Elementi del processo di revisione scientifica – App.A al Rapporto Conclusivo

Questa appendice contiene i principali documenti del processo di revisione scientifica, iniziato il giorno 1 dicembre 2004 con un incontro fra il gruppo di revisori istituito dalla Commissione Grandi Rischi del Dipartimento della Protezione Civile e alcuni componenti del gruppo che ha redatto la mappa di pericolosità sismica.

I documenti contenuti nella Appendice sono:

- considerazioni e richieste del gruppo di revisori, con allegate note di singoli revisori (allegato al verbale della riunione della Commissione Grandi rischi, sezione Rischio Sismico dell'1 dicembre 2004);

- considerazioni e risposte del gruppo di lavoro per la redazione della mappa, con lettere di accompagnamento del Presidente dell'INGV (20 gennaio 2004);

- considerazioni del gruppo di revisori a valle dell'evaluation meeting tenutosi a Milano il 22 e 23 gennaio 2004;

- considerazioni e risposte del gruppo di lavoro (17 febbraio 2004).

Commissione Grandi Rischi – Sezione Rischio Sismico
Riunione del 1 dicembre 2003

ALLEGATO 1

Seismic Hazard Map of Italy
Ordinanza PCM 20 marzo 2003, n.3274

Evaluation, Experts Panel

Preamble

Following the Ordinanza PCM 20 marzo 2003, n. 3274, a new map of seismic hazard of Italy is being produced by a national Working Group (WG) under the coordination of Dr. M. Stucchi at INGV. An Experts Panel was nominated by the Chairman of the Seismic Section of the Commissione Grandi Rischi, Prof. G. M. Calvi, with the goal of verifying the adherence of the seismic hazard map to the criteria expressed in the Ordinanza and its Documento Esplicativo.

The Experts Panel is composed by J. Bommer, Imperial College London, M. Garcia-Fernandez, ICTJA-CSIS Barcelona, D. Giardini, ETH Zurich, F. Barberi, Università di Roma 3, P. Gasparini, Università di Napoli Federico II, P.E. Pinto, Università di Roma La Sapienza, D. Skejko, OGS Trieste.

The hazard map and accompanying report were submitted by the WG on November 14, 2003, and presented and discussed in a joint workshop on December 1, 2003; F. Barberi and P. Gasparini could not be present. This initial evaluation is provided by the Experts Panel to the CGR following a joint meeting with the CGR, held also on December 1, 2003. In a separate document (Attachment) we also list technical commentaries addressed directly to the Working Group.

While much information was provided in the report and in the discussion on December 1, we note that a number of questions and unresolved issues raised in our evaluation could be probably clarified by having access to a more complete documentation.

Evaluation

We compliment the WG for the comprehensive and careful work done and the remarkable results achieved in a limited time. This success derives from the comprehensive work conducted over the last two decades in Italy in the fields of earthquakes, seismic hazard and earthquake engineering, and owes largely to the contributions, structure and coordination of the Working Group.

The hazard model combines a synthesis of the large body of knowledge and experience available in Italy with novel elements, databases and relations derived specifically for this new hazard iteration. The Working which could not be fully explored in the initial phase of work, but which could be further developed during the on-going revision and within the time constraints expressed by the Ordinanza. Group has worked in the right direction to provide a new seismic hazard map of Italy suitable for direct and informed application for seismic zonation, as required by the Ordinanza and its Documento Esplicativo.

In keeping with the spirit and technical specifications of the Ordinanza, we consider essential that the hazard model and the corresponding databases have to be fully justified, defendable and complete, beyond the purpose of the definition of a new seismic zonation. In addition, of course, we expect that the principle of transparency and availability of all databases and information will be maintained once the hazard map is made public. We also recommend that the final report will be compiled in a comprehensive fashion, detailing all of the input data used for the hazard calculations and the assumptions and justifications underlying each of the decisions related to the input and the computations.

The revision of the seismic hazard is by its nature a continuous, on-going effort, and the new hazard map represents an important step of a longer phase of revision, which is likely to continue for several years and involve large sectors of INGV and of the Italian scientific community. As such, it's important to identify those elements which can be introduced already in this phase in the hazard model and those which require a longer elaboration and are suitable for inclusion in a future hazard generation.

We encourage the WG to complete the hazard model already in this first phase with a formal treatment of hazard uncertainties, in order to convey in a clear and understandable way the statistical uncertainty associated to the hazard, very variable in different regions of Italy, required for a correct and informed seismic zonation application. To this end, the identification and separation of epistemic and aleatoric uncertainties must be carried out with a formal and correct approach. The hazard assessments need to capture the epistemic uncertainties in all aspects, including the input parameters (source zones, completeness intervals, maximum magnitudes, choice of attenuation relationships, etc.) and the methods adopted for the hazard calculations.

Presently the hazard variability in the Italian model is explored with respect to only two parameters (three attenuation laws and two completeness periods) and individual maps are presented for the parameter combinations. A more rational approach to display and convey hazard values and its uncertainties is through maps for the median and 84-percentile levels, and to this end the adoption of a decision tree approach is today considered the proper way to account for epistemic uncertainty. An immediate advantage in adopting a logic tree approach is the possibility of identifying those branches contributing the majority of the hazard and to perform a correct de-aggregation analysis. In addition, the logic tree would constitute the basis for future expansions of the hazard model.

A number of different hypotheses and competing models could be tested with a logic tree approach. We provide here an indicative list of items emerged during the discussion on December 1, with the understanding that the actual list of the branches to be introduced in this first phase will be defined by the WG on the basis of the availability of data, of the available resources and of their relevance for the present generation of seismic hazard:

- alternative models of seismic sources, including models combining extended back-ground sources and main active faults and lineaments
- offshore seismic sources, with specific regards to Northern Sicily and Liguria
- different models of Mmax
- the adoption of standard magnitude calibrations
- alternative models to express the seismicity rate, i.e. GR and characteristic earthquake
- source models incorporating strain-rate constraints on location and rate of seismic activity
- extended sources and appropriate distance metric for earthquakes larger than M6.5
- realistic distributions of earthquake hypocenters with depth
- calibration of regional reference rock profile
- additional strong-motion attenuations
- scaling for large earthquakes and scaling for weak-to-strong motion correlation
- different branch weighting schemes

In closing, the Experts Panel confirms its availability to support the WG in their efforts.

The Experts Panel:

J. Bommer, Imperial College London
M. Garcia-Fernandez, ICTJA-CSIS Barcelona
D. Giardini, ETH Zurich
P.E. Pinto, Università di Roma La Sapienza
D. Skejko, OGS Trieste

(F. Barberi and P. Gasparini were not present during the first meeting)

Technical Comments addressed to the Working Group

J. Bommer

Hazard mapping

In order to reduce the presentation to a single map, the median hazard could be shown on a coloured map, over which shading (hashed areas) could be superimposed that indicate the level of epistemic uncertainty, perhaps based on the ratio of the 84-percentile and median PGA levels. A paper on how to prepare such maps is G. Woo (2002), "Overlaying uncertainty on maps", *Proceedings of the Twelfth European Conference on Earthquake Engineering*, London, Paper no. 007.

The report needs to clearly state, and also substantiate, the ground conditions for which the hazard maps are derived, demonstrating the site class used for each of the attenuation equations and demonstrating that these are compatible.

A constant focal depth for each source zone has been fixed in the hazard calculations, which influences the results from the Malagnini *et al*. equations. It would be more appropriate to use distributions of depths, since the shallowest events could generate significant ground motions, and the use of an average fixed depth may be leading to an underestimation of the hazard.

Attenuation Relations

The definition of the horizontal PGA used in each equation needs to be clearly defined. Sabetta & Pugliese (1987) and Ambraseys *et al*. (1996) both use the larger horizontal component of motion; it is necessary to confirm that this is also the definition used by Malagnini *et al*. (2000, 2002).

The very low standard deviations associated with the Malagnini *et al*. (2000, 2002) equations need to be substantiated. In the original papers, there is a distinct lack of analysis of uncertainties and trade-offs, leading to the suspicion that the aleatory variability may be underestimated, with the consequence of underestimating the hazard.

The high relative weights given to the Malagini *et al*. equations need to be justified, particularly for those regions for which the equations were not derived and taking account of the fact that the equations are being applied up to magnitudes well above the range in which these equations have been constrained.

A point that particularly needs attention is the fact that the equations of Ambraseys *et al*. (1996) are being employed using epicentral distance in place of the Joyner-Boore distance (measured from the surface projection of the fault rupture) for which they were derived. For larger earthquakes (M > 6.0), for which fault rupture dimensions are of the order of several kilometres, the epicentral distance, on average, will be appreciably larger than the Joyner-Boore distance. As a result of this, the calculations will be leading to an underestimation of the ground accelerations, artificially reducing the hazard levels.

In Figure 13 of the report, the anchor point for the three curves is supposed to correspond to the PGA obtained from the equations of Ambraseys *et al*. (1996) for a distance of 1 km. Assuming $M_s = M_w$, the median PGA on rock obtained from this equation is 0.29*g*, whereas the value shown is of the order of 0.37*g*. If a stiff soil site is assumed, the Ambraseys *et a*l. (1996) equation gives 0.38*g*. This needs to be clarified or corrected.

In revising the hazard estimates, it may be helpful to use Eq.(9) – and the coefficient in Table V – of Bommer, Douglas & Strasser (2003), "Style-of-faulting in ground-motion prediction equations", *Bulletin of Earthquake Engineering* **1**(2), 171-203. The equations are derived using the database of Ambraseys *et al*. (1996) but including the fault rupture mechanism as an additional explanatory variable; since the dominant mechanism is known for most source zones in Italy, this could help to refine slightly the hazard estimates.

D. Slejko

<u>Seismic Sources</u>

A1) One good point of ZS4 is that it is kinematically constrained. It is not demonstrated in the report that ZS8 is kinematically constrained.

A2) The modification of ZS4 to ZS8 is also motivated by the need to have a larger number of eqs in each zone, but in 3 zones the eq number remains very low (below 10). A large eq number is important especially to assess the G-R parameters: a branch with the G-R parameters is, then, suggested. Moreover, you state that some recent eqs occurred outside the SZs of ZS4: some of them remain also outside ZS8 (e.g.: the Merano eq).

A3) Seven zones are not used in the calculation. Some of them are rich of eqs (e.g. Slovenia) and could influence the hazard in the Italian border region: their use is suggested.

A4) It is stated in the report that eqs with magnitude 4.9 can occur everywhere in Italy: the definition of background zones (at least one covering the whole studied area, or better the area where SZs are not defined) is suggested.

A5) The definition of the active layers in depth is too detailed with respect to the accuracy of the locations used (10 km, but also 30 km).

<u>Seismic Catalogue</u>

B1) Give more description about the magnitude regressions (e.g.: how many Mw values are available and where do the low values come from?)

B2) The use of DISS implies that a better definition of the SZs than in ZS4 is proposed. For this reason I suggest to give preference to instrumental data when their quality is at least similar to the macroseismic ones.

<u>Attenuation</u>

C1) The use of the Malagnini attenuation relation is questionable because it is not calibrated on large eqs, information on the source (depth) is needed, and it is defined only for some regions of Italy. Moreover, the results do not seem very good (see Fig. 14 left) and very different from those the robust relations (Figs. 19 and 20). A low weight is, then, suggested for it.

C2) I suggest not to export the Friuli relation (thrust environment) to areas where the thrust environment does not dominate.

<u>Seismicity rates</u>

D1) The criteria to define the complete periods do not seem objective: it should be pointed out where the expert judgement is applied.

D2) Given the very poor evidence of Mmax from geological evidence, an additional method for Mmax computation is suggested. To consider that all Mmax are contained in the catalogue is very questionable, although the influence on hazard can be marginal.

<u>Hazard results</u>

E1) An evaluation of the uncertainty is needed: this can be done computing the Gaussian distribution of the results of the different branches.

E2) A branch with the results from the smoothed seismicity approach is suggested. This approach should take into account the present comments, especially about the attenuation relations.

E3) The final map shows several areas with expected values below the actually recorded ones.

Specific remarks (page number refers to the Italian report)

Page 6: The blue limits are not evident.

Page 10: it is not clear if the location error (30 km) is the maximum ellipsoid axis or each component.

Page 10: Say how many active layers were computed from the depth distribution and how many on expert judgement.

Page 13: Specify that Italy cannot be considered a stable continental region.

Page 16: The 2 curves for zones 2 and 3 seem similar for distances larger than 20 km and are not defined for distances below 10 km. Comment about their difference.

Page 17: The description of attenuation relations for intensity is out of the matter of the report.

Page 19: Explicit that the zonations for the historical and statistical completeness are the same.

Page 20: The graphs of Fig. 17 are not clear. If the magnitude range is 0.6 there is not a clear reference of the classes on the magnitude axis.

Page 21: The singularity of the seismicity rates can be artefacts caused by the conversion of intensity into magnitude and, therefore, there is no need to maintain these singularities.

Page 22: I am doubtful about the different magnitude steps used (0.24Mw, 0.28 ML).

Page 22: It is not clear to me the use of depth in the Malagnini attenuation relation. If each SZ has an active layer and this value is used, what does it mean "attribuendo un peso maggiore alle profondità dei terremoti usati per la calibrazione delle relazioni stesse"?

Page 22: It is not stated that the hazard maps are with the standard deviation of the attenuation relations used.

Page 23: In the caption of Fig. 19, CO-03.7 should be CO-03.6.

Page 28: the final considerations refer to the application of the hazard map rather than to the map itself. Comments on pros and cons of the work done would be useful.

D. Giardini

Seismic zone in Northern Sicily

The Task I report (seismic zones) recognizes the issue of the deformation taking place north of Sicily, but it discards it too quickly in my opinion. Today we know that just north of Palermo is located the largest strain rate of all Italy. GPS and instrumental data confirm this picture. We also know that not all the strain is released seismically, as also observed in other convergent areas in the Mediterranean (only about 20% of convergence is seismic on the Aegean trench). However, two additional elements must be considered:

1. the incompleteness of the historical record of the offshore area; not only it's likely that the mid-size events have gone largely undetected, but large historical events have

been mislocated on the coastal area (i.e. 1823); the code used here to treat extended sources is unsuited for off-shore events. The CPTI catalogue does not contain enough seismicity in the area north of Sicily, but this is considered incorrect also in the Task I report.

2. The whole southern Italian region displays strong time-dependent behaviour. For example, the high strain rate in Calabria was recorded in a restricted period of history and Calabria has been very quite since the 1908 event. The possibility that the area north of Sicily behaves in the same way must be considered.

It would be appropriate to conduct hazard tests relocating the historical coastal seismicity on the offshore area, with additional constraints on the activity rate corresponding to a shortening of 2-3 mm/yr, to evaluate the contribution to the hazard in Palermo and Northern Sicily.

Magnitude regressions

Magnitude conversion relations which do not follow conventional scaling (for example the ML-MW relation) are derived. This could be well justified by the instrumental calibration used in the last 30 years in Italy. However, the data are quite dispersed, and it would be very important to verify the effects of the finiteness and dispersion of the dataset, if it is appropriate to extend the derived regressions to higher magnitudes, if the magnitude definitions correspond to those used in the attenuation relationship (is it the same ML ?) and how would the hazard vary if standard relationships are adopted.

Attenuation laws

The adoption of highly variable regional attenuation laws should be treated with utmost care, as it has a profound influence on many aspects of hazard. A few are mentioned here:

1. An important consequence of adopting strongly varying regional attenuation curves is the effect on magnitude scales. There is a compensation effect which needs to be taken into account: in areas with low attenuation, ground motions will be higher than expected from an average attenuation law, and in turn magnitudes will be overestimated when using an average attenuation law (as it is common practice). In the end, the effects of low attenuation and lower magnitudes compensate. It is incorrect to adopt very different attenuation laws without correcting the effects on magnitude. Tests should be carried out to verify the effect of the regional attenuations in southern Sicily and Friuli.

2. Large differences from a 1/r decay of amplitudes with distance must be justified on clear physical grounds, not only on fit to data (i.e. the effect of crustal reflections in the 70-100 km distance). Some of the regional attenuations used are published, but a comprehensive framework of regional attenuation laws is missing and cannot be patched together by using very local attenuation curves: for example, the high hazard in the Iblean province is due to the adoption with a 40% weight of the regional attenuation derived for Friuli.

3. The reference rock adopted in the attenuation and hazard is unclear. An EC8 type A rock is mentioned, of 800 m/sec. Is this the average rock value of the strong-motion sites ? A harder rock (1500 m/sec or higher, as observed in the Alps) rock would produce a much smaller hazard. This issue is again tied to the calibration of the attenuation and of the magnitude scales.

Activity rates

A GR or other more complex regularization of the seismicity rate are normally adopted to balance the incompleteness of the historical record and the non-stationarity of seismic activity, which is present in many seismic areas of Italy. Even when moving from the smaller source zones of ZS4 to the larger zones of ZS8 the problem remains, as some areas have always a low seismicity rate. The joint adoption of observed activity rates and of catalogue completeness is contradictory, as it artificially and implicitly imposes physical constraints on the seismicity that are only based on our insufficient record of seismicity. A complete presentation is required on the observed activity rates, on the corresponding GR parameters, on the resulting hazard, on the adopted Mmax.

Mariano García-Fernández

General Comment

Although the report include all the topics related to the generation of the seismic hazard map, as it should be expected from a summary report, most of them need to be explained in more detail in order to perform a complete review; especially in what regards the expert criteria involved in some of the decisions, e.g. delineation of sources, magnitude homogenisation, completeness analysis, selection of attenuation relationships. This additional information could be provided in form of additional working reports on the specific topics.

Specific comments According to the 'Criteria for the Assessment of the Seismic Zones', included as Annex 1 in the Ordinanza PCM 20 marzo 2003 n.3274

Criteria c.i)

The methodology used, although not very recent, is of common use to develop seismic hazard maps for building code purposes, so it can be considered as a standard with wide consensus in the international community.
Nevertheless, to follow recent standard practice, the map should be complemented with a minimum reasonable (according to the limited time schedule) level of uncertainty evaluation, including both the input parameters and the calculated hazard values.

Criteria c.ii)

Sources

- The possibility of offshore sources, either individual or by extension of inland ones, should be addressed.
- Definition of background sources should be evaluated, considering the assumption of Mmax=4.9 outside the seismogenic sources identified in the model.
- Seismicity smoothing among sources ('soft' boundaries) could be an option to address location uncertainty, and it should be evaluated.
- It should be clearly explained why some of the defined sources are not used in the calculation, specially those which could influence the hazard because of its seismic activity (e.g. Slovenia).
- Check if Mmax could move among sources due to location uncertainty.
- Check if Mmax fault-size fits into the source dimensions.
- An additional zoneless approach could complement the uncertainty analysis. It can be applied either for the whole map or inside the individual sources.

Catalogues

- It is not clear how the magnitude homogenisation was carried out and how the conversion errors influence the rate calculation and the estimation of Mmax.
- The completeness approach is not fully explained, and it seems there are expert decisions that should be clarified.

Attenuation

- It should be clarified if the regional relations used correspond to the average soil conditions considered.
- Regional attenuation relationships should be only applied to the regions from where they were developed, and still they should consider all the specific characteristics at this scale, e.g. focal mechanism. Their use in different regions, even if having similar tectonic characteristics, could be dangerous and they might introduce more uncertainty than using standard general relations like Ambraseys et al. (1996).
- The comparison to pga records from single individual events should not be the only criteria to select an attenuation relationship.

Criteria c.iii)

At the moment this criteria could not be fulfilled.

Criteria e)

Not yet fulfilled. A restricted distribution to the reviewers could help the review process.

Criteria f)

The available studies at the same scale, if any, should be submitted to the reviewers, or the references to available published papers provided.

Roma, 20 gennaio 2004

Al dott. Vincenzo Spaziante
Vicecapo Dipartimento Protezione Civile

al prof. GianMichele Calvi
Presidente della Commissione Grandi Rischi
Sezione Rischio Sismico

Oggetto: note dell'expert panel (riunione dell'1 dicembre 2003) sulla mappa di pericolosità sismica consegnata da INGV.

Questo Istituto ha preso in considerazione le note sottoposte dal panel in oggetto, in parte anticipate già nell'incontro dell'1 dicembre 2003.

L'Istituto ringrazia il Dipartimento e i reviewers per l'attenzione posta e per i suggerimenti forniti, cui viene data una risposta di massima nell'allegato, in vista di un approfondimento nel corso dell'incontro ad-hoc che si terrà il 22 e 23 gennaio presso la sede INGV di Milano.

Per una miglior comprensione delle risposte e delle proposte contenute nell'allegato, si ritiene necessario precisare quanto segue:

a) la ricerca in oggetto è stata progettata per fornire, come richiesto da CGR (10 giugno 2003), un prodotto entro la fine di ottobre 2003, in modo da anticipare la scadenza prevista dall'Ordinanza (maggio 2004). A questo scopo è stato formulato un programma di lavoro strettamente commisurato al tempo a disposizione, programma che è stato inviato a DPC e da questo approvato, quindi reso pubblico su web (allegato);

b) in vista di questa scadenza, così ridefinita, INGV ha operato e consegnato il rapporto finale nel novembre 2003. Si vole osservare che, in questo quadro, la ricerca è stata svolta a costo zero, in quanto l'ente ha ritenuto di poter ricomprendere i costi nell'ambito della convenzione INGV-Dipartimento in scadenza alla fine del 2003;

c) preso atto delle richieste dei reviewers, alla luce di quanto sopra INGV ritiene che parte di esse possa essere accolta nell'ambito di un breve prolungamento dalla iniziativa in corso, e che parte debba invece riferirsi a una fase successiva, prevista dalla Ordinanza stessa in termini di alcuni anni, non riconducibile alla scadenza di maggio 2004 che, come richiesto, è stata anticipata.

Cordiali saluti.

prof. Enzo BOSCHI

all.1. Working programme (July 2003)
all.2. Answers to questions and comments raised by the evaluation panel

All.1 - Working Programme (July 2003)

Foreword. The Prime Minister Ordinanza n. 3274 of 20 March 2003, suppl. n.72 to the Official Gazette 8 May 2003, n.105, has updated the building code in seismic areas according to the results of the Working Group put in place with decree 4485 of 4 December 2002 by the Secretary of the Prime Minister, dr. G. Letta, giving also practical issues to the Legislative Decree n. 112/1998, art.93 e 94 concerning the share of the responsibilities between the State and the Regions.
With respect to seismic zonation the Ordinanza has adopted, as initial reference, the map attached to the "seismic classification proposal" compiled in 1998 by ING, GNDT and SSN, dividing the whole Italian territory into 4 classes.
Starting from that it foresees:

a) a first phase, one year long, in which the Regions are allowed to adopt changes, not greater than 1 class, to the aforementioned map;
b) a second phase in which the Regions use a new reference map compiled at a national scale in such a way to fulfil the criteria established by the Ordinanza, all.1, to be compiled within one year (May 2004);
c) a third phase in which the map of point b) will be updated at time-intervals not longer than 5 years.

While the mid-term improvement (phase c) requires intensive investigation, short-term phases (a and b) mostly requires full use of available information and know-how. They represent a sort of "emergency activity" to be performed in a transition period during which both sinergy among the institutions (Department of Civil Protection, Regions, Research Institutions) and role and task distinction are required.

After considering the needs which emerged in the frame of the meeting of the Commission for Large Risks, Seismic Risk Section, held on 10 June 2003, INGV decided to start, according to its istitutional tasks (Legislative Decree 381/1999) and to similar initiatives performed to support the Public Administrations, a investigation devoted to compile, within 31 October 2003, a reference seismic hazard map according to the criteria required by the Ordinanza, all.1, making also use of the expertise and the results acquired in the frame of the running GNDT Project "Earthquake Probababilities..." (coord. A.Amato).
In the following the main lines of the investigation are proposed.

Framework and goal. The main issues and the criteria according to which the map must be compiled are clearly established by all.1 to the Ordinanza (see all.b) and by the very close deadline (31.10.03), which requires procedures compatible with the need of matching the deadline. In particular (criteria <u>a</u> and <u>b</u>):

- the map must be compiled in terms of PGA, with 10% exceedence probability in 50 years;
- PGA values will be used to assess the zone - out of the four - to which each Commune will be assigned. They will not be used directly as design values; these are provided by the 4 values of the elastic response spectrum dictated by the code (see table).

In this phase it is therefore useless to consider other ground motion parameters, which are not required by the Ordinanza. Elaborations performed in terms of parameters other than PGA might be considered under the perspective mentioned by the document of the Committee which has prepared the materials of the buiding code (*"further shaking parameters, better describing the seismic damage suffered by buildings might be considered with the aim of making the PGA distribution more robust").*

The deadline of 31.10.03 requires a strong committment of the researchers who are ready to collaborate to this initiative, in order of make the best possible use – within the tight time-window - of the data and the expertise made availablein the last years.
This will be possible mainly because the already ongoing research activities and of the fact that the new code requires a map of PGA. The last issue will make the working time shorter with respect to previous cases, when the expected distribution of ground motion parameters needed to be further elaborated in order to supply maps of "seismic classification". Problems connected with the use of PGA maps will be dicussed later with the main users, the Regions.

The short time-window and the necessity of using well established and widely agreed methodologies do not prevent this initiative from being a high scientific level one.
The investigators who have promoted this initiative are sure that the contribution of new information will be considerable, mostly in terms of data on: i) seismicity; ii) seismogenic potential; iii) energy propagation, etc. They are also convinced that a distinctive quality of this initiative is the sinergy between those who have made available the data and those who will use them for the compilation of the PGA map.

Methodology. With reference to criterion c), PGA distribution will be evaluated by making use, as a first step, of standard methodologies, widely used at international level for building code purposes. One of such methodologies is the one of Cornell (Cornell, 1968; Bender e Perkins, 1987), which was used at a European scale in the frame of the projects *"Global Seismic Hazard Assessment Project - GSHAP"* (Giardini, 1999) and "*SESAME*" (Jimenez et al., 2001; Giardini et al., 2003).
Further methodologies, such as the ome by Frankel et al., 1996, or hybrid approaches will be tested with lower priority. Moreover, there is a general agreement that *time-dependent* approaches are not enough well established and tested for the whole Italian territory, to be used within this short time-span. Special cases or examples will be taken into consideration anyhow.

All the elaboration procedures will be described in detail, in such a way to make transparent the performed choices. When possible, "logic trees" approaches will be used with reference to particular choices of basic data or elaboration procedures.

Input data. For the standard evaluations the following input will be used: i) one or more seismogenic zonations, made coherent with the most updated knowledge of active tectonics and seismogenesis; ii) the earthquake catalogue CPTI (GdL CPTI, 1999), or an updated version extended to 2002; iii) time-intervals of data completeness determined with the help of historical approaches; iv) ground motion attenuation relationships calibrated against Italian data.

For the non conventional evaluations, further than the above mentioned data all the available knowldge on the seismogenic processes, with special reference homogeneous data collections of potential strong earthquake sources, will be used.

Transparency. To fulfill the request of criterion e) a website will established devoted to make available to public: i) information about the Ordinanza and its application; ii) working progamme for the compilation of the reference seismic hazard map; iii) work progress, preliminary results, open problems.
In addition, a forum dedicated to discuss opinions and queries of contributors and users will be open. The forum will be sureveyed by one or more moderators, who have the task of not publishing contributions out of the topic and/or offensive; it will be open to anybody and will foresee the possibility of register in a mailing list.
In ordere to satisfy what requested by the second part of criterion e) ("*peer review*"), in the short time span it is suggested that the Department oc Civile Protection establishes a small "review and steering committee", open to European investigators.

Coordination committee. The President of INGV has established a coordinating committee (INGV Decree n. 183 of 24 July 2003 which comprises investigators of INGV and other research institutions): A. Akinci (INGV), D. Albarello (Univ. of Siena), A. Amato (INGV), E. Faccioli (Polit. of Milano), F. Galadini (CNR), P. Gasperini (Univ. of Bologna), L. Malagnini (INGV), C. Meletti (INGV), F. Meroni (INGV), G. Selvaggi (INGV), M. Stucchi (INGV-coord.), G. Valensise (INGV), G. Zonno (INGV). The Department of Civil Protection has proposed the collaboration of F. Sabetta (DPC) and A. Lucantoni (DPC).

All investigators who desire to collaborate are invited to contribute. All contribution will be acknowledged.

All. 2 - Answer to the document

Commissione Grandi Rischi – Sezione Rischio Sismico
Riunione del 1 dicembre 2003 - ALLEGATO 1
Seismic Hazard Map of Italy
Ordinanza PCM 20 marzo 2003, n.3274

Evaluation, Experts Panel

prepared by the Working Group for the compilation of the reference seismic hazard map of Italy (January, 2004)

Note: the original document is reported below. Answers and comments are inserted at the relevant place(bold, right aligned)

Preamble

Following the Ordinanza PCM 20 marzo 2003, n. 3274, a new map of seismic hazard of Italy is being produced by a national Working Group (WG) under the coordination of Dr. M. Stucchi at INGV. An Experts Panel was nominated by the Chairman of the Seismic Section of the Commissione Grandi Rischi, Prof. G. M. Calvi, with the goal of verifying the adherence of the seismic hazard map to the criteria expressed in the Ordinanza and its Documento Esplicativo.

The Experts Panel is composed by J. Bommer, Imperial College London, M. Garcia-Fernandez, ICTJA-CSIS Barcelona, D. Giardini, ETH Zurich, F. Barberi, Università di Roma 3, P. Gasparini, Università di Napoli Federico II, P.E. Pinto, Università di Roma La Sapienza, D. Skejko, OGS Trieste.

The hazard map and accompanying report were submitted by the WG on November 14, 2003, and presented and discussed in a joint workshop on December 1, 2003; F. Barberi and P. Gasparini could not be present. This initial evaluation is provided by the Experts Panel to the CGR following a joint meeting with the CGR, held also on December 1, 2003. In a separate document (Attachment) we also list technical commentaries addressed directly to the Working Group.

While much information was provided in the report and in the discussion on December 1, we note that a number of questions and unresolved issues raised in our evaluation could be probably clarified by having access to a more complete documentation.

We agree. Some material has already been forwarded; something more will be presented at the 22/23 meeting.

Evaluation

We compliment the WG for the comprehensive and careful work done and the remarkable results achieved in a limited time. This success derives from the comprehensive work conducted over the last two decades in Italy in the fields of earthquakes, seismic hazard and earthquake engineering, and owes largely to the contributions, structure and coordination of the Working Group.

The Working Group has worked in the right direction to provide a new seismic hazard map of Italy suitable for direct and informed application for seismic zonation, as required by the Ordinanza and its Documento Esplicativo. The hazard model combines a synthesis of the large body of knowledge and experience available in Italy with novel elements, databases and relations derived specifically for this new hazard iteration, which could not be fully explored in the initial phase of work, but which could be further developed during the on-going revision and within the time constraints expressed by the Ordinanza.

Sorry, this sentence was corrupted in the file we have received. We have reconstructed it, but we are not sure

In keeping with the spirit and technical specifications of the Ordinanza, we consider essential that the hazard model and the corresponding databases have to be fully justified, defendable and complete, beyond the purpose of the definition of a new seismic zonation.

we partially agree. Most of the elaborations are made within the scope of this initiative, as it happens in all similar experiences around the world.

In addition, of course, we expect that the principle of transparency and availability of all databases and information will be maintained once the hazard map is made public.

We agree. It will be our pride and challenge to other initiatives, either Italian and European !

We also recommend that the final report will be compiled in a comprehensive fashion, detailing all of the input data used for the hazard calculations and the assumptions and justifications underlying each of the decisions related to the input and the computations.

We'll do our best

The revision of the seismic hazard is by its nature a continuous, on-going effort, and the new hazard map represents an important step of a longer phase of revision, which is likely to continue for several years and involve large sectors of INGV and of the Italian scientific community. As such, it's important to identify those elements which can be introduced already in this phase in the hazard model and those which require a longer elaboration and are suitable for inclusion in a future hazard generation.

ok

We encourage the WG to complete the hazard model already in this first phase with a formal treatment of hazard uncertainties, in order to convey in a clear and understandable way the statistical uncertainty associated to the hazard, very variable in different regions of Italy, required for a correct and informed seismic zonation application. To this end, the identification and separation of epistemic and aleatoric uncertainties must be carried out with a formal and correct approach. The hazard assessments need to capture the epistemic uncertainties in all aspects, including the input parameters (source zones, completeness intervals, maximum magnitudes, choice of attenuation relationships, etc.) and the methods adopted for the hazard calculations.

Presently the hazard variability in the Italian model is explored with respect to only two parameters (three attenuation laws and two completeness periods) and individual maps are presented for the parameter combinations. A more rational approach to display and convey hazard values and its uncertainties is through maps for the median and 84-percentile levels, and to this end the adoption of a decision tree approach is today considered the proper way to account for epistemic uncertainty. An immediate advantage in adopting a logic tree approach is the possibility of identifying those branches contributing the majority of the hazard and to perform a correct de-aggregation analysis. In addition, the logic tree would constitute the basis for future expansions of the hazard model.

A number of different hypotheses and competing models could be tested with a logic tree approach. We provide here an indicative list of items emerged during the discussion on December 1, with the understanding that the actual list of the branches to be introduced in this first phase will be defined by the WG on the basis of the availability of data, of the available resources and of their relevance for the present generation of seismic hazard:

- alternative models of seismic sources, including models combining extended back-ground sources and main active faults and lineaments
- offshore seismic sources, with specific regards to Northern Sicily and Liguria
- different models of Mmax
- the adoption of standard magnitude calibrations
- alternative models to express the seismicity rate, i.e. GR and characteristic earthquake
- source models incorporating strain-rate constraints on location and rate of seismic activity
- extended sources and appropriate distance metric for earthquakes larger than M6.5
- realistic distributions of earthquake hypocenters with depth
- calibration of regional reference rock profile
- additional strong-motion attenuations
- scaling for large earthquakes and scaling for weak-to-strong motion correlation
- different branch weighting schemes

Although in principle we share the spirit of the recommendation, we want to make clear that the suggested procedure is still at an experimental stage at international level and, mostly, with reference to single sites and high exposure manufacts. We aew not aware that such procedure is commonly used for conventional PSHA for building code purposes.

However we believe that, in the frame of this research, the panel recommendations can be followed in a preliminary way with reference to a few parameters. We believe that the use of a formal, complete "logic tree" procedure – already discarded when the workprograamme was compiled – whas to be postponed to the next phase.

In particular our final result will be presented, as recommended, in the form of maps for the median and 84-percentile levels, which will be obtained by exploring the variability of the following parameters:

i) completeness time-intervals
same as in the november 03 version

ii) alternative models to express the seismicity rate

two branches: a) individual rates as in the 03.11 version; b) GR rates determined under the assumption of conservative Mmax values for the ZS where no strong geological constraints are available.

iii) attenuation relationships

5 branches: a) Ambraseys et al 96; b) same, with fault distance used; c) Sabetta andPugliese; d) and e) regionals with varied depth and parameters attribution to the zones.

We are skeptic about exploring alternative magnitude calibrations and we are not sure about the request of “adoption of standard magnitude calibrations. Two possible branches might follow from the alternative use of M and M-sigma/2 values, in order to account for the uncertainty of M assessment.

Finally, we do not believe useful, in this phase, to explore the variability of the seismogenic model which, as already mentioned, is the result of discussion, compromise and crossfeeding from the proposers. We do not have at this stage any alternative, independent model. We will explore the impact of local alternatives, such as in the case of Northern Sicily, and we will adopt soft bounds for those ZS which shows larger uncertainties.

In the following we answer specific questions from the reviewers. If explicitely requested we can do the same for questions or comments raised by members of CGR.

Technical Comments addressed to the Working Group

J. Bommer

Hazard mapping

In order to reduce the presentation to a single map, the median hazard could be shown on a coloured map, over which shading (hashed areas) could be superimposed that indicate the level of epistemic uncertainty, perhaps based on the ratio of the 84-percentile and median PGA levels. A paper on how to prepare such maps is G. Woo (2002), “Overlaying uncertainty on maps”, *Proceedings of the Twelfth European Conference on Earthquake Engineering*, London, Paper no. 007.

ok

The report needs to clearly state, and also substantiate, the ground conditions for which the hazard maps are derived, demonstrating the site class used for each of the attenuation equations and demonstrating that these are compatible.

ok

A constant focal depth for each source zone has been fixed in the hazard calculations, which influences the results from the Malagnini *et al*. equations. It would be more appropriate to use distributions of depths, since the shallowest events could generate significant ground motions, and the use of an average fixed depth may be leading to an underestimation of the hazard.

ok, see comments on paragraph “evaluation” (above)

Attenuation Relations

The definition of the horizontal PGA used in each equation needs to be clearly defined. Sabetta & Pugliese (1987) and Ambraseys *et al*. (1996) both use the larger horizontal component of motion; it is necessary to confirm that this is also the definition used by Malagnini *et al*. (2000, 2002).

Confirmed

The very low standard deviations associated with the Malagnini *et al*. (2000, 2002) equations need to be substantiated. In the original papers, there is a distinct lack of analysis of uncertainties and trade-offs, leading to the suspicion that the aleatory variability may be underestimated, with the consequence of underestimating the hazard.

The aleatory variability is not smaller than that indicated by the more popular relationships obtained on strong-motion data (e.g., Sabetta and Pugliese, 1996). We will discuss it further in the meeting

The high relative weights given to the Malagini *et al*. equations need to be justified, particularly for those regions for which the equations were not derived and taking account of the fact that the equations are being applied up to magnitudes well above the range in which these equations have been constrained.

The validation study performed on strong-motion data from different regions yielded good results. However, the weight will be reconsidered

A point that particularly needs attention is the fact that the equations of Ambraseys *et al*. (1996) are being employed using epicentral distance in place of the Joyner-Boore distance (measured from the surface projection of the fault rupture) for which they were derived. For larger earthquakes (M > 6.0), for which fault rupture dimensions are of the order of several kilometres, the epicentral distance, on average, will be appreciably larger than the Joyner-Boore distance. As a result of this, the calculations will be leading to an underestimation of the ground accelerations, artificially reducing the hazard levels.

We have performed some trials. To be discussed

In Figure 13 of the report, the anchor point for the three curves is supposed to correspond to the PGA obtained from the equations of Ambraseys *et al*. (1996) for a distance of 1 km. Assuming $M_s = M_w$, the median PGA on rock obtained from this equation is 0.29*g*, whereas the value shown is of the order of 0.37*g*. If a stiff soil site is assumed, the Ambraseys *et a*l. (1996) equation gives 0.38*g*. This needs to be clarified or corrected.

Actually, there was a mistake in figure 13: the curves were related to Mw = 6.0 instead of 5.5. Please, take fig. 10 of the ppt instead. Thanks Julian!

In revising the hazard estimates, it may be helpful to use Eq.(9) – and the coefficient in Table V – of Bommer, Douglas & Strasser (2003), "Style-of-faulting in ground-motion prediction equations", *Bulletin of Earthquake Engineering* **1**(2), 171-203. The equations are derived using the database of Ambraseys *et al*. (1996) but including the fault rupture mechanism as an additional explanatory variable; since the dominant mechanism is known for most source zones in Italy, this could help to refine slightly the hazard estimates.

We agree in principle. However, this issue can be adressed in the next phase.

D. Slejko

Seismic Sources

A1) One good point of ZS4 is that it is kinematically constrained. It is not demonstrated in the report that ZS8 is kinematically constrained.

ZS8 is largely based on the model on which ZS4 is based. From the kinematic point of view it seems even better constrained (see Central Italy, Gargano etc.).

A2) The modification of ZS4 to ZS8 is also motivated by the need to have a larger number of eqs in each zone, but in 3 zones the eq number remains very low (below 10).

this is an improvement, after all. Perfection next time....

A large eq number is important especially to assess the G-R parameters: a branch with the G-R parameters is, then, suggested.

not very clear. However, the recommendation is accepted

Moreover, you state that some recent eqs occurred outside the SZs of ZS4: some of them remain also outside ZS8 (e.g.: the Merano eq).

Yes. They do not exceed the Mmax allowed for the background areas, however

A3) Seven zones are not used in the calculation. Some of them are rich of eqs (e.g. Slovenia) and could influence the hazard in the Italian border region: their use is suggested.

We made some tests before: they will be proposed

A4) It is stated in the report that eqs with magnitude 4.9 can occur everywhere in Italy: the definition of background zones (at least one covering the whole studied area, or better the area where SZs are not defined) is suggested.

We have considere this option and disregarded it because we feel that it would make the seismic hazard distribution flat without benefit.

A5) The definition of the active layers in depth is too detailed with respect to the accuracy of the locations used (10 km, but also 30 km).

will be discussed in detail

Seismic Catalogue

B1) Give more description about the magnitude regressions (e.g.: how many Mw values are available and where do the low values come from?)

We used a moment dataset including 218 earthquakes occurred in Italy and surrounding regions (within a rectangular area ranging 35-47 in latitude and 8-20 in longitude) from 1976 to 2002. The data are taken from the Harvard on-line CMT catalog, the paper by Ambraseys (1990) and the INGV RCMT catalog (Pondrelli et al. 2002). The data of earthquakes with Mw<4.5 (down to Mw=4.04) all come from the INGV RCMT database. The number of data used for each regression is: 121 for M_0-ML, 109 for M_0-Ms, 204 for M_0-mb, 130 for Ms-ML and 280 for Ms-mb.

Ambraseys, N.N., 1990, Uniform magnitude re-evaluation of European earthquakes associated with strong-motion records, Earth. Eng. Struct. Dyn., 19, 1-20.
Pondrelli S., Morelli A., Ekström G., Mazza S., Boschi E., Dziewonsky A.M., 2002, European-Mediterranean regional centroid moment tensor catalog 1997-2000, Phys. Earth. Plan. Int., 130, 71-101.

B2) The use of DISS implies that a better definition of the SZs than in ZS4 is proposed. For this reason I suggest to give preference to instrumental data when their quality is at least similar to the macroseismic ones.

We prefer to have homogeneously determined parameters

Attenuation

C1) The use of the Malagnini attenuation relation is questionable because it is not calibrated on large eqs, information on the source (depth) is needed, and it is defined only for some regions of Italy. Moreover, the results do not seem very good (see Fig. 14 left) and very different from those the robust relations (Figs. 19 and 20). A low weight is, then, suggested for it.

The regional relationships for the prediction of the ground motion were obtained on data sets where the bulk of the information comes from small earthquakes. Thus, the idea of extrapolating the predictions to magnitudes well above the maximum available ones it must always be a concern. However, this is not the case for the Eastern Alps, where every available strong-motion waveform was included in the data set. The largest magnitude available in the data set was Mw 6.5, the largest ever recorded in the region. The results for the Eastern Alps show that, up to magnitude Mw 6.5, the predictive relationships by Malagnini et al. (2001) well reproduce the empirical spectra and the peak values, even if they were developed over a data set that for the most part was made of small earthquakes. A good agreement between observations and theoretical predictions in the Eastern Alps characterizes all magnitudes, within the available data set. About the other attenuation zones, the validation effort showed that the peak values of large earthquakes, not included in the original data sets, could be well predicted with the regionalized attenuation relationships. As for the depth of the sources, it is necessary that they agree with the median of the distribution of the earthquakes used for the calibration of the predictive relationships. The mere fact that strong-motion relationships do not contain the depth of the earthquakes does not make them any better, since depth variability may always be an important issue.

C2) I suggest not to export the Friuli relation (thrust environment) to areas where the thrust environment does not dominate.

We agree that the faulting mechanism may have an important role even in defining the predictive relationships to be used in a region. There is a study by Herrmann and Malagnini (2004) that explores the effects of different faulting mechanisms to the crustal attenuation term. Specifically, there is a potential for strong effects of the radiation pattern at short distances; moreover, since a large portion of the energy is radiated through limited areas of the focal sphere (i.e., limited ranges for the take-off angle), supercritical reflections are also affected (i.e., large distances). The mentioned problem, though, is not solved through the use of the available strong-motion equations, since they are also based on a mixture of data, and do not represent specific tectonic environments. In particular, the problem is more important at the largest magnitudes, where the vast majority of the waveforms come from normal-fault events (Irpinia, for example), but need also to be applied in thrust environments (like the Eastern Alps).

However, we will propose a branch addressing this issue too.

Seismicity rates

D1) The criteria to define the complete periods do not seem objective: it should be pointed out where the expert judgement is applied.

It should be well known to the reviewer that so called "Objective" criteria only look inside available data and need to assume seismicity stationarity.

The used approach is based on a mix of expert, historical judgement (looking outside the data) and "pseudo-objective" method. In our opinion it reperesents a step forward with respect to the most common procedures addressing this issue. More information on this topic will be delivered.

D2) Given the very poor evidence of Mmax from geological evidence, an additional method for Mmax computation is suggested.

We disagree that the Mmax evidence from geological data is poor. However, we are ready to adopt any alternative, provided that it is suggested and not in strong contrast with the mentioned evidence

To consider that all Mmax are contained in the catalogue is very questionable, although the influence on hazard can be marginal.

We agree with the last sentence, partially with the first.

Hazard results

E1) An evaluation of the uncertainty is needed: this can be done computing the Gaussian distribution of the results of the different branches.

ok

E2) A branch with the results from the smoothed seismicity approach is suggested. This approach should take into account the present comments, especially about the attenuation relations.

We disagree. At this stage this would not be a branch of this project but a complete new project. Next time

E3) The final map shows several areas with expected values below the actually recorded ones.

several ? which ones ?

We will produce a map of observed PGA, as allowed from the well known problem of (Italian) data availability. However, we want to recall that a 10%/50y PGA map is not a maximum expected PGA map

Specific remarks (page number refers to the Italian report)

Page 6: The blue limits are not evident.

we will do our best

Page 10: it is not clear if the location error (30 km) is the maximum ellipsoid axis or each component.

see the material delivered by ppt

Page 10: Say how many active layers were computed from the depth distribution and how many on expert judgement.

Out of 35 SZs, expert judgment was used for 12 cases (including the volcanic areas) and actual depth distributions for the remaining 23 cases.

Page 13: Specify that Italy cannot be considered a stable continental region.

Of course Italy is not a stable continental region (SCR). The phrase just specifies that the regressions computed by Johnston (1996) concern SCR. We referred to such paper, because it represents the most reliable and comprehensive investigation made on such a matter. We believe however that empirical regressions among magnitudes are not so strongly influenced by the tectonic style to make the comparison insignificant. In fact our result are almost coincident to ones obtained by Johnston (1996) except for ML. In this latter case we believe that the difference found might be due to the fact that, different from Johnston (1996), we only used, for our computations, true Wood-Anderson and synthetic Wood-Anderson estimates.

Johnston A.C., 1996, Seismic moment asessment of earthquakes in stable continental regions-I, Instrumental seismicity, Geophys. J. Int., 124, 381-414.

Page 16: The 2 curves for zones 2 and 3 seem similar for distances larger than 20 km and are not defined for distances below 10 km. Comment about their difference.

Curves for Zones 2 and 3 (peak ground acceleration) almost overlap for distances larger than 20 km, for a moment magnitude Mw 5.5. This is not surprising: peak values are carried at different distances by different frequencies. They result from the combination of seismic radiation (source characteristics: stress drop vs. moment relationships, single/multiple corner frequency spectra, etc.) and crustal attenuation (combination of geometrical spreading: structure/predominant source mechanisms, and anelastic attenuation: Q(f)/high-frequency attenuation parameter). At smaller/larger magnitude levels, the same curves would not overlap. For distances less than 10 km, near-field relationships are used.

Page 17: The description of attenuation relations for intensity is out of the matter of the report.

ok

Page 19: Explicit that the zonations for the historical and statistical completeness are the same.

yes, they are

Page 20: The graphs of Fig. 17 are not clear. If the magnitude range is 0.6 there is not a clear reference of the classes on the magnitude axis.

will be improved

Page 21: The singularity of the seismicity rates can be artefacts caused by the conversion of intensity into magnitude and, therefore, there is no need to maintain these singularities.

not “can be”, they are! if we do not respect singularities, we will have empy M classes and fictiously filled M classes (as the reviewer well knows from the PS4 experience, where he took this problem in due care....).

However, G-R branches will take care of it.

Page 22: I am doubtful about the different magnitude steps used (0.24Mw, 0.28 ML).

which kind of doubt ? The explanation is related to the problem above and the fact that the relationships among Mw, Ms and Msp are not linear

Page 22: It is not clear to me the use of depth in the Malagnini attenuation relation. If each SZ has an active layer and this value is used, what does it mean "attribuendo un peso maggiore alle profondità dei terremoti usati per la calibrazione delle relazioni stesse"?

We have defined a layer with a thickness. Then we have adopted one depth value inside the layer. We will be more precise.

Page 22: It is not stated that the hazard maps are with the standard deviation of the attenuation relations used.

yes, they are

Page 23: In the caption of Fig. 19, CO-03.7 should be CO-03.6.

yes, thank you Dario

Page 28: the final considerations refer to the application of the hazard map rather than to the map itself. Comments on pros and cons of the work done would be useful.

Good point, although we were sure receiving enough coments from outside. However, the map is compiled for a very clear purpose, that is, to be used

D. Giardini

<u>*Seismic zone in Northern Sicily*</u>

The Task I report (seismic zones) recognizes the issue of the deformation taking place north of Sicily, but it discards it too quickly in my opinion. Today we know that just north of Palermo is located the largest strain rate of all Italy. GPS and instrumental data confirm this picture. We also know that not all the strain is released seismically, as also observed in other convergent areas in the Mediterranean (only about 20% of convergence is seismic on the Aegean trench). However, two additional elements must be considered:

1. the incompleteness of the historical record of the offshore area; not only it's likely that the mid-size events have gone largely undetected, but large historical events have been mislocated on the coastal area (i.e. 1823); the code used here to treat extended sources is unsuited for off-shore events. The CPTI catalogue does not contain enough seismicity in the area north of Sicily, but this is considered incorrect also in the Task I report.
2. The whole southern Italian region displays strong time-dependent behaviour. For example, the high strain rate in Calabria was recorded in a restricted period of history and Calabria has been very quite since the 1908 event. The possibility that the area north of Sicily behaves in the same way must be considered.

It would be appropriate to conduct hazard tests relocating the historical coastal seismicity on the offshore area, with additional constraints on the activity rate corresponding to a shortening of 2-3 mm/yr, to evaluate the contribution to the hazard in Palermo and Northern Sicily.

we will do something; however, we believe that the present model is more conservative. Actually, earthquakes to be relocated offshore are a few only, the rest being land earthquakes (Madonie type).
We have prepared an instrumental catalogue (30 years) for the offshore area, from which seismicity rates can be computed and used for comparison.
The use of activity rates compatible with geodetical measurements will be for a next phase.
A significant consideration of the strong time-dependent behaviour of many Italian regions is out of the scope of this research.

<u>*Magnitude regressions*</u>

Magnitude conversion relations which do not follow conventional scaling (for example the ML-MW relation) are derived. This could be well justified by the instrumental calibration used in the last 30 years in Italy. However, the data are quite dispersed, and it would be very important to verify the effects of the finiteness and dispersion of the dataset, if it is appropriate to extend the derived regressions to higher magnitudes, if the magnitude definitions correspond to those used in the attenuation relationship (is it the same ML ?) and how would the hazard vary if standard relationships are adopted.

We do not well understand which *standard* relations are referred. ML, Ms and mb are empirical in nature as well as Mw that actually derives from a physical quantity (M_0) but whose scaling have been *arbitrarily chosen* by Hanks and Kanamori ($\Delta\sigma/\mu=0.5\times10^{-4}$). Thus a true physical relation does not exist among them and their relations can only be deduced from the data. We derived such regressions using quite large datasets of corresponding estimates for more than 100 earthquakes occurred in Italy and surrounding regions (see above). The amount of variance explained by the regressions (R^2) is larger than 80% for almost all of them and the magnitude range of earthquakes used for fitting (3.6-6.8 for ML, 3.3-7.0 for Ms, 3.6-6.2 for mb) well covers the magnitude range of significant earthquakes of the area. To reduce the effects of saturation at large magnitudes we limited the validity of Mw-mb relation to mb≤5.5 and we fitted a different (steeper) Mw-Ms regression for Ms≥6.0. We could agree on the last point raised, concerning the basically unknown nature of the scales actually used by attenuation relationships. However the existence of two Wood-Anderson instruments in Italy in the period from 1975 to 1989 (at Trieste and Rome seismic stations) should grant that the most of the ML estimates used by Sabetta and Pugliese coincide with the standard definition and then they are homogeneous with our dataset. On the other hand the regionalized relations by Malagnini and collegues are calibrated on Mw estimates made by waveform inversion that thus should also be homogeneous with our dataset.

<u>Attenuation laws</u>

The adoption of highly variable regional attenuation laws should be treated with utmost care, as it has a profound influence on many aspects of hazard. A few are mentioned here:

1. An important consequence of adopting strongly varying regional attenuation curves is the effect on magnitude scales. There is a compensation effect which needs to be taken into account: in areas with low attenuation, ground motions will be higher than expected from an average attenuation law, and in turn magnitudes will be overestimated when using an average attenuation law (as it is common practice). In the end, the effects of low attenuation and lower magnitudes compensate. It is incorrect to adopt very different attenuation laws without correcting the effects on magnitude. Tests should be carried out to verify the effect of the regional attenuations in southern Sicily and Friuli.

This point seems to largely for the future. Magnitudes have been re-evalutated in this work to the maximum possible extent. The attenuation tomography of intensity data recently published by Gasperini partly respond to this criticism. In general we can agree with this comment. However the local crustal attenuation properties certainly influence ML but only to a lesser extent Mw, Ms and mb that are based on the amplitudes of seismic phases travelling mainly in the mantle.

The reviewer should say whether he believes that regional curves cannot be used at this stage

2. Large differences from a 1/r decay of amplitudes with distance must be justified on clear physical grounds, not only on fit to data (i.e. the effect of crustal reflections in the 70-100 km distance). Some of the regional attenuations used are published, but a comprehensive framework of regional attenuation laws is missing and cannot be patched together by using very local attenuation curves: for example, the high hazard in the Iblean province is due to the adoption with a 40% weight of the regional attenuation derived for Friuli.

Large differences from 1/r always reflect the "filtering" actions due to the crustal structure, and the contribution of the dominant focal mechanism (through systematic effects the radiation patterns). Specifically, since the empirical relationships quantify the apparent crustal attenuation, body-wave-like geometrical spreading must always be observed at short distances, and correspond to direct shear-waves. Cylindrical geometrical spreading, instead, is to be related to well-developed wavetrains of multiply-reflected shear-waves (i.e., observed at large distances). At intermediate distances, where the first supercritical bounces from the Moho interfere with direct-waves, the behavior is not as clear, and a number of phenomena can take place. In the Apennines, a constant geometrical spreading term was invoked, but in the Eastern Alps the crustal structure produced complex apparent attenuation, to be fitted with an effective geometrical spreading stronger than 1/r, which may be due to velocity inversions at depth.
Radiation patterns of the dominant mechanisms may also contribute in affecting the apparent geometric spreading, although horizontal motion is least sensitive to mechanisms. This phenomenon is explained in details in Herrmann and Malagnini (2004).

Herrmann, R.B, and L. Malagnini (2004). Interpretation of high frequency ground motion from regional network observations, BSSA, submitted.

3. The reference rock adopted in the attenuation and hazard is unclear. An EC8 type A rock is mentioned, of 800 m/sec. Is this the average rock value of the strong-motion sites ? A harder rock (1500 m/sec or higher, as observed in the Alps) rock would produce a much smaller hazard. This issue is again tied to the calibration of the attenuation and of the magnitude scales.

Does the reviewer refer to regional or traditional attenuation relationships, or to both ?
The point of harder rock is not new; if the proposed PGA values are higher than expected, we are on the safety side. Local conditions are to be dealt with by the local governments.

Activity rates

A GR or other more complex regularization of the seismicity rate are normally adopted to balance the incompleteness of the historical record and the non-stationarity of seismic activity, which is present in many seismic areas of Italy. Even when moving from the smaller source zones of ZS4 to the larger zones of ZS8 the problem remains, as some areas have always a low seismicity rate.

In our opinion this is mainly valid for low seismicity areas. GR do not overcome the problem. However, we will do something in this direction, with main reference to low seismicity rates areas.

The joint adoption of observed activity rates and of catalogue completeness is contradictory, as it artificially and implicitly imposes physical constraints on the seismicity that are only based on our insufficient record of seismicity.

Disagree. However, what does the reviewer propose?.

A complete presentation is required on the observed activity rates, on the corresponding GR parameters, on the resulting hazard, on the adopted Mmax.

ok

Mariano García-Fernández

<u>*General Comment*</u>

Although the report include all the topics related to the generation of the seismic hazard map, as it should be expected from a summary report, most of them need to be explained in more detail in order to perform a complete review; especially in what regards the expert criteria involved in some of the decisions, e.g. delineation of sources, magnitude homogenisation, completeness analysis, selection of attenuation relationships. This additional information could be provided in form of additional working reports on the specific topics.

we'll do our best. As for magnitude, many details on the procedure followed to homogenize the magnitudes can be found above. Other details can be found in the extended relation.

<u>*Specific comments According to the 'Criteria for the Assessment of the Seismic Zones', included as Annex 1 in the Ordinanza PCM 20 marzo 2003 n.3274*</u>

Criteria c.i)

The methodology used, although not very recent, is of common use to develop seismic hazard maps for building code purposes, so it can be considered as a standard with wide consensus in the international community.
Nevertheless, to follow recent standard practice, the map should be complemented with a minimum reasonable (according to the limited time schedule) level of uncertainty evaluation, including both the input parameters and the calculated hazard values.

ok

Criteria c.ii)

<u>**Sources**</u>

- The possibility of offshore sources, either individual or by extension of inland ones, should be addressed.

ok, we will discuss it. However, the impact onland is practically negligible.

- Definition of background sources should be evaluated, considering the assumption of Mmax=4.9 outside the seismogenic sources identified in the model.

see answer to Slejko

- Seismicity smoothing among sources ('soft' boundaries) could be an option to address location uncertainty, and it should be evaluated.

ok

- It should be clearly explained why some of the defined sources are not used in the calculation, specially those which could influence the hazard because of its seismic activity (e.g. Slovenia).

it is stated: they do not influence hazard! We will prove it

- Check if Mmax could move among sources due to location uncertainty.

source zones ? most probably not. We will do it

- Check if Mmax fault-size fits into the source dimensions.

This is a fudamental aspects of DISS

- An additional zoneless approach could complement the uncertainty analysis. It can be applied either for the whole map or inside the individual sources.

in our opinion it would introduce more uncertainty and reduce the overall hazard distribution. This possibility was discarded from the beginning

<u>Catalogues</u>

- It is not clear how the magnitude homogenisation was carried out and how the conversion errors influence the rate calculation and the estimation of Mmax.

See above

- The completeness approach is not fully explained, and it seems there are expert decisions that should be clarified.

ok

<u>Attenuation</u>

- It should be clarified if the regional relations used correspond to the average soil conditions considered.
-

This is an issue regardless if strong- or weak-motion data are used. About the regional relationships, only rock sites contributed to them. In other words, all sites with preminent effects were excluded from the site constraints and let free to vary. They did not contribute to the results on excitation/attenuation of the ground motion. The fact that weak motion waveforms were used meant that a large number of time history were available. The latter, in turn, meant that the exclusion of weird sites was never a problem. The same is not true for strong-motion data sets, where the available waveforms are few, and we cannot afford to exclude a significan part of them because of the site geology.

- Regional attenuation relationships should be only applied to the regions from where they were developed, and still they should consider all the specific characteristics at this scale, e.g. focal mechanism. Their use in different regions, even if having similar tectonic characteristics, could be dangerous and they might introduce more uncertainty than using standard general relations like Ambraseys et al. (1996).

The problem is there also if the strong-motion relationships are used. With the regionalized relationships we are able to define regions with similar natures. Strong-motion relationships always mix all kinds of observations.

- The comparison to pga records from single individual events should not be the only criteria to select an attenuation relationship.

The reviewer should indicate the alternative.

Criteria c.iii)

At the moment this criteria could not be fulfilled.
we believe that we did more than the common practice around Europe. However, we will improve the situation

Criteria e)

Not yet fulfilled. A restricted distribution to the reviewers could help the review process.
This point was not supposed to be fulfilled BEFORE the publication (see "evaluation main section, too), also because reviewers can ask for changes. Moreover, the international, scientific reviewing procedures does not ask to submit the whole database together with the paper

Criteria f)

The available studies at the same scale, if any, should be submitted to the reviewers, or the references to available published papers provided.

Reference were provided.
The requested material will be on display in Milano, also in order to compare the amount of information provided by each study to the one provided by this study. Slides will also be available

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Zürich, February 4, 2004

Seismic Hazard Map of Italy
Ordinanza PCM 20 marzo 2003, n.3274

Minutes

Evaluation meeting of Working group and Experts Panel

Milano, January 22-23, 2004

Preamble

The national Working Group (WG), under the coordination of Dr. M. Stucchi at INGV, and the Experts Panel nominated by the Commissione Grandi Rischi met in Milano on January 22-23, 2004, to discuss the evaluation of the seismic hazard model and map for Italy.

These Minutes summarize the consensus reached at the meeting between the Experts Panel and the WG, and lists the activities to be carried out by the WG toward the preparation of the final hazard map, for approval at end March 2004. These Minutes do not attempt to report all the discussions which took place during the two-day meeting.

The member of the Experts Panel attending the meeting were: J. Bommer, Imperial College London, M. Garcia-Fernandez, ICTJA-CSIS Barcelona, D. Giardini, ETH Zurich, P. E. Pinto, Università di Roma La Sapienza, D. Slejko, OGS Trieste.

General evaluation

The Experts Panel recognizes the hard work and successful efforts of the WG to meet the recommendations of the Panel expressed in the evaluation document of December 3, 2003, and in particular the decision to adopt more rigorous procedures to assess the uncertainty associated to the hazard assessment. The Experts Panel recognizes the very high scientific and technical value of the new hazard model of Italy, presently the most advanced in Europe.

Both the Experts Panel and the WG agree that the efforts of the WG in the next weeks will be geared to achieve the highest-quality product within the restricted time-schedule established by the Ordinanza PCM 20 marzo 2003, n.3274, whereas a more extended hazard study for Italy is foreseen for the coming years.

A. Source zones

A.1 The definition of characteristic faulting styles and focal mechanisms for all ZS8 seismic sources will be included in the report, as basis for the application of attenuation relationships.

A.2 With the present knowledge of seismicity distribution and attenuation it has proven until now impossible to produce a realistic seismic source model for Northern Sicily which also accounts for the expected ground motion. The WG will conduct additional modeling, with the understanding that the final report will specify that in Northern Sicily an ad-hoc catalogue and source zone model has been produced.

A.3 It is recognized that a few ZS8 source zones cover wider areas than justified on the basis of the existing knowledge of large historical faulting (i.e. Southern Apennines). Additional experiments with soft-boundaries will be performed in selected regions, chosen by the WG.

A.4 Back-ground seismicity with Mmax 4.9 will be introduced for all areas not covered by ZS8.

A.5 A simpler hypocentral depth definition will be adopted. For each ZS8 source zone the reference depth will be computed as the mode or median of the hypocentral distribution. The possible presence of a magnitude dependence in the hypocentral distribution will be checked.

B. Earthquake catalogue and seismicity rates

B.1 The use of a non-standard ML-MW calibration is approved, provided that the consistency of the ML definition across the whole hazard process is verified and documented.

B.2 Taking into account the insufficient data, a standard coefficient 1 will be adopted in the MS-MW regression for MS>6. The consistency of the MS definition across the whole hazard process will be verified and documented.

B.3 The effect of the bi-linear MS magnitude scale on the assessment of GR regressions and activity rates will be checked. A solution could be to estimate the GR regressions in MW.

B.4 A more conservative definition of Mmax is adopted, starting from the integrated seismicity+geology model presented by the WG. The model used for the computation will have a minimum Mmax=6.1 in all active source zones in ZS8 (moving up from the present 5.5 and 5.8 limits) and a Mmax=4.9 for the whole background area. The integrated seismicity+catalogue model will be presented in the report.

B.5 The hazard model will contain two branches with 0.5 weight: GR and activity rates. The activity rates will be restricted to those observed in the catalogue. The GR regressions will be documented. If needed, source zones will be bundled to produce robust b-values. The overall consistency of the seismicity modeled with GR or activity rates will be verified and documented, with special attention to holes in the frequency-magnitude distributions.

B.6 The hazard model will contain two branches reflecting the historical and statistical estimates of catalogue completeness. Weights will be established by the WG and may be different for different regions of Italy, if warranted by the data.

B.7 The effect on b-value computation induced by a possibly too conservative completeness estimation will be tested for the Calabria region.

C. Attenuation

C.1 A single logic tree for the whole ZS8 with four branches will be used, with the following weights: 0.33 Ambraseys et al 1996 (with corrections for style-of-faulting after Bommer et al 2003), 0.33 Sabetta & Pugliese 1996 (with corrections for style-of-faulting after Bommer et al 2003), 0.34 regional attenuation relationships of Malagnini et al. The application of a regionalized logic tree with higher weights for the regional attenuation relationships in the calibrated regions has been discussed and remains an option for the WG.

C.2 The conversion functions from epicentral central distance to fault distance for the application of Ambraseys et al 1994 attenuation relationship have been approved.

C.3 In the use of the regional attenuation relationships of Malagnini et al, the trade-off of the anomalous attenuation on the calibration of local magnitudes will be verified and documented.

D. Hazard computation

D.1 A full logic tree formulation will be used. The WG will evaluate how to display in a single map the information about the spatially varying uncertainty.

D.2 It is agreed that the “smoothed seismicity” approach will not be introduced as a specific branch in the logic tree, but it will be used to test the validity of the hazard model, as presented in the first report. The final report should include a description of these validation tests.

Future activities

The WG will produce its final hazard and report by early-mid March, to be distributed to the Commissione Grandi Rischi and to the Experts Panel by March 20. The final evaluation meeting is scheduled in Roma for March 29-30.

Milano, February 17, 2004

Dear Domenico and colleagues,
thank you for your document and the nice words about our work. We made some progress and we want to report it, and to keep in touch with you before the end of the work. Also, tanks for the assistance you are providing on the way. Below you find our notes and issues. We will be grateful of receiving unanimous comments.
Best regards

Max Stucchi

Answers and comments are inserted at the relevant place (red, bold, right aligned)

Minutes

Evaluation meeting of Working group and Experts Panel

Milano, January 22-23, 2004

Preamble

General evaluation

A. Source zones

A.1 The definition of characteristic faulting styles and focal mechanisms for all ZS8 seismic sources will be included in the report, as basis for the application of attenuation relationships.

dones: see ppt

A.2 With the present knowledge of seismicity distribution and attenuation it has proven until now impossible to produce a realistic seismic source model for Northern Sicily which also accounts for the expected ground motion. The WG will conduct additional modeling, with the understanding that the final report will specify that in Northern Sicily an ad-hoc catalogue and source zone model has been produced.

we found the last statement too severe. We will demonstrate that the adopted solution (both ZS and catalogue) is the most conservative with respect to present knowledge and to hazard computation. still in progress

A.3 It is recognized that a few ZS8 source zones cover wider areas than justified on the basis of the existing knowledge of large historical faulting (i.e. Southern Apennines). Additional experiments with soft-boundaries will be performed in selected regions, chosen by the WG.

Some changes were introduced according to these requests, so that we have now a new zonation ZS9 : see ppt. Tests with soft boundaries are in progress

A.4 Back-ground seismicity with Mmax 4.9 will be introduced for all areas not covered by ZS8.

ok. As a result of the shift to Mw aa "prime magnitude", Mwmax for background is now 5.2Mw, which corresponds to Ms4.9

A.5 A simpler hypocentral depth definition will be adopted. For each ZS8 source zone the reference depth will be computed as the mode or median of the hypocentral distribution. The possible presence of a magnitude dependence in the hypocentral distribution will be checked.

done, see ppt. Please, remember that two sets of depth will be used in the two regional attenuation branches (see C.1). The considerations above apply to the second one (B)

B. Earthquake catalogue and seismicity rates

B.1 The use of a non-standard ML-MW calibration is approved, provided that the consistency of the ML definition across the whole hazard process is verified and documented.

in progress

B.2 Taking into account the insufficient data, a standard coefficient 1 will be adopted in the MS-MW regression for MS>6. The consistency of the MS definition across the whole hazard process will be verified and documented.

done: will be explained

B.3 The effect of the bi-linear MS magnitude scale on the assessment of GR regressions and activity rates will be checked. A solution could be to estimate the GR regressions in MW.

in progress

B.4 A more conservative definition of Mmax is adopted, starting from the integrated seismicity+geology model presented by the WG. The model used for the computation will have a minimum Mmax=6.1 in all active source zones in ZS8 (moving up from the present 5.5 and 5.8 limits) and a Mmax=4.9 for the whole background area. The integrated seismicity+catalogue model will be presented in the report.

we will adopt two sets of Mmax, both conservative but different for activity rates and GR (see ppt) For activity rates Mmax will be increased: a) to match geological data; ii) by one Mw class when Mwmax in the catalogue is larger than the centre of the corresponding class; iii) by two classe for ZS Northern Sicily.

For GR the recommendatons of the panel will be adopted

B.5 The hazard model will contain two branches with 0.5 weight: GR and activity rates. The activity rates will be restricted to those observed in the catalogue. The GR regressions will be documented. If needed, source zones will be bundled to produce robust b-values. The overall consistency of the seismicity modeled with GR or activity rates will be verified and documented, with special attention to holes in the frequency-magnitude distributions.

in progress

B.6 The hazard model will contain two branches reflecting the historical and statistical estimates of catalogue completeness. Weights will be established by the WG and may be different for different regions of Italy, if warranted by the data.

the proposed solution is 0.6 to 0.4

B.7 The effect on b-value computation induced by a possibly too conservative completeness estimation will be tested for the Calabria region.

will be tested

C. Attenuation

C.1 A single logic tree for the whole ZS8 with four branches will be used, with the following weights: 0.33 Ambraseys et al 1996 (with corrections for style-of-faulting after Bommer et al 2003), 0.33 Sabetta & Pugliese 1996 (with corrections for style-of-faulting after Bommer et al 2003), 0.34 regional attenuation relationships of Malagnini et al. The application of a regionalized logic tree with higher weights for the regional attenuation relationships in the calibrated regions has been discussed and remains an option for the WG.

remember that two branches (with total weight 0.34) will consider two sets of depth and two regional zonings, as proposed in Milano (see ppt). We will not use a regionalised logic tree.

C.2 The conversion functions from epicentral central distance to fault distance for the application of Ambraseys et al 1994 attenuation relationship have been approved.

adopted. An explanation is found in the ppt

C.3 In the use of the regional attenuation relationships of Malagnini et al, the trade-off of the anomalous attenuation on the calibration of local magnitudes will be verified and documented.

in progress

D. Hazard computation

D.1 A full logic tree formulation will be used. The WG will evaluate how to display in a single map the information about the spatially varying uncertainty.

see ppt

D.2 It is agreed that the "smoothed seismicity" approach will not be introduced as a specific branch in the logic tree, but it will be used to test the validity of the hazard model, as presented in the first report. The final report should include a description of these validation tests.

please, be more explicit. What else or more with respect to the first report?

Future activities

The WG will produce its final hazard and report by early-mid March, to be distributed to the Commissione Grandi Rischi and to the Experts Panel by March 20. The final evaluation meeting is scheduled in Roma for March 29-30.

ok