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Late Cretaceous tectonic framework of the Tibetan Plateau

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ABSTRACT

New research, coupled with previous data, reveals the Late Cretaceous paleo-geography, and related paleo-tectonic movement of the Tibetan Plateau. A vast ocean, the Neo-Tethys Ocean, perhaps as wide as ~7000 km, existed between the Indian and Eurasian Continental Plates in the early Late Cretaceous. In addition, a Himalaya Marginal Sea lay along the border of the Indian Plate and other marginal seas were present to the north in both the southern Lhasa and southwestern Tarim Blocks. Northward subduction of the Neo-Tethys Oceanic Plate along the Yalung-Zangbu Suture closed most of the ocean and led to intensive thrusting, tight folding, magmatic plutonism and volcanic eruptions in the central plateau to the north. A magmatic arc up to 500 km wide formed across the southern margin of the continental plate in central Tibet and its varying granitic composition appears to reflect the depth to the subducted plate and define its geometry. A series of large, chiefly north-dipping thrust systems also developed across central Tibet. These include thrusts along the Yalung-Zangbu and Bangong-Nujiang Sutures, the North Gangdese and North Lhasa Thrusts in the Lhasa Block, the Qiangtang and North Tangula Thrusts in the Qiangtang block, the Hoh-Xil and Bayan Har Thrusts in the Hoh-Xil Block, as well as the sinistral-slip South Kunlun and Altyn Tagh Faults in northern Tibet. Uplifts formed above the hanging walls of the major thrusts and their eroded debris formed thick red-beds in basins below them. The central Tibetan Plateau maintained a low elevation and coastal vegetation was dominant during the Late Cretaceous.

1. Introduction

Understanding the Late Cretaceous tectonic evolution, which is related to the paleo-oceanic plate subduction prior to the Indian-Eurasian continental collision, is very important in unraveling the subsequent growth of the Tibetan Plateau (Dewey et al., 1988; Yin and Harrison, 2000; Ding and Lai, 2003; Kapp et al., 2003, 2005, 2007; DeCelles et al., 2007; Volkmer et al., 2007; Leier et al., 2007; Wang et al., 2008; Pan et al., 2012; Zhang et al., 2012; Hu et al., 2012; Li et al., 2013). However, this has been hampered by the lack of regional geological data on the Late Cretaceous tectonic movements bearing on the subduction of the Neo-Tethys Oceanic Plate (Pan et al., 2012; Chung et al., 2005). This is now being remedied by new regional mapping. The China Geological Survey has conducted geological mapping at a scale of 1:250,000 or larger across the Tibetan Plateau since 2000 (Pan et al., 2004, 2012; Wu et al., 2013a,b), in which the authors finished geological mapping in the central portions of the Lhasa, Qiangtang and Kunlun blocks (Wu et al., 2004, 2009, 2012). This mapping has provided abundant data on Late Cretaceous stratigraphy, magmatism, structure, and tectonic processes of the Tibetan Plateau. It forms the context for, and in many cases supersedes, previous isolated studies that necessarily relied on more limited sampling of data.

A Late Cretaceous paleo-tectonic map of the Tibetan Plateau has now been compiled from selected information on the strata, structures, magmatic plutons and volcanic rocks of this age from the 1:250,000 scale geological maps, field studies of typical thrust faults, along with previous research from the Kunlun to Himalaya Mountains. Such map data coupled with chronological dating, magmatic geochemistry and paleo-magnetic analyses reveal the paleo-geography and paleo-tectonic movement of the Tibetan Plateau resulting from the northward subduction of the Neo-Tethys Oceanic Plate during the Late Cretaceous. The purpose of this paper is to present this comprehensive and conservative description of the Late Cretaceous paleo-tectonic framework and the related geodynamic movement in the Tibetan Plateau. The

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emphasis is on revelations and control from the new field data and no attempt is made to present an overall listing or review of all the literature that touches upon the subject.

2. Stratigraphy and depositional environment

The pattern of Late Cretaceous deposition varies across the region from marine deposits in the southern part of the Tibetan Plateau through terrestrial deposits in its northern parts to marine deposits again in the Tarim Basin. Marine strata formed in the Himalaya Belt, southern Lhasa Block and southwest Tarim Basin while terrestrial deposition was occurring in the northern Lhasa, Qiangtang, Hoh-Xil, Kunlun-Qaidam and Qilian Blocks (Fig. 1). Marine limestone intercalated with radiolarian silicate of the Zongshan Formation and sandstone, siltstone, shale and radiolarian silicate of the Gangba Formation formed in the Zanda, Zhongba, Burang, Tingri and Gangba Depressions in the western Himalaya Belt (Fig. 2) while marine limestone, shale, siltstone intercalated with radiolarian silicate of the Zongzuo Formation formed in the Gyangzi-Nagazi Depression in the eastern Himalaya. The silicate, shale and limestone of the Zongzuo Formation contain the planktonic foraminifera *Globotruncanita stuariformis*, *Globotruncana linneiana*, *G. vertricosa*, *G. carinata*, *Contusotruncana fornicana*, and *Heterohelix globulosa*, *H.* sp. in the Gyangzi area of the eastern Himalaya (Li et al., 2004). Lacustrine conglomerate, sandstone, siltstone and shale of the Shexing Formation and marine limestone of the Takena Formation formed in the central Lhasa Block (Wu et al., 2003) while radiolarian limestone and shale of the Yingjisha Group was laid down in the southwest Tarim Basin (Sun et al., 2003; Zhang et al., 2010).

Lacustrine, fluvial and alluvial deposits accumulated in terrestrial basins of the central and northern Tibetan areas during the Late Cretaceous. These include red-beds of the Jingzhushan Formation, which is dominated by conglomerate and sandstone, in the Cuoqin Basin, northern Lhasa Block; Late Cretaceous-Early Palaeogene reddish conglomerate and sandstone of the Fenghuoshan Group and red-beds of the Abushan Formation, which is dominated by sandstone, siltstone, marl and conglomerate, in the Qiangtang and Hoh-Xil Blocks; Late Cretaceous reddish conglomerate, sandstone and siltstone intercalated with coal of the Upper Quanyagou Formation in the Qaidam Basin and reddish sandstone, conglomerate, siltstone and mudstone intercalated with coal of the Minhe Formation in the Qilian Block (Fig. 1). The red-beds of the Abushan Formation contain interbedded andesites and trachy-andesites whose zircons gave U–Pb isotopic ages that range from 79.9 ± 2.7 Ma to 75.9 ± 0.49 Ma (Li et al., 2013).

The depositional environment of the stratigraphic units has been interpreted by the contemporary vegetation, as reconstructed from sporopollen assemblages found in the terrestrial and marine strata of five areas across the region. The recorded plant communities of gymnosperms, ferns and a few angiosperms indicate growth in coastal and low lacustrine basins. The assemblage found in the marl, mudstone and siltstone southeast of Ando, south of Shuanghu and west of Silin Co indicates a dry, hot, salty environment. The marl southeast of Ando contains such sporopollen as *Chasmatosporites*, *Callialasporites*, *Exesipollenites*, *Cingutriletes*, *Polycingulatisporites*, *Klukisporites*, *Biretisporites*, *Lygodiumsporites*, *Leptolepidites*, *Verrucosisporites*, *Aequitriradites*, *Baculatisporites*, *Tenuicontactosporites*, *Ceratosporites* and *Classopollis,* whose percentage ranges from 32.6% to 43.9%. The marl south of Shuanghu contains sporopollen representing *Cingutriletes, Cingutriletes* clavu, *Densoisporites*, *Polycingulatisporites*, *Exesipollenites*, *Callialasporites*, *Triporopollenites*, *Cicatricosisporites*, *Schizaeoisporites*, *Parcisporites*, *Araucariacites*, *Ephedripites*, *Classopollis*, *Rhoipites*, *Rutaceoipollenites*, *Sapotaceoidaepollenites*, *Euphorbiacites* and *Anacolosidites*. Here the percentage of *Classopollis* reaches as high as 22.6%. The muddy siltstone west of Silin Co contains sporopollen such as *Polycingulatisporites*, *Verrucosisporites*, *Araucariacites*, *Parcisporites, Taxodiaceaepollenites*, *Inaperturopollenites*, *Inaperturotetradites* and a high percentage of *Classopollis*. High percentages of *Parcisporites* and *Cingutriletes* clavu occur in the coastal and lacustrine marl and muddy siltstone in the Tarim basin. A sporopollen assemblage of *Classopollis-Exesipollenites-Cycadopites* is dominant amongst many types of angiosperm and gymnosperm pollen and shelly fauna in the limestone, marl and mudstone in the northern coastal basin of Zhongba north of the Yarlung-Zangbo Suture that was deposited in shallow sea and littoral swamp environments (Li et al., 2008; Liu et al., 1988).

The sporopollen representing gymnosperms includes conifers such as *Araucariacites* and *Classopollis*. Araucaria is a tall pine-like tree that still grows in southeast Queensland, Southeast Asia-southwest Pacific islands, Chile and Argentina in coastal to low montane areas; the altitude range in Queensland is 150–1000 m (Kershaw and Wagstaff, 2001; Farjon, 2008). High pollen abundances suggest a dense emergent cover of Aruacaria growing under relatively dry climatic conditions in a marginal rainforest

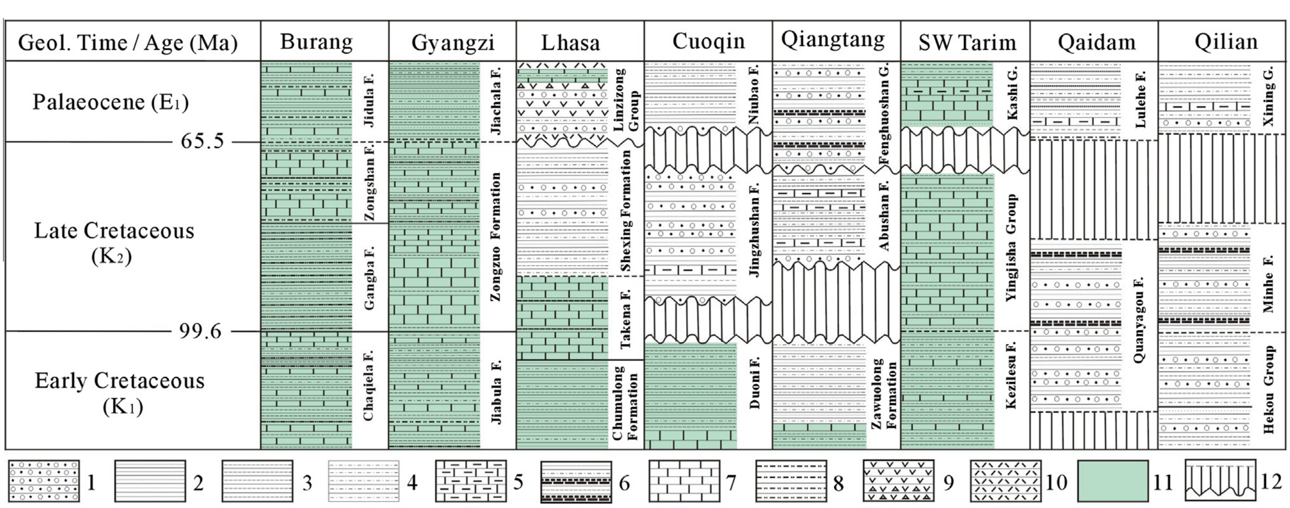

Fig. 1. Late Cretaceous stratigraphic columns in the Tibetan Plateau Explanation: (1) conglomerate; (2) sandstone; (3) mudstone and shale; (4) siltstone and silty mudstone; (5) marl; (6) sandstone, mudstone and coal; (7) limestone; (8) radiolarian silicate; (9) andesite and volcanic breccia; (10) rhyolite; (11) marine deposits and (12), unconformity and sedimentary break. Marine deposits of the Linzizong Group refer to the limestone containing marine fossils discovered by Xu et al. (1992) and Wu et al. (2003) at the base of the Nianbo Formation that demonstrate transgression from the Neo-Tethys Ocean into the Linzhou basin in the Late Paleocene (Wu et al., 2013a).