

Evolution of the Mesozoic Qamdo (Changdu) Basin, Eastern Tibet: Linkages between Sedimentation, Climate, and Regional Tectonics*

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Search and Discovery Article #30280 (2013)

Posted August 26, 2013

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013, AAPG©2013

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Abstract

Although the bulk of hypotheses currently under investigation assume that the formation of the Tibetan Plateau is inextricably linked with tectonic collision of India with Asia (e.g. Garzanti, 2008; Rowley, 1996), several studies suggest that construction of the Plateau may have started tens of millions of years before the Cenozoic Indo-Asian collision during accretion of ancestral terranes of Tibet in the Mesozoic Era (Yin and Harrison, 2000). This study aims to investigate the Mesozoic tectonic evolution of the Qamdo Basin by examining its sedimentological records. Since tectonics can greatly influence the geomorphic and stratigraphic development of sedimentary basins, studying the sedimentary records of the Qamdo Basin could help us better understand the regional tectonics of the Qamdo region in eastern Tibet.

Background

The Qamdo Basin, located in eastern Tibet, covers an area of approximately 12,000 km² ([Figure 1a](#)). The NW-SE elongated basin contains ~7000 m of well-exposed Upper Triassic to Lower Cretaceous basin fill that rests on top of the Precambrian and Paleozoic basement of the Qiangtang terrane (Weislogel and Robinson, 2010; Du et al., 1997). The basin is bracketed by two major suture zones, the Jinsha Suture to the northeast and the Bangong-Nujiang Suture to the southwest. The former suture marks the boundary between the Yidun Arc complex and the Qiangtang terrane that formed during closure of the Paleotethys, while the latter one separates the Lhasa and the Qiangtang terranes that formed from closure of the Mesotethys (Gehrels et al., 2011; Yin and Harrison, 2000).

The Mesozoic Qamdo Basin contains Upper Triassic-Cretaceous strata that record a shift from deep-marine/marginal-marine to lacustrine, then to alluvial fan and braided river systems ([Figure 1b](#)) (Du et al., 1997). This continuous shallowing-upward trend occurred over about 100 million years.

The lower Upper Triassic Jiapila Formation comprises marine black shale with turbidite sandstone interbeds deposited in a clastic deep-marine setting. Vitrinite reflectance (%Ro) analysis of the Jiapila Shale shows an average Ro value of 2.17%, indicating a maximum burial depth of 8000 m based on geohistory modeling (Wu et al., 2010). The overlying bioclastic middle Upper Triassic Bolila Limestone formed as carbonate platform deposits. The carbonate is characterized by a well-developed secondary porosity system with an average porosity of 25%. The uppermost Triassic unit is the Bagong Group which comprises siliciclastic sediments deposited in a marginal marine deltaic setting.

Overlying the Triassic marine-influenced deposits are Jurassic lacustrine deposits of the Chaya Group, which consists of interbedded fine-grained sandstone, siltstone, red mudstone, and calcisols. The sandstone/mudstone cyclothems in the Jurassic Chaya Group occurs at all scales from centimeter to regional-scale cycles of basin filling, which may reflect both regional climatic variations and tectonic-driven signals. Mud-crack structures are abundant in the Chaya Group, especially in its upper part. This is probably due to increased aridity during Middle-Late Jurassic, which may have resulted from regional surface uplift associated with the coeval tectonism related to the Qiangang-Lhasa collision (Yin and Harrison, 2000).

The Lower Cretaceous Xiangdui Formation comprises abundant clast-supported conglomerates, cross-stratified pebbly sandstone, red mudstone, and abundant calcisols, which suggest the deposition occurred proximal to source areas under arid climatic settings, which may have resulted from surface uplift and denudation of nascent mountain ranges related to accretion and convergent margin tectonism during the Early Cretaceous period.

Detrital Zircon Geochronology Results

We analyzed six sandstone samples using detrital zircon U-Pb geochronology in order to constraint the sandstone provenance. Samples were collected from 4 major stratigraphic horizons in the northern and southern Qamdo, including the Upper Triassic Jiapila Sandstone, the Jurassic lower and upper Chaya groups, and the Lower Cretaceous Xiangdui Formation ([Figure 1c](#)). Zircon isotopic analyses were conducted at the Arizona LaserChron Center using a laser ablation-inductively coupled plasma-mass spectrometer (LA-ICP-MS). The results were used to generate an age distribution curve for each detrital sample, and then the age distributions were compared with published zircon ages of the surrounding geological units to determine the origin of the detritus. Comparisons of age distributions are primarily based on presence of specific ages or age groups, and the age of an individual zircon grain is used with caution (Gehrels et al., 2011). Maximum depositional age of strata can be constrained using the youngest single grain age or the more robust criteria of using the youngest peak in age probability that is defined by at least three overlapping ages (Gehrels et al., 2011). Accompanied by sedimentary facies and sandstone compositional data, detrital zircon age signatures of the Qamdo Basin allow us to distinguish sediment inputs from adjacent major tectonic units (e.g., Yidun arc complex, Songpan-Ganzi block, Qiangtang block, and Lhasa block), and thus make reconstruction of the tectonic evolution history of the Qamdo region possible.

Upper Triassic

Detrital zircon age results from the Jiapila Formation share great similarity with the age distribution of the Songpan-Ganzi complex reported by Weislogel et al. (2010). Four major age groups within the Songpan-Ganzi detrital zircon have been reported: 2.4-2.5 Ga, 1.85-1.95 Ga, 400-450 Ma, and 250-280 Ma, and they can all be observed in the Jiapila zircon ages ([Figure 2](#)). Considering that the depositional setting of the Jiapila Formation is characterized by a clastic deep-marine environment, similar to that of the Songpan-Ganzi turbidite system, it is possible that the Qamdo Basin was once connected with the Ganzi-Litang ocean during early Late Triassic, receiving sediments from the Songpan-Ganzi turbidite system. Subsequent closure of the Ganzi-Litang ocean at ~220 Ma (Roger et al., 2008) finally shut down the clastic input from the Songpan-Ganzi turbidite system, leading to the development of extensive micritic and bioclastic limestone layers of the middle Upper Triassic Bolila Formation. The overlying Bagong Group consists of a very similar suite of ages as that of the Songpan-Ganzi complex. However, sandstone compositional data show considerable differences between Jiapila and Bagong strata. The Jiapila sandstone is primarily composed of well-sorted, fine- to very-fine-grained, sub-rounded, monocrystalline quartz grains, indicating a continental block provenance. The Bagong Group, however, consists mainly of poorly-sorted, sub-angular, medium-grained quartz sands along with abundant large sedimentary lithic fragments, indicating a recycled-orogen provenance. Petrological data suggest that the Bagong Group was primarily sourced from the inverted Songpan-Ganzi Basin.

Jurassic

Detrital zircon age signatures suggest that two distinct depocenters were developed in the Qamdo Basin during the deposition of the lower Chaya Group in Early Jurassic, which divide the basin into southern and northern depocenters. In the northern depocenter, the lower Chaya zircon ages are more compatible with that of the Songpan-Ganzi complex, suggesting that the sediments were probably recycled from the Upper Triassic strata ([Figure 3a](#)). In the southern depocenter, however, the lower Chaya Group contains a major group of younger ages at 220-250 Ma ([Figure 3b](#)). Similar zircon U-Pb ages of 229-245 Ma have been reported by Reid et al. (2007) from the Triassic Yidun volcanic arc system located north of the Qamdo Basin, suggesting that the Yidun Arc was probably a major source area for the southern Qamdo Basin during Early Jurassic. Petrographic data show that the lower Chaya Sandstone is generally composed of monocrystalline quartz grains with variable amounts of volcanic, sedimentary, and low-metamorphic lithic fragments. The lower Chaya Sandstone in the southern Qamdo Basin is characterized by a larger grain size, as well as a higher lithic content when compared with its counterpart exposed in the northern depocenter. Here, we propose that the differences in sandstone composition and zircon age signature of the lower Chaya Group between the southern and northern depocenters were probably attributed to diachronous closure of the Paleo-Tethys ocean from east to west, causing heterogeneous uplift and exhumation of the Yidun Arc from south to north along the Jinsha Suture.

The Paleozoic detrital zircon ages of the upper Chaya Group generally resemble those of the Upper Triassic strata, except for the presence of a dominant younger age group at 170-190 Ma in the Chaya Group ([Figure 3b](#)). Two youngest overlapping ages give a maximum depositional age of the upper Chaya Group at ~165 Ma. The younger age group is consistent with the U-Pb ages of an extensive granitoid emplacement (170-185 Ma) found within the Amdo crystalline basement (Guynn et al., 2006). The Jurassic granitoids are thought to represent a 'missing' continental arc developed in the Meso-Tethys realm that paralleled the length of the Bangong-Nujiang suture during Jurassic that was later subducted beneath the Qiangtang terrane as the result of the closure of the Meso-Tethys ocean basin (Guynn et al., 2006). Although no volcanic

arc-type rocks that have ages between 170 and 185 Ma have been found near the Qamdo Basin, detrital zircon signatures of the Upper Chaya Group provide important for the existence of the Jurassic continental arc in eastern Tibet. The upper Chaya Group was sourced from both northern recycled-orogens and the coeval volcanic arc system that existed along the southern margin of the Qamdo Basin.

Cretaceous

The Cretaceous strata were mainly found in the southern part of the Qamdo Basin. Detrital zircon ages from the Lower Cretaceous Xiangdui sandstone show predominant zircon ages between 220~250 Ma ([Figure 3c](#)), indicating a strong affiliation with the Yidun Arc during Early Cretaceous. In addition, petrographic data show that the Xiangdui Sandstone is characterized by sub-angular, medium- to coarse- grained quartz and feldspar grains with a significant amount of volcanic and metamorphic lithics, indicating a locally sourced recycled-orogen provenance. As suggested by paleo-environmental, petrographic and provenance data, deposition of the Xiangdui Formation was probably related to accretionary tectonics of the Yidun Arc region, causing surface uplift and rapid denudation of the Yidun Arc during Early Cretaceous.

Conclusion

Preliminary paleo-environmental, petrological, and sedimentary provenance studies of the Mesozoic Qamdo Basin revealed that the development of the Qamdo Basin was closely associated with the accretionary tectonics of the region. To further understand the impact of the Mesozoic accretionary tectonics on the pre-Cenozoic topographic development of eastern Tibet, we will study the pedogenic carbonates preserved in the Lower Cretaceous strata of the Qamdo Basin using the stable isotope based paleo-altimetry method. The resulting paleo-elevation estimate could further help us assess the impact of the Mesozoic accretionary tectonics in eastern Tibet.

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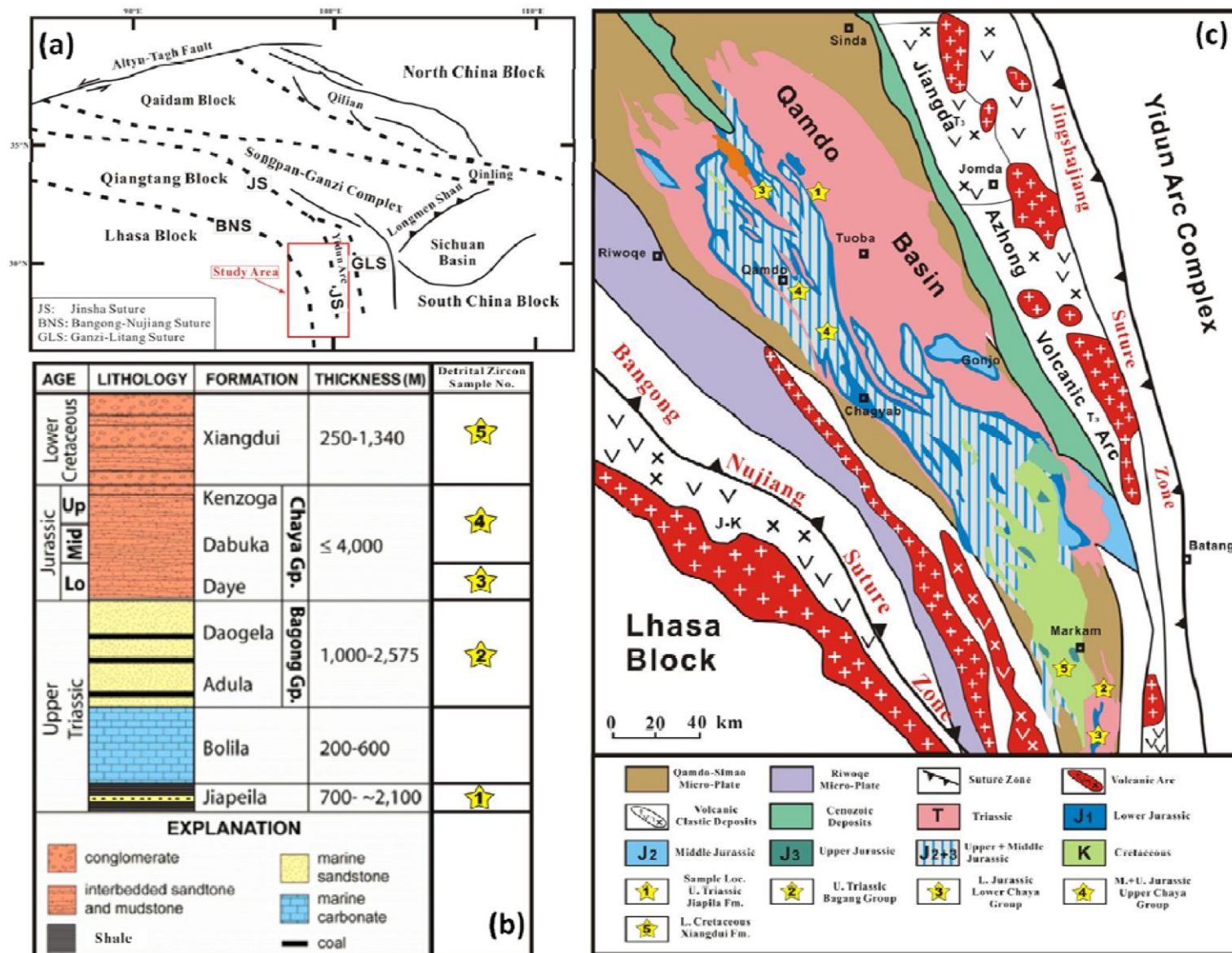


Figure 1. (a) Simplified tectonic map of the Tibetan Plateau showing the major tectonic units of the region and the location of the study area (modified from Enkelmann et al., 2007). (b) Chronostratigraphy of Qamdo basin fill. Detrital zircon sample number is shown in the rightmost column (modified from Weislogel and Robinson, 2010). (c) Geologic map of the Qamdo region showing the local tectonic units, distribution of Mesozoic rocks, and detrital zircon sample localities (Du et al., 1997).

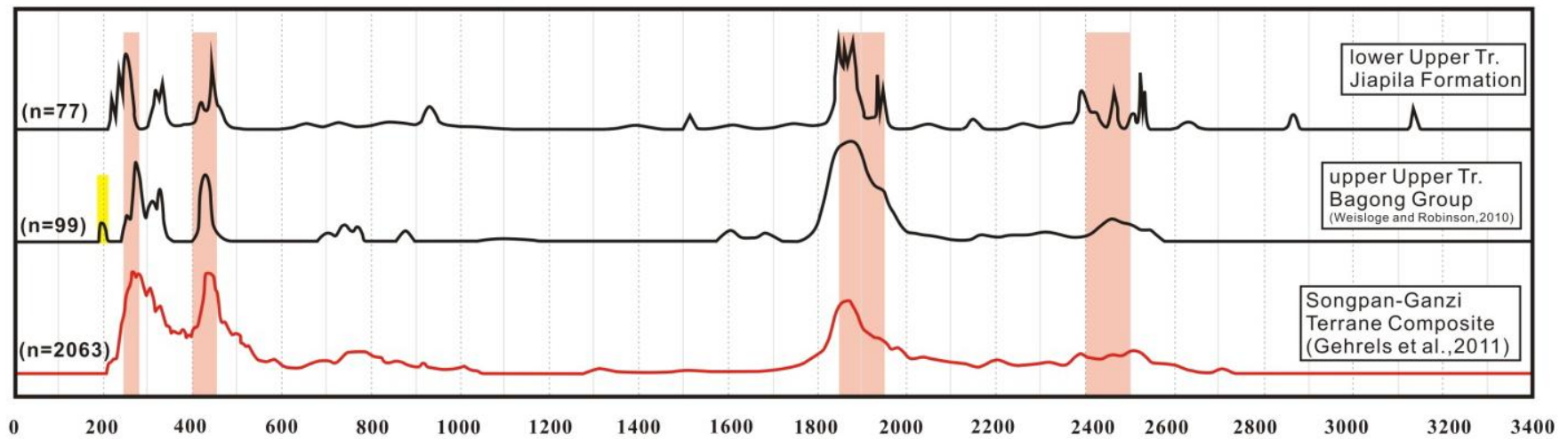


Figure 2. Probability-density plots for the Jiapila Formation., Bagong Group, and Songpan-Ganzi complex. Pink bars highlight the four major age groups of the Songpan-Ganzi complex zircon ages reported by Weislogel et al. (2006) (2010). Yellow bar represents age of syn- to post-orogenic granites (220-188 Ma) found within the Songpan-Ganzi fold belt, reported by Roger et al. (2008).

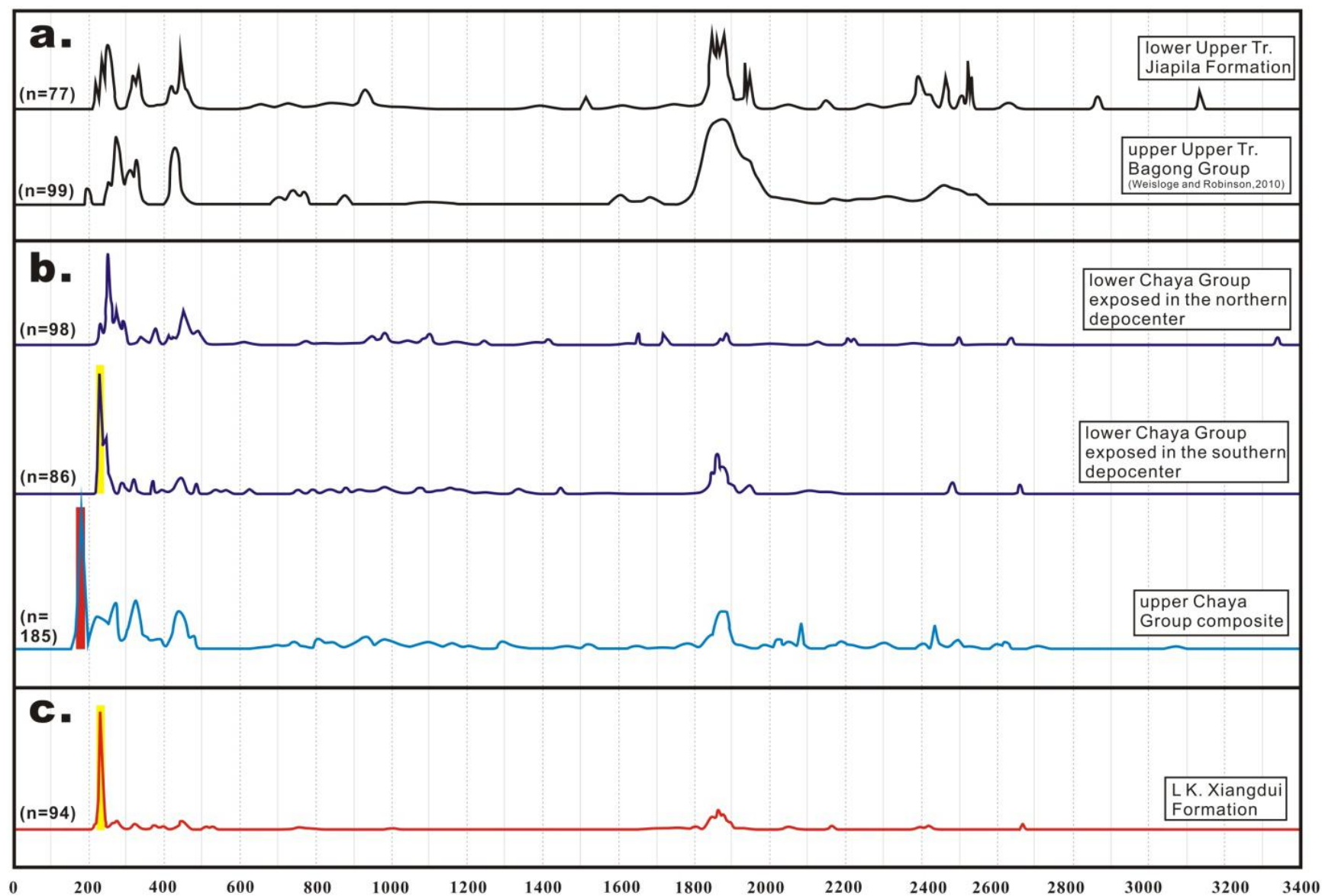


Figure 3. (a) Probability-density plots for the Jiapila Fm. and Bagong Group. (b) Probability-density plots for the Jurassic lower and upper Chaya groups. Note that the yellow bars represent Yidun arc zircon ages reported by Reid et al. (2007), and the red bar highlights the cooling age of an extensive granitoid emplacement found in Amdo basement, reported by Guynn et al. (2006).