Geology. — *Fractures and faults near the surface of moving geanticlines.* IV. *The elastic rebound of the earth crust in Central Honshu.* By Prof. H. A. BROUWER.

(Communicated at the meeting of January 29, 1927).

During the 3d Pan Pacific Science Congress (October, November 1926) some of the members including myself were so fortunate to visit the regions that were devastated by the Mino-Owari earthquake of 1891 in Central Japan, guided by Prof. S. NAKAMURA of the University of Kyoto. This part of Central Japan is known for its numerous and important fractures and faults with horizontal and vertical displacements, formed during this earthquake, and which are clearly visible in the topography. The fault-scarp near Midori, which cuts a new road in two, showing clearly a vertical displacement of 6 m. and a horizontal one of 4 m., is reproduced in many handbooks as a typical example of movement along fractures during earthquakes.

Of this earthquake an extensive description is given by KOTO [1]). He describes a fracture which can be followed over a distance of 112 km. from the Kisogawa to Fukui with striking regularity and clearness right through the mountains, valleys and plains of Central-Japan.

The origin of this great transverse fracture is of importance in connection with my views exposed a few years ago, about the relation between earthquakes and the movement of geanticlines in space [2]) [3]). It is clear, that such a regular and sharply defined transverse fracture, which can be followed nearly over the whole width of Central-Japan cannot be connected with local deformations and differences of velocity, but that here the deformation of the whole island Honshu has to be considered.

So we find a confirmation of my thesis, that *important tranverse fractures near the surface of moving geanticlines will occur near the bending points of the horizontal projection of the geanticlinal axes* [4]).

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[1]) B. KOTO. On the cause of the great earthquake in Central-Japan. 1891. Journ. Coll. of Science. Imp. Univ. Japan. Vol. **5**. Part IV, p. 295. Tokyo. 1893.

[2]) H. A. BROUWER. Some relations of earthquakes to geological structure in the East-Indian archipelago. Bull. Seism. Soc. of America. **11**, 1921, blz. 166.

[3]) H. A. BROUWER. The geology of the Netherlands East-Indies. University of Michigan Studies. Scient. Ser. Vol. **3**. p. 84—92.

[4]) H. A. BROUWER. The horizontal movement of geanticlines and the fractures near their surface. Journ. of Geology. Vol. **29**, 1921, p. 576.

Fig. 1 gives a schematic geanticlinal axis of the island Honshu and it is evident, that the great transverse fracture along which movement took place during the Mino-Owari earthquake intersects the island near this point. Thus follows, that the deformation and movement of the island Honshu take place in a way which are incidental to important differences in velocity in a horizontal direction f.i. near the fracture in the central part of the island. These slow deformations which take place continually, cause a strain in the crust which is occasionally relieved by sudden and rapid movements along the fractures, causing the earthquakes. [1]

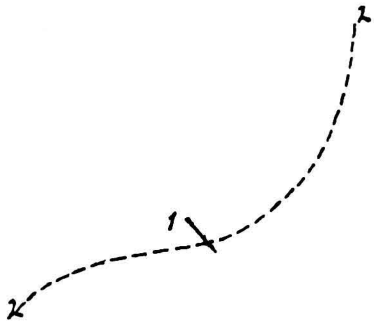

Fig. 1. Schematical representation of the geanticlinal axis of the island Honshu (2) and the fracture of the Mino-Owari earthquake of 1891 near the bending point of the geanticlinal axis (1).

The strength of the rocks will generally be exceeded in the first place where the differences in velocity of the slow movements are the greatest.

The displacements are shown in fig. 2. During an earthquake the crust suddenly springs back to positions of equilibrium as shown by the arrows 1 in fig. 2.

In applying this theory to the movements during the earthquake of 1891 in Central-Japan we find, that in contradiction to what could be concluded from the above mentioned considerations, the N.E. part along

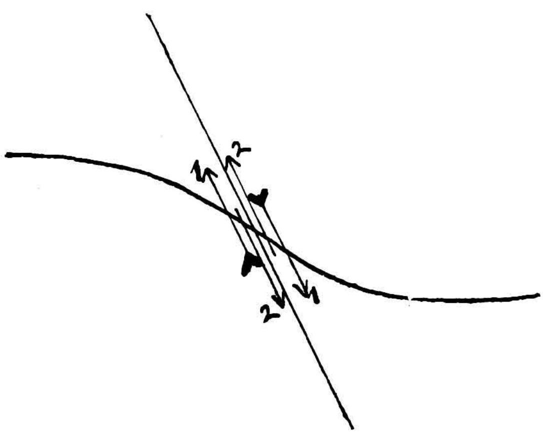

Fig. 2. Relative displacements along the fracture of the Mino-Owari earthquake. 1, derived from the shape of the geanticlinal axis of the island Honshu. 2, the observed relative displacements.

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[1]) H. F. REID. The elastic rebound theory of earthquakes. University of Calif. Publ. Bull. Dept. Geol., Vol. 6, N⁰. 19, 1911.

the fracture has been moved to the N.W., with regard to the S.W. part (2 in Fig. 2).

It could be concluded, that the movement of 1891 was an exception to the general rule, but in the following it will be shown that this needs not be the case and that the displacement at the surface can be in opposite direction of that at greater depth, the shape at the surface of the geanticlines being in the first place dependent on the movement at greater depths.

We did formerly already point out [1]) the existence of tectonic zones and zones of movement at different depths. The velocity of horizontal movement at greater depth can show an important difference with that near the surface and if the horizontal movement is considered during a sufficiently long period the result will be, that points which in the beginning of the movement were situated on a vertical line, afterwards are on an irregular curve.

The deformation and the shear, tension and compression will change from place to place. In fig. 3 we have supposed for the sake of simplicity that of two adjacent parts of the crust one part deforms but slightly. In the other part the forces cause bending as well as compression. In the upper part, that is in the part nearer to the surface, the lengthening by bending is greater than the shortening by compression; in the lower

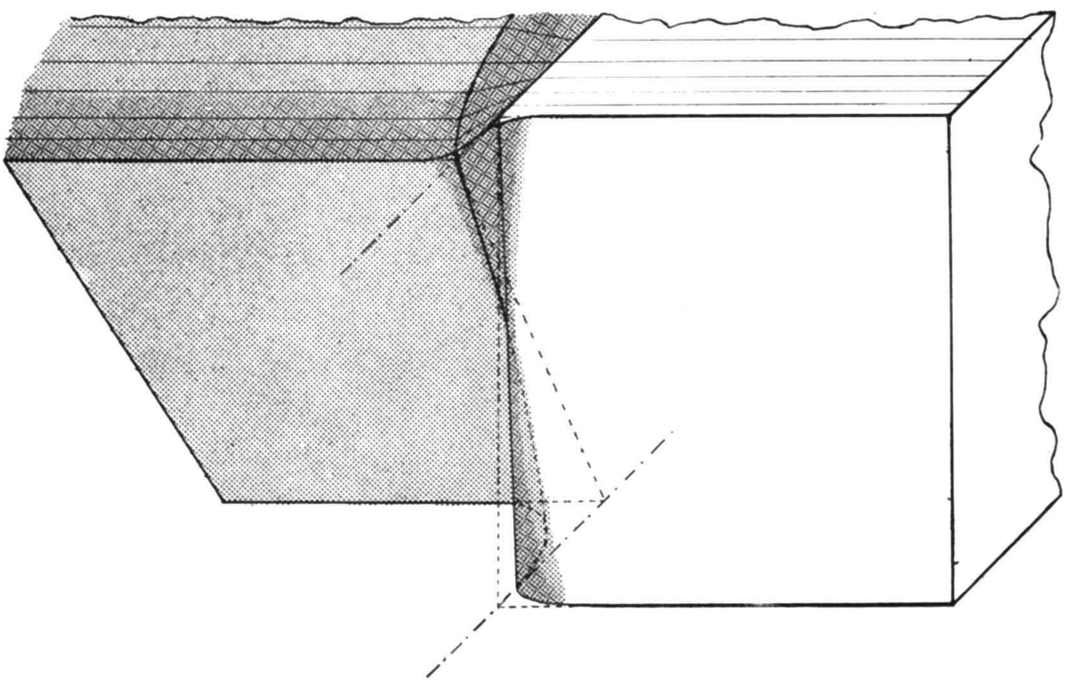

Fig. 3.

[1]) H. A. BROUWER. Fractures and Faults near the surface of moving geanticlines. II. Abnormal strikes near the bending-points of the geanticlines. Proceed. Kon. Akad. v. Wet. Amsterdam. Vol. **25**, Nos 7 and 8, 1922.

part, that is in the part farther from the surface, shortening is due to bending as well as to compression.

When the strength is exceeded a sudden movement takes place along a fracture plane as is shown in exaggerated proportion in fig. 3. This movement causes a variable vertical displacement, the horizontal displacement in the upper part will have a direction *opposite* to that of the part situated farther from the surface.

The dimensions of the above mentioned parts of the crust can be left unconsidered. The distribution of the stress can vary very considerably for different depths. All this shows, that with a certain distribution of stress the movement described above can occur and that it is not permitted to make conclusions with regard to the direction of movement based on relative displacements at the surface.

When the horizontal projection of a geanticlinal axis shows a bending point, this proves differences of velocity at greater depths. The movements may be directed differently at both sides of the bending point, they can, however, also have the same direction but with a difference of velocity.

The strain near the bending point will differ from place to place and the amount of horizontal and vertical displacement will also differ from place to place. But the tendency of movement, which can be derived from the shape of the geanticline permits the supposition that a certain strain will predominate over greater distances near the fracture plane, so that definite vertical and horizontal relative displacements can also predominate.