第6卷 第2期 西北地震学报 Vol.6, No.2
1984年6月 NORTHWESTERN SEISMOLOGICAL JOURNAL June, 1984

SOME PHYSICAL EXPLANATION ON ANOMALOUS AMPLITUDE VARIATION OF SEISMIC WAVES

Li Qinghe
(*Lanzhow Seismological Institute*)

Abstract

In this paper the variation of anomalous amplitude of seismic wave observed before stronger earthquakes and the results of simulated experiment and theoretical analyses have been closely combined and a comparison between them has been made. With the aid of variation of crustal medium, the explanation of the premonitory anomalous characteristics of amplitude ratio have been given. Since the variation of medium reflects that of tectonic stress, the physical explanation may possess the view of cause of formation.

Introduction

In recent years many examples on amplitudes variations of seismic waves before and after strong and moderate earthquakes have been accumulated at home and abroad, but the physical causes resulted in these variations are not much down for discussion.

This paper combines some examples summarized by Seismic Wave Groups of Lanzhou Seismological Institute in recent years with some results of simulated experiment made by Premonitory Laboratory of this institute and gives corresponding theoretical analyses. The author holds that the change of crustal medium takes its source at the change of tectonic stress and integrating physical explanation about anomalous amplitude with judgement target of earthquake prediction is perhaps useful for earthquake prediction.

1. Precursor Anomaly of Seismic Amplitude before Large Shocks

We dealt with some amplitude ratio variations before and after large events, such as Xiji M5.5 (December 3, 1975), Kangding M5.9 (September

27, 1972), Nanping M5.7(November 30, 1974), Tangshan M7.8(July 28, 1976) and Haicheng M7.3(February 4, 1975) et al (Feng De—yi, Gu Jin—ping, Li Qing-he 1983, Feng De-yi, Gu Jin-ping, Li Qing-he, Yu Xue-jun, Sheng Guoying, 1983; Li Qing-he, Feng De-yi 1982, Li Qing-he 1982), Fig 1 is a scheme of As/Ap—time variation of Haicheng earthquake and the schemes of other events are similar to this. The scheme of spatial distribution of anomalous region and dangerous region of major shock of Haicheng earthquake is illustrated in Fig 2.

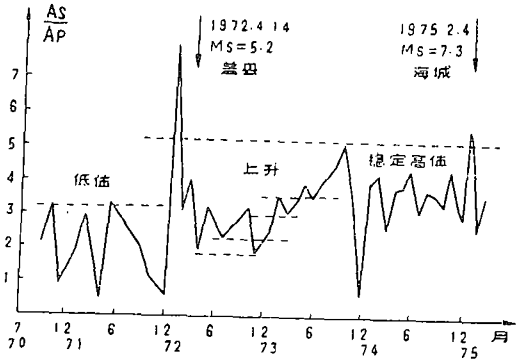

Fig. 1 The variation of monthly average value of amplitude ratio before Haicheng earthquake (Feb, 4, 1975) by many stations in Liaoning province

Fig. 3 and Fig. 4 are schemes of amplitude ratio-time of impending Haicheng earthquake recorded by Yingkou station and other stations in Liaoning province respectively, the precursor time of impending shock peak value of amplitude ratio related to epicentral distance and azimuth, and the relationship for Haicheng earthquake is shown in Fig 5.

From these we can see:

(1) The shape of amplitude ratio—time is that:

Lower value (negative anomaly)—rising to a stable higher value (positive anomaly)—occurring event—returning to normal. (see Fig 1).

(2) The dangerous region of major shock is located in the anomalous region and most of large earthquakes are used to occur at the place where the higher region of average amplitude ratio value is bounded on the lower region, i.e. gradient of amplitude ratio is large (see Fig 2).

(3) The amplitude ratio of direct path wave gains suddenly before impending events, but the time appearing peak value of amplitude ratio is different at various stations and they appear order relationship between time and epicentral distance and azimuth (see Fig 4.5).

(4) The anomalous amplitude ratio has some relation with different kinds of earthquakes (Feng De-yi, 1974). Such fault with stress on the horizontal thrust fault can mainly observe anomalous amplitude ratio.

2. Some Results of Simulated Experiments

In recent years, the Premonitory Laboratory of Lanzhou Seismological

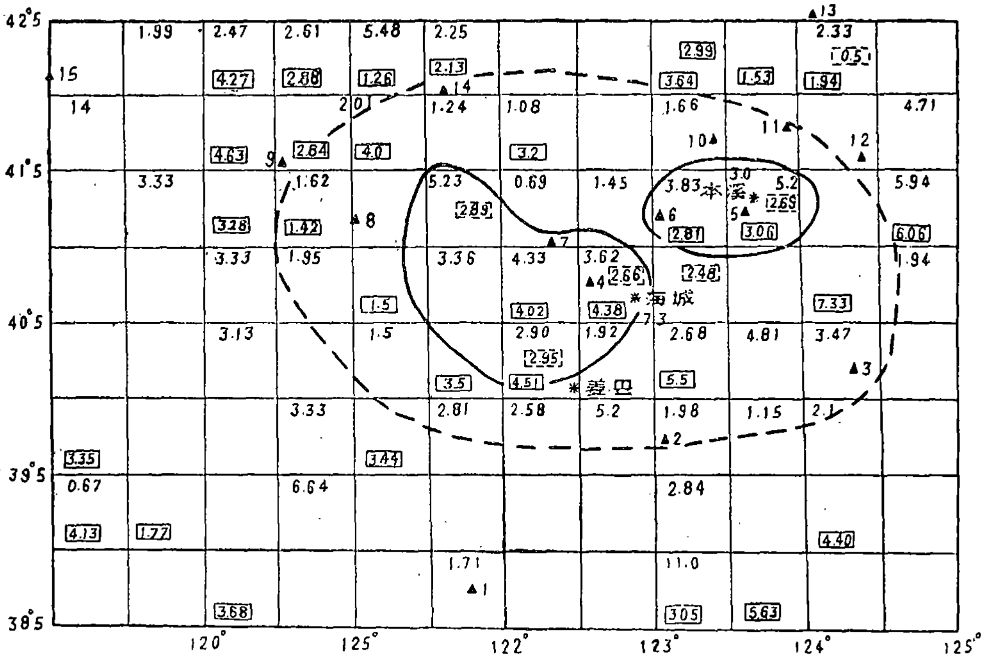

Fig. 2　The spatial distribution of S-and P-waves amplitude ratio in Liaoning province before and after Haicheng earthquake

The upper numberes show the amplitudes ratioes from1970 to April, 1974, the lower numberes show the amplitudes ratioes from April, 1974 to Feb, 4, 1975; and the numberes in dashed line show the amplitudes ratioes from Feb, 4, 1975 to March, 1975.

The stations are: 1.Dalian; 2.Zhuanghe; 3.Dandong; 4.Yingkou; 5.Jiguanshan; 6.Liaoyang; 7.Helan; 8.Jinzhou; 9.Chaoyang; 10.Shenyang; 11.Fushun; 12.Qinghe; 13.Tieling; 14.Fuxin; 15.Chifeng;

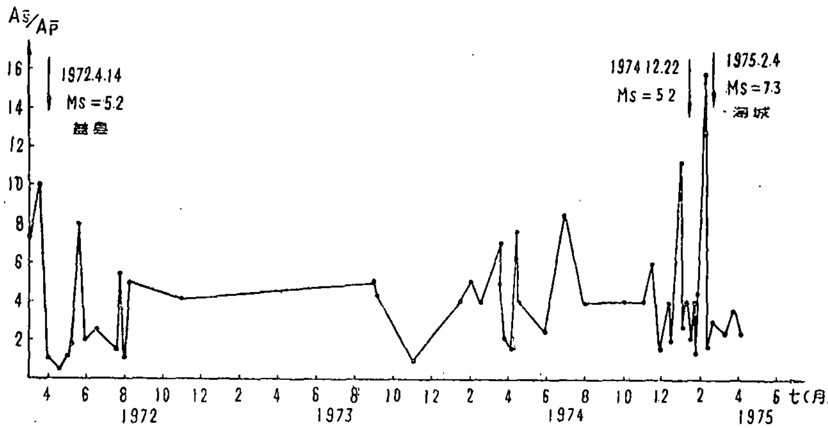

Fig. 3　The variation of amplitude ratio before and after Haicheng earthquake M7.3 by Yingkou station.

ude ratio are as follows:

(1) The change of Ap, As (P, S-wave amplitude) and As/Ap versus load for dry, partial saturated and saturated rocks respectively are as

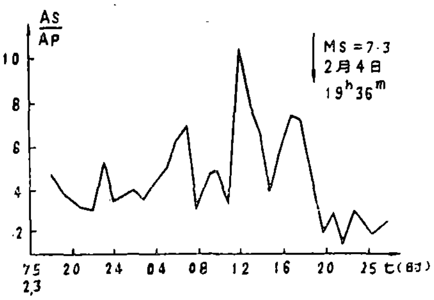

Fig. 4 The variation of hourly average value of amplitude ratio for impending Haicheng earthquake M7.3 by many stations.

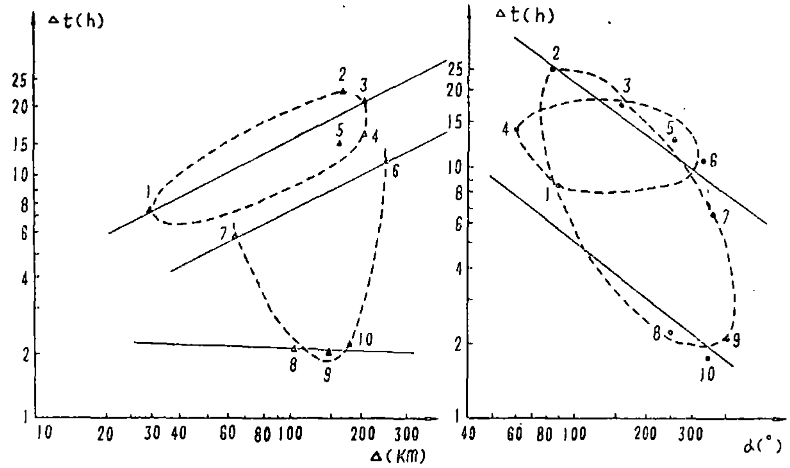

Fig. 5 The relationship between the time difference appearing amplitude ratio peak value and the epicenter (left), azimuth (right)

The stations are 1.Yingkou; 2.Jinzhou; 3.Dalian; 4.Chaoyang; 5.Dandong; 6.Tieling; 7.Helan; 8.Jiguanshan; 9.Shenyang; 10.Fushun;

Institute made a series of experiments on dynamical characteristics of seismic wave, among these the major results about amplitude and amplit-follows (Ding Bo-yang, 1983; Shao Shun-mei etal, 1983);

(a) From Fig.6 we can see that, at first, when the samples were loaded, no matter dry or saturated, and whether the load direction was parallel bedding or vertical, the change of P-wave amplitude mostly appeared to be slightly falling down,then stable, minority of this had not any change or rose up slightly.After the load rose up to arrivt at 50—60 per cent of failure strength of rocks, P-wave amplitudes were continuously falling to 50 per cent with the continuous increasing of load, even more, no matter what changes took place at the beginning.

(b) The maximum S-wave amplitude also varied when loaded, but the variation ranges of As for dry, partial and whole saturated were quite different, the maximum variable range were sA = 8 %, Ap = 37% for dry rocks, As = 58%, Ap = 45% for partial saturated rocks and As = 44%, Ap = 49% for saturated rocks.

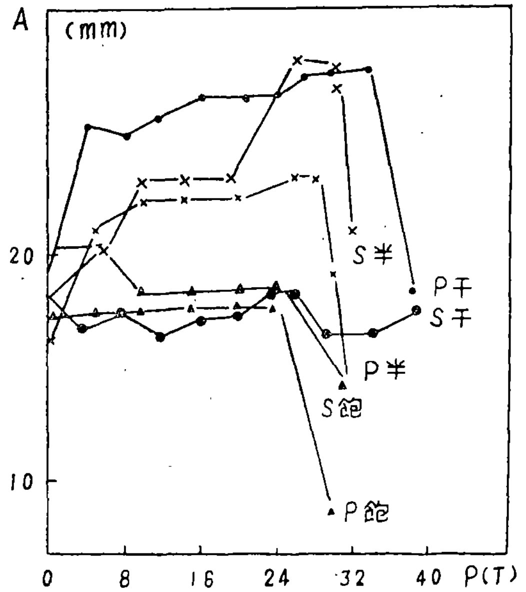

Fig. 6　The variation of marimum amplitued Ap, As with respect to the load pressure

(c) Fig 7 is a scheme of As/Ap versus time. When the stress was loaded on the samples, the As/Ap value were all falling with different ranges whether they were dry, partial or whole saturated, this falling process stopped while the load was approximinately equal to 90 per cent of failure strength, then returned quickly and the failure of rocks happened.

(2) The samples filled with water were loaded to 95% of failure strength then the load was stable, the P-wave amplitudes decreased in all direction at the same time, but the decreasing ranges were large in vertical bedding direction and small in parallel bedding, as shown in Fig 8. This has shown that water have great effect on seismic wave amplitude.

3. Theoretical Research for Anomalous Amplitude

For the sake of illustration of anomalous amplitude in the theory, the crustal medium in preparing earthquake is assumed as follows:

First, the crust rocks contain a large number of microcracks and posses's porefluids, second, the microcracks have been deformed and the sta-

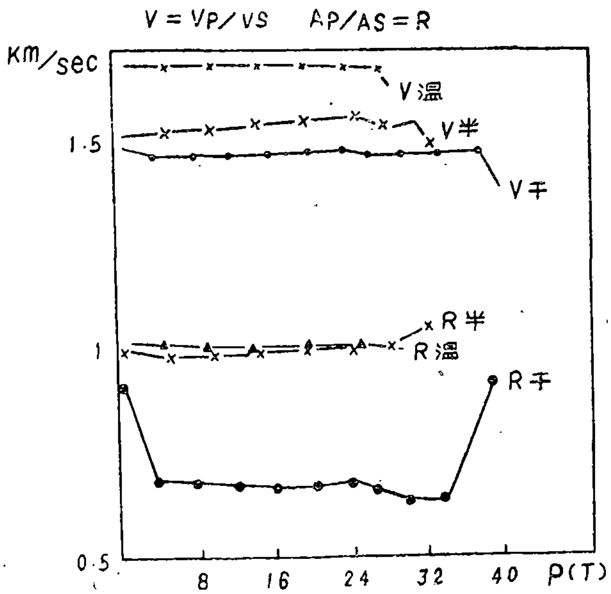

Fig 7 The variation of wave velocity ratio r = Vp/Vs and amplitude ratio R = As/Ap with respect to the load pressure

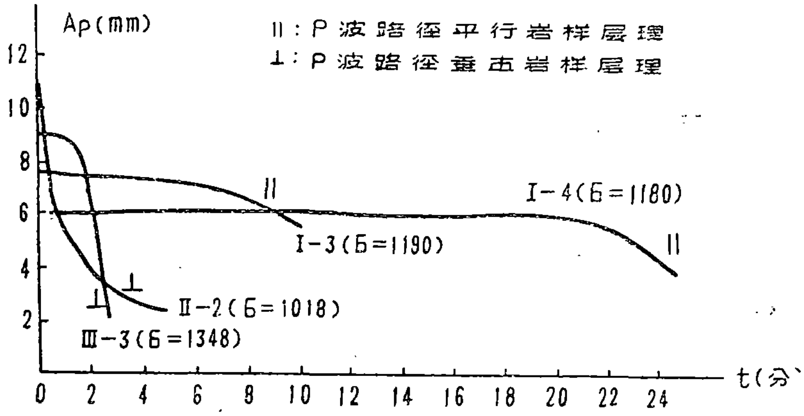

Fig 8 The variation of P-wave amplitude after the samples filled with water and loaded stablty

tes of porefluids have been also changed under the external stress (Guo Zheng-jian, Qin Bao-yan, 1979).

The basic model, for which we describe the crustal medium, is two-phase medium, whose major structure is solid rock, that is a monophase medium, and whose minor structure, i.e. fluit phase (including porefluid, gas or vapour), plays a considerable role only when an earthquake is preparing, we called it a preparing medium (Li Qing-he, Feng De-yi, 1982; Li Qing-he, 1982).

The basic mechanical relation in preparing earthquake medium is;

$$\left.\begin{aligned}\sigma_{ij}^{[1]} &= -\alpha_2\delta_{ij}+\lambda_1\delta_{ij}e^{[1]}+2\mu_1 e_{ij}^{[1]}+\lambda_3\delta_{ij}e^{[2]}\\ \sigma_{ij}^{[2]} &= \alpha_2\delta_{ij}+\lambda_2\delta_{ij}e^{[2]}+\lambda_4\delta_{ij}e^{[1]},\quad \alpha_2=\lambda_3-\lambda_4\end{aligned}\right\}\qquad(1)$$

where 1, 2 denoted that relevant symboles are parts of the solid, fluid phases respectively, λ_1, μ_1, λ_2, are elastic moduli of solid, fluid phase respectively, λ_3, λ_4 are the elastic moduli of action each other of solid and liquid phase, δ_{ij} denoted kroneck delta.

The motion equation representing by stress are:

$$\left.\begin{aligned}&\sum_i \frac{\partial\sigma_{ji}^{[1]}}{\partial x_i}-N_j=\rho_{11}\frac{\partial^2 u_j^{[1]}}{\partial t^2}+\rho_{12}\frac{\partial^2 u_j^{[2]}}{\partial t^2}\\ &\sum_i \frac{\partial\sigma_{ji}^{[2]}}{\partial x_i}+N_j=\rho_{12}\frac{\partial^2 u_j^{[1]}}{\partial t^2}+\rho_{22}\frac{\partial^2 u_j^{[2]}}{\partial t^2}\\ &N_j=\frac{\alpha_2}{\rho}\left[\rho_1\frac{\partial}{\partial x_j}\nabla\cdot\vec{u}^{[2]}+\rho_2\frac{\partial}{\partial x_j}\nabla\cdot\vec{u}^{[1]}\right]+r\frac{\partial}{\partial t}(u_j^{[1]}-u_j^{[2]})\end{aligned}\right\}\qquad(2)$$

where r is the diffusion coefficient which can be represented by the viscosity η, permeability ε and porosity k_0, ρ_{ij} (i, j=1.2) are the total effictive mass of the solid moving in the fluid (i=j=1) and of the fluid moving into the solid (i=j=2) respectively and a mass coupling parame ter between fluid and solid ($i\neq j$).

Calculating with mathematics and obtain:

$$\left.\begin{aligned}V_{pj}^2&=\frac{A_1+\beta_j\cdot B_1}{\rho_{11}+\beta_j\cdot\rho_{12}}=\frac{B_2+\beta_j\cdot A_2}{\rho_{12}+\beta_j\cdot\rho_{22}}\\ V_{sj}^2&=\frac{\rho_{22}\mu_1}{\rho_{11}\rho_{22}-\rho_{12}^2}\end{aligned}\right\}\qquad(3)$$

$$\left.\begin{aligned}&A_1=\lambda_1+2\mu_1-\frac{\alpha_2\rho_2}{\rho}\quad B_1=\lambda_3-\frac{\alpha_2\rho_1}{\rho},\quad B_2=\lambda_4+\frac{\alpha_2\rho_2}{\rho}\\ &A_2=\lambda_2+\frac{\alpha_2\rho_1}{\rho}\quad \alpha_2=\lambda_3-\lambda_4\end{aligned}\right\}\qquad(4)$$

where β_j satisfies quadratic equation and has two roots corresponding two P-waves velocities.The second P-velocity attenuates quickly and is found difficultly.S-wave has one velocity.

We found a displacement field engendered by an expansive central source in infinite medium of preparing earthquake and compared the results with monophase (Li Qing-he 1982), Fig 9 is a diagram of the comparason.

In order to further approach the practical occurring process of earthquake, the author studied the displacement field in two-phase half space acted by a shear stress, the representation of a ground vertical displacement field was as follows (Li Qing-he, 1982):

$$\left.\begin{aligned} u_z^{(1)}|_{z=0} &= -e^{i\omega t}\int_0^\infty [2P_2 e^{-\mu' h}\frac{k^3}{v^1}+A_1v_1+A_2v_2+BK^2]J_0(kr)dk \\ u_z^{(2)}|_{z=0} &= e^{i\omega t}\int_0^\infty [2P_0\frac{\rho_{12}}{\rho_{22}}e^{-\bar{\gamma}' h}\frac{K^3}{v^1}-\beta_1A_1v_1-\beta_2A_2v_2+\frac{\rho_{12}}{\rho_{22}}BK^2]J_0(kr)dk \end{aligned}\right\} \quad (5)$$

Transferring and integrating branch line applied with complex function, we find a final result of the integration of body wave is as follows (Li Qing-he, 1982):

$u_z^{(1)} =$

$$e^{i\omega t}\frac{(i+1)}{\sqrt{\pi}}\frac{P_0}{\mu_1}\frac{1}{r^2}\left[\frac{e^{-iksr}e^{\frac{-iksh^2}{2r}}}{K_s^{7/2}}E+\frac{e^{-ik_{\bar{p}2}r}\cdot e^{-\beta'' h}}{K_{p2}^{7/2}}F+\frac{e^{-ik_{\bar{p}1}r}e^{-\beta' h}}{K_{p1}^{7/2}}G\right] \quad (6)$$

where E, F, G are corresponding coefficents. Give parameters of the medium and calculate, we can draw schemes of displacement versus time, as illustrated in Fig10, 11, 12 (Li Qing-he, 1982).

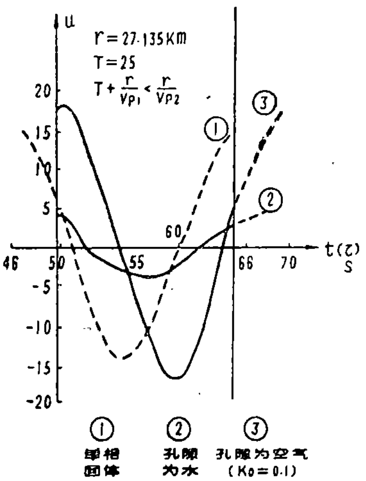

Fig 9 Comparison of the P-wave displacement in two-phase medium with monophse. (theoretical curve)

In this scheme, (1) showes the monophse solid, (2) showes the pore-medium with water, (3) showes the pore-medium with air. the porosity $K_0=0.1$

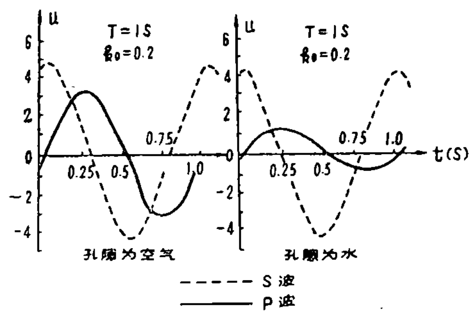

Fig10 Th eseismic displacement in two-phase medium (theoretical curve). The porosity $k_0=0.1$

In this diagram, left one showes the medium with air; right one showes the medium with wat er. The dashed line showes S-wave and the solid line showes P-wave.

From Figs 9—12 we can see that:

(1) The component of porous medium has a large effect on the displacement of seismic wave. If porous medium is gas (such as air, vapou and others), then As/Ap is small than water;

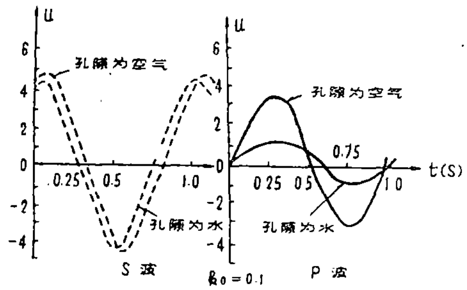

Fig11 The seismic displacement in two-phase medium (theoretical curve). The porosity is $k_0=0.1$

In this figure, left one showes S—wave, right one showes P—wave. The dashed line showes the medium with air, the solid line showes the medium with water.

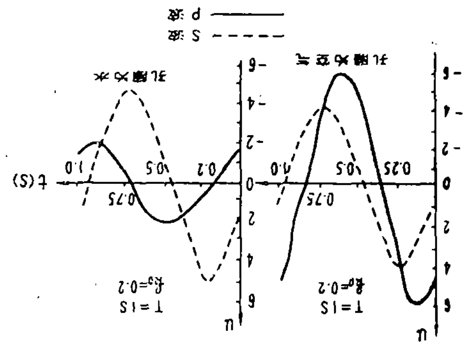

Fig12 The seismic displacement in two-phase medium (theoretical curve). The porosity is $k_0=0.2$

In this figure, left one showes the medium with air, right one showes the medium with mate.r The dashed line showes S—wave and the solid line showes P—wave.

(2) When the component of the porous medium changes, both of amplitudes of P, S-waves will all change, but the variation of P-wave is more larger than S-wave, so that the variation of amplitude ratio depends mainly on the P-wave;

(3) The effect of the porosity on the displacement field of seismic wave is large also, in a general way, if porosity becomes large, then amplitude ratio will become small.

The Author gives the displacement field engendered by a finite move source in two-phase medium and in layered multiphase medium (Li Qing he, 1982), it is unnecessary to go into details in this paper.

4. Some Physical Explanation of Anomalous Amplitude

The practical data of amplitudes and their ratio, the results of simulate experiments in laboratory and the results of the theoretical study are foundation of interpreting anomalous amplitude, they have a good agreement in some foundamental property, so we can give the following physical interpretatton and analyses.

(1) Under what condition does the anomalous amplitude happen?

The amplitude of seismic wave recorded is practically ground displacement. It is mainly affected by the way of occurring events, the medium in a propagation path and the receiving instruments. Jin-yan et al utilized the variation of seismic amplitude for studying the dislocation way in the source region, (Jin-yan, Zhao-yi, Chen-rong et al, 1976), Chen-rong utilized the stability of maximum amplitude ratio of S, P-waves for distinguishing foreshock and earthquake swarms (Chen-rong, 1978). Since the strain state of crustal medium can directly reflect the change of tectonic stress. However, provided we fixed both of effects of source and receiver, we can understand the effect of the medium on amplitude and its ratio. With further understanding the crust stress and contacting with the precursor. Feng De-yi indicated that, if the source mechanism of a certain region is a strike slip fault with nearly vertical, then amplitude ratio does not generally depend on the azimuth, but is relative with the medium property; if the source mechanism is arbitrary, then we can handle it with statistics. We deal with the vertical amplitudes of direct P, S-waves of the near earthquake here, both waves are foundamentally same straight frequency level range on the characteristics frequency curve of the instruments, so that their amplification are generally the same, the amplitude ratio basically reflects the variation of the crustal medium.

The basic supposition about medium demonstrated above is objective reality. The triple of the theory, experiment and observation state identically that, if the crustal medium is regarded as a solid-phase with full elasticity and multi-phase fractured medium respectively, the seismic amplitude will have considerable variation, and the fluid compounds in the cracks, porosity have considerable effect on the amplitude as well Therefore, if we regard the medium as a monophase and multiphase medium during unpreparing earthquake and preparing earthquake respectively, a series of results obtained are all in good agreement with the results of observation.

(2) The temporal forms of the anomalous amplitude

(a) If there is no stress concentration in the crustal medium, though there are a lot of microcracks in the rocks, they are small and in disorder, in this case the solid rocks play a leading role, and the medium can be dealt with by elastic monophase and the amplitude ratio value of small earthquakes in the vicinity of some region during this period can be regarded as reference base value.

When the stress is concertrated and the strain energy is accumulated in the source region, although the amplitude and its ratio have variations, it is not marked. The experiment indicated that the amplitude has unconsiderable change till the load is approximinately 50—60 per cent of rock failure strength (Shao Shun-mei et al, 1983), so this stage is still regarded as a normal period of the amplitude ratio.

(b) If the load exceeds 50—60 per cent of the failure strength, as the experiment indicated, the amplitude has considerable change and, therefore, amplitude ratio changes also, the basic form of A_S/A_P becomes small (Figs 6, 7). Under this condition, the crustal medium probably have the following variations. First, the microcracks open, and some new microcracks probably grow also, the porosity becomes larger, although As, Ap all become larger, the variation of Ap is still larger, so A_S/A_P become smaller (Figs10, 12). Second, because the porosity becomes larger, then the speed of the water runing into pore will be slower and unsaturated, the gas is, of course, the main component in the pore and it brings the A_S/A_P to become small (Figs 7, 10, 11, 12). The lower pore-pressure and the higher medium strength will restrict the development of the cracks. This stage is a lower value stage, i. e. negative anomaly stage belonging to the precursor (Fig 1).

(c) If the stress is continuously concertrated, and the strain energ is continuously accumulated, the amplitude and its ratio will display a new turn. When the load arrive to 90 per cent of the failure strength of the rocks in the experiment, the P-wave amplitude drops, and its drop quantity is large, S-amplitude drops also, so A_S/A_P rises(Figs6,7), it will be rising to high value stage. The crustal medium now probably may have two states: the stress beyond pore is larger than the pore-pressure and the porosity will become large that the water may be driven into pores, and the fluid component in the pore will be mainly the liquid, thus bringing A_S/A_P to be larger. In other case the large porosity may bring A_S/A_P become smaller in case of water, but the speed of the water running into pore is larqer than that of porosity increasing, so that the speed of the amplitude rising is larger than falling, in the general tendency, amplitude ratio will be rising (Figs10, 11, 12).

(d) When the stress is concetrated to be close to failure strength, the water around some volume may run so acceleratively that the friction on the fault plane decreases, and preseismic slip happened. This process is in agreement with the process that the P-wave amplitude rapidly falls, amplitude ratio sharply rises after the sample is loaded to 95 per cent of failure strength and full of water in the experiment. This process, of course, is not synchronism for whole source volume. In the periphery probably fhe preseismic slip appears early, then it gradually moves into source volume and the stress releases partially, the pore closes partially and porosity decreases. The futher running of water causes the pore to be saturated and the porosity to become small, so the peak value appears in the amplitude ratio. We found that the events occurred when the amplitude ratio peak value came to an end and dropped. In other worde, the amplitude ratio peak value observed in the stations around source volume reflected the preseismic slip there; that the preslip propagated into central locked zone needs a period of time, which is the time of the peak value falling.

(3) The spatial distribution of the anomalous amplitude.

We take the Haicheng earthquake (Feb, 4, 1975) as an instance to study the spatial distribution of the anomalous amplitude (Fig. 2).

(a) Before April, 1974, i.e. at the prior period of preparing earthquake, in the periphery of the anomalous region appeared lower value earlier, i.e. the negative anomaly. It is thought that the periphery belongs to the stress adjustment unit, in which the medium strength is lower accumulation of larger stress is difficult and the precursor appears earlier.

(b) At the same time, the amplitude ratio in Haicheng-Yingkou-Benxi district is 40—60 per cent higher than the whole anomalous region. This shows that the place is a stress accumulation unit, the tectonic stress is easily accumulated. Moreover, the medium strength is higher here (Zhu Chuan-zhen, 1977). The major axis of the higher value region of amplitude ratio is the same as the principal compressional stress direction N66°E of Haicheng earthquake.

(c) Several months before the occurence of the event, i.e. from April, 1974 to early in Feb, 1975, the amplitude ratio value of every small region was generally higher than prior in this or neighbouring region, the average high value reached 58 per cent. In this period, the average amplitude ratio in the principal failure plane direction (N68°W) was 10 per cent higher than in the principal compressional stress direction (N66°E). This shows that the shear stress along principal failure plane was highly concentrated and the medium had considerable variation.

(d) The main shock occurred in the border of the danger region (high value) and the anomalous region (low value), where the amplitude ratio has a larger gradient. There may be two causes: the inhomogencity of medium and the directivity of the seismic radiation, The amplitude ratio, for instance, is small on the nodal plane, but it is large in the principal failure plane and its perpendicular direction, moreover, owing to the structual reasons, the amplitude ratio is certainly different, on both sides of the fault.

(e) At each station appeared the amplitude ratio peak value earlier or later before impending main shock. Fig 5 illustrates the relationship between the time and the epicentral distance and azimuth. The basic features are: the peak value appeared on the periphery and southwest of epicenter early, inside and northeast of epicenter later. Because accelerative concertration of stress moved from outer to inside, the impending precursor appeared on the periphery early. Someone held that the locked zone before earthquake concentrated from outside to inside, finally, the fracture and violent displacement of fault happened in the impending locked zone (source volume) (Zhang-chao, 1983). This view is in agreement with the interpretation of this paper. Moreover, under the principal compressional stress, the water would originally run to the epicenter from the direction of southwest and northeast at the same time, but on account of the separation of the tectonic blocks synchronism did not appear.

(4) Medium state, stress variation and precursor

The exploration of crustal tectonic stress is one of the keys to solve earthquake prediction. Seismic waves directly bring the information of source, the variations of seismic characteristics can directly reflect the variation of source and medium can directly reflect the crustal state, so we must pay attention to the relation between various characteristics of seismic waves and the stress states, and further study the relation among the precursor, variation of medium and stress states The author puts forward the following for further inquiry.

(a) When the crustal stress is accumulated to about 60 per cent of the failure strength of medium, the strain property of rocks may have an obvious change, and the seismic kinematical and dynamical characteristics show obvious preliminary anomaly, simultaneously, other survey results for deformation should also change.

(b) Before the stress comes to 90 per cent of the failure strength, the strain states basically keep the priorforms, so various anomalies are analogous to those mentioned above, if it exceeds 90 per cent, the strain state of medium will have an obvious turn, and the seismic kinematic and dynamic characteristics will show opposed variations to prior. Other survey results tend to be analogous, only the mechanism and influence factors of various survey are different and their variation forms are not the same.

(c) Owing to the high concentration of stress, preslip or near fracture some new precursor phenomena may appear, This show that the strain state of medium possesses an omen of some substantive change. We noted that the precursor which directly relected medium′ strain mostly appeared near the epicenten, and that the precursor phenomena of additional strain in other places caused by the medium strain in the source were opposite to the epicenten, and they were in the periphery.

(d) The study for stress state medium variation and precursor anomaly should be different with various regions. The broken medium, accumulation value of stress, failure strength and resistance to shear stress, et al, of the area where occurred strong earthquakes before are quite different from those in the area whese no strong earthquakes took plaee before. Because of the inhomogeneity of the medium, the precursor anisotropies are regular.

References

〔1〕Chen-rong. Consistency of Focal Mechanism as a New Parameter in Describing Seismic Activity. Acta Geophsica Sinica. V21, N2, 1978.

〔2〕Ding Bo-yang. Sythetical Experimental Study and Theoretical Analyses of the Seismic Characteristics before the Fractured Medium with Compression. the Thesis of Master's Degree, Lanzhou Seismological Institute. 1983.

〔3〕Feng De-yi, Gu Jin-ping, Li Qing-he. Anomalous Amplitude Variation of Seismic Waves Propagating in Fractured Media. Acta Seismologica Sinica. V. 5, N2, 1983.

〔4〕Feng De-yi, Gu Jin-ping, Li Qing-he, Yu Xue-jun, Sheng Guo-ying. Premonitory Variations of Dynamic Characteristics of Seismic Waves inMedium of Earthquake Preparation. Northwestern Seismological Journal. V5, N1. 1983.

〔5〕Feng De-yi. Anomalies of Amplitude Ratio of S and P Waves from Near Earthquakes and Earthquakes Prediction. Acta Geophysica Sinica. V17, N3, 1974.

〔6〕Guo Zheng-jian, Qin Bao-yan. Physics in the Source of Earthquake. Seismic publishing house, 1979.

〔7〕Jin-yan, Zhao-yi, Chen-rong, Yan Jia-quan, Zhou Yu-ru. A Characteristic Feature of the Dislocation Model of Foreshocks of the Haicheng Earthquake, Liaoning Province. Acta Geophysica sinica. V21, N2, 1978.

〔8〕Li Qing-he. A Theoretical and Practical Study on the Amplitude Characteristics of Seismic Waves in the Preparing Earthquake Medium. the Thesis of Master's Degree, Lanzhou Seismological Institute. 1982.

〔9〕Li Qing-her, Feng De-yi. Some Theoretical and Practical Study on the Amplitude Characteristics of Seismic Waves in the Developing Earthquake Medium. Northwestern Seismological Journal. V4, N1, 1982.

〔10〕Shao Shun-mei, Li Liu-yu, Zhou Jian-guo, Shan Deng-long, Gao Zhong qiang, Xie Yuan-ding. Variation Characteristics of P-Wave Velocity in the Sandstone under Uniaxial Comprssion. Northwest ern Seismological Journal. V5, N1, 1983.

〔11〕Zhang-chao. The Preseismic Stress Field Due to a Compressional Torsional Fault and Stress Variation. Acta Seismologica Sinica V 5, N 2, 1983.

〔12〕Zhu Chuan-zhen, Fu Chang-hong, Jung Zhen-kwei, Luo Sheng-li. Source Parameter for Small Earthquakes and the Quality Factor of the Medium before and after the Haicheng Earthquake. Acta Geophysics Sinica. V20, N 3, 1977.

(**Received Dec. 15, 1984**)

本刊因故延期出版，希谅

编辑部

地震波振幅异常的某些物理解释

李清河
（兰州地震研究所）

摘　要

本文把较大地震前观测到的地震波振幅异常变化与模拟实验的结果及理论分析加以对比，借助于地壳介质的变化对振幅比前兆异常特征提出了某些物理解释。

较大地震前观测到的地震波振幅比时间变化呈“低值——上升到稳定高值——发震——回到正常值”的形态；主震危险区位于异常区内，多数在比值梯度大的地方，临震时比值骤增，各台比值峰值出现时间由震中距，方位角不同而有序。岩石压力实验中压力达岩石破坏强度50—60%以后，P波振幅随压力增加而下降，幅度较大；$\frac{A_S}{A_P}$随加压而下降，达破坏强度90%以后，迅速回升；若加载达破坏强度之95%时充水稳压，P波振幅在各方向均减小。在理论上把孕震过程中介质的变化分别用单相和多相介质模拟，多相介质中考虑以气和水为孔隙流体，给出本构关系，求出速度和垂直向位移。理论工作表明：$\frac{A_S}{A_P}$在孔隙介质为气时比为水时小；P波振幅变化大；孔隙度大，振幅比变小。

介质中应力集中程度达岩石破坏强度60%前后，可分别用单相和多相来描述介质。两相中，微裂隙张开，以气体为主，$\frac{A_S}{A_P}$变小，呈负异常；达90%时，$\frac{A_S}{A_P}$上升，围压大于孔隙压，孔隙流体以水为主，且水进速率大于孔隙度增大速率；临震时予滑，应力部分解除，孔隙部分闭合，孔隙饱和，振幅比出现峰值，至于空间分布则要考虑应力积累与调整部位介质强度不同，可能造成孔隙度及饱和度不同所致。

由于本文的物理解释中综合了实际观测，模拟实验和理论分析的结果，又把应力状态与介质变化联系起来，故此种解释可能具有成因观点。

（本文1983年12月15日收到）