

RUPTURE ZONES AND REPEAT TIMES OF GREAT EARTHQUAKES
ALONG THE ALASKA-ALEUTIAN ARC, 1784-1980

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Abstract. The dimensions of the rupture zones of known great earthquakes along the plate boundary in Alaska and the Aleutians are inferred from the distribution of aftershocks, the intensity and duration of strong shaking, seismic sea waves and ground deformation. The historic record of great shocks for a segment of the arc is extended back nearly 200 years using Russian documents prior to 1867 as well as more recent descriptions. A great earthquake off the Alaska Peninsula in 1847 re-ruptured most of a 600-km long zone that broke 59 years earlier in 1788. At least half of a major seismic gap in the Shumagin Islands ruptured during those shocks but has not been the site of a great earthquake for at least 77 years. The rupture zone of an earthquake in 1938 also broke in 1788 and 1847 and may have broken between 1899 and 1903. Average repeat times for that zone are 50 to 75 years. The longest repeat time, 91 years, is obtained assuming the zone did not rupture between 1899 and 1903. It is likely that the Shumagin gap will be the site of a great earthquake within the next 10 to 20 years. Large parts of the plate boundary along southern Alaska and the Aleutians ruptured in sequences of major and great shocks from 1898 to 1907 and from 1938 to 1965. This and some other plate boundaries appear to be nearly quiescent for large earthquakes for long periods of time and then to rupture in a series of major shocks. Almost all of the plate boundary along the Alaska-Aleutian arc is now known to have ruptured previously in large or great earthquakes. Hence, presently-existing seismic gaps should be considered to be probable sites of future large shocks and not regions where the plate motion is relieved mainly by aseismic slip.

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Introduction

The Alaska-Aleutian island arc is one of the world's most active zones of earthquake activity, volcanism and subduction. From 1938 to 1979 nine earthquakes (Figure 1) of magnitude (M) 7.4 or larger have ruptured much of the zone of contact between the North American and Pacific plates from offshore British Columbia to southern Alaska and thence along the Aleutian arc. Plate motion is largely strike slip off British Columbia and southeast Alaska and occurs mainly by thrust faulting along the Aleutians. The rupture zones, magnitudes and seismic moments of several of these shocks are among the largest known anywhere in the world. Even for great earthquakes (M > 7.7) the historic record for the Alaska-Aleutian zone was thought to be very short and incomplete. Hence, previous authors have debated whether the repeat time of large earthquakes at a given place on the plate boundary is about 30 to 60 years [Sykes, 1971; Kanamori, 1977a] or as much as 500 to 1350 years [Plafker and Rubin, 1978]. A better knowledge of repeat times of large earthquakes is obviously needed to estimate seismic hazards more accurately, to understand the subduction process in more detail and to make realistic progress toward the prediction of earthquakes.

We have translated a number of documents from Russian that contain material on earthquakes and volcanism in the Aleutians and in coastal Alaska prior to the advent of a global instrumental record in 1897. These descriptions along with more recent instrumental data now allow us to map (Figure 1) the rupture zones of great earthquakes for nearly the past 200 years in a 600 to 1000-km long segment of the arc adjacent to the Alaska Peninsula and to Kodiak Island. We show that two great earthquakes ruptured and re-ruptured at least a 500 km segment of this plate boundary in 1788 and 1847. These and more recent great earthquakes in that area indicate an average repeat time of about 50 to 75 years between great shocks that involve thrust faulting at shallow depths along the same segment of the plate boundary. A

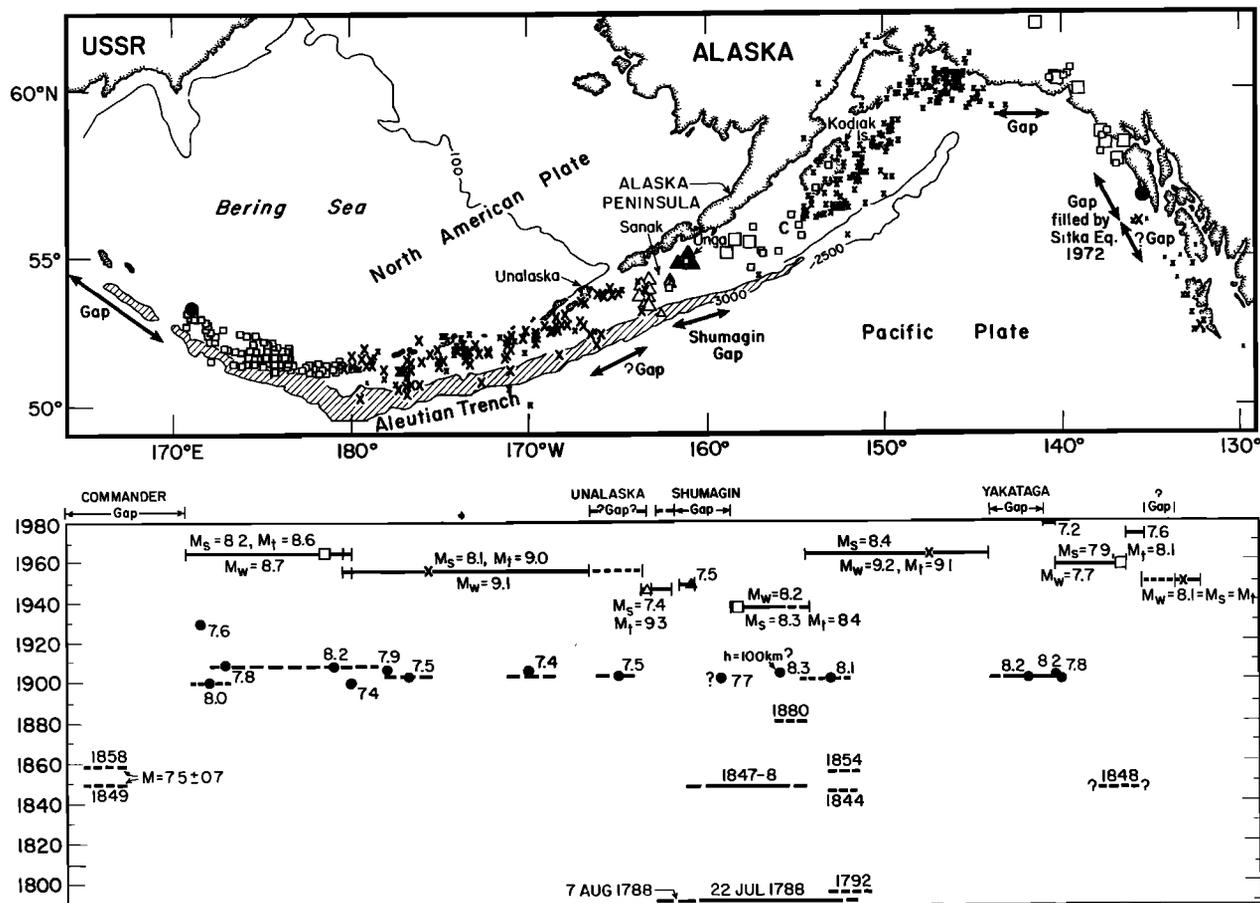


Fig. 1. Above: Rupture zones of earthquakes of magnitude $M \geq 7.4$ from 1925-1971 as delineated by their aftershocks along plate boundary in Aleutians, southern Alaska and offshore British Columbia [after Sykes, 1971]. Contours in fathoms. Various symbols denote individual aftershock sequences as follows: crosses, 1949, 1957 and 1964; squares, 1938, 1958 and 1965; open triangles, 1946; solid triangles, 1948; solid circles, 1929, 1972. Larger symbols denote more precise locations. C = Chirikof Island. Below: Space-time diagram showing lengths of rupture zones, magnitudes [Richter, 1958; Kanamori, 1977b; Kondorskaya and Shebalin, 1977; Kanamori and Abe, 1979; Perez and Jacob, 1980] and locations of mainshocks for known events of $M \geq 7.4$ from 1784 to 1980. Dashes denote uncertainties in size of rupture zones. Magnitudes pertain to surface wave scale, M_s unless otherwise indicated. M_w is ultra-long period magnitude of Kanamori [1977b]; M_t is tsunami magnitude of Abe [1979]. Large shocks in 1929 and 1965 that involve normal faulting in trench and were not located along plate interface are omitted. Absence of shocks before 1898 along several portions of plate boundary reflects lack of an historic record of earthquakes for those areas.

250-km long segment of the arc in this area, the Shumagin seismic gap, has not been the site of a great earthquake for at least 77 years. Davies et al. [1980] discuss earthquake prediction and earthquake hazards for the Shumagin gap in more detail. An abbreviated version of this paper is published by Sykes et al. [1980].

Rupture Zones of Large Earthquakes

1929-1980. Sykes [1971] mapped the rupture zones of large ($M \geq 7.0$) earthquakes of the past 50 years along the plate boundary in southern Alaska and the Aleutians by relocating aftershocks

of those events and by assuming that the latter are a good measure of the area of the rupture surface. Aftershocks of events of $M \geq 7.4$ are shown in the upper half of Figure 1 from 1925 to 1971. The inferred rupture zones of all known shocks of $M \geq 7.4$ from 1784 to 1980 are indicated in the lower half of Figure 1. Rupture zones of events of $M < 7.4$ do not exceed about 70 km [Sykes, 1971; Kelleher et al., 1973], a dimension small compared with the rupture dimensions of great events, which for this arc extend 200 to 1000 km along strike. Shocks of $M \geq 7.4$ account for most of the slip that occurs seismically between large lithospheric plates. Small shocks

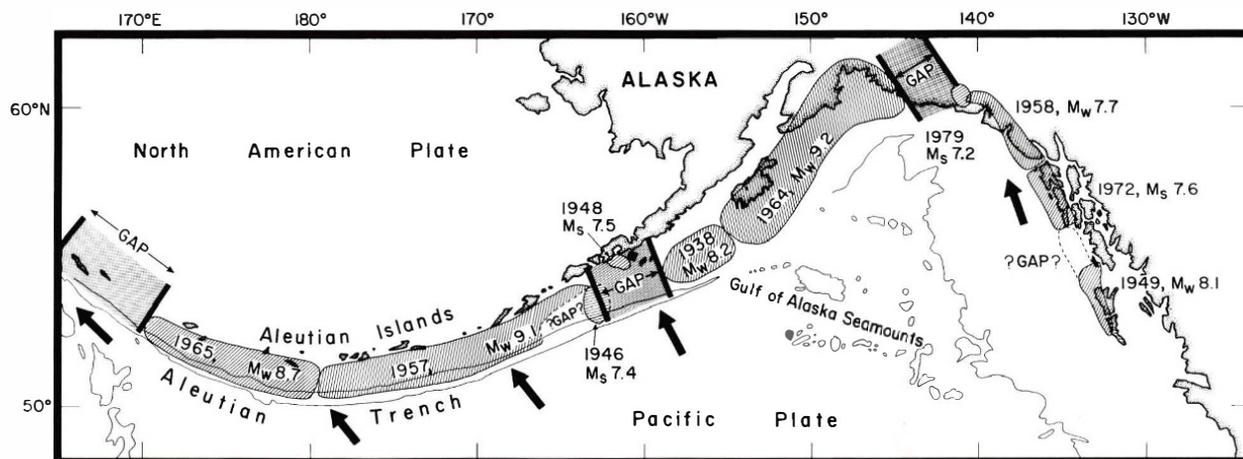


Fig. 2. Aftershock areas of earthquakes of magnitude ≥ 7.4 in the Aleutians, southern Alaska and offshore British Columbia from 1938 to 1979, after Sykes [1971] and McCann et al. [1979]. Heavy arrows denote motion of Pacific plate with respect to North American plate as calculated by Chase [1978]. Two thousand fathom contour is shown for Aleutian trench. M_s and M_w denote magnitude scales described by Kanamori [1977b].

generally account for only a few percent of either the cumulative seismic moment, seismic energy release or total plate movement. From 1938 to 1971, nine large earthquakes ruptured much of the length of the plate boundary of Figures 1 and 2. Aftershock zones of several of these earthquakes abut without significant overlap, which indicates that the rupture pattern of sequences of large shocks is rather simple.

Most of the large earthquakes of the past 15 years that have occurred along simple plate boundaries of the world ruptured areas that had not been the sites of large shocks for many decades. Sykes [1971] pointed out that three segments of the plate boundary in Figure 1 had not broken in large earthquakes for several decades and called them seismic gaps. One of these gaps was ruptured by the Sitka earthquake of 1972. Only a small portion of a major seismic gap near 60°N , 142°W was ruptured by the St. Elias earthquake ($M = 7.2$) of February 28, 1979 [Lahr et al., 1980; McCann et al., 1980; Perez and Jacob, 1980]. The remaining unruptured area, the Yakataga gap, extends for about 175 km along the coast of southern Alaska between the rupture zones of the 1964 and 1979 shocks. Another gap in the Commander Islands of the westernmost Aleutians has not experienced a great earthquake in the 20th century and may not have been the site of such a shock since 1858 (Figures 1 and 2).

Sykes [1971] was uncertain about the dimensions of the rupture zone of a great earthquake that occurred near the Alaska Peninsula in 1938. Recent work [Davies et al., 1980] on the aftershocks of that event, the source region of the seismic sea wave (tsunami) generated by the main-shock, and the rupture area inferred from the seismic moment all indicate that the 1938 event did not rupture west of about 158.5°W into what is

called the Shumagin gap in Figure 1. Although the 1946 earthquake generated a great tsunami that affected many areas in the Pacific, the generating area of the sea wave appears to have been largely confined to the rather small aftershock area. Hence, that event neither ruptured into the Shumagin gap to the east nor into the possible Unalaska gap to the west. The possible Unalaska gap is described in the accompanying paper by House et al. [1981].

The rupture zones and seismic gaps in Figure 1 only pertain to large earthquakes of the thrust type that occur along the plate interface at shallow depth. Large shocks do occur less frequently beneath the deeper part of the trench, at intermediate depths and to the north of the plate boundary in south-central Alaska. No attempt is made here to apply gap theory to events of those types. Two large earthquakes involving normal faulting [Kanamori, 1972; Abe, 1972] within the deeper part of the Aleutian trench in March 1929 and March 1965 are omitted from Figure 1 since they occurred within the Pacific plate and were not situated along the plate interface.

The rupture zone of the 1948 shock of magnitude 7.5 near 161°W is small and is located farther from the trench than most shallow events of the thrust type. Its main shock is located in the midst of a band of high activity along the north-west side of the gap. Data from a recently-installed seismic network in the area indicate that the region of high activity is centered at a depth of about 40 to 50 km near the downdip end of the zone of shallow thrusting [Davies et al., 1980]. These observations and the greater depths (44 and 48 km) computed from the times of pP-P for the two largest aftershocks of the 1948 event suggest that it may not have ruptured the plate boundary at shallow depths. The magnitude and

size of the aftershock zone of the 1948 event indicate it could not have ruptured more than about 15% of the Shumagin gap. It is not clear if the great Aleutian earthquake of 1957 ruptured the shallow, thrust portion of the plate boundary in the area near Unalaska [Davies et al., 1980; House et al., 1981]. Hence, that area may also be a seismic gap.

1907-1929. Since aftershocks of large events in the Alaska-Aleutian zone before about 1929 generally cannot be located very precisely, the dimensions of rupture zones for older shocks can only be estimated qualitatively. Nevertheless, the record of great ($M > 7.7$) shocks appears to be complete or nearly complete since 1898. Hence, it is clear that no great shock ruptured any of the plate boundary in Figure 1 from 1907 to 1938. This quiescence for great shocks is remarkable since numerous events of that class occurred there from 1938 to 1965 and from 1898 to 1907. Only one shock of $M \geq 7.4$, an event of $M = 7.6$ in the westernmost Aleutians, occurred along the entire plate boundary from 1907 to 1938.

1898-1907. A remarkable sequence of 14 shocks of $M \geq 7.4$ ruptured large parts of the plate boundary in the decade starting soon after the beginning of a world-wide instrumental record in 1897. The distribution of felt reports of aftershocks, the occurrence of landslides and reports of strong shaking [Tarr and Martin, 1912] led McCann et al. [1980] to conclude that two great earthquakes in 1899 ruptured all or most of the Yakataga gap. Similar information appears to be very scarce, however, for the other large events in Figure 1 that occurred near the turn of the century. An event of $M = 8.1$ on October 9, 1900 was felt with decreasing intensities proceeding in a northeasterly direction away from Kodiak Island [Tarr and Martin, 1912; McCann et al., 1980]. Hence, its rupture zone appears to have been centered either to the south or southwest of Kodiak Island as indicated by dashes in Figure 1. Richter [1958] lists a shock of $M = 8.3$ on June 2, 1903 near 57°N , 156°W with a questionable depth of 100 km. That event may have ruptured either the Shumagin gap or the zone that subsequently broke in 1938 or it may, in fact, have been of deeper focus. A shock on July 14, 1899 of $M = 7.7$, for which the epicentral location [Kanamori and Abe, 1979] is very poor, was felt on Unalaska in the eastern Aleutians and on Unga in the Shumagin Islands [Tarr and Martin, 1912]. It also may have occurred in the Shumagin gap.

The occurrence of five earthquakes of $M > 7.4$ between about 177°W and 170°E from 1898 to 1907 strongly suggests that at least that portion of the plate boundary that ruptured in the great shock of February 4, 1965 previously broke about 60 years earlier. Two shocks of magnitude 7.5 occurred in the central Aleutians near 177°W and 165°W on December 31, 1901 and January 1, 1902, only 20 hours apart. While the two events may be related in some way, their relatively modest magnitudes suggest that they ruptured only two

small portions of the zone that broke in 1957. It is difficult to estimate the amount of displacement or the extent of rupture in the series of events near the turn of the century in the western and central Aleutians since their seismic moments have not been measured and felt reports are almost lacking. The apparent absence of large tsunamis accompanying these events suggests, however, that individually they were not as large as the great earthquakes of 1957, 1964 and 1965 [Abe, 1979; H. Kanamori, written communication, 1979]. Nevertheless, that absence may be attributed to rupture of a considerable portion of the arc being distributed among several large shocks from 1898 to 1907 rather than in a few very great events. Hence, large portions of the plate boundary from about 153°W to 170°E appear to have broken in a series of at least 11 large shocks from 1898 to 1907. Whether the Shumagin gap, the questionable Unalaska gap or the rupture zones of the 1938 and 1957 earthquakes definitely broke between 1899 and 1903, however, cannot be resolved at present.

1784-1867. When we examined several catalogues in the English language of earthquakes in Alaska and the Aleutians for the period of permanent Russian settlement from 1784 to 1867, we soon realized that they contain mainly third and fourth-hand accounts. We translated a number of descriptions from Russian in an attempt to obtain as original documentation as possible for earthquakes during that period. The material that follows is a summary of more extensive descriptions published elsewhere [Davies et al., 1980; Kisslinger et al., 1980]. To our knowledge, the important catalogue by Doroshin [1870] for the period 1840 to 1866 was not consulted in the preparation of catalogues of Alaskan earthquakes that were published subsequently. That paper and other early sources [Merkul'ev, 1789 in Solov'iev, 1968; Davydov, 1812; Veniaminov, 1840, 1888; Grewingk, 1850; Mushketov and Orlov, 1893] contain invaluable qualitative descriptions of strong shaking, seismic sea waves, landslides, changes in sea level and aftershock sequences from which we infer the approximate rupture zones of previous major and great earthquakes. In fact, several of these reports of earlier earthquakes are more complete and more useful in this regard than information available to us for many of the large shocks that occurred from 1898 to 1907. Many of the seismic events listed in early reports appear to be clearly local in their effects and to have been associated with volcanic eruptions. Hence, they are not included in Figure 1 as large events.

The first permanent Russian settlement was established on Unalaska Island near 167°W in 1784. By the time of the great earthquake of 1788 reports of the shock and its tsunami were available (Figure 1) from Unga in the Shumagin Islands, Sanak Island, Kodiak Island, the Alaska Peninsula and Unimak Island (55°N , 164°W). Most of the descriptions of earthquakes during the period of Russian control come from either that 1000-km long segment of the arc, the Commander

Islands in the westernmost Aleutians or the region near Sitka in southeast Alaska. The absence of shocks in other areas in Figure 1 is attributed to the lack of an historic record prior to 1897.

We take two or more of the following as indicative of an earthquake that ruptured a considerable (> 100 km) portion of the plate boundary: extremely strong shaking or extensive damage of intensity IX or greater on the Modified Mercalli scale at two or more separated localities [Kelleher, 1972], shaking lasting a minute or more, permanent changes in sea level, a large tsunami associated with the shock, ground breakage, landslides, or aftershocks lasting for weeks to months. Places experiencing such effects are taken to have been located near the rupture zone.

Descriptions of these types for an earthquake on July 22, 1788 lead us to interpret it as a great shock that ruptured at least a 600 km segment of the plate boundary from Kodiak Island to Unga in the Shumagin Islands (Figure 1). [Note that considerable confusion arises in the literature about date of events since some are reported on the old (Julian) calendar and some on the modern (Gregorian). For the first event of 1788, July 11 (old) = July 22 (modern); for second, July 27 (old) = August 7 (modern)]. In a letter of 1789 to G. I. Shelikov, Merkul'ev [in Solov'iev, 1968, p. 235] describes very intense shaking on Kodiak Island, an intense flood (tsunami) consisting of two large waves and other smaller waves, aftershocks every day for a month or longer and a permanent change in sea level. Davydov [1812, p. 154] also mentions landslides on Kodiak Island and that the sea first withdrew from shore, surged onshore and carried a vessel onto the top of a cabin. Veniaminov [1840, 1888] describes strong shaking, landslides and a "horrible flood" on Unga on the same date. He refers to another flood on Unga 16 days later in which the water rose to 50 sazhen, about 91 m. It is not clear, however, if 91 m is the vertical height of water or the distance the waves ran up the beach. Veniaminov [1888] states, "The deluge or flood which took place on Unga and on the southern side of Alaska (Peninsula) in 1788 did not have any effect on the northern side of Unimak." "The tradition of Aleuts...reports that during the flood which took place on Sanak around the year 1790 the water preceded as strong and infrequent large waves."

Solov'iev [1968] interpretes the second flood on Unga 16 days later (i.e. on or about August 7) as a great tsunami generated by a second earthquake that ruptured the area from Sanak Island near the western end of the Shumagin gap in Figure 1 to Unga. He takes the vertical height of that tsunami to be greater than 30 m at those two islands. A 30-m sea wave generated by an earthquake on April 1, 1946 to the west of the Shumagin gap destroyed the nearby Scotch Cap lighthouse on Unimak Island. If the second flood was, in fact, generated by a second earthquake, its source area would seem to have been close to Unga. Neverthe-

less, neither the date of the flood on Sanak nor the occurrence of an earthquake on August 7 is mentioned in any of the older Russian documents we examined. Dall [1870, pp. 310, 467], a secondary source, reports tsunami damage to Sanak Island on the date of the second flood on Unga. Solov'iev [1968] proposes that Dall used some other primary source in addition to Veniaminov [1840] for the events of 1788. Hence, while the evidence that an earthquake ruptured the zone from Kodiak Island to Unga is quite strong, we are forced to rely on Dall's account to infer that a second large event appears to have ruptured the western half of the Shumagin gap 16 days later.

Doroshin [1870] describes ground cracking, landslides, shaking continuing for about 4 hours, and aftershocks lasting about 5 weeks on Ukamok (Chirikof Island, C in Figure 1) in association with a large earthquake in 1847. He states that it was impossible to remain standing on Unga during the earthquake and that shocks were felt several times on the Alaska Peninsula. He also describes another large shock accompanied by its own aftershocks on Chirikof Island in 1848. From these reports we infer that at least a 500 km segment of the plate boundary between Chirikof Island and Unga ruptured in 1847 and 1848. The sequence of 1847-1848 is particularly significant since that portion of the plate boundary appears to have also broken 60 years earlier in 1788. This is probably the best documented repeat time obtained thus far for the plate boundary in Alaska and the Aleutians. Although the effects described by Doroshin [1870] are similar to those reported for the 1788 event he does not mention a tsunami accompanying the shock of 1847.

From similar reports [Davydov, 1812; Doroshin, 1870] of strong shaking and aftershocks we infer that large earthquakes also ruptured the plate boundary somewhere near Kodiak Island in 1792, 1844 and 1854. Local tsunamis are also described in association with the events of 1792 and 1854. Since reports of these three shocks are only available from Kodiak Island, the dimensions of their rupture zones cannot be ascertained. While their rupture zones in Figure 1 are indicated as being off Kodiak Island, the events may well not have ruptured the same segment of the plate boundary. The portion of the 1964 rupture zone opposite Kodiak Island does appear to have moved several times in the last 200 years.

An earthquake on March 18, 1848 [Doroshin, 1870; Veniaminov, 1897, p. 210] may have ruptured either that portion of the Fairweather fault that broke in 1958 or the part that ruptured near Sitka in 1972 (Figure 1). That shock and one listed for an unknown date in 1847 by Dall [1870] may be identical. The evidence for inferring either the size, dimension of the rupture zone or the causative fault zone, however, is poor and fragmentary. Aftershocks were felt at Sitka for nearly a month after the event of 1848 [Doroshin, 1870].

Two large earthquakes that occurred in the

Commander Islands in the westernmost Aleutians on September 28, 1849 and January 22, 1858 are assigned magnitudes of 7.5 ± 0.7 by Kondorskaya and Shebalin [1977]. They incorrectly list the date of the 1849 event as October 28. The shock of 1849 generated a local sea wave that affected the Commander Islands [Doroshin, 1870; Kondorskaya and Shebalin, 1977] and islands of the South Pacific [Ella, 1890]. Since the configuration of its rupture zone or that of the poorly documented shock of 1858 cannot be ascertained, the respective rupture zones are merely indicated in Figure 1 to be somewhere off the southern coast of the Commander Islands. The generation of a tsunami along the southern coast is in accord with the observation that thrust faulting and vertical motion typify movements along that coast while strike-slip motion occurs along the north coast [Cormier, 1975].

1867-1897. We infer that a large earthquake occurred off the Alaska Peninsula near Chirikof Island on September 28, 1880 based on the following effects [Secretary of War, 1883, p. 120] aftershocks continuing for 19 days, numerous deep fissures, strong shaking lasting about 20 minutes, extensive damage to a log house, several sea waves that travelled about 55 m onshore, and permanent changes in sea level. Moore [1962] concludes that a vertical displacement of 2 m, which is still preserved in dammed streams and uplifted wave-cut terraces, occurred along a northeast-striking fault on Chirikof Island during the earthquake of 1880. Hence, the earthquake at least ruptured that fault, a secondary imbricate fault within the upper plate. While the full extent of rupture is not clear, the earthquake of 1880 also may have broken a segment of the main plate boundary to the southwest of the 1964 rupture zone. The evidence is unclear whether that segment also ruptured in 1938. One or more imbricate faults also appear to have ruptured in conjunction with movement on shallow dipping thrust faults during the great earthquakes of 1899 and 1964 [Tarr and Martin, 1912; Plafker and Rubin, 1978; McCann et al., 1980].

Rupture Sequences Along Plate Boundaries

As noted earlier, large portions of the plate boundary in Figures 1 and 2 ruptured in a series of major and great earthquakes from 1898 to 1907 and then again from 1938 to 1965. Each sequence encompassed a time interval that was short compared to the repeat time of great shocks which appears to be at least 60 years for individual segments of this arc. Similarly, much of the plate boundary along the North Anatolian fault in Turkey ruptured in a series of large earthquakes from 1939 to 1943 [Richter, 1958, p. 612]. Also, the entire plate boundary off northern Japan and the southern Kuril Islands ruptured in a series of large thrust earthquakes from 1952 to 1973, a time interval that is short compared to repeat times of about 50 to 100 years [Abe, 1977]. Thus, a strong

temporal clustering of large events appears to be a common feature of several simple plate boundaries. In some instances, rupture along one segment (i.e. 1957 in Figure 1) is followed (with a time delay) by rupture along an adjacent part of the plate boundary (i.e. 1965 zone). Other events in a sequence, however, do not appear to be triggered in such a simple manner.

Almost the entire plate boundary in Figure 1 is known to have ruptured in a previous large earthquake. If any of the boundary moves dominantly in a non-seismic manner, i.e. by slow slip or creep, the total lengths of such segments cannot exceed more than a few percent of the length of the plate boundary. A conservative approach to seismic zonation seems to demand that all of the remaining gaps in Figure 1 be considered probable sites of future large earthquakes.

Repeat Times of Great Earthquakes

A repeat time of 59 years is indicated by the occurrences of shocks in 1788 and 1847 for a segment of the plate boundary near the Alaska Peninsula (Figure 1). Both of those shocks appear to have ruptured the entire portion of the arc that broke in 1938. Since it is not clear if that segment also ruptured between 1899 and 1903, an average repeat time of 50 to 75 years is obtained by dividing 150 years (1938-1788) by either two or three earthquake cycles. The longest possible repeat time, 91 years (1938-1847), is obtained if that zone did not rupture in 1880 or between 1897 and 1903.

At least the eastern half of the Shumagin gap also broke in 1788 and 1847. The entire Shumagin gap has not been the site of a great shock since at least 1903 and possibly even since 1847. Thus, the interval that has elapsed since 1903 is somewhat more than the average repeat time of 50 to 75 years estimated for the 1938 rupture zone, but it is still somewhat less than the upper limit of 91 years. Thus, if the observations from the 1938 zone can be applied to the Shumagin gap, it seems likely that one or more large earthquakes will rupture the Shumagin gap sometime in the next 15 years. The history of tsunamis from that region, including waves locally reaching heights of more than 30 m, indicates that a large future earthquake in the Shumagin gap could be expected to generate a sizable seismic sea wave.

Repeat times of historical earthquakes at a given place along the Nankai trough of southwest Japan vary by a factor of about two [Ando, 1975]. Shimazaki and Nakata [1980] find that the longer repeat times in that area are associated with larger seismic displacements and larger rupture zones. The experience from Japan suggests that the interval between the last major shock and a future large event will be in the shorter end of this spectrum of repeat times for both the Shumagin gap and the 1938 rupture zone since the 1938 shock and events between 1899 and 1903 appear

to have had shorter rupture dimensions than the shocks of 1788 and 1847.

Sykes and Quittmeyer [1981] find that the average repeat times of great earthquakes along simple plate boundaries of the world are governed by three factors: the relative velocity of the interacting plates, the ratio of seismic to aseismic motion and the geometry of the zone of plate contact, particularly the down-dip width. Using the observed repeat times of about 60 years for the 1938 and 1965 rupture zones (Figure 1), they conclude that most of the slip in those areas occurs seismically in great earthquakes and that the amount of aseismic slip is small. They calculate a longer repeat time, about 180 years, for the 1964 rupture zone, where the zone of plate contact has a greater down-dip width, and a shorter repeat time for the central and western Aleutians, where the width is less. The actual repeat time of great shocks in the 1964 zone, however, is not known. The calculated repeat time of 180 years, however, is much smaller than that estimated by Plafker and Rubin [1978] from uplifted marine terraces, 500 to 1350 years. Those very long repeat times, however, appear to us to reflect the movement of a secondary imbricate fault within the upper portion of the North American plate rather than slip along the main plate boundary. This is understandable since such splay faults may not move during every major thrust event along the main plate boundary. Hence, we conclude that the actual repeat times of great earthquakes at a given place along the Alaska-Aleutian zone are likely to be much shorter than those estimated from those marine terraces.

The Commander gap in the westernmost Aleutians is not known to have been the site of a large earthquake since 1858, i.e. 122 years ago. Since plate movement along the southern side of the Commander Islands is nearly parallel to the plate boundary and occurs along shallow-dipping thrust faults [Cormier, 1975], the repeat time of large earthquakes in that area may well differ from that farther east where a large component of plate convergence is present. Also, it is not clear that the historic record of large shocks is complete for the last 122 years.

A repeat time of 110 to 125 years is obtained for the rupture zones of either the 1958 or the 1972 earthquakes in Southeast Alaska if the shock of 1848 (Figure 1) did, in fact, rupture one of those zones and the zone did not rupture during that interval. The 1972 zone may have broken in the magnitude 7.1 shock of 1927. From the measured seismic moments [Thatcher and Plafker, 1977] of two great earthquakes in southern Alaska during September 1899 and the areas of the inferred rupture zones, McCann et al. [1980] estimate an average displacement of about 5 m. Approximately 5 m of potential slip could have been built up as strain by plate movements in the 81 years since 1899 if aseismic slip is negligible. Hence, since there is no historical record of large earthquakes in that region prior

to 1899, estimates of repeat time are uncertain to the extent that the seismic moment is uncertain for the 1899 sequence (by at least 50%) and to the extent that the amount of aseismic slip is unknown. A small portion of the zone that ruptured in 1899 appears to have broken again in 1979.

Hence, repeat times appear to be about 50 to 100 years for several portions of the Alaska-Aleutian arc and to exceed 100 years for much of the rupture zone of the 1964 earthquake, the Commander gap and possibly for the strike-slip portion of the plate boundary in southeast Alaska. Nevertheless, knowledge of repeat times for this plate boundary must still be regarded as incomplete.

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