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Relation of Isotope Geochemical Steep Zones with Geophysical Fields and Tectonics in the Junction Area of the Cathaysian, Yangtze and Indochina Plates

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Abstract Through lead isotope geochemical mapping in the Yunnan-Guizhou area geochemical steep zones (GSZ) have been established, which clearly reveal the junction relationship of the Cathaysian, Yangtze and Indo-China plates. GSZ are closey related to gravity Moho gradient zones and lithospheric thickness. The GSZ between the Yangtze and Cathaysian plates is consistent with the Shizong-Mile tectonic belt, where island arc basalts are well developed. The Yangtze-Indo-China GSZ is parallel to the Jingdong-Mojiang volcanic belt in rift-island arc environments. The evidence of geology, geophysics and geochemistry all indicates that Cathaysia was subducted towards the Yangtze plate and that the Yangtze plate was underthrust beneath the Indo-China, which took place from the Early Carboniferous to the Early Triassic.

Key words: junction relationship of the Cathaysia, Yangtze and Indo-China plates, geochemical steep zone, gradient zone of gravity Moho

Geological, geochemical and geophysical studies of mantle and crust have shown that there exist distinct vertical and lateral heterogeneity of the lithosphere in composition and structure. The geochemical steep zones (GSZ) established through Pb isotopic mapping provided important information for revealing the boundaries of the Cathaysian, Yangtze and Indochina plates (Yang et al., 1995), as well as their relationships in southwestern China. The geophysical exploration in this area has revealed that there existed sharp variation of Moho and lithosphere thickness. A deep subduction zone dipping towards southwest was also discovered through tomographic images. Although the GSZ is well consistent with the geophysical evidence, there existed, however, discordance with the previous geological viewpoint. Recently, a series of island arc volcanic rocks were found in this area, which provided important evidence for illustrating the correlation between geochemical and geophysical fields.

1 Geochemical Steep Zones (GSZ)

Studies show that the $^{206}Pb/^{204}Pb$ ratios for various igneous rocks and ores in the Yangtze plate are generally lower than 18.2 and higher than 18.4 in Cathaysia, and the values in the Indochina plate are slightly higher than those in Cathaysia. The vector V2 of Pb isotopic compositions shows an accurate boundary value of 40±1 (Zhu, 1995; Zhu et al., 1996). The V2 boundary value between Cathaysian and Indochina plates is about 50. Pb isotopic mapping shows that the Cathaysia-Yangtze GSZ is along the Jianshui-Shizong-Mile-Xingren area in a NE direction. The Yangtze-Indochina GSZ is situated in the Chuxiong basin on the northeastern side of the Ailaoshan Mountains. The Cathaysia-Indochina GSZ extends from Gejiu to Maguan (Fig. 1). The model ages of Nd isotopes in the Kangdian block of the Yangtze plate are older than 2.0 Ga, whereas those in Indochina and Cathaysian are younger than 2.0 Ga (Zou et al., 1997). The boundary value between the Yangtze and Cathaysian plates in east China is nearly consistent with that in southwestern China, but the features of Nd model ages are just opposite (Zhu et al., 1997). Thus, the western Yangtze plate (Kangdian block) and eastern

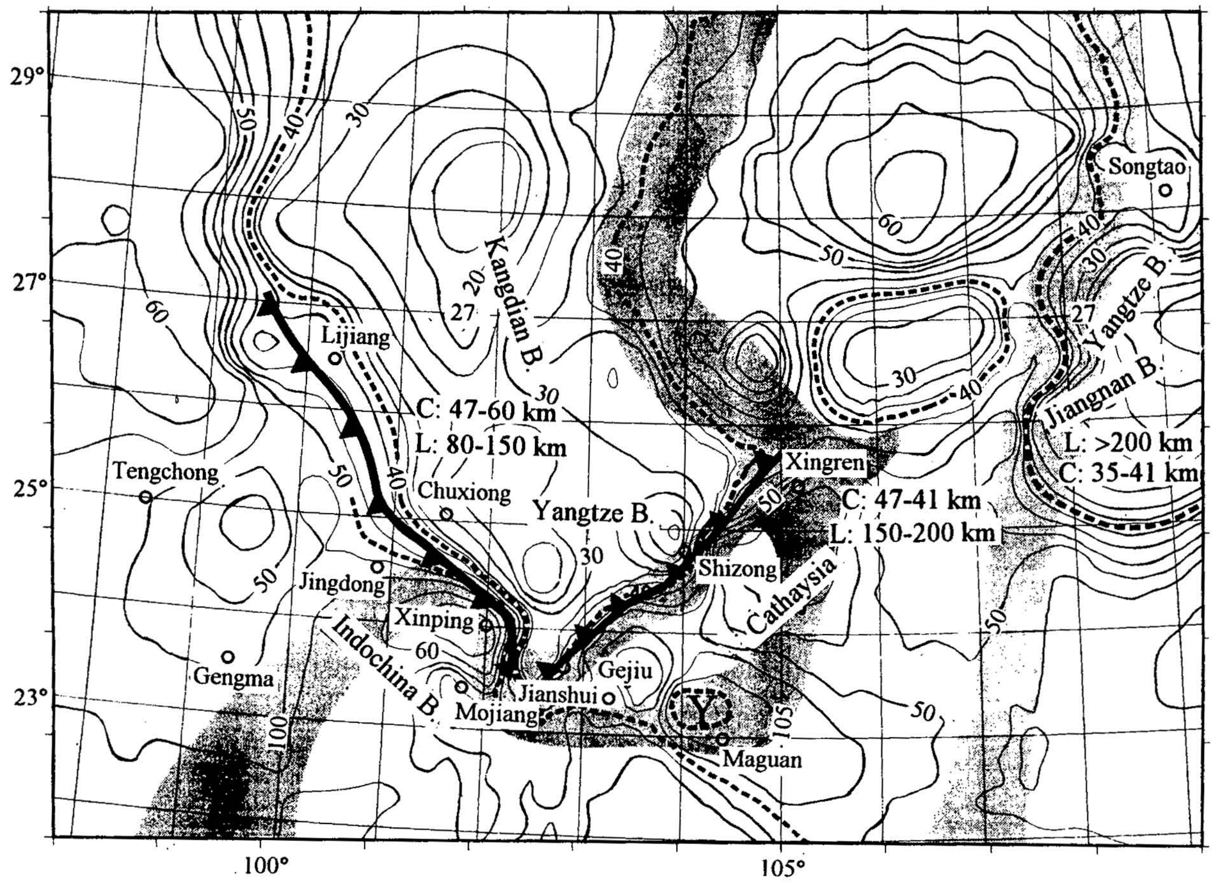

Fig. 1. A map showing the relations of the GSZ with the gravity Moho gradient zone, lithospheric thickness and tectonic junction belts.

Thin black lines denote contours of Pb isotopic V2; thick dashed lines: GSZ (boundaries); shaded areas: gravity Moho gradient belts; C: crustal thickness; L: lithospheric thickness.

Cathaysia are palaeo-continental blocks. The $^{208}Pb/^{204}Pb$ ratios of the Kangdian block are evidently lower than those in the eastern Yangtze plate, which shows V1≤V2 in the western Yangtze plate, in contrast with V1≥V2 in the eastern Yangtze plate. Therefore, the Kangdian block is neither a part of Gondwana nor a part of Laurasia, but could be formed from the North Pacific old land (Zhu, 1998).

2 Features of Geophysical Field

The variation of crustal thickness in southwestern China has a range of 35–60 km, thicker in the northwest and thinner in the southeast (Fig. 1). The lithosphere thickness varies in a range of 80–350 km, inversely correlated with the variation of crustal thickness. The crustal thickness is 35–41 km from the Xuefang Mountains to the Songtao area in Guizhou and Hunan provinces, whereas the lithosphere thickness reaches 200–350 km. The Cathaysian part of the Yunnan-Guangxi-Guizhou area appeared has a lithospheric thickness of larger than 150 km and a relatively thin crustal thickness, being less than 47 km, while the Kangdian block in the Yangtze plate has a thinner lithosphere (80–150 km) and a thicker crust (47–60 km) (Zhao et al., 1992; Xiong et al., 1993; Wang et al., 1994). There existed a distinct gradient belt of gravity Moho (GBGM) along the Jianshui-Shizong-Mile-Xingren area, which is entirely consistent with the GSZ between the Cathaysian and Yangtze plates. The GBGM in the Xinping-Yuanjiang-Jianshui area is sharply turned, which also corresponds to the turning point of GSZ (See Fig. 1). The GBGM in the Xinping-Jingdong area is intersected by the GSZ. The GBGM in the Gejiu-Maguan area turns northwestwards and is intersected by the GSZ between the Cathaysian and Indochina. A flat Moho, about 47 km thick, occurs in the Gejiu-Qiubei area.

The seismic tomographic image in the Yunnan area clearly shows the Yangtze plate underthrust beneath the Indochina plate westwards at a depth of 250–300 km. There is an evident asthenospheric upwelling into the mantle wedge over the subduction zone in the Gengma-Tengchong- Lushui area and the lithosphere here is 40–60 km thick. This mantle wedge stretches towards the Lijiang-Chuxiong-Mojiang areas. Therefore, Cenozoic volcanic rocks in the Tengchong and Pu'er areas show strong isotopic features of mantle in the subduction zone, whose Pb isotopic compositions show an affinity with the Yangtze plate ($^{206}Pb/^{204}Pb$= 17.9–18.2) and different from those of Indochina and Cathaysia (Xu et al., 1992).

3 Tectonic Implication of GSZ

The NE-SW-stretching GSZ along the Jianshui-Shizong-Mile-Xingren area in eastern Yunnan basically coincides with the Shizong-Mile tectonic zone (SMZ). Geological observation shows that the SMZ is a faulted zone with a complicated litho-structural assemblage. The tectonic zone was composed mainly of a series of overthrust faults, dipping NW with an angle of 40–60° and associated microlithons, including Palaeozoic, Triassic and Proterozoic strata and magmatic blocks.

The SMZ is a boundary of tectono-lithostratigraphic units, which separates old strata and active magma in the northwest from Triassic sediments in the Nanpanjiang basin. The northwest terrenes, composed mainly of upper Palaeozoic and secondarily of Palaeozoic and Proterozoic strata, thrust onto the Triassic strata in the southeast along the SMZ. The strata on both sides of the SMZ are characterized by folding, whereas the inside part of the SMZ is characterized by strong extrusion and breakup and sheared as tectonic mélange. Analyses of lithostratigraphy, sedimentary environment and metamorphism in this region suggest that the SMZ is a boundary of lithofacies and palaeogeography. On the other hand, the metamorphism shows that the SMZ is a distinct boundary separating metamorphic terrenes of low-greenschist facies in the northwest of the SMZ from the unmetamorphosed Triassic sediments in the southeast.

The SMZ is an active magma zone. There exist broadly a lot of lava blocks in the SMZ, which are mainly basic in lithology with pillow structure. The pillow lava is characterized by depleted Nb and Ta and enriched Th, which suggests that the magma source was influenced by the subducted components and that the pillow lava was erupted in an island-arc setting. The whole-rock U-Pb isochron age is 351±17 Ma, indicating that the plate subduction has taken place since the early Carboniferous.

The above evidence suggests that the SMZ was the convergence zone between Cathaysia and the Yangtze plate (Duan et al., 1981). The GSZ in eastern Yunnan is consistent with the SMZ and represents a geochemical boundary between the Cathaysian and Yangtze blocks after their convergence. The genetic mechanism is controlled by the tectonic evolution and geodynamics of Tethys.

The Ailaoshan orogen strikes NW-SE and is parallel to the GSZ. It is indicated based on current studies that there existed a left-lateral shear movement on a large scale in the Tertiary (Tapponnier et al., 1990; Harrison et al., 1995), which reflects the features of the Cenozoic inland orogen. A great deal of information about the Tethyan tectonic evolution in Ailaoshan can be found when removing the Cenozoic structural features. Tectonically, the most important thing is that the Ailaoshan orogen is a representative of the suture zone between Cathaysia and Indochina. An ophiolite-mélange zone stretches in a NW-SE direction on the west side of the metamorphic basement of Ailaoshan, where ophiolites, island arc volcanics and various tectonic rock masses derived from different tectonic environments are well developed. The Shuanggou ophiolites are composed mainly of lherzolites, diabases, gabbros, basalts and pillow lavas, which are emplaced as tectonic masses in the strongly sheared volcanic-sedimentary sequence. Basaltic rocks in the ophiolites show geochemical features of P-midoceanic ridge basalt (MORB) and N-MORB, which formed in an environment of a small ocean basin (Zhong, 1998).

Jingdong volcanic rocks and Shuanggou ophiolites, as part of the Ailaoshan ophiolite mélange, occur in its northwest and middle part respectively (Sun et al., 1997). The bulk features of trace elements of Jingdong volcanic rocks indicate that they belong to P-MORB. Its whole-rock U-Pb isochron age is 358±36 Ma, which is nearly consistent with that of the island arc volcanics in Jianshui. Gravel of ultra-mafic rocks from the ophiolites occurs in the conglomerates of the Upper Triassic Yiwanshui Formation, which indicates that the tectonic emplacement of the ophiolites should be earlier than the Late Triassic. The Shuanggou ophiolites were emplaced in the upper Palaeozoic strata, in which there exist Late Carboniferous-Early Permian limestone masses. Thus, the emplacement age of the ophiolite mélanges is constrained to be later than the Early Permian. The U-Pb discordant age of the zircon from the gabbro in the Shuanggou ophiolites is 362±41 Ma (Jian, 1998) and the ^{40}Ar-^{39}Ar plateau age of the hornblende in this gabbro is 349±13 Ma (Zhang, 1996), which represents the formation age of the gabbro and is also in agreement with that of the Jingdong volcanic rocks. This geochronological evidence shows that the subduction of the Yangtze plate towards Indochina took place in the Early Carboniferous. The NW-SE-stretching Mojiang island-arc volcanic rock belt is distributed in the west of the ophiolite belt and is parallel to it, indicating the westward subduction of the Ailaoshan oceanic basin. Therefore, the new geologic evidence is consistent with the observation for geochemical boundaries and geophysical tomographic images. Although there are a series of NE-dipping faults in surface, which are regarded as the evidence for the subduction of Indochina towards the Yangtze plate, drilling records bellow depths of 200 m has demonstrate that these faults all turn into SW-dipping ones in depth (Zou et al., 1997). Thus, the faults in the Ailaoshan area resulted from the strike-slip movement during the Mesozoic-Cenozoic.

4 Conclusions

The isotope GSZ is a synthetic effect of deep geophysical fields and crust-mantle interaction in conjunction with plate tectonic movements, thus being of great importance for studying deep structures of lithosphere and tectonic evolution processes.

Geological and geophysical evidence and establishment of geochemical boundaries indicate that the combination of the Cathaysian, Yangtze and Indochina plates took place at the same time, from the Early Carboniferous to the Early Triassic, and there were subduction events of Cathaysia towards the Yangtze plate and the Yangtze plate towards Indochina.

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