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Subduction Initiation and Mafic Intrusions: Rethinking the South China Sea-Luzon Connection

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Abstract: The conventional view suggests that the subduction of the South China Sea plate beneath Luzon occurred due to the oceanic lithosphere's high density, facilitating subduction initiation. However, before the South China Sea opened, a continental margin likely existed, meaning that Luzon was directly adjacent to the continental margin rather than the oceanic basin. This would make subduction initiation more challenging. Here, we propose a new model suggesting that during the formation of the South China Sea, extensive mafic magmatic underplating occurred along its continental margin. The high-density magmatic additions may have increased the overall density of the continental margin, potentially exceeding that of Luzon, thereby enabling subduction to proceed.

Keywords: Manila Trench; mafic intrusions; Luzon; subduction initiation

俯冲起始与基性岩浆侵入：重新思考中国南海与吕宋的构造联系

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摘要：传统观点认为，中国南海板块在吕宋岛下方的俯冲是由于海洋岩石圈密度较高，从而促进了俯冲的发生。然而，在中国南海形成之前，该区域可能存在大陆边缘，这意味着吕宋岛直接与大陆边缘相邻，而非海洋盆地。这种地质环境使得俯冲的起始过程变得更加困难。本研究提出一个新的模型，认为在中国南海形成的过程中，沿其大陆边缘发生了广泛的基性岩浆底侵。高密度岩浆的加入可能导致大陆边缘整体密度增加，使其可能超过吕宋岛的密度，从而使俯冲得以顺利进行。

关键词：马里拉海沟；基性岩侵入体；吕宋；俯冲起始

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1　Introduction

The dynamics and mechanisms of subduction initiation have long been a central topic in geological research[1]. In intra-oceanic settings, subduction—whether induced or spontaneous—is commonly understood to occur when an older, denser oceanic plate sinks beneath a younger, less dense plate[2]. However, the South China Sea plate (~33-16 Ma), despite being relatively young, is subducting beneath the older western Philippine Sea plate (~59-33 Ma) along the Manila Trench[3] (Fig.1). This atypical subduction

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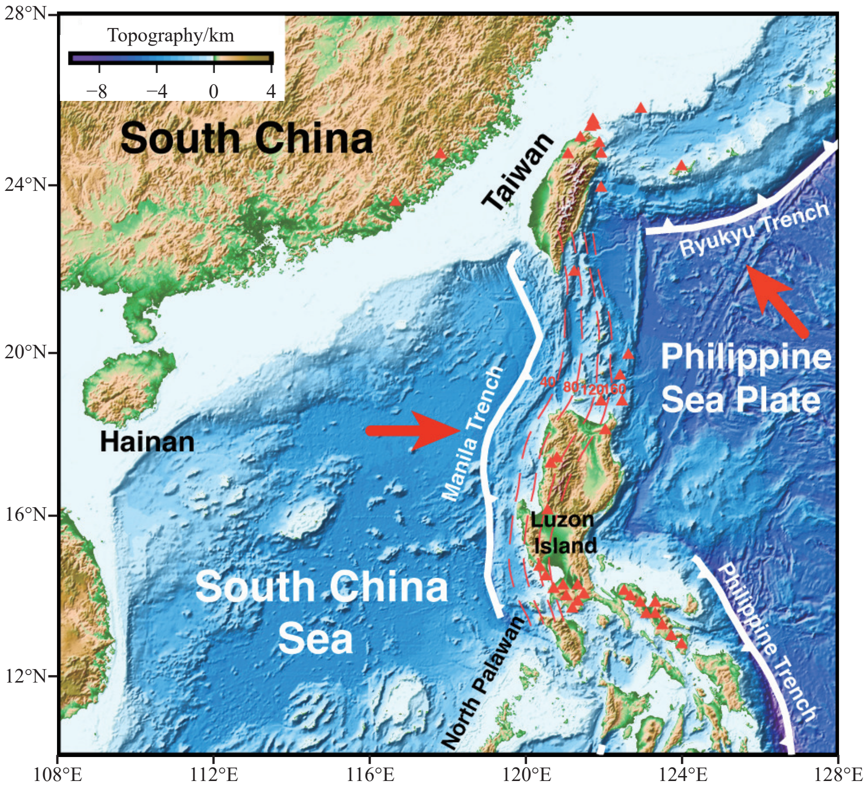

Fig.1 Topography and tectonic framework of the Philippine-Manila-Taiwan region. Red arrows indicate the movement direction of the Philippine Sea Plate and the South China Sea[4]. Red triangles mark active volcanoes. Dashed red lines, along with adjacent numbers, represent the depth contours of the eastern subducting Manila slab at 40 km intervals, based on the Slab 2 model[5]

scenario challenges conventional models and necessitates a reevaluation of the underlying processes governing intra-oceanic subduction initiation.

A previous study[6] attributed this atypical subduction initiation to the presence of micro-continents, which may act as triggers for the process. Specifically, the existence of microcontinental blocks within the Luzon arc is supported by the presence of ancient zircon in modern intra-oceanic arcs. This model is compelling as it facilitates subduction initiation by introducing these exotic components. The concept is plausible, given that microcontinental blocks exhibit continental characteristics, making them inherently less dense than the subducting South China Sea plate.

Unfortunately, multiple studies suggest that the South China Sea likely has an eastern continental margin[7-9]. If true, this implies that Luzon was directly adjacent to the continental margin rather than an oceanic basin. Such a configuration complicates sub-duction initiation, as a continental margin subducting beneath a microcontinent presents a unique challenge, given that both share continental characteristics.

In this study, we attribute subduction initiation to lower-crustal mafic intrusions within the continental margin, which facilitate the progression of subduction. The following section will further elaborate on this process.

2 Lower-crustal mafic intrusions promoting subduction initiation

2.1 Lower crustal mafic intrusions

High-velocity, high-density anomalies in the continental lower crust have been widely detected across the northern[10], southern[11-12], and northeastern[13-15] margins of the South China Sea. These anomalies have been attributed to either magmatic activity associated with paleo-Pacific subduction or post-rift magmatic modification[14]. They play a crucial role in subducting plate deformation and hydration processes, particularly in interactions with the Manila Trench[16]. Existing observations indicate that high-density anomalies are

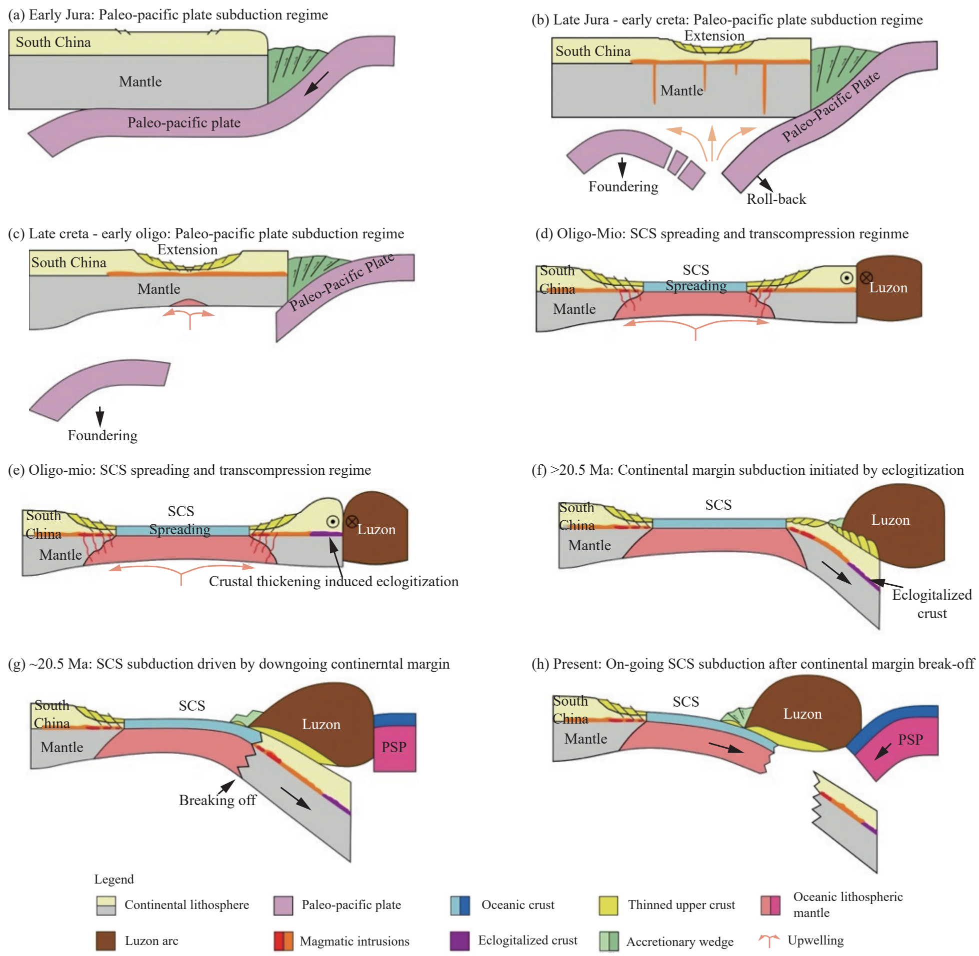

Fig.2 A schematic model illustrating the evolutionary processes driving the transition from a continental margin to oceanic subduction. The shift from Paleo-Pacific plate subduction to a transcompression regime is based on two studies[7,9]. The timing of South China Sea subduction initiation follows a previous work[9], while the evolutionary history related to Paleo-Pacific plate subduction is derived from a previous work[14]

widely distributed along the continental margins of the South China Sea.

Therefore, it is reasonable to infer that similar anomalies were also present along the eastern margin, though most have since been subducted into the deep mantle.

2.2 New subduction initiation model

The key factor in subduction initiation is the density contrast between two colliding lithospheres[1]. Given that the high-velocity anomaly in the lower crust suggests increased density, we propose that it plays a critical role in facilitating subduction initiation. Without intrusive materials, the density difference between the continental margin and Luzon may be insufficient to drive subduction. However, after mafic intrusions, the continental margin becomes denser than Luzon, enabling subduction to proceed. An evolutionary model illustrating subduction initiation along the Manila Trench is presented in Fig.2.

Key components of this conceptual framework include magmatic intrusions driven by Paleo-Pacific subduction, post-spreading magmatic activity, and the transformation of mafic intrusions into eclogites following collision-induced crustal thickening, ultimately leading to continental margin break-off.

Recent regional seismic tomography[17], has identified aseismic high-velocity anomalies beneath Luzon at depths greater than 300 km, which may reflect remnants of the South China Sea's continental margins. These anomalies appear to have partially detached from the subducted South China Sea slab, thereby reinforcing the plausibility of the model proposed in this study.

3 Summary

This study revisits the conventional understanding of South China Sea subduction beneath Luzon by introducing a new model. Traditionally, subduction initiation was thought to be driven by the high density of oceanic lithosphere. However, before the South China Sea opened, a continental margin likely existed, complicating direct subduction.

Our findings suggest that extensive mafic magmatic underplating during South China Sea expansion increased the density of the continental margin, potentially surpassing that of Luzon. This density contrast could have facilitated subduction, offering new insights into the geodynamic evolution of the region. In the future, plate reconstruction studies combined with numerical modeling will provide deeper insights into the role of lower-crustal mafic intrusions in intra-oceanic subduction initiation.

参考文献

[1] WANG X, CAO L, ZHAO M, et al. What conditions promote atypical subduction: Insights from the Mussau Trench, the Hjort Trench, and the Gagua Ridge[J]. Gondwana Research, 2023, 120: 207-218. DOI:10.1016/j.gr.2022.10.014.

[2] TONG Z, DING W, WANG C, et al. Analogue modelling of subduction initiation: A review and perspectives[J]. International Geology Review, 2023: 1-43. DOI:10.1080/00206814.2023.2272273.

[3] MA L, CHEN L, CHENG Z, et al. Bathymetric highs control the along-strike variations of the manila trench: 2D numerical modeling[J]. Frontiers in Earth Science, 2022, 10: 943147. DOI:10.3389/feart.2022.943147.

[4] FAN J, ZHAO D. P-wave tomography and azimuthal anisotropy of the Manila-Taiwan-southern Ryukyu region[J]. Tectonics, 2021, 40: e2020TC006262. DOI:10.1029/2020TC006262.

[5] HAYES G P, MOORE G L, PORTNER D E, et al. Slab2, a comprehensive subduction zone geometry model[J]. Science, 2018, 88: eaat4723-10. DOI:10.1126/science.aat4723.

[6] ZHU M, YAN Z, PASTOR-GALÁN D, et al. Do micro-continents nucleate subduction initiation?[J]. Geology, 2023. DOI:10.1130/g51222.1.

[7] WU J, SUPPE J, LU R, et al. Philippine Sea and East Asian plate tectonics since 52 Ma constrained by new subducted slab reconstruction methods[J]. Journal of Geophysical Research, 2016, 121(6): 4670-4741. DOI:10.1002/2016JB0129.

[8] WU J, SUPPE J. Proto-South China Sea plate tectonics using subducted slab constraints from tomography[J]. Journal of Earth Science, 2018, 29(6): 1304-1318. DOI:10.1007/s12583-017-0813.

[9] SIBUET J C, LIU S, ZHAO M, et al. A revolution in understanding SE Asia geodynamics since 20.5–18 Ma[J]. Tectonophysics, 2024, 884: 230397. DOI:10.1016/j.tecto.2024.230397.

[10] CHANG J H, HONG Z L, MIRZA A, et al. Spatial distribution and possible origin of the high velocity lower crust in the northern margin of the South China Sea[J]. Geoscience Letters, 2024, 11(1): 51. DOI:10.1186/s40562-024-00364-4.

[11] ZHANG C, XIA S, FAN C, et al. Submarine volcanism in the southern margin of the South China Sea[J]. Journal of Oceanology and Limnology, 2023, 41(2): 612629. DOI:10.1007/s00343-022-2088-z.

[12] HE Q, PAN Z, LU S, et al. Origin of a high-velocity layer: Insights from seismic reflection imaging (South China Sea)[J]. Marine and Petroleum Geology, 2024: 106798. DOI:10.1016/j.marpetgeo.2024.106798.

[13] WAN K, XIA S, CAO J, et al. Deep seismic structure of the northeastern South China Sea: Origin of a high-velocity layer in the lower crust[J]. Journal of Geophysical Research: Solid Earth, 2017, 122(4): 2831-2858. DOI:10.1002/2016jb013481.

[14] CHENG J, ZHANG J, ZHAO M, et al. Spatial distribution and origin of the high-velocity lower crust in the northeastern South China Sea[J]. Tectonophysics, 2021: 229086. DOI:10.1016/j.tecto.2021.229086.

[15] WANG X, ZHAO M, HE X, et al. Seismic imaging revealing the processes from subduction to arc-continental collision in the northeastern South China Sea[J]. Tectonophysics, 2025: 230684. DOI:10.1016/j.tecto.2025.230684.

[16] PAN C, HE X. Subducting passive continental margins with crustal (ultra)mafic intrusions: An underappreciated mechanism for recycling water back into the mantle[J]. Earth and Planetary Physics, 2023, 7(5): 1-6. DOI:10.26464/epp2023074.

[17] FAN J, ZHAO D. P-wave tomography and azimuthal anisotropy of ryukyu rthe Manila-Taiwan-Southerntomography and azimuthal anisotropy of ryukyu region[J]. Tectonics, 2021, 40(2): e2020TC006262. DOI:10.1029/2020tc006262.