A look back at the Great Alaska Earthquake of March 27, 1964

George Plafker, U.S. Geological Survey (Emeritus) and Plafker Geohazard Consultants

Historic Setting

The great 1964 earthquake in Alaska, with a moment magnitude (Mw) of 9.2, was the second largest seismic event ever recorded. The earthquake occurred at a particularly critical point in the earth sciences revolution of the early 1960's that was fostered by the concepts of sea floor spreading and its implications for the evolving global plate tectonics paradigm of the late 1960's.

Suggestions that the oceanic rises marked zones of sea floor spreading began to emerge in 1961 and 1962. By 1963 it was recognized that subparallel sea floor magnetic stripes might be caused by reversals of Earth's magnetic field and paleomagneticists working on land (including at Nunivak and Pribolof islands in Alaska) had begun to piece together the paleomagnetic time scale that ultimately provided a quantitative yardstick for spreading rates. By 1965, an explanation had been proposed for transform faults based on the seafloor magnetic stripes, and by 1966 seismic data were employed to confirm extension at the ridges and strike-slip motion on the transform faults.

In contrast to the steady advances that were being made at the spreading ridges during the early 60's, investigations into the more complex convergent margins was in a state of relative disarray. Benioff published his classic paper on dipping seismic zones—including the Aleutian arc—in 1954, and papers by Dietz and Hess in 1961 and 1962 suggested that oceanic trenches and arcs probably marked zones of crustal convergence. In a remarkably insightful 1962 paper, Bob Coats who was studying the geology and volcanology of the Aleutian ridge, proposed a model for underthrusting of oceanic crust beneath the arc. He incorporated first use of the term "megathrust", subduction and metamorphism of oceanic sediments, and formation of a subparallel differentiated andesitic volcanic arc above the underthrust oceanic crust in a model that is barely distinguishable from present-day models (Figure 1). Unfortunately, Coats' paper was published in an obscure journal and was generally unread or ignored. Also, about that time strong arguments were being made to the effect that circum-Pacific arcs represented major strike-slip zones related to counterclockwise rotation of the Pacific Ocean basin. These arguments were based on studies of circum-Pacific transform faults, deformation related to the great 1960 Chile earthquake, earthquake focal mechanism results, and by the theory that Benioff zone earthquakes were caused by phase transitions rather than faults. Most importantly, none of the marine geophysicists working in the world's trenches could find any evidence for the postulated compression, and many proposed that trenches were actually zones of extension.

Arguments about the tectonics of arcs were to continue, with gradually diminishing intensity, for several years after the 1964 Alaska earthquake conclusively provided direct evidence for major convergence and thrust faulting in an arc environment that was consistent with the known history of deformation in late Cenozoic rocks along the Gulf of Alaska margin (Figure 2).

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1964 Alaska Earthquake Tectonic Displacements

The March 27, 1964 Alaskan earthquake (Mw 9.2) resulted from rupture of a segment of the eastern Aleutian megathrust 800 km long and from 200–250 km wide down dip. This major tectonic event was characterized by: (1) shallow seismicity (<30 km), with most of the earthquakes located between the Aleutian trench and the zero isobase between the zones of major uplift and subsidence; (2) regional vertical displacements in a broad asymmetric downwarp to 2 m centered over the Kodiak, Kenai, and Chugach Mountains with flanking zones of marked uplift to 11.3 m on the seaward side and minor uplift to about 0.3 m on the landward side that extends north of the Alaska Range; and (3) horizontal displacements that involved measured systematic shifts of the land in a generally seaward direction of at least 18 m, and possibly as much as 23, in the region between Anchorage and Montague Island, and at least 7 m between Montague Island and Middleton Island located near the continental shelf edge. The 1964 Alaska earthquake resulted in the largest area of tectonic deformation in a single event that has ever been documented. The earthquake caused sudden changes in elevation along several thousand kilometers of shoreline over an area of Alaska that is about equal to the area of the combined states of Oregon and Washington.

Subordinate northwest-dipping intraplate reverse faults, the Patton Bay and Hanning Bay faults, displaced the surface on Montague Island. The Patton Bay fault, with at least 7.9 m dip-slip, is part of a zone of imbricate thrust faults that extends to the southwest on the continental shelf ~500 km. Evidence of young submarine faults, and folds, and possible coseismic uplift of the sea floor was found along the zone off Kodiak Island by marine geophysical surveys and two of the largest aftershocks lie along it. In addition, a northwest dipping thrust fault seaward of Middleton Island near the continental shelf edge is suggested by ~3.5 m coseismic uplift and northeastward tilting of the island.

The intraplate thrust faults at Montague and Middleton Islands alone accommodate at least 23 m of the total slip on the Aleutian megathrust, assuming average fault dips of about 30 degrees. Although the total slip is uncertain, this leaves very little, if any, slip for the segment of the megathrust seaward of Middleton Island and may explain the virtual lack of aftershocks in that region. Similarly, the vertical displacement profile data for the great 1960 Chile earthquake (Mw 9.5) can not be modeled using slip solely on the megathrust; the best-fit dislocation model requires an intraplate fault with dip of about 35° that intersects the surface offshore on the upper continental slope.

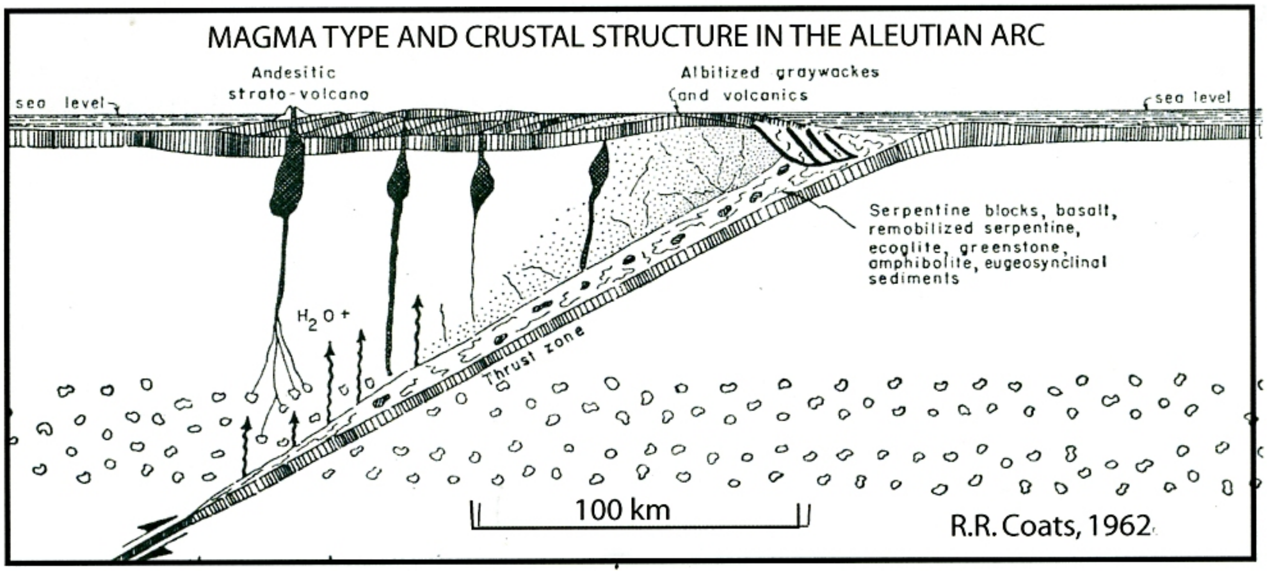

Fig. 1. Cross section through crust and upper mantle of a generalized arc showing suggested mechanism for development of andesitic rocks through addition of water and hyperfusible materials from eugeosynclinal deposits to eruptible basaltic material in the mantle.

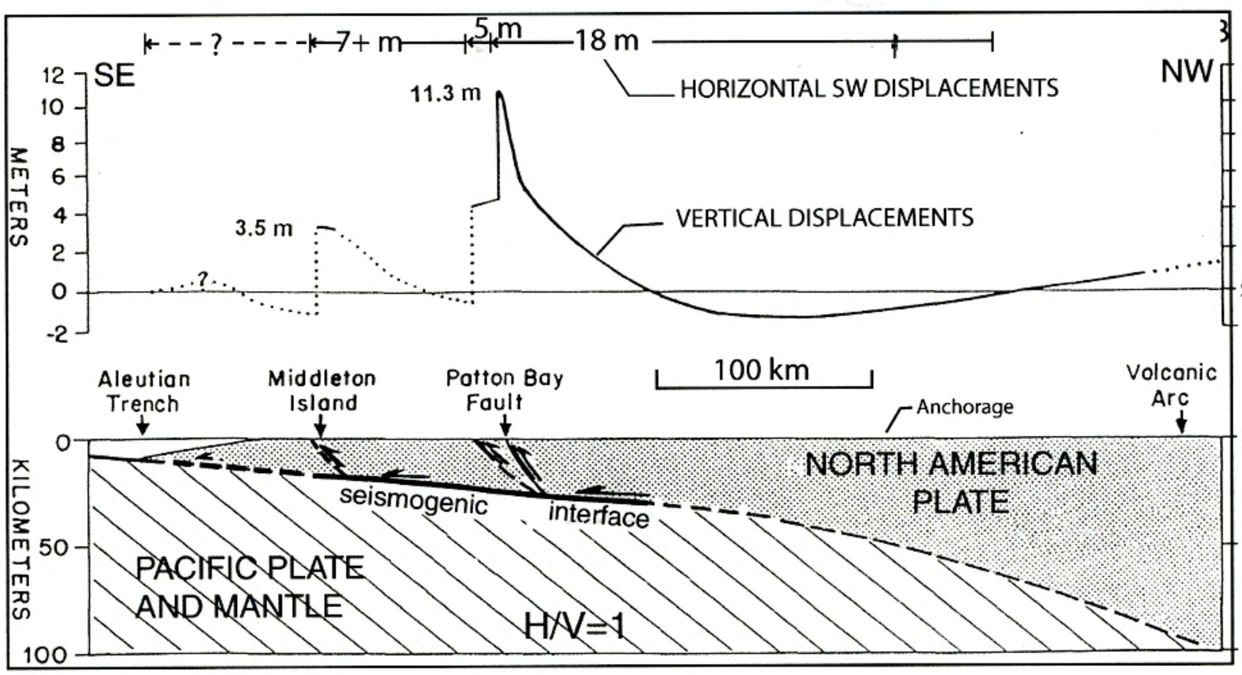

Fig. 2. Profile and section of coseismic deformation associated with the 1964 Alaska earthquake across the Aleutian arc (oriented NW-SE through Middleton and Montague Islands). Profile of horizontal and vertical components of coseismic slip (above) and inferred slip partitioning between the megathrust and intraplate faults (below). From Plafker (1965, 1967).