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The INQUA Scale Project: linking pre-historical and historical records of earthquake ground effects

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Modern macroseismic intensity scales have been developed and formally defined at the end of the XIX century as an empirical tool for measuring the strength of an earthquake, and deriving information on several physical characteristic of a seismic events, such as source parameters, attenuation, and site effects. Most important intensity scales used worldwide, such as the MCS, MM and MSK scales, are 12 degrees scales. Intensity scales are based on the effects of the earthquake. The effects on humans are the most important indicators of intensity up to the V degree. The assessment of intensity in the range between the VI and XII degree is based mostly on effects on man-made structures (damage) and on the environment (ground effects or environmental earthquake effects, EEE). This is true for all the early intensity scales. Assessment of "intensity" that is not based on the combined and comprehensive evaluation of effects on humans, human environment and nature, is simply assessment of something different from the macroseismic intensity as formally defined in the original scales. Therefore, scales that do not use environmental effects cannot be defined as intensity scales.

The "INQUA Scale Project", funded by INQUA and co-sponsored by several institutions in the world, is aimed at applying the recently introduced INQUA scale of macroseismic intensity based only on ground effects. The INQUA scale has been proposed at the XVI INQUA Congress, Reno, USA, in 2003 for a trial period of 4 years. This period is devised for verifying and apply this approach to the study of coseismic ground phenomena from both contemporary earthquakes and past seismic events. After this trial period, an update version of the scale will be presented in Cairn, Australia, at the next INQUA Congress in 2007. The current version of the INQUA scale and related project materials are posted on the INQUA Subcommission on Paleoseismicity

web page at http://www.apat.gov.it/site/en- GB/Projects/INQUA_Scale/

The rationale for developing the INQUA scale is that paleoseismological and Quaternary geology research in recent decades has contributed significantly to the understanding we have today of the response of the physical environment to earthquakes. In our opinion, it is necessary to update and redefine the effects on the physical environment in the "traditional" intensity scales, in order to take into account the advanced knowledge that has been presently achieved on these effects. Based on the definition of the macroseismic intensity given above, the INQUA scale is not a scale that can be used alone, since it is based only on ground effects. Therefore, the INQUA scale should be seen only as an integration of early scales. This integration has been developed as an independent scale because in sparsely inhabited regions, EEE are the only indicators of macroseismic intensity. Also, an independent scale can facilitate the use of ground effects in conjunction with any of the "classic" scales for the assessment of macroseismic intensity.

The INQUA scale is suitable to define epicentral intensity beginning at the VI – VII level, with increasing accuracy towards higher levels. In this higher intensity range, up to IX – X, the scale facilitates comparison of EEE and damage indicators, emphasizing the role of primary tectonic effects, which are independent of the local economy and cultural setting. In the intensity range below XI, the INQUA scale should not be used alone, but in concurrence with the other scales. In the intensity range XI to XII, the INQUA scale is arguably the only suitable tool for assessing intensity in the epicentral area. Also, the INQUA scale is a vital tool for drawing isoseismals of IX, X, XI and XII degree in the epicentral areas of large earthquakes.

Comparison between recent large earthquakes with similar focal depth shows serious inconsistency between "intensity" assessment in the epicentral area and earthquake size. For instance, MM scale epicentral intensity of IX, X, X, respectively, have been assigned to the Mw 7.9, Novembre 3, 2002, Denali fault, Alaska, the Mw 7.7, January 26, 2001, Bhuj, India, and the Mw 7.6, August 17, 1999, Izmit, Turkey, earthquakes. In the seismological literature, in some case the prevailing tendency is not to assign intensity values greater than IX in the epicentral area, because of the reported saturation of "traditional" intensity for higher values (e.g., Grünthal, 1998; Ambrasyes and Bilham, 2003). Liquefaction, landslides and rock-falls are often considered not criteria suitable for the assessment of intensity. In our opinion, this use of the scales is well beyond the original definition of intensity, and cannot be accepted, since it can lead to a completely wrong description of the effects of an earthquake.

This is clearly due to the lack of understanding of the local physical environment, in terms of geomorphology, stratigraphy, climatic setting, hydrogeology, and active tec-

tonics. For example, the “low” epicentral intensity of IX MM assigned to the Denali Fault earthquake, which produced more than 300 km of surface faulting mostly across glaciated landscapes, is a result of the low density of population living in the epicentral area during this seismic event. In this case, earthquake ground effects, if used consistently with the original definition in the MM scale, clearly point out epicentral intensity of XI or greater. We argue that if this approach is pursued, it will be impossible to compare contemporary and future earthquakes with historical earthquakes, and effects of large earthquakes occurred in desert regions with effects of large earthquakes occurred in densely populated regions. Using the scales without taking into account EEE analysis will provide an image of the earthquake that reflects only the economy of the area, and not the physical parameters of the event. In terms of seismic hazard assessment, this would be a dramatic loss of information.

In fact, the original versions of the “classic” intensity scales (MM, MKS, MCS) do not allow this kind of assessment. And the results of ongoing activity within the INQUA Scale Project confirm this point. The application of the INQUA scale in different tectonic environments worldwide (including former USSR, Greece, Italy, Israel, Japan), that will be discussed in this presentation, allow a better understanding of the studied earthquakes in terms of site effects, intensity in the epicentral area, earthquake size, and relations with the causative tectonic structure.