Geol. Soc. Malaysia, Bulletin, 10, Dec. 1978; pp. 53–62

Reconnaissance Palaeomagnetic Measurements on Triassic and Jurassic Sedimentary Rocks from Thailand

SANDRA M. BARR
Department of Geology, Acadia University, Wolfville, N.S., Canada

ALAN S. MACDONALD*
Department of Geological Sciences
Chiang Mai University, Chiang Mai, Thailand

NEVILLE S. HAILE
Department of Geology, University of Malaya, Kuala Lumpur, Malaysia

Abstract: Reddish siltstones of Triassic and Jurassic age in northern Thailand are suitable for palaeomagnetic measurements. Groups of samples from east of the Khorat Plateau (Loei—Lomsak—Pitsanulok area), from the Ngao—Phrae highway, and from the Tak—Mae Sod Highway yield fairly consistent palaeomagnetic directions, with mean declination 26.3°, inclination 35.7°. This direction gives a palaeomagnetic pole at 64°N, 171°E for Thailand in Triassic—Jurassic time.

INTRODUCTION

Sedimentary rocks acquire Natural Remanent Magnetism (NRM) at the time of their deposition as a result of preferred orientation of constituent magnetic minerals so that their magnetic fields lie parallel to the Earth's magnetic field at the time and place of deposition. This palaeomagnetism (fossil magnetism) is normally retained by the rocks up to the present time, unless it is modified by events capable of affecting magnetic fields, such as chemical alteration, heating, or lightning strikes. The past occurrence of these types of events can usually be detected by examination of the rocks, by multiple sampling, or by behaviour of the magnetism as the rock specimens are progressively demagnetized by heating in the laboratory (Collinson and others 1967).

Measurements of palaeomagnetic directions in rocks may be used to indicate the position of the rock formation on the surface of the Earth relative to the magnetic poles (palaeopoles) at the time of sediment deposition. If the samples represent an age span of some thousands of years, the mean palaeopole determined is believed to approximate to the geographic pole. Thus they reveal relative movements of blocks of the Earth's crust, and provide important evidence for continental drift and plate tectonics. Prior to the present study, palaeomagnetic measurements had been made on only nine sedimentary rocks from Thailand (Haile and Tarling, 1975), in spite of the potential importance of such data in providing or disproving interpretations of tectonic history, as shown for example by Stauffer (1974) and McElhinney, and others (1974). Several geological formations in Thailand are very suitable for palaeomagnetic studies, especially the Mesozoic redbeds of the Lampang and Khorat Groups.

On field trips during July, 1975 and April, 1976 oriented hand samples were collected by the first two authors from several outcrops of Triassic and Jurassic sedi-

*Present address: R.R. 3, Wolfville, N.S., Canada.

mentary rock formations in northern Thailand (Fig. 1). Hand samples were oriented by magnetic compass. Two or three oriented cylindrical specimens were drilled from each and measured by the third author in the palaeomagnetic laboratory of the Department of Geology, University of Malaya, Kuala Lumpur, Malaysia.

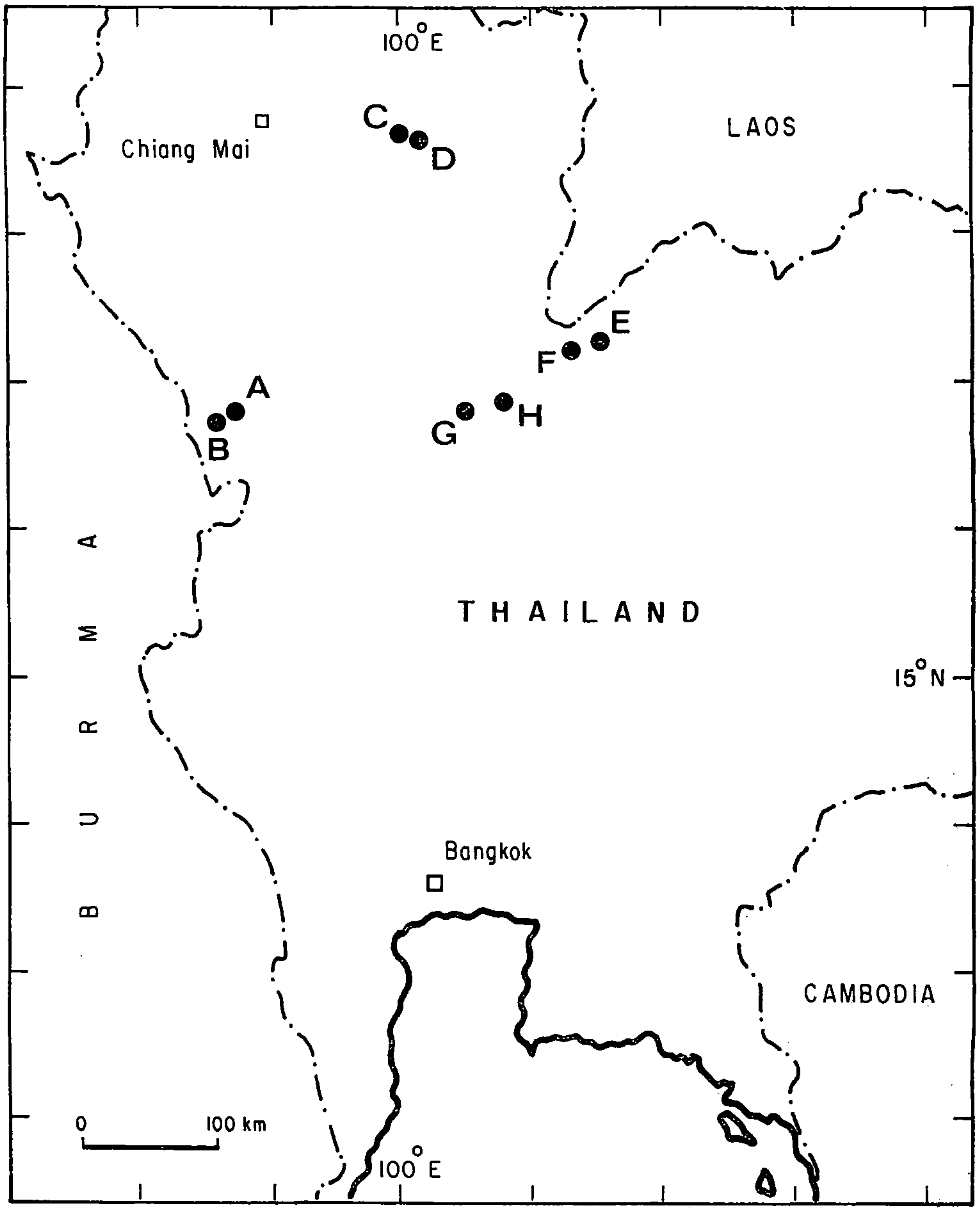

Fig. 1. Sampling localities of Triassic—Jurassic sedimentary rocks for palaeomagnetic studies. Localities A to F, this study. Localities G and H from Haile and Tarling (1975).

SAMPLING LOCALITIES

Samples were collected from six separate localities (A to F, Fig. 1). All samples were collected from roadside outcrops. Previously published magnetic data (Haile and Tarling, 1975) were for samples from Localities G (Lower Jurassic) and H (Upper Jurassic), also shown on Figure 1.

Locality A: Tak—Mae Sod Highway, Km 50.0 from Tak.
Lat. 16.8°N, Long. 98.7°E.
Samples SMB—10, 11, 12.
Middle Triassic pink calcareous siltstones, occurring in a block faulted down into Permian sedimentary rocks (R.B. Stokes, pers. comm., 1975).

Locality B: Tak—Mae Sod Highway, Km 68.0 to 68.4 from Tak.
Lat. 16.7°N, Long. 98.6°E.
Samples SMB—16, 17, 18, 19, 20, 21.
Red siltstones interbedded with shales. These rocks are considered to be Lower Middle Jurassic (R.B. Stokes, pers. comm., 1975). However, other workers (Braun and Jordan, 1976) consider these same rocks to be Lower Triassic.

Locality C: Phrae—Ngao Highway, Km 61.5 from intersection with Phrae—Nan Highway.
Lat. 18.7°N, Long. 100.0°E.
Samples SMB—51, 52, 53.
Red sandstones, interbedded with shales. These rocks are shown as part of the Lampang Group, Hong Hoi Formation (Middle Triassic) on the geological map of Changwat Lampang (Piyasin, 1971). However, more recent work indicates that they may belong to the Upper Triassic Pha Daeng Formation (M. Liengsakul, pers. comm., 1977).

Locality D: Phrae—Ngao Highway, Km 44.4 from intersection with Phrae—Nan Highway
Lat. 18.6°N, Long. 100.1°E.
Samples SMB—54, 55, 56.
Red siltstones interbedded with shales. These rocks belong to the Lampang Group, Hong Hoi Formation, Middle Triassic (Piyasin, 1971).

Locality E: Loei—Dan Sai—Lomsak Highway, Km 29.0 from Loei.
Lat. 17.5°N, Long. 101.4°E.
Samples SMB—44, 45, 46, 47.
Red siltstones interbedded with shales. These rocks belong to the Khorat Group, Phu Kradung Formation, Upper Triassic to Lower Jurassic (Geological Map of Thailand, 1969).

Locality F: Loei—Dan Sai—Lomsak Highway, Km 75.5 from Loei.
Lat. 17.2°N, Long. 101.2°E.
Samples SMB—48, 49, 50.
Red siltstones interbedded with shales. These rocks belong to the Khorat Group, Phu Kradung Formation, Upper Triassic to Lower Jurassic (Geological Map of Thailand, 1969).

RESULTS

Initial intensities of NRM ranged from 90 mA m^{-1} to less than 0.1 mA m^{-1}. These are typical intensity values for sedimentary rocks.

One core from each sample was progressively demagnetized by heating in steps of 50°C or 100°C to a maximum of 550°C. In general, palaeomagnetic directions did not change significantly during this "cleaning" until at least 400°C, and many samples were stable throughout the entire range of cleaning to 550°C. At this temperature the intensity of magnetization had typically been decreased to between 10 and 70 percent of its original value, indicating that the magnetization, while stable, varies considerably in hardness. Exceptions to this pattern are samples from Locality C, which possessed both soft and unstable magnetization; these samples will be further discussed below.

On the basis of these pilot demagnetizations of one core from each sample, all cores were demagnetized to 100°C, or 200°C, and mean cleaned directions (Nagata, 1961), were calculated for each sample. Original and cleaned directions of NRM are given in Table 1, and plotted on Figure 2. Samples from Haile and Tarling (1975) were cleaned at 300°C.

DISCUSSION

Reasonable agreement exists among palaeomagnetic directions of samples from Localities A, D, E, F. and G (Table 1, Fig. 2 A). All these samples are from Middle Triassic to Lower Jurassic formations. Their mean cleaned direction has declination 35.6°, inclination 38.8°, which gives, using the method of Nagata (1961), a palaeomagnetic pole at 56°N, 176°E.

The three samples from Locality C show very different directions (Table 1, Fig. 2 A). As noted above, behaviour of these samples during cleaning was not typical. The reason for inconsistent results from this locality is not known, but may be caused by magnetic effects since the rocks were formed. Further sampling from this locality is required to clarify the situation, and hence data from Locality C are disregarded at this time.

Samples from Localities B and H indicate palaeomagnetic directions somewhat different from the first group of localities, with mean declination 2.0° and inclination 22.6 (Table 1, Fig. 2 B), which indicate a palaeomagnetic pole at 80°N, 111°E (Table 2, Fig. 3). Insufficient sampling exists to know whether or not the difference between this palaeopole and that derived from the Triassic-Lower Jurassic rocks (Fig. 3) represents a significant change in the palaeoposition of Thailand during the Jurassic, although this seems quite probable. Furthermore, uncertainty exists as to the age of samples from Locality B (see section on Sampling Localities). In view of these limitations, it is perhaps safest to use all samples (excluding Locality C) to determine a mean palaeomagnetic direction for Triassic and Jurassic sedimentary rocks in Northern Thailand—declination 26.3°, inclination 35.7° (Table 2), giving a palaeomagnetic pole at 64°N, 171°E (Fig. 3).

Although the number of samples and sampling localities is really insufficient to draw definite conclusions, similarity in palaeomagnetic directions between samples from "western" Thailand (Localities A, B, D) and "eastern" Thailand (Localities E, F, G, H) support the geological evidence and tectonic interpretation of Stauffer (1974) that Thailand was essentially a single tectonic block by Early Mesozoic time.

TABLE 1

Remanent magnetism of samples from Triassic and Jurassic sedimentary rocks from Thailand. Samples localities are shown on Figure 1 and described in the text. Localities G and H are from Haile and Tarling (1975).

Locality	Sample Number	Sample Mean NRM Direction D	Sample Mean NRM Direction I	Sample Mean Cleaned Direction* D	Sample Mean Cleaned Direction* I	Locality Mean Cleaned Direction* D	Locality Mean Cleaned Direction* I	R	K	α
	SMB-10	21.1	54.2	27.1	60.1	11.8	41.2	2.8742	15.9	32
A	SMB-11	12.3	30.9	13.9	24.1					
	SMB-12	12.5	42.3	359.8	38.4					
	SMB-16	22.1	6.1	14.7	-11.7	4.2	6.8	5.7261	18.3	16.1
	SMB-17	18.2	11.2	5.5	- 6.2					
B	SMB-18	353.8	3.8	1.5	0.6					
	SMB-19	23.2	15.5	17.4	9.6					
	SMB-20	357.4	39.1	355.9	26.7					
	SMB-21	1.0	38.7	348.8	22.8					
	SMB-51	354.3	3.1	329.9	-23.5	320.7	-21.1	2.8393	12.4	37
C	SMB-52	3.0	- 3.1	339.1	-22.8					
	SMB-53	326.3	- 4.8	294.0	-13.9					
	SMB-54	32.0	35.9	52.5	30.8	54.9	46.1	2.9249	26.6	24
D	SMB-55	29.9	46.9	50.6	61.4					
	SMB-56	43.2	42.6	61.0	46.1					
	SMB-44	52.7	33.5	55.6	35.0	54.2	30.6	3.9312	43.6	14
E	SMB-45	62.0	40.8	64.6	41.7					
	SMB-46	54.1	21.7	56.2	22.6					
	SMB-47	42.5	22.6	42.7	22.4					
	SMB-48	33.6	37.0	34.6	37.9	26.7	39.4	2.9689	64.2	16
F	SMB-49	24.1	47.1	25.0	48.3					
	SMB-50	20.4	31.5	20.8	31.6					
	T-16	40.8	45.1	40.6	46.6	38.3	38.0	2.9685	63.4	16
G_1	T-17	43.5	21.6	35.6	27.1					
	T-18	29.9	43.2	39.3	40.5					
	T-19	41.3	25.5	48.8	33.9	27.6	31.3	2.9003	20.1	28
G_2	T-20	16.0	21.3	13.3	20.3					
	T-21	15.2	34.7	22.8	37.1					
	T-22	12.7	38.3	6.0	36.5	359.1	38.4	2.9828	116.3	11.4
H	T-23	3.6	36.6	349.3	42.4					
	T-24	356.6	32.2	1.1	35.7					

*Samples thermally cleaned at 100, 150, or 200°C

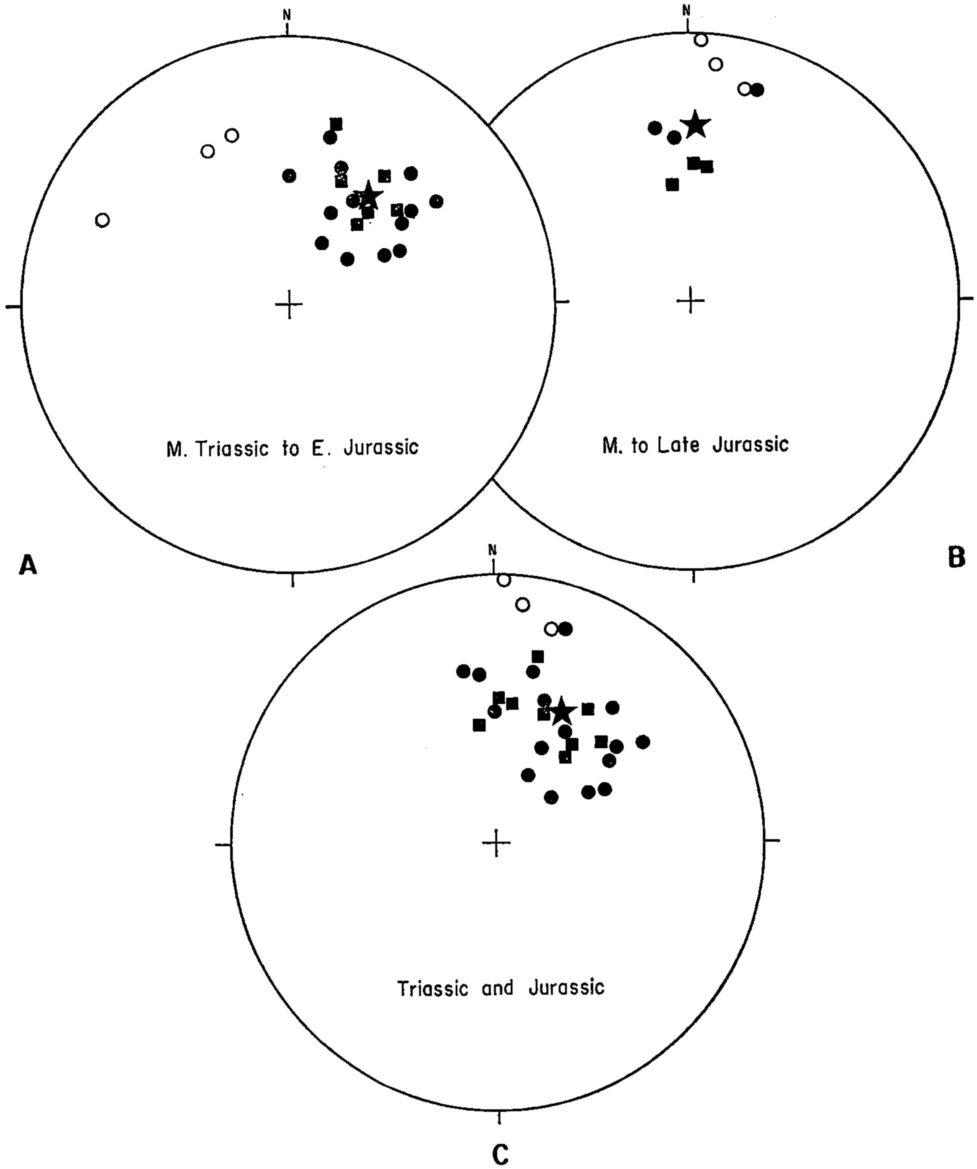

Fig. 2. Magnetic directions for sedimentary rocks. A. Sedimentary rocks of Middle Triassic to Early Jurassic age. Circles represent samples from localities A, D, E, F. Squares represent samples from Localities G (Haile and Tarling, 1975). Open circles represent samples from Locality C. The star is the mean magnetic direction for samples from Localities A, D, E, F, G. Inclinations are positive plotted on the lower hemisphere, except for those from Locality C which are negative plotted on the upper hemisphere.
B. Sedimentary rocks of Middle to Late Jurassic age. Circle represent samples from Locality B. Squares represent samples from Locality H (Haile and Tarling, 1975). The star is the mean magnetic direction for all samples from Localities B and H. Inclinations are positive plotted on the lower hemisphere, except for open circles which are negative plotted on the upper hemisphere.
C. Magnetic directions for all samples from Localities A, B, D, E, F, G, and H. The star is the mean magnetic direction for all these samples.
Plotted on stereonet, after thermal cleaning and correction for tilt. Primitive is horizontal.

TABLE 2

Mean cleaned magnetic directions and palaeomagnetic poles from Triassic and Jurassic sedimentary rocks from Thailand. Samples Localities are shown on Figure 1 and described in the text.

Locality or Set of Localities	Locality Mean Cleaned Direction D	I	R	K	α_{95}	dp	dm	Palaeomagnetic Poles Lat.	Long.	R	K	A_{95}
A	11.8°	41.2°						77.0°N	155.1°E			
B	4.2	6.8						76.0	116.2			
D	54.9	46.1						39.1	169.4			
E	54.2	30.6						38.3	183.7			
F	26.7	39.4						64.4	175.4			
G_1	38.3	38.0						53.5	176.3			
G_2	27.6	31.3						63.2	185.5			
H	359.1	38.4						84.6	97.4			
Mean of A, D, E, F, G_1,G_2 (M. Triassic—E Jurassic)	35.6	38.8	5.8424	31.7	12	8.5	14.3	56	176	5.8049	25.6	35
Mean of B, H (M—Late Jurassic)	2.0	22.6	1.9228	13.0	76	42.7	80.6	80	111	1.9938	160.3	20
Mean of All Samples (Triassic—Jurassic)	26.3	35.7	7.5303	14.9	15	10.1	17.3	64	171	7.5853	16.9	14

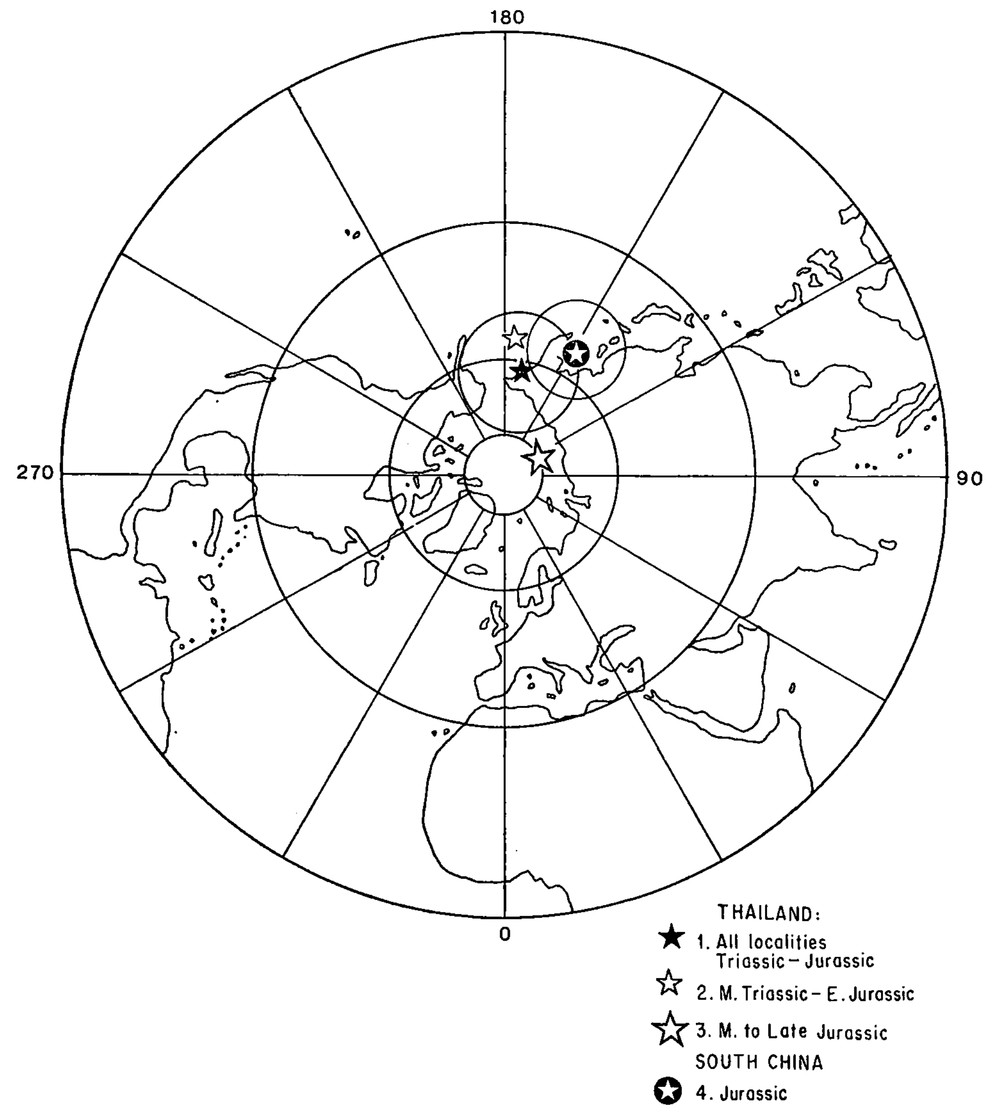

Fig. 3 Polar projection showing palaeomagnetic poles for sedimentary rocks of Triassic—Jurassic age. 1=Localities A, B, D, E, F, G, H (Triassic—Jurassic). 2=Xichuan and Yunnan Provinces, SW China (Jurassic). 3=Localities A, D, E, F, G (Middle Triassic—Early Jurassic). 4=Localities B and H (Middle to Late Jurassic). Circles of 95 percent confidence are shown for 1 and 4.

The mean palaeomagnetic pole for Triassic and Jurassic lies about 15° from the Jurassic palaeomagnetic pole reported for southwest China (Lee, and others, 1963; Chen, and others, 1965), but the circles of 95 percent confidence overlap, indicating no statistically significant separation (Figure 3). Likewise the Middle Triassic to Early Jurassic and Middle to Late Jurassic, poles (2 and 3 on Figure 3) have circles of confidence which overlap with the southwest China Jurassic pole. Thus the results are compatible with southwest China and Thailand having been part of the same lithospheric plate since the Jurassic, a view postulated by Stauffer (1974) on geological evidence.

CONCLUSIONS

Reddish siltstones of Triassic and Jurassic age in northern Thailand prove quite suitable for palaeomagnetic measurements. Groups of sample from localities on the western edge of the Khorat Plateau (Loei—Lomsak—Pitsanulok area), from the Ngao—Phrae highway, and from the Tak—Mae Sod highway yield fairly consistent palaeomagnetic directions, indicating that these areas were in or close to their present relative positions by early Mesozoic time. This agrees with geological and tectonic interpretations (Stauffer, 1974).

Samples of Middle Triassic to Early Jurassic age have a mean cleaned direction of declination 35.6°, inclination 38.8°, whereas samples of Middle to Late Jurassic age yield a mean cleaned direction of declination 2.0°, inclination 22.6°. However, insufficient sampling and uncertainty concerning the ages of many of the Jurassic samples limit the reliability of this difference. A safer interpretation, combining all samples to obtain a mean palaeomagnetic direction for Triassic—Jurassic gives a mean declination of 26.3° and inclination 35.7°. This mean direction gives a Triassic—Jurassic palaeomagnetic pole for Thailand at 64°N, 171°E, which is about 15° from the Jurassic palaeomagnetic pole reported for southwest China (Chen, and others, 1965) although the circles of confidence overlap. Further determinations on Jurassic rocks in Thailand, and Triassic in southwest China, could settle the question as to whether Thailand has been part of the same plate as southwest China since the Mesozoic.

ACKNOWLEDGEMENTS

We thank Dr. R.B. Stokes (formerly Colombo Plan Instructor in the Department of Geological Sciences, Chiang Mai University) for providing transportation in the field and supplying stratigraphic information on the Tak—Mae Sod trip. Mr. Henry H. Lee, Department of Geology, Unversity of Malaya, made some of the palaeomagnetic measurements. CUSO Thailand (Bangkok) kindly provided a vehicle for some of the field work. Most of this work was completed during the employment of the first two authors as CUSO Volunteers in the Department of Geological Sciences, Chiang Mai University, and we appreciate kindness shown to us by Staff and Students in that Department.

REFERENCES

BRAUN, E. VON, and JORDAN, R., 1976. The stratigraphy and palaeontology of the Mesozoic sequence in the Mae Sot area in western Thailand. *Geol. Jb.*, 21, 5-51.

CHEN ZHIQIANG, WANG CENGCHANG, and DENG XINGHOI, 1965. Some results of palaeomagnetic research in China. In "*Nastayashcheye i Proshleye magnitnogo Polia Zemli*" (The Present and Past of the Geomagnetic Field), 309–311 Moscow. "Nauka" Press. English translation (T462R) by Directorate of Scientific Information Services, DRB, Canada, 1966.

COLLINSON, D.W., CREER, K.M., and RUNCORN, S.K., 1967. Methods in palaeomagnetism. *Proceedings of NATO Advanced Study Institute on Palaeomagnetic Methods, Dept. Physics, Univ. Newcastle-Upon-Tyne, April* 1–10, 1964. Elsevier Publ., Amsterdam, 609 p.

Geological Map of Thailand, 1969. Dept. Mineral Resources, Bangkok.

HAILE, N.S., and TARLING, D.H., 1975, Note on reconnaissance palaeomagnetic measurements on Jurassic Redbeds from Thailand. *Pacific Geol.*, 10, 101–103.

LEE CHUAN TI (LI OUNTI), LEE HWA ME (LI HUAMLI), LIU HAISHAN, LIU CHUN and YEH SHU JUAN (YE SUJUAN), 1963. Preliminary study of palaeomagnetism of some Mesozoic and Cenozoic redbeds of South China. *Acta Geologica Sinica*, 43, 241–246. English translation (T8C) by Directorate of Scientific Information Services, DRB, Canada, 1966.

MCELHINNY, M.W., HAILE, N.S., and CRAWFORD, R. 1974. Palaeomagnetic evidence shows that the Malay Peninsula was not part of Gondwanaland. *Nature*, 252, 641–645.

NAGATA, T., 1961. *Rock magnetism.* Maruzen, Tokyo, 350p.

PIYASIN, S., 1971. *Geological map of Changwat Lampang, scale* 1:250,000. Dept. Mineral Resources, Bangkok.

STAUFFER, P.H., 1974. Malaya and Southeast Asia in the pattern of continental drift. *Bull. Geol. Soc. Malaysia.*, 7, 89–138.