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Geometry and Kinematics of Thrust Tectonics of the Northern Longmenshan Mountains: Constraints for the Multi-phase Uplifting and Spreading of the Southeast Boundary of Qinghai-Tibet Plateau

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The Longmenshan Mountains thrust belt (LMSTB) is the southeastern boundary of the Qinghai-Tibetan plateau (QTP). To study its structural geometry and kinematics is of great significance to constrain the formation mechanism and evolution processes of the Qinghai-Tibetan plateau. Bounded by Guanxian and Anxian area, LMSTB is subdivided into three segments from SW to NE (i.e. the southern, middle and northern segment). The northern Longmenshan segment, lying around Anxian to Guangyuan area, is located at the southwestern end of the Qinling Orogenic Belt and the northeastern end of the Songpan-Ganzi folded belt, and is connected with the Bikou block and the Micangshan thrust belt at its northernmost part, which leads to a distinct superimposed tectonic setting for it. By employing the sandstone apatite fission track (AFT) and electron spin resonance (ESR), together with the study of regional unconformities and strata development, the paper analyzes the differential uplifting history and the uplifting migration processes in different area. Based on the surface geology, and the high resolution seismic profiles and drilling data, the fault arrays, the structural style and its variations in this area are studied and by balanced geological cross-section restoration, the kinematics with time of these faults is discussed. It shows that prior to the Late Triassic, the tectonic setting was extensional at the northern Longmenshan. Yet, at the early stage of the Late Triassic, it transited to be compressional and experienced tectonic inversion, which made the Upper Triassic Xujiahe Formation (T3x) lies above the Middle Triassic Leikoupo Formation (T2l) with a lower angular unconformity. When came to the end of the depositional period of the third member of T3x, the northern Longmenshan began to uplift regionally, which resulted in the lower-angular unconformities and disconformities between T3x3 and T3x4. At the end of the T3x, the northern Longmenshan experienced intensive deformation, which led to the angular unconformities between the Upper Triassic Xujiahe Formation (T3x) and the Lower Jurassic Baitianba Formation (J1b) and the structural deformation migrated from the Longmenshan to the interior basin. In the early Middle Jurassic, the tectonic movement was moderate compared to the last stage and a large-scale fluvial- lacustrine depositional environment was relatively stably developed, while in the Late Jurassic, moderate uplifting occurred and led to the huge thick conglomerates in the mountain front. Since the Late Cretaceous, the northern Longmenshan has been experiencing regional uplifting and in the late-middle Cenozoic, extensive thrusting and nappe tectonics were developed. AFT simulation indicates that Guangyuan area experienced rapid uplifting during 155-90Ma with a rate of 0.012-0.072mm/a and slow uplifting afterwards and rapid uplifting once again around 10Ma with a rate of 0.10-0.24mm/a. By Comparing the AFT simulations between the northern and the middle Longmenshan segments, apparent differential uplifting is recognized, that is, in the late Triassic and the late Jurassic, the uplifting migrated from the northern Longmenshan to the middle Longmenshan while during the Oligocene- Miocene, the uplifting was migrating oppositely from the later to the former. Combining the quartz ESR data of the drilling cores in the Jiulongshan area and the AFT simulation results in the northwest Langzhong area in the basin, it is disclosed that the uplifting was migrating from the northern Longmenshan to the interior basin since Oligocene and the deformation transferred from the NW to SE with a tendency of structural style to be simple. Bounded by the Maowen, the Beichuan and the Majiaoba Fault from NW to SE, the northern Longmenshan segment is sub-divided into the western, the central and the eastern zones accordingly. A series of thrust imbricate structures are developed in the western and the central zones, resulting in the exhumation of the basement metamorphic complex around the Jiaoziding area in the central zone. The Multi-level detachment deformation system is developed to the east of the Majiaoba Fault (same as the Kuangshanliang Fault) with the foreland monocline developed above the Middle- Lower Triassic gypsum detachment beds and gradually transiting to lower amplitude folds towards the basin, and with the duplex developed below the above detachment intervals. The duplex is bounded by the above-mentioned gypsum beds as the roof detachment and soled into the Pre-Sinian weak zone with the Paleozoic strata involved. Displacement thrust backward to northwest and resulted in a syncline in the hangingwall of the Kuangshanliang Fault. The eastern zone of the northern Longmenshan segment has a shortening of approx-

imately 40km or a shortening rate roughly of 50%. The study indicates that on the basis of the uplifting due to the closing of the South QinLing oceanic basin in the late Late Triassic, the northern Longmenshan uplifted again in the late Jurassic and the Late Cretaceous respectively controlled by the intra-continental deformation, and experienced extensive uplifting and large-scale thrusting towards the basin owing to the spreading and propagation of the SE boundary of QTP during the Miocene to Oligocene. The development of late-period tectonics was limited by the early-period tectonic activities. Thrusting is the predominant structural style and oil and gas resources are rich in the tectonic wedge underlying the piedmont monocline and the frontal thrust-related anticlines.