Sedimentology and Chronology of Paleogene Coarse Clastic Rocks in East-Central Tibet and Their Relationship to Early Tectonic Uplift

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Abstract: A systematic sedimentological and chronological study of typical Paleogene basins in east-central Tibet suggests that the depositional characteristics of extensively developed huge-bedded, purplish-red coarse clastic rocks formed in a tectonic setting of regional thrusting and strike-slipping represent a typical dry and hot subaerial alluvial fan environment formed in a proximal and rapid-accumulating sediment body in debris flows and a fan-surface braided river. Combining results from basin-fill sequences, sequences of coarse clastic rocks, fauna and sporo-pollen associations and thermochronological data, it is concluded that the coarse clastic rocks formed in the period of 54.2–24.1 Ma, nearly coeval with the formation of Paleogene basins in the northern (Nangqên-Yushu thrust belt), middle (Batang-Lijiang fault belt), and disintegration of large basins in the southern (Lanping-Simao fold belt) segments of Tibet. The widespread massive-bedded coarse clastic rocks, fold thrusting and strike-slip, thrust shortening, and igneous activities in the Paleogene basins of east-central Tibet indicate that an early diachronous tectonic uplift might have occurred in the Tibetan Plateau from Middle Eocene to Oligocene, related to the initial stage of collision of the Indian and Asian plates.

Key words: Paleogene, clastic rocks, tectonic uplift, chronology, east-central Tibet

1 Introduction

The uplift of the Tibetan Plateau is closely related not only to many important theoretical questions, such as intracontinental deformation, crust-mantle interaction, and the deep processes of lithosphere, but also to the formation of the monsoon cycle in eastern Asia and global climatic changes. Although investigating the former has obtained many important results of tectonics, sedimentology, geochemistry, ecology, glacial geology, pedology and paleoclimatology, no consensus has yet been reached in understanding the dynamic mechanism, time, and amplitude of the plateau uplift (Tapponnier and Molnar, 1976; Harrison et al., 1992; Molnar et al., 1993; Coleman and Hodges, 1995; Searle, 1995; Wu et al., 2004; Chen et al., 2005; Zheng et al., 2005; Li et al., 1979; Li and Fang, 1998; Li et al., 2001;Yin and Nie, 1996; Shi et al., 1998; Zhong and Ding, 1996; Xu et al., 1996; Sun and Zheng, 1998; Pan and Kong, 1998; Wang et al., 2004). Through studying tectonics, sedimentology, paleoclimatology and chronology, overseas scientists have proposed that the Tibetan Plateau is the result of continuous contraction and uplift since the Indo-Asian collision at 50 Ma. With lateral extrusion of blocks, a compressive fold thrust and a diachronous collision from west to east, the Tibetan plateau had achieved altitude at 20–8 Ma (Tapponnier and Molnar, 1976; Harrison et al., 1992; Yin and Nie, 1996; Coleman and Hodges, 1995; Searle, 1995; Rowley, 1996). However, local scientists who have studied widely and in depth on the uplift of the Tibetan plateau from the points of view of physical geography, features of the paleobiota on the plateau, synthetical chronostratigraphy, mineral fission track, chronology, intraplate magmatic activity,

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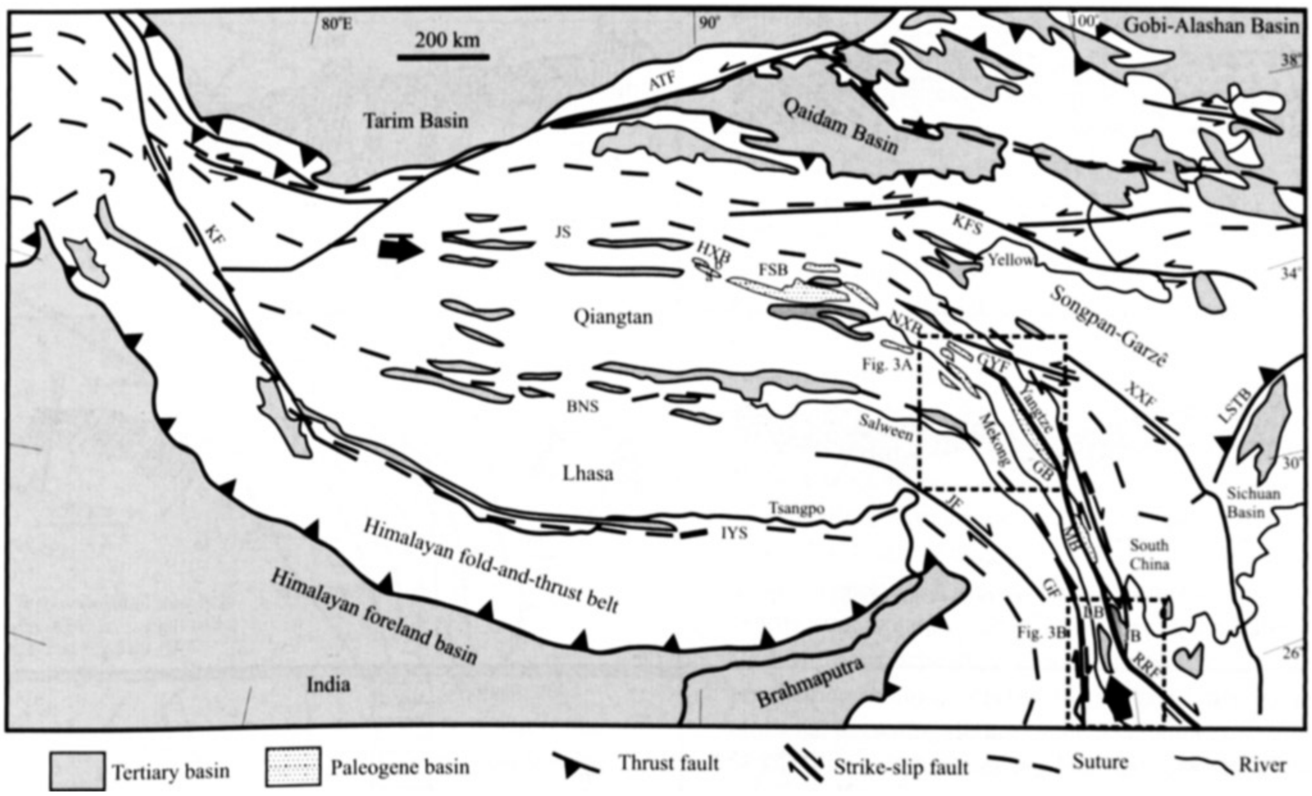


Fig. 1. Sketch tectonic map of the Tibetan Plateau, including sedimentary basins, faults, suture zones, and rivers (modified from Yin and Harrison, 2000).

Shaded areas represent Cenozoic nonmarine deposits. Rectangular outlines show location of the Nangqên-Yushu (Fig. 3a) and Lanping-Simao (Fig. 3b) study regions.

Basins (B): HXB – Hoh Xil and section a-b; FSB – Fenghuo Shan; NXB – Nangqên-Xialaxiu; GB – Gongjue; MB – Markam; LB – Lanping; JB – Jianchuan; Sutures (S): JS – Jiansha; BNS – Banggong-Nujiang; IYS – Indus-Yalu; Major Faults (F = fault): KF – Karakorum; ATF – Altun Tagh; KFS – Kunlun system; GYF – Garzê-Yushu; XXF – Xianshuihe-Xiaojiang system; LSTB – Longmenshan thrust belt; RRF – Red River; GF – Gaoligong; JF – Jiali.

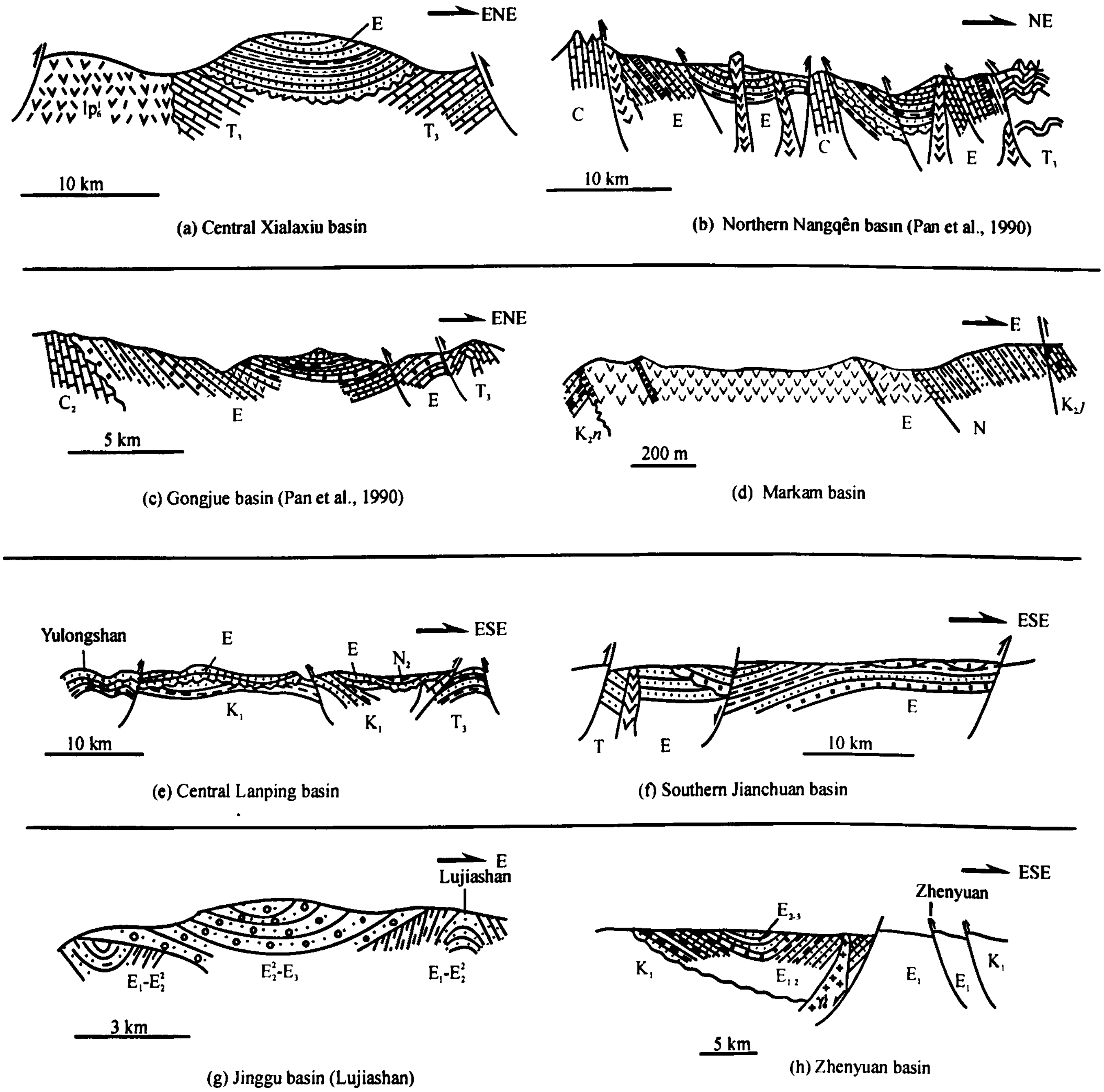
loess-paleosol sequence of the plateau, plateau glacier-frozen earth, and propagation zoology, etc., generally consider that it is the result of an imbalance uplift of multi-factors, multi-stages, multi-hierarchy. There was multiple-stage uplift and planation, and rapid uplift has been a geological event since 3–4 Ma before present (Xu et al., 1996; Wu et al., 2004; Li and Fang, 1998; Zhong and Ding, 1996; Shi et al., 1998; Zhang et al., 2001). Recently, the importance of research on coarse clastic rock has revealed that such widely-developed deposits are an indicator of plateau uplift. Yet, systematic study of sedimentology and geochronology is still lacking (Liu et al., 1996; Li and Fang, 1998; Wang et al., 2004; Yi et al., 2000; Liu et al., 2001; Jin et al., 2001; Zhang et al., 2001; Yani et al., 2001). Based on the data of the widespread occurrence of magmas and the sedimentary record on the Tibetan Plateau, a diachronous collision or diachronous uplift history during 45–38 Ma has been reported (Rowley, 1996; Chung et al., 1998; Liu et al., 2001).

Thick-bedded purplish-red coarse clastic sediments fill in more than 20 small- and medium-scale Tertiary basins in east-central Tibet (Fig. 1). We present the results of sedimentological observations, regional correlation and isotopic dating of igneous rocks in typical Paleogene basins in east-central Tibet, and discuss the development of the coarse clastic rocks and its relationship to the early tectonic uplift of the east-central plateau.

2 Tectonic Setting

The formation and evolution of the Tibetan Plateau and development of Paleogene basins exposed in the east-central Tibet may record the collisional process and post-collisional intracontinental deformation related to the Indo-Asian collision (Pan et al., 1990; Yin and Nie, 1996; Sun and Zheng, 1998; Pan and Kong, 1998; Yano et al., 1994; He et al., 1996; Wang et al., 1998; Horton et al., 2002; Zhou et al., 2002). These basins have been strongly reworked by thrusting compressive deformation, magmatism, and strike-slipping. Studying the southern and northern segments in east-central Tibet has revealed that there was a clear tempo-spatial difference in the tectonic setting between the Paleogene basins, described in detail below (Fig. 2).

In the northern Nangqên-Yushu thrust belt, coeval basins formed via late-stage thrusting and strike-slipping



(Legend see Fig. 4, sections location see Fig. 3)

Fig. 2. Structural and stratigraphic framework of typical Paleogene basins in east-central Tibet.

based on long-term uplift and erosion of the Mesozoic basin basement (Spurlin et al., 2005). Deposition of the Paleogene coarse clastic rocks was mostly controlled by the corresponding period of activity of the basin margin thrust fault, and the contact with the underlying Carboniferous and Triassic basement is via an angular disconformity. The basins were strongly reworked by syntectonic and latterly superimposed deformation, showing wide folding of the Paleogene beds, thrusting and vigorous magmatism, and widespread occurrence of huge thicknesses of coarse clastic rocks, which are overlain by volcanic rocks and cut by intrusive rocks (Horton et al., 2002; Zhou et al., 2002; Spurlin et al., 2005) (Fig. 3a). However, in the southern Lanping-Simao fold belt, the Paleogene basins were produced by differential uplift and disintegration derived from a large-scale coastal inland lake basin in the Mesozoic. The Paleogene clastic series is conformable with the underlying Mesozoic rocks. These basins are characterized by weak tectonism and magmatism, integrated depositional sequences, faulting on the basin margins, folded stratigraphy, and thinner and local coarse clastic rocks (BGMR of Yunnan, 1990; He et al., 1996; Wang et al., 1998) (Fig. 3b).

Conglomerate compositional analyses provide

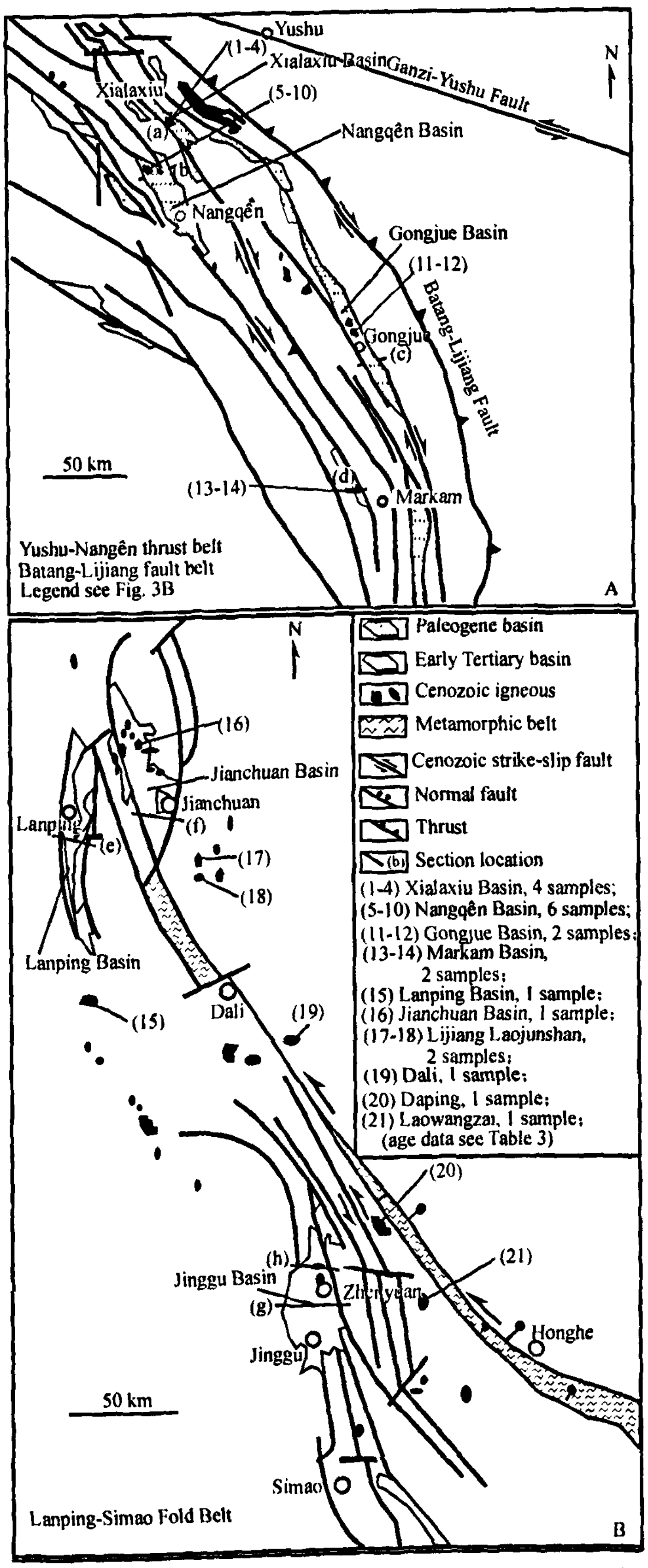


Fig. 3. Cenozoic tectonics, igneous rocks and sedimentary basin distribution in east-central Tibet.
(a) Nangqên-Yushu thrust belt; (b) Lanping-Simao fold belt.

information on the location and composition of numerous sediment source areas during basin development (Horton et al., 2002). Compositional data are from the Nangqên, Niuguoda, Shanglaxiu and Xialaxiu basins, 21 measured sections, >150 clast counts (~100 clasts identified per count), each performed over ~1 m^2 on individual conglomerate outcrops. Clast-count data indicate that conglomerates in the basins were almost exclusively derived from three Carboniferous units and four Triassic units composed of carbonate, quartz sandstone, quartzite, and argillite. A few rare volcanic clasts present in the Xialaxiu Basin were probably derived from limited Triassic volcanic beds. The only igneous clasts derived from Tertiary intrusions or volcanic units occur in the uppermost levels of the Nangqên Basin. In some cases, unique varieties of clasts can be directly linked to nearby source areas. The relatively limited number of Carboniferous-Triassic source units and the lack of pre-Carboniferous detritus would suggest fairly limited erosional unroofing during basin development.

The above differences indicate that a heterogeneity of the duration, styles and intensity of intracontinental deformation has occurred since the Indo-Asian collision, and controlled the development of the Paleogene basins in east-central Tibet.

3 Sedimentological Setting of Coarse Clastic Rocks

3.1 Facies associates and sequences

The sedimentologic investigations of typical Paleogene basins indicate that the facies types of coarse clastic rocks include massive or imbricated conglomerate facies (Gm, Gms), massive or imbricated granule-pebble conglomerate facies (Gh), large-scale planar or trough cross-bedded pebble-bearing sandstone facies (Sp and St), paralled and graded bedding pebble-sandstone or sandstone facies (SGh, Sh), seldom massive sandstone facies (Sm), and massive or poorly laminated pebble-bearing siltstone facies (Fg) (Miall, 1990; Horton et al., 2002; Zhou et al., 1998). Table 1 and Plate I provide complete descriptions of different facies and their associations.

The statistic results of 12 measured sections indicate that the thickness of a single bed of coarse clastic rocks ranges from 5 to 60 m, the thickness of a whole sequence is evidently different in the northern, middle and southern segments in east-central Tibet, and the sequence thickness ranges from 100 to 2500 m in the Nangqên and Xialaxiu basins in the north, 50 to 1200 m in the Gongjue and Markam basins in the middle,

Table 1 Summary of Facies Associations

Facies	Thickness of single bed	Description	Interpretation
Massive sandstone or pebble-bearing siltstone facies Sm, Fg	from 10 to 50 cm.	Massive, thin bedded or planar lenticular sandstones or pebble-bearing siltstones with moderately or poorly sorting, subrounded pebbles.	Rapid loading of sheeted flood flows or suspension fallout, waning flood flows deposit (Plate I-6).
Parallel and graded bedding pebble-bearing sandstone or sandstone facies SGh, Sh	Generally from 0.5 to 2 m.	Sheeted, long lenticular (pebble-bearing or not) sandstones with parallel or graded bedding, subrounded or rounded, moderately or poorly sorted pebbles. Swash marks and scour-filling and load structures usually occur at the bottom of sandstone beds.	Sheeted flood deposit in the high-density turbidity current (Plate I-5).
Large-scale trough or planar cross bedding pebble-bearing sandstone facies St, Sp	Generally from 2 to 5 m.	Moderately or poorly sorted, subrounded or rounded, large-scale planar or trough cross bedding pebble-sandstone, sandstone or sandy conglomerates.	Fan-surface deposit in the braided river with lower flows migrating dunes or bars (Plate I-3 and 4).
Massive or imbricated granule-pebble conglomerate facies Gh	Generally ranges from 5 to 10 m.	Massive or imbricated, moderately sorted, subrounded or rounded, matrix-supported granule-boulder conglomerates with the matrix of pebble-bearing sandstones. Clastic sizes are from 5 to 10 cm in diameter, and the maxmium 20–30 cm.	Fan-surface deposit in the braided river with hyperconcentrated flows (Plate I-2).
Massive or imbricated conglomerate facies Gm, Gms	Generally from 5 to 20 m, the maxmium is 50–60 m.	Ungraded, normally or weakly inversely graded, poorly sorted, subangular or subrounded, matrix- or grained-supported and granule-boulder conglomerates. Clastic sizes ranges from 5 to 10 cm in diameter, and the maxmium 50–80 cm. The matrix consists of pebble-bearing sandstones.	Debris-flows deposit with a proximal and rapid accumulation (Plate I-1).

and 1500 to 2000 m in the Lanping and Jinggu basins in the south. Because of poor outcrop of margin facies in the Lanping-Simao Basin, there is only partial exposure of the Neogene Baoxianshi Formation conglomerate in the northern Jianchuan Basin. In the northern basins, the single beds of conglomerate are thicker, with a coarser average grain size than those in the middle and south. The vertical facies associations in a coarse clastic sequence include Gm or Gms-Gh-SGh-Sh, Gm-Sh, St-Sh and SGh-Sp or St (Plate I).

The sequences of Paleogene coarse clastic sediments consist of purplish-red conglomerates, fine-grained conglomerates and sandy-conglomerates interbedded with purplish-red pebble-bearing sandstones and siltstones and thin-bedded or lenticular limestones. The main depositional types include the deposits of debris flows, a braided river on a fan-surface, a waning flood and sheeted flows (Zhou et al., 1998; Miall, 1990; Horton et al., 2002) (Table 1).

3.2 Depositional environments

Comparison of rocks in Paleogene basins between south and north shows that the coarse clastic rocks such as in the Nangqên and Xialaxiu basins in the north are mainly distributed along basin margins and characterized by the huge thickness of a single bed, moderately poor sorting and rounding, grain or matrix supporting and better stratification, but the coarse clastic rocks such as in the Lanping, Jianchuan and Jinggu basins in the south are mainly developed in the mid section of sequences, and characterized by grading with upward decrease of grain size, thinner single bedding, small pebble size and good sorting and rounding. The measured paleocurrent data in the coarse clastic rocks in east-central Tibet suggest that the general trends in the Nangqên Basin are SE166° and NW280°, and NW291° and SE160° in the Xialaxiu Basin, indicating multiple paleocurrent directions in the north, but there is only one trend of SE150° in the Langping Basin, and SW250° in the Jinggu Basin in the south, indicating a single paleocurrent direction which is evidently different from that in the north (Zhou et al., 1998).

The above comprehensive sedimentalogical characteristics of coarse clastic rocks shows that the changeable paleocurrent system in the northern Nangqên-Yushu thrust belt might have resulted from the strictly limited depositional space in the narrow-long Paleogene basins in the north and an abundant supply of sediment from the intensive uplift and erosion area in two sides of the basin. Huge-bedded coarse clastic rocks were formed by the vertical superimposition of multiple alluvial-fan bodies and deposition occurred in the proximal part and there was a rapid accumulation subaerial alluvial fan environment in a dry and hot climate condition. However, in the southern Lanping-Simao fold belt, a stable paleocurrent trend might have originated from a wide and zoned depositional space, and the majority of the coarse clastic rocks were developed within an early-stage lacustrine-delta system; the characteristics of the conglomerates with good bedding, sorting and rounding indicate that the dominant coarse clastic rocks belong to a sedimentary body formed in a braided alluvial plane, which was deposited in a wide and stable alluvial fan environment near the basin margins. Combined with analysis of the tectonic setting, the basins in the Nangqên-Yushu area were developed via thrusts and strike-slips

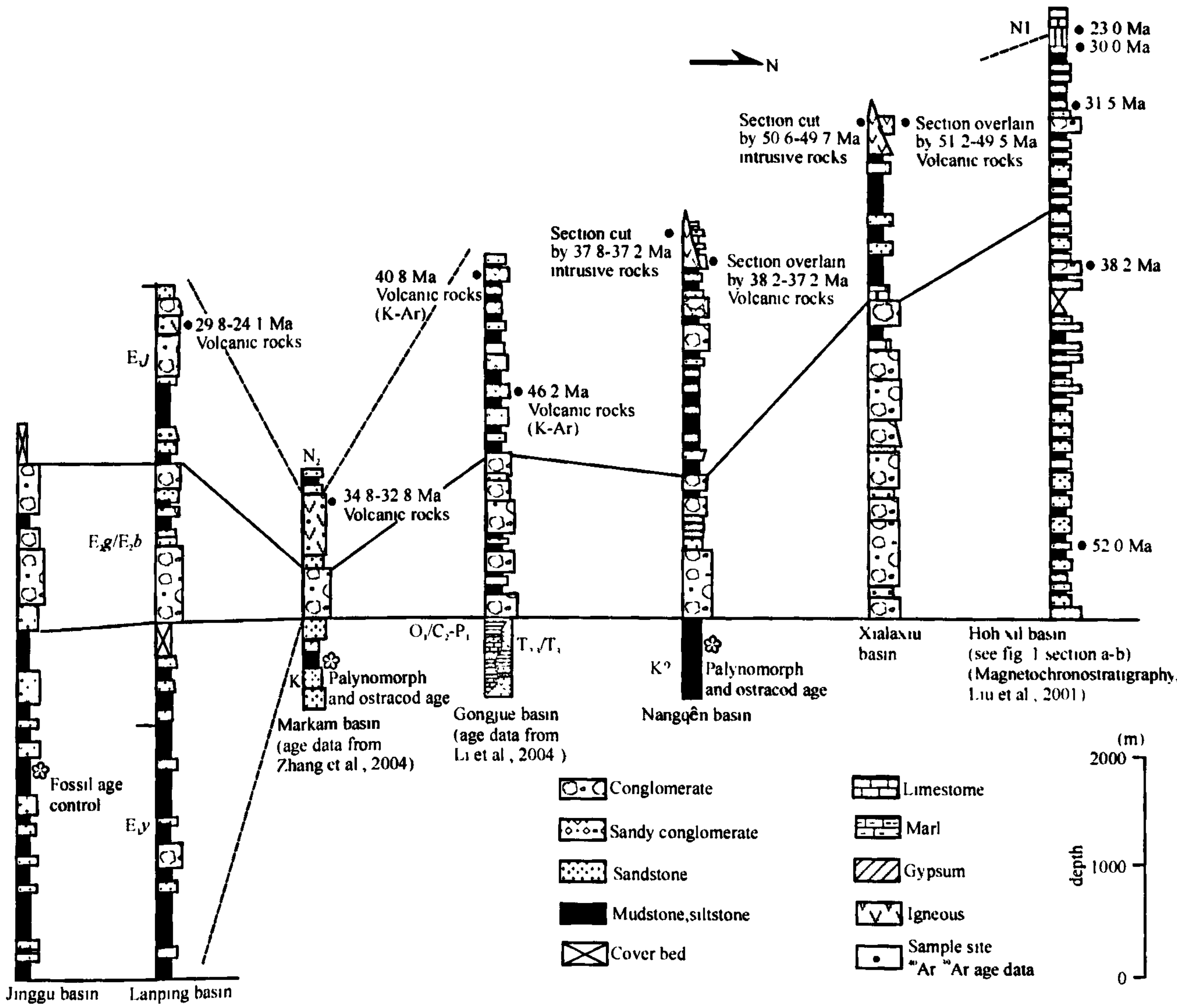


Fig. 4. Measured sequences from the seven separate sedimentary basins in east-central Tibet, including information on lithology, stratigraphic correlations, $^{40}Ar/^{39}Ar$ dates from tuffs and intrusives, magnetochronostratigraphy, and locations of fossil samples.

during long-term uplift and erosion of the Mesozoic basin basement, whereas the basins in the Lanping-Simao area formed within a large-scale coastal lake basin via a different uplift and disintegration regime.

4 New Ages of Coarse Clastic Rocks

It is difficult to directly date the age of younger coarse clastic rocks using radioactive isotopic methods, but we may constrain the formation time by using the sequences of basin-filling and coarse clastic rocks, fossils and dating of igneous rocks in the basins (Fig. 4).

In the northern Nangqên-Yushu area, the Paleogene bottom conglomerates directly contact with Carboniferous clastic rocks and Triassic limestones via unconformity. There is a continuous deposition between the upper fine and lower coarse clastic rocks. The fauna and palynomorphs found in the upper fine clastic rocks (Horton et al., 2002) indicate that this series formed during the period from the Late Eocene to Early Oligocene. In the southern Lanping-Simao area, the several Paleogene coarse clastic beds directly contact either conformably and/or disconformably the fine clastic rocks formed in a lacustrine-delta system. The fauna and palynomorphs in the fine clastic rocks indicate an age of Middle-Late Eocene to Early Oligocene (BGMR of Yunnan, 1990) (Table 2).

The high-potassic magma in east-central Tibetan Paleogene basins directly cut the coarse clastic rocks and the upper volcanic rock beds indicate that the intrusion was later than the formation of the clastic rocks. The high-potassic volcanic rocks developed in the Nangqên, Gongjue and Markam basins are located on the top of the coarse clastic rocks, indicating that the magma eruption

Table 2 Age constraints for coarse clastic rocks of Paleogene basins in east-central Tibet

→ To South			
	Lanping-Simao fold belt	Batang-Lijiang fault belt (Gongjue-Markam area)	Lanping-Simao fold belt
$^{40}Ar/^{39}Ar$ dating of cut by intrusive rock	50.6 – 37.2 Ma		
$^{40}Ar/^{39}Ar$ dating of overlain by volcanic rock	51.2 – 32.9 Ma	46.2 – 34.8 Ma	29.8 – 24.1 Ma
Fossil control in fine clastic rocks*	**Ostracodes and pollen:** *Eucypris* sp., *Hippeutis* sp., *Negulus* sp., *Cininna* sp., *Pterisporites* sp., *Ephedripites* sp.,		**Stonewort:** *Gyrogona-Raskyaechara* and *Amblyochara-Maedlerisphaera-Harrisichara-Rhabdochara* **Ostracodes:** *Pinnocypris-Limnocythere*
	Coarse clastic rock member		**Consisting of coarse to fine sequences**
Underlying strata	Carboniferous clastic rocks and Triassic limestones	Cretaceous clastic rocks or Triassic volcanic clastic rocks, slate interbedded coal beds	Peleocene clastic rocks
Age control of coarse clastic rock	Middle Eocene	Middle and Late Eocene	Eocene-Late Oligocene

* Fossil data from Horton et al., 2002 and BGMR of Yunnan, 1990.

Table 3 Summary of $^{40}Ar/^{39}Ar$ age for igneous rock in the eastern Tibet

No.	Sample	Rock type	Phase	Plateau age (Ma±σ)	Isochron age (Ma±σ)	Location
1	S-12-0-1	lamprophyre	biotite	50.2 ± 0.1	50.6 ± 0.2	Xialaxiu Basin
2	99-5-10-1	rhyolite	biotite		51.2±0.2	
3	99-5-12-2	granite	biotite		49.7±0.2	
4	99-5-12-1	rhyolite	biotite		49.5±0.2	
5	96-17	trachyte	whole rock	32.9 ± 0.2	32.9 ± 0.2	Nangqên Basin
6	S7-1	trachyte	whole rock	37.9 ± 0.6	37.0 ± 0.4	
7	S8-4	lamprophyre	biotite	38.0 ± 0.4	37.2 ± 0.7	
8	ZM-2	lamprophyre	biotite	37.7 ± 0.1	37.8 ± 0.2	
9	99-4-27	trachyandesite	biotite		37.2 ±0.1	
10	99-4-28	trachydacite	biotite		38.2±0.1	
11	Bm20	tuff	biotite	46.2 (Ma,K-Ar apparent age)		Gongjue Basin (Li et al., 2004)
12	Bm55	tuff	biotite	40.8 (Ma, K-Ar apparent age)		
13	MK391-6	trachyte	whole rock	33.7 ± 0.2	32.8 ± 0.9	Markam Basin (Zhang et al., 2004)
14	MK-75-2	trachyte	whole rock	33.3 ± 0.1	34.8 ± 0.3	
15	ZP-5	orthophyre	nepheline	36.9 ± 0.2	24.1 ± 0.3	Lanping Basin
16	Y-9	orthophyre	whole rock	29.4 ± 0.3	29.8 ± 0.8	Jianchuan Basin
17	GO35-1	orthophyre	K-feldspar	37.0 ± 0.1	37.0 ± 0.4	Lijiang
18	GO35-4	orthophyre	K-feldspar	32.2 ± 0.9	30.8 ± 0.8	
19	MC1-1	orthophyre	K-feldspar	30.6 ± 0.5	29.1 ± 0.5	Dali
20	DP19-1	trachyandesite	biotite	35.2 ± 0.5	34.0 ± 1.2	Daping

was slightly later (Li et al., 2004; Zhang et al., 2004) (Table 3).

Twenty-one new $^{40}Ar/^{39}Ar$ age samples (their localities and ages are presented in Fig. 3 and Table 3) dated with high accuracy (six at the Guangzhou Institute of Geochemistry, Chinese Academy of Sceinces; others at UCLA) suggest that the ages of the intrusion in the Paleogene basins correspond to 50.6–29.8 Ma, with the eruption around 51.2–32.8 Ma. The earliest ages of the intrusion correspond to 50.6–49.7 Ma, present in the northern Xialaxiu Basin, and 37.8–37.2 Ma in the southern Nangqên Basin (Fig. 4).

Obviously, the minimum age of the deposition of coarse clastic rocks in the Paleogene basins is Middle Eocene, ~51.2–38.2 Ma (in the northern Nangqên-Yushu area), Middle-Late Eocene, ~46.2–34.8Ma (in the central Gongjue-Markam area) and Late Oligocene, ~29.8–24.1Ma (in the southern Lanping-Simao area). The rapid tectonic uplift of the Tibetan Plateau might have resulted not only in regional distribution and instant accumulation of coarse clastic rocks, but also in widespread igneous activity and fold thrusting.

5 Regional Correlation and Early Plateau Tectonic Uplift

The widespread thick-bedded coarse clastic rocks are closely related to rapid regional uplift (Rowley, 1996; Liu et al., 1996; Sun and Zheng, 1998; Li et al., 1979; Liu et al., 2001). Coarse clastic rocks are widely developed in more than 20 Paleogene basins in east-central Tibet and margins, such as the Tarim, Xigaze, Hoh Xil, Caidam, Kunlun Shan, Linxia, Lanzhou, and Guide basins, but the beds are relatively thin (Sun and Zheng, 1998; Liu et al., 2001; Wang et al., 2004). A comparison of the basins shows that the coarse clastic deposit of the Qiuwu Formation and the Liuqu Group formed from the Middle-Early Eocene to Oligocene in the Xigaze Forearc Basin, the early tectonic uplift time being ~54.2–24.1 Ma in the Nangqên and Hoh Xil basins, ~32 Ma in the Lanzhou Basin, and ~24 Ma in the Guide Basin (Liu et al., 2001; Yue et al., 2000; Song et al., 2001). A ~61 km (43%) NE-SW crustal shortening in the Nangqên-Yushu fold-thrust belt in the Late Eocene was consistent with a ~41% shortening of the Fenghuoshan area in the Late Oligocene. This suggests a diachronous tectonic uplift history for the Tibetan Plateau in the Paleogene, consisting of a process of diachronous collision from south to north (Rowley, 1996; Chung et al., 1998; Horton et al., 2002; Liu et al., 2001; Wang et al., 2004; Spurlin et al., 2005). In the southern Langping-Simao Paleogene basins, coarse clastic rock beds were almost developed, with at least two to three conglomerate (including muddy-conglomerate) beds. Widespread and longer developed coarse clastic rocks suggest that there is near-corresponding relationship to the fold-thrust and strike-slipping tectonic background related to the early tectonic uplift process on the Tibet plateau.

The spatial difference between the development of basins and the sedimentological features in east-central Tibet can be attributed to the different responses of the plateau uplift due to their different tectonic locations. The above differences present as follows: proximal, rapid accumulation; dry and subaerial alluvial fan environment in the north; and a wider alluvial fan-delta environment in the south. The basin-filling sequences, volcanic activity, and coarse clastic rock chronology indicate that the closure time of the Paleogene basins in the northern Nangqên-Yushu area was earlier than that in the south and the Tibet Plateau margin. The closure time of the northern Paleogene basins was gradually later than in the southern basins, which indicates the possible process of diachronous tectonic uplifting in the Paleogene on the east-central Tibet Plateau.

6 Conclusions

(1) The Paleogene basins in the northern Nangqên-Yushu thrust belt were formed in a proximal and rapid accumulation subaerial alluvial fan environment in dry and hot climatic conditions and developed via a background of extruding thrusts and strike-slip tectonics. By contrast, the basins in the southern Lanping-Simao fold belt were developed in a wide and stable alluvial fan environment near the basin margins and formed in a large-scale coastal lake basin with a strike-slipping tectonic setting and disintegration.

(2) Widespread coarse clastic rocks occur in the Paleogene basins in east-central Tibet. A mid- Eocene to Oligocene (51.2–24.1 Ma) age for the coarse clastic rocks is supported by fossils, magnetochronostratigraphy, and $^{40}Ar/^{39}Ar$ ages from interbedded volcanic rocks in the uppermost or intrusive rocks cutting the basin filling.

(3) Paleogene basin development in east-central Tibet was produced by N-S contraction during the initial stage of the India-Asia collision. The widespread huge-bedded coarse clastic rocks, fold thrusting and strike-slip, thrust shortening, and igneous activity in the Paleogene basins are closely related to early plateau tectonic uplift. Combined with regional correlation of the Paleogene basins, it is suggested that there was a development of an early stage of diachronous tectonic uplift (51.2–24.1 Ma) in the Tibet Plateau.

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Explanation of plate

Plate I. Representative photographs of facies associations in coarse clastic rocks of Paleogene basins in Nangqên-Yushu thrust belt .

1. Massive or imbricated conglomerate facies Gm, Gms;debris-flows deposit with a proximal and rapid accumulation;
2. Massive or imbricated granule-pebble conglomerate facies Gh;fan-surface deposit in the braided river with hyperconcentrated flows;

3 and 4. Large-scale trough or planar cross bedding pebble-bearing sandstone facies St, Sp;fan-surface deposit in the braided river with lower flows migrating dunes or bars;

5. Parallel and graded bedding pebble-bearing sandstone or sandstone facies SGh, Sh; sheeted flood deposit in the high-density turbidity current;
6. Massive sandstone or pebble-bearing siltstone facies Sm, Fg;rapid loading of sheeted flood flows or suspension fallout, waning flood flows deposit.

Plate I