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Focal Rupturing Processes and Seismogenic Structures of the Chichi Earthquake

The impact of the great Chichi earthquake of last September 21st still lingers over Taiwan (for instance, the June 11th earthquake, which had a magnitude greater than six, is considered to be an aftershock). Research performed by the Institute of Earth Sciences of the Academia Sinica has proved that the Chichi earthquake actually involved seismicity in both upper and lower seismogenic layers; while the upper layer contains the relatively familiar Chelungpu fault, in fact many aftershocks originated in another, relatively deeper, geological structure. This formerly unknown layer is located at a depth of approximately 30 kilometers, some 15 kilometers directly below the Chelungpu fault.

This research was performed jointly by Associate Research Fellow Honn Kao, of the Academia Sinica Institute of Earth Sciences, and Prof. Wang-Ping Chen of the Geology Department of the University of Illinois. The project was funded by the NSC. The results of the project were published in the most recent issue (June 30, 2000) of the authoritative international periodical *Science*. The authors assert that while quakes of a similar type will be certain to occur in the western part of Taiwan, but from the standpoint of energy accumulation, in the near future such a large quake is very unlikely to occur along the same structure.

Earth scientists from around the world have been very busy pursuing various lines of investigation since the occurrence of the Chichi earthquake. The NSC has given funding to many domestic scientists engaging in relevant projects. The study undertaken

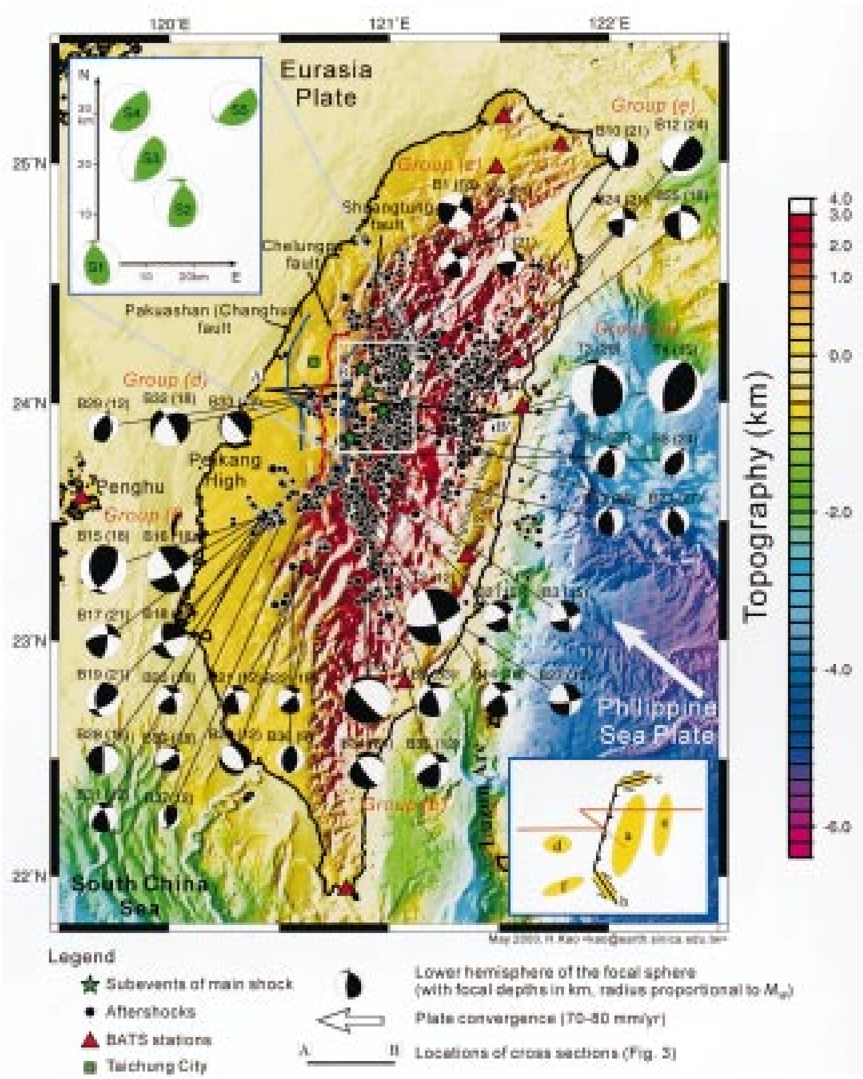

Fig. 1 Map showing the locations the September 20, 1999, Chi-Chi earthquake sequence mainshock (green stars) and aftershocks (solid circles). Earthquake fault plane solutions are plotted in the low-hemisphere projection of the focal spheres.

by Prof. Kao and his colleagues had the main goals of investigating the focal characteristics of the main Chichi earthquake, analyzing the sequence of aftershocks that followed, and determining the significance of the earthquake with regard to plate tectonics and orogenic processes in the vicinity of Taiwan.

The data employed in the project consisted mainly of the earthquake waveform data collected by the Aca-

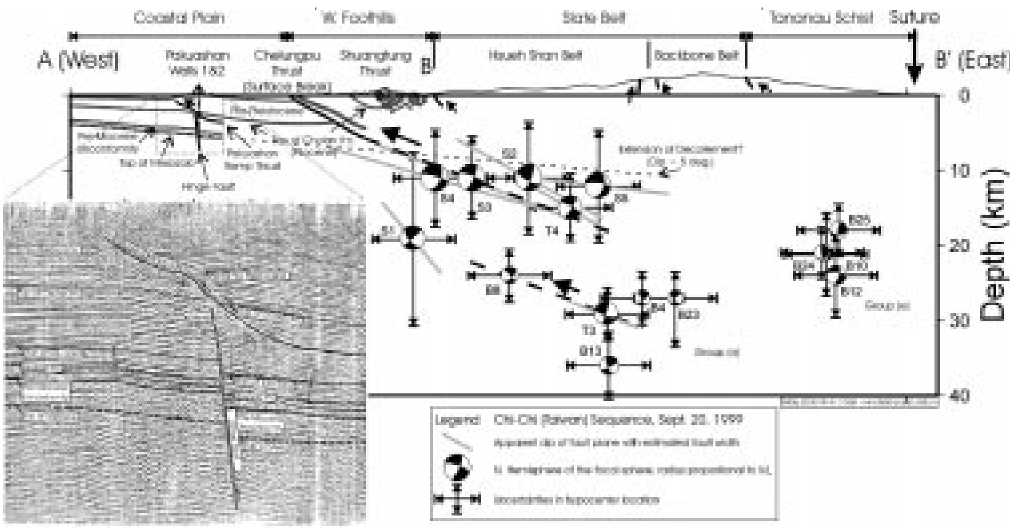

Fig. 2 Cross section of the Taiwan orogen. Fault plane solutions of the Chichi earthquake mainshock (S1-S5) and aftershocks are shown in back-hemisphere projection of the focal spheres, together with surface geology and seismic exploration results beneath west Taiwan.

demia Sinica's "Broadband Array in Taiwan for Seismology," plus some data collected by the "Global Seismic Network." The technique employed was to use the earthquake waveform to deduce the depth at which the quake occurred, the magnitude of the energy released, the form of faulting, and the rupturing process.

We can infer that the main shock of Chichi earthquake consisted of five subevents. The initial rupturing occurred at 23.86N, 120.81E (near the town of Chichi). The main rupture shifted in a northward direction and gradually increased in size. The greatest associated shock was located approximately 30~35 kilometers north of the initial rupture. The rupture mostly took the form of a thrust fault with an average dip angle of 25°. Although the fault originally trended in a north-south direction, it gradually rotated to a northeast-southwest orientation in the process of shifting towards the north.

The locations of the aftershocks of the Chichi quake can be categorized as six groups. Each group had its own characteristic focal mechanism, and the most surprising fact was the researchers' proof that the Chichi earthquake sequence contained upper and lower source structures. The main shock and numerous aftershocks occurred along the Chelungpu fault; the rupture along this fault extended from the surface to approximately 15 kilometers in depth. However, many aftershocks occurred in another, relatively deep, structure. This formerly-unknown structure is located 15 kilometers directly below the Chelungpu fault. Most of the aftershocks occurring in this structure were also reverse-thrust type earthquakes with rupturing similar to that of the Chichi quake. At present there is no evidence suggesting that this structure extends upward to Taiwan's western lowlands. As for the likelihood that the structure will generate further quakes, there is a relatively high probability that earthquake-susceptible structures remain in the upper layer.

From the point of view of Taiwan's overall tectonic structure and orogenic processes, the Chichi quake basically reflected the plate collision and mountain-building activity occurring in the region. The entire Chichi earthquake sequence (including both the mainshock and aftershocks) can be seen as the result of the motion of a crustal block approximately 80~100km in length located behind the leading edge of deformation; this block moved towards the west within an interval of several tens of seconds, causing reverse thrust faulting under western Taiwan. However, the principle of energy accumulation suggests that the likelihood of an earthquake of similar magnitude occurring within the same structures is very low for the time being.

The Chichi earthquake has provided valuable first-hand information for seismology and tectonics research. The above project took advantage of the high occurrence frequency of earthquakes in Taiwan, as well as the quantity and quality of geological/geophysical observations, and employed advanced research techniques to perform an in-depth, rigorous investigation of the devastating Chichi earthquake. As a result, the project was able to propose very scientifically-valid conclusions about the earthquake source and the tectonic implications. These conclusions have attracted international attention, and may in the future help the ROC to gain access to international research centers.

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New Draft Version of the NSC "Experimental Guidelines for Gene Recombination"

I. International Status

Due to rapid progress in biotechnology and molecular biology, the past two decades have seen the emergence of genetic recombination as a tool for creating new varieties of plants and animals. For instance, the gene for bovine growth hormone has been successfully used to accelerate weight gain and increase milk production by 8% in cattle. The more than fifty genetically-modified crops currently in existence include new varieties of maize, soybeans, tomatoes, cotton, oilseed, potatoes, sugar beets, rice, and wheat. These transgenic crops contain genes of toxic proteins of *Bacillus thuringiensis* and genes that produce herbcide resistance proteins and carotene, etc.

The roughly 800 representatives of 130 countries who attended the "Biodiversity Conference" held in Montreal this year (January 24~28, 2000) completed and passed the draft version of the Cartegena Protocol on Biosafety. This protocol was finalized on May 15 at a conference held at Nairobi, and will be signed by national governments during the year after June 2000. The protocol will take effect within 90 days after having been signed by 50 nations. The passage of the Protocol on Biosafety will have a tremendous impact on biotech research and industry around the world. The protocol's purpose is to insure public safety, maintain biodiversity, and protect and utilize biological organisms by providing guidelines for the import, export, cross-border transfer, and use in foods, animal feed, and processed goods of genetically-modified organisms and their products.

In light of the international trend towards the regulation of genetic technology, the ROC had to act quickly to complete relevant biosafety guidelines. This task included the drafting of guidelines on research methods involving the modification of genes and on the import, export, cross-border transfer, and use in foods, animal feed, and processed goods of genetically-modified organisms.

II. New Draft Version of the NSC "Experimental Guidelines for Gene Recombination"

Due to rapid progress in biotechnology and molecular biology over

Fig. 1 P3 physical containment at College of Medicine, National Taiwan University.

the past decade, including the development of many new biotech techniques, the 1989 "Experimental Regulations for Gene Recombination" was obviously inadequate to meet contemporary needs. To bring these regulations up to date, the NSC has recently revised them to expand their scope to cover transgenic plants and animals, as well as microbes.

The current draft version of the "Experimental Guidelines for Gene Recombination" was composed by a team whose members included specialists and academics from National Taiwan University, the Academia Sinica, National Yang Ming University, National Tsinghua University, National Cheng Kung University, National Chungshing University, Chang Gung University, the National Health Research Institute (NHRI), and the NSC Laboratory Animal Research Center. Following the collection of relevant data, this team composed a draft of the Guidelines with a content that reflected national sentiments and public morality. Eleven discussion meetings were then held throughout northern, central, southern, and eastern Taiwan during January 2000. Specialists from industry, academia, and the research community invited to these meetings exchanged their views concerning the practical aspects of the new guidelines. This completed the drafting process.

The NSC's "Experimental Guidelines for Gene Recombination" seeks to foster the development of genetic recombination research and the implementation various safeguards in Taiwan. To achieve these purposes, the Guidelines include the following objectives: (1) to establish guidelines for safe gene recombination experiments; (2) to clarify the organizational status, responsibilities, and duties of personnel involved in gene recombination experiments; (3) to institute safety measures addressing gene recombination experiments; (4) to institute guidelines for the disposal of various experimental objects, biological entities, and recombinant materials used in gene recombination experiments; (5) to institute education, training, and health management guidelines for personnel involved in gene recombination experiments; (6) to implement work safety protections for research personnel; and (7) to instill public confidence in scientific research and its products.

The Guidelines contains the following eight chapters: Chap. 1–General Principles; Chap. 2–Physical Safeguards; Chap. 3–Biological Safeguards; Chap. 4–Disposal of Recombinant Materials; Chap. 5–Experiments Using Animals as Hosts; Chap. 6–Experiments Using Plants as Hosts; Chap. 7–Laboratory Safety Organizations and Tasks; Chap. 8–Education, Training, and Health Management.

The main purpose of the recent revision is to expand the scope of the Guidelines so that, besides microbes, it also encompasses animals and plants as hosts. For instance, there are now guidelines governing stem cells and transgenic plants and animals. In addition, in keeping with international trends, there are new rules concerning protective measures and the types of organisms and recombinant materials that may be used.

III. Conclusions

Genetic recombination and modification offers a shortcut for the development of new products. From Eli Lilly's pioneering production of human insulin using microorganisms in 1982 to the completion of a rough draft of the human genome in 2000, it has become clear that the biotechnology industry will play a crucial role in developing future drugs, foods, and other everyday products.

While genetic technology promises to bestow great blessings upon mankind, gene recombination is an extremely precise and complex process. It is possible that carelessness or inadvertent leaks under non-proper physical containments may harm human beings or seriously affect the environment. In order to effect the lasting protection of people and the environment, it is imperative that every member of the international community minimize risk by instituting strict and reasonable regulations governing gene recombination and derivative products. Since genetic technology has already developed to a very significant level in Taiwan, the drafting of a unified set of guidelines regulating all personnel involved in genetic is a very timely and important achievement.

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