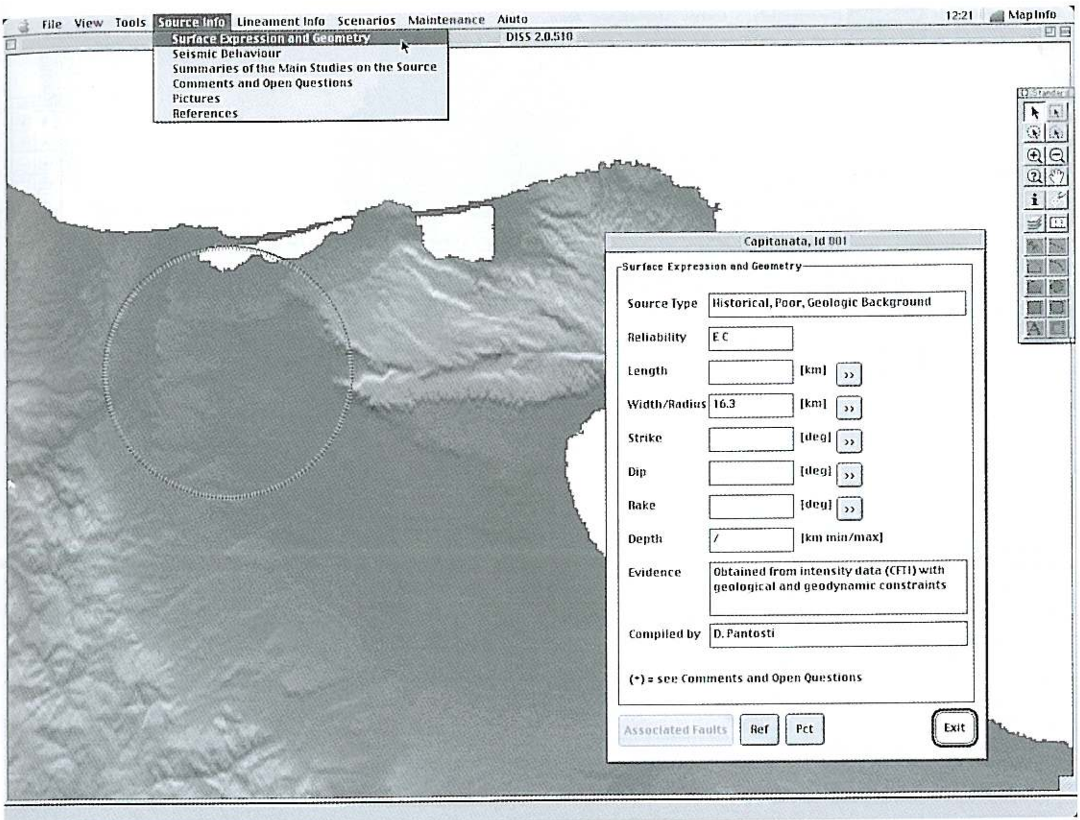


**Fig. 3.24.** *Capitanata* source, ID 801. The window in the foreground shows the data about the *Surface Expression and Geometry* of this source.

historical data with geological background. An example (fig. 3.24) of this type of sources is the *Capitanata* source (ID 801) located in the Gargano promontory, Central Italy. This source is represented by a circle whose radius equals the half-length obtained from length *versus* magnitude empirical relationships. Therefore, unlike rectangle-shaped sources, the area of circle-shaped sources is not proportional to the correlative earthquake magnitude. This means that the source might extend for its entire length in any direction. For this type of sources the first reliability qualifier is always E (see also § 2.2.3.2. for details on reliability rating criteria).

### 3.3.2.3. Sources derived exclusively from well constrained and from poorly constrained historical data

This section presents an overview of the *Calabria (1783, Mar 28)* source (ID 258), located in the Calabrian Arc, Southern Italy.

The basic information on the source is given in the *Surface Expression and Geometry* window, which first reminds the user that the source is one of those derived from good historical data. The

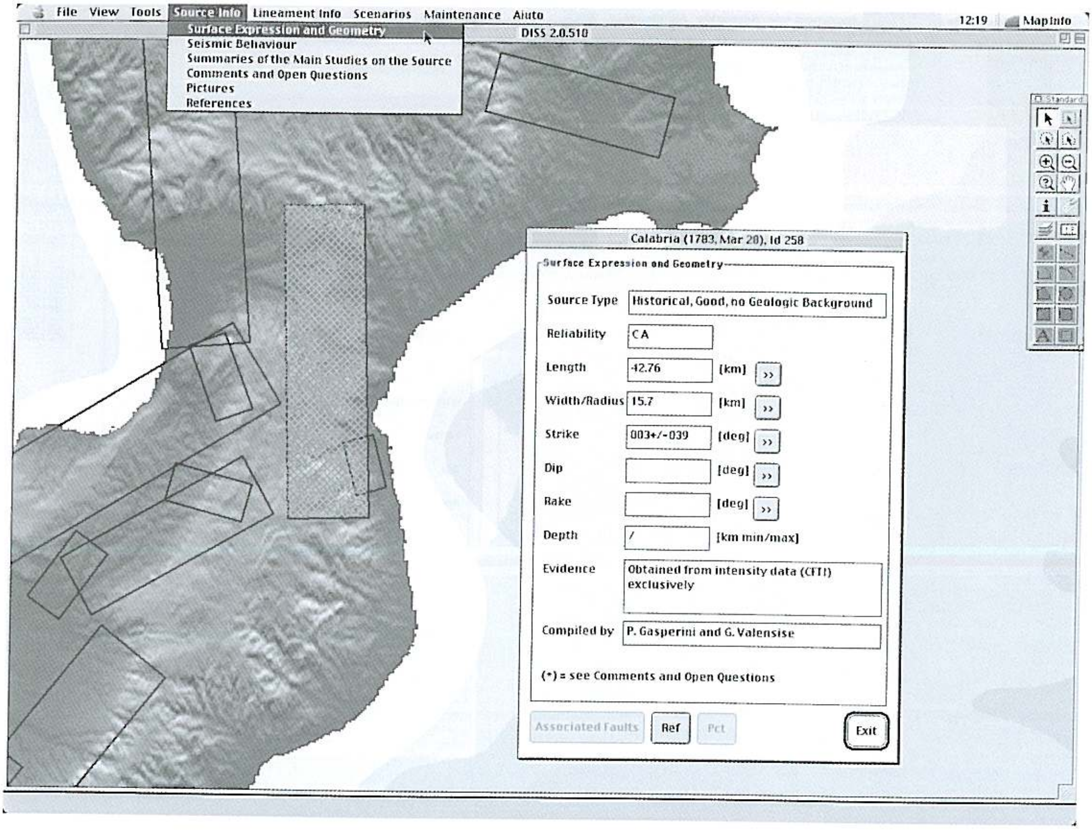


**Fig. 3.25.** *Calabria (1783, Mar 28)* source, ID 258. The window in the foreground shows the data about the *Surface Expression and Geometry* of this source.

source is represented by an oriented rectangle whose orientation and size were derived from intensity data, following the approach by Gasperini *et al.* (1999). No additional geological information exists for this type of sources. As stated in the *Database* record shown in fig. 3.25, the location, geometry and size of the fault were *"Obtained from intensity data (CFTI) exclusively"*. The user is then invited to make his/her own inferences if further characterisation of the source is required.

This source belongs to a category of earthquake sources that have not yet been studied by the compilers of the *Database* from the geological/geophysical point of view. Only the automatic solution is thus available. This may either be the result of poor documentation about the correlative earthquake, or of the poor geological/geophysical documentation available for the area. However, further studies may succeed in retrieving an adequate amount of published information, such as summaries, comments, pictures and/or original data, such that the source might be upgraded to one of the categories presented above.

The source reliability is C-A, which indicates conventionally that the uncertainty of the source orientation is between 25° and 49° and that more that 500 intensity data points were available in the adopted historical catalogue (CFTI in this case) for the associated earthquake (see also § 2.2.3.2. for details on reliability rating criteria). The source size is quite big (length 42.76 km, width 15.70 km), which implies that a relatively large earthquake is associated with it because these dimensions are

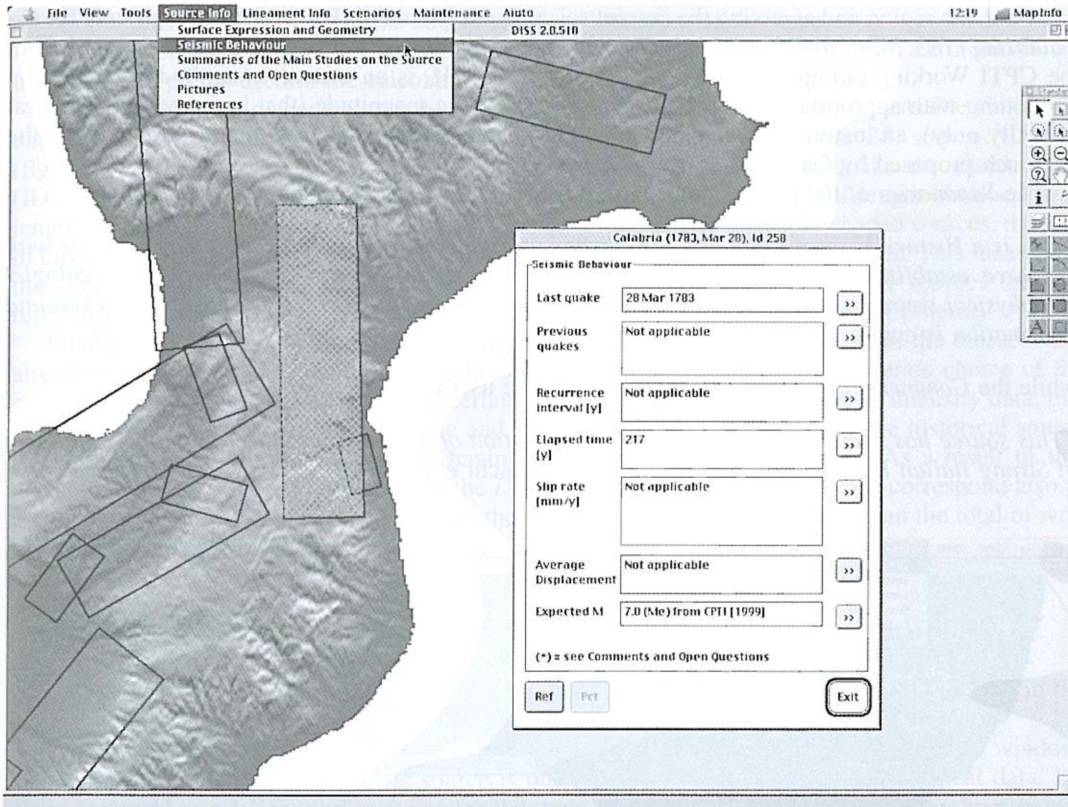


**Fig. 3.26.** *Calabria (1783, Mar 28)* source, ID 258. The window in the foreground shows the data on the *Seismic Behaviour* of this source.

obtained from empirical relationships of magnitude *versus* length/width. This may also partly explain why the earthquake was felt at over 500 localities. Even though the Calabrian Arc recorded several large earthquake in the historical past, the user is advised to look carefully at the information provided in the historical earthquake catalogues before any further inference based on source size.

Source strike is 003° ± 039°. It may be noticed that the strike accuracy is rather low. This may depend on the particular configuration of Calabria, a narrow strip of land with a quite inhomogeneous distribution of villages with respect to mountains and plains. However, a roughly N-S running fault represents a reasonable hypothesis considering the trend of the Calabrian Arc at this latitude.

Finally, notice that for this type of sources no geological data are provided in the *Database*; therefore no information can be supplied concerning the dip, rake, and depth of the earthquake causative fault.

The *Seismic Behaviour* window informs that the *Calabria (1783, Mar 28)* source is correlated with the 28 March 1783 earthquake (fig. 3.26). Although 217 years have elapsed since 1783, this source is not to likely to generate a new large earthquake soon if one considers that the average recurrence interval of large Italian earthquake sources is generally longer than a millennium. However, the correct characterisation of a source like this is fundamental for understanding the modes of seismic release in the region and assessing the current seismogenic potential. The expected magnitude for the *Calabria (1783, Mar 28)* source is $M_a$ 6.9, which corresponds to the estimated magnitude taken from the CPTI Working Group (1999) catalogue. Notice that $M_a$ is an average magnitude obtained by combining with appropriate weights a purely macroseismic magnitude (that is, based on epicentral intensity only), an instrumental magnitude and a magnitude obtained from intensity data using the approach proposed by Gasperini *et al.* (1999).

The *Summaries of the Main Studies on the Source* inform the user that

*"This is a Historical source that was established using intensity data only, but it may coincide with a source established from Geologic/Geophysical data. If this is the case, check the Geologic/Geophysical source for information on any Previous Studies. If this is not the case, no background information is available."*

while the *Comments and Open Questions* remind the user that

*"This source has been obtained through the elaboration of intensity data taken from the Catalogue of Strong Italian Earthquakes, 461 b.C. to 1997 (*Boschi *et al.*, 2000*)."*

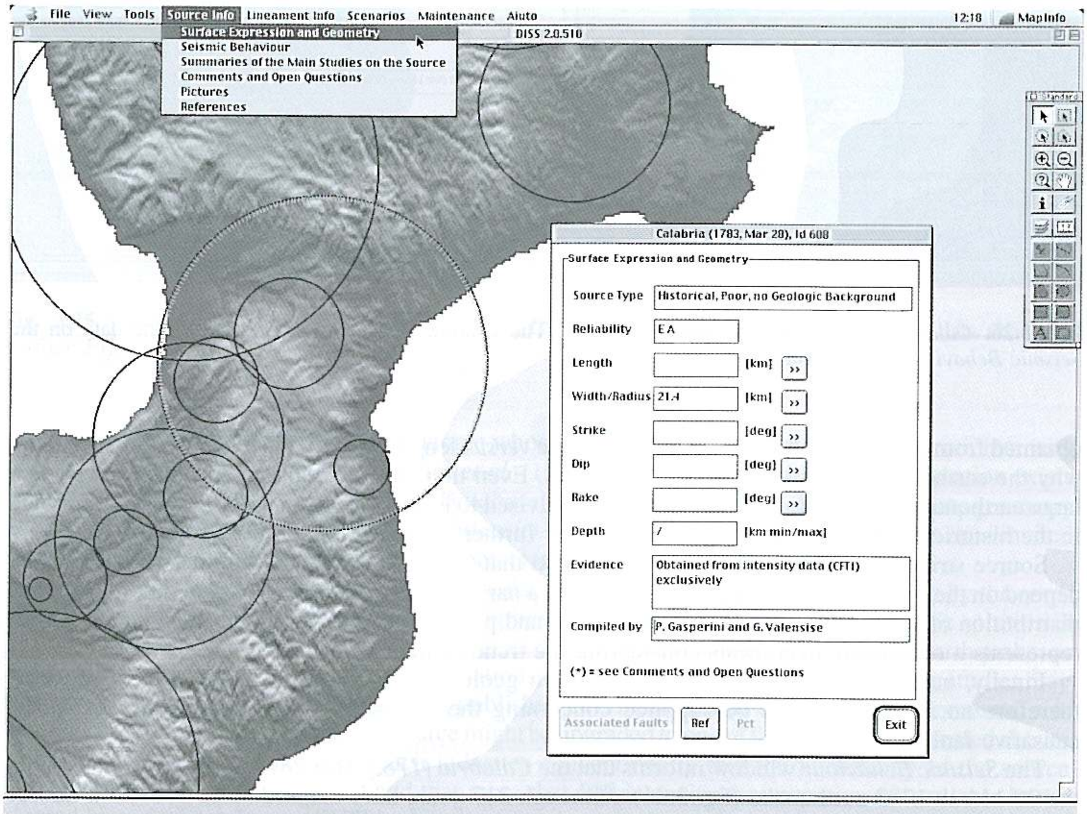


**Fig. 3.27.** *Calabria (1783, Mar 28)* source, ID 608. The window in the foreground shows the data about the *Surface Expression and Geometry* of this source.

No *Pictures* are provided for this source and for all sources of this type.

The *References* inform from which of the available catalogues of historical earthquakes the intensity data points used in the calculation of the automatic solution were taken.

A similar information content may be found for sources derived from poorly constrained historical data exclusively. An example of this source type is the *Calabria (1783, Mar 28)* source (ID 608) (fig. 3.27), which is the lower-quality source corresponding to the earthquake discussed above (ID 258). This source is represented by a circle whose radius equals the half-length obtained from length *versus* magnitude empirical relationships. Therefore, unlike rectangle-shaped sources, the area of circle-shaped sources is not proportional to the correlative earthquake magnitude. This means that the source might extend for its entire length in any direction. For this type of sources the first reliability qualifier is always E (see also § 2.2.3.2. for details on reliability rating criteria).

Finally, notice that obtaining a poor-quality (circular) historical source from all the datasets that already permitted the calculation of a higher-quality historical source is a deliberate choice of the compilers of the *Database*. Given the uncertainties involved in the elaboration of intensity data, this choice allows the user to retain the basic and most reliable information about the historical source (location and size) without necessarily having to trust its hypothesised strike. As a result of this decision, many sources are duplicated in the *Database* (or even triplicated if they correspond also to a *Geologic/Geophysical* source), and hence their total number is much smaller than the total of well constrained plus poorly constrained sources.

### 3.3.2.4. Sources derived from historical data suspected to be deeper than usual

This section presents an overview of the *Cagliese (1781, Jun 03)* source (ID 901) located in the Northern Apennines, Central Italy.

The basic information on the source is given in the *Surface Expression and Geometry* window, which first reminds the user that the source is one of those derived from good historical data. No additional geological information exists for this type of sources. As stated in the *Database* record shown in fig. 3.28, the location, geometry and size of the fault were *"Obtained from intensity data (DOM) exclusively"*. This is to remark that only intensity data were used to shape the source as it appears in the map, following the approach by the Gasperini *et al.* (1999). The user is then invited to make his/her own inferences if further characterisation of the source is required.

This source belongs to a category of earthquake sources that have not yet been studied by the compilers of the *Database* from the geological/geophysical point of view. Only the automatic solution is thus available. This may either be the result of poor documentation about the correlative earthquake, or of the poor geological/geophysical documentation available for the area. However, after a visual inspection of the distribution of intensity datapoints and having considered the geodynamic framework of the area, the compiler concluded that the correlative earthquake may have been generated by a source which is deeper than the usual depth at which the largest earthquake of the region occur. If this interpretation holds true, there are very little chances that further geological studies, at least those that concern surface geology, will provide enough information to upgrade the source to one of the categories presented above.

The *Seismic Behaviour* window informs that the *Cagliese (1781, Jun 03)* source is correlated with the 3 June 1781 earthquake (fig. 3.29). In the case of a deeper source such as that responsible for the 1781 earthquake, the standard recurrence models adopted for shallower sources are not likely to apply. This is due to the fact that, in general, the deeper the source the less the level of knowledge about the physical structure that governs the occurrence of earthquakes. Therefore, nothing can be safely said about the possible repetitions of *Cagliese*-like earthquakes, the predictability of which is further complicated by their limited magnitude. Nevertheless, the identification and characterisation

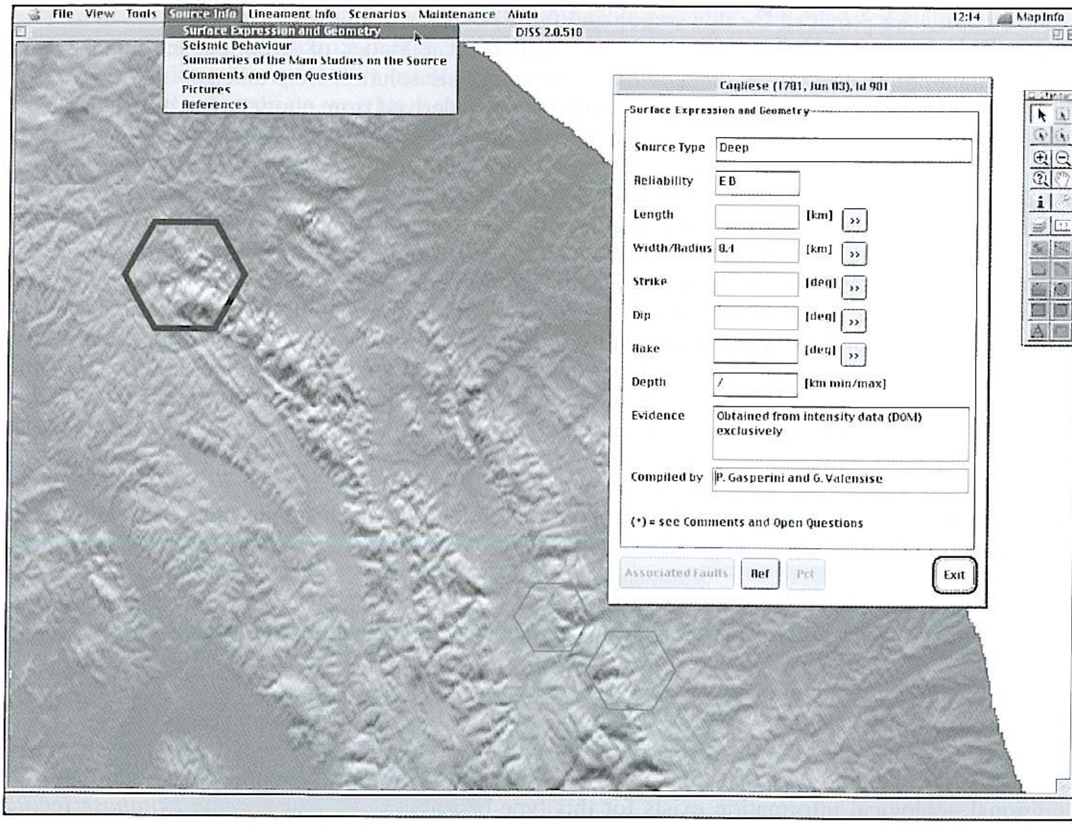


**Fig. 3.28.** *Cagliese (1781, Jun 03)* source, ID 901. The window in the foreground shows the data about the *Surface Expression and Geometry* of this source.

of these sources is fundamental to understand the seismogenic potential of the region provided that a satisfactory geodynamic framework is adopted.

The expected magnitude for the *Cagliese (1781, Jun 03)* source is $M_a$ 6.2, which corresponds to the estimated magnitude taken from the CPTI Working Group (1999) catalogue. Notice that $M_a$ is an average magnitude obtained by combining with appropriate weights a purely macroseismic magnitude (that is, based on epicentral intensity only), an instrumental magnitude and a magnitude obtained from intensity data using the approach proposed by Gasperini *et al.* (1999). Since the area over which a deep earthquake is felt is generally larger than that of a shallow earthquake, the magnitude estimation for this type of earthquake-derived sources should be considered less accurate than that obtained for other events.

Similarly to the previous case, the *Summaries of the Main Studies on the Source* inform the user that

*"This is a Historical source that was established using intensity data only, but it may coincide with a source established from Geologic/Geophysical data. If this is the case, check the Geologic/ Geophysical source for information on any Previous Studies. If this is not the case, no background information is available".*

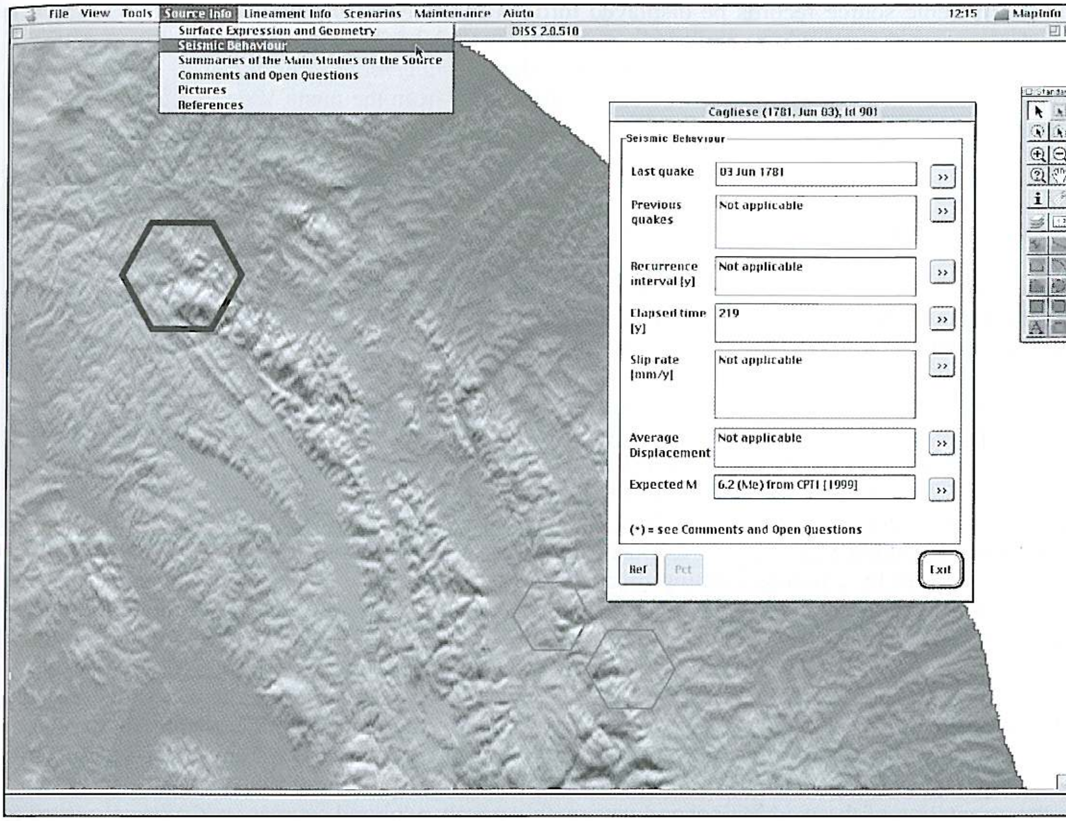


**Fig. 3.29.** *Cagliese (1781, Jun 03)* source, ID 901. The window in the foreground shows the data on the *Seismic Behaviour* of this source.

while the *Comments and Open Questions* remind the user that

*"This source has been obtained through the elaboration of intensity data taken from the Database Osservazioni Macrosismiche (DOM), version 4.1* (Monachesi and Stucchi, 1997)".

No *Pictures* are available for this source and all the sources of this type.

Finally, the *References* inform from which of the available catalogues of historical earthquakes the intensity data points used in the calculation of the automatic solution were taken.

### 3.3.3. Making the seismogenic source records interact with the other data stored in the *Database*

This section describes some of the several ways of exploring how the *Database* records interact with each other and how a seismogenic source can be investigated in the light of the other data stored in the *Database*. A few examples will be illustrated below to suggest the user how to use all the possibilities offered by the relational structure of the *Database* and by its tools. It is recommended that the seismogenic source records be displayed through the *Integrated Source Dataset* (§ 3.2.3.14.), which represent the compilers' preferred set of sources (§ 2.2.3.7.), although the user may prefer to view one or more of the layers available under the *Seismogenic Source* menu (§ 3.2.3.14.). All complementary data can be retrieved by displaying a layer from the menu *View* (§ 3.2.3.) and/or the menu *Scenario* (§ 3.2.7.).

### 3.3.3.1. Relationships among adjacent seismogenic sources

Individual seismogenic sources derived from geological and/or geophysical investigations are usually incorporated into the *Database* by different compilers. Although there could be a tendency for the same compiler to take care of the records of more than one source falling within the same region, the possible relations between neighbouring sources may not have been explicitly treated in the *Database* records. The practice of exploring these possible relations is left to the user.

An example that may focus attention onto such practice is represented by the *Boiano Basin* (ID 4), *Tammaro Basin* (ID 5), and *Ufita Valley* (ID 6) seismogenic sources, located in the Southern Apennines (fig. 3.30). These three sources align along the NW-SE direction, dip toward the northeast and are rather regularly spaced. All three sources have about the same size, suggesting that an earthquake of similar size could be associated with each one of them. In addition, all three sources are characterised by a normal faulting mechanism. All in all, these characteristics suggest that the three sources belong to the same regularly segmented fault system. It is also worth noticing that all three sources have produced a large earthquake in historical times, respectively (North to South) on 26 July 1805 ($M_a$ 6.6), on 6 May 1688 ($M_a$ 6.7), and on 29 November 1732 ($M_a$ 6.6).

The inspection of the relations among different seismogenic sources opens the way for addressing important questions that would not be stimulated by the investigation of a single source, such as: does this fault system extend further toward the northeast and southwest? Does any other seismogenic source of any category exist in the vicinity? If the answer to any of these two questions is Yes, what is the orientation of these additional and presumably poorly explored sources (with special regard to those derived from historical data)? A direct consequence of answering these questions is the identification of a large area subjected to the same tectonic process that has been able to build a coherent geological structure through time. Similar observations may help preparing the grounds for substantial improvement in understanding unexplored sources as soon as knowledge progresses for any of the better known sources that fall in the region under inspection.

### 3.3.3.2. Relationships between a seismogenic source and the tectonic setting of its environs

The previous section described the possible interrelations among adjacent seismogenic sources. When a seismogenic source is established, either on the basis of geological and geophysical data or using earthquake intensity data, all the available information about its characterisation is included and commented in its exclusive record in the *Database*. Significant inferences can then be made simply by comparing the spatial properties of adjacent sources. However, new insight about any seismogenic source may come from observations made at a larger scale than that at which an individual source is represented. These observations might not necessarily be mentioned in the source record. This section will briefly elucidate this concept through a few examples.

A stimulating and informative way of acquiring the maximum possible knowledge from the *Database* is to have a specific seismogenic source plotted against a map or georeferenced table that was prepared outside the framework and objectives of the *Database* itself. The map or the data are

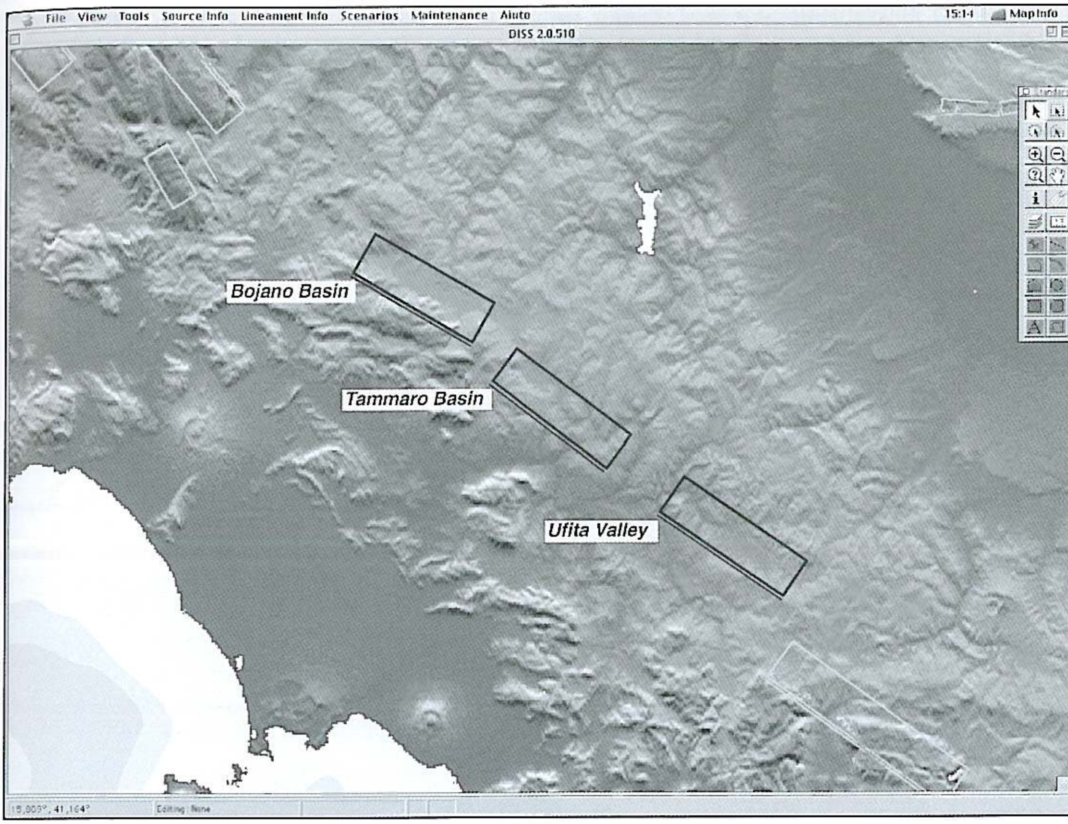


**Fig. 3.30.** *Boiano Basin*, ID 4, *Tammaro Basin*, ID 5, and *Ufita Valley*, ID 6, sources (from North to South) and their spatial relationships.

normally taken from the literature in the form of a *Previous Fault Compilation* (§ 2.2.5.2.3. and 3.2.3.10.), but may also have been added by the compilers as a layer of *Additional Geophysical/ Seismological Data* (§ 2.2.5.2.4.). To get a more complete picture, one or more of the other available layers under the menu *View* may be added to the overlay at the user's convenience, the only limitation being the readability of the final map. This exercise may suggest answers to several compelling questions, from the most obvious to the most stimulating ones, such as: had the seismogenic source under inspection ever been identified/mapped by other investigators? If so, does the faults/source look about the same? If not, why? Do other faults/sources exist in the region surrounding the seismogenic source at hand, which are not included in the *Database*? What are the spatial relationships between a specific source and the local topography/drainage/water divide? How far/close does a specific recent earthquake fall from the closest seismogenic source? Clearly, given the number of informative layers supplied with the *Database* and given the possibility of plotting along new data as they become available (*e.g.*, a new earthquake sequence), the number of possible questions is clearly limited only by the user's imagination.

A map produced following this reasoning is shown in fig. 3.31. The *Fucino Basin* seismogenic source, ID 2, along with its own *Associated Faults*, is plotted against a cropped section of the

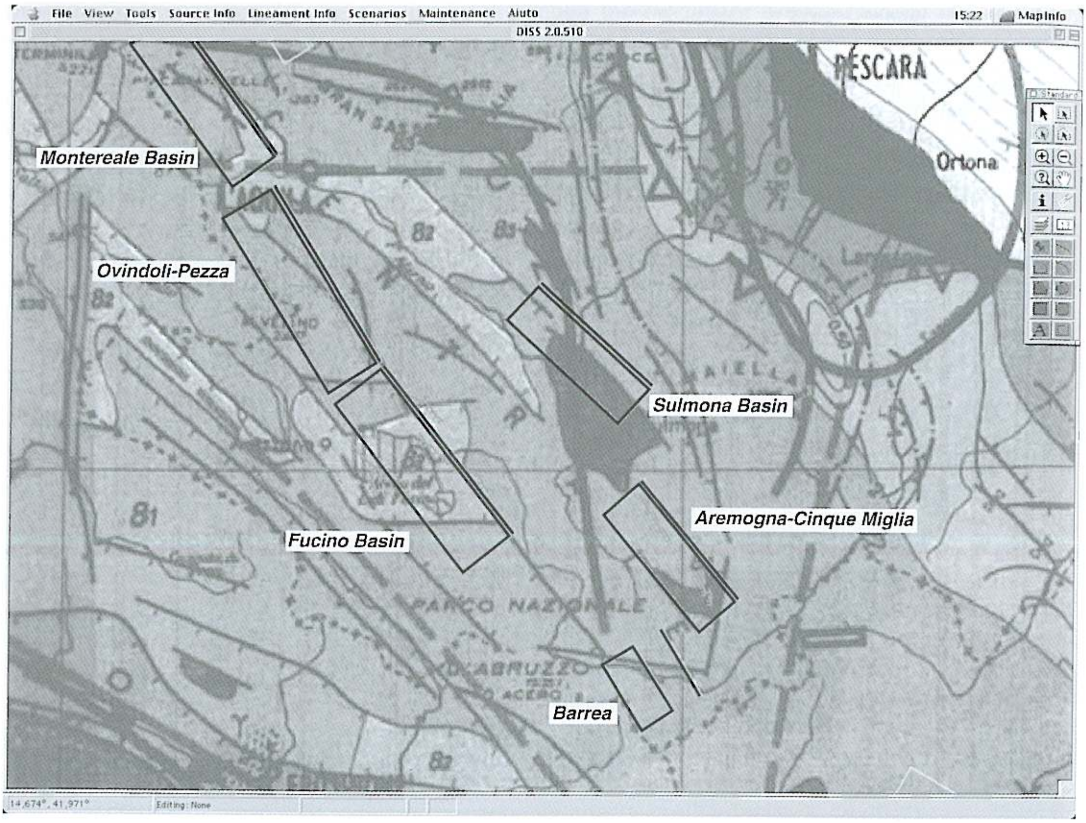


**Fig. 3.31.** *Fucino Basin* source, ID 2, plotted over the Neotectonic Map of Italy (Ambrosetti *et al.*, 1987).

Neotectonic Map of Italy at the scale 1:1 500 000 (Ambrosetti *et al.*, 1987) (the grey scale geocoded bitmap in the background), representing a large portion of the Central Apennines. At least three main differences can be readily noticed:

**a.** the *Database* and the Neotectonic Map use a substantially different strategy of representation of the tectonic structures; only the cut-off line of faults is represented in the Neotectonic Map, while the sources derived from geological/geophysical data feature a fully tri-dimensional representation. The Neotectonic Map delineates a general trend of normal faulting that extends along the eastern margin of the Fucino Plain and beyond, while the *Database* proposes that this trend is segmented and hence that two singularities occur along the main extensional trend near Celano and near Gioia dei Marsi, respectively at the northern and southern end of the basin;

**b.** a large portion of the surface breaks (red hachured line) generated by the 1915 earthquake and mapped in the *Database* following Galadini and Galli (1999) was not mapped in the earlier compilation. Conversely, Ambrosetti *et al.*'s (1987) map displays a number of faults that lie off the *Fucino Basin* source and that often exhibit an orientation that is substantially different from that of the main active structures;

**c.** the overall area of influence of the *Fucino Basin* source does not coincide with the structural delineation of the Fucino Plain offered by the Neotectonic Map. In particular, the source affects a mountainous area southeast of Fucino and at the same time does not explain the existence of the northeastern corner of the basin, which falls in the footwall of the large normal faults that comprises the *Fucino Basin* source. This discrepancy between the geological structure and the most active tectonic features can probably be explained by the complexity of the tectonic history of the basin in contrast with the young age of inception of the currently active faults.

### 3.3.3.3. Relationships between a seismogenic source and its associated earthquake

All seismogenic sources derived from earthquake intensity data exclusively (§ 2.2.3.2.-2.2.3.6.) are necessarily correlated with a large earthquake of the past. This means that all source parameters (location, size, orientation) reflect the seismological properties of that particular event. In contrast, seismogenic sources derived from geological and/or geophysical data (§ 2.2.3.1.) may be correlated

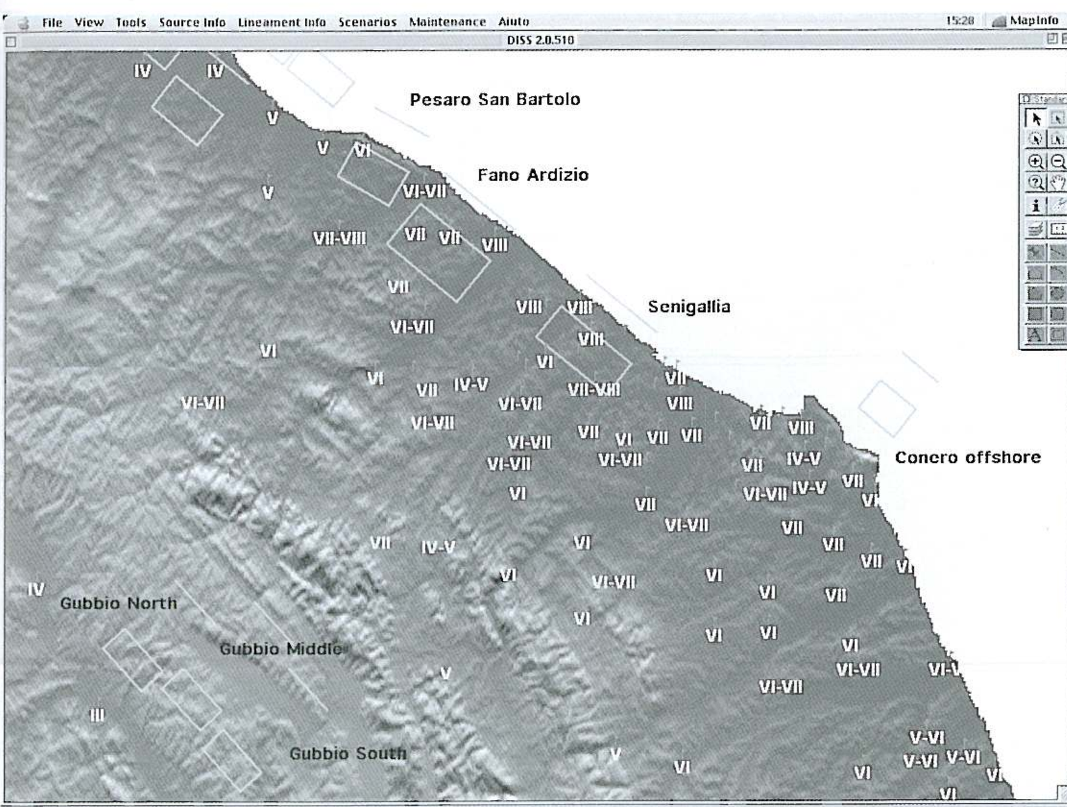


**Fig. 3.32.** *Senigallia* source, ID 30, and intensity distribution of the 30 October 1930 Marche Settentrionali earthquake (data from CFTI3, Boschi *et al.*, 2000).

with an earthquake that occurred in the past and that is well recorded in historical or instrumental catalogues, but may also be correlated only with a hypothetical earthquake. Therefore, the parameters of sources of this category (location, size, orientation, behaviour) may either reflect the seismological properties of a real earthquake or be suggestive of the seismogenic potential of a structure the activity of which has not yet left a historical record.

It has already been illustrated that the tools of the *Database* not only allow the intensity data points of any earthquake listed in the CFTI3 (Boschi *et al.*, 2000) and NT (Camassi and Stucchi, 1997) catalogues to be plotted (§ 3.2.3.9.), but also allow scenarios of hypothetical earthquakes to be calculated and displayed (§ 3.2.7.). The example below illustrates the case of two adjacent sources and their correlative earthquakes. The first source is *Senigallia*, ID 30, correlated with the 30 October 1930, Marche Settentrionali earthquake. The second source is *Fano Ardizio*, ID 31, for which no historical earthquake exists.

Figure 3.32 displays the *Felt Reports* (§ 3.2.3.9.), that is to say, the recorded intensity data points taken from the CFTI3 earthquake catalogue (Boschi *et al.*, 2000) for the 1930 earthquake. Localities within 10 km of the earthquake epicentre recorded intensities up to VII-VIII. Intensities VI and lower are seen systematically at epicentral distance larger than 30-40 km, but a few intensity VIII datapoints

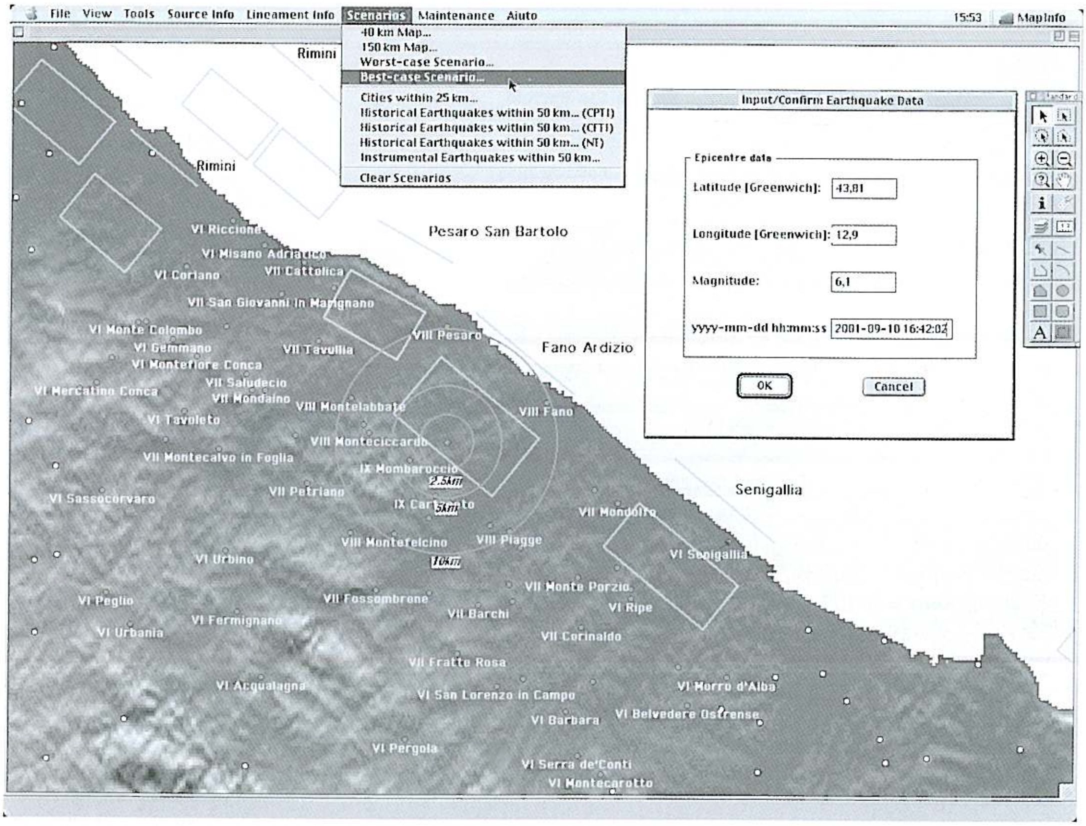


**Fig. 3.33.** *Fano-Ardizio* source, ID 31, and the *Best-case Scenario...* calculated for the largest hypothesised earthquake associated with it.

lie at less than 25 km distance. Notice that intensity decreases more rapidly along the direction orthogonal to the coastline.

Figure 3.33 displays the *Best-case Scenario...* (§ 3.2.7.4.) for an earthquake whose location (Latitude North 43.81°; Longitude East 12.90°) and magnitude ($M_w$ 6.1) are compatible with the full activation of the *Fano Ardizio* seismogenic source. The epicentre is located at mid-length directly above the lower fault-edge. The magnitude equals the expected value reported in the *Seismic Behaviour* window for this source. The map shows that in case of such an earthquake cities within 10 km of the epicentre would suffer a level of damage up to intensity VIII-IX. Intensity VI would be recorded at distances of 25 km to 35 km. This scenario looks somewhat worse than the actual distribution of intensities observed following the 1930 earthquake in Senigallia. This is mainly due to the higher magnitude used for the scenario ($M_w$ 6.1) compared to the magnitude observed in 1930 ($M_a$ 5.9). It is also worth noticing that the intensity distribution shown in the scenario is generally much more regular than that of the actual earthquake. This is a result of the simplified attenuation law used for generating the scenarios, which assumes circular decay of intensity and does not take into account possible local amplification/attenuation effects resulting from the local geology, from earthquake directivity, or from the geometry and kinematics of the source.

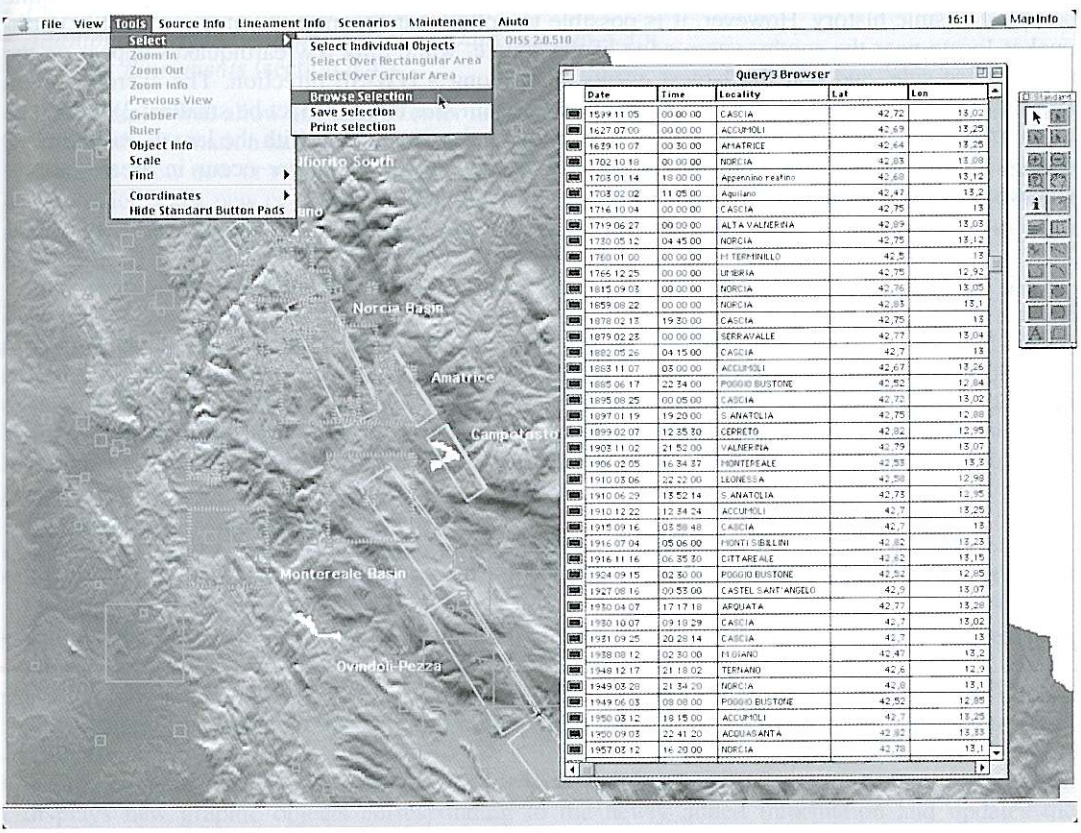


**Fig. 3.34.** *Norcia Basin* source, ID 16, and the historical earthquakes that occurred in its surroundings according to the CPTI catalogue (*CPTI Working Group*, 1999).

### 3.3.3.4. Relationships between a seismogenic source and other earthquakes in the surroundings

Every seismogenic source in the *Database* is associated with an earthquake that already occurred or is likely to occur. Conversely, not all known earthquakes of magnitude larger than 5.5 have been assigned to an identified and fully characterised seismogenic source. A comprehensive analysis of any earthquake-prone area would require not only the identification of all potential sources of large earthquakes, but also an evaluation of the main characteristics of the minor seismicity.

The *Database* offers an opportunity to explore in a very easy and effective way the relationships between the largest earthquake associated with a given seismogenic source and the other major/minor earthquakes in its surroundings. This task can be accomplished by generating an overlay of a catalogue of historical earthquakes (§ 3.2.3.8.) and of one of the layers containing seismogenic source (§ 3.2.3.14.).

Figure 3.34 shows an overlay created by displaying the historical earthquakes contained in the *Catalogo Parametrico dei Terremoti Italiani* (CPTI Working Group, 1999) and the seismogenic sources of the category *From Geologic/Geophysical Data*. The figure focuses on the Central Apennines. The *Norcia Basin* source, ID 16, is associated with the 14 January 1703 earthquake, but over 50 generally smaller historical earthquakes may be counted within a distance of 20 km from the source centre. This suggests that the region where the *Norcia Basin* source is located has a quite complex seismic history. However, it is possible to notice that the majority of these smaller earthquakes locate near the southwestern edge of the source, while only few earthquakes appear on the northeastern side, and that the largest events align along a NW-SE direction. The exercise might suggest: 1) that sources that have been assigned a certain size might in fact be smaller; 2) that some of the minor seismicity might occur next to the slip patches associated with the largest earthquakes, and 3) that some of the seismogenic sources presented in the *Database* occur in areas that are characterised by a more complex structure than presently hypothesised.