Tectonophysics, 41 (1977) T27—T33 T27

Letter Section

Paleomagnetism of the Triassic Chugwater redbeds revisited (Wyoming, U.S.A.)[1]

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(Submitted February 1, 1977; accepted March 29, 1977)

ABSTRACT

Van der Voo, R. and Grubbs, K.L., 1977. Paleomagnetism of the Triassic Chugwater redbeds revisited (Wyoming, U.S.A.). Tectonophysics, 41: T27—T33.

Paleomagnetic results from 107 samples of the Chugwater Group near Lander, Wyoming, show a regular progression in pole positions from bottom to top of the sequence. This pole position trend of about 25° matches very well the North American apparent polar wander path between Early Permian and Early Triassic. It could be argued that this "agreement" results in a conflict between the apparent magnetic age (Permian) and the Early to Late Triassic age generally assigned to the Chugwater Group. However, similar progressions of paleomagnetic pole positions have been reported for the Early Triassic Moenkopi Formation in Colorado; thus it appears that long-term variations and swings characterized the geomagnetic field at that time. With detailed paleomagnetic sampling, these features can be utilized for stratigraphic correlation in addition to magnetic-reversal stratigraphy. This will eliminate, to some degree, part of the non-uniqueness inherently present in correlations based on reversal stratigraphy only.

INTRODUCTION

Comparatively speaking, paleomagnetic results from North American rocks with ages between Late Carboniferous and Late Triassic form one of the most abundant and internally consistent data sets in the paleomagnetic literature. Consequently, it can be argued that further studies of rocks of these ages are a waste of time. However, a study of tectonic rotations in the Western Wyoming fold-thrust belt, published earlier (Grubbs and Van der Voo, 1976), revealed that the redbeds studied had consistently low inclinations when compared with results from contemporaneous rocks. These redbeds of the Woodside and Ankareh Formations are generally thought to be

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of Triassic age, though age-significant fossils are rare and ages have been assigned mostly on lithological correlations (High and Picard, 1969; Boyd and Maughan, 1972). Since the redbeds in the thrust-fold belt itself are not very suitable for paleomagnetic stratigraphy because of their isolated occurrences and complex structural relationships (e.g., Dorr et al., 1977) we decided to investigate the paleomagnetic directions of similar redbeds in the adjacent foreland, in particular those of the Chugwater Group west of Lander, Wyoming.

Black (1960), Collinson and Runcorn (1960), and Picard (1964) first studied the paleomagnetism of the Chugwater. Picard found evidence for correlatable reversals in six sections in central Wyoming. However, all these early results were not obtained through demagnetization analysis and a few of Picard's "normal polarity" zones may, in fact, be reversed zones with a strong secondary overprinting of recent origin.

SAMPLING AND RESULTS

West of Lander, Wyoming, a section of about 220 m of the Chugwater redbeds, consisting of alternating shaley and more competent silty to sandy layers, is exposed continuously in a red canyon. Two formations, the Red Peak and the Popo Agie, make up the Chugwater Group; a thin limestone unit, the Alcova limestone, is very characteristic and is found near the base of the younger Popo Agie Formation. Paleomagnetic samples were drilled at stratigraphic intervals of generally less than one meter from the more competent beds, which form massive cliffs of 5—20 m thickness. For convenience, samples from a given massive bed are grouped into a site; six sites were sampled in the lower Red Peak Formation, and one site in the upper Popo Agie Formation, comprising in total about 200 m of the stratigraphic section. In addition, one site in the uppermost part of the redbeds was sampled north of the Gros Ventre River. Geographic coordinates are given in Table I. In total, 107 samples were measured and demagnetized.

The natural remanent magnetization of the samples was measured with Schonstedt, cryogenic and Digico magnetometers. About 25% of the samples initially displayed directions that were steeply down and could be mistaken for normal polarity. Thermal demagnetization, however, removed a large secondary magnetization in these samples and revealed in all but one site reversed polarities (Fig. 1). Behavior during demagnetization was identical to that of our earlier study and we refer for further details of thermal stability, blocking temperatures, analysis methods, etc., to Grubbs and Van der Voo (1976). All samples were thermally demagnetized in at least four steps up to 650°C.

After demagnetization and (minor) correction for the tilt of the strata, the directions cluster nicely (Fig. 1). Only three samples had "intermediate" directions of magnetization (Fig. 1, triangles) reminiscent of the intermediate directions found by Picard. The overall mean pole of the eight sites (48.5°N,

TABLE I

SITE-MEAN DIRECTIONS OF MAGNETIZATION

Site	*N*	Mean direction of magnetization				Site location		Pole position		Remarks
Nr.		Decl.	Incl.	*k*	α_{95}	long.	lat.	long.	lat.	
8	10	166.5	−19.4	13.5	13.6	−108° 28′	42° 25′	95.5°	55.5°	youngest site
7	28	158.0	−11.4	33.9	4.8	−110° 33′	43° 38′	102.9°	47.4°	
6	9	338.0	+ 7.2	45.7	7.6	−108° 28′	42° 25′	104.5°	46.5°	the only normal-polarity site
5	18	158.7	−17.2	34.4	5.9	−108° 28′	42° 24′	106.8°	51.5°	one sample excluded
4	25	154.0	−19.5	27.6	5.6	−108° 28′	42° 24′	114.3°	50.4°	
3	6	150.2	−11.8	49.4	9.6	−108° 28′	42° 24′	116.0°	45.0°	one sample excluded
2	2	139.9	−17.1	233.4	16.4	−108° 28′	42° 24′	129.6°	41.3°	
1	6	146.6	−19.6	34.9	13.1	−108° 28′	42° 24′	123.5°	46.4°	one sample excluded oldest site

Mean of all 8 sites: decl. 154.0, incl. −15.5; $k = 77.8$ $\alpha_{95} = 6.3°$

Mean of 8 pole positions: long. 112.2°, lat. 48.5°, $k = 86$; $\alpha_{95} = 5.9°$

N is the number of samples used in the computation of the mean direction; decl. and incl. are declination and inclination, respectively; *k* and α_{95} are the statistical parameters.

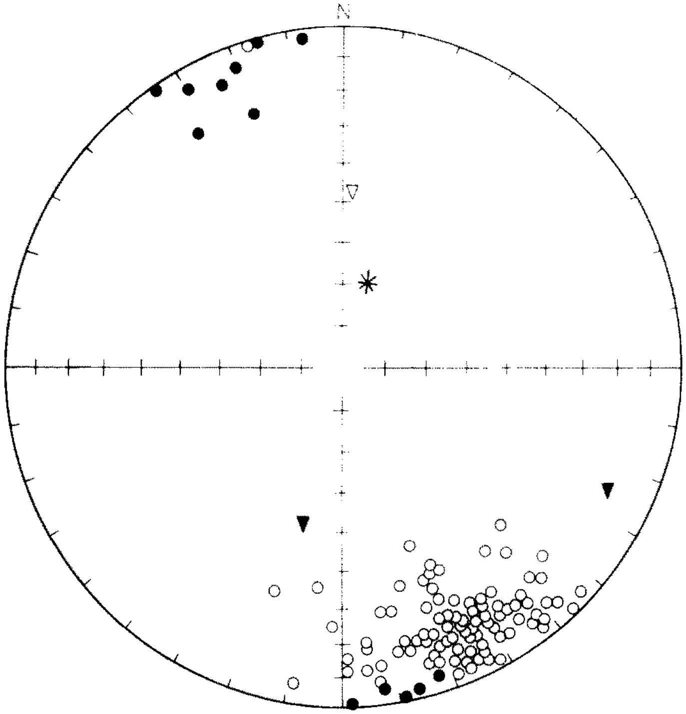

Fig. 1. Characteristic directions of magnetization, obtained through thermal demagnetization of all 107 samples of the Chugwater Formation. Directions are corrected for the (minor) tilt of the strata and are plotted in equal-area projection. Closed (open) symbols represent projections in the lower (upper) hemisphere; the asterisk is the present-day geomagnetic direction; the three triangles are from samples which have not been included in the computation of the mean directions.

112.2°E) agrees very well with the previous poles for the Chugwater published by Black (1960: 51°N, 108°E) and by Collinson and Runcorn (1960: 48°N, 112.5°E). In Table I the results are grouped by site; only site 6 showed normal polarity. This site, just below the Alcova limestone, corresponds to the unambiguously normal polarity zone 6 of Picard (1964). However, since the more shaley intercalations of the sequence were not sampled, it would be unwise to attach undue significance to the magnetic stratigraphy.

On the other hand, an unexpected result came out of the directions of the successive sites. As can be seen in Table I, their directions progress from old to young in a fairly regular manner: the declination changes gradually from about 140° to 166°, whereas the inclination is consistently low, but does not change nearly as much. This progression is even more striking in a plot of the resulting pole positions (Fig. 2). Since all but one of the sites were located in the same structural unit, relative rotations between the sites can be ruled out.

Also plotted in Fig. 2 are published pole positions from North America, derived from Late Permian and Early Triassic formations in northeastern Canada and from the Colorado Plateau. These poles are taken from the compilation by Van der Voo and French (1974), with some recent additions (Peterson and Nairn, 1971; Gose and Helsley, 1972; Helsley and Steiner, 1974). The sequence of Late Permian and Early Triassic poles forms a regular streak between the mean Early Permian and Late Triassic poles (Fig. 2: stars;

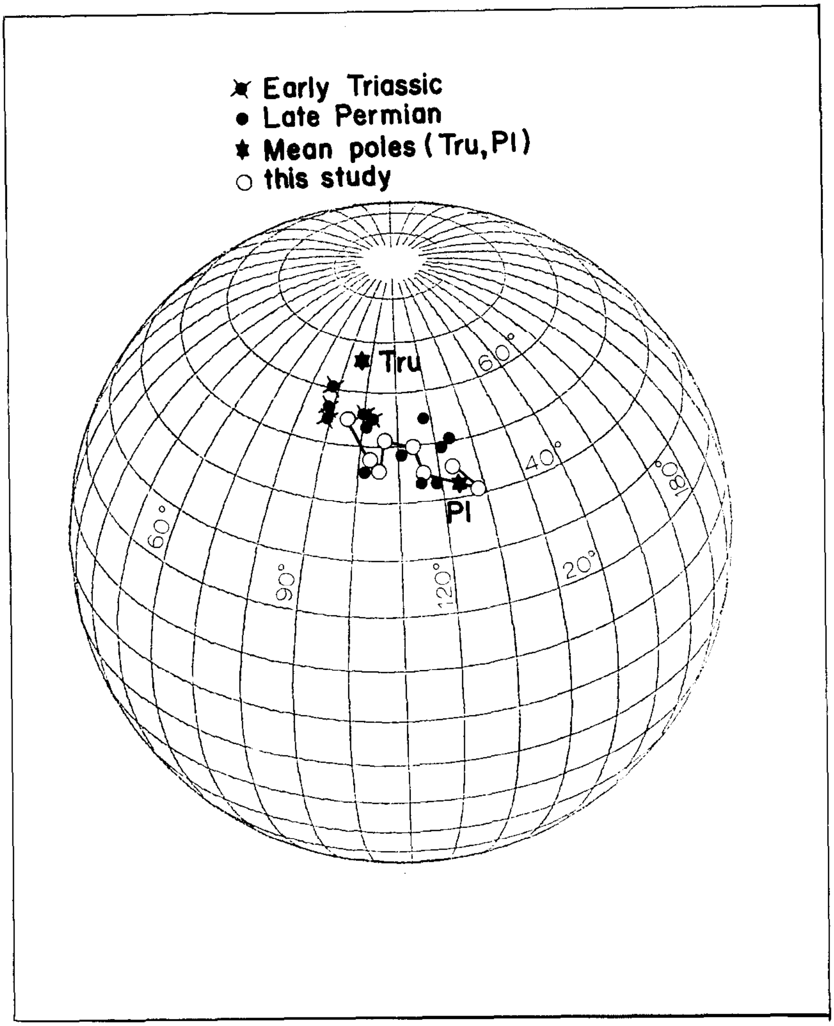

Fig. 2. Pole positions from this study (see Table I) and from the literature (see text). The mean poles for the Early Permian and the Late Triassic are from Van der Voo and French (1974); the mean poles for Late Permian and Early Triassic have not been plotted to avoid crowding.

from Van der Voo and French, 1974). The apparent polar wander path for North America appears to progress regularly from SE to NW, as recently noted also by Diehl and Shive (1976). In Fig. 2 it can be seen that the general trend of our site-mean poles matches this apparent polar wander path extremely well. What is remarkable, however, is that the Triassic age brackets as presently assigned to the Chugwater Group (High and Picard, 1969; Boyd and Maughan, 1972) appear to disagree with the ages of the other poles. Assuming that the ages of the Colorado Plateau formations and of the Manicouagan structure in Quebec (225 Ma; Robertson, 1967; Larochelle and Currie, 1967) as well as of the Prince Edward Island sill (Larochelle, 1967) are all correctly assigned, one conclusion would be that the Chugwater Group is older than previously believed and straddles the Permian—Triassic boundary. The normal polarity of site 6, just below the Alcova limestone, would then be one of the first post-Kiaman interval (Irving, 1964) reversals.

On the other hand, it is very well possible that the geomagnetic field during the Triassic displayed long-term variations which are in part recorded in the Chugwater redbeds. Helsley and Steiner (1974) found evidence for such variations in the Early Triassic Moenkopi Formation in Colorado. Pole positions, calculated by them for each stratigraphic level, were located along the entire path between the mean Permian and uppermost Triassic poles for North America, displaying great similarity with the results of Fig. 2. They concluded that paleomagnetic poles derived from short stratigraphic sections would not have been valid representations of the pole for the entire formation.

Comparing our pole positions and reversals (Table I) with the sequence of poles for the Moenkopi redbeds (Helsley and Steiner, 1974: table 1) a tentative correlation can be made between our site 6 and their interval N4. Our sites 1—5 would then correlate with interval R4 (plus possibly R3), whereas sites 7 and 8 agree with interval R5.

Detailed paleomagnetic sampling at a few other locations, and including the less competent shales, could establish this correlation more firmly. Potentially, the directional variations in the Early Triassic redbeds can be utilized for good stratigraphic correlations in addition to reversal stratigraphy.

ACKNOWLEDGEMENTS

We thank Drs. D.W. Boyd, J.A. Dorr Jr., D.V. Kent, N.D. Opdyke and M. Steiner for valuable comments and critique of the manuscript. Especially Maureen Steiner contributed greatly by pointing out the analogies between the Moenkopi and Chugwater paleomagnetic results.

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