Low-Frequency Earthquakes and Earthquake Swarms in the Northern Ryukyu Trench

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Introduction

- Slow earthquakes (e.g., VLFE: very-low frequency earthquake) provide insights into stress and fluid dynamics in subduction zones.
- The northern Ryukyu Trench shows low seismicity (LSA) despite the 1911 event.
- This study aims to detect VLFEs around Amami Island using broadband OBS data and clarifying their relationship with regular earthquakes, particularly earthquake swarms, to better understand the seismic processes in this subduction zone.

Data

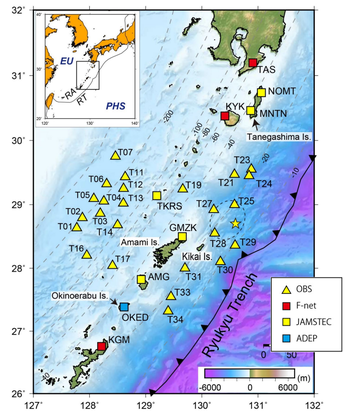

Fig. 1. OBS deployment and station locations.

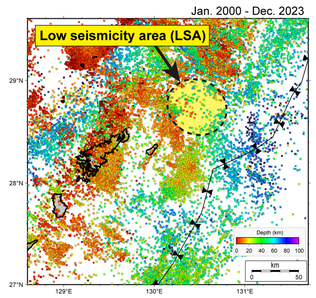

Fig. 2. Seismicity and low seismicity area (LSA).

Observation Period:
Sep 2018 – Jun 2019

Stations:
Broadband OBSs, F-net, JAMSTEC, ADEP (Fig. 1)

Method

- Band-pass filtering (0.05–0.1 Hz)
- Envelope computation using the Hilbert transform
- Cross-correlation of envelope functions
- Event classification based on JMA/NEIC catalog
- Grid search for epicenter determination

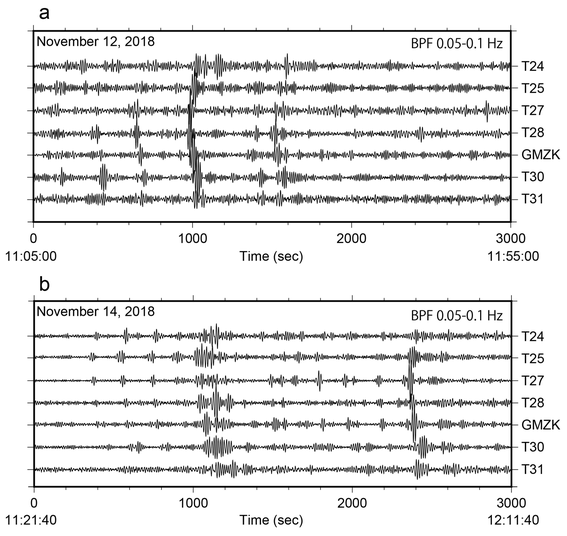

Fig. 2. Example of waveforms of VLFEs.

Results: VLFE Distribution

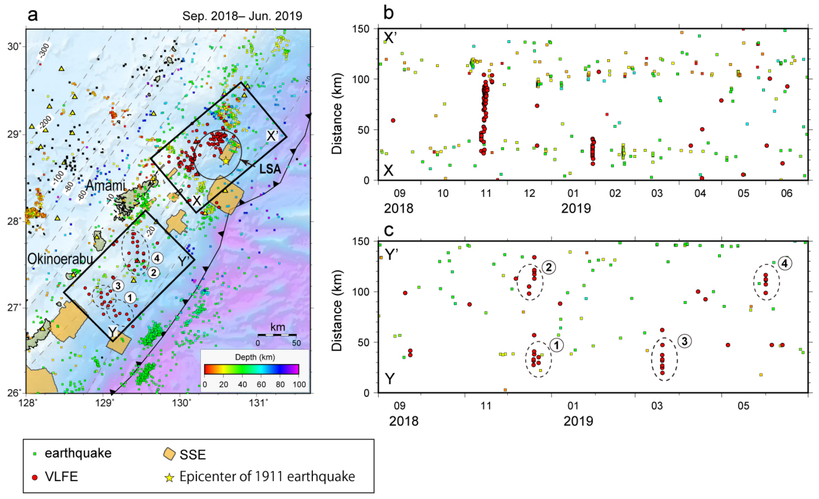

Fig. 3. (a) Distribution of earthquakes and VLFEs from September 2018 to June 2019.

(b) Spatiotemporal distribution of earthquakes and VLFEs in Amami (c) The same as (b) but in Okinoerabu.

- VLFEs concentrated northeast of Amami and east of Okinoerabu Islands.
- Near Amami: separated from regular seismicity.
- Near Okinoerabu: clustered in multiple regions (Areas 1–4).

Results: Earthquake Swarms and Migration

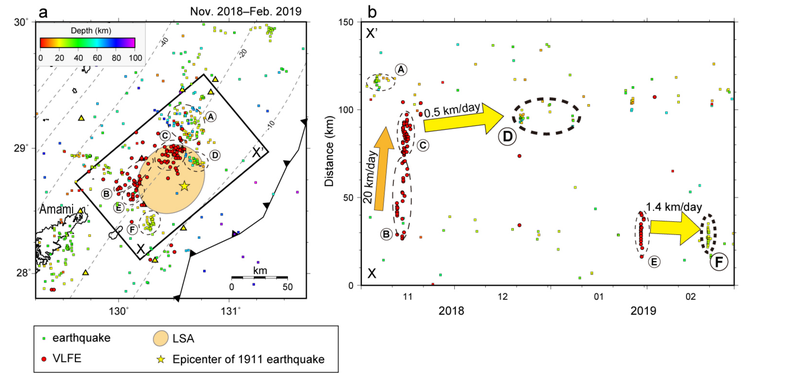

Fig. 4. (a) Distribution of earthquakes and VLFEs from November 2018 to February 2019. (b) Spatiotemporal distribution of VLFE and earthquake swarms along X-X'.

- An earthquake swarm in Area A preceded VLFE activity in November 2018, followed by additional seismic events.
- VLFE activity migrated from Area B to Area C. About one month later, an earthquake swarm occurred in Area D, which is located closer to the trench than Area C. These events all took place within the LSA (low seismicity area).
- In January 2019, VLFE activity was observed in Area E, located near Area B. About 20 days later, an earthquake swarm occurred in Area F, which lies closer to the trench than Area E.
- Migration speeds: 0.5–1.4 km/day (NE direction).

Discussion – VLFE and Swarm Relationship in D and F Regions

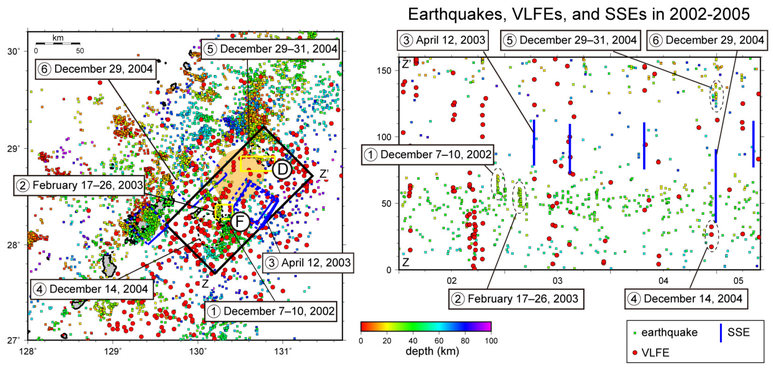

Fig. 5. Spatiotemporal distribution of VLFE, SSE, and earthquakes from 2002-2005. SSE: Nishimura 2014.

- In contrast to the 2003 event (no slow activity), the 2004 sequence involved both VLFE and SSE, indicating variability in triggering mechanisms (Fig. 5 and 6).
- The 2019 sequence (VLFE in E → swarm in F) demonstrates a clear migration pattern from inland to trenchward direction (Fig. 4 and 6).
- These patterns suggest that pore-fluid pressure plays a key role in stress redistribution and in triggering of seismic activity. Similar spatiotemporal interactions are known in the Nankai Trough and offshore Boso.
- Overall, the phenomena support a model of fluid-induced seismicity where elevated pore pressure reduces fault strength and promotes slip and swarm activity.

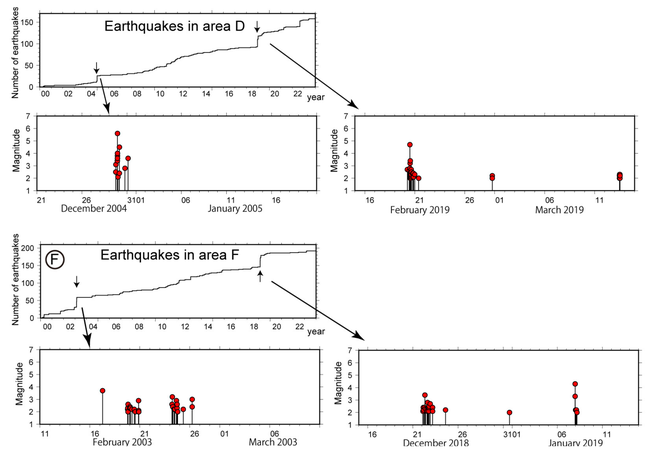

Fig. 6. Magnitude-Time diagram of earthquakes in the area D and F

Conclusions

- VLFE activity was clustered northeast of Amami Island and east of Okinoerabu Island, separate from regular earthquakes.
- VLFEs were frequently preceded or followed by earthquake swarms, indicating an interaction between slow and regular seismic events.
- High pore-pressure fluid along the subducting plate may trigger both VLFE and regular seismic events.

For more details, see: Nakamura et al. (2024), *Earth, Planets and Space*.
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