

SEDIMENTOLOGY, PETROGRAPHY, AND TECTONIC SIGNIFICANCE
OF CRETACEOUS TO LOWER TERTIARY
DEPOSITS IN THE TINGRI-GYANGTSE AREA, SOUTHERN TIBET

By

Bin Zhu

A Dissertation

Submitted to the University at Albany, State University of New York

in Partial Fulfillment of

the Requirements for the Degree of

Doctor of Philosophy

College of Arts & Sciences

Department of Earth & Atmospheric Sciences

2003

Abstract

Cretaceous and Lower Tertiary sedimentary rocks are well exposed in the Tingri-Gyangtse area, tectonically belonging to the central Tibetan Himalayas, to the south of the Indus-Yarlung-Zangbo suture. The Cretaceous Tianba flysch in the Tianba-Jiabula region is correlative with the Giumal Group sandstone in Zaskar, northwestern Himalayas. There are significant amounts of chrome-rich spinels in turbiditic sandstones from the upper part of Tianba Flysch, which might suggest ophiolite derivation and a Cretaceous ophiolite obduction event on the northern Indian continental margin in southern Tibet. However the compositional range of these detrital spinels closely matches that of spinels from intra-plate basalts. About 5% of the spinels contain melt inclusions. The compositions of melt inclusions correlate well with those of host spinels. Melt inclusion geochemistry also suggests a source of hotspot basalts. It is concluded that the Rajmahal volcanics were the source for these Cr-rich spinels. The continuous Cretaceous to Lower Eocene marine sedimentary series in the Gamba and Tingri areas suggest that the Indian-Asian collision must have started after the deposition of the youngest marine shelf sediments. Petrographical analysis of sandstones reveals that the monocrystalline quartz grains of cratonic origin are dominant in the Paleocene Jidula Formation; in contrast there are significant amounts of immature framework grains with a distinct ophiolitic and volcanic arc influence present in the Eocene Youxia Formation and the younger Shenkeza Formation. Geochemistry in both sandstones and shales complement the petrographic data indicating that the source of the Jidula Formation primarily consisted of quartzose basement rocks, while the Youxia and Shenkeza Formations are mainly derived from the uplifted Gangdese arc-trench system. The compositions of Cr-rich spinels in the Youxia and Shenkeza sandstones are similar to those from fore-arc peridotites, most likely from the arc and ophiolite rocks along the Yarlung-Zangbo suture to the north. No spinels have been observed in the Jidula sandstones. Therefore the early Tertiary detrital sediments in Tingri record a marked change in provenance in the early Tertiary, which indicates that the onset of India-Asia collision was at ~47 Ma in southern Tibet.

**I would like to dedicate this dissertation
to my parents, Weilan Jiang & Shouqing Zhu,
who would have been proud to have seen its completion.**

Acknowledgements

Without the help and encouragement of numerous people, the successful completion of this work would have been impossible. I owe a great deal of gratitude to the Department of Earth and Atmospheric Science. To each of the members of the Department who have worked with me, and help me, I express my most sincere thanks. In particular, members of my committee, Drs. John Delano, Greg Harper, Bill Kidd, and David Rowley, are greatly thanked for continuous support, inspiring discussions during my graduate studies in Albany, and for meticulously reading and correcting my early draft of this thesis. Their criticisms and concerns were sometimes difficult to overcome, but this thesis and I clearly benefited. Special thanks go to the two faculty members who have given me the most in terms of their time, advice and support. Bill Kidd introduced me to the fantastic world of the Himalayan geology, and supervised this thesis with much patience during its ups and downs. I especially appreciate him for his financial support through my graduate career. I learned a tremendous amount from him, including the importance of self-reliance, accuracy, organization, logic, and imagination. His support for this project and for me is immeasurable. John Delano introduced me to the geochemistry of melt inclusion and chrome spinel, and provided working facilities in the Petrology Lab. His expertise at geochemistry of melt inclusion gave form and substance to the melt inclusion chapter of this thesis. He also taught me, both in words and by example, how to be careful and dedicated in a scientific research.

Two field trips in southern Tibet laid the foundation of this thesis. I am highly grateful to the help and support from Drs. Binggao Zhang and Yugan Jin in Nanjing. Successful fieldwork would have been impossible without their well-made preparation and organization. I will never forget the ‘bear’ cave in the top of the Zhepure Shan Mountain, where we spent a night on October 22, 2000 without winter coats and tents. Special thanks go to Drs. Brian Currie, Bill Kidd, David Rowley and Binggao Zhang for their help in the field.

Moral support and encouragement also came from other faculty members, staff and fellow students. Students’ seminars were part of my graduate experience here, and very important for me to develop this thesis. I appreciate Drs. Win Means, John Arnason,

Brad Linsley for their thought-provoking questions and inspiring discussions in the seminars. Special thanks go to Diana Paton, our department secretary, for taking care of my administrative and family troubles in Albany. I greatly benefited from almost daily discussions with my fellow graduates. They are Adam, Barbara, Chul, Elizabeth, Fasong, James, Lei, Steffi, Stefan, Taohong, Vera, Youshe, who help me to maintain my motivation and excitement for this project.

The electron microprobe results in this thesis were generated at RPI Probe Lab, and I am grateful to Kiera Becker and David Ward for their insight and patience during endless hours of probe analysis. Special thanks are due to Steve Howe for his advice on heavy mineral separation.

None of this would have been possible without the love and support from my family. My wife Weiwei is something very special. I want to thank her for the patience and understanding during my adventurous graduate career over the past years. My son Frank makes a difference in my life every day, and I am sorry for I cannot be with him during many weekends and evenings. Wutong Miao and Zhanme He, my in-laws, are thanked for their moral support and encouragement. Very special thanks go out to my brother, Tao Zhu, his wife, Meihua He, and his daughter Xiaomin. They have helped me in many ways, both large and small. I am very happy to have them as part of my life. Thank you all for your love and support.

This research was supported by National Science Foundation grant to Bill Kidd and David Rowley. Microprobe work was partially supported by SUNY Benevolent Association Research Grant and SUNY GSO Research Grant to Bin Zhu.

TABLE OF CONTENTS

ABSTRACT	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	vi
LIST OF TABLES	viii
LIST OF FIGURES	viii
 CHAPTER 1. INTRODUCTION OF THE HIMALAYA IN SOUTHERN TIBET	 1
Introduction	1
Two tectonic problems in southern Tibet	6
Approach to the problems	7
1. Petrographic studies and detrital modes of sandstones	7
2. Heavy mineral analysis	9
3. Geochemical analysis	12
Organization of text	13
 CHAPTER 2. STRATIGRAPHY OF THE CRETACEOUS AND LOWER TERTIARY STRATA IN THE TETHYAN HIMALAYA OF SOUTHERN TIBET	 15
Abstract	15
Introduction	16
Gamba area	16
Tingri area	25
Gyangtse-Kangmar area	34
Discussion	38
 CHAPTER 3. CHEMICAL COMPOSITIONS AND TECTONIC SIGNIFICANCE OF CHROME-RICH SPINELS IN TIANBA FLYSCH, SOUTHERN TIBET	 41
Abstract	41
Introduction	42
Geologic overview	44
Detrital modes of Tianba Flysch	53
Heavy mineral analysis of Tianba Flysch	64
Samples preparation and analytical method	69
Cr-rich spinel chemical compositions	71
Volcanic source for the detrital spinels	73
Trace elements in detrital spinels	75
Possible source rock lithology	79
Discussions	84
Correlation of Tianba Flysch with the Giumal Group sandstones in Zaskar	84

Continent-wide, Early-Mid Cretaceous volcanic event	86
Late Jurassic to Early-Mid Cretaceous	87
Oceanic island arc and ophiolite obduction	
Conclusion	89
 CHAPTER 4. MELT INCLUSIONS IN DETRITAL CR-RICH SPINELS FROM THE CRETACEOUS GREYWACKES OF THE EASTERN TETHYAN HIMALAYA: EVIDENCE FOR HOTSPOT-RELATED VOLCANIC EVENT	 91
Abstract	91
Introduction	92
Geologic setting	93
Samples preparation and analytical method	96
Cr-rich spinel	99
Melt inclusions	100
Discussion	112
Heating time of homogenization experiment	112
Source of the volcanic clastics for Tianba Flysch	113
Conclusion	114
 CHAPTER 5. GEOCHEMISTRY AND PROVENANCE OF THE TIANBA FLYSCH, SOUTHERN TIBET	 117
Introduction	117
Major elements	119
Trace elements	126
Geochemical discrimination of tectonic environment	133
Conclusion	136
 CHAPTER 6. PROVENANCE AND TECTONIC SIGNIFICANCE OF LOWER TERTIARY CLASTIC ROCKS IN TINGRI, SOUTHERN TIBET	 139
Abstract	139
Introduction	140
Geological framework	141
Lithostratigraphy in the Tingri region	143
Sedimentary provenance studies	154
Sandstone petrology	155
Jidula Formation	158
Youxia Formation	158
Shenkeza Formation	163
Interpretation of sandstone modes	171
Sandstone geochemistry	172
Major elements	173
Trace elements	180
Geochemical discrimination of tectonic environment	182
Chemical compositions of Cr-rich spinel	185
Source of Cr-rich spinel	186

Discussion	191
Regional correlatives of lower Tertiary clastic rocks	191
Timing of Indian-Asian collision in southern Tibet	192
Conclusion	196
References	198

LIST OF TABLES

CHAPTER THREE	
Table 3.1 Representative analyses of Cr-rich spinels from Tianba Flysch	72
CHAPTER FOUR	
Table 4.1 Representative analyses of melt inclusions and host spinels from the Tianba Flysch	104
CHAPTER FIVE	
Table 5.1 Geochemical data of the Tianba Flysch, southern Tibet	118
CHAPTER SIX	
Table 6.1 Framework grain mode parameter of sandstones from the lower Tertiary terrigenous clastics in the Tingri region	157
Table 6.2 Geochemical analyses of the lower Tertiary terrigenous clastics in the Tingri region	175
Table 6.3 Microprobe analyses of Cr-rich spinels from the Zongpubei Formation in the Tingri region	187

LIST OF FIGURES

CHAPTER ONE	
Figure 1.1 Himalayas-Tibetan Plateau Topography	2
Figure 1.2 Regional geological map of Tethyan Himalaya	4
Figure 1.3 Schematic cross-sections of the India-Asia convergence up to the initiation of collision	5
Figure 1.4 Detrital mode distribution in three major tectonic settings	8
CHAPTER TWO	
Figure 2.1 Simplified geologic map of Tingri-Gyangtse area, southern Tibet	17
Figure 2.2 Simplified geologic map of the Gamba region	18
Figure 2.3 Geologic map of the Zhepure Shan Mountain	27

CHAPTER THREE

Figure 3.1 Regional geological map of Tethyan Himalaya	45
Figure 3.2 Simplified tectonic map of the study area	46
Figure 3.3 Sketch geologic map at Tianba showing three measured sections 1-3	48
Figure 3.4. Tianba cross-section	49
Figure 3.5 View to north of Tianba section	50
Figure 3.6 Sedimentary structures in the Tianba Flysch	51
Figure 3.7 Well-bedded turbidite sandstones with shale interbeds in the center part of the Tianba Flysch	52
Figure 3.8 Top of the Tianba Flysch, north of Tianba village	54
Figure 3.9 Sideritic sandstone bed showing graded-bedding	55
Figure 3.10 Outsized (up to 1 m across) calcareous nodules in the greenish-grey shales, north of Tianba village	56
Figure 3.11 Measured Section (2), north of Tianba village	57
Figure 3.12 Measured stratigraphic sections at Tianba	59
Figure 3.13 Photomicrograph (crossed polars) of quartz-rich sandstone in the basal part of western section	60
Figure 3.14 Photomicrograph (crossed polars) of a metamorphic rock fragment in the quartz-rich sandstones in the basal part of western section	61
Figure 3.15 Detrital mode plot of sandstones in the Tianba sections	62
Figure 3.16 Photomicrograph (plane polars) of greywackes in the Tianba measured section	63
Figure 3.17 Photomicrograph (crossed polars) of feldspar (perthite) in the greywackes of the Tianba section 2	65
Figure 3.18 Photomicrograph of a volcanic rock fragment composed of plagioclase phenocrysts within fine-grained ground mass	66
Figure 3.19 Photomicrograph (crossed polars) of a rock fragment with trachytic texture in TB6 sample in the Tianba section 2	67
Figure 3.20 Histogram showing the different detrital modes between quartzite and greywackes in the Tianba sections	68
Figure 3.21 Chemical compositions of detrital Cr-rich spinels using pairs plot from S-plus	74
Figure 3.22 Backscattered electron images of melt inclusions in the detrital spinels from Tianba Flysch	76
Figure 3.23 Covariation of minor elements with $Mg/(Mg+Fe^{2+})$ in spinel	78
Figure 3.24 Major element contents of spinels and tectonic setting discriminant plot	80
Figure 3.24(continued) Major element contents of spinels and tectonic setting discriminant plot	81
Figure 3.25 Comparison of lithostratigraphy between Tianba, Zanskar (after Garzanti, 1993), Thakkhola (Garzanti, 1999) and Wolong (Jadoul, et al. 1998)	85

CHAPTER FOUR

Figure 4.1 Backscattered electron images of a crystallized melt inclusion	94
---	----

(grey) in Cr spinels (white) from Tianba Flysch	
Figure 4.2 Simplified tectonic map of the study area	95
Figure 4.3 Backscattered electron image of melt inclusions (grey) in Cr spinels	98
Figure 4.4 Major element contents of spinels and tectonic setting discriminant plots	101
Figure 4.5 Elemental maps of a melt inclusion quenched from 1250C	102
Figure 4.6 Major-element compositions of melt inclusions in the detrital spinels from Tianba Flysch	105
Figure 4.7 Total alkalis vs silica plot	107
Figure 4.8 Positive correlation between Al ₂ O ₃ and TiO ₂ contents in melt inclusions and hosted spinels	109
Figure 4.9 TiO ₂ -MnO-P ₂ O ₅ plot	110
Figure 4.10 Discriminant function plot of basalt from three tectonic settings	111
Figure 4.11 Reconstruction map at about 117 Ma	115

CHAPTER FIVE

Figure 5.1 CIA ternary plot of the Tianba Flysch	120
Figure 5.2 SiO ₂ -Al ₂ O ₃ plot of the Tianba Flysch	122
Figure 5.3 MgO-FeO _t plot of the Tianba Flysch	124
Figure 5.4 Al ₂ O ₃ -TiO ₂ plot of the Tianba Flysch	125
Figure 5.5 Th/Sc-Zr/Sc plot of the Tianba Flysch	128
Figure 5.6 Th/U-Th plot of the Tianba Flysch	130
Figure 5.7 Cr/V-Y/Ni plot of the Tianba Flysch	132
Figure 5.8 Chondrite-normalized REE plot of the Tianba Flysch	134
Figure 5.9 Tectonic discriminant diagram for the Tianba Flysch	135
Figure 5.10 K ₂ O/Na ₂ O-SiO ₂ (a) and SiO ₂ /Al ₂ O ₃ -K ₂ O/Na ₂ O (b) plots of the Tianba Flysch	138

CHAPTER SIX

Figure 6.1 Sketch geologic map of Tingri region, southern Tibet	142
Figure 6.2 Simplified geologic map showing the location of the studied sections in the Tingri region on the western flank of Zhepure Shan Mountain	144
Figure 6.3 Stratigraphic columns of lower Tertiary sequence in the Tingri region	145
Figure 6.4 View to E of the upper part of the Youxia Formation in the head of the Shenkeza valley	149
Figure 6.5 View to N of Shenkeza Formation of red shales and occasional intercalations of fine-grained sandstones	150
Figure 6.6 View to NW of the unconformity between the Youxia and Shenkeza Formations	151
Figure 6.7 Hummocky cross-stratification in the top sandstones of the Youxia Formation	153
Figure 6.8 Detrital mode plot of lower Tertiary sandstones in the Tingri region	156
Figure 6.9 Photomicrograph (crossed polars) of quartz-rich sandstone (Jul2) in the Jidula Formation, Gongza section	159
Figure 6.10 Photomicrograph of well-rounded monocrystalline quartz grains with calcite cement in the Jul 75 sandstone	160

of Jidula Formation, Gongza Formation	
Figure 6.11 Photomicrograph (crossed polars) of a metamorphic rock fragment in Jul 75 sandstone of Jidula Formation	161
Figure 6.12 Photomicrograph (crossed polars) of lithic-rich sandstone (Shen88) in the Youxia Formation	162
Figure 6.13 Photomicrograph (crossed polars) of volcanic rock fragments in the Shen88 sandstone of the Youxia Formation	164
Figure 6.14 Photomicrograph (crossed polars) of Shen94 sandstone in the Youxia Formation, Shenkeza section	165
Figure 6.15 Photomicrograph (crossed polars) of volcanic and sedimentary rock fragments in the Shen87 sandstone of the Youxia Formation	166
Figure 6.16 Photomicrograph (crossed polars) of a plagioclase grain in the Shen94 sandstone of the Youxia Formation, Shenkeza section	167
Figure 6.17 Photomicrograph (crossed polars) of a broken plagioclase and a metamorphic rock fragment in Shen88 sandstone	168
Figure 6.18 Photomicrograph (crossed polars) of angular-subangular greywackes (Shen145) of Shenkeza Formation, Shenkeza section	169
Figure 6.19 Photomicrograph (crossed polars) of angular quartz grains and a plagioclase in the Shen148 sandstone	170
Figure 6.20 CIA ternary plot of lower Tertiary clastics in the Tingri region	176
Figure 6.21 Geochemical plot of the lower Tertiary clastics in the Tingri region	177
Figure 6.21(continued) Geochemical plot of the lower Tertiary clastics in the Tingri region	178
Figure 6.22 Tectonic discrimination plots	184
Figure 6.23 Geochemical plot of Cr-rich spinels from the Youxia and Shenkeza sandstones	188
Figure 6.24 Comparison of stratigraphic columns of the Himalayan foreland basin	193