PHYSICAL ANALYSIS ON EARTHQUAKE PREDICTABILITY

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Abstract: In the paper, some analyses about the failure of rocks are made. It is suggested that earthquakes are actually the instability of nonlinear system, and that load-unload response ratio (LURR) reflects the closeness of rocks to the peak of stress and marks the danger level of some earthquake prone areas. It is found that the difficulty of impending earthquake prediction happens after the peak of stress. The possibility of impending earthquake prediction is also discussed.

Key words: **Earthquake prediction**; **Rock rupture**; **Stress**; Physical analysis

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0 Introduction

Years' research of earthquakes indicates that earthquakes are complicated natural phenomena. Many observational studies semmed to show that the occurrence of major earthquakes was preceded, at least on some occasions, by anomalous behavior in a wide variety of physical variables-increases of fluctuations in the frequency of smaller events, anomalous fluctuations of magnetic and electric field, and anomalous animal behavior etc. Today, though the prediction of large seismic events depends on a combination of several indicators such as electric rock resistivity changes, deformation, strain measurements, b-value changes, microgravimetric anomalies, dynamic change of radon in groundwater, and various statistical tests etc, no consistently reliable precursory phenomena have still been found.

It is obvious that, out of so many possibilities concerned or not, only those (if we could find) which, like rising river levels for flooding, would provide the basis for early warnimg procedures against earthquakes. Here come two problems which puzzled us for many years: one is that if there would be such (even one) possibility which appears before and when earthquakes occur case by case; another, how we could find some and set up useful formulas mathematically related to earthquake parameters, such as epicenter, origin time and magnitude etc. Only the two problems are solved, could we predict earthquakes physically, not experientially or statistically.

1 Instability of Nonlinear Systems

Earthquakes occur with the fracture of rock mass in crust, so it is not surprising that many seismologists have been efforting to explain earthquakes with experiments of rock deformation under pressure, and a lot of work has been done about this. Fig. 1 is a typical constitutive relation of rock[1], it shows how strain varies with the increase of stress under uniaxial compression. The whole variation includes five periods (or five phases). Generally the preceding three phases is called 'hardening period (OA)', 'linear-elastic period (AB)', and 'weakening period (BC)' respectively, while C, representing rock strength, is the maximum load that rock bear. It is found that rock under loading would not fail immediately when the stress reaches its strength because of the effect of rigidity of the surrounding rocks, but deeps integrity macroscopically and can still bear certain stress as its deformation increases. The stress will decrease when the deformation increases, therefore, the stress-strain curve suggests the strain-weakening model of rock failure. This phenomenon is of significance for studies of seismic precursors and seismogenic process.

In last few years, a new approach to earthquake prediction-the load/unload response ratio (LURR) theory has been proposed and developed[2~7]. The constitutive relation of rock in high pressure and high temperature is showed in Fig. 2 where P means general load while R representing response to P. R can be dislocation, strain, or some mechanic/non-mechanic variable responsing to P. With response rate X defined as

$$X = \lim_{\Delta P \to 0} \frac{R}{P} \tag{1}$$

The load/unload response ratio Y is calculated by

$$Y = \frac{X_+}{X_-} \tag{2}$$

where '+' means loading while '−' means unloading, and in Yin's research loading and unloading are thought to be generated by the tidal force of the sun and the moon. Y is defined as

$$Y = \frac{\left(\sum_{i=1}^{N_+} E_i^m\right)_+}{\left(\sum_{i=1}^{N_-} E_i^m\right)_-} \tag{3}$$

where E is the energy of small quakes which occur before a strong earthquake. During linear-elastic period there is $Y = 1$, but from A on Y begin to increase as P increase. It is easily learned that as P gets closer and closer to C, there should be $Y \to \infty$. It is what according to parameter Y could be used to measure the level of instability. The variation of LURR(Y) before some strong earthqaukes on Chinese mainland and outside China with different magnitudes and the reservor-induced earthquakes and the mining-induced shocks have been studied[8], the results show that the value of LURR increased obviously before over 80 percent earthquake cases, and Y in regions with low seismicity always fluctuate slightly about 1. Although it is proved that the LURR theory could be an approach to earthquake prediction, but there are still some problems such as larger area ($6^\circ \times 6^\circ$) of high-Y regions for $M > 7$ earthquakes, unsatisfactory precision of occurrence time, to be solved[8, 9]. It seems difficult to make further improvement on short-impending earthquake prediction through LURR.

Just as mentioned above, rock under loading would not fail immediately when the stress reaches its peak. In fact, the failure of rock is not only related to it, but also related to rigidity of the surrounding rocks. They together consist of a system, and failures or earthauqkes should be considered as instability of the system. A typical instability condition of rock sample-load machine system is as following[1]

$$K + f'(u) < 0 \tag{4}$$

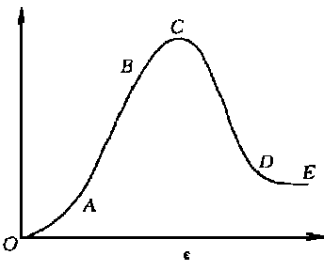

Fig. 1　Strain varying with the increase of stress under uniaxial compression.

where K is the rigidity of load machine, $f(u)$ represents constitutive relation of rock sample, so $f'(u)$ is the equivalent rigidity of rock sample. The formula (4) means failure occurs after the peak of stress. Similar procedure happens before and when an earthquake occurs, but the situation is more complicated of the interaction between rock masses, the equivalent rigidities related to bordering condition, expressed as the form of matrix, difficulty to define. Thus we can see that so called earthquake system consists of rock masses with diferent equivalent rigidities, and with the stress in crust increases, these rock masses interact continuously till the whole system get into a nonlinear state what may brings about large earthquakes. So any progressive researches about the period from the peak of stress to failure of rocks are meanful to impending earthquake prediction. An impression is beginning to emerge that in seismically active areas, large segments of the earth's crust are in some sense close to a critical state; small perturbations can produce unexpectedly large effects, even at a distance; energy, stored gradually in a volume of the crust, is released sporadically throung a complex network of interacting faults, in patterns that have a fractal rather than a regular character.

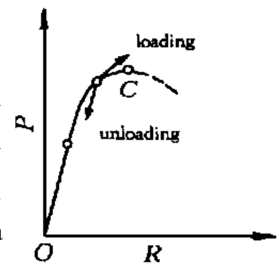

Fig. 2　The constitutive relation of rock in high pressure and high temperature.

2　Conclusions and Discussions

Though a lot of work about earthquake prediction have been done, it is still diffcult for us to predict earthquakes accurately by now. It seems that the most difficult thing is to set up mathematical equations of fromulas that reflect not only the stress-strain state where an earthquake would occurs, but also the concerned relations with surrounding crust rocks. Moreover, the original materials we get and use are always far from completeness. What we are doing and what we will do should be helpful to these if we want to make further progress to impending earthquake prediction.

[References]

[1]　Chen Yong. Mechanical properties of crust rocks (Basic theory and experimental techniques) (In Chinese) [M]. Beijing: Seismological Press, 1988.

[2]　Yin X C. A new approach on earthquake prediction (in Chinese)[J]. Earthq Res China, 1987, 3(1): 1~7.

[3]　Yin X C & Yin C. The precursor of instability for nonlinear systems and its application to earthquake prediction (in Chinese and in English)[J]. Science in China (B), 1991. 34(8): 977~986.

[4]　Yin X C. A new approach to earthquake prediction (in Russian)[J]. Russian Nature, 1993, 1: 21~27.

[5]　Yin X C, Yin C & Chen X Z. The precursor of instability for nonlinear systems and its application to earthquake prediction-the

load/ unload response ratio theory[M] . In: Newman W. I. & Gabrelov A. M.(Eds) Nonlinear Dynamics and Predictability of Geophysical Phenomena, Geophysical Monograph 83, Washington, 1994. 55~61.

[6] Yin X C, Chen X Z, Song Z P, et al. A new approach to earthquake prediction-the load/ unload response ratio (LURR) theory [J] . Pure Appl. Geophys., 1995, 145(3/4): 701~715.

[7] Yin X C, X Z and Song Z P. Load/ unload response ratio (LURR) theory-with which the Northridge earthquake etc. have been predicted beforehand[C] . IUGG XXI General Assembly, Boulder, Colorado, U. S. A., 1995. 2~14.

[8] Song Z P, Yin X C, Chen X Z. The spatial temporal evolution characteristics of the load/ unload response ratio(LURR) and its implications for predicting the three elements of earthquakes[J] . Acta Seismologica Sinica, 1996, 9(2): 235~244.

[9] Wang Y C, Song Z P, Wakayama, Chen X Z, Yin X C. The evolution characteristics of positive and negative earthquakes before strong quakes in Kanto area and the Hyugo earthquake in Japan[J] . Acta Seismologica Sinica, 1998, 11(1): 35~42.

地震预报可能性的物理分析

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摘要: 分析了岩石的破裂过程，认为地震是非线性系统失稳的结果. 加卸载响应比反映了岩体趋近应力峰值的程度，其异常仅标志着某地区具有发生地震的危险性. 指出临震预报的困难在于地震往往发生在应力峰值之后，同时还讨论了临震预报的可能性.

主题词: 地震预报；岩石破裂；应力；物理分析

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