

ROCK FAILURE AND EARTHQUAKES CAUSED BY STRESS DECREASING

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Abstract

The triaxial experiments of rock mechanics completed recently show that rock failure can be caused not only by increasing of maximum principal stress, but also by change (increasing or decreasing) of intermediate principal stress and by decreasing of minimum principal stress. Concerning that earthquakes are rock failure under triaxial stress state in the crust, it is pointed that earthquakes can be caused not only by increasing of maximum principal stress, but also by decreasing of intermediate principal stress or minimum principal stress. Before earthquakes there must be a process of increasing of stress or renergy, but earthquakes mustn't happen in the process of increasing of stress or energy. Earthquakes can happen in the process of decreasing of stress or energy. The action which can cause the stress decreasing in the crust was discussed, and the possibility of earthquakes caused by stress decreasing was searched by seismic activity.

INTRODUCTION

At the beginning of this century Reid⁽¹⁾ submitted that when the stress in the crust increased to a certain value, the fault movement happened, then the earthquake was caused. It means that before an earthquake there is a process of increasing of stress or energy. This idea corresponds to physical laws and was confirmed by observational results of earthquakes. It has become the base of physics of seismic foci. For earthquake prediction people want to know which level the stress or the energy increase up to the earthquake happens. People have less interest in decreasing of stress in the crust, at least when they consider the

problem of earthquake formation. When they do experiments of rock mechanics in laboratories, they put samples under various circumstances, and let the maximum principal stress σ_1 increases until the samples failure. In this process both the stress and the energy in the samples increase.

Recently series of experiments of rock failure were made by loading methods other than the conventional triaxial tests. The experiments show that in the samples after the maximum principal stress σ_1 increased to a certain level, keeping the σ_1 constant, the decreasing of the minimum principal stress σ_3 and the change (increasing or decreasing) of the intermediate principal stress σ_2 can lead the samples to failure. (2-4) The major results of these two kinds of experiments are given in Fig. 1 and Fig. 2.

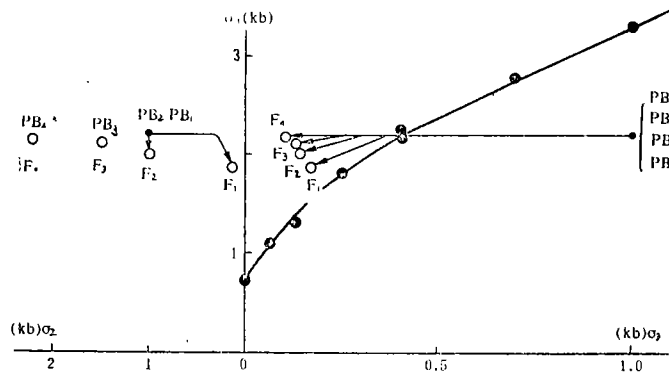


Fig. 1 Rock failure caused by decreasing of minimum principal stress

In Fig. 1 the circles are the strength of Yamaguchi marble in conventional triaxial experiments, given by Mogi. K. (5) The solid curve is the strength curve. From state P_{B1} , P_{B2} , P_{B3} or P_{B4} , when the maximum principal stress σ_1 kept constant or both the maximum principal stress σ_1 and the intermediate principal stress σ_2 kept constant, rock samples can be led to failure by decreasing of the minimum principal stress σ_3 . The failure points are F_1 , F_2 , F_3 and F_4 .

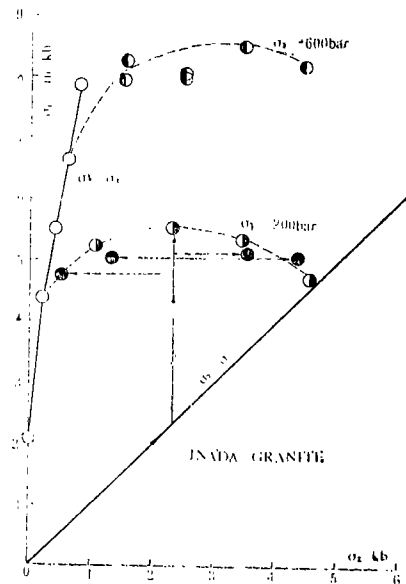


Fig. 2 Rock failure caused by change of intermediate principal stress

In Fig.2 the circles are the strength of Inada granite in conventional triaxial experiments. The half black points are the strength of Inada granite in different σ_2 . From state P_{M1} , P_{M2} or P_{M3} , when the maximum principal stress σ_1 and the minimum principal stress σ_3 kept constant, rock samples can be led to failure by change (increasing or decreasing) of the intermediate principal stress σ_2 .

The experiments suggested that before earthquakes there must be a process of increasing of stress (maximum principal stress σ_1) and energy, but the earthquake events can happen not only in process of continuous increasing of stress and energy, but also in process of decreasing of stress and energy.

It is very difficult to measure the stress in the earth crust. We do not know the change of three principal stresses before and after earthquake events. Therefore, we can't confirm this idea directly. We'll discuss the action of stress decreasing which may take place in the earth crust. Then we'll discuss the possibility of earthquakes caused by stress decreasing according to seismic activity.

THE PROCESS OF STRESS DECREASING IN THE EARTH CRUST

There are a lot of actions that can cause the stress increasing and the stress decreasing in the crust. Some actions can cause the stress increasing in a region, but cause the stress decreasing in another region. And they sometimes cause the stress increasing, but they cause the stress decreasing later. People have paid much attention to the stress increasing, this paper points that the stress decreasing can't be ignored, especially when the maximum principal stress is in high level and the intermediate principal stress or the minimum principal stress are decreasing, it must be considered that the stress decreasing might be a factor which can cause earthquakes.

There are some capable actions of stress decreasing in the crust: 1. Plate movement; 2. Fault movement; 3. Vertical movement; 4. Action of mantle materials; 5. Plastic deformation of rocks; 6. Change of temperature; 7. Liquid migration; 8. Change of earth turning velocity; 9. Influence of celestial bodies; 10. Meteorologic factors.

THE LAWS OF SEISMIC ACTIVITY AND THE POSSIBILITY OF EARTHQUAKES CAUSED BY STRESS DECREASING

Earthquakes are specific form of stress decreasing in the crust. When earthquakes happen, the stress decreases suddenly in the region of seismic

source. In a certain period after earthquakes the region of stress decreasing extend. of course earthquakes can cause the stress concentration too. The earthquakes often happen in groups. One earthquake can be caused by another. Some characters of seismic activity support the possibility of causing earthquakes by stress decreasing.

1. Active periods of earthquakes

The earthquake distribution in time is not equipollent. There are active periods and statical periods. Kanamori, H. gave the energy release curve of earthquakes all over the world.⁽⁶⁾ It shows that there were three active periods of earthquakes in this century. Mogi, K. studied the problem of active periods in Japan and in the world.⁽⁷⁾ This problem was studied also by Chinese scientists.⁽⁸⁾ It is a law that active periods and statical periods happen alternatively. Generally speaking in statical periods the stress and the energy in crust increase, in active periods the stress and the energy in crust decrease. Of course, energy and stress can increase in active periods in some regions, but in active periods, the major process in the crust is decreasing of energy and stress. The experiments have showed that the rock failure can occur in process of stress decreasing, and most of earthquakes occur in active periods, therefore some of earthquakes may occur in process of decreasing of the intermediate principal stress or the minimum principal stress.

2. Seismic gaps

In 1965 Fedotov studied the seismic activity of North Pacific Seismic Belt, and pointed that the future great earthquake would happen in unrupture region.⁽⁹⁾ Mogi, K. studied seismic gaps in Japan and divided in two kinds of seismic gaps.⁽¹⁰⁾ There are some theories of seismic gaps in China.^(11,12) The respects of seismic gaps of different scientists are not the same, but the seismic gaps have two characters: (1) In this region no great earthquake happened recently; (2) Around this region or on the same seismic belt a series of earthquakes happened. The earthquakes which already happened will influence the seismic gap. One kind of influences may be stress increasing, the another may be stress decreasing. Both of these two situations can cause earthquake in seismic gaps.

3. Migration of earthquakes

In 1958 Richter, C. F. described the migration of great earthquakes in Turkey started from 1939.⁽¹³⁾ People began pay attention on migration of earthquakes. Mogi, K. studied three kinds of migration of earthquakes in Japan.⁽¹⁴⁾ This problem was studied in Europe⁽¹⁵⁾ and in China.⁽¹⁶⁾ The

mechanism of migration of earthquakes is not clear. If we consider that the stress change caused by an earthquake has influenced on a region and caused another earthquake, this influence may be one kind of stress decreasing.

CONCLUSION

Both the stress increasing and the stress decreasing exist in the earth crust, however scientists often pay more attention on the first than the second. People live on earth surface which has confining pressure of 1 atmosphere. This confining pressure has no influence on failure of solid. The failure can be seen in nature and in engineering is led by stress increasing. The circumstance in which earthquakes happen is quite different from earth surface. In crust rocks are always in high pressure position and three principal stresses are not equal. In rocks there are a lot of energy, but the rocks keep stable by high pressure. The movement of crust can cause the change of three principal stresses and the energy in rocks. The earthquakes happen in the processes of stress change.

People often say that some factors stimulate earthquakes. Seismic stimulus has been used widely, but it is not clear how the factors stimulate earthquakes. If stimulus means a stress change on crust rocks, which are near failure, the stress change ought include both the stress increasing and the stress decreasing.

In this paper we discuss the stress decreasing as an opposite action of the stress increasing and divided them in time and space. It must be pointed that two opposite actions can occur at the same time in the same place, but on different principal stress. In crust when the maximum principal stress increases and the minimum principal stress decreases the earthquakes can be caused; when the maximum principal stress decreases and the minimum principal stress increases the rocks remain steady.

Therefore, in crust the stress increasing can't be considered as an absolutely dangerous factor and the stress decreasing can't be considered as an absolutely safe factor.

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应力减小引起的岩石破坏与地震

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摘 要

最近完成的岩石力学三轴实验表明,岩石的破坏既能由最大主应力的增加引起,又能由中等主应力的变化(增加或减小)或最小主应力的减小引起,因此联系到地震的发生也是如此。地震前必须有一个应力和能量的增加过程,但地震不一定发生在应力和能量的增加过程中,地震也可以发生在应力和能量的减小过程中。文章还讨论了能够引起地壳中应力减小的作用,并从地震活动性方面探索应力减小引起地震的可能性。