

Paleointensity of the Geomagnetic Field in the Lower Early Permian

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We have obtained the value of the ratio of the ancient geomagnetic moment (M_{an}) to the present value (M_0) for specimens from two sections of effusive rocks (Aksaut River, northern Caucasus) dated as the bottom layers of the Early Permian: 1.25 ± 0.09 and 1.50 ± 0.09 .

Considering previous paleointensity determinations for the Early Permian and Middle and Late Carboniferous, we concluded that a significant decrease in H_{an} occurred in the bottom layers of the Early Permian.

During the Middle and Late Carboniferous, M_{an} was close to M_0 , though slightly higher [1, 2].

In rocks from the early Permian section of the northern Caucasus of representative thickness, $M_{an}/M_0 = 0.46$, and on specimens from an older Early Permian exposure in Uzbekistan, the magnetic moment ratio was 0.82 [3]. These data suggest a complex alteration of geomagnetic field paleointensity (H_{an}) in the bottom layers of the Early Permian. We thus collected new H_{an} data in this time interval.

Two Lower Permian sections were studied at the upper reaches of the Aksaut River in the northern Caucasus (average $\phi = 43^\circ N$, $\lambda = 41^\circ E$). According to geological estimates [4, 5], the constituent rocks belong to the lowest layers of the Early Permian, i.e., older than the rocks studied in [3].

The first section (left bank, Aksaut River) is approximately 400 m thick. It displays interstratified thin effusive flows and their pyroclastic varieties. The second section (right bank, Aksaut River) is less representative in terms of thickness (at most 150 m) but is similar to the first section in composition. Geologists consider it to be older than the left-bank section.

We selected oriented cores from baked contacts and baking porphyrites, and mainly we collected specimens from slagging zones and local reddened areas. In the left-bank section, we found 15 baked contacts and just 4 in the other exposure. About 900 oriented cores were collected.

In laboratory investigations, nearly half the specimens had magnetite as their main ferromagnetic component. After prolonged heating (according to

Tel'ier method), specimens were often oxidized and could not be used to determine geomagnetic field paleointensity. Such determinations were conducted according to the Wilson-Burakov method [6] (see right-hand side of the table).

We observed variations in the direction of I_n during laboratory heating after Tel'ier (usually up to 300-350°C). They were insignificant, and temperature cleaning produced good clustering of I_n vectors both for specimens from individual streams (contacts) and for entire sections. These paleomagnetic data are given in the left-hand side of the table. Averaged I_n direction for sections and the position of paleopoles were consistent with the data reported in [7] for rocks of a similar age from the same region.

In the right-hand side of the table, we give H_{an} determination data after Tel'ier and Wilson-Burakov. Average similarity coefficient $K = I_n/I_{rt}$ for the left-bank section, calculated separately using each method, diverges by ~9%. This may be due to the fact that Wilson-Burakov heating is associated with slight hematitization of specimens, which results in overestimation of K . Average K for right-bank rocks was virtually equal, regardless of heating method.

The large number of specimens (>500) used to estimate H_{an} , the large number of baked contacts (especially from the left-bank section), and the calculation of paleointensity on baking rocks should ensure the reliability of the obtained M_{an}/M_0 values.

About half the M_{an} determinations were on specimens whose ferromagnetic component was magnetite. Other H_{an} calculations were on hematite-containing specimens. No regular differences dependent on type of ferromagnetic material were observed.

Figure 1 gives two plots for specimens with different ferromagnetics. Figure 1a is the Arai-Nagata relation (after Tel'ier) for a hematite-containing specimen obtained from site 6 in the right-bank section. Figure 1b shows the relation after Wilson-Burakov on a specimen with $T_c = 575^\circ C$ from site 1 in the left-bank section. The different K in plots reflect the unequal average M_{an} for

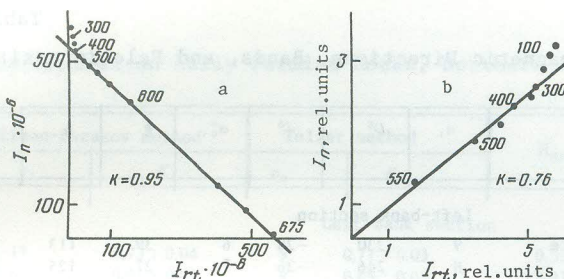


Fig. 1. Arai-Nagata relation: a) for hematite-containing specimens (Telier method); b) magnetite-containing specimens (Wilson-Burakov method).

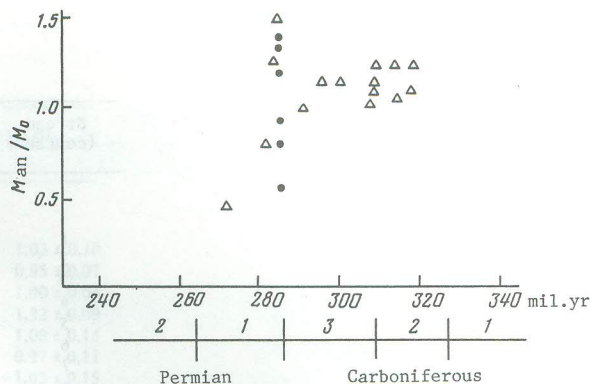


Fig. 2. M_{an}/M_0 determined on Permian/Carboniferous rocks. Author's results are shown by triangles and data of other investigators by circles.

sections but not a difference in ferromagnetic composition.

For final calculation of average K for sections, we took values determined after Telier. Only where such data were absent did we take K calculated after Wilson-Burakov. In the left-bank section, 372 specimens from 41 streams (contacts) had $K = 0.83 \pm 0.02$, $H_{an} = (0.43 \pm 0.02)$ Oe,

$M_{an}/M_0 = 1.25 \pm 0.09$. The position of the paleopole was $\phi = 34^\circ$, $\Lambda = 155^\circ$ at $A = 3^\circ$. For the right-bank exposure (155 specimens, 14 streams (contacts)), $K = 1.00 \pm 0.01$, $H_{an} = (0.51 \pm 0.01)$ Oe, $M_{an}/M_0 = 1.50 \pm 0.09$. The average position of the paleopole was $\phi = 30^\circ$, $\Lambda = 123^\circ$, $A = 6^\circ$.

The geomagnetic moment in the oldest Lower Permian section studied exceeds the present value by 25-30%. The standard deviation of M_{an}/M_0 from average S was 0.19 for the left-bank section and 0.13 for the right-bank section.

We now consider the set of M_{an} determined from our study. In the Middle and Late Carboniferous, average M_{an} remained above M_0 for a long time [1, 2]. The situation was similar at the bottom of the Early Permian (Aksaut sections). These data were followed by H_{an} determinations on a younger Lower Permian section in Uzbekistan ($M_{an}/M_0 = 0.82$). Finally, the large section of the upper portion of the Early Permian in Teberda [3] yielded $M_{an}/M_0 = 0.46$. These data are shown by triangles in Fig. 2.

The results indicate that approximately at the boundary between the Carboniferous and the Permian and most likely in the bottom portion of the Early Permian, geomagnetic field paleointensity decreased by approximately a factor of 2. Judging by the stratigraphic position of sections, the diminution in M_{an} occurred within a relatively short geological time period (probably just a few million years).

The circles in Fig. 2 mark M_{an} in the Early Permian determined by other investigators [8-11]. One is struck by the wider scatter of M_{an}/M_0 (from 0.4 to 1.4), which at first seems difficult to explain. However, we can resort to the hypothesis of a significant variation in H_{an} in the Lower Permian.

Because of the lack of exact datings, all H_{an} values from other investigators have been assigned in [8] to a single time point in the lower portion of the Early Permian by way of convention. In reality, M_{an} values probably belong to different geologic epochs: large M_{an} were determined on older rocks and small M_{an} on relatively younger formations after the paleointensity level had declined. Intermediate M_{an} refer to the period when the process of variation of the paleointensity of the earth's magnetic field took place. If this hypothesis is correct, the scatter of M_{an}/M_0 values in the bottom portion of the Early Permian is fully accounted for.

The hypothesis of a cyclic variation in M_{an} with a period of 260-280 million years was advanced from a statistical analysis of reliable M_{an} data for the past 400 million years. This suggestion was consistent with the available knowledge on H_{an} at that time. New information on the paleointensity of the Permian and Carboniferous should modify the shape of the M_{an} variation curve presented in [8]. In fact, the 260-280 million year cycle has now been called into doubt. The relatively low M_{an} in the Early Permian and the approximately similar paleointensity of the geomagnetic field established

Table
Paleomagnetic Directions, Bands, and Paleointensity

Stream (contact)	Rock	n_1	D°	j°	α_{D}°	Φ	Λ	A
Left-bank section								
1	Red porphyrite	9	230	-28	6	39	113	5
2		8	246	-26	7	27	125	6
3	Red porphyrite	10	244	-6	6	21	115	4
4		6	241	-12	8	25	115	5
5		5	235	-28	9	36	119	7
6		8	234	-36	6	40	124	5
7	Red tuffobrecchia	4	224	-28	10	43	108	8
8	Red porphyrite	7	242	-44	8	37	125	8
9		5	219	-20	9	43	99	7
10		7	241	-41	6	37	131	6
11	Red slag	6	232	-42	9	44	131	9
12	Porphyrite	8	259	-29	7	19	131	6
13	Red slag	6	248	-20	9	23	124	7
14	Porphyrite	6	227	-16	6	36	105	4
15	Red slag	8	218	-28	8	47	102	6
16	Red porphyrite	9	224	-30	7	44	109	6
17		14	230	-33	6	41	116	5
18	Red slag	11	223	-33	6	46	110	5
19	Ref tuff	10	222	-25	8	43	104	6
20	Red porphyrite	14	227	-23	7	39	108	5
21		12	244	-25	6	28	124	5
22		10	250	-12	5	19	122	4
23	Red porphyrite	9	240	-8	8	24	112	6
24		10	224	-5	6	34	98	4
25		10	254	-28	9	22	131	7
26		5	254	-21	10	19	127	8
27		8	252	-20	6	20	126	5
28		11	237	-16	5	29	113	4
29	Red slag	15	230	-30	6	40	115	5
30	Red porphyrite	15	233	-20	6	34	110	5
31	Tuff	18	228	-20	5	38	109	4
32	Red porphyrite	13	224	-28	8	44	110	6
33	Red tuffobrecchia	7	236	-18	7	31	114	5
34	Ref tuff	16	226	-25	6	40	107	5
35	Red porphyrite	8	229	-28	8	40	113	6
36	Tuff	9	225	-29	7	43	110	6
37		4	235	-30	10	36	118	8
38	Red porphyrite	6	249	-40	9	31	131	8
39	Ref tuff	6	238	-21	11	30	115	8
40	Red porphyrite	8	254	-11	9	20	131	6
41	Ref tuff	17	220	-9	7	38	95	5
	Total for section	378	235	-25	4	34	115	3
					$K_1 = 33$			
Right-bank section								
1	Tuffoclay	12	254	-37	7	25	125	6
2	Tuffosandstone	5	254	-32	10	23	127	8
3	Red porphyrite	13	248	-32	6	29	131	8
4		11	260	-20	8	14	128	6
5	"	5	252	-27	10	23	131	8
Right-bank section								
6	Red porphyrite	4	234	-40	10	41	122	9
7		7	238	-44	9	40	126	9
8	Porphyrite	11	242	-26	9	30	123	7
9	Red porphyrite	8	237	-31	10	35	120	8
10	"	8	240	-22	8	30	120	6
11	"	8	228	-5	7	31	101	5
12	"	8	235	-10	9	29	110	6
13	"	7	234	-14	8	31	110	6
14	"	7	238	-20	10	30	115	8
	Total for section	114	242	-26	7	30	123	6
					$K_2 = 33$			

Note: 1: Streams (contacts) are numbered from younger to older rocks. 2: amount of specimens. 4: K_1 and K_2 are similarity coefficients equal to I_n/I_{rt} ; rections are calculated in present-day coordinate system.

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Determined on Early Permian Rocks, Northern Caucasus

Wilson-Burakov method		Telier method		H_{an}, Oe	M_{an}/M_0
n_2	K_1	n_3	K_2		
Left-bank section					
17	0.73 ± 0.04	9	0.71 ± 0.03	0.36 ± 0.03	1.03 ± 0.10
6	0.91 ± 0.02	8	0.65 ± 0.02	0.33 ± 0.02	0.95 ± 0.07
11	0.86 ± 0.02	8	0.63 ± 0.02	0.32 ± 0.02	1.00 ± 0.04
6	0.84 ± 0.03	—	—	0.43 ± 0.03	1.32 ± 0.09
7	0.79 ± 0.03	10	0.75 ± 0.03	0.38 ± 0.03	1.08 ± 0.15
12	0.83 ± 0.02	8	0.71 ± 0.03	0.36 ± 0.03	0.97 ± 0.11
8	0.82 ± 0.04	8	0.70 ± 0.03	0.36 ± 0.03	1.03 ± 0.15
11	0.84 ± 0.02	8	0.80 ± 0.02	0.41 ± 0.02	1.02 ± 0.12
5	0.84 ± 0.02	6	0.66 ± 0.02	0.34 ± 0.02	1.01 ± 0.10
5	0.82 ± 0.02	7	0.57 ± 0.02	0.29 ± 0.02	0.75 ± 0.09
9	0.86 ± 0.03	—	—	0.44 ± 0.03	1.37 ± 0.17
2	0.94 ± 0.02	—	—	0.48 ± 0.02	0.98 ± 0.13
4	0.93 ± 0.02	—	—	0.48 ± 0.02	1.43 ± 0.12
4	0.89 ± 0.02	6	0.61 ± 0.02	0.31 ± 0.02	0.94 ± 0.08
9	0.84 ± 0.02	6	0.92 ± 0.03	0.47 ± 0.03	1.34 ± 0.13
2	0.89 ± 0.02	9	0.79 ± 0.02	0.41 ± 0.02	1.15 ± 0.11
7	0.88 ± 0.02	16	0.80 ± 0.02	0.41 ± 0.02	1.13 ± 0.10
11	0.87 ± 0.01	15	0.79 ± 0.02	0.41 ± 0.02	1.13 ± 0.10
8	0.94 ± 0.03	9	0.81 ± 0.02	0.42 ± 0.02	1.22 ± 0.11
12	0.97 ± 0.01	—	—	0.50 ± 0.01	1.47 ± 0.08
14	0.95 ± 0.01	13	0.81 ± 0.01	0.42 ± 0.01	1.22 ± 0.07
14	0.92 ± 0.02	10	0.73 ± 0.01	0.37 ± 0.01	1.14 ± 0.05
10	0.94 ± 0.02	10	0.69 ± 0.02	0.35 ± 0.02	1.09 ± 0.08
7	0.96 ± 0.03	—	—	0.49 ± 0.03	1.52 ± 0.10
12	0.93 ± 0.02	—	—	0.48 ± 0.02	1.37 ± 0.14
5	0.95 ± 0.03	5	0.83 ± 0.03	0.43 ± 0.03	1.28 ± 0.15
10	0.92 ± 0.03	—	—	0.47 ± 0.03	1.40 ± 0.13
7	0.91 ± 0.02	10	0.87 ± 0.02	0.45 ± 0.02	1.37 ± 0.09
6	0.83 ± 0.04	6	0.89 ± 0.03	0.46 ± 0.03	4.30 ± 0.14
6	0.91 ± 0.02	13	0.89 ± 0.01	0.46 ± 0.01	1.37 ± 0.07
13	0.87 ± 0.01	14	0.92 ± 0.01	0.47 ± 0.01	1.39 ± 0.07
12	0.88 ± 0.02	13	0.95 ± 0.01	0.49 ± 0.01	1.40 ± 0.10
6	0.89 ± 0.03	7	0.91 ± 0.02	0.47 ± 0.02	1.41 ± 0.10
13	0.87 ± 0.02	18	0.91 ± 0.01	0.47 ± 0.01	1.37 ± 0.07
9	0.89 ± 0.02	8	0.91 ± 0.02	0.47 ± 0.02	1.34 ± 0.13
6	0.86 ± 0.03	10	0.90 ± 0.02	0.46 ± 0.02	1.30 ± 0.12
8	0.88 ± 0.02	4	0.94 ± 0.02	0.48 ± 0.02	1.35 ± 0.15
4	0.92 ± 0.03	6	0.90 ± 0.02	0.46 ± 0.02	1.19 ± 0.15
7	0.94 ± 0.02	6	0.85 ± 0.01	0.44 ± 0.01	1.31 ± 0.10
7	0.85 ± 0.02	8	0.93 ± 0.02	0.48 ± 0.02	1.48 ± 0.10
13	0.86 ± 0.02	16	0.92 ± 0.02	0.47 ± 0.02	1.46 ± 0.08
345	0.88 ± 0.01	310	0.81 ± 0.01 $S = 0.19$	0.43 ± 0.02	1.25 ± 0.09
Right-bank section					
13	0.99 ± 0.02	4	1.03 ± 0.03	0.53 ± 0.03	1.41 ± 0.16
6	1.00 ± 0.02	5	0.99 ± 0.02	0.51 ± 0.02	1.42 ± 0.16
17	0.99 ± 0.02	10	0.97 ± 0.03	0.50 ± 0.03	1.39 ± 0.14
8	1.01 ± 0.03	—	—	0.52 ± 0.33	1.55 ± 0.15
16	0.94 ± 0.03	—	—	0.48 ± 0.03	1.38 ± 0.17
Right-bank section					
4	0.96 ± 0.02	4	0.94 ± 0.03	0.48 ± 0.03	1.25 ± 0.11
6	0.98 ± 0.03	7	0.99 ± 0.04	0.51 ± 0.04	1.27 ± 0.17
16	1.05 ± 0.02	—	—	0.54 ± 0.02	1.56 ± 0.14
13	1.00 ± 0.03	—	—	0.51 ± 0.03	1.43 ± 0.18
9	1.04 ± 0.03	—	—	0.53 ± 0.03	1.57 ± 0.15
12	1.03 ± 0.03	—	—	0.53 ± 0.03	1.65 ± 0.11
18	1.01 ± 0.02	—	—	0.52 ± 0.02	1.61 ± 0.10
13	1.01 ± 0.03	—	—	0.52 ± 0.03	1.59 ± 0.11
11	1.07 ± 0.04	—	—	0.55 ± 0.04	1.64 ± 0.18
162	1.01 ± 0.01	33	0.99 ± 0.01 $S = 0.13$	0.52 ± 0.01	1.50 ± 0.09

Underlines in second column indicate baked contacts. 3: η_1 , η_2 , and η_3 are K_3 is clustering of I_n vectors for entire sections. 5: All paleomagnetic di-

in several studies for the Devonian can no longer unequivocally support an H_{an} variation with this period.

The variation in the earth's magnetic moment during the last 400 million years may have been more complex than what was suggested in [8]. It

is possible that there are not one but several different H_{an} variation cycles. New M_{an} data should help supply answers to these questions.

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