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Research Article

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Differential uplift process in mesozoic-cenozoic Longmen mountains along eastern margin of Tibetan Plateau

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ABSTRACT

Based on analysis on fission track dating of apatite and zircon in the granite and sand samples collected from the south, middle and north segment of Longmen mountain, it is found that the uplift process of Longmen mountain had segmentation on strike and zonation on dip. On dip direction, from Songpan-Ganzi fold belt to Longmen thrust belt and to western Sichuan foreland basin, the entire Songpan-Ganzi fold belt has experienced regional uplift, and the fission track age has positive correlation with altitude; while in Longmen thrust belt, the age has negative correlation with altitude, or is independent of it, which suggests thrust fault play a dominant role during the uplift process. However, in western Sichuan foreland basin, the samples have partly or entirely annealed with burial depth. At both sides of Maoxian-Wenchuan fault, zircon fission track age is obviously different, but for apatite there is no evident difference. This reveals that the west of Maoxian-Wenchuan fault has undergone more rapid uplift during 38-10Ma. At the sides of Beichuan fault, apatite fission track age difference is obvious, suggesting a quick uplift process at the west of Beichuan fault during 10-0Ma. On strike direction, zircon fission track age tends to increase gradually from north to south part of Longmen Mountains, which may indicate a more rapid uplift process during late Indosinian or early Yanshanian in the northern part. Apatite fission track age generally decreases from north to the middle and south, reflecting more rapid uplift in the middle and south in Cenezoic.

Key words: Longmen Mountains; fission track; differential uplift

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INTRODUCTION

Longmen thrust belt, lying between Sichuan basin and Songpan-Ganzi fold belt (orogen), defines the eastern margin of the Tibetan Plateau and the western boundary of the middle and upper Yangtze area, (Figure 1). Many domestic and foreign scholors have paid close attention to this belt for its key tectonic location and typical foreland thrust structure. Firstly, Longmen thrust belt is located at the convergent juncture of marginal Pacific and Tethyan-Himalayan tectonic domain, related to the two important events, assembly of China's main continent in Indonian and Indo-Asian collision in Cenezoic. Its dynamics evolution is the crux in studying Mesozoic-Cenezoic continental tectonic in south China [1-10]. Secondly, Longmen structural belt and Sichuan basin to its east are the typical areas in middle and west China that thrust structure and foreland basin were developed. The structural features and foreland basin development has been the basic content and main direction in Longmen mountain geological tectonic research [11-20]. Thirdly, Longmen structural belt is not only the topography boundary between east and west China, but also located on the gravity gradient belt of Helan-Chuandian, forming an important part of south-north seismic zone (structural belt). The eastward extent and active structure of the Tibet plateau is becoming significant in the study of Longmen structure [21-24].

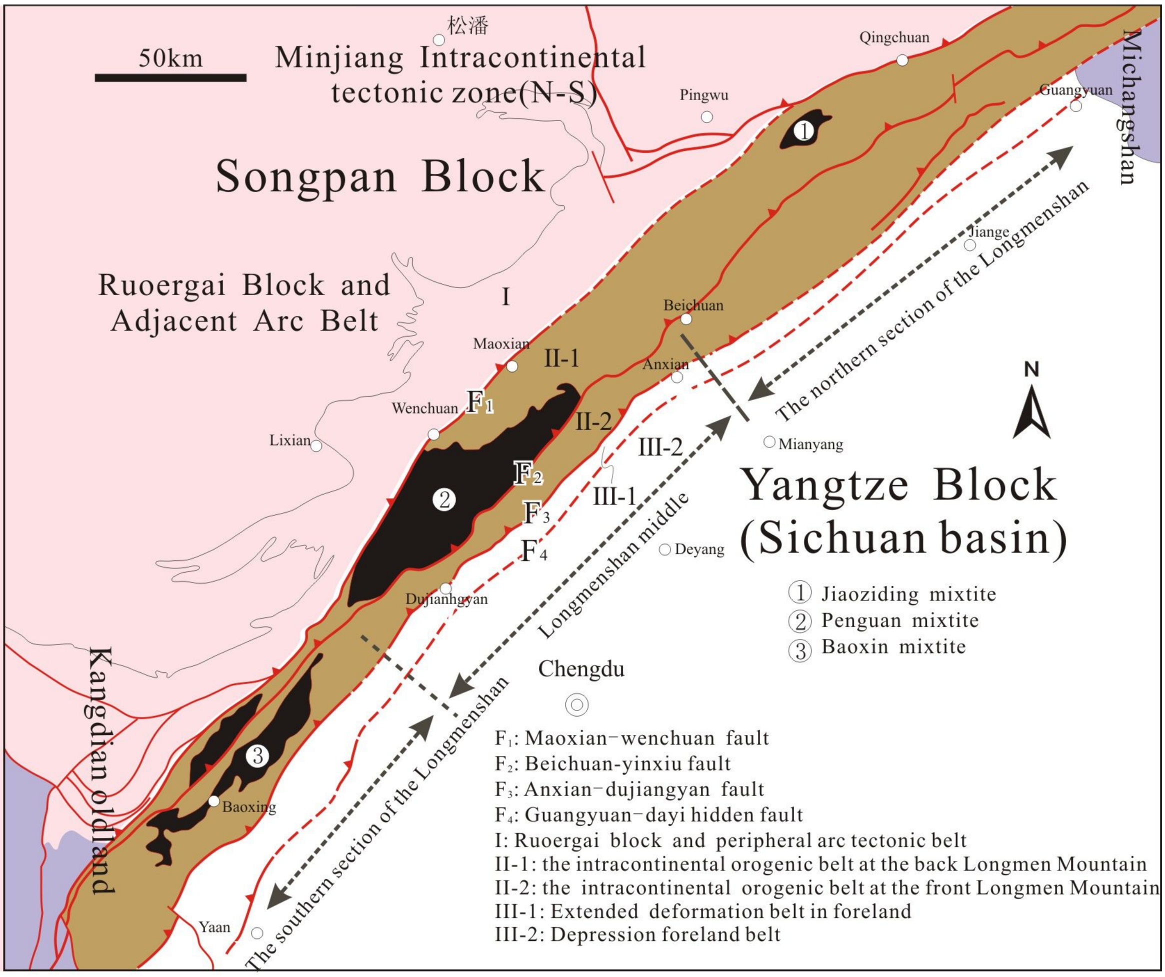

Fig.1 Segmentation and Zonation Structural Pattern of Longmen Thrust Belt[25]

Since unified basement was formed during Jinning movement and Chengjiang movement in Mesoproterozoic-Neoprotozoic, Longmen Mountains and the adjacent area has undergone two developing periods in Phanerobiotic: differential fluctuation and passive continental margin period in the tension background of Sinian-Triassic, thrust uplift and foreland basin period in the extrusion background from late Triassic up to now [3,13].Two stratigraphic successions were correspondingly developed in this area: marine clastics and carbonate rock before late Triassic, and continental clastics after later Triassic.

Violate rift-faulting happened along Longmen Mountains from about middle and late Silurian[3,12-16]coming to the peak in late Permain, and lasting to middle Triassic.[26]named it “Emei Tafrogeny”. This rift-faulting activity was an important event in the geological history of Longmen Mountains, having significant effect on its evolution and structural pattern after Indosinian. On one side, a series of north-east syndepositional fault were developed during the rift-faulting and formed the embryo of the later main fault in Longmen Mountains [17,26]. On the other side, some thousand meters of Silurian Maoxian group and Devonian Weiguan group (Yue Lizhai group) fine clastics was accumulated in the taphrogenic trough, forming major medium for the transition of Longmen thrust belt to Songpan-Ganzi fold belt in later period. Since late Triassic, influenced by the two geological events, assembly of China’s main continent in Indonian and Indo-Asian collision in Himalayan stage, Longmen Mountains and Songpan-Ganzi area at the west has undergone violate deformation-metamorphism and thrust uplift, and formed western foreland basin to the the east [3,4,6,12-19].

It may be infered that since late Triassic, the uplift of Longmen thrust belt has important coupling relation to western Sichuan foreland basin. Systymatic revealment of the differential uplift of each segment and belt has great significance for detailed study of the formation, evoluation and basin-mountain coupling process of western Sichuan foreland basin. It is also a key point in the reasearch of continent formation and evolution in south China.

1. Samples, testing results and the tentative interpretation

In order to understand the strike differential uplift features of Longmen thrust belt, granite and sand samples were collected along Qingchuan-Jiange in the north, Qianfoshan-Anxian in the middle and Baoxing-Lushan in the south to carry out apatite fission track analysis. Meanwhile, samples were also collected from both sides of Beichuan fault to find out how the curtain thrust can influence differential uplift on the dip. Furthermore, zircon fission track testing was performed for some samples to make clear the early uplift since Indosinian. The testing results are recorded in table 1 and its distribution in figure 2.

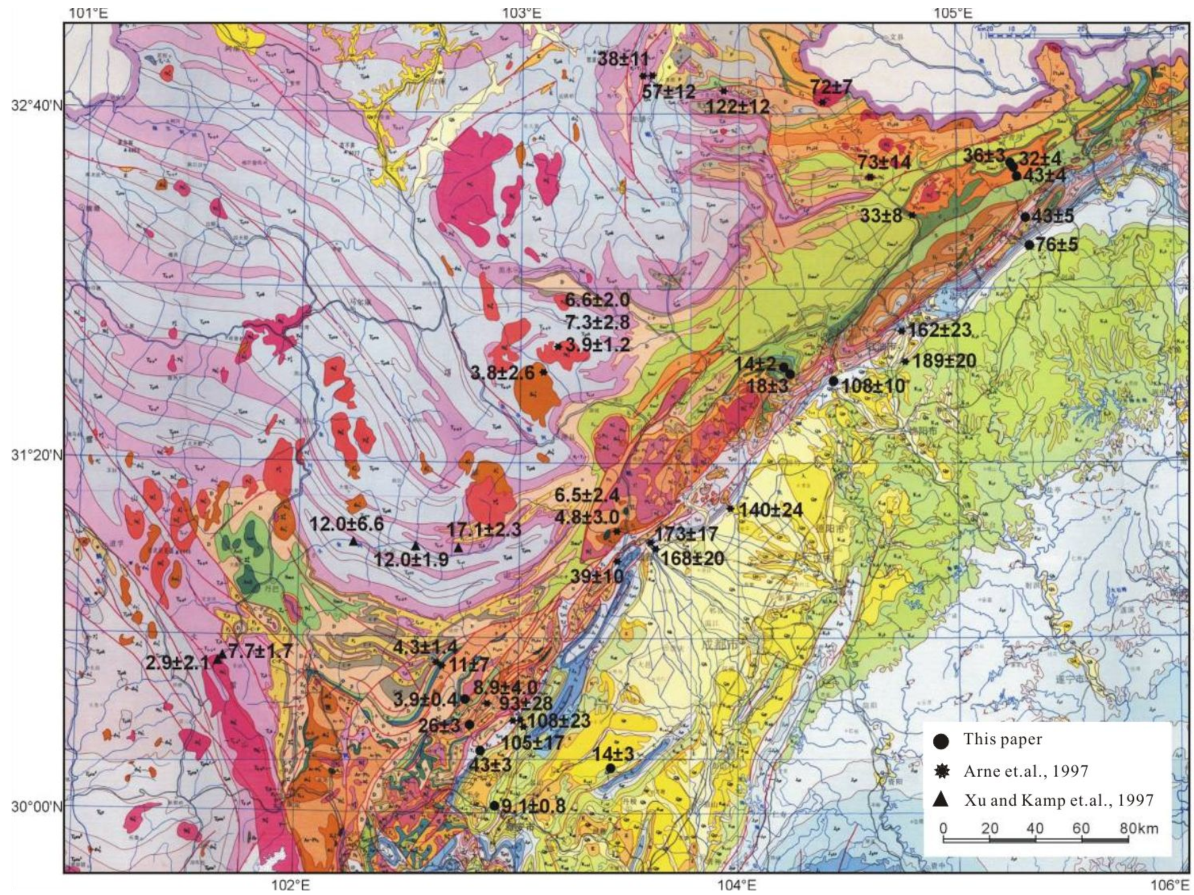

Fig.2 Fission Track Age Distribution of Longmen Thrust Belt and the Adjacent Area

1.1 Zircon fission track dating

The apparent age was tested to be 184~306Ma based on 4 samples collected from the northwest of Beichuan fault (Figure 3) (the age can only be used as reference for there is little B2-063-z grain in the samples), obviously younger than the actual age, suggesting entire annealing has happened on these samples. From north to south part of Longmen Mountains, the age tends to increase, implying more rapid uplift in the north in late Indosinian or early Yanshanian.

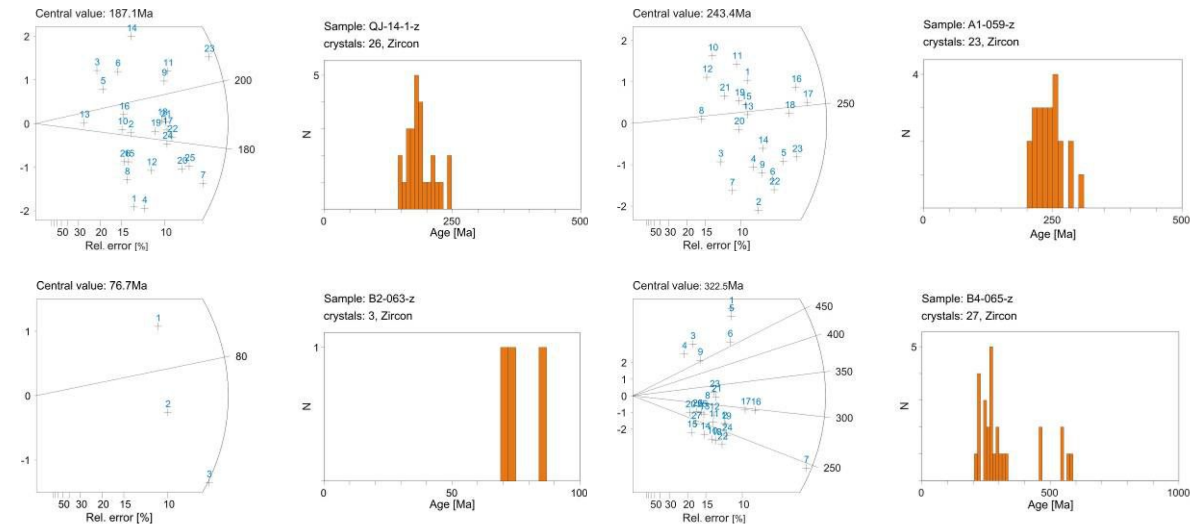

Fig.3 Single Grain Zircon Dating Testing Results of Longmen Thrust Belt

1.2 Apatite fission track age

Generally, the achieved apatite fission track age is dispersing, from 3.9Ma to 108Ma, but mainly distributed in two age groups: 3~20Ma and 25~50Ma. All the testing age is younger than the stratigraphic age, revealing entirely or partly annealing of the samples. Age tested from sample A3-061-a collected from basin margin is 108Ma, but the single grain age is very disperse, partially older than the actural age (Figure 4), suggesting the sample has not experencied entire annealing. Single grain can contain source material age , so it is not suitable for uplift analysis. The age tested from the other sample B6-067-a is 9.1Ma. According to the present residual bruial depth at the front of south Longmen mountain, the largest depth of this sample is less than 3500m, so it may not experience entire annealing, and the age of sample B5-066-a collected from further northwest, was tested to be 43Ma. This is difficult to be interpretated based on normal uplift, while the possible interpretation is that this sample has experienced local thermal perturbation (such as local thermal fluid activity), therefore, uplift analysis based on this sample can only be used as reference.

Table 1 Zircon and Apatite Dating Testing Results of Longmen Thrust Belt

Sample no.	Location	Altitude（m）	Rock unit (litho)/Ma	n	ρ_s (10^5/cm^2)(Ns)	ρ_i (10^5/cm^2)(Ni)	ρ_d (10^5/cm^2)(Nd)	P(x^2) (%)	Central age (Ma)(±1σ)	Pooled age (Ma)(±1σ)	L(μm) (N)
The north longmenshan											
QJ-03-1-a	Qingchuan-Jiange	1274	S (Ss.)	28	1.094(282)	1.160(299)	2.008(3144)	80.9	36±3	36±3	12.0±2.2(93)
QJ-06-1-a	Qingchuan-Jiange	1149	Є (Ss.)	20	1.170(116)	1.260(125)	1.797(3144)	53.3	32±4	32±4	11.5±2.1(40)
QJ-14-1-a	Qingchuan-Jiange	715	Є (Ss.)	28	2.271(363)	1.652(264)	1.628(3144)	94.3	43±4	43±4	12.2±2.1(105)
QJ-14-1-z	Qingchuan-Jiange	715	Є (Ss.)	26	111.928(4302)	106.803(4105)	26.789(27782)	28.1	184±9	184±9	
QJ-44-1-a	Qingchuan-Jiange	586	T_3x (Ss.) /200-230	28	2.612(700)	1.802(483)	1.712(3144)	0.01	43±5	48±3	11.9±2.0(115)
QJ-56-1-a	Qingchuan-Jiange	769	J_3l (Ss.) /145-155	28	3.693(920)	1.682(419)	1.797(3144)	9.0	75±6	76±5	12.2±1.6(107)
The middle longmenshan											
A1-059-a	Qianfoshan-Anxian	1165	Z (Ss.)	28	0.485(146)	1.205(363)	1.839(3144)	88.8	14±2	14±2	12.1±2.7(17)
A1-059-z	Qianfoshan-Anxian	1165	Z (Ss.)	23	181.906(7081)	133.533(5198)	26.932(27782)	25.6	239±11	239±11	
A2-060-a	Qianfoshan-Anxian	926	S (Ss.)	28	1.732(87)	3.066(154)	1.670(3144)	100	18±3	18±3	11.6±2.2(25)
A3-061-a	Qianfoshan-Anxian	597	J_3l (Ss.) /145-155	27	6.330(542)	2.476(212)	2.219(3144)	95.3	108±10	108±10	11.8±1.9(57)
The south longmenshan											
B2-063-a	Baoxing-Lushan	1088	Pt (Gr)	28	0.449(98)	4.416(1009)	2.092(3144)	100	3.9±0.4	3.9±0.4	11.8±2.4(53)
B2-063-z	Baoxing-Lushan	1088	Pt (Gr)	3	82.010(524)	182.800(1168)	25.154(27782)	24.7	75±5	74±5	
B4-065-a	Baoxing-Lushan	924	Pt (Gr)	8	3.486(122)	4.858(170)	1.860(3144)	26.0	26±3	26±3	11.7±2.1(27)
B4-065-z	Baoxing-Lushan	924	Pt (Gr)	27	237.531(4880)	134.001(2753)	26.647(27782)	0	303±22	306±15	
B5-066-a	Baoxing-Lushan	796	T_3x (Ss.) /200-230	28	1.800(544)	1.562(472)	1.966(3144)	97.4	43±3	43±3	11.7±2.0(90)
B6-067-a	Baoxing-Lushan	620	K_2j (Ss.) /85-130	27	0.831(191)	3.796(872)	2.156(3144)	17.8	9.1±0.8	9.1±0.8	11.4±2.1(70)

Suffix a in the sample number stands for apatite, z stands for zircon; n is the grain quantity; ρ_d and N_d respectively stands for standard track density and statistics track quantity; $\rho_s$and N_s respectively stands for spontaneous track density and statistics track quantity; ρ_i and N_i respectively stands for created track density and statistics track quantity; single grain age was calculated by extra detector measurement and Zeta constant method, and CN_5 sandtand uranium glass was used for apatite, ζ was determined as 385±12; CN_2 sandtand uranium glass was used for zircon, ζ was determined as 132.7±5.5; P(x^2) is Chi-sp testing probility, when P(x^2)>5%, it is commonly accepted that the tested single grain ages are in the same age group, otherwise, they belong to different group; L and N respectively stands for average confining track length and track quantity.
Testing institute: Institute of High Energy Physics Chinese academy of Sciences

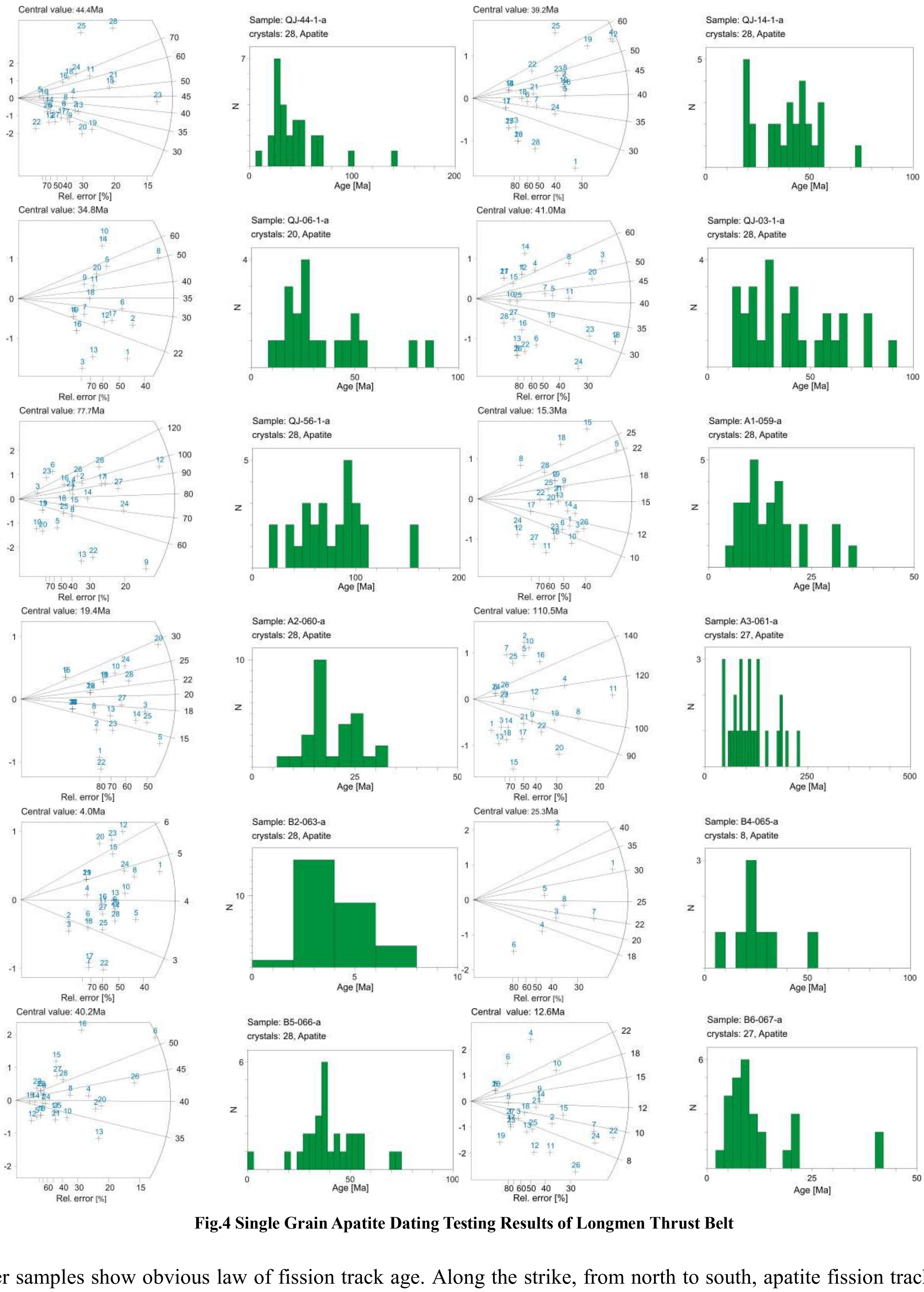

Fig.4 Single Grain Apatite Dating Testing Results of Longmen Thrust Belt

Other samples show obvious law of fission track age. Along the strike, from north to south, apatite fission track age decreases gradually, reflecting more rapid uplift in the south of Longmen mountain in Cenezoic. No matter in the north, middle or south, from thrust belt to internal basin, apatite fission track age tends to increase gradually. It is obvious that the age distribution is connected with trhust acitivities in late Mesozoic-Cenezoic Longmen belt, but not the unified regional uplift. Differential uplift on the dip resulted from the thrust activities is more apparent in the south than in the north.

CONCLUSION

Combined with avaliable fission track test results (Figure 4), we made the following conclusions for the uplift history of Longmen thrust belt and the adjacent areas in Mesozoic-Cenezoic.

(1) Songpan-Ganzi fold belt has undergone entire regional uplift. The fission track age has positive correlation with altitude. Longmen thrust belt was dominated by thrust uplift in the regional uplift background, and thrust fault played the most important role during the uplift process. The fission track age has negative correlation with altitude or is independent of it. Western Sichuan foreland basin has undergone entire uplift. The samples have partly or entirely annealedwith layer (or burial depth).

(2) The fission track age has apparent difference at the sides of Maowen fault, Beichuan fault and Anxian-Guanxian fault, reflecting that thrust fault played a dominant role during uplift process. The effect was revealed more clearly at the middle and south part of Longmen Mountains. At the sides of Maowen fault, zircon fission track age difference was apparent, while the apatite fission track age has little difference, suggesting more rapid uplift happened to the west of Maowen fault in 38-10Ma. At the sides of Beichuan fault, apatite fission track age difference was obvious, indicating quick uplift happened to the west of Beichuan fault in10-0Ma .

(3) Zircon fission track age implies the north of Longmen Mountains has undergone more rapid uplift in Mesozoic, while the middle and south has undergone more rapid uplift in late Mesozoic and Cenezoic. The apatite fission track age generally decreases from north to the middle and south, also reflecting more raplid uplift in the middle and south part in Cenezoic.

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