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SEPARATION OF SOURCE AND SITE EFFECTS IN ACCELERATION POWER SPECTRA OF MAJOR CALIFORNIA EARTHQUAKES

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SUMMARY

Recently Phillips and Aki (Ref. 1) determined the site effects at various seismograph stations in California using the coda method. They found a strong frequency dependent site amplification factor for the "average site" of U.S.G.S. seismograph stations relative to the median of granite sites. Assuming that the median granite site is a homogeneous half space, we applied the correction for the average site effect to the observed acceleration power spectra and reinterpreted the result of Papageorgiou and Aki (Ref. 2). Reinterpretation leads to the following revised estimation of the range of source parameters; local stress drop of 100 to 200 bars and the source f_{max} of 5 to 10 Hz.

INTRODUCTION

Papageorgiou and Aki (Ref. 2) developed an idealized model of inhomogeneous faulting called "specific barrier model" and applied it to observed acceleration power spectra for several major California earthquakes. Their model consists of circular cracks with the same radius filling up a rectangular fault plane (hence nick-named cookie box model), and is specified by the length of the fault plane, the width of the fault plane, the diameter of the circular crack (also called barrier interval), the maximum slip on the crack, the rupture velocity and the upper limit frequency f_{max} beyond which the acceleration spectrum decays quickly with increasing frequency.

By fitting the model to observed strong motion data from Kern County (1952), San Fernando (1971), Borrego Mountain (1968), Long Beach (1933), and Parkfield (1966) earthquakes for which some of the source parameters were known from earlier studies, they determined the barrier interval and f_{max}. They found that the barrier interval is roughly proportional to the maximum slip, and therefore the local stress drop within each crack is roughly independent of earthquake magnitude. The local stress drop was estimated to be 200 to 400 bars; a slight increase with the increase of magnitude. The value of f_{max} was found also stable, to be 2.5 to 5 Hz; a slight decrease with the increase of magnitude.

These results were interpreted in terms of cohesive zone (or breakdown zone) of the slip-weakening model of earthquake failure by Papageorgiou and Aki in Ref. 2.

In deriving the above source parameters, they eliminated the effect of propagation path, but did not consider any correction for the local site effect of recording station, in as much as thy did not find obvious differences between rock and soil sites within their data set.

Recently, however, a quantitative study of the site effect was made by Phillips and Aki (Ref. 1) at most of the stations of U.S. Geological survey central California network by the coda method, and different frequency dependent site effects were found for different geological conditions. In the present paper, we shall try to revise the estimate of source parameters by Papageorgiou and Aki (Ref. 2) by including the correction for the newly discovered site effect.

Site amplification Factor Relative to the Granite Site The regression analysis made by Phillips and Aki (Ref. 1) cannot give the absolute value of site amplification factor, but only that relative to the average for the stations in the network. In order to infer the absolute value, we assumed here that the median of granite sites can be approximated by a homogeneous half-space for the whole frequency range. Under this assumption, we find the absolute value of site amplification factor averaged over the stations in the network as shown in the following table.

Frequency in Hz	1.5	3	6	12	24
Site amplification factor	2.7	2.0	1.0	0.63	0.50

There exists a very strong frequency dependence of the average amplification factor, namely, amplification by more than a factor of 2 at the low frequency end and deamplification by a factor of 0.5 at the high frequency end. The former may be attributed to the amplification due to lower impedance, and the latter to the attenuation due to higher absorption at the average site relative to the granite site.

We shall apply the above site amplification factor for the average station to the result obtained by Papageorgiou and Aki (Ref. 2). This implies that we are assuming that the average site effect for the strong motion seismograph stations used by them is identical to the average site effect for the seismograph stations of the U.S.G.S. central California network.

Revised Results by Correcting for the Site Effect Fig. 1 shows the original source power spectral density obtained by Papageorgiou and Aki (Ref. 2) by open symbols and crosses, and the revised one by correcting for the site effect by closed circles connected by solid lines. The effect of revision is to lower the flat level of acceleration power spectra several times, and increase the estimate of f_{max} by a factor of about 2. The former revision will increase the revised estimate of barrier interval by a factor of about 2, and consequently for a given maximum slip (which is constrained by independent observations), decrease the revised estimate of local stress drop by a factor of 2.

Fig. 2 shows the relation between the barrier interval and the maximum slip. Solid circles show those estimated from acceleration power spectrum, arrows indicating the revision of barrier interval by a factor of 2. Triangles in Fig. 2 show the barrier intervals estimated geologically from the average length of fault segments mapped by geologists (Aki, Ref. 3). We see now that the seismologically estimated barrier intervals are close to the upper limit of geologically estimated barrier intervals. This may be reasonable because some of the fault segmentation geologically observed on the surface may be due to the complex effect of surficial layers. Revised barrier intervals, however, are closer to the estimates for Japanese earthquakes made by Kamiyama (Ref. 4) using the specific barrier model.

Except for the Long Beach earthquake, the revised spectra still show the f_{max}

effect, namely, the sharp decay with increasing frequency, although the value of f_{max} now ranges from 5 to 10 Hz. We must attribute these f_{max} to the source effect if our correction for the site effect is right. At present, we cannot draw a firm conclusion on this matter, because our result is based on the assumption that the median of granite sites is a homogeneous half-space, and that the average site effect of strong motion seismographs sites are the same as that of U.S.G.S. central California network stations. Further work is needed to resolve whether f_{max} for major earthquakes is due to the local site effect or the source effect.

ACKNOWLEDGMENT

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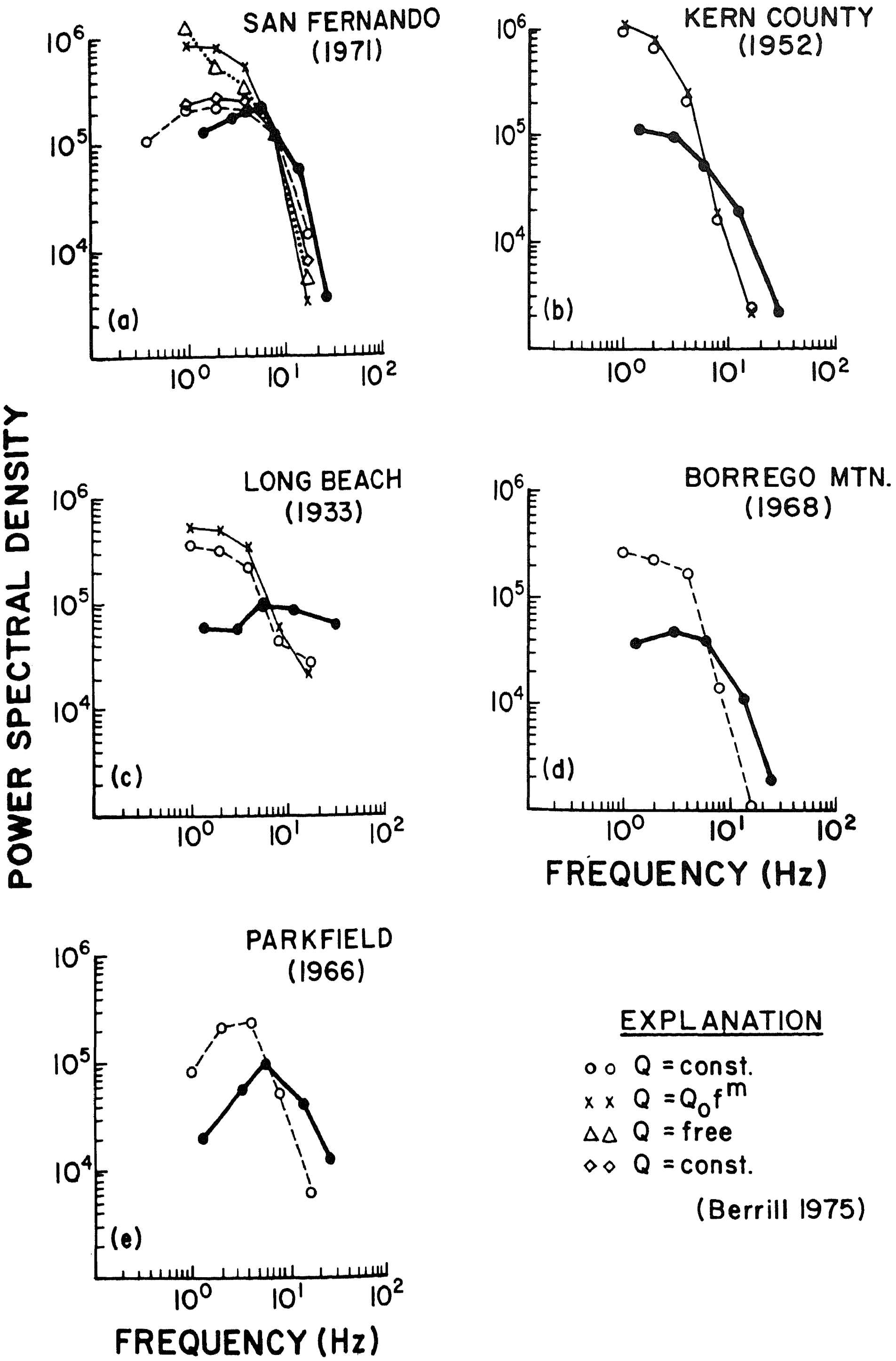
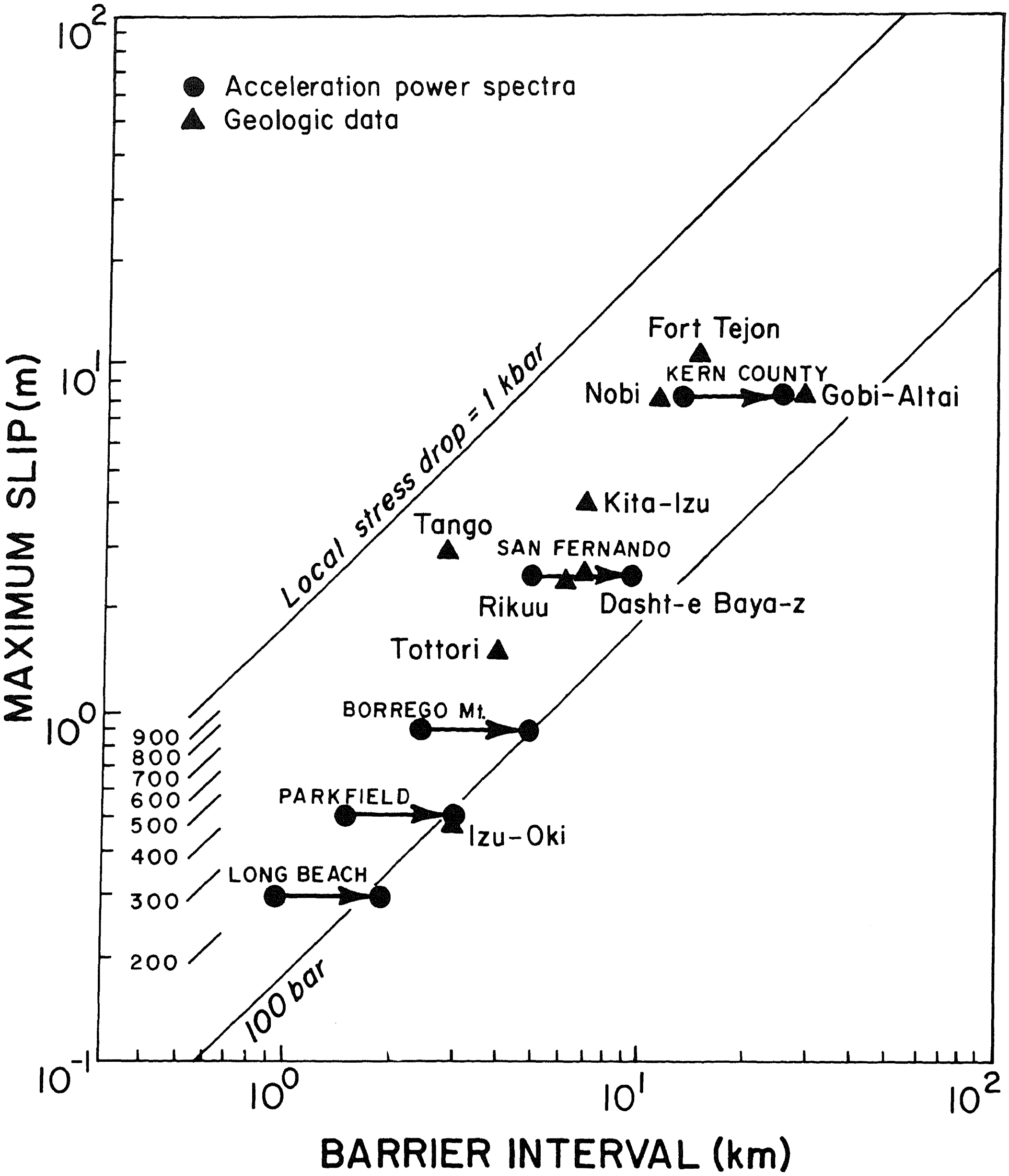

SAN FERNANDO (1971)
KERN COUNTY (1952)
LONG BEACH (1933)
BORREGO MTN. (1968)
PARKFIELD (1966)
POWER SPECTRAL DENSITY
FREQUENCY (Hz)
(a)
(b)
(c)
(d)
(e)
EXPLANATION
o o Q = const.
x x Q = Q0 f m
ΔΔ Q = free
◇◇ Q = const.
(Berrill 1975)

Fig. 1



Acceleration power spectra
Geologic data
MAXIMUM SLIP (m)
BARRIER INTERVAL (km)
Local stress drop = 1 kbar
100 bar
Fort Tejon
KERN COUNTY
Nobi
Gobi-Altai
Kita-Izu
Tango
SAN FERNANDO
Rikuu
Dasht-e Baya-z
Tottori
BORREGO Mt.
PARKFIELD
Izu-Oki
LONG BEACH
900
800
700
600
500
400
300
200

Fig. 2