Thrusting, exhumation and basin fill on the western margin of the South China block during India-Asian collision

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November 23, 2022

Abstract

The pattern and timing of deformation in the southeast Tibet resulting from the India-Asian collision remain poorly constrained. Detailed field mapping, structural analysis and geo-thermochronogic data within a newly-defined Ludian-Zhonghejiang fold-thrust belt stretching over 120 km between the Diancang Shan and Xuelong Shan metamorphic belt in western Yunnan, China document Early Cenozoic tectonic evolution of the conjunction area between the Lanping-Simao and South China blocks. The study area is cut by two major northwest-striking, southwest-dipping brittle faults, named Ludian-Zhonghejiang fault and Tongdian fault from east to west. Kinematic measurements and indicators of S-C fabrics and striations, as well as juxtaposition of Triassic meta-sedimentary rocks overlying on Paleocene strata indicate thrusting along the Ludian-Zhonghejiang fault. Similarly, structural analysis show the Tongdian fault is also a reverse fault. Between these structures, fault-bounded Permo-Triassic and Paleocene strata are strongly deformed by upright southwest-vergent folds with axes that trend nearly parallel to the traces of the principal faults, consistent with reserve faulting related to regional NE-oriented compression. Zircon and apatite (U-Th)/He and apatite fission track ages from a Triassic granitic pluton in the hanging wall of the Ludian-Zhonghejiang thrust assisted by inverse modeling reveal a period of accelerated cooling from 50 Ma to 37 Ma, which is interpreted to record the lifespan of the fold-thrust system collaborated by the intrusive relations between magmas of ˜35 Ma dated by zircon U-Pb and the fold and thrust belt. Since 37 Ma, decreasing cooling rates implies cessation of the thrusting. Early Cenozoic activity of the deformation system likely controlled deposition of the Jianchuan-Liming basin evident by coeval sediments derived from the proximal hanging wall of the fold-thrust belt. These results, together with tectonic records of contraction in east Tibet, suggest crustal shortening related to the India-Asian collision and convergence prevailed the southern and eastern part of the Tibetan Plateau, which predated Oligo-Miocene onset of extrusion tectonics in southeast Tibet.

Thermo 2018 **P6-64**

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Introduction

Quantifying the spatial distribution and temporal evolution of intracontinental strain resulting from the India-Asian collision and convergence is essential to understanding how the continental lithosphere has deformed through time. One major question central to this topic is what the tectonics look like prior to large-scale extrusion tectonics in the Tibetan Plateau. Key to this issue relies on determining the geometry and kinematics of the first-order structures along the escaped block margins that predated the occurrence of the extrusion within the collision belt. However, such quantitative data are generally lack. The southeast Tibet is characterized by block extrusion accommodated by large-scale strike-slip fault systems in middle-late Cenozoic times and thus an ideal region to address the above question [*Leloup et al.*, 1995, 2001]. Our field and analytical data provide quantitative constraints on the geometry, kinematics and timing of the Ludian-Zhonghejiang fold-thrust belt on the western margins of the South China block, western Yunnan, which predates the onset of the Ailaoshan-Red River shear zone. Theses results allow establishing casual links between early Cenozoic thrusting-induced rock exhumation and deposition in the Jianchuan basin. Accordingly, we proposed a model accounting for widespread crustal shortening and relevant flexural sedimentation across the Tibetan Plateau accompanying the India-Asian collision, which predated large-scale block extrusion.

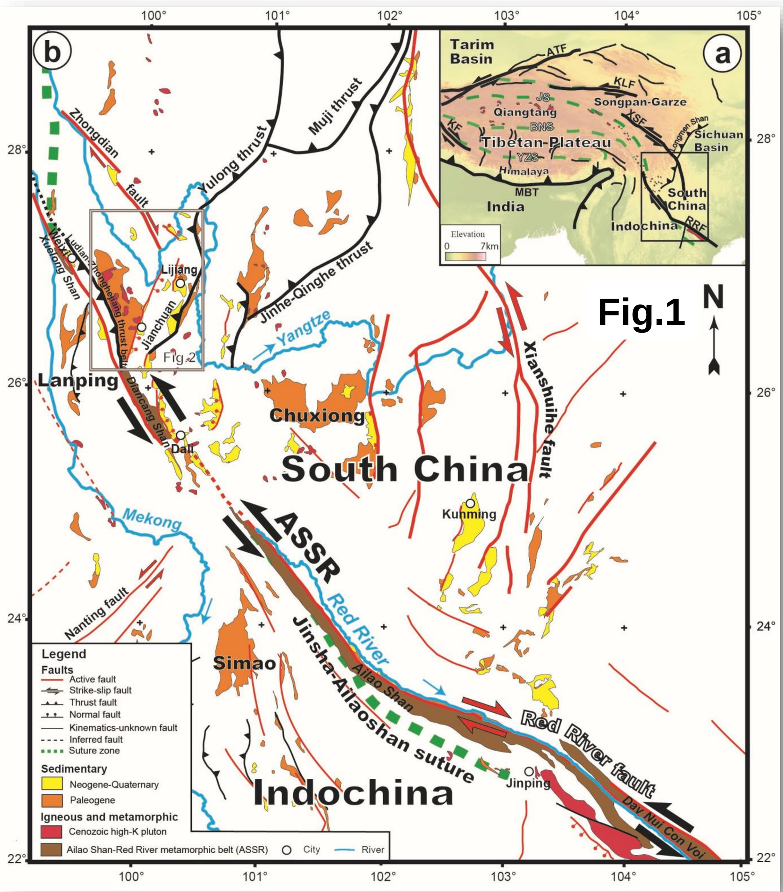


Fig.1 (a) Simplified geological map of the southeast Tibet, showing major Cenozoic structures and sediments, modified from *Leloup et al.* [1995]. (b) The inset shows location within Tibet. Abbreviations: ASSR–Ailao Shan-Red River shear zone, ATF–Altyn Tagh fault, BNS–Bangong-Nujiang suture, MBT–Main boundary fault, JS–Jinsha suture, KLF–Kunlun fault, KF–Karakorum fault, RRF–Red River fault, XSH–Xianshuihe fault, YZS–Yarlung-Zangbu suture.

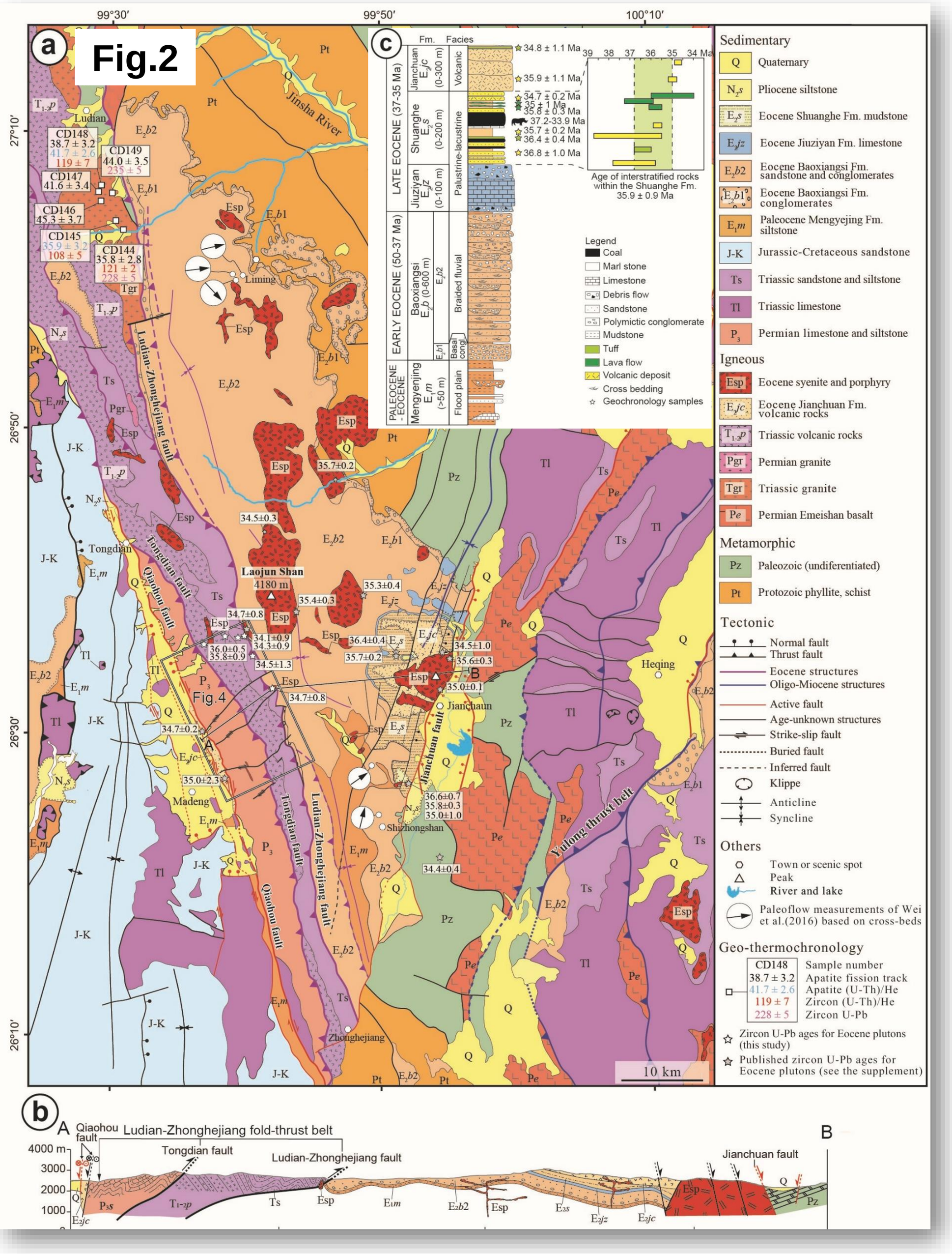
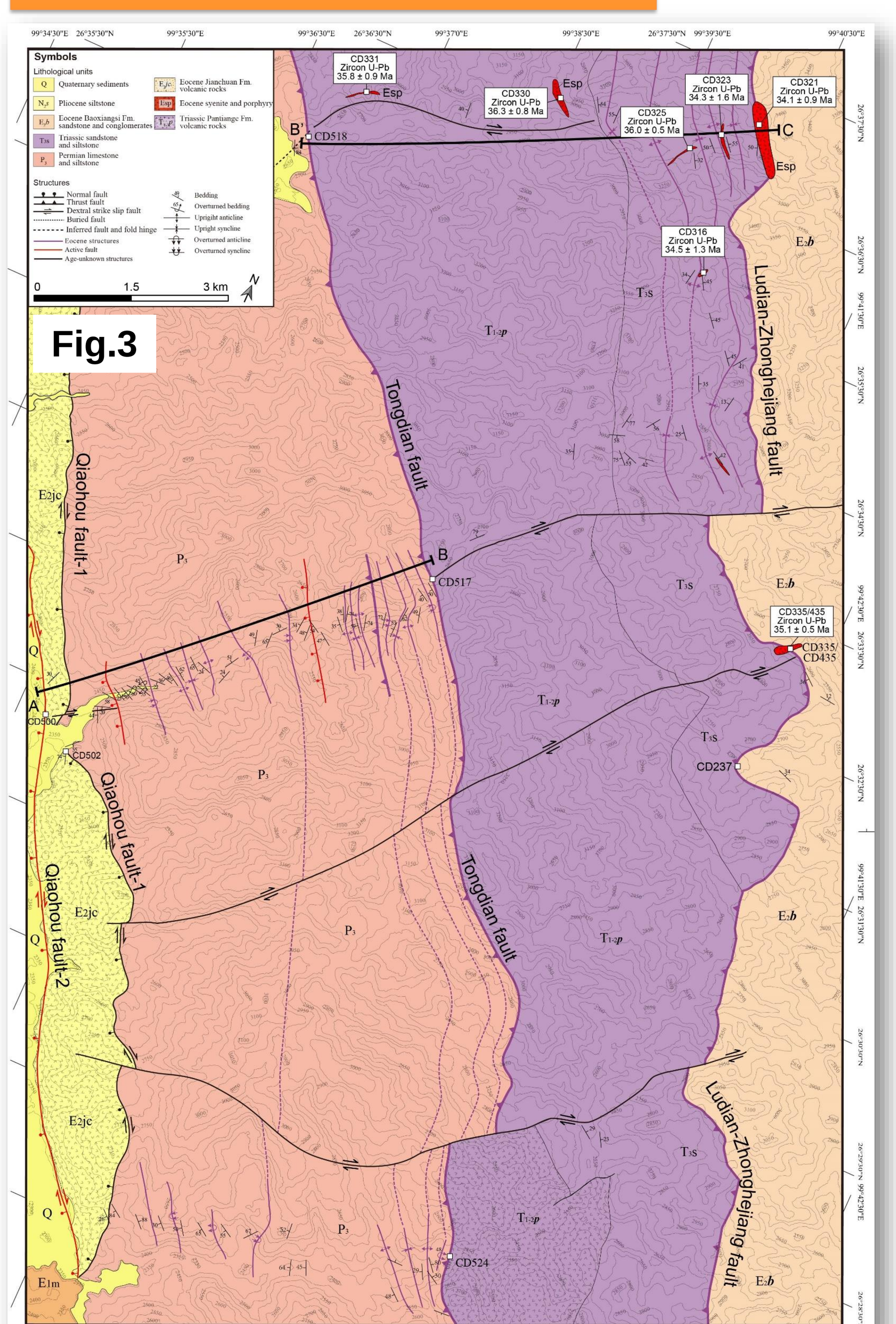


Fig.2 (a) Geological map of the Jianchuan-Madeng area, southeast Tibet, based on *BGMRY* [1990], *Gourbet et al.* [2017], *Cao et al.* [in review] and new mapping results. (b) Sketch geological cross-section across the Ludian-Zhonghejiang fold-thrust belt and the Jianchuan basin, reflecting basic contact relationships between major structures and lithological units. Sections are located on Fig. 2A. (c) Stratigraphy of the Jianchuan basin with age constraints on the upper part of the sediment sequences, modified from *Gourbet et al.* [2017] and *Sorrel et al.* [2017].

Geological mapping



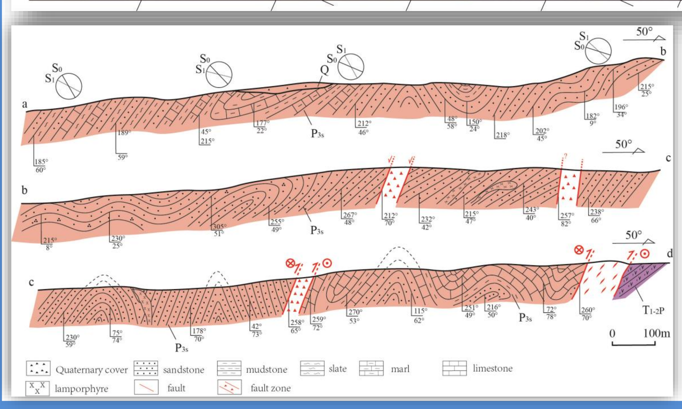


Fig.3 Geological mapping results in the central segment of the Ludian-Zhonghejiang fold-thrust belt, focusing on the major structures and lithological units to the west of the Jianchuan basin based on *BGMRY* [1990]. Lower panel show a geological cross section AB in the upper panel.

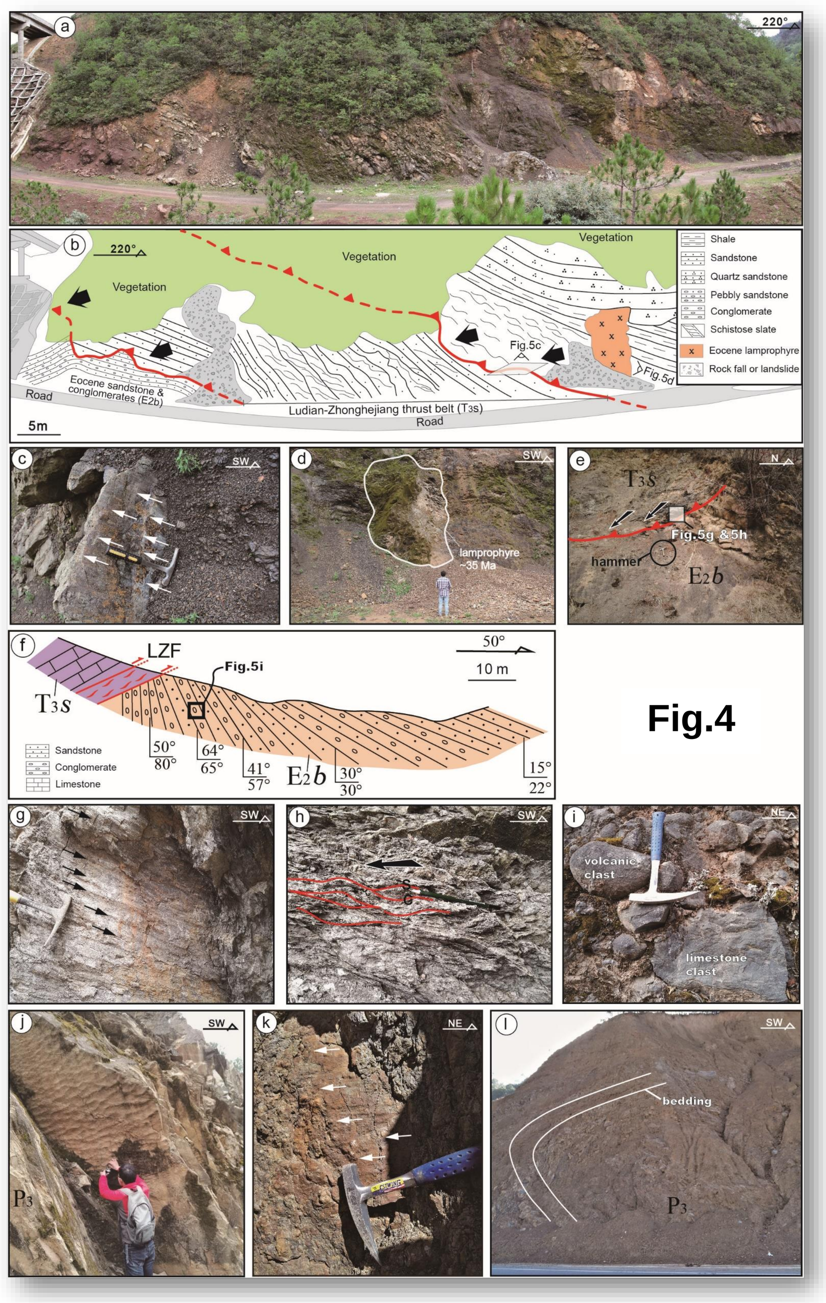


Fig.4 (a) field photos and (b) interpretations present that the LZF juxtaposed schistose Triassic meta-sandstone and coal-bearing slate over folded Eocene sandstone and conglomerates in the Jianchuan basin at site CD335 in Fig.4. (c) gently-dipping slickenlines and slickensides on the fault surface indicating thrust motion of the LZF. (d) a ~35 Ma lamprophyre dyke intruding the LZF indicative of main thrusting prior to ~35 Ma. (e) the LZF placed Triassic coal-bearing slate overlying Eocene sandstone at site CD237. (f) Sketch showing the LZF placing Triassic strata over growth strata of the Baoxiangsi Fm. at site CD237. A class of kinematic indicators in the fault zone of the LZF including (g) gently-dipping striae and slickensides and (h) S-C fabrics in highly schistose Triassic slate indicating low-angle thrusting. (i) syn-tectonic conglomerates in the growth strata in the footwall of the LZF near site CD237 bearing abundant cobbles and boulders of volcanic and limestone sourced from the hanging wall of the fault. (j) asymmetrical ripples in the late Permian sandstone near site CD502 indicative of overturned bedding. (k) recumbent fold proximal to the Tongdian fault near site CD517.

Deformation generations

Four Cenozoic deformation generations:

- D1: Ludian-Zhonghejiang fold-thrust belt, composed of the Tongdian fault, Ludian-Zhonghejiang fault and syn-deformed folds, prior to late Eocene.
- D2: Qiaohou fault-1, dextral strike-slip with a normal component, Late Miocene-Pliocene;
- D3: NE-trending dextral strike-slip fault, Pliocene?;
- D4: Qiaohou fault-2, active fault.

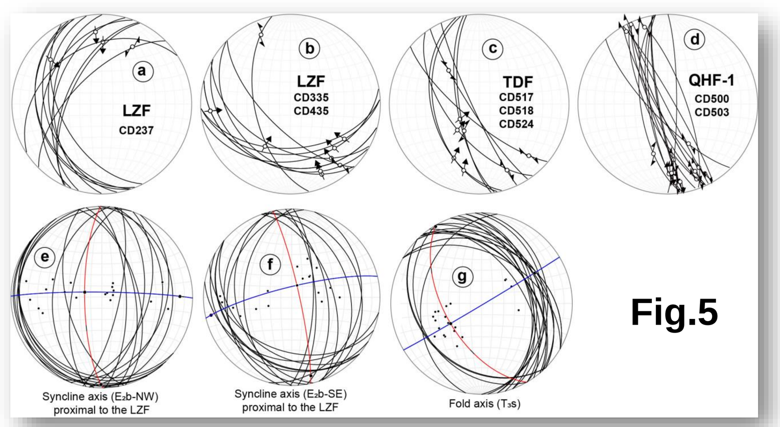


Fig.5 Structural and stratigraphic data from selective outcrops projected in lower hemisphere for major brittle faults and folds in the mapping area. (a) and (b) Ludian-Zhonghejiang fault at outcrops CD237 and CD335/CD435, (c) Tongdian fault at outcrops CD517, CD518 and CD524, (d) Qiaohou fault at outcrops CD500 and CD503; (e), (f) and (g) stratification (red great circles) and poles to stratification (dots) for syncline of the Eocene sediments (E2b) proximal to the LZF and fold assemblages of the Triassic meta-sediments (T3s) within the fold-thrust belt. The axis and axial surface orientations of the folds involved in the LZTB are stereographically calculated based on representative strike-and-dip measurements of the limbs of the folded bedding surface.

Dating crust shortening

Cooling history of Ludian granite in the hanging wall of the LZF:

- Zircon U-Pb ages: 228-235 Ma;
- Zircon (U-Th)/He ages: ~100-140 Ma
- Apatite fission track ages: 35.8-45.3 Ma
- Apatite (U-Th)/He ages: 29-50 Ma.
- QTQt inverse modeling: rapid exhumation from 50Ma to 37 Ma at a rate of ~0.3-0.4 mm yr^{-1}.

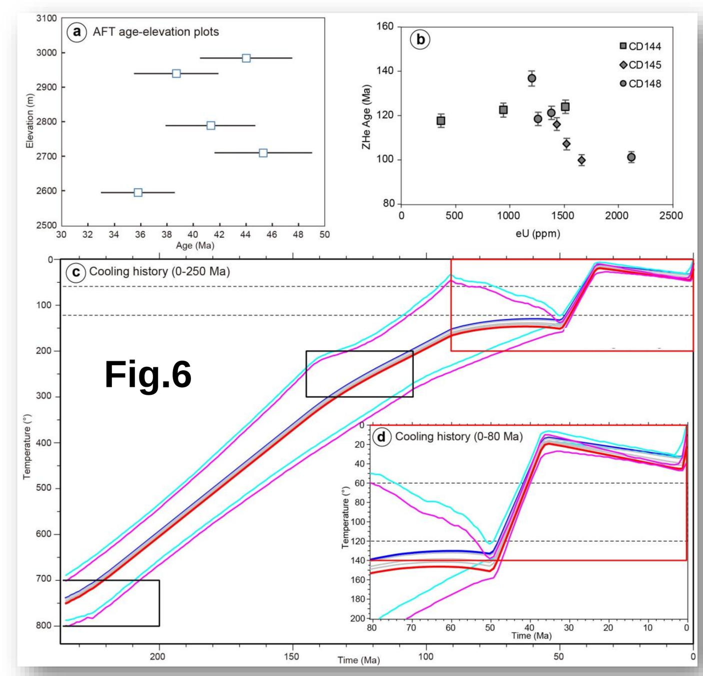


Fig.6 (a) Apatite fission-track ages against elevations for the Ludian pluton in the hanging wall of the LZF. (b) Corrected ZHe ages versus effective uranium content (eU). (c) Cooling history of the Ludian pluton derived from QTQt inverse modelling. (d) Cooling history of the Ludian pluton highlighting the thermal window of 80-0 Ma.

Discussion

Syn-tectonic deposition in the Jianchuan basin

Evidence for syn-tectonic deposition of the Baoxiangsi Fm.(E_2b):

- growth strata;
- significant change of sedimentary facies;
- eastward and northeastward paleocurrents;
- pebble and boulder composition.

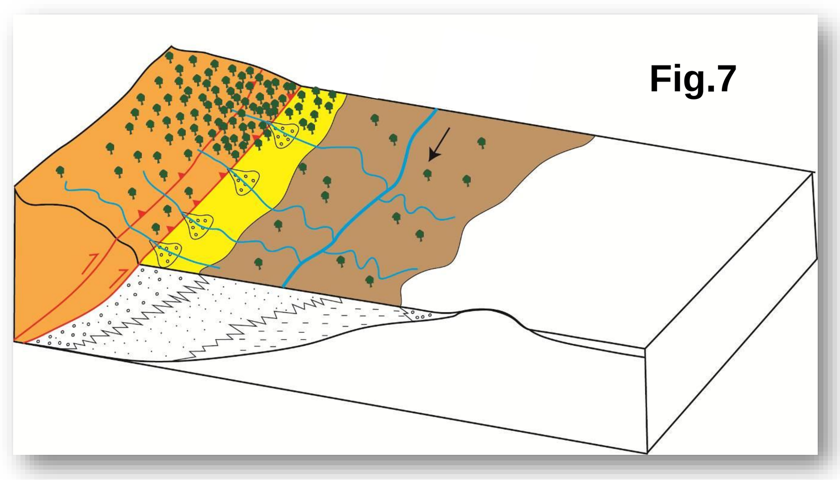
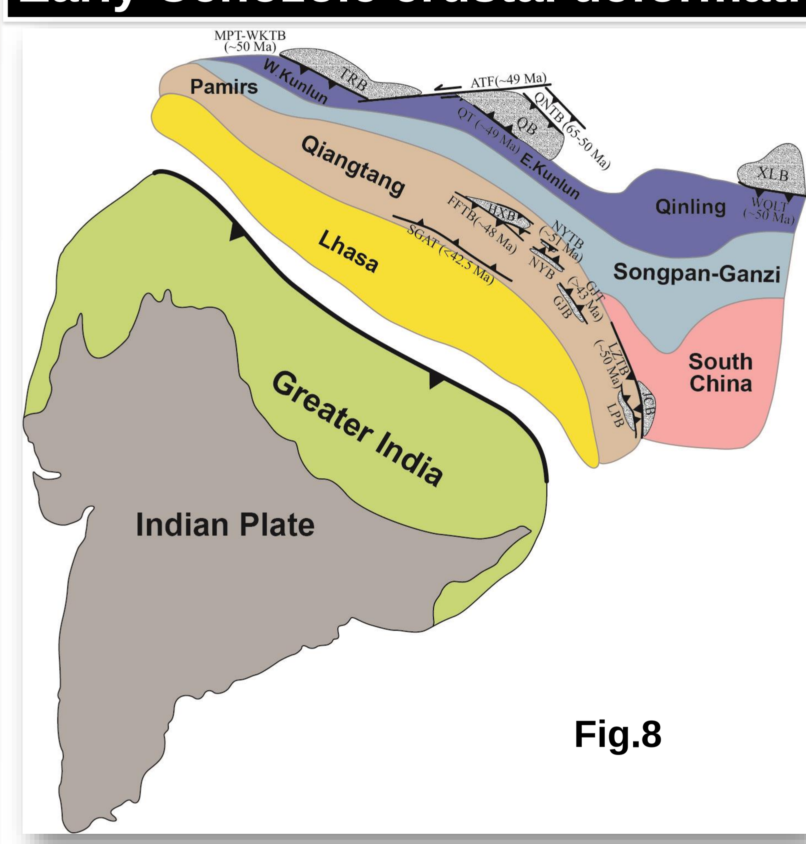


Fig.7 Cartoon showing source-to-sink process of the Baoxiangsi Fm. in response to the deformation of the LZTB.

Early Cenozoic crustal deformation across the Tibet and mechanism



Widespread upper crust shortening across the Tibetan Plateau as a result of strain propagation in a quasi-rigid Tibetan lithosphere soon after the India-Asian collision prior to Oligo-Miocene onset of extrusion tectonics.

Fig.8 Eocene tectonic scenario across the Tibetan plateau with emphasis on the structures and syn-tectonic flexural basins in response to the India-Asian collision. The size of the Greater India with respect to the Tibet is approximated from *van Hinsbergen et al*. [2011]. Abbreviations: AFT–Altyn Tagh fault, FFTB–Fenghuoshan fold-thrust belt, GJB–Gonjo basin, GJT–Gonjo thrust, HXB–Hoh Xil basin, JCB–Jianchuan basin, LPB–Lanping basin, LZTB–Ludian-Zhonghejiang thrust belt, MPT-WKTB–Main Pamir thrust-West Kunlun thrust belt, NQT–North Qaidam thrust, NYTB–Nangqian-Yushu thrust belt, NYB-Nangqian-Yushu basin, QT–Qaidm basin, QT–Qaidam thrust, TRB–Tarim basin, WQLT–West Qinling thrust, XLB–Xining basin. Initial timing for major faults are labeled: FFTB at ~48 Ma [*Staisch et al.*, 2016], WQLT at ~50 Ma [*Clark et al.*, 2010; *Duvall et al.*, 2011], GJT at >43 Ma [*Studnicki-Gizbert et al.*, 2008], NYTB at ~51 Ma [*Horton et al.*, 2002; *Spurlin et al.*, 2005], SGAT at <42.5 Ma [*Yin and Harrison*, 2000], MPT-WKTB at ~50 Ma [*Cao et al.*, 2013; *Yin et al.*, 2002] , QNTB at 65-50 Ma [*Yin et al.*, 2008], QT and ATF at ~49 Ma [*Yin et al.*, 2002] and LZTB [this study].

Conclusions

- **Detailed field mapping, structural analysis and geochronologic and thermochronogic data defined a new Ludian-Zhonghejiang fold-thrust belt stretching over 120 km between the Diancang Shan and Xuelong Shan metamorphic belt in western Yunnan, China.**
- **Low temperature thermochronology from a Triassic pluton in the hanging wall of the LZTB assisted by inverse modeling revealed a period of accelerated cooling from 50 Ma to 37 Ma, which is interpreted to record the lifespan of the fold-fault system, collaborated by the intrusive relationships of Eocene magmas of ~35 Ma dated by zircon U-Pb into deformation zone.**
- **Widespread upper crustal shortening prevailed across the Tibetan Plateau as a result of strain propagation in a quasi-rigid Tibetan lithosphere soon after the India-Asian collision, which predated Oligo-Miocene onset of extrusion tectonics.**

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Acknowledgements: We thank Peter Decelles, Jay Chapman for inspiring discussion. LA-ICP-MS apatite fission-track dating was accomplished by Raymond Donelick and Paul O'Sullivan at Apatite to Zircon, Inc., Viola, Idaho, USA. We are grateful to Peter Reiners and Uttam Chowdhury for help in the (U-Th)/He lab at University of Arizona. This study was funded by the Geological Survey of China (No. 1212011121261), the NSF China (Nos. 41202144, 41672195, 41302279, 91755213), and the Fundamental Research Funds for the Central Universities, China University of Geosciences (No. G1323511641) and China Scholarship Council (No. 201606415003).