Chapter 10

SOURCE MECHANISM OF THE TSUNAMI OF MARCH 28, 1964 IN ALASKA

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ABSTRACT

The distribution of permanent, vertical crustal dislocations, the times and directions of early water motion in and around the generation area, and the unusual low-frequency character of the tsunami record obtained from Wake Island, all suggest that the tsunami associated with the great Alaskan earthquake of March 28, 1964 was produced by a dipolar movement of the earth's crust, centered along a line running from Hinchinbrook Island (Prince William Sound) southwesterly to the Trinity Islands. The positive pole of this disturbance encompassed most of the shallow shelf bordering the Gulf of Alaska, while the negative pole lay mostly under land. Thus, the early effect was the drainage of water from the shelf into the Gulf, thus generating a long solitary wave, which radiated out over the Pacific with very little dispersion.

Tilting of Prince William Sound to the northwest produced strong seiching action in the deep, narrow adjacent fjords, thus inundating inhabited places already suffering from earth shock and slumping of the deltas on which they were situated.

Preliminary calculations indicate that the initial positive phase of the tsunami contained about 2.3×10^{21} ergs of energy, as compared with 2.7×10^{22} ergs computed for the tsunami of March 9, 1957 in the Andreanof Islands.

The dipolar dislocation also produced a 'tsunami' in the atmosphere, which was recorded in La Jolla, indicating that the dislocations must have occurred during the period (circa 2-6 min.) of strong ground motion near the epicenter.

INTRODUCTION

On March 28 at 0336 GMT the largest North American earthquake of this century occurred in Southeastern Alaska. The epicentral coordinates for the principal shock (Richter magnitude 8.4) are currently taken as 61.05N, 147.5W, focal depth less than 20 km, although these coordinates may be subject to later revision, owing to the long-continuing nature of the seismic signals, and the fact that lesser shocks occurred as much as two hours earlier in the same vicinity. The great strength and shallow depth of this quake were visibly manifested by violent dynamic earth motions over a radius of more than 200 km in all directions. The duration of these motions, during which time it was difficult or impossible for people to run or even stand erect, was reported to be from three to eight minutes in various localities. Deep ground fissures, snow and rock avalanches, and permanent changes in land elevations relative to sea level also occurred in most of the areas of strong ground motion, and, presumably, over a similar period of time. Closely following the principal shocks, tsunami waves were reported in many areas of the Gulf of Alaska and adjacent Prince William Sound. The tsunami which subsequently spread out over the Pacific Ocean, appears to have been of rather moderate intensity, generating oscillations in bays and harbors around the Pacific of several feet in amplitude, but causing relatively little damage beyond the immediate area of generation.*

There is no question that the severity of this tsunami was substantially mitigated because it occurred near the time of low tide in all areas where the waves were largest.

This great natural catastrophe, which may well have jeopardized the future of the state of Alaska, was the immediate focus of attention of earth scientists from all over the world. To the author, it represented an unprecedented opportunity to reconstruct the generation mechanism for a tsunami, because the earthquake epicenter was located in a region where fairly precise geodetic control has existed for some decades, and because of the likelihood that enough local eyewitness accounts of the water wave chronology might be obtained to put together a systematic picture of the generation process. Although it is apparent at this writing that many months will elapse before the land elevation changes relative to sea level will be known in detail, obvious vertical displacements occurred in many places along the sea coast and islands in the Gulf of Alaska of sufficient magnitude to be easily distinguishable from the normal tide range by the trained eye. Thus, it is already possible to draw some fairly firm qualitative conclusions regarding the generation process, although its quantitative aspects must await more accurate data. An essential feature of this reconstruction is the wave record for the tsunami obtained at Wake Island, at a special

* "Some damage to waterfront establishments occurred along the coast of southeastern Alaska, British Columbia, and as far south as Crescent City, California."

recording station installed there in 1960 (Van Dorn, 1960). Because this record can be used within limits as an indicator of the deep water nature of this tsunami, it serves as a check on the mode of generation hypothesized from other considerations.

BACKGROUND

There have been several attempts to estimate the generation mechanism of tsunamis. Most of these are inconclusive for lack of specific evidence of the seafloor readjustment, although Nagata (1950) has shown in the case of the great Nankaido earthquake of December 21, 1946 near Shikoku that the dislocations on land can be quite complex. Miyabe (1934) attempted to compute the size of the tsunami generation area for the Sanriku earthquake (March 3, 1933) by projecting wave fronts back towards the epicenter from observation stations along the shore. According to Takahasi (personal communication) the generation areas determined by such constructions generally agree with those delimiting the areas of earthquake aftershocks obtained from seismic evidence. Van Dorn (1963) computed the equivalent axisymmetric source which could have produced the wave spectrum observed for the tsunami of March 1957 at Wake Island. Kajiura (1963) has pointed out that, aside from explosions, seismic sources cannot be expected to be axisymmetric, and has given solutions for asymmetric sources of various types. Never before, however, has a sufficiently detailed knowledge been obtained of seafloor motion, type of wave action, and the deep-water spectrum offshore, to permit a convincing reconstruction of the generation mechanism.

GEOMORPHOLOGY

According to the U. S. Coast and Geodetic Survey (1964), the substructure of the region affected by the earthquake is underlain by a blanket of cretaceous sediments which have subsequently been uplifted and deformed into a series of geanticlines and geosynclines, having a vertical relief as great as 10,000 ft. The axes of this accordian-like structure have been mapped from the Trinity Islands through Kodiak, up the Kenai Peninsula, and identified as outcrops at elevations as high as five or six thousand feet in the Chugak Mountains (Figure 1). The entire structure is bent in an arc around the Gulf of Alaska, essentially paralleling the coast. Although the old tectonic history of this region appears to have been very complex, its present general appearance gives the impression that it is a coastline of submergence (Twenhofel, 1951) which has undergone recent, gradual uplift, except for small areas in the Prince William Sound and Copper River delta areas. Figure 2 shows the general pattern of uplift as evidenced by a series of exposed marine terraces. Twenhofel reports that such secular changes have, in fact, been observed since the turn of the century in several areas where geodetic control exists, and rates of uplift as high as seven or eight feet per century have been recorded.

SEISMOLOGICAL HISTORY

The Gulf of Alaska, in common with the Aleutian Arc and the entire western border of North America, has a long history of repeated seismic activity and associated volcanism. The epicenters of earthquakes larger than magnitude 6 which have occurred since 1900 are shown in Figure 3, and it is apparent that several of the largest quakes

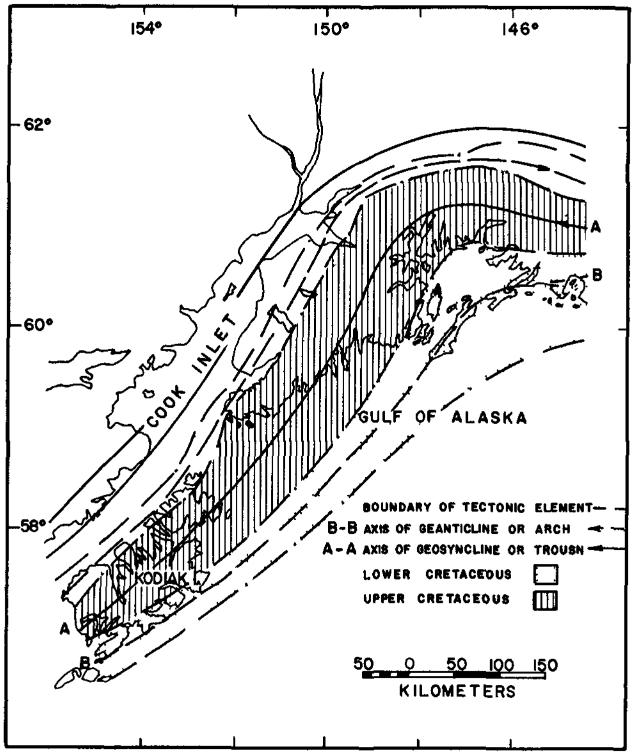

FIG 1 --TECTONIC MAP OF EPICENTRAL AREA (USC & GS)

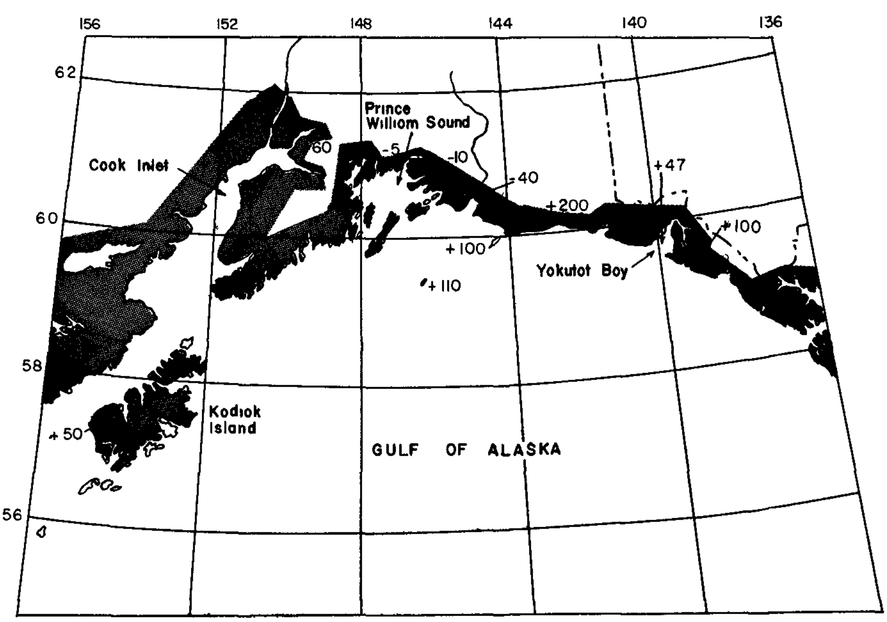

FIG 2 --RECENT LAND ELEVATION CHANGES IN GULF OF ALASKA (AFTER TWENHOFEL) occurred in the immediate region of Prince William Sound. Thus, the present quake was not particularly anomalous, either from the standpoint of magnitude or frequency of occurrence, since the most recent previous quake of this magnitude (8.4) occurred in nearby Yakutat Bay in 1899.

St. Amand (1957) has probably made the most thorough study of the fault system of this region, which tends to follow the synclinal substructure parallel to the coast. Aftershocks from the present quake, however, (Figure 4) are clustered in two loci; one in the vicinity of Hinchinbrook Island (A) and the other southeast of Kodiak (B), and these loci are connected by scattered aftershocks in the region between them. It appears as if the aftershock activity was essentially confined to the region of the westerly geanticline of the cretaceous substructure, being mostly underwater beneath the shallow coastal shelf, and bounded to the southeast by the Aleutian Trench.

NATURE OF THE GROUND MOTION

A remarkable feature of this earthquake, which became apparent very early during the field survey, was the enormous extent of the areas which have undergone relatively large vertical changes in elevation relative to sea level. Virtually the entire Kenai Peninsula, from the Turnagain Arm of Cook Inlet, including the Kenai-Kodiak Ridge, and Kodiak Island itself, appears to have subsided by two to six feet. At the same time most of the land areas along the seacoast from the Yakutat area to the center of Prince William Sound have been elevated by similar amounts. The time rates of these displacements are unknown, but appear to have been of the same order as that of the intense ground motion (2-6 min.), since many observers reported immediate

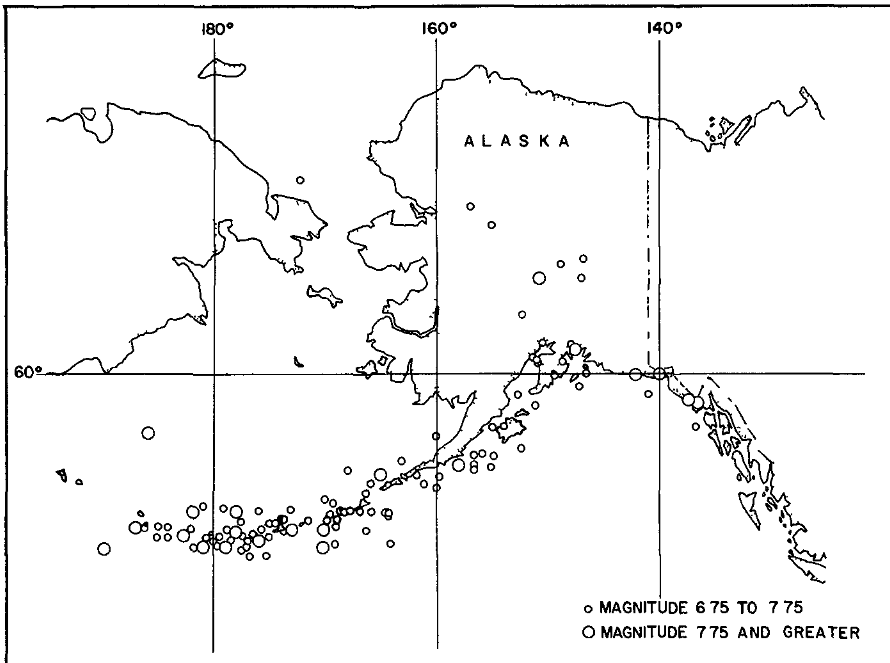

FIG 3 --DISTRIBUTION OF LARGE EARTHQUAKES IN GULF OF ALASKA SINCE 1899 (USC ¢ GS)

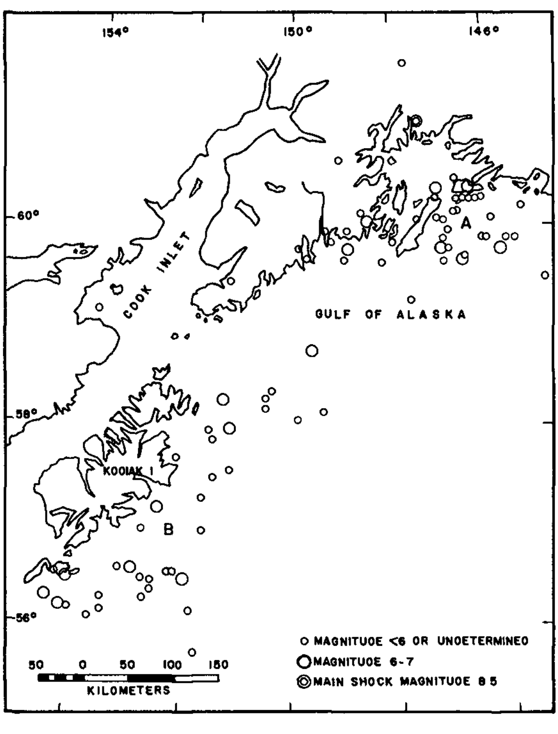

FIG 4 --DISTRIBUTION OF AFTERSHOCKS OCCURRING DURING
FIRST 9 DAYS FOLLOWING EARTHQUAKE OF MARCH 28, 1964 (USC & GS)

water withdrawal from the elevated regions. Additionally, an atmospheric gravity wave transient was recorded on a special microbarograph at the Scripps Institution of Oceanography, beginning at 280655Z, (Figure 5). Such atmospheric pulsations are a common feature associated with the detonation of large nuclear explosions, but, to the authors knowledge, have not previously been observed in connection with earthquake motions. Pressure pulses from the explosions outside of the region of hypercompression, propagate at acoustic velocity in the lower atmosphere (about 1050 ft/sec ± 30 ft/sec). Therefore, the initiating disturbance - if it originated in the vicinity of the reported epicenter - occurred at about the same time as the principal shock. Such a pressure disturbance in this case could only have been produced by vertical motions of the earth over a very large area, and in a time of the order of that required for an acoustic wave to propagate across dimensions of the generator. Thus, a substantial fraction of the net motion inferred from relative sea level changes must have occurred very rapidly.

The present picture of the areas of permanent dislocation which is now emerging is shown in Figure 6. It should be born in mind that most of these figures are tentative, some being obtained on the basis of preliminary surveys by the U. S. Coast and Geodetic Survey, while others are only estimated by measurements to local sea level at some later time, and are largely based on the long-term experience of local inhabitants. Such observations as these, carried on over a period of several weeks, are probably accurate to about 1 foot, although smaller changes are readily apparent to fishermen and mariners, who have had long experience with the tides in a particular area.
The tentative distribution of these dislocations is included,

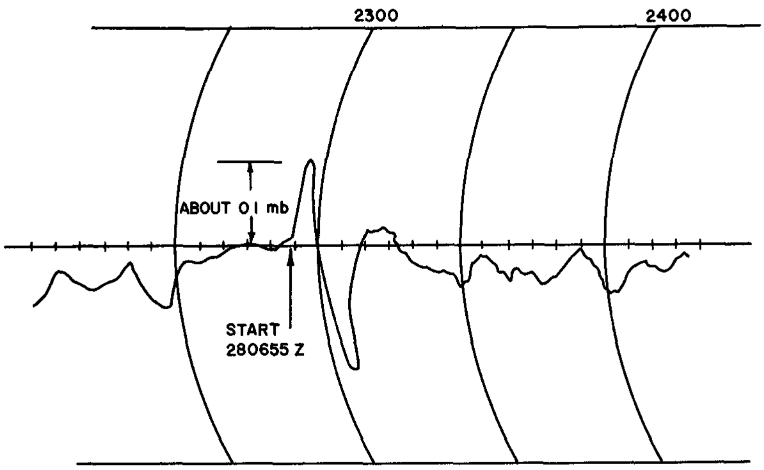

FIG 5 --MICROBAROGRAPH RECORD FROM LA JOLLA, SHOWING ATMOSPHERIC TSUNAMI FROM ALASKAN EARTHQUAKE (SIGNATURE IS TYPICAL OF THAT FOR LARGE DIPOLE SOURCE)

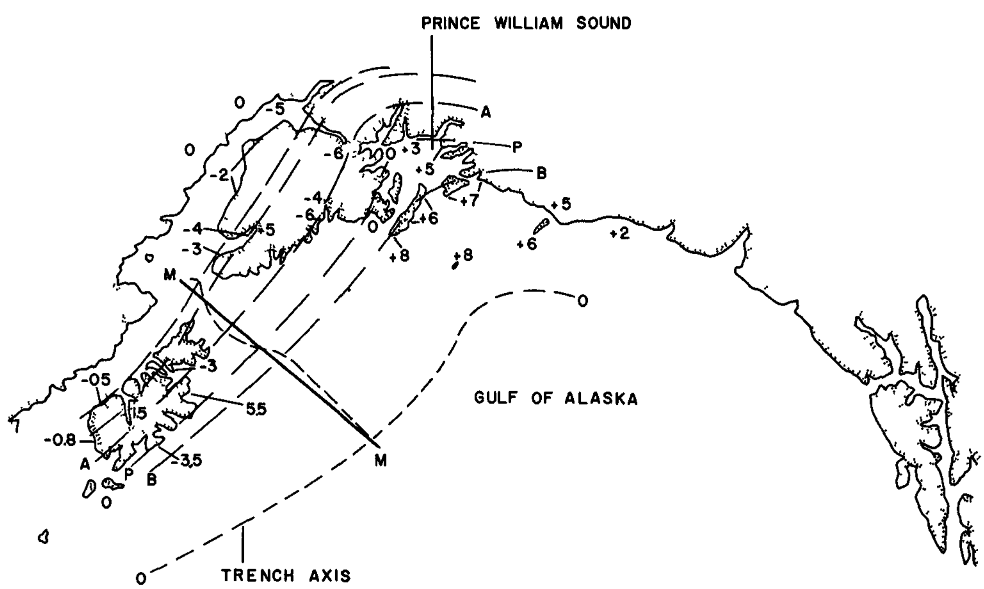

FIG 6 --TENTATIVE DISTRIBUTION OF LAND DISLOCATIONS (IN FEET) RELATIVE TO SEA LEVEL IN GULF OF ALASKA FOLLOWING EARTHQUAKE OF MARCH 28, 1964 for the most part, within the same perimeter which circumscribes the earthquake aftershocks. Also shown in this figure are the axes of the synclinal ridges and troughs of the cretaceous substructure, transferred from Figure 1, and a schematic profile section M-M. Significantly, perhaps, the general trend of surface dislocations is well mapped by the "contour lines" of the substructure; negative elevation changes lying to the west and north of the line P-P dividing the Kodiak geosyncline from the shelf geanticline, and all of the areas of positive elevation lying to the south and east of this line. It almost appears as if the observed dislocations could have been produced by slight increase in the subsurface deformation. It is certainly beyond the author's training and experience to comment on this seeming coincidence, but, as will be shown, this interpretation permits an extrapolation of the pattern of surface dislocations out under the sea, which is quite consistent with that obtained from interpretation of the surface wave history.

THE PATTERN OF EARLY WATER MOTION

A strenuous attempt was made during the field survey to obtain information on the chronology and direction of early water motion, particularly in Prince William Sound, since it was felt that the key to the tsunami generation problem might hinge on the decision as to whether the tsunami originated close to the reported epicenter, or in some other region outside the Sound. As it turned out, the region of wave generation was very much larger than the Sound, encompassing most of the shelf bordering the Gulf of Alaska.

The hydrodynamic situation in Prince William Sound at early times following the principal shock is shown in Figure 7. The land elevation changes in feet are shown by the large numerals in this figure. As already mentioned, the positive changes and negative changes are separated into two regions by a line of zero change in elevation. Within the Sound, this line runs through Pt. Elrington, up the Knight Island Passage, through Perry Island, and curves away towards the east - possibly through Port Valdez. So far, no specific data is available on change of elevation at Valdez. The reported subsidence there was most probably due to the settling of the alluvial delta on which the town is built. The pattern of earthquake and wave damage at Valdez is typical of what occurred also at Seward, Whittier and at numerous other uninhabited areas of the Sound. Such glacial deltas possess very steep angles of repose (approximately 45°) beneath the water level. During the violent earthquake motion, the edges of these deltas simply slumped into the fjords, carrying with them any indigenous waterfront structures. Alluvial slumping also precipated local seiche action which, in turn, was large enough in some cases to cause inundation of waterfront areas.

The pattern of elevation changes indicates that the entire Prince William Sound region was tilted about the axis (P-P) of zero elevation change. This tilting action caused an immediate flux of water in the direction of the tilt gradient. Prince William Sound is a very deep basin (200-300 fathoms), compared with the broad continental shelf outside (50-100 fathoms). It is also of complex shape, containing many mountainous islands, and radiating into numerous deep fjord-like inlets, some of which are more than 100-miles in length. The hydrodynamic motions of this body of water were extremely complicated, and it

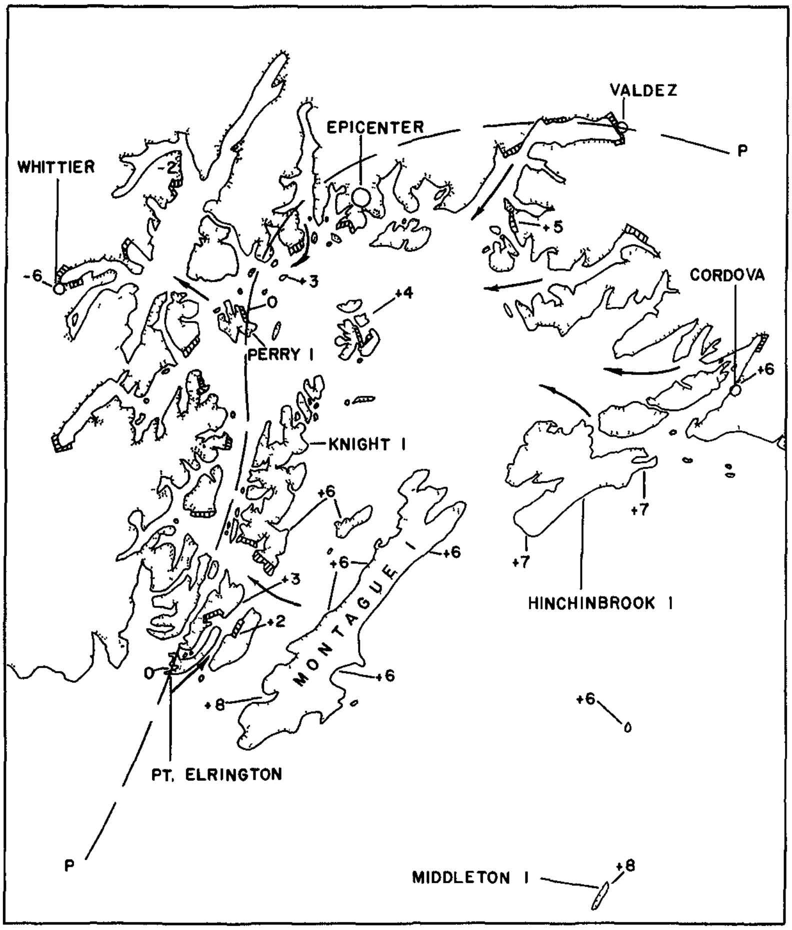

FIG 7 --LAND ELEVATION CHANGES WITHIN PRINCE WILLIAM SOUND

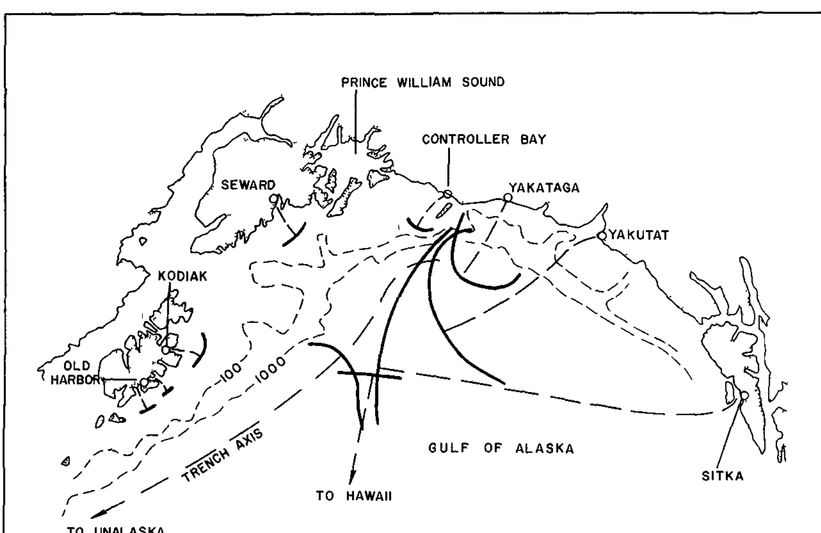

FIG 8 - PROJECTION OF IMAGINARY WAVE FRONTS FROM OBSERVATION STATIONS BACK TOWARD TSUNAMI SOURCE is not always easy to predict details of the initial motion, except to state that the water withdrew from elevated areas almost immediately, and began to rise in depressed areas very soon after the earthquake. Large seiches were set up in the main basin and the adjacent fjords, although it appears that there was relatively little exchange of energy between Prince William Sound and the Gulf of Alaska. The Sound is virtually cut off from the Gulf by a cluster of islands, the largest of which are Montague Island and Hinchinbrook Island, as well as by the extreme shoalness of the shelf outside. The general early flow of water within the Sound was northwest as indicated by the heavy arrows in Figure 7. Strong northerly currents and violent seiching action were observed immediately in the Knight Island Passage. Water was observed to drain southerly and easterly out of Unakwik Inlet. A large wave was observed to propagate out of Valdez Narrows into the Sound immediately after the principal shock. Strong seiching action within the Sound continued for at least twelve hours after the earthquake. In many regions the greatest inundation damage occurred about five to six hours after the earthquake, at the time of high tide.

Although the details of the wave activity within Prince William Sound are of great practical interest because of the extensive damage to habitation, it is apparent that this activity is of only secondary importance to the tsunami generated outside of the Sound.

In the Gulf of Alaska (Figure 6), the general picture is the same, except that much less specific detail is available: Immediate water withdrawals were reported at Boswell Bay (Hinchinbrook Island), Cape St. Elias, and Middleton Island, all of which were regions of uplift; while similar withdrawals were reported at Rocky Bay and Nuka Bay, at the end of the Kenai Peninsula, and in Marmot Bay, Afognak Island, all of which are located on the northwest side of the axis of major depression. No early water motion was reported from regions on the synclinal axis running from Chiniak Bay, Kodiak Island, to just easterly of Resurrection Bay on the Kenai Peninsula. Aside from local turbulence and seiching generated by the earthquake motions, no wave action or water motions were reported anywhere within the Cook Inlet until several hours after the earthquake. This pattern of water motion is again consistent with the concept of uplift along the shelf geanticline and subsidence along the Kodiak geosyncline, and suggests that the tsunami was produced by drainage of water away from the anticlinal ridge running from the Trinity Islands southeast of Kodiak through Montague and Hinchinbrook Islands in Prince William Sound. As will be shown, this view is also supported by the wave observations.

WATERWAVE OBSERVATIONS

Reproductions of tide gage records were obtained from the U. S. Coast and Geodetic Survey for tide stations at Sitka, Yakutat, Hilo Hawaii, and Unalaska. Additionally, fairly complete early chronologies of wave motion were available from Cape Yakutaga and Chiniak Bay, Kodiak (U. S. Naval Station). Less reliable, but useful information of the time of arrival and sense of first wave motion were also reconstructed from eyewitness accounts at numerous places along the Gulf of Alaska. Pertinent data on initial wave motion are given in Table 1. It is significant that, outside of the immediate area of tsunami generation, the sense of the initial wave motion was everywhere positive, being strongly upwards at all points in the southeasterly quadrant, and weakly positive westerly along the Aleutian Chain.

TABLE I

TSUNAMI TRAVEL TIMES TO OBSERVATION STATIONS

Station	Arrival Time of First Motion (GMT)	Sense of First Motion	Travel Time (min)	Travel Distance (n.min)	Effective Depth	Travel Time Correction (min)	Corrected Travel Time (min)
Old Harbor	0424*	UP	48	29	117	0	48
Chiniak Bay	0420	UP	44	26	111	0	44
Seward	0411*	UP	35	45	510	0	35
Controller Bay	0415	UP	39	51	530	0	39
Cape Yakataga	0425	UP	45	78	930	1	44
Yakutat	0450	UP	74	169	1630	2	72
Sitka	0508	UP	92	347	4420	3	89
Unalaska	0903	UP	157	840	8900	5	152
Hilo Hawaii	0900	UP	324	2440	17600	8	316

* These times are average of 2 or more estimates

In order to obtain some concept of the size of the tsunami generation area, imaginary wave fronts were projected according to Huygen's principle back towards the epicenter at velocity $c = \sqrt{gh}$ (h=depth) from each of the several points of wave observations over time intervals equal, respectively, to the time intervals between the main shock and the observed times of arrival of the first wave motion at these stations. The most recent analysis of the nature of the leading wave of a tsunami (Kajiura, 1963) points out that the toe of the leading wave actually precedes the wave 'front', which travels at $\sqrt{gh}$ velocity. The correction term is given by, approximately

$$\left(\frac{6}{t\sqrt{gh}}\right)^{1/3}\left(\frac{r}{h} - t\sqrt{g/h}\right) = 4$$

where $h = \frac{1}{g}\left(\frac{r}{t}\right)^2$, r = distance, g = gravitational acceleration,

and t = time of arrival of first disturbance. These corrections increase as the cube root of travel time, and were subtracted from the observed arrival times for first motion at all stations The corrections are also listed in Table 1.

In order to maintain accuracy these graphical - numerical constructions were commenced on very small scale charts in the immediate vicinity of each station, and the coordinates successively transfered to larger scale charts, until deep water was reached. Such constructions are carried out routinely by Japanese scientists in tracking tsunamis, and can be considered accurate to about 2% in time. The results are shown in Figure 8 by the heavy curves, each of which is connected to its source station by dashed lines. The best representation of the area of tsunami generation is construed to be the region which is circumscribed by an envelope which touches each of these heavy curves. It seems clear from the distribution of these curves that the origin of the tsunami was a broad region of uplift somewhere near the central part of the continental shelf in the Gulf of Alaska; the waves which radiated to the northwest appear to have originated from a line source which coincides with the presumed axis of the geanticline, while the wave system traveling towards the south and east seems to have originated along the northeasterly end of the Aleutian Trench itself.

Since the wave front constructions depend on the assumption that the ground motion took place instantaneously at the time of the principal shock, it is apparent that any finite time required for this action would modify this picture somewhat, pushing back the constructed wave fronts towards their sources by distances corresponding to travel times equal to the appropriate time delay in each case. For example, the time of the principal shock is listed by the U. S. Coast and Geodetic Survey as 0336Z, while the inception of strong ground shocks in Kodiak (Navy Weather Central) is given as 0342Z, or about six minutes after the first shock.

THE TSUNAMI IN THE OPEN SEA

The tsunami generated by the earthquake of March 28 was recorded at Wake Island, 3050 nautical miles from the source region, at a station specifically constructed for this purpose in 1960. A portion of this record showing the first two hours of this tsunami is shown in Figure 9. The recording element of this station is an absolute pressure transducer on the bottom in fifty feet of water, and connected to a plastic garden hose extending to a depth of

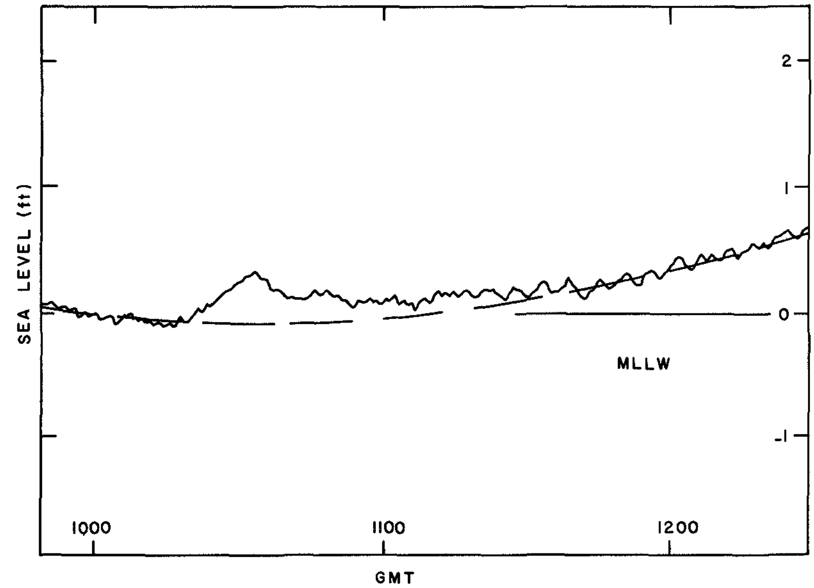

FIG 9 --WAVE RECORD FROM WAKE ISLAND, SHOWING ARRIVAL OF TSUNAMI (INITIAL MOTION IS POSITIVE AND REMAINS ABOVE NORMAL TIDE CURVE FOR OVER AN HOUR)

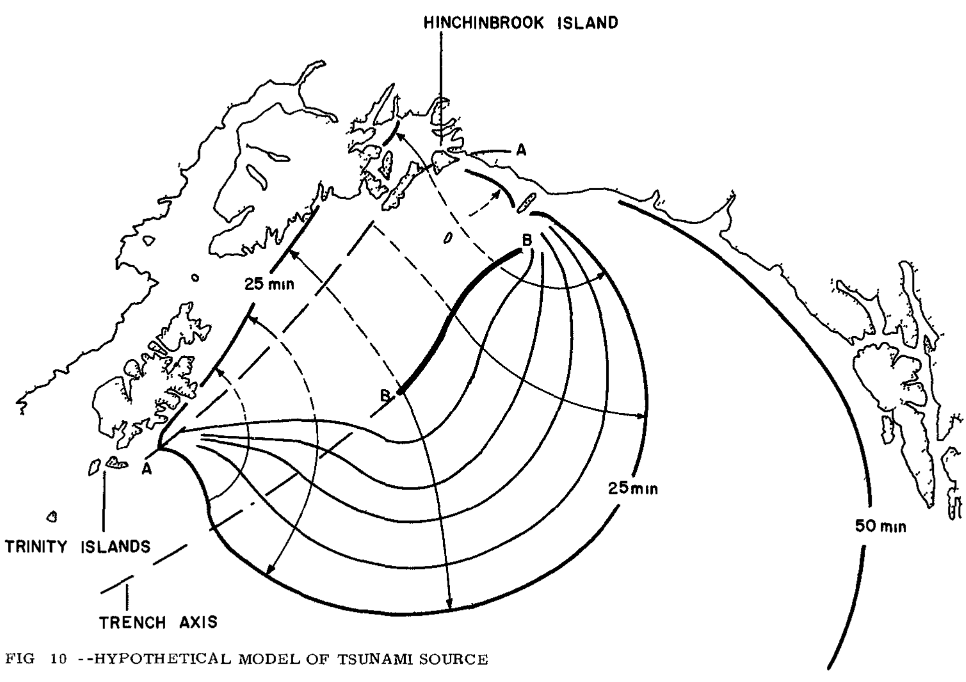

FIG 10 --HYPOTHETICAL MODEL OF TSUNAMI SOURCE

800 feet off shore on the south side of Wake Island. The hose depth, together with an electrical low-pass filter, restrict the excursions of ordinary wind waves to negligible amplitudes. For wave periods longer than about forty seconds the response is unity, and the resolution of the record is about .02 ft of water. The tsunami begins with a slow increase in sea level to a height of about 4 in. over a period of fifteen minutes, followed by a normal dispersive wave train of rather small amplitude. The remarkable feature of this record is that it does not return to normal tide level - as indicated by the dashed line in this figure - for more than an hour. At the time of the tsunami the local wind velocity was about 7 knots and extremely steady, and therefore the record obtained can be considered to be a reasonably accurate representation of the actual tsunami characteristics in deep water.

From the general appearance of this record, one has the impression that a large fraction of the energy of the tsunami was contained in a single, long solitary wave, formed in the Gulf of Alaska by drainage of water from the coastal shelf. The small amplitude of the dispersive signature attests to the lack of sudden or discontinuous variations in the rate of drainage. Kajiura (1963) has investigated in some detail the theoretical aspects of the leading wave of a tsunami for a variety of source conditions. But the theory applies only to tsunamis generated and propagating in water of uniform depth, and thus it cannot be applied directly to the present situation without some suitable modification of the initial conditions, and consideration of the effect of depth variations along the travel path. Some speculations in this connection, and the results of model tests in the author's wave channel at the Scripps Institution, will be reported later.

A broad solitary wave of the type observed at Wake can only be produced by the net (albeit temporary) addition of water to the ocean. The nature of the tsunami source described above appears to fulfil this condition, if the gross ground motion is considered to be dipolar, as evidenced by the signature of the barometric wave recorded at La Jolla. Judging by the pattern of ground dislocations, the positive pole was mostly on the shelf, under water, while the negative pole was largely on land. This circumstance would not be expected to influence the barometric wave, which was fairly symmetric, but implies that the net signature in the Gulf was strongly positive, as shown by the initial motion at all coastal observation stations. The later stages of the Wake record (not shown in Figure 6) exhibit slow, lesser oscillations of both above and below the local tide stage, which are probably due to readjustments of sea level in the Gulf to the initial outflow of water from the shelf, and reflection from the Kenai-Kodiak Ridge produced by subsidence of the Kodiak geosyncline.

RECONSTRUCTION OF THE TSUNAMI ORIGIN - AN HYPOTHESIS

The tsunami of March 28, 1964 is construed to have originated from a dipolar dislocation of the earth's crust centered about the axis P-P in Figure 6. The dipole appears to have had positive and negative extrema along the axes B-B and A-A, respectively, along which severe bending or ground rupture occurred. The dislocations probably took place within six minutes following the initial shock, beginning in the region of maximum dislocation, in the vicinity of Hinchinbrook Island, and propagating southwesterly along these axes to a point of zero dislocation southeast of Kodiak.

An hypothetical reconstruction of the early wave motion is given in Figure 10. The entire, quasi-rectangular area of the coastal shelf between the lines A-A and B-B is considered to have been uplifted in a pattern indicated by the dotted gradients between these lines. Water motion towards the south and east commenced concurrently with the uplift at all points within this region, and parallel to the direction of the gradients. Successive wave fronts, constructed from the topography, are shown for five minute intervals out to 25 minutes, as is the wave front at 50 minutes, which encompasses most of the Gulf of Alaska. Also shown in this figure is a positive front propagating northwest 25 minutes after the earthquake. The negative wave, which was presumably generated within the small negative dipole region over the subsiding geosyncline, would not be observed within the generation area, and was probably immediately reflected by the shallow ridge connecting Kodiak with the Kenai Peninsula.

Within Prince William Sound, no negative phase was generated, and the local tsunami was caused by tilting of the entire region of the Sound towards the northwest, followed by extensive seiching in the deep, complex basin, with little exchange of energy with the Gulf.

Outside the region of generation, the tsunami radiated into the Pacific basin, principally as a solitary wave, followed, some hours later, by lesser slow oscillations, as described above. Judging by the circumpacific distribution of reported tide gage heights, the tsunami source was somewhat directional, radiating energy preferentially towards the southeast. Local shoreline wave heights were larger at similar distances all along the coast of North America than along the Aleutian Islands. A maximum height of four feet was reported from the Palmer Peninsula in Antartica, while heights in Japan were only a foot or so. Despite the long-continuing nature of the disturbance observed at Wake, tide records around the Pacific exhibited their usual strong perodicities, characteristic of the local environment, showing that such records cannot be depended upon to give much information about the nature of a tsunami in the open sea.

A preliminary estimate of the total energy for this tsunami can be obtained by consideration of the potential energy of the dipole uplift over the shelf. Taking the source dimensions as 240n miles x 100n miles, and the uplift as six feet at the northeasterly end of the long axis and zero at the southwesterly end, the total energy E_t is

$$E_t = \tfrac{1}{2}\rho g h^2 A = \frac{35 \times 36 \times 100 \times 240 \times 6080^2}{2 \times 6} = 1.7 \times 10^{14} \text{ ft-lbs} =$$

2.3×10^{21} ergs

which is about 10% of that (2.7×10^{22} ergs) computed for the tsunami of March 9, 1957 in the Andreanof Islands (Van Dorn, 1963). This calculation, of course, ignores the energy of wave motion within Prince William Sound, but is consistent with the general magnitude of shoreline heights reported around the Pacific, relative to those from the previous tsunami.

ACKNOWLEDGEMENT

Much of the data presented here was collected by the author in person, in the course of ten days following the earthquake, either by direct observation, or by conversations with eye-witnesses - many of whom were contacted through the courtesy of the extensive military communication network of the Alaskan Headquarters Command. Contributors to the fund of information available are too numerous to mention here, but particular advice and assistance was provided by Dr. Pierre St. Amand, Navy Ordnance Test Station, China Lake, California, and by Lt. Delmer L. Brown, U. S. Army Engineers, who cooperated with the author during his survey, and later remained for some weeks to collect additional data under the terms of his temporary assignment for this purpose. The tide gage data and the bulk of the seismic evidence presented herein was obtained through the auspices of the U. S. Coast and Geodetic Survey, whose representatives were among the earliest scientific personnel to appear after the earthquake. Most of the data thus collected has yet to appear in print, although the Coast Survey (1964) has issued a special publication intended as an early information advisory. The author was considerably impressed by the number of people who, without any official concern for the collection of data, had the initiative and interest to keep detailed logs of all available information as it occurred. Among these should be mentioned Lt. Barney, U. S. Fleet Weather Central, Kodiak, Mr. Jim Reardon, Area Biologist, Alaskan Fish and Wildlife Service, Homer, Alaska, and Mr. C. R. Bilderbock, fisherman and ten-year resident of remote Cape Yakataga. Upon just such detailed information, the conclusions drawn herein heavily depend.

REFERENCES

Kajiura, Kinjiro (1963). The leading wave of a tsunami: Bul. Earthquake Res. Inst., vol. 41, pp. 535-571.

Miyabe, Naomi (1934). An investigation of the Sanriku tunami based on mareogram data: The earthquake Res. Inst., Supp. vol. 1, pp. 112-126.

Nagata, Takesi (1950). Summary of the geophysical investigations on the great earthquake in southwestern Japan on December 21, 1946: Trans. Amer. Geophys. Union, vol. 31, No. 1, pp. 1-6.

St. Amand, Pierre (1957). Geological and geophysical synthesis of the tectonics of portions of British Columbia, the Yukon Territory, and Alaska: Bul. Geol. Soc. of Amer., vol. 68, pp. 1343-1370.

Takahasi, Ryutaro. Director Earthquake Research Institute, Tokyo University.

Twenhofel, W. S. (1951). Recent shore-line changes along the Pacific coast of Alaska: Amer. J. of Sci., vol.250, pp. 523-548.

U. S. Coast and Geodetic Survey (1964). Preliminary report; Prince William Sound, Alaskan earthquakes: Washington D. C.

Van Dorn, Wm. G. (1960). A new long-period wave recorder: J. Geophys. Res., vol. 65, No. 3, pp. 1007-1012.

Van Dorn, Wm. G. (1963). The source motion of the tsunami of March 9, 1957 as deduced from wave measurements at Wake Island: Int. Union of Geodesy and Geophys.; Proceedings of the Tsunami Meetings; Tenth Pacific Science Congress, Univ. of Hawaii, pp. 39-48.