INTENSE LATE CENOZOIC CRUSTAL SHORTENING IN SOUTHERN QIANGTANG, WESTERN CHINA

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The magnitude of Cenozoic crustal shortening within the Tibetan plateau is a question of key importance in the models for its development. Earlier investigators proposed that the Cenozoic shortening within the plateau is generally less than 40%. Here, we present two exactly constrained structural sections, which show that the late Cenozoic crustal shortening within southern Qiangtang is upto 57-67%. This indicates that the internal crustal shortening within the plateau can play a vital role in the doubling of the crust of the Tibetan plateau.

INTRODUCTION

There are two radically different interpretations of the development of the Tibetan plateau (Fig.1) (Burchfiel and Royden, 1991). Argand (1924), Barazangi and Ni (1982), Powell and Conaghan (1975), and Zhao and Morgan (1987) believed that the great thickness (50-70 km) of the crust beneath Tibet has resulted from the doubling of continental crust by replacement of the Tibetan upper mantle by underthrust Indian continental crust. In contrast, Dewey and Burke (1973) and Dewey et al. (1988) suggested that the thick crust beneath the Tibetan plateau was the result of shortening of the Tibetan crust due to the India/Eurasian convergence. Although the seismic reflection profiles revealed that the Indian continent indeed is underthrust beneath the Tibetan plateau (e.g. Zhao et al. 1993), the underthrusting is limited to the south of the Bangonghu-Nüjiang suture (Fig.1) (Owens and Zandt, 1997). Low shear wave velocity and high Poisson's ratio has been detected in northern Tibetan, which reveal that there could not be cool Indian crust underthrust beneath there (e.g. McNamara et al. 1994; Owens and Zandt, 1997). Therefore, the underthrusting of India cannot convincingly interpret the doubling of the Tibetan crust (Burchfiel and Royden, 1991). During the last 20 years, several Chinese-foreign joint field investigations have discovered numerous Cenozoic fold and thrust structures along the Qinghai-Xizang (e.g. Chang et al. 1986; Coward et al. 1988; Dewey et al. 1988) and the Xinjiang-Xizang highway (e.g. Matte et al. 1996), but the Cenozoic crustal shortening of the plateau generally is less than 40% (e.g. Chang et al. 1986; Coward et al. 1988; Dewey et al. 1988; Matte et al. 1996). Such weak shortening cannot have led to the doubling of Tibetan crust (Burchfiel and Royden, 1991). Therefore, the mechanism of the Tibetan plateau still is a focal point of considerable debate and the magnitude of Cenozoic crustal shortening within the Tibetan plateau is of key importance in evolving genetic models for its development (Burchfiel and Royden, 1991).

Recently, we conducted detailed measurement twice at

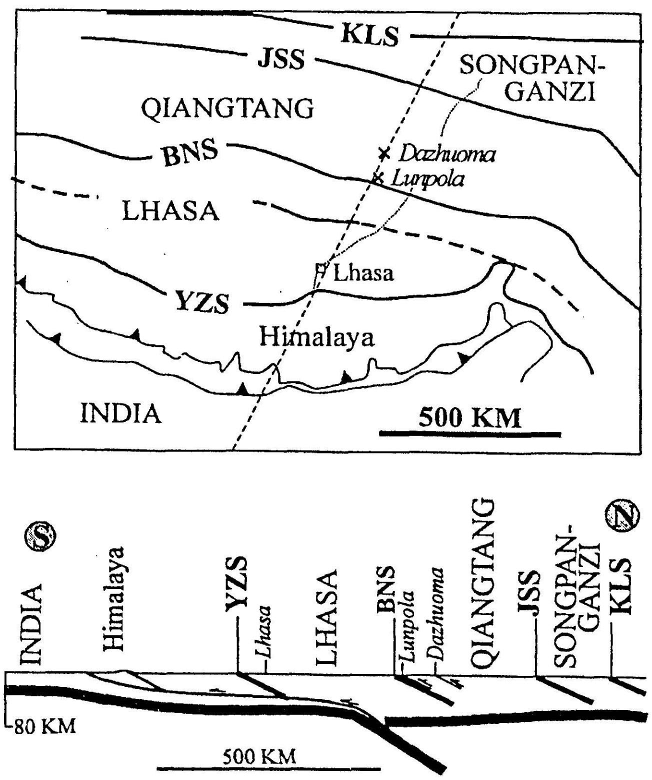

Fig.1. Tectonic sketch map (upper) and highly simplified crustal section (lower) of the Tibetan plateau, after various data sources. BNS-Bangonghu-Nüjiang suture, JSS-Jinsajiang suture, KLS-Kunlun suture, YZS-Yarlung-Zangbo suture. In the upper map, the dashed straight line corresponds to the location of the lower section and the dotted line represents the Qinghai-Xizang highway.

a scale of 1:2000 on the Dazhuoma structural section in southern Qiangtang. Our fieldwork, together with seismic and drilling exploration in another structural section of nearby area, shows that the late Cenozoic crustal shortening within southern Qiangtang is more than 50%. This indicates that the internal crustal shortening within the plateau can play a crucial role in the doubling of the Tibetan crust.

THE DAZHUOMA STRUCTURAL SECTION

The Dazhuoma structural section, ca. 6 km long, is generally located at a height of 5100 m above sea level (Fig.2a) and approximately 100 km west of the Qinghai-Xizang highway. Based on key fossils or fossil assemblages and lithology, the strata were divided into 528 units and

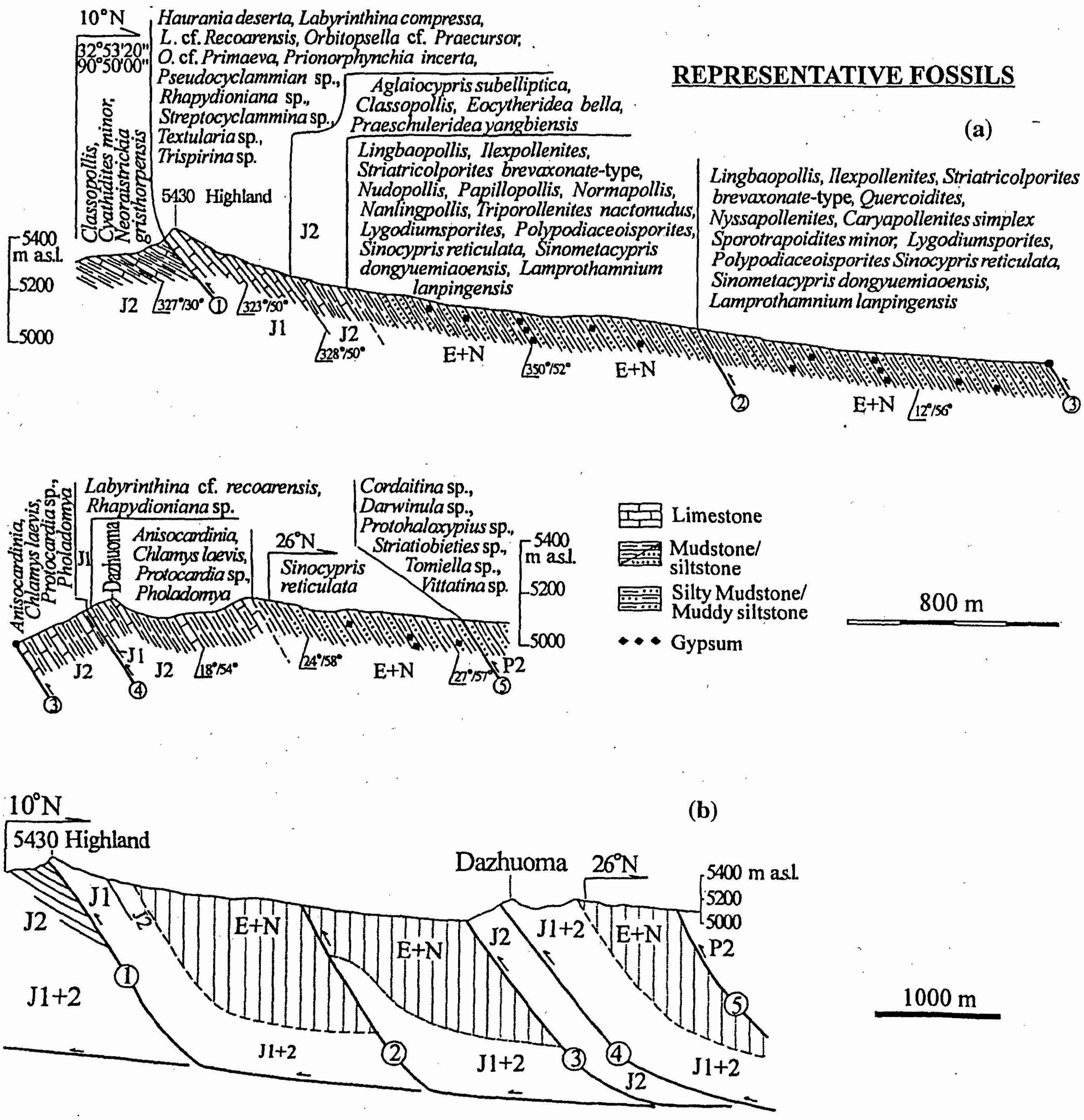

Fig.2.a. Dazhuoma structural section with fossil data. **b.** Restored Dazhuoma structural section. P2- Upper Permian, Jl- Lower Jurassic, J2- Middle Jurassic, Jl+2- Lower + Middle Jurassic, E+N- Palaeogene-Miocene.

are assigned Late Permian, Early-Middle Jurassic, and Tertiary ages (Fig.2a). The stratigraphy and palaeontology regarding the section will be published elsewhere and all the fossils described in Fig.2a are exhibited in the Nanjing Institute of Geology and Paleontology, Academia Sinica.

Upper Permian and Lower-Middle Jurassic sequences appear to have been deposited in a marine environment but Tertiary strata were formed in a continental setting (Zhang et al. 2002). Upper Permian sequence is composed of grey, thin-bedded mudstone and siltstone, and bears rich Late Permian sporomorphs and marine ostracoda. The Lower Jurassic sequence is made up of bioclastic limestone and Middle Jurassic sequence of interbedded limestone and fine-grained clastic rocks such as shale and siltstone, both sequences constituting a total thickness of about 350 m. Tertiary sequence of 1100 m thickness lies unconformably on Middle Jurassic strata and comprises grey to purple thin-bedded fine-grained clastic rocks such as siltstone, silty mudstone and mudstone. This sequence was deposited from Palaeogene through Miocene time according to rich sporomorphs, ostracoda, charophytes and insect fossil records (Fig.2a).

Five main thrust faults were identified (Nos.1-5. Figs.2a, b). The microstructural features characteristic of thrusting were observed along some fault planes, although the thrusts did not apparently change the occurrences of the strata near the faults. The thrust fault within Tertiary sequence (No.2 in Fig.2a, b) was established based on the repeated fossil assemblage and lithology and the microstructures along the fault plane. All the thrust faults have similar occurrences and dip northwards at a large angle (50° ±), thus forming a typical imbricate fault zone (Figs.2a, b). The southernmost fault (No.1), parallel to the overlying beds but angular to the underlying beds, is a lower ramp structure, and other faults (Nos. 2-5), parallel to both the overlying and underlying beds, form flat structures (Fig.2b).

We infer there is a floor fault within Lower Jurassic sequence on the basis of the fault geometry and its relation with the strata (Fig.2b), and this floor fault is buried approximately at a depth of 1800 m. Only with the undenuded beds taken into consideration, we preliminarily estimate that the crust along the Dazhuoma structural section is shortened by 20 km or 67%, according to line-length balance principle. Because Tertiary sequence is composed of distal fine-grained clastics and the impossibility of its being syntectonic deposits, we believe the Dazhuoma imbricate thrust zone should have formed after Miocene stage.

DISCUSSION AND CONCLUSIONS

To the south of the Dazhuoma structural section and to the north of the Bangonghu-Nujiang suture, the Lunpola structural section also documented intense post-Oligocene contractional deformation. This section is located on the famous Lunpola oilfield in the Tibetan plateau and was well constrained by seismic and drilling data (e.g., Lei et al. 1996). The deformation, verging southwards, involved Jurassic-Tertiary sequence and should have formed after Oligocene time (Fig.3). A simple calculation estimates that the crust was shortened by 57% along the section based on line-length balance principle.

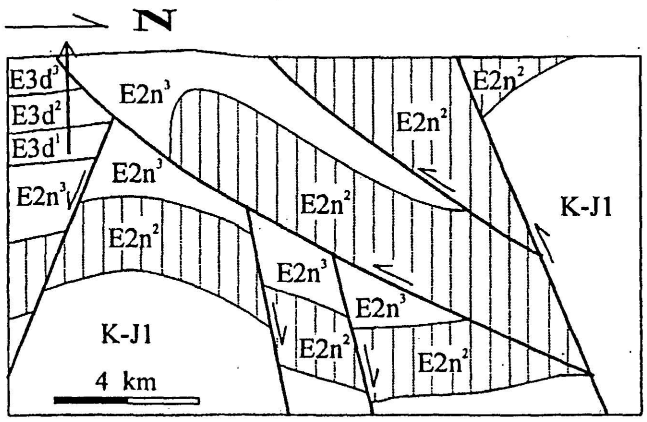

Fig.3. Lunpola structural section (revised after Lei et al. 1996). This section is well constrained by seismic and drilling data. K-Jl- Cretaceous-Lower Jurassic, E2n- Eocene Niubao Formation, E3d- Oligocene Dingqing Formation.

The intense late Cenozoic crustal shortening along the Dazhuoma and Lunpola structural sections shows that intense Cenozoic crustal shortening could have spread all over southern Qiangtang, or even possibly all over the entire Tibetan plateau, not only in Cenozoic rocks but also in areas where Cenozoic rocks are not involved (Dewey et al. 1988; Burchfiel and Royden, 1991). The gentle beds along the Qinghai-Xizang highway observed by the British/Chinese joint investigation (Coward et al. 1988) could be the exposures of the rocks near the floor-thrust in Fig.3. Therefore, we believe that the magnitude of Cenozoic shortening within the Tibetan plateau could be rather great and that the role internal crustal shortening plays in the doubling of the Tibetan crust should be crucial.

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