IC/89/18
INTERNAL REPORT
(Limited distribution)

International Atomic Energy Agency
and
United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

PALEOMAGNETIC STUDY OF SHANWANG FORMATION, SHANDONG PROVINCE, CHINA *

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ABSTRACT

The measured direction of the stable remanence of Shanwang Formation, Shandong Province, is D = 355.8°, I = 47.1°. According to the axial geocentre dipole model, the paleolatitude there during Miocene was 28.3°N. The corrected value based on far-sided effect is 32.4°N. The uncorrected and corrected pole positions were (81.0°N, 323.1°E) and (84.6°N, 339.7°E) separately. Comparing them with paleo-flora shows that the corrected value of paleolatitude is probably reasonable.

MIRAMARE - TRIESTE
January 1989

* To be submitted for publication.

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1. Introduction

Shanwang section is located near Sanwang village, Linju county, Shandong Province (36°33'N, 118°41'E). This section has a good crop and plenty of fossils, both in the quantity and in species. It is one of the typical section of Miocene in China and in the world as well, being known as an ancient zoo and botanical garden. In 1930s, Young C.C. (1936) first discovered it and carried out an early study in stratigraphy and paleontonogy. Since then, a lot of researches have been done by chinese and foreign scientists. Lots of fossils have been unearthed including ones of mammals (Teihard de Chardin, 1939; Hu Changkang, 1957; Wang Banyue, 1965; Li Chuankuei, 1974; Chow Benshun and Shih Mochuang, 1978), birds (Yeh Hsiankuel, 1977), insects (Hong Youchong, 1985) and plants. These researches indicate that paleoclimate recorded in flora and animals in Shanwang Formation was much warmer and damper than now. But as to determination of climatic zone, there are great divergencies yet. Hu Xianxiao, Chaney (1940) and Tao Junrong (1984) thouhgt the climatic zone reflected by flora of Shanwang Formation was similar to that of the valley in today's middle and lower reaches of Yangzi River, or north subtropic. According to the data of sporo-pollen, Song Zhichen at al (1983) thought the paleoclimate there seemed to be even warmer. Lin Jingxing (1984), based on the plant and fish fossils, inferred that the sedimental environment of Shanwang Formation probably belonged to subtropic to tropic. In view of the above, to determine the latitude of Shanwang during the sedimenting with paleomagnetic method will provide an independent, Quantatiye information for the change and its cause in paleo-vegetation and climate. Naturely, the VGP yielded from remanence is also useful for research in the drift and feature of stress of North Block of China since Cenozoic.

2. Geology

The Shanwang area is situated in the south of the Changle basin and the east edge of great Yidu Fault. Volcanos were active in the region in Miocene. The volcanic buttes, low ridges and hills of basalt spread all over the region. The landforms last to the present. The Shanwang ancient lakes were a series of near closed small lakes formed in the hollows of basalt. The largest of those was about $1(km)^3$. A sequence of aluvio-locustrine deposits named Shanwang Formation accumulated in the lake about 100 m in thickness. The characteristic of the main part of the sequence is diatom varved clay. Shanwang Formation can be divided into three menbers (Fig.1). Following is the description of the strata (from lower to upper).

1. The underlying beds, Nioushan Formation of Miocene, are made up of basalt, in which main minerals are pyroxene and livine. There are almond textures and aboundary joints in the rock. Its thickness is more than 80 m.

2. The lower menber of Shanwang Formation is yellow gravels and coarse sands of fluvial facies. Main gravels are made of basalt. The diameter of the gravels are about 2-30 cm. More the upper, more the rounded and sorted. These mammal fossils were found in this menber. They are plesiaceratherium gracile Young, Hyotherium penisulus Chang and so on. The thickness of the menber is about 10-10 m. It is of uncomformity over the Nioushan Formation.

3. The middle menber. It is composed of grey, grey-black and grey-green diatom varved clay, shales and thick beds of silt. There are two thin beds of basalt in the upper part of the menber. There are aboundary fossils, such as plants, pollen, insects, proiegs, mussel-shrimps, fishes, reptites, birds and mammals. The important mammals are *Diatomys shantungensis* Li, *Shanwangia unexpectula* Young, *Logomeryx teilhardi* Young, *Paleomeryx* sp., *Plesiaceratherium Shauangensis* Wang and so on. The thickness of the menber is about 40-70 m. It is conformable over the lower menber of Shanwang Formation.

4. The upper menber. It is grey-yellow sands and pebbles of flurvial facies. Its thickness is about 30-50 m. The pebbles are made of basalt, granite and metamorphic rock. The sorting of pebbles is not well, and the largest ones are about 1 m in diameter. Some mammalian fossils were found in the menber: *Amphicyon confucianus*, *Felinae*, *Plesiacerathrim Shanwangensis*, *Lagomeryx colberti*, *Lagomeryx simpsoni*, *Paleochoerus* cf. *pascoei* and so on.

5. The overlying beds, Yaoshan Formation of Pleocene, is olivine-basalt. Its thickness is over 60m and it is unconformable over Shanwang Formation.

3. Measurement and results

Sixteen oriented hand samples were collected from the middle menber of Shanwang Formation and cut into twenty two cubic specimens of 23x23x23 mm in the laboratory. They were subjected to stepwise thermodemagnetization with Schonstedt thermodemagnetizer and measured with model GM401A superconducting rock magnetometer. The data were analyzed with the combine of vector diagram, difference vector and principal component analysis. Only one specimen is counted for each hand sample in statistics .

Almost all specimens have the similar behavior in successive demagnetization. The natural remanent moment before magnetic cleaning are about 1x10-9 Am^2. They all carried a very soft component which were larger than a half of NRM in intensity and erased at 100°c or 150°c. Above these temperature a stable characteristic component is revealed as a stable end point corresponding to a linear segment passing through the origin of vector diagram (Fig.2). Beyond about 260°c the remanences decayed to a few percent of NRM, and the directions scattered drastically. It can be noticed from Fig.3 that the soft component is steeper than the harder one. The directions of the two components from all samples cluster each in a small region in stereonet, seperately (Fig.3). Table 1 lists their statistics based on Fisher distribution. As a comparision, the table also shows the paleomagnetic results of Yaoshan Formation given by Lin Jinlu (1987).

4. Correction for far-sided effect

The relation between magnetic inclination I and colatitude θ for an axial geocentric dipole is

$$\tan I = 2\cot\theta \qquad (1)$$

Correspondingly, the palaeolatitude of the region being sampled seems to be 28.3°N. The present latitude is 36.5°N. The difference between both goes up to 8.2°, signifying that this region has moved about 900 km northwards since Miocene. This figure looks much larger than it should be. A possible explanation is that the measured value of inclination is a combine effect of the axial north-off geocentric dipole and continent drift. If so, it is necessary to separate them so as we can determine the actual latitude during deposit.

As Wilson first pointed out that there was a far-sided effect in pole data from the late Tertiary, i.e., a tendency for the mean poles for different parts of the world surface to lie on the far side of the geographic pole from the sampled region. It can be explained if suppose that the long term average of geomagnetic field is one of an axial north-shifted dipole, instead of one of an axial geocentric dipole. Obviously, the axial north-shifted geocentric dipole should result in a shallover inclination in north hemisphere and a steeper inclination in south hemisphere than that produced by a centre dipole. And it is the change in inclination that makes the far-sided effect of pole positions, if we use the axial geocentric dipole formula (1). Let r is northwards off distance of the axial dipole from the geocentre and R is radius of the earth. The equivalent relation between I and becomes

$$\tan[I+\sin^{-1}(r\sin\theta/\rho)]=2\cot[\theta+\sin^{-1}(r\sin\theta/\rho)] \qquad (2)$$

where $\rho=(r^2+R^2-2rR\cos\theta)^{1/2}$. Suppose r=285 km, Wilson (1971) got minimum scatter in the poles for ninety six Upper Tertiary and Quaternary data. And the average position of geomagnetic poles is very closed to present geographic pole.

The latter fact, e.i., the consistence of average geomagnetic pole during Late Tertiary with present geographic pole, no means that all parts have not drifted since that time. In contrast, there are variety of evidence showing that the plates have drifted in a measurable size. Therefore, the average pole should be regarded, on its original sense, as an average pole for all sampled plates which drifted with different rate at different sense. The consistence between both poles, maybe, is of coincidence, or due to the bias in palaeomagnetic data. Furthermore, it should be pointed out that, in principle, it is unable to separate the change in the geomagnetic field and the movement of continent each other, since, as we mentioned above, the effect of both on pole position are mixed. Apart from the necessity of ultimate text of it, we can accept Wilson's model as the first proximation of the field, then we have a base to discuss the movement of each plate separately. We will discuss the above results of remanent magnezation upon Wilson's model in the below.

The inclination of the presant field of axial geocentre dipole at Shanwang is 56°, while the corrected value is 51.8° according to Wilson's model of north-shifted dipole. The measured inclination value of high temperature component in present geographic coordinate is I=44.6°. Obviously, the stable component is different from the long term average of present geomagnetic field according to either axial centre dipole or north shifted-dipole at 95% confidence level.

As to the lower temperature component, the direction in present coordinate is: D=354.1°, I=62.7°. At the first sight it seems to agree with the present magnetic field (the inclination of the latter is 56°). But it is much larger than the corrected value (51.8°) of the latter upon far-sided effect. Therefore, it is quite doubted to identify the soft component as present field.

Lin Jinlu (1987) made a measurement of basalt samples from Yaoshan Formation, the overlying bed of Shanwang Formation. The average of direction of his three groups of data is D=14.6°, I=62.7°. The inclination is quite similar to the one of our lower temperature component either in present geographic coordinate (D=354.1°, I=62.7°) or in paleogeographic coodinate (D=358.3°, I=65.3°). It shows that the remanence of basalt has the same source of field with the soft component of sediment, no matter the eruption of lava occured before or after the tilting of the beds in this area. Therefore, the most possibility is that the soft component of the sediment reflects the effect of the lava eruption or the overprinting due to the magma activity in this area. The fact that the direction of stable component of sediment much differs from the one of basalt (also the soft component) shows that the remanence of basalt was the instantaneous record of geomagnetic field at that time. The long-term change wasn't averaged out. So the remanence data of basalt shouldn't be compiled into virtual pole wander curve.

After correction of far-side effect the pole position deduced from the stable component of sediment was (84.6°N, 339.7°E) and the paleolatitude of sample-collected place was 32.4 N. The pole position deduced from baslt result is (76.6°N, 170°E), the corresponding paleolatitude is 44.1°N. If we correct the latter with north-shifted dipole model, the pole position becomes (74.3°N, 157.2°E), paleolatitude becomes 48°N. Opposite to expection, the corrected pole is more far away from the geographic pole. This shows again that basalt remanence doesn't represent the dipole field. The far-sided effect don't apply to it at all. The pole positions of both kind of rocks are considerably different each other. The result of basalt means that the north block of China has drifted at least 800 km southwards since 10 Ma ago. This figure is too large to find evidences of tectonics. Besides, as we will see below, the flora in Shanwang Formation doesn't support a large southwards drift either. However, the drift direction is northwards according to the results of sediment. The problem of

drift direction is concerned with the general distribution of stress of North Block of China, and it also related to the tectogenesis of Tanlu fault. This remains to take a futher study. The drift got from the result of sediment after correction based on far-sided effect is about 460 km. This value rather reasonable than the value of 800 km.

5. Correlation to the fossils

A lot of plant fossils were found in the middle menber of Shanwang Formation where we sampled the paleomagnetic samples. Having been gathered and studied for tens of years, 125 species of the flora were identified. They are bryophyte, pteridophyte, gymnosperm and angiosperm, and the latter has advantage over others. The main families are etulaceae (12 spcies), Rosceae (9 sbpecies), Leguminosae (8 species), Ulmaceae (8 species), Aceraceae (8 species), Salicaceae (7 species), Juglandaceae (5 species), Fagaceae (5 species), Rhamnaceae (7 spebcies), and Lauraceae (4 species). The overwhelming majority of Shanwang flora are deciduous broadleaf trees. the plants of the largest number are Carpinus, Acer and Zelkova. They are typical plants of temperate zone. But there are some evergreen broadleaf plants in the Shanwang flora, such as Cinnamomum, Sapindus, Litsea, Lindera paraobtusiloba and Ficus. Most of those are subtropical elements. So Shanwang flora is one kind of deciduous and evergreen broadleaf mixed forest, which reflects the transition climate from temperate zone to subtropical zone.

The similar forests live now in the Yangzi valley which extends along thirty degrees of latitude north. For example, the piedmont plains and lower slope of Huangshan Mountion and Lushan Moution. Many species in those forests are similar to Shanwang flora, such as Zelkova serrulata, Rhus succedanea, Diospyros kaki, Betula luminfera, Acer mono, Acer henryi, Sophora japonica, Koelreuteria integrifolia, Tapiscia sinesis, Hovenia duleis, Lindera obtusiloba, Cinnamomum camphora, Carpinus cordata, Hamamelis mollis, Cercis sinesis, Gleditsia sinensis and so on.

The pollen (Song Zhichen, 1959) and insects fossils (Hong Youchong, 1985) in Shanwang Formation also yielded the similar result.

6. Conclusion

The remanence of the sediment of Shanwang Formation is composed of two components. Among them the lower temperature component has the close direction with the one of the overlying basalt, reflecting the instantaneous geomagnetic field during magma activity after sedimention. For the stable high temperature component the declination D=355.8° and inclinatin I=47.1°. According to north-shifted dipole model, the paleolatitude of the sampled site is 32.4°N, pole position is (84.6°N, 339.7°E). It is infered that the north block of China has drifted northwards at least 4°. This conclusion can explain the elements in Shanwang flora. The latter **does not** conform to the statement that a large southwards drift occured since Miocene.

ACKNOWLEDGMENTS

One of the authors (L.H.) would like to thank Professor Abdus Salam, the International Atomic Energy Agency and UNESCO for hospitality at the International Centre for Theoretical Physics, Trieste.

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Table 1. The paleomagnetic results of Shanwang Formation*.

	D (°)	I (°)	K	α_{95} (°)	λ (°N)	VGP (°N, °E)	λ (°N)	VGPu (°N, °E)
Hard	355.8	47.1	418	4.0	28.3	81.0, 323.1	32.4	84.6, 339.7
Soft	358.3	65.3	134	7.0	47.4	79.1, 112.4	51.1	75.4, 114.4
Yaoshan Format.**	14.6	62.7	222	5.4	44.1	76.6, 170.0	48.0	74.3, 157.2

*D-declination. I-inclination. K-accuracy parameter. α_{95} -radius of 95% confidence cone. λ and VGP are the paleolatitude of the sampled site and pole position based on model of axial centre dipole. λ_{μ} and VGPu are the corresponding values after correction of far-side effect. the results come from sixteen samples of three sites.

**From Lin Jinlu (1987)

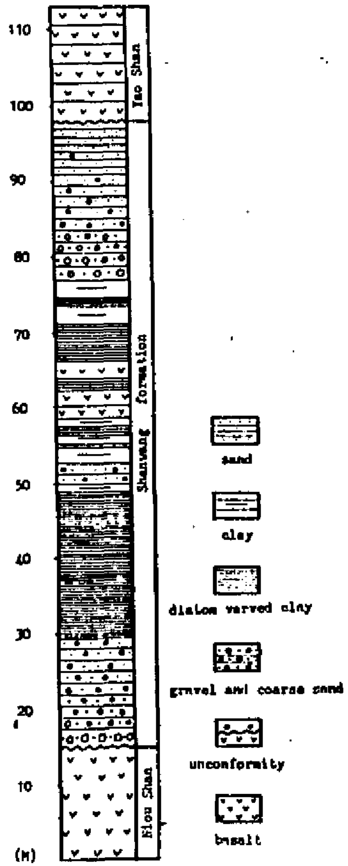

Fig.1. Colomnar section of Shanwang area.

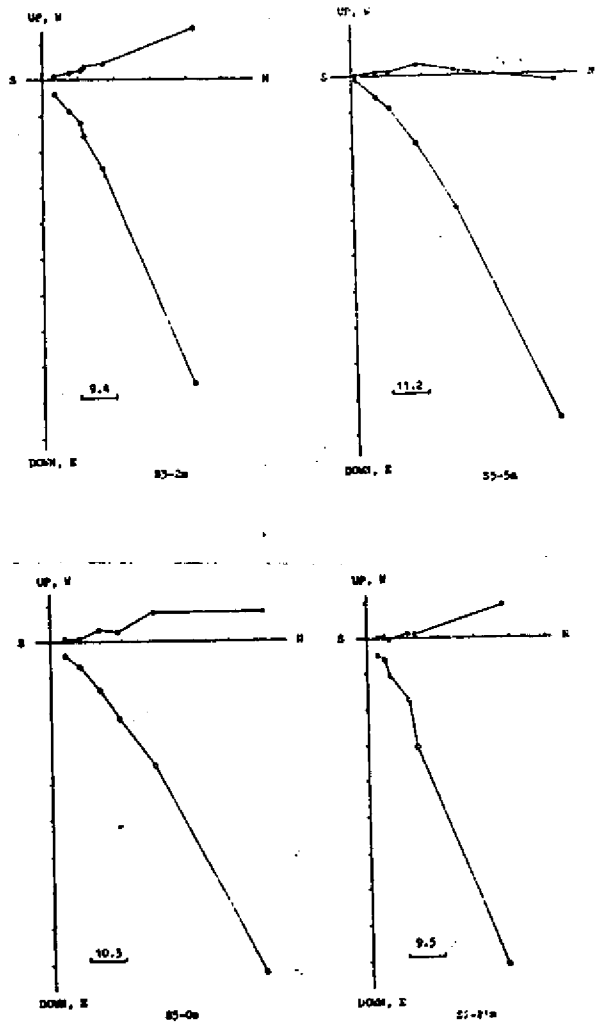

Fig.2. Vector diagrams. Open (closed) circles show directions projected onto horizontal (vertical) planes. Two components can be seen clearly in each diagram.

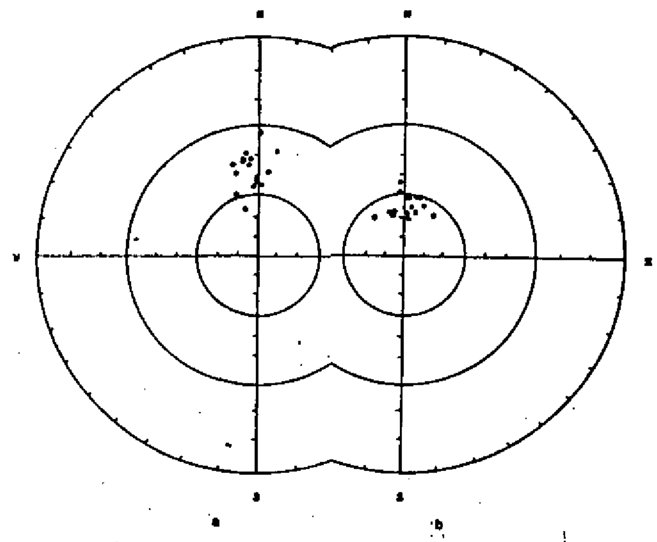

Fig.3. Stereonets For directions from all samples: a. hard component. b. soft component.