alysis to aftershocks of the 1984 Morgan Hill earthquake in order to decompose the waves impinging upon the earthquake cluster (in the sense of experiment 2) into their plane wave constituents. From such a decomposition we recover the take-off angles of both the direct and scattered waves which travel from the cluster to the surface.

S51-11 1104H

Prediction of Strong Ground Motion due to Extended Earthquake Sources in a Three-Dimensionally Varying Crust: the Effect of a Fault Zone

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The technique of isochron integration[1] is combined with dynamic ray tracing[2] to investigate the tradeoff between rupture parameters and crustal structure in the strong ground motion recorded from the April 24, 1984 Morgan Hill (Halls Valley), California earthquake. The structure investigated is a wedge-shaped zone of low velocity that surrounds the surface trace of the Hayward-Calaveras fault. At most locations the effect of 3-D structure on isochron acceleration is small compared to its effects on geometric spreading and radiation pattern. Within a 2 km zone centered on the surface trace of the fault, the largest effects of the fault zone on ground motion are due to a combination of focusing on the geometric spreading function and distortions of the radiation pattern. On the immediate flanks of the fault zone, the amplitude effects of focusing and defocusing are less important than the distortions of the radiation pattern. For a station at 3 km. range from the surface trace of the fault, the S radiation from some regions of the fault plane is decreased by as much as a factor of 4 compared to that predicted using a laterally homogeneous crust. These effects may account for differences in the amplitudes of body waves recorded by stations within the fault zone versus those recorded by stations outside of the fault zone. These differences cannot be matched with a rupture model in a laterally homogeneous crust.

1. Spudich and Frazer, Bull. Seism. Soc. Am., 74, 2061-2082, 1984.
2. Červený, V., Seismic Exploration, (G.Dohr, ed.), vol. on Shear Waves (Treitel and Helbig, eds.), Geophysical Press, London, 1985.

S51-12 1118H

Spontaneous Dynamic Extension of a Pre-Existing Circular Shear Crack

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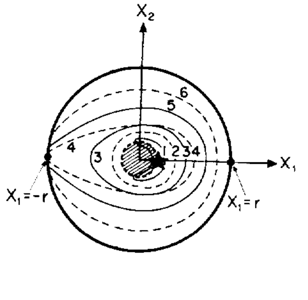
The spontaneous fracture process for a pre-existing circular crack is calculated using a numerical boundary integral technique and a 'critical stress level' fracture criterion. Instead of having the initial crack appear instantaneously and start extending as has generally been done in dynamic fracture problems, the initial static crack problem is first solved to determine the initial stress distribution around such a crack. The final crack is made circular by placing an unbreakable circular barrier around the initial crack. The final crack radius is five times the initial crack radius (stippled in figure). The stress concentration in the in-plane direction is always larger than that in the anti-plane direction for circular shear cracks. The fracture is thus initiated at one of the two in-plane points along the crack perimeter (shown by asterisk), and the fracture front is shown by dotted and solid lines on the figure. Due to such a complex fracture process, directivity effects are very complicated, as can be seen by examining the particle velocity and acceleration pulses radiated by such a propagating crack.



S51-13 1132H

Fractal Analysis of Characteristic Fault Segments of the San Andreas Fault System

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We present results from two independent methods of determining the fractal dimension (D) of the San Andreas Fault System (SAF). A single main trace from Pt. Arena to the Salton Sea was sampled at .1 km spacing and analyzed using the spectral techique of Berry and Lewis (1980) and the Mandelbrot yardstick method (1977). Also examined are subsections of the SAF corresponding to major earthquakes. We characterize the complexity perpendicular to strike by the splay density and distance from the single main trace and correlate this with the fractal dimension.

Spatially dependent heterogeneity of the dimension D with window length observed for the 1906 section by Scholz and Aviles (1985) is here confirmed for the whole SAF and its major subsections by the spectral method. Variations in D of .2 or greater between different subsections confirms heterogeneity of D along the length of the fault, possibly indicating the charcteristic length of faulting for any subsection.

We typically observe a change in fractal dimension at wavelengths of about 10-12 km, with D being lower for longer wavelengths. Thus, there is a change in the geometrical self-similarity of the fault at this wavelength. This corresponds with the depth of the fault and also with the division between large and small earthquakes, which are known to scale differently. Changes in D along strike appear to reflect variations in tectonic complexity.

S51-14 1146H

Interaction of Cracks and the Convergence of Foreshock Activity to the Main Shock

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We have constructed a model for the occurrence of foreshocks and the accelerated occurrence of foreshocks culminating in a main shock. Both the foreshocks and the main shock are assumed to occur because of the sudden coalescence of preexisting cracks. Coalescence occurs if the stress intensity factors at the crack tips exceed a certain critical value. Each crack is assumed to extend quasistatically due to stress corrosion when the stress intensity factor is below its critical value.

We assume that the cracks are colinear in two-dimensions and deform under plane strain. The distributions of the sizes and the spacings between the cracks are given by power laws. Several models are assumed for the spatial distributions of the critical value of the stress intensity factor. Cracks are assumed to interact in a pairwise manner only.

It is shown that the frequency distribution of the moments of foreshocks is well-described by the Gutenberg-Richter formula. The rate of foreshock occurrence increases as the occurrence time of the main shock is approached and is well-described by a power law function of time. The power law function is independent of the distributions of crack sizes, spacings and fracture strengths. Thus, in principle, foreshocks may be useful for the prediction of occurrence time of large earthquakes. However, the temporal variation of the energy release shows considerable diversity.

Induced Seismicity, Explosions, and General Seismology

Room 319 Fri PM

Presider, Steven D. Acree, Univ. of South Carolina

Jerry A. Carter, Rondout Associates, Inc.

S52-01 1330H

Spatial and Temporal Variation of Induced Seismicity at Monticello Reservoir

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Monticello Reservoir, South Carolina has been a site of continuing seismicity since its impoundment in Dec. 1977. After filling, seismicity rapidly increased from a pre-impoundment level of approximately one event per week to a peak average of 81 events per week in 1978. The frequency has since fallen to a low of 3.25 events per week in 1984. Hypocenters of 1332 quality A and B events, located using the same station distribution were analysed. The seismicity migrated downward from 1978 through 1982. In 1978 approximately 84% of the events located within 2 km of the surface compared with 51% in 1982. This trend subsequently reversed and by the end of 1984, 86% of the events were again located within the top 2 km.

Inspection of the distribution of hypocentral depths reveals the presence of a "layer" of anomalously high seismicity between 1.6 and 2.1 km throughout the area, which is probably associated with fractures in the migmatic granite bodies along geologic contacts. These contacts were defined by both field mapping and detailed gravity surveys. These results are compared with those at Lake Jocassee, another site of reservoir induced seismicity in northwest South Carolina.

S52-02 1343H

Stress and Pore Pressure Changes Due to Annual Water Level Cycles in Seismic Reservoirs

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Although annual water level changes in seismic reservoirs are only fractions of maximum reservoir depth, the corresponding fluctuations in stress and pore pressure at depth apparently trigger seismic activity. The changing water level can be approximated as a harmonically time-varying two-dimensional reservoir load on the surface of a porous elastic half space. By numerically inverting horizontally transformed solutions, mean stresses and pore pressures due to such a load were calculated, both assuming and neglecting coupling between deformation and diffusion. Frequency enters the coupled stress solutions, and both pore pressure solutions, through a dimensionless quantity that ranges from 0.002 to 200.0, assuming an annual period, diffusivities of 10^3 to 10^6 cm^2/s, and reservoir widths from 1 to 10 km. Within this range, the coupled solution exhibits a transition from drained to undrained behavior as dimensionless frequency increases. The amplitude of the coupled mean stress is nearly frequency-independent within this range, and its peak compressive value is almost simultaneous with peak water level. For dimensionless frequencies less than 0.01, and for the coupled as well as the uncoupled solution, pore pressure is nearly equal to and in phase with mean stress to a depth of 5 times the reservoir width. As dimensionless frequency increases, peak pore pressure for both solutions falls off more rapidly with depth. The coupled solution, however, approaches an undrained high-frequency limit in which pore pressure is proportional to mean stress. This limit is approximately reached at dimensionless frequencies greater than 500. Whether or not coupling is assumed, peak pore pressure can lag peak reservoir water level and peak mean stress, thus producing periodic decreases of effective stress that may play a role in triggering seismicity.

S52-03 1356H

Induced Seismicity at Kariba Reservoir - A Re-Examination

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Earthquakes at Kariba reservoir on the Zambezi River (dam height=128m, reservoir volume=$160\times10^9m^3$) provided one of the first well-documented cases of induced seismicity (Gough and Gough, 1970). Data from the Bulawayo Observatory (1959-1984) provide a 25 year history of the seismicity at Kariba for earthquakes of M>2. Because of the large dimensions of the reservoir (250 km long), the spatial resolution of the epicentral determinations is sufficient to identify major temporal changes in the spatial distribution of seismicity. The early activity in 1959-1966 (including the two largest events of M=5.8 in 1963) was confined to the northern end of the reservoir near the dam. Since 1966, the activity has extended to cover the entire 250 km length of the reservoir. Bursts of activity occurred near the northwestern edge of the reservoir in 1973, in the central part of the reservoir in 1979, and at its southern end in 1981. The largest earthquakes in 1963 followed shortly after the water level first reached maximum and the rate of seismicity during 1963-1966 (as shown by Gough and Gough) was correlated with changes in water level. This early activity, directly beneath the deepest part of the reservoir, may have been produced by induced changes in pore pressure due to compaction from the reservoir load. The later activity, which does not show an obvious short-term correlation with water level and which occurs on faults adjacent to the reservoir, may have been delayed due to the time required for pore pressure to diffuse away from the reservoir along these faults.