# pebble project

## BACKGROUNDER

## ASSESSING AND MANAGING SEISMIC RISK

The Pebble Project in the Bristol Bay region of southwest Alaska is one of the most important concentrations of copper, gold, silver and molybdenum in the world. Development of a modern mine will generate thousands of highly skilled and well-paid jobs, much-needed community infrastructure, significant capital investment and business opportunities for the region and the state over many decades.

Northern Dynasty Mines (NDM) is conducting a broad range of technical and environmental studies to support the development of a comprehensive plan for the Pebble Project. This plan will then form the basis for permit applications, which NDM expects to submit in late 2008 or 2009. These applications will be subject to an exhaustive regulatory review process involving 11 state and federal agencies and the citizens of Alaska. The collected data will also support an Environmental Impact Statement (EIS) and applications for more than 60 state and federal permits. The combined review and permitting process is expected to take at least three years to complete.

The Bristol Bay region is also known for its fisheries, abundant wildlife and scenic wilderness. Some people have asked if the proposed Pebble mine will place these natural resources at risk. Tailings management, seismic risk, and the protection of downstream fisheries and waterways have emerged as core concerns.

The question has been asked: *How can NDM assure Alaskans that an earthquake will not damage Pebble Project facilities, particularly its tailings embankments, given that Alaska is the most earthquake-prone state in the union and one of the most seismically active regions in the world?*

## Assessing Seismic Risk

Alaska's seismic-risk status is shared by other countries within the Circum-Pacific Seismic Belt, otherwise known as the **"Pacific Ring of Fire."** Extending from Chile along the western coasts of North and South America, including Alaska and the Aleutians, to Japan, the Philippines, Indonesia, the South Pacific Islands, and New Zealand, the Pacific Ring of Fire is also famous for its world-class mineral deposits. It is no coincidence that Chile, the United States, Indonesia, and Peru lead the world in copper production.


*The "Pacific Ring of Fire" is an extensive zone of seismic and volcanic activity encircling the basin of the Pacific Ocean.*

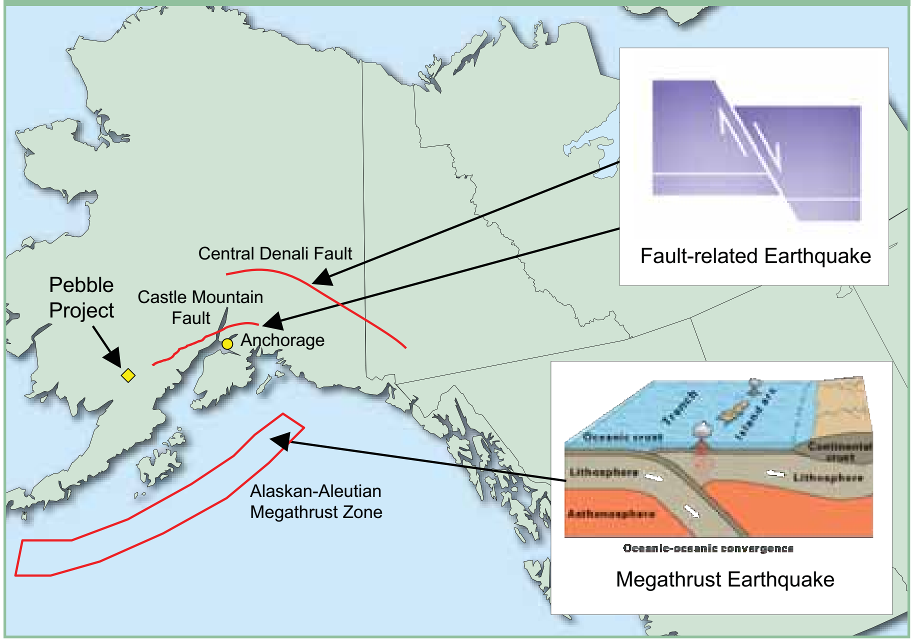
Assessing and managing seismic risk is a scientific process undertaken by seismologists, engineering firms, government agencies and resource developers in high seismic-risk zones around the world. One of the first steps in this process is to determine the potential for various types of earthquakes to occur in a particular area of interest. Earthquakes occur when minute movements within rock formations in the earth's crust cause stresses to build up along potential planes of weakness. As stresses build up over time, slippage occurs along these planes of weakness, and this sudden movement creates an earthquake.

Two different kinds of earthquakes must be assessed, megathrust earthquakes and fault-related earthquakes.

- **Megathrust earthquakes** occur when massive continental or oceanic plates collide or slide past one another. They are typically the most severe type of earthquake, whose intense seismic energy can also trigger aftershocks and tsunamis.

- Earthquakes can also occur away from plate margins, along a fault, which is a fracture or zone of fractures within the bedrock that forms the earth's crust. **Fault-related earthquakes** occur when bedrock on one side of the fault slips relative to the other. Fault-related earthquakes can cause significant damage in a localized area, but are typically of lower magnitude and shorter duration than megathrust earthquakes. This is because crustal faults are generally smaller in scale than the line of contact along continental or oceanic plates where megathrust earthquakes occur.

SEISMIC SOURCE ZONES NEAR THE PEBBLE PROJECT




## Seismic Zones in Alaska

**Seismic source zones** in Alaska are well known. Seismic activity is highest along portions of the south coast, where megathrust earthquakes are generated by the Pacific Plate being pushed under the North American Plate. This seismic source region, known as the **Alaskan-Aleutian megathrust zone,** has triggered some of the largest earthquakes ever recorded, including the Prince William Sound earthquake of 1964. This mega-thrust earthquake registered 9.2 on the Richter Scale, a method used worldwide to characterize seismic energy released by earthquakes.

Several known faults have also generated large earthquakes in Alaska over the past century. A magnitude 7.9 earthquake occurred along the **Denali Fault** in 2002 while a magnitude 7.0 earthquake occurred along the **Castle Mountain Fault** in 1933.

Seismologists can reliably calculate the **maximum possible magnitude earthquake** for each seismic zone based on its physical characteristics. The Alaskan-Aleutian megathrust zone has the highest maximum magnitude at 9.2 because of its tremendous size. The Denali Fault has a maximum magnitude of 8.0, while the Castle Mountain Fault, which is slightly smaller, has a lower maximum magnitude of 7.8.

## Peak Ground Acceleration

Although the magnitude and duration of earthquakes are important factors in determining their potential to damage man-made structures, another important factor is **"peak ground acceleration" (PGA)**. PGA is a measure of how hard the earth shakes at a specific site, and is influenced by that site's proximity to the epicenter of an earthquake and the nature and composition of the surrounding ground and bedrock. PGA is stated as a fraction of the acceleration due to gravity.

Most people understand that the further they are from an earthquake, the less likely they are to feel the ground shaking. By determining the PGA associated with different types of earthquakes of different magnitudes and at different distances from a potential development site, engineers can use this understanding as a key project design parameter.

Once engineers determine the PGA that can occur at a development site, they can reliably design structures and facilities to withstand all possible seismic events. This is certainly the case for engineers designing mine facilities such as tailings embankments. The European Commission (Directorate-General Environment) confirmed in 2001 that **"No embankment dam, designed and built to modern standards, has failed as a result of earthquake shaking…"**

## Pebble Project

The two most prominent seismic sources associated with the Pebble Project are the Alaskan-Aleutian megathrust zone and the Denali Fault. Both are situated about 125 miles from the project site. Although smaller and possessing less seismic potential, the Castle Mountain Fault in the Cook Inlet Basin is the closest seismic source to the Pebble site at 19 miles. This well-known fault comes to surface near Anchorage and has been mapped and defined along its entire length by government geologists.

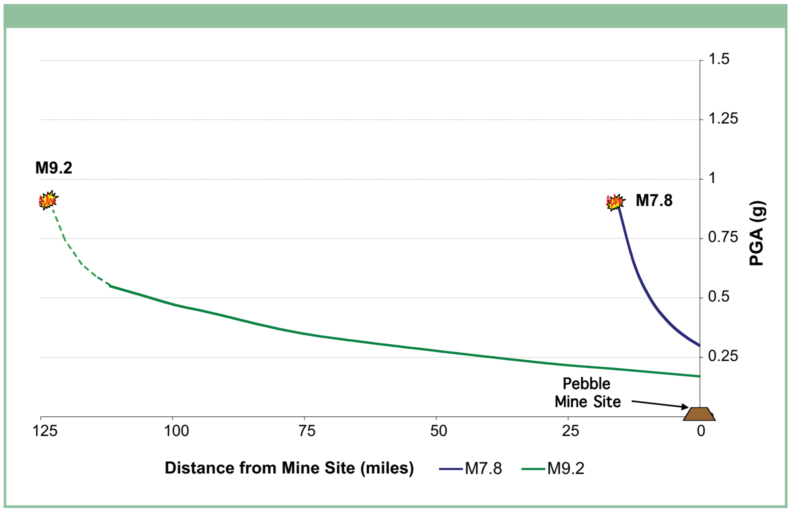
Studies and investigations by NDM and its consultants have focused on identifying the maximum magnitude earthquake that each of these seismic zones can create, and then translating that information to determine potential PGA at the Pebble site. Based on these calculations, a maximum possible magnitude 7.8 earthquake along the Castle Mountain Fault will generate the highest PGA of 0.3g (i.e 0.3 times the acceleration due to gravity) at the project site.

The other seismic sources have potential to generate higher magnitude earthquakes, but PGA at Pebble would be lower because they are more distant from the project site than the Castle Mountain Fault. The Alaskan-Aleutian megathrust zone has potential to generate a magnitude 9.2

earthquake, which would result in a maximum PGA of 0.17g at Pebble. However, the duration of shaking associated with a magnitude 9.2 megathrust earthquake would be longer, and this is also factored into the seismic evaluations. The Denali Fault has a lower seismic risk, with a maximum PGA of 0.08g at the site.

NDM will design and build its facilities to withstand the ground motions resulting from any and all of these seismic events. In fact, tailings facilities at Pebble will be engineered to withstand seismic events of such magnitude that they could never actually occur.

The work of Pebble engineers is reinforced by the United States Geological Survey (USGS), which prepares seismic hazard maps for Alaska and other states. These maps indicate that the maximum PGA that could occur at the Pebble site due to any extreme earthquake within a 2,500-year period is 0.25g. Alaskan regulations require that this maximum seismic event be considered in the design of Pebble's facilities. By designing its embankments to withstand an even higher PGA (0.3g), the company is adding another factor of safety to the project.




*Peak Ground Acceleration (g) for a M9.2 megathrust and M7.8 shallow crustal earthquake versus distance from the Pebble Project.*

NDM intends to reach beyond Alaskan regulatory requirements in other ways to address concerns raised by local stakeholders. In addition to designing its facilities to withstand a higher PGA than the USGS predicts would occur at Pebble, NDM will design and construct its tailings embankments to exceed the guidelines of the Alaska Dam Safety Program. An engineering assessment based on these guidelines suggests a Class II (Significant) Hazard Potential Classification is appropriate for Pebble, however NDM plans to incorporate more stringent design criteria for flood and earthquake events consistent with a Class I (High) classification.

## Tailings Management in Earthquake Zones

Safe and stable tailings facilities can be built at the Pebble site using modern engineering techniques and construction methods specifically designed for earthquake-prone areas.

| POTENTIAL EARTHQUAKE SOURCE | MAXIMUM MAGNITUDE (M) | EPICENTRAL DISTANCE (MILES) | PEAK GROUND ACCELERATION (G) |
|---|---|---|---|
| Alaskan-Aleutian Megathrust Zone | 9.2 | 125 | 0.17 |
| Castle Mountain Fault | 7.8 | 18 | 0.30 |
| Denali Fault - Central | 8.0 | 125 | 0.08 |

*Seismic Risk At Pebble*

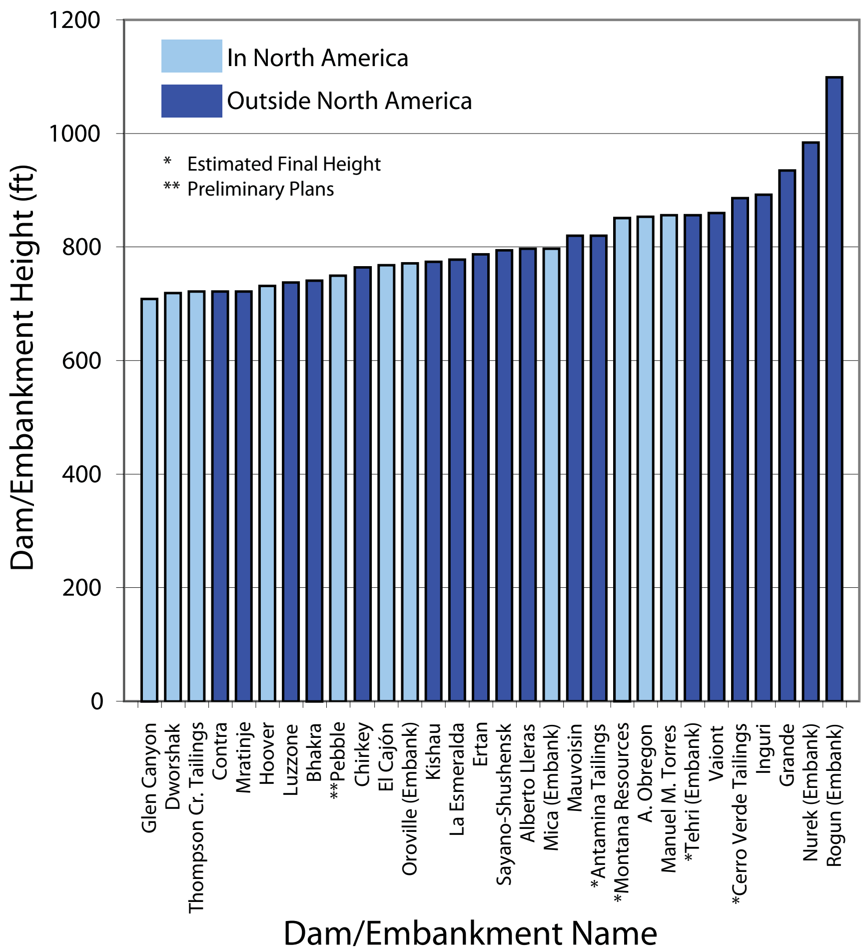
Chile is a seismically active region, and in 1960 experienced a magnitude 9.5 earthquake, the highest ever recorded by modern instruments. Despite its seismic-risk status, this mineral-rich nation has hundreds of operating copper mines – including some of the largest in the world.

Neighboring Peru is also within the Pacific Ring of Fire, yet has some of the world's highest embankments for large-scale operating mines. Tailings facilities at the Cerro Verde and Antamina mines will eventually reach heights of 886 feet and 820 feet, respectively. These modern tailings facilities in Peru are designed and built to withstand intense, high-magnitude earthquakes. The ultimate height of their embankments will be much greater than what is proposed for the Pebble Project.

Over the past century, hundreds of dams and tailings embankments within the Pacific Ring of Fire have endured thousands of seismic events. A total of only 18 tailings embankments have failed to withstand earthquake-related events over this period of time, but all of them employed construction methods that are not acceptable today.

Sixteen of the 18 tailings facilities that have failed due to seismic events employed upstream construction methods, which are potentially unstable due to seismic shaking. Chile and Peru, both major copper-producing nations, have banned the use of this construction technique in favor of more stable downstream or combined downstream-centerline

**HIGH DAMS AND TAILINGS EMBANKMENTS**




*No tailings embankment designed and built to modern standards has failed as a result of a seismic event.*

construction. These stable construction methods will be used for the Pebble Project.

The other two tailings embankments failed more than 40 years ago and were built using outmoded engineering and construction practices. Through modern advances in engineering and construction, it is now possible to design and build permanent tailings facilities that are able to withstand severe earthquakes, floods, and other catastrophic events.

## Tailings Management at Pebble

NDM and its consultants have conducted a broad range of studies and investigations to determine the best design options for a proposed tailings facility at the Pebble Project. Preliminary design proposals were submitted to the Alaska Department of Natural Resources in 2006 as part of an application to secure the future right to use water in three watersheds surrounding the project. The final project proposal to be submitted for government and public review in the years ahead will provide specific information about the location and ultimate size of the tailings facilities at Pebble.

Upstream construction techniques of the type that have generated most of the past failures will not be used, reflecting industry practice elsewhere in the world. Instead, NDM will rely on stable downstream or combined downstream-centerline construction methods.

NDM continues to refine its plans for proposed tailings impoundments at Pebble, but each option will include embankments designed to withstand any seismic event that could conceivably occur in the region. Sites will be selected based on topographic features and natural barriers that support the design concept and provide multiple layers of environmental protection. The proposed facilities will retain tailings solids that over time will become consolidated and form a dense barrier at the base of the embankments for additional stability. The tailings solids will be covered by a shallow layer of water. The design will incorporate seepage control and collection measures to ensure no impairment of water quality downstream of the project. Seepage water will be recovered and pumped back into the impoundment for re-use as process water in the mill.

NDM anticipates that good tailings water quality will be achieved in the tailings pond. Experience at other similar copper mines suggests that healthy fish populations can be supported in these waters, which are also safe for consumption by people and wildlife. Any water released to the downstream environment during operations or post-mine closure will meet both aquatic life and drinking water standards.

NDM can assure Alaskans that a properly designed and constructed tailings facility at the Pebble Project will protect downstream water quality and important fisheries. The goal is not to build a mine at the expense of the environment or the fisheries, but rather one that will complement existing natural resources and contribute to the long-term sustainability and economic diversity of the region and state.