# Rock Creek Project
# Seismic Hazard Assessment

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**Project 1011A**

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## 1.0 Introduction

The purpose of this study is to evaluate the seismic hazard at Alaska Gold Company's (AGC) proposed Rock Creek and Big Hurrah mine sites. Both sites are components of AGC's Rock Creek Project (RCP) currently being designed and are located near Nome, Alaska, on the Seward Peninsula along the west coast of Alaska.

## 1.1 Rock Creek Site

The Rock Creek site is located approximately 10 kilometers (km) north of Nome on the east flank of the Snake River Valley at Latitude 64.7 North and Longitude 165.47 West. The site is located at a mean elevation of approximately 100 meters above mean sea level (AMSL). The site is characterized by cool summers and cold winters. Summer temperatures range between plus 8 degrees Centigrade (+8°C) and +15°C; winter temperatures average around -15°C. The Rock Creek site is characterized by relatively low annual precipitation averaging less than 50 centimeters (cm), with the majority of the precipitation falling as rain in the summer months. Monthly winter snowfall totals range between 12 and 28 cm on average.

The facilities to be constructed at the Rock Creek site include the following:

- Open Pit
  - Approximately 1.1 km long by 0.6 km wide, trending northeast/southwest
  - Current depth is approximately 130 m
- Tailings Storage Facility (TSF)
  - Single Phase (1 cell): potential for second phase in future
  - Embankment to be constructed on bedrock
  - Construction to be staged: 3 stages
  - Crest elevation at maximum embankment section: 60 m

  - Maximum crest height: 24 m - Phase 1 (29 m Phase 2, if needed)
  - Crest width – 10 m
  - Side slopes: 2.5:1 (horizontal:vertical)

- Development Rock Dumps
  - Potential for two dumps: North and South dumps
  - Three lifts maximum
  - Lift height: 15 m
  - Lift slope: 1.4:1 (horizontal:vertical)
  - Bench between lifts: 24 m
  - Composite (Overall) slope: 3:1 (horizontal:vertical)

- Mill Site Area
  - Approximate Size: 450 m x 350 m
  - Facilities will include crushing, grinding, administration and maintenance facilities
  - Some foundations to be constructed on bedrock (mill foundation)
  - Some equipment to be founded on fill (crushing/screening)

## *1.2 Big Hurrah Site*

The Big Hurrah site is located approximately 50 km east of Nome at a Latitude of 64.65 North and a Longitude of 164.25 West. The site is positioned within the Big Hurrah drainage, which is a tributary to the Solomon River, and is located at a mean elevation of approximately 90 m AMSL. Similar to the Rock Creek site, the Big Hurrah site is characterized by cool summers and cold winters. There is insufficient site climate data available to define the precipitation, evaporation, and temperature conditions at the site. Therefore, regional information has been used to provide a general description of the site climatology. Based on correlations performed by Ecological Resource Consultants, Inc., expected precipitation at the site is estimated to be approximately 1.37 times the value recorded at the weather station in Nome, Alaska. This correlation would indicate that the site is also characterized by relatively moderate annual precipitation averaging less than 56 cm, with the majority of the precipitation falling as rain in the summer.

The facilities to be constructed at the Big Hurrah site include the following:

- Open Pit
    - Approximately 500 m long by 250 m wide, trending northwest/southeast
    - Current depth is approximately 100 m
- Development Rock Dumps
    - Current design is for one dump
    - Three lifts
    - Lift height: 15 m
    - Lift slope: 1.4:1 (horizontal:vertical)
    - Bench between lifts: 24 m
    - Composite (Overall) slope: 3:1 (horizontal:vertical)
- Admin/Maintenance Site Area
    - Approximate Size: 40 m x 50 m
    - Facilities will include administration and maintenance facilities
    - Foundation design/requirements to be determined

## 2.0 *Regional and Local Geology*

The Seward Peninsula is underlain by bedrock consisting of several metamorphic rock sequences belonging to the Nome Group that have undergone at least two periods of metamorphism and accompanying deformations (Norwest, 2003). The parent rocks of this Group are considered to be Cambrian to Devonian sediments consisting of shales, siltstones, sandstones, marls and limestones, deposited in a shallow water continental shelf setting. The Nome Group appears locally as a progression consisting of four major units. There are three units that are closest to the ground surface in the area (carbonaceous schist, calc schist, and a mixed schist) with the carbonaceous schist being present in the stream valley and the mixed schist generally to the east and the calc schist generally to the west (Krzewinski et al, 2004).

## 3.0 *Local Soil Conditions*

### ***Rock Creek Site***

Geotechnical field investigations were conducted at the Rock Creek site by Golder Associates in 2003 and by Smith Williams Consultants Inc. (Smith Williams) in August 2004, November 2004, and August 2005. The results of Golder's investigation are presented in their February 2004 draft report (Golder, 2004). The results of Smith Williams 2004 field investigations and evaluations are summarized in their April 2005 report with a composite geotechnical investigation report currently in progress.

The Rock Creek mine site mineralized zone covers an area of approximately 500 by 1500 meters. The main rocks are schist and quartz muscovite (QMS). QMS is dominant but other types of schist are common in the deposit area (Norwest, 2003).

A review of the test pit and boring logs generated during the investigations indicates that except in areas that have been previously disturbed by exploration activities, a vegetative tundra mat underlain by a thin layer of silt exists across most of the site. Below this thin layer of silt, silty gravel or silty sand materials generally exist until the weathered bedrock is encountered. This weathered bedrock material consists of coarse gravel materials, with varying amounts of silt and sand, that increase in density and structure with depth. The soils conditions encountered at each of the facilities, with the exception of the open pit area, are summarized below.

> Plant Site – A total of three borings were drilled and 19 test pits excavated. Subsurface conditions were found to be fairly consistent across the plant site. Highly weathered bedrock was encountered at depths ranging from 0.61 m to 3.2 m below the existing

ground surface. The highly weathered bedrock is generally greater than 1.5 m thick. Permafrost was encountered in all three borings drilled at depths of 0.75 m to 0.9 m and in 11 of the 19 test pits at depths ranging from 0.46 m to 0.91 m.

Tailings Storage Facility – A total of seven borings were drilled and 34 test pits excavated in and around the Tailings Storage Facility Stage 1 area. Slightly to highly weathered bedrock was encountered a depths ranging from about 0.6 m to 5.8 m below the existing ground surface. Permafrost was encountered in four of the test pits at depths ranging from 0.85 m to 1.55 m and in five of the borings at depths ranging from 0 m to 2.2 m. In some of the borings the base of the permafrost was not reached.

Development Rock Dumps – A total of three borings were drilled and 27 test pits excavated. Frozen soils were encountered in approximately half of the north dump area at depths ranging from 0.37 m to 1.22 m. Highly weathered bedrock was present at depths from 1.37 m to over 5.5 m in the north dump. Soil conditions found in the south dump indicate weathered bedrock exists at depths between 0.5 m and 2.0 m. No test pits in the south dump detected permafrost but visual observations of the topography and vegetation indicate permafrost may exist near the upper limits of the area.

## ***Big Hurrah Site***

Geotechnical investigations at the Big Hurrah site are limited to an investigation performed by Smith Williams in August 2005 and a few miscellaneous test pits performed by other consultants and presented in historic geologic and environmental reports. Smith Williams performed 15 test pits during the recent field investigation.

Similar to the Rock Creek site, a review of the test pit logs indicates that except in areas that have been disturbed by historic and current exploration activities, a vegetative tundra mat underlain by a thin layer of silt exists across much of the site. Below this thin layer of silt, silty gravel or silty sand materials generally exist until the weathered bedrock is encountered. This weathered bedrock material consists of coarse gravel materials, with varying amounts of silt and sand, that increase in density and structure with depth. The depth to bedrock in the undisturbed areas vary between 0.5 m to 1.2 m.

The areas previously disturbed are concentrated around the proposed pit, haul roads, shop locations and the natural creek channels. The development rock dump area is mostly undisturbed. In areas outside of the natural creek channels that have been disturbed, the weathered and competent bedrock has been exposed. The disturbance activity near the natural creek channels consisted of placer mining, leaving the bedrock layer intact and covered with a sand/gravel matrix. The depth to bedrock in these areas varied from 1 m to 2 m. In addition to the exposed bedrock in the disturbed areas, there exists naturally exposed bedrock and talus slopes at the site. These areas are either within the proposed open pit limits or higher on the slopes than was investigated and above the locations of proposed facilities.

Permafrost at the site is discontinuous and identified in only four of the 15 test pits performed by Smith Williams. The historic investigations did not identify permafrost but indicate it may be present at the site. The permafrost identified was found at depths ranging from 0.9 m to 2 m below the surface.

## *4.0 Site Class Definition*

Site Class definitions for use in developing seismic design response spectra are presented in the 1997 Uniform Building Code (UBC) and the 2003 International Building Code (IBC). These are based on the average soil properties existing within the upper 100 ft (30 m) of the soil profile. When the average shear wave velocity of the soil profile, $(V_s)_{avg}$, is not known Standard Penetration Resistance, N, or soil undrained shear strength, $S_u$, may be used in accordance with Table 1615.1.1 of the IBC. Field studies have been conducted by others in permafrost regions to measure the compression ($V_p$) and shear wave ($V_s$) velocities of permafrost (Nieto et al, 2002). Measured values of $V_s$ of about 2000 m/s (6562 ft/sec) have been obtained. It is our understanding that the major facilities at the Plant site will be founded on the underlying weathered bedrock. Permafrost was not encountered in several of the test pits excavated at the plant site to depths of up to 3.2 m. On this basis, a Site Class B (Rock) is considered appropriate for developing design response spectra for the Plant site.

## *5.0 Historical Seismicity*

Alaska is the most seismic state in the U.S. and spans 4800 km of the active boundary between the Pacific and North American Plates. It is the site of three of the world's ten largest earthquakes of this century (see Figure 1). The largest of the three – the moment magnitude $M_w$ 9.2 earthquake that struck southern coastal Alaska in 1964 – ranks second only to the $M_w$ 9.5 Chilean earthquake of 1960 (Page et al, 1991). The earth's most active seismic feature, the circum-Pacific seismic belt, brushes Alaska and the Aleutian Islands, where more earthquakes occur than in the other 49 States combined. More than 80 percent of the planet's tremors occur in the circum-Pacific belt, and about six percent of the large, shallow earthquakes are in the Alaska area, where as many as 4,000 earthquake at various depths are detected in a year. The historical seismicity in Alaska for the period from 1880 to 1996 is shown on Figure 2 for earthquake of moment magnituge equal to or greater than 5.5. Most of the shallow earthquakes in continental Alaska, with the exception of those in central western Alaska, appear to result from the interaction of the Pacific and North American lithospheric plates. A brief discussion of significant earthquakes in Alaska taken from the *Earthquake Information Bulletin, Volume 2, Number 2, March - April 1970* follows.

Early reports of earthquakes in Alaska are fragmentary. The first event in this incomplete record occurred on Sanak and Shumagin Islands, south of the Alaska Peninsula, in July 1788. Instrumental locations of earthquakes since about 1900 indicate that earthquakes in Alaska center principally in two seismic zones. The most important is the Aleutian Island Arc, one of the planet's most active seismic areas, which extends about 2,500 miles, from Fairbanks in central Alaska through the Kenai Peninsula to the Near Islands. It maintains a width of nearly 200 miles throughout most of the zone. The second zone begins north of Yakutat Bay in southeastern Alaska and extends southeastward to the west coast of Vancouver Island.

From 1899 to 1991, 30 earthquakes of magnitude 7.0 or larger have originated in and adjacent to continental Alaska. From 1899 to 1969, eight great earthquakes of magnitude 8 or more on the Richter scale have occurred in Alaska. Four caused extensive property damage and topographic changes; four centered in areas with no nearby towns, and, except for being recorded by seismographs, went relatively unnoticed.

The Alaskan earthquake that is outstanding in the memory of most occurred in the Anchorage area on March 27, 1964. The magnitude $M_s$ 8.5 (recalculated to $M_w$ 9.2) shock devastated downtown Anchorage and left homes twisted and broken in the residential section of Turnagain. A tsunami virtually destroyed many of Alaska's coastal towns and spread death and destruction along the west coast of the United States, Hawaii, and Canada.

The Yakutat Bay area of southeastern Alaska experienced one of the notable earthquakes of the last century on September 10, 1899. Although this shock was preceded one week earlier by a magnitude 8.2 earthquake, most of the effects were associated with the September 10 event which was rated magnitude 8.6 on the Richter scale.

A magnitude 7.9 earthquake which occurred in October 1900 was felt from Yakutat Bay to Kodiak, and probably farther westward. On Kodiak Island chimneys were downed, and a man was thrown from his bed. The shock probably centered near Cape Yakataga in southeastern Alaska. Property damage was very moderate for such a great shock, due to the sparsity of population.

On July 22, 1937 a magnitude 7.3 earthquake occurred in central Alaska, about 25 miles southeast of Fairbanks, that was felt over most of Alaska's interior, about 300,000 square miles. About ten years later, on October 15, 1947, a magnitude 7.3 shock occurred in the same region. It was preceded by a swarm of shocks, some very minute, others violent.

The Andreanof Island sustained a magnitude 8.8 earthquake in March 1957 that caused very severe damage on Adak and Unimak Islands. A damaging tsunami was generated, and a wall of water 40 feet high smashed the coastline of Scotch Cap on Unimak Island. Sand Bay, near Adak, reported 26 foot waves inundated its shores. This earthquake initiated a series of aftershocks that extended more than 700 miles along the southern edge of the Aleutians.

On April 7, 1958, a magnitude 7.3 shock centered in central Alaska near Huslia occurred. Within a 40 to 50 miles radius of Huslia, cracks in lake and river ice, and many ground cracks and mud flows, were observed. Evidence of pressure ridges, lakes thawing, numerous lakes filled with black slimy mud, and craters 20 feet across and 6 feet deep were reported. Some minor damage to log structures was sustained in Huslia.

The strongest shock since those of September 1899 at Yakutat hit southeastern Alaska on July 9, 1958. It was rated magnitude 7.9 on the Richter scale. Three persons were killed on Khantaak Island, and two were missing and presumed dead after being caught in a huge wave generated by the shock in Lituya Bay. This magnitude 7.9 shock was felt by residents over 400,000 square miles of Alaska, as far south as Seattle, Washington, and east to Whitehorse, Yukon Territory, Canada.

The largest magnitude earthquake in the central interior of Alaska since October 1947 occurred on October 29, 1968. Rated magnitude 6.5, the shock centered southeast of the village of Rampart, on the Yukon River. This area was severely shaken but no damage was sustained since most buildings at Rampart were of log construction.

The historical record of seismicity in Western Alaska includes four earthquakes of magnitude 6.0 or greater of which the largest is the 1958 magnitude 7.3 Huslia earthquake and two subsequent aftershocks of magnitudes 6.75 and 6.1 (see Figures 3 and 4). The remaining event is a magnitude 6.5 earthquake that occurred on the southern Seward Peninsula in 1950 about which little is known. Regional seismicity monitoring in the vicinity of the Seward Peninsula from 1977 to 1982 shown on Figure 1 indicates that seismic activity in the 2 to 5 magnitude range seems to be widespread throughout this part of Alaska and the adjacent offshore regions and is confined mainly to shallow crustal events with no prominent linear trend. The broad distribution of activity suggests that seismic deformation is distributed over various active faults and not concentrated on one or two major fault systems (Page et al, 1991). The Bedeleben and Kigluaik faults are the principal mapped active faults on the Seward Peninsula, both of which exhibit Holocene normal displacement (Hudson and Plaker, 1978). Activity also concentrates along the eastern end of the late Cenozoic offshore faults west of Teller, but not along the more recently active Bendeleben fault. Fault plane solutions from west-central Alaska, particularly the Seward Peninsula, generally exhibit normal faulting with northerly oriented tensional axes.

The historical seismicity in the vicinity of the RCP was also assessed using the U.S. Geological Survey (USGS) worldwide earthquake database search. The database search contains catalogs of earthquakes supplied by various worldwide sources (NOOA, PDE, USHIS). The primary search in this assessment was conducted for all historical earthquakes at a radial distance of 200 km or less from the Rock Creek and Big Hurrah mine sites. Due to the proximity of the two mine sites the results of the earthquake search were quite similar. Thus, only the results from the Rock Creek site are presented. Ninety earthquakes for the period from 1907 to 2004 were identified. They range in magnitude from 2.6 to 6.5 at distances of 15 to 194 km from the mine site. Only two events of magnitude $\geq$ 6.0 were contained in the search. The 6.5 event of August 1950 occurred at a distance of 168 km from the mine site whereas the 6.0 event of December 1964 occurred at a depth of 28 km at a distance of 20 km. Because of its magnitude and close proximity to the mine site a search for additional information on the 6.0 event was conducted with limited success. Page and others (1991) assign a body wave magnitude ($m_b$) of 5.3 instead of the 6.0 contained in the USGS database (see Figure 4). Thus, there is considerable uncertainty about the actual magnitude of this event. Results of the earthquake search conducted are summarized in the tables and figures included in Appendix A.

## *6.0 Acceptable Risk Level*

Strong ground shaking from an earthquake occurring in the vicinity of the mine sites could result in minor to moderate damage to the various facilities depending on its magnitude, duration of strong shaking and predominant period. The purpose of this SHA is to establish seismic design criteria, based on the proposed facilities and the operational and post-closure durations, that will minimize potential damage. For this study, a seismic event with a 475-year return period is considered appropriate for design during the 6 to 9 year operational life of the facilities. This event has a 10% probability of exceedance in 50 years and a 2% probability in 9 years. For the TSF and development rock dumps a post-closure life of 200 years has been assumed. For this closure life, a seismic event with a return period of 2500 years is recommended which corresponds to a probability of exceedance of 8 %.

The acceptable level of seismic risk for design of major structures is usually prescribed by regulatory agencies or is the responsibility of the owner. Acceptable levels of risk are often prescribed based on the consequences of failure or damage to the facility. It is our belief that the level of risk considered in this study is reasonably conservative and is therefore provided as a guideline.

## *7.0 Seismic Design Criteria*

As part of this study a probabilistic seismic hazard assessment (PSHA) was also conducted for the RCP using the U. S. Geological Survey (USGS) Seismic Hazard Deaggregation procedure and earthquake data for Alaska (Wesson et al, 1999). These data are contained in the internet on the USGS web site. The analysis assumes that the site is a firm rock site ($S_B$) with an average shear wave velocity of 760 m/sec which is consistent with the geologic conditions existing at the RCP. Analyses were conducted for various earthquake return periods ranging from 475 to 4975 years. Values of peak horizontal ground accelerations (PHGA) obtained from the analyses are plotted on Figure 5. Seismic design criteria for the two design events (475 and 2500 year return periods) are included in the following tables for both mine sites.

**Seismic Design Criteria for Rock Creek Mine Site**
**(Latitude: 64.70$^0$ N; Longitude: 165.476$^0$ W)**

| Design Earthquake Return Period (years) | Moment Magnitude ($M_w$) | Source to Site Distance (km) | Peak Horizontal Ground Acceleration (PHGA) (g) | |
|---|---|---|---|---|
| | | | Firm Rock ($S_B$) | Surface of TSF and Development Rock Dumps |
| 475 | 6.0 | 24.7 | 0.10 | 0.20 |
| 2500 | 6.1 | 12.8 | 0.24 | 0.36 |

| Seismic Design Criteria for Big Hurrah Mine Site (Latitude: 64.65$^0$ N; Longitude: 164.250$^0$ W) | | | | |
|---|---|---|---|---|
| Design Earthquake Return Period (years) | Moment Magnitude ($M_w$) | Source to Site Distance (km) | Peak Horizontal Ground Acceleration (PHGA) (g) | |
| | | | Firm Rock ($S_B$) | Surface of TSF and Development Rock Dumps |
| 475 | 6.0 | 28.4 | 0.10 | 0.20 |
| 2500 | 6.1 | 14.7 | 0.21 | 0.32 |

Notes: 1) Results based on USGS 2002 Probabilistic Seismic Hazard Interactive Deaggregation Analysis

2) Return Period, Moment Magnitude and Source to Site Distance are mean values obtained from USGS PSHA.

3) Dynamic response analyses were not conducted to establish values of PHGA at the surface of the TSF or Waste Rock Dumps. PHGAs at the surface of the TSF are only best estimates provided for use in pseudo-static deformation slope stability analyses.

A horizontal design response spectrum for 5 % damping and rock site conditions (Site Class B) was also developed for design of the Plant facilities and is shown on Figure 6. The spectra was developed in accordance with the 2003 International Building Code (IBC) recommended procedures and corresponds to a 2% probability in 50 years (2500 year return period).

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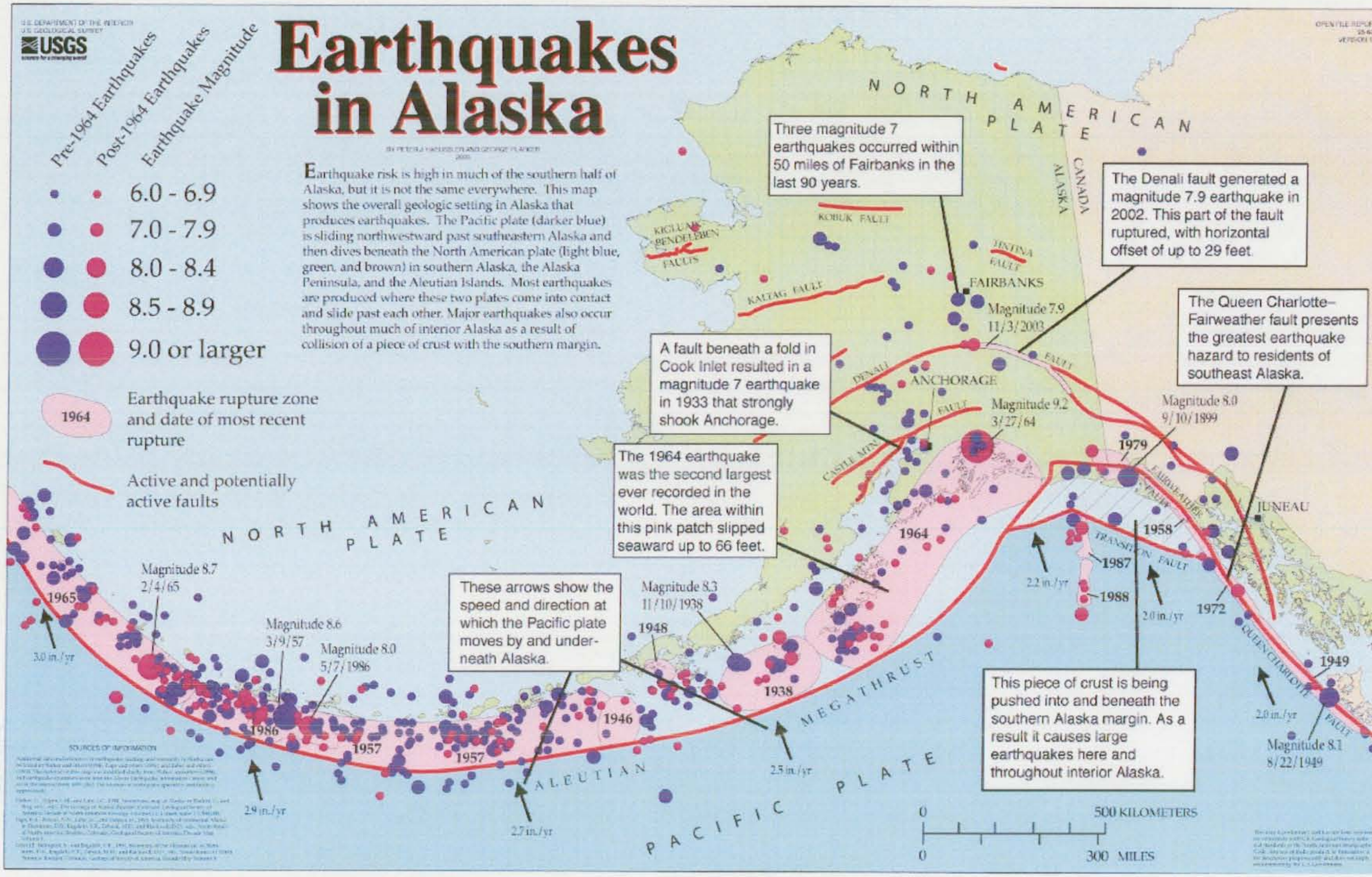


USGS
Earthquakes in Alaska
Pre-1964 Earthquakes
Post-1964 Earthquakes
Earthquake Magnitude
6.0 - 6.9
7.0 - 7.9
8.0 - 8.4
8.5 - 8.9
9.0 or larger
Earthquake risk is high in much of the southern half of Alaska, but it is not the same everywhere. This map shows the overall geologic setting in Alaska that produces earthquakes. The Pacific plate (darker blue) is sliding northwestward past southeastern Alaska and then dives beneath the North American plate (light blue, green, and brown) in southern Alaska, the Alaska Peninsula, and the Aleutian Islands. Most earthquakes are produced where these two plates come into contact and slide past each other. Major earthquakes also occur throughout much of interior Alaska as a result of collision of a piece of crust with the southern margin.
1964
Earthquake rupture zone and date of most recent rupture
Active and potentially active faults
NORTH AMERICAN PLATE
PACIFIC PLATE
ALEUTIAN MEGATHRUST
Three magnitude 7 earthquakes occurred within 50 miles of Fairbanks in the last 90 years.
The Denali fault generated a magnitude 7.9 earthquake in 2002. This part of the fault ruptured, with horizontal offset of up to 29 feet.
The Queen Charlotte–Fairweather fault presents the greatest earthquake hazard to residents of southeast Alaska.
A fault beneath a fold in Cook Inlet resulted in a magnitude 7 earthquake in 1933 that strongly shook Anchorage.
The 1964 earthquake was the second largest ever recorded in the world. The area within this pink patch slipped seaward up to 66 feet.
These arrows show the speed and direction at which the Pacific plate moves by and underneath Alaska.
This piece of crust is being pushed into and beneath the southern Alaska margin. As a result it causes large earthquakes here and throughout interior Alaska.
FAIRBANKS
ANCHORAGE
JUNEAU
CANADA
ALASKA
KOBUK FAULT
KALTAG FAULT
DENALI FAULT
CASTLE MTN FAULT
TINTINA FAULT
TRANSITION FAULT
QUEEN CHARLOTTE FAULT
Magnitude 7.9 11/3/2002
Magnitude 9.2 3/27/64
Magnitude 8.0 9/10/1899
Magnitude 8.1 8/22/1949
Magnitude 8.3 11/10/1938
Magnitude 8.7 2/4/65
Magnitude 8.6 3/9/57
Magnitude 8.0 5/7/1986
1965
1986
1957
1946
1948
1938
1964
1979
1958
1987
1988
1972
1949
3.0 in./yr
2.9 in./yr
2.7 in./yr
2.5 in./yr
2.2 in./yr
2.0 in./yr
500 KILOMETERS
300 MILES
SOURCES OF INFORMATION


Figure 1

## Historical Seismicity of Alaska for Period 1880 - 1996
## Earthquake Magnitudes $M_w \geq 5.5$

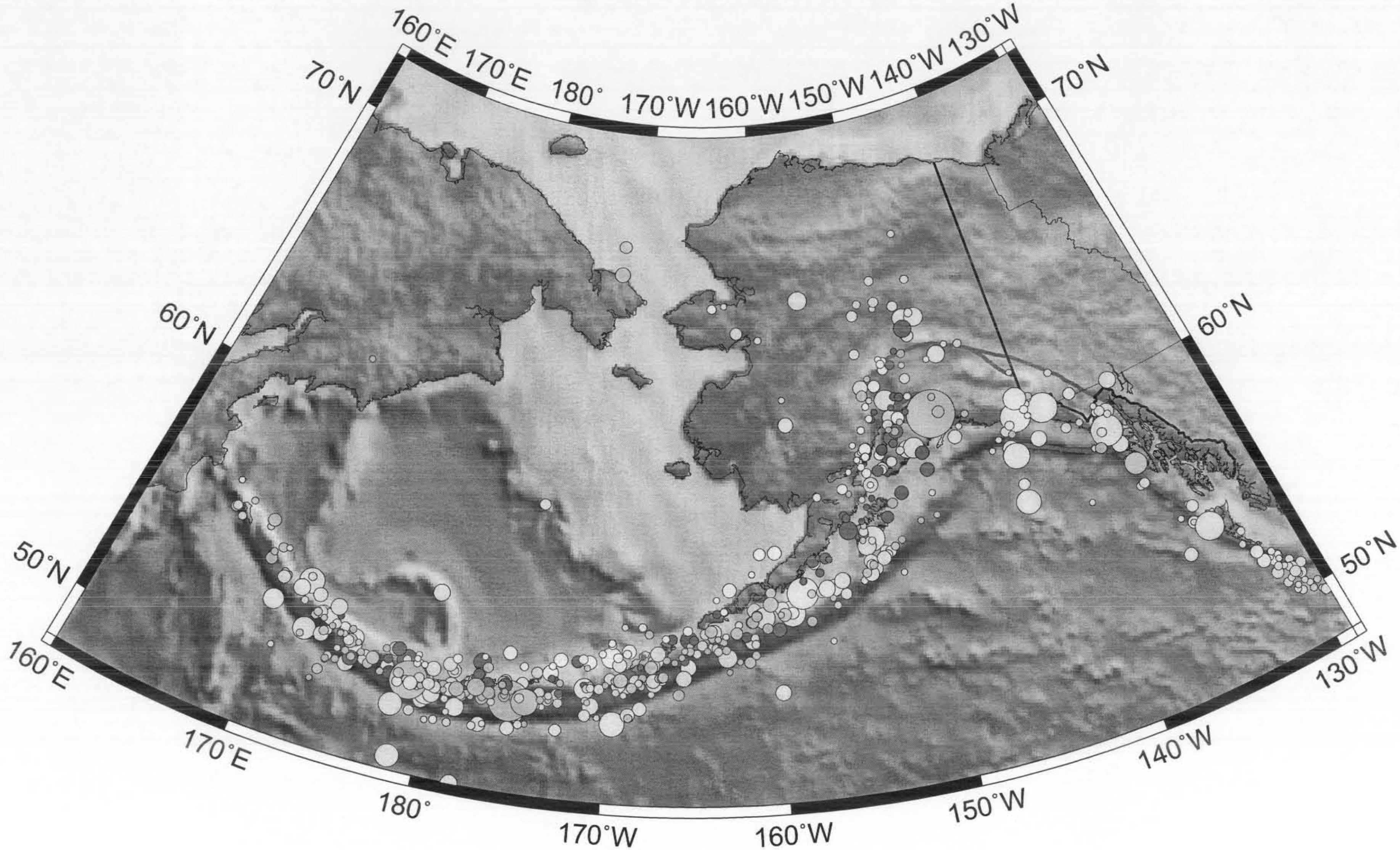



Figure 2

# Western Alaska Seismicity

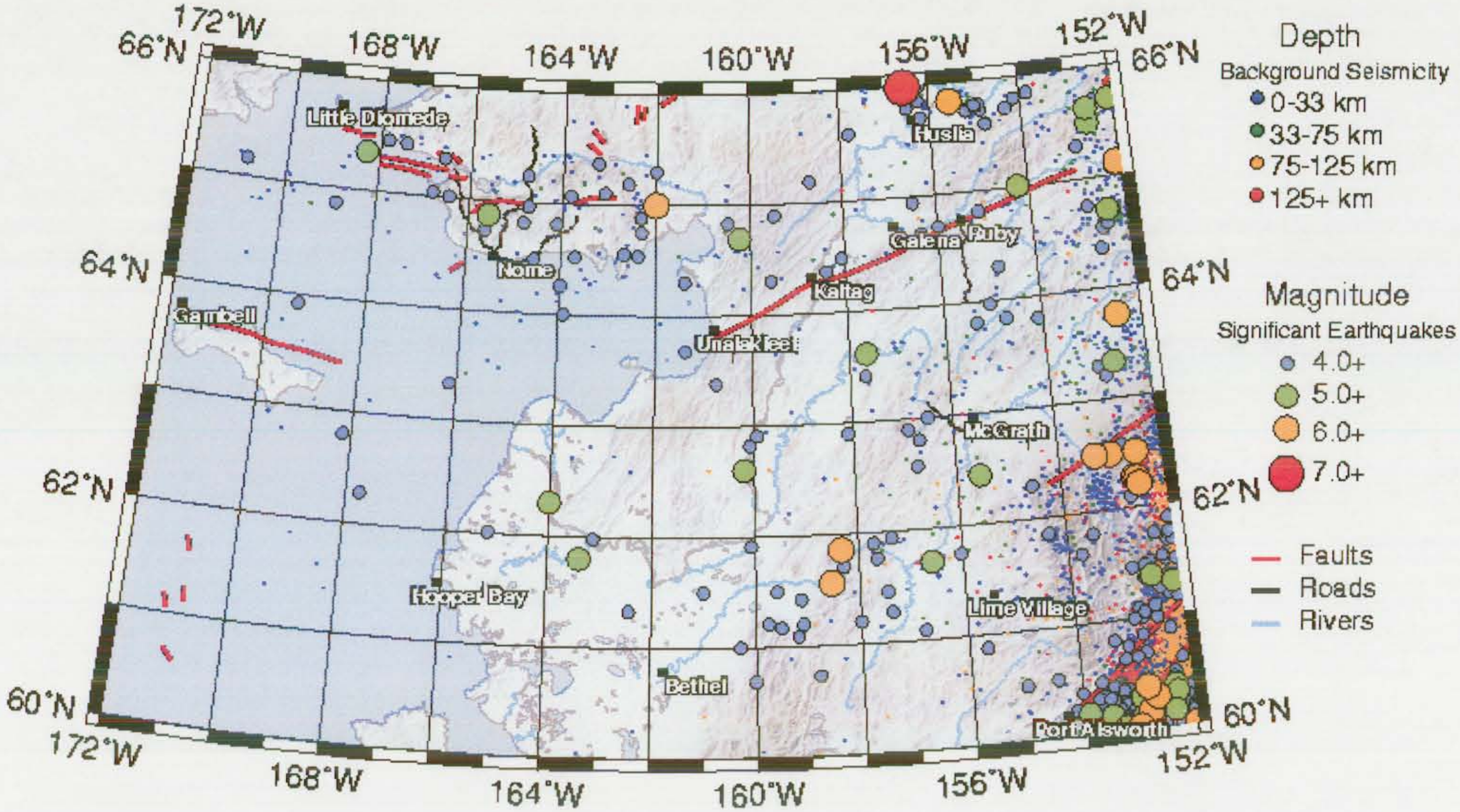
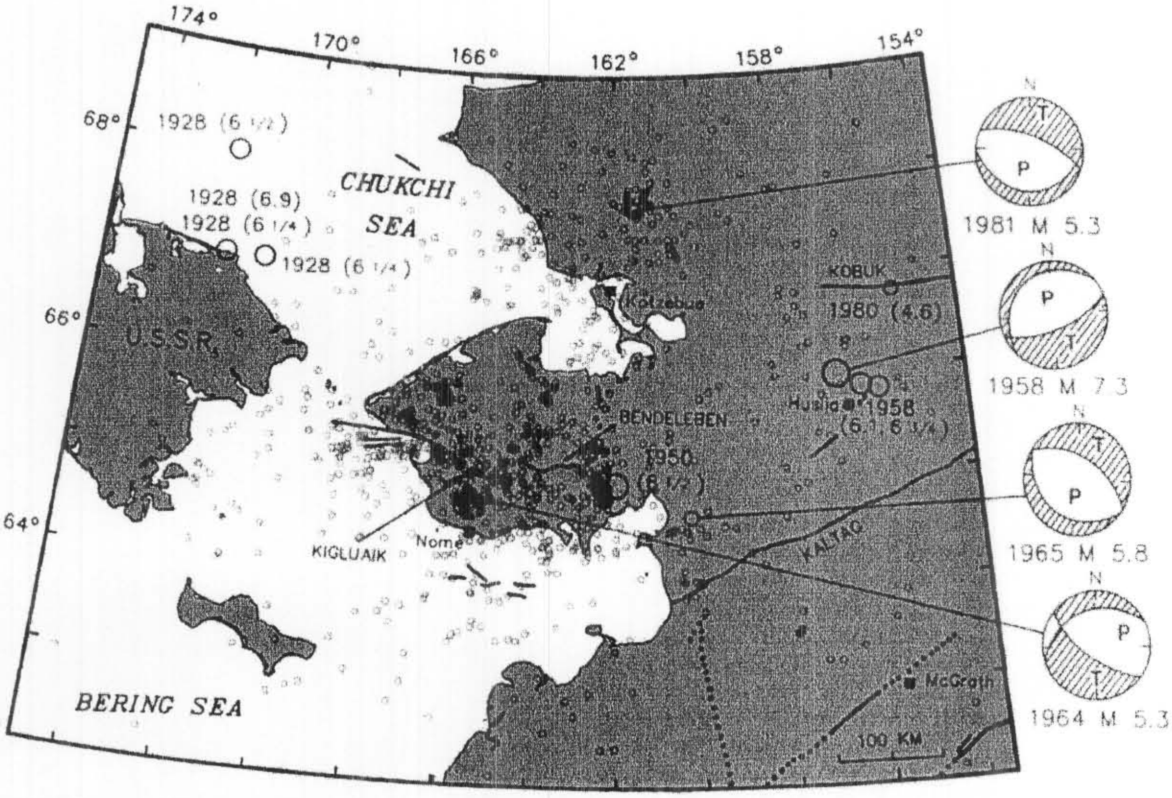



Figure 3




Epicenters of earthquakes in and around Seward Peninsula, western Alaska. Large circles represent historical shocks of magnitude $M_w$ 6.0 or greater and smaller shocks with fault-plane solutions (Tables 1 and 2). Small circles are shocks from University of Alaska Fairbanks earthquake catalog for 1977 through June 1982, when a regional network was operating on the Seward Peninsula; most shocks are in the magnitude interval $M_w$ 1.0 to 4.0. Known (solid) or suspicious (dashed) late Cenozoic faults modified from Plafker and others (1991). Sources of fault-plane solutions: 1958 (No. 23, Table 1), Wickens and Hodgson (1967); 1964 and 1981 (Nos. 21 and 35, Table 2), Biswas and others (1986b); and 1965 (No. 22, Table 2), Sykes and Sbar (1974). Alternative solutions for 1964 and 1981 shocks in Estabrook and others (1988). Fault-plane solution conventions as in Figure 10.

## Earthquake Epicenters in Vicinity of Seward Peninsula, Western Alaska

**Figure 4**

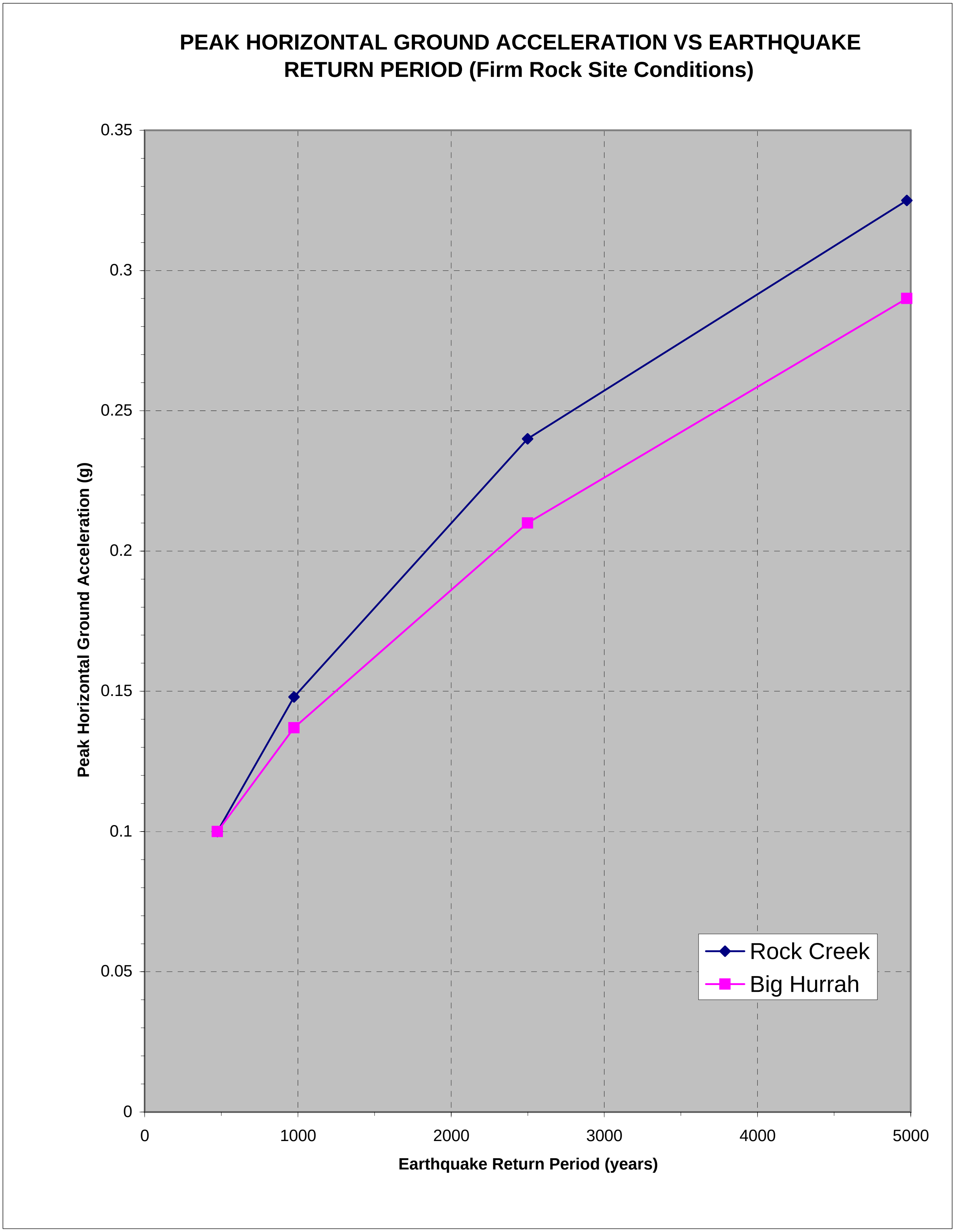

PEAK HORIZONTAL GROUND ACCELERATION VS EARTHQUAKE RETURN PERIOD (Firm Rock Site Conditions)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Peak Horizontal Ground Acceleration (g)
0
1000
2000
3000
4000
5000
Earthquake Return Period (years)
Rock Creek
Big Hurrah

**Figure 5**

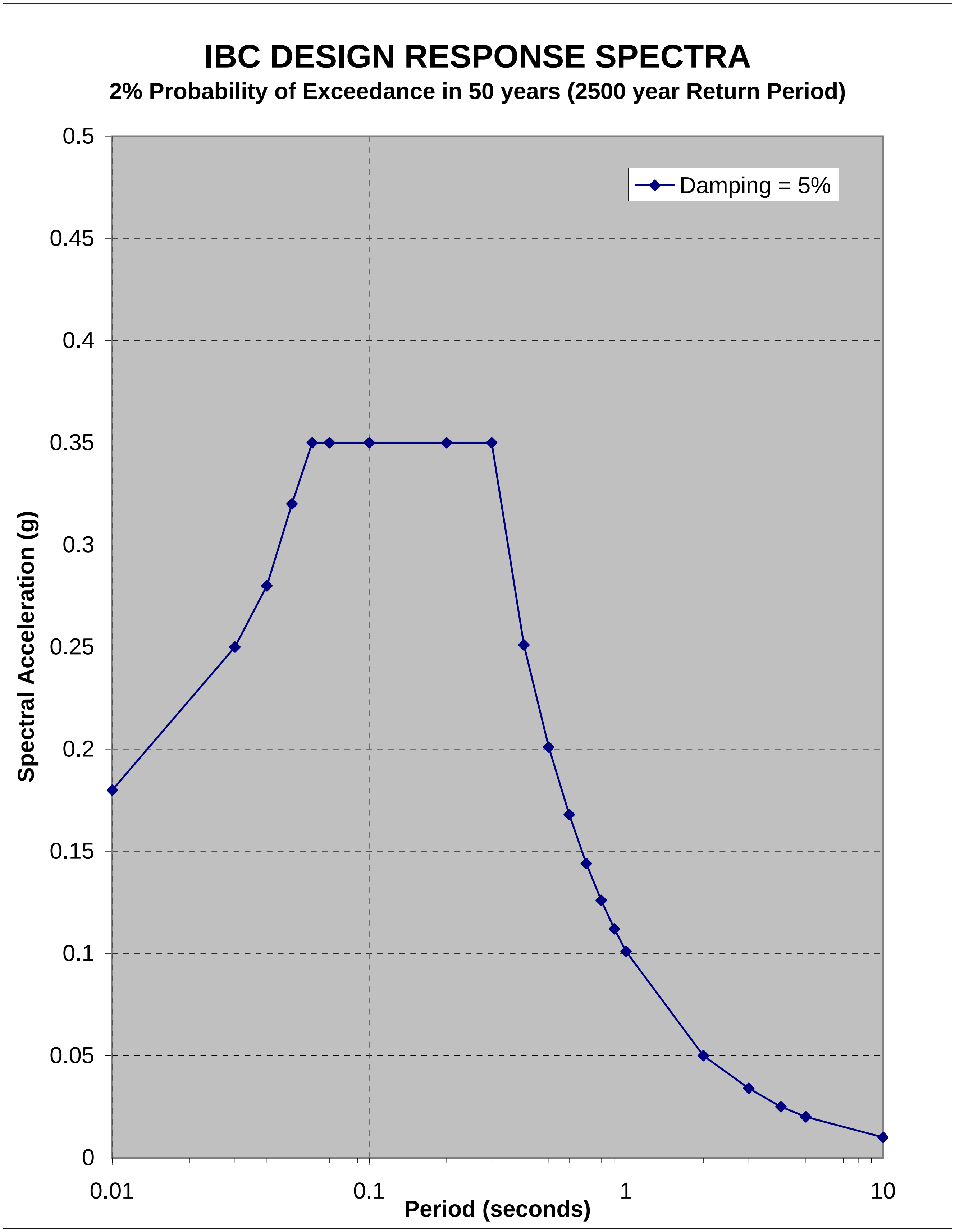

IBC DESIGN RESPONSE SPECTRA
2% Probability of Exceedance in 50 years (2500 year Return Period)
Damping = 5%
Spectral Acceleration (g)
Period (seconds)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.01
0.1
1
10

**Figure 6**

# Historical Earthquake Search

- Distribution by Year
- Distribution by Magnitude
- Distribution by Depth
- Distribution by Distance

HISTORICAL EARTHQUAKE SEARCH FOR ROCK CREEK PROJECT (NOME, ALASKA)
(PERIOD: 1907 - 2004)

Circle Search — Earthquakes: 90
Circle Center Point: Latitude: 64.70 N Longitude: 165.470 W
Radius: 200 km
Catalog Used: PDE & USHIS
Data Selection: Historical & Preliminary; Significant U.S. Earthquakes

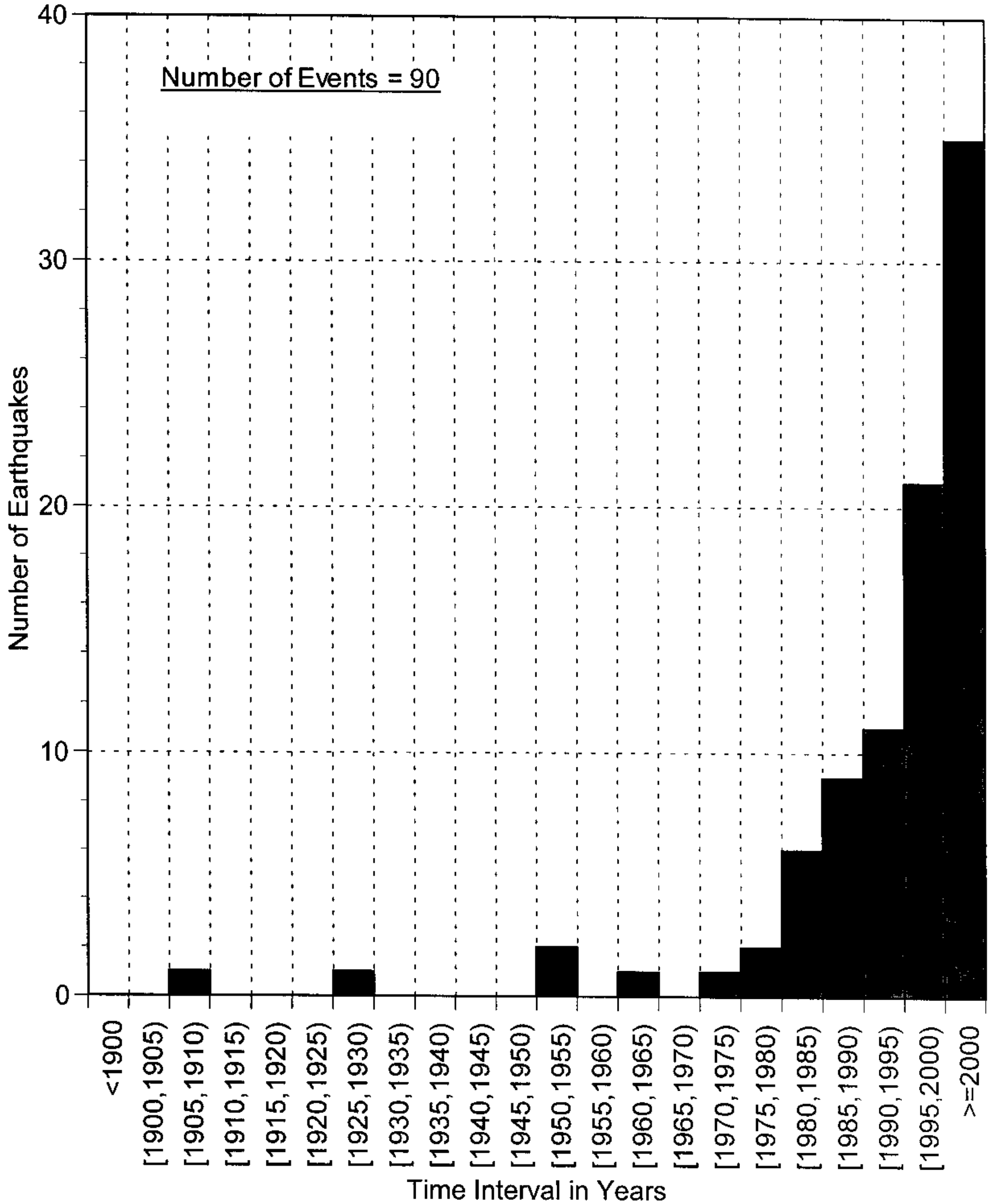
| Catalog | Year | Month | Day | Origin Time | Latitude | Longitude | Depth (km) | Magnitude | | Distance km |
|---|---|---|---|---|---|---|---|---|---|---|
| USHIS | 1907 | 12 | 29 | | 66.00 | -168.00 | | | | 186 |
| USHIS | 1926 | 7 | 14 | 222225 | 66.00 | -163.00 | | 5.60 | Ms GR | 185 |
| USHIS | 1950 | 8 | 26 | 43927 | 65.00 | -162.00 | | 6.50 | UK PAS | 168 |
| USHIS | 1952 | 12 | 28 | 45507 | 65.80 | -167.80 | | | | 164 |
| USHIS | 1964 | 12 | 13 | 3326.9 | 64.88 | -165.57 | 28 | 6.00 | UK PAL | 20 |
| PDE | 1974 | 8 | 11 | 125748.1 | 64.88 | -165.51 | 33 | 4.10 | mb GS | 20 |
| PDE | 1977 | 10 | 27 | 85320.5 | 64.64 | -164.97 | 33 | | | 24 |
| PDE | 1979 | 10 | 24 | 221935.5 | 65.24 | -164.74 | 33 | 4.40 | mb GS | 69 |
| PDE | 1980 | 1 | 26 | 144933.1 | 66.08 | -168.03 | 33 | 4.50 | mb GS | 194 |
| PDE | 1982 | 8 | 7 | 195346.13 | 66.00 | -166.77 | 15 | 4.80 | mb GS | 157 |
| PDE | 1982 | 8 | 15 | 154727.14 | 65.01 | -162.07 | 33 | 4.60 | $M_L$ PMR | 165 |
| PDE | 1983 | 3 | 3 | 182604.94 | 65.14 | -165.63 | 33 | 3.90 | $M_L$ PMR | 50 |
| PDE | 1983 | 11 | 4 | 54120.52 | 65.74 | -167.79 | 33 | 3.70 | $M_L$ PMR | 158 |
| PDE | 1983 | 11 | 4 | 75515.72 | 65.72 | -167.94 | 33 | 4.20 | $M_L$ PMR | 162 |
| PDE | 1985 | 4 | 7 | 100656 | 65.02 | -166.45 | 15 | 4.20 | $M_L$ PMR | 58 |
| PDE | 1985 | 9 | 15 | 82312.24 | 63.33 | -166.15 | 15 | 4.50 | mb GS | 156 |
| PDE | 1986 | 12 | 14 | 121734.96 | 65.70 | -168.83 | 33 | | | 192 |
| PDE | 1987 | 2 | 4 | 1845.56 | 65.04 | -166.80 | 33 | 4.70 | mb GS | 73 |
| PDE | 1987 | 4 | 21 | 123956.92 | 64.83 | -169.40 | 33 | | | 187 |
| PDE | 1988 | 2 | 26 | 33217.49 | 65.69 | -167.79 | 10 | 3.50 | $M_L$ PMR | 154 |
| PDE | 1988 | 9 | 11 | 82900.43 | 65.47 | -167.84 | 33 | 4.60 | $M_L$ PMR | 140 |
| PDE | 1989 | 4 | 1 | 92543.72 | 63.56 | -164.27 | 33 | 4.10 | $M_L$ PMR | 139 |
| PDE | 1989 | 11 | 17 | 224651.67 | 65.09 | -164.71 | 5 | 3.50 | $M_L$ PMR | 56 |
| PDE | 1990 | 11 | 24 | 41604.12 | 65.38 | -165.77 | 10 | 3.90 | $M_L$ PMR | 76 |
| PDE | 1992 | 3 | 21 | 103638.61 | 65.28 | -162.75 | 33 | 3.00 | $M_L$ PMR | 143 |
| PDE | 1992 | 4 | 8 | 10149.84 | 64.97 | -162.93 | 10 | 3.50 | $M_L$ PMR | 124 |
| PDE | 1992 | 8 | 30 | 135113.22 | 64.82 | -165.66 | 18 | 4.80 | $M_L$ AEI | 16 |
| PDE | 1992 | 9 | 14 | 52515.41 | 64.47 | -165.94 | 0 | 3.70 | $M_L$ AEI | 34 |
| PDE | 1992 | 9 | 14 | 83107.01 | 64.67 | -165.79 | 0 | 3.90 | $M_L$ AEI | 15 |
| PDE | 1992 | 9 | 28 | 193422.83 | 63.96 | -162.04 | 0 | 3.60 | $M_L$ AEI | 185 |
| PDE | 1993 | 5 | 8 | 192952.75 | 65.18 | -161.57 | 10 | 3.20 | mb GS | 192 |
| PDE | 1993 | 7 | 31 | 210938.66 | 64.42 | -162.45 | 10 | 4.00 | $M_L$ AEI | 148 |
| PDE | 1993 | 9 | 24 | 170336.85 | 64.20 | -164.41 | 0 | 3.90 | $M_L$ PMR | 75 |
| PDE | 1994 | 4 | 21 | 10246.08 | 64.81 | -164.82 | 10 | 4.20 | $M_L$ PMR | 33 |
| PDE | 1995 | 5 | 18 | 180421.24 | 64.75 | -162.31 | 25 | 3.80 | $M_L$ PMR | 150 |
| PDE | 1995 | 12 | 1 | 82114.81 | 65.11 | -162.43 | 10 | 3.60 | $M_L$ PMR | 150 |
| PDE | 1996 | 3 | 16 | 164923.45 | 65.48 | -168.38 | 10 | 3.90 | mb GS | 162 |
| PDE | 1996 | 5 | 25 | 70826.69 | 64.51 | -162.85 | 10 | 3.80 | mb GS | 127 |
| PDE | 1996 | 5 | 25 | 132340.73 | 64.56 | -163.71 | 20 | 4.00 | $M_L$ AEI | 85 |
| PDE | 1996 | 8 | 27 | 13303.78 | 65.20 | -165.44 | 10 | 4.40 | mb GS | 56 |
| PDE | 1996 | 10 | 18 | 234202.05 | 64.42 | -165.09 | 10 | | | 35 |
| PDE | 1997 | 2 | 23 | 231120.21 | 65.29 | -167.08 | 10 | 3.70 | $M_L$ PMR | 101 |
| PDE | 1997 | 3 | 2 | 203915.74 | 64.27 | -166.54 | 10 | 3.70 | $M_L$ PMR | 70 |
| PDE | 1997 | 4 | 15 | 45847.47 | 65.26 | -165.96 | 10 | | | 66 |
| PDE | 1997 | 5 | 21 | 225955.28 | 65.39 | -166.98 | 5 | 4.70 | $M_L$ PMR | 104 |
| PDE | 1997 | 5 | 22 | 142708.42 | 65.38 | -167.12 | 5 | 4.40 | $M_L$ PMR | 108 |
| PDE | 1997 | 5 | 31 | 1905.94 | 65.34 | -166.95 | 10 | 3.70 | $M_L$ PMR | 99 |
| PDE | 1997 | 6 | 14 | 165325.6 | 65.19 | -163.57 | 33 | | | 105 |

HISTORICAL EARTHQUAKE SEARCH FOR ROCK CREEK PROJECT (NOME, ALASKA)
(PERIOD: 1907 - 2004)

Circle Search Earthquakes: 90
Circle Center Point: Latitude: 64.70 N Longitude: 165.470 W
Radius: 200 km
Catalog Used: PDE & USHIS
Data Selection: Historical & Preliminary; Significant U.S. Earthquakes

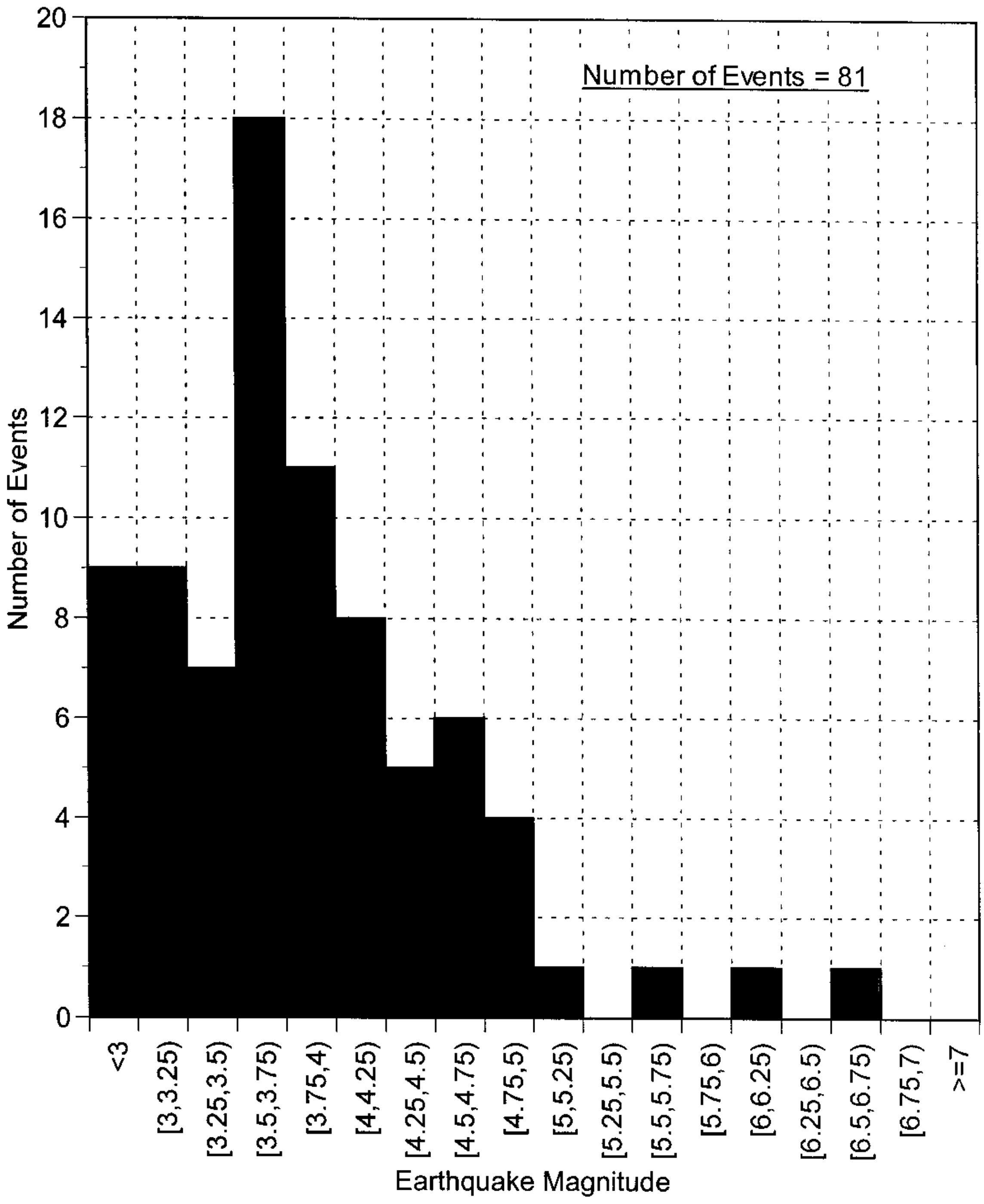
| Catalog | Year | Month | Day | Origin Time | Latitude | Longitude | Depth (km) | Magnitude | | Distance km |
|---|---|---|---|---|---|---|---|---|---|---|
| PDE | 1997 | 6 | 15 | 203716.28 | 64.95 | -163.97 | 10 | 3.20 | $M_L$ PMR | 76 |
| PDE | 1997 | 7 | 14 | 215556.77 | 64.96 | -164.72 | 10 | 4.40 | $M_L$ AEI | 45 |
| PDE | 1997 | 11 | 21 | 14105.05 | 64.99 | -168.70 | 10 | 3.60 | mb GS | 156 |
| PDE | 1997 | 12 | 15 | 142233.12 | 64.56 | -162.67 | 25 | 4.80 | $M_L$ AEI | 134 |
| PDE | 1998 | 5 | 18 | 184156.25 | 64.46 | -162.59 | 0 | 2.90 | $M_L$ AEI | 140 |
| PDE | 1998 | 7 | 21 | 105942.68 | 64.88 | -162.32 | 10 | 4.00 | $M_L$ PMR | 151 |
| PDE | 1998 | 8 | 23 | 131312.25 | 65.42 | -163.90 | 10 | 3.40 | mb GS | 109 |
| PDE | 1998 | 11 | 5 | 101241.39 | 63.88 | -165.68 | 10 | 3.70 | $M_L$ PMR | 91 |
| PDE | 2000 | 4 | 19 | 112042.71 | 65.09 | -164.85 | 10 | 3.30 | mb GS | 52 |
| PDE | 2000 | 4 | 30 | 80007.55 | 64.34 | -162.68 | 10 | 3.50 | $M_L$ PMR | 139 |
| PDE | 2000 | 6 | 18 | 153713.54 | 65.32 | -164.08 | 10 | 5.10 | $M_L$ PMR | 95 |
| PDE | 2001 | 4 | 3 | 4853.16 | 65.59 | -162.98 | 30 | 3.60 | $M_L$ AEI | 153 |
| PDE | 2001 | 4 | 30 | 123602.8 | 64.51 | -163.83 | 8 | 4.80 | $M_L$ AEI | 81 |
| PDE | 2001 | 4 | 30 | 134021.69 | 64.42 | -163.69 | 10 | 3.20 | $M_L$ AEI | 91 |
| PDE | 2001 | 6 | 10 | 120003.11 | 64.30 | -163.92 | 10 | 3.40 | $M_L$ PMR | 86 |
| PDE | 2001 | 7 | 2 | 85718.01 | 63.93 | -164.79 | 6 | 3.40 | $M_L$ PMR | 92 |
| PDE | 2002 | 4 | 16 | 55848.95 | 65.94 | -166.86 | 10 | 3.60 | mb GS | 152 |
| PDE | 2002 | 8 | 5 | 204751 | 65.43 | -164.26 | 10 | | | 99 |
| PDE | 2002 | 8 | 13 | 184729.92 | 64.00 | -164.42 | 6 | 3.70 | $M_L$ AEI | 92 |
| PDE | 2002 | 8 | 13 | 203904.82 | 63.96 | -164.46 | 0 | 3.50 | $M_L$ PMR | 95 |
| PDE | 2002 | 12 | 22 | 70303.51 | 65.39 | -162.12 | 10 | 3.90 | $M_L$ PMR | 175 |
| PDE | 2002 | 12 | 29 | 215944.41 | 65.38 | -162.16 | 10 | 3.90 | $M_L$ PMR | 173 |
| PDE | 2003 | 2 | 4 | 224957.16 | 63.78 | -165.77 | 33 | 3.90 | $M_L$ PMR | 103 |
| PDE | 2003 | 9 | 21 | 31144.77 | 65.01 | -161.80 | 19 | 2.80 | $M_L$ AEIC | 177 |
| PDE | 2003 | 9 | 21 | 31239.14 | 65.27 | -162.23 | 1 | 3.00 | $M_L$ AEI | 165 |
| PDE | 2003 | 10 | 22 | 1131.45 | 65.45 | -167.45 | 9 | 4.40 | mb GS | 125 |
| PDE | 2003 | 10 | 22 | 22245.36 | 65.52 | -167.57 | 21 | 3.80 | $M_L$ AEIC | 134 |
| PDE | 2003 | 10 | 22 | 41700.44 | 65.43 | -167.48 | 8 | 3.70 | $M_L$ AEIC | 124 |
| PDE- | W 2004 | 2 | 9 | 182348.31 | 64.01 | -162.05 | 14 | 3.20 | $M_L$ AEIC | 182 |
| PDE- | W 2004 | 2 | 19 | 112457.45 | 64.00 | -162.11 | 35 | 3.00 | $M_L$ AEIC | 180 |
| PDE- | W 2004 | 3 | 22 | 125724.6 | 64.36 | -162.60 | 3 | 2.70 | $M_L$ AEIC | 143 |
| PDE- | W 2004 | 3 | 22 | 165136.3 | 65.31 | -166.98 | 6 | 2.70 | $M_L$ AEIC | 98 |
| PDE- | W 2004 | 3 | 30 | 55022.29 | 63.71 | -168.39 | 10 | 3.30 | $M_L$ AEIC | 179 |
| PDE- | W 2004 | 4 | 2 | 13735.15 | 65.51 | -167.48 | 18 | 2.70 | $M_L$ AEIC | 131 |
| PDE- | W 2004 | 4 | 2 | 44047.15 | 65.48 | -167.44 | 14 | 3.10 | $M_L$ AEIC | 127 |
| PDE- | W 2004 | 5 | 31 | 133154.77 | 65.92 | -162.49 | 10 | 2.80 | $M_L$ AEIC | 194 |
| PDE- | W 2004 | 6 | 13 | 10252.9 | 65.14 | -163.09 | 11 | 3.20 | $M_L$ AEIC | 122 |
| PDE- | W 2004 | 7 | 4 | 230401.74 | 65.24 | -162.33 | 3 | 2.60 | $M_L$ AEIC | 159 |
| PDE- | W 2004 | 7 | 5 | 84730.02 | 65.82 | -163.52 | 10 | 2.80 | $M_L$ AEIC | 154 |
| PDE- | W 2004 | 7 | 9 | 143711.05 | 64.36 | -161.51 | 10 | 2.70 | $M_L$ AEIC | 193 |
| PDE- | W 2004 | 7 | 14 | 160842.31 | 65.86 | -164.45 | 4 | 3.30 | $M_L$ AEIC | 137 |
| PDE- | Q 2004 | 7 | 20 | 215706.26 | 65.81 | -164.43 | 14 | 3.40 | $M_L$ AEIC | 133 |

Notes: $M_l$ = Local earthquake magnitude; $M_w$ = Moment magnitude; $m_b$ = Body wave magnitude
A depth of 33 km corresponds to a default value for a shallow event



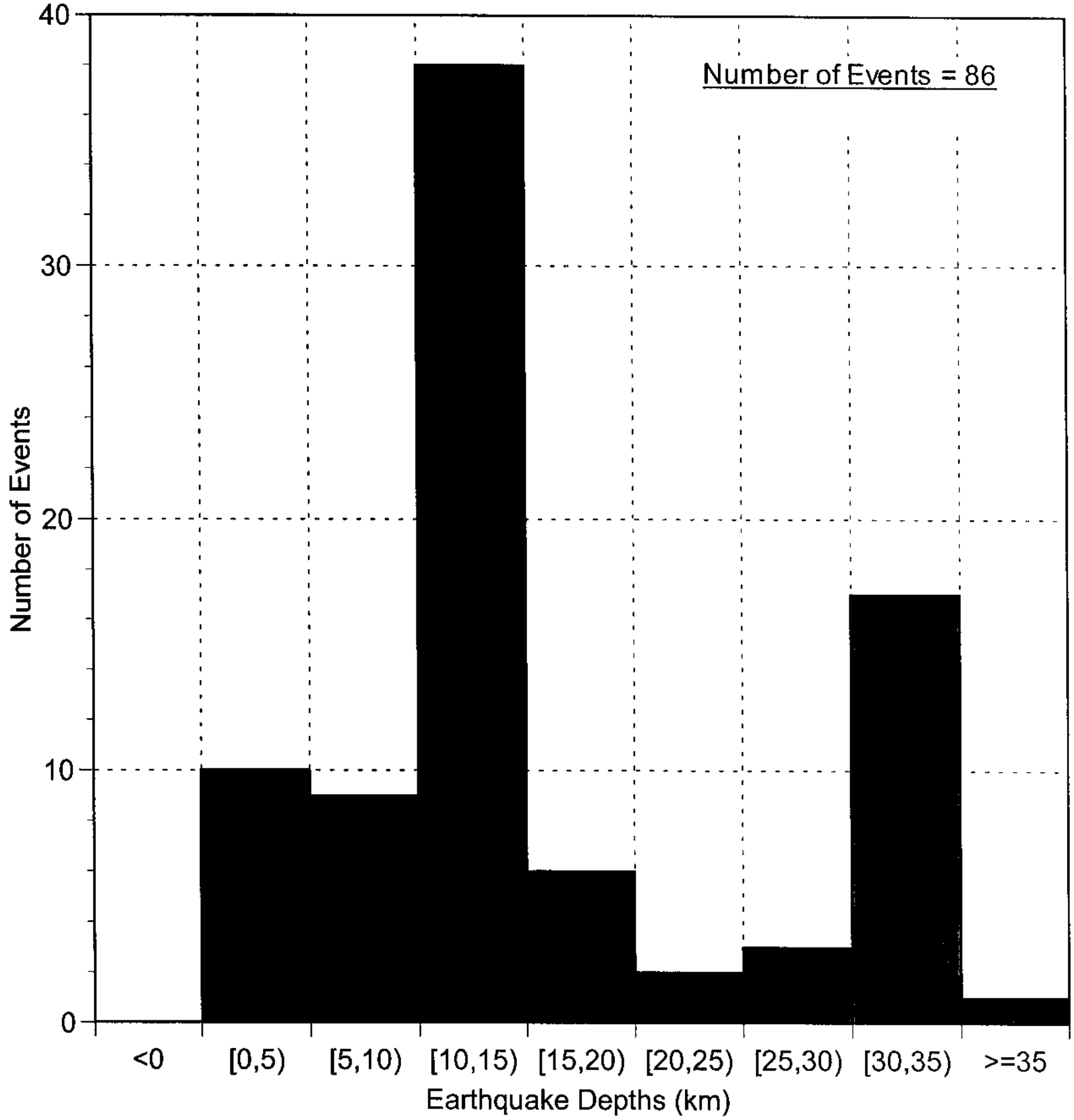

**ROCK CREEK PROJECT**
**DISTRIBUTION OF EARTHQUAKES OVER TIME**
**EARTHQUAKES WITHIN A 200 KM RADIUS FROM SITE**
**HISTORICAL SEISMICITY (1907 - 2004)**

Figure A-1



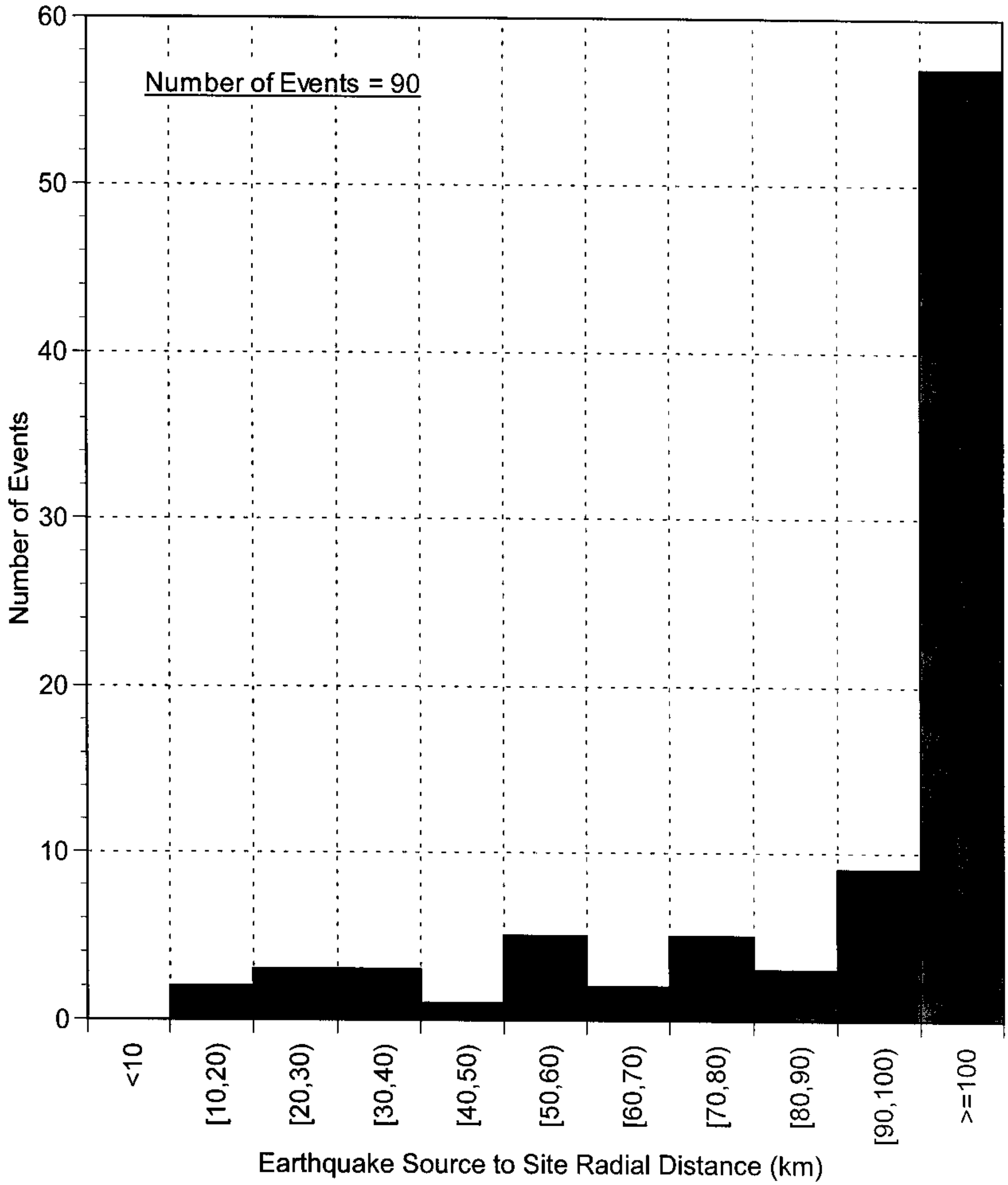

**ROCK CREEK PROJECT**
**DISTRIBUTION OF EARTHQUAKE MAGNITUDES**
**EARTHQUAKES WITHIN A 200 KM RADIUS FROM SITE**
**HISTORICAL SEISMICITY (1907 - 2004)**

FigureA- 2




**ROCK CREEK PROJECT**
**DISTRIBUTION OF EARTHQUAKE DEPTHS**
**EARTHQUAKES WITHIN A 200 KM RADIUS FROM SITE**
**HISTORICAL SEISMICITY (1907 - 2004)**

Figure A-3




**ROCK CREEK PROJECT**
**DISTRIBUTION OF EARTHQUAKE RADIAL DISTANCE**
**EARTHQUAKES WITHIN A 200 KM RADIUS FROM SITE**
**HISTORICAL SEISMICITY (1907 - 2004)**

FigureA- 4