Meetings

Earthquake Prediction: United States–Japan Cooperative Science Program

Recent and very substantial progress in understanding the earthquake mechanism and its relation to earthquake prediction was discussed by scientists from Japan and the United States at a Joint Conference on Premonitory Phenomena Associated with Several Recent Earthquakes and Related Problems. The conference was under the auspices of the U.S.–Japan Cooperative Science Program and was held at the U.S. Geological Survey's National Center for Earthquake Research in Menlo Park, California, 28 October to 1 November 1968. Those who had attended in 1964 and 1966 the earlier U.S.–Japan meetings on research related to earthquake prediction were impressed by the advances in this field that have come about not only because of developments in seismology but also because of related advances in the study of fault creep, geodesy, geomagnetism, field geology, high-pressure phenomena, and global tectonics. In Japan, which has a national program of research on earthquake prediction, some successful and valuable, although relatively crude, predictions were made in the case of the Matsushiro earthquakes (1966). These events have encouraged an expanded effort of research in the hope of extending and improving capability for prediction. The new Japanese program, in fact, aims at actual prediction.

The United States has no such national program, but scientists at many laboratories are working on basic problems that may provide valuable information. With the current downward trend of funding of science in the United States in general, however, it seems unlikely that a major research effort or a directed program in earthquake prediction will be initiated in the United States prior to the next large, destructive earthquake.

During the last few years, some of the most important advances in understanding the earthquake phenomenon in California have depended on the realization that fault creep, that is, slow fault slippage unaccompanied by large earthquakes, is an important mode of deformation along a number of faults, notably parts of the San Andreas system. By combining information on creep with data on deformation from other types of measurements (such as triangulation and trilateration on both small and large scales, leveling, slip and fault configuration determined from seismicity data, field observations on small- and large-scale movements, and regional rate of displacement based on global tectonic patterns), a view of fault dynamics has been developed that appears to be far superior to any previously held. Papers by Pakiser, Wallace, Eaton, Raleigh, and Burford (all USGS); Plafker (USGS) and Savage (University of Toronto); Hofmann (California Department of Water Resources); Jahns (Stanford); Brune, Allen, and Smith (Caltech); Tocher and Whitten (ESSA); and Sykes, Oliver, and Isacks (Columbia) discussed one or more of these points. Several speakers attempted to synthesize the measurements in an effort to arrive at a prediction technique and even to suggest where the next large earthquake along the San Andreas fault and its subsidiaries might occur. Hofmann discussed past attempts at prediction in both space and time in California with indications of significant success.

Observations of fault creep are not so common in Japan as in California; only one creep location is now known (Watanabe, Kyoto University). This difference may be simply an indication of the different styles of tectonic deformation, but it may be that in Japan, as in California and other active areas throughout the world, many sites of fault creep remain to be discovered. Japanese studies of earth deformation based on the data of field geology (Nakamura, Tokyo University), geodetic surveying (Kasahara, Tokyo University), Harada (Geographical Survey Institute, Tokyo), and seismology (Hagiwara, Tokyo University; Miki, Kyoto University; Ichikawa, Japan Meteorological Agency) are very advanced. Their application and utility were demonstrated during a session on the Matsushiro earthquake swarm. Most casual observers and many of the U.S. participants at this conference were or are inclined to believe, on the basis of the swarming tendency of the seismic events, the volcanic history of the area, and other evidence, that the earthquakes are associated with magmatic activity. However, the prevailing opinion among the Japanese is that the shocks are primarily tectonic in origin. This reasoning is based on information on seismicity, the focal mechanisms of the earthquake, and on geodetic, geologic, and magnetic data. Nakamura proposed that interstitial water played an important role in the release of the tectonic energy.

As the conference progressed it turned out that the role of water, or other interstitial fluid, in the earthquake phenomenon is receiving considerable attention and emphasis. Evans (Potential Gas Agency, Colorado School of Mines) stressed this point in a discussion of the Denver earthquakes. Bolt and Eisenberg (Berkeley) demonstrated seasonal fluctuations in seismic activity that showed some correlation with rainfall. Griggs (UCLA) and Raleigh further emphasized the possible importance of fluids, but Major and Romig (Colorado School of Mines) showed some evidence that does not fit simply the fluid pressure explanation for the earthquakes in Denver.

Knopoff (UCLA) and Ryall (University of Nevada) discussed triggering of earthquakes by tides. The evidence in favor of triggering is suggestive but not overwhelming. Several papers were presented on new techniques. Slemmons (University of Nevada) used low-angle illumination to study surface faulting; Rikitake (Tokyo University) discussed the seismomagnetic effect and an unusually sensitive resistivity variometer that measures resistivity changes due to very small strains. Kovach (Stanford) reported on anomalous variations in the magnetic field and their possible association with earthquakes. Pomeroy (University of Michigan) presented a study of seismic waves of acoustic frequencies associated with a mine collapse. Stacey (Lamont) discussed a new very sensitive tiltmeter of short length, and Herrin (Southern Methodist), thermoluminescent effects in deformed limestones.

Laboratory studies of rock fracturing as it relates to seismic phenomena were presented by Brace (MIT) and Mogi (Tokyo University).

Kisslinger (St. Louis) discussed spectra of P-waves from Matsushiro earthquakes, and Aki (MIT) used the coda to determine the size of the microearthquake source, some 10 × 10 meters for a shock of magnitude zero.

The meetings included several local field trips and an extended trip for the visiting Japanese along the San Andreas fault from San Francisco to Mexico.

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Photoionization and Ion-Molecule Reactions

Fifteen years ago, a conference on mass spectrometry which lasted 2 days could encompass the essential elements of the entire field in which the mass spectrometer was applied. It is significant of the rapid growth in the uses of mass spectrometry that a conference of several days duration now can encompass only one or two of the principal fields of mass spectrometry. The growth has been extremely rapid so that today workers in one part of the field are often hard put even to understand work carried out in other parts of it. Thus, a mass spectrometry conference held at Hakone, Japan, was limited in coverage to photoionization and ion-molecule reactions. The conference was jointly sponsored by the National Science Foundation and the Japan Society for the Promotion of Science and was held during the week of 23 September 1968 under the joint chairmanship of Hirohiko Ezoe and the writer.

It is particularly significant that the two topics of the conference are both of relatively recent inception. Although one or two initial papers had been written on each subject in 1955, very little work had been done so that both topics have had essentially their complete development since about that date. Prior to around 1955, ionization was brought about in most instruments by electron impact. However, electron impact has certain disadvantages, especially in obtaining precise data on ionization and appearance potentials. This is a fundamental difficulty resulting from the fact that with electrons the ionization efficiency curve crosses the energy axis at an angle that is often acute. This, combined with the normal spread of electron energies, makes interpretation difficult and obscures small energy effects resulting from the appearance of higher energy states of the ion. Many of these disadvantages are eliminated if ionization is brought about by ultraviolet light rather than by electrons. This is due to the fact that ionization by radiation is a step function. Thus, excited electronic states can often be observed in normal ionization efficiency curves. In some instances, it has been possible to observe vibrational states as well. Some fine structure is obscured by the peaks corresponding to Rydberg states that occur in the ionization efficiency curves. This can be eliminated if, instead of mass analysis, the energy analysis of admitted electrons is made. With such analysis it has been possible to observe not only electronic and vibrational states but, in some instances, rotational states as well. In the most recent advance, Mark Inghram (University of Chicago), during his lecture on the development of photoionization, described experiments in his laboratory in which both mass analysis of the ions and energy analysis of the electrons are being made. Although this work is in its very early stages, it already offers promise of extremely interesting results.

In describing his work, Itiro Omura (Central Research Laboratory of Hitachi Ltd.) showed excellent data resulting from the coupling of a Quadrupole mass spectrometer to a photoionization source. It might be mentioned that one of the most useful developments in mass spectrometry in recent years has been the widespread application of the Quadrupole mass filter which is an instrument with many advantages, not the least of which is that it is relatively inexpensive.

In spite of the great advantages of photoionization, it suffers from one obvious disadvantage, namely that it is not capable of generating negative ions by resonance attachment. Thus, there is still a need for a relatively simple, practical source of electrons having a narrow spread in energy. Kogoro Maeda (Electrotechnical Laboratory, Tokyo) described several devices for obtaining beams of progressively narrower energy spread and including a double hemispherical energy selector capable of providing, relatively easily, a beam having a spread of only 0.1 ev.

During the past approximately 15 years, one of the principal topics that has concerned mass spectrometrists has been a theory of the origin of mass spectra. Two principal approaches to the problem have been advanced. The one most generally accepted by Western mass spectrometrists is the absolute rate theory approach developed by Eyring and his students. This treats the formation of fragment ions as a series of rate processes and can be approached by the methods of first-order kinetics. An alternate approach is that of relating the intensities of fragment ions to the distribution of charge in the molecules calculated by a variation of the molecular orbital method. This was originally proposed by Hall and is being applied rather successfully to a number of systems by Kozo Hirota (University of Osaka) and Toshikazu Tsuchiya (Government Chemical Industrial Research Institute, Tokyo). The method requires certain empirical adjustments in order to obtain agreement with experiments, but these are relatively easy to make and result in a satisfactory agreement. Thus, although the absolute rate theory approach appears to be more nearly in accord with the natural phenomena and certainly predicts more of the behavior of ions under decomposition, it is less useful in the actual prediction of mass spectra because of the complexities of the calculation and the large amount of input information required.

In the literature of mass spectrometry, research on positive ions far outweighs the studies of negative ions. The reason for this is that studies of negative ions are generally more difficult. The ion intensities are usually considerably smaller than are those for positive ions and, at least in the resonance region, the negative ion can be observed over a narrow