STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

Tony Knowles, *Governor*

John T. Shively, *Commissioner*

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PLANNING SCENARIO EARTHQUAKES FOR SOUTHEAST ALASKA

by
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Planning Scenario Earthquakes for Southeast Alaska

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This document describes the "maximum credible" planning earthquakes for Southeast Alaska. In a meeting on February 9, 1998, attendees from the American Red Cross, Alaska Division of Emergency Services, Alaska Division of Geological & Geophysical Surveys, and the University of Alaska Geophysical Institute, proposed maximum credible earthquakes following the same guidelines as proposed in 1997 for Anchorage (i.e., an event in the next 50 years to occur in the region). The format of this document will include sections on the seismotectonic setting of Alaska, the likely seismic sources for the Southeast, and potential for tsunamis from earthquake sources.

Seismotectonic Setting of Alaska

Alaska spans 4,800 km of the seismically active boundary between the oceanic Pacific and continental North American plates and is one of the world's most active regions of earthquake activity associated with subduction and volcanism. Nearly the entire state is seismically active. The greatest concentration of earthquakes is along the Pacific margin where the Pacific plate is being subducted beneath southern Alaska and the Aleutian Islands. The historical record indicates that magnitude 7 and larger shocks are about three times more frequent in southern Alaska than in California. Three of the ten largest earthquakes in the world this century originated in Alaska on the boundary between the Pacific and North American plates. In 1964, the eastern end of the Aleutian subduction zone spawned the moment magnitude (M_w) 9.2 Prince William Sound earthquake, the second largest earthquake of this century. Alaska's other two great earthquakes occurred in the central and western parts of the Aleutians Islands -- the 1957 Mw 8.6 Andreanof- Fox Islands earthquake and the 1965 Mw 8.7 Rat Islands earthquake. The seismicity of Alaska stems primarily from the interaction of the Pacific and North American plates. The northwestward motion of the Pacific plate relative to the North American plate is accommodated by dextral transcurrent faulting in southeast Alaska on the Queen Charlotte-Fairweather fault system, and by underthrusting and subduction of the Pacific plate along the Aleutian megathrust, which crops out on the seafloor at the Aleutian trench. The seismicity related to various tectonic elements can be divided into five distinct source zones as follows: 1) Plate-boundary earthquakes along the interface between the Pacific plate and the North American plate; 2) subsea earthquakes within the Pacific plate beneath or seaward of the trench and the Transition fault; 3) Wadati-Benioff Zone earthquakes within the subducted part of the Pacific plate landward of the trench; 4) North American plate earthquakes, exclusive of those along the volcanic arc; and 5) volcanic-axis earthquakes within the North American plate along the axis of active volcanoes.

Of particular interest for this report are the large events that have occurred on the strike-slip faults associated with the Queen Charlotte-Fairweather fault system (fig. 1). This plate boundary between the North American plate and the Pacific plate is very analogous to the well known San Andreas fault system in California, and is essentially a northward extension of the right-lateral

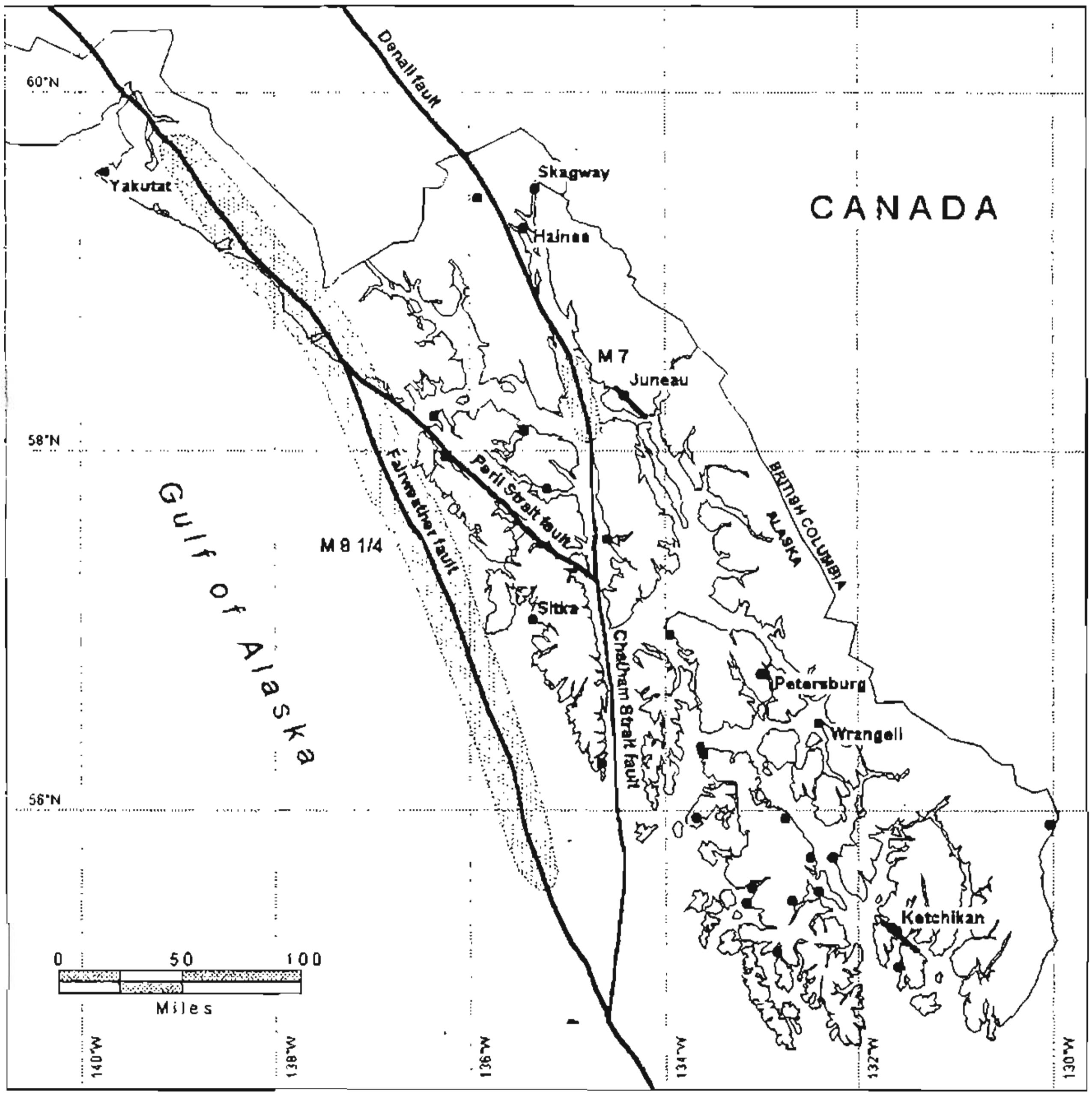

Figure 1 - Active and potentially active faults in southeastern Alaska. The Fairweather fault is clearly active, having caused three recent moderate to large earthquakes (M8.1 in 1949, M7.9 in 1958, and M7.6 in 1972). The age of most recent displacement on other depicted faults is unknown. However, nearby seismicity and indirect geologic evidence indicate possible activity of these faults during recent geologic time (Plafker and others, 1994). These include suspected faults near Juneau (Gastineau Channel fault) and Ketchikan (Tongass narrows fault). Stippled patterns depict possible rupture areas of scenario earthquakes on the Fairweather fault (M8¼) and Chatham Strait fault (M7). The rupture areas shown represent the probable worst-case scenarios because they are closest to existing population centers. However, the ruptures could occur anywhere along these faults.

motion as the two plates slide past each other. At the northern end of this fault system, near Yakutat Bay, spectacular surficial effects were produced by a magnitude 8.2 earthquake in 1899. Here a vertical fault displacement of 15 meters was observed as the plates collide. In addition a destructive tsunami over 10 meters high was generated in Yakutat Bay. To the south four earthquakes occurred this century with magnitudes greater than 7.0, all of which involved dextral slip: In 1927 an event of magnitude 7.1 located near latitude 57.7 degrees north; in 1949 a magnitude 8.1 event on the Queen Charlotte fault originating near 53.6 degrees north, and rupturing nearly 500 km to the north and south; in 1958, a magnitude 7.9 earthquake ruptured about 350 km of the Fairweather fault, with measured onshore displacement up to 6.6 meters (shaking from this event induced a large landslide at the head of Lituya Bay causing a spectacular water wave that surged up and deforested the opposite shore of the fjord to an elevation of 530 meters); and the magnitude 7.4 Sitka earthquake in 1972, which ruptured a 190-km segment of the fault system between the northern limit of the 1949 event and the southern limit of the 1958 event. The Sitka event had been identified as a seismic gap and a likely site for an earthquake, and thus was a successful forecast.

Although all the well recorded historic shocks larger than magnitude 7.0 have occurred on the main plate boundary, significant seismicity occurs eastward of the Queen Charlotte-Fairweather fault system. For example, seismicity follows the southern end of the Denali fault system and has produced historic earthquakes up to at least magnitude 6.5. The Denali fault appears to join to the Chatham Strait fault system and continue past the Juneau area. While little historic seismicity is associated directly with the Chatham Strait fault, their is sufficient geologic evidence of activity to consider this fault as a capable fault for a planning scenario earthquake due to its proximity to the population center in Juneau.

Tsunami Potential

Tsunamis (seismic sea waves) are generated by sudden vertical motion of the sea floor. Because the Fairweather and Denali/Chatham Strait fault systems are strike-slip (sideways motion parallel to the fault), they are not likely to generate tsunamis. However, earthquake ground shaking can indirectly cause locally generated waves by triggering landslides in the steep terrain nearby. If a major landslide enters sea water or occurs on the seafloor, a large local wave can be generated that can be devastating to people and facilities along nearby shorelines. There is little warning because the waves can travel from the source to nearby coastal areas in a matter of minutes. Areas most vulnerable are deep bays and inlets adjacent to steep slopes. In these semi-enclosed basins, the water can oscillate to create a large wave, called a seiche, which can impact the shorelines several times before dissipating. The waves that destroyed much of old Valdez after the great 1964 earthquake were caused by an earthquake-triggered submarine slide. In 1958, an earthquake on the Fairweather fault triggered a large landslide that crashed into the head of Lituya Bay, generating a wave that stripped trees to an elevation of 1,700 ft. on the opposite shoreline. A non-earthquake related seiche occurred in Skagway Harbor in November 1994, destroying part of the state ferry dock and city boat harbor. This seiche was caused by a submarine landslide, which apparently was triggered by an extreme low tide. There may be many similar unstable areas in southeastern Alaska where damaging landslide-generated waves can occur as a result of earthquakes or other triggering events.

Vertical seafloor motion resulting from a future earthquake in the Yakataga seismic gap could produce a damaging tsunami. Southeastern communities most vulnerable to a tsunami from this area are those along the outer coastline, including Yakutat and Sitka. These communities are also vulnerable to tsunamis from more distant sources, such as the Aleutian seismic zone and Japan.

Scenario Seismic Sources

We propose that two potential earthquake scenarios be considered for emergency planning in Southeast Alaska. As indicated on Figure 1 and Table 1 strong shaking could result from either a supposed magnitude 8¼ on the Queen Charlotte - Fairweather fault system, or a magnitude 7 on the Denali/Chatham Strait fault system. The planning meeting participants considered these earthquakes to be the maximum credible planning events for southeast Alaska based on current understanding of the seismic sources. The likelihood or recurrence frequency of these earthquakes has not been determined. The rupture areas of these events are confined to vertical

Table 1 - Maximum credible planning earthquake for southeast alaska (likely to occur within 50 years)

	Earthquake #1	**Earthquake #2**
Magnitude	7	8¼
Description	Shallow crustal	Shallow crustal
Location	Denali-Chatham Strait fault (any 50 km section)	Fairweather fault (any 500 km section)
Depth	3-15 km	3-15 km
Peak acceleration	Depends on location	Depends on location
Duration	~30-50 sec	~1½-2 min
Characteristics	Sudden jolt, then high frequency shaking, 0.1-1 sec/cycle (1-10 motions/second)	Continuous rolling motion, 2-5 sec/cycle (0.2-0.5 motions/sec)
Rupture area	50x20 km	500x20 km
Secondary hazards	Landslides Snow avalanches Submarine landslides	Landslides Snow avalanches Submarine landslides
Local tsunamis	Landslide-generated waves	Landslide-generated waves

faults extending to a depth of 20 km and continuing for a length of 500 km for a magnitude 8.25, and 50 km for a magnitude 7. While the rupture areas drawn on Figure 1 indicate the extended length of an example scenario earthquake, for planning purposes, the scenario earthquake location should be placed along the respective fault system closest to the population center of interest. For example, the locations of the rupture areas on Figure 1 are suitable for planning in the Juneau region, but the magnitude 7 scenario earthquake on the Denali/Chatham Strait fault system should be located northward next to Haines when considering planning scenarios for the

Haines and Skagway areas. Likewise, the magnitude 8¼ scenario earthquake on the Queen Charlotte - Fairweather fault system should be shifted southward when planning for Ketchikan and surrounding areas.

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Reference Cited

Plafker, George, Gilpin, L.M., and Lahr, J.C., 1994, Neotectonic map of Alaska, *in* Geology of Alaska, Geology of North America, v. G-1, pl. 12: Boulder, Geological Society of America, scale 1:2,500,000.