Mechanism of Volcanic Earthquakes of the Sheveluch Volcano, Kamchatka

V. M. ZOBIN
Institute of Volcanology, Siberian Branch, U.S.S.R.,
Academy of Sciences

Abstract

Determinations of the focal mechanisms of three volcanic earthquakes are given connected with the eruption of the Sheveluch volcano (November, 1964). As initial material the data on first arrivals of P-waves are used. The focal mechanism of all three earthquakes is close to a strike-slip type of faulting and similar to the focal mechanism of tectonic earthquakes of Kamchatka. One nodal surface of all the volcanic earthquakes strikes in the same direction as the outbursts of the directed volcano explosions.

Eruption of the Sheveluch volcano (Kamchatka) occurred on November 11, 1964 after a long interval and was one of the greatest eruptions of the XX century. It was preceded by earthquake swarms in April-May and October-November. The strongest earthquakes of the November swarm reached a magnitude of 5.5 and took place only a few hours prior to the beginning of the eruption. A detailed description of the eruption and of the earthquakes associated with them is given in the reports by B. I. PIIP and E. K. MARKHININ (1965), P. I. TOKAREV (1967), *and* G. S. GORSHKOV and Yu. M. DUBIK (1969). G. S. Gorshkov and Yu. M. Dubik believe that there was a very powerful explosion directed southwards which nearly completely removed the dome of the crater top. The eruption lasted not much more than an hour.

For three volcanic earthquakes of the November swarm the focal mechanism was determined. One of the earthquakes coincided in time with the beginning of the directed explosion of the volcano.

These earthquakes were apparently associated with magma movements near the Earth's surface and have focal depths of 0-10 km. A study of the focal mechanism of volcanic earthquakes may enable us to estimate the system of tectonic stresses that existed near the effluent channel at the moment of eruption.

The calculations were based on the signs of first arrivals of P-waves at seismic stations of Kamchatka and of other Soviet and foreign seismic stations given in the Bulletin of the International Seismological Center (Edinburgh) and the U. S. Coast and Geodetic Survey. The data of 40 seismic stations were used in total.

Determination of the focal mechanism of the earthquakes was carried out according to A. V. VVEDENSKAYA's method (1960). The angles of emergence of seismic rays were defined by calculating plots of L. N. Malinovskaya (KEILIS-BOROK, 1957). All the constructions were made on the Wolff net, which is a projection on the upper hemisphere. The results of constructions are given on Fig. 1 (a-c).

The main data on parameters of movements in the source are given in Table 1.

The mechanism of the source of each earthquake is as follows:

November 11, 13^h 17^m. M - 5.5, K - 12. The focal depth is 0-10 km. A diagram of constructions on the Wolff net is given on Fig. 1a. The data of 31 stations are used. As you can see the axes of maximum stresses of compression and extension are close to horizontal. Both possible surfaces of faulting as the source of the earthquakes are nearly vertical and dip steeply to the south-southwest and west-northwest respectively. The focal mechanism is close to a strike-slip type of faulting.

November 11, 17^h 28^m. K - 11. The focal depth 0-10 km. The diagram of constructions on the Wulff net is given on Fig. 1b. The data of 15 stations are used. The axes of maximum stresses of compression and extension are close to horizontal. Both possible surfaces of faulting are almost vertical and dip steeply to the south-southwest and west-northwest respectively. The focal mechanism is close to a strike-slip type of faulting.

November 11, 19^h 07^m. M - 5.5, K - 13. The focal depth is 0-10 km. This earthquake coincided with the beginning of the directed explosion on the volcano. The diagram of construction on the Wulff net is given

on Fig. 1c. The system of stresses in the source of this earthquake is similar to the system of stresses in the sources of the first two earthquakes.

The focal mechanism of all three considered volcanic earthquakes of the Sheveluch volcano is similar to the focal mechanism of tectonic earthquakes in Kamchatka.

It is interesting to note that the orientation of the directed

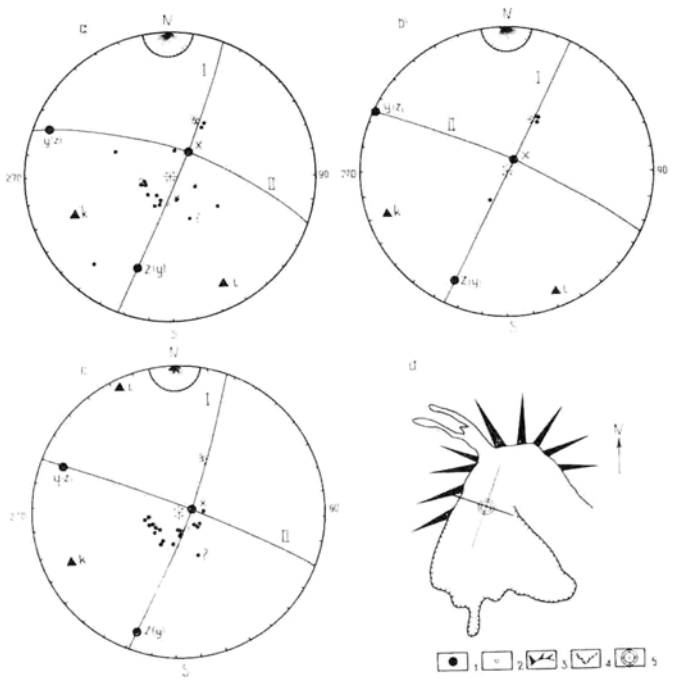

FIG. 1 - Diagrams of volcanic earthquakes projected on a Wulff net (a-c). Each point in the space was determined by two coordinates: the azimuth Az from the epicenter to the station of observations (the readings are made from the North) and angle of emergence of the seismic ray with a horizontal surface *e* (the readings are from the equator of the net). The *i* and *k* axes correspond to the axes of maximum compression and extension, respectively. The *x* axis corresponds to the axis of intermediate stress.

a - Nov. 11, $13^h\ 17^m$

b - Nov. 11, $17^h\ 28^m$

c - Nov. 11, $19^h\ 07^m$

d - Relation of the nodal planes to the directed explosions from the crater of Sheveluch (GORSHKOV and DUBIK, 1969).

1 - Compression;

2 - Dilatation;

3 - Volcanic construction of the Sheveluch volcano;

4 - Outlines of the deposits of directed explosion;

5 - Possible fault surface directions of the volcanic earthquakes.

outbursts of the volcanic explosion and the strike of one of the two possible surfaces of the faulting in the volcanic earthquakes coincided for all three earthquakes (Fig. 1d). Studies of the orientation of outbursts of the directed explosions of Katmai, Bandaisan, Asama, Hibok-Hibok and Bezymyannyi (ZOBIN, 1970) indicate that this is a general relationship for directed outbursts of volcanoes.

TABLE 1

NN	Origin time (G.M.T.)			Depth of the source	M	Nodal surface I		Nodal surface II		Compression axis i		Extension axis k	
	Day	hour	min	km		Az°	e°	Az°	e°	Az°	e°	Az°	e°
1	11.XI.64	13	17	0-10	5,5	200	85WNW	290	70SSW	155	10	250	20
2	11.XI.64	17	28	0-10	5,0	205	90	295	80SSW	160	5	250	10
3	11.XI.64	19	07	0-10	5,5	200	80WNW	290	85SSW	335	5	245	15

Az = azimuth from the epicenter to the station of observations.
e^{o} = angle of emergence of the seismic ray with a horizontal surface.

Conclusions

1) The focal mechanism of three strong volcanic earthquakes of the Sheveluch volcano is close to a strike-slip type of faulting and similar to the focal mechanism of tectonic earthquakes in Kamchatka.

2) The orientation of the outburst of the directed volcanic explosion is close to the orietation of one of the two possible fault surfaces of the earthquakes.

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