Italy’s Database of Individual Seismogenic Sources (DISS), 20 years on: lessons learned from the construction of a SHA-oriented fault database

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The DISS Working Group

Founded in 1999, the DISS WG has compiled fault databases at various scales and for various purposes.

- Roberto Basoli, PhD in Earth Sciences, twists geologic data into digital shapes.
- Pierfrancesco Burattini, Earthquake Scientist, active tectonics, morphotectonic and 3D modeling.
- Umberto Fracassi, PhD in Earth Sciences, puts imagine-action in subsurface data.
- Vanja Kastelic, PhD in Geological Sciences, studies active faults for seismic hazard input.
- Francesco E. Maessano, PhD in Structural Geology, works on seismic reflection profiles and 3D geological modeling for investigating active faults.
- Gabriele Tarabus, PhD in Earth Sciences, masters a number of IT tools to help the group turning intuitions into actual data.
- Mara Monica Tiberi, PhD in Geodynamics, parameterizes unfamiliar geologic objects into prospective seismogenic sources.
- Gianluca Valenzano, senior member of the group, brings in an insatiable curiosity for past and future earthquakes.
- Roberto Valone, Geologist and IT expert. He aims to become the link between rocks and code. For the rest of the time he runs almost everywhere.
- Paolo Vannoli, PhD in Earth Sciences, joins earthquakes and geology into Earthquake Geology.
The **prototype version** of the DISS database was launched and published on **20 July 2000**. Twenty years later we present an **appraisal** of how the database started off, how it evolved, and how it served the seismological and engineering communities.
Where we stand today | DISS 3.2.1 (2018)

http://diss.rm.ingv.it/diss/
The European Database of Seismogenic Faults

(EDSF, November 2013)

http://diss.rm.ingv.it/share-edsf/
Other European initiatives

- Garcia-Mayordomo et al. [2012]
- Vanneste et al. [2014]
- Caputo & Pavlides [2013]
THE DATABASE

A database structure is currently in place that allows importing (rich) existing datasets (such as the active fault datasets from the United States and New Zealand). New discoveries and data can be uploaded to the database after review, by using the data capture tool.

Contents Version 1

The first version of the database (2014) will contain the following datasets:

- New Zealand: active fault and active fault source data
- Japan: active fault database
- Alaska: active fault and fold database
- Europe: through collaboration with the SHARE project
- South Asia: frontal fault system Himalayas
- South-East Asia & Pacific: what data is still under discussion with collaborators in the region, such as in Indonesia and Thailand
- South America: what data is still under discussion

In addition to the above national data, other data may also be...

- Global Subduction Zone Database
- Oceanic Transforms

Likely are also datasets from the USA (faults and folds).

- Alaska: active fault and fold database
- Europe: through collaboration with the SHARE project
- South Asia: frontal fault system Himalayas
DISS 1.0-2.x: Individual Seismogenic Sources, each one responsible for a specific quake, stemming from geological-geophysical data combined with historical seismology observations.

DISS 1.0 2000
DISS 2.0 2001
FAUST 2002
DISS 2.x 2003
(input for Italy’s MPS04)
DISS 1.0-2.x:
Individual Seismogenic Sources, each one responsible for a specific quake, stemming from geological-geophysical data combined with historical seismology observations.

DISS 3.0-3.x:
Introduced the Composite Seismogenic Source, which include an unknown number of individual ruptures, a new specific layer for Subduction Zones and a set of Debated Seismogenic Sources.

The 3.x versions are used in international initiatives for fault-based, standardized SHA, and have served as input for earthquakes and tsunami hazard assessment efforts.

All recent versions are OpenQuake-ready
We started off from Italy’s long-standing tradition for investigations in historical seismology. But of course, even reliable earthquake locations do not say much about the exact location of the main seismogenic sources, and less than less about the geometry of the main seismogenic trends.

At first, we derived intensity-based seismogenic sources using the new analytical earthquake catalogues that had recently become available (1995), along with a new processing technique named Boxer.

As expected, and despite some scatter, the geology-independent sources we obtained did delineate rather faithfully the main active trends.

Gasperini et al. (BSSA 1999)
Geophysical and seismotectonic data finally took firm control of the situation, yet historical seismology data turned out to be essential for revealing the existence of blind faults, stressing the continuity (or discontinuity) of poorly visible tectonic trends, and highlighting the presence (or absence) of seismic gaps.

Valensise & Pantosti, eds. (Ann. Geophys. 2001)
The ISSs are intended to supply the most accurate information available for the best identified sources, and specifically for known instrumental or pre-instrumental earthquakes, but the completeness of the sources themselves cannot be guaranteed. They assume characteristic behavior and can be used for calculating earthquake and tsunami scenarios and for tectonic and geodynamic investigations, but are not meant to comprise a complete nor a realible input dataset for PSHA.
Requirements of a SHA-oriented fault DB

During the early years of its development we learned that the fundamental requirements of any SHA-oriented fault database are (in descending order of importance):

- the capacity to **represent seismogenic sources in 3D**, thus providing a **standardized quantitative basis** for subsequent SHA calculations;
- the **completeness**, i.e. the ability to portray the vast majority of seismogenic sources existing in the region of relevance and to progressively **address the emerging lack of knowledge**;
- the **reliability** of the geometrical parameters of each seismogenic source and of the relevant **slip and strain rates**, and the ability to **assess the associated uncertainties**;
- the **ability** to devise a correct structural **hierarchization scheme** for all faults that exist in a region, separating the **main elements** from their **subsidiaries**;
- the capacity to assess the **seismic coupling**, i.e. the ratio between the **seismic moment** released by each fault and the **total geological moment** inferred from geology, paleoseismology, GPS etc.
The **CSSs** were conceived to achieve completeness of the record of potential earthquake sources, although this may imply a lesser accuracy in their description. They are not assumed to be capable of a specific-size earthquake, or to exhibit a specific recurrence behavior. In conjunction with seismicity and modern strain data, CSSs may contribute to the development of regional probabilistic seismic hazard assessment and to investigate large-scale geodynamic processes.
From its prototype to its current version the DISS database has evolved not only in terms of quality and quantity of the stored data, but also in terms of a progressive evolution of its cataloguing structure and of its user-interface.

After the introduction of **Composite Seismogenic Sources** (2005), which complemented the **Individual Seismogenic Sources**, other improvements included:

- the introduction of **Subduction Zones** and of **Debated Seismogenic Sources**;
- the elaboration of a detailed scheme for **ranking the reliability** of all published parameters, and
- the **elaboration and publication of regional summaries** for homogeneous source groups, so that any progress in the understanding of the seismotectonics of any given region could be reflected on the largest possible number of nearby seismogenic sources.

Facing outstanding issues
The **SUBDZ layer** represents the **dipping slab at mantle depth**, the **interface between the two plates at crustal depth**, and also the **detachment at the base of the accretionary wedge**.

We identify the **main seismogenic source with the slab interface** and provide its extent in terms of minimum and maximum depth. Subduction zones are **not assumed to be capable of generating a specific-size earthquake**, or to **exhibit** a specific **recurrence behavior**.
The **DSSs** are active faults that have been **proposed in the literature** as potential seismogenic sources but were **not considered reliable** enough to be included in DISS. They may include faults:

- for which only **minimal surface evidence** is supplied in literature;
- that are based on **inherently ambiguous** geological evidence;
- that are **secondary** to a **master** fault lying beneath them;
- for which only **highly contrasting views** exist;
- that **occur in low or very low seismicity** areas;
- whose characteristics are **in open contrast** with those of nearby, well known, established seismogenic sources, or that **violate tectonic and seismological evidence**.
Every source comes with a great deal of accompanying information, ranging from a detailed parameterization to literature data and images to references to original elaborations by the database authors.

Text summaries inform the reader about the history of the investigations of that source, including the open questions on its geometry, behavior and significance.
The DISS database keeps track of all changes between all versions published since July 2000.

All changes to the different categories of contents of the database, all contributions of new data from other colleagues and correspondents, and all projects that provided support to the ongoing research are accounted for, one by one.

Even more importantly, all previous versions can be downloaded and imported in a GIS, thus allowing any changes and improvements in the data to be explored in detail.
The value of data exchanging in a GIS domain

The adoption of the **WMS** and **WFS** standards of the Open Geospatial Consortium allows for a **smooth interoperability** of **DISS** data within different **geophysical repositories**. The image shows how DISS data can be **consulted in conjunction** with data from the Catalogue of Strong Italian Earthquakes (**CFTI5Med**: Guidoboni et al., Nature Sci. Data, 2019). Intensities and environmental effects of the 28 December 1908, Messina Straits earthquake (MW 7.1) are plotted along with the region’s seismogenic sources. Clicking on its presumed source takes you back to DISS.
The need to bridge a knowledge gap

The seismogenic sources listed in the DISS database are simply the master elements of complex fault systems. The detailedness of conventional fault maps portrays these fault systems in their full complexity: but these maps are generally unable to isolate the main seismogenic faults effectively.

Therefore, the seismogenic sources shown in the DISS database and the faults shown in any active fault map are not extraneous elements, one belonging to Seismology, the other to Geology: they are just the two sides of the same coin.

In 2017 INGV and the Italian Civil Protection launched a project for bridging this gap and clarify the relationships between seismogenic sources and their brittle surface expression(s), wherever possible.
The need to bridge a knowledge gap

**ISPRA - ITaly Hazard from CApable faults (ITHACA)**

Detailed **2D** representation; all **faults** are shown in map as **raster** GIS elements.

May be used as a basis for **microzonation** and for **surface faulting hazard** assessment.

**INGV - Database of Individual Seismogenic Sources (DISS)**

Simplified **3D** representation; all **faults** are shown as **vector** GIS elements through their **surface projection**.

It may be used as a basis for **ground shaking** and **tsunami hazard** models, and for **geodynamic models**.
The need to bridge a knowledge gap

**INGV - Database of Individual Seismogenic Sources (DISS)**
Simplified 3D representation; all faults are shown as vector GIS elements through their surface projection.

It may be used as a basis for ground shaking and tsunami hazard models, and for geodynamic models.

**ISPRA - ITaly Hazard from CApable faults (ITHACA)**
Detailed 2D representation; all faults are shown in map as raster GIS elements.

May be used as a basis for microzonation and for surface faulting hazard assessment.

Not to be used for ground shaking hazard and tsunami hazard

Not to be used for microzonation and for surface faulting hazard
Reconciling active faults & seismogenic sources

Calculating the CFF

Slip and dilation tendency

Dislocation modeling

An example from the causative fault of the devastating 1915 Fucino, central Italy earthquake (shown in yellow) and its associated secondary faults.
Conclusions

✓ It was about time that SHA practitioners acknowledged the fundamental role of geological data in constraining SHA and reducing the associated uncertainties. Our community knows that – and must be assured that – geological data will provide evidence that no other data will ever reveal.

✓ Nevertheless, earthquake geologists and seismotectonicists must be aware (a) of the great complexity of the geological world, (b) of the importance of approaching it in a 3D perspective, (c) of the need to quantify their findings, and (d) of the need to respect and deal with any carefully collected and interpreted instrumental evidence.

✓ The surface evidence for active faulting and the surface deformation pattern must agree with the fault structure at depth, and any slip on the fault at depth must be reflected in discernible surface strains. There is only one Geology, whether one looks at it from above or from below.
Thank you for your attention!