Sedimentary environment of the Dajin conglomerate in Tibet, age of foraminiferan assemblages and their tectonic significance

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Abstract The Dajin conglomerate, which is one of the most important sedimentary successions of the Xigaze forearc basin in Tibet, China, consists of deep-shallow marine tuffaceous turbidites and clastic rocks bearing Nummulites, Asstilina, Alveolina and Lockhartia. These fossils are very similar to the foraminiferan in the Jialazi and Mailsi conglomerates, and those in Gangdese and Dingri areas. They developed in the Eocene. By analyzing the spatial variation of Eocene sedimentary environments of Tibet Plateau and the foraminiferan in the Dajin conglomerate, we found that Eocene sedimentation should take place on both sides of the Yarlung Tsangpo suture, and the late Eocene tectonic uplifting should make the forearc basin expose out of the sea level and begin to receive nonmarine deposits.

Keywords: Dajin conglomerate, marine deposits, Eocene foraminiferan, Yarlung Tsangpo suture.

Various sedimentary basins developed during orogenic processes and mountains building, which record important information about the history of the orogenic history. The continuous sequence of Late Cretaceous to Paleogene in the north margin of the Yarlung Tsangpo suture zone, which is an integral stratigraphic assemblage associated with continental collision including the Xigaze forearc basin, shallow-marine carbonate and nonmarine molasses[1-4], has become an important reference for studies on the Tibetana geological evolution[5-17]. Previous studies mainly focused on the Mailsi conglomerate[18], Jialazi conglomerate[2] in the middle section of the Gangdese mountains and Cretaceous to Tertiary foraminiferan in the Tibet area[2-17, 19]. However, studies on tectonic significance of these conglomerates are relatively poor.

We systematically studied the Dajin conglomerate that crops out in the Gangriboche peak area in the field (Fig. 1) and abundant Eocene foraminiferan fossils were collected and identified, which can provide credible geological evidence for studying the Tethyan ocean evolution, India-Eurasia collision and Tibet uplifting.

1 Geological backgrounds

The Dajin conglomerate crops out about 20 kilometers west of the Dajin Hotel and are overlain by the nonmarine Gangdese conglomerate continuously. It is adjacent to the Gangdese island arc in the north and Yarlung Tsangpo ophiolite melange in the south, respectively. It was regarded as one part of the nonmarine molasses — the Gangdese conglomerate formed by the India-Asia collision[2]. In fact, its lithofacies, sedimentary environment, and foraminiferan assemblages are very similar to that of the Mailsi and Jialazi conglomerates in the Zhongba area, and that of the Hemis conglomerate of the Indus basin in the Ladakh area. All of these stratigraphic units were considered one important marine component of the xigaze forearc basin and they discontinuously outcropped in different areas along the north margin of the Yarlung Tsangpo suture.

2 Lithofacies assemblages and sedimentary environments

Our fieldwork demonstrated that the Dajin conglomerates was mainly composed of coarse-graded clastic rocks with rough parallel beddings. Their thickness is more than 90 meters in the outcrop. Three lithofacies assemblages were identified in terms of lithofacies and sedimentary structures (Fig. 2): tuffaceous turbidites in the lower part, sandstones
interbedded with lenticular conglomerates in the middle, and thick-layered conglomerates interbedded with coarsely grained sandstones in the upper.

2.1 Turbidites

This unit occurs in the lower part of the section with a thickness of 22 meters. It is composed of grey-green and grey tuffaceous siltstones, coarse sandstones and pebbly sandstones. Tuffaceous siltstones are the main lithofacies in the bottom of the section, which is associated with thin tuffaceous coarse-grained sandstones, forming many circle sequences with in 5 meters. Three rhythmic sequences consist of pebbly sandstones, coarse sandstones and siltstones in the middle part with a thickness of 6.7 meters. The top of these assemblages is dominant in siltstones whose thickness is 10.3 m. Scour base and graded bedding developed locally within the pebbly sandstones, coarse-grained near the bottom and finer-grained toward the top and ultimately merging to siltstone with ripple cross-lamination, which separates it from the next unit. Pebbles usually are subrounded-rounded volcanic fragments with 1—2 cm in diameter. Some embayed crystalline and lithic fragments in the siltstone (Fig. 3(a)—(c)) based on the studies from thin sections indicate that volcanic activities should have taken place during the deposition of this unit. Coarse-grained sandstones consist of about 15% matrix, 45% lithic fragments, 25% quartz, and 15% feldspar, respectively (Fig. 3(e), (f)). Besides phyllite, slate, chert, siltstone and basalt fragments in the sandstone, basalt and andesite fragments increase in the pebbly sandstone downward. Basalt, andesite, chert and sandstones are the major components of the Yarlung Tsangpo ophiolitic mélangé[21]. This demonstrates that in the early period of the deposition, the Gangdese island arc was the main source area for the turbidites, and the ophiolite mélangé adjacent to the Dajin conglomerate was the second contributor for the deposition.

2.2 Tuffaceous sandstone and lenticular conglomerate

Tuffaceous and calcareous siltstone, greywacke and conglomerate assemblages mainly crop out in the middle section with a total thickness of 44 meters (Fig. 2). Usually, calcareous siltstones and conglomerates are lenticular and interbedded with the tuffaceous siltstones. The sizes of siltstone lenses are smaller than that of the conglomerate lenses. Conglomerate lens with thickness of 10—15 cm are siltmatrix-supported. Pebbles are rounded-subrounded, consisting of volcanic, chert, tuffaceous siltstone, metamorphic fragments. They vary from 1 to 3 cm in size. Pebbly greywacke has a well-developed scour base and graded bedding, coarse-grained near the bottom and finer-grained toward the top. Graded bedding, parallel and ripple cross-lamination also developed in the greywacke and siltstone. Pebbly greywacke, greywacke and siltstone formed a finer-grained upward in the whole section. Foraminiferan occurs in the calcareous siltstones and matrix of the conglomerates.
2.3 Conglomerates and lenticular sandstone

Grey conglomerates with thin greywacke interlayers are the main lithofacies assemblages in the upper section, with a thickness of 24 meters. Conglomerate is lenticular, disorganized, graded, matrix- or clast-supported. Angular slate and chert fragments are the primary clasts, and some volcanic fragments are also occurred in the outcrops. This character suggests these clasts were not transported for a long
Fig. 3. Microtexture photograph of the Dajin conglomerate. (a) and (b) are tuffaceous greywacke with embayed quartz crystal fragments of F727-5 and F727-12 respectively; (c) siltstone containing andesite fragment with platyctinic texture (F727-3); (d) greywacke with siltstone, phyllite, volcanic and carbonate fragments, and with more than 15% matrix (F727-10); (e) litharenite with basalt, chert and phyllite fragments (F727-22); (f) litharenite with abundant foraminifera (F727-54).

distance but deposited near the source area quickly. Wavy laminations and tabular cross-beddings develop well in the sandstones; thick conglomerates usually consist of several thin conglomerate lenses with scouring base and normal-reversal graded bedding. Conglomerate unit together with coarse sandstone and siltstone beds formed several cyclical beds. Tabular cross-beddings and graded-bedding are abundant in the sandstone beds, but small-scale wavy lamination occurs in the siltstone bed. Foraminifera is very abundant in this section. At the top of this unit, the lithofacies varies from conglomerate into thick, massive sandstone with large-scale tabular cross-beddings of the Gangdese conglomerate, indicating they deposited in the fluvial environment.

Vertically, the Dajin conglomerate consists of deep-marine turbidites and shallow marine clastic rocks with foraminifera, which contains tuffaceous siltstone in the bottom, coarse-grained in the middle and ultimately merging into fluvial coarse-grained sandstone and conglomerate upward. This feature may be related to the variable geomorphic feature and tectonism. Siltstone bed is stable in its lateral extension, but conglomerate bed usually is not continuous. Siltstone and pebbly sandstone are fining upward, which indicates that they may be the channel deposits; massive, coarse-grained sandstone and siltstone may be the deposit between the channels; lenticular conglomerate is possibly the channel lag. Pebbles vary from rounded-subrounded to angular up-
wards implies that in the early deposition they were
near source area but not transported for a long dis-
tance; abundant volcanic components of the sandstones
in the lower section also imply that volcanism should take
place in the source area during its early deposition.

3 Foraminiferan assemblages and their age

It was observed in the field that abundant
foraminiferan fossils developed in every conglomerate
bed in the outcrop. These fossils also occurred in the
greywacke based on thin-section studies (Fig. 3(f))
and were identified by us in the laboratory. Location
of the foraminiferan in the cross section was marked
in Fig. 2. The fossils contain four genus: Num-
mulites, Assilina, Alveolina and Lockhartia
(Fig. 4). Nummulites and Lockhartia haimei
(Davies) also occur in the greywacke and matrix of
the conglomerate (Fig. 3(f)). They have a good
shape and clear structure without being destroyed by
diagenesis. Angular fossil fragments in the greywacke
should be resulted from wave action, diagenesis and
post-tectonism, and they should not be transported
from other places[22]. Thus, the age of these fossils is
synchronous to the deposition in this region.

Fig. 4. Photograph of Paleogene foraminiferan from the Dajin conglomerate (all foraminiferan magnified 30 times). 1, Lockhartia haimei
(Davies) (vertical cross section through embryo; F727-29); 2 and 3, Assilina dandotica Davies (plane section and vertical cross section
respectively; F727-58); 4—7, Assilina sp. (vertical section; F727-51, 57); 8, Alveolina sp. (middle cross section; F727-51); 9,
Nummulites sp. (vertical cross section; F727-57); 10—13, Nummulites rotulatus Dehayes (10, plane section; 12, inclined plane
cross section; 11 and 13, vertical cross section; 10 and 11, F727-54; 12 and 13, F727-43); 14 and 15, Nummulites sp. (vertical cross
section; F727-29, 63).
Regionally, the Eocene Nummulites rotularius Deshayes occurs in the thin limestone interlayers of the Maila conglomerate in the south of the Maila Mountain, Zhongba County. Nummulites rotularius Deshayes, Ranikothalia tibetica Liu (sp. nov.), Ranikothalia bermudezi (Palmer), Textularia sp., Lochhartia sp., Miliola sp., Assilina subspinoso Davies, A. ranikoti Nuttall, A. levis Sheng et Zhang and Discocyclina seunesi H. Douville occur in sandy marl beds of the Jialazi conglomerate of the Cuojingding section in the Zhongba County. Abundant Fasciolites and Assilina. Assilina, Nummulites, Discocyclina, Fasciolite and Operculina occur in the limestone interlayers of the thick conglomerates in the Dingri, Zhongba and Gangrinboche areas, and abundant Nummulites occur in the limestone of the Indus forearc basin in the Ladakh area. These facts demonstrate that Assilina danotica Davies, Nummulites rotularius Deshayes, Lochhartia haimei (Davies), Alveolina sp. and Rootaliiids of the Dajin conglomerate are very similar to the fossils in the Maila and Jialazi conglomerates and limestone beds of the Gangba, Dingri areas and Indus basin. This further demonstrates that the Dajin conglomerate together with Maila and Jialaz conglomerates should deposit in the Eocene, and Eocene foraminifera should develop on both sides of the Yarlung Tsangpo suture.

Fasciolites Sheng et Zhang, Fasciolites tibeticus Sheng et Zhang, Fasciolites nutalli Davies, Nummulites rotularius Deshayes also occur in the limestone pebbles of the Gangdese conglomerate. They are similar to the fossils from the Dajin, Maila and Jialazi conglomerates. This fact provides evidence for that the depositional age of the Gangdese conglomerate is younger than that of the Dajin, Maila and Jialaz conglomerates, and limestone beds with foraminiferae within the Dajin, Maila and Jialaz conglomerates in some areas may provide clastic fragments for formation of the Gangdese conglomerate.

4 Tectonic significance

Regionally, Gangdese magmatic arc in the north of the Yarlung Tsangpo suture zone together with the Ladakh magmatic arc to the west forms a large-scale magmatic island arc chain in the Tibet. From the west to the east, discreted molasses along the south margin of this island arc chain containing Indus molasses and Gangdese conglomerate, together with the Xigaze Group, constitute a continuously sedimentary sequence within the Xigaze forearc basin, which provides credible evidence for the India/Asia collision. Marine molasses in the Mailashan, Cuojiangding and the Dajin Hotel in the Gangrinboche peak area were the products of later phase during the evolution of the Xigaze forearc basin, which record the evolution of the Tethys and India/Asia collision together with Paleocene-Eocene marine molasses in the Indus basin. These marine molasses were overlain by the Gangdese conglomerate conformably, and limestone pebbles of the Gangdese conglomerate with Eocene foraminiferae originate from the marine molasses. It demonstrates that marine deposition did not die in the Eocene.

The poorly sorted Maila conglomerate contains sandstone, shale, limestone, quartzite, granite and volcanic fragments, and the Jialazi conglomerate mainly consists of litharenite and bioclastic limestone with abundant organic composition and pyrite. Lithic fragments in the litharenite mainly consist of granite and dacite. Marine molasses in the Indus basin were deposits of turbidite in the lower part with abundant shallow-water Nummulitic limestone pebbles and shallow marine clastic rocks in the upper part with Eocene foraminiferae. Conglomerate and greywacke of the Dajin, Maila and Jialazi conglomerates have very similar compositions. Turbidite deposits also developed in the lower section of the Dajin conglomerate, and nonmarine Gangdese conglomerate overlies these marine molasses. All of these facts demonstrate that Eocene deposition within and on both sides of the Yarlung Tsangpo suture was marine deposits; uplifting of the Tibet Plateau should take place during late Eocene, which modified the marine deposition of the forearc basin and provided clastic fragments for forming extensive nonmarine deposits that was similar to the Gangdese conglomerate.

Ding found Paleocene radiolarian from deep-water chert and flysch in the Sengdanlin and Zheba sections in the south of the Yarlung Tsangpo suture zone and separated four Radiolarian zones RP1-RP6 (65—55 Ma). Recently, we found late Eocene Radiolaria fossils in the same section (unpublished data). The highest marine strata in the Zhongba area is late Paleocene-early Eocene Jialazi Formation, late Eocene Zhepuya Formation in the Gangba area, and Dajin conglomerate in the Gangrinboche peak area. If deep-marine chert with Eocene radiolarian and flysch would represent the existing new Tethyan sea, this sea should have developed into a small basin.
along the Yarlung Tsangbo suture during the late Eocene. The water on both sides of the suture zone should be connected, which provided a pass for the migration of the foraminifera.

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