

THE GEOLOGY OF THE ALBULA PASS AREA,
EASTERN SWITZERLAND IN ITS TETHYAN SETTING:
PALAEO-TETHYAN FACTOR IN NEO-TETHYAN OPENING

"quot homines tot sententiae"

by

A. M. Celâl Şengör

A Dissertation

Submitted to the State University of New York at Albany

in partial fulfillment of

the requirements for the degree of

Doctor of Philosophy

College of Science and Mathematics

Department of Geological Sciences

1982

THE GEOLOGY OF THE ALBULA PASS AREA,
EASTERN SWITZERLAND IN ITS TETHYAN SETTING:
PALAEO-TETHYAN FACTOR IN NEO-TETHYAN OPENING

"quot homines tot sententiae"

by

A. M. Celâl Şengör

Abstract of a Dissertation

Submitted to the State University of New York at Albany

in Partial Fulfillment of

the Requirements for the Degree of

Doctor of Philosophy

College of Science and Mathematics

Department of Geological Sciences

1982

ABSTRACT

This study deals with the tectonic evolution of Tethys during the Mesozoic. A critical question concerning Tethyan geology is how far the Tethys ocean extended westwards in the Mediterranean region. Because this question can only be answered by studying in detail the opening history of the Alpine ocean, a critical area involving Triassic and Jurassic sediments was mapped in the Albula Pass area in eastern Switzerland. The mapping shows that the main rifting in the Alps took place during the Lias with a very weak extensional event during the medial Triassic. The record of these events is now found in the Lower and Middle Austroalpine units, which deformed through a complex sequence of events involving a hitherto unknown early south-vergent folding of the Middle Austroalpine Aela Nappe. The stratigraphic analysis undertaken during this study demands that the Aela Nappe be placed farther north than hitherto believed, near the Lower Austroalpine facies realm, mainly because of the demonstration that the typically Lower Austroalpine Alv Breccia also occurs in the Aela Nappe. In order to place the Jurassic and the Triassic rifting events into their appropriate tectonic settings, a regional tectonic synthesis of the Mediterranean Alpides was undertaken. This synthesis shows that the Triassic and Jurassic rifting events in the Alps was related to the opening of Neo-Tethys and to the opening of the Atlantic ocean respectively. Because only Jurassic rifting eventually led to generation of ocean-floor, the Alpine ocean and the Mesozoic-Cainozoic oceans west of it formed as parts of the Atlantic Ocean and are tectonically unrelated to Tethys. The two oceanic systems merged in the western Carpathians. Neo-Tethyan opening, which controlled the Triassic rifting events in

the Alps was controlled and was largely coeval with the closing of the Palaeo-Tethys, described in detail for the first time in this dissertation. The closure of Palaeo-Tethys generated an orogenic belt, extending from the Carpathians to the Pacific Ocean. It is herein named the Cimmerides and follows closely the later Alpides, products of Neo-Tethys, throughout southern Eurasia. This spatial association resulted in complex overprinting of the Cimmerides by the Alpides, which hindered the recognition of the former for nearly a century. The Cimmeride orogenic system was completed by the latest Jurassic with some late events during the early Cretaceous along the Great Khingan-Shitka suture in the Far East. An important result of this study is the recognition of the dominating effect of the Palaeo-Tethys on the tectonic evolution of the Mediterranean Alpides until the latest Triassic.

THIS THESIS IS DEDICATED TO THOSE WHO MADE IT AND ITS

AUTHOR POSSIBLE:

MY PARENTS

&

THE OTTOMAN IMPERIAL FAMILY

ACKNOWLEDGEMENTS

The research reported in this thesis began many years ago, much earlier than the start of my university education, when I first developed an interest in the evolution of Tethys in 1966 through the books that my parents had bought me. Since then a large number of individuals have assisted me in my quest for knowledge concerning both Tethys and other things. They are so many that it is impossible to acknowledge their individual contributions that made an evolution possible, which culminated in this dissertation. However, a number of them stand out such that their names must be mentioned in tones of respect and gratitude for without them I could not have existed as I now do!

Drs. Kevin C.A.Burke, John F. Dewey, and W.S.F.Kidd have taught me not only the essential language of Geology, but they have been, for many years, my most cherished conversation partners in that magical language, in which we have questioned and been generously instructed by our beloved Planet. In Istanbul I have enjoyed a similar privilege with Drs. Nezihi Canitez, Sirri Erinc, Ihsan Ketin, and Yücel Yilmaz. That Geology is only a part of the intellectual activity created by the intelligent curiosity has been taught to me when I was still very young mainly by two outstanding people, the late Mr. Mustafa Bahaeddin Gürfirat and Dr. Mim Kemal Öke.

In my pursuit of knowledge I have been most profoundly influenced by my following teachers throughout my career: Miss Nuriye Güneyi (Natural History in junior high school), Mr. Tarik İnözü (Geography in high school), Mr. Münir Aysu (Turkish

Literature in high school), Mr. James Lovett (English Literature in high school). In Albany, in addition to Burke, Dewey, and Kidd, I have learned a great deal about small-scale structural geology from Dr. Winthrop D. Means. Dr. Akiho Miyashiro not only taught me most of what I know about metamorphic rocks and processes, but has always been an enormous source of encouragement. Dr. Stephen E. De Long has enriched my understanding of many a geochemical problem and has been a delightful discussion and work partner. So was Dr. Jeffrey Fox.

The work in the Albula region in particular and on Tethys in general would not have been possible, had I not enjoyed the active support and encouragement of Dr. Rudolf Trümpy of Zürich (ETH). He visited me regularly in the field and essentially made my field work possible.

Drs. Albert W. Bally, B. Clark Burchfiel, Ian Evans, Augusto Gansser, K. Jinghwa Hsü, and Olivier Monod have helped me in various ways both in relation to Tethys and otherwise.

The actual field work in the Albula area had the benefit of the assistance of Mr. Steve Tanski and Dr. Naci Görür. The thin section work was much helped by the supervision of Drs. Naci Görür and Yücel Yilmaz. Mr. Gültekin Savci was very helpful in connection with the micro-scale structural interpretation; he also helped me with the draughting of many of my plates. Without the help of Mr. Gregor Eberli, it would not have been possible to identify the Kössenerschichten in the Albula area.

Life in Albany was possible largely because of the friendly hospitality of the Burke, Dewey, and Fox families. Dr. P.C. Benedict

has done marvels to dampen my incurable nostalgia for my home continent.

Mr. David G. Gallo deserves a very special place in these acknowledgements, for it was he who has been my closest friend in the American population. With his broad knowledge, contagious enthusiasm, and gentlemanly character, he has always been a fine example, which I have not always been capable enough to follow. I owe much of what I know in oceanic tectonics and geophysics, and also on strike-slip systems to Dave's patient explanations. He also taught me much on the philosophy and history of science.

In the Albula Pass, the Schwab Family looked after me for three years and provided a lovely environment for living. There I also enjoyed the close friendship of Mr. Hermann Bearth, Alpenhirt, philosopher, and gentleman.

In Zürich, Mrs. Claudia Colombini, formerly of the Geologischen Institut of the ETH, gave me much friendly help. Miss Esther Chappuis, the librarian of the Geological Institute, was a constant source of assistance during my stays in the ETH.

To Miss Maja Pool of Vicosoprano I am grateful not only for her very friendly help during my stay in the Albula Pass in the Summer of '79, but also for her warm friendship that I have enjoyed ever since. Most important, I think, has been Maja's role in keeping me closer to humanity than would have been possible otherwise.

This thesis began under the supervision of Prof. Dr. John F. Dewey, and was concluded under that of Dr. W.S.F.Kidd. Drs. Burke,

Kidd, and Means read the final draughts of this thesis and made many helpful comments. Greatly appreciated and critical was their role in allowing me to complete my PhD requirements in about one week. Mrs. Diana Paton, the Departmental Secretary at SUNYA, has done the impossible of seeing to it that I got finished in the one week that was available. She also largely typed the final manuscript.

Last, but not least, I owe nearly all I have accomplished to my parents and to my sister. Above all else, they have provided me with a home and family, which I consider to be the most valuable things I own.

Albany, Summer 1982

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	
ACKNOWLEDGEMENTS	
TABLE OF CONTENTS	
LIST OF FIGURES	
LIST OF PLATES	
CHAPTER I: INTRODUCTION	1
CHAPTER II: INTRODUCTION TO THE GEOLOGY OF THE ALBULA PASS AREA	3
II.1 Purpose and Scope	3
II.2 Location and access; cartographic base	10
II.3 History of Investigation	13
II.4 Tectonic synopsis of the Albula Pass region and its vicinity	14
CHAPTER III: THE STRATIGRAPHY OF THE ALBULA PASS AREA . .	31
III.1 Introduction: The justification of the method of presentation herein adopted	31
III.2 The Lower Austroalpine Units of the Albula Pass Area	33
III.2.a The Err crystalline complex	33
III.2.b Intra-Err crystalline sedimentary wedge . .	35
III.2.c.A. The Lower Slice	38
III.2.c.B. The Upper Slice	67
III.3 The Middle Austroalpine Units of the Albula Pass Area	70
III.3.a The Aela Nappe	71

	<u>Page</u>
III.3.b The Sub-Silvrettide Slices	98
III.3.b.A. The Lower Slice.	98
III.3.b.B. The Upper Slice.	99
CHAPTER IV: STRUCTURAL GEOLOGY OF THE ALBULA PASS	
REGION	100
IV.1 Introduction: Methods Employed and Their Limitations	100
IV.2 Err crystalline nappe and the intra-Err sedimen- tary wedge	106
IV.3 Supra Err Slices	110
IV.3.a The Lower Slice	110
IV.3.b The Upper Slice	135
IV.4 The Aela Nappe	141
IV.5 Sub-Silvrettide Slices	148
IV.5.a The Lower Slice	148
IV.5.b The Upper Slice (Sub-Silvrettide Lenses). .	149
IV.6 The Silvretta Nappe	151
IV.7 Correlation of structures between different tectonic units	151
CHAPTER V: SUMMARY OF THE GEOLOGICAL HISTORY OF THE	
ALBULA PASS AREA	154
V.1 Introduction	154
V.2 Pre-"Tethyan" history	154
V.3 Pre-orogenic Tethyan history	156
V.4 Orogenic "Tethyan" history	158
COLLECTIVE REFERENCES: CHAPTER I - V	160

	<u>Page</u>
CHAPTER VI: TECTONIC EVOLUTION OF THE MEDITERRANEAN	
REGION DURING THE JURASSIC PERIOD	166
VI.1 Introduction.	166
VI.2 Sutures and continental fragments involved in the Jurassic evolution of the Mediterranean Region	169
VI.3 Pangaeen assembly of continental fragments in the Mediterranean region	189
VI.4 Medial Triassic to Early Cretaceous Tectonic Evolution of the Mediterranean Region	194
IV.4.a Medial Triassic	197
IV.4.b Late Triassic-Early Jurassic	201
IV.4.c Medial Jurassic	207
IV.4.d Late Jurassic-Early Cretaceous	212
VI.5 CONCLUSIONS	220
REFERENCES - CHAPTER VI	232
CHAPTER VII: EVOLUTION OF THE CIMMERIDE OROGENIC SYSTEM	
AND ITS IMPLICATIONS FOR THE TECTONICS OF	
EURASIA: PRODUCTS OF THE CLOSURE OF PALAEO-	
TETHYS	246
VII.1 Introduction and the history of the Tethys concept	246
VII.1.a The concept of Tethys before plate tectonics	247
VII.1.b Plate tectonics and the emergence of the current concept of Palaeo-Tethys	255

	<u>Page</u>
VII.1.c The definition of the terms Alpide and Cimmeride and the purpose of this chapter	258
VII.2 Regional review	261
VII.2.a Longitudinal subdivisions of the Cimmeride Orogenic System	261
VII.2.b Mediterranean Cimmerides	261
VII.2.c Southwest Asian Cimmeride	283
VII.2.d Chinese or Sino-Cimmerides	306
VII.2.e Indochinese Cimmerides.	327
VII.3 Orogenic history of the Cimmerides	339
VII.3.a Late Palaeozoic reconstruction and tectonic events	340
VII.3.b Triassic events	351
VII.3.c Jurassic events	363
VII.3.d Cretaceous events	372
VII.4 Discussion and Conclusions	373
REFERENCES - CHAPTER VII	387

LIST OF FIGURES

	<u>Page</u>
 CHAPTER II	
Figure II.1 Schematic tectonic map of Graubunden	16
Figure II.2 Present structure of the Lower Austroalpine Nappes	21
Figure II.3 Pre-orogenic palaeogeography of the Western Alps	28
 CHAPTER III	
Figure III.1 Myrmekitic texture in high-K granite	41
Figure III.2 Metamorphic tuff	43
Figure III.3 Complex plagioclase twinning in the metamorphic tuff	44
Figure III.4 Photomicrograph of the metabasite. .	46
Figure III.5 Psammite-phyllite transition	48
Figure III.6 Metaconglomerate	52
Figure III.7 Quartzite with partially recrystal- lized quartz vein	55
Figure III.9 Hand specimen of the Upper Rach- wacke	66
Figure III.10 Alv Breccia	78
Figure III.11 Sketch showing the formation of the Alv Breccia	80
Figure III.12 Photomicrograph of Kieselkalk . . .	89
Figure III.13 Parallel-laminated Kieselkalk	90
Figure III.14 Dolomite clast in a micritic matrix	94

	<u>Page</u>
Figure III.15 Conglomeratic bottom part of a Blaisun turbidite bed	97
 CHAPTER IV	
Figure IV.1 Schematic representation of the nappe pile in the Albula Pass area	105
Figure IV.2 Details of the Intra-Err sedimen- tary slice	108
Figure IV.3 Stereographic plots of the struc- tural data from the Albula Pass region	111
Figure IV.4 Fold styles in domain II	125
Figure IV.5 Photomicrographs of the S_1 foliation in the Lower Supra-Err slice . . .	126 - 130
Figure IV.6 A comparison of fold hinge disrup- tion in late Devonian limestone- shale intercalation from Istanbul and in the carbonate lithologies of domain II	133
Figure IV.7 Fold styles in domain I	136 - 137
Figure IV.8 Tension gashes in the Emmat Shales.	140
Figure IV.9 Rodding in Fuora da l'Uertsch limestone	145
Figure IV.10 Stretched belemnite	146
Figure IV.11 Fold styles in the Aela Nappe and in domain IV	148
Figure IV.12 Detail of the Sub-Silvrettide Haup- tdolomit and its contact relations	150

CHAPTER VI

Figure VI.1	The Medial Triassic reconstruction of the Mediterranean area and its surroundings	199
Figure VI.2	The latest Triassic-early Jurassic reconstruction of the Mediterranean area and surrounding regions	203
Figure VI.3	Medial Jurassic reconstruction of the Mediterranean area and surrounding regions	211
Figure VI.4	The late Jurassic to early Cretaceous reconstruction of the Mediterranean area and surrounding regions	214

CHAPTER VII

Figure 1	Neumayr's <u>Centrales Mittelmeer</u> . . .	248
Figure 2	Argand's Tethys and Gondwana-Land	250
Figure 3	Tethys according to Stille	253
Figure 4	Alpides and Cimmerides	259
Figure 5	Tectonic map of the Cimmerides and associated structures	263
Figure 6	Stratigraphic synopsis of the Cimmerides	270
Figure 7	Tectonic map of the Balkan-Carpathian Regions	275
Figure 8	Sketch maps showing the formation of the Central Iranian narrow oceans	298
Figure 9	Schematic tectonic maps comparing the North Sea with Turan	302

	<u>Page</u>
Figure 10	
Tectonic map and evolution of the	
Songpan-Ganzi System	310
Figure 11	
Hidden subduction.	317

LIST OF PLATES

Plate I	Geological Map of the Albula Pass area
Plate II	Stratigraphic Synopsis of the Albula Pass area
Plate III	Tectonic Map of the Albula Pass area
Plate IV	Geological cross-sections of the Albula Pass area
Plate V	Stratigraphy of the base of the Aela Nappe in the Albula Pass
Plate VI	Outcrop and Index Map of the Albula Pass area
Plate VII	Main tectono-stratigraphic units of the Circum-Mediterranean Alpides
Plate VIII	Late Triassic to early Cretaceous schematic stratigraphic synopsis of the Circum-Mediterranean Alpides