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# Initial Stress Measurement of Horonobe Siliceous Rocks by DSCA Method

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## 1. Introduction

It is known for the Neogene siliceous rock mass in Hokushin, Horonobe, Hokkaido that there is a region where a rapid change in physical properties along depth is seen (the transition zone) [1]. It is thought that such change in physical properties has some influences on the initial stress state. Only the magnitude and direction of the maximum ($\sigma_H$) and minimum ($\sigma_h$) principal stresses in the horizontal plane were evaluated in the stress measurement by the hydraulic fracturing method[1](HFM) and no information on 3-dimensional stress state was obtained.

In this study, evaluation of the 3-dimensional stress state was tried applying DSCA method, one of the stress measurement methods using rock core specimens. Two specimens from the transition zone and two specimens from hard shale seam, which is located lower than the transition zone, were sampled from HDB-11[1] and used.

## 2. Test procedure

Usually an unsaturated cubic specimen is used and strains of 9-12 directions on mutually perpendicular three planes (3-4 directions for each plane) are measured increasing hydrostatic pressure in the DSCA method. However, tests were carried out under the drained condition using cylindrical specimens whose diameter and height were 30 mm and 60 mm, respectively, because it was necessary to use saturated specimen since physical properties of the siliceous rock specimens could be affected by change in water content and also enough effective hydrostatic pressure might not be obtained if a saturated specimen was used. The specimen on which strain gauges were glued was attached to the end pieces through porous metals and was covered with a heat shrinkable tubing. The jacketed specimen was inserted in the ultra compact triaxial cell[2] (**Fig. 1**). Upper and lower end pieces have small holes and pore water is drained from the holes. The directions of the specimens were identified based on the strike and dip of the neighbor cracks obtained by BHTV log of HDB-11.

## 3. Example of results for specimens from transition zone (Transition zone 1)

The hydrostatic pressure-strain curves are shown in **Fig. 2**. The regression lines were evaluated for 4-6 MPa of hydrostatic pressure, *y*-intercept was read and the initial stress state was calculated (**Table 1**). The average $\sigma_H$ and $\sigma_h$ are 14.2 MPa and 7.8 MPa, respectively, and the direction of $\sigma_H$ is N42E.

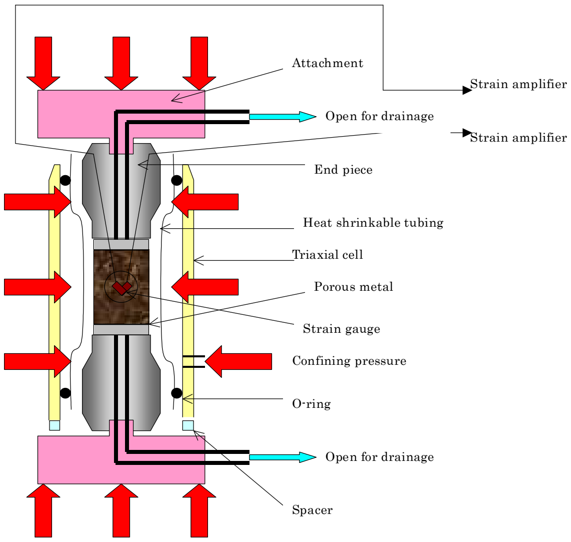



**Fig. 1** A schematic figure of the apparatus

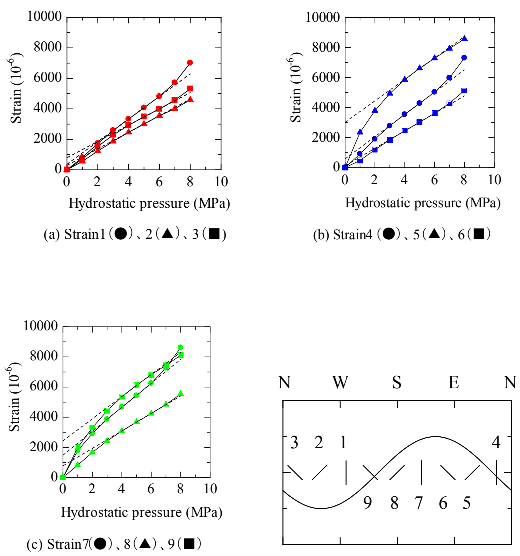



**Fig. 2** Hydrostatic pressure-strain curves and position of strain gauges

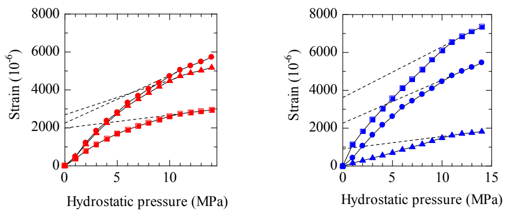
## 4. Example of results for specimens from hard shale seam (Hard shale seam 1)

The hydrostatic pressure-strain curves are shown in **Fig. 3**. The regression lines were calculated for 10-13 MPa for gauges 1 and 2 and 11-14 MPa for gauges 3-6, 8 and 9 for only this specimen to use almost linear parts (**Table 2**). The average $\sigma_H$ and $\sigma_h$ are

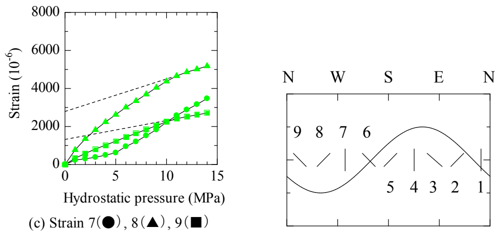
13.7 MPa and 7.9 MPa, respectively, and the direction of $\sigma_H$ is N104E.

**Table 1** Estimation of initial stress ($\sigma_v$: Overburden pressure, SD: Standard deviation, $\sigma'$: Effective stress, $\sigma$: Total stress)

| $\sigma_v$ (Total stress) | | Depth | | $\sigma_v'$ (Effective stress) | |
|---|---|---|---|---|---|
| 7.19 MPa | | 450 m | | 2.69 MPa | |
| | Strain ($\mu$) | SD | $\sigma'$ (MPa) | SD | $\sigma$ (MPa) |
| xx | 1388 | 786 | 4.60 | 2.61 | 9.10 |
| yy | 1948 | 786 | 6.46 | 2.61 | 10.96 |
| zz | 811 | 297 | 2.69 | 0.99 | 7.19 |
| xy | 1364 | 594 | 4.52 | 1.97 | 4.52 |
| yz | −766 | 297 | −2.54 | 0.99 | −2.54 |
| zx | −1133 | 297 | −3.76 | 0.99 | −3.76 |




(a) Strain1(●), 2(▲), 3(■)  (b) Strain4(●), 5(▲), 6(■)




(c) Strain 7(●), 8(▲), 9(■)

**Fig. 3** Hydrostatic pressure-strain curves and position of strain gauges

**Table 2** Estimation of initial stress

| $\sigma_v$ (Total stress) | | Depth | | $\sigma_v'$ (Effective stress) | |
|---|---|---|---|---|---|
| 10.91 MPa | | 650 m | | 4.11 MPa | |
| | Strain ($\mu$) | SD | $\sigma'$ (MPa) | SD | $\sigma$ (MPa) |
| xx | 2453 | 252 | 4.79 | 0.49 | 11.29 |
| yy | 1903 | 252 | 3.72 | 0.49 | 10.22 |
| zz | 2259 | 113 | 4.41 | 0.22 | 10.91 |
| xy | −202 | 184 | −0.39 | 0.36 | −0.39 |
| yz | 643 | 92 | 1.26 | 0.18 | 1.26 |
| zx | 1115 | 92 | 2.18 | 0.18 | 2.18 |

## 5. Comparison between HFM and DSCA

The features of the initial stress field of this area which were obtained by HFM are as follows[1].

(1) The direction of $\sigma_H$ is roughly E-W.

(2) $\sigma_h$ is less than the overburden pressure.

(3) The value of $\sigma_H$ is within 1.5 times of $\sigma_h$.

(4) The stress state in horizontal plane for Koetoi seam is more isotropic than that for hard shale seam.

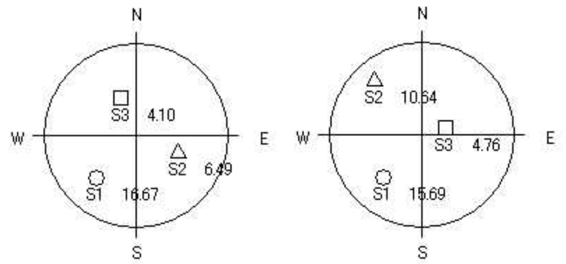
The results of DSCA method are compared to HFM results **(Table 3)**. The direction of $\sigma_H$ by HFM is different from the result by DSCA for transition zone but is similar to the DSCA result for the hard shale seam. $\sigma_H$ / $\sigma_h$ by DSCA are slightly larger than / similar to that by HFM.

**Table 3** Comparison between results by HFM and DSCA

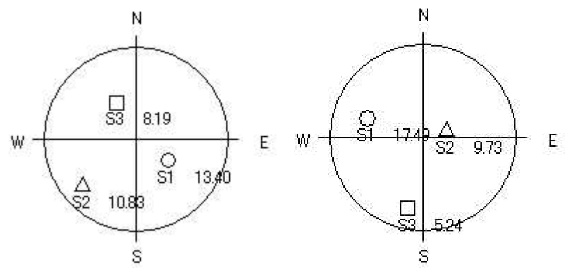
| | HFM. | DSCA (Transition zone) | DSCA (Hard shale seam) |
|---|---|---|---|
| Direction of $\sigma_H$ | Approx. N90E | N42E | N104E |
| $\sigma_h$ | $< \sigma_v$ | 1.1 $\sigma_v$ | 0.7 $\sigma_v$ |
| $\sigma_H$ | $< 1.5\ \sigma_h$ | 1.8 $\sigma_h$ | 1.7 $\sigma_h$ |

## 6. Information of 3-dimentional initial stress state

The evaluated 3-dimentional stresses are shown in **Fig. 4** by the stereo projection onto the lower hemisphere (○ : $\sigma_1$、△ : $\sigma_2$、□ : $\sigma_3$). The results for the transition zone are similar with each other and $\sigma_1$ is approximately parallel to the strata and perpendicular to the anticline axis. The results for hard shale seam are not similar with each other.




**(a) The result of T.Z.1** **(b) The result of T.Z.2**




**(c) The result of H.S.S.1** **(d) The result of H.S.S.2**

**Fig. 4** Estimated 3-dimentional stresses by DSCA (T.Z.: Transition zone, H.S.S.: Hard shale seam)

## 7. Conclusions

The initial stress measurement for the Neogene siliceous rock were carried out by using DSCA method. There are not significant differences between the hydraulic fracturing method and DSCA results except for the direction of $\sigma_H$ for transition zone. $\sigma_1$ is approximately parallel to the strata and perpendicular to the anticline axis.

## References


1) S. Niunoya and H. Matsui: Proc. 35th Symp. on Rock Mech, pp. 177-182.

2) Y. Fujii: Proc. MMIJ Fall Meeting (2004), Vol. AB, pp. 73-74.