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Fission-Track Dating of the Upper Part of Miocene Honda Group in La Venta Badlands, Colombia

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INTRODUCTION

La Venta Badlands, located between the Central and Eastern Cordillera of Colombian Andes (Fig. 1), are famous for the occurrence of fossil mammals (La Venta fauna) from the Miocene deposits. This fauna is correlated with the Friasian stage defined by a local fauna found from the Collón Curá Formation in South Argentine (Hirschfeld & Marshall, 1976). K-Ar ages of the Friasian stage were reported by Marshall et al. (1977), and range from 15.4 to 14.0 Ma.

Takemura & Danhara (1983) reported a fission-track age of the Gigante Formation overlying the Honda Group, and Hayashida (1984) reported paleomagnetism of the Honda Group and estimated the age of the Honda Group on the basis of paleomagnetic stratigraphy. But, it is necessary to obtain directly radiometric ages from the Honda Group including the La Venta fauna.

Fortunately, we succeeded in the age determination on 3 samples of the upper part of the Honda Group by fission-track method.

GEOLOGICAL SETTING AND SAMPLES

Late Cenozoic deposits in La Venta Badlands are the Honda Group and Mesa Group. The Honda Group is about 700 m thick, and is divided into three parts (Fields, 1959). The lower part consists mainly of siltstones with sandstones (El Libana Sands and Clays). The middle part is composed mainly of pebble to cobble conglomerates interbedding coarse-grained sandstones and siltstones (Cerbatana Gravels and Clays). The upper part is composed mainly of sands and clays with two characteristics red beds and fossiliferous members (Monkey Unit and Fish Bed) (Fig. 2). The Mesa Conglomerate of the Mesa Group covers unconformably the Honda Group.

Samples for fission-track dating were collected from 8 sites at La Venta and around Villavieja, and fission-track ages were measured from 3 samples of them. Stratigraphic horizons of the fission-track samples are shown in Fig. 2 and belong to the upper part of the Honda Group. Locality names are the same as those of Takemura (1983, 1986) and are shown in Fig. 1.

The sample of the loc. LV 8 is gray tuffaceous silt below the sandstone bed A. The sample of the loc. KS 4 is gray tuffaceous silt below the sandstone bed B. The sample of the loc. LV 13 is bentonite intercalated in the Lower Red Bed. Each sample was crushed and washed by water, and heavy minerals were concentrated by panning in Villavieja.

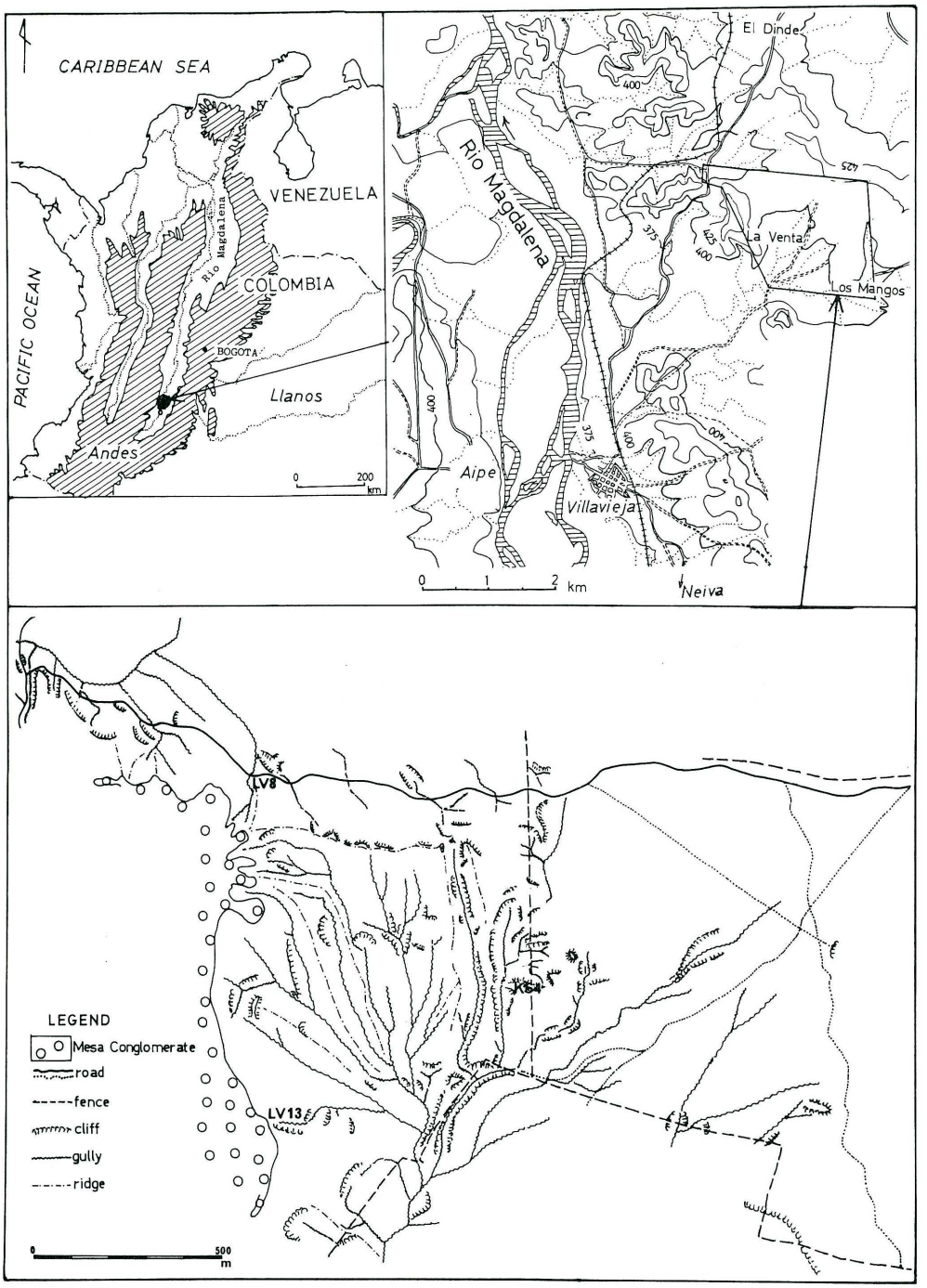

Fig. 1. Map showing the surveyed area and sampling localities for fission-track dating.

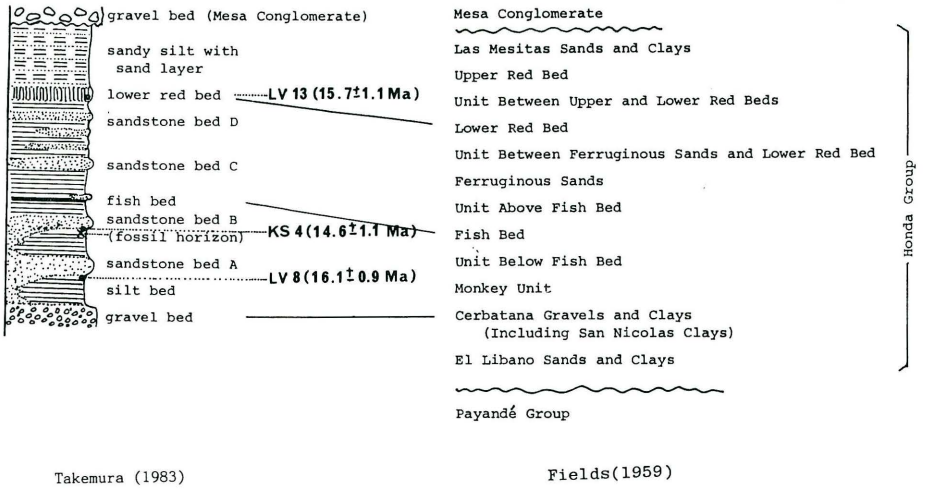

Fig. 2. Stratigraphy of the Honda Group in the La Venta Area and sampling horizons for fission-track dating.

FISSION-TRACK DATING

In this time, we applied conveniently the external detector method to external surfaces of zircons (ED2: Gleadow, 1981) because zircon crystals were very small and high fission-track density was expected.

At first, zircon grains were mounted in PFA (copolymer of tetrafluoroethylene-perfluoro-alkoxyethylene) sheets, and after etching for 20 hours in a melt of KOH and NaOH at 225°C, spontaneous fission-tracks on the external surfaces were counted. Next, PFA sheets were

Table 1 Results of fission-track dating in the La Venta Area.

Sample	N_s tracks	$\rho_s \times 10^5$ tracks/cm^2	N_i tracks	$\rho_i \times 10^6$ tracks/cm^2	N_Φ tracks	$\rho_\Phi \times 10^4$ tracks/cm^2	T Ma	$\varepsilon \cdot T$ Ma	n	r	U ppm
LV 8 (except No. 2)	643	8.40	1215	1.59	1211	8.19	16.1	0 9	35	0 170	156
KS 4 (except Nos. 6, 10 15,16)	302	8.24	632	1.73	1214	8.20	14.6	1.1	16	0.869	169
LV 13 (except Nos. 13, 14)	371	10.5	715	2.03	1209	8.17	15.7	1.1	15	0.941	199

N_s and ρ_s: total count and density of spontaneous fission tracks
N_i and ρ_i: total count and density of induced fission tracks
N_Φ and ρ_Φ: total count and density of induced fission tracks on neutron flux monitor
n: number of grains
r: correlation coefficient between ρ_s and ρ_i
U: Uranium concentration in zircons
The fission track date was obtained using the following constants:
Calibration constant: $B = 6.23 \times 10^9$ ($= \Phi/\rho_\Phi$, Φ: thermal neutron flux)
Spontaneous fision decay constant: $\lambda_f = 7.03 \times 10^{-17}$ (/year)
Thermal neutron fission cross section for ^{235}U: $\sigma_f = 5.77 \times 10^{-22}$ (cm^2)
Isotope ratio ^{235}U/^{238}U: I $= 7.253 \times 10^{-3}$
These constants give the ζ-value, $\zeta = 371$, and the fission track date, T (Ma), and counting error, ε, are given as follows:

$$T = \zeta \cdot (\rho_s/\rho_i) \cdot \rho_\Phi$$

$$\varepsilon = \{(1/\sqrt{N_s})^2 + (1/\sqrt{N_i})^2 + (1/\sqrt{N_\Phi})^2\}^{1/2}$$

covered with external fission-track detectors of muscovite and irradiated in the TRIGA II reactor at Musashi Institute of Technology. The neutron dose was monitored with a muscovite detector firmly attached to NBS glass SRM612. Induced fission-track were counted on the muscovite detectors.

RESULT AND DISCUSSION

Fission-track dating results are summarized in Table 1 on the basis of following considerations.

LV 8:

Fission-track dating was carried out on 36 grains, and ages of each zircon crystal were calculated (Table 2). Because of high track density and track condition for etching, No. 2 grain was excluded from calculation. Then, plots of the spontaneous and induced fission-track densities of single zircon grains revealed relative high correlation (Fig. 3). Consequent-

Table 2 Fission-track ages of individual grains of zircon crystals from the LV 8 sample in the upper part of the Honda Group.

No.	N_s	N_i	S $\times 10^{-5}$ (cm^2)	ρ_s $\times 10^5$ (cm^{-2})	ρ_i $\times 10^5$ (cm^{-2})	T (Ma)
1	10	24	1.94	5.15	12.37	12.67
2	62	45	1.84	33.70	24.46	41.88
3	15	44	1.66	9.04	26.51	10.36
4	28	36	2.77	10.11	13.00	23.64
5	9	32	2.31	3.90	13.85	8.55
6	9	31	1.48	6.08	20.95	8.82
7	20	19	1.48	13.51	12.84	32.00
8	30	26	1.11	27.03	23.42	35.07
9	46	49	1.84	25.00	26.63	28.54
10	19	43	3.69	5.15	11.65	13.43
11	7	15	2.21	3.17	6.79	14.18
12	23	46	2.31	9.96	19.91	15.20
13	33	58	2.77	11.91	20.94	17.29
14	50	60	2.21	22.62	27.15	25.33
15	4	10	3.32	1.20	3.01	12.16
16	8	24	1.11	7.21	21.62	10.13
17	23	67	3.32	6.93	20.18	10.43
18	10	24	2.31	4.33	10.39	12.67
19	12	30	1.38	8.70	21.74	12.16
20	9	20	1.84	4.89	10.87	13.68
21	56	55	2.77	20.22	19.86	30.95
22	13	23	2.58	5.04	8.91	17.18
23	9	20	1.84	4.89	10.87	13.68
24	13	44	2.21	5.88	19.91	8.98
25	14	26	1.84	7.61	14.13	16.37
26	6	14	0.83	7.23	16.87	13.03
27	22	28	1.11	19.82	25.23	23.88
28	5	8	1.11	4.50	7.21	19.00
29	15	29	2.77	5.42	10.47	15.72
30	17	35	2.77	6.14	12.64	14.76
31	9	33	2.31	3.90	14.29	8.29
32	22	58	2.77	7.94	20.94	11.53
33	45	87	3.32	13.55	26.20	15.72
34	15	45	3.23	4.64	13.93	10.13
35	8	27	1.84	4.35	14.67	9.01
36	9	25	2.21	4.07	11.31	10.94

Table 3 Fission-track ages of individual grains of zircon crystals from the KS 4 sample in the upper part of the Honda Group.

No.	N_s	N_i	$S\times10^{-5}$ (cm^2)	$\rho_s\times10^5$ (cm^{-2})	$\rho_i\times10^5$ (cm^{-2})	T (Ma)
1	15	30	3.69	4.07	8.13	15.23
2	4	15	2.31	1.73	6.49	8.12
3	31	68	3.69	8.40	18.43	13.88
4	32	70	2.31	13.85	30.30	13.92
5	7	20	1.84	3.80	10.87	10.66
6	67	24	1.38	48.55	17.39	85.02
7	20	32	2.31	8.66	13.85	19.03
8	16	38	2.77	5.78	13.72	12.82
9	45	89	4.61	9.76	19.31	15.40
10	71	12	1.11	63.96	10.81	180.20
11	24	24	2.77	8.66	8.66	30.46
12	7	45	2.21	3.17	20.36	4.74
13	23	46	1.66	13.86	27.71	15.23
14	21	43	1.38	15.22	31.16	14.87
15	68	17	1.48	45.95	11.49	121.82
16	101	62	2.31	43.72	26.84	49.61
17	17	36	1.66	10.24	21.69	14.38
18	8	15	1.11	7.21	13.51	16.24
19	25	34	0.83	30.12	40.96	22.39
20	7	27	1.48	4.73	18.24	7.90

Table 4 Fission-track ages of individual grains of zircon crystals from the LV 13 sample in the upper part of the Honda Group.

No.	N_s	N_i	$S\times10^{-5}$ (cm^2)	$\rho_s\times10^5$ (cm^{-2})	$\rho_i\times10^5$ (cm^{-2})	T (Ma)
1	34	59	2.77	12.27	21.30	17.48
2	23	43	1.94	11.86	22.16	16.23
3	16	22	1.84	8.70	11.96	22.06
4	33	74	3.69	8.94	20.05	13.53
5	38	69	4.61	8.24	14.97	16.71
6	21	49	1.84	11.41	26.63	13.00
7	55	104	4.61	11.93	22.56	16.04
8	16	33	2.31	6.93	14.29	14.71
9	14	42	2.77	5.05	15.16	10.11
10	11	16	1.38	7.97	11.59	20.86
11	31	41	1.84	16.85	22.28	22.94
12	12	27	1.84	6.52	14.67	13.48
13	71	27	2.77	25.63	9.75	79.77
14	70	22	1.94	36.08	11.34	96.52
15	34	73	1.84	18.48	39.67	14.13
16	27	46	0.83	32.53	55.42	17.81
17	6	17	1.11	5.41	15.32	10.71

ly, fission-track age of LV 8 sample is calculated 16.1 ± 0.9 Ma from 35 grains except for No. 2 grain.

KS 4:

Age determination was carried out on 20 zircon grains, and ages of each zircon grain were calculated (Table 3). 4 grains (Nos. 6, 10, 15, 16) of them reveal old age, and calculating except for 4 grains (Nos. 6, 10, 15, 16), correlation efficient between ρ_s and ρ_i reveals high value as shown in Table 1 and Fig. 3.

Consequently, fission-track age of KS 4 sample is calculated 14.6 ± 1.1 Ma from 16 grains except for 4 grains (Nos. 6, 10, 15, 16).

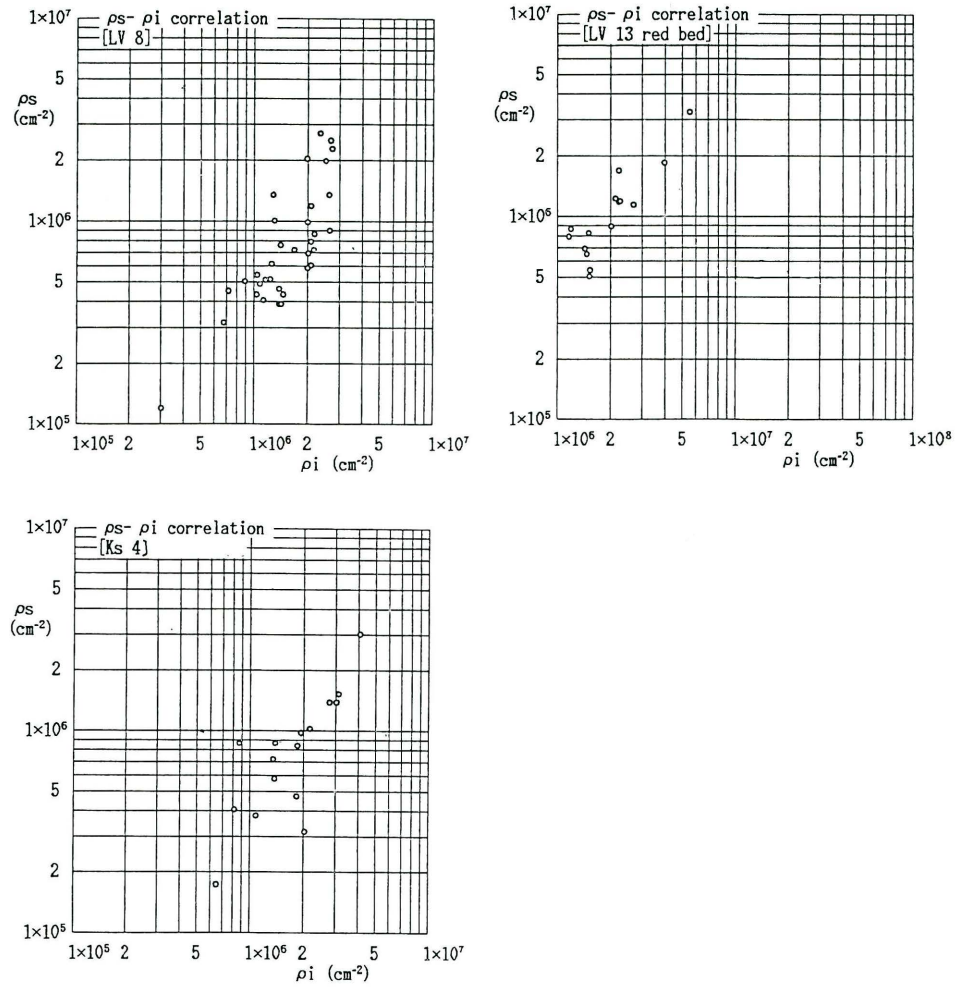

Fig. 3 Correlation diagram between the spontaneous track densities (ρ_s) and the induced track densities (ρ_i) of the single zircon grains.

LV 13:

Age determination was carried out on 17 zircon grains, and ages of each zircon grain were calculated (Table 4). 2 grains (Nos. 13, 14) of them indicate old age, and after calculating except for 2 grains (Nos. 13, 14), correlation efficient between ρ_s and ρ_i shows high value as shown in Table 1 and Fig. 3.

Consequently, fission-track age of LV 13 sample is calculated 15.7 ± 1.1 Ma from 15 grains except for 2 grains (Nos. 13, 14).

The La Venta fauna was correlated with the Friasian stage of the South American Land Mammal Age (Hirschfeld & Marshall, 1976), and Marshall et al. (1977) reported K-Ar ages ranging from 15.4 to 14.0 Ma from the Collón Curá Formation which includes the fauna of the Friasian stage in south Argentine.

Hayashida (1984) reported a thick normal magnetozone covering the middle to upper part of the Honda Group, and mentioned that this normal polarity zone was probably

correlated to a part of Epoch 15 dated from 15.2 to 13.6 Ma if the La Venta fauna is assigned to the Friasian stage.

From fission-track ages in the upper part of the Honda Group, the La Venta fauna is dated from about 16 to 14.5 Ma. This result is concordant with the ages from the Collón Curá Formation and indicates that the La Venta fauna is probably assigned to the Friasian stage and normal magnetozone may be correlated to a part of the Epoch 15.

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