Introduction to the volume

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The Irpinia 1980 earthquake is the largest natural catastrophe to have occurred in Italy since the second World War and marks an important turning point for the country's seismological community, social environment and earthquake regulations.

On November 23, 1990, exactly ten years from the earthquake, researchers and technicians met in Sorrento to discuss and synthesize the earthquake's characteristics, what was learned from studying its impact on the natural and social environment, and the latest methods for seismic risk assessment. This publication completes the preliminary work presented in the preprint volume that was distributed to the participants at the meeting, reporting in final form the results obtained and the main conclusions reached. Reflecting the original structure of the meeting, this volume is divided in three sections. The first section deals with the strictly seismological aspects of the earthquake, and includes studies on the geometry of the source observed at different distance and with different instrumentation, and studies on the dynamics of the rupture process. The second section covers analyses of the impact of the earthquake on the environment, public works and public and private buildings, and includes discussions on the evolution of the methods for seismic-risk assessment in the light of the lesson learned in 1980. The third and last section of this publication collects papers that were presented in a special poster session. Some of these papers concern investigations on specific aspects of the earthquake, while the others deal with aspects discussed in the first two sections but relating to areas other than Irpinia.

With this brief introduction we wish to offer the reader an interpretative key of the main body of the volume: chapters I and II. The main results, the most innovative aspects and the principal disputes that still exist between the different studies will be progressively pointed out. The volume also includes a comprehensive analytical index of the bibliography relating to the 1980 earthquake.

Chapter I
Studies of the Seismic Source

The Irpinia earthquake was a very particular event in comparison with other large earthquakes that have occurred in the rest of the world during the past twenty years. The first of its peculiarities appeared soon after the earthquake hit on November 23, 1980, in the form of widely scattered estimates on the actual size of the earthquake. The very first analyses of seismograms recorded at teleseismic distance, such as that by *Boschi et al.* (1981), showed that its magnitude was lower than 7 (see the contribution of *Giardini*). Based on this estimate and following the standard seismological terminology, the 1980 earthquake was paradoxically rated as «moderate». However, the length of the area affected by aftershock activity was almost 60 km, at least twice as much as in Friuli following the 1976 earthquake. Although the peak ground acceleration values measured in the epicentral area appeared to be comparable or smaller than those measured in 1976, and far smaller than those recorded following large Californian earthquakes, the destruction was total and the loss of human lives overwhelming. The amplitude of the body-waves recorded at teleseismic distance was relatively small, as demonstrated by the surprising estimate of 6.0 for the M_B (NEIS), but the length of the *P*-pulse suggested a rupture duration of a few tens of seconds, such as that observed for much larger earthquakes that occur in subduction zones or along transform boundaries. On the other hand, the «E.N.E.L.», the «Ente Acquedotto Pugliese» and other service companies reported limited damage or even no damage at all for several important civil engineering works, essentially artificial reservoirs and underground aqueducts located within the epicentral area. The combination of these observations made the task of estimating the effects of the earthquake extremely contradictory. Indeed, while on one hand the earthquake could be rated as *moderate* based on the traditional seismological evaluation criteria, on the other hand its *severity* required that this rating be overturned, as the extent of damage suggested to anyone who visited the epicentral area. However, the engineering works built merely following appropriate engineering standards had brilliantly overcome the trial of an earthquake which was certainly not smaller than the many historical earthquakes of the Apennines.

Ten years have been barely enough for us to explain the contradictions that arose from the early observations of the 1980 earthquake. The approach toward the current stage of our knowledge was slow and progressive, flaring up occasionally thanks to the publication of fundamental datasets or of the results of large research papers. Among the contributions that proved to be starting points for many of the studies that followed we must mention those of the *Gruppo di Lavoro Sismometria del Terremoto del 23.11.1980* (1981), *Berardi et al.* (1981), *Arca and Marchioni* (1983), and *Westaway and Jackson* (1984). A brief description of these studies is certainly advisable as it will lead to a better understanding of some of the results obtained several years later and discussed in Sorrento.

The observations contained in the first of these contributions have been analyzed by many investigators both with traditional approaches aimed at locating the aftershocks to delineate the main fault, and with innovative ones, such as the seismic tomography methods used for imaging the local crustal structure (see *Amato and Selvaggi*). This dataset was used to constrain the actual location and extent of the seismogenic structure activated in 1980, a task that would have given controversial and misleading results simply based on the distribution of damage.

The accelerometric dataset recorded by the E.N.E.A.-E.N.E.L. network and described in the second contribution (*Berardi et al.* (1981)) was also extensively analyzed but only starting in 1986, when the publication of a study of *Crosson et al.* (1986) prompted a lively scientific confrontation on the complexity of the rupture process of the 1980 earthquake. The confrontation was animated by studies conducted by several groups, both in Italy and abroad, each of which proposed to explore the source complexity by investigating jointly the accelerometric recordings and other available datasets. Indeed, due to the characteristics of the accelerometric dataset (lack of an absolute time reference, number of available recordings and instrumental response), all the proposed source models were strongly influenced by the starting assumptions and hence non-unique. This volume contains four studies (see the works of *Bernard et al.*, *Cocco and Pacor*, *Siro and Chiaruttini*, and *Vaccari et al.*) where this fundamental and previously unexplored characteristic of the 1980 earthquake is investigated from different standpoints, a difference that accounts only partially for the quite wide range of the conclusions reached. The contribution by *Westaway*, who was also the author of one of the first synthetic models of the 1980 earthquake source, should also be listed among those dealing with the rupture complexity. Quite unexpectedly, *Westaway* proposes a new location for the hypocenter of the 1980 earthquake. Although this may seem a secondary adjustment, in fact the revised hypocenter implies drastic changes in the stacking of the accelerometric time histories, and therefore different conclusions for all the studies based on this dataset.

The third contribution, which dealt with the precise determination of the elevation changes induced by the earthquake, *Arca and Marchioni* (1983) promoted the diffusion and the improvement of computation techniques that relate the strain field associated with a large earthquake to its source geometry. Several investigators followed this line of research (see the contribution of *Pingue et al.*) by progressively improving the analytical techniques. The last step in this process was to explore the distribution of the moment release associated with the mainshock under external constraints for the fault geometry.

The fourth contribution, a description of surface faulting traces in the epicentral area, *Westaway and Jackson* (1984), was maybe the most innovative of the studies carried out on the 1980 earthquake. Indeed, this study acknowledged the tectonic nature of phenomena that for over three years had been interpreted as purely gravitational. This work prompted further studies that investigated in detail the location and geometry of the surface expression of the fault activated in 1980 (see *Pantosti and Valensise*).

At the end of the '80s, several years after the earthquake and after the publication of these basic contributions, a set of new studies appeared aimed at combining all the available field and instrumental observations into a single model of the 1980 mainshock. Thanks to the availability of relatively unusual types of observations (such as a large geodetic dataset and a set of direct measurements of the fault throw at the surface) the approach and the results of these studies turned out to be quite innovative for the Italian seismological community. Naturally, even though all these studies shared a multidisciplinary approach, the choice of the datasets to be used and their relative weight relied on the experience and critical ability of the investigators. For instance, *Westaway and Jackson* (1987) proposed a reconstruction of the fault geometry and of the source time function that was based mainly on seismometric and accelerometric recordings and subordinately on geologic and geodetic observations. *Bernard and Zollo* (1989) proposed a more detailed analysis of the accelerometric dataset, accepting some of the conclusions of *Westaway and Jackson* (1987) and adding a qualitative interpretation of the geodetic observations as a constraint for some key aspects of the model. Finally, *Pantosti and Valensise* (1990) focused on the geometry, location and extent of the seismogenic fault using surface deformation data from both field geology and geodetic surveys, and constrained the time-dependent parameters of their model based on the conclusions reached by the previous studies.

The main features, merits and limitations of these synthetic models are described in detail in many of the articles comprising this volume. All of the models envision a master seismogenic structure subdivided in at least three distinct subsources, each of which could act as an independent source but only part of which could be unequivocally associated with faults observed at the surface.

In spite of their variability, the solutions set forth in this volume do contribute to settle some of the controversies that were mentioned above. In particular, they agree in attributing the *severity* of this earthquake to the extent of the seismogenic structure and to the duration of the strong ground shaking more than to the observed peak ground motion.

Chapter II
Earthquake Impact on the Natural and Social Environment, Seismic Engineering and Methods for Seismic-Risk Assessment

The second part of this volume includes most of the studies presented at the meeting within the sessions «Earthquake Impact on the Natural and Social Environment and Seismic Engineering Problems» and «Methods for Seismic Risk Assessment». While a comprehensive description of all the studies presented in those sessions can be found in the preprint volume that was distributed during the meeting, most of them are also briefly commented in the paper written by *Slejko* for this volume.

Understandably these two sessions cover a wide range of research topics which may appear weakly tied to each other. In fact the scientific community has never considered these subjects as a unitary research object, as in the case of the studies of the seismic source described previously. Conversely, from many points of view the 1980 earthquake has acted as a starting or turning point in studies, approaches and experiences which then became the guidelines for the improvement of these disciplines during the following decade. This may also explain the Italian origin of most of the contributions that were presented.

Most of the subjects deal with the impact of seismic events, and in particular of the 1980 earthquake, on urban areas. Indeed, the scientific community was not found unprepared by the 1980 earthquake: on the contrary it promptly developed sophisticated tools for analyzing the different aspects of the earthquake's impact and their possible interactions.

It was only after the experience of the 1980 earthquake that the Italian scientific community adopted a more systematic approach for the assessment of seismic risk. Also, only after 1980 it accepted the concept that, although we still lack a univocal definition for it, the seismic risk is represented by the product of three almost totally independent components: the *ground shaking*, the *vulnerability*, and the *value* (see the contribution by *Slejko*). In particular, after the first, urgent and preliminary evaluation of the seismic risk based on a new seismic classification of the whole Italian territory (*Petrini*, 1980), the acceptance of that concept has immediately determined the need for an equilibrium in the relative importance to be given to each of the three components. Many of the contributions presented at the meeting described the state-of-the-art of the development of each component also considering its interaction with the remaining ones in the assessment of the seismic risk.

The subject of seismic hazard can be considered at two different scales: regional or local. An interesting experiment was conducted to assess the seismic risk at a regional scale in the framework of TERESA, a project sponsored by the European Seismological Commission (see the article of *Mayer-Rosa et al.*). A group of investigators evaluated the seismic risk of a region in the southern Apennines (not far from Irpinia), each of them applying a different method to the same starting dataset. The wide dispersion in the results gave rise to an important scientific dispute: many scientists share the opinion that such differences can only result from the inaccurate application of the computational methods (for instance when determining the coefficients of the macroseismic attenuation relations). Some of the known limitations of the current methods can be overcome by abandoning some of the common working hypotheses, for instance separating the distribution of earthquake recurrence intervals at the study site from the distribution of earthquake intensities at the same site (see the article by *Grandori*).

The quantification of possible ground shaking attenuation or amplification effects is extremely important for the evaluation of seismic hazard at the local scale. A large number of investigators have dealt with this subject using both theoretical and experimental approaches (see *Siro and Del Grosso*). Another extremely interesting aspect was the attempt to quantify the local response using simplified approaches rather than through complete quantitative analytical modeling (*Siro*, 1983). Some of the effects of the 1980 earthquake were also used to explore the problem of finding a relation between damage (in particular damage expressed in terms of macroseismic intensity) and acceleration (see the contribution by *Gürpinar*).

The Irpinia earthquake also marked the beginning of a new era in the collection of macroseismic data, both historical and modern. The investigations on historical seismicity have greatly developed in Italy thanks to the large amount of research work promoted by the «E.N.E.L.» first and then by the «Gruppo Nazionale per la Difesa dai Terremoti» of the Italian National Research Council (C.N.R.), a cooperative effort between seismologists and historians (see the contribution by *Stucchi*). A systematic review of historical data lends a very important contribution to the assessment of seismic risk and may lead to drastic changes in the description of local seismicity (for instance in the case of the city of Venice).

Another field of research that was spurred by the 1980 earthquake was the analysis of the seismic vulnerability of buildings. The scientific community begun a detailed and careful examination of the enormous amount of data regarding the behavior of buildings subject to instrumentally well-documented strong ground shaking. The work of *Corsanego and Gavarini* contains a review of the development of Italian theories and research methods. The work of *D'Agostino and Viggiani* deals with the impact of earthquakes on the monumental heritage, an interesting problem that combines *vulnerability* and *value* aspects. This problem arose after the Friuli, 1976 earthquake and came to a more general attention following the 1980 earthquake. In their study, *D'Agostino and Viggiani* analyze several problems, theories and solutions of this research field, with special reference to the past 10 years and without forgetting that the earthquakes are just one of the possible causes of damage to the monumental heritage. In the framework of assessment and reduction of the *exposition* to earthquakes, when considering the *exposition* as one of the possible indicators of the *value*, *Thier and Midoro* approach the problem of earthquake preparedness by offering a comparison between current trends in California and in Italy.

The assessment of seismic risk cannot be based on a model or on a paradigm. Based on a comparative analysis of several cases, *Corsanego* reaches the conclusion that each case requires a carefully gauged approach.

A general conclusion that can be derived from the studies presented in Sorrento is that an effective reduction of the seismic risk requires that the risk level be evaluated at a given time, so that the effectiveness of the preventive steps can be evaluated and the scientific goals and methods can be clearly separated from the political measures.

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