EGU General Assembly 2020

Online | 4–8 May 2020

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

Gianluca Valensise, Roberto Basili, Pierfrancesco Burrato, Umberto Fracassi, Vanja Kastelic, Francesco Emanuele Maesano, Gabriele Tarabusi, Mara Monica Tiberti, Roberto Vallone and Paola Vannoli

*Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy*

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# The DISS Working Group

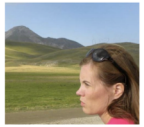
EGU General Assembly 2020

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

*Roberto Basili*, PhD in Earth Sciences, twists geologic data into digital shapes.

*Pierfrancesco Burrato*, 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. Maesano*, PhD in Structural Geology, works on seismic reflection profiles and 3D geological modelling for investigating active faults.

*Gabriele Tarabusi*, PhD in Earth Sciences, masters a number of IT tools to help the group turning intuitions into actual data.


*Mara Monica Tiberti*, PhD in Geodynamics, parameterizes unfamiliar geologic objects into prospective seismogenic sources.

*Gianluca Valensise*, senior member of the group, brings in an insatiable curiosity for past and future earthquakes.

*Roberto Vallone*, Geologist and IT expert. He aims to become the link between rocks and code. For the rest of the time he runs almost everywhere.

*Paola Vannoli*, PhD in Earth Sciences, joins earthquakes and geology into Earthquake Geology.

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# Proudly part of SEISMOFAULTS.EU

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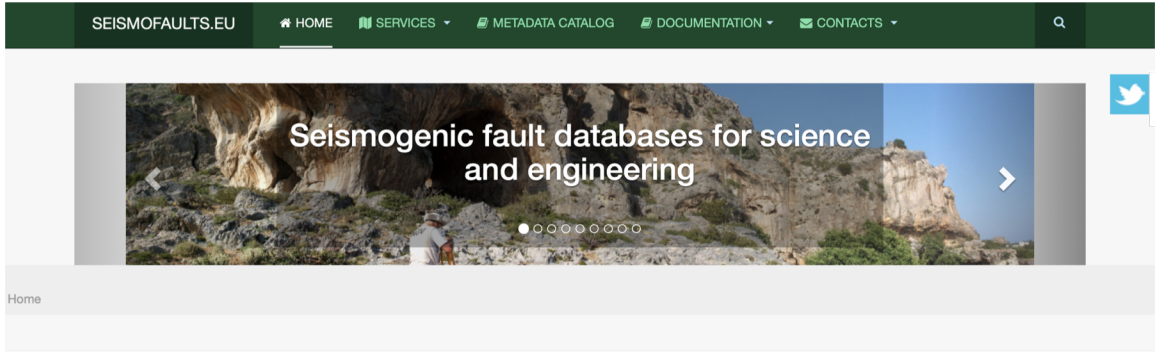


**EUROPEAN DATABASE OF SEISMOGENIC FAULTS 2013**

SHARE EFEHR

The European Database of Seismogenic Faults (EDSF) was compiled in the framework of the EU Project SHARE. It includes only faults that are deemed to be capable of generating earthquakes of magnitude equal to or larger than 5.5 and aims at ensuring a homogeneous input for use in ground-shaking hazard assessment in the Euro-Mediterranean area.

Go to the EDSF13 website

Go to the OGC services URLs

**DATABASE OF INDIVIDUAL SEISMOGENIC SOURCES**

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DISS is a georeferenced repository of tectonic, fault, and paleoseismological information expressly devoted, but not limited, to potential applications in the assessment of seismic hazard at regional and national scale in Italy. DISS represents faults in 3D and all its records are fully parameterized. It tends to completeness.

Go to the DISS website

Go to the OGC services URLs

**EUROPEAN FAULT SOURCE MODEL 2020**

SERA EFEHR

The European Fault-Source Model 2020 (EFSM20) is a product of the EU H2020 Project SERA (WP25-JRA3). It is designed to fulfill the requirements related to active faulting of the 2020 update of the European Seismic Hazard Model (ESHM20) following the probabilistic framework established for the 2013 European Seismic Hazard Model (ESHM13).

Go to the EFSM20 page

*OGC services URLs (to be released in late 2020)*

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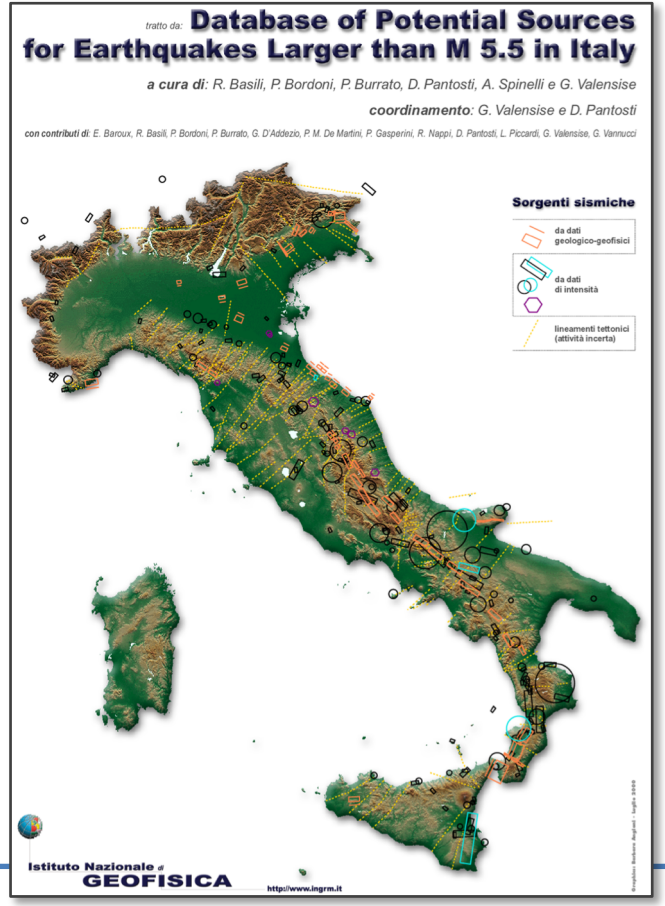
# 2000-2020 | Twenty years on

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.

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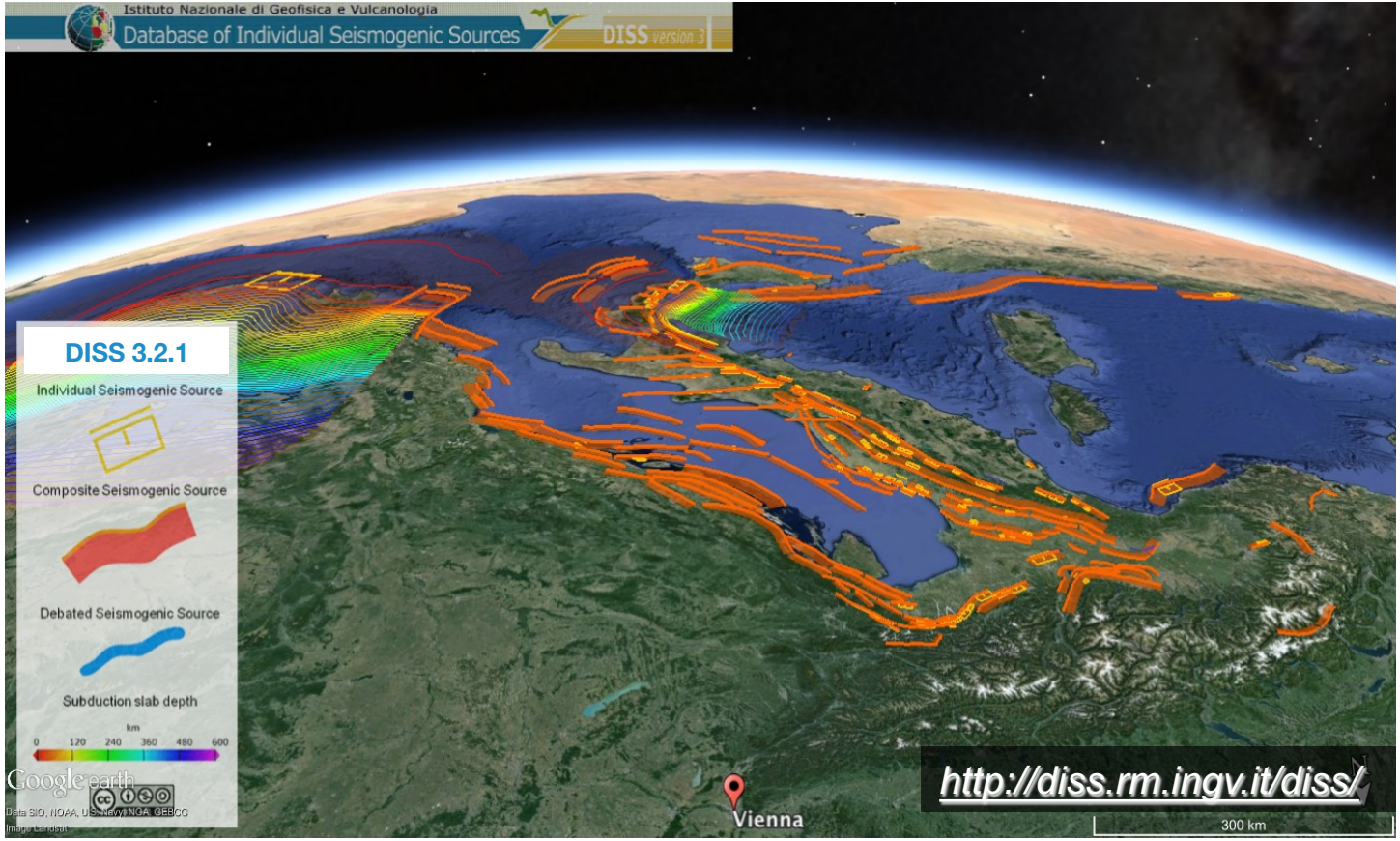
# Where we stand today | DISS 3.2.1 (2018)





# The European Database of Seismogenic Faults

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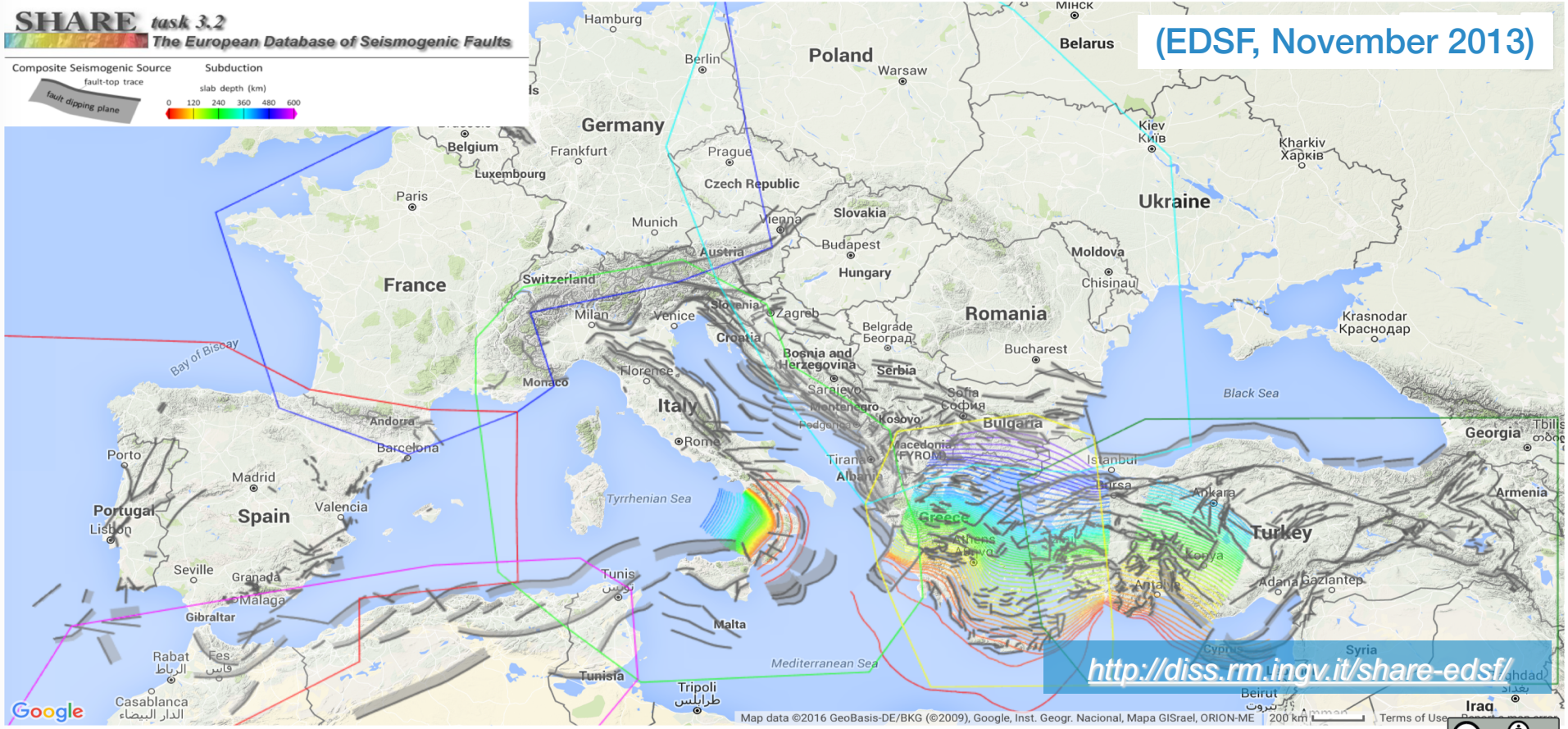
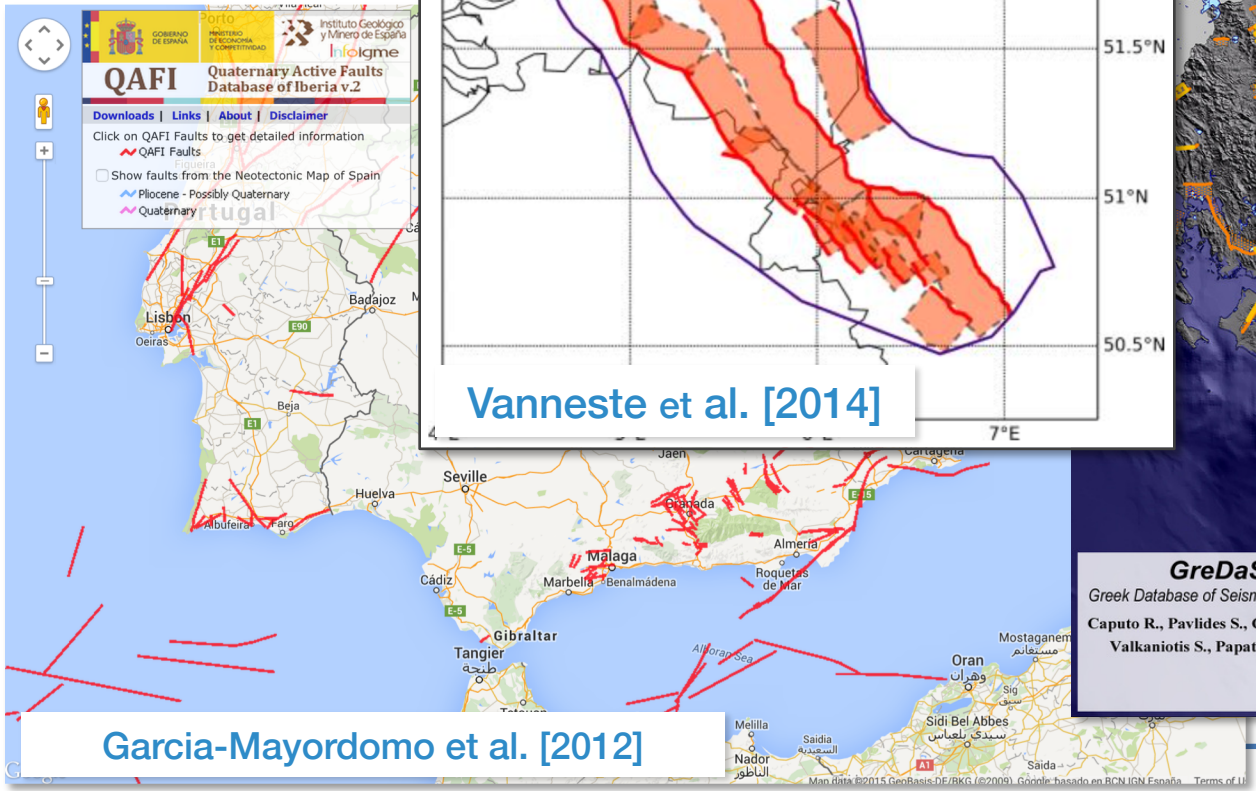


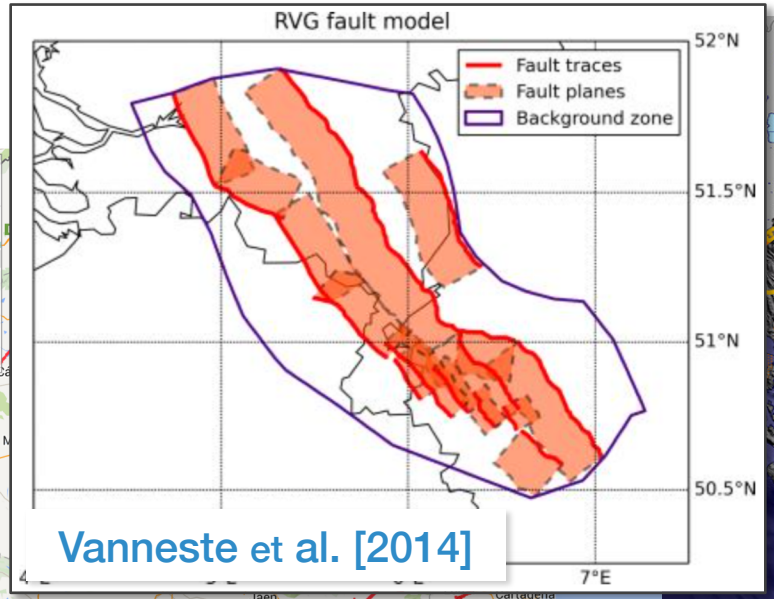

☑ Composite Seismogenic Sources ☑ Subductions ☑ Regional Data Contributions

# Other European initiatives

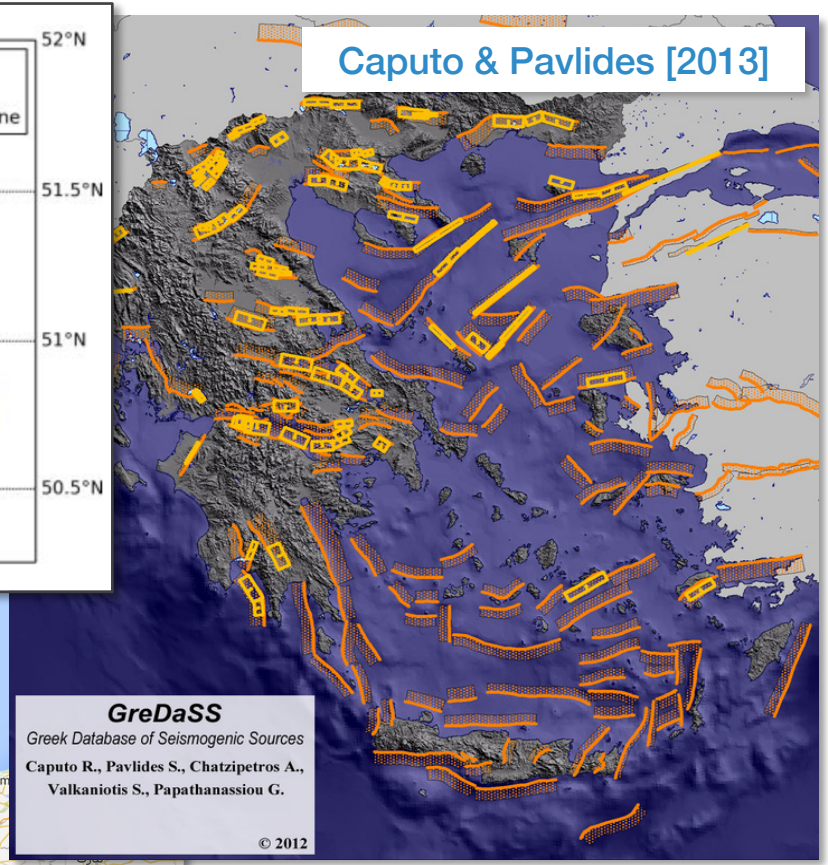





Garcia-Mayordomo et al. [2012]




Vanneste et al. [2014]




Caputo & Pavlides [2013]

# Representing Europe within GEM

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## THE DATABASE

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

### Contents Version 1

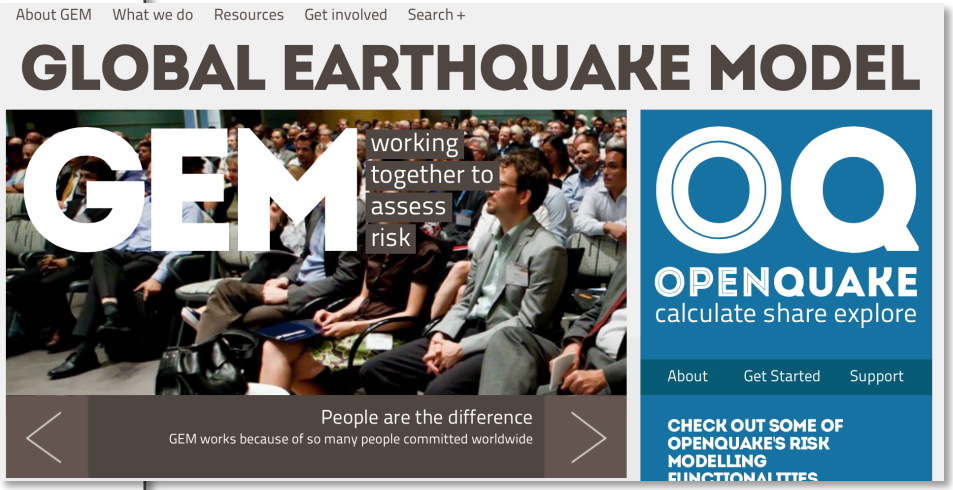
The version of the datab (2014) will contain the following datasets:

- New Zealand: active fault and a e fault source data
- Japan: active fault database
- Alaska: active fault and fold datab e
- **Europe: through collaboration wit he SHARE project**
- South Asia: frontal fault system H alayas
- South-East Asia & Pacific: what d a is still under discussion with collaborators in the region, such as in Indonesia and ailand
- outh America: what data is s der discussion

In additi onal data, a lso 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

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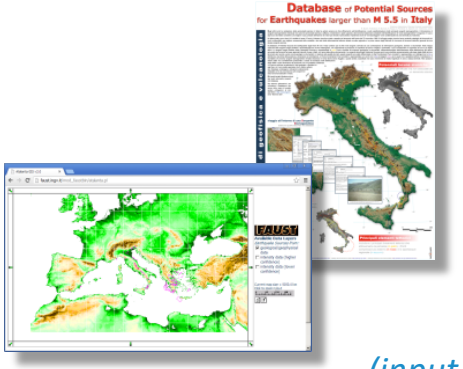



DISS 1.0 **2000**

DISS 2.0 **2001**

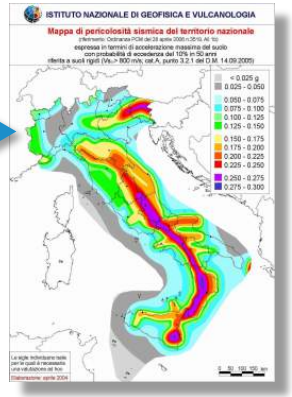
FAUST **2002**

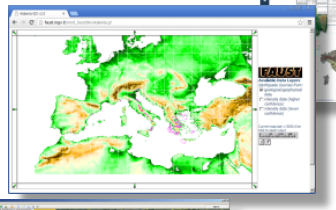
DISS 2.x **2003**

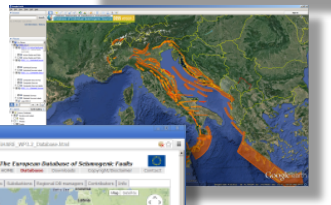
*(input for Italy's MPS04)*

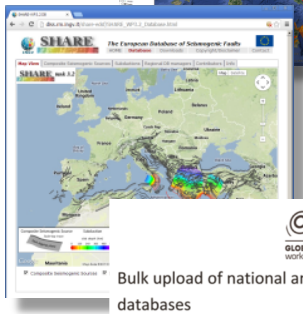
**DISS 1.0-2.x:**

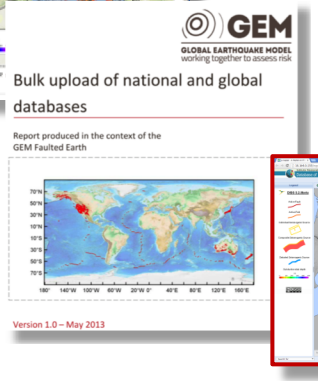
Individual Seismogenic Sources, each one responsible for a specific quake, stemming from geological-geophysical data combined with historical seismology observations.

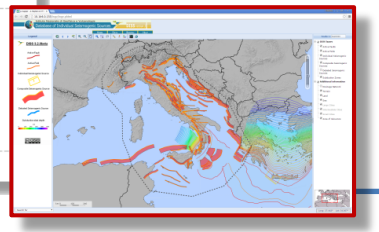




DISS 1.0 **2000**

DISS 2.0 **2001**

FAUST **2002**

DISS 2.x **2003**

*(input for Italy's MPS04)*

DISS 3.x.y **2005**

EDSF **2013**

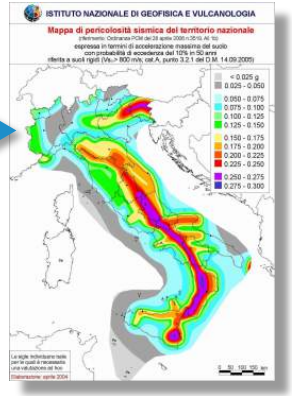
*(input for ESHM13)*

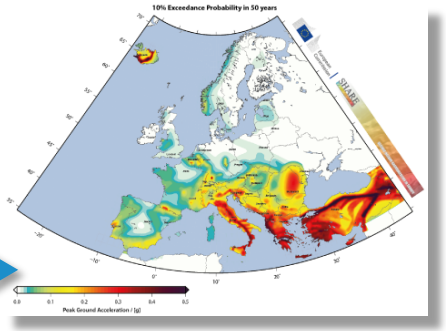
GEM-Faulted Earth **2013**

**DISS 3.2.1 2018**

**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**

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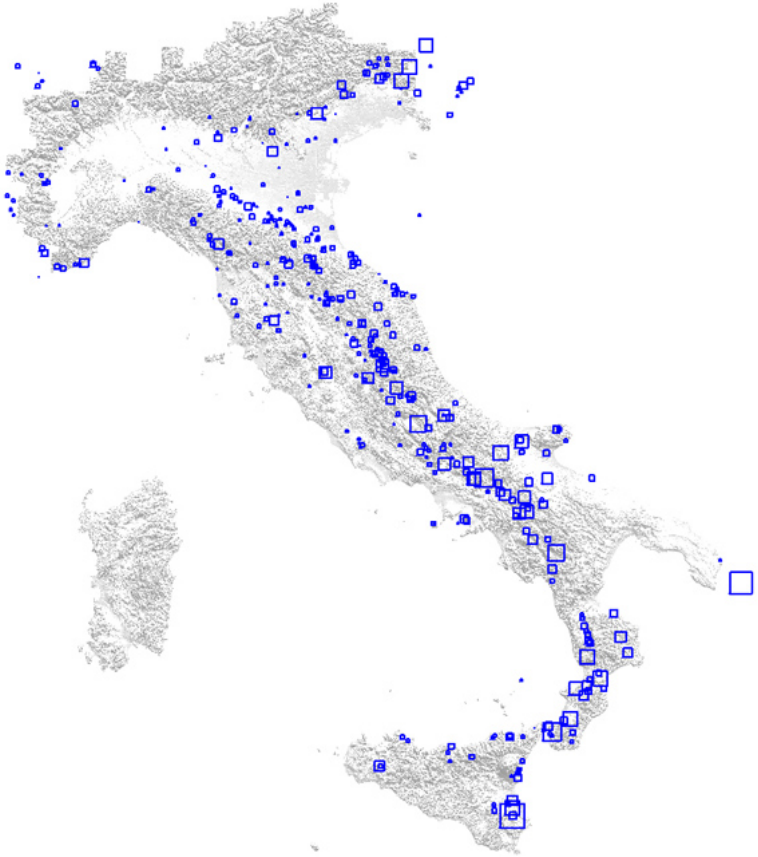
# We started off from... all known earthquakes

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**.



*Boschi et al.* (1995, 1997, 2000)

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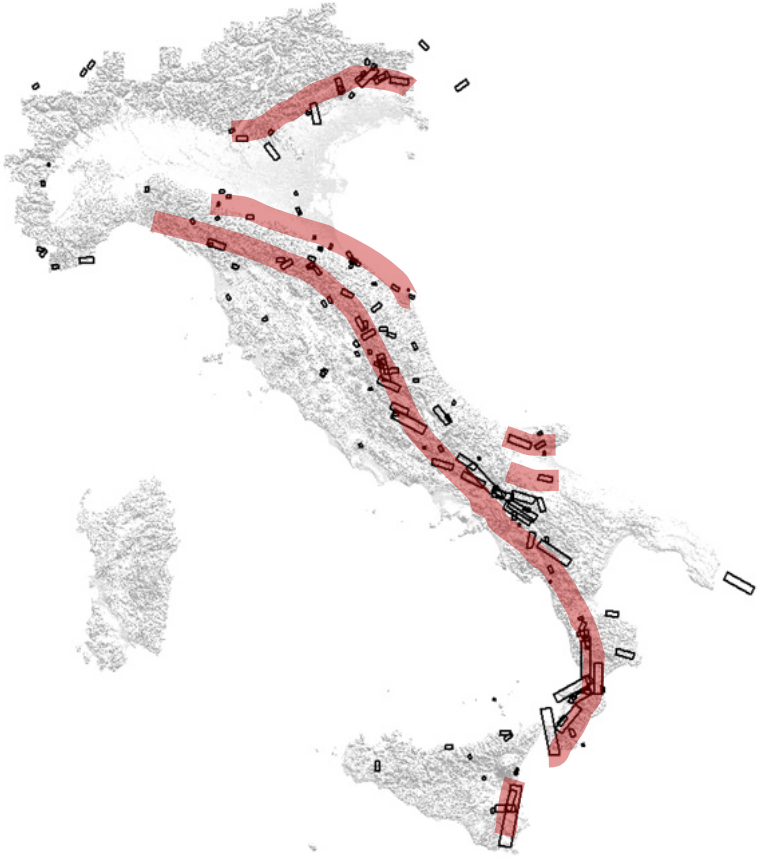
# A proxy for a first-order seismogenic model

**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)

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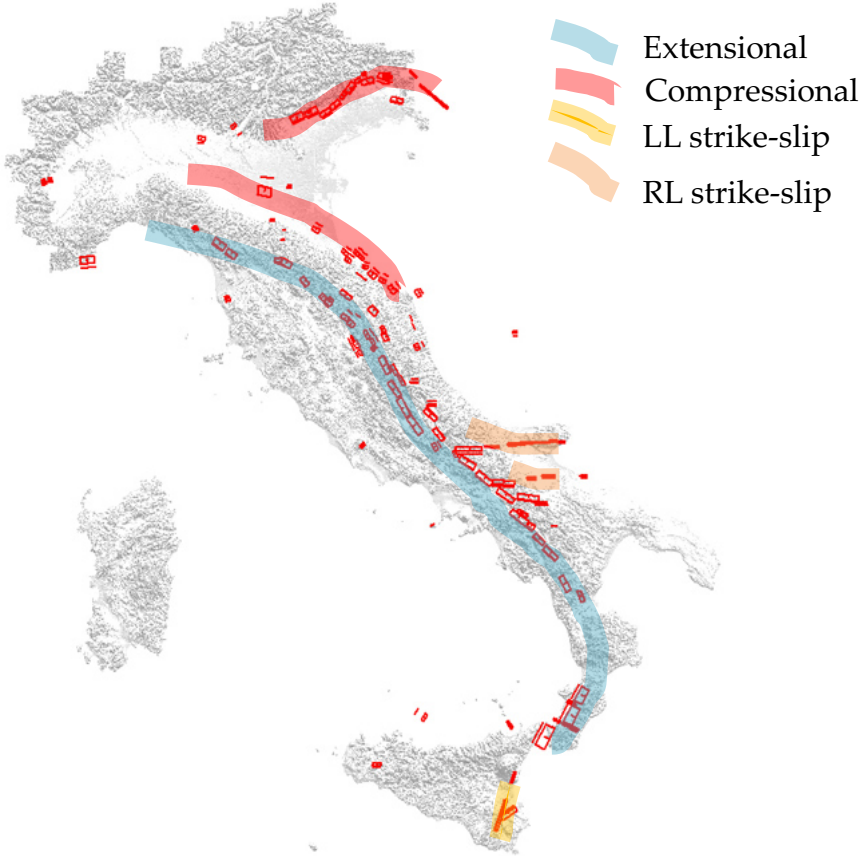
# Indeed, tectonic/geologic data made the difference



**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)

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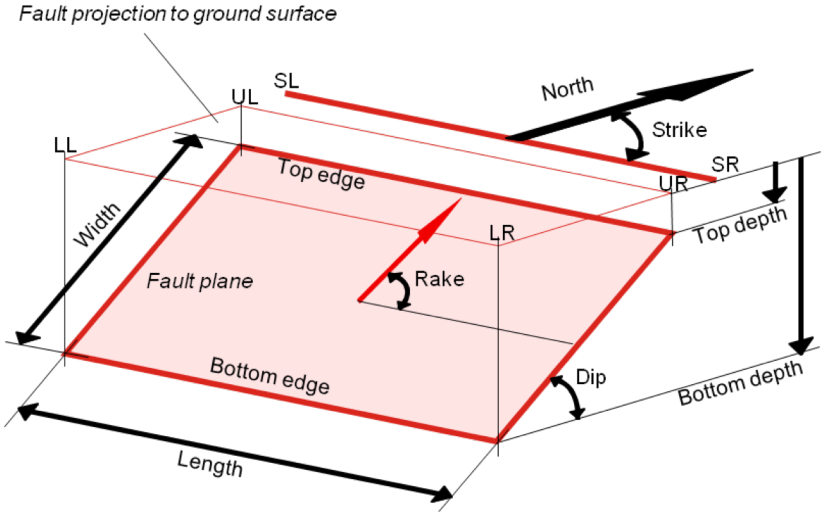
# The basic data entity | The Individual Seismogenic Sources




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**.

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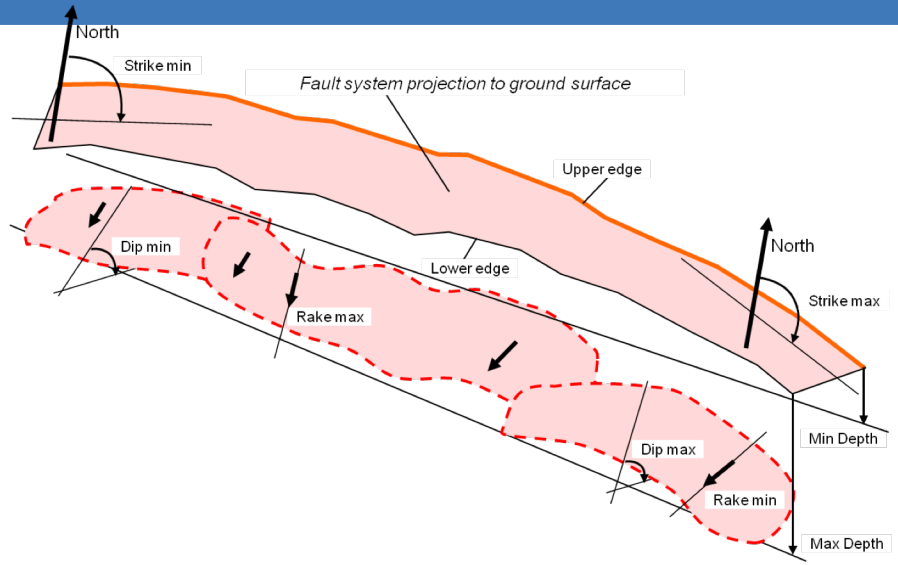
# Requirements of a SHA-oriented fault DB



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.**

# Coping with completeness | The Composite Seismogenic Sources




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.

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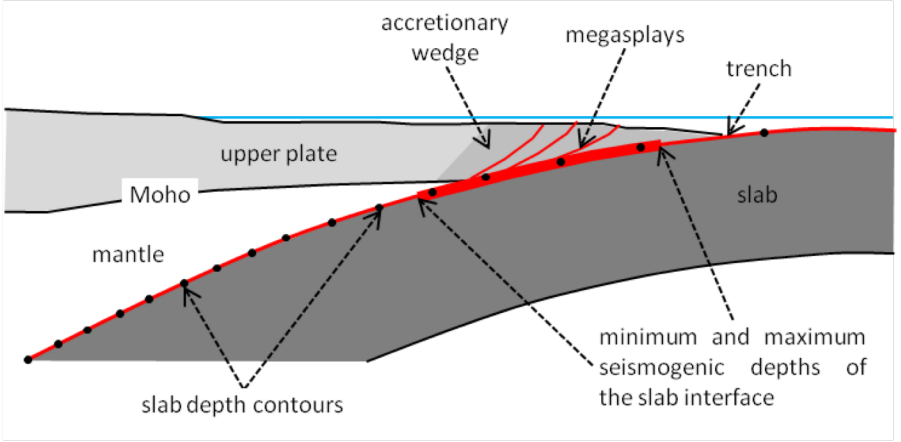
# Facing outstanding issues

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.

# Mapping slabs interfaces | The Subduction Zones




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**.

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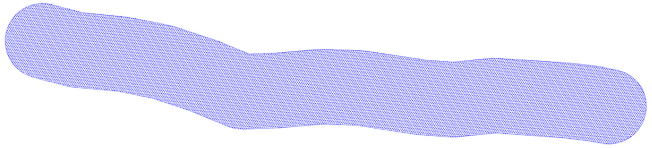
# Dealing with contrasting opinions | The Debated Seismogenic Sources



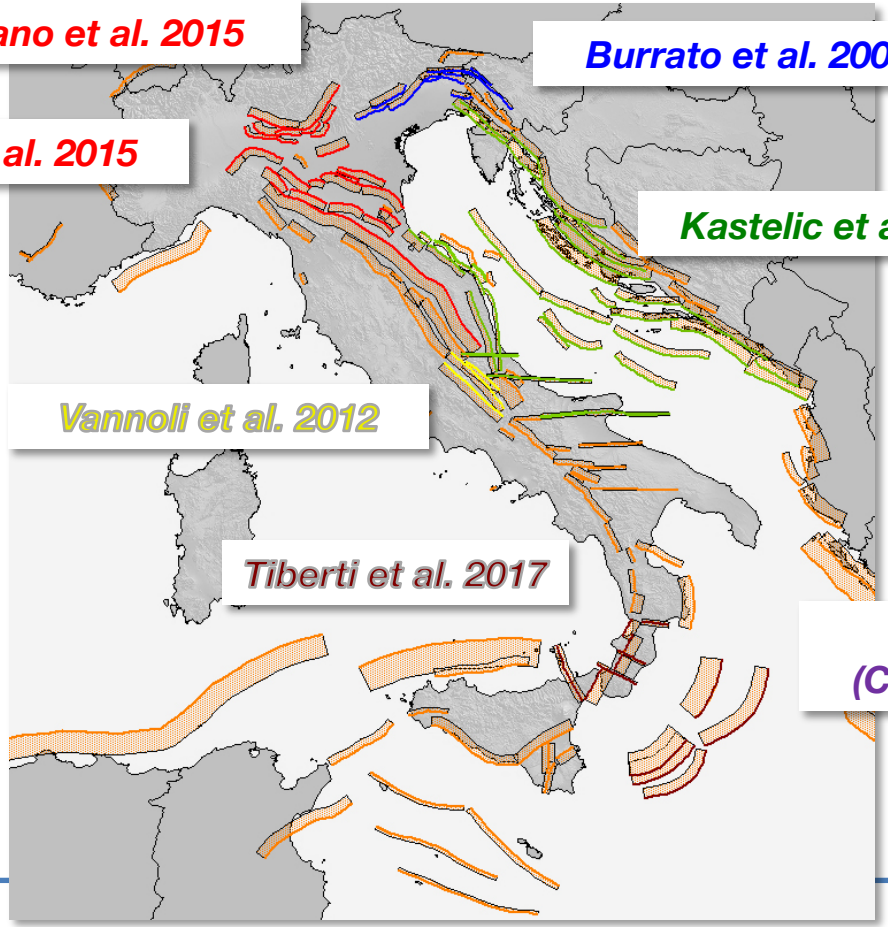


The **DSSs** are active faults that have been **proposed in the literature** as potential seismogenic sources but were **not considered reliable** enough to be included in DISS. They may include faults:

- 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**.

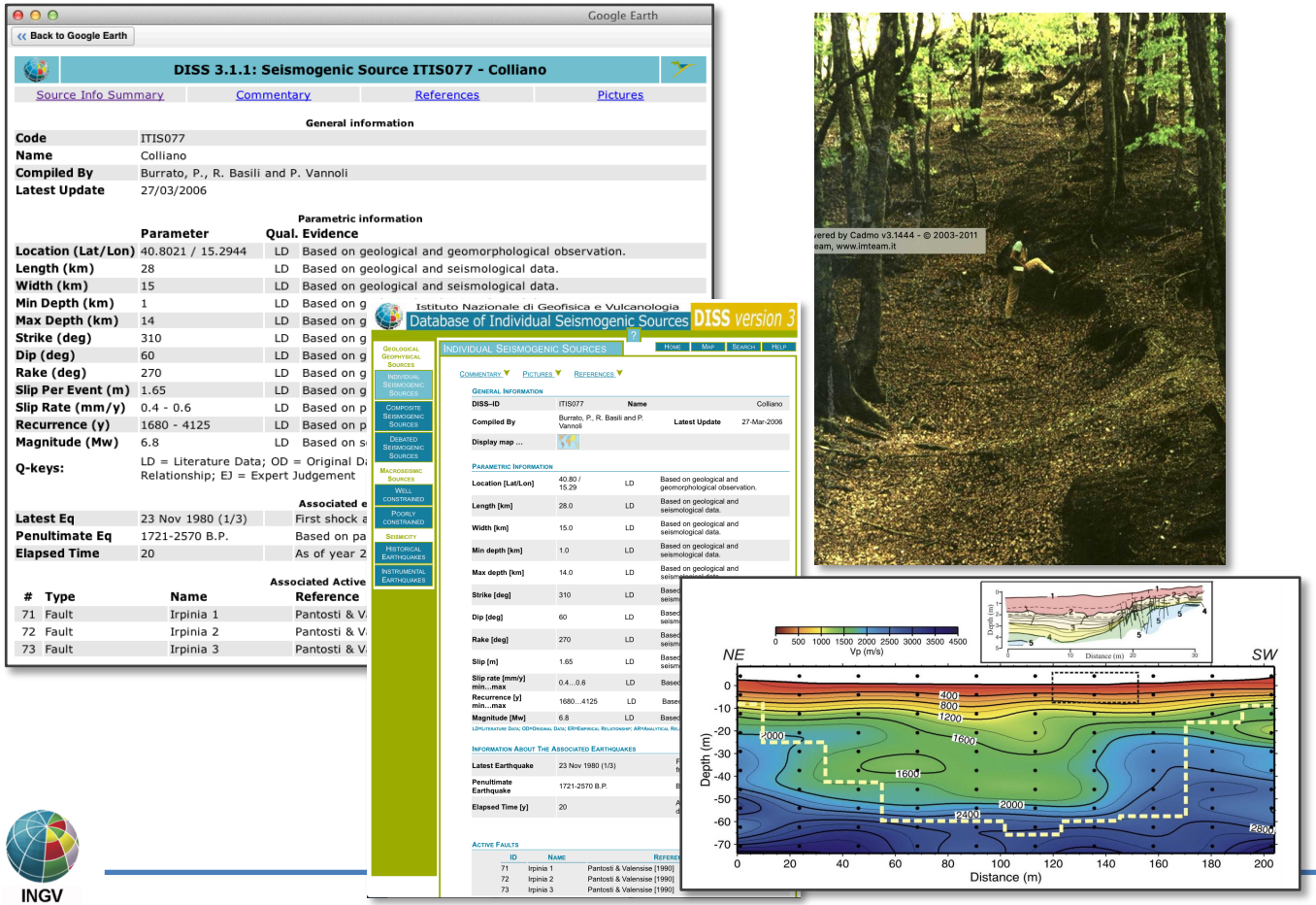
# Regional summaries in JCR journals





# A wealth of ancillary materials






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 ithe nvestigations** of that source, including the **open questions** on its geometry, behavior and significance.

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# The importance of proper versioning



Istituto Nazionale di Geofisica e Vulcanologia
Database of Individual Seismogenic Sources
DISS version 3
A compilation of potential sources for earthquakes larger than M 5.5 in Italy and surrounding areas
HOME | ABOUT | HELP | CREDITS | COMMUNITY

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.

## Documentation

The "Database of Individual Seismogenic Sources" was conceived in the late '90s by a group of scientists of Istituto Nazionale di Geofisica e Vulcanologia. The Database has since been greatly improved through successive releases.

Here are some excerpts from our reviewers.

**Final review of DPC-INGV S-projects 2004-2006 (September 2007)**
**Final review of DPC-INGV S-projects 2007-2009 (July 2010)**

List of scientific **papers** that cite the DISS concepts or data content or used the DISS in an analysis or application.

Database updates are irregular and can be expected to appear approximately once in a few years. Users will be notified of any further versions through this website. Join our community to stay updated.

Following is a summary of its history and evolution.

- July 2018: Version 3.2.1 (**read more and download...**). This version of DISS was completed in early July 2016 as one of the input datasets of Italy's Seismic Hazard Map MPS16. Its use was restricted to participants in the MPS16 program until the public release of the Database in April 2018.
- June 2015: Version 3.2.0 (**read more and download...**). Planned update.
- July 2010: Version 3.1.1 (**read more and download...**) released as the final contribution to the project "Analysis of the seismic potential in Italy for the evaluation of the seismic hazard", funded by the Italian Department of Civil Protection.
- June 2009: Version 3.1.0 (**read more and download...**) released as a contribution to the project "Analysis of the seismic potential in Italy for the evaluation of the seismic hazard", funded by the Italian Department of Civil Protection.
- July and October 2007: Versions 3.0.3 (**read more and download...**) and 3.0.4 (**read more and download...**) released as a contribution to the project "Assessing the seismogenic potential and the probability of large earthquakes in Italy", funded by the Italian Department of Civil Protection.
- September 2006: Version 3.0.2 (**read more and download...**) released, which includes a substantial extension of the database to the Mediterranean area.
- April 2006: Version 3.0.1 goes on Google Earth®. DISS takes advantage of the free software Google Earth to facilitate its users and expand its capabilities in disseminating data.
- November 2005: release of version 3.0.1 (**read more and download...**), a stable version of the database both as a standalone application and as an online cartographic interface.
- May 2005: Beta release on the Internet of the standalone version of DISS 3.0.0, a simple MapInfo® application that shares the same data and the same structure with its web counterpart.
- January 2005: release of the web version of DISS 3.0.0 (**read more and download...**), an Internet-based GIS application especially developed by IMteam. DISS 3.0.0 has an entirely new architecture and includes a substantial amount of new data structures and new information with respect to Version 2.0.
- September 2004: the new DISS (which is now the acronym of *Database of Individual Seismogenic Sources*) was presented as Version 3.0 at the XXIX General Assembly of the European Seismological Commission in Potsdam.
- October 2002: release of the *Database of Potential Sources for Earthquakes Larger than M 5.5 in Europe*, a web version of DISS 2.0 including seismogenic sources of the Euro-Mmediterranean area. The database was one of the outcomes of Faust (Faults as a Seismologists' Tool), a research project funded by the European Community.
- July 2001: new official version of DISS, Version 2.0 (**read more and download...**), that was subsequently published in a special issue of Annali di Geofisica (Valensise and Pantosti, 2001, *Annali di Geofisica* 44(4) Suppl.). The volume included explanations on the database structure, an operating manual and the full database on a CD-ROM.
- July 2000: first official version of DISS (Version 1.0), a standalone MapInfo® application released for circulation within INGV and a few selected institutions. DISS' structure was developed jointly by INGV scientists and by IMteam, a software consulting firm based in Bergamo.

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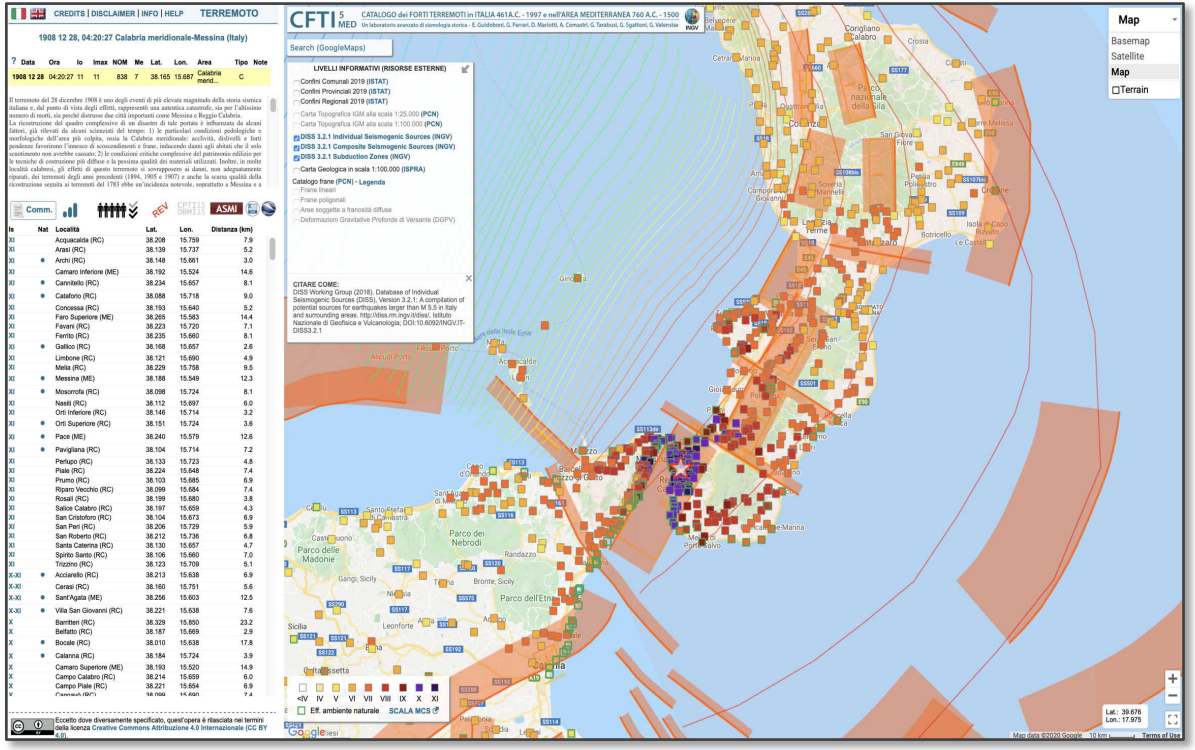
# The value of data exchanging in a GIS domain






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 ($M_w$ 7.1) are plotted along with the region's seismogenic sources. Clicking on its presumed source takes you back to DISS.

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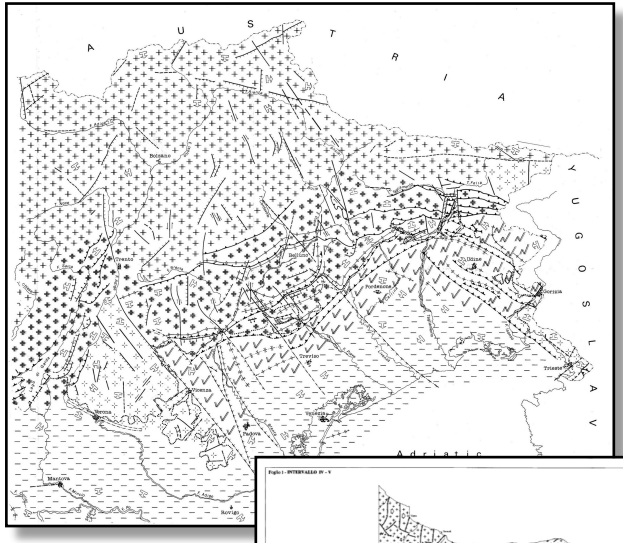
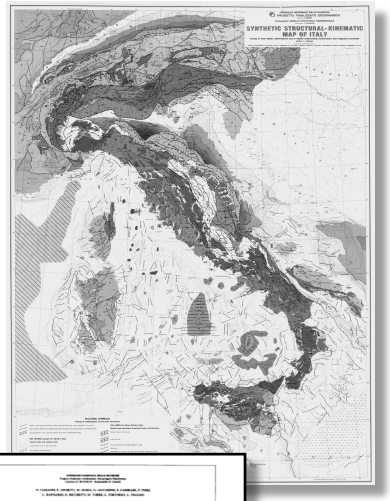
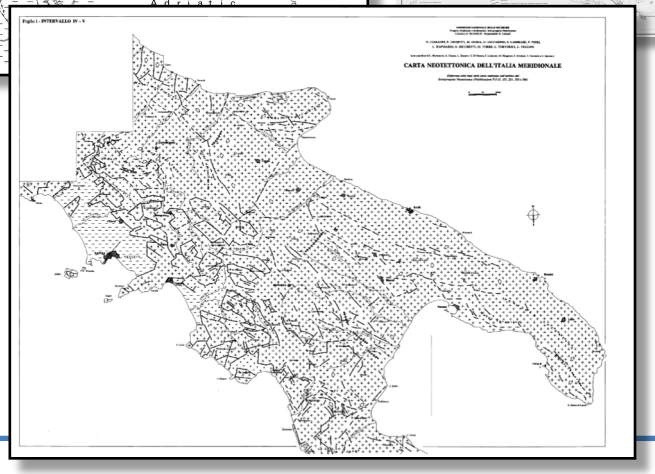
# The need to bridge a knowledge gap






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** ant their **brittle surface expression(s)**, wherever possible.

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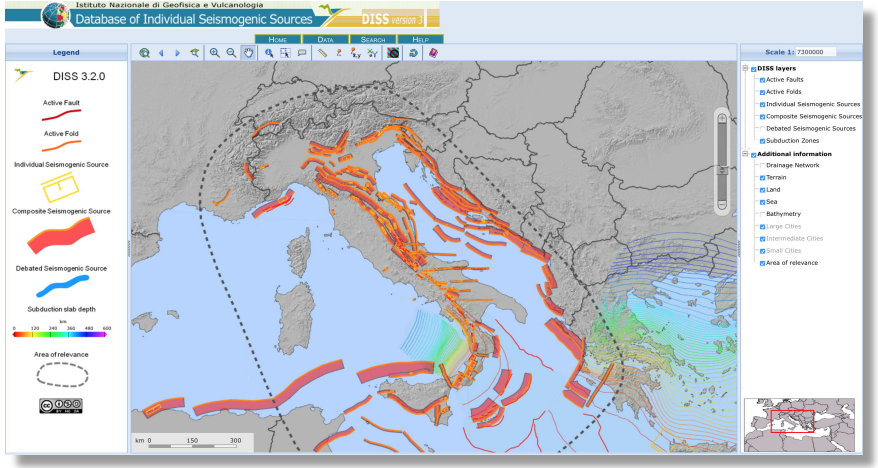
*ISPRA - ITaly Hazard from CApable faults (ITHACA)*

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 a a basis for **ground shaking** and **tsunami hazard** models, and for **geodynamic models.**

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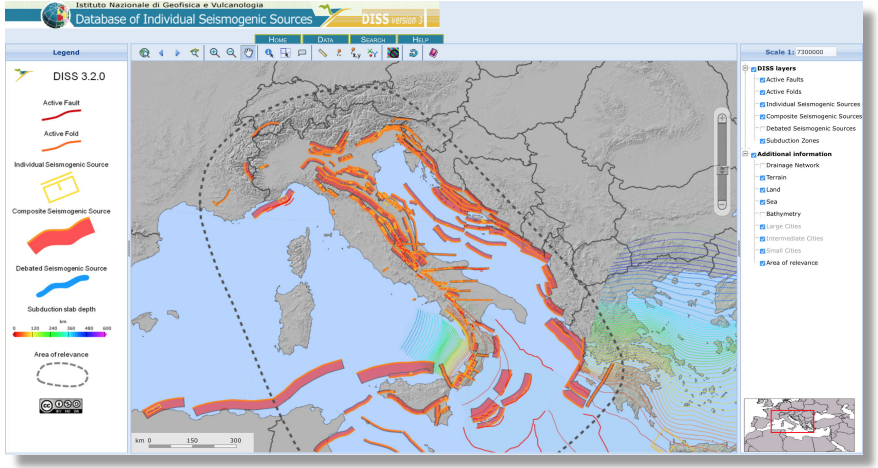
**Not to be used for ground shaking hazard and tsunami hazard**

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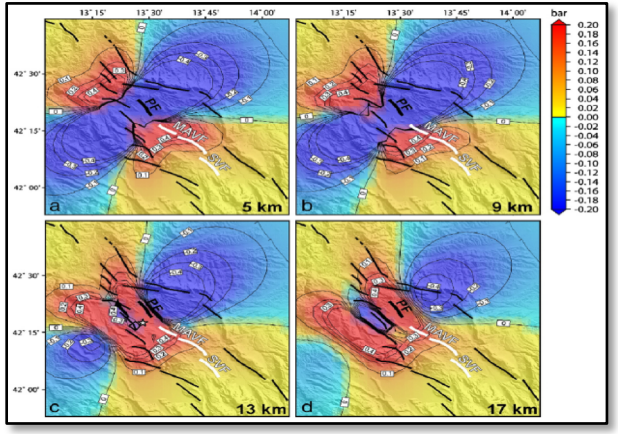
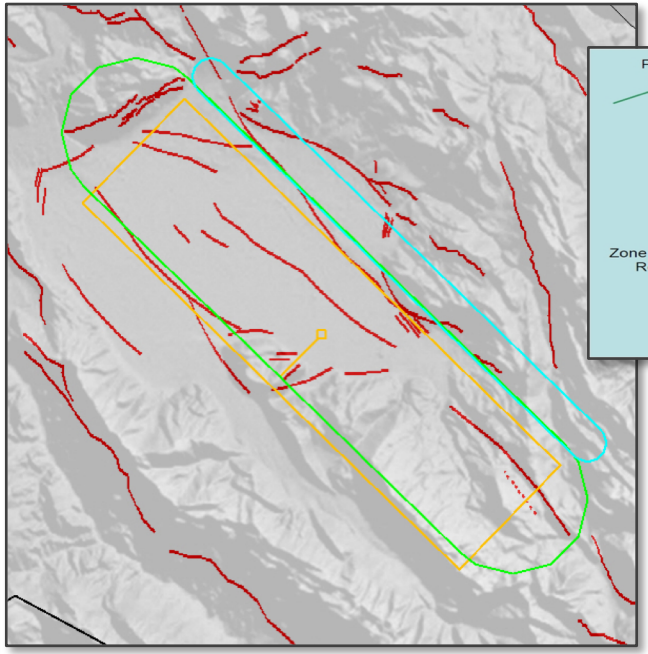
# Reconciling active faults & seismogenic sources

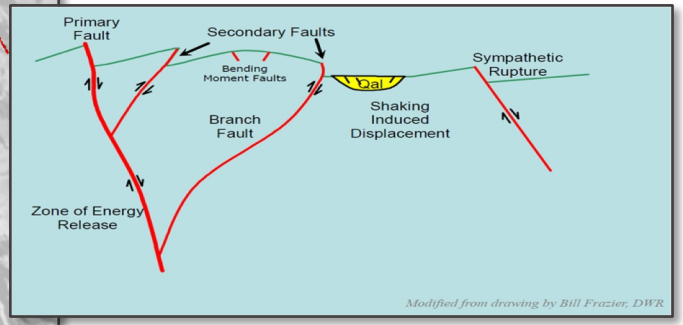





## Calculating the CFF

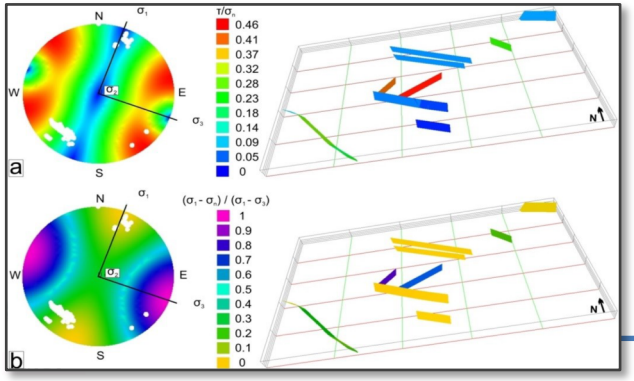


An example from the causative fault of the devastating 1915 Fucino, central Italy earthquake (shown in yellow) and its associated secondary faults

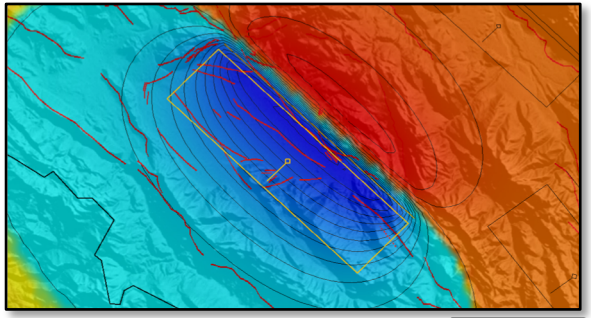



## Conceptual framework

## Slip and dilation tendency



## Dislocation modeling



# Conclusions



- ✓ It was about time that SHA practitioners acknowledged the fundamental role of geological data in constraining SHA and reducing the associated uncertainites. 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 intepreted 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!