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A tribute to George Plafker

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ABSTRACT

In a long and distinguished career, George Plafker made fundamental advances in understanding of megathrust tectonics, tsunami generation, paleoseismology, crustal neotectonics, and Alaskan geology, chiefly by means of geological field observations. George discovered that giant earthquakes result from tens of meters of seismic slip on subduction megathrusts, and he did this before the theory of plate tectonics had become a paradigm. The discovery was founded on George's comprehensive mapping of land-level changes in the aftermath of the 1964 earthquake in Alaska, and on his follow-up mapping, in 1968, in the region of the 1960 earthquakes in Chile. The mapping showed paired, parallel belts of coseismic uplift largely offshore and coseismic subsidence mostly onshore – a pattern now familiar as the initial condition assumed in simulations of subduction-zone tsunamis. George recognized, moreover, that splay faulting can play a major role in tsunami generation, and he also distinguished carefully between tectonic and landslide sources for the multiple tsunamis that accounted for nearly all the fatalities associated with the 1964 Alaska earthquake. George's classic monographs on the 1964 earthquake include findings on subduction-zone paleoseismology that he soon extended to include stratigraphic evidence for cyclic vertical deformation at the Copper River Delta, as well as recurrent uplift evidenced by flights of marine terraces at Middleton Island. As a geologist of earthquakes, George also clarified the tectonics and hazards of crustal faulting in Alaska, California, and other areas worldwide. All the while, George was mapping bedrock geology in Alaska, where he contributed importantly to today's understanding of how terranes were accreted and modified. Especially important was his documentation of the origin, movement, subduction, and collision of the Yakutat terrane in southern Alaska.

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1. Introduction

George Plafker advanced understanding of plate tectonics worldwide and of bedrock geology in Alaska. George is best known for determining the style of faulting that produced the two largest earthquakes in instrumental earthquake history—the 1960 Chile earthquake of moment magnitude (Mw) 9.5, and the 1964 Alaska earthquake of Mw 9.2. The discovery hastened the plate-tectonics revolution by showing grand examples of subduction in action. George also showed how trans-oceanic and local tsunamis are generated, how records of prior megathrust earthquakes are encrypted in sediments and uplifted terraces in the source regions of megathrust earthquakes, and how Alaska has evolved through time and through the processes of terrane accretion, sedimentation, volcanism, and fault offset.

2. George's impacts on Earth science

It is difficult today for the younger generation of Earth scientists to picture the giant 1960 Chile and 1964 Alaska earthquakes outside a framework in which Pacific Ocean floor subducts beneath the Americas. Yet this picture was far from clear until George Plafker painted it.

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George was the first Earth scientist to propose, and to demonstrate with field and other evidence, that these were megathrust earthquakes. His discovery for the 1964 Alaskan event (Plafker, 1965) preceded the demonstration by others that plate tectonics (then variously called "paving stone theory of world tectonics" and "new global tectonics") was a viable model for the Earth's tectonic processes, with plate consumption occurring at trenches (McKenzie and Parker, 1967; Issacs et al., 1968; Le Pichon, 1968; Morgan, 1968). The demonstration that plate generation, or sea-floor spreading, was occurring at oceanic ridges occurred almost contemporaneously (Vine and Matthews, 1963; Vine, 1966). George further supported his megathrust hypothesis by mapping land-level changes associated with the Chilean earthquakes of May 21 and 22, 1960, and by collaborating with colleague, J.C. Savage, to re-analyze relevant geodetic and seismic data (Plafker and Savage, 1970). In both Alaska and Chile, seismologists had sought to explain the earthquakes by rupture on steeply dipping faults (e.g., Saint-Amand, 1961; Aki, 1962; Press and Jackson, 1965; see summary in Plafker and Savage, 1970; Plafker, 1972). The field data collected by George and colleagues proved that the ruptures had occurred as thrusting motion on giant shallowly dipping faults, or megathrusts.

George deciphered the Alaskan and Chilean earthquakes in several ways. He had a boundless drive to understand the workings of the Earth in producing such exceptional instances of deformation. He readily incorporated data from many disciplines, including biology, seismology, field geology, and hydrology, to fully explain the observations. His courage and thoroughness in the field enabled him to observe, in often forbidding coastal environments, the natural phenomena that proved crucial to a full understanding of what had happened.

Nobody expected the extensive land-level changes that George and his coworkers found in the months after the 1964 Alaskan earthquake. Some expected little more than a survey of surface rupture along a high-angle fault, much like the faulting near San Francisco in 1906. George soon recognized, from uplifted shorelines of Prince William Sound and the broad areal extent of aftershocks, that the 1964 earthquake required some other kind of tectonic mechanism. He estimated amounts of land-level change by using the growth limits of intertidal and other organisms, particularly emerged barnacles in areas of uplift and submerged trees and brush in areas of subsidence. Crucially, he proceeded to map the uplift at nearly all accessible locations in an area measuring approximately 100×800 km in coastal southern Alaska, and he graded each uplift estimate by uncertainty. He supplemented these largely biological observations by interviewing eyewitnesses and by incorporating instrumental data that others obtained from tide gauges, level lines, and triangulation stations. The fault-rupture model that best fit all these observations laid groundwork for later seismological estimates that assigned the 1964 earthquake a moment magnitude (Mw) of 9.2 (Kanamori, 1977).

This comprehensive set of observations defined a belt of uplift that extended offshore, nearly to the Aleutian trench, and an adjoining belt of tectonic subsidence that included much of Cook Inlet. Within the region of uplift was a belt of enhanced uplift chiefly along two faults that ruptured both the seafloor offshore Montague Island and ground surface onshore Montague Island, in Prince William Sound (Plafker, 1967a, 1967b, 1969). George ascribed the uplift to slip on an underlying megathrust, the subsidence to elastic extension of the overriding plate chiefly landward of the megathrust rupture area, and the enhanced uplift on Montague Island to upward splay faulting from the megathrust. These pioneering tectonic interpretations provide today's paradigm for subduction-zone thrusts worldwide.

After drafting several monographs on the 1964 earthquake, including his classic USGS Professional Papers on the earthquake's tectonics (Plafker, 1967b, 1969), George visited south-central Chile, in 1968, to explore the tectonics of the 1960 earthquake sequence. These earthquakes included a foreshock now rated as Mw 8.1 and a