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EARTHQUAKE AND TSUNAMI HAZARDS IN ALASKA

Rod Combellick, *Division of Geological & Geophysical Surveys*

It is no surprise to anyone who has lived in Alaska a few years that our state is one of the most seismically active regions of the world. Most of us have felt earthquakes at one time or another, or have at least learned of their occurrence through the media. Three of the world's six largest recorded earthquakes have occurred in Alaska since the turn of the century. Earthquakes of magnitude 7 or greater have shaken some part of the state an average of at least once annually, including events of magnitude 8 or greater that have taken place an average of once every 13 years (fig. 1). Although the large majority of these major earthquakes have been in remote areas, some have affected our population centers. The great 1964 earthquake, which at magnitude 9.2 was the second largest ever recorded, unfortunately struck close enough to Anchorage and other cities in southcentral Alaska to inflict serious damage. The tsunami generated by that earthquake killed more than 100 people in Alaska and 16 people on the coasts of Oregon and California. Damaging earthquakes will continue to occur in Alaska and some will undoubtedly affect our cities. Although no one can predict exactly when or where these earthquakes will occur, we can identify areas that are at greatest risk of damage. In these areas, measures can be taken in advance of the next earthquake to reduce the likelihood of damage and to plan for appropriate emergency services.

Since the early 1980s, DGGS has maintained a small but active program to evaluate and report on earthquake hazards in Alaska. Although by statute DGGS addresses earthquake issues that arise anywhere in the state, most projects have concentrated in the Anchorage and upper Cook Inlet regions. High earthquake frequency and population density there combine to pose arguably the highest earthquake risk in the state. DGGS's recent and current earthquake projects include paleoseismology studies and earthquake-hazard mapping. Many of these projects have received partial funding from the U.S. Geological Survey's (USGS) National Earthquake Hazards Reduction Program. This year, a new cooperative program in tsunami-hazard evaluation will produce the first of a planned series of tsunami-inundation maps for coastal communities. DGGS does not operate seismometers; real-time earthquake monitoring is performed by USGS, the University of Alaska Fairbanks Geophysical Institute (UAFGI), and the West Coast & Alaska Tsunami Warning Center in Palmer.

Paleoseismology

The first step in evaluating earthquake hazards in a region is to determine how often potentially damaging earthquakes occur. Generally speaking, the long-term frequency of earthquakes tends to remain roughly the same, so we can estimate how often major earthquakes will occur in the future by knowing how often they have occurred in the past. Unfortunately, instrumental monitoring of earthquakes using

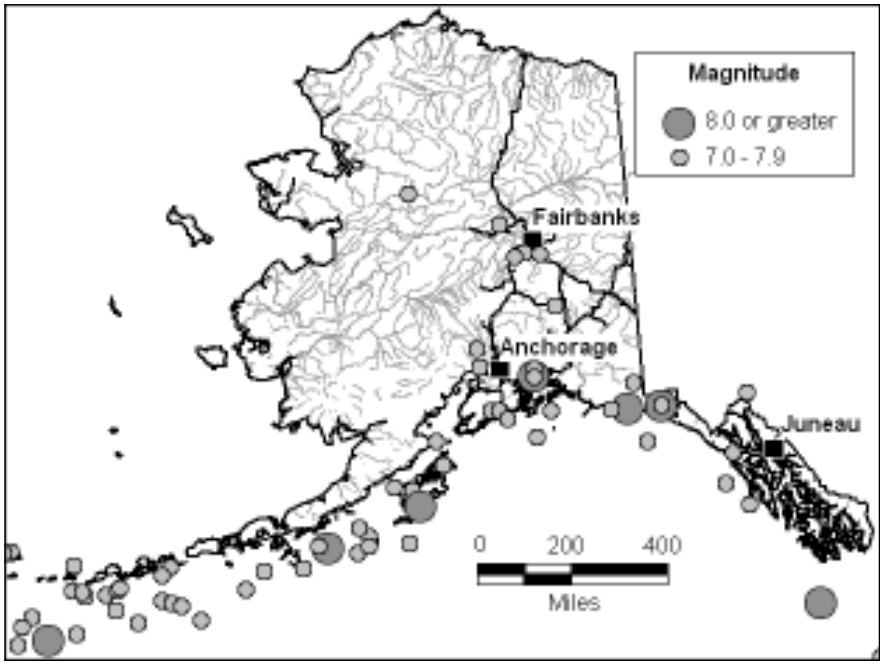

Figure 1. *Earthquakes of magnitude 7 and greater in and near Alaska (western Aleutian Islands not shown). Data from the Alaska Earthquake Information Center at UAFGI.*

(continued on page 2)

seismometers has taken place for only a few decades in Alaska and the historic record of major earthquakes goes back only about 200 years. This time frame is too brief to determine the frequency of major earthquakes like the 1964 event (no other earthquake of that magnitude has occurred in the same region during historic time). Although earthquake frequency can be estimated from the known slip rates of faults and the characteristic magnitudes of earthquakes they generate, it is important to corroborate these estimates using knowledge of the actual occurrence history of major events.

Paleoseismology is a relatively young field of geology that uses geologic evidence of past earthquakes to address these questions. During the past decade, DGGS has conducted several paleoseismology projects in the Cook Inlet region to determine the past frequency of 1964-style earthquakes. Together with similar studies by the U.S. Geological Survey along the shorelines of northwestern Gulf of Alaska, these projects have revealed evidence of six to nine very large earthquakes during the past 5,000 years, giving an average recurrence interval of roughly 600–800 years. The evidence shows that the most recent of these major pre-1964 events was around 700–900 years ago. Although we don't know their magnitudes, we know that these prehistoric earthquakes must have been as large or nearly as large as the 1964 event because of the extent of accompanying deformation of the earth's crust.

While it is comforting to think that another 1964-style earthquake may not occur near Anchorage for a few hundred years, it is important to realize that the subduction-zone fault that generated the 1964 earthquake is capable of producing smaller but still damaging events (magnitude 7.5 to 8.5) in the near future. Equally important, there are numerous other known and suspected faults in the Anchorage area that pose as much or perhaps even greater threat than a repeat of the 1964 quake. As residents of Northridge, California, discovered during their magnitude 6.7 earthquake in January 1994, it doesn't take a "big one" to do serious damage if the epicenter is near or beneath a populated area. At least three suspected active faults are within 25 miles of Anchorage and are capable of generating earthquakes as large as magnitude 7.5. Unfortunately, there have been too few large earthquakes on these faults during historic time and too little paleoseismic data to determine how often they occur. The prudent approach to reducing earthquake risk is to assume that earthquakes of this magnitude will occur in the near future and to plan accordingly.

Earthquake hazards mapping

In addition to strength and duration of ground shaking, the severity of earthquake damage depends greatly on the type, thickness, and water content of soils beneath a site. The slope of the ground nearby is also a factor. Numerous historic earthquakes, including the 1964 Alaska event, have demonstrated that certain types of soil are prone to failures that include loss of bearing strength, sliding, and spreading (fig. 2). Thick, soft soils tend to amplify ground motion, exacerbating the damage potential. Maps that show the distribution of these soils can help identify areas where building codes should be strengthened and where emergency-response resources should be concentrated. A ground-failure susceptibility map prepared in 1979 for the Municipality of Anchorage is currently being used to delineate areas where geotechnical studies are required for new construction (fig. 3). DGGS is currently compiling Anchorage borehole data in a Geographic Information System (GIS) database in preparation for new maps that will provide additional geologic information to help in the design and construction of more earthquake-resistant structures. DGGS will publish two maps in 1999 to complement the 1979 ground-failure map. One of these is a liquefaction-susceptibility map, which will identify areas underlain by wet, sandy soil that has high potential of turning to "quicksand" during strong shaking. The second map, being prepared in cooperation with UAFGI, is a seismic soil-type map that will depict soil types in a manner consistent with the Uniform Building Code earthquake provisions. This map will, for many facilities, allow builders to determine earthquake-related building-code requirements according to the seismic soil type shown for the construction site. UAFGI is also preparing maps of Anchorage that will show ground-motion amplification factors.

Figure 2. *Damage in the Turnagain Heights subdivision of Anchorage in 1964, caused by earthquake-induced landsliding in an area underlain by weak, clay-rich soils. Photo from National Geophysical Data Center.*

Tsunami hazards

By far the greatest damage and loss of life during the 1964 Alaska earthquake resulted from the tsunamis and landslide-induced waves that the earthquake generated. Just as earthquake-hazard maps help planners and designers reduce losses from earthquakes, tsunami-inundation maps are used to designate safe evacuation routes and to plan emergency response. Because of the complex ways that approaching tsunamis are affected by the sea floor and shape of the coastline as they reach shallow water, predicting how far inland they travel is difficult. With modern computer technology, it is possible to model these complex processes so that the extent of tsunami inundation can be predicted under various scenarios of earthquake location and size.

In a newly established cooperative project, DGGS will participate with UAFGI and the Alaska Division of Emergency Services (ADES) to generate tsunami-inundation maps of communities along the Gulf of Alaska coast where this hazard is greatest. The initial funding for this project came from the National Oceanic and Atmospheric Administration through ADES under a new congressionally mandated National Tsunami Hazard Mitigation Program. The first project will provide tsunami-inundation and evacuation maps for three areas in the Kodiak vicinity (City of Kodiak, U.S. Coast Guard Reservation, and Women's Bay). UAFGI will perform tsunami-inundation modeling at the Arctic Region Supercomputing Center. Using its GIS capability, DGGS will incorporate the results of the modeling into draft maps along with topographic and cultural base-map information. Based on the draft maps, ADES and the City of Kodiak will identify appropriate evacuation routes using local knowledge of terrain and facilities. These evacuation routes will be incorporated into the final published maps.

Future projects

In 2000, DGGS plans to expand its earthquake-hazard mapping program to other urban areas, starting with Fairbanks and Juneau but eventually encompassing 20 high-risk communities in seismically active areas of the state. Tsunami-inundation mapping will be expanded to additional communities along the Gulf of Alaska coast in cooperation with ADES and UAFGI. DGGS's goal is to provide reliable information on earthquake and tsunami hazards that communities and private citizens can use to help reduce risks from these hazards. By reducing its vulnerability to these hazards, Alaska will become less dependent on federal disaster aid and insurance, both of which are likely to be more restrictive in coming years in the wake of recent catastrophic losses in other parts of the country.❖

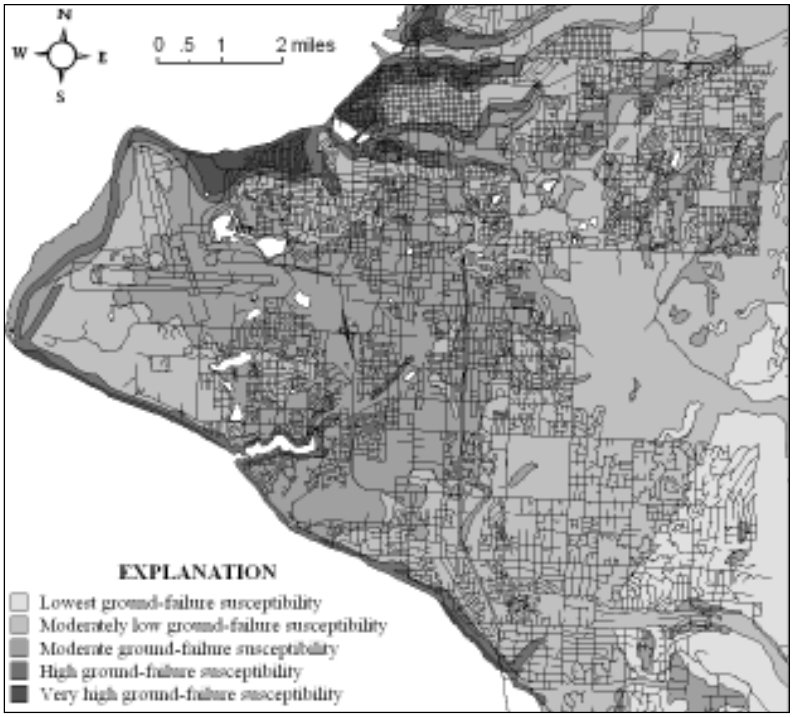

Figure 3. *Map of Anchorage showing relative ground-failure susceptibility during earthquakes. Modified from Harding-Lawson Associates, 1979, Geotechnical Hazards Assessment Study, Municipality of Anchorage (available as DGGS Miscellaneous Publication 32 in color at 1:25,000 scale).*

Information Circular 44
Guide to Alaska Geologic and Mineral Information

page 60–**USGS Technical Data Unit** phone number should be 907-786-7457.

page 65–**Geophysical Institute GeoData Center** information should be

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Dear Readers:

It is my pleasure to announce that DGGS has recently hired two new geologists. **Melanie Werdon**, Geologist III, will fill the mineral program position authorized by the Legislature in FY99. Melanie comes to us from Avalon Development Corporation based in Fox, Alaska. She has participated in several mineral exploration programs and recently successfully defended her Ph.D. dissertation, *"Geology and timing of zinc–lead–silver mineralization, northern Brooks Range, Alaska,"* at the University of Alaska Fairbanks. Melanie will assume the lead role in the Division's federally funded Alaska [mineral] Resource Data File project and will be a key member of the Fortymile airborne geophysical/geological mineral inventory project.

Frank Ganley has joined DGGS as a Geologist I to work within the DGGS–USGS–UAF cooperative Alaska Volcano Observatory program. Frank will be responsible for developing digital databases and maintaining the AVO web site so that Alaska volcano information can be disseminated over the Internet. In addition, Frank will help AVO scientists produce geologic maps using the ArcInfo geologic data modeling system.

DGGS is fortunate to have two such qualified professionals join our program.

Motivated by the Legislature's admonition to pursue "outcomes," DGGS has completed a review of its four primary programs—minerals, energy, engineering geology, and geologic information management. In this issue, Rod Combellick summarizes two of the geologic hazard concerns that pose a threat to Alaskans and, along with volcanic hazards, are high priorities for our Engineering Geology Section's work. As a state, we face the challenge of mitigating geologic threats to personal safety and disruption of Alaska commerce. DGGS's assessments of the spatial extent and potential severity of natural geologic hazards provides fundamental data required for all subsequent mitigation and emergency response measures.

Milton Wiltse
Director and State Geologist

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DGGS NEW PUBLICATIONS

MP 32. **Seismically induced ground-failure susceptibility, Anchorage, Alaska, digitally recompiled with 1993-1994 revised topography,** by S.M. Weems and R.A. Combellick, by Harding-Lawson Associates, 1998, 1 sheet, scale 1:25,000. $13.

MP 33. **Map of selected mines, coalfields, and significant mineral resources of Alaska,** by D.J. Szumigala, 1998, 1 sheet, scale 1:2,500,000. $13.

MP 34. **Planning scenario earthquakes for Southeast Alaska,** by Roger A. Hansen and Rodney A. Combellick, 5 p. $2.

RI 98-15. **Recent retreat of Le Conte Glacier and associated calving and iceberg hazards, southeastern Alaska,** by Roman J. Motyka, James Begét, and Paul Bowen, 1998, 9 p. $2.

RI 99-1. **Total field magnetics of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, 1999, 2 sheets, scale 1:63,360. Topography included. Full color plot from electronic file, 400 dpi. Made on request. $26.

RI 99-2. **900 Hz coplanar resistivity of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, 1999, 2 sheets, scale 1:63,360. Topography included. Full color plot from electronic file, 400 dpi. Made on request. $26.

RI 99-3. **7200 Hz coplanar resistivity of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, 1999, 2 sheets, scale 1:63,360. Topography included. Full color plot from electronic file, 400 dpi. Made on request. $26.

RI 99-4. **Total field magnetics of part of the Livengood mining district, Alaska, central Livengood Quadrangle,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, 1999, 1 sheet, scale 1:63,360. Topography included. Full color plot from electronic file, 400 dpi. Made on request. $13.

RI 99-5. **900 Hz coplanar resistivity of part of the Livengood mining district, Alaska, central Livengood Quadrangle,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, 1999, 1 sheet, scale 1:63,360. Topography included. Full color plot from electronic file, 400 dpi. Made on request. $13.

RI 99-6. **7200 Hz coplanar resistivity of part of the Livengood mining district, Alaska, central Livengood Quadrangle,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, 1999, 1 sheet, scale 1:63,360. Topography included. Full color plot from electronic file, 400 dpi. Made on request. $13.

Public-Data Files (PDF) are unpublished documents that make project data immediately available to the public. PDFs usually comprise raw data and have not undergone peer review or been edited by DGGS staff. In many cases, PDFs are later released as DGGS Reports of Investigations (RI), Special Reports (SR), or Professional Reports (PR). Prices for PDFs are determined by their individual reproduction prices and are thus sold at copying costs. Information Circulars (IC) are normally free.

PDF 98-32a. **Geochemical trace-element data from rocks collected in the Petersville (Yentna) mining district, 1998,** by D.S. Pinney, D.J. Szumigala, J.L. Mayer, S.A. Liss, K.H. Clautice, A.M. McCarthy, D.L. LePain, R.A. Combellick, and N.M. Strandberg, December 1998, 19 p., 1 sheet, scale 1:63,360. $19.90.

PDF 98-32b. **Geochemical major-oxide and trace-element data from rocks collected in the Petersville (Yentna) mining district, 1998,** by D.S. Pinney, D.J. Szumigala, J.L. Mayer, .S.A. Liss, and K.H. Clautice, December 1998, 6 p., 1 sheet, scale 1:63,360. $18.60.

PDF 98-42. **Combined geology and airborne geophysical data of the Ruby-Poorman mining district, Alaska compiled by L.E. Burns,** by C.C. Puchner, G.M. Smith, R.W. Flanders, D.E. Crowe, S.C. McIntyre, DGGS Staff, Dighem Staff, and W.G.M. Staff, November 1998, 2 sheets, scale 1:125,000. $26.

PDF 99-1. **Flight lines of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 2 sheets, scale 1:63,360. Blueline. Topography included. $23.

PDF 99-2. **Total field magnetics and electromagnetic anomalies of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 2 sheets, scale 1:63,360. Blueline. Magnetic contours and section lines included. $23.

PDF 99-3. **Total field magnetics and electromagnetic anomalies of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 2 sheets, scale 1:63,360. Clear diazo film. Magnetic contours and section lines included. Made on request. $39.

PDF 99-4. **900 Hz coplanar resistivity of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 2 sheets, scale 1:63,360. Blueline. Resistivity contours and section lines included. $23.

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PDF 99-6. **Portfolio of aeromagnetic and resistivity maps of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by L.E. Burns and S.A. Liss, January 1999. Includes color and shadow maps. Maps fit 8½" x 11" sheet. $10.

PDF 99-7. **Project report of the 1998 geophysical survey data for of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles.** Price to be determined.

PDF 99-8. **Zip disk containing gridded files and section lines of 1998 geophysical survey data for part of the Fortymile and Livengood mining districts, Alaska, southern Eagle, northern Tanacross, and central Livengood quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 1 zip disk. $15.

DGGS NEW PUBLICATIONS

PDF 99-9. **CD-ROM containing profile and gridded data and section lines of 1998 geophysical survey data for part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 2 CD-ROMs. $150.

PDF 99-10a. **Total field magnetics and detailed electromagnetic anomalies of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 1 sheet, scale 1:31,680 (western part of B-3 Eagle Quadrangle). Blueline. $10.50.

PDF 99-10b. **Total field magnetics and detailed electromagnetic anomalies of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 1 sheet, scale 1:31,680 (northwestern A-3 and small part of A-4 Eagle Quadrangle). Blueline. $10.50.

PDF 99-10c. **Total field magnetics and detailed electromagnetic anomalies of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 1 sheet, scale 1:31,680 (most of the eastern A-3 Eagle Quadrangle). Blueline. $10.50.

PDF 99-10d. **Total field magnetics and detailed electromagnetic anomalies of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 1 sheet, scale 1:31,680 (A-2 Eagle Quadrangle). Blueline. $14.

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PDF 99-10g. **Total field magnetics and detailed electromagnetic anomalies of part of the Fortymile mining district, Alaska, southern Eagle and northern Tanacross quadrangles,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 1 sheet, scale 1:31,680 (northern part of D-1 Tanacross Quadrangle). Blueline. $11.

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PDF 99-12. **Total field magnetics and electromagnetic anomalies of part of the Livengood mining district, Alaska, central Livengood Quadrangle,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 1 sheet, scale 1:63,360. Blueline. Magnetic contours and section lines included. $7.

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PDF 99-16. **Portfolio of aeromagnetic and resistivity maps of part of the Livengood mining district, Alaska, central Livengood Quadrangle,** by L.E. Burns and S.A. Liss, January 1999. Includes color and shadow maps. Maps fit 8½" x 11" sheet. $9.

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PDF 99-20b. **Total field magnetics and detailed electromagnetic anomalies of part of the Livengood mining district, Alaska, central Livengood Quadrangle,** by DGGS, Geoterrex-Dighem, and Stevens Exploration Inc. Staff, January 1999, 1 sheet, scale 1:31,680 (northwestern B-3 and northeastern B-4 Livengood Quadrangle). Blueline. $10.