The tectonic evolution of the North Qiangtang terrane at Mesozoic and Cenozoic determined by deformation in the Raggyorcaka area, Tibet

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Abstract

The Mesozoic and Cenozoic deformation of the North Qiangtang terrane reflects a portion of the tectonic evolution of the Tethys Ocean, involving Indosinian, Late Yanshanian, and Cenozoic intraplate structures of shallow-superficial tectonic levels. The structural mapping of the Permian-Triassic tectonic layer indicates that the Mesozoic tectonic style was dominated by Late Yanshanian horizontal contractional deformation characterised by NW-SE trending thrust faults inheriting and transforming early-formed folds and their accommodation faults. These folds and thrusts were superimposed on Indosinian buckle folds. Structural analysis on deformations of the Neogene tectonic layer indicates that there were two transitions in the tectonic evolution of North Qiangtang terrane dividing the Cenozoic deformation into three stages. In episode I (50-40 Ma to 8-4 Ma), the crust experienced large-scale N-S horizontal shortening, and buckle folds and thrust faults increased the vertical crustal thickness. In episode II (8-4 Ma to the Pleistocene), E-W passive stretching formed conjugate strike-slip fault systems and pull-apart basins. During this episode, the Qiangtang basin was extruded eastwards, and a number of superficial N-S trending buckle folds were formed. In episode III (the Pleistocene to the present), the stress field was reversed, and the Qiangtang basin experienced E-W active stretching, forming conjugate normal faults and graben structure.

Introduction

The lithosphere pattern of Eastern Asia, and especially the pattern of the Tibetan Plateau, was produced by the collision of fractured plates in northern Gondwana after the Devonian, and the suture zone of welding terranes recorded the evolution of the Tethys Ocean (Dewey et al., 1988; Yin and Harrison, 2000; Metcalfe et al., 2006). The Longmu Co-Shuanghu suture, which is located in the Central Qiangtang basin, is an extremely important Indosinian tectonic zone in the Tibetan Plateau that separates the South Qiangtang accretionary complex belt and the North Qiangtang terrane; this suture retains important information regarding the evolution of the Palaeo-Tethys Ocean (Li et al., 1987, 1995, 2009; Yin and Harrison, 2000; Liu et al., 2002; Wang et al., 1995, 2009; Zhai et al., 2011; Liang et al., 2012). After the Jurassic, the South Qiangtang accretionary complex belt and the North Qiangtang terrane merged into one unified terrane and became a Mesozoic-Cenozoic sedimentary basin. In approximately the year 2000, petroleum geologists performed geological surveys in the Qiangtang basin for the purpose of oil and gas exploration and established the overall tectonic pattern of the Qiangtang basin; over time, investigations expanded to focus on the Mesozoic tectonic evolution of this location (Lu et al., 2001; Huang, 2001; Lei et al., 2001; Wang et al., 2001; Wang et al., 2004; Li et al., 2008). On the whole, the North Qiangtang terrane has been an actively researched region of the Tibetan Plateau, and the major results of the tectonic research in this region may be summarised as follows: (1) geophysical data have been analysed and utilised to divide the Qiangtang basin into three tectonic units: the North Qiangtang depression, the central uplift belt, and the South Qiangtang depression (Lu et al., 2001; Huang et al., 2001; Wang et al., 2001; Wang et al., 2004); (2) based on the type and degree of tectonic development in various regions, the Qiangtang basin has been divided into a marginal thrust-fold belt, an internal composite fold belt, and a central basement metamorphic belt (Huang et al., 2001; Lei et al., 2001; Wang et al., 2001; Wang et al., 2004); (3) the combination patterns and distribution laws of folds and faults have been summarised and the stress field setting of these structures in the Qiangtang basin has been analysed (Huang, 2001; Lei et al., 2001; Wang et al., 2004; Li et al., 2008). In addition, the Cenozoic deformation of the Qiangtang basin has attracted attention from tectonic geologists, and there have been continuing reports and studies of thrust faults, strike-slip fault systems, and N-S trending rifts in this region (Yin et al., 1999; Yin, 2000; Yin and Harrison, 2000; Li et al., 2001; Zhang et al., 2002; Taylor et al., 2003; Xie et al., 2009).

Although a degree of knowledge exists regarding the overall tectonic framework of the Qiangtang basin, existing studies of the tectonic evolution of the North Qiangtang terrane remain limited (Yin and Harrison, 2000; Taylor et al., 2003). For example, the scale of these investigations has been too small; thus, there is a lack of tectonic analysis on the outcrop scale. The deformation sequence of this terrane since the Mesozoic has not been stablished, and folds and faults from different eras are often confused. Furthermore, there is a lack of systematic analysis of Cenozoic deformation in the North Qiangtang terrane, and there is a limited understanding of the combination of this deformation with the dynamic processes of the uplift of the Tibetan Plateau (Taylor et al., 2003). Actually, the solvement of these questions contributes to an understanding of the early evolution of the Tethys Ocean and the Cenozoic tectonic uplift process in the central Tibetan.

Method

To answer these questions, we conducted structural mappings of the Raggyorcaka area in Central Qiangtang on 1:50,000 and 1:10,000 scales; subsequently, these results were combined with high-precision remote sensing images to detailedly study the medium-small structures of the Mesozoic and Cenozoic strata. Based on geometric and kinematics analyses on these structures, this paper will determine the stages of the Mesozoic-Cenozoic intraplate deformation processes in North Qiangtang and establish the structural style and formation mechanisms at various deformation stages, thereby providing a detailed and accurate tectonic account of the geological evolution of the central Tibetan Plateau.

Regional geological setting

The Qiangtang basin is situated in northern Tibet, where it is sandwiched between the Jinsha suture zone and the Bangong-Nujiang suture zone (Fig. 1B). With an area of nearly 180,000 km2, this basin is the largest Mesozoic-Cenozoic residual basin in China; the Qiangtang basin features extensive outcroppings of Triassic-Jurassic marine sedimentary strata, and it was gradually transformed into a continental sedimentary basin after the Cretaceous (Zhao and Li 2000; Lu et al., 2001; Wang et al., 2001; Wang et al., 2004). Geophysical data indicate that the Qiangtang basin has the tectonic framework of one uplift sandwiched by two depressions. The central uplift of the basin in the Gangma Co-Gemu Ri-Mayer Kangri-Shuanghu area separates the North Qiangtang depression and the South Qiangtang depression, which lie on each side of this central uplift (Zhao and Li 2000; Lu et al., 2001; Huang 2001; Lu et al., 2011).

The Longmu Co-Shuanghu suture zone, which is located on the north of the central uplift(Figs. 1A and 1B), was formed during the Indosinian and became an important biogeographic boundary of the Qiangtang basin that separates the North Qiangtang terrane, which has Yangtze affinity and lies on the north side of this basin, from the accretionary complex belt with Gondwana affinity, which lies on the south side of the basin (Li et al., 1987, 1995, 2009; Liu et al., 2002; Wang et al., 2009; Geng et al., 2011; Zhai et al., 2011; Liang et al., 2012). The accretionary complex is primarily composed of Late Palaeozoic-Triassic passive continental flysch and oceanic ophiolite (Wang et al., 2009), and the metamorphism, deformation processes, and geochemical characteristics of the rocks from this complex indicate that the Palaeo-Tethys Ocean demonstrated unidirectional northward subduction (Zhai et al., 2011; Liang et al., 2012). From the spatial perspective, the central uplift area and Indosinian accretionary complex belt are rather consistent with respect to their morphology and distribution ranges (Fig. 1B). The North Qiangtang terrane on the north side of the suture zone was dominated by stable carbonate sediments in the Late Palaeozoic and Late Triassic, which were supplemented by a small quantity of continental or littoral-neritic clastic deposits (Li et al., 1995, 2009; Wang et al., 2001; Wang et al., 2004).

After the Jurassic, the North Qiangtang and South Qiangtang terranes joined into one unified terrane, although the central uplift remained an important ancient geographic boundary; in addition, there is a significant difference between the deposition on the north and south sides of this unified terrane. The Jurassic deposition of the North Qiangtang terrane was characterised by intermingling between the land and the sea. The carbonate rocks of the platform facies are mixed with transitional facies clastic rocks, and an angular unconformity is constructed on carbonate rocks from the mid- to late Triassic (Wang et al., 2001; Wang et al., 2004). The deposition of the South Qiangtang basin is closely related to the evolution of the Bangong-Nujiang Ocean. The depositional environment changed gradually from neritic facies to bathyal-abyssal facies in the Late Triassic-Middle Jurassic and subsequently transformed into transitional facies (Wang et al., 2001; Wang et al., 2004). In the Cretaceous, the sedimentation in the Qiangtang basin was largely transformed to continental facies and was subjected to overall uplift and denudation in combination with the minor distribution of clastics of fluvial-lacustrine facies (Wang et al., 2001; Wang et al., 2004). Since the Cenozoic, due to the collision between the Indian plate and the Eurasian plate, the Qiangtang basin has been constantly uplifted, and its sedimentation has been characterised by clastics of fluvial-lacustrine facies (Wang et al., 2001; Wang et al., 2004).

The deformation of the North Qiangtang terrane since the Mesozoic has been closely related to the evolution of the Tethys Ocean (Metcalfe, 2006) and is superposed with the tectonic responses of Indosinian orogenesis in the Palaeo-Tethys Ocean, Yanshanian orogenesis in the Meso-Tethys Ocean, and Cenozoic orogenesis in the Neo-Tethys Ocean. The Raggyorcaka area is outcropped with a relatively complete North Qiangtang formation (Fig. 1, 2) that can be divided into the following three tectonic layers based on their angular unconformity surfaces: (1) Upper Permian-Middle Triassic, (2) Miocene-Pliocene, and (3) Pleistocene. Various tectonic layers exhibit the deformation of the North Qiangtang terrane that occurred at different times; although these tectonic layers are distinct, all of these layers demonstrate shallow-superficial intraplate buckle folds, brittle faults, and the phenomena of superposition and replacement.

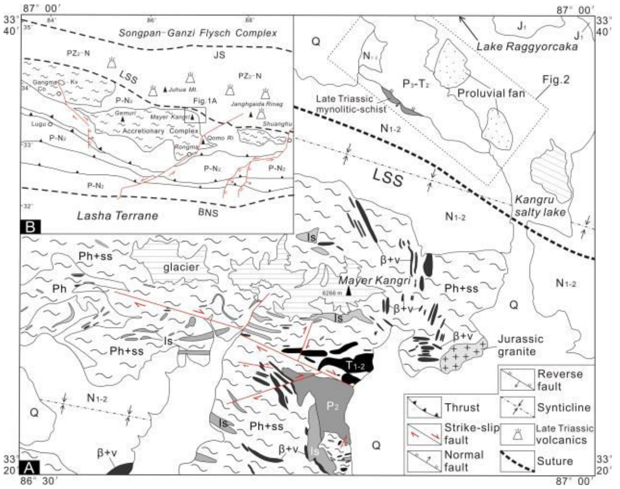

Figure 1. A geological-tectonic sketch map of the Raggyorcaka area and the Qiangtang basin. In Fig. 1A, the Qomo Ri accretionary complex lies to the south of the Longmu Co-Shuanghu suture, whereas the North Qiangtang Late Paleozoic-Mesozoic sedimentary strata are to the north of this suture. Fig. 1B illustrates the tectonic setting of the Raggyorcaka area; the Qomo Ri accretionary complex extends southward for >70 km and is covered by Mesozoic marine sedimentary strata.

Abbreviations: JS: Jinsha suture, LSS: Longmu Co-Shuanghu suture, BNS: Bangong-Nujiang suture; PZ2-N2: North Qiangtang Late Palaeozoic-Pliocene sedimentary strata, P-N2: South Qiangtang Permian-Pliocene sedimentary strata, N1-2: Miocene-Early Pliocene continental red layers; ph+ss: phyllite and metamorphosed quartz-sandstone, ph: phyllite, ls: recrystallised limestone, P2: Middle Permian carbonatite layers, β+v: Late Carboniferous-Permian basic magmatic rock relics, T1-2: Early-Middle Triassic limestone and OIB-type ophiolite, Q: Quaternary pluvial-alluvial sediments.

Results

1. Upper Permian-Middle Triassic deformation patterns

The exposed bedrock in the Raggyorcaka area is in good condition; thus, we utilised true-colour remote sensing images (3-, 2-, and 1-band images with 30 m resolution) from the American satellite Landsat-7 and true-colour images (with 2.5 m resolution) from Google Earth to interpret the tectonics of certain folds and faults and extract relevant geometric and kinematic parameters.

This tectonic layer includes Upper Permian Raggyorcaka Formation (P3r), which is littoral-neritic siltstone mixed with bioclastic limestone; Lower Triassic Kanglu Formation (T1k) of transitional sandstone; and Lower-Middle Triassic Yingshuiquan Formation (T1-2y) of neritic carbonate rocks. Horizontal contraction structures are well developed within these layers, and three distinct tectonic stages can be observed in the outcrop. The second deformation formed the main structural style, which is manifested as thrust faults, buckle folds and fold-accommodation faults (Fig. 2).

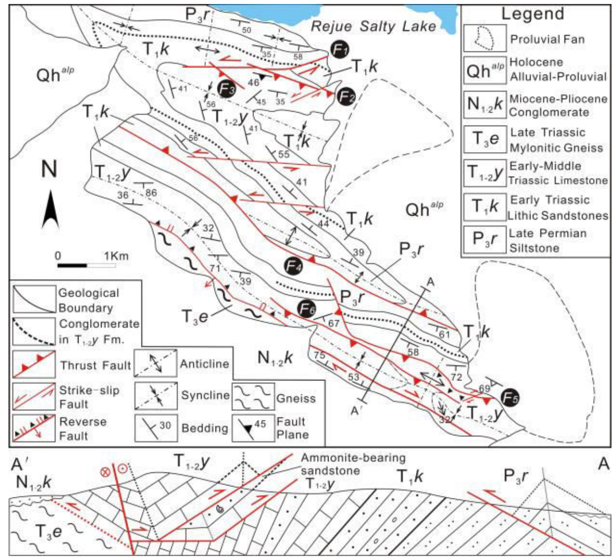

Figure 2. The structural style of Late Permian-Middle Triassic sedimentary strata in the Raggyorcaka area of North Qiangtang terrane. In the stratigraphic chart, the era becomes newer from the bottom to the top. The thrust fault belt is composed of six faults: F1, F2, F3, F4, F5, and F6. The cross-section A-A′ indicates that F4, F5, and F6 have step and ramp geometries, and exhibit an imbricated combination pattern.

2. Cenozoic tectonic deformation

Due to the influence of the Cenozoic tectonic uplift of the Tibetan Plateau, the Qiangtang basin was widely filled with a set of fluvial-lacustrine sediments during the course of the stable uplift. The Cenozoic strata in the Raggyorcaka area can be broadly divided into two tectonic layers: the purplish-red Miocene-Early Pliocene fluvial-lacustrine clastics named the Kangtog Formation and the Pleistocene alluvial and fluvial sediments. In the outcrop, the deformations of these two tectonic layers all appear as buckle folds and brittle faults on shallow level; however, their differences on structural types and combinations record the important deformation information of the uplift of the Qiangtang basin (Fig. 3).

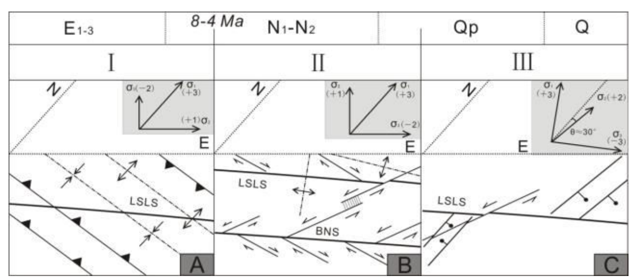

Figure 3. The stage division of the Cenozoic tectonic evolution of the North Qiangtang terrane. The grey insets reveal the three-dimensional stress field. Assuming that σ1, σ2, and σ3 are all unit vectors, the total magnitude of the stress field will lie between -3 and +3 (where a positive sign indicates compressive stress and a negative

sign indicates tensile stress). Therefore, the directions and magnitudes of the three principal stress can reflect the stress fields that exist during various stages.

Conclusions

The tectonic deformation of the North Qiangtang terrane since the Mesozoic is closely related to the evolution of the Tethys Ocean; this deformation is the consequence of the intraplate deformation superposition of Indosinian, Late Yanshanian, and Cenozoic in shallow-superficial tectonic level.

The Mesozoic tectonic pattern of this region is dominated by Late Yanshanian horizontal contraction deformation and NW-SE-trending thrust faults that have been inherited and developed on prior folds and their accommodation faults. They were superimposed on Indosinian NE-SW-trending buckle folds. The thrust faults have the geometric features of footwall ramps, and the fault zone features penetrative cleavage or the directional arrangement of giant tectonic lens bodies. In these faults, rock strata in the hanging wall were thrust in the NE or NW direction, truncated footwall rock strata, and developed anticlinic and synclinic fault-bend folds. Argillaceous limestone layers acted as the decollement layer for the thrust, and plastic rheology formed a large number of sheath folds and asymmetric shear folds.

The Tibetan Plateau was uplifted after the Cezonoic, and the North Qiangtang terrane demonstrated strong tectonic responses during this time. There were two distinct transitions of deformation regimes, allowing for the deformation of this terrane to be divided into three stages. Episode I is the N-S horizontal contraction deformation stage (50-40 Ma to 8-4 Ma); during this episode, buckle folds were aligned in a nearly E-W direction, thrust faults were developed, the vertical thickness of the crust gradually increased, and the Qiangtang basin was gradually uplifted. Episode II is the strike-slip and passive extension deformation stage (8-4 Ma to the Pleistocene); during this time, conjugate strike-slip fault systems associated with a pull-apart basin were formed. N-S-trending buckle folds associated with extrusive tectonics were developed in the middle and eastern portions of the Qiangtang basin, and the alluvial layer developed horizontal contraction structures. Episode III is the active extension stage (the Pleistocene to the present); during this stage, the stress field reversed, and the Qiangtang basin gradually shifted from passive extension to active extension in the nearly E-W direction, which led to the formation of normal faults and grabens.

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References

ARMIJO, R., TAPPONNIER, P. & TONGLIN, H. 1986. Late Cenozoic right-lateral strike-slip faulting in southern Tibet. Journal of Geophysical Research, 94, 2787-2838.

BOYER, S.E. & ELLIOTT, D. 1982. Thrust system. The American Association of Petroleum Geologists Bulletin, (66)9, 1196-1212.

Dewey, J. F., SHACKLETON, R.M., CHANG, C.F. & SUN, Y.Y. 1988. The Tectonic Evolution of the Tibetan Plateau. Philosophical Transactions of the Royal Society of London, Series A, 327, 379-382, 384-402.

Erslev., E.A. 1991. Trishear fault-propagation folding. Geology, 19, 617-620.

GENG, Q.R., PAN, G.T., WANG, L.Q., PENG, Z.M. & Zhang, Z. 2011. Tethyan evolution and metallogenic geological background of the Bangong Co-Nujiang belt and the Qiangtang massif in Tibet. Geological Bulletin of China, 30 (8), 1261-1274. (in Chinese with English abstract).

Huang, J.J. 2001. Structural Characteristics of the Basement of the Qiangtang basin. Acta Geologica Sinica, 75, 333-337. (in Chinese with English abstract).

JIA, B.J., LIU, J.Q. & YANG, P. 2006. Domal structures: An important type of folds in northern Qiangtang. Sedimentary Geology and Tethyan Geology, 26 (4), 8: 12-13. (in Chinese with English abstract).

JAMISON, W.R. 1987. Geometric analysis of fold development in overthrust terranes. Journal of Structural Geology, 9, 207–217.

Lei, Z.Y., Li, Y.T., Liu, Z. & Lu, B. 2001. Structural deformation and dynamic mechanism of the Qiangtang basin, North Tibet. Geological Review, 47, 415-418. (in Chinese with English abstract).

LI, C. 1987. The Longmucuo-Shuanghu-Lancangjiang plate suture and the north boundary of distribution of Gondwana facies Permo-Carboniferous system in northern Xizang, China. Journal of Changchun College of Geology, 17, 156-162. (in Chinese with English abstract).

LI, C., CHEN, L.R., HU, K., YANG, Z.R. & HONG, Y.R. 1995. Study on the paleo-Tethys suture zone of Lungmu Co-Shuanghu, Tibet. Beijing, China, Geological Publishing House, 129-132.

LI, C., ZHAI, G.Y., WANG, L.Q., YIN, F.G. & MAO, X.C. 2009. An important window for understanding the Qinghai-Tibet Plateau—A review on research progress in recent years of Qiangtang area, Tibet, China. Geological Bulletin of China, 28 (9), 1169-1177. (in Chinese with English abstract).

LI, Y.L., HUANG, J.J., WANG, C.S., YIN, H.S. & WANG, M. 2005. Division of the tectonically reworked areas and delineation of the favourable areas for hydrocarbon accumulation in the Qiangtang Basin. Sedimentary Geology and Tethyan Geology, 25 (4), 11-16. (in Chinese with English abstract).

Li, Y.L., WANG, C.S. & HUANG, J.J. 2008. Deformation characteristics and finalizing age of the folds in the Qiangtang Basin and their relations to oil and gas accumulation. Oil & Gas Geology, 29 (3), 283-289. (in Chinese with English abstract).

LI, Y.L., WANG, C.S., YIN, H.S., DENG, B, ET AL. 2001. Shuanghu graben and Cenozoic extension in North Tibet. Sciences in china, series D, 31, 228-232.

Liang, X., WANG, G.H., YUAN, G.L. & Liu, Y. 2012. Structural sequence and geochronology of the Qomo Ri accretionary complex, Central Qiangtang, Tibet: Implications for the Late Triassic subduction of the Paleo-Tethys Ocean. Gondwana Research, 22, 470–481.

Liu, B.P., Feng, Q.L., Chonglakmani, C. & Helmcke, D. 2002. Framwork of paleotethyan archipelago ocean of western Yunnan and its elongation towards North and South. Earth Science Frontiers, 9, 163-164. (in Chinese with English abstract).

LU, B., LIU, C.Y., LIU, Z. & LI, Y.T. 2001. Basement formation and structural features of the Qiangtang basin and their implications. Seismology and Geology, 23 (4): 510-517. (in Chinese with English abstract).

LU, Z.W., GAO, R., LI, Y.T. ET AL. 2011. Structure of basement and its N-S direction transformation in Qiangtang basin in Tibet: Discovered by a 270 km seismic reflection profile. Acta Petrologica Sinica, 27 (11), 3319-3320. (in Chinese with English abstract).

METCALFE, I. 2006. Palaeozoic and Mesozoic tectonic evolution and palaeogeography of East Asian crustal fragments: The Korean Peninsula in context. Gondwana Research, 9, 24-25, 30, 35-43.

MITRA, S. 2002. Fold-accommodation faults. AAPG Bulletin, 86 (4), 671–692.

MO, X.X., HOU, Z.Q., NIU, Y.L. ET AL. 2007. Mantle contributions to crustal thickening during continentalcollision: Evidence from Cenozoic igneous rocks in southern Tibet. Lithos, 96, 225–242.

PELTZER, G. & TAPPONNIER, P. 1988. Formation and evolution of strike-slip faults, rifts, and basins during the India-Asia Collision: An experimental approach. Journal of Geophysical Reseach, 93 (B12), 15, 085-15, 117.

SEARLE, M.P., ELLIOTT, J.R., PHILLIPS, R.J. & Chung, S.L. 2011. Crustal–lithospheric structure and continental extrusion of Tibet. Journal of the Geological Society, London, 168, 633–637, 646, 649, 662-666.

SUPPE, J. 1983. Geometry and kinematics of fault-bending folding. American journal of science, 283, 684-690.

SUPPE, J. & MEDWEDEFF., D. A. 1990. Geometry and kinematics of fault-propagation folding. Eclogae Geologicae Helvetiae, 83 (3), 409–454.

TAPPONNIER, P. & MOLNAR, P. 1976. Slip line field theory and large-scale continental tectonics. Nature, 264, 319–324.

TAYLOR, M., YIN, A., RYERSON, F.J., KAPP, P. & DING, L. 2003. Conjugate strike-slip faulting along the Bangong-Nujiang suture zone accommodates coeval east-west extension and north-south shortening in the interior of the Tibetan Plateau. Tectonics, 22 (4), 18-1-18-20.

WANG, C.S., YIN, H.S., ET AL. 2001. The geological evolution and prospective oil and gas assessment of the Qiangtang basin in Northern Tibetan Plateau. Beijing, China, Geological Publishing House, 86-95, 167-170.

Wang, G.H., Han, F.L., Yang, Y.J., Li, Y.Q. & Cui, J.L. 2009. Discovery and geologic significance of Late Paleozoic accretionary complexes in Central Qiangtang, northern Tibet, China. Geological Bulletin of China, 28 (9), 1181-1187. (in Chinese with English abstract).

WANG, G.H., ZHOU, X., PUBU, C.R. & ZENG, Q.G. 1996. Structural characteristic and tectonic evolution of Taniantaweng Mountain chain, Tibet. Beijing, China, Geological Publishing House, 1-76.

WANG, J., TAN, F.W., LI, Y.L. ET AL. 2004. The potential of the oil and gas resources in major sedimentary basins on the Qinghai-Tibet plateau. Beijing, China, Geological Publishing House, 20-24, 95-100.

Xie, C. M., Li, C., DONG, Y.S., WU, Y.W., WANG, M. & HU, P.Y. 2010. Gangmari -Juhuashan thrust nappe were discovered in central Qiangtang, northern Tibet, China. Geological Bulletin of China, 29 (12), 1857-1861. (in Chinese with English abstract).

YIN, A. 2000. Mode of Cenozoic east-west extension in Tibet suggesting a common origin of rifts in Asia during the Indo-Asian collision. Journal of geophysical research, 105 (B9), 21, 745-21, 757.

YIN, A. & HARRISON, T.M., 2000. Geological evolution of the Himalayan-Tibetan Orogen. Annual Review of Earth and Planetary Science Letters, 28, 211-263.

YIN, A., KAPP, P.A., MURPHY, M.A. ET AL. 1999. Significant late Neogene east-west extension in northern Tibet. Geology, 27 (9): 787–790.

YONG, Y.Y. 2004. Some aspects of the geology, tectonics and mineral resources in the Qiangtang-Hol Xil region, western China. Sedimentary Geology and Tethyan Geology, 24 (1), 1-12. (in Chinese with English abstract).

ZHAI, Q.G., ZHANG, R.Y., JAHN, B.M., LI, C., SONG, S.G. & Wang, J. 2011. Triassic eclogites from central Qiangtang, northern Tibet, China: Petrology, geochronology and metamorphic P–T path. Lithos, 125, 173-176.

Zhang, K.J., WANG, Q.F., XIA, B.D. ET AL. 2002. Post-Miocene Imbricate Thrust Structures in Middle Qiangtang, Western China. Journal of Nanjing University (Natural Sciences), 38 (2), 266-269. (in Chinese with English abstract).

ZHAO, Z.Z. & LI, Y.T. 2000. Conditions of petroleum geology of the Qiangtang basin of the Qinghai-Tibet plateau. Acta Geologica Sinica, 74 (3): 661-665.