Photographs of NIED Nojima Fault Drilling Cores at Hirabayashi Borehole

Kentaro OMURA *[1], Ryuji IKEDA *[2], Tatsuo MATSUDA *[1], Takashi ARAI *[3], Kenta KOBAYASHI *[4], Koji SHIMADA *[5], Hidemi TANAKA *[6], Tomoaki TOMITA *[7], and Satoshi HIRANO *[8]

*[1] *National Research Institute for Earth Science and Disaster Prevention (NIED), omura@bosai.go.jp, mtatsuo@bosai.go.jp*
*[2] *National Research Institute for Earth Science and Disaster Prevention (NIED); current affiliation:Hokkaido University, ikeryu@ep.sci.hokudai.ac.jp*
*[3] *University of Tokyo; current affiliation: National Institute of Advanced Industrial Science and Technology (AIST), t.arai@aist.go.jp*
*[4] *Niigata University, kenkoba@gs.niigata-u.ac.jp*
*[5] *Waseda University; current affiliation: University of Tokyo, shimada@eps.s.u-tokyo.ac.jp*
*[6] *University of Tokyo, tanaka@eps.s.u-tokyo.ac.jp*
*[7] *University of Tsukuba*
*[8] *Japan Marine Science and Technology Center (JAMSTEC), hiranos@jamstec.go.jp*

Abstract

We collected fault zone cores from the Nojima Fault, which was activated by the 1995 Hyogoken Nanbu Earthquake, continuously from depths between 1,000 m and 1,838 m by drilling through the fault plane about one year after the earthquake. The cores were all granitic rocks, including porphyritic intrusive rocks in spots and remarkably fractured zones consisting of cataclastic rocks at three depths: around 1,140, 1,300, and 1,800 m. Core samples in fracture zones were polished for precisely observing fault related rock structures. In total, about 2,210 polished pieces were made and photographed. In addition, we took photographs of all the cores placed in core boxes. Those photographs were converted into digitized images (JPEG format) and stored on two volumes of CD-ROM. These digitized images of fracture zone cores are suitable for mesoscopic observation and quantitative image processing.

Key words: Fracture zone, Fault rocks, Digital image, Nojima Fault, 1995 Hyogoken Nanbu Earthquake

1. Introduction

Analysis of fault rocks provides important information on the slip behavior of fault planes. In particular, precise observation of the structure of fault rocks is indispensable for illustrating their distribution across a fault plane. We succeeded in collecting fault rocks continuously from depths between 1,000 and 1,838 m by drilling through the Nojima Fault plane about one year after the 1995 Hyogoken Nanbu Earthquake, which activated the fault (Ikeda, 2001; Ikeda *et al*., 2001).

Cores were all granitic rocks, including porphyritic intrusive rocks in spots and remarkably fractured zones consisting of cataclastic rocks at three approximate depths: 1,140, 1,300, and 1,800 m (Ikeda *et al*., 2001; Omura *et al*., 2001a). Core samples in fracture zones were so damaged that we fixed the surface of each core piece with an epoxy resin and cut it vertically into two halves. The cut surface of one of the two halves was fixed again by epoxy resin and was polished into a plane surface (polished piece). The other half of the core was used for chemical analysis or making a thin section, etc. (Matsuda *et al.* 2001a, 2001b). A total of about 2,210 polished pieces were made from the cores from three fracture zone intervals: 1,054.00 - 1,189.55 m, 1,276.70 - 1,336.70 m, and 1,774.90 - 1,828.40 m. By means of macroscopic observations with the naked eyes, we investigated the precise distribution of fault related rocks in the fracture zones and its mechanical significance for the fracture zone activity (Tanaka *et al*., 2001; Kobayashi *et al*., 2001a, 2001b; Omura *et al*., 2001b). We took photographs of all the cores placed in core boxes and the all polished pieces. Those photographs were converted into digitized images (JPEG format) and stored on two volumes of CD-ROM.

We introduce in this technical note the CD-ROM volumes containing the digital images. Those images of fracture zone cores are suitable for mesoscopic observation and quantitative image processing. The images will provide important records of the fault that have just slipped by the earthquake.

Table 1 Outline of drilling and core recovery of the NIED Hirabayashi borehole.

Drilling site (**Fig. 1, Fig.2**)	About 302 m SE from the surface trace of the Nojima fault. Lat.: N 34∞ 34" 42.9' Long.: E 134∞ 58" 23.6' Alt.: 65m
Drilling Depth	1838.8 m (drilling length, strictly speaking)
Drilling Radius	193.7 mm (10 - 250 m) 149.2 mm (250 ñ 1,000 m) 97.5 mm (1,000 m ñ 1,838 m)
Inclination	Increase from 0∞ to 7∞ 20' (0 - 994 m) Decrease from 7∞ 20' to 1∞ (994 ñ 1,450 m) Less than 1∞ (1,450 ñ 1,838 m)
Coring	Spot coring at 5 points (0 ñ 1,000 m) All coring (1,001 ñ 1,838 m) 64 mm radius
Lithology (**Fig. 3**)	Granodiorite and Tonalite. Porphyritic intrusive rocks in spots. Cataclastic rocks in three fracture zones around 1,140, 1,300 and 1,800 m.

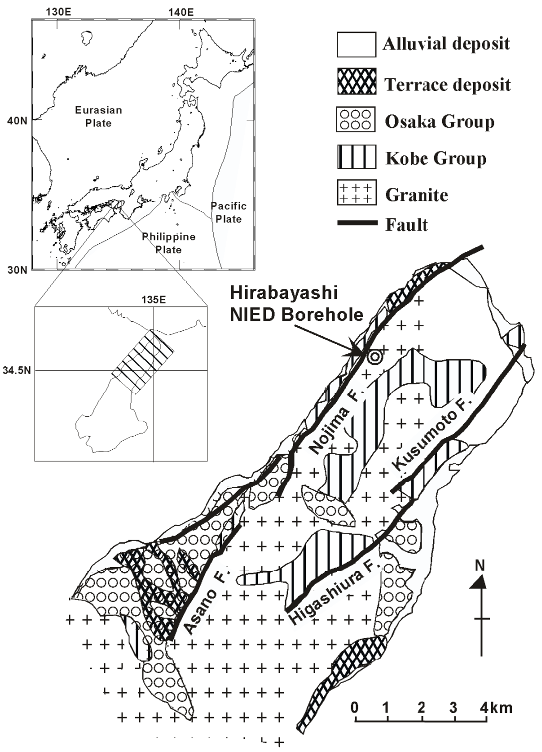

Fig. 1 Location of the NIED Hirabayashi borehole and geological map around the borehole.

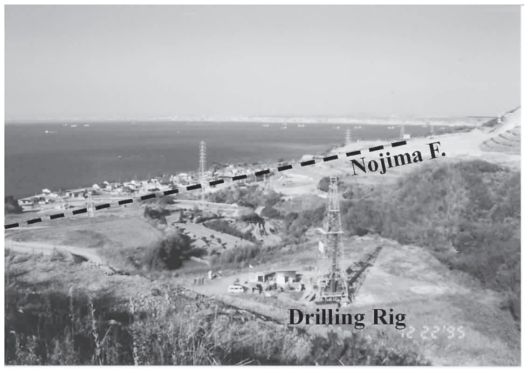

Fig. 2 Photograph of the drilling rig at the NIED Hirabayashi borehole beside the surface trace of the Nojima Fault.

2. Core collection

Drilling of the NIED Hirabayashi borehole and core recovery is described in **Table 1**. The coring recovery rate was almost 100 % below a depth of 1,101.5 m. Collected cores were placed in a total of 188 core boxes (5 lines ◊ 1 m = 5 m length in a box).

3. Core handling

About 2,210 polished pieces were made from cores in 25 boxes from depths between 1,054.00 and 1,189.55 m, 12 boxes from depths between 1,276.70 and 1,336.70 m, and 11 boxes from depths between 1,774.90 and 1,828.40 m. We made polished pieces according to the following procedure and

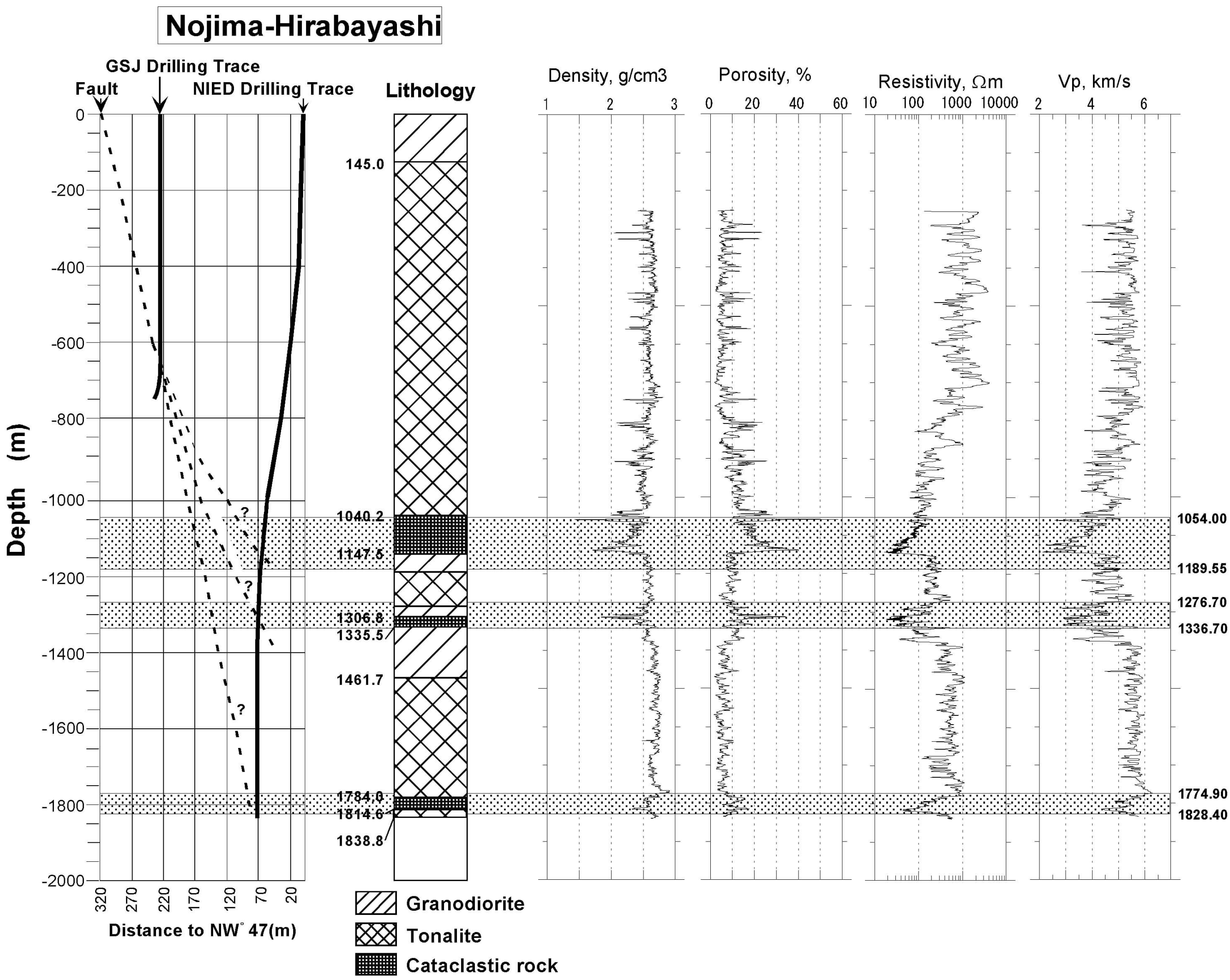

Fig.3 Vertical projection of the NIED Hirabayashi borehole and the Nojima Fault with lithological columns as determined by core observations, and with profiles of physical properties in the borehole as determined by borehole loggings. Three fracture zones were found around the depths of 1,140, 1,300 and 1,800 m. GSJ (Geological Survey of Japan) also drilled into the Nojima Fault next to the NIED borehole and found a fracture zone around a depth of 700 m. One of the three fracture zones found in the NIED borehole may connect with the fracture zone found in the GSJ borehole. We made polished core pieces from cores in three depth intervals shown by hatched area in the figure, corresponding to the three fracture zones.

Fig. 4. (Tanaka *et al.*, 1999; Matsuda *et al.*, 2001b).

(1) Fix the core pieces in a core box with epoxy resin.
(2) Number the fixed core pieces.
(3) Cut the fixed core pieces vertically into two halves: one for a polished piece (archival half), and the other for analysis (working half).
(4) Fix with epoxy resin again if necessary and polish the cut surface of the archival half.
(5) Take photographs of polished surfaces with 35 mm color film.
(6) Make Photo-CD from the 35 mm negatives.
(7) Convert from the highest resolution image on the Photo-CD to JPEG format image for each polished piece.
(8) Copy JPEG format images onto CD-R.

4. Contents of CD-ROM

We copied all digital images (JPEG format) of the core boxes and polished pieces onto two volumes of CD-ROM.; The first CD-ROM consists of images of core boxes Nos. 1 to 100 and images of polished pieces from around the fracture zone at 1,140 m made from cores in core box Nos. 31 to 55., The second CD-ROM consists of images of core boxes Nos. 101 to 188 and images of polished pieces from fracture zones at around 1,300 and 1,800 m made from core box Nos. 74 to 85 and Nos. 175 to 185. Each CD-ROM has two folders, each consisting of photographs of the core box and polished pieces. The former consists of core box photographs in numbered order, and the latter consists of folders corresponding to the core boxes, from which polished pieces were made (**Fig. 5**).

In addition, each volume contains a file describing the depths and lengths corresponding to the core piece numbers. The file also contains data on degrees of deformation, or pulverization and alteration of the core pieces estimated by the method proposed by Tanaka *et al*. (1999). According to mesoscopic observations, the degrees of deformation, or pulverization and alteration were classified into four categories based on the relative density of the microfractures and on the decreasing percentage of mafic minerals: 0 (weak), 1, 2, 3 (strong). **Figure 6** shows the relative distribution frequency of cores corresponding to each of the 4 (deformation) ◊ 4 (alteration) categories in the analyzed depth intervals. This diagram has information on the history of fracture and alteration processes to form the present-day distribution of fault rocks in the fracture zones.

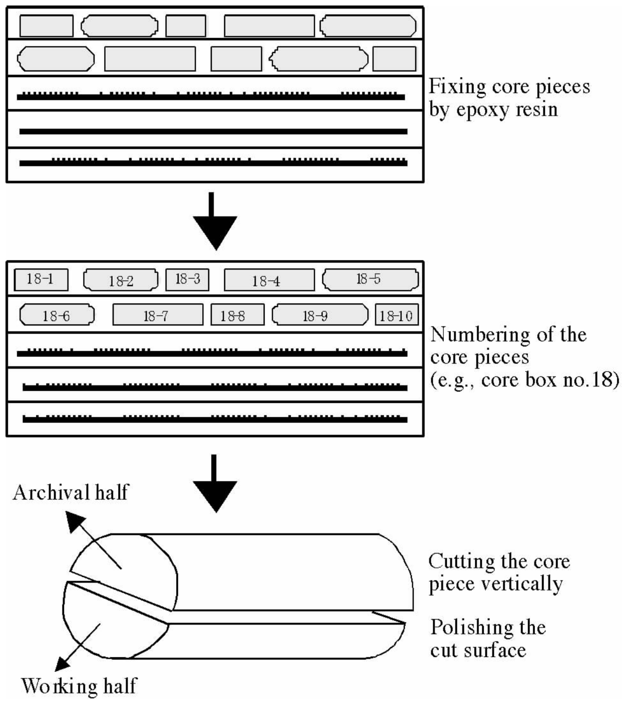

Fig.4 Core handlings to make polished pieces from fracture zone core samples.

5. Summary

Fracture zone cores retrieved by drilling through the Nojima Fault, which was activated by the 1995 Hyogoken Nanbu Earthquake, were cut into polished core pieces. Digital images of the polished surfaces as well as all cores placed in core boxes were stored on CD-ROM in two volumes. These digitized images are suitable for mesoscopic observation and quantitative image processing.

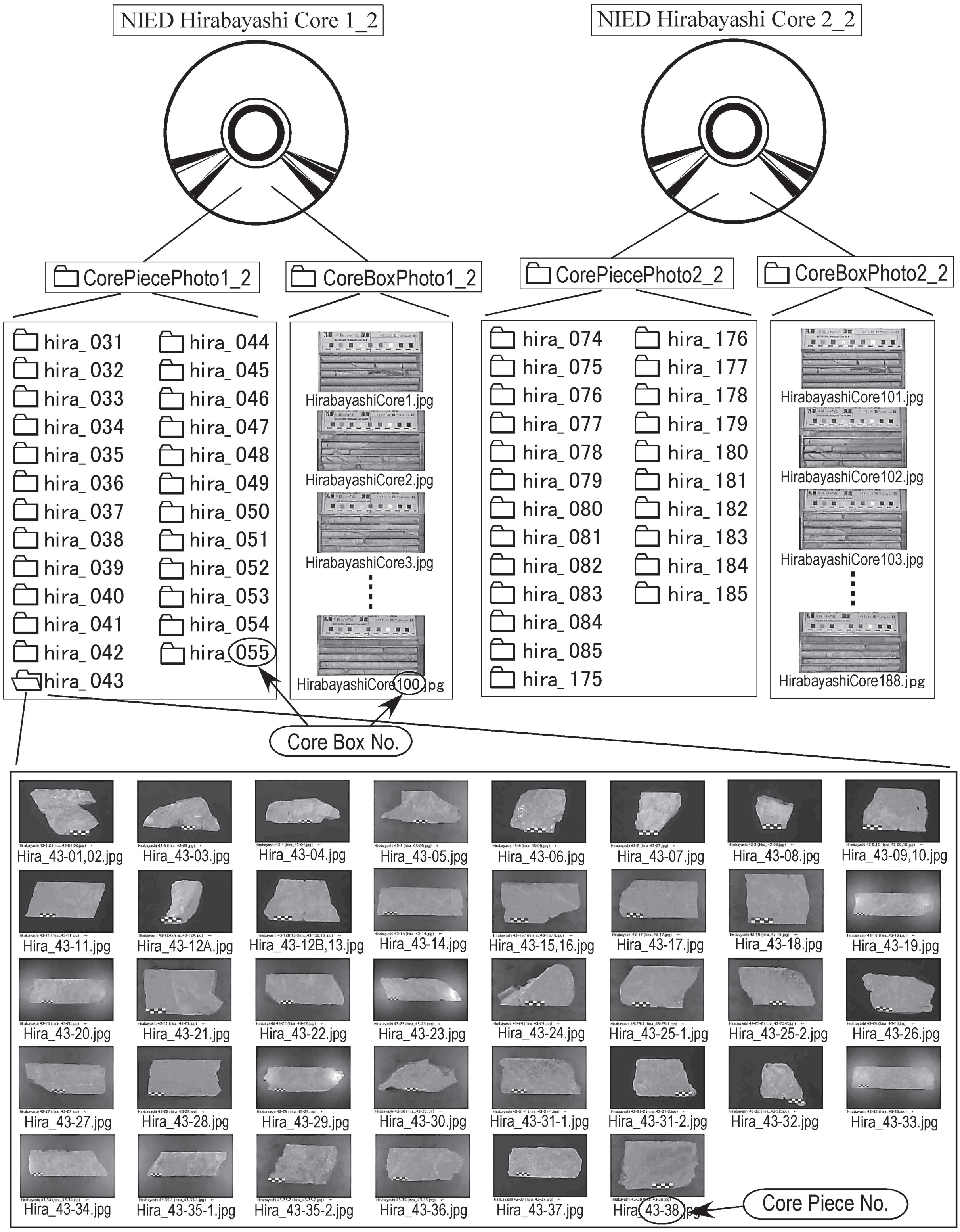

Fig. 5 Schematic diagram of the contents of the two CD-ROM volumes. Each CD-ROM has two folders: one (ìCoreBoxPhotoóî) consists of core box photographs and the other (ìCorePiecePhotoóî) consists of photographs of the polished pieces. The width of a core box equals about 1 m. Black and white scale bar in a core piece photo equals 2.5 cm.

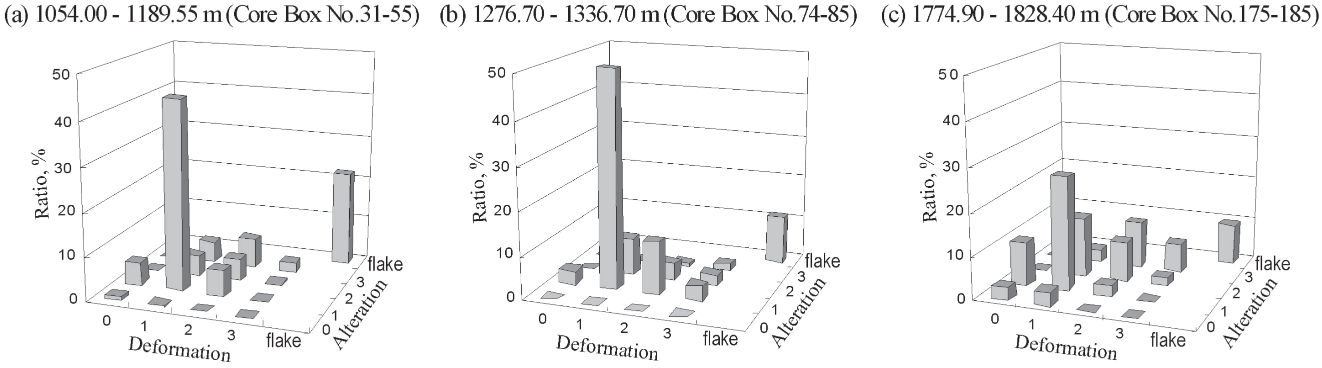

Fig. 6 Relative distribution frequency of cores corresponding to deformation and alteration categories. The summation of the length of the core pieces corresponding to each category is divided by total length of the analyzed interval: (a) 1,054.00 ñ 1,189.55 m, (b) 1,276.70 ñ 1,336.70 m, and (c) 1,774.90 ñ 1,828.40 m. Flakes are smashed fragments that could not be fixed to make polished pieces.

Acknowledgments

We would like to A. Yamasaki, T. Sawaguchi and N. Tomida for their help preparing a large number of core pieces. We also thank to staff of Sumiko Consultants Co., Ltd for their efforts in drilling through the fault fracture zone and recovering cores.

References

1) Ikeda, R. (2001): Outline of the fault zone drilling project by NIED in the vicinity of the 1995 Hyogo-ken Nanbu earthquake, Japan. The Island arc, **10**-3/4, 199-205.

2) Ikeda, R., Iio, Y., and Omura, K. (2001a): In situ stress measurements in NIED boreholes in and around the fault zone near the 1995 Hyogo-ken Nanbu earthquake, Japn. The Island arc, **10**-3/4, 252-260.

3) Ikeda, R., Omura, K., Iio, Y., Arai, T., Kobayashi, K., Matsuda, T., Shimada, K., Tanaka, H., Tomita, T., and Hirano, S. (2001b): Drilling Investigation through the Nojima Fault of the 1995 Hyogo-ken Nanbu Earthquake, Japan. Rep. NIED, **61**, 141-153.

4) Kobayashi, K., Hirano, S., Arai, T., Ikeda, R., Omura, K., Sano, H., Sawaguchi, T., Tanaka, H., Tomita, T., Tomida, N., Matsuda, T., and Yamazaki, A. (2001a): Distribution of fault rocks in the fracture zone of the Nojima Fault at a depth of 1,140 m: Observation from the Hirabayashi NIED core. The Island arc, **10**-3/4, 411-421.

5) Kobayashi, K., Arai, T., Ikeda, R., Omura, K., Shimada, K., Tanaka, H., Tomita, T., Hirano, S., and Matsuda, T. (2001b): Textures of Fault Rocks in the Fracture Zone of the Nojima Fault at a Depth of 1,300 m: Observations from the Hirabayashi NIED Drilling Core. Rep. NIED, **61**, 223-229.

6) Matsuda, T., Arai, T., Ikeda, R., Omura, K., Kobayashi, K., Sano, H., Sawaguchi, T., Tanaka, H., Tomita, T., Tomida, N., Hirano, S., and Yamazaki, A. (2001a): Examination of mineral assemblage and chemical composition in the fracture zone of the Nojima Fault at 1,140 m depth: Analyses of Hirabayashi NIED drill core. The Island arc, **10**-3/4, 422-429.

7) Matsuda, T., Arai, T., Ikeda, R., Omura, K., Kobayashi, K., Shimada, K., Tanaka, H., Tomita, T., and Hirano, S. (2001b): Chemical Analysis along Fracture Zones (1,140 m, 1,300 m, 1,800 m Depth) of the Hirabayashi NIED Drilling Core of the Nojima Fault. Rep. NIED, **61**, 183-193.

8) Omura, K., Ikeda, R., Iio, Y., Arai, T., Kobayashi, K., Shimada, K., Tanaka, H., Tomita,T., Hirano, S., and Matsuda, T (2001a): Characteristics of Logging Data for Fracture Zones in Hirabayashi NIED Borehole Drilling through Nojima Fault. Rep. NIED, **61**, 155-171.

9) Omura, K., Ikeda, R., Arai, T., Kobayashi, K., Shimada, K., Tanaka, H., Tomita, T., Hirano, S., and Matsuda, T (2001b): Fault Rock Distribution in a Fracture Zone at a 1,800 m Depth of the Hirabayashi NIED Core Collected by Nojima Fault Drilling. Rep. NIED, **61**, 173-182.

10) Tanaka, H., Higuchi, T., Tomida, N., Fujimoto, K., Ohtani, T., and Ito, H. (1999): Distribution, deformation and alteration of fault rocks along the GSJ core penetrating the Nojima Fault, Awaji Island, Southwest Japan. Jour. Geol. Soc. Japan, **105**-1, 72-85.

11) Tanaka, H., Matsuda, T., Omura, K., Ikeda, R., Kobayashi, K., Shimada, K., Arai, T., Tomita, T., and Hirano, S. (2001b): Complete Fault Rock Distribution Analysis along the Hirabayashi NIED Core Penetrating the Nojima Fault at 1,140 m Depth, Awaji Island, Southwest Japan. Rep. NIED, **61**, 195-221.

(Accepted : March 28, 2002)

野島断層 NIED 平林ボーリングコア写真

小村健太朗[*1]・池田隆司[*2]・松田達生[*1]・新井崇史[*3]
小林健太[*4]・島田耕史[*5]・田中秀実[*6]
富田倫明[*7]・平野　聡[*8]

[*1] 防災科学技術研究所
[*2] 防災科学技術研究所（現在;北海道大学）
[*3] 東京大学（現在;産業技術総合研究所）
[*4] 新潟大学
[*5] 早稲田大学（現在;東京大学）
[*6] 東京大学
[*7] 筑波大学
[*8] 海洋科学技術センター

要　旨

1995年兵庫県南部地震で活動した野島断層を貫く掘削により，地震の約1年後に1,000mから1,838mの深さまで連続的に断層帯コア試料が採取された．コア試料は，ほとんどが花崗質岩で，所々にporphyriticな貫入岩を含み，また1,140m，1,300mと1,800m周辺の3箇所で破砕および変質の著しい断層岩からなる破砕帯が見いだされた．破砕帯のコア試料は,断層活動に関連した構造の詳細観察のため,全体でおよそ2,210個の研磨片に整形され,研磨面の写真が撮られた．写真画像はJPEG形式のデジタル画像データに変換され，2枚のCD-ROMに収録された．破砕帯コア試料のデジタル化されたイメージは,メソスコピックな観察と定量的な画像解析に有効である．

キーワード：破砕帯，断層岩，デジタル画像，野島断層，1995年兵庫県南部地震