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Fault Processes and Liquefaction in the Marine Environment

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INTRODUCTION

Earthquake geotechnology for the design of offshore structures involves many issues concerned with the estimation of magnitude, acceleration and sediment stability. In the following sections fault processes and attenuation of earthquake ground motion for subduction zone and thrust faults will be discussed. In addition, evidence of liquefaction in the marine environment will also be presented.

Fault Processes and Attenuation of Earthquake Ground Motion for Subduction Zone and Thrust Faults

The Cascadia Subduction zone offshore is being subjected to a north-south directed compression, Spence (1987a, b). This compression is a result of the Pacific plate pushing the Cascadia subduction zone in a northwest direction via the Blanco and Mendocino Faults. Faults in the Gorda Plate are believed to be aligned along in situ zones of weakness which parallel the magnetic anomalies and are orientated approximately north-south further offshore, then fanning to a more northeast-southwest direction immediately offshore (McPherson, 1989). This pattern of faults mimics the magnetic anomaly trends, as shown in Fig. 1. Earthquake epicenters in the Gorda Plate propagate along the magnetic anomalies.

There are a number of attenuation relationships that have been developed for subduction zone and thrust faults (Joyner and Boore, 1988; Kawashima et al., 1984). The distance (D) used in developing these relationships is typically from the surface rupture to the site at which the acceleration is being recorded. This is a reasonable approximation for high angle thrust or strike slip faults, Fig. 2b, but may not be realistic for low angle thrust faults or subduction zones as shown in Fig. 2a. In the case of low angle thrust faults the rupture plane may pass under the site. In this case the distance from the rupture plane to the site can potentially be less than the distance from the site to the surface rupture. The result of using the smaller of the two distances will be an increased acceleration level.

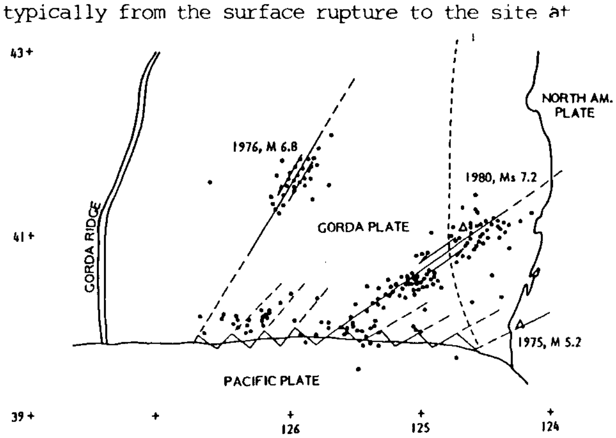
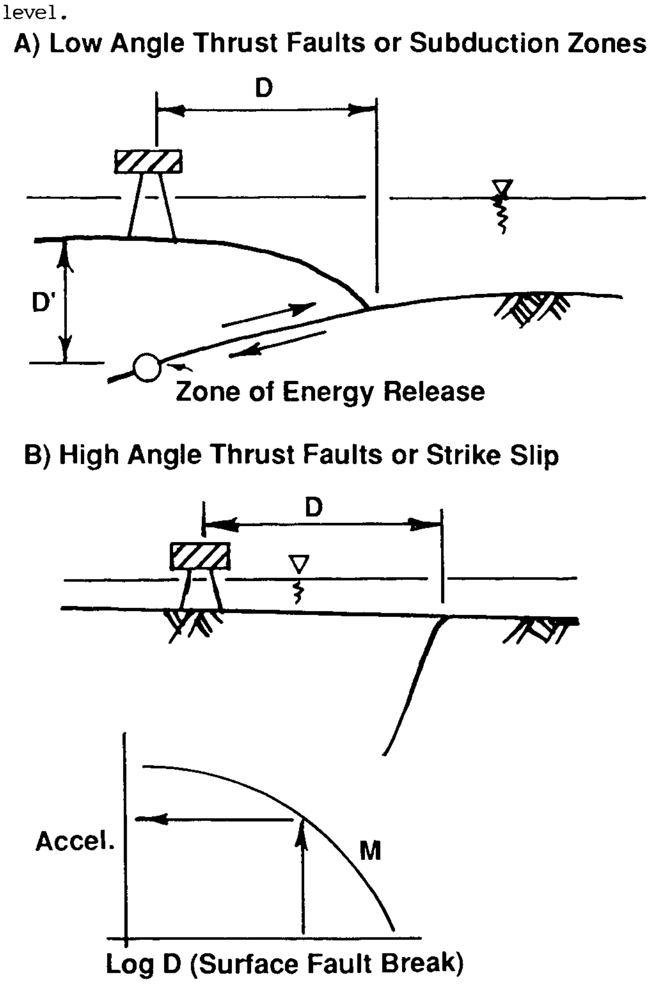


Fig. 1 - Break-up of the Gorda Plate: three intraplate earthquake sequences (Ref. Smith et al., 1981; McPherson, R. C., 1989).



Typical Form of Attenuation Relationship

Fig. 2 - Determination of Acceleration At a Site Based on Distance.

Site location for a normal and thrust faulting environment will influence its expected acceleration during a seismic event.

Attenuation curves for normal and thrust faulting as a function of whether the site is on the upper or lower block are presented in Fig. 3. A review of Fig. 3 shows that for distances to the fault less than 100 km, the upper block gives a higher peak acceleration as compared to the lower block, Bureau (1978).

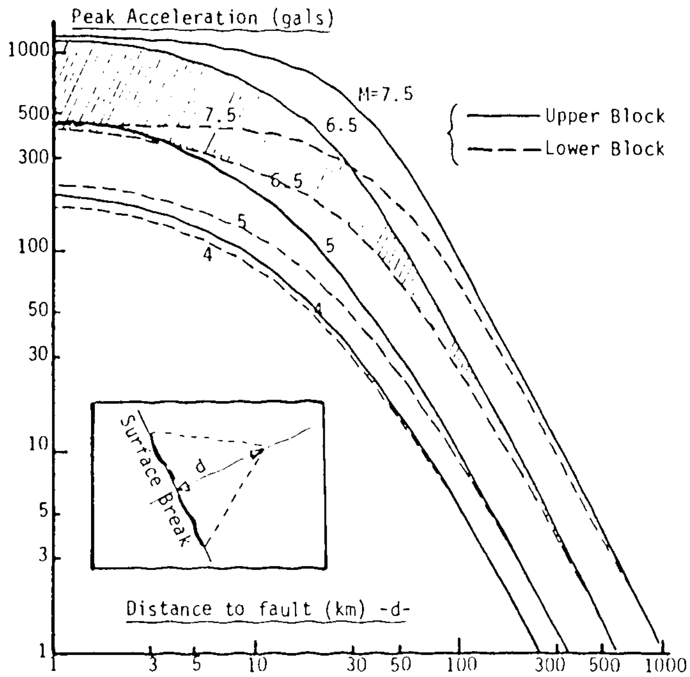


Fig. 3 - Attenuation Curves for Normal and Thrust Faulting (Ref. Bureau, 1978).

Liquefaction in the Marine Environment

When the Humboldt County Earthquake (M=7.0) struck the Northern California coast on November 8, 1980 liquefaction failures occurred at Big Lagoon and offshore of the Klamath River. At Big Lagoon extensive soil failure occurred all along a 3 mile long and approximately 300 foot wide natural sand spit as shown in Fig. 4. The types of soil failures experienced ranged from lateral spreading to sand boils. The sand boils were observed on both the dry sand spit and submerged in the lagoon. Similar sand spits have been used for both commercial and residential development in many seismic areas.

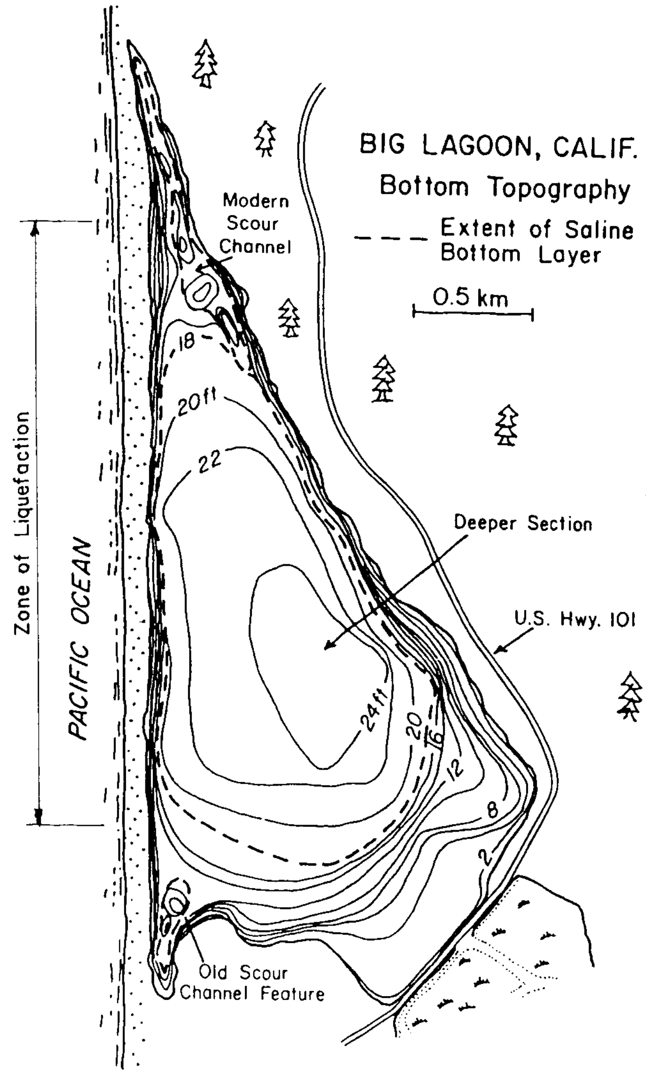


Fig. 4 - Liquefaction of Sand Spit At Big Lagoon, California During the Magnitude 7.0 Earthquake on November 8, 1980.

The liquefaction failure offshore of the Klamath River was controlled initially by sediment type. The seaward boundary of the failure zone coincides with the contract between muddy sand and sandy clayey silt. The variety and the specific nature of features observed on sonographs indicate several modes of sediment failure. The modes that are indicated are liquefaction, lateral spreading and sediment collapse and flowage (Field and Hall, 1982; Field, 1984) as shown in Fig. 5. Subsurface liquefaction is inferred at shallow depths as result of excess pore pressures generated in sand by the earthquake, refer to Fig. 6.

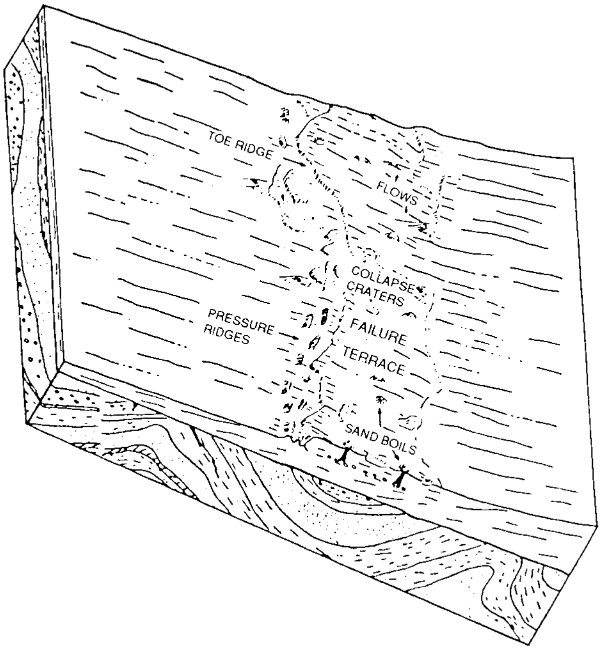


Fig. 5 - Conceptual block diagram showing variety and types of features observed in the failure (Field, 1984).

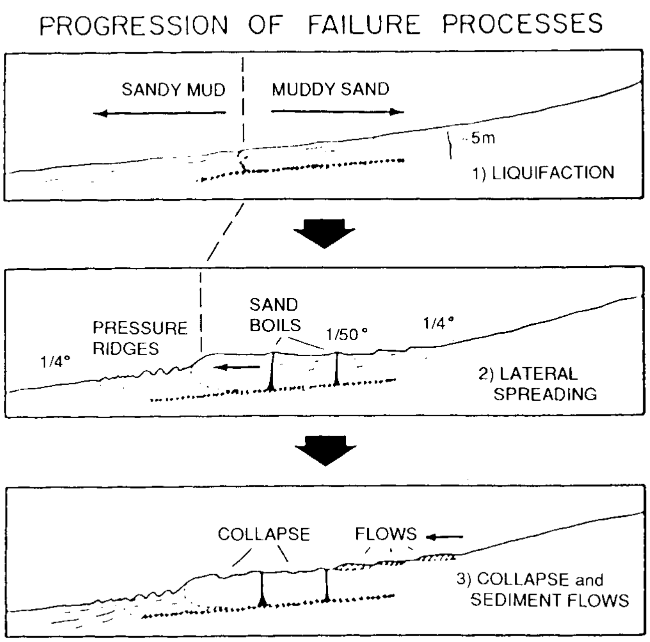


Fig. 6 - Schematic illustration showing conceptual Progression of failure from subsurface Liquefaction (top) to lateral spreading (middle) and ending with sediment collapse and flow (bottom). Interpretation based on sonographs and high-resolution seismic reflection data. This progression is in part sequential but may have been largely contemporaneous. Lateral spreading followed liquefaction but collapse and sediment flows may have occurred coincident with spreading. (Ref. Field, 1982).

CONCLUSIONS

Based on the preceeding discussion, the following conclusions can be made:

(1) Determination of acceleration levels resulting from low angle thrust faults based on distance from surface breaks may be low.

(2) Construction of shore facilities on sandspits can experience liquefaction and lateral spreading.

(3) Liquefaction and lateral movement occurs on very low angle (¼°) sea beds.

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