Crustal-scale deformation history of the Longmen Shan polyphased range located at the eastern border of the Tibetan plateau

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The Longmen Shan range is a very peculiar margin of the Tibetan plateau because high mountains with a steep topographic gradient subsists whereas GPS measurements indicate almost no present day horizontal shortening across the range (Shen et al., 2009). Furthermore, seismological and gravimetric data also indicate that a steep 20km Moho step exists between the Tibetan crust and the Yangtze craton (Robert et al., 2010a,b). Two large crustal provinces were therefore identified in the Longmen Shan : (1) The Songpan Garze unit which is mostly composed of a thick sequence of turbiditic flysch and (2) The Yangtze affinities unit which consists in Neoproterozoic crystalline massifs, their sedimentary cover and mostly platform and continental sediments of the Sichuan Basin. Today, this margin appears as a major boundary between two contrasted crusts (figure 1) whereas original depositional environments indicate this boundary was a passive margin by Triassic times.

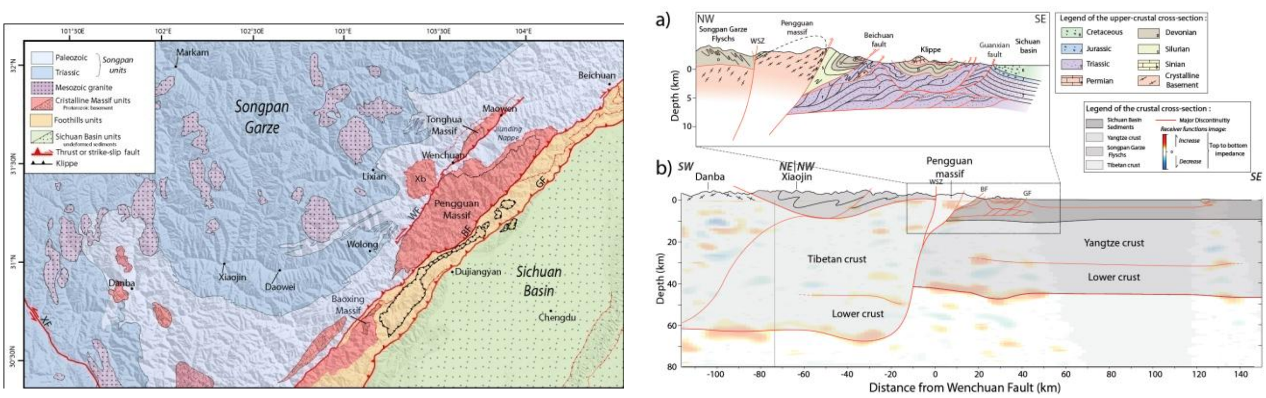

Figure 1. Left : Structural sketch of the Longmen Shan area drapped on SRTM data Right : a) Upper crustal scale cross-section of the Longmen Shan range showing the geometry of the faults structuring the range b) Schematic crustal-scale cross-section across the Longmen Shan from the Receiver functions imaging that indicate the sharp Moho offset between the 63km-thick Tibetan crust and the 45km-thick Yangtze crust. From Robert et al. (2010a).

It is commonly accepted that the tectonic history of this belt began during late Triassic with the Indosinian orogeny, which was synchronous with the collision of the North China block with the South China block (Yangtze craton), and ended with the closure of the Paleotethys (Mattauer et al., 1992). Some authors mentioned a Yanshanian deformation phase that affected the belt but the timing (Middle Jurassic to Cretaceous), and the deformations associated to this phase are not well constrained.The last tectonic phase (8-11Ma) reactivated old structures and was associated with major exhumation of the range (Godard et al., 2010).

Unfortunately, few studies quantify deformation and exhumation history of the range as a consequence of the lack of minerals indexes of metamorphism. Therefore we used especially adapted methods to study this kind of rocks as the RSCM method (Raman Spectroscopy of Carbonaceous Material) (Beyssac et al., 2002) or P-T estimates relying of the multiequilibrium between chlorites and phengites (Vidal et al., 2006 ; Lanari et al. *submitted*). In few samples, the occurrence of synchronous garnets and biotites allows the application of the biotite/garnet geothermometer and pseudo-sections calculations using Perple_X programs (Connolly, 2005).

Our results highlight three major phases of deformation that occurred in the Longmen Shan range:

1) Indosinian orogeny (Late Trias to Early Jurassic) that affects the Songpan Garze flysch is mostly characterized by nappe tectonics with a motion directed toward the South-East. This tectonics was associated with the peak of pressure and temperature (crystallization of garnet, biotites ± staurolite ± kyanite) that is recorded in sediments exhumed in the Wenchuan-Maowen shear zone and in the Danba area (zones of major exhumation). Pseudosections using Perple_X on samples in the Wenchuan-Maowen shear zone indicates pressures of 6.5kbar and temperatures of 550°C for the peak of metamorphism associated with crystallization of garnets. Furthermore, temperatures maxima of about ~500°C were recorded in most parts of the flysch. The end of the Indosinian orogeny could be associated with minor thick-skin tectonics and relatively low exhumation.
2) Late Mesozoic tectonics restricted to the Wenchuan Shear Zone and the Danba area and was associated to greenschists facies metamorphism. In the Wenchuan-Maowen shear zone, structural features indicate a sinistral transpressional event. Chorites-Phengites multiequilibrium P-T estimates point out pressures varying from ~6 to ~3kbar with temperatures of 350°C-400°C suggesting a rapid exhumation of the greenschist rocks. The in situ (LaICPMS) Th-Pb ages for monazites (including chlorite and phengite) indicate ages ranging from 90 to 70Ma.
3) Miocene to Present-day tectonics consists of a reactivation of the front of the Longmen Shan (Beichuan, Guanxian faults and triangular zone of the Sichuan Basin) due to the India-Eurasia collision and is associated with rapid exhumation localized principally on the Beichuan fault.

Indosinian orogeny was mostly characterized by thin-skin tectonics affecting a very thick sedimentary pile and relatively low exhumation was perform during this deformation phase. A late Yanshanian event (90 to 70 Ma) affected the Longmen Shan range and is characterized by a sinistral transpressional event. Our results highlight that important exhumation was performed during this deformation event in the Wenchuan Maowen shear zone. We consider that this event was a prior phase of thickening of the Tibetan crust. The last deformation phase is Miocene and correlated to the India-Eurasia collision and the formation of the Tibetan plateau. This late phase is also associated to diffuse crustal thickening of the whole Tibetan crust. The major role of the tectonic heritage in the crustal-scale geometry of the belt, which conditions the location of the major thrusts and the thickening of the Tibetan crust is pointed out by our study.

References

Beyssac O., et al., 2002, Raman spectra of carbonaceous material in metasediments: a new geothermometer, Journal of Metamorphic Geology, 20, 859-871.

Connolly, J. A. D., 2005, Computation of phase equilibria by linear programming: A tool for geodynamic modelling and its application to subduction zone decarbonation. Earth and Planetary Science Letters 236:524-541.

Godard V., et al. 2010, Late Cenozoic evolution of the central Longmen Shan (Eastern Tibet), insight from (U-Th)/He thermochronometry, Tectonics, 28.

Mattauer M., et al., 1992, La chaîne triasique du Songpan Garze (Ouest Sechuan et Est Tibet) : Une chaîne de plissement-décollement sur marge passive , C.R. Acad. Sci. Paris, 314, 619-626.

Robert A., et al., 2010a, Structural and thermal characters of the Longmen Shan (Sichuan, China), Tectonophysics, 491, 165-173.

Robert A., et al., 2010b, Crustal structures in the area of the 2008 Sichuan earthquake from seismologic and gravimetric data, Tectonophysics, 491, 205-210.

Shen Z.K., et al., 2009, Slip maxima at fault junctions and rupturing of barriers during the 2008 Wenchuan earthquake, Nature Geoscience, 2.

Vidal O., et al., 2006, P-Tdeformation-Fe3+/Fe2+ mapping at the thin section scale and comparison with XANES mapping. Application to a garnet-bearing metapelite from the Sambagawa metamorphic belt (Japan), Journal of Metamorphic Geology, 24,669-683.

Wang E.C. and Q.R. Meng, 2009, Mesozoic and Cenozoic tectonic evolution of the Longmenshan fault belt, Science in China Series D ; Earth Sciences, 52, 579-592.