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Remagnetization history of Middle Triassic Leikoupo Formation on Wangcang section in Sichuan Province, China

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Abstract An intensive paleomagnetic investigation has been conducted on the Middle Triassic Leikoupo Formation on the Wangcang section (32.14°N, 103.17°E). The results indicate the magnetic minerals are dominant by multidomain magnetite or maghemite, and the characteristic remnant magnetization revealed by stepwise thermal/alternating field demagnetization is close to the present-day geomagnetic direction of the sampling site. This suggests that dolomitization/thermal viscous magnetization is responsible for the remagnetization of this kind of rocks.

Keywords: Yangtze Block, Middle Triassic, remagnetization.

The collision between the Yangtze and the North China Blocks has played a crucial role in shaping the Chinese continent. Generally, the Yangtze and North China Blocks were thought to be collided by the Late Permian and then jointed together[1—4]. To provide further constraints on the time of suturing and kinematics of the two blocks, more paleomagnetic studies on the Yangtze Block have been desired. Recently, the remagnetization history in the Yangtze Block has been discussed[5,6]. To identify the remagnetization history, detailed rock magnetic and paleomagnetic investigation has been conducted on the Middle Triassic Leikoupo Formation in Wangcang section, Sichuan Province. We find that the Middle Triassic rocks from the Leikoupo Formation was severely remagnetized, and further propose a preliminary mechanism for the remagnetization history.

1 Geological setting

The Wangcang section is tectonically located in the northern part of the Yangtze Block beyond the Micang Mountain para-anticlise. The Middle Triassic bedding strike is usually an E-W trend in this area. The Middle Triassic was constituted by the Leikoupo Formation, which mainly consists of gray dolomite. Many fossils have been found in the Leikoupo Formation, such as *Progonoceraties pulcher*, *Eumorphotis Ammodiscus*, *Nodosariad*, etc. The Leikoupo Formation is about 200 m in thickness. The Leikoupo Formation conformably overlies on the Early Triassic Jialingjiang Formation and leurodiscontinuously underlies below the Late Triassic Xujiahe Formation. There are only small faults cut through this area. The dip of bedding of the Leikoupo Formation varies from 40° to 70°.

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Paleomagnetic sampling was restricted to the Leikoupo Formation. A total of 75 oriented samples distributed at 6 sites were collected using a portable gasoline-powered drill and oriented with a magnetic compass. In laboratory, all samples were cut into 95 specimens. We demagnetized 60 specimens by the thermal and alternative field demagnetization method, the other 10 specimens were used for rock magnetic study.

2 Paleomagnetic results

In order to identify the magnetic minerals in the samples, the isothermal remnant magnetization was given to representative specimens. The measurement was carried out at the Paleomagnetic Laboratory of the Institute of Geophysics of CAS, Beijing. The results show that the specimens reached saturation at 150 mT field (fig. 1(a)), and the coercivity is less than 70 mT (fig. 1 (b)). To further determine the magnetic carry mineral in the samples, three axial composite IRMs[7] were given to representative specimens. Thermal demagnetization of the soft (<0.12 T), medium (0.12—0.4 T) and hard (0.4—1.2 T) coercivity components show distinct unblocking temperature (fig. 1(c)). The soft coercivity component is dominant in the gray dolomite, and the three coercivity components are blocked within 380—500℃, indicating the presence of multi-domain magnetite/maghemite.

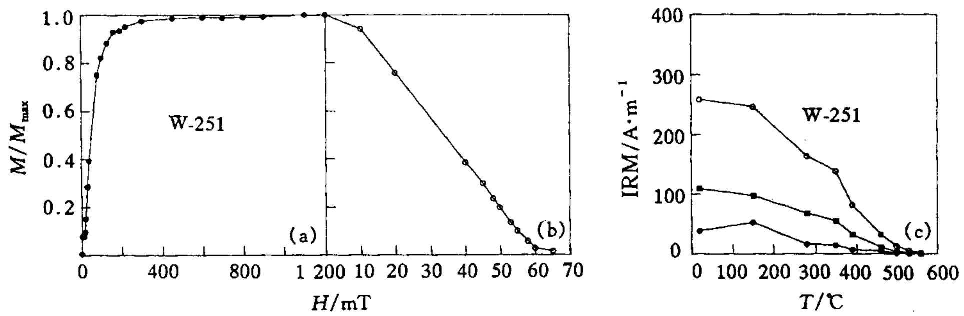

Fig. 1. Thermal demagnetization of IRM acquisition and demagnetization curves and three axial composite IRMs. ■, ● and ○ represent hard coercivity (0.4—1.2 T), medium coercivity (0.12—0.4 T) and soft coercivity (<0.12 T) respectively; W-701, W-648 represent the red fine-grained sandstone and red mudstone respectively.

All specimens were subjected to stepwise thermal/alternative field demagnetization in an MMTD60 oven and an AF demagnetizer and measured using a 2G superconductor magnetometer at the Paleomagnetic Laboratory in the Institute of Geophysics of CAS, Beijing.

It can be identified from orthogonal plots[8] of AF demagnetization that one stable component can be isolated within 10—140 mT for the dolomite specimens. Their declination is unstable, and inclination is deeply downward after tilt correction (fig. 2(a), (b)). The thermal demagnetization results show one stable component within 300—470℃ for the dolomite specimens and their declination is also unstable, while the inclination is deeply downward after tilt correction (figure 2 (c), (d)).

Site and formation means were calculated using Fisher statistics when directions only were obtained within a site or by the McFadden and McElhinny's method when individual characteristic directions have to be combined with great circle intersections with sector constraints[9,10]. The overall mean direction of the stable component for gray dolomite is characterized by northerly de-

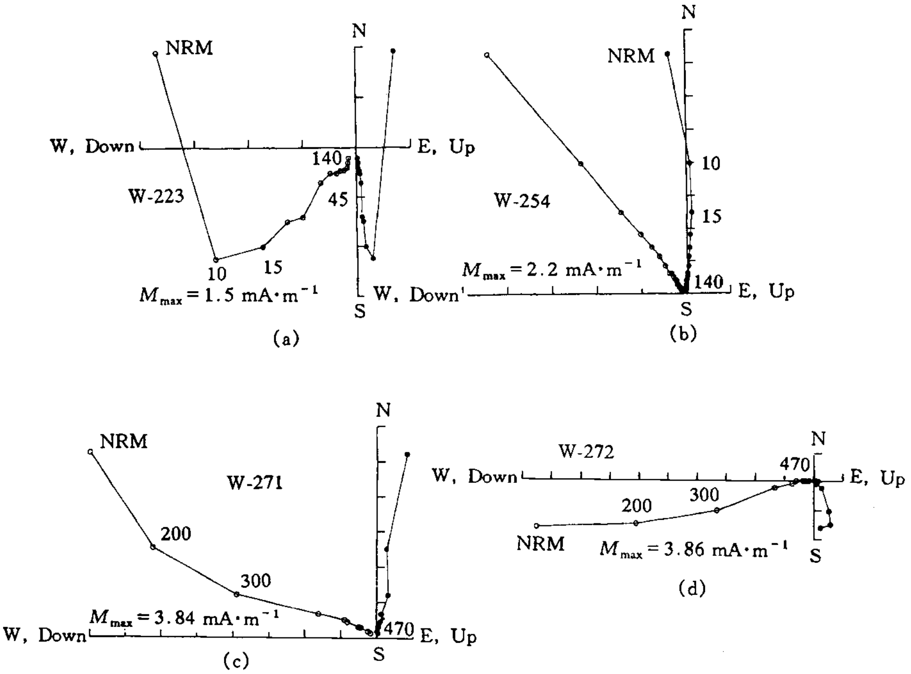

Fig. 2. Orthogonal plots of demagnetization of middle Triassic samples (*in-situ*). Solid (open) circles are plotted on horizontal (vertical) planes. Treatment levels are in ℃.

clination and moderate to deep inclination ($D=9.0°$, $I=54.2°$, $k=54.2$, $\alpha_{95}=8.9°$, *in-situ*), and a pole (82.1°N, 174.7°E, $dp=13.6°$, $dm=19.4°$) close to the present-day geomagnetic direction of the sampling site (table 1), indicative of secondary magnetization. The Middle Triassic sequences are all unicline in the Wangcang section, so we cannot perform the fold test. However, the strata occurrence varies greatly, makes it possible to perform the generalized fold test ($k_s/k_g=0.43$), indicating that the characteristic magnetization was obtained after the Late Cretaceous folding. This further supports that the characteristic remnant magnetization has a secondary origin.

Table 1 The paleomagnetic results for Middle Triassic

Site	$n(N)$	n_+/n_-	D_g/I_g	D_s/I_s	k_s	α_{95}	k_s/k_g
1	8(10)	8/0	6.5°/58.9°	133.1°/70.5°	189.1	4.0°	-
2	5(10)	5/0	18.3°/51.1°	115.7°/70.4°	91.2	8.1°	-
3	6(10)	6/0	351.7°/63.2°	208.5°/84.4°	35.8	11.4°	-
4	6(10)	6/0	15.8°/46.7°	43.9°/66.0°	21.6	14.7°	-
5	7(10)	7/0	1.9°/62.9°	109.1°/78.8°	73.7	7.1°	-
6	5(10)	5/0	11.1°/40.8°	32.7°/63.1°	48.1	11.1°	-
Average	-	-	9.0°/54.2°	82.9°/77.9°			0.43
	$k_g=54.5$	$k_s=24.5$	$\alpha_{95}=13.8°$	$\lambda_g=82.1°$			$dm=19.4°$

n/N, Number of samples or sites used/number of samples or sites measured; n_+/n_-, number of normal/reversed polarity samples; D_g/Ig, D_s/I_s, declination and inclination before and after tilt correction; k_s, k_g, Fisher Precision parameters before and after tilt correction; α_{95}, confidence circle about the mean direction; λ_g, φ_g, paleopole latitude and longitude *in situ*.

The direction of the characteristic magnetization (*in-situ*) is close to the present-day magnetic field (fig. 3(a)), indicating that the magnetization is related with the present magnetic field. To further identify the time of the characteristic magnetization, we recalculate the paleopole of the Middle Triassic and Cretaceous which we have collected according to the criteria of reliability for paleomagnetic data[11]. The results show that the paleopole in this study (fig. 3(c), ▲) does not correlate to the Middle Triassic one for the Yangtze Block (fig, 3(c), ★), but close to the present-day pole (fig. 3(c), ×). Additionally, the paleopole we have obtained is significantly different from that of the Cretaceous within the error range (fig. 3(c), ●), indicating that the characteristic magnetization of the Leikoupo Formation in the Wangcang section suffered from severe Late Cretaceous to recent remagnetization.

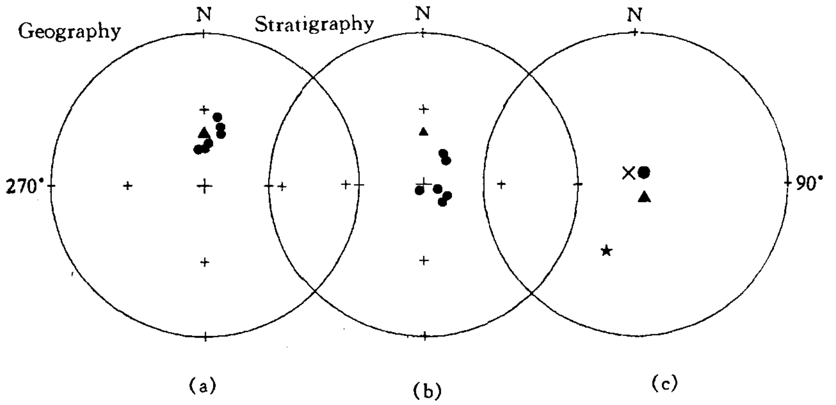

Fig. 3. Equal-area projections of characteristic magnetization before and after tilt correction (a, b), Equal-area projections of magnetic pole of Middle Triassic, Late cretaceous and present-day in the Yangtze Block (c).

3 Discussion

Pervasive Triassic to Jurassic remagnetization of the Paleozoic rocks in the Yangtze Block have been reported[6]. Such an event by "orogenic fluids" driven through a large mass of rock as a result of continental collision may result in the oxidation of pyrite to magnetite and also the formation of secondary hematite[12]. On the other hand, in the region where rocks suffered from remagnetization there are still some rocks which were not influenced by the fluids[13], indicating that the fluids are not the only factor that causes the remagnetization, and also some researchers doubt whether the fluids would migrate so long a distance[14]. The rock magnetic study and the nature of the characteristic magnetization indicate that the Middle Triassic rocks in the Wangcang section was remagnetized. To further investigate the reason for the remagnetization, we used the KLY-3 to measure the magnetic fabric of some Middle Triassic specimens (fig. 4). The minimum susceptibility axis is perpendicular to the bedding (tilt-corrected), indicating that the primary magnetic fabric could be possibly preserved. According to Addison et al.[15], the outstanding characteristics that the fluids caused remagnetization of the Leikoupo Formation rocks have no relationship with the fluids. Consequently, why were the rocks of the Leikoupo Formation pervasively remagnetized, whereas the Early Triassic rocks preserved characteristic magnetization in the same section[16]? We propose that the late diagenesis reorganization may cause the remagnetization of Leikoupo formation. According to this study, there is the salt lake environment at the Middle Triassic in the Wangcang area. The primary deposit is mainly crystal calcite, and the argillic component is relatively low, and the acicular crystal calcite suffered from severe dolomitization at the eogenetic stage[17], which may make the primary magnetization of Leikoupo Formation completely overprinted by the secondary magnetization. On the other hand, the sedimentary environment of the Early Triassic Feixianguan Formation is neritic facies, and the rocks are mainly composed of micrite, and the argillic in the rocks is relatively high. The late diagenesis is weaker than the salt lake environment deposit, so the Early Triassic limestone is favourable for preserving the characteristic magnetization.

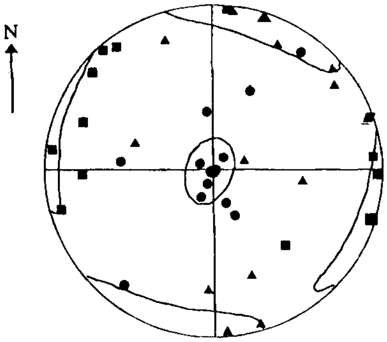

Fig. 4. Equal-area projections of the susceptibility axis ■, ▲, ● represent K_1, K_2, K_3 respectively. $K_1 = 1.020$; $K_2 = 1.005$; $K_3 = 0.974$.

The rock magnetic and thermal demagnetization results of Middle Triassic specimens show that the remnant magnetization are stable between 380—500℃. According to the similarity of thermal viscous magnetization between the maghemite and magnetite, and referring to the relation curves between the magnetite relaxation time-blocking temperature (t-T)[18] proposed by Middleton and Schmidt, the remnant magnetization can be obtained at ambient temperature in 10 Ma (fig. 5), indicating that the remagnetization of the Leikoupo Formation rocks may be caused by thermal viscous magnetization after the Cretaceous. It is worth pointing out that the blocking temperature of the main magnetic mineral in the Early Triassic rocks at the Wangcang area is 580℃ and 670℃ respectively, and the corresponding relaxation time is more than 10Ma. The characteristic magnetization of the Early Triassic rocks is not influenced by the thermal viscous magnetization.

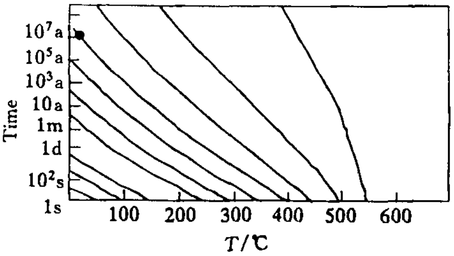

Fig. 5. The magnetite relaxation time-blocking temperature (t-T).

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