A Resistivity Variometer

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An unusually sensitive variometer for measuring changes in the earth's resistivity has been constructed by Yamazaki of the Earthquake Research Institute. The working principle of the variometer is similar to what we call the four-pole method for measuring earth resistivity. When 67 cps electric currents are made to flow into the ground through the two outer electrodes, a voltage appears between the two inner electrodes. The voltage can be balanced by another voltage taken from the power source through a transformer. The system is automated in such a way that a small deviation voltage drives a servomotor, which makes the balance recover again by rotating a variable resistance. The rotation of the motor then represents changes in the earth's resistivity.

A running test of the variometer has been going on at a near-shore geophysical station about 60 km south of Tokyo. Changes in the resistivity caused by extension and contraction of the ground due to tidal loading are observed. In contrast to the mechanical strain amounting to the order of 10^{-6}, the rate of resistivity change amounts to 10^{-3}. It is interesting to note that the ground, a lapilli tuff layer, plays a role of amplifier.

We had an earthquake of magnitude 8.0 off Hokkaido on May 16, 1968. A change in the resistivity took place on the record at the time of the earthquake, although the epicenter is some 700 km from the observation point. The change is equal to 10^{-7} in the mechanical strain. As the change is completed within several minutes and the system is highly overdamped, it seems likely that the variometer recorded a permanent deformation associated with the earthquake. At the times of aftershocks having magnitude of 7.5 and 7.3, slightly smaller changes were observed. The directions of change are opposite to that for the main shocks, and this fact is compatible with the difference in earthquake mechanism between the main shock and aftershocks.

Seismo-Acoustic Measurements in a Highly Stressed Natural Environment

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Seismo-acoustic measurements made before and after major mine subsidence on March 27, 1968, show significant changes in the level of activity and in the *b* value associated with the magnitude-frequency relationship. At one mine level (-400 ft), the following observations were recorded:

Date	Events per time interval	*b* value
3–06–68	157	1.03
3–28–68	119	.73
6–30–68	223	4.01
8–25–68	376	2.14

Both the changes in the number of events and the *b* value can be correlated with stress changes in the mine as a result of the subsidence. The use of high-gain instrumentation with significant reponse in the acoustic range allows the recording of large numbers of events. These measurements provide information on the link between the laboratory measurements on rock specimens and the ultramicroearthquake field observations.

An Investigation of Novel Techniques for Sensing Earth Stress and Strain

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An important problem is to distinguish elastic strain, accompanied by stress in the crust, from anelastic strain or creep. Simultaneous observations of both stress and strain are required. A number of methods of measuring various aspects of strain are more or less well developed in several laboratories, but the recognition of crustal stress is more difficult, and for routine observations resort must be made to secondary effects of stress.

Two such effects are being investigated: the seismomagnetic effect and the stress-dependence of acoustic velocity. The magnetic experiment has been set up on two New Zealand volcanoes where local field variations up to 10 γ occurred in a period a few hours before a recent eruption and reverted to normal afterward. As in the case of seismomagnetic effect, the piezomagnetic effect offers the most plausible explanation. Preliminary measurements of ultrasonic phase velocity have been made by a method that gives a precison to 1 part in 10^6; stress effects observed so far appear to be dominated by cracks, even in rocks that appear superficially to be quite solid.

Shear strain is monitored by means of a photographically recording Michelson interferometer and tilt with a mercury level tiltmeter, based on a new displacement transducer that gives a dynamic range of 140 db. Interferometric methods are found to suffer from the disadvantage that inadvertent breaks in a record spoil the observation of secular strains; a stable capacitative transducer, having sufficient dynamic range, can be left untouched for years and can be used to monitor a secular trend with high sensitivity without the necessity for a continuous record.

Thermoluminescence of Deformed Limestone

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Summary not available.

Mechanical Instabilities Observed in Laboratory Experiments on Rocks

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At a mechanical instability in our usage, the stress drops suddenly and an elastic shock is produced. Instabilities on two very different scales are observed in the laboratory: those that are clearly audible and involve a stress drop of about 10 bars or more, and those of the sort studied by Mogi, Scholz, Byerlee, and others, which can only be detected with considerable amplification. The latter type are termed microfracturing events or microshocks. Earthquake-oriented studies in our laboratory are based on the assumption that in the earth significant earthquakes result from the first of these instabilities. This assumption may not be valid and needs study.

Instabilities of the first type may occur as unfractured rock is loaded for the first time or as previously fractured rock is loaded subsequent to fracture. We characterize behavior in either of these situations as unstable or stable, depending on the presence or absence of an instability. We have observed many combinations of stable and unstable behavior as rock samples were repeatedly loaded, for example unstable faulting followed by stable sliding or stable faulting followed by stable sliding, and so on. The parameters that determine stability seem to be confining pressure, rock type, and temperature. Stiffness has no effect on frictional sliding but may affect faulting stability. The effect of pore pressure is, in nearly all situations, that predicted by the effective stress concept, although pore fluids under pressure may on occasion produce unusual and unexpected effects.

We recently described a new high-pressure instability, which occurs in rocks whose behavior under high pressure was always thought to be stable. At pressures in excess of 7 kb at room temperature, unstable faulting was observed in altered mafic rocks, in sandstone, and even in a sand composed of crushed granite. This 'upper brittle region' may correspond to the region found for a granodiorite by Giardini and to observations made by Bridgman in high-pressure shearing experiments.

Fields of stability and instability can be identified for different classes of rocks as a