Characteristics of Strain Migration in the Norththiastern Japanese Arc. (?)-Propagation Characteristics-

Characteristics of Strain Migration in the Northeastern Japanese Arc (I) — Propagation Characteristics —

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(Received April 3, 1978)

Abstract: Strain analysis of the data from the extensometers arranged across northeastern Honshu, Japan, is performed.

The results show that the maximum shear strain migrated in the N50°W direction at a velocity of about 38 km/year. It is also made clear that the propagating maximum shear strain shows the dispersion characteristic.

Comparison of the characteristics of the strain with other geophysical data is also discussed.

1. Introduction

Recently some workers (e.g. Mogi, 1968a, b; Scholz, 1977) pointed out the migration of great earthquake epicenters. Further, Yamada (1963) found a similar propagation phenomenon of ground tilt by the use of data from the water-tube tiltmeter. The appearance of striking phases of secular crustal movements over a wide area in Japan were also reported (Ishii, 1976).

However, the characteristics of a slow-moving crustal deformation have not been investigated in detail. The purpose of this paper is to clarify the characteristics of migrating strain by analyzing the data recorded by the extensometers at the array stations.

2. Strain Observation

Crustal strain in the Tohoku District was observed at the stations of Oga (OGA), Niebtsu (NIB), Himekami (HMK), Miyako (MYK), and Sanriku (SNR) operated by the Akita Geophysical Observatory and the Sanriku Geophysical Observatory, Tôhoku University. The locations of the stations and the plane figures of observation vaults are illustrated in Fig. 1. Only the data obtained by the extensometers are investigated in this paper. Fig. 2 shows examples of the strain components analyzed by the use of Chebychev function. The method of the data analysis and the characteristics of the strains have already been described in the previous paper (R.G.C.M., 1978).

In this work we investigate the characteristics of the maximum shear strain in detail. From Fig. 2b it is found that the maximum shear components at MYK and

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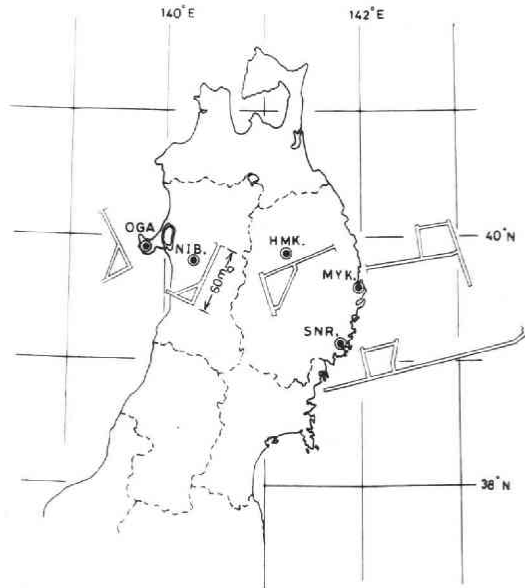* Akita Geophysical Observatory, Faculty of Science, Tôhoku University

Fig. 1.   Locations of crustal movement observatories of Tôhoku University and plane figures of
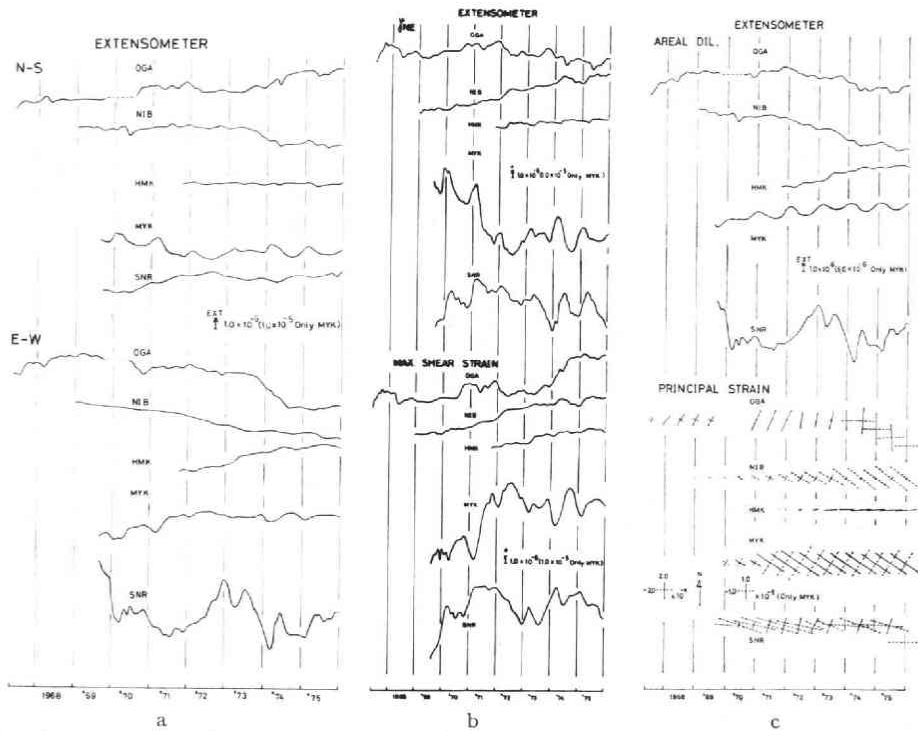   observation vaults.

Fig. 2a.   Ground strain components, e_{NS} and e_{EW}, computed from the data by extensometers at
           five crustal movement observatories.
Fig. 2b.   Ground strain components, γ_{NE} and maximum shear strains, computed from the data
           by extensometers at five crustal movement observatories.
Fig. 2c.   Ground strain components, areal dilatations and principal strains, computed from the
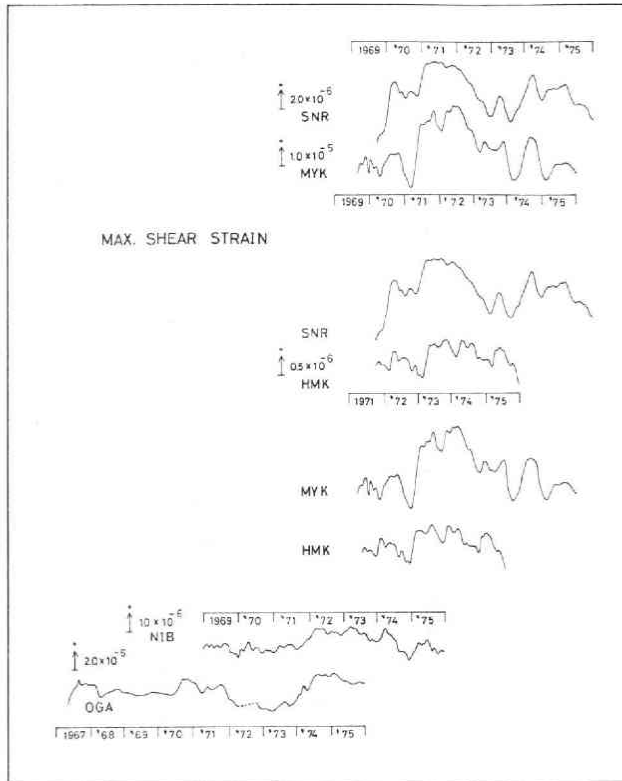   data by extensometers at five crustal movement observatories.

Fig. 3. Comparison of maximum shear strains at recording stations, the time being shifted from each other.

SNR show greater variations than those at the other stations. By filtering out the linearly varying components, which corresponds to the first degree terms, we can get the secular components of the maximum shear strain. We have the values 8.3×10^{-7}/year for OGA, 8.4×10^{-7}/year for NIB, 6.4×10^{-7}/year for HMK, 48.0×10^{-7}/year for MYK. and 10.2×10^{-7}/year for SNR. Next, filtering off the first degree term, namely, removing the linearly varying components from the maximum shear components, we can have Fig. 3 from Fig. 2b. In this figure the arbitrary time shift is given between the corresponding maximum shear strains. It is found that a pair of the curves has a similar waveform. A striking phase occurred at the end of 1970 at SNR is seen at other stations, but this phase does not seem to reach the OGA station. Therefore, the evidence supports the idea that the maximum shear strain is propagating across the northeastern Japanese arc. It is of interest that the waveform of the maximum shear is similar each other though the amplitude is different.

Fig. 4 shows the auto-covariance functions of the maximum shear strain. The annual variation in maximum shear is found on the curves, particularly on the curve of HMK. MYK, HMK and NIB show a similar curve at this auto-covariance domain. In addition SNR and OGA exhibit a similar variation.
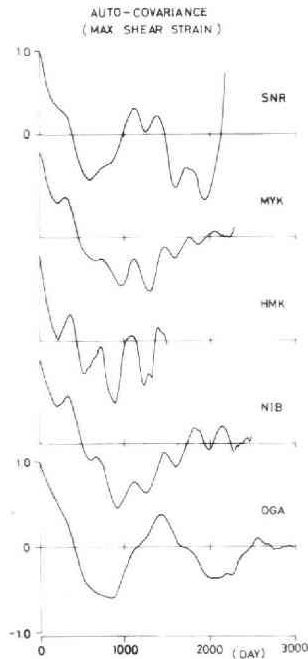
Fig. 4. Comparison of auto-covariances of maximum shear strains.

3. Characteristics of strain wave

In Fig. 5, some of the corresponding phases are marked with the same symbols and joined by lines. We can calculate the average propagation velocity and direction, using the arrival times of the phases from three of the observation stations (SNR, MYK and HMK). The calculated velocity and direction are about 38 km/year and N50°W as shown in Fig. 6. The maximum shear strain curves from SNR to OGA are rearranged in Fig. 5, assuming the migration direction to be N50°W. This kind of curve is called the travel time curve in seismology. Slopes between NIB and OGA are smaller than those between SNR and NIB. Therefore, it is inferred that the propagation velocity is different from one station to another. Assuming the same propagation direction, the velocity propagating from NIB to OGA is about 19 km/year. Yamada (1973) obtained an apparent velocity of 20 km/year for the migration of tilt between Nokogiriyama and Aburatsubo in the Kanto District.

Next, the cross-covariance functions of the maximum shear strains between the stations are calculated as shown in Fig. 7. A dispersion relationship is derived by the use of the cross-covariance, applying the method employed in the seismic surface waves (Dziewonski et al., 1968). Assuming the curves in Fig. 7 to be the cross-covariances for the inter-station phase velocity, we can obtain the phase velocity vs. period curve as in Fig. 8a. It is seen that the longer the period, the slower becomes the phase velocity. The phase velocities are about 41 km/year for a period of 5.1 years, and 19 km/year for a period of 5.8 years. The wavelengths correspond to about 210 km for a period
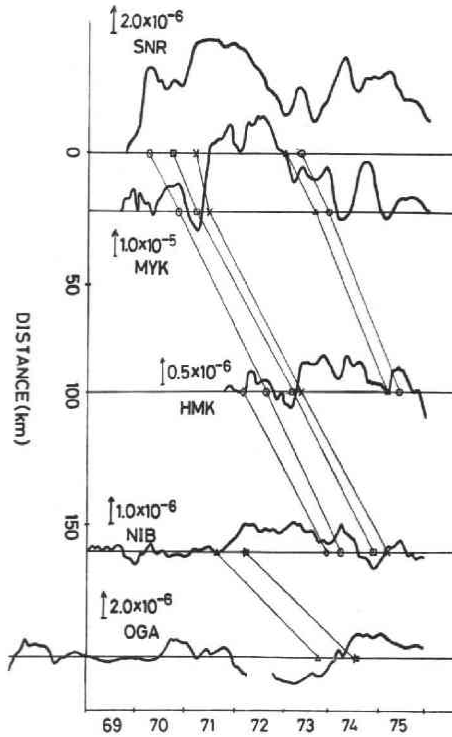
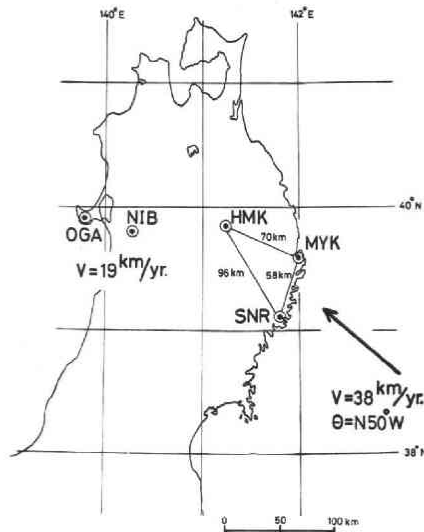Fig. 5.   Time-distance relation of maximum shear strain.

Fig. 6.   Direction and velocity for migration of maximum shear strain.

5.1 years and 110 km for a period 5.8 years.   The group velocity curve computed by differentiating the phase velocity curve is shown in Fig. 8b.   It is found that the longer the period, the faster becomes the group velocity.   It is to be noted that the group
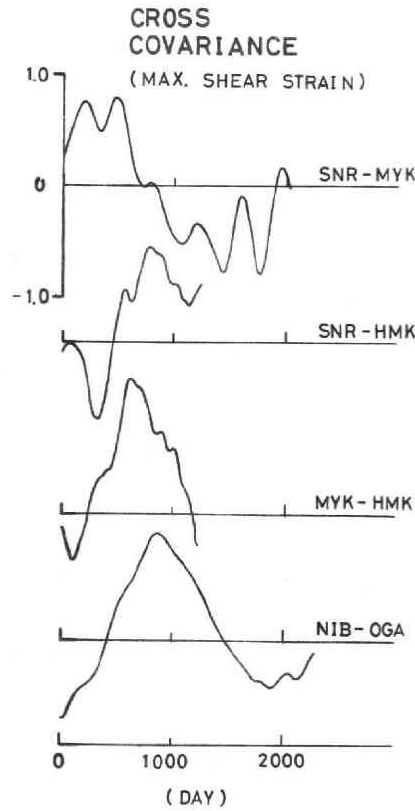
CROSS
COVARIANCE
(MAX. SHEAR STRAIN)

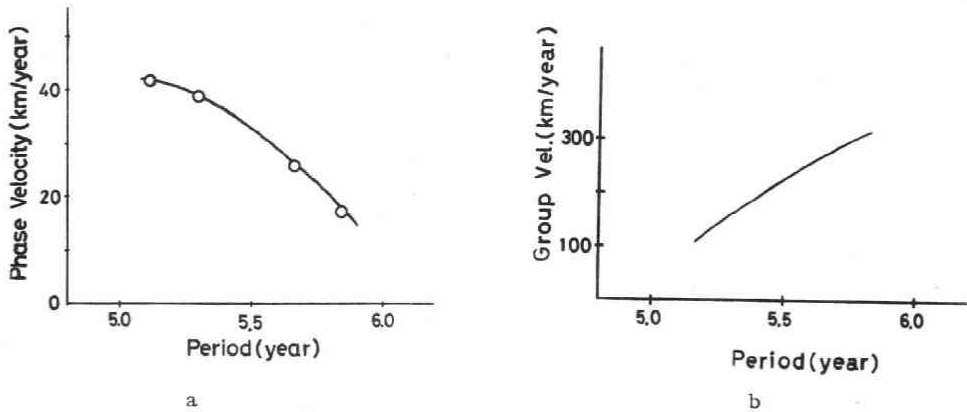Fig. 7.   Cross-covariance of maximum shear strains.

Fig. 8a, b.   Dispersion relation of maximum shear strain.

velocity is larger than the phase velocity at the corresponding periods.

4.   Discussion

In the preceding sections, the characteristic behavior of the maximum shear strain in the Tohoku District, northern Japan, was revealed, and the migration of the maximum

shear strain in the direction N50°W was found.   Fig. 9a is a schematic representation in vertical projection of the focal depth distribution of the microearthquakes that occurred in the region between 39°N and 40°N.   Fig. 9b shows the average mechanisms of microearthquakes that occurred in the area A, B, C, D and E in Fig. 9a (Hasegawa et al., 1978).   NW-SE compression is seen for the areas A, B and C, but not for the areas D and E.   It is of interest that a pressure axis of the average mechanism solution of microearthquakes in the upper plane of the double-planed deep seismic zone is nearly identical with the propagation direction of the maximum shear strain.   It is also interesting to note that the propagation direction of the maximum shear strain almost coincides with a direction of the motion of the pacific plate obtained by Morgan (1972).
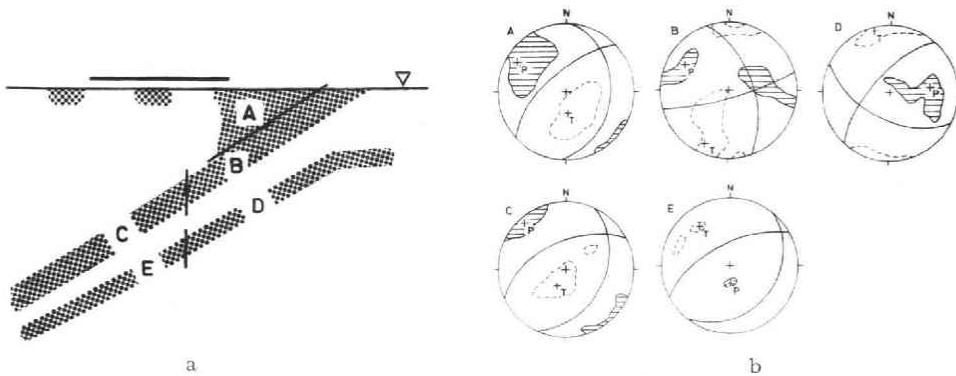

a   b

Fig. 9a; A schematic expression in vertical projection of the hypocenters of the microearthquakes happened in the region between 39°N and 40°N. (after Hasegawa et al., 1978)

Fig. 9b; Average mechanisms of microearthquakes happened in the area A,B,C,D and E in Fig. 9a.

Tanaka et al. (1977) found the migration of tilt in Peru and obtained apparent velocities of about 60 to 100 km/year.   A velocity of about 80 km/year was obtained for the migration of seismic activity along the Anatolian fault by Mogi (1968a, b). Scholz (1977) pointed out that the 1975 Haicheng earthquake was triggered by a deformation front with a propagation velocity of about 110 km/year.   Therefore, it is said that deformation propagates at different velocities depending upon the period or wavelength.   Studies of migration of crustal deformation were summarized by Kasahara (1977).   Since the wavelength is several hundred kilometers, it is considered that the propagation characteristics of the maximum shear strain are related to the substances and structures of the crust and the upper mantle beneath the earth.   According to Takagi et al. (1977), earthquakes at the inland of the Tohoku District occur in the layer of the crust with P wave velocity 5.9 km/sec, but do not occur in the layer of the crust with the velocity 6.6 km/sec.   The layer with the velocity 6.6 km/sec is likely to be more ductile than the layer with the velocity 5.9 km/sec.   Therefore, it is reasonable to consider that the layer with the velocity 6.6 km/sec plays an important role in a slow move like the migration of the maximum shear strain.

5. Summary

The characteristics of strain migration in the Tohoku District were investigated by analyzing data obtained by extensometers at the crustal movement observatories arranged across the northeastern Japanese arc. The results of the present study are summarized as follows:

(1) Migration of maximum shear strain was found in the northeastern Japanese arc.

(2) The maximum shear strain propagates in the direction N50°W with the average velocity of 19 to 38 km/year.

(3) The propagating maximum shear strain has a dispersion property, and the dispersion curves have been obtained.

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