Laboratoires de Géologie de la Faculté des Sciences de Lyon* **15**, 1-369.

Moussavi-Harami, R. and Brenner, R. 1990. Lower Cretaceous (Neocomian) fluvial deposits in eastern Kopet Dagh. *Cretaceous Research* **11**, 163-174

Moussavi-Harami, R. and Brenner, R. 1992. Geohistory analysis and petroleum reservoir characteristics of Lower Cretaceous (Neocomian) sandstones, Eastern Kopet Dagh basin, North eastern Iran. *The American Association of Petroleum Geologists Bulletin* **76**, 1200-1208.

Moussavi-Harami, R. and Brenner, R. 1993. Diagenesis of non-marine petroleum reservoirs, the Neocomian Shurijeh Formation, Kopet Dagh basin, NE Iran. *Journal of Petroleum Geology* **16**, 55-72.

Murphy, M. A. 1975. Palaeontology and Stratigraphy of the lower Chickbally Mudstone (Barremian-Aptian) in the Ono Quadrangle, Northern California. *University California Publications in Geological Sciences* **113**, 1-52.

Nagy, J. 1970. Ammonite fauna and stratigraphy of Lower Cretaceous (Albian) rocks in southern Sptisbergen. *Norsk Polarinstitutt Skrifter* **152**, 1-58.

Neaverson, E. 1955. *Stratigraphic palaeontology*, 806 pp., Oxford Clarendon.

Neumayr, M. and Uhlig, V. 1881. Über ammonitiden aus den Hilsbildungen Norddeutschlands. *Palaeontographica* **27**, 3-6, 129-203.

Newell, R. S. 1967. Revolutions in the history of life. *Geological Society of America, Special Paper* **89**, 63-91.

Nikolov, T. 1964. Barremian Ammonites from north-eastern Bulgaria. *Travaux de Geologique Bulgarie* **6**, 117-131.

Obata, I. and Futakami, M. 1992. Some selected ammonites from the Aptian and Albian Miyako Group, Japan. *Bulletin of the National Science Museum*, Tokyo, Series C (Geology) **18**, 79-99.

Obata, I., Hawigara, S. and Kamiko, S., 1975. Geological age of the Cretaceous Choshi Group. *Bulletin of the National Science Museum*, Tokyo, Series C (Geology) 1, 17-36. [In Japanese]

Obata, I., Maiya, S., Inoue, Y. and Matsukawa, M. 1982. Integrated mega- and micro-fossil biostratigraphy of the Lower Cretaceous Choshi Group, Japan. *Bulletin of the National Science Museum*, Tokyo, Series C (Geology) 8, 145-179.

Obata, I. and Matsukawa, M. 1988. Some Boreal or Subboreal ammonites in the Japanese Barremian. In *Cephalopods, Present and Past, Second International Cephalopod Symposium* (eds Wiedmann, J. and Kullmann, J.), pp. 469-476, Schweizerbart'sch Verlagbuchhandlung, Stuttgart.

Obata, I., Matsukawa, M., Tanaka, K., Kanai, Y. and Watanabe, T. 1984. Cretaceous cephalopods from the Sanchu area, Japan. *Bulletin of the National Science Museum*, Tokyo, Series C (Geology) **10**, 1, 9-37.

Obata, I., Matsukawa, M., Tsuda, H., Futakami, M. and Ogawa, Y. 1976. Geological age of the Cretaceous Ishido Formation, Japan. *Bulletin of the National Science Museum*, Tokyo, Series C (Geology) **2**, 121-138.

Okamoto, T. 1984. Theoretical morphology of *Nipponites* (a heteromorph ammonite). *Palaeontological Society of Japan* **36**, 37-51.

Okamoto, T. 1988a. Analysis of ammonoids by different geometery. *Palaeontology* **31**, 35-52.

Okamoto, T. 1988b. Change in life orientation during the ontogeny of some heteromorph ammonoids. *Palaeontology* **31**, 281-294.

d'Orbigny, A. 1840-1842. *Paléontologie Francaise*. Terrains Crétacés, 1-Céphalopodes, 662 pp. Masson, Paris.

d'Orbigny, A. 1840. *Paléontologie Francaise*. Terrains Crétacés, 1-Céphalopodes, 1-120, Masson, Paris.

d'Orbigny, A. 1841. *Paléontologie Francaise*. Terrains Crétacés, 1-Céphalopodes, 121-430, Masson, Paris.

d'Orbigny, A. 1842. *Paléontologie Francaise*. Terrains Crétacés, 1-Céphalopodes, 431-662, Masson, Paris.

d'Orbigny, A. 1851. Notice sur le genere *Heteroceras*, de la classe des Cèphalopodes. *Journal de Conchiologie* **2**, 217-222.

Owen, H. G. 1971. Middle Albian stratigraphy in the Anglo-Paris Basin. *Bulletin of the British Museum* (Natural History) Geology series, Supplementary **8**, 1-164

Owen, H. G. 1973. Ammonite faunal provinces in the Middle and Upper Albian and their palaeogeographical significance. In *The Boreal Lower Cretaceous* (eds Casey R. & Rawson, P. F.), pp. 145-154, Seel House Press, Liverpool.

Owen, H. G. 1988. Correlation of ammonite faunal province in the Lower Albian (mid-Cretaceous). In *Cephalopods-Present and Past, Second International Cephalopod Symposium* (eds Wiedmann, J. & Kullmann, J.), pp. 477-489. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Owen, H. G. 1996. Boreal and Tethyan Late Aptian to Late Albian ammonite zonation and palaeobiogeography. *Mitteilungen aus dem Geologisch Paläontologischen Institut der Universitat Hamburg* **77**, 461-481.

Owen, H. G. 1999. Correlation of Albian European and Tethyan ammonite zonations and the boundaries of the Albian stage and substages: some comments. *Scripta Geologica, Special Issue* **3**, 129-149.

Page, K. N. 1996. Mesozoic Ammonoids in space and time. In *Ammonoid paleobiogeology* (eds Neil H. L., Kazushige, T., & Richard, A. D.), Topics in Geobiology, Volume 13, pp. 755-799. Plenum Press, New York.

Papp, K. 1907. Beschreibung der während der Forschungs-reisen M.V. Dechys im Kaukasus gesammelten versteinerugen. In *Kaukasus, Reisen und Forschungen im kaukasischen Hochgebirge* (ed. von Déchy, M.), pp. 143-173, Berlin.

Pictet, F. J. and Renevier, E., 1854-58. Description des fossils du Terrain Aptien de la Perte-du-Rhône et des environs de Ste. Croix **1**. *Matèriaux pour la Palèontologie Suisse*, 184 p.

Raisossadat, N. 1992. *Biostratigraphy and historical sedimentation of Sarcheshmeh and Sanganeh Formations in the east of Kopet Dagh Basin, NE-Iran*. Unpublished MSc. thesis Tarbiat Moallem University, Tehran, 284 pp. [In Persian, English abstract]

Raisossadat, N. and Moussavi-Harami, R. 1993. Stratigraphy and biozonation of Sarcheshmeh and Sanganeh Formations in eastern Kopet Dagh Basin. *Geoscience* **2** (7), 58-73. [Geological Survey of Iran, English abstract]

Raisossadat, N. and Moussavi-Harami, R. 2000. Lithostratigraphy and facies analyses of the Sarcheshmeh Formation (Lower Cretaceous) in the eastern Kopet Dagh Basin, NE Iran. *Cretaceous Research* **21**, 507-516.

Rawson, P. F. 1981. Early Cretaceous ammonite biostratigraphy and biogeography. In *The Ammonoidea: The evolution, classification, mode of life and geological usefulness of a major group*, (eds House, M. R. & Senior, J. R.), Systematics Association, Special Volume 18, pp. 499-529, Academic Press, London.

Rawson, P. F. 1983. The Valanginian to Aptian Stages- current definitions and outstanding problems. *Zitteliana* **10**, 493-500.

Rawson, P. F. 1993. The influence of sea-level changes on the migration and evolution of Early Cretaceous (pre-Aptian) ammonites. In *The Ammonoidea: Environment, ecology and evolutionary change* (ed. House M. R.), Systematics Association, Special Volume 47, pp. 224-242. Clarendon Press, Oxford.

Rawson, P. F. 1995. Biogeographical affinities of NW European Barremian ammonite faunas and their palaeogeographical implications. *Memorie Descrittive della Carta Geologica D'Italia* **51**, 131-136.

Rawson, P. F. (Compiler) 1996. The Barremian Stage. *Bulletin de L'institut Royal des Sciences Naturelles de Belgique, Sciences De La Terre* **66**, 25-30.

Rawson, P. F., Hoedemaeker, Ph. J., Aguirre-Urreta, M. B., Avram, E., Ettachfini M., Kelly, S. R. A, Klein, J., Kotetishvili, E., Owen, H. G., Ropolo, P., Thomson, M. R. A., Wippich, M., Vasicek, Z. 1999. Report on the 4th International Workshop of the

Lower Cretaceous Cephalopod Team (IGCP-Project 362), *Scripta Geologica, Special Issue* **3**, 3-13.

Reboulet, S. 1995. L'évolution des ammonites du Valanginien-Hauterivien inférieur du basin Vocontien et de la plateforme provencale (sud-est de la France): relations avec la stratigraphie séquentielle et implications biostratigraphiques. *Documentes des Laboratoires de Géologie de la Faculté des Sciences de Lyon* **137**, 1-371.

Reboulet, S. and Atrops, F. 1997. Quantitative variations in the Valanginian ammonite fauna of the Vocontian Basin (south eastern France) within limestone-marl cycles and within parasequence sets. *Palaeogeography, Palaeoclimatology, Palaeoecology* **135**, 145-155.

Renngarten, V. 1926. La fauna des dépots crétacés de la region d' Assa-Kamileevka, Caucase de Nord. *Trudy Geologischeskogo Komiteta* **147**, 1-132.

Renz, O. 1982. *The Cretaceous ammonites of Venezuela.* 132 pp. Birkhäuser Verlag Basal.

Reyment, R. A. 1970. Vertically inbedded cephalopod shells. Some factors in the distribution of fossil Cephalopods, 2. *Palaeogeography, Palaeoclimatology, Palaeoecology* **7**, 103-111.

Reyment, R. A. 1980. Floating orientations of cephalopod shell models. *Palaeontology* **23**, 931-936.

Riedel, L. 1937. Amonitas del Cretácico inferior de la Cordillera Oriental. *Estudios Geológicos y Paleontológicos sobre la Cordillera Oriental de Colombia*, Parte Segunda, 7-78.

Roch, E. 1927. Etude stratigraphique et paléontologique de l'Aptien inférieur de la Bédoule (Bouches-du-Rhone). *Memoires de la Societé Géologique France* (N.S.) **4**, 1-37.

Roch, E. 1930. *Etudes géologiques dans la région méridionale du Maroc occidental.* Service des Mines et de la Carte Géologia. 542 pp., Paris.

Roman, F. 1938. *Les ammonites jurassiques et crétacées, Essai de genera.* Masson, 554 pp. Paris.

Ropolo, P., Cecca, F. and Gonnet R. 1998 (2000). The stratigraphic position of *Ammonites consobrinus* D'Orbigny (Deshayesitidae, Ammonoidea) in the Lower Aptian of Cassis-La Bedoule (SE France). *Géologie Mediterranéenne* **25**, 159-165.

Ropolo, P., Gonnet R., Conte G. 1999. The '*Pseudocrioceras* interval' and adjacent beds at la Bèdoule (SE France): implications to highest Barremian/lowest Aptian biostratigraphy. *Scripta Geologica, Special Issue* 3, 159-213.

Rouchadzé, J. 1933. Les ammonites aptiennes de la Géorgie occidentale. *Bulletin de l'Institute Géologique de Georgia* 1, 165-273.

Rouchadzé, J., 1938. Céphalopodes nouveaux ou peu connus de l'Aptien de Géorgie. *Bulletin de l'Institute Géologique de Georgia* 3, 129-191.

Royo Y Gomez, J. 1945. Fosiles del Barremiense Colombiano. *Compilacion de los Estudios Geologicos Oficiales en Colombia* 6, 459-494.

Ruffell, A., and Rawson, P. F. 1994. Palaeoclimatic control on sequence stratigraphic patterns in the Late Jurassic to mid Cretaceous, with a case study from Eastern England. *Palaeogeography, Palaeoclimatology, Palaeoecology* **110**, 43-54.

Ruttner, A. W. 1984. The pre-Liassic basement of the eastern Kopet Dagh Range. *Neues Jahrbuch für Geologie und Palaeontologie Abhandlungen* **168**, 256-268.

Ruttner, A. W. 1991. Geology of Aghdarband area (Kopet Dagh, NE-Iran). *Abhandlugen der Geologischen Bundesanstalt A* 38, 7-79.

Ruttner, A. W. 1993. Southern borderland of Triassic Laurasia in Northeast Iran. *Geologische Rundschau* 82, 110-120.

Saks, V. N., Shulgina, N. I. and Sazonova, I. G. 1975. Paleogeographic Survey. In *The Jurassic-Cretaceous boundary and the Berriasian Stage in the Boreal Realm* (ed. Saks, V. N.), pp. 286-305, Israel Program for Scientific Translations, Jerusalem.

Sarasin, Ch. 1893. Etude sur les *Oppelia* du groupe du nisus et les *Sonneratia* du groupe du *bicurvatus* et du *raresulcatus*. *Bulletin de la Societé Géologique de France* (3) **21**, 149-164.

Saveliev, A. A. 1973. Lower Albian stratigraphy and ammonites of the Mangyshlak (*Leymeriella tardefurcata* and *Leymeriella regularis* zones). *Trudy Vsesoyuznogo Nauchno-Issledovatelskogo Geologo-Razvedochnogo Instituta* **323**, 1-340. [In Russian]

Saveliev, A. A. 1992. *Lower Albian ammonites of Mangyshlak, their phylogeny and importance for Albian zonal stratigraphy of South of the USSR* (*Cleoniceras mangyschlakense* Superzone), 223 pp., Nedra, Saint Petersburg. [in Russian]

Schindewolf, O. H. 1966. Studien zur Stammesgeschichte der Ammoniten. *Abhandlugen der Akademie Wissenschaften und Literatur in Mainz, Mathematisch-naturwissenschaftliche Klasse* 8, 643-730.

Schindewolf, O. H. 1968. Analyse eines Ammoniten-Gehäuses. Abhandlugen der Akademie Wissenschaften und Literatur in Mainz, Mathematisch-naturwissenschaftliche Klasse **8**, 135-188.

Scott. G. 1940a. Cephalopods from the Cretaceous Trinity Group of the south-central United States. *University of Texas Publication* **3945**, 969-1106.

Scott. G. 1940b. Paleoecological factors controlling the distribution and mode of life of Cretaceous ammonoids in Texas area. *Bulletin of American Association Petroleum Geologists* **24**, 1164-1203.

Sengor, A. M. C. 1990. A new model for the late Palaeozoic-Mesozoic tectonic evolution of Iran and implications for Oman. In *The Geology and Tectonics of the Oman region* (eds Robertson A. H. F., Searle M. P. & Ries A. C.), Special Publication of Geological Society of London 49, pp. 797-831, London.

Seunes, J. 1887. Sur quelques ammonites du Gault. *Bulletin de la Societé Géologique de France* (3) **15**, 557-571.

Seyed-Emami, K. 1980. Parahoplitidae (Ammonoidea) aus dem Nordost und Zentraliran. *Neues Jahrbuch für Geologie und Paläeontologie Monatsheftte* **1980**, 719-737.

Seyed-Emami, K. 1997. Stratigraphy, paleobiogeography and paleogeography of the Middle Cretaceous strata (Barremian-Albian) in central Iran. *Geoscience* **6** (21-22), 50-69. [Geological Survey of Iran, English abstract]

Seyed-Emami, K. and Alavi Naini, M. 1990. Bajocian Stage in Iran. *Memorie Descrittive della Carta Geologica D'Italia* **40**, 215-222.

Seyed-Emami, K. and Aryai, A. A. 1981. Ammoniten aus dem unteren Cenoman von Nordostiran (Koppeh Dagh). *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und Historische Geologie* **21**, 23-39.

Seyed-Emami, K., Brants, A. and Bozorgnia, F. 1971. *Stratigraphy of the Cretaceous rocks southeast of Esfahan*. Geological Survey of Iran, Report **20**, pp. 5-40, Tehran, Iran.

Seyed-Emami, K., Forster, R. and Mojtahedi, A. 1984. Ammoniten aus dem mittleren Cenoman von Nordost-Iran (Koppeh-Dagh). *Neues Jahrbuch für Geologie und Paläontologie Monatsheftte* **1984**, 159-172.

Seyed-Emami, K. Immel, H. and Alavi Naini, M. 1993. Neue Leymeriellen (Kreide-Ammoniten aus dem tieferen Unteralb (*tardefurcata* zone) des nördlichen

Zentralirans. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* **187**, 325-343.

Seyed-Emami, K. and Immel, H. 1995. Ammoniten aus dem Alb (Kreide) von Shir-Kuh (N Yazd, Zentraliran). *Paläontologische Zeitschrift* **69**, 377-399.

Seyed-Emami, K., and Immel, H., 1996. Ammoniten aus dem Alb (Höhere Unterkreide) des Zentraliran, *Palaeontographica Abteilung A* **241**, 1-26

Seyed-Emami, K., Schairer, G. and Behroozi, A. 1994. Einige ammoniten aus der Kashaf Rud Formation (Mittlerer Jura) E Mashhad (NE-Iran). *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und Historische Geologie* **34**, 145-158.

Seyed-Emami, K., Schairer, G. and Behroozi, A. 1996. Ammoniten aus dem Oberen Bajoc (Mittlerer Jura) des SE-Koppeh Dagh und SE-Alborz (NE-Iran). *Mitteilungen der Bayerischen Staatssammlung für Paläeontologie und Historische Geologie* **36**, 87-106.

Shulgina, N. I. 1996. Biostratigraphic chart for the Lower Cretaceous of the central and eastern European (Russian) Platform. *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universitat Hamburg* **77**, 89-93. (Proceedings of the 4th International Cretaceous Symposium, Hamburg 1992).

Simoniescu, I. 1898. Studii geologice si paleontogice din Carpatii Sudicii, II, Fauna neocomiana din basenul Dimbovicioarei. *Academia Romana, Publicatiunile Fondului Vasilie Adamachi* **2**, 101-167.

Simonovich, S., Bastevich, L. and Sorokin, A. 1875. Description of geology of the Kutaiski region. *Materialy dlya Geologichskago Gruzinskoi* **5**, 91-160. Tiflis. [In Russian]

Sinzow, I. 1898. *Bemerkungen über einige Ammoniten des Aptien.* 16 pp. Odessa.

Sinzow, I. 1905. Über eingie evolute Ammonitiden-Formen aus dem oberen Neokom Russlands. *Materialien zur Geologie Russlands* **22**, 291-348.

Sinzow, I. 1907. Untersuchung einiger Ammonitiden aus dem unteren Gault Mangyschlaks und des Kaukasus. *Verhandlugen der Russisch-Kaiserlichen Mineralogischen Geselschaft* **45**, 455-521.

Sinzow, I. 1909. Beiträge zur Kenntniss des sudrussischen Aptien und Albian. *Verhandlugen der Russisch-Kaiserlichen Mineralogischen Geselschaft* **47**, 1-48.

Soffel, H. C. and Forster, H. G. 1984. Polar wander path of the Central-East-Iran Microplate including new results. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* **168**, 165-172.

Sohl, N. F. 1969. North American Cretaceous biotic provinces delineated by gastropods. In *Proceedings North American Paleontologic Convention II*, pp. 1610-1637. Allen Press Lawrence, Kansas.

Sowerby, J. de C. 1820. *The mineral conchology of Great Britain*, 3, Plates 272-306.

Spath, L. F. 1922. On Cretaceous Ammonoidea from Angola, collected by Prof. J. W. Gregory, D. Sc., F. R. S. *Transactions of the Royal Society of Edinburgh* **53**, 91-160.

Spath, L. F. 1923-43. *A monograph of the Ammonoidea of the Gault.* 787 pp. 1-72 (1923); 73-110 (1925a); 111-146 (1925b); 147-186 (1926); 187-206 (1927a); 207-266 (1928); 267-311 (1930a); 313-378 (1931); 379-410 (1932); 411-442 (1933); 443-496 (1934); 497-450 (1937); 541 (1939a); 609-668 (1941); 669-720 (1942); 721-287 (1943) (Palaeontographical Society Monograph).

Spath, L. F. 1924. On the ammonites of the Speeton Clay and the subdivisions of the Neocomian. *Geological Magazine* **61**, 73-89.

Spath, L. F. 1929. Correction of cephalopod nomenclature. *Naturalist* **871**, 269-71.

Spath, L. F. 1930b. On some Ammonoidea of the Lower Greensand. *Annals and Magazine of Natural History* **5**, 417-464.

Spath, L. F. 1939b. Problems of ammonite nomenclature. On *Ammonites jacobi* (Collet) and the *jacobi* Zone of the Folkestone Sands. *Geological Magazine* **76**, 236-239.

Stoyanow, A. 1949. Lower Cretaceous stratigraphy in southeastern Arizona. *Geological Society of America Memoir* **38**, 1-170.

Stevens, G. R. 1973. Cretaceous Belemnites. In *Atlas of Palaeobiogeography* (ed. Hallam, A.), pp. 385-401. Elsevier Scientific Publishing Company, Amsterdam.

Stocklin, J. 1977. Structural correlation of the Alpine ranges between Iran and Central Asia. *Memoire Horse Serie Sociètè Gèologique de France* **8**, 333-353.

Stoyanow, A. 1949. Lower Cretaceous stratigraphy in south eastern Arizona. *Geological Society of America, Memoir* **38**, 169 pp.

Suess, E.1906. *The face of the earth.* Volume 2, Clarendon Press, Oxford.

Swinnerton, H. H. 1935. The rocks below the Red Chalk of Lincolnshire and their cephalopod faunas. *Quarterly Journal of the Geological Society* **91**, 1-46.

Szives, O. 1999. Ammonite biostratigraphy of the Tata Limestone Formation (Aptian-Lower Albian), Hungary. *Acta Geologica Hungarica*, **42**, 401-411.

Tanabe, K. 1979. Palaeoecological analysis of ammonoid assemblages in the Turonian Scaphites facies of Hokkaido, Japan. *Palaeontology* **22**, 609-630.

Tanabe, K., Obata, I. and Futakami, M. 1978. Analysis of ammonoid assemblages in the Upper Turonian of the Manji area, Central Hokkaido. *Bulletin of the National Science Museum*, Tokyo, Series C (Geology) **4**, 37-63.

Taylor, B. J. 1972. Stratigraphical correlation in south-east Alexander Island. In *Antarctic Geology and Geophysics* (ed. Adie, R.), pp. 149-153, Universitetsforlaget, Oslo.

Teichert, C., Kummel, B., Sweet, W. C., Stenzel, H. B., Furnish, W. M., Glenister, B. F., Erben, H. K., Moore, R. C. and Zeller, D. E. N. 1964. *Treatise on Invertebrate Paleontology* (ed. Moore, R. C.) *Part K, Mollusca 3, Cephalopoda General features, Endoceratoidea, Actinoceratoidea, Nautiloidea, Bactritoidea.* pp. K1-K520, The Geological Society of America and University Kansas Press, New York and Lawrence.

Thomson, M. R. 1974. Ammonite faunas from the Lower Cretaceous of south-eastern Alexander Island. *British Antarctica Survey Scientific Report* **80**, 1-44.

Tietze, E. 1872. Geologische und paleontologische Mittheilungen aus dem südlichen theil des Banater Gebirgsstockes. *Jahrbuch Kaiserlich-Königlichen Geologischen Reichsantalt* **22**, 35-142.

Tovbina, S. Z. 1963. On the Upper Barremian ammonites of Turkmenia. *Trudy Vsesoyuznogo Nauchno Issledovatelskogo Geologischeskogo Instituta* **109**, 98-119. [In Russian]

Tovbina, S. Z. 1965. The ontogeny of ammonites of the genus *Colchidites*. *Paleontologicheskiy Zhurnal* **3**, 40-48. [In Russian]

Tovbina, S. Z. 1968. About the Zone *Acanthohoplites prodromus* in the Aptian-Albian boundary beds of Turkmenia. *Izvestiya Akademya Turkmmenoski SSR, seriya Physico Technicheskogo, Chemicheskogo and Geologicheskogo Nauk* **2**, 100-109. [In Russian]

Tovbina, S. Z. 1979. On systematic and phylogeny of the Family Parahoplitidae. In *The stratigraphy of the Lower Cretaceous deposits of the oil-gas bearing regions of the USSR*, (eds Mesezhnikov, M. S. and Kirichovka, A. I.), pp.109-122. Moscow [In Russian]

Tovbina, S. Z. 1980. On the Zone *Acanthohoplites prodromus* of the Upper Aptian of Turkmenia. *Izvestiya Akademya Nauk SSSR, seriya Geologiskaya* **7**, 142-144. [In Russian]

Tsujita, C. J. and Westermann, G. E. G. 1998. Ammonoid habitats and habits in the Western Interior Seaway: a case study from the Upper Cretaceous Bearpaw Formation of southern Alberta, Canada. *Palaeogeography, Palaeoclimatology, Palaeoecology* **144**, 135-160.

Uhlig, V. 1883. Die Cephalopoden-fauna der Wernsdorfer Schichten. *Denskschriften der Kaiserlichen Akademie der Wissenschaften Mathematisch-Naturwissenschaftliche Klasse Wien* **46** (2), 127-290.

Vail, P. R., Mitchum, R. M., Todd, R. G., Widmier, J. M., Thompson, S., Sangree, J. B., Bubb, J. N. and Hatlelid, W. G. 1977. Seismic stratigraphy and global changes of sea level. *American Association of Petroleum Geologists, Memoir* **26**, 49-212.

Vakhrameev, V. A. 1975. Main feature of phytogeography of the globe in Jurassic and Early Cretaceous time. *Paleontological Journal* **9**, 247-255.

Vakhrameev V. A. 1987. Cretaceous palaeogeography of the U.S.S.R. *Palaeogeography, Palaeoclimatology, Palaeoecology* **59**, 57-67.

Vasicek, Z. 1995. Aptian and Albian ammonites in the western Carpathians (the Czech and Slovak Republics). *Memorie Descrittive della Carta Geologica D'Italia* **51**, 167-171.

Vasicek, Z. Michalik, J. and Borza, K. 1983. To the "Neocomian" biostratigraphy in the Krizna-Nappe of the Strazovske Vrchy Mountains (northwestern Central Carpathians). *Zitteliana* **10**, 467-483.

Vasicek, Z. and Rakus, M. 1995. Lower Aptian ammonites from the Medziholie locality (The Malá Fatra Mountains, Slovakia). *Memorie Descrittive della Carta Geologica D'Italia* **51**, 173-183.

Vermeulen, J. 1996. Nouvelle biozonation du Barrémien basée sur la famille de pulchelliidae (Ammonoidea). *Géologie Alpine* **71**, 199-221.

Van Wagoner, J. C. V., Posamentier, H. W., Mitchum, R. M., Vail, P. R., Sarg, J. F., Loutit, T.S. and Hardenbol, J. 1988. An overview of the fundamentals of sequence stratigraphy and key definitions. In *Sea-level changes-An integrated approach*, (eds Wilgus, C. K., Hastings, B. S., Kendall, C. G. St., Posamentier, H. W., Ross, C. A. & Van Wagoner, J. C.), Society of Economic Palaeontologists and Mineralogists, Special Publication 42, 35-45.

Ward, P. D. 1976. *Stratigraphy, paleoecology and functional morphology of heteromorph ammonites in the Upper Cretaceous Nanaimo Group, British Columbia and Washington.* Unpublished PhD. thesis, Dept. of Geology, McMaster University, Hamilton, Ontario, Canada.

Ward, P. D. 1980. Comparative shell shape distribution in Jurassic-Cretaceous ammonites and Jurassic-Tertiary nautilids. *Paleobiology* **6**, 32-43.

Ward, P. D. and Westermann, G. E. G. 1977. First occurrence, systematics and functional morphology of *Nipponites* from the Americas. *Journal of Paleontology*, **51**, 367-372.

Warren, P. S. 1937. An Aptian horizon in the Cretaceous of the Lower Mackenzie Valley. *Journal of Paleontology* 11, 69-72.

Westermann, G. E. G. 1977. Form and function of orthoconic cephalopod shells with concave septa. *Paleobiology* **3**, 300-321.

Westermann G. E. G. 1990. New development in ecology of Jurassic-Cretaceous ammonoids. In *Fossili Evolutione, Ambiente,* Atti II Convention International Pergola 1987 (eds Pallini, G., Cecca, F., Cresta, S. & Santantonio M.), pp. 459-478, Tecnostampa, Ostra Vetere, Italy.

Westermann, G. E. G. 1996. Ammonoid Life and Habitat. In *Ammonoid palaeobiogeography,* (eds Neil, H. L., Kazushige, T. & Richard, A. D.), Topics in Geobiology, Volume 13, pp. 607-707. Plenum Press, New York.

Westermann, G. E. G. 2000a. Biochore classification and nomenclature in paleobiogeography: an attempt at order. *Palaeogeography, Palaeoclimatology, Palaeoecology* **158**, 1-13.

Westermann G. E. G. 2000b. Marine faunal realms of the Mesozoic: review and revision under the new guidelines for biogeographic classification and nomenclature. *Palaeogeography, Palaeoclimatology, Palaeoecology* **158**, 49-68.

Wiedmann, J. 1962. Unterkreide-Ammoniten von Mallorca. 1. Lieferung Lytoceratina, Aptychi. *Abhandlugen der Akademie Wissenschaften und Literatur in Mainz, Mathematisch-naturwissenschaftliche Klasse* **1962**, 1-148.

Wiedmann, J. 1966. Stammesgeschichte und System der posttriadischen Ammonoideen, ein überblick. *Neues Jahrbuch für Geologie und Paläeontologie Abhandlungen* part 1, **125**, 49-79; part 2, **127**, 13-81.

Wiedmann, J. 1969. The heteromorphs and ammonoid extinction. *Biological Reviews* **44**, 563-602.

Wiedmann, J. 1988. Plate tectonic, sea level changes, climate - and relationship to ammonite evolution, provincialism and mode of life. In *Cephalopods-Present and Past, Second International Cephalopods symposium* (eds Wiedmann J. & Kullmann, J.), pp. 757-765, Schweizerbart'sch Verlagsbuchhanlung, Stuttgart.

Wiedmann, J. and Deini, I. 1968. Die Kreide Sardiniens und ihre Cephalopoden. *Palaeontographia Italica* (New Series 34), **64**, 1-171

Whitehouse, F. W. 1926. The Cretaceous Ammonoidea of Eastern Australia. *Memoirs of the Queensland Museum* **8** (3), 195-242.

Wright, C. W. 1953. Notes on Cretaceous ammonites, Scaphitidae. *Annals and Magazine of Natural History* **12**, 473-476.

Wright, C. W. 1956. Recitification of nomenculture- Raspailiceras nom. Nov. *Proceedings of the Geological Society of London* **1535**, 73-74.

Wright, C. W. 1981. Cretaceous Ammonoidea. In *The Ammonoidea: The evolution, classification, mode of life and geological usefulness of a major group* (House, M. R. & Senior, J. R., Eds.), Systematics Association, Special Volume 18, pp. 157-174, Academic Press, London.

Wright, C. W., Callomon, J. H. and Howarth, M. K. 1996. *Treatise on Invertebrate Palaeontology* (ed. Kaesler, R.) *Part L, Mollusca 4,* (*Revised*) *Cretaceous Ammonoidea*. 362 pp., The Geological Society of America and the University of Kansas, Boulder, Colorado, and Lawrence, Kansas.

Young, K. 1974. Lower Albian and Aptian (Cretaceous) ammonites of Texas. *Geoscience and Man* **8**, 175-228.

Zahedi, M. 1973. *Etude géologique de la region de Soh* (*W de l'Iran Central*). Geological Survey Iran, Report 27, 1-197, Tehran.

Ziegler, B. 1963. Die fauna der Lemis-Schichten (Dalmatien) und ihre Bedeutung fur den mediterranean oberjura. *Neues Jahrbuch für Geologie und Paläontologie, Monatsheft* **8**, 405- 421.

Ziegler, B. 1967. Ammoniten-Öklologie am beispiel des Oberjura. *Geologische Rundschau* **56**, 439-464.

Plates

Plate 1

Figure 1- *Phylloceras* sp., Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 50/ 5.

Figure 2- *Phyllopachyceras* sp., Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 53/ 2.

Figure 3- *Eogaudryceras* (*Eogaudryceras*) sp., Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TAK 36/ 9.

Figure 4- *Eogaudryceras* (*Eotetragonites*) sp., Sarcheshmeh Formation, Lower Aptian, Raz section, Sample no. Raz 9/ 1.

Figure 5- *Aconeceras haugi*, Sanganeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 39.

Figures 6, 7- *Pseudosaynella* sp., Sanganeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 65.

Figure 8- *Barremites* cf. *difficilis*, Sarcheshmeh Formation, Upper Barremian, Amand section, Sample no. Am 9/1.

Figure 9- *Melchiorites* aff. *melchioris*, Sanganeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 66.

Figure 10- *Pedioceras* cf. *anthulai*, Sanganeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 51/1/.

Figure 11- *Pedioceras* cf. *anthulai* Sarcheshmeh Formation, Lower Aptian, Sheykh section, Sample no. SH 13/ 4.

Plate-1

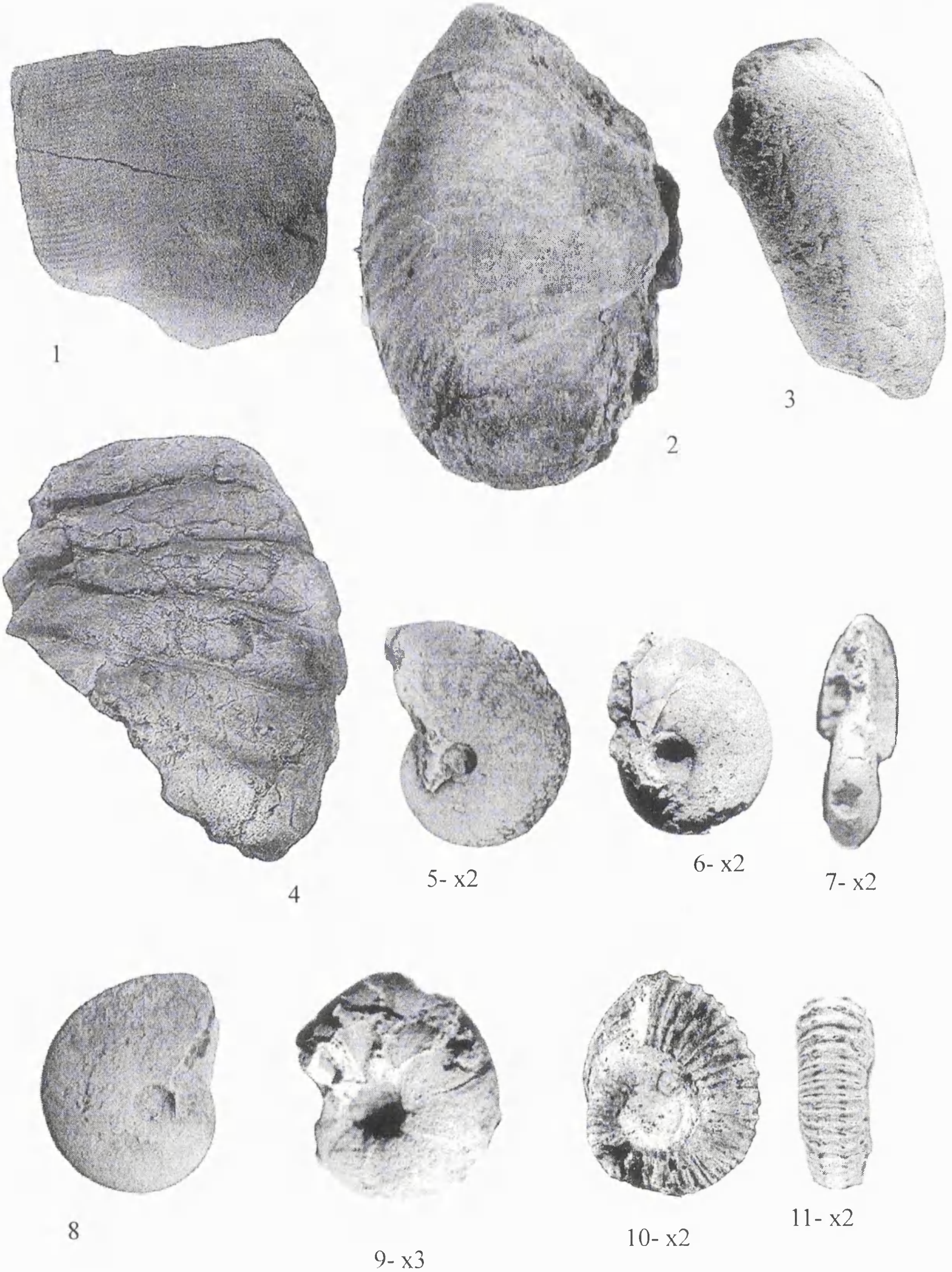


Plate 2

Figure 1- *Australiceras* sp., Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 36/ 24.

Figure 2- *Ancyloceras* cf. *mantelli*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 28.

Figure 3- *Tonohamites* sp., Sanganeh Formation, Lower Aptian, Takal Kuh section (2), TAK 37.

Figure 4- *Pedioceras* sp., Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 25/ 1.

Figures 5, 6- *Toxoceratoides* sp., Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (1), Sample no. TK 16.

Plate-2

Plate 3

Figures 1, 2, 3- *Heteroceras* cf. *colchicus*, Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (2), Sample no. TAK 7/ 1 & TAK 6/ 1; Takal Kuh section (1), Sample no. TK 14-15/ 6

Figure 4- *Heteroceras* sp., Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (1), Sample no. TK 14-15/ 1.

Figures 5, 6- *Argvethites* sp., Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (1), Sample no. TK 14-15/ 15; Takal Kuh section (2), TAK 6/ 10.

Figure 7- *Argvethites* sp., Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 6/2.

Figure 8- *Imerites sparcicostatus*, Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (1), Sample no. TK 4/ 1.

Figure 9- *Paraimerites* sp., Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (1), Sample no. TK 14-15/ 3.

Figures 10, 11- *Martelites* cf. *tenuicostatus*, Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (1), Sample no. TK 18/ 4; Amand section, sample no. Am 2/ 2.

Figures 12, 13- *Martelites securiformis*, Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (2), Sample no. TAK 12/ 4; Takal Kuh section (2), Sample no. TAK 12/ 8.

Figures 14, 15- *Martelites* cf. *tinae*, Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (1), Sample no. TK 18-20/ pocket 2; Amand section, Sample no. Am 1/ 6.

Figure 16- *Martelites* sp. 2, Sarcheshmeh Formation, Upper Barremian, Amand section, Sample no. Am 1/ 4.

Figure 17- *Martelites* sp. 1, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 9/ 2.

Figures 18, 20- *C.* (*Cheloniceras*) sp., Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 32/ 6, Sample no. TAK 36/ 1.

Figure 19- *C.* (*Cheloniceras*) sp., Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 58/ 11.

Figure 21- *C.* (*Epicheloniceras*) sp., Sanganeh Formation, Middle Aptian, Sanganeh section, Sample no. Sn 21/ 3.

Plate-3

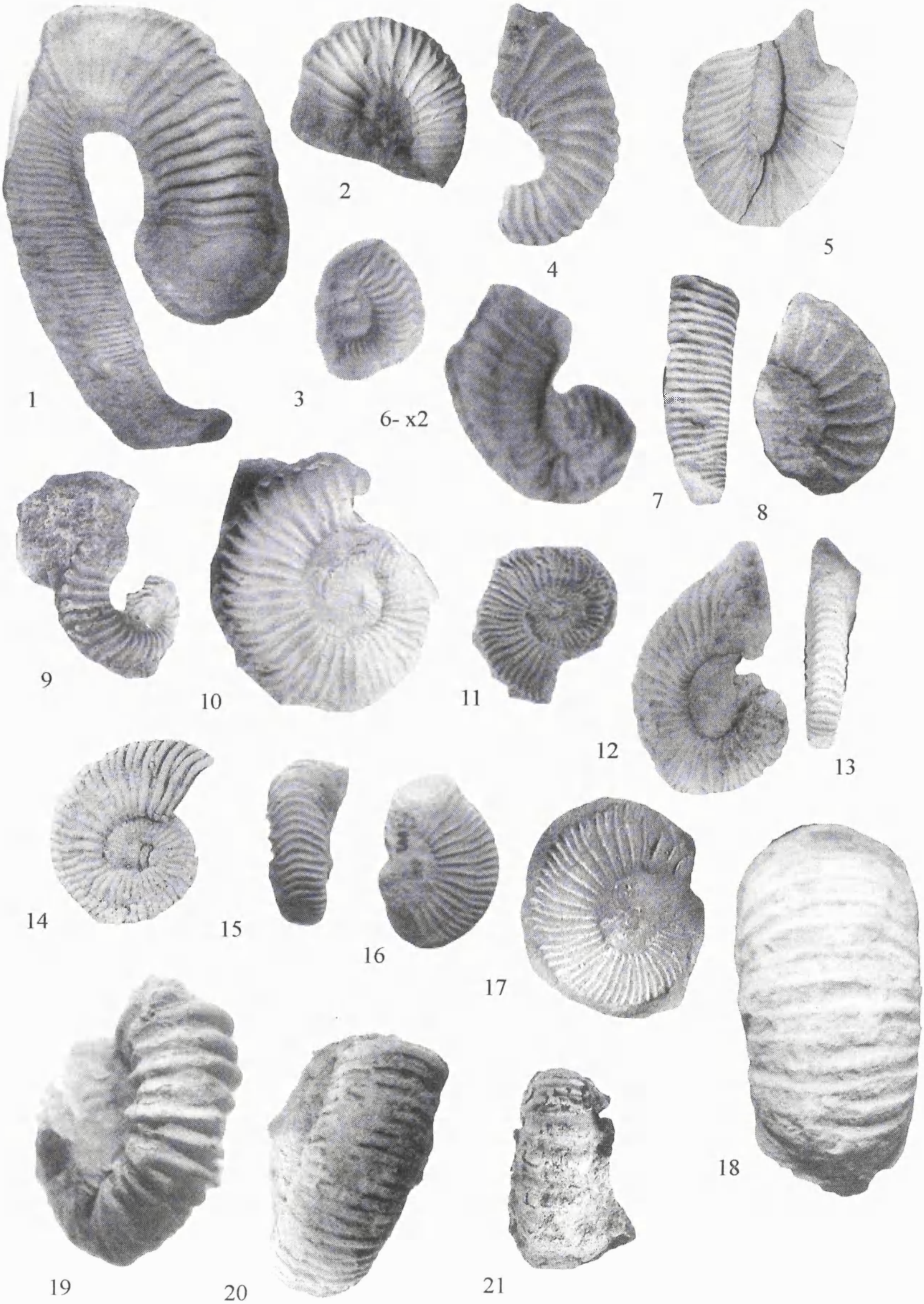


Plate 4

Figures 1, 5, 14a-c- *Turkmeniceras multicostatum*, Sarcheshmeh Formation, Upper Barremian, Amand section, Sample no. Am 10/ 1; Amand section, Sample no. Am 10/ 13; Amand section, Sample no. Am 9/1.

Figures 2, 3, 4- *Turkmeniceras multicostatum*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 15/ 1; Takal Kuh section (2), Sample no. TAK 14/ 7; Takal Kuh section (2), Sample no. TAK 13/ 11.

Figures 6, 8- *Turkmeniceras* cf. *tumidum*, Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (1), Sample no. TK 21/ 1; Takal Kuh section (1), Sample no. TK 20/ 1.

Figure 7- *Turkmeniceras* cf. *tumidum*, Sarcheshmeh Formation, Upper Barremian, Takal Kuh section (2), Sample no. TAK 14/ 1.

Figure 9- *Deshayesites* cf. *tuarkyricus*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no TAK 18/ 1.

Figure 10- *Deshayesites oglanlensis*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 43/ 1.

Figure 11- *Deshayesites oglanlensis*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 48/ 18.

Figure 12, 15- *Deshayesites* cf. *weissiformis*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 17/ 1; Takal Kuh section (2), Sample no. TAK 18/ 2.

Figure 13- *Deshayesites* cf. *euglyphus*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 22/ 2.

Figure 16- *Deshayesites weissi*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 48/ 8.

Plate-4

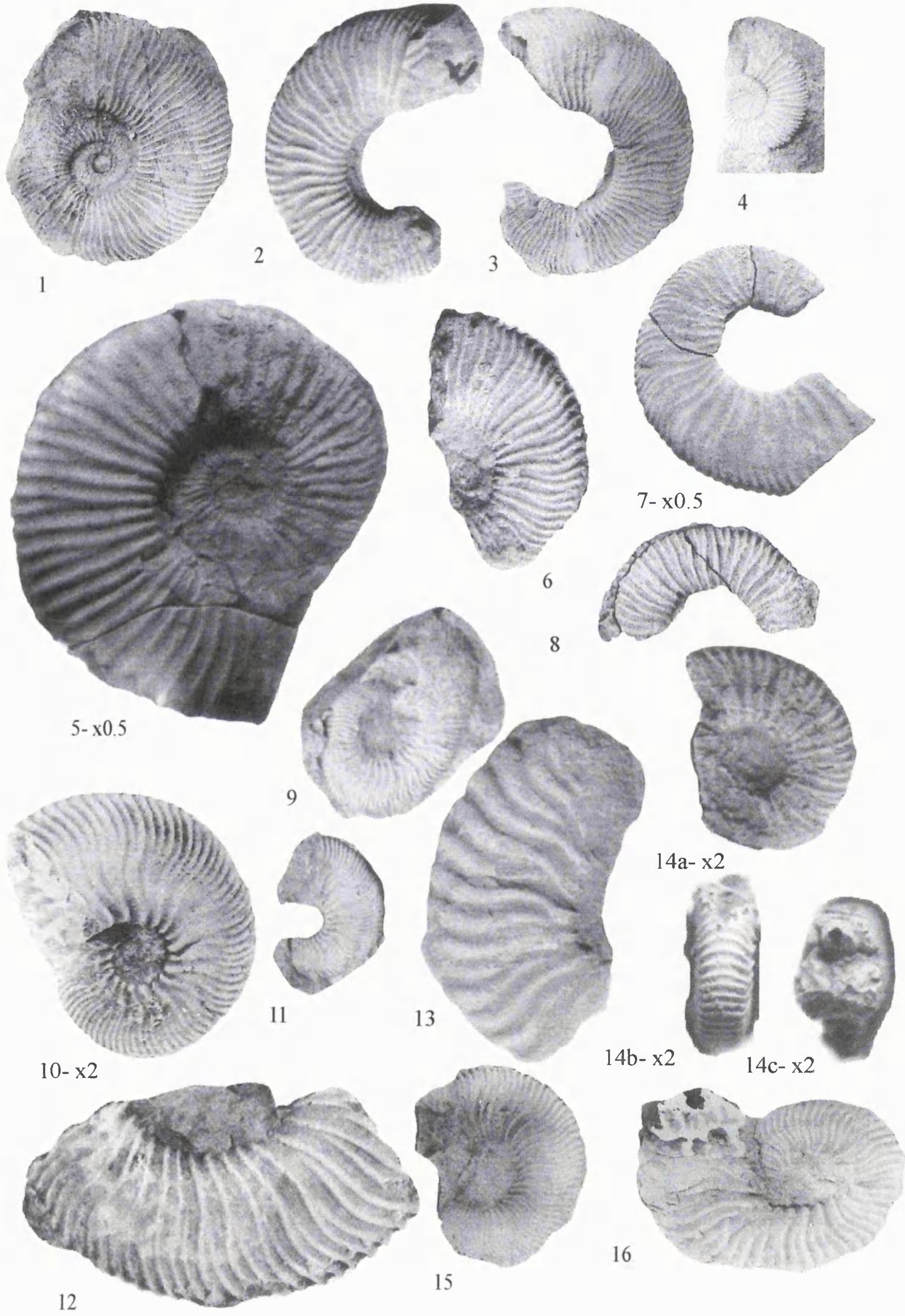


Plate 5

Figures 1, 2- *Deshayesites luppovi*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 45/ 2.

Figure 3- *Deshayesites luppovi*, Sarcheshmeh Formation, Lower Aptian, Amand section, Sample no. Am 16/ 3.

Figure 4- *Deshayesites dechyi*, Sarcheshmeh Formation, Lower Aptian, Amand section, Sample no. Am 17/ 2.

Figure 5- *Deshayesites dechyi*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 46/ 12.

Figure 6- *Deshayesites dechyi*, Sarcheshmeh Formation, Lower Aptian, Amand section, Sample no. Am 16/ 1.

Figures 7, 8- *Deshayesites* cf. *consobrinoides*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 36/ 20.

Plate-5

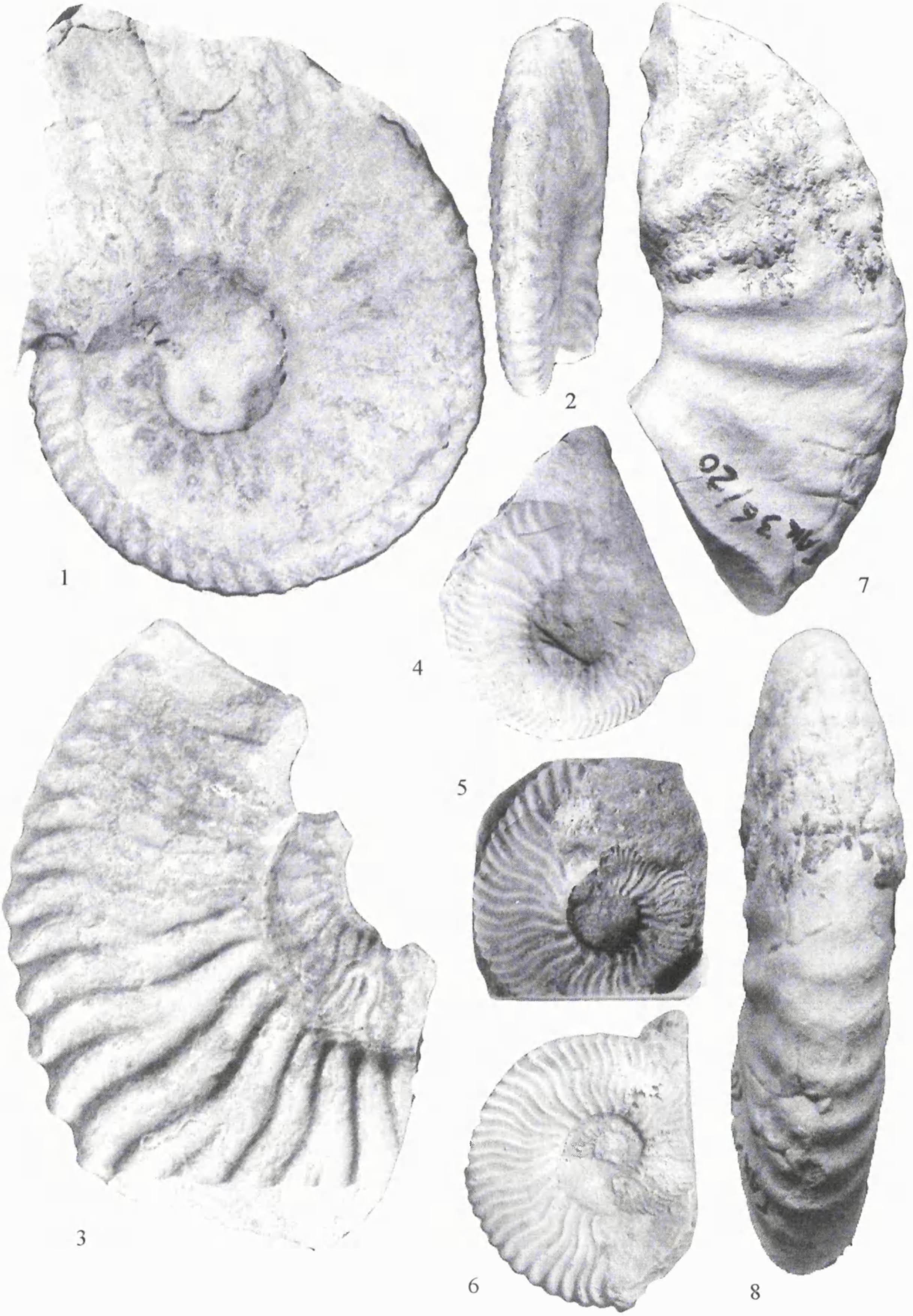


Plate 6

Figure 1- *Deshayesites* cf. *involutus*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 58/ 8.

Figure 2- *Deshayesites* cf. *involutus*, Sarcheshmeh Formation, Lower Aptian, Amand section, Sample no. Am 21/ 4.

Figures 3, 4- *Deshayesites* cf. *involutus*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 58/ 2.

Figure 5- *Deshayesites* cf. *planus*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 54/ 2.

Figure 6- *Deshayesites* cf. *planus*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 29/ 4.

Figure 7- *Deshayesites* cf. *consobrinoides*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 51/ 4; Takal Kuh section (2), Sample no. TAK 36/ 18.

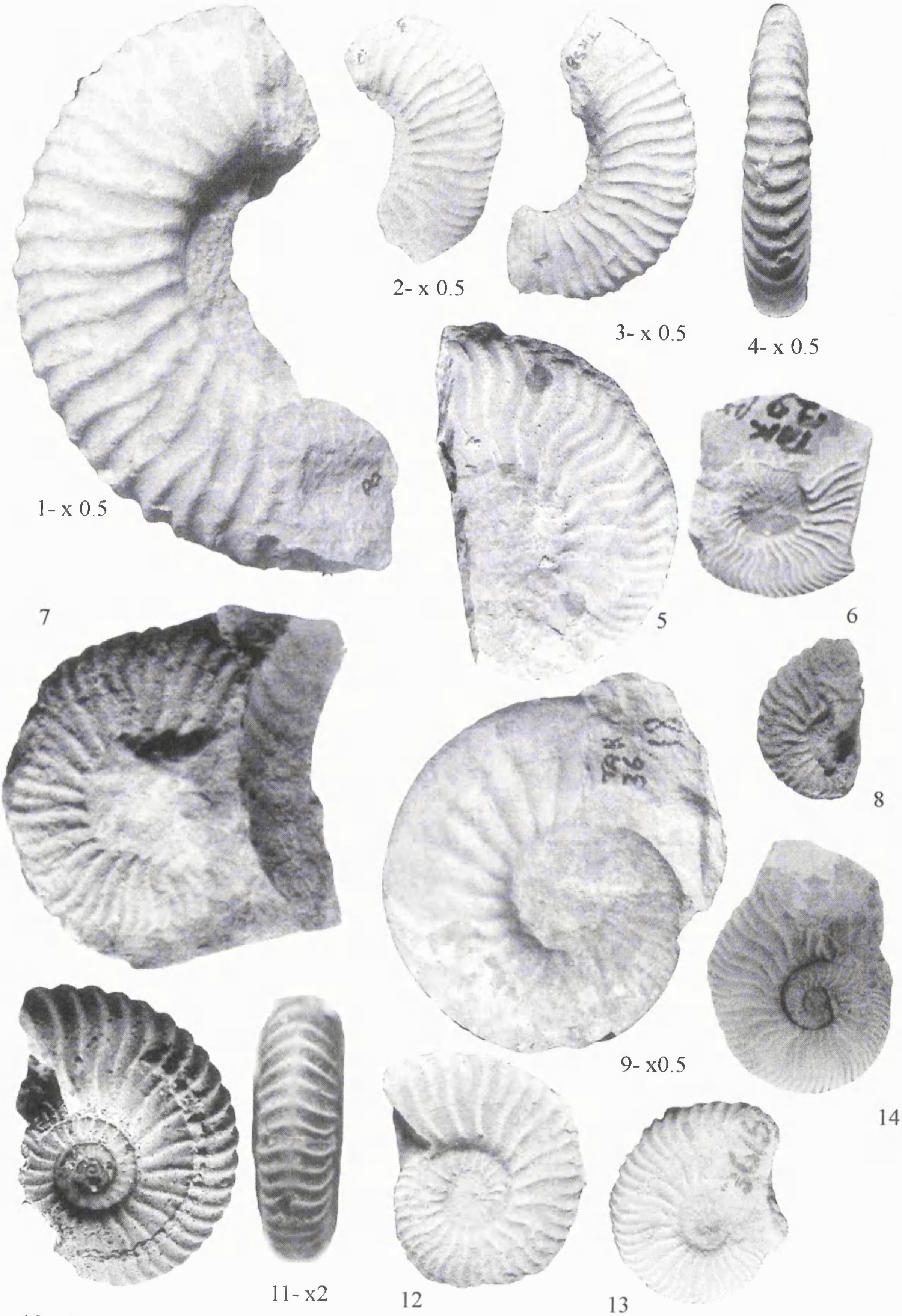
Figure 8- *Deshayesites* cf. *consobrinoides*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 82.

Figure 10, 11- *Deshayesites deshayesi*, Sanganeh Formation, Lower Aptian, Takal Kuh section, Sample no. TK 65.

Figures 12, 13- *Deshayesites deshayesi*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 36/ 8; Takal Kuh section (2), Sample no. TAK 36/ 5.

Figure 14- *Deshayesites luppovi*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 46/ 21.

Plate-6



1- x 0.5
2- x 0.5
3- x 0.5
4- x 0.5
5
6
7
8
9- x0.5
10- x2
11- x2
12
13
14

Plate 7

Figures 1, 2- *Deshayesites* cf. *involutus*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 63/ 1.

Figure 3- *Deshayesites* cf. *multicostatus*, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 51/ 5.

Figure 4- *Deshayesites* sp. 1, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 24/ 2.

Figure 5- *Deshayesites* sp. nov, Sanganeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 40.

Figure 6- *Deshayesites* sp. 3, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 64/ 1.

Figure 7- *Deshayesites* sp. 3, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 50/ 1.

Figure 8- *Deshayesites* sp., Sanganeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 51/ 3.

Figure 9- *Deshayesites* sp. 2, Sarcheshmeh Formation, Lower Aptian, Takal Kuh section (1), Sample no. TK 46/ 7.

Plate-7

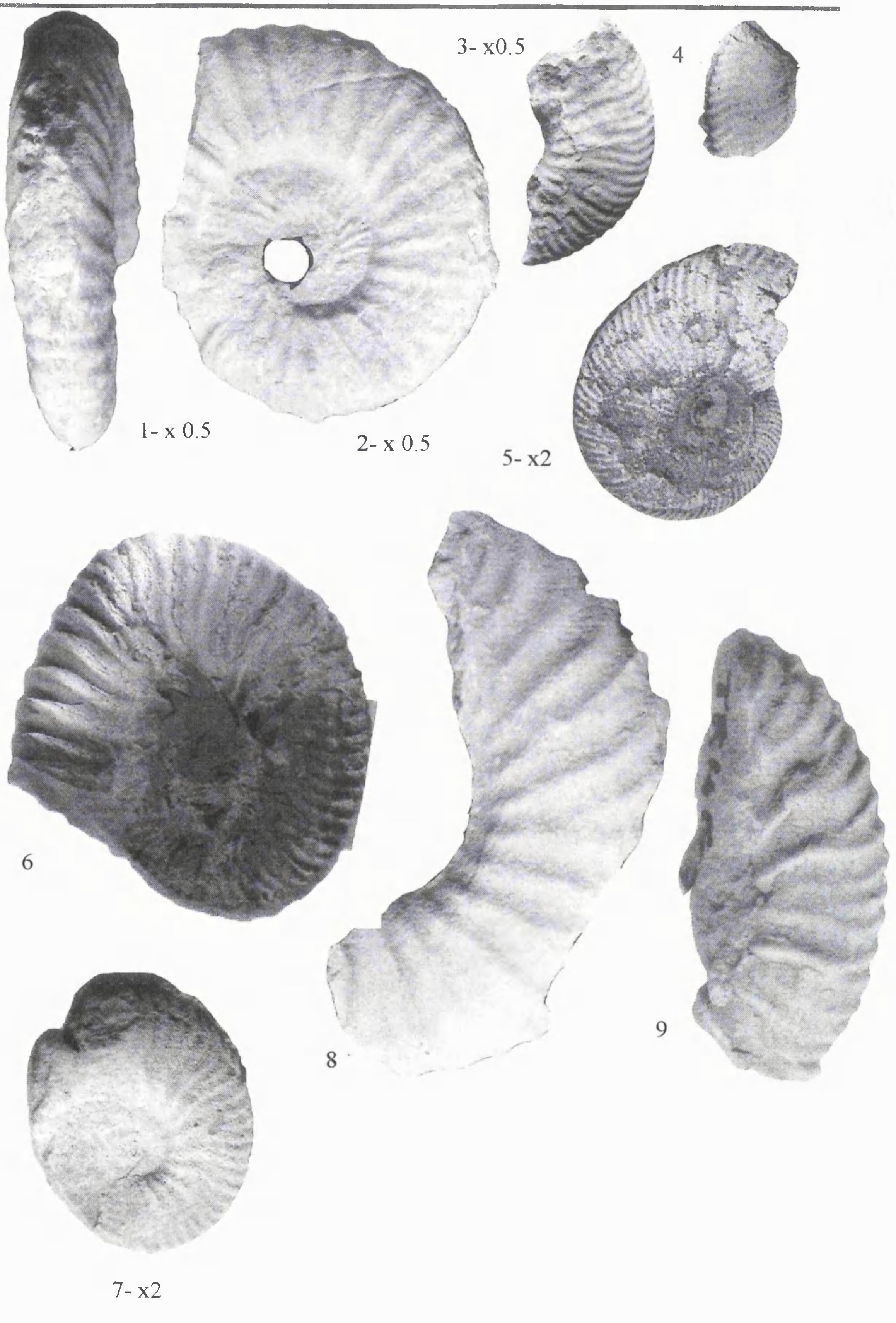


Plate 8

Figure 1- *Dufrenoyia* sp., Sarcheshmeh Formation, Lower Aptian, Raz section, Sample no. Raz 6/ 4.

Figure 2- *Dufrenoyia* sp., Sanganeh Formation, Lower Aptian, Ghorghoreh section, Sample no. Gho 12.

Figures 3, 4- *Dufrenoyia* sp., Sanganeh Formation, Lower Aptian, Takal Kuh section (2), Sample no. TAK 55; Takal Kuh section (1), Sample no. TK 71/ 6.

Figure 5- *Hypacanthoplites uhligi*, Sanganeh Formation, Upper Aptian, Sanganeh section, Sample no. Sn 25/ 2; Sanganeh section, Sample no. Sn 25/ 3.

Figure 6, 7- *Hypacanthoplites uhligi*, Sanganeh Formation, Upper Aptian-Lowermost Albian?, Bibahreh section, Sample no. Bib. 23/ 6; Bibahreh section, Sample no. Bib. 23/ 8.

Figure 9- *Hypacanthoplites* cf. *clavatus*, Sanganeh Formation, Upper Aptian, Bibahreh section, Sample no. Bib 23/ 21.

Figure 10- *Hypacanthoplites* cf. *clavatus*, Sanganeh Formation, Upper Aptian-Lowermost Albian?, Bibahreh section, Sample no. Bib 23/ 10.

Figure 11- *Hypacanthoplites* cf. *elegans*, Sanganeh Formation, Upper Aptian, Tirgan section, Sample no. Tr 24-26/ 15.

Figure 12- *Hypacanthoplites* cf. *elegans*, Sanganeh Formation, Upper Aptian, Tirgan section, Sample no. Tr 26-28/ 1.

Figure 13, 14, 14- *Hypacanthoplites* cf. *subrectangulatus*, Sanganeh Formation, Upper Aptian, Tirgan section, Sample no. Tr 24-26/12; Tirgan section, Sample no. Tr 24-26/ 4; Tirgan section, Sample no. Tr 26-28/ 2.

Figure 16- *Hypacanthoplites* sp., Sanganeh Formation, Lower Albian, Sanganeh section, Sample no. Sn 31.

Plate-8

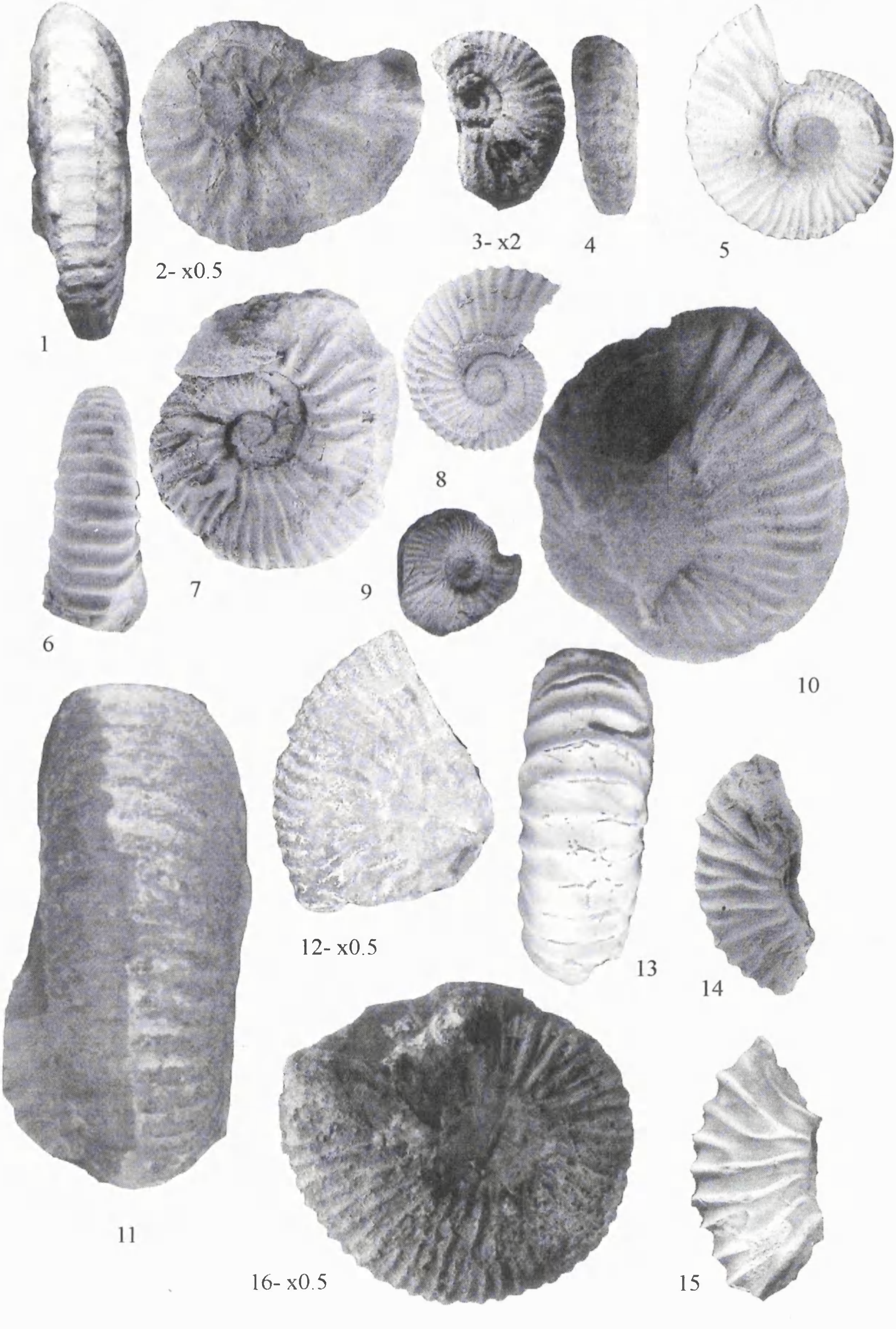


Plate 9

Figure 1- *Acanthohoplites* cf. *bigoureti*, Sanganeh Formation, Upper Aptian, Sanganeh section, Sample no. Sn 23/ 11.

Figure 2- *Acanthohoplites* cf. *bigoureti*, Sanganeh Formation, Upper Aptian, Sanganeh section, Upper Aptian, Sample no. Sn 23/ 14.

Figure 3- *Hypacanthoplites* cf. *anglicus*, Sanganeh Formation, Upper Aptian, Tirgan section, Sample no. Tr 38.

Figure 4- *Acanthohoplites* cf. *aschiltaensis*, Sanganeh Formation, Upper Aptian, Sanganeh section, Sample no. Sn 23/ 12.

Figure 5- *Acanthohoplites* sp. 1, Sanganeh Formation, Upper Aptian, Sanganeh section, Sample no. 21/ 12.

Figure 6a, b- *Acanthohoplites* sp. 2, Sanganeh Formation, Upper Aptian, Raz section, Sample no. Raz 10/ 1.

Figure 7- *Acanthohoplites* sp. 2, Sanganeh Formation, Upper Aptian, Raz section, Sample no. Raz 10/ 2.

Figure 8- *Colombiceras* sp., Sanganeh Formation, Upper Aptian, Sanganeh section, Sample no. Sn 21/ 1.

Figure 9- *Colombiceras* sp., Sanganeh Formation, Upper Aptian, Sanganeh section, Sample no. Sn 21/ 4.

Figure 10- *Acanthohoplites* sp., Sanganeh Formation, Upper Aptian, Tirgan section, Sample no. Tr 37.

Figure 11- *Acanthohoplites* spp., Sanganeh Formation, Upper Aptian, Bibahreh section, Sample no. Bib 21.

Plate-9

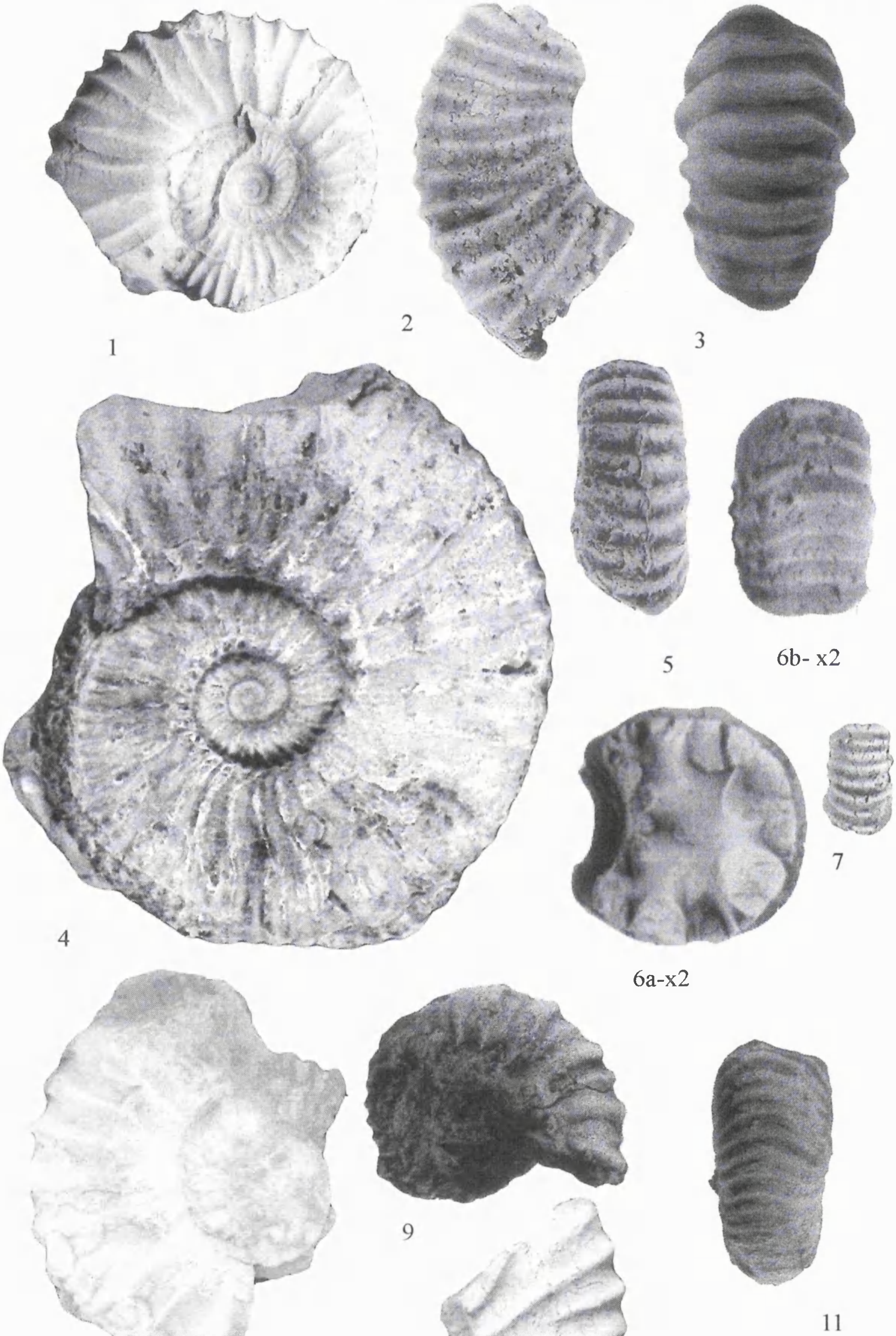


Plate 10

Figures 1, 2- *Parahoplites* cf. *campichii*, Sanganeh Formation, Middle Aptian, Sanganeh section, Sample no. Sn 21/ 10.

Figure 3- Cymatoceratidae, Sarcheshmeh Formation, Lower Aptian, Amand section, sample no. Am 21/ 6.

Figure 4- *Parahoplites* cf. *maximus*, Sanganeh Formation, Middle Aptian, Ghorghoreh section, Sample no. Gho 13.

Plate-10

1- x0.5

2- x0.5

3- x0.5

4