

# ISC-EHB: Reconstructing the EHB Earthquake Database

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Dmitry Storchak<sup>1</sup> & Domenico Di Giacomo<sup>1</sup>**

- 1. International Seismological Centre, UK**
- 2. University of Colorado, Boulder, USA**



# Outline

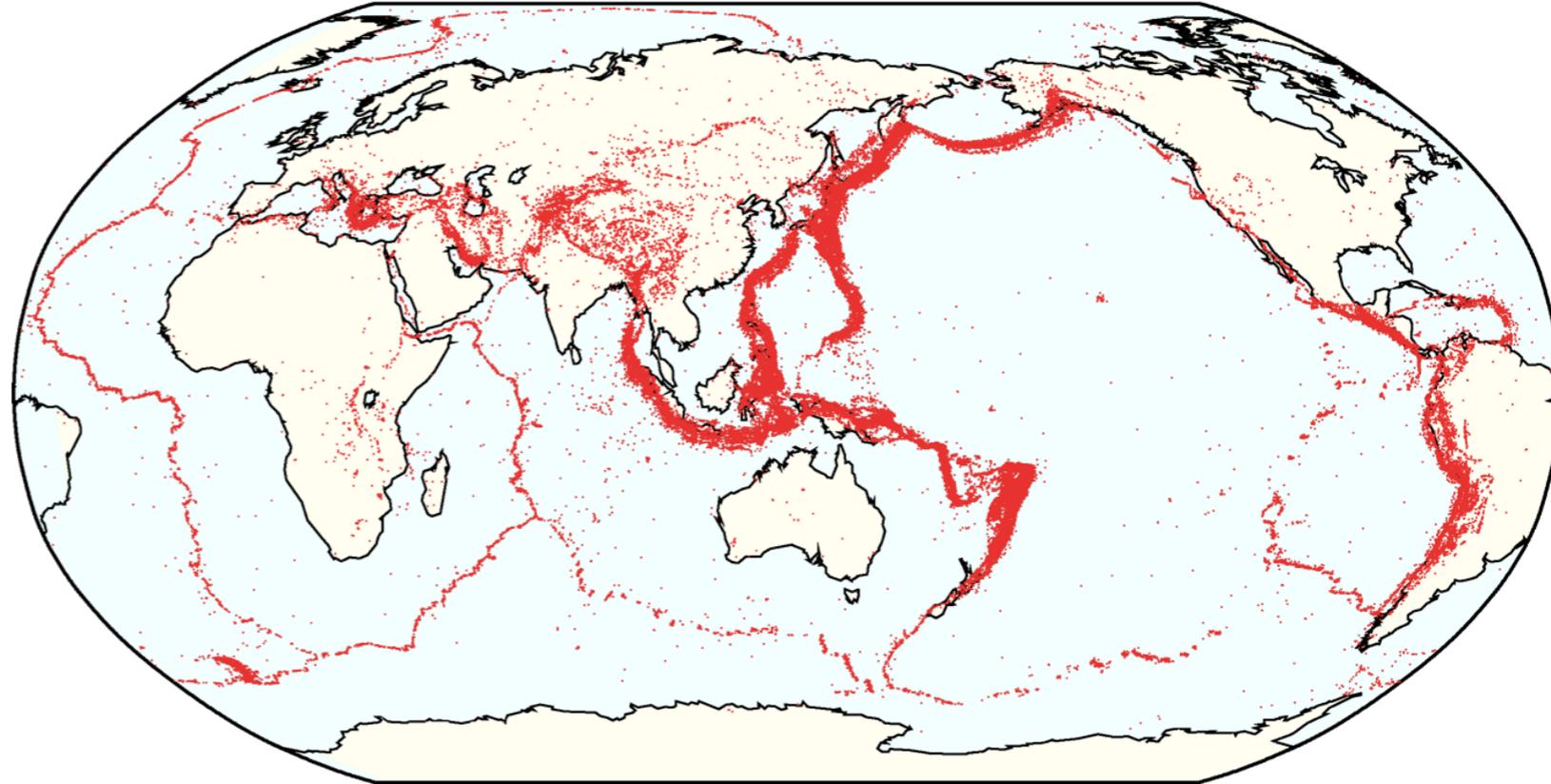
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- **EHB**
- New criteria and procedures for ISC-EHB
- **ISC-EHB: 2000-2003**
- Comparisons with other catalogues
- **Plans for rebuilding and extending ISC-EHB**

# Engdahl, van der Hilst, Buland (EHB)

- A database of teleseismically well constrained events selected from ISC Bulletin and relocated using algorithm (Engdahl et al., 1998).

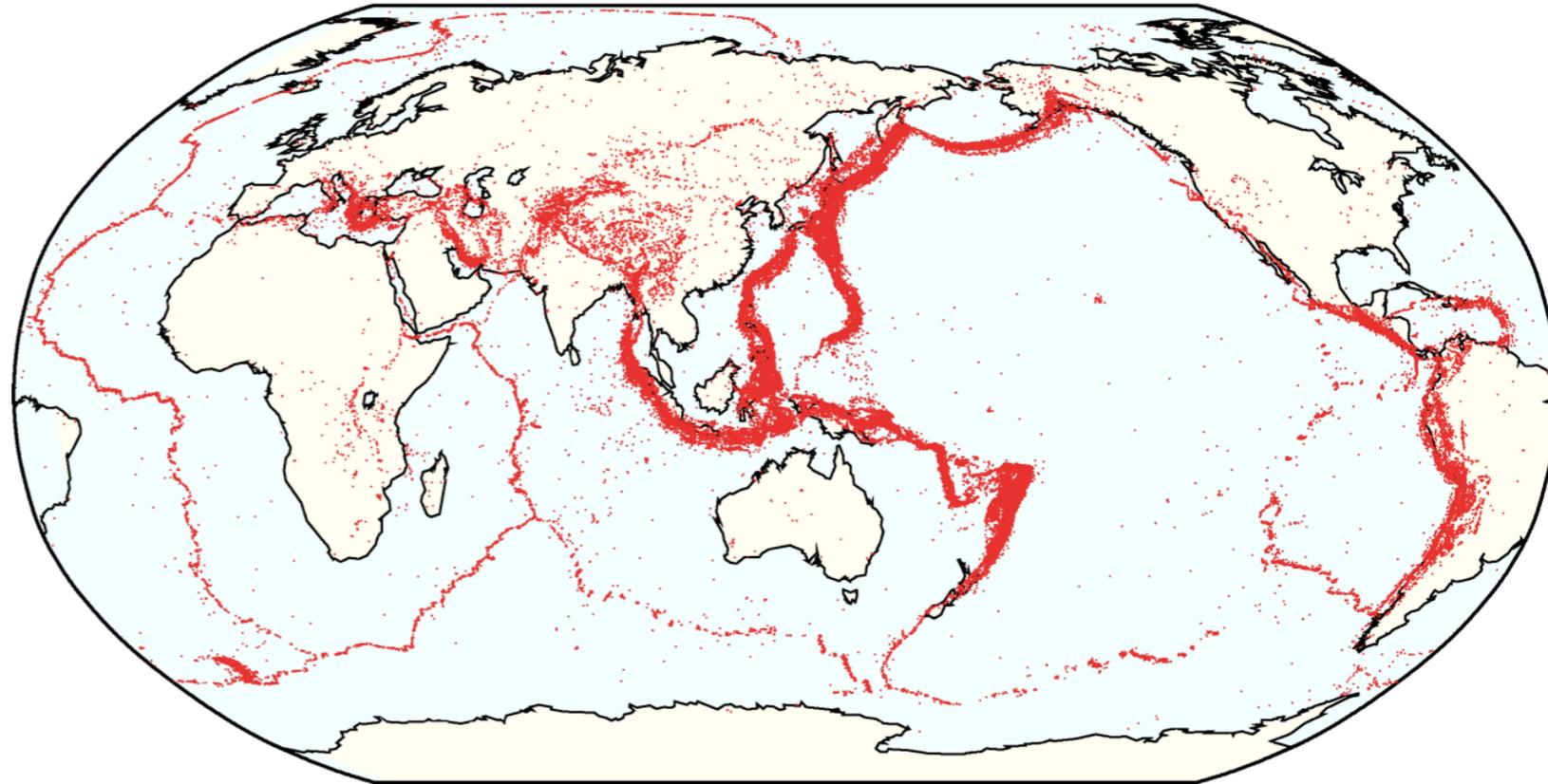
EHB 1960-2008, 141478 events



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- Good depth resolution due to use of; pP, pwP, sP, PcP as well as PKiKP, PKPdf, PKPbc, PKPab.

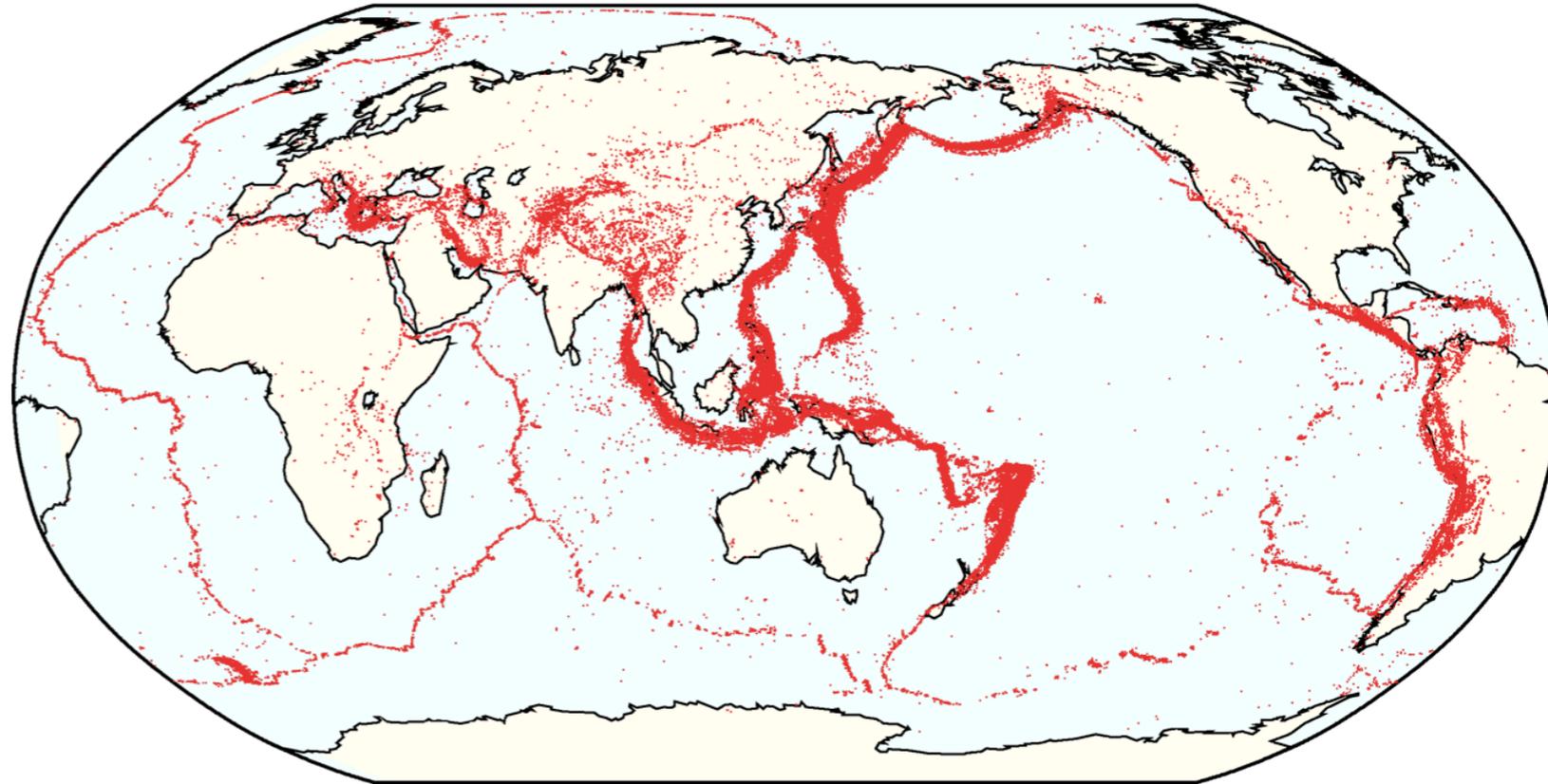
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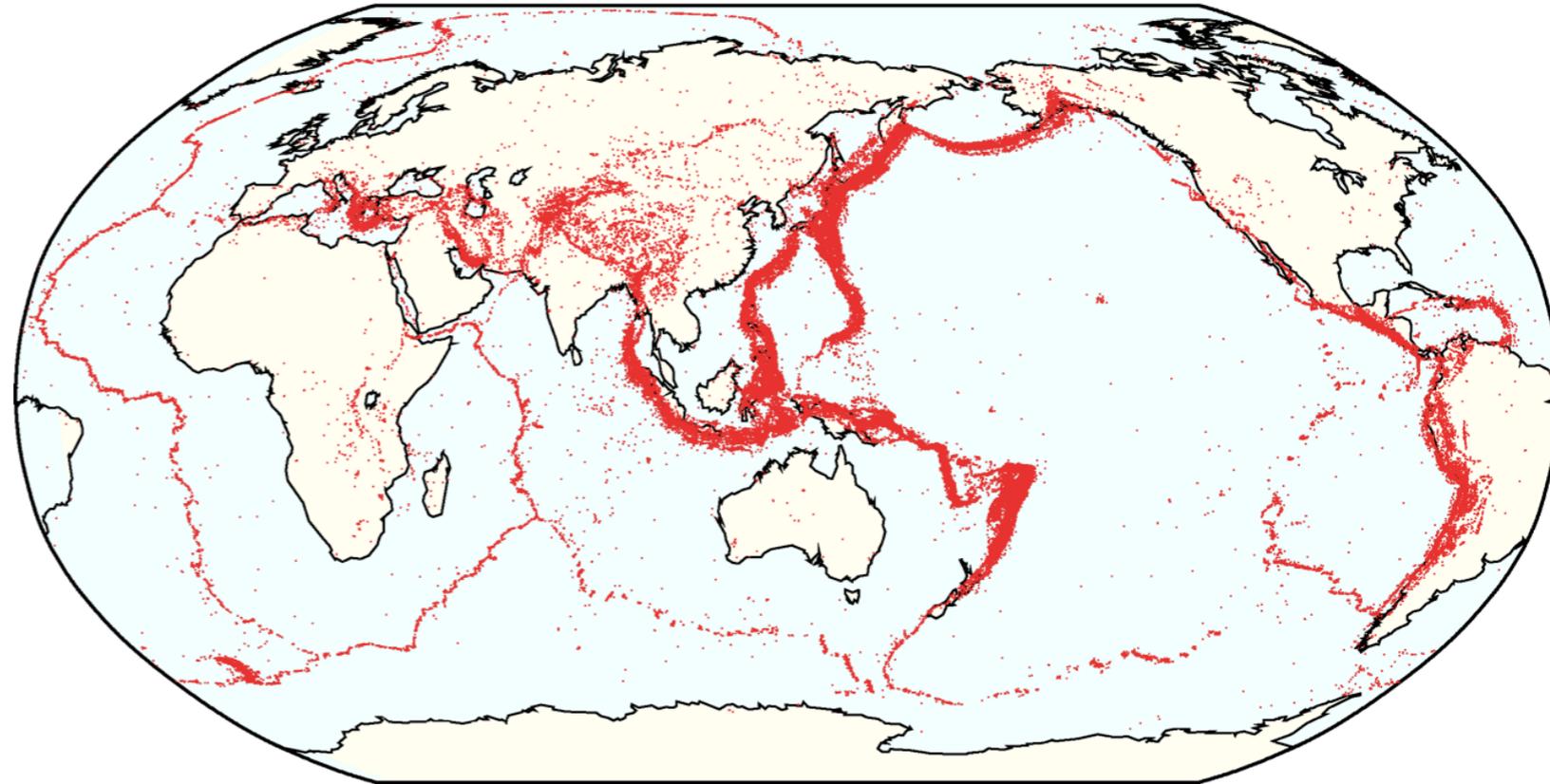
- A database of teleseismically well constrained events selected from ISC Bulletin and relocated using algorithm (Engdahl et al., 1998).
- Good depth resolution due to use of; pP, pwP, sP, PcP as well as PKiKP, PKPdf, PKPbc, PKPab.
- 141,478 events between 1964 and 2008.

EHB 1960-2008, 141478 events



# Engdahl, van der Hilst, Buland (EHB)

EHB 1960-2008, 141478 events



## Why extend it?

It is a valuable dataset for tomography and seismicity studies on regional and global scales.

## Why reinvent it?

Since 2008 the data quality and volume has increased so changes are needed to produce a cleaner and more robust dataset, the ISC-EHB.

# ISC-EHB: Event selection criteria

Events are selected from the ISC Bulletin if they meet both these criteria:

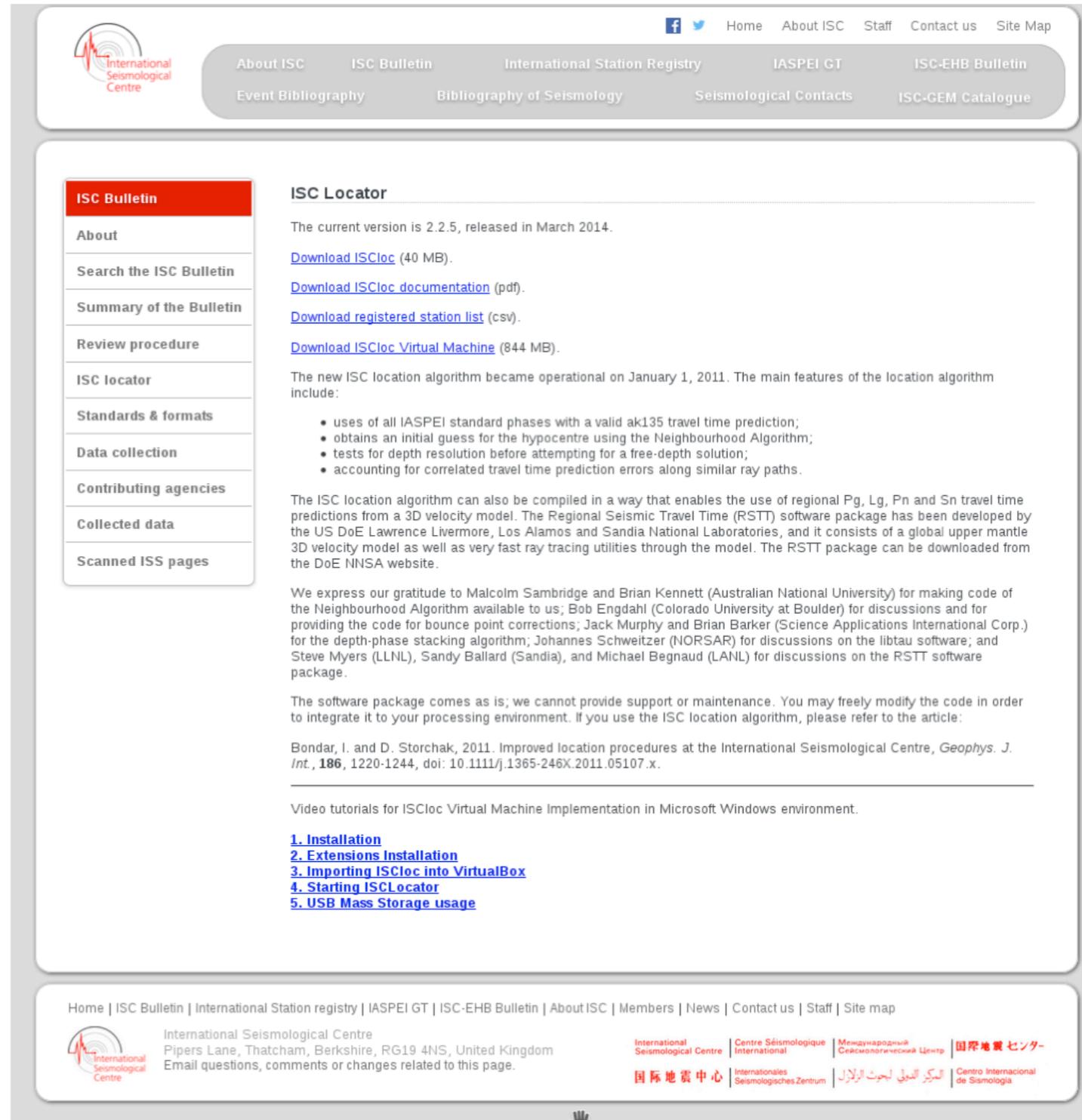
1) There are  $> 15$  teleseismic ( $>28^{\circ}$ ) time-defining stations with a secondary teleseismic azimuth gap  $< 180^{\circ}$ .

AND

2) The defining prime magnitude  $> 3.75$  (Di Giacomo & Storchak, 2016).

# ISC-EHB: Processing

1. ISCloc (Bondar & Storchak, 2011) is used to obtain an initial solution.



The screenshot shows the ISC website interface. At the top, there is a navigation bar with links for Home, About ISC, Staff, Contact us, and Site Map. Below this is a secondary navigation bar with links for About ISC, ISC Bulletin, International Station Registry, IASPEI GT, ISC-EHB Bulletin, Event Bibliography, Bibliography of Seismology, Seismological Contacts, and ISC-GEM Catalogue.

The main content area is titled "ISC Locator". It includes a sidebar menu on the left with options like "ISC Bulletin", "About", "Search the ISC Bulletin", "Summary of the Bulletin", "Review procedure", "ISC locator", "Standards & formats", "Data collection", "Contributing agencies", "Collected data", and "Scanned ISS pages".

The "ISC Locator" section contains the following text:

The current version is 2.2.5, released in March 2014.

[Download ISCloc](#) (40 MB).

[Download ISCloc documentation](#) (pdf).

[Download registered station list](#) (csv).

[Download ISCloc Virtual Machine](#) (844 MB).

The new ISC location algorithm became operational on January 1, 2011. The main features of the location algorithm include:

- uses of all IASPEI standard phases with a valid ak135 travel time prediction;
- obtains an initial guess for the hypocentre using the Neighbourhood Algorithm;
- tests for depth resolution before attempting for a free-depth solution;
- accounting for correlated travel time prediction errors along similar ray paths.

The ISC location algorithm can also be compiled in a way that enables the use of regional Pg, Lg, Pn and Sn travel time predictions from a 3D velocity model. The Regional Seismic Travel Time (RSTT) software package has been developed by the US DoE Lawrence Livermore, Los Alamos and Sandia National Laboratories, and it consists of a global upper mantle 3D velocity model as well as very fast ray tracing utilities through the model. The RSTT package can be downloaded from the DoE NNSA website.

We express our gratitude to Malcolm Sambridge and Brian Kennett (Australian National University) for making code of the Neighbourhood Algorithm available to us; Bob Engdahl (Colorado University at Boulder) for discussions and for providing the code for bounce point corrections; Jack Murphy and Brian Barker (Science Applications International Corp.) for the depth-phase stacking algorithm; Johannes Schweitzer (NORSAR) for discussions on the libtau software; and Steve Myers (LLNL), Sandy Ballard (Sandia), and Michael Begnaud (LANL) for discussions on the RSTT software package.

The software package comes as is; we cannot provide support or maintenance. You may freely modify the code in order to integrate it to your processing environment. If you use the ISC location algorithm, please refer to the article:

Bondar, I. and D. Storchak, 2011. Improved location procedures at the International Seismological Centre, *Geophys. J. Int.*, **186**, 1220-1244, doi: 10.1111/j.1365-246X.2011.05107.x.

Video tutorials for ISCloc Virtual Machine Implementation in Microsoft Windows environment.

[1. Installation](#)  
[2. Extensions Installation](#)  
[3. Importing ISCloc into VirtualBox](#)  
[4. Starting ISCLocator](#)  
[5. USB Mass Storage usage](#)

The footer of the page contains a navigation bar with links for Home, ISC Bulletin, International Station registry, IASPEI GT, ISC-EHB Bulletin, About ISC, Members, News, Contact us, Staff, and Site map. It also includes the International Seismological Centre logo and contact information: Pipers Lane, Thatcham, Berkshire, RG19 4NS, United Kingdom. Email questions, comments or changes related to this page. The footer also features the name of the centre in multiple languages: International Seismological Centre, Centre Sismologique International, Международный Сейсмологический Центр, 国際地震センター, 國際地震中心, Internationales Seismologisches Zentrum, المركز الدولي لبحوث الزلازل, and Centro Internacional de Sismología.

# ISC-EHB: Processing

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Bulletin of the Seismological Society of America, Vol. 88, No. 3, pp. 722–743, June 1998

## Global Teleseismic Earthquake Relocation with Improved Travel Times and Procedures for Depth Determination

by E. Robert Engdahl, Rob van der Hilst, and Raymond Buland

**Abstract** We relocate nearly 100,000 events that occurred during the period 1964 to 1995 and are well-constrained teleseismically by arrival-time data reported to the International Seismological Centre (ISC) and to the U.S. Geological Survey's National Earthquake Information Center (NEIC). Hypocenter determination is significantly improved by using, in addition to regional and teleseismic *P* and *S* phases, the arrival times of *PKiKP*, *PKPdf*, and the teleseismic depth phases *pP*, *pwP*, and *sP* in the relocation procedure. A global probability model developed for later-arriving phases is used to independently identify the depth phases. The relocations are compared to hypocenters reported in the ISC and NEIC catalogs and by other sources. Differences in our epicenters with respect to ISC and NEIC estimates are generally small and regionally systematic due to the combined effects of the observing station network and plate geometry regionally, differences in upper mantle travel times between the reference earth models used, and the use of later-arriving phases. Focal depths are improved substantially over most other independent estimates, demonstrating (for example) how regional structures such as downgoing slabs can severely bias depth estimation when only regional and teleseismic *P* arrivals are used to determine the hypocenter. The new data base, which is complete to about *Mw* 5.2 and includes all events for which moment-tensor solutions are available, has immediate application to high-resolution definition of Wadati–Benioff Zones (WBZs) worldwide, regional and global tomographic imaging, and other studies of earth structure.

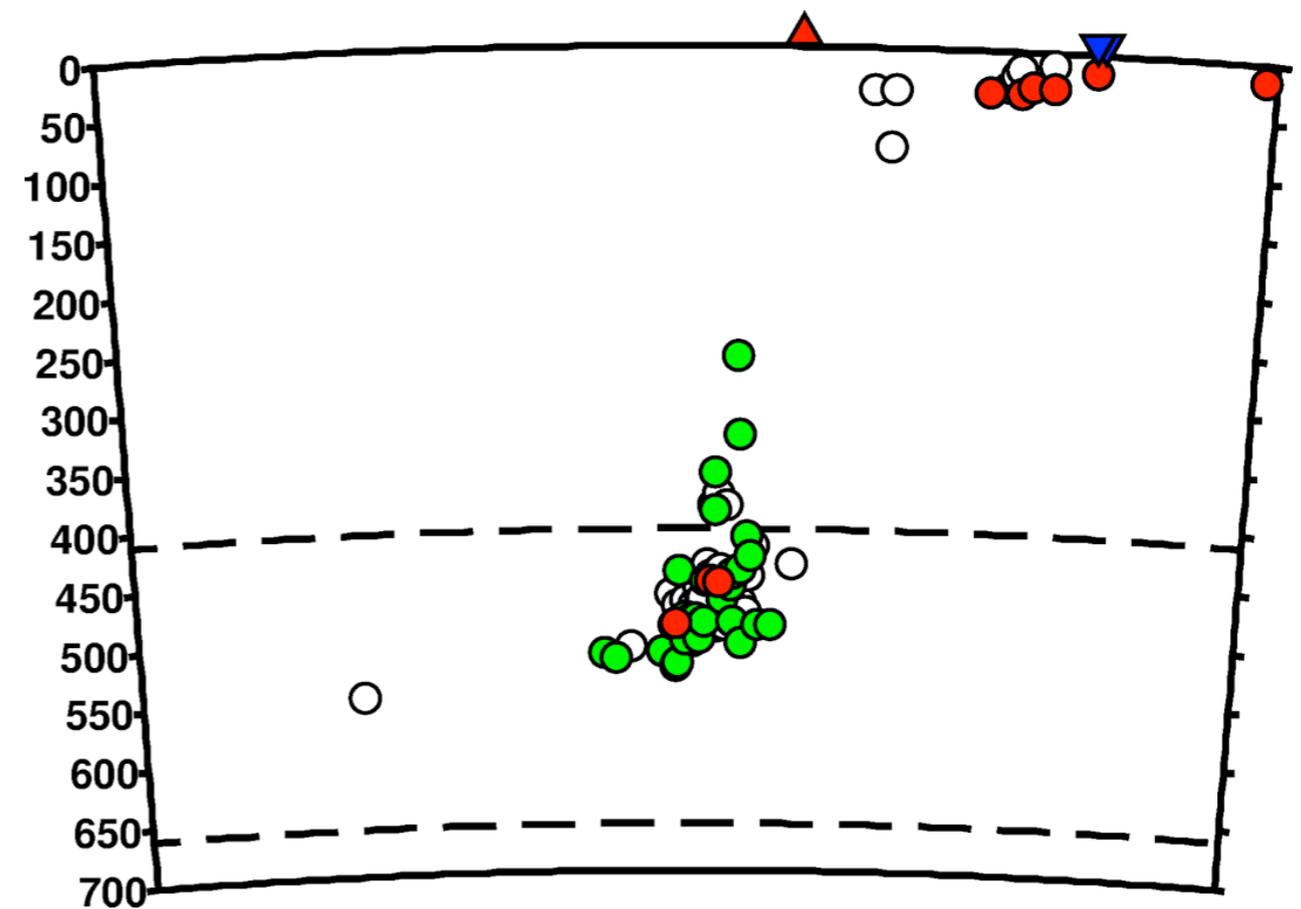
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1733408																									
FEQ	x	iter	=	2	0	3	7	h	=	1	4	59.55	lat	=	31.996	lon	=	50.904	depth	=	15.0	0.0	smdel	=	0.000
1733412																									
FEQMd	iter	=	2	0	3	7	h	=	4	32	17.99	lat	=	19.139	lon	=	-104.172	depth	=	10.0	0.0	smdel	=	0.000	
0	3	7	COLM	0.46	18.85	264.84	100.08	84.68	Pg	iP	iP	4	32	25.36	-1.74	0.0	0.4								
			COLM	0.46				84.68	Sg	iS	iS	4	32	31.46	-1.55	0.0	0.1								
0	3	7	CJM	0.90	19.04	113.40	95.86	293.69	+	Pg	iP	iP	4	32	34.94	-0.34	0.0	0.4							
			CJM	0.90				293.69	Sg	iS	iS	4	32	48.16	1.18	0.0	0.1								
0	3	7	ZIIG	2.99	13.75	301.07	45.92	120.23	+	Pn	eP	eP	4	33	4.28	-1.18	0.0	0.4							
			ANMO	15.88				353.12	PcP	eS	eS	4	40	39.38	-21.50*	0.4	0.0								
			NVAR	22.81				330.36	PcP		PcP	4	41	13.60	-1.44*	-1.4	2.1	0.0							
			PDAR	23.99				350.21	PcP		PcP	4	41	14.90	-1.91*	-1.9	1.5	0.0							
			ULM	31.74				10.14	PcP	PcP	PcP	4	41	31.98	-1.10*	-1.1	-0.4	0.0							
			SADO	32.97				33.62	PcP	PcP	PcP	4	41	36.76	0.18*	0.2	-0.4	0.0							
			YKA	43.92				353.04	PcP	PP	PcP	4	42	9.96	-0.24*	-0.2	-0.4	0.0							
			SCHQ	45.52				29.46	PcP	PcP	PcP	4	42	17.90	1.92*	1.9	-0.3	0.0							
			ILAR	53.69				338.85	PcP	PcP	PcP	4	42	45.80	0.06*	0.1	-0.2	0.0							
1733414																									
FEQMx	iter	=	2	0	3	7	h	=	5	48	20.50	lat	=	-49.190	lon	=	164.658	depth	=	10.0	0.0	smdel	=	0.000	
			ARMA	21.20				327.41	PcP	eS	eS	5	57	12.90	-0.67*	-0.7	2.0	0.0							
			ASAR	35.10				305.37	PcP	PcP	PcP	5	57	44.70	0.65*	0.6	-1.5	0.0							
1733416																									
FEQ	x	iter	=	2	0	3	7	h	=	6	28	24.60	lat	=	23.360	lon	=	142.658	depth	=	155.0	0.0	smdel	=	0.000
			WMQ	49.16				308.43	PcP	PcP	PcP	6	38	18.50	0.23*	0.2	0.4	0.0							
0	3	7	YKA	75.22	5.81	292.02	154.15	27.93	pP	epP	eP	6	40	25.70	-0.48*	-0.5	-6.4	-0.2	0.0						
1753014																									
FEQ	x	iter	=	2	0	3	7	h	=	12	39	29.10	lat	=	-20.273	lon	=	168.793	depth	=	30.0	0.0	smdel	=	0.000
0	3	7	BKM	2.64	13.75	168.72	53.87	348.54	-	Pn	iPn	iP	12	40	9.50	-0.23	0.0	0.4							
0	3	7	DZM	2.83	13.75	51.21	53.86	230.37	+	Pn	ePn	eP	12	40	10.36	-2.02	0.0	0.4							
0	3	7	NOUC	2.95	13.75	52.40	53.86	231.50	Pn	ePn	eP	12	40	12.59	-1.36	0.0	0.4								
			STKA	26.95				239.10	PcP	PcP	PcP	12	48	30.60	1.12*	1.1	-0.1	0.0							
			ASAR	32.48				257.56	PcP	PcP	PcP	12	48	44.18	1.62*	1.6	-1.5	0.0							
			ASPA	32.49				257.56	pwP	esP	epP	12	46	10.30	-1.46*	6.7	-1.5	3.5	-0.6	0.0					

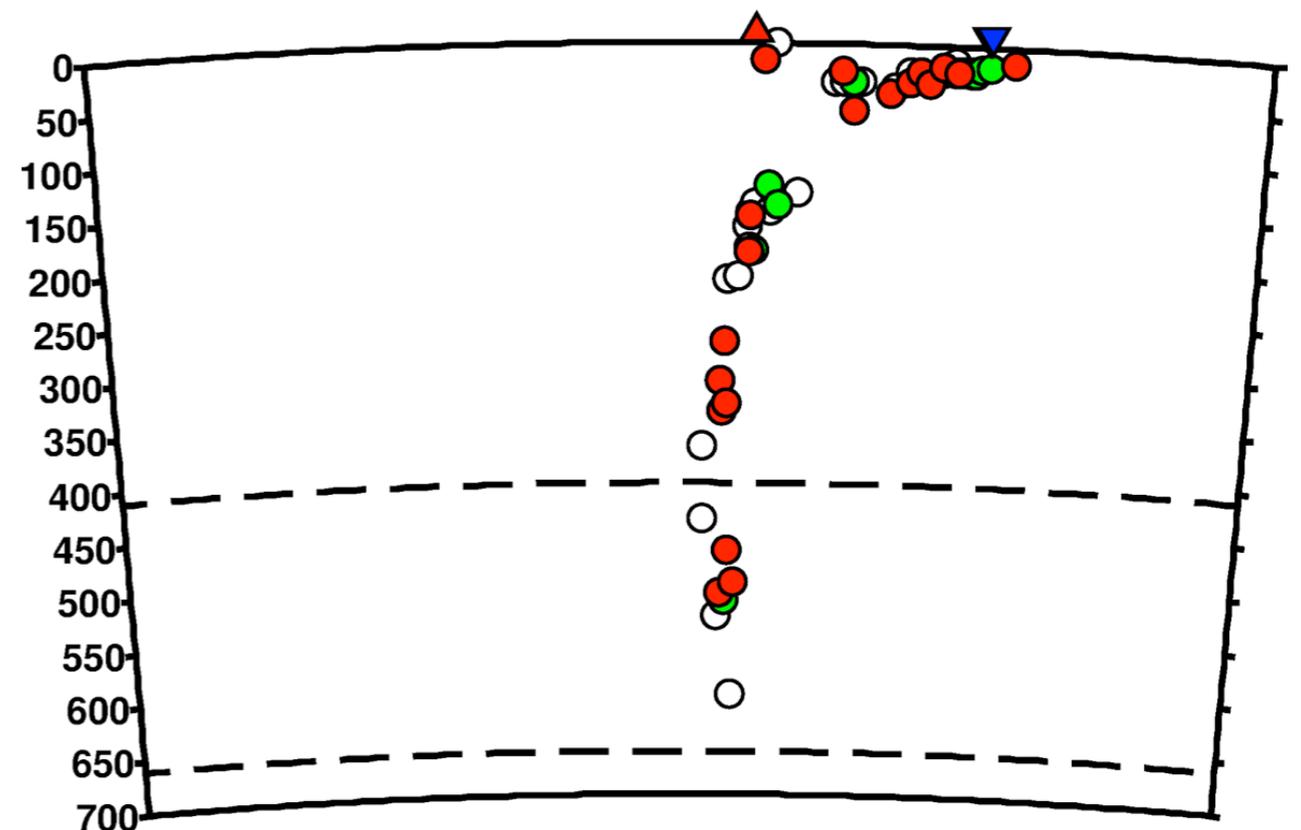
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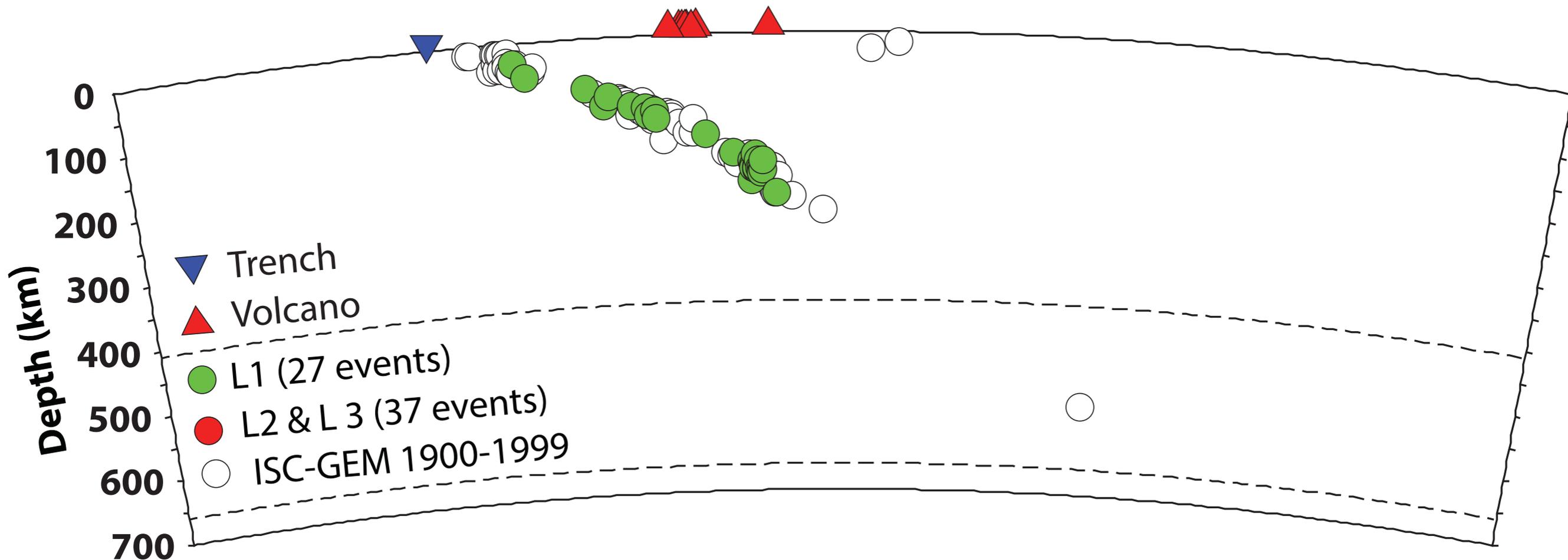
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5. These plots are used to confirm or modify poorly constrained depths.



# ISC-EHB: Depth Categories

**Level (L1)** - Free depth with standard depth error  $< 5$  km, or fixed depth well constrained by depth phases.

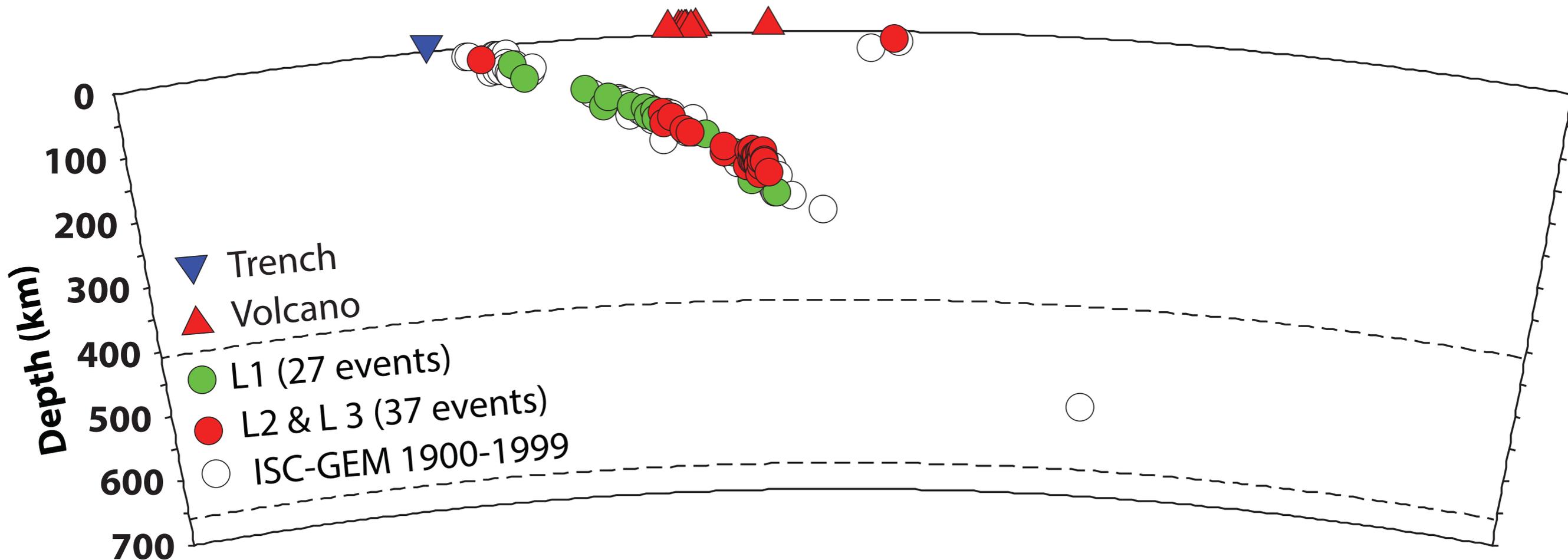


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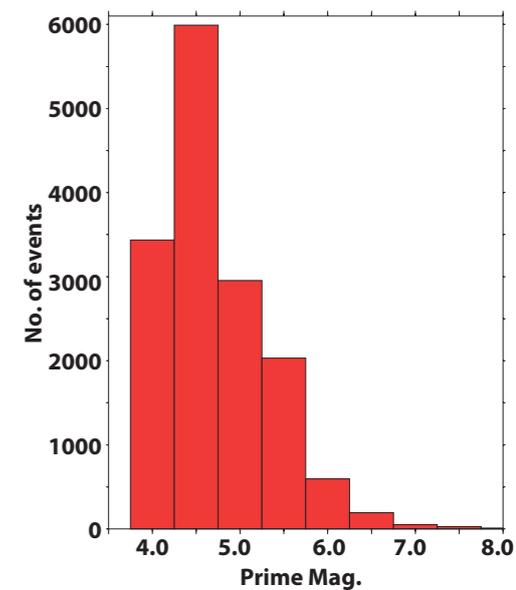
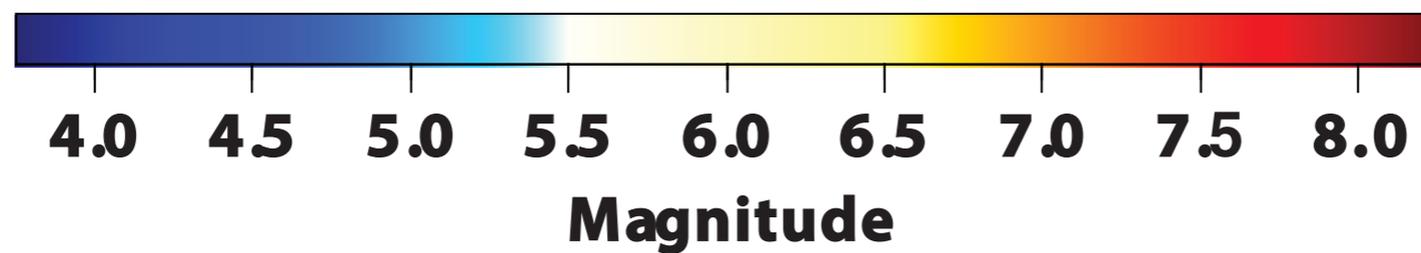
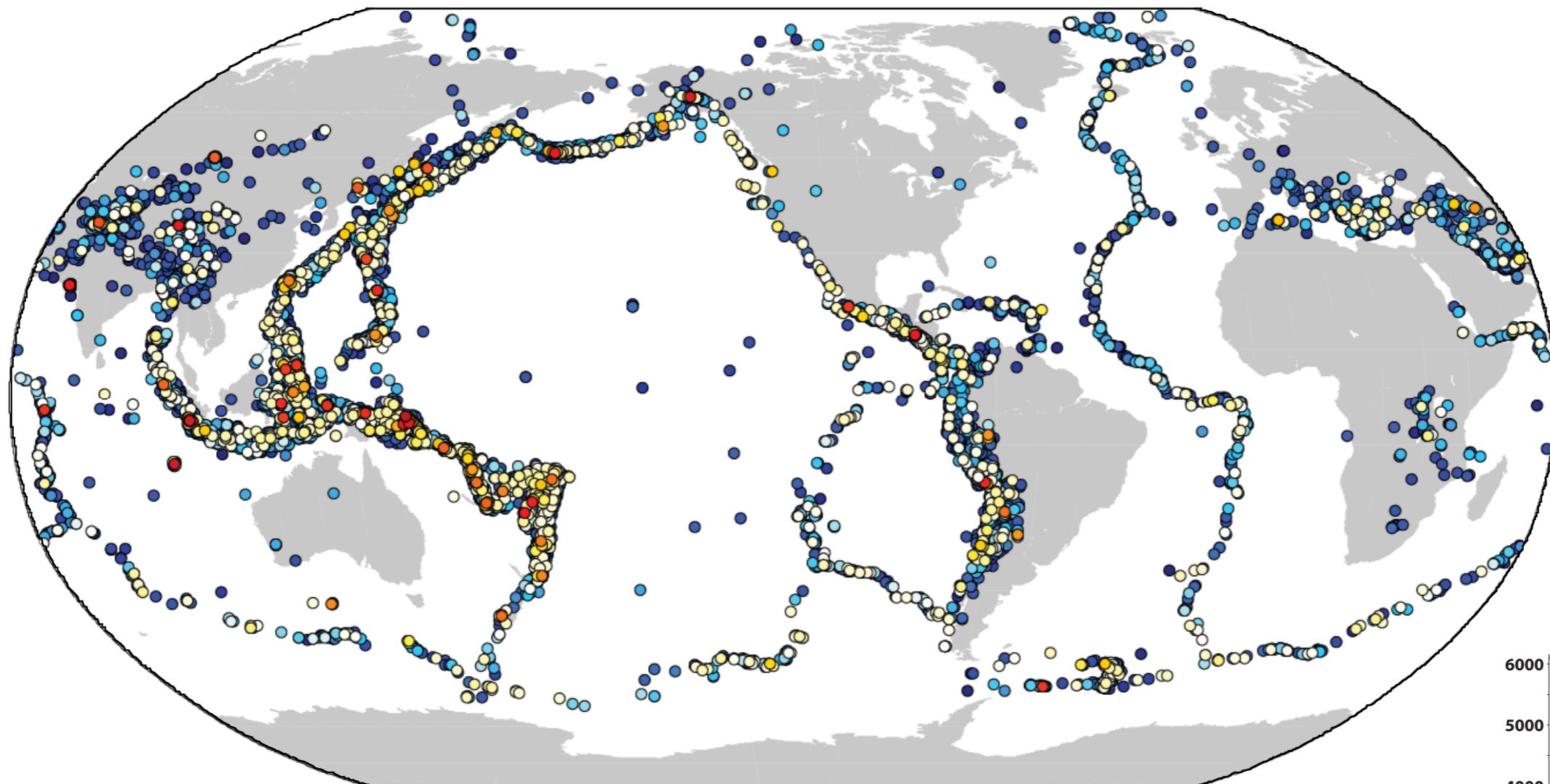
**Level (L2)** - Free depth with depth error 6 - 15 km, or a fixed depth based on the GCMT solution.

**Level (L3)** - Free depth with depth error  $> 15$  km, or a fixed depth based on review of local/nearby seismicity, or tectonic regions.



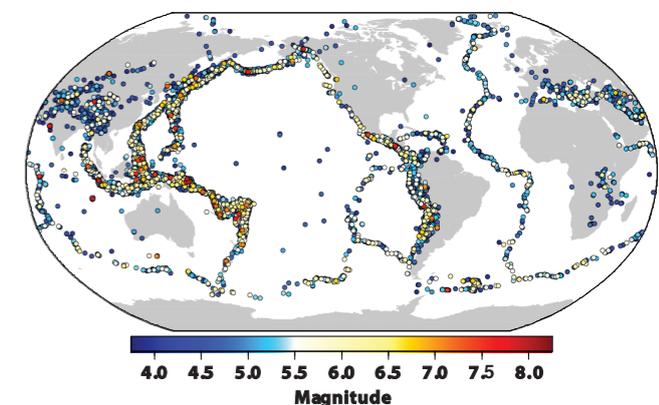
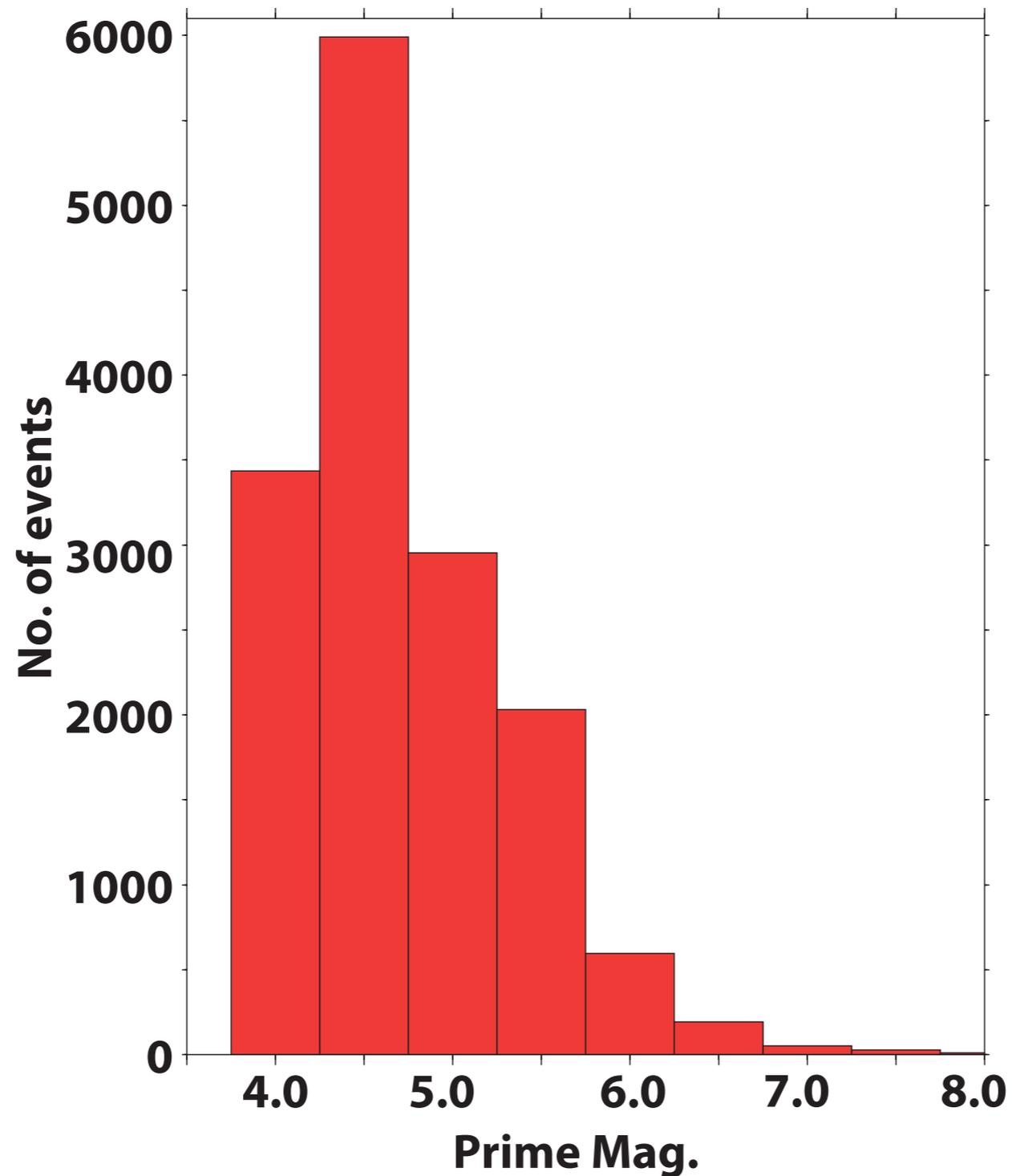
# ISC-EHB 2003: Location and Magnitude

15,133 events between 2000-2003



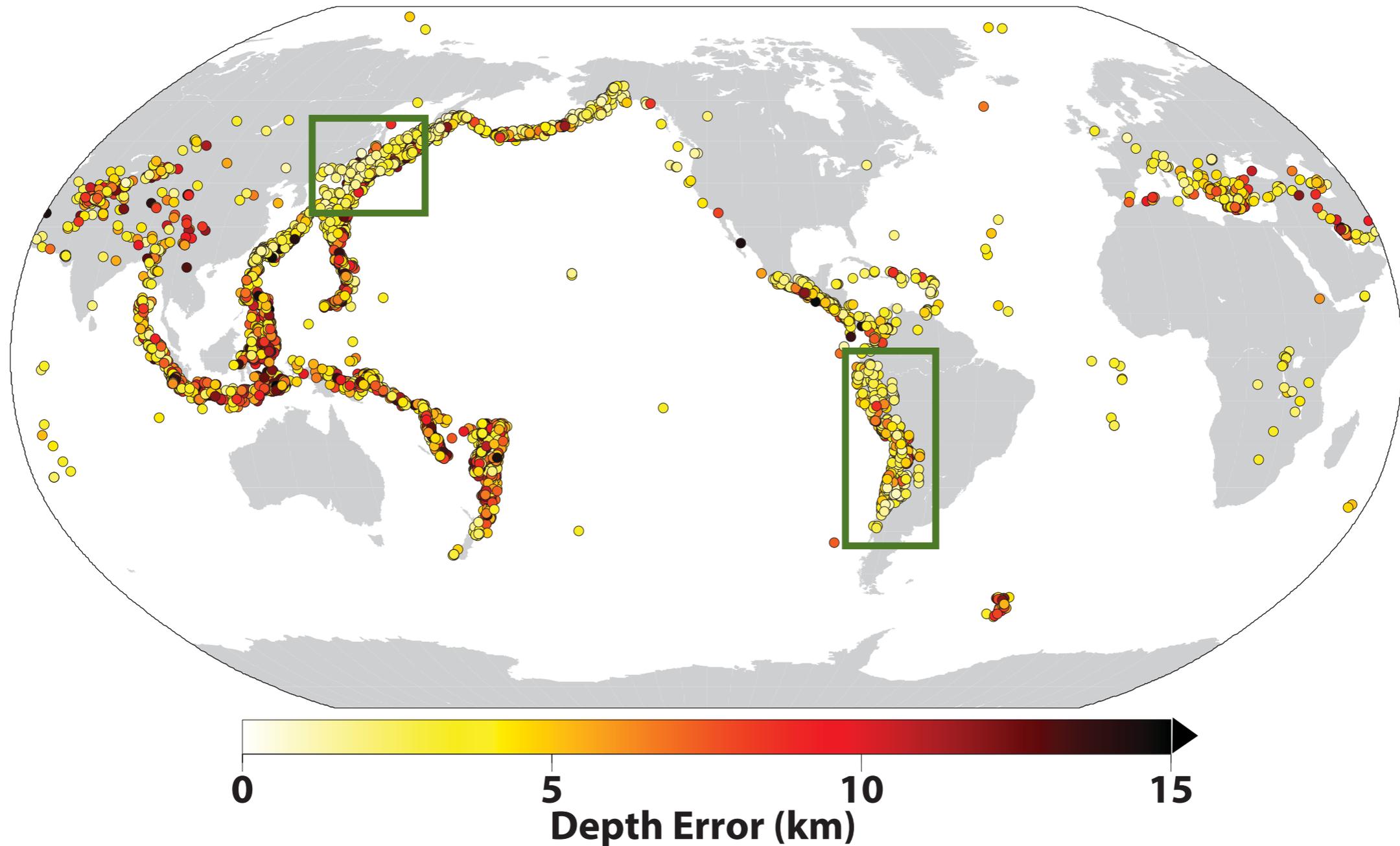
# ISC-EHB 2003: Location and Magnitude

15,133 events between 2000-2003  
Magnitude range 3.7 - 8.3



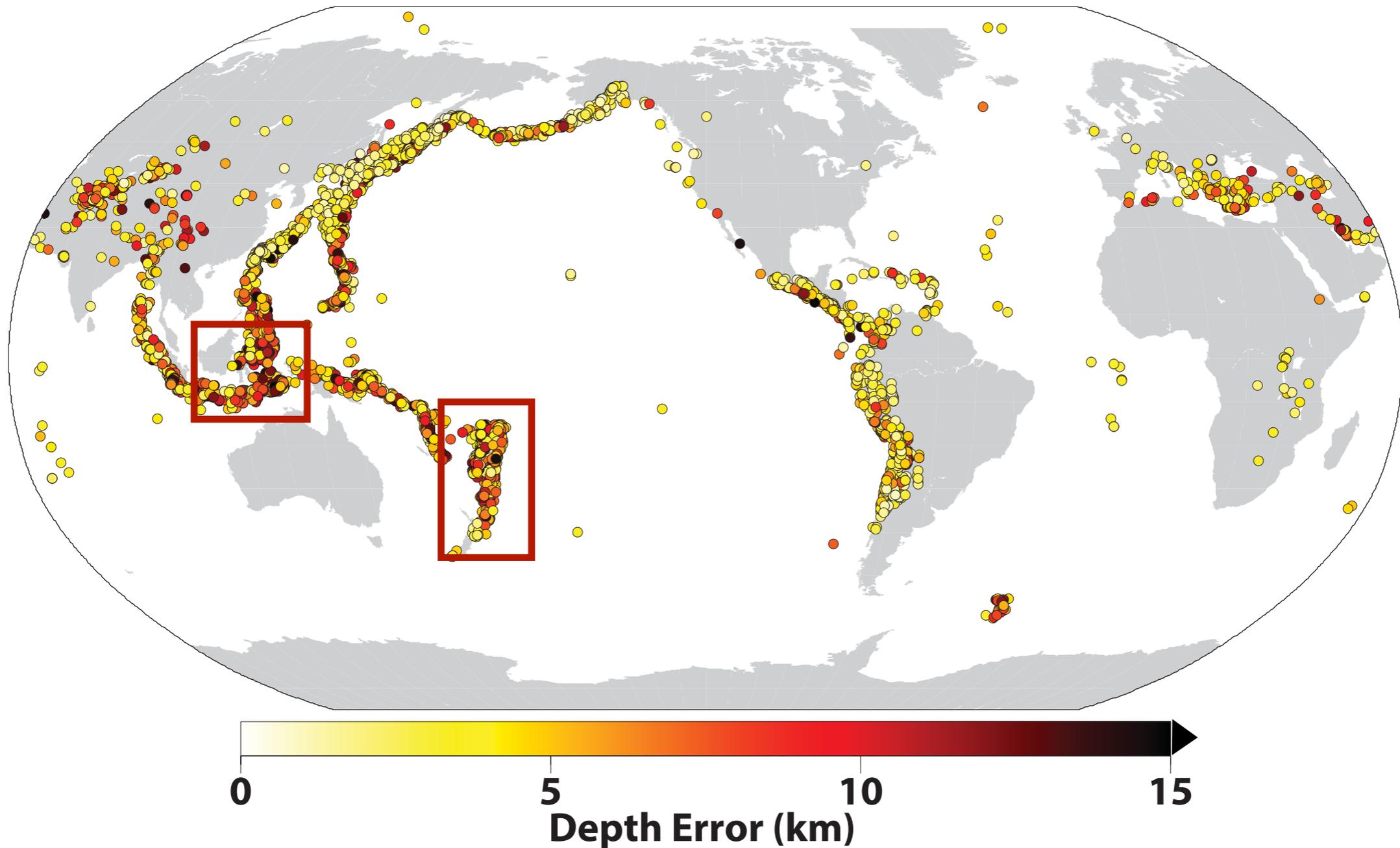
# ISC-EHB 2003: Depth error

Depth Category	No. events	Median (km)
L1	5760	3.3
L2	2878	8.7
L3	6658	n/a

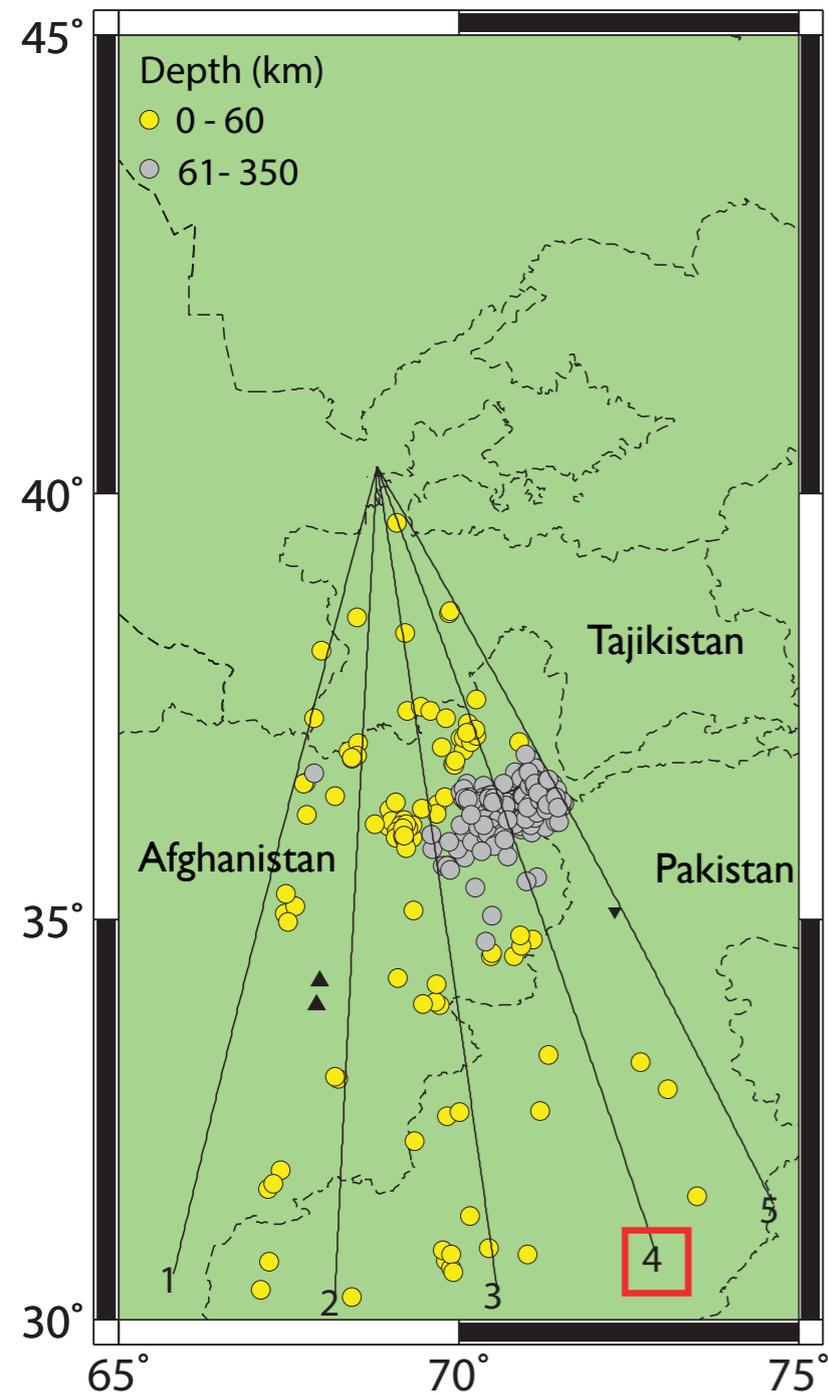


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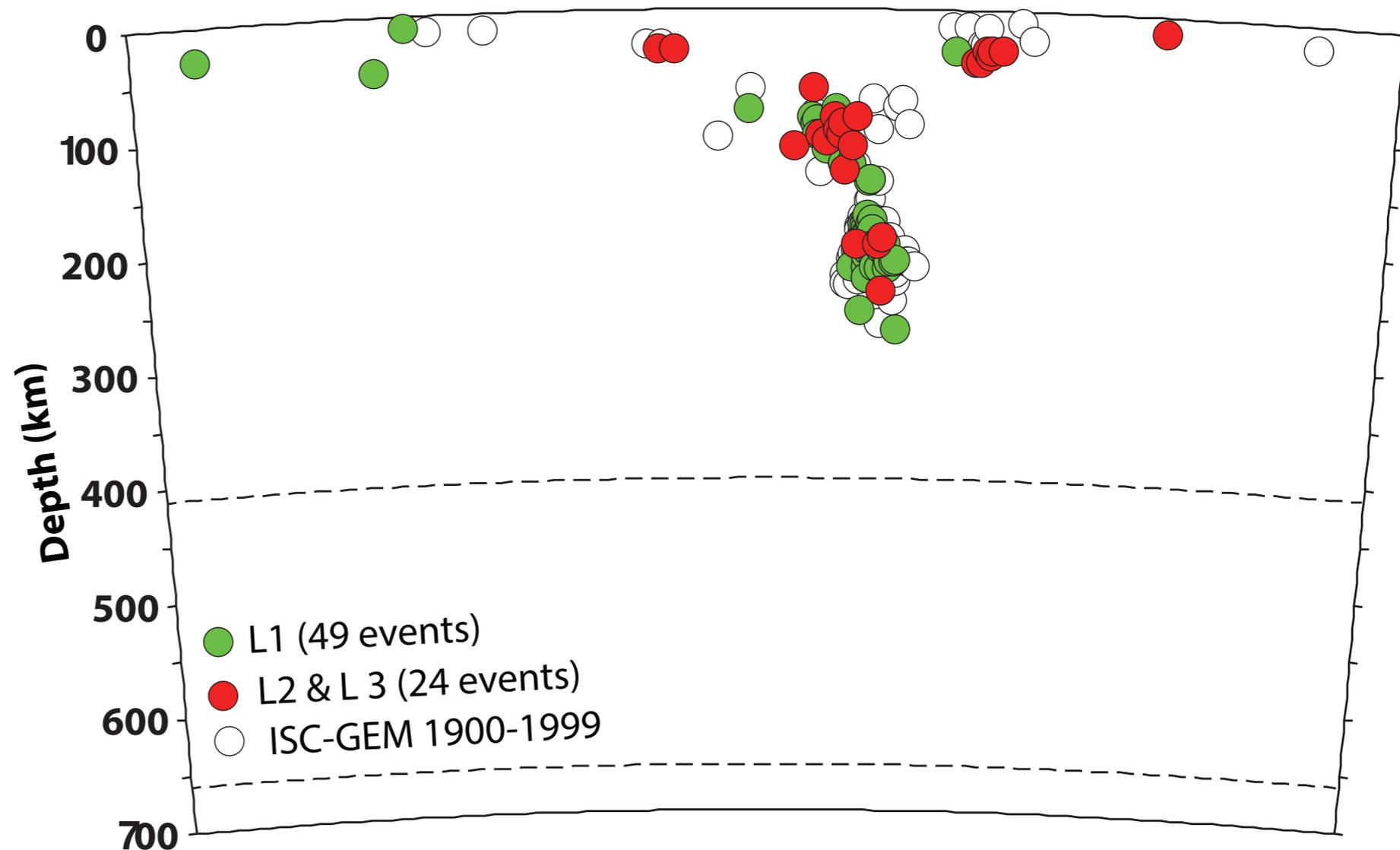
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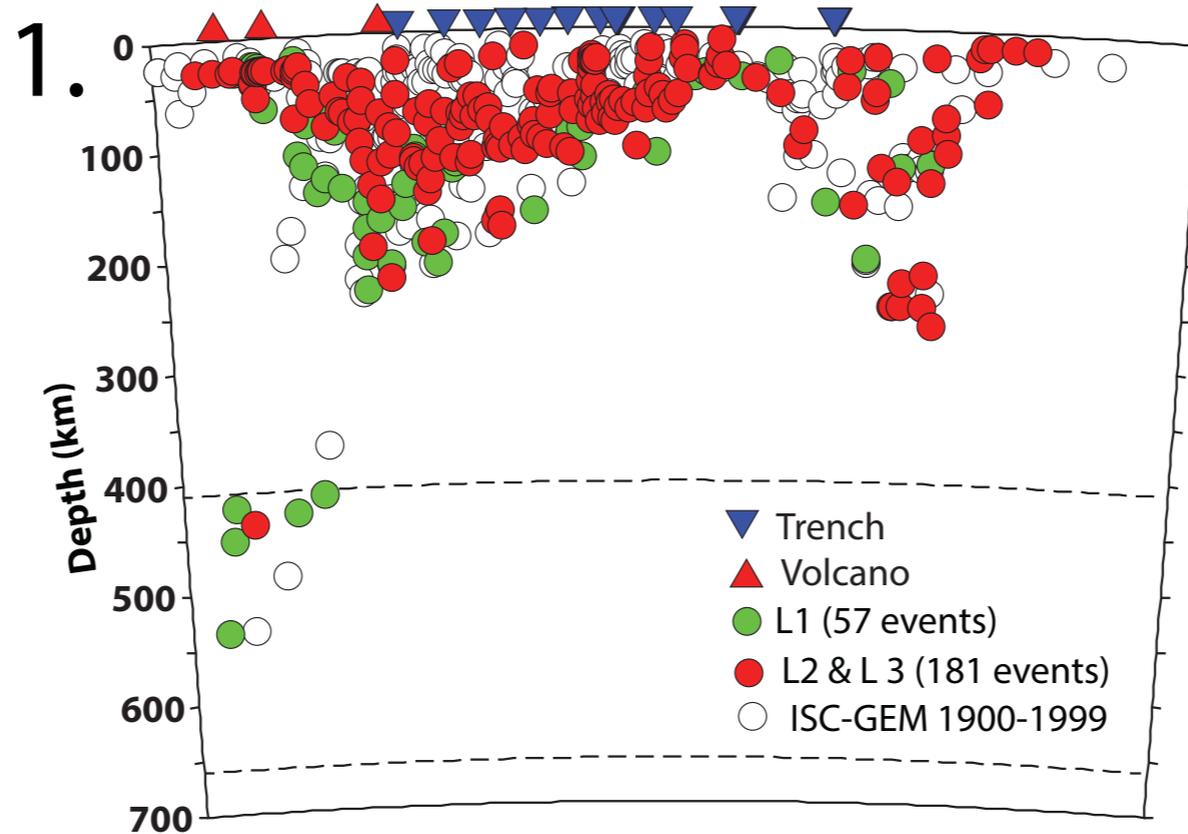
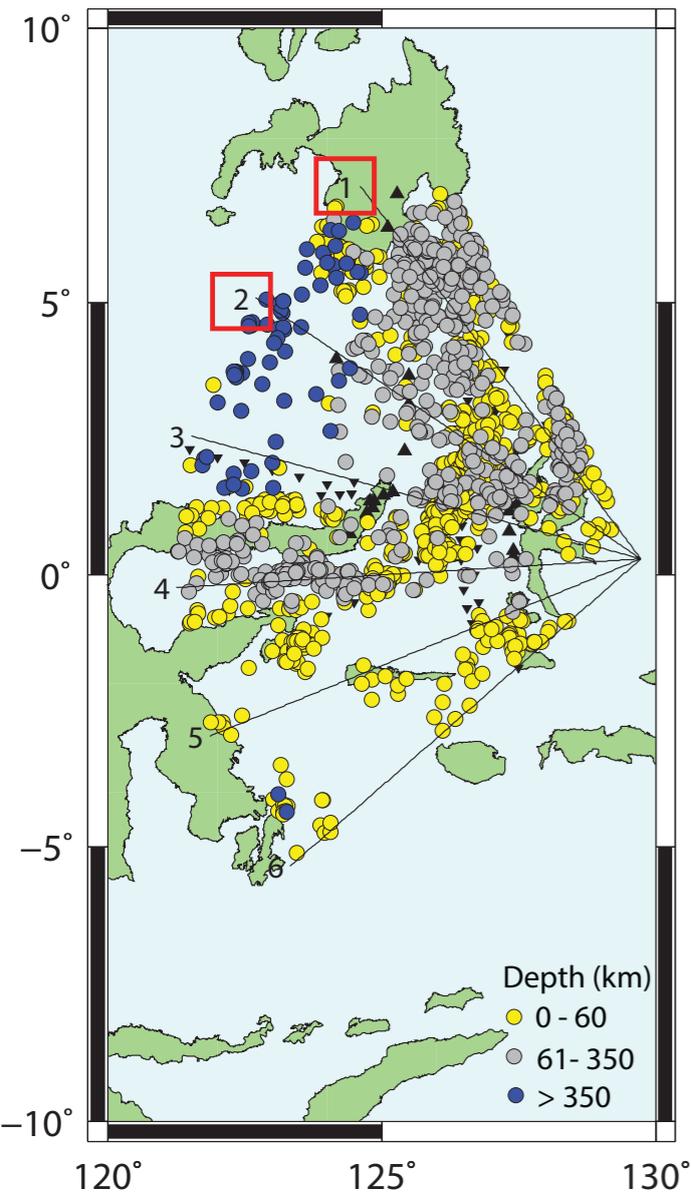
# Intermediate depth - Hindu Kush



Cluster at intermediate depth, similar shape to that reported in other studies Sipl et al. (2013)

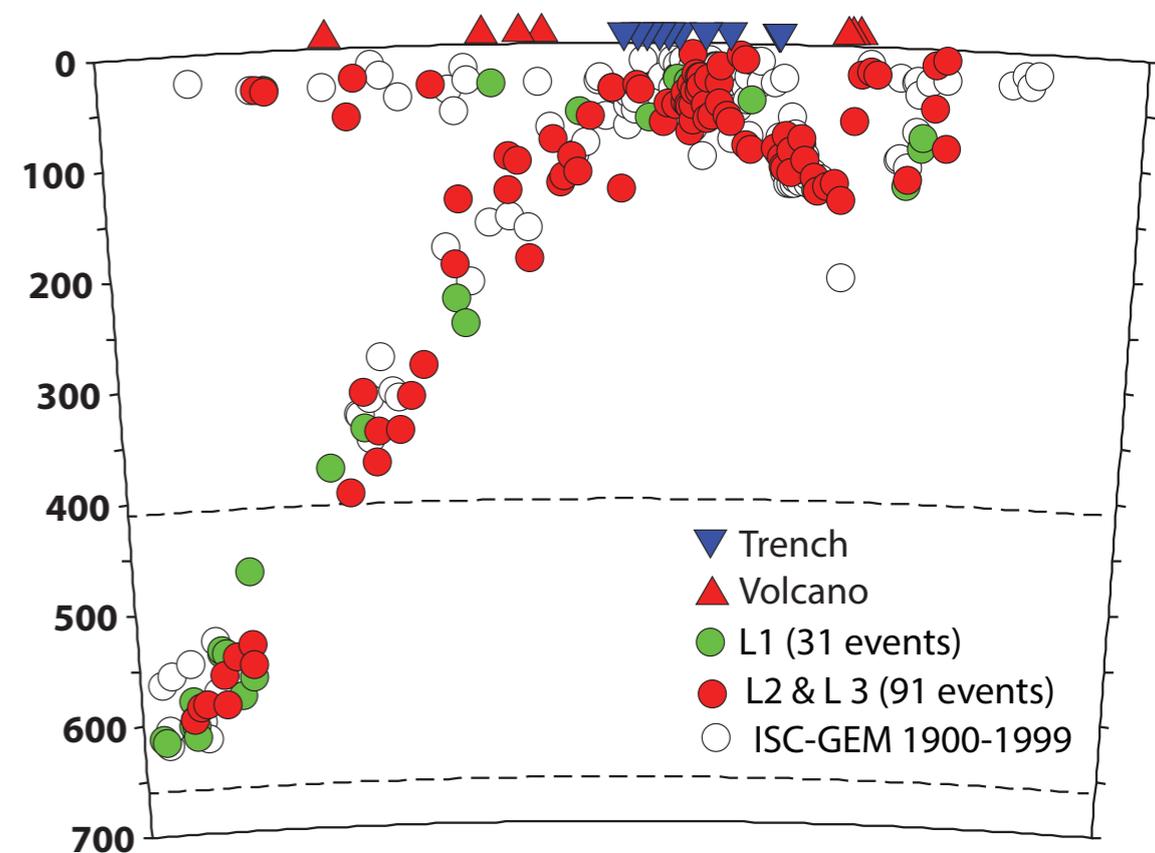


# Complicated regions - Halmahera



In some regions  
it is easier to  
identify a  
structure and  
outliers.

2.



# Comparison with other catalogues

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## **Original EHB**

- Original EHB 20,632 events between 2000-2003.
- 525 new events.
- Median distance between EHB and ISC-EHB locations is 2 km, and difference in depth is 4 km.

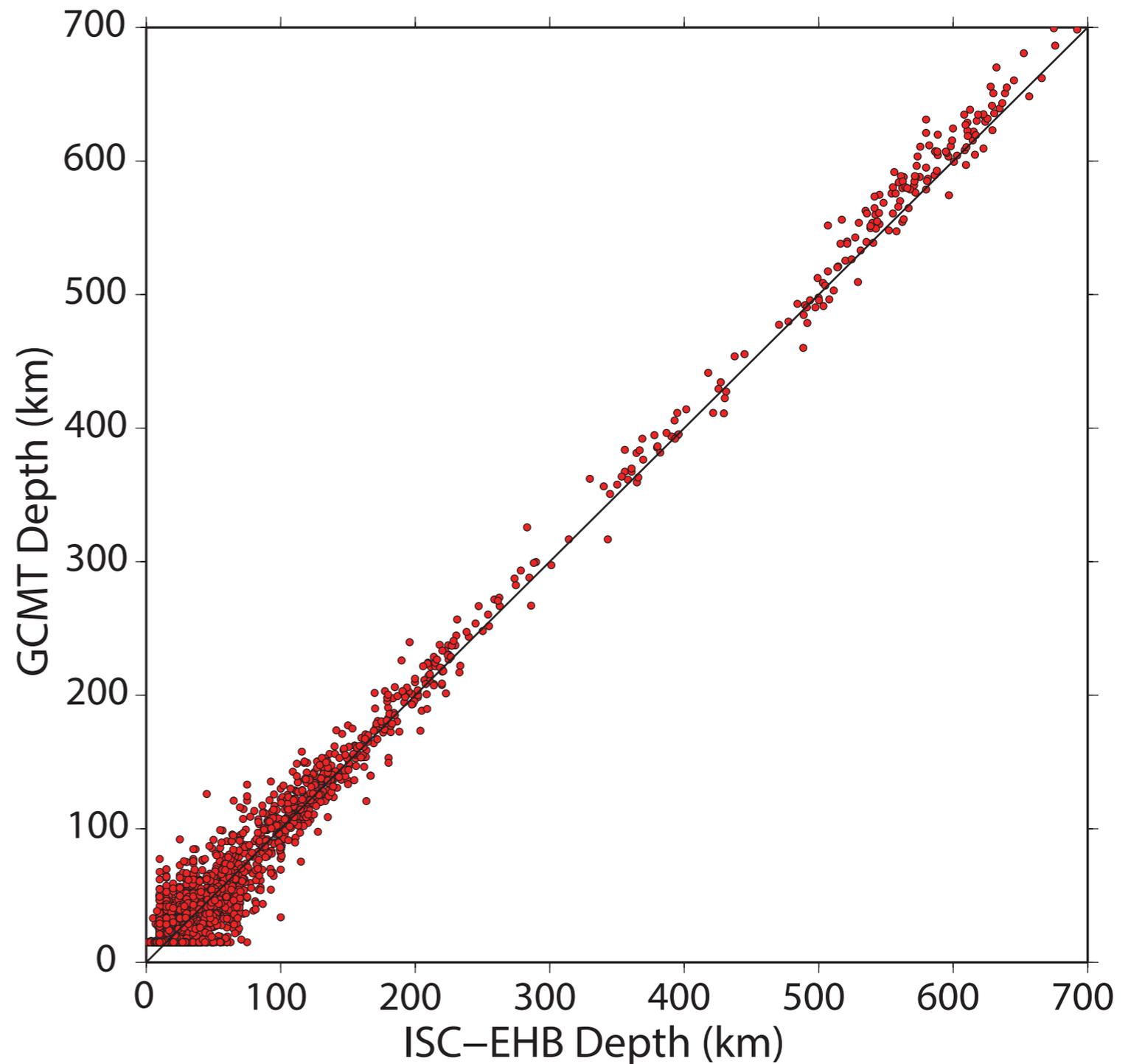
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## GCMT

- General good agreement between ISC-EHB and GCMT.
- Greater bias at large depths.
- Large scatter at shallow depths.





# Summary

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- New more rigorous procedures for event selection and processing are applied to produce the ISC-EHB earthquake database.

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## **What data are available now and where?**

The ISC-EHB Bulletin contains 136,024 seismic events from 1964-2008, where the period 2000-2003 has been rebuilt.

[www.isc.ac.uk/isc-ehb](http://www.isc.ac.uk/isc-ehb)

# Future Plans

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- Subduction zone cross sections for 2000-2003 will be available soon.
- Currently processing 2004-2013, which will hopefully be released later in 2017.
- Process 1964-1999.

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Download ISC-EHB at: [www.isc.ac.uk/isc-ehb](http://www.isc.ac.uk/isc-ehb)  
Any questions about ISC-EHB, email me at [jen@isc.ac.uk](mailto:jen@isc.ac.uk)

# Acknowledgements

**64** Institutions in **48** countries, including the **Royal Society**, **BGS** and **Blacknest** in UK, make the annual **membership** subscriptions to the ISC.

**14** international, public or commercial entities sponsor individual ISC **projects**:



**CTBTO**

PREPARATORY COMMISSION

*CTBTO Link to ISC database*

**REF TEK**  
A DIVISION OF TRIMBLE

**GeoSIG**  
swiss made to measure



**güralp**

*International Station Registry*



*ISC Event Bibliography*



**OYO**  
oyo corporation

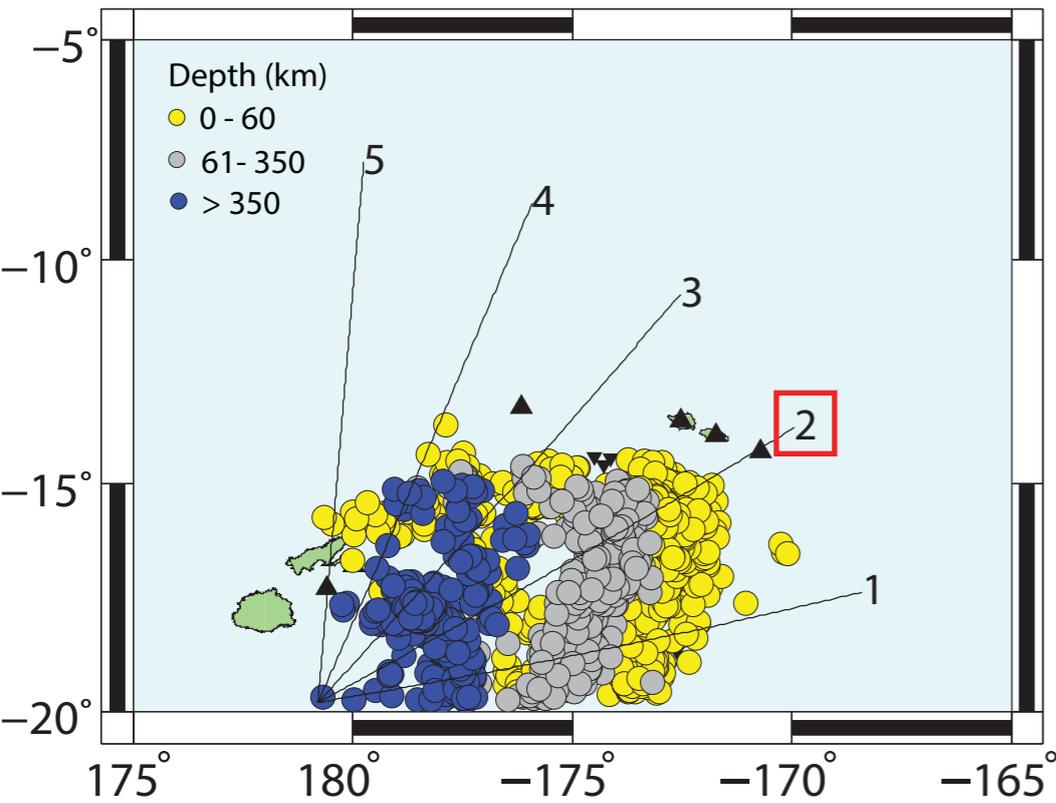
THE LIGHTHILL  
RISK NETWORK

*Aon Benfield,  
Lloyd's,  
Guy Carpenter,  
Catlin.*

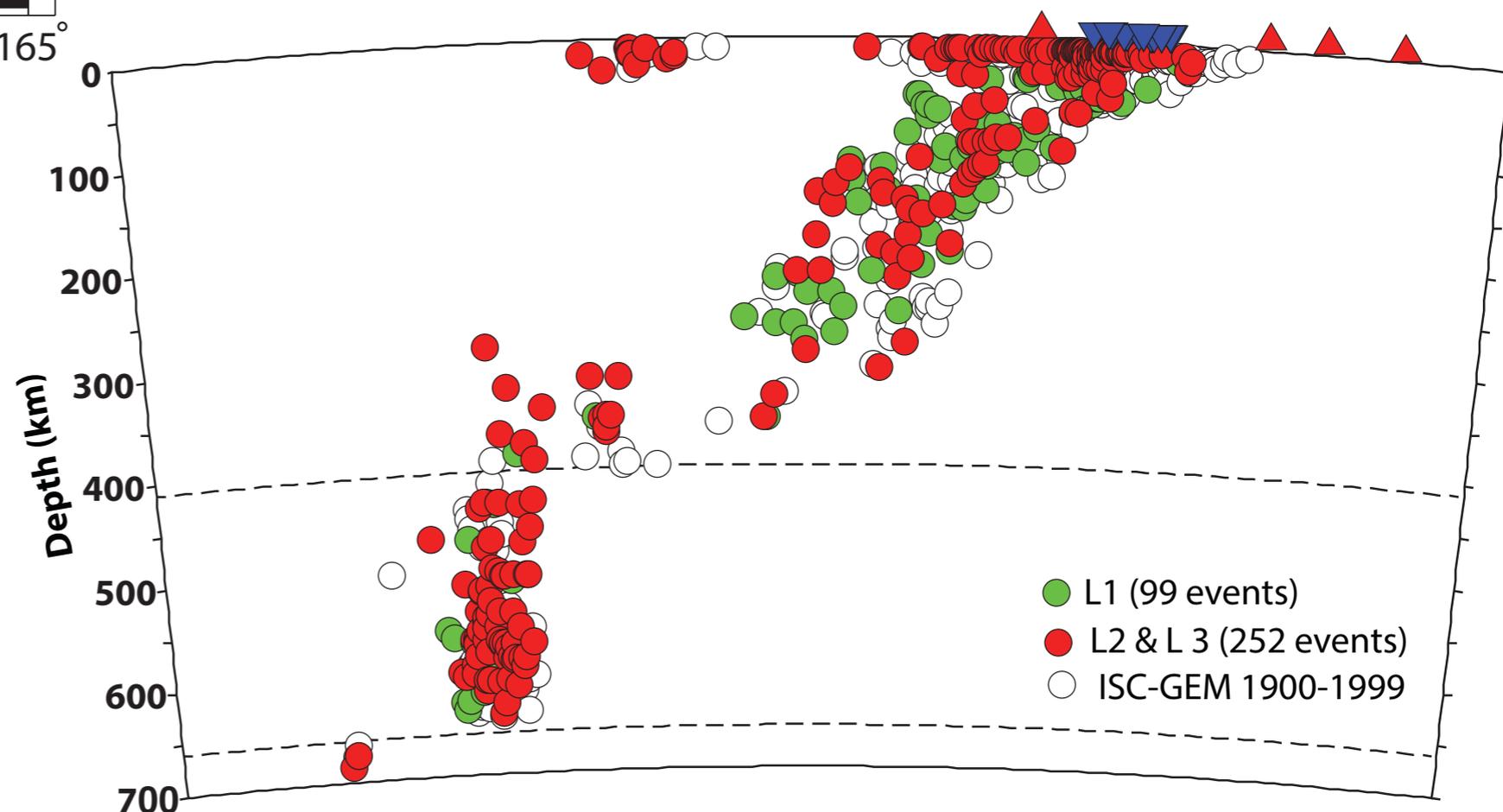


*ISC-GEM Catalogue*

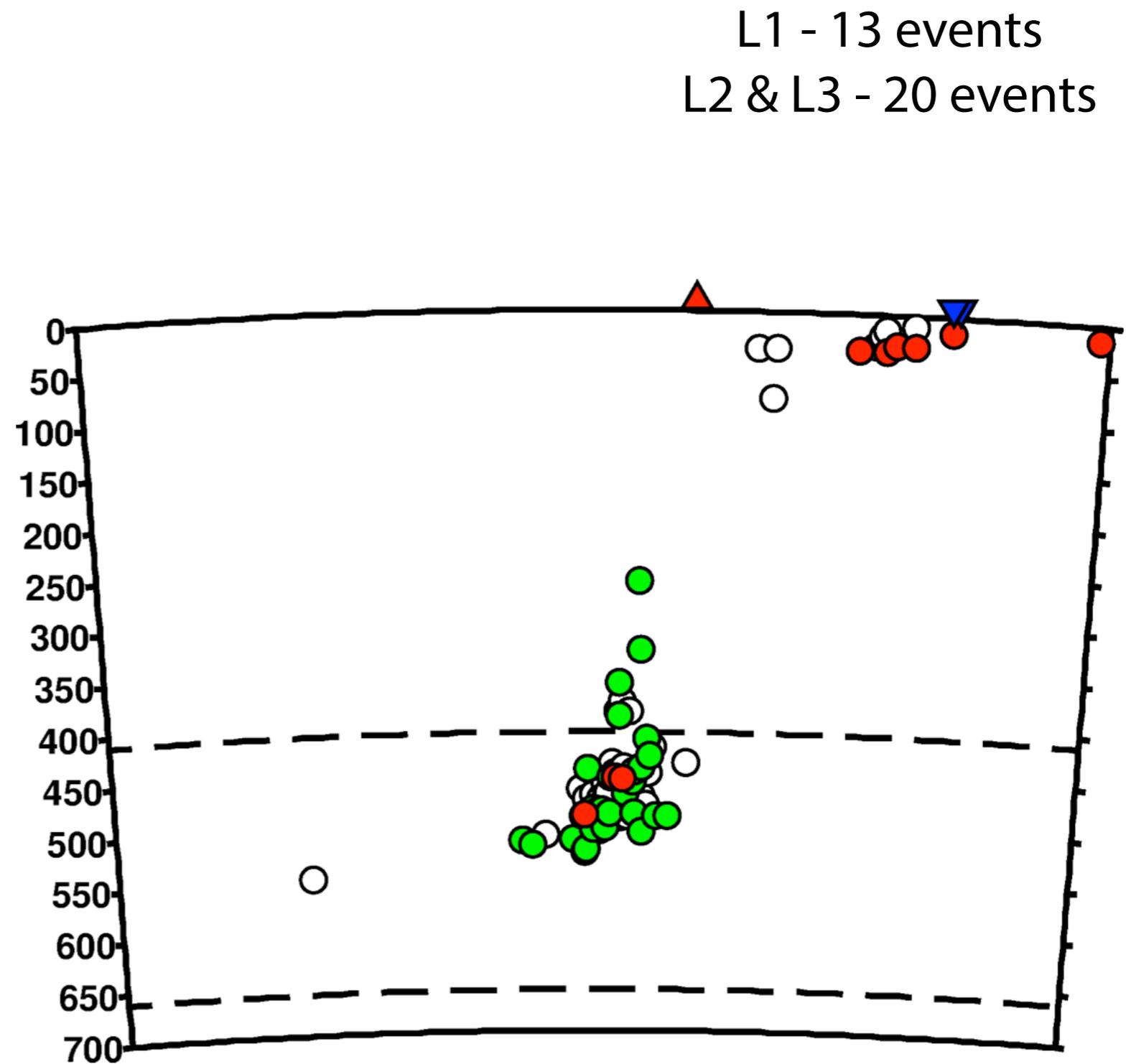
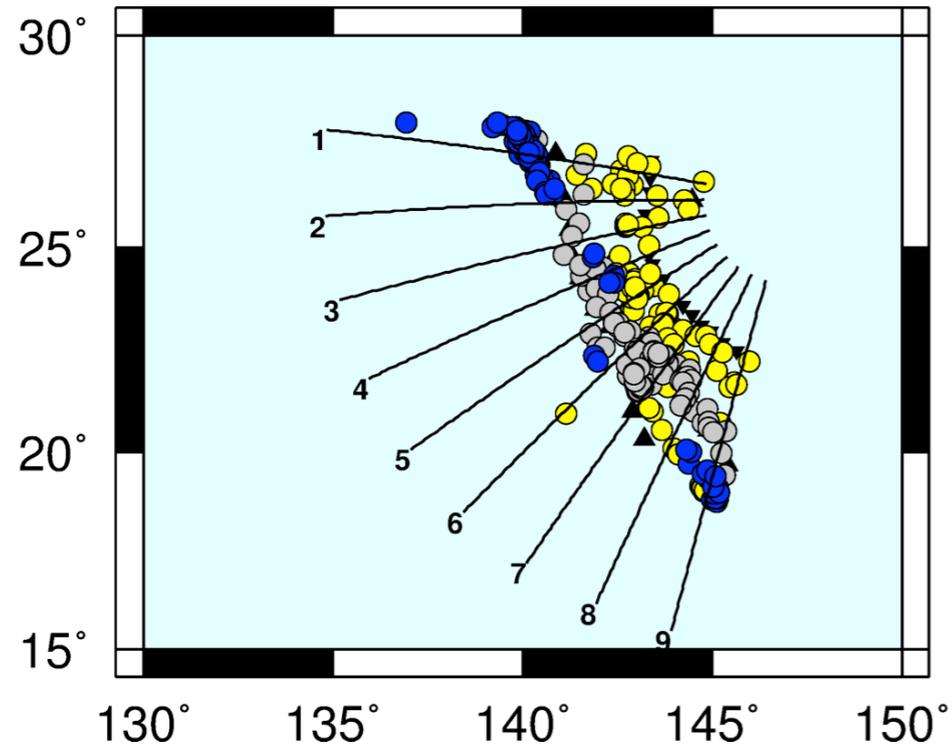
# Subduction zone structure - Tonga



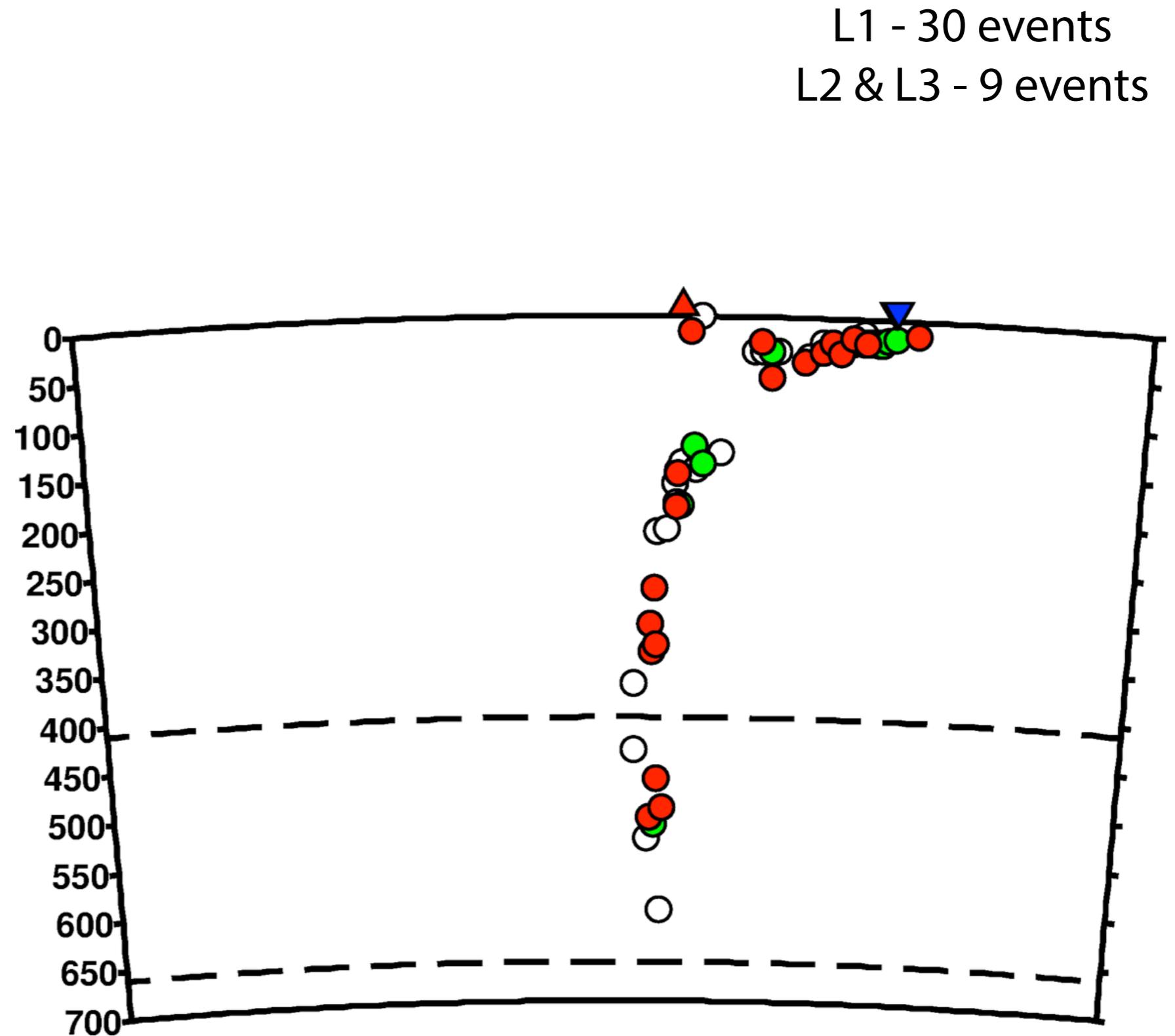
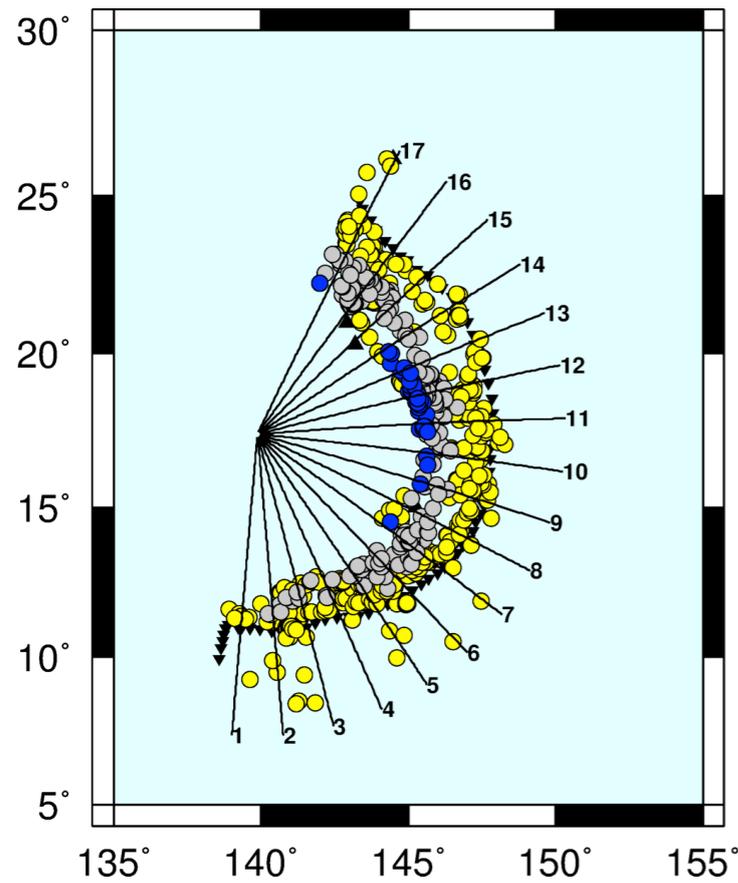
- Subduction zones feature heavily in the dataset.
- In regions of good azimuthal coverage some structures can be seen clearly.
- A potential detached slab structure is observed in Tonga.



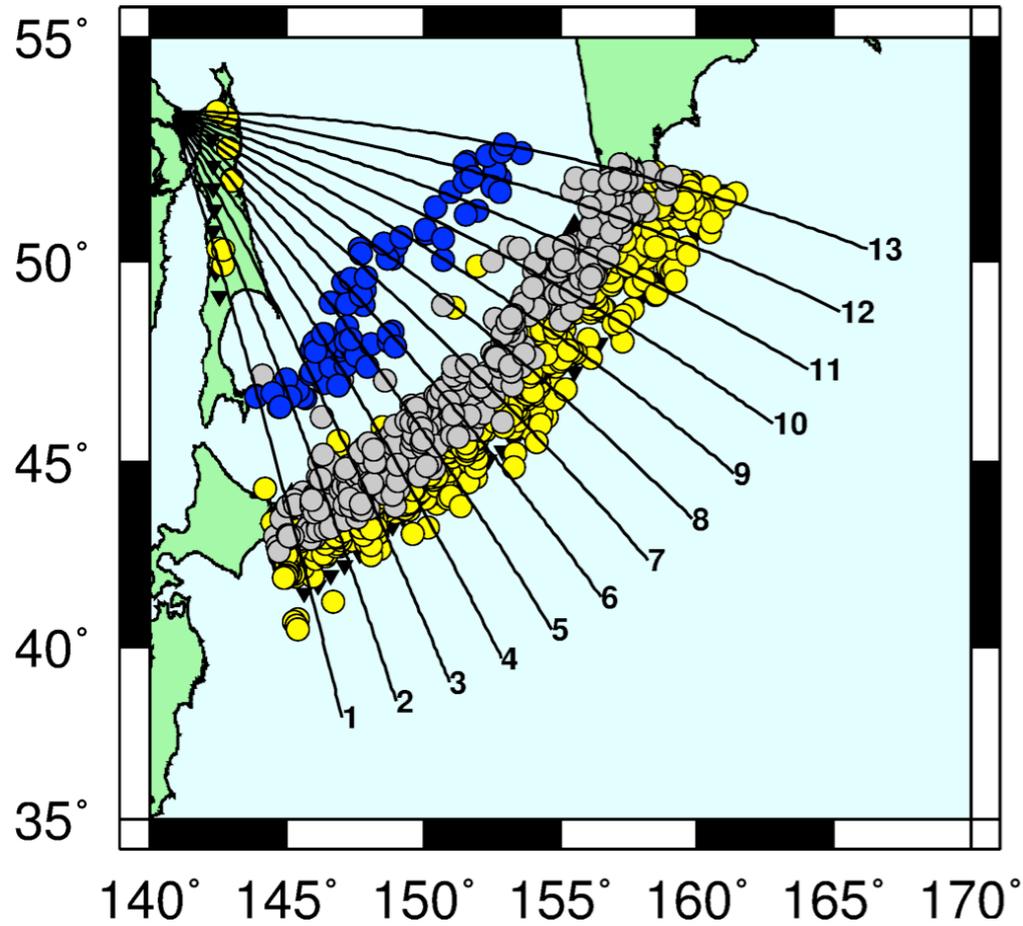
# Bonin - Cross Section 1



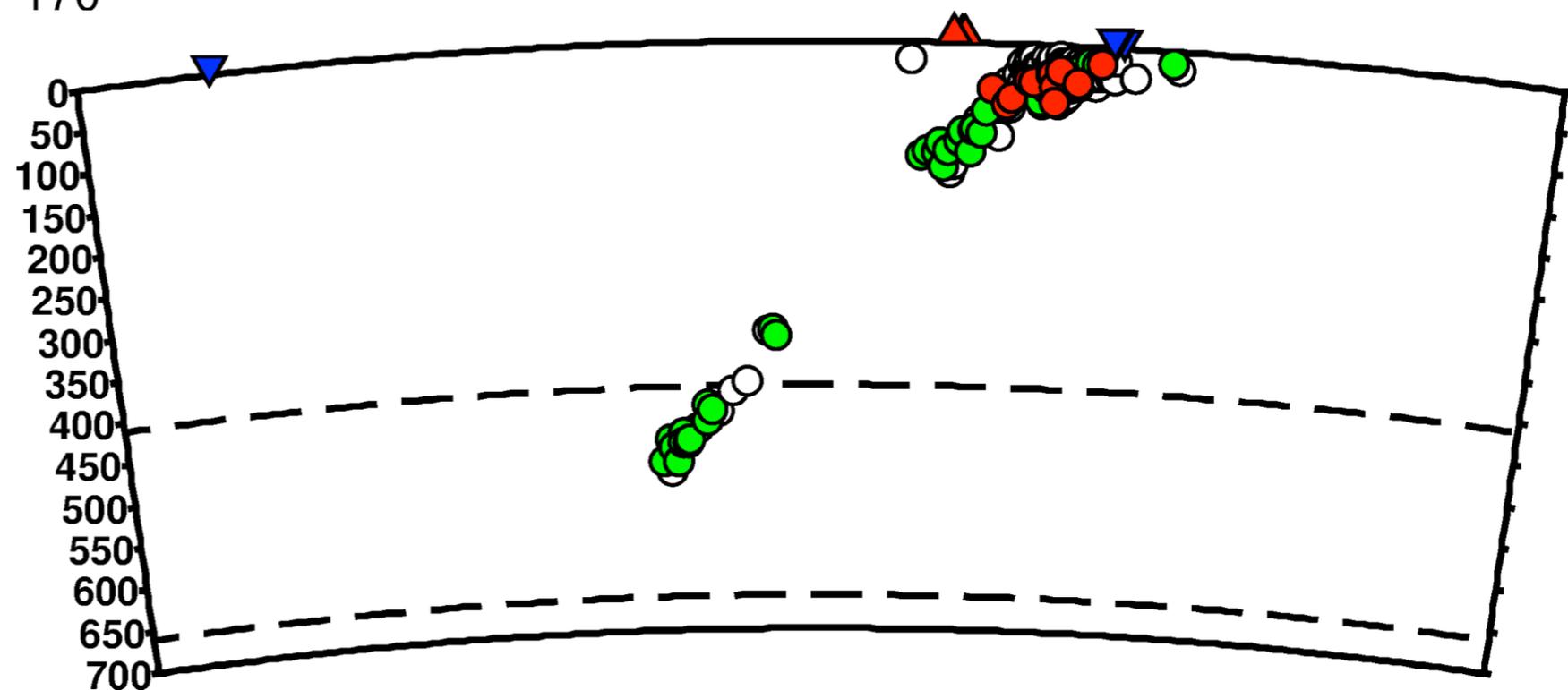
# Marianas - Cross Section 11



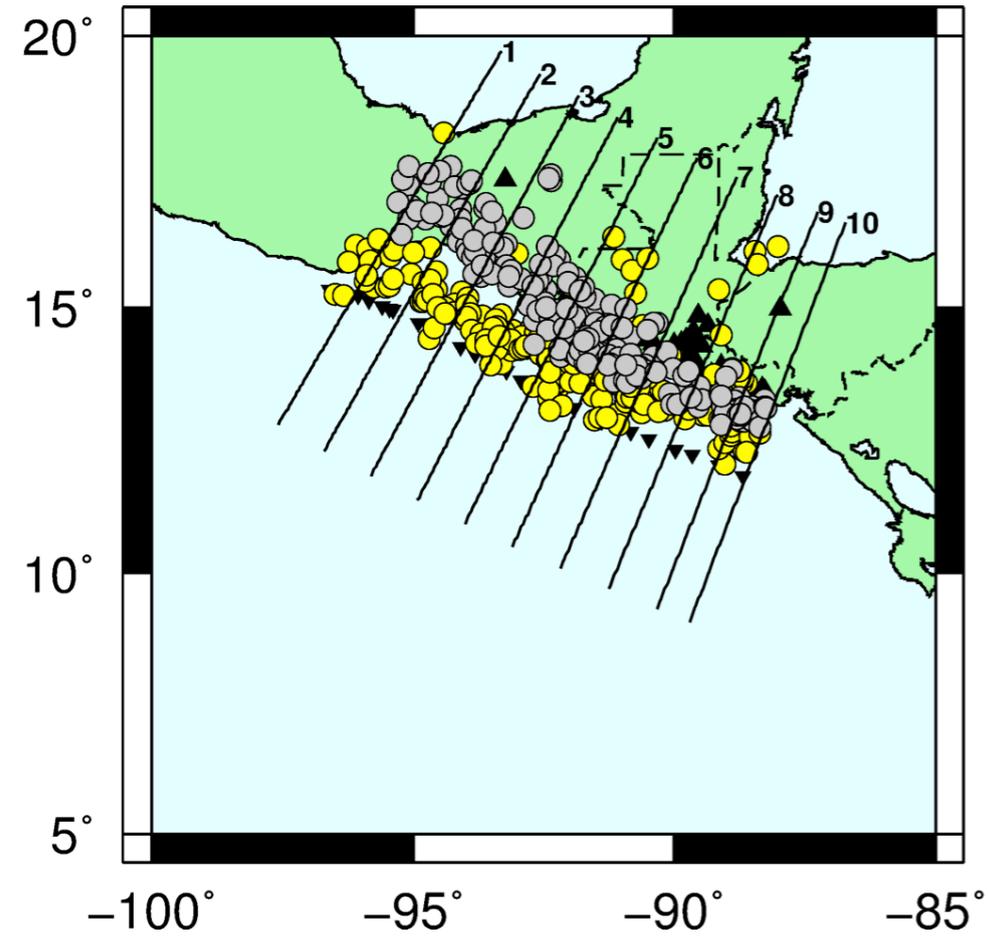
# Kurile - Cross Section 4



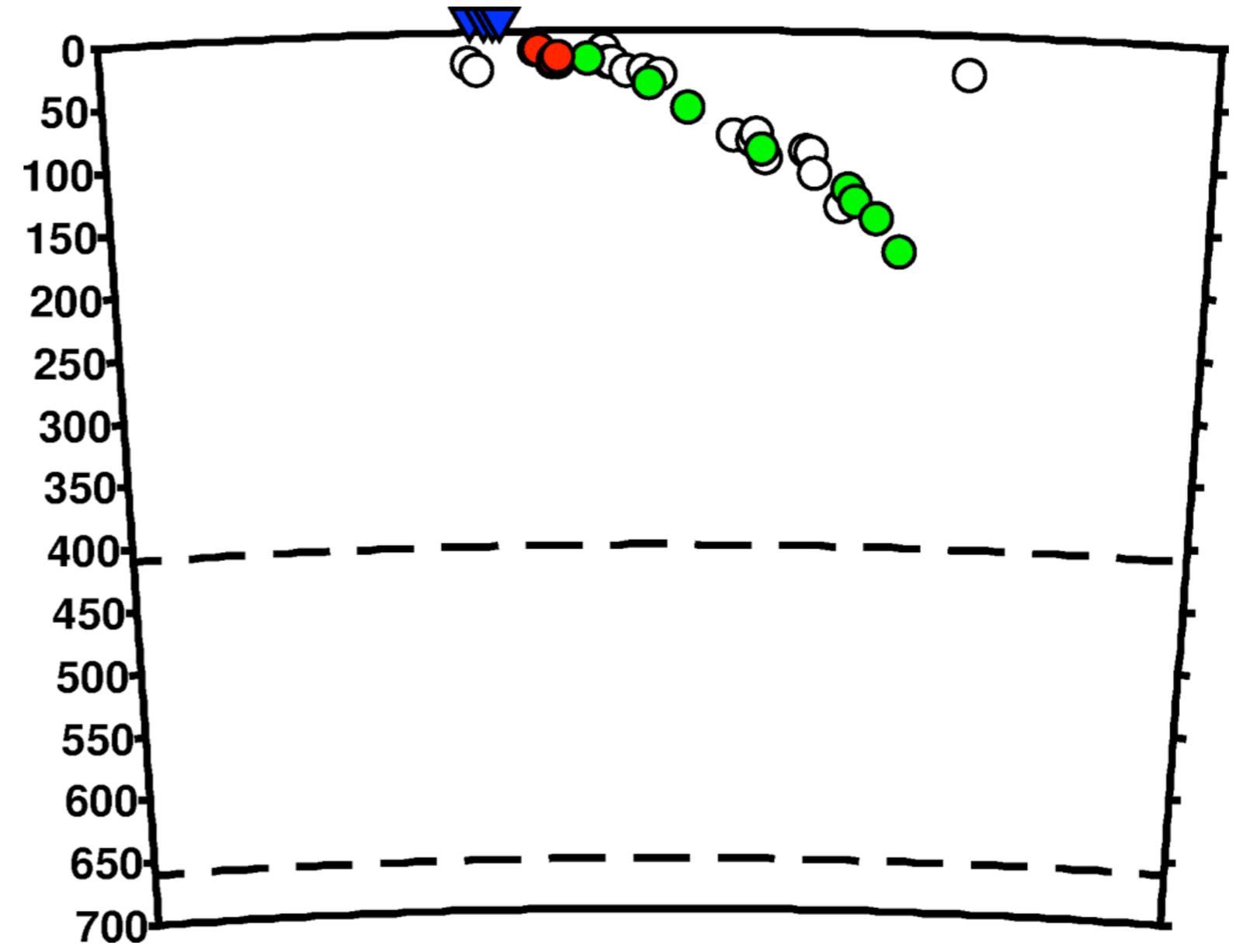
L1 - 42 events  
L2 & L3 - 32 events



# Central America - Cross Section 1



L1 - 9 events  
L2 & L3 - 3 events



# Sunda - Cross Section 2

