- **Lecture Overview**
    - Application of earthquake faulting, seismic waves, magnitude, and intensity scales to real case studies.
    - Focus on:
        - Subduction zone case study: Tohoku megathrust earthquake (Japan, March 2011, magnitude 9.0).
        - Continental collision zone case study: Bam earthquake (Iran, 2003, magnitude 6.6).
        - Intraplate earthquakes: Occurring within tectonic plates.
- **Tohoku Megathrust Earthquake (March 2011)**
    - Magnitude: 9.0, second largest of our lifetimes.
    - Death Toll: Approximately 20,000 people due to triggered tsunami.
    - Comparison: Largest earthquakes (by magnitude) are not always the most damaging.
- **Bam Earthquake (2003)**
    - Magnitude: 6.6, death toll up to twice that of Tohoku.
    - Reflection of regional patterns: Occurrence in Mediterranean, Middle East, South and East Asia.
- **Categories of Earthquakes in Subduction Zones**
    - **Megathrust Earthquakes**
        - Shallow fault interface, can exceed moment magnitudes of 8 or 9.
    - **Crustal Events**
        - Smaller magnitudes (up to ~7), occur directly beneath continents, potential for severe damage.
    - **Intermediate-Depth Earthquakes (Intra-slab Earthquakes)**
        - Focal depths: 50 to 300 km, may reach magnitudes ~7, often normal faulting.
    - **Deep Earthquakes**
        - Depths > 300 km, rarely damaging.
    - **Outer Rise Earthquakes**
        - Occur at shallow depths due to flexing oceanic lithosphere.
    - **Volcanic Earthquakes**
        - Triggered by rising magma, typically low magnitude.
- **Case Study Examples**
    - 2017 Puebla Earthquake: Intermediate depth, caused extensive damage in Mexico City.
    - 2018 Anchorage Earthquake: Example of liquefaction effects in Alaska.
    - 2001 Nisqually Earthquake: Magnitude 6.8, caused $1-$4 billion in damages in Washington State.

- **Earthquake Cycle at Subduction Zones**
    - Inter-seismic period: Oceanic plate converges with overriding plate, megathrust fault is locked.
    - Co-seismic phase: Sudden slip restores position, triggers tsunami.
- **Tohoku Earthquake Tectonic Setting**
    - Subduction of Pacific Plate below Japan along Japan Trench.
    - Triple junction: convergence of Pacific and Philippine Sea Plates.
- **GPS Monitoring and Inter-seismic Contraction**
    - East coast of Honshu moving towards the west at 2-3 cm/year.
    - Contraction rate indicates strain buildup.
- **Rupture Pattern and Slip Distribution**
    - Estimated fault length: 300-400 km.
    - Deepest rupture: Extended from 40 km to seafloor.
    - Peak slip: 40m, potentially up to 60m.
- **Tsunami Characteristics**
    - Tohoku tsunami height: Average 10-20m, maximum recorded height of 39m.
    - Previous tsunamis did not exceed around 6m height.
- **Paleoseismology and Historical Tsunami Evidence**
    - Study of sediment layers reveal past events similar to Tohoku.
    - Evidence suggests large tsunamis occur on average every 500-1,000 years.
- **Cascadia Megathrust Considerations**
    - Potential behavior of Cascadia similar to Japan Trench observed in Tohoku.
    - Research focuses on the shallow part of the megathrust and its implications for tsunami height.
- **Models of Potential Cascadia Earthquake**
    - Scenarios include varying peak slips (not reaching trench, reaching trench).
    - Impact on tsunami run-ups and shaking experienced in coastal regions like Victoria.
- **Final Thoughts**
    - Ongoing uncertainties in predicting impact magnitude and tsunami behavior.
    - Importance of active research and monitoring in the region.

Part 1: Continental Plate Boundary Earthquakes

- **2003 Ban Earthquake**: Main case study.
- **Types of Continental Plate Boundaries**:
    - **Convergent Collision Zones**: Example: India-Eurasia collision (Himalayas).
    - **Continental Shear Zones**: Example: San Andreas Fault, California.

    - **Divergent Continental Rifts**: Illustrated in a cartoon depiction.

- **Earthquake Types**:

    - Continental collision zones: Reverse or thrust faults, strike-slip faults, normal faults (e.g., Tibet).
    - Continental shear zones: Primarily strike-slip faults, but may contain reverse and normal faults.
    - Continental rifts: Mostly normal faulting, some strike-slip faults.

- **Seismogenic Zone**:

    - Thickness: About 15 km.
    - Earthquake depth: Typically do not exceed 30-40 km.
    - Magnitude: Large earthquakes of 7-8 common; >8 very rare.

- **Faulting Characteristics**:

    - Generally spread over wide plate boundary zones rather than focused on major faults.

- **Examples of Notable Earthquakes**:

    - **2016 Kaikoura Earthquake, New Zealand**: 20 individual faults, including strike-slip and reverse faults.
    - **2019 Ridgecrest Earthquake, California**: Occurred in eastern California shear zone.
    - **2016 Norcia Earthquake, Italy**: Normal faulting in Apennine Mountains.

Part 2: 2003 Bam Earthquake Case Study

- **Location**: Southern Dasht-e Lut desert, Iran.

- **Event Date**: December 26, 2003, at 5:30 AM local time.

- **Impact**:

    - Destruction of the medieval citadel (UNESCO site).
    - Casualties: 26,000 - 40,000 fatalities (approximately 50% of Bam's population).
    - Damage: 60% of modern buildings, 90% of older adobe structures.

- **Faulting and Analysis**:

    - Bam does not lie on any mapped fault line.
    - Satellite remote sensing (INSAR) used to reveal fault responsible.
    - Result: Identification of a main right-lateral strike-slip fault and a secondary reverse fault.

- **Geological Features**:

    - Bam-Barabat Ridge: Uplifted by repeated earthquakes.
    - Importance of **Canats**: Ancient underground irrigation tunnels reliant on raised water tables due to active faults.

Part 3: Earthquake Preparedness in Iran

- **Seismic Hazard in Iran**:

    - Extensive active fault network indicated by mapped faults.
    - High earthquake history leading to significant fatalities.

- **Major Cities and Earthquake Risks**:

    - Tehran's location adjacent to active faults (North Tehran Fault).
    - Historical earthquake occurrences in Tehran (855, 958, 1177, 1830 CE).

- **Fatal Attraction**:

    - Urban centers situated along active faults for water access.
    - Ongoing risk of destructive earthquakes due to increasing populations in fault-prone areas.

Part 4: Intraplate Earthquakes

- **Definition**: Earthquakes occurring within tectonic plates, not at plate boundaries.

- **Causes**:

    - Tectonic stresses from boundaries transmitting through plate interiors.
    - Internal stresses from geological processes (e.g., post-glacial rebound).

- **Notable Areas**:

    - Charlevoix seismic zone in eastern Canada, associated with ancient faults.
    - Labrador Sea and Grand Banks: Sites of significant intraplate earthquakes historically.

- **Human-Induced Seismicity**:

    - Activities causing induced earthquakes (fluid injection, mining, reservoir impoundment).
    - **Fracking's Impact**: Dramatic increase in recorded seismicity in the US since 2009.

- **Canadian Context**:

    - Induced seismicity linked to fracking in northeast British Columbia and Alberta.
    - Observations of delayed seismic response to increased fracking activity.

Conclusion

- **Understanding Earthquake Dynamics**:
    - Essential for hazard assessment and urban planning along active faults, particularly in regions like Iran and the continental margins.