GROWTH OF ASIA DURING THE PHANEROZOIC ERA

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Fragmentation of the late Proterozoic Pangea had reached its zenith during the Early Proterozoic. The continental crust which now underlies Asia formed the nuclei of four continents and/or microcontinents in Asia; they are, from north to south, Angara, North China, South China, and Paleo-Gondwana.

Hsu (1994) introduced the concept of tectonic facies as a method to unravel the history of mountain belts and to reconstruct paleogeography. Former island arcs or continental basement are deformed mainly by rigid-basement overthrusts, and those are called **Rhaetides**. The sedimentary covers of the rhaetide basement have been folded or deformed by detachment thrusts, and those are called **Alemanides**. The crust and deep-sea sediments under oceans or backarc basins are deformed by underthrusting down subduction zones, and those ophiolite melanges are the **Celtides**.

Sengör and others (1993) postulated that the Paleozoic Angara and North China was separated by an Altay Ocean, formed by sea-floor spreading. The Angara Continent north of the ocean was bordered by a magmatic front and by an archipelago of islands and back-arc basins. Sengör and others identified the following tectonic facies south of the Angara Craton, and they are from north to south Vitim Celtides (J), Northern Tuva/Mongolia Rhaetide and Alemanide (H), Khanghai/Khantey Celtide (G), Southern Tuva/Mongolia Rhaetide and Alemanide (F), and the Altaides including the Gobi-Altay Celtide, the Karamai/ Xinjiang-Altay Rhaetides and Celtides, and the relic ocean crust under the Junggar Basin (E). Those are a part of the Altaids, which extended from the Urals, through Kazakhstan, Altay/Sayan to Mongolia and Okhotsk. Sengör (in Sengör and others, 1993) postulated that the Altaids all evolved along a single arc-trench complex. This arc had been rifted apart from the Baltic/Siberian hinterland and became multipliably bent and separated during the Paleozoic.

Hsü (in Hsü and Chen, 1999) disagreed: the ophiolite melanges of the Altaids are not all fore-arc accretionary wedges. The orogenesis on southern border of the Angara Continent was not only related to fore-arc subduction, but also related to back-arc collapses. Nor were all the magmatic rocks of the Altaids the partial-melting product of the underthrust slab of forearc subduction. Both fore-arc and back-arc volcanisms took place during different periods in different parts of an archipelago. He considered, therefore, that those Angara facies-units the deformed rocks of an archipelago behind a south-facing magmatic front. The Southern Tuva/Mongolia Rhaetide was the basement of island arc on that magmatic front. The geology of Northern Tuva/Mongolia Rhaetide indicated that fore-arc magmatism started in late Precambrian time, and the geology of the Circum-Junggar mountains indicated that arc-magmatism continued until late Paleozoic. The Vitim Celtides, Khanghai/Khantey Celtide, and the Gobi-Altay Celtides (J, G, E') were ophiolite melanges, formed as a consequence of the subduction of collapsed back-arc basins. The Northern Tuva/Mongolia Rhaetide, the Southern Tuva/Mongolia Rhaetide, and the Xinjiang-Altay Rhaetides (H, F) were basement of island-arcs or relic-arcs. The Karamai/Xinjiang Altay Celtides (E') were forearc accretionary-prism. The last remnant of the crust under the former Altay Ocean is now trapped between the circum-Junggar celtides.

On the south side of the Altay Ocean was the Cathaysian Continent or continents, consisting of combined or separated North and South China micro-continents. Hsü identified the South Mongolia Celtide (E) as the deformed relic of the former Altay Ocean. The Uliasti/South Gobi Arc (D) was the north-facing arc or the northern magmatic front of the North China Block. The arc extended westward, as witnessed by the fore-arc magmatism of Middle Tianshan Arc (D'). South of the frontal arc was an archipelago of basins and islands. The deformed rocks formed the following tectonic-facies units: the Southern Tianshan and Hegenshan celtides (C', C), the Kalpin/Kuruktag Rhaetide and Alemanide (B') and Sonidzuoqi Rhaetide(B).

Orogenesis in the form of fore-arc subduction and arc-arc collisions took place during various periods of the Paleozoic Era, before the Altay Ocean was eliminated by late Paleozoic continental collisions. With the accretion of North China onto Angara Continents, the Asian Continent grew.

The separation of the North and South China took place during the Ordovician Period. The Qinling/Dabie Ocean separating the two microcontinents is now represented by ophiolitic melanges of central China. North China was bordered on the south by a Paleozoic island-arc: the south-facing magmatic front extended from Qinling/Dabie to Kunlun Mountains. North of the island arc were marginal seas on the fringe of the Sino-Korean Craton in the east, and the Tarim/Qaidam Archipelago in the west.

The thin-skinned deformation on the margin of the Sino-Korean Craton resulted in several alamanides, such as the well-known Western Hills Folded Belt north of Beijing. The Tarim/Qaidam Archipelago was deformed by back-arc subductions and by arc-arc collisions, forming the Tianshan, Kunlun, Qilian, and Qaidam mountains.

The Qinling/Dabie Ocean was eliminated as the oceanic curst was subducted and consumed under North China. The two microcontinents collided during early Mesozoic, forming the Qingling and Tongbai-Dabie mountains, as well the Sulu/Jiaodong Hills on the east side of the Tanlu Transform Fault. With the accretion of South China onto the Angara/North China Continent, the second stage of the growth of the Asian Continent was completed.

South China had a passive margin on the north. The microcontinent was bounded by a magmatic front on all other sides during the Paleozoic and Mesozoic. The western front extended from the border region of Tibet (Jiangda Arc) to Yunnan (Lincang Arc). The southern front extended from Vietnam eastward to Guangdong and Fujian (Min-Yue Arc). The eastern front now underlies the floor of East China Sea. Inside the magmatic front was an archipelago of islands and backarc basins.

The Precambrian continental crust of the Yangzi region constituted the nucleus of the microcontinent. The back-arc basins of the archigo collapsed, the oceanic basement was subducted, and the arc-arc collisions took place during the Paleozoic and Mesozoic eras. The thin-skinned deformation of the sedimentary covers formed fold-and-thrust belts, notably the Yangzi and Xiang-Gui alemanides, and the thick flysch and molasse units. The continental crust under islands, such as Jiangnan Old Land, was deformed by rigid-basement thrusting

and became rhaetides. Partial melting of the subducted sediments and ocean crust under backarc basins gave rise to the widespread Paleozoic and Mesozoic granites of South China, as well as the Mesozoic volcanics of coastal southeastern China.

The growth of Asia during the Mesozoic involved mainly the accretion of lithospheric fragments rifted apart from the Gondwana to the Angara/Cathaysia Continent.

The accretion of Tibet to China resulted from the elimination of the Paleotethyan Ocean. The ocean was bordered on the north by the Mesozoic magmatic fronts of Cathaysia. Behind the Qiangtang Arc and the Jiangda/Lincang Arc was an archipelago of island arcs and basins. The arcs were underlain mainly by a basement of the metamorphosed Paleozoic rocks rifted apart from the accretional wedge of the Paleozoic Kunlun Arc. Very thick flysch sediments were deposited in various backarc basins, notably in Songpan-Garze. The accretion of those sediment-filled flysch basins to Cathasia during the Paleozoic contributed to the growth of Asia.

Tibet was underlain by the continental crust rifted apart from Gondwanaland. The Paleotethyan margin of Tibet was also a magmatic arc, represented by the Baingoin Rhaetide in northern and the Gaoligongshan Rhaetide in eastern Tibet. Whereas the archipelago (Lhasa Block) south of the magmatic front had its origin in early Mesozoic, Tibet was not separted from the India until the birth of Neotethys in the Jurassic Period. Tibet was bordered on the south also by an island-arc front - the Himalayan Arc. The orogenic history of Tibet was characterized by Mesozoic and early Tertiary back-arc collapses and arc-arc collisions. The most prominent of the backarc basins are the northern and southern Zhanbo basins.

The Paleotethys was eliminated during Late Cretaceous. The addition of Tibet was another step to enlarge the continent of Asia. Other fragments rifted apart from Gondwanaland are collectively referred to Sibumasu. They were accreted to Asia by means of arc-continent collisions during late Mesozoic.

The last major act of the growth of Asia was the accretion of India and Middle East. Those Gondwana microcontinents were separated from Asia by Neotethys. Hsü, Pan, Sengör and others (1996) found evidence that the Zhanbo melanges do not represent a suture zone between Tibet and India. The suture zone lies south of the High Himalayas. The consumption of the Neotethys was a mid-Tertiary event. The subduction of the Neotethyan floor under Tibet caused the uplift of the plateau, and the collision of Tibet and India caused the deformation that gave rise to the mighty Himalaya/Karakorum Range.

Island-continent collisions on the eastern margin caused the growth of East Asia. The suture zones lie in the mountains of Manchuria/Siberia (Nadahada Celtide) and of Taiwan (Kenting and Lichi Celtides). Meanwhile, back-arc seafloor spreading caused the origin of the Indonesian Archipelago and of marginal seas. The filling of the back-arc basins by sediments and their deformation are setting the stage of a further growth of Asia.

The talk will be illustrated by maps from Geologic Atlas of China.

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