Award Nomination

Crawford Mountains Reclamation Project

2002 National Abandoned Mine Land Reclamation Awards

Location

The Crawford Mountains are located five miles east of the town of Randolph (75 miles northeast of Salt Lake City), near the border of Utah and Wyoming, Rich County, Utah.
Townships 11 and 12 North, Ranges 7 and 8 East, SLBM.

Submitted By

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Abandoned Mine Reclamation Program
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Project Dates

Start: September 22, 1992
Completion: October 31, 2000

Project Cost

Construction:	$2,241,674
Engineering/Management:	$ 532,487
Total Project Cost:	$2,774,161

Date Submitted

March 15, 2002

Project Managers
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Contractors
E.T. Technologies, Inc.,
Salt Lake City, Utah
Minchey Digging, Cleveland, Utah
Ned B. Mitchell, Altamont, Utah
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Preliminary Investigation and Engineering
Morgan Mining and Environmental Consultants

Final Engineering
Spectrum Engineering and In-House

Historical Involvement
Utah SHPO

Landowners
Arickaree Development Company
Astaris
BLM
Crawford Mountain Properties, Inc.
FMC Corporation
Phosphate Industries, Ind.
Rich County (Right-of-Way)

Project Location and Mining History

The Crawford Mountains, a small and isolated mountain range located in extreme Northeastern Utah, reflects the legacy of over seventy-five years of phosphate mining activity. The remnants of this mining has created some of the most unstable mining impacted land in the United States. The Crawford Uplift, responsible for the mountainous topography, is the result of two parallel fault systems. The east bounding fault is expressed as an eroded mountain front, deeply incised by drainages. In contrast, the younger west bounding fault is expressed as a steep relative uneroded mountain front that rises abruptly from the Bear River Valley. This complex uplift results in a triplet of plunging and ascending synclines. The phosphate ore, in various concentrations, was discovered in four beds within the Meade Peak Member of the Phosphoria Formation. These beds are referred to as A, B, C, and D beds in order of increasing depositional age. Generally the 'A' bed contained the highest concentration of phosphate ore, approximately 34%. The dip of the phosphate beds range from relatively flat to an extreme of 70 degrees, depending on the geological structure and location on the east or west limb of the syncline.

The climate in the area is semi-arid with less than 14 inches of annual precipitation, much of this coming in winter as snowfall. Elevations range from 6,250 feet at the floor of the Bear River Valley to over 8,000 feet at Rex Peak, the range's highest point. The vegetation is shrub-steppe, comprised of sagebrush, rabbit brush, grasses such as Bromus and Stipa spp., and occasional juniper trees.

The Crawford Mountains were mined extensively from 1902 through 1972 utilizing both underground and surface mining techniques. However, the primary method for extracting the phosphate ore was stope mining. Initially, crosscuts were driven across both synclinal limbs from the Bear River Valley floor. Drifts or horizontal tunnels were then developed along the strike of the phosphate rock's synclinal limbs. Raises or vertical shafts were developed on 250 foot centers to the surface of each limb, each of which consisted of a manway and ore chute compartment. Depending on the topography, these raises extended from 250 to 800 feet in height. Once raises were complete, a stope was developed through a series of drifts from the top to bottom of the stope, manually slushing the ore to the ore chute compartment.

Extraction ratios were reported to have been between 50 and 75%. The average thickness of the 'bed' mined was about 13 feet. In 1907 a tonnage of 1,444 tons was recorded in the Rich County court house. As technology progressed, output averaged 33 tons per man shift with a record daily tonnage of 2,500 tons in 1967. The complex geology and extreme dip of the ore beds resulted in very hazardous mining conditions. Twenty-five unconfirmed deaths occurred during the extraction process, as reported by Rich County residents. With 8.5 to 9 million tons of ore mined, this represents a dismal safety record of nearly one death per 350,000 tons of phosphate mined. This same complex geology with its steeply angled hanging wall overlying the phosphate bed would exacerbate and ultimately be responsible for the modern day abandoned mine land problem.

During mining, the operation proceeded from drifts deep in the ground towards the surface. As mining approached the surface, a thickness of ground support known as the crown pillar was left between the mine void and the surface. Failure or collapse of this crown pillar caused dramatic and often catastrophic subsidence events in many locations across the mountain range (see Figure 1). Often these failures extend laterally into adjacent rocks, leaving not single openings but deep "trough-like" expressions on

Figure 1 Crown pillar failures openinginto 500 to 800 foot deep mine.

Figure 2 Generalized cross section of mined area.

the surface. In more extreme cases, the failure of the crown pillar results in a totally open, vertical feature extending from 500 to 800 feet deep into the mine (see Figure 2). Compounding the severity of these vertical subsidence openings, the thickness of remaining crown pillars is unknown and catastrophic failure can occur with out warning. Inventory crews experienced frightening examples of this instability while ground truthing recently taken aerial photography to specifically identify hazards. Crews were surprised to discover subsidence openings that did not appear in the photographs and were previously unrecorded. A comprehensive inventory of the entire mountain range revealed 234 hazardous features, including horizontal openings, air shafts, vertical openings, and crown pillar failures.

Project History

The Crawford Mountains Reclamation Project is the largest non-coal project undertaken by the Utah Abandoned Mine Reclamation Program. Due to funding limits and the large extent of the hazards associated with the Crawford Mountains, the reclamation was phased over a nine year period with eight separate construction projects. Innovative techniques and a methodic approach reduced the initial estimated $25 million design and construction costs to a final cost of $2.77 million.

Inventory

In 1991, a consulting contract was issued to conduct an inventory of hazardous features, a feasibility study to evaluate the potential to reclaim these features and to provide a refined cost estimate for the reclamation. This preliminary work, completed during the 1992 field season, proposed an estimated reclamation cost of over $25 million. Because limited funding was available to address a problem of such magnitude, the hazards in the Crawford Mountain range were ranked and divided into ten initial reclamation segments. This allowed the most dangerous areas to be mitigated first and to phase the entire reclamation effort. A total of 173 hazardous features were discovered along the east and west limbs of the syncline distributed over the seven mile length of the mountain range. These features included 12 horizontal openings, 44 air shafts, 28 vertical openings, 55 crown pillar/hanging features, and 34 compound subsidence features for a total of 173 hazard features. When compound subsidence features were separated into single features the total number of hazardous features increased to 234.

Reclamation

Brazier Demonstration Project

The Brazier Demonstration Project, the first phase of the Crawford Mountains reclamation construction, is located in Brazier Canyon, which contained the only east-west county road through the mountain range. The road was failing into the mined out area and crossed an unknown thickness of crown pillar. The initial reclamation plans called for the use of drilling and explosives to collapse the remaining crown pillars. But the nature of the highly fractured and jointed phosphate rock caused the drilling operation to be ineffective. However, the crown pillars were found to be jointed enough to allow excavation by large track mounted excavators (see Figure 3 and 4). This method of crown pillar excavation and collapse proved to be the quickest and most economical method to reclaim the un-subsided crown pillars. Using this technique the subsidence in the bottom of the canyon was excavated to the forty foot level and backfilled using the top six inches of the roadway as fill. Numerous other subsidence features located in the bottom of the canyon were successfully excavated and backfilled. A total of 40,993 cubic yards of material was moved including 2,700 feet of crown pillar excavation. Six acres of land were revegetated using adapted native species.

Figure 3 Caterpillar 345 Trackhoe excavating crown pillar.

Figure 4 Caterpillar 345 Trackhoe and D-9 excavating and backfilling crown pillar and shaft location.

Molly's Canyon Project

Molly's Canyon lays along the

east limb of the syncline. This was the second most hazardous area and contained horizontal openings and large subsidence features. The horizontal openings in Molly's Canyon were excavated and backfilled along with huge subsidence openings that extended to the south. Two remote horizontal openings were also excavated and backfilled. A total of 71,562 cubic yards of material were moved and 950 feet of crown pillars were excavated. After revegetation 10 acres were brought back into productive use.

Arickaree Project

The Arickaree project is located at the northern end of the Crawford Mountains Reclamation Project area. The project contained six horizontal openings, three air shafts and numerous subsidence openings. Over 915 feet of crown pillars were excavated. Abandoned waste rock dumps were used to backfill excavated mine workings. The six horizontal openings and three air shafts were also excavated and backfilled using abandoned waste rock dumps. A total of 80,094 cubic yards of material were moved eliminating the hazards and completing the reclamation of 15 acres.

Coal Hollow Project

The Coal Hollow project spans the Coal Hollow drainage transecting the area north to south. The project area contained numerous subsidence features occurring along the west limb of the syncline. A large subsidence feature located in the bottom of the canyon diverted drainage into the underground workings. The project included 2,400 feet of crown pillar excavation and the realignment of the drainage after the mine workings were backfilled. A total of 138,040 cubic yards of material were moved and 17 acres were revegetated.

Molly's Canyon West Project

The Molly's Canyon West project connected the reclamation of Brazier and Coal Hollow canyons. The crown pillar configuration consisted of an almost continuous zone of failure forming a line of deep trench-like features opening into the workings estimated at depths of 300 to 600 feet. A total of 5,100 feet of crown pillars were excavated with 411,371 cubic yards of material placed as backfill into the workings. Final revegetation covered 43 acres.

Emma's Canyon Project

The Emma's Canyon project extended along the west limb of the syncline from the north crossing three drainages and wrapped around to the south along the east limb. Multiple subsidence features were present along with two horizontal openings accessing underground workings. The crown pillar excavation covered 4,810 linear feet and 278,520 cubic yards of material were placed as backfill and to re-establish the three drainages. Revegetation covered 27 acres.

Tuscarora Project

The Tuscarora project crossed five major drainages in the Crawford Mountains extending south along the east limb of the syncline. Major subsidence features extended south from the Tuscarora Mine. The crown pillar excavation comprised 8,430 linear feet with 519,000 cubic yards of material placed as backfill and to re-establish drainages. The revegetation covered 40 acres.

Otto Project

The Otto project was the last phase of the reclamation in the Crawford Mountains extending south towards Rex Peak. In addition to crown pillar excavation the Otto project closed seven horizontal openings into abandoned mine workings. A total of 5,200 linear feet of crown pillars were excavated with 231,000 cubic yards of material placed as backfill. Revegetation covered over 22 acres.

Extreme Roughening and Revegetation

All areas disturbed during the reclamation effort were seeded with a mix of native grasses, forbs and shrubs. Prior to seeding all areas were prepared using straw mulch and extreme roughening. Extreme surface roughening of all final grading aids in the control of erosion and enhances vegetation establishment. This technique creates surface relief of greater than 36 inches. The "pocking" pattern creates numerous micro-basins across the landscape where fine grain sediment and seeds can collect and where runoff can be trapped to improve conditions for seedling establishment and growth (see Figure 5). Straw mulch incorporated at a rate of one ton per acre increases the organic matter in the soil and encourages

Figure 5 Extreme roughening, deep "pocking" of reclaimed subsidence area.

microbial activity. Rock, deadfall and other natural materials were incorporated into the finished surface to improve micro-habitat and create a more natural appearance.

Project Summaries

The Crawford Mountains Reclamation Project phased over eight construction projects encompassed almost six miles of crown pillar excavation. The total earthwork amounted to over 1.78 million cubic yards of material at a cost of just under $2.24 million. Over 180 acres of land were revegetated using native species.

Summary

After almost a century, the cycle of phosphate mining activity in the Crawford Mountains that began in the early 1900's has been completed and reclaimed by the Utah AMRP in 2000. The ore has been extracted utilized in industry and agriculture. The landscape has been restored to as close to pre-mining conditions as possible and hazards have been eliminated (see Figure 6). Crown pillars above mine workings were collapsed to prevent further catastrophic subsidence into old workings. Native species of desirable grasses and forbs have replaced weeds and bare soil to provide a plant community consistent with the surrounding community thus enhancing wildlife habitat and grazing. Extreme roughening has reduced erosion and is protecting off-site water quality. And most importantly, Rich County is no longer the home of some of the most hazardous abandoned mine features in the nation.

Figure 6 Completed reclamation, recontoured and revegetated landscape.