SAMPLES AND METHODS

Lithology and Samples

Lithology of the two sections is very similar. The top Permian limestone bed (bed 24e, 20 cm thick) in the Meishan sequences, except for the top 2 cm (24e-1), is dark gray limestone containing abundant calcareous microfossils. The top 2 cm (24e-2 and 24e-3) is characterized by low carbonate content (Fig. 1). The overlying basal part of bed 25 is an Fe-rich grayish black thin layer (25-1; black layer; 0.1 mm thick). Layers 24-2 (1 cm thick), 24-3 (1 cm), and 25-1 (0.1 mm) contain grayish black, thin fragments. The overlying dark yellowish orange, thin layer (25-2; orange layer; 0.3-1 mm thick) is mostly gypsum. The remaining part of bed 25 (25-3; 2-4 cm thick) is a light bluish gray illite-montmorillonite clay (white clay). The subsequent dark gray shale (bed 26; 6-8 cm thick) is overlain by marl beds (beds 27 and 29). The Permian-Triassic (P-T) boundary was identified, on the basis of biostratigraphy, to be in the middle of marl bed 27 (Yin, et al., 1996); the event-stratigraphic P-T boundary (EPTB) was placed at the base of bed 25 (Wang, 1994). We focused our efforts on the 60-cm-thick interval spanning the EPTB and obtained fresh, unweathered samples by taking large blocks using large hummer. Very thin laminae (0.1 to 0.5 mm) near the EPTB were cut by a cutter knife in our laboratory.

Paleontological Analyses

Thin sections (4-6 cm^2) of sediment samples 2 cm thick were made by cutting perpendicularly to bedded planes for the Meishan A section. Numbers of small foraminifers in a thin section of each sample were counted and the number of microfossils per square centimeter was determined. The number of last occurrences of Permian marine genera in each bed was also determined using data compiled from Zhao et al. (1981), Sheng et al. (1984), Yang et al. (1987), Yin et al. (1996), and Chen et al. (1999).

Elements in Magnetic Fragments

Powdered samples were placed in pure water and small particles removed by Branson ultrasonic cleaner 1210 for 5 μm; samples were then heated with filtered paper for one hour. A strong magnetic device and tweezers were used to separate clear grains by hand on filter paper. Elements in Fe-rich grains included in magnetic spherule-like

fragments were also measured using an analytical scanning electron microscope JSM5000 (with JED2001 SYSTEM). Element percentages of each grain can be obtained from the computer softwear of the SPRINT, JEOL JED-2001 system with standard calibration of Si, Al, K, Ca, Fe, Ni, and S, without oxygen calculated. The analytical point is less than 1 μm in diameter.

Elements in Bulk Samples

Samples were crushed to a fine powder after drying at 40 to 50 °C and were split into several subsamples for element analyses. The analyses of major and minor trace elements in bulk sediments were performed by ion coupled plasma spectrometry (ICP). Following the ICP method, 100 mg of powdered sample were decomposed using 5 mL of ultrapure hydrofluoric acid (HF), 3 mL of ultrapure nitric acid (HNO_3), and ultrapure hydrochloric acid (HCl) two times. The solution was diluted with 5 mL of concentrated ultrapure nitric acid (HNO_3) and double-distilled MILLI-Q water to adjust the total volume to exactly 100 mL. The prepared solution was analyzed by ICP Atomic Emission Spectrometry at the Geological Survey of Japan. Estimated on replicate analyses, precision is within 3%. Solutions prepared from pure chemicals and JB-2, JB-3, JA-1, JA-2, JG-1, and JG-2 from the Geological Survey of Japan were used for standards. The reproducibility of these measurements was better than 2%.

Sulfur Isotope Ratio

The ^{34}S values of the sulfate sulfur from the rock samples were determined by combining the Kiba reagent method (Sasaki et al., 1979) with some chemical separation techniques and analyzed using a Finnigan Mat delta-E mass spectrometer (Kajiwara et al., 1997).

Strontium Isotope Ratio

Two hundred milligrams of the powdered sample were reacted with 10 mL of 5% acetic acid (5% CH_3COOH) at room temperature for given number of hours to collect Sr in carbonate. In order to collect acid-insoluble minerals, we reacted about 3 g of powdered sample with 40 mL of 20% hydrochloric acid (20% HCl) at ~20° C. After 24 h, it was centrifuged, and about 100 mg of the residual fraction was dissolved with 0.5

mL HNO_3, 0.5 mL $HClO_4$, and 1.0 mL HF in a Teflon vessel at 100° C for 12 hours and then dried. The remaining residue after HCl treatment was used for the determination of Rb and Sr. The experiments were done in a Teflon air-proofed system, and all reagents used in the leaching procedure were of analytical grade. The Sr isotopic composition was determined using a Finnigan MAT 262RPQ multicollector mass spectrometer; the concentrations of Rb and Sr in the HCl residue were determined using a Phillips 1404 wavelength sequential automatic spectrometer (XRF); this equipment is at the Institute of Geoscience, University of Tsukuba. The $^{87}Sr/^{86}Sr$ ratio of the standard NIST-SRM987 throughout the analysis was 0.71024 (± 0.00001). The detailed analytical procedures for the mass spectrometer and XRF analyses are given in Na et al. (1992) and Nakano et al. (1997), respectively.

Clay Minerals

For clay mineral analyses, the <2 μm fraction of each sample was separated and analyzed by the preferred orientation method on a Rigaku Rint 1200 System X-ray diffractometer; Cu Kα radiation at an accelerating voltage of 40 kV and 30 mA was used. Ethylene glycol was used to saturate the <2 μm oriented clay specimens. Percentage evaluations of clay minerals were based on peak intensity by using 001 reflections of smectite (17 Å), illite (10 Å), and kaolinite (7 Å) on ethylene glycolated samples. We recognized kaolinite, illite, and interstratified minerals of illite-smectite in this study.

REFERENCES CITED

Kajiwara, Y., Kaiho, K., and Ohkouchi, N., 1997, An invitation to the sulfur isotope study of marine sediments: implications and constraints for the exogenic sulfur cycle: Annual Report, Institute of Geoscience, University of Tsukuba, n. 23, p. 69-74.

Na, C-K, Nakano, T., Ito, T., Sakagawa, M., and Kajiwara, Y., 1992, Analysis of the rare-earth elements and inductively-coupled plasma atomic emission spectrometry: Annual Report, Institute of Geoscience, University of Tsukuba, n. 18, p. 94-97.

Nakano, T. Jeon Seo-Ryeong, and Sueno, S., 1997, X-ray fluorescence analysis of rock samples using Philips PW1404(1): Simultaneous determination of major and traoe

elements using glass beads of GSJ igneous rocks reference samples: Annual Report, Institute of Geoscience, University of Tsukuba, n. 23, p. 63-68.

Sasaki, A., Arikawa, Y., and Folinsbee, R. E., 1979, Kiba reagent method of sulfur extraction applied to isotopic work: Bulletin of Geological Survey of Japan, v. 30, p. 241-245.

TABLE A. EXTINCTION RATE OF MARINE GENERA ACROSS THE PERMIAN-TRIASSIC BOUNDARY IN MEISHAN, SOUTHERN CHINA

Bed number	Thickness (m)	Number of LO of gener	Number of LO of genera/	Number of LO of genera/ total number of genera/m
29	0.26	0	0.000	0.000
28	0.04	0	0.000	0.000
27	0.16	9	56.250	0.136
26	0.06	2	33.333	0.081
25	0.04	5	125.000	0.303
24	0.81(0.20)	35	175.000	0.424
23	1.30	2	1.538	0.004
22	2.07	6	2.899	0.007
21	1.17	2	1.709	0.004
20	1.20	0	0.000	0.000
19	4.00	2	0.500	0.001
18	0.40	0	0.000	0.000
17	0.09	0	0.000	0.000
16	4.10	0	0.000	0.000
15	4.00	3	0.750	0.002
14	1.53	7	4.575	0.011
13	5.03	2	0.398	0.001
12	1.93	3	1.554	0.004
11	3.87	0	0.000	0.000
10	0.93	0	0.000	0.000
9	2.83	5	1.767	0.004
8	1.67	0	0.000	0.000
7	0.07	0	0.000	0.000
6	0.85	0	0.000	0.000
5	1.80	2	1.111	0.003
4	2.60	0	0.000	0.000
3	0.30	0	0.000	0.000
2	0.80	0	0.000	0.000
1	0.60	4	6.667	0.016

The numerical value in the parenthesis shows the thickness of the bed 24e. Number of last occurrence (LO) of genera/meter arcalculated by the thickness because last occurrences of most genera are concentrated in the bed 24e. Data compiled from Zhao et al.(1981), Sheng et al. (1984), Yang et al. (1987), Yin et al. (1996), and Chen et al. (1999).

TABLE B. GEOCHEMICAL AND PALEONTOLOGICAL DATA FROM THE UPPERMOST PERMIAN-BASAL TRIASSIC SECTIONS IN MEISHAN, SOUTHERN CHINA

Sample	Thickness (cm)	Kaolinte /Illite	$^{87}Sr/^{86}Sr$ HOAC-leachate	$^{87}Sr/^{86}Sr$ HCl-residue initial	δ^{34}Sulfate vs CDT (‰)	foraminifera /cm^2	Mn (%)	Ca (%)	Ni (ppm)	P (%)
CHMI+37-+39	38.000	0.450			12.61		0.086	14.650	9.54	0.908
CHMI+35-+37	36.000						0.083	15.470	5.41	0.909
CHMI+33-+35	34.000						0.058	19.580	22.22	0.896
CHMI+31-+33	32.000				8.17		0.082	22.980	16.74	0.900
CHMIA+30-+33.5	31.750	0.690		0.717674						
CHMI+28-+31	29.000						0.086	24.430	10.70	0.863
CHMI+26-+28	27.000						0.076	21.880	14.67	0.906
CHMIA+23-+28	25.500	0.810				1.6				
CHMI+22-+24	23.000						0.077	22.550	10.51	0.896
CHMIA21-23	22.000					8.6				
CHMI+20-+22	21.000						0.070	21.200	11.15	0.929
CHMIA+19-+21	20.000	0.721		0.719279						
CHMI+19-+20	19.500						0.067	20.660	14.15	0.382
CHMI+17-+18	17.500						0.056	18.790	10.96	0.254
CHMIA+15-+17	16.000	0.941			14.80					
CHMI+15-+16	15.500						0.072	21.770	15.50	0.361
CHMIA13-15	14.000					2.9				
CHMI+13-+14	13.500						0.080	21.540	19.18	0.260
CHMI+11-+12	11.500						0.077	22.720	26.91	0.270
CHMIA+10-+13	11.500	0.810	0.707996	0.732623						
CHMI+9-+10	9.500						0.013	3.150	13.77	0.266
CHMI+8-+9	8.500						0.004	0.340	20.98	0.256
CHMI+7-+8	7.500						0.008	2.200	18.06	0.291
CHMI+6-+7	6.500						0.005	0.350	36.56	0.227
CHMI+5-+6	5.500						0.008	0.330	27.74	0.274
CHMI+4-+5	4.500						0.007	0.480	26.14	0.282
CHMI+3-+4	3.500						0.004	0.200	24.18	0.275
CHMI+2-+3	2.500						0.028	0.380	44.81	0.293
CHMI+0.3-+2	1.150						0.002	0.310	4.61	0.229
CHMI+0-+0.3	0.150						0.008	0.350	87.98	0.442
CHMIA+8-+10	9.000	0.511								
CHMIA+6-+8	7.000	0.480	0.710651	0.729470						
CHMIA+4-+10	7.000				1.98					
CHMIA+4-+6	5.000	0.442		0.718297						
CHMIA+4-+5	4.500					0.0				
CHMI0-+4	2.000					0.0				
CHMIA+0.3-+2	1.150	0.356								
CHMIA+0.01-+0.0	0.025	1.130								
CHMIA0-+0.01	0.005	2.905								
CHMIA-0.05-0	-0.025	2.750								
CHMIA-0.2--0.05	-0.125									
CHMIA-1-0	-0.500	1.180	0.707447	0.708058	3.95	0.5	0.046	12.754	35.33	0.271
CHMIA-2--1	-1.500	0.810	0.707324	0.713268	8.99	3.1	0.044	10.397	66.97	0.358
CHMIA-3--2	-2.500		0.707265	0.714737		7.7				
CHMI-4--2	-3.000				22.91		0.040	36.530	1.65	1.433
CHMIA-6--3	-4.500		0.707212			4.2				
CHMI-6--4	-5.000				25.86		0.034	36.580	4.13	1.440
CHMI-8--6	-7.000	0.000			28.57		0.031	35.390	6.43	1.434
CHMI-10--8	-9.000	0.000					0.069	34.870	5.44	1.457
CHMI-11--9	-10.000					4.0				
CHMI-12--10	-11.000				16.63		0.057	27.810	26.79	1.329
CHMIA-14--11	-12.500			0.725492						
CHMI-14--12	-13.000	0.000					0.062	30.560	16.95	1.412
CHMI-16--14	-15.000				19.60					
CHMI-16	-16.000						0.026	35.390	6.41	1.563
CHMI-20--18	-19.000	0.000			19.85					
CHMI-19--20	-19.500						0.019	22.720	20.37	1.199

CHMI: D section, CHMIA: A section. Sample number shows thickness in cm in which the base of the Fe-rich black layer is defined as 0 cm; positive and negative numbers correspond to thickness above and below the latter horizon.