



## Mesozoic Remagnetization in the South China Block

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### Abstract

The South China Block has experienced multiple tectonic events. During the Mesozoic, the Indosinian and Yanshanian orogenic events played a significant role in shaping its present-day tectonic framework, producing widespread deformation, metamorphism, and magmatism. These tectonic processes also drove widespread fluid migration through sedimentary successions. Such tectonically induced fluid–rock interactions profoundly modified primary mineral assemblages and promoted the formation and transformation of magnetic minerals, leading to widespread Mesozoic remagnetization in sedimentary strata across the South China Block. These remagnetization records provide a valuable archive for constraining the timing, duration, and spatial extent of tectonic processes and their associated diagenetic responses in sedimentary rocks. This paper presents a systematic review of Mesozoic remagnetization phenomena in sedimentary rocks of the South China Block in relation to the Indosinian and Yanshanian tectonic events. We further synthesize current understanding of the role of tectonic processes in influencing burial diagenesis, hydrocarbon generation, migration, and accumulation, and the destruction of hydrocarbon reservoirs, as well as mineralization. Finally, we highlight the value of remagnetization as a quantitative spatiotemporal tool for reconstructing geological processes involving fluid flow and thermal evolution.

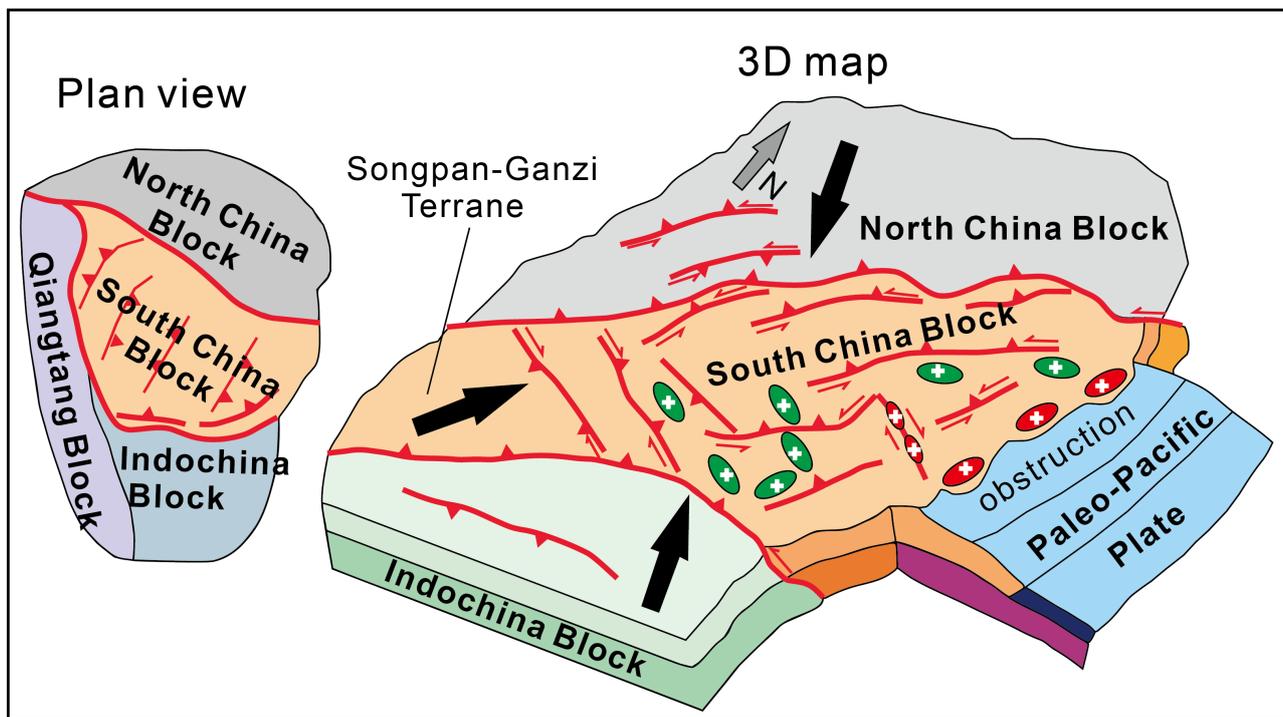
**Keywords:** Mesozoic, remagnetization, South China Block, Indosinian, Yanshanian

### Introduction

Among the major tectonic events recorded in the South China Block, the Indosinian and Yanshanian orogenic events exerted first-order control on the present-day geological architecture of the region (Zhang *et al.*, 2015; Shu *et al.*, 2021; Xu, 2023). In detail, during the Late

Triassic, convergence among the South China, North China, and Qiangtang blocks contributed to the establishment of the fundamental framework of continental assembly in China (Roger *et al.*, 2010; Ding *et al.*, 2013). Progressive convergence and diachronous collision between the South China and North China blocks propagated from the Early Triassic in the Lower Yangtze region to the Late Triassic–Early Jurassic in the Upper Yangtze area (Zhao & Coe, 1987). In addition, the Triassic collision between the Indochina Block and the southwestern South China Block further modified the regional tectonic framework (Faure *et al.*, 2014). During the Jurassic–Cretaceous, widespread Yanshanian tectonism, largely related to Paleo-Pacific plate subduction, profoundly reshaped the tectonic configuration of the South China Block (Zhou & Li, 2000; Li & Li, 2007; Fig. 1).

These tectonic processes were accompanied by widespread deformation and magmatism (Zhou *et al.*, 2006), which collectively promoted large-scale fluid circulation within sedimentary basins and fold–thrust belts (*e.g.*, Tannock *et al.*, 2020). Such fluid migration extensively modified primary mineral assemblages in sedimentary rocks, producing complex diagenetic overprints on original depositional records (Kyser, 2007). Therefore, one important and regionally widespread consequence of Mesozoic tectonism in the South China Block is the development of remagnetization in sedimentary rocks (*e.g.*, Zhang *et al.*, 2020). Over the past several decades, paleomagnetic studies have shown that many Palaeozoic–Mesozoic sedimentary successions carry secondary remanent magnetization acquired significantly after deposition, with ages commonly clustering around the Indosinian and Yanshanian periods (*e.g.*, Zhang *et al.*, 2016, 2019, 2020; Hu *et al.*, 2023a). These remagnetization signals are typically carried by authigenic magnetic minerals, such as magnetite and



**FIGURE 1.** Simplified tectonic framework showing the relationship between the South China Block and surrounding blocks (modified after Wang et al., 2021; Xu et al., 2023).

pyrrhotite, which formed or were transformed in response to changes in temperature, redox conditions, and fluid chemistry.

Rather than representing isolated occurrences, remagnetization has been increasingly recognized as a regionally developed phenomenon that reflects fundamental geological processes operating at basin to orogen scales. However, current investigations of Mesozoic remagnetization in the South China Block remain relatively fragmented. Most studies have focused on individual basins, stratigraphic intervals, or structural domains, primarily emphasizing the identification and dating of secondary magnetization components. Fewer efforts have attempted to integrate these observations within a regional framework that links remagnetization with tectonically driven fluid circulation. Consequently, the broader geological significance of remagnetization—as a quantitative recorder of tectonic timing, fluid flow pathways, and basin-scale responses—has not yet been fully synthesized.

In this paper, we present a comprehensive review of Mesozoic remagnetization in sedimentary rocks across the South China Block, with particular emphasis on remagnetization associated with the Indosinian and Yanshanian tectonic events. By synthesizing paleomagnetic, rock magnetic, mineralogical, and geochemical evidence from different tectonic settings, we aim to clarify the timing and mechanisms of remagnetization and evaluate its relationship with tectonically induced fluid processes.

We further explore how remagnetization records can be used to constrain the spatiotemporal evolution of burial diagenesis, hydrocarbon systems, and mineralization (e.g., Hu *et al.*, 2017), highlighting its value as a quantitative tool for reconstructing Mesozoic geological processes in the South China Block.

### Remagnetization and Its Research Background

Iron is the fourth most abundant element in the Earth's crust, and iron-bearing compounds are therefore ubiquitous in crustal rocks (Beard & Johnson, 2004). Among these, iron oxides and iron sulphides constitute the most common magnetic minerals. These iron-bearing phases are highly sensitive to physical and chemical changes during fluid-rock interactions and readily undergo dissolution, recrystallization, or mineralogical transformation during diagenesis (e.g., Roberts, 2015). As a result, changes in temperature, pressure, oxygen fugacity, or fluid chemistry may generate new magnetic minerals or modify pre-existing ones, thereby changing the types and proportions of magnetic minerals in a rock (e.g., Machel, 1995).

In the presence of the geomagnetic field, magnetic minerals acquire remanent magnetization that may be either primary—formed at deposition or crystallization—or secondary, acquired during later geological processes. Primary remanence forms the basis for paleolatitude determination and quantitative paleogeographic reconstruction, whereas remagnetization represents a

secondary overprint that can partially or completely reset earlier magnetic records (Elmore *et al.*, 2012). Given the pervasive nature of tectonism, burial, thermal events, and fluid circulation throughout geological history, remagnetization is common, particularly in older rocks (*e.g.*, (Elmore *et al.*, 1985, 1987, 2002; Elmore & Leach, 1990; Elmore & Dulin, 2007).). A robust understanding of the mechanisms is therefore essential not only for reliably isolating primary remanent magnetization in paleomagnetic studies, but also for using remagnetization itself as an independent and quantitative tool to constrain the timing, duration, and spatial extent of the geological processes that trigger magnetic overprinting (Elmore *et al.*, 1985, 1987, 2002; Elmore & Leach, 1990; Elmore & Dulin, 2007).

Because remagnetization is both widespread and geologically informative, understanding its origin and timing has long been a central issue in paleomagnetic research. The concept of remagnetization was first proposed in the 1960s, when anomalous paleomagnetic directions obtained from Lower Palaeozoic rocks in North America and Europe raised doubts about the primary origin of their remanent magnetization (*e.g.*, Creer, 1964, 1968; McCabe & Elmore, 1989). The development and application of the fold test in the 1970s provided important evidence for the existence of Late Palaeozoic remagnetization (*e.g.*, Steiner, 1973). By the 1990s, the Late Palaeozoic remagnetization in North America had become widely accepted, leading to extensive investigations primarily focused on its mechanisms—that is, identifying the geological processes and factors responsible for magnetic resetting. These studies established the basic framework for linking remagnetization to fluid activity, diagenesis, and tectonic processes (McCabe & Elmore, 1989).

In the South China Block, remagnetization was first mentioned by Lin *et al.* (1985), and was soon documented in Carboniferous to Triassic strata from Nanjing and Yichang, where widespread Late Mesozoic remagnetization was reported (Kent *et al.*, 1987). Several additional studies were published in the 1990s, coinciding with the peak of remagnetization research in North America and Europe. Since 2010, research on Mesozoic remagnetization in the South China Block has entered a period of rapid growth, as evidenced by more than twenty papers. Existing studies indicate that Mesozoic remagnetization in the South China Block involves a range of mechanisms, including orogenic-fluid alteration, hydrocarbon migration, hydrothermal and mineralizing fluid overprinting, maturation of organic matter, and smectite-to-illite transformation during diagenesis. The dominant magnetic minerals are typically authigenic magnetite, hematite, and pyrrhotite, indicating complex redox-controlled mineral transformations during tectonic and diagenetic evolution.

## Mesozoic Remagnetization in the South China Block

This section reviews the key studies that document Mesozoic remagnetization in sedimentary rocks of the South China Block. The discussion is organized according to the remagnetization age, with separate subsections for Triassic and Jurassic–Cretaceous events. For both time intervals, we summarize the reported remagnetization ages in detail and the proposed mechanisms or tectonic background. Detailed information on these remagnetization events is also summarized in Fig. 2 and Table 1.

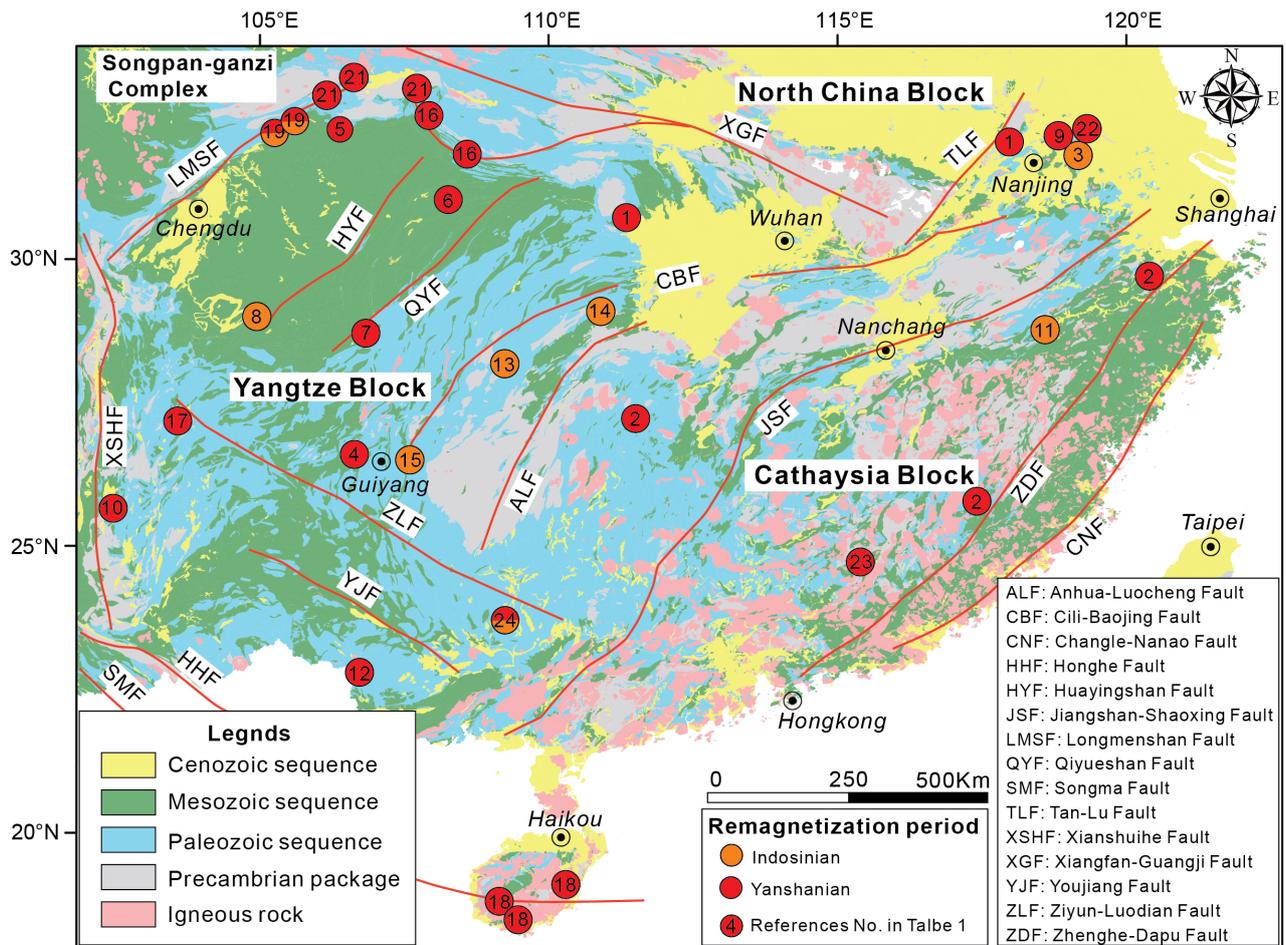
### *Triassic remagnetization in the South China Block*

During the Triassic, the South China Block experienced several major tectonic events that strongly influenced regional remagnetization. The most significant process was the collision between the South China and North China blocks along its northern margin. Such large-scale tectonic interaction likely triggered widespread remagnetization in northern parts of the Yangtze Block. Multiple remagnetization phases corresponding to the Early–Middle Triassic, Middle Triassic, and Late Triassic have been recognized across the Lower, Middle, and Upper Yangtze regions, respectively (Zhang *et al.*, 2016; Jiao *et al.*, 2018, 2019).

Along the western margin of the South China Block, Triassic convergence with the Qiangtang Block led to the development of the Longmenshan fold–thrust belt and the formation of the Sichuan foreland basin. This tectono-sedimentary framework left widespread remagnetization records in both the belt and the basin. Within the basin, rapid burial beneath a thick clastic succession likely promoted thermal maturation, and Late Triassic remagnetization in organic-rich black shales of the Longmaxi Formation has been linked to this process (Zhang *et al.*, 2016). In the Longmenshan fold–thrust belt, by contrast, strong Indosinian compression generated extensive fracture and fault systems that likely facilitated large-scale fluid migration and fluid–rock interaction. Widespread remagnetization in Permian hydrocarbon-bearing strata has accordingly been interpreted to record hydrocarbon fluid migration driven by Indosinian compression during this tectonic stage (Hu *et al.*, 2023a).

In the southwestern South China Block, collision between the Indochina Block and the South China Block during the Triassic may have produced similar fluid-driven remagnetization processes. Late Triassic remagnetization identified in the Penglai area of Guangxi provides a representative example of this tectonically related fluid overprinting (Zhang *et al.*, 2025).

In the middle section of the South China Block, Late Triassic remagnetization has been reported from the Majiang and Songtao areas of Guizhou Province. Available evidence suggests that these remagnetized



**FIGURE 2.** Simplified tectonic map of the South China Block showing the spatial distribution and timing of reported remagnetization events (data from Wang *et al.*, 2013; Zheng *et al.*, 2013; Ye *et al.*, 2017).

components were associated with Indosinian orogenic-fluid alteration (Gong *et al.*, 2019; Zhang *et al.*, 2019).

#### *Jurassic–Cretaceous Remagnetization in the South China Block*

Yanshanian tectonics were widespread across the South China Block and are generally linked to Paleo-Pacific plate subduction (*e.g.*, Li & Li, 2007). The eastern South China Block, being closer to the Paleo-Pacific tectonic domain, preserves particularly clear geological evidence of subduction-related deformation, magmatism, and fluid activity. These processes promoted tectonically driven fluid migration and widespread chemical remagnetization in sedimentary strata, as documented since the 1980s (Kent *et al.*, 1987). For example, extensive Yanshanian magmatism and hydrothermal activity in the Ningzhen Mountains have produced strong fluid–rock interaction with surrounding organic-rich sedimentary strata (*e.g.*, black shale in the Gaojiabian Formation), resulting in remagnetization carried by newly formed framboidal pyrrhotite (Wang *et al.*, 2025). Comparable Yanshanian

remagnetization has also been identified in Triassic strata in the Lower Yangtze region near Nanjing, interpreted to be related to tectonically driven fluid activity (Jiang *et al.*, 2017). Similar tectonically related Jurassic–Cretaceous remagnetization has also been recognized in eastern Zhejiang (Dobson & Heller, 1992). Late Cretaceous remagnetization reported from Hainan Island may also be associated with this tectonic background. The effects of Paleo-Pacific subduction may not have been confined to the eastern margin of the South China Block. Far-field transmission of compressional stresses related to Paleo-Pacific subduction may have influenced the central and northwestern parts of the South China Block. Evidence for tectonically driven fluid remagnetization has been identified in several inland regions. For example, Cretaceous remagnetization related to syn-orogenic fluid activity has been reported from the Chongqing region (Zhang *et al.*, 2007). Similar Yanshanian remagnetization signatures have also been recognized in Palaeozoic and Mesozoic strata in Guizhou (Huang & Opdyke, 1996; Liu *et al.*, 2013).

**TABLE 1.** Summary of reported Mesozoic remagnetization in the South China Block.

Num.	Site Location	Rock age	Rock type	Magnetic minerals	Remagnetization age	Mechanism of Remagnetization	Reference
1	Nanjing, Yichang	C <sub>1</sub> -T <sub>1</sub>	Carbonate and clastics	Magnetite Pyrrhotite	Yanshanian	Orogenic fluid	Kent et al., 1987
2	Shaoyang, Zhuji, Shangcao	C	Limestone	Magnetite Hematite	Yanshanian	Orogenic fluid	Dobson & Heller, 1992
3	Nanjing	O <sub>2</sub> -P <sub>1</sub>	Carbonate and sandstone	Magnetite Hematite	Indosinian	Orogenic fluid	Wang & Van der Voo, 1993
4	Guiyang	T <sub>1,2</sub>	Carbonate	Magnetite Hematite	Yanshanian	?	Huang & Opdyke, 1996
5	Wangcang	T <sub>2</sub>	Dolomite	Magnetite Maghemite	Yanshanian	Thermal	Bai et al., 1998
6	Wanzhou	T <sub>2</sub> -J <sub>2,3</sub>	Limestone and sandstone	Magnetite	Yanshanian	Orogenic fluid	Zhang et al., 2007
7	Zhengan	O	Carbonate	Magnetite Pyrrhotite	Yanshanian	Orogenic fluid	Liu et al., 2013
8	Changning	S <sub>1</sub>	Shale	Magnetite	Indosinian	Maturation of organic matter	Zhang et al., 2016
9	Nanjing	T <sub>2</sub>	Clastics	Magnetite Hematite	Yanshanian	Orogenic fluid	Jiang et al., 2017
10	Luquan	O <sub>1</sub>	Sandstone and Shale	Hematite	Yanshanian	Hydrothermal fluid	Gao et al., 2018
11	Jiangshan	Є	Limestone	Magnetite Pyrrhotite	Indosinian	Orogenic fluid	Jiao et al., 2018
12	Bukang	D <sub>1</sub>	Ore layer and chert	Magnetite Hematite	Yanshanian	Hydrothermal fluid	Gao et al., 2019
13	Guiyang	Z	Carbonate	Pyrrhotite	Indosinian	Orogenic fluid	Gong et al., 2019
14	Waergang	Є <sub>3</sub>	Limestone	Magnetite Pyrrhotite	Indosinian	Orogenic fluid	Jiao et al., 2019
15	Majiang	Z-Є <sub>3</sub>	Tillite, mudstone, shale, carbonate	Magnetite	Indosinian	Orogenic fluid	Zhang et al., 2019
16	Dabashan	Z, Є, S, P	Tillite, mudstone, shale, carbonate	Magnetite	Yanshanian	Orogenic fluid	Zhang et al., 2020
17	Zhaotong	P <sub>2,3</sub>	Basalt	Magnetite	Yanshanian	Orogenic fluid	Liu et al., 2020
18	Ledong, Qionghai, Sanya	K	Limestone and sandstone	Hematite	Yanshanian	Hydrothermal fluid	Meng et al., 2022
19	Zhuyuan, Changjianggou, Chejiaba	P	Carbonate	Magnetite	Indosinian, Yanshanian	Orogenic fluid	Hu et al., 2023a
20	Puer	S-D <sub>1</sub>	Dacite	Magnetite	Yanshanian	Hydrothermal and mineralizing fluids	Hu et al., 2023b
21	Ningqiang	Cy-Є	Limestone, mudstone, siltstone, siliceous	Magnetite Hematite	Yanshanian	Orogenic fluid	Li et al., 2024
22	Nanjing	O-S	Limestone and shale	Pyrrhotite	Yanshanian	Hydrothermal fluid	Wang et al., 2025
23	Changpu	J <sub>1</sub>	Volcanic rock	Magnetite	Indosinian, Yanshanian	Hydrothermal fluid	Yang et al., 2025
24	Laibin	P	Limestone	Magnetite Maghemite Hematite	Indosinian, Yanshanian	Fluid migration	Zhang et al., 2025

Some Yanshanian remagnetization may also reflect Jurassic continued block convergence following the Indosinian collision between the South China and North China blocks. For example, in the Dabashan and surrounding regions, compressional deformation persisted into the Jurassic period after the collision (Dong *et al.*, 2013). Meanwhile, widespread Jurassic remagnetizations were reported in the Palaeozoic strata of the belt, which have been interpreted to result from orogenic fluid migration (Zhang *et al.*, 2020). Similar Jurassic remagnetization has also been recognized in the northern Upper Yangtze region (Li *et al.*, 2024).

In addition to orogenic-fluid alteration, widespread Yanshanian magmatism throughout the South China Block likely provided another important mechanism for remagnetization through magmatic–hydrothermal systems. Hydrothermal remagnetization associated with Yanshanian magmatic events has been reported from several regions, including the Changpu Basin in Jiangxi Province (Yang *et al.*, 2025) and magmatic–hydrothermal systems in Yunnan Province (Gao *et al.*, 2018, 2019).

Overall, Jurassic–Cretaceous remagnetization was more widely distributed across the South China Block and reflected multiple mechanisms, including tectonically driven fluid flow, far-field compressional deformation, and magmatic–hydrothermal overprinting associated with the Yanshanian tectonic regime.

### **Lithological Hosts of Remagnetization in the South China Block**

#### *Carbonate rocks*

Another way to understand Mesozoic remagnetization in the South China Block is through the lithological hosts of remagnetization. Studies in the South China Block indicate that chemical remagnetization occurs in a variety of lithologies but is most commonly reported in carbonate rocks. This observation suggests that carbonates represent one of the most important archives of remagnetization signals in the South China Block, recording numerous cases related to orogenic fluids, hydrocarbon migration, and, in some cases, hydrothermal or mineralizing fluid alteration (*e.g.*, Gao *et al.*, 2018; Zhang *et al.*, 2018, 2020; Hu *et al.*, 2023b). Carbonate rocks may be particularly favourable for preserving stable remanent magnetization for several reasons. First, magnetic particles in carbonate rocks are commonly fine-grained and may fall within the single-domain (SD) to pseudo-single-domain (PSD) size range, allowing them to retain stable remanent magnetization over geological timescales. Second, carbonate rocks are commonly involved in basin-scale fluid migration and frequently serve as reservoirs for hydrocarbon fluids. These characteristics make carbonate rocks common recorders of fluid-alteration–related chemical remagnetization.

#### *Shales, mudstones, and sandstones*

Shales represent an important lithology associated with remagnetization. Organic-rich black shales commonly host remagnetization related to the maturation of organic matter (Zhang *et al.*, 2016). Some shale units record remagnetization linked to orogenic-fluid alteration. Mudstones can host chemical remagnetization associated with illitization and orogenic fluid migration (Zhang *et al.*, 2019, 2020). Fine-grained sandstones can host remagnetization that is related to the migration of orogenic fluids (Zhang *et al.*, 2020).

### **Magnetic Minerals of Remagnetization in the South China Block**

#### *Magnetite*

Several types of magnetic mineral have been identified as carriers of Mesozoic remagnetization in the South China Block, including magnetite, hematite, maghemite, and pyrrhotite. Among these, authigenic magnetite is the most commonly reported magnetic carrier mineral (Fig. 3A–C). It occurs in remagnetization related to nearly all types of mechanisms, including those related to organic matter maturation, hydrothermal fluids, orogenic fluids, and hydrocarbon migration. SEM observations often reveal the transformation of pyrite into magnetite. Authigenic magnetite may occur as euhedral crystals distributed along fractures, or as spheroidal and botryoidal aggregates within the host rocks (Fig. 3A–C).

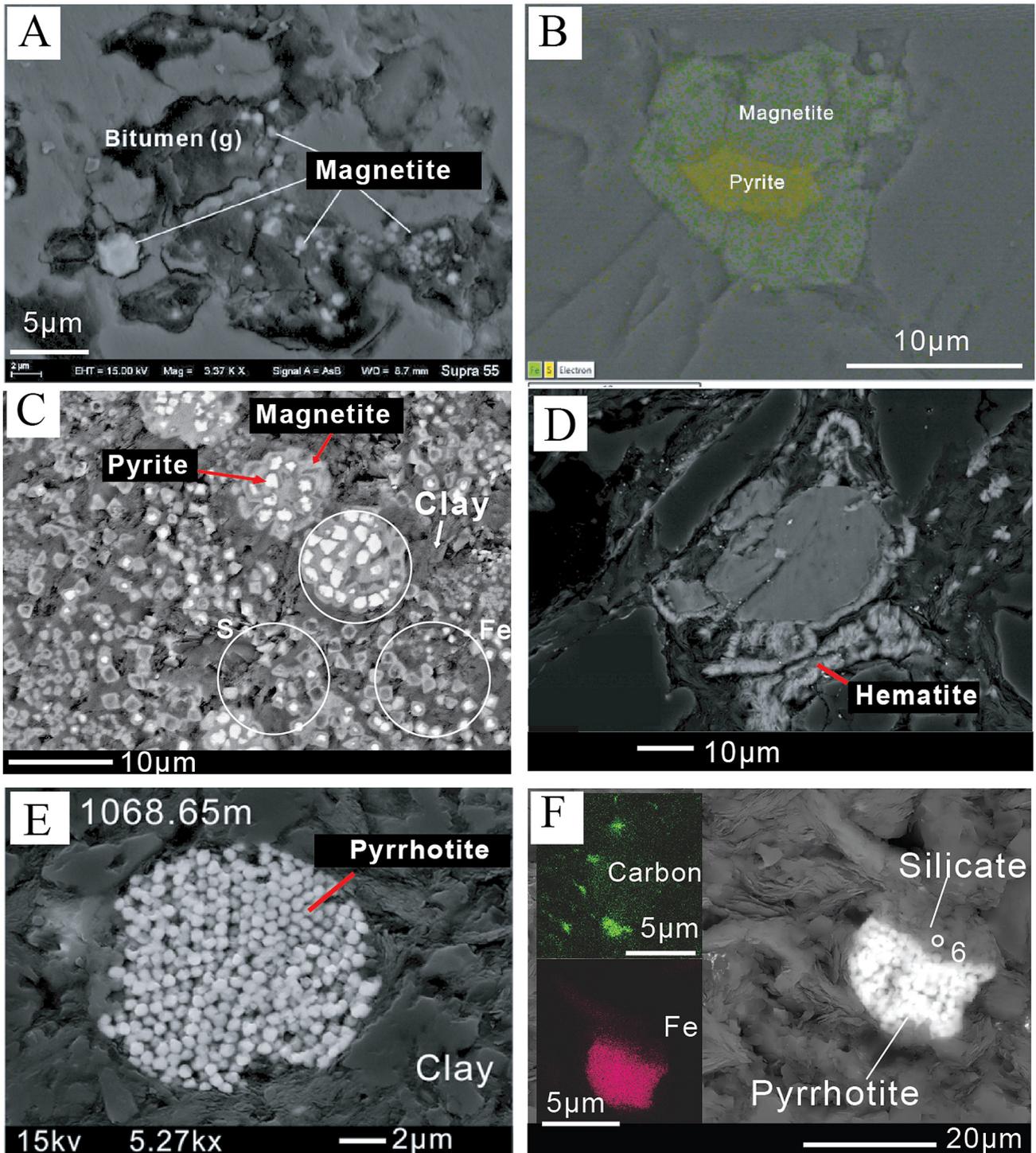
#### *Hematite or maghemite*

Hematite, and in some cases maghemite, is typically associated with remagnetization formed under oxidizing fluid conditions, particularly those related to orogenic fluids. Authigenic hematite commonly occurs as dispersed or locally concentrated flocculent aggregates (Fig. 3D).

#### *Pyrrhotite and greigite*

Pyrrhotite is commonly associated with remagnetization formed during hydrothermal alteration or low-grade metamorphic processes (Appel *et al.*, 2012; Wang *et al.*, 2025; Fig. 3E and F). In addition, a few studies have reported pyrrhotite as the magnetic carrier of orogenic fluid-related remagnetization (Liu *et al.*, 2013; Gong *et al.*, 2019). Although greigite has not yet been reported as a magnetic carrier of Mesozoic remagnetization in the South China Block, it is widely documented in remagnetized sedimentary rocks elsewhere, typically occurring as framboidal aggregates (*e.g.*, Roberts & Weaver, 2005).

Therefore, the magnetic carriers of remagnetization in the South China Block vary systematically with remagnetization mechanism and fluid redox conditions.



**FIGURE 3.** SEM images showing the magnetic minerals associated with remagnetization (modified after Gao et al., 2018; Zhang et al., 2019; Zhang et al., 2020; Hu et al., 2023a; Wang et al., 2025). **A**, Iron oxides associated with bitumen. **B** and **C**, Magnetite formed by the transformation of pyrite during chemical remagnetization. **D**, Flocculent aggregates of authigenic hematite carried the remagnetization. **E** and **F**, Framboidal iron sulphide aggregates carried the remagnetization.

### Mechanism of Remagnetization in the South China Block

In terms of mechanism, remagnetization in Mesozoic sedimentary rocks of the South China Block has been

attributed to several diagenetic or fluid-related processes, including maturation of organic matter, smectite-to-illite transformation, and alterations of hydrocarbon fluid, orogenic fluid, hydrothermal fluid, and mineralizing fluid.

### Maturation of Organic Matter

The maturation of organic matter is an important mechanism for chemical remagnetization in organic-rich sedimentary rocks (Blumstein *et al.*, 2004; Manning & Elmore, 2015; Zhang *et al.*, 2016). Previous studies have shown that remagnetization ages obtained from organic-rich strata coincide with independently constrained ages of organic matter maturation, which has been regarded as a significant line of evidence supporting this mechanism (Blumstein *et al.*, 2004). In addition, many studies infer this mechanism through correlations between total organic carbon content and magnetic parameters such as the intensity of natural remanent magnetization or magnetic susceptibility (Zhang *et al.*, 2016; Fig. 4A). Experimental studies further suggest that organic fluids generated during organic matter maturation may promote the transformation of pyrite into magnetite, leading to the formation of new magnetic minerals and associated chemical remagnetization (Brothers *et al.*, 1996). In the South China Block, a representative example is the Late Triassic remagnetization identified in the organic-rich black shales of the Longmaxi Formation in the southern Sichuan Basin (Zhang *et al.*, 2016).

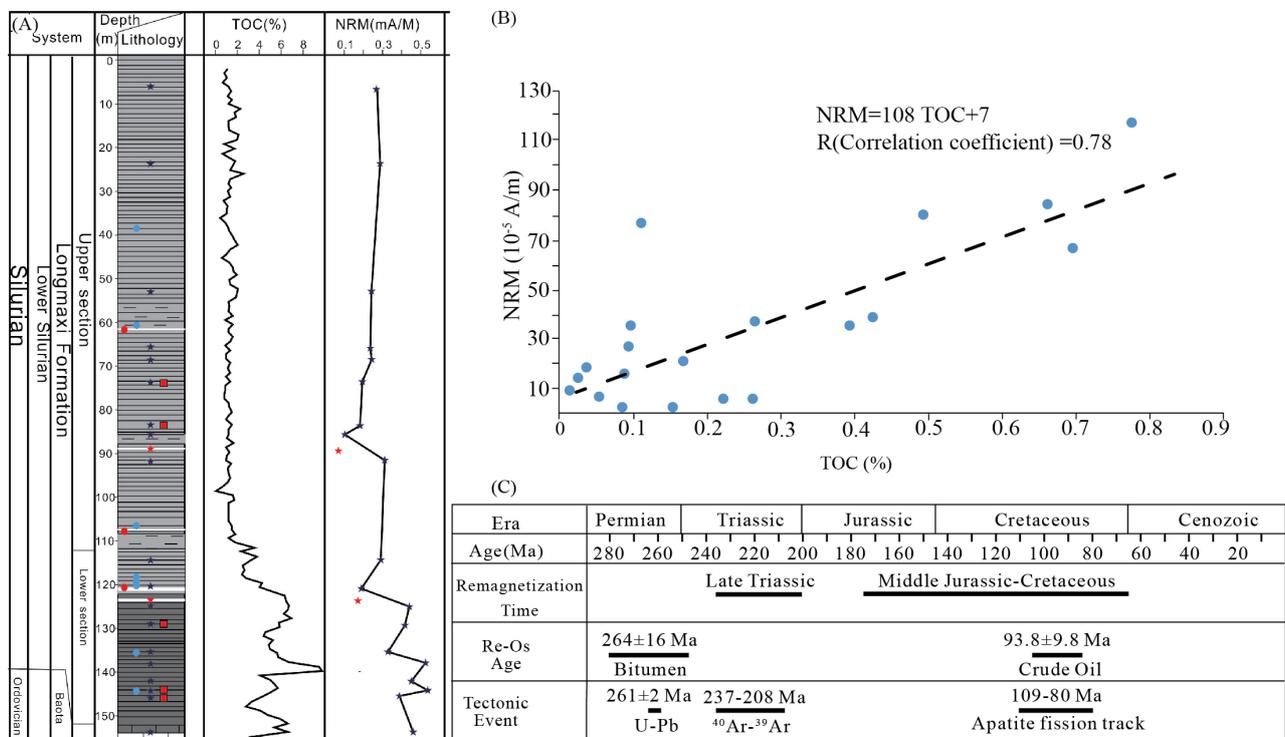
### Hydrocarbon Migration

Hydrocarbon migration is an important driver of chemical remagnetization in sedimentary basins (Kilgore & Elmore,

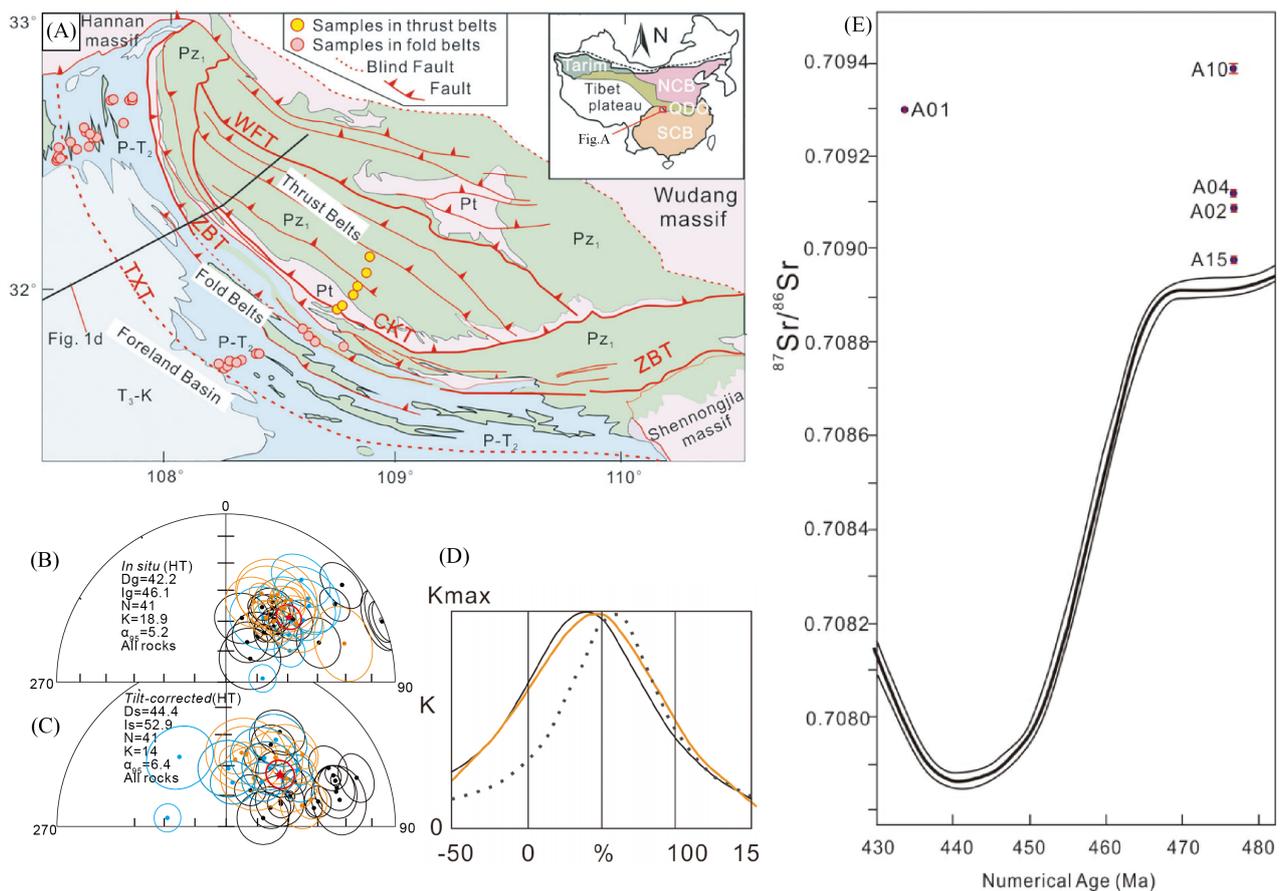
1989; Elmore & Leach, 1990; Cioppa & Symons, 2000; Manning & Elmore, 2013; Zhang *et al.*, 2018; Abdulkarim *et al.*, 2022). Evidence for this mechanism is typically obtained by examining correlations between hydrocarbon-related parameters and magnetic properties. In some cases, a simple presence-absence test is applied, whereby remagnetization occurs only in hydrocarbon-bearing strata but is absent in equivalent non-hydrocarbon-bearing rocks (Elmore *et al.*, 2012). Several examples have been reported in the South China Block. In the northwestern Longmenshan belt, hydrocarbon migration driven by the Indosinian tectonic event has been linked to regional remagnetization events (Hu *et al.*, 2023a; Fig. 4B and C). Similarly, another case in the Taishan paleo-reservoir has been reported in the Lower Yangtze region (Zhang *et al.*, 2018). Hydrocarbon-related remagnetization may record not only hydrocarbon generation and migration, but also later reservoir modification or destruction caused by tectonically driven fluids (Zhang *et al.*, 2019).

### Orogenic Fluids

Orogenic fluids are usually invoked to explain regionally extensive remagnetization (Oliver, 1986; Elmore *et al.*, 1993, 2001; Enkin *et al.*, 2000; Weil & Van der Voo, 2002; Cox, 2007; Bian *et al.*, 2024). Numerous studies in North America during the 1990s demonstrated that remagnetization events commonly show close temporal



**FIGURE 4.** Evidence for remagnetization related to organic matter maturation and hydrocarbon migration in the South China Block (modified after Zhang *et al.*, 2016 and Hu *et al.*, 2023a). **A**, Stratigraphic variation of lithology, TOC, and NRM intensity in the studied section. **B**, Positive correlation between TOC and NRM. **C**, Comparison between remagnetization ages, hydrocarbon generation ages (Re-Os), and regional tectonic events.



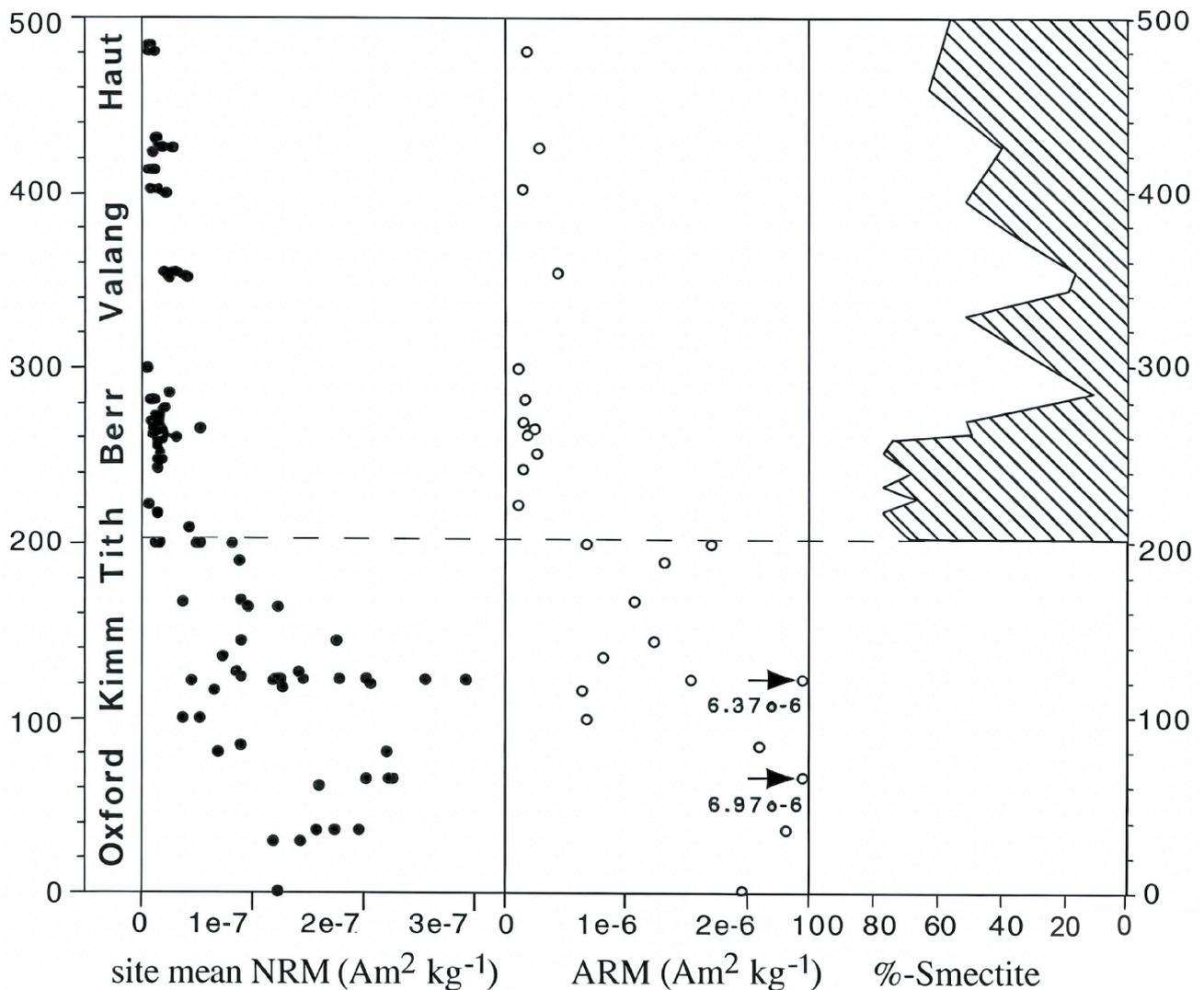
**FIGURE 5.** Evidence for remagnetization related to orogenic fluid in the South China Block (modified after Zhang *et al.*, 2019 and 2020). **A**, Distribution of remagnetized samples within the fold–thrust belt. **B–C**, Equal-area stereographic projections of characteristic remanent magnetization directions recording remagnetization. **D**, Fold test result. **E**, Elevated  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios relative to the contemporaneous seawater curve.

and spatial relationships with orogenic events. Elevated  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios relative to contemporaneous seawater are frequently regarded as important geochemical indicators of externally derived basinal or orogenic fluids (Elmore *et al.*, 1993; Zechmeister *et al.*, 2012; Zhang *et al.*, 2019, 2020; Fig. 5). In the South China Block, this mechanism has also been widely documented. Representative examples include the widespread Middle–Late Jurassic remagnetization documented in the Dabashan orogenic belt, which has been interpreted to reflect large-scale fluid circulation associated with compressional deformation and orogenic processes (Zhang *et al.*, 2020), as well as the widespread Late Triassic remagnetization recognized in the Majiang area west of the Xuefeng Shan orogenic belt, where available evidence suggests a similar origin related to orogenic–fluid alteration (Zhang *et al.*, 2019). These remagnetization events attributed to orogenic fluids occur in sedimentary strata of different ages and lithologies and commonly show broad regional distribution. Such laterally extensive and stratigraphically widespread remagnetization has been interpreted as evidence for

large-scale fluid circulation associated with regional tectonic events (Zhang *et al.*, 2019, 2020; Fig. 5).

#### *Smectite-to-Illite Transformation*

The smectite-to-illite transformation is a diagenetic process occurring during burial, typically at moderate temperatures (Katz *et al.*, 1998, 2000; Woods *et al.*, 2000; Gill *et al.*, 2002; Tohver *et al.*, 2008; Zwing *et al.*, 2009). During this transformation, iron released from clay-mineral structures may contribute to the formation of new magnetic minerals and the acquisition of chemical remanent magnetization. In many studies, correlations between the proportion of smectite and illite in clay minerals and magnetic parameters are used as key evidence for this mechanism (Katz *et al.*, 1998, 2000; Tohver *et al.*, 2008; Fig. 6). Direct isotopic dating of authigenic illite and comparison with remagnetization ages can also provide independent constraints on this process (Tohver *et al.*, 2008). However, reports of smectite-to-illite-related remagnetization remain relatively limited in the South China Block, with only a few cases reported from areas adjacent to the South China Block (Hu *et al.*, 2023b).



**FIGURE 6.** Relationship between magnetic parameters and clay mineral composition showing a remagnetization related to smectite–illite transformation (modified after Katz et al., 1998).

#### Hydrothermal Fluids

Hydrothermal fluid-related remagnetization was rarely recognized in early studies but has received increasing attention in recent years. Evidence for this mechanism typically includes petrographic observations of magnetic-mineral formation, temperature estimates derived from mineral assemblages or fluid inclusions, and consistency between isotopic ages of hydrothermal events and remagnetization ages (Gao *et al.*, 2018, 2019; Wang *et al.*, 2025). Several examples have been documented in the South China Block. In the Lower Yangtze region, hydrothermal alteration of the Wufeng–Gaojiabian black shales has been shown to produce framboidal pyrrhotite, leading to remagnetization of the host strata (Wang *et al.*, 2025). Hydrothermal-related remagnetization has also been reported from the Lower Ordovician Hongshiya Formation in the southwestern Yangtze Block (Gao *et al.*, 2018). In addition, remagnetization associated with

magmatic-hydrothermal activity has been documented in a large Palaeozoic manganese deposit in the South China Block (Gao *et al.*, 2019).

#### Mineralizing Fluids

Remagnetization related to mineralizing fluids is a widespread phenomenon in North America, particularly in association with Mississippi Valley–type (MVT) Pb–Zn deposits (*e.g.*, Lewchuk & Symons, 1995; Symons *et al.*, 2000). However, it is important to note that remagnetization observed in mineralized regions does not necessarily record the mineralizing fluid itself. In some cases, particularly where mineralization occurred earlier, remagnetization in mineralized strata may instead reflect younger tectonically driven fluid events. A representative example is provided by the Carboniferous carbonates of Ireland, where remagnetization has been interpreted to record a post-mineralization orogenic fluid event rather

than the mineralizing fluids themselves (Wilkinson *et al.*, 2017). In the South China Block, reports of mineralizing-fluid-related remagnetization remain relatively limited, although Gao *et al.* (2019) reported a representative example from a Paleozoic Mn deposit in Guangxi

#### *Thermal Remagnetization*

Thermal effects are a common mechanism of secondary magnetization in sedimentary rocks because burial heating commonly accompanies basin evolution. Elevated temperatures during burial, magmatic heating, or regional tectono-thermal events may partially reset pre-existing remanent magnetization, resulting in thermoviscous remanent magnetization (Schmidt & Embleton, 1981; Dunlop *et al.*, 1997). Evidence for this mechanism is typically inferred from the correspondence between remagnetization ages and regional thermal events, together with geological evidence indicating that temperatures were high enough to reach the unblocking range of the characteristic remanent magnetization. In the South China Block, Bai *et al.* (1998) suggested that remagnetization in Palaeozoic carbonate strata was related to regional heating associated with tectono-thermal processes, indicating that elevated temperatures may locally contribute to secondary magnetization in the region.

#### *Other Possible Mechanisms*

According to the comprehensive review by Elmore *et al.* (2012), additional mechanisms may include weathering fluids and tectonic-pressure effects (Oliva-Urcia *et al.*, 2008). However, studies investigating these mechanisms in the South China Block remain limited, and their potential roles in regional remagnetization processes require further investigation.

### **Geological Implications and Applications of Mesozoic Remagnetization in the South China Block**

In the South China Block, Mesozoic remagnetization is important not only as a secondary magnetic overprint, but also as a record of tectono-diagenetic responses to the Indosinian and Yanshanian tectonic events. Because remagnetization is commonly linked to burial heating, tectonically driven fluid migration, and hydrothermal alteration, it can provide relatively independent constraints on geological processes that are otherwise difficult to date or correlate regionally.

Its geological significance differs between the two main Mesozoic tectonic stages. Indosinian remagnetization is particularly useful for tracing the effects of Triassic convergence and compression associated with interactions among surrounding blocks, which produced widespread tectono-diagenetic responses in both orogenic belts and adjacent basins. These responses include rapid burial in

foreland basins, deformation-related fluid circulation in fold belts, and hydrocarbon migration or remobilization associated with compressional tectonics. Yanshanian remagnetization, by contrast, records a more complex tectonic setting. In some areas, it reflects compressional deformation and fluid activity broadly similar to those of the Indosinian stage, whereas in others it is more closely associated with Jurassic–Cretaceous tectono-magmatic overprinting, especially in eastern South China, where Paleo-Pacific-related deformation, widespread magmatism, and hydrothermal activity strongly modified earlier sedimentary records. Remagnetization during this stage may therefore preserve the combined effects of compression and magmatic–hydrothermal overprinting associated with the evolving Paleo-Pacific tectonic regime, possibly including slab rollback.

Remagnetization therefore provides an effective means of comparing how different tectonic events were expressed across the South China Block. In basin interiors, it can help constrain burial diagenesis, thermal evolution, and hydrocarbon system evolution, including hydrocarbon generation, migration, accumulation, and local reservoir modification or destruction. In fold–thrust belts and tectonically active margins, it can record fault-controlled fluid activity, hydrothermal alteration, and mineralization-related processes, and in some cases may also preserve evidence for post-accumulation destruction of earlier hydrocarbon reservoirs by later tectonically driven fluids. This is particularly important because destruction of pre-Cenozoic hydrocarbon reservoirs is widespread, and recognizing such late-stage modification is essential for understanding petroleum system evolution and resource evaluation (Zhang *et al.*, 2019).

### **Conclusions and Future Perspectives on Mesozoic Remagnetization in the South China Block**

Mesozoic remagnetization is widespread in sedimentary rocks of the South China Block and reflects a range of post-depositional processes operating under different tectonic and diagenetic settings. Existing studies indicate that these remagnetization events were generated by multiple mechanisms, including orogenic fluid activity, burial-related diagenesis, hydrocarbon-related fluid processes, hydrothermal alteration, and, locally, thermal resetting. The dominant magnetic carriers are typically authigenic magnetite, hematite, and pyrrhotite, reflecting complex mineral transformations during tectonic, diagenetic, and fluid-related evolution. Despite substantial progress, the regional distribution, full diversity of mechanisms, and temporal relationships among different remagnetization events remain incompletely understood.

Future work should therefore focus on improving the identification, dating, and mechanistic interpretation of

remagnetization in the South China Block. In particular, greater integration of paleomagnetic, rock-magnetic, petrographic, mineralogical, and geochemical approaches will be essential for distinguishing different generations of magnetic overprints and clarifying their geological significance. New analytical tools are expected to provide important opportunities for resolving complex remagnetization histories. For example, quantum diamond microscopy (QDM) provides high-resolution magnetic imaging that enables direct observation of magnetic signals associated with different remagnetization events and their microscale spatial distributions (Qi *et al.*, 2025). In studies of hydrocarbon-related remagnetization, techniques such as nano-infrared spectroscopy (Nano-IR) provide the potential to directly detect organic matter (Zhao *et al.*, 2024) associated with newly formed magnetic phases. In addition, recent developments in isotopic dating of hematite offer a promising and more direct method for constraining the timing of remagnetization processes (Jensen *et al.*, 2023) and understanding their mechanisms. Overall, continued work in the South China Block will not only refine our understanding of remagnetization mechanisms, but also strengthen the use of remagnetization in broader geological research.

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