Palaeomagnetic Study on the Precambrian-Cambrian Boundary Candidate Stratotype Section at Meishucun, Yunnan

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Abstract

The Meishucun secton has been recommended as an international candidate stratotype secton of the Precambrian-Cambrian boundary. The paper deals with the palaeomagnetic study on the section. A total of 159 palaeomagnetic samples were successively collected from the platform-facies sequence of carbonates and phosphates at the section. Thermal demagnetization results indicate a great majority of the rocks at the section have been strongly overprinted by recent magnetic field, but 57 samples have preserved remanent magnetization with antipodal directions (mean $D/I = 4.2°/7.1°$, $K=9$, $\alpha_{95}=6.6°$). Baaed on calculation, the location of the palaeomagnetic pole was at 68.8° N and 270.7° E, which is different from any palaeopoles obtained from younger Phanerozoic rocks in South China. The results reveal a polarity zonation which includes at least 9 reversal events. A comparison of China's magnetostratigraphic records with those from Siberia, Australia and the western U.S.A. shows that all the sections are characterized by frequent polarity reversals.

Meishucun (24° 44′ N and 102° 34′ E), situated on the southwest margin of the Yangtze platform, 72 km southwest of Kunming, is easy of access by bus. There the Sinian and Lower Cambrian are extensively developed. The Meishucun section is present in the Kunyang phosphorite mining district. The strata, extending for 12 km, striking E-W, dipping 10°–20° south, and having an exposed thickness of 313 m, are a set of carbonate and phosphate sediments of platform or bay facies. Based on lithology and fossil assemblage, the section is divided into 2 formations and 6 members (Table 1). The section consists of fresh and unmetamorphosed rocks, has no magmatic intrusion nearby, and belongs to a stratigraphically complete and structurally stable area.

Table 1. Upper Precambrian (Sinian) to Lower Cambrian Stratigraphy of the Meishucun Section (after Luo Huilin et al., 1984)

Chronostratigraphic unit			Lithostratigraphic unit		
System	Series	Stage	Formation	Member	Symbol
Cambrian	Lower Cambrian	Qiongzhusi Stage	Qiongzhusi Fm.	Yu'anshan Mem.	$€_1q^2$
		Meishucun Stage		Badaowan Mem.	$€_1q^1$
			Yuhucun Fm.	Dahai Mem.	$€_1y^5$
Sinian	Upper Sinian	Dengyingxia Stage	B	Zhongyicun Mem.	$€_1y^4$
			A	Xiaowaitou-shan Mem.	$€_1y^3$
				Baiyanshao Mem.	Z_2y^2

Note: A and B are possible positions of the Precambrian–Cambrian boundary.

Palaeomagnetic Measurement and Analysis

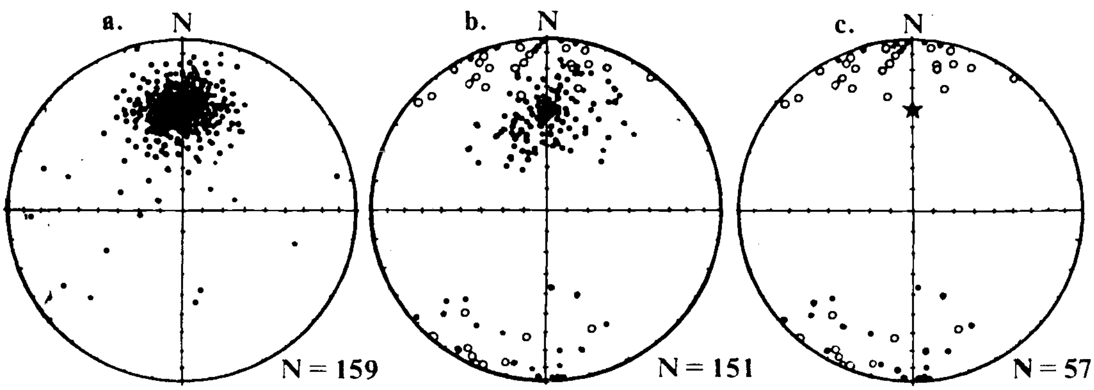

Fig. 1. Equal-area projections of palaeomagentic data.

a, Natural remanent magnetization direction before demagnetization; b, characteristic remanent magnetization directions of groups A, B and C after demagnetization; c, intrinsic remanent magnetization direction of groups B and C (all the above directions not corrected for structure). ● Lower hemisphere projection; ○ upper hemisphere projection; ★ direction of recent geomagnetic field.

The 159 specimens obtained were cut into 229 samples 2.2 cm high and 2.5 cm in diameter each. After being treated in alternating magnetic field and by thermal demagnetization, the samples were measured with a superconductive magnetometer. The palaeomagnetic vectors were approximately determined on an AC demagnetization graph diagram (Zijderveld, 1967) and then calculated using the vector analytical method of Kirschvink (1980).

The natural remanent magnetization (NRM) generally is 0.1–1 mA / m, and the rock types obviously have no direct relation with NRM. The NRM directions of samples are densely concentrated around the direction of the recent magnetic field (Fig 1–a), indicating that the rocks of the Meishucun section have been strongly overprinted by the field.

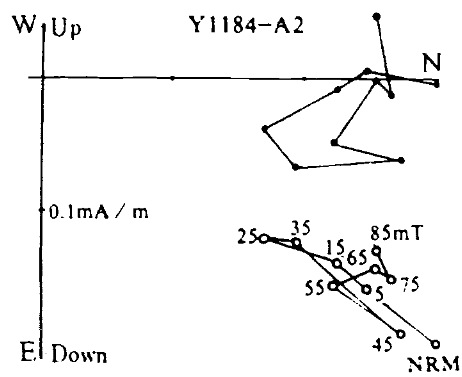

Fig. 2. Orthogonal vector diagram of AC demagnetization data (after Zijderveld, 1967).

Showing that the AC demagnetization can not decompose the natural remanent magnetization obtained from specimens. The points represent remanent magnetization vectors measured after each step of demagnetization (AC magnetic field intensity is in mT). ● Horizontal projection; ○ vertical projection; the remanent magnetization is plotted on the coordinate axis; the sample Y1184–A2 is from the dolomite of the Xiaowaitoushan Member.

The AC demagnetization method can not eliminate the overprinting effect of the recent magnetic field. Fig. 2 shows that in the alternating magnetic field with the intensity as high as 85 mT, the remanent magnetization vectors of dolomite samples from the Xiaowaitoushan Member have not changed greatly in magnitude and directon. Therefore all other samples were treated by thermal demagnetization method. Afterwards, a group of stable remanent magnetization directions was selected from many samples (Fig. 3), and was in conformity with the direction of the recent magnetic field, indicating that this group of remanent magnetization directions is in fact the product of remanence magnetization of the recent geomagnetic field. Among the 159 samples, 94 show the direction of the above group which is called the group A direction. The 53 samples collected from the sandstone and shale of the Badaowan and Yu'anshan Members in the upper part of the section, almost without exception, assume the direction of group A. Thus the rocks in the upper part of the section are considered unsuitable for palaeomagnetic study because they have not preserved the record of the ancient geomagnetic field. However, the dolomite and phosphorite in the lower half of the Meishucun section have revealed more than one group of stable remanent magnetization directions (Fig. 3). In the temperature range of 200 ° −250 ° −300℃, the overprinting effect of recent magnetic field on these rocks can be eliminated. The samples after thermal treatment at 300℃ show two groups of remanent magnetization direcions distinctly different from group A: one group dips gently north and upward, called the group B direction; the other dips gently south and downward, called the group C direction. The two groups of stable remanent magnetization directions are evidently antipodal to each other in distribution. Of the samples, 29 show the group B direction (only 3 samples are from the upper part of the section), and 28 display the group C direction (all samples from the section). Directions of the above three groups are shown in Figs. 1, 2, 3 and 4.

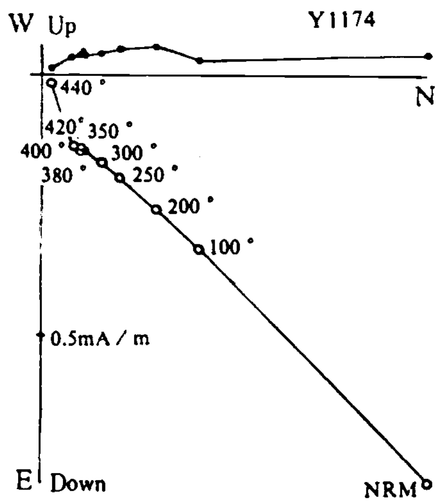

Fig. 3. Orthogonal vector diagram. One of the three samples (Y1174 collected from the dolomite of the Baishaoyan Member, and the other two from the siltstone of the Badaowan Member) reveals the only direction of magnetization, i.e. the group A direction, which conforms to that of the recent geomagnetic field.

Table 2. Group Means of Characteristic Magnetization Directions at the Meishucun Section

Magnetic vector group	*N*	*K*	α_{95} (°)	Mean before structural correction	Mean after structural correction	
				D / *I*(°)	*D* / *I*(°)	Position of magnetic pole(°)
A	94	138	3.3	1.4 / +45.6	356.0 / 58.2	75.1N, 90.1E
B	29	12	7.9	355.6 / −9.0	356.0 / +7.0	68.8N, 293.4E
C	28	9	9.6	192.8 / 8.7	193.0 / −7.3	65.8N, 249.1E
B+C*	57	9	6.6	4.0 / −9.1	4.2 / +7.1	68.8N, 270.7E

N = Number of samples for calculating the mean values; *K* and α_{95} are the mathematical statistics parameters correlative with the mean values.

* In calculating the mean values of the B + C group, the antipodal direction is used for group C.

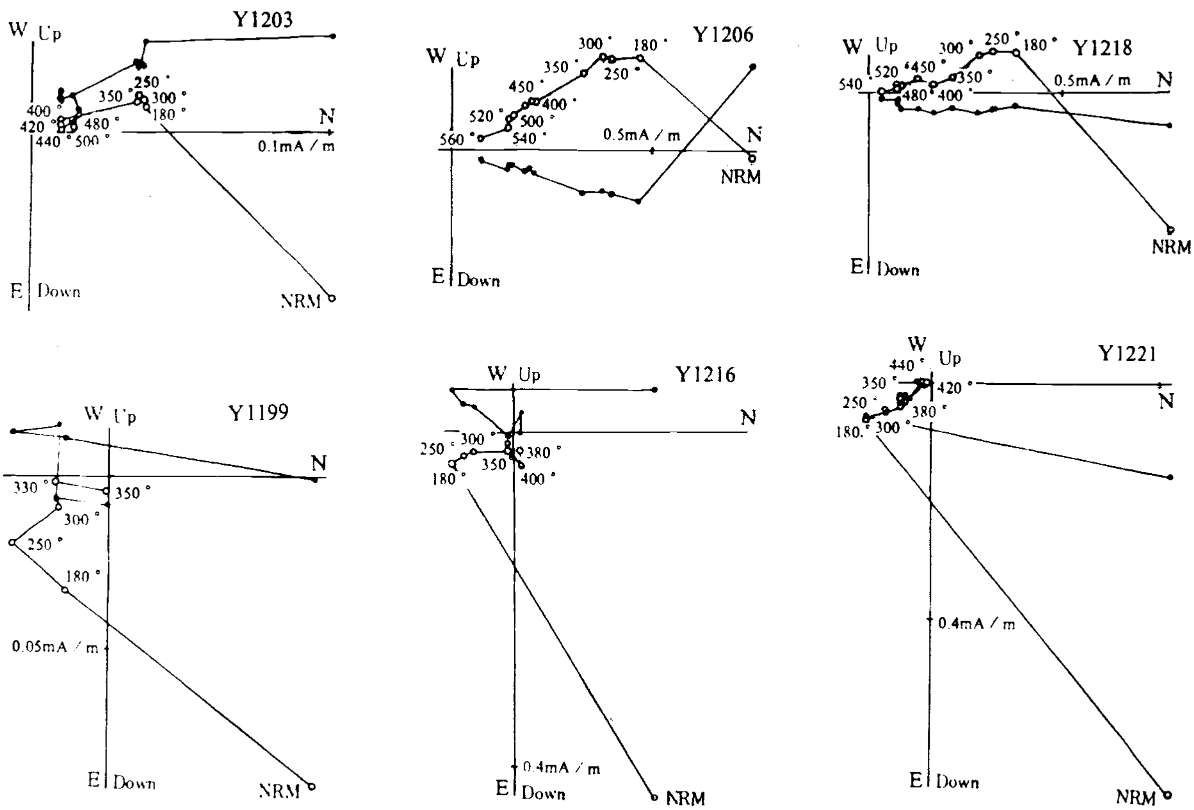

Fig. 4. Orthogonal vector diagrams.

The upper 3 samples reveal remanent magnetization directions of groups A and B; when heated to over 200℃, the vector of group B began to occur, which dips gently north and upward. The lower 3 samples show the remanent magnetization directions of groups A and C; when heated to over 200℃, the vector of group B began to occur, which dips gently south and downward. Groups B and C are the characteristic directions of the Meishucun section and are antipodal to each other.

The stable remanent magnetization data of groups A, B and C obtained through thermal treatment are listed in Table 2. Vectors of groups B and C are antipodal to each other, indicating the reversal of the ancient geomagnetic field.

Owing to the low intensity (0.08–0.4 mA / m) of the remanent magnetization after thermal demagnetization, the measurement precision of magnetic vector direction decreases. Therefore the magnetization directions of groups B and C are somewhat scattered (e.g. Fig. 1–c), but do not affect the judgement on positive and negative polarities of individual samples.

The blocking temperature of the remanent magnetization directions of groups B and C ranges roughly from 200 ° to 500℃, hence the magnetite is probably the carrier of NRM. Fig. 5–a shows the test results of magnetization at constant temperature for 5 representative samples. The magnetization intensity of the samples rapidly increases under the action of a weak (less than 50 mT) magnetic field, and continues to slowly increase in a stronger

(50 to 1000 mT) magnetic field, suggesting that besides magnetite grains, there are minerals with a higher coercivity in the rocks. Fig. 5–b shows the result of Curie- point thermomagnetic analysis of powdered dolomite from the Xiaowaitoushan Member. The diagram reveals two Curie temperatures (570℃ and 680℃), clearly indicating the coexistence of two minerals (magnetite and hematite) inthe samples.

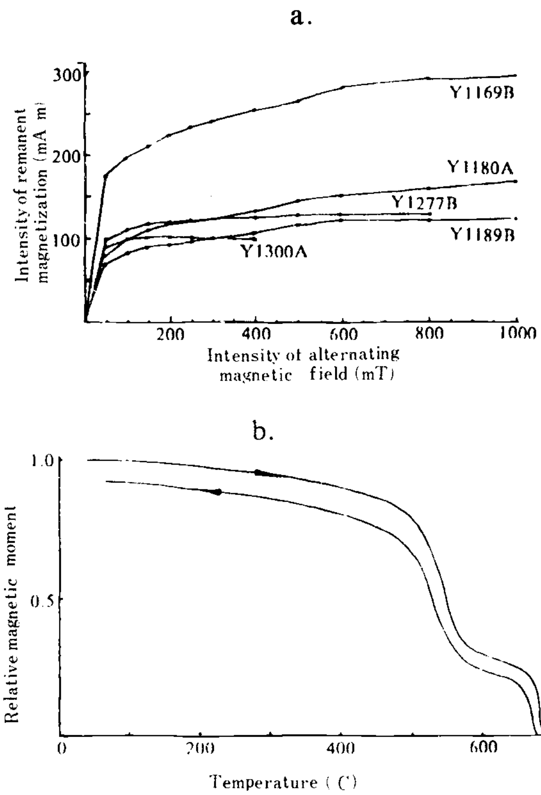

Fig. 5. a. Test results of isothermal remanent magnetization, indicating that the samples contain not only lower-coercivity mineral (magnetite) but also higher-coercivity minerals such as hematite.

b. Thermomagnetic analysis of powdered dolomite samples, showing Curie temperatures at about 570℃ and 680℃ and further confirming the coexistence of magnetite and hematite in the samples.

Discussion of the Results and Positions of Palaeomagnetic Poles

It is certain that the stable remanent magnetization of the group A direction is the product of the recent geomagnetic field. As an overprinted component, the group A direction is seen in almost every sample from the Meishucun section. Such an extensive remagnetization is also quite common in other parts of China (Kent et al., 1987). But quite a few samples (of groups B and C) from the lower part of the section have, to a certain degree, preserved the record of an earlier geomagnetic field.

The remanent magnetization directions of groups B and C alternate in the section and are distinctly different from the direction of the recent magnetic field. But whether they are the initial magnetization directions of the Late Sinian to Early Cambrian is now uncertain. To acquire the palaeomagnetic data of some strata in the vicinity, we collected 32 Sinian and Cambrian samples and 6 Devonian samples respectively from the sandstone cover of the Haikou Formation at the top of the Meishucun section and from the Sinian, Cambrian and Devonian at Wangjiawan 60 km away from the section. Unfortunately the samples showed only the remagnetization direction of group A or an erratic result, and can not be used to check the remanent magnetization direction of the section.

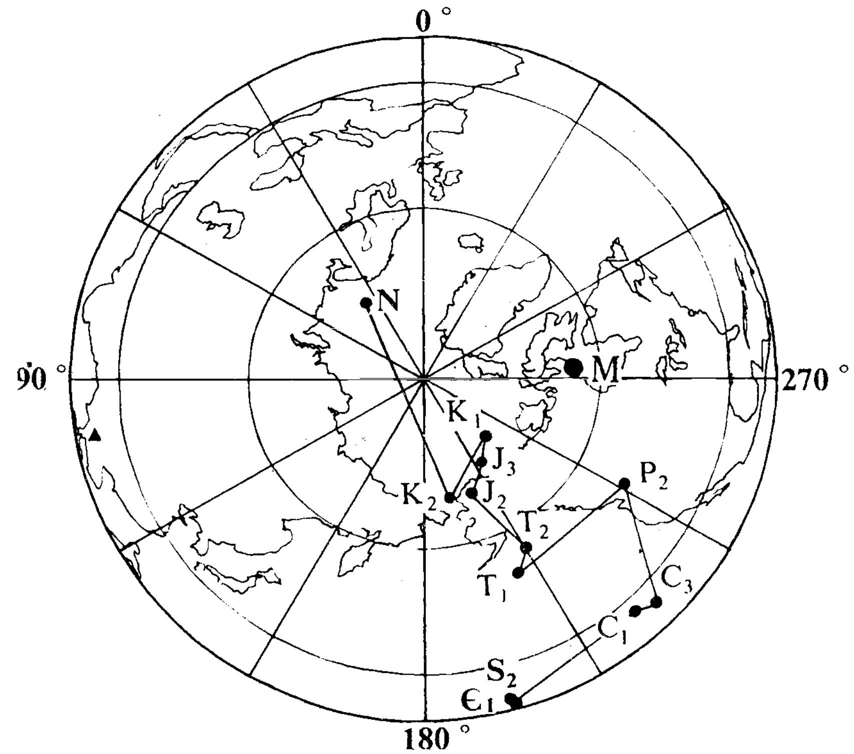

Fig. 6. Distribution of palaeomagnetic poles of the Yangtze platform (South China block).
Є$_1$, Early Cambrian; S_2, Middle Silurian (Opdyke et al., 1987); C_1, Early Carboniferous; C_3, Late Carboniferous; P_2, Late Permian (Zhao Xixi and Coe, 1987); T_2, Middle Triassic; J_2, Middle Jurassic; J_3, Late Jurassic; K_1, Early Cretaceous; N, Middle- Late Tertiary; M, Meishucunian palaeomagnetic pole. ▲ Geographic position of Meishucun. Other palaeomagnetic poles are from Lin Jinlu et al. (1985).

With regard to the effect of tectonism and regional magmatism in the geological past, the study area, all along situated in the stable tectonic domain of the Yangtze platform since the Sinian, is dominated by gentle structural elevation and subsidence manifested by frequent absence of strata and presence of disconformities. It is noticeable, however, that the Late Permian eruption of basaltic magmas in the Sichuan-Yunnan belt also caused the extensive exposure of basalts in the area. Has this resulted in the remagnetization of the strata in the area? The study results of Permian basalts obtained by Lin Jinlu (1984) from Xiongjiachang, Guizhou and by Huang Kainian (1986) from Binchuan, Yunnan indicate that the remanent magnetization directions of the two districts are respectively as follows: $D = 224.5°$ and $I = 30.3°$; $D = 242.0°$ and $I = 1.3°$, which are obviously hardly comparable (Lin Jinlu, 1987; Huang Kainian et al., 1986). Therefore it is necessary to further determine the magnetization direction of Permian basalts of the area.

In order to test the remanent magnetization directions of groups B and C, the authors again went to Meishucun and Wangjiawan in March 1989 to find corresponding horizons at different segments of the Sinian-Cambrian boundary and collect samples along the section, in an attempt to study whether the magnetic polarity sequence is continuous laterally. If the polarity column were laterally comparable, the magnetization direction would be initial, i.e. formed during the formation of the rock.

Fig. 6 shows the palaeomagnetic pole position (M) calculated on the basis of remanent magnetization directions of groups B and C. It is located at 68.8° N and 270.7° E, approaching none of the so far published palaeomagnetic poles of the Yangtze platform. The Early €ambrian pole ($€_1 = 3.4°$ N, 195.6° E) obtained by Lin Jinlu et al. from sedimentary rocks in Zhejiang and Hubei is also far from the pole (M) of the Meishucun section (Lin Jinlu, 1987). But it should be pointed out that the palaeolatitudes estimated from the positions of $€_1$ and M are respectively 1° and 3° (N or S), suggesting that the Meishucun area lay near the equator at that time. However, there is a difference of about 80° for the magnetic declination estimated from $€_1$ and M. This is probably due to the time difference between sampled strata, or the occurrence in the geological past of a horizontal rotation of about 80° between the Meishucun area and other areas of the Yangtze platform.

Magnetostratigraphic Scale

Assuming that the remanent magnetization directions of groups B and C obtained from the lower half of the Meishucun section do belong to initial magnetization, we may establish a magnetostratigraphic scale for the Precambrian-Cambrian boundary stratotype section (Fig. 7). In this figure, the number of samples, their remanent magnetization directions of groups A, B and C, the latitudinal distribution of palaeomagnetic poles calculated from the groups B and C directions and the resultant polarity zones are separately plotted according to the actual positions of the samples in the section. Drawn in the figure is also the trial magnetostratigraphic scale published by Liang Qizhong et al. (1984), which reveasls few group C directions probably due to low sampling density, weak magnetism of the rock and low sensitivity of the apparatus.

In Fig. 7, the group B directions are temporarily presumed to be normally magnetized and the group C directions, reversely magnetized since there is for the time being no other evidence to prove whether the magnetic pole preserved in the old rocks is the north or south. There will most probably be new evidence in the future that will make it necessary to reverse all the polarities presumed now. But this has no substantial influence on the interpretation of the magnetostratigraphic scale of the Meishucun section. According to the distribution of the remanent magnetization directions of groups B and C, there are at least 9 reversely magnetized zones in th lower part of the Meishucun section, of which 3 zones obtained by Liang Qizhong et al. (1984) have all been verified by this study (Liang Qizhong et al., 1984).

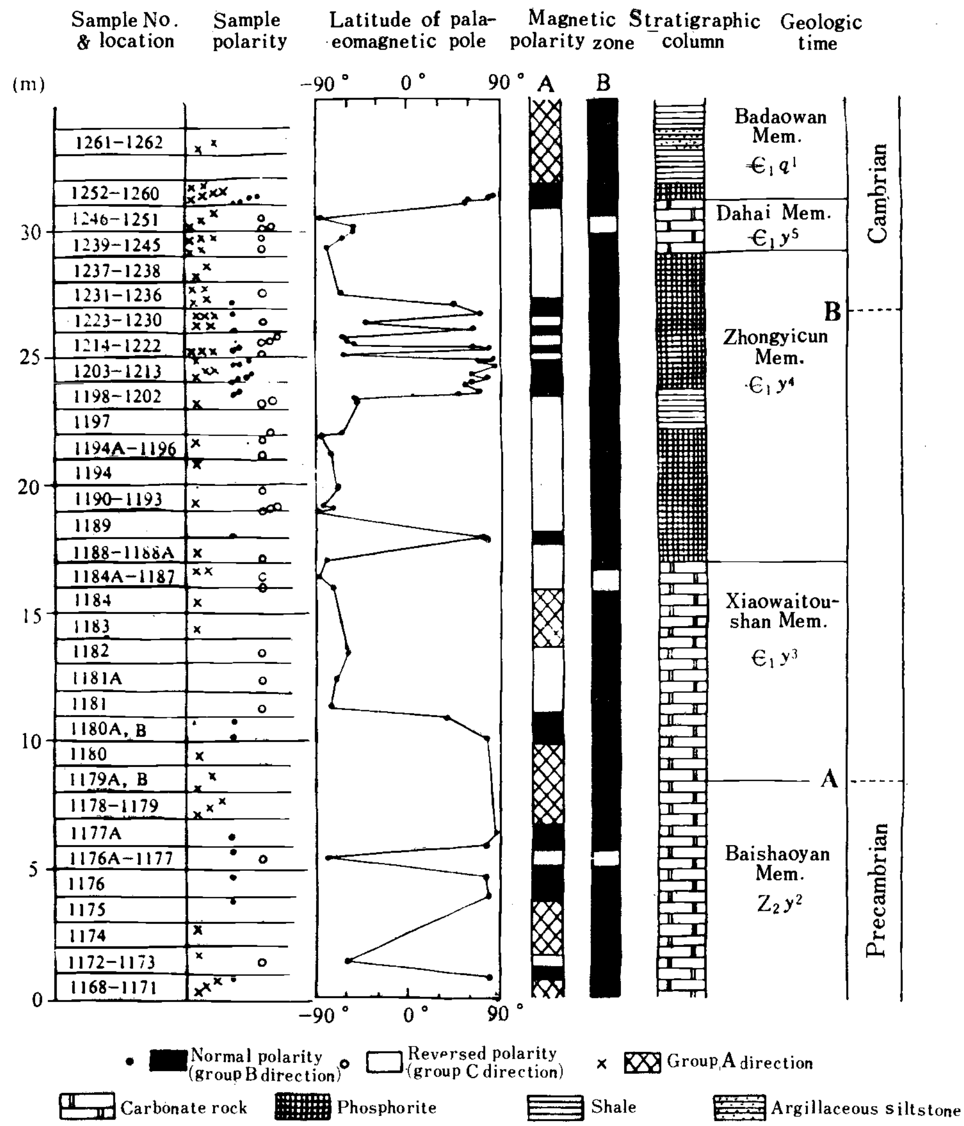

Fig. 7. Magnetostratigraphic scale of the lower half of the Meishucun section.

Distribution of the magnetic zones is based on the intrinsic remanent magnetization directions of groups B and C. The stratigraphic classification and points A and B (Precambrian-Cambrian boundary points) are after Luo Huilin et al. (1984) and consistent with Table 1.

● Remanent magnetization direction of group B; ○ remanent magnetization direction of group C; × remanent magnetization direction of group A revealed by samples (used to establish magnetic polarity column). Magnetic polarity column A is based on the results of this paper and magnetic polarity column B, on the test results obtained by Liang Qizhong et al. in 1984.

Magnetostratigraphic features of the Meishucun section are as follows: the Xiaowaitoushan Member and the lower part of the Zhongyicun Member are dominated by reversed polarity; the upper part of the Zhongyicun Member and the Dahai Member are characterized mainly by a zone of frequent polarity transitions. Point B, as a candidate site for the Precambrian-Cambrian boundary, lies just in the zone.

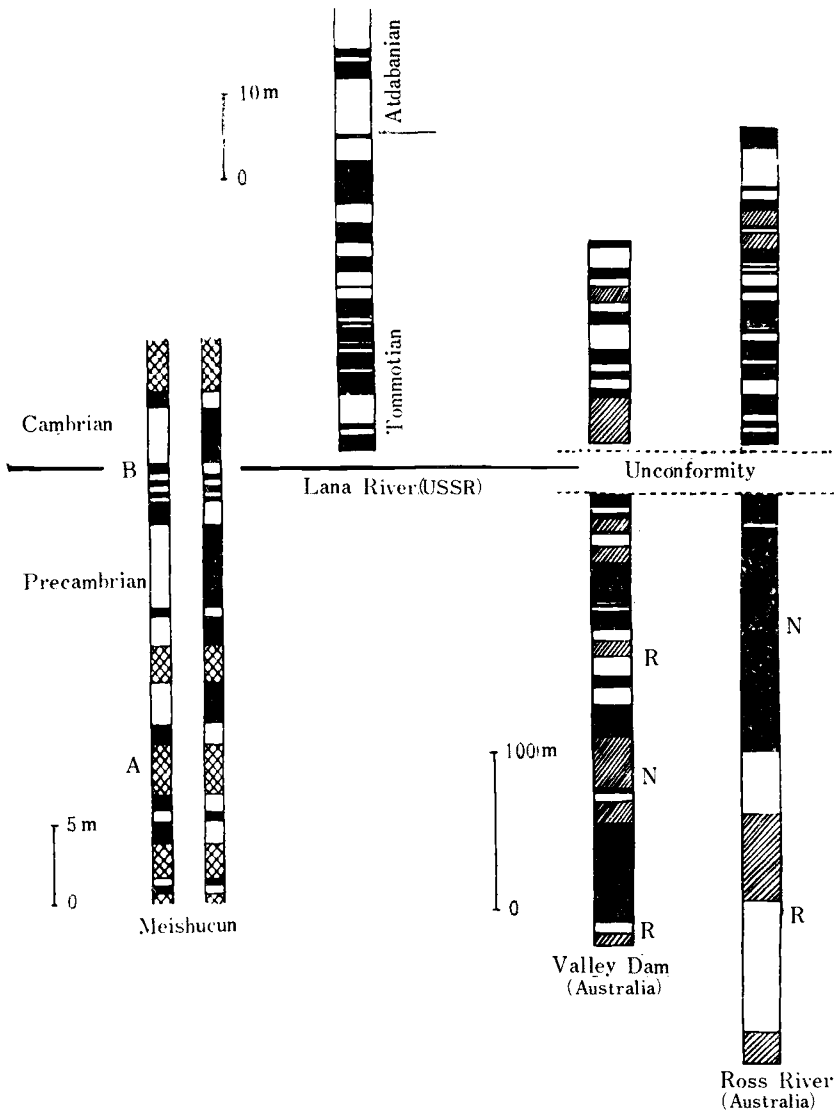

Fig. 8. Palaeomagnetic polarity correlation of the Meishucun section, the Lana River section in Siberia, and the Valley Dam and Ross River sections in Australia. For the Meishucun section, two equally possible polarity columns are shown since we do not know whether the polarity is reversed or normal. It can be seen that the criteria for the correlation are not remarkable. Therefore a further study is needed.

The above- said magnetostratigraphic scale represents only a preliminary understanding. Palaeomagnetic data so far published from the vicinity of the Precambrian-Cambrian boundary in the Amadeus Basin (Ross River and Valley Dam) of Australia suggest that strata of the Late Precambrian are mainly of normal polarity, whereas those near the Precambrian-Cambrian boundary are characterized by a zone of frequent polarity transitions (Kirschvink, 1978). Based on the test results of pole positions and folds, this polarity sequence is considered to belong to initial magnetization but, due to the presence of unconformity and absence of stratum near the boundary, is still incomplete. The strata in the Lana River area, Siberia, the USSR are chiefly of the Tommotian-Atdabanian, and their magnetostratigraphy also reveals frequent polarity reversals (Kirschvink et al., 1984). The presence of an evident erosional surface in the lower part of the Tommotian indicates that the strata are not completely developed either and the polarity sequence is unclear. The Meishucun section, however, is stratigraphically continuous, and point B, as the Precambrian-Cambrian boundary candidate section, lies just in the zone of frequent polarity transitions, which in turn occurs at the boundary between fossil zones I and II of the Meishucunian. Here some of the species of small shelly fossils became extinct but some occurred and multiplied in large quantities. This polarity zone is also correlative with the bottom of the Tommotian of the Aldan River in Siberia, the USSR.

This further suggests that point B of the Meishucun section has a wider intercontinental correlativity. Fig. 8 is a magnetostratigraphic correlation based on corresponding positions of strata of Meishucun, Siberia and Australia.

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