The Total Intensity of Geomagnetic Field in Southern China for the Period from 4500 B.C. to A.D. 1500

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The total intensity of geomagnetic field for the period 4500 B.C.–A.D. 1500 was determined with archaeological samples collected from the southern part of China by the Thellier's stepwise heating method. Results indicate that the total intensity of geomagnetic field in this area (28° – 32° N, 111° – 120° E) varied between 38–90 μ T during the period 4500 B.C.–A.D. 1500. The high value occurred during the first centuries of Anno Domini with subsequent decreasing while the relative low value was at about 900 B.C. Earlier than 1000 B.C. the average value of the total intensity of geomagnetic field was close to the present day level with evident fluctuations.

1. Introduction

Great advances in the production of large data sets of ancient geomagnetic field intensity have been made since the excellent work of the Thelliers (THELLIER and THELLIER, 1959), especially during the last ten years. There have been published paleointensity data for different parts of the world and attempts have been made to analyse the variation of the field strength with time (SHAW, 1985).

Nevertheless, the amount of intensity data is still insufficient in comparison with direction data, especially since the most continuous and comprehensive declination and inclination records have been coming from lake sediments. After the scarcity of archaeomagnetic data for such a large area as China was noticed some results of both direction and intensity determination have been published (WEI *et al.*, 1980–1984; DENG and LI, 1965). The present paper provides some new results of paleointensity determination for the southern part of China, namely the area around the middle and lower reaches of Yangtze River.

2. Samples and Measurements

The Yangtze River valley is one of the birthplaces of China's ancient culture. There are a lot of human relics, tombs, kilns, etc. in this area, which includes Hubei, Hunan, Jiangxi, Zhejiang, Jiangsu provinces. So, baked earth, bricks, tiles and pottery shards useful for archaeomagnetic research are available there. The location of sampling sites is shown in Fig. 1. Among samples collected from this area are some bricks of kilns called "horseshoe", "calabash", "dragon", etc. because of their shape from famous Jingdezhen, Jiangxi province and Longquan, Zhejiang province. Some baked earth specimens were taken from vertical copper-smelting furnace in Tonglushang, Hubei province and from dragon kiln in Yixing, Jiangsu province and

Fig. 1. Map of sampling localities. 1: Beijing, 2: Shanghai, 3: Nanjing, 4: Changsha, 5: Jingdezhen.

other places. As for the pottery ware, only some thick bases or legs of tripod were used.

All data pertaining to samples used in this work are listed in Table 1. A brief description of each site is given along with the archaeologist's estimated age rounded off to decades. Some bricks from tombs or city constructions are carved with accurate dates.

Laboratory measurements of remanent magnetization were made on cubic specimens (30 or 40 mm edges) using astatic and parastatic magnetometers. The Thellier's method was employed for paleointensity determination. An NRM-TRM diagram was constructed and a line was fitted to appropriate sets of points using the least square method (WEI *et al.*, 1980). The slopes of the fitted lines were used for estimates of ancient field intensity. For every group of samples collected from the same site the average value of ancient field intensity was calculated. Hubei province is located in this area so the paleointensity data for Hubei (WEI, *et al.*, 1983) were included in this paper for discussion.

3. Results and Discussion

Experimental results are summarized in Table 1 and some representative NRM-TRM diagrams are shown in Fig. 2. Because of the small difference in latitudes the intensity values for different sites in this area are plotted against time together in Fig. 3.

One of the interesting features that is apparent in these results is the maximal value at about A.D. 500 and the gradual decrease of geomagnetic field intensity

Table 1. Paleointensity data.

Dynasty	Age	SLA (deg.,min)		SLO (deg.,min)		Sample type	<i>N</i>	F_0/F	<i>S</i>	F_0	S_0	<i>M</i>	S_m
Neolithic	5000–4000 B.C.	30	17	112	13	Pottery	1	0.92	0.03	51	1.7		
Neolithic	3000–2600 B.C.	30	26	111	45	Baked earth	3	0.98	0.01	54	0.5		
Neolithic	2200–1800 B.C.	30	32	111	23	Baked earth	2	0.76	0.01	42	0.5		
Shang	1600–1028 B.C.	30	54	114	23	Pottery	4	1.06	0.02	58	1.1		
Western Zhou	1027– 771 B.C.	30	32	111	23	Tripod	2	0.69	0.02	38	1.1		
Spring-Autumn	770– 220 B.C.	30	03	114	58	Baked earth	1	1.05	0.02	58	1.1		
Warring States	480– 220 B.C.	30	21	112	12	Baked earth	3	1.08	0.07	60	3.8		
Western Han	206B.C.–A.D.8	28	12	112	59	Baked earth	1	0.80	0.04	44	1.8		
Han	206B.C.–A.D.220	30	21	112	12	Grave brick	4	1.39	0.03	77	1.7		
Han	206B.C.–A.D.220	31	22	119	48	Grave brick	2	1.30	0.04	71	2.1	13.6	0.4
Han	206B.C.–A.D.220	32	03	118	50	Brick	2	1.63	0.06	90	3.2	18.2	0.6
Eastern Han	A.D. 25– 220	28	12	112	59	Baked earth	3	0.70	0.02	41	1.1		
Eastern Wu	A.D. 229– 231	30	15	120	08	Brick	3	1.43	0.02	78	1.1	16.1	0.2
Three Kingdoms	A.D. 220– 265	28	35	112	21	Brick	2	1.19	0.02	66	1.1		
Three Kingdoms	A.D. 238– 251	30	15	120	08	Brick	2	1.45	0.04	80	2.1	17.6	0.5
Eastern Wu	A.D. 222– 280	32	03	118	50	Brick	4	1.41	0.04	78	2.1	15.2	0.4
Wu	A.D. 272– 274	30	15	120	08	Brick	3	1.56	0.02	86	1.1	17.1	0.2
Wu	A.D. 275	30	15	120	08	Brick	3	1.47	0.04	81	2.1	17.1	0.4
Western Jin	A.D. 280– 289	30	15	120	08	Brick	3	1.21	0.01	67	0.6	14.7	0.1
Western Jin	A.D. 265– 316	31	22	119	48	Brick	2	1.26	0.05	69	2.7	14.5	0.5
Western Jin	A.D. 291– 299	30	15	120	08	Brick	2	1.38	0.04	76	2.1	14.4	0.4
Jin	A.D. 265– 420	28	11	112	59	Brick	2	1.06	0.05	58	2.7		
Eastern Jin	A.D. 317– 420	32	22	119	28	Brick	3	1.49	0.07	82	3.7	15.6	0.7
Northern Dyn.	A.D. 477– 499	30	15	120	08	Brick	3	1.19	0.03	65	1.6	13.4	0.3
South.-Northern	A.D. 420– 589	30	21	112	12	Grave brick	2	1.21	0.06	67	3.3		
Liang	A.D. 502– 530	32	03	118	50	Brick	3	1.44	0.08	79	4.2	15.7	0.8
Tang	A.D. 760– 907	32	22	119	28	Brick	3	1.06	0.03	58	1.6	11.7	0.3
Northern Song	A.D. 960–1127	29	08	119	11	Kiln brick	3	1.06	0.02	58	1.1	11.4	0.2
Northern Song	A.D. 960–1127	28	10	119	12	Kiln brick	3	0.93	0.02	51	1.1	9.9	0.2
Song	A.D. 960–1279	31	20	121	10	Brick	3	0.91	0.03	50	1.6	9.8	0.3
Southern Song	A.D.1127–1279	29	17	117	11	Kiln brick	5	1.15	0.02	63	1.1	12.8	0.2
Southern Song	A.D.1227–1279	31	16	121	35	Brick	2	1.02	0.01	56	0.6	10.8	0.1
Yuan	A.D.1271–1368	28	08	119	11	Kiln brick	3	1.14	0.01	63	0.6	12.5	0.1
Yuan	A.D.1271–1368	28	10	119	12	Kiln brick	3	1.00	0.02	55	1.1	11.7	0.2
Yuan	A.D.1271–1368	29	17	117	11	Kiln brick	5	0.86	0.01	47	0.6	9.8	0.1
Ming	A.D.1368–1661	29	17	117	11	Kiln brick	3	0.82	0.01	47	0.6	10.4	0.1
Ming	A.D.1368–1370	32	03	118	50	Brick	3	1.24	0.03	68	1.6	14.6	0.3
Ming	A.D.1368–1661	28	10	119	12	Kiln brick	4	0.78	0.01	45	0.6	10.2	0.1
Ming	A.D.1488–1505	32	03	118	50	Brick	3	0.88	0.03	48	1.6	10.2	0.3

1. Dynasty is a historical interval according to the Chinese chronology. SLA and SLO are north latitude and east longitude of sampling site. *N* is number of samples used. F_0/F is the ratio of the ancient intensity of geomagnetic field F_0 to the present day value F in the laboratory. *S* and S_0 are standard error of F_0/F and F_0 , respectively, i.e., $S_0 = S \cdot F$ (WEI, *et al.*, 1980). *M* and S_m are VDM and its standard error. F_0 and S_0 are given in μT ; *M* and S_m are given in 10^{22}Am^2 .

2. For some dynasties only paleointensity data have been quoted from previous results (WEI, *et al.*, 1983).

(a)

(b)

Fig. 2. NRM-TRM diagrams for samples from Shanghai, Southern Song(a); Dabaian, Northern Song(b); Hangzhou, Western Jin(c); Yixin, Western Jin(d); Jingdezhen, Yuan(e) and Anfu, Northern Song(f). Both NRM and TRM are in relative units.

Fig. 2. (continued).

afterwards. This general tendency of changes in intensity of geomagnetic field is undoubtedly true, even though the total error is about 20% when the effect of non-dipole field, experimental error, local geomagnetic anomaly and the error in the age of sample are all taken into account. It's interesting to compare these results with those for the Loyang region (WEI, *et al.*, 1982a). It can be noticed immediately that they agree quite well with each other for the period from 500 B.C. to A.D. 1500 (see Fig. 4) in spite of the difference in latitudes between the two regions.

As for the earlier period, for example, 1500 B.C.–A.D. 500, the value of ancient intensity decreased reaching a minimum at about 900 B.C. and subsequently increasing till the maximum at about A.D. 500. Before this period the total intensity of geomagnetic field was close to the present day level, with possibly slight increase between 2000 B.C. and 1300 B.C..

When the results for China are compared with those for Japan (TANAKA, 1982) it can be seen clearly that both Chinese and Japanese data for the last 6500 years reveal the same major features, even though the difference in latitude and longitude of sampling localities are not negligible. Moreover, the data sets obtained from China and the Middle-Near East by using ceramics (WEI and AITKEN, 1982) display similar characters of changes in ancient intensity for the period 3000 to 1000 B.C. and 500 B.C. to A.D. 1400.

In order to compare the new results of the present work for the southern part of China with the results of previous works for other parts, mainly Northern part of China, the Virtual Dipole Moment (VDM) was calculated and the variations of VDM with time are shown in Fig. 5. It is clear that all of the data agree that the magnetic moment of the Earth generally increased with time and reached maximum at about A.D. 500. Then it decreased gradually to the present-day value. It is also evident that the variations of shorter periods exist superposed on the gradual variations during the whole period under discussion, especially during the last 3000 years.

4. Conclusions

The results of present work provide some new data of ancient field intensity in southern part of China, along the Yangtze River valley, for the period between 4500 B.C. and A.D. 1500. These data agree well with those obtained previously from other parts of China, mainly along the Yellow River valley. Chinese paleointensity data for the last 6500 years agree with the already proposed interpretation that the total intensity of geomagnetic field has a maximal value at about A.D. 500 and then decreased to the present-day value. Before this period the field intensity has a slight minimum at about 900 B.C. (see Fig. 3(a)). Thus, the total intensity of geomagnetic field has changed more than twice during the period of about 1500 years between 900 B.C. and A.D. 500 and by about 60% during the last 1500 years.

Fig. 3. Variation of the total intensity of geomagnetic field in southern part of China for the period 4500 B.C. to A.D. 500 (a) and 500 B.C. to A.D. 1500 (b). ● is the present day value. F_0 is given in μT .

Fig. 4. Comparison of results for Loyang (curve) (Wei *et al.*, 1982a) and southern part of China.

Fig. 5. Variation of VDM from results for southern part (—) and all other parts (---) of China (Wei *et al.*, 1983) during the period 1000 B.C. to A.D. 1800.

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