Northern California Offshore Wind Study: Overview of Geological Hazards

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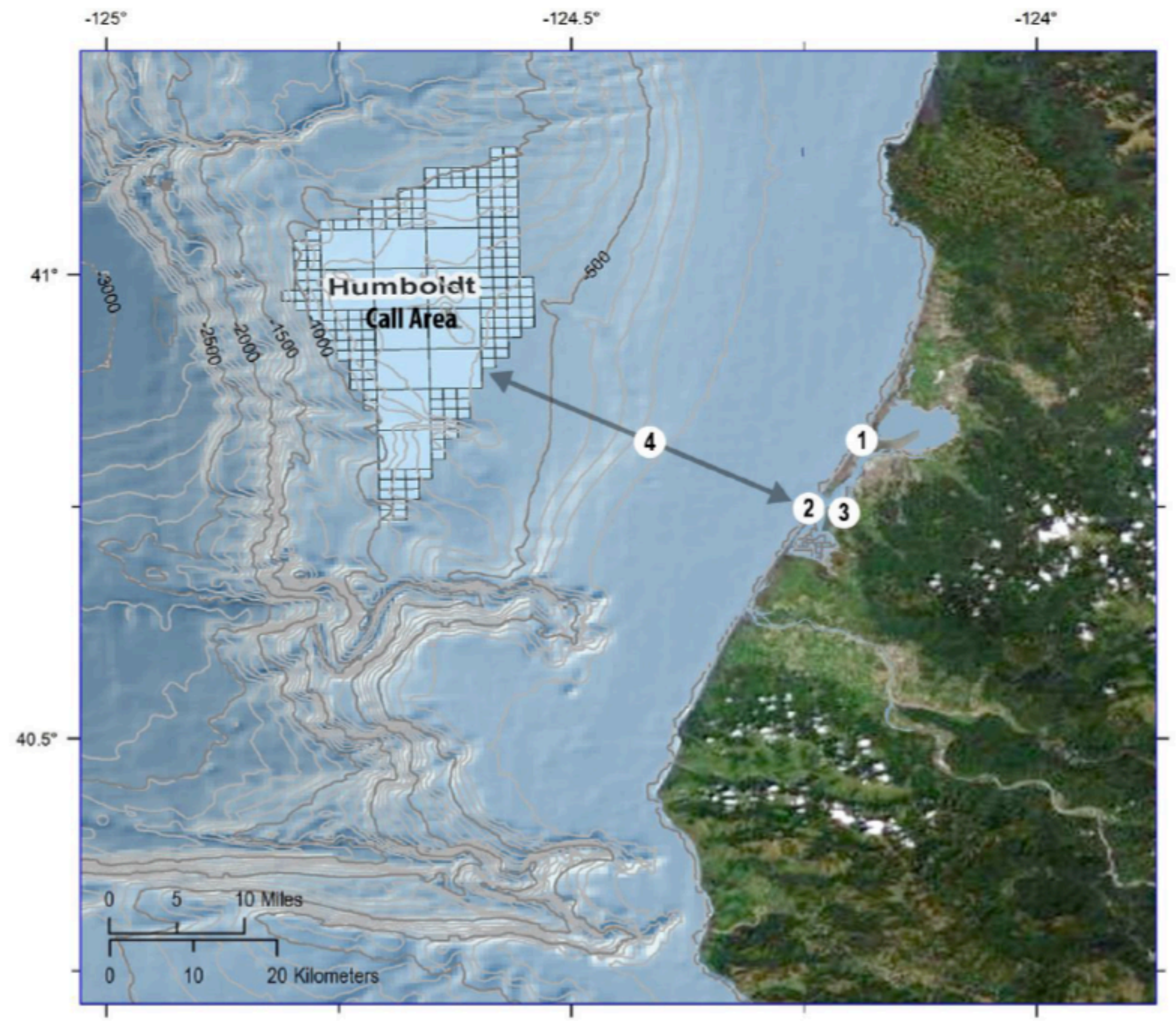
NCOW areas of consideration

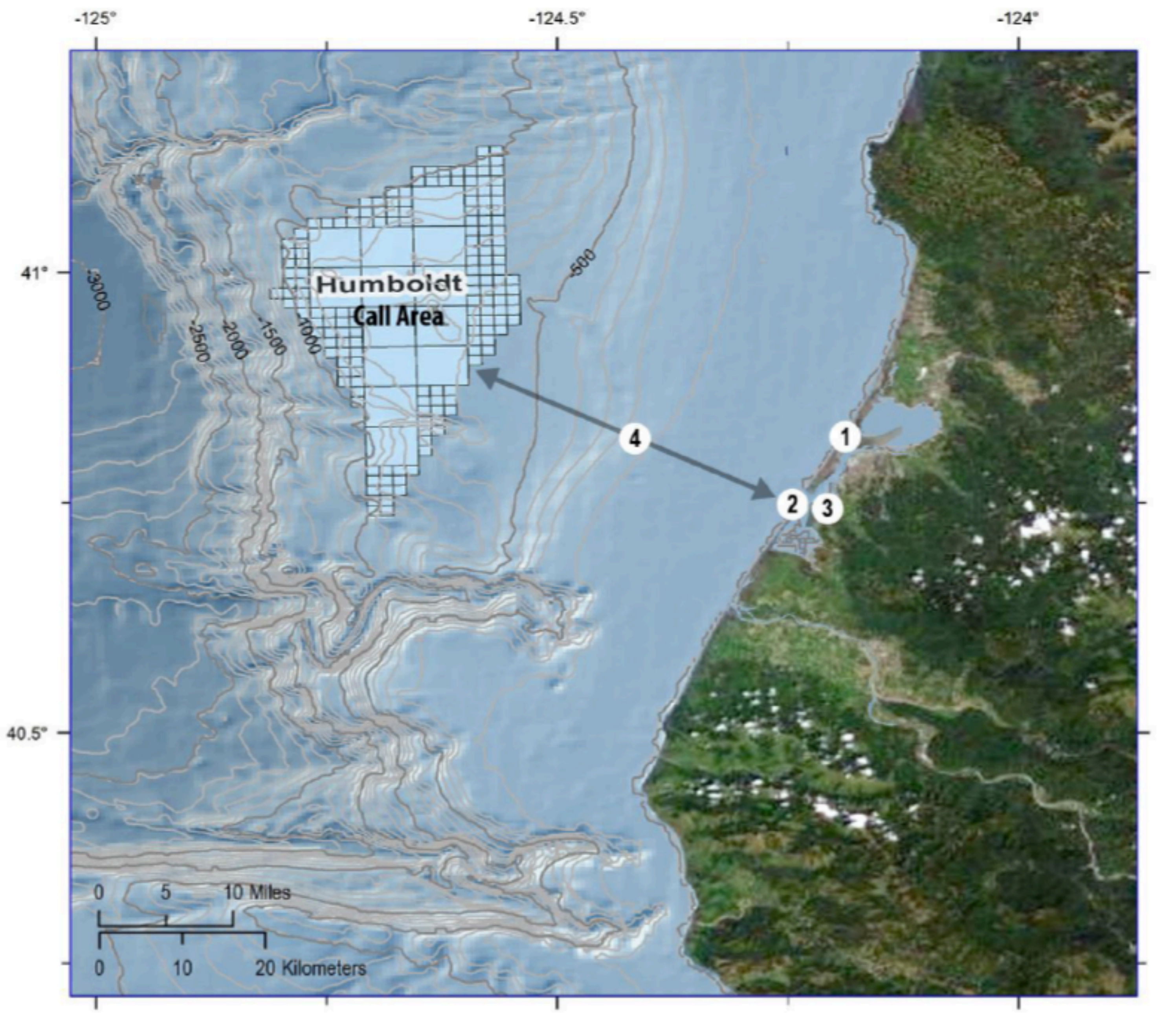
Call Area

1. Turbine assembly area
2. Transmission cable landfall
3. Humboldt Bay Generating Plant
4. Approximate area of transmission cable corridor



Hazards to be considered

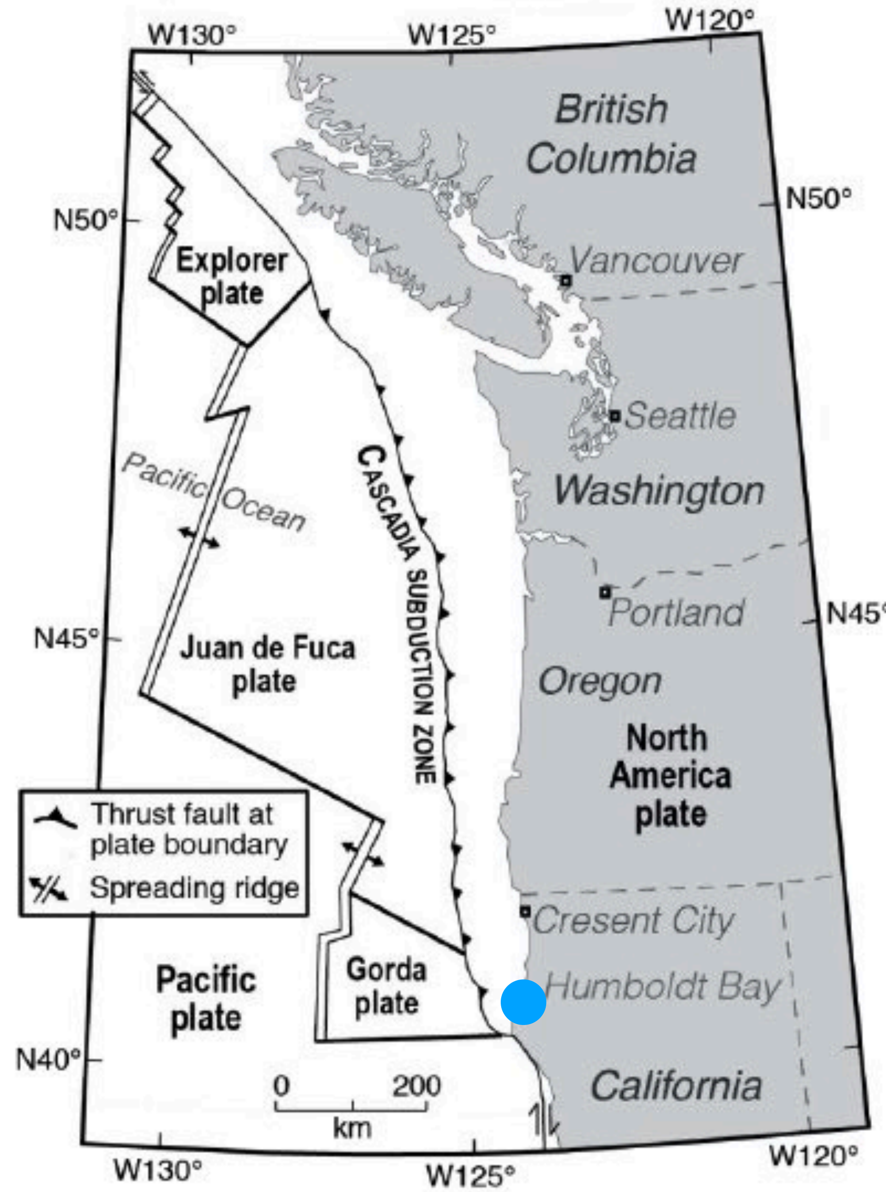
- Strong motion
- Surface rupture
- Gas hydrates
- Liquefaction
- Submarine landslides
- Tsunamis
- Coseismic sea level change



- This study based on literature review of available data. No new data collection conducted during this period.
- No attempt to serve as proponent or opponent of potential wind farm - informational

Earthquake shaking caused by multiple sources

- Cascadia Subduction zone
- San Andreas fault
- Gorda plate
- Mendocino fault
- Numerous faults onshore and offshore



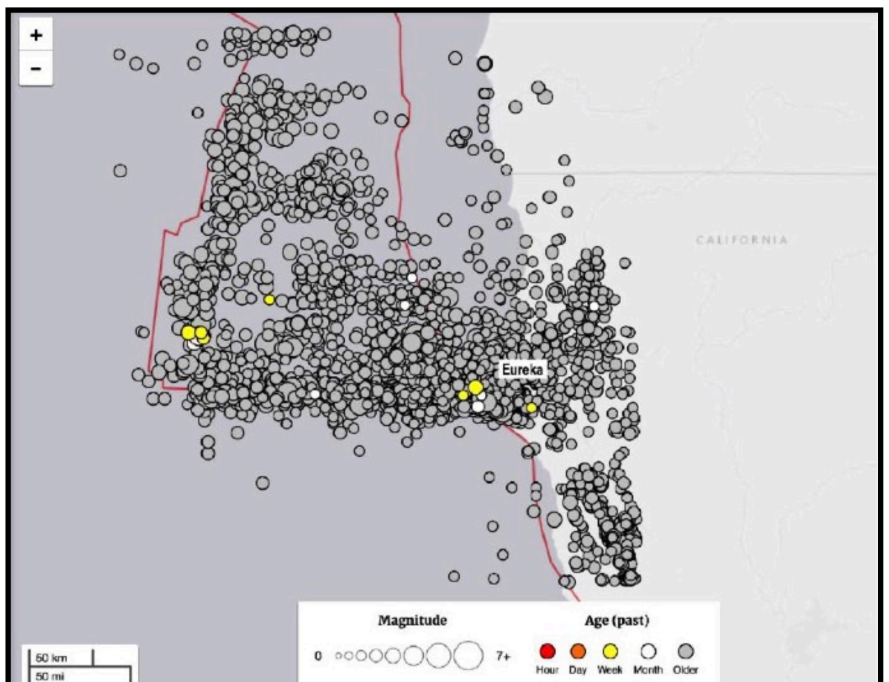


Figure 17. Map showing earthquakes > M2.5 in the North Coast region in the time period 2000-2020. The majority follow the east-west trend of the Mendocino fault.

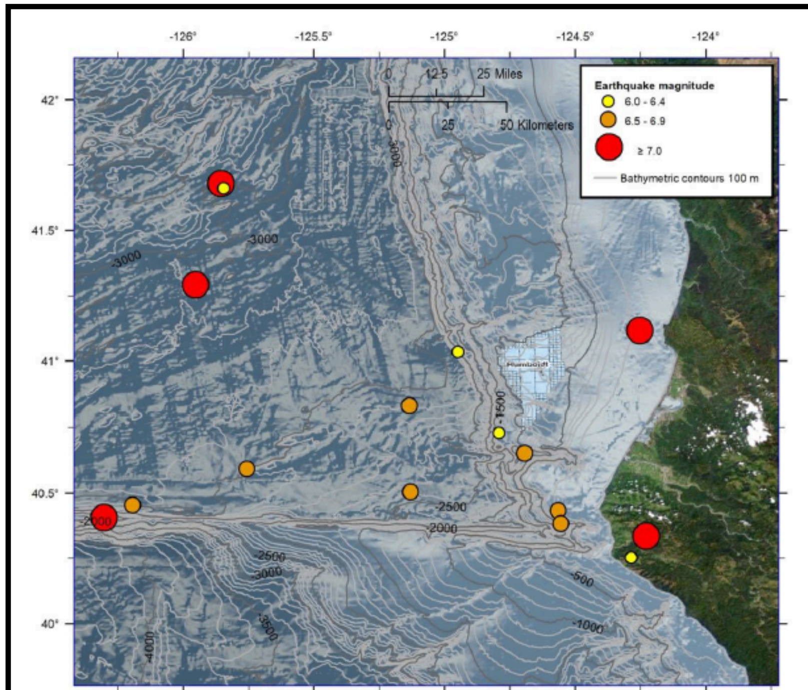


Figure 18. Regional earthquakes > M6 since 1960.

Potential impacts:

- Damaging shaking
- Can induce most of the other hazards under consideration

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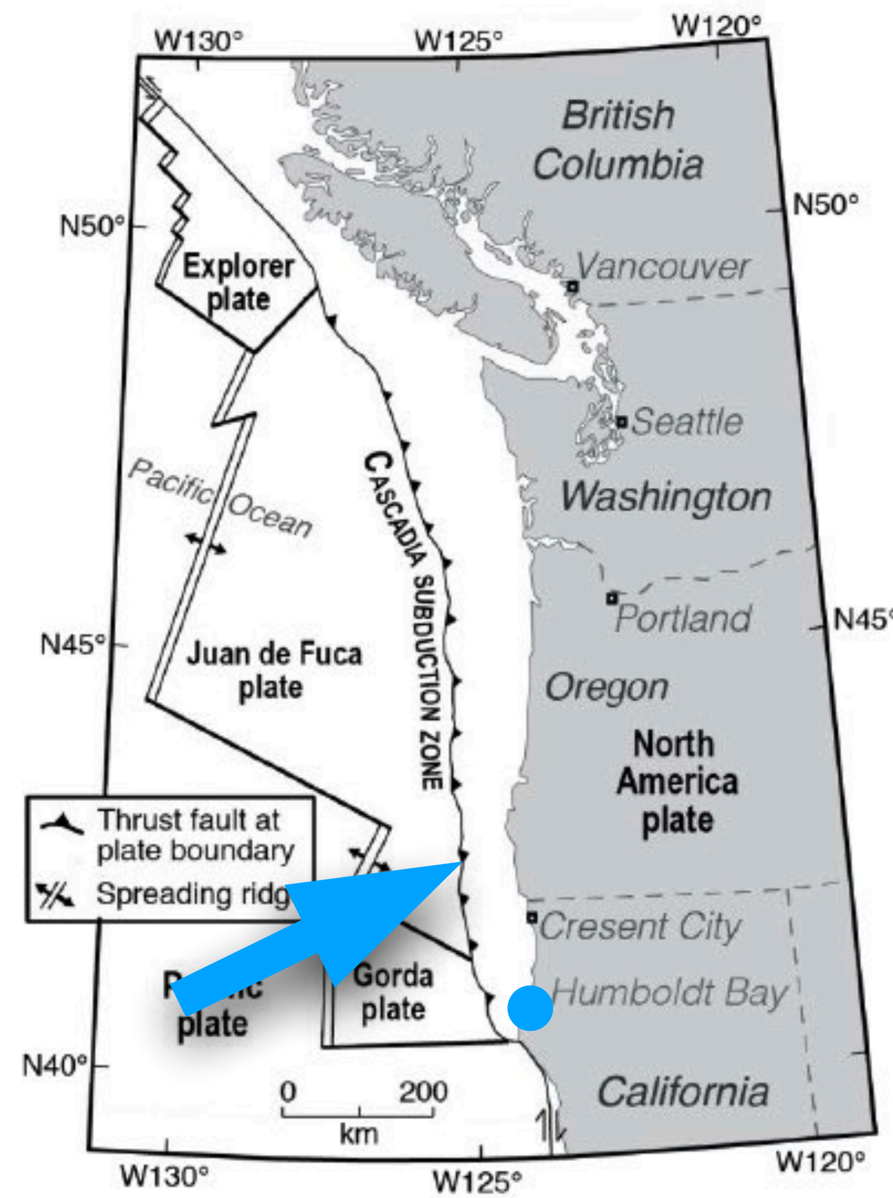

- Extends from Vancouver, CA to Cape Mendocino
- Capable of M 9+ earthquakes
- Last event was in 1700 AD
- Native American oral history describes event
- Time between earthquakes approximately 245-720 years

Strong motion

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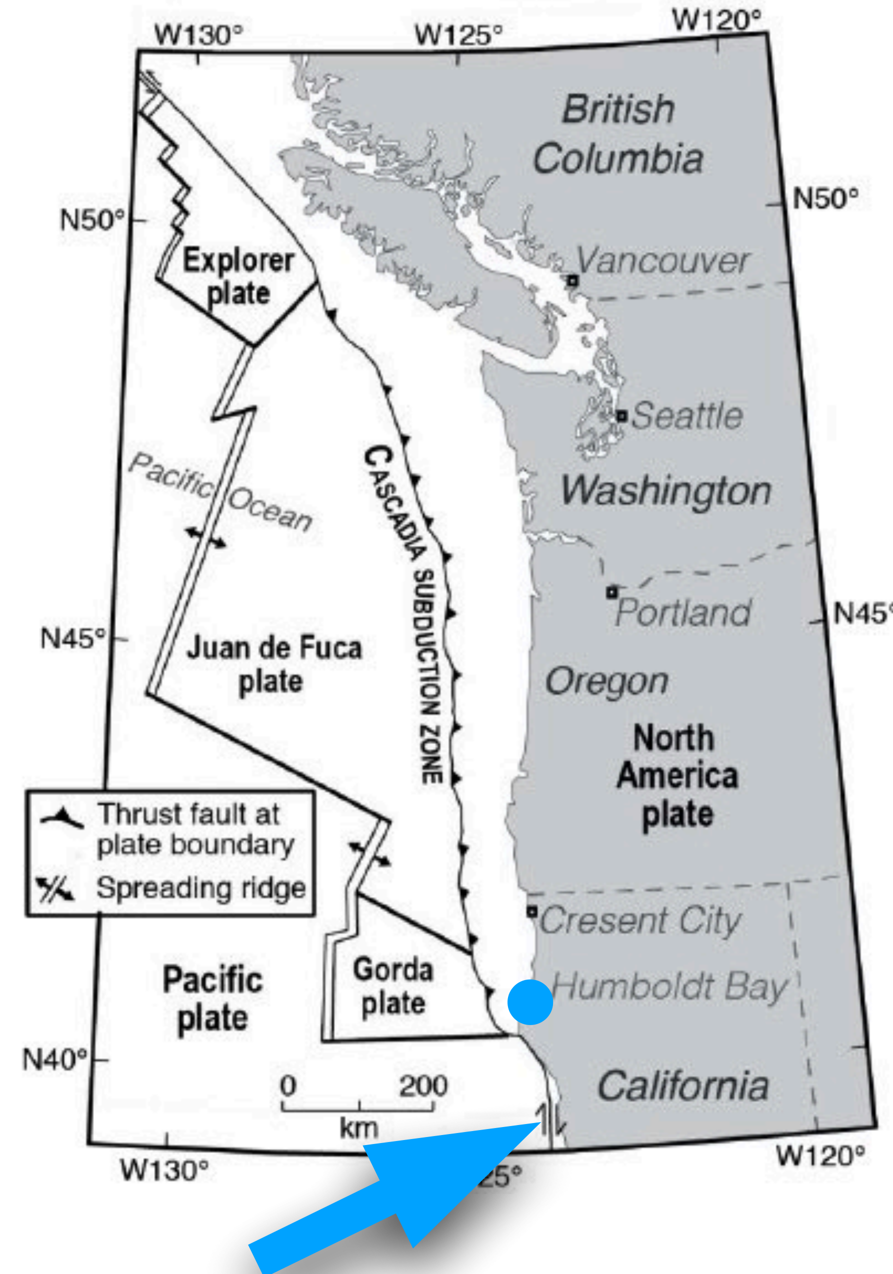


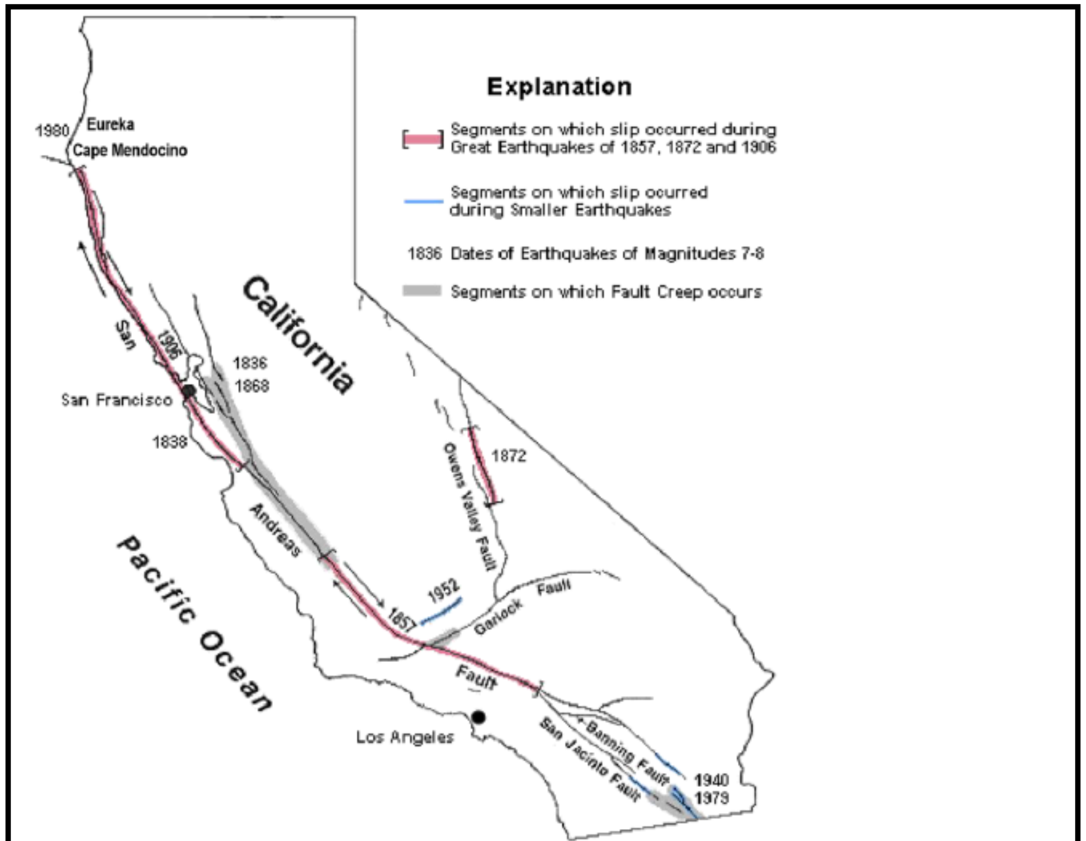
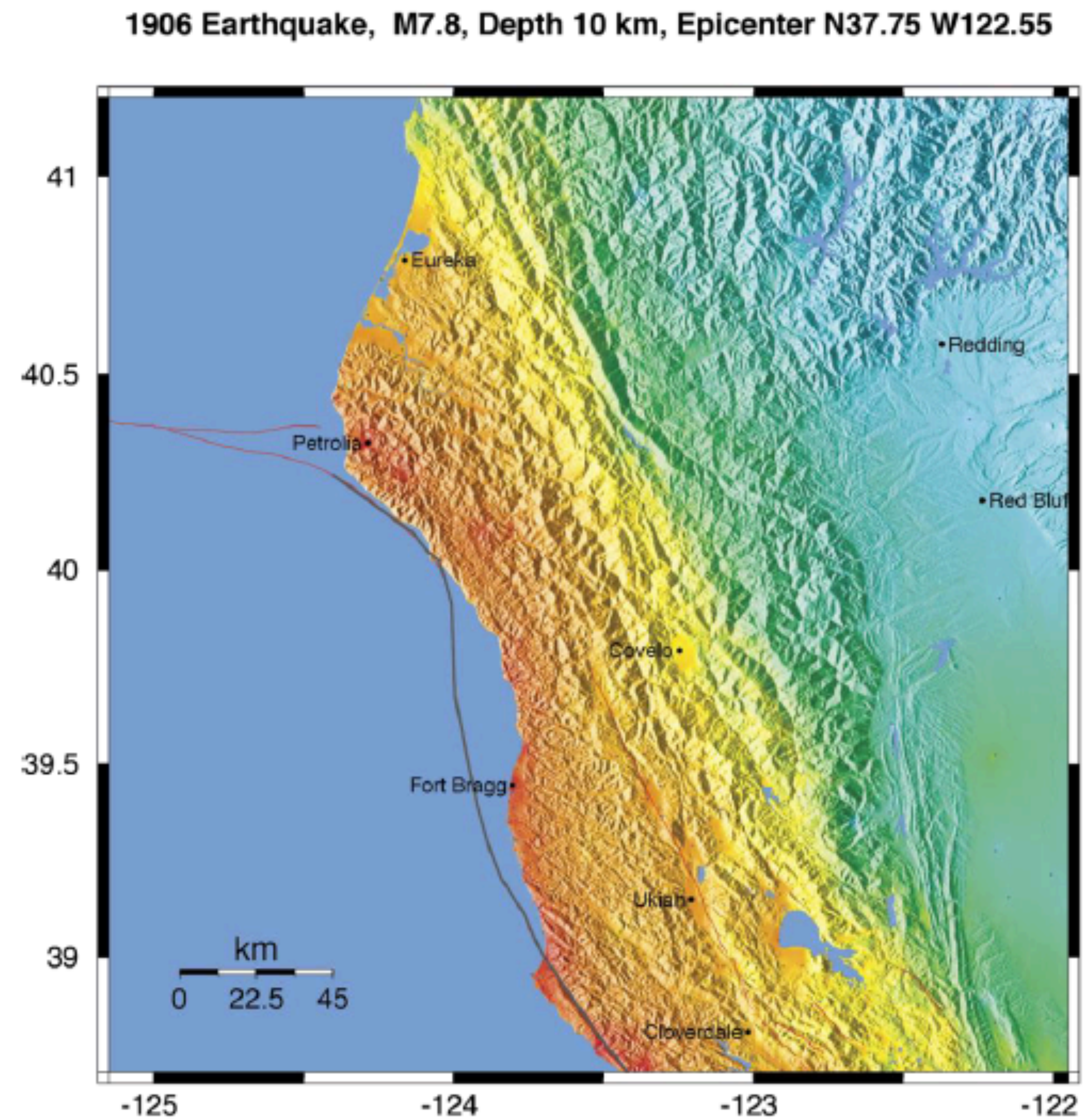


Figure 4. USGS base map of the San Andreas fault in California. The 1906 rupture extended from San Juan Batista in the south to off Cape Mendocino in the north (Accessed June 2020 from: https://pubs.usgs.gov/gip/earthq3/where.html).

- 1906 - most recent event on Northern SAF
- M 7.8 with large displacements near Shelter Cove
- Arguably largest shaking event in Humboldt area in modern history



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 6. Modified Mercalli Intensity shake map of northern California for the 1906 San Andreas fault earthquake. (From Boatwright and Bundock, 2005, <https://pubs.usgs.gov/of/2005/1135/IntensityMaps.html>.)

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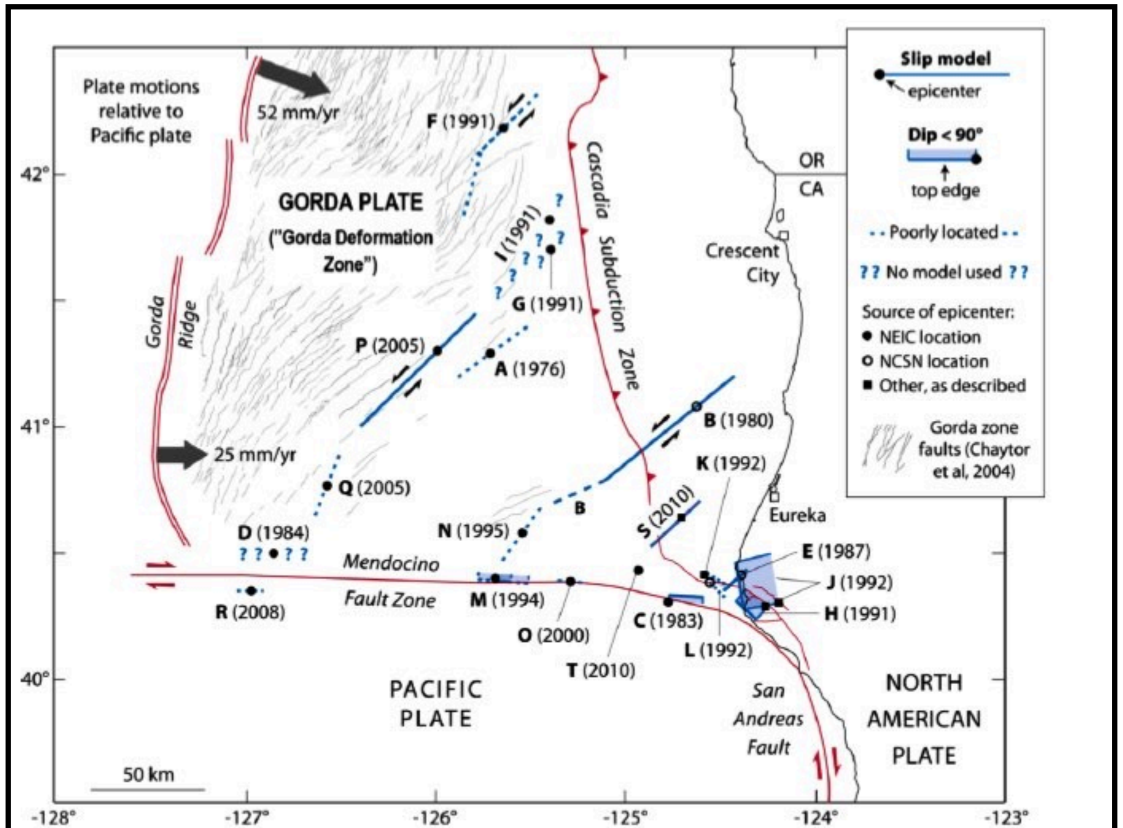
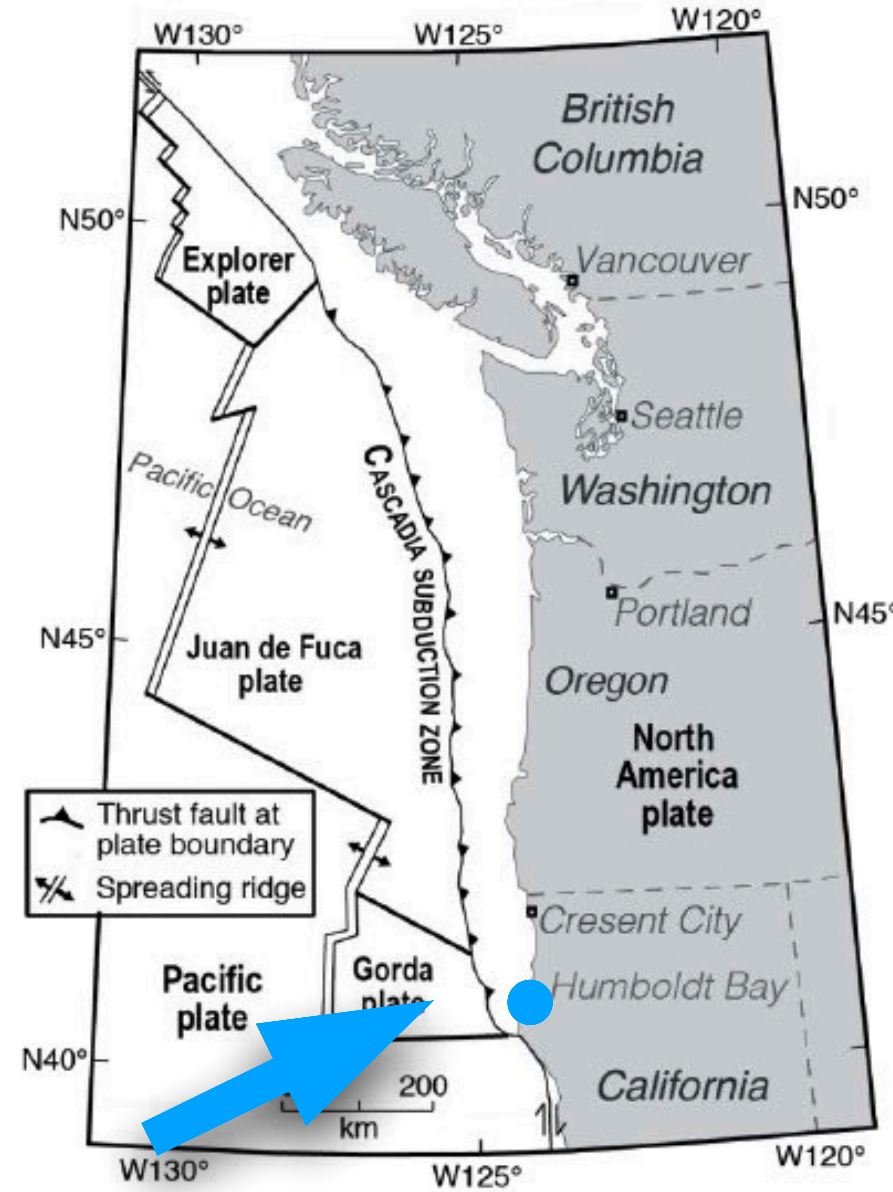


Figure 8. Map of the Gorda plate ("Gorda deformation zone") by Rollins and Stein, 2010. Letters indicate epicenters for earthquakes > M5.9 between the years 1976 and 2010. Earthquake magnitudes are listed in Table 6.



Earthquake shaking caused by multiple sources

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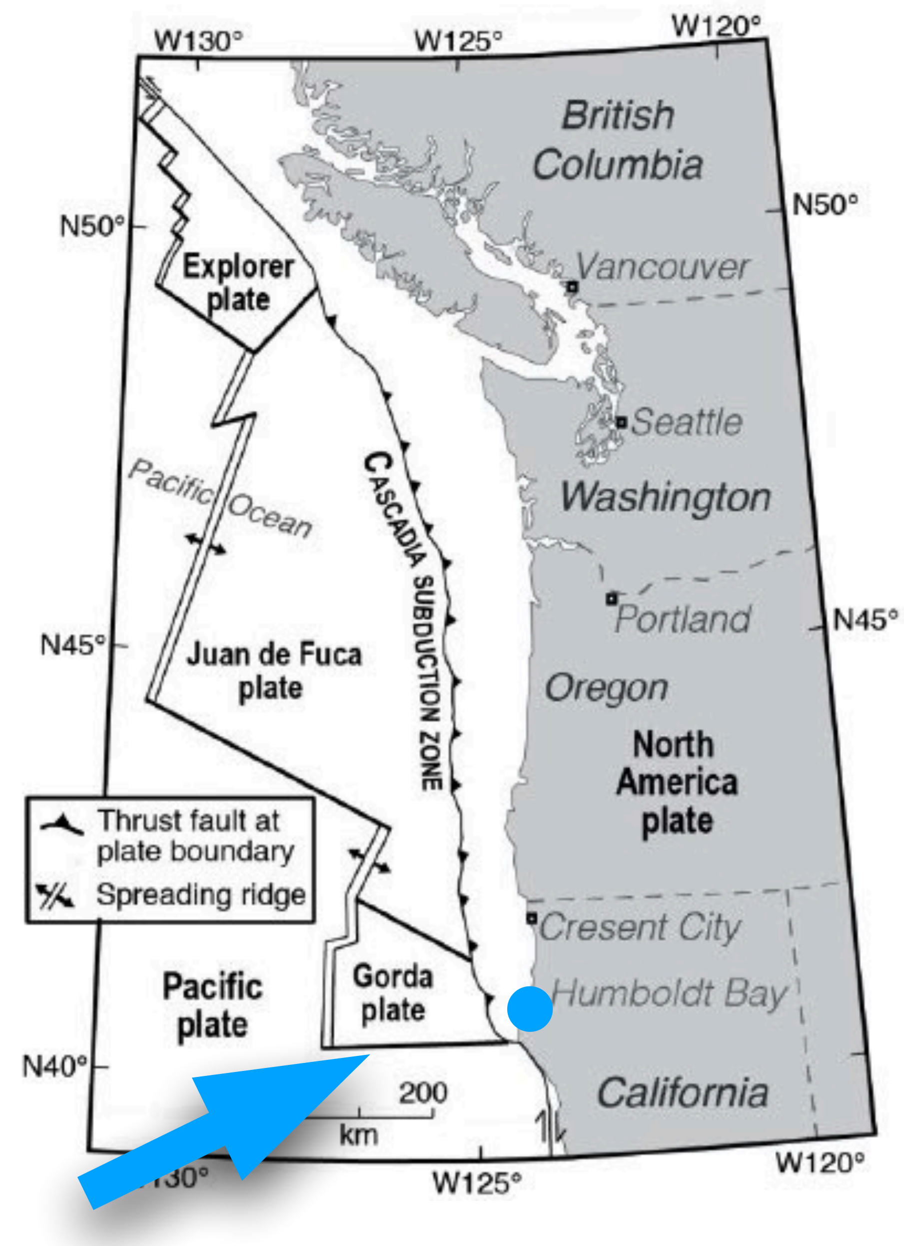
- **Mendocino fault**
- Numerous faults onshore and offshore



- More than 400 earthquakes greater than M 4.5 since 1960
- Greatest impact to onland facilities from earthquakes on eastern end of fault

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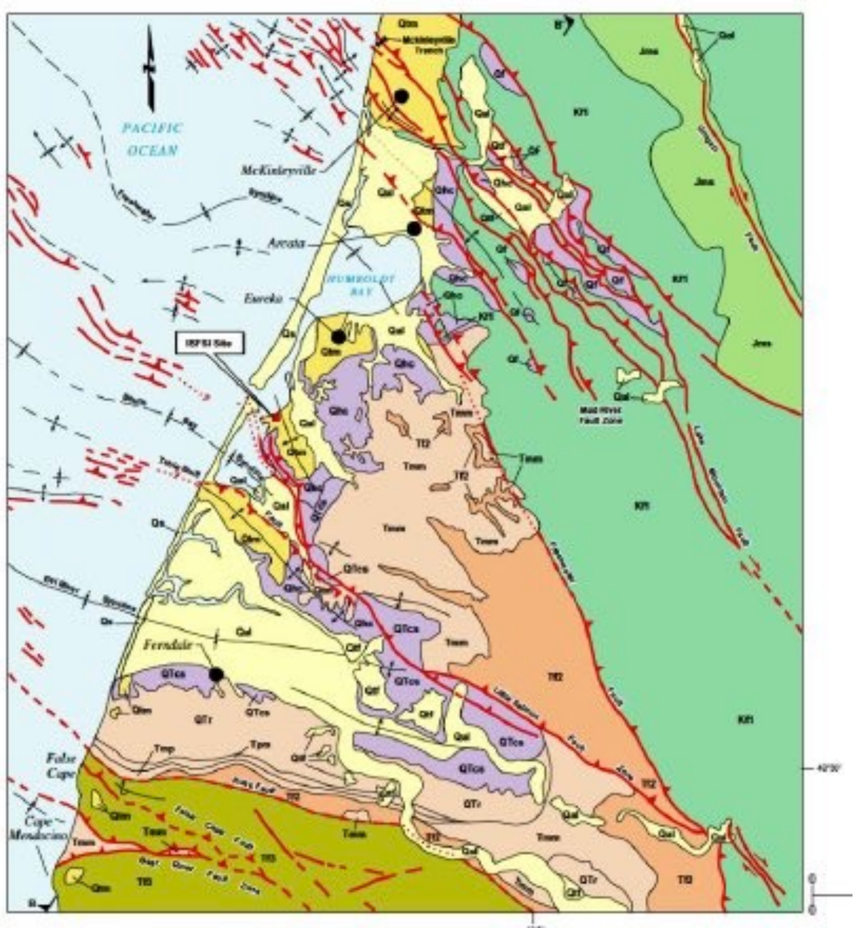
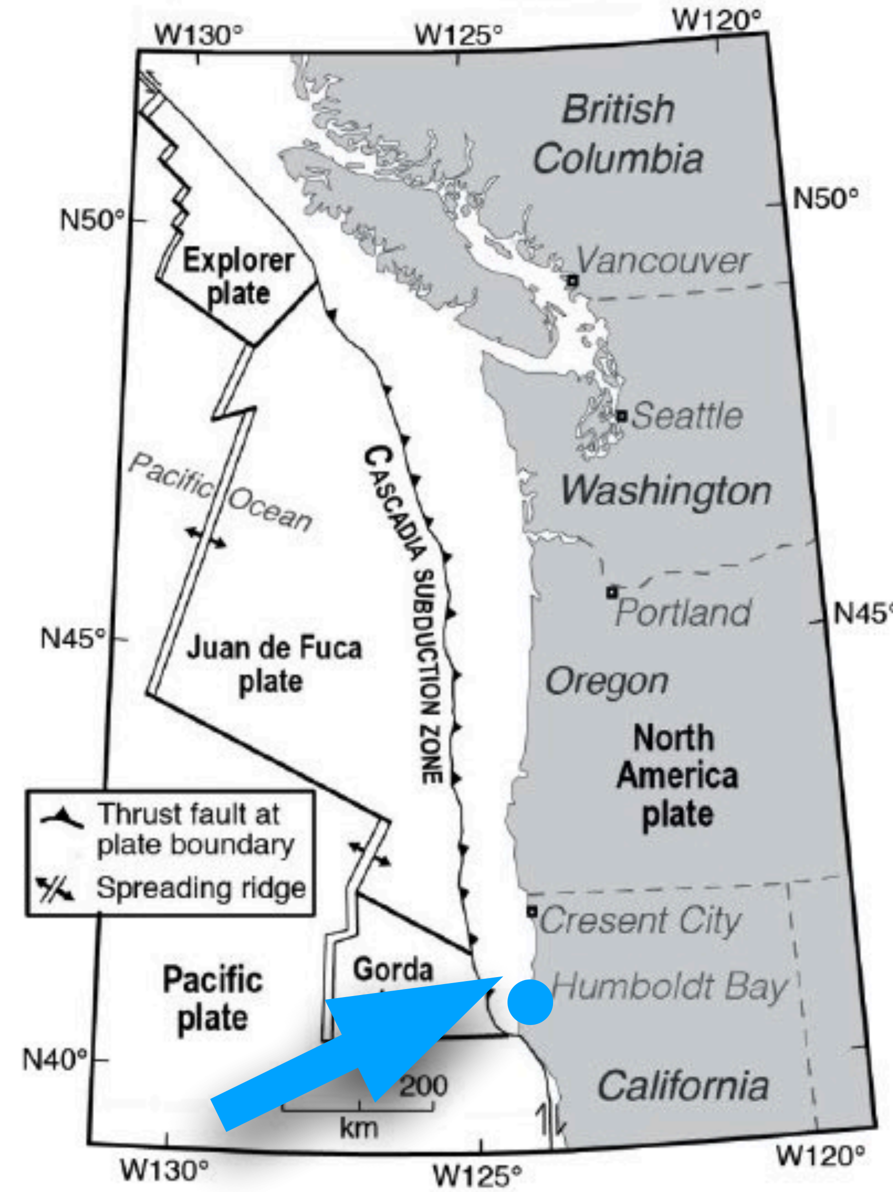




Active faults capable of significant displacements occur on- and offshore

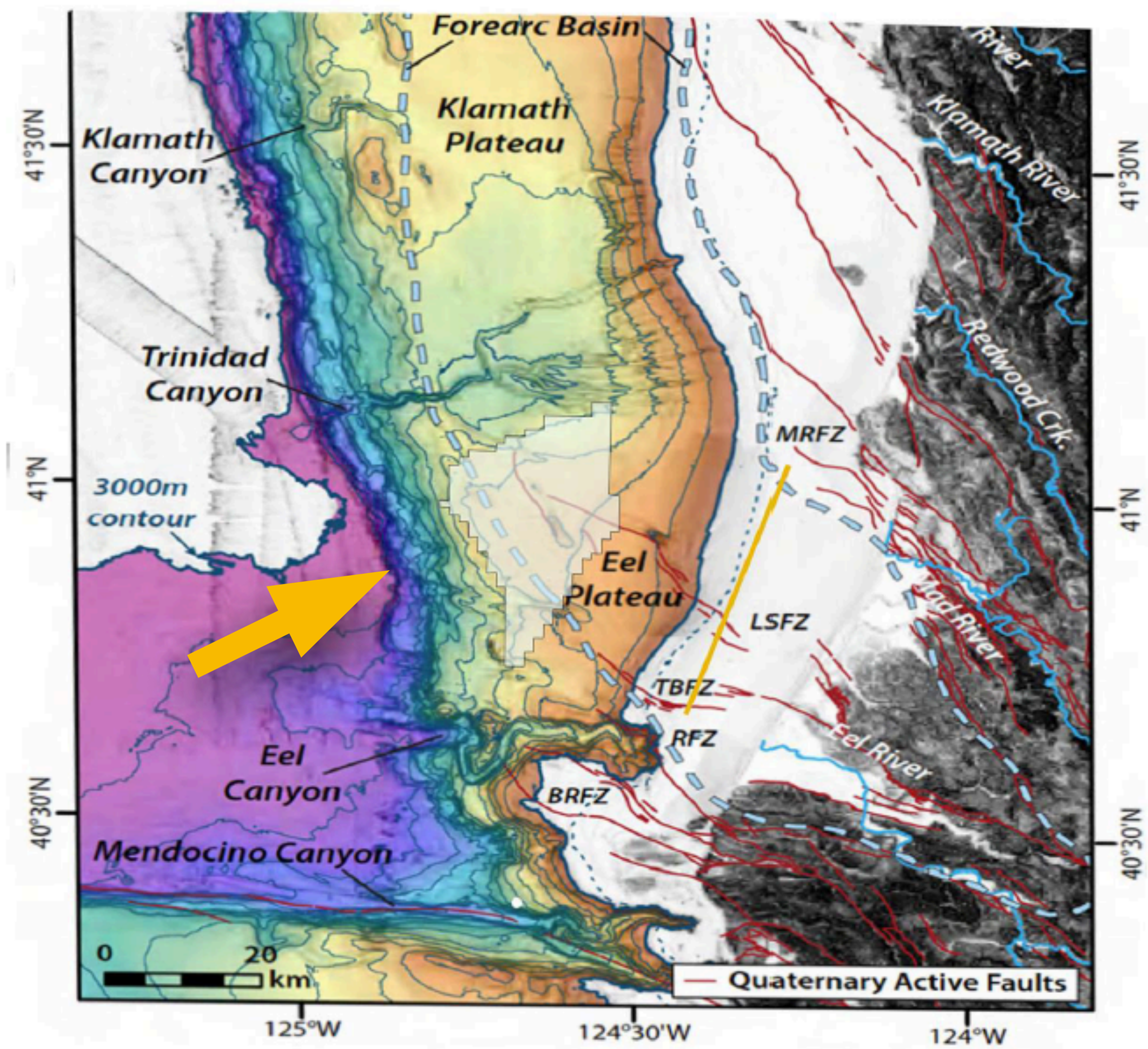


Figure 25. Map showing the bathymetry and topography of the southernmost Cascadia subduction zone in and near the Humboldt Call Area (in center of map with pale-yellow shading and black outline). Quaternary active faults in the onshore and offshore area primarily from USGS Quaternary fault and fold database (USGS, 2020k) and McCrory (2000). Onshore faults extend offshore in the accretionary prism. Yellow solid line is approximate location of seismic profile from Burger et al. (2002) shown in Figure 27.

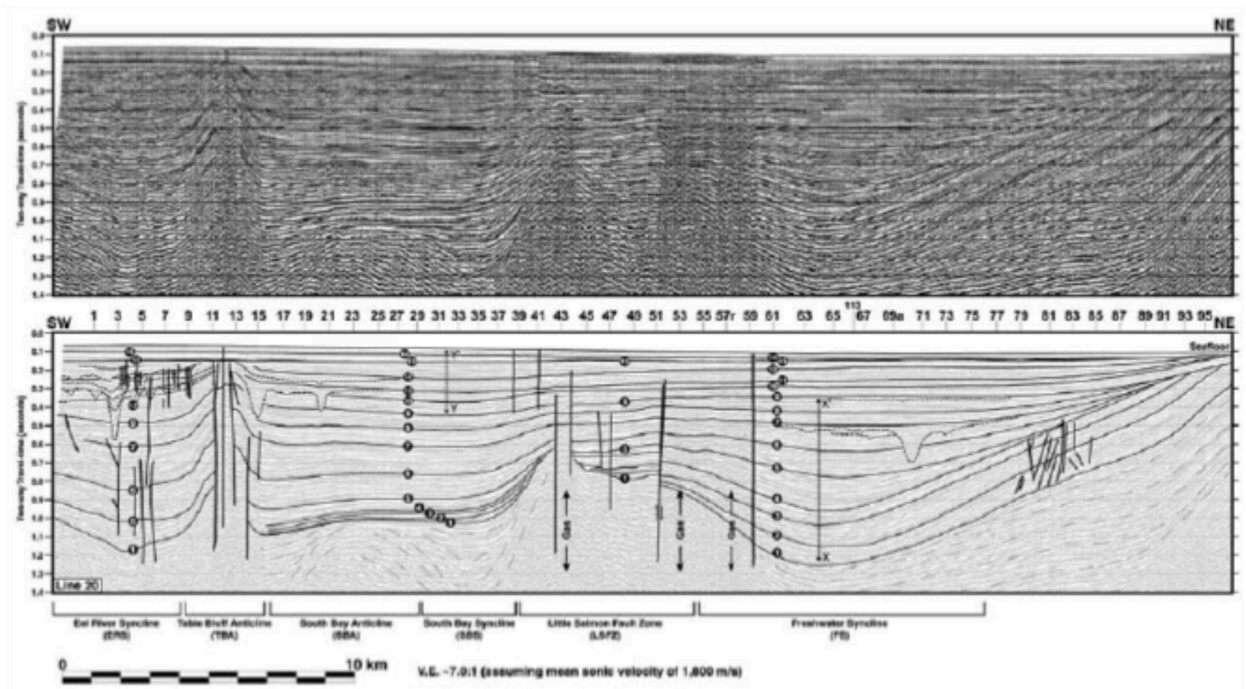


Figure 27. Uninterpreted and interpreted seismic profile from transect approximately parallel to coastline (see Figure 25 for location). Near vertical lines are interpreted faults. Of note are faults within the Little Salmon fault zone (LSFZ) and Table Bluff anticline (TBA). Note that some fault structures extend through the youngest sediments to the seafloor. Also, faults here are depicted as near vertical while the onshore projections of these structures are mapped as low angle thrust faults. (From Burger et al., 2002, their Figure 3.)

Potential impacts to infrastructure:

- ground or ocean bottom displacement
- distortion and folding

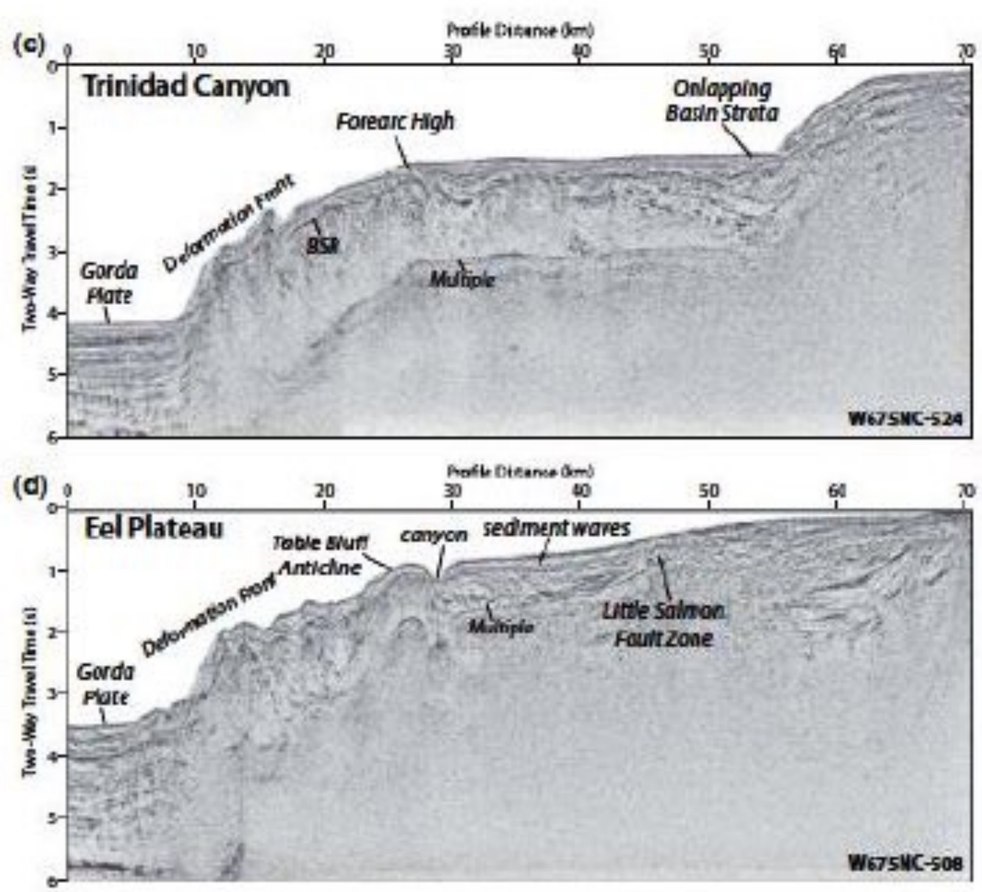
Gas Hydrates

Frozen methane formed within sediments due to appropriate temperature and pressure conditions

Methane formed by decay of biogenic material

Can become destabilized by

- strong shaking
- landsliding
- surface rupture
- climate change



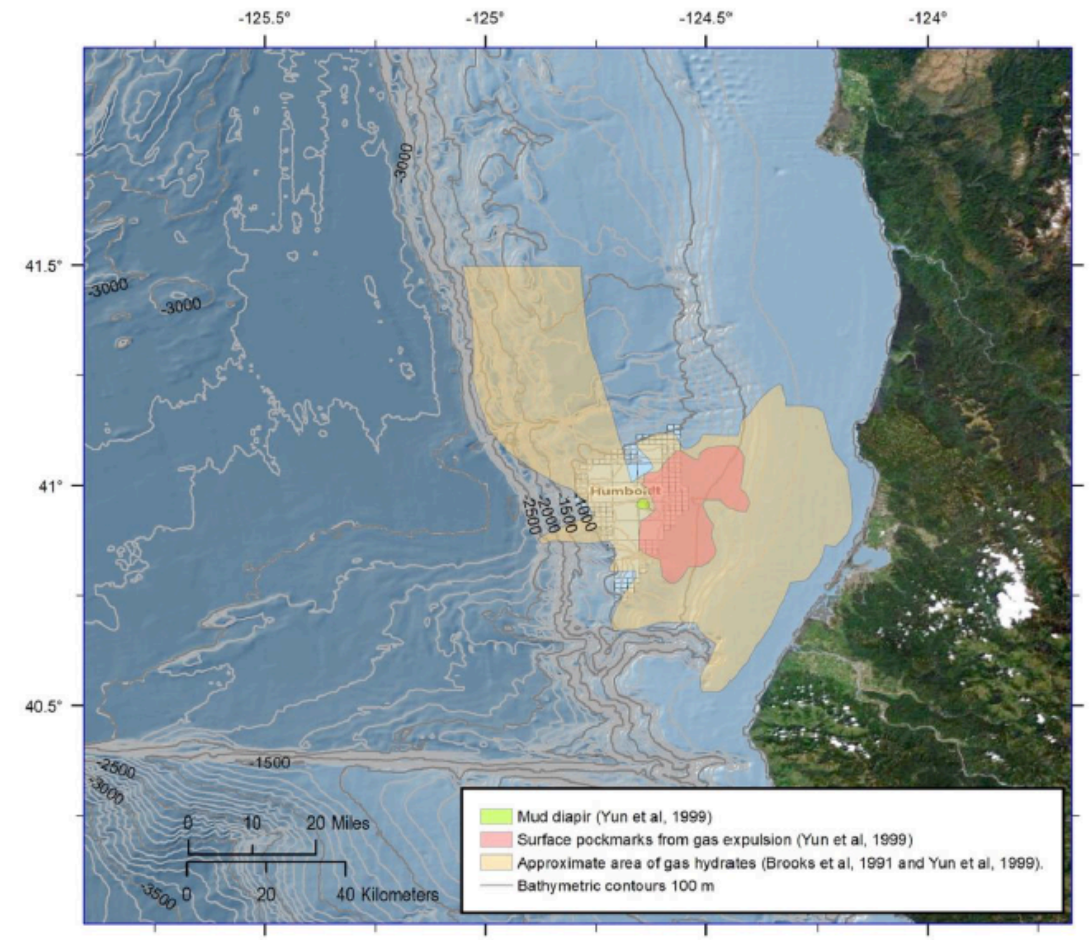


Figure 35. Map showing location of gas hydrates (yellow polygon) in the vicinity of the Humboldt call area based on available data from seismic reflection surveys. The possible extent of gas hydrates beyond the areas shown by the polygons is unknown. Red polygon: areas of surface pockmark identified from side-scan sonar and ocean bottom photography (Yun et al., 1999). Green polygon: location of mud diapir interpreted from seismic reflection data (Yun et al., 1999).

Potential impacts

- liquefaction
- gas blowouts (pockmarks)
- landslides

Liquefaction

When water- or gas- saturated sediments temporarily lose strength and volume due to sudden shaking. Can occur onshore and offshore.

Liquefaction-induced collapse of buildings in Niigata, Japan during 1964 M7.6 event (Wikipedia)

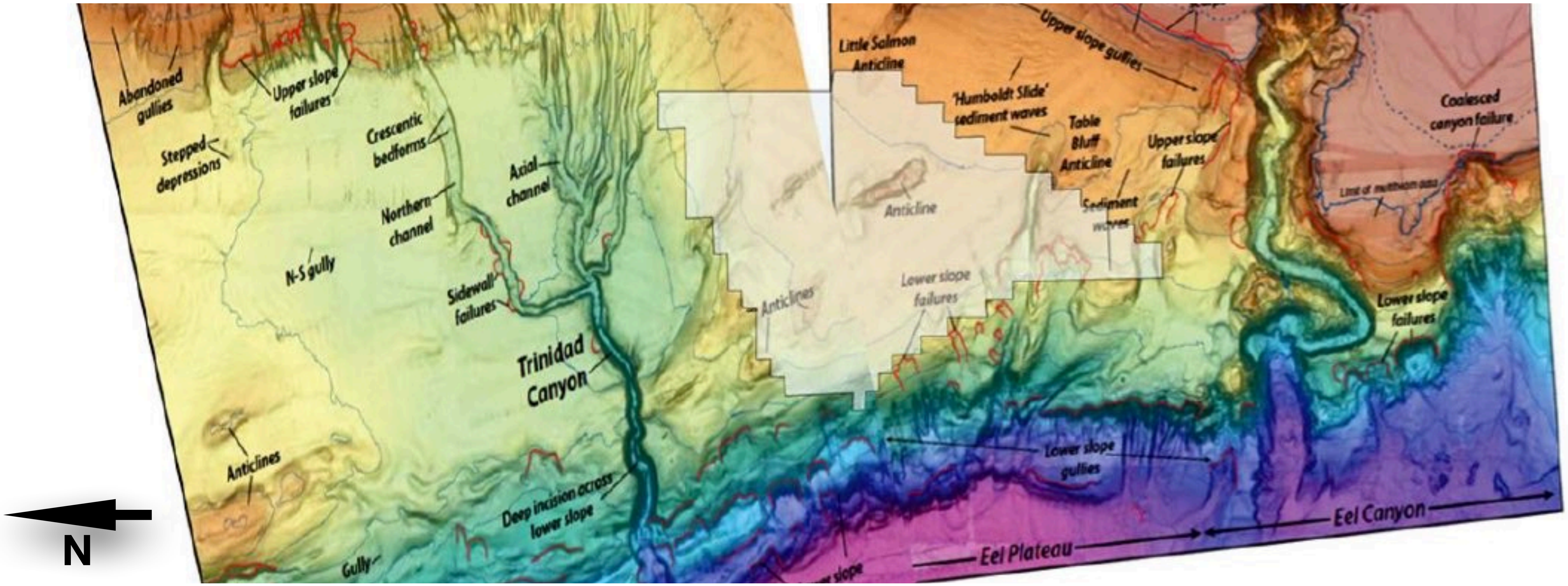
Liquefaction-induced lateral spread at Port Kenyon, lower Eel River, formed during 1906 earthquake (From Dengler, 2008)

Potential impacts to infrastructure:

- loss of foundation support
- displacement

Landslides

Greatest hazard from offshore landslides



High-resolution bathymetry of Trinidad Canyon and Eel Plateau portions of the southern Cascadia subduction zone, modified from Hill et al. (2020, their Figures 10 and 12). The NCOWS callout area is shown in the center as a pale-yellow polygon.

Potential Impacts

- Displacements of ocean sediments and attached infrastructure
- Liquefaction
- Tsunami generation

Tsunamis

"Triggered by earthquakes, volcanic eruptions, submarine landslides, and by onshore landslides in which large volumes of debris fall into the water… [They] typically consists of multiple waves that rush ashore like a fast-rising tide with powerful currents" USGS, 2020

Potential impacts to infrastructure:

- flooding
- scouring
- deposition of debris and scoured sediments

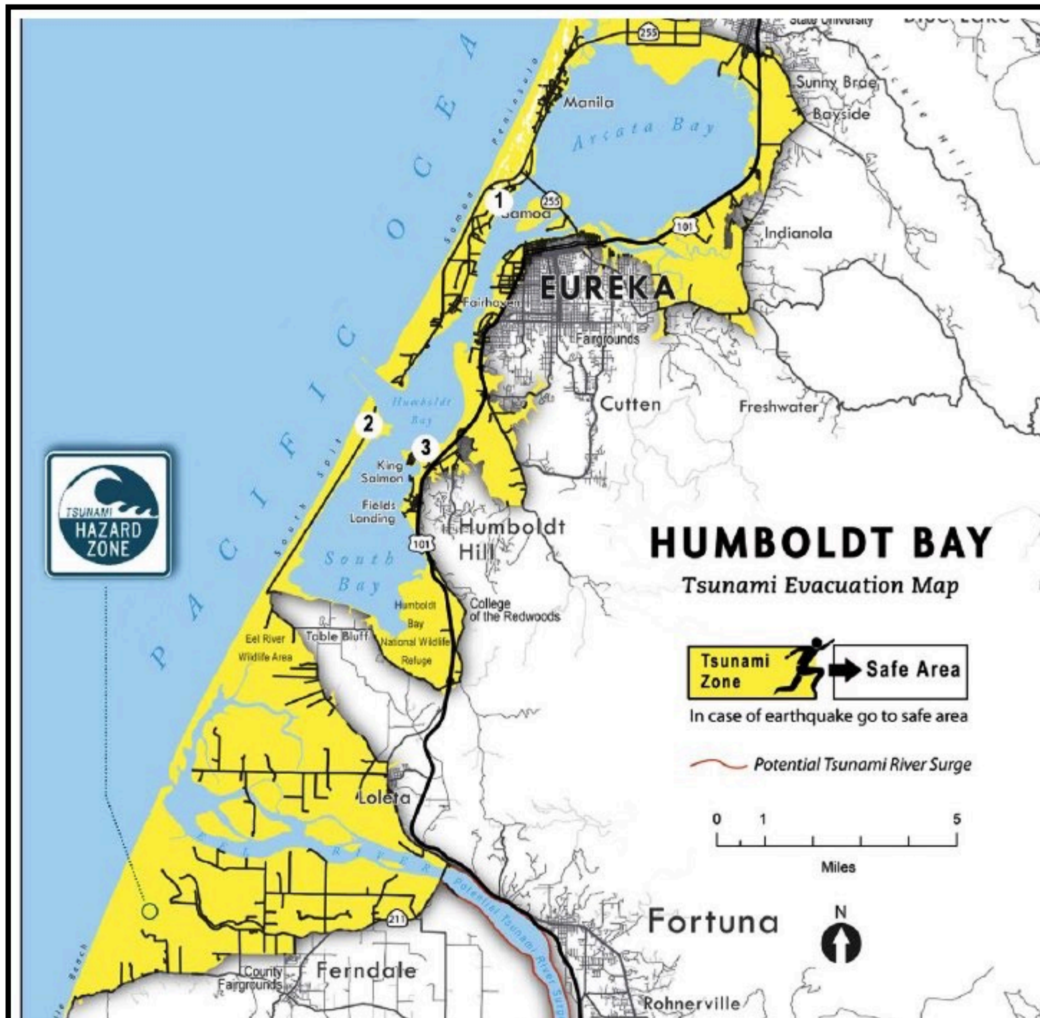


Figure 49. Map of tsunami inundation zone for area of Humboldt Bay that will include the (1) Redwood Marine Terminal I on North Spit, (2) the proposed transmission cable landing site on the South Spit, and (3) the location of the Humboldt Bay Generating Station (HBGS). (Modified from RCTWG, 2020, Humboldt Bay Tsunami Evacuation Map, <https://rctwg.humboldt.edu/sites/default/files/regional-crop.pdf>.)

Newly released maps for Humboldt County at https://maps.conservation.ca.gov/cgs/informationwarehouse/ts_evacuation/

Coseismic and interseismic sea-level change

Coseismic change - during the earthquake - abrupt change in land level due to earthquake-related displacement , especially during subduction zone earthquakes.

Interseismic change - between earthquakes - gradual change in relative sea level due to loading along a fault or climate induced sea level change

1992 M 7.2 Cape Mendocino earthquake (uplifted sea floor ~ 2 m)

2004 M 9 Sumatra earthquake (subsided sea floor ~ 2 m)

Potential Impacts

- sudden emergence or submergence of near coastal infrastructure

Conclusion

There are significant potential geological hazards within the region that will need to be investigated and addressed for possible development of an offshore wind farm.