

CENOZOIC TECTONIC HISTORY OF THE SOUTHERN TIBETAN PLATEAU
AND EASTERN HIMALAYA: EVIDENCE FROM $^{40}\text{Ar}/^{39}\text{Ar}$ DATING

by

Peter Copeland

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 Sciences and Mathematics

Department of Geological Sciences

© 1990

CENOZOIC TECTONIC HISTORY OF THE SOUTHERN TIBETAN PLATEAU
AND EASTERN HIMALAYA: EVIDENCE FROM $^{40}\text{Ar}/^{39}\text{Ar}$ DATING

by

Peter Copeland

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 Sciences and Mathematics
Department of Geological Sciences

1990

ABSTRACT

The collision between India and Asia began between 40 and 55 million years ago. At that time southern Tibet was at an elevation very near sea level; the Tibetan plateau today has an area of over 700,000 km² and an average elevation of ~5000 m and is underlain by continental crust with a thickness of 65–75 km. During the collision India has continued to move northward relative to Siberia at ~5 cm/year. The tectonic mechanisms by which the continued convergence has been accommodated within Asia have varied considerably in both time and space. This dissertation concerns rocks from three distinct areas, southern Tibet, central Nepal, and the southern Bengal Fan, and relates geochronologic data from these rocks to the tectonic history of the India–Asia collision in southern Tibet and the eastern Himalaya.

In the area of Tibet around Lhasa thermochronologic data from plutons of the Gangdese batholith suggest that the cooling histories of these rocks have varied considerably since 40 Ma. These cooling histories can be linked to the unroofing of these rocks and, in some cases, to the uplift of the surface of the earth relative to sea level. In two plutons, Quxu and Pachu, there exists evidence for brief (< 1 million years) episodes of rapid unroofing (> 4 mm/year) at approximately 18 Ma and 14 Ma, respectively. Excepting significant tectonic denudation by normal faulting, for which there is no evidence, these rates of unroofing could not have been maintained without substantial relief. Therefore, the results from Quxu indicate that the southern margin of the Tibetan plateau had begun to be a prominent topographic feature by the early Miocene. The episodic nature of the unroofing of these plutons indicates that the uplift of the southern Tibetan plateau varied in both space and time.

⁴⁰Ar/³⁹Ar dating of detrital K-feldspar and muscovite from the southern Bengal fan (ODP Site 116) also illustrates the episodic nature of the uplift and erosion of the Himalaya and southern Tibet. Four to 13 K-feldspars and muscovites were dated from each of seven stratigraphic levels which represent the past 18 million years of sedimentation. In every level at least one K-feldspar and one muscovite had minimum ⁴⁰Ar/³⁹Ar apparent ages equal to the stratigraphic age. Because we can rule out the possibility of a volcanogenic origin for this material and because of the paucity of deep crustal rocks in the source area, these results indicate that many distinct portions of the provenance area of the Bengal fan have experienced rapid erosion (> 5mm/year) during the past 18 million years.

U-Pb dating of a granite which cross-cuts a fault near Mt. Everest indicates that this fault was active prior to 20 ± 1 Ma. This structure has been interpreted to be the

result of gravitational collapse of a high-standing Tibetan plateau and, under this interpretation, this result suggests significant uplift of the southern Tibetan plateau by the Early Miocene. The isotopic results from this sample suggest a closure temperature of Pb in monazite of ~720-750 °C, significantly higher than previous estimates.

There are a series of N-S trending grabens in southern Tibet which have been interpreted to be the result of the Tibetan plateau spreading under its' own weight. The Nyainqentanghla mountain range bounds one of these grabens; thermochronologic data from this range suggest that this graben began forming before 5 Ma and perhaps before 10 Ma. This suggests that the southern Tibetan plateau achieved an elevation and crustal thickness similar to its present day values by the end of the Miocene.

$^{40}\text{Ar}/^{39}\text{Ar}$ dating of the Manaslu granite together with the new appreciation of the behavior of Pb in monazite suggests the Manaslu granite is composed of a group of isotopically diverse batches of magmas which coalesced over a brief period of time at ~20 Ma. Thermochronologic data from rocks of the Greater Himalayan Crystallines and the Lesser Himalaya Formations, south of the Manaslu granite, indicate a profound thermal disturbance centered on the Main Central Thrust at the end to the Miocene. This disturbance is interpreted to be the result of the passage of hot fluids through the MCT zone at about this time. These fluids remained at peak conditions between 500,000 and 1 million years. The fluids are thought to be a result of thrusting of hot hanging wall rocks of the Main Boundary Thrust over colder footwall rocks, inducing dehydration in the latter. This is essentially the same model which has previously been suggested for the production of the High Himalaya granites, such as the Manaslu granite, by dehydration of the footwall of the MCT.

The data presented here do not favor tectonic models for the Tibetan plateau in which the uplift proceeds at an even pace nor those in which most of the uplift takes place in the past 5 million years. The available data do permit models in which much of the convergence in the Oligocene is accommodated by continental escape, the Miocene is dominated by crustal thickening of the Tibetan plateau, through distributed shortening, and the past 5 million years have included E-W extension, continental escape, crustal thickening, and incipient plate re-organization.

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the help of many others. I have benefited from involvement with people from no less than eleven institutions in four countries. This has been a collaborative effort in which my education and research has been greatly aided. I have benefited from the close collaboration with my two major advisors T. Mark Harrison and W.S.F. Kidd. The specific contributions of those who have helped are detailed below.

The samples analyzed in this study come from three diverse locations; the samples discussed in the individual chapters were collected by the following individuals: Ch. 2.: W.S.F. Kidd; Ch 3: P. Copeland, W.S.F. Kidd, and T.M. Harrison; Ch. 4: B.C. Burchfiel, K.V. Hodges, and L. Royden; Ch. 5&6: P. Le Fort and A. Pêcher, Ch. 7: W.S.F. Kidd; Ch. 8: P. Copeland, W.S.F. Kidd, and T.M. Harrison; Ch. 9: W.S.F. Kidd; Ch. 10: J. Corrigan and J. Cochran.

Randy Parrish, Canadian Geological Survey, performed the U-Pb analysis in Chapter 4; the important contribution in this chapter is a direct reflection of his careful and patient work. Carl Wirth, Cornell University, did the neutron activation analysis on sample $\Delta 33$. The XRF analysis in this chapter was done at McGill University through the assistance of John Delano.

The work in Chapters 5 and 6 would not have been possible without the generous support of Patrick Le Fort, Institute Dolomieu, Grenoble. In addition Kip Hodges, MIT, was an important participant in the analysis and presentation which went into Chapter 6. The work on these samples from the Himalaya was an beneficial extension of the originally planned work in Tibet and I am grateful to all those who made it possible. Thanks particularly to Patrick Le Fort for his hospitality. Thanks to Frank Spear, who provided the finite difference program.

My work on the material from Ocean Drilling Program Leg 116 would not have been possible without the assistance of Jim Cochran, Lamont-Doherty Geological Observatory and Jeff Corrigan, Univ. of Texas.

My experience in Tibet was enhanced by Pan Yun's translation. This was not always an enviable task which he handled with much grace. Zhang Yuquan and Xie Yingwen expedited field transportation and sample collection.

I benefited almost daily from informal discussions with fellow graduate students about tectonics and geochemistry. Thanks go particularly to David Foster, Matt Heizler, Terry Spell, and Pan Yun. I would like to also acknowledge discussions in various locations with John Delano, Steve Delong, Paul Tapponnier, Kip Hodges, Arnaud Pêcher, Christian France-Lanord, Patricia Maruéjol, Phillipe Vidal, Nicholas Arnaud,

Oscar Lovera, Frank Richter, Bruce Watson, and Kevin Chamberlain. Thanks also to Clark Burchfiel for serving as the external examiner on my dissertation committee. Gary Cook and the staff at the Phoenix Memorial Laboratory, University of Michigan are acknowledged for expediting the irradiations of minerals.

Finally, I wish to thank those who have played the biggest role in my development at SUNY. Thanks to Matt Heizler. Matt's ubiquitous bright attitude and positive outlook always helped me to look forward to walking into the lab. Moreover, his considerable assistance in mineral preparation and sample analysis was invaluable in making over 2800 isotope analyses possible in just three years time. Thanks to Bill Kidd. His financial assistance went well beyond what might be expected and I greatly appreciate it. I could not have placed the results from these studies in proper context without the perspective of Bill's experience and expertise. I look forward to building on my knowledge of the geology of Asia to which Bill laid the foundation. Thanks to Mark Harrison. Under Mark's tutelage I have grown in ways that I did not even know existed four year ago and I think that I have yet to fully appreciate how this experience has benefitted me and how it will so in the future. Mark's generous financial assistance has also helped to make my Ph.D. experience a rich one. He also did what he could to enrich other aspects of my time in Albany which were not the best and I have appreciated his genuine concern and friendship.

This dissertation was supported, in part, by NSF grant EAR-87-21403, DOE grant DE-ACO-82ER13013, and a SUNY Benevolent Association grant.

TABLE OF CONTENTS

ABSTRACT	i
ACKNOWLEDGMENTS	iii
LIST OF FIGURES	xiii
LIST OF TABLES	x
CHAPTER 1. INTRODUCTION	
1.1 Statement of the problem	1-1
1.2 Proposed uplift and thickening models	1-4
1.2.1 Underthrusting of India	1-6
1.2.2 Delayed continental underthrusting	1-6
1.2.3 Continental injection	1-7
1.2.4 Distributed shortening	1-7
1.3 Approach to the problem	1-7
1.4 Organization of the dissertation	1-12
 CHAPTER 2. A THERMOCHRONOLOGIC STUDY OF THE QUXU PLUTON, GANGDESE BATHOLITH, SOUTHERN LHASA TERRANE	
2.1 Introduction	2-1
2.2 Experimental procedures	2-3
2.3 The Gangdese belt	2-4
2.3.1 Quxu pluton	2-5
2.3.2 Dagze pluton	2-18
2.4 Uplift rates	2-21
2.4.1 Quxu pluton	2-22
2.4.2 Dagze pluton	2-26
2.5 Discussion	2-26
2.6 Conclusions	2-32
 CHAPTER 3. COOLING HISTORY OF THE GANGDESE BATHOLITH, SOUTHERN TIBET.	
3.1 Introduction	3-1
3.2 $^{40}\text{Ar}/^{39}\text{Ar}$ results	3-1
3.2.1 Dazuhka area	3-24
3.2.2 Pachu area	3-24
3.2.3 Yangbajian area	3-26
3.2.2 Lhasa region	3-29
3.2.2.1 Gu Rong granite	3-29
3.2.2.2 Lhasa granite	3-31
3.2.2.3 Dagze granite	3-35
3.2.5 Quxu pluton	3-35
3.2.6 Samye area	3-40
3.3 Discussion	3-40
3.3.1 Timing of magmatism in the Gangdese batholith	3-40

3.3.2 Post-40 Ma denudation and uplift of the Gangdese batholith	3-43
3.4 Conclusions	3-54

CHAPTER 4. A U-Pb AND $^{40}\text{Ar}/^{39}\text{Ar}$ STUDY OF A TWO-MICA GRANITE ASSOCIATED WITH A DOWN-TO-THE-NORTH NORMAL FAULT ZONE IN THE HIGH HIMALAYA: EVIDENCE FOR INHERITED Pb IN MONAZITE AND HIGH STANDING TOPOGRAPHY IN SOUTHERN TIBET PRIOR TO 20 Ma.

4.1 Introduction	4-1
4.2 U-Pb results	4-2
4.3 $^{40}\text{Ar}/^{39}\text{Ar}$ results	4-10
4.4 Tectonic implications	4-14
4.5 Conclusions	4-15

CHAPTER 5. AGE AND COOLING HISTORY OF THE MANASLU GRANITE: IMPLICATIONS FOR HIMALAYAN TECTONICS

5.1 Introduction	5-1
5.1.1 Geologic setting	5-1
5.1.2 Composition	5-3
5.1.3 Previous isotopic investigations	5-3
5.1.4 Analytical procedure	5-4
5.2 $^{40}\text{Ar}/^{39}\text{Ar}$ results	5-4
5.2.1 Muscovites	5-4
5.2.2 Biotites	5-20
5.2.3 Alkali feldspars	5-24
5.3 Discussion	5-29
5.3.1 Age of crystallization	5-29
5.3.2 Depth of crystallization	5-35
5.3.3 Timescales of emplacement	5-35
5.4 Conclusions	5-37

CHAPTER 6. A LATE MIOCENE - EARLY PLIOCENE THERMAL PERTURBATION ALONG THE MCT RELATED TO MOVEMENT ON THE MBT: RECURRING TECTONOTHERMAL CONSEQUENCES OF COLLISION

6.1 Introduction	6-1
6.2 Analytical Methods	6-4
6.2.1 Sampling	6-4
6.2.2 $^{40}\text{Ar}/^{39}\text{Ar}$ methods	6-7
6.3 Isotopic results	6-7
6.3.1 Hornblendes	6-23
6.3.2 Micas	6-23
6.3.3 K-feldspars	6-34
6.4 Discussion	6-42
6.4.1 Overview	6-42
6.4.2 Modelling	6-50
6.4.3 Summary and tectonic implications	6-62
6.5 Conclusions	6-66

6.6 Speculations	6-66
Appendix 6.1 Sample descriptions	6-67
CHAPTER 7. $^{40}\text{Ar}/^{39}\text{Ar}$ RESULTS FROM ROCKS FROM THE TETHYAN HIMALAYA	
7.1 Introduction	7-1
7.2 Results	7-1
7.2.1 $^{40}\text{Ar}/^{39}\text{Ar}$ results	7-1
7.2.1.1 Granites	7-1
7.2.1.2 Augen gneiss	7-12
7.2.2 Microprobe data	7-14
7.3 Discussion and conclusions	7-14
CHAPTER 8. NEOGENE TECTONICS OF THE NYAINQENTANGHLA RANGE, CENTRAL LAHSA TERRANE: EVIDENCE FROM $^{40}\text{Ar}/^{39}\text{Ar}$ DATING	
8.1 Introduction	8-1
8.2 $^{40}\text{Ar}/^{39}\text{Ar}$ results	8-4
8.2.1 Southern Nyainqentanghla	8-13
8.2.2 Northern Nyainqentanghla	8-18
8.2.3 Central Nyainqentanghla	8-23
8.3 Discussion	8-32
8.3.1 Thermal history of the Nyainqentanghla	8-32
8.3.2 Tectonic implications	8-34
8.4 Conclusions	8-37
CHAPTER 9. RESULTS OF $^{40}\text{Ar}/^{39}\text{Ar}$ ANALYSIS OF SAMPLES NORTH OF DAMXUNG	
9.1 Introduction	9-1
9.2 Results	9-1
9.3 Discussion	9-12
9.4 Conclusions	9-14
CHAPTER 10. $^{40}\text{Ar}/^{39}\text{Ar}$ AGES OF DETRITAL MUSCOVITE AND K-FELDSPAR FROM THE SOUTHERN BENGAL FAN (ODP LEG 116): IMPLICATIONS FOR HIMALAYAN TECTONICS	
10.1 Introduction	10-1
10.2 Analytical methods	10-4
10.3 Results	10-7
10.4 Discussion	10-42
10.5 Conclusions	10-49
CHAPTER 11. SUMMARY	11-1
BIBLIOGRAPHY	12-1

APPENDIX 1. ANALYTICAL METHODS	
A1.1 Sample preparation	A1-1
A1.1.1 Mineral separations	A1-1
A1.1.2 Packaging	A1-3
A1.2 Irradiations	A1-3
A1.3 Mass Spectrometry	A1-5
APPENDIX 2. TREATMENT OF ARRHENIUS DATA	A2-1

LIST OF FIGURES

1.1 Location and topography of the Tibetan plateau and Himalaya	1-2
1.2 Proposed models of uplift and thickening for the Tibetan plateau	1-5
1.3 Study area, Lhasa region, southern Tibet	1-8
1.4 Study area, Manaslu region, central Nepal	1-9
1.5 Location of ODP Leg 116, southern Bengal Fan, Indian Ocean	1-10
2.1 Simplified geologic map of the Lhasa area	2-2
2.2 Age spectrum and isochron diagrams for hornblende M369	2-12
2.3 Age spectrum and isochron diagrams for hornblende M370	2-12
2.4 Age spectrum and isochron diagrams for hornblende M371	2-13
2.5 Age spectrum and isochron diagrams for hornblende M372	2-13
2.6 Age spectrum diagram for biotites	2-14
2.7 Topographic profile of field traverse in the Quxu pluton	2-14
2.8 Age spectrum diagram for K-feldspars	2-17
2.6 Arrhenius diagram for K-feldspar from sample M370	2-17
2.7 Age spectra for biotite and K-feldspar from sample M8-3	2-19
2.8 Uplift history of the Quxu pluton	2-24
3.1 Geologic map of Himalaya and southern Tibet	3-2
3.2 Geologic map of the study area	3-3
3.2 Arrhenius diagrams for minerals from K-feldspars	3-21
3.4 Age spectra for sample H4	3-25
3.5 Age spectra for minerals from Pachu granite	3-27
3.6 Age spectra for minerals from Yangbajian area	3-28
3.7 Age spectra for minerals from sample PC-88-39	3-30
3.8 Age spectra for minerals from Lhasa granite	3-32
3.9 U-Pb concordia diagram for zircons from Lhasa granite	3-34
3.10 Age spectra for minerals from Dagze granite	3-36
3.11 Age spectra for minerals from Quxu pluton	3-37
3.12 Age spectra for minerals from Samye tonalite	3-39
3.13 Crystallization ages of plutons of the Gangdese batholith	3-41
3.14 Temperature-time histories for plutons of the Gangdese batholith	3-44
3.15 Estimates of post-40 Ma denudation for the Gangdese batholith	3-48
3.16 Two ways to get rapid cooling	3-51
4.1 Concordia diagram for zircons from sample $\Delta 33$	4-4
4.2 Concordia diagrams for monazites from sample $\Delta 33$	4-7
4.3 Age spectrum and isochron diagrams for muscovite, biotite, and K-feldspar	4-11
4.4 Arrhenius diagram for K-feldspar from sample $\Delta 33$	4-12

5.1	Location of Manaslu granite	5-2
5.2	Geographic distribution of $^{40}\text{Ar}/^{39}\text{Ar}$ ages in the Manaslu granite	5-16
5.3	Age spectrum and isochron diagrams for muscovites	5-17
5.4	Age spectrum and isochron diagrams for biotites	5-21
5.5	Age spectrum and isochron diagrams for alkali feldspars	5-22
5.6	Arrhenius diagrams for alkali feldspars	5-27
5.7	Interpretation of U-Pb results from the Manaslu granite	5-31
5.8	Cooling histories of selected samples from the Manaslu granite	5-34
6.1	Map of Himalaya	6-2
6.2	Generalized geologic map of study area with sample locations	6-5
6.3	Simple cross-section of area with sample locations	6-6
6.4	Hornblende age spectra	6-21
6.5	Map showing areal distribution of hornblende ages	6-22
6.6	$^{40}\text{Ar}/^{39}\text{Ar}$ age spectrum and isochron diagrams for micas	6-24
6.7	Map showing areal distribution of muscovite ages	6-29
6.8	Map showing areal distribution of biotite ages	6-30
6.9	$^{40}\text{Ar}/^{39}\text{Ar}$ age spectrum and isochron diagrams for K-feldspars	6-35
6.10	Map showing areal distribution of K-feldspar ages	6-37
6.11	Arrhenius diagrams for K-feldspars	6-39
6.12	Mineral age vs. distance above the MCT	6-43
6.13	Fractional loss of biotite vs. distance from MCT	6-54
6.14	Temperature-time curves for model 9 (Table 6.5)	6-56
6.15	Age spectrum of AP483 hornblende with theoretical loss profiles	6-58
6.16	Cartoon tectonic model	6-64
7.1	Geologic map of southern Tibet and the Himalaya	7-2
7.2	Age spectra and isochron diagrams for H1	7-8
7.3	Age spectra and isochron diagrams for H7f	7-9
7.4	Age spectra and isochron diagrams for H7	7-10
7.5	Age spectra and isochron diagrams for H8	7-11
8.1	Location of Quaternary grabens, southern Tibet	8-2
8.2	Geologic map of Nyainqentanghla and surrounding area	8-3
8.3	Arrhenius diagrams for K-feldspars	8-14
8.4	Age spectra for minerals from southern Nyainqentanghla	8-16
8.5	Age spectrum for hornblende PC-88-44	8-17
8.6	Age spectra for minerals from sample PC-88-56	8-19
8.7	Age spectra for minerals from sample PC-88-53	8-20
8.8	Age spectra for minerals from samples M64-5 and M65-1	8-21
8.9	Age spectrum for muscovite M47-7	8-22
8.10	Photo of central Nyainqentanghla	8-24
8.11	Age spectra for minerals from sample PC-88-48	8-25
8.12	Age spectrum for K-feldspar G41	8-26
8.13	Photo of leucocratic dike, Goringla Valley	8-28
8.14	Age spectrum and isochron diagram for K-feldspar H-88-15	8-30
8.15	Age spectrum and isochron diagram for hornblende PC-88-22	8-31
8.16	Cooling history of Nyainqentanghla	8-33
9.1	location map	9-2
9.2	Age spectra for minerals from north of Daxumg	9-3
9.3	Age spectra for minerals from Wanbougou granite	9-4
10.1	Location of ODP Leg 116, southern Bengal Fan, Indian Ocean	10-2

10.2	Stratigraphy of ODP sites 717 and 718.	10-3
10.3	Age spectra for bulk separates of muscovite and K-feldspar, Bengal Fan	10-24
10.4	Age spectra diagrams for K-feldspar from level 717-220	10-25
10.5	Age spectra diagrams for K-feldspar from level 717-420	10-26
10.6	Age spectra diagrams for K-feldspar from level 717-520	10-27
10.7	Age spectra diagrams for K-feldspar from level 717-720	10-28
10.8	Age spectra diagrams for K-feldspar from level 718-560	10-29
10.9	Age spectra diagrams for K-feldspar from level 718-660	10-30
10.10	Age spectra diagrams for K-feldspar from level 718-760	10-31
10.11	Age spectra diagrams for muscovites	10-32
10.12	Stratigraphic vs. mineral age for K-feldspars and muscovites	10-35
10.13	Age spectra diagrams for K-feldspar from Tsangpo River	10-40
10.14	Probability dist. of minimum ages from K-feldspars from Tsangpo River	10-41
10.15	Bulk ages vs. stratigraphic age	10-44
11.1	Estimate of the relative contribution of accommodation mechanisms	11-3
A1.1	Schematic drawing of the extraction system and mass spectrometer	A1-13
A2.1	Arrhenius diagrams for K-feldspars H-88-15 and NL208	A2-3

LIST OF TABLES

1.1	Present and planned publication history for the chapters of this dissertation	1-13
2.1	Results of Ar isochron analysis for hornblendes from the Quxu pluton	2-6
2.2	$^{40}\text{Ar}/^{39}\text{Ar}$ results from Quxu pluton	2-7
2.3	Results of Ar isochron analysis for biotites from the Quxu pluton	2-16
2.4	$^{40}\text{Ar}/^{39}\text{Ar}$ results for biotite and K-feldspar from the Dagze pluton	2-20
2.5	Mineral ages and calculated uplift rates for the Quxu pluton	2-24
3.1	$^{40}\text{Ar}/^{39}\text{Ar}$ results from Gangdese batholith	3-5
4.1	U-Pb isotope results for zircon and monazite from sample $\Delta 33$	4-3
4.2	Chemical composition of sample $\Delta 33$	4-5
4.3	$^{40}\text{Ar}/^{39}\text{Ar}$ results for muscovite, biotite, and K-feldspar from sample $\Delta 33$	4-13
5.1	$^{40}\text{Ar}/^{39}\text{Ar}$ results from the Manaslu granite	5-5
5.2	Summary of $^{40}\text{Ar}/^{39}\text{Ar}$ ages and K_2O concentrations for micas and K-feldspar	5-15
6.1	Summary of $^{40}\text{Ar}/^{39}\text{Ar}$ ages	6-8
6.2	$^{40}\text{Ar}/^{39}\text{Ar}$ results	6-9
6.3	Temperature time combinations to produce 75% loss from hornblende	6-48
6.4	Calculated fractional loss from biotites	6-49
6.5	Parameters of thermal models of hot fluid infiltration along the MCT	6-52
6.6	Diffusion parameters for K-feldspars	6-59
7.1	$^{40}\text{Ar}/^{39}\text{Ar}$ results	7-4
7.2	Microprobe results	7-13
8.1	$^{40}\text{Ar}/^{39}\text{Ar}$ results for samples from the Nyainqentanghla	8-5

9.1	$^{40}\text{Ar}/^{39}\text{Ar}$ results for samples from north of Daxmung	9-5
10.1	Estimates of stratigraphic ages for sampled intervals, Sites 717 and 718	10-5
10.2	$^{40}\text{Ar}/^{39}\text{Ar}$ results for bulk separates of K-feldspar and muscovite	10-9
10.3	$^{40}\text{Ar}/^{39}\text{Ar}$ results for single crystals of K-feldspar and muscovite	10-11
10.4	$^{40}\text{Ar}/^{39}\text{Ar}$ results for total fusion of bulk separates	10-20
10.5	$^{40}\text{Ar}/^{39}\text{Ar}$ results for single crystals of K-feldspar from Tsangpo River	10-21
10.6	Summary of $^{40}\text{Ar}/^{39}\text{Ar}$ ages from Sites 717 and 718	10-38
A1.1	Time, duration and correction factors for irradiation used in this study	A1-4
A1.2	Sample analysis histories	A1-7
A2.1	Calculated diffusivities for steps from K-feldspar H-88-15	A2-4
A2.2	Calculated diffusivities for steps from K-feldspar NL208	A2-5