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<tr>
<td>Author(s)</td>
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<tr>
<td>Citation</td>
<td>京都大学防災研究所年報. B = Disaster Prevention Institute Annuals. B (2002), 45(B): 591-594</td>
</tr>
<tr>
<td>Issue Date</td>
<td>2002-04-01</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/2433/129042">http://hdl.handle.net/2433/129042</a></td>
</tr>
<tr>
<td>Type</td>
<td>Departmental Bulletin Paper</td>
</tr>
<tr>
<td>Textversion</td>
<td>publisher</td>
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Temporal and Spatial Variations of Seismicity during the 1998 Hida Mountain Earthquake Swarms, Central Honshu, Japan

— Preliminary Results —

Bogdan ENESCU and Kiyoshi ITO

Synopsis

We analyze the spatio-temporal distribution of b-value in the frequency-magnitude relation of earthquakes, for the 1998-1999 Hida Mountain earthquake swarms. We found a b-value that varies from 0.8 to 1.5-1.7 when depth is increasing from 4 to 6 km. The high b-value is located in a crustal region that is characterized, according to some previous studies, by low-velocity and low-density. The results suggest that the b-value can be a useful tool for mapping such “anomalous” areas, possibly associated with magma movements. Our study confirms other similar investigations in volcanic areas.

Keywords: volcanic region; seismicity; b-value; magma; Yake-dake volcano

1. Introduction

The seismic activity that occurs in volcanic regions can give valuable information on some processes associated with magma movement. One of the most important parameters to characterize seismicity is the b-value, defined as the slope of the frequency-magnitude distribution of earthquakes. A high b-value shows a relative abundance of smaller events comparing with larger ones. Extensive laboratory and field studies suggest that an increased material heterogeneity or a high thermal gradient can cause an increase in b-value from an average of about one. In several papers (Wyss et al., 1997, Wiemer et al., 2001, for example), the authors map spatially the b-value in several volcanic regions in United States and Japan. They found a high value of b, probably associated with the cracking produced by magma intrusion or the presence of a magma chamber. These studies suggest that the b-value may be a useful tool for studying and tracing the magma-related processes and also for volcanic hazard assessment.

2. Data and method of analysis

Large earthquake swarms in the Hida Mountains started in August 1998 and continued for about one and a half years. The Kamitakara Observatory, Kyoto University, has located more than 9200 events in this time period (Wada et al., 1999). We analyze the seismic activity from August 1998–end of 1999, especially the temporal and spatial variations in the frequency-magnitude distribution of earthquakes. Figure 1 shows the epicentral map of the events. The focal depth is shallower than 20 km. Only the events from Aug.25–
3. Results and discussion

The magnitude of completeness (Mc) for all data is found to be around 1 (Fig. 2). However, when representing the variation of Mc in time, values bigger than one are found (Fig. 3). This result is taken into account when computing the time variation of b-value, shown in Fig. 4 (Mmin = 1.5; number of events in a moving window = 200). The b-value increases steeply from an average of 0.8, reaches a maximum of about 1.2, and then decreases gradually in time to about 0.8-0.9. The relative increase in b-value occurs during the most active period of the earthquake swarms. Both ML (a) and WLS (b) methods show a similar pattern of b-value variation.

An interesting feature is observed when representing the depth variation of the frequency-magnitude distribution (Fig. 5): until about 4.5 km depth b-value oscillates around an average of about 0.8, then b-value starts increasing, reaching a maximum of about 1.5-1.7 at around 5.5 km, below which gradually decreases with depth.

In order to have more information on the variation of the frequency-magnitude distribution in space, we compute a cross-sectional map of b-value, using a gridding technique. Again, some anomalous, high b-values can be observed (Fig. 6). They are localized in the south part of Hida Mountain, below 4km depth. Figure 7 shows two frequency-magnitude distributions observed in regions with high b-values and low b-values respectively. We have computed the probability P that the two distributions come from the same
population (Utsu, 1992). The very small value of \( P \) (3.4x10^{-15}) is a proof that the differences in \( b \)-value found in the cross-sectional view are highly significant.

![Graph of b-value variation with depth](image)

**Fig. 5** Variation of b-value with depth by using WLS and ML methods. Mmin = 1; time-window = 100 events and max. depth = 15km.

![Cross-sectional view of b-value](image)

**Fig. 6** Cross-sectional view of b-value in N-S direction. Grid-spacing is 0.2km. A b-value at each node was determined by using the ML method.

The anomalous b-values occur in a crustal volume characterized by relatively small size earthquakes, as can be seen in Fig. 8: most of the shocks with \( M \geq 3 \) are located between 0-4 km depth.

The high b-value anomaly is observed in the same region, at about the same depths, when using JMA data, even though there are some differences between the hypocentral locations in the two catalogues. Therefore, more accurate hypocenter locations are desirable and we are planning this for our future study.

Possible explanations for these high b-values include increased heterogeneity, temperature and stress conditions. Such anomalies were reported in several volcanic areas, sometimes occurring during earthquake swarms. It is interesting to note in this respect that several studies (Katsumata et al., 1995, for example) showed that the crust at 5-15 km depth beneath Hida Mountain Range is characterized by low Q, low velocity and low density. Thus, an increase in cracking or heterogeneity of the material and the presence of a partial melt in the porous region (increased temperature) may be valuable explanations for the observed high b-values.

![Comparison of b-values](image)

**Fig. 7** Comparison between b-values of two representative samples in Fig. 6. The b-value and number of events are given at each distribution. Mc is the magnitude of completeness.

![Time-depth distribution](image)

**Fig. 8** Time-depth distribution of seismicity. Large, solid circles show events of \( M \geq 3.5 \), small, solid circles, \( 3.0 \leq M < 3.5 \) and open circles, \( M < 3.0 \).

### 4. Conclusions

1. The frequency-magnitude distribution shows a statistically significant variability in time and space during the 1998-1999 Hida Mountain Earthquake swarms.
2. During the most active period of the earthquake swarms, a relative increase in b-value can be noticed.
3. Some anomalous, high b-values can be observed in the south part of Hida Mountain, below 4km depth.
4. The high values of b below 4km depth seem to agree with reported low Q, low velocity and low density in the crust, between 5-15 km depth.
Acknowledgments

The authors thank S. Wiemer for permitting them to use the ZMAP software. They also thank H. Wada for his diligent processing of the swarm activity data. One of the authors (be) is grateful to the Japanese Ministry of Education for providing him a Monbu-Kagakusho scholarship for studying in DPRI, Kyoto University.

References


要旨

1998年飛騨山脈群発地震のマグニチュード頻度分布の係数、b値について、京大および気象のデータについて、時空間分布を調べた。その結果、b値が深さ4kmから6kmにかけて、通常値の0.9から約1.5~1.7に増加することがわかった。このことはb値が火山地域における「異常領域」の検出に有効であることを示している。これらはマグマの存在に関連していると思われる。

キーワード: 火山地域, b値, 地震活動, マグマ, 善岳