Northern Dynasty Mines' Pebble project: a strategic resource for Alaska

In September 2005, Northern Dynasty Mines announced the discovery of a new, high-grade deposit at its Pebble project in southwest Alaska. The product of insightful geological investigation, Pebble East, as it is now known, is quickly growing into one of the most significant copper deposits in the world. Preliminary analysis shows it could reduce the U.S. copper supply deficit by a third.

The new deposit has also altered Northern Dynasty's view of how Pebble should be developed. This article describes the Pebble project as it is currently understood and outlines the work planned for the next several years.

The Pebble project in southwest Alaska has the potential to reduce the United States' copper deficit by a third. The use of helicopters and immediate land reclamation are part of the environmental plans at the project.

Project location

The Pebble project is situated about 320 km (200 miles) southwest of Anchorage and 112 km (70 miles) from tidewater at Cook Inlet, within rolling terrain at an elevation of about 305 m (1,000 ft) (Figs. 1 and 2). The moderate terrain will mitigate many construction issues. The proximity to tidewater and the "Great Circle Route" from North America to Asia will reduce transportation costs.

The climate of the Pebble project area is classified as maritime continental. Based on long-term temperature data from Iliamna, 27 km (17 miles) away, the average annual temperature at the project site is estimated to be 0.3° C (31.4° F), with average monthly temperatures ranging from 11.2° C (52.1° F) in July to -10.7° C (12.7° F) in December. Maximum and minimum recorded temperatures are 33° C (91° F) and -52.6° C (-47° F). Annual precipitation is 914 mm (36 in.), with most of it falling as rain from June through September.

The project is located within a 396-km^2 (153-sq mile) claim block on state-owned lands. In 2005, the state of Alaska completed a major land-use planning process for southwest Alaska, resulting in the "Bristol Bay Area Plan." This comprehensive planning document identifies five land parcels totaling 2.7 percent of the study area as containing "significant mineral potential" – including the lands surrounding Pebble.

The stated management intent for these lands is to accommodate mineral exploration and development. No objections were registered to this classification during the public land-use planning process.

Project history

What is now known as the Pebble West deposit was originally discovered by geologists from Cominco American (now Teck Cominco) in 1988. By the time Northern Dynasty acquired rights to the project in 2001, Cominco had outlined approximately 1 Gt (1.1 billion st) of moderate grade, openpitable resource. In the midst of an industry downturn, Northern Dynasty had seized an opportunity to acquire a large mineral deposit on terms that would be impossible to duplicate today.

Northern Dynasty began its field work in 2002, initially evaluating a number of induced polarization anomalies on what the U.S. Geological Survey had identified as the largest sulfide system in the world. Several discoveries were made, and in 2003 the company refocused its efforts on Pebble West. Existing core was re-logged and the deposit geology reinterpreted. This work identified two opportunities for Pebble West – the possibility of expanding

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the known higher grade core of the deposit and geological indicators that were evidence of even higher grades to the east.

Drilling in 2003 and 2004 was successful on both fronts. By the end of 2004, sufficient resources (Table 1) had been identified for Northern Dynasty to commission a feasibility study for a large, openpit project.

Although this study commenced in 2005, Northern Dynasty's geologists were convinced that more discoveries were possible. The 2005 drill program proved this hypothesis correct by discovering a deeper, richer deposit, which was subsequently named Pebble East. Drilling continued through 2006, defining the deposit resource (Table 2). Pebble East remains open to the north and south with possible extensions to the west. Drilling continues at the site.

At the 2007 annual convention of the Prospectors and Developers Association of Canada, the Northern Dynasty exploration team received the Thayer Lindsley Award as project of the year in recognition of this achievement.

Pebble East implications

Northern Dynasty drilled 12 holes in what is now known as Pebble East by the conclusion of its 2005 drill season. The results of those few holes were significant enough to dramatically alter the development timeline for the entire project.

Northern Dynasty immediately put its feasibility study for Pebble West on hold. The company used the 2006 drill season to explore the extent of the new deposit and assess its implications for mine planning. This drilling continues in 2007. The company's current expectation is that mine planning for Pebble East and West will be incorporated into an "integrated development plan" (IDP) in 2008.

Pebble West is a substantial but moderate grade deposit. Engineering plans developed in 2005 incorporated a large plant to take advantage of economies of scale. Mineral grades at Pebble East are significantly higher than those at Pebble West and, in fact, are among the highest in the world for known porphyry copper-gold deposits. These higher grades would allow different development scenarios – including a smaller project that could be expanded after startup, as well as the large throughput alternative envisioned in 2005.

Although higher grade, Pebble East is also significantly deeper than Pebble West – with mineralization between 460 to 610 m (1,500 to 2,000 ft) below the surface. This means that underground mining methods may be more viable. To properly assess an underground mine, Northern Dynasty has begun collecting additional baseline information and other data necessary for underground mine planning.

As these data become available and the deposit is more precisely defined, Northern Dynasty consultants will consider how Pebble East development will best fit with Pebble West development, and how to adapt the

Table 1

Pebble West deposit. Measured plus indicated mineral resources.

Cutoff	Size	Grade				Contained metal		
CuEQ %	million tonnes	Copper %	Gold g/t	Molybdenum %	CuEQ[2] %	Copper B lb	Gold M oz	Molybdenum M lb
0.30	3,026	0.28	0.32	0.015	0.56	18.8	31.3	993
0.40	2,413	0.31	0.35	0.016	0.61	16.5	27.0	855
0.50	1,628	0.35	0.39	0.018	0.69	12.7	20.5	629
0.60	970	0.41	0.45	0.020	0.78	8.7	13.8	420
0.70	569	0.46	0.50	0.021	0.88	5.8	9.1	265

Inferred mineral resources.

Cutoff	Size	Grade				Contained metal		
CuEQ %	million tonnes	Copper %	Gold g/t	Molybdenum %	CuEQ[2] %	Copper B lb	Gold M oz	Molybdenum M lb
0.30	1,130	0.24	0.30	0.014	0.50	5.9	10.8	361
0.40	756	0.27	0.34	0.017	0.57	4.5	8.2	278
0.50	417	0.31	0.42	0.018	0.67	2.9	5.6	168
0.60	226	0.36	0.49	0.020	0.77	1.8	3.6	101
0.70	143	0.40	0.56	0.021	0.85	1.3	2.6	62

Note 1 — By prescribed definition, "Mineral Resources" do not have demonstrated economic viability. An Inferred Mineral Resource is that part of a mineral resource for which quantity and grade can be estimated on the basis of geological evidence and limited sampling and reasonably assumed, but not verified, geological and grade continuity. **Note 2 —** Copper equivalent calculations use metal prices of US$1/lb for copper, US$400/oz for gold and US$6/lb for molybdenum. Copper equivalent has not been adjusted for metallurgical recoveries. Adjustment factors to account for differences in relative metallurgical recoveries for copper, gold and molybdenum will depend upon the completion of definitive metallurgical testing. CuEQ = Cu percent + (Au g/t x 12.86/22.05) + (Mo percent x 132.28/22.05). **Note 3 —** A 0.3 percent CuEQ cutoff is considered to be comparable to that used for porphyry deposit openpit mining operations in the Americas. For bulk underground mining, higher cutoffs, such as 0.6 percent CuEQ, are typically used. All cutoffs are subject to a feasibility study. **Note 4 —** The March 2005 resource estimates for Pebble West were prepared by David Rennie, physical engineer, of Roscoe Postle Associates, and R. Mohan Schrivastava, physical geologist, of FSS Canada Consultants.

project infrastructure. Given the environmental sensitivities of the project area, the nature and scale of a large underground mine must be well understood before planning can proceed.

Plans for disposal of tailings must also be refined for the larger overall deposit. An analysis of alternatives has commenced, including possible additional tailings sites, methods of construction, construction materials and material disposal techniques.

FIGURE 1

Location map.

Pebble East drilling program

The primary objective of Northern Dynasty's 2006 drilling program was to define the extent of the Pebble East deposit by drilling it at approximately 305 m (1,000 ft) centers.

Approximately 22,555 m (74,000 ft) of core drilling was completed in 2006, expanding the resource estimate to approximately 3.4 Gt (3.7 billion st).

The 2006 drilling program had to overcome a number of challenges, the first of which was initially encountered in 2005. Until that time, core holes had been between 305 and 610 m (1,000 and 2,000 ft) deep. However, the bottom of Pebble East is 1,220 to 1,525 m (4,000 to 5,000 ft) or more below the surface. Virtually all of the holes drilled at Pebble East in 2005 stopped in mineralized material simply because the rigs could not drill any deeper. Drill rigs were upgraded in 2006 to allow N-size core to be drilled to a depth of 1,830 m (6,000 ft).

Surging metals markets have led to heightened mineral exploration activity around the world and limited the availability of skilled personnel. This is certainly true in Alaska where Northern Dynasty has been confronted with a shortage of qualified drillers. This shortage is exacerbated by the depth of the holes to be drilled as well as the difficult drilling conditions at Pebble.

Throughout much of 2006, inquiries for additional drills were met with a typical response. No drillers were available, particularly for such deep drilling. To overcome this challenge, and as part of Northern Dynasty's local hire program, the company's contractors employed a large number of local residents as drill helpers. Some of these people subsequently became drillers.

Since the Pebble deposit was initially discovered in 1988, both Cominco and Northern Dynasty have implemented practices to minimize the environmental impact of exploration activities. These practices reflect Northern Dynasty's "Responsible Mineral Development' policy. It includes refraining from using all-terrain vehicles or snow machines at the site unless adequate snow cover is present, wildlife avoidance and prohibiting hunting, fishing and gathering by project personnel.

However, the primary means of minimizing site impacts at Pebble is the use of helicopters. Northern Dynasty uses helicopters to transport all drill rigs to the property, as well as between drill sites. This reduces surface impacts. Although there has been a significant cost to this approach, it had generally not restricted the exploration program. However, this changed in 2006 with the deeper drill program. The size of the rigs to drill these deeper holes, and therefore their availability, was constrained by what a helicopter could lift. Thus, the challenges of deep drilling at Pebble were exacerbated by the

FIGURE 2

Deposit terrain at the Pebble project in southwest Alaska.

FIGURE 3

Helicopter support at the Pebble project.

need to support the program with helicopters. (Fig. 3).

Another manifestation of Northern Dynasty's Responsible Mineral Development policy is the concurrent reclamation of drill sites. This ensures that the amount of area disturbed at any one time is minimal and that disturbed areas return to a natural condition as quickly as possible.

Reclamation usually begins before a rig is set up at a drill site, when the organic layer is removed and set aside. Within a few days of the drill rig moving to another site, the reclamation crew moves in to recontour the affected area by hand, to replace surface vegetation and to reseed as required. Land reclaimed in this manner is often indistinguishable from surrounding tundra within a few weeks.

Environmental field programs

In addition to its geological exploration program, Northern Dynasty is also collecting and collating all of the environmental and socioeconomic data necessary to prepare a feasibility study, design the project and support permit applications (Fig. 4).

In fact, the effort expended on Pebble's environmental study program during the past two to three years has rivaled that of its drilling program. On many occasions, more than half of the 100 to 120 people at site are working on the environmental baseline and geotechnical data collection programs.

These activities have included extensive mapping, sampling, soils drilling, test pitting, seismic surveys and hydrological data collection to support facilities design. As befitting a project of Pebble's scale, Northern Dynasty is conducting a massive effort to collect the full range of environmental data from the site, the waterways that drain the site, the proposed road alignments and possible port sites. The discovery of Pebble East in 2005 further expanded the type and extent of geotechnical and hydrogeological data being collected to support the evaluation of a deep underground mine.

Geotechnical data collection

Although Northern Dynasty continues to review development options for Pebble East, it is possible that block caving will be selected as the preferred underground mining method. Frequency and orientation of discontinuities such as faults and joints are being collected as part of the resource drilling program. This work is being enhanced in a number of areas by recently developed technology.

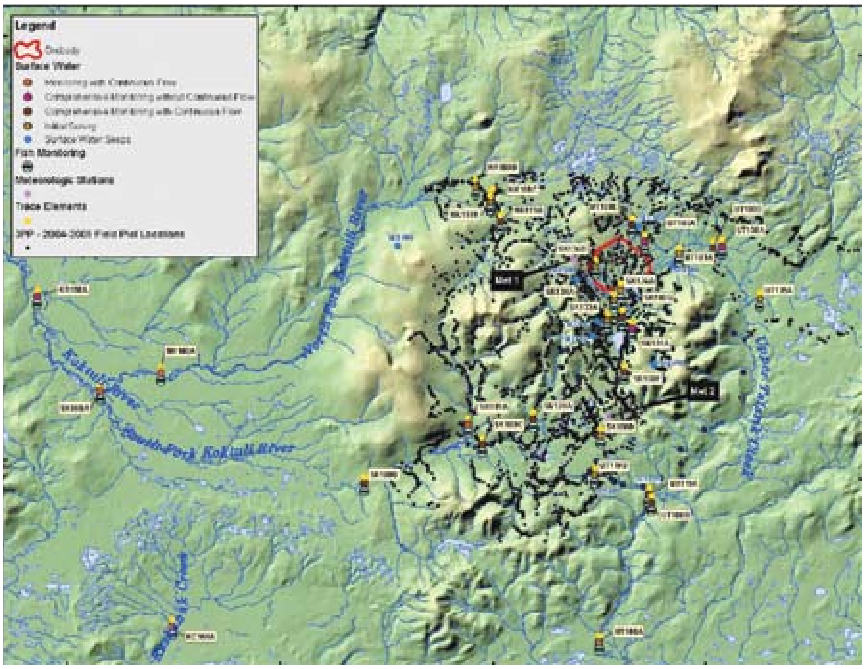
For instance, Northern Dynasty consultants are using the Ace Core Orientation Tool to determine the true orientation of rock core. The tool is attached to the top of the core barrel before it is lowered into the hole. Silicon accelerometers inside the tool sense the low side of the inclined borehole and store this orientation in the tool's memory. When the core is retrieved, the operator lays the core barrel on a table then rotates the barrel until the tool reproduces the low side of the core.

Northern Dynasty is also using an acoustic logger to sound the holes. This technology has been used in the oil industry for some time. However, its use in mining applications is relatively rare. It is typically used at large scale mines where understanding rock mass characteristics is critical.

The tool takes an ultrasound picture of the borehole

FIGURE 4

Environmental data collection.



wall as it is lowered. These data are loaded into computer software that displays the "picture" as if the borehole wall was laid flat. Joints and other discontinuities appear like sine waves in the picture. These are interpreted by an engineer and compared with the core, core photos and orientation data to determine the orientation of the joints.

The collection of hydrogeological data is critical for both underground mine design and for determining baseline characteristics. Typically, these data are acquired using inflatable packers lowered into core holes. However, Pebble East's depth has created another challenge, as conventional packers typically cannot be set more than 305 m (1,000 ft) below water level.

Northern Dynasty has addressed this challenge at Pebble by installing the Westbay ground water monitoring system. This unit is permanently set up in a hole to allow pumping tests and water quality sampling to be conducted at isolated locations.

Tailings system

Prior to deferring completion of its Pebble West feasibility study, Northern Dynasty and its consultants had completed a significant portion of the study engineering, based on an openpit mine feeding a 200-kt/a (220,000-(nominal) stpd) flotation plant (Fig. 5).

The tailings facility dominates the layout. It was designed for co-disposal of 1.8 Gt (2 billion st) of tailings and 907 Mt (1 billion st) of potentially reactive mine waste within an impoundment bounded by two embankment structures built primarily from the 907 Mt (1 billion st) of non-reactive mine waste derived from the openpit.

The location and capacity of the tailings management system at Pebble are under review as part of the process of developing an IDP. Nonetheless, the basis of the design — particularly the seismic conditions, concepts related to seepage control and tailings deposition methodologies — are still valid.

The facility was designed to safely impound all tailings and potentially reactive waste rock by meeting four important objectives:

- Use a facility management strategy that renders the potentially reactive material inert and protects water quality within the impoundment.
- Develop a water management plan for the facility that safely impounds the water as required, minimizes the amount of water used and protects downstream water quality.
- Minimize water seepage from the impoundment and capture those trace amounts of seepage that do occur.
- Meet or exceed the seismic design parameters required by the state of Alaska.

The process of rendering the potentially reactive material inert has two elements. The first of these is to place this material under water, which prevents oxidation and the creation of acidic conditions. The second consists of entombing the potentially reactive material within non-reactive tailings by co-disposal.

At Pebble, this is possible because 90 to 95 percent of the feed to the process plant will be rejected as tailings during the rougher flotation step. Testwork has shown that rougher tailings will contain virtually no sulfides and will be non-reactive. This material will be transported by a pipeline to be discharged at numerous locations around the perimeter of the tailings facility. Sandy tailings beaches will form adjacent to the discharge points, with the result that the tailings pond will be set back more than 305 m (1,000 ft) from the embankments. The clear tailings water overlying the settled tailings particles will be recycled back to the process plant for re-use in the milling process.

The remaining 5 to 10 percent of tailings will contain a higher proportion of sulfides and have been classified as potentially reactive. These potentially reactive tailings will be separated and discharged from a separate slurry pipeline to ensure that they are submerged within the tail-

Table 2

Pebble East deposit. Inferred mineral resources.

Cut off	Size	Grade			Contained metal			
CuEQ %	million tonnes	copper %	Gold g/t	Molybdenum %	CuEQ[2] %	Copper B lb	Gold M oz	Molybdenum M lb
0.60	3,379	0.57	0.36	0.036	1.00	42.6	39.6	2.7
0.70	2,835	0.62	0.38	0.037	1.06	38.8	34.9	2.3
0.80	2,312	0.67	0.40	0.038	1.14	34.3	30.1	1.9
0.90	1,841	0.73	0.43	0.038	1.21	29.6	25.4	1.5
1.00	1,421	0.79	0.46	0.039	1.29	24.6	20.9	1.2
1.10	1,057	0.85	0.49	0.039	1.37	19.8	16.6	0.9

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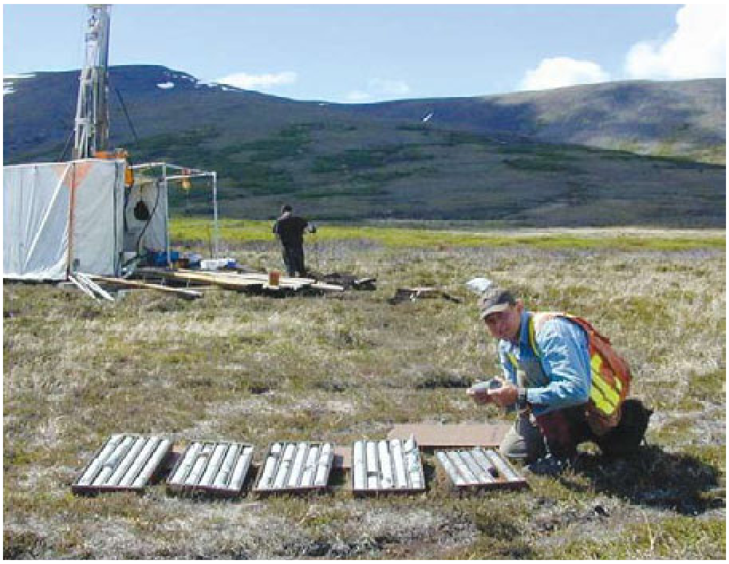
Drilling core samples at the Pebble project are examined.



ings pond. Likewise, potentially reactive waste rock from the openpit will be placed in waste dumps situated within the tailings impoundment. Potentially reactive waste rock piles will be progressively inundated by non-reactive tailings solids and submerged under the tailings pond.

The proposed tailings impoundment at Pebble will be primarily a solids retention facility with a relatively shallow surface water pond. The benign rougher tailings will fully encapsulate potentially acid generating materials.

A key objective of the tailings facility design is to minimize seepage.

The first of these is a trench excavated through the alluvium to bedrock. At the base of the trench, a grout curtain will be injected into the underlying bedrock to minimize ground water flow beneath the structure.

The second seepage control feature is a seepage control zone built into the embankment structure. During the initial phase of development, this seepage control zone will consist of a high density polyethylene geomembrane, laid on the face of the embankment and connected by a plinth to the grout curtain. Later, the construction method will convert to the center-line method, at which time compacted glacial till will form the seepage control zone.

The third seepage control feature is a series of high permeability collection zones, from which collected seepage will be pumped back into the tailings facility.

Northern Dynasty's engineering consultants are using industry standard probabilistic and deterministic techniques to assess seismic risk at the Pebble project and to quantify parameters for tailings design.

Among the data studied are the epicenter of the 9.2 magnitude earthquake that struck Prince William Sound in 1964, and the more recent 7.9 magnitude earthquake that shook Fairbanks in 2002. Project engineers have used these data, and that collected from more than 5,000 other seismic events in Alaska since the late 1800s, for probabilistic analysis. It is apparent that there has been no seismic activity in the immediate vicinity of the Pebble project in this timeframe.

Earthquakes in Alaska are centered along three key axes – the Denali Fault south of Fairbanks, the Castle Mountain Fault that terminates near the Pebble site and the Alaskan-Aleutian megathrust zone that extends from Prince William Sound along the south side of the Alaska Peninsula and the Aleutian chain.

These zones highlight two distinctly different types of earthquakes that affect Alaska.

The Denali and Castle Mountain Faults are crustal faults that create earthquakes when there is movement along fractures or zones of fracture within the bedrock that forms the earth's crust. Seismologists can reliably predict the maximum energy that can be released by fault-related earthquakes by considering their length and depth. For the Castle Mountain Fault, the maximum earthquake that can be generated by simultaneous movement along its entire length is estimated to be a 7.8 magnitude event.

Megathrust earthquakes occur due to movement at the collision point of tectonic plates – in the case of Pebble, the North American and Pacific plates. Movements along this subduction line can result in immense earthquakes with magnitudes as high as 9.2 (as encountered in 1964).

Northern Dynasty engineers are using these maximum possible earthquakes as the conservative basis for designing stable tailings embankments at Pebble. In fact, the tailings embankments at Pebble are being designed to withstand seismic events of such magnitude that they could never actually occur.

Earthquake magnitude is not the only factor that must be considered in design, however. Another key component is the project's distance from possible seismic events. Like sound that diminishes in intensity the further one is from the source, earthquake waves attenuate with distance. This attenuation is considered by design engineers who calculate the maximum possible earthquakes that may occur near Pebble, as well as the resulting peak ground acceleration at the project site. Peak ground acceleration (pga) is a key design parameter.

For Pebble, an earthquake in the Alaskan-Aleutian megathrust zone has the potential to release more energy and have a greater duration than fault-related earthquakes, but it would also be more than 161 km (100 miles) away. By contrast, an earthquake on the Castle Mountain Fault may be only 29 km (18 miles) away. After allowing for attenuation, the maximum possible earthquake along the Castle Mountain Fault has the potential to develop greater peak ground acceleration at the Pebble mine site than the maximum possible megathrust earthquake — a value of 0.3g.

As noted previously, tailings embankments at Pebble are being designed to withstand seismic events of such magnitude that they could never actually occur. This includes a 7.8 magnitude earthquake on the Castle Mountain fault (peak ground acceleration of 0.3g), a 9.2 magnitude earthquake in the Alaskan-Aleutian megathrust zone (peak ground acceleration of 0.17g) or an 8.0 magnitude earthquake on the Denali Fault (peak ground acceleration of 0.08g).

To corroborate its analysis, these calculations were compared with information recently published by the U.S. Geological Survey (USGS). The USGS indicates significantly less seismic risk at the Pebble site than is seen at Anchorage. The USGS predicts maximum peak ground acceleration due to seismic events at the Pebble site of 0.25g, which is lower than the 0.3g value being used as the basis for designing tailings embankments.

A strategic resource

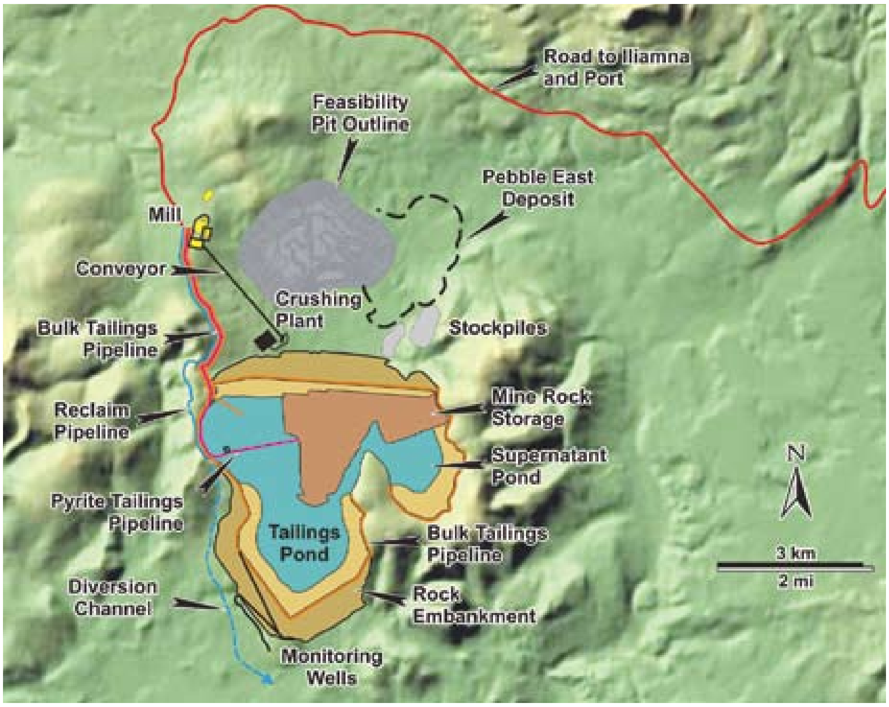
The value of Pebble as a strategic resource for Alaska and the United States is becoming more evident as the deposit grows and emerging economies in Asia strive to obtain greater access to resources. This situation is exacerbated by the apparent inability of the copper market to meet rising demand.

Statistics for the United States tell a similar story, with domestic copper production falling and reliance on imports growing. In fact, the United States currently imports 40 percent of the copper it consumes – a shortfall that is expected to grow to 50 percent (about 907 kt/a or 1 million stpy) within the next several years.

Pebble alone could fill one-third or more of America's current copper deficit. The current resource estimate is sufficient for a mine life of 60 or more years and the 2006 drilling program left the deposit open to the north and south. That Pebble is located on American soil only highlights the importance of the discovery. Not only does it have the potential to be a long-term, secure source of American copper, Pebble can also become a foundation for diversifying the economy of southwest Alaska.

FIGURE 5

Project overview.



In 2005, the Alaska Miners Association commissioned a study to assess the contribution that mining makes to the state. It revealed a number of interesting facts:

- Mining contributes significantly to the state's economy, including more than 5,000 jobs and $280 million in salaries and compensation.
- Mining pays its own way with respect to state regulation and contributes substantially to state government coffers and the Permanent Fund.
- Mining employs the highest percentage of Alaskans of all resource industries, higher than the petroleum industry and significantly higher than fish processing.
- Mines tend to be located in rural areas with few other economic engines and are often the most significant source of tax revenues to local governments.

With the scale of the project and its location on state land, Pebble promises to continue the proud legacy of mining in Alaska and to increase the industry's importance to the tate's economy.

Northern Dynasty estimates that the Pebble project will require an initial capital investment of between $1 billion and $3 billion. Hundreds of millions of dollars in operating expenditures will be made each year during its 60-plus year life. Annual tax revenues to state and local governments will be in the tens of millions.

Some 2,000 direct jobs will be created during the project's two to three year construction phase, with another 1,000 high-wage, high-scale, stable positions created during the mine's operating life. Thousands more would be created through supply and service contracts, and by the spending of mine employees' wages. Most importantly, Pebble will provide much needed jobs in southwest Alaska and leave a sustainable legacy of new social and economic infrastructure for a region in desperate need of economic opportunity.

Going forward

Northern Dynasty has four key objectives for the next 12 to 18 months.

The first is to form a consortium partnership with a major mining company to advance the Pebble project toward permitting, construction and operations. Northern Dynasty expects to have the first phase of this consortium in place by mid-2007.

The second is to fully delineate Pebble East so that it can be incorporated into project planning. The 2006 drill program continued to early December last year and, for the first time since Northern Dynasty optioned the project, re-commenced in early February. The 2007 program will continue to explore for the limits of the Pebble East deposit, while upgrading the resource classification.

Once the consortium is in place and Pebble East has been drilled off, the third objective will be to complete an IDP. Northern Dynasty is defining this study as a feasibility-level planning study for Pebble West, the plant and related infrastructure, and a prefeasibility-level study for Pebble East.

Finally, based on the project description within the IDP and three-plus years of baseline environmental data, Northern Dynasty expects to begin preparing permit applications after completing the IDP. ■