



Modified-sterographic conformal projection

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1088

DISCUSSION

The Benioff zone beneath southwestern Alaska and the Aleutian Islands is a zone of convergence of the North American and Pacific plates and is characterized by earthquakes and volcanic activity. The western Aleutian Islands, a region of oblique convergence, are not included in this study. Espinosa and Rukstales (1986) developed a method to determine the geometry of the subducted part of the Pacific plate by calculating a set of best-fit, second-order equations for numerous cross sections containing earthquake hypocenters. The updated seismicity data base (Espinosa, 1984) contains teleseismic, instrumentally determined hypocenters for earthquakes having magnitudes (m_b or M_b) equal to or greater than 4.5, reported by ten or more stations, from the years 1964 through 1986. Each hypocentral cross section has the following characteristics: (1) represents an earth slice 40 km wide, 650 km long along the surface of the earth, and extending to a depth of 300 km below the surface of the earth; (2) has its reference point near the oceanic trench; (3) is parallel to the direction of relative plate motion; and (4) is contiguous with another cross section. The hypocenters within each cross section are projected onto a plane defined by the length and depth of the cross section. A second order equation is fit to the hypocenters contained within each cross section. The set of equations is used to generate, using a finite-difference technique, a large space-matrix that represents the mean surface of the subducted lithospheric plate. The application of this methodology directly affects other areas of research such as (1) seismic-hazards mitigation, (2) seismic zonation in a subduction region, (3) determination of the geometry and attitude of convergent plates, (4) seismic-wave velocity-depth distribution in a subduction zone, (5) seismic-potential and vulnerability studies, and (6) seismic-wave-attenuation studies, and (7) three-dimensional modeling of plate-subduction processes in earthquake-active regions.

Figure 1 is a map of southwestern Alaska, the Aleutian Islands, and neighboring areas. Shown within the rectangle that outlines the study area are contours, at 25 km intervals, of depth to the mean surface of the subducting Pacific plate, which has an average thickness of 50 km as determined in this study. The gray arrows show the direction of relative motion of the Pacific plate with respect to the North American plate (NAP) (Minster and Jordan, 1978). The depth of seismic activity varies along the lateral extent of the subducting plate; maximum depth of seismic activity is about 225 km. The contours beneath Alaska terminate where deep seismic activity is absent; the westward-trending contours beneath the Aleutian Islands are limited to the spatial extent of our model of the Benioff zone.

Figures 2-5 are connected by blue vertical lines indicating the region under study as viewed from about latitude 75° N. at an inclination angle of 20°. Figure 2 shows the location of the same rectangular study area shown in figure 1, but from a different perspective. The perspective of figure 2 is used in figures 3-5 in order to depict a three-dimensional representation of the mean surface of the Pacific plate in the Benioff zone.

Figure 3 shows the locations of volcanoes that have been active in Holocene time (Simkin and others, 1981); the three most recently active ones are identified with their names and the dates of their last eruptions. The location of the volcanic chain in this region correlates with the isodepth line of about 100 km.

Figures 4 and 5 show the contortions the Pacific plate is undergoing as it collides with the North American plate. They also show a bend of the subducting plate beneath eastern Alaska that penetrates to a depth of about 75 km. The volcanoes located to the east of this bend, which have been active in Holocene time, must be a byproduct of the interaction between the Pacific plate, which is dipping northeastward, and the North American plate. Figure 5 shows the contours of depth to the mean surface of the Pacific plate in the Benioff zone, as is shown on figure 1, but in three dimensions and at a 10 km contour interval.

Four different modes of subduction are clearly illustrated in figures 1, 4, and 5. Between long. 142° and 146° W, the mode of subduction is shown by a relatively very gentle dip of 20° in a northeastward direction. At about long. 146° to 152° W, the mode of subduction is defined by a gentle dip angle in a northwestward direction. From about long. 152° to 156° W, the mode of subduction is defined by a steeper and more westward dip, and from about long. 156° to 179° W, the dip of the plate becomes very steep (about 50°). The small undulations that appear in the Benioff zone at about long. 169° to 179° W are due to the quality of the data and should not be interpreted as small corrugations of the plate.

There are several quiescent seismic gaps at different depth intervals where earthquakes with magnitudes equal to or greater than 4.5 did not occur from 1964 through 1986, and these are located (1) between long. 155° and 157° W, at depths of 33-50 km, (2) between long. 158° and 160° W, at depths of 51-65 km, (3) several at depths of 66-80 km and at depths of 81-100 km, and (4) between long. 158° and 160° W, for earthquakes with hypocenters at depths greater than 100 km. The earthquake potential due to the rupture of one of these seismic gaps in Alaska and neighboring regions is a threat to urban areas in this part of the world.

SELECTED REFERENCES

Davies, J. N., Sykes, L. R., House, L. S., and Jacob, K. H., 1981, Shumagin seismic gap, Alaska Peninsula: History of great earthquakes, tectonic setting and evidence for high seismic potential. *Journal of Geophysical Research*, v. 86, no. B5, p. 3821-3855.

Espinosa, A. F., 1984, Seismicity of Alaska and the Aleutian Islands, 1960-1983: U.S. Geological Survey Open-File Report 84-855, 1 sheet, scale 1:2,500,000.

Espinosa, A. F., and Rukstales, K. S., 1986, Seismological mapping of the Benioff zone in Alaska and the Aleutian Islands and in central western South America [abs.]: *EOS Transactions, American Geophysical Union*, v. 67, no. 16, p. 303.

House, L. S., and Jacob, K. H., 1983, Earthquakes, plate subduction, and stress reversals in the eastern Aleutian arc. *Journal of Geophysical Research*, v. 88, no. B11, p. 9347-9373.

Lahr, J. C., Pfaffner, George, Stephens, C. D., Fogelman, K. A., and Blackford, M. E., 1979, Interim report on the St. Elias earthquake 28 February 1979: U.S. Geological Survey Open-File Report 79-670, 35 p.

Minster, J. B., and Jordan, T. H., 1978, Present-day plate motions: *Journal of Geophysical Research*, v. 83, no. B11, p. 5331-5354.

Perez, O. J., and Jacob, K. H., 1980, Tectonic model and seismic potential of the eastern Gulf of Alaska and Yakutatga seismic gap: *Journal of Geophysical Research*, v. 85, no. B12, p. 7132-7150.

Pfaffner, George, 1986, Generalized map showing suspected or known Late Cenozoic faults in Alaska, in Hays, W. W., and Gori, P. L., eds., *A workshop on evaluation of regional and urban earthquake hazards and risk in Alaska*: U.S. Geological Survey Open-File Report 86-79, p. 77.

Pulpan, Hans, and Frohlich, Cliff, 1985, Geometry of the subducted plate near Kodiak Island and lower Cook Inlet, Alaska, determined from relocated earthquake hypocenters: *Bulletin of the Seismological Society of America*, v. 75, no. 3, p. 791-810.

Simkin, Tom, Siebert, Lee, McClelland, Lindsay, Bridge, David, Newhall, Christopher, and Latter, J. H., 1981, *Volcanoes of the world*: St. Louis, Mo., Hutchinson Ross Publishing Co., 232 p.

Snyder, J. P., 1984, A low-error conformal map projection for the 50 states: *American Cartographer*, v. 11, no. 1, p. 27-39.

GEOMETRY OF THE BENIOFF ZONE AND MODE OF SUBDUCTION BENEATH SOUTHWESTERN ALASKA AND THE ALEUTIAN ISLANDS

By

A. F. Espinosa and K. S. Rukstales

1988

For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225