# PECULIAR PHENOMENA IN THE PROPAGA-
## TION OF EARTHQUAKES.

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It has long been a recognized fact and one which has been
repeatedly demonstrated, that many of the severer earthquakes,
whilst exhibiting in flat districts an area of no mean extent,
have soon found a limit to their spreading in the adjacent
mountains, notwithstanding that the waves have struck the foot
of the mountains with considerable force and have, here and
there, even caused the greatest destruction to the base itself or
to places in the vicinity. In cases of this nature the mountains
have often been likened to a wall which the shocks were
powerless to pierce.

In Europe the Alps are regarded as a rampart of this nature
against many an earthquake of Upper Italy, and in South
America the Andes with their parallel chains are looked upon
as forming, in a more especial degree, a wall against the fre-
quent and oft-times intense shocks of the plains of the western
coast.

The reason for this peculiar phenomenon has been sought
in mighty zones of rejection which the waves are unable to
pass, or in which the shocks lose a considerable portion of
their intensity; a second explanation is based on the supposi-
tion that the seismic energy is insufficient to produce vibrations
in such huge mountain masses; and other similar causes have
been adduced. Reasons of this kind are either directly refuted
by the fact that earthquakes pass in undiminished intensity

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from mountains to the plains at their base, in which case the supposed cleavage zones would necessarily have to produce a like paralysing effect, or they are, on the other hand, too often little supported by facts, or else utterly and entirely unscientific.

In the following pages an attempt has been made to give a purely general explanation of the above-mentioned peculiarity in the propagation of many earthquake shocks.

The seismic origin whether central, linear, or acting in a plane may be either; (1) beneath the foot of the mountains; (2) beneath the level ground stretched at their base; or, (3) beneath the mountains themselves.   These three cases deserve to be considered separately.*

### 1.—The Seismic Focus $O$ (Fig. 1) lies Beneath the foot of the Mountain.

If $A B$ be the plain at the mountain's base, $B C$ the side of the mountain, and $D E F$ the section of a sphere of disturbance of optional, but equal, intensity, the last will cut the plain at $G$ and the side of the mountain at $\mathcal{J}$.  If $D E F$, for instance, be the ultimate curve of intensity corresponding to a scarcely perceptible surface shock, it is to be concluded from the figure that the foreland was shaken to a considerable distance, namely along $B G$, the side of the mountain, on the other hand, only as far as $\mathcal{J}$.  The latter distance, which is considerably shorter, and which diminishes still more in the horizontal protection of a map, is, therefore, simply a necessary geometrical result of the wave propagation of a shock in spherical shells or in a form similar thereto, and the effect of a mountain range as an earthquake wall is thereby explained.

In the case under review, with a central as well as with a transverse† shock, the depth of the focus $O B = t$ can be easily

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* The author wishes it to be understood that the following explanation of the apparent stemming of shocks only holds good in its entirety in the case of the steeper mountain slopes.

† The section Fig. 1 is here taken to be perpendicular to the line of the shock.

calculated from the isoeists, or from the extent of the earth-quake (final isoseist).

If $B\,G=a$, and $H\,\mathcal{J}=b$, and the relative height of $\mathcal{J}$ above the foreland $B\,G=h$, and a radius $r=O\,G=o\,F$ corresponds to the sphere under consideration, then in $\triangle\,O\,B\,G$ and in $\triangle\,O\,H\,\mathcal{J}$ respectively

$$r^2 = a^2 + t^2$$

and $\quad r^2 = b^2 + (t + h)^2$, from which we obtain

$$t = \frac{a^2 - h^2 - b^2}{2h}$$

### 2.—THE SEISMIC FOCUS O (Fig. 2) LIES BENEATH THE FORELAND.

In this case the geometrical relations are to a great extent similar to those in the preceding case. The area of propagation in the direction of the mountains will appear on the map to be less than that on the plain by the distance $K\,F$; the intensity is, however, less at the foot $B$, and the rampart-like effect of the mountain range will seem the less strange as slight disturbances in the course of the isoseists may be dependent on the most various influences.

If the epicentrum $L$ can be determined as the district, for instance of the vertical shocks and the like, the depth of the seismic focus can be calculated in the same manner as in the case first considered.

### 3.—THE SEISMIS FOCUS O (Fig. 3) LIES BENEATH THE MOUNTAIN.

The epicentrum is at $L$; from this point the shock spreads up the side of the mountain as far only as $\mathcal{J}$; on the plain, how-ever, it reaches as far as $D$.

Here a peculiar phenomenon may occur: where, namely, the seismic focus is situated at a great depth and the slope is steep, the foot $B$ will be the point nearest to the centrum $O$ and will, therefore, be most affected, the shock will, in fact, be greater here than at the epicentrum $L$, and from this point the

intensity will diminish outwards over the plain as well as in the mountains. In the event of $D\ E\ F$ being the final isoseist, nearly vertical shocks would be felt on the confines of the area of disturbance on the mountain side at $\mathcal{F}$, whereas at the foot of the mountain, and where the intensity would be much greater, lateral vibrations would occur.

This case shows a quite peculiar eccentrical position of the epicentrum $L$ with reference to the isoseists, which would have their centre at $B$, whereas one is accustomed to seek the epicentrum centrically in the midst of the lines of equal intensity.

It is scarcely necessary to point out that if the epicentrum $L$ be ascertained according to one of the well-known methods, the depth $t$ of the focus can be found with the help of the final curve $DEF$ in manner similar to that adopted in the preceding cases. If $LO = t$, and if $LM = h$ be the relative height of $L$ above $AB$, and the difference in height of $\mathcal{F}$ and $L = h_{,}$, the previous formula will become

$$t = \frac{a^2 - b^2 + h^2 - h_{,}^2}{2\ (h + h_{,})}$$

A fact which has been repeatedly demonstrated in mountainous districts is that an earthquake has been felt in two or more neighbouring parallel valleys, but not on the heights; or that the strength of a shock has been incomparably greater in the valleys than at places situated at a height.

The opposite distribution of intensity is also known.

The explanation of all these phenomena, apparently so replete with contradictions, is in the same way based on the positions of the curves of intensity with respect to the terrestrial formation.

If $O$ (Fig. 4) be the seismic focus and $A\ B\ C$ a curve of intensity, the lower portion of the ground, the portion, that is to say, nearest to $O$, will vibrate more than that situated above it,—the earthquake will be felt in the valleys $D$ and $F$ more than on the ridge $E$. If $A\ B\ C$ be the final isoseist to which the shock attains, the places lying higher will not feel a shock

that is very perceptible in the valleys.   The term " earthquake-
bridge " has been applied to mountain ranges of this kind.

In Fig. 5, $O$ lies comparatively near the earth's surface.   I.
is a curve of greater intensity than that denoted by II., and
greater still than that marked III.   The summit $E$ will, there-
fore, be affected to a greater extent than the slopes $A$ and $B$;
in the valleys $D$ and $F$, on the other hand, the earthquake
may possibly be scarcely perceptible.

Whilst in Fig. 4, the focus $O$ is at a greater depth than the
centre of a circle passing through the valleys $D$ and $F$ and the
summit $E$, in Fig. 5 the contrary is the case.

A simple geometrical construction gives, with the help of
the three points $D$, $E$, and $F$, the radius of the circle corre-
sponding to the profile of the mountain, which permits, there-
fore, of an estimate being made of the depth of the seismic
focus, presuming that the latter lies in the profile plane.   With
the help of four points of equal earthquake intensity, the
geometrical position of the focus can be exactly ·determined,
even where the focus does not fall within the vertical plane of
the profile drawn.   The problem to be solved runs thus :

" Through four points lay a spherical shell and determine
the position of its centre (seismic focus)."

If several spheres of intensity are successfully determined
with the help of in each case at least four points, they would
necessarily possess, in the case of a central shock, a common
centre.   On the other hand, the geometrical positions of the
centres of the spheres would lie in the case of linear quakes at
a substantial distance from each other, and all the more so if
the four points are situated at one end and the four others at
the opposite end of the extended area of disturbance.

The sources of· error unavoidable in the observation of an
earthquake can only be eliminated by combining the greatest
possible number of most trustworthy statements; none but
average values procured in such fashion and controlling each
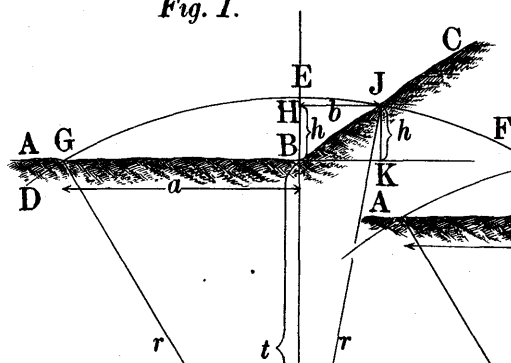other can form a satisfactory basis for further conclusions.
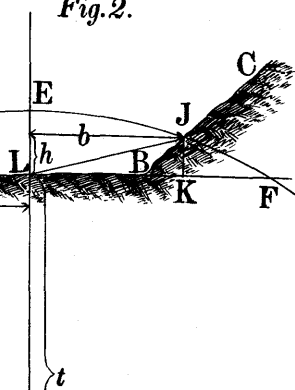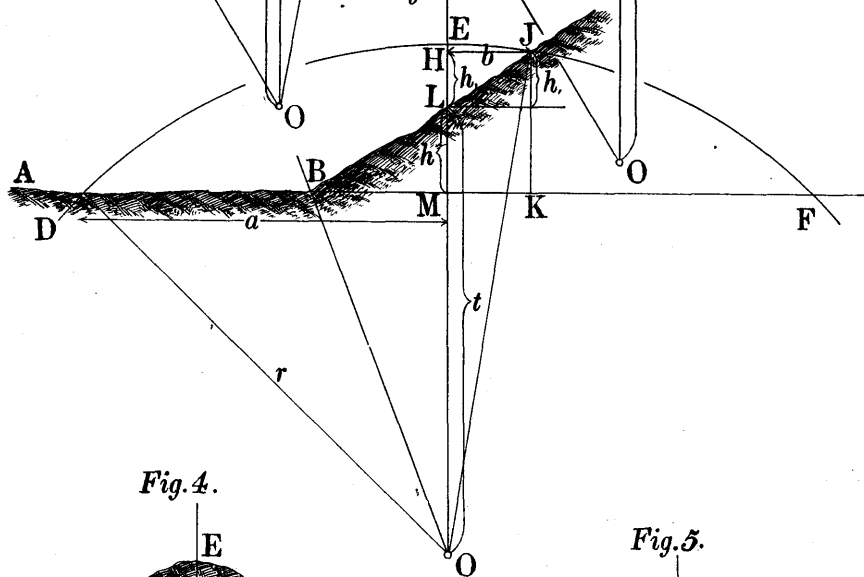
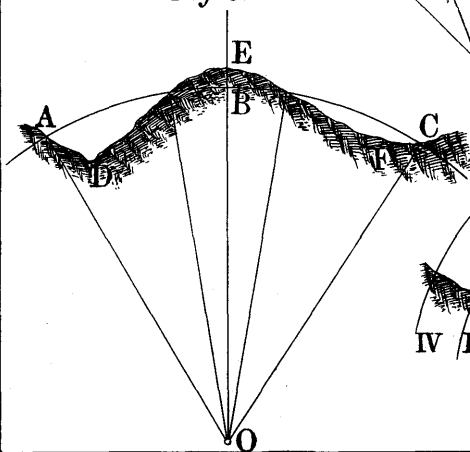Leoben, March 1st, 1888.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.