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Double-Difference Hypocentral Relocation and Seismic Moment Calculation of the Valle de la Trinidad Seismic Sequence, Baja California, Mexico

ANIVERSARIO CICESE

SISMOLOGÍA CICESE

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INTRODUCTION

- Better definition of the region tectonics through double-difference relocations.
- Update of the ML-Mo relationship first stated by Vidal and Munguía (1991): catalog homogenization and a discriminant between tectonic and man-made seismic events (Woods et al., 1993).
- Since moment tensor is the best representation of the size of an earthquake, its calculation is fundamental for the interpretation of relocation results.

METHODS/DATA

- **Data:** 1278 seismic events with 0<ML≤5.2 between years 2020-2022. North of Baja California Peninsula, NE of Valle de la Trinidad town.
- **HypoDD:** Applied to RESNOM original locations.
- **Mo calculation** (Brune, 1970) SEISAN.
- **Mo calculation** (Moment Tensor Inversion) ISOLA.

START

RESULTS

- A seismicity alineation, orthogonal to the main trend of the San Miguel Fault, is well defined after HypoDD relocation.
- ML-Mo relationship for this study is not linear from ML≥4.0.
- The ML-Mo relationship obtained works as an effective discriminant between tectonic and man-made seismic events (Woods et al., 1993)
- Moment tensor inversion preliminary results: Mw=5.48 and a strike-slip faulting mechanism.

CONCLUSION

- Orthogonal seismicity alineations are also observed at other sites of the Baja California Peninsula and South of California (USA) (Hauksson et al., 2022).
- ML-Mo relationship for this study sequence is not linear. Besides, it represents a valuable resource for any seismological service as a discriminant between man-made and tectonic events.
- Moment tensor inversión results corresponds with the faulting mechanism reported in the literature for the región.
- Nodal fault plane related to the largest event of the Valle de la Trinidad seismic sequence could be the one with an NE-SW trend, as the strike of the orthogonal alignment observed after relocation.

*This study is a contribution to CICESE Internal Project 641189 and CONAHCYT project CF- **194151.**

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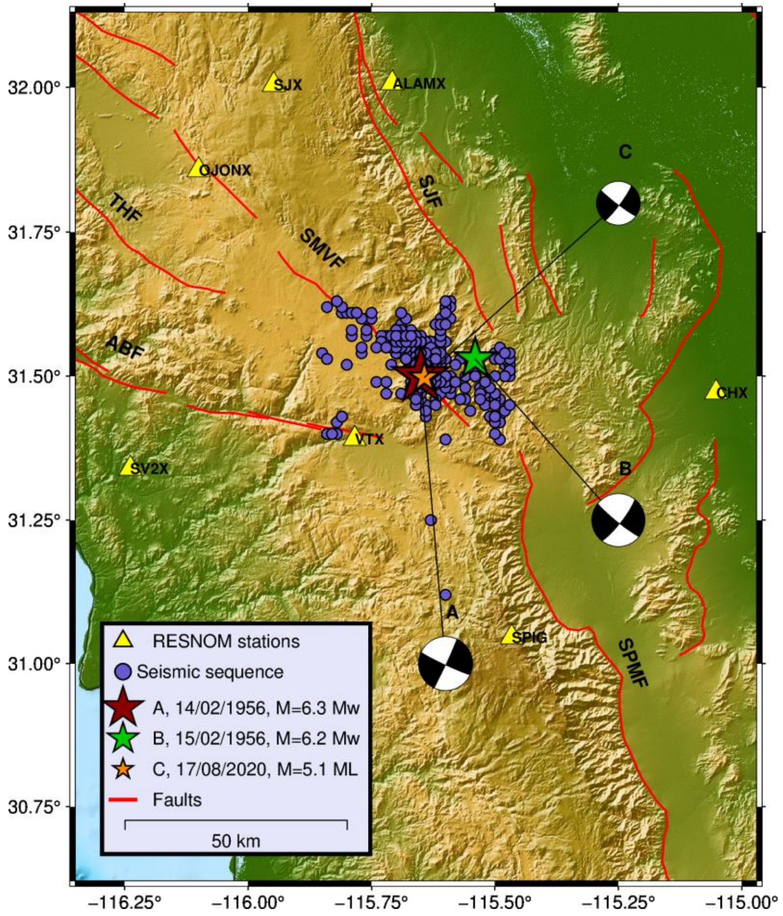
P1.2-100

INTRODUCTION

Study area

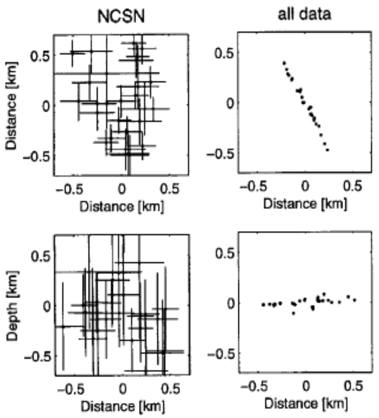
NE of Valle de la Trinidad town

North of Baja California Peninsula



Double-Difference hypocentral relocations

- Waldhauser and Ellsworth (2000). High-resolution hypocentral locations.
- Widely used to relocate seismicity in regions with active tectonics around the world. Tobosi and Buenavista faults (Costa Rica) (Araya, 2017), rift structures in the Gulf of Corinto (Greece) (Mesimeri et al., 2018), and the active fault system of the Western Nagaoka Basin (Japan) (Yukutake et al., 2008), among others.



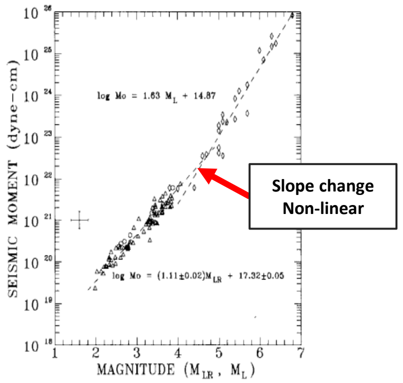
Modified from Waldhauser y Ellsworth (2000)

Mo calculations and Mo-ML relationship

- Vidal and Munguía (1991). Baja California Peninsular Ranges. Two relationships Mo-ML.

2≤ML≤4 and 4≤ML≤6.8

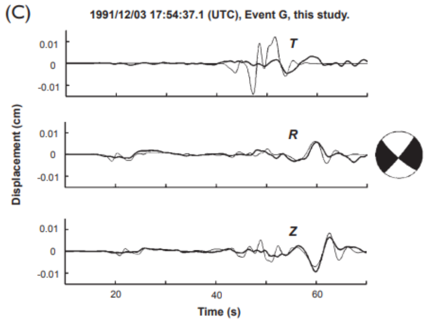
- Mo and source parameters (Brune, 1970).
- **NON-LINEAR BEHAVIOR OF THE Mo-ML RELATIONSHIP.**
- **Application:** Discriminant between tectonic and man-made seismic events (Bradley et al., 1993)



Vidal y Munguía (1991)

Seismic Moment Tensor

- Fault parameters for Baja California Peninsular Ranges. (Vidal et al., 2010).
- Computation of faulting parameters of earthquakes with magnitudes 4.1≤ML≤5.3
- 1991-1996
- Waveform modeling of broadband records at regional distances



Vidal et al. (2010)

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OBJECTIVES

GENERAL

Characterization of the Valle de la Trinidad seismic sequence from 2020 to 2022 through its hypocentral relocation and seismic moment calculation, with a view to a better definition of the area tectonics and seismic source characterization.

SPECIFIC

- Compilation of seismological data registered by the Seismic Network of Northwest Mexico, to visualize de statistical behavior of the Valle de la Trinidad seismic sequence.
- Seismic sequence relocation through the double-difference method (Waldhauser and Ellsworth, 2000) to achieve high-resolution hypocentral locations and provide more information and a better definition of the tectonics in the area.
- Mo and source parameters calculation through the Brune (1970) model and seismic moment tensor inversion, to provide more information about the non-linearity of the Mo-ML relationship proposed by Vidal and Munguía (1991) and characterize the sequence in terms of its source parameters.

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METHODS/DATA

Seismic source model (Brune, 1970)

Seismic moment

$$M_o = \frac{4\pi\rho V_S^3 \Omega_O R}{2.0 \; x \; 6.0}$$

Stress drop

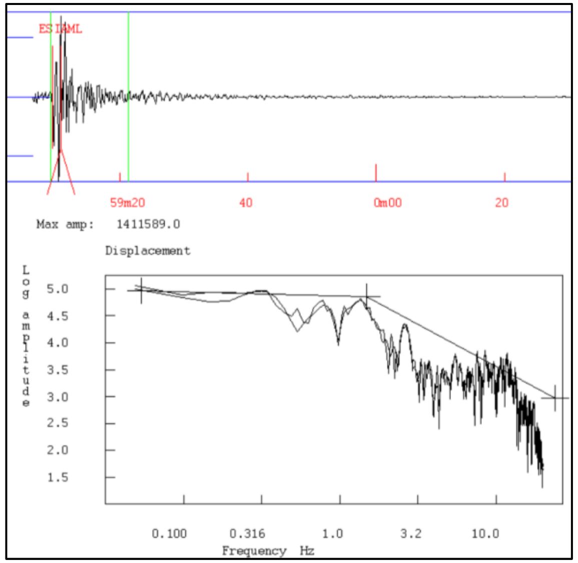
$$\Delta\sigma = \frac{7 M_O}{16 r^3}$$

Source radius

$$r = \frac{0.372 V_s}{f}$$

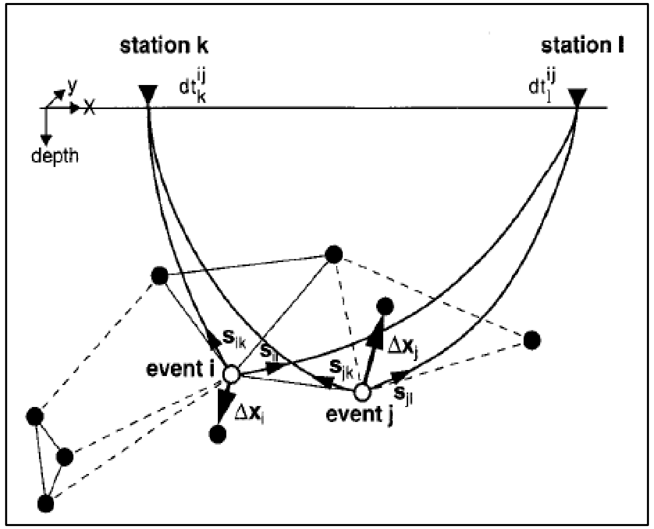
SEISAN

Havskov y Ottemoller (1999)



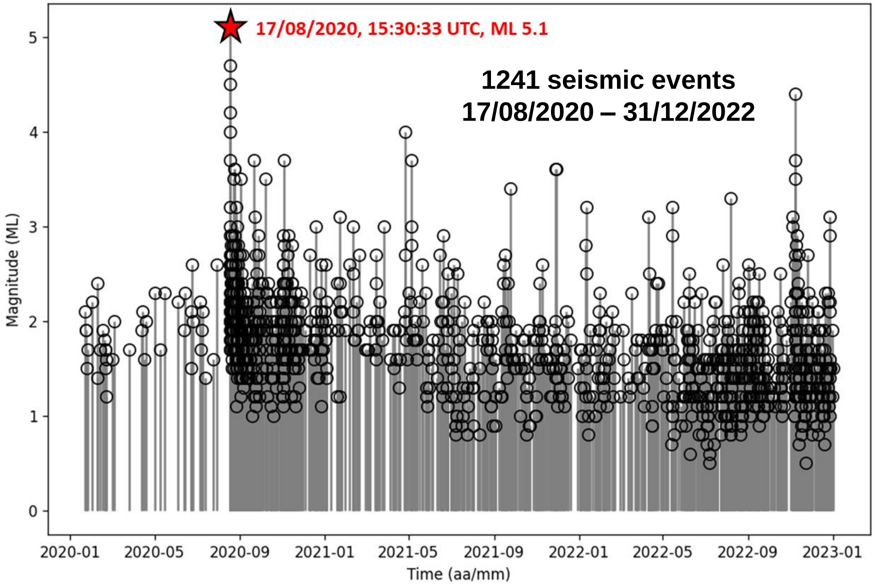
Double-Difference relocations

HypoDD



Waldhauser and Ellsworth (2000)

Valle de la Trinidad seismic sequence



Seismic moment tensor inversion

isola

Sokos and Zahradnik (2008)

$$u_n = M_{pq} * G_{np,q}$$

Seismic Moment Tensor

$$\mathbf{M}_{pq} = M_0 \begin{bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{bmatrix}$$

$\mathbf{u_n}$(n=1,2,3)→ displacement field

$\mathbf{G_{np,q}}$ → Green functions. Synthetic waveforms

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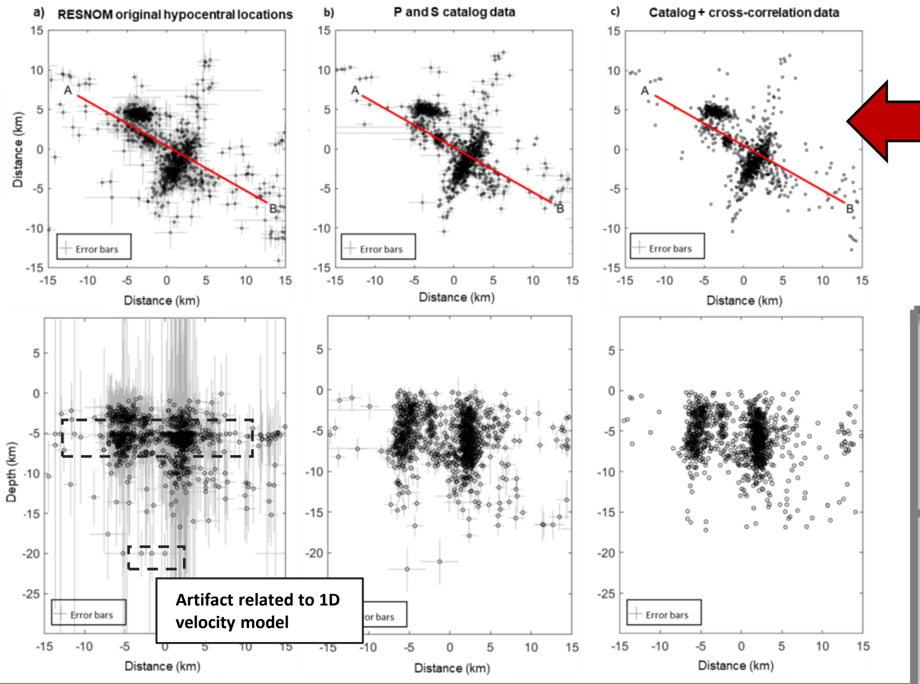
RESULTS

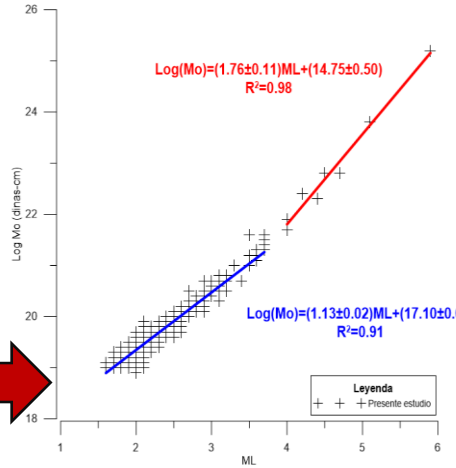
Double-Difference relocations



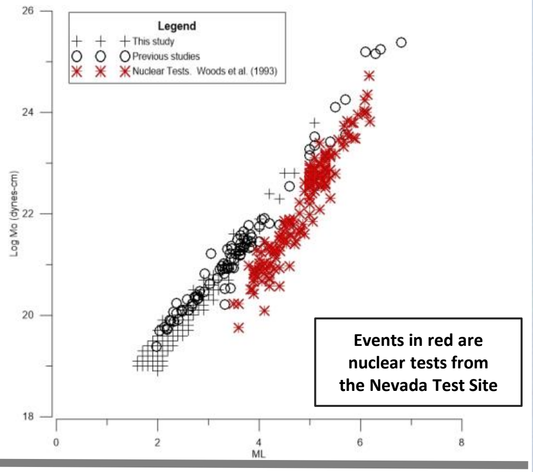
Hypocentral locations uncertainties were considerably reduced

Mo-ML relationship appears to be non-linear as stated by Vidal y Munguía (1991).

Mo-ML relationship



Mo-ML as a discriminant between tectonic and man-made seismic events

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MOMENT TENSOR SOLUTION
-----------------------------
HYPOCENTER LOCATION (RESNO)
---------------------------
Origin time 20200817 15:30:33.30
Lat 31.5 Lon -115.638 Depth 5.5

--------
Trial source number : 4 (Fixed Epicenter inversion)
Centroid Lat (N)31.5 Lon (E)-115.638
Centroid Depth (km) : 8
Centroid time : +2.1 (sec) relative to origin time
----------------------------------------------------
Moment (Nm) : 1.883e+17        Mw : 5.48
Inversion Type:Deviatoric
VOL% :0
DC% :84.3
CLVD% :15.7                                      SNR   CN   FMVAR  STVAR
Var.red.:(for stations used in inversion):0.29   NaN   1.8  4±4    0.16
Var.red.(for all stations)              :
```

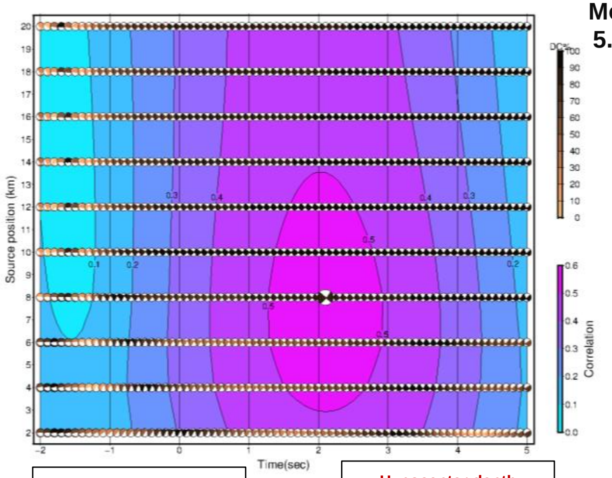
Mw : 5.48

Preliminary results obtained through seismic moment tensor inversion

Mw calculated through Brune's (1970) model

5.1

Source correlation diagram



Centroid position

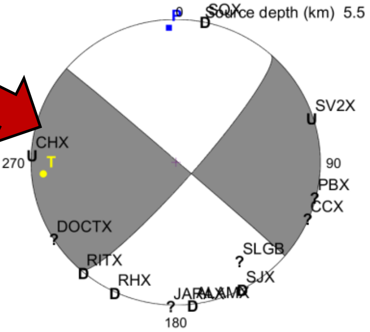
t= 2s , depth= 8km

Hypocenter depth

RESNOM = 5.5 km ; HypoDD= 4 km

Seismic moment tensor inversion

Moment tensor inversion
5.1 ML focal mechanism



First arrival polarities
5.1 ML focal mechanism

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DISCUSSION/CONCLUSION

- The double-difference method is efficient in relocating local seismic events within an area with good azimuthal coverage around the source. It considerably minimizes the uncertainties associated with unmodeled velocities. It is ideal for relocating seismic sequences that do not show alignments with geological structures or faults, but rather a diffuse image.

Mean error: RESNOM (before HypoDD) x=1.08; y=1.08; z=5 (km) ; **Catalog data (after HypoDD) x= 0.60; y=0.50; z=0.84 (km)**; **cc+ct (after HypoDD) x=0.0056; y=0.0049; z=0.0080 (km)**

- After double-difference relocation, earthquakes are clearly aligned with an NW-SE strike, orthogonal to the main trend of the San Miguel fault. Hauksson et al. (2022) report 40 years of seismicity in southern California characterized by seismic sequences that show a ladder pattern orthogonal to the strike of the region's main faults. These orthogonal alignments show the same trend NE-SW observed for the Valle de la Trinidad seismic sequence in this study.

- The ML-Mo relationship obtained for Valle de la Trinidad seismic sequence is not linear, as Vidal and Munguía (1991) established. For this study, seismic records come from broad-band stations, covering a wider range of frequencies and eliminating the instrumental limitation mentioned by these authors. On the other hand, Hutton and Boore (1987) suggest that this phenomenon may be due to differences in the radiated frequency content.

- The ML-Mo relationship can be used as an efficient discriminant between tectonic and man-made seismic events. We use the obtained relationship to prove this with Nevada Test Site nuclear tests reported by Woods et al. (1993). This author attributes this to the fact that ML is a short-period energy measurement, while the seismic moment is determined in long-period phases for body and surface waves.

- Regarding the seismic moment tensor inversion, although it is a preliminary result, the magnitude obtained is quite close to the value calculated through Brune (1970) model and the local magnitude originally calculated by RESNOM, 5.1 ML, Mw. Besides, the centroid position is 2s from the origin time and its depth is 8 km. Although the centroid is not the same as the hypocenter, it should not be too far from the other, which is why the obtained results are considered consistent.

- The mechanism obtained through the seismic moment tensor inversion is consistent with the obtained through a first-arrival polarity analysis. According to Hauksson et al. (2022), usually, the nodal plane with NE-SW direction of the largest event of the sequences (in this study, magnitude 5.1 event) aligns with a linear distribution of aftershocks or secondary seismic events, as is the case of the orthogonal alignment observed after double-difference relocation for Valle de la Trinidad seismic sequence.

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